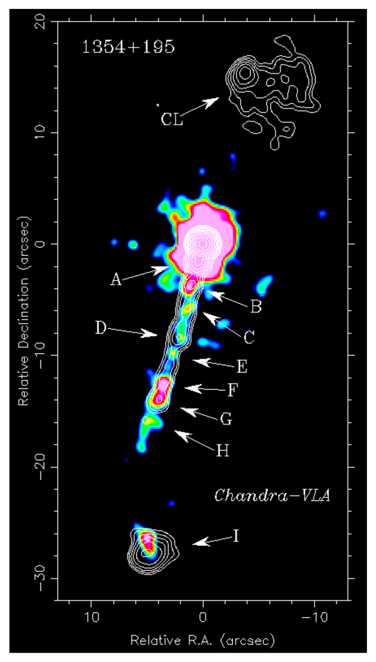
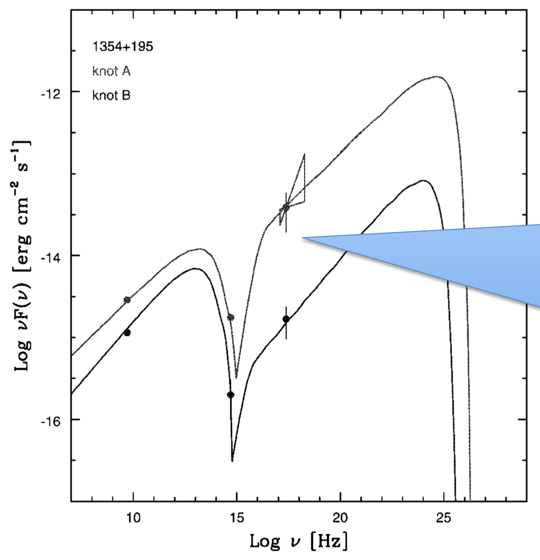
The surprising nature of quasar jets as revealed by Fermi

Eileen T. Meyer[1], Markos Georganopoulos[2], William B. Sparks[1]
1. STScI 2. University of Maryland, Baltimore County

1. Chandra Observes dozens of Quasar Jets that are *Anomalously Bright.*



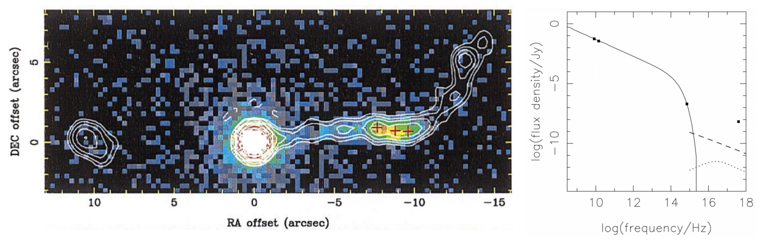


e.g., PKS 1354+195
(Sambruna et al., 2004)-

These X-rays cannot possibly be from the same synchrotron population producing the radio-optical emission.

2. Which Model can best explain these X-rays?

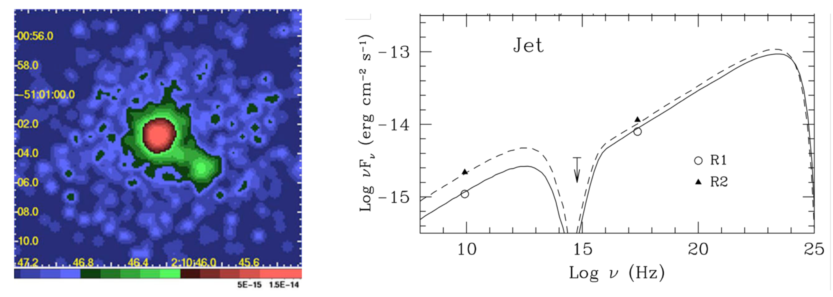
Possibility A: Inverse Compton scattering of CMB photons (IC/CMB)



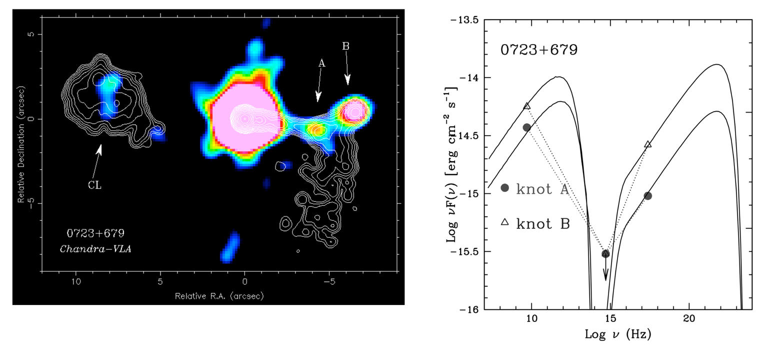
At far left is shown the quasar PKS 0637-752 as seen by Chandra with 8 GHz ATCA contours overlaid. At right, the radio-optical-Xray spectrum of the brightest knot.
NOTE that SSC (dashed) and IC/CMB (dotted) can NOT reproduce the observed X-rays under the assumption of equipartition and no beaming.

> The IC/CMB model requires that the jet remain relativistic on the kpc scale (Γ ~ 10)

If you further assume a jet oriented close to the line-of-sight, then strong beaming effects can enhance IC/CMB to match the observed X-rays. **This is now the most widely used model for the origin of the anomalously bright X-rays in quasar jets.**



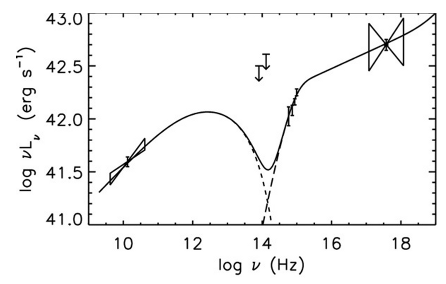
PKS 0208-512 (Tavecchio et al., 2007)



3C 179 (Sambruna et al., 2002)

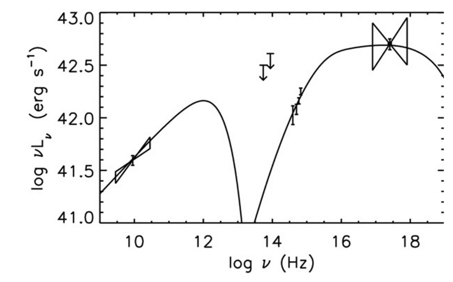
Possibility B: Synchrotron X-rays from a second electron population

There is nothing to rule out a second population of electrons, reaching higher energies, producing the X-rays. In fact, the two models can equally well fit the SEDs, due to the number of free parameters.



IC/CMB

PKS 1136-135
SAME DATA,
Different Models



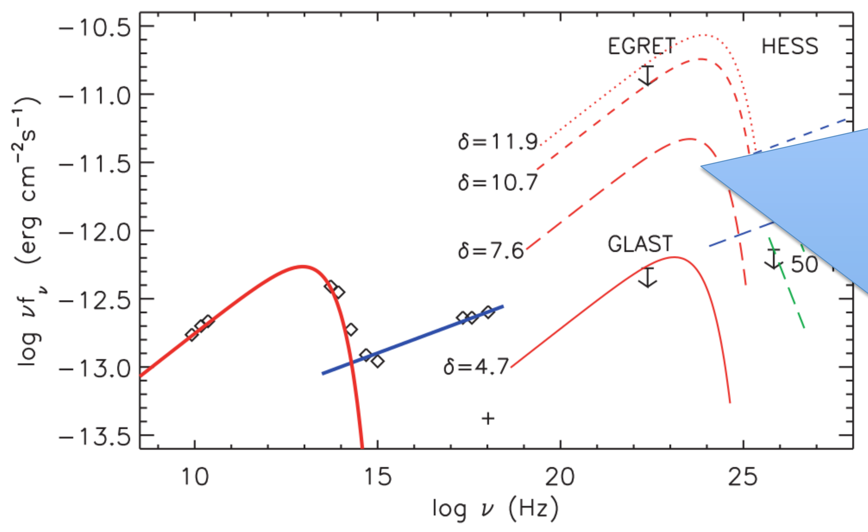
synchrotron

3. There are problems with IC/CMB

1. Predicts extreme jet lengths in some cases, longer than the longest jets in the plane of the sky (e.g., Sambruna et al., 2008)
2. Requires near- and super-Eddington jet powers to reach the observed X-ray flux levels (e.g.,Dermer & Atoyan 2004, Jester et al., 2006)
3. Requires fast jets on the kpc scale, which has not been confirmed.

4. Can we test IC/CMB Conclusively?

Yes! **The IC/CMB model predicts gamma-ray emission at a high level (Georganopoulos et al., 2006)**

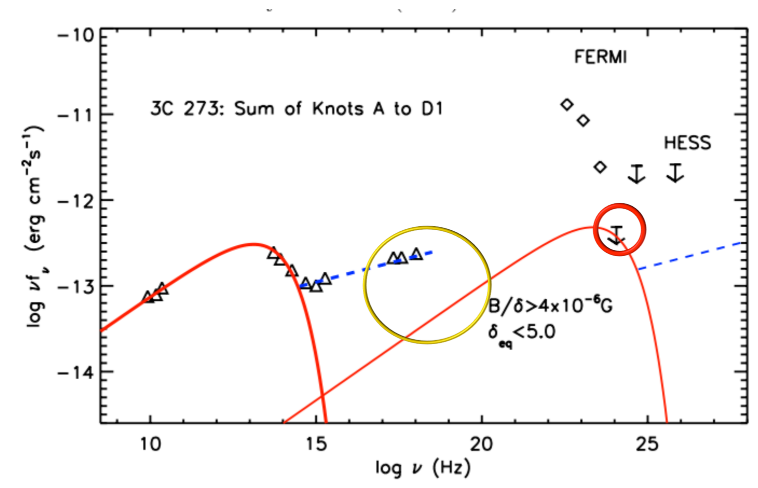


A plot of the radio-to-Xray emission of 3C 273. The red solid curve is a synchrotron fit. Notice that the X-rays are from a different component.

These red curves represent possible IC/CMB spectra, depending only on the beaming factor δ, which determines the level. The IC/CMB emission is essentially a 'copy' of the synchrotron spectrum. Thus, the gamma-rays are predicted without any freedom, as the level is fixed by the requirement to produce the observed X-rays.

5. Do we see the exepcted IC/CMB gamma-ray emission?

Case 1: 3C 273
IC/CMB is ruled out as the source of the X-rays.



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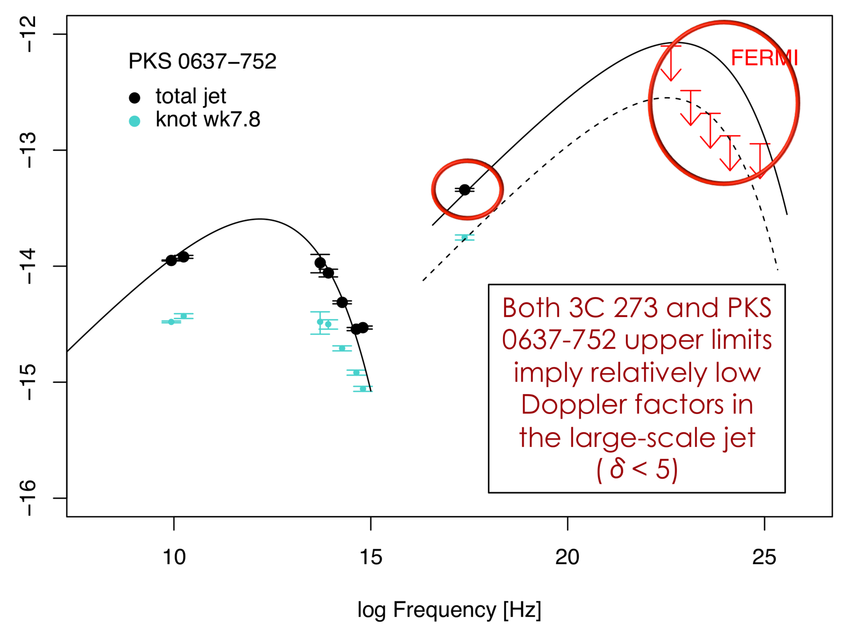
The expected IC/CMB gamma-rays were not observed in 3C273.
The highest limit from 3-10 GeV rules out IC/CMB emission at the 99.9% level.

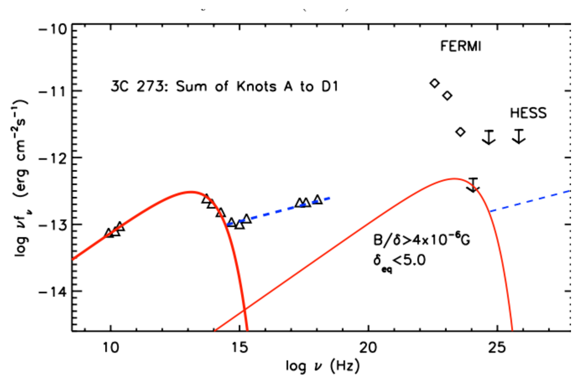
Case 2: PKS 0637-752

Fermi limits on the large-scale jet emission also rule out IC/CMB in PKS 0637-752

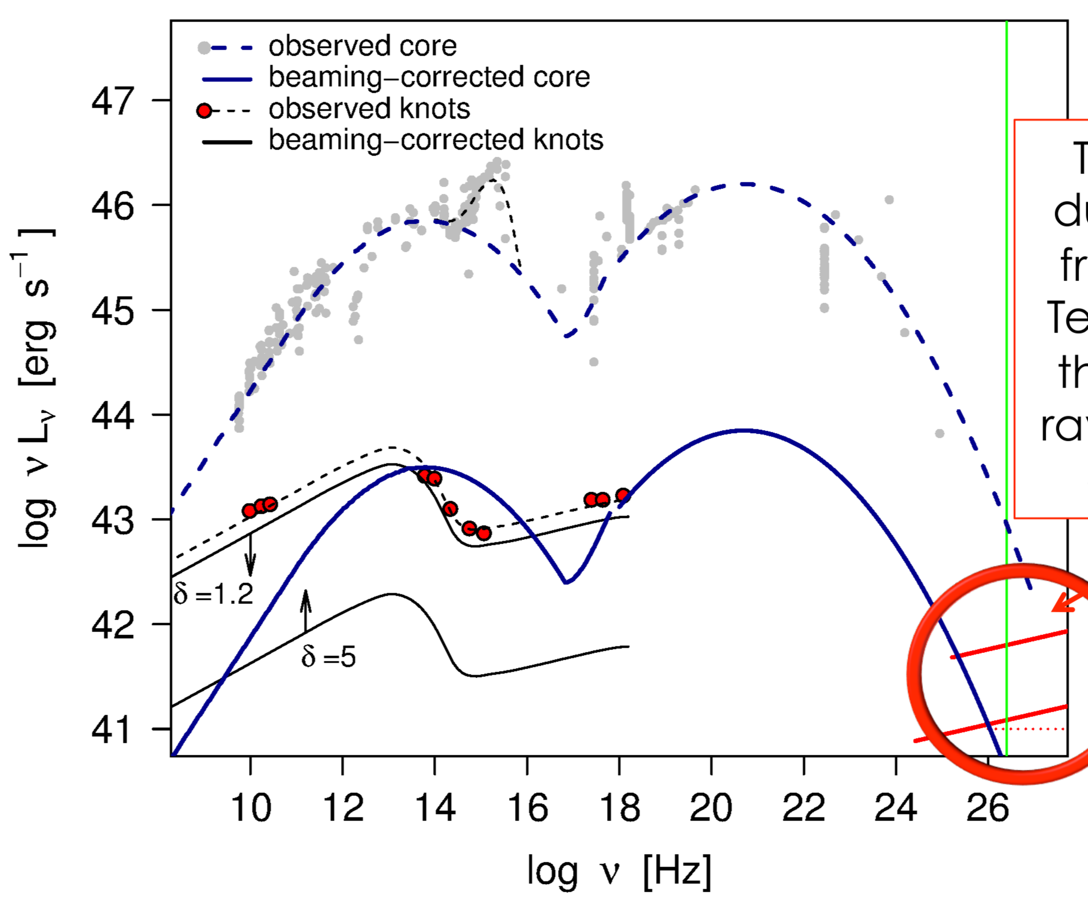


Meyer+, in prep.

6. Surprising Implications of Slow, Synchrotron X-ray Jets



Respecting the Fermi limits requires that the jet have a Doppler factor < 5 (for both 3C 273 and PKS 0637-752)



When beaming is taken into account, the kpc-scale quasar jet may actually produce more radiation than the core (see left comparison of the core and jet emission of 3C 273), in particular *at TeV energies.*

STAY TUNED…

Are 3C 273 and PKS 0637-752 exceptions to the rule? The four jets at right, along with 4 others, will be observed with Chandra, VLA, and HST in the coming year to test the IC/CMB model conclusively for a variety of jet powers and redshifts.