N89-10729

COMPANIONS TO PECULIAR RED GIANTS: HR 363 AND HR 1105

Thomas B. Ake, III — Astronomy Programs, Computer Sciences Corporation, Space Telescope Science Institute

Hollis R. Johnson — Astronomy Department, Indiana University

Benjamin F. Peery, Jr. — Dept. of Physics and Astronomy, Howard University

ABSTRACT

We report recent IUE observations of two Tc-deficient S-type peculiar red giants that are also spectroscopic binaries, HR 363 and HR 1105. A 675 min SWP exposure of HR 363 shows emission lines of O I 1304 and Si II 1812 and a trace of continuum. Compared to the M giants, the far UV flux may be relatively larger, indicating a possible contribution from a white dwarf companion, but no high temperature emission lines are seen to indicate that this is an interacting system where mass-transfer has recently occurred. HR 1105, on the other hand, appears to have a highly variable UV companion. In 1982, no UV flux was discerned for this system, but by 1986 C IV was strong, increasing by a factor of 3 in 1987 with prominent lines of Si III], C III], O III], Si IV and N V. Using orbital parameters, these observations are consistent with high activity occuring when the side of the S-star primary illuminated by the companion faces the Earth, but since the IUE data were taken over 3 orbits, a secular change in the UV component cannot be ruled out.

1. INTRODUCTION

It is becoming increasingly apparent that the peculiar abundance red giants (PRGs) of type MS, S, SC and C are a heterogeneous group of objects with different evolutionary histories. One group of these, the stars of considerable s-process element overabundances but without Tc, appear to be more closely related to Ba II stars than to K-M giants and thus may have been mass-transfer binaries in the past (Ref. 1). Under this scenario, the current primary did not evolve into a PRG, but was polluted by material from a companion that once went through this phase. Since the primary itself is not in a thermally pulsating state, its composition reflects that of the PRG phase of the companion, except that elements such as Tc should have decayed away. This companion should now be a white dwarf (WD) star.

The latest list of PRGs that have been searched for Tc is by Little *et al* (Ref. 2). If the above scenario is correct, the Tc-deficient stars should be binaries with WD secondaries. Two surveys for WD companions of the MS and S stars have been published (refs. 3-4) and companions to a few stars have been discovered serendipitously (refs. 5-6). These observations were undertaken without regard to Tc abundance or indications of binary nature, but have resulted in the discovery of three stars with hot secondaries: HD 35155, HR 1105 and o^1 Ori. The first two show no Tc but have strong emission lines in the UV, while the third has Tc but no high temperature lines. HD 35155 also has been noted to be highly variable in the UV, both in the continuum and the lines. Thus HD 35155 and HR 1105 may be interacting mass-transfer binaries while o^1 Ori is not, and the expected correlation with Tc holds. We report here observations on another Tc-poor S star, HR 363, and demonstrate that HR 1105 is also a UV variable as HD 35155 has been found to be.

2. HR 363

HR 363 (S3+/2-) was noted in the General Catalogue of Stellar Radial Velocities as being a spectroscopic binary, based presumably on its velocity variations, but no orbit or period was established. Ake and Johnson (Ref. 4) determined an upper limit on the luminosity of a degenerate secondary based on a quick SWP survey, but due to the importance of this object on the binary hypothesis, we have reobserved it with a longer exposure. Figure 1 shows the resultant spectrum after removing extraneous hits and reprocessing with a Gaussian extraction routine. A low level continuum and emission lines of S I + O I 1300 and S I + Si II 1815 are prominent as is typical in deep exposures of M giant stars (Ref. 7). The feature at 1815 unfortunately is affected by a cosmic-ray hit that probably has only been partially removed by our re-extraction technique since the normal Si II 1808/1817 splitting is not apparent. Compared to other red giants, other chromospheric emission is suggestive but not obvious. In Figure 1 we show in comparison an M giant of similar temperature, γ Cru (M3 III). The stronger emission lines are as noted from high dispersion observations by Carpenter *et al* (Ref. 8). While there are corresponding excursions in the HR 363 data at some of the these points, in general the spectrum is too noisy for positive confirmation. Since HR 363 has a composition dissimilar from the M giants and may have undergone convective mixing, the existence of a chromosphere similar to the M giants should not be automatically assumed.

Since we are looking for a hot companion to HR 363, we are

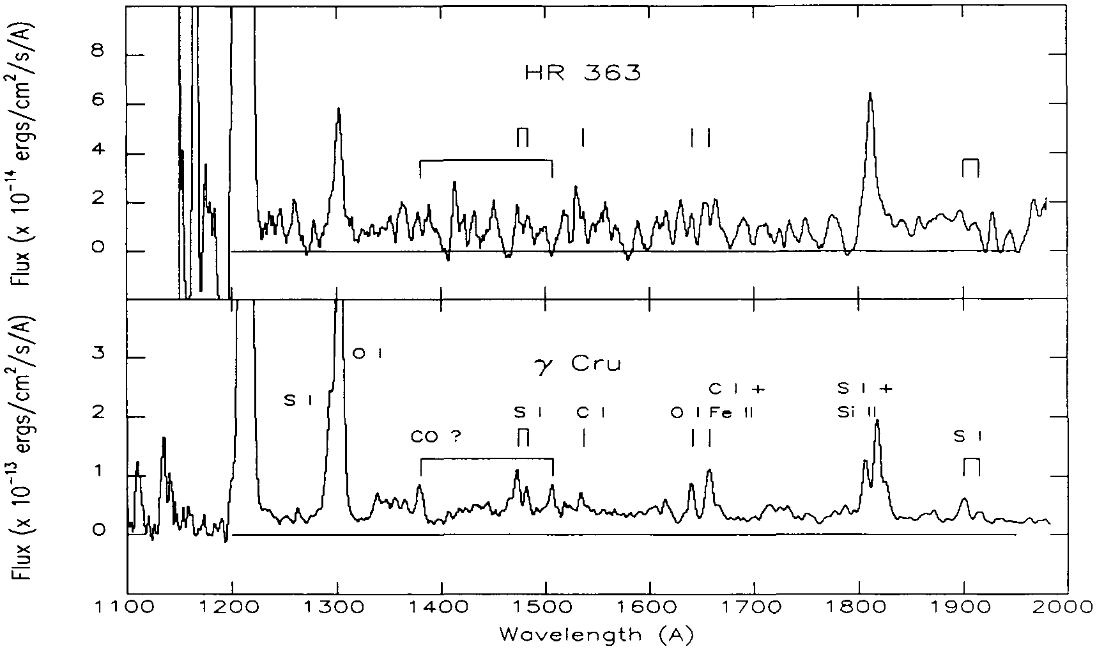

Figure 1. SWP spectra of the PRG HR 363 and the M3 III star γ Cru. Chromospheric lines in γ Cru are identified. Corresponding positions are shown for HR 363, where the reality of the weaker lines is unclear.

interested in whether there is additional continuum flux compared to other stars. While there has been much work done on the emission line spectra of cool giants, little has been said about the general underlying continuum, perhaps because of concerns about scattered light in the SWP. From rough estimates of the contamination, Stickland and Sanner (Ref. 7) argue that the continuum in this region for M giants is not due to grating scatter, but arises from the lower chromospheres in these stars. Since their paper, Basri *et al* (Ref. 9) have derived an improved scattering model for the SWP. We have calculated the scattered light contribution as prescribed in the revision by Basri (Ref. 10) and find that it cannot contribute more than 25% of the flux at 1900 A, and likely is below 5%. Thus the far UV continuum in single M giants is real and one must exercise some caution in interpreting the data as evidence for companions.

By the flatness of the spectrum for HR 363, a WD with $T_{eff} > 15000K$ is not present. In Ref. 4 we describe a method for determining the upper limit to the luminosity of a hot secondary by measuring the average flux in the region 1250 to 1950 A, converting it to a magnitude scale by computing $m_{1600} = -2.5\ log(f_{1600}) - 21.1$, and using the resultant $m_{1600} - V$ color with similar determinations for field white dwarfs and the absolute magnitude of the primary to compute the upper limit. In Table 1 we present the $m_{1600} - V$ colors for HR 363 as well as for 3 late-type M giants. The data is corrected for the tabulated reddening values, which we obtained for the M giants by comparing published *UBVRI* observations with mean colors for their spectral type, and for HR 363 from Eggen (Ref. 11). Note that the color for HR 363 is about 0.5 mag bluer than the M stars indicating there is added flux in the SWP region. If the entire continuum in HR 363 is due to a companion, we derive M_V=11.2, but the flux for a WD of this magnitude should curve upwards at the shortest wavelengths (see Ref. 4). If we assume that HR 363 has a chromospheric spectrum comparable to the M giants, we find that the added flux yields M_V=11.7 for the companion, which would then have a flatter energy distribution.

Table 1. Average Fluxes at 1600 A for Red Giants

Star	HR 363	γ Cru	ρ Per	g Her
Spectral Type	S3+/2	M3 III	M4 II-III	M6 III
V	6.43	1.62	3.2	5.05
$E(B-V)$	0.05	0.00	0.03	0.00
SWP Number	32472	5891	32553	1387
Exp Time (min)	675	90	240	154
Observer	Ake	Sanner	Ake	Wing
$(m_{1600} - V)_o$	9.63	10.24	10.05	10.00

3. HR 1105

HR 1105 (S3.5/2) is a 596 day spectroscopic binary (Ref. 12) whose secondary was first reported by Peery (Ref. 6). He had obtained 2 SWP exposures of 20 min. and 87 min. duration on the same day, the longer one taken after C IV emission was found in the first image. Interestingly a 20 min. exposure was obtained by O'Brien and Johnson in 1982 and no emission was seen. We have obtained 2 other observations and can confirm the variability of this object. In Figure 2 we show plots of the spectra with the stronger emission lines identified, and in Table 2 we present the integrated line fluxes and a continuum flux centered in the relatively line free region at 1460 Å. Orbital phases from Griffin's determination are also indicated.

The recent observations have caught the system in a higher state than previously seen, with a subsequent decline from December 1987 to March 1988 in both the continuum and

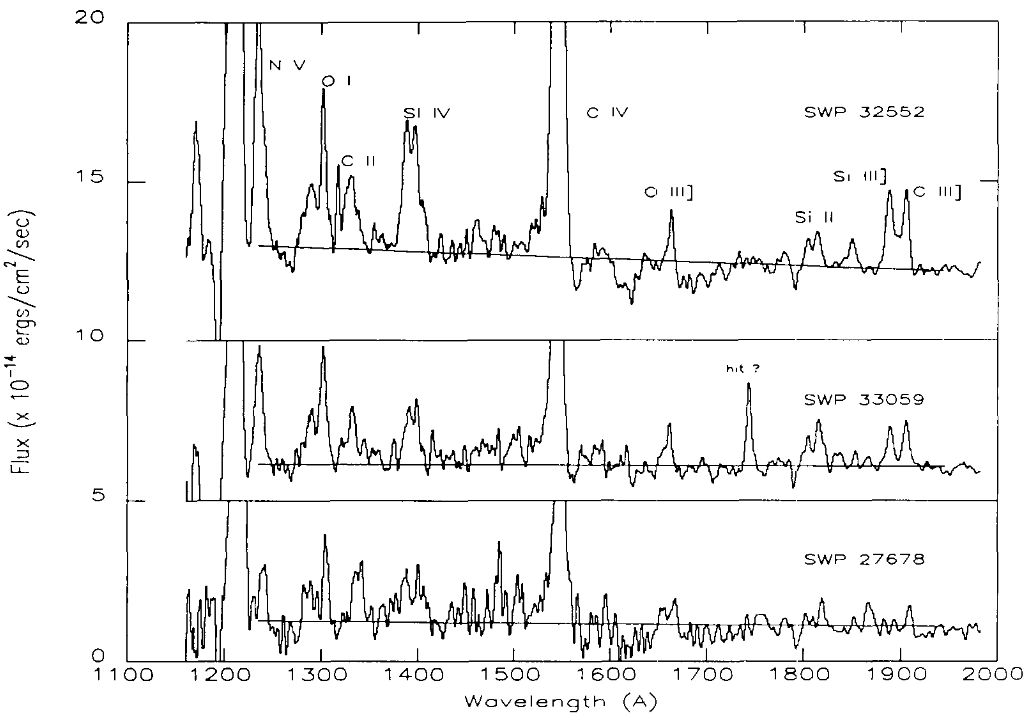

Figure 2. Temporal variation of the PRG HR 1105 in the SWP region. Successive plots are offset by 5×10^{-14} ergs/cm^2/sec/Å each. Prominent emission features are labelled and continuum slopes are indicated.

emission lines. In general, the lines and continuum scale together, with little change in the relative line strengths and the continuum slope, although the continuum is slightly bluer in December 1987. The density sensitive Si III]/C III] ratio is essentially unchanged, as are ratios of lines of different excitation. These observations argue that the decline was not associated with a change in the energetics of the system, but rather the total luminosity was reduced by a decrease in the apparent size of the emitting region. Compared to the observation in 1986, however, some variations in the lines are seen, although the exposure is somewhat weak. The continuum flux at 1460 Å is nearly the same in the Feb 1986 and March 1988 observations, but in 1986 N V is weaker and the Si III]/C III] ratio is < 1. Thus on a longer time scale, the physical conditions of this system appear to be variable.

4. DISCUSSION

While both HR 363 and HR 1105 are Tc-deficient spectroscopic binary PRGs, their characteristics in the far UV are quite different and the evidence for the mass-transfer hypothesis for the origin of their current abundance peculiarities is mixed. Based on comparison with the M giants, a WD companion to HR 363 can only be inferred. Further analysis of the chromospheres of other red giants is required to confirm that appropriate comparison objects were chosen. From the Stickland and Sanner data, we find that the $(m_{1600} - V)$ color for K and earlier type M giants is even redder, so using other standards would opt for a brighter companion. Finally we note that if excess UV flux is from a WD companion, the absence of high temperature emission lines such as C IV indicates that this is not currently an interacting system like HD 35155 and HR 1105.

For HR 1105, clearly a hot companion is present, but as with the symbiotics, the source of the UV radiation is not clear. The variability and brightness of the continuum indicate that the photosphere of a WD companion is not directly observed. Possible locations of the radiation for systems such as these are an accretion disk around the secondary, a stream between the components, or a hot outer atmosphere of the primary heated by the companion. In the last two cases, the observed changes should be correlated with orbital phase. In Figure 3 we show the points at which the observations have been made. There is

Table 2. IUE Observations of HR 1105

			Flux (x 10^{-13} ergs/cm^2/s)						
Date	SWP No.	Phase	N V	O I	Si IV	C IV	Si III]	C III]	f_{1460} (ergs/cm^2/s/Å)
1982 Aug 31	17816	4.057	-	-	-	-	-	-	8.63(-15)
1986 Feb 7	27678	6.163	1.38	1.71	2.34	9.27	0.18	0.49	1.60(-14)
1987 Dec 17	32552	7.302	7.60	3.02	6.17	$> 27^a$	2.03	1.78	3.01(-14)
1988 Mar 6	33059	7.436	3.80	2.69	1.75	11.7	1.12	0.92	1.63(-14)

[a] Overexposed

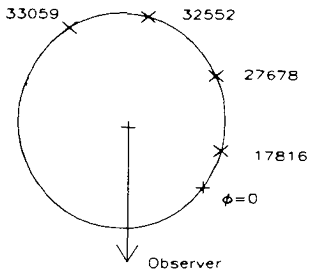

Figure 3. Motion of the HR 1105 S-type primary about the system center of mass. Phases at which SWP spectra have been taken are marked.

a general relationship in that the highest state occurred when the hemisphere of the primary illuminated by the companion was nearly face on, while the lowest phase (i.e., no emission seen in 1982) occurred when the primary was in front of the plane of the sky. But except for the observations made in the past year, the data was collected at different orbital cycles, so the correspondences are somewhat suspect since secular variations cannot be ruled out. Further observations are required to confirm if the changes are actually periodic.

6. ACKNOWLEDGEMENTS

We gratefully acknowledge the assistance of the IUE staff in obtaining these observations and the GSFC RDAF in the specialized extraction routines. The work by T. B. A. is supported by NASA grant NAS 5-28749.

5. REFERENCES

1. Smith V E & Lambert D L 1988, preprint.
2. Little S J, Little-Marenin I R & Bauer W H 1987, *Astron J*, **94**, 981.
3. Smith V E & Lambert D L 1987, *Astron J*, **94**, 977.
4. Ake T B & Johnson H R 1988, *Astrophys J*, **327**, 214.
5. Johnson H R & Ake T B 1983, in *Cool Stars, Stellar Systems, and the Sun*, eds. S L Baliunas & L Hartmann, (New York: Springer-Verlag), p. 362.
6. Peery B F Jr 1986, in *New Insights in Astrophysics: 8 Years of UV Observations with IUE*, ed. E Rolfe, ESA SP-263, p. 117.
7. Stickland D J & Sanner F 1981, *Mon Not Roy Astr Soc*, **197**, 791.
8. Carpenter K G, Pease J E, Stencel R E, Brown A, Johansson S & Wing R F 1988, *Astrophys J*, submitted.
9. Basri G, Clarke J T & Haisch B M 1985, *Astron Astrophys*, **144**, 161.
10. Basri G 1985, *NASA IUE Newsletter*, No. 28, p. 58.
11. Eggen O J 1972, *Astrophys J*, **177**, 479.
12. Griffin R F 1984, *Observatory*, **104**, 224.