Photometric Analysis of Two Contact Binary Systems: USNO-A2.0 1200-16843637 and V1094 Cassiopeiae

Surjit S. Wadhwa
Astronomical Society of New South Wales, Sydney, NSW, Australia; surjitwadhwa@gmail.com

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Abstract Ground-based photometry of two contact binary systems—USNO-A2.0 1200-16843637 and V1094 Cas—was analyzed using the Wilson-Devinney method. Both systems were found to be A-Type, with the smaller star being significantly cooler. Both systems show complete eclipses with good physical contact and almost identical mass ratio of approximately 0.23.

1. Introduction

The W Ursae Majoris (W UMa) group of short-period contact eclipsing binaries are important test beds for theories of stellar evolution. Numerous new contact systems have been discovered recently through automated sky survey programs and dedicated observing efforts using small telescopes. Quite a large percentage of the new discoveries remain largely un-analyzed even though data are of sufficient quality to yield at least basic physical information. In previous papers published in this journal I have demonstrated how analysis of survey or small telescope observations of contact binary stars for which little other information is available can yield a satisfactory photometric solution (Wadhwa 2004, 2017). In this paper I present photometric solutions for two such neglected contact systems.

USNO-A2.0 1200-16843637 (R.A. 21^{h} 01^{m} 53.0^{s}., Dec. +34° 25' 02" (2000)) was recognized as a contact binary system by Kryachko *et al.* (2010) with a magnitude range of 0.46 and period of 0.316 day. Approximately 130 observations (available from the website of the cited journal) extending over most of the cycle were available for analysis. Data available in the SIMBAD database would suggest a B–R of 0.7 magnitude corresponding to an effective temperature of 6500 K (Popper 1980).

V1094 Cas (R.A. 01^{h} 20^{m} 23.0^{s}., Dec. +59° 17' 15.7" (2000)) was reported as a contact binary variable by Hambálek (2008) and detailed photometry obtained by Virnina *et al.* (2012; all photometric data are available on the website of the cited journal). They reported a magnitude range of 0.47 and period of 0.514 day. The photometric data are extensive, extending over several years with several different telescopes. To limit the extent of possible errors only the R-band photometry carried out in 2009 was used in the current analysis as this was carried out over a relatively short period and included data over most of the phase cycle. Even so, nearly 1,800 data points were available, and these were binned along the entire phase cycle to yield a more manageable 180-point normalized observed light curve. The normalized curve was used in the analysis. Data available in the SIMBAD database would suggest a J–H of 0.21 magnitude, corresponding to an effective temperature of 6250 K (Popper 1980; Yoshida 2010).

2. Light curve analysis

Light curve analysis was carried out using the Wilson-Devinney code as included in the Windows-based software supplied by Bob Nelson through the Variable Star South website (Nelson 2009). In each case the available data indicated a probable convective envelope, therefore gravity brightening was set at 0.32 and bolometric albedos were set at 0.5. Black body approximation was used for the stars' emergent flux and simple reflection treatment was applied. VanHamme (1993) limb darkening coefficients were used as included in the Bob Nelson software package. The maximum magnitude of the stars is not well known, therefore the photometric data were normalized to the mean magnitude between phases 0.24 and 0.26 in each case. This methodology has previously been applied to the analysis of All Sky Automated Survey and ground-based amateur observations (Wadhwa 2004, 2005).

The mass ratio of a contact binary system is usually determined by radial velocity studies. The mass ratio is then used to determine other features of the system such as the inclination, degree of contact, and temperature variations. However, where radial velocity data are not available, under certain circumstances, such as when the system exhibits at least one total eclipse, the Wilson-Devinney (Terrell and Wilson 2005) method can be sucessfully employed, as the parameter space is well constrained by the presence of the total eclipse and the best fit solution is quickly obtained. As both the systems have a clear well-defined total eclipse, rather than using the tedious grid method to find a starting point for the final iterations, the light curve part of the software, along with direction from Anderson and Shu's (1979) theoretical atlas of contact binary light curves, a very good visual fit was quickly obtained through simple trial and error. For the final iterations, it is well known that the mass ratio as a free parameter when combined with inclination and the potential of the star can lead to strong correlation between the parameters. However, the problem can be solved using multiple subsets in sequence (Wilson and Biermann 1976). The free parameters were divided into two subsets as follows: $\{q, L_1\}$ and $\{i, T_2, \Omega\}$, and iterations were carried out until the error of a parameter was greater than the estimated correction.

3. Individual systems

3.1. USNO-A2.0 1200-16843637

As noted above, this system has an effective temperature of 6500 K (based on SIMBAD database). The visual estimation of the approximate mass ratio was 0.25, cooler smaller star with high fillout of 0.5 and high inclination exceeding 80°.

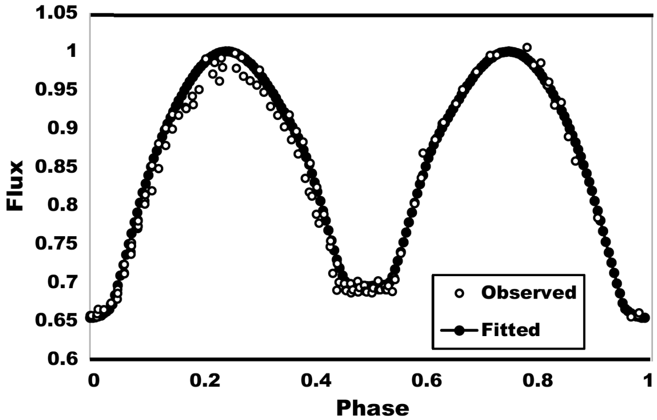

Figure 1. Observed and fitted curve for USNO-A2.0 1200-16843637.

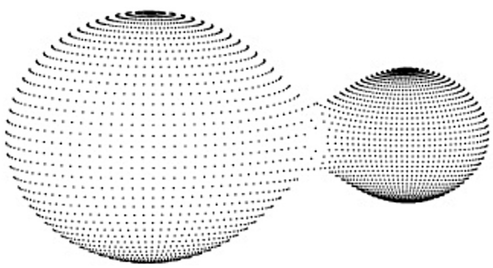

Figure 2. 3D representation of USNO-A2.0 1200-16843637.

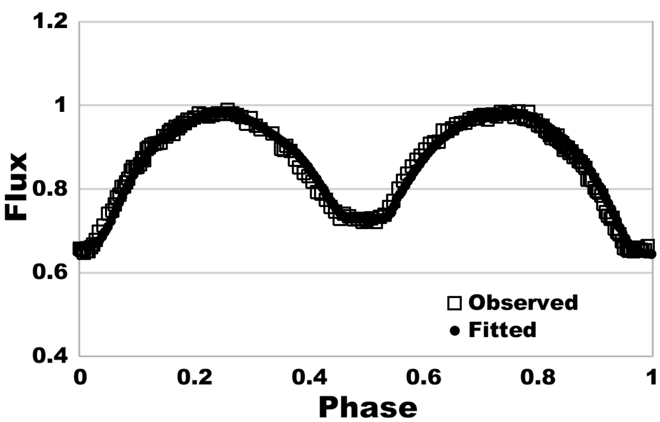

Figure 3. Observed (open squares) and Fitted (solid line) for V1094 Cas.

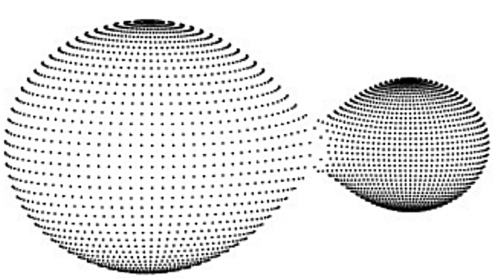

Figure 4. 3D representation of V1094 Cas.

Table 1. Basic photometric elements for USNO-A2.0 1200-1684363.

Parameters	*Value*
T_2	6243 K ± 55 K
Inclination (i)	83.7° ± 1.3°
Potential (Ω)	2.25 ± 0.02
Mass Ratio (q)	0.236 ± 0.003
Fillout	48%

Table 2. Basic photometric elements for V1094 Cas.

Parameters	*Value*
T_2	5568 K ± 51 K
Inclination (i)	80.6° ± 1.7°
Potential (Ω)	2.275 ± 0.02
Mass Ratio (q)	0.235 ± 0.007
Fillout	30%

With these starting parameters the differential correction part of the Wilson-Devinney code was carried out using multiple subsets alternatively, as described above. The results of the best fit are summarized in Table 1 and the curves and three-dimensional representation (Bradstreet 1993) are shown in Figures 1 and 2, respectively. It is clear the system is an A-Type W UMa star with a cooler smaller star in poor thermal contact. There is, however, good physical contact between the stars with a fillout ratio of 0.48.

3.2. V1094 Cas

As noted above, this system has an effective temperature of 6250 K (based on SIMBAD database). The visual estimation of the approximate mass ratio was 0.20, cooler smaller star with mid-range fillout of 0.25 and high inclination exceeding 75°. With these starting parameters the differential correction part of the Wilson-Devenny code was carried using multiple subsets alternatively, as described above. Even after the differential corrections had achieved the best fit the visual inspection suggested the entire curve was slightly out of phase. The differential correction was again run using the previously obtained best solution, but with the phase being the only correctable parameter. This resulted in a significant improvement in the fit. The phase correction required was –0.104. This is likely due to the select normalized curve being folded based on the ephemeris derived from the entire photometry set from multiple instruments over several years. The results of the best fit (after correcting the phase) are summarized in Table 2 and the curves and three-dimensional representation (Bradstreet 1993) are shown in Figures 3 and 4, respectively. It is clear the system is an A-Type W UMa star with a cooler smaller star in quite poor thermal contact. There is, however, reasonable physical contact between the stars with a fillout ratio of 0.30.

4. Conclusion

Photometric analysis using the Wilson Devinney code is presented for two almost identical systems, USNO-A2.0 1200-16843637 and V1094 Cas. Both systems are of A-Type and have a mass ratio of approximately 0.23, high inclination exceeding 80° with poor thermal contact but with good physical contact.

5. Acknowledgement

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