AOGS 2006

Comparative Spectral Analysis of Non-Thermal Emissions and Study of Electron Transport in a Solar Flare

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Characteristics of high energy (non-thermal) electrons in solar flares is discussed from the hard X-ray (HXR) and/or optically thin radio observations. HXRs are thought to be emitted from electrons with energy below several hundred keV, whereas radios are thought to be emitted from electrons with energy above several hundred keV. Then the comparative study using the HXR and radio observations is useful for discussing the flare non-thermal electrons over a wide range of energies. There have been reported that the electron spectra inferred from the HXR and radio spectra are significantly different (e.g., Silva et al.2000). The electron spectrum inferred from the radio spectrum is often harder than that inferred from the HXR spectrum. This implies that the electron spectrum becomes flat toward the higher energy. To explain this discrepancy of electron spectra inferred from the HXR and radio spectra, two models have been proposed, namely, second-step-acceleration (e.g., Bai & Ramaty 1976), and trap-plus-precipitation (e.g., Melrose & Brown 1976). Here we present the comparative spectral analysis of the 29 May 2003 X1.2 flare using the RHESSI (Lin et al.2002) and Nobeyama Radio Polarimeters (NoRP) observations. The temporally-resolved non-thermal spectra of HXR (50 - 200 keV) and radio (17 - 35 GHz) are fitted by a double power-law and a single power-law function. Then we obtain three spectral indices of lower-energy HXR, higher-energy HXR, and radio. We compare them and find the following features: (1) The values of them are significantly different. The spectrum of radio is the hardest, and that of higher-energy HXR is the softest. (2) There are time delays in the time profiles of them toward the higher energy. The time profile of the spectral index of higher-energy HXR lags that of lower-energy HXR, and the time profile of the spectral index of radio lags that of higher-energy HXR. To explain these observational features, we consider the trap-plus-precipitation model. We numerically solve the spatially-homogeneous Fokker-Planck equation (Leach & Petrosian 1981; Lu & Petrosian 1988; Hamilton et al.1990) with the additional term of precipitation flux (McClements 1990). Two physical variables are obtained from the calculation, the electron energy distribution and the precipitating electron flux. Former is treated as the radio emitter via gyrosynchrotron, and latter is treated as the HXR emitter via thick-target bremsstrahlung (Brown 1971). We analyze the numerically obtained spectra and find the following features: (1) Although the injection flux has single power-law energy distribution, the resulting spectra are significantly modified. The spectrum of radio is the hardest, and that of higher-energy HXR is the softest. (2) When the pitch-angle distribution of injection flux is pancake-like, there are considerable time delays in the time profiles of the spectral indices toward the higher energy. Our model can qualitatively explain the observational features of the 29 May 2003 flare. At the same time, our model can remove the reported discrepancy of electron spectral indices inferred from the HXR and radio spectra.