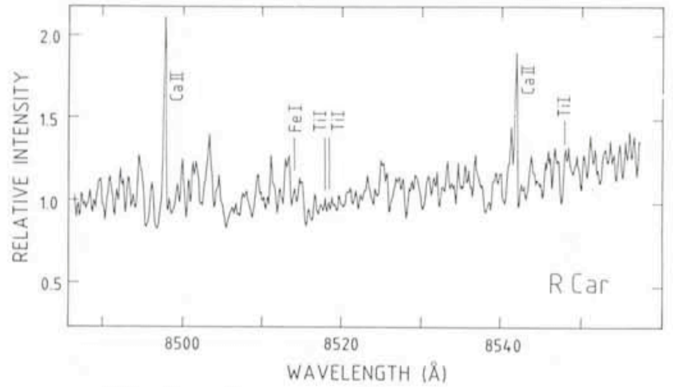

Fig. 3: *Approximately the same wavelength range, resolution (85 mÅ) and signal-to-noise ratio (~ 200) as in Fig. 2 but for a typical Mira star (R Car) also near the luminosity maximum. Here, the molecular blends do not permit observation of the intrinsic line profiles.*

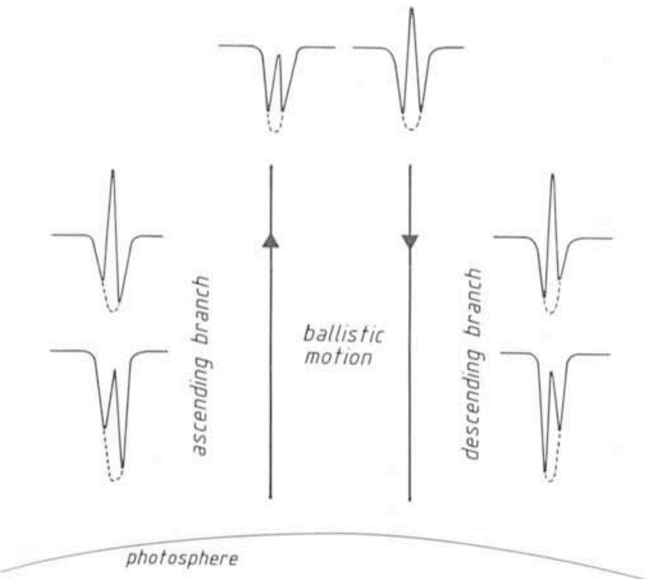

Fig. 4: *Schematic diagram showing the different types of profile expected to form during a ballistic motion close to the photoshere. Apparently like double absorption or P-Cygni types, these profiles are in fact made of an emission superposed on an underlying broad photospheric absorption (see text).*

matter reaches its maximum altitude, the emission is centred on the photospheric absorption and the two absorption components are equal. During the descending branch, one gets the symmetrical profiles to those of the ascending branch (Fig. 4).

A complete study of this line doubling phenomenon observed in S Car can be found in GMBF. Further high resolution, high signal-to-noise observations of other Mira stars are needed before generalizing our interpretation. It is not even yet established if all double absorption lines (like molecular ones) observable in S Car can be explained by the same mechanism.

Conclusion

Optical high resolution, high signal-to-noise ratio spectroscopy is well suited to tackle the atmospheric dynamical state of Mira stars. More generally, significant progress concerning our knowledge of all pulsating stars can be rapidly reached by using recent resources of line profile analysis.

We have shown here such examples, related to o Ceti and S Car. Their Hα profiles seem to indicate that the shock wave does not stay close to their photospheres. Also, the varying profiles observed in the near-infrared region of S Car seem incompatible with the classical interpretation of the so-called line doubling phenomenon (two-component model).

References

Gillet, D., Maurice, E., Baade, D.: 1983, *Astron. Astrophys.* **128,** 384.
Gillet, D., Maurice, E., Bouchet, P., Ferlet, R.: 1985, *Astron. Astrophys.,* submitted.
Hinkle, K.H., Scharlach, W.W.G., Hall, D.N.: 1984, *Astrophys. J. Suppl.* **56,** 1.
Lund, G., Ferlet, R.: 1984, *The Messenger* **36,** 2.
Joy, A.H.: 1947, *Astrophys. J.* **106,** 288.
Willson, L.A.: 1976, *Astrophys. J.* **205,** 172.
Wing, R.F.: 1980, *Current Problems in Stellar Pulsation Instabilities,* Eds. Fischel, D., Lesh, J.R., Sparks, W.M., p. 533.

W Serpentis Stars—A New Class of Interacting Binaries

W. Strupat, H. Drechsel and J. Rahe, Remeis-Sternwarte, Bamberg

Introduction

In August 1978, Plavec and Koch made the first IUE satellite observations of a group of eclipsing binaries known for their complex photometric and spectroscopic behaviour in the optical range, namely W Serpentis, RX and SX Cassiopeiae, W Crucis, and AR Pavonis.

The UV spectra were very conspicuous, showing a wealth of pronounced emission lines, e.g., resonance lines of relatively high ionization stages like N V, C IV, Si IV, O III, Al III or Fe III as well as intercombination and forbidden lines of, e.g., C III, N IV, and O III, while no absorptions could be detected at all.

The remarkable similarity of the IUE spectra suggested comparable physical conditions at the place of origin of these lines, especially in the circumbinary region, where a large amount of circumbinary matter must exist.

The presence of high ionization lines in both UV and optical ranges is surprising, since neither of the two binary components is apparently hot enough to supply the ionizing photons; except for AR Pav, all objects are of spectral type later than A5. All members of the considered object class have semidetached or contact configurations: in the case of, e.g., W Cru and RX Cas, the Wilson-Devinney approach was used to analyze their photometric light curves; convergence could only be achieved in the contact mode. Some features are similar to those observed in symbiotic stars and RS CVn binaries.

There are several further indications of a possible relationship between these stars, e.g., strongly distorted radial velocity and light curves and orbital period changes; one might conclude that these objects are presently in an active evolutio-

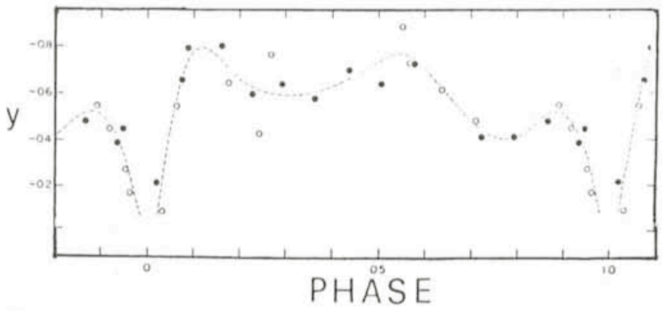

Fig. 1: *y-light curve of W Ser after Lynds (1957); open and filled circles refer to observations in different epochs.*

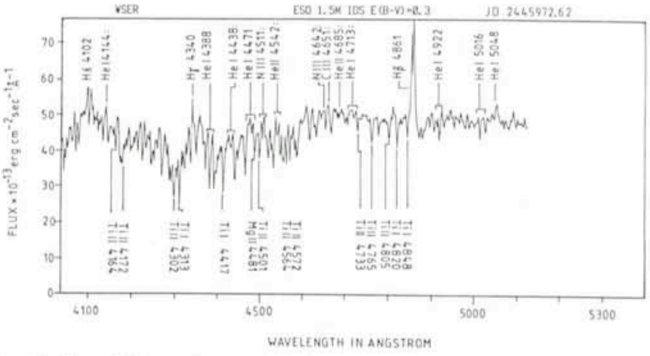

Fig. 3: *Blue IDS spectrum of W Ser, taken at orbital phase Φ = 0.16.*

nary stage, probably in the phase of rapid mass transfer or shortly after the reversal of the mass ratio, when mass loss through the Lagrangian points is expected. This overall similarity of physical properties and interaction processes and the fact that the observed common characteristics cannot fully account for the definition pattern of any subgroup of close binaries led Plavec to "invent" a new class of interacting binary systems, called "W Serpentis objects".

However, in spite of extensive observations, a precise definition of the actual evolutionary stage and of exact parameters of these highly interacting systems has not been possible so far. This was reason enough to establish a still ongoing programme to take a closer look at these objects, incorporating observations from different spectral ranges between the UV and IR regions.

In this article, we describe some results of recent ESO observations of the prototype W Serpentis, obtained by means of simultaneous spectroscopic (ESO 1.52 m telescope + IDS) and photometric (ESO 1 m telescope, UBVRI) measurements performed in September 1984.

Photometry

The light curve of W Serpentis is very unusual for an eclipsing binary: there are three maxima between two successive primary minima, due to appreciable light depression close to quadrature phases (see Fig. 1). Lynds (1957) gives for the elements of heliocentric primary minimum: HJD = $2435629^d.60 + 14^d.15667 \times E$; the period is increasing with the considerable rate of about 15 seconds per year.

The period increase is confirmed by a comparison of our recent photometric measurements with the data of Lynds

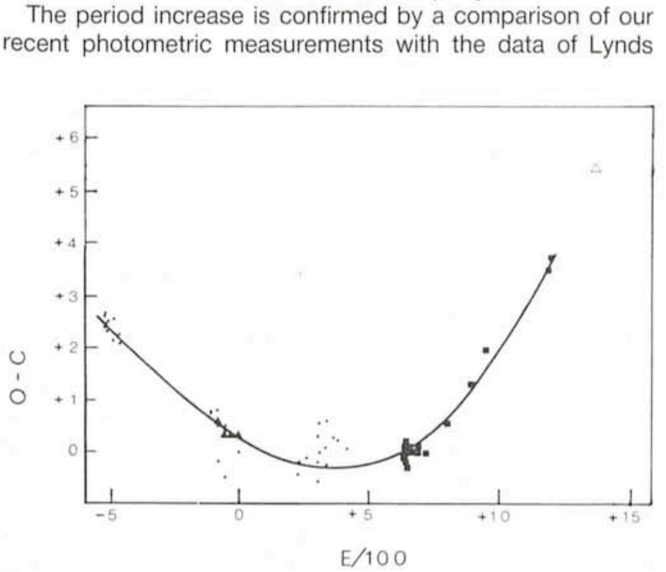

Fig. 2: *(O–C) diagram of W Ser according to Koch and Guinan (1978). (O–C) is given in days; the zero epoch corresponds to JD_o = $2426625^d.493$. The meaning of the symbols is explained in the text.*

yielding a phase difference of $\Delta\Phi$ = 0.445. The resulting (Observed-Computed) value of $5^d.477$ fits well into the (O-C) diagram and is represented by an open triangle in Fig. 2. The least squares cubic polynomial fit of the data as a function of epoch is shown as a smooth line; photoelectric, photographic and visual observations are given as squares, circles and filled triangles, respectively.

Spectrophotometry

UBVRI magnitudes have been converted into absolute fluxes and used in combination with our optical and UV spectra to derive the absolute continuum flux distribution of W Ser (de-reddened with E_{B-V} = 0.30 mag) over a broad range. Close to quadrature phase, the spectrum is reasonably well represented by a blackbody of 6,600 K. During the primary minimum, however, when the secondary should contribute the largest relative fraction to the observed flux, the spectral distribution of the reduced light remains essentially unchanged. As the shape of the light curve indicates that the eclipse is not total, one can conclude that the residual intensity of the optical continuum at primary minimum still arises mainly from the primary component, while the contribution of the secondary is negligible in this spectral region.

The observed flux distribution agrees with spectral classification of the primary as F4III. Since the flux in the UBVRI region is steadily decreasing towards longer wavelengths, we conclude that the secondary must be a very cool object, which agrees with its spectroscopic undetectability in the optical and UV ranges. Assuming central eclipses, the depth of the primary minimum yields a value of about 0.7 for the ratio of radii R_2/R_1 of the two components. With a radius of the F4III primary of $R_1 \sim 5R_\odot$, we obtain $R_2 \sim 3.5\,R_\odot$; with an effective temperature of, say, 3,100 K for an M subgiant, its luminosity amounts to about $1L_\odot$, which is only a few per cent of the luminosity of the primary component, and thus explains that it has so far not been detected spectroscopically.

Spectroscopy

Figs. 3 and 4 show blue and red IDS spectra of W Ser in the range between 4000 and 5200 Å, and between 4500 and 6500 Å, respectively, obtained at orbital phases Φ = 0.16 and Φ = 0.30. The optical spectrum is dominated by strong Hydrogen Balmer, HeI and HeII lines, some of which are identified in the figures.

The profiles of the Balmer lines display broad emission components with superimposed central absorptions. The Hβ profile, as observed at orbital phase Φ = 0.16, is shown in Fig. 5. An especially striking feature is the inverse P Cygni profile of the HeI triplet line at 5876 Å; a similar profile shape is also indicated at Hβ (see Fig. 4).

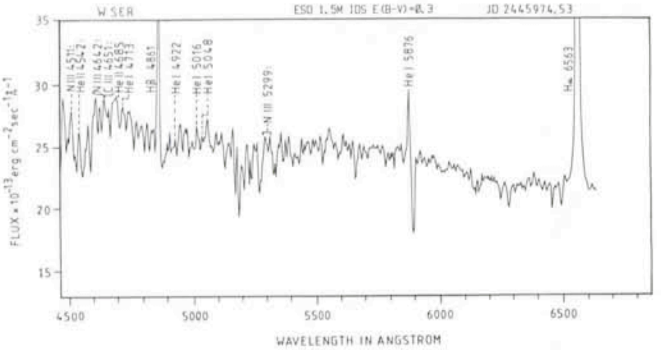

Fig. 4: *Red IDS spectrum taken at orbital phase Φ = 0.30.*

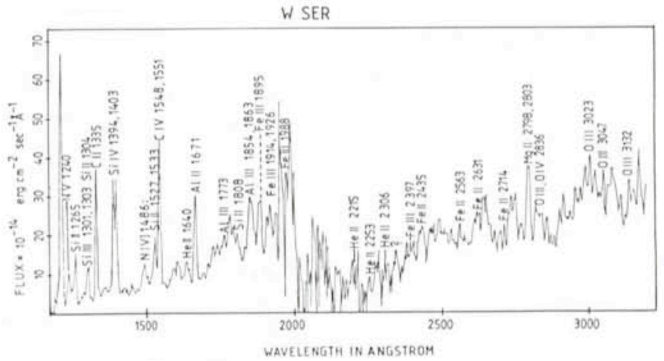

Fig. 6: *IUE spectrum of W Ser (SWP 22414 + LWP 2890) taken at the same orbital phase.*

The central absorption dips are conceivably due to a stream of matter transferred from the cool secondary contact component to the hotter primary; the double-peaked emission may also arise from a gaseous ring around a detached primary. The red-shifted absorption component of the inverse P Cygni profile of He I (5876 Å) in a spectrum taken close to the quadrature phase 0.25 can be explained by the motion of the primary (with a velocity component in the direction of the observer) relative to a nearly stationary circumstellar envelope surrounding the whole binary system.

As a typical example for the W Ser class, the spectral appearance in the UV range of the prototype W Ser is illustrated in Fig. 6. Our combined SWP and LWP IUE spectra show a wealth of strong UV emission lines of partly semi-forbidden intercombination or forbidden transitions, as indicated in the figure.

Evolutionary Stage

Even with a very low effective temperature of $T_2 \sim 3{,}000$ K, the secondary still has approximately solar luminosity, and therefore appears overluminous for its mass, so that we are presumably dealing with an evolved M-type subgiant. This would imply that the system has already passed through the first phase of rapid mass transfer during which the mass ratio was reversed on a thermal Helmholtz-Kelvin time scale, and primary and secondary have interchanged their roles. In the course of this short-lived scenario, the originally more massive primary became an inconspicuous cool star—slightly evolved and probably close to the Hayashi limit—, while the mass gainer first moved up the main sequence and then evolved along the giant branch, where it can presently be observed.

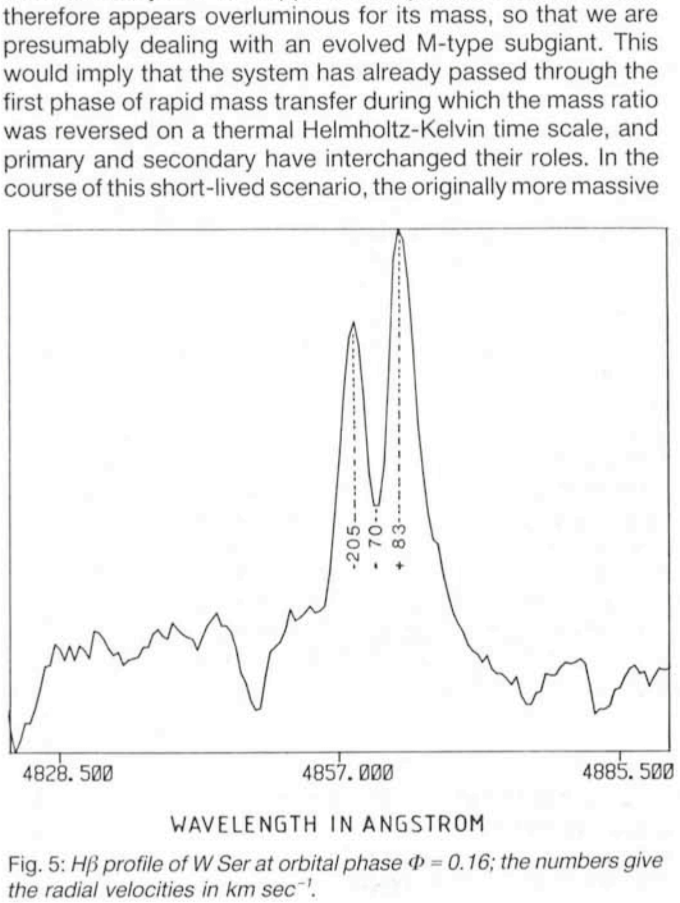

Fig. 5: *Hβ profile of W Ser at orbital phase Φ = 0.16; the numbers give the radial velocities in km sec⁻¹.*

Close binary evolution theory predicts that the previously more massive star is still in contact with its Roche lobe, and continues to transfer matter onto its companion at a rate which has been reduced as a consequence of re-establishment of thermal equilibrium and due to the fact that the evolution time scale of the original primary has now slowed down to a nuclear one.

The observed properties of W Ser are in qualitative agreement with what is expected in such a situation:

– mass transfer in a direction from the less massive to the more massive component can explain the observed increase of the orbital period;

– the continuing mass exchange is further assumed to be non-conservative, particularly in view of the present binary configuration as a near contact system, consisting of two evolved stars which fill their Roche limits;

– gaseous streams will arise and a large amount of circumstellar matter will accumulate around the binary, since the radiation pressure of only slightly evolved intermediate- and late-type stars is not effective enough to be the driving mechanism of a massive wind. Thus, the high ionization level can be explained in terms of accretion shock heating or acoustic wave dissipation in extended chromospheric regions.

It is too early to outline a more sophisticated model of these complex systems, which definitely deserve enhanced attention in the future, especially with respect to their importance for binary evolution theory.

References

Koch, R.H., Guinan, E.F.: 1978, *IBVS* **1483.**
Lynds, C.R.: 1957, *Ap.J.* **126,** 81.
Plavec, M., Koch, R.H.: 1978, *IBVS,* **1482.**

Visits to La Plata Observatory

La Plata Observatory will welcome visitors to ESO-La Silla that are willing to make a stop at Buenos Aires on their trip to Chile or on their way back. There is a nice guesthouse at the Observatory that can be used, for a couple of days or so, by astronomers interested in visiting the Observatory and delivering talks on their research work to the Argentine colleagues. No payments can, however, be made at present. La Plata is at 60 km from Buenos Aires. In the same area lie the Instituto de Astronomía y Física del Espacio (IAFE), in Buenos Aires proper, and the Instituto Argentino de Radioastronomía (IAR), about 40 km from Buenos Aires on the way to La Plata. Those interested should contact: Sr Decano Prof. Cesar A. Mondinalli, or Dr Alejandro Feinstein, Observatorio Astronómico, Paseo del Bosque, 1900 La Plata, Argentina. Telex: 31216 CESLA AR. *A. Feinstein*