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The Effect of the Dissipation Range on the Heliospheric Modulation of Cosmic-Ray Electrons

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Abstract: At low energies, cosmic-ray nuclei experience the adiabatic limit where their intensity becomes proportional to their kinetic energy per nucleon, independent of the diffusion tensor and interstellar spectrum. Low-energy electrons, on the other hand, do react to changes in the diffusion tensor and are therefore ideal probes of its spatial- and rigidity dependence. To construct a diffusion tensor that is valid for low-energy electrons, we need to know at least the wavenumber k_D where the dissipation range occurs, and the latter's spectral index. We consider two relationships for k_D suggested by Leamon et al. (2000 ApJ, 537), based on observational results. In one case, the proton gyrofrequency is used as predictor for the steepening wavenumber k_D where the dissipation range occurs, and in the second case, the ion inertial scale is used. Leamon et al. (2000) showed that best fits to *Wind* data cannot distinguish whether the proton gyrofrequency or the ion inertial scale is the best predictor for the break frequency. In principle, this question could be addressed by studying the modulation of low-energy electrons. In our steady-state three-dimensional modulation model a Fisk-Parker type heliospheric magnetic field (Kruger 2006, MSc dissertation, North-West University) is used. For the parallel mean free path (MFP) we use an analytical expression for random sweeping slab turbulence that includes the effect of a dissipation range (Teufel and Schlickeiser 2002, A&A, 393) and for the perpendicular MFP an approximation derived by Shalchi et al. (2004, ApJ, 604) for the nonlinear guiding center model (NLGC) of Matthaeus et al. (2003, ApJ, 590). The drift coefficient is from Burger et al. (2000, JGR, 105). Simplified expressions for the slab- and the two-dimensional correlation lengths and the magnetic field variance are used. One of our key findings is that for galactic electrons at Earth, the spectra obtained with the two different expressions for k_D begin to differ below about 1 GeV, and differ by about two orders of magnitude at 20 MeV. In one case, drift effects disappear (i.e. spectra for $A > 0$ and $A < 0$ merge) below about 100 MeV, while in the other case this only occurs below about 20 MeV. When plotted as function of global latitudinal gradient, the amplitude of the 26-day cosmic-ray intensity variations produced by the two expressions for k_D differ by about 20%. Before firm conclusions regarding an appropriate model for the steepening wavenumber k_D based on cosmic-ray electron observations can be made, other factors such as the spectral index in the dissipation range and the presence of Jovian electrons, will have to be studied.

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