A A V S O   A B S T R A C T S

Edited by R. Newton Mayall

PAPERS PRESENTED AT THE LONG BEACH MEETING, APRIL 24 - 29, 1963

The 52nd Spring Meeting of the AAVSO was held in Long Beach, California at the invitation of the Los Angeles Astronomical Society. One of our observers, Father Ronald Royer is President of the Society, and another, Ernest Lorenz, the Local Chairman for our meeting is President of the Excelsior Telescope Makers.

This is the first time the AAVSO has met west of the Mississippi. Here in the vicinity of two great observatories -- Mt. Wilson and Palomar -- was just cause for a grand celebration. Although the Meeting was scheduled for 28 and 29 April, the activities were extended from the 24th to 29th, during which period members visited Mt. Wilson and Palomar Observatories, Disneyland, Marineland, went yachting, made special trips to Cave Optical Company, and to many western amateur observatories as well as to other interesting sites, such as San Juan Capistrano.

Many outstanding astronomers met with us and addressed our meeting (see abstracts), and the final session was held jointly with Los Angeles Astronomical Society on 29 April at the Griffith Planetarium, where Dr. Robert Kraft of Mt. Wilson and Palomar Observatories delivered the Society's Morrison Lecture on "Dwarf Novae".

At the dinner on Sunday evening, Clinton Ford announced Larry Bornhurst's observing record and presented him with an illuminated certificate which reads:

SPECIAL COMMENDATION IS HEREBY GIVEN TO
LARRY BORNHURST
FOR HIS PHENOMINAL RECORD OF
2802 OBSERVATIONS
IN HIS FIRST YEAR OF OBSERVING
\- - -
GIVEN AT THE FIRST WESTERN MEETING
APRIL 28, 1963
(Signed)MARGARET W. MAYALL, DIRECTOR. (Signed)CLINTON B. FORD, SECRETARY

Not only was this an historic meeting, from the point of view of being the first on the west coast, but it was one of our largest and most memorable. Our host did everything possible to make our visit interesting, enjoyable and fruitful. Those who came from the East found the time all too short. Our gratitude is expressed to the Los Angeles Astronomical Society, and in particular to Ernest Lorenz and his aides, who made this a memorable occasion.

Many from the East went West. The honors for the longest distances go to the DeKinders from Montreal, the Davises and Margaret Mayall from Boston, and the Fords from Wilton, Connecticut.

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INVOCATION, by Father Ronald E. Royer

Our Father we are thankful for this occasion of coming together with fellowship and for the opportunity to share our scientific interest. When we consider the universe that is to us without limit, with its billions of galaxies, each with its billions of stars and see the vast span of order of the universe, we realize that to know astronomy is to know God for there can be no plan without a planner. We recognize

God as the Great Architect of the Universe who is also The Universe. We also recognize as God's, those great beings who are regents of clusters of galaxies, galaxies, systems and planets and to the Regent of our own solar system, the Christ.

As we get to know astronomy, may we grow in reverence of the wonders of this great plan and of the Planner.

Now as we are about to open our sessions, guide us in increasing our knowledge of your great universe and may we transmute that knowledge into understanding and wisdom, making us better individuals. This we ask in thy name. Amen.

TELESCOPIC METEORS, by Robert Adams

It seems to me that we who are members of the AAVSO have an obligation to learn to follow and record telescopic meteors since we use charts that give comparison magnitudes, and we have become adept at figuring magnitudes. When I began observing back in 1949, I did not pay much attention to telescopic meteors. It was not until 1954 that I finally became aware of their existence and made my first report to C. P. Olivier. Since that time I have submitted reports to him every year. According to Dr. Olivier's Meteor Reports published annually, there are only a few of us who contribute to this worthy cause.

I have consistently used a 10" reflector which enables me to see telescopic meteors down to about 14.5 magnitude on nights of good seeing. My yearly counts amounted to 23 for 1955, 37 for 1956, 34 for 1957, 33 for 1958, 32 for 1959, 49 for 1960, 41 for 1961 and 39 for 1962. According to Lovell, in his Meteor Astronomy most of the recorded telescopic meteors reported by telescope and radio echo technique are of the tenth magnitude or brighter -- presumably due to the difficulties of recording meteors of faint magnitude. On the other hand after I became used to spotting faint meteors, my count of telescopic meteors sharply rose so that by 1960 I counted one meteor of the 9th, two of the 11th and 3 of the 12th but 13 of the 13th and 30 of the 14th. Ever since this time my counts of meteors of the 13th and 14th have been consistently high.

I have not been able to glean much in the way of color differences. The brighter telescopic meteors(i.e. those under about 10 magnitudes)seem to be more of a yellowish color. Some of these brighter meteors seem to have jagged paths of tiny streaks issuing at angles to the line of flight much like the non-telescopic meteors. Among the brightest which may be above the 5th or 6th magnitude there is a distinct though momentary glow in the wake of the meteor's path. I have never observed any such wake among the faint meteors. There have been rare instances when I have seen two faint telescopic meteors running along side of each other. I have seen two or three telescopic meteors coming head on as it were. This was manifested by a faint point of light very rapidly increasing in intensity then almost as immediately fading. Other questions that present themselves to those who analyze the results of telescopic meteor observations are: Is there an increase in the number of sporadic meteors during meteor showers? Is there an increase in the number of telescopic meteors during sunspot maxima or during periods of solar flares?

Most of my observations have been prior to midnight so I have not been able to obtain an inventory of those meteors that occur after the earth turns towards the path of incoming meteors. It would be interesting to see if there would be an increase of observable meteors after midnight.

I still think that variable star observers can contribute to the overall knowledge of faint meteors by faithfully attempting to record the faint meteors.

I will admit that the technique of observing telescopic meteors is not an easy one to acquire and if an observer does not psychologically condition himself to be aware of and to be constantly on the alert to swing his telescope in declination and right ascension, he will easily get out of the habit of recording them. However, if any of you have had the thrill of seeing innumerable tiny specks flit across small paths wherever and whenever you move your 'scope on an occasional evening, you will never forget it. I have learned that you have to educate yourself to see this striking phenomenon. And I for one am aware of the very great contribution we of the AAVSO are in a position to make if we will but train ourselves to follow these illusive missiles.

FIFTEEN YEARS AS A SOLAR OBSERVER, by Frank J. DeKinder

It was Delisle Garneau who introduced me to Solar Observations. He had been observing the Sun more or less regularly during the maximum period of 1947-1948 and reported to the Solar Division of the AAVSO. The fact that I possess a fine four-inch refractor, equatorially mounted and electrically driven, housed in a domed observatory in the garden behind my home on the outskirts of Montreal, combined with the circumstance that I can always go home for lunch from my regular occupation, put me in an advantageous position to undertake this fascinating work. Since 1948 I have regularly made at least one observation of the sun per day, weather and circumstances permitting.

A domed observatory is not an ideal location from which to carry on Solar Observations. Although it protects the instrument and the observer from the wind, the Sun beating down mercilessly on the metal of the dome raises heat waves which make a perfectly calm image very rare indeed. Also, in the Province of Quebec, we do not enjoy in wintertime the calm weather of Southern California. This last winter 110" of snow fell without any thaw between December and the middle of March. A pathway has to be shoveled from the house to the observatory. The snow on the roof has to be removed to secure proper operation of the dome for it soon freezes tight. With temperature often below the 0° F. point, it is not always comfortable in an unheated observatory, although admittedly more so than in the open air.

The best set-up seems to be an enclosed observatory with a roof sliding away to the North. But Mrs. DeKinder objects to the shacklike appearance of such a structure whereas a domed observatory gives it a more dignified appearance. So I just have to make the best of it.

Many are the days however that I could record "excellent" seeing with "good" seeing in the majority of cases. Below "fair" seeing observations are rejected by the AAVSO.

When I started observing in May 1948, the maximum phases had already passed although in February 1949 a secondary maximum occurred when, in 17 observations, I recorded 162 groups with 2653 individual spots.

The Sunspot cycle is recorded in so-called "R" numbers, which are computed by multiplying the number of sunspot groups visible in any one observation by ten and add to the quotient the number of individual spots. This system was started 130 years ago by Rudolf Wolf and, although quite arbitrary, it has been adhered to ever since for reasons of continuity and comparison.

A group of members of the Solar Division of the AAVSO spread over 10 countries in five continents, keep the sun under daily observation and send in their monthly reports to Harry Bondy in Flushing, New York, who in turn forwards them to Dr. Sarah Hill at Whitin Observatory where they are processed and the monthly mean of the American Sun Spot number established. A complete report of the combined observations is sent back to every member, together with a comparison with the Zurich monthly mean, which is the reduction of another group of observers, located at the Swiss Federal Observatory in Zurich and its stations in Locarno and Arosa. Apparently the Zurich "R" numbers, which are often quite different from the AAVSO "R" numbers, are taken in most countries as the official record of Solar Activity.

Grouping is done in accordance with Waldmeier's chart which lists groups in classes from A to J with four types, 1, 2, 3 and 4 in each class. In this chart an A-1 group is a single spot without any penumbra, whereas the E and F groups represent huge formations, sometimes as much as 20 degrees of the Solar circumference in length(54286 miles or 7 x dia. of the Earth).

In the beginning I enthusiastically started making many drawings of individual groups and spots and following their day to day development. But I soon discovered that this work takes a lot of time, too much for a working man to keep up during lunch hour observations. Moreover, careful day to day comparison of a sunspot group presupposes near perfect seeing all the time, which is often lacking in our part of the world.

My observations are made by the "projection method' in which the image of the sun is projected on a screen about 18 inches from the eye-piece. The image is reversed from East to West but has the North on top. A group will appear at the right side of the projection which is the East side of the Sun and progress slowly over the disk with the sun's rotation to reach the left or west edge about 14 days later, if it does not die out in the meantime. Often groups are born on the visible hemisphere and it is fascinating to see them develop gradually, sometimes into huge E and F groups.

Groups are seldom evenly distributed over the Solar disk and quite often there is a marked difference between the activity in the two hemispheres, sometimes the Northern hemisphere undergoing a marked activity, at other times the Southern. In the last year or so the main activity seems to have been concentrated in the Northern Hemisphere.

A typical Solar cycle starts with groups appearing far from the equator, sometimes as much as 40° North or South and gradually working their way to the equator as the cycle progresses. This however is only a general trend and much of the time spots are seen anywhere between the equator and 35° North or South. In the minimum phase whole months may pass without a single spot being recorded on the Solar disk.

With all the professional work constantly going on in different specialized Solar observatories, I often ask myself if our humble work is really worth while, if this work can not be done much better and more dependably in these large observatories. On raising this question before, I have always received as an answer that our amateur work really is worth while and that it should be continued by all means. (In order to calibrate the newer methods, it is necessary to have a long series of overlapping observations. Ed.)

However, as long as the AAVSO considers it opportune to carry on this work, having the facilities to participate in it, I shall be glad to make my little contribution. If it were only to personally keep posted on the activity of the central body of our planetary system, it is a fascinating hobby, more really rewarding than so many pastimes without intellectual compensation.

XX TAURI, by Claude Carpenter

XX Tauri is an old Nova. I don't know how many AAVSO observers have charts of this star, but unless one has a sixteen-inch telescope or larger, trying to observe this variable would be useless.

In looking up old estimates of this star made in Michigan with a 12 1/2", I find the first estimates of its brightness I ever made were in 1937 and were around 15.0 magnitude. They seemed to continue near this estimate until 1940. Then I started observing the star again out here (California) in 1953 with an 18-inch and got estimates in the low 16's; and gradually through the years to 1958 it seemed to dim some to approximately 16.5.

The regular chart only goes down to 14.7 magnitude and there is a 14.5 very near the variable which I am sure some have mistaken for the variable. Accurate estimates were very difficult with only a 14.7 star in the field to use for comparison until about a year ago when Tommy Cragg made a chart using a plate he exposed with the 60" telescope on Mt. Wilson. This chart has comparison stars down to about 17.2 mag.

On December 28th of last year we had one of those extra good nights when the transparency just could not have been better. I glimpsed the 16.9 and 17.2 close to XX and the variable itself seemed to be about 16.6 mag.

It is quite a satisfaction to feel I had been looking at the right star through the years as its exact position was difficult to determine until Tommy made the new chart. On the 60-inch plate itself the variable does not show up very well, probably due to its peculiar spectrum.

PELTIER'S 12" CLARK REFRACTOR, by Don and Carolyn Hurless

Mrs. Hurless showed color movies of Peltier in his old Observatory, then showed the finishing of his new Observatory, -- which houses the 12" Clark Refractor given to him by Miami University in Ohio. Mrs. Hurless showed some excellent pictures taken through the 12" telescope.

The Hurless's then showed pictures of the presentation of the Hummel figurine "The Little Astronomer" (a small boy looking through a telescope), which Mrs. Mayall had brought back from Germany last fall, for presentation to the observer who made the 2,000,000th observation. The Diedrichs delivered the figurine and assisted at the presentation.

TELESCOPE CONSIDERATIONS FOR VARIABLE STAR WORK, by Tom Cave, Jr.

Mr. Cave's talk centered around the reflecting telescope. His recommendations were that the practical maximum size is a 10-inch working at f/5 or f/6, with a good field at low power. Another criteria suggested was that the telescope be easy to move, for the benefit of the city-dweller who may take his instrument to the country for observing sessions.

SEEING THE FAINT ONES - A Symposium - Tommy Cragg, Chairman

Lined-up on the podium were Claude Carpenter, Clinton Ford, Larry Bornhurst and Carolyn Hurless, and a chair for the weather man. Each stated the salient factors contributing to seeing faint ones, or one might say "How to become a member of the Inner Sanctum".

Hurless: First find the field. Use "in" and "out" of focus. Rocking head and averted vision.

Bornhurst: Uses power 200+.

Carpenter: Uses 260 power. Counts flickers.

Ford: Uses 210 power with 10" at f/8.

All agreed that the most important factor was to have the weather man on our side, hence the chair.

RHO PERSEI VERSUS ALGOL, by Joseph Matte

According to various texts Algol varies in magnitude from 3.28 to 2.06. Rho Persei, a semi-regular variable with a period of 33 to 55 days, varies from 4.0 to 3.3. On the morning of 4 July 1960 I began observing Algol about an hour and a half before minimum which was to occur at 0239 EST. As Algol approached minimum Rho Persei appeared to be getting brighter. After Algol had completely disappeared to my unaided eye I still could see Rho which was as bright as Mirfak (α Persei) for at least another 15 minutes or so. If we consider the 3.3 maximum of Rho as being correct, and the minimum of Algol being 3.28, how could I still see Rho which is supposed to be fainter at maximum than Algol at minimum? Did Rho suddenly decide to become a "flare star"? Was there a minor stellar explosion that special morning to help celebrate the American's 4th of July? I don't know. Perhaps someone else can corroborate my observation.

THE FIRST HYPERNOVA*, by Harlan Smith and E. Dorrit Hoffleit

Two years ago we took our Yale students, in the class on variable stars, to Harvard to examine the "radio star" 3C48 on the unique Harvard photographic plate collection. We had hoped for evidence of supernova activity. This year there were four more such objects to be examined, three of them so faint that not many significant observations could be found. The fourth, however, proved a bonanza. After the first half dozen plates we examined, it revealed itself as a variable. As this object is normally about 12.5 photographic magnitude, we could examine it on several thousand plates.

The object is 3C273 in Virgo, at $12^h\ 26^m\!.6$, $+2^\circ\ 20'\!.6$(1950). Astronomers at the California Institute of Technology have reported to the English Journal, Nature, that 3C273 is an abnormally luminous nucleus of a galaxy showing a large red-shift.

From observations covering a span of 76 years we found that 3C273 varies in three modes. First, the average brightness appears to have declined at a rate of about 0.2 mag per century. Secondly, we find irregular cycles the order of ten years in duration. The most pronounced such cycle showed a maximum at 12.5 in 1940 flanked by minima of nearly 13 mag. in 1930 and 1947. The first of these two minima was preceded by a flat plateau at 12.5 lasting more than ten years. Finally, on iso-

*(This paper was presented at the Tucson meeting of the A.A.S. and through the kindness of the authors was presented again at the AAVSO Meeting.)

lated plates we found images nearly a magnitude brighter than normal. Such flashes appeared most frequently in 1929, above our flat plateau and shortly before a relatively abrupt decline to minimum.

The most highly luminous supernovae on record, of Type II, are not known to have exceeded a brightness of absolute magnitude -19. In the galaxy 3C273, whose absolute magnitude is -26.5, a Type II supernova would increase the apparent brightness by only a trivial 0.001 mag, yet we find variations of over a whole magnitude. What we have been observing must therefore be looked-upon as some sort of hypernova activity, perhaps involving a considerable area of the galaxy as a whole.

Fortunately 3C273 is sufficiently bright for many AAVSO members to help keep watch over it. This important object may well prove to be one of the beacons to the astronomy of the future.

SOLAR TRANSIT OF UNKNOWN OBJECT, 15 FEBRUARY 1963, by Cyrus Fernald

On 15 February 1963 at 10:16 A.M. EST I observed the transit of an object across the sun while I was making my daily sunspot observation, with my Questar (40 power eyepiece) -- seeing conditions good, clear sky 0 cloud cover. Location 314 Wood Avenue Tangerine, Florida. Road map shows Longitude 81.6 W, Latitude 28.8 N.

The object started its transit at a point about 8 o'clock (clock face with 12 at north point of the sun). It passed off at about 1:30. In other words, nearly but not quite a central transit. The apparent size of the object was between 1/30 and 1/20 the sun's apparent diameter, something over 1 second of arc. The object appeared to be perfectly round, with very sharp clean edges. It was very black, with no trace of sunlight showing through it.

At the time of making the observation my wife was in the house, some 50 feet away from my observing location. I called to her and she came out immediately. She had a good look, when the object was not quite half-way across. My second look started when the object was about 3/4 across and continued through 3rd and 4th contacts. This helps to fix the time of transit as about 20 seconds. The edge of the object was perfectly sharp as it left the sun. (See Explanation below. Ed.)

AN EXPLANATION OF FERNALD'S OBSERVATION, by Clinton B. Ford

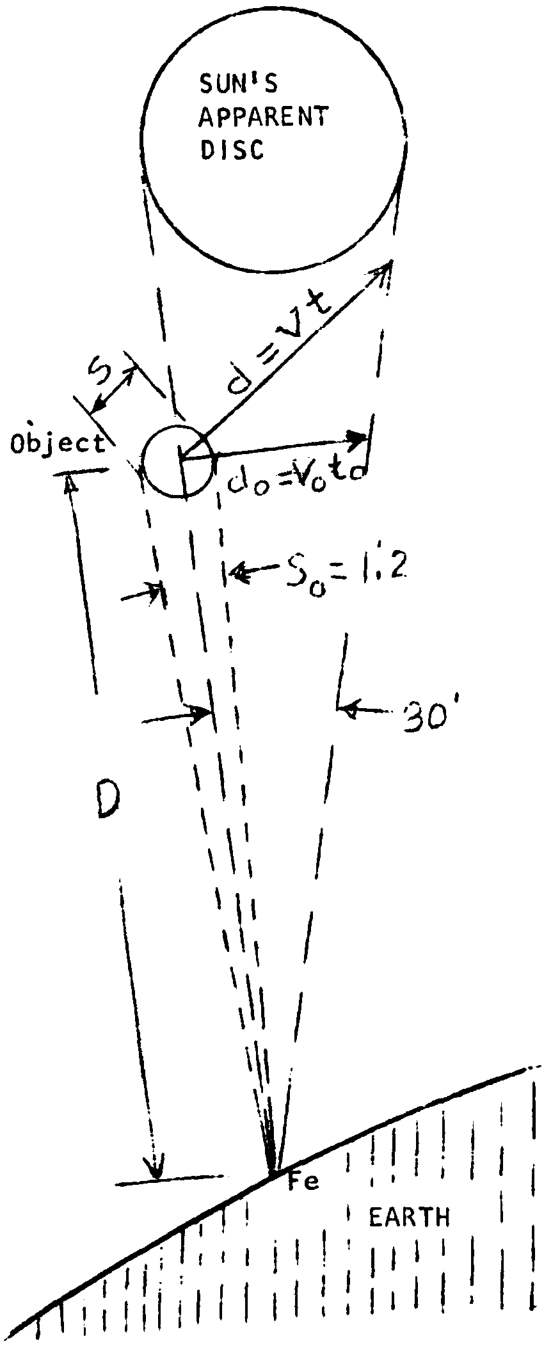
Fernald's observations permit some rough calculations which may explain the nature of the object. We will define the following quantities:

- D = slant height distance of the transitting object from the observer (feet or miles):
- d_o = "proper motion" distance component travelled by the object in space across the observer's line of sight (feet or miles):
- V_o = "proper motion" component of true space velocity of the object across the observer's line of sight (Feet/second or miles/hour):
- S = object's linear diameter (feet or miles):
- t_o = elapsed time taken for complete transit of the object as observed (seconds
- s_o = observed angular diameter of the object.

Since the object was observed to transit "from 8 o'clock to 1:30", we will assume that a central transit occurred, across a full diameter of the sun's apparent disc. The object was thus observed to move across the observer's field of view through an arc of 30 minutes, or one-half degree in 20 (plus or minus 5) seconds of time.

The slant height D is given by

$$D = d_o \times \cot (1/2)^{\circ} = 114.6 \times d_o \quad , \qquad \ldots\ldots\ldots\ldots (1)$$



and since the space velocity component V_o is given by $V_o = d_o/t_o$, we have $d_o = V_o\ t_o$, and (1) may be written

$$D = 114.6 \times V_o \times t_o \qquad \ldots\ldots\ldots\ldots (2)$$

This may be solved for V_o in terms of D only, since t_o was observed to equal 20 seconds. Thus we have

$$V_o = \frac{D}{114.6 \times 20} = .000436 \times D \ \ldots (3)$$

Also we have, in general,

$$D = S \times \cot s_o \quad , \qquad \ldots\ldots\ldots\ldots (4)$$

and since the average value of s_o was observed to be 1/25 of the sun's apparent diameter, or 1.2 minutes of arc, we have in this case

$$D = S \times \cot (1.2)' = 3094 \times S \ \ldots\ldots (5)$$

Inasmuch as the observer's location at Tangerine, Florida is about 70 miles W. by N. from the U.S. Guided Missile Testing Base at Cape Canaveral, Florida, it is interesting to see whether the above figures can be explained on the assumption that the object was a large rocket, test missile, or other artificially projected body located within a few miles of the earth's surface.

Assuming a rocket diameter S = 40 feet, we find D = 114,000 feet (approx. 21 miles), and V_o = 55 feet/sec = 40 miles/hour across the line of sight. The true space velocity of the outward-bound rocket or missile would be greater than V_o, perhaps by a factor of 20, (equivalent to an ascent angle of 87 degrees from the observer's horizon plane), or about 800 miles per hour. These figures are all in line with what one might expect of, for instance, a Saturn C-5 rocket with two 260-inch diameter motors, seen end-on or very nearly so. The overall diameter of this rocket body is approximately 42 feet, and it is a rocket which is currently at or near the testing stage at Cape Canaveral.

The observed perfectly round shape of the object implies that the rocket (?) was seen almost exactly end-on for the full 20-second duration of transit. While this seems unlikely, it is the only apparent explanation for the observed round shape.

SOME INTERESTING VARIABLES, by Margaret W. Mayall

Blueprints of light curves covering 50 years or more were exhibited for most of these variables:

015254	U Per.	Depth of minima varies from about $9^1/2$ to 14.
053326	RR Tau.	An RW Aurigae-type variable with overlapping periods of about 40, 200, and 500 days.
082405	RT Hya.	At times seems to show RV Tauri-type variation, but may be due to overlapping periods. Range varies from 3 mags. to less than 1 mag.
104620	V Hya.	Period of 530 days with 2 mag. range and overlapping period of 6500 days and range from about 7 to 12.
115158	Z UMa.	Period of 200 days, but sometimes nearly constant for several hundred days.
132422	R Hya.	A long period variable with change of period, decreasing from over 500 days in 1700, to less than 400 days at present.
154428	R CrB.	Comparison of 1960 min. with current 1962-63 min.
181141	Nova Her 1963.	Light curve showing slow drop of 3 mags. in 100 days.
192745	AF Cyg.	A semi-regular variable which has 97 day and 1000 day periods.
193449	R Cyg.	Shows alternating bright and faint maxima.
232848	Z And.	A "Nova-like" variable, which brightens 3 magnitudes about every 20 years, then gradually returns to minimum.

Set of curves for 9 variables: R And, o Cet, R Gem, R LMi, R Leo, R Hya, R Cyg, chi Cyg, and T Cep. Shows predicted mean curves from 1959-1964, with the observed curves superposed.

(Note. Copies of these blueprints may be purchased by members at cost: about $3.00 maximum, depending on size. The largest are about 3 x 5 feet.)

HOW WE EXPLORE SPACE, by Robert B. Leighton

Time lapse movies of the planets showing their rotation and changes. Taken at Mt. Wilson and Palomar, they were of excellent quality, and most interesting.

THE AAVSO, by Claude Carpenter

Mr. Carpenter showed a reel of his movies taken at various AAVSO Spring and Fall Meetings of the past. His films are of historic value and a fine supplement to the AAVSO 50th Anniversary movie. He had pictures of many old friends known only by name to our newer members.

SANCTUM OBSERVERS AND THE MINIMA OF THE MIRA STARS, by T.A. Cragg

There was a reason that the largest number of stars selected for the AAVSO in its early stages would be Mira stars, since basically they are the easiest to observe with large numbers of observers watching only once or twice per month. In more recent times observers have tended to side-step these objects for the more exciting irregulars. Yet Mira stars constitute one of the major populations (when compared with the more exotic variables) when looking over the general stellar population. Their very complex spectra and essentially regular variations have scared off many researchers to greener pastures.

The real challenge in Mira stars are good light curves over a long time period, and timing of maxima and minima, as well as brighter and fainter than normal maxima and minima. Probably one of the more interesting features is a flat minimum -- indicating perhaps the existence of a companion. Flat minima are very important and can be picked up only with concerted effort by several observers. Since most of the Mira stars we observe have minima from 13th to 15th magnitude, a real effort is at hand when one wishes to follow one of them through minimum.

Three Mira stars are known to have companions, and are listed below:

1. o Cet (M6e). Visual companion(Bep)probably irregular variable.
2. X Oph (M6e). Non-variable companion(K).
3. R Aqr (M7e). Spectroscopic behavior indicates an unresolved variable companion(Bep).

In 1955 Leon Campbell published "Studies of Long Period Variables", a compilation of the work of the AAVSO covering 44 years of accumulated data. Dr. Merrill published a list[1] of those included in the Campbell Volume whose light curves indicated they may have companions(flat minima). Probably no two people could go through those curves and come up with the same list of stars since some judgment is necessary as to what constitutes a flat minimum. Merrill's suggestion was to observe the color of the stars on his list at minimum photoelectrically to see if their color changes when the companion appears to dominate the light curve. Also, look to see if the "flat minima" group have variations in the flat minima, suggesting variability in the companion if its presence is the cause of the flat minimum in the first place. Table I lists the pertinent information concerning 31 Mira stars with flat minima suitable for working on this problem. Also listed are the next three minima for the convenience of those who wish to tackle this problem.

Note that the three Mira stars known to have companions do not appear on the list. The reason is that with the possible exception of R Aquarii, they don't have flat minima! Obviously, the degree of flattening of the minima depends entirely on whether or not the companion is brighter than the red star at minimum. Therefore, it is entirely possible many Mira stars have companions, but only those where the companion is brighter than the red star can be found by looking for flat minima.

One must be careful, for a class of Mira stars where increasing period varies with increasing rate of climb from minimum to maximum, the minimum phase is thusly drawn out to be rather flat[2]. X Cephei (210382) is a very good example of an advanced member of that class. So, with a Mira star whose period is in excess of 400 days one should be aware of this possibility.

I was concerned over this problem rather recently when comparing my sanctum estimates with values found in the various recent Quarterly Reports. The annual reports of recent years indicate steadily some 25 or so sanctum observers (those who submit estimates at 13.8 or fainter). One might be led to believe, as was I, that as a result of that many, most of the minima of the fainter Mira stars were being covered well; especially since in the 40's and early 50's there were less than 10 sanctum observers. However, I was startled to find in many cases my own observations made up 50% or more of what was published for many minimum phases of these stars.

Two conclusions are immediately apparent: 1) There is a lack of interest in working Mira stars at minimum, or 2) many "sanctum" observers get only very few "sanctum" estimates since they're probably made when visiting a large instrument. At any rate, whatever the cause, the minima of Mira stars are NOT currently being covered sufficiently well to answer questions concerning their flatness. Therefore, I should appeal strongly to those whose location and instrumentation permit them to reach into the 14's so let's get with it and see what the faint end of the curve is doing.

1. P.A.S.P., 68, 162, 1956.
2. "The Story of Variable Stars", by Campbell & Jacchia, Figs. 39 & 40, pp. 96 & 97.

TABLE I

LIST OF STARS TO WATCH FOR FLAT MINIMA

Number	Star	Period	Days Flat	1st Min	2nd Min	3rd Min
042209	R Tau	324^d	40^d	12/17/63	11/05/64	9/25/65
053337	RU Aur	468	130	5/16/63	8/25/64	12/06/65
054615a	Z Tau	495	200	7/10/64	11/18/65	3/27/67
061647	V Aur	353	65	10/19/63	10/06/64	9/24/65
070772	R Vol	452	180	2/04/64*	5/01/65	7/27/66
072811	T CMi	317	80	8/27/63	6/30/64	5/02/65
072820b	Z Pup	509	220	9/25/63	2/12/65	7/07/66
083019	U Cnc	305	120	11/17/63	9/18/64	7/15/65
092551	Y Vel	446	160	2/04/64*	4/25/65	7/14/66
093178	Y Dra	326	60	5/02/63	3/23/64	2/07/65
111561	RY Car	416	240	5/08/64	6/28/65	8/16/66
132202	V Vir	249	90	10/17/63	6/21/64	2/24/65
140512	Z Vir	306	100	1/19/64	11/21/64	9/23/65
142205	RS Vir	350	50	6/21/63	6/05/64	5/21/65
143417	V Lib	256	60	11/07/63	7/20/64	4/01/65
144646a	S Lup	335	110	6/07/63	5/07/64	4/07/65
155018	RR Lib	277	70	4/27/63	1/28/64	11/01/64
161122a	R Sco	222	50	9/29/63	5/08/64	12/15/64
171401	Z Oph	351	50	9/19/63	9/04/64	8/21/65
173543	RU Sco	367	60	10/01/63	10/02/64	10/04/65
184243	RW Lyr	505	180	8/20/63	1/06/65	5/26/66
185512	ST Sgr	395	120	10/19/63	11/17/64	12/17/65
190925	S Lyr	438	210	10/21/63	1/01/65	3/15/66
203611	Y Del	466	290	9/09/63	12/18/64	3/27/66
204215	U Cap	204	90	9/18/63	4/09/64	10/30/64
204318	V Del	533	240	6/13/63	11/17/64	5/02/65
205030a	UX Cyg	557	250	5/13/64	11/20/65	5/29/67
210124	V Cap	277	45	12/31/63	10/03/64	7/07/65
220613	Y Peg	206	45	6/16/63	1/08/64	8/02/64
222129	RV Peg	391	110	11/08/63	12/03/64	12/27/65
235715	W Cet	350	45	12/21/63	12/05/64	11/20/65

* Derived from dates in the Campbell Memorial Volume.

Other "1st" dates derived or copied directly from Bulletin 25, the 1963 Annual Predictions of Long Period Variables, by Margaret W. Mayall.

PHOTOMETRY OF SOME CATACLYSMIC VARIABLES, by George S. Mumford

I am not going to discuss in detail how the light curves you are about to see were obtained. Suffice it to say that all observations were made photoelectrically, principally in blue light, with occasional readings on a comparison star, and infrequent readings on a check star.

EM Cygni is called an old nova because of its spectral appearance. The magnitude difference, on the instrument system, is in the sense variable minus comparison with zero arbitrary. A depression of roughly two tenths of a magnitude has been temporarily identified as a partial eclipse. On the basis of four dips and three others observed by Krzeminski while he was at Lowell Observatory, a preliminary period of close to 4 hours 53 minutes was computed and used for calculating the phases. The ticks indicate the computed times of minima where zero phase was arbitrarily chosen.

Note the indication of a shoulder prior to eclipse, the asymmetry of the eclipses, and the small-amplitude fluctuations, all of which seem to be characteristic of eclipsing binaries among the old and dwarf novae. I hope during the coming summer to be able to obtain complete light curves in three colors.

About two weeks ago, I received word from Dr. Kraft that his spectroscopic observations of Z Camelopardalis were best represented by a period near 6 hours 55 minutes. At that time, I had not even begun reducing the traces of this star I had made at Kitt Peak, so a crash program was initiated. Three dips are among the most prominent features of the light curves, and they align quite well for a period of about 6 hours 54.5 minutes.

The scale used is too compressed to allow all the observed points to be shown. I have selected only those that came at intervals of about two minutes, so intrinsic variation as well as observational error accounts for the great scatter.

The same general features are apparent as in the curve of EM Cygni. Both Krzeminski and I have additional data going back for more than a year, and hence corroboration that this is or is not an eclipse should be forthcoming shortly.

A tremendous amount of flare-like activity is exhibited by a number of dwarf novae at minimum light. The best observed case is AE Aquarii, with SS Cygni coming a close second. My candidate is SU Ursae Majoris as indicated on a two-hour section of a ten-hour run. Once again, these observations were made in blue light. The magnitude difference is on the instrument system with zero arbitrary. Each point is based on a single deflection made with ten-second integration time.

The oscillations of 0.3 to 0.4 magnitude seem to indicate a periodicity on the order of 5 minutes, but I have not had the opportunity to make a complete analysis. These fluctuations persist while the system is going through an over-all increase of some 0.5 magnitude.

I have computed mean magnitudes at five-minute intervals in order to show the long term features. Some of the major peaks and dips seem to fit periods around three hours, and may be related to analogous features observed on other nights. But, again, I have not yet attempted a complete period analysis.

About the only comment one can make from seeing a light curve like this is that the visual observers should take heart, the scatter in their observations of this star is not entirely accidental.

Before continuing, a brief summary of some of the observed characteristics of U Geminorum stars is pertinent. All spectra at minimum light indicate the presence of a blue component, probably analogous to a star in the pre- or post-nova stage, but certainly an early type subdwarf. This object is generally felt to be responsible for the rapid intrinsic fluctuations whose amplitudes are greatest at short wave lengths, and considerably less in yellow light; and also the blue star is supposedly the seat of the major outbursts.

In at least three of these systems: EY Cygni, SS Cygni, and RU Pegasi, an absorption spectrum, presumed due to a late-type component, has been observed. The appearance of the lines indicates this color companion is either a main sequence or subgiant, G or K star.

I was extremely lucky to obtain light curves in three colors of U Geminorum on the night of December 2 - 3, 1962. Here the magnitude differences are relative to star 114 on the Petit-Brun chart. Phases were computed using Krzeminski's photometric period of nearly 4 hours 14 minutes, about 3.5 minutes longer than that determined by Kraft.

Two separate minima were observed. During the interval omitted (from slide), the star was monitored in blue light, and decreased more or less steadily in brightness by about 0.2 magnitude with oscillations of a tenth of a magnitude range. If any one is interested, I have the complete light curve with me.

Notice the well-defined shoulder prior to the second eclipse. My observations started just before the first one, after the peak of the shoulder had been reached.

When the evidence from the velocity curve is considered, the conclusion is inescapable -- the blue star is being eclipsed. Thus, the shoulder can be explained in the same way that Herbig, for example, has explained a similar feature in the light curve of VV Puppis -- the blue star has a hot spot on it.

There is no pronounced secondary minimum, if indeed there is a secondary minimum at all. This would seem to indicate that the red star is fainter than the blue one, or the red star must also be a subdwarf and not on or above the main sequence as previously thought.

According to Krzeminski, who probably has the most complete set of photoelectric observations in existence on this star, the first eclipse is perfectly normal. The star attains a minimum brightness of about 14.9 visual. Notice that the second visual minimum is about 0.2 magnitude brighter, corresponding to an increase of 0.05 magnitude per hour.

The following night was cloudy at Kitt Peak, but when Krzeminski observed from Mt. Hamilton, he found U Geminorum to be 1.5 magnitudes brighter than I had found it 24 hours before, and it was still brightening. The 0.05 magnitude per hour increase suggested would account for this. Apparently the observations shown here were made at or during the interval a major outburst of this star began, and apparently the seat of these outbursts is the red star -- not the blue one.

Color curves have been derived from all my observations. Colors are on the standard system. There is a characteristic blue increase prior to eclipse, and a pronounced reddening of the system at the second eclipse.

The ultraviolet excess is astonishing to say the least, and I would rather not speculate for the moment on its cause. The same feature has been found in other closely related objects, in particular, RW Trianguli as Walker has recently shown.

It would be very illuminating to obtain continuous, three-color observations of this star, covering an entire cycle from one major outburst to another. The most feasible way to obtain such data is probably through an orbiting astronomical observatory. Certainly much remains to be learned from the photometry of these stars and others like them.

NOTES ON FOUR N-STARS, by T.A. Cragg

N-stars are among the reddest stars known and are probably the most difficult variables to observe. Disagreement between observers can be as much as a magnitude. N-stars generally have smaller ranges and longer periods than M's, and they have a strong tendency towards humps on the rising branch of their light curves.

Recent observations of two N-stars (R Lep and S Aur) have shown them considerably fainter than they were supposed to be. An investigation of the activity of 25 N-stars, where sufficient observations by the author existed, was embarked upon to see how rare such a phenomenon was.

It is well known that the 530 day period of V Hya is superposed upon a much longer 18-year period[1], and it is the total range of the 18-year period that is given as the variable's range. None of the rest of the N-stars on the AAVSO observing list indicates anything of that nature. Table I lists the 25 stars investigated.

In Table I note that the ranges for R Lep (045514) and S Aur (052034) are 6.7 - 9.4 and 8.8 - 10.7 respectively. During the last 2500 days (7 years) I have never found R Lep brighter than 9.3; and it was as faint as 11.3 twice. However, prior to that time (1945-1955) it appeared essentially normal, but definitely fainter in 1955 than in 1945. If this behavior represents a superposed very long period like V Hya, it would seem some evidence of it should have shown up by now in the AAVSO records. If this behavior really represents a long superposed period it would have to exceed 20 years, in fact 40 looks more like it!

A similar case exists with S Aur (052034). With perhaps only one or two exceptions prior to JD 2435600 it seemed to be quite normal. From then on only one minimum was brighter than 12th magnitude, and currently it has been running between 12 and 14 instead of its published maxima and minima. Its performance therefore is almost a carbon copy of R Lep. Again it is evident that there exists a very long superposed period well in excess of 20 years. In both R Lep and S Aur one must remember that half a cycle hardly constitutes confirmation of a period, but the fact remains that something like a very long superposed period is currently operating.

V Aur (061647) shows only a tendency in the same direction as R Lep and S Aur, but nowhere near as conspicuously. The notable exception is that the maxima have remained essentially stable while the minima have faded rather consistently over the last 20 years.

Although fewer estimates were available for T Dra (175458a) than the other three, it appears there is a definite tendency for the current minima to be brighter than those in the 1940's and early 1950's, suggesting the possibility of a long superposed period. As you note this is the exact counterpart of V Aur, or say the other half of the cycle.

Of the 25 N-stars investigated, four (16%) showed rather strong tendencies toward a superposed very long period. Since I had the impression V Hya was the only N-star having this characteristic, it came as a bit of a surprise that four others were doing essentially the same thing. We may conclude that this is not common behavior among N-stars but is not quite as rare as perhaps previously thought.

It is interesting to note that information of the above kind can be gleaned from rather scattered but regular observations over a long period of time. It further demonstrates a valid reason for watching these "predictable" stars for very extended periods of time. It might be well to point out also that photoelectric accuracy is certainly not required for this kind of work, contrary to the way most people think nowadays.

1. "The Story of Variable Stars", Campbell and Jacchia, p. 117.

TABLE I

N-Stars Commonly Observed by T.A. Cragg

Number	Star	Max		Min		Spectrum		Period	Type
		C	K&P	C	K&P	C	K&P		
014958	X Cas	10.7	9.7	12.5	13.2	N1e	Ne	426.0 d	M
022426	R For	8.6	7.5	11.9	13.0	Ne	Nee	389.1	M
032043	Y Per	8.6	8.1	10.3	10.9	R4e	C4,3e	251.5	M
033362	U Cam	7.6	11.0p	8.8	12.8p		N5	419	SRb
045307	R Ori	9.6	9.1	13.4	13.4	S1e	Ne	378.7	M
045514	R Lep	6.7	5.9	9.4	10.5	N6e	N6e	423.5	M
052034	S Aur	8.8	8.2	10.7	12.5		N3e	578	SRa
053920	Y Tau	6.	10.1p	3.	12.2p	N2	N2	240.9	SRa
061647	V Aur	9.2	8.5	12.0	13.0	N3e	N3e	354.0	M
063159	U Lyn	9.7	8.3	14.3	13.5	M8e	N0e	437.6	M
081633	T Lyn	8.0	10.9p	12.0	14.8p	N2e	N0e	419	M
085120	T Cnc	8.5	7.6	10.1	10.5		N3	485	SRa
104620	V Hya	6	10.9p	12	16 p		N6e	530	M
122001	SS Vir	6.9	6.0	8.9	9.6	Ne	Ne	358.0	M
154639	V CrB	7.4	6.9	10.4	12.2	Ne	N2e	357.5	M
162112	V Oph	7.5	7.3	10.0	11.0	N3e	N3e	298.0	M
175458a	T Dra	9.9	7.2	12.0	13.5	Ne	N0e	421.0	M
200514	R Cap	10.6	9.4	13.3	14.7	Ne	Ne	344.9	M
200938	RS Cyg	7.4	6.5	8.9	9.3	Npe	N0pe	419.8	SRa
201121	RT Cap	7	8.9p	10.5	11.7p		N3		SRb
201437b	WX Cyg	10.1	8.8	12.6	13.2	N3e	N3e	409.8	M
201647	U Cyg	7.6	6.7	10.7	11.4	R8e	Npe	463.2	M
203847	V Cyg	9.4	7.7	12.7	13.9	Ne	Npe	420.7	M
213678	S Cep	8.5	7.4	10.9	12.9	N8	N8e	486.3	M
220133b	RZ Peg	8.9	7.6	12.9	13.6	Ne	N	439.2	M

C = Data obtained from the Campbell Memorial Volume "Studies of Long Period Variables"

K&P = Data obtained from Russian General Catalogue of Variable Stars
p (after magnitude = photographic magnitude; others are visual)

R CORONAE BOREALIS - A "BREAD BOARD" VARIABLE, by Carolyn Hurless

In April of 1962, the President of our Lima Astronomy Club asked me if I would give a talk on variable stars. I said yes, and began to outline my talk. First a brief outline of the AAVSO then on to what variable stars are and what they do. But how can I really convince my audience that variable stars are a worth while subject to follow after the moon and planets have been well observed?

There are hundreds of beautiful photos which well illustrate the moon and planets in all their glory. But alas.... of variable stars we do not have such fine photos that I could point to and explain. So I drew up some copies of light curves of popular variable stars. When finished, I was quite satisfied with my art work, but still very uncertain as to how convincing I would be as to the fascination of following variable stars.

I could draw a diagram of an actual field on the blackboard, putting down the comparison stars and their magnitudes, and then the location of the variable, going on to explain how one estimates a variable.

I lamented to Don that it was such a shame I didn't have some really scientific kit I could assemble for all to see the workings of a variable star. I even mentioned that I could take the whole group outside and show them a "field" in my telescope, but it wasn't likely that the variable located would perform any fantastic light fluctuations within a half hour no matter how hard we looked at it.

Don spoke up saying, "If we had a series of different watt light bulbs we could show comparisons"; -and I added, "we could show what variables are -- or even better, why not construct a reproduction of an actual field?"

We then fell to planning the "bread-board" as it was immediately nick-named. We chose SS Cygni, as it is a variable well within the amateur's telescope. Need I say that we put the point across as to "What is a Variable Star".

I wrote to Tom Cragg describing our 'invention' and he thought it quite a good idea. We thought you'd enjoy seeing it, so we brought it along. We made a 'bread-board' of R CrB because of its latest antics. For my own interest I plotted a light curve of R CrB, combining my observations with those of Tom Cragg and Leslie Peltier.

This 'bread-board' is also very useful when someone persists on wanting to know, "what do you REALLY look at with your telescope"? From then on you've got a captive audience. I've also mentioned to Leslie that if it clouds over while we are viewing, we'll use our own stars!

The Bread-board is a piece of plywood 18" x 24" painted black. The 'field' is drawn on the board to an enlarged scale. Holes are then drilled through the board where each star is to appear. Small wheat bulbs are then painted with a frosty paint to cut down glare. The small bulbs, are, of course, inserted into each hole drilled on the board. Each 'star' is then wired from its individual socket to a main wire: -the wire to each light having an individual resistor to determine its 'magnitude'. The variable star is individually wired to a potentiometer so as to control its variability.

The board is essentially useful as a teaching device.. We feel that it would be worthwhile for variable star observers who lecture on variables to use it to illustrate their topic.

TIMING LUNAR OCCULTATIONS, by Father Ronald E. Royer

Two years ago, not too encouraged by the times of our school track team, I decided to use my 0.1 second stopwatch on the heavens. At about the same time I had acquired a Zenith transistor portable shortwave set which enabled me to receive time signals right at the telescope. So one evening I was watching the five day old moon approaching the star Aldebaran.

The eerie earthshine-lit limb of the moon bore down steadily on the bright red star, and then, without the slightest fading, Aldebaran was gone, quicker than the twinkling of an eye. I started the stopwatch and kept it running until the five minute tone returned on station WWV. Then I stopped the watch. Subtracting the watch reading from the announced radio time at the tone return, gave me, to a 0.1 second, the time of the occultation, assuming that my reaction time in starting the watch at the occultation was the same as in stopping the watch at the radio tone.

Now I had an observation. What to do with it? I remember seeing in "Sky and Telescope" that such observations should be sent to the Royal Greenwich Observatory in England. I asked Mr. Thomas Cragg of Mt. Wilson and Palomar Observatories what they did with these observations, if anything. He suggested that I send in my observation and ask them. I did. And quickly got this reply, by airmail:

> "This Office collects as many observations of occultations as it can although we do prefer that the observers should make those observations regularly. The observations are analysed and can be used to determine the difference between the Moon's actual and tabular positions, or to determine the Moon's semi-diameter, or other constants in connection with the Moon's orbit. It was chiefly from observations of occultations in the past that it was realized that the rotation of the Earth was not uniform. This led to the fundamental ephemerides being published in Ephemeris Time, and the observations of occultations are one of the principal methods by which the difference between Universal Time and Ephemeris Time can be determined.
>
> "I published a short acticle on predicting and observing lunar occultations in "Sky and Telescope" December, 1959. You might find this article of some interest if you can borrow a copy of this publication."
>
> Yours sincerely,
>
> (signed) Flora McBain Sadler

I got the hint about the regular observations, and so made four more in 1961.

Occultation prediction tables are printed yearly in the November issue of "Sky and Telescope". Exact times to within six seconds are predicted for certain standard stations, and correcting factors are given so that one might calculate the time for his own position to that same accuracy. I noticed that all my observed times were running later than predicted, the least by 12 seconds, and the greatest by 80 seconds.

At the end of the year I sent in my observations to the Nautical Almanac Office of the Royal Observatory.

In this report I included the kind of telescope used, the power, my stopwatch reading, the radio time recorded, my geographical latitude and longitude to the second of arc, my height above sea level to the foot, which latter information is available from the U.S. Geological Survey.

I also included the predicted time, and asked why all my observations occurred late. I got this reply: "I think it must be sheer chance that all your observations come later than the predicted time: I should be very much surprised if, when you have made a large number of observations, you do not find the distribution is more even." (signed) Flora McBain Sadler. This kept me at the telescope, but seven subsequent observations were late, varying from 6 to 151 seconds.

This little mystery was finally solved for me, thanks to David W. Dunham of the University of California at Berkeley. This student pointed out to me that when one calculates the time of an occultation for a position removed from the standard station, one does not maintain the same accuracy, and this for no less than three reasons:

1. The correcting factors assume that the moon's limb is straight, not curved. This makes immersions late, but emersions early. Sure enough, my first observed emersion occurred 14 seconds early. One will actually have less chances to see emersions, at least it worked out this way for me, and so gave me the uneven distribution.
2. The correcting factors assume that latitude and longitude lines are straight and perpendicular. For my position in Pico Rivera this will always cause both immersion and emersion to occur somewhat late.
3. The correcting factors assume that the observer is in a plane tangent to the earth at the standard station. Consequently, when removed from this station, one is below this plane, and times can be early or late when timing an occultation involving the moon low in the sky.

I enjoy making these observations, and it is my purpose in presenting this paper to encourage others in making these easy and useful observations. Just keep track of the predictions, and sandwich them in between your variable observations. For the most part, large apertures are not necessary. In fact my first observation of Aldebaran was observed by our Boy Scout troop members standing around the scope, and we all observed immersion at the same instant. Of course, with fainter stars and a bright portion of the Moon's disk near the star, you will appreciate all the aperture you can get.

A short-wave set sometimes is an obstacle, but I am sure you have a "ham" living down the street to whom you can run while your stopwatch is ticking off the 0.1 seconds. This will work fine, until you make that 2:00 A.M. observation, knock on the door of your friend with the radio set, and find his enthusiasm for Ephemeris Time waning at that time. Then you will invest in your own set. (The AAVSO Occultation Division is a prime contributor to H. M. Nautical Almanac's work on occultations. Ed.)

STUDIES OF RW TAURI, by Dr. Alfred H. Joy
Mt. Wilson and Palomar Observatories

For observers who enjoy seeing many forms of activity in stars, few celestial objects furnish the variety of interest shown by the eclipsing variable RW Tauri. During the partial eclipse, which lasts for three hours, the change in brightness is extremely rapid reaching as much as a magnitude in 15 minutes.

Some years ago I undertook to make spectroscopic observations of this star because the great range of four magnitudes in its brightness indicated that the component causing the severe loss of light must be of low surface brightness and late spectral type. From results obtained by several spectroscopic and photometric observers it now appears that the star is remarkably worthy of study in several respects.

1. A MULTIPLE STAR.

Three components have been observed and a 4th suspected. They have different dimensions, spectra, and periods.

A,B --- The eclipsing pair.

The two close components A and B form a total-eclipsing binary whose period of 2.77 days is sufficiently variable to cause considerable trouble in predicting the exact time of totality. The disk of component A is entirely covered for 84 minutes by component B whose diameter is 1/3 larger than that of star A and 3 times that of the sun. The brightness and spectrum of the fainter star can be observed only at this time.

From photoelectric observations at the McDonald Observatory by Grant the dimensions of the system and the individual stars were determined. The distance from the sun was estimated to be 1400 light-years.

Spectrograms made during the partial phases indicate that the rotation of the principal star, type B9, is shorter than if it kept the same face towards its companion star. A slower rotation of the fainter star, type sgK0, is indicated by the width of the spectral lines.

C --- The visual companion.

In 1941, a 12.5 magnitude visual companion to the eclipsing pair was discovered with the 100-inch reflector at Mount Wilson at a distance of about 1". A single spectrogram of the star indicates that it is somewhat later than the sun in type. While no motion has yet been detected it must be a physical companion with a period of many years. Its absolute magnitude is +4.0.

D --- The unseen companion.

The existence of component D has been proposed in order to account for the changes in the period of the eclipses. The deviations from the predicted eclipses have been as much as 1 1/2 hours. If we assume that the deviations are due to the time required for light to cross the orbit of AB around D in a period of 60 years, a distance of 0."1 and a mass of 3 times the sun's mass may be inferred for D. Since the luminosity is not sufficient to make this star seen and since the time-deviations have not been entirely regular the existence of star D is in doubt. No more probable explanation has yet been suggested. Continued accurate OBSERVATIONS OF THE ECLIPSES ARE badly needed.

2. SPECTROSCOPIC OBSERVATIONS OF THE B9 STAR.

The radial velocity observations of the hot bright star at McDonald Observatory by Hiltner and Hardie and at the Mount Wilson Observatory yield a highly eccentric orbit although the photometric observations of eclipse times show no indications of such peculiarities. This strange discrepancy can be attributed to distortion of the hydrogen and helium lines by absorbing gases that have been expelled from the principal star and are whirling around the secondary with high velocities. Such streams have been observed in several eclipsing stars. The total velocity range is about 110 km/sec.

3. THE SPECTRUM AT TOTALITY.

When the disk of the B9 star is completely hidden at totality the spectrum of the secondary can be seen for 84 minutes. Superposed on this K0 spectrum for about 20 minutes near the beginning and again near the end of totality strong bright lines arising from the envelope of the B9 star often appear. They are the lines of hydrogen, helium, iron II, silicon II, and calcium II. Apparently the hot star has jets, prominences, or a gaseous ring surrounding it. These gases were either intermittent, occurring at some minima but not at others, or were in such a position that they were not always visible.

For 44 minutes during the middle total phase the ring is hidden as well as the disk of the hot bright star. This indicates that the prominence material showing emission reaches a height of about 1/10 the radius of the B9 star but its light intensity is only 1/1000 as great. The bright lines indicate velocities of about 300 km/sec, receding on one limb of the star seen near the beginning and approaching on the other seen near the end of totality. The components displaced to the red indicating recession are generally stronger than those to the violet.

4. EXPLANATION OF THE EMISSION.

The eclipsing pair with its emission features seems to be an example of a close pair of stars in which material from the larger K0 star has filled its surface of zero velocity and loses mass to its primary B9 star through the inner Lagrangian point. Some of this material is sufficiently excited by the hot star to produce the observed bright lines.

AMATEUR SOLAR ECLIPSE PROGRAMS - A Symposium - Clinton Ford, Chairman

Members of the panel: Robert Adams, Ralph Buckstaff, Thomas Cragg, and Frank De Kinder. In addition to photographs of the partial and total phases, the following programs were suggested.

Make observations of Mercury. Adams recommended having several observers make sketches at the same time. He also suggested some variable star observations. (U Geminorum is due for a maximum some time in July -- perhaps some one could catch it! It will be about 2 degrees north of the sun. MWM).

The outer corona is difficult to photograph, but sketches could be made from visual observations. The polar streamers or plumes should be looked for.

Ford plans to continue his polarization measures of the sky at several selected points -- so-called neutral points.

Bailey's Beads are spectacular and better seen near the edge of the totality zone.

Look for a bright nova or comet.

Cragg suggested using a pinhole camera for the partial phases of the eclipse. The pinhole should be about the size of a pea.

De Kinder invited observers to the Province of Quebec and assured them of a welcome there and many good observing sites.

A MULTIPLE PURPOSE CATADIOPTIC TELESCOPE, by Thomas J. Johnson

It is not necessary to have a large reflector in order to take advantage of the catadioptic system.

The Maksutov telescope is limited to one point of observation only -- at the Cassegrain focus. An article in the April 1962 Sky & Telescope magazine compared various Cassegrain combinations, and concluded that the Schmidt-Cassegrain is one of the best combinations. One of the reasons the Schmidt is preferred over the Maksutov, is that it is easier to construct.

The classical Schmidt system is a wide angle camera, and the corrector plate is much smaller than the mirror. However, a more versatile instrument can be made by having the focal point of the system just behind the corrector plate. To obtain narrower fields of from 1° to 3° or 4° the corrector plate can be full aperture, therefore a large instrument will not be required.

The basic system uses a 10"-12" short focal length primary mirror about 36"-48" F. A wide rich field can be obtained by using a long focal length eyepiece at the Newtonian focus. With a short system like this power as low as 30 can be useful. With this basic system, there are a number of variations that can be applied to it. (A picture of Mr. Johnson's 18 3/4-inch Cassegrain appears on the cover of Sky-Telescope for March 1963. Further details may be found in Sky-Telescope, April 1962, p.226; and April 1963, p.232. ED).

A VISUAL PHOTOMETER, by Larry Bornhurst

Larry is trying his hand at designing a visual photometer. The description of such a photometer in the book "Tools of the Astronomer" is what started him thinking.

Basically his photometer consists of a "light barrel". A light source at the rear of the barrel is transmitted through a circular variable neutral density filter. The light then enters a pinhole which makes it look like a star image, through a condensing lens into a prism type of beam splitter, then into the star field at the eyepiece.

The range of the present filter is 0.0 to 4.0 which appears to be too large. He is contemplating using a filter with a range of 0.0 to 1.0, made of optical glass. The light source is a 24 volt aircraft reading lamp, which has a long life. He pointed out that it is necessary to keep a constant voltage on the bulb. This is a critical point and he suggested a wet cell of about 12 volts, such as a car battery, which is probably the best to maintain voltage. (ED.)

MT. WILSON OBSERVATORY, by Thomas A. Cragg

(Given at special meeting held in Mt. Wilson Museum. Mr. Cragg substituted for Dr. Horace Babcock who was detained in Pasadena)

Mt. Wilson Observatory has been in existence since 1904. The horizontal Solar telescope, called the "Snow" telescope, located in a long galvanized iron shed, was the first telescope installed and had at that time the largest optics extant. The primary mirror has a diameter of 30 1/2" and the secondary 28 1/2". The off-axis lens is 24" in diameter and gives a 7" Solar image by the Cassegrainian method. This image is fed into the slit of the Spectrograph, an ideal set-up for studying the infra-red spectrum of the Sun.

Then the idea of a vertical tower for Solar observations was conceived and the 60 ft. tower was the first vertical Solar telescope ever constructed. In those days it was quite a job to get material to the site atop the Mountain, as the present beautifully paved road was not constructed. It had to be carried up the side of the 5500 ft. high mountain along a winding trail, much of it on donkey or mule back. But constructed it was and with the 50 ft. spectrograph connected with this telescope George Ellery Hale first discovered the magnetic field of the Sun.

Afterwards the 150 ft. tower was constructed, with a 50 ft. deep pit below the ground level from where the image of the Sun is reflected back and fed into the Spectroscope, which is located in the ground level laboratory. These towers are really refracting telescopes with matched objectives.

During the construction of the 60 ft. tower telescope a near fatal accident happened to the main lens. One of those carrying it slipped on the snow underfoot causing the others to lose their hold and the lens went sailing down. By an extraordinarily fortunate chance it landed in a deep snow bank and was picked up undamaged.

The 150 ft. tower was put in operation in 1910-1911 and has since been used to study the magnetic fields in Sun Spots and the general magnetic field of the Sun. Dr. Babcock in 1951-1952 used the solar magnetograph to test Zeeman effect of the Sun.

The Spectroscope gives a very long spread to the spectrum which makes for very fine detail in spectral lines. The slit is set on the center of the line thus showing two wings, one on each side of the line. One wing is polarized in one direction,the other wing is polarized in the other direction. Zeroing equipment moves the spectrum back and forth and permits either the violet or the red component of the Zeeman effect to come through.

The magnetograph is operated for 1 hour and 15 minutes to make the picture of one observation of the whole disk. In scanning over sunspots the aperture is minimized to cover the sunspots. With a certain apparatus it is possible to make the motion of the motor coincide with the motion of the surface of the Sun. When properly adjusted, it shows a pulsating up and down motion of the Solar surface in periods of about five minutes, somewhat like variable stars. Bumps go along for 30 to 40 minutes and this action has no relation whatever to what went on before in the same location.

Other projects are just starting such as checking the differential role of the rotation of the Sun through all cycles. The necessary equipment is being set up at the 60 ft. tower where the spectroheliograph is located. The filter is quite superior to the spectroheliograph. A recent article in the Scientific American describes this filter in detail.

Another novelty in the work is an image tube. It is a rather complicated piece of equipment and quite expensive, but it is reputed to give excellent results.

Of the main telescopes, the 60" was installed in 1908 and the 100" in 1918, and very interesting and useful work has been done with these two instruments. But since their installation a city has grown up in the fairly close neighborhood and now the sky at night is not really black any more. Up to about 1943 the night sky was still really dark but since twenty years the light has increased enormously. Now it is not possible to expose photographic plates for more than 1/2 hour without fogging them.

Both telescopes are booked every night of the year, except on the 24th and 25th of December when they are closed.

Very little direct photography is done any more. Direct photography is now principally done with the 48" Schmidt and at the prime focus of the 200" Palomar reflector.

A new idea is to incorporate a photo-electric photometer with a new 60" telescope on Mount Palomar. This is to be a very short focus f/8 Cassegrainian with f/2 to f/4 at the primary. The project is now in the works. The initial work has been laid out. The question of who is to pay for it still has to be settled.

A chicken wire mesh has been affixed to the slit of the 100" dome. This is to counteract a diffraction problem caused by nearby television antennae. The emissions are so strong that when cowboys on television take shots at each other the shots can be seen in the observatory instrument. The wire mesh is to stop this reaction. It takes only about 2% of the light away. There are no television antennae on Mount Palomar so they do not have this problem.

After the talk, the group of about 60 persons, divided into three, under leadership of Messrs. Lorenz, Bjornholm and Cragg to visit the different parts of the Mount Wilson establishment. (Reported by Frank J. De Kinder)

SPECTRA OF LONG PERIOD VARIABLES, by Armin Deutsch

Mira variables are very enigmatic objects which remain rather badly understood. We don't know where they came from or where they are going. They represent one of the last and most fascinating puzzles in astronomy. When we finally do come to understand them, it will be due, very largely, to efforts of devoted amateurs such as the members of the AAVSO who have been able to supplement the intensive observations of professionals with the indispensable continued photometric observations needed for the interpretation of their own more detailed observations.

This paper will concentrate on reporting certain aspects of the spectra of long period variables, in particular recent work which represents a continuation of the pioneering efforts in this field by Dr. Merrill and Dr. Joy at Mt. Wilson and Palomar over the last few decades. Dr. Merrill and Dr. Deutsch, of Mt. Wilson and Palomar, together with Dr. Philip Keenan, of Perkins Observatory at Ohio State, collaborated in this recent work, which is concerned with little-known properties of the absorption spectra of Mira variables. The earlier work, very properly, concentrated on the bizarre phenomena displayed by the emission spectra of such stars. Those emission spectra are characteristic of the Mira variables, and show the strongest and most interesting emission spectra of any stars. Just for this reason, the absorption spectra were neglected.

Mira variables comprise the most populous group of variable stars known, representing more than 3,500 out of the 14,000 variable stars listed in the catalog of Kukarkin and Parenago. They are extremely large stars -- the closest, Mira itself, yielded the largest stellar diameter measured some years ago with the stellar interferometer -- about 300 times the diameter of the sun. The masses of the Mira variables are not well known but it is clear that the average densities must be exceedingly low, very likely less than the density of air at atmospheric pressure. They have been characterized as "red hot vacuums", and are the seat of fascinating physical processes which are not well understood but about which we can get important clues by a detailed study of the spectra of the light emitted from the outermost layers.

The Mira variables are rather cool stars, having surface temperatures of less than 3000°. For Mira itself, the surface temperature ranges from 1900° at minimum to about 2600° at maximum. Because of the relatively low surface temperature, the spectra exhibit strong bands of the molecule TiO. As the temperature of the stellar atmosphere increases, fewer and fewer of these molecules, which are among the hardest molecules to dissociate, are able to survive the intermolecular jostling, and therefore the strength of these bands decreases. Although the relative strength of the TiO bands can thus be used as an indication of the temperature of the stellar atmosphere, it is found that all lines forming these TiO bands do not vary in strength with temperature in the same way. In particular, lines corresponding to transitions from the lowest vibrational energy levels increase in strength much more steeply with temperature than do lines corresponding to transitions from higher vibrational energy levels. A detailed study of the variation in relative strength of particular lines in the absorption bands of TiO shows that temperature differences of the order of 100° produce observable differences, thus yielding a very sensitive "molecular thermometer" by means of which it is possible to arrange stars in a temperature sequence with much greater fidelity and sensitivity than had been possible before.

If we plot Mira variables on the usual sort of Hertzsprung-Russell diagram, showing absolute luminosity as ordinates and spectral type (or temperature) as abcissae,we find that Mira variables fall into two classes; the first, of which Mira itself is a member, having periods from 350 to 450 days and reaching spectral types as early as M5 or M6 at maximum; and the second, having periods of around 250^d, reaching spectral types as early as M1 or M0 at maximum, and being systematically about 4 times as luminous. A detailed study of the absorption spectra of this second group of relatively high luminosity, short period, early spectral type Mira variables shows that certain absorption lines are systematically weaker than the corresponding lines in the spectra of other stars of the same spectral type. Analysis shows that strong lines are weakened much more than weak lines, and that the weakening is much less in the absorption lines of ions than in those of neutral atoms. This result is just that which would be expected if these relatively high luminosity, short period, early spectral type Mira variables were systematically deficient in metal atoms as compared with other stars by a factor of about 100. The exact numerical factor characterizing this metal deficiency is obtained from theory which predicts that the strength of strong absorption lines of neutral metal atoms will vary as the minus one-fourth power of the metal abundance; however, this theory assumes that the negative hydrogen ion is the source of the continuous absorption in the atmosphere of the star, and there is some doubt as to the correctness of that assumption with respect to these very cool and rarified stars.* In spite of this uncertainty, it seems clear that this particular class of Mira variables is in fact deficient in metal atoms, and the deficiency factor is probably of the order of 100 times. This result is of interest in the light of similar results obtained for other objects, such as the stars in globular clusters, the RR Lyrae variables, and the sub-dwarfs in the solar neighborhood, all of which have been found to be systematically deficient in metal atoms, all of which have relatively large velocities relative to that of the sun, and all of which belong to the group of stars characterized by Baade as Population II. Now, this particular group of Mira variables also has high velocities compared with the sun and with the relatively less luminous, later spectral type, longer period Mira variables -- and thus would seem to clearly belong to Population II and, like the other members of that Population II, may well have condensed out of the pre-stellar medium at an epoch before most of the metal atoms found in Population I stars like the sun had yet been formed, and before large scale processes of nucleogeresis had produced those metal atoms.

Mira itself, as well as the other relatively low luminosity, later spectral type, long period, low velocity Mira variables, exhibits a similar though less marked systematic weakening of the strong absorption lines of neutral atoms, indicating a metal deficiency with a factor of perhaps only ten or twenty. However, this group of Mira variables also shows another phenomenon -- that of showing a relatively strong absorption line spectrum throughout some cycles, and relatively weak absorption lines throughout other cycles. The reasons for this phenomenon are not yet known; it seems clear that it can not be an abundance effect, since a strong-lined cycle may be followed a year later by a weak-lined cycle. Although it appears that a portion of this effect may be explained by stratification, and the resulting production of different lines and bands in different levels of the stellar atmosphere, it seems clear that this is not a complete explanation.

One thing is clear -- there is a significant correlation between the spectroscopic and photometric behaviors of these late-type Miras; that is, if one of these Mira variables has a maximum which is significantly less bright than usual, it is likely to show a weak-lined spectrum -- and vice versa. In order to confirm this correlation, as well as to alert professional astronomers to the possible occurrence of weak-lined cycles, the AAVSO can furnish a valuable contribution by continued observation of these variables and by informing the professional when any of these variables appears to be headed for an unusually faint maximum.

* See Armin J. Deutsch, "Metal Deficiencies in Late-Type Giants", The Observatory, Vol. 83, No. 932, pp.28-30 (1963)

Note: For reproduction of some of the spectrograms used by Dr. Deutsch to illustrate this paper see: Paul W. Merrill, Armin J. Deutsch and Philip C. Keenan, "Absorption Spectra of M-type Mira Variables", Astrophysical Journal Vol. 136, No. 1, pp.21-34 (1962) (Reported by Richard H. Davis)

STAR CLUSTERS AND PHOTO-ELECTRIC PHOTOMETRY, by Dr. Halton C. Arp of Mt. Wilson and Palomar Observatories

Star Clusters and color-magnitude diagrams are the key to modern Astrophysics and Astronomy. A good deal of information has been obtained from their study using relatively simple techniques of which the photo-electric photometer is one of the more useful. The star clusters afford a powerful means for studying the stars on account of two features: first, the individual stars are all at the same distance; and second, we can measure their color with great accuracy. We may not know what the actual distance is, but we can conclude that the relative luminosity is a measure of the relative absolute brightness or magnitude of the individual stars. It is hard to establish colors with the eye as human vision is limited to a narrow band around the 5500A region of the spectrum, on the other hand with the photo-electric photometer and proper filters we can measure light intensities in two bands which I shall call the Visual, extending from about 4500 to 6000A and the Blue, from 4000 to 5000A.[1] The magnitude difference between the Blue and the Visual is called the color index, i.e. B-V = CI.[2] For the bluest star that we know of the color index is about -0.4 magnitude and for the reddest +2.0 magnitude. These differences can be measured to an accuracy of ±0.001 magnitude with the photo-electric photometer, hence we have a range of about 2500 divisions in the color scale.

When studying star clusters we find that the individual stars have essentially the same age and chemical composition and this is of enormous help.

There are three regions where we may find star clusters:

1. In the Halo region of the Milky Way where we find the large Globular Clusters such as M13, which may have 100,000 down to a few thousand stars.
2. In the Disk of the Milky Way with the Galactic Clusters with 10,000 down to a few hundred stars, such as the Pleiades.
3. In the Spiral Arms within the Disk which has the young Galactic Clusters.

It is only within our own Galaxy and the Magellanic Clouds that we can work on the individual stars of the Clusters. I'll show a few examples of clusters in the Magellanic Clouds from photographs taken in South Africa. NGC 330 is a young cluster, NGC 419 is similar to our own M13.

When using a P.E.P. we have to establish first a zero point transfer; that is, select an individual star and measure its magnitude with our calibrated photometer. We can do this to an accuracy of ±0.03 mag. We then select a sequence of stars within the cluster and measure their relative magnitudes. The internal accuracy of our scale is better than about ±0.02 mag. while the color scale has an accuracy of the order of ±0.01 mag. The reason the color scale is more accurate than the zero point transfer is that the latter is more seriously affected by atmospheric fluctuations. When using a P.E.P. we are handicapped by two limitations. First, we have to measure each star individually (a photographic plate may show thousands of stars on one exposure) and second, the stars are so crowded that we have to use a very small diaphragm to exclude light from the unwanted stars. With the 200" we use apertures of about 10" of arc and on exceptional nights of good seeing 5" is about the limit.[3] For these reasons we now use photographs of the clusters and measure the magnitudes with an iris photometer,[4] reserving the direct use of P.E.P. to a relatively smaller number of selected stars in the field.

I am now showing two color-magnitude diagrams of M3 and M5 which show remarkable similarities.[5] The individual measurements of most of the stars in these clusters were made from photographs and the iris photometer.

Note that the sequence bands in these diagrams are relatively narrow and we may ask why. This is a consequence of the Vogt-Russell or Uniqueness Theorem which roughly states that if we take a chunk of material from which we are going to make a star, we will get a star having a unique luminosity and unique temperature. We conclude that the stars in the globular clusters are formed from masses of identical composition and that the differences that we observe are due to difference in masses. In other words the large masses form bright blue stars, the less massive form cooler stars and so down to the red dwarfs. It is the blue stars that evolve first and move off the main sequence. It has been estimated that when a star has burned about 10% of its hydrogen into helium, it starts to evolve and the time it takes for this to happen in the case of the older stars is about 10^{10} years. When a star has burned 25% of its hydrogen it is well into the evolutionary track.

The H-R diagrams of the clusters as they break off the main seauence give us an indication of their age. Thus M13 is younger than M2 and M5. Not many clusters of intermediate age are found near the Sun. NGC 2158 is 5,000 parsecs away.[6]

This introduces us to the problem of Star Evolution and particularly that of the Variable Stars in general which we are now able to treat as a whole in a coherent or synthetized basis, just from the study of these luminosity-color diagrams. Although we have many classes of variables they can be treated as adjacent stages of

star evolution.
I would classify stars in general into three divisions or Populations which briefly would be as follows:

1. Old Low Metal Content Stars which comprise the Globular or Halo Population Clusters, the Long Period Variables with periods of 100 days which are rare around the Sun, and RR Lyrae and type II Cepheids.
2. Old High Metal Content Stars.(Our Sun being one of them).Long Period Variables of the Mira Type. Dwarf Cepheids and Cataclysmic variables(Novae etc.).
3. Young High Metal or Normal Content Stars. This contains the T Tauri, the Classical Cepheids and the supergiant M type Variables with long periods of 300-1000 days.

We take up another subject, that of the chemical composition of the stars as revealed by the color-magnitude diagram. For this purpose we add another set of measurements in the Ultra Violet which serves two objects. First it gives us an indication of absorption of light or reddening of the stars as the light travels through the dusty and gaseous space, and second it gives a means of determining the chemical composition of the star. We can do this in two ways: empirically and theoretically by inference. If a star has a high metal content, the absorption bands tend to crowd into the UV. There is of course some absorption in the B and V but the UV is more depressed and if you can eliminate the effect of reddening, then you can get an indication of the metal content of the star. Using this knowledge we can by inference determine the composition of stars in the distant clusters in the Magellanic Clouds. I am showing two cluster color-magnitude diagrams of the previously mentioned NGC 419 and NGC 361. These are old clusters similar to our own Globular Clusters and of about the same age. On the other hand NGC 458 is a young Cluster about the same age as the Pleiades. However, the Pleiades have only A stars and no yellow stars. There are not enough stars in the Pleiades to show the same range of color as NGC 458. The other Cluster I am showing is NGC 330 which has the same age as the h-X Cluster in Perseus. Here again, the Perseus Cluster is not rich enough to have any red stars.

Finally, I superimposed all of these four clusters into one picture and compared it to the field stars, not belonging to the clusters, which surround them in the Magellanic Clouds, to show that the Clouds have stars of all ages.

The next decade ought to give us more clues about the stars from a study of the clusters.

1. For similar curves see PASP 69, 408, June 1957, Figure 1.
2. See AAVSO P.E.P. Manual(1962), pp. 9-12 for description of Color indices.
3. By way of contrast this reporter, in the North Eastern States, using a 12", f/17 Cas. has never been successful in using apertures of less than 30" corresponding to a hole about 3/4 mm in diameter, a very small hole indeed requiring a good drive.
4. For a description of an iris photometer see Cuffey: Sky-Tel,April 1956,p. 258.
5. See a reproduction of the diagram of M3, Struve: "The Universe", p. 52.
6. For an H-R diagram of cluster sequences as they break off the main sequence,see Kraft: "Pulsating Stars", Scientific American, July 1959, p. 54. Also Struve: "The Universe", p.53, which resembles Dr. Arp's slides.

(Reported by John J. Ruiz).

EXTRA GALACTIC DISTANCE, by Dr. George Abell
of the Department of Astronomy, U.C.L.A.

Extra-galactic distance scale and some of the problems of surveying the large scale distribution of matter in space are important, especially for the purpose of testing models of cosmology. Variable stars are directly connected as all of you know to the studies of extra galactic distances. Unfortunately today we don't know exactly how connected they are. It is one of the major problems to tie down more accurately exactly what the scale of distance is.

Probably the first person to make a systematic effort to analyze the distribution of stars in our own galaxy was William Herschel. He picked out selected regions of the sky and, by counting the stars, deduced the shape of the galaxy.

There are many open star clusters, which lie in the direction of the Milky Way. We live in a system of stars which is not very transparent. Dust clouds hide from our view, most of the star clusters and most of the stars in our galaxy.

If we attempt to survey the extra galactic universe beyond the galaxy we must look out either face of this wheel shaped system.

Although Herschel was the first person to give us this general view of the galaxy, the idea of a galaxy or stellar system to which the sun belonged goes back much further.

Thomas Wright(about 1750)and Emmanual Kant(about 1755)both speculated that the sun was a part of a huge system of stars; but Kant went farther and speculated there were other such systems he called island universes, far out beyond the borders of the Milky Way system. We can see with the naked eye three things that Kant could have called island universes. These are the 2 clouds of Magellan and Andromeda galaxy M31.

About the time of the great visual survey of the Herschels, William(late 1700's)and son John(in early 1800's), these men saw numbers of objects such as these (island universes). The identification of these things as galaxies was much slower in coming. Herschel remarked to his sister once, that he had found over a thousand universes. Apparently Herschel later grew to doubt the character of these faint spots of light he could see around the sky, as other galaxies.

The Andromeda galaxy, viewed with binoculars, is not clear as to whether it is a group of stars or just a blot in our own system. An early photograph by Bernard shows it as a wheel, and it might resemble our own galaxy. But in his photo you can not resolve the object into individual stars.

As the 20th Century got rolling, people began to recognize individual stars in some of these galaxies. But the question is; what kind of stars are they? If the stars in M31 are stars like the sun, that means they have absolute magnitude about +5, and an apparent magnitude near 18, which would put the Andromeda Galaxy(M31)rather near-by. These must be solar type stars for us to see them in such a near object. On the other hand if they are luminous giant stars, then they could be very far away; so it became very important to determine what kind of stars we are looking at in these neighboring galaxies or nebulae. And the controversy as to whether they were galaxies or nebulae rested upon the identification of these stars.

Well, it turns out that even Pease himself described these things not as stars but as sort of nebulous stars. The early observers at Mt. Wilson were not quite willing to stick their necks out and say that they could observe individual stars in the neighboring galaxies. By the 1920's the situation was very confused. To add to the confusion, in front of the neighboring galaxies like the Andromeda, a few novae were found.

These novae were of 2 classes, some like S Andromedae which appeared in 1885 about 5th magnitude, but most were much fainter, around 17th or 18th magnitude.

Suppose these novae were like those known to occur in our own galaxy; the question is: which kind of Nova in M31 say, corresponds to the kind of nova we find in our own galaxy? Most investigators felt that the ones like S Andromedae were actually the real kind of novae, like those that appeared in Herculis last spring. If S Andromedae which had an apparent magnitude of about +5 was an ordinary nova, that means this galaxy is not very far away. On the other hand those novae that have an apparent magnitude of 17 or 18, if they were the ordinary novae, then this galaxy would be very far away. So it became critical to find out more, if possible, about the kind of stars they were. The fly in the ointment that really seemed to settle the question was a result of very careful measurements of motions of stars made by Van Maanen. He began a program of measuring proper motions of stars in these nebulae. The point was, if we can detect any motion in these objects we now call galaxies, it would be a clue to their distances. Van Maanen, by very careful measures, did find motions in them. We know today that the galaxies are rotating.

However, one can never hope to observe these proper motions, for they would not be observable even after many hundreds of years. Nevertheless, these measurements must have been accidental, or systematic errors, or perhaps he(Van Maanen)wanted too much to see them. If you multiply the angular motion by the distance of the galaxy you find the linear motion, in miles per second of the stars. And if this was as far away as 2 million light years or anywhere outside our own galaxy, these stars would have to be moving many times the speed of light, and of course that would not be possible; so the fact that Van Maanen detected or thought he detected rotation seemed to prove that these galaxies were nearby.

About 1923 a variable star was found in one of these galaxies and Hubble investigated this star and then began a systematic search for variable stars in other neighboring galaxies. Within a year he had found quite a large number of them, and by looking at their light curves, he found they were Cepheid Variables. We know these objects are extremely luminous and therefore from their apparent faintnesses, we know the galaxies must be very far away. Hubble determined distances from many of these Cepheids. This was a dramatic resolution of the problem and showed once and for all that the galaxies were galaxies and not nebulae, although Hubble called them nebulae all his life.

So the Cepheids became the first step in the extra-galactic distance scale. In order to find distances to more remote galaxies one must calibrate something else in the Galaxy that is brighter than the Cepheids, which are very faint, about 18m. Hubble attempted to determine the apparent brightness of the brightest appearing resolved stars in other galaxies and use these bright stars as the matched distance indicator. Hubble found that brightest appearing stars apparently had absolute magnitudes of about -6; -6.3 was his adopted absolute magnitude for the brighter stars. So the Cepheids served as the calibration, and comparing the brighter stars with them gave the absolute magnitudes of the brighter stars. Thus the brighter stars can be used as distance criteria for more remote galaxies.

In Hubble's time it was possible to measure distances out as far as the Virgo Cluster which contains about a thousand galaxies. There were errors in the distances that were not Hubble's fault, for the Cepheids are more luminous by about a factor of 4 than Hubble thought at that time, which was due to the difficulty of determining the luminosity of these stars in our own galaxy.

The trouble is, there is no Cepheid variable whose parallax can be measured, and at that time these distances to the Cepheids had to be determined from a statistical analysis of their proper motions. Statistically stars which are closer to us appear to move the fastest. You need a large number of stars to do good statistics of this sort, and you need accurate measurements of their motions, which takes many years. After you have found the average distances to the Cepheids by this method, to get their average absolute brightness you then had to measure their apparent faintnesses. The problem is the Cepheid Variables in our own galaxy all lie in regions which are obscured, at least partially, by interstellar material or cosmic dust. Consequently the apparent brightnesses or apparent faintnesses of these stars were all under-estimated; that is, the stars were found to be apparently fainter than they really were. Had adequate corrections been made for interstellar dust, and had more correct proper motions been measured on the photographs in Hubble's time, it would have been known then that the Cepheids were more luminous than the adopted figure at that time.

This is just one source of error, but that error alone is enough to double the extragalactic distance scale. The distances Hubble measured were off by a factor of two just because the Cepheids were wrong.

Another trouble was that some of the things Hubble identified as brighter stars were not always stars. They were gaseous nebulae. You can't tell a condensed gaseous nebula from a star on photographs in blue light.

The text books say that only 15% of galaxies are elliptical, but this is wrong. It is true that among the brightest that can be seen by telescope, elliptical ones are in the minority. In reality the most luminous galaxies in the Universe, by many times over, are elliptical; and also the most numerous are elliptical.

Probably one of the poorest galaxies known is the Draco system. It is only visible to us because it is quite near to us -- about a million light years away. It is completely transparent, and you can see background galaxies through it. You only see the brightest stars in it and they are probably only a few hundred times more luminous than the sun. Probably there are about a million or so stars in this galaxy, spread over a region of 2 or 3 thousand light years in diameter. This is a typical dwarf elliptical galaxy -- typical of about 6 such dwarf ellipticals in our own local group of galaxies.

There may be galaxies smaller than Draco, and there may be a few globular clusters shown on the sky survey photos, that have distances of several hundred thousand light years. Many people regard these as extra galactic globular clusters. They are as far away as the Magellanic Clouds. We don't know whether they are true intergalactic objects. We have to know whether these extra-galactic globulars are strewn out more or less uniformly through the local group, to know whether they should be classed as galaxies or outlying members of our own system.

About 50 million light years away we find the nearest fairly respectable cluster -- the Virgo Cluster -- which contains about a thousand visible galaxies. The most common galaxies in the Virgo Cluster are dwarf ellipticals.

How can we find the distance to groups and galaxies beyond the neighboring groups and beyond the Virgo Cluster, which is as far away as we can see things like individual stars in galaxies, or in globular clusters belonging to other galaxies? For more distant systems we have to use the integrated luminosity of the whole galaxy.

There is some hope that for some kinds of spiral galaxies one might estimate the intrinsic luminosity from the apparent form of the whole galaxy. Then by measuring the apparent faintness of it you can find its distance. This method is still in its beginning stage and has not been a very useful method yet for pushing the distances out further.

When you look at elliptical galaxies you see the range goes from dwarfs like the Draco system that may have a million suns, up to things like NGC 4486, a giant elliptical that may have a mass as much as possibly a trillion times the mass of the sun, which would make it 10 or more times more massive than our own galaxy. And there may be still larger galaxies.

The question is, how can you tell when you look at an elliptical galaxy, what kind of guy it is? So how can you get distances? The answer is, you must confine your distances beyond the nearest galaxies to whole clusters, where you have a variety of galaxies of different types and different brightnesses, all at the same distance.

The cluster in Corona Borealis, about a billion light years away, is one of the most famous of the rich clusters photographed with the 200" telescope. A rich cluster is one that has many member galaxies. If you look at the radial distribution of galaxies in a cluster like this it resembles the radial distribution of stars in globular clusters, except there are not as many galaxies as there are stars in a globular cluster. A globular cluster may have as many as a million stars. A cluster like this may have as many as 10 thousand member galaxies, of which only about 2,000 can be seen on photos made by the 200' telescope, most of them elliptical in form. Most of the galaxies shown on the photos will have to be much more luminous than our own galaxy in order to be seen.

You can tell the relative distances of clusters by seeking the 10th brightest galaxy in each cluster, and measuring the apparent faintness. Then suppose the 10th brightest galaxy in every cluster is about the same. In that way you can tell the relative distance to different clusters, by comparing the relative brightnesses of their brightest members. Obviously certain systematic errors occur.

One of the most famous clusters of galaxies is the rich cluster in Coma Berenices, about 300 million light years away. It is the nearest of the great clusters.

The universe seems to be isotopic and homogeneous which means that no matter where you are in space you can see about the same kind of thing. This is called the Cosmological Principle.

By a series of slides Dr. Abell demonstrated how distances to galaxies can be determined by comparing galaxies and their brightnesses. The problems in extra-galactic astronomy today are many, but one of them is to obtain distances to relatively remote clusters sufficiently accurately so that we can choose between cosmological models. As we get better ideas as to how the distribution of galaxies of various brightnesses fall in clusters, and better techniques for measuring these brightnesses, we may be closer to the answer. (Reported by Richard H. Davis)

DWARF NOVAE AND OTHER CATACLYSMIC VARIABLES, by Dr. Robert P. Kraft (Mt. Wilson and Palomar Observatories)

The group of stars known as cataclysmic or exploding variables contains 3 main types -- Dwarf Novae, Ordinary Novae, and Supernovae.

Dwarf Novae, or U Geminorum stars, produce as much energy in a single outburst as does the sun in one day. They tend to be quite faint at minimum and to "flicker", that is, over a few minutes there are abrupt fluctuations in brightness from a few hundredths to a few tenths of a magnitude. This flickering is interrupted every so often by an outburst in which the brightness rapidly increases from 2 to 5 magnitudes descending again to minimum with a period of a week or two to several months or a year or more. U Geminorum stars are divided into 2 sub-groups -- SS Cygni stars, and Z Camelopardalis stars, the difference being that the latter tend to hang up and maintain some magnitude between max. and min. for a long period of time. However, spectroscopically, there seems to be no significant difference between the sub-groups.

Ordinary Novae produce as much energy in a single outburst as that put out by the sun in from 10,000 to 100,000 years. Here again are two sub-groups -- Recurrent Novae such as T CrB which had outbursts in 1866 and 1946; and Ordinary Novae observed in only a single outburst but which may be recurrent with very long time scales. Both types display a certain amount of activity, like flickering, at minimum. T CrB is now spectroscopically like it was just prior to the 1946 outburst. Is it about to flare again?

Supernovae produce as much energy in a single outburst as does the sun in a time equal to the age of the universe, about 10^{10} years. Therefore it must be concluded that a supernova after an outburst can not be similar to what it was before; and we have no information about the behavior of supernovae at minimum.

If we are to learn what Dwarf Novae are and why they act as they do, probably it will be from studies of their behavior at minimum light. The first inkling as to the nature of Dwarf Novae at min. came from Dr. Joy's announcement in 1940 that RU Pegasi at minimum, showed a composite spectrum characteristic of a star a little bit later in spectral type than the sun and a hot sub-dwarf. In 1954, Dr. Joy showed that SS Cygni was a double-lined spectroscopic binary, one component being a dwarf G5 star, and the other a hot blue sub-dwarf with lines of hydrogen, helium, and ionized calcium. Two very interesting results from studies of the radial velocity were that the period was very short (6^h38^m) and that the separation of the two components was only about twice the radius of the red star.

Earlier, Dr. Roscoe Sanford had shown that the recurrent nova T CrB had a composite spectrum, and that the absorption spectrum characteristic of a giant M3 star showed a small radial velocity variation with a period of 227 days. In 1955-56 Dr. Kraft showed that T CrB was a double-lined spectroscopic binary, with the separation of the components being about twice the radius of the red star, thus being merely a scaled-up version of SS Cygni.

Merle Walker at Mt. Wilson, made the celebrated discovery that the ordinary nova Nova Herculis 1934 was an eclipsing binary with a period of 4^h39^m. The model proposed for this star is a flat disc of gas around the blue star, which is seen edge-on, in binary motion about what is probably an ordinary star. Obviously, normal analysis of an eclipsing binary does not apply to this system.

In all the above systems -- SS Cyg, T CrB, and Nova Herculis 1934 -- it appears that we can explain the leading spectroscopic peculiarities by supposing that we are dealing with a double star system in which one component fills the critical zero-velocity surface defined by the restricted problem of 3 bodies, in which there is continuous mass transfer from the primary red star; and that the emission lines seen come from atoms transferred from the primary red star to orbits around the hot blue secondary.

Because of the faintness of these objects at minimum, the need for high spectral dispersion, and the requirement of relatively short exposures, further work in this area will require the use of the largest telescopes available, and even the 200-inch is not adequate in some cases.

Recent work at Mt. Wilson and Palomar in this area has shown that the spectra of U Gem variables form an extraordinarily compact group. In some cases the absorption lines of a late type star can be seen; and in some cases emission lines are doubled.

U Geminorum has been shown to be a single-lined spectroscopic binary with a radial velocity range of 550 km/sec and a period of 4^h15^m. Photoelectric photometry by Mumford and Krzeminski has shown it to be an eclipsing binary with a primary eclipse of amplitude almost a full magnitude from a tremendous shoulder, possibly total, lasting about 15 minutes, and probably observable visually. Precise visual timings of eclipses will be valuable in further analysis of this system. The doubled emission lines seen in the spectrum of this object indicate that the emission lines come from a ring lying and rotating in the plane of the binary orbit seen edge on -- and suggest that those objects of this class which show doubled emission lines are most likely to be eclipsing binaries.

RX Andromedae a Z-Cam type, is a spectroscopic binary with period of 5^h5^m, and the only object of this type with a highly-eccentric orbit. So far as is known, it is not an eclipsing binary.

Z Camelopardalis has proved to be extremely valuable, since it is a double-lined spectroscopic binary which is also an eclipsing binary, thus permitting calculation of all of the parameters of the system, including masses, which turn out to be 0.8 and 0.7 times the mass of the sun. The period is 6^h55^m, the velocity amplitudes are fairly large, and the eclipse curves (PEP) indicate a grazing eclipse with an inclination of about 70°.

RU Pegasi has been shown to be a double-lined spectroscopic binary, with the longest period yet found, 8^h54^m.

If we look at this group as a whole, we recognize that they are in an advanced evolutionary stage, since one component is a hot blue sub-dwarf, and if we ask if they are descended from any other recognizable type of object, it seems clear that the W Ursae Majoris stars are the most likely progenitors of the dwarf novae.

The following table compares the physical parameters of the dwarf novae and the W Ursae Majoris stars. It can be seen that these two types of objects are much alike:

	Dwarf Novae	W Ursae Majoris
Mean Period	1/4 day	1/3 day
Absolute Magnitude (from studies of motions)	plus 9	plus 4.5
Average sum of masses	1.5-3 Suns	1.2-2.5 Suns
Average ratio: mass of one component to sum of masses of both components	1/2	1/3
Average Mass Ratio	1:1	2:1
Dispersion in radial velocity, referred to local standard of rest	20 km/sec	26 km/sec
Mean distance above or below galactic plane (all stars in each group down to comparable apparent magnitudes)	50 parsecs	40 parsecs

We can infer an evolutionary pattern something as follows: W Ursae Majoris stars are F and G stars on the main sequence, with an average mass ratio of 2:1. As the system ages, the more massive component starts to swell up and move to right on the H-R diagram. However, in this process, it encounters the critical zero-velocity surface, and starts to lose mass, which is either lost to the system or transferred to the other component. Now, theory predicts that if mass is lost from the system, the period will increase; while if mass is transferred to the other component, the period will decrease. Here, we know that the sum of the masses of the two components remains about the same, indicating that mass transfer is more important than mass loss; and, by the time enough mass has been transferred to reduce the mass ratio to unity, the period should decrease by just about the amount that is observed. As the evolutionary process continues, the originally more massive component becomes a hot blue star and the other component then swells up, and begins to lose mass back to the hot blue companion. It is in this stage of evolution that the dwarf novae are observed today.

In conclusion, with respect to the dwarf novae, it appears that they all are binary stars; and it seems reasonable to suppose that they have evolved from W Ursae Majoris stars originally lying on or close to the main sequence. The most curious puzzle about the dwarf novae stars at present is the question of why they are so under-luminous for their masses. They seem to be systematically from 2 to 4 magnitudes too faint for their masses, and thus don't obey the mass-luminosity law at all. The clue to this puzzle is probably the fact that they are losing mass.

Turning finally to the old novae, which have been under investigation at Mt. Wilson and Palomar, mostly during the last year, some definite results have already been obtained. It has been mentioned that T CrB and Nova Herculis 1934 had been found to t be binaries with widely different periods.

Last year, Merle Walker at Lick Observatory announced that Nova T Aurigae was an eclipsing binary, with a period of 4^h54^m, apparently quite similar to Nova Herculis 1934 with its period of 4^h39^m.

A sample collection of the spectra of old novae shows that they do not form a compact group, as do the spectra of the dwarf novae. Some spectra, such as that of Nova Persei 1901 are clearly composite, with bright lines as well as absorption features; others show no sharp features at all, but merely continuous spectra with the hint of widely-broadened absorption features which can not be measured with sufficient precision to determine whether or not there are periodic variations in radial velocity (see Nova Lacertae, 1910).

Nova WZ Sagittae,(15th magnitude)by the use of a novel technique in which the image of the star was allowed to trail for 90^m from one end to the other of a very long slit, was recently found to be a spectroscopic binary with a period of 80^m. (See Binary Stars among Cataclysmic Variables II, Robert P. Kraft, Jon Mathews and Jesse L. Greenstein, Astrophysical Journal, Volume 136, No. 1, pages 312-314). Krzeminski found the photoelectric light curve in the ultra-violet to be typical of a W Ursae Majoris type binary. However, this object has certain puzzling features; first, although the absorption lines observed indicate that one of the components is a white dwarf, calculation yields a minimum mass for that component substantially in excess of the maximum theoretical mass for a white dwarf of 1.2 suns. Second, simultaneous spectroscopic and photoelectric observations, permitting the phasing of the radial velocity and light curves, shows that primary eclipse maximum occurs -- not at conjunction of the two components -- but almost at elongation. Though it is obvious that the variation in radial velocity of the emission lines has something to do with binary motion, this result seems to indicate that the emitting region, though reflecting the period of the binary motion, is not carried along with either of the binary components. Because of these two problems, it is not known at the present time just how this object is to be interpreted, beyond the fact that it is plainly a binary star.

Nova Aquilae 1918, of 10.8 magnitude, was bright enough so that spectra could be secured at the Coude focus of the 200", with an initial dispersion of 38 angstroms/millimeter. The spectra indicate that this object is a single-lined spectroscopic binary with a period of $3^h19.5^m$; although the radial velocity variation is so small that the system is probably seen almost pole-on, as is indicated by the fact that the emission lines are clearly single. The amplitude of the velocity variation is so small that it would be unobservable in spectra made at the prime focus of the 200" -- suggesting that there must be many such objects which can never be shown to be binary with even the most powerful of present telescopes because they are just too faint for adequate spectral resolution to be used.

Nova Persei 1901 has been shown to be a double-lined spectroscopic binary with quite a large radial velocity variation and a period of a little more than 1.9 days. This is the first old nova found with a period intermediate between the few hour period of Nova Herculis 1934 and the 227 day period of Nova T CrB.

At present, we can say that in addition to the old novae discussed above, there are 6 known spectroscopic binaries among the old novae. A 7th, the recurrent nova Nova Sagittarii 1919, has a composite spectrum and is clearly a binary. Thus, slightly more than one-third of the old novae accessible from Palomar have been shown to be binary stars; and it is probably safe to assume that all old novae are binaries. Very likely, the same model found for the dwarf novae applies, that is: a red component with a blue companion, in which the red component is overflowing the critical zero velocity surface.

In conclusion, we can make certain comments about the significance of novae in the scheme of stellar evolution -- and in the problem of stellar populations.

First, it will be recalled that some years ago it was believed that the nova phenomenon was one which occurred in the course of single-star evolution to the white-dwarf stage, and the nova process was looked on as the mechanism by means of which the mass loss made necessary by the theoretical limit of 1.2 suns for the mass of a white dwarf was to be accomplished. This idea now must be rejected, not only because the gradual and continual loss of mass by red giants discovered by Armin Deutsch is a much more efficient mechanism for this purpose, but also because novae, having been shown to be binary stars, obviously have nothing to do with single-star evolution.

Secondly, it had been thought for many years that the novae were members of population II. However, it has now been shown that the novae are binary stars and there aren't supposed to be any binary stars in population II systems, especially not in globular clusters, the classical population II systems. However, there have been novae in globular clusters -- and at least one dwarf nova has been observed in a globular cluster. Thus, it must be concluded that at least some binary stars occur in population II systems. It may well be that population II systems have not been properly searched for binaries. At any rate, the difference is probably more of degree than of kind. Whenever you get a suitable close binary system, you may get a nova. Such binary systems are at least relatively rare in Population II systems, characterized by slow stellar rotations. Such binary systems are much more frequent in the galactic disc population, characterized by rapid stellar rotations -- and thus the novae tend to be found in the disc population.

(Reported by Richard H. Davis)

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