Highlights of Astronomy, Vol. 13
International Astronomical Union, 2003
O. Engvold, ed.

Contact Binaries of the W UMa Type as Distance Tracers

Slavek M. Rucinski

David Dunlap Observatory, University of Toronto P.O. Box 360, Richmond Hill, Ontario, Canada L4C 4Y6

Contact binary stars of the W UMa-type (also known as W) are unique objects: The luminosity, produced almost exclusively in the more massive component is efficiently distributed through the common envelope so that the surface brightness is practically identical over the whole visible surface of the binary. Mass ratios are known to span the whole wide range, from almost unity to very small values, as small as $q = 0.066$. Typically, the primary component provides the luminosity, while both components provide the radiating area. The range of the primary masses is moderate and corresponds to Main Sequence spectral types from middle A to early K and roughly maps into the orbital-period range of about 1.5 days to 0.22 days.

With their special properties, the contact binaries of the W UMa type form a distinct group of objects, very easy to find and identify in massive stellar variability programs, even in short-duration ones, thanks to the short orbital periods and large amplitudes of photometric variations. Contact binaries are not as convenient as detached binaries for distance determinations. Although described by fewer parameters than detached binaries, they have more complex geometry. Thus, the contact binaries are more like pulsating stars and – with still many uncertainties about their structure and adherence to the strict Roche model – do require empirical luminosity calibrations.

The rationale for the existence of a period - luminosity relation is based in the strong geometric constraints imposed by the common equipotential envelope which permit to consider an equivalent of the $Q = P\sqrt{\rho}$ relation for contact binary systems. By defining the mean density of the whole configuration, $\rho = (M_1 + M_2)/V$, by eliminating a^3 using the Kepler law and by expressing the quantities in familiar units, one obtains the "pulsation equation", $P\sqrt{\rho} = Q(q,F) = \sqrt{0.079/v(q,F)}$, with P in days and ρ in g/cm^3 (q is the mass ratio and F characterizes the degree of contact, $F = 0$ for inner contact at L_1 and $F = 1$ for outer contact, opening up at L_2). The similarity of contact binaries to pulsating stars is not accidental as the underlying physical time scale, of the pulsation or of the orbital revolution, is the same familiar dynamical time scale.

The full calibration equation:

$$\begin{aligned} M_V &= -10\log T_{eff} + B.C.(T_{eff}) - 10/3\log P \\ &\quad -5/3\log M_1 - 5/3\log(1+q) - 2.5\log s(q,F) + const \end{aligned}$$

can be simplified for situations when only photometric data are available to

$$M_V = C_1 * colour + C_2 \log P + C_3$$

https://doi.org/10.1017/S1539299600016233 Published online by Cambridge University Press

where *colour* is any of the available color indices. The currently best calibrations utilizing de-reddened $B - V$ and $V - I$ color indices are:

$$M_V = -4.44 \log P + 3.02\,(B - V)_0 + 0.12$$
$$M_V = -4.43 \log P + 3.63\,(V - I)_0 - 0.31$$

There are several sources of uncertainties in the current calibrations. The trigonometric parallaxes from the Hipparcos mission introduce errors typically < 0.25 mag. In addition, some of the binaries are unrecognized triple systems with an associated offset in brightness, loss in accuracy and even entirely false data for the parallaxes. The main source of errors is in the photospheric spots on individual binaries. These binaries are very active and almost always show spots. A brightness calibration must simply assume some sort of an average. When a simple mean weighted error is considered, then the deviations are characterized by $\sigma M_V \simeq 0.35$ mag. Monte–Carlo simulations indicate that within the main range of the applicability, the typical errors are $\sigma M_V \simeq 0.25$ mag.

As with any calibration for pulsating stars, one must establish the metallicity dependence of the period–color–luminosity relation. It has been found that there exists no discernible trend in the deviations from the predicted values of M_V as a function of [Fe/H]. Although the contact binaries with low metallicity content are structurally different than the disk population ones, there exists no need to introduce the metallicity corrections in M_V at the current level of accuracy. Population II contact binaries are bluer and smaller i.e. have shorter orbital periods then the disk–population Main Sequence systems, but the shifts in the color–magnitude diagram are practically horizontal in M_V. This is a preliminary result which must be checked again as the data become more accurate.

Since the M_V calibrations utilizing de-reddened color indices $B - V$ or $V - I$ and the periods can predict individual values to about ± 0.25 mag, about a thousand systems are needed to reduce the group uncertainty to the level of ± 0.01. Such large numbers will be discovered in the nearby galaxies once the surveys pass the threshold of $M_V \simeq 3 - 5$ which, for the Local Group typically corresponds to $V > 23 - 25$. The current calibrations involve de-reddened color indices and thus remain sensitive to the reddening corrections. The widespread availability of the K-band data suggests calibrations based on the $V - K$ or $I - K$ indices; this is a matter of the current work.