Astrophysical relevant laboratory experiment of laser-created plasma interaction with a magnetic field in the context of star formation: jets formation and accretion dynamic.

G Revet[1,2], S.N. Chen[1,2], R. Bonito[3], B. Khiar[4], E. Filipov[5,6], C. Argiroffi[3], D. P. Higginson[2], S. Orlando[7], J. Béard[8], M. Blecher[9], M. Borghesi[10], K. Burdonov[1], D. Khaghani[11], K. Naughton[10], H. Pépin[12], O. Portugall[8], R. Riquier[2,13], R. Rodriguez[14], S.N. Ryazantsev[5,6], I.Yu. Skobelev[5,6], A. Soloviev[1], O. Willi[9], S. Pikuz[5,6], A. Ciardi[4], J. Fuchs[1,2]

[1] Institute of Applied Physics, 46 Ulyanov Street, 603950 Nizhny Novgorod, Russia
[2] LULI - CNRS, École Polytechnique, CEA: Université Paris-Saclay; UPMC Univ Paris 06: Sorbonne Universités - F-91128 Palaiseau cedex, France
[3] Dipartimento di Fisica e Chimica Università di Palermo, Italy
[4] LERMA, Observatoire de Paris, CNRS UMR 8112, Paris France.
[5] National Research Nuclear University 'MEPhI', 115409 Moscow, Russia
[6] Joint Institute for High Temperatures, RAS, 125412, Moscow, Russia
[7] INAF - Osservatorio Astronomico di Palermo, Italy
[8] LNCMI, UPR 3228, CNRS-UFJ-UPS-INSA, 31400 Toulouse, France.
[9] Institut für Laser- und Plasmaphysik, Heinrich-Heine-Universität Düsseldorf, D-40225 Düsseldorf, Germany
[10] The Queen's University of Belfast, Belfast BT7 1NN, United Kingdom
[11] GSI Helmholtzzentrum für Schwerionenforschung GmbH, 64291 Darmstadt, Germany
[12] INRS-EMT, Varennes, Québec, Canada.
[13] CEA, DAM, DIF, 91297 Arpajon, France
[14] Departamento de Fisica de la Universidad de Las Palmas de Gran Canaria, E-35017 Las Palmas de Gran Canaria, Spain

In the context of pre-stellar core collapse, outflows of matter and their interaction with the ambient magnetic field is crucial in acquiring a complete picture of the first stages of star formation. There have been thus several reported observations of the degree of collimation of the outflows, as a function of the angle between the outflow and the magnetic field orientation. Strom *et al.*, 1986 and Menard *et al.*, 2004 highlight the preferential alignment of well collimated, bright, long-range jets with the cloud-scale (10 000 AU) magnetic field, while weaker or wider jets, oppositely, present a preferential misalignment.

We propose here an experimental setup in order to study the interaction of a plasma outflow with an ambient magnetic field. This is performed using a laser-created thermal plasma embedded in an external 20T pulsed magnetic field. By tilting the target surface with respect to the poloidal magnetic field lines, we study the interaction of the plasma outflow with an intentionally misaligned poloidal magnetic structure. It is found similar results as astrophysical observations, where for a large misalignment, the symmetry of the system, that allows collimation into a narrow jet, is broken and the flow cannot be redirected efficiently along the poloidal magnetic field direction.

Later on in the forming of young stars, accretion dynamics is still widely investigated because of limitations in observations and modelling. In our present understanding, matter from the accretion disk (10^{11}-10^{13} cm^{-3} / 2000 K) is connected to the star by the extended magnetosphere (0.1 –1 kG) and falls down into the stellar surface at the free fall velocity (500 $km.s^{-1}$). At the impact, a shock is forming, leading to observable X-ray and UV emissions, the amount of each channel being still incompatible with the present shock dynamic modelling at the impact region.

Using the same setup as presented above, using a perfect alignment between outflow and magnetic field lines, we open the first experimental window on this phenomenon by tracking, with spatial and temporal resolution, the dynamics of the system and simultaneously measuring multiband emissions. The laboratory jet, acting as the accretion column following the magnetic field lines then impacts a solid obstacle located on its path, mimicking the stellar surface. This setup differs by many ways from previous experiments using unmagnetized shock-tube configurations having unwanted edge-constraints.

We observe in our experiment that matter, upon impact, is laterally ejected from the solid surface, then refocused by the magnetic field toward the incoming stream. Such ejected matter forms a plasma shell that envelops the shocked core, reducing escaped X-ray emission. Discussed in the light of 3D-MHD simulations in the laboratory conditions as well as 2D-MHD astrophysical-scaled simulations, these experimental results shed light on one possible structure reconciling current discrepancies between mass accretion rates derived from X-ray and optical observations.