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BVRI photometry of the extrinsic S star HR 1105*

S.J. Adelman

Department of Physics, The Citadel, 171 Moultrie Street, Charleston, SC 29409, USA (Adelmans@Citadel.Edu)

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Abstract. BVRI photometry of the extrinsic S star HR 1105 shows a stable periodic light variability with a period of 24.76 days superimposed upon long term changes presumably related to the orbital period. The variations are in phase for all four magnitudes with the amplitude of this variability being about the same for B and V, but smaller for R and even smaller for I. As the primary is a M3 III star, these brightness changes are mostly likely due to the pulsation of the primary star.

Key words: stars: AGB, post AGB – binaries: close – stars:individual: HR 1105 – stars: variables: other

1. Introduction

S type cool peculiar red giants have envelopes enriched in carbon and heavy elements by the s-process (Smith & Lambert 1990). There are (Iben & Renzini 1983) the intrinsic S stars which have high luminosity, contain Tc lines, and partake in the MSC evolutionary sequence on the AGB and owe their chemical peculiarities to intrinsic nucleosynthetic processes and the extrinsic non-Tc, binary S stars which have probably have evolved from the hotter lower luminosity barium stars which are binaries (see, e.g., McClure & Woodsworth 1990). The giant primaries presumably acquired their s- processed material from their white dwarf companions. Jorissen & Mayor (1992) found the orbital elements of five non-Mira S stars and discussed their evolutionary link to the barium stars. These S stars have mass functions which indicate that their companions are white dwarfs. They may be populating the first giant branch. According to Groenewegen (1993) the infrared properties of such systems are consistent with warm stellar bodies with at most very little circumstellar material.

Jorissen et al. (1992, 1996) showed that the photometry of the extrinsic S star HD 35155 exhibits intrinsic variations superimposed upon an eclipsing behavior which is related to the orbital motion. BD -8° 1900 exhibits quasi-periodic photometric variations with a time scale of about 59 days (Jorissen et al. 1997), but its status as an extrinsic S stars still remains to confirmed as contrary to Groenewegen (1993) whether or not its spectrum contains Tc lines is still unclear. Observations of HD 35155 with the Four College Automated Photoelectric Telescope were reported by Adelman (1997) who showed that it exhibited definite variability. The light curve may not repeat exactly with orbital phase.

Griffin (1984) discovered the spectroscopic binary nature of HR 1105 (= BD Cam = HD 22649, V = 5.10, spectral type S3.5/2) and derived an orbital period of 596.21 $\pm$ 0.19 days. The companion was found using IUE spectra (Peery 1986, Ake, Johnson & Peery 1988, Johnson, Ake & Ameen 1993). This system exhibits an ultraviolet spectrum similar to those of interacting binary systems. Bieging & Latter (1994) performed a millimeter survey of S stars and deduced a mass loss rate of 1.7 x 10^{-8} $M_\odot$ yr^{-1} for HR 1105. Jorissen et al. (1993) find that HR 1105 does not have a circumstellar shell using infrared colors as it does not show the proper deviations from the values expected from a photometric black body. Shcherbakov & Tuominen (1992) obtained spectra of HR 1105 near He I $\lambda 10830$. The primary red giant produces a 50 km s^{-1} isotropic wind which is observed in line absorption. The He I emission originates near the inner Lagrangian point of the system. Mass flows toward the secondary with a velocity of 5 km s^{-1}.

2. Photometry

With the 0.75-m Four College Automated Photoelectric Telescope on Mt. Hopkins, AZ, differential photometry of HR 1105 was obtained with Johnson B and V and Cousins R and I filters. The pattern of observing was to measure the dark count and then in each filter the sky-ch-c-v-c-v-c-v-c-ch-sky where sky is a reading of the sky, ch that of the check star, c that of the comparison star, and v that of the variable star. The instrumental magnitudes are given in Table 1 along with means and their standard deviations for each year. The comparison star was HD 23089 (= HR 1129, V = 4.80, spectral type G0 III+A3 V) and the check star HD 23005 (= HR 1124, V= 5.80, spectral type F0 IV). Both stars are sufficiently non-variable for differential photometry as the standard deviations for the ch-c values are about 0.01 mag. for each filter. Further Hipparcos photometry (ESA 1997) shows that the mean magnitudes, standard errors,

Send offprint requests to: S.J. Adelman

* Table 1 is only available in electronic form at the CDS via anonymous ftp to cdsarc.u-strasbg.fr (130.79.128.5) or via http://cdsweb.u-strasbg.fr/Abstract.html

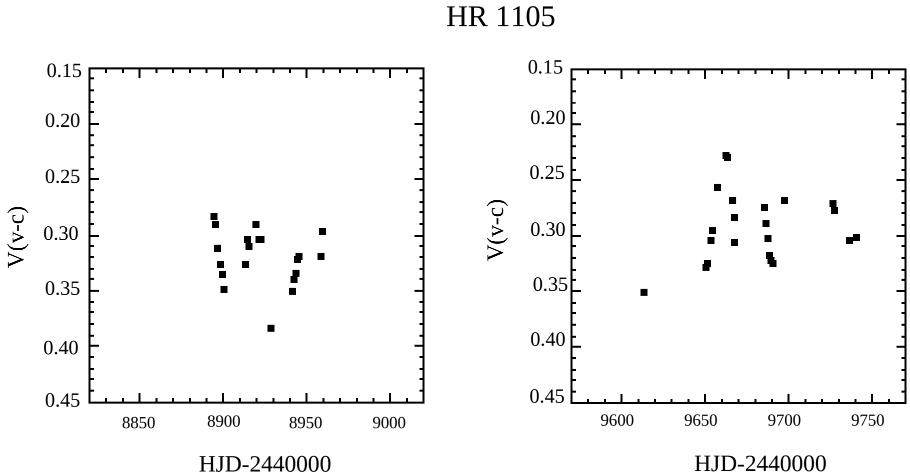

Fig. 1. V(v-c) photometry of HR 1105 for the fall 1992/winter 1993 observing season (left) and for the fall 1994/winter 1995 season (right).

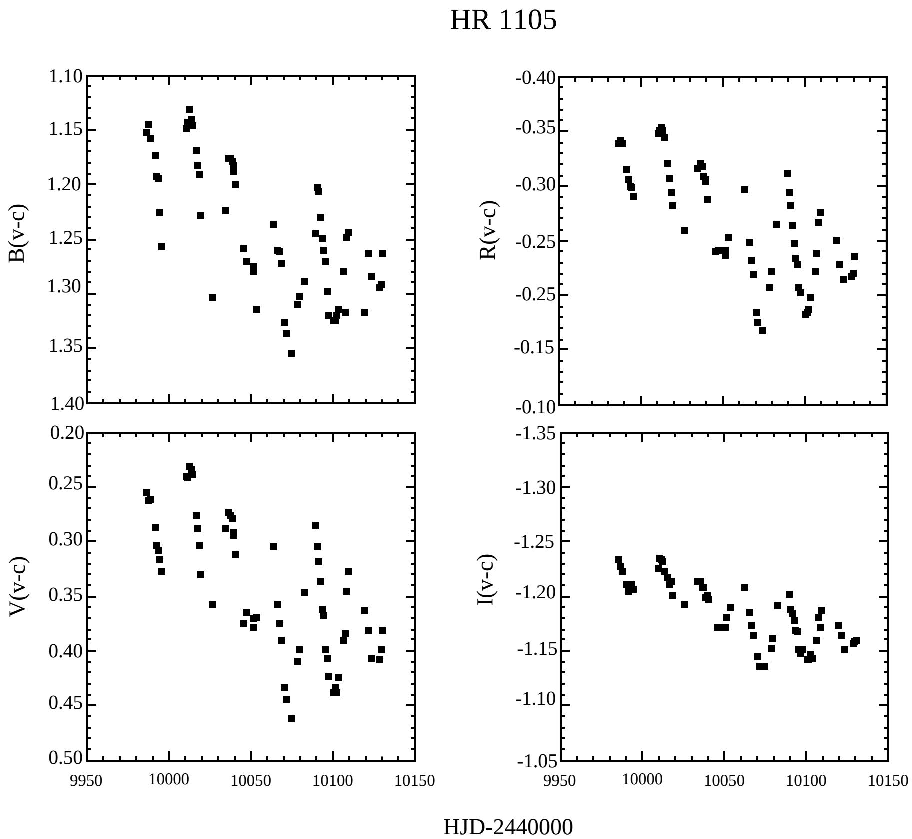

Fig. 2. BVRI(v-c) photometry of HR 1105 for the fall 1995/winter 1996 observing season.

and amplitudes (taken to be the difference between the 95 th and 5 th percentile values) in magnitudes are respectively: 5.0956, 0.0035, and 0.10 for HR 1105; 4.9220, 0.0005, and 0.02 for HD 23089, and 5.8718, 0.0007, and 0.03 for HD 23005.

Six 20, 9, 22, and 63 high quality observations were obtained respectively in the fall 1991/winter 1992, fall 1992/winter 1993, fall 1993/winter 1994, fall 1994/winter 1995, and fall 1995/winter 1996 observing seasons. There is clear evidence in the last data set of a 25 day period. I used Fullerton's IDL implementation of the Scargle periodogram (Scargle 1982, Horne & Baliunas 1986) to refine the period to 24.76 days. It is extraordinary that a 0.25 magnitude variation in V in a star as bright as this has not been documented. Comparisons between different years suggest that the 24.76 day period might be slightly variable.

Fig. 1 shows the fall 1992/winter 1993 (left panel) and fall 1994/winter 1995 (right panel) V photometry. This is similar to the fragmentary photometry of other extrinsic S stars. Fig. 2 shows the more complete data obtained during fall 1995/winter 1996. The photometry consists of a series of maxima superimposed on a variable background. The variations in B, V, R, and I are in phase. The B and V magnitudes have similar amplitudes with that for R being smaller and I being even smaller. Fig. 3 shows as an example of the ch-c star values those for V in fall

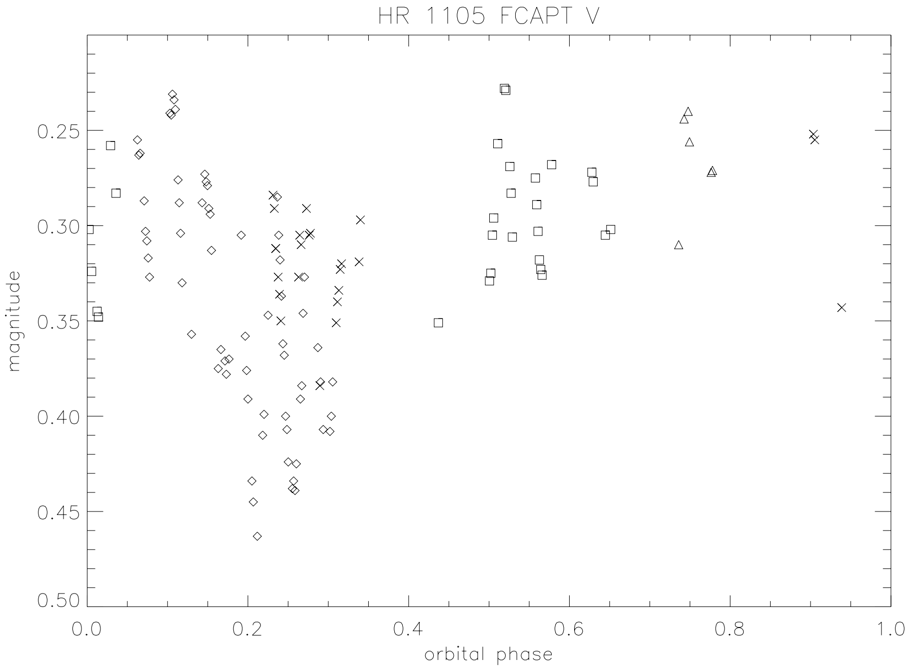

Fig. 4. V(v-c) photometry plotted against orbital phase according to the ephemeris 2442794 + 596.21E. Values from orbit 10 are indicated by open triangles, from orbit 11 by x's, from orbit 12 by open squares, and from orbit 13 by open diamonds.

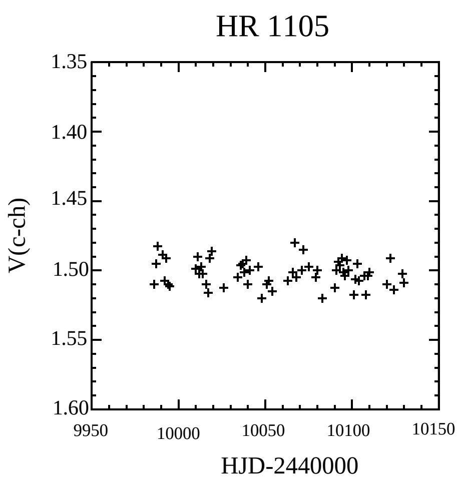

Fig. 3. The V(ch-c) photometry for the fall/winter 1996 observing season plotted to the same scale as that for V(v-c). No trend is seen with time.

1995/winter 1996. There is no trend with date for the photometric differences while in Fig. 2 the V (v-c) data (lower left diagram) shows dramatic changes.

Fig. 4 shows the V photometry plotted against orbital phase according to the ephemeris 2442794 + 596.21 E which corresponds to Griffin (1984)'s orbital solution. Values from orbit 10 are indicated by open triangles, from orbit 11 by x's, from orbit 12 by open squares, and from orbit 13 by open diamonds. There are some suggestions that the 24.76 day variations are not commensurate with the orbital period. The fall 1992/winter 1993 and fall 1995/winter 1996 values in the region of orbital phase overlap have similar v-c values, but they do not form a single light curve. More complete orbital coverage is desirable especially for phases 0.4 to 0.0.

Observations from the Hipparcos satellite have recently become available (ESA 1997). The Hipparcos photometry has smaller errors than the Tycho photometry. Fig. 5 shows the Hipparcos magnitudes for HR 1105 plotted against orbital phase. This photometry does not randomly sample the 24.76 day period. Values from orbit 9 are indicated by + signs, from orbit 10 by open triangles, and from orbit 11 by x's. In the regions of this diagram where there are values from different orbits, they do not fall on top of one another which confirms that the two periods are not commensurate.

In Fig. 4, there is apparently a broad dip near phase 0.25 which is close to the time of transit of the companion in front of giant which occurs near phase 0.33 of the current ephemeris. Fig. 5 may show the same effect. However, the different phase coverages and bandpasses of the two data sets make comparison tricky.

3. Discussion

The 24.76 day period is more evident in B and V than I with R intermediate. The usual explanation of the variability of M giants is in terms of pulsations. The spectral type of HR 1105 primary is M3 III. Such stars are small amplitude red variables (SARV) (Percy et al. 1996) with time scales of 20-200 days. The 1992/1993 data is not particularly affected by the long term variations. If we use the standard deviation σ_v = 0.023 mag, the variations fit the trend found by Jorissen et al. (1997) for late K-early M stars.

If one looks at Figs. 1, 2, and 3 and tries to extract the peak-to-peak amplitude, excluding longer term variability, then the results range from 0.10 to 0.16 mag. As the photometry may not have recorded the extrema, these values may be underestimates. But, the uncertainties in the data act in the other sense. Cristian et al. (1995) found that stars with its period should have pulsational

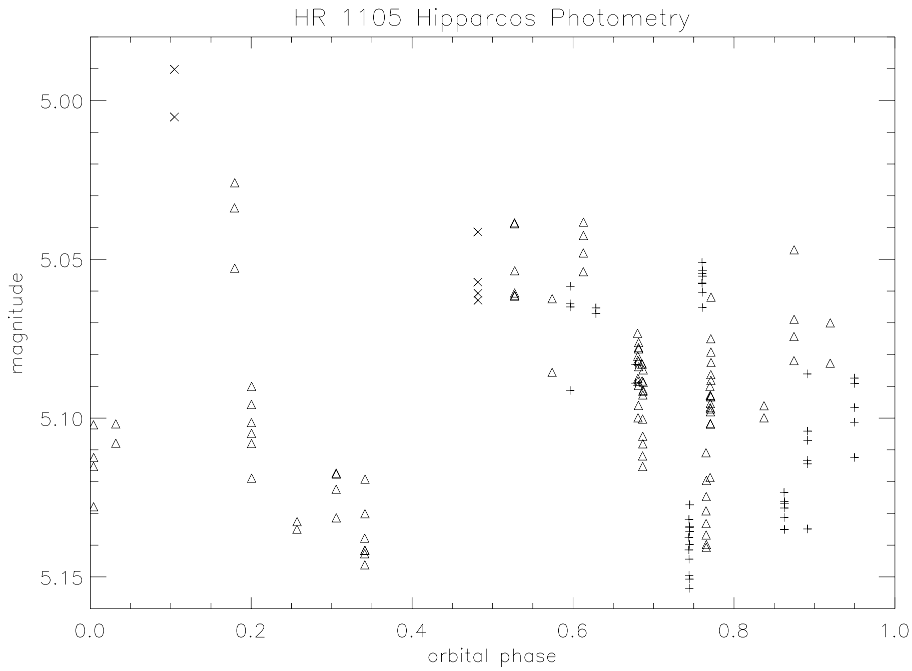

Fig. 5. Hipparocs photometry plotted against orbital phase according to the ephemeris 2442794 + 596.21E. Values from orbit 9 are indicated by + signs, from orbit 10 by open triangles, and from orbit 11 by x's.

peak-to-peak amplitudes about 0.10 mag. (see also Percy et al. 1994).

The published fragmentary photometry of other binary S stars probably can be understood in terms of the more complete data for HR 1105. Pulsationally induced variability of order 30 days is superimposed upon variability with a longer orbital period. What is needed is more extensive measurements of HR 1105 and other S stars to determine the class properties which will enable more complete tests of the models for such systems. For example in this regard, there is is a similarity of orbital modulation between HR 1105 and the barium system HD 46407 (Jorissen 1994, 1997). In the later case they correspond to a general fading of the system associated with its reddening for a substantial fraction of the orbital system near the time when the companion transits in front of the giant.

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