Atmospheric NLTE-Models for the Spectroscopic Analysis of Blue Stars with Winds. III. X-ray emission from wind-embedded shocks

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Context. X-rays/EUV radiation emitted from wind-embedded shocks in hot, massive stars can affect the ionization balance in their outer atmospheres, and can be the mechanism responsible for the production of highly ionized atomic species detected in stellar wind UV spectra.

Aims. To allow for these processes in the context of spectral analysis, we have implemented the emission from wind-embedded shocks and related physics into our unified, NLTE model atmosphere/spectrum synthesis code FASTWIND.

Methods. The shock structure and corresponding emission is calculated as a function of user-supplied parameters (volume filling factor, radial stratification of shock strength, and radial onset of emission). We account for a temperature and density stratification inside the post-shock cooling zones, calculated for radiative and adiabatic cooling in the inner and outer wind, respectively. The high-energy absorption of the cool wind is considered by adding important K-shell opacities, and corresponding Auger ionization rates have been included into the NLTE network. To test our implementation and to check the resulting effects, we calculated a comprehensive model grid with a variety of X-ray emission parameters.

Results. We tested and verified our implementation carefully against corresponding results from various alternative model atmosphere codes, and studied the effects from shock emission for important ions from He, C, N, O, Si, and P. Surprisingly dielectronic recombination turned out to play an essential role for the ionization balance of OIV/OV in stars (particularly dwarfs) with Teff approx. 45,000 K. Finally, we investigated the frequency dependence and radial behavior of the mass absorption coefficient, kappa_nu(r), important in the context of X-ray line formation in massive star winds.

Conclusions. In almost all considered cases, direct ionization is of major influence (because of the enhanced EUV radiation field), and Auger ionization significantly affects only NVI and OVI. The approximation of a radially constant kappa_nu is justified for r > 1.2 Rstar and lambda < 18 A, and also for many models at longer wavelengths. To estimate the actual value of this quantity, however, the HeII opacities need to be calculated from detailed NLTE modeling, at least for wavelengths longer than 18 to 20 A, and information on the individual CNO abundances has to be present.

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