VIII. Models for Core

A. Low frequencies (radio) $\nu < \nu_m$: core = place where $\tau(\nu) \approx \tau_m$

To calculate $z_{core}(\nu)$, need to specify $B(z)$, $K(z)$

Frozen-in field: $B(z) \propto z^{-1}$ $(\vec{B} \perp \hat{z})$, $B(z) \propto z^{-2}$ $(\vec{B} \parallel \hat{z})$

$K(z)$ is more involved:

$$u \propto p \propto n^{4/3} \quad \text{and} \quad u = \langle\gamma\rangle n$$
$$\langle\gamma\rangle \propto n^{1/3}$$

constant Γ jet: $n \propto z^{-2} \longrightarrow \langle\gamma\rangle \propto z^{-2/3}$

$$n = \int_{\gamma_{min}}^{\gamma_{max}} K\gamma^{-(2\alpha+1)}\,d\gamma = \frac{K}{2\alpha}\left[\gamma_{min}^{-2\alpha} - \gamma_{max}^{-2\alpha}\right] \quad \left[= K \ln(\gamma_{max}/\gamma_{min}) \text{ for } \alpha = 0.5\right]$$

$$K \propto n\langle\gamma\rangle^{2\alpha} \propto n^{1+\frac{2\alpha}{3}} \propto z^{-\frac{2}{3}(3+2\alpha)}$$

[Blandford + Königl (1979 ApJ, 232, 34) use $K \propto z^{-2}$, which requires that expansion cooling be offset by some heating process.]

Prior equations for τ_ν and F_ν can be used to solve for $z_{core}(\nu)$:

$$z_{core}(\nu) \propto \nu^{\frac{-(2\alpha+5)}{2b+a(2\alpha+3)-2}} \quad \text{where } B \propto z^{-a},\ K \propto z^{-b}$$

$$F_\nu(\nu<\nu_m) \propto z_{core}^{3-b-a(1+\alpha)}(\nu)\,\nu^{-\alpha} \propto \nu^{\alpha_{thick}}$$

$$\alpha_{thick} = \frac{[b+a(1+\alpha)-3](2\alpha-5)}{2b+a(2\alpha+3)-2} - \alpha = \frac{4\alpha(a-1)+5(a+b-3)}{2b+a(2\alpha+3)-2}$$

ex.: $\alpha = 0.7$, $b = \frac{2}{3}(3+2\alpha)$, $a = 1$: $\alpha_{thick} = 0.56$

Testable: z_{core} dependence on ν is measurable with phase-reference VLBI (with mixed results!)

Why does α_{thick} not continue above ν_m?

– self-similarity of jet must stop at $z_{core}(\nu_m)$

Two ideas: (a) standing shock(s) accelerates electrons at $z_{core}(\nu_m)$, jet is "cool" at lower z's

(b) Jet accelerates out to parsec scales, $z_{core}(\nu_m)$ is where δ reaches maximum value