Study on character of ambient gas in Planetary Nebula Morphology with poloidal collimation magnetic field using laser-produced plasma

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Planetary nebulae are a series of astrophysical objects consist of a central star (AGB, post AGB or binary system) and its outer gas envelop. Most of them shows a non-spherical expanding shape, along with young stellar objects (YSO) and some red giants who all share the same large collimated outflow structure. In various models, poloidal field collimation becomes a promising explanation.

From the basis of previous experimental and simulation results aiming to recreate jet by applying poloidal magnetic field in an expanding laser produced plasma, we add magnetized ambient to mimic the envelop gas or interstellar wind. Allowing external field strength and ambient density change separately to cover states from field dominated jet shaping to another extreme of pure non-symmetry wind. And more importantly, intermediate regions where field and ambient interacts to create complex structures like the butterfly nebula. FLASH code which coupled energy deposition and MHD were used to illustrate a way of using powerful laser and strong external field generator to recreate some of the processes like mass ejection, directed flow and magnetic field shaping in a highly magnetized plasma ambient, which share similarities with astrophysical counterpart in a dimensionless sense.

Observations from the simulation results indicate that ambient properties like density and magnetic field strength can greatly change the dynamics and geometry of the plasma jet, force it to evolve from elongated and highly supersonic directed flow to a nearly isotropic expanding bubble. In more detailed analysis, there exist a critical point which can be determined by a function of shell speed, B field and ambient density. Beyond which jet will not emerge, and even the flow properties inside the non-magnetized regions can be transfer from supersonic expansion to subsonic stagnation. By scanning a wide range of parameter space in simulation, one model based on magnetize shock and cascaded plasma acceleration are employed and verified here, with key non-dimensional parameters to determine the long term evolution of astronomical systems of this type.