

Stochastic Electron Acceleration by Whistler Waves within Earth's Bow Shock Layer

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High-energy electrons with relativistic velocities are produced at high Mach number astrophysical shocks, as have been indicated by emissions such as synchrotron X-rays and radio waves. In the standard 'diffusive shock acceleration' scenario, electrons are accelerated stochastically by receiving energization 'kicks' multiple times while being scattered back and forth across the shock front. A challenge is that electrons need to be sufficiently energetic before being injected into the standard process for further energization. The lack of such a seed population is termed "injection problem" and has been a subject of theoretical debate. In interplanetary space where in-situ measurements are available, non-thermal electrons have been detected, but the precise location and mechanism of electron acceleration have remained unclear. Here we show that electrons are energized through bursts of whistler waves within the transition layer of Earth's bow shock. We further found evidence of the diffusive shock acceleration although, unlike the standard scenario, electrons were accelerated even in a low energy range (>0.1 keV) and were confined within the shock layer. The new observation at Earth suggests a need for revisiting current models of electron injection and subsequent acceleration to high energies at astrophysical shocks.

キーワード : electron acceleration、 shock、 whistler waves

Keywords: electron acceleration, shock, whistler waves