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Ion fractions and the weak wind problem

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Abstract. Some late-type O stars display anomalously weak winds, possibly due to decoupling of the main driving ions from the bulk plasma. This issue and the uncertainty about the nature of wind clumping are a challenge to line-driven wind theory and need resolving in order to fully understand hot stars. We describe the results from the computation of ion fractions for the various elements in O star winds using non-LTE code CMFGEN, including parameterisation of microclumping and X-rays.

Keywords. stars: mass loss, ultraviolet: stars

1. Introduction

There are several spectroscopic diagnostics available for measuring the mass-loss rate of O stars. Each of these has certain advantages and drawbacks, and often requires ill-determined information or parameter knowledge. In the ultraviolet, wind profiles can be matched using the SEI (Sobolev with Exact Integration) method of Lamers *et al.* (1987) to yield the product of the mass-loss rate and the ion fraction of the element. The mass-loss results are therefore very dependent upon the wind ionization balance. We compiled a grid of O star models using the spherical non-LTE model atmosphere code CMFGEN (Hillier & Miller, 1998), producing a variety of model types from O3 to O9.5, with different wind-clumping scenarios and with or without X-rays. These models have a large number of applications, but here we focus on the run of ion fraction with effective stellar temperature, which was derived for each clumping and X-ray scenario, to assess the possible effects of these two phenomena on the ionization balance in O star winds.

2. Model Ion Fractions

For each spectral type a set of mean ion fractions was calculated for each element, normalised to the range 0.2-0.9v_∞. This was done in order to ensure a direct comparison to empirical fits described in a separate paper, in which the very lowest and highest velocity positions are excluded so as to avoid any variable phenomena such as DACs.

Figure 1 shows the results for C^{3+} and C^{4+} for dwarfs, which are predicted to account for most of the total carbon population. N, O, Si, P and S were also processed but for brevity are not shown here; they will be published separately. We focus discussion on carbon, which is pertinent to the project to fit CIV profiles in O dwarfs, published separately. The clumping scenario is either unclumped (smooth wind, volume filling factor 1.0) or moderately clumped (with a volume filling factor of 0.1). The models with X-rays have an X-ray luminosity consistent with the relation $\log L_x/L_{bol} \sim -7$ from e.g. Naze (2009). When changing to a clumped wind in the absence of X-rays, the higher ionization stage reduces in population at higher tempertures as recombination from higher local density forces the balance in favour of the lower stage. In general this balance appears

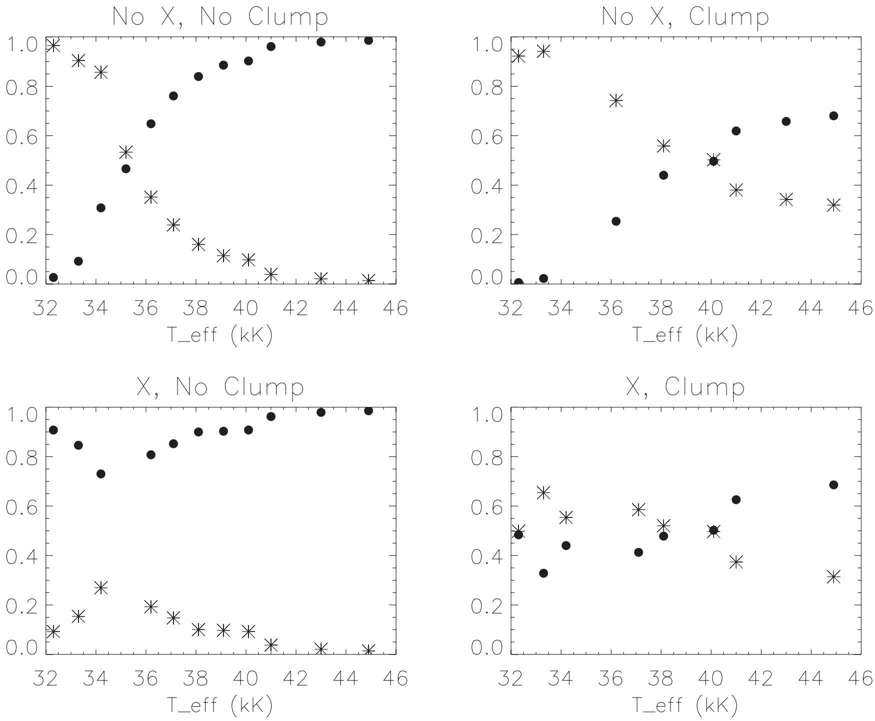

Figure 1. Carbon ion fractions.

more fragile when X-rays are implemented and the effect is greater. Bringing X-rays into the unclumped scenario shifts the balance strongly in favour of the upper stage but with a non-negligible portion still in the lower. The supposedly most detailed description of the wind (i.e. with both clumping and X-rays) yields a somewhat uncertain picture, in which it is unclear for much of the O star range whether either ion becomes dominant. A stark difference in the X-ray models is brought about by introducing moderate clumping. Whilst in the unclumped wind, the X-rays cause C^{4+} to be dominant for the whole O star range, the clumping then changes the ionization balance much more than in the non-X-ray models. In order to distinguish the most likely scenario, the profiles in the corresponding model spectra were examined and compared to observations (*IUE, Copernicus, FUSE*). For later type objects we find that it is crucial to include a treatment of X-rays to get realistic NV and OVI lines. The model profiles also seem to suggest a very low level of clumping to be most likely, implying that the bottom-left panel in Fig. 1 is that which should be used.

References

Hillier, D. J. & Miller, D. L. 1998, *ApJ*, 496, 407
Lamers, H. J. G. L. M., Cerruti-Sola, M., & Perinotto, M. 1987, *ApJ*, 314, 726
Nazé, Y. 2009, *A&A*, 506, 1055

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