JAAVSO

Volume 40
Number 1
2012

The Journal of the American Association of Variable Star Observers

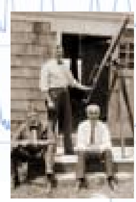
Part A
of two parts
pages 1–266

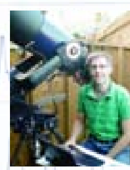
100th Anniversary Edition



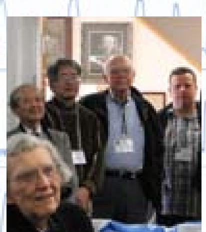








- History
- Associations
- Science
- Review Papers



THE AMERICAN ASSOCIATION OF VARIABLE STAR OBSERVERS
AAVSO
FOUNDED 1911
49 Bay State Road
Cambridge, MA 02138
U. S. A.

ISSN 0271-9053

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The American Association
of Variable Star Observers

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History
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The *Journal of the American Association of Variable Star Observers* is a refereed scientific journal published by the American Association of Variable Star Observers, 49 Bay State Road, Cambridge, Massachusetts 02138, USA. The *Journal* is made available to all AAVSO members and subscribers.

In order to speed the dissemination of scientific results, selected papers that have been refereed and accepted for publication in the *Journal* will be posted on the internet at the *eJAAVSO* website as soon as they have been typeset and edited. These electronic representations of the *JAAVSO* articles are automatically indexed and included in the NASA Astrophysics Data System (ADS). *eJAAVSO* papers may be referenced as *J. Amer. Assoc. Var. Star Obs., in press,* until they appear in the concatonated electronic issue of *JAAVSO*. The *Journal* cannot supply reprints of papers.

Page Charges

Unsolicited papers by non-Members will be assessed a charge of $15 per published page.

Instructions for Submissions

The *Journal* welcomes papers from all persons concerned with the study of variable stars and topics specifically related to variability. All manuscripts should be written in a style designed to provide clear expositions of the topic. Contributors are strongly encouraged to submit digitized text in MS WORD, LATEX+POSTSCRIPT, or plain-text format. Manuscripts may be mailed electronically to journal@aavso.org or submitted by postal mail to *JAAVSO*, 49 Bay State Road, Cambridge, MA 02138, USA.

Manuscripts must be submitted according to the following guidelines, or they will be returned to the author for correction:

Manuscripts must be:
1) original, unpublished material;
2) written in English;
3) accompanied by an abstract of no more than 100 words;
4) not more than 2,500–3,000 words in length (10–12 pages double-spaced).

Figures for publication must:
1) be camera-ready or in a high-contrast, high-resolution, standard digitized image format;
2) have all coordinates labeled with division marks on all four sides;
3) be accompanied by a caption that clearly explains all symbols and significance, so that the reader can understand the figure without reference to the text.

Maximum published figure space is 4.5” by 7”. When submitting original figures, be sure to allow for reduction in size by making all symbols and letters sufficiently large.

Photographs and halftone images will be considered for publication if they directly illustrate the text.

Tables should be:
1) provided separate from the main body of the text;
2) numbered sequentially and referred to by Arabic number in the text, e.g., Table 1.

References:
1) References should relate directly to the text.
2) References should be keyed into the text with the author’s last name and the year of publication, e.g., (Smith 1974; Jones 1974) or Smith (1974) and Jones (1974).
3) In the case of three or more joint authors, the text reference should be written as follows: (Smith *et al.* 1976).
4) All references must be listed at the end of the text in alphabetical order by the author’s last name and the year of publication, according to the following format:
   Brown, J., and Green, E. B. 1974, *Astrophys. J.*, **200**, 765.
   Thomas, K. 1982, *Phys. Report*, **33**, 96.
5) Abbreviations used in references should be based on recent issues of the Journal or the listing provided at the beginning of *Astronomy and Astrophysics Abstracts* (Springer-Verlag).

Miscellaneous:
1) Equations should be written on a separate line and given a sequential Arabic number in parentheses near the right-hand margin. Equations should be referred to in the text as, e.g., equation (1).
2) Magnitude will be assumed to be visual unless otherwise specified.
3) Manuscripts may be submitted to referees for review without obligation of publication.

Journal of the American Association of Variable Star Observers
Volume 40, Number 1, 2012

100th Anniversary Edition

100th Spring Meeting of the AAVSO, in conjunction with the 218th Meeting of the American Astronomical Society, held in Boston, Massachusetts, May 21–25, 2011

100th Annual Meeting of the AAVSO, held in Cambridge and Woburn, Massachusetts, October 5–8, 2011

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About This 100th Anniversary Issue

John R. Percy, Editor, *JAAVSO*
Department of Astronomy and Astrophysics, University of Toronto, Toronto ON M5S 3H4, Canada

Welcome to the Centennial Issue of *The Journal of the American Association of Variable Star Observers*! The AAVSO was founded in 1911 by a small group of amateur astronomers, led by William Tyler Olcott, and encouraged by Edward Pickering, Director of the Harvard College Observatory. By 2011, it had become the most important organization through which amateurs can contribute significantly to astronomical research. In media articles about "citizen science," the AAVSO is almost always mentioned.

Initially, the work of AAVSO observers was collected by the Recorder, and made available to researchers as needed, usually in the form of light curves. By the time I became aware of the AAVSO, half a century ago, its work was being reported by Director Margaret Mayall in "Variable Star Notes," in the *Journal of the Royal Astronomical Society of Canada* (I joined the RASC in 1961). Her output was remarkable: she published dozens and dozens of these notes, highlighting both specific and general results of AAVSO observations. Some research, based on AAVSO data, was (and still is) published in other astronomical research journals.

In 1972, *JAAVSO* was launched. On its first page, Director Mayall writes "sixty-one years after the founding of the Association, we now launch an important new project—one we have hoped for and needed for many years—our own *Journal of the AAVSO*. It will be a place where professional and non-professional astronomers can publish papers of interest to the observer...." Our audience continues to be all those who are interested in variable stars, including AAVSO members and other observers, and professional astronomers and students engaged in variable star research. Together, they constitute a special "family" within the astronomical community, making the AAVSO one of my favorite organizations.

Over the years, *JAAVSO* has grown and changed, as the AAVSO has. Most obviously, it is now primarily an electronic journal, though hard copies can be ordered. Happily, therefore, *JAAVSO* is freely available, all over the world. It no longer contains the administrative reports of the Association; these (such as the Director's Report) are found in the *AAVSO Annual Report* and elsewhere on the AAVSO website. The AAVSO's 75th anniversary was marked by a special issue (volume 15, number 2, 1986). Volume 25, number 2 contained the proceedings of an AAVSO session on Mira variables, marking the 400th anniversary of the discovery of Mira's variability. Papers from our 1997 meeting in Sion, Switzerland, were (belatedly) published in volume 35, number 1, 2006. The proceedings of our first truly international meeting were published as a separate book (Percy, Mattei, and Sterken 1992).

In 2011, the AAVSO Centennial was celebrated in several ways, including by the publication of an official history of the AAVSO (Williams and Saladyga 2011), and two meetings—a joint meeting with the American Astronomical Society in the spring (May), and a Centennial meeting in October (the Annual meeting). The Spring meeting included several invited papers related to the history of the AAVSO, presented jointly with the Historical Astronomy Division of the AAS. These, and most of the invited history papers from the Annual meeting, are contained in one section of this Centennial Issue. The history sessions were organized by Dr. Thomas R. Williams, who has provided a short introduction to those papers.

The spring AAVSO-AAS meeting also included two sessions of invited papers on scientific themes relevant to the work of the AAVSO. These sessions were organized by Dr. Matthew R. Templeton, who has provided an introduction to that section.

We also commissioned a set of short science reviews of variable star types, to give a flavor of variable star astronomy at the start of the 21st century. The authors are professional astronomers with special ties to the AAVSO. We thank them for their reviews, and also for their ongoing interest in the Association. I have provided a separate introduction to those review papers.

Finally, there were a large number of papers which were contributed to the two meetings, by members, observers, and other friends of the Association. These reflect the remarkable diversity of the interests and activities of the AAVSO—observation, analysis, instrumentation, education, history, biography, and so on. Most of these papers are contributed by amateur astronomers, who carry out their work voluntarily, as a labor of love.

I close by thanking all the authors of the papers in this issue, Drs. Tom Williams and Matt Templeton for organizing the sessions on AAVSO history and science, Rebecca Turner and the rest of the AAVSO staff for their work in organizing the meetings and other Centennial events. I extend special thanks to the astronomers who review these and all other papers contributed to this *Journal*. These reviewers are normally anonymous, and therefore go unthanked in public. They play an important role in maintaining the standards of *JAAVSO*, and in improving virtually every submitted paper. Last and not least, I thank the production editor of the *JAAVSO*, Dr. Michael Saladyga, Associate Editor Elizabeth O. Waagen, and Assistant Editor Dr. Matt Templeton, for the quality and vast quantity of their editorial work, and their patience in dealing with many challenges in producing a volume like this one, not the least of which is the diversity of content and format of the "raw material." Thanks, Mike, Elizabeth, and Matt!

We hope that all readers will enjoy this collection of papers, and that many of you will order a printed version of the issue. It, along with the official history (Williams and Saladyga 2011), provides an outstanding and lasting picture of an organization that we know and love.

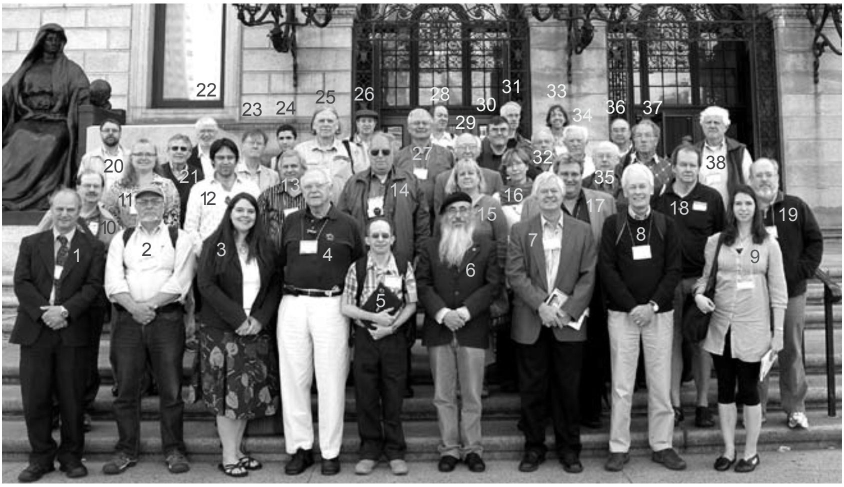
References

Percy, J. R., Mattei, J. A., and Sterken, C. 1992, *Variable Star Research: An International Perspective*, Cambridge Univ. Press, Cambridge.

Williams, T. R., and Saladyga, M. 2011, *Advancing Variable Star Astronomy: The Centennial History of the American Association of Variable Star Astronomers*, Cambridge Univ. Press, Cambridge.

Key to the cover photographs *(from upper left): 7th Annual Meeting of the AAVSO, November 10, 1917; 100th Annual Meeting of the AAVSO, October 4–8, 2011; M. Alberta Hawes, AAVSO Charter Member; AAVSO member/observers Barbara Harris, Mary Glennon, Michael Linnolt; William Tyler Olcott, William Henry, and Leon Campbell at the AAVSO Spring Meeting, 1923; at Mount Holyoke College, South Hadley, Mass., for the AAVSO's 1924 Spring Meeting; AAVSO member observer Shawn Dvorak; AAVSO members and observers at the 100th Annual Meeting—Martha Stahr Carpenter, Seiichi Sakuma, Seiichiro Kiyota, Thomas R. Williams, and Eric Broens. The background image is a portion of the historical light curve of the variable star SS Cygni.*

The 100th Spring Meeting of the AAVSO, Boston, Mass., May 21–25, 2011



The 100th Spring Meeting of the AAVSO, Boston, Mass., May 21–25, 2011

KEY TO THE PHOTOGRAPH

1 Mario Motta
2 Gary Walker
3 Pamela Gay
4 Thomas R. Williams
5 Richard Kinne
6 Jaime García
7 Arne Henden
8 David Boyd
9 Helena Uthas
10 David Lane
11 Martina Arndt
12 Michael Koppelman
13 Richard Huziak
14 John Centala
15 Kristine Larsen
16 Jeno Sokoloski
17 Mike Simonsen
18 Joe Patterson
19 Eric Martin
20 Gary Billings
21 Dave Hurdis
22 David Turner
23 John Percy
24 Dan Majaess
25 George Sjoberg
26 Ed Los
27 Richard Sabo
28 John Pazmino
29 Arlo Landolt
30 Matthew Templeton
31 John O'Neill
32 Richard Post
33 Sara Beck
34 Phillip Coker
35 Ken Menzies
36 Donn Starkey
37 Pierre de Ponthiere
38 Bill Goff

The 100th Spring Meeting of the AAVSO, Boston, Massachusetts, May 21–25, 2011

List of Participants

Martina Arndt	Bridgewater, Massachusetts
Sara Beck	AAVSO HQ, Massachusetts
Gary Billings	Calgary, Canada
David Boyd	Oxford, England
Katherine Bracher	Austin, Texas
Maria Cahill	Fort Myers, Florida
John Centala	Marion, Iowa
Phillip Coker	Colorado Springs, Colorado
Pierre de Ponthiere	Lesve, Belgium
Emily Elert	Brooklyn, New York
Jaime Garcia	Mendoza, Argentina
Pamela Gay	Edwardsville, Illinois
Owen Gingerich	Cambridge, Massachusetts
Bill Goff	Sutter Creek, California
Edward Guinan	Villanova, Pennsylvania
Jim Hatfield	St. Albans, West Virginia
Arne Henden	AAVSO HQ, Massachuestts
Anna Hillier	Lexington, Massachusetts
David A. Hurdis	Narragansett, Rhode Island
Richard Huziak	Saskatoon, Canada
Margarita Karovska	Allston, Massachuestts
Richard Kinne	AAVSO HQ, Massachusetts
Michael Koppelman	Minneapolis, Minnesota
Arlo Landolt	Baton Rouge, Louisiana
David Lane	Halifax, Canada
Kristine Larsen	New Britain, Connecticut
Edward Los	Nashua, New Hampshire
Daniel Majaess	Halifax, Canada
Eric Martin	Salem, Massachusetts
Will McMain	AAVSO HQ, Massachusetts
Ken Menzies	Framingham, Massachusetts
Nancy Morrison	West Newton, Massachuestts
Mario Motta	Gloucester, Massachusetts
Gordon Myers	Hillsborough, California
Paul Norris	Quincy, Massachusetts
John O’Neill	Rush, Ireland

continued on next page

Maria Osborn	Delevan, Wisconsin
Wayne Osborn	Delevan, Wisconsin
Joseph Patterson	New York, New York
John Pazmino	Brooklyn, New York
John Percy	Toronto, Canada
Richard Post	Lexington, Massachusetts
Aaron Price	AAVSO HQ, Massachusetts
Richard Sabo	Bozeman, Montana
Michael Saladyga	AAVSO HQ, Massachusetts
Mike Simonsen	AAVSO Staff, Michigan
George Sjoberg	Duxbury, Massachusetts
David Soderblom	Baltimore, Maryland
Jeno Sokoloski	New York, New York
Matthew Stanley	New York, New York
Donn Starkey	Auburn, Indiana
Matthew Templeton	AAVSO HQ, Massachusetts
David Turner	Dartmouth, Canada
Rebecca Turner	AAVSO HQ, Massachusetts
Helena Uthas	New York, New York
Elizabeth Waagen	AAVSO HQ, Massachusetts
Gary Walker	South Yarmouth, Massachusetts
Barbara Welther	Woburn, Massachusetts
Anna Fay Williams	Houston, Texas
Thomas R. Williams	Houston, Texas
Donna Young	Bullhead City, Arizona

Schedule for the 100th Spring Meeting of the AAVSO, in conjunction with the 218th Meeting of the American Astronomical Society, held in Boston, Massachusetts, May 21–25, 2011

Friday, May 20

8:00	a.m.	Council Meeting at Headquarters

Saturday, May 21

12:00	*p.m.*	*registration*
1:00		AAVSO Membership Meeting
2:00		Special Session: AAVSO Paper Session I
7:00		AAVSO Banquet (AAVSO Headquarters)

Sunday, May 22

10:00	*a.m.*	*registration*
9:30		Special Session: AAVSO Paper Session II
1:30	*p.m.*	Special Session: HAD I—Women in the History of Variable Star Astronomy
3:20		Special Session: HAD II—Variable Star Astronomy in Theory and Practice

Monday, May 23

7:30	*a.m.*	*registration*
8:00		AAVSO Poster Session
10:00		Special Session: AAVSO—Astrophysics With Small Telescopes
2:00	*p.m.*	Special Session: AAVSO—Variable Stars in the Imaging Era
7:00		AAVSO Open House

Tuesday, May 24, and Wednesday, May 25

non-AAVSO AAS sessions

The 100th Annual Meeting of the AAVSO, Cambridge and Woburn, Mass., October 5–8, 2011

The 100th Annual Meeting of the AAVSO, Cambridge and Woburn, Mass., October 5–8, 2011

KEY TO THE PHOTOGRAPH

1 Carol J. Beaman
2 Dee Sharples
3 Robert Alan Hatch
4 Yvonne Roe
5 Jaime Garcia
6 Bill Dillon
7 Tom Williams
8 Martha Stahr Carpenter
9 Kristine Larsen
10 Richard "Doc" Kinne
11 Winston Wilkerson-Montout
12 Carmen Wilkerson-Montout
13 Seiichi Sakuma
14 Paul Norris
15 Josch Hambsch
16 James Roe
17 Anna Fay Williams
18 Richard Wagner
19 Scott Tracy
20 Anna Sudaric Hillier
21 Doug Welch
22 Arlo U. Landolt
23 John Toone
24 Alice Moat
25 Seiichiro Kiyota
26 Barry B. Beaman
27 Dan Lorraine
28 Ken Menzies
29 Chris Watson
30 Arne Henden
31 Mario Motta
32 Karen Meech
33 Gary Billings
34 Gerry Samolyk
35 Albert Holm
36 Sebastian Otero
37 Richard Sanderson
38 Jeremy Shears
39 Helmar Adler
40 Barbara L. Welther
41 Lee Anne Willson
42 John Percy
43 Marvin Baldwin
44 Mike Simonsen
45 Matthew Templeton
46 Peter Lake
47 Gerald P. Dyck
48 Will McMain
49 Frank Dempsey
50 Ann Saladyga
51 Ronald Zissell
52 Neil Simmons
53 Charles E. Scovil
54 George Sjoberg
55 Richard Post
56 Tim Crawford
57 Chris Norris
58 Robert Stine
59 Gil Lubcke
60 Louis B. Cox
61 Russell Chabot
62 Frank Schorr
63 Kevin B. Paxson
64 Gordon Myers
65 Shaun Keller
66 Tom Bretl
67 Bill Goff
68 Donn Starkey
69 Nancy Clark
70 Jeff Horne
71 Wayne Clark
72 Henri M. van Bemmel
73 Jerry Horne
74 Chris Stephan
75 Brad Walter
76 Richard Sabo
77 Adrian Ormsby
78 Gary Walker
79 George Emmons
80 Stephanie Slater
81 Horace Smith
82 Paul A. Valleli
83 John Briggs
84 Gary Ahrendts
85 Shelby Delos
86 Patrick Wils
87 Timothy Barker
88 Katrien Kolenberg
89 David Williams
90 Eric Broens
91 Edward J. Los
92 Michael Saladyga
93 Marco Ciocca
94 Sara Beck
95 John O'Neill
96 Joe Patterson
97 Elizabeth O. Waagen
98 Mike Mattei
99 Aaron Price
100 James Cottle
101 Lauren Rosenbaum
102 Ed Guinan

The 100th Annual Meeting of the AAVSO, Cambridge and Woburn, Massachusetts, October 5–8, 2011

List of Participants

Helmar Adler	Danvers, Massachusetts
Gary Ahrendts	Norton, Massachusetts
Charles Alcock	Cambridge, Massachusetts
Leonard Amburgey	Fitchburg, Massachusetts
Marvin Baldwin	Butlerville, Indiana
Mary Lou Baldwin	Butlerville, Indiana
Timothy Barker	Norton, Massachusetts
Barry B. Beaman	Rockford, Illinois
Carol J. Beaman	Rockford, Illinois
Sara Beck	AAVSO HQ, Massachusetts
Gary Billings	Rockyford, Canada
Donna Bretl	Plymouth, Minnesota
Tom Bretl	Plymouth, Minnesota
John W. Briggs	Eagle, Colorado
Eric Broens	Mol, Belgium
Leslie Brown	Waterford, Connecticut
Tom Callinan	Norwich, Connecticut
Martha Stahr Carpenter	Charlottesville, Virginia
Russell Chabot	Oak Creek, Wisconsin
Glen Chaple	Townsend, Massachusetts
Marco Ciocca	Richmond, Kentucky
Nancy Clark	St. Louis, Missouri
Wayne Clark	St. Louis, Missouri
Lou Cohen	Cambridge, Massachusetts
James Cottle	Fiddletown, California
Louis B. Cox	Deep River, Canada
Carole L. Crawford	Arch Cape, Oregon
Tim R. Crawford	Arch Cape, Oregon
Keith Danskin	Amherst, New Hampshire
Sylvia Danskin	Amherst, New Hampshire
Kate Davis	Arlington, Massachusetts
Shelby Delos	Johnston, Rhode Island
Frank Dempsey	Pickering, Canada
Dennis di Cicco	*Sky & Telescope*, Massachusetts
Bill Dillon	Missouri City, Texas
Gerald P. Dyck	Assonet, Massachusetts

continued on following pages

George Emmons	Acton, Massachusetts
Rick Fienberg	Belmont, Massachusetts
Jaime Garcia	Mendoza, Argentina
Miriam Gingerich	Cambridge, Massachusetts
Owen Gingerich	Cambridge, Massachusetts
Bill Goff	Sutter Creek, California
Ed Guinan	Villanova, Pennsylvania
Josch Hambsch	Mol, Belgium
Robert Alan Hatch	Gainesville, Florida
Arne Henden	AAVSO HQ, Massachusetts
Linda Henden	AAVSO HQ, Massachusetts
Dustin Hendrickson	Somerville, Massachusetts
Anna Sudaric Hillier	Lexington, Massachusetts
Albert Holm	Columbia, Maryland
Jeff Horne	Irvine, California
Jerry Horne	San Jose, California
Valerie Horne	Irvine, California
Margarita Karovska Neily	Allston, Massachusetts
Shaun Keller	Lexington, Massachusetts
Richard Kinne	AAVSO HQ, Massachusetts
Seiichiro Kiyota	Tsukuba, Japan
Katrien Kolenberg	Cambridge, Massachusetts
Roger Kolman	Glen Ellyn, Illinois
Peter Lake	Wonga Park, Australia
Arlo U. Landolt	Baton Rouge, Louisiana
Kristine Larsen	New Britain, Connecticut
Daniel Lorraine	Cranston, Rhode Island
Edward J. Los	Nashua, New Hampshire
Gilbert C. Lubcke	Middleton, Wisconsin
Alan MacRobert	*Sky & Telescope*, Massachusetts
Mike Mattei	Littleton, Massachusetts
Will McMain	AAVSO HQ, Massachusetts
Karen Meech	Kaneoeh, Hawaii
Ken Menzies	Framingham, Massachusetts
Alice Carpenter Moat	Orefield, Pennsylvania
Joyce Motta	Gloucester, Massachusetts
Mario Motta	Gloucester, Massachusetts
Gordon Myers	Hillsborough, California
Bob Naeye	*Sky & Telescope*, Massachusetts
Clark Neily	Allston, Massachusetts
Chris Norris	Rosenberg, Texas
Paul Norris	Quincy, Massachusetts

continued on following pages

John O'Neill	Rush, Ireland
Adrian Ormsby	Saline, Michigan
Sebastian Otero	Buenos Aires, Argentina
Joe Patterson	New York, New York
Kevin B. Paxson	Spring, Texas
Arthur E. Pearlmutter	Auburn, Massachusetts
John Percy	Toronto, Canada
Richard S. Post	Lexington, Massachusetts
Aaron Price	AAVSO HQ, Massachusetts
Jamie Riggs	Greeley, Colorado
James Roe	Wentzville, Missouri
Yvonne Roe	Wentzville, Missouri
Lauren Rosenbaum	AAVSO HQ, Massachusetts
Jessica Roy	Canton, Massachusetts
Richard Sabo	Bozeman, Montana
Atsuo Sakuma	Kawasaki, Japan
Nobuko Sakuma	Kawasaki, Japan
Seiichi Sakuma	Kawasaki, Japan
Ann M. Saladyga	Somerville, Massachusetts
Michael Saladyga	AAVSO HQ, Massachusetts
Gerry Samolyk	Greenfield, Wisconsin
Richard Sanderson	Springfield, Massachusetts
Frank Schorr	Lawrenceville, Georgia
Charles E. Scovil	Stamford, Connecticut
Dee Sharples	Honeoye Falls, New York
Jeremy Shears	Tarporley, England
Neil Simmons	Salem, Wisconsin
Irene Simonsen	Imlay City, Michigan
Mike Simonsen	AAVSO Staff, Michigan
George Sjoberg	Duxbury, Massachusetts
Linda Sjoberg	Duxbury, Massachusetts
Stephanie Slater	Laramie, Wyoming
Horace A. Smith	East Lansing, Michigan
Jeno Sokoloski	New York, New York
Connie Starkey	Auburn, Indiana
Donn Starkey	Auburn, Indiana
Christopher Stephan	Sebring, Florida
Chris Stine	Newbury Park, California
Robert Stine	Newbury Park, California
Richard J. Strazdas	Westford, Massachusetts
Vladimir Strelnitski	Nantucket, Massachusetts
Paula Szkody	Seattle, Washington

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Matthew Templeton	AAVSO HQ, Massachusetts
John Toone	Shrewsbury, England
Scott Tracy	North Granby, Connecticut
Paul A. Valleli	Burlington, Massachusetts
Henri M. van Bemmel	Keswick, Canada
Arline Waagen	Arlington, Massachusetts
Elizabeth O. Waagen	AAVSO HQ, Massachusetts
Richard Wagner	Ottawa, Canada
Gary Walker	South Yarmouth, Massachusetts
Kathy Walker	South Yarmouth, Massachusetts
Bradley S. Walter	Lockhart, Texas
Christopher Watson	San Diego, California
Doug Welch	Dundas, Canada
Barbara L. Welther	Woburn, Massachusetts
Carmen Wilkerson-Montout	New York, New York
Winston Wilkerson-Montout	New York, New York
Anna Fay Williams	Houston, Texas
David B. Williams	Whitestown, Indiana
Thomas R. Williams	Houston, Texas
Lee Anne Willson	Ames, Iowa
Patrick Wils	Hever, Belgium
Robert F. Wing	Columbus, Ohio
Ronald Zissell	South Hadley, Massachusetts

Schedule for the 100th Annual Meeting of the AAVSO, held in Cambridge and Woburn, Massachusetts, October 5–8, 2011

Tuesday, October 4

8:00 a.m.
Council Meeting at Headquarters

Wednesday, October 5

8:00 *a.m. breakfast provided*
8:30 *a.m. registration*
9:00 History Papers Session 1: Women in AAVSO History
10:30 *coffee break*
11:00 History Papers Session 2: Women in AAVSO History
12:30 *p.m. lunch break*
2:00 History Papers Session 3: History of Variable Star Organizations
3:30 *coffee break*
4:00 History Papers Session 4: History of Variable Star Organizations
6:30 AAVSO Leadership Banquet at Headquarters

Thursday, October 6

10:00 *a.m.*
HQ building dedication and time capsule ceremonies
12:00 *p.m. lunch break*
5:00 Duck boat tour and lobsterbake

Friday, October 7

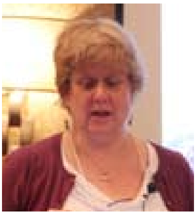
8:00 *a.m. breakfast provided*
8:30 *registration*
9:00 Membership meeting
11:00 *coffee break*
11:30 Book reading and signing; musical performance
12:00 *p.m. lunch break*
1:30 Paper Session 1
2:30 Paper Session 2
7:00 History Papers Session 5: Variable Star Observers

Saturday, October 8

8:00 *a.m. breakfast provided*
8:30 *registration*
9:00 Paper Session 3
10:30 *coffee break*
11:00 Paper Session 4
12:30 *p.m. lunch break*
2:00 Paper Session 5
3:30 *coffee break*
4:00 Poster and centennial picture session
6:30 *cash bar*
7:00 AAVSO Centennial Banquet

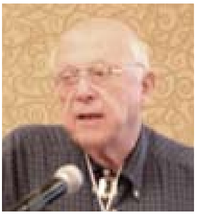
The Paper Sessions—photographs of the presenters

History Sessions

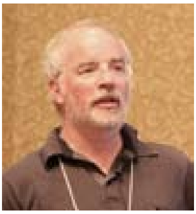

Kristine Larsen


Michael Saladyga

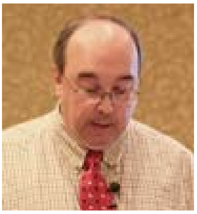

Elizabeth O. Waagen


Thomas R. Williams

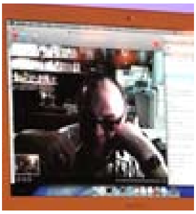

John Toone

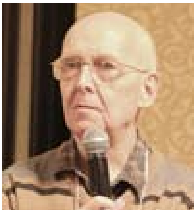

Josch Hambsch


Patrick Wils


Donn Starkey
for Stan Walker

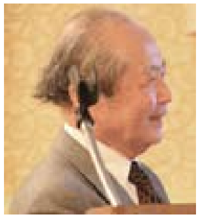

David Williams


Roger S. Kolman
via cyberspace


Charles Scovil

Scientific and General Sessions

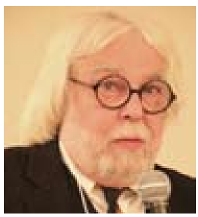

Mario Motta


Seiichi Sakuma


Karen Meech


John Percy


Paula Szkody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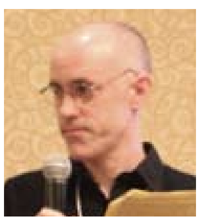
Barry Beaman

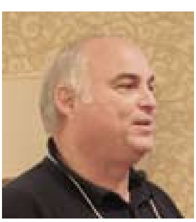

Gerald Dyck


Jamie Riggs


Sebastian Otero


Chris Watson


Stephanie Slater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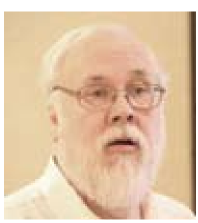
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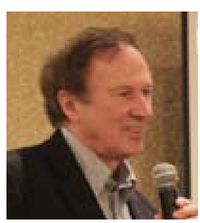
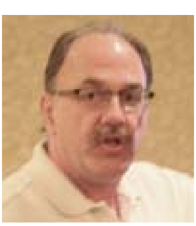
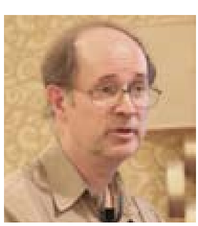
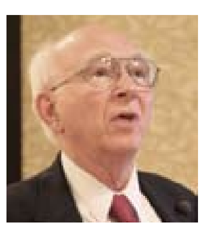

Ed Guinan


Lee Anne Willson


Kevin Paxson


Ed Los


Arlo Landolt

Meeting photo not available:

Caroline Moore
Rodney Howe

History session papers presented at the 100th Spring and Annual Meetings of the AAVSO

Introduction to the History Paper Sessions

Thomas R. Williams
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The AAVSO Centennial celebration occurred in many parts over the year 2011. But importantly, both the Spring and the Annual meetings (held in May and October, respectively) afforded opportunities to enlarge upon the general themes of the AAVSO's history presented in *Advancing Variable Star Astronomy* (AVSA; Williams and Saladyga 2011). In writing an institutional history like AVSA, it is difficult to incorporate as much detailed information about a large number of people who were active participants in variable star astronomy but not a part of the main flow of the AAVSO's history. Thus "people" became the primary focus for the history sessions in the semi-annual centennial meetings.

That keen interest in presenting more information about little known as well as major players in the history of the AAVSO actually stimulated plans for two separate series of papers: A series on women in the history of the AAVSO, and another series on important variable star astronomers. For these sessions, we solicited papers from our members and from well-known historians and other parts of the academic community where we knew interest in the individuals we wanted to highlight was high. Part of our strategy for the latter section was to couple the biographies with the history of stellar evolution and variable star astronomy to the extent possible.

It was particularly gratifying that the Women in AAVSO History section produced several nice surprises. One of those was the discovery that a biography of Helen Sawyer Hogg was being written and that the author, Maria Cahill, was willing to present a paper for the centennial meeting. Hogg had served as AAVSO president, but also provided important support to the AAVSO in other ways over her lifetime. Another surprise came when Kate Bracher volunteered a nice paper on Anne Sewell Young, another feminine figure from the earliest days in AAVSO history about whom too little was known. The grandest surprise of all, however, was that Kristine Larsen, who agreed to find out what she could about Martha Stahr Carpenter, not only did that but also discovered that Carpenter was alive and could attend the meeting. It was delightful to meet Martha Carpenter, the only president of the AAVSO to serve three consecutive terms in that position. During her term as president, she resisted attempts to relocate the AAVSO out of Massachusetts at the time the association was evicted from Harvard College Observatory (HCO). Carpenter thus preserved an important aspect of our heritage, the location of our headquarters in Cambridge, Massachusetts, near HCO.

The history of variable star astronomy received additional emphasis from historians and astronomers who considered various aspects of the discipline from its origins to modern times. Historian Robert Hatch debunked previously well-accepted understandings about the discovery of Mira as the first known variable star with an appropriate corrective discussion of "discovery" from the historian of science's perspective. That complete paper will appear in two parts in a future volume of *JAAVSO* and appears here only in the form of an abstract. Astronomer Linda French enriched the well-known story of Goodricke and Pigott's searches for, and studies of, variable stars, while historian Matthew Stanley explained in his paper on Arthur Stanley Eddington how surprisingly important the evolution of pulsation theory was to the entire development of stellar evolution theory. Steve Kawaler then carried the story of stellar evolution to modern times. Photoelectric photometry (PEP) received its share of attention when Barry Beaman summarized the earliest work of Joel Stebbins as he developed the equipment and techniques involved, and made important discoveries using them, while John Percy reviewed the history of the AAVSO PEP Committee.

Yet another theme in which we were interested involved the organization of variable star astronomy, recognizing that the AAVSO was by no means the only organized effort in this discipline. Representatives of other well-known associations of variable star observers were invited to participate in the centennial celebration with papers summarizing the history of their own organizations. We were pleased that many of these important associations accommodated our request. John Toone (BAA-VSS), Josch Hambsch (BAV and GEOS), Patrick Wils (WVS), and Stan Walker with Albert Jones (RASNZ-VSS) contributed to these presentations from other organizations, while David Williams reviewed the history of eclipsing binary observation as promoted by others, and eventually as an organized part of the AAVSO's program.

Finally, we were aware that many longer-term members of the AAVSO had stories to relate regarding their vso-ing friends who have passed from the scene. Roger Kolman chose to express those memories of many friends through his own story as a member for nearly a half-century, while Tony Hull focused on just one friend, Clint Ford, as an early supporter of a child's interest in astronomy. Charles Scovil recalled Ford as well as many other members with whom he had contact over his extended service to the AAVSO. Gerry Dyck, on the other hand, recalled an important variable star observer, Frank Seagrave, who was observing well before the founding of the AAVSO but never joined after William Tyler Olcott established our organization a century ago.

I hope you enjoy reading these and many other papers presented in these history sessions as part of the AAVSO's centennial celebration.

Reference

Williams, T. R., and Saladyga, M. 2011, *Advancing Variable Star Astronomy: The Centennial History of the American Association of Variable Star Astronomers*, Cambridge Univ. Press, Cambridge.

Women in the History of Variable Star Astronomy

Anne S. Young: Professor and Variable Star Observer Extraordinaire

Katherine Bracher
Department of Astronomy, Whitman College, Walla Walla, WA 99362; kbracher@earthlink.net

Presented at the 100th Spring Meeting of the AAVSO, May 22, 2011; received March 15, 2012; accepted March 19, 2012

Abstract One of the original eight members of the AAVSO, but not well known today, was Professor Anne Sewell Young of Mount Holyoke College. Miss Young taught there for thirty-seven years, and trained many women astronomers during the first third of the 20th century. This paper will attempt to present her life as an inspiring teacher, as well as a contributor of more than 6,500 variable star observations to the AAVSO.

1. Biography

Anne Sewell Young was born in Bloomington, Wisconsin, on January 2, 1871, into a family with many connections to astronomy (see Hazen 1985). Her grandfather, Professor Ira Young, held the Chair of Natural Philosophy and Astronomy at Dartmouth College. The Shattuck Observatory at Dartmouth was built for him, and designed by his older brother Ammi B. Young, a well-known architect. Ira's wife Eliza Adams' father, Ebenezer Adams, also taught astronomy and mathematics at Dartmouth. Ira and Eliza Young had two sons. Charles Augustus Young became a well-known astronomer at Dartmouth and Princeton, where he taught such luminaries as Henry Norris Russell. The younger son, Albert Adams Young, a Congregational minister and Home Missionary, served as a pastor at various churches in Wisconsin, Iowa, and Indiana; he also had an interest in science (geology). Albert married Mary Sewell, who had come from Halstead, England, as a child in 1834. Their two daughters were Anne Sewell Young and Elizabeth Adams Young, who was four years older than Anne.

Anne Young attended public schools in New Lisbon, Wisconsin, and graduated in 1886. In the fall of 1888 she entered Carleton College in Minnesota, which had been founded by the General Conference of Congregational Churches in 1866. Its founder was Charles M. Goodsell, after whom their observatory, begun in 1887, was named. The Goodsell Observatory was quite active, and as early as 1882 began to publish *The Sidereal Messenger*, which in 1893 became *Popular Astronomy*. Although Anne Young completed a B.L. degree at Carleton, she took quite a bit of mathematics and astronomy as an undergraduate.

In the fall of that year she took up a post as Instructor in Mathematics at Whitman College in Walla Walla, Washington. The College had been founded as a secondary academy in 1859, in memory of Marcus Whitman and his wife

Narcissa, early Congregational missionaries to the Oregon territory who had been massacred in 1847. In 1883 it had become a full-fledged college, with sixty students and three senior faculty. By 1892 the faculty of about five all taught a wide range of subjects: Miss Young taught geometry, algebra, analytic geometry, German, elementary rhetoric, mid-prep English, and commercial law during her three years there, and in spring 1894 offered a course in Elementary Astronomy. She also served as Secretary of the Faculty, taking minutes of monthly faculty meetings, and during her first year she founded an Astronomical Club for students. President Stephen B. L. Penrose, who came to Whitman in 1894, described her as "highly admirable for her mathematical ability, her teaching skill and her personal character" (Penrose 1935).

In 1895, however, at the end of the school year, she resigned her position for reasons of ill health, and probably returned to her family. By September of 1896 she was back at Carleton, working on a Master's degree, which she received in December 1897. She then spent the spring term at the University of Chicago's newly opened Yerkes Observatory, where she worked with J. A. Parkhurst on photometric work. She continued this collaboration for many years, returning to Yerkes in summers as a volunteer research assistant. In the fall of 1898 she became principal of a high school in St. Charles, Illinois. But the turning point of her career came when she accepted an appointment as Head of the Department of Astronomy and Director of John Payson Williston Observatory at Mount Holyoke College, in South Hadley, Massachusetts. In September 1899 she arrived in South Hadley, where she was to spend the next thirty-seven years of her life (Figure 1). It seems possible that her uncle, Charles A. Young, was involved in her securing this post, as he was a Trustee of Mount Holyoke and a frequent lecturer there.

Mount Holyoke was a venerable and highly respected college for women, founded in 1837 by Mary Lyon. From its inception a brief course in astronomy had been included in the curriculum, and was required of all students until 1888. The Williston Observatory was dedicated in 1881, and provided with an 8-inch Alvan Clark refractor. A classroom was added in 1903; the observatory remains the oldest building on campus. Professor Elizabeth Bardwell taught astronomy from 1866 until her retirement in 1899. Her introductory course was by no means elementary, requiring trigonometry and physics as prerequisites; though in 1895 she added a one-credit non-mathematical course. Seniors could elect a history of astronomy course or a course in practical astronomy; an astronomy major was introduced in 1895. In 1896–1897, Mount Holyoke had 330 students, of whom 61 took astronomy. Thus when Anne Young arrived in 1899 to take Miss Bardwell's place, she found a well-equipped observatory and a firmly established program awaiting her.

At first Miss Young offered the same courses as her predecessor. But in her second year she added an observational course, and she and the students observed Nova Persei 1901. In 1900 she also began keeping daily sunspot records, an activity which was continued at Williston Observatory for at least the next sixty years (it was still being done when I was a student there in the late 1950s.) She soon added a course in celestial mechanics. And in 1902 she began observing variable stars for E. C. Pickering at Harvard College Observatory, an activity which she continued for many years.

In 1905 Miss Young decided to take a leave and pursue a Ph.D. degree; she attended Columbia University in 1905–1906, and worked under Harold Jacoby on the Double Cluster in Perseus, utilizing plates taken in the 1870s by Lewis M. Rutherfurd, a wealthy amateur astronomer and photographer. Her final result was a catalogue of 145 stars, giving right ascension, declination, precession and its secular variation, and magnitudes obtained from measures of star diameters. This dissertation earned her a Columbia Ph.D. in June of 1906.

Dr. Young then returned to Mount Holyoke, to a consistent pattern for the next several years of classes and observations during the academic year, and some time during the summer at Yerkes as a volunteer research assistant. In 1910 she held open houses at the observatory to show Halley's Comet to visitors. And in 1911, as an outgrowth of the variable star work done for Pickering, she was one of eight original members of the AAVSO, founded in that year by William Tyler Olcott. She contributed data to their monthly reports until 1935.

In 1913 a second full-time instructor position in astronomy was added to the department, and this gave Miss Young time to try a new course in General Astronomy, emphasizing recent developments. In its first year Irene Southworth (later Coulton; class of 1915) was the only student to sign up for it; but Miss Young wanted to try it out, so they did it together. Mrs. Coulton recalled in a letter that during the fall Miss Young was ill for some weeks, but gave her written assignments to do and progress reports to make in her absence. The course evidently became a success, as it was continued in subsequent years and expanded to two semesters (Coulton 1980).

The astronomy program remained unchanged during the war years, though Miss Young was in charge of Red Cross work at Mount Holyoke in 1918. She continued to attend meetings of the AAS and AAVSO (Figure 2), as she had done for years, and was elected AAVSO vice-president in 1919 and then President in 1922. In the fall of 1920 her former student Alice H. Farnsworth (class of 1916) joined the faculty as an instructor in astronomy; this marked the beginning of a long and happy association between the two.

In the late summer of 1923 the two of them, along with many other astronomers, traveled to southern California's Catalina Island to observe the total solar eclipse of September 10. Some seventy astronomers set up observing stations at Camp Wrigley, and made elaborate preparations for the much-vaunted good weather of California. But they were all doomed to disappointment, as eclipse day dawned completely cloudy and remained so all day.

However, at Mount Holyoke they soon were preoccupied with plans for the eclipse of January 24, 1925, which would be total in Connecticut, not far from the college. The eclipse would occur during the final examination period, but no tests were scheduled for that day, so that all students could go observe it. Miss Young arranged for Mount Holyoke and Smith Colleges to use the golf links at Plymouth Meadow Country Club of Windsor, Connecticut, and she also arranged for a special train to take students there.

As soon as classes resumed after the Christmas holidays, Miss Young began preparing the students for what to expect. Their chances of clear weather were about 50%; the trip would go regardless of weather, since she knew of occasions where it had been pouring rain ten minutes before totality and yet was clear at the crucial moment. By January 16 about 700 students had signed up to go to Windsor, and another seventy planned to observe at some thirty other places in the path. Pieces of dark film to look through were sold at the college post office for five cents; the train ticket cost $1.31.

On Saturday, January 24, the college was awakened at 5:15 a.m. by the fire alarm bells. An hour later, eight hundred students crowded into trolleys for Holyoke and then onto special trains to Windsor. The partial stages had begun before they arrived. Crowds toiled through the snow to the top of the hill, and stood in four below zero degrees weather to observe, under clear skies. The corona showed long streamers, out to a couple of solar diameters. Everyone saw planets, and some saw the stars of the Summer Triangle. They also remarked on the colors: the deep blue sky, with topaz yellow along the western horizon, and purple tints on the distant hills. Nearly a hundred students subsequently turned in written reports to Miss Young, and some also provided photographs. Helen Sawyer Hogg (class of 1926) remembered later the glorious spectacle and the careful training which Miss Young gave to her observers (Sawyer Hogg 1962).

After this excitement life continued more normally at Mount Holyoke. Miss Young and Miss Farnsworth went to Europe in the summer of 1927, hoping to see the solar eclipse of June 29 in England; but it was cloudy. Miss Young took a well-deserved sabbatical in 1928–1929, and spent it on the west coast as a research associate at the University of California at Berkeley. Her sister Elizabeth accompanied her, and they had a small apartment together. The two spent a few weeks at Christmas in southern California, visiting friends and Mount Holyoke graduates, and going to Mount Wilson. They met many AAVSO members during this year, especially in the San Francisco area, and noted in California considerable interest in astronomy, but not many regular observers.

After this the sisters settled back in at South Hadley, and continued their practice of entertaining students at tea. Miss Farnsworth was on leave in 1930–1931, and her place was taken by Helen Sawyer Hogg ’26. Mrs. Hogg had started at Mount Holyoke as a chemistry major, but upon taking astronomy from Miss Young in her junior year she was converted, and she went on to a distinguished career in astronomy. In the 1930s Miss Young and Miss Farnsworth added some new observational courses, and continued observing occultations, variable stars and sunspots.

On August 31, 1932, a total solar eclipse crossed the state of Maine. This was during the summer holidays, so no major venture like that of 1925 was planned. But Miss Young, Miss Farnsworth, and several others went to an alumna's home in South Portland to see the event. Their chances for good weather were about 50%. Miss Farnsworth went to Douglas Hill, at the Perkins Observatory site, and was clouded out; Miss Young and those who stayed at South Portland had a clear sky and 93 seconds of totality. They saw prominences and a fine corona.

The next few years were Miss Young's last before retirement in 1936. She continued her usual routine of courses, carrying out observations and speaking to amateur astronomy groups. Her last annual departmental report lamented the fact that since students were no longer required to take mathematics, there was an increasing reluctance among many to take anything involving figures. And she concluded by modestly saying that though she had always fallen short of what she hoped to accomplish, what she had achieved was largely due to the support of her co-workers. She was delighted to be able to leave the department in the capable hands of Alice Farnsworth.

In June 1936 she retired, at the age of sixty-five, and became Professor Emerita. She and her sister then returned to the family home in Winona Lake. But in November of 1937, the Misses Young went to Claremont, California, for the winter. By March they had decided they liked it so well that they would move there. They spent the summer of 1938 at Winona Lake, and in the fall began to build in Claremont's Pilgrim Place, a settlement for retired missionaries and their relatives. In 1939 the Indiana house was sold, and they settled in Claremont, where they happily spent the rest of their lives (Figure 3).

Anne Young never did return east to Mount Holyoke. Even in 1948, when the AAVSO met at Mount Holyoke and there was a special ceremony in her honor, she could not attend, but sent a telegram. In 1955 Carleton College gave her an Alumni Award of Merit, for "unusual accomplishments in research and college teaching." But this too was awarded in absentia. In October of 1956 she suffered a stroke, and eventually she and Elizabeth gave up their house and moved into a nursing home at Pilgrim Place, where they had rooms across the hall from each other. Miss Young still kept up her correspondence, even when she had to dictate to others, and she continued to keep in touch with her former students and keep them up to date on each other. On August 15, 1961, at the age of ninety, she died in the nursing home.

2. Conclusion

Anne Young was a thorough, careful astronomer and an enthusiastic and dedicated teacher. Helen Sawyer Hogg (1962; class of 1926) has written that "she impressed me as being devoted to her astronomy students and eager to encourage young women to major in astronomy." Margaret W. Beardsley (1980; class of 1934) noted that she was "a good teacher, an interesting lecturer and an enthusiastic astronomer," and that she and Alice Farnsworth accomplished more in the small Williston Observatory than many other departments did in much better surroundings.

Her students also remembered her as one who took a personal interest in them and their welfare. In several cases when she heard of an illness of one of her students, she paid a visit and offered the services of her own doctor. She was reserved in manner, but warm and sympathetic to those she knew.

Her influence on the astronomy program at Mount Holyoke was profound, and lasted far beyond her own time there. In 1956 we were doing lab exercises (mapping the sunset point along the Mount Tom range, drawing constellations, timing star transits with the meridian circle) which Irene Southworth Coulton (class of 1915) described doing when she was in Miss Young's class in 1913 (Coulton 1980). And students whom she trained have done much to further astronomy at Mount Holyoke and elsewhere. As Margaret Wallace (1980; class of 1916) wrote me, "for me, Miss Young was one of the real stars at Mount Holyoke."

3. Postscript

Miss Young's career and mine seem to have paralleled each other in a number of ways. I grew up in Claremont, California, where Miss Young lived in retirement; indeed, I visited her once there during my years in college. In the fall of 1956 I entered Mount Holyoke College, and took introductory astronomy from Miss Farnsworth. Unfortunately during the Christmas break she suffered a stroke, and was unable to teach thereafter; the college brought in various visiting lecturers to cover the spring semester for us. Two of these were Helen Sawyer Hogg and Dorrit Hoffleit, discussed in other papers in this issue. That spring of 1957 saw the visit of Comet Arend-Roland; I spent much extra time observing the comet, and that along with the exposure to several impressive women astronomers hooked me on majoring in astronomy. After I finished my graduate work at Indiana University, and taught for two years in southern California, I went to Whitman College in Walla Walla in the fall of 1967, and taught astronomy there for thirty-one years. My successor there is Andrea Dobson, one of my former students, as I was to Alice Farnsworth and she was to Anne Young. And so the dynasty continues, with Andrea being Anne Young's academic great-granddaughter.

4. Acknowledgements

I would like to thank Thomas Williams for suggesting this project, and for useful information. I would also like to thank the archives of Mount Holyoke, Carleton, and Whitman Colleges for access to their files, and the various Mount Holyoke alumnae who shared their memories of Miss Young with me.

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Figure 1. Anne Sewall Young, during her early years at Mt. Holyoke College. The photograph, which hangs in the Williston Observatory at Mt. Holyoke, was first unveiled there during the spring meeting of the AAVSO, May 22, 1948.

Figure 2, Anne S. Young with S. A. Mitchell of Leander McCormick Observatory, about 1919.

Figure 3. Anne S. Young with astronomer Alfred H. Joy of Mt. Wilson Observatory, in the garden at Pilgrim Place, Claremont, California, where Anne Young and her sister, Elizabeth, resided. The occasion was a visit by Helen Sawyer Hogg and the Joys in 1956. Photo courtesy of Helen Sawyer Hogg to the author.

The Stars Belong to Everyone: Astronomer and Science Writer Helen Sawyer Hogg (1905–1993)

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Presented at the 100th Spring Meeting of the AAVSO, May 22, 2011; received January 31, 2012; revised March 1, 2012; accepted March 7, 2012

Abstract As a scientist and science educator, Helen Sawyer Hogg served astronomy, and especially variable star astronomy, in diverse ways while raising a family. Her long interest in and support of the AAVSO over many years took place in the context of not only that busy scientific and writing career, but also one of personal struggle to achieve parity as a female in a largely male profession. This biographical sketch demonstrates that her path to eventual status as "the Canadian face of astronomy" was both difficult and filled with uncertainty.

1. Introduction

University of Toronto astronomer Helen Sawyer Hogg (AAVSO President 1939–1941; Figure 1) served her field through research, teaching, and administrative leadership. Additionally, she reached out to students and the public through her *Toronto Star* newspaper column entitled "With the Stars" for thirty years; she wrote *The Stars Belong to Everyone* (Hogg 1976), a book that speaks to a lay audience; she hosted a successful television series entitled *Ideas*; and she delivered numerous speeches at scientific conferences, professional women's associations, school programs, libraries, and other venues. Eventually, she became known as the "Canadian face of astronomy" (Faught 2002). This article will illuminate her life and the personal and professional forces that influenced her work.

2. Early educational influences

In a speech given to the American Association of Physics Teachers and the American Physical Society, Helen spoke of childhood years with a family that was

> keenly interested in all aspects of nature. My father took me for walks along the Lowell waterways; my mother collected many things, including minerals; my aunt pressed wild flowers, and they all took me as a small child out at night to see the stars, especially the magnificent constellation of Orion, the only constellation visible

> from these latitudes with two first magnitude stars, and Halley's comet. (Hogg 1985)

Unfortunately, when Helen was only twelve years old, her father passed away; however, he was an astute banker who left his family in comfort. Helen's mother did not have to work and was able to send her daughter to college. Education was a priority (MacDonald 2004b). And when Helen began her college studies at Mount Holyoke, she took her family's love of nature and the stars with her and, briefly, became a chemistry major (Clement and Broughton 1993). However, at Mount Holyoke, the library was adjacent to Williston Observatory, and Helen found herself reading many books on astronomy (Gingerich 1987). Then Helen's professor, Dr. Anne S. Young, took her astronomy students on a special train from Massachusetts to Connecticut to view the total eclipse of the sun. On January 24, 1925, the students stood with "horribly cold feet...almost knee deep in the snow [and] view[ed] the eclipse from the path of totality." Many years later, Helen exclaimed that "the glory of the spectacle seems to have tied me to astronomy for life" (Clement and Broughton 1993). So, Helen's interest in and love of astronomy grew over time but cemented itself on that auspicious day in 1925.

Paving the way for Helen's success in her new-found field was a meeting with noted Harvard astronomer, Annie Jump Cannon, just one year after the eclipse. Shortly after their meeting, Cannon arranged for Helen to continue graduate studies under the Harvard College Observatory director, Dr. Harlow Shapley (Clement and Broughton 1993). Her graduate appointment changed her life. Of her years at the HCO, Helen said:

> My office was next to [Miss Annie J. Cannon's] and for many hours I heard the sound of her voice as she called out the spectral classifications of stars to her assistant, sometimes for many thousands of stars on one 8 by 10 inch plate. I really did not realize at the time that I was myself participating in the start of the major graduate school in astronomy at Harvard or Radcliffe, ...sparked by the dynamic personalities of Cecilia Payne and Harlow Shapley, each of whom was worthy of the term genius in various ways.... Cecilia's astronomical genius was really ahead of her time and it left her with years of frustration that, because she was a woman, she was not receiving fair treatment. Also in September 1926 Frank Scott Hogg arrived at the observatory to begin doctorate studies.... He was able to complete his doctoral work under Cecilia Payne as supervisor in three years and in 1929 he received the first Ph.D. [in] astronomy awarded by Harvard University. My own doctoral degree was in 1931, the third awarded by Radcliffe in astronomy. It was certainly one of the happy circumstances of my life that Frank and

> I were attracted to each other and were married in September, 1930, with many common interests to share. (Hogg 1985)

At Harvard, Helen established her scholarly voice and first collaborated on scholarly work with Shapley, who became her foremost professional confidante until his death in 1971. Helen's other mentor was her beloved husband and colleague, Frank Hogg. By the time she completed her Ph.D., she had already published a dozen or so papers with Dr. Harlow Shapley (Clement and Broughton 1993).

3. Early professional years as scientist, wife, and mother

In 1931, shortly after their marriage, Frank Hogg was hired at the Dominion Astrophysical Observatory (DAO) in Victoria, British Columbia (Clement and Broughton 1993). According to Helen Hogg,

> In 1924 J. S. Plaskett wrote to Henry Norris Russell asking for a recommendation for an open position at the DAO. Russell noted that "quite the best of the young folks" in astrophysics was Cecilia Payne. J. S. Plaskett responded that "there would be difficulty about the observing end of it with a woman in this isolated place and I think we can hardly consider her." Not till I read this statement did I realize that my superb observing privileges with the 72-inch reflector had been made possible by the automatic presence of a built-in chaperone, my husband. (Hogg 1988)

It is not clear, other than J. S. Plaskett's simple statement, why Cecilia Payne did not receive a job offer. However, Owen Gingerich interviewed Helen in 1987, and she reflected on this critical period in her and Frank's life. According to Helen, Frank, although Cecelia Payne's student, also worked directly with J.S. Plaskett's son, H. H. Plaskett, at Harvard. Frank and H. H. Plaskett had become close. Helen did not indicate that she suspected this relationship was the reason for her husband's employment; however, it seems logical. When the DAO position opened, J. S. Plaskett had more than one qualified candidate; he picked the male astronomer who was qualified, would meet social conventions, was friends with his astronomer son, and would, indeed, bring with him another highly qualified astronomer for free: Frank's wife, Helen.

However, Helen's participation was still limited because, during the Depression, the Canadian Government considered it unconscionable to employ two individuals from one family. Therefore, Helen worked as an unpaid volunteer from 1931 to 1936. She utilized the "72-inch...telescope to search for and study variable stars in globular clusters as a 'volunteer astronomer'" (Clement and Broughton 1993). According to Helen, "I took my first globular cluster plates on September 22, 1931" (Hogg 1988). Globular cluster variable stars, the subject of her graduate research, remained the focus of her interest throughout her astronomical career (Clement and Broughton 1993).

During her years at the DAO, Helen gave birth to the Hoggs' first child, Sally, on June 20, 1932; Helen halted work for five weeks, and resumed observing on July 27th:

> As I was nursing her, it meant that she had to come to the dome with us for the night. This resulted in some world-wide publicity because the Astronomer Royal of England, Sir Frank Dyson paid a visit to the Dome. A jovial individual and traveler and a great story teller, he loved to tell how as he mounted the stairs to the observing floor of the dome he heard a whimpering and exclaimed "What's that!" and [J. S.] Plaskett calmly replied, "Oh, that's the Hoggs' baby in its basket on the platform by the pier." The story has come back to me in various forms, including one in which I was said to let the baby in her basket down on a rope from the Newtonian platform. (Hogg 1988)

In reality, Sally stayed below while her mother stood at the top of the dome in the Newtonian cage and worked. Although Helen remained a volunteer, in 1932, J. S. Plaskett helped her with a grant (Hogg 1988). In the end, Helen's work at the DAO put her in a position to eventually be hired by Dr. C. A. Chant of the David Dunlap Observatory (DDO) and the University of Toronto (UT) (Clement and Broughton 1993).

4. The University of Toronto years

For a year following Frank's employment at the DDO, while she was establishing their new home, she worked as an unpaid volunteer. However, she did not complain and continued publishing all along; and in 1936, Helen was offered a paid position as a research assistant (Clement and Broughton 1993).

Then once the depression passed and Helen was finally employed, few opportunities escaped her. In Toronto, she had a growing family of three children, and she worked hard both as a scientist and as a mother. Although employed by the University of Toronto, Helen worked as acting chair at Mount Holyoke during the 1940–1941 academic year. More than likely, she was chosen because she was a successful and collegial alumna with strong family ties to the area, yet the circumstances regarding that position are unclear. When she returned to the University of Toronto in 1941, she was promoted to a teaching position. It was the onset of WWII. Four researchers from the DDO joined the Canadian armed forces, as Helen described it, leaving only "Dr. R. K. Young, Dr. Frank Hogg, with a heart ailment, myself and Ruth Northcott, who ran the 74-inch telescope nights and taught classes at the St. George campus of the University of Toronto by day." In 1946, Frank became director of the DDO and a full professor (Clement and Broughton 1993). During the war, many women assumed positions they had not been allowed previously. However, after the war, many women gave them up because they wanted to return to their former lives. It is possible that Helen may have advanced given those historic times, but she was already a trained and experienced scientist. Leaving was not an option for her, and she only received support from Dr. Chant and her husband, Frank.

5. Harlow Shapley and Frank Hogg

In spite of Helen's professional advancement, through the years, she became exhausted and frustrated with her combined role of astronomer and parent. Helen was a private person, however, who did not openly share her fears or frustrations. But she shared them with the two men she trusted—Frank Hogg and Harlow Shapley. The letters that follow allow us to see Helen as few knew her. In the late 1940s, Helen experienced a strong desire to leave the university and her research at the DDO, work that she loved. In a letter to Shapley on July 25, 1949, she wrote:

> All Spring I have felt very doleful.... I left the Ottawa meetings more depressed than when I went; and the night observing which I have been tackling systematically since my return has served only to convince me once more that I cannot fit in night work with my heavy family responsibilities. In other words, I seem to have reached the end of my tether. I have asked Frank to get me an indefinite leave of absence from my university position here, but he is very much upset at the thought.... Shortly after my return from Ottawa I had a letter from the secretary of the A.A.S. informing me of the Annie J. Cannon award, which of course you know about. In my opinion, this award carries with it a certain amount of responsibility, when made to a person my age, that is. In other words, it does not look so good to take the award and quit! Therefore I have not replied to Dr. Huffer's letter, but am turning the matter over in my mind. It has probably not crossed his mind that circumstances might make it advisable for me to refuse the award. (Hogg 1949)

This letter points to depression and a sense of overwhelming responsibilities to work and family. When she wrote this letter, she had already consulted her husband who strongly opposed her resignation. So, she turned to Shapley who, in his July 29, 1949 letter, said,

> There is little doubt but what you are undertaking too much in running a family at this critical stage...and doing everything else. A leave of absence from the University work is obviously a good idea; but a study, with astronomical literature in it, and some photographs of clusters and the computing machine—that should not be given up, even if it must be established in one corner of some room at home. And also probably there is some interesting and not too laborious writing about old books that should be done, just to keep the finger in the game until strength and time are less expensive. About that award—don't be silly, even if the weather is hot. The award is made for past accomplishments, and carries with it no responsibility for future activities. Suppose I should commence turning in medals because I have degenerated into being just a blank, blank director, personality smoother, instigator of labors by others. Let's both cheer up. One particular reason for such a resolve is that after fifteen or twenty lectures on cosmogony in the Harvard Summer School I have convinced myself that this is unquestionably the best universe I know of. (Shapley 1949)

Shapley is light-hearted and amusing, coaxing Helen out of her doldrums, while also suggesting a practical, though temporary, solution to her troubles. Shapley and Frank helped Helen persevere through this difficult time, and her work did not suffer. Over the next year and a half or so, Helen continued on, unaware of how much worse her life would become, and in such a short time.

6. A time of loss

When Frank and Helen married, they knew that he didn't have a normal life expectancy; in fact, he couldn't even get life insurance. As a boy, Frank had rheumatic fever, but it had gone undiagnosed for some time and had damaged his heart. In 1941, Frank developed a two-star sextant; quickly, radar superseded it. However, he took the sextant in a small plane to test. As a result, he caught pneumonia, and it damaged his heart even more (MacDonald 2004a).

On January 1, 1951, ten years following his bout with pneumonia, Frank Hogg went into the bedroom to take an afternoon nap. He appeared to be fine that day. But he fell asleep and did not awaken. Helen and all three children were with him at the time. Frank's death was a deep emotional loss for Helen, Sally, David, and James. Fortunately, Helen had prepared. She had an astute business sense, and she had purchased stock, one share at a time, so that when her husband died, she had a nest-egg and knew how to manage her finances. Her and her children's financial future was relatively secure (MacDonald 2004a).

Helen had always been a hard worker, but following Frank's death on January 1, 1951, she threw herself into her work. She was fearful that *The*

Toronto Star would drop Frank's column, which he had written for ten years. Even though the column was established, the agreement Frank had had with *The Star* remained week-to-week. Helen wanted to write the column because she loved writing, particularly for a lay audience, and because she also wanted the income. But it is possible, although it cannot be verified, that Helen longed to continue her beloved husband's column simply because they had been close as husband and wife as well as colleagues, and she hoped to continue the column in his tradition. Therefore, on her behalf, friends appealed to *The Star*'s management, and she was allowed to assume Frank's column at a compensation of $5.00 per week. In her grief and bereavement, Helen remained focused. Fortunately, her children were teenagers and had already achieved some degree of independence (MacDonald 2004a).

Nonetheless, Helen wrote a letter to Shapley on February 7, 1951, just five weeks after Frank's death, expressing her exhaustion between personal obligations and work:

> The past month has seemed impossibly heavy for me with the work that had to be done, but eventually I shall get some of the backlog caught up, and not feel that I am behind with everything. Dr. Heard is the acting head of the observatory. It is my understanding that the new permanent head will be appointed as of July 1 [replacing Frank Hogg]. My own promotion as Assistant Professor has come through simultaneously with a good boost in the salary scale here.... At present I am teaching two courses, which takes me virtually all of two full days in the city. I have the weekly article in The Star, which takes me several hours, but I consider quite vital. Do you know how many astronomical articles have a circulation of 400,000? I think I am making out quite well with the column. I enclose a copy of my first one, which I wrote about Frank. Then I have "[Out of] Old Books" (essays on the history of astronomy, published in *JRASC*), and all fall I had been working hard on a series about Le Gentil from the volumes I got at H.C.O. in November. This particular job ran into a hundred or more hours, and I am struggling for time to get it in final shape for three installments in the Journal. Then there are the usual meetings, long distance visitors...which cut in to time, not to mention household activities. I am well along with the settlement of Frank's estate, and have written about 200 acknowledgements so far. The time that is left from the above activities I can spend on globular cluster research. The past month there has been none left. But I think this state of affairs will alter markedly the first of April when lectures stop. I hope so. I am wondering if there is any chance that I can get over to Michigan to hear you, as I would certainly enjoy a chat with you. (Hogg 1951a)

In spite of her dedication, Helen found herself caught up in personal and professional obligations that kept her from her research. At first glance, her letter appears matter of fact, yet it is dotted with phrases like "impossibly heavy" when describing her work; "struggling for time" in reference to her writing for "Out of Old Books"; and "200 acknowledgements" when referring to correspondence resulting from her husband's death. Of course, with three teenage children, there's much not said in this letter. Noticeably, Helen speaks positively of her writing for *The Star*, "which takes me several hours, but I feel is quite vital.... I think I am making out quite well with the column."
Then, after twenty years of work in the field and fifteen years with DDO and UT, she received a promotion to assistant professor, and she mentions this to Shapley without complaint. Frank received full professorship in 1941; however, he had worked only a few years longer than she and was not known for his research. Helen wrote to Shapley on April 14, 1951, and then, again, on May 17th: But she still felt overwhelmed, expressing both gratitude with those who had proved their friendship and frustration with those who had not (Hogg 1951b, c).

This was a season of loss for Helen. Although generally healthy and vital, along the way, she had her own health problems. In 1946, she had a hysterectomy. In 1952, following Frank's death, she became very ill with serious bowel obstructions. However, while in the hospital, her daughter, Sally, stated that in a hushed, croaked voice, her mother said, "I have to write the column" [for *The Star*]. Helen was terrified if she missed a week of her column, *The Star* would drop her. So, she wrote that week's column from her hospital bed (MacDonald 2004b). Although it has been impossible to legitimize Helen's fear of being dropped, her concern was clearly confirmed by her daughter, Sally, who served as her mother's typist for several years.

From 1949 to 1953, her frustration with her work-related life and responsibilities only increased, as read in her March 3, 1953, letter to Shapley:

> This has been one of the dreariest winters I ever lived through. I think I have never in my life hated my work as I have this year. (This of course is confidential, as I am not yet willing to go on public record as an astronomy-hater.) This has been due to an unfortunate combination of a variety of circumstances. No one person is to blame for the sum total. But the past several months I have been driven more and more toward what appears to me now as an inescapable conclusion, namely that I never will be in control of my life here. I am battling too many separate things that I do not like, and I will never be able here to feel that the game is worth the struggle. It is still my hope to remain in Canada two more years, until James finishes Grade XIII at Richmond Hill high school.... I have started a separate bank account into which I am pouring a substantial sum of cash reserves. All this is preparation for the fact that I propose to

> work through one more academic year here, which I agreed to do some time back, and then for the following year, beginning July 1 1954 I intend to be as free as the proverbial birds of the air. I intend to keep on with my Star column as long as the editors will take it, because that is still pure enjoyment for me, and provides a small bit of income as well. I have felt better in my mind since I embarked on a definite course of action. I am going to the bank this noon to make my March deposit on my F. F. (Freedom Fund). All the above is super-confidential as I have discussed this matter with no one here. As you are probably aware I am not given to discussing my problems with a dozen or more friends. I do not intend to announce my plan here until next fall, which I consider fair notice. (Hogg 1953a)

Just two years following her husband's death, she was ready to leave her work at UT and DDO—leave astronomy altogether—except for her column. In the numerous interviews, no one expressed knowledge of Helen's despair. A lack of control over one's destiny can, indeed, prove the most frustrating of all. She does not, however, elaborate over the situation(s) and indicates that the problems come from a number of directions.

Shapley returned Helen's letter with a lengthy one of his own, and he did so within the week, thus dated March 9, 1953:

> Since you write me with confidence I can reply in an equally confidential manner from your old school. Things are not going well here. It has been the unhappiest of the thirty-two years I have spent in this institution.... All was sweet and rosy until I walked out of the administrative picture with the resolve and expectation of having nothing more to do with the administration here. The past should not govern the future. I have stuck with my resolution, of course.... I shall send you a copy, if I can find one, of my last report as Director. It will remind you that this was, and has been, up to now, a nice place! And now here comes the most important paragraph of this confidential communication. Almost certainly within two or three months a new director will be chosen. Mr. Conant has left the University permanently. There will be a new president.... I am hopeful not only that Harvard's eye-hold in the southern hemisphere may be in part retained, but also that the Harvard Observatory friendly spirit of past years can be rescued. Instead of those foregoing paragraphs I should have written you my regret and also my astonishment at the general tenor of your letter, I sympathize with you. (Shapley 1953)

Within this letter Shapley responds with his own departmental "woes," reflecting fondly on a time when the H.C.O. was a respected and congenial unit, and he provides his former student with words of understanding and consolation.

7. The tide turns

Just days following Shapley's response on March 24, 1953, the tide turned for Helen, and she writes that Dr. Baade offered her a summer vacation job in 1955: "especially since Frank's death, I have become a globular cluster on a desert island. I need more company with other globular clusters.... Dr. Baade does not know me personally very well, and of course he did not realize he was giving my dejected spirits a real lift!" (Hogg 1953b). Helen was twirling many plates in the air when Frank Hogg died, and it finally caught up with her. Dr. Baade's offer gave her something concrete to hold onto.

Just two years later, she was offered a year-long position at the National Science Foundation (NSF) (Hogg 1955). From September 1955 to June 1956, Helen was Program Director of the National Science Foundation in Washington, D.C. Even though UT had been unhappy with her departure, when she returned from Washington, she was offered a better appointment; her daughter, Sally MacDonald, speculated that her mother took the NSF position not only out of interest, but to hedge against struggles at UT (MacDonald 2004b). Yet, this isn't evident in her letters to Harlow Shapley. In the past, Helen had struggled with the university enough to consider leaving. From this point on, however, she remained entrenched in the University of Toronto and in her teaching and research.

8. Influence

Over the years, Helen wrote a variety of articles (for professional and lay readers) for the *Journal of the Royal Astronomical Society of Canada* (*JRASC*). In addition to her teaching at the University of Toronto, Helen's column in *The Star*, her book, and her television series exemplify her commitment to education. At the time of Helen's death in 1993, the president of the RASC, Peter Broughton, said, "But perhaps her greatest memorial is the appreciation of a larger universe which her popular writing instilled in thousands of ordinary Canadians" (Pipher 1993). Because of Helen's public writings, she became a well-known name in Canada. According to Helen's former graduate student, Christine Clement (2004), Helen said, "We women need to stick together," and she demonstrated this belief by mentoring her students and modeling the relationship that she and Shapley held.

In January 1993, Helen, Dr. Robert Garrison, and other scientists from UT (primarily female), created a film, *Discovering Science*, geared toward late elementary and middle school girls. One of the movie's final scenes is of young, middle-school-aged girls sitting around Helen and listening to her talk about the pursuit of knowledge, in general, and science, in particular. Helen looks at the girls, smiling, and says, "Not to know what's beyond is like spending your life in the cellar, being completely oblivious of all the wonderful things around us" (Garrison 2004).

On the morning of January 25, 1993, Helen had a two hour taping session at the DDO. The evening of that last taping, Helen felt that she had made a small error, and she called the director to ask him to correct it. She became ill early the next morning, and she passed away two days later, January 28, 1993 (MacDonald 2004b; Garrison 2004).

9. Conclusion

Dr. Helen Sawyer Hogg's dedication was evident to all. She took more than 2,000 photographs, discovered hundreds of variables, and published more than 200 papers. Her knowledge of the night sky was phenomenal. Her series of catalogues, *Variable Stars in Globular Clusters*, are valuable reference sources that are frequently cited in the literature. She published three editions: in 1939, 1955, and 1973, and was working on the fourth at the time of her death. Even in her final days, she remained involved in attracting women to the sciences, as in her participation in a video, *Discovering Science* (Clement and Broughton 1993; Univ. Toronto Women's Assoc. 1993). A significant reason for her success, no matter her gender and the attitudes surrounding her, was persistence.

If Helen had protested and objected too strenuously to the annoying everyday inequities, they would have consumed her personal and professional life. Instead, she focused on her own goals and accomplishments because, as a child, her family taught her to appreciate the science they could see along a wooded road or in the stars of a dark night's sky. Then, as a young college student, teachers and female scientists such as Anne S. Young and Annie Jump Cannon provided inspiration and direction. Once an astronomer, Helen's husband, Frank, refused to let her quit, and her mentor and friend, Harlow Shapley, provided an enduring and supportive friendship. Within this framework of education, friendship, and family, Dr. Helen Sawyer Hogg succeeded in her beloved field of astronomy.

10. Acknowledgements

The archival materials researched for this article include Helen Sawyer Hogg's personal correspondence, diaries, and notes; drafts of her articles, public addresses, and drawings; four complete drafts of her book, *The Stars Belong to Everyone*; thirty years of her weekly column in *The Toronto Star*; transcripts from her eight-week television series, *Ideas*, as well as interviews with various friends, family members, former colleagues, and students. Because of its personal nature, this article is based largely on personal letters and interviews.

I am indebted to Christine Clement, Robert Garrison, and John Percy from the University of Toronto Department of Astronomy and Astrophysics, and to Harold Averill, University of Toronto Archives, as well as Helen Sawyer Hogg's children, Sally MacDonald and David Hogg. All of these individuals have been more than generous with their time and consideration during this project and others regarding Helen Sawyer Hogg; their first-hand knowledge has proven invaluable. Finally, to Helen Sawyer Hogg, herself, I share much and will be forever grateful.

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Figure 1. Helen Sawyer Hogg is second from left in this photo from the June 1940 meeting of the AAVSO held in Toronto. Pictured from left: Eugene Jones (AAVSO member/observer), HSH, Margaret Mayall (HCO/AAVSO), Martha and Harlow Shapley (HCO), R. Newton Mayall (AAVSO), Frank Hogg (DDO) and son David, Clinton B. Ford (AAVSO), and Leon Campbell (HCO, AAVSO Recorder).

Variable Stars and Constant Commitments: the Stellar Career of Dorrit Hoffleit

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Presented at the 100th Spring Meeting of the AAVSO, May 22, 2011; Received June 29, 2011; revised September 13, 2011; accepted November 22, 2011

Abstract The career of professional astronomer and AAVSO member Dorrit Hoffleit is summarized, highlighting her myriad contributions to variable star astronomy.

1. Early life

The daughter of German immigrants Fred and Kate Sanio Hoffleit, Ellen Dorrit Hoffleit was born on her father's farm in Alabama on March 12, 1907. According to Dorrit, her father named her Ellen, her mother named her Dorrit, and in her words, "the woman in the house always has her way" (Larsen 2009). After a suspicious fire destroyed the family farmhouse when Dorrit was still an infant, Fred moved the family to New Castle, Pennsylvania, where he had been working as a bookkeeper for the Pennsylvania Railroad. The marriage eventually fell apart and Fred moved back to the farm by himself when Dorrit was nine years old.

Dorrit recounted that watching Perseid meteors with her older brother Herbert was an important step towards becoming an astronomer (Hoffleit 1994). As a child, Dorrit fell into her brilliant older brother's shadow, facing constant comparisons from teachers who were impressed with his natural talent for languages. Dorrit was deeply proud of her brother, who received a Ph.D. from Harvard in Classics at the young age of twenty-one, and subsequently became a professor at the University of California, Los Angeles. However, she later explained that "The contrast between my brother and me is an exemplification of the childhood tale of the tortoise and the hare. Herb learned quickly and achieved early in life. I was slow but deliberate and finally made the grade. It is hard to say whose influence was the greater on our respective students" (Hoffleit 1996).

2. Education and first astronomy work

Dorrit was sent to Radcliffe College by her mother "so that her brilliant son wouldn't be ashamed of his 'dumb' sister" (Larsen 2009). At Radcliffe, Dorrit became a mathematics major as Radcliffe only offered two astronomy courses at the time. Dorrit experienced her first taste of independent research quite by accident at Radcliffe when, after completing an assigned transit experiment at Harvard's student observatory, she continued to use the instrument to observe the motion of Polaris relative to the crosshairs. For her, it was a valuable learning experience, but she later wrote "I don't think my professor appreciated the educational value of that experiment. I think I got a lot more out of the pole star than I did out of what the thing was intended for. So you see, independence wasn't appreciated even then" (Larsen 2009). Dorrit graduated from Radcliffe cum laude in 1928 and began taking graduate classes at Radcliffe while looking for work. Through a classmate she landed a job as a research assistant at the Harvard College Observatory (HCO) for forty cents per hour, half of a man's salary. She turned down a higher paying statistician job to work there, and several times subsequently turned down other, higher paying offers because of her growing love for the HCO and respect for its Director, Harlow Shapley, whom Dorrit has lauded for encouraging independent thinking (Larsen 2009). Her original position was working as an assistant to Henrietta Swope, daughter of the president of General Electric Company. Henrietta had discovered a large number of variable stars, and her father was so proud of her that he funded the assistant position that Dorrit filled. Dorrit proved herself to be an expert discoverer of variable stars as well, finding approximately 1,200 while at Harvard.

At Harvard Dorrit came into contact with the American Association of Variable Star Observers (AAVSO), an organization of amateur and professional astronomers that had been founded in 1911 by variable star observer William Tyler Olcott in order to help the Harvard College Observatory collect observations of variable stars. Dorrit became an official member of the organization in 1930, and a life member in 1943 (Henden 2006). Of her eventual 450+ publications, her first two (published in 1930) were directly related to variable stars: the first was on variable stars in Centaurus, and the second was a collaboration with AAVSO Recorder Leon Campbell on the color curve of the variable star RV Centauri. Thus began Dorrit's lifelong love for the AAVSO and its members, an organization which she once explained to this author was "my favorite" and "the friendliest organization that I'm aware of, at least in astronomy" (Larsen 2009).

Dorrit completed a M.A. in Astronomy from Radcliffe in 1932, under the tutelage of meteor expert W. J. Fisher, as she put it, "the highest degree for which I felt qualified" (Hoffleit 1992). She continued her work on variable stars during the day and worked on independent research projects at night on her own time. A question that especially intrigued her was the possibility of compiling light curves for meteors (Hoffleit 2002). This led to a pioneering study of the light curves of meteors using the accidental photographs of meteors in the Harvard plate collection. She brought her completed paper to Shapley, who submitted it for publication (Hoffleit 1933) and then called Dorrit into his office, where colleague Bart Bok was also waiting. As Dorrit described it, Shapley said, "'We were wondering why you were not continuing to work for your Ph.D. Go back to your office and think it over.' I had never been particularly bright, and this was the greatest expression of confidence in my abilities I had ever heard" (Hoffleit 1987). With more prodding from Bart Bok, Dorrit went back for her Ph.D. at Radcliffe, which she completed in 1938 with work on determining the absolute magnitudes of stars from their spectra. Part of this work was published in the *Proceedings of the National Academy of Sciences* (Hoffleit 1937). Her thesis was awarded the Caroline Wilby Prize for the best original work in any department by a student that year.

3. Astronomy career at Harvard College Observatory

Dorrit continued her work at the HCO as a research associate and then astronomer with permanent appointment, continuing her research on variable stars and other astronomical objects. She came into contact with some of the biggest names in astronomy and made a reputation for herself as a diligent worker. For example, Ejnar Hertzsprung sent her so many requests for observations of variable stars that Shapley had to finally put his foot down because it was taking too much time away from Dorrit's Harvard assignments (Hoffleit 2002). However, Shapley did continue to funnel some individual requests for variable star observations to Dorrit. In a classic example of her sense of humor, she immortalized a request from Mount Wilson astrophysicist Rudolph Minkowski, for verification of a supposed nova, in a poem included in the pamphlet A*AVSO Humor* (Hoffleit and Overbeek 1984), which concludes

On a plate of the given date / This lustrous star did glare at me;
But when another plate I searched / The culprit from its place had lurched!
To one old almanac it jolted me / And there the planet Uranus did be!

At Harvard, Dorrit met and worked with many of the now-famous female "computers" and astronomers, including Antonia Maury, Annie Jump Cannon, and Cecilia Payne-Gaposchkin, all of whom made contributions of their own to variable star astronomy. But her favorite was undoubtedly Antonia Maury, with whom she became good friends (Larsen 2009). After Antonia's death, Dorrit became a champion for her and the rightful place of her work in astronomical history, and wrote numerous articles about her friend. In her later years, Dorrit frequently reflected upon her experience working with these women, and in works such as *Maria Mitchell's Famous Students and Comets Over Nantucket* (Hoffleit 1983), *Women in the History of Variable Star Astronomy* (Hoffleit 1993), and *The Education of American Women Astronomers Before 1960* (Hoffleit 1994) illuminated the important role played by women in astronomy. She also began writing popular level articles on astronomy, including work as an unpaid volunteer for *Sky & Telescope* magazine, authoring a column from 1941 to 1956. These short "News Notes" articles on recent discoveries and astronomical events numbered several per monthly issue, with the final total of nearly 1,200 individual items over her run.

During World War II, Dorrit, like many Harvard astronomers, became involved in "war work." She felt more compelled than most to become involved because of her German heritage, and because during World War I young classmates considered her one of the enemy (Hoffleit 2002). In 1943 she took a leave from Harvard and began work at the Aberdeen Proving Ground in Maryland, preparing aircraft firing tables. There she found herself in a private war against gender discrimination. As an academic with a Ph.D., she was clearly eligible for a professional rating but was instead relegated to a subprofessional class even though she was assigned professional class work. This led to a conflict which Dorrit rates as a defining experience in her career. Dorrit eventually won her "war" with the military, achieved her deserved rank, and after the war returned to Harvard, but continued as a consultant at the Proving Ground until 1961 (see Hoffleit 2002).

4. Dual careers: Yale and Directorship of the Maria Mitchell Observatory

Dorrit's life was drastically changed by Shapley's retirement from Harvard in 1952. As she has described it, his replacement, Donald Menzel, did not apparently value independence and, much to her horror, began discarding sections of Harvard's unique and valuable photographic plate collection in order to make more office space (Hoffleit 2002). He also played an important role in the AAVSO's eviction from Harvard, a defining event in the history in the AAVSO. (For a more balanced historical view of these events, see DeVorkin 2006, and Williams and Saladyga 2011.) Dorrit believed its eviction from HCO to be the AAVSO's "greatest blessing in disguise," for it led to the AAVSO becoming "an important independent research organization" (Hoffleit 2002).

In spite of having a permanent position at Harvard, Dorrit was forced to follow her conscience and "defected" to Yale in 1956 where she worked on large astrometric catalogue projects and where, to her unhappy surprise, she was not afforded the same independence she had enjoyed at Harvard. In her own words, "when I came to Yale, boy that was a revelation" (Larsen 2009). Fortunately, at the same time, she was offered the Directorship of Nantucket's Maria Mitchell Observatory. Due to the financial situation of the observatory, she held a split six month/six month appointment between Yale and Nantucket.

Dorrit's two decades on Nantucket allowed her to encourage a new generation of astronomers through her summer variable star research program for undergraduates. Over the years 102 young women (and 3 young men) conducted research on approximately 650 variable stars, taking and analyzing photographs, identifying variables, and determining light curves. The result was over 200 new or revised periods (Mattei and Saladyga 1999). Dorrit proudly noted in her autobiography that over 100 papers were presented by her students at AAVSO meetings, and many of these presentations were published in the *Journal of the AAVSO* (Hoffleit 2002). In many ways the summer program modeled a professional research institution, including weekly seminars and invited speakers. The success of this program goes far beyond the number of papers and presentations it yielded, for as Dorrit noted, at least thirty-five of her former students became professional astronomers and in her words “their achievements are a joy to behold” (Hoffleit 1987). To this day, being called “one of Dorrit’s girls” is considered a supreme honor.

One of Dorrit’s most beloved “girls” was Janet Akyüz Mattei, who assumed the responsibility of hosting the October 1969 meeting of the AAVSO on Nantucket at the last minute when Dorrit was unable to travel back to the island due to extreme fog. As Dorrit has often recounted, “my girl Janet had done such a marvelous thing running the meeting for me that when Margaret Mayall [Director of the AAVSO] was looking for an assistant…I got the two of them together again and Margaret of course grabbed Janet…and then when Margaret was ready to retire there were a half a dozen people who wanted her job and [Janet] was unanimously elected to that job, all because of the Nantucket fog” (Larsen 2009). It should be noted that Janet also made an equally deep impression on a young AAVSO member at that meeting, Michael Mattei, who became her husband.

Dorrit remained an untenured research associate and astronomer at Yale (supported entirely through grants—a feat she was especially proud of) even after her “official” retirement in 1975. Her main contributions at Yale include the first paper on the light variability of quasars (Smith and Hoffleit 1963), catalogues containing the proper motions of 30,000 stars (Hoffleit 1967–1970), and the third and fourth editions of the *Bright Star Catalogue* and its *Supplement* (Hoffleit 1964; Hoffleit and Jaschek 1982; Hoffleit *et al.* 1983).

5. Career achievements

Over her career Dorrit received numerous awards, including the Graduate Society Medal, Radcliffe College (1964), the Alumnae Recognition Award, Radcliffe College (1983), the Wedgwood Medallion of the Coat of Arms, Yale University (1992), the Glover Award, Dickinson College, Pennsylvania (1995), the Maria Mitchell Women in Science Award, Nantucket Maria Mitchell Association (1997), the George van Biesbroeck Award from the University of Arizona for outstanding service to astronomy (1988), the Annenberg Foundation Award from the American Astronomical Society for “service to the community in education” (1993), and the AAVSO’s William Tyler Olcott Distinguished Service Award (2002). She received honorary doctorates from Smith College (1984) and Central Connecticut State University (1998), and was inducted into the Connecticut Women’s Hall of Fame (1998). Asteroid *Dorrit* (3416) was named in her honor (1987).

Dorrit’s service to astronomy is impressive and wide-reaching; her service to variable star astronomy was perhaps nearest and dearest to her heart. Of her approximately 450 publications, 41% were related to variable stars, and over fifty were published by the AAVSO (Hoffleit 2002). She served the AAVSO in many capacities, including President (1961–1963) and Council member (1943–1945, 1954–1958, 1977–1981, 1989–1993), hosting five AAVSO meetings while Director of the Maria Mitchell Observatory, and serving on the editorial board of the *Journal of the AAVSO*. She was undoubtedly the organization's greatest cheerleader (Figure 1).

In honor of her lifetime of accomplishments, Yale University hosted special symposia for her 90th birthday in 1997, and for her Centenary year in 2006. She continued to be active in research on topics of her choice until shortly before her death on April 9, 2007, at the age of 100, and often remarked of her later years "I have become as happy and independent as I had been in my youth at Harvard" (Hoffleit 1992). Those who knew Dorrit treasured her for her intelligence, work ethic, loyalty, sense of humor, and her hearty full-body laugh. I once asked her what she liked to do outside of astronomy—she replied without hesitation "eat and sleep," and then laughed with gusto (Larsen 2009). She was a mentor to many, and a role model to many, many more. She will not be matched, and she is dearly missed.

6. Conclusion

I had the honor of introducing Dorrit when she was inducted into the Connecticut Women's Hall of Fame, and nominated her for the Honorary Doctorate she received from Central Connecticut State University. Dorrit liked my introduction of her at both events so much she included it in her autobiography, *Misfortunes as Blessings in Disguise*, and I conclude with these same words:

> *It is a basic tenet of stellar astronomy that those stars which burn hottest and brightest and draw the most attention to themselves also burn out the quickest, rapidly becoming nothing more than fading memories. Meanwhile, those unassuming stars which steadily shine in the background, content to diligently produce energy at a more modest pace, continue to influence the universe with their light and heat for many generations to come. Such is the record of your long and amazingly productive career.*

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Figure 1. Dorrit Hoffleit, on left, with AAVSO Director Janet A. Mattei in an undated photograph.

Reminiscences on the Career of Martha Stahr Carpenter: Between a Rock and (Several) Hard Places

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Presented at the 100th Annual Meeting of the AAVSO, October 5, 2011; received February 13, 2012; revised March 21, 2012; accepted March 24, 2012

Abstract An overview is presented of the life and work of Martha Stahr Carpenter, three-term president of the AAVSO and member since 1946, based on her reminiscences and archival research.

1. Introduction

Martha Stahr Carpenter was the AAVSO president who served during a critical time in the organization's history: its eviction from Harvard. Very little has been previously published about her life and career, and this work is the most complete biographical study of her to date.

2. Early life

Martha Elizabeth Stahr (pronounced STAIR), or "Patty" to her friends and family, was born in Bethlehem, Pennsylvania, on March 29, 1920, the middle child and younger daughter of Reverend Doctor Henry Irvin Stahr and his wife Alice Stockwell (Moat 2011). Henry was devoted to public service, and was not only a minister for many years, but was also one of the founders and first president of the United Way of Frederick County, Maryland. He was also deeply involved with the Boy Scouts of America (Anon. 1930). As a young girl Carpenter was interested in astronomy, and joined a club in junior high school, but was disappointed when the teacher who sponsored it "didn't know anything pertinent. He mostly made imaginative speculations on such topics as little people who might be living on the moon" (Carpenter 2011b).

When she was fourteen years old her father became President of Hood College in Frederick, Maryland. There she met astronomy professor and AAVSO member Leah B. Allen, who encouraged her interest in astronomy by showing her objects through the Clark telescope. Carpenter spent her first year of college at Hood and took Allen's astronomy course, and "it suddenly dawned on me that I could actually become an astronomer" (Carpenter 2011a). She transferred to Wellesley (the college her mother had attended), where there was a full astronomy major. She joined the AAVSO, and began attending meetings. As she told the author, "I yearned to have a telescope of my own so I myself could make observations for the AAVSO" (Carpenter 2011a). With the help of another student (who had taken a mirror-making course at the Franklin Institute in Philadelphia) she began grinding her own mirror in the basement of Wellesley's observatory. She recounts that she could not find an oil drum for her grinding base, despite an exhausting campus and town-wide search; one of the food service workers in her dormitory inquired why she looked so tired, and offered her an old vegetable oil drum to use instead—a base that afterwards smelled rather distinctive (Carpenter 2011c). She attended meetings of the Amateur Telescope Makers of Boston, and with their help mounted her mirror into a telescope and portable mount, and attended the Stellafane amateur telescope-making convention. She later used the instrument to observe variable stars at her family's oceanfront summer home in Scituate, Massachusetts, and her family still owns the telescope (Carpenter 2011a, 2011b).

Carpenter remembers that the summers of 1944–1945 offered particularly great skies. There were heavy black curtains over the windows during war-time, and the skies were very, very dark. She recounted that one time the Coast Guard came to their house and "wondered about what this contraption was that I had set up" (Carpenter 2011b). They apparently wanted to make sure her telescope wasn't some kind of enemy device. Under the observer code SME Carpenter contributed 396 variable star observations to the AAVSO between 1940 and 1950, including 83 of SS Cygni, 22 of Mira, 19 of R CrB, and 16 of RS Cygni.

Carpenter graduated from Wellesley in 1941 and began graduate work at the University of California, Berkeley. She worked on a number of projects there, for example finding twenty-nine new variables in the Scutum cloud from a single photographic plate (Federer 1942). She and fellow student Leon E. Salanave also tried to calculate an orbit for Comet Vaisala 2, but according to Julie Vinter Hansen (1942) "met with difficulty." But she also did work in statistics, and obtained a Master's Degree in 1943 with the thesis "A Method of Calculating Curves of Growth." Afterwards, she spent 1944–1945 at Lick Observatory, where, using the spectrograph on the 36-inch refracting telescope, and supported by a University of California Fellowship and the Alice Freeman Palmer Fellowship of Wellesley College, she measured the radial velocities of fifty F- and G-type stars of eleventh magnitude situated within two degrees of the north galactic pole (in other words, far from the galactic plane). This study became the foundation for her Ph.D. thesis (Anon. 1944; Moore 1946). Carpenter recalls that students would ordinarily never have been allowed to use this instrument, but since it was the war years, "most of the astronomers had left. There was a discussion as to whether a woman could handle the big telescope, [but] I just went up there. The man was there doing all he could to handle it, and it wasn't before long that I was doing it with him, so they were very glad that the telescope was kept in use, because it was more than one person could handle" (Carpenter 2011b). This tension surrounding women in astronomical observatories can also be seen in the careers of Margaret Burbidge, Helen

Sawyer Hogg, and Vera Rubin, among others, and severely limited the roles for women in astronomy (Burbidge 1994; Larsen 2009; Mack 1990; Rubin 1997).

After completing her Ph.D. in 1945, she taught at Wellesley for two years. During this time she made twelve observations of Comet 1946a Timmers with the 12-inch refractor there and published the results in *The Astronomical Journal* (Stahr 1946). Her class in Practical Astronomy made variable star observations and submitted them to the AAVSO, and she herself became a life member of the organization in 1946 (Carpenter 2011b). The 1947 Spring meeting of the AAVSO was held at Hood College, with Carpenter's parents acting as hosts. According to the meeting minutes, the AAVSO members were treated to a tour of Mrs. Stahr's extensive collection of 250 vases (Seeley 1947). The following year Henry Stahr retired to Scituate, Massachusetts, and over the next few years the elder Stahrs attended a number of AAVSO social events.

3. Early career at Cornell

In 1947 Carpenter became an assistant professor in astronomy at Cornell University, and in so doing was the first woman faculty member in Cornell's College of Arts and Sciences (Rossiter 1995). That first summer she did some variable star observing with one of the female Cornell students, but devoted most of her time to a joint Astronomy Department/School of Electrical Engineering project to observe radio waves from celestial objects (such as the sun and galactic center), the first research program in radio astronomy at an American university. She noted that when the program initially wrote its grants the engineers had a collaborating astronomer already in mind, but in Carpenter's words "they ended up with me instead" (Carpenter 2011c). According to the 1948 report of Cornell's Fuertes Observatory, Carpenter

> represented the Department in the radio-wave astronomy project operated jointly with the School of Electrical Engineering. Problems include the planning of observational programs, preparation of astronomical data for the project, and the general coordination of developments in theory and observation. Qualitative observations are now being obtained with an Army 268 Radar which has been converted to receive solar and cosmic noise at 205 megacycles. (Shaw 1948)

Carpenter presented a summary of the July 1948–June 1949 Cornell solar radio observations at the June 1949 meeting of the American Astronomical Society (AAS). The Cornell data did not break any new ground, instead verifying results previously obtained by A. E. Covington of the National Research Council in Canada (Stahr 1949). In his 1948 report, Shaw had also noted that the "construction of the 'radio-wave telescope' with 17-foot parabola is nearly complete" (Shaw 1948). However, to Carpenter's frustration, it would take more than another year to get the parabolic dish scope up and running (Cornell 1949). Carpenter was troubled by what she saw as the lack of organization surrounding the building of the new dish radio telescope. As she recalls, "there were lots of delays, lots of administrative difficulties, seven changes in director in a year and a half in the School of Engineering" (Carpenter 2011b).

While waiting for the new facilities to come online, she began a project that she could do on her own, and that she felt was "appreciated," namely the creation of lengthy bibliographies of publications on radio astronomy. As she explains it, "I tried to find all the world's pertinent literature. Much of it was unknown to astronomers. A lot of it was in engineering journals and much of it was in foreign publications" (Carpenter 2011a).The result was a number of collections of "abstracts of the published literature pertaining to radio noise of extraterrestrial origin" and "lists of references for temporary use" until published abstracts could be provided (Carpenter 1958). The resulting volumes of *The Bibliography of Radio Astronomy* and *Supplements* appeared in 1948 through 1950 (under her maiden name), *The Bibliography of Extraterrestrial Radio Noise* and *Supplements* covered the field from 1950 to 1958, and *The Bibliography of Natural Radio Emission From Astronomical Sources* surveyed the literature of 1961 through 1963 (Appendix A). Her bibliographies (like the Cornell radio work in general) were funded by a grant from the U.S. Navy, and some of her supplemental bibliographies were issued as part of various reports to the International Scientific Radio Union and IAU Commission 40. She was a member of IAU Commission 40 and represented the Cornell Radio Astronomy Project at the General Assembly of the IAU at Rome. Carpenter wrote the abstracts for the *Bibliographies*, but relied on anonymous assistants to help her locate the pertinent articles. She found married women with children who had backgrounds in physics, engineering, astronomy, or foreign languages, and who had the time and interest to help her. Much of the work was done by correspondence. Some of the women were paid through Carpenter's grants, while others were strictly volunteers (Carpenter 2011c). Not only were these bibliographies important to radio astronomers of that time, but in recent years historians of radio astronomy have found these bibliographies to be "indispensable" in their studies (Sullivan III 2009, 211). Interestingly, Carpenter understood that some of her work (and reports of the radio astronomy work at Cornell in general) was classified by the U.S. Government, though the exact status of that classification is unclear at this distance (see note in the Appendix at the end of this paper).

Carpenter regularly attended AAVSO meetings and gave talks on "The Sun as a Microwave Variable" at three successive spring AAVSO meetings, in 1947, 1948, and 1949. She also presented on the Cornell solar observations at the AAS meeting in 1949, and lectured on radio astronomy to the General Electric Science forum, the General Electric Research Laboratory, and the Cornell Chapter of Sigma Xi. Her paper "Radio Waves from the Sun" appeared in the book *Science Marches On*, published by General Electric in 1950 (Shaw 1954, 1956). When asked to describe her radio work at Cornell, Carpenter explained that she would point the radio telescope at the moon to see if there would be a radio reflection from solar flares. One night, she got a really nice "swish" that was clearly not static, and thought she had finally observed this effect. She contacted astronomers in Japan to corroborate but their equipment wasn't working that night, so nothing ever came of these results. She never saw the effect again (Carpenter 2011c).

For many of her years as a faculty member at Cornell she was one of only two full-time astronomy professors, the other being the Fuertes Observatory Director R. William Shaw. According to the annual observatory reports published in the *Astronomical Journal*, she developed and taught a variety of courses at the undergraduate and graduate level, including courses in the Milky Way, External Galaxies, Astrometry, Radio Astronomy and Geodetic Astronomy, Orbit Theory, Galactic Structure, and Introductory Astronomy (Shaw 1948, 1949, 1951, 1952, 1953, 1954). One of the first graduate students she worked with at Cornell was Vera Cooper Rubin, and acted as advisor for Rubin's M.A. thesis on large-scale systematic motion of galaxies apart from Hubble flow. Rubin credits one of Carpenter's courses with initially getting her interested in galactic motions, and also noted that Carpenter was very supportive of her work (Rubin 1997, 154, 198).

At Cornell, Carpenter met and then married fellow faculty member Jesse Thomas Carpenter. The son of a Durham, North Carolina farmer, Jesse was twenty-one years Carpenter's senior. A Harvard Ph.D., he came to the New York State School of Industrial and Labor Relations at Cornell in 1947 from his position as Labor Economist with the U.S. Bureau of Labor Statistics. He had previously taught Political Science at New York University for many years. An expert in collective bargaining and labor arbitration, he was the author of two books: *The South as a Conscious Minority 1789–1861: A Study in Political Thought* and *Employers' Associations and Collective Bargaining in New York City* (Cooke 2010). After a short engagement, they married on August 18, 1951, in Scituate, Massachusetts, with Carpenter's father performing the ceremony (ILR Cornell 1951, 4).

4. Carpenter and the AAVSO

During this time she took on increasing leadership roles within the AAVSO, starting with her election to the Council in 1946. She served as second Vice President, first Vice President, and finally President in 1951. During her tenure as president she had to deal with several thorny issues, such as the future of the publication of "Variable Star Notes" (given the demise of the journal *Popular Astronomy*), and serious difficulties within the AAVSO Solar Division (Figure 1). But Carpenter's second term as president also coincided with the most stressful period in AAVSO history, the ouster of the organization from Harvard. This pivotal time in the organization's history is carefully detailed in *Advancing Variable Star Astronomy* (Williams and Saladyga 2011); therefore this essay will only focus on Carpenter's role in this turbulent time.

In a November 1952 letter, Clint Ford congratulated Carpenter for her excellent stand at the October council meeting (Saladyga 2011). At that meeting Donald Menzel had spearheaded the creation of a re-evaluation committee to consider the future of the AAVSO, one of the first steps toward the eviction of the AAVSO from Harvard. Although she does not remember her actual words at this meeting, Carpenter recalls that all throughout this difficult time she was steadfast in her belief that the AAVSO should remain in Cambridge. As she explained, "it was a great part of the life of people who lived there" (Carpenter 2011b). Nevertheless, she was given the difficult task of creating this re-evaluation committee, and when she received a letter from Donald Menzel requesting that the AAVSO report be submitted by the unexpectedly early date of January 20, 1953, she had to take responsibility for handing in the report on behalf of the organization without sufficient time for the entire Council to thoroughly review, digest, and approve it (Williams and Saladyga 2011; Carpenter 2011b).

During this time, Carpenter also recalls being

> suddenly presented with a plan for the AAVSO to be moved far away, to an institution that was already planning to acquire it, and had worked out the details of hosting the organization. All that was needed to make it a "done deal" was my signature as president of the AAVSO. Apparently those who had made the decisions thought that I would immediately sign the relevant papers on behalf of the AAVSO. My response, however, was that I was not at all sure the AAVSO members would agree to such an agreement, and that first the Council members should discuss it and present their recommendations to the membership. Apparently the powers that be (or were) at Harvard were entirely surprised that I, and therefore the AAVSO, did not immediately accept their proposal. (Carpenter 2011a)

When pressed, Carpenter could not recall who actually gave her the papers, and where the AAVSO was to be moved, except that it was a small college in the Midwest she had never heard of (and cannot remember the name of to this day). In her words, "Menzel had already given the AAVSO to this organization—he must have been embarrassed when he couldn't deliver it" (Carpenter 2011b). Carpenter recounts that some claimed that she "saved the AAVSO," but she says that she "merely refused to make a decision that I felt the organization could, and should make. Harvard had every right to discontinue its AAVSO sponsorship, but I felt that it should not have tried to decide unilaterally our future course." (Carpenter 2011a)

Carpenter also had to deal with what she calls "the intense politics within the organization with regards to Harvard. Some people were so imbued with remembering how prominent Harvard and Menzel were and to do anything against their suggestions would be unheard of" (Carpenter 2011b). Others (including Margaret Mayall) were less restrained. For example, in a February 19, 1953, letter Mayall asked Carpenter if she thought Menzel should be asked to resign from his position as First Vice President of the AAVSO; in Margaret's words, "it was a very low thing to accept an office in an organization he was planning to ruin" (Mayall 1953). Carpenter replied on March 3, 1953, that "The matter of asking Dr. Menzel to resign is a delicate one but one which I suppose we shall have to face if he doesn't do so of his own accord. Personally I have been expecting that he *would* resign" (Carpenter 1953).

With Carpenter's second term as president nearing its end, the organization was thus in a serious quandary as to what to do about the next round of officers. Past president David Rosebrugh was not so quick to count out Menzel, noting in a February 22, 1953, letter to Clinton Ford that Menzel

> is merely acting upon instructions, so it might well show our confidence in him to elect him our president next fall. On the other hand others may think differently. If so we might consider electing Carpenter to a 3rd term, dropping the present First VP from the line-up, which would be somewhat smoother that failing to elect the present first VP to the presidency. However I would favor giving serious thought to continuing the succession at present. (Rosebrugh 1953a)

However, after discussing the matter with other members at a picnic in honor of Harlow Shapley, Rosebrugh declared in a May 10, 1953, letter sent to Carpenter, Ford, and others that "Third term opposed for any one" and it would be best to find a "financial man" to become president. In his words, "No honor, big headache" (Rosebrugh 1953b).

Despite some hopes of finding another candidate, in the end history was made, and Carpenter continued for another term. In the AAVSO's V*ariable Comments*, Jocelyn Gill noted that Carpenter's re-election was due to her "inspired leadership and devotion to the interests and work of the Association through this difficult period" (Williams and Saladyga 2011, 185). During her last term, Carpenter and the Council spent considerable time crafting fundraising letters by committee, an arduous task. She was also a part of the organization's Endowment committee until 1964.

5. Opportunities and new challenges

Despite the considerable problems, Carpenter's tenure as president also brought with it professional and personal joys. First, she was promoted to associate professor at Cornell in 1953 (Shaw 1953). Then in 1954 the

Carpenters finally realized their dream of visiting Australia. Jesse received a Fulbright research award for a sabbatical to study Australia's compulsory arbitration system, and Carpenter received a research grant from the Australian Commonwealth Scientific and Industrial Organization to do radio astronomy for a year. According to the AAVSO Council Minutes of May 1954, Carpenter wanted to resign the AAVSO presidency (as she would miss the October meeting) but was persuaded to remain in that role during the few months of overlap with her Australia trip, and during her time away she made a point to visit as many of the Australian AAVSO members as she could (Ford 1954).

In Australia Carpenter worked on mapping the spiral arms of the Milky Way by using the Potts Hills' radio telescopes to observe 21-cm radio waves from hydrogen, "a fascinating subject if there ever was one," she proclaimed in an October 8, 1954, letter to Margaret Mayall (Carpenter 1954). She and radio astronomers F. J. Kerr and J. V. Hindman extended the map of the Milky Way made by researchers at the University of Leyden, resulting in a number of conference presentations and publications featuring this now famous map of the galaxy, the first to combine radio data from the northern and southern hemispheres (Kerr *et al.* 1956; Kerr *et al.* 1957; Carpenter 1957). "It was so exciting to be actually able to see where the arms of the galaxy were actually made out," Carpenter later recounted (2011b). She coordinated the observations, while her collaborators focused on the analysis. Such observations not only allow for mapping of the spiral structure of the galaxy, but also provide vital information for determining the location of the plane of the galaxy. The hydrogen was found to be "remarkably flat in the inner parts of the galaxy," leading Carpenter and her colleagues to define the average plane in this region as the "principal plane of the galaxy" (Kerr *et al.* 1957, 679). Their research also found that the arms tilted up at the outer regions; in other words, they weren't just confined to the galactic plane, but they curve up at the outer edge, a phenomenon now seen in many spiral galaxies with extended HI disks (Garcia-Ruiz *et al.* 2002). At the Annual 1955 AAVSO meeting in Springfield, Massachusetts, Carpenter gave a talk on her experiences in Australia, including her meetings with AAVSO members.

With their return from Australia, change came to the Carpenters. Margaret Rossiter erroneously wrote in her seminal work *Women Scientists in America* that because Carpenter married another Cornell faculty member, she was appointed a research associate rather than promoted to associate professor. This is patently wrong, as Carpenter had already been promoted before her time in Australia. In addition, as Carpenter explained to the author (2011c), her 1955 shift to Research Associate was her own personal choice. When she and Jesse returned from Australia their goal was to start a family, which they thought would not be easy (given that she was 35 and he was 56). She therefore gave up teaching and wanted to devote her professional time to research and writing her bibliographies, which she felt would be a better fit with raising a family. Fortunately, their first daughter, Martha Alice, was conceived within their first year back at Cornell. A second daughter, Sarah Margaret, followed three years later. However, because of her relatively advanced age, Carpenter's doctors were, in her words, "trying to take extra care of me" so when she developed a cold while pregnant with Alice she had to remain in bed and missed the May 1956 AAVSO meeting at Cornell that she herself had organized (Carpenter 2011c).

When Jesse retired in 1966, the Carpenters began to make plans to move, in Carpenter's words, "below the Mason-Dixon line" so that their children could get to know Jesse's large extended family in North Carolina (Carpenter 2011b). While Jesse worked on his third and last book, *Competition and Collective Bargaining in the Needle Trades, 1910–1917*, Carpenter began investigating opportunities for astronomical research closer to North Carolina. She says that the most responsive institution was the University of Virginia (UVA) in Charlottesville, "so that's where we ended up" and where she lives to this day (Carpenter 2011b). Before Carpenter left Cornell in 1969 she had stopped her radio astronomy bibliography project, in her words "because by then it was something astronomers knew about. In the beginning they didn't really know about what was observed beyond the earth—it was something that had to sink in a little in astronomical knowledge" (Carpenter 2011b). She began as a part-time lecturer at UVA in 1969, and became an associate professor in 1973 (Fredrick 1969; Jaques Cattell Press 1992).

While UVA had a radio astronomy program (in concert with the National Radio Astronomy Observatory), between 1972 and 1981 Carpenter's research centered on using optical observations and her statistical skills to increase our understanding of the distance scale within our galaxy. This work centered on the Hyades star cluster, and was conducted with graduate and undergraduate students. Using parallax, proper motion, radial velocity, and other data, they investigated the true membership of the cluster and determined its convergent point and distance, one of the building blocks for determining the cosmic distance scale and calibrating the HR diagram. The convergent point and distance Carpenter and her student colleagues announced at an AAS meeting in 1975 was well-cited in the literature for two decades (Corbin *et al.* 1975; Perryman *et al.* 1998). Over the years she continued to refine these calculations based on increased sets of data produced by other UVA colleagues. She also studied the high proper motion, low metallicity, visual binary 85 Pegasi (Carpenter *et al.* 1975; Fredrick *et al.* 1975; Fredrick 1977; O'Connell 1981).

In 1970–1973, Carpenter served again on the AAVSO council, and encouraged one particular UVA graduate student's increasing involvement with the AAVSO: Janet Mattei (Carpenter 2011b). Most importantly, when Mattei submitted her name for the AAVSO director's position (to succeed Margaret Mayall), Carpenter requested that Mattei's credentials be "discussed at length" (Williams and Saladyga 2011, 239). Carpenter also hosted the 1973 Spring meeting of the organization at UVA. Around this time, many astronomy departments across the U.S. began the sometimes painful shift from an emphasis on astrometry to astrophysics. UVA was one of these institutions. Former colleague Bob Rood very candidly summarized this transition in an email to the author: "[Carpenter] was very much a classic old-line astronomer in my view. I was very astrophysically oriented. Early in my career I became what today would be called director of graduate studies. This led to some professional conflicts with a number of older faculty" (Rood 2011). Carpenter retired from UVA in 1985, and Jesse died the next year, after thirty-five years of marriage. She had intended to keep her hand in research, but found that UVA was slow to get her the new computer she needed to run her calculations. Eventually she let it go, and has not been active in astronomy in many years (Carpenter 2011b). However, she continues to be active in her community, and is a benefactor to community organizations and the Astronomical Society of the Pacific. At ninety-one she still drives a car and runs many of her own errands, but only in town (Moat 2011).

6. Conclusion

Despite the difficulties she encountered in her terms as president, in her words (2011a) she "so fondly enjoyed" her time of service to the AAVSO and was delighted to hear that the AAVSO still remembers her as an important member of the organization. She and her daughter Alice attended the dedication of the AAVSO Headquarters on October 6, 2011 (Figure 2), and they were greatly impressed with the growth of the organization over the past few decades. Carpenter describes her role in the field as "an observational astronomer" (2011c) and it was clear in her correspondence with this author that she did not relish the astronomical politics that she had become involved in at several stages in her career. In reflecting on her mother's career, Alice Moat, herself a computer scientist, shared that she was once asked if she became interested in science because of her father. She had replied, "no, because of my *mother*" (Moat 2011). In conclusion, the struggles and successes in the life and career of Martha Stahr Carpenter shed additional light on the history of women in American astronomy in general, and the history of the AAVSO in particular.

7. A note on the sources

This paper was largely based on three types of sources:

1) Published annual reports of observatories where she worked and studied, and her published professional papers;

2) Letters and reports housed in The Thomas R. and Anna Fay Williams AAVSO Archive; and

3) Personal communications with Martha Stahr Carpenter (Carpenter 2011a, letter dated September 7, 2011; Carpenter 2011b, telephone call

dated September 16, 2011; and Carpenter 2011c, personal conversation dated October 6, 2011) and her daughter Alice Moat (Moat 2011, personal conversation dated October 6, 2011).

8. Acknowledgements

Many thanks must be given to Michael Saladyga for his help with the AAVSO Archive materials, to Thomas R. Williams for suggesting that the author take on this project in the first place, and to Martha Stahr Carpenter and Alice Moat for their time in answering questions.

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Figure 1. AAVSO Spring Meeting at Clarkson College, Potsdam, New York, May 1952. Martha Carpenter is in front row, second from right. To her right are AAVSO Recorder Margaret Mayall (with cane), and Helen Sawyer Hogg.

Figure 2. Martha Stahr Carpenter at the AAVSO's 100th Anniversary Meeting, October 2011, Cambridge, Massachusetts.

Appendix A: Carpenter's *Bibliographies*

Note: Examples of the bibliographies for which a security classification was considered and the ultimate classification status is unclear can be found at the Defense Technical Information Center, Fort Belvoir, Virginia (http://handle.dtic.mil/100.2/AD0008460 and http://www.dtic.mil/dtic/tr/fulltext/u2/007563.pdf). This repository also houses copies of Carpenter's Bibliographies *and the Cornell Radio Astronomy status reports. The* Bibliographies *are here listed in order of publication.*

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Guiding Forces and Janet A. Mattei

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Presented at the 100th Annual Meeting of the AAVSO, October 5, 2011; received July 23, 2012; accepted July 27, 2012

Abstract We are all shaped by the guiding forces in our lives—some we seek out, some seek us out, many are beyond our control. These forces may be human or not, constructive or destructive, personal, cultural, social, political, historical, or environmental. If we are fortunate we have had at least one human mentor who has nurtured us and helped us to grow towards our potential. Throughout her life, Janet Akyüz Mattei was the recipient of the effects of guiding forces—good and bad—and was herself a guiding force. From childhood on, she was blessed by having mentors and she responded constructively to them. Here Janet Mattei is discussed both as she was shaped by guiding forces and mentors and how, as a mentor and guiding force herself, she shaped others.

1. Earliest influences

Janet Hanula Akyüz was born January 2, 1943, in Bodrum, Turkey, the eldest of five. Her parents, Baruh and Bulisa Akyüz, were merchants who owned several shops. University educated, Janet's father was a local leader to whom people brought problems, antiquities they had discovered for him to refer to the proper authority, and so on. Sephardic Jews who had lived in Turkey for generations, the Akyüz family was and is one of strong traditions, history, and pride. The environment in which Janet was born and grew up shaped her from the beginning. On Turkey's west coast, Bodrum was an ancient city, a crossroads of civilizations for centuries, and Izmir, a coastal resort city to which the family later moved, was the ancient Smyrna. Janet grew up being aware of history and the multicultural nature of the world; Turkey was Muslim, Jewish, and Christian. Turkey is a secular state but post-WWII there was still religious prejudice, and women were not in any way considered the equals of men.

Janet's earliest education was in a one-room elementary school, where the teacher recognized her as very intelligent. Education was highly valued in the family, and since the secondary schools in Bodrum were limited, the family moved to Izmir to provide Janet with better opportunities (Figure 1). She attended Roberts American School, a high school with college courses. Janet mentored her siblings, sisters Kadem and Beki and brothers Yusef and Hayim, checking their homework and tutoring them when needed. Miss Naomi Foster, Janet's math and science teacher at Roberts, saw her potential, and mentored

Janet in the sciences. Many of the teachers at Roberts were women—highly unusual in the Turkish culture—and so were excellent role models. Mrs. Blake, the American principal of Roberts, also strongly supported Janet, as did Janet's mother (Figure 6).

Janet encountered prejudice early: she won a national contest to represent Turkey in a student exchange but was told she could not do so because she was Jewish.

In 1961 Janet came to the U.S. to attend Brandeis University in Waltham, Massachusetts, having won a prestigious 4-year Wien International Scholarship (open by competition to international students) (Figure 3). Prior to the term starting, Janet spent three months in Vermont with AFS host family Janet and Bob MacLennan and their young children. Janet MacLennan (later Janet MacLennan Zisk after marrying planetary astronomer Stan Zisk), an archaeologist, historian, and archivist, was Janet's first mentor in the U.S. They became and remained very close friends, and Janet Mac was Janet's administrative assistant 1984–1986 at AAVSO and a mentor on organizational management (Figure 3).

Janet graduated from Brandeis in the class of 1965 with a B.S. in Physics (Figure 4). During her college years the MacLennans were her American family and her Uncle Rafael Akyüz and family in the U.S. were a source of support and family connection when her immediate family was so far away (Figures 2 and 5).

Janet had planned on attending medical school. After graduation from Brandeis she worked for one year as a hospital hematology lab supervisor, but she didn't really like it. She returned to Turkey, and in 1967 started graduate school in physics at Ege University (near Izmir). At the same time she taught math and physics at the Roberts School, where she was a very popular teacher.

Miss Foster knew the Turkish astronomer Paris Pişmiş, and in 1969 she introduced Janet to Paris as the most brilliant student she had known, telling her she thought Janet would make a good scientist—Janet was known as the "Einstein of Turkey" at this time. Paris mentored Janet, delighting in fostering her rare talent and encouraging another Turkish woman in the sciences.

Paris knew the astronomer Dorrit Hoffleit—Dorrit had been her mentor—and in a fateful move, suggested to Janet she should study under her at the Maria Mitchell Observatory (MMO) on Nantucket and introduced Janet to Dorrit. Dorrit had mentored Paris, Paris mentored Janet and introduced her to Dorrit, who also mentored Janet—they were a trio embodying the power of mentoring (Figure 7).

Janet applied to the MMO summer research program. Dorrit had already selected students for the summer, but Paris' recommendation led her to add Janet. That summer Janet photographed and analyzed RR Lyr stars while learning much about many things from Dorrit. That initial meeting led to a lifetime mentor-mentee relationship and friendship (Figure 8).

In October 1969 AAVSO held its annual meeting on Nantucket at MMO. Janet stayed to help Dorrit host the meeting and finish research. As the meeting began, Dorrit went to the mainland to a meeting at Woods Hole. Bad weather prevented her return until the concluding banquet, so she delegated hosting the AAVSO meeting to Janet, who did so very capably with the assistance of Nancy Gregg, another MMO student. At that meeting Janet joined the AAVSO, gave a paper on her research, and met AAVSOer Michael Mattei.

Her experience on Nantucket and with Dorrit and Paris decided Janet on a career in astronomy. She returned to Turkey and earned a M.S. in Physics at Ege University (near Izmir) in 1970. She then continued graduate studies in Astronomy at University of Virginia in Charlottesville. There she experienced considerable prejudice, both personal and academic—she was a woman, she was foreign, and she was Jewish—and was told not to try for a Ph.D. as she was "not Ph.D. material." She earned her M.S. in Astronomy (her thesis was on T Tauri stars) from UVa in 1972. During her sometimes very difficult days at UVa, AAVSO member and faculty astronomer Martha Stahr Carpenter (Figure 14) was a mentor to Janet (and all the astronomy female students).

Dorrit encouraged Janet to apply for the position of AAVSO Director Margaret Mayall's assistant. Her recommendation led to Margaret's hiring Janet in 1972. Mike and Janet married later that same year (Figure 9).

Margaret was planning to retire and wanted Janet to succeed her. The search committee had been active since 1971, but no real action had been taken. Janet applied for the position in January 1973 and was ultimately chosen, becoming AAVSO Director on November 1, 1973, at the age of 29. Margaret was appointed Consultant to the Director for at least one year (Figure 10).

Although Janet had been Margaret's right arm for a year, the position of Director entailed a very steep learning curve with all the science, administration, and politics to master. Things were complicated by significant issues within AAVSO Headquarters that needed resolving (for example, lack of communication with members, availability of data to researchers), the absence of budget for more staff or materials, and the delicate diplomatic issue of not offending her mentor Margaret Mayall, who was in the office all day every day.

As Janet picked up the Director's baton (Figures 11, 12), she began working to resolve these issues as she worked on learning management skills, more about types of variables in-depth, and so on. She was also her own mentor; she constantly studied organizational and financial management and grantwriting—skills she needed in her position.

Janet attended professional meetings as AAVSO Director, where she was often snubbed because she did not have a Ph.D. She re-enrolled in Ege University long-distance and earned her Ph.D. in Astronomy (her thesis was on cataclysmic variables) in 1982. Afterwards she became a full member of the IAU and participated vigorously in the appropriate variable star and education commissions and committees.

Her life-long experiences with prejudice because of her sex and religion made her determined that others would not be treated as she had been. Also, she felt very strongly that girls and young women needed to be mentored/encouraged in pursuing math and science and wanted the AAVSO to play a role, as some handwritten notes by Janet indicate: "Offer opportunity to women in science to provide unique opportunities for scientific research in the analysis of data on CVs. Policy of AAVSO: Women are minority in astronomy. to encourage women in science majors to enter the field[.] recent examples Meech, Pope, Hammel. by offering them part time research assistant" (AAVSO archives).

Thus, from a very early age Janet had experienced strong guiding forces—positive and negative—and had been both a mentor and mentee. This pattern continued for the rest of her life.

2. AAVSO mentors

Numerous AAVSOers over the decades offered guidance to Janet, including:

John Bortle—cataclysmic variables, publishing observations (*AAVSO Circular* editor) (Figure 13);

Louis Cohen—finances and investments (AAVSO Treasurer) (Figure 15);

Clinton B. Ford—finances, AAVSO history, charts (Figure 12);

Grant Foster—both mentor and mentee, AAVSO staff member, programmer and mathematician, data analyst, statistician; Grant mentored Janet in aspects of advanced data analysis and statistics; Janet mentored Grant, encouraging his great abilities in mathematics and logic (Figure 16);

Owen Gingerich—Harvard University and Smithsonian Astrophysical Observatory; history of astronomy (Figure 17);

Katherine Hazen—Mt. Holyoke College '26 chemistry major (Martha's mother), fundraising, member relations and communications (Katherine was a Headquarters volunteer and a mentor to all of us there) (Figure 18);

Martha Hazen—Harvard College Observatory plate collection curator; variable stars, member relations, astronomical community relations, organizational politics (Figure 19);

Arne Henden—U.S. Naval Observatory, Flagstaff; photometry, instrumentation (Figure 20);

Margarita Karovska—Smithsonian Astrophysical Observatory, Chandra X-Ray Center; long period variables, interferometry, astronomical community relations (Figure 21, right);

Howard Landis—photoelectric photometry (Figure 22, left);

Wayne Lowder—comparison star sequences, binocular observing (Figure 23);

Mario Motta—education, community outreach (Figure 21);

John Percy—University of Toronto; pulsating variables, particularly red variables, photoelectric photometry, science education (*Hands-On Astrophysics* co-creator, *Journal of the AAVSO* Editor) (Figure 24);

Charles Scovil—publications, charts, sequences, photometry (Figure 25);
Arthur Stokes—photoelectric photometry (Figure 22, right);
Paula Szkody—University of Washington; cataclysmic variables, astronomical community relations (Figure 26);
Theodore Wales—financial management, investments (AAVSO Treasurer); Ted believed in Janet's vision for the AAVSO and supported her sometimes substantial financial expenditures on behalf of the AAVSO (Figure 27);
Barbara Welther—Smithsonian Astrophysical Observatory; computerized data processing; she advised Margaret Mayall as well as JAM (Figure 28);
Charles Whitney—Harvard University, Smithsonian Astrophysical Observatory; stellar variations, stellar atmospheres, (*Journal of the AAVSO*, Editor) (Figure 29);
David B. Williams—organizational management, fundraising, binocular observing (Figure 30);
Thomas R. Williams—organizational management, financial management, AAVSO historian (Figure 31);
Lee Anne Willson—Iowa State University; pulsating variables, especially long period variables, stellar models, pulsation theory, astronomical community relations (Figure 32, left).

3. Government grant mentors

Janet sought out mentors in the government grants community for advice in developing grants for AAVSO programs. Among her colleagues who were particularly helpful were *Nahide Craig* (NASA Science Education Gateway (SEGway) on education; *Gerald J. Fishman* (NASA Marshall Space Flight Center, Principal Investigator on the Compton Gamma-Ray Observatory Burst And Transient Source Experiment) on high-energy astrophysics and gamma-ray bursts (GRBs); *Chryssa Koveliotou* (Universities Space Research Association and National Space Science and Technology Center, a partnership with NASA Marshall Space Flight Center) on high-energy astrophysics and GRBs; *Gerhard L. Salinger* (National Science Foundation, NSF Program Director for Advanced Technological Education Discovery Research K-12) on education; and *Edward J. Weiler* (NASA, Chief Scientist for the Hubble Space Telescope 1979-1998) on HST and other satellite mission applications.

4. Janet as mentor in teaching

Janet was passionate about education, and, a born teacher, was active in many science educational initiatives through the AAVSO and other organizations. Among the AAVSO initiatives were *Hands-On Astrophysics* (today updated and expanded as *Variable Star Astronomy*), a curriculum to teach the scientific research process through variable star astronomy and observing developed with John Percy and Donna Young (Figure 33), and *Partnership in Astronomy*, developed with Mario Motta (Figure 21) and others. A major educational program Janet (and Mike Mattei) taught in was *Towards Other Planetary Systems* (TOPS), developed by Karen Meech as an annual summer astronomy education (and much more) program for Hawaii and Pacific Rim high school teachers. Over the ten years of TOPS, variable star observing and AAVSO's *Hands-On Astrophysics* curriculum were an integral part of the program (Figure 34).

Among those outside the AAVSO was the Eighth United Nations/European Space Agency Workshop on Basic Space Science in the Developing Countries, held in 1999 in Jordan, and subsequent UN/ESA meetings, in which she successfully had *Hands-On Astrophysics* incorporated into the curricula for the participating national observatories.

Janet also was involved in alumnae mentoring and outreach in the Wien International Scholarship program at Brandeis University, the program that she had benefitted from so as an undergraduate (Figure 35). In addition, she was an active member of the Women in Science network that facilitated connections and experiences for women in the sciences in the New England area.

5. Janet as mentor at AAVSO Headquarters

Everyone who worked at AAVSO Headquarters, whether as a summer, semester, or volunteer assistant or as a permanent employee, learned from Janet far more than the details of their jobs. A particular skill or interest (astronomical or other) was always encouraged and supported by her. (Her own enthusiasm for photographing flowers was fostered by everyone at headquarters (Figure 36)). The way she interacted with everyone, responded to pressure, constant interruptions, even hostility, was a model for living life with kindness and compassion, and with fierce determination to succeed, be proactive, and find solutions. The author, who worked with Janet as her assistant and senior assistant for twenty-four years, knows this from long and cherished personal experience. Janet also taught that being a mentor or a mentee wasn't all hard work and serious discussion—it could be a lot of fun, too! (Figure 37)

Permanent assistants' work varied tremendously, depending on what needed doing. Everyone was hired with specific responsibilities and/or projects to be done, but took on other tasks as needed—no one ever said "that's not my job." Summer assistants' areas of work and research typically included identification and variability research (literature and HCO plates) of stars for preliminary charts, problematic stars, field stars, period analysis and/or mean curve creation using AAVSO data, data validation and light curve plotting for AAVSO publications, creating specialized program charts—a great variety of types of research and work. All assistants gave a presentation on their research at the AAVSO Annual meeting and published an article in *JAAVSO*—part of Janet's teaching the skills needed in the scientific research process.

Janet had over forty permanent or summer assistants (many Margaret Mayall summer assistants) during her tenure as Director. Figure 38 is a composite photo of her last staff in 2003; it stands for all of us from Headquarters since 1973. Many of Janet's assistants have gone on to professional careers as scientists and have acknowledged the importance of their time working with Janet. Some of these individuals are mentioned briefly below.

Heidi Hammel was hired as a Summer Assistant in 1980. Today, Heidi is a planetary astronomer, specializing in the outer planets. She is Executive Vice President of AURA (Association of Universities for Research in Astronomy) and is a recipient of the American Astronomical Society's (AAS) Klumpke-Roberts Award for outstanding contributions to the public understanding and appreciation of astronomy, Harold C. Urey Prize for outstanding achievement in planetary science by a young astronomer, and Carl Sagan Medal for her exemplary work in outreach and public education (Figure 39).

Karen Meech was a Mayall Assistant in summer 1979 and a Special Research Assistant during graduate school at MIT. Today Karen is Director of the Astrobiology Institute, University of Hawaii (NASA), emphasizing education and outreach, and a planetary astronomer and co-investigator on NASA cometary missions. Her awards include the AAVSO William Tyler Olcott Award for contributions in mentoring/promoting variable stars, the AAS Annie Jump Cannon Award for distinguished contributions to astronomy within five years of receipt of a Ph.D., and the Harold C. Urey Prize (Figure 40).

Shelly Pope was a Mayall Assistant in summer 1982. Today she is a professional astronomer at Lunar and Planetary Labs and Scripps Institution of Oceanography specializing in atmosphere studies, solar radiation and greenhouse gases, global warming, solar wind, and space weather (Figure 41).

Meg Lysaght Thacher was a Research Assistant 1988–1990 working on the Hipparcos mission. Today, with an M.S. in Astrophysics, she is a Laboratory Instructor in the Five College Astronomy and Physics Departments, Smith College, and a Lecturer in the English Department at Smith teaching the engineering course "Writing about Science" (Figure 42).

Mary Dombrowski, daughter of AAVSO longtime AAVSOer Phil Dombrowski, did a high school science fair project on IP Peg, observing, then analyzing—at increasingly sophisticated levels over several years—the light curve to explain evidence of an eclipsing companion, and won numerous local, state, and national awards. Today she is an M.D. in Neurology, finishing a Neurology Fellowship at Yale, and is married with a young son (Figure 43).

Ann Piening McMahon was an undergraduate Assistant 1978–1979, doing data- and science-related work. Ann became a laser communications satellite specialist for McDonnell Douglas, then a science educator for two-to-five year olds (author of *Catalyst and Friends*), and today is director of MySci, a hands-on science program for elementary students at Washington University, St. Louis (Figure 44).

Tanja Foulds was AAVSO Project and Meeting Coordinator 1991–1995. Today she is Director of Event Planning for a major hotel in Hawaii (Figure 45).

Jill Gustafson was an undergraduate Assistant 1978–1980 doing data entry and clerical tasks, and a Summer Assistant in 1980 helping with the final checking and cleaning of the *AAVSO Variable Star Atlas*. Today Jill is an M.D. in pediatrics.

Jim Allen was a high school student Summer Intern in 1979 who analyzed two stars and published a paper with Janet in *JRASC*. His AAVSO internship led to a summer job at Goddard Institute for Space Studies; in a letter he thanked Janet for encouraging his "budding interest in astronomy and astrophysics."

Peter Garnavich was a Clinton Ford Summer Research Assistant in 1982. Today he is a professor of astrophysics and cosmology physics at Notre Dame University, and specializes in supernovae, interacting binaries, and cosmology, and as a co-discoverer of dark energy, is a member of the team that won the 2011 Nobel Prize in Physics (Figure 46).

Benjamin D. Oppenheimer met Janet at a middle school star party, after which he wrote telling how much he loved astronomy and asking if he could volunteer at AAVSO Headquarters (he would gladly make coffee, anything). Janet welcomed him as a volunteer at age thirteen (the first thing he learned was how to make coffee) and took him under her wing for the next eight years and more, from middle school into graduate school. She assigned him the recurrent nova RS Oph to study and analyze, teaching him how to do research in increasing depth over the years, prepare and give presentations at the AAVSO and AAS levels, and turn those presentations into publications, and helping him develop his analytical and inquiry skills. After attending Harvard University and graduate school in astrophysics, Ben worked in cosmological modeling and simulations at the University of Arizona; he is currently at Leiden University (Figure 47).

6. Conclusion

As a child, Janet was guided by many forces. As an adult, and with her courage, determination, tenacity, persuasiveness, kindness, charity, and optimism, Janet was a guiding force herself even as forces continued to act on her. She shaped the AAVSO through her vision and continual efforts. She shaped the international amateur astronomy community through outreach to national groups and fostering collaborations with groups and individuals from other groups. She shaped the professional astronomy community—the variable star section of it, at least, and perhaps others such as education—through her unceasing efforts to teach that amateur astronomers can and do contribute valuably to research and science. Through her volunteer work for the Wien International Scholarship of Brandeis University, who knows what other areas of human endeavor she may have affected—after all, the Wien students become leaders around the world in their fields, from science of all kinds to jurisprudence to international relations to the arts. She helped to shape young lives as a mentor and encourager to many young people in many countries. Truly, guiding forces were part of Janet Hanula Akyüz Mattei.

7. Acknowledgements

My sincere thanks go to Mike Mattei, Thomas R. Williams, and Mike Saladyga for helpful discussion, to Mike Saladyga for the formatting and layout of the photos, and to Rebecca Akyüz for sharing the childhood and graduation photos of Janet Mattei with the AAVSO.

It is always risky to list individuals involved in many ways over a long time because omissions are sure to be made. My apologies go to any I may have omitted—please send omissions and/or corrections to eowaagen@aavso.org.

Figure 1. A teenaged Janet (second from right) with extended family, being embraced by her paternal grandmother.

Figure 2. Janet and her Aunt Liana, July 1962.

Figure 3. Janet and Janet MacLennan.

Figure 4. New graduate Janet with her Uncle Rafael Akyüz.

Figure 5. Janet holds her niece, Rebecca.

Figure 6. Janet and her beloved mother Bulisa (Bella) Akyüz.

Figure 7. A study in mentoring: Janet, Dorrit Hoffleit, Paris Pişmiş.

Figure 8. Presenting Dorrit with the William Tyler Olcott Award at the 2002 AAVSO Annual Meeting.

Figure 9. Janet and Michael Mattei at their engagement party in 1972.

Figure 10. Publicity photo: AAVSO Director and mentor Margaret Mayall handing over the Directorship to Janet Mattei.

Figure 11. Janet at work in 1977—the Director is in!

Figure 12. Clinton Ford, Mike, and Janet at an AAVSO Banquet in the late 1970s.

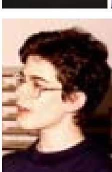
Figures 13–32, AAVSO Mentors. From top left: John Bortle; Martha Carpenter; Louis Cohen; Grant Foster; Owen Gingerich; Katherine Hazen; Martha Hazen; Arne Henden; Mario Motta and Margarita Karovska; Howard Landis and Arthur Stokes; Wayne Lowder; John Percy; Charles Scovil; Paula Szkody; Theodore Wales; Barbara Welther; Charles Whitney; David B. Williams; Thomas R. Williams; Lee Anne Willson with Janet.



Figures 33–35: JAM and pupil at a *Hands-On Astrophysics* workshop; teaching at TOPS; Rachel Zimmerman, Brandeis Univ. ‘95, JAM ‘65, Robin Shostack ‘97.


Figures 36, 37. Photographing wildflowers; mentor and mentee share a treat.

Figure 38. JAM’s last staff (2003): from left—Sara Beck, Katherine Davis, Carl Feehrer (volunteer), Kerriann Malatesta, Gamze Menali, Gloria Cruz-Ortiz, Aaron Price, Arthur Ritchie (volunteer), Michael Saladyga, Travis Searle, Sarah Sechelski, Barbara Silva, Matthew Templeton, Rebecca Turner, Elizabeth Waagen.

Figures 39–47. AAVSO Mentees: from upper left—Heidi B. Hammel; Karen J. Meech; Shelly K. Pope; Meg Lysaght Thacher; Mary Dombrowski; Ann Piening McMahon; Tanja J. Foulds; Peter M. Garnavich; Benjamin D. Oppenheimer.

The AAVSO Widow—or Should We Say Spouse?

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Presented at the 100th Annual Meeting of the AAVSO, October 5, 2011; received April 4, 2012; accepted April 4, 2012

Abstract In past discussions of AAVSO observers over our first century of progress, the familial consequences of membership received little attention. However, non-astronomer friends commonly ask AAVSO observers, "But how does your wife feel about your spending so much time at the telescope and not in bed with her?" Although our Directors have not all been "observers," they too are forced to keep unusual office hours, answer telephones in the middle of the night, and so on. This paper attempts to portray the many surprising ways in which the AAVSO spouse (not all observers are male nor directors female!) responds to their partner's pre-occupation with variable stars.

1. Introduction

While thinking about individuals who had been inadequately recognized as part of the AAVSO's centennial celebration, it occurred to me that one whole class of individuals who had been almost completely ignored were the marital partners of AAVSO members. Some spouses of members actually not only attend meetings, but also participate actively in AAVSO work, either as observers, or in other direct support to the Association. AAVSO has been one of the corners of astronomical history in which there have been active participants of both genders. In turn, that recognition led to another realization—the AAVSO director's spouse seems always to be on call but receive little recognition for their sacrifices.

One should consider whether or not the spouse always has a choice in the matter. Some spouses accepted the problem by agreeing to marry someone already actively committed to the AAVSO. Furthermore, the problem might be complicated by consideration of other variations on the theme. Did an AAVSO member's or director's spouse really have an option that could be exercised? Well, if the marriage came before the involvement in variable star astronomy, then the answer is "probably so." Under those circumstances, the potential spouse is only confronted with the problem after consummation of the marriage. If on the other hand, a career in astronomy is already under way, the avocational or vocational involvement should be evident to the potential partner and should be a consideration. But in every case, there are later decisions to be made involving the degree of commitment; those judgments drastically influence the outlook and productivity of the astronomer whether an observer or administrator. Thus, the impact (positive or negative) of the spousal attitude on the degree of a participant's commitment to astronomy is a real concern to be recognized as part of this centennial.

So for this paper, I categorized spousal reactions to variable star astronomy as follows:

- The Director's Spouse
- The Active Participant
- The Cheerful Supporter
- The Variable Star Widow
- The Black Widow

This paper will discuss a few examples in each category. I hope to convince all AAVSO spouses that we members mean well, though we may not express it as well as we might from time to time as we walk out the back door for another session of observing, or spend hours on the on the computer in internet meetings and on discussion lists. My hope, then, is to make this paper a token of our appreciation for the sacrifices our spouses make to support us.

2. The Director's Spouse

This paper begins by honoring those whose spouse served as the leader of the AAVSO at any given point in time (Figure 2). The Association has been blessed with strong supporters in every case, and it is a good thing. The job of the Director, Recorder, or in Olcott's case, the Secretary, always proved to be time consuming and called for a great deal of sacrifice in the family. It is evident that this is the case because, whether by choice or accident of physiology, only one of the spouses involved was actually involved in parenting. Even there, four of the five Campbell children were born before Leon accepted full-time responsibility for the AAVSO. Thus, the AAVSO was spared the resulting distractions of its leadership by the extra issues related to children in the family.

2.1. Clara Olcott

On their wedding day, neither William Tyler Olcott nor Clara Hyde knew what lay ahead of them in terms of the AAVSO. Tyler displayed no interest in astronomy; that would come later. After being initiated to the beauty of the night skies by one of Clara's friends, Tyler Olcott's interest in astronomy slowly expanded until variable stars captured his attention. His subsequent founding of the AAVSO, with all the work that entailed, had to be balanced with a busy social life with Clara and her family. They lived among the social leading lights in the community of Norwich, Connecticut. World War I imposed major new work loads on both Clara and Tyler. She volunteered to work as a leader of the local American Red Cross while Tyler took on a full-time job as Secretary of the Norwich Draft Board. The burden was more than Tyler could stand physically. Under this pressure he neglected variable star astronomy somewhat during the war, leading others to take more responsibility for AAVSO. Eventually this led to the incorporation of the AAVSO in 1918. After incorporation, the new AAVSO by-laws provided for elections and a full slate of officers to ensure the continuity of the organization.

Tyler's health never quite recovered from the wartime stress, but Clara apparently sailed through the war effort smoothly while continuing to support and care for Tyler. For the next two decades, Tyler's health required that they spend winters away from Norwich, either in Florida or Arizona. Unfailingly supportive, Clara was usually seen by the AAVSO membership, hanging on Tyler's arm, helping him through his sickness and the press of AAVSO duties as well as other work. Although Tyler's health failed and he died in 1936, Clara lived until 1951. In an amazing coincidence, she passed away on exactly the same day that Leon Campbell died.

2.2. Frederica Campbell

We know a lot less about Frederica Campbell than we do about Clara Olcott. Born (and educated) in Columbia, Connecticut, in 1881, Frederica met Leon early in the twentieth century. Columbia is located between Hartford and Waterbury, and even today claims a population of only a few thousand citizens. Thus, it seems very likely that Leon met Frederica through some church activity; Columbia is otherwise a long way from Cambridge. They married in June 1905 and established their home in Cambridge. Their first child, Leon Jr., was born in August 1906, followed by their first daughter in January 1908. Some older AAVSO members will remember her as Florence Bibber (she later was Margaret Mayall's assistant for many years). A second son, Malcolm, arrived in January 1909. Another daughter, Ruth, was born in Peru while their last daughter, Ellen, was born when they returned to Cambridge from Arequipa. Thus, as a busy mother, Frederica limited her participation in AAVSO events out of necessity; it is clear that she had her hands full for most of the first thirty years of their marriage. Small wonder, then, that she shows up with Leon in so few of the pictures we have of him involved in various AAVSO activities over more than forty years.

2.3. Newton Mayall

The extensive support given to Margaret Mayall by her husband Newton over the many years of their lives together is yet another example of the importance of the spouse to the AAVSO, whether as the observer's spouse or the director's spouse. Newton joined AAVSO before he ever met Margaret; it was through Newton's work as a variable star observer that they became acquainted in 1924 at her first AAVSO meeting.

Newton was born in 1904 in Waltham, Massachusetts. As the son of a commercial designer, Newton's professional career as a civil engineer focused on design more than on construction. Sundials were a hobby for Newton and Margaret. Professionally his most prominent project was likely the sundial at front of the entrance to the National Bureau of Standards in Washington, D.C. In contrast to many of our director's spouses, Newton served actively in the AAVSO leadership as well. He served on the Council for twenty-two years, including six years as Treasurer during some of the AAVSO's toughest financial times. Newton also designed a headquarters building for the AAVSO; his design featured an observatory on top. Perhaps someday, if Arne Henden lives long enough at his current pace, we will see Newton's dream of a rooftop observatory realized on top of the present building.

2.4. Michael Mattei

Mike Mattei, like Newton Mayall, met his future bride and AAVSO director at an AAVSO meeting. Born in 1940 and educated in New Haven, Connecticut, Mike quit school before graduating, but learned carpentry during a year in a trade school at his father's suggestion. Night school helped him finally earn a high school diploma, but in the meantime he also apprenticed as an eyeglass lens grinder and became a skilled optical worker. After doing quite a bit of reading about astronomy, Mike discovered the New Haven Astronomical Society. David Dunham, then a graduate student at Yale, insisted that Mike accompany him to Nantucket for the October 1966 AAVSO meeting. Mike not only joined AAVSO at that meeting but learned of openings for night assistants at the Harvard College Observatory's Oak Ridge Station. Eventually his work at Oak Ridge played out, but in the meantime Mike attended the 1969 Fall AAVSO meeting, again at Nantucket, where he met and later began to court Janet Akyüz. Eventually, Mike went back into precision optical work and finished his career as a specialist in that field. As a long term member of the Association of Lunar and Planetary Observers, Mike specialized in observation of the clouds on Venus. So while Mike has been a long-time variable star observer, he is far better known as an amateur planetary astronomer. Mike served on the AAVSO Council from 1972 to 1976, and as as the Clerk from 1979 to 2007.

Unlike Newton Mayall, Mike's contributions to AAVSO were, for the most part, behind the scenes; he never got involved in office or council politics directly. However Janet relied upon Mike as a sounding board with whom she could discuss problems and possible solutions. Anyone close to Janet knew of the enormous insecurities that plagued her all her adult life, though she gave little evidence of her concerns to anyone except her closest friends and associates. In an oral interview, Mike revealed that she suffered a recurring concern that she would not live past age 60, and frequently expressed her desire that they should grow old together. Her concern first surfaced shortly after they were married, and again about every ten years according to Mike. So in fact

Mike's support of Janet behind the scenes facilitated the substantial progress made by AAVSO during her tenure as director.

2.5. Linda Henden

Our present Director's spouse, Linda Henden, presents an amazing contrast in styles compared to all of her predecessors. Mike Mattei remained quietly in the background, constantly available to Janet as an advisor on the home front. In vivid contrast, Newton Mayall, had his thumb in much of what happened in the AAVSO. In Linda we find yet another model of spousal behavior, a constant, quiet, and immensely supportive presence in what goes on around the office.

Born on Long Island, New York, in 1950, Linda Horn moved to Albuquerque, New Mexico, with her family. There, she attended junior and senior high school and studied biology at the University of New Mexico. While at the university, she met and began dating an astronomy graduate student by the name of Arne Henden. After they both graduated in 1968, she married Arne in 1971 and thereafter committed herself to the life of an astronomer's wife.

I said a lot less about all contemporary spouses in this presentation by design, but I can't ignore Linda's steadfast support to AAVSO as well as Arne, during their time in Cambridge. I spent a lot of time in Headquarters over a two year period; during that time Linda and Arne were present and working almost every hour, in Linda's case either at a desk doing bookkeeping and accounting for the association, or with a paintbrush in her hand. I was frankly amazed at the energy and dedication they both exhibited in fixing up 49 Bay State Road, but then Linda says it seems like she has spent most of her life fixing up homes, so I guess her current situation is part of a life-time trend.

3. The Active Participant

A few of our observers' spouses participated actively in amateur astronomy if not in variable star observing or other aspects of AAVSO (Figure 3). There may be many more, but here are just a few examples:

3.1. William Maybrick Kearons

The Rev. William Maybrick Kearons, was very well known in astronomical circles, more so than his variable star observing wife, Winifred Crossland Kearons. They lived in West Bridgewater, Massachusetts, where Rev. Kearons served for over twenty-five years as the Rector of Episcopal Parishes. Born in Liverpool, England, in 1878 William Kearons immigrated to the United States in 1907, where in 1914 he married Canadian native Winifred Crossland.

Rev. Kearons mastered the art of photographing projected images of the Sun's surface in which he captured excellent pictures of sunspots. He provided Harvard astronomer Donald Menzel with daily images of the Sun for every clear day for a number of years; his pictures of sunspots are featured in Menzel's book *The Sun*, and also in *Scientific American* and *The Telescope* magazine in the late 1930s.

3.2. Winifred Kearons

Though I don't plan to do this in most cases, I would also like to say a word or two more about the actual variable star observer in this family, Winifred Kearons. Too little attention has been paid to her separate career as an amateur astronomer. For quite a number of years Winifred Kearons' observing totals led all female and many male observers of variable stars in AAVSO. During the 1930s and early 1940s, Mrs. Kearons also observed the Sun on a daily basis. But in contrast to her solar photographer husband, and perhaps reflecting her more scientific inclinations, Winifred counted sunspots and reported the counts on a monthly basis to the international solar astronomy center in Zurich, Switzerland. When the AAVSO organized its Solar Division, the charter members included both Winifred and William Maybrick Kearons. Using her 3-inch refractor, and reporting observations as KR from 1925 to 1951, her total amounted to 9,769 variable star observations, by no means an insignificant contribution. Winifred also served as a member of the AAVSO Council for four years from 1939 to 1943. At the time of her death in 1957, Winifred Kearons ranked as the leading woman variable star observer and placed well up on the list of all variable star observers for the first forty years of AAVSO history. It was not until the early 1970s that Diane Lucas, and later Carolyn Hurless, both of Ohio, surpassed her total.

3.3. Emily Fernald

Moving forward in time to the 1950s, Cyrus Fernald, already "the ace observer" in AAVSO according to none other than Leslie Peltier, married for the first time at the age of forty-nine years. His bride, Emily Parsons Sanborn, a school teacher and accomplished organist, was ten years younger. It will come as no surprise that the Fernald's marriage produced no children. After their marriage, Emily, or Em as Cy used to refer to her, picked up on his astronomical interest, perhaps as a form of self-defense. She contributed about a hundred variable star observations but became, along with Cy, a regular solar observer and contributed sunspot observations to the AAVSO Solar Division and to Zurich. Cy claimed Em had a lot better eyes than he did and always saw more spots than he could. She made 900 observations of sunspots over her observing career.

But Em's real contribution was through her support of Cy as one of the leading variable star observers in the AAVSO as well as a council leader during the eviction from HCO. In addition to astronomy, the Fernalds shared another passion as avid birdwatchers. In fact, in decades from the 1950s through the 1970s, a number of other couples in AAVSO shared the hobby of bird watching with the Fernalds, including Leslie Peltier and his wife Dottie, and former president Ralph Buckstaff and his wife Annie Laurie. In those pre-internet days of inexpensive gasoline, these couples made driving visits to each other for purposes of bird watching as well as socializing.

3.4. Other forms of participation

Two other active couples of note include the Wilkersons and the Beamans (Figure 4). Carmen and Winston Wilkerson both served on the Council of the AAVSO, and in Carmen's case, she also served as the AAVSO Auditor for a number of years. Joint participation in AAVSO also characterized the efforts of Carol and Barry Beaman. Both observed variable stars and both participated regularly in AAVSO meetings. While Barry served on the Council, the Beamans organized an AAVSO Spring meeting in their hometown of Rockford, Illinois. After decades of service to the Astronomical League as well as the AAVSO, the Beamans rank among the strongest supporters of amateur astronomy in the United States.

4. The Cheerful Supporter

Now in many cases, equally important spousal support rendered to AAVSO observers and leaders did not involve active observing or participation in the leadership of the Association. I chose to separate these spousal supporters into a slightly different but no less important category. In these cases, it is frequently more difficult to find out something about the spouse, but that should not diminish their importance to the AAVSO (Figures 3 and 4).

4.1. Lillian Pickering

Three years older than jeweler David Bedell Pickering, his wife Lillian raised their five sons, which in itself is a life-time of work for most women. She also played an important role in the early years of the AAVSO, even before its incorporation. Lillian and David hosted the earliest large meetings of the AAVSO in their home in East Orange, New Jersey. Those successful meetings eventually led to the incorporation of the AAVSO, but outgrew the capacity of the Pickering home.

4.2. Margaret Yalden

Almost the same might be said of Margaret Yalden, the spouse of another member of "The Old Guard" (charter or very early AAVSO members), Born in 1865 in Pennsylvania, Margaret Lyon remained unmarried in New York City until she met J. Ernest G. Yalden, an Englishman who came to the United States in search of opportunities. They married in 1895, and by 1900 had settled in Leonia, New Jersey, in what was to remain their home for the rest of their lives. Five years older than Ernest, Margaret maintained a stable home for him and supported his extensive involvement in variable star observing and other forms of astronomy, especially his lunar occultation work for the AAVSO. The Yaldens frequently entertained other Old Guard members in their home. In May 1925, the Yaldens hosted the Spring meeting of the AAVSO, the last formal meeting to be held in a private home as the AAVSO outgrew such intimate surroundings.

4.3. Jane Halbach

Wisconsin native Jane E. Roth met Ed Halbach at church and they married in 1942. This happy marriage produced a family of six children. In spite of the parenting difficulties involved with such a family of six children, Jane worked full-time selling advertising for the Yellow Pages Telephone Directory. Verbally eloquent, persuasive and successful in her job, Jane had a way with words. For example, she wrote radio jingles for which she won many prizes. Most *JAAVSO* readers may not remember musical jingles as a sales technique, but in the days in which radio advertising was the most direct route to consumer awareness, jingles played a major role. Through it all Ed continued his full-time employment and his full-time service to astronomy as well, as a founder and observatory director of the Milwaukee Astronomical Society, eclipse chaser for the National Geographic Society, observing grazing lunar occultations for IOTA, and photographing aurorae for Cornell University. Ed served as founding President of the Astronomical League, in addition to observing variable stars and raising his wonderful family with Jane. Those important contributions could not have occurred without Jane's support; she loved to travel, so as often as possible, she accompanied Ed to meetings of both the Astronomical League and the AAVSO.

4.4. Barbara Kaiser and Elizabeth Dillon

Dan Kaiser and Bill Dillon served as presidents of the AAVSO during one of the most trying periods in our history, when AAVSO Director Janet Mattei fell ill and died. Their exemplary handling of this catastrophe (Dan's during the remainder of his tenure as President, through October 2003 and as Past President through October 2004, and Bill's as his successor through October 2006) stabilized the Association and ensured continuity of its leadership in a critical period. Dan relied heavily on the support of his wife Barbara as a pillar of strength and support while Bill's wife Elizabeth was an incredible source of support throughout his tenure. For that alone Barbara and Elizabeth represent exactly the type of spousal support that this paper intends to celebrate.

But Barbara had another characteristic that makes her memorable; she joined enthusiastically into the spirit of AAVSO meetings to enjoy, and to help others enjoy, the opportunities presented wherever the meeting was being held. A good example of that occurred when the AAVSO met in Houston. Earlier it was mentioned that bird watching had been a second past-time enjoyed by many AAVSO couples. Barbara and Dan had also been active as bird watchers, and always looked for opportunities to observe birds that neither had on their life-time lists. Birding is now their full time avocation as I understand it. More on that in a minute as I will come back to this story.

4.5. Bruce McHenry

Our long time member Martha Locke Hazen supported the AAVSO in many ways as the curator of the Harvard College Observatory plate stacks. Elected to the AAVSO council, she served as president, eventually resigning the presidency to serve as secretary for a decade as Clint Ford's replacement. An acrimonious divorce left her to raise two children in addition to her employment, but nevertheless Martha was steadfast in her involvement and support for AAVSO. So it was a special delight for everyone, especially those who had survived divorces and remarried, to meet Bruce McHenry as Martha's new spouse. After a career as a senior park naturalist and interpretor for the National Park Service, Bruce and Martha shared interests in many things, including travel and especially their common interest in canals and canal barges as a mode of waterway transportation. They visited modern as well as historical systems deserving of preservation. Quickly accepted as a regular spousal participant in AAVSO meetings, Bruce supported Martha as she switched from being president to secretary and extended her service on the Council. My wife Anna Fay returned enthusiastically from a whale watching trip during one of our meetings on Nantucket Island to describe how Bruce had become the de facto tour guide based on his knowledge as a naturalist and well-developed sense of the drama of nature as well as the nature of drama.

Going back now to the Houston meeting and Barbara Kaiser, Bruce and Barbara struck up a friendship because of his extensive knowledge of birds. During the Council meeting in Houston, the two of them took off on a bird hunting expedition. The Gulf coast is well known as birding territory so such a side trip could be expected. When we gathered for dinner that evening, however, Barbara and Bruce were nowhere to be seen. They eventually straggled in, claiming to have gotten lost following a pink footed whistling duck. A likely story we all laughed, and went on with the party with a sigh of relief that they were safe.

I think that short story characterizes one of the great characteristics of all of the AAVSO spouses I've met over the years—their ability to enjoy the circumstances as they find them. That personality characteristic is certainly necessary when one accepts a spouse who already has an active involvement in an organization like the AAVSO. Bruce joined an honored list of such spouses many of whom are mentioned in this paper, including Lillian Pickering, Emily Fernald, Annie Laurie Buckstaff, and Dorothy Peltier, all of whom bought into variable star observing and the AAVSO as a part of their marriage.

4.6. International associates

Over its history, AAVSO enjoyed support from other countries, most notably Canada. As AAVSO presidents, Canadians Frank DeKinder, Charles Good, George Fortier, and John Percy have all been blessed with spousal support that included regular participation in semi-annual meetings. I would mention especially Maire Percy as a frequent participant in AAVSO meetings, supporting John for thirty years or more of his active participation. Whenever our Japanese member and observer Seiichi Sakuma came to AAVSO meetings his quiet and gracious wife Nobuko accompanied him. It may be that Nobuko spoke little or no English, but she always seemed grateful for our recognition. We honor all wives who travel from other continents at considerable expense in terms of both time and wealth to help their spouses participate in the AAVSO.

5. The Variable Star Widow

Moving on to other types of AAVSO spouses, the next to be considered are those strong supporters who do not for the most part participate in AAVSO activities, identified for purposes of this paper as The Variable Star Widows (Figures 4 and 5). There are two clear sub-categories of Widows: The Strong Silent Type and The Complainers. There is no doubt some friction in the marriages of many if not most AAVSO observers, as there is in most marriages. However, the more active an observer becomes the more likely there is to be some friction.

5.1. Barbara Bortle

Of the two types, those who endure in silence and never complain (at least as far as we know), I would cite John Bortle's wife Barbara as one good example. As with the Halbachs mentioned above, the Bortles had a few children and the attention demanded by those children likely provided more than enough distraction for Barbara so that she did not object to John's heavy observing schedule. Their case is a bit more complicated, however. In addition to the limitations imposed by a large family, John and Barbara lived well away from city lights to facilitate his observing, also a disadvantage to her in all likelihood. But then there is also the fact that John's place of work for many years as a fireman in a suburb near New York City was a long way from where he lived. It was an occupation John pursued so he could work two and/or three day continuous shifts at the firehouse, and thereby have longer uninterrupted periods of time at home to observe. That pattern of frequent separations continued for many years until John's serious injuries, suffered when he fell through a roof during a fire, forced his disability retirement. I cite Barbara as an example mainly because I know about the circumstances of her case. The AAVSO is fortunate, I am sure, to be populated with many observers with spouses who were similarly supportive.

5.2. Donald Hurless

AAVSO members who visited Ohio, on the other hand, were sure to have met Donald Eugene Hurless, the spouse supporting our most prolific feminine contributor to date, Carolyn Jane Hurless. There were many different reasons why AAVSO observers might pass through north central Ohio, but one was no doubt Leslie Peltier's presence in Delphos, Ohio. Nearly as important in all likelihood was the fact that Lima, Ohio, where the Hurless family lived, was nearby. Informal gatherings in the Lima/Delphos region were a social event for AAVSOers in the central states and for many from outside the region as well.

Don, a piano player, composer, and arranger, played in his own small groups, trios and quartets, for dance clubs, and also led a larger orchestra. Born in Lima in 1928, Don was actually six years older than Carolyn Jane Klaserner, also a Lima native, when they decided to marry in 1959. Don supported Carolyn's hobbies to the extent that he could. As musicians, Don and Carolyn relied on their musical talents for their existence, Carolyn by teaching piano, and Don by teaching as well as by playing local gigs with his various musical groups. Both were also piano tuners; they maintained a comfortable life style that allowed Carolyn plenty of time for her hobbies. At first she engaged in amateur radio, then later switched to variable star astronomy. Don qualifies for the Variable Star Widower category for a variety of reasons. Obviously he and Carolyn shared many interests but astronomy was not one of them. Don came to only one AAVSO meeting that I recall (1983, where he, Clint Ford, and Dorrit Hoffleit's sister Norfleet gave a wonderful evening concert). But so far as I know, Don never complained about Carolyn's separate work as a variable star observer, publisher of *Variable Views* newsletter, or Council member and officer of AAVSO.

5.3. The Complainers

Now a different situation existed for those wives who endured their spouse's avocation, but let their unhappiness be known to others. Who knows how many are in this category, we hope not many, but it seems likely that more than a few cases exist. Dottie Nihiser must have known when she married Leslie Peltier in 1933 that she was marrying a renowned amateur astronomer, whose avocation required long hours at the telescope eyepiece at night. By then, Peltier was already well known as a variable star observer, and as a discoverer of novae and comets; Dottie knew that he would be less than fully attentive to her every whim. They did manage to have a family, two sons, Stanley H. and Gordon J. Peltier, so their relationship was one of marital bliss in the early days, as Leslie himself described it in his books.

Dorothy Nihiser was born in the same community, Marion, Ohio, into which Leslie had been born, but almost eleven years later. Privileged to attend some college at Ohio Wesleyan University, Dottie displayed a substantial interest in archeology. That likely explains the one month honeymoon that she and Leslie took in the southwestern states. There they could camp and study geology and the archeology of ruins to their heart's content.

By the 1960s though, things began to change. At the time of the August gatherings in Lima and Delphos, Dottie's attitudes were clearly on display, and in spite of her apparently cheerful serving of pancake breakfasts at the end of all-night observing sessions, she also was quite vocal in expressing her displeasure about these sessions to those present in the kitchen, always in a tone and worded in such a way that a dual interpretation was possible, that she was both ribbing Leslie but also scolding him and making her displeasure known. Though I never attended one of these gatherings, I get this message from enough different sources that I feel that the contention must have merit. The story is further supported by the fact that the Fitz and Clark lenses for Peltier's two telescopes, instruments that the AAVSO felt belonged to it, were never returned to AAVSO and have apparently disappeared into the family coffers. Dottie died in Delphos in 2008 at the age of 98.

6. The Black Widow

Some marriages break up in situations in which one of the obvious strains in the relationship involves variable star observing. VSOing inevitably infringes on a married couple's time together. It would be inappropriate to identify anyone who might fit in this category. It seems likely that variable star observing is frequently only one of many problems found in a troubled marital relationship, perhaps not even the major problem. But, one can also observe that a large number of our outstanding observers married very late in life, or suffered separations or divorces, in some noteworthy cases multiple divorces or at least very extended separations. It is quite clear in those cases that dedication to the AAVSO and/or to observing played a part in the collapse of the marriage. And of course there is no way of knowing how many would-be or actual variable star observers threw in the towel and stopped observing rather than break up a marriage. It would be unfair to stigmatize the spouses involved in all such cases, but acknowledgement of the possibility serves to reinforce the main thrust of this paper, that is, more frequent acknowledgement of the importance of spousal support to AAVSO success is important.

7. Conclusion

The AAVSO and variable star observing must be considered a family effort, an idea that had more emphasis in the past, and needs more emphasis in the future! Everyone should acknowledge from time to time how important such relationships are for all of us. Perhaps the AAVSO will make a greater effort in the future to make meetings more family-friendly, provide alternatives to the growing intensity of the science, acknowledging the fact that even those observers who are sleeping with their wives while their automated telescopes grind away through the night have devoted family resources to the project, and time to maintain the effort, reduce the data, and attend meetings.

As the founding father of the AAVSO's photoelectric photometric program, John Ruiz would readily testify that there are always times when only the family can help (Figure 6), and those of us lucky enough to be part of understanding and helpful families need to acknowledge our need and nourish those relationships right along with the science we all value so highly.

8. Acknowledgements

This paper is based on the author's historical research, and personal experiences in the AAVSO.

Editorial comment: Surely one of the most visible and appreciated AAVSO spouses of recent decades has been Anna Fay Williams! (Figure 1) Tom's contributions to the Association have been numerous, diverse, and very significant, and Anna Fay has been there to support him—and occasionally rescue him from medical emergencies. And she's not just an appendage; she has her own scholarly and cultural pursuits, so she doesn't have to come to AAVSO meetings for want of something to occupy her mind. Indeed, her varied talents make her one of the most interesting meeting attendees. Tom and Anna Fay are one of the AAVSO's "royal couples." They help make AAVSO meetings a joy to attend! —John Percy

Figure 1. Anna Fay and Tom Williams at the dedication of the AAVSO Archives named in their honor during the AAVSO Annual Meeting, October 2011.





Figure 2. From top left: Tyler and Clara Olcott; Leon and Frederica Campbell; Margaret and Newton Mayall; Mike and Janet Mattei; Linda and Arne Henden.





Figure 3. From top left: William and Winifred Kearons; Margaret and J. E. G. Yalden (with W. T. Olcott); Lillian and David Pickering; Emily and Cy Fernald; Jane and Ed Halbach and family.





Figure 4. From top left: Carmen and Winston Wilkerson; Barry and Carol Beaman; Dan and Barbara Kaiser; Bruce McHenry and Martha Hazen; Seiichi and Nabuko Sakuma.


Figure 5.Left to right: Carolyn and Don Hurless; Dottie and Leslie Peltier.

Figure 6. AAVSO observer John Ruiz's family helping him up a steep hill, Puebla, Mexico. From their family Christmas card in 1967.

The Legacy of Annie Jump Cannon: Discoveries and Catalogues of Variable Stars *(Abstract)*

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Presented at the 100th Spring Meeting of the AAVSO, May 22, 2011

Abstract This paper will review the many variable star projects and publications that Annie Jump Cannon brought to fruition in her forty-five-year career at Harvard College Observatory. In 1896, when Cannon joined the "Corps of Women Computers" at HCO, Williamina Fleming already enjoyed world-wide acclaim for her discoveries of novae on photographs of stellar spectra. Antonia Maury had also become renowned: she had discovered and analyzed a rare spectroscopic binary star, β Aurigae. At that time, such discoveries made headlines in newspapers, especially because they were made by women who studied astronomy by day! When Cannon was not actively involved in classifying stellar spectra, she took up HCO's project of cataloguing observations of variables. As a result, she discovered thousands of long period variable stars and half a dozen novae in the Milky Way. In 1903 she published "A Provisional Catalogue of Variable Stars" in *Harvard Annals 48*. Subsequently, Margaret Walton Mayall and Florence Campbell Bibber continued cataloguing the variables through 1941, when Cannon died. In 1918, when Cannon and others such as Edward Pickering and Solon Bailey, were made honorary members of the American Association of Variable Star Observers, Cannon wrote: "I assure you it is a pleasure to be associated in this way, with a company of ardent observers and investigators, whose results are of so much value and carried on with such enthusiasm. It well be a spur to me in my future work, especially as to the new Catalogue of Variable Stars, which I hope to finish before very long."

Margaret W. Mayall in the AAVSO Archives *(Abstract)*

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Presented at the 100th Annual Meeting of the AAVSO, October 5, 2011

Abstract AAVSO Director Margaret W. Mayall's presence in the AAVSO Archives is unique in that it was only by her effort that the AAVSO's institutional memory survived the organization's years of struggle. The history of the AAVSO could not have been written thoroughly and accurately without its archival collections. Similarly, the story of Mayall and the AAVSO within that history is not only informed, but is also formed by the materials that she chose to collect and preserve over the years.

History of Variable Star Astronomy in Theory and Practice

Twenty-Eight Years of CV Results With the AAVSO

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Presented at the 100th Annual Meeting of the AAVSO, October 7, 2011; received November 22, 2011; accepted November 29, 2011

Abstract Working with AAVSO data and AAVSO staff on cataclysmic variables since the 1980s resulted in twenty-nine papers from 1984 to 2011. The early work began with characterization of optical light curves of various dwarf novae and novalikes, then moved into coordination of optical observations with satellites (IUE, EUVE, XMM, Chandra, HST, GALEX) to explore the ultraviolet and X-ray regimes of disk systems versus those containing magnetic white dwarfs. The major advances in the field that were derived from these results are summarized, ending with the recent results on the cooling of the white dwarfs and the return of pulsations in GW Lib and V455 And following their 2007 outbursts, and on the spectra of the two peculiar Z Cam systems IW And and V513 Cas.

1. Introduction

A Centennial is a time for looking back and pondering the progress that has been made and remembering the people responsible for that progress. After finishing my Ph.D. in 1975 in the field of cataclysmic variables (CVs), I was eager to pursue new objects and new ways of doing things. Having met Janet Mattei at a CV meeting, I was introduced to the AAVSO and its archives and observers who had their own telescopes. Thus began a collaboration that has continued to the present time. A brief summary of twenty-eight years of data, highlighting my personal results from twenty-nine papers that used AAVSO data is given below. This summary is divided into the eras of its two directors during that period of time, and ends with results on the ongoing projects of observing the accreting, pulsating white dwarfs in CVs and spectral observations of two peculiar Z Cam stars. The CV types that will be discussed include typical systems containing accretion disks, the systems containing highly magnetic (B > 10MG) white dwarfs termed Polars, and the subset of Low Accretion Rate Polars termed LARPs.

2. The Janet era: 1984–2004

The hot topics in the 1980s were centered on the cause of dwarf novae outbursts and the observed UV delay from the optical during the rise to outburst, the differences in outburst cycles for different objects, and the differences between theoretical predictions and observations of the boundary layer (the area where the accetion disk meets the white dwarf surface). The tools to explore these issues included the International Ultraviolet Explorer (IUE), used for ultraviolet spectra, and ROSAT and EXOSAT for the X-ray regimes. To lay the groundwork on outbursts, the large AAVSO data archive on dwarf novae was used to measure the outbursts of twenty-one well-studied dwarf novae. The rise, maximum, decline, and total outburst duration were measured and correlated with various properties (Szkody and Mattei 1984). These first studies showed a correlation of outburst duration with orbital period, as well as a bifurcated pattern of outbursts for some systems like SS Cyg. While this work provided a framework for theoreticians, only bright systems were well-observed. Since that time, it was discovered that the faint WZ Sge systems or Tremendous Outburst Amplitude Dwarf novae (TOADs; Howell, Szkody, and Cannizzo 1995) are the shortest orbital period systems but have the longest outbursts (as they only show superoutbursts which last weeks). The early work for the 1984 paper also showed some intriguing behavior apparent in Z Cam: a rising quiescent magnitude in the outbursts preceding a standstill. Some of this odd behavior is now being pursued in the Z CamPaign of Mike Simonsen (Simonsen 2011). The 1983 outburst of GK Per was well-followed and compared to past outbursts in 1975 and 1991 (Szkody *et al.* 1985) to reveal long outburst durations (50–60 days) with a high excitation emission spectrum present at ouburst. This object was then identified as an intermediate polar when the white dwarf spin was found in X-rays (Watson *et al.* 1985).

To explain dwarf novae outbursts in general as well as the peculiar outbursts of some CVs, theorists presented models for accretion disk instabilities or mass transfer instabilities. These theories had to explain the 1/2- to 1-day delay in the ultraviolet outburst compared to the optical as well as the change (or lack of change) in the accretion disk during quiescence. While several satellite campaigns used AAVSO light curves to study the delay on outburst rise, my work concentrated on the quiescent interval. Using AAVSO light curves to phase IUE data to the outburst cycle for fifteen systems, we found that the majority showed decreasing UV fluxes after optical quiescence began (Szkody *et al.* 1991). This result was contrary to the expectations for the popular theory of accretion disk instability and was a puzzle until later work showed that white dwarfs cool after outburst (Godon *et al.* 2006) and thus, the UV follows this cooling as a flux decrease.

The AAVSO light curves of systems after superoutburst also provided fodder for theorists. The photometry of AL Com after its 1995 outburst (Howell *et al.* 1996) showed a dip similar to WZ Sge that was modeled with a cooling front passing through the disk, while the orbital light curves showed the first harmonic as well as the orbital period. This was among the first indications of the common property of disks in very short orbital period systems that is indicative of a thickening of the disk at the stream impact point as well as on the opposite side of the disk. Other topics in the 1990s moved toward identifying the underlying stars in the fainter, short period systems where the disk contribution is minimal, and understanding the effects of the outburst and accretion on the white dwarf. The observed lack of the predicted boundary layer also remained a problem for CVs at this time. With the start of Hubble Space Telescope (HST), the Extreme Ultraviolet Explorer (EUVE), and Chandra X-ray observations, the probe of the white dwarf and the boundary layer could go much deeper and to different wavelength regimes than previously possible.

With the aid of the AAVSO light curves, HST was used to catch dwarf novae at outburst and quiescence, as well as to follow the effects of the outburst on the white dwarf. The HST spectra of U Gem at outburst (Sion *et al.* 1997) showed a peculiar emission profile in the wings of HeII, indicating a chromospheric structure of the disk. EUVE spectra at outburst (Long *et al.* 1996) revealed the boundary layer of U Gem for the first time, showing it to be at a temperature of 140,000K, and with a size comparable to the white dwarf. The orbit-resolved spectra revealed the presence of a wind, with emission far from the orbital plane. The HST spectra obtained at several times during a quiescent interval showed that the white dwarf cooled after heating by the outburst (Sion *et al.* 1998). Details on the interplay of the various wavelength regions was provided by an intensive campaign with RXTE, ROSAT, IUE, and optical throughout the 45-day supercycle of V1159 Ori (Szkody *et al.* 1999). The results from this compilation showed an inverse correlation between the optical and UV light curves and those from X-ray, as well as the presence of a wind during outbursts, while model fits to the UV data showed a standard disk model did not fit the observed data.

3. The Arne era: 2005 (2002)–present

Collaboration with Arne Henden began in 2002, a few years before he became Director in 2005. The hot topics of the new millenia included the general population of CVs, Polars, and a new area of pulsating white dwarfs in CVs. The Sloan Digital Sky Survey (SDSS) took center stage in the optical, while the Far Ultraviolet Spectroscopic Explorer (FUSE) and the Galaxy Evolution Explorer (GALEX) provided data in the UV and XMM was added to the X-ray scene.

The first HST data on the low state of the Polar EF Eri showed a unique spectrum with a large dip near 1600 Å, and a large amplitude modulation throughout the orbit (Szkody *et al.* 2010b). These data could be interpreted with either a cool white dwarf (the dip being a quasi-molecular hydrogen feature apparent in cool white dwarfs) and the modulation due to the viewing of a hot spot on the white dwarf throughout the orbit, or with two cyclotron components due to different magnetic fields. XMM data on the eclipsing polar SDSSJ0155+00 delineated a viewing geometry that allowed observation of the accretion flow through the base of the accretion funnel, leading to estimates for the physical parameters of these areas (Schmidt *et al.* 2005).

Work with the SDSS spectral database led to the identification of 285 CVs, resulting in eight papers in a series in the *Astronomical Journal* (*AJ*) (see Szkody *et al.* 2011 which includes previous papers in the series). These new CVs probed to fainter magnitudes and larger distances than previous surveys. Followup observations conducted by Arne and other AAVSO members, using the U.S. Naval Observatory (USNO) telescope as well as telescopes around the world, led to the ultimate identification of orbital periods of over 100 of the new objects. These results changed the picture of the orbital period distribution of CVs, bringing the observed periods much closer to the theoretical population models and showing that the previous results were largely due to selection effects (Gaensicke *et al.* 2009). Two surprising results also emerged from these SDSS results: the identification of a likely large population of LARPs and the presence of several pulsating, accreting white dwarfs among the SDSS objects. Followup XMM observations of the LARPs SDSS1553+55 (MQ Dra) and SDSS1324+03 showed low X-ray temperatures and luminosities, implying the source of X-rays was the M dwarf secondary, not the accretion shock (Szkody *et al.* 2004).

Followup HST spectra of the pulsating white dwarfs in CVs revealed a much hotter instability strip for these systems than the hydrogen-atmosphere non-accreting white dwarf pulsators (Szkody *et al.* 2010a) and the presence of increased amplitudes of pulsation in the UV compared to the optical regions. The outbursts of two of these pulsators (GW Lib and V455 And) in 2007 allowed the unique opportunity to follow these two systems as the white dwarf, heated by the outburst and moved out of its instability strip, cooled and resumed pulsations (Bullock *et al.* 2011). AAVSO data outlined the outburst and provided the required ground coverage to determine that the observed fluxes would not harm the HST observations. While the optical magnitudes were within a few tenths of a magnitude of the quiescent brightness by years 2010 and 2011, the temperatures determined from the UV spectra were still elevated. At years three and four after outburst, GW Lib was 3700K and 1300K hotter than quiescence, while V455 And was 600K and 200K hotter. In both objects, shorter periodicities than at quiescence (interpreted as the return of pulsations) are apparent in the UV by year three after outburst. Continued observations of these two objects will provide clues as to the mass accreted during the outburst and the amount of heating of the interior of the white dwarf.

Another ongoing project stems from the Z CamPaign (Simonsen 2011) which resulted in the identification of two peculiar Z Cam stars (IW And and V513 Cas). These systems show brightenings to an outburst following a standstill, in contrast to the usual behaviour of decline to quiescence following a standstill. Spectral observations of IW And and V513 Cas combined with the AAVSO photometry of these two systems throughout the various states of outburst, standstill, and quiescence are being used to study the accretion rates during these states. The available data so far show IW And has a traditional change from Balmer emission at quiescence to absorption at outburst, while V513 Cas shows emission cores flanked by broad absorption at quiescence and an unusual strength of high excitation HeII emission during outburst.

4. Conclusions

The past twenty-eight years has shown some large changes in understanding of CVs due in large part to the coverage of outbursts and optical states provided by the AAVSO observers and archive. The long term records of outbursts and the simultaneous determination of optical states during spacecraft observations at other wavelengths have been a vital part of the research undertaken. With the continued help of AAVSO observers, these advances into the understanding of accretion disks, magnetic white dwarfs, pulsating white dwarfs, and the makeup of the CV population will continue for the next twenty-eight years.

5. Acknowledgements

The many observers of the AAVSO that contributed to all the scientific work described here are gratefully acknowledged. This work was funded by

NSF grant AST1009734 and NASA grants HST-GO-1163.01-A, HST-GO-11639-01A, and HST-GO-12231.01A from the Space Telescope Science Institute which is operated by the Association of Universities for Research in Astronomy, Inc., for NASA, under contract NAS 5-26555.

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The Development of Early Pulsation Theory, or, How Cepheids Are Like Steam Engines

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Presented at the 100th Spring Meeting of the AAVSO, May 22, 2011; received December 23, 2011; revised January 17, 2012; accepted January 17, 2012

Abstract The pulsation theory of Cepheid variable stars was a major breakthrough of early twentieth-century astrophysics. At the beginning of that century, the basic physics of normal stars was very poorly understood, and variable stars were even more mysterious. Breaking with accepted explanations in terms of eclipsing binaries, Harlow Shapley and A. S. Eddington pioneered novel theories that considered Cepheids as pulsating spheres of gas. Surprisingly, the pulsation theory not only depended on novel developments in stellar physics, but the theory also drove many of those developments. In particular, models of stars in radiative balance and theories of stellar energy were heavily inspired and shaped by ideas about variable stars. Further, the success of the pulsation theory helped justify the new approaches to astrophysics being developed before World War II.

1. Introduction

The idea that stars could change brightness was bizarre enough that Aristotle rejected it on general principles. Even at the end of the nineteenth century, with the existence of variable stars well documented, their exact nature remained mysterious and problematic. The key to solving this puzzle was the theoretical astrophysics developed in the early twentieth century, but in an important sense variable stars were also the keys to theoretical astrophysics. Cepheid variables inspired, framed, and functioned as laboratories for many of the critical investigations that established the discipline.

2. The Binary hypothesis

Cepheid variables were completely inexplicable until the discovery of periodic radial velocity shifts in their spectra. This led to the double-star interpretation of variability: given the evidence for regular motion toward and away from observers, it was the most natural interpretation of the data at hand. There were other suggestions offered, such as the close approach of two stars causing tidal variations and eruptions of gas at higher temperatures than the stellar surface (Renaudot 1917). But none of these had the conceptual clarity and ease of explanation of the binary theory.

Harlow Shapley in 1914 called it a "misfortune" that the lines could be so easily understood this way. This paper focused on the problems with the binary interpretation, which he called "insurmountable" (Shapley 1914). Chief among these problems was the irregularity of Cepheid light curves. He noted that the continual change of the shape of the light curve made it quite difficult to assign the hypothetical binary a normal periodic orbit. He objected that instead of these messy curves, "regularity and continuity" (Shapley 1914) would be expected of any orbital phenomena. Shapley also brought up the observed changes in spectral type, which seemed nonsensical for a binary.

Some astronomers (including Campbell, Plummer, and Ludendorff) had also argued that there were internal inconsistencies in the double star hypothesis. For example, the average Cepheid was 700 times brighter than the Sun, which yielded a volume between 15 and 20,000 times as great as the Sun. As binaries, they would thus have an orbit less than 1/10 the radii of the stars themselves, which seemed impossible.

Shapley admitted that he could "offer no complete explanation of Cepheid variability as a substitute for the existing theories that are shown to be more and more inadequate." His paper was just suggesting new avenues of approach to these problems. He did offer one intriguing, if poorly defined, possibility. Perhaps the variability was caused by "internal or surface pulsations of isolated stellar bodies." (Shapley 1914) Shapley listed points in favor of the pulsation hypothesis: as a result of some original disturbance there would be oscillations of several different periods, explaining the complex light curves; for pulsation maximum velocity and light would be correlated just as observed; ebb and flow of heat would explain the change of spectral type. It is important to understand that pulsation was only a hazy hypothesis at this point, without any clear technical articulation. Shapley said the difficulty of making the hypothesis more precise lay in the lack of knowledge of the processes inside stars.

3. Early pulsation theory

Martin and Plummer (1915, 1917) followed up on Shapley's idea, integrating the Cepheid velocity curve to get a radial displacement function over time. Interpreting this displacement as actual movement of the star's surface yielded an expansion of the order of hundreds of thousands of kilometers. Like Shapley, they did not claim any proof or decisive evidence, and their most important contribution was laying out the technical issues that needed to be solved for pulsation theory to be useful.

They argued that one of the benefits of the pulsation hypothesis was that it could explain a number of different types of variables: "There seems to be no very cogent reason against the view that, outside the eclipsing systems, the great majority of variable stars manifest the operation of one essentially uniform process in nature." (Martin and Plummer 1917) The uniform process they were referring to was the struggle between radiative expenditure and mechanical equilibrium, a presumably fundamental process in stellar interiors. This demonstrates an important point in the early history of variable star theory. There was continual disagreement about whether Cepheids should be explained in terms of a process organic to the normal functioning of stars, or whether it should be a process outside ordinary stellar behavior.

Around the same time, A. S. Eddington had begun theoretical investigations into many of these fundamental processes, most importantly the radiative balance with gravity. In 1917 he followed Shapley to discuss the pulsation hypothesis explicitly. He noted the enormous amplitudes of expansion that would be required, commenting that since Cepheids were giant stars it was possible, "but the consequent internal changes in the star must be very far-reaching." (Eddington 1917) This framed the problem in a definite way: the validity of the pulsation hypothesis was to be solved by understanding the stellar interior. The processes of the stellar interior were essentially unknown at this point, and Eddington was largely working with a blank slate.

He began by assessing a major difficulty key to the pulsation theory. Why do the pulsations not die out? It seemed unlikely that such massive alterations in the star's structure would last for very long:

> The most difficult question is, how can these pulsations be maintained? It is suggested by Shapley that, if the pulsations were started by some cataclysm, there is one type which would decay extremely slowly; it might persist almost indefinitely with inappreciable dissipation. But I do not think this conclusion is warranted by such investigations as have been made. The problem is essentially a thermodynamical one. The main cause likely to lead to a decay of vibrations is thermal dissipation of energy due to the flow of heat between different parts of the star. (Eddington 1917)

That is, Shapley thought of this as a problem in wave mechanics. Eddington proposed treating this as a problem in energy transfer. The vibrations would presumably dissipate a great deal of energy, and there must be a system by which this energy was replaced. Stellar heat was clearly "continually liberated within the star and passes outward into space; this may be borrowed and converted into energy of pulsation." (Eddington 1917) If these were the key issues, Eddington suggested, one should use an existing body of detailed theory developed for a physically different, but conceptually similar problem: the action of a steam engine. This helped clarify what a pulsation theory would require:

> But in order to convert heat of any kind into work, the star, or some part of it, must behave as an engine in the thermodynamical sense: that is to say, it must take in heat when it is at a higher temperature than the average and give out heat at a lower temperature - just the opposite of what usually happens in natural conditions. (Eddington 1917)

He pointed out that by means of radiation pressure a portion of this energy could be captured mechanically, just as a piston captured the expansion of steam.

Eddington confessed that understanding the vibrations of a star was "a very difficult analytical problem" and it has not yet been possible to figure out how a star could "behave in the manner of an engine." (Eddington 1917) However, he said, it was important not to obsess over certainty when conceptual progress could be made:

> Though we cannot offer any adequate theory as to how the star manages to behave as an engine, we can point out some evidence that it does so behave. I am not sure whether the following mode of regarding the question is strictly allowable; but I venture to put forward the suggestion tentatively. (Eddington 1917)

The key was to find a thermodynamic situation where the stellar waves neither decayed nor increased. He speculated that varying transparency inside the star could regulate the radiation pressure and therefore the expansion forces. Also, since the outflow of radiation was greatest when the star was expanding, that would help it expand, and vice versa, which would also help maintain vibrations. He explicitly avoided the question of the origin of the pulsations, only considering their survival: "How this comes about must be left unsolved; but since it is so, it seems clear that the pulsations are likely to be maintained." (Eddington 1917) It was clear that to proceed further more detailed studies of radiation pressure would be needed, and this drove Eddington's broader studies of radiation pressure in stars.

By 1918 the pulsation theory had made serious strides. The Council of the Royal Astronomical Society (CRAS) commented that the binary theory was imperiled, but that the pulsation hypothesis had not been proven (CRAS 1918). Eddington agreed that there was no proof while still stating that there was "little doubt" that Cepheid variation must be attributed to some form of pulsation (Eddington 1918). His new investigations used dimensional analysis to shows that "globes of fluid" would oscillate in periods inversely proportional to the square root of the density, a relation that he found to be fulfilled by nearly all the known Cepheids. This allowed determination of density changes in Cepheids by measuring the change of their period (which could be done very precisely). Noting that the most recent measurements of δ Cephei showed its period decreasing by about 1 in 9 million per year, this suggested it would take 10 million years to pass from type G to F (Eddington 1918). This seemingly minor detail had enormous implications:

> This is a far slower change than that derived from the assumption that a star's heat is provided by the energy of contraction. In fact, our time-scale is enlarged a thousand-fold, and becomes much more

> easily reconciled with current theories as to the age of terrestrial rocks, the development of the Earth-Moon system, and geological change. (Eddington 1918)

Thus measuring the periodicity of Cepheids could provide a clue to the critical question of the age of the stars, and therefore, of the universe. The time scale of stellar and cosmic evolution could finally be settled (Eddington 1918, 1919a). This link of stellar evolution to variable stars provided a useful hook on which new investigations of stellar aging could begin.

Another consequence of these calculations was the suggestion that if a star's energy came solely from gravitational contraction, then its change of period should be quite large. The observed change of period of δ Cephei was 0.1 second per year, while contraction theory predicted about 40 seconds per year. Eddington confidently asserted that "I see at present no escape from the conclusion that the energy radiated by a star comes mainly from some source other than contraction." (Eddington 1919b) Investigations of variable stars had unexpectedly advanced the long stalemated mystery of the energy source of stars.

By 1919 the pulsation theory had been developed far enough that Eddington was willing to state more firmly that:

> it is concluded that the binary hypothesis of Cepheids must be ruled out, because (a) the distance of the centres of the components would have to be less than the radius of one of them, (b) because there is a uniform relation between the period and density which seems to point to a cause intrinsic in the star. (Eddington 1919a)

He made the case that the hypothesis of pulsating stars leads to results in agreement with observation, specifically the absolute value of the periods, the advance of spectral type toward the red with increasing luminosity, and the asymmetric form of the velocity curve. Eddington had made a powerful case for the likelihood of the pulsation hypothesis, and along the way provided serious impetus to the longstanding problems of stellar evolution and stellar energy.

A handful of astronomers, including Shapley, Eddington, Martin, and Plummer, moved ahead with the pulsation theory. Even with the theory in an embryonic form, they were able to make significant progress. Their success drove other investigators to ask more detailed questions about the observational consequences of the pulsation theory and to present alternative ideas.

4. Objections and alternatives to pulsation

Despite its problems, many astronomers continued to do work with the binary hypothesis—its familiarity and conceptual straightforwardness kept it popular for some time (Henroteau 1919). Others, such as Walter Adams, were reluctant to accept the pulsation theory due to a number of unresolved issues, such as the narrow, well-defined spectral lines of Cepheids being unlikely given the enormous disruption that pulsations would be expected to cause (Adams 1919).

A characteristic example of both positions can be found in C. D. Perrine, director of the Argentine National Observatory. In 1919 he vigorously defended the binary hypothesis: "The closeness with which these variations are represented by orbital motion...is in itself, in the absence of proof to the contrary, almost conclusive evidence of their binary character." (Perrine 1919) He maintained that the characteristics of light curves of known binary systems were perfectly consistent with Cepheid curves. And like Adams, he found it difficult to believe that internal pulsations could be so uniform in length and period. Perrine pointed out that the light curves show no sign of violent disturbance, and sunspots and novae persuaded him that all forms of stellar brightness variation would be irregular. Further, it seemed impossible to reconcile the "quiescent spectra of the Cepheids with such violent activity as the hypothesis of pulsations demands" (Perrine 1921).

Perrine argued that so little was known about what was happening inside stars that one could not use the pulsation theory. Instead, he wrote, we should assume that even mysterious stars such as Cepheids did not involve any truly novel processes. Astronomers should rely on "strong presumption of a similarity in constitution and evolutionary processes among all stars" (Perrine 1919). On this reasoning, they should be treated as binary stars in the absence of extraordinary evidence. He closed by making the case that the "almost deciding factor as to the nature of Cepheid variation" was their preference for the plane of the Milky Way. This, he said, indicated that their variation did not come from "the operation of general physical or gravitational laws" but rather some external condition (Perrine 1919). That is, Cepheids were ordinary binaries driven to unusual behavior by some local property in their neighborhood of the universe.

Many of the critiques of pulsation theory were based on hopes that Cepheid variation could be explained solely through celestial mechanics and other well-understood physics. There was a wide realization that pulsation would require a great deal of messy, novel physics unpalatable to an older generation of scientists. For example, James Jeans proposed a well developed alternative that relied solely on classical astronomy and physics. In 1919 he derived a functional formula for the light curve of δ Cephei with two major terms.He proposed that the first term could be the rotation of a single elongated body and the second term was "arising from some sort of explosion which occurs whenever this body assumes a particular orientation." The observed changes of spectral type would just be the result of the progress of the explosion (Jeans 1919). On this hypothesis, a theory would require little more than traditional calculations of spinning bodies. The period of a Cepheid would simply be the period of rotation of an elongated body tidally locked to a companion. This suggested that Cepheids were merely one peculiar type of binary star (Jeans 1925).

There were plenty of more exotic proposals as well. Johann Hagen at the Vatican Observatory rejected both the pulsation and binary theories, instead suggesting cometary tidal forces (Hagen 1921). The notoriously heterodox American astronomer T. J. J. See argued that both sunspots and Cepheid variation were caused by tidal forces from Jovian planets (See 1922). Kyoto University's Shinzo Shinjo dismissed the pulsation theory and instead proposed the rotation of an "eccentrically condensed nucleus" moving in a spherical mass of meteoric material (Shinjo 1922).

A 1924 article by François Henroteau, working at the Allegheny Observatory and later the Dominion Observatory in Ottawa, provided a massive compilation of Cepheid observations and also assessed the competing theories:

> The present state of our knowledge of Cepheid variation is scarcely adequate to explain all the phenomena involved. The ordinary binary theory may almost certainly be definitely ruled out of court, while on the pulsation theory there are certain points not accounted for. (Henroteau 1924)

His assessment was fairly accurate. The binary theory had been wounded fatally, but the pulsation theory was only appealing to those investigators willing to grapple with strange new physics. The central continuing concern for everyone was whether Cepheids were a distinct class of star, a phase of a typical star's development, or some other possibility. The nature of δ Cephei remained uncertain.

5. A comprehensive pulsation theory

The full foundation of the pulsation theory was presented in Eddington's highly influential book *The Internal Constitution of the Stars* (1926). Its chapter on variable stars was strategically designed to remove competitors and leave the pulsation theory as the only option. He chose his words carefully, stating that it appeared "improbable" that Cepheids were binaries, and that the pulsation theory was now the "most plausible" (Eddington 1926). He warned that getting rid of the binary hypothesis did not necessarily mean the pulsation theory was correct. But, he said, doing so does leave a Cepheid as a single star, and the variation must therefore be intrinsic to it. If we have only one star, then pulsation and rotation were the only real options. The rotational theory (largely put forward by Eddington's archrival Jeans) was dismissed casually: "We do not know of any theory connecting the variations with the star's rotation, sufficiently plausible to be discussed here." The problem with rotational models was the expected but unobserved line broadening. He thus left the reader with pulsations as the only reasonable alternative:

> I have never regarded the hypothesis of symmetrical pulsations as conclusively established but I am not persuaded that anything has transpired in the recent discussions to weaken the case for it as here set forth. (Eddington 1926)

Eddington built his Cepheid theory on the same structure as his general theory of stellar constitution. The core of his Cepheid analysis was his calculation of adiabatic oscillations. He rejected the idea that the pulsations were just left over from a disaster, leaving the alternative that there were causes inside the star that tended to increase and maintain a pulsation. He followed the analogy of the heat engine quite closely—looking for the stellar equivalents of cylinders, valves, and so on (Eddington 1926; subsequent developments are described in Kawaler and Hansen 2012, this volume).

Eddington linked the critical question of energy transfer to the pulsations to the larger question of stellar energy generation in general. He pointed out that the values of density and temperature needed for the energy transfer to reinforce the pulsations were quite narrow. And interestingly, those values were virtually identical to the conditions necessary for energy liberation via the transmutation of hydrogen into helium (Eddington 1926). This calculation brought three important points forward. First, it was a major clue to the stellar energy source. Second, this calculation made Cepheids fairly rare, which was a point in its favor—it explained why most normal stars do not pulsate. Finally, it succeeded in calculating a size for Cepheids that closely matched observations. Eddington reminded his readers that investigating the Cepheids was not important just for themselves, but for their ability to help understand stars in general: "If this explanation is correct we have an opportunity of extending the study of the internal state of a star from static to disturbed conditions" (Eddington 1926).

6. Conclusion

The pulsation theory was on a firm footing by the late 1920s because the hypothesis was an integral part of the wider theory of stellar structure developed in that decade. Its deep connections to the successes of the broader theory made it highly plausible, and more appealing than invoking a hypothesis that thought of Cepheids as entities completely different from normal stars. And conversely, the success of stellar structure theory in explaining the bizarre behavior of Cepheids was a major feather in its cap. The ability of stellar structure theory to explain such strange objects was an important tool for convincing skeptics of its power, and also helped legitimate the use of the innovative approaches and methods critical to that theory. In particular, the Cepheid pulsation theory provided critical stimulus to develop the theory of radiative balance, the idea of fusion as the stellar energy source, and the timescale of the lifetime of stars.

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The AAVSO Photoelectric Photometry Program in Its Scientific and Socio-Historic Context

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Presented at the 100th Spring Meeting of the AAVSO, May 22, 2011; received November 30, 2011; accepted December 9, 2011

Abstract In this paper, I review the work of the AAVSO in the area of photoelectric photometry (PEP). This work was influenced by several trends: in science, in technology, and in the sociology of amateur astronomy. Through the 1980s, the AAVSO photoelectric photometry program competed with other such programs and, in recent years, has been overshadowed by CCD photometry programs. Nevertheless, the AAVSO PEP program has, through careful organization, motivation, and feedback, produced extensive scientific results, and can continue to do so. In the case of my own research, AAVSO PEP observations have also contributed significantly to the education of my students.

1. Introduction

The AAVSO Photoelectric Photometry (PEP) program tends to be overshadowed by the venerable visual program, and by the charge-coupled device (CCD) program which is now generating hundreds of thousands of observations each year. Nevertheless, the PEP program has played a significant scientific and technological role in the evolution of AAVSO variable star research; it has produced good science—dozens of research papers—and continues to do so. It has also demonstrated the way in which observers with diverse talents and interests can engage with and contribute to variable star astronomy in their own preferred way.

The history of PEP observing in the AAVSO has been formally and professionally examined in the centennial history of the AAVSO (Williams and Saladyga 2011), and more informally in the last issue of the *AAVSO Photoelectric Photometry Newsletter* (Percy 2008), which can be found at: http://www.aavso.org/sites/default/files/newsletter/PEP/lastpepnl.pdf

2. Photoelectric photometry

Photoelectric photometry developed over a century ago, when physicists developed the quantum theory of light. Light consists of bundles of energy called *photons*. The photon energy is inversely proportional to the wavelength of the light—light has both wave and particle properties. When light illuminates certain materials, the photons liberate electrons from that material. This is called *the photoelectric effect*. It was for this that Albert Einstein received his Nobel Prize in Physics, not for his development of the theory of relativity. The number of these *photoelectrons* could be measured; it was proportional to the brightness of the light. *Photoelectric photometry* was born.

The photoelectric effect was soon applied to measuring the brightness of stars and other celestial objects, especially by Joel Stebbins in the United States and by Paul Guthnick in Germany. Early photometers, with detectors based on selenium, were relatively insensitive, and were therefore usable only on bright stars. They were also idiosyncratic, and observers had to understand their instruments well. However, the brightness could be measured to an accuracy of 0.01 magnitude or better—an order of magnitude better than with photographic or visual photometry. It was also possible to insert standard color filters into the light path (UBV: near-ultraviolet, blue, and yellow, for instance), and measure a “standard” magnitude, or measure the color of the star.

3. The development of amateur photoelectric photometry

Not surprisingly, some amateur scientists soon took up photoelectric photometry. There were no off-the-shelf photometers in the early days; you had to make your own. Electronics was a popular pursuit among amateur scientists, right through to the 1960s and beyond. When I was in high school in the 1950s, there was no science club, just a radio club! The American Radio Relay League had been founded in 1914, and was a magnet for amateur scientists and hobbyists. Radio amateurs also provided crucial communication services in times of emergency, so there was a sense of “citizen science” (or technology) in the hobby—especially during WWII. Amateur interest in electronics re-emerged with the post-war availability of electronic (including photometer) components. Electronics was the future!

Amateur telescope making blossomed in the 1920s, with the publication of articles by Russell W. Porter and Albert G. Ingalls, and the latter’s three-volume book *Amateur Telescope Making* (Ingalls 1926). The Stellafane clubhouse and observatory were founded in 1923, and the annual Stellafane convention started shortly after.

In the 1950s, the “space bug” struck, in many ways. The Smithsonian Astrophysical Observatory established *Operation Moonwatch* as a citizen science (and patriotism) project in 1956, to track the anticipated artificial satellites to be launched by the USSR and USA. “Professional” optical tracking stations were not operational until two years later. *Operation Moonwatch* grew out of *Operation Skywatch*, in which hundreds of thousands of volunteers in the Ground Observers Corps watched for Soviet bombers—another fusion of citizen science and patriotic civil defence.

As well, the Space Age produced widespread and varied interest in both space science and technology, and in astronomy in general. This interest extended to young people, especially as school science and math curricula were expanded and strengthened in response to the Space Race.

By the 1970s, the "computer bug" struck also. The first computers, developed during WWII, were large and unwieldy but, with the development of transistors and then microelectronic circuits, handheld calculators, programmable calculators, and then "personal computers" were developed. Some of these were available as kits, which appealed to electronics enthusiasts. The recent (October 2011) death of Apple computer co-founder Steve Jobs reminded us of the excitement and innovation of those times. It was not long before a few amateurs, such as David Skillman (Skillman and Sinnott 1981) were automating their telescopes and their photometers.

4. The amateur PEP revolution

Several things happened around 1980 that revolutionized the field of amateur PEP. One was the availability of moderate-sized commercial telescopes at reasonable price; observers no longer had to build their own telescopes. A second was the development of a relatively simple off-the-shelf photometer, the SSP-3, based on a solid-state photodiode detector, by Optec Inc. Another was the publication of two very useful textbooks on PEP: *Astronomical Photometry*, by Arne Henden and Ron Kaitchuck (1982) and *Photoelectric Photometry of Variable Stars: A Practical Guide for the Smaller Observatory* by Doug Hall and Russ Genet (1988; a preliminary edition had been published in 1982 by International Amateur-Professional Photoelectric Photometry (IAPPP), and Fairborn Observatory). Yet another was the formation of IAPPP itself: "bringing amateurs, students, and professionals together for research in astronomy since 1980" (to quote the cover of the *IAPPP Communications*). The IAPPP later spawned "wings" in regions of the United States and overseas. The *Communications* provided a forum for publication of instrumental developments, advice on observing programs, and preliminary results. Related to this was the organization of PEP conferences, and the publication of several books on PEP, such as *Advances in Photoelectric Photometry*, volumes 1 and 2, edited by Russell M. Genet, Robert C. Wolpert, and others. But by the early 2000s, the IAPPP was dormant; CCD photometry was on the rise; and PEP topics became a small but significant part of regular variable star conferences.

5. The AAVSO PEP program—origin

The first record of AAVSO-associated PEP is some correspondence in 1919 between AAVSO Recorder Leon Campbell and Lewis Judson Boss, who had constructed a primitive selenium photocell, and was experimenting with it on Frank Seagrave's 8-inch (or possibly 8.5-inch) Clark refractor (Williams and Saladyga 2011). Boss published two articles about his efforts in *Popular Astronomy*. He joined the AAVSO in 1921 and continued this work for a few years before his professional duties caused him to stop the project. He did, however, serve as the founding chair of the AAVSO PEP Committee from 1954 until 1967.

Organized AAVSO PEP goes back at least as far as 1952—perhaps earlier. John J. Ruiz had expressed an interest in PEP as far back as 1947 and, in 1957 (Ruiz 1957a) published a paper in *PASP* on "A Photoelectric Light Curve of u Herculis" (an Algol binary), based on photometry from 1952 to 1955, and indicating that he was a "Member of the Photoelectric Committee of the AAVSO." In the same year (Ruiz 1957b), he published "Photoelectric Observations of 12 Lacertae" (a β Cephei star) in the same journal.

AAVSO Director Margaret Mayall proposed the formation of the PEP committee in 1954, and Lewis Boss chaired it from its inception until 1966. Boss, however, acknowledged that it was Ruiz who had done most of the work of the committee (Boss 1980). In 1956, Ruiz had written the *AAVSO PEP Handbook*. In 1967, Art Stokes (1967) published PEP observations of Nova Delphini 1967; he also chaired the PEP Committee from 1966 to 1975. Throughout the 1970s, Howard Landis published many PEP papers, mostly on eclipsing and RS CVn variables in collaboration with Doug Hall (e.g. Landis *et al.* 1973). In 1975, Landis replaced Art Stokes as chair of the PEP Committee. Art and Howard were the PEP pioneers who introduced me to the potential of AAVSO PEP observations. Howard noted, in his 1978–1979 committee report, that 844 PEP observations of eclipsing binaries had been made in that year. So AAVSO PEP was well underway by then. Its organizational evolution, however, was affected by certain questions of observer recognition which are discussed in some detail by Williams and Saladyga (2011).

A more formal PEP program was organized by Janet Mattei in the early 1980s, primarily to complement the observations of some of the stars in the AAVSO visual program—ones that had both medium- and small-amplitude variability. Typical amplitudes were one magnitude or less. Most were small-amplitude pulsating red variables—giants and supergiants. I assisted in choosing the final set of program and comparison stars (no mean task for red variables!), and became the main scientific advisor to the program. The program grew from about sixty to about eighty stars, including stars that were added—or dropped because they proved to be non-variable. As of 1998, almost sixty observers had contributed to the program. For a discussion of the science and sociology of the program, see Percy (2000).

6. The AAVSO PEP program—growth

The best way to visualize the growth of the formal AAVSO PEP program is to look at Figure 1, which includes the prehistory of the program. The formal program started small, with only a few dozen observations the first year. But, especially through the patient work of Howard Landis, other observers gradually joined.

Initially, there was a "sociological" problem. The program was competing with Doug Hall's PEP program on RS CVn stars, and that yielded new results almost every season. Papers were published regularly, with the observers included as co-authors—as they should be. The AAVSO PEP program, on the other hand, was not designed to produce quick results; its power was in the information that it provided about the long-term behavior of the stars. But the program grew, as Figure 1 shows.

There are several reasons for the decline after 2000: the program was partly "in limbo" while it was being transferred to AAVSO Headquarters; some observers migrated to CCD observing; and some very active observers retired—champion observer Ray Thompson, for instance.

One way in which you can visualize the results of the program is to choose a star from the program, and go to the Light Curve Generator, entering its name (EU Del, for instance), choosing V data only, and asking for the last 10,000 days of data.

7. The *AAVSO PEP Newsletter*

The *AAVSO PEP Newsletter* was founded in 1979 with the name of *AAVSO PEP Bulletin*. By Volume 2, Number 1, dated February 21, 1980, it was *Newsletter*. It was produced by Howard Landis, Art Stokes, and Dave Skillman. The next issues are Volume 3, Numbers 1–4, which came from Russell M. Genet. The first that I edited was Volume 4, Number 1, dated June 1983. It begins by thanking "my predecessor Russell M. Genet for his enthusiastic and effective work in editing this newsletter." Apparently he wisely turned it over to willing hands (mine), because I continued to edit it, two or three times a year, often with an abject apology, in the editorial, for its lateness. Russ went on to other exciting things.

In 1992, I turned the *Newsletter* over to Michael S. Smith, in Tucson. He edited it for a few years, before handing it back to me in 1996. I edited it, with decreasing frequency, until 2008. As more and more of the work was done at AAVSO Headquarters, it has made more and more sense for communications to come from there.

During my editorships, there was a wide variety of content, usually provided by me, though I always appealed for contributions. Quite often (even before the age of widespread email), I would get brief notes and queries that I published. The most faithful contributor was Howard Landis, who always contributed a PEP Committee report, on time, with useful statistics, and acknowledgement of observers. We announced forthcoming PEP-related meetings and, where possible, summarized the contents. In particular: I published PEP highlights from the AAVSO Annual and Spring meetings. We published notices of "campaigns" (see below), and other special requests for observations. We discussed charts, the ins-and-outs of submitting and archiving observations, and data reduction and analysis. I cheerfully published mini-biographies of the observers. I often wrote about how my students had benefitted from analyzing AAVSO PEP observations for their projects, so that observers would know that their work had double benefit—to research and to education. Sometimes I would write mini-essays on the types of stars on the PEP program, or which turned up as annoying micro-variable comparison stars. Or I would summarize interesting photoelectric papers in the literature.

But most of my contributions were feedback to observers, telling them about new scientific results that their observations had produced. Often these were preliminary reports on results that were later published in *JAAVSO* or elsewhere.

8. Scientific results from the AAVSO PEP program

The scientific results from the AAVSO PEP program have been described by Percy (2008), and references given to select publications. Here, I shall review and update the results on small-amplitude pulsating red variables, which make up the majority of the program.

Until the 1980s, these very common variables were simply described as semiregular or irregular, and largely ignored. Thanks in part to the AAVSO PEP program, we now know that: all M giants are photometrically variable; these stars pulsate in one (or more) low-order radial modes; they occasionally switch modes; many have a long secondary period (LSP) of unknown cause; the amplitude is greater in cooler stars; since cooler stars are more luminous (because they lie on the giant branch in the H-R diagram), the cooler stars have longer periods. For each pulsation mode, these stars obey a period-luminosity relation almost as tight as that for Cepheids. An ensemble of these stars shows a series of period-luminosity relations, corresponding to different pulsation modes. For this reason, these stars can be especially powerful astrophysical tools.

One part of the program was *Project SARV*, in which a total of sixty-one bright red giants, suspected to be variable, were assigned to interested AAVSO PEP observers. The result was an eighteen-author paper, Percy *et al.* (1994).

In parallel with the analysis of the AAVSO PEP data on these stars (Percy *et al.* 1996), we analyzed data from a robotic telescope in Arizona (Percy *et al.* 2001). We subsequently combined the AAVSO data with the robotic telescope data for the thirteen stars in common (Percy *et al.* 2008). The combined data were especially powerful: the AAVSO data filled in the gaps in the robotic telescope data, caused by the summer monsoon season; and the AAVSO observations, which were continued long after the robotic telescope observations ceased, produced a dataset that was over two decades long. We were not only able to refine the primary periods, and LSPs, but we were also able to identify very-long-term variability.

The periods which were determined from the AAVSO PEP data have also contributed to a study of the period-luminosity relation(s) for pulsating red variables (Tabur *et al.* 2010). That was possible because our program stars are relatively bright, and therefore close enough for their parallaxes to be determined by the *Hipparcos* satellite.

9. The AAVSO near-infrared photometry program

Long-term near-infrared (NIR) photometry is valuable for all the same reasons that long-term V-band photometry is, especially for stars that emit much or most of their energy in the near-infrared. But few professional observatories were interested in or equipped for such photometry. Once again, skilled amateurs stepped into the breech. The AAVSO NIR PEP program was established in 2003. Much planning was needed, and a professional-amateur committee was formed to do this, with Doug West as a driving force. There were no off-the-shelf NIR photometers, so the AAVSO worked with Optec Inc. to develop one—called the SSP-4—that operated in the J (1.25 microns) and H (1.65 microns) bands. Five photometers were purchased by the AAVSO, and lent to interested, experienced observers. There are now about thirty stars in the program, mostly red giants, Cepheids, and eclipsing variables. See http://www.aavso.org/infrared-photoelectric-photometry-program for much more information.

10. PEP Campaigns

A *campaign* is a project in which one or a few carefully-selected stars are observed intensively for a period of time. In a sense, the AAVSO PEP program is a campaign! There are *multi-wavelength campaigns* in which the objects are observed simultaneously at a variety of wavelengths. There are *multi-longitude campaigns* in which the objects are observed from enough different longitudes to ensure continuous twenty-four-hour time coverage.

The AAVSO PEP program has participated in several campaigns. One notable one was organized by Roger Griffin, Cambridge University. ζ Aurigae binaries are long-period binaries in which one component is a supergiant. Eclipses, if they occur, would occur infrequently, but at predictable times, i.e., when one star was predicted to possibly be in front of the other. Roger provided times of possible eclipses in known or suspected ζ Aurigae binaries; we helped choose suitable comparison stars; and the observers determined which stars showed eclipses, and when, and how deep. The most significant campaign of this sort was the AAVSO's *Citizen Sky* project, in which dozens of new observers were recruited, trained, and motivated to observe the 2009–2011 eclipse of ε Aurigae; see: http://www.citizensky.org.

A more recent campaign was of a completely different kind: it was to monitor IM Peg, the guide star for the *Gravity Probe B* satellite; see http://einstein.stanford.edu. GPB was designed to test aspects of the theory of relativity by looking for two small, subtle effects on the orientation of the satellite. The RS CVn star IM Peg was chosen as the guide star because it was a point radio source whose position could be measured to milli-arc-second accuracy with radio telescopes, and it was bright enough to be seen by GPB's optical guide scope. But RS CVn stars have starspots, and the change in the starspot distribution on the star can artificially change its apparent position. Therefore a photometric campaign was organized to monitor the starspots through their effect on the brightness of the star. Much of the work was done by robotic telescopes, but these, being in Arizona, were "monsooned out" during the summer. That's where AAVSO PEP observers could fill in, and make a special contribution.

11. Educational spinoffs from the AAVSO PEP program

The observation and analysis of variable stars can be effectively connected to the goals of science and math education; that is the basis of the AAVSO's famous *Hands-On Astrophysics* project. It has since morphed into the much more powerful *Variable Star Astronomy* (http://www.aavso.org/education/vsa). The scientific research process involves elements of inquiry, investigation, problem-solving, discussion, and communication—the cornerstones of science education. Variable star observation, analysis, and interpretation is well suited for student projects and activities. Making measurements of variable star brightness visually may be simple, but the applications, analysis, and interpretation of the data involve a wide range of scientific and mathematical skills—some simple, but others quite challenging, even for experts.

Many undergraduate students carry out PEP research at universities and colleges around the world. I have even heard of high school students doing PEP, often for science fair projects. One or two did so through the AAVSO PEP Committee. At one time, my undergraduate students made PEP observations from downtown Toronto, sometimes of AAVSO PEP program stars; Doug Welch, well-known to AAVSOers, was a "graduate" of that program. But, for the last decade or two, their work has consisted of analysis and interpretation—usually of AAVSO PEP or visual data. Such projects involve doing real science with real data. They develop and integrate a wide variety of science, math, and computing skills, starting from background reading and planning; research judgement, strategy and problem-solving; continuing with pattern recognition, interpolation and measurement; recognizing and understanding random and systematic errors; construction, analysis, and interpretation of graphs; concepts of regularity and prediction, curve fitting and other statistical and numerical procedures; all the way to the preparation and presentation of oral and written papers.

My own students are of two kinds. The first are undergraduate students, either summer research assistants, work-study students, or students in our Research Opportunities Program (ROP), a competitive, prestigious program in which second-year students can work on a research project for course credit. The second are students in the University of Toronto Mentorship Program (UTMP), which enables outstanding senior high school students to work on research projects at the university.

In 2007–2008, two of my former students received special awards. One, former UTMP student Wojciech Gryc, received a Rhodes Scholarship. Another, undergraduate Kathy Hayhoe (who subsequently evolved from astronomy to climatology), won 1/2000 of half of the Nobel Peace Prize, because she is now a member of the Inter-Governmental Panel on Climate Change!

12. Final reflections

The AAVSO PEP program still attracts fifteen to twenty observers from all over the world, and produces good data and good science. It is administered by AAVSO Headquarters, with Dr. Matt Templeton as scientific advisor, and Jim Fox as chair of the PEP Committee. Collectively, the program has produced over 52,000 observations over thirty years of a total of 223 stars which are or have been on the program, mostly small-amplitude pulsating red giants. The "official" list of program stars is at:

http://www.aavso.org/content/aavso-photoelectric-photometry-pep-program

What are the strengths of a good observing program? Obviously it should produce useful scientific results, in the short or long term. Therefore its scientific value should be regularly and critically reviewed, so it will continue to be of value. Ongoing advice and support from the astronomical research community, that is, professional astronomers, can help to provide this. The program should be well-coordinated and standardized; this is especially important for programs whose strength is long datasets. It should have the opportunity for continuity, which is much easier if it is run by a well-established organization like the AAVSO than if it is run by an individual professional astronomer whose interests or status may change. It will succeed if observers receive instruction, feedback, support, motivation, and recognition—all of which the AAVSO does admirably. In this way, the program not only provides useful scientific data, but it also provides enjoyment and satisfaction to human observers. Indeed, the strength of the AAVSO is its combination of scientific relevance and human spirit.

13. Acknowledgements

The success of the AAVSO PEP program is due to the skill and dedication of the sixty-plus observers who have contributed; to the AAVSO Headquarters staff who received, processed, and archived the data; and to the chairs and members of the PEP Committee who guided the program. My personal thanks go to Howard J. Landis and the late Janet A. Mattei. I am grateful to Tom Williams for inviting me to participate in the May 2011 AAS-AAVSO history session, and to Mike Saladyga for reading a draft of this paper. I thank the Natural Sciences and Engineering Research Council of Canada, the Ontario Work-Study Program, and the organizers of the University of Toronto Mentorship Program for facilitating my work, and that of my students—whose help and inspiration I also acknowledge here.

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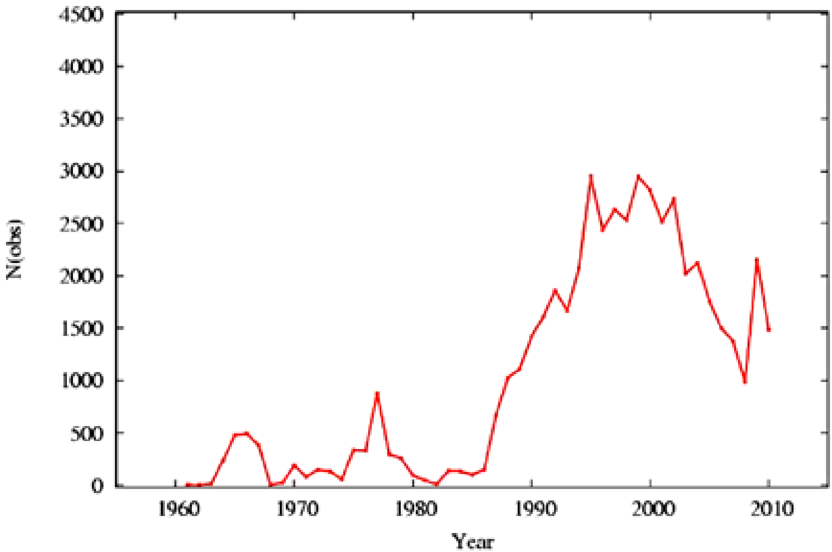

Figure 1. The number of PEP observations carried out through the AAVSO as a function of time. Data provided by the AAVSO.

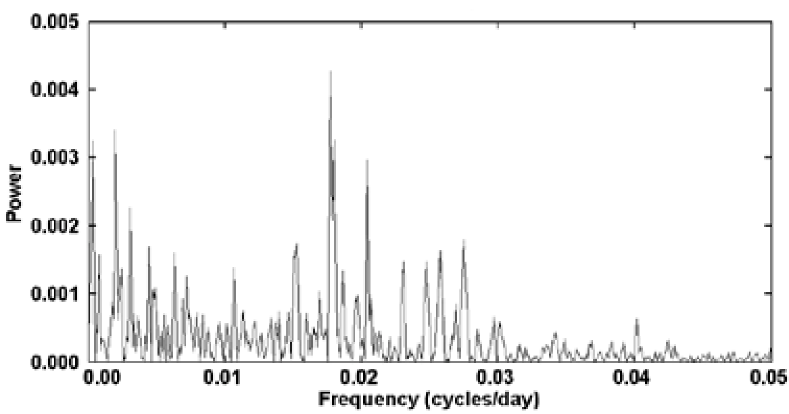

FIgure 2. The power spectrum of RZ Ari from combined AAVSO and robotic telescope photometry, showing periods of 56.5 days (0.0177 cycle/day), 37.7 days (0.0265 cycle/day), and 370 days (0.00270 cycle/day). The first two periods represent two different pulsation modes, the last period is a "long secondary period." From Percy *et al.* 2008.

John Goodricke, Edward Pigott, and Their Study of Variable Stars

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Presented at the 100th Spring Meeting of the AAVSO, May 22, 2011; received February 28, 2012; revised April 17, 2012; accepted April 17, 2012

Abstract John Goodricke and Edward Pigott, working in York, England, between 1781 and 1786, determined the periods of variation of eclipsing binaries such as β Persei (Algol) and β Lyrae and speculated that the eclipses of Algol might be caused by a "dark body," perhaps even a planet. They also determined the periods of variation of the first two known Cepheid variables, the stars whose period-luminosity relation today enables astronomers to determine distances to distant galaxies. Goodricke holds special interest because he was completely deaf and because he died at the age of 21. The lives and work of these two astronomers are described.

1. Introduction

The name of John Goodricke (1764–1786; Figure 1) is recognized by many astronomers today, but few details of his life and work are widely known. Some know that he observed variable stars, some know that he was profoundly deaf, and some know him as an amateur astronomer. Goodricke's collaborator, Edward Pigott (1753–1825), is even less well known. Together, these two determined the periods of variation of eclipsing binaries such as β Per (Algol) and β Lyrae, speculating that the eclipses of Algol might be caused by a "dark body," perhaps even a planet. They also discovered and determined the periods of variation of η Aquilae and δ Cephei, the first two known Cepheid variables. The period-luminosity relation of Cepheids, of course, would later enable astronomers to determine distances to distant galaxies. In 2010, the author was able to spend a sabbatical semester at the University of York, studying the journals and notebooks of Goodricke and Pigott in order to understand how these pioneers went about their work.

Richard Holmes (2008) cautions about the shroud of myths that often envelops scientists of great accomplishment. One such myth is that of the lone, heroic figure, struggling against misconceptions perpetrated by lesser minds, against his (or her) own family, and perhaps even against society itself. This myth does not apply to John Goodricke. Rather, he was able to attend forward-thinking schools that addressed his learning needs and nurtured his talents, and he had the support of a family who clearly valued and encouraged his studies.

2. John Goodricke: background and family life

The Goodricke family line is long, with several branches in England. The Goodrickes of Yorkshire took up residence at Ribston, just west of the city of York, in 1533 when Henry Goodricke became steward of Great Ribston (Figures 2 and 3). In 1641 Sir John Goodricke was created the first Goodricke baronet for his service to the King during the Civil Wars. John, the astronomer, was the eldest grandson of the fifth baronet, also named Sir John (1708–1789).

Zdeněk Kopal, the Czech-British astrophysicist, once described the Goodrickes as “fox-hunting country squires” (Kopal 1986), a characterization that the facts do not support. The Goodricke baronets were, for the most part, not content to sit at home on the Ribston estate. Sir Henry, the second baronet, was the English Ambassador to Spain from 1678 until 1682, and Sir John, the astronomer’s grandfather, was Envoy Extraordinary to Sweden from 1764 until 1773. Both men, as well as the astronomer’s father, Henry (1741–1784), served as Members of Parliament, and both baronets were members of the King’s Privy Council (somewhat similar to the U.S. President’s Cabinet).

John Goodricke, the astronomer, was born on 17 September 1764 in Groningen, the Netherlands, where his father, Henry, was employed in diplomatic service. John’s mother was born Levina Benjamina Sessler; her father was Peter Sessler, a merchant of Namur, Belgium. John was the eldest surviving child, and so he would have been the heir to the baronetcy had he lived to succeed his father and grandfather.

According to the family history, John became deaf at the age of five due to a severe illness that has been conjectured to be scarlet fever. At the age of seven he went to study at Thomas Braidwood’s Academy for the Deaf and Dumb in Edinburgh, the first school for deaf children in the British Isles. Braidwood was very secretive in his teaching methods. We do know that Braidwood advertised “to undertake to teach anyone of a tolerable genius in the space of about three years to speak and to read distinctly” (quoted in Pritchard 1963); that his pupils read lips and signed; and that Braidwood had originally been a mathematics teacher (Branson and Miller 2002).

John went on to study at the Warrington Academy for three years after leaving Braidwood’s. Warrington was one of the “Freethinking” or Non-Conformist academies originally founded to prepare clergymen in denominations other than the Church of England. It was well known for its emphasis upon mathematics and natural philosophy; the chemist Joseph Priestley had taught there but had moved on before John Goodricke arrived in 1778 (Parker 1914). John was described as “a very tolerable classic and an excellent mathematician” in a school report (Turner 1813). During John’s time at Warrington, the mathematics curriculum (which included astronomy in the second year) was taught by William Enfield (McLachlan 1943). Enfield was primarily a theologian, but he worked diligently at his teaching and eventually published his notes as a textbook, *Institutes of Natural Philosophy* (Enfield 1785), which went through many editions on both sides of the Atlantic. John's mathematics notebook is preserved in the Goodricke collection of the York City Archives, and the figure seen there can be found on the inside back cover (Goodricke 1779; Figure 4).

2.1. The Warrington sketch

The drawing shows several constellations: Orion's belt can be seen, along with the brightest star in Taurus, "The Eye of the Bull," Aldebaran; the constellation of Auriga; and "the two brightest stars in the Gemini." The Milky Way is shown, as well as the zodiac (or ecliptic), and the Moon. At the bottom of the page is a sentence describing the position of various stars on either side of the meridian, a line connecting the north and south points on the horizon and passing through the zenith. The star positions, together with the Moon's position in the sky, permit determination of the approximate date of the drawing. The only time that matches both the Moon and star positions is a one-week period in late November of 1779. On 23 November 1779, a total lunar eclipse was visible over England (Borkowski 1990). John Goodricke would have had access to textbooks with tables of predicted eclipses (such as Ferguson 1756); he would also have been taught to do such calculations in his schoolwork (Enfield 1785). Exactly how he came to produce this drawing we may never know. What is significant, however, is that he was already observing the sky in 1779, at the age of fifteen.

2.2. Correcting some popular misconceptions about John Goodricke: a "deaf-mute"?

John Goodricke is often described as "deaf and dumb," or a "deaf-mute." Evidence from the Goodricke journals suggests that, while he was certainly deaf, he almost certainly spoke. He evidently was able to read lips (teaching students to lip-read and to speak if they were capable of it was part of the curriculum at the Braidwood Academy). The evidence for this is in two passages from Goodricke's *Journal of the Going of My Clock* (Goodricke 1782a):

> 17 November 1782: Whilst I was winding up the Clock the second hand did not go on as usual–I spoke to Mr Hartley [the clockmaker] about it & he said it was caused by my not pulling down the Spring hard enough....
>
> 15 December 1782: Whilst I was winding up the Clock on the 15th the second hand did not go on as usual–As this is now the 3rd time it did so; I remonstrated with Mr Hartley about it & asked him ye reasons of it doing so–He gave me the same answer as on the 17th of Nov. last but I did not credit him–However after several trials I have since hit upon the true course & found that it was owing to a fault

> of my own in not pulling the spring down hard enough according to Hartley's directions which I did not rightly understand or he was not very particular in explaining them to me.

From the words alone, nothing could be clearer: he *spoke* with Mr. Hartley, he *remonstrated* with Mr. Hartley. The second passage makes it even more explicit that the conversation was a verbal one; Hartley explained and Goodricke did not initially understand the explanations. Had the directions been written out, it is much less likely that such a breakdown in communication would have occurred. Thus, the available evidence suggests that Goodricke read lips well enough to carry on business transactions, and that he may well have spoken.

2.3. Burial Place

Zdeněk Kopal, in his scientific autobiography *Of Stars and Men* (1986), described a visit to the churchyard of St. John the Baptist at Hunsingore (Figure 5), the burial place of John and the other Goodrickes, and came to the conclusion that John Goodricke had been buried apart from his family in an unmarked grave. Kopal wrote: "Why does he rest there forgotten by all his clan; why was he not buried with them in their family vault[?]...." He went on to speculate that John's parents and grandparents found his deafness to be "a blot on the family escutcheon." Kopal apparently did not investigate the history of the present church; if he had he would have discovered that it dates to 1868, after the Goodricke family estate at Ribston had been purchased by the Dent family. There was a Goodricke family vault under the old church, and that vault still exists. It is marked in the churchyard by a stone identical to that used for the new church, with only the words "Goodricke Vault" engraved upon the side (Figure 6). The burial records still exist (N. Yorkshire County Record Office MIC 1685), and they show that John Goodricke was indeed buried alongside his parents and grandparents in the family vault. Although the deaf were often treated inhumanely in the eighteenth century, John Goodricke's family gave him the best possible education both for his scientific research and for his stature as the Heir Apparent to a baronetcy.

The previous Goodricke baronets had attended university at either Cambridge or Aberdeen, and John surely would have been intellectually qualified for university. Why he returned to York at seventeen to live with his family is somewhat puzzling. Both John, in his journal, and Edward Pigott, in a diary, make occasional references to John's not being well, so perhaps his health had already begun to fail. At any rate, the first entry in John's formal observing journal (Goodricke 1781) comes early November 1781, when he writes: "Last evening at 9 p.m. Mr. E. Pigott discovered a comet."

During the first few entries John describes Edward's correspondence with William Herschel and with Nevil Maskelyne, the Astronomer Royal. Edward's contacts in the astronomical world, as well as his discoveries, clearly impressed John, who immediately set about keeping a record of his own observations.

3. Edward Pigott: background and family life

Edward Pigott's father, Nathaniel (1725–1804), was also an astronomer, and he was the primary source of Edward's astronomical training. The Pigotts were related to the wealthy, landed Fairfax family of Yorkshire; Nathaniel's mother Althea Fairfax Pigott was the sister of Charles Gregory Pigott (d. 1772), ninth Lord Fairfax and Viscount Emley. As Catholics, the Pigotts found life in France more congenial than life in the north of England, and they spent a great deal of time there. Edward went to school in both countries, but French was his first language, which gives an occasional "invented" feel to the wording and spelling of his journals.

Nathaniel's primary interest was in using astronomical methods such as the timing of eclipses of the Moon and the Jovian satellites to determine latitude and longitude. Although not a wealthy man, he was able to acquire instruments made by the finest craftsmen of the time, including Ramsden, Dollond, Sisson, and Bird. Between 1773 and 1775 Nathaniel and Edward collaborated with continental astronomers including Messier and Mechain to determine the latitude and longitude of several cities in the Austrian Netherlands (now Belgium; Pigott 1778).

Nathaniel Pigott owned property in Middlesex and in Wales, and in 1781 the family settled in York, where Nathaniel hoped to manage the estates of Lady Anne Fairfax, the sole surviving daughter of Lord Fairfax, and to eventually secure the estates as an inheritance for Edward's younger brother, Charles Gregory Pigott. The Pigott family took up residence in York, approximately one-quarter mile from where the Goodrickes were living. Here Nathaniel constructed an observatory said to be amongst the finest private observatories in England.

A diary kept primarily by Edward Pigott with some entries by Nathaniel (now in the Beinecke Library of Yale University) includes stories of joint Goodricke-Pigott family outings. Thus, even though the start of the official collaboration dates from John's beginning to keep the observing journal, it seems likely that the two discussed astronomy at an earlier date.

3.1. Interest in variable stars

Stellar astronomy was still in its infancy in the eighteenth century (see, for example: Hoskin 1982; Williams and Hoskin 1983). Among variable stars, a period had been determined only for the long period variable o Ceti (Mira). Ismael Boulliau, better known by his Latinized name Bullialdus, observed the star systematically between 1660 and 1666, obtaining an accurate period of nearly 333 days (Hoskin 1982; Hatch 2011). Bouilliau went on to consider sources of the star's variability, and hypothesized that the most likely cause of the variation was dark regions on the star coming into view as it rotated; in other words, spots analogous to sunspots. That long period variables do not always show an exact periodicity or reach the same peak brightness was to be expected, since the variation in the Sun's light due to sunspots is not exact. Boulliau's explanation was accepted and adopted by Newton in Book 3 of the *Principia*, and by William Herschel in his first published paper (1780), which contained observations of Mira (Hatch 2011).

As early as 1778, while observing from Wales, Edward Pigott was noticing that both the reported positions and brightnesses of stars varied from one catalogue to another, and he speculated on possible sources of the noted discrepancies. He continued this practice from York. In July of 1781, for example, Edward wrote in his journal:

> The 22nd star of Tycho's Andromeda is probably the o (omicron) of that constellation, tho' it differs very considerably both in Longitude and Latitude, which I am convinced is occasioned by an error either in the Observation or Calculation, the Prince Hesse [probably William IV, Landgrave of Hesse-Kassel] observed the o therefore it was visible in Tycho's times and has been since; See Hevelius's & Flamsteed's Observations; now it is not probable that Tycho would have overlooked a star of the 3rd or 4th mag. (Pigott 1781)

A discussion of the positional uncertainties in the catalogs of Tycho, Hevelius, Flamsteed, and the Landgrave is beyond the scope of this paper. What is significant in this passage is Edward's taking note of discrepant magnitude estimates and commenting that Tycho would not have omitted a star as bright as the third or fourth magnitude—exactly the magnitude range of the stars that he and John would soon study systematically. The implication is that the star might well have varied in brightness.

In the autumn of 1782 John and Edward decided to pursue observations of "Stars which are Variable or Thought to be so," as John wrote in the heading of one journal entry in early November (Goodricke 1782b). The first star on his list is β Persei (Algol), whose changes in brightness had been noted as early as 1672 by the Italian astronomer Geminiano Montanari. In October 1782, Edward Pigott noted, "This star is variable" for Algol, almost certainly as a result of a literature search, as he had made no extensive observations of the star up to that date. Other stars on John's list as candidates for variability included δ Ursae Majoris, not thought today to be variable, and α Herculis, now classed as a semiregular variable with amplitude of nearly one magnitude.

On 12 November 1782, John noted,

> This night I looked at Beta Persei [Algol], and was much amazed to find its brightness altered—It now appears to be of about 4th magnitude. I observed it diligently for about an hour—I hardly believed that it changed its brightness because I never heard of any

> star varying so quickly in its brightness. I thought it might perhaps be owing to an optical illusion, a defect in my eyes, or bad air, but the sequel will show that its change is true and that I was not mistaken. (Goodricke 1782c)

The two began checking Algol every clear night. They did not see another diminution of light until 28 December. By April they had seen consecutive episodes of darkening, and were able to determine that the period was very short compared to that of Mira: only 2 days and 21 hours. According to the custom of the time for reporting scientific results, John sent off a memorandum to Anthony Shepherd, Plumian Professor of Astronomy at Cambridge, to be read at the Royal Society of London. At the same time, Edward Pigott notified Nevil Maskelyne, the Astronomer Royal, and William Herschel, both of whom were eager to observe Algol. The variability was quickly confirmed by Herschel and other astronomers of the Royal Society. In his report, published in the *Philosophical Transactions of the Royal Society*, John states:

> I should imagine [the diminution of light] could hardly be accounted for otherwise than either by the interposition of a large body revolving round Algol, or some kind of motion of its own, whereby part of its body, covered with spots or such like matter, is periodically turned towards the earth. (Goodricke 1783)

The two discussed the idea of a "large body" revolving around Algol, as their journals both indicate, and in the journals both call the large body a planet. It is likely, as Michael Hoskin (1982) suggests, that the planet hypothesis originated with Edward Pigott, the more experienced observer and always the more adventurous theorizer of the two. Yet Goodricke wrote the formal report, and in August of 1783 he was awarded the Copley Medal of the Royal Society.

We now believe transits of a fainter stellar companion to be the correct explanation for the Algol system. Observations of transits are currently being used by NASA's Kepler mission to detect Earthlike planets around other stars. Yet in their own time Goodricke and, to a lesser extent Pigott, would abandon the transit hypothesis in favor of starspots. In his last completed paper, on the period of variation of δ Cephei, Goodricke would write:

> What I have before mentioned, that the greatest brightness of δ Cephei does not seem to be always quite the same, is not peculiar to this star, but is also to be observed in the other variable ones.... Even Algol does not seem to be always obscured in the same degree, being perceived to be sometimes a little brighter than ρ Persei, and sometimes less than it....This may, I suppose, be accounted for by a

> rotation of the star on its axis, having fixed spots that vary only in their size. (Goodricke 1786)

Several factors could have contributed to Goodricke's change of mind. By this time, he had visited Nevil Maskelyne at Greenwich and been exposed to the opinions of senior astronomers, who favored sunspots, as we have seen. But also, the nature of δ Cephei's light curve differs from that of Algol. There is not one single isolated diminution, but a continuous fading and brightening; a pattern that is less easily interpreted in terms of an eclipse. Finally, ρ Persei, conveniently placed for comparison with Algol, is itself a variable star, and so it may well have been "sometimes a little brighter" and sometimes less bright than Algol. Most modern observers can relate to the dilemma of choosing a comparison star that turns out to be variable! Only a century later was the eclipse hypothesis confirmed using spectral analysis (see Batten 1989 for a review).

4. Other astronomical work

John Goodricke's remaining time on Earth was short. He continued to observe Algol; in addition to determining the period of δ Cephei he also obtained the period of β Lyrae. In the autumn of 1784, as Goodricke studied δ Cephei, Edward Pigott detected the variation of another Cepheid, η Antinoi (today η Aquilae). Edward would eventually discover two more variable stars, R Scuti and R Coronae Borealis; he discovered the spiral galaxy known as M64 before Bode, and Jerome La Lande would write him that

> The observations which you sent me in 1782…have been very useful in my research into a theory for Mercury, which I have published… their ephemerides showed me for the first time that the place of the aphelion was too far advanced in my tables. (LaLande 1786)

Thus, Edward Pigott's observations may well have been among the first showing the advance of the perihelion of Mercury!

John Goodricke died on April 20, 1786, in York, 14 days after being elected to membership in the Royal Society at the age of 21. Edward Pigott completed their determination of the latitude and longitude of York and wrote of Goodricke:

> This worthy young man exists no more; he is not only regretted by many friends, but will prove a loss to astronomy, as the discoveries he so rapidly made sufficiently evince: also his quickness in the study of mathematics was well known to several persons eminent in that line. (Pigott 1786)

5. The Goodricke-Pigott legacy

John Goodricke is better known today than Edward Pigott. The University of York has a Goodricke College, and the dramatic story of Goodricke's short life figures prominently in several astronomical textbooks (for example, Fraknoi *et al.* 2006). Surely Goodricke's being awarded the Copley Medal and elected to membership in the Royal Society brought him recognition. It is clear that Edward Pigott deserves at least equal credit for their joint work. Today, Edward would be recognized as a co-discoverer of the periods of Algol, δ Cephei, and β Lyrae, while John would be credited with helping discover the period of η Aquilae and determining the coordinates of York.

The petition nominating John Goodricke to membership in the Royal Society was apparently initiated by Nathaniel Pigott; co-signers include Nevil Maskelyne, Anthony Shepard, Thomas Hornsby, Savilian Professor of Astronomy at Oxford, and William Wales, a member of the Board of Longitude, among others. Edward Pigott, on the other hand, although deserving, was never even nominated. Was this due to differences in the social standing of the two? Was there a reluctance on Nathaniel's part to push for his son's nomination? Or was Edward simply not considered a "clubbable man"? It is possible that all of these played a part.

What is certain is that the two held each other in high regard and frequently expressed that regard both in their journals and in their publications. Edward Pigott felt, justly, that his father Nathaniel did not give him enough credit for his astronomical work, and it is certain that Nathaniel cut Edward out of his will, as evidenced by Edward's pleading letters to his great-aunt Lady Anne Fairfax (N. Yorkshire County Record Office ZDV F: MIC 1132/1201). Edward did not suffer slights lightly. Yet Edward frequently mentions John Goodricke's talents both as an observer and in the interpretation of data. Neither in print nor in Edward's journals is there any hint that he resented Goodricke's authorship of the Algol paper, his reception of the Copley medal, or his election to the Royal Society.

John Goodricke clearly admired and learned from Edward Pigott. Edward's long-held interest in the nature of the stars, especially their possible variability, flowered into a productive scientific research program almost as soon as he and John Goodricke began their joint investigations. These two deserve to be better known, and to share joint credit for their discoveries.

6. Acknowledgements

It is a pleasure to thank Joy Cann and Caroline Stockdale for assistance while working at the York City Archives. The author thanks Alison Brech, Charles and Annie Dent, Martin Lunn, Anita McConnell, John Percy, and Ian Stuart for fruitful discussions; Ron Emmons for research assistance; and Thomas

Williams for a helpful referee's report. Research for this work was carried out while the author was a Visiting Professor of Physics in the University of York. Support from the Herbert C. Pollock Award of the Dudley Observatory and from a Small Research Grant of the American Astronomical Society is gratefully acknowledged.

Unless otherwise cited, information on John Goodricke and his family comes from a family history originally written by Charles Alfred Goodricke (1897). An abbreviated version is currently maintained online by Michael Goodrick (2010). The primary source of information on Edward Pigott is the 1999 article by Anita McConnell and Alison Brech (1999) entitled "Nathaniel and Edward Pigott, Itinerant Astronomers."

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Figure 1. John Goodricke (1764–1786). Pastel portrait by James Scouler, now the property of the Royal Astronomical Society. Used with permission of the RAS.

Figure 2. Ribston Hall in the seventeenth century. From the Goodricke family history website maintained by Michael Goodricke at http://www.goodrick.info/main.htm

Figure 3. Ribston Hall today. © Copyright Gordon Hatton <http://www.geograph.org.uk/profile/4820> and licensed for reuse under this Creative Commons License<http://creativecommons.org/licenses/by-sa/2.0/

Figure 4. Drawing found in the inside back cover of John Goodricke's mathematics notebook from Warrington Academy, 1779–1780. The constellations of Orion, Taurus, Auriga, and Gemini are shown, along with the Moon, Milky Way, and Zodiac. Positions of stars are given that are consistent with the drawing having been made in November 1779. Reproduced from an original held by City of York Council Archives and Local History (Goodricke 1779).

Figure 5. The church of St. John the Baptist in Hunsingore. The low, flat stone just to the left of center in the photograph marks the location of the Goodricke vault.

Figure 6. The east-facing side of the marker stone for the vault. The only engravings are the letter "E" at the top and the words, "The Goodricke Vault."

Frank Elmore Ross and His Variable Star Discoveries

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Presented at the 100th Spring Meeting of the AAVSO, May 22, 2011; received October 20, 2011; accepted December 17, 2011

Abstract Frank Ross (1874–1960) was a talented astronomer who excelled in such diverse fields as computational astronomy, optical instrument design, and astrophotography. His career and astronomical contributions are briefly summarized. One contribution was finding 379 probable new variable stars. Most of these variables are poorly studied, and for a number the identifications are still uncertain and the variability not yet confirmed more than eighty years after publication. Ross's original observing cards and plates are being used to re-examine the stars and resolve the problem cases. Follow-up work on a few stars has yielded interesting results. This work is illustrated with one example.

1. Introduction

Part of the celebration of 100 years of the American Association of Variable Star Observers in 2011 was a special joint meeting with the Historical Astronomy Division of the American Astronomical Society. This paper summarizes a talk at that session, the subject being chosen because of its connection to both astronomical history and variable star astronomy. The paper starts with the history—a discussion of the career of the astronomer Frank Ross. Then it is shown how some of the historical material from Ross's career has relevance to today's variable star research.

2. Career of Frank Ross

Frank Elmore Ross (Figure 1) was a talented astronomer and optical system designer whose career can be roughly divided into three phases. His early professional years were spent as a computational astronomer. This was followed by about a decade working as an industrial physicist. His later years were spent as an observational astronomer at the Yerkes Observatory. In all three of these rather different fields he made significant scientific contributions.

Ross was born in San Francisco, California, on April 2, 1874. After attending local schools, he enrolled at the University of California (Berkeley) from which he received his B.S. in 1896 and his Ph.D. in 1901, both degrees being in mathematics. His Ph.D. was one of the first two awarded by California in mathematics (Morgan 1967), and his strong mathematical abilities can be seen throughout his career. Ross's graduate mathematics studies included work in astronomy. He both did some observing at Lick Observatory, leading to his first published paper (Ross 1899), and learned the techniques of astronomical orbit computation that he would successfully employ in his early career. His early computational strength can be inferred from the references to his work on calculating perturbations of the Watson asteroids (Newkirk 1904a, 1904b, Leuschner 1910).

In 1902 Ross moved from the west to the east coast after accepting a position as an assistant in the Nautical Almanac Office in Washington D.C. He served one year there followed by two years in a similar position at the Carnegie Institute. These appointments involved carrying out computations under the supervision of Simon Newcomb, and he continued providing service to the Nautical Almanac Office until shortly before he left the east for Yerkes Observatory in 1924 (van Biesbroeck 1961). Projects included determinations of orbits for comet 1844 II Mauvais (Ross 1905a), Saturn's distant satellite Phoebe (Ross 1905b), and the then recently-discovered Jovian satellites VI Himalia (Ross 1905c, 1905e, 1907a) and VII Elara (Ross 1905d, 1906, 1907b), as well as working on improving the theories for the observed motions of the Moon (Newcomb and Ross 1907; Ross 1910, 1911a, 1911c, 1914b, 1915, 1918a), the Sun (Ross 1916a), Venus (Ross 1913d), and Mars (Ross 1916b, 1918b; Ross and Newcomb 1917).

In 1905 Ross became the director of the International Latitude Observatory (ILO) at Gaithersburg, Maryland. There he expanded his theoretical investigations to the problem of latitude determination (Ross 1912a, 1912b, 1913a, 1913c, 1913e, 1914c). But one also finds evidence of his instrumental and experimental interest that is first seen in a 1905 paper on improving the mounting of the Lick Crossley reflector (Perrine and Ross 1905). At the ILO he investigated the zenith tube used for observations (Ross 1911b) and then developed an improved version that used photography (Ross 1914a). His PZT (photographic zenith tube) doubled the accuracy of the observations and it became the standard for latitude observations for over fifty years. Its use of photography stimulated Ross's investigations of photographic emulsions and their characteristics (Ross 1913b).

Budget considerations caused a temporary closure of the ILO in 1915 (Bowers and Sengstack 1984; Butowsky 1989) and Ross accepted a position as a physicist with Eastman Kodak in Rochester, New York. During his nine-year period in industry he carried out several of his seminal studies of the photographic process and image effects that eventually resulted in over twenty papers and culminated with his classic book *Physics of the Developed Photographic Image* (Ross 1924). Also during this period Ross began designing camera systems. This work was initially driven by the need for aerial reconnaissance cameras in World War I, but eventually resulted in a design for an efficient wide-field doublet for astronomical use (Ross 1921, Ross 1922). "Ross cameras," which can produce good star images over fields of 20° or more across, were soon installed at several observatories.

In 1924, at the age of fifty, Ross was appointed a professor of astronomy at the University of Chicago assigned to the university's Yerkes Observatory. As described by Osterbrock (1997), the appointment was recommended by Yerkes Director Edwin Frost who was seeking someone with photography experience to replace the recently deceased eminent astrophotographer E. E. Barnard. Frost expected Ross to carry on Barnard's photographic program, and he did so very productively. Ross realized that re-observation of the fields that Barnard had photographed would permit moving and variable objects to be detected, and this project was very successful. He also used a camera based on his design to produce a new atlas of the Milky Way (Ross, Calvert, and Newman 1934) that complemented the posthumously-published one of Barnard (Barnard, Frost, and Calvert 1927). But Ross also developed projects independent of those pioneered by Barnard. He continued his optics work, designing field-correcting systems and new cameras (Ross 1932, 1933, 1934, 1935), and his photographic experiments (Ross 1931b). He explored how to do accurate photometry (Ross 1936) and how to best image the planets, including photographing them in the ultraviolet and infrared as well as in visible pass bands. His UV observations led to his discovery of cloud features on Venus (Ross 1927c, 1928c).

Ross retired in 1939. He had always been a Californian at heart, and even during his Yerkes years had spent considerable time most years observing at Mt. Wilson and Lick Observatories. It was natural therefore that on retirement he relocated to southern California. He became associated with the Mt. Wilson Observatory as a consultant on optics, working on optical components for the 48-inch Schmidt and 200-inch reflector planned for Mt. Palomar. He also designed lenses for the motion picture industry (Nicholson 1961). Ross passed away on September 21, 1960, at the age of 86.

3. The Ross variable Stars

How Frank Ross is connected to modern variable star research lies in some of the work he carried out at Yerkes Observatory. Yerkes is known for its 40-inch refractor. Once the largest astronomical telescope in the world, by the time Ross joined the Yerkes staff it had been surpassed by several much larger and more versatile reflectors and was relegated to specialized observing programs. One of the areas for which the great refractors were well suited was astrometry—the determination of accurate positions—and Yerkes had a well-established program for the determination of stellar parallaxes.

The pioneer astrophotographer E. E. Barnard had taken a large number of deep plates with the Yerkes wide-field Bruce telescope in the period 1904–1922. Ross realized that by re-photographing the fields with the same camera he would be able to compare the plates through blinking and detect stars of large proper motion. Such stars would be excellent candidates for the Yerkes parallax program as large proper motion typically reflects a rather small distance. Ross eventually published eleven papers listing 1,069 high proper motion stars, three of which are even today among the fifteen closest stars known.

Ross's blinking of plate pairs also led to discoveries of 379 suspected variable stars. These were announced in ten papers published between 1925 and 1931 (Ross 1925, 1926a, 1926b, 1927a, 1927b, 1928a, 1928b, 1929, 1930, 1931a). Today, most of the Ross variable candidates have been confirmed as variables, but only a few have been studied. About 40 of his suspected variables have not been confirmed; some were shown to result from minor planets visible on one plate of a blinked pair (Bedient 2003, Marsden 2007), while for others the published positions were in error or too imprecise to unambiguously identify the star.

4. Recent work on the Ross variables

In 2010 a project was begun at Yerkes to review the Ross plates and identity the "lost" variable candidates (Figure 2). It was quickly found that Ross had marked the fields of his variables on the plates (Figure 3). More importantly, Ross's note cards for his variable work were located (Figure 4), and the combination of the cards and the plates made identification of the objects certain.

We have elected to systematically examine all of the Ross variables, not just the ones with identification problems. This has allowed us to not only determine better positions when needed but also to derive better epochs (Ross only published the local dates for the plates he used) and magnitudes more closely related to B of the UBV system (Ross's values are systematically about 2 magnitudes too bright); such data may be useful in that these observations are often the earliest known for the variable. This approach has also allowed us to look more closely at some of the more interesting objects. So far we have worked through about half of the stars (Osborn and Mills 2011).

An interesting example of how this work ties in to variable star research is provided by the star Ross Variable 4, also known as NSV 1436. Ross's note card is shown in Figure 5, and the field on the two discovery plates is shown in Figure 6. Ross 4 is the fairly bright star visible on the 1905 plate taken by Barnard but not seen on the 1925 plate by Ross. The star's position is very close to an X-ray source, so we elected to investigate its light curve using other plates of this field in the Yerkes collection. The object was found to be always at B = 16 or fainter except for two outbursts—the one in 1905 and another in 1948, when it brightened to at least B=13 (see Figure 7). These results suggested Ross 4 is a cataclysmic variable, and possibly of the rare recurrent novae type (Brown *et al.* 2010). A third outburst was observed in March 2011, and the recent observations indicate a classification as a dwarf nova is more likely. (Osborne *et al.* 2011).

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Figure 1. Frank E. Ross (1874–1960). From Nicholson (1961).

Figure 2. Yerkes volunteer O. Frank Mills prepares to examine a Ross plate. Figures 2–6 are from the author.

Figure 3. Ross's plate number 22 (R-22) with his markings of several proper motion and variable stars.

Figure 4. The box containing Ross's note cards for his variable star discoveries.

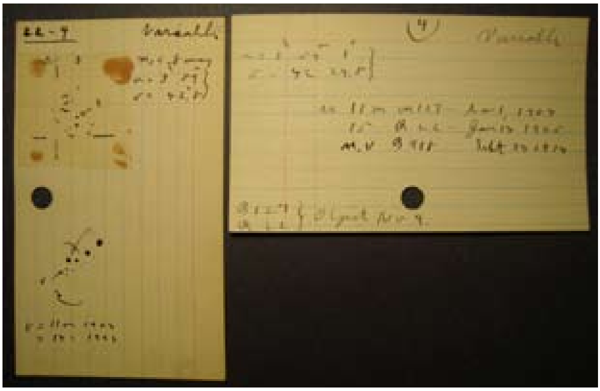

Figure 5. Ross's note cards for Ross 4 (NSV 1436). The card on the left has the finding chart (compare the lower sketch on the card to the field shown in Figure 6). The card on the right gives the determined 1875 coordinates and estimated magnitudes on three plates.

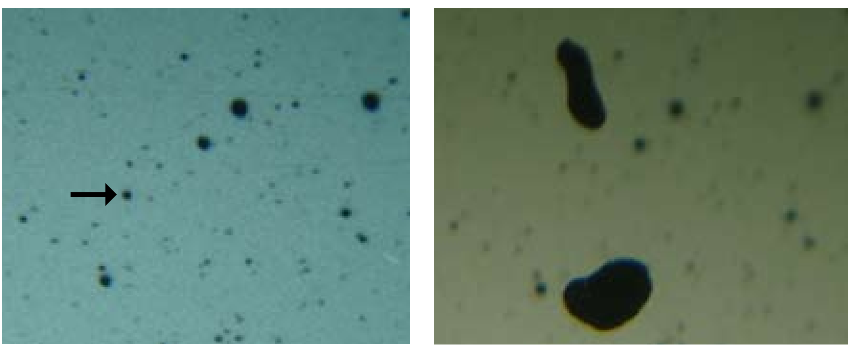

Figure 6. The field of Ross 4 (NSV 1436) on the discovery plates. The image from Barnard's 1905 plate B-127 is on the left, and that from Ross's 1925 plate R-22 is on the right. The variable is marked with an arrow on the left image, and Ross's ink marks are seen on the right image that show its approximate location.

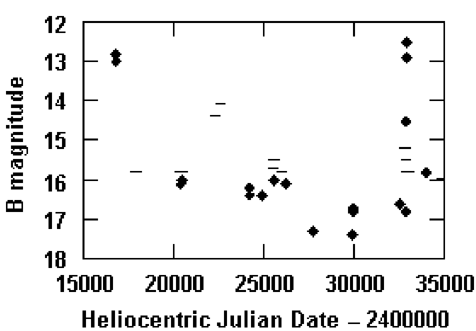

Figure 7. The light curve of Ross 4 (NSV 1436) from 1904 to 1952 From Brown *et al.* 2010.

Illinois—Where Astronomical Photometry Grew Up

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Presented at the 100th Annual Meeting of the AAVSO, October 7, 2011; received January 21, 2012; revised February 2, 2012; accepted February 6, 2012

Abstract In 1903 Dr. Joel Stebbins joined the University of Illinois faculty as an astronomy instructor and Director of the University of Illinois Observatory. In 1905 he and F. C. Brown began experimenting with selenium sell photometry and developed the equipment and many of the photometric practices used then. Those practices formed the foundation on which present day photometry processes are based. This paper will trace the history of Stebbins' career and his development of photoelectric photometry from 1903 to 1922. This story explains how Stebbins' wife, May, caused a change in astronomical observing that continues today.

1. Introduction

The prairies of central Illinois may seem an unlikely place to begin a photometric revolution. Illinois is a flat land state with only about 100 clear nights per year, the average elevation is only 600 feet above sea level, and the highest point is only at 1,500 feet. Yet, Illinois has produced its share of prominent and innovative astronomers. George Ellery Hale built his Kenwood Observatory in the heart of Chicago. Edwin Hubble spent his teen years in the Chicago suburbs and was educated at University of Chicago. Grote Reber built the World's first parabolic-steerable radio telescope. It was thirty feet in diameter and located in Reber's backyard in Wheaton. Rumor has it that Wheaton still has a city ordinance limiting the size of antennas residents can construct at their homes. And then there was Joel Stebbins.

Chicago was not the only cradle of astronomical innovation, there was also Urbana, home to the University of Illinois Observatory. Built in 1896 as a teaching facility, the Observatory was typical of late 19th century facilities with its Warner and Swasey/Brashear refractor, pendulum clocks, transit telescopes, and focus on visual observations. It stands in contrast to modern observatories in which star light typically falls upon some type of electronic detector. Trace the linage of these electronic devices back through the decades and you arrive at the doorstep of the University of Illinois Observatory where you will meet

Dr. Joel Stebbins, who "[r]aised on the astronomy of the 19th century, he lived to witness much of the new astronomy of the 20th-which he helped create" (Svec 1992). Stebbins arrived in 1903 as the new observatory director. While the skies may not be as dark and clear as the western mountain top observatories, the UI Observatory did have ready access to the campus. Astronomy was a division in the Mathematics Department and Stebbins had teaching responsibilities in both math and astronomy. Stebbins was able to develop and improve new photometric instruments and pursue an astronomical research program because of willingness and ability to collaborate with the Illinois physicists.

2. The story

Joel Stebbins was born in Omaha, Nebraska, on July 30,1878, and educated in the Omaha Public Schools. His interest in Astronomy started from an elementary school class. He built his first telescope by attaching lenses to a tube made from rolled up newspapers. Stebbins' advanced education was at the University of Nebraska where he received a Bachelor of Science degree. Graduate study started at the University of Nebraska, continued at the University of Wisconsin, and concluded at the University of California at Lick Observatory and on the Berkeley campus. Stebbins received the third Ph.D. in Astronomy granted by the University of California, in May of 1903 (Whitford 1978).

Stebbins' first employment after receiving his Ph.D. was as the Astronomy Instructor at the University of Illinois in Urbana. Along with the instructor position he was assigned the Directorship of the UI Observatory (Figure 1). While the Observatory was a relatively new facility in good condition and well equipped with a 12-inch Brashear refractor and a polarizing photometer, it had no operating budget! The Observatory's first year budget ended up being $7.00 and it came out of Stebbins' pocket! But, life does get better. In 1905 he received a budget of $750.00 from the University Trustees.

Stebbins first major project at UI was a survey of 107 double stars to determine their brightness using the Observatory's 12-inch Brashear telescope and a Pickering Polarizing Photometer made by Alvan Clark and Sons. This project was ongoing when a good thing happened. On June 27, 1905, Stebbins married his college sweetheart, May Louise Prentiss, also of Omaha. Then, in August, they travelled with Lick Observatory astronomer Heber Curtis and his wife, Mary, to study the 1905 Solar Eclipse in Labrador.

Upon returning to Urbana, Stebbins resumed his photometry program; but life at the Observatory was about to change, and the way astronomy research was conducted was about to change forever! In Stebbins' own words:

> The photometric program went along well enough for a couple of years until we got a bride in our household, and then things began to happen. Not enjoying the long evenings alone, she found that if

> she came to the observatory and acted as a recorder, she could get me home earlier. She wrote down the numbers as the observer called them, but after some nights of recording a hundred readings to get just one magnitude, she said it was pretty slow business. I responded that someday we would do all this by electricity. That was a fatal remark. Thereafter she would often prod me with the question: "When are you going to change to electricity?" (Stebbins 1957)

In the following summer Stebbins attended a Physics Department demonstration where he met a young instructor, Fay C. Brown. Brown was demonstrating a selenium cell that, when illuminated by a lamp, would ring a bell. Stebbins had an idea: "why not turn on a star to a cell on the telescope and measure a current?" On 23 June 1907, after some improvements, Stebbins and Brown began the project to measure the variation of the Moon's light with phase:

> I soon made friends with Brown, and in due time we had a selenium cell on the 12-inch refractor; I operated the telescope and a shutter while Brown looked after the battery, galvanometer, and scale. The first trial was on Jupiter-no response; several more trials, still no response. I said to myself, "I'll fix him." The moon was shining through a window; I took the cell with attached wires off the telescope and exposed it to the moon. The galvanometer deflection was measurable with plenty to spare. Result: We spent a couple of months measuring the variation of the moon's light with phase. Our resulting light curve turned out to be the first since the time of Zollner in the 1860s. (Stebbins 1957; see Figure 2)

The involved process for the Moon project would begin with Stebbins, at a window in the observatory classroom, making a set of four ten-second exposures by pointing the cell at the Moon. One minute was allowed between each exposure for the cell to recover. Brown, at the galvanometer in the West Central Transit room, recorded the deflection and the time for each exposure. After each set the photometer was calibrated at various distances from a standard Kohl candle. A second set of lunar observations would follow the calibration. The author suspects that calibration was done at the beginning and end of the process (Figure 3).

This was not the World's first attempt at photoelectric photometry. In 1892 selenium cells made by G. M. Minchin of Dublin were used by a Professor Fitzgerald and W. H. S. Monck, an amateur astronomer who owned a 9-inch refractor that they used to detect Jupiter, Venus, and Mars. In 1895 Minchin joined with Mr. W. E. Wilson to measure some stars with Wilson's 24-inch reflector. Two short papers were published by Minchin and his associates in 1895 and 1896. In Germany E. Ruhmer used his homemade cells to observe a solar eclipse on October 31, 1902, and a lunar eclipse on April 11–12, 1903. These are the only known successful applications of selenium cells prior to Joel Stebbins' work. Stebbins (1940) wrote that he learned of Minchin and others while preparing the literature review for the paper on the phases of the moon. Hearnshaw (1996) noted: "It is doubtful that the experiments made by Minchin had much influence on the future course of stellar photometry."

Brown left Illinois for a fellowship at Princeton at the end of the summer of 1907 yet returned to Urbana to work with Stebbins during the following two summers to improve the photometer. Progress was both deliberate and occasionally serendipitous. A dropped and broken selenium cell led to the discovery that smaller cells produced a signal with the same strength but less noise. A clear, sub-zero night provided evidence that cold sensors produce less noise.

Continued improvements to the selenium cell allowed Stebbins to detect third magnitude stars. This allowed the collection of sufficient data to publish a light curve for β Persei (Algol; Figure 4). Here is Stebbins' (1940) account of the first efforts toward continuing studies of stars with photoelectric photometry:

> After many experiments we learned that the irregularities of a selenium cell were much reduced if the cell was kept at a uniformly low temperature in an ice pack, but even so there were only a few bright stars within reach of the apparatus. We began with the comparison of Betelgeuse and Aldebaran with the assumption that any changes in the relative magnitude would be due to Betelgeuse. Finally a new cell from Giltay gave about a three-fold improvement over previous cells, and we were able to take up a detailed study of Algol, which is about second magnitude.
>
> One observing season of six months was devoted almost entirely to this star, and it was possible to detect for the first time the secondary minimum of Algol, and the continuous variation between eclipses. Following this study, we tested a number of bright spectroscopic binaries for small variations in light. As luck would have it, the first two stars so tested turned out to be eclipsing binaries, Beta Aurigae, period 4 days with two equal minima of about 0.08 mag. each, and Delta Orionis, period 5.7 days, with minima of 0.08 and 0.05 mag. spaced in agreement with the eccentric orbit. Of the other stars tested Alpha Coronae Borealis also gave unmistakable evidence of an eclipse, which was confirmed later with the photoelectric cell. (Stebbins 1940)

After completion of the Algol observations in 1909, the photometry process was sufficiently developed for use as a research tool. A much higher level of observational accuracy had been achieved and allowed Stebbins the opportunity to study eclipsing variables for the direct determination of the diameter, mass, and density of stars. Stebbins concluded that there must be many spectroscopic binaries with eclipses of small range that could not be discovered using older photometric processes. He made a list the most favorable cases. The previously mentioned first two bright stars tested—β Aur and δ Ori—showed eclipses at the predicted times of about ten percent of the light at constant phase. A systematic campaign at Urbana over the following years turned up many more. As an example of this campaign, during March 1911, photometric observations were made of β Aur, α Gem, ξ UMa, δ Ori, α Ori, and α UMi, and by the following March, ι Ori, α Vir, and β Sco joined the observing program. Although productive, the selenium photometer was a challenge to operate.

3. Enter the photoelectric cell

Swiss born and educated physicist Jakob Kunz arrived in Urbana in 1909 and began a research program focusing on photoelectric cells. In 1911, Kunz and fellow Illinois physicist W. F. Schulz met Stebbins and suggested he might consider replacing the selenium cell with a photoelectric cell. One of Kunz's graduate students, J. G. Kemp, completed a dissertation in 1912. Kemp found that a potassium-hydrogen cell was about 200 times the sensitivity of the selenium cell and noted that "A design has been made for a sensitive photoelectric cell for photometric work in astronomy. It is expected to get a cell which will be sensitive enough to use instead of the erratic selenium cell now used." (Kemp 1913). It is interesting that this change replaced a solid state device (selenium cell) with a glass tube device containing special coatings and small amounts of hydrogen or other suitable gases. The potassium-hydrogen cell is a specific version of the alkali-cathode cell.

Stebbins continued with the selenium photometer up to his departure in the fall of 1912 for a sabbatical in Europe. Kunz and Schulz first observed α Aur with a photoelectric photometer in December of 1912 and then α Boo the following April. While in Europe on sabbatical in August 1913, Stebbins met Hans Rosenberg of Tübingen who was successfully using an alkali-cathode photometer. Campbell (1913) recounts:

> By way of comment on Rosenberg's paper, Stebbins went to the blackboard and wrote down the following table, contrasting the work of Meyer and Rosenberg's electric-cell photometer and his own selenium photometer...

Photometer	Telescope	Star of	Time to make observation	probable error of one determination
Electric-cell	5-inch	5th mag	2 min	+ 0.003 mag
Selenium	12-inch	2nd mag	60min	+ 0.01 mag

After returning from sabbatical, Stebbins and Kunz concentrated on developing the new photometer incorporating a photoelectric cell and Wulf string electrometer. The selenium photometer was never used again for published research. In the summer of 1915 the photometer had progressed to the point that Stebbins used it on the 12-inch refractor at Lick Observatory (Figure 5) to obtain a light curve of β Lyr.

Back in Urbana he began an aggressive research program which resulted in a series of papers in the *Astrophysical Journal* on eclipsing binaries λ Tau, σ Aql, β Per, AR Cas, ellipsoidal variables π^5 Ori and b Per, and Nova Aql No. 3 (1918). Stebbins and Kunz also travelled to Wyoming to study the solar eclipse. Public open houses were suspended in 1918 due to navigation classes supporting the war effort and time needed to reduce data from the Nova and eclipse expedition. Dr. Elmer Dershem joined the Observatory staff in 1917 and rebuilt the photometer in the summer of 1919. Dershem would leave for Berkeley and help Edith Cummings at Lick Observatory build their photometer in 1920. By 1922, Charles Clayton Wylie completed the first Illinois astronomy doctorate for his photoelectric studies of the Cepheid η Aql, and σ Aql, noting its variations due to tidal distortions.

In 1922 Stebbins moved to the University of Wisconsin to become Director of the Washburn Observatory. He completed work on an impressive number of eclipsing binaries over a period of several years. From 1925 onward, he moved to other fields of astronomical photometry and spent many summers at Mt. Wilson as a research associate. Although he was in Madison, he took with him C. M. Huffer, an Illinois mathematics graduate, who went on to become a photoelectric pioneer in his own right recording thousands of observations of eclipsing, late type, and red variables as well as galaxy magnitudes for Edwin Hubble. From the early 1930s Huffer was Stebbins' main collaborator on the photometric study of interstellar reddening. Stebbins also maintained a professional and personal relationship with Kunz who continued to provide Stebbins and the rest of the astronomical community with photoelectric cells until Kunz's death in 1938. Of the thirteen American observatories identified by Hearnshaw as conducting photoelectric research before World War II, six used Kunz photocells (Urbana, Washburn, Lick, Yerkes, Mt. Wilson, and Harvard).

4. Postscript

The Observatory continues to be a teaching facility. In recognition of the significance of the development of photoelectric photometry, the Observatory was declared a National Historic Landmark by the U.S. Department of the Interior. Deferred maintenance, harsh winters, and age have taken their toll on the University of Illinois Observatory. In conjunction with the Astronomy Department, a Friends of the University of Illinois Observatory group has formed in hopes of restoring and preserving the historic structure. For more information visit: https://www.facebook.com/U.of.lllinois.Observatory and http://www.astro.uiuc.edu/friends/fuio/

5. Conclusion

Stebbins (Figure 6) did not see central Illinois as a limitation to astronomical research. He commented "One doesn't have to go to a place where there is a large observatory to find something to do. I have found conditions here in Urbana more favorable to my work than anywhere else. At large observatories there is always something the matter" (Anon. 1916). Joel Stebbins continued to use, create, and improve photoelectric equipment and processes for the rest of his life. His last paper, written with his former student, Dr. Gerald Kron, dealt with the standardization of the six-color system in terms of black-body temperature. It was published in 1964 just two years before Stebbins died. While not the first to use photoelectric photometry, Joel Stebbins deserves the credit for developing and proving, with many papers based on countless hours of observations and many equipment and process improvements, photoelectric photometry to be the tremendous scientific tool that it has become. The key to the astronomer's success was the collaboration with physicists. Stebbins' research was motivated by astrophysics and his papers reflect that emphasis with data and analysis. It was the collaboration with F. C. Brown and then Jakob Kunz who solved the technical instrument problems that enabled the instrument to gather the data presented by Stebbins, proving the value of the photoelectric photometer. And it all started out on the Illinois prairie in a little town named "Urbana" because May had writer's cramp!

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Figure 1. The University of Illinois Observatory in 1905 when Dr. Stebbins was starting to think about using electricity. From the collection of M. Svec.

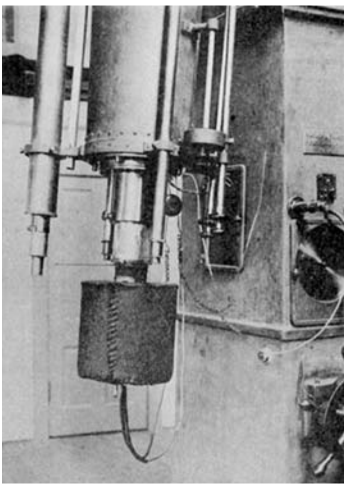

Figure 2. The University of Illinois Observatory selenium cell photometer about 1910. The cell is in an ice pack attached to the 12-inch refractor. From Stebbins (1910).

Figure 3. Page (top) from Stebbins notebook titled “Selenium 1907 Febr. 15 to 1908 January 25.” The note states that F. C. Brown was at the galvanometer in the transit room and Joel Stebbins was in the classroom exposing the selenium cell (bottom) to the Moon. Provided by M. Svec, courtesy of University of Wisconsin Archives.

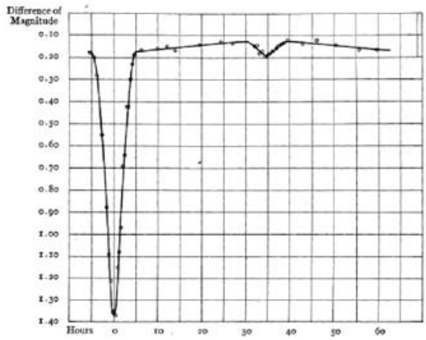

Figure 4. Classic Light curve of β Per showing two new features: the secondary eclipse and the reflection effect. From Stebbins (1910).

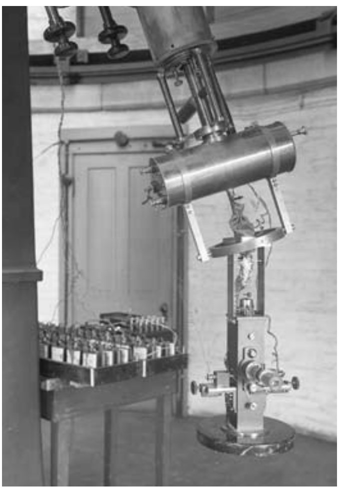

Figure 5. The photometer Stebbins used from about 1915 at the UI Observatory. The photometer contains a Kunz rubidium cell with a direct connection to a string electrometer specifically built for Stebbins by William Gaertner and Company of Chicago. The other parts were constructed by Mr. J. B. Hayes, mechanician of the Illinois physics department. The telescope is the UI 12-inch Brashear refractor. Provided by M. Svec, courtesy of University of Illinois Archives.

Figure 6. Dr. Joel Stebbins at Washburn Observatory, University of Wisconsin, about 1924. The telescope is a 15.3-inch Clark refractor. The photometer is possibly an early gimbal-mounted string electrometer.

The Man with the measuring tool! All because May had writer's cramp!

Provided by M. Svec, courtesy of University of Wisconsin Archives.

Stellar Pulsation Theory From Arthur Stanley Eddington to Today *(Abstract)*

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Presented at the 100th Spring Meeting of the AAVSO, May 22, 2011

Abstract While one could question that Eddington was the pioneer in theoretical work directly addressing the pulsating variable stars, there is no doubt that his work in the first part of the 20th Century set the stage for a transformation of theoretical astrophysics. After Eddington (the 1940s to the present day) stellar pulsation theory evolved from analytic theory into the realm of computational physics. Starting from Eddington's formulation, the flexibility provided by numerical solutions enabled exploration of systematics of pulsating variable stars in vastly greater detail. In this talk, we will trace this development that led to theoretical explanations of period-luminosity relations, new mechanisms of pulsation driving, connections with mass loss and stellar hydrodyamics, and to modern asteroseismic probes of the Sun and the stars.

King Charles' Star: A Multidisciplinary Approach to Dating the Supernova Known as Cassiopeia A *(Abstract)*

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Presented at the 100th Spring Meeting of the AAVSO, May 22, 2011

Abstract Few astronomical phenomena have been as studied as the supernova known as Cassiopeia A. Widely believed to have occurred in the latter half of the seventeenth century, it is also thought to have gone unrecorded. This paper will argue that Cas A did not go unobserved, but in fact was seen in Britain on May 29, 1630, and coincided with the birth of the future King Charles II of Great Britain. This "noon-day star" is an important feature of Stuart/Restoration propaganda, the significance of which has been widely acknowledged by historians and literary experts. The argument here, however, is that in addition

the historical accounts provide credible evidence for a genuine astronomical event, the nature of which must be explained. Combining documentary analysis with an overview of the current scientific thinking on dating supernovae, the authors put forward their case for why Charles' star should be recognized as a sighting of Cas A. Finally, it will be argued that a collaborative approach between the humanities and the sciences can be a valuable tool, not just in furthering our understanding of Cas A, but in the dating of supernovae in general.

Ed. note: this paper is expected to appear in a future issue of JAAVSO

The History of Variable Stars: a Fresh Look

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Based on a paper presented at the 100th Annual Meeting of the AAVSO, October 7, 2011

Abstract For historians of astronomy, variable stars are important for a simple reason—stars change. But good evidence suggests this is a very modern idea. Over the millennia, our species has viewed stars as eternal and unchanging, forever fixed in time and space—indeed, the Celestial Dance was a celebration of order, reason, and stability. But everything changed in the period between Copernicus and Newton. According to tradition, two New Stars announced the birth of the New Science. Blazing across the celestial stage, Tycho's Star (1572) and Kepler's Star (1604) appeared dramatically—and just as unexpectedly—disappeared forever. But variable stars were different. Mira Ceti, the oldest, brightest, and most controversial variable star, was important because it appeared and disappeared again and again. Mira was important because it did not go away. The purpose of this essay is to take a fresh look at the history of variable stars. In re-thinking the traditional narrative, I begin with the first sightings of David Fabricius (1596) and his contemporaries—particularly Hevelius (1662) and Boulliau (1667)—to new traditions that unfolded from Newton and Maupertuis to Herschel (1780) and Pigott (1805). The essay concludes with important 19th-century developments, particularly by Argelander (1838), Pickering (1888), and Lockyer (1890). Across three centuries, variable stars prompted astronomers to re-think all the ways that stars were no longer "fixed." New strategies were needed. Astronomers needed to organize, to make continuous observations, to track changing magnitudes, and to explain stellar phases. Importantly—as Mira suggested from the outset—these challenges called for an army of observers with the discipline of Spartans. But recruiting that army required

a strategy, a set of theories with shared expectations. Observation and theory worked hand-in-hand. In presenting new historical evidence from neglected printed sources and unpublished manuscripts, this essay aims to offer a fresh look at the history of variable stars.

Ed. note: This paper is expected to appear in JAAVSO Vol. 41.

History of Variable Star Organizations

British Astronomical Association Variable Star Section, 1890–2011

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Presented at the 100th Annual Meeting of the AAVSO, October 5, 2011; received January 30, 2012; accepted January 30, 2012

Abstract A summary history is given of the British Astronomical Association Variable Star Section, the longest established organized group of variable star observers whose work extends from the latter stage of the 19th Century until today.

1. Introduction

The British Astronomical Association Variable Star Section (BAA VSS) is the World's oldest currently active amateur association of variable star observers, having been established in 1890. However, it was not the first such group to be formed as that was the Liverpool Astronomical Society Variable Star Section (LAS VSS); the BAA VSS was a direct successor to the LAS VSS that had been active for six years leading up to 1889. This paper is a summary outline of the history of the BAA VSS and was presented at the Centenary Meeting of the American Association of Variable Star Observers (AAVSO) held in Woburn, Massachusetts, on the 5th October 2011.

2. Pre-history

The formation of an association of variable star observers in Great Britain proved to be both a lengthy and difficult task in the 19th Century. As early as 1833 Sir John Herschel advocated that amateur astronomers take up variable star observing but it would not be until the 1850s that Joseph Baxendell, Norman Pogson, and George Knott commenced systematic observations. Baxendell and Knott attempted to form the World's first association of variable star observers in 1863 known as the "Association for the Systematic Observation of Variable Stars" (ASOVS) but were unsuccessful due to general disagreement over the stellar magnitude scale and lack of suitable charts and sequences. Nevertheless the proposed structure of the ASOVS was visionary and elements would be later adopted, but Britain and the World were clearly not yet ready for an association purely dedicated to observing variable stars. However, in 1881 the LAS was formed and it established a VSS in 1883, and this demonstrated that an organized group of variable star observers could be sustained provided it was supported by a large astronomical society. The LAS suddenly collapsed in

1889 due to financial difficulties and political infighting but within a year the LAS had been replaced by the BAA, which was more adequately managed on a sound financial footing.

3. 1890–1899

The BAA VSS was formed at the first meeting of the BAA in London on 24th October 1890. Besides the VSS, sections were also formed for solar, lunar, Jupiter, meteors, double stars, coloured stars, and spectroscopic and photographic work. John Gore was appointed Director of the VSS and he brought with him experience of directing the LAS VSS from 1884 to 1889. Gore was a prolific writer and binocular observer who had discovered variables such as W Cyg, X Her, and U Ori. Gore's initial plan for the VSS was to concentrate upon neglected and suspected variable stars but by 1892 he had also introduced a nova search plan (probably inspired by Anderson's discovery of T Aur in January 1892). Although initially unsuccessful the nova search plan did establish the standard method for such patrols by allocating regions of the Milky Way to specific observers to search. In 1891 the VSS had twelve members which included two clergy, two army officers, two persons based in the Colonies, and one lady. Two outstanding members of the VSS in the 1890s were Alexander W. Roberts and A. Stanley Williams. Roberts was based in South Africa and made 65,000 highly accurate visual observations and discovered twenty variable stars. Williams used photography to discover over fifty variable stars including RX And. Gore published three *BAA Memoirs* and prepared summaries of members' observations and reported LPV maxima and minima. Unfortunately Gore's eyesight began to deteriorate after 1900 and he died following being struck by a horse car in Dublin in 1910.

4. 1900–1909

Colonel E. E. Markwick (Figure 1) was appointed as VSS Director at the end of 1899 and made an immediate and lasting impact. Previously Markwick had used his binoculars to good effect on military postings and discovered T Cen and RY Sgr from Gibraltar. Markwick had a clear strategy for the VSS that was based upon encouraging systematic quality observations to a uniform photometric system. This meant preparing standard charts based on Hagen's *Atlas Stellarum Variabilium* (ASV) sequences (the first charts for eighteen LPVs were released in 1901) and introducing a fixed program of stars for the observers to concentrate upon. Initially the program covered just twelve stars in 1900 but within a year it was expanded to forty-six stars, the majority being LPVs. In 1904 the program was further expanded to include U Gem and SS Cyg, then classed as irregular variables. In 1904 the ASV sequences were replaced by Harvard photometry although the comparison stars were still identified on the charts by the ASV numbers. Markwick requested that the members adopt Knott's step method and introduced a standard report form for observations which were to be submitted on a monthly basis. Markwick also introduced *BAA Circulars* for rapid feedback to the members and established a format (including observer codes) for presenting the observations within the *Memoirs*. Markwick's energetic leadership and directives were positively received and soon useful homogenous data were being accumulated. This meant that densely packed light curves could be constructed for the program stars, some of which were published in the *Journal of the BAA* (*JBAA*) and put on display at the Franco-British Exhibition in London in 1908. Markwick publicized the work of the VSS in *Popular Astronomy* in 1904 and the first meeting of the VSS took place on December 10, 1906. Also in December 1906 the VSS recorded the second brightest maximum (to that of 1779) of Mira at magnitude 1.9. During Markwick's term twenty-seven reports appeared in the *JBAA*, fifty-two *Circulars* were issued, and three *Memoirs* were published. In all 39,940 observations of the program stars were logged (the leading observer was Arthur Brown) and when Markwick's ten-year directorship terminated at the end of 1909 the VSS was firmly established as the model format variable star association.

5. 1910–1921

Charles Brook succeeded Markwick as VSS Director on New Year's Day 1910. Brook's strategy was to consolidate and expand on the firm foundation laid by his illustrious predecessor who continued to assist in the management and administration of the VSS. Brook had previously assisted Markwick in this respect and had in 1906 implemented the reduced scatter experiment which involved using uniform instrumentation and eyepieces. In 1911 the observing program consisted of five Algol, nine short period, twenty-seven long period, and nine irregular variables. In 1914 the short period variables were dropped from the program after a summary paper on the data acquired was published. They were effectively replaced by four long period variables that were added to the program in the same year. The Great War (1914–1918) only had a slight impact on the work of the VSS because Markwick (who returned to military duties) had relinquished the directorship and the principle observers were too senior to be called up to the armed forces. During Brook's twelve year term thirty-seven interim reports appeared in the *JBAA* and three *Memoirs* were published. The *Memoir* on DN Gem (nova in 1912) was written jointly with the Spectroscopic Section. Brook was a stickler for detail and the VSS data and publications during this period are a model of high quality. The most compelling fact, however, was that 83,796 observations were logged of the program stars by twenty members (the leading observer was Charles Butterworth), which represented a doubling on the output of the previous decade.

6. 1922–1939

Felix de Roy (Figure 2) succeeded Brook as VSS Director on New Year's Day 1922. De Roy, a Belgian national, had been a member of the BAA since 1906 and had taken refuge in Croydon near London throughout the Great War. Now back in Belgium, de Roy directed the VSS with the able assistance of the VSS secretary Arthur Brown (succeeded by William Lindley upon Brown's death in 1934). Brown distributed charts and report forms, received and archived the observations, and dealt with member's correspondence, whilst de Roy analyzed the data and prepared the reports. De Roy attempted to initiate coordination with the AAVSO following IAU meetings. In 1922 he proposed to Leon Campbell that the AAVSO and BAA VSS have separate observing programs to avoid duplicated effort (this was never implemented). In 1932 de Roy was a pivotal figure in the formation of the Joint Committee of Variable Star Associations (JCVSA) which involved the AAVSO, AFOEV, and BAA VSS and was primarily concerned with standardization of sequences. Following this the VSS set up its first chart committee in 1935 tasked to update the VSS sequences in line with the directives of the JCVSA. The chart committee also replaced the comparison star ASV numbers with letters on the charts. In 1928/1929 U Gem was recorded to have spent a record time of 255 days between outbursts. Manning Prentice discovered nova DQ Her in 1934 and the γ Cas eruption in 1936 was well covered by the VSS (including an independent detection by Patrick Moore). During de Roy's seventeen-year term eleven *Circulars* were issued, thirty-five interim reports appeared in the *JBAA,* and four *Memoirs* were published. 147,495 observations were logged (Butterworth again the leading observer) and the program was expanded to cover fifty-two long period and ten irregular variables. De Roy resigned the directorship of the VSS due to ill health at the time of the outbreak of World War II.

7. 1939–1958

William Lindley is the longest serving Director of the VSS but he presided over its most difficult period. Lindley's term began positively in 1939 with three interim reports appearing in the *JBAA* and Butterworth becoming the first observer to reach the milestone of 100,000 visual observations. World War II then hit hard as Lindley received his call-up papers and most of the VSS members were soon involved directly or indirectly in the war effort. The annual observations dropped to below 2,000 in 1941 and 1942, having been at 18,000 in 1938. Extraordinary efforts were made by military personnel to continue sporadic observations. Frank Knight for instance recorded the onset of a fade of R CrB from a foxhole on the eve of the battle of El Alamein. By the time the battle was over and the sky cleared R CrB had disappeared from binocular range. BAA HQ suffered flooding from bomb damage and de Roy died in occupied Belgium just when it seemed he might be the second observer to reach the 100,000 observation milestone. Frank Holborn was the leading observer during this period despite having been inconvenienced by flying bombs in 1944. A backlog of reports soon built up and it would take another twenty years after hostilities ceased for the VSS to generate the numbers of observations being produced in 1938. Despite all this the program was expanded in 1945 to include the dwarf novae RX And, Z Cam, and SU UMa. In 1946 Knight was the first person to detect the second outburst of T CrB but his report to Greenwich Observatory was not acted upon promptly so he did not receive the proper credit for this discovery. Upon the completion of the much delayed final *Memoir* in November 1958 (LPV observations for the years 1930–1934) Lindley resigned the directorship.

8. 1959–1971

Reginald Andrews was appointed Director at the end of 1958 and he immediately set about stimulating a recovery of the VSS from the setbacks suffered during the Lindley term with a particular objective to increase the number of active observers from fifteen. One of the first tasks was to resume the work of the pre-war chart committee and 140 charts were issued in 1959 and 1960. Andrews then worked on clearing the backlog of VSS reports with thirty-three interim reports appearing in quick succession in the *JBAA*. In 1959 Holborn wrapped up his four-year campaign to monitor Z Cam when a rise to outburst from a standstill was recorded. The first VSS meeting since 1935 was held on June 23, 1963, and twelve additional stars (dwarf novae) were added to the program in 1964. By 1964 the number of observers was forty-one and they reported 13,000 observations. This enhanced level of activity by the VSS caused some concern amongst BAA council members and a dispute arose about the quantity of VSS papers being published in the *JBAA*. Andrews resigned in 1964 as a result of this dispute. John Glasby assumed the role of Director in 1965 and applied a more sedate approach to managing the VSS which was aligned with the BAA council directives. Ten interim reports appeared in the *JBAA* over five years and the observing program was adjusted (introduction of additional cataclysmic variables) following the IAU congress in 1967. In 1969 the binocular program was established in response to the formation of the independent Binocular Sky Society (BSS) in 1968 and the discovery of the nova HR Del by George Alcock in 1967. Alcock had memorized the patterns of 30,000 stars as they appeared in his binoculars and he also found novae LV Vul in 1968 and V368 Sct in 1970. Brian Carter was the leading observer during this period and Glasby resigned the directorship in 1971.

9. 1972–1980

John Isles commenced his initial term as VSS Director in 1972 and his first action was to reintroduce the *Circulars* which had been discontinued in 1935. In 1972 Melvyn Taylor prepared a large number of charts and sequences for the BSS which were adopted for the binocular program. The first results of an eclipsing binary project were published in 1973. There were special observing projects launched on flare stars and supergiant variables following requests from professional astronomers. The BSS merged with the VSS in 1974 and the observing programs were overhauled the same year with several LPVs being dropped. The VSS collaborated with the AAVSO on visual nova and supernova searching in the period 1973–1978. In terms of visual nova discoveries Alcock found NQ Vul in 1976 and John Hosty found HS Sge in 1977 as part of Guy Hurst's UK Nova Patrol managed jointly with *The Astronomer*. When nova V1500 Cyg appeared in 1975 there were multiple VSS observers who discovered it independently with the naked eye. Taylor was the leading observer throughout this period and in 1976–1977 observers reported 27,000 observations. Isles resigned in 1977 owing to business commitments and his successor was Ian Howarth. During the period 1977–1979 Howarth collaborated with Jeremy Bailey to provide improved linear sequences for the dwarf nova on the VSS program. As a by-product of this work Howarth and Bailey also calculated a visual (mv) to V conversion formula. In 1979 X-ray emission from SS Cyg detected by the satellite Ariel V was interpreted by comparison with VSS visual data. Howarth concentrated upon updating the section reports and during the period 1972–1980 forty-three interim reports appeared in the *JBAA*. Howarth was forced to resign due to increasing professional commitments in 1980.

10. 1981–1992

Douglas Saw directed the VSS from 1981 to 1987. In 1981 the North Western Association of Variable Star Observers (NWAVSO) was merged with the VSS. The NWAVSO journal *Light Curve* was amalgamated with the VSS *Circulars* and the first AGN's (NGC 4151, Markarian 421, and 3C-273) were added to the VSS program. In 1982 VSS data were used to interpret UV and IR data on SS Cyg and SU UMa at Stavropol Astrophysical Observatory. In 1982 microcomputers were used for the first time to record observations and a digitized database was established in 1991 by Dave McAdam. In 1983 Robert McNaught visually detected an outburst of VY Aqr for the first time. During this period there was success for the UK Nova Patrol team by photographic means with McNaught detecting V842 Cen in 1986 and V4135 Sgr in 1987 while McAdam detected PQ And in 1988. Alcock made his final visual nova discovery with V838 Her in 1991. Jack Ells, Andy Hollis, and Richard Miles produced extensive photoelectric photometry during the early 1980s but could not reach the output capacity of the visual observers. John Isles began his second term as Director in 1987 and Saw took up the post of deputy Director. In 1987 51,000 visual observations were reported which was a record annual total. Also in 1987 John Toone was appointed Chart Secretary and tasked to standardize all the charts to a new format (this work was still in progress in 2011). In 1988 the VSS held a meeting with professional astronomers at University College London with the object of fostering closer professional-amateur collaboration in the study of variable stars. The immediate outcome was the formation of the Professional Amateur Liaison Committee (PALC) with Roger Pickard appointed as the primary amateur interface point. The centenary meeting of the VSS was held at Crayford on October 19–20, 1991, with a main theme of professional/amateur collaboration (Figure 3). Toone was the leading observer during this period and Ed Collinson reported his last observation in 1987 some sixty-seven years after recording his first.

11. 1992–1999

Tristram Brelstaff became VSS Director on 1st November 1992. Brelstaff was previously responsible for the Eclipsing Binary Program and had become a proficient writer with his monthly publication *The Variable Star Observer* in 1991/1992. The Jack Ells automatic photoelectric telescope at Crayford produced extensive photometry of eclipsing binaries during the years 1988–1997. In 1994 the *Circulars,* which had previously been issued at irregular intervals, were fixed at quarterly intervals (March, June, September, and December). Funding was made available from the RAS to support the development of the database which reached one million observations in January 1997. In February 1995 Gary Poyner became VSS Director and immediately introduced the Recurrent Objects Program (ROP) that had previously been an initiative of *The Astronomer*. The ROP proved to be very successful in determining the true nature of many poorly observed cataclysmic variables. Mark Armstrong found the first supernova from the UK by CCD imaging in 1996 and this triggered an avalanche of discoveries by the UK Supernova Patrol team. In November 1996 the VSS web page was set up by McAdam. Poyner was the leading observer during this period accumulating up to 15,000 observations annually and in 1998 became the second VSS member (and only Director) to record 100,000 visual observations. Mike Collins used photography for nova searching and in doing so identified 157 new variables in the Milky Way in the years 1989–1998. These were given *The Astronomer* Variable (TAV) designations and many were incorporated into the VSS program in 2000.

12. 1999–2010

Roger Pickard became VSS Director on September 1, 1999, and provided stable leadership during the transition into the CCD/DSLR era (Figure 4). The PALC was discontinued in 2000 as direct e-mail communication had finally rendered it redundant. In 2000–2002 Toone worked with the AAVSO within the International Chart Working Group to establish guidelines for future visual sequences using V photometry. In 2001 there was a joint campaign with the AAVSO to monitor SU UMa for the University of Leicester who were monitoring X-Ray emission with the RXTE satellite. A mentor scheme was set up by Karen Holland in 2002 and the VSS alert group was launched in 2004 with Poyner as administrator. In 2007 Miles used a DSLR camera to record Mira at V magnitude 2.16 (brightest for 101 years) and undertake daytime photometry of β Lyr. A joint meeting with the AAVSO was held at Cambridge (England) in 2008. In 2009 Tom Boles who had the ability to image up to 1,700 galaxies per night became the world's most prolific individual supernova discoverer (he had a total of 144 confirmed discoveries by October 2011). Robin Leadbeater revived spectroscopic work on variable stars and produced outstanding data during the 2009/2010 epsilon Aur eclipse. A fade of R CrB commenced in 2007 and two years later VSS observers were reporting it to be at a record low level of magnitude 15.0. The first CCD observations were reported in 2003 and by 2008 they had exceeded the quantity of visual observations reported annually. In 2010 there were 30,000 visual and 90,000 CCD observations reported. David Boyd was the leading observer during this period and became the first VSS member to record 100,000 CCD observations by 2009. Other observers reaching milestones during this period were Toone, 100,000 visual observations in 2002; Poyner, 200,000 visual observations in 2007; Tony Markham, 100,000 visual observations in 2008 (all non-telescopic); and Ian Miller, 100,000 CCD observations in 2010. Pickard introduced the "Charles Butterworth Award" for outstanding achievements in variable star research and the first recipients were Arne Henden in 2006 and Gary Poyner in 2008 (Mike Simonsen was the third recipient in 2011).

13. 2011 and future plans

By the end of 2010 the VSS database contained 1,700,000 visual and 340,000 CCD observations undertaken by over 900 observers. A number (perhaps 300,000) of legacy visual observations and all the photoelectric photometry had still to be input and it was planned that the database itself would be accessible online from 2012. It was also planned to introduce online data submission and link the database to the AAVSO International Database in 2013 or 2014. The VSS database has a unique ability to update the data to the current sequences which means that any analyst can be confident about the homogeneity of the data. The sequences themselves are being progressively converted to the V system with a limited color range which aligns with the work of the AAVSO sequence team. In the long term the feasibility of adjusting the legacy visual data to the V system will be investigated. By October 2011 seven members of the UK Supernovae Patrol team had found 244 supernovae as well as four novae in M31. The primary internal publication remains the VSS *Circular* which is issued quarterly and covers news items and preliminary reports, but the formal refereed VSS papers and annual report are published in the *JBAA*. The Director is supported by a panel of eight officers who are all experienced amateur variable star observers and also by volunteers who assist in data inputting. The Director and officers meet regularly to ensure the smooth running of the section and members' meetings are held annually. The VSS is recognized as the most active and scientifically important of the sections within the BAA. The VSS continues to encourage undertaking all methods of photometry and considers that a national group still has a role to play in promoting the acquisition of systematic data on variable stars.

14. Summary

The BAA VSS was launched in the 19th Century and was the prototype body that set the standard for the variable star organizations that were to be formed in the 20th Century. It was never global in scale but has a long and eventful history which has been summarily recounted in this paper. Today it embraces new technology and techniques for photometric data acquisition whilst at the same time retaining its Victorian standards and values. It is as active in the 21st Century as it has ever been and fully expects to celebrate its bicentenary in 2090.

Figure 1. Ernest Elliot Markwick (1853–1925). Director of the BAA VSS 1900–1909 and president of the BAA 1912–1914.

Figure 2. Felix de Roy (1883–1942; in dark suit, right-center). Director of the BAA VSS 1922–1939. On de Roy's right is AAVSO Recorder Leon Campbell, and on Campbell's right is HCO astronomer Donald Menzel. Photographed at the 1932 IAU meeting, Cambridge, Massachusetts. Courtesy Jet Katgert, Leiden University.

Figure 3. Officers of BAA VSS at the centenary meeting of the VSS, October 19–20, 1991. From left are: John Toone, Roger Pickard, John Isles, Melvyn Taylor, Guy Hurst, and Storm Dunlop.

Figure 4. Officers of the BAA VSS, November 5, 2005, with AAVSO Director Arne Henden attending. Clockwise around table, from left: Gary Poyner, Arne Henden, Karen Holland, John Saxton, David Boyd, Andrew Wilson, Roger Pickard, John Toone, Tony Markham, Richard Miles, Guy Hurst, and Melvyn Taylor.

The "Werkgroep Veranderlijke Sterren" of Belgium

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Presented at the 100th Annual Meeting of the AAVSO, October 5, 2011; received October 11, 2011; accepted November 29, 2011

Abstract The "Werkgroep Veranderlijke Sterren" (Working Group on Variable Stars) of the Belgian "Vereniging Voor Sterrenkunde" (Society for Astronomy) was founded in 1969. The group and its individual members have been among the pioneers in several areas of amateur variable star astronomy: CV alert bulletin boards and telegrams, CCD observing, automatic handling of observations and online availability of the data, collaboration with professional astronomers, telescope automation, remote observing, and data-mining. Realizing the importance of international collaboration for a small group, there has always been a close contact with other variable star organisations. As a result also the first European meeting of the AAVSO was hosted in Brussels in 1990.

1. **Introduction**

Although observations of variable stars were made by professional astronomers at the Royal Observatory in Uccle in the 19th and early 20th century, variable star astronomy in Belgium really started with Felix de Roy (1883–1942). Although living in Antwerp, he was Director of the Variable Star Section of the British Astronomical Association for seventeen years. A recent account of his life has been given by Shears (2010). After his death, however, no variable star observations seem to have been done until the early 1960s.

The population of Belgium is divided in two major language groups, a French speaking part in the South and a Dutch speaking part in the North. After the Second World War, most cultural (and scientific) associations split into two separate entities, and new associations were formed directed to one specific language only. Not surprisingly, the same was true for the astronomical associations in general and specifically also for the variable star groups. The French speaking observers joined the Groupe Européen d'Observation Stellaire (GEOS; http://geos.webs.upv.es/) together with observers from France, Spain, Italy, and Switzerland. This paper describes the history of the Werkgroep Veranderlijke Sterren (WVS; Working Group on Variable Stars) of the

Vereniging voor Sterrenkunde (VVS; Association for Astronomy) in Flanders, the Dutch speaking Northern part of Belgium.

2. Foundation of the Werkgroep

Interest in astronomy started to grow during the 20th century. The VVS, an astronomical association for both professional and amateur astronomers, was founded in 1944. Currently there are about 2000 members. In the 1960s more and more amateur astronomers joined. Because of the increasing availability of telescopes, many self-built, interest in observing also started to rise. Among them was an avid amateur, Frans Van Loo, who observed variable stars in cooperation with the Dutch Variable Star Section. The latter was founded in 1960, ironically after Georg Comello, one of the founders, had been observing variable stars in cooperation with a professional astronomer of the Royal Observatory in Belgium. The Belgian celestial mechanics expert Jean Meeus, a prominent member of the VVS, was also a co-founder of the Dutch Variable Star Section.

To foster the local amateur astronomers' interests in scientifically valuable observations, the VVS decided to start a number of working groups in 1969, dedicated to observing meteors, planets, artificial satellites, lunar occultations, the Sun, and variable stars, the latter with Frans as the working leader.

3. The early years

Only a few observers submitted observations in the first years, until a project on observing the naked-eye eclipsing binary Algol was started in 1975. This raised the interest of a number of young people, some of them still active at this moment. As a result in 1977 twenty observers contributed some 17,000 visual observations, a first top year. Although most of the following years the number of observers stayed between fifteen and thrty (with many new observers and other ones retiring) the total number of observations declined. In those years most of the observations were of Mira stars.

4. Years of growth

Being a small group it was soon realized also that significant results could only be obtained through international collaboration. From the early years most observations were therefore sent to the AAVSO. Intensive contacts with the AAVSO lead to the organization of the first European meeting of the AAVSO in Brussels in July 1990 (Mattei 1990).

In the early 1990s, the interest in cataclysmic variables started to increase. At the same time bulletin boards and email became more common in use. This led to many opportunities and a series of Cataclysmic Variable Circulars were published between 1994 and 1998 by Paul Van Cauteren and Tonny Vanmunster (from 1996 onwards only by Tonny) to alert an international group of observers to rare dwarf novae outbursts. The yearly number of observations increased as well, reaching 35,000 in 2003.

Almost from the very beginning when micro-computers appeared on the market, it was realized that the data gathered by the Werkgroep needed to be available electronically. At first the data were keyed in from paper forms by a few volunteers, but when the internet and email became available, soon a procedure was established to enter the data into the database observations in almost real time. An online light curve generator was created, so that observers could easily see the results of their observational work. This also resulted in a book with thirty-year light curves of variable stars (Broens *et al.* 2001). Analyzing the data (and data-mining other publicly available data) has also become an important aspect of variable star astronomy.

As soon as CCDs became available to amateurs, members of the Werkgroep started to use them to observe variable stars. Most notably Tonny Vanmunster became an early and active collaborator of the Center for Backyard Astrophysics (Vanmunster 1997). Paul Van Cauteren worked with a number of professional astronomers on short-period pulsating stars. These early contacts opened the path for other members and further projects. Some of the observers have gained a lot of experience in automating their observatories, and in using remote telescopes.

5. Recent years

The Werkgroep Veranderlijke Sterren continues its activities. As in other groups the number of visual observers and observations is diminishing (with pioneer Frans Van Loo still among the most active observers), and interest is shifted more and more to CCD observing. A project to observe High Amplitude δ Scuti stars (HADS) has been initiated (Wils *et al.* 2009). This project serves several aspects. Besides the scientific goal to detect period changes and multi-periodic pulsations in these stars, it proves to be a useful project to stimulate collaboration, exchange experiences, and help new CCD observers with their first attempts in the CCD world.

Personal contact is still an important aspect, so that in addition to other more general meetings organized by the VVS, twice a year a meeting is held by the Werkgroep, of which at least one is together with the Dutch Variable Star Section; the location alternates between Belgium and the Netherlands.

6. Summary of observations

During the forty years of the Werkgroep's history some 440,000 visual observations have been amassed and about an equal number of CCD observations (an exact tally is not kept) have been done by its members.

The most active visual observers have been Eddy Muyllaert (110,000 observations), Alfons Diepvens (82,000), Johan Van Der Looy (47,000), and Frans Van Loo, Tonny Vanmunster, and Hubert Hautecler (30,000). Mira stars and dwarf novae are the types that are mostly observed (see Figure 1). The top targets are SS Cyg (10,000 observarions), R CrB (7000), Z Cam (5000), and the symbiotic variables AG Dra and CH Cyg (4500).

The most prolific CCD observers are Josch Hambsch, Tonny Vanmunster, and Paul Van Cauteren, but many others are following in their footsteps. Almost all of the CCD observers do time-series work on cataclysmic variables, eclipsing binaries, and RR Lyrae and δ Scuti stars.

7. Conclusion

The Werkgroep Veranderlijke Sterren has been a very active group in many aspects of variable star astronomy. Being a small group, a lot of attention has been and is being given to international collaboration. Working on small projects to which many members can contribute has been shown to be fruitful to the group, as it encourages contacts and enhances activities.

Further details can be found at the website of the group: http://www.vvs.be/wg/wvs/.

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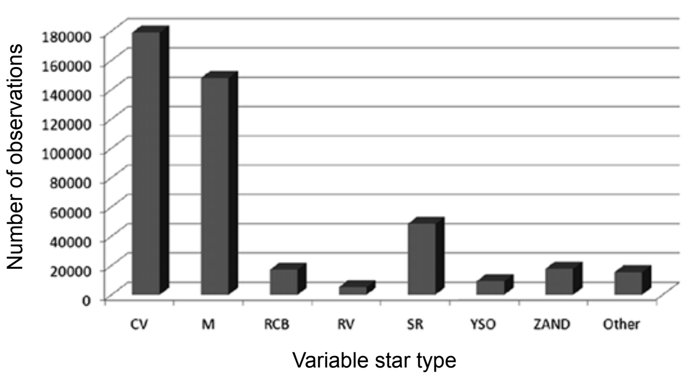

Figure 1. Distribution of WVS visual observations by variability type.

The RASNZ Variable Star Section and Variable Stars South

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Presented at the 100th Annual Meeting of the AAVSO, October 7, 2011; received December 5, 2011; accepted December 9, 2011

Abstract The Variable Star Section of the Royal Astronomical Society of New Zealand (RASNZ-VSS) began in 1927 and has now been revived in the shape of Variable Stars South. This review introduces Variable Stars South (VSS), then continues by outlining some of the history of the RASNZ-VSS, discusses the more worthwhile achievements of the old RASNZ-VSS, and mentions some of the observers and others who contributed to those successes.

1. Introduction

Let's look a little at Variable Stars South (VSS) as it is in 2011 before beginning a review of the Royal Astronomical Society of New Zealand Variable Star Section (RASNZ-VSS) which it has rejuvenated—but in a rather different manner. History is most useful when it allows looking at other people's actions and providing an insight into what best to do in the future. Whilst the old Variable Star Section did very good work in producing charts, encouraging measures from members, and publishing these, it was weak in the area of communications with members at times by not making them feel an important part of the organisation. In spite of this it achieved outstanding results in variable star astronomy in the Southern Hemisphere. But we'd like to make variable star astronomy even more rewarding and enjoyable in the twenty-first century.

At New Plymouth in 2006 Pauline Loader, the acting coordinator of the old Section, convened a meeting to discuss what could be done about reviving variable star observing in this part of the world. We concluded that all observational material should be held in one area, in this case the International Database maintained by the AAVSO, and that the best role for a southern group would be to stimulate observations. The methods of achieving this were not clear at the time although a variety of ideas were discussed and thought about for the next couple of years.

Variable Stars South began early in 2009 when Thomas Richards offered his services as Director of a revived group to the parent body, the Royal Astronomical Society of New Zealand. He proposed that it should be largely a project-oriented organization with the emphasis upon astrophysics in that any projects entered into be designed to find and publish information about stars—not merely accumulate large numbers of measures of random targets. Variable Stars South furnishes reports of activities to the RASNZ each year but apart from that operates independently.

As well, information and communications with members and others is a vital part of the operation. Richards had set up the Austral Variable Star Observer Network (AVSON) website a few years previous to his appointment and at this moment the Variable Stars South website (www.variablestarssouth.org) offers information on projects and techniques and is being added to frequently. VSS also publishes a quarterly Newsletter.

Observations are the lifeblood of a variable star group. This is what it's all about. Our projects encourage these. Once analysed all observations become part of the AAVSO International Database (AID) and are available to a wide range of astronomers. In the short time we've been operating some papers have been published and several others are in progress.

The group is still feeling its way. Initially coordinators were set up in several areas—visual observing, long period variables (LPVs) (later changed to pulsating variables), cataclysmic variables, eclipsing binaries—but this proved unnecessarily complex. It now tends to operate on the basis of setting up groups when there is a demand, such as SPADES for eclipsing binaries, bright Cepheids which has partially evolved into a DSLR group, a recent eclipse of BL Telescopii and similar ideas which can be seen on the website.

2. Back to the beginning

New Zealand was a much different place in 1927. About one and a half million people were scattered over 103,000 square miles, with most living in the four main cities. Roads were poor and most travel was along the main railway which had a few branch lines. Coastal shipping was strong. There were few telephones but the mail service was good. Australia was a week away by boat, although the first crossing of the Tasman Sea by air in 1928 was not far away in time!

In this environment a young Frank Bateson persuaded the Royal Astronomical Society of New Zealand to allow him to set up a variable star observing section. Few people were much interested in astronomy—but Ron McIntosh in Auckland was looking at Jupiter and the Moon, Charles Michie of Kaitaia was observing the Sun with some special equipment, and Ivan Thomsen was later to direct the Carter Observatory.

3. Early progress

The first circular appeared on July 27, 1928, and listed nineteen variable star targets. On September 12, 1928, a further twenty stars were listed in response to observers' requests. A review of the group appeared in 1944 when the first *Memoir* was published. This mentioned a total of 35,379 observations from 1927 to 1940. From then on circulars listing the observations appeared at intervals. By the time of the Golden Jubilee in 1977 almost a million measures had been made by more than 400 observers.

Apart from Bateson another prolific early observer was Gordon Smith who contributed 15,827 of the measures quoted above. He was encouraged by an article of Alec Crust's (who wrote many articles about variable stars) in the *Dunedin Star* and made his first observation in September 1929. When observing became difficult in 1973 for health reasons he took over the recording until it became computerized in 1987.

On January 18, 1943, a new era began. Albert Jones (Figure 1) made his first measure of Nova Puppis 1942, after reading an article published in *Southern Stars* by Crust. Later Albert became interested in dwarf novae and prepared a chart for VW Hydri. Intrigued by its behavior, he checked out stars from Hoffmeister's list of suspected dwarf novae and observed Z Cha, EK TrA, and a few others. In the 1950s and early 1960s Jones' measures usually provided between 25% and 70% of the recorded observations. Later the contributions became more balanced.

One very good feature involved circulars relating to specific stars. Often these were merely summaries of observations for stars such as novae, but a few dealt with periods and changes in these and tried to understand why these happened. Simple stuff by today's standards but then today's range of detection and computing equipment, and the understanding of stellar evolution, didn't then exist. But it made people think a little about what they were observing.

4. The chart project

Charts and comparison stars have always been a problem to observers. In the south, star photographs of any type were scarce. Thus many of the Section's first published charts came from work by Jones—both in sketches of the area and sequences.

The upsurge in the 1960s saw a demand for more than the original published set of twelve stars. Bateson secured a grant from the International Astronomical Union (IAU) to produce charts of all variables brighter than a certain magnitude and south of 30 degrees south. This was to be self-funding so charts were sold to members in sets of fifty. Well over a thousand charts were produced in this manner. Comparisons were a problem as published values could differ up to half a magnitude dependent upon the source.

Jones, Ian Stranson, and Bateson began the chart task but later Mati Morel took over most of the work (Figure 2). Robert Winnet and Bruce Sumner also helped with many charts. Barry Menzies and Peter Gordon led the sequence-determining team at Auckland Observatory and produced many sequences in V, with B–V colors available. Pamela Kilmartin and Alan Gilmore also measured some sequences from Mt. John and occasionally professionals like Nicholas

Vogt or Brian Warner produced a sequence for a star of particular interest like EX Hydrae, an intermediate polar.

5. A decade of growth

The years 1966 to 1976 saw a dramatic change in the local variable star scene. One main catalyst to this was the opening of the Mt. John Observatory in 1965, which led to considerable interest in the Christchurch area. The Auckland Observatory also opened in 1967 and a strong variable star group was associated with this.

The Christchurch amateur group, led by Clive Rowe, decided to emulate Mt. John with photoelectric equipment—but of a more current design—which had interesting results which are described in another paper at this Centennial (see http://www.variablestarssouth.org/index-php/member-publications/posters/149-aavso-centennial-conference-poster-paper-rasnz-photometry-section).

On the visual scene the Auckland group was strong. Charts were obtained from Bateson, some meetings were held to discuss results, and about fifteen to twenty people, later more, began observing. Coincidentally, around this time Nova Delphini 1967 (HR Del) appeared and at third magnitude for some months it created considerable interest.

Discussions with Bateson continued at intervals and many Auckland observers, as well as observing LPVs, developed an interest in Cataclysmic Variables, a relatively new field where they were to make some useful contributions for many years.

Most of these new observers were members of the RASNZ and attended the Annual Conferences where informal discussions about variable star observing, both photoelectric and visual, attracted many amateurs in other areas of New Zealand. Many observers developed an interest in CVs using charts based upon Jones' work. Developments along similar lines took place in Australia.

6. IAU Colloquium 46

This colloquium celebrated fifty years of the RASNZ Variable Star Section. It was held in Hamilton from November 27 to December 1, 1978, and attracted eighty-one participants.

There were many well-known names: David Allen, M. K. V. Bappu (then IAU President), Barnes, Fabian, Feast, Gascoigne, Kron, and Keenan, Robinson and Schoembs; Shobbrook, Slee, Whelan, and Warner, who were all to help the Auckland Observatory; Smak, Sterken, Vogt, and Wood were others.

A small contingent of AAVSO people was also there: Clint Ford, Dorrit Hoffleit, Tom Cragg, and Danie Overbeek.

The Variable Star Section was well represented with Brian Marino, Stan Walker, Frank Bateson, Albert Jones, Arthur Page, John Beuning, Graham

Blow, Harold Kennedy, Bill Allen, and Mervyn Thomas all presenting papers or collaborating in them. But there were many other members there. A most enjoyable and informative gathering.

The first sessions related to Cataclysmic Variables were highlighted by a review by Brian Warner. Many of the astronomers mentioned above were working in this field and it was particularly interesting. At that time new discoveries were being made frequently, new observing techniques used, and the whole area was exciting and stimulating. Flare stars at that time came under this heading but they're a different type of object physically.

From there the timescale changed dramatically to red variables—Miras, LPVs, R CrBs and similar. These sessions were perhaps noteworthy for a north/south clash over pulsation modes in Miras and some interesting discussions. Cepheids also featured prominently.

Relatively high-speed variables of assorted types were discussed; modern photoelectric techniques had already produced a considerable amount of new observational material. Even eclipsing binaries were not overlooked. And, to follow up an earlier section of this paper, Clinton Ford outlined the then present work on AAVSO charts.

In all, sixty separate papers were presented and included in the proceedings: *Changing Trends in Variable Star Research* (1979), edited by F. M. Bateson, J. Smak, and I. Urch.

7. After the colloquium

The next few years were some of the most productive for New Zealand astronomy. The original photoeletric conference, PEP1, was held at Carter Observatory in 1976 and was followed by PEP2 in 1982 in Auckland, the Small Telescope Symposium in 1985 in Christchurch, as well as some easily accessible meetings in Eastern Australia, and PEP3 in Blenheim. The University of Canterbury set about building a 1-meter telescope for Mt. John Observatory and improving their spectrographic equipment.

The Carter Observatory set up the Black Birch outstation and transferred the Ruth Chrisp telescope to that site. The Auckland University became strongly involved with developing high-speed photoelectric equipment for use at Auckland Observatory and the other two major sites, Black Birch and Mt. John. The U.S. Naval Observatory also set up an outstation for a five-year project at Black Birch.

The Colloquium had been attended by many local variable star observers and the enthusiasm was contagious. Numbers of observations increased and Bateson's encouragement of observers to write articles for the *Communications* strengthened the astrophysical aspect of observer's ways of thinking. Now we not only observed the changes in brightness but thought more about why these were happening and modified the techniques to provide more and better information about the target stars.

8. The photoelectric separation

It was gradually becoming clear to the photoelectric observers that their presence in the Variable Star Section was a little awkward, perhaps unwanted. The Director did not understand what the capabilities of filtered photoelectric photometry were and tended to strongly favor the visual observers to the extent of failing to pass on PEP measures to researchers.

This led to the setting up of the Photometry Section of the RASNZ based upon the Auckland Photoelectric Observers' Group (APOG). The Photometry Section had considerable support from many astronomers. But it should have been an integral part of the RASNZ-VSS which would then have kept up more closely with technological developments. In retrospect the decline and almost disappearance of the VSS would not have occurred if Bateson had not forced this separation. The AAVSO has avoided this mistake, treating all observers and methods of observing as equally important.

9. Clouds on the horizon

The continued pressure of directing the Section began to affect Bateson's health in the 1980s. As well, his eyesight was failing. Whilst Ranald McIntosh, Albert Jones, and Mati Morel were assuming many of the responsibilities none of the other variable star observers wanted to lead the group unless Bateson would partially stand aside and allow a more member-interactive structure.

On the positive side McIntosh set up a computerised database in 1984 and began by loading data from monthly paper summaries by observers. By 1989 many observers were sending the data by mail on a disc each month. As well, Don Brunt of Murupara digitized over half a million observations from the archived records. These were included in the database and ultimately included in the AAVSO International Database.

Operation of the Section demanded time and space. Various ideas to resolve these problems were explored. To provide room at Headquarters much of the old literature on variable stars was sent to the Auckland Observatory. But publication of the *Communications* became very sporadic and offers by Gordon Herdman and Grant Christie to edit these were declined. Effectively the Section in the 1990s was operated by Jones, Morel, and McIntosh.

But even in these latter years useful research was done in collaboration with others. Karen Pollard from the University of Canterbury spent some time at "Headquarters" studying the records of R CrB and RV Tauri stars, and an analysis of eighty-eight Mira stars to explore what appeared to be period changes but which were actually alternations of periods was presented by Peter Cottrell (1998)—coauthors, Jones, Bateson, and Walker—at the IAU General Assembly in 1997. Peter Williams, McIntosh, and Morel contributed articles for the *Communications*.

In 1989 Bateson attended one of the very popular PEP Conferences, PEP3 at Blenheim. At this event several speakers paid tribute to his work and the very profitable relationship between the visual observers and photoelectric photometry. This meeting effectively was his retirement although in the absence of a formal notification the Section continued under his direction, although not effectively and many observers were lost. Fortunately many continued to observe and submitted their measures directly to the AAVSO.

10. A final meeting of the old variable star section

In 2004 the RASNZ sponsored a meeting to celebrate Bateson's eighty years in astronomy. Many observers, friends, and family attended as did Brian Warner (Figure 3). Papers from this meeting were published in *Southern Stars* (Vol. 44, No. 1) in 2005. At this meeting Bateson announced his retirement, thus clearing the way for a much anticipated revival of the Section.

11. The revival in the new century

The continued operation of the Section in the 1990s can be attributed to the dedication of three people: Albert Jones, Mati Morel, and Ranald McIntosh, with support from the Director's secretary, Maureen Phizacklea.

Whilst Jones had achieved the 100,000 visual observations target many years before (and has since passed the 500,000 visual mark) about this time two Australian observers, Rod Stubbings (Figure 4) and Peter Williams (Figure 5), also achieved this milestone, making three members of a rather select group from the Section.

After the 2004 meeting Pauline Loader, Secretary of the RASNZ, assumed the role of coordinator. Some circulars were published and requests from researchers placed on the RASNZ website but it was not until Conference 2006 (where AAVSO Director Arne Henden was a welcome visitor) that any formal attempt was made to seek a way forward.

In mid-2008 Walker offered to oversee the publication of a quarterly newsletter for the next two years and the first of these appeared in November of that year.

Shortly thereafter Tom Richards discussed with Pauline Loader and interested others the possibility of him assuming the role of Director in a new organization, Variable Stars South, operated in a more friendly and project-oriented manner than the old RASNZ VSS. Richards was appointed in early 2009 and we were under way again!

12. What did the RASNZ VSS achieve?

We should conclude by looking at what the Section achieved. In simple terms it added about 1.5 million visual observations of variable stars to the AAVSO International Database, produced charts for about 2,000 southern variables, and put together good comparison star sequences for many of these. Numbers are hard to be certain about as many observations were made of stars not on the Section's official listing and other observers, mainly Tom Cragg and Danie Overbeek of the AAVSO, supplied both the RASNZ-VSS and the AAVSO with measures. Some members of the BAA did the same.

Most importantly, it persuaded many people that good science could be carried out with a small telescope and simple equipment. It provided a sense of belonging to a group with a worthwhile purpose—not just celestial sightseeing.

It also created a situation where observers were encouraged to do more than just observe: it challenged them to find out what the observations meant and to understand what the stars were doing and why. As well, in offering research projects which needed more than visual measures, it saw the adoption of techniques such as photography and, more importantly, UBV photometry. But it was not really involved in CCD photometry. Many of the PEP people inspired by the old Variable Star Section now support the Center for Backyard Astrophysics (CBA) and other specialized groups such as those for Gamma-Ray Bursters (GRBs) and microlens searches for planets.

Many of the visual observers collaborated in projects, both in New Zealand and overseas, often supplying information about what various southern stars were doing at the moment. This was very helpful in the early days of CV observing when almost everything about them was new and little observed. However, the longer period stars received their share of attention as well.

The 1978 Colloquium introduced many amateurs in New Zealand and Australia to professionals either using their observations or looking at the same stars with similar equipment and, in its way, led to the successful PEP conferences. These are discussed in a separate poster paper which is essential to understanding the amateur variable star scene in our part of the world.

The authors and Tom Richards are pleased, as are many others, to have been part of the local variable star scene and look forward to even better things in the future.

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Figure 1. Albert Jones, the Section's most prolific observer, with more than 500,000 visual observations to his credit, relaxing in his office. Courtesy John-Paul Pochin.

Figure 2. Frank Bateson with Mati Morel, who produced most of the charts, and Peter Williams, with more than 100,000 visual observations to his credit.

Figure 3. Frank Bateson's farewell conference celebrating his eighty years of astronomy. Frank is seated center front with his daughter Audrey. To Audrey's right are Carolyn and Albert Jones, John Toone representing the BAA, and Interim Director Elizabeth Waagen representing the AAVSO; at the other end of the row is Brian Loader, RASNZ President, and Brian Warner, University of Cape Town. Tauranga, New Zealand, December 4, 2004.

Figure 4. Another prolific observer, Rod Stubbings, who now has made over 200,000 visual observations.

Figure 5. Peter Williams, who has passed the 100,000 visual observations mark.

The RASNZ Photometry Section, Incorporating the Auckland Photoelectric Observers' Group *(Poster abstract)*

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Presented at the 100th Annual Meeting of the AAVSO, October 8, 2011

Abstract This review traces the development of amateur photoelectric and CCD photometry in New Zealand from its beginnings in the late 1960s at Christchurch and Auckland, through the Auckland Photoelectric Observers' Group and the RASNZ Photometry Section to its present place in Variable Stars South. For this period of over forty years the participants have been heavily involved with southern hemisphere variable star astronomy and observatories such as Carter, Mt. John, and Auckland, together with which were sponsored the highly successful photoelectric conferences, PEP 1-5. Samples of various projects are shown and described. The full text can be seen at http://www.variablestarssouth.org/index.php/community/member-publications/posters

Introduction to BAV *(Abstract)*

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Presented at the 100th Annual Meeting of the AAVSO, October 5, 2011

Abstract The Bundesdeutsche Arbeitsgemeinschaft für Veränderliche Sterne was founded 1950 in Berlin. The intention was—and still is—to support amateurs in the systematic observation of variable stars. The history of the German workgroup, the classical working focus (maxima and minima and single estimates), and the main publications (*BAV Mitteilungen* and Lichtenknecker-Database of the BAV) will be described.

The GEOS Association of Variable Star Observers *(Abstract)*

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Abstract Groupe Européen d'Observation Stellaire (GEOS) is an astronomical association created in the 1970s to promote research among amateurs in Europe. We started in Belgium, France, and Italy, later extended to Spain, Switzerland, and Germany, and more recently, added U.S. amateurs. The basic idea was that amateurs should themselves extract scientific information from their observations (visually at first and later electronically) and publish their results. Some GEOS members have become professional astronomers and the amateur-professional collaboration has strengthened over the years. From the beginning, it has been clear that the study of variable stars is a privileged topic where such projects can develop. Since the 1980s GEOS members have published a number of scientific papers, even in refereed professional journals. Presently, observations are mainly done using CCD cameras though visual measurements still exist. In the past decade our main development has been the creation of a public RR Lyr star maxima database. This is a unique tool for the study of RR Lyr stars, as it enables the user to follow period variations since a star's discovery, some over 100 years ago. In parallel to the database, a project called "GEOS RR Lyr survey" was designed. Its aims include: first, add significantly more maxima timings of the brightest RR Lyr stars essentially using robotic telescopes; second, study fainter understudied stars to refine their period and find new stars which exhibit the so-called Blazhko effect; third, characterize the Blazhko effect, one of our main research topics. Other variable stars are also studied: eclipsing binaries, δ Scuti stars, and so on. GEOS has a good cooperation with other variable star associations, mainly BAV and AAVSO.

History of Amateur Variable Star Observations in Japan *(Poster abstract)*

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Presented at the 100th Annual Meeting of the AAVSO, October 8, 2011

Abstract Japan has about 100 years of history of variable star observing since Naozo Ichinohe, professional astronomer in Tokyo Observatory, observed δ Cep in 1906. The first amateur variable star observer is Yoshihiko Kasai, who began observing variable stars in 1918. I introduce a brief history of Japanese amateur variable star observation, including topics of variable star organizations, nova and supernova hunters, collaborations with the AAVSO and the world, PEP and CCD observations. I also introduce the most active variable star observer, Hiroaki Narumi, who made over 260,000 visual estimates since 1975. VSOLJ was established in 1987 in collaborations with the variable star sections of Nihon Tenmon Kenkyu-kai (NTK) and the Oriental Astronomical Association (OAA). VSOLJ maintains a database of Japanese variable star observations (http://vsolj.cetus-net.org) and publishes the *Variable Star Bulletin* in English.

History of AAVSO Observers, Programs, and Supporters

The Visual Era of the AAVSO Eclipsing Binary Program

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Presented at the 100th Annual Meeting of the AAVSO, October 5, 2011; received January 23, 2012; accepted January 23, 2012

Abstract The beginning of eclipsing binary minima timings by visual observers in North America is described, and the history of the AAVSO's Eclipsing Binary Committee during the era of visual observation is outlined, with particular attention to the observational programs, the production of charts and ephemerides, and the reduction and publication of the minima timings. During the period 1965–2005, AAVSO observers timed more than 17,000 minima, determined periods and light-curve types for neglected and newly discovered eclipsing binaries, and improved the light elements and corrected erroneous periods for many more.

1. Introduction

If Harvard College Observatory Director E. C. Pickering was the godfather of the AAVSO, Dr. Joseph Ashbrook, editor of *Sky & Telescope*, fulfilled that role for the AAVSO's eclipsing binary program. Before 1960, pioneer amateur photoelectric observers such as John Ruiz and Donald Engelkemeier timed a few minima of bright eclipsing binaries, but no visual observers in North America were timing minima. Indeed, visual observers were unaware that they could make a useful contribution in this field.

Pickering himself suggested adding Algol-type eclipsing variables to the AAVSO program as early as 1913, but William Tyler Olcott didn't think the more intensive observing required for such stars would appeal to observers, and AAVSO remained focused on the more leisurely long period variables. In 1951, AAVSO Recorder (Director) Margaret Mayall consulted with Ashbrook (Figure 1), then at Yale University, about the possibility of visual observers timing the minima of eclipsing binaries. Ashbrook had a longstanding interest in the subject, having observed β Lyr as far back as the 1930s. Ashbrook drafted a memorandum on how to observe these stars and noted that minima timings were "of sufficient importance to warrant such a program" (Williams and Saladyga 2011).

Nothing further was accomplished at that time, but in 1957 AAVSO member Jeremy Knowles authored an Observer's Page article in *Sky & Telescope*, "Another Look at Algol" (Knowles 1957). He noted that the period of Algol is variable and described the tracing paper method for determining an eclipsing binary's time of mid-eclipse. He also declared, "There is a broad field open to amateurs in the timing of minima of eclipsing variables." Visual estimates of an Algol minimum made by Ashbrook were used for illustration. Ashbrook now served on the magazine's editorial staff and was surely responsible for selecting this article for publication.

Ashbrook made a first attempt at stimulating visual minima timings with an Observer's Page article on U CrB in the April 1959 *Sky & Telescope*, including a chart, comparison sequence, and predictions of future minima (Ashbrook 1959). But U CrB is a difficult star with a long, slow minimum requiring a night-long vigil, and apparently no readers responded to this appeal.

In June 1960, astronomer Alan H. Batten authored a feature article in *Sky & Telescope*, "Why Observe Stellar Eclipses?" in which he noted the professional astronomer's need for EB observations (Batten 1960). In the same issue, Ashbrook tried again and published a Celestial Calendar article about the eclipsing binary SZ Her with a chart and minima predictions (Ashbrook 1960). A few months later he published a similar article on RZ Cas. Both of these stars have rapid, deep minima and can be observed effectively in only two or three hours. This time several readers responded. Ashbrook reduced the observations and published the resulting times of minima in later issues. The era of visual timings of EB minima had begun.

Over the next few years, Ashbrook introduced additional eclipsing binaries, such as X Tri, XZ And, and Y Leo, good targets for visual observation and known to exhibit period variations. By 1964, several observers were regularly reporting minima timings to *Sky & Telescope* and represented a growing community of interest.

The birth of the AAVSO Eclipsing Binary Committee had some parallels with the birth of the AAVSO. In 1912, William Tyler Olcott became section leader for variable stars in the new Society for Practical Astronomy (SPA) at the same time he was organizing the AAVSO. When Olcott resigned from his SPA position to devote himself to the AAVSO, most of the other section members followed him. In 1965, Illinois college student David B. Williams took the first steps to organize amateur eclipsing binary observers as part of a proposed National Association of Stellar Observers. This activity seems to have attracted the AAVSO's notice, because he soon received a letter from AAVSO Director Margaret Mayall, inviting him to chair an AAVSO Eclipsing Binary Committee. He and most of the other EB observers were already AAVSO members, so he immediately accepted.

Ashbrook, who was also named to the committee, prepared instructions for observers and, calling upon his vast knowledge of the literature, compiled a list of ninety-eight EBs that were suitable for visual observation and were known to have variable periods or other features of interest. Ashbrook's list became the "official program" and, with Williams providing predicted times of minima and charts, the AAVSO Eclipsing Binary Committee was off and running.

Williams (Figure 2) continued as chairman until 1969, when he was succeeded by the program's most active observer at the time, Marvin E. Baldwin, who continued to lead the EB Committee for almost forty years. Baldwin was succeeded in 2007 by Gerard Samolyk, who had served effectively as Baldwin's deputy on the committee for many years (Figure 3).

2. Observations

Unlike most of the variables in the traditional AAVSO program, for which a single estimate of brightness could be made at any time, an eclipsing binary required estimates made every 10 or 15 minutes, covering both the descending and ascending branches of the light curve, to determine the time of mid-eclipse. This meant a commitment of two to four hours (and sometimes more), depending on the rapidity of the light changes, so that at least 0.5 magnitude of variation was observed.

At first, the AAVSO EB program operated conventionally, with most observers timing minima of the recommended stars. But for some, this short list didn't satisfy their observing appetites. Baldwin was the first to start investigating non-program stars, identifying likely candidates in the catalogs, calculating predictions from the published light elements, and then trying to catch a minimum. His discovery that the eclipses of V342 Aql were arriving 2.5 hours early led to publication of a report in the *Information Bulletin on Variable Stars* (*IBVS*; Baldwin and Robinson 1965), the first of many papers to appear in *IBVS*, *JAAVSO*, and the weightier professional journals, all emanating from the AAVSO EB program and its growing corps of enthusiastic observers.

Within a few years, there were enough accumulated minima timings to begin tracking period variations. The first papers based on AAVSO visual timings reported improved light elements for sixteen stars that had drifted from their predicted times of minima (Baldwin 1973, 1974).

By the mid-1970s, the program usually involved fifteen to twenty active observers, who were reporting from 300–500 minima timings each year. The earlier solo efforts to investigate neglected EBs also evolved into several team efforts. The Puppis Project targeted more than a dozen EBs with unknown periods or types in that constellation. Observers were invited to monitor these stars on a continuous basis until enough minima were found to reveal the period and plot a complete phased light curve. One target of this project, MP Pup, was found to have the remarkably inconvenient period of 0.999 day (Baldwin *et al.*, 1994).

One very important but brief campaign involved θ^1 Orionis A in the Trapezium, a newly discovered EB with an announced period of 195 days.

Baldwin monitored this star and found it faint at a time that suggested the period might be only one-third of the published value. The next minimum based on this shorter period was predicted for August 23, 1976, and AAVSO observers were asked to examine θ^1 Orionis A low in the east at dawn. Two observers were favored with clear skies and horizons and found the star faint, confirming the shorter period (Baldwin 1977).

The Southern Project, to begin observing some of the sorely neglected EBs at far southern declinations, was launched in 1978. Jan Hers in South Africa prepared some charts, but this project never gained real momentum due to lack of dedicated southern observers. Finally, in 1994 Samolyk took direct action and, taking a portable telescope to Bolivia during a solar eclipse expedition, he timed half a dozen minima of far southern stars.

Newly discovered EBs provided many additional opportunities for cooperative observing campaigns. When nova hunter Dan Kaiser noticed the deep eclipse of the suspected variable NSV 3005 (now OW Gem) on his search photos, he alerted chairman Baldwin and the remainder of the 16-day minimum was documented (Kaiser *et al.* 1988). An examination of the Harvard patrol plates revealed the 1,259-day period (Kaiser 1988). Williams (1989) used photoelectric photometry to find the shallow, highly displaced secondary minimum. A successful campaign was organized to record the next observable primary eclipse (Hager 1996, Kaiser *et al.* 2002), and eventually AAVSO CCD observers provided a light curve that, combined with radial velocities, allowed professional investigators to determine the radii and masses of the component stars and the unusual evolutionary status of this remarkable binary system (Terrell *et al.* 2003).

Over the next several years, Kaiser continued to discover new EB stars brighter than tenth magnitude, and he was soon joined (and put out of business) by the ROTSE and Hipparcos satellites, which found dozens more, several with minima deep enough to be timed by careful visual observers. All these new discoveries led to the development of a conveyor-belt process of investigation: the visual observers monitored each star until the period could be determined, then the CCD observers compiled a complete light curve, and finally the professionals added radial velocities and performed the combined analysis, resulting in publication.

3. Charts

The first charts for eclipsing binaries with comparison star magnitudes were presented in *Sky & Telescope* in the articles introducing each star—small fields encompassing only the variable and its comparison sequence. AAVSO observers were accustomed to charts of various scales to assist in finding as well as observing variables. So in 1965, chairman Williams began drafting and distributing charts that showed each field on a broader scale, similar to the "a" scale charts with which AAVSO observers were familiar, with an inset box identifying the variable and its comparison sequence.

A few new stars were added to the chart list using the resources then available. Some EBs were already identified on existing AAVSO charts—RT And, for example, with a good comparison sequence for nearby RZ And. V346 Aql and SS Lib were also plotted on existing AAVSO charts for other variables. Z Dra was located and charted using the Franklin-Adams photographic atlas accessed at a professional observatory. To provide visual comparison star sequences for these stars, Williams used the classical "step" method to estimate the brightness differences of selected comparison stars; then the variable's published visual magnitudes at maximum and minimum provided two calibration points on the step scale that could be used to convert the step values to magnitudes.

Baldwin began to identify many additional EBs and create his own sketch charts by using published light elements to calculate times of minima, then monitoring the stars nearest the variable's position until one of them dimmed into eclipse. Having identified the variable, he then chose suitable comparison stars differing by approximately 0.5 magnitude and assigned them arbitrary values of 10, 20, 30, and so forth. This "modified" step method was rough but adequate for timing minima, since the only requirement was that the light curve be symmetrical.

When observer David Florkowski enrolled in the astronomy program at the University of Florida, a center for EB research, he was able to exploit the library and find identification charts for many EBs. Finally, with the advent of the Vehrenberg photographic *Atlas Stellarum*, the persistent chart problem could be solved in a comprehensive manner. Ed Halbach and his team at the Milwaukee Astronomical Society made enlargements of EB fields from the Vehrenberg atlas and produced 380 charts in AAVSO format (mostly "d" scale). Gary Wedemayer performed extensive library research at the University of Wisconsin-Madison to identify many EBs for this project. These charts served the program well for a quarter of a century, until in 2002 the AAVSO's computerized chart-plotting program began to generate standard charts.

Chart distribution was a less creative but no less vital task. Williams distributed charts from 1965–1967; Leonard Kalish 1967–1973 (he copied and distributed 21,000 charts during his term of service); Gary Wedemayer during the 1974–1980 interval; and finally Gerard Samolyk from 1981 until standard charts became available from AAVSO headquarters at the end of the visual era.

4. Ephemerides

Along with charts, the essential ingredient in the growth of the AAVSO EB program was the provision of predictions of future minima of target stars. Without predicted times of minima, observers could not know when to give their attention to an EB and obtain the needed run of estimates covering both branches of the eclipse light curve. Each observer could, of course, make these calculations for himself, but to do so for a large number of stars was neither appealing nor practical.

The first ephemerides were published in *Sky & Telescope* for the stars introduced in its pages. But these occasional listings included only one, two, or three stars, so on many nights there were no observable minima. As the number of charted stars increased, Williams was able to address this need by preparing and distributing a monthly table of predictions. In those pre-computer days, he used a desktop adding machine, beginning with the JD day and decimal of a known time of minimum for each star and simply adding its period value over and over again, then selecting the minima observable from North America and converting the JD days and decimals into calendar dates and UT times.

Fortunately, this formidable monthly chore was soon eliminated when the Computer Age dawned early for the AAVSO EB program. Observer Don Livingston had access to a computer at his place of employment. (Readers born after 1965 need to realize that in those days, computers were the size of automobiles and were possessed only by a few universities and large commercial enterprises.) He was able to program this machine to generate monthly tables of predicted minima almost instantly for any number of stars, and a major obstruction to the continued growth of the EB program was eliminated.

Livingston provided this vital service from 1967 to 1979. He was succeeded by Peter Taylor, 1980–1983, Paul Sventek 1984–1985, and Gerard Samolyk from 1986 through the remainder of the visual era (and continuing in the CCD era). Eventually, printed ephemerides were supplemented by more flexible, Web-based services, such as Shawn Dvorak's Eclipsing Binary Ephemeris Generator (www.rollinghillsobs.org), which can include an unlimited number of stars, select those that are visible during dark hours from each observer's location, indicate the orbital phase of each system at any particular time, and provide links to additional information.

5. Reduction and publication

One spur to the success of the AAVSO EB program was the publication of minima timings with the identity of the observer attached to each timing. This provided much more recognition than the traditional AAVSO observing program (a need now met by the Quick Look page and Light Curve Generator on the AAVSO Web site for all reported observations).

The reduction and publication of times of minima were initially handled by Ashbrook at *Sky & Telescope* until 1965, when he passed this responsibility to assistant editor Leif J. Robinson. The lists of minima timings were now too long for publication in *Sky & Telescope*, so Robinson began submitting lists to the *IBVS*. When *Sky & Telescope* withdrew from the EB program in 1969, chairman Baldwin assumed responsibility for both reduction and publication of data. He continued to publish the results in *IBVS* until that publication ceased to accept papers based on visual observations in 1973. Baldwin then shifted publication to the new *JAAVSO*, 1974–1978. Then from 1993–2007, Baldwin and Samolyk prepared a series of twelve monographs, *Observed Minima Timings of Eclipsing Binaries*. Each of the first eleven monographs included new times of minima for fifty stars. Each star's new timings were presented on a separate page, which included an O–C diagram showing all the accumulated timings plotted against a constant period, so readers could see each star's period variations at a glance. The final monograph included all remaining unpublished times of minima.

At first, and for many years, the classic tracing paper method was used to determine the times of mid-eclipse. This involved plotting the observations, tracing the plot on transparent paper, then flipping the tracing and moving it left and right over the original plot to find the position of best fit between the original and the reversed light curves. This simple graphical procedure is surprisingly effective but required an enormous investment of time to plot the thousands of estimates for hundreds of minima each year. Calculating the heliocentric correction for each timing was an additional burden, which was partly ameliorated by preparing graphs of the heliocentric corrections for each of the most commonly observed stars. The correction could be read off the graph for any day of the year without having to enter the long formula into a scientific calculator (with the potential for input errors).

After 1975, the flood of observations created a growing backlog of minima timings. Finally, in 1986, with the assistance of Ron Baldwin, the chairman's son, and Samolyk, the tracing paper procedure was computerized with a program running on an Apple II. After the times and estimates were entered and verified, the program read a sequential file of observations with each light curve separated by a delimiter. The program displayed the first light curve on the screen with a mirror image. The operator moved the mirror image back and forth using the arrow keys until the best fit was found. Hitting "enter" produced the time of minimum with heliocentric correction, saved that result to a file, and displayed the next light curve. Thanks to this program, a large number of light curves could be reduced in a single session.

6. The visual era ends

During most years of the visual era, one or two photoelectric observers submitted a very few high-precision minima timings. But the arduous nature of the observing procedures meant that PEP could never compete with visual timings in quantity, and most PEP observers were limited to stars brighter than about eighth magnitude. Then in 1994, Gilbert Lubcke submitted the first minimum timing derived from CCD observations. Five years later, ten CCD observers were contributing timings.

Image-based CCD photometry was much more efficient than PEP because the variable and comparison stars were recorded simultaneously and a new image could be taken and downloaded every few minutes. CCD images also recorded much fainter stars than could be reached by PEP with the same aperture. CCD timings could equal the precision of PEP timings if all the correct procedures were followed. The final step to victory for CCD cameras in the timing of EB minima was the advent of computer-controlled telescopes, which could acquire a field, take a prescribed number of timed images, then move to another field with little or no intervention by a human operator.

In 2002, twenty percent of the entries in *Observed Minima Timings of Eclipsing Binaries #7* were derived from CCD photometry. A year later, thirty-three percent of the timings in *Observed Minima Timings #8* were CCD. In 2004, the CCD timings in *Observed Minima Timings #9* still represented only a fraction of the total, but the minima lists for forty-eight of the fifty stars included CCD timings. This was the tipping point. When visual timings were the only data available, they were invaluable. But when CCD timings were also available, researchers would ignore the visual timings because the CCD timings were ten to one-hundred times more accurate. By 2005, automated telescopes with CCD cameras were providing at least one CCD timing (and often more) for almost every EB within reach of visual observers, and the visual era of the AAVSO program had reached its terminus.

The visual era of the AAVSO eclipsing binary program was highly productive. More than 17,000 times of minima were observed and published, and a continuous record of the period variations of hundreds of EBs was compiled. Periods and light-curve types were found for many new or unstudied EBs, and erroneous periods were corrected. Many amateur astronomers enjoyed the opportunity to contribute observations of real astrophysical interest and to see their timings used in research papers. Everyone who participated in the visual program can feel a justified sense of accomplishment, and many of those observers continue to advance eclipsing binary astronomy as CCD photometrists for the re-named Eclipsing Binary Section.

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Figure 1. Joseph Ashbrook of Yale University and, later, *Sky & Telescope* editor, advised AAVSO Director Margaret Mayall on establishing a program to monitor eclipsing binary stars. From *Sky & Telescope*, October 1980; courtesy of *Sky & Telescope*.

Figure 2. David B. Williams, AAVSO Eclipsing Binary Program chair 1965–1969.

Figure 3. Marvin E. Baldwin (left), EB chair 1969–2007, with Gerard Samolyk, EB chair 2007–2009 and since 2009 co-chair with Gary Billings.

Walking With AAVSO Giants—a Personal Journey (1960s)

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Presented at the 100th Annual Meeting of the AAVSO, October 7, 2011; received January 25, 2012; revised March 26, 2012; accepted March 27, 2012

Abstract Through pictures, anecdotes, and remembrances, the authors recount the inspiration, friendship, and camaraderie Roger S. Kolman shared with such legendary AAVSO figures as Leslie Peltier, Clinton B. Ford, Carolyn Hurless, Thomas A. Cragg, Margaret Mayall, and others during the decade of the 1960s that led to his fifty years as an AAVSO member and observer, and a career as a physicist, astronomer, and educator.

1. Background

The idea for a presentation at the AAVSO's 100th Anniversary Meeting arose when AAVSO historian Thomas R. Williams and AAVSO staff member Mike Simonsen requested information regarding the origin of the so-called "August Orgies" in Delphos and Lima, Ohio, in the 1960s. After some conversations, we decided to set up a narrative on how the "Giants of the AAVSO" had inspired a new, young observer. Since I was unable to attend the centennial meeting personally, Mike and I decided that we would prepare the material through a series of interviews, Mike would give the presentation at the Historical Session, and I would participate by remote connection (Skype). We then prepared this narrative with Mike providing the prompts (in italics) followed by my responses.

2. 1961 got it all started

Mike: How did you get started in observational astronomy in general and the AAVSO in particular?

I had a friend across the street from me who had a Tasco 60-mm refractor. We did quite a bit of observing with it, mostly the moon, planets, and a few deep sky objects. One evening we were looking for M81. My friend was searching for it without success. After about forty-five minutes I asked him if I could try to find it. He dismissed my comments, but finally agreed to let me try. I quickly found it. This led to my purchase of the scope from him.

We went to the Adler Planetarium each month since we had no other place to purchase *Sky & Telescope*. In December 1961 I read an article by AAVSO Secretary Clint Ford entitled "Sidelights on Observing Variable Stars" (Figure 1). To think that an individual with a small telescope could make observations of scientific value excited me. I wrote to AAVSO Director Margaret Mayall for information and was sent a packet of material. I made my first observation of R Leo on April 12, 1962. I was hooked! My enthusiasm led to my correspondence with Margaret and Clint on a regular basis. To their credit, they answered every letter I sent. Finally, even though I was four months shy of the lower age limit for membership, Clint told Margaret, "Let the kid in" (perhaps remembering that he, too, was allowed to join at age 15). My membership commenced on May 11, 1962.

3. Meeting Dick Wend

What local mentoring help made you take off as an observer?

In those days the AAVSO published a list of members along with contact information. Richard E. Wend was one of the names on this list (Figure 2). He lived only a couple of miles from my home and only two blocks from the high school I attended. After several attempts at meeting Dick (he was a travelling salesman), we finally got together. By this time I had a 4-inch Dynascope. We immediately clicked. This led to a friendship that lasted almost fifty years, until his death in 2009.

A few months after we met, Dick felt that I should have a larger telescope with which to observe variables. He assisted me in obtaining a 6-inch Dynascope. This telescope proved to be a short-term solution to aperture fever!

One evening I was visiting Dick and he showed me a 16-inch mirror blank on which he was working. I spotted a large tube in his basement that I thought was an old water heater. He told me that this was a tube for a 10-inch Cave reflector that he had. It had no mount. We talked about it and he said we could sell the Dynascope and he would help me assemble the 10-inch. I was working as a junior draftsman at a local railroad engineering company. I designed a mount for the scope, the company fabricated it for me, we sold the Dynascope, and the 10-inch Cave became my main scope until the 1980s.

4. First trip to Delphos

When did you first get the chance to meet Leslie Peltier and Carolyn and Don Hurless?

Dick Wend and I enjoyed discussing the AAVSO and the many great observers of the 1950s. He was a long time member of the Milwaukee Astronomical Society (MAS) and a friend of such luminaries as Ed Halbach, Walter Scott Houston, Bill Albrecht, and A. R. Ball. I was in awe when I met and observed with all of them, except Ball, whom I never had the chance to meet. Dick brought up the possibility of meeting the celebrated observer Leslie Peltier, which greatly excited me. He contacted Carolyn Hurless (Figure 3) and a visit was scheduled for November 23, 1963. This was, of course, the day after the assassination of John F. Kennedy, so our trip began on a somber note.

We had a great time visiting with the Peltiers and the Hurlesses. Talk and viewing went far into the night. Carolyn suggested contact with Curtis Anderson and a correspondence began with him and many other AAVSOers. Carolyn could not keep up with all of the correspondence and ultimately launched an informal newsletter which she called *Variable Views*. She did this with a "ditto" spirit duplicator machine sending a compilation of notes and observations to those on her subscriber list. Incidentally, Leslie commented to Carolyn after our visit "I thought they would never leave." I guess my enthusiasm was overwhelming to him. Carolyn felt otherwise and she told us that she was looking forward to another visit, soon.

5. 1964—first AAVSO meeting

When did you first attend an AAVSO meeting?

My first was the AAVSO Spring Meeting in 1964, held in St. Louis. Dick Wend and I made the trip where I gave my first paper. This eighteen-year-old was quite nervous, about to speak in front of an audience that included Clint Ford, Tom Cragg, and many others about whom I had read. Margaret Mayall took me to the side and told me to just speak to her—not to pay attention to the rest of the audience. This settled my nerves and the talk went well. Following a question and answer session, J. Allen Hynek (at the time the Department Head of Astronomy at Northwestern University) came up from the bar with a martini in hand and said, "That was a fine talk, young man. Margaret has been saying some fine things about you." I almost lost it then. This was my first face-to-face meeting with many of the Giants of the AAVSO.

6. August 1964—Schoonover Observatory dedication and the first "August Orgy"

Tell me about the legendary "August Orgies."

The Lima (Ohio) Astronomical Society (LAS), in concert with the City of Lima, built the Schoonover Observatory. The main instrument is a 12-1/2-inch Cassegrain reflector. The city financed the building and LAS managed it. Carolyn invited AAVSOers from around the country for this event. We had the opportunity to meet Carolyn's protégés, Ernst Mayer (who served as AAVSO President), Paul Sventek (who served several terms on Council), and Vicki Schmitz (who went on to become a highly regarded lawyer and judge). Carolyn knew how to pick them!

Headquarters for the gathering was the Hurless home in Lima that was buzzing with activity. Sessions went far into the night. Among those attending from out of town were Tom Cragg, Clint Ford, Chuck Scovil, George and DeLorne Diedrich, Diane Lucas, Art Stokes, John Ruiz, Ed Oravec, Newton Mayall, Leslie Peltier, and Curtis Anderson.

Speaking of Curtis Anderson (Figure 4), I must say that he was a most remarkable man. Carolyn met him at the 1959 AAVSO Spring Meeting at the Adler Planetarium in Chicago. He was an imposing figure standing at six feet, eight inches. Observing with a 10-inch reflector from his home in a Minneapolis suburb, he submitted prolific numbers of variable star observations—many of them Inner Sanctums (13.8 magnitude or fainter). Shortly after the meeting, he was diagnosed with Multiple Sclerosis. His case was particularly aggressive and, by 1961, he was confined to a wheelchair. In spite of this, he continued to observe at virtually the same rate as before his confinement. Meeting him was an additional inspiration to me, seeing how the passion he had for variable stars could help him overcome his great handicap. He was awarded the AAVSO Merit Award in 1965 and was a member of AAVSO Council from 1965 to 1969. During his time as an observer, he contributed 600 consecutive monthly reports! Sadly, he succumbed to his disease in 1976. In more ways than one he was a Giant of the AAVSO!

Tell me about the SS Cygni contest you had with Carolyn Hurless.

We had an observing session at Leslie's observatory in Delphos, Ohio. Carolyn had brought her 8-inch reflector from Lima and I brought my 10-inch reflector from home. During the evening a discussion arose about who could find SS Cygni (which was our favorite variable) using the star-hopping technique. Each of us felt that we could do so faster. Finally, Curtis Anderson said, "Why don't you have a race and settle this once and for all?" We agreed.

Each of us put our telescopes in a neutral position, Curtis made the call, and we were off. In a few seconds, we each found the field and SS Cygni. I made the call first, just ahead of Carolyn. She maintained she found it first, but had not made the call. In reality, it was too close to call. Each of us maintained we won. Those in attendance got a good laugh out of the race.

7. Ford Observatory dedication, 1965

I understand that the next August Orgy took place on the road. Tell me about it.

We had learned that there was going to be a mountain near Wrightwood, California, named after Leslie Peltier, and an observatory placed on the mountain. The observatory was to be named after Clint Ford and would house an 18-inch telescope donated by Claude Carpenter. Once we were invited to the dedication, Dick Wend and I planned a western vacation.

Dick had been a long time member of the Association of Lunar and Planetary

Observers (ALPO), so he asked ALPO leader Walter Haas to set up a meeting in Las Cruces with Clyde Tombaugh on the way out to Mt. Peltier (Figure 5). I brought my 6-inch $f/4$ richest-field telescope (RFT) along so I would not miss any observing time. Upon arrival at the Tombaugh home, Clyde saw the 6-inch RFT in the back seat of Dick's car and got excited. "I haven't seen one of those since I made one in 1920-something." We then exchanged views through the 6-inch and Tombaugh's 16-inch telescope.

Tombaugh's telescope was a behemoth! It was of long focus, since he was a planetary observer. It looked like an oil derrick. Tombaugh wanted to show us Jupiter, which was not easily accessible to the eyepiece. Being very practical, he had a long plank near the observing platform. He pulled out the plank, and told Dick and me to stand on one end to weigh it down. He then walked out to the end of the plank to reach the eyepiece and observe. When he was done, he walked back and said, "Okay, now it's your turn." Dick and Clyde stood on the end of the plank to weigh it down for me. Now, I was much skinnier then, but it was still pretty scary. However, this was a chance to observe with Clyde Tombaugh, so I wasn't about to chicken-out. After I finished, Clyde and I stood on the plank for Dick. Another interesting tidbit is the fact that Tombaugh, being the practical man he was, used a peanut butter jar for the secondary cover, and a garbage can lid for the mirror cover.

We did a great deal of sightseeing on the way to Wrightwood. Finally, we arrived, settled into a motel, and were off to see the Ford Observatory.

We arrived a few days before the dedication and found that there was much to do before the site would be suitable for visitors. We pitched in to help with the preparations. While cleaning up things, Dick called out to me, "What kind of snake is this?" There was a rattler coiled up in front of him. Fortunately, I had been a pitcher on my high school baseball team. I told him to stand very still, picked up a rock, and sent the snake to its maker. We threw the snake off the side of the mountain. Later, when we told the story to Larry Bornhurst (one of the Ford Observatory group), he said, "So where are the rattles? You didn't save the rattles? My kids are saving them!"

There were no "facilities" available, but bizarre as it may seem, there was a toilet just sitting there in the middle of the observing field on top of the mountain! So we fashioned a porta-potty out of some leftover plywood and made a sign: one side said "Be careful, in use"; the other side said, "It's Okay now."

Thomas A. Cragg was a solar observer at the 150-foot tower at Mount Wilson Observatory in Pasadena, California. He arranged a tour for us and, while we were in the 60-inch telescope dome, we heard that word had spread among the astronomers on the mountain that Leslie Peltier was visiting. They stopped what they were doing to come meet the legend in person—a Giant of the AAVSO.

8. The 1966 meeting in Chicago

The AAVSO held its 1966 Spring Meeting in Chicago. I was now 21 and of age to be included in the legendary "Clint Ford Hospitality Suite." I had heard about it, but had never been allowed in because of my age. Now, I was allowed in! It was awesome. He had a room filled with all kinds of liquor and beer. Early on, the partying was rather mild-mannered. Then Carolyn Hurless said she was pretty tired and told everyone "goodnight." A minute after she left, Clint said, "all right, let the fun begin!" He then proceeded to quote limerick after limerick, many of which would make a sailor blush. Clint loved his limericks and he knew a LOT of them. I was now indoctrinated!

9. The 1968 meeting in Lima, Ohio

In 1968, you gave two papers at the Lima, Ohio, meeting. Tell me your memories of that meeting.

I do recall that among the speakers at that meeting were: Newton Mayall, Leif Robinson, Clinton Ford, Charles Scovil, Marv Baldwin, Carl Anderson, Robert Cox, Walter Scott Houston, Lawrence Hazel, Tom Cragg, Cyrus Fernald, and Art Stokes. I was shocked when Margaret Mayall asked me to chair one of the sessions. Giving two papers was a treat, but chairing some of the Giants of the AAVSO was unbelievable!

10. Conclusion

My first exposure to the AAVSO came in the form of an article in *Sky & Telescope* magazine (December 1961) about amateurs observing variables, written by Clint Ford. I was so impressed by the fact that ordinary people using backyard telescopes could contribute to science that it impacted the rest of my life. I became a physicist and now teach astronomy courses at Harper College in Palatine, Illinois.

I joined the AAVSO as a teenager in 1962, which makes me one of the longest-standing members of the AAVSO. My first variable star observation was R Leo in April of that year. In 2012, I will reach the fifty-year mark (Figure 6). I have witnessed decades of development and have known many of the famous personalities in AAVSO history personally. Sadly, almost all the AAVSO Giants of the 1960s are gone now, but their influence and legacy lives on through me and the generations of dedicated observers that have followed in their footsteps.

Figure 1. Clint Ford, about 1963.

Figure 4. Oravec, Kolman, Peltier, Hurless, Cragg, Anderson, Ford: Delphos, Ohio, 1964.

Figure 2. Dick Wend, 1964.

Figure 5. Kolman, Tombaugh, Wend, 1965.

Figure 3. Carolyn Hurless, in Peltier's "Merry-Go-Round" observatory, 1964.

Figure 6. Roger Kolman, observing with his 18-inch reflector.

Variable Star Observers I Have Known

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Presented at the 100th Annual Meeting of the AAVSO, October 7, 2011; received February 16, 2012; accepted February 29, 2012

Abstract I would like to share with *JAAVSO* readers some personal recollections of a few of the outstanding individuals I have become acquainted with through forty-five years as an AAVSO member. In one manner, or another, all have played an important role in the AAVSO's 100 years of service to the astronomical community.

1. Introduction

By virtue of my forty-five years as an active visual observer with the AAVSO, as a small part of our celebration of 100 years as amateur scientists contributing to the field of variable star monitoring and solar observation through the auspices of the AAVSO, I would like to share with you some personal recollections of a few of these individuals (Figure 1). Some of you who have devoted decades to the association, as I have, will undoubtedly recognize these names immediately. For others of you who have joined the organization more recently, but perhaps have perused the volume *Advancing Variable Star Astronomy*, it may add a degree of more personal familiarity to those individuals otherwise known to you only as written names on a page. In one manner, or another, all have played an important role in the AAVSO's 100 years of service to the astronomical community.

2. Clinton B. Ford, observer par excellence

I first met Clint Ford in 1962 when I discovered Stamford Observatory and joined the Fairfield County Astronomical Society which runs it. He became president of the Society a couple of years later. We became quite good friends. I think he saw a potential observer in me. At the time I was building myself a 4-inch refractor, and I had never heard of variable stars. The observatory's 22-inch telescope was still under construction. Clint bribed me by loaning me a 10-inch reflector he had just replaced with a new 12.5-inch in his backyard observatory. His one requirement was that I build an observatory in my backyard to house the telescope, since the 10-inch would be too big to haul in and out. The paint on the observatory had hardly dried when he came over with some strange blueprint star charts and a gleam in his eye. He taught me how to make variable star estimates, and as the saying goes, the rest is history. Eight years later I was president of the AAVSO.

Clint first started observing variables at age fourteen in Michigan where his father was a math professor at The University of Michigan. Clint was too young to be accepted formally as an AAVSO member until he turned fifteen in 1928, so he became a member the year I was born. Also in 1928 he had the privilege (for one of his tender years) of attending his first AAVSO meeting, where he met such dignitaries as Leon Campbell, William Tyler Olcott, and David Pickering. This cemented his interest in variable stars. In Michigan near the family home Clint had an observatory at the top of an old tower, where he used a borrowed 3.5-inch Clark refractor. He made many observations from that location, and from the family summer place on Cayuga Lake in central New York State. He spent part of one summer as an assistant at Yerkes Observatory where he used an 8-inch refractor for his observations. Through three years at Carleton College in upper New York State, and later at the University of Michigan for his senior year and his studies for his Master's degree he continued observing as time permitted.

The war years proved difficult for observing, but again, whenever he could he stuck with it. He spent part of the war as a Naval Reserve Lieutenant teaching navigation at Rensselaer Polytechnic Institute in Troy, New York, where he used their observatory's 12-inch.

Clint and his first wife, Alice, built a home in Suffield, Connecticut, in 1948. In Suffield he built his first roll-off roof observatory, which housed the 10-inch telescope. That telescope was built by a friend of Clint's and was pretty good. It would regularly reach the mid-14th magnitude range even in not so good Connecticut skies. That meant that Clint was often able to reach the "Inner Sanctum" (positive estimate fainter than 13.8 or fainter-than estimate fainter than 14.0) and he liked to observe the fainter end of the variables' cycles.

After Clint's divorce and remarriage he moved to Wilton, Connecticut, to work for the Perkin-Elmer Corporation. There he built his second roll-off roof observatory, a slightly larger version of the one in Suffield. The new observatory housed a 12.5-inch scope made by Cave Optical Co. in California. By that time Clint knew Tom Cave quite well, so he got a fine telescope. With it he was able to reach into the mid-15th magnitude range. Clint willed his 12.5-inch scope to Ithaca College where it is in use again.

While still in Michigan, Clint had become friends with Claude Carpenter, who owned an 18-inch telescope. When Claude retired from his job with the Post Office he moved to Southern California and set up the telescope in a rickety observatory out in the desert. Several other amateur friends got together and found a site in the mountains near Wrightwood, California, where they built a new observatory to house the 18-inch. Since Clint supplied most of the funds for the building they named it after him. The project made the cover of *Sky & Telescope* for March, 1966, with a feature article inside.

The 18-inch was a big brute of a scope, and being a Newtonian it required climbing on a ladder or platform to get to the eyepiece. At first the eyepiece location in the usual spot opposite the attachment point of the Declination axis sometimes made it impossible to reach. Clint eventually solved that problem by having a rotating top end built. At any rate, once the 18-inch was operational the limit was about 17th magnitude. Now we were getting somewhere! Clint used to go to California with his wife three or four times a year, usually for two or three weeks spanning the dark of the Moon. At first they stayed in a local motel, but that got old pretty soon so Clint bought a three-bedroom house for his visits and for use by the local observers. I stayed there on many occasions when we went to California together after his second divorce. Altogether Clint made 61,874 observations in his lifetime.

Clint was Secretary of the AAVSO for forty-four years so he always had a report to give at meetings. His writing style was rather dry and old fashioned. I suppose it was a product of his times and his educational background. I always found it rather stuffy but I never complained. Later when we got into the chart making we differed strongly on many issues and I let him know my opinion. John Griesé used to say we sounded like an old married couple—always bickering.

We knew that there were far more visually observable variables than the AAVSO had charts for. Clint had gotten a bunch of material for new charts from Dr. Charles Olivier of the University of Pennsylvania. He started drawing charts from that material but the photos supplied were of poor quality and very hard to work with. He constructed what he called his “e-maker” (e-scale charts) with a couple of mirrors and an opaque projector to enlarge the photos. Soon after our 22-inch Gregory-Maksutov telescope came on line in Stamford I began taking photos for the new charts, and then assisting with the drawing of them. Clint was not a good draftsman and it drove me nuts to see what he turned out. First I made up a chart form to get away from his sloppy outlines. Soon computers came along and we were able to start at least drawing the chart forms and the lettering that way. The next step was a program to take the irregular star dots from my photos and make them into perfectly round dots that we could scale any way we wanted to. The program was written by our local Society member Gil Wiengarten. We called it very scientifically “Roundify.” At last we could make charts entirely using the computer. There was still a bit of art in it since we had to choose the disk scale that would make it look like the sky. Local Society member Bob Leitner and I designed the computerized chart forms and consulted with Janet Mattei on final details.

Clint and I often went to various scientific meetings together. In 1988 we went to a reunion of astronomy graduates and staff at Cornell where many notables including Carl Sagan gave talks. Clint was involved with Cornell in supplying a part of the funds for them to use the 200-inch at Palomar.

Clint was prevailed upon by Dorritt Hoffleit to write his memoirs. They are called *Some Stars, Some Music* and make fascinating reading. Copies are still available from AAVSO Headquarters. I highly recommend this booklet. Also, Dorrit Hoffleit wrote an obituary of Clint after he died in 1992 that was published in *JAAVSO*, Vol. 21, No. 2, pp. 144-146.

3. Danie Overbeek

At the 1972 AAVSO Meeting we met South African observer Danie Overbeek and his wife Jeanne. After the meeting we all met at Clint's house in Wilton. We all got along famously and they said "You simply must come visit us in S.A." Of course we never thought it would happen, but in 1975 Clint and I did just that. We spent twenty days touring South Africa with Danie and Jeanne, and had a great time. We talked to every astronomy Centre in the country (sixteen of them) about amateur astronomy in the U.S.

Danie had his observatory on top of his garage, ten feet from his kitchen door. It was accessed by climbing a vertical ladder up the side of the building. He had a home-made 12-inch reflector of rather short focal length, ideal for variable work. The finder had a mechanical shutter type arrangement so that he could cut down the aperture when using it on very bright variables. When he needed to go back into the house he wore a set of WW II red aviator goggles to preserve his night vision.

Danie worked for South African Airways as head of their pilot training department. Since they bought their planes from Boeing, he was frequently in the United States to check out the latest simulators and we got together now and then.

While in Cape Town we met Reginald de Kock, who held the AAVSO's lifetime record at that time with 160,777 variable star observations. Danie later exceeded that mark by a considerable margin with 292,711 visual observations. *[Ed. note: there is a memoria page to Danie, who died in 2001, at http://www.aavso.org/memorium-danie-overbeek]*

4. Wayne Lowder

Wayne lived not too far from Stamford and became a member of our Society. He often came to visit and observe because we had better skies than he did at home. He used binoculars and his own 8-inch and a 10-inch telescope we had. He was so interested in variables that he taught himself to read Russian so he could do research in the library at Harvard and find out what they were writing about stars that might prove to be of interest. Wayne was one of those who checked each new chart we turned out. We called him "The electronic eyeball" because his estimates were so good. He would even make new sequences by eye-estimates. Wayne made 208,571 visual variable star observations, many of them highly-precise estimates of small-amplitude variables. *[Ed. note: there is a memorial page to Wayne, who died in 2003, at http://www.aavso.org/memorium-wayne-m-lowder]*

5. Ed Oravec

Ed lived in nearby Westchester County, New York, only a few miles from us, and like Wayne he often visited us since our skies were better than he had at home. He brought his own large binoculars and did mostly bright stars. His observations were extremely accurate. Ed doesn't observe any more, but he made 170,453 visual observations between 1943 and 2003.

6. John Bortle

John Bortle was another member who came from Mt. Vernon, New York. He did both binocular and telescopic observing, and was also interested in comets. That was a subject for which he became world famous. He later married and moved to a far better location in Stormville, New York, where he built his own observatory. In those early years at Stamford Observatory we also had as members Bill and Florence Glenn from the Bronx, New York. They were also binocular observers and came very often to observe. It was this total group who dreamed up and proposed the two new AAVSO publications: *The Journal of the AAAVSO*, and *AAVSO Circular*. We proposed them to Margaret Mayall, and with her approval and input both were started. John Bortle became editor of *AAVSO Circular* which dealt with rapidly varying stars such as CVs and novae, and Bill Glenn became editor of *JAAVSO*. I was production manager and typist/layout editor of *JAAVSO*.

That group was also the genesis of *The AAVSO Variable Star Atlas*, since we realized that there was no atlas of the heavens that showed where all our "pet" variables were. I proposed that as a trained draftsman I could make such an atlas if we could find as suitable base atlas giving us the stars. We finally got the right to use *The Smithsonian Astrophysical Observatory Atlas*, and I was off and running. *[Ed. note: John is still going strong and has just passed the 200,000 visual variable star observations mark.]*

7. Tom Cragg and Claude Carpenter

I first met Tom at a Spring Meeting in Tucson, Arizona, in May 1972. Of course we went to Kitt Peak and I got my first look at really large telescopes. Tom was in his element, having worked with the 60-inch and the 100-inch at Mt. Wilson, where he was the Solar Observer and jack of all trades. He and Clint Ford were old pals and Tom was a very amiable guy, so we all got along well. We went on from there to California to observe with the 18-inch at Ford Observatory on Mt. Peltier near Wrightwood. I think it was on that trip that I first visited Mt. Wilson. Naturally Tom showed us around, and I also briefly met Larry Bornhurst, who was one of the founders of and did most of the actual building of Ford Observatory. Larry had his own little dome on Mt. Wilson.

Tom Cragg had the use of a wonderful 6-inch Clark telescope at Mt Wilson. His eyesight was so good that he regularly broke into the 15th magnitude range.

On that same trip I also met Claude Carpenter, who owned the 18-inch scope in Ford Observatory. He was a bit of a character. You didn't want to cross him or you could expect a tongue-lashing. All bark and no bite, of course. In general he was a likeable person. He was older than the rest of us and rather set in his ways, having lived as a bachelor most of his life. *[Ed. note: Claude died in 1992. There is a memorial page to Tom, who died in 2011, at http://www.aavso.org/thomas-cragg]*

8. John W. Griesé, III

John Griesé showed up at the Observatory as a high school student in the early 1970s. He lived across the road from Richard Perkin (of the Perkin-Elmer Corp.) and had observed with Perkin's 24-inch reflector on a few occasions. He joined our group and began observing variables, eventually becoming my assistant at Stamford. He helped in taking photos for the chart work and also ran the public open house nights for years. He taught Adult Education courses throughout Connecticut. He studied for and got his Master's Degree and is now going on studying for his Ph.D. John was elected to the AAVSO Council where he served from 1985 to 1990. John has made nearly 22,000 visual variable star observations so far.

9. Fr. Ronald Royer

On one of our trips to Ford Observatory I met Fr. Ronald Royer (now Msgr. Royer). At the time he was one of several priests at his church, but later he became the Rector. He was a regular guy who had started observing variables in his teens and continued even through his studies for the priesthood. He had his own 12-inch scope in the backyard of the church. He was also one of the founders of Ford Observatory, and frequently went there to observe on his days off. On one of our later trips to California, one night John Griesé and I stayed at the Rectory, which was also the residence of the local Bishop. As I recall, that was on our trip to the Riverside Telescope Makers Convention at Big Bear. He has made nearly 10,000 variable star observations so far, mostly visual but some PEP and CCD, too.

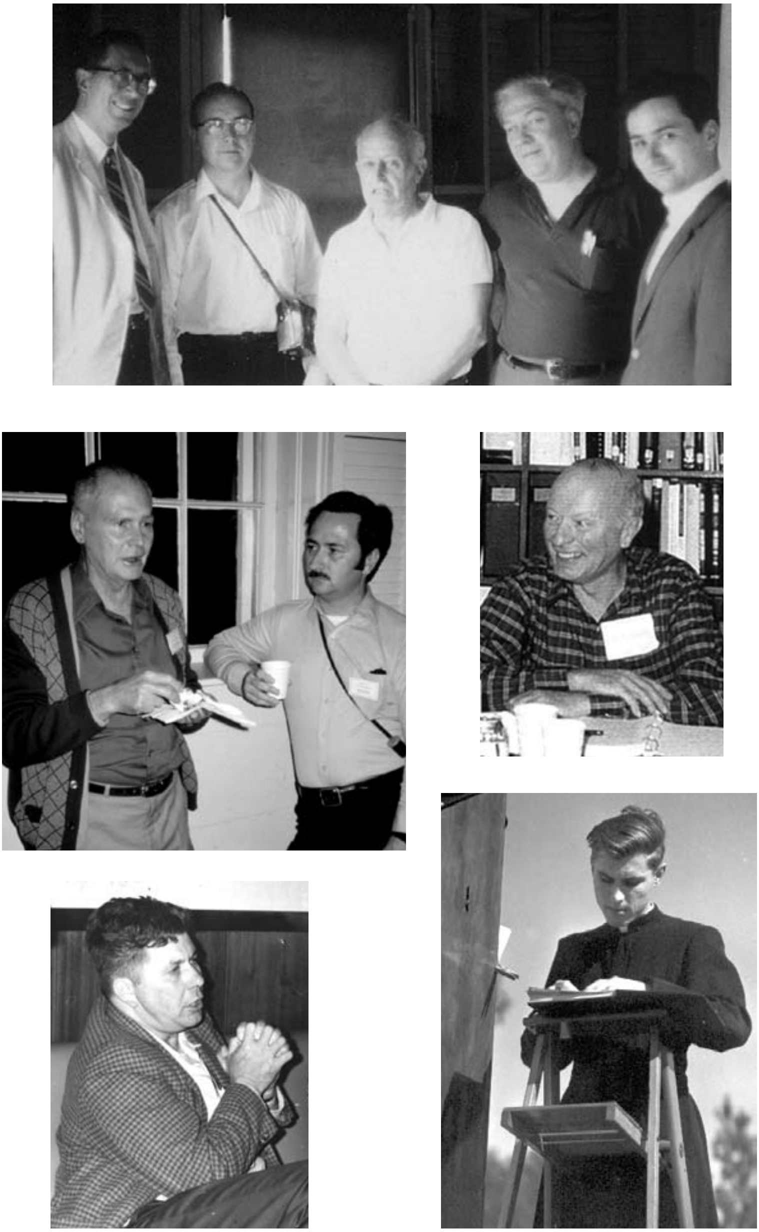

Figure 1. AAVSO Observers: *top*, Ed Oravec, Charles Scovil, Leslie Peltier, Clint Ford, John Bortle; *middle left,* Danie Overbeek and John Bortle; *middle right,* Wayne Lowder; *bottom left,* Tom Cragg; *bottom right,* Fr. Ron Royer.

An Appreciation of Clinton B. Ford and the AAVSO of Fifty Years Ago

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Presented at the 100th Annual Meeting of the AAVSO, October 7, 2011; received March 2, 2012; accepted March 2, 2012

Abstract This is a rather personal story about Clinton B. Ford, my boyhood mentor in astronomy, and about the influence of the AAVSO and Clint on my life and career. While much has been written on Clint, this addresses the man, and his kindness.

1. The start

Clint and Alice Ford (Figure 1) lived on Loomis Road in Suffield, Connecticut, a 300-year-old tobacco farming town on the Massachusetts border, and on the West Bank of the Connecticut River. They were neighbors of my family, living just 0.4 mile to the East. Clint worked for a company that made photographic developing equipment in nearby Springfield, Massachusetts, owned by another Suffield resident, Hinny Smith. I recall that Clint was vice president and also did engineering at this company, yet due to Clint's father's foresight in buying early IBM stock, part of his life was managing this investment. However, his love was clearly astronomy and in particular the AAVSO.

The Fords became great friends of my mother and grandmother, and by 1953 it was standard Sunday afternoon fare for either Clint and Alice to visit us, or for us to visit the Fords. This always pleased me, especially visiting the Fords. My interest in the night sky started at age eight. Part of this was a childlike fascination with the radio show *Buzz Corey and the Space Patrol*. My little brother and I had learned to climb out on the roof of our old farmhouse after mother thought we had gone to bed and lie there, with blankets, looking up. It was two or three years later when the close friendship between the Fords and the Hulls matured. I remember sitting in the Ford's living room, full of adult talk by the others, and being quite happy thumbing through Clint's *Sky & Telescope* magazines. Clint would notice, and was always happy to answer questions. And I asked many. Then off to the observatory we would go to look at hardware, always a special pleasure.

The AAVSO was integral to Clint's and Alice's social life. I had the opportunity to meet and see frequent Suffield guests Margaret and Newton Mayall, Claude Carpenter, Cy Fernald, and others. Later Clint generously donated a 4-inch Unitron Refractor to my high school, Suffield Academy. I became the first president of the School's Astronomy Club, and enjoyed assembling the scope and using it for the first time.

It was rather cool to be interested in astronomy then. After all, this was the start of the space race, with Sputnik being all the talk in the fall of 1957 (Figure 2). Starting in 1955, some of my interest had diverted into rockets, an interest which Clint did not share. With my little brother and best friend, we learned the basics of rocket design, nozzles, and how to pour a fuel core and had some successes, a little like the film *October Skies*. We also had a fantastic failure which pretty much ended my rocket career. Fortunately no one was hurt.

When I was fifteen, Clint nominated me to membership in the AAVSO, and there was little surprise that I was elected to membership at the 48th Annual Meeting at Nahant, Massachusetts, October 1–4, 1959. The meeting was coincident with the October 2nd Sunrise Total Eclipse which was "rained out." I watched what I could of it through Suffield clouds.

After making some variable star observations, in a period competing with time for playing sports, and crushes on girls, the momentous 50th Annual Meeting at Harvard College Observatory came up in October 1961. This was the first trip on my own, taking a bus from Springfield to Boston, the MTA to Harvard Square, and a very long cab ride to my very nearby hotel. It also involved a choice. I was on the football team, and missing a game would mean being dismissed from the team. I did the right thing and never had a single regret.

I loved being at the 50th Annual Meeting (Figure 3), and regret that I could not be at the 100th Annual Meeting. I recall seeing Harlow Shapley and Donald Menzel and other great names in 20th Century astronomy there. I was somewhat familiar with these from reading *Sky & Telescope*, and the books I had begun to collect. I also recall meeting Constantine Papacosmos of Montreal, just a few years older than I and a person with much enthusiasm. Clint kindly kept an eye on me from a distance but let me have my own experience. I still recall the dinner speaker making the classic joke over dessert of this "seeming to be a meeting of a gastronomy society" rather than an astronomical society. Overall this was a great experience and the AAVSO enriched my love of astronomy.

2. Clint's Suffield observatory

Clint's home observatory was a marvel of intention and practicality. While Clint had the means to have much more, his observatory was ideally matched to his interest. He described the utility of the roll-off roof design, allowing him to nimbly move about the sky. Suffield of the late 1950s still had fairly dark skies, and wind was not much of a factor. His telescope of choice was a 10-inch Newtonian reflector (Figure 4), built by someone else and acquired by him. Clint explained to me that there are two kinds of astronomers: those who develop telescopes and do little astronomy and those who do astronomy with telescopes developed by others. I had not realized then that this lesson had special relevance for me. After graduate school, I elected to work in aerospace developing telescopes and instruments, largely for spaceborne projects.

Rather than an optical finder, Clint preferred a piece of tubing in the "pea-shooter" configuration. Clint understood in detail everything about the observatory. He knew optics, to the level that he could sit down with a pad of paper and explain the optical difference between the war surplus Erfle eyepiece he loved and his Kelner eyepieces. Clint would spend hours teaching me about telescopes, both in showing me equipment in the observatory, and in chats in his living room. The latter was inevitable as I devoured his *Sky & Telescopes*, and wanted to know about everything. Clint taught me all, from the basics of astronomy to the utility of rare earth glasses in optical design. This interest in design became more intense when I encountered the *Amateur Telescope Maker* three-book series by Albert G. Ingalls. While Clint's interest was clearly in observing, he had a consummate knowledge of telescopes and was very generous with his time as I asked a thousand questions.

Clint valued his clear night observing time, and had a schedule of what observations he would want to make in each month of the year. Nevertheless, he would make time to not only have Cub Scouts visit, but to teach me how to observe, how to hold a chart correctly, find objects in the sky, and use averted vision to see faint objects. On that note, Clint had a "lazy eye," and my family had concern that this was an artifact of observing at the telescope. Nevertheless, they, too, continued to encourage me with astronomy. I started saving up the sum of $33.75 to buy a 3.5-inch Skyscope. While a very simple *f*/11 Newtonian telescope, Clint felt the optics were good and that it would let me do variable star observations on brighter objects. I still have this telescope.

3. Clint the observer

Astronomers come in various flavors. I have met many over my career, both professional and amateur. Of these only a handful had a love for being at the telescope the way Clint did. In fact, of the astronomers I have known, I think only University of Pennsylvania Professor Leendert Binnendijk matched Clint's love of being beside the telescope. Clint was happiest as he observed variable stars, and moved his telescope about with a sense of complete familiarity with the sky. His proficiency at variable star observing is written into the records of the AAVSO. Clint was an amateur in the best sense: one who is motivated by his love for the field. He also loved the sense of contributing in a meaningful way to the understanding of time-domain astronomy, variable stars. He often led campaigns on interesting faint stars within reach of his telescope. I think of Clint also as a professional, including having received a M.S. degree in Astronomy from the University of Michigan, but more so because of his consummate knowledge of what he was doing. He clearly had the stuff the best professional astronomers are made of.

I would like to report that among the equipment Clint showed me was a photoelectric polarimeter he had developed in the late 1940s, roughly contemporary with the work on the interstellar medium by Hiltner and Hall and the predictions of Chandrasekhar of intrinsic polarization in late type stars. This certainly anticipated the fluorescence of photoelectric polarimetry. While I never saw Clint operating this instrument, I was impressed that he had recognized the importance of measuring the polarization attribute of light, and that it might be relevant to the stellar objects he studied. Years later in graduate school at the University of Pennsylvania, I had the opportunity to conduct a polarization survey of contact and over-contact eclipsing binary stars. As I did this, I recalled that Clint could have been a pioneer in this field.

4. Clint the mentor

I can trace the progression of opportunities I have had in astronomy to Clint's mentorship. I would be remiss in not stating this. Because of the background training Clint had given me, and my experience with the AAVSO, I was already at the intermediate astronomy course knowledge level when I went to college. As a freshman at Penn, I was put into an advanced Practical Astronomy class, competing with two junior majors, two senior majors, and two graduate students. Practical Astronomy was an in-depth class aimed at acquiring a working knowledge of Spherical Astronomy, the application of precession and nutation, the precise calculation of time, and the method of least squares for reducing observations. The rigor of this class in turn enabled me to obtain summer work with Peter van de Kamp at Sproul Observatory, Swarthmore College, and then two summers and a semester at MIT's new Haystack Observatory, where I published my first paper, still cited, on the radio star method of correcting the pointing of large altitude-azimuth telescopes, which expanded on the principles of reducing meridian transit observations. In turn this assured that I would pursue graduate studies in astronomy.

While I have chosen mostly the telescope and instrument development side of astronomy, the course of my life would have been very different if it had not been for the mentorship and kindness that Clint Ford showed a neighborhood child. I have had the privilege to build imaging systems used throughout the solar system, to be NASA technologist for the Terrestrial Planet Finder Coronagraph, and Program Manager for the optical manufacture of the James Webb Space Telescope mirror suite, NASA's next flagship mission and sequel to Hubble. There is something about being behind a telescope I still love. I frequently think back to those early days in Suffield with Clint's example. Clint's love of astronomy, and the sense of its importance, has been a central and consistent inspiration for who I have become—and I am just one of the people whom Clint trained and the AAVSO continues to train to aspire to the stars.

Per Aspera ad Astra.

Figure 1. Clint and Alice Ford (top row) at the AAVSO spring meeting in 1952, about a year before my family started regular Sunday visits with them.

Figure 2. At the 1957 Annual Meeting. Dorrit Hoffleit is holding a newspaper announcing the USSR Sputnik satellite launching. Clint is at the right in this photo.

Figure 3. 50th Annual Meeting of the AAVSO in 1961 at Harvard College Observatory. This was my first trip away from home alone, and resulted in being kicked off the football team for missing a game, but it was worth it. The left arrow indicates the author; the right arrow points to Clint Ford.

Figure 4. Clint at his 10-inch Newtonian reflector at his home in Suffield, Connecticut, about 1964.

An Overview of the AAVSO's Information Technology Infrastructure From 1967 to 1997

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Based on a poster presented at the 100th Spring Meeting of the AAVSO, May 22, 2011; received February 13, 2012; revised March 6, 2012; accepted March 9, 2012

Abstract Computer technology and data processing swept both society and the sciences like a wave in the latter half of the 20th century. We trace the AAVSO's usage of computational and data processing technology from its beginnings in 1967, through 1997. We focus on equipment, people, and the purpose such computational power was put to, and compare and contrast the organization's use of hardware and software with that of the wider industry.

1. Introduction

There are some organizations and purposes for which data processing and computers seem to have been tailor-made. One of these is the AAVSO. To their credit, the organization's leaders, specifically Directors Margaret Mayall and, later, Janet Mattei, realized this synergy fairly early on. During the AAVSO's Annual meeting in 1966, Mayall consulted with AAVSO member Professor Owen Gingerich at the Smithsonian Astrophysical Observatory (SAO) about the feasibility of digitizing the AAVSO's variable star observational data (Welther 1970). In 1967, with the cooperation of SAO, Mayall and the AAVSO began digitizing observations for what would become the AAVSO International Database. This was followed, in fairly short order, by the start of custom programming, again with the cooperation of SAO, to analyze the observational data being compiled (Welther 1970).

Along with other organizations of the AAVSO's size and non-profit mission, the 1980s were a transitional decade that saw computer technology used not just for data, programming, and analysis (although that certainly continued), but also for routine office work. The 1990s, for both the AAVSO and the wider world, was the "decade of networking," with Janet Mattei overseeing both the installation and use of a local area network, and the marriage of the organization to the then new World Wide Web.

2. Early developments

As early as 1958, Margaret Mayall considered "the possibility of processing all variable star data at headquarters by means of IBM punched cards" (Williams and Saladyga 2011); but it was not until 1966 that Mayall and the AAVSO Council began to bring that idea into fruition. During the AAVSO's Annual Meeting in 1966 Gingerich, Mayall, and the AAVSO Council discussed how this might occur. Gingerich, in what would become the first of a long line of important contributions to the AAVSO, believed he could donate some free access time on the SAO computers to the AAVSO. All that the AAVSO would need to invest in, he said, would be a card punch (keypunch) machine. At the May 1967 meeting, the AAVSO Council decided to rent a keypunch machine to begin a critical process of remaining relevant and moving to increased professional acceptance of the organization (Saladyga and Williams 2011).

Prior to this decision, observations were recorded in ledger books, and light curves were hand-plotted from these data for particular, special, or requested stars. Incoming data started to grow in leaps and bounds at this point and new ways had to be found to graphically represent the data. Data digitization enabled plotting and analysis programs to be used, which greatly enhanced the usefulness of the data for both amateur observers and professional astronomers alike. Once the AAVSO crossed this Rubicon, going back was unthinkable.

Digitized cards had other uses that observations in ledgers could never approach. Cards could be handled in discrete batches, sorted automatically based on criteria, and could serve as input to computer programs.

Once photometric data were digitized, it was easy to find reasons to use them in that form. Over the next few years, for example, the AAVSO made an effort to use computer programs and software plotters to help automate and produce compilations of observations and light curves of selected stars—the *AAVSO Report* series—using the keypunched data that had been collected.

By 1971 the AAVSO had digitized one million observations. There were millions more, but it was decided at that time that digitizing current observations as they came in would take precedence, assuming that astronomers would need current data more than archival data.

By 1973 keypunch machines were common in large office and scholastic environments. Charles Scovil, for example, made arrangements with Darien High School in Connecticut to use their keypunch machines during off hours (Scovil 1972). The AAVSO developed its own keypunch training program which enabled volunteers and staff to enter the observations that came in each month (Figure 1). Some observers were already starting to send observations to AAVSO Headquarters on keypunched cards (Mayall 1973).

In just six years the number of cards being processed and physically stored by the AAVSO—then at about 100,000—was becoming a problem (Mattei 1974). At this point only data from 1960 on, with the exception of a two-month period in 1973, had been digitized; the project of digitizing AAVSO observations from 1911 to 1960 had not yet begun. *Report 30* was being compiled, and the 130,000 published observations used for *Report 28* and *Report 30* were stored on four separate magnetic tapes kept in four separate locations for safety. With those tapes the AAVSO had a small taste of the future, and was gearing up for its second data processing revolution.

The AAVSO had digitized its membership list by 1973 as well, allowing the office to create computerized mailing labels and to generate selective mailings (Ford 1974; Mattei 1974). Data analysis programs had been part of the AAVSO from the start of its digitization process created at that point by AAVSO member Barbara Welther, who was a staff researcher at SAO. One program written by Welther during this period was one that found and noted maximum and minimum dates for Mira variables for *Report 30*. Up to this point the AAVSO staff were processing these data by hand, augmented by a program that produced 10-day mean light curves. It now became faster to do it all by computer, and Barbara Welther came up with the program with which to do it.

3. The second revolution—better control of data

1974 saw its first of many AAVSO in-house programmers when MIT student Richard Strazdas joined the staff (Figure 2). Under Strazdas the AAVSO continued to move away from the hand-plotting of light curves, a road which eventually led to the web-based Light Curve Generator that we know today. Strazdas' method involved deriving light curves from density curves where the number of observations at specific magnitudes were printed at each date. This method, for the first time, allowed the AAVSO staff to easily find observational outliers, notifying and guiding observers toward gathering better data. At this point light curves were produced using alphanumeric characters on line printers. Their resolution was quite poor. It was not possible to plot individual observations, only 5-day means, using this technology (Mattei 1975).

Over the next four years Strazdas wrote several programs in FORTRAN (a language the AAVSO still uses productively today) that specifically used data that were stored and read from magnetic tapes. The data processing procedure began with observations being keypunched onto cards, which were then stored on magnetic tape. A program called VALID initially checked the data and corrected or flagged it for errors in designation, star name, and so on. BSORT then read the output of this program, which was also stored on tape, taking the place of a mechanical card sorter. A third program, BMERGE, combined the two different sorted data sets. Thus the first half of the second data revolution for the AAVSO had been accomplished. Instead of using cards for computer program input, the cards were now a backup to the much more flexible magnetic tapes (Hill 1977).

The second half of the second revolution involved two computer plotting units then owned by SAO; a Versatec electrostatic plotter, and a Calcomp ink-based plotter. These plotters, under the direction of Strazdas-written programs, aided by Robert S. Hill, allowed for the first time individual data points to be plotted as the computerized light curves that we would recognize today. With such improved resolution in computer produced light curves, the observational density and scatter in a plot of observations (always evident on the data hand-plots) finally became apparent (Ford 1977). This method was used for all future reports and publications, thus completing the AAVSO's second data processing revolution (Hill 1977). It had started with punch card processing and gone to tape processing, and from line-printer produced 10-day mean light curves to plotted individual observations. The plotting aspect of the revolution, while seemingly starting out well, had a hard birthing.

Technology continued to move forward in late 1978, but the AAVSO had to halt for a technological pit stop. The Harvard-Smithsonian Center for Astrophysics (CfA) upgraded its main computer from a CDC 6400 to a DEC VAX 11/780 and all the programs that ran on the CDC 6400 had to be rewritten for the DEC VAX architecture. Having no full-time programmer at the AAVSO, this conversion took weeks—it was supervised by Richard Strazdas with the help of two students, Christopher Walton and Sandra Galejs. The switchover put the publication of *Reports 38* and *39* on hiatus while Strazdas and his team converted the needed programs and developed new ones (Mattei 1979).

Data entry, something the AAVSO had gotten rather good at, forged ahead through mid-1980. Under Elizabeth Waagen's direction, all data from 1960 up to the then current time—325 boxes of IBM punch cards comprising 650K of data—were now on magnetic tape and sorted by star name and date. Light curve plotting stumbled, however, and the *Reports* could not be published. The Calcomp plotter that Strazdas had written his plotting programs for had never been moved to the new DEC VAX 11/780 from the CDC 6400. The AAVSO purchased a new plotter—an FRS80 Graphics computer from AVCO Computer Services—and Strazdas adapted his plotting programs to it (Mattei 1980).

By mid-1981, with the data from 1960 onward now machine-readable, progress towards the goal of converting into machine-readable format all data from the founding of the AAVSO to 1960—2.5 million observations—began (Mattei 1981). With this project, and the need to continue keeping up with incoming observations, the AAVSO was pushed into its next revolution, its largest yet: independence.

4. The first in-house computer system

The technology and cost of microcomputers had just gotten to a point where they might be a feasible alternative for the AAVSO. At the other end of the scale, the increasing volume of IBM punch cards was literally filling Headquarters and squeezing everything else out. An in-house system was needed that could deal directly with floppy disks and maintain the publishing schedule the AAVSO had created. Mattei initiated a massive research and funding project to find and purchase an appropriate and affordable microcomputer system. It culminated in the AAVSO obtaining, through a grant from the Research Corporation, two

Ithaca Intersystems computers in December of 1981 (Mattei 1982). The first was a Z80-based computer running CP/M, with a graphics terminal and a plotter. The other was the DPS-8000, a Z8002-based multi-user system running COHERENT, a UNIX look-a-like operating system, with three terminals for data entry, word processing, and other office work (Figure 3). Both systems boasted 64,000 bytes of random-access memory.

The acquisition of its own computer did not immediately cut the AAVSO's ties to Harvard—not by a long shot. While the Ithaca Intersystems computers were advanced microcomputers for the time, they were too small to handle the AAVSO's data processing needs. The Ithaca's greatest contribution was that it enabled the AAVSO to move past punch card storage to eight-inch floppy disks for temporary data storage. Now, instead of data being punched onto cards which were stored and then retreived to be read onto magnetic tape, data were keyed onto the disks, then verified (re-keyed to check for errors), then converted to a DEC-readable format, read into the PDP 11/60, transferred to the DEC VAX 11/780 for processing, and stored on permanent tape, while storing the diskettes as a backup.

The monthly data inflow to the AAVSO—15,000 to 20,000 observations at this point (Waagen 1984)—was too much for the microcomputer to handle; observations were still stored on magnetic tape which the AAVSO could not read on its own. When observations of a specific time period were needed for publication, the storage tape would be read into the VAX, transferred to the PDP, and copied onto diskettes for processing at the AAVSO. In 1984 the PDP 11/60 was decommissioned and its disk readers transferred to the VAX 11/780, taking one step out of this process (Waagen 1984).

While diving into computer use itself, the AAVSO also recognized that its observers were able to take advantage of this technology as well. To assist them, the AAVSO sponsored a computer workshop as part of its AAVSO 73rd Spring Meeting in 1984, in Ames, Iowa.

Despite the advances in information processing, the huge *Reports* were abandoned as Mattei learned that researchers preferred a long span of data on one star to a short span on hundreds. Capitalizing on the information technology that it did have, the AAVSO began publishing a *Monograph* series, each of which concentrated on the twenty-year light curve of a specific star. The International Astronomical Union (IAU) welcomed and praised this initiative (Mattei 1984).

5. Growth in data processing capability and application

In 1986 the AAVSO moved to Birch Street and prepared to celebrate its 75th Anniversary. As one can imagine, the move put most work on hold for awhile as things were packed, moved, and unpacked (Mattei 1986). Still, the staff, under Mattei's leadership, continued to gain technological ground. A

Perkin Fund grant enabled the hiring of two full-time staff for the archival data entry project. With their help, by 1986, twenty-five percent of the AAVSO archival data for 1911–1961 had been converted to machine-readable form.

The IBM PC clone, and the first stages of networking, came to the AAVSO in 1987. The clone, sporting a 40-megabyte hard drive, connected the AAVSO to CfA through a modem device. The Kenilworth Fund bought Headquarters a laser printer and scanner. Observers began submitting data to Headquarters using diskettes and email. By 1989 the first articles featuring computer analysis of variable star data by AAVSO members were being published in *JAAVSO* (Mattei 1988). FORTRAN programs originally written for the VAX 11/750 were now rewritten for the IBM PC. Also, Grant Foster (Figure 4) began to write a series of graphical programs which allowed real-time manipulation of light curve data on the computer screen; these programs were not for data entry and editing, but for actual statistical analysis of the data (Mattei 1989).

The addition of 600 megabytes of hard drive space on the main computer in 1990 allowed all the variable star photometry from 1960 onward to come home from CfA. AAVSO staff migrated the data from storage tape to magnetic cartridges. The AAVSO installed its first local area network (LAN) in 1991 using 10base-2 LANtastic technology. These were used to tie together ten PC clones bought for the staff through a NASA grant (Mattei 1991). Headquarters began experimenting with commercial data services by putting astronomical data on Compuserve in 1992 (Mattei 1992).

A Theodore H. Dunham Fund for Astrophysical Research grant expanded the hard drive storage capability at AAVSO Headquarters to 2.4 gigabytes in 1993, just in time to aid in the completion of the archival project. Now the AAVSO had the entire AAVSO International Database in computer readable form right on site! Spearheaded by Grant Foster, AAVSO staff wrote programs to facilitate analysis of the data that Headquarters had spent more than twenty years digitally archiving.

In 1995 William Mackiewicz (Figure 5) became the AAVSO's first webmaster; he created the organization's first website and file transfer protocol (FTP) server. An IBM PC clone running GNU/Linux provided the AAVSO's first Internet services. By 1997, the AAVSO used its website to provide charts, and its *AAVSO News Flash*, *Circulars*, and *Alert Notices* to the public. With over 400 visits a day, the AAVSO website was named one of the top education-related sites on the Net (Mattei 1998). Users responded in kind with fully fifty percent of the monthly reports being sent to Headquarters electronically by 1997.

The AAVSO went from one computing strength to the next, but there were a few potholes along the way. Increasing reliance on technology meant that problems would crop up from time to time, and the AAVSO was not immune to this. In 1991 a bad sector on a hard drive caused the first AAVSO data loss. Through redundant diskette backups the staff was ultimately able to recover the data. In 1997 a vandal broke into the Linux server but did not compromise data. The vandal only created and ran his own chat room.

6. Successfully riding the technological wave?—an assessment

It seems clear that the AAVSO had a good track record of using technology to accomplish its mission. How close was the AAVSO to "riding the technological wave" that confronted it? Some non-profits don't do well with this, usually due to limited funds.

It is difficult to assess the exact state of a technological wave in a practical sense. Keypunch machines and keypunch cards were in use before WWII. The AAVSO started using them in the mid-1960s, borrowing time and resources from larger organizations to build its computational legacy. The AAVSO's computational technology from the mid-1960s until 1980 was dependent on the resources used at SAO and CfA, so during this time how the AAVSO fared technologically was somewhat tied to how those organizations fared.

The AAVSO moved to punch cards at the very end of their practical life. For programming purposes punch cards had fallen out of use in production environments by the 1970s, but they would continue to be used for data storage at the AAVSO right through the early 1980s, largely due to the availability of older machines in large data centers. In the end, the AAVSO was driven from cards for the exact same reason everyone else was—lack of space.

The AAVSO, through its partnership with CfA, kept up with hardware advances pretty well with the VAX 11/780 mini-computer. CfA upgraded to this computer in 1978, less than a year after DEC announced it at the Annual Shareholder's Meeting in 1977 (Digital Equipment Corp. 1997).

Sometimes being close to the edge can have its downside if looked at in hindsight. The AAVSO spent a good bit of time and research toward purchasing their two Ithaca Intersystems computers. To modern eyes the purchase of a CP/M system in 1981 looks shortsighted, but at that point there really wasn't any other microcomputer option available. The very first IBM PC went on sale in August of that year and had no track record as yet. Furthermore, DOS was not designed as a multi-user operating system, or as a file server. CP/M had over a ten-year history and, indeed, IBM itself had originally selected CP/M as the operating system of the IBM PC, but talks in 1980 with Digital Research, Inc. failed, and IBM decided to go with with Microsoft for its operating system (Anthony 2011).

While perhaps the best choice, the Ithaca Intersystems computers also featured a swan song in terms of storage. The system initially used eight-inch floppy disks introduced for CP/M in 1977. This was the last introduction of an eight-inch floppy drive. While old technology, the drive featured one megabyte of storage formatted for CP/M, while the best a 5.25-inch floppy could do at the time was 87.5 kilobytes (Sollman 1978).

The first IBM-compatible was released in late 1982. Several companies struggled for a year or so before finally achieving an acceptable level of compatibility with it (Reimer 2005). It took until 1987 for PC-compatible computers to show up at AAVSO Headquarters, by which time they had become commodities. In this case the AAVSO waited five years to enter the PC market. In parallel, that first AAVSO PC-compatible allowed communication with the CfA through a Hayes Smartmodem compatible, which was released in July of 1981 (Markoff 1983).

In contrast, in terms of local area networking, once the PCs arrived at Headquarters, the AAVSO stepped right into setting up a LAN. While Artisoft's LANtastic is not widely remembered today, at that time it rivaled Novell in the PC networking market. Neither Novell nor Artisoft foresaw the rise of TCP/IP networking, but both products still exist today. LANtastic is currently on version 8.

Arguably, one of the most significant information technology events for the AAVSO was its adoption of the World Wide Web. Sir Tim Berners-Lee released the Web in August of 1991 (Berners-Lee 1991). The AAVSO's first web server went online in 1995. While a four-year lag may seem somewhat significant, Berners-Lee's Web did not take off until the introduction of the Mosaic web browser in 1993 (Andreessen 1993).

In the same year that Berners-Lee introduced the Web, Linus Torvalds introduced the Linux kernel (Torvalds 1991) which the AAVSO's first, and all subsequent, web servers ran on. Torvalds' release of the kernel under the GNU General Public License in 1992 accelerated the creation of the free UNIX-like operating system which we know today as GNU/Linux (Stallman 1997). In March 1994 Linux reached version 1.0 and Linux distributions such as Slackware and Debian were in wide release. The AAVSO adopted GNU/Linux just over a year after it became practical.

7. Conclusion

While the AAVSO is a non-profit corporation, it may not be valid to compare them to other non-profits such as librairies in their technological adoption curve. At its heart the AAVSO is a technological organization and so it needs to come up to a higher bar. Couple this with the financial issues that most non-profits seem to go through—and the AAVSO is no stranger to financial challenges—the organization seemed to do a pretty impressive job of taking advantage of technology whenever it could.

Taking advantage of technology when it became available requires adaption to change at a very fundamental level. Both people and organizations find that difficult. It takes strength in an individual and strong leadership in an organization. Margaret Mayall, with the help of technologically astute people on the AAVSO Council at the time such as Clint Ford, as well as friends at SAO such as Owen Gingerich and Barbara Welther, allowed the AAVSO to make its initial leaps into using technology to improve the efficiency of the organization.

When Janet Mattei initially came on board she continued with the progress that Mayall had begun. Soon, though, spurred on by the success of the initial digitization project that allowed her to reach for larger government contracts and backing, Mattei made significant steps of her own that not only continued to improve the efficiency of the organization, but allowed it be stay competitive and relevant in the face of progress.

8. Acknowledgements

The author would like to acknowledge Elizabeth O. Waagen, AAVSO Senior Technical Assistant, and Michael Saladyga, AAVSO Technical Assistant, for serving as co-authors on the poster that preceded this paper. Dr. Saladyga's assistance with the AAVSO Archives was invaluable. We would like to acknowledge the rest of the AAVSO staff as well, especially Dr. Aaron Price, for their inspiration and support.

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Table 1. Timeline of events in the development of AAVSO information technology.

Date	*Event*
1967	Computer processing starts for the AAVSO using facilities at the Smithsonian Astrophysical Observatory to put data on IBM punch cards.
1972	Charles Scovil makes arrangement with Darien (Connecticut) High School to use its key punch machine in off hours. With that help, the AAVSO staff is working on keypunching incoming observations and working on starting work on reports from 1911 and later.
1973	The AAVSO membership list information is now put on IBM punch cards. The main data processing thrust at this point is using keypunched entered data in preparing the *Reports*. At this point *Report 30* is being compiled. The published data for *Reports 28* and *29*—130,000 observations—are being put onto four copies of magnetic tape.
1975	MIT student Richard Strazdas develops (based on an existing program) a method wherein light curves are obtained as density curves in which the number of observations at specific magnitudes are printed at each date. The program then plots the light curve. This allows the study of computerized plots and the detection of anomolous observations. Observational data from 1960 to May 1968 are processed. June 1968–November 1974 is not processed or must be reprocessed due to error. This became known as "The Gap." AAVSO staff computerizes the membership database and mailing labels for mailings which are made using SAO computers and printers.
1978	Harvard-Smithsonian Center for Astrophysics (CfA) upgrades its CDC 6400 computer to VAX 11/780. The AAVSO converts all data and programs to be compatible with the DEC VAX 11/780. The PDP 11/60 is still in use there as a data reader.
1979	All data from 1960, sorted by star and date, are now on magnetic tape and are machine-readable.
1980	The "Gap Data" are finally processed. The AAVSO begins computerization of data from 1911 to 1961. This is a multi-year project. AAVSO Headquarters is taken over by punch cards; Director Mattei is determined that something needs to be done about their storage. The AAVSO researches the feasibility of purchasing its own computer system using 8-inch floppy diskettes as storage media. An in-house system is needed to offset increasing publishing costs. The

table continued on following pages

Table 1. Timeline of events in the development of AAVSO information technology, cont.

Date	*Event*
	system needs to have a graphics terminal, plotter, and printers and be compatible with the DEC VAX at CfA.
1981	Through the Charles M. Townes Fund, the AAVSO buys two Ithaca Intersystems microcomputers with the CP/M operating system. One is a single-user system comprised of a computer, terminal, graphics terminal, and plotter which is used to plot data on screen, check, edit, and plot the data to paper. The other is a multiuser system with three terminals, two for data entry, and one for word processing for *JAAVSO*, correspondence, mailing list, and other office work. Incoming observations are now stored on 8-inch disks and processed using the VAX at CfA, and stored on magnetic tape at CfA.
1982	AAVSO Treasurer Theodore Wales buys a terminal and a pair of disk drives for the new AAVSO computer system. The monthly inflow of observations attains the 15,000–20,000 level—too big for the Intersystem computer to handle. These data still processed at CfA.
1984	CfA decommissions its PDP 11/60. The disk readers are put on the VAX allowing the VAX to read AAVSO data directly. Charles Jones, an MIT student, writes a data editing program for the Intersystems computer allowing editing to be done in-house. The AAVSO holds a Computer Workshop as part of its 73rd Spring Meeting.
1985	25% of archival data from 1911 to 1960 is put to tape. HQ uses its computers to produce the *AAVSO Monograph* series.
1986	The AAVSO moves to Birch Street. HQ begins exploring the possibility of observers submitting data on diskettes or via modem. There is a near-complete turnover in AAVSO programming staff.
1987	A new IBM PC connects AAVSO HQ with the DEC VAX at CfA via modem. The PC has a 40 megabyte hard drive. The Kenilworth Fund buys HQ a laser printer and scanner for the PC clone.
1989	The first *JAAVSO* articles detailing computer use in amateur variable star observation and research begin appearing. VAX FORTRAN programs are rewritten to run on PC clone. Data processing is now done at HQ, not CfA, but CfA equipment is still used for tape storage. The AAVSO begins supporting the HIPPARCOS data mission. The AAVSO researches data storage solutions with the goal of migrating

table continued on next page

Table 1. Timeline of events in the development of AAVSO information technology, cont.

Date	*Event*
	all CfA-stored data to in-house storage. The archival data project is 77% complete. Grant Foster writes a new light curve plotting program that uses a scale compatible with existing hand-plotted light curves.
1991	NASA grants provide a terminal or stand-alone computer system (IBM clone 186, 386, 486) for each staff member (ten in all). All workstations are networked via LANtastic LAN to the main computer for file access. First reported data problem: bad sectors on a disk cause data loss that needs to be recovered. The archival data project is 97% complete.
1992	Grant Foster writes programs to plot light curves on-screen for any star, expand any portion of the light curve, identify observations of observers on the light curve, and evaluate an observation and change its status. The AAVSO is now listing data on Compuserve.
1993	AAVSO staff complete the data entry phase of the archival data project. Now the data have to be processed! The plan is to have this done in three years. A Dunham Grant adds 1.8 gigabytes of storage to the main computer system bringing its total to 2.4 gigabytes. The AAVSO now switches its focus somewhat to writing programs to analyze its data.
1994	The AAVSO purchases its first Pentium computer and CD-ROM reader through a NASA HIPPARCOS grant.
1995	The AAVSO appears on the World Wide Web. William Mackiewicz, the AAVSO's first webmaster, also establishes an FTP site. Internet services are being run on a PC clone using GNU/Linux.
1996	The AAVSO acquires two Pentium computers, and places 114 charts on its FTP site. The AAVSO website sees about 228 visits per day.
1997	The AAVSO uses its website to distribute the *AAVSO News Flash, Circular*, and *Alert Notices*. The website now sees 483 visits per day. The FTP site has 2,179 files downloaded each month. The entire AAVSO database is archived on ZIP disks. 50% of monthly observing reports arrive electronically, up from 32% the previous year. Archival processing completed. Grant Foster writes WWZ, a time-series analysis program. All workstations are running Windows95 and are upgraded to 486s or Pentium. A vandal breaks into the GNU/Linux server. The AAVSO website named one of the best education-related sites on the web.

Figure 1. Keypunching operations performed by work-study students at AAVSO's Concord Street Headquarters in the early 1980s.

Figure 2. Richard Strazdas, MIT student who wrote data processing and file-transfer programs for the AAVSO beginning in 1974.

Figure 3. The Ithaca-Intersystems computer at AAVSO's Concord Street Headquarters, early 1980s. The system brought AAVSO's data processing operations in-house. Some of the hundreds of boxes of punch cards can be seen on the left, forming a work-area partition.

Figure 4. Grant Foster, AAVSO programmer from the late 1980s to the early 2000s.

Figure 5. William Mackiewicz became the AAVSO's first webmaster in 1995.

20 Million Observations: the AAVSO International Database and Its First Century *(Poster abstract)*

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Presented at the 100th Spring Meeting of the AAVSO, May 23, 2011

Abstract The American Association of Variable Star Observers (AAVSO) turns 100 in 2011—a century of service to the astronomical community! Another milestone was reached in 2011: the AAVSO International Database (AID) received its 20 millionth variable star observation! The AID contains observations of over 14,750 objects contributed by over 7,500 amateur and professional astronomers worldwide. Data on hundreds of objects extend from the AAVSO's founding in 1911 or earlier (mid-1800s) to present. Some objects' data are of shorter duration but of intense, high-precision coverage. Historical datasets come from published/unpublished professional/amateur observations, astronomical plate collections, and contributed archives of other variable star observing organizations. Hundreds of observations are added to the AID daily as observers upload their data in near real-time. Approximately 69% (~13.9M) of AID observations are visual, 30.4% (~6.2M) CCD (BVRI, unfiltered, Sloan colors, others), 0.5% (~75K) PEP (BVJH), and 0.1% (~17K) photographic/photovisual. Many objects have exclusively visual data, some PEP or CCD data only, and many a combination of types and bands. Objects range from young stellar objects through highly evolved stars. Included are intrinsic variables—pulsating (SX Phe stars through Miras and semiregulars) and eruptive (cataclysmic variables of all types)—and extrinsic variables—eclipsing binaries, rotating (RS CVns)—and exoplanets and suspected variables. Blazars, polars, quasars, HMXBs - today's AID is a thriving, exciting resource! The AID is maintained in a dynamic MySQL database, easily accessible to contributors and users alike through the AAVSO website (http://www.aavso.org). The Light Curve Generator, Quick Look page (recent observations), and Data Download form offer different ways to view/investigate your targets. Quality control performed from submission through validation ensures reliable data for your research. Visit the AAVSO website if you need data; contact us if we may help you observe your targets. We are here for you!

Professional Astronomers in Service to the AAVSO *(Poster abstract)*

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Presented at the 100th Spring Meeting of the AAVSO, May 23, 2011

Abstract Throughout its 100-year history, the American Association of Variable Star Observers (AAVSO) has welcomed professional astronomers to its membership ranks, and has encouraged their participation as organization leaders. The AAVSO has been fortunate to have over 60 distinguished professionals serve as officers (Directors, Presidents, Council), and as participants in its various scientific and organizational committees.

The Variable Star Observations of Frank E. Seagrave *(Abstract)*

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Presented at the 100th Annual Meeting of the AAVSO, October 7, 2011

Abstract I will discuss the relationship between Frank Evans Seagrave (1860–1934) of Providence, Rhode Island, and the Harvard College Observatory, and analyze the modest contribution Seagrave made to our database between 1895 and 1913, relating a few anecdotes from his life as a self-taught astronomer whose relationship with Dr. Pickering ended in controversy, but whose legacy is carried on by Skyscrapers Inc., the astronomical society which now owns and operates Seagrave Observatory in North Scituate, Rhode Island.

Apollo 14 Road Trip *(Poster abstract)*

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Presented at the 100th Annual Meeting of the AAVSO, October 8, 2011

Abstract In January-February 1971, five astronomy enthusiasts, Dennis Milon, Alan Rowher, Sal LaRiccia, Mike Mattei, and Paul Valleli, drove from New Haven, Connecticut, to the Kennedy Space Center at Cape Canaveral, Florida. They joined with ALPO Jupiter Recorder Julius Benton in Atlanta.

After several stops along the way, the six arrived at the Apollo 14 launch site to observe pre-launch activity, met NASA personnel, and toured various facilities. On launch day, thanks to press passes provided by Dennis Milon who was there as the official photojournalist for *Sky & Telescope*, they met the Apollo crew and witnessed the launch. On the return trip, they made time to meet Mike Mattei's new girlfriend, Janet Akyüz, who was working on her Master's at Leander-McCormick Observatory in Charlottesville, Virginia. Janet gave the six men a tour of the observatory, including the the 26-inch Clark Telescope.

Scientific session papers presented at the 100th Spring Meeting of the AAVSO, in conjunction with the 218th Meeting of the American Astronomical Society

Introduction to the Joint AAS-AAVSO Scientific Paper Sessions

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Preparations for the joint AAS-AAVSO meeting (May 2011) were well underway in 2010 when I began planning the joint sessions that would bring the AAS and AAVSO together. As someone with roots in both organizations, I wanted to plan science sessions that would bring the Amateur and Professional researchers and observers into the same room and provide an opportunity for each to learn about new science and new initiatives by the other. I worked closely with AAS Vice Presidents Lee Anne Willson and Christine Jones-Forman to schedule a day's worth of sessions that would interest both of our communities. We settled on two special sessions that would highlight both the field of amateur observing and the astrophysics that we hope to gain from studying variable stars.

On the observing side, we chose "Astrophysics with Small Telescopes" to give a forum to researchers using small telescopes to do big things. There are two parallel trends operating in research astronomy today. On one hand, astronomical researchers face smaller budgets and more competitive access to astronomical facilities, and those professional facilities that exist increasingly consist of very large telescopes not necessarily appropriate for doing astrophysics on bright variables. On the other hand, we are seeing increasingly sophisticated detectors and telescopes of high quality but low cost available through the consumer market. Given the technology that's currently available, the number of projects available to researchers with modest equipment is growing rapidly, and we wanted to highlight some recent novel uses of small telescopes that have brought us new and valuable astronomical and astrophysical knowledge. Ultimately, the goal of the session was to highlight the fact that there remains a great deal of astrophysics left to be learned at brighter magnitude limits, exactly where the amateur observer community can make its greatest contributions to science.

AAVSO Director Arne Henden led the session with an overview of how observers with very modest telescopic resources can and do make observations of remarkable quality, opening new opportunities for astrophysical research. This was followed by a talk by Michael Simonsen, who led the AAVSO's "Z-CamPaign," a wholly-amateur effort to characterize a large number of candidate Z Camelopardalis variables, yielding light curves of superb quality along with some surprising astrophysical results, chief among them that many "Z Cam" stars are not Z Cam stars at all! Long-time Pro-Am leader Joseph Patterson then gave a review of the Center for Backyard Astrophysics research program on cataclysmic variables, which has not only produced great new astrophysics but also serves as a model for how Pro-Am collaborations among geographically distributed, dedicated researchers can work. Gaspar Bakos presented a talk on HATNet, a novel robotic observatory using small telescopes to search for transiting exoplanets. The fact that HATNet can produce such great science on exoplanets highlights the fact that small-telescope observers can and do make great contributions to this new field of stellar astrophysics, but HATNet also highlights a growing trend of using very small telescopes to survey bright nearby variables that are being left behind by ever-larger professional facilities. Robert Stencel provided a review of the recent multi-year campaign on ε Aurigae, with extensive participation in observations by the amateur community. Stencel highlighted the enormous contributions that the amateur community has made via the most recent and historic eclipses, as well as new tools—like digital photography and amateur spectroscopy—that provided novel astrophysical information about ε Aurigae's once-in-a-generation eclipse. To end the session, John Percy highlighted one of the AAVSO's greatest treasures—our long-term data archives. Data archives such as those held by the AAVSO and other amateur Variable Star Organizations provide astrophysicists with one of their only views of variable star behavior on long timescales. Such data archives are a rich mine of data for variable star researchers—amateur, professional, and student alike.

For the afternoon session on astrophysics, we chose "Variable Stars in the Imaging Era" as the unifying theme. We are moving forward into a new era where we see stars not as astrophysical point sources but as resolved objects with detectable structure using technology like optical interferometers and space-based observatories operating at all wavelengths of the electromagnetic spectrum. Variable stars are of particular interest in this field because we can then gain deeper understanding by coupling knowledge of their spatial structure with knowledge gained from studying their variability. By combining the new information from imaging with additional photometry by the amateur community, we can improve our understanding the underlying astrophysics.

Margarita Karovska led the session with a discussion of direct imaging of stars and systems with space-based telescopes like the Hubble Space Telescope and Chandra X-ray observatory, and how these observations expand our understanding of stars and stellar systems across the Hertzsprung-Russell diagram. This was followed by a talk by Thomas Barnes on the use of interferometric measurement of Cepheid diameters as an important direct check on the Cepheid distance measure calibration so critical in modern cosmology. Brian Kloppenborg presented a talk on the use of interferometric imaging in the optical and infrared, and how such measurements complement photometric measurements obtained by more traditional variable star observation. We note especially that Brian was a member of the team that made interferometric observations of the ε Aurigae system that proved so strikingly the eclipse of the primary star by a large disk around the secondary. Angela Speck gave a talk on the critically important role that stars play in the evolution of the interstellar medium. She highlighted recent results on mass loss from AGB stars and the properties of interstellar medium surrounding them, gained from observations with new and greatly-improved infrared instrumentation on the ground and in space. Finally, Sam Ragland ended the session with a talk on how optical and near-infrared interferometry are allowing us to probe structure in AGB star atmospheres. Ragland and collaborators have made a number of fascinating discoveries in recent years, including the remarkable one that most if not all Miras show asymmetries suggestive of large-scale photometric variations in their photospheres. New techniques in imaging these stars will provide new insight in this important phase of stellar evolution.

I hope that attendees took at least two things away from these sessions beyond the specific projects outlined here. First, there is an enormous amount of astrophysics left to be learned "at the bright end." While the technological capabilities of astrophysics continue to expand, there remains a great deal of extraordinary science to be done with "ordinary" instrumentation that is within the means of a far larger pool of researchers than major research facilities can serve. Second, the professional and amateur research communities can and do complement one another in the modern era, just as they always have. Fundamentally the amateur community continues to provide support to the professional research community by providing things like long-term observations of variable stars. However, what has changed more recently is the capability of the amateur community to innovate and become more directly involved in specific research projects, either in collaboration with individual professionals or through novel research programs of their own. There remains a great deal of room for observers at all levels—from casual amateurs enjoying an evening outside under the stars to dedicated amateur researchers pursuing their own astrophysical questions—to contribute to variable star astrophysics in the modern era. The community of variable star astronomers remains a diverse and thriving one.

I would like to extend my thanks to all of the speakers who were willing to contribute to these sessions and present their work and ideas to a diverse audience. I would also like to thank the two people who assisted with the planning and scheduling of these sessions, Dr. Lee Anne Willson of Iowa State University, and Dr. Christine Jones-Forman of the Harvard-Smithsonian Center for Astrophysics. I am greatly indebted to all of you.

Astrophysics With Small Telescopes

Long-Term Visual Light Curves and the Role of Visual Observations in Modern Astrophysics

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Presented at the 100th Spring Meeting of the AAVSO, May 23, 2011; received November 30, 2011; accepted November 30, 2011

Abstract Thanks to organizations such as the AAVSO, visual observations of variable stars have scientific strengths: they are numerous, sustained, and standardized. Though many people have predicted the demise of visual observation, the demand for such observations increased dramatically in the last quarter of the 20th century. In addition to their value in detecting, timing, and studying outbursts in CVs, fadings in R CrB stars, and eclipses in binaries, they are uniquely useful in studying the behavior of pulsating stars, especially slow, irregular, and long-term behavior, and changes in period and amplitude. In this review, I give a general review of this topic, with some emphasis on my own work on pulsating red and yellow variables, and on T Tauri stars. Much of this work has been done by undergraduate students and outstanding high school students; I highlight the importance and potential of AAVSO visual data for educational use.

1. Introduction

AAVSO observers have accumulated over 13.7 million visual measurements of variable stars in the last 100 years. Indeed, earlier visual and photographic measurements are now being digitized, so that the AAVSO International Database (AID) is being extended *backward* as well as forward. The AID is a unique resource for studying the long-term behavior of variable stars. For many stars, observations are made on an almost daily basis, often by multiple observers, so the datasets are often also dense and continuous.

Furthermore: the AAVSO has endeavored to maintain uniform sequences and magnitudes of comparison stars over time, so the measurements are stable over time. From time to time, however, the AAVSO and other variable star observing groups have noted that their comparison star sequences and magnitudes differed. Also: photoelectric V magnitudes are now available for most comparison stars. In the first decade of the 21st century, the AAVSO embarked on a massive project to create the best possible set of charts and comparison star sequences, and make them available on-line.

2. Long-term visual light curves

For stars in the AID for which the datasets are long and dense, the light curve shows the behavior of the star on time scales from days to decades. This is important for classifying the star, and for noting novel or unusual behavior, as well as for discovering and studying long-term variability which would not be evident in shorter datasets. I remember when the AID first became digitized, and it was possible to plot long term light curves of variable stars. I was especially interested in yellow supergiants at the time, and was excited to see the long term light curve of the RV Tauri star U Mon. It was known to have a long secondary period of about 2,500 days; hence it is classified as an RVB star. The AID light curve clearly showed multiple minima, separated by 2,500 days, which were reminiscent of an eclipsing binary. It is now generally accepted that most/all RVB stars are binaries containing a dust ring or torus which periodically eclipses the star (e.g. Van Winckel *et al.* 1999).

Individual visual observations, from an ensemble of observers, have an average typical accuracy of 0.25 magnitude, as determined by self-correlation analysis (e.g. Percy and Terziev 2011 and many other similar studies). An individual experienced observer, with a good chart and sequence, can probably achieve better than 0.1 magnitude accuracy if the sequence is given to hundredths of a magnitude, and if they are not rounding to the nearest tenth of a magnitude; a group of observers using the same chart and equipment, and under the same sky conditions, is also probably good to 0.1 magnitude (Templeton 2011a).

If the observations are sufficiently dense, and if the time scale of the variability is sufficiently long, then the observations can be binned in, for example, 30-day means whose accuracy is much higher—sometimes approaching photoelectric accuracy. This approach has been used to delineate the variability of stars such as ρ Cas, with a period of about a year and a small amplitude (Percy *et al.* 1985).

3. Timing semi-predictable minima and maxima

The AAVSO has a long history of timing the minima of eclipsing variables, and the maxima of RR Lyrae stars. In these cases, the stars are sufficiently periodic to predict the *approximate* time of minimum or maximum. The observer monitors the star for a short interval around the predicted time, and is more-or-less assured of being rewarded. The precise time can be determined from the observations, using Hertzsprung's method or the tracing-paper method.

Of course: if the time was *perfectly* predictable, there would be no need to observe the star, but both types of stars show period changes. Also, the observations can be used to refine the value of the period, even if the period is constant.

In eclipsing variables, period changes are generally due to mass transfer or loss in the system. Uniform mass loss causes O–C (observed minus predicted or calculated time of minimum) to vary parabolically with time. Stars with non-parabolic (O–C) behavior are of special interest, since the cause of the period change is less obvious.

In RR Lyrae stars, the period changes are generally due to evolution. The slow evolutionary expansion or contraction of the star, if uniform, produces parabolic (O–C) behavior. However, the observed rates of period change seem to be greater than those predicted by evolutionary models and, in some stars, the behavior is distinctly non-parabolic (Smith 1995). Long term period changes in RRab stars (which are pulsating in the fundamental mode, and have maxima which are sharp and easy to measure) have recently been determined by Le Borgne *et al.* (2007). RRc stars, which are pulsating in the first overtone mode, and have maxima which are flatter and harder to measure, have been less well-studied. My students are currently working on some of these.

Visual timing of these minima and maxima is gradually being replaced by CCD observations, but the visual observations, stretching back for many decades, are essential for measuring rates of period change. The accuracy of these increases as the *square* of the length of the dataset.

Cepheid variables are arguably the most important pulsating variables, because of their use in distance determination, and because their period changes can be directly and effectively compared with evolutionary models. This work is almost exclusively done with photoelectric photometry; visual observations have played and probably will play a minor role (Turner 2012, this volume).

In Mira stars, the (O–C) behavior is dominated by the effects of random cycle-to-cycle period *fluctuations*, first studied by Eddington and Plakidis (1929). Such fluctuations are also found in RV Tauri stars, a few long period Cepheids, and at least one W Virginis star; see Turner *et al.* (2009) for a brief review.

In the 1980s, Petrusia Kowalsky, Janet Mattei, and I, with support from the J.P. Bickell Foundation, carried out a study of seventy-five years of visual data on almost 400 Mira stars. We measured the cycle-to-cycle period fluctuations; they typically averaged a few percent of a cycle (Percy and Colivas 1999). A very few stars showed large period changes which were due to rapid evolution; these have been studied in more detail by Templeton *et al.* (2005). Beneath these random changes, however, we were able to detect the slow evolution of the ensemble of stars, at least at the 2σ level (Percy and Au 1999).

Professional astronomers often need to know the visual brightness or phase of a variable star at the time when they make observations using other techniques or at other wavelengths. If the star is strictly periodic, this is straightforward. If the star is irregular, it is not, but AAVSO monitoring can help. As one example: the European Space Agency *Hipparcos* mission observed Mira stars in order to measure their parallax, but the magnitudes of the stars, when observed, had to be optimal. AAVSO observers monitored a large sample of target Mira stars continuously, providing the *Hipparcos* team with the necessary magnitude data (Menessier *et al.* 1992).

4. Observing unpredictable maxima and minima

One of the most important contributions of AAVSO visual observers to modern astrophysics has been in monitoring and reporting outbursts in dwarf novae, recurrent novae, and novae. These result from mass transfer in a close binary system consisting of a normal star and a white dwarf or neutron star. When an outburst occurs, astronomers can quickly mobilize ground-based and space telescopes to study the outburst and its mechanism. AAVSO observers also monitor the visual variability of the star during outburst, for comparison with other data. This work is so important and interesting that there is a separate paper on it in this volume, by Paula Szkody.

Unpredictable *minima* occur in R Coronae Borealis stars—hydrogen-deficient, carbon-rich stars which occasionally eject a cloud of sooty dust which obscures and dims the star. These are rare objects; only a few dozen are known in the Milky Way and nearby galaxies. AAVSO observers monitor these and, when a fading begins, notify professional astronomers who can use a variety of techniques and facilities to study the progress and nature of the fading.

The times of onset of the fadings serve another purpose: it has gradually been realized (Crause *et al.* 2007) that, in many or most of these stars, the onset of fading is "locked" to a pulsation period in the star. This implies that the ejection of the cloud may be caused by the pulsation. The times therefore contribute to our understanding of the *cause* of the R CrB phenomenon. In a few stars (notably RY Sgr: Figure 1), the pulsation is large enough to be studied using visual observations; one of my students is currently studying the long term systematics of the pulsation in this star.

5. Period analysis of variable stars

For decades, the AAVSO's "bread and butter" was observing Mira stars. These are large-amplitude pulsating red giants. From this came periods and amplitudes in hundreds of Mira stars. Both the periods and amplitudes are notoriously variable, and the importance of studying these variations has only recently been appreciated.

For periodic variables, *time-series analysis* (Templeton 2004) provides information about the periods and amplitudes, and their changes. Fourier analysis of visual observations of semiregular (SR) pulsating red giants (Kiss *et al.* 1999) reveals multiple periods, representing multiple pulsation modes, and also "long secondary periods" (LSPs) whose nature and cause is still not understood. Wavelet analysis of AAVSO Mira star data reveals a small fraction of stars whose periods are changing due to the rapid evolution of the star (Templeton *et al.* 2005; Templeton 2011b).

Smaller-amplitude pulsating red giants are normally observed photoelectrically; indeed, most of the stars on the AAVSO Photoelectric

Photometry (PEP) program are stars of this type. Visual observations of these stars can, however, yield pulsation periods and LSPs (Percy *et al.* 1993), as long as the periods are reasonably coherent and the dataset is sufficiently dense and long.

One of the best examples of the power of visual observations is the study by Kiss *et al.* (2006) of pulsating red supergiants. They studied forty-eight SRc and Lc stars, using visual observations from the AID. The mean time-span of the data was sixty-one years. They found pulsation periods, typically hundreds of days in length, in most of the stars. Eighteen stars showed multiple pulsation periods. In some of these cases, there was a long secondary period, similar to the LSPs found in about a third of pulsating red giants. From the Lorentzian shape of the individual power spectra, they deduced the presence of period "noise," which they ascribe to interplay between pulsation and convection. Thus in this study, visual observations revealed fundamental properties of the stars (pulsation periods), an astrophysical mystery (LSPs), and clues to the physical processes (convection) going on in the stars. There may be useful astrophysical information in the detailed power spectra of other kinds of stars in long term datasets in the AID.

An interesting case, from my own research, involved T Tauri stars—sunlike stars in the process of formation. They vary, usually irregularly, on many time scales, mostly due to variations in the rate of accretion of gas onto the star. But the stars are also rapidly rotating, and have non-uniform surfaces, so may also be rotating variables with coherent periods of a few days, which are their rotation periods.

Back in the 1970s, some AAVSO visual observers began observing these stars. They tend to occur in specific star-forming regions, so they can be observed very efficiently. The observers were able to make many thousand observations of them each year, and thus rank high on the annual lists of top observers. Finally, Director Janet Mattei declared that visual observations of T Tauri stars would be devalued by a factor of ten in the annual observer totals. The observations languished, unvalidated.

I was able to convince AAVSO staff to validate the observations of a few well-observed stars, as a pilot project, and my student Rohan Palaniappan (a high school student at the time) analyzed them (Percy and Palaniappan 2006). Using Fourier analysis, he was able to detect and measure the rotational periods with amplitudes of only about 0.03 mag in the visual data!

6. Irregularity

A large fraction of all stars in the AID are classified as irregular, often because there are insufficient observations to characterize the behavior of the star more fully. As one example: RV Tauri stars are defined as pulsating yellow supergiants showing alternating deep and shallow minima; SRd stars are irregular pulsating yellow supergiants. Detailed analysis of AAVSO visual observations of these stars shows that there is a smooth continuum of behavior from RV Tauri to SRd. There is even a link to W Virginis stars, in that some of these show a slight alternation between deep and shallow minima.

As mentioned above: many of the semiregular pulsating red giants (SR stars) are multiperiodic. My students and I have just completed a study of visual observations of several dozen red giants in the AID which have 250 or more observations, and which are classified as *irregular* (L type stars) (Percy and Terziev 2011). Their amplitudes are a few tenths of a mag in only a few stars; many/most are microvariable; quite a few are or probably are non-variable. A very few have a detectable period. Most of these stars are candidates for photoelectric observations, but the scientific value of such observations is not clear.

In pulsating yellow supergiants such as RV Tauri and SRd stars, there is strong evidence that the irregularity is a consequence of dynamical chaos. The same physical principles which produce coherent pulsation in dense, compact stars produce irregular pulsation in more distended stars. Theoretical studies have been made by Toshiki Aikawa, Robert Buchler, Zoltan Kollath, Geza Kovacs, Pawel Moskalik, Mine Takeuti, and their colleagues, and compared with long term AID light curves of Miras, RV Tauri, and SRd stars.

7. Other applications of visual observations

There are many other applications of visual observations, some of which are described elsewhere in this volume:

- Visual discovery and study of supernovae: observers such as Robert Evans in Australia have discovered dozens of supernovae in relatively nearby galaxies; these are very useful for calibrating supernovae as "standard candles" for cosmological purposes.

- Monitoring hypergiants such as P Cygni and ρ Cas for outbursts or other unusual behavior.

- Visual monitoring of T Tauri stars for slow, long term variations which are usually due to variations in their rate of mass accretion.

- Visual monitoring of symbiotic stars—close binaries with a cool giant component and a hot normal or compact star: these undergo eruptions, eclipses, and, in some cases, pulsation.

- Although visual observation of small-amplitude variables is not usually recommended, there are a few observers who, given the right star and the right circumstances, can achieve a visual accuracy of a few hundredths of a magnitude. A notable example is the study by Otero (2011) of the Be star δ Sco.

8. Educational considerations

The AID is a wonderful treasure chest of publicly-available scientific data which can be used by high school and university students to develop and integrate their science, math, and computing skills. Some of the data have never been fully analyzed; by analyzing these data, students can be motivated by the thrill of doing real science research. I have co-authored dozens of papers and presentations with undergraduate research students, and with outstanding senior high school students in the University of Toronto Mentorship Program (Percy *et al.* 2008). This educational potential was recognized early on by me and the late Janet Mattei; it led to the AAVSO's *Hands-On Astrophysics* (Mattei *et al.* 1996) which has evolved into *Variable Star Astronomy* (www.aavso.org/education/vsa).

Students can also observe bright stars (such as Mira and δ Cep) visually, just as the first variable star astronomers did centuries ago. In the case of δ Cep, they can tie their observations of the time of maximum brightness with those of John Goodricke and Edward Pigott in the 18th century, and actually detect the evolution of this star. There is great interest, among historians of science, in re-creating the key observations and experiments in the history of science.

9. Final reflections

Are visual observations obsolete? This is a question which has been asked for over three decades. In the first twenty-five years of "the space age" (the last twenty-five years of the 20th century), however, the demand for visual observations *increased* by a factor of 25, due to the rise of high-energy astrophysics (Szkody 2012, this volume). In 2011, the question is driven by the fact that visual observations now represent a small fraction of all the observations submitted to the AID, and by the impending advent of massive nightly robotic surveys of the sky. A slightly different driver is the fact that so many long-time visual observers are retiring, but this factor is more related to the "greying" of amateur astronomy; we must recruit more younger people to amateur astronomy, and variable star observing. And we must recruit both men and women, of all races and backgrounds. The popularity of projects such as *Galaxy Zoo* suggests that there are many thousands of untapped "citizen astronomers" out there.

My personal view is that visual observations can still play an important role, but it would help if the AAVSO provided stronger guidance, and if observers were willing to take it. Observers need a certain amount of flexibility and freedom, but they probably don't want to think that their observations are of little scientific value. Through a combination of training, motivation, and feedback, we can provide observers with the assurance that their observations are continuing to contribute to science.

Users of AAVSO data, such as myself, have a responsibility here; that's why my students and I like to use AAVSO data and to present our results at AAVSO meetings, and publish them in *The Journal of the AAVSO*. The newly-formed observing sections can also play a role in guiding the observing programs so that they are maximally effective. Formal reviews of the AAVSO observing programs, by either internal or external reviewers, could be carried out every few years. Those of us with research grants have our observing plans reviewed every time we apply to renew our grants!

Even if robotic sky surveys were to provide complete coverage of the sky currently performed by visual observers alone, existing and future visual observations (and the backward extension mentioned in the first paragraph) would continue to be useful because, for many purposes, the usefulness of a light curve increases with its length. It would therefore be important to be able to "match" the visual data to data from these surveys.

I would like to think that visual observations of variable stars will continue to be useful for decades to come—if only because there is a special joy in having the human eye and brain come in direct contact with the cosmos.

10. Acknowledgements

I thank the AAVSO observers and staff for providing, validating, and archiving millions of visual observations for the benefit of science and education. I also thank Dr. Matthew Templeton for his comments on this paper. Special thanks to the late Janet Mattei, my long-time colleague, friend, and guide to AAVSO data. I thank my students for their inspiration, talent, and hard work. Finally, I thank the Natural Sciences and Engineering Research Council of Canada for research support, and the Ontario Work-Study Program and the University of Toronto Mentorship Program for facilitating the involvement of my students.

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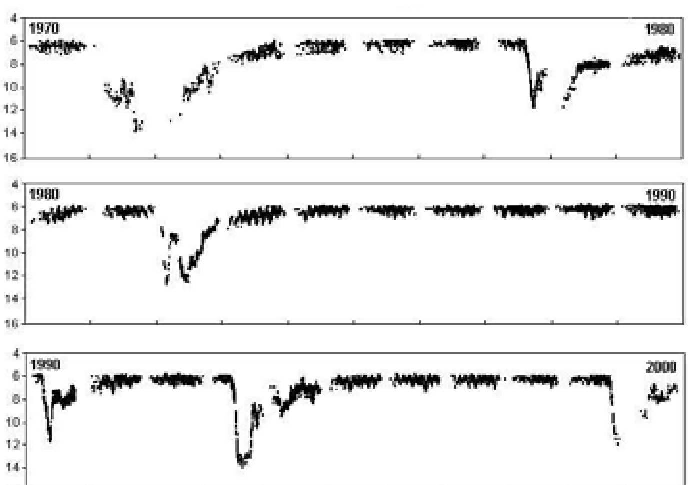

Figure 1. AAVSO thirty-year visual light curve of the R CrB star RY Sgr. The fadings, and their onsets, are clearly visible. The small-amplitude 40-day pulsational variability is also visible as a “sawtooth” when the star is at maximum.

Contributions by Citizen Scientists to Astronomy *(Abstract)*

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Presented at the 100th Spring Meeting of the AAVSO, May 23, 2011

Abstract The AAVSO's experience in utilizing the skills, equipment, and enthusiasm of amateur astronomers towards its research is not unique in astronomy. Citizen Scientists have contributed to our understanding of asteroids, exo-planets, solar system weather, light echoes, and galactic streaming, as well as inventing new equipment and software. This talk will highlight some of the recent advances by Citizen Scientists, and suggest some areas where they can contribute in the future.

Lessons Learned During the Recent ε Aurigae Eclipse Observing Campaign *(Abstract)*

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Presented at the 100th Spring Meeting of the AAVSO, May 23, 2011

Abstract The eighteen-month-long eclipse of the third-magnitude star, ε Aurigae, is forecast to end during May 2011, based on six eclipse events, in 2010, 1982, 1955, 1930, 1902, and 1874. In partnership with AAVSO, Hopkins Phoenix Observatory, and others, we have organized observing campaigns during the past several years in order to maximize data acquired during this rare event and to promote reporting and analysis of observations of all kinds. Hundreds of registered participants have signed up for alert notices and newsletters, and many dozens of observers have contributed photometry, spectra, and ideas to the ongoing effort—see websites: www.CitizenSky.org and www.hposoft.com/Campaign09.html. In this presentation, I will provide an update on the participation leading to extensive photometric results. Similarly, bright star spectroscopy has greatly benefited from small telescope plus spectrometer capabilities, now widely available, that complement traditional but less-frequent large telescope high dispersion work. Polarimetry provided key insights during the last eclipse, and we promoted the need for new data using this method. Finally, interferometry has come of age since the last eclipse, leading to the direct detection of the transiting dark disk causing the eclipse. Along with these traditional measurements, I will outline campaign-related efforts to promote Citizen Science opportunities among the public. Support for

these efforts derives in part from AAVSO/NSF-Informal Science Education, NSF AAG grant 10-16678, and a bequest to the University of Denver Astronomy Program by alumnus William Herschel Womble, for which I am grateful.

Ed. note: a more complete version of this paper will appear in the forthcoming epsilon Aurigae special issue, part of JAAVSO *Vol. 40, No. 2.*

Cataclysmic Variables in the Backyard *(Abstract)*

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Presented at the 100th Spring Meeting of the AAVSO, May 23, 2011

Abstract The last decade has seen plummeting prices and significant advances in CCD-camera and smart-telescope technology, reaching all the way to the humblest of telescopes. There are now thousands of well-equipped amateur astronomers interested in using their telescopes for research, and many hundreds already doing so in coordinated campaigns. Variable star science has benefited tremendously. Since it's always dark and always clear somewhere, coordinated photometry can accumulate nearly 24-hour coverage—and since the observers own their telescopes, very long campaigns are feasible, with little worry about weather. I'll describe one network of observers, the Center for Backyard Astrophysics (CBA). The telescope apertures are 20–50 cm, enabling good signal-to-noise and time resolution down to V=18. We organize campaigns of time-series photometry of cataclysmic variables (novae, dwarf novae, magnetic variables, some X-ray binaries)—and routinely achieve thousand-hour campaigns with no significant aliasing, since the telescopes are distributed around the world. This enables sensitive searches for periodic signals, extending even to long time scales (months). We now produce most of the world's supply of accretion-disk precession periods, and keep close watch on all the other clocks in cataclysmic variables (orbit, white-dwarf rotation and pulsation, and quasiperiodic oscillations).

Planet Hunting With HATNet and HATSouth *(Abstract)*

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Presented at the 100th Spring Meeting of the AAVSO, May 23, 2011

Abstract Transiting exoplanets (TEPs), especially those found around bright stars, are particularly important as they provide unique opportunities to study the physical properties of planetary mass objects. The Hungarian-made Automated Telescope Network (HATNet) project—one of the small telescope surveys—has been extremely successful in the field of TEPs, contributing twenty-seven published discoveries, and one independent discovery of a previously published planet. Publications on several additional planetary systems are in preparation. I will discuss how HATNet operates around the globe, and how these fully automated small (11cm diameter) telescopes produce big science. I will also mention the related HATSouth project, now in full operation, and monitoring selected southern fields round-the-clock. Finally, I will conclude on how small and big telescopes collaborate in exoplanet science.

The Z CamPaign Early Results *(Abstract)*

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Presented at the 100th Spring Meeting of the AAVSO, May 23, 2011

Abstract The Z CamPaign is an observing project designed to acquire enough detailed, long-term data to unambiguously classify dwarf novae as bona fide members of the Z Cam sub-type or not. Because the defining characteristic of all Z Cam dwarf novae are “standstills,” a temporary period of relative quiet between maximum and minimum light, we are monitoring these systems for this specific activity. Amateur astronomers are gathering all the data with backyard telescopes as part of an AAVSO Cataclysmic Variable Section observing initiative. We will discuss the organization, science goals, and present early results of the Z CamPaign.

Ed. note: this paper was published in JAAVSO *Vol. 39. No. 1.*

Variable Stars in the Imaging Era

Variable Stars and the Asymptotic Giant Branch: Stellar Pulsations, Dust Production, and Mass Loss

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Presented at the 100th Spring Meeting of the AAVSO, May 23, 2011; received February 17, 2012; revised March 26, 2012; accepted May 11, 2012

Abstract Low- and intermediate-mass stars (1–8 $M_{\odot}$; LIMS) are very important contributors of material to the interstellar medium (ISM), and yet the mechanisms by which this matter is expelled remain a mystery. In this paper we discuss how interferometry plays a role in studying the interplay between pulsation, mass loss, dust formation and evolution of these LIMS.

1. Introduction

1.1. The importance of cosmic dust

At the beginning of the Universe, all matter was in the form of hydrogen and helium: all elements heavier than helium form via nuclear fusion in stars. Newly-formed elements are ejected from stars either explosively (in the case of supernovae) or more gently over a few hundred thousand years for lower-mass stars like the Sun. These new elements then become part of the interstellar medium (ISM), from which new stars and their planets form.

With the emergence of infrared (IR) astronomy in the late 1960s, the importance of dust particles in the Universe began to be revealed. Dust is a vital ingredient in many astrophysical environments (Videen and Kocifaj 2002; Draine 2003; Krishna Swamy 2005). It plays an essential role in star formation processes, and contributes to several aspects of interstellar processes such as gas heating and molecule formation (Krügel 2008). In addition, since mass loss from evolved stars is driven by radiation pressure on dust grains, it is intimately linked to the precise nature of the circumstellar dust (Woitke 2006). Furthermore, dust has been observed at higher redshifts than expected, and understanding this phenomenon is vital to our understanding of the cosmos at large and its evolution (Sloan *et al.* 2009; Bussmann *et al.* 2009). Moreover, the detection of dust at high redshift raises concerns about the use of standard candles (for example, Type Ia Supernovae) as accurate distance indicators (Jain and Ralston 2006). Understanding the dust at high redshift is vital to cosmological models and dark energy studies (Corasaniti 2006; Jain and Ralston 2006). Dust needs to be well understood in its own right, if we are to understand how it contributes to many aspects of astrophysics.

1.2. Low- and intermediate-mass stars (LIMS)

The type of stars that produce the majority of the dust complement for the Galaxy start their lives as low- and intermediate-mass stars (0.8–8$M_\odot$; LIMS). Up to 95% of stars are LIMS (Kwok 2004). Studying the nature of dust around LIMS is important for three reasons: (1) this is where the dust originates, and thus knowing its initial state will allow us to predict more accurately its fate in and effect on the ISM and beyond; (2) the environment around most of these LIMS is relatively benign (little UV) and thus has simplified chemistry, which aids in our attempts to understand the processes in play and test current hypotheses of dust formation (which are also applied to many, more complex astrophysical environments); and (3) the evolution of LIMS is intimately linked to their dust production, and thus a feedback loop exists between dust production and stellar evolution. The precise nature of the dust grains must be assessed in order to understand this evolution. Since LIMS are major contributors of new elements to the ISM from which the next generation of stars and planets form, understanding their contribution to the ISM is crucial to our understanding of Galactic and Universal chemical evolution. In fact, mass loss is the main reason that LIMS do not explode as supernovae. We cannot understand mass loss fully until we understand the physical nature of the dust. As will be discussed below, interferometric techniques can provide data on evolved LIMS that are essential to understanding dust formation.

2. Stellar evolution

LIMS eventually evolve off the main-sequence to the red giant branch and subsequently become asymptotic giant branch (AGB) stars, ending their lives as cooling white dwarfs. Between the AGB phase and the white dwarf phase some of these stars may become planetary nebulae (PNe) as the previous AGB mass loss is illuminated by the shrinking, heating central core. However, precisely which AGB stars go through the PNe phase is not clear (see, for example, Sahai *et al.* 2010, and references therein).

2.1. Asymptotic giant branch stars

As LIMS evolve they become asymptotic giant branch (Iben and Renzini 1983) stars: luminous ($L_\star \approx 10^4 L_\odot$), cool ($T_{eff} \approx 3000$ K) giants ($R_\star \approx 1$ AU), which lose mass at high rates (10^{-7} to a few times $10^{-4} M_\odot$/yr). AGB stars pulsate due to dynamical instabilities, leading to intensive mass loss and the formation of a circumstellar shell of gas. Pulsations levitate atmospheric material, allowing it to achieve an altitude where temperatures permit molecules to form, followed by the formation of small particles (dust grains). The dust grains tap into the tremendous luminosity power of the star and drive a radiation-pressured wind (see, for example, Höfner and Dorfi 1997), leading to a circumstellar outflow of dust and gas. This outflow (wind) causes AGB stars to lose mass at such tremendous rates that they wither into white dwarfs rather than explode as supernovae. Generally, the mass-loss rate, $\dot{M}$, increases over time as an AGB star evolves, and ends in an episode of extremely high mass loss, the superwind (SW) phase (Iben and Renzini 1983; Bowen 1988; Bowen and Willson 1991; Blöcker and Schönberner 1991; Vassiliadis and Wood 1993; Willson 2000). During the SW phase $\dot{M}$ exceeds $10^{-5} M_\odot/yr^{-1}$. Continued AGB star mass loss causes the dust shell to increase in depth both optically and geometrically as mass-loss rate increases, shown schematically in Figure 1. As these stars approach the SW phase they become invisible at optical wavelengths and very IR-bright. During this SW stage, intense mass loss depletes the remaining hydrogen in the star's outer envelope, and terminates the AGB phase. The rapid depletion of material from the outer envelope of the star means that while AGB mass loss may last for > 10^5 yrs, this extremely high mass-loss SW phase must have a relatively short duration (a few × 10^4 years; Volk *et al.* 2000).

During their ascent of the AGB, these stars also evolve chemically, starting with oxygen-rich atmospheres. Helium burning forms ^{12}C, which is dredged up to the stellar surface by strong convection currents in the mantle. Thus, carbon is injected into the stellar atmosphere. The stability of the CO molecule in the stellar atmosphere means that the carbon-to-oxygen ratio (C/O) controls the chemistry around the star: whichever element is less abundant will be entirely locked into CO molecules, leaving the more abundant element to control dust formation. Therefore, AGB stars can be either oxygen-rich or carbon-rich. For the O-rich AGB stars C/O can vary from approximately cosmic C/O ≈ 0.4) to just less than unity. Once C/O is greater than unity these stars become C-rich. Other nuclear processes (for example, the *s-process*) also occur in the He- and H-burning shells of AGB stars and thus other new elements are also dredged up and enrich the dust formation region. For a more detailed description of AGB stars we refer to Habing (1996) and Habing and Olofsson (2004).

2.2. Post-AGB stars

Once the AGB star has exhausted its outer envelope, the AGB phase ends. At this stage the mass loss virtually stops, and the circumstellar gas and dust shell begin to drift away from the star. At the same time, the central star begins to shrink and heat up from ~3000 K until it is hot enough to ionize the surrounding gas, at which point the object becomes a planetary nebula (PN). The short-lived post-AGB phase, as the star evolves toward to the PN phase, is also known as the proto- or pre-planetary nebula (PPN) phase. However, not all post-AGB stars will become PNe; for some post-AGB objects the expansion speed of the circumstellar shell, combined with its density, will preclude a visible nebula of ionized gas. (Indeed, the term pre-PN was adopted to replace proto-PN to reflect the idea that not all PPNe will end up as PNe.)

As the detached dust shell drifts away from the central star, the dust cools, causing a PPN to have cool IR colors. Meanwhile, the dust shell spreads out, becoming less dense and optically thinner, leading to changes in its spectral characteristics that may also be related to an evolution in the intrinsic nature of the dust grains (that is, composition, crystal structure, grain size, and grain shape, not just optical depth and temperature). This structural evolution of the dust shell is illustrated schematically in the upper panel of Figure 1. This post-AGB evolution of the circumstellar envelope changes its appearance, revealing features that were hidden during the AGB phase.

The geometry of the dust shell also changes. Whereas observations suggest that the AGB phase has mostly spherically-symmetric mass loss, there is clearly a deviation from spherical symmetry somewhere in the evolution of these stars and their mass loss, since PNe are rarely spherical. It has been suggested that mass loss can explain the structural changes alone (Dijkstra and Speck 2006). By studying the distribution of matter in these AGB and post-AGB circumstellar shells we can gain a better understanding of the mass-loss processes involved in the evolution of these stars and test hypotheses for the effect of dust. However, the observations needed require high angular resolution, and thus interferometric techniques are vital to these studies.

3. Astromineralogy

Astromineralogy is the study of the precise nature (that is, the composition, crystal structure, size, and shape) of dust grains in space. This field has developed rapidly over the last decade or so (see reviews in Speck *et al.* 1997; Speck 1998; Speck *et al.* 2000; Molster 2000; Waters and Molster 1999; Henning 2003; Kwok 2004; Pitman *et al.* 2010; Guha Niyogi *et al.* 2011a, and references therein).

The major factors that determine the astromineralogy of dust grains are the chemistry, density, and temperature of the gas from which the dust forms. The chemistry determines the type of atoms available to form dust particles, whereas the density determines how likely these atoms are to come into contact and make dust particles. The temperature determines which solid state materials will be stable. For AGB stars the chemistry and density of the dust-forming region are in turn determined by the nature of the central star, including its metallicity and its initial mass, and by the evolution of the star. Stellar changes may lead to a transformation in the nature of the dust that is produced, which may in turn influence stellar evolution, indicating a feedback relationship between the changes in the star and dust formation in its circumstellar envelope. For instance, if mass loss is radiation-driven, the opacity of the dust grains affects the force of the radiation and thus mass-loss rate. Opacity is determined by the astromineralogy of the dust grains. Therefore, the nature of the dust grains affects mass-loss rates (and changes therein) which, in turn, affects stellar evolution. Stellar evolution cannot be fully understood until we determine the nature of the dust in the circumstellar region.

Typically, astromineralogy is studied by means of IR spectroscopy; dust in a circumstellar envelope absorbs visible light from the central star and re-radiates it at IR wavelengths. Dust particles of a given size, shape, temperature, structure, and composition have their own signature IR spectra. We can thus use the IR spectra of candidate dust species studied in the laboratory to identify IR spectral features observed in astronomical environments. However, many astromineralogical studies have yielded contradictory results. For instance, a spectral feature at ~13 μm has been attributed to a variety of minerals including corundum, spinel, and silica (see Sloan *et al.* 2003, and references therein) and its true identity remains a mystery. The shapes and positions of the spectral features have sometimes been used to make attributions without thorough consideration of the nature of the dust-forming environments in which they occur (see, for example, Zhang *et al.* 2008). There are other constraints or lines of evidence that can be used to aid our studies of dust in space, including spatial distributions of materials, theoretical models for dust formation and evidence from meteoritic studies of presolar grains (see section 4).

4. Dust Formation

4.1. Competing dust formation mechanisms

There are effectively three competing dust formation mechanisms for circumstellar environments: (i) thermodynamic equilibrium condensation (see, for example, Lodders and Fegley 1999); (ii) formation of chaotic solids in a supersaturated gas followed by annealing (see, for example, Stencel *et al.* 1990); (iii) formation of seed nuclei in a supersaturated gas, followed by mantle growth (see, for example, Gail and Sedlmayr 1999). The latter should follow thermodynamic equilibrium as long as density is high enough for gas-grain reactions to occur.

Several observational studies support the thermodynamic condensation sequence (see, for example, Dijkstra *et al.* 2005; Blommaert *et al.* 2007), which is consistent with both (i) and (iii). In mechanism (ii), chaotic grains form with the bulk composition of the gas, and then anneal if the temperature is high enough (Stencel *et al.* 1990). This mechanism predicts that at low C/O ratios, the dust grains would comprise a mixture of olivine, pyroxene, and silica, rather than be dominated by olivine alone. At high C/O ratios, Al-O bonds are predicted to form preferentially, leading to dust dominated by oxides rather than silicates. These predictions are inconsistent with observations (Dijkstra *et al.* 2005; Blommaert *et al.* 2007).

If we assume that dust formation follows either (i) or (iii) we expect to see a condensation sequence shown schematically in the left panel of Figure 2.

4.2. P-T space in the condensation zone around AGB stars

The composition of AGB star dust depends upon pressure and temperature

(P-T) in the dust-formation zone around the star. The precise astrominerals that can form depend on various parameters, most notably C/O ratio and gas pressure (Lodders and Fegley 1999; Gail and Sedlmayr 1999). Gas pressure is a measure of the mass-loss rate ($\dot{M}$) convolved with the photospheric temperature ($T_\star$) and outflow velocity (v_{exp}). Detailed calculations of the outflow structure (and its temporal variations) require the stellar temperature, radius, and luminosity. These can be provided using interferometric methods.

Applying the method from Speck *et al.* (2008, 2009) we can estimate the P–T space around a mass-losing star and compare with theoretical models for dust compositions forming under various P–T conditions. For a star with a mass-loss rate $\dot{M}$ and an expansion velocity of v_{exp}, the density ρ of the circumstellar shell at a radius r is given by:

$$\rho = \frac{\dot{M}}{4\pi r^2 \, v_{exp}} \tag{1}$$

If we know the temperature and luminosity of the star and the composition of the outflowing material we can combine this information with the Ideal Gas Law and a $T(r) \propto 1/\sqrt{r}$ temperature distribution to determine the gas pressure at the condensation radius, which is the distance from the star where the gas has the condensation temperature.

For simplicity, the solid and gas phases are assumed to be at the same temperature. While this is clearly a simplification (Chigai and Yamamoto 2003), the temperature difference is small compared to the difference needed to significantly affect dust formation. We assume that most of the outflowing material is atomic hydrogen. In fact it will probably be a mixture of atomic and molecular hydrogen (H_2) since H_2 forms around 2000 K and the temperature in the outflow is decreasing from the stellar surface temperature of ~3000 K to the dust condensation temperature in the 1000–1800 K range. An entirely molecular hydrogen gas would halve the gas pressure compared to the the atomic gas. However, we also assume an outflow velocity of 10 km/s, which reflects the speed of the outflowing material after radiation pressure acceleration. Adopting the pre-dust-formation outflow speed ($\lesssim$5km/s) would increase the pressure. Thus we can estimate where dust condensation zones fall in P–T space as a function of mass-loss rate, as shown in Figure 3. For C-rich environments we expect to form carbon before SiC in most cases, but the order is sensitve to mass-loss rate, C/O ratio, and metallicity (Speck *et al.* 2006). For O-rich environments, the condensation sequence is essentially the classic condensation sequence and is similar to that shown schematically in the left panel of Figure 2.

4.3. Presolar grains

The isotopic compositions of certain grains found in primitive meteorites indicate that they originated outside the solar system and are thus dubbed "presolar". The majority (~99%) of the "presolar" dust grains emanated from AGB stars based on their isotopic compositions and the nuclear processes expected to occur in those stars. Presolar grains demonstrate that the AGB dust grains become part of the next generation of stars and planets (Clayton and Nittler 2004, and references therein). This also means that we have real samples of the circumstellar dust that we can observe spectroscopically around evolved stars. The precise physical characteristics of these meteoritic dust grains (for example, sizes, crystal structures, and compositions) can be used to help constrain the nature of the dust we see in our astronomical observations.

Silicon carbide was the first presolar grain to be found in meteorites (Bernatowicz *et al.* 1987) and remains the best studied (see Bernatowicz *et al.* 2006, and reference therein). Other carbon-rich grains, such as graphitic onions and seed-core grains of various refractory carbides, have also been well studied (see Bernatowicz *et al.* 2006, and reference therein). Presolar examples of refractory oxides, spinel and alumina, have been found in meteorites. Detailed studies of the nature of these grains (especially crystal structure) are in their infancy, but can be used to constrain candidates for the 13μm feature. For example, Stroud *et al.* (2004) have analyzed the crystal structure of two presolar alumina grains and found that one is indeed a crystalline form (corundum), while the other is amorphous. Many astronomical studies have falsely assumed that the use of the word "corundum" in the meteoritics literature refers to this particular crystal structure, when it actually refers only to the composition of the presolar grains.

Isolating the C-rich grains can be achieved chemically, whereas presolar silicates can not be separated chemically from their terrestrial/solar system brethren. However, *in situ* techniques have been developed which led to the discovery and analysis of presolar silicate grains. Recent work on these presolar silicate grains suggests that there is more iron in silicate grains around AGB stars than our current models allow (see, for example, Stroud *et al.* 2008; Bose *et al.* 2010).

5. Astronomical observations of AGB circumstellar dust

For carbon stars the dominant dust formed is amorphous or graphitic carbon which does not have diagnostic spectral features, merely contributing to the IR continuum. SiC exhibits a spectral feature at ~ 11.3μm which has been used extensively to diagnose the physical parameters of carbon star dust shells (see reviews in Speck *et al.* 2005, 2009; Thompson *et al.* 2006).

The spectra of O-rich AGB stars exhibit a diverse range of IR dust spectral features. The spectra of AGB stars are generally classified according to the gross shape of the silicate emission feature at ~10μm. Various attempts have been made to classify these mid-IR features according to their shapes and positions, which reflects a progression from a broad feature to the classic narrow 10μm silicate feature (see, for example, Little-Marenin *et al.* 1990; Sloan and Price 1995; Speck *et al.* 2000; Sloan *et al.* 2003; see Figure 4). This progression of the spectral features can be interpreted in terms of a dust condensation sequence (see, for example, Grossman 1972; Tielens 1990; shown schematically in Figure 2) and expected to represent evolution of the dust from the early forming refractory amorphous oxides to the dominance of amorphous silicates (the classic 10μm feature; see SE 8 in Figure 4).

The most recent version of this IR spectral classification scheme divides the observed AGB spectra into eight groups based on the silicate emission (SE) feature from SE1 to SE8 (Sloan and Price 1995; Sloan *et al.* 2003). Classes SE1–SE3 are expected to correspond to low-contrast alumina-rich amorphous dust seen in evolved stars losing mass at low rates and have optically thinner shells. Moving up the sequence, classes SE3–SE6 show structured silicate emission, with features at 10 and 11μm. The upper end of the silicate dust sequences (SE6–SE8) consist of sources with the classic silicate emission feature believed to be produced by amorphous silicate grains. These sources have optically thicker shells and higher mass-loss rates than sources at the other end of the sequence. However, recent findings (for example, Pitman *et al.* 2010; Guha Niyogi *et al.* 2011a) show the evidence for Fe-rich crystalline silicates on some of the stars from SE1 class (for example, T Cep, RX Lac, T Cet), which calls the classic dust condensation sequence into question. The new condensation sequence is shown schematically in the right panel of Figure 2. These empirical observational results cannot easily be reconciled with the classic conception of dust formation as shown in the left panel of Figure 2. In order to understand these new findings we need interferometry measurements of closeby AGB stars to provide stellar radii for input into models of dust formation. In particular the variations in dust formation as a result of stellar pulsation require precise information on how the stars change in radius, temperature, and luminosity with time.

6. Acknowledgements

AKS would like to thank her students past and present for their contributions to her research. NSF is also thanked for their continued support. Finally I am grateful to Alan “Elric” Whittington for help with figures.

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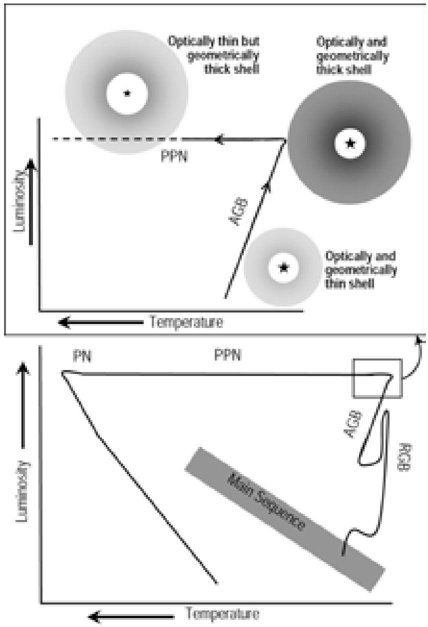

Figure 1. Schematic H-R diagram showing post-main-sequence evolution of LIMS. RGB = Red Giant Branch; AGB = Asymptotic Giant Branch; PPN = pre- or proto-planetary nebula; PN = planetary nebula; *upper panel* shows close up on AGB and PPNe phases and cartoons the changes in dust shell densities.

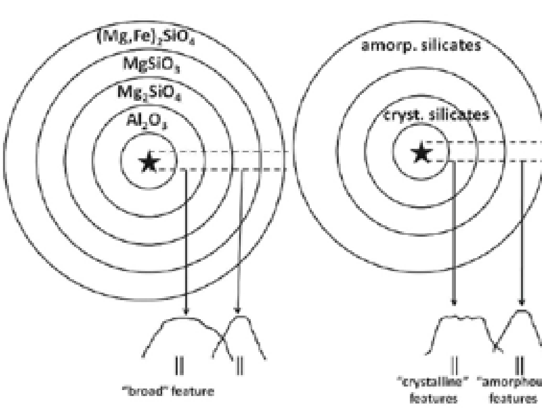

Figure 2. Schematic structure of dust shells. *Left*: Classic condensation sequence from, for example, Grossman (1972), Tielens (1990); see also thermodynamic equilibrium sequence in Figure 3; *Right*: New sequence suggested by the study of low mass-loss rate stars (for example, T Cep) as shown in Guha Niyogi *et al.* (2011a, 2011b) and Guha Niyogi (2011).

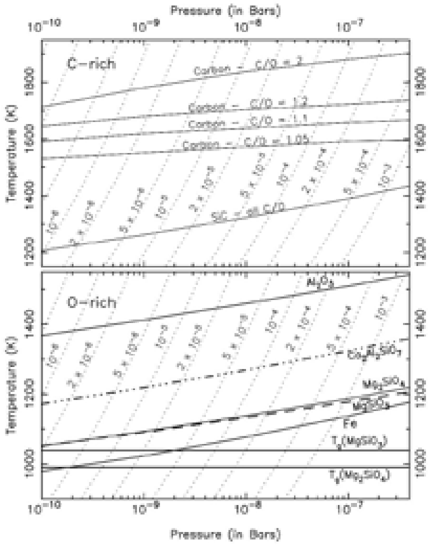

Figure 3. Pressure-temperature space in dust-condensation zone around AGB stars. *Top panel* is for C-rich stars; *bottom panel* is for O-rich stars. *x*-axis is outflow gas pressure in bars, *y*-axis is outflow gas temperature in Kelvin. Solid and dashed lines indicate T_{dust} for a given pressure from thermodynamic equilibrium calculations (relevant compositions are labeled; from Lodders and Fegley 1995, 1999). For all $\dot{M}$ values, Al_2O_3 forms at a significantly higher temperature than the silicates, and thus can form a seed nucleus. Light grey dotted lines indicate the P–T paths for the outflowing gas for a range of $\dot{M}$ (indicated in $M_{\odot}$/yr) as calculated from equation 1 and described in the text. Thick dark grey horizontal lines indicate glass transition temperatures (T_g) for Mg_2SiO_4 and $MgSiO_3$.

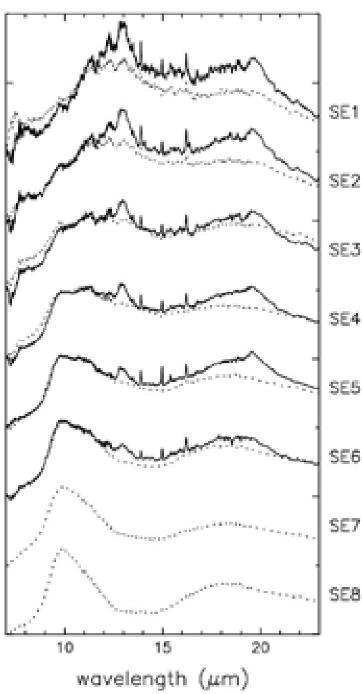

Figure 4. Continuum-subtracted ISO SWS spectra of O-rich AGB stars. Spectra are divided into classes according to the shape/strength of their silicate feature (designated by SE#, where # = 1 to 8; SE8 has the strongest classic silicate feature, SE1, the weakest). Solid lines: spectra which exhibit the 13μm feature. Dotted lines: spectra which do not exhibit a 13μm feature. From data presented in Sloan *et al.* (2003).

Interferometry and the Cepheid Distance Scale

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Presented at the 100th Spring Meeting of the AAVSO, May 23, 2011; received February 9, 2012; accepted February 10, 2012

Abstract Systematic uncertainties in the Cepheid distance scale have been greatly reduced in recent years through stellar interferometric observations. Interferometry has made possible direct measurement of Cepheid distances through interferometric pulsation distances. These results compare very well with recent Hubble Space Telescope trigonometric distances. Interferometry has also demonstrated that infrared surface brightness distances are quite reliable, making possible direct comparison of Cepheid luminosities in the Galaxy and the Magellanic Clouds.

1. Introduction

This year is the centennial of Henrietta Leavitt's discovery of the period-luminosity relation for classical Cepheid variables (Leavitt and Pickering 1912). In honor of Leavitt's discovery, the Cepheid period-luminosity relation is now usually called the Leavitt Law. This year is a good time to see just how far we have come in calibration of the Leavitt Law in the preceding century.

Leavitt's discovery made use of Cepheids in the Small Magellanic Cloud, all of which are sensibly at the same distance from us. A plot of their apparent magnitudes versus log (P) thus demonstrates the Leavitt Law (Figure1). Within the Galaxy, Cepheids are not so conveniently located. We must combine many individual distances to Cepheids to establish the relation. It has proved to be a very difficult task to achieve the accuracy that we desire in the relation. New techniques have significantly improved the situation.

Much of the progress is based on trigonometric parallax measures made with the Hubble Space Telescope (HST; Benedict *et al.* 2007) and on pulsation distances made with stellar interferometers. In the following I discuss the interferometric distances and then compare them with HST parallaxes. A more extensive review has been given by Barnes (2009).

2. Cepheid distance measurements

There are four principal means for determining Cepheid distances: open cluster distances, infrared surface brightness distances, interferometric pulsation distances, and trigonometric parallax distances.

2.1. Open cluster distances

There are twenty-four Cepheids known to be members of Galactic open clusters and associations (Turner 2010). Using the cluster main sequence fitting method, we may determine a distance to each cluster and thus to the Cepheids within them. This is accomplished in a color-magnitude diagram by comparing the apparent magnitudes of stars on the main sequence of the cluster to the absolute magnitudes of main sequence stars in a cluster at a known distance. The displacement in magnitude is attributed to distance. A good example of this method in application is given by Turner (1986) for S Nor in the cluster NGC 6087. Ever since Cepheids were discovered in open clusters (Irwin 1955), this has been the preferred method for establishing the Cepheid distance scale.

Cluster distances are limited in precision by several effects. Open clusters lie in the Galactic plane and are usually affected by considerable interstellar reddening. Correcting for the reddening is difficult, and the difficulty is often compounded by changes in the reddening across the face of the cluster. A second effect comes from the varying metal abundances of open clusters. The main sequence location in the color-magnitude diagram can change with metal abundance, impacting the distance measurement. Finally, the number of Cepheids in open clusters is modest, which affects our ability to define the Leavitt Law well. The table in Turner (2010) shows that Cepheid distances based on open cluster distances have precisions in the range ±4–22%. Fouqué *et al.* (2007) have demonstrated that open cluster distances are fully consistent with distances from the infrared surface brightness technique and trigonometric parallaxes.

2.2. The Infrared Surface Brightness Technique

As a Cepheid variable pulsates, the photosphere expands and contracts relative to deeper layers of the star. The linear motion of the photosphere along the line of site to the Cepheid can be measured through the Doppler effect, that is, a radial velocity curve. An integration of the radial velocity curve, with appropriate correction for geometric and atmospheric effects, gives the linear distance that the surface moves over a pulsation cycle. The angular motion of the surface perpendicular to the line of site can be inferred from photometric measurements through a method called the surface brightness technique, introduced by Barnes and Evans (1976). The method was later improved by using infrared (VK) photometry (Welch 1994; Fouqué and Gieren 1997). The Infrared Surface Brightness Technique is an improvement upon the well-known Baade-Wesselink method for Cepheid radius determination.

By matching the angular distance traveled to the linear distance traveled, we can determine the distance through simple trigonometry. The beauty of the method is that it is applicable to any Cepheid for which radial velocities and infrared photometry may be measured. This puts Cepheids throughout the Local Group of galaxies within range of individual distance measurements.

The method was suspect early in its use for two reasons. First, the conversion of the photometric measurements into angular distances was thought to be subject to potential systematic errors. Second, the conversion of radial velocity into true pulsational motion could be subject to additional systematic errors. These concerns were finally put to rest. Kervella *et al.* (2004c) showed that angular diameters inferred from the infrared surface brightness technique were fully compatible with diameters found using interferometry. This resolved the photometric issue. Regarding the radial velocity correction, Barnes (2009) and Storm *et al.* (2011a) compared determinations of Cepheid distances using the infrared surface brightness technique, which depends on this correction, to trigonometric determinations, which do not, and found excellent agreement at the few percent level.

Storm *et al.* (2011a) applied the infrared surface brightness technique to 111 Cepheids in the Galaxy and the Magellanic Clouds. The mean precision in distance was better than ±5%, with a range of 2–16%.

2.3. Interferometric pulsation distances

For relatively bright Cepheids, stellar interferometers can now measure the angular diameter of the Cepheid directly as it pulsates. Once again, the angular distance traveled by the photosphere (from interferometry) is matched to the linear distance traveled (from integrated radial velocities). This method eliminates the photometric inference involved in the infrared surface brightness technique.

A new, potential uncertainty is introduced. The conversion of interferometric observations into angular diameters for Cepheids requires prior knowledge of the Cepheid limb darkening, which is obtained from theoretical models; there may be errors in those models although the uncertainty is expected to be small in the infrared. Any errors in conversion of the radial velocities to linear distances remain in this method.

There are eight Cepheids for which distances have been determined this way (Table 1). The most distant is *l* Car at 525 parsecs. This distance method produces distances precise to ±2–45%.

2.4. Trigonometric distances

Trigonometric parallaxes are the gold standard, geometric method for measuring distances. There are very few assumptions that enter into the method. However, Cepheids are distant and their parallaxes are small which has made determination of their distances by trigonometry very difficult. Recently the HST Fine Guidance Sensor was used to determine trigonometric distances to ten Cepheids (Benedict *et al.* 2007) as listed in Table 2. The most distant one is T Vul at 526 parsecs (coincidentally similar to the above distance to *l* Car). The precisions are ±4–14%.

3. Stellar interferometry

Stars are frustratingly small in angular size on the sky. The largest stellar disk (other than the Sun) is less than 0.06 arcsecond across. The largest Cepheid angular diameter is that for *l* Car which is twenty times smaller. The change in angular size due to its pulsation is five times smaller yet. (For a list of angular diameters of bright Cepheids, see Moskalik and Gorynya 2006.) Cepheid diameters are far below the capabilities of even the largest single telescopes to measure. It takes a special technique to measure such small angles.

It is impossible in this short paper to do justice to the principles of interferometry. For a summary see Hajian and Armstrong (2001). The basic concept of stellar interferometry is most easily understood using the wave nature of light. Consider two separate telescopes viewing the same star as shown in Figure 2. After correcting for the different distances of the two telescopes from the star, the wavetrains arriving at the two telescopes are interfered to form a "fringe pattern." As the telescopes are moved further apart, the fringe pattern changes in a manner that depends on the stellar angular diameter and the separation of the telescopes. This change is quantified in a parameter called the "visibility" as shown in Figure 3. If the star is a point source the visibility does not change with baseline. On the other hand, the larger the stellar angular diameter, the sharper the visibility pattern and thus the easier it is to measure the diameter. Adding additional telescopes to the system can improve the capabilities of the interferometer.

There are four stellar interferometers that have measured the change in angular diameter as the Cepheid goes through its pulsation cycle. The following list gives the name, citation for a description of the interferometer, the baseline used for the Cepheid observations, and the Cepheids for which measured angular diameter variations were obtained. Not all of these interferometers are still in operation.

1) Palomar Testbed Interferometer; three 0.4 m telescopes with a 110-m baseline (Colavita *et al.* 1999): η Aql (in 2002), ζ Gem (2002);

2) Very Large Telescope Interferometer; two 8-m telescopes with two 0.35-m siderostats with a 140-m baseline (Glindemann *et al.* 2000; Kervella *et al.* 2003): η Aql (2004), W Sgr (2004), β Dor (2004), *l* Car (2004);

3) Center for High Angular Resolution Astronomy; six 1-m telescopes up to a 313-m baseline (ten Brummelaar *et al.* 2003): δ Cep (2005), Y Oph (2007), Y Sgr (2007); and

4) Sydney University Stellar Interferometer; 0.14-m telescopes with a 40-m baseline (Davis *et al.* 1999): β Dor (2006), *l* Car (2009).

4. Interferometric pulsation distances

A good example of a Cepheid distance by interferometry is that for *l* Car (Davis *et al.* 2009) obtained with the Sydney University Stellar Interferometer. In Figure 4 Davis *et al.* (2009) show the radial velocity curve assembled from several sources. This velocity variation is integrated and corrected for projection and atmospheric effects to obtain a curve showing the movement of the atmosphere over the pulsation cycle (not shown here).

Figure 5 shows the angular diameters measured using SUSI (symbols in the figure). The mean angular diameter is 2.99 ± 0.01 mas. The amplitude of the variation is 0.56 mas with a typical uncertainty on each datum of ± 0.035 mas.

This measurement is equivalent to watching a 5.5-m ball on the surface of the moon vary in size by ± 50 cm and measuring the variation with a precision of ± 6 mm. It is a remarkable, technical achievement.

In Figure 6 Davis *et al.* show the measured angular diameters against the linear displacement at the same phase in the pulsation. The slope of the fit is inversely related to the distance and the zero point of the fit, to the mean angular diameter. They determined a distance of 525 ± 26 parsecs, the mean angular diameter quoted above, and a linear radius for the Cepheid of 169 ± 9 solar radii. The linear displacements are scaled to the distance and to the measured linear diameter to obtain the smooth curve in Figure 5. The curve fits the observed angular diameters well without any systematic deviations.

5. Discussion

Figure 7 demonstrates that interferometric pulsation distances determined for Cepheids are fully compatible with trigonometric distances. Unfortunately there are few additional Cepheids for which interferometry and trigonometry can provide new distances with current instruments. Thus the importance of the agreement between the two methods lies in the demonstration that a distance determined from the pulsation of a Cepheid is as accurate, and sometimes as precise, as a trigonometric distance.

Recall from the discussion of the infrared surface brightness method that it has been shown to give angular diameters in agreement with those from stellar interferometers. That result, combined with the excellent agreement between interferometric pulsation distances and trigonometric distances, gives us confidence that distances from the infrared surface brightness method are reliable. This has recently been demonstrated by Storm *et al.* (2011a, 2011b). They have determined distances to 111 Cepheids in the Galaxy, LMC and SMC using this method. The infrared K magnitude Leavitt Law they obtained is shown in Figure 8. The scatter about the relation is ± 0.22 magnitude.

I believe Henrietta Leavitt would be pleased.

6. Acknowledgements

The author thanks Dr. Hal McAlister for permission to use two of his figures, and Dr. Antoine Mérand for permission to quote an unpublished result. The author also thanks Dr. G. Fritz Benedict for his review of the draft of this paper.

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Table 1. Cepheids with interferometric pulsation parallaxes. Adapted from Fouqué *et al.* 2007.

Star	*Log P (days)*	*π (mas)*	*σ(π) (mas)*	*Distance (pc)*	*σ(d) (%)*	*Source*
δ Cep	0.72	3.52	0.10	284	2.8	Mérand *et al.* (2005)
Y Sgr	0.76	1.96	0.62	587	30.6	Mérand *et al.* (2012)
η Aql	0.85	3.31	0.05	302	1.5	Lane *et al.* (2002)
W Sgr	0.88	2.76	1.23	362	44.6	Kervella *et al.* (2004b)
β Dor	0.99	3.05	0.98	328	3.1	Kervella *et al.* (2004b), Davis *et al.* (2006)
ζ Gem	1.01	2.91	0.31	344	10.6	Lane *et al.* (2002)
Y Oph	1.23	2.16	0.08	463	3.7	Mérand *et al.* (2007)
l Car	1.55	1.90	0.07	525	4.9	Kervella *et al.* (2004a), Davis *et al.* (2009)

Table 2. Cepheids with trigonometric parallaxes from Benedict *et al.* 2007.

Star	*Log P (days)*	*π (mas)*	*σ(π) (mas)*	*Distance (pc)*	*σ(d) (%)*
RT Aur	0.57	2.40	0.19	417	7.9
T Vul	0.65	1.90	0.23	526	12.1
FF Aql	0.65	2.81	0.18	356	6.4
δ Cep	0.73	3.66	0.15	273	4.0
Y Sgr	0.76	2.13	0.29	469	13.6
X Sgr	0.85	3.00	0.18	333	6.0
W Sgr	0.88	2.28	0.20	438	8.8
β Dor	0.99	3.14	0.16	318	5.1
ζ Gem	1.01	2.78	0.18	360	6.5
l Car	1.55	2.01	0.20	497	9.9

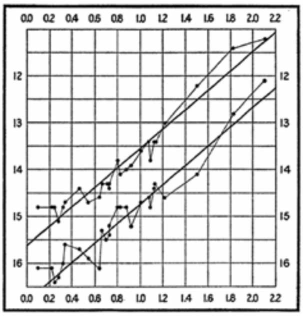

Figure 1. The first Cepheid period-luminosity relation as found in the Small Magellanic Cloud. Apparent magnitude at maximum light and at minimum light vs. log (period) for 25 variables. From Leavitt and Pickering (1912).

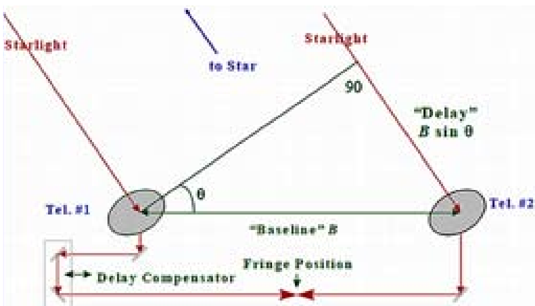

Figure 2. A simple interferometer. Figure courtesy of McAlister (2012).

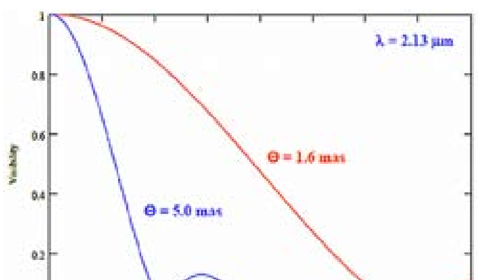

Figure 3. Examples of visibility curves for two different angular diameters. The separation of the telescopes (baseline) is given in meters. The units of angular diameter in the figure are milliarcseconds (mas). Courtesy of McAlister (2012).

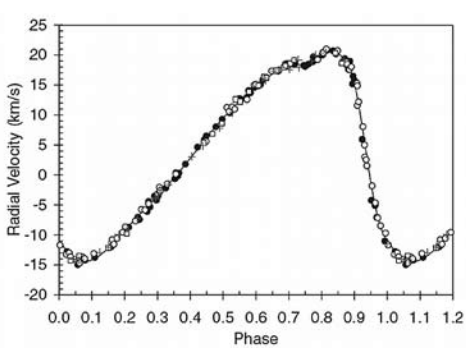

Figure 4. The radial velocity variation as a function of pulsation phase for the atmosphere of the Cepheid *l* Car. Courtesy of Davis *et al.* (2009).

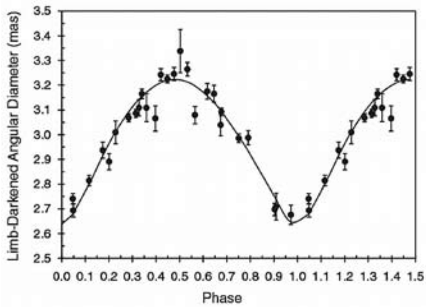

Figure 5. The observed angular diameter variation of *l* Car (symbols) and the linear displacement variation scaled to the measured distance (curve). Courtesy of Davis *et al.* (2009).

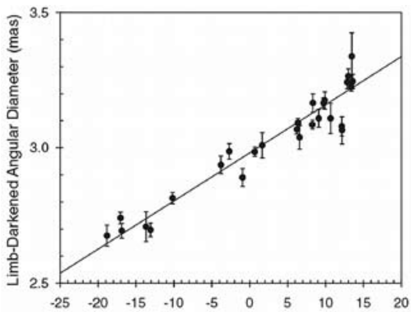

Figure 6. The fit of the angular diameter variation onto the linear variation for *l* Car. Courtesy of Davis *et al.* (2009).

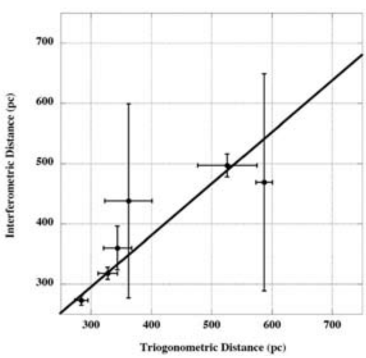

Figure 7. A comparison of interferometric pulsation distances to trigonometric distances for Cepheids. η Aql and Y Oph do not have trigonometric distances and are not plotted.

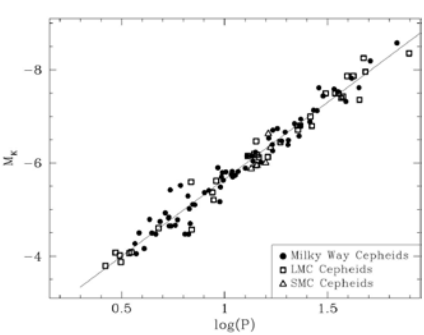

Figure 8. The Leavitt Law in the K magnitude based on Galactic, LMC, and SMC Cepheids. Courtesy of Storm *et al.* (2011a).

Imaging Variable Stars With HST *(Abstract)*

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Presented at the 100th Spring Meeting of the AAVSO, May 23, 2011

Abstract The Hubble Space Telescope (HST) observations of astronomical sources, ranging from objects in our solar system to objects in the early Universe, have revolutionized our knowledge of the Universe its origins and contents. I highlight results from HST observations of variable stars obtained during the past twenty or so years. Multiwavelength observations of numerous variable stars and stellar systems were obtained using the superb HST imaging capabilities and its unprecedented angular resolution, especially in the UV and optical. The HST provided the first detailed images probing the structure of variable stars including their atmospheres and circumstellar environments. AAVSO observations and light curves have been critical for scheduling of many of these observations and provided important information and context for understanding of the imaging results of many variable sources. I describe the scientific results from the imaging observations of variable stars including AGBs, Miras, Cepheids, semiregular variables (including supergiants and giants), YSOs and interacting stellar systems with a variable stellar components. These results have led to an unprecedented understanding of the spatial and temporal characteristics of these objects and their place in the stellar evolutionary chains, and in the larger context of the dynamic evolving Universe.

Probing Mira Atmospheres Using Optical Interferometric Techniques *(Abstract)*

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Presented at the 100th Spring Meeting of the AAVSO, May 23, 2011

Abstract Modern optical interferometric observations of Mira atmospheres are discussed. The earlier near-infrared closure-phase measurements of a sample of Asymptotic Giant Branch (AGB) stars and subsequent imaging observations of a handful of brighter ones show that asymmetry is common in the cool atmospheres of late-type stars. The potential of optical interferometric observations in conjunction with radio interferometric observations in studying the structure and kinematics of the envelope around Mira stars are highlighted.

We explore the use of other interferometric observables, such as, (1) null-leakage in the mid-infrared combined with near-infrared squared-visibilities in constraining the temperature structure of the extended atmosphere of Mira stars, and (2) differential phase in detecting asymmetry in the molecular and dusty shells of Mira stars.

Spots, Eclipses, and Pulsation: the Interplay of Photometry and Optical Interferometric Imaging *(Abstract)*

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Presented at the 100th Spring Meeting of the AAVSO, May 23, 2011

Abstract Present optical/IR interferometers like CHARA are not only capable of probing the environment surrounding stars, but also resolving surface details on the stars themselves. Because of this, interferometers can produce results on the classical topics of photometry: namely pulsation, eclipses, and star spots. In this talk I discuss these three common areas, and how interferometry and photometry can be used in conjunction to yield superior results.