64. Assessing the sensitivity of atmosphere fits to accretion disc spectra

Martin D. Still, Keith Horne

*Physics and Astronomy, University of St. Andrews, North Haugh, St. Andrews, Fife KY16 9SS, U.K.*

Ivan Hubeny

*Laboratory for Astronomy and Solar Physics, NASA Goddard Space Flight Centre, Greenbelt, MD 20771, U.S.A.*

**Abstract.** By applying eclipse mapping to time-resolved spectrophotometry we "observe" spectra from each part of an accretion disc surface (Rutten et al. 1994). We can interpret reconstructed spectra in terms of physical parameter distributions within the disc atmosphere using radiative transfer codes. Approaches so far have been to fit blackbody spectra and uniform slab models to broad-band eclipse photometry (Vrielmann et al. 1997). Ideally we aim to employ a fully self-consistent disc atmosphere code to determine surface density, $\Sigma$, and temperature, $T_{\text{eff}}$, from emission line spectra of quiescent discs. We have built a grid of pure hydrogen disc atmosphere models and investigate the sensitivity of continuum distribution and emission lines to $T_{\text{eff}}$ and $\Sigma$.

The grid contains disc atmospheres assumed to be isothermal and radiating in LTE. Vertical disc structure and spectra have been computed by solving the hydrostatic and radiative transfer equations (Hubeny 1995). Calculated spectra belong to a discrete disc ring 0.25$R_\odot$ from a 0.8$M_\odot$ central object i.e., they are subject to the conditions within the outer disc of a typical cataclysmic variable. If we assume the Hamada and Salpeter (1961) white dwarf mass radius relation this distance corresponds to 26$R_\ast$. Microturbulence has been fixed at 50 km s$^{-1}$ and the orbital inclination is 0°. Spectra span 3700–6700 Å with an instrumental resolution of 10 km s$^{-1}$. A sample of spectra from the grid is provided in Fig. 1a. Fig. 1b presents the results of a $\chi^2$ test between these spectra and their nearest neighbours in the ($\Sigma$,T) plane. Contours represent equal increments in the $\chi^2$ statistic. Contours in each window have separate linear scales. The greyscale represents the $\chi^2$ probability statistic where a probability of 0 maps to white, and 1 to black. Gaussian noise has been introduced into each test spectrum where $\sigma = 2\%$ of the maximum pixel intensity. The source distance is assumed known as is normally the case in eclipse mapping. Where $T_{\text{eff}} < 5000$ K and where $\Sigma > 2$ g cm$^{-2}$, $T_{\text{eff}}$ is strongly constrained whereas fits are insensitive to $\Sigma$. In these regions either the Balmer decrement or the continuum distribution approximates to Planckian. The significance of fit improves with decreasing $T_{\text{eff}}$ as the maximum of the Planck function moves into the optical. If $\Sigma < 0.3$ g cm$^{-2}$ and $T_{\text{eff}} > 12000$ K, fits constrain $\Sigma$ but not $T_{\text{eff}}$ because spectra exhibit an...
optically thin Balmer decrement which is largely insensitive to $T$. Constraints on $\Sigma$ improve as $\Sigma$ increases due to the increasing influence of continuum opacity on $\chi^2$ as we approach the Planck limit. We find the best opportunity to constrain $\Sigma$ and $T_{\text{eff}}$ simultaneously in regions of the plane which correspond to transitions between optically thick and thin regimes, in lines or continuum.

We can similarly calculate the $\chi^2$ distribution in the Balmer jump and emission lines only. At $\Sigma < 0.3 \, \text{g cm}^{-2}$ the distribution is similar to Fig. 1b because emission line flux dominates the spectrum. As $\Sigma$ approaches the optically thick limit, $\sim 1 \, \text{g cm}^{-2}$, we find a $\chi^2$ structure significantly different to Fig. 1b. This is a consequence of the rapid increase in continuum opacity as a function of $T_{\text{eff}}$ close to the limit. In this region the consideration of Balmer flux alone provides further valuable constraint.

In summary, $T_{\text{eff}}$ is well-determined in regions of accretion discs which emit optically thick continua or are dominated by optically thick line emission. $\Sigma$ is best determined in optically thin regions. Both $T_{\text{eff}}$ and $\Sigma$ are constrained in the transition regions. Further atmosphere calculations including more line species should improve the confidence of fits further. In particular HeI emission should provide constraints on $T_{\text{eff}}$ in the high temperature, low $\Sigma$ regime, where only $\Sigma$ can be fit with confidence at present.

References