ray emission is the same in late-type main-sequence stars, RS CVn systems and T Tauri stars. The enhanced X-ray emission displayed by T Tauri stars and RS CVn systems compared to main-sequence stars can be accounted for by their higher rotational velocities. Since X-rays originate from coronae in main-sequence late-type stars and RS CVn systems, this result suggests the presence around T Tauri stars of coronae responsible for a relatively low-level X-ray emission (of the order of 10^{30}erg/s) onto which strong flare-like eruptions are superimposed. The existence of coronae around T Tauri stars has been a topic of controversy in recent years, and this result may represent the best, albeit indirect, piece of evidence for coronae to date.

Conclusions and Prospects

An important aspect of our results is that the RS CVn class can be used as a "stick" to measure magnetic surface activity in T Tauri stars. Since RS CVn stars are not fully understood yet, it is not a perfect measuring stick; but it is a definite help, since by comparing the different properties of T Tauri stars to those of RS CVn systems, we can, at least in principle, find out which are due to magnetic activity and which must be accounted for by other physical mechanisms.

To reach this goal, various activity indicators in both T Tauri and RS CVn stars must be observed systematically, and their relationship with rotation studied. For example, we plan to follow chromospheric indicators such as the Ca II H and K lines over at least one rotation period to find out the range of variation of their flux and to study possible correlations with phase. We already know that Hα emission strength is not correlated to rotation rate, which means that Hα emission is probably not directly related to magnetic activity, but a detailed study of Hα variability would be needed to confirm this result. Also, more data are needed on the rotation rates of T Tauri stars in order to improve statistics and to allow us to study correlations within the T Tauri class. But thanks to the friendliness of our Swiss colleagues and to CORAVEL's excellence, we know now that this is possible even for faint T Tauri stars.

Double Emission and Line Absorption Doubling in Mira Stars: A New Approach

D. Gillet and P. Bouchet, ESO
R. Ferlet, Institut d'Astrophysique de Paris
E. Maurice, Observatoire de Marseille

The spectra of Mira variables present a large number of emission and absorption lines which vary in strength and profile with phase. According to current models, these lines are the consequence of strong shock waves propagating through the stellar atmosphere. However, the dynamics of the shock propagation is so far not completely understood, and the interpretation of the emission and absorption line variability can only be made through semi-empirical models. Extensive studies during a whole variability period (Hinkle, Scharlach and Hall, 1984; Gillet, Maurice, Bouchet and Ferlet, 1985; hereafter: GMBF) can provide fundamental clues to the knowledge of the underlying physics. In the present note, through two examples, we show that it is possible to know the dynamical and physical conditions of the line emitting regions, using high resolution optical observations with modern detectors. All observations presented hereafter have been obtained with the Coudé Echelle Spectrometer (CES) of ESO equipped with a 1872-diode Reticon. The 1.4 m Coudé Auxiliary Telescope (CAT) or 3.6 m telescope were used to feed the CES. The resolving power was between 80,000 and 100,000. In the case of the 3.6 m telescope, the observations were obtained through a fiber optic link whose details are given in Lund and Ferlet (1984).

The Double Hα Emission Line: A Fundamental Geometric Effect

It is a classical result that the Balmer emission profiles in cool Mira stars present strong mutilations very likely due to absorptions by atoms and molecules of the upper atmosphere, i.e. above the shock wave (Joy, 1947). In o Ceti, these absorptions disappear before the luminosity minimum (phase ~0.36) when the shock reaches the low density part of the atmosphere (Gillet, Maurice, Baade, 1983; hereafter: GMB and Fig. 1a). In S Car, the effective temperature is too high during the luminosity maximum, and the profile does not show any mutilations (GMBF and Fig. 1b).

The wavelength scale in these two figures is given in the rest frame of the stars. It is obvious that there is a strong absorption centred at the laboratory wavelength. For o Ceti, it appears clearly around phase 0.4 when the redshifted emission component is fully developed, whereas it is already visible at the luminosity maximum for S Car.

We suggest that this large absorption is intrinsically different from the narrow absorptions observed in the blueshifted emission component of o Ceti around the luminosity maximum and discussed above. This absorption is only apparent and is the consequence of a geometrical effect. Indeed, if one assumes that the front velocity is high (70–80 km/s), the shock will reach already around phase 0.4 a layer far from the photosphere. The observer would then begin to receive the emission from the part of the shock propagating away from him, previously occulted by the stellar disk, and corresponding to the redshifted component. In this frame, the large absorption is not real, contrary to what was previously assumed in the literature.

This interpretation is consistent with the high shock front velocities deduced from the detailed Hα profile studies by GMB and GMBF, and with the jump velocities derived from the fluorescent lines by Willson (1976). Note that the presence of both emission components already at the luminosity maximum in the hot Mira star S Car is explained by the absence of a dense molecular atmosphere contrary to o Ceti (see GMBF).

The True Nature of the Absorption Line Doubling Phenomenon

It is another classical result that around the luminosity maximum many absorption lines in the near-infrared and infrared ranges are observed double. The current interpretation assumes the existence of two atmospheric regions with different velocities (two-component model), as a consequence of the propagation of the shock through the atmosphere (Wing, 1980).

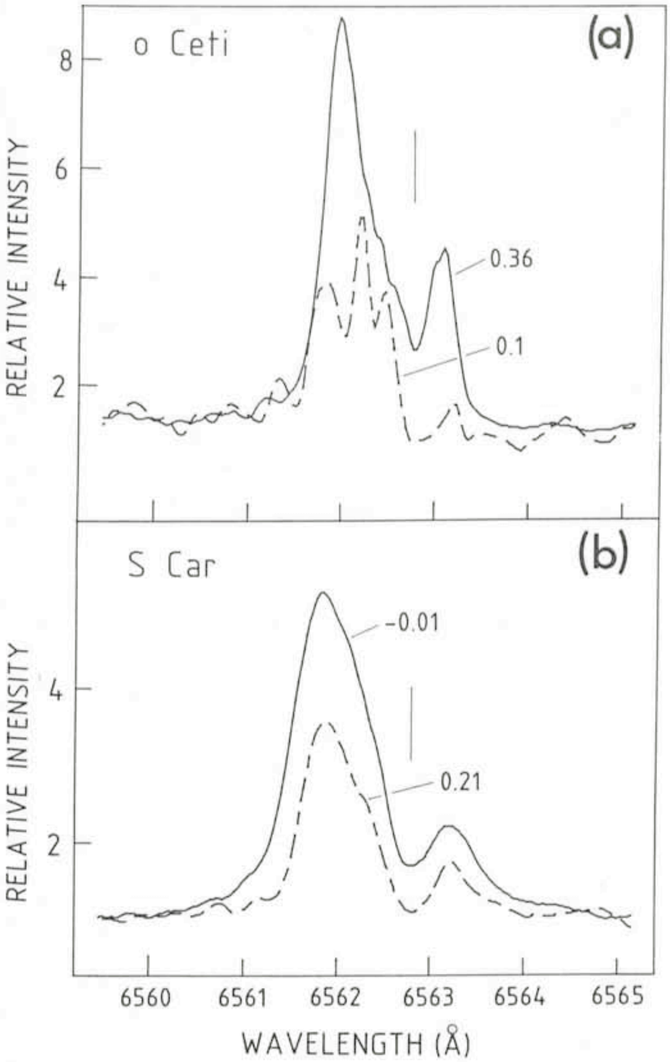

Fig. 1: *CES-Reticon spectra of Hα emission profiles in two Mira stars observed with a resolution of 66 mÅ. The wavelength scales are in the rest frame of the stars and the Hα laboratory wavelength is indicated by a vertical line.*

(a) in o Ceti at phases 0.1 and 0.36 (0.0 is the luminosity maximum). At 0.10, there are large mutilations within the profile due to molecular absorptions. These absorptions are virtually absent at 0.36, but the emission shows a blueshifted and a redshifted component.

(b) in the hot Mira star S Car at phases −0.01 and 0.21. There are no mutilations, but the two emission components are already well visible from luminosity maximum.

This phenomenon is well observed in the infrared (0.8–5 μm) because, in the blue, spectra of Mira stars are extremely blended. S Car offers a further advantage because its effective temperature is so high at luminosity maximum (3,600 K or K5e type) that the profiles are practically free of blend (compare Figs. 2 and 3). Fig. 2 shows the two bluest lines of the Ca II infrared triplet, along with some Fe I and Ti II lines, observed at phases 0.05, 0.13 and 0.20. The result is striking at first glance: inverse Ca II P-Cygni profile on top of a broad absorption; both P-Cygni and inverse P-Cygni characteristics for Ti I at the same phases (0.05 and 0.13); the classical double absorption for Fe I (Figs. 2b and 2c).

However, the Fe I profile at phase 0.05 (Fig. 2a) presents a central emission above the continuum. Its relative intensity decreases from phases 0.05 to 0.20 to become weaker than the continuum, thus giving the classical double absorption profile. This strongly suggests that the Fe I line doubling is only apparent, the real profile corresponding to an emission superposed on an underlying otherwise normal photospheric absorption.

On the other hand, the Ca II, Ti I and Fe I emission intensities decrease together during the phase interval of Fig. 2. This variation is not due to the effect of the variation of the continuum because its intensity decreases. Therefore, one may think that these lines are affected by the same physical phenomenon and thus could be produced within the same emitting region.

Consequently, as the Fe I lines are produced close to the photosphere, the Ca II and Ti I P-Cygni type are only apparent. They can be understood also by an emission superposed on an underlying photospheric absorption.

We propose that these different kinds of profiles might be formed during the ballistic motions of the atmospheric matter previously driven by the shock wave propagation (see Fig. 4). The large rate of thermal energy transferred from the front to the gas is realized during the ballistic motion which is by this fact not adiabatic. When the gas is in the ascending branch, the emission is blueshifted with respect to the laboratory wavelength, giving rise to an apparent double absorption line with a blue component weaker than the red one. When the

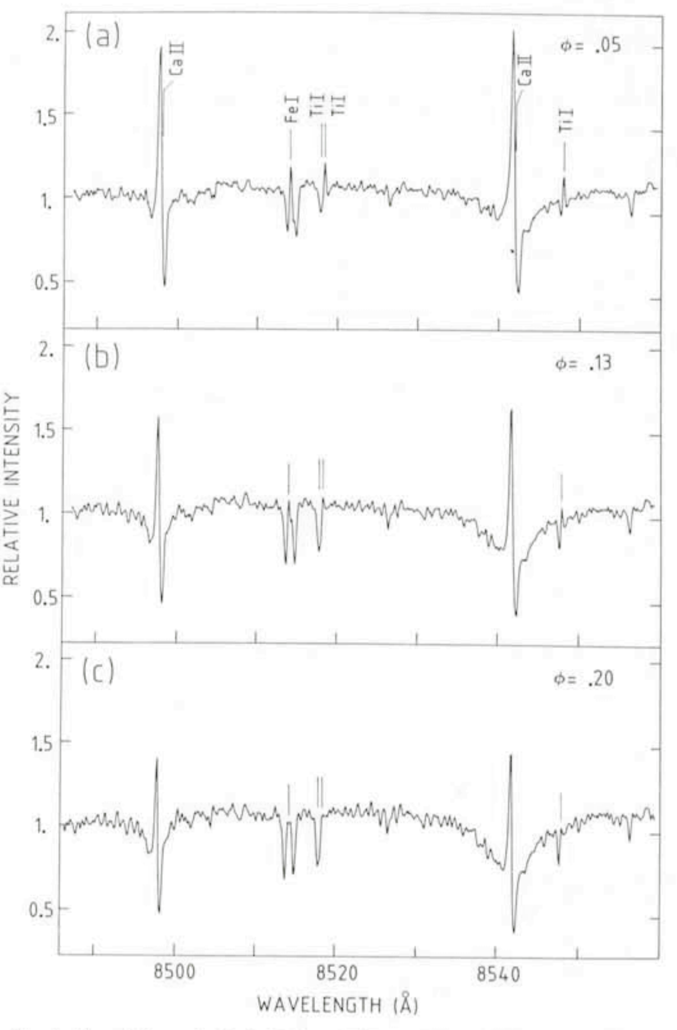

Fig. 2: *Near-infrared, Ca II, Fe I and Ti II profiles in S Car just after the luminosity maximum. All these lines originate near the photosphere and their profiles are explained by ballistic motions due to the shock wave propagation. The P-Cygni types (Ca II, Ti I) and the double absorption lines are only apparent. Note that the majority of small features on the continuum are present on each spectrum and are certainly of stellar origin.*

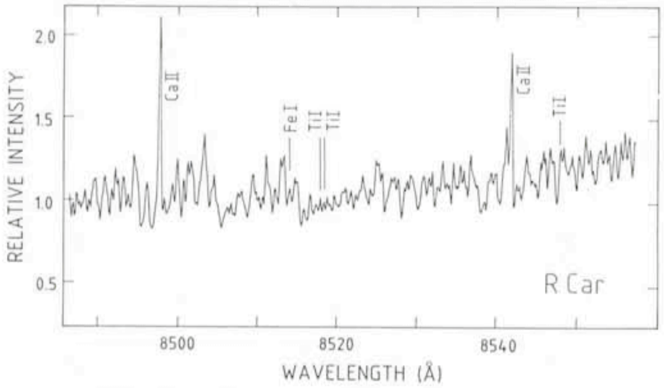

Fig. 3: *Approximately the same wavelength range, resolution (85 mÅ) and signal-to-noise ratio (~200) as in Fig. 2 but for a typical Mira star (R Car) also near the luminosity maximum. Here, the molecular blends do not permit observation of the intrinsic line profiles.*

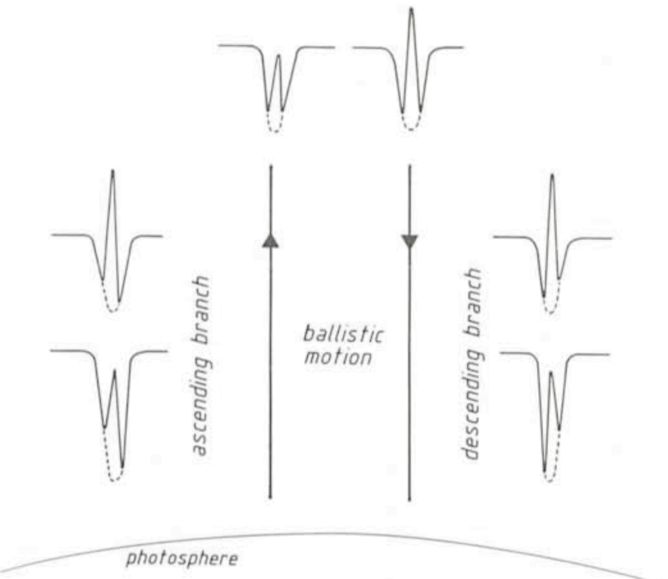

Fig. 4: *Schematic diagram showing the different types of profile expected to form during a ballistic motion close to the photoshere. Apparently like double absorption or P-Cygni types, these profiles are in fact made of an emission superposed on an underlying broad photospheric absorption (see text).*

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 semi-detached 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-