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HD 35155: The first eclipsing binary S star (P=642 days)

1. Binarity: a key property of chemically peculiar red giants

Binarity is a characteristic property of peculiar red giants like barium or Tc-deficient S stars (McClure et al. 1980, McClure 1983, Jorissen & Mayor 1988, Brown et al. 1990, McClure & Woodsworth 1990, Jorissen & Mayor 1992). Since their companions systematically appear to be white dwarfs (WD; Böhm-Vitense et al. 1984, Webbink 1986, McClure & Woodsworth 1990), the asymptotic giant branch progenitor of that WD is believed to have polluted the present red giant through mass transfer in a former evolutionary state of the binary system (e.g. Boffin & Jorissen 1988). In the present state of the system, the wind off the cool-giant primary may interact with the WD companion, as indicated by UV and IR (HeI λ10830) spectra of several S stars (see Johnson 1992 for a review). Given the similarities between the orbital elements of S and symbiotic stars (Jorissen 1992), it is in fact surprising that binary S stars do not show more conspicuous features of symbiotic stars, like emission lines in the visible part of the spectrum or outbursts. Johnson & Ake (1989) suggested that ER Del (=BD+8°4506) may be the first example of a symbiotic S star[1], since emission lines are not only found in the UV but also at Hα. Moreover, Ake et al. (1991; AJA91) showed that the S star HD 35155 behaves in the UV very much like a symbiotic system, with high-excitation emission lines (CIV, NV,...) and a variable continuum. This similarity is further strengthened by the results of the *uvby* monitoring of HD 35155 reported in the present short note, which confirms the suggestion by AJA91 that HD 35155 is an eclipsing-binary system.

2. Long-term photometric monitoring of the S star HD 35155

The S4,1 star HD 35155 ($V = 6.91$, $b - y = 1.17$) has been monitored since 1988, along with other peculiar red giants, in the framework of the ***Long-Term Photometry of Variables*** (LTPV) program (Sterken 1983) operating at ESO. All measurements will be published in the second LTPV catalog (see Manfroid et al. 1991a for the first one, which also gives details on the observations and the reduction procedures).

The comparison stars HR 1784 (G8III, $V = 4.14$, $b - y = 0.58$) and HD 37828 (K0, $V = 6.87$, $b - y = 0.73$), hereafter referred to as A and B, respectively, were used. Our differential photometry has good internal accuracy over long time spans, yielding a standard deviation of differential magnitudes and colors that amounts to only 0.005 mag over 4 years.

Figure 1 presents the differential y lightcurve of HD 35155, as a function of orbital phase computed from the orbital elements derived by Jorissen & Mayor (1992). An eclipse is visible around phase 0.13, in agreement with the spectroscopic ephemeris predicting the time of minimum light at phase 0.14 (±0.06). From the depth of the eclipse ($\Delta y \sim 0.14$) and from the magnitude $V = 7.0$ of the S star during eclipse, follows $V = 9.2$ for the magnitude of the eclipsed body. This corresponds to an absolute magnitude of about −1, since $M_{\rm bol} \sim -3$ for the S star (Eggen 1972; we assumed similar bolometric corrections). If that light were to originate from the photosphere of the companion, the latter should either be a hot main-sequence star, or a red giant. The former hypothesis is rejected on the basis of the small mass function derived for the system (Jorissen & Mayor 1992). A giant companion, on the other hand, could never account for the strong variations in the far UV continuum that were observed by

[1]not to be confused with S-type symbiotics, exhibiting photospheric IR colors at variance with D-type symbiotics which are dominated by dust emission in the IR

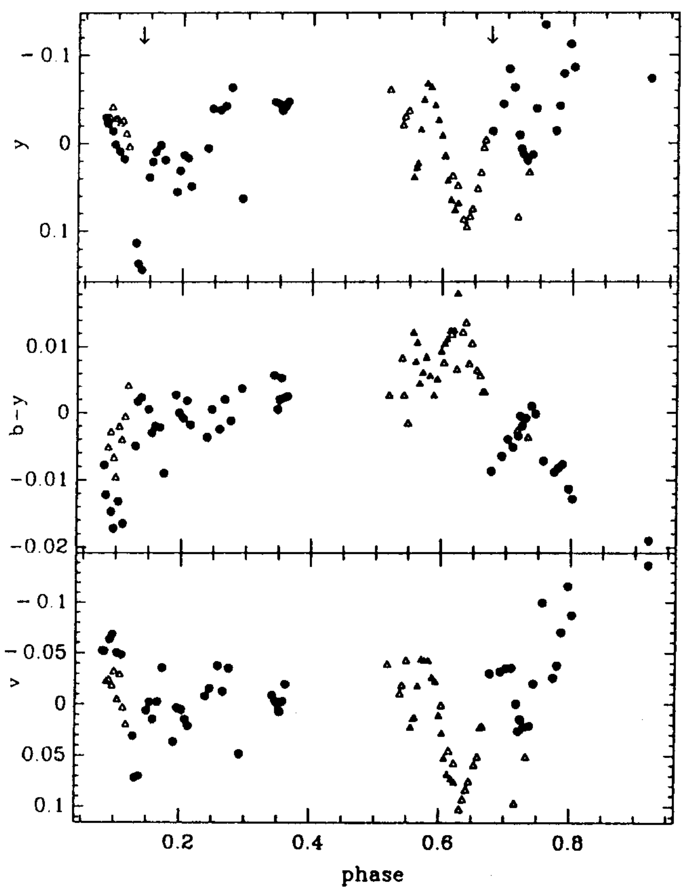

Figure 1: The y, $b-y$ and v differential (P-(A+B)/2) lightcurves of HD 35155 as a function of orbital phase. The orbital elements (P = 642 d, e = 0.07, ω = 214°, T = 2 445 494) are from Jorissen & Mayor (1992). Filled triangles correspond to the first cycle observed, whereas open triangles and dots respectively refer to cycle 2 and cycle 3. Magnitudes are plotted with respect to their average value over the whole monitoring. The arrows in the upper panel correspond to the spectroscopic ephemeris for eclipse and transit.

AJA91. In fact, *the eclipse is also present in the far UV*: among all IUE spectra obtained by AJA91, those corresponding to phases 0.09 and 0.13 (taken on August 5 and September 1, 1983, respectively) are the ones with the weakest continuum. It is thus beyond doubt that HD 35155 is an eclipsing binary system, with the eclipsed light being emitted close to the (WD) companion interacting with the giant's wind. The radial velocity V_2 of the UV CIII] and SiIII] lines observed by AJA91 suggests that these lines are tied to the companion ($V_2 \sim 60$ km s^{-1} at phase 0.46 while $V_1 = 86.3$ km s^{-1} and $V_0 = 79.7$ km s^{-1}, where indices 0, 1 and 2 respectively refer to velocities of the system, the giant star, and the companion). A mass ratio $M_1/M_2 = (V_0 - V_2)/(V_1 - V_0) \sim 3.0$ follows. Combining this value with the mass function of 0.028 $M_\odot$ derived by Jorissen & Mayor (1992) yields the relation $M_2 \sin^3 i = 0.45$ $M_\odot$. The eclipsing nature of the system requires in turn that $\sin i \geq 0.9$, so that $0.45 \leq M_2(M_\odot) \leq 0.6$. This analysis thus provides strong evidence that the companion is indeed a WD. Moreover, a mass $1.3 \leq M_1(M_\odot) \leq 1.8$ is derived for the S star, confirming the suggestion by Jorissen & Mayor (1992) that Tc-deficient S stars are *low-mass* stars on their way to the He-flash. These parameter values then yield $1.8 \leq A(\mathrm{AU}) \leq 2.0$ for the semi-major axis of the system. Assuming that the eclipsed light originates from a point source (AJA91 derive 4 $R_\odot$ for the CIII] emitting volume), the eclipse duration (≤ 0.04 in phase) implies that the S star has a radius of the order of 50 to 150 $R_\odot$, in agreement with the value of 100 $R_\odot$ deduced by AJA91 from the effective temperature and luminosity. The S star then lies well within its Roche radius ($R_1/R_{R,1} \sim 0.3$ to 0.7).

The spectral index of the eclipsed light implied by our *uvby* measurements appears rather surprising. A flux of 7.7 10^{-13} erg cm^{-2} s^{-1} Å^{-1} at 5500 Å follows from the magnitude $V = 9.2$ derived above and the absolute calibration of the Strömgrem photometry (taken from Lamla 1982). This flux is actually *larger* than the UV continuum observed by AJA91 (about 5 10^{-14} erg cm^{-2} s^{-1} Å^{-1} at 2000 Å) and does not fit the $f_\lambda \sim \lambda^{-1}$ law derived from that UV continuum. Moreover, the eclipse is equally deep in the y and b bands, but vanishes in the v band (Fig. 1). At 2000 Å, it is deep again, amounting to about 0.75 mag, as derived from the IUE fluxes during and outside eclipse.

Contrarily to Eggen (1972), who finds HD 35155 to be constant at the 0.1 mag level in V, our monitoring reveals variations outside eclipse as well. It is not clear yet whether these variations are caused by a pulsation of the stellar envelope, or whether they are related to the interacting nature of the binary system. The latter hypothesis is supported by the correlation between the visual magnitude measured by IUE and the level of UV activity reported by AJA91. Finally, there is a slight indication that the system looks redder when it is fainter (Fig. 1), a characteristic also seen in the case of the eclipsing-binary barium star HD 46407 (Jorissen et al. 1991).

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3. References

Ake, T.B., Johnson, H.R., Ameen, M.M., 1991, ApJ 383, 842 (AJA91)

Boffin, H.M.J., Jorissen, A., 1988, A&A 205, 155

Böhm-Vitense, E., Nemec, J., Proffitt, Ch., 1984, ApJ 278, 726

Brown, J.A., Smith, V.V., Lambert, D.L., Dutchover, E.Jr., Hinkle, K.H., Johnson, H.R., 1990, AJ 99, 1930

Eggen, O.J., 1972, ApJ 177, 489

Johnson, H.R., 1992, in: Evolutionary processes in interacting binary stars (IAU Symp. 151), eds. Y. Kondo, R. Polidan & R. Sistero, Dordrecht, Kluwer, in press

Johnson, H.R., Ake, T.B., 1989, in: Evolution of Peculiar Red Giants (IAU Coll. 106), eds. H.R. Johnson & B. Zuckerman, Cambridge U.P., p. 371

Jorissen, A., 1992, in: Late stages in the evolution of close binary systems (XIIIe Journée de Strasbourg), ed. G. Jasniewicz, Observ. de Strasbourg, in press

Jorissen, A., Mayor, M., 1988, A&A 198, 187

Jorissen, A., Manfroid, J., Sterken, C., 1991, The Messenger 66, 53

Jorissen, A., Mayor, M., 1992, A&A, in press

Lamla, E., 1982, in: Numerical Data and Functional Relationships in Science and Technology, Landolt-Börnstein, Group VI, vol. 2b, Springer, Berlin, p.59

Manfroid, J., Sterken, C., Bruch, A., Burger, M., de Groot, M., Duerbeck, H., Duemmler, R., Figer, A., Hageman, T., Hensberge, H., Jorissen, A., Madejsky, R., Mandel, H., Ott, H., Reitermann, A., Schulte-Ladbeck, R., Stahl, O., Steenman, H., vander Linden D., Zickgraf, F.-J., 1991a, First Catalogue of Stars Measured in the Long-Term Photometry of Variables Project (1982 – 1986), ESO Scientific Report No. 8

McClure, R.D., 1983, ApJ 268, 264

McClure, R. D., Fletcher, J.M., Nemec, J.M., 1980, ApJ 238, L35

McClure, R.D., Woodsworth, A.W., 1990, ApJ 352, 709

Sterken, C., 1983, The Messenger 33, 10

Webbink, R.F., 1986, in: Critical Observations vs Physical Models for Close Binary Systems, eds. K.C. Leung and D.S. Zhai, New York, Gordon and Breach, p. 403