Multi-D models of circumstellar shells around evolved massive stars

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Massive stars shape their surrounding medium through the force of their stellar winds, which collide with the circumstellar medium. Since the characteristics of these stellar winds vary over the course of the evolution of the star, the circumstellar matter becomes a reflection of the stellar evolution and can be used to determine the characteristics of the progenitor star. In particular, whenever a fast wind phase follows a slow wind phase, the fast wind sweeps up its predecessor in a shell, which is observed as a circumstellar nebula. We make 2-D and 3-D numerical simulations of fast stellar winds sweeping up their slow predecessors to investigate whether numerical models of these shells have to be 3-D, or whether 2-D models are sufficient to reproduce the shells correctly. We focus on those situations where a fast Wolf-Rayet (WR) star wind sweeps up the slower wind emitted by its predecessor, being either a red supergiant or a luminous blue variable. As the fast WR wind expands, it creates a dense shell of swept up material that expands outward, driven by the high pressure of the shocked WR wind. These shells are subject to a fair variety of hydrodynamic-radiative instabilities. If the WR wind is expanding into the wind of a luminous blue variable phase, the instabilities will tend to form a fairly small-scale, regular filamentary lattice with thin filaments connecting knotty features. If the WR wind is sweeping up a red supergiant wind, the instabilities will form larger interconnected structures with less regularity. Our results show that 3-D models, when translated to observed morphologies, give realistic results that can be compared directly to observations. The 3-D structure of the nebula will help to distinguish different progenitor scenarios.

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