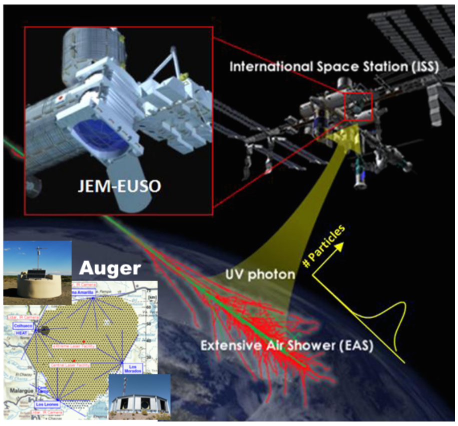
# High-Energy Astronomy and Astrophysics; Signal-Image Processing / Numerical Methods

## Modelling of space- and ground-based observations of Ultra-High Energy Cosmic Rays




*Cosmic Rays (CRs) play a major role in many important phenomena at work in the Galaxy, among which the heating and ionization of the interstellar medium, the creation and amplification of turbulent magnetic field, the regulation of star formation, the control of some astrochemical reactions, and the nucleosynthesis of the light elements, Li, Be and B. CRs have a remarkably continuous energy spectrum from sub-GeV energies to beyond $10^{20}$ eV, amounting to an overall energy density of the order of 1 eV/cm$^3$ in our Galaxy, similar to that of magnetic fields, thermal energy or stellar light. One of the key open questions in the field of astroparticle physics / high-energy astrophysics concerns the origin of the so-called Ultra-High Energy CRs (UHECRs). They consist of protons and nuclei traveling through the universe with macroscopic energies, reaching $10^{20}$ eV and beyond, which makes them by far the most energetic particles known in the universe. However, their sources and acceleration mechanism(s) are still to be identified. A major challenge is the very low flux, namely about 1 particle per km$^2$ per millennium at the highest energies! For this reason, detectors with a huge field of view must be developed to study UHECRs with reasonable statistics. Objective of the METEOR is a full immersion in the topic of UHECRs, with lectures on cosmic rays science and detection tecniques. A significant fraction of the time will be devoted to conduct data analysis, simulation studies or experiments in the framework of the Pierre Auger Observatory or JEM-EUSO projects.*

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by M. Bertaina

### Theory

UHECRs are very interesting for high energy astrophysics and particle physics, despite their very low fluxes and overall energy density. They represent a challenge for particle acceleration models in astrophysical environments. The so-called diffusive shock acceleration model proposed for Galactic CRs can not accelerate particles above $10^{14}$ eV. To reach higher energies, other types of accelerators must be considered, such as superbubbles, fast rotating pulsar, magnetars, active Galactic nuclei (AGNs), relativistic jets, termination shocks of AGNs, gamma-ray bursts, Galactic accretion shocks, etc. No consensus has been reach so far. However, it is recognized that the acceleration of particles up to $10^{20}$ eV is extremely challenging for astrophysical scenarios, which make the quest for the UHECR sources all the more interesting and important. An other reason why the UHECRs attract so much attention is that they may deliver crucial information about the most powerful sources in the universe, which is complementary to the information obtained from the observations in the framework of multi-wavelength photonic astronomy (radio, infrared, visible, ultraviolet, X-ray and gamma-ray, up to TeV energies). The study of UHECRs is indeed part of a global effort to develop multi-messenger astronomy, which aims at gathering knowledge from the cosmos using not only photons as messengers, but also cosmic rays, neutrinos and gravitational waves.

### Applications

The trainee will use and possibly improve available numerical codes to analyse data acquired by the ground-based Pierre Auger Observatory or space-based JEM-EUSO path-finder missions or simulate the cascade of UHECRs in atmosphere and their detection. Part of the program will include also the possibility to conduct experiments using the facilities of the University of Torino and the National Institute for Nuclear Physics.

### See also

Details 1
Details 2

### Contacts

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