*Solar Activity and its Magnetic Origin*
*Proceedings IAU Symposium No. 233, 2006*
*V. Bothmer & A. A. Hady, eds.*

doi:10.1017/S1743921306001785

# Altitude Dependence of Hard X-Ray Spectra in Solar Flares

**Q. R. Chen, M. D. Ding and P. F. Chen**

Department of Astronomy, Nanjing University, Nanjing 210093, China; dmd@nju.edu.cn

**Abstract.** We investigate the altitude dependence of hard X-ray (HXR) spectra in solar flares, i.e., whether the HXR spectra are related to the altitudes of reconnection sites. We assume that the reconnection altitude can be scaled by the distance between the two conjugate HXR footpoints in the flare. By searching the *RHESSI* flare list from 2002 to 2004, we find 42 solar flares below X-class that have enhanced 50–100 keV HXR emission and two well-resolved HXR footpoints at the nonthermal peak time. The preliminary results show that there is a weak correlation ($\sim -0.31$) between the HXR spectral index and the HXR footpoint distance. We further discuss the possible implications.

**Keywords.** Sun: flares, Sun: X-rays, gamma rays

## 1. Introduction

Nonthermal hard X-ray (HXR) observations provide the most direct information concerning energy release and particle acceleration processes in solar flares. Recently, Chen and Ding (2006) showed that, in a low-lying flare on 2002 September 30, the HXR spectrum is very soft ($\gamma \sim 7$), possibly related to energy release relatively low in the atmosphere. Previously, Dennis (1988) noted that the type A flares, which are featured with very soft spectra (i.e., large $\gamma$), may be linked to a higher density at the energy release site; type C flares, which follow soft-hard-hard spectral evolution, are associated with much lower density and magnetic field. It is therefore interesting to investigate whether the HXR spectra are related to the altitudes of reconnection sites. We study this topic using the *RHESSI*, *TRACE*, *SOHO*/MDI, and *SOHO*/EIT observations.

## 2. Observations and Data Analysis

*RHESSI* provides unprecedented high-resolution HXR imaging and spectroscopic observations for solar flares since 2002 February (Lin *et al.* 2002). Among the very large number of *RHESSI* events available, we select those with enhanced 50–100 keV emission from 2002 to 2004, which gives a sample of 392 events. We further restrict the sample by choosing those below X-calss to avoid complex instrumental effects, with coverage of the impulsive phase and a quiescent background, and with existence of two HXR footpoints around the 25–50 keV peak time. Finally, 42 C- and M-class flares from 2002 to 2004 meet the above criteria. For each flare, the distance between the two HXR footpoint, $D_{25}$, is obtained from the *RHESSI* CLEAN image in 25–50 keV (generally with 60 s integration time) and is corrected for the projection effect. The spectral index, $\gamma$, is obtained by forward-fitting the the coincident HXR spectrum with a thermal spectrum plux a single or broken power-law; for the latter, the index below the broken energy is taken. In Figure 1, we show the analysis of the 4110305 flare as an example.

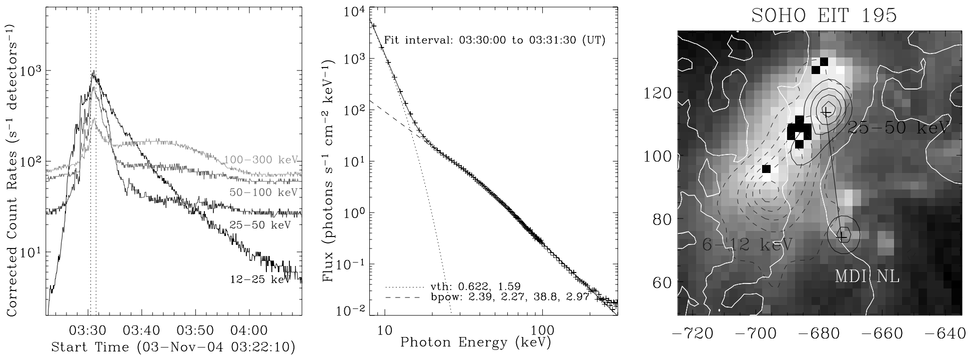


**Figure 1.** Analysis of the 4110305 Flare. *Left*: Corrected *RHESSI* count rates. The vertical lines show the interval (03:30:30 – 03:31:30 UT) for imaging and spectroscopy. *Middle*: Spectral fitting with a thermal spectrum plus a broken power-law. *Right*: RHESSI images showing the flaring loop (6–12 keV) and two footpoints (25–50 keV) superposed on the EIT 195 Å image.

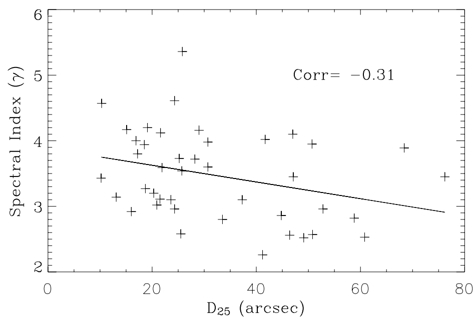


**Figure 2.** Spectral indices of HXR spectra versus the corrected distances between two footpoints in the 42 solar flares from 2002 to 2004. The line shows the linear fitting.

## 3. Results and Discussions

Figure 2 plots the spectral indices versus the corrected footpoint distances for the 42 flares. The figure shows a rough trend that the larger the flare loops (i.e., the higher the reconnection sites), the harder the HXR spectra. Their correlation coefficient is ∼–0.31, with a significance slightly higher than $r = 0.05$. Note there is a large scatter in the plot.

At present, there is no theory predicting the efficiency of particle acceleration at different atmospheric layers. Our preliminary results show there may be an altitude dependence of particle acceleration efficiency. In the future, we will include flares with enhanced emission up to 25–50 keV for a more representative sample. In addition, we will compare the results for two-ribbon flares and compact flares, which are thought to be due to reconnection at different altitudes (Chen *et al.* 1999).

## Acknowledgements

This work was supported by NKBRSF under grant G20000784, NSFC under grants 10025315, 10221001, and 10333040, and FANEDD under grant 200226.

## References

Chen, P. F., Fang, C., Ding, M. D. and Tang, Y. H. 1999
Chen, Q. R. and Ding, M. D. 2006 *ApJ*, 641, 1217
Dennis, B. R. 1988, *Solar Phys.* 118, 49
Lin, R. P. *et al.* 2002 *Solar Phys.* 210, 3 *ApJ*, 520, 853

https://doi.org/10.1017/S1743921306001785 Published online by Cambridge University Press