From Bipolar to Elliptical: Simulating the Morphological Evolution of Planetary Nebulae

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The majority of Proto-planetary nebulae (PPN) are observed to have bipolar morphologies. The majority of mature PN are observed to have elliptical shapes. In this paper we address the evolution of PPN/PN morphologies attempting to understand if a transition from strongly bipolar to elliptical shape can be driven by changes in the parameters of the mass loss process. To this end we present 2.5D hydrodynamical simulations of mass loss at the end stages of stellar evolution for intermediate mass stars. We track changes in wind velocity, mass loss rate and mass loss geometry. In particular we focus on the transition from mass loss dominated by a short duration jet flow (driven during the PPN phase) to mass loss driven by a spherical fast wind (produced by the central star of the PN). We address how such changes in outflow characteristics can change the nebula from a bipolar to an elliptical morphology. Our results show that including a period of jet formation in the temporal sequence of PPN to PN produces realistic nebular synthetic emission geometries. More importantly such a sequence provides insight, in principle, into the apparent difference in morphology statistics characterizing PPN and PN systems. In particular we find that while jet driven PPN can be expected to be dominated by bipolar morphologies, systems that begin with a jet but are followed by a spherical fast wind will evolve into elliptical nebulae. Furthermore, we find that spherical nebulae are highly unlikely to ever derive from either bipolar PPN or elliptical PN.

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