THE IONIZATION AND THERMAL BALANCE IN P CYGNI'S WIND REVISITED

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ABSTRACT. The statistical and thermal equilibrium of P Cygni's wind as a function of radius is investigated using the model of Drew (1985) with an improved treatment of hydrogen. Provisional calculated hydrogen and helium line fluxes are compared with observation. The wind temperature is found to be cooler than observation implies, and a further heating source is tentatively identified.

1. The wind model and its aims

The basic structure and input parameters of the wind model were described by Drew (1985). One of the main aims of the current study is to update the treatment of hydrogen and helium in order to obtain reliable theoretical fluxes for the observed Hα, Hβ, Hγ, Brα and HeI 1μm, 2μm lines. So far, only the hydrogen treatment has been updated (to allow for 16 bound levels instead of just 6). The modelling of the neutral helium atom will ultimately be extended up to levels of principle quantum n=4, using the data of Berrington and Kingston (1987). It is hoped that determination of the He abundance in the wind of will then be possible, providing a valuable indicator of P Cygni's current evolutionary state.

Before this can be done, it is appropriate to consider the extent to which the solution obtained is sensitive to various model assumptions. One of these is the form of the input photospheric radiation field at the base of the wind. We check the sensitivity of the calculated wind structure by trying different low gravity Kurucz-Fitzpatrick atmospheres (Fitzpatrick, 1987) with effective temperatures falling in the range $T_{\star}$= 20000 - 25000 K. Another important assumption used by Drew (1985) was that the hydrogen Lyman lines are in radiative detailed balance. This is no longer imposed.

2. Results & Discussion

The temperature profiles obtained are displayed in Figure 1. The differences between the temperature profiles are relatively slight, although there is a definite correlation between effective temperature and wind temperature. In large measure the decrease in temperature (and consequent decrease in ionization) with respect to the results of Drew (1985) is due to the relaxation of the constraint of radiative detailed balance in the HI Lyman lines.

The computed hydrogen line fluxes (Hα, Hβ, Hγ and Brα) vary by a factor of 2 to 3 across the span of input atmospheres used, depending upon which line is considered, showing that the incident radiation field has to be chosen carefully. They are consistently lower than Johnson et al's

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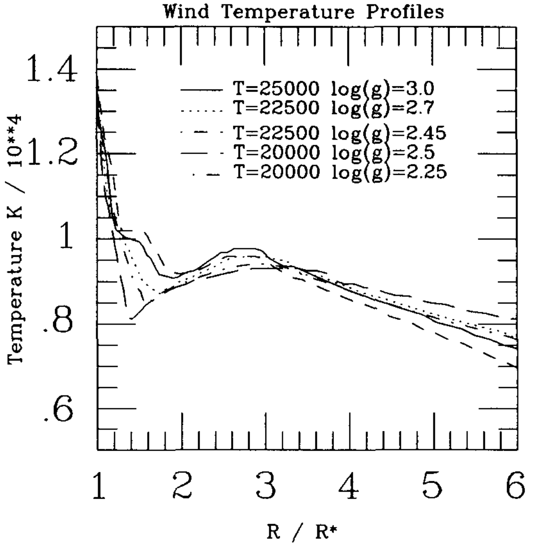

Figure 1. The computed temperature profiles labelled by their input Kurucz-Fitzpatrick atmosphere.

(1978) and Felli et al's (1984) observations by no more than a factor of 3. The computed HeI1μm and HeI 2μm fluxes fall well short of their observed values (Meisel et al (1982); A. Longmore and T. Geballe, private communication) and indeed switch to net absorption in two cases. This is undoubtedly due to the calculated wind temperatures being too low.

The near-neutrality of helium throughout the wind and the extremely low calculated HeI 1μm and 2μm line fluxes indicate a failure to populate the n=2 levels (Drew 1985 found that the main mechanism for ionization of H and He in P Cygni's wind was via n=2 excited states). We consider that this indicates the calculated wind temperature is too low since we expect the n=1 and n=2 HeI states to be roughly in Boltzmann equilibrium. Cassatella et al (1979) obtained a FeII excitation temperature of 12000 $\mp$ 900 K, well in excess of the 8000 K that prevails throughout the majority of the computed profiles. Clearly, it is necessary to establish what is responsible for the missing wind heating.

It has been noted that the UV spectrum of P Cygni is riddled with broadened FeII and FeIII absorption lines that are formed in the wind (Cassatella et al, 1979). It thus seems reasonable that these ions may play a large part in controlling the wind's thermal balance. At present, the only UV lines included in the thermal balance from these ions are FeII UV 1, 2 & 3 and some FeIII forbidden lines. We have thus just begun a pilot study of the Fe^{+}-Fe^{2+} equilibrium with a view to improving the thermal balance calculation.

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