White-Light Emission and Related Particle Acceleration Phenomena in an X1.8-class Flare on 2012 October 23

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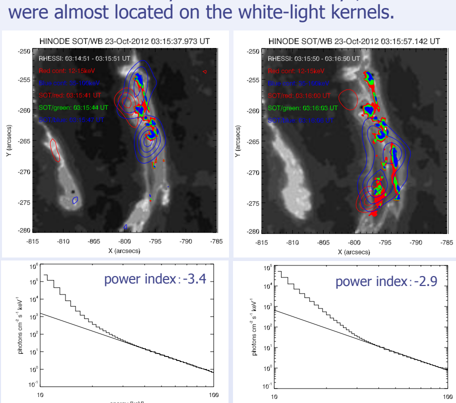
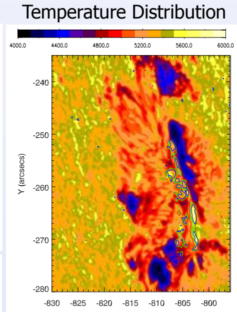
On October 23, 2012, white-light emission was observed by *Hinode*/SOT in association with an X1.8 class flare. Although the main phenomena of this solar flare occurred in a very compact region and the two Ca II H ribbons are separated only by less than 5 arcseconds, the white-light kernels are clearly observed along the Ca II H ribbons. Moreover, hard X-ray, and γ-ray emission up to about 1 MeV, is also observed by the *RHESSI* satellite, and most of this emission is associated with the white-light kernels. However, there are some white-light kernels without hard X-ray emission and they have different behaviors compared to the white-light kernels with hard X-ray emission. This observational result might mean that the origin of white-light emission cannot be explained by non-thermal electrons. Furthermore, the *Hinode*/EIS also performed a raster scan over this flaring active region starting before the flare, and the flare occurred during the scan. Strong red shifts were observed in FeXII etc. over the white-light kernel without any hard X-ray radiation.

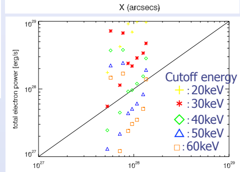
2012 Oct 23 X1.8-class flare

White-light emission was observed in association with an X1.8-class flare in the three continuum band (red, green and blue) of *Hinode*/SOT. These emissions were almost located on the Ca II H ribbons and followed their expansion. *RHESSI* also observed hard X-rays and >1MeV γ-rays, and the observed hard X-ray emissions were almost located on the white-light kernels.



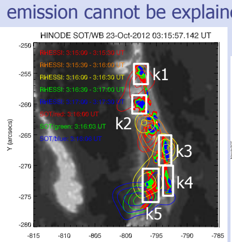
Temperature Distribution



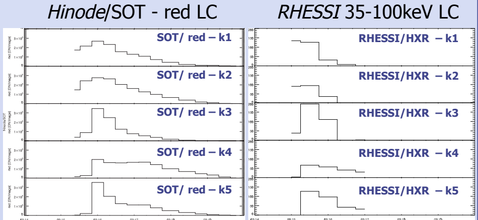


From the data of the three continuum bands, we estimate the temperature of the white-light emissions by fitting the 3 points using the Planck formula. All white-light temperatures are calculated to be around 5600K. We calculate the power of the white-light emissions from the obtained temperature, and compare with the power of the observed hard X-ray emission. We confirmed that the energy of the white-light emission can be explained by >40keV non-thermal electrons. (Watanabe et al. 2010.)

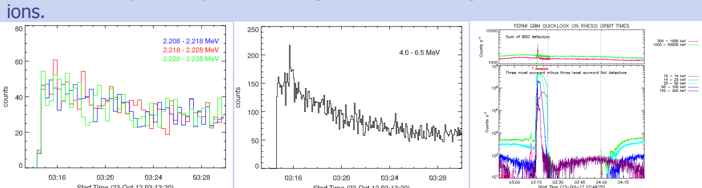
However, when we look at the time series of *RHESSI* hard X-ray images, we find that there are some white-light kernels without hard X-ray emission (k2 & k4). Although, the observed strength of the white-light emission were almost at the same level as the other white-light kernels, the strength of the hard X-ray emission was significantly low. For k4, where white-light emission can be seen for a long time. This observational result might mean that the origin of the white-light emission cannot be explained by non-thermal electrons.



Hinode/SOT - red LC *RHESSI* 35-100keV LC



One of the candidates for the origin of this white-light emission is accelerated ions. We checked the existence of the 2.223MeV neutron capture line in *RHESSI* data, which originate from ion acceleration, but there is no evidence of it. However, 4.0-6.5MeV γ-rays, which contain the lines of de-excited ions, were observed by *RHESSI*, and *FERMI*/GBM also observed hard X-rays and γ-rays for this event. So there is still a possibility that the origin of this white-light emission is accelerated ions.



RHESSI 2.223MeV LC *RHESSI* 4.0-6.5MeV LC *FERMI*/GBM LC

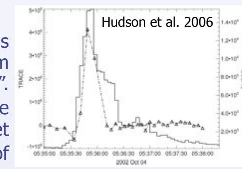
Origin of white-light emission

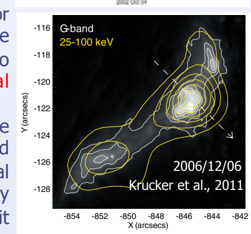
In association with solar flares, we sometimes observe enhancements of visible continuum radiation, which is known as a "white-light flare". Because many observed events show a close correlation between the time profiles (cf. Hudson et al., 2006) and locations (cf. Krucker et al., 2011) of white-light emission, and the hard X-rays and/or radio emission, there is some consensus that the origin of the white light emission is due to accelerated particles, especially non-thermal electrons.

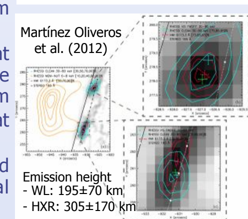
However, there was a problem related to the emission height. White-light emission is emitted from near the photosphere, however, non-thermal electrons are almost thermalized by the time they reach the lower chromosphere, and hard X-rays emit around this height. There is a more than 500km difference between the emission sites.

Recently, Martínez Oliveros et al. (2012) found that the white-light emission is located almost at the same height as the hard X-ray emission. So, from this event, one of the observational results is that accelerated electrons can reach the photosphere.

So, now, we can explain the energy budget and white-light emission location by non-thermal electrons (cf. Watanabe et al., 2010, 2012)

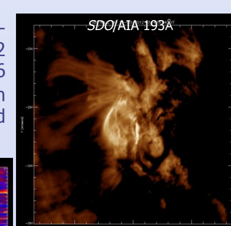


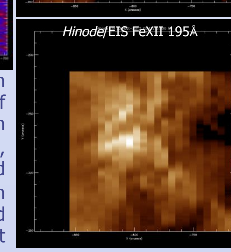




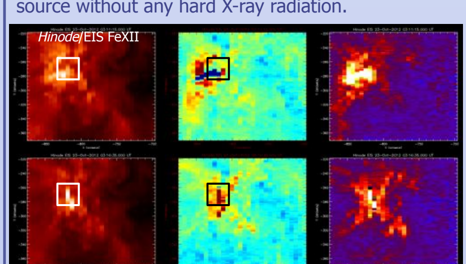
Hinode/EIS observation

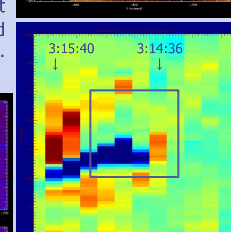
The *Hinode*/EIS also successfully observed this X-class flare. EIS performed a coarse raster scan (2 arcseconds slit and 5 arcseconds step) with about 6 minutes cadence over this flaring active region starting before the flare, and the flare occurred during the scan.





Because the main flare was very compact, the main EUV emission was caught only by a part of two of the scans. However, strong blue shifts were seen in FeXII from white-light kernel "k5". Furthermore, strong red shifts were also observed in FeXII around kernels "k3" and "k4". These red shifts can be seen before white-light emission is observed, and continues for a long time. There is a possibility that these red shifts indicate that part of the accelerated ion injections affected the white-light emission. source without any hard X-ray radiation.





The red & blue shift observed by *Hinode*/EIS FeXII. Speed range is±50km/s. The large square at the center is the size of the white-light image.