The origin of nonthermal electrons in solar flares

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We study the evolution of coronal electron density in solar flares with EUV imaging spectroscopy by using Hinode/EIS to search the location of where electrons are evacuated due to the acceleration. From these analyses, we find the depression of electron density at the beginning of several flares.

In this presentation, we show the results of the time-dependent density distribution of electrons in the coronal flare region to identify the electron acceleration site in the solar flares. We also compare the amount of the depressed electron and the amount of the nonthermal electrons estimated from hard X-ray observation using RHESSI data to check the quantitative agreements between them. As a result, we find that the amount of depressed electrons are about 20 times larger than the amount of nonthermal electrons estimated from hard X-ray observation.

"Number Problem" in solar flares

When we assume that all the nonthermal electrons in solar flares are accelerated in corona;

- number of accelerated electrons estimated from HXR → 10^{36} /s
- Plasma density in solar corona → 10^{10} /cm^3
- volume of flaring region → $(10^4$ km$)^3 = 10^{27}$ cm^3

→ coronal electrons are evacuated in 10 seconds !?

Which is the erroneous assumption?

- electron number estimated from HXR is to large?
- electrons are accelerated only in corona?

In any case, electron density must decrease near the region where electrons are accelerated.

EUV electron density diagnosis might tell us:

- the electron acceleration site
- the number of accelerated electrons
- the energy of the electrons which are to be accelerated

and, with the HXR observations,

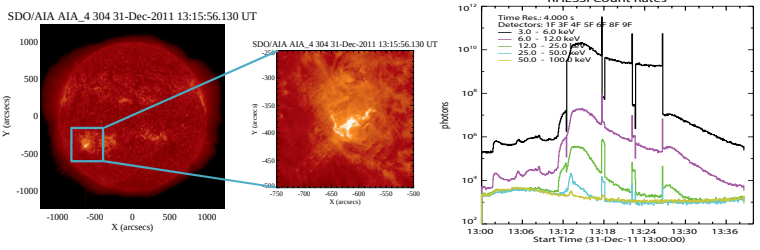
- the number of accelerated electrons

about flare event

We investigate flares which are simultaneously observed with Hinode/EIS and RHESSI before Jun 2013 (754 events) and selected events that have following criteria:

- density sensitive lines are observed in Hinode/EIS
- found decreasing of electron density in coronal flaring region at the onset phase (before the evaporated plasma enhances)
- not associated with CME (LASCO event) to avoid coronal dimming

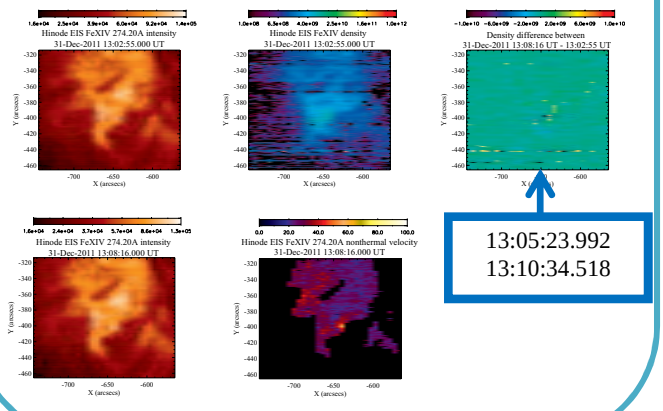
→ 2011-12-31T13:09 (M2.4) event has remained



electron density in FeXIV (logT=6.3)

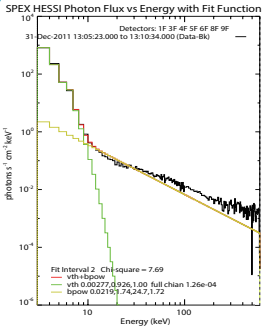
electron density depressed

- of the volume of 1.1×10^{26} cm^3 around the looptop (depression over 2×10^9 /cm3)
- where the nonthermal velocity changes 50 km/s → 40 km/s
- around the onset of soft X-ray flux enhancement
- from 8.9×10^9 /cm^3 in 4.0×10^9 /cm^3 (mean)
- of the total amount of **4.0×10^{35} electrons**



13:05:23.992
13:10:34.518

HXR spectrum



thick target bremsstrahlung (Brown et al. 2008)

$$I(\epsilon) = \frac{nV}{4\pi R^2} \int_{\epsilon}^{\infty} \bar{F}(E) Q(\epsilon, E) dE$$

under

- the Kramers approximation for bremsstrahlung cross section
- assumption of a purely collisional thick target
- power law index of photon flux 1.7 (from obs.)
- 0.00277 photons/s cm^2 keV @50keV (from obs.)

the accelerated electron flux is

$$F(E) = 4.8 \times 10^{33} E^{-2.7} \text{ electrons/s keV}$$

assuming lower limit energy of electron of 10 keV, the number of nonthermal electrons between 13:05:23 – 13:10:34 is **1.8×10^{34}** electrons

discussions

From the analysis, number of depressed electrons in FeXIV is about 20 times larger than nonthermal electrons derived from HXR observation. Note that the number of depressed electrons we investigate is only in the temperature of logT=6.3 so that all the amount of thermal electrons which are to be heated or accelerated can be much larger. This result might suggest that thermal energy which is produced by energy release of solar flare is much larger than nonthermal energy.