Hydrodynamics of hypersonic jets: experiments and numerical simulations

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Astrophysical jets are collimated outflows of matter and fields propagating at supersonic, and often relativistic, velocities. Jets are ubiquitous in the Universe, in fact they are observed emerging from protostellar objects, from stellar X-ray binaries, as well as from supermassive black holes located at the center of active galaxies. Jets are thougth to originate from a central object surrounded by a magnetized accretion disk, there a significant fraction of the inflowing matter is ejected along the rotation axis by magnetohydrodynamic processes.

The studies about launching, propagation and stability of jets are carried out by analytical and semi-analytical means, by numerical simulations and laboratory experiments. The physics that encompasses all classes of astrophysical jets is magnetohydrodynamics. We have conceived laboratory and three-dimensional numerical mid-long term simulations of hypersonic Newtonian jets, in the hydrodynamic limit, which meet the two main scaling parameters for protostellar jets, i.e. the formation Mach number and the ambient/jet density ratio. In the laboratory experiments jets are generated, in a quasi-isentropic way, with the property of being either lighter or heavier than the ambient. These simulations show a few of the universal morphological properties observed in the intermediate-far field of protostellar jets. Both experimental and numerical simulations highlight that a high collimation is achieved and maintained for the two kind of jets, at least within the experimental limits. Moreover, light jets show aligned bright high density regions in form of knots with quasi-regular spacing.

It is noticeable that even the intense interaction with the exteriors experienced by a light jet is not sufficient to spoil its collimation – which thus is an expression of the prevailing inertial effects. These results show that high Mach number jets survive and maintain the collimation for several jet radii even without the confining effects of magnetic fields, as suggested for astrophysical jets in many instances. The good qualitative agreement between laboratory and numerical results is, in a more general context, a significant validation for the numerical schemes adopted for the treatment of highly compressible flows in presence of strong shocks.

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