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ECLIPSE MAPPING OF RW Tri IN THE LOW LUMINOSITY STATE

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RW Tri is a bright well known eclipsing nova-like system. It was discovered in 1937 (Protitch, 1937). Walker (1963) determined the orbital period to be 5.57 h. Africano et al. (1978) found that eclipse timings demand that the ephemeris has a cyclic term with a period of 2777 or 4980 days. Different authors give different values of the system inclination angle i: 80° (Longmore et al. 1981), 82° (Frank & King 1981), 70.5° (Smak 1995). Frank & King (1981) found that the disc size is about $0.4a$ where a is the orbital separation.

Horne & Stiening (1985) performed the first eclipse mapping of the system. They found that the temperature of the inner part of accretion disc is about 40000 K. Also using the eclipse mapping technique, Rutten et al. (1992) determined the mass accretion rate to be $3{\cdot}10^{-8}$ $M_\odot$ year^{-1}.

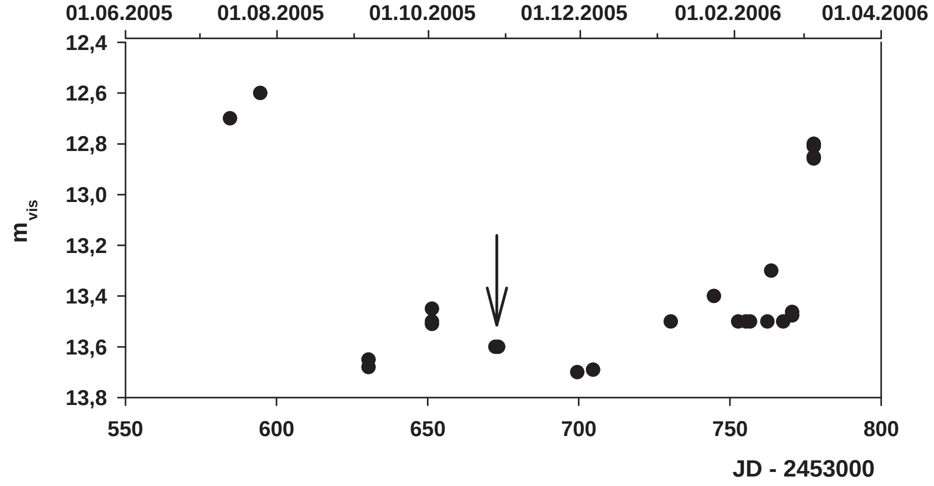

Figure 1. Fragment of the AAVSO visual light curve of RW Tri. Eclipse observations are marked with an arrow.

Poole et al. (2003) estimated the range for the primary and secondary stellar masses as 0.4 - 0.7 and 0.3 - 0.4 $M_{\odot}$ respectively. Groot et al. (2004) using spectral eclipse mapping found that the mass accretion rate is about 10^{-8} $M_{\odot}$ year^{-1}.

In our paper we used AAVSO observations of RW Tri, obtained by Keith Graham with a Meade LX200 f/10 12" telescope and SBIG ST-9E CCD camera in *V* band. The exposure duration is 70 sec and the read time for this CCD is less than 1 sec. Observations were obtained during the low luminosity state (Fig. 1) on October 10, 2005 (JD 2453672). The star out-of-eclipse brightness dropped from $12^{\rm m}\!.6$ to $13^{\rm m}\!.7$ visual magnitudes for about 150 days. There are no outbursts observed during this state although the time interval between AAVSO visual measurements was sometimes longer than 25 days. This shows that the accretion disc temperature is high enough even in low state to hold the hydrogen in the ionized state and to prevent the appearance of the outbursts (this situation is typical for nova-like stars).

The eclipse light curve is shown in Fig. 2. For our observations, the out-of-eclipse brightness of the system was $13^{\rm m}\!.74 \pm 0^{\rm m}\!.06$ and in the mid-eclipse the magnitude was $15^{\rm m}\!.83 \pm 0^{\rm m}\!.04$. There is a small effect of the hotspot presence on the post eclipse light curve (0.05 - 0.1 phase interval). The light curve before the eclipse does not show the typical hump usually associated with a bright spot. This feature appears in cataclysmic variables due to anisotropic radiation of the hot spot in the place where the accretion flow shocks the accretion disc. Apparently the outer part of accretion disc is optically thin and we can see the hotspot structure from most directions.

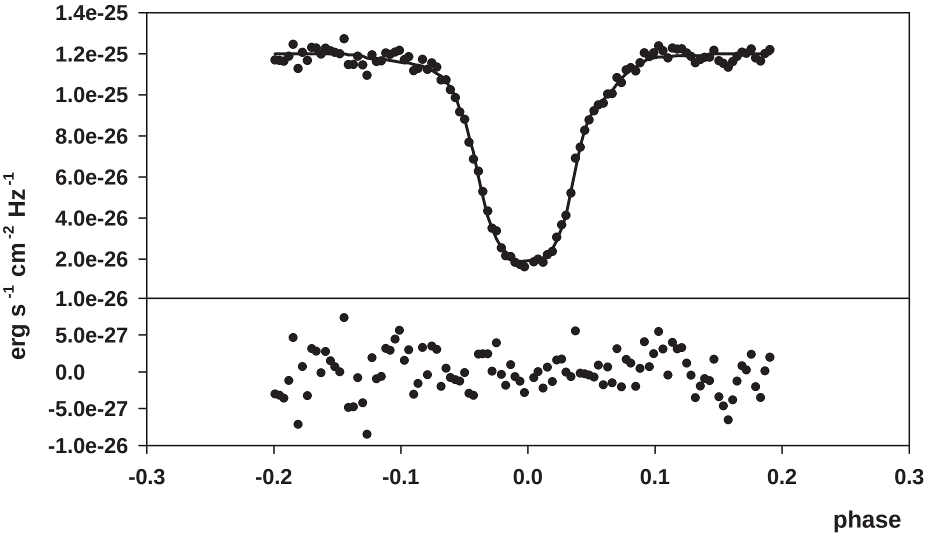

Figure 2. Top: normalized light curve of RW Tri and the model fit. Fluxes were calculated using zero magnitude absolute fluxes, determined by Bessel et al. (1998). Below: residuals for the fit. One can see that large amplitude residuals correspond to the flickering on out-of-eclipse parts of the light curve.

In this paper we used zero magnitude absolute fluxes, determined by Bessel et al. (1998) to prepare our observations for the eclipse mapping procedures.

We applied a genetic algorithm eclipse mapping technique (see Halevin, 2007 for detailed description) to calculate the eclipse map of the RW Tri accretion disc. In our modification the accretion disc brightness is modeled with a distribution of radiating points in the orbital plane inside the Roche lobe of the primary star. Our technique looks for an optimal spatial distribution of the points to fit the observed eclipse light curve. The system flux is reconstructed here by summing of the brightness of points visible at different phases.

To remove smooth orbital brightness variations we used a second-order polynomial approximation for the out-of-eclipse parts of the light curve. After that we divided the eclipse light curve by the approximation values and scaled the result with the polynomial value at zero phase.

In our models we used system parameters taken from Groot et al. (2004) ($M_{wd} = 0.7 M_\odot$, $M_{rd} = 0.6 M_\odot$, i=75°). Eclipse models for other system parameters estimates show either shifted or highly asymmetric accretion disc eclipse maps (Halevin & Henden, 2008).

One can see the normalized phase light curve of the eclipse with the fit and residuals in Fig. 2. To estimate the errors of our observations we calculated the scattering of the residuals in the eclipse time range where the flickering is not significant. The error value was obtained is σ_{me}=1.2·10^{-27} erg s^{-1} cm^{-2} Hz^{-1}. So in the mid-eclipse the signal-to-noise rate is about 15. Because the mid-eclipse and out-of-eclipse flux are f_{me}=2·10^{-26} and f_{oe}=1.2·10^{-25} erg s^{-1} cm^{-2} Hz^{-1} respectively, the error for the out-of-eclipse flux is $\sigma_{me}\sqrt{f_{oe}/f_{me}} \approx 2.94 \cdot 10^{-27}$ erg s^{-1} cm^{-2} Hz^{-1} and therefore has a signal to noise of ≈40.

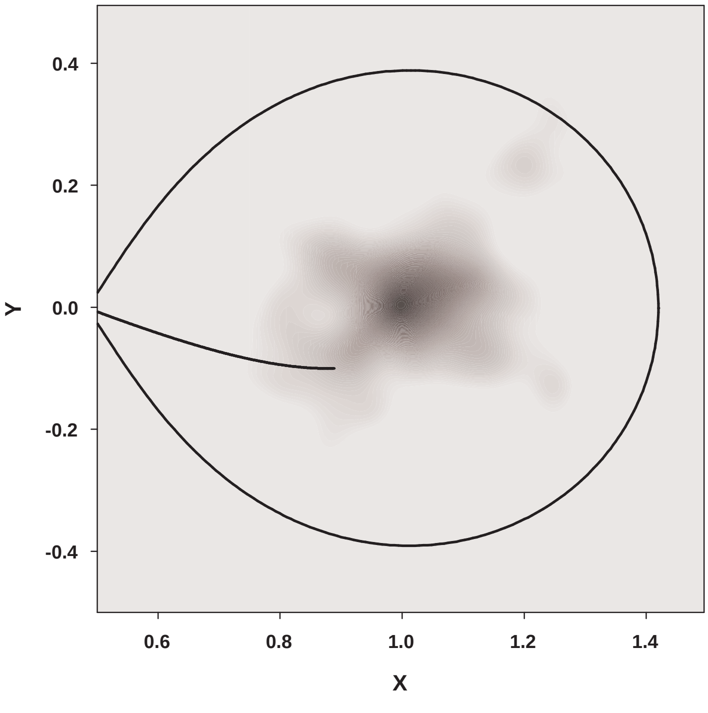

Figure 3. Eclipse map for the JD 2453672 light curve of RW Tri calculated for the system parameters $q = 0.86$ and $i = 75°$. The solid line is the ballistic trajectory of the accretion stream. Spatial coordinates are in orbital separation units.

To build the map of accretion disc we used a model with 300 radiating points. The corresponding smoothed map for the brightness distribution in the accretion disc is in Fig. 3. The solid line inside the Roche lobe shows a ballistic stream trajectory.

One can see that the brightest part of accretion disc is about $0.1a$ in radius and the hotspot distance is about $0.17a$. We consider this value as the real size of accretion disc.

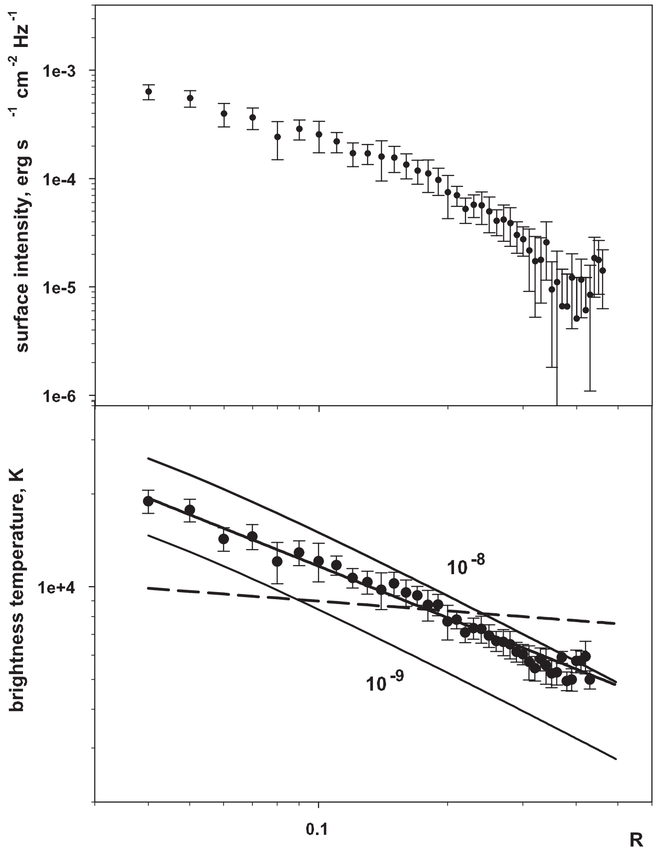

Figure 4. Azimuthally averaged radial intensity distribution in accretion disc for Fig. 3 eclipse map (top). Radial brightness temperature distribution in accretion disc. Solid lines are theoretical temperature distribution for steady state disc in the case of 10^{-8} and 10^{-9} M$_\odot$ year^{-1} mass accretion rate (bottom). Dashed line shows critical temperature above which gas is in steady accretion regime Warner (1995).

Trigonometric parallax determination with the Hubble Space Telescope gave a distance of 341 pc to RW Tri (McArthur et al. 1999). Using this distance estimate and the interstellar extinction $A_V = 7\overset{\mathrm{m}}{.}8\cdot 10^{-4}$ pc^{-1} was taken using the value for the nearest object from Neckel et al. (1980), we calculated the radial brightness temperature distribution in the disc and compared it with predictions of accretion disc models. In the case of the $A_V = 0$ one would obtain the temperature becomes about 13 percent lower. It shows the importance of the interstellar extinction accounting in our case.

In Fig. 4 the radial brightness temperature plot is shown. Here we compare the observed distribution with that predicted for steady state solutions for accretion rates of 10^{-8} and 10^{-9} solar masses per year. Our fit of the temperature distribution with that predicted from the steady state disc model gives the value $\dot{M} = (3.9 \pm 0.2)\cdot 10^{-9}$ M$_\odot$ year^{-1}. This result is close to that obtained from eclipse mapping by Rutten et al. (1992) value $\dot{M} = 3\cdot 10^{-9}$ M$_\odot$ year^{-1} (during the low luminosity state).

We fitted the observed temperature distribution with the function $T = T_0 R^{-b}$ and found $b = 0.56(\pm 0.01)$. Our estimate of parameter b is far from that predicted in the steady state model 3/4 value. From Fig. 4 one can see that the temperature distribution consists of two different parts: for R less than $0.14a$ and for R greater than this radius. If we fit these parts separately, we obtain values $b = 0.52 \pm 0.04$ for $R < 0.14a$ and $b = 0.74 \pm 0.03$ for $R > 0.14a$. This difference is typical for SW Sex type stars.

Our mass accretion rate estimate is less than that determined by the Horne & Stiening (1985) value of $\dot{M} = 10^{-7.9}$ $M_\odot$ year^{-1}, but during their observations the system was in the high luminosity state (V $\approx 12^{\mathrm{m}}.5$) and the authors used lower distance value to be 300 pc. According to their data the temperature in the disc does not drop below the critical value, above which gas remains in the steady state accretion regime, typical for classical nova-like systems.

The dashed curve in Fig. 4. shows the critical temperature level Warner (1995), calculated for the RW Tri system parameters. One can see that the temperature drops below critical value immediately after the hotspot distance and, hence, the most probable accretion disc radius. It is enough for the accretion disc to remain in the steady state.

Using eclipse mapping techniques we calculated the radial brightness temperature distribution. For inner parts of accretion disc the slope of this distribution is close to the $R^{-1/2}$ law. For outer parts the temperature distribution corresponds to a steady state $R^{-3/4}$ law. We estimated the mass accretion rate in the system as $\dot{M} = (3.9 \pm 0.2) \cdot 10^{-9}$ $M_\odot$ year^{-1}. Our results show that even during the low luminosity phase, disc remains in the hot steady state.

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