Relativistic Turning Acceleration of Resonant Electrons by Coherent Whistler-Mode Waves in a Dipole Magnetic Field

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We report a very efficient process for accelerating high energy electrons by coherent whistler-mode waves in the Earth's dipole magnetic field, which we have found in our recent test particle simulations [1,2]. The efficient acceleration process takes place for weakly relativistic seed electrons of a few hundred keV. Under an assumption that the whistler-mode wave packets are excited near the equatorial plane of the inner magnetosphere and propagate away from the equator, the acceleration process becomes irreversible. With a sufficiently long whistler-mode wave packet of the order of one second, the energetic electrons are accelerated to a relativistic energy range of a few MeV through a single resonant trapping process. We call this particular acceleration process relativistic turning acceleration (RTA), which could be a viable mechanism for increasing relativistic electron fluxes in the outer radiation belt. Necessary conditions for RTA are a relatively large amplitude of whistler-mode waves, in the range of 50 pT to a few hundred pT, and an initial kinetic energy of trapped electrons in the energy range of a few hundred keV. The minimum energy of electrons accelerated by the RTA process, and the maximum energy attained by it are derived analytically, and verified by the test particle simulations.

The time scale of each RTA process is only of the order of a second. If a sufficiently large temperature anisotropy is maintained by continuous injection of high energy particles into the inner magnetosphere, successive chorus emissions are generated [3,4]. Then, a series of effective RTA processes take place, resulting in a rapid formation of a flux of relativistic electrons with a time-scale much shorter than that typically predicted by quasi-linear diffusion theory. RTA is a unique feature of the dipole magnetic field geometry. The process should also be operative in the magnetospheres of Saturn and Jupiter.

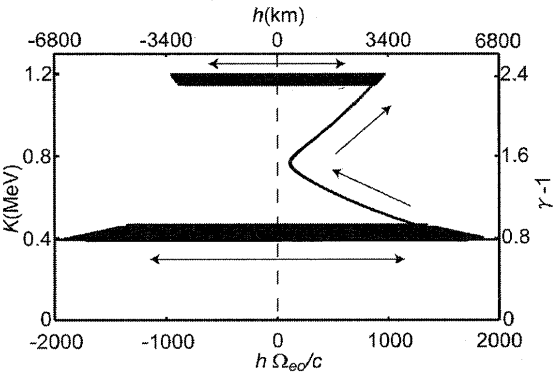

Figure 1. Trajectories of resonant electrons interacting with a coherent whistler-mode wave.

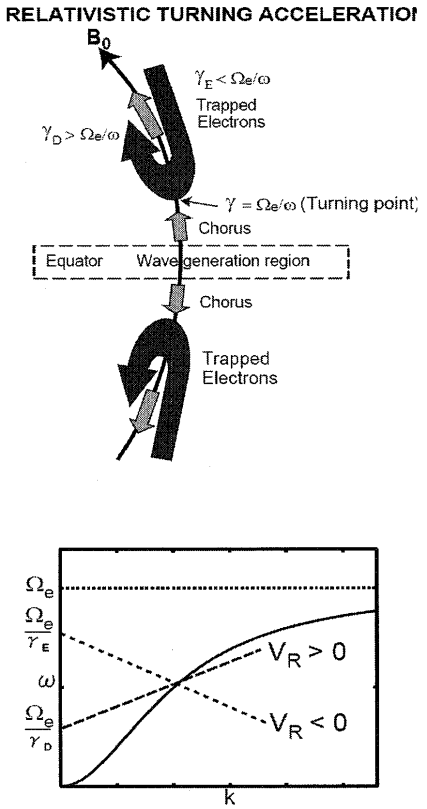

Figure 2. Schematic illustration of RTA (top panel) and the relativistic cyclotron condition for whistler mode wave (bottom panel).

REFERENCES

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