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Modeling the Acceleration and Transport of Energetic Particles in Solar Flares Based on Macroscopic MHD Simulations

Xiangliang Kong[1], Fan Guo[2], Bin Chen[3], Chengcai Shen[4], Feiyu Yu[1], Zelong Jiang[1], Ze Zhong[1], Jing Ye[5], Meng Jin[6], Yao Chen[1], Joe Giacalone[7]

[1] Institute of Space Sciences, Shandong University, [2] Los Alamos National Laboratory, [3] Center for Solar-Terrestrial Research, New Jersey Institute of Technology, [4] Harvard-Smithsonian Center for Astrophysics, [5] Yunnan Observatories, Chinese Academy of Sciences, [6] Lockheed Martin Solar and Astrophysics Lab, [7] Department of Planetary Sciences, University of Arizona

e-mail (speaker): kongx@sdu.edu.cn

Particle acceleration and transport are at the heart of the high-energy aspects of solar flares. Observations have suggested that an enormous number of particles are accelerated to high energies in the corona, and the accelerated particles further propagate and precipitate, producing nonthermal footpoint sources in the dense chromosphere. Recently, we develop a macroscopic particle model that naturally incorporates electron acceleration and transport by combining the particle transport equation with large-scale MHD simulation of a solar flare. We showed that electrons can be efficiently accelerated by the reconnection-driven termination shock, and a concave-downward magnetic trap with a local minimum of magnetic field strength plays an important role in both accelerating and confining energetic electrons. The acceleration of electrons can be dynamically modulated as the plasmoids collide with the looptop, which may explain the quasi-periodic pulsations of nonthermal emissions. By including both MHD and particle processes in a realistic flare geometry, our model can reproduce emission signatures that are well matched to the microwave, EUV, and X-ray imaging and spectroscopy observations. Our simulation results provide new insights into understanding the acceleration and transport of energetic particles, and nonthermal emissions in solar flares.

References
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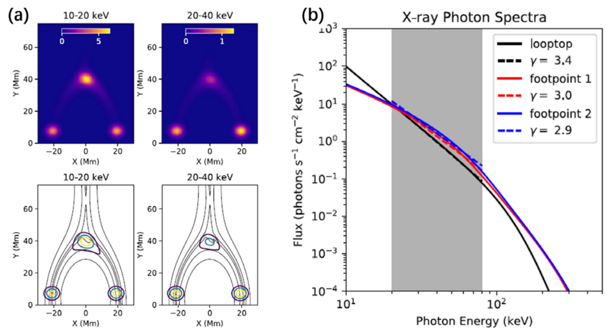

Figure 1. (a) Synthetic HXR images at different photon energy ranges based on the MHD-particle simulation results. The black curves indicate magnetic field lines. (b) X-ray photon flux spectra at the loop top and two footpoints.

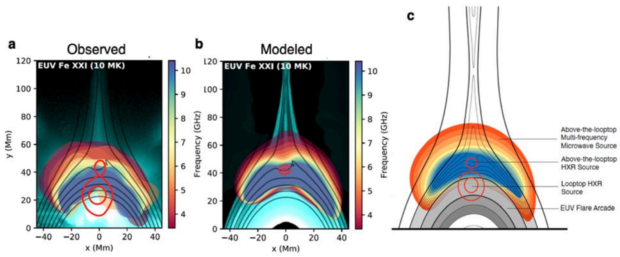

Figure 2. (a) EOVSA multifrequency observations overlaid with RHESSI 25–60 keV HXR contours for the solar flare on 2017 September 10. (b) Synthetic SDO/AIA (background), 25–60 keV HXR (red contours), and multifrequency microwave sources (filled color contours) as calculated from the combined MHD and particle model. (c) A schematic of thermal and nonthermal emissions.