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MEASURING THE MASS RATIOS OF X-RAY TRANSIENTS FROM THE ROTATIONAL BROADENING OF THE SECONDARY STAR'S SPECTRUM

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We describe a new computer program for calculating the spectra of stars that fill their Roche lobes in close binary stars.

Soft X-ray Transients (SXTs) are interacting binary stars in which a compact star is stripping mass from a relatively-normal companion star (the secondary star). One step in the usual method for measuring the mass of the compact stars in these systems is to determine the mass ratio from the rotational broadening of the absorption lines in the spectrum of the secondary. With a few outstanding exceptions (e.g., Shahbaz 2003), the observations have typically been analyzed assuming that the observed spectrum can be modeled by convolving the spectrum of a non-rotating star with a line-broadening function appropriate for a rotating, spherical star. The results are often inadequate because 1) the profiles of the absorption lines vary strongly with orbital phase, and 2) the limb darkening differs from line to line so that no single broadening function can represent the behavior of all lines.

We have developed a new program LinBrod for calculating the spectrum of a star that fills its Roche lobe in a binary star. We assume that the photosphere of the star coincides with its Roche lobe and that it is rotating synchronously. The local surface gravity g is given by the gradient of the zero-velocity potential at the photosphere and the local effective temperature T_{eff} is given by the gravity-darkening law

$$T_{eff} = < T_{eff} > \left(\frac{|g|}{< |g| >} \right)^{\beta}, \qquad (1)$$

where the gravity darkening coefficient β is taken from Claret (2000).

We have calculated a grid of stellar atmospheres using the ATLAS 9 stellar atmosphere program (Kurucz 1993). We modified the spectral synthesis program MOOG 2002 (Sneden 2002) so that it produces specific intensities as a function of μ instead of integrated flux ($\mu = \cos\theta$, where θ is the angle of incidence), and have calculated specific intensities as a function of wavelength and μ for each atmosphere in the grid. LinBrod approximates the surface of the star by covering it with many flat tiles on which T_{eff} and g are constant. For each orbital phase LinBrod calculates the specific intensities emerging from each tile, Doppler shifts the intensities to the radial velocity of the tile, and then adds the intensities together to give the observed spectrum. An example of spectra calculated by LinBrod is shown in Figure 1.

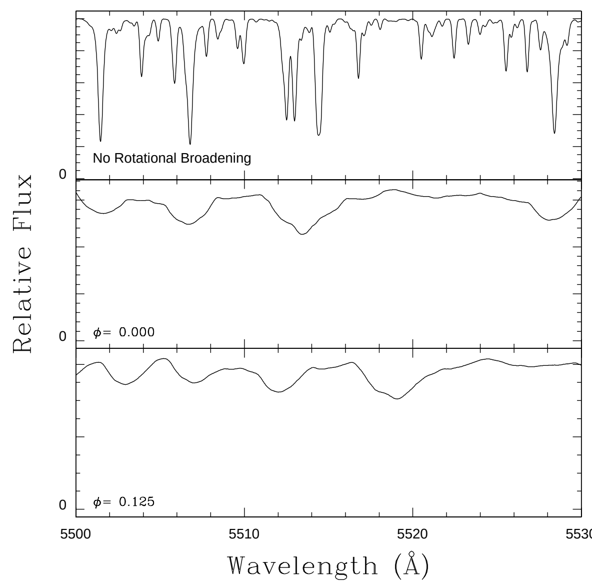

Fig. 1. Theoretical spectra calculated with LinBrod. The top panel shows the spectrum calculated for a non-rotating single star with $T_{eff} = 4500$ K and $\log g = 4.3$. The two bottom panels show the spectrum calculated for a lobe-filling star with the same effective temperature and gravity, and with $K_2 = 433$ km/s, $i = 45°$, and $q = 0.067$, values appropriate for the secondary star in the SXT V616 Mon (Marsh et al 1994). The spectrum is shown for two orbital phases.

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