# Oral session 1
## Thursday May 16

• **17:30-17:45:** *Fabio Cruz (IST/Princeton)*

**Particle-in-cell simulations of pair discharges at pulsar polar caps**

When subject to the rotationally induced electric field of pulsar polar caps, electrons and positrons are accelerated along the magnetic field, producing gamma-ray curvature radiation. The emitted gamma-rays, in turn, are absorbed by the magnetic field, converting to new electron-positron pairs. The repetition of this process leads to a cascade of elementary particles that are the source of pulsar magnetospheric plasma. The final number of particles created in pair cascades and their connection with pulsar radio emission remains an open problem. Obtaining numerical models of pulsar pair discharges is a challenging endeavor and one that was only addressed in simplified one-dimensional simulations. In this work, we present two-dimensional particle-in-cell simulations of pair discharges near pulsar polar caps, including the Quantum Electrodynamics effects responsible for gamma-ray and pair production processes from first principles. These simulations allow studying the time dependence and distribution in altitudes and latitudes of pair cascades while resolving the relevant plasma electrodynamic scales. We analyze the particle spectra and discuss the constraints that our simulations put on pair production rates for use in global pulsar simulations, underlining the differences to previous models with simplified prescriptions. We also estimate the fraction of gamma-rays that escapes the polar cap and contributes to the flux of polar gamma-rays in Fermi data.

• **17:45-18:00:** *Virginia Bresci (Arcetri)*

**A possible explanation for the anomalies in secondary cosmic rays spectra**

The ratio between secondary and primary cosmic rays (CRs) is the most important observable source of information. Primary cosmic rays are thought to be accelerated mainly in Supernova Remnant shocks and then released in the interstellar medium where secondary particles can be created by occasional collisions with interstellar matter. As a result, the ratio between the fluxes of secondary and primary particles carries information about the amount of matter CRs have encountered and is expected to monotonically decrease with energy roughly as the inverse of the diffusion coefficient.Recent measurements by AMS-02 revealed some deviations from this behavior: the B/C ratio flattens above some energy and the antiproton over proton fraction is almost constant. These anomalies might be explained by taking into account two effects: firstly, some fraction of secondary particles can be produced within the acceleration region, and hence undergo acceleration immediately after birth, and secondly, there is a non-negligible probability that secondary particles encounter an accelerator (and are reaccelerated) during propagation. Accounting for both effects allows us to well-reproduce both the fluxes of the best measured nuclei and the secondary-to-primary ratios mentioned above.

• **18:00-18:15:** *Benjamin Crinquand (IPAG)*

**Electromagnetic cascade in Kerr black hole magnetospheres**

A variety of astrophysical phenomena can only be explained, in the framework of our current theories, as being powered by black holes. In particular, accreting supermassive black holes are responsible for launching relativistic plasma jets and for accelerating ultra energetic particles. The mechanism that channels energy from the black hole to the particles remains a mystery. The Event Horizon Telescope (EHT) collaboration, which aims at resolving the event horizons of the two black holes with largest angular size (Sgr A* and M87), will give new clues to tackle these questions. Constructing theoretical models to solve the magnetospheric structure is necessary to understand the images provided by the EHT. This problem involves complex interactions between collisionless plasma dynamics in high gravitational field, and pair creation due to the interaction of energetic particles with surrounding photons. Only kinetic simulations can hope to capture all these effects. In this talk, I will present recent General Relativistic Radiative Particle-in-Cell (GRRPIC) simulations of an axisymmetric black hole magnetosphere possessing a monopolar magnetic field and embedded in a soft background radiation field. These simulations show for the first time the development of an electromagnetic cascade, which could explain the high variability of high-energy emission from Sgr A* and M87.

• **18:15-18:30:** *Loann Brahimi (LUPM)*

**Non-linear diffusion of Cosmic Rays (CRs) escaping from Supernovae Remnants (SNRs) in the weakly ionized Interstellar Medium (ISM)**

We will discuss about the Cosmic Ray (CR) propagation in the weakly ionized environments of supernovae remnants (SNRs) and based the Cosmic Ray Cloud (CRC) model developed by Malkov et al. (2013) and Nava et al. (2016). It consists in solving two transport equation simultaneously: one for the CRs pressure and one for the Alfvén waves energy density where CRs are initially confined in the SNR shock. CR trigger a streaming instability and produce slab-type resonant Alfvén modes. The self-generated turbulence is damped by ion-neutral collision and by non-correlated interaction with Alfvén modes generated at large scale. We show that CRs leaking in cold dense phases as Cold Neutral Medium (CNM) and Diffuse molecular Medium (DiM) can still be confined over distances of a few tens of parsecs from the CRC center for a few kyrs. At 10 TeV CR diffusion can be suppressed by two or three orders of magnitude. This effect results from a reduced ion-neutral collision damping in the decoupled regime. We calculate the grammage of CR in these environements. We find both in single or multi-phase set ups that at 10 GeV CNM and DiM media can produce grammage in the range 10-20 g/cm^2 in the CNM and DiM phases. At 10 TeV because of non-linear propagation the grammage increases to values in the range 0.5-20 g/cm^2 in these two phases. We also present preliminary calculations in inhomogeneous ISM combining two or three different phases where we obtain the same trends.

• **18:30-18:45:** *Lev Arzamasskiy (Princeton)*

**Hybrid-Kinetic Simulations of Low- and High-Beta Turbulence**

A lot of astrophysical environments, such as accretion flows around black holes, the intracluster medium, and the solar wind, are weakly collisional (or collisionless) and well magnetized. We present results from hybrid-kinetic simulations of turbulence relevant to these systems. Our low-beta simulations (where beta is the ratio of thermal and magnetic pressures) reproduce the observed preferential perpendicular ion heating and the development of non-thermal beams in the ion distribution function in the solar wind. Our high-beta simulations focus on the effects of kinetic micro-instabilities on the turbulent cascade, in particular, how they disrupt inertial-range Alfven waves and introduce an effective collisionality in otherwise collisionless plasma.

• **18:45-19:00:** *Paola Domínguez-Fernández (Universität Hamburg)*

**Spectral properties of magnetic fields in merging galaxy clusters**

We investigate the evolution of magnetic fields in galaxy clusters starting from constant primordial fields using highly resolved ($\approx$ 4 kpc) cosmological MHD simulations. The magnetic fields in our sample exhibit amplification via a small-scale dynamo and compression during structure formation. In particular, we study how the spectral properties of magnetic fields are affected by mergers, and we relate the measured magnetic energy spectra to the dynamical evolution of the intracluster medium. The magnetic energy grows by a factor of $\sim$ 40-50 in a time-span of $\sim$ 9 Gyr and equipartition between kinetic and magnetic energy occurs on a range of scales ($<$ 160 kpc at all epochs) depending on the turbulence state of the system. We also find that, in general, the outer scale of the magnetic field and the MHD scale are not simply correlated in time. The effect of major mergers is to shift the peak magnetic spectra to smaller scales, whereas the magnetic amplification only starts after $\sim$ 1 Gyr. In contrast, continuous minor mergers promote the steady growth of the magnetic field. We discuss the implications of these findings in the interpretation of future radio observations of galaxy clusters.

• **19:00-19:15:** *John Mehlhaff (CU Boulder)*

**Kinetic Beaming of Emission Produced by Radiatively Cooled Relativistic Magnetic Reconnection**

Relativistic collisionless magnetic reconnection is often invoked to explain high-energy emission observed in astrophysical sources such as pulsar wind nebulae, gamma-ray bursts, and relativistic blazar jets. Reconnection produces nonthermal spectra, as are commonly observed in these sources. Reconnection may also explain distinctive short-timescale flaring. Such flares could arise because reconnection-accelerated particles—and their emitted photons—tend to be focused into beams with greater collimation at higher energies. This kinetic beaming may produce rapid high-energy flares when beams sweep across the observer's line of sight. Using large-scale 2D particle-in-cell simulations, we systematically investigate the robustness (i.e. existence and duration) of kinetic beaming in emission powered by reconnection subject to external inverse Compton (IC) cooling. We find that only strongly cooled energetic particle beams can radiate most of their energy before they disperse. Thus strong cooling promotes kinetic beaming, while weak cooling suppresses it. Our results support the view that reconnection may power rapid IC gamma-ray flares in sources such as blazar jets.