SXT observations of flares

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The engine for solar flares is magnetic reconnection with shocks. The magnetic energy of inflow is converted to plasma heating and the outflow jets. It appears that equi-partition of the released energy between heating and outflow holds. If the Mach number of the outflow is high, the fast shock can make further energization of the outflow plasma through the Fermi process. The Fermi acceleration at the fast shock in between the slow shocks efficiently converts the energy of the bulk outflow heated by the slow shocks to that of individual particles. The only key-question here is whether we have enough evidence of slow and fast-modes shocks in the X-ray images.

The story upto this point is clear to me, and I do not need to spend too much time for these issues. (Those are already published.) The primary question that I want to address in this talk is how the system without X-point dynamically evolves to the system with X-point through an MHD instability. Although we understand the local issues (reconnection), I must say that we are still ignorant of the global issue. Therefore, we should go back to the careful examination of the data: Flares that took place at various positions of the Sun allow us to investigate the 3D evolution; formation of X-point and plasmoid.

Key Observation I:
Thin long thread along the photospheric neutral line is often seen in the soft X-ray images before and around the start of flares. Portion of the spine has upward motion, and the other part not. Cusp-structure with high temperature is formed beneath the spine without rise motion. It appears that spine goes through the top of the cusp or slightly above the top. On the other hand, nothing spectacular is seen beneath the rising portion of the spine. Flares have a tendency to take place in the non-erupting portion of the system. The key question here is how we connect the frequently-observed soft X-ray erupting features with this observation, and is whether the spine is the locus of the X-point or the O-point above the X-point.

Key Observation II:
Sheared sometimes S-shaped structure essentially along the neutral line is seen before the start of on-disk flares. The spine appears to be part of this highly sheared structure. The reconnected loops, bright in soft X-rays, is highly sheared in early phase, evolving to larger less-sheared loops. Finally, these loops become potential-like loops without any shear. The key question here is whether the shear is essential for flare initial trigger as well as for the energy storage in the corona.

The minimum energy principle with constraint of global helicity conservation (Taylor) may give insight to these observations. The system can reach lower energy state from higher energy state, if we allow magnetic reconnection (Kusano). In this process, the helicity is conserved, while magnetic energy is dissipated through magnetic reconnection. Then, the helicity of the initial sheared field lines is transferred to the helicity of the plasmoid. This process makes the magnetic energy dissipation possible. These two key observations and its relation to Kusano's MHD bifurcation theory will be discussed in the talk.