Contributions of Amateur Astronomers to Variable-Star Observing

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Astronomy is a unique field of science in which amateur astronomers have made and continue to make significant contributions.

One major area of the science of astronomy is the study of variable stars. There are more than 28,000 known and catalogued stars that change in brightness – variable stars – and about 15,000 suspected to be variable. These stars need continuous and systematic observing over decades to determine their behaviour and to record any of their unusual or rare activity. However, there are not enough professional astronomers or telescopes to observe these stars regularly. Therefore, variable star astronomy needs amateur astronomers to be the record keepers for these stars. It was for this reason that as early as 1844 and continuing throughout the second half of the nineteenth and early twentieth centuries, the astronomers F.W. Argelander of Germany, Sir John Herschel and J. Baxendell of England, D.F.J. Arago of France, and E.C. Pickering of the United States all advocated systematic variable star observing for amateur astronomers. The encouraging appeals from these leading professional astronomers resulted in the formation of several organized groups of variable stars observers, first in England – the British Astronomical Association (1890), Variable Star Section; then followed by the American Association of Variable Star Observers (1911); the Association Française des Observateurs d'Etoiles Variables (1921); the Royal Astronomical Society of New Zealand, Variable Star Section (1927); and the Japanese Astronomical Study Association (1945). Today, there are about 25 variable star observer groups around the world.

Since 1970, with the advancement of technology, variable stars have gained special significance as observations by professional astronomers have extended from X-ray to radio wavelengths. During this time, the number, range, and importance of contributions from amateurs have increased dramatically.

I wish to share with you some specific examples of the significant contributions variable star observers have made in recent years. Although these are examples from AAVSO records, they are testimonies to variable star observers around the world, for more than 50% of the observations received annually by the AAVSO come from observers outside of the USA. In fact, France, South Africa, Hungary, Germany, Canada, and the Netherlands were the leading countries in contributing observations to AAVSO data files last year.

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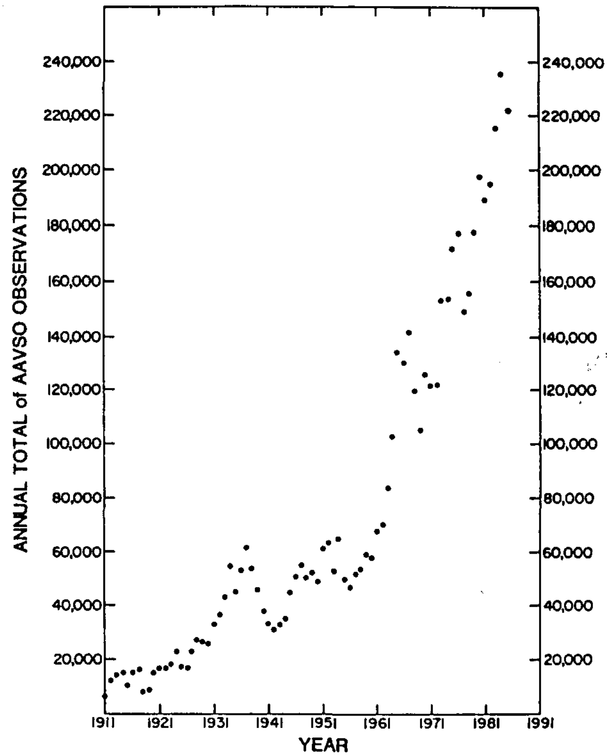

Fig. 1. Observations received each year by AAVSO, 1911–1986.

As interest in variable stars has grown in the professional community, the interest and the dedication of variable star observers also has grown. The number of observations received annually by the AAVSO has increased exponentially, as seen in Figure 1. The grand total of the observations archived by the AAVSO since 1911 is now over 5.5 million, contributed by more than 4000 observers around the world, Figure 2. In fact, the dedicated French variable star observer, Paul Vedrenne, made the 5,000,000 observation in the AAVSO data files.

In the 13 years that I have been the director of the AAVSO, we have supplied variable star observations made by amateur astronomers to over 1200 professional astronomers and researchers. Figure 3 is a histogram of the number of requests for data filled each year since 1974. These requests are for the following information :

1) to correlate data in multi-color wavelengths;

2) to schedule observing programs with large telescopes;

3) for simultaneous monitoring of scheduled stars;

4) for data analysis;

5) for reference materials to write articles on variable stars; and

6) for student science projects.

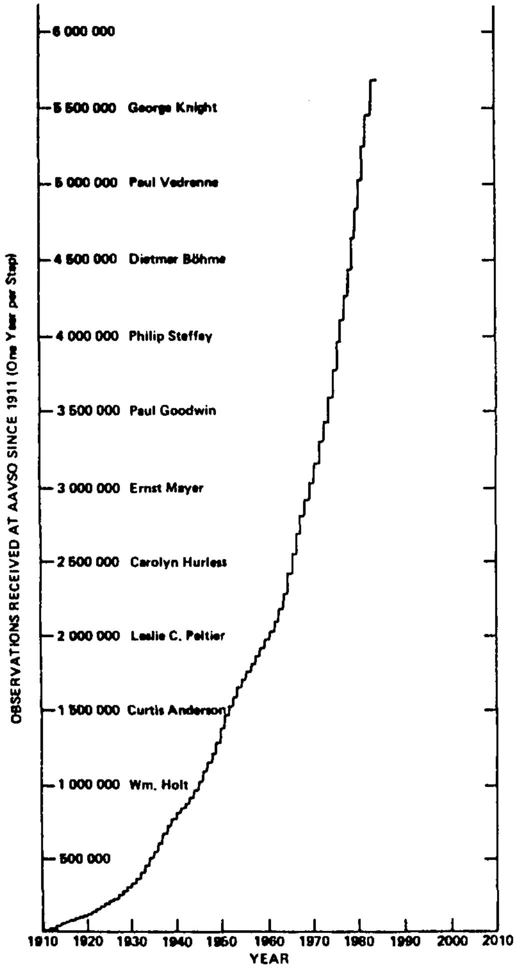

Fig. 2. Total of observations received by AAVSO, 1911–1986. Observers who made milestone observations (1,000,000; 1,500,000; etc.) are indicated on the graph.

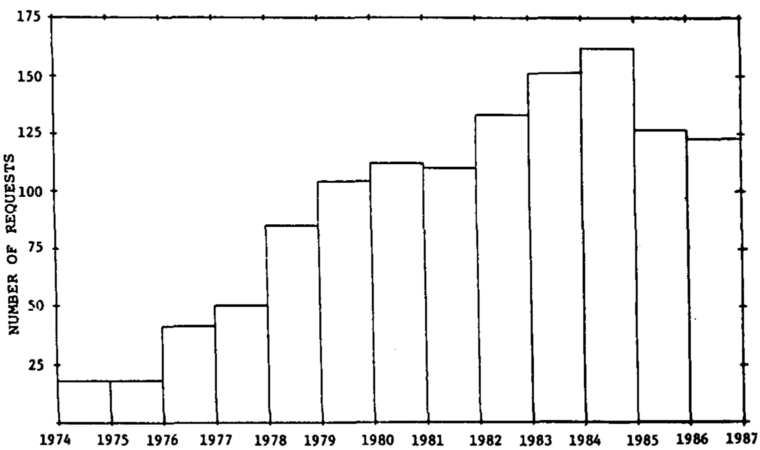

Fig. 3. Number of special requests for AAVSO data filled each year since 1974.

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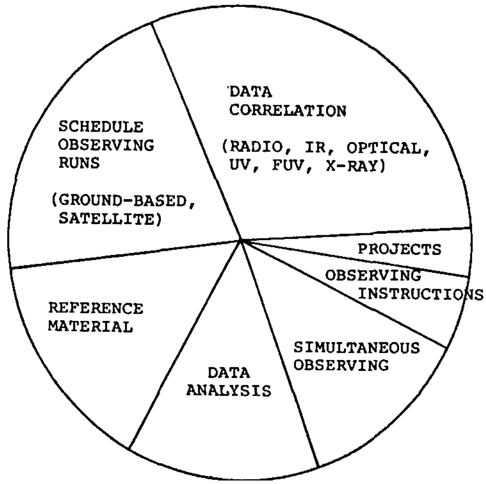

Fig. 4. Areas in which AAVSO data and services were used during 1984.

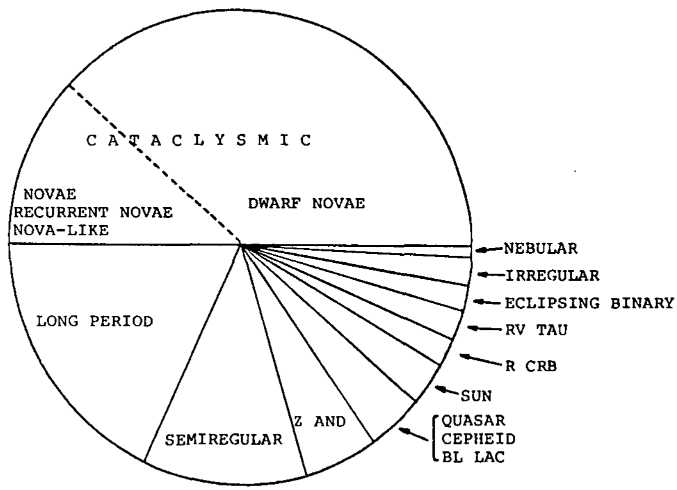

Fig. 5. Types of variable stars for which AASVO data were requested during 1984.

Figure 4 is a piegram showing in what areas the AAVSO observations were used in 1984. Observational information has been requested on all types of variable stars, but due to very active satellite research programs in recent years, the largest number of requests has been for observations on cataclysmic variables. Figure 5 is a piegram showing the different types of variable stars for which AAVSO observations were requested in 1984.

The most important and vital contributions of variable star observers in recent years have been :

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1) assisting professional astronomers in scheduling observing programs with large telescopes or instruments aboard satellites;

2) providing simultaneous optical coverage and immediate notification of the behaviour of the scheduled stars during the observing runs; and

3) providing high quality optical observations for data correlation in multi-color wavelengths.

I would now like to expand on these contributions.

1. Scheduling observing programs

Continuous observations provided by amateur astronomers are essential to professional who wish to schedule observing programs with large earth-based telescopes or satellites equipped with specialized instruments during a specific phase of light variation of a variable star.

In the area of pulsating, long period variables, using both long-term and up- to-date observations provided by observers, together with AAVSO mean curves for each star, we predict the maxima and minima dates of 560 stars each year and publish this information in the AVVSO Bulletin. This publication is indispensable to both professional and amateur astronomers in setting up observing programs of long period variables. In addition to this, for specific observing programs we are able to predict the date and the brightness of a variable star at the requested phase, information which is crucial for the most efficient use of time on large telescopes.

We recently assisted astronomers at the University of California in this way. They were interested in observing with a radio telecope those bright long period variable stars known to be SiO masers, at maximum light. They called us to ask if the stars in their observing list would be bright at the time scheduled for observing. Extrapolating the AAVSO data, we found that all the stars on their list would be faint, below the limit of detection of the radio telescope, at the time the radio observations were scheduled. This crucial information enabled the astronomers to reschedule their observing time for a later date and thus make maximum use of the radio telescope.

In the area of close binary eruptive systems, usually referred to as cataclysmic variables, amateur astronomers have been playing a crucial role since 1973, when astronomers surveying the Cygnus Loop in X-ray wavelengths with sounding rockets accidentally detected ultra-soft X-ray emission from one of the most popular cataclysmic variables, SS Cygni. This important finding, predicted earlier theoretically, accelerated both earth-based and space research on these systems. Since the AAVSO observing program and data files contain a large number of these stars, professional astronomers have sought and continue to seek the help of variable stars observers in planning and scheduling almost every observing program of cataclysmic variables.

We had a very interesting and exciting collaboration recently with Dr. Janet Drew and her colleagues at Oxford University, England. They were interested in observing the eruption

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of the cataclysmic variable, YZ Cancri, in the ultraviolet with the IUE satellite. This star has frequent eruptions every 12 to 17 days that last one to three days. Superimposed on this behavior are bright and long superoutbursts that occur every two hundred days or so. To predict the occurrence of either of these eruptions is very difficult, indeed. The IUE satellite has to be scheduled months in advance. However, one can make the best guess as to when the next outburst will occur only about a month beforehand. The IUE run for YZ Cancri was scheduled for the seconf half of February, and astronomers were going to travel to the IUE station in Spain during the observations. January data on YZ Cancri indicated that the expected outburst most probably would take place not in the second hal of February but in early March. Using this crucial information, astronomers rescheduled their observing for early March. On March 1st, they went to Spain and waited to be alerted, depending on the observations of amateur astronomers. Observers all around the world were observing YZ Cancri very closely, and on the night of March 3, Gerald Duck, a dedicated observer in Massachusetts, reported that the explosion of this star had started. His detection was followed by observers around the world, such as Stephen Lubbock in England and Sei-ichi Sakuma in Japan. Throughout the ourburst, observers from around the world called to give us the most up-to-date information. YZ Cancri started to fade on March 5. The astronomers were able to obtain the earliest and most complete UV spectra of the short outburst of this star. This type of data is vital to understand the disk structure around the white dwarf on this close binary system, and the nature and cause of the outbursts. Since the duration of these outbursts is so short, to be able to schedule and observe this type of outburst is a real challenge and an astronomical victory only to be won with the help of dedicated variable star observers around the world.

2. <u>Simultaneous optical coverage and immediate notification</u>

During scheduled earth-based and satellite observing programs, astronomers again request variable star observers to provide simultaneous optical coverage of the scheduled stars and to inform them of the stars' behavior regularly. This simultaneous optical coverage has been crucial for the most effective use of telescope and instrument time, and for obtaining vital information during rare events of variable stars. It is very exciting to know that in this age of high technology, professional astronomers depend on amateurs in planning their observing, and in selecting the object at which to point their large earth-based telescopes or satellites. The dedication, the enthusiasm, and the high quality data of variable star observers have made this unique collaboration possible.

The following expert from a letter from an astronomer who has benefited from data provided by variable star observers demonstrates the pivotal role amateur astronomers play. Dr. Michael Bode from the University of Manchester, England, wrote :

"The AAVSO has several times recently provided me with data on the visual behavior of variable stars being observed at other wavelengths by satellite or ground-based facilities... In one classic case recently we obtained precise simultaneous observations of the dwarf nova SU

UMa with EXOSAT, IUE, and IRAS. Although several large ground-based observatories were prepared to make optical observations they were all 'clouded out'. The only point in this part of the spectrum was obtained by an AAVSO member... This is only one example of the many occasions that the AAVSO has provided invaluable assistance."

Amateur astronomers around the world have played a vital role in research on cataclysmic variables with X-ray and ultraviolet satellites. The observers have worked closely with Drs. France Cordova and John Middleditch of the Space Astronomy and Astrophysics Group at Los Alamos National Laboratory, and Keith Mason, of the Mullard Space Science Laboratory of the University of London, England. The fruitful collaboration between this group of astronomers and the AAVSO resulted in 23 scientific papers. Dr. Cordova wrote, "The AAVSO data were used to augment high energy X-ray and ultraviolet satellite data and were essential to the conclusions drawn in these papers."

Dr. Cordova and her colleagues enumerated some of the astrophysical research programs that they collaborated on with the AAVSO and described how the AAVSO helped them in their investigations using the X-ray and ultraviolet satellites :

"1. During the 6 month all-sky scanning phase of the X-ray astronomy satellite HEAO-1, AAVSO observers kept vigil over ~200 dwarf novae so that nearly simultaneous visual data would be obtained during the X-ray observations of these stars. The result was the first survey of the X-ray emission from a cataclysmic variable and the detection of X-ray emission from a few members of each cataclysmic variable subclass.

"2. During the pointing phase of HEAO-1, AAVSO observers alerted us to optical outbursts of dwarf novae so that these stars could be observed by the satellite during outbursts, when enhancements in the X-ray flux could be expected. The result was the discovery of soft X-ray pulsations from two dwarf novae (SS Cygni and U Geminorum); these were the first detection of soft X-ray pulsations from any astrophysical source.

"3. To clarify the nature of the soft X-ray pulsations we undertook a program of high time resolution optical photometry of dwarf novae using ground-based telescopes. AAVSO observers monitored a large sample of dwarf novae before and during our observing runs, and alerted us to incipient outburst activity. In this way we maximized our chances for detecting optical pulsations by observing only those dwarf novae undergoing outbursts. The results were the first multi-color spectra of dwarf nova pulsations.

"4. AAVSO observers alerted us to the outbursts of dwarf novae during our many observing runs using the International Ultraviolet Explorer (IUE) Satellite. The result was the accumulation of many UV spectra of dwarf novae in various optical outburst states. The AAVSO light curves of dwarf nova outbursts were essential in interpreting the UV data, and led to the discovery that the UV outburst is delayed with respect to the optical outburst.

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"5. The HEAO–2 satellite (or "Einstein") with its much improved sensitivity over HEAO–1, discovered X-ray emission from about 70% of the 70 or more cataclysmic variables it observed. AAVSO observers monitored nearly all of these stars near the time of the X-ray observations. This information was vital in deriving a luminosity function for cataclysmic variables, and in testing theories for the high–energy emission in these compact systems.

"... The above examples represent only the results from our own collaborations with the AAVSO, and, as such, only a small part of the significant contribution AAVSO observers are making towards furthering basic research in astrophysics."

3. Data correlation

Variable star observations made by amateur astronomers have been used by professional astronomers to correlate polarimetric, photometric, and spectroscopic multi-wavelength data, ranging through radio, infrared, optical, ultraviolet, far ultraviolet, extreme ultraviolet, and X-ray wavelengths, obtained with earth-based large telescopes at observatories such as Mount Palomar, Kitt Peak, Cerro Tololo, Lick, McDonald, Mount Lemon, Whipple Multi-Mirror, Dominion Astrophysical, Tenerife, and Jodrell Bank, the Very Large Array Radio Telescope, and instruments aboard satellites such as the International Ultraviolet Explorer (IUE), High Energy Astronomical Observatories 1 and 2 (HEAO–1 and 2), Apollo–Soyuz, Voyager, Infrared Astronomical Satellite (IRAS), and the European X–ray Observatory Satellite (EXOSAT).

In the area of pulsating long period variables, observations made by amateur astronomers are essential both to theoretical astronomers working to understand the mechanism of the variation in these stars, and to observational astronomers who are observing these stars in optical, infrared, and radio wavelengths to obtain more information on the kinematics, chemistry, and evolution of the extended atmospheres of these stars.

Drs. L.A. Willson, G. Wallerstein, and C.A. Pilachowski, in their scientific paper entitled "Atmospheric Kinematics of High Velocity Long Period Variables ", in the Monthly Notices of the Royal Astronomical Society, 198, 483 - 516, used AAVSO observations and acknowledge the AAVSO in the following way :

"No paper on LPVs is complete without an acknowledgement to observations would be uninterpretable."

In the area of symbiotic variables, the data from variable star observers again played a crucial role in correlating observations obtained with radio telescopes. The star in question was the bright circumpolar variable CH Cygni, which has recently been reclassified as a symbiotic star consisting of a red giant and a hot blue component, imbedded in nebulosity. CH Cygni has two periods, a short one of 100 days, and another, longer period of 700 days. This variable star had been unusually bright since 1977. Both its short and long period variations were washed

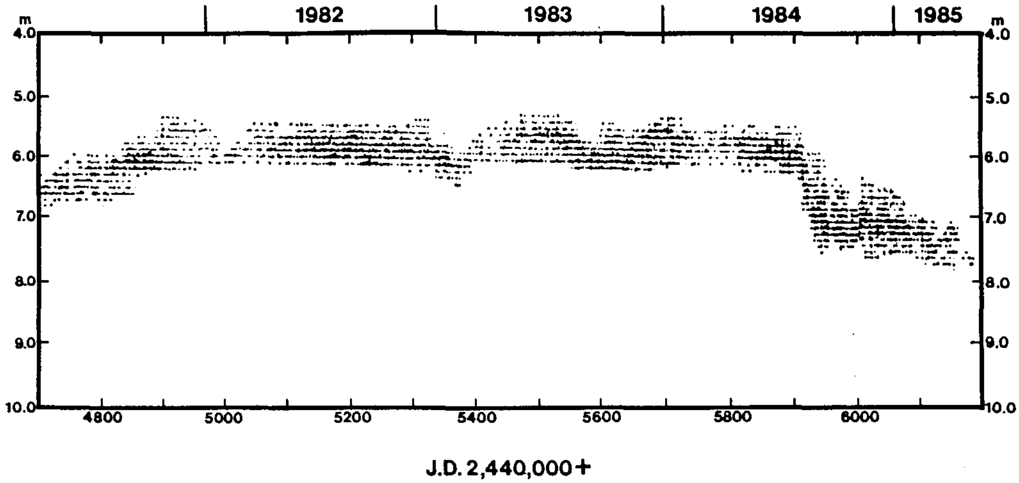

Fig. 6. AASVO visual light curve of CH Cygni from April to May 1985. Each dot represents one observation.

out. In June 1984 observers reported a sharp decline in its light variation, in which it faded from magnitude 5.5 to 7.5, Figure 6. During this time, Dr. R. Taylor from the University of Groningen, Netherlands, and Dr. E. Seaquist of University of Toronto, Canada, observing with the Very Large Array radio telescope, discovered a radio outburst and jets accompanied with increased flux density observed from April 1984 to April 1985. The increased flux density corresponded to the optical drop. Recently Dr. Seaquist wrote :

"...The AAVSO light curve for this star is playing a crucial role in the analysis of this event. What would we have done without the work of all the variable star observers ?"

The analysis of long-term visual data of cataclysmic variables has thus far revealed interesting correlations. There is, for example, a strong correlation among the duration of the outburst, rate of rise and decline from outburst, and the orbital period and the mass of the secondary component of the system. There is a relationship between the orbital period and the decline from outburst, in that the smaller the orbital period the faster is the decline from outburst. The orbital period of an eruptive close binary system is an important physical parameter that has a direct bearing on the mass of the secondary, the rate of mass transfer, the size of the system, and possibly the evolution of the system. To obtain orbital periods of cataclysmic variables spectroscopically requires large telescopes and is a difficult procedure. However, an indirect way to obtain the orbital period of a special type of cataclysmic variable – SU Ursae Majoris stars – is to observe the small-amplitude, periodic modulations (superhumps) during long outbursts (supermaxima) and to obtain their periods which are two to three percent longer than the orbital period of the system itself. Thus, if supermaxima of a system can be predicted, then through the observations of superhumps the orbital period of a SU UMa system may be determined.

Long-term analysis of the light curves of these types of stars has shown that one can predict the occurence of supermaxima (Mattei 1983) and in the recent years through the correlation of high speed photometric data and the AAVSO optical light curves six dwarf novae (RZ Sagittae, TY Piscium, HT Cassiopeiae, SW Ursae Majoris, VY Aquarii, and T Leonis) have been confirmed to belong to SU Ursae Majoris subclass, and orbital periods have been obtained for them.

Amateurs astronomers, through their valuable observations of variable stars, have provided complete, historical records on hundreds of variable stars, and, as we have seen, have played a major role in helping professional astronomers push back the frontiers of astronomy and gain understanding of a number of important and puzzling phenomena in astrophysics such as stellar pulsations, stellar instability, and time-varying processes in stars. The value of the contributions of variable star observers may be summarized by Dr. F. Cordova, who said, "The real discoveries of these stars belong to the men and women who keep vigil on them."

It is certainly both an honor and a pleasure for me, representing the AAVSO, to be joining in the celebrations of the 100th anniversary of the Société Astronomique de France. May the success of SAF and the valuable contribution of its members to astronomy continue for many centuries.