Stochastic Shock Drift Acceleration in the Shock Transition Region with Finite Pitch-Angle Anisotropy

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The acceleration of non-thermal electrons is one of the important subjects in space physics. The shock accelerated non-thermal electrons have been observed at Earth's bow shocks (Gostling et al. 1989). These electrons are supra-thermal (with energies from 1keV to 100keV), and their distribution is power-law. However, acceleration models proposed in the past could not reproduce such observed spectra. Recent in-situ satellite observations of Earth's bow shock found wave-particle interactions between whistler waves and electrons at the shock transition region (Oka et.al. 2017). These results indicate that whistler waves play an important role for the acceleration of supra-thermal electrons.

We propose the stochastic shock drift acceleration (SSDA) model as a new acceleration mechanism for non-thermal electrons. It takes into account the effect of stochastic pitch-angle scatterings by whistler waves during the course of the Shock Drift Accelerations (SDA), which is a classical acceleration model for supra-thermal electrons at the shock transition region (Wu 1984, Leroy and Mangeney 1984). By introducing stochasticity with pitch-angle scatterings, the acceleration efficiency may be improved. We theoretically analyzed this acceleration model. We showed that the electron energy spectrum becomes a power-law consistent with observations in the limit of strong scatterings. We also found the maximum energy attainable through the proposed model, and it scales linearly with the pitch-angle scattering coefficient which represents the strength of scatterings. In our previous study, we have assumed the electron pitch-angle distribution is isotropic, and an effective shock speed $u/\cos\theta$ (u: shock speed, θ: shock normal angle) is non-relativistic. The SSDA model cannot consider an anisotropy of the electron pitch-angle distribution. It is well known that the shock with a relativistic effective shock speed has a finite pitch-angle anisotropy. Therefore it is difficult to compare the SSDA model with full particle-in-cell (PIC) simulations which can reproduce only the shock with a relativistic effective shock speed because of the limitation of parameters we can take. To fix this problem, we extend the SSDA model so that it can be applied to such a shock. In this presentation, we discuss the consistency between the extended SSDA model and PIC simulation results.

Keywords: acceleration of particle, Earth, shock waves

