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Multiscale matters: when coupling across multiple scales drives the dynamics of solar system plasmas

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The sun, solar wind and magnetospheres exhibit non-linear processes that can couple across a broad range of space and time scales. These multiscale processes can be central to the dynamics of far from equilibrium plasmas, where collisionless processes dominate. This talk offers highlights from two interconnected approaches to advancing our understanding of multi-scale processes in solar system plasmas.

From the plasma physics: If sufficient simplifications can be made, we can study the plasma dynamics from first principles. The non-linear scattering and acceleration of energetic particles in current sheets, by wave particle interactions, and in shocks, can be approached from non self-consistent single particle dynamics allowing the full non-linear physics, including low-dimensional chaos, to be considered. The physics of shocks, reconnection, and its interplay with turbulence can be approached by fully kinetic self-consistent simulations, albeit with restrictions on physical dimension and the range of scales resolved. If bursty energy and momentum transport is an emergent process, then it can be captured by reduced models.

From the data: The full dynamics is revealed in all its richness in observations. A wealth of in-situ and remote observations are available from the fastest physical timescales of interest to across multiple solar cycles. In principle, these afford the study of specific physical process such as reconnection and turbulence, and system-scale processes such as the dynamics of magnetospheres, all of which are fully multiscale and non-linear. In practice, determining the physics from observations relies upon establishing robust, reproducible patterns and relationships from multipoint data in these inhomogeneously sampled, non time-stationary systems. As well as providing fundamental physical insights, these can deliver quantitative estimates of space weather risk.