Mass loss from inhomogeneous hot star winds III. An effective-opacity formalism for line radiative transfer in accelerating, clumped two-component media, and first results on theory and diagnostics}

J.O. Sundqvist(1), J. Puls(1), S.P. Owocki(2)

1 - University of Munich; 2 - University of Delaware

Aim: To provide a fast and easy-to-use formalism for treating the reduction in effective opacity associated with optically thick clumps in an accelerating two-component medium. Method: We develop and benchmark effective-opacity laws for continuum and line radiative transfer that bridge the limits of optically thin and thick clumps. We then use this formalism to i) design a simple method for modeling and analyzing UV wind resonance lines in hot, massive stars, and ii) derive simple correction factors to the line force driving the outflows of such stars. Results: Using a vorosity-modified Sobolev with exact integration (vmSEI) method, we show that, for a given ionization factor, UV resonance doublets may be used to analytically predict the upward corrections in empirically inferred mass-loss rates associated with porosity in velocity space (a.k.a. velocity-porosity, or vorosity). However, we also show the presence of a solution degeneracy: in a two-component clumped wind with given inter-clump medium density, there are always two different solutions producing the same synthetic doublet profile. We demonstrate this by application to SiIV and PV in B and O supergiants and derive, for an inter-clump density set to 1 % of the mean density, upward empirical mass-loss corrections of typically factors of either ~5 or ~50, depending on which of the two solutions is chosen. Overall, our results indicate that this solution dichotomy severely limits the use of UV resonance lines as direct mass-loss indicators in current diagnostic models of clumped hot stellar winds. We next apply the effective line-opacity formalism to the standard CAK theory of line-driven winds. A simple vorosity correction factor to the CAK line force is derived, which for normalized velocity filling factor fvel simply scales as fvel^alpha, where alpha characterizes the slope of the CAK line-strength distribution function. By analytic and numerical hydrodynamics calculations, we further show that in cases where vorosity is important at the critical point setting the mass-loss rate, the reduced line force leads to a lower theoretical mass loss, by simply a factor fvel. On the other hand, if vorosity is important only above this critical point, the predicted mass loss is not affected, but the wind terminal speed is reduced, by a factor scaling as fvel^(alpha/(2-2alpha)). This shows that porosity in velocity space can have a significant impact not only on the diagnostics, but also on the dynamics and theory of radiatively driven winds.

Reference: Accepted for publication in Astronomy and Astrophysics. Pre-print available at ArXiv.
Status: Manuscript has been accepted

Weblink: http://arxiv.org/abs/1405.7800

Comments:

Email: mail@jonsundqvist.com