AAVSO PHOTOELECTRIC PHOTOMETRY NEWSLETTER

John R. Percy
University of Toronto, Toronto ON Canada M5S 3H4
Email: john.percy@utoronto.ca

In the early 1980's, the AAVSO established a formal photoelectric photometry (PEP) observing program, administered by a PEP Committee, and guided by Janet Mattei and me. It built on three decades of previous AAVSO activity in PEP. At about the same time, the AAVSO established the PEP Newsletter, as a vehicle for providing instructions, information, and feedback. We also have a webpage that can be found under "committees" on the AAVSO website.

[link: http://www.aavso.org/observing/programs/pep/]

The PEP program flourished, as I shall outline below. In the last few years, however, the program has been taken more and more under the wing of AAVSO HQ, for a variety of reasons – not the least of which is because AAVSO Director Arne Henden is an acknowledged expert on photoelectric photometry!

It is therefore appropriate that, from now on, PEP instructions and feedback will be issued by AAVSO HQ as it is for most other variable star observing programs. But, with Arne's permission, I am preparing one last PEP NL to offer my historical perspective.

Photoelectric Photometry

Until the mid-19th century, the brightness of stars was determined from their effect on the human eye – *visual photometry* – just as AAVSO visual observations are done today. [I am always amazed that the demand for AAVSO visual observations has actually *increased* by a factor of 30 in the last 30 years, since the beginning of the space age!].

In the 19th century, photography and *photographic photometry* were developed. Star brightness could be measured from the effect of the light on a photographic emulsion. Hundreds or thousands of stars could be recorded and measured on a single photograph. And when telescope technology allowed, it became possible for telescopes to track star fields across the sky, and make time exposures of up to several hours. Much fainter stars could be recorded and measured.

A century ago, physicists developed the quantum theory of light. Light consisted 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 illuminated 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, especially by Joel Stebbins in the US and by Paul Guthnick in Germany. The brightness of stars could be measured with this technique, to an accuracy of 0.01 mag 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 the color of the star.

Amateur Photoelectric Photometry

Not surprisingly, amateur astronomers soon took up photoelectric photometry. Electronics was a popular pursuit among amateur scientists, right through to the 1960's and beyond. When I was in high school, there was no science club, just a radio club!

But there were no real off-the-shelf photometers. Even professional photometers tended to be one-of-a-kind. As a result, both professional and amateur photometrists had to be very knowledgeable about the nature and peculiarities of their equipment. None of the "black box" approach to instruments that we have now!

The Amateur PEP Revolution

As I shall outline in the next section, AAVSO PEP goes back a long way. But several things happened around 1980 that revolutionized the field. One was the development of a relatively simple off-the-shelf photometer, based on the solid-state photodiode detector, by Optec Inc. The second was the publication of two very useful textbooks on PEP: *Astronomical Photometry*, by Arne Henden and Ron Kaitchuck (Van Nostrand Reinhold, 1982) and *Photoelectric Photometry of Variable Stars: A Practical Guide for the Smaller Observatory, 2nd edition* by Doug Hall and Russ Genet (Willmann-Bell, 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*). 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*. These books were edited by Russell M. Genet, Robert C. Wolpert, and others.

The AAVSO PEP Program – Origin

Organized AAVSO PEP goes back at least as far as 1952 – perhaps earlier. In 1957, John J. Ruiz published a paper on "A Photoelectric Light Curve of u Herculis" in *PASP*, **69**, 261, based on photometry from 1952-55, and indicating that he was a "Member of the Photoelectric Committee of the AAVSO". In the same year, he published "Photoelectric Observations of 12 Lacertae" in the same journal. According to his obituary in *JAAVSO*, **9**, 48 (1980), Ruiz had started the committee in 1956 and, in the same year, written the *AAVSO PEP Handbook*. In 1967, Art Stokes published PEP observations of Nova Delphini 1967. Throughout the 1970's, Howard Landis published many PEP papers, mostly on eclipsing and RS CVn variables in collaboration with Doug Hall. Art and Howard were the PEP pioneers who introduced me to the potential of AAVSO PEP observations. Howard noted, in his committee report, that 844 PEP observations of eclipsing binaries had been made in 1979. So AAVSO PEP was well underway by then.

A more formal PEP program was organized by Janet Mattei in the early 1980's, 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 red variables – giants and supergiants. I assisted in choosing the final set of program and comparison stars, and became the main scientific advisor to the program. The program grew from about 60 to about 80 stars, including stars that were added, or dropped because they proved to be non-variable. As of 1998, almost 60 observers had contributed to the program. For a discussion of the science and sociology of the program, see Percy, J.R., Landis, H.J. and Mattei, J.A. 2000, in *Amateur-Professional Partnerships in Astronomy*, ASP Conference Series, **220**, 57 [link if possible].

The AAVSO PEP Program – Growth

The best way to visualize the growth of the formal AAVSO PEP program is to look at the graph on the PEP pages of the AAVSO website:

[link: http://www.aavso.org/observing/programs/pep/pepgraph.shtml]

The 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. We were competing with Doug Hall's PEP program on RS CVn stars, and that yielded new results almost every season. Papers got 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. The figure below shows the number of PEP observations submitted each year. There are several reasons for the decline in the last few years: the program was partly "in limbo" while it was being transferred to AAVSO HQ; some observers migrated to CCD observing; and some very active observers retired – Ray Thompson, for instance.

Figure 1: Annual number of PEP observations submitted between 1980 and 2007. [Insert Figure here]

One way in which you can visualize the results of the program is to choose a star from the program (using the web link above, for instance), 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.

link: http://www.aavso.org/data/lcg/

The AAVSO PEP Newsletter

The PEP NL was apparently founded by Dave Skillman in 1979-1980, with the name of *AAVSO PEP Bulletin*. The first edition in my possession is Volume 2, Number 3, dated September 29, 1980, and by then called a 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 have edited it, with decreasing frequency, since that time. As more and more of the work has been done at HQ, it has made more and more sense for communications to come from there. By 2006, my efforts had petered out.

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 Fall 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, such as my good friend and champion PEP observer Ray Thompson, now retired in Halifax. 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 the *JAAVSO* or elsewhere.

PEP Campaigns

A *campaign* is a project in which one or a few carefully-selected stars are observed intensively for a period of time. 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 time coverage.

The AAVSO PEP program has participated in several campaigns. One notable one was organized by Roger Griffin, Cambridge University. Zeta 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 Zeta Aurigae binaries; we helped choose suitable comparison stars; and the observers determined which stars showed eclipses, and when, and how deep.

Yet another "campaign" (of sorts) was *Project SARV*, organized by me. A total of 61 bright red giants, suspected to be variable, were assigned to interested AAVSO PEP observers. At the end, we published the results in a 18-author paper: John Percy et al., 1994, "Photometric Surveys of Suspected Small-Amplitude Red Variables. III. An AAVSO Photometric Photometry Survey", *Publ. Astron. Soc. Pacific*, **106**, 611. [link if possible]

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. 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.

The AAVSO Near-Infrared Photometry Program

Long-term near-infrared (NIR) photometry is valuable for all the same reasons that long-term visual 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 pro-am committee was formed to do this. 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 30 stars in the program, mostly red giants, Cepheids, and eclipsing variables. See http://www.aavso.org/observing/programs/pep/ir.shtml for much more information.

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, well described on the AAVSO website (http://hoa.aavso.org). 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. 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, 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!

Scientific Results from the AAVSO PEP Program

Small-Amplitude Red Variables: These are the core of the AAVSO PEP program, and much of what we know about them is a result of AAVSO efforts: (i) Virtually all giants, cooler than K5III, are variable [warmer giants are microvariable in a more complex way]; (ii) In general, the cooler the giant, the larger the amplitude; (iii) Most stars seem to have one or more periods, which are consistent with low-order radial pulsation; (iv) Yes, some stars are multi-periodic; they have two or more periods, providing even more information about the stars; (v) These multiple periods explain some of the apparent irregularity of these stars, but maybe not all of it; (vi) About a third of the stars have "long secondary periods", about ten times the basic period. The cause of these is not known, and is regarded as one of the leading mysteries in stellar pulsation today. See, for instance, "Pulsating Red Giants: New Results, New Problems", by John Percy, Akos Bakos, Gurtina Besla, Joanne Hosick, and Vince Velocci, 2003, *ASP Conference Series*, **292**, 153. [link if possible]

Gamma Cas (Be) Variables: These are defined as non-supergiant stars with temperatures of 10,000-30,000 K which have shown emission lines in their spectra on at least one occasion. There are about 200 Be stars in the *Bright Star Catalogue*. They vary photometrically and spectroscopically for several reasons, but notably because of the occasional ejection of a bright equatorial disc of gas (hence the emission lines in their spectra). The cause of the ejection is not clear, but is likely due to a combination of rotation, radiation pressure, and the effects of non-radial pulsation. AAVSO photometry of Be stars has been useful for studying the outbursts, and for comparison with spectroscopic observations. See "Be Stars in the AAVSO PEP Program", by John Percy, Adrien Desjardins, and David Yeung, 1996, *JAAVSO*, **25**, 14 [link]

RVT/SRd Variables: RV Tauri (RVT) variables are yellow supergiants whose light curves are characterized by alternating deep and shallow minima; periods are typically weeks to months, and amplitudes are a magnitude or two. Yellow supergiants which are semi-regular but without alternating minima are classified as SRd (yellow semi-regular) variables. It takes years of observations to be sure that minima are alternating, so the classification – RVT or SRd – is often quite

uncertain. Some RVT variables, subclassified as RVb, have long secondary periods whose origin seems to be connected with motion in a bizarre binary system in which there is a ring of dust around one star. Since yellow supergiants are in an advanced stage of evolution, the nature and history of these binary systems is of great interest. See "AC Her and U Mon: RV Tauri Stars in the AAVSO PEP Program", by John Percy and Akos Bakos, 1998, *JAAVSO*, **26**, 112. [link]

RS CVn Variables: are short-period binary stars, with sun-like components whose rotation has been "spun up" by the tidal effects of its companion. Rotation, in sun-like stars, produces various kinds of stellar activity, including star-spots, flares, hot coronae and therefore X-ray emission. As with the sun, the activity changes from month to month as the star rotates, and from year to year as the solar "cycle" progresses. The changing star-spot activity in RS CVn stars can be monitored by PEP. For a summary of the results of AAVSO PEP observations, see "RS CVn Stars in the AAVSO PEP Program", by John Percy, Devi Soondarsingh, and Vince Velocci, 2001, *JAAVSO*, **29**, 82 [link]

Supergiant Variables: Most supergiant stars are photometrically variable, with the amplitude increasing with increasing luminosity of the star. There are several red supergiants (notably Betelgeuse) included among the small-amplitude red variables, and the RVT/SRd variables, noted above, are yellow supergiants. The most famous blue supergiant – actually a *hypergiant* – on the AAVSO PEP program is P Cygni. It varies on time scales from a week or two, to many decades, due to various instabilities (including complex pulsation) in its outer layers. In 2007, it became unusually active, and was the subject of an AAVSO campaign. Previous AAVSO PEP and visual observations of P Cyg had been reported in "Long-Term VRI Photometry of P Cygni", by John Percy, Trevor Evans, Greg Henry, and Janet Mattei", 2001, in *ASP Conference Series*, **233**, 31. [link]

Variable Comparison Stars: During the transition of the PEP program to AAVSO HQ, there was a concerted effort to re-reduce the data using improved methods, and improved magnitudes for the comparison stars. This effort confirmed what I had suspected all along: several of the chosen comparison stars were microvariables. My student assistant Joanne Hosick and I made an effort to "solve" these new variables, but without much luck. Maybe next year. What are they? Most are likely to be small-amplitude rotating variables such as sun-like stars with spots. A few may be pulsating variables such as Delta Scuti or Gamma Doradus stars.

Constant Stars: And one or two program stars turned out to be non-variable! This is not surprising. Given the many centuries of observing variable stars, often with less-than-ideal precision, it is not surprising that there are many "suspected variables", and that some of them are constant. In fact, there is a whole *Catalogue of Suspected Variable Stars* (which one of my colleagues irreverently refers to as the "Suspect Catalogue of Variable Stars"!

Acknowledgements

As I end this 25-year chapter in my astronomical life, I want to thank several obvious individuals and groups who have made all this possible. One is my students; virtually all of the co-authors listed in the references in the previous section are undergraduate or UTMP students. Personally, I think the Natural Sciences and Engineering Research Council of Canada, for funding that has enabled me and my students to do much of our work. The third is the AAVSO staff who have designed the program, reduced the data, and made it available. I shall include Howard Landis in this group; as long-time Chair of the PEP Committee, he was responsible for much of its success. Most of all, I thank the AAVSO PEP observers, who have voluntarily made these observations for the good of science – and, I hope, for their own enjoyment and satisfaction. Along with other AAVSO observers, they are "heroes of science".

A postscript from Matthew Templeton, AAVSO Headquarters

As you've read, this is the last AAVSO PEP Newsletter edited by Dr. John Percy. The AAVSO is deeply indebted to John for his guidance of the AAVSO PEP Program during his tenure, and also for his editorship of the PEP Newsletter. We'll do our best to uphold his standard of excellence with the Newsletter as we transition to a new editorship in the coming months, and we wish John all the best in his retirement; if it is anything like most other academic "retirements" (which rarely are) we wish him great productivity as well, and look forward to his continued contributions and mentorship of the AAVSO PEP Program, and the AAVSO as a whole.

Recently, the AAVSO International Database (ID) has been expanded and enhanced to include more information useful to researchers analyzing AAVSO data. Much of this information was already collected as part of the PEP program, and the rest of the organization is "catching up" to what the PEP program has been doing all along. The web-based "PEPObs" data submission tool under the Blue & Gold section of our website was recently enhanced and adapted to work within this new database structure, and if you're using PEPObs to submit data, you shouldn't notice much difference. As always, if you have questions or comments about PEPObs or anything else relating to the PEP Program, please email me (Matthew Templeton) at matthewtaavso.org.

Thanks again to John for all of his hard work over the years, and thanks to you all for participating in the AAVSO PEP Program. The data you provide are unique in the variable star observing community – and many of the stars in our program wouldn't be photometrically observed at all if it weren't for you. Keep up the great work! Here's to clear skies and good observing in 2008.