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A Predictive and Analytic Model for Solar Modulation

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Significant uncertainties in solar modulation inhibit our ability to understand the physics of interstellar cosmic-ray injection and propagation. The effect of solar modulation on the propagation of cosmic-rays from the heliopause to the Earth is extremely complex, requiring the careful treatment of diffusion, particle drift, convection and adiabatic energy losses. Particle propagation codes are becoming increasingly sophisticated to meet these challenges. However, they require significant processing power and are not well suited to scans covering the large parameter space of cosmic-ray propagation. Models seeking to constrain cosmic-ray propagation parameters have instead utilized the force-field approximation, where the effect of solar modulation is treated as a simple, charge-dependent potential which cosmic-rays must climb before reaching the Earth. However, the magnitude and time-dependence of this potential is unconstrained, significantly increasing the number of degrees of freedom in the parameter space scan.

In this talk, I will discuss an intermediate option, based on a physically motivated correlation between heliospheric propagation parameters and solar observables. This allows us to construct a time-, charge-, and rigidity-dependent model for the solar potential that is analytic, and can be quickly applied to a wide parameter space of particle propagation models. Moreover, this model is predictive, as the only inputs relate to observable solar parameters such as the strength of the solar magnetic field at Earth, and the tilt of the heliospheric current sheet. Thus, this model significantly reduces the systematic uncertainty in models of interstellar cosmic-ray propagation. Finally I will discuss the implications of these models for our understanding of the rising cosmic-ray positron fraction, as well as an intriguing hardening in the antiproton spectrum recently observed by AMS-02.

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