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Hardening of the X-ray spectrum and signature of Fe abundance in Mrk 501 based on the filamentary jet model

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Abstract. We evaluate the synchrotron spectrum of Mrk 501 based on our filamentary jet model. Integrating the contribution from the magnetic fields induced by numerous current filaments with various transverse sizes, we reproduce the observed hardening of the spectrum around X-rays. It is found that the spectral change during 1997-1998 can be explained by the evolution of turbulence. We also propose that the observed dip around 80 keV is attributed to bound-free absorption by Fe atoms, which implies the abundance of heavy nuclei at the tip of the jet.

Keywords. diffusive shock acceleration, synchrotron radiation, absorption, etc.

1. Introduction

Markarian 501 has been monitored for a long term by multi-wavelength observations as a powerful TeV blazar. The double-humped spectrum and variabilities are almost in favor with synchrotron self Compton (SSC) models. The conventional diffusive shock acceleration mechanism, however, cannot explain the spectrum extending to X-rays which require sufficiently energetic electrons. In this paper we shed light to this issue in addition to the absorption around 80 keV.

2. Method

We at first review our filamentary jet model (Honda & Honda 2002). When the energetic plasma flow is injected from a central engine, huge currents are generated due to the inertia difference of positive and negative particles. Because of the electromagnetic current filament instabilities, these currents break up into numerous filaments with self-induced toroidal magnetic fields. These randomly oriented local fields are cancelled in the inside of the jet except large scale toroidal fields along the envelope, which is in good accordance with polarization measurements (Capetti *et al.* 1997). When a shock wave is allowed to propagate in AGN jets with such magnetized filaments, the magnetic field inclination to the shock normal is likely to be quasi-perpendicular. In low plasma beta state, electrons are strictly bound to the local magnetic field induced by each filament. If these electrons are passing through the quasi-perpendicular shock, they are efficiently energized due to the first order Fermi acceleration (Honda & Honda 2010).

Suppose a jet as a bunch of numerous magnetized filaments with various transverse sizes. As a consequence of kinetic simulations that the amplification of magnetic fields accompanies the coalescence of filaments, we have considered a situation in which the larger filaments sustain stronger magnetic field. We then use the magnetic field scaling

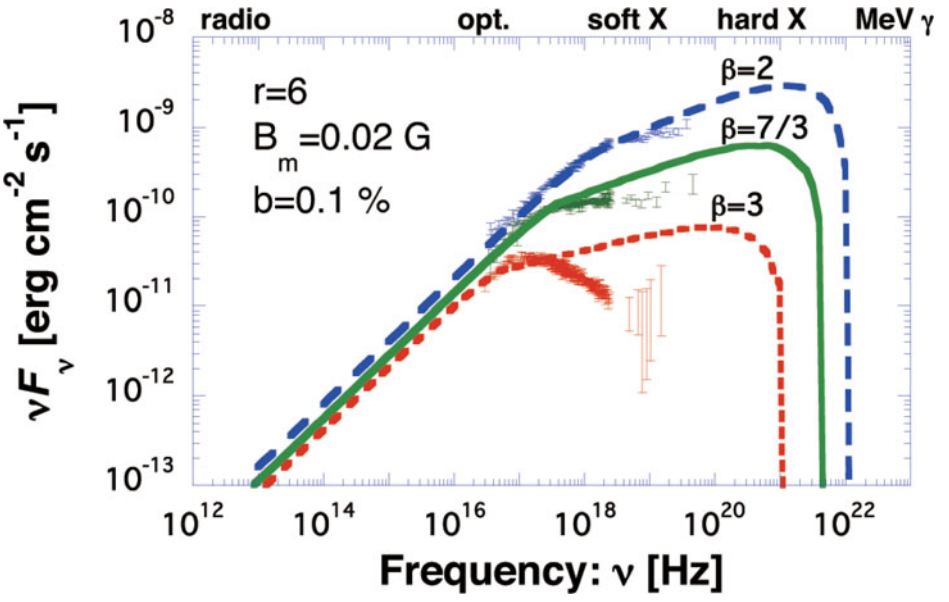

Figure 1. Synchrotron spectral fitting of Mrk 501

of the power-law of the transverse filament sizes. The attainable maximum energies of accelerated electrons and hence, frequencies of their synchrotron photons are determined by the megnetic field of individual filament. The superposition of contribution from each filament accounts for the spectrum extending to the X-ray region.

3. Results

In comparison with the observed spectrum by BeppoSAX sattelite (Tavecchio *et al.* 2001), we focused on the turbulent evolution. Parametrizing the turbulent spectral indices in conceivable range, we evaluate the spectrum from radio to X-rays (Fig. 1). It is shown that the spectral change during 1997-1998 is characterized by this parameter.

In Fig. 1 there seems a slight dip around 80 keV throughout the observational term. This energy just corresponds to the Doppler-shifted bound-free absorption of synchrotron photons by the K-shell electrons of Fe-atoms provided the beaming factor around 10. It suggests a signature of Fe abundance at the tip of the blazar jet. In order to include this absorption effect into the spectrum, however, we should consider some detailed broadening mechanism.

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