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OBSERVATIONS OF INTERACTING
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IUE Observations of the Interacting S Star Binary HR 1105

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Title: Coordinated Observations of Interacting Peculiar Red Giant Binaries - II

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Results:

IUE and H alpha observations continued on a two-year program to monitor the UV variability of three interacting peculiar red giant (PRG) binaries, HD 59643 (C6,2), HD 35155 (S3/2), and HR 1105 (S3.5/2.5). All of these systems were suspected to involve accretion of material from the PRG to a white-dwarf secondary, based mainly on previous IUE investigations. They were primary candidates from earlier surveys of PRGs to test the hypothesis that the Tc-poor PRGs are formed as a result of mass transfer from a secondary component rather than from internal thermal pulsing while on the asymptotic red giant branch.

Of the three systems, HR 1105 exhibited the most regular behavior. Over the course of its 596-day orbit, line and continuum fluxes were consistent with orbital variation due to streaming through the inner Lagrangian point. Similar behavior was seen in He I 10830 A by Shcherbakov and Tuominen (1992, A&A, 255, 215). The secondary object itself is not evident in the IUE spectra. No variations were seen in H alpha, apparently due to the weakness of the interaction in this system.

HD 35155 displayed characteristics of a symbiotic, nova-like system, similar to T CrB. H alpha was highly variable, often asymmetric and accompanied by emission wings to the blue or red (Asbury and Bopp 1992, BAAS, 24, 769). The IUE spectra were considerably different compared to our previous observations (Johnson, Ake and Ameen 1993), indicating that an outburst had occurred prior to our monitoring. Thus these data could not be combined with our earlier spectra to study the UV variations with orbital phase. Further IUE observations were proposed for the sixteenth episode to follow the decline to pre-outburst levels and cover the full orbit in this state, but the time was not granted.

HD 59643 did not exhibit any cyclical behavior, either in the optical or UV spectra. No further insight could be gained about this system beyond the previous study by Johnson et al (1988, A&A, 204, 149).

Publications:

"IUE Observations of the Interacting S Star Binary HR 1105", T.B. Ake, H.R. Johnson, and B.W. Bopp 1993, BAAS, 25, 876.

"The Unusual Interacting S Star Binary HR 1105", T.B. Ake, H.R. Johnson, and B.W. Bopp 1994, in Interacting Binary Stars, ed. A.W. Shafter, ASP Conference Series, Vol. 56, 413.

Figure 1. Model of HR 1105 showing the relative sizes of the components and the Roche surface, assuming a typical mass of the S star of $1.5 M_{\odot}$ and a white dwarf of $0.5 M_{\odot}$. Viewing angles at various orbital phases are indicated.

Figure 2. SWP spectra near velocity quadratures and conjunctions. The UV line and continuous emission is always most intense near inferior conjunction of the hot companion ($\phi = 0.3$), but reaches a secondary maximum half a cycle later ($\phi = 0.8$). At the brightest phases, lines due to N V $\lambda 1240$, O I $\lambda 1300$, C II $\lambda 1335$, S IV $\lambda 1400$, C IV $\lambda 1550$, Si III] $\lambda 1892$, and C III] $\lambda 1909$ are present. However at $\phi = 0.8$, N V disappears, indicating that the hottest area of the UV source is occulted by the red giant.

Figure 3. Orbital variation of various SWP features. Open squares are data from 1982-1989 taken over 4 orbits; closed squares are during the same orbit in 1992-1993. A $100 \text{ \AA}$ region centered at $\lambda 1460$ is relatively free of emission lines and thus was used as a continuum measurement, f_{1460} . The continuum and emission lines (as illustrated by the behavior of C IV) vary together, reaching maxima near the conjunctions. The Si III]/C III] ratio, which increases with increasing N_e , is also highest at these phases. The lowest recorded fluxes occur at $\phi = 0.89$, which is a sign that the inclination of the system is high and the secondary is partially eclipsed.

Figure 4. Orbital variation in the LWP region. Symbols are as in Figure 3. The $200 \text{ \AA}$ continuum region at $\lambda 3100$ shows no cyclical variation, indicating the dominance of the flux from the red giant photosphere in this region. The $200 \text{ \AA}$ region centered on $\lambda 2600$ and the Mg II flux show similar variations as seen in the SWP, but of smaller amplitude. Thus these regions have comparable flux contributions from the S star and hot companion. A dotted line shows the expected level of Mg II flux from an M giant with the (V-K) color of HR 1105.

Figure 5. High dispersion Mg II profiles at the conjunctions and near the quadrature of maximum velocity of approach of the S star ($\phi = 0.68$). The motion of the lines is best seen by the changes in the violet and red peaks of the emission, especially the h-line at $2802 \text{ \AA}$. At phase 0.68, the line is blue-shifted with respect to the central absorption, indicating it follows the red giant. At phase 0.3, when the hot component is in front, the Mg II line is much stronger than at other phases, and an absorption trough appears at -78 km/sec (as indicated by vertical bars). Compared to the systemic velocity, this represents a flow of about 55 km/sec towards the observer.

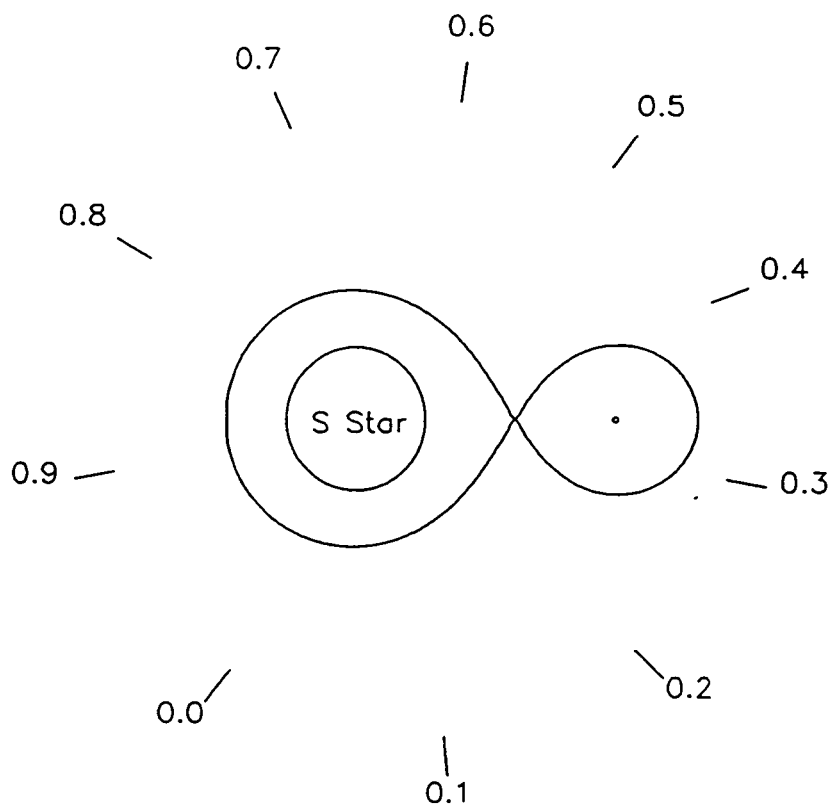
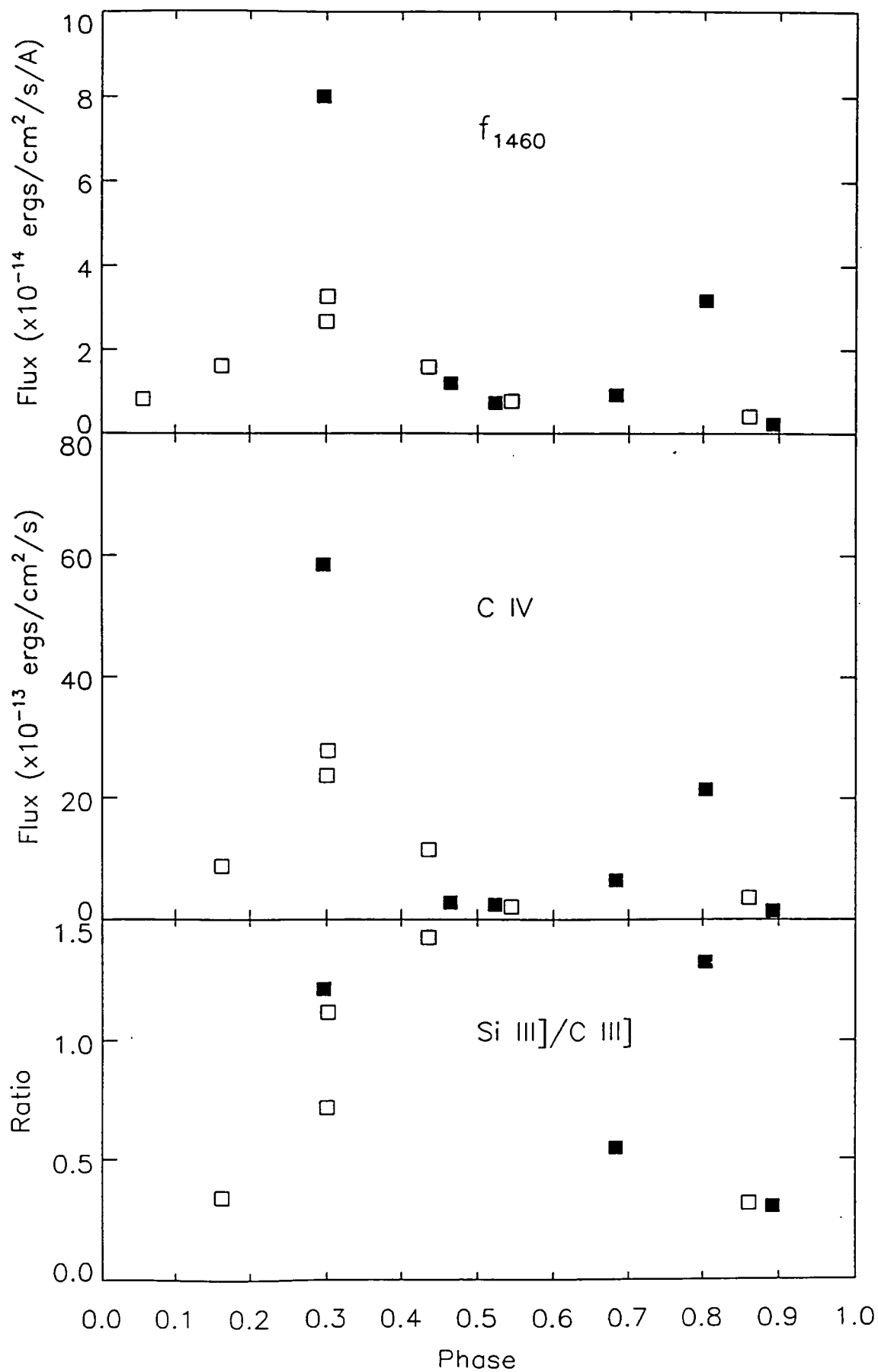
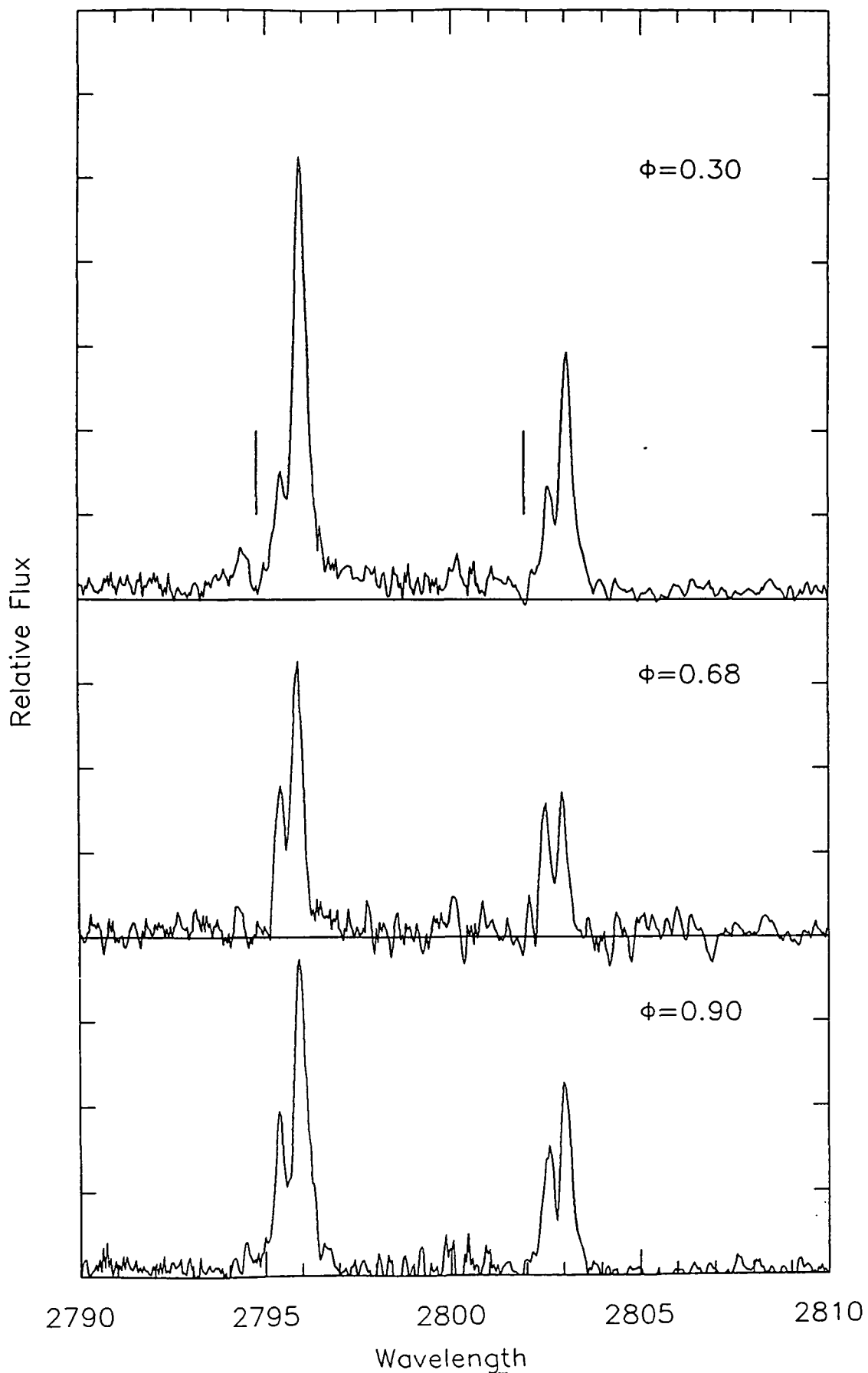


Fig 1





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Fig 5

The Unusual Interacting S Star Binary HR 1105

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Abstract. *IUE* observations of HR 1105 over its 596-day orbit show strong orbital modulation of both continuum and emission lines. These are most intense just before both conjunctions and nearly disappear near quadratures, the most intense phase being just before the hot component passes in front of the S star. High dispersion observations exhibit a blue-shifted absorption feature in Mg II, representing an outflow of material of about 55 km s^{-1} . These observations are consistent with the UV source being an optically thin gas stream between the components of the system (Shcherbakov & Tuominen 1992), which is partially eclipsed when the S star is in front.

1. Introduction

HR 1105 is a symbiotic-like, interacting binary comprised of an S3.5/2 red-giant primary and a hot compact companion. The orbit of the primary was determined by Griffin (1984) to be nearly circular at 596 days. Peery (1986) discovered the hot secondary with *IUE*, and Ake et al. (1988) found evidence for orbital modulation of the UV flux, although they could not distinguish between possible sources of the emission (an accretion disk, streaming, or atmospheric heating of the red giant by the hot star). Shcherbakov & Tuominen (1992) found that He I $\lambda 10830$ has a complex variation of the absorption-emission profile over the orbit, which they argued is due to gas-streaming near the inner Lagrangian point of system. Thus HR 1105 is a prime example of a Tc-deficient S star that is not a thermally pulsing AGB star, but rather is a system where mass transfer has modified the composition of the red giant when the secondary component, which is now a white dwarf, was on the AGB (Johnson et al. 1993, and references therein).

We have undertaken further *IUE* observations of HR 1105 over nearly a complete orbit from 1992-1993, including critical phases near conjunctions of

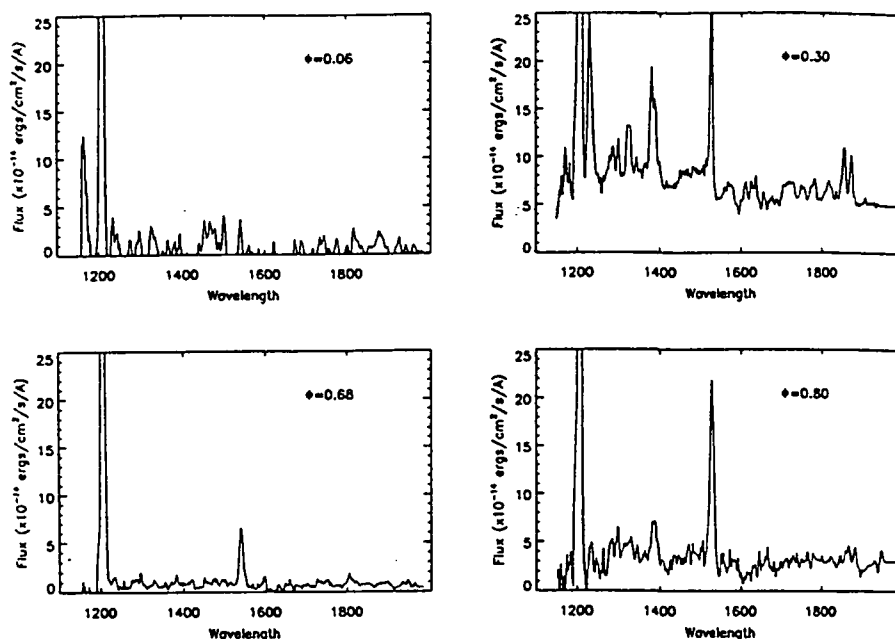


Figure 1. SWP spectra of HR 1105. Phases are determined from the Griffin (1984) orbit, such that the secondary is in front of the S star at $\phi = 0.33$, and the S star is in front at $\phi = 0.88$. The other two figures are near quadratures.

the components and at velocity quadratures. Using other observations taken over several different cycles, we now have *IUE* data over the full orbit.

2. Observations and Analysis

In our *IUE* monitoring program, we obtained low dispersion SWP and LWP/R spectra, and LWP/R high dispersion images of the Mg II emission lines. Because the red giant contributes significant UV light in the LW region, the SWP spectra show the most dramatic variations (Fig. 1). The UV line and continuous emission is most intense near inferior conjunction of the hot companion ($\phi = 0.3$), but reaches a secondary maximum half a cycle later ($\phi = 0.8$). This secondary maximum rules out the UV source as being due to atmospheric heating of the S star by a hot companion since it occurs when the heated face faces away from the observer. At the brightest phases, lines due to N V $\lambda 1240$, O I $\lambda 1300$, C II $\lambda 1335$, S IV $\lambda 1400$, C IV $\lambda 1550$, Si III] $\lambda 1892$, and C III] $\lambda 1909$ are present. However at $\phi = 0.8$, N V disappears, indicating that the hottest area of the UV source is occulted by the red giant.

Figure 2. Co-phase. Open squares indicate the primary component, closed squares indicate the secondary component.

In Figure 2, we show a 100 Å region centered on the Lyα line, free of emission lines. The Lyα fluxes of the various components are shown (as illustrated in Figure 1). The Lyα lines are near to, but not at, the Lyα line, with increasing N_e , the Lyα line is denser region then. The Lyα line is that the inclination is near to the Lyα line. There is also evidence of secular variation of the Lyα line.

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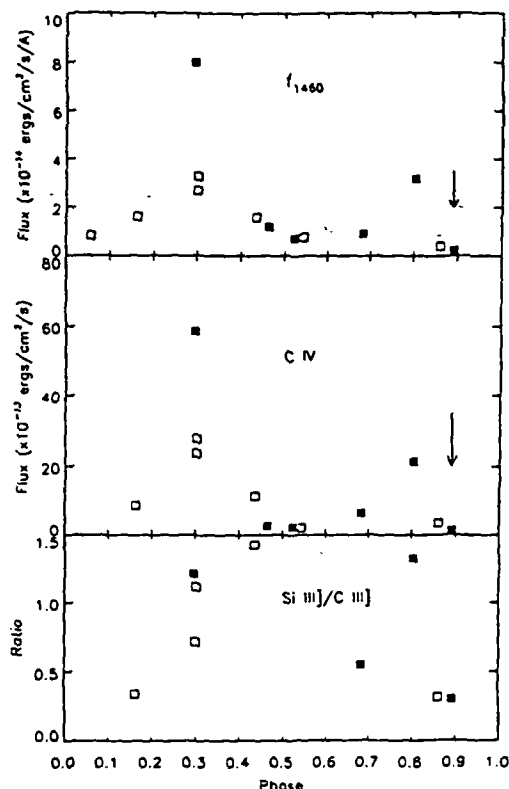


Figure 2. Continuum and line measurements as a function of orbital phase. Open squares are data from 1982-1989 taken over 4 orbits; closed squares are during the same orbit in 1992-1993. The arrow indicates the phase at which the secondary object should be eclipsed.

In Figure 2, we show the orbital variations of various SWP features. We use a 100 Å region centered at $\lambda 1460$ as a continuum point, f_{1460} , since it is relatively free of emission lines. Other measurements were made of the net integrated line fluxes of the various emission lines. We find that the continuum and emission lines (as illustrated by the behavior of C IV) vary together, reaching maxima near to, but not at, the conjunctions. The Si III]/C III] ratio, which increases with increasing N_e , is also highest at these phases, indicating we are seeing into a denser region then. The lowest recorded fluxes occur at $\phi = 0.89$, which is a sign that the inclination of the system is high and the secondary is partially eclipsed. There is also evidence, based on the multiple observations near $\phi = 0.3$, of a secular variation of the UV flux.

In the LW region, we find that the flux at 3100 Å shows no cyclical variation because of the dominance of the flux from the red giant photosphere in this region. The Mg II lines and flux at $\lambda 2600$ show similar variations as seen in the SWP, but of smaller amplitude. The minimum Mg II flux is consistent with

that of an M giant of similar V-K color as HR 1105. Thus the Mg II lines have contributions from both the S-star chromosphere and the UV source.

In high dispersion, the Mg II profiles show changes in the ratio of the violet to red emission peaks around the centrally reversed absorption core. At $\phi = 0.68$, the line is blue-shifted with respect to the central absorption, indicating it arises close to the red giant since the S star is at maximum velocity of approach at that phase. At $\phi = 0.3$, when the hot component is in front, the Mg II line is much stronger than at other phases, and an absorption trough appears at -78 km s^{-1} . Compared to the systemic velocity, this represents a flow of about 55 km s^{-1} towards the observer. It is unclear whether this feature is seen in all data (i.e., it arises from a wind from the S star), or if it is strongest at this conjunction (i.e., it is formed in a stream).

3. Discussion

Of the possible scenarios for the orbital modulation of the UV flux in HR 1105, the Shcherbakov & Tuominen gas-streaming model is the most consistent with the *IUE* observations. Because the UV source nearly disappears far from conjunction, it cannot be due to atmospheric heating or an accretion disk. The secondary maximum also rules against atmospheric heating. Although detailed observations near the conjunctions are not available, there is evidence that the peak emissions occur at $\Delta\phi \sim 0.1$ before conjunctions, i.e., when looking down a stream of material from the S star towards the secondary. This is also consistent with the appearance of the blue-shifted absorption feature in Mg II. The stream is optically thin since it is only seen at certain orientations. The absence of N V and low fluxes near inferior conjunction of the S star indicate parts of the UV source are eclipsed.

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 Shcherbakov, A.G. & Tuominen, I. 1992, *A&A*, 255, 215

Separation of Co Physical Proper

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