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Dependence of decay rates of SEP events on characteristics of interplanetary medium and on radial distance

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We consider the decay parts of SEP event time profiles and their dependence on radial distance from the Sun. The solution of [1] of the propagation equation neglecting diffusion, gradients, and drift, but keeping adiabatic cooling yields a flux decay $J \propto \exp(-t/\tau)$, with $\tau = 3r / 2V (2 + \alpha \gamma)$, where r is radial distance, V is the solar wind speed and $\alpha = T+2mc^2/(T+mc^2)$.

Numerical results: Figure 1 shows a model simulation assuming an impulsive power-law source spectrum of $f = p^{-\gamma}$ with $\gamma = 8$, corresponding to dlnJ/dlnT=-3. Calculations are restricted to low latitudes, the radial diffusion coefficient, $\kappa_{rr} = \kappa_{\parallel}\cos^2\psi + \kappa_{\perp}\sin^2\psi$, includes the radial dependence of diffusion mean free path, $\lambda_{\parallel}$ ($\propto$ r and independent of p) and the effect of the spiral angle, ψ, reducing κ_{rr} as the spiral is more tightly wound at larger radii. The ratio $\kappa_{\perp}/\kappa_{\parallel}$ was taken constant. We find that a smaller diffusion coefficient tends to give decays closer to the theoretical prediction (in-ferred from the assumption of fast diffusion).

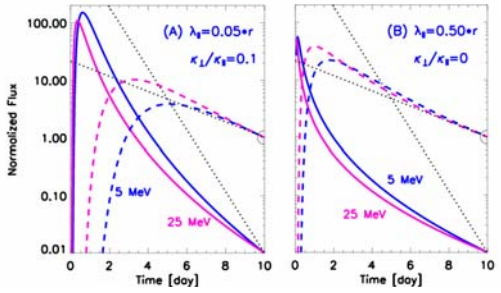

Figure 1 Comparison of simulated time profiles at 1 (solid lines) and at 4 AU (dashed) normalized at 10 days for small (left) and large $\lambda_{\parallel}$ (right panel) at two energies. Dotted lines indicate theoretical prediction [1].

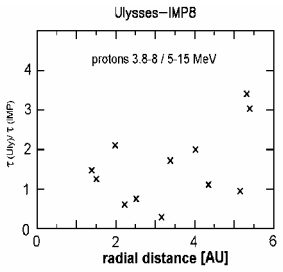

Figure 2 Variation of the ratio of best-fitting τ values for SEP observed at 1 AU and at distances 1-5 AU at Ulysses.

Observations: We analyzed data on simultaneous observations of protons in SEP events measured at various radial distances (Helios 1-2, IMP-8, ACE, and Ulysses). The comparison of Helios and IMP profiles indicates that the decay time is longer at 1 AU in the majority of events. The decay profiles of events seen by Ulysses at 1.4 to 5.4 AU (at latitudes within 20° from the ecliptic) indicate, in agreement with [2], that the decays at 2-5 AU are even longer. As Figure 2 suggests, τ rises by a factor about 2 from 2 to 5 AU at energies 1-10 MeV. Assuming power-law increase with r this would correspond to an exponent of ~0.5 as compared to 1 from the theoretical formula, but it is in a better agreement with low κ numerical results (~0.4).

References

[1] M.A. Lee, AIP Conf. Proc. 528, 3 (2000).
[2] R. B. McKibben et al., Ann. Geophys. 21, 1217 (2003).