ABSTRACT. We calculate the time dependent electron distribution under the assumption of continuous injection of new, relativistic particles, and assuming radiative cooling (by synchrotron and inverse Compton) and particle escape. Resulting photon spectra are calculated taking into account the time delays introduced by the different light travel times across the source. We apply these calculations to the varying X-ray spectrum of Mkn 421.

1. Need of time dependent calculations

Blazars vary violently at all wavelengths, with timescales as short as hours–days. This suggests that the injection mechanism and/or the cooling processes operate on timescales shorter than the light crossing time \( R/c \). This implies symmetric light curves during rapid flares, as observed during particularly intensive monitoring campaigns. To interpret in detail the variability pattern at different wavelengths we need to study the time dependent behavior of the emitting particle distribution.

2. The model: assumptions

- The source, of typical dimension \( R \), embedded by a tangled magnetic field \( B \), moves relativistically, and the radiation is beamed with a Doppler factor \( \delta \).
- Relativistic electrons are injected homogeneously throughout the source for a time which can be less than \( R/c \).
- We consider Synchrotron and Self Compton cooling, and particle escape.
- The electron distribution is found by solving the continuity equation:

\[
\frac{\partial N(\gamma, t)}{\partial t} = \frac{\partial}{\partial \gamma} [\dot{\gamma} N(\gamma, t)] + Q(\gamma) - \frac{N(\gamma, t)}{t_{esc}}
\]

where \( Q(\gamma) \) is the injection term, \( \dot{\gamma} \) is the cooling term, and \( t_{esc} \) is the escape timescale of the particles, assumed to be independent of their energy. We solve this equation numerically, according to the scheme proposed by Chang & Cooper (1970).

Since the cooling and injection timescales are shorter than \( R/c \), the particle distribution evolves more rapidly than the light crossing time. The observer will see a
3. Application to Mkn 421

In May 1994 Mkn 421 underwent a X–ray flare during an high state of the Tev emission (Macomb et al. 1995). Fig. 1 shows the overall spectra taken from Macomb et al. (1996) fitted by two SSC spectra calculated with our program assuming that the particle distribution reached equilibrium. The two models differ only by the total injected power (factor 2) and the $\gamma_{max}$ (factor 3). Takahashi et al. (1996) studied the time lag between hard and soft X–rays (ASCA data), finding a time delay of $\sim$1 hour. The also note that the Tev flux varied with approximately the same amplitude of the X–rays, while the optical flux remained quasi constant. We qualitatively reproduce these features by assuming: i) injection of a flat power electron distribution ($\propto \gamma^{-1.5}$) between $\gamma = 1000$ and $\gamma = 8 \times 10^5$ for a time equal to $R/c$; ii) $R = 1.5 \times 10^{16}$ cm, $B = 0.07$ G, $\delta = 15.5$, $L_{inj} = 0.6 \times 10^{42}$ erg/s; iii) the flaring emission corresponding to the fast varying electron distribution is summed to a constant component. Fig. 2 shows the light curves at four different frequencies: note that the soft X–rays lag the hard X–rays (approximately 1 hour), and the optical flux remains quasi constant. The peak of the optical emission lags the hard X–rays by $\sim$3 hours, while the Tev peak has a delay of 2 hours. The seed photon for the TeV emission have IR frequencies, and they lag the X–rays; this is the reason for the delay of the TeV emission w.r.t. the X–rays.

References

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