Cross Scale Wave–Particle Interaction in Geospace

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This presentation will synthesize current understanding of how solar wind forcing — such as interplanetary shocks or dynamic-pressure pulses—drives fundamental processes within Earth's magnetosphere, including electromagnetic-wave generation, plasma heating, and energetic-particle acceleration. Drawing on in-situ spacecraft data, ground magnetometer observations, and both MHD and kinetic simulations, we highlight advances in radiation-belt electron physics, ring-current ion dynamics, and plasmaspheric behavior in response to solar wind forcing. We demonstrate that a generalised theory of drift and drift-bounce resonance with localised ultra-low-frequency (ULF) waves can account for related insitu spacecraft observations.

Beyond these macroscale responses, we address how energy cascades from macro- to micro-scales in collisionless plasmas. By analyzing Magnetospheric Multiscale (MMS) events in which hot ions simultaneously interact with macroscale (~105 km) ULF waves and microscale (~10 km) electromagnetic ion-cyclotron (EMIC) waves, we demonstrate that cross-scale wave-particle interactions mediate an efficient, direct energy transfer. Energy injected at ULF scales is rapidly conveyed to EMIC waves and dissipated through ion energization within about ten EMIC periods (~1 min). These results experimentally confirm that the generalized ULF-wave theory, combined with cross-scale coupling, constitutes a new paradigm for energy transfer and particle acceleration in space and astrophysical plasmas.
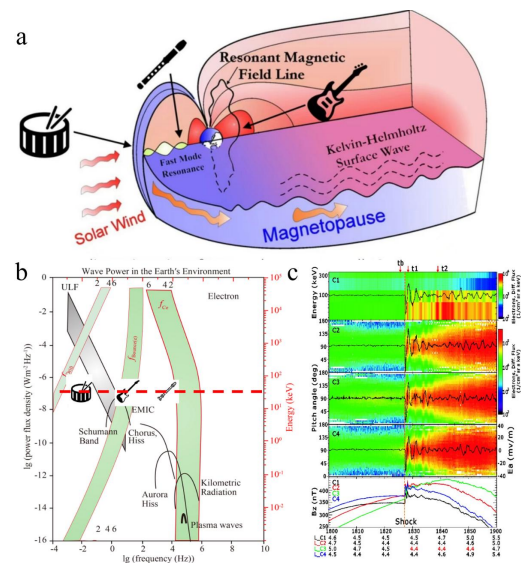

Figure 1. Prof. Zong revealed ultra-low-frequency (ULF) wave-driven "killer electron" acceleration in Earth's radiation belts.
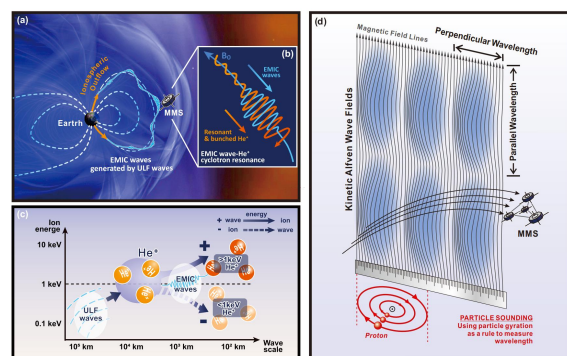

Figure 2. Pro. Zong developed particle sounding method and demonstrated cross-scale energy transfer as a universal framework for plasma energization in astrophysical systems.

Note: Abstract should be in (full) double-columned one page.