Suzaku/WAM Hard X-ray Observations of Solar Flares

– from 2005 to 2014

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Abstract

Solar flare is the largest explosive phenomenon in the solar system, which suddenly releases magnetic energy built up in the solar atmosphere through reconnection. The rate of solar flare is correlated with the solar activity whose 11-year period is well known. Solar flare is observed in entire band that we observe. In particular, hard X-ray radiation is produced by non-thermal electrons accelerated at the magnetic field reconnection, although the detailed mechanism of particle acceleration is still in debate. The Suzaku Wideband All-sky Monitor (WAM) had observed over 700 solar flares in 50 keV to over MeV band through the life of the hard X-ray detector (HXD) from 2005 to 2015. The first catalog was published by Endo et al. (2010). They showed the hard X-ray properties of flares in the solar minimum from 2005 to 2009. Following their study, we carried out systematic spectral analysis of solar flares observed with WAM during the solar maximum from 2010 to 2014. We recognized no significant difference between the solar maximum and minimum in the hard X-ray spectrum, and found following "common" characteristics. First, the hard X-ray flux of each event is well correlated with the thermal soft X-ray flux. Second, the spectral slope of the non-thermal hard X-ray component shows clear correlation neither with event duration nor hard X-ray flux of each event.

Key words: Solar flare: Suzaku/WAM: Hard X-ray:

Solar flares are triggered by magnetic field reconnection above the photosphere of the sun (Shibata & Magara 2011). The magnetically accelerated particles produce hard X-ray radiation via non-thermal bremsstrahlung (Dennis 1985) and soft X-rays from the heated plasmas in the magnetic loop follows thermal bremsstrahlung. Therefore, the hard X-rays are important to know triggering process, but the detailed mechanism of particle acceleration is still in debate.

Endo et al. (2010) having showed the hard X-ray properties of flares in the solar minimum from 2005 to 2009, following, we show hard X-ray properties of the solar flares observed with Suzaku/WAM throughout the 10 years of Suzaku. We use the observation data of the Wide band All sky Monitor (Yamaoka et al. 2009) that is active shield of Suzaku (Mitsuda et al. 2007) onboard Hard X-ray Detector (Takahashi et al. 2007). WAM had observed 586 solar flares from 2005 to 2014 (Fig.1).

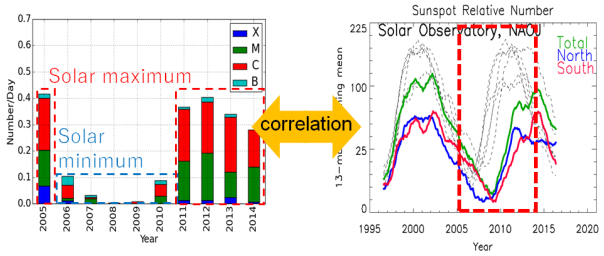

Fig. 1. Left : Detection number of solar flare by WAM transition. Right : Sunspot transition (© NAOJ). The rate of solar flare is correlated with the solar activity. So, we define from 2006 to 2010 as the solar minimum, from 2011 to 2014,2005 as the solar maximum. Hereafter we divide the observation time in two.

We carried out systematic spectral analysis of 586 events observed with the WAM from 2005 to 2014.The event criteria are :(1) Simultaneous observation at *GOES satellite*[1], (2) Detected about 200 keV or more, (3) No Earth occultation and SAA during the solar flare event. We analyze thus reduced 274 events (X class 4.4%, M class 48.2%, C class 43.8 %, B class 3.6 %). Observed spectra are evaluated with a power law function,

$$A(E) = KE^{-\alpha}, \quad (1)$$

where K and α are the normalization factor and the photon index, respecting. We derived T_{90}[2], 100–300 keV flux and Photon Index from averaged spectrum of each event. The derived values are summarized in Fig.2,Fig.3.

The results that we have obtained are summarized as follows. (1) The hard X-ray flux and duration of each event

*1 American satellite observing the soft X-ray emission of the solar flare.

*2 The time duration from the sum of 50–110 keV counts reaches 5 % to 95 % the entire event.

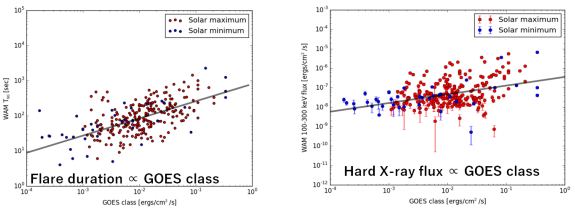

Fig. 2. Correlation plot between averaged hard X-ray flux, duration time T^{90} and soft X-ray flux. Red plots are events in solar maximum, blue plots are events in solar minimum.

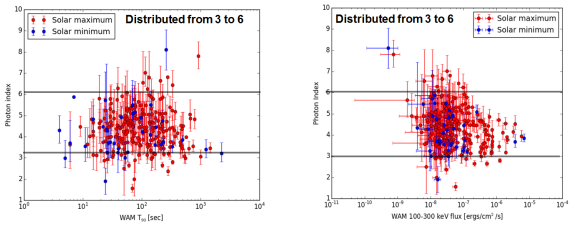

Fig. 3. Left : Scatter plot between Hard X-ray flux, duration time T_{90} and photon index from WAM spectral. Each data property are the same as Fig. 2

is well correlated with the thermal soft X-ray flux.This is consistent with the hypothesis that acceleration particles heat the thermal plasma. (2) The spectral slope of the non-thermal hard X-ray component shows no significant correlation with duration,hard X-ray flux. This supports the idea that long duration flares consist of small scale flares. (3) We recognize no significant difference in spectral parameters between those in the solar maximum and minimum.

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