ENIGMA Winter School - Lesson 2 Marscher

Assignment:

Divide into 3 groups - Explain with 2 models each observation.
For each model, make 2 further predictions

1. 3C 279 has strongly correlated optical + X-ray flux variations, with X-ray lagging optical by ~10 days.
2. PKS 1510-089 has strongly correlated 15 GHz radio + X-ray flux variations, with X-ray lagging radio by ~15 days.

[Light curves + correlation plots were shown; see www.bu.edu/blazars]

Variability of Nonthermal Emission from Blazar Jets

I. Single-zone models ("blobs") - van der Laan / Shklovskij models

Conflict with radio data: predict strong dependence of amplitude of variability on frequency: $F_m \propto \nu_m^s$, $s = 1-2$ for typical set of time dependences ($B \propto r^{-1}$ or r^{-2}, $K \propto r^{-(2\alpha+3)}$) where electron energy distribution $N(\gamma) = K\gamma^{-(2\alpha+1)}$

Also, time lags at lower radio ν's are longer than observed

Light-travel effects were ignored $\rightarrow$ $t_{evolve} > R/c$ case only

II. Gradients in maximum electron energy (Marscher + Gear 1985, ApJ 298, 114)

Accelerate particles at a front (probably a shock), which cool from radiative + expansion losses as they advect behind front (in frame of front)

Critical frequency of electron with energy γmc^2: $\nu(\gamma) = 2.8\times10^6 B\gamma^2$

Approximate $B \simeq$ const. (+ const. velocity of advection $\beta_{ad}c$) in cooling zone; then $\frac{d\gamma}{dx'} \propto \frac{d\gamma}{dt} = -bB^2\gamma^2$, $b = 1.3\times10^{-9}$

integrate, replace γ with $\left[\frac{\nu}{2.8\times10^6 B}\right]^{1/2}$, solve for $x' \simeq 0.4\, B^{-3/2} \nu_{GHz}^{-1/2} \left(\frac{\delta}{1+z}\right)^{\frac{1}{2}} \beta_{ad}$ pc, $x \approx \Gamma x$

- valid for $x' < x'_{shock}$ = thickness of shocked region

Assume that behind the shock $B = \text{const.}\, B_{jet}(Z)$, $K = \text{const.}\, K_{jet}(Z)$ (Z = distance down jet)

optical depth at peak in F_ν spectrum $\tau_m \sim 0.5 \propto B^{\frac{2\alpha+3}{2}} K s \nu^{-\frac{(2\alpha+5)}{2}}$

where s = line-of-sight thickness of region that emits at frequency ν

see §III
- $s = x$ for viewing angle $\theta = 0$
- $s = 2r$ for viewing angle $\theta \approx \sin^{-1}(1/\Gamma)$
- $s \propto x$ for other viewing angles

Flux density

$F_m \equiv F_\nu(\nu_m) \propto B^{\alpha+1} K r^2 x \nu^{-\alpha}$