BOSTON UNIVERSITY

Boston University College of Arts & Sciences
Center for Space Physics

2023—2024 SPACE PHYSICS SEMINAR SERIES

Matching Theory and Observations on Rapid Nonlinear Electron Acceleration in Earth's Radiation Belts

During solar storms, drastic changes in Earth's geomagnetic field configuration can result in an almost total depletion of highly relativistic MeV outer radiation belt electrons. Subsequently, a rapid recovery of □1–3 MeV outer zone electrons can take place in a matter of a few hours, in a manner which strongly suggests the presence of nonlinear physical mechanisms. So called 'killer electrons' at these relativistic energies can inflict significant damage to spacecraft electronics, and their dynamic pathways thus have large interest not only to first-principles physical understanding but also to the applied space community. The launch in 2012 of the twin Van Allen Probes radiation belt mission, with comprehensive particle momentum and energy diagnostics, has triggered large observational and modeling advances for new understanding of fast nonlinear dynamics involved in Earth's radiation belts, first discovered by van Allen and colleagues at the beginning of the space era.

In a causal chain, rapid radiation belt recovery involves local acceleration of 100s keV seed electrons to multi-MeV energies in the low-density region outside the plasmapause through wave-particle interactions with whistler mode very low frequency (VLF) chorus waves. Mathematical simulations have accentuated the critical role chorus waves play in accelerating electrons up to several MeV during radiation belt recovery. We will summarize recent work in collaboration with J. C. Foster and Y. Omura's group on detailed VLF chorus wave properties, down to individual wave cycles, from the EMFISIS instruments on Van Allen Probes during radiation belt recovery events. Sub packet electric and magnetic field wave observations have been combined with both cold plasma estimates from EFW vehicle potential and upper hybrid EMFISIS data to enable direct calculations of radiation belt acceleration theories.

Results demonstrate the significant efficiency of nonlinear processes in the acceleration of electrons to MeV energies. Of particular note, seed electrons, with initial energies of 100s keV to 3 MeV, can be accelerated by 50 keV–200 keV in resonant interactions over only a single strong chorus rising tone wave element, on a time scale of 10–100 ms. In accordance with theory, nonlinear wave development strongly depends on inhomogeneous properties of a rising-tone chorus element. Furthermore, nonlinear wave growth in one studied event during the March 17, 2013 storm recovery period took place at more than 50% of the theoretical maximum value during the development of the observed strong sub packets. For several cases examined, resonant electron energies and pitch angles closely match those of the observed injected electron flux enhancements responsible for chorus development and the nonlinear acceleration of MeV radiation belt electrons. Such results suggest that nonlinear mechanisms are ultimately important for storm chorus wave element generation, and they foster a better community understanding of storm time recovery within the relativistic outer radiation belt electron population.

Thursday, April 25th

4:00-5:00 p.m.

725 Commonwealth Ave | Room 502

Philip Erickson

Massachusetts Institute of Technology