Cosmic Ray Anisotropy Workshop 2023

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Loyola University - Chicago

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Modeling of cosmic-ray anisotropy at TeV energies in an MHD model heliosphere

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Past and on-going cosmic-ray experiments have reported small (~0.1%) anisotropies in the arrival directions of TeV cosmic rays observed at the Earth.
We are attempting to estimate anisotropic features at the heliospheric boundary by applying the idea of Liouville mapping to the data of the Tibet ASγ experiment.
Our preliminary results have indicated small, possibly spurious, anisotropic structures, with angular scales of ~10° in the cosmic-ray intensity distribution at the heliospheric boundary, and we expect that the higher-order residues of these structures at the heliospheric boundary could be removed if the stochastic scattering of cosmic-ray particles by magnetic irregularities inside the heliosphere are somehow taken into account in the mapping process.
In this presentation we will present the latest results of our improved intensity-mapping method.

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Review of the Local ISM

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The local interstellar medium (LISM), consisting of neutral and ionized gas, dust, and magnetic fields, is the environment for the heliosphere and stellar astrospheres. LISM gas and magnetic fields penetrate deeply into these environments. The LISM consists of the partially ionized gas clouds extending to about 10 pc from the Sun, the surrounding Local Bubble with its fully ionized hydrogen gas extending to several hundred parsecs from the Sun, and interactions with the external Galaxy. Absorption in resonance lines, primarily in the ultraviolet, observed by the Hubble Space Telescope and in situ measurements by the Voyager, New Horizons, Ulysses, and IBEX spacecraft are providing important data concerning the composition and properties of the LISM. This talk will review what we have been learning about the LISM - its structures, thermal and non-thermal properties, turbulence, ionization, inhomogeneity, and pressure balance among its components. As the Sun speeds through the LISM at 25 km/s, large changes in the size and properties of the heliosphere occur when it passes through cold dense clouds, partially ionized gas, or fully ionized gas. Cosmic rays traverse the different structures in the LISM and are modified by these environments.

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IceCube: The first Decade of Neutrino Astronomy

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Cosmic rays in a turbulent interstellar medium: Recent progress and open questions

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TBD

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The IBEX Ribbon and its Relation to the Solar-Interstellar Interaction

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NASA's Interstellar Boundary Explorer (IBEX), an Earth-orbiting Small Explorer spacecraft, measures energetic neutral atom (ENAs) produced primarily by charge exchange in the outer heliosphere. There are two main sources of ENAs. The first, called the "globally distributed flux", is formed from neutralization of interstellar pickup ions that were preferentially accelerated at the heliospheric termination shock and advected with the bulk plasma flow through the inner heliosheath. Once these ions experience charge exchange, they may travel back towards in the inner heliosphere and be detected by IBEX. The second main source, called the "Ribbon", is a narrow enhancement of ENA emissions circling the sky that come from outside the heliopause. It is widely believed that the Ribbon is ordered by the draping of the local interstellar magnetic field (ISMF) around the heliosphere and has allowed us to pinpoint the pristine (far from the heliosphere) ISMF strength and orientation. I will present a review of Ribbon modeling studies that analyze the relationship between the Ribbon and the draped ISMF, the importance of understanding particle pitch angle scattering outside the heliopause, and the evolving solar wind that serves as the primary source of the Ribbon flux through the secondary ENA process.

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The curious maximum-rigidity distribution of ultra-high-energy-cosmic-ray accelerators

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A standard assumption among models of candidate source populations of ultra-high energy cosmic rays (UHECRs) is that all sources in a candidate source population accelerate particles to the same maximum energy. Motivated by the fact that candidate astrophysical accelerators exhibit a vast diversity in terms of their relevant properties, such as luminosity, Lorentz factor, and magnetic field strength, we study the compatibility of a population of sources with non-identical maximum cosmic-ray energies with the observed energy spectrum and composition of UHECRs at Earth. For this purpose, we compute the UHECR spectrum emerging from a population of sources with a power-law, or broken-power-law, distribution of maximum energies applicable to a broad range of astrophysical scenarios. We find that for a wide range of studied models, the maximum energies of the UHECR accelerators must be nearly identical in order to be compatible with the UHECR data, in stark contrast to the variance expected for the astrophysical source models considered. A substantial variance of the maximum energy is only consistent with the UHECR data if the maximum energies of the UHECR sources follow a broken power-law distribution with a very steep spectrum above the break. However, in this scenario, the individual source energy spectra must be unusually hard with increasing energy output as a function of energy. These findings have implications for the arrival-direction distribution of UHECRs.

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Cosmic Ray Anisotropy with the Telescope Array

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Ultra-high energy cosmic rays (UHECRs) are charged particles that are extremely energetic, with $E > 10^{18}$ eV. They impinge on the Earth's atmosphere from outer space. The Telescope Array experiment, the largest UHECR observatory in the northern hemisphere, is situated in the western desert of Utah, USA, and has been collecting data continuously since May 2008. It is designed to detect extensive air showers (EAS) which are a cascade of subatomic particles induced by a primary UHECR particle interacting with the atmosphere. The Telescope Array uses two types of detectors: fluorescence detectors (FDs) and scintillator surface detectors (SDs). The FDs measure the scintillation light produced when the shower travels through the atmosphere's gas while the SDs sample the EAS's footprint at ground level. To understand the origin of UHECRs, we analyze the distribution of their arrival directions, looking for indications of anisotropic patterns. In this presentation, we summarize the results of the anisotropy study of UHECR events observed by the Telescope Array SD array, taking full advantage of its high duty cycle.

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Observation of cosmic-ray anisotropy with LHAASO

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Observation of cosmic-ray anisotropy with LHAASO

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Observation of cosmic-ray anisotropy with LHAASO (remote)

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Recent Results in Cosmic-Ray Astrophysics

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