Photoionization models with accretion discs

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ABSTRACT. The diagnositic possibilities for identifying the ionizing source in symbiotic systems are explored. As possible sources we consider hot blackbodies and accretion discs. It turns out that main sequence accretors and hot blackbodies may have the same appearance in both, emission line and continuum flux distribution. However, UV continuum indices of models containing an accretion disc around a white dwarf are confined to a very small region, separated from main sequence accretors and blackbodies. Furthermore, if symbiotic systems containing a white dwarf accretor exist, they might be recognizable by strong emission in Fe X λ6374.

INTRODUCTION, ASSUMPTIONS AND CONCLUSIONS

We investigate the possibilities of nebular diagnostics as a tool for distinguishing blackbody sources from accretion discs. For this purpose we compare calculated nebular spectra (e.g. Nussbaumer and Vogel 1987), where the ionizing sources are blackbodies of various temperatures, and accretion discs simplified in the following way :

(i) The contributions from the hot spot and from the accreting star can be neglected.

(ii) The accretion disc is treated according to the standard disc theory as summarized for example by Shakura and Sunyaev (1973) and Pringle (1981). Thus, we assume a steady, geometrically thin and optically thick disc, where every surface element radiates as a blackbody with a temperature given by the energy dissipation rate.

(iii) Since up to now no rigorous theory for the boundary layer is available, we introduce a free parameter f for defining a boundary layer blackbody temperature T_{BL}.

$$L_{BL} = L_{disc} = \frac{1}{2} L_{acc} = \frac{GM\dot{M}}{2R^*} = 2\ (2\pi R^* b)\ \sigma T_{BL}^4 = (4\pi R^{*2})\ f\ \sigma T_{BL}^4 \quad ,$$

where M and R^* are the mass and the radius of the accretor and $\dot{M}$ is the mass accretion rate. The parameter f represents the ratio of the boundary layer aera to the surface of the accreting star. All other parameters adopted for our calculations are the same as used by Kenyon and Webbink (1984) in their study on the nature of the hot component in symbiotic stars.

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Since the nebular density distribution around an accreting object is unknown, we disregard the angular dependence of the ionizing radiation and assume for simplicity that all photons from the disc and the boundary layer are emitted spherically symmetrically and that they cross a nebula of constant density with $N(H) = 10^6 \mathrm{cm}^{-3}$ and cosmic abundances.

Due to the energetic photons emitted from the boundary layer, accretion discs around white dwarfs can be distinguished from hot stellar sources by increased fluxes from the highly ionized ions relative to the low and medium ionized ones. Unfortunately, for most of these lines the fluxes are either not strong enough for an easy detection or they lie shortward of 912 Å and are affected by nebular absorption. The multiplets O VI $\lambda\lambda$1032, 1038 and Ne VI $\lambda\lambda$988, 1001, which would reveal the presence of a hot boundary layer, are not accessible to IUE. From the observable strong emission lines the O IV multiplet at λ1400 and the red coronal line Fe X λ6374 are the most suitable lines for detecting boundary layer photons. As an example we show in Fig.1 the flux of Fe X λ6374 and Fe XIV λ5303 relative to H_β.

In the case of an accretion disc around a main sequence star, most of the ionizing photons are provided by the boundary layer. The disc photons contribute an additional flux to the UV continuum, and can therefore best be distinguished from hot stellar sources by the slope of the UV continuum. Kenyon and Webbink (1984) propose reddening-free colour indices C_1 and C_2 for this task.

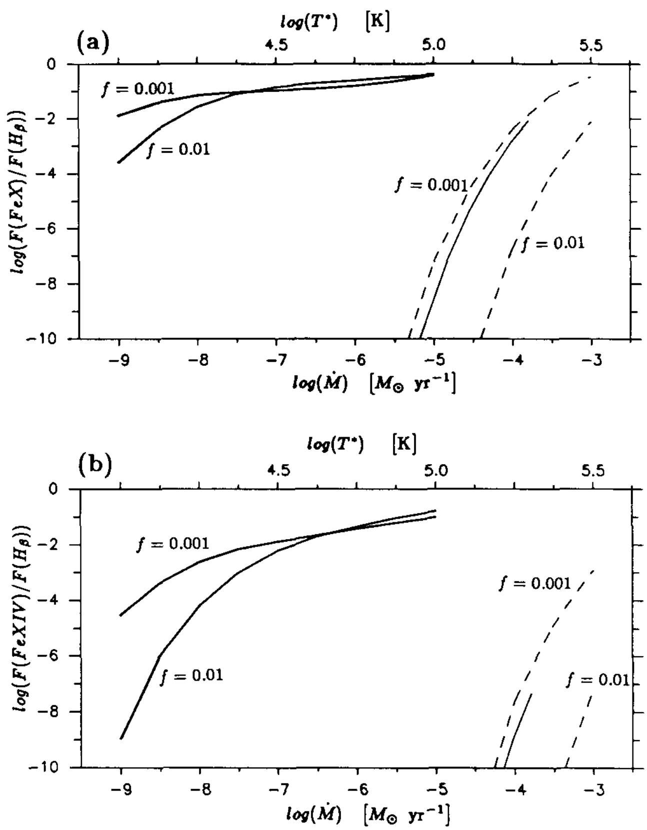

Figure 1.
Logarithmic line flux ratios Fe X λ6374 / H_β (a) and Fe XIV λ5303 / H_β (b) as functions of the accretion rate for white dwarf (heavy lines) and main sequence accretors (dashed lines), and as a function of the effective temperature for hot blackbodies (thin solid line). The trajectories of the blackbodies and the $f = 0.001$ main sequence accretors are only close to each other due to the scaling of T^* on the $\dot{M}$ axis.

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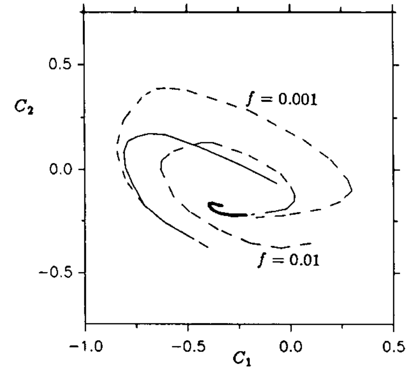

Figure 2.
Colour indices C_1 and C_2 for white dwarf (heavy line) and main sequence accretors (dashed lines), and for hot blackbodies (thin solid line).

For main sequence accretors and for the hot stellar objects we have reproduced the colour indices of Kenyon and Webbink (1984). For the white dwarf accretors however, our results are different. This is particularly interesting because they found no correlation between their theoretical colour indices for white dwarf accretors and observations of symbiotic stars. Kenyon and Webbink (1984) pointed out that the reddening–free colour indices are not very sensitive to the adopted parameters. This is true for hot stellar sources and white dwarf accretors. However, for main sequence accretors the colour indices depend on the assumed boundary layer parameter f. Therefore, some symbiotics, identified as hot stellar sources, might nevertheless belong to the group of main sequence accretors. In Fig.2 we show our trajectories in the reddening–free colour–colour plot. Kenyon and Webbink used an estimate by Lynden–Bell and Pringle (1974) for the boundary layer temperature which is equivalent to $f = 0.01$, for all M, R^* and $\dot{M}$.

Although a main sequence accretor has relatively more soft UV continuum than that of a blackbody or a white dwarf accretor, distinguishing them observationally may still be impossible because of interstellar reddening. Another reddening independent criterion would be the Balmer jump measurement as shown and defined in Fig.3, where F^- and F^+ is the continuum flux short– and longwards of the Balmer jump. For some symbiotics, the practical determination of $\mathcal{B}$ may not be easy. Furthermore, in some systems the cool component may already contribute some radiation to that wavelength region.

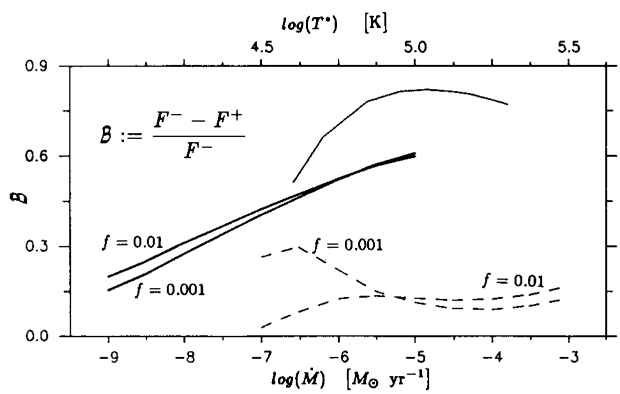

Figure 3.
The behaviour of the Balmer jump index $\mathcal{B}$ as a function of the accretion rate for white dwarf (heavy lines) and main sequence accretors (dashed lines), and as a function of the effective temperature for hot blackbodies (thin solid line).

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