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Title: Ultra-relativistic Electrons in the Van Allen Radiation Belts

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Ultra-relativistic Electrons in the Van Allen Radiation Belts

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Abstract:
Cold plasma has a controlling effect over the ultra-relativistic electrons that are over million times more energetic. Novel analysis of phase space densities at multiple energies allows for differentiation between various acceleration mechanisms at ultra-relativistic energies. This method allows us to trace how particles are being accelerated at different energies and show how long it takes for acceleration to reach particular energy. This method clearly demonstrates the importance of local acceleration and also demonstrates the importance of the outward radial diffusion in transporting electrons to GEO. Acceleration to such high energies occurs only when cold plasma in the trough region is extremely depleted, down to the values typical for the plasma sheet. We perform event and statistical analysis of these depletions and show that the ultra-relativistic energies are reached for each such depletion that is accompanied by the intensification of ~2MeV. VERB-2D simulations are then used to explain these observations. There is also a clear difference between the loss mechanisms at MeV and multi-MeV energies due to EMIC waves that can very efficiently scatter ultra-relativistic electrons but leave MeV electrons unaffected. Modeling and observations clearly show that cold plasma has a controlling effect over the ultra- relativistic electrons that are 10^6-10^7 times more energetic. The difference in the acceleration (continuous acceleration for MeV and sudden acceleration, when density is very low, at multi-MeV), difference in loss (loss by VLF waves at MeV and very fast loss by EMIC waves at multi-MeV) together with observations of different evolution and morphological structures, justify classifying ultra-relativistic electrons as a population different from the bulk populations of the radiation belts. Similar to how the ring current is considered a population different from the radiation belts, multi-MeV electrons form a new population that co-exists with the relativistic outer electron radiation zone.