Inhomogeneities in Wolf-Rayet atmospheres

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1. Introduction and results

By progress in both computer speed and the development of efficient solution algorithms (Accelerated Lambda Iteration, ALI) nowadays detailed models for Wolf-Rayet (WR) atmospheres can be calculated on a desktop computer. In the last years much work was focused on the correct treatment of all relevant opacities with the success that now hundreds of atomic levels in with thousands of spectral lines of light elements (e.g. He, C, N, O) and millions of iron lines can be accounted for in non-LTE. With respect to the opacities these new models are complete, but they are all based on the standard assumptions for WR atmospheres, namely the spherically-symmetric expansion and the stationarity and homogeneity of the outflow (c.f. Hamann et al., these proceedings).

From the observation of line profile variabilities (Prinja & Smith 1992), polarization variabilities (Brown et al. 1995, Owocki 1994, Feldmeier 1995) and X-ray emissions (Pollock 1995, Baum et al. 1992) the clumpiness of WR atmospheres is clearly evident. As Hillier (1984) pointed out, the clumpiness of the atmospheres can be also directly measured from the strength of the line wings due to electron scattering. In this paper we investigate four massive WR stars which are representative for different spectral types.

We apply in principal the same approximations as Schmutz (1997): The clumps are optically thin and have densities which are enhanced by a factor D compared to a smooth model with the same mass-loss rate. The interclump medium is void. The non-LTE rate equations are solved for the clumps, while in the radiation transfer the opacities and emissivities are averaged. Because WR spectra are dominated by ρ^2 processes, increased clumping factors can be compensated by decreased mass-loss rates by $\sqrt{D}$ to get similar spectra. For processes scaling linearly with ρ (like Thomson scattering) the volume filling factor $f_{\rm V} = D^{-1}$ and D cancel out and consequently they are reduced by $\sqrt{D}$.

We find that models with $D \approx 4$ fit the observed line wings in WN stars best, while for the early-type WC star the clumping factor might be slightly higher. The ratio of wind momentum and the momentum of the radiation field is consequently decreased by a factor of two which leads to $\eta \approx 4$ for late-type and weak-lined early-type WR stars and to approximately 15 for strong-lined early-type stars. More details are given in Hamann et al. (these proceedings).

References

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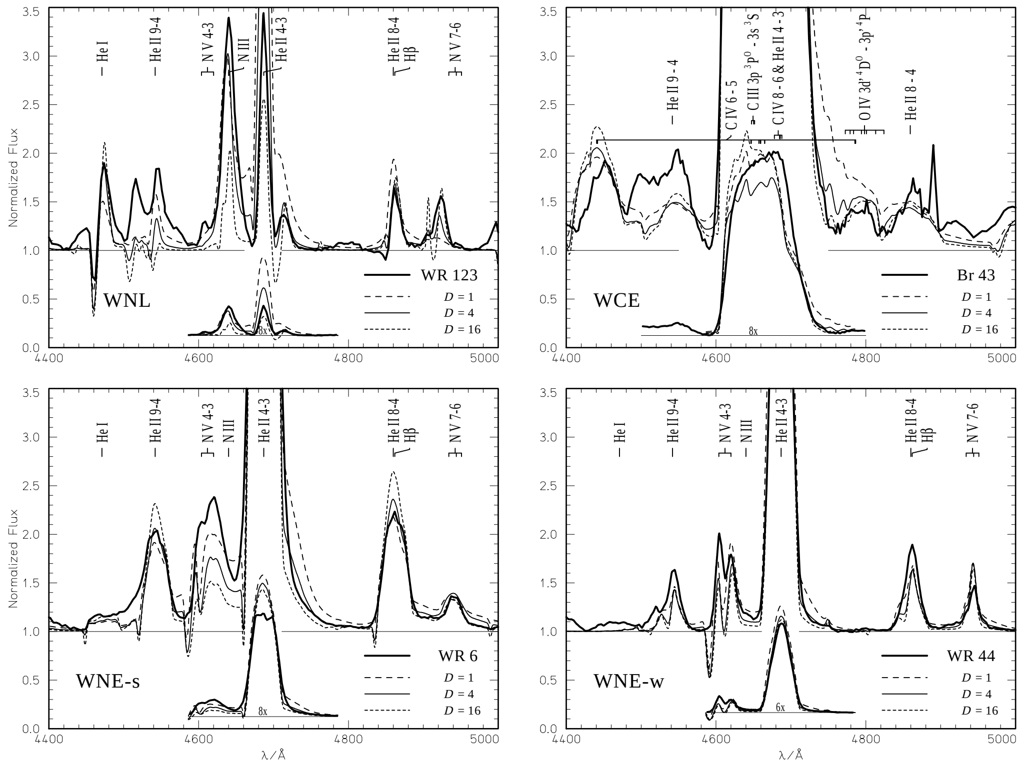

Figure 1. Observations of 4 Pop I WR stars compared with synthetic spectra of different clumpiness. For prototypes of the subclasses WNL (WR 123), WNE-s (WR 6), WNE-w (WR 44) and WCE (Br 43) observations around He II 4686 Å are shown together with three synthetic spectra. For each star one model (long-dashed) is calculated without any clumping while in the two other models density contrasts of $D = 4$ (solid) and $D = 16$ (short-dashed) are accounted for. The synthetic spectra differ in the line wings while the peak height of most lines changes only marginally. The observed line wings of the three WN stars are best matched by models with $D = 4$ while the density contrast of the WCE atmosphere is higher.

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