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Experiments with supersonic plasma jets at Omega

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Large-scale directional outflows of supersonic plasma, also known as jets, are often encountered in astrophysics. These jets propagate through the interstellar medium which is often clumpy and where inhomogeneities affect the morphology of the shocks that are generated. The hydrodynamics is difficult to model as the problem is inherently 3D, and the clumps are subject to a variety of fluid instabilities as they are accelerated and destroyed by shocks. Very large scale inhomogeneities may result in deflection of the jet itself. The traditional approach to understanding such phenomena is through theoretical analysis and numerical simulations. However, such numerical simulations have limited resolution, often assume axial symmetry, do not include all relevant physical processes, and may fail to scale correctly in Reynolds number and other key dimensionless parameters. They are frequently not tested by comparison with laboratory experiments. In recent years, we have carried out experiments at the University of Rochester's Omega laser, to investigate the physics associated with the propagation of plasma jets and shocks through both homogeneous and inhomogeneous media. These experiments have close analogues with structures observed in jets from young stars. Jets and shocks are created in experimental assemblies that are ablatively driven by a 190-eV temperature 'hohlraum' (which is itself heated by the Omega laser), and subsequently propagate into a low density hydrocarbon-foam medium. The foam is either of uniformly low density, or contains localised (higher density) perturbations. Interaction of jets with this fluid results in the development of a bow shock, and, in the case of a single density perturbation, results in deflection of the jet (a laboratory analogue of the astrophysical object HH110). In the case of a shock propagating through an inhomogeneous medium (foam containing one or more sapphire spheres), the resulting complex shock interactions are analogous to the flow of clumpy interstellar matter through the working surfaces of HH objects. The hydrodynamic structures that develop in these experiments are revealed by x-ray 'backlighting' radiography. These complex experimental data challenge both astrophysical and laser-plasma hydrodynamics computer codes. We discuss 2D and 3D simulations of these experiments, and their potential scaling to astrophysical systems.