INTERACTING BINARIES: AN EXCELLENT PROJECT FOR SMALL TELESCOPES

Mirek J. Plavec
Department of Astronomy
University of California at Los Angeles
Los Angeles, CA 90024
U.S.A.

ABSTRACT. Discussed are meritorious projects for small and moderate telescopes in the field of interacting binaries with non-degenerate component stars. These interacting binaries are undergoing a mass transfer process, as a consequence of which the mass-accreting star may be partly or completely hidden in an accretion disk, and the system may be shrouded in dense clouds of circumstellar matter. This makes the observation, interpretation and modeling difficult; but it is important to study these "bizarre" binaries since they tell us a lot about stellar evolution in binary systems. Needed are various observations: Timing of eclipses; observation and re-observation of light curves in several colors (in uvby rather than in UBV; and in the red and infrared); radial velocity studies; spectrophotometry of crucial regions of the spectrum. As examples for these needs, the following systems are discussed in some detail, and their problems revealed: RX Cassiopeiae, W Serpentis, and W Crucis as examples of the strongly interacting systems (W Serpentids); υ Sagittarii as a helium-rich binary in a rare evolutionary stage, which will be better understood if we decide whether the star eclipses or not; and KX Andromedae as a representative of non-eclipsing interacting binaries and of Be and shell stars, which may or may not be binaries.

1. INTRODUCTION

My favorite celestial body is the Moon. Not that I care much about it; already in my amateur years, I somehow felt that everything within about 20 parsecs would sooner or later become geology rather than astronomy. No; I love the Moon because when it shines, the sky background is so bright that extragalactic astronomers must leave the big telescopes to stellar astrophysicists. We occasionally hear that everything about stars has already been discovered and they are no longer interesting; yet the Moon has the last word, and is therefore the stellar astrophysicist's best friend. Recently, however, we seem to have found another powerful ally: all the smart instrumentalists who have developed the Reticons and CCD's and all the other gadgets to such a perfection that even with rather small telescopes, one can nowadays perform photometric and spectrographic studies on quite faint objects. This is why I believe that this Symposium is extremely important. I have come here to lobby

J. B. Hearnshaw and P. L. Cottrell (eds.), Instrumentation and Research Programmes for Small Telescopes, 173–186.

among the users of small and moderate-size telescopes to point them to interacting binary stars. Occasional as well as regular photometric observations in several colors, spectrophotometric studies and radial velocity measurements are highly desirable. For the photometric work, the most sophisticated gadgets are not needed; a good photoelectric photometer will do a splendid job, too, and today such a photometer is not rare even among amateur observers.

2. MEET THE INTERACTING BINARIES

Interacting binaries are those binary systems which transfer mass between the components on such a large scale that the structure and future evolution of both stars are significantly altered compared to single stars. Astronomically speaking, mass transfer proceeds on a relatively short time scale. Thus when you observe interacting binaries, you are more directly in touch with stellar evolution than in many other observations. Naturally a supernova explosion beats everything else, but if you had been waiting for a bright galactic supernova on every night since 1604, you would still be waiting. Betelgeuse and Antares may blow up pretty soon now, but "now" means anything between tonight and about 100,000 years hence.

The interacting binary stars come in two varieties, a violent and a non-violent one. The violent kind, the cataclysmics, includes novae and dwarf novae, certainly attractive because of their outbursts. However, these outbursts may be mere showmanship, just showing off, and no real stuff. Holland Ford (1978) argued that a classical nova can undergo as many as 10,000 outbursts and still remain the same white degenerate dwarf reacting irritably to a slow inflow of cool hydrogen from a red dwarf. I am pleading here for the non-violent type of interacting binaries, in which both components are non-degenerate stars. A very crude but very nice model of such an interacting binary is in Fig. 1. The component that was initially more massive has evolved faster and eventually filled all its available volume (the critical Roche lobe). It then has the shape of a droplet. Fig. 1 is not too suitable to show its shape, so please look at Fig. 2 which represents a model I do not dare to call nicer, but it is hopefully closer to reality and in any case mathematically more tractable. The conical point of the "droplet", called the First Lagrangian Point, plays the same role as a hole in the inner tube of a bicycle tire: gas pressure from inside pushes gas molecules through this orifice into a stream towards the other component. Depending on the relative size of that "gainer" with respect to system dimensions, the stream either impinges on the gainer or forms an accretion disk around it. Although most of the gas will spiral inward and eventually fall on the gainer, conditions in both cases are sufficiently chaotic so that circumstellar matter surrounds the stars and may become so dense that it will contaminate the spectra, the flux from the system, and even obscure the stars. Certainly much depends on the available volume and on the rate of mass transfer. Every eclipsing binary with an eclipse deeper than 0.75 mag is an interacting binary, for only binary star evolution with mass transfer produces a loser which is cooler and less massive but larger than the gainer. A large majority of eclipsing binaries with deep

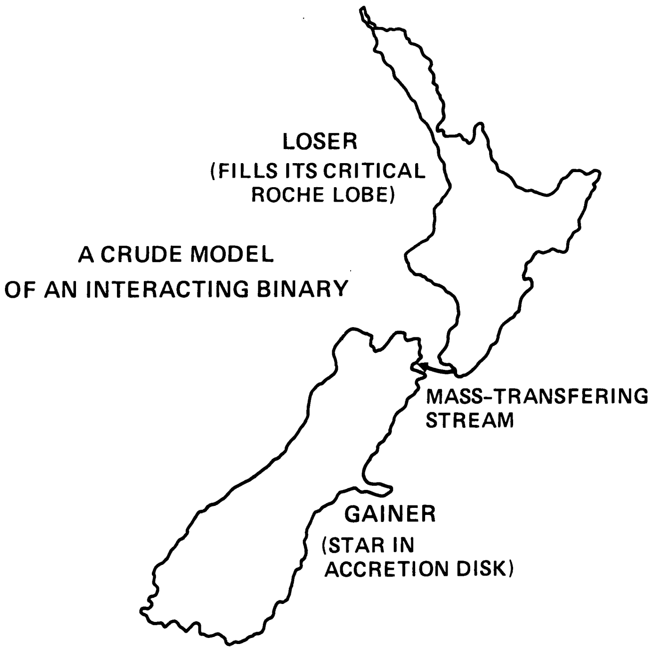

Fig. 1. - An extremely crude but nice model of an interacting binary.

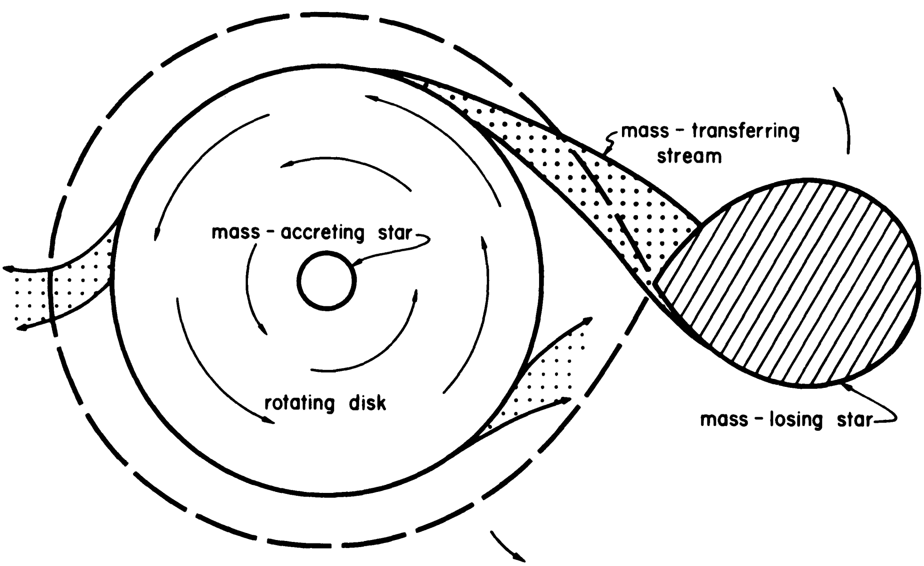

Fig. 2. - A (hopefully) more realistic model of an interacting binary. (after S. Kříž and P. Harmanec).

https://doi.org/10.1017/S0074180900151319 Published online by Cambridge University Press

eclipses are Algols, a well-behaving variety near the end of the mass-transfer stage, in which the mass transfer rate is so small that it is easy to see the stars but difficult to detect the circumstellar matter. Only an emission at Hα and distortions of absorption line profiles may indicate that the system is not perfectly clean. So why try hard to see the circumsttelar matter in Algols? The weak structures and processes we observe in them offer clues to the much rarer and much more difficult cases of a high mass transfer rate.
The circumstellar matter in Algols is best observed if and when the hotter component (the gainer) is totally eclipsed. Fig. 3 shows that at that time, the out-of-eclipse spectrum, dominated by the hotter component (of spectral type B7 in this system) is replaced by a K0 III spectrum of the loser. But note that there exists excess radiation at and shortward of the Balmer limit at 3650 Å, due to optically thin radiation of circumstellar hydrogen. More exciting is the ultraviolet spectrum shown (for U Cephei) in Fig. 4, and obtained with the International Ultraviolet Explorer satellite (IUE). We note emission lines of C IV, Si IV, N V, and similar species, quite conspicuous in totality but invisible outside it because of the strong flux from the accreting star.

3. AN IMPORTANT TASK: TIMING THE ECLIPSES

And here is where the need for cooperation with photometrists enters. The IUE observations in totality must be extremely well timed. What happens when they are not, shows the ultraviolet spectrum of RW Tauri in Fig. 5. Here I was late by only about 15 minutes. The strongest emission lines remain just barely visible against the quickly increasing flux from the hotter, B8 star, just emerging from behind the K0 III subgiant. The entire totality in RW Tauri lasts about 80 minutes, but 60 minutes are needed for a good exposure. Thus very accurate timing is needed, but the interacting binaries do not keep constant periods. This is natural, since mass and angular momentum are on the move in them. The change, expressed as dP/P, is usually quite small, but its effects accumulate in such a way that eventually the difference O - C, i.e. observed minus calculated time of eclipse, may become quite large.
A good example is RX Cassiopeiae, an eclipsing binary with a period of 32.3 days. For years, Martynov of Moscow exhorted observers world-wide to watch this rather bizarre system. At the end of his article published in 1975 (Martynov 1975), he remarked to the effect that his older linear ephemeris, based on scattered observations during the first half of the century, was still good. In fact, by that time, the (O-C) deviations were already growing rapidly, as Fig. 6 shows, and by now, the delay with respect to the original ephemeris is already more than four full days.
Now please realize the plight of an IUE observer who wants to study the eclipse spectrum of RX Cas. The competition for observing time is tremendous, and if he is lucky, he will be allocated three 8-hours shifts per year. He must apply for a specific shift several months in advance. The fact about the large (O-C) deviation in RX Cas would be unknown were it not for one or two photometrists. So our IUE observer would obtain an ordinary out-of-eclipse spectrum and the star would laugh behind his back and gracefully go into eclipse four days later.

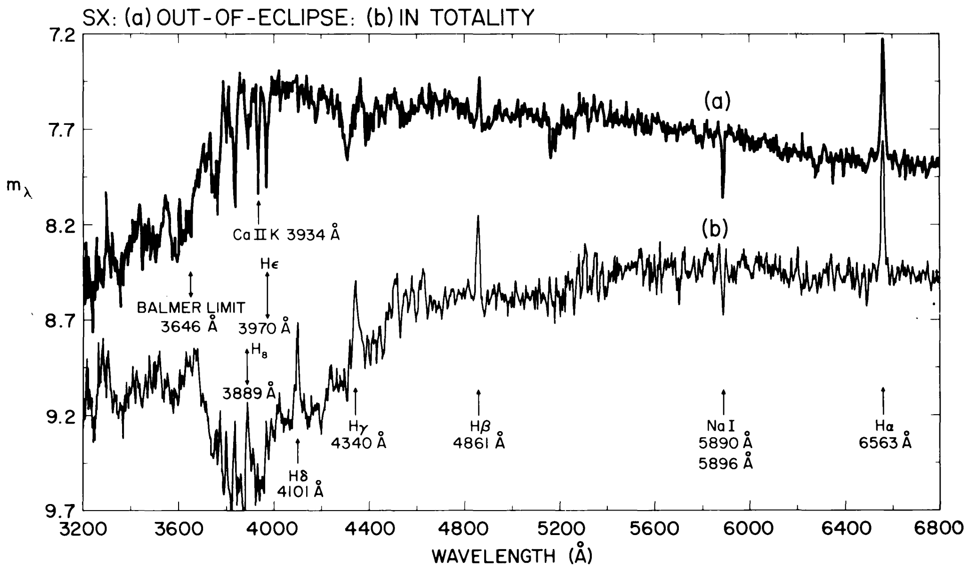

Fig. 3. - Optical spectrum of SX Cassiopeiae, outside eclipse and in total eclipse. Observations with ITS scanner, Lick Obs.

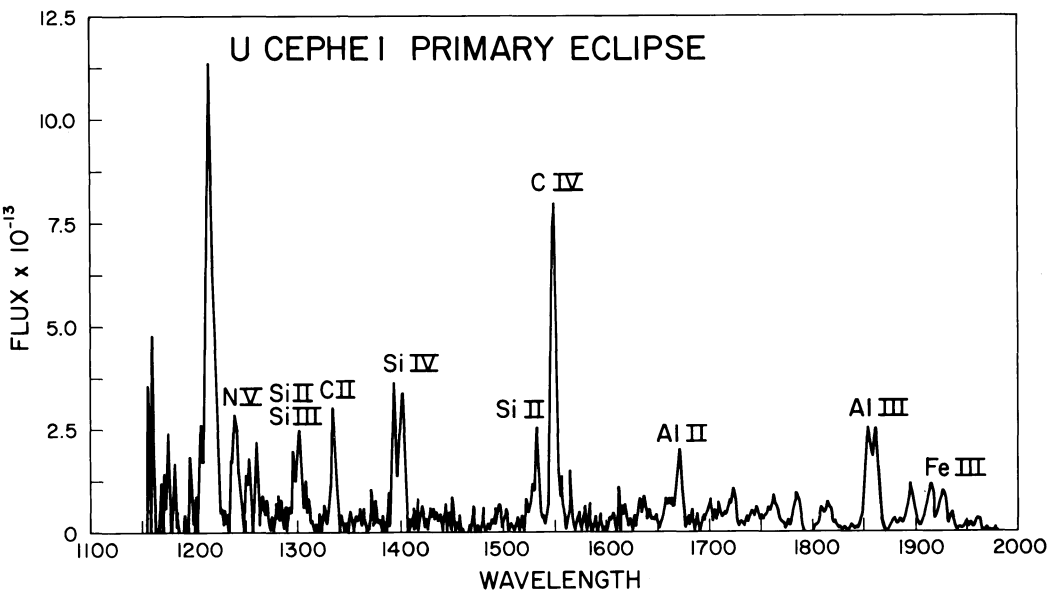

Fig. 4. - Ultraviolet (IUE) spectrum of U Cephei in total eclipse.

https://doi.org/10.1017/S0074180900151319 Published online by Cambridge University Press

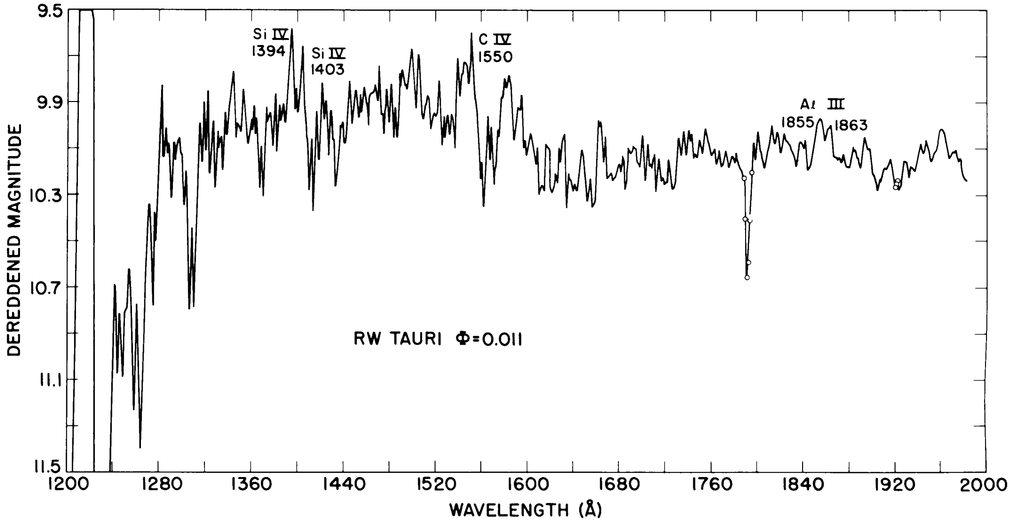

Fig. 5. - Ultraviolet spectrum of RW Tauri, observed at end of totality.

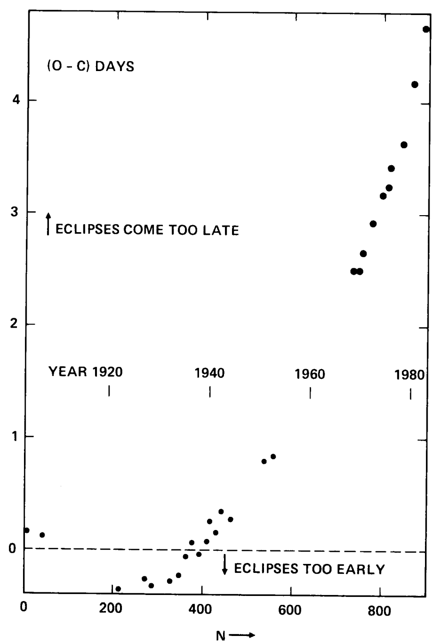

Fig. 6. - RX Cassiopeiae: Deviations of eclipse times from linear formula.

https://doi.org/10.1017/S0074180900151319 Published online by Cambridge University Press

I had exactly this worry recently with W Crucis, whose period is 198.5 days. A very brief total eclipse is suspected, probably no longer than one day. But with so long a period, a very small fractional change dP/P may shift the eclipse easily by several days with respect to an ephemeris derived thirty years ago. Thus I appealed to southern observers for help (Plavec 1984); and it indeed worked: Messrs. Marino and Walker from Auckland, New Zealand, and several South African observers determined the time of eclipse and enabled me to time my IUE observations correctly. The period changes in eclipsing binaries do have a positive aspect, since they are telling us something about the process of mass transfer. For a process conserving mass and orbital angular momentum of the system, the formula for the period change reads:

$$dP/dt = 3\ P\ (dM_l/dt)\ (M_l - M_g)\ /\ (M_l \times M_g) \qquad (1)$$

Here M_l and M_g are the masses of the loser and gainer, respectively. We see that if the period is increasing, this means that gas is flowing from the less massive star to the more massive one. From a parabolic fit to the deviations in Fig. 6, we conclude that the rate of mass transfer in RX Cas is somewhere between 10^{-5} and 10^{-7} solar masses per year. This figure is both large and very uncertain, and the two aspects of it are closely related. The system of RX Cas is so "clouded over" by circumstellar material that it is nearly impossible to get a clear picture about the masses and spectral types of the components. RX Cas is not a classical Algol; it is one of the strongly interacting systems which I called the W Serpentis stars (Plavec 1980). In these binaries, the circumstellar material plays a dominant role in the photometric and spectroscopic appearance of the system. Since this implies a higher rate of mass transfer, the W Serpentis stars promise to tell us more about it, but their messages are so garbled that deciphering requires very concentrated effort. Here comes the need for complete light curves.

4. LIGHT CURVES NEEDED, IN PARTICULAR FOR THE MORE BIZARRE SYSTEMS

No eclipsing binary displays an ideally simple light curve; there is always some light fluctuation, although often only at about the level of observational errors. But the light curve of RX Cas shows an enormous scatter, which is shown half-schematically in Fig. 7, based on a selection of the observations accumulated by Kalv (1979). The Figure conveys the impression strongly advocated by Kalv, namely that the system undergoes another periodic variation on a time scale of about 516 days, during which it gradually shifts its out-of-eclipse light level from "MAX" to "MIN", in Kalv's terminology. More recent photoelectric observations by the German amateur astronomer Mario Fernandes (1985) cast some doubt on the strict periodicity of this long wave, but not on its existence.

The shape of the light curve of RX Cas indicates that both the loser and the gainer are non-spherical objects. The large light fluctuations cease during the short total primary eclipse, so that their source is associated with the gainer, which is eclipsed at that time. We have concluded (Weiland and Plavec 1986) that the gainer is a star surrounded

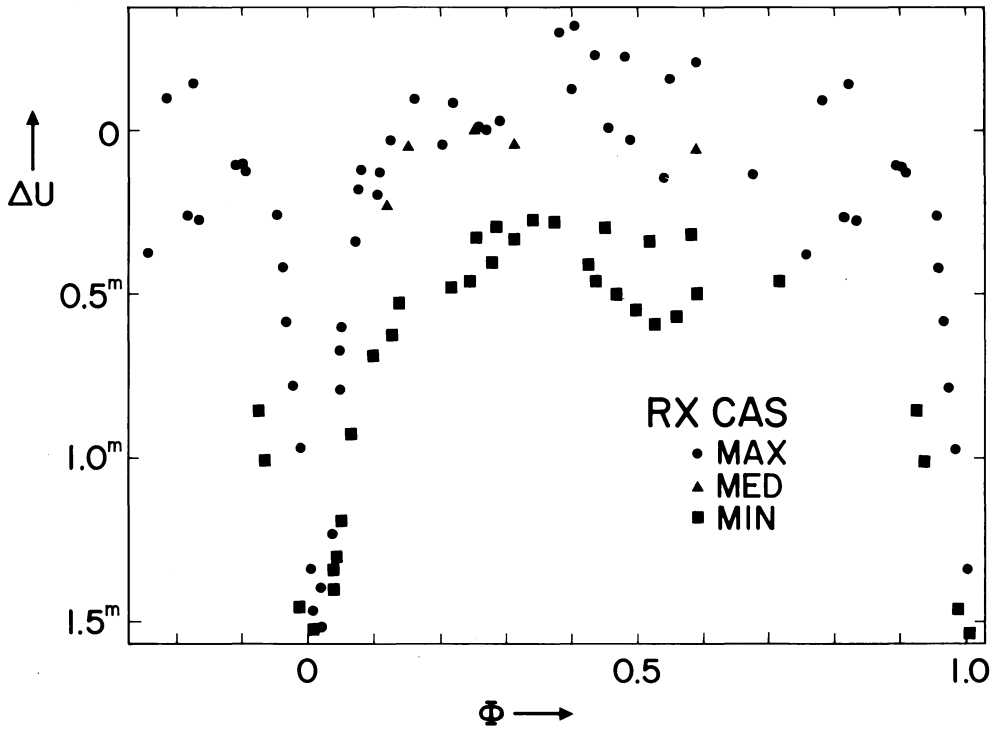

Fig. 7. - Light curve of RX Cassiopeiae after Kalv (1979).

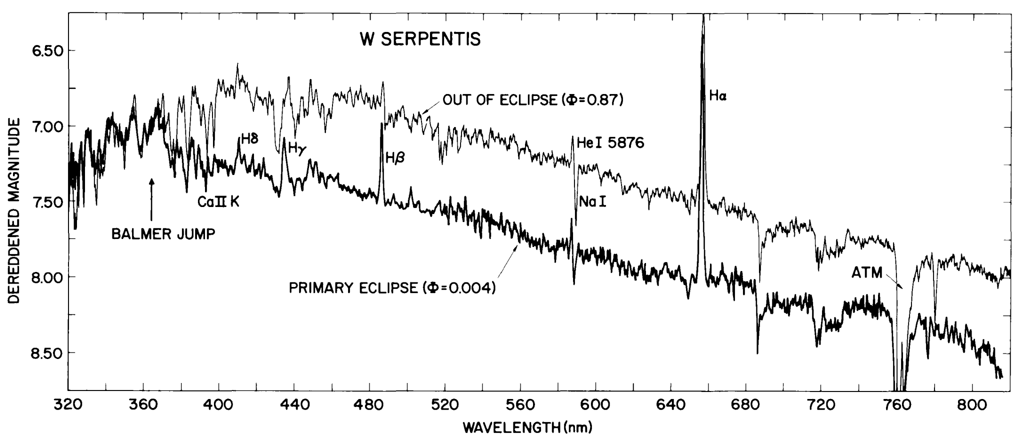

Fig. 8. - Optical spectrum of W Serpentis in eclipse and outside eclipse.

by a thick accretion disk. The disk varies in size, and is largest but coolest at the "MIN" stage, when it is about equal in radius and in surface temperature to the loser, which is a K1 III giant. At the "MAX" stage, the disk shines like an F8 - G2 star. Thus we have two cool objects in RX Cas, and UV observations will not tell us much about them. Visual and infrared photometry is needed, first to cover the light curve well and then to follow its changes. One day the circumstellar clouds may clear up a little and perhaps grant us a look at the accreting star.

5. PLEASE SEARCH FOR THE COMPANION IN W SERPENTIS!

Poorly visible even from California is the prototype of the strongly interacting binaries, W Serpentis. At a declination of -15°, this eclipsing binary with 14.16 days period is waiting for a dedicated southern observer. Its light curve is at least as badly distorted as that of RX Cas. The secondary eclipse, which is variable, distorted, and unusually broad but present in RX Cas, is missing in the light curve of W Serpentis. Yet the star is a binary system, and the star causing the primary eclipse is unlikely to be completely non-luminous, and must be quite large. So what is it?

The trouble is that we are not even sure about the nature of the visible star. Its many strong, sharp absorption lines suggest a spectral class of F5 II. However, Hack (1963) suggested that this spectrum probably originates in a circumstellar shell, less dense and cooler than the photosphere of the underlying star. From the appearance of the Mg II line at 4481 Å, it appears that the star may be an early A type. My own observations, if anything, tend to compound the puzzle. The flux in the optical region, studied with the IDS scanner at the 3-m Shane telescope of Lick Observatory, seems to confirm the F5 classification. But I know, from our work on SX Cas (Plavec, Weiland and Koch 1982) that flux contribution from the secondary component and from circumstellar matter may change the slope of the Paschen continuum seriously and cause it to simulate a rather different temperature. Moreover, as my IUE observations show, the flux continues to rise across the Balmer jump and reaches levels and shape in the far ultraviolet reminiscent of about a B7 star. So one could imagine a B7 star surrounded by a cooler disk in such a way that only a part of the star's surface is visible. Or we can envisage another model in which the star is completely invisible and the ultraviolet flux comes from the transition region between the star and its accretion disk. The theory of this transition layer (Pringle 1977), applied to a non-degenerate star (Plavec 1980) makes this model viable. Janet Weiland thinks that the UV continuum is a "warm spot" on a disk. During the primary eclipse, the far ultraviolet fluxes almost do not change; in fact, as Fig. 8 shows, the eclipse is perceptible only just longward of the Balmer jump. This seems to indicate that the eclipsed star (or disk) may indeed be F5 or something not much earlier in spectral type, and that the "warmer" radiation in the ultraviolet comes from an extended circumstellar source.

Even more puzzling is the other star in the system. I believe that some of its absorption lines may be observable in the red and infrared spectral regions, either at all phases or at least at primary eclipse, when the light from the primary star is dimmed by about one magnitude.

6. W CRUCIS -- ANOTHER CHALLENGE: SEARCH FOR THE SECONDARY STAR!

If W Serpentis is a challenge mainly to the southerners, W Crucis is of course entirely within their domain. Very few facts are known for sure about this eclipsing binary with a long period (198.5 days) (Woolf 1961): The only visible spectrum looks like a G1 supergiant, except for some circumstellar Balmer line components and Hα in emission. Its radial velocity curve appears reasonably reliable, but leads to a terrible dilemma. If the two component stars are equally massive, then each has a mass of about 24 $M_{\odot}$. This is perhaps acceptable for a supergiant, but where is the other supergiant? It leaves no trace in the spectrum. If we assume that it is less massive than the observed star, both masses become unacceptably large: for a mass ratio of 1:2, they would be 55 $M_{\odot}$ for the unknown star and 110 $M_{\odot}$ for the observed supergiant! Clearly, if we want to stay within the realm of common sense, we must assume that the star we do not see is more massive than the one we do see. For example, should the mysterious ghost be twice as massive, then the mass of the visible supergiant would be only 7 $M_{\odot}$, but then we must ask: Where is the light from the star with 14 $M_{\odot}$?
This situation is not quite unheard of, and in β Lyrae we are almost sure that the "invisible" star is more massive than the B8 II giant which dominates the optical spectrum. But in β Lyrae, the companion is not really invisible, only we are unable to detect its spectral lines. It does generate measurable continuous flux in the optical region, and in the IUE ultraviolet, its flux is equal to that of the B8 II star. The companion is a flattened, optically thick disk. It is natural to make the same assumption about W Crucis. But there is no trace of the companion in the ultraviolet: I have found only radiation from a huge, rarefied circumstellar plasma at a surprisingly high electron temperature, near 100,000 °K. The companion of W Crucis is not entirely invisible, since its eclipse seems to cause a measurable minimum in the light curve (unless the minimum is due only to the ellipticity of the G1 supergiant). Perhaps farther in the red and infrared, its signature will be better legible. The system calls for a good photoelectric light curve and a thoughtful solution for elements. A thorough examination of the optical spectrum with a high signal-to-noise ratio is also desirable.

7. THE NEED FOR LIGHT CURVES IN SEVERAL COLORS

It is rather obvious that a reliable determination of the nature of the component stars in many binaries prerequires good photoelectric light curves in more than one color. I would like to point out that the UBV system is not the best system for this purpose, because of the frequent presence of radiation from a circumstellar hydrogen shell or cloud. The U filter of the UBV system is sensitive in the spectral range of about 3,100 - 4,100 Å, with its peak sensitivity going right across the Balmer jump. This is an outright disaster for studies of interacting binaries, in which an optically thin hydrogen cloud may contribute strong

but often very variable continuous flux shortward of the Balmer jump, but a much weaker flux longward. Many light curves in the U color are practically useless for determining the stellar characteristics and dimensions, but then we are left only with the (B-V) color index, which is often insufficient.
The Strömgren four-color photometry is much better, since the u and v filters peak at opposite sides of the Balmer jump.

8. UPSILON SAGITTARII: DOES IT ECLIPSE OR NOT?

The Roche lobe overflow can carry away so much mass from the loser that exposed now may be the layers that originally were deep inside the star and underwent CNO processing during which carbon was mostly converted into nitrogen, and helium has become four times more abundant than hydrogen (Lambert 1982, Plavec 1986). This helium abundance, however, is nothing compared to what we see in two peculiar binaries, υ Sagittarii and KS Persei, in whose atmospheres there may be some 10,000 atoms of helium per one atom of hydrogen (Drilling and Schönberner 1982). This extreme He/H ratio can be explained by a complicated evolution with two separate stages of mass loss from the same star, but this type of evolution can occur only for stars within a fairly narrowly defined initial, intermediate, and present masses (Plavec 1973; Schönberner and Drilling 1983; Plavec 1986). Therefore, a good determination of the component masses is important for verifying the model.
υ Sagittarii has a good radial velocity curve for the star that dominates the optical spectrum, and there is hope that the other radial velocity curve can be obtained from far ultraviolet observations of the companion. But a really good mass determination also requires the knowledge of orbital inclination. In the past, shallow eclipses were reported (Eggen, Kron and Greenstein 1950), but they are unconfirmed by other observers. If they do occur, the inclination will be much better known. It takes a very skilled photometrist and a very good climate to detect eclipses or light fluctuations of less than 0.1 mag. It is also possible that the eclipse depths will be greater at other wavelengths.

9. THE NEED FOR IMPROVED RADIAL VELOCITY CURVES

Radial velocity curves remain our most important way of determining the masses and absolute dimensions of the component stars, without which it is impossible to model the interacting systems and compare the observations with theoretical calculations. It was in fact the work of Otto Struve and his collaborators in the 1940's that led to the discovery of interacting binaries. But that pioneering work was done on spectrograms whose dispersion and quality are far below those required for reliable mass determination (Popper 1980). Since the masses vary with the third power of the radial velocity range, tremendous errors may be incurred if old crude data are still used today.
RX Cassiopeiae may serve as a case in point. Struve (1944) classified the component stars as gG3 + gA5e and gave their radial velocity ranges as 34 km s^{-1} and 36 km s^{-1}, respectively. Combined with P = 32.3 days,

this gives us a system of two dwarf stars, 0.59 M_o and 0.56 M_o, separated by only 5 R_o, and crawling around the center of gravity of this minuscule system once in a month. This led to various speculations about collapsed objects in the system, but in fact the dispersion used by Struve failed to reveal serious blending, the spectral types are actually different (Weiland and Plavec 1986), and both velocity ranges must be rejected. A new value for the loser, obtained by Johannes Andersen with CORAVEL, is 97.7 km s^{-1}; although correct masses are still not available, all reasonable values of mass ratio lead to entirely normal masses. I hope that this example shows that in many important interacting binaries, new radial velocity curves are badly needed.

10. KX ANDROMEDAE: A CASE FOR OBSERVING Be AND SHELL STARS

A large majority of interacting binaries are not seen as eclipsing from the Earth. Some of them may be known as Be stars or shell stars (Kříž and Harmanec 1975). They gave KX Andromedae (HD 218393) as a good example, since its radial velocities show an almost-periodic variation with a period of 38.9 days. And, indeed, the secondary component was subsequently discovered in the near infrared (Polidan 1976) and tentatively classified as a K1 III star. This is the loser in this interacting system.
The gainer presents a more complicated problem and may indeed be a complicated object. From its absorption lines and Balmer jump, the star has been variously classified as everything between A5 and B0. This is no small difference, since often we must estimate masses on the basis of the spectral types of the stars, but in this case the possible range is between 2 and 20 solar masses! An extension of the spectral coverage into the ultraviolet did not bring any definite answer either. In 1978, I obtained the first IUE spectra which bear close resemblance to the strongly interacting star SX Cas: A strong ultraviolet continuum suggests a star of about 11,000 K, while the Paschen continuum indicates only about 9,000 K (Plavec 1979; Goraya, Singh, and Chaubey 1984). It could be an optically thick disk as in β Lyrae. Or it could be a B star partly obscured by a shell. Our optical scanner observations show that the transparency of the shell in the continuum is quite variable: so, one day we may see the accreting star almost without a veil. But there is another approach possible and promising: To examine the He I absorption lines with an apparatus yielding high signal-to-noise ratio, and derive the spectral type from the line profiles of He I 4471 Å etc.
KX Andromedae is by no means a unique case. Many Be stars show light and spectrum variations which may help decide if they are interacting binaries or if some other model (stellar wind? non-radial oscillations?) applies. An international campaign is currently being conducted (see Harmanec, Horn, and Koubsky 1982; Barker 1982).

11. CONCLUSION: MT. EVEREST, HURRICANES, AND INTERACTING BINARIES

I have attempted to present suggestions as to what could be studied in interacting binaries, using small and moderate telescopes. I discussed

https://doi.org/10.1017/S0074180900151319 Published online by Cambridge University Press

individual cases. They have one thing in common: All of them are rather bizarre systems, difficult to understand. The question may be asked: Why study extreme cases when there are many well-behaving systems? I am all in favor of observing simple systems for the sake of determining fundamental characteristics of stars. However, the complicated cases should not be ignored. One reason is the classical Mt. Everest argument: We must study them because they are there. I would like to present a more powerful argument: It may be comfortable for the meteorologists to study only gentle sea breezes; but one probably learns much more about the dynamics of atmospheric circulation if one tries hard to understand tornadoes and hurricanes.

And one last opinion: I hope that it transpires from all the cases that the proper way to success is cooperation -- between photometrists, spectroscopists, and theoreticians; between optical and infrared and ultraviolet people; between the northern and southern hemispheres, and so on.

REFERENCES

Barker, P.K. 1982, in Be Stars, ed. M. Jaschek and H.-G. Groth, (Dordrecht: Reidel), 269.

Drilling, J.S. and Schönberner, D.: 1982, Astr. Ap. 113, L22.

Eggen, O.J., Kron, G.E., and Greenstein, J.L.: 1950, P. A. S. P. 62, 171

Fernandes, M. 1985, BAV Rundbrief 34, 49.

Ford, H.C. 1978, Ap. J. 219, 595.

Goraya, P.S., Singh M., and Chaubey, U.S. 1984, Inf. Bull. Var. St. 2519.

Hack, M. 1963, Mem. Soc. Astr. Ital. 34, 3.

Harmanec, P., Horn, J. and Koubsky, P. 1982, in Be Stars (see above), 275

Kalv, P. 1979, Tartu Astr. Obs. Teated 60, 3.

Kříž, S. and Harmanec, P. 1975, Bull. Astr. Czech. 26, 65.

Lambert, D. L. 1982, in Advances in UV Astronomy, NASA Conf. P. 2238, 114

Martynov, D. Ya. 1975, Astr. Circ. USSR 891, 4.

Plavec, M.J.: 1973, in Extended Atmospheres etc., ed. A. H. Batten, (Dordrecht: Reidel) 216.

Plavec, M.J. 1979, Bull. Amer. Astron. Soc. 11, 648.

Plavec, M.J.: 1980, in Close Binary Stars: Observation and Interpretation ed. M.J. Plavec, D.M. Popper, and R.K. Ulrich (Dordrecht: Reidel), 251

Plavec, M.J. 1984, Inf. Bull. Var. Stars 2524.

Plavec, M.J., Weiland, J.L., and Koch, R.H. 1982, Ap. J. 256, 206.

Plavec, M.J. 1986, IAU Coll. 87 on Hydrogen Deficient Stars etc.

Polidan, R.S. 1976, in Be and Shell Stars, ed. A. Slettebak (Dordrecht: Reidel), 401.

Popper, D.M. 1980, Ann. Rev. Astr. Aph. 18, 115.

Pringle, J.E. 1977, Mon. Not. R.A.S. 178, 195.

Schönberner, D. and Drilling, J.S.: 1983, Ap. J. 268, 225.

Struve, O. 1944, Ap. J. 99, 295.

Weiland, J.L. and Plavec, M.J. 1986, submitted for publication.

Woolf, N.J. 1961, Mon. Not. R.A.S. 123, 399.

DISCUSSION

Warner: I agree with your attack on cataclysmic variables. If you want to observe white dwarfs the worst place to look is in a cataclysmic variable since it is immersed in the accretion disk. The real reason to look at cataclysmics is to investigate the disks.

Plavec: I agree with Dr Warner that the cataclysmics are very important for studying the properties of accretion disks. But the results about the α-disks in the cataclysmics cannot be transferred to non-degenerate systems. As I showed for U Cephei (Ap. J. 1983), the latter systems have geometrically much thicker circumstellar structures. I think we should agree that all types of interacting binaries should be ardently observed.