Laboratory unravelling of matter accretion in young low-mass stars

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Accretion dynamics in the forming of young stars 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.

Through scaled laboratory experiments of collimated plasma accretion onto a solid in the presence of a magnetic field, 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. This is performed using a laser-created thermal plasma embedded in an external 20T pulsed magnetic field. As a result of the magnetized plasma expansion, a collimated jet is formed, having an aspect ratio >10, a temperature of tens of eV, an electron density of 1.5.10^{18} cm^{-3} and propagating at 750 km.s^{-1}. This 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.