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OPTICAL OBSERVATIONS OF COLLIDING WINDS IN γ^2 VELORUM

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RESUMEN

Se presentan resultados preliminares de nueva espectroscopía óptica de la binaria Wolf-Rayet γ^2 Velorum. Se muestra que las variaciones observadas en la línea de C II λ5696 Å recuerdan los cambios en los perfiles debidos a los efectos de colisión de vientos. La variabilidad observada no puede explicarse mediante eclipses atmosféricos selectivos.

ABSTRACT

Preliminary results are presented for new optical spectroscopy of the Wolf-Rayet binary γ^2 Velorum. It is shown that variations observed in the C II λ5696 Å line are reminiscent of profile changes due to colliding-wind effects. Selective atmospheric eclipses are found to be inadequate to explain the observed variability.

Key words: **BINARIES: SPECTROSCOPIC — STARS: INDIVIDUAL (γ^2 VELORUM) — STARS: MASS LOSS — STARS: WOLF-RAYET**

1. INTRODUCTION

γ^2 Velorum, the brightest Wolf-Rayet (WR) star in the sky, is a well-known binary system (WC8+O9I) with an eccentric orbit and a period of 78.5 days. Many episodes of non-periodic line-profile changes have been observed in the optical and ultraviolet, on short (minutes and night-to-night) and long (several days) time-scales. In this paper, only phase-dependent variations will be discussed.

Willis & Wilson (1976) found strong UV line-profile variations using the S2/68 survey telescope on board the TD-1A satellite which they interpreted as eclipses of the O-star light by the WR wind at selective wavelengths. The changes, confined to resonance and low-excitation transitions of common ions, were later confirmed by Willis et al. (1979), who studied a series of high-resolution *IUE* spectra of γ^2 Vel. Brandi, Ferrer, & Sahade (1989), based on a detailed analysis of the variability in the Si IV, C IV and N V resonance profiles of the same *IUE* dataset, offered a different interpretation of the variability. Those authors suggest that the changes are caused by the presence of a stream of gas moving away from the system at an angle of 110° from the direction of the line joining the WR to the O star and resulting from the collision of the winds from the two components. In view of these two very discrepant interpretations, St-Louis, Willis, & Stevens (1993) had a fresh look at the *IUE* dataset complemented with some *Copernicus* spectra ($\lambda\lambda = 912 - 1450$ Å and $1700 - 3250$ Å) and concluded that, in fact, both effects are present. Meanwhile, Willis, Schild, & Stevens (1995) found further evidence for colliding winds in this system through spectacular x-ray phase-dependent variability using the *ROSAT* satellite.

We have searched for evidence of phase-dependent variability due to colliding winds or atmospheric eclipses in a dataset of *optical* spectra of γ^2 Vel. Preliminary results are presented in this paper.

2. OBSERVATIONS

Our dataset comprises observations obtained in three different wavelength regions (centered at $\sim$ 4000, 4800 and 5700 Å) over a period of more than three years using the University of Toronto Helen Sawer Hogg 60-cm telescope in Las Campanas, Chile. The spectra have been obtained with a dispersion of $\sim$ 1.7 Å/pixel. Only a small subset of these observations will be discussed in this paper.

3. RESULTS

In Figure 1 two series of spectra obtained in January 1993 and January 1995 are shown in the wavelength region of the C III λ5696 Å transition. The spectra are arranged chronologically from the bottom and have been shifted for clarity. Phase-dependent variations are found in the form of changes in the peak of the flat-topped profile. Within this dataset, minimum emission in this line occurs at ϕ=0.131, and therefore, this spectrum was used as a reference and over-plotted on each of the other profiles. In January 1993, the line emission is seen to gradually increase over the 17-day observing period, while in January 1995, a gradual decrease is observed over a period of 16 days. The orbital phase of each observation is indicated on the right-hand side of the plot (the ephemeris of Moffat et al. 1986, E_0=2445768.96 and P=78.5002 days, has been used throughout this paper). In Figure 2 (a), the total equivalent width of the line is plotted as a function of orbital phase. Filled circles and stars were used for the 1993 and 1995 data, respectively.

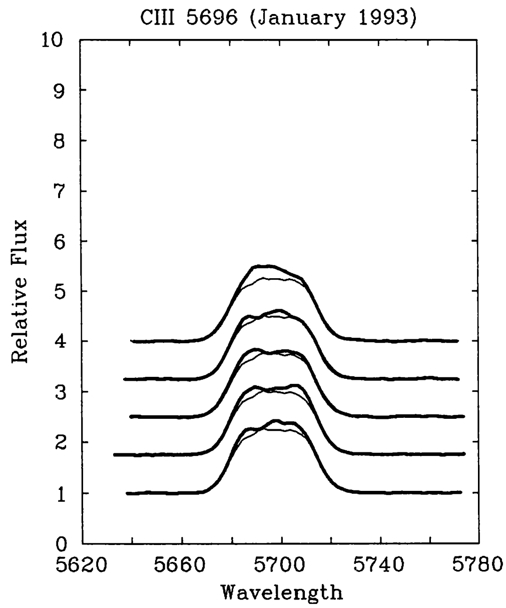

Fig. 1. Line-profile variability in the C III λ5696 Å transition of γ^2 Velorum.

A gradual increase in the strength of the line as the O-companion orbits to the front of the WR star (ϕ=0.5) is expected in the case of selective wind eclipses. When the O star is behind the WR wind, maximum absorption arises and as the O star moves to the front, the extra absorption gradually disappears. However, in this model, the detailed behavior of the changes does not withstand scrutiny. Indeed, as the extent of the WR wind which is absorbing the light varies with phase, the velocity range over which the absorption occurs should vary drastically as a function of phase, as is observed in the UV (St-Louis et al. 1993). Instead, the variations occur mostly in the same velocity range over the entire cycle. Therefore, selective wind eclipses are unlikely to be the cause of the variability observed in the C III λ5696 Å line. This is not entirely surprising since in the UV such effects were limited to resonance or low-excitation lines.

Colliding winds effects are a much more likely interpretation for the observed variations. The C III λ5696 Å line has been found to be very sensitive to such effects (i.e., Lührs 1996; Hervieux 1995; Bartzakos et al. 1995; Hill & Underhill 1995). The changes can be described as extra emission peaks, superposed on top of the global wind profile, which move back and forth as a function of phase. These extra emission peaks are formed downstream on the cone-shaped shock surface, where the material has sufficiently cooled down. The expected variability pattern strongly depends on the orbital inclination and on the cone opening angle (Moffat et al. 1996), which are not very well-known for γ^2 Vel. Nevertheless, we observe stronger emission on the blue side of the line at phases when the O star is in front of the WR star ($\phi \sim 0.35 - 0.5$) and the shock surface is pointing towards us, which is what is generally expected in the case of colliding winds.

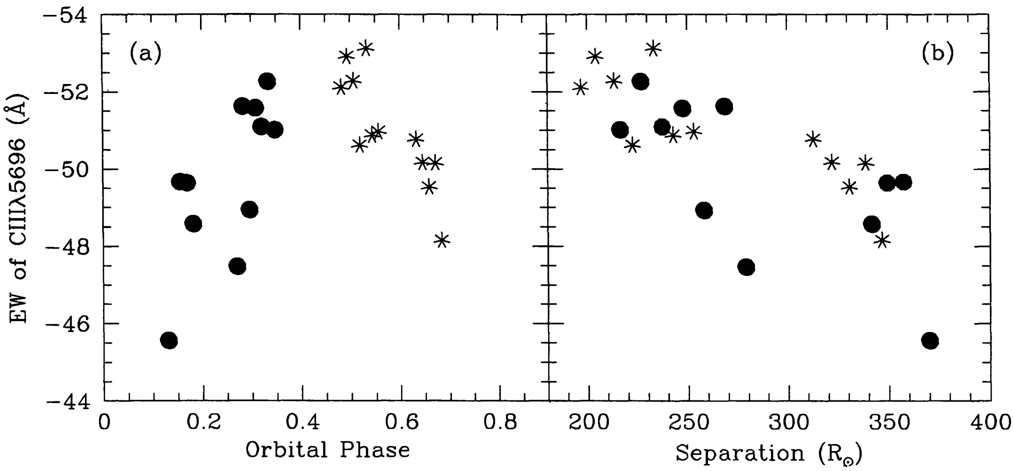

Fig. 2. Equivalent width measurements of the C III λ5696 Å emission line. Filled circles and stars correspond to observations for 1993 and 1995, respectively.

As γ^2 Vel has an eccentric orbit, colliding wind effects should vary in strength as a function of orbital separation. In Figure 2 (b) we have plotted the equivalent width of emission of C III λ5696 Å as a function of the distance between the O and WR stars. A loose correlation is observed, suggesting that the extra emission peaks are stronger when the stars are closer, as expected.

4. CONCLUSIONS

We have detected variability in a series of optical spectra of the WR binary γ^2 Velorum, which we interpret as extra emission peaks originating in a cone-shaped shock surface formed following the collision of the two stellar winds. As expected, this extra emission is found to be larger when the stars are closer together and the interaction between the winds is more intense.

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