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Adiabatic cooling and nonthermal spectrum of blazars

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Abstract. Here we study the effect of adiabatic cooling on the non-thermal synchrotron spectra of blazars from radio to X-ray region resulting when blazars are in the flaring state.

1. Introduction

Blazars are characterized by highly time-variable non-thermal emission spectrum extending from radio-to-γ-rays from the relativistic jet. The basic mechanisms responsible for radio-to-soft X-ray and hard X-ray-to-γ-ray regions of the spectra are believed to be the synchrotron and inverse Compton processes, respectively. Existing models in the literature consider the emission of radiation from energetic electrons in the continuous jet or in the form of a spehrical blob (Sikora et al. 1994; Inoue & Takahara 1996; Chiaberge & Ghisellini 1999). The size of the blob is constrained by the variability time scale. Here, we study the effects of adiabatic cooling of electrons on the radiation emission during a flare, when blob expansion in the jet outflow is included.

2. Model

We consider a uniformly expanding spherical blob of size $R(t)$, containing a homogeneous population of energetic electrons and a frozen-in magnetic field $B(t)$, being convected out with a Doppler factor δ. At $t = 0$, $R(t) = R_0$ and $B(t) = B_0$ and a homogeneous population of energetic electrons fill the blob, the particle luminosity being constrained by the overall source radiation luminosity. Thereafter, interactions of electrons with $B(t)$ and adiabatic energy loss of electrons are considered to obtain the electron distribution and hence the synchrotron radiation output for $t > 0$. Flare is represented here by a sudden enhancement of electron population in the expanding blob.

Particle-distributions in the acceleration region (from which electrons are fed into the blob) and in the cooling region, are obtained by solving the relevant kinetic equations Bhattacharyya et al. 2000. Radiation spectrum is next obtained by convoluting the particle spectrum in the blob with the single-particle synchrotron emissivity.

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3. Results and discussion

The numerical solution of the kinetic equations and of the synchrotron emissivity equation show that the inclusion of adiabatic cooling of electrons, blazar non-thermal spectra softens for frequencies $\nu \leq 10^9\,Hz$. This is discussed in detail in Ref. (4). Here we show in Figs. *Ia* and *Ib* the time variation of the flux for different radiation energies in the non-adiabatic and adiabatic cases, respectively. In the non-adiabatic case, peak fluxes are attained earlier and, the FWHM are comparatively smaller for $1keV$ and $10keV$ energies and larger for $10eV$ and $100eV$ energies as compared to the adiabatic case.

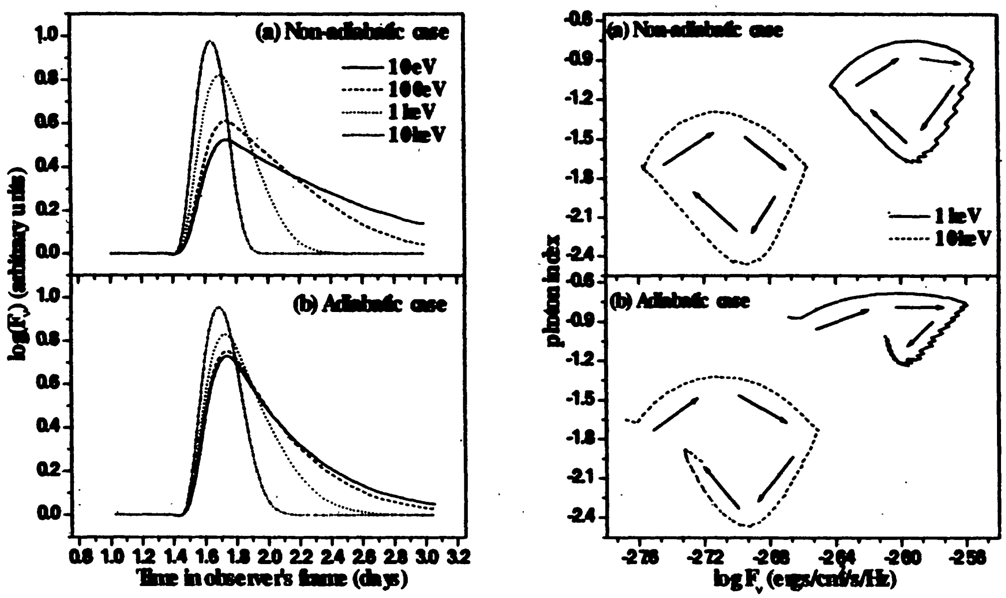

Fig. I Fig. II

Figure 1. Fig. from shows the time evolution of flux at different frequencies. Fig. from shows the variation of photon spectral index with flux at different energies (hysteresis loops).

Figs. IIa and IIb show the variation of the spectral index of emitted radiation at energies $1keV$ and $10keV$ with the emitted flux during a flare for the non-adiabatic and adiabatic cases, respectively. The arrows indicate the sense of time evolution of the flare. We find that loops are closed in the non-adiabatic case, whereas, they are open for the adiabatic case. Furthermore, in the non-adiabatic case, the hardening of spectra during a flare is more pronounced. Clearly, if open-loop plots, like the ones shown here, are indeed observed in practice, they would validate the importance of adiabatic cooling of energetic electron population in blazar jets and thus provide a valuable insight into the dynamics of jets.

References

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