The magnetic ion streaming instability in space and in laboratory plasmas

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Energetic charged particles streaming in a magnetized medium are the source of an instability that results in the non-linear growth of magnetic fluctuations, enhanced wave activity and heating. The instability is thought to occur in a variety of space environments, and in particular it plays a crucial role in the transport of cosmic rays in the interstellar medium and their acceleration in supernovae shocks.

Recent technological advances have now made it possible to study the instability in the laboratory. And within the context of high-energy density laboratory astrophysics we have developed the first experimental platform to study the magnetic streaming instability using high-power lasers. The technique involves using a pico-second laser to generate a beam of protons with energies in the range ~ 0.1 - 1 MeV. These are then injected in a pre-formed plasma created with a nano-second laser and embedded in a 0.4 MG (40 T) magnetic field. Results from the first experimental campaign show clear "collective" effects that modify, non-trivially, the protons' energy distribution functions. However, at this point it is unclear if the effects observed are due to the magnetic streaming instability or some other, yet unexplained, mechanism. A new experimental campaign will take place on the ELFIE laser in the LULI laboratory at the Ecole Polytechnique, in March-April 2018.

The aim of the internship is to provide the first theoretical interpretation of the experimental results and to explore the implications for astrophysics.

The student's work will be to perform and analyse simulations of the magnetic streaming instability under laboratory conditions. The simulations will be primarily carried out with our hybrid-PIC code HECKLE (kinetic ions and massless electron fluid). If needed and time permitting, additional simulations will be performed using our 3D resistive MHD code GORGON, which includes laser-matter interaction and charged test-particles.

The student is expected to (i) implement (in C language) new initial conditions, such as the injected protons' energy distribution function; (ii) run the simulations on computing clusters within the Linux environment; (iii) write PYTHON scripts to analyse and visualize the results; (iv) critically interpret the numerical results and compare it to analytical models and experimental data. While no previous knowledge of experimental plasma physics is necessary, curiosity is a must.