Large-Scale Anisotropy Studies of Ultra High Energy Cosmic Rays

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Abstract
The anisotropy patterns of the flux of ultra high energy cosmic rays (UHECR), when combined with other observables, can bring us valuable information about their origin. A multipolar expansion of the flux in spherical harmonics allows us to access any anisotropy signal encoded in the set of cos(nmθ,φ) moments. The partial and non-uniform coverage of the sky forced us to use a correlation method to recover the truly expansion coefficients. Systematic effects such as pressure and temperature variations that affect detection efficiency should also be corrected.

Introduction
The main features of the UHECR energy spectrum are the slope change ("ankle") at an energy around $10^{18.5}$ eV and the flux suppression above $5 \times 10^{19}$ eV. The origin of the ankle is uncertain and could be associated with both the galactic-extragalactic transition and the way an extragalactic proton beam loses energy when interacting with the CMB. These models differ markedly in the predominant chemical composition as well as in the exact energy of the transition. The anisotropies studies are a powerful tool for identifying chemical composition of these particles, locating astrophysical sources of production and acceleration, and for determining transitional energy between galactic and extragalactic components.

Pierre Auger Observatory
The Pierre Auger Observatory is located in Malargüe, Argentina (latitude $-35.2^\circ$, longitude $69.5^\circ$). The detection and reconstruction of the events is done with an hybrid detection technique, using water-Cherenkov surface detectors and fluorescence telescopes simultaneously, arranged in an area of about 3000 km$^2$ of surface. The observatory has been taken data since January 1, 2004, gathering the biggest and highest quality data sample of UHECR nowadays.

Large-Scale Anisotropies
Above the knee of cosmic rays spectrum up to the ankle, there are predictions for anisotropies that are small but increasing with energy, which can be described by the regular and turbulent components of the assumed galactic magnetic field, as well as the distribution of sources and composition of cosmic rays. Further, at ultrahigh energies, cosmic rays are expected to be less smeared out by galactic and extragalactic magnetic fields, leading to a possible extraction of information about the positions of the sources. In particular, it is expected to observe some evolution of the amplitudes and phases of the multipoles coefficients around the energy in which there is the galactic-extragalactic transition of the flux.

About the GZK cut the high magnetic rigidity of the UHECR implies moderate angular deviations so that correlation studies with point sources are still possible. However, at lower energies any correlation to small angular scales is destroyed by both galactic and extragalactic magnetic fields, therefore anisotropy studies should be limited to regions of appreciable size of the sky (large-scale studies).

Detection efficiency corrections
The large-scales anisotropy studies are closely related to detectors stability for long periods of time. It is known, for example, that the detection efficiency of the surface detectors depends on atmospheric variables such as local temperature and pressure. The average trigger rate of SD as a function of time clearly presents diurnal and seasonal modulation, which can introduce fictitious anisotropies signals, predominantly a dipolar pattern, that must be properly corrected.

On going and future works
At this step we are carrying out the analysis and statistical processing of the data set. Taking into account local temperature and pressure as much as exposure corrections. Later the results obtained will be confronted with the main models predictions.

References
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Acknowledgements