A Massive Star Odyssey, from Main Sequence to Supernova
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Clumps and shocks in the outer winds of hot stars

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Abstract. We present a moving periodic box technique to study the outer-wind evolution of instability-generated structure in hot-star winds. This has considerable computational and conceptual advantages

1. Introduction

It is well known that the winds of hot, massive stars show a great deal of structure (such as clumps and shocks). One plausible explanation for the existence of structure is the instability of the radiative driving mechanism that maintains these winds. This instability generates small-scale, stochastic structure, distributed throughout the wind. In this poster, we investigate how this structure evolves as it moves out to large distances ($> 100R_*$). This is relevant for thermal radio emission (and the determination of mass-loss rates), for non-thermal radio emission, for soft X-rays from some stars (such as ζ Pup) and possibly for the structure seen in nebulae around Wolf-Rayet stars.

2. A new technique

In a previous paper (Runacres & Owocki 2002) we studied the evolution of wind structure up to a distance of $100R_*$, using one-dimensional, time-dependent hydrodynamical models that take into account the instability of line-driving. In these models, the wind material is compressed into a sequence of narrow, dense shells, bounded by shocks. We found that the radiative force plays little role in maintaining the structure in the outer wind (beyond $30R_*$).

As the evaluation of the radiative force dominates the computing time of these simulations, its negligible role for the evolution of outer wind structure allows us to construct cheaper models. This in turn allows us to run them for longer and study the structure at very large distances, say a thousand stellar radii. The technique we propose is a pseudo-planar, moving periodic box model. Despite its rather grand name, the technique is simple. Instead of keeping track of the whole stellar wind, we select a representative region at a given time, and put it in a box that moves outward at a convenient speed, generally close to the terminal velocity. Unlike their planar counterparts, the spherical equations of

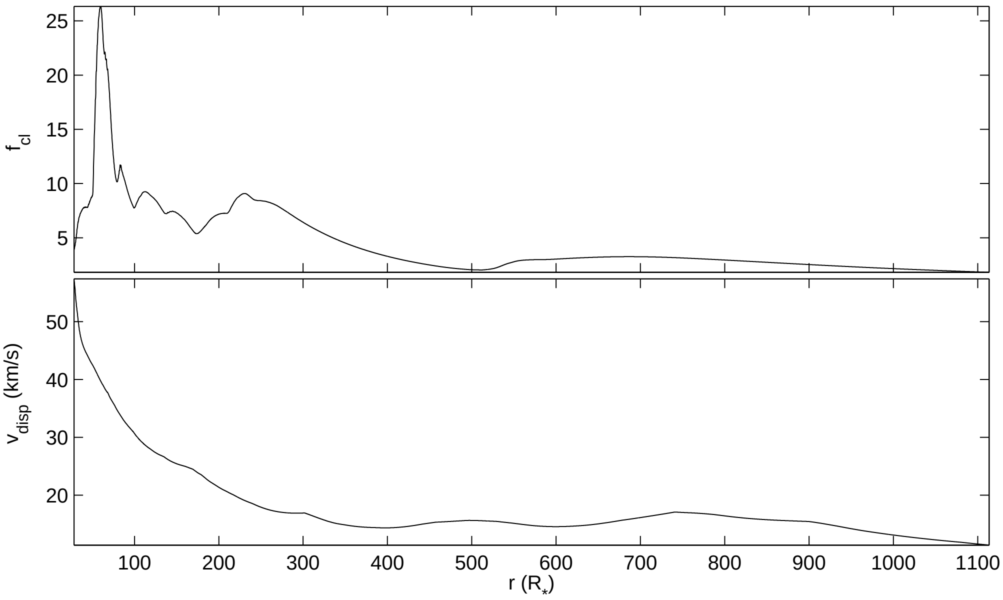

Figure 1. Clumping factor and velocity dispersion as a function of distance, for a periodic box simulation of wind structure

hydrodynamics are not invariant under a Galilean transformation. We therefore rephrase them using variables that are scaled to take into account the secular expansion of the gas. This gives equations that describe a spherically symmetric stellar wind but have almost the same form as the planar equations and can be used in a moving box. Finally, we impose periodic boundary conditions on the box. Details of this technique will be given in a subsequent paper.

3. Results

All parameters used in the model presented here are the same as for the reference model in Owocki & Runacres (2002), with the exception of the floor temperature, below which the wind is not allowed to cool. The floor temperature mimics the effect of photoionization heating and is set here at 10 000 K. This is an important parameter for the evolution of structure, as it sets the expansion speed of the dense shells.

The figure shows the clumping factor (top panel) and velocity dispersion (lower panel) for a periodic-box simulation. The clumping factor drops under the influence of pressure expansion and rises when shell collisions occur. As these collisions can occur far from the star, the wind remains clumped up to very large distances: the clumping factor is 9 at 230 R_*. Just as for the radiatively driven calculations, the velocity dispersion decreases more gradually.

References

Runacres, M.C, Owocki, S.P. 2002, A&A, 381, 1015