AMERICAN ASSOCIATION OF VARIABLE STAR OBSERVERS

ABSTRACTS

OF

PAPERS

PRESENTED AT LOUISVILLE MEETING

24 MAY 1969

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187 Concord Avenue, Cambridge, Massachusetts 02138

Edited by R. Newton Mayall

We were invited to hold our 58th Spring Meeting in Louisville, Kentucky, by the Louisville Astronomical Society, from 23-25 May 1969. Professor Walter L. Moore was the official host and representative of the Society. Louisville is in the Blue Grass section of Kentucky and is the home of Churchill Downs where the famous Kentucky Derby is run. It is an important distilling center and one of the world's largest tobacco-manufacturing centers. It is a baseball bat manufacturing center and is the home of the world's largest publishing house for the blind, which publishes books and magazines in Braille and talking book form. Situated on the Ohio river, Louisville is a shipping center.

On the way to Louisville Mrs. Mayall spent the day at Bellcomm Inc. and conferred with Dr. W.I. McLaughlin about the AAVSO's ability to work with Bellcomm in determining the magnitude of the water dumps by Apollo 10. Bellcomm says the "most important contribution observers can make is collection of data on the spacecraft waste water dumps.

"Immediately after a water dump, the apparent brightness of the spacecraft will increase markedly. Construction of a light curve for this event, either by a trained visual observer or an observer using photometric equipment, would be of the greatest importance to an analyst attempting to model the cloud. Although this cloud is an extended source, it should appear essentially star-like to the eye, allowing the use of standard stellar magnitude estimation techniques. Photographs, or a series of photographs, would also be an aid in the study of this event."

Much of the material pertinent to Apollo 10 was rushed to a select group of members, most of whom were clouded out at the time of the dump. Then too it is not always possible to say exactly when dumps will be made. It is hoped to have much more material ready for the Apollo XI flight. AAVSO observers will be able to point their telescopes to the spacecraft and hopefully make observations that are useful. When the time comes, explicit instructions will be sent out.

Friday evening, 23 May, the Louisville Junior Astronomical Society entertained us in the Library at the University. These young boys showed a remarkable interest and insight into our favorite subject -- astronomy -- from instruments to radio waves (see Abstracts).

Saturday morning was given to reports and other matters; and the afternoon was given to papers. During the noon recess, and in the afternoon, representatives of the Cincinnati Country Day School, under the leadership of David Laird, set up a terminal which was tied into a GE 265 Computer in Cleveland, Ohio, and ran off several light curves of RR Leonis. General Electric Information Services provided the terminal and computer time for the demonstration.

Our banquet was a huge success, as usual. Frank De Kinder was presented with a birthday cake -- it being his 78th birthday. Margaret Mayall accepted for the Association a gift of a model reflecting telescope, made and presented by Ted Szybowicz.

Following the dinner, Dr. Wasley S. Krogdahl of the University of Kentucky, at Lexington, spoke to us about pulsars and supernovae. He told of the many problems that have cropped up and how they are trying to solve them. (See also paper by Lewis J. Boss in Abstracts)

Sunday morning several went out to visit Walter Moore's observatory. He has an 18-inch reflector which was focused on the sun.

We had many long-distance travelers at this meeting, but Marvin Baldwin from Great Falls, Montana gets the prize -- whatever it is. He was followed by Sweetsir from Florida; the Goods and DeKinder from Montreal, and Johnston from Toronto, Canada; the Welches from Massachusetts with their daughter from Maine; the Bibbers, Davis and the Mayalls from Massachusetts; and the Fords and Scovil from Connecticut.

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COMPUTER PLOTTING OF VARIABLE STAR LIGHT CURVES, by Henry Gale, Jonathan Taft, Jeffry Spain, and David E. Laird

In December, 1967, the Cincinnati Country Day School installed a time-sharing computer terminal. We used the terminal to access a GE 265 computer in Cleveland. Within a week the senior author and Jeffry Spain had written a FORTRAN program for reducing lunar occultations. This program has since been used to reduce over 130 observations. Prior to this, we had actually tried to reduce about five occultations by hand computation. After spending up to eight hours of work on each of these, two were successfully computed! Now each occultation is reduced in less than a second! We have since written a program to predict grazing occultations; this program produces latitude-longitude points at the rate of four to five per second, each of which would easily represent a day's work for the human calculator.

At this point, we needed some new program ideas, so the editors of Sky & Telescope published our note[1] to the effect that we would tackle computing jobs that other amateurs might send us. Within a few days we received a letter from Major Marvin E. Baldwin telling us about his variable star work. In particular, he described the work he had done with RR Leonis in preparing a light curve which had been published in the previous issue of Sky & Telescope.[2] Major Baldwin soon sent us the raw data and the work sheets which he used in making this analysis. Initially we have undertaken only to reproduce this work by computer; we are now ready to attempt to modify this program to make it sufficiently flexible to perform similar analyses on a wide range of variable types.

The raw data come to us on cards which have punched in them the star name, the Julian date of the observation (in decimals), the estimated magnitude, and an observer code. Since we cannot handle cards in our present set-up, we must first have these cards interpreted or printed out. We then punch the J.D.-magnitude pairs into paper tape at the teletype. The first step in the reduction is the conversion of the J.D. of observation to heliocentric time.

The heliocentric time correction, in minutes, is obtained by the following formula[3]:

$$\text{Hel.-Geo.} = A(\cos\delta\cos\alpha) + B(0.398\sin\delta + 0.917\cos\delta\sin\alpha)$$

Given the right ascension and declination of the star, the computation of the appropriate trigonometric functions is no problem; even a medium speed computer can compute the sine or cosine of an angle in less than a milli-second. The A and B factors must be obtained from a table. The table accompanies the above-cited formula. We therefore began by punching a tape containing the pairs of numbers in the A and B tables. We could have written a routine to perform this table look-up and interpolation, but this is a fairly difficult problem and it also requires storing a fairly lengthy table. Instead, we analyzed the table with a program which produces the coefficients of a polynomial which fits the data. We tried polynomials up to the seventh degree at which point the fit was very good. In fact, it was so good that, had we continued further, we would have been trying to reproduce the "steps" in the tabular function which are introduced by rounding the input values to two decimal places. The resulting polynomials for A and B are:

$$\begin{aligned} A = {} & -1.4434 - 0.141586\,T + 1.30506\times10^{-4}\,T^2 + 9.34687\times10^{-6}\,T^3 \\ & -2.25183\times10^{-8}\,T^4 - 8.94269\times10^{-11}\,T^5 + 3.44557\times10^{-13}\,T^6 \\ & -2.96541\times10^{-16}\,T^7 \end{aligned}$$

$$\begin{aligned} B = {} & 8.03794 - 2.50531\times10^{-2}\,T - 1.25615\times10^{-3}\,T^2 + 4.55310\times10^{-7}\,T^3 \\ & + 5.3548\times10^{-8}\,T^4 - 1.96636\times10^{-10}\,T^5 + 2.14977\times10^{-13}\,T^6 \\ & - 3.53436\times10^{-17}\,T^7 \end{aligned}$$

In these formulae, T is the number of days since January 0, but A and B are in minutes of time. The polynomials were produced from a table giving points 10 days apart. Although the polynomials reproduce these points almost exactly, it is still possible for such high-order polynomials to "go wild" in between the given points. We have evaluated them for steps of one day and find no sign of alarming behavior, so we believe they are valid.

We are now ready to proceed with the construction of the main program, REDVAR. It is written in FORTRAN IV for the GE 635 Time-Sharing computer. The main program is quite short, since it only calls a number of sub-routines and reads and writes data from and to files. This technique was used to permit three people to work on the program simultaneously, each working on a particular section. The main program links these sub-sections.

The raw data, the uncorrected J.D.'s and magnitudes, are first entered into a file called VARDAT and this file is now saved in the disc memory of the computer. The subroutine HELIO reads this file and puts the data into two lists or arrays. A do-loop now takes each J.D. and determines how many days it is from the beginning of the year. These days are now values of T, which are entered into the two polynomials for obtaining A and B. The values of A and B are then combined with the trig functions of the star coordinates and the resulting J.D. is now converted to heliocentric time. The new J.D.'s are written into the file VAROUT. This permits the processed data to be removed for inspection or to be combined with other data in a different analysis. A second subroutine, FAZCOMP, takes each corrected J.D. and converts it to a phase date by the use of the formula for the Ephemeris of the star, which in the case of RR Leo is:

$$\text{J.D.}_{max} = 2436610.441 + 0.^{d}4523874\ E$$

These phase dates and the corresponding magnitudes are written into the file FAZTIME. A sorting subroutine, FAZSORT, now takes the phase dates from FAZTIME and sorts them in ascending order, keeping each magnitude with its respective phase date. This new table is written into the file POLYDAT.

A sub-program STARFIT is now run on these pairs of phase dates and magnitudes. This program uses the method of least squares to produce the coefficients of a polynomial which represents the mean light curve. These coefficients are input to the final program STARPLOT. This program plots the derived polynomial. The plot is somewhat crude in that the magnitude increment is determined by the availability of only fifty positions on the teletype. Even at this, it is likely that the plot is adequate in precision, due to the inherent uncertainties in the raw data.

This is only the beginning. The program must be made much more flexible. We will have to handle problems involving variable periods and we must provide for a variable width phase "slot"; we must be able to determine the probable period from the data. But before these problems can be tackled, some others must be solved, and one of these is money.

Thus far, we have run this program out of the school budget for computing time. These are lengthy programs and require large amounts of time for their development and running. The development of such programs constitutes valuable educational training and can be justified. The processing of large amounts of data is another matter. Fortunately, we have just received a grant in the amount of $4,000 from the Martha Holden Jennings Foundation of Ohio. Under its provisions, we are setting up a research astronomy class which will devote its efforts to just this kind of work. Other students will now help in the task. We must also find a way to convert Hollerith cards to punched tape, at least so long as we continue to process data by time-sharing computer. And, finally, after production is well underway, we shall need to investigate additional funding so that the reductions can be continued in something approaching a real-time environment. Eventually, one might envision a national net based on the time-sharing system, which would collect and analyze data from all the widely-scattered observers.

1. Laird, David E., Sky & Telescope, May, 1968, p. 287.
2. Baldwin, Marvin E., Sky & Telescope, April, 1968, p. 267
3. Manual for Astronomical Photoelectric Photometry, A.A.V.S.O., 1962, p.8

APOLLO 10, by Newton Mayall

On the way to Louisville, Margaret and I visited Bellcomm, Inc., in Washington, D.C. and talked with Dr. W.I. McLaughlin about the possible ways the AAVSO might be of help to him in obtaining data on this flight of Apollo 10 and subsequent flights of 11, 12, 13, and 14. Also we discussed certain changes that might be made in the print-out data sent to observers. I have brought along print-out data for Louisville, which gives the Julian Day; UT time; sun's elevation; azimuth, elevation of spacecraft; the slant range; and right ascension and declination. I will leave these with you, so that you can try observing the spacecraft Sunday evening if it is not cloudy.

Associated with the program is Argus-Astronet, a network of amateur radio stations for communications and from which you can get up-to-date information, and accurate times of water dump, which is Bellcomm's interest. The Astronet frequency is 3885 Kc/s. Those of you who have short wave radios might try listening-in for up-to-the-minute information. Bellcomm is particularly interested in the visual magnitude of the water dumps. This should not be hard work,for the length of observing time, if seen, is only about 20 minutes. From magnitude determinations a light curve can be drawn.

THE PULSAR PUZZLE, by Lewis J. Boss

About fifteen months ago Dr. Antony Hewish of the Mullard Radio Astronomy Observatory at the University of Cambridge, announced the discovery of a starlike source of radio frequency pulses, the origin of which is still one of the major mysteries of astrophysics. It was found that some weak radio signals being radiated from a point in the constellation Vulpecula were a succession of broadband impulses as regularly spaced as the time signals from the Naval Observatory transmitter at WWV, recurring at extremely rapid intervals. Interest was further increased when it was determined that these impulses appeared to be emanating from a planetary sized body having a mass at least, and perhaps exceeding, that of the sun.

Since that time some two dozen of these regularly pulsating radio sources, emitting enormous bursts of energy at fantastic speeds have been found by astronomers at radio observatories in many parts of the world. During this time these observers have done a brilliant piece of scientific detective work in fitting together the numerous bits of information supplied by many investigators to determine the nature of these strange objects. This achievement is the more remarkable since no one, until very recently, has ever actually seen a pulsar. All of the data so far obtained has been gleaned from the radio signals received by giant radio telescopes.

Early in the investigation it became apparent that only two classes of stars could possibly meet the requirements summarized by the existing observations. One of these classes, the white dwarf stars, was fairly well known. These are stars that have collapsed after burning up their nuclear fuel. The mass of these stars, in most cases is about right, approximating that of the sun, and this is compressed into planetary volume. Such a body, as massive as the sun and coming to the point of exhaustion of its nuclear fuel, would reach equilibrium when gravity had reduced the star's diameter to about 6000 miles. Many white dwarfs have, approximately, this mass and volume. However, because of the absence of light that could be confirmed as coming from a pulsar source many astronomers became convinced that a second type of body, the neutron star was the more probable source of the pulsing radiation. Additionally it did not appear that the white dwarf stars could produce pulses spaced at such brief intervals as the pulsars.

The neutron star has never been observed, up to now; but the idea of stars that alternately expand and contract has long been entertained by astronomers, especially with regard to the Cepheid and RR Lyrae type of variables. It is possible to conceive of a star a great deal more massive than the sun, eventually collapsing after consuming its nuclear fuel, but if the gravitational forces involved compact the residual matter into too small a space a somewhat different situation arises than the production of a white dwarf star. The remaining matter will reach a rather critical condition of instability and then explode into a super-nova, spreading vast clouds of material over immense distances. If the star's mass is more than that of the sun the gravitational forces eventually become so enormous that the electrons in the remaining material are squeezed up against the protons, and neutrons are formed. When this occurs the electrons disappear and the outward pressure resulting from their motion vanishes while the gravitational inward pressure creates a hard packed mass of neutrons, emitting very little light and forming a neutron star consisting of an ultra-dense globe 15 to 150 kilometers in diameter in the midst of the super-nova's remnants.

Last October the National Radio Observatory, at Green Bank, West Virginia located a pulsar in the middle of the Crab Nebula, having the shortest pulse period found so far. Radar type measurements have confirmed that the pulse period is 33 milliseconds, each pulse having a duration of 4 milliseconds. Doppler comparison of the times of arrival of the high frequency portion of the pulse with the low frequency signals has confirmed that the source is indeed in the midst of the Crab Nebula which is about 6500 light years distant. It appears to have been formed by the explosion of a super-nova in AD 1054 which was observed and recorded by the Chinese some 900 odd years ago.

Astronomers at the Steward Observatory at the University of Arizona found a 15th magnitude star which was located precisely where the radio telescopes had located the pulsar, which had been given the designation NP 0532 meaning R.A. 05^{o} 32' and although no variation in this star's light could be seen they thought that perhaps the optical flashes were being produced in synchronism with the radio pulses and hence at a rate which the eye could not detect unaided. Accordingly the output of a photoelectric photometer was fed into a device known as an electronic signal analyser and averager. This instrument when properly synchronized with the pulsar's peak emission period produced a visual wave form on the screen of a cathode ray tube. It also counted the visual light peaks and altogether made about 12,000 separate measurements of light intensity per second. It was found that the optical flickering corresponded exactly with the peak-to-peak radio pulses from pulsar NP 0532 in the middle of the Crab Nebula.

This observation was confirmed by other astronomers at McDonald Observatory in Texas, and at Kitt Peak in Arizona. Observers at Lick Observatory on Mt. Hamilton, California, used a different method to observe the optical variations, comprising an image intensifier, a television camera tube and a television receiver. They trained the 120-inch reflector on the star and picked up the image at the Coudé focus of the telescope with the image intensifier. This was closely coupled to a TV camera tube utilizing secondary electron emission principles. The star's light, before it entered the image intensifier was interrupted by a spinning disc shutter having six slots and driven by a variable speed motor. When the shutter speed was correctly adjusted a stroboscopic effect was achieved and it was possible to see and photograph the star's light slowly fluctuating in brilliance on the screen of the television receiver. The signals from the television camera were also recorded on television tape so that they may be studied at leisure later on. The Lick observers corroborated the fact that the optical signals were in phase with the radio pulses.

The observation of NP 0532 has uncovered one more feature of the pulsars -- their pulse rate is gradually slowing down which is another factor in building the case for the neutron star theory of origin. In view of the extremely high rates of pulsation it seems possible to discard the white dwarf explanation of pulsars because the very brief peak-to-peak periods could not be produced by a rapid enough axial rotation without insuring the star's prompt disintegration. Although we still do not know the "why" and "how" of the pulsar flashes, now that the astronomers have "seen the light", perhaps the way is opened along which the research may be guided. Certainly with these new suggestions from numerous sources, investigators should be able to discover more of the physical attributes and features of the pulsars and advance closer to a total solution of the unique and mysterious pulsar problem.

ONE OF SKY & TELESCOPE'S "LITTLE KNOWN VARIABLES", by Charles E. Scovil

In mid-April John Bortle pointed out to me the article in S&T for April 1969 (page 262) on little known variables, suggesting that we might photograph one of these and solve the questions connected with it.

This variable is BH Draconis at 1950 Co-ordinates RA 19^h 02.8^m, Dec +57° 23'. The star was said to be an Algol type binary with a photographic range of 8.0-8.6 and a period of 1^d 19.6^h. Visual range was expected to be about the same as photographic due to the A0 spectral type. Eclipses were said to be partial and have a duration of seven hours.

The variable is one component of a double with a separation of about 10" and it was not known which of the pair it was. The star was studied by Drs. Strohmeier and Knigge, who reported the elements as J.D. min. 2,425,774.480 + 1^d.817232E. Ephemerides were given in the S&T article, which asked for observations to verify the period and determine which component of the pair was which.

On April 21 I took a photograph of the area with our 22" telescope to see if we could split the double on our plate scale, and to prepare a chart of the area. The double was not split due to overexposure of the relatively bright stars. Exposure was 5 minutes on Tri-X Pan Professional film, at f/3.7. It covers a field of about 3x5°. Not much shows since the images are so small. On an enlargement to D chart scale of the central area of the plate, the brightest image is the variable with its companion. The photo was sufficient to make a chart of the area. Magnitudes were taken from the SAO Catalogue. The brighter comparison stars are scattered and require a low power, wide field ocular to get them in the same field, making it doubly difficult to eliminate the effect of the companion star.

On April 26th I observed an eclipse of the star. It was soon apparent that the brighter of the pair was the variable. The drop in magnitude was quite rapid for such a long eclipse, taking only an hour and a half. There was then a period of two hours with no change, and a rapid rise to maximum, again about 1 1/2 hours. The plot of the eclipse indicates a central time of about 7^h 25^m, which agrees well with the ephemeris.

On May 7th I observed a second eclipse, which was also observed in part by Clint Ford. In this case the drop in magnitude was slower and the period of minimum was only about one hour. The rise was more rapid than the drop. I took a photo before the start of the eclipse, at the f/15 visual focus and another during mid-eclipse. A composite of the two negatives, slightly offset, shows a noticeable difference in magnitude.

Two more eclipses were observed on May 16th and 18th. A comparison of the plots of all the observations was made. From the comparison of the first two I thought we might be seeing alternate eclipses, but it turns out they are both "A" type eclipses if we label alternates A & B. The eclipse of May 16th is quite a bit shallower and the slopes are not too steep. This is a "B" eclipse, which may account for the difference, or it may be just subjective. The May 18th eclipse is the next in the series, an "A" eclipse. This started in daylight, but the portion observed seems to show the steeper curve. Further observations might give a statistical analysis and answer the question of alternate eclipses. A photoelectric run on alternate eclipses would probably solve the question more quickly. I don't think the star is easily enough observed to add to our regular eclipsing program.

VARIABLE STAR OBSERVING SKILLS APPLIED TO AN ASTEROID, by Marvin Baldwin

Although my observing interests over the past few years have been limited almost exclusively to variable stars, I recently found myself enticed to another type of observing problem. An article in the November 1968 issue of Sky & Telescope discussed the periodic changes in brightness of the asteroid Eunomia as it rotated, and the possibility of timing its maxima and minima in the same manner that I use for short period variables fascinated me.

By the 18th of November I was able to locate Eunomia within range of suitable comparison stars and made a series of visual observations with my 10-inch reflector. The results were even better than I had hoped for. On 24 and 26 November I continued observing by adjusting to new comparison stars. From these observations I was able to establish approximate times for six maxima and seven minima and verify the given period of rotation for Eunomia of six hours five minutes. Thereafter, a long period of very poor weather caused my interest to wane until Frederick Pilcher's new feature, "Observing the Asteroids," appeared in the February 1969 issue of Review of Popular Astronomy.

I wrote to Mr. Pilcher explaining my observations of Eunomia, and my interest quickened when he responded with information that very little work had been done on the period of rotation for asteroids and that I had excellent opportunity, if I could obtain more observations, to obtain the period of rotation of Eunomia with greater accuracy than has ever before been achieved. Mr. Pilcher provided me with extended information of Eunomia's path which enabled me to resume observations with the return of clear weather on 18 and 26 February and 11 and 12 March. Thus, I obtained five more maxima and four minima. There was no difficulty whatever in determining the exact number of cycles between the November and February-March observations. Further analysis through application of the least squares method of reduction lead me to establish an initial epoch at maximum at JD 2440178.578 and a period of rotation of $0^d.253432$, remembering that a rotating object of this type will have two maxima and two minima per cycle. The following listing gives the observed times of maxima and minima to the nearest five minutes, number of cycles since the initially observed maximum, and the observed less the computed time of each maximum or minimum relative to the above elements.

UT		JD	CYCLE	O-C (day)
18 Nov 68	- 0205 M*	2440178.587	0.00	+0.009
	- 0325 m	.642	0.25	+0.001
	- 0455 M	.705	0.50	0.000
	- 0625 m	.767	0.75	-0.001
24 Nov 68	- 0220 m	2440184.597	23.75	0.000
	- 0330 M	.646	24.00	-0.014
	- 0525 m	.726	24.25	+0.002
	- 0650 M	.785	24.50	-0.002
	- 0815 m	.844	24.75	-0.006
26 Nov 68	- 0140 M	2440186.569	31.50	+0.008
	- 0300 m	.625	31.75	+0.001
	- 0430 M	.688	32.00	0.000
	- 0605 m	.754	32.25	+0.003
18 Feb 69	- 0325 m	2440270.642	363.25	+0.005
	- 0435 M	.691	363.50	-0.010
	- 0625 m	.767	363.75	+0.003
26 Feb 69	- 0255 m	2440278.622	394.75	+0.002
	- 0425 M	.684	395.00	0.000
11 Mar 69	- 0540 M	2440291.736	446.50	+0.001
12 Mar 69	- 0305 M	2440292.627	450.00	+0.005
	- 0425 m	.684	450.25	-0.002
	- 0555 M	.747	450.50	-0.002

* -- M = maximum
m = minimum

Ordinarily, without further information, we would suspect that an appreciable adjustment in this period would be necessary due to the changes in aspect angle during the observing period. However, Mr. Pilcher informs me that a large periodic brightness range during November and May oppositions and a small range during February and August oppositions indicates that the axis of rotation is near the plane of the orbit. Therefore, probably very little adjustment in the period is required to compensate for changes in the aspect angle.

Another source of error in my period for Eunomia's rotation which has not been fully evaluated results from the increasing distance between the earth and Eunomia during the period of observation. During 1968 - 1969 observations this will have the effect of resulting in a period slightly longer than the true period. Magnitudes of this error may be on the order of seven or eight minutes over the 450 cycles. If this proves to be the case when the mechanics of the problem are analyzed, the period may be as much as $0\overset{d}{.}000012$ shorter than shown above.

A statistical study of the probable error in the newly determined period, assuming that errors due to change in aspect angle and distance variations can be determined and therefore eliminated, gives us an error of $\pm 0\overset{d}{.}000006$ with better than 95% confidence. This will allow us to project the rotation of the asteroid through a period of nearly 7000 cycles expecting a drift of no more than 1/8 cycle with a high degree of confidence. This would give us capability of projecting through about 1750 days. Thus, the chances appear excellent for establishing the exact number of rotations between maxima or minima of one opposition and the next. If this can be accomplished, then we should be able to tie together all known timings of maxima and minima and establish a very accurate period of rotation for Eunomia.

Apparently, of all the asteroids, only Vesta has a period of rotation determined with sufficient precision that the epoch can be identified from one opposition to the next. This being the case, we have here one more area in astronomy where the field is wide open and nearly anyone can push back the frontiers of knowledge.

I hope that any prospective amateur astronomer who is about to despair over the difficulties and expense of obtaining and properly utilizing intricate electronic or other equipment to compete with the professional astronomer will take note of the fact that this project was accomplished via simple visual observations with a simple reflecting telescope. Although this paper illustrates the attainment of new information on an asteroid using the methods of the variable star astronomer, there can be little doubt that the area where the amateur can take the greatest strides for the advancement of the astronomical sciences today is with variable stars themselves. This opportunity awaits simply because the professional astronomer has not had time to investigate variable stars in great detail.

HOW TO OBSERVE VARIABLE STARS, by Carolyn Hurless

Carolyn has put together a series of slides which she uses when lecturing to various groups, to show what fun it is to observe variable stars. She went through the groups of slides quite quickly but not so fast that we couldn't see the humor in many of them. She shows the interior of her huge observatory -- at least it looks huge in the pictures, but actually it is only about 6 x 7 feet. And, of course, if you remove the telescope you have more room to move around to take pictures. Anyway, she obviously has an interesting talk illustrated with very good color slides. (ED)

LIGHT CURVE BY COMPUTER OF R SCUTI, by Margaret W. Mayall

Among the many requests we got for information on the light curves of variables was one from Dr. K. Serkowski of the Mt. Stromlo & Siding Spring Observatories in Australia. He is preparing for publication a paper on the changes in polarization of the two RV Tauri stars R Scuti and U Monocerotis. He said the changes were large and spectacular, but he needs more information on brightness changes to be sure of a correlation.

We punched cards for about 2500 observations of R Scuti covering the 2 years of Dr. Serkowski's program. This seemed to be a good set of data to use in setting up a computer program for taking means and plotting a light curve. Barbara Welther of the Smithsonian Astrophysical Observatory with the advice of Owen Gingerich took over the project.

Miss Welther has given us a very fine light curve of R Scuti plotted from 162 5-day means over an 800-day interval. The mean values depend on from 1 to 57 observations each. She used different symbols to indicate the following numbers of observations: 1-3, 4-6, 7-9, and 10 or more. There is room along the side of the paper for a print-out of the average magnitude and number of observations for each interval.

One of the toughest problems is to do a certain necessary amount of editing in order to throw out values which are obviously in error. Each variable is almost an individual case and we have to be extremely careful that the computer does not smooth out the irregularities so important to observe.

It is fairly certain that the forthcoming AAVSO Report 28 will be in the form of a plot of the mean curve with an accompanying print-out of the numerical values.

SOLAR OBSERVER REDUCTION CONSTANTS, by Richard H. Davis

In October of 1967, it was reported that reduction constants (scale and weight factors) had been computed for a selected list of 31 sunspot observers for each month during 1966, using a computer program written by Miss Connie Stowe under the supervision of Mrs. Gerald Vanek.

In October of 1968, it was reported that similar scale and weight factors for most of the observers reporting to the AAVSO Solar Division were about to be computed for each month of 1967 using the computing facilities at Smithsonian Astrophysical Observatory made available through the courtesy of Dr. Owen Gingerich. At the same time, it was reported that it was hoped to utilize a time-sharing computer terminal, made available to the AAVSO by an anonymous benefactor of the Solar Division, to compute such scale and weight factors on a current basis for all observers reporting to the AAVSO Solar Division.

I am pleased to report that at least some progress has been made on this project. The constants for 1967 were computed using the facilities at Smithsonian Astrophysical Observatory and have been used since January, 1969 in the computation of the American Relative Sunspot Numbers. Furthermore, a program for computing reduction constants has been written for the time-sharing computer terminal installed in the AAVSO office and has been successfully used in computing scale and weight factors for selected observers for selected months during 1968 and 1969.

Although it now appears that the time-sharing computer terminal will not be available to the AAVSO after June 30, 1969, I hope and expect by that time to have computed scale and weight factors on a monthly basis for the period from 1966 through May of 1969 for a sufficient number of observers to permit detailed analysis of the month-to-month variations in those constants. Mr. David W. Rosebrugh has already done some preliminary plotting and analysis of the scale and weight factors for 1967 and his preliminary results indicate that this project may eventually yield some interesting results.

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(On Friday evening the members of the Louisville Junior Astronomical Society entertained us with papers on a variety of subjects. These young boys have kindly sent us their papers, which are reproduced below. ED)

SUNSPOTS, by Donald J. Richardson (Age 12)

Father Scheiner said he discovered sunspots before Galileo because Galileo held it back for two years to clarify whether sunspots were on the sun or were small bodies. Once they thought a large sunspot was Mercury.

Galileo was the first to determine the sun's rotation. He said it was even, and he said it was 27 days.

Carrington and Spores found out that solar rotation was uneven about 1800.

Galileo found out that sunspots were not completely dark and that sunspots did not appear in latitudes greater then 30°.

In 1843, Schwabe, a German apothecary, noted that the waxing and the waning of sunspots were each 10 years, but R. Wolf said it was 11.1 years.

Most spots lie within 40° and the maximum is between 15° and 20°. Most spots begin at 40° and die at 5°. One spot may last a day or two, up to several weeks.

Sunspots have a diameter of 10,000 miles to 100,000 miles. They usually occur in pairs, one due west of the other.

Why sunspots are darker then the rest of the sun is because sunspots are about 7,000°F with the rest of the sun 10,000°F.

Sunspots can upset radio and TV when the particles from the sunspot bombard the ionosphere.

LIBRATION CENTERS, by Eric L. Grace

As you know, lots of curious things are floating through space, which turned out to be unimportant, just objects gathering dust. But since the dawning of the space age, some of these curiosities have now become very important. One of these is the Libration Center. If you are not familiar with the name, they are associated with Greek and Trojan Camps, Gegenschein, and Kordylewski's clouds.

The first research into these centers was in 1772 by a French Astronomer by the name of Joseph LaGrange. He calculated that there were points in space near the Earth and Moon where the gravitational pull of the two bodies balanced out to zero.

The Libration Centers are found in any two body systems, such as the Earth and Moon or Sun and Saturn.

These are roughly spherical in shape and occupy thousands of miles in diameter of space. The lesser body orbits the larger body of the two body system in synchronization (that is, they are in step with the larger orbiting body).

It is thought that these centers are stable. Example, if we put a space station in the middle of Libration Center 1 of the Earth/Moon system, it would tend to stay in the center. Any drifting of the space station would be caused by an outside influence. Such as in the Earth/Moon system, it would be the gravity of the sun, and in the Sun/Jupiter system, it would be the gravity of Saturn.

As stated before, we think these centers are stable. In support of this, in 1906, astronomers found five (5) asteroids in the Libration Centers of the Sun/Jupiter system. Some are several miles in diameter. This group of asteroids became known as the Trojan Camp and eventually seven (7) were found in Libration Center five (5) of the same system. The group became known as the Greek Camp since it seemed to oppose the Trojan Camp.

In 1961 a Polish astronomer, K. Kordylewski of Krakow Observatory announced he had discovered faint glows at Libration Centers LC-4 and LC-5 of the Earth/Moon system. He said that these glows could be seen with the naked eye under the right conditions. He promised the world proof and photographs. The photographs were never released and nothing has been heard from him since 1963.

A group of employees of Lockheed Missiles and Space Company built an observatory in the Santa Cruz Mountains for recreational purposes. Since they were space men, they were interested in Kordylewski's Glow. So a hand picked staff of specialists, under direction of J.W. Simpson, began their work at the "Locksley" Observatory.

First of all, they had to determine what factors would hamper seeing these glows. Kordylewski said the glow would be fainter than the seventh magnitude. A medium intensity star or a cluster of faint stars being at a low altitude would prevent successful observation.

On January 4, 1964, they were rewarded for their work when they got their first confirmed sighting of the Libration Center Glow. The sighting was not made with a telescope but with the unaided eye. They had other sightings after the first, but they realized the power of suggestion could account for some of them. An advanced amateur astronomer with excellent vision, who knew nothing of the work they were doing, was brought in. After watching the area of Libration Center, the man soon pointed out the area of faint glow. Other people also confirmed the sighting with drawings made by them at about the same time.

The drawings made by different people on the same night showed the glow changes shape and sometimes the glow could be seen in two areas, and side by side.

It is thought that the glow is due to sunlight reflected from concentrations of meteors, or small particles.

Some uses these areas could be put to are as interesting as the Centers themselves are. They could be used as supply and space station parking areas, since in these areas the gravity gradient is a lot lower. Another use is when we settle the front and back sides of the Moon, communications between distant locations will be a problem, because of the lack of an atmosphere. This would limit Radio communications to line of sight, thus the small diameter of the moon will limit line of sight communications to only a few miles. The Centers could then be used for Tel-Star Satellites, thus improving communications to greater distances.

A large radio-telescope positioned about 41,000 miles beyond the moon at Libration Center LC-2 would be ideal for Radio viewing of the heavens. By placing the telescope on a center line of the Earth/Moon system there wouldn't be any physical limitations. The moon would act as a filter and stop all interfering signals from the Earth. The same idea could be applied to optical telescopes. It is amazing to think of a 500-inch telescope out in space.

Some day we may see dozens of "Anchored" supply stations merging with the Libration Center Glow.

SOME TELESCOPE PURCHASING TIPS, by Mark Stein

The big question, for the amateur, is what telescope to buy. I say buy, for most times he (or she) will find amateur telescope making too risky and laborious.

Popular texts on amateur astronomy recommend at least a three-inch refractor or a six-inch reflector. A new three-inch refractor costs around $125. A six-inch reflector costs an easy $50 more. To the beginning amateur this may be a small fortune.

The best answer is a four-inch reflector, some costing as low as $50 and performing well under the 1.5 sec. of arc limit usually set for a three-inch refractor. Fully equipped four-inch reflectors cost around $100.

In my opinion, today it is incorrect to say a refractor is superior to a reflector of equal aperture. If made properly, today's reflector telescopes will be able to perform as well as any refractor of good quality.

Under the best seeing conditions, some reflector manufacturers give performance ratings as low as .7 sec. of arc and well over 13th magnitude for their six-inch reflectors. This is as good as any six-inch refractor rating that I know of.

It is mostly because of their low cost and various other reasons that I usually prefer reflectors, except in 2-inch, 2.4-inch and 3-inch sizes. But here again, for the price of a more expensive 2.4-inch refractor which comes with a fully equipped altazimuth or sometimes an equatorial mount and performs at its best 1.9 sec. of arc and maybe $11^1/2$ mag., you could purchase a fully equipped 4 or $4^1/2$-inch reflector with equatorial mount, circles, and electric drive, or equatorial mount, circles and flexible cable slow motion and good performance -- 1.0 sec. of arc and at least 12.1 mag.

As for mounts, if you own anything over a 3-inch refractor or reflector the equatorial mount is usually the only mount that will do. I know of one company that produces an excellent altazimuth mount for a refractor, with full slow motion. For a 2.4 or 3-inch refractor, this type of mount is completely acceptable and some people may think it easier to use than the equatorial.

Tripods are fine for 2 and 3-inch refractors; but for any reflector over $4^1/2$ inches, a tripod could mean trouble. The same can be said for large refractors.

As far as eyepieces are concerned Ramsdens are all right for low powers but Kellnors are better.

Ramsdens are useable for high powers, but orthoscopic eyepieces would be the best choice. Coupled with a good reflector, you have almost 100% color-free images.

Many years ago when you purchased a telescope you never knew if it was of any value until you looked through it. Nowadays if you purchase your telescope from a well known company such as Edmund Scientific, Criterion, Cave Optical or Unitron, you are sure to get an acceptable one. Beware of performance ratings and high sounding objectives -- for example, parabolic mirrors at an absurdly low price; and resolving powers lower than the Dawes limit.

Many companies exaggerate too much, as in one old ad for a 3-inch reflector, "Not one but two Ramsdens."

No one telescope can suit every amateur's needs. If you are just beginning and not sure of your interest, maybe a 4-inch Dynascope would be to your taste. For only $49.95, it is an excellent "first" telescope and has the power to do more advanced work. If you are advanced, how about a 6-inch Edmund or Dynascope at about $200. The important thing to remember is to check all the companies. Don't just look at one or two because telescope prices vary too much.

Today there are many different telescopes to choose from -- so many that it often becomes confusing. There are heated rivalries between companies.

More than one fellow amateur that I have known has had to make a choice between Criterion's Dynascope RV-6 and Edmund's Super Space Conqueror. Both have their advantages and disadvantages. Which one is better is really up to the buyer.

The main advantage of the RV-6 is its rotating tube which Edmund should but does not have. It also has metal setting circles, not plastic, and a cover over the drive. The price is $194.95.

The Super Space Conqueror's main advantage is a better drive, a more massive mount and a larger eyepiece selection (3). It also has a variable Barlow. I have never seen a performance rating for the RV-6 but the Edmund's is .75 sec. of arc. The price is $199.95. Edmund and Criterion are the best priced and best selling 6-inch reflectors on the market. (The opinions expressed above are the author's, and are not necessarily the AAVSO's. ED.)

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