Implications of Solar Magnetograms for the Drifts of Cosmic Rays

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1 Executive Summary

Even after many years of research and despite significant progress regarding the modeling of the transport of energetic charged particles in turbulent magnetic fields it is unclear whether a combination of current models of the kinetic transport of cosmic rays with magnetohydrodynamic (MHD) models of the turbulent Solar wind plasma turbulence can satisfactorily explain three-dimensional (3D) multi-point spacecraft data.

In an attempt to help to clarify this issue, we developed a numerical model suite to investigate the cosmic ray transport in realistic configurations starting from magnetograms provided by the Global Oscillation Network Group (GONG) to construct the inner boundary conditions at the so-called heliobase. While gradient and curvature drifts are well-established elements of the propagation of cosmic rays in the heliospheric magnetic field, their perturbation by the Solar activity-induced large-scale distortions of dipole-like field configurations even during Solar minima and by magnetic turbulence is an open problem. Various empirical or phenomenological approaches have been suggested to quantify these effects so that they can be straightforwardly incorporated in modulation models covering the 22-year periodicity (including the sign) of Solar activity. These approaches, however, either lack clear physics-based parametrizations (e.g., in terms of the tilt-angle of the heliospheric current sheet) or have been shown to be incompatible with measurements (like a dependence on the normalized turbulence level. We propose here a new approach to the treatment of drifts over an entire Solar cycle including maximum periods, which is based on Solar magnetograms. This not only provides a physics-based approach to the reduction of drifts during Solar activity maxima but also a treatment that is fully consistent with those MHD models of the Solar wind and the embedded heliospheric magnetic field that exploit Solar magnetograms as inner boundary conditions.

By using a new quantity, the topological sign σ_{t}, it is now possible to model the scaling down of cosmic ray drift during periods and to self-consistently determine the sign for each Carrington Rotation during a Solar cycle.