New atmosphere models for massive stars: line-blanketing effects and wind properties of O stars

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Massive stars are at a cornerstone of modern astrophysics. Their nucleosynthesis produces the elements heavier than Oxygen which are spread in the interstellar medium when they end their life as supernovae. They also emit high energy photons which ionise the surrounding medium, creating HII regions. They continuously emit powerful winds which interact with the interstellar medium, giving birth to bubbles, cavities and triggering the collapse of molecular clouds. The very first massive stars (the so-called population III stars) are also thought to be the precursors of gamma-ray bursts and may be responsible for the reionisation of the Universe at high redshift. Understanding quantitatively these objects is then crucial for a number of astrophysical studies. This requires the development of complex evolutionary models to explain the structure of their interior and their nucleosynthesis. And atmosphere models are necessary to make the link between the interior of the star and the observable quantities, and to constrain the stellar and wind properties of massive stars.

This thesis focuses on the second kind of models. The main reason is that significant progress has been made in the modelling of massive stars atmospheres in the last few years. In particular, it is now possible to include reliably metals in such models. This allows the production of realistic models and synthetic spectra which can be used to improve our knowledge of the stellar and wind properties. In this thesis, we have built such new atmosphere models computed mainly with the code CMFGEN (Hillier \& Miller 1998).

The first part of this work has been devoted to the analysis of the effects of the inclusion of metals in atmosphere models (the line-blanketing effects). We have confirmed the expected fact that both the atmospheric structure and the emergent spectrum are modified by the presence of metals. The temperature is increased in the interior of the atmosphere (backwarming effect) and reduced in the outer layers (line-cooling effect). The ionisation is also higher in the interior and lower in the upper atmosphere. This change of ionisation modifies the strength of He lines used for the spectral classification compared to models without metals, lowering the effective temperature scale of O dwarfs by 1500 (4000) K for late (early) type O dwarfs with solar abundances.
For a lower metallicity typical of the Small Magellanic Cloud, the reduction of the $T_{\rm eff}$ - scale is roughly half that of the solar case. We also investigate the effect of line-blanketing on the spectral energy distribution of O stars. In particular, a study of compact Galactic HII regions observed in the mid-IR by ISO reveals that the new generation of atmosphere models allows a better, although not perfect, reproduction of the excitation sequences defined by ratios of nebular lines of the same element emitted in the HII region.

The second part of this thesis is devoted to the study of wind properties of dwarf O stars thanks to new atmosphere models. We first focus on the stellar components of the High Excitation Blob N81 in the Small Magellanic Cloud. The quantitative spectroscopic analysis of UV STIS spectra reveals that these stars are young O dwarfs with lower luminosities than typical O stars of the same spectral type and showing very weak winds. These characteristics may indicate that they belong to the class of Vz stars, a class of O stars thought to lie close to the ZAMS. With mass loss rates of the order of $10^{-8..-9}$ $M_{\odot}$ yr^{-1}, the winds are weaker than ever observed for such stars, and are weaker by 1 to 2 orders of magnitude compared to the predictions of hydrodynamical simulations. The modified wind momenta show the same trend, indicating possibly a break-down of the modified wind momentum - luminosity relation (WLR) or a steeper slope at lower metallicity. Different hypothesis are investigated to explain this strange behaviour (low metallicity, decoupling, line strength parameterisation in hydrodynamical simulations) without success. A possible link between the youth of the star and the weakness of developing winds may possibly explain such a behaviour.