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Observations and modeling of solar flare energetic electrons in hard X-ray, radio and in-situ near 1 AU

The behavior of energetic electrons from solar flares traveling through interplanetary space is crucial for understanding space environment and its impact on Earth. This transport is effectively influenced by the pitch-angle scattering due to the broad existence of interplanetary magnetic turbulence. However, how does the strength of pitch-angle scattering change over the electron energy and other parameters is still to be ascertained. In this work, we present the pitch-angle scattering dependence on the traveling distance and the electron energy. We analyze 14 energetic electron events that are detected in-situ by the Wind 3D Plasma and Energetic Particle instrument and accompanied by coincident hard X-ray (HXR) emission and interplanetary type III radio bursts. These events are with single short-duration electron injection as indicated by HXR light curves, and the injection time is determined from HXR observations. We find that the arrival time of the electrons in energy bands from 27 to 520 keV are delayed for around a thousand seconds with respect to their free-flying time; and find the statistical energy dependence of the rise and decay time of electron flux profiles. We numerically model the transport of electrons considering the pitch-angle scattering and magnetic focusing. By conducting simulation experiments, we obtain the scattering mean free path as well as its dependence on distance from the Sun and the electron energy that best suits the observations.

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