

# **Circumstellar Spirals/Shells/Arcs: the Messages from Binary Stars**

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In this talk, I will review the recent theoretical and observational investigations on the spiral-shell patterns surrounding solar-mass evolved stars. The diverse morphology of planetary nebulae and their progenitors (asymptotic giant branch stars) suggests that the mass loss processes of many of them are significantly affected by companion stars. The coexistence of both highly asymmetric (bipolar or multipolar) structures and nearly-spherical structures (shells, rings, arcs, and spirals) in many planetary nebulae is puzzling as that implies a simultaneous presence of both "close" and "wide" binary interactions. Locating the companion stars, however, has been challenging as they are mostly invisible due to the surrounding material ejected from the evolved stars. The circumstellar patterns, observed previously by the Hubble Space Telescope and now the Atacama Large Millimeter/submillimeter Array (ALMA), provide the fossil records of the influence of binary orbital motion on the mass loss dynamics. Along with the discoveries of such patterns, the detailed three-dimensional modeling has been developed toward the goal of constraining the stellar orbital properties (such as the binary stellar masses, orbital separation, and inclination) and accordingly the mass loss properties.