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Cosmic-ray Modulation: The past, the present and the future

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From their birth in some supernova remnant to their detection at Earth, galactic cosmic rays traverse regions with varying turbulence, a variety of magnetic structures and stellar winds, and shocks. While we have a good idea of which processes play a role in the heliospheric modulation of galactic cosmic, our detailed knowledge is still incomplete. Current ab initio modulation models are becoming more complete (and therefore more complex) but they are not yet able to fit cosmic-ray data. This is no great surprise, because we still lack proper theories for, e.g., anisotropic perpendicular diffusion and the effect of turbulence on particle drift. We should always keep in mind that we may be attributing changes in cosmic ray intensities to changes in one quantity while it may in fact be partially or even totally due to changes in another quantity. The possible link between cosmic rays and Earth's climate has sparked a renewed interest in cosmic ray modulation models. They are typically applied to study modulation during epochs when changes in quantities like the magnitude of the heliospheric magnetic field have also been observed. However, ad hoc assumptions have to be made in order to obtain good fits to cosmic-ray data. To study the cosmic-ray flux during periods like the Maunder Minimum when heliospheric conditions are believed to have been quite different from what we are used to, various questions should be addressed, like: (1) Was the structure of the heliospheric magnetic field Parker-like or Fisk-like? (2) Was the solar wind speed fast, slow or something in between? (3) Were there any changes in the driving mechanisms of the turbulence? (4) What was the level of turbulence compared with recent values? (5) Did anisotropic perpendicular diffusion occur? An additional, and perhaps more general question is: If our only goal is to calculate cosmic ray intensities at Earth, do we really need complicated modulation models? I will discuss some of these questions, and show how uncertainties impact on results from modulation models.