How is the GeV emission of blazars *really* produced?

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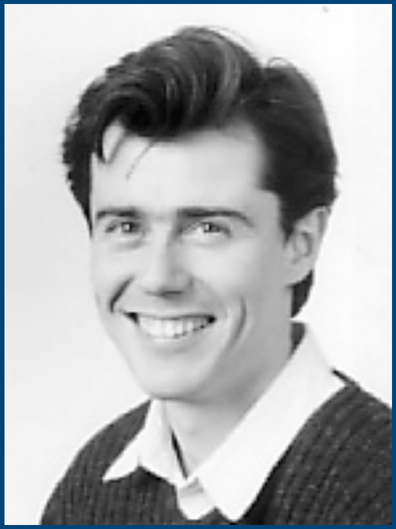


See also astro-ph/0506567

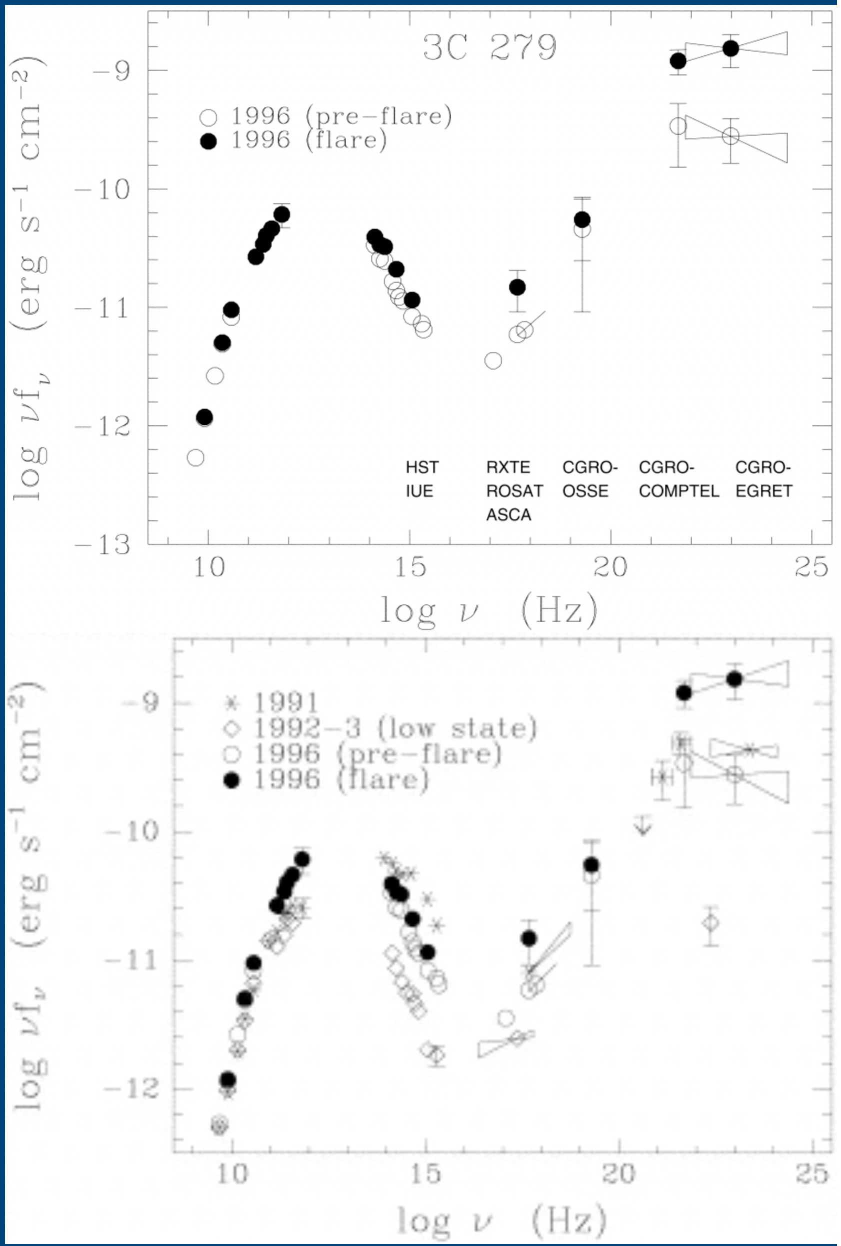
1: UMBC
2:NASA/GSFC

Original motivation for External Compton

Variability of 3C279 is 'superquadratic': GeV variations are more than the square of opt/UV

Believed to be impossible for SSC to explain

Wehrle et al. 1998



External Compton scattering off the broad line ~10 eV photons

Sikora, Begelman, & Rees '94

Assume a spherical broad line region (BLR) with $R \sim 10^{18}$ cm

Have the blazar emission site inside the BLR

$$U_o \approx U_{BLR} \ \Gamma^2$$

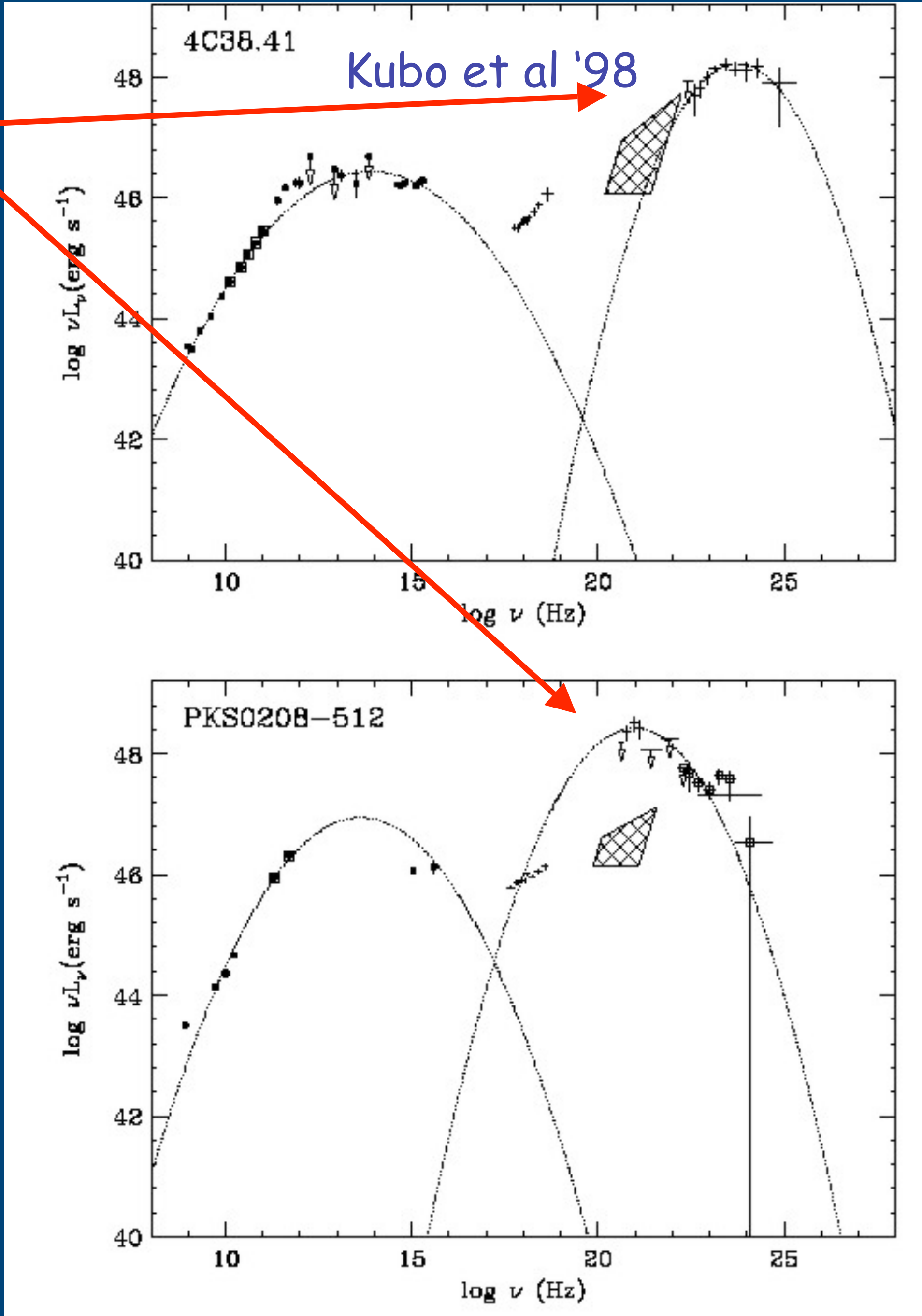
$$\varepsilon_o \approx \varepsilon_{BLR} \ \Gamma \approx 2 \ 10^{-4} \quad \text{in } mc^2 \text{ units}$$

Observed Compton dominance up to a few 100's => External Compton losses dominate

Photons of ~ few GeV out ⇒ electrons of at least the same energy ($\gamma \sim 10^4$) in.

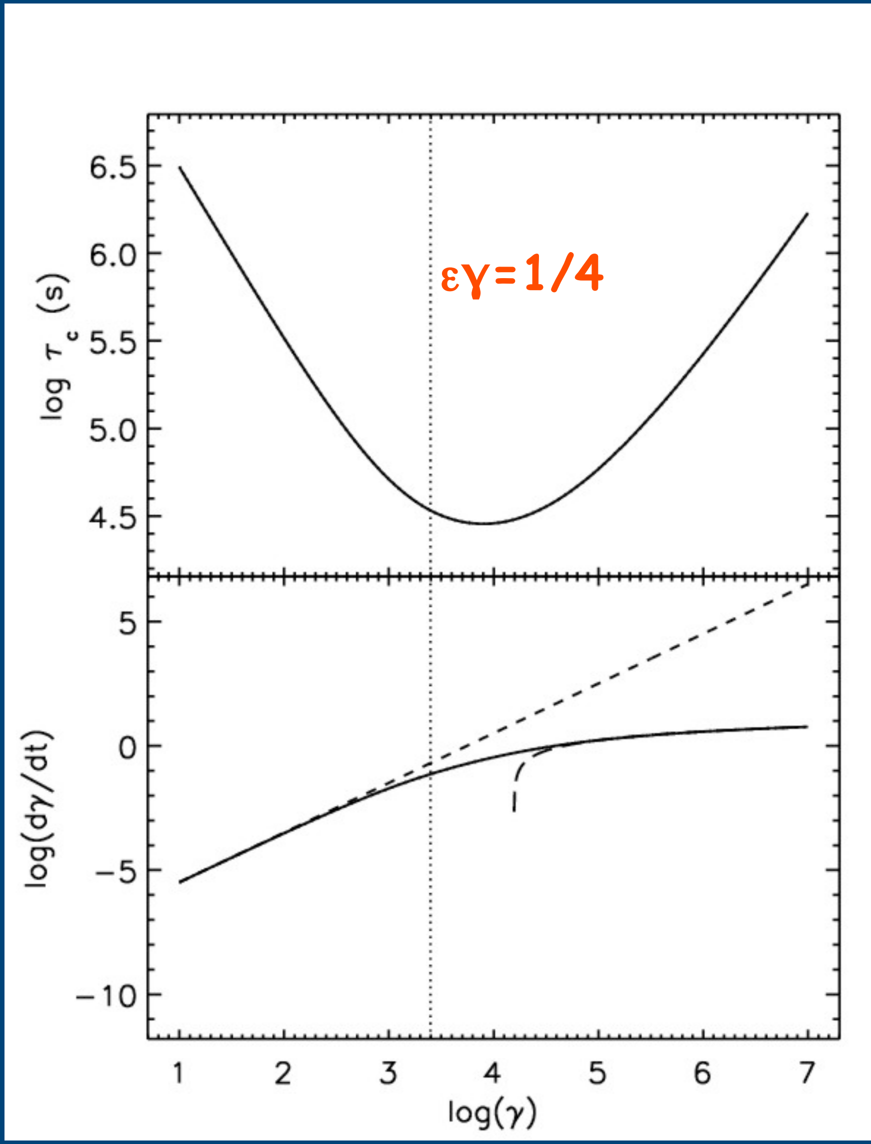
For seed photons $\varepsilon_o \sim 10^{-4}$, $\varepsilon_o \gamma \sim 1$

GeV emission comes from scatterings in the gray area between the Thomson and Klein-Nishina regimes



The devil is in the details…

Thomson	KN
$\varepsilon_0\gamma \ll 1$	$\varepsilon_0\gamma \gg 1$
$\dot{\gamma} \propto \gamma^2$	$\dot{\gamma} \propto \gamma^0$
$\tau_c = \frac{\gamma}{\dot{\gamma}} \propto \frac{1}{\gamma}$	$\tau_c = \frac{\gamma}{\dot{\gamma}} \propto \gamma$



At GeV electron energies the cooling time is ~ energy independent!

Effect on n(γ) ?

The electron distribution

$$\frac{\partial(\dot{\gamma} n)}{\partial \gamma} = K \gamma^{-p} \Rightarrow$$

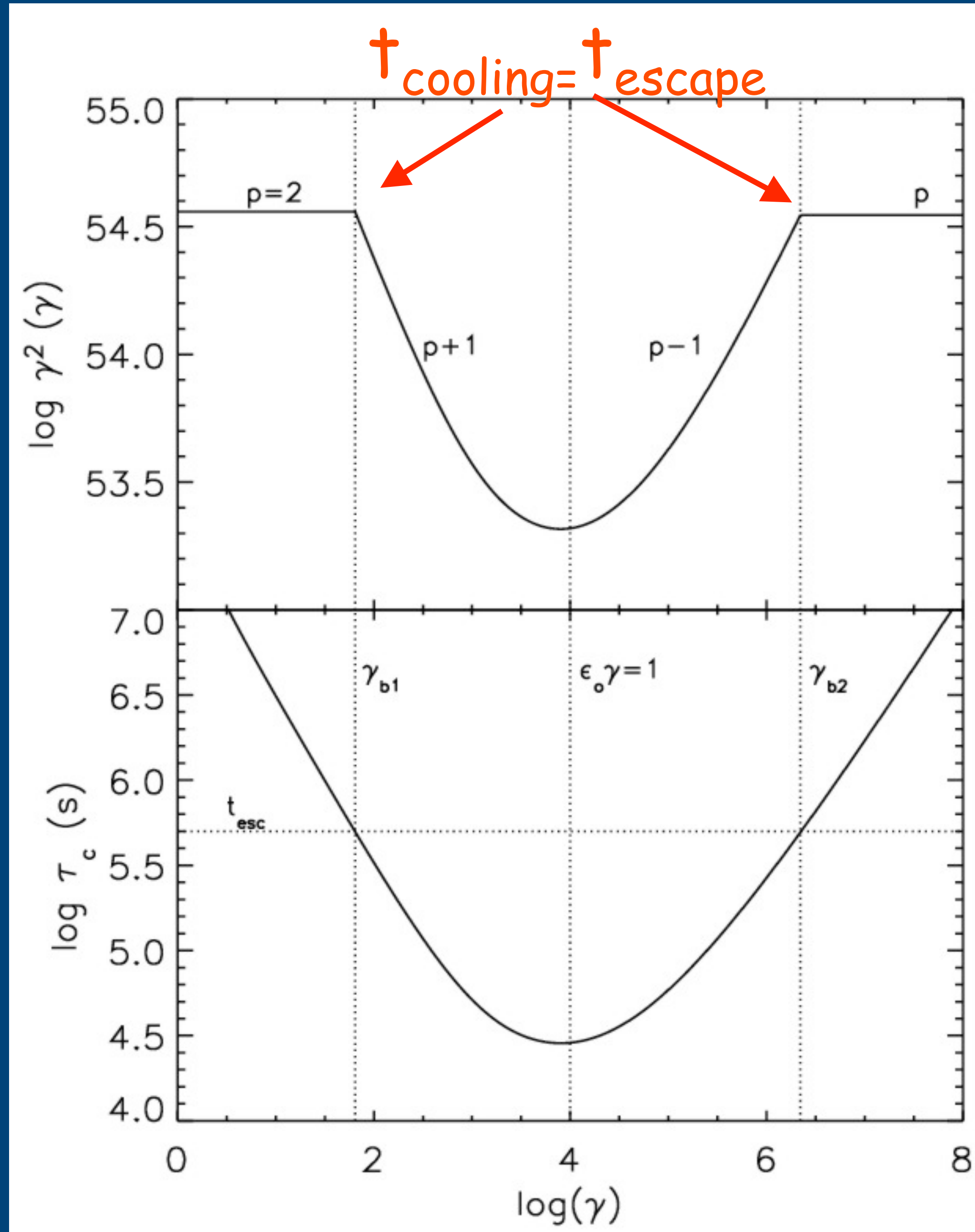
$$n \propto \frac{\gamma^{1-p}}{\dot{\gamma}}$$

Thomson: $\dot{\gamma} \propto \gamma^2$

$$n(\gamma) \propto \gamma^{-(p+1)}$$

KN: $\dot{\gamma} \propto \gamma^0$

$$n(\gamma) \propto \gamma^{-(p-1)}$$



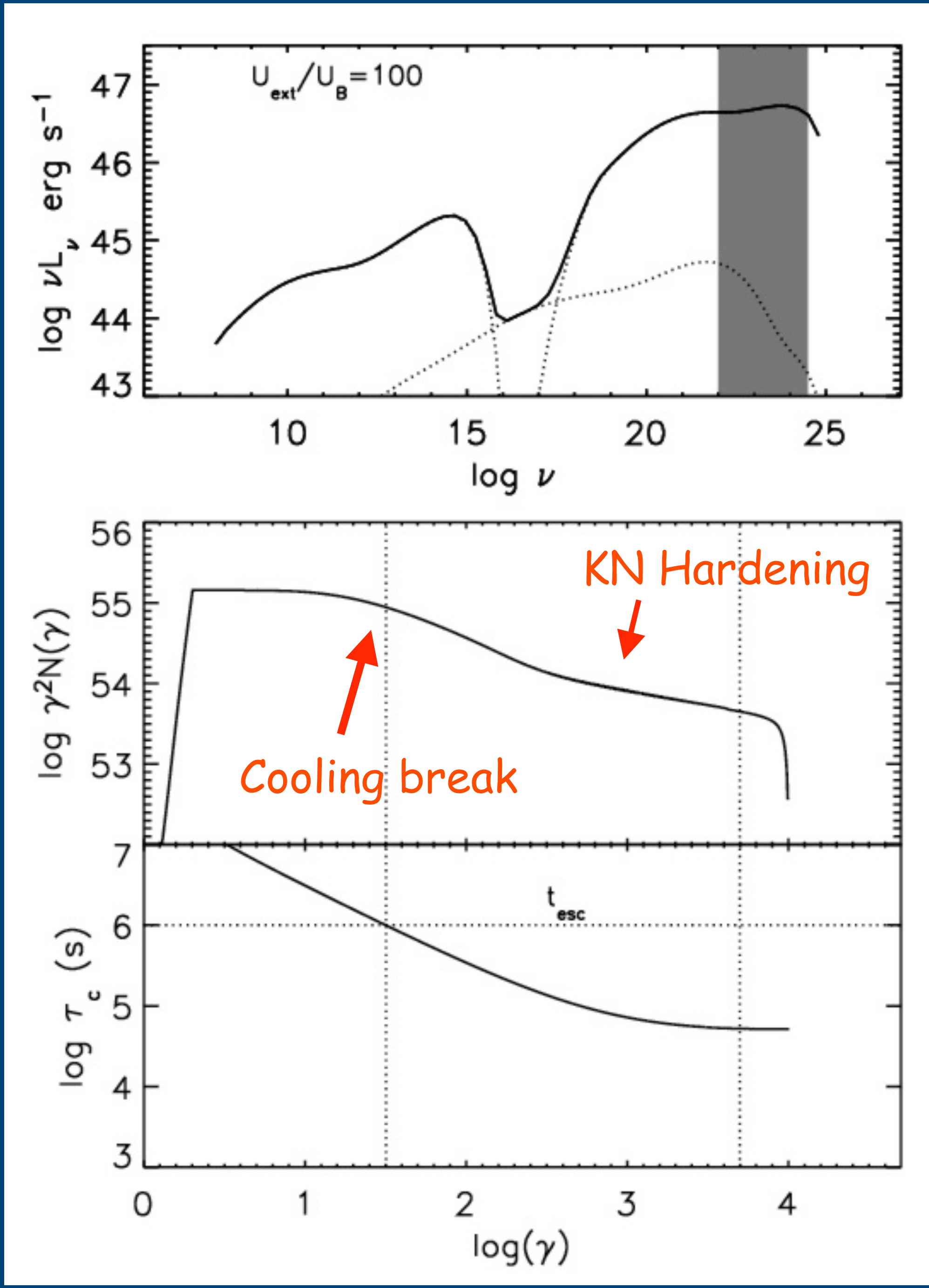
See also Moderski et al. astro-ph/0504388

"Compton Sphere"

The code used for this simulation is a time-dependent homogeneous code that will soon become publicly available at

http://jca.umbc.edu/csphere

The code treats the inverse Compton losses in the KN regime as a discrete process.



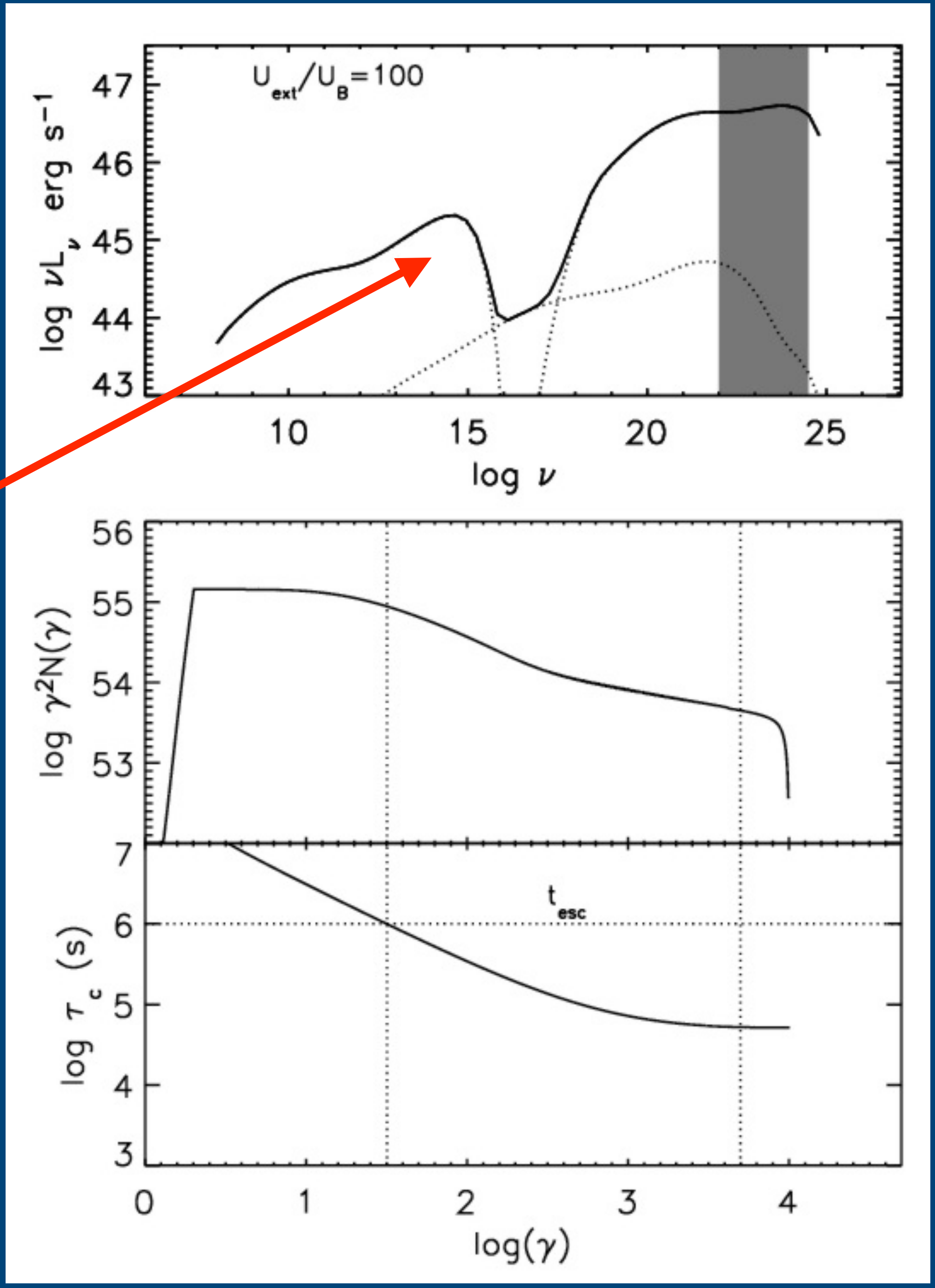
How EC dominated blazars should look

Unavoidable but unobserved marks:

1. The hump in the synchrotron component

2. The flat/rising SED of the GeV component (rarely seen, typical GeV spectrum is steep)

3. Achromatic variability for the synchrotron hump and the GeV regime.



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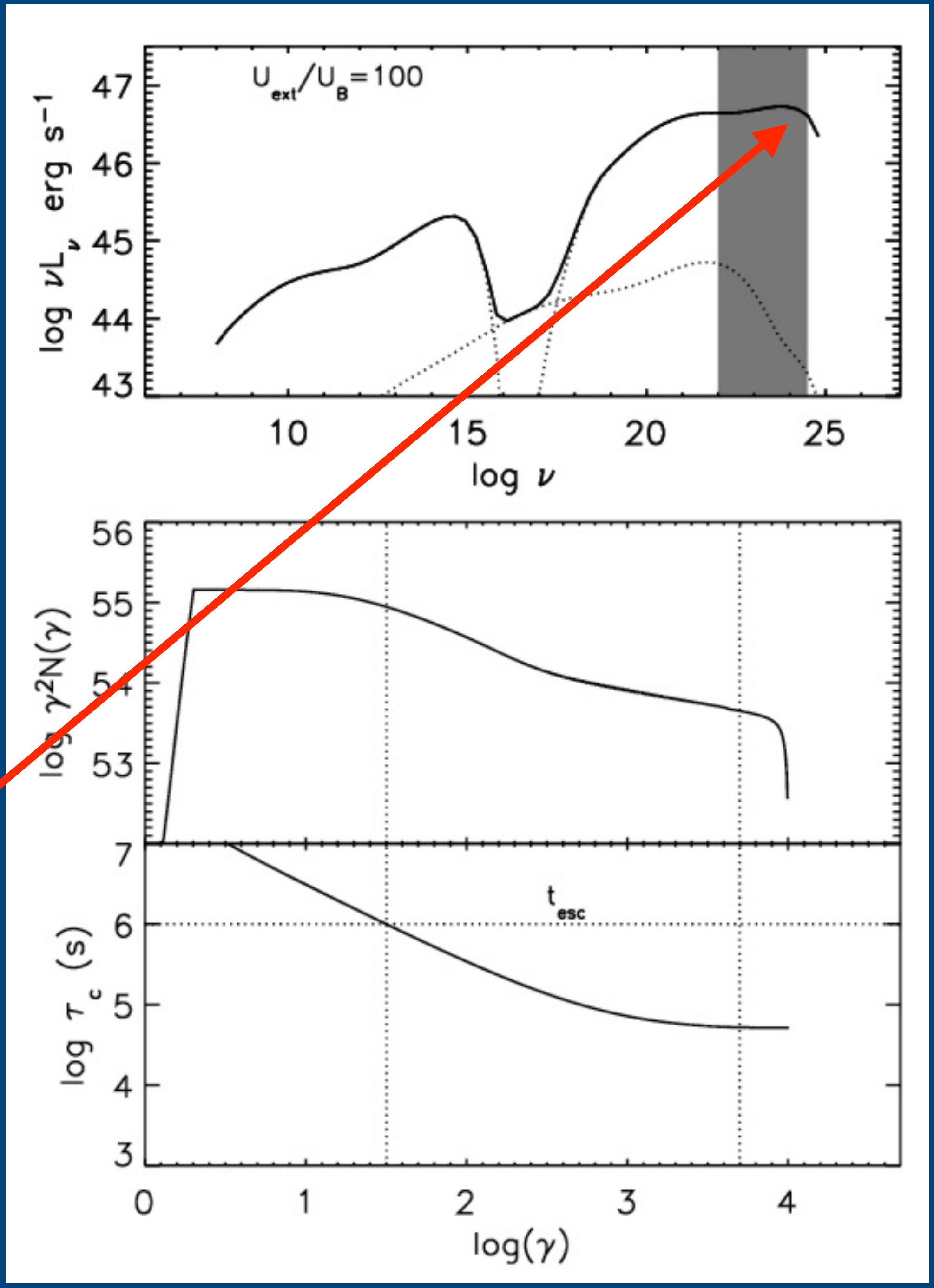

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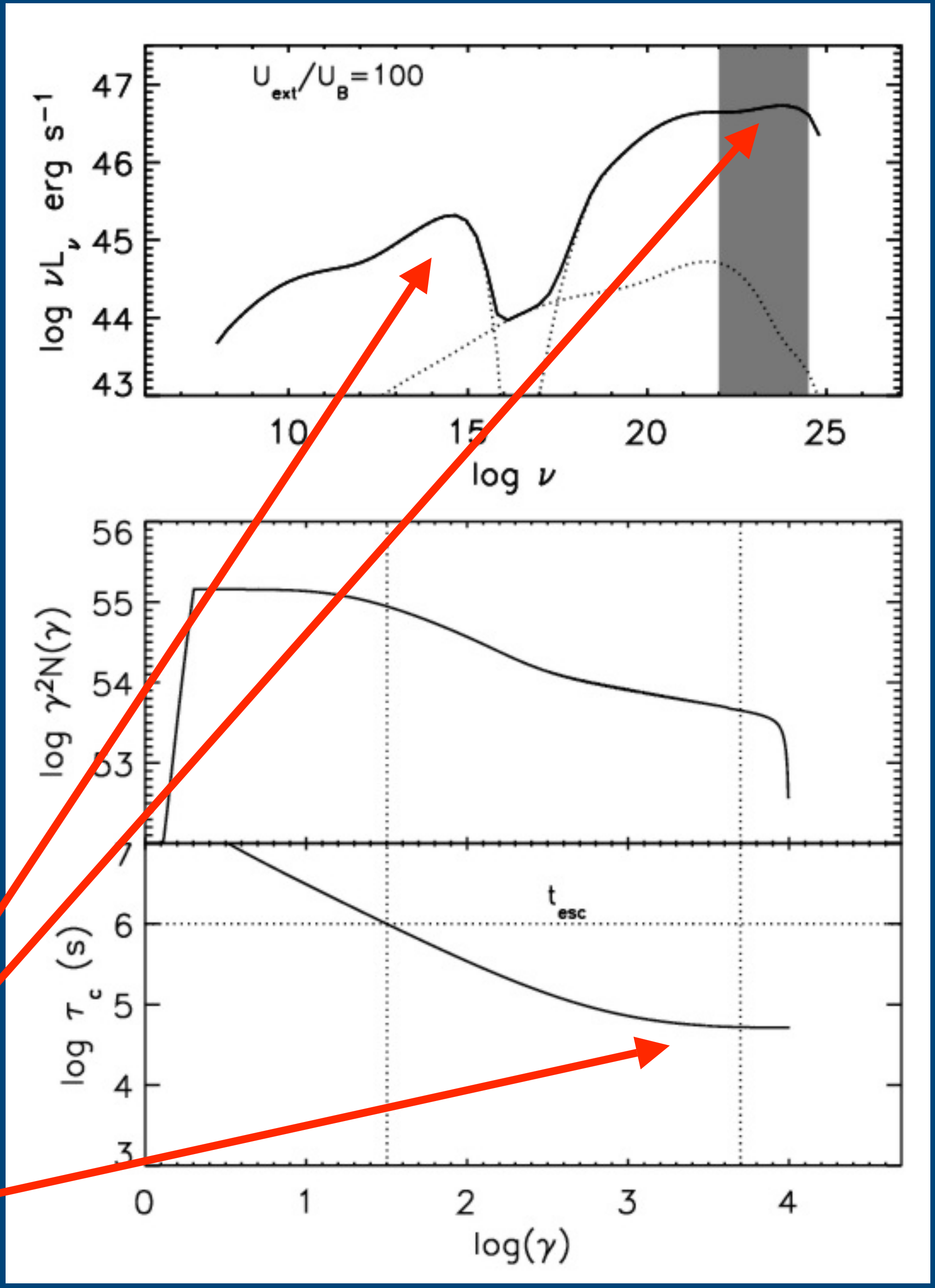
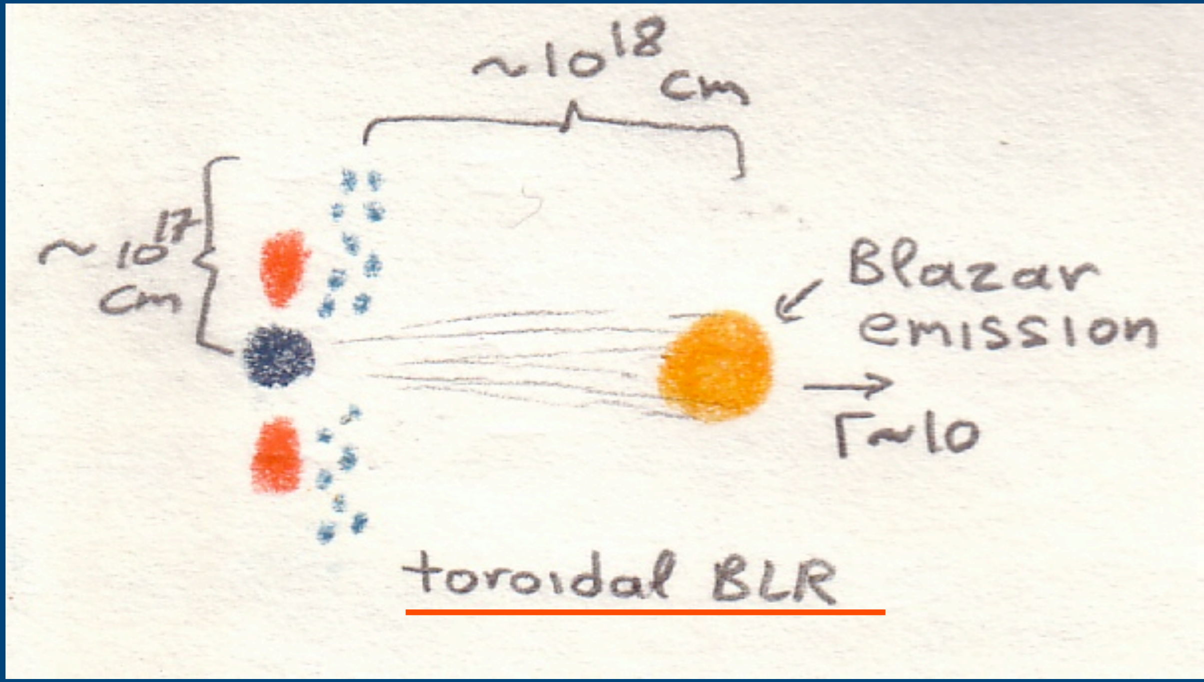


How can it not be EC off the BLR? If the BLR is flat!

Kaspi et al. 2000: BLR size from reverberation mapping:

$R=1.5\ 10^{17}\ L_{46}^{0.7}$ cm

for a source like 3C 279



The BLR energy density, as measured in the blazar's comoving frame drops:

$U \propto 1/\Gamma^2$ instead of Γ^2

This reduces the EC power by up to Γ^4 ~10,000

Arguments for a flattened BLR geometry

R: core (beamed) to extended (unbeamed) radio power.

>Anti-correlation between R and line FWHM (many groups, e.g. Wills & Browne 1986)

>Predominant motion of the line emitting gas confined to a disk perpendicular to the radio axis

>Disk thickness to diameter ratio 0.15-0.3

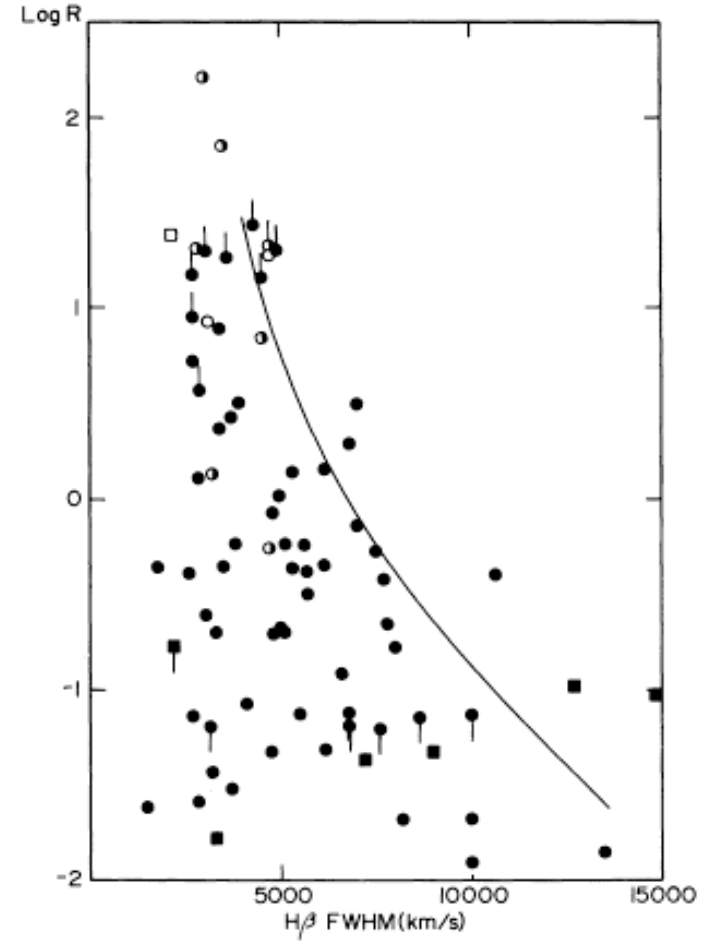


FIG. 1.—Ratio of 5 GHz core to extended component flux density R as function of FWHM for the broad Hβ line for quasars (*circles*) and BLR((*squares*). Open symbols represent sources with observed superluminal expa sion. Half-open symbols represent optically violent variables and highly po arized quasars. Vertical bars indicate points with upper and lower limits to Curve represents the change of R with FWHM, predicted by beaming mod discussed in text.

broad line radio galaxies, 3C 382, 3C 390.3, and 3C 234, ha

Arguments for a flattened BLR geometry

Maiolino et al. 2001:

UV spectra of QSOs (from the ratio of line to continuum photons): the covering factor of the BLR clouds must be larger than 30%.

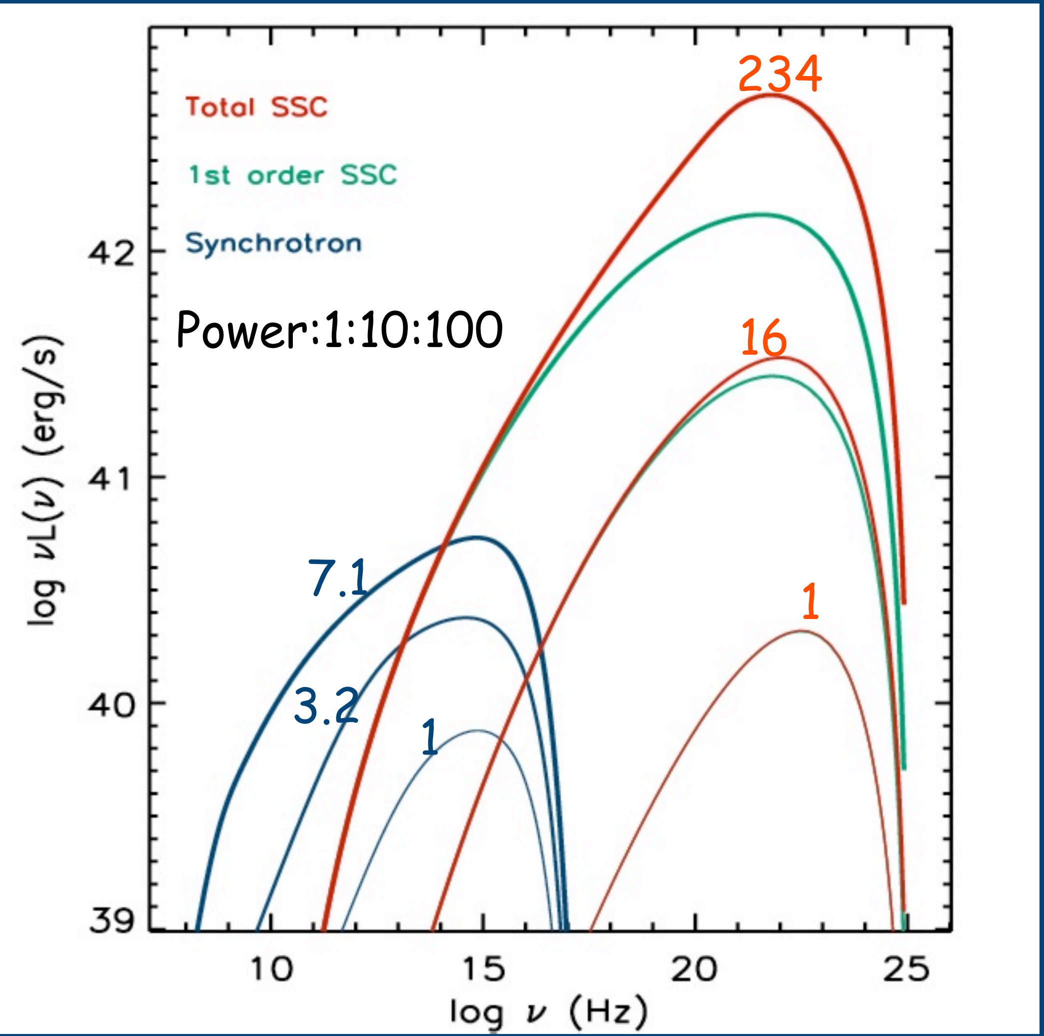
- => More than 30% of the lines of sight should intersect a BLR cloud and show a sharp Ly-edge in absorption.
- Problem: This has never been observed
- Solution: the BLR is flattened and the dusty gas in the outer parts, on the same plane, prevents the observation along the lines of sight passing through the BLR clouds.

SSC, back to where we started from (almost)

Q: *But can SSC produce superquadratic variations like those seen in 3c 279?*

A: Yes, it does so naturally, when the SSC power is comparable or higher than the synchrotron power.

Even more so when the second order (SSC2) is relevant.



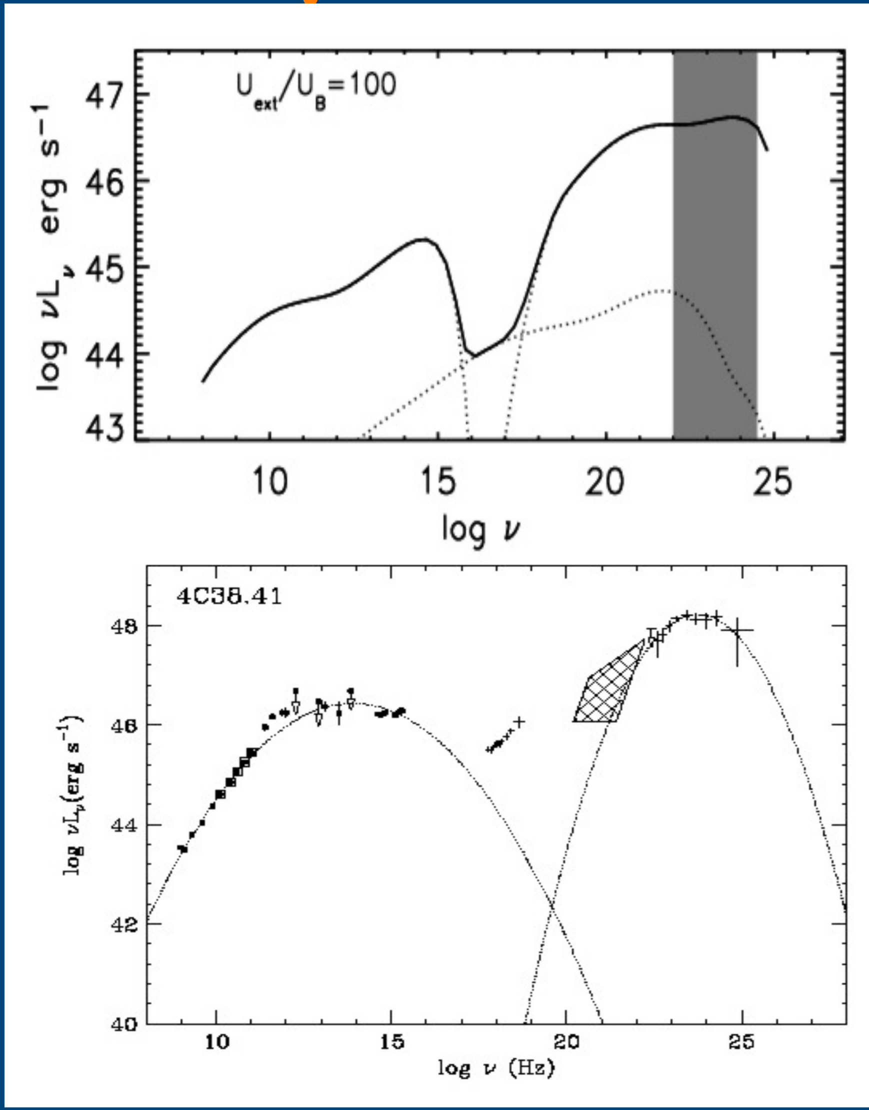
Three conclusions,

a suggestion,

and our goals…

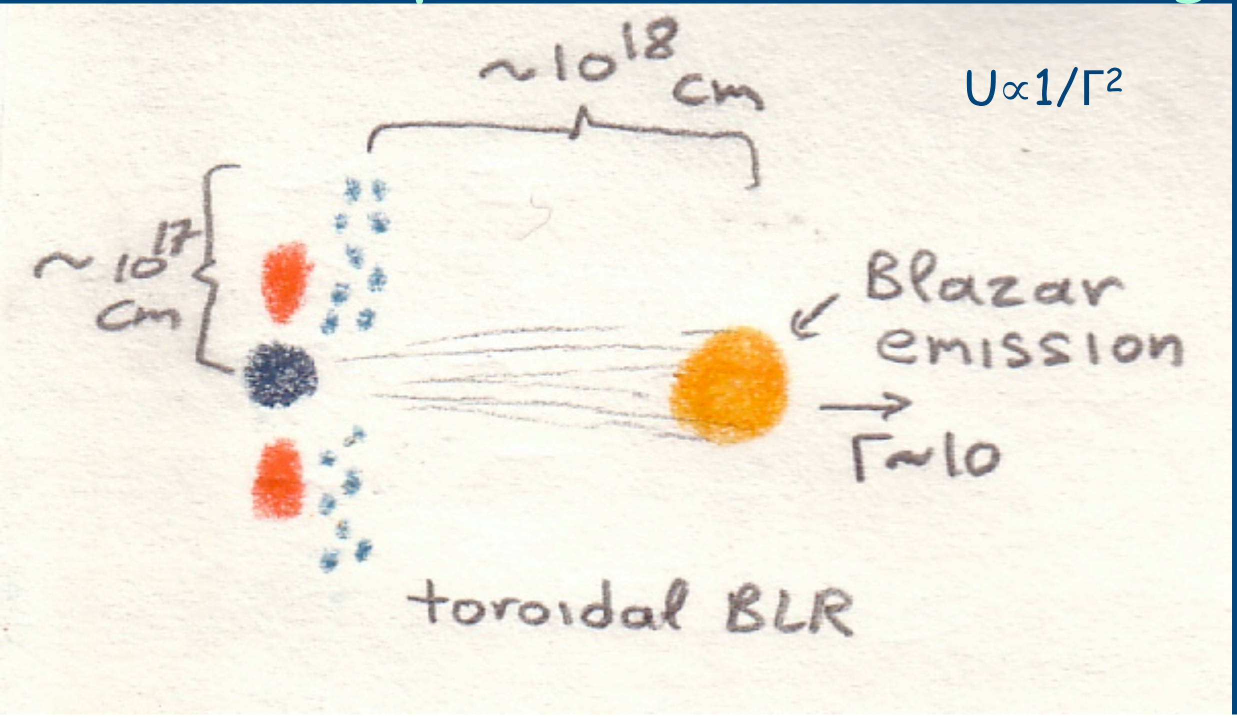
1. EC off the BLR has problems

- External Compton scattering of BLR photons disagrees with the spectra of high Compton dominance blazars.
- Final confirmation/ rejection of this will have to wait for GLAST.



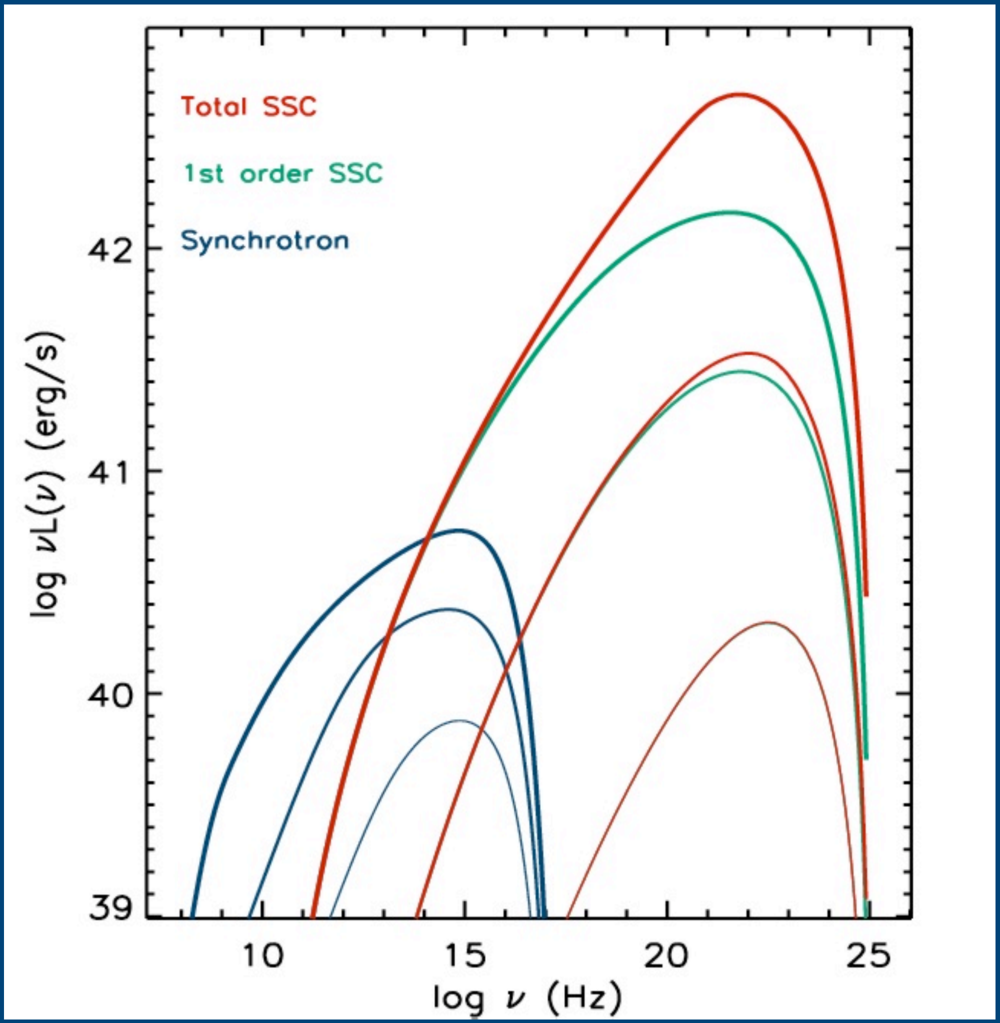
2. Do not consider a spherical pancake

If the BLR has a pancake geometry with R~10^{17} cm, then the BLR photon energy density in the comoving blazar emission site is strongly reduced and with it the power of EC scattering



3. SSC2 is in

- SSC2 (SSC with the inclusion of higher order scatterings) works, naturally reproducing superquadratic variations.



Suggestion

Use the Compton Sphere

It's fast, it's accurate, it treats discrete Compton losses,

and

It's coming soon at

http://jca.umbc.edu/csphere

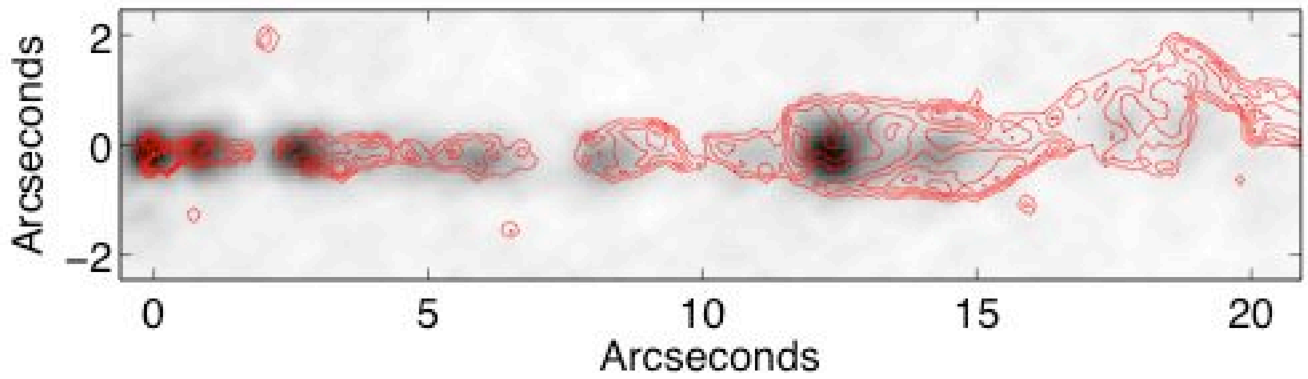
Our goals

- Inclusion of this code into a multi-zone framework
- Explaining both small-scale and large-scale interplay between physical processes and jet spectra and other observations

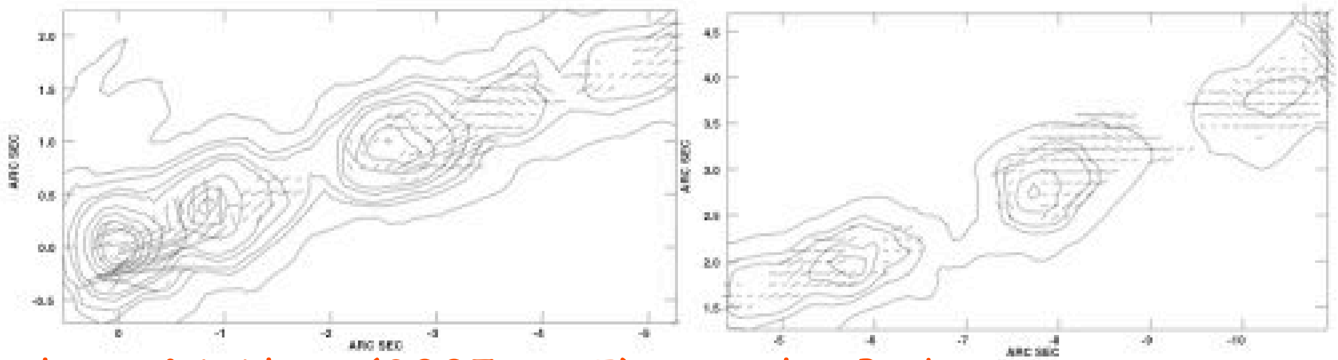
    The data are beginning to be gathered at large scales to directly test multi-zone models.

    Right now mostly on low power jets … badly need high-power obj's.

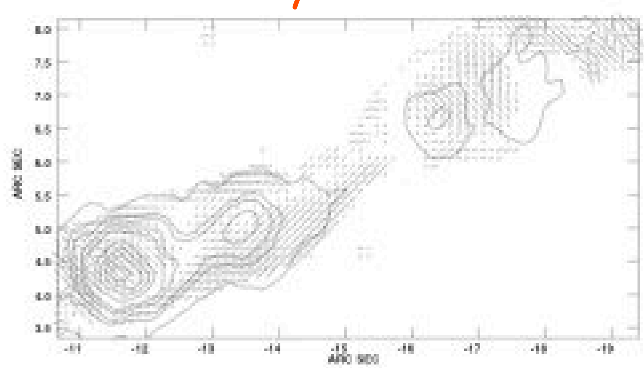
Image: Chandra 0.3–1.5 keV   Contours: HST V band %Pol

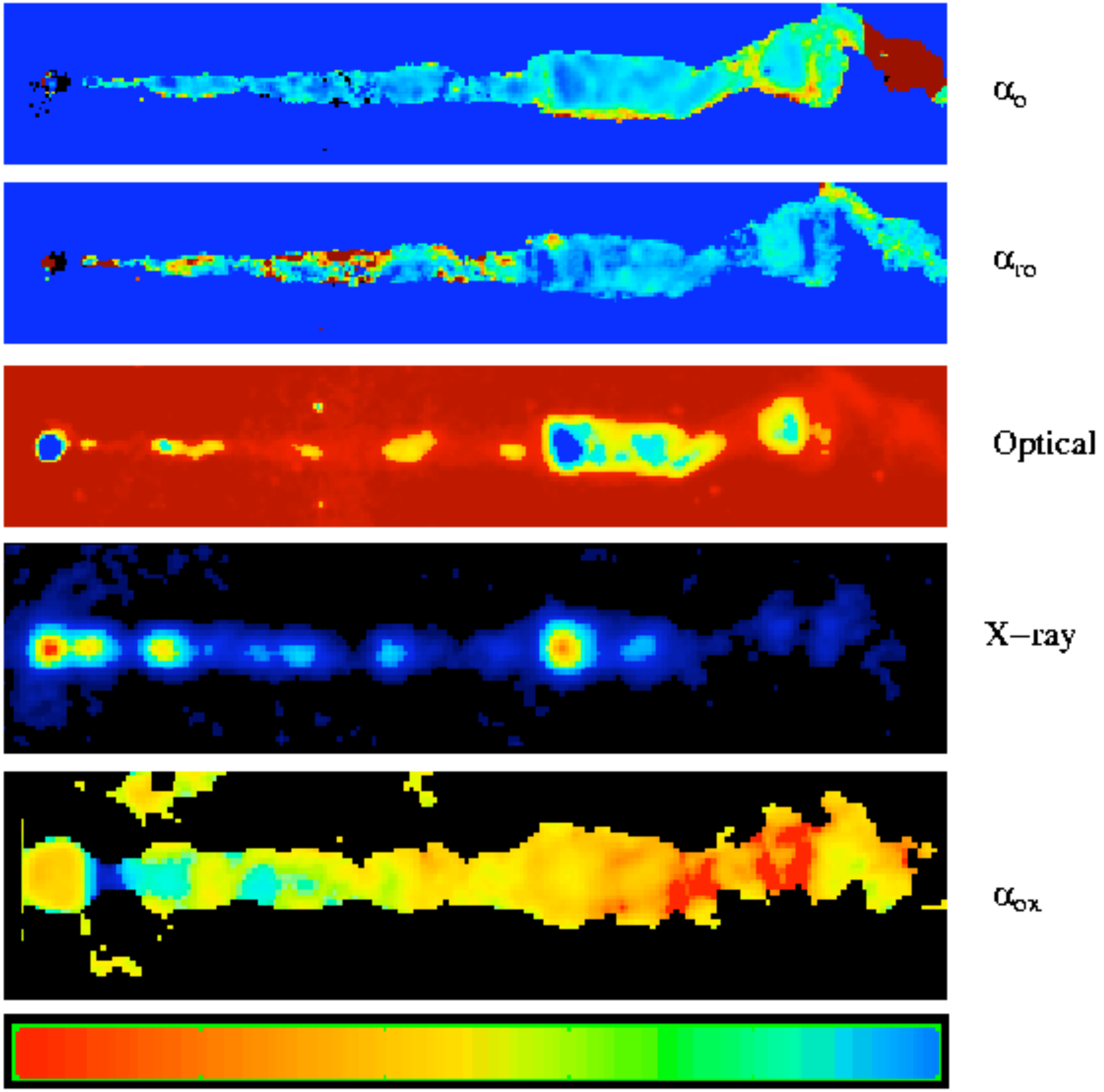


Contours: X–ray emission (Chandra) Vectors: Optical Polarization (B–field)



Perlman & Wilson (2005, ApJ); see also Padgett poster:
Other FRIs do not necessarily follow the M87 pattern (each is different!)





Perlman & Wilson 2002