Oral session 2
Thursday May 23

• **17:30-17:45:** *Aysegul Tumer (Bogazici University)*

Multi-scale study of turbulence in intracluster media: from AGN feedback to cluster merging processes

Clusters of galaxies are the largest gravitationally bound structures in the Universe. Due to their deep gravitational potential well, the history of physical processes which the clusters went through, can be investigated. Galaxy clusters contain mostly dark matter (~85%), intracluster medium (ICM) (~12%) and galaxies (~3%). ICM is the hot plasma that fills in between the galaxies inside the cluster, and was discovered by the X-ray images of clusters. The X-ray emitting processes in the ICM are mainly due to thermal bremsstrahlung and line emission. Reiprich and Böhringer (2002) sampled 64 galaxy clusters with a flux limit of 2 x 10-11 erg s^-1 cm^-2 in 0.1-2.4 keV band which is known as HIghest X-ray FLUx Galaxy Cluster Sample (HIFLUGCS). This sample contains clusters which are categorized by their central cooling time as Strong-Cool Core (SCC), Weak-Cool Core (WCC) and Non-Cool Core (NCC) clusters. When clusters collide, this process creates discontinuities in the temperature and abundance inside the plasma. These mergers are extremely energetic processes and depending on the stage of the merger, clusters give birth to several new structures such as shock fronts and cold fronts. In this talk, we will present the temperature and abundance maps of HIFLUGCS NCC clusters at different merger stages, namely; Abell 3391 and Abell 3395 (pre-merger), Abell 1656 (ongoing merger), and Abell 3158 (post merger) to discuss the plasma turbulences. In addition, we will present a SCC case (Abell 780 - Hydra A) from HIFLUGCS for comparison where the activity of the Brightest Cluster Galaxy (BCG) also affects the hot ICM plasma with cooling flows and Active Galactic Nuclei (AGN) jets. These analyses will be realized with X-ray Multiscale Analysis Program (XMAP) software developed by Bourdin et. al. (2004) using archival XMM-Newton observations.

• **17:45-18:00:** *Atul Kumar (Institute for Plasma Research)*

A new absorption mechanism for direct ion heating based of high power CO2 laser

The possibility of ion heating directly with short pulse, intense lasers has gained a significant interest in recent years because of their practical applications in a variety of contexts e.g. fast ignition scheme of laser fusion, proton radiography, biomedical applications etc. [1]. Some of the well-known mechanisms in this regard are the RPA (Radiation Pressure Acceleration) [2] and TNSA (Target Normal Sheath Acceleration) [3]. A new mechanism of ion heating with a p-polarized, pulsed CO2 laser when incident normal to an over-dense plasma with sharp interface has been shown to be operative in presence of an external magneto-static field. The external magnetic fields are chosen so as to restrict the electron motion and the heavier ions be allowed to respond to the laser electric field. The difference of electron and ion dynamics leads to charge separation and drives large amplitude ion plasma oscillations resonantly, thereby transferring the laser energy directly to heat ions (~ MeV). The proposed mechanism has been demonstrated by carrying out Particle-in-Cell (PIC) simulations under OSIRIS 4.0 framework [4] using parameters for nonrelativistic intensities (I = 3.46 x 10^14 W/cm2) of pulsed CO2 laser for which the requirement of external magnetic field strength is smaller. Furthermore, for a relativistic laser intensity (I = 7.0 x 10^17 W/cm2), Korteweg - de Vries (KdV) magnetosonic solitons have been observed to get excited. These solitons, as expected, propagate stably for several hundreds of ion plasma periods. However, subsequently, they are observed to develop transverse modulations which grow with time. It is important to note that with the recent technological advancements on CO2 pulsed lasers and the possibility of attaining magnetic fields of Kilo-Tesla order in the laboratory [6], this domain of studies will soon be within the reach of experimental explorations. References: [1] Ion accelerations by superintense laser-plasma interaction, A. Macchi, M. Borgeshi, and M. Passoni, Rev. Mod. Phys. 85, 751, 2013 [2] Radiation-Pressure acceleration of ion beams driven by circularly polarized laser pulses, A. Henig et. al., Phys. Rev. Lett. 103, 245003, 2009. [3] Scaling of proton acceleration driven by petawatt-laser-plasma interactions, L. Robson et. al., Nat. Phys., 3, 58-62, 2007. [4] OSIRIS: A three dimensional, fully relativistic Particle-in-Cell code for modelling of plasma-based accelerators, R. Fonseca et. al., Springer Berlin Heidelberg, Berlin, Heidelberg, 2002. [5] Excitation of KdV Alfven solitons by a pulsed CO2 laser in plasma in the presence of an external magnetic field, Atul Kumar et. al., arXiv: 804.08327v1 [physics.plasm-ph], 2018. [6] Record indoor magnetic field of 1200 T generated by electromagnetic flux-compression, D. Nakamura et. al., Review of Scientific Instruments, 89, 095106 (2018).

• **18:00-18:15:** *Florian Regnault (Institut d'Astrophysique Spatiale)*

20 years of ACE data: how superposed epoch analyses reveal generic features in interplanetary CME profiles

Interplanetary Coronal Mass Ejections (ICMEs) result from solar flares occuring in our star's atmosphere. These large-scale magnetised structures propagate in the interplanetary medium where they can be probed by spacecraft. Depending on their speed, ICMEs may accumulate enough solar wind plasma to form a turbulent sheath ahead of them. They therefore consist of two main substructures, a sheath and a magnetic ejecta (ME), with the magnetic ejecta being the main body of an ICME where the magnetic field intensity is larger, and its variance smaller, than that of the ambient solar wind. We present a statistical study using the superposed epoch analysis technique, of a little less than 300 ICME parameter profiles (the magnetic field intensity, the speed, temperature, ...) seen at 1 AU by the ACE spacecraft. In particular, we investigate different possible classifications of ICMEs, for example based on their speeds, when they are detected during the solar cycle, the detection of a magnetic clouds (MCs, a subset of ME with a clear rotation of the magnetic field as well as a low plasma temperature compared with the solar wind), and finally the distance of the spacecraft from the ICME's main axis. We find that slow ICMEs have a more symmetric profile than fast ICMEs, therefore generalising the work made on a sample of 44 ICMEs with clearly identified magnetic clouds by Masias-Meza et al. (2016). We also find that ICMEs ejected during the maximum of the solar cycle are also more asymmetric and faster than their solar-minimum counterpart. . This analysis provides a better understanding of the interplay between the solar wind and ICMEs, in particular on the relaxation process taking place for slow/slowed-down ICMEs compared with fast ICMEs. Furthermore, the superposed epoch analysis on ICMEs with no clear-detection of MCs show similar tendencies for all the parameters expected for the magnetic profiles as those with an identified MC, suggesting that ICMEs with no detected MCs are either probed further away from the core of the MC, or with a strongly degraded MC.

• **18:15-18:30:** *Roman Kislov (Space Research Institute of the Russian Academy of Sciences)*

Quasi-stationary current sheets of the solar origin in the heliosphere

The solar magnetic field has historically been considered as dipole in order to build models of the radially expanding corona, i.e. the solar wind, in the solar minimum. The simplified approach suggests the existence of only one quasi-stationary current sheet (QCS) of the solar origin in the heliosphere, namely the heliospheric current sheet (HCS). However, the solar magnetic field (SMF) becomes more complicated over the solar cycle, comprising higher-order components. The overlapping of the dipole and multipole components of the SMF suggests a formation of more than one QCS in the corona, which may expand further to the heliosphere. We study the impact of the quadrupole and octupole harmonics of the SMF on the formation and spatial characteristics of QCSs, building a stationary axisymmetric MHD model of QCSs in the heliosphere. It is shown that if the dipole component dominates, a single QCS appears in the solar wind at low heliolatitudes as the classic HCS. In other cases, the number of QCSs varies from one to three, depending on the relative input of the quadrupole and octupole components. QCS possess a conic form and may occur at a wide variety of heliolatitudes. The existence of QCSs opens wide opportunities for explanations of puzzling observations of cosmic rays and energetic particles in the heliosphere and, at the same time, raises a risk of misinterpretation of in situ crossings of QCSs because of mixing up the HCS and higher-heliolatitude QCSs which can be significantly disturbed in the dynamical solar wind.

• **18:30-18:45:** *Sonakshi Sachdev (Chennai Mathematical Institute)*

Conservative regularization of ideal fluid and plasma equations

Ideal systems like Euler and one and two-fluid MHD may develop singularities in vorticity and magnetic field. Viscosity and resistivity provide dissipative regularizations of the singularities. In analogy with the KdV regularization of the inviscid Burgers' equation, we propose a local, conservative, nonlinear dispersive regularization of dissipationless compressible 3D Euler and 2-fluid plasmas and models derived therefrom (quasi-neutral, Hall and ideal MHD). The regularization involves micro-scale cutoff lengths which may be taken to be the collisionless skin depths. Our regularization preserves the symmetries of the ideal systems. Energy and enstrophy are subject to a priori bounds in contrast to the ideal systems. The proposed regularization could facilitate numerical simulations of fluid/plasma equations and provide a consistent statistical mechanics of vortices/current filaments in 3D, without blowup of enstrophy. We also discuss a Hamiltonian formulation, generalizations of Kelvin-Helmholtz and Alfven theorems, the minimality of the proposed regularization and applications.

• **18:45-19:00:** *Ayushi Vashistha (Institute for Plasma Research, Homi Bhabha National Institute)*

Absorption Mechanism for coupling laser energy directly into ions

The interaction of laser with plasma mainly results in coupling of laser energy into lighter species of the plasma i.e. electrons and the absorption of laser energy by ions becomes a subsequent process. In our proposed mechanism, we have been able to give a dominating role to the ions in the absorption of laser energy. With the help of 2-D Particle-In-Cell (PIC) simulations using OSIRIS4.0, we show that pulsed CO_2 lasers (λ = 10μm) can be used to directly couple the laser energy to plasma ions in the presence of ambient external magnetic field. The external magnetic field is chosen so as to magnetize the electrons and keep them tied to the magnetic field lines. The system is found to generate ion plasma oscillations in the presence of external magnetic field. In this way, we have observed ions dominated mechanism for laser energy coupling. This coupling of laser energy into ions can be a result of EXB drift experienced by plasma species which creates a charge separation and hence results in the absorption of laser.This new technique of ion heating would be discussed in detail.