TIME-RESOLVED SPECTROSCOPY OF RW TAU AND X PER

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Abstract. Time-resolved spectroscopy of the gaseous ring of RW Tau has revealed characteristics of its structure. Observations of H-alpha emission during one eclipse show a partial eclipse of the ring which is brighter at second contact than at third contact. The radial velocities became nearly constant after mideclipse. During two other eclipses the emission continued to strengthen after second contact. X Per has shown variability on a time scale of minutes. On one occasion H-alpha emission decreased in strength by a factor of two in 90 seconds.

RW Tau often shows emission lines during the total phase of eclipse whose radial velocity behavior suggest the presence of a gaseous ring rotating about the primary star (Joy, 1942). Previous studies have been unable to follow the rapid variations of these lines as the ring undergoes eclipse. We have begun a study of this system at Goethe Link Observatory using the 0.91-meter telescope and a SIT vidicon spectrometer. This equipment can record a spectrum every five minutes during the 80 minute totality. The Doppler components from each side of the ring are not separated with the 8 A resolution used for most of this study. The table below lists the eclipses observed thus far and the average equivalent width of H-alpha during totality. On three nights the emission was

Date (UT)	Eq. Width	Date (UT)	Eq. Width
Feb. 7, 1978	7.8 A	Nov. 8	1.2 A
Sept. 8	3.8	Nov. 19	1.4
Oct. 25	0.7	Dec. 28	7.3
Oct. 28	$<$ 0.1	Feb. 2, 1979	4

strong enough to be measured on individual spectra. On the remaining nights the spectra were co-added to detect the emission. The observations of October show that the emission can disappear in one orbit.

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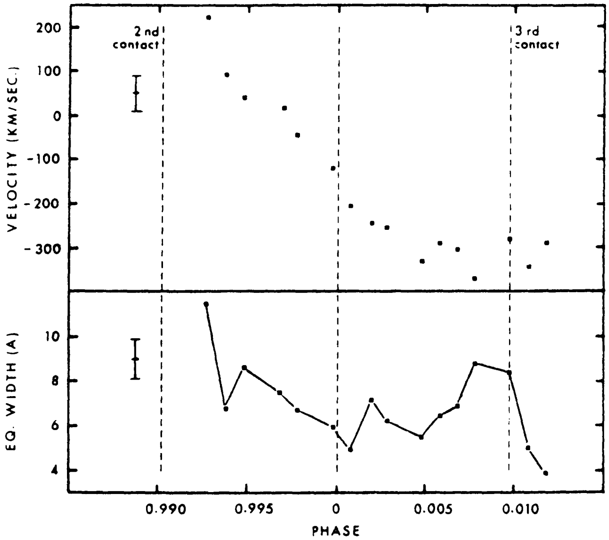

Fig. 1. The radial velocity and equivalent width of H-alpha emission during the December 28, 1978 eclipse of RW Tau.

The December eclipse represents a major outburst of the system. The start of totality was lost due to an equipment problem. Figure 1 shows the equivalent width of H-alpha during totality. The ring is partially eclipsed and brightest at the contact points when the maximum area is visible. Data points outside totality are low due to the bright continuum of the primary star. The ring is asymmetric, being brighter at second contact than at third contact. Apparently the material on the receding side of the primary is brighter compared to the advancing side. This appears consistent with a hydrodynamical calculation for the similar system U Cep by Prendergast and Taam (1974). These models predict a different distribution of density on the leading and trailing sides of the primary star. Assuming that the brightening which begins at phase 0.005 marks third contact of the ring eclipse and that the ring is roughly circular, the ring has a radius of 1.4 times the primary star. Figure 1 also shows the radial velocity of H-alpha during eclipse obtained by fitting a Gaussian to the wide (19 A FWHM) profiles. In addition to the error bar shown, a systematic error of ± 46 km/sec is possible. Even taking this into account, the rest wavelength is reached well before mideclipse. The velocity varies as expected until phase 0.005 when it becomes approximately constant and the line begins to strengthen. In the models of Prendergast and Taam, this is approximately the point where the majority of gas on the receding side of the primary is eclipsed. Furthermore, the models imply that the dense inner regions emerging from eclipse should not show a large variation in velocity. Olson (1979) obtained photometry of this same eclipse up to second contact. There was an ultraviolet excess of over

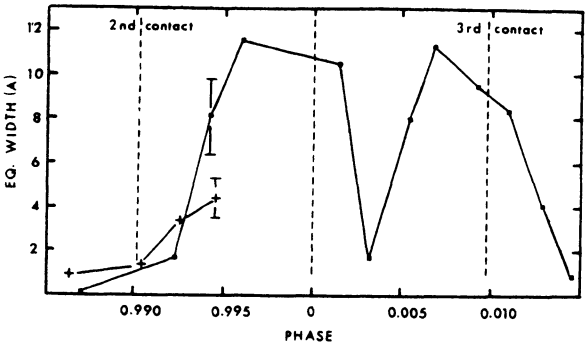

Fig. 2. The equivalent width of H-alpha emission during the February 7, 1978 (dots) and the February 2, 1979 (crosses) eclipse of RW Tau.

one magnitude and smaller excesses at longer wavelengths. This data, together with the emission line strengths, are consistent with hydrogen free-free and free-bound emission from a region optically thick in the continuum at 15,000 K and $N_e = 2 \times 10^{12}$ cm^{-3} .

Figure 2 shows the data for February 1978. Unlike the December eclipse the line strength continues to increase after second contact. This same behavior was apparent in the February 1979 eclipse until clouds ended observing. Simultaneous photometry by Burkhead (1979) clearly shows that the contact point occurred as indicated in Figure 2. This brightening is still apparent after the points prior to second contact are corrected for the light of the primary star. This behavior implies material is uncovered at the advancing side of the primary. However, it is then difficult to explain the dimming at phase 0.003. It is interesting that the average equivalent width for December and February 1978 are almost the same; yet the ring appears to have a different structure, at least on the receding side of the primary.

X Per is an unusual Be star. It is an intrinsically weak x-ray source. White et al. (1976) has found 13.9 minute and 22.4 hour periodicities in the x-ray flux. The current model for the system is a Be star with a neutron star companion. On August 23, 1978 X Per was observed simultaneously by Goethe Link Observatory and HEAO-A1. At this time the x-ray data is not available; however the optical spectroscopy recorded a remarkable event. The upper part of Figure 3 shows the equivalent width of H-alpha versus time. A resolution of 2 A and 90 second integration times were used. Between 9:28 and 9:31 UT the equivalent width dropped from 7.3 to 3.3 A. This was followed by a more extended event of 540 seconds duration in which the equivalent width dropped from 7.7 to 2.6 A. Standard stars were observed and the event does not appear to be instrumental in origin. The line widths became smaller and the central wavelength increased during the event. This strongly suggests a weakening of the unresolved, blueshifted component. This type of event is not uncommon for X Per. Murdin et al. (1976) reported

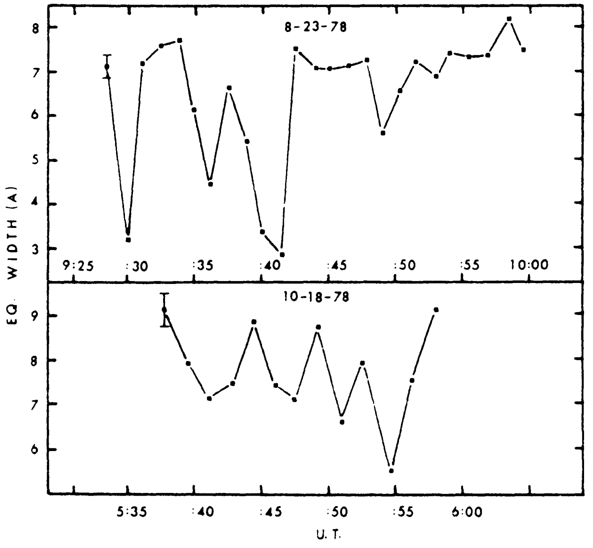

Fig. 3. The equivalent width of H-alpha emission from X Per on August 23 and October 18, 1978.

a similar event from H-alpha photometry with a duration of 600 seconds. Campisi and Treves (1976) reported dips in the ultraviolet continuum. One large event had a 600 second duration. It is interesting that these events are always characterized by a drop in flux followed by a return to the previous level. The strongest events observed have time scales of 500 to 600 seconds. On September 25, 1978 the equivalent width was higher (10.2 A) and showed only a hint of variation over a three hour interval. The bottom part of Figure 3 shows the observations of October 18, 1978. The equivalent width appears to oscillate between 7 and 9 A. Unlike the August data, the line width increases as the equivalent width decreases. There appears to be no central wavelength variation.

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