The Amateur and Eclipsing Binary Stars

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Probably no other branch of science has benefited as much from the work of dedicated amateurs as has the science of Astronomy. While some amateurs have made many useful types of astronomical observations— comets, meteors, occultations, etc. — perhaps none has been as extensive and as useful as those made in the field of variable stars. There are not nearly enough professional astronomers to keep under proper observation the increasingly large number of known variables. While all kinds of them are well worth continuous study, this paper will call attention to the importance of eclipsing variables and in particular the systematic and continuing observation of their times of minimum light.

The systematic study of eclipsing binaries goes back to the year 1783 and an amazing amateur astronomer, John Goodricke. His paper in the Philosophical Transactions of the Royal Society, London (Vol. 73, p. 474) not only announced the variability in brightness of Algol —which Goodricke discovered without the use of a telescope and working in the English climate— but also determined the period of this light variation. He even gave two theories as to the cause and one of these —the periodic passing between us and the star of a "dark body"— is essentially correct. Indeed, the other possibility —the existence of highly variable star spot areas is now used to explain certain details of the changes in a few other close systems. Goodricke even searched the earlier literature and found that Montanari and Miraldi had much earlier discovered the variability but not the periodicity, and he gave them credit. Since 1783, the study of eclipsing binaries has been of ever increasing volume and no attempt will be made to give a detailed picture. I could at least mention that the eclipse hypothesis was firmly established when changes of radial velocities in eclipsing systems were determined.

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There are several reasons for observing eclipsing binaries. If observations covering the entire light curve have been made, then methods exist of deriving from the light changes the relative sizes of the two stars and the inclination of the orbital plane to the line of sight. With these known, the study of the velocity curve can yield sizes, masses and densities —i.e., the fundamental data concerning the stars themselves and matters not directly obtainable from single stars. These determinations require observations of the entire light curve and in many cases re-observation to exhibit whether or not changes occur which are not necessarily connected with the eclipse effects. Account must be taken of the distortions of each star from a sphere caused by the gravitational effects of the other, the brightening (especially in the colder component) of the hemisphere facing the companion and frequently various other effects not completely understood. The exact "solution" can be a difficult and time consuming chore and is probably best left to the experts in the field. Further, in many cases, the wave-length region of observation must be carefully specified and this means standard stars, color differences and other difficulties.

However, there is one extremely valuable contribution which can be made by the amateur which is free from color differences and which is a contribution which will grow in value as time goes by. That is to say, all future studies will have to relate back to this and thus the present observations will be of increasing value the more the system is observed in the future. This contribution is the determination and publication of the times of minimum light of eclipsing binary systems.

The amateur astronomer wishing to observe these will probably do well to establish contact with one of the various organizations for the study of variable stars. These exist in many nations but their membership lists cross international boundaries. Many but not all of these have been described in the Journal of the AAVSO 15, No. 2, Pg. 141-161-75th Anniversary Edition. A few of these confine their work almost entirely to minima of eclipsing systems. (An excellent example might be noted by looking through the BRNO contributions).

One such highly productive organizations is the BBSAG (Bedeckungsveranderlichen Beobachter der Schweiezerischen Astronomischen Gesellschaft) whose present headquarters are c/o K. Locher, Rebrain 39, 8624 Grut, Switzerland. The membership

consists of observers from a number of different countries. A major contribution from this association lies in the publication of the observed times of minima in a publication which receives world wide distribution in the astronomical community. The most precise observations are of little value if they remain only in the observing notes of the astronomer himself. Also, while I know that I do not have to tell this audience how to observe stellar brightness, the presentation of them in a form to be of maximum value requires the reduction of the observed times to Julian days and fractions of a day and correction of these heliocentric times so that the observation not be vitiated by the movement of the earth about the sun. These corrections must be applied before a meaningful period study can be made. For any astronomer not familiar with means of determining these, contact with an established group of variable star observers (such as the BBSAG) or with a major professional observatory will probably answer all questions. The publication Rocznik Astronomiczny of the Astronomical Observatory of the Jagiellonian University in Cracow is also of great value in selecting an observing program. Astronomers with photoelectric photometers might wish to get in touch with the IAPPP - International Amateur and Professional Photoelectric Photometry.

Perhaps now we should consider just why it is important to observe these times of light minima. Just what will we learn that will justify the long hours at the telescope? There are various answers.

One is simply the determination of better light elements. (The light elements are simply the time of one well determined light minimum-the epoch- and the period or length of time from one minimum to the next. These permit computation of future minima or phases at any given time.) This is of particular importance to spectroscopists or to photometric observers planning a program.

However, frequently it is not possible to fit all the observed minima with any given set of light elements. This indicates that there have been changes in the period and it is of interest to note very briefly what can be learned from these.

On a few rare occasions, the close "double" star is a member of a triple star system with a companion well removed from the binary. The changes of period are caused by the motion of the close binary around the center of mass of the system. This can give information especially as to the masses of the stars involved which is of interest in

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studies of triple star systems. In all cases, the variation of period as determined by the (O-C)'s —the difference between the observed and computed minima— when plotted against time show a sinusoidal fluctuation with those of secondary minimum following the same pattern as primary.

A case of more importance from the point of view of astrophysics is when the two components are moving in elliptical orbits about the common mass center. Without going into details it can be mentioned that in this case the line of apsides joining the stars will rotate and that the rate of this rotation will depend, among other things, on the "model" in which the star is built or, more specifically, on the degree of central condensation. This relation will cause a periodic change of period as observed from the earth; the (O-C)'s of secondary will show a similar periodic change but one exactly out of phase with the primary. Such systems can be detected most easily by the fact that the secondary will not occure half way between primaries but will be displaced. (A more complete discussion can be found in Photoelectric Astronomy for Amateurs, Ed. F.B. Wood, published by the Macmillan Company in 1963, and unfortunately now not always easily available). However, it takes many epochs of observation to establish whether or not the period variation is indeed itself periodic and not the result of one or two apparently sudden changes. One clue is that the (O-C)'s of the secondary minimum should also vary periodically but exactly out of phase with those of the primary.

The most common changes are apparently abrupt lengthening or shortening of the period which effects both primary and secondary alike. Again, the conventional treatment is the plot of the (O-C) curve against epoch. Also continuous observation is important. Nearly forty years ago it was pointed out (F.B. Wood, Ap. J.112, 196, 1950) that in almost all of these cases at least one component of the system was near the zero-velocity surface outside of which the star is no longer is in complete gravitaitional control. (For a more complete discussion of this see Interacting Binary Stars by J. Sahade and F.B. Wood, Pergamon Press 1978). Stars well within these limits generally show no such sudden period changes. The suggestion first made was that these changes could be caused by sudden, violent mass loss to the system; today, the idea of mass transfer from one star to the other is widely discussed. However the business of the observer is to make and to publish the times of minima. Since the period changes are

usually rather small, observation over many years are usually required to establish the reality of the variation and even more to establish its nature. Thus the observer of today is indeed laying the basis for all future work.

The planning of an observing program is extremely important. The size of his telescope and the sensitivity of his detector will set magnitude limits. The latitude of the observer will set limits of declination. Stars with very long periods will present difficulties; observation on two or more successive nights may be necessary to obtain one well determined time of minimum. Yet this very difficulty means that the system is less frequently covered and therefore the observation of greater importance. Consultation with the organized observing groups, (AAVSO, BAV, BBSAG, BRNO, IAPPP, and others) will be of great help. A few copies of the fifth edition of "A Finding List for Observers of Interacting Binary Stars" (Publ. of the Dept. of Astronomy, University of Florida, Vol. I) are still available and will be supplied on request while they last. This gives also suggestions as to comparison stars because observations are always given as differences of brightness between the variable and one or more stars of constant light. For almost all systems at least rough light elements exist and these can be used to compute future minima so that the observer will not spend a lot of time observing phases of constant light. In addition to the scientific value, there is something exciting in seeing the star actually change in brightness with time.

In conclusion, the above recommendations are in no way intended to belittle the many other fields in which amateurs can make useful contributions to astronomy, but merely to call attention to the excitement and the permanent value of determination and publication of the time of minimum light of eclipsing binary systems.

All good wishes for skies of high photometric quality.

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