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Cosmic ray acceleration and transport

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Supernova remnants are believed to be the source of galactic cosmic rays, which are then propagating in the Galaxy to generate radio and gamma-ray emission and to finally reach us. Recent particle-in-cell simulations and gamma-ray observations revealed spectacular insight into the particle acceleration process. However, these simulations are subject to fundamental limitations so that it is unclear whether we can extrapolate and apply these results to observations of supernova remnants. In this talk, I will present three-dimensional magnetohydrodynamics simulations where we self-consistently include cosmic ray protons and follow the time evolution of the cosmic ray electron spectrum. By matching the observed morphology and non-thermal spectra of shell-type supernova remnants (SN 1006, RXJ 1713, and Vela Jr.) in radio, X-rays and gamma-rays, I demonstrate how we gain insight into the following topics: 1) leptonic vs. hadronic model of the gamma-ray emission, 2) origin of patchiness of TeV gamma-ray maps and how this relates to interstellar magnetic turbulence, 3) quasi-parallel vs. quasi-perpendicular acceleration of cosmic ray electrons, 4) nature of magnetic field amplification and damping in supernova remnants (turbulently vs. Bell-amplified magnetic field). In the second part of this talk, I will revisit the theory of cosmic ray transport through the magnetized plasma of the interstellar medium and decipher the various modes of cosmic ray propagation: advection, diffusion and streaming. Finally, I will show that we can observationally test these theoretical considerations with high-sensitivity MeerKAT radio observations of the Galactic center and conclude that the popular assumption of dominant cosmic ray diffusion is ruled out by the data which requires us to consider plasma wave-particle scatterings for cosmic ray transport.

Keywords

Supernova remnants; particle acceleration; cosmic ray transport; plasma physics; gamma-rays; radio synchrotron; Galaxy

Collaboration

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