New Observations of Close Binary Systems

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Surely, Algol systems and W UMa stars are evenly distributed over the whole sky, and close binaries with circumstellar matter in their surroundings can therefore be observed from the northern as well as from the southern hemisphere. But the number of really *outstanding* eclipsing variables of this kind—like U Cep with its strange light-curve outside the eclipses, which has been known since the days of Dugan, and with its spectral peculiarities—is not large, and it may therefore be considered very worthwhile to test southern eclipsing binaries in the hope of discovering new, particularly interesting systems. Let us first consider the systems of Algol type, i. e. systems in which the light minima are well defined and the light-curve outside the minima is reasonably flat; the prototype is β Persei, also called Algol.

Professor Kurt Walter from the Astronomical Institute of the Tübingen University is a frequent visitor on La Silla. Together with another German astronomer, Dr. H. Duerbeck, he has collected a large and very accurate observational material from which it appears that much more information is present in the light-curves of close binary stars than earlier generations of astronomers would ever have dreamt of. Various estimates show that a large part, possibly about 50 per cent, of all stars are double and it is therefore of obvious importance to gain insight into the mass-transfer processes that are at work in close systems and which apparently play a large role in their evolution.

Though spectroscopists began already in the forties to study gas streams and rings which they found in these binaries, photometric observers only much later succeeded in giving valuable contributions to the problems of circumstellar matter in close binaries. However, they could then not only confirm the results of the spectroscopists but often give important new insight into the mechanism and the position of the circumstellar matter.

Photometry of Algol-type systems

The photometric consequences of the presence of circumstellar matter in typical Algol systems have been largely underestimated for a long time. Although the gas stream which is flowing from the secondary, subgiant component to the bright and massive primary component is almost invisible in broad-band photometry, this stream becomes photometrically observable chiefly by absorbing the light of the primary at those orbital phases, where it is placed between the terrestrial observer and the primary star; variations in the gas stream in this position may also cause a variation in the measured intensities as sometimes seen by comparing observations at the same phase of the light-curve from different nights.

Another effect which may disturb the light-curve within and outside the eclipses is the light coming from "hot spots" arising on the surface of the bright primary component at regions where the particles of a gas stream strike the atmosphere of this star at large velocities. The additional light of the luminous regions is directed towards us during one-half of the orbital revolution. In order to get a reliable photometric solution of a system (i. e. to determine its geometrical and photometric properties by means of the observed light-curve), the influence of hot spots and the absorption effects must be carefully taken into account at the evaluation of the light-curve. Several typical Algol systems which have been thoroughly investigated in this way show that the primary eclipses are actually composed of *two* eclipses: that of a star with a normal luminosity distribution across the stellar disc and a second eclipse of the additional light. When the exact geometry of the system is known, the phases of disappearance and reappearance of the additional light enable us to fix the position of the luminous region(s). It is somewhat surprising that the hot spots are mainly situated near the poles of the accreting primary component.

For a thorough study of a typical Algol system that aims at a full description of the binary model including the effects of circumstellar matter, very precise measurements must be made that uniformly cover the light-curves. As an example, observations from more than fifty nights are needed for systems with periods of a few days. Of course the continuous observation of an Algol star outside eclipse (nearly constant light) over a long part of a night would be a waste of time. Therefore during the night the observer frequently changes from one system to another in order to get the maximum of valuable information about them for a minimum amount of observing time and an optimal distribution of the observed phases. Thus the observation is often not a simple task, it is dependent on observing and weather conditions, and it also requires day-time work to keep at least a rough check on the actual state of the coverage of the light-curves by the observations. Sometimes the difficulties caused by missing phases are overcome by exchange of observing time with colleagues.

Observations on La Silla

The 50-cm ESO photometric telescope on La Silla has been found to be a very useful instrument for observations of this kind. Four Algol systems have now been observed by us on La Silla, and for each of them clear indications of interstellar matter were found. For three of them—RW Ara, XZ Sgr, X Gru, systems with periods between 4.4 and 2.1 days and very deep total primary eclipses—the model expected for typical Algol systems (Walter, *Astrophys. Space Sc.* **21,** 289 (1973)) could be confirmed. The intensity of the observed hot spots near the visible pole of the primary components were 1–2 % of the intensity of the uneclipsed system and does by far not reach the intensity of the hot spots of the U Cep system (ca. 8 %), but U Cep is also known for its exceptionally large mass flow. From these results we may state that the existence of gas streams flowing towards the polar regions of the massive component in Algol systems seems to belong to the normal picture. Moreover the paths of the transfer of matter towards polar regions hint to the presence of magnetic fields.

There are open questions about the models of close binaries with orbital periods of about two days and shorter. Observations obtained on La Silla during several years have shown that X Gru (P = $2^{d}.1$) and V 505 Sgr ($1^{d}.2$) have slightly variable light-curves outside the eclipses. Apparently some other phenomenon is here added to the characteristics of the Algol systems as described above. As matters now stand, the origin of this variability may be surmised on the basis of results from recent investigations of two systems with similar periods, U Cep ($2^{d}.5$) and TV Cas ($1^{d}.8$). It appears that the long-period variations of the light-curves are controlled by the precessional periods of the rotational axes of the primary components. This as yet unknown and quite unexpected property of close binaries which is closely connected with the gas streams flowing towards the primary components may be realized by accurate photometric observations of the shape of the total eclipse, as it was shown for U Cep (Walter, *Astron. & Astrophys.*, **42,** 135 (1975)) or by observations of the light-curves outside primary eclipses like for TV Cas, where periodical fluctuations could be found and explained in this way from the reduction of observations obtained over six years (in preparation for publication). Recalling earlier experiences of observers with W UMa variables the question arose, whether it would not be worthwhile to test some southern W UMa variables by means of a good instrument under the clear Chilean skies.

W UMa Variables

In 1975, Dr. H. Duerbeck and I began to observe some W UMa stars on La Silla. We decided to observe them with an unusual method. Because of the suspected transient characteristics of the light-curves of very close binaries, we decided not to observe our three programme stars, ST Ind, RV Gru and AE Phe, in the usual way, where each star is continuously observed for as long a time as possible to get a complete light-curve within a few nights. We went the opposite way and tried to distribute the observations of all programme stars as uniformly as possible over the whole allotted observing period of about two months, with the aim of obtaining in this way true *mean* light-curves and also accurate *deviations* of the individual observations from these curves. Indeed all three observed variables showed systematic, time-dependent deviations. They were present in the case of RV Gru and AE Phe in a very clear manner and indicated a periodic behaviour. Thus the results of 1975 strengthened our suspicions about the transient characteristics of W UMa light-curves.

In the astronomical literature some large variations of W UMa light-curves have been reported, among them the very interesting case of AH Vir (Binnendijk, *Astr. Journ.* **60,** 372 (1965)). This variable was found in 1957 to exhibit a light-curve for which three-quarters of the phases were several hundredths of a magnitude lower than that in 1955; and one-quarter, a descending branch, did not change. Almost exactly the same was observed in 1976 with AE Phe, as compared to 1975. Additionally, during the 1976 observations the gradual return to a light-curve very similar to that of 1975 could be followed. It is difficult to believe that the repetition of such a peculiar variation of the light-curve, as observed first in AH Vir and now in AE Phe, should not be caused by a typical property of the close binary model. But to answer the question what really happens within these systems, many more observations, photometric as well as spectrographic, are needed.

What Does the Helium Abundance in Young Stars Tell Us About the Universe?

Dr. Poul Erik Nissen from the Astronomical Institute of the Århus University in Denmark has recently used the ESO 1-metre telescope to investigate the very early moments of the Universe just after the "Big Bang"! Many people may wonder how a comparatively small telescope can penetrate into the area of astronomy that is normally reserved for the largest telescopes. The surprising answer is given by Dr. Nissen in the following introduction to the theoretical and practical aspects of his programme:

According to current cosmological theories the Universe has expanded from a hot dense state—the so-called "Big Bang Primeval Fireball". The isotropic microwave background radiation can be explained as emitted from this Fireball and cooled down to a temperature of 3 degrees Kelvin due to the expansion of the Universe. Furthermore the model of the Fireball predicts that the ratio between the number of helium and hydrogen atoms in the Universe should be in the range from 0.07 to 0.10, which agrees well with the ratio of 0.10 observed for interstellar gas and young stars. However, most of the accurate helium abundance determinations refer to gas and stars that are rather close to the Sun. It is therefore of great interest to extend helium abundance determinations to more distant objects in order to see whether a helium-to-hydrogen ratio of 0.10 is really universal.

The Echelle Spectrophotometer

The helium abundance of O and B stars can be determined from equivalent widths of helium absorption lines. Normally equivalent widths are measured on photographic spectrograms of stars, but this method is cumbersome and limited to the brightest stars. In order to observe the strength of helium lines for rather faint stars I have therefore developed a photoelectric method that is based on the use of the echelle spectrophotometer shown on Fig. 1. In this instrument a spectrum is formed by an echelle grating on a rotatable wheel with different exit slots. The light passing one of the slots is imaged on a photocathode and the intensity measured by pulse-counting techniques. Thus the intensity ratio of nearby spectral bands can be observed just by turning the wheel forth and back. Quite narrow