ENIGMA Lesson 3 ② Marscher

III. Brightness Temperatures (Radio) – measure of "compactness"

$$T_B = \frac{c^2}{k}\frac{F_\nu}{\nu^2 \Omega}$$ Ω = solid angle of source as projected on sky

$$= 3.5\times10^{12} F_{\nu,Jy}\, \nu_{GHz}^{-2}\, \Theta_{mas}^{-2} \;\; K$$

Θ measured with VLBI ($\Theta = \sqrt{\Theta_1 \Theta_2}$ if elliptical Gaussian model is used to fit VLBI data; Θ_1 + Θ_2 are FWHM size along major + minor axes)

or from variability: $\Theta \lesssim \frac{c t'_{var,min}}{D}(1+z)^2$

where $t'_{var} = t_{var} \cdot \frac{\delta}{1+z} \cdot \frac{\langle F_\nu \rangle}{\Delta F_\nu}$

SSC luminosity: $\frac{L_{ssc}}{L_{synch}} \approx \left(\frac{T_B}{2\times10^{11}\, \delta/(1+z)\, K}\right)^5 \left(\frac{\delta}{1+z}\right)\left(\nu_{max}/10^{11}\, Hz\right)$

(Kellermann + Pauliny-Toth 1968)

$\Rightarrow T_B \gtrsim 10^{12}\, K \left(\frac{\delta}{1+z}\right)^{6/5}$ gives $L_{ssc} \gg L_{synch}$ "Inverse Compton catastrophe"

$T_B \approx$ few $\times 10^{10}$ K : equipartition between magnetic + relativistic electron energy densities

Highest measured T_B: 3C 279 (VLBI with space antenna): 2×10^{13} K

0405-379 (scintillation) : 2×10^{14} K

(0405-379: not sure of name)

(scintillation) ← requires distance of scattering "screen" – T_B lower if distance ~ 5-10 pc

(2×10^{14} K) ← problematic (some coherent emission process? Γ ~ few 100?)

IV. Polarization

A. Linear: synchrotron radiation $\Pi \approx \underbrace{\frac{3(\alpha+1)}{3\alpha+5}}_{0.72 \text{ for } \alpha=0.7} \frac{B^2_{unif}}{B^2_{unif} + B^2_{rand}}$

(Burn 1966, MNRAS, 133, 67)

Observed: most jet features have $\Pi \lesssim 10\% \rightarrow B_{rand} \sim 2.5\, B_{unif}$

Direction = electric vector position angle (χ) (EVPA) $\perp$ projected $\langle \vec{B} \rangle$.

– But optically thick case: $\Pi \lesssim 0.05$, $\chi \parallel \vec{B}_{proj}$

Shock: Component of $\vec{B}$ that is $\parallel$ shock front is amplified $\Rightarrow$ EVPA $\rightarrow \perp$ shock front

Face-on:  Fairly random

Edge-on: ($\Theta \approx \sin^{-1}(1/\Gamma)$)  ↑ net $\vec{B}$ direction