Binary Paths to Type Ia Supernovae Explosions
Proceedings IAU Symposium No. 281, 2011
R. Di Stefano, M. Orio, & M. Moe, eds.

doi:10.1017/S1743921312015025

Modeling of the IR Light Curves of the Symbiotic Recurrent Nova T CrB

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Abstract. We analyze the results of our IR photometric monitoring of T CrB during 1987-2003 and describe the ellipsoidal variability of the Roche lobe filling cool component. We obtain limits to the binary inclination of $i \in [50, 60]$ deg and binary mass ratio $q \in [0.4, 2]$ (90 per cent confidence). The mass of the hot component is therefore 1.3-3 $M_\odot$. If the hot component of T CrB is a white dwarf, its mass will be near the Chandrasekhar limit.

Keywords. binaries: symbiotic — stars: individual (T CrB)

1. Observations

T Coronae Borealis is a recurrent nova which underwent two outbursts, one in 1866 and one in 1946. The double bump visible in the optical and IR light curves indicates that the giant of T CrB is tidally distorted (Kraft 1958; Yudin & Munari 1993).

Photometric JK observations of T CrB have been carried out with the 1.25-m telescope at the Crimean Station of the Sternberg Astronomical Institute during 1987 - 2003. The IR standard is BS 5947 ($J = 2.09$ mag, $K = 1.30$ mag). The observational errors do not exceed 0.02 mag.

2. Calculations

A theoretical light curve for a tidally distorted red giant was calculated in the frames of the classical model of the ellipsoidal variability (Tjemkes *et al.* 1986). According to the radial-velocity analyses, we assumed that the orbit of T CrB is circular. Each local surface of the red giant radiates as a black body with a temperature determined by Lucy's law for stars with convective envelopes (the mean temperature is equal to the effective temperature $T_{eff} = 3300\,K$). The J band is the most suitable band for approximation of a real red giant's energy distribution by black body radiation (Shahbaz *et al.* 1997). A non-linear limb-darkening law has been assumed and the coefficients have been interpolated from the tables of Claret for the temperatures on the local surfaces (Claret 2000). Figure 1 shows a convolution of the J light curve with a period $P(J) = 227.^d56$, which was searched by Kolpakov's program (http//infra.sai.msu.ru/prog/kolpakov).

In Figure 2 we plotted two areas of possible values for binary parameters (q, i) according to Fisher's distribution (dark grey – 75% confidence limit, light grey – 90% confidence limit). The lack of eclipses in the UV continuum observed with International Ultraviolet Explorer indicates that T CrB is not an eclipsing binary (Selvelli *et al.* 1992). The limits based on the lack of eclipses are shown in Figure 2 as a dashed line. The parameters (q, i) of T CrB must be below this curve. A reasonable limit to the mass of the red giant is $M_{giant} \geqslant 0.6\,M_\odot$ (the secondary can evolve to a giant during the lifetime of our Galaxy). Using the mass function derived by Fekel *et al.* (2000) we plotted the line corresponding to $M_{giant} = 0.6\,M_\odot$ (solid line). The dotted lines are the lines of the constant hot component masses (thick dotted line – $M_{hot} = 1.44\,M_\odot$).

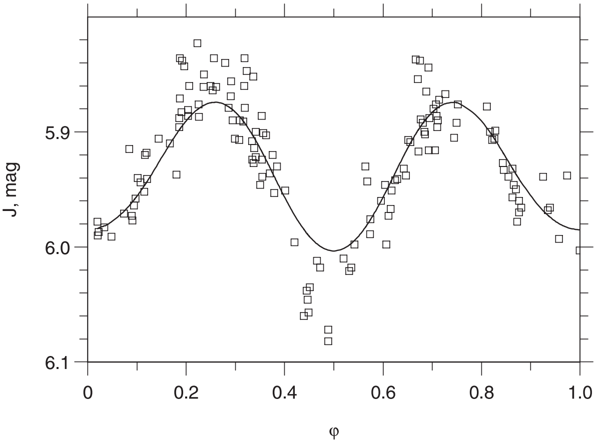

Figure 1. The J light curve of T CrB folded with orbital period $P = 227.^{d}56$ and the synthetic light curve for the model with $q = 0.5$, $i = 53$, $T_{eff} = 3300\,K$
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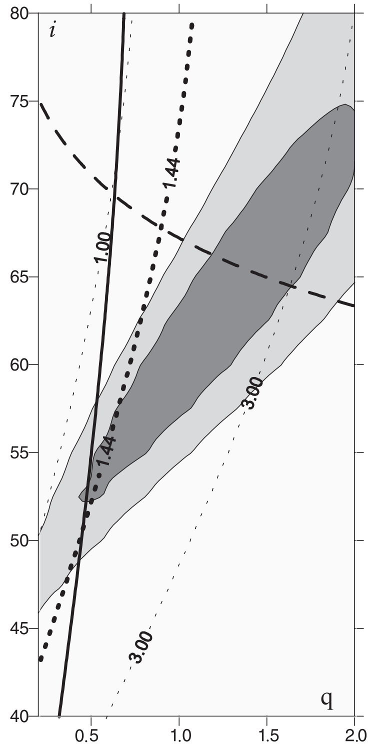

Figure 2. The parameter space diagram (q-i) for T CrB (dark grey – 75% confidence limit, light grey – 90% confidence limit). The solid line corresponds to $M_g = 0.6\,M_{\odot}$. The dashed line is the limit based on the lack of eclipses. The dotted lines are the lines of the constant hot component masses (thick dotted line is $M_h = 1.44\,M_{\odot}$).

From Figure 2 we conclude that, if the hot component of T CrB is a white dwarf its binary parameters will be $q \in [0.5, 0.8]$ and $i \in [52, 62]$. It should be noted that the hot component's mass is not less then $1.25 M_{\odot}$. Therefore, according to Iben & Tutukov (1996), T CrB can be considered as a real progenitor of a Type Ia supernova.

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https://doi.org/10.1017/S1743921312015025 Published online by Cambridge University Press