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Diagnosis of accelerated electrons in solar flares

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Solar flares, first observed in 1895 in white light, have been observed in wide frequency range: in optical and radio with ground-based telescopes; in UV, X-ray, and gamma-ray with space telescopes. However, the mechanism of particle acceleration is not understood yet, which is so energetic that emits gamma-rays. Thus, particles acceleration is the most mysterious phenomena in solar flare. Since high energy particle acceleration is important physics occurring commonly in the universe, solving problems of particle acceleration in solar flare is not only for solar physics but also for constructing accurate model of particle acceleration in other astrophysics. Solar flares provide us unique opportunity to observe them in wide frequency range, in high spatial and temporal resolution, and magnetic structure directly around them.
There are three temporal phases in solar flare. Preflare phase: pre-activation of energy release, impulsive phase: explosive energy release, and gradual phase: emergence of thermal emission from energy released region. In preflare phase, there are many case-studies on triggers of energy release. In impulsive phase, accelerated electrons and ions precipitate into the chromosphere. The electrons colliding with elements in the chromosphere emit bremsstrahlung of hard X-rays. On the other hand, accelerated ions radiate fluorescent gamma-ray by collision to nuclei of chromospheric elements. Excited ions in chromosphere make thermal emission in optical and UV. At the same time, mildly relativistic electrons, accelerated to about 1/3 of light speed, are trapped by flare loop of the magnetic field, and emit gyro-synchrotron radiation in radio during repeating stroke by the magnetic mirroring effect. In gradual phase, chromospheric plasmas evaporated by the accelerated particles fill the flare loop and emit thermal-bremsstrahlung in soft X-rays. Those thermal emissions are observed in UV and radio other than soft X-rays. After that, evaporated electrons in the flare loop cool down gradually and they emit EUV (Extreme Ultra Violet), optical lines. They can be seen clearly as the magnetic loop structure, called" post flare loop". Therefore we can know structure of the flare loop and position of radiation of each frequency from the post flare loop and magnetic field on the photosphere.
These observations show us rough model of particles movement in solar atmosphere. However many problems remain in particle acceleration in solar flare; position of energy release, mechanism of particle acceleration, ratio between released whole energy and particles-gained energy, maximum energy of particles, energy spectrum of accelerated particles, spatial and temporal scale of acceleration, difference of accelerated condition between ions and electrons, etc. In this study, we discuss the movement of accelerated electrons mainly on the number of accelerated electrons, pitch angle distribution of accelerated electrons, and the region of energy release. We are doing statistical study using results of multi-wavelength observations, mainly radio and hard X-ray data with non-thermal emission process. The data we analyze are from Nobeyama Radioheliograph (17 GHz intensity and polarization, 34GHz intensity), RHESSI space telescope (X-ray, gamma-ray), SOHO space telescope (magnetic field in photosphere, EUV line emission), TRACE space telescope (UV, EUV) and from optical data of ground-based telescopes.

Keywords: solar flare, particle acceleration, radio emission, hard X-ray