Chin. J. Astron. Astrophys. Vol. 2 (2002), No. 2, 103–105
(*http://www.chjaa.org* or *http://chjaa.bao.ac.cn*)

Chinese Journal of
Astronomy and
Astrophysics

LETTERS

On the Evolution of the Lower Energy Cutoff of Nonthermal Electrons in Solar Flares

Wei-Qun Gan ⋆, You-Ping Li and Jin Chang

Purple Mountain Observatory, Chinese Academy of Sciences, Nanjing 210008
National Astronomical Observatories, Chinese Academy of Sciences, Beijing 100012

Received 2002 January 31; accepted 2002 February 2

Abstract Using the method recently developed by Gan et al. (2001a, 2002), We investigate the time variation of the lower energy cutoff (E_c) of nonthermal electrons for three BATSE/CGRO hard X-ray events. The result shows that E_c changes with time, from smaller before the peak flux, to larger at the peak, and then back to smaller after the peak. Such a variation of E_c, being a preliminary conclusion for the first time, should be checked in the future by using data with a higher energy resolution.

Key words: Sun: hard X-rays — Sun: gamma-rays — Sun: flares — Sun: particles

1 INTRODUCTION

Gan, Li and Chang (2001a) proposed a quantitative method to obtain the lower energy cutoff (E_c) of power-law electrons from the observed broken-down double power-law hard X-ray spectrum. Most recently Gan et al. (2002) improved the method and let it be more self-consistent. They applied their improved method to the 54 hard X-ray events observed with BATSE/CGRO and acquired more general results in comparison with those obtained by Gan et al. (2001b). Despite the data is relatively poor, Gan et al. (2002) found that about 44% of the sample hard X-ray spectra at their peak flux can be directly explained by a power-law electron beam with a lower energy cutoff, which value, varying from 45 keV to 97 keV, is on average 60 keV; another approximately 44% sample hard X-ray spectra could be explained by a beam of power-law electrons with the energy cutoff lower than 45 keV, which is yet beyond the availability of BATSE/CGRO; still another 11% sample hard X-ray spectra cannot be explained by a beam of power-law electrons with a lower energy cutoff. These results indicate that the usually taking $E_c = 20$ keV is not proper at all, while the so-called standard scenario of solar flares is based on $E_c = 20$ keV, with which the energy carried by electrons is substantial (e.g., Lin & Hudson 1976; Gan & Fang 1990). If the value of E_c is much higher than 20 keV, the

⋆ E-mail: wqgan@pmo.ac.cn

energy carried by nonthermal electrons would decrease orders of magnitude, then the electrons might not be so important as it was thought in powering a solar flare.

In this Letter, we tentatively extend our work to study the evolution of E_c. Does E_c change with time? How does it evolve with time? We believe that the way the E_c evolves during a flare must be related to the acceleration mechanism or the environment where the flare happens.

2 RESULTS

Not every event in the 54 samples (Gan et al. 2001b) is suitable for studying the evolution of E_c. First, the counts should be great enough before and after the peak flux, so that the energy range can be kept the same in fitting spectra taken at different times, and so avoiding any possible systematic error due to the fitting energy ranges being different. Secondly, we require at least two effective time moments before, and two after the peak, so that we can distinguish the time evolution clearly. Thirdly, considering the possible evolution of E_c, we are limited to study those events which has a photon broken energy (ϵ_b) greater than 45 keV at the peak flux, otherwise due to the limited spectral resolution of the BATSE/CGRO, there would be a large uncertainty if ϵ_b evolves to smaller than 40 keV. Besides, the lightcurve should be perfect in reflecting only a single impulsive peak.

With the foregoing criteria, we eventually acquired three events: 1998 June 28, 11:41 UT; 1998 December 10, 23:45 UT; 2000 March 20, 10:03 UT. We first select a suitable time interval, then for each time moment, we use the two power-law to fit the hard X-ray spectrum. The fitted parameters of γ_1, γ_2, and ϵ_b are then compared with the figure 1 or 2 of Gan et al. (2002). Then we obtain E_c and its evolution with time. Figure 1 shows the results for these three events, in which from the top to the bottom it gives respectively the count rate (in 32.5–37.0 keV for 1998 June 28; in 33.9–44.3 keV for 1998 December 10; in 33.1–40.9 keV for 2000 March 20), the photon spectral index γ_2 (above the broken energy ϵ_b), photon broken energy ϵ_b, and E_c, variation with the time. We should emphasize that in order to ensure the comparison be meaningful, we keep the electron distribution below E_c in saturation form (see Gan et al. 2001a), that is the reason why some error bars in the figure are so large for E_c. As a matter of fact, we find that the electron distribution below E_c could change during the course of the flare.

From Figure 1 we see that E_c changes with time. For the three events studied, without exception, E_c always changes from a smaller value to a larger value, then back to the smaller value. At the peak flux, E_c also reaches its maximum. The photon spectral indices evolve in their usual manner (e.g., Tanaka 1987), i.e., from softer to harder, then to softer, while the broken energy ϵ_b seems to decrease after the peak flux.

In summary, we have presented the E_c evolution for the three hard X-ray events observed with the BATSE/CGRO, by using the method proposed by Gan et al. (2001a, 2002). E_c evolves from smaller before the peak flux to larger at the peak, and then back to smaller after the peak. These results set a new constraint for the acceleration theory. However, the events studied here are only those with large values of E_c. How the results for the events with smaller E_c will be is still unknown at present, due to the limited spectral resolution of BATSE/CGRO. Therefore, our results here are only preliminary. It is anticipated that the upcoming observations with a higher spectral resolution, like HESSI, may resolve this problem.

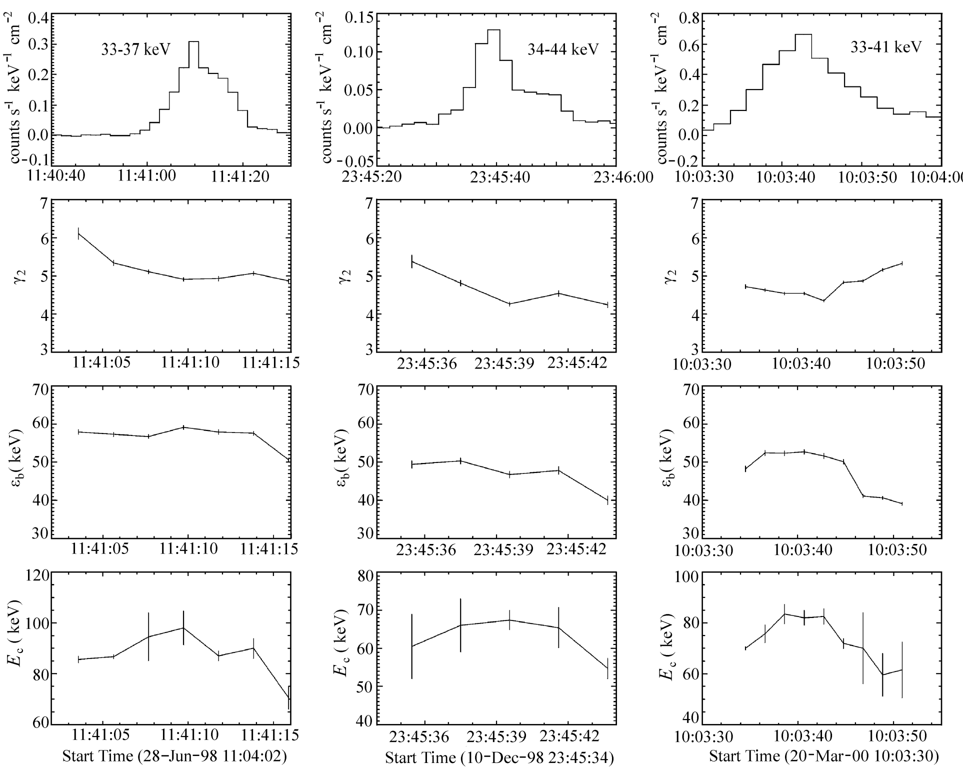

Fig. 1 Evolution of E_c, together with the lightcurve, power-law photon spectral index, and the photon spectrum broken energy for the three BATSE/CGRO hard X-ray events.

Acknowledgements This work is supported in part by National Natural Science Foundation of China via grants 19525308, 9883002, 49990451, 10173027 and by grant G2000078402 from the Ministry of Science and Technology of China.

References

Gan W. Q., Fang C., 1990, Solar Phys., 125, 333
Gan W. Q., Li Y. P., Chang J., 2001a, ApJ, 552, 858
Gan W. Q., Li Y. P., Chang J., 2001b, Chin. J. Astron. Astrophys., 1(5), 453
Gan W. Q., Li Y. P., Chang J., McTiernan J. M., 2002, Solar Phys., in press
Lin R. P., Hudson H. S., 1976, Solar Phys., 50, 153
Tanaka K., 1987, Publ. Astron. Soc. Japan, 39, 1