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ORIGINAL ARTICLE

Variable synchrotron emission from BL Lacertae objects. I. Shock-in-jet scenario

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Abstract This paper presents a modeling of the variable synchrotron emission in the BL Lacertae sources (BLLs). Flux variability is assumed to be a result of the interaction between a relativistic shock wave with a magnetized jet material. Long-term flares (of months to years durations) are modeled via the propagation of a plane relativistic shock wave though the emission zone of a cylindrical form with the radius R and length H. As for short-term bursts (lasting from days to weeks), they may result from shock passage through the jet inhomogeneities such as a shell of enhanced density downstream to a Mach disc, originated due to pressure imbalance between the jet and its ambient medium. Emitting particles (electrons) gain the energies, sufficient to produce synchrotron photons at optical—X-ray frequencies, via the first-order Fermi mechanism. Observation's frequency is the main parameter determining a rate of the increase/ decay of the emission via the characteristic decay time of emitting electrons. The magnetic field, assumed to be turbulent with an average field constant throughout the entire emission zone, is another key parameter determining the slope of a lightcurve corresponding to the flare—the higher strength the magnetic field has, the steeper the lightcurve is. The rest input parameters (shock speed, jet viewing angle, maximum/minimum energies of the electrons, particles' density etc.), as well the strength of average magnetic field, influence the energy output from a flare.

Keywords Galaxies: active · BL Lacertae objects · Radiation mechanisms: non-thermal · Shock waves

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1 Introduction

Synchrotron emission from the relativistic electrons is one of the prominent features of the blazars, i.e. BL Lacertae objects (BLLs) and flat spectrum radio quasars (FSRQ). In their spectral energy distribution (SED), constructed in the $\log\nu - \log\nu F_1$ representation, the synchrotron emission emerges as a lower frequency component with a peak located between the infrared and hard X-ray parts of the spectrum (see, e.g. Böttcher 2007 for a review). According to the position of a synchrotron peak, the BLLs are divided among LBLs (i.e. low-energy peaked BLLs with $\log\nu_{peak} \le 14.50$), IBLs (intermediate BLLs, $14.50 < \log\nu_{peak} \le 16.50$), and HBLs (high-energy peaked ones with $\log\nu_{peak} > 16.50$; Nieppola et al. 2006). The higher-energy part of the blazar SED is thought to be a result of the inverse Compton (IC) scattering of the low-energy photons at ultra-relativistic electrons (see, e.g., Giommi et al. 2005).

Flux variability is indeed one of the important blazar characteristics that spreads over the wide ranges of timescales and amplitudes. It provides a powerful tool to distinguish among the hypothetic emission mechanisms and study the internal structure of blazars as well as to investigate instable processes occurring in these extreme cosmic objects.

Despite the significant progress in understanding of the blazar phenomenon, the possible mechanisms that trigger a flux variability still remain controversial. Long-term blazar flares are mainly explained by a propagation and evolution of relativistic shock waves through the blazar jets (see, e.g., Marscher and Gear 1985; Hughes et al. 1989a; Gomez et al. 1993). These shocks should originate near the base of a relativistic jet and then travel downstream. At a shock front, the bulk kinetic energy is dissipated into a thermal energy of the charged particles. This leads of acceleration of the particles (mainly electrons) up to very high