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Symmetric and triangle-shaped variability of blazars

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Abstract. Symmetric and triangle-shaped flux variability in X-ray and gamma-ray light curves is observed from many blazars. We derived the X-ray spectrum changing in time by using a kinetic equation of high energy electrons. Giving linearly changing the injection of low energy electrons into accelerating and emitting region, we obtained the preliminary results that represent the characteristic X-ray variability of the linear flux increase with hardening in the rise phase and the linear decrease with softening in the decay phase.

Keywords. galaxies: jets, BL Lacertae objects: general, X-rays: galaxies

1. Introduction

The high-energy emission with the rapid and large amplitude variability has been observed in blazars (e.g., Kataoka (2000)). It is usually believed that the X-ray emission of many blazars arises as synchrotron emission of electrons accelerated at a shock front moving down a jet, and that the gamma-ray emission is due to inverse Compton scattering by the electrons. However, there are no conclusive models which represent the characteristic X-ray and gamma-ray variability with the rise time equal to the decay time. In this proceeding, we propose a simple model to give a description of the symmetric and triangle-shaped variability in blazars and discuss the physical origin.

2. Model

In this work, we use a kinetic equation of the spectrum of accelerating and emitting electrons, expressed by

$$\frac{dN_e}{dt} + \frac{\partial}{\partial E}(g(E)N_e) + \frac{N_e}{T(E)} = Q(E,t), \qquad g(E) = \beta E - bE^2, \tag{2.1}$$

where E is the electron energy, t is the time, β is the acceleration efficiency, b is the coefficient of energy loss, T is the escape time, and $Q(E,t)$ is the injection rate. The general solution of this equation is given by Makino *et al.* (1996) and Makino (2000). We propose that the injection rate Q of low energy electrons increases linearly in the rise phase and decreases linearly in the decay phase in the following,

$$\begin{aligned} Q(E,t) &= K\delta(E-E_0)t \qquad (0 < t < t_{cros}/2), \\ Q(E,t) &= K\delta(E-E_0)(t_{cros}-t) \qquad (t_{cros}/2 < t < t_{cros}), \end{aligned} \tag{2.2}$$

where K is the normalization factor, E_0 is the energy of injected electrons and t_{cros} is the duration time of the rise to decay phase. For the rise phase, the electron spectrum is

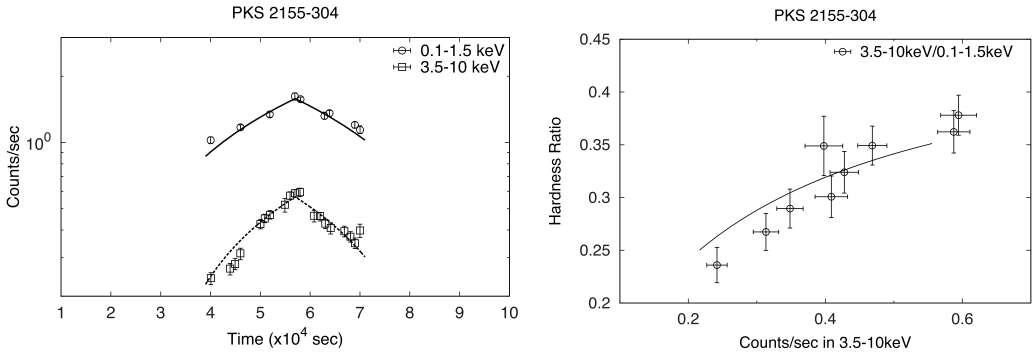

Figure 1. The calculated X-ray flare light curves in two energy bands (0.1-1.5 keV, 3.5-10 keV) and the X-ray hardness ratio (3.5-10 keV/0.1-1.5 keV) vs. the X-ray flux (3.5-10 keV), compared to an observed X-ray flare of PKS 2155-304 taken from Maraschi *et al.* (2000).

given by

$$N_e = K(\frac{\beta - bE}{\beta - bE_0})^{\frac{1}{\beta T}-1}(\frac{E}{E_0})^{-\frac{1}{\beta T}-1}(t - \frac{1}{\beta}log\frac{E}{E_0} + \frac{1}{\beta}log\frac{\beta - bE}{\beta - bE_0}). \tag{2.3}$$

In a similar way, the electron spectrum in the decay phase is derived. The X-ray spectrum is converted from the electron spectrum by using a monochromatic approximation.

3. Results

We calculated the time variations of X-ray flares by using our model. The preliminary results are presented in Fig. 1, compared to an observed X-ray flare of PKS 2155-304 taken from Maraschi *et al.* (2000). Here, the magnetic field strength B is 0.1 G, E_0 is 1 MeV, β is 3×10^{-5} s^{-1}, T is 2×10^4 s, and the beaming factor δ is 10. As shown in Fig. 1, the calculated results are consistent with the observed flare.

4. Summary and Discussion

This model can represent the characteristic X-ray flare variability as follows: (1) the X-ray flux increases linearly with time in the rise of the flare and decreases linearly in the decay, (2) the rise time of the flare is equal to the decay time, and (3) the spectrum becomes harder in the rise and softer in the decay. In the internal shock scenario (e.g., Spada *et al.* (2001), X-ray flares occur through shock formation in the collisions of faster blobs with slower blobs in jets. In the crossover region of a faster blob with a slower blob, low energy electrons are injected, leading to acceleration to high energy electrons and generation of synchrotron X-ray emission. Corresponding to the crossover region size, the injection rate of low energy electrons might increase linearly in the catching up phase and decrease linearly in the passing phase.

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