Acceleration of relativistic electrons in Earth's outer radiation belt by whistler mode chorus: Evidence and the importance of energetic particle injections

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Earth's magnetosphere acts as a very efficient particle accelerator, with processes acting within it capable of accelerating electrons by many orders of magnitude to relativistic energies in only a few hours during active periods. There is much evidence supporting that wave-particle interactions between electrons in the outer radiation belt and ring current and whistler-mode chorus waves can be responsible for such rapid acceleration, and we begin by reviewing such evidence. Next, we present results indicating the relationship between chorus wave growth and energetic particle injections from Earth's magnetotail. We highlight how the anisotropic distributions that arise naturally due to energy dependent drift of freshly injected 10s of keV particles are ideal to support chorus wave growth, and we show several examples from NASA's MMS and Van Allen Probes missions to support this. Next, we present new results investigating why energetic particle injections alone do not seem to be accountable for enhancements of >500 keV electrons in the outer radiation belt. Intriguingly, despite apparently sufficient source populations associated with energetic particle injections in the plasma sheet and deeper into the magnetotail, energetic particle injections in the inner magnetosphere and outer radiation belt rarely involve any direct enhancements of electrons at more than a few hundred keV. Thus, some additional acceleration mechanism is necessary for outer belt electrons to reach >500 keV levels, which we argue is acceleration by whistler-mode chorus. In summary, we'll present the case that energetic particle injections rarely serve as a direct source of relativistic electrons in Earth's outer radiation belt, though the injections are responsible for the growth of strong chorus wave activity, which can then locally accelerate a seed population of 10s to 100s of keV electrons up to relativistic energies in only a few hours.