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The Acceleration of Energetic Electrons at the Solar Flare Termination Shock

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Particle acceleration in solar flares is a long-standing unsolved problem in solar physics community. Nonthermal looptop sources in solar flares are the most prominent observational signatures that suggest energy release and particle acceleration in the solar corona. Although several scenarios for particle acceleration have been proposed, the origin of the looptop sources remains unclear. Here we present a model that combines a large-scale magnetohydrodynamic simulation of a two-ribbon flare with a particle acceleration and transport model for investigating electron acceleration by a fast-mode termination shock (TS) at the loop top. Our model provides spatially resolved electron distribution that evolves in response to the dynamic flare geometry. We find a concave-downward magnetic structure located below the flare TS, induced by the fast reconnection downflows. It acts as a magnetic trap to confine the electrons at the loop top for an extended period of time. The electrons are energized significantly as they cross the shock front, and eventually build up a power-law energy spectrum extending to hundreds of keV. We suggest that this particle acceleration and transport scenario driven by a flare TS is a viable interpretation for the observed nonthermal looptop sources.

Figure 1 shows our picture for explaining the looptop source in the framework of standard flare model by including a concave-downward magnetic trap structure in the looptop region based on our simulations. A termination shock (TS) is created as high-speed magnetic reconnection outflow collides with the looptop region. Electrons are accelerated by the TS and confined in the looptop region by the magnetic trap structure where they produce the looptop nonthermal emissions.

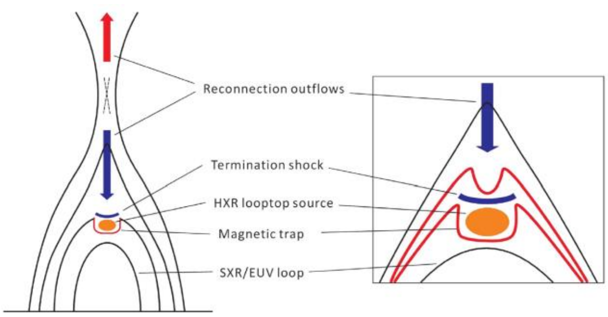

Fig. 1: Schematic illustration of our model for explaining the looptop HXR sources.

Figure 2(a) shows the plasma velocity-divergence map from MHD simulation and the TS is manifested by a negative divergence. The magnetic trap structure is illustrated by the magnetic field lines in red color. Figures 2(b-d) show that accelerated electrons are distributed below the TS and above closed loops, and the source size of electrons with higher energies is smaller and the source is located closer to the TS.

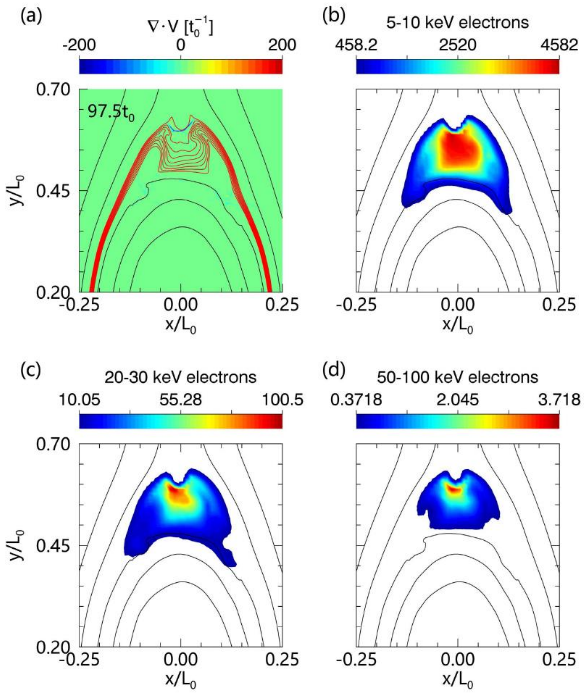

Fig.2: Spatial distributions of accelerated electrons for different energies.

References

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[2] C. Shen et al., The Dynamical Behavior of Reconnection-driven Termination Shocks in Solar Flares: Magnetohydrodynamic Simulations, ApJ, 869, 116, (2018)