Laboratory modelling of astrophysical plasma processes with high-power lasers

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Numerical studies as well as scaled laboratory experiments suggest that bipolar outflows arising from young stellar objects (YSOs) could be collimated into narrow and stable jets as a result of their interaction with a poloidal magnetic field. However, this magnetic collimation mechanism was demonstrated only for the simplified topology of the uniform poloidal B-field, which, in fact, is significantly different from the hourglass B-field topology actually observed near the YSOs. Using the high-power PEARL laser in combination with a unique 15-T magnetic system, for the first time we conducted laboratory experiments in which laser plasma flows interact with a highly non-uniform poloidal magnetic field modelling an YSOs' hourglass magnetic structure. Laboratory experiments and 3D numerical modeling allow us to unveil the various stages of plasma jet formation in an hourglass-like poloidal magnetic field. The results evidence (i) the fundamental possibility and the necessary conditions for magnetic collimation of a plasma outflow originating from the central part of a hourglass magnetic structure, and (ii) the stability of the collimated jet as it propagates ballistically through the region of weak and strongly divergent magnetic fields. As a result, we have extended the model of YSO jets collimation by poloidal magnetic field to more realistic YSO magnetic field topologies.

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