Mass Loss from Stars and the Evolution of Stellar Clusters
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Do we understand Wolf-Rayet stars?

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Abstract. The spectra of Wolf-Rayet stars can be reproduced by line-blanketed model atmospheres. WR winds are strongly inhomogeneous; one means to study wind clumping is provided by the X-ray line profiles. First hydrodynamically consistent WR wind models now exist for some WR subtypes. The new evolutionary models for massive stars which account for rotation can still not reproduce well the Galactic WR population.

1. Wolf-Rayet spectra

Fantastic progress has been achieved during the last two decades modelling Wolf-Rayet spectra. Nowadays we can calculate the radiative transfer in expanding atmospheres with many hundred non-LTE levels and iron line blanketing, see e.g. Hamann et al. (2004). The observed WN spectra can be well reproduced (e.g. Hamann et al., in press), while WC spectra still make some troubles.

2. Wind inhomogeneities ("clumping")

Wind inhomogeneities are mostly accounted for in the approximation of optically thin clumps. However, the X-ray line profiles recently resolved observationally indicate optically thick shell fragments (Oskinova et al. (2004) and in press). A better understanding and modelling of clumping is urgently needed, and has far-reaching implications because of its impact on the derived mass-loss rates.

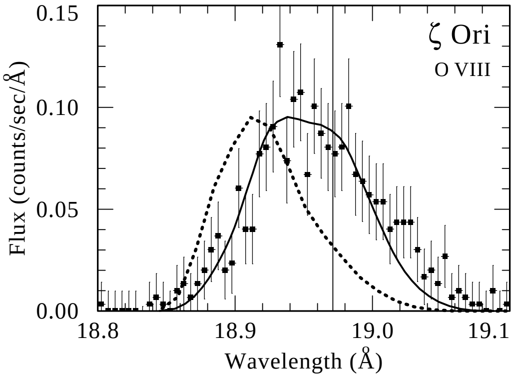

Figure 1. Line profile in the X-ray spectrum of ζ Ori, observed with Chandra. A homogeneous-wind model (dotted) cannot reproduce the observation, while a model with radially compressed wind fragments (solid line) fits well.

3. Wind driving

The radiation-driven wind theory, working fine since long for the much thinner winds from O stars, is also able to explain the winds from Wolf-Rayet stars if multiple-scattering effects and all relevant opacities are included. This has been shown first for the WC5 star WR 111 by Gräfener & Hamann (2005), and recently for some late WN subtypes (see Gräfener & Hamann, these proceedings). However, for certain subtypes the models still fail by far. The hydrodynamic effects of optically thick clumping and rotation are not yet considered in the stationary models. Observed patterns in the wind variability, obviously due to inhomogeneous structures, remain enigmatic.

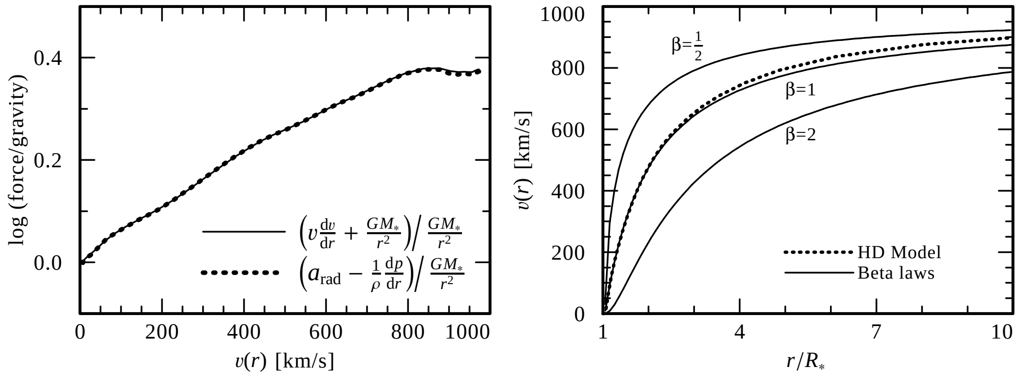

Figure 2. Self-consistent HD model for WR 22 (subtype WN7h). *Left panel:* Inward forces (inertia + gravity, solid line) are perfectly balanced by outward forces (radiation pressure + gas pressure, dotted). *Right panel:* Velocity field of the self-consistent model (dotted). The solution lies close to the analytical "beta law" with $\beta = 1$ (solid curves)

4. Evolution

We have analyzed a comprehensive sample of Galactic WN stars, and compared the results with synthetic populations based on evolutionary tracks (Hamann et al., in press). While there is a rough qualitative agreement between the synthetic and observed WN population, the quantitative discrepancies are still severe. There is even no clear preference for the new evolutionary models with rotation. One problem is the distinguished high luminosity of the late-type WN stars showing much surface hydrogen. Another problem is the large radius of many hydrogen-free early-type WN stars, which are cooler than their predicted position on the helium main sequence. It is still completely unclear how the different WN- and WC subtypes are evolutionary related.

References

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