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Numerical Studies on Spectroscopic Signatures of Heating Processes in the Solar Corona

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How the hot corona is heated and maintained above the cold chromosphere and photosphere is one of the great mysteries in solar physics. The energy to heat the corona is thought to be originated from the convection in the photosphere and transported along the magnetic field. The problem is how the magnetic energies are dissipated in the corona. To explain the coronal heating problem, two energy conversion processes are proposed. One is wave dissipation[1], and the other is small-scale magnetic reconnection, which is so-called nanoflares[2]. The differences between these processes are supposed to be amplitude, frequency, and duration of heat input into the magnetic loop. In this paper, we focus on how to diagnose these heating parameters by soft X-ray spectroscopic studies and identify spectroscopic feature that characterizes the different heating processes by numerical studies. The keys to understand these heating parameters are temperature structure and ionization processes.

In a local region in a coronal loop, we can assume that electron distribution is under an equilibrium state, and a temperature and an emission measure are defined. From the information of the temperature distribution in a coronal loop, we can estimate frequency and amplitude of heat input[2]. In the case of high-frequency heating, timescale of heat input is much shorter than the timescale of radiative and conduction cooling. As a result, temperature as a function of time is relatively uniform. On the other hand in the case of low-frequency heating, timescale of heat input is comparable to or longer than the cooling time. This results to be a dynamic temperature change, and, thus, broad temperature distribution. The amplitude of heat input directly reflects the maximum temperature.

Lines in soft x-ray ranges are emitted from highly charged ions. The intensities depend on electron density, electron temperature, and density of ions at each charge state and element. When electron temperature changes, the ionization and recombination process of each element follows to become equilibrium. During the rapid heating processes, ionization and recombination processes sometimes do not get to be equilibrium, and repeating heating and cooling process affects ion fraction, i.e. line intensities between different charge states.

To examine the spectra emitted from plasmas under different heating processes, we perform 1-dimensional hydrodynamic simulations by using CANS code[3] and obtain temperature structures in a coronal loop under different heating conditions but the same average heat rate. After solving heat and mass transfer, we calculate ionization and recombination processes for each element and solve collisional-radiative model for each ionization state to obtain intensities of the soft x-ray spectra based on the ADAS atomic database[4].

The calculation results show that dynamic temperature structures appear in the shape of the continuum, and heating frequency and duration appear in the line intensities especially from S^{14+} as shown in Figure 1.

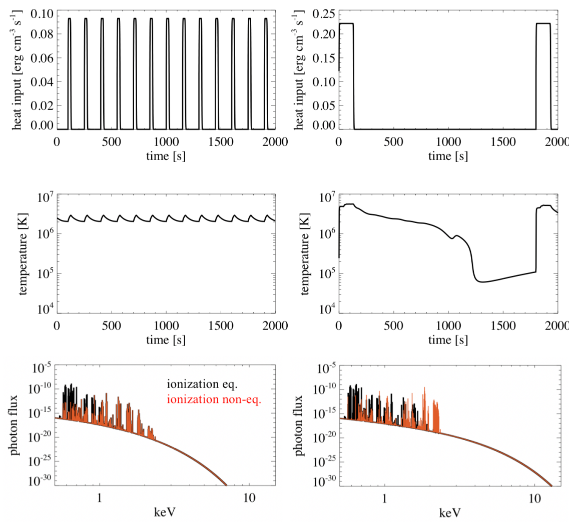

Figure 1. Spectra calculated under high-frequency (left column) and low-frequency (right column) heatings. Black spectra are the results under ionization equilibrium, whereas red spectra are the results under non-equilibrium ionization.

References

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