The Broken Power Sequence of Radio-Loud AGN
+
Collective Evidence for Inverse Compton emission from External Photons in High-Power Blazars

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Fermy meets Jansky
St. Michael's, MD
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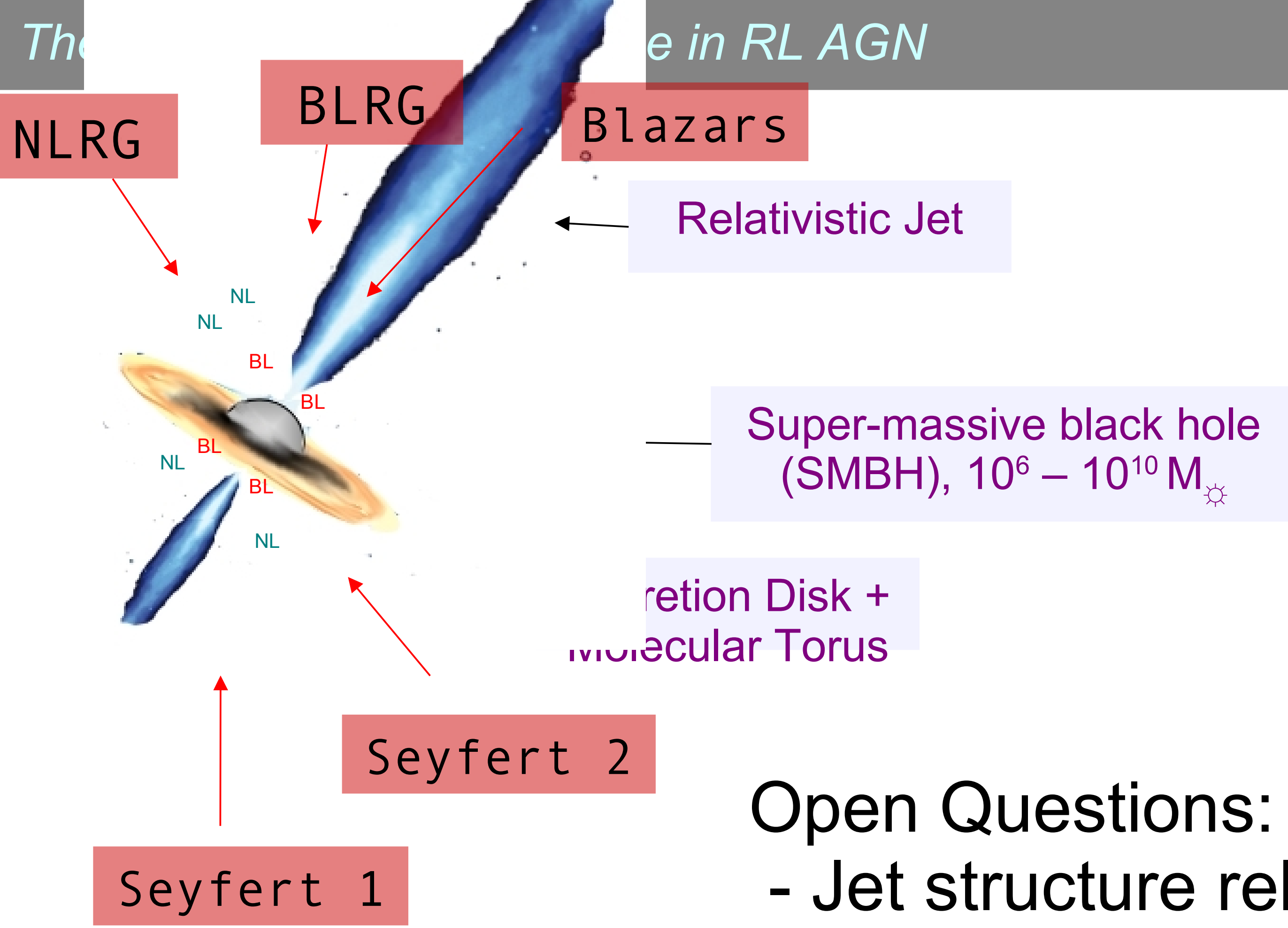
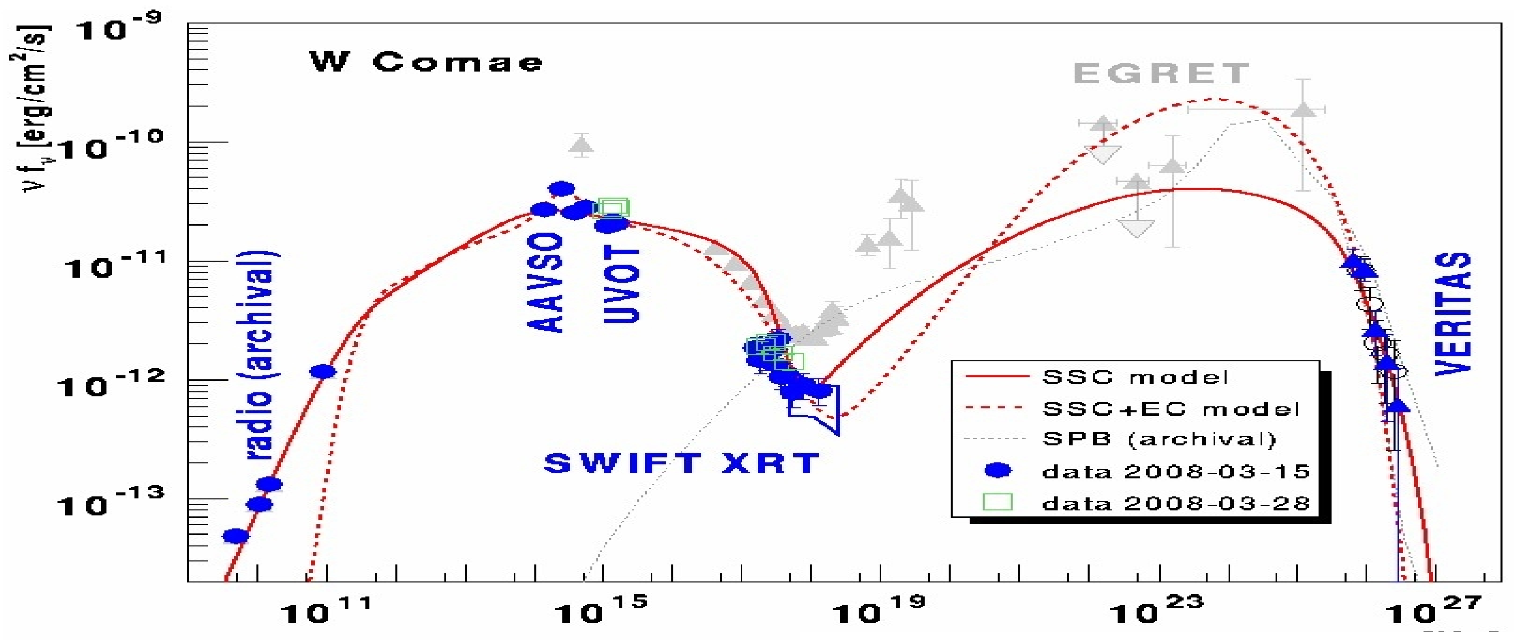
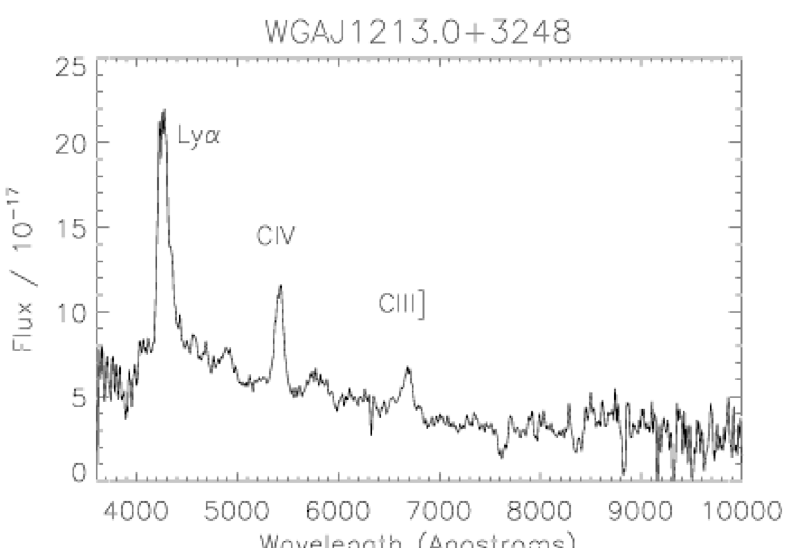


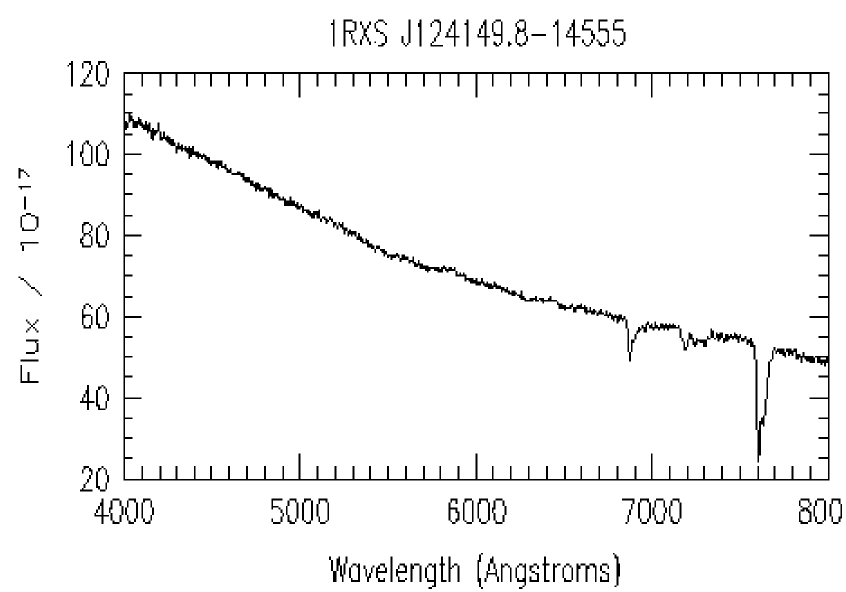
Open Questions:
- Jet structure relate to Morphology?
- Site of the Gamma-ray emission?
- Role of the Black Hole mass, spin, accretion rate?

→ What can we learn from studying populations?

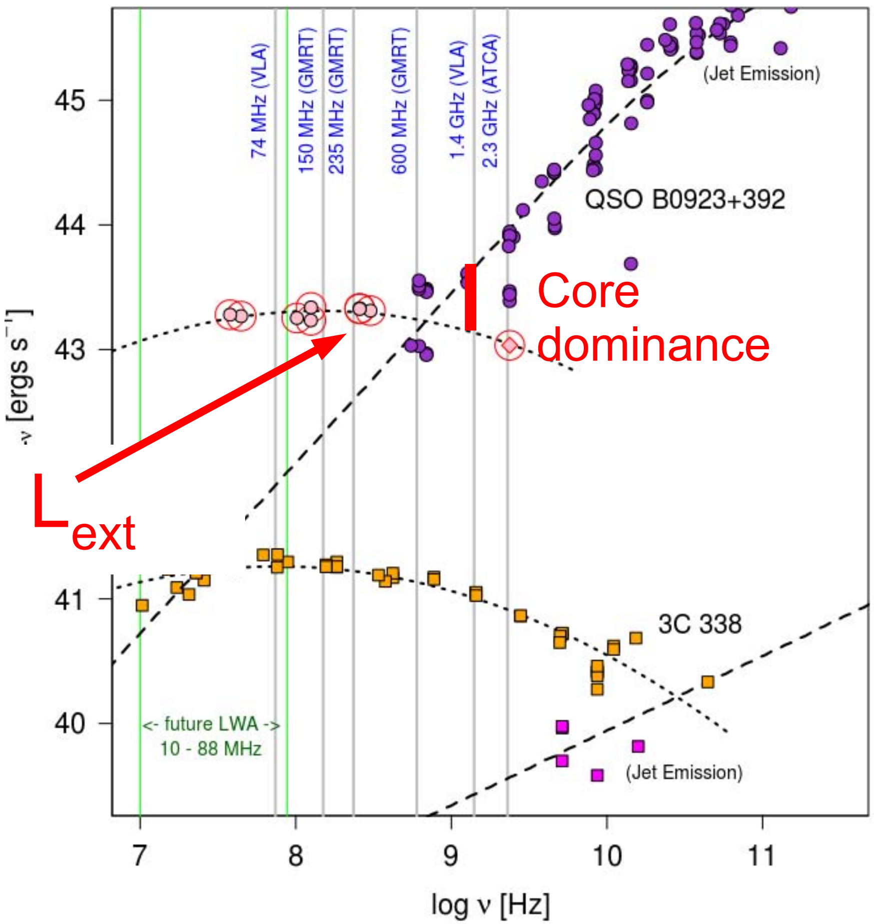
The Blazar View of the Relativistic Jet

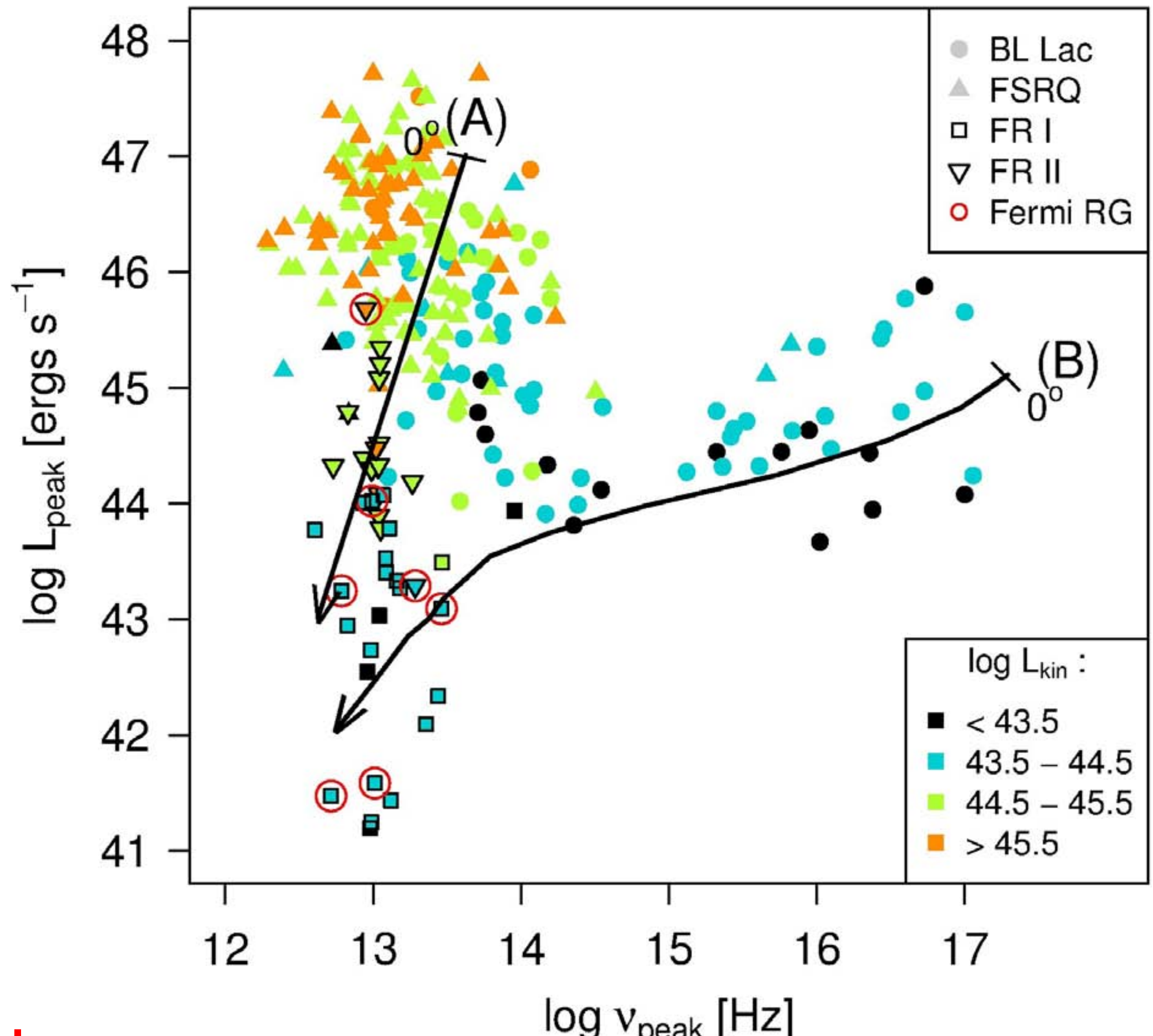






The Broken Blazar Sequence

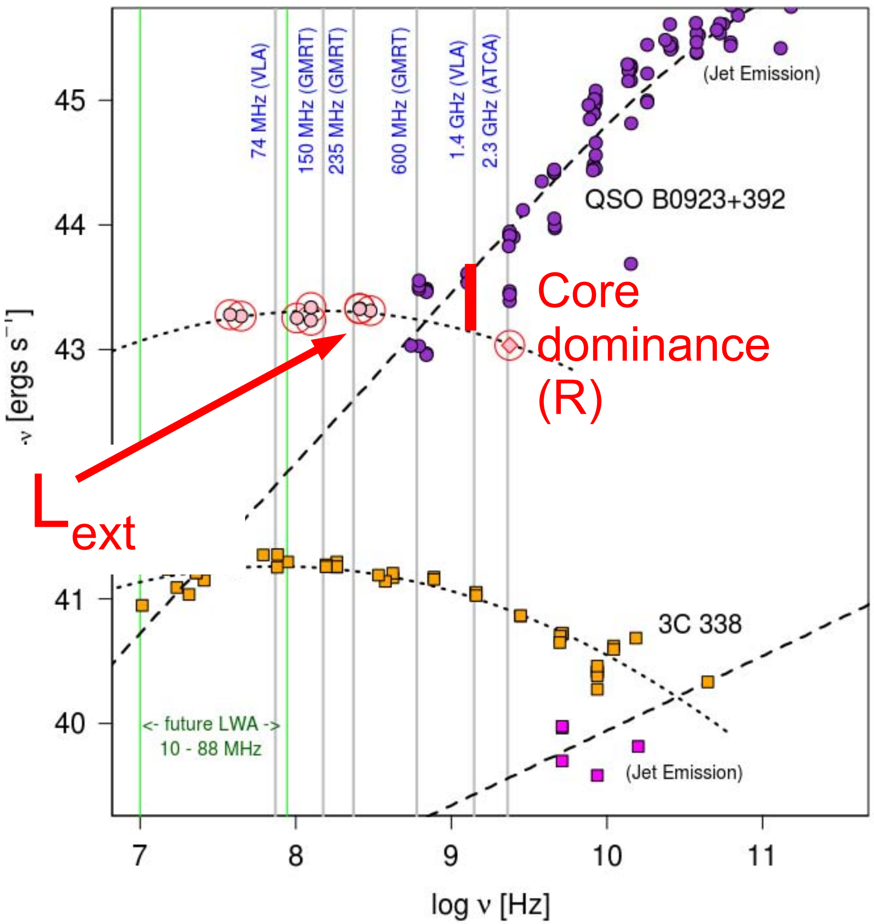


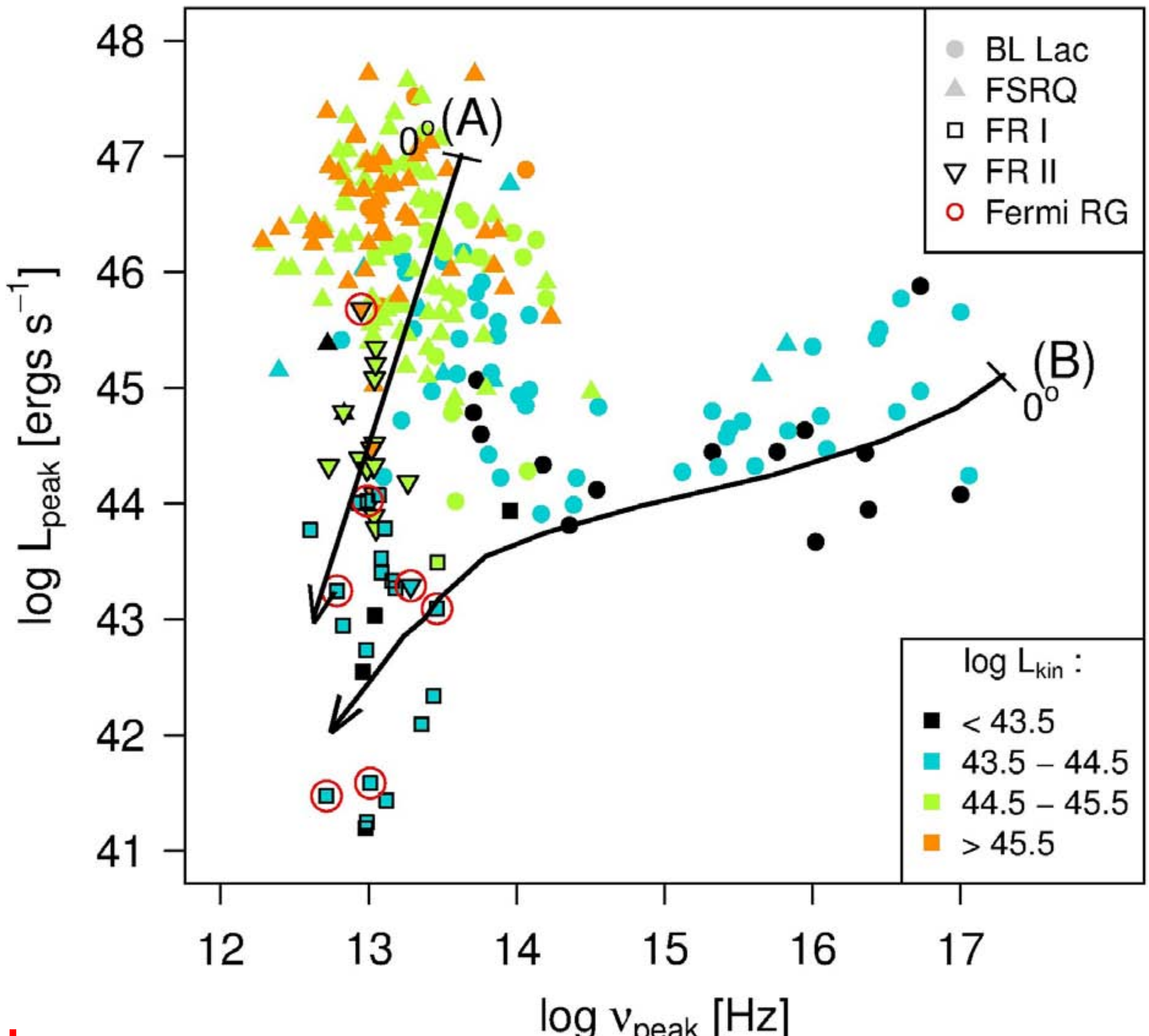


Lext → Jet Power
Core Dominance → Angle

Meyer et al., 2011

The Broken Blazar Sequence





Lext → Jet Power

Core Dominance → Angle

Meyer et al., 2011

The Broken Blazar Sequence

> Weak Jets consistent with velocity gradients in the radiating plasma

(spine-sheath – Ghisellini 2005, Chiaberge 2000 and/or decelerating flow – Georganopoulos 2003)

> Strong Jets drop quickly in Luminosity (1:4)

> many BL LACS in the strong jet branch (more on this)

> ISPs more misaligned versions of HSP?

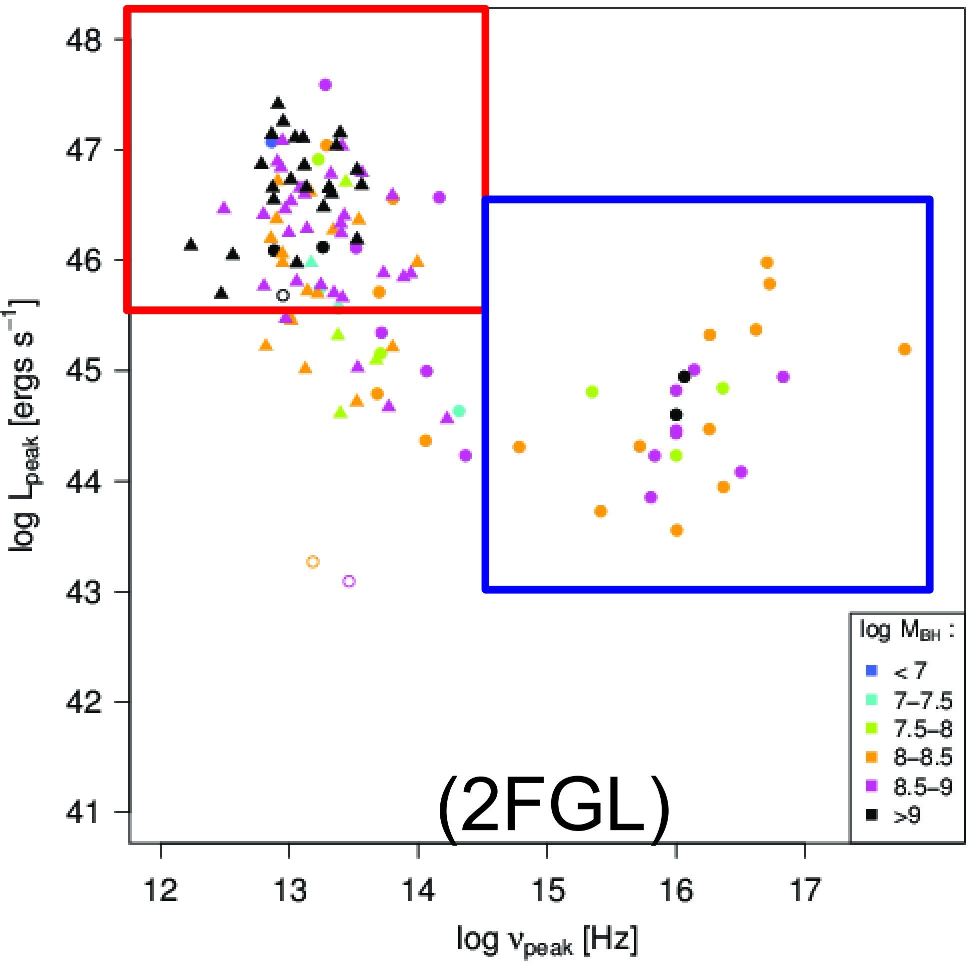
– explains many recent findings “at odds” with the sequence:

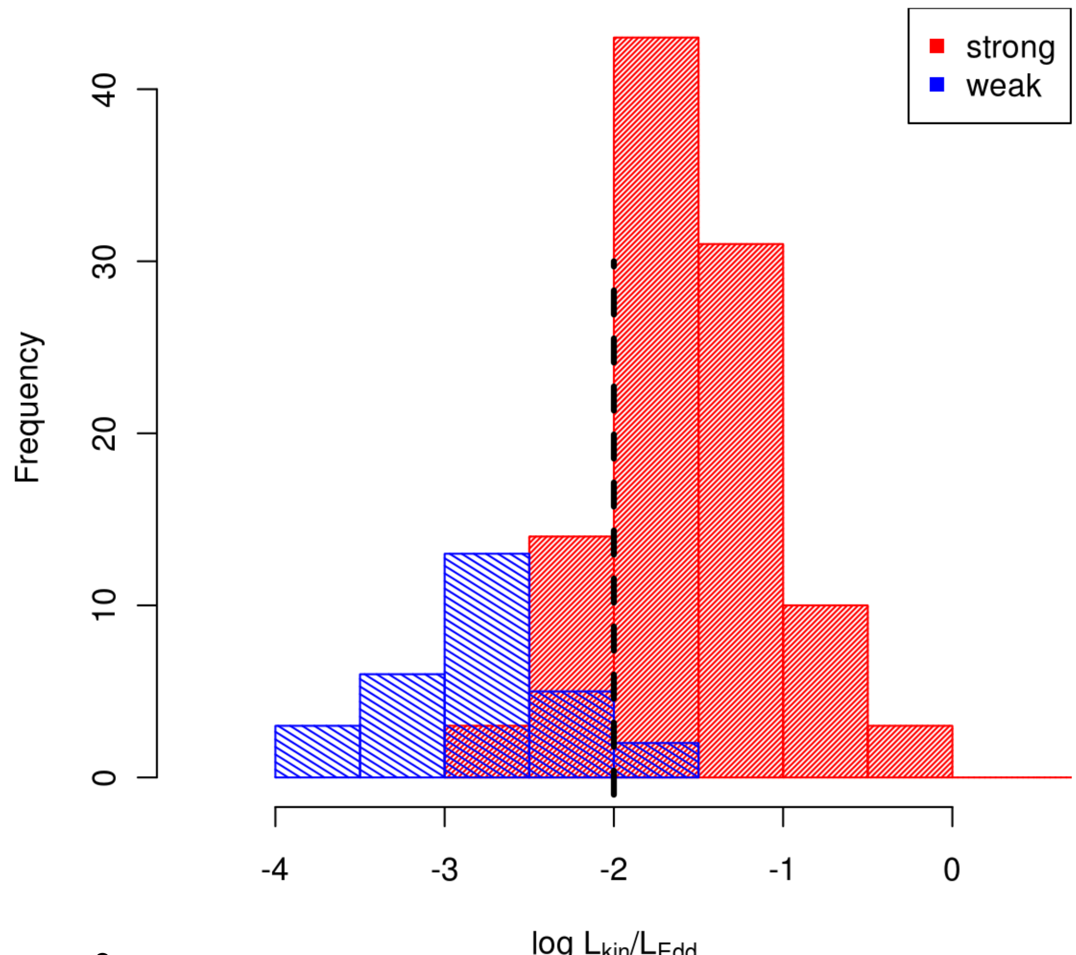
– Caccianiga & March˜a (2004): high R, low Lum., low peak

> Confusion at low synchrotron peaks/overlap with RG

> *There is not a continuous sequence*

L_{kin}, θ, … $\mathring{m}$?



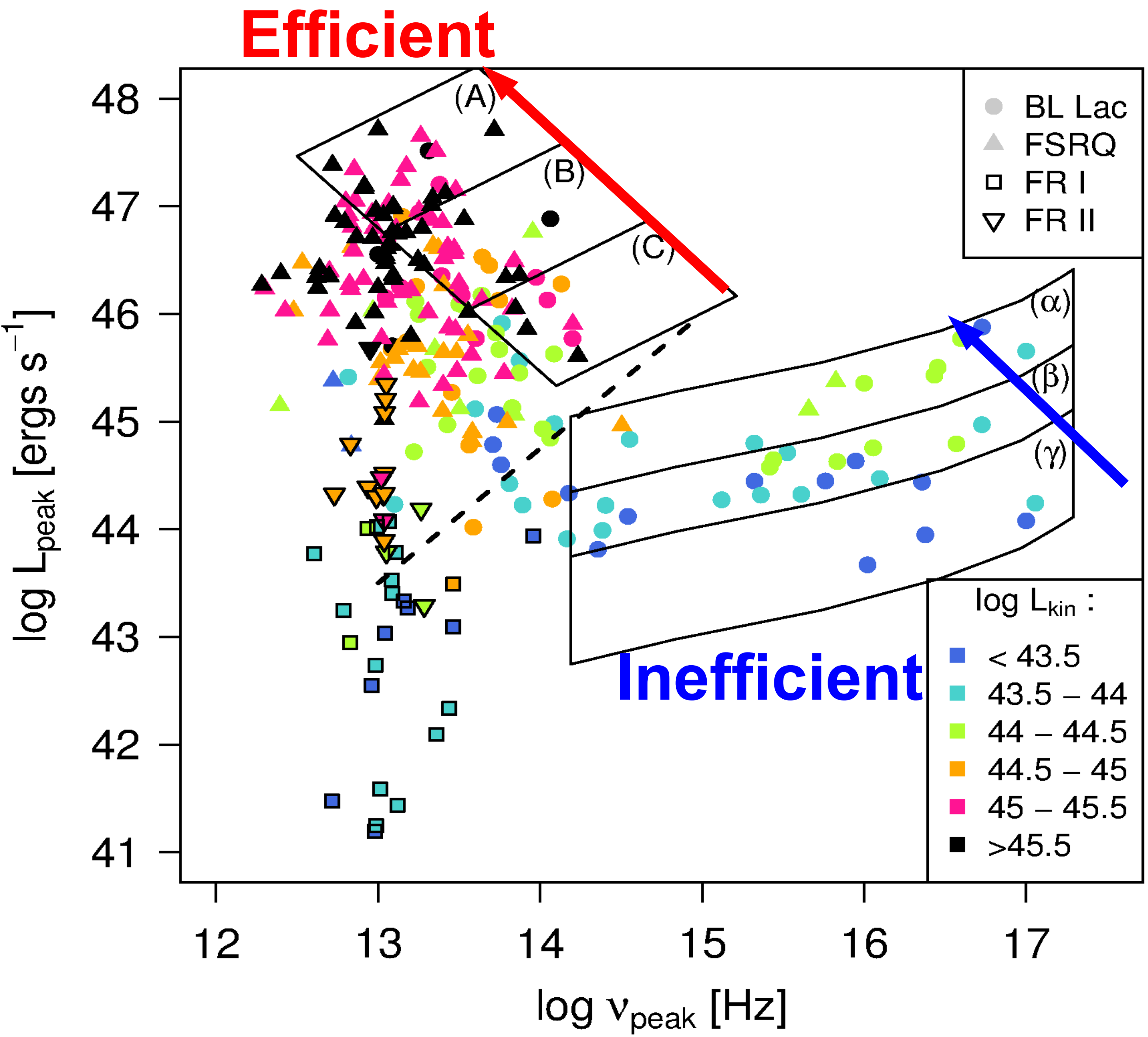


(Mass estimates from reverberation mapping, velocity dispersions, mass-luminosity scalings)

$\mathring{m} = L_{kin}/L_{Edd}$

$L_{Edd} = 1.3\text{x}10^{38}\ M_{BH}$

The Broken Power Sequence



Inefficient Case:

- no broad lines, SSC
- assume const Γ with L_{kin}
- assume $n(\gamma) = k\gamma^{-2}$

$L_{peak} \sim kB^2 \sim L_{kin}^{\ 2}$

$\nu_{peak} \sim B\gamma_b^{\ 2}\delta \sim L_{kin}^{\ -3/2}$

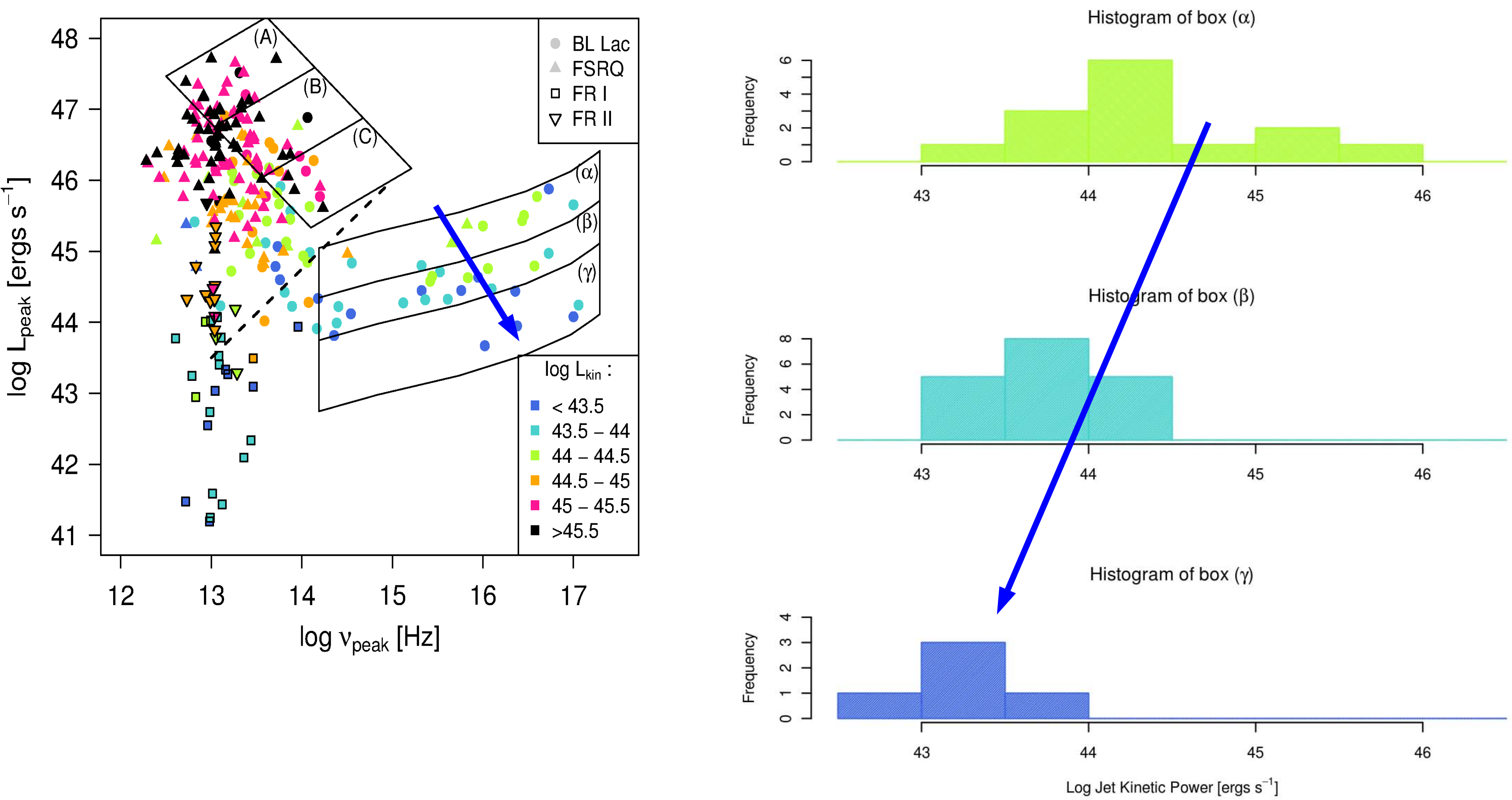
$\mathbf{L_{peak} \sim \nu_{peak}^{\ -4/3} \sim L_{kin}^{\ 2}}$

Efficient Case:

- BBB,IR emission, EC
- assume scaling $L_{kin} \sim \Gamma^2$

$\mathbf{L_{peak} \sim \nu_{peak}^{\ -4/3} \sim L_{kin}^{\ 2}}$

The Broken Power Sequence



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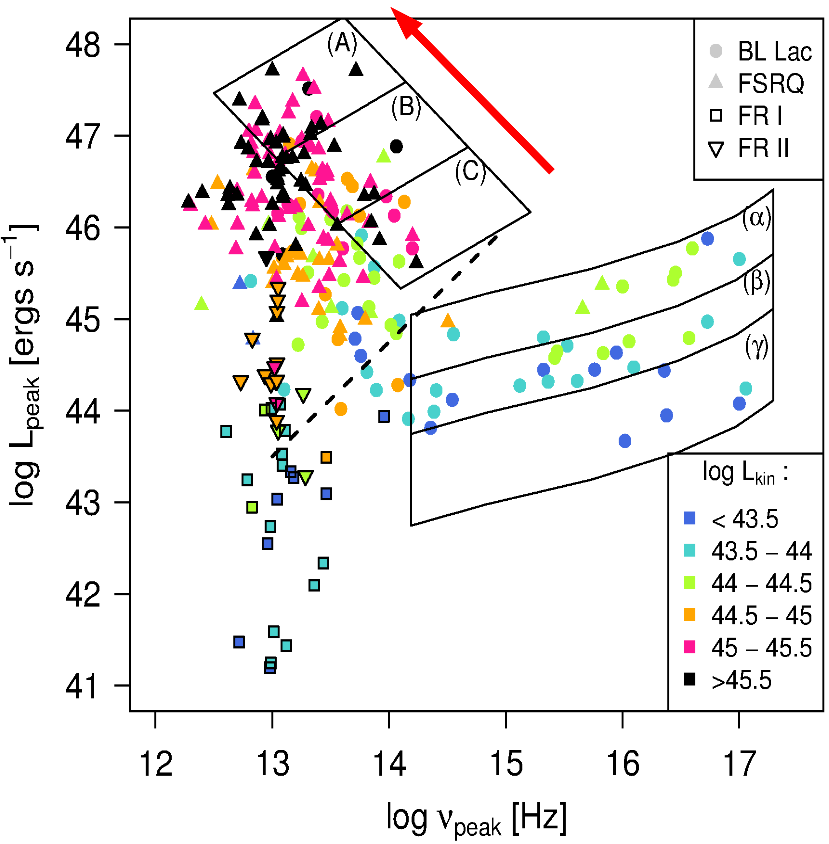
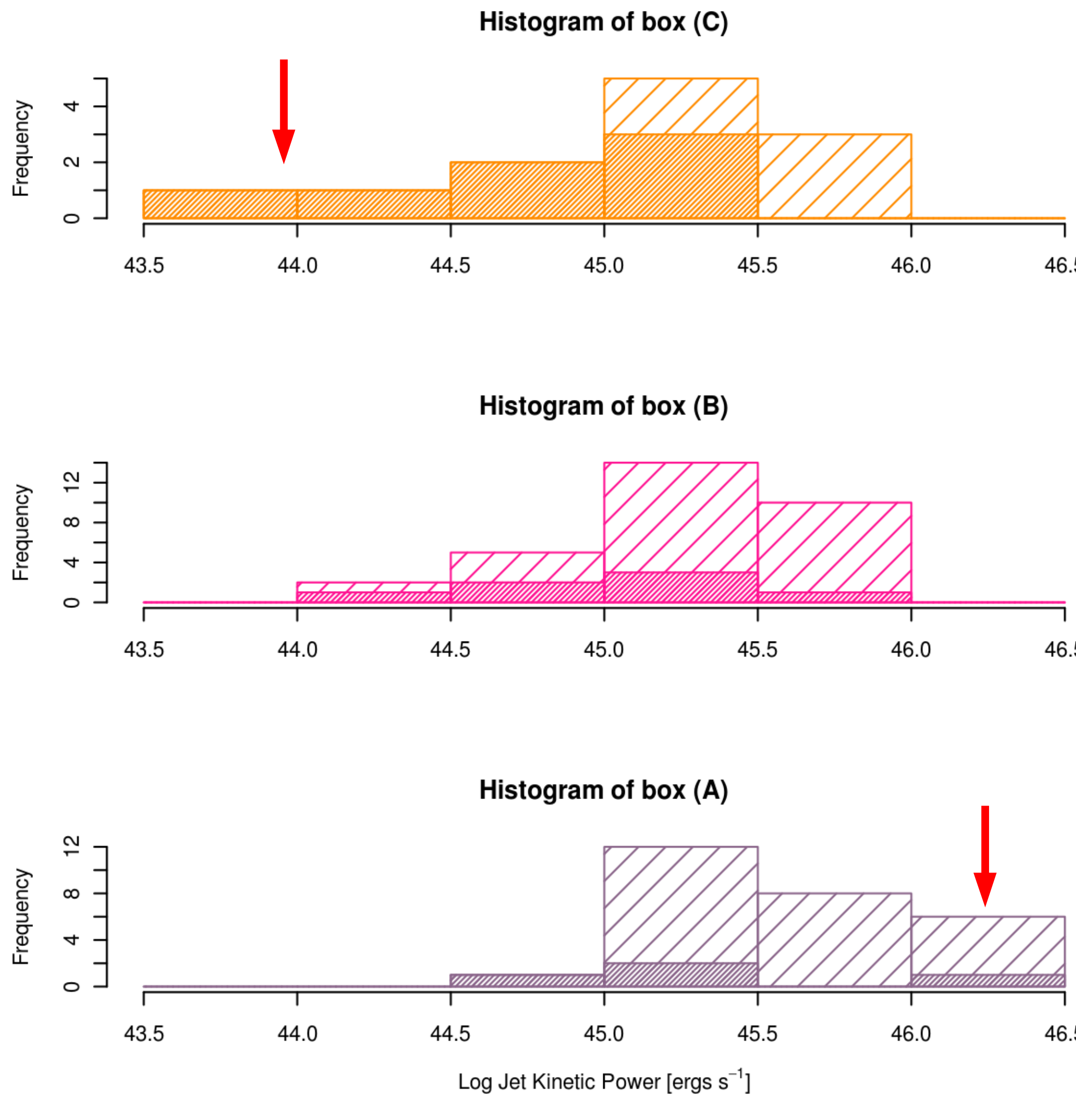
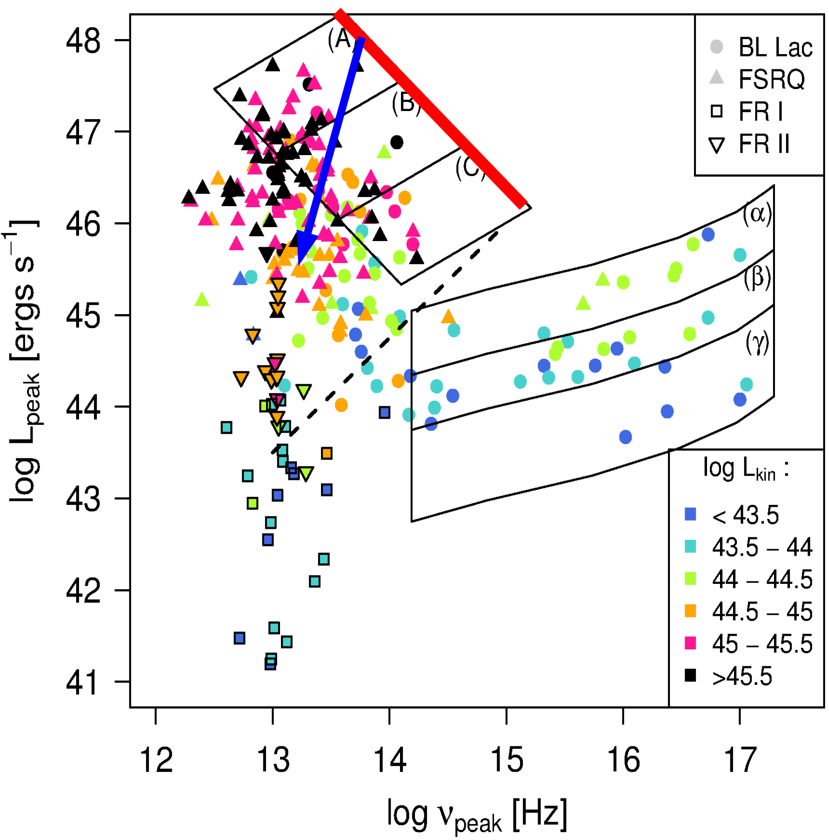
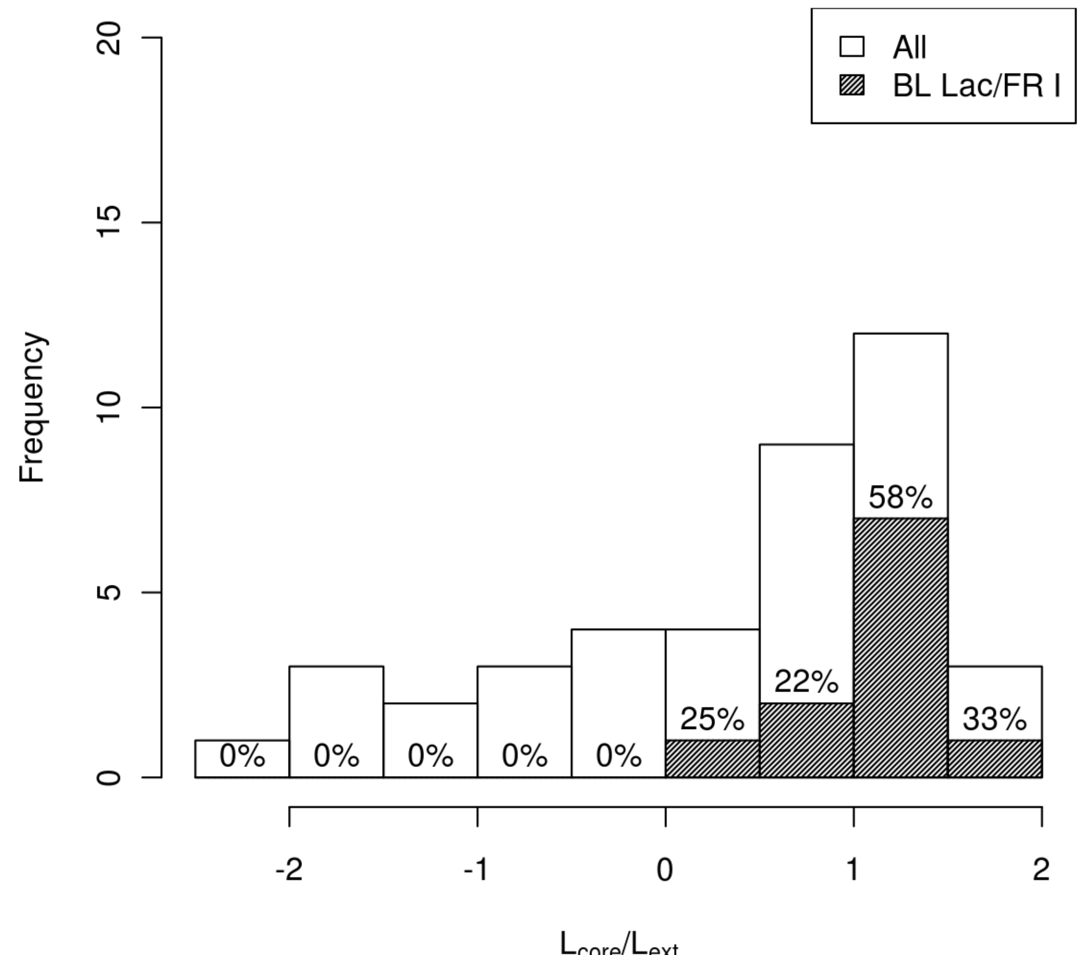
The Broken Power Sequence





About those BL Lacs...



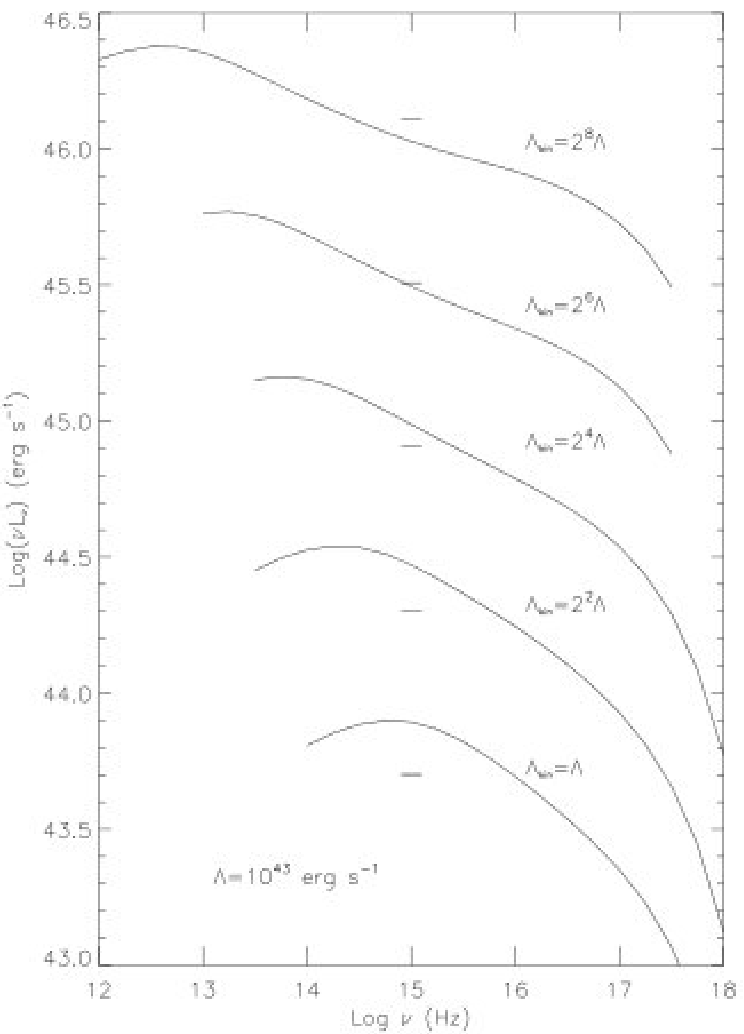


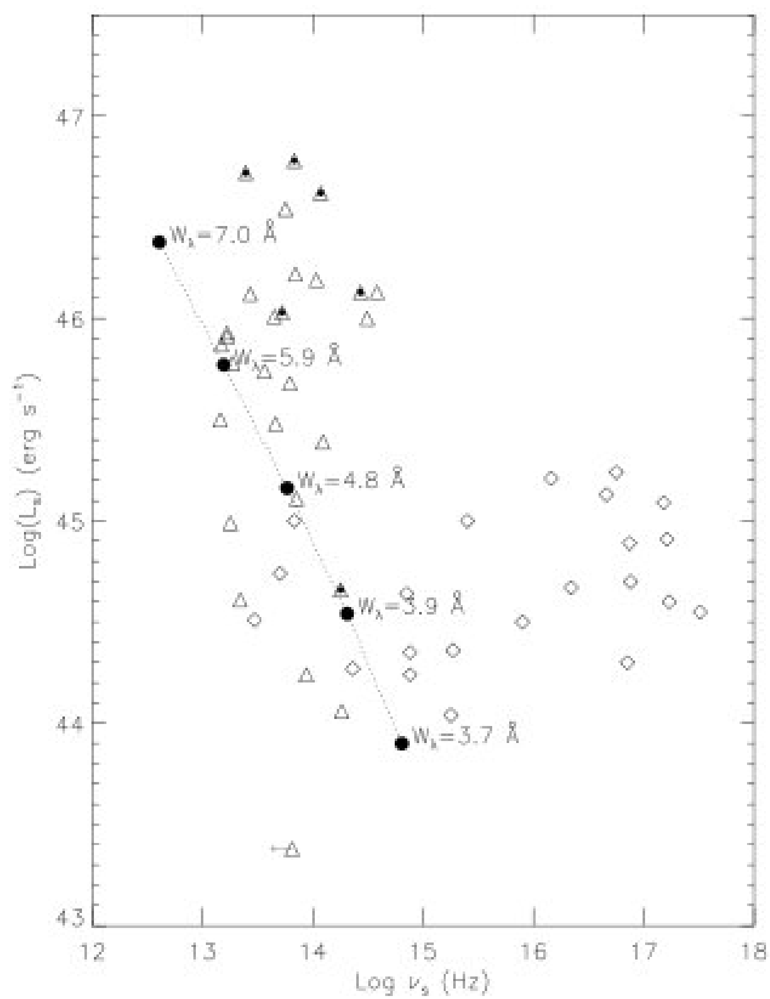
1:4 Δfrequency:ΔLuminosity

$\delta/\delta_0 = \nu_{peak}/\nu_0$

Fermi/Jansky, Nov 2011

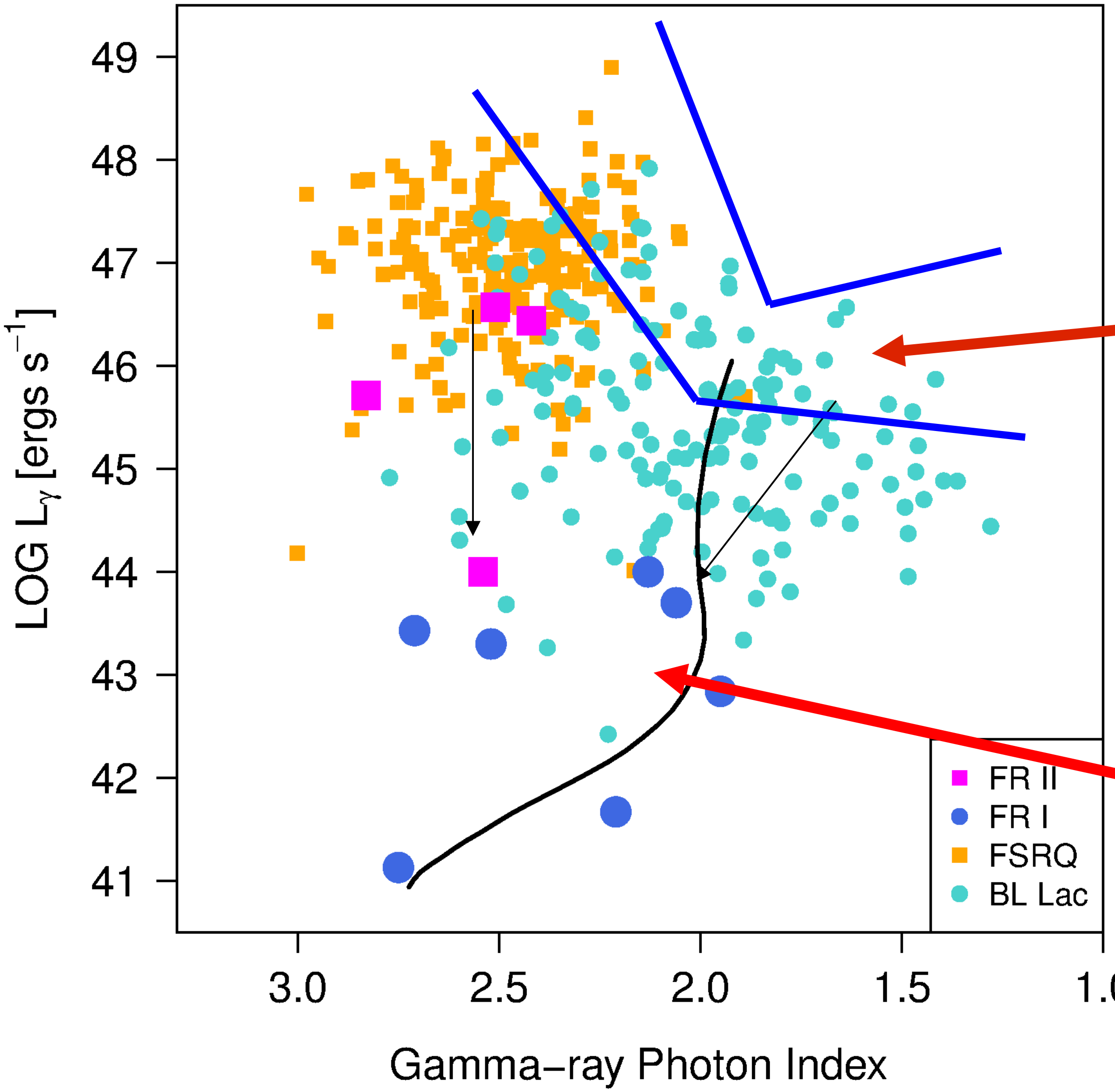
About those BL Lacs...





(Georganopoulos & Marscher 1998)

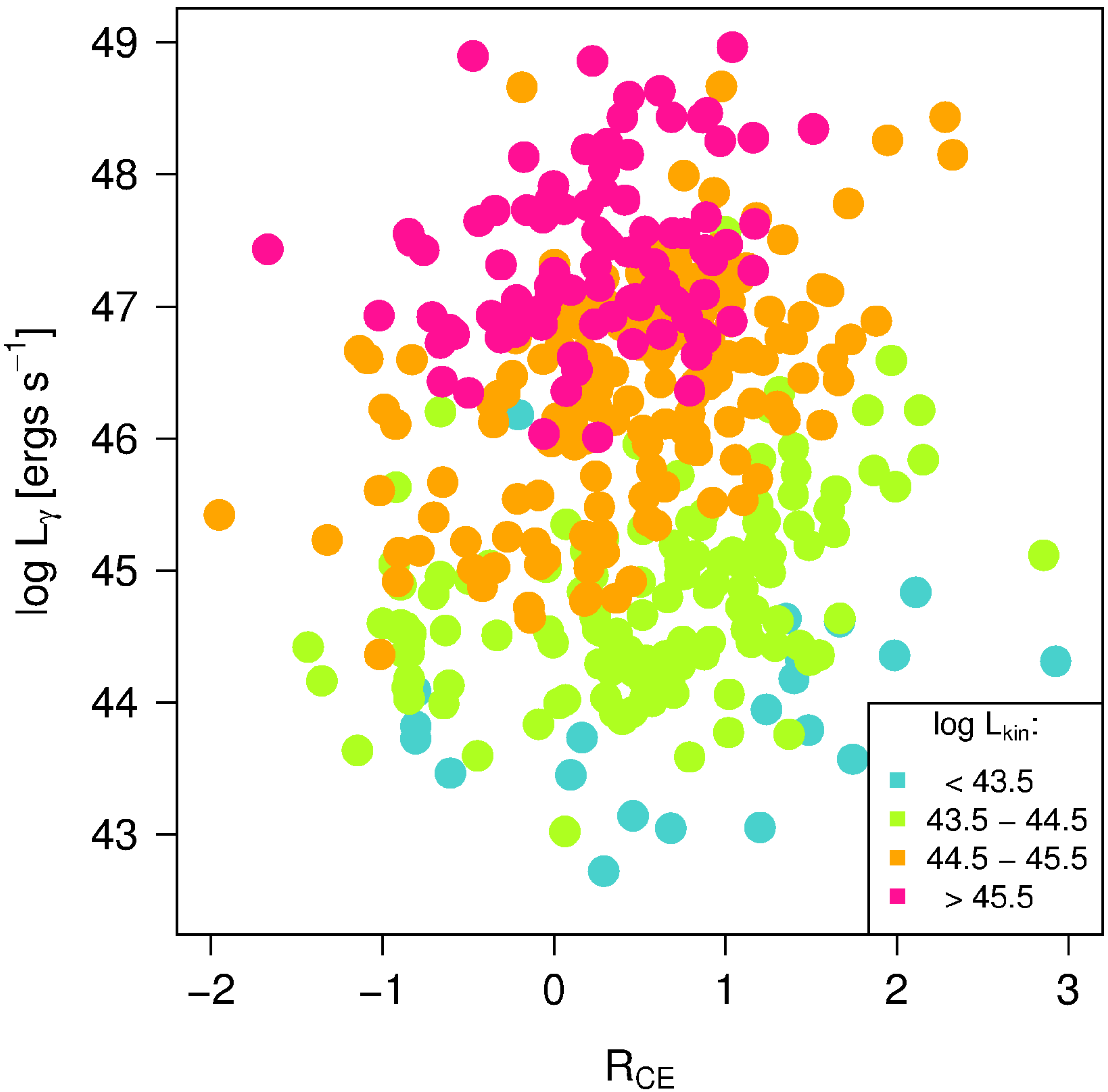
What can we learn from Fermi ?



Gamma-ray spectral index hardens as they drop in luminosity (just like synchrotron sequence)

Radio galaxies De-beamed luminosities

What can we learn from Fermi ?



SSC versus EC

SSC – upscatter synchrotron photons

-IC peak is a "copy" of synch

-beaming pattern is the same:

$L \sim \delta^{3+\alpha}$ synchrotron peak or IC peak

EC – upscatter photons from outside the jet (BLR, molecular torus, accretion disk?)

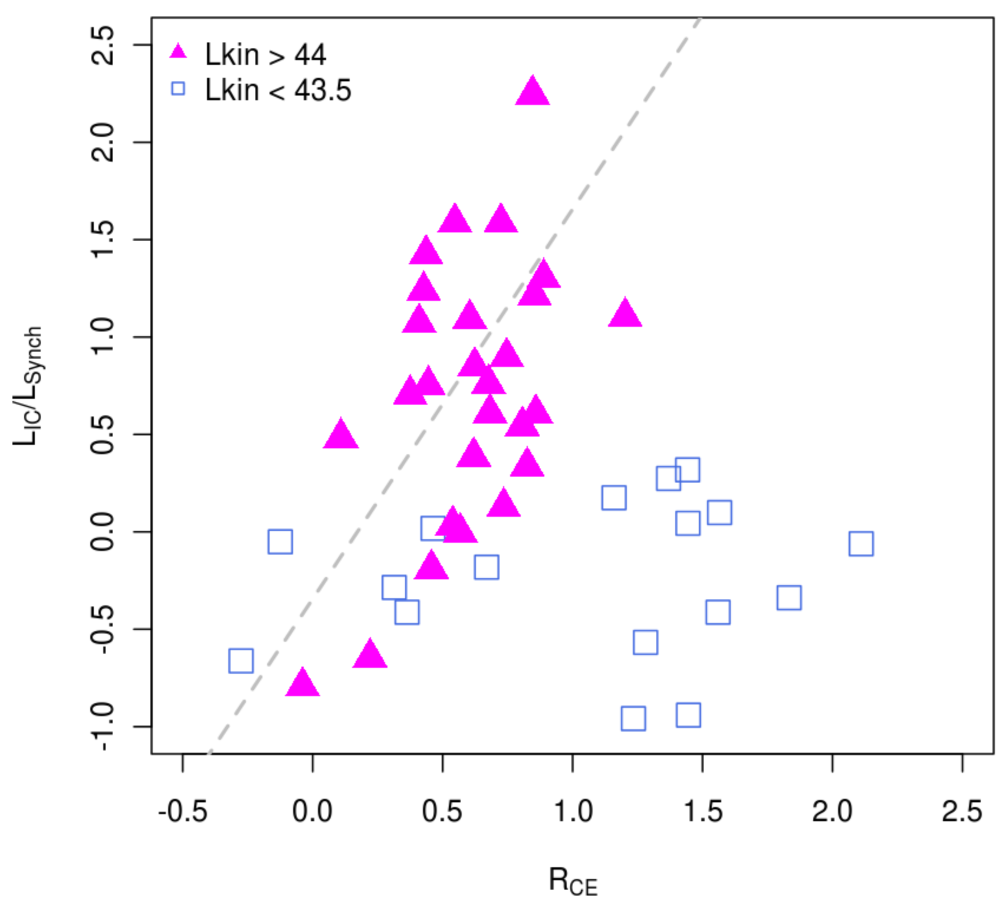
-beaming pattern is different:

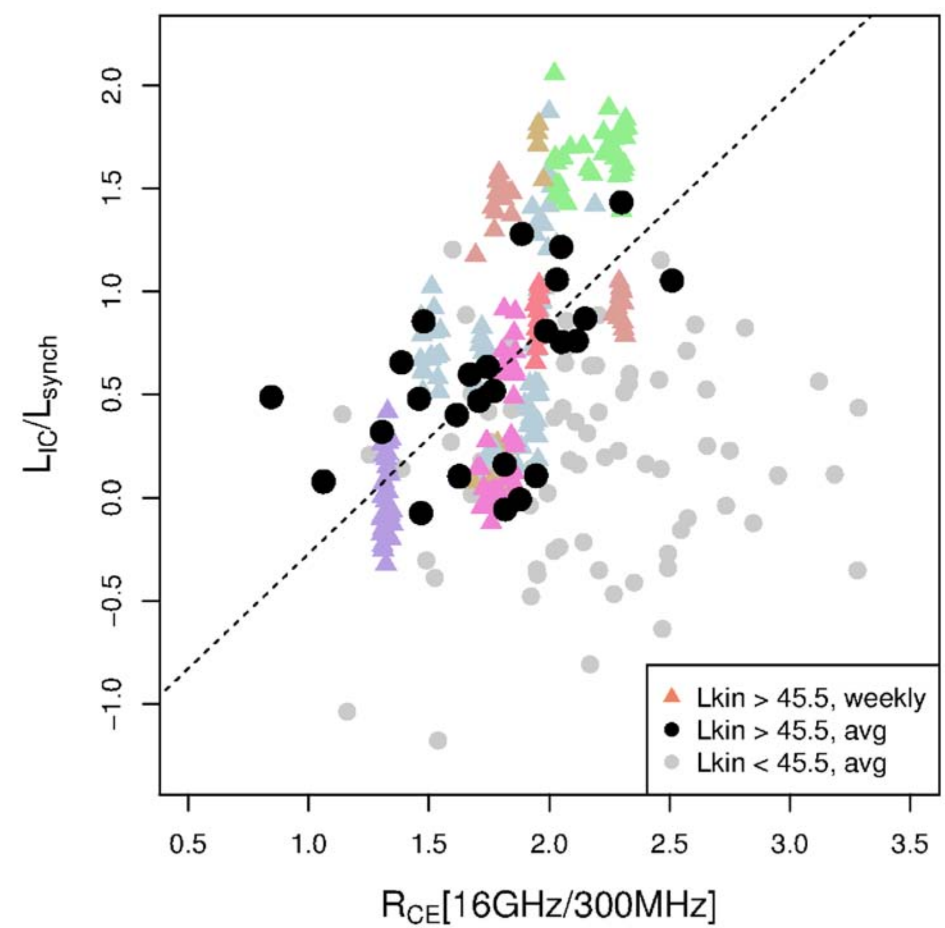
$L \sim \delta^{3+\alpha}$ synchrotron peak

$L \sim \delta^{5+\alpha}$ IC peak

(For radio, $L_{core}/L_{ext} \sim L \sim \delta^{3+\alpha}$, $\alpha \sim 0.2$)

EC in powerful jets?





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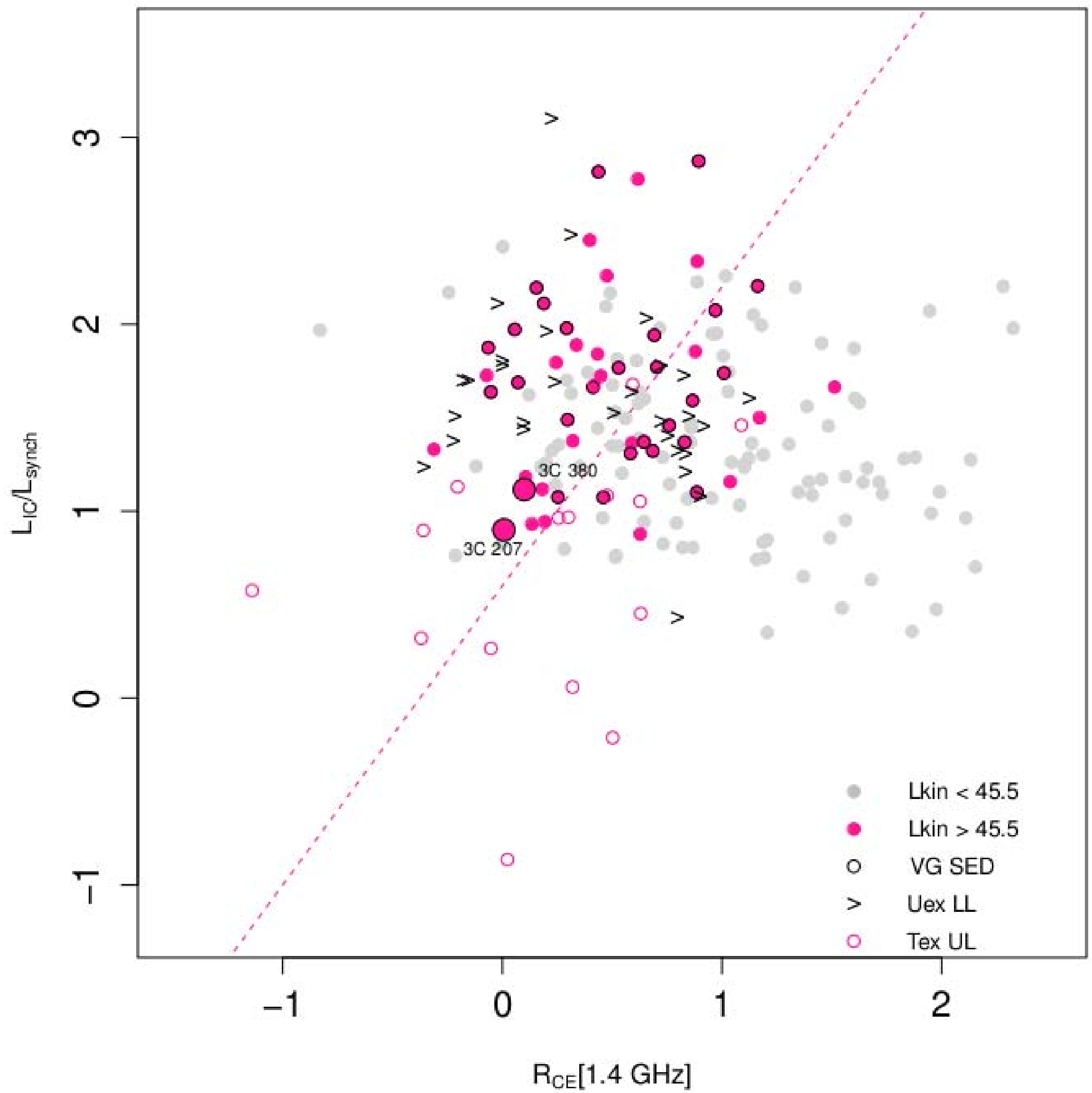
EC in powerful jets?



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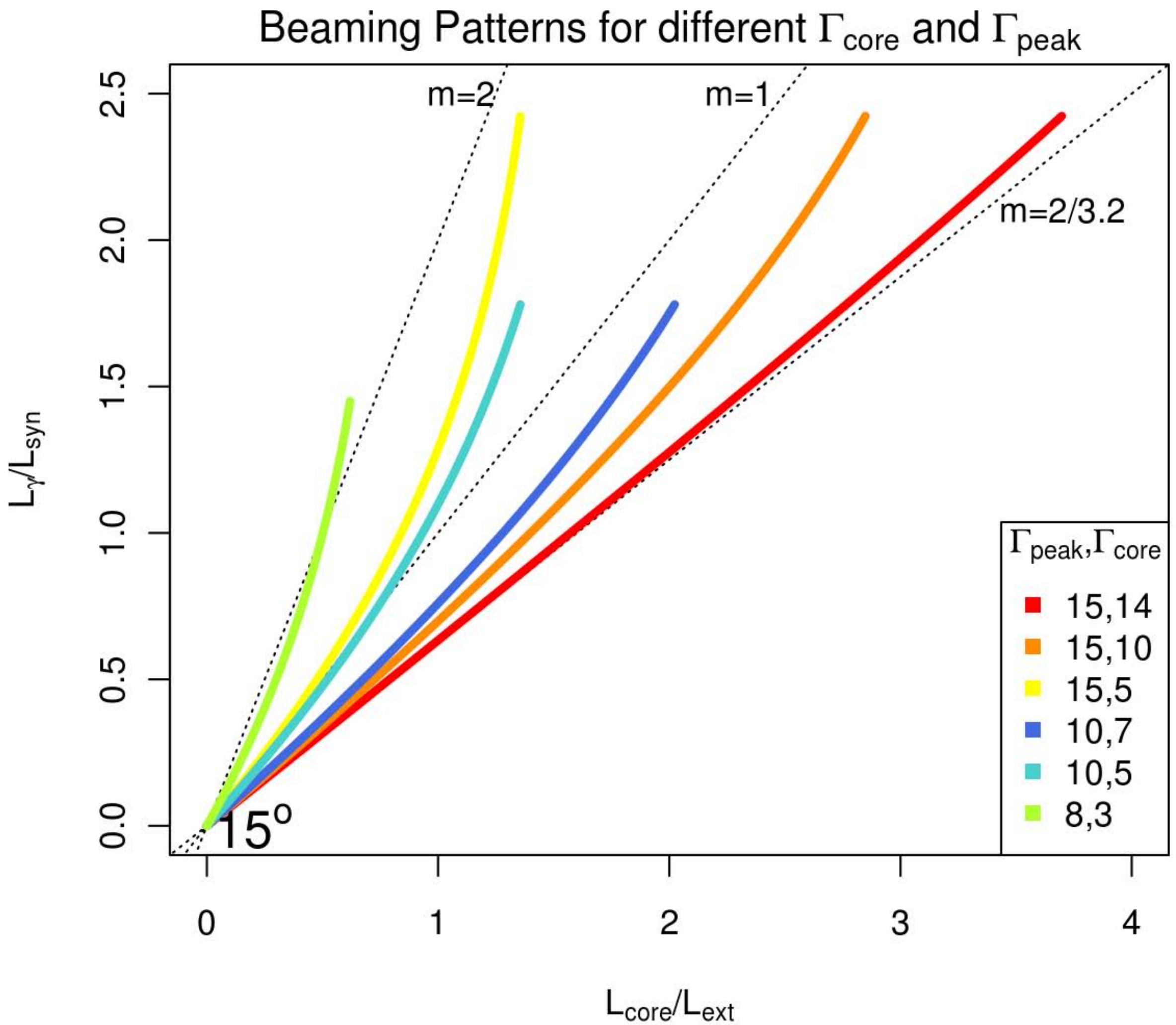
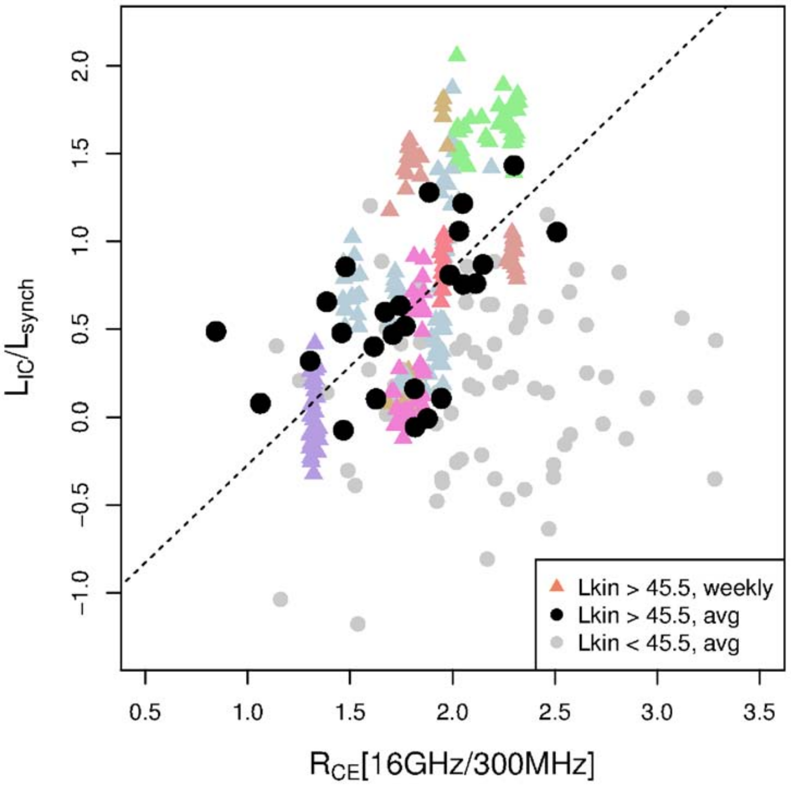
EC versus SSC





Conclusions/Key Observations

From the Blazar (synchrotron) Envelope:

+ No High-Luminosity, High-Peak sources
+ Suggestion of Two populations: “weak” / “strong”
+ Jet Power important, but not fundamental: spin, M_{BH}, or accretion rate?
+ ISP sources are a key diagnostic population
+ spectral types are not clearly associated with a pop., this may be explained as jets overtaking lines
+ no high-synchrotron-peak radio galaxies

New Orientation Scheme:

+ Observations consistent with a change in accretion mode at a critical rate of ~ 10^{-2} Eddington mass rate, *linked to a divide in jet SED characteristics.*
+ The sequence remains in 'broken' form, power increasing along the theoretically predicted line

From new Fermi analysis

Next Steps

- Complete the high-energy characterization of the IC spectra for the 3-year data set, with additional data from TeV, X-ray
- Expand the sample to include NLSy1
- Look at VLBI data: jet speeds, morphologies
- Expand the sample (small)
- Apply to evolution studies, EGRB

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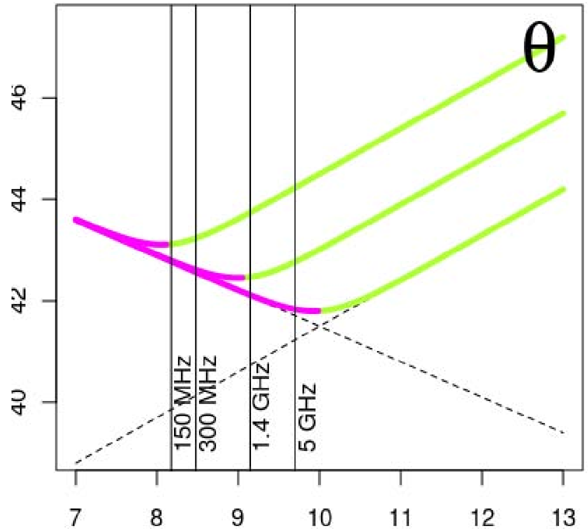
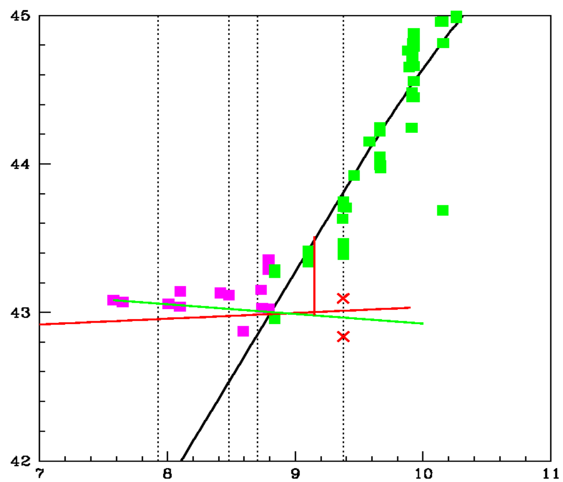
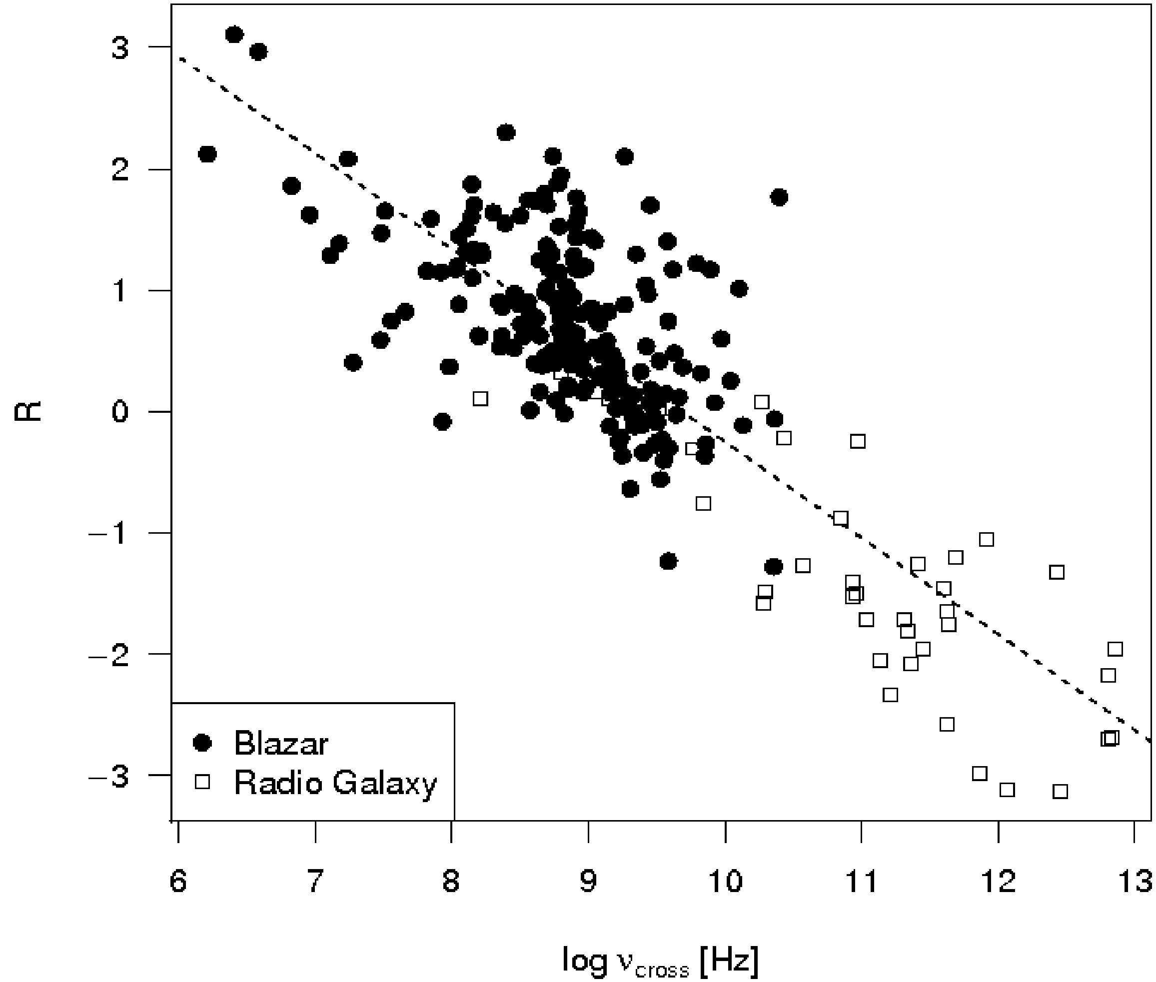
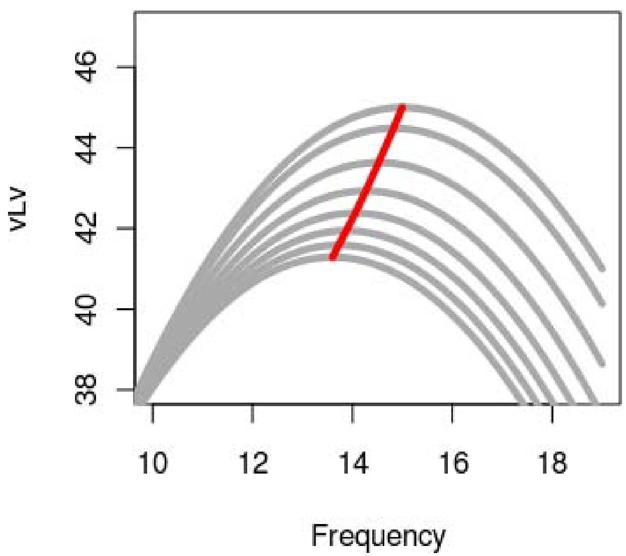
Measuring the Power of Relativistic Jets

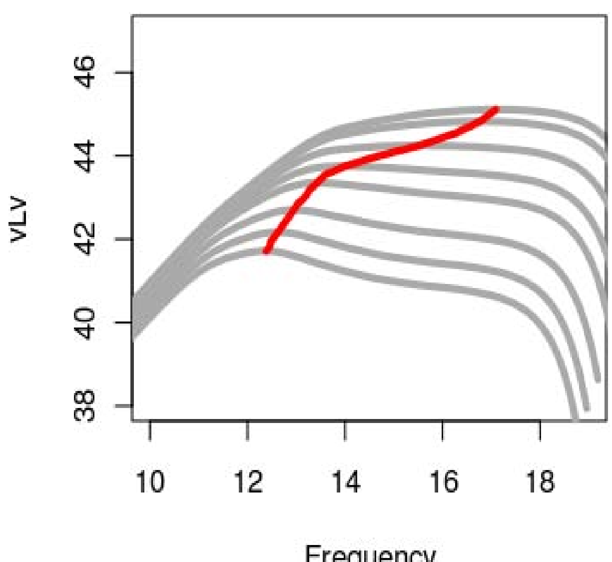


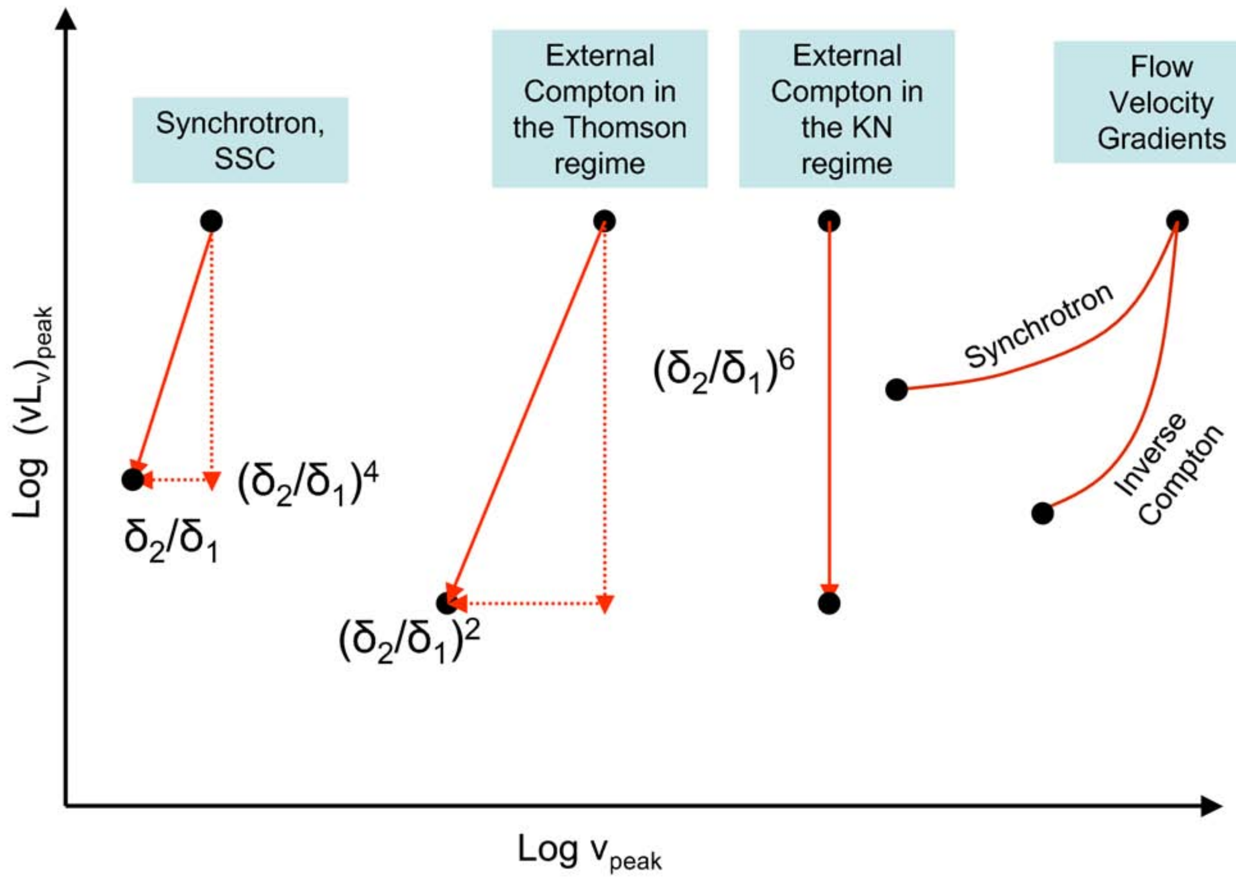




How does Beaming affect the SED?

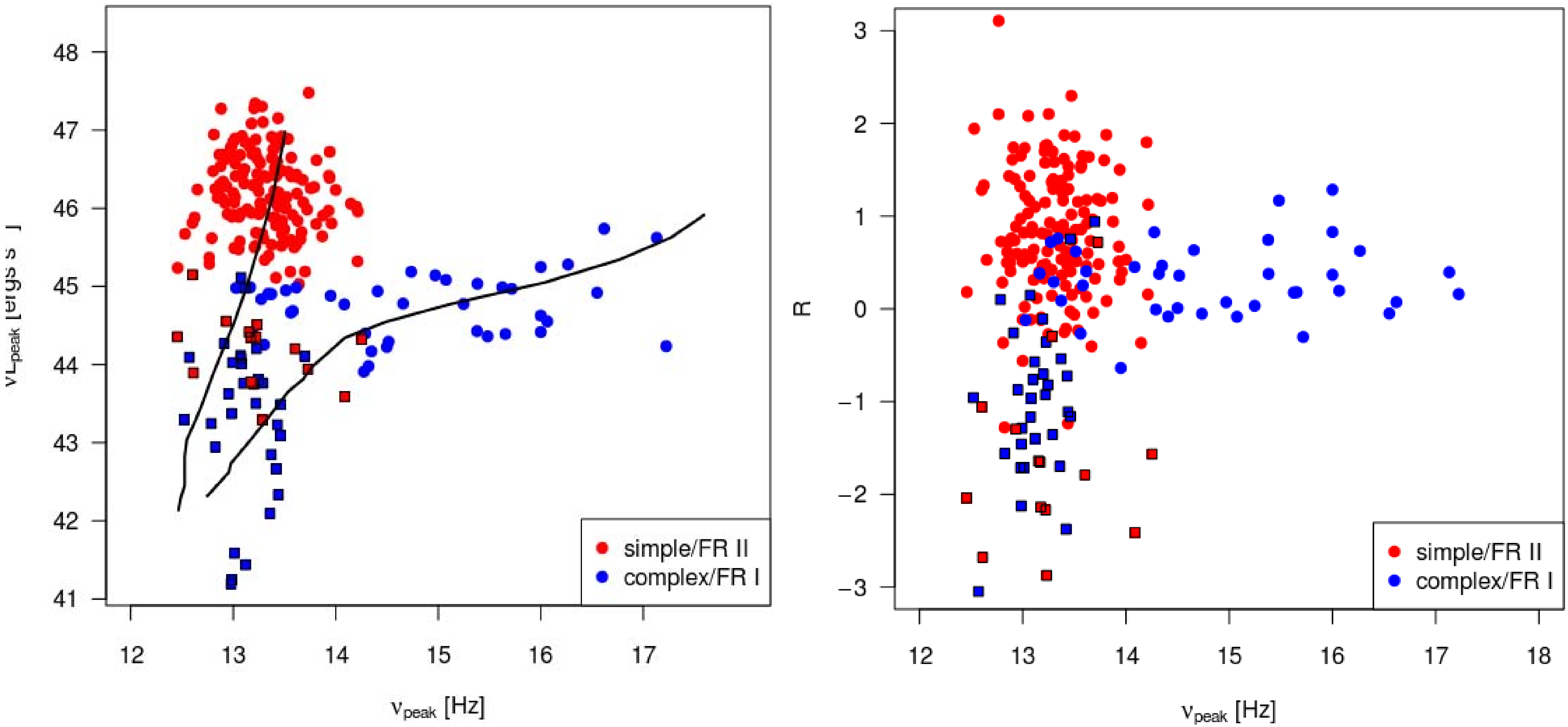






$\partial = \Gamma^{-1}(1 - \beta\cos\theta)^{-1}$ $\Gamma = 5 - 50$

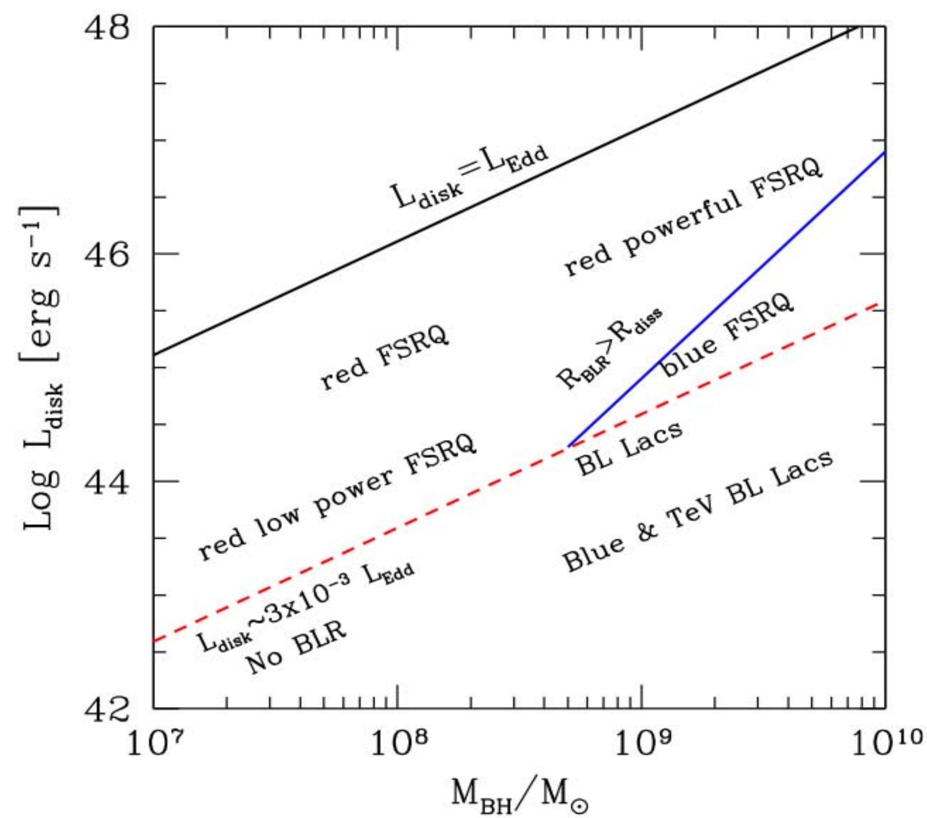
$L \sim L_\theta \partial^p$

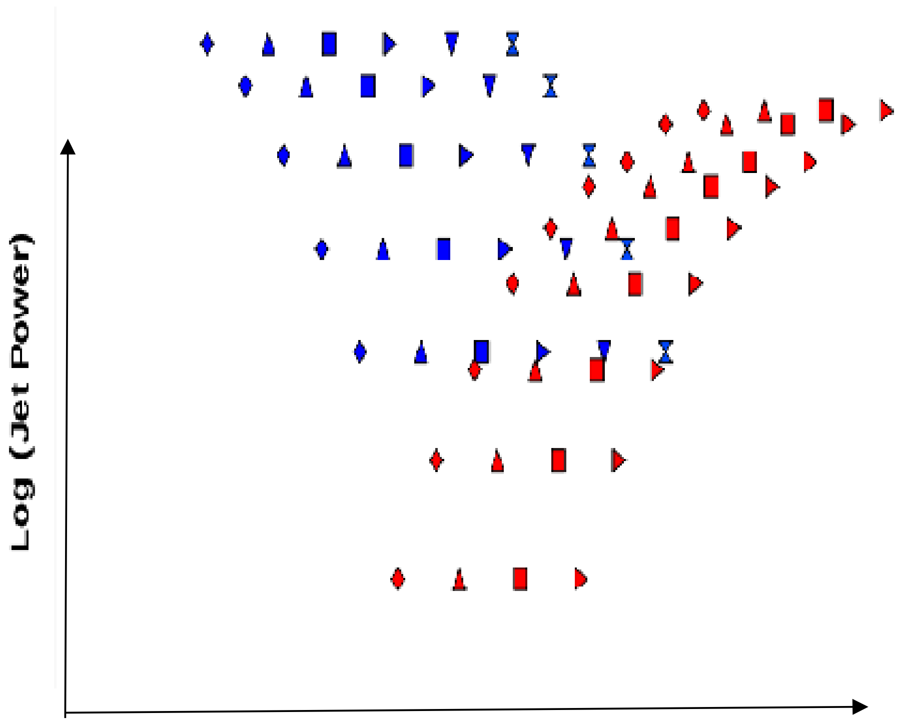


Simple/Complex are co-spatial as radio galaxies
As a theoretical source is aligned:
+ fast component of complex jets is revealed →
dramatically higher peak frequencies
+ simple jets follow 1:4 rule

Are two populations expected?

The updated theoretical sequence (Ghisellini 2008) predicts blue quasars, low power FSRQ, but is still a continuous sequence →





← Alternative: Spin Paradigm

Rapidly retrograde-spinning black holes able to extract more energy, forming powerful FR II, spin down to moderately powerful FR I (Garofalo 2010)

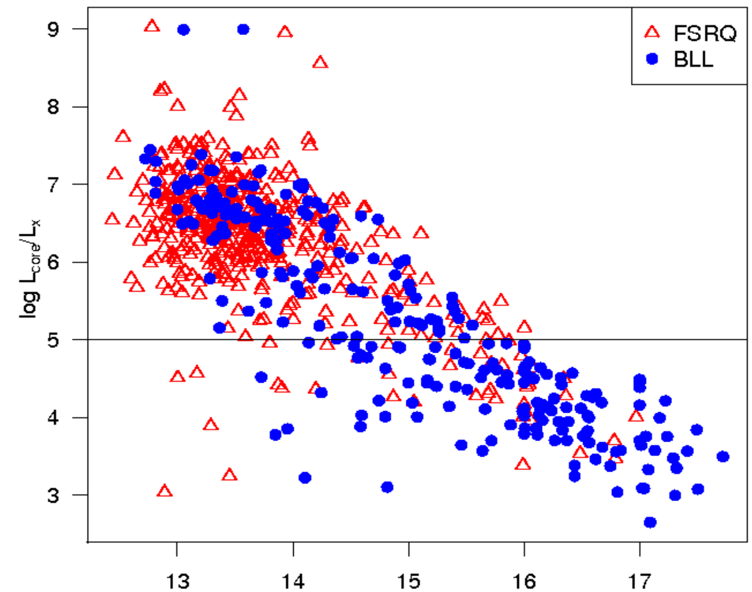
Verified Simple/Complex population divide would support the spin-based unification scheme

1. Fit the average synchrotron spectrum

All sources from every flux-limited blazar sample =~4000 candidates

NED + SIMBAD, literature search =~ 1700

Fitted with phenomenological SED,hand selection = 737 sources with accurate ν_{peak}, L_{peak}



CANNOT use simple ratios for determining peak