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# Simulating solar flare by combining MHD method and analytic fast electron model

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In a solar flare event, up to $10^{33}$ erg of free energy stored in magnetic field can be released in solar corona within one hour via magnetic reconnection. Most of the released energy is finally converted thermal energy and emitted to the space via radiative loss, where energetic electrons play an important role in the energy conversion.

A large amount of non-thermal electrons of energy several tens keV are produced in coronal height in flare events. They move downward to thick chromosphere layer along magnetic field lines, lose energy via collision there and produce strong upward evaporations. The generated evaporation flows fill the coronal loop formed in reconnection with hot and dense plasma, and then leads to a rapidly increase of loop emission at soft X-ray waveband and high temperature emission lines. The contribution of fast electrons deposition to the evaporations is mainly investigated in one-dimensional magnetohydrodynamics (MHD) simulations, in which the collisional transport of the non-thermal electrons and the resulted heating effect to the chromosphere is often evaluated with analytic electrons models. In those simulations, the energy flux carried by the fast electrons, which determines the response of chromosphere, is artificially given.

Here we present two and a half dimensional (2.5D) MHD flare simulations that the influence of fast electron deposition is also included. Analytic fast electron model is employed in multiple selected magnetic field lines to evaluate the chromospheric heating by fast electrons, where the fast electron energy flux is related to the reconnection process to gain reasonable value. Chromospheric heating due to non-thermal electron deposition is successfully reproduced in our simulation. We also successfully reproduce hard X-ray sources often observed in flare events, which is widely thought to be caused by high energy electrons, with information of non-thermal electrons in the analytic fast electron model. Figure 1 shows the thermal soft X-ray emission and non-thermal hard X-ray emission of our flare simulations.

References
[1] Ruan, W., Xia, C., & Keppens, R. 2020, The Astrophysical Journal, 896, 97

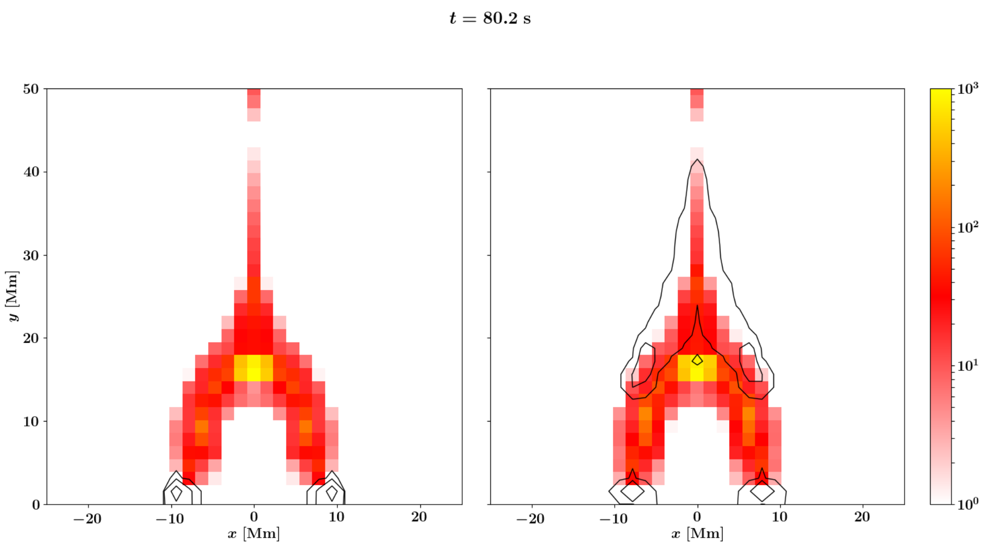


**Figure 1**. SXR emission (6–12 keV, images) and HXR emission (25–50 keV, black contours) of two simulated flares observed at 1 AU, where the unit of SXR is photon arcsec$^{-2}$ cm$^{-1}$ s$^{-1}$ and the levels of the HXR contours are 0.1, 0.4, and 0.8 photon arcsec$^{-2}$ cm$^{-1}$ s$^{-1}$. Non-thermal electrons are produced near the top of the panels and then propagate downward along magnetic field lines. The non-thermal electrons in the left case has smaller initial average pitch angle than the right case.