Chandra Observations of the Extended X-ray Structure of Relativistic Jets


Challenges of Relativistic Jets:
Q: How can the X-ray to Radio flux remain roughly constant over great distances?
A: Ratio is less sensitive to parameters if X-rays are IC/CMB!
Q: How can the emission decrease over distances shorter than $c \times t_{\text{jet}}$?
A: Changes in direction have large effects on relativistic jets!

What do we expect for the X-ray/Radio Relation?

Emission Mechanisms

$\text{I}_{\text{sync}} \propto R T_{\text{sync}}^{2} \rho_{\text{IC}}^{3/2} \rho_{\text{IC}}^{3/2}$
$\text{I}_{\text{IC}} \propto R^{2} \rho_{\text{IC}}^{3/2}$

Non-relativistic: X-ray and radio synchrotron $H \approx 60$ to $120 \mu$G $\gamma_{\text{sync}} \approx 4000$, $\tau_{\text{sync}} \approx 10^{6}$ yrs. $\gamma_{\text{sync}} \approx 2.7 \times 10^{-4}$, $\tau_{\text{sync}} \approx 150$ yrs.

Relativistic: X-ray IC/CMB and radio synchrotron. $H \approx 10 \mu$G, $\delta \approx 3$ to $15$ $\gamma_{\text{sync}} \approx 10^{4}$, $\tau_{\text{sync}} \approx 6 \times 10^{6}$ yrs. $\gamma_{\text{sync}} \approx 300$, $\tau_{\text{sync}} \approx 2 \times 10^{6}$ yrs.

Morphology Summary and Interpretation

- Roughly constant $I_{y}/I_{x}$ within $2^\circ$. X-rays end when radio makes sharp bend. IC/CMB: Strong Bending Dependence
  Examples: PKS 0035+30, PKS 1305-30, PKS 2201-22, PKS 2201-52
- X-ray profile decreases, Radio profile increases, $I_{y}/I_{x}$ changes more than $10x$. Multiple Electron-Population Synchrotron Contributions
  Example: IC 273

Roughly constant $I_{y}/I_{x}$ within $2^\circ$. X-rays persist beyond radio. IC/CMB: Longest Live Low Energy Electrons

Example: IC 319

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