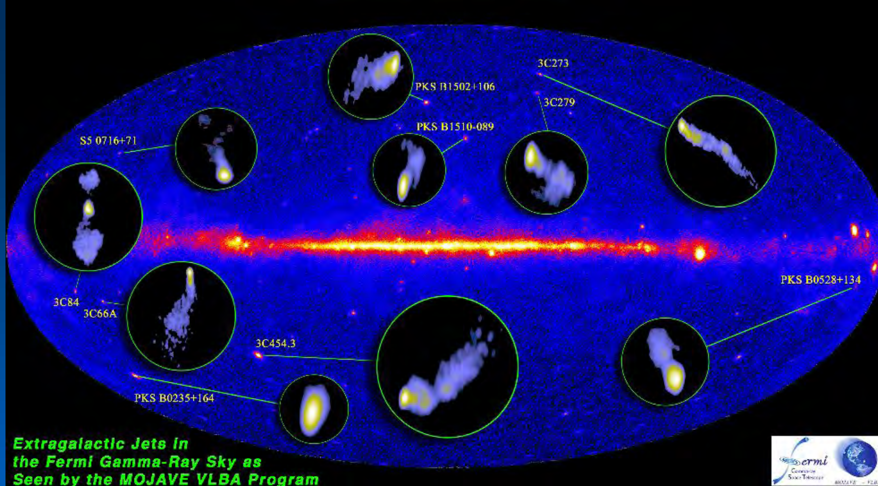

γ-Ray Loudness and the Parsec-Scale Jet Properties of a Complete Sample of Blazars From the MOJAVE Program

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Acknowledgements

Fermi-LAT collaboration

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- A. Pushkarev (Pulkovo, Russia)
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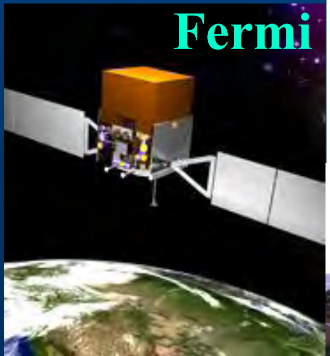
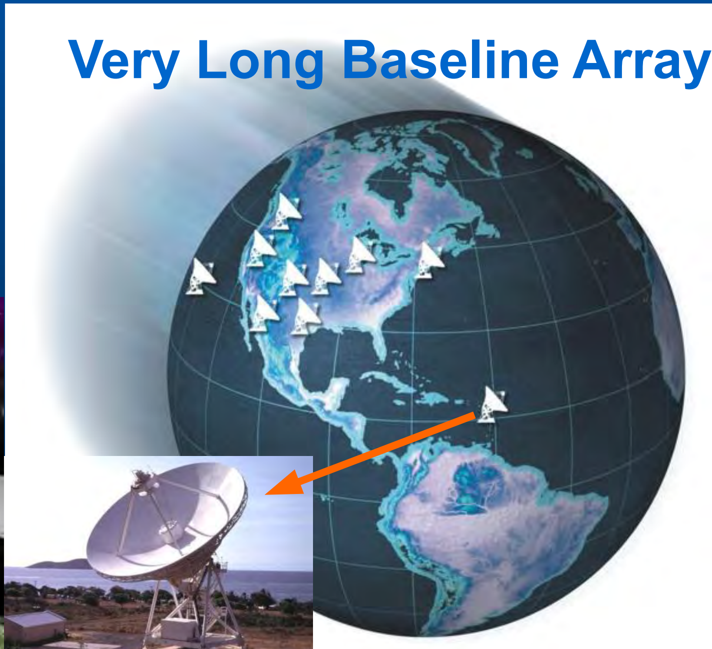
Monitoring
Of
Jets in
Active Galaxies with
VLBA
Experiments





Overview:

- **Selection effects are the bane of blazar studies**

- **Goals of this study (Lister et al. 2011 ApJ 742, 27) :**

  - **Assemble complete ɣ-ray & radio flux-limited AGN samples for study with the VLBA**

  - **Compare pc-scale radio jet and ɣ-ray emission properties**

  - **What can we learn about beaming in different regimes and in different blazar classes?**

MOJAVE Bright AGN Sample

Complete for:

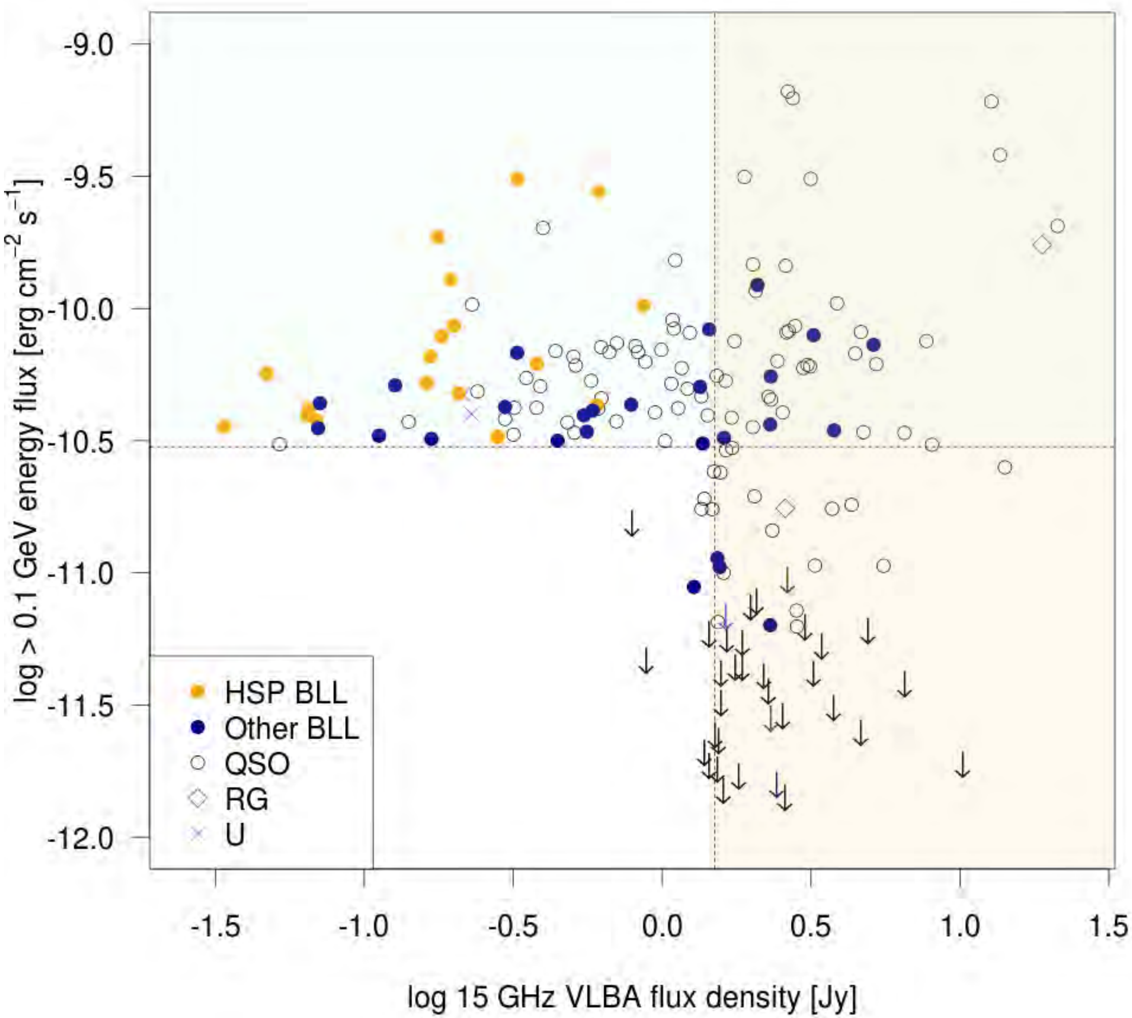
- dec. > -30º, |b| > 10º
- 1LAC >100 MeV energy flux above 3×10^{-11} erg s^{-1} cm^{-2}

OR

- 15 GHz VLBA flux density has exceeded 1.5 Jy at any time during 11month Fermi 1LAC period

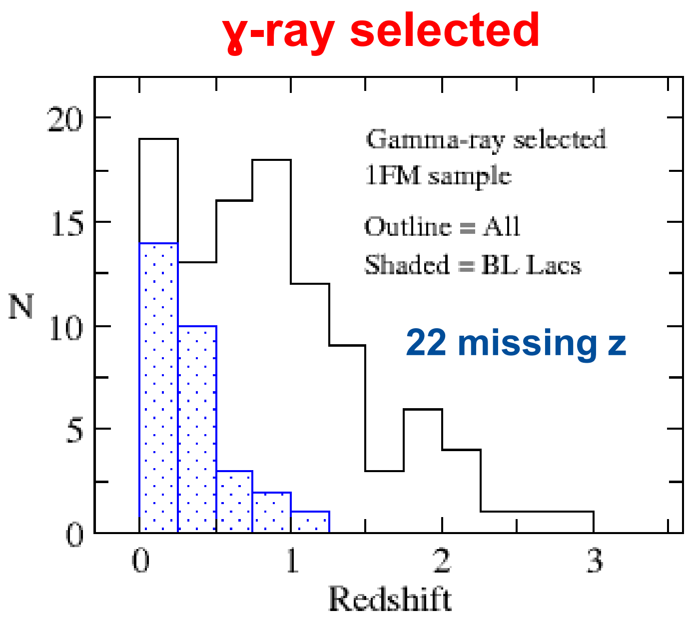
➢ Only one missing (unassociated) source: in top left corner region

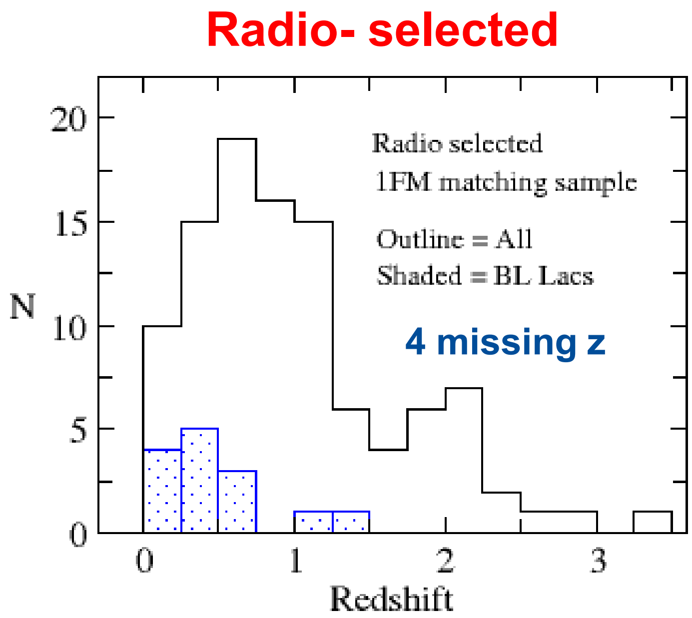
➢ 173 AGNs in total, 48 are both radio- and ɣ-ray selected (top right corner)



Lister et al. 2011, ApJ 742, 27

Redshift distributions



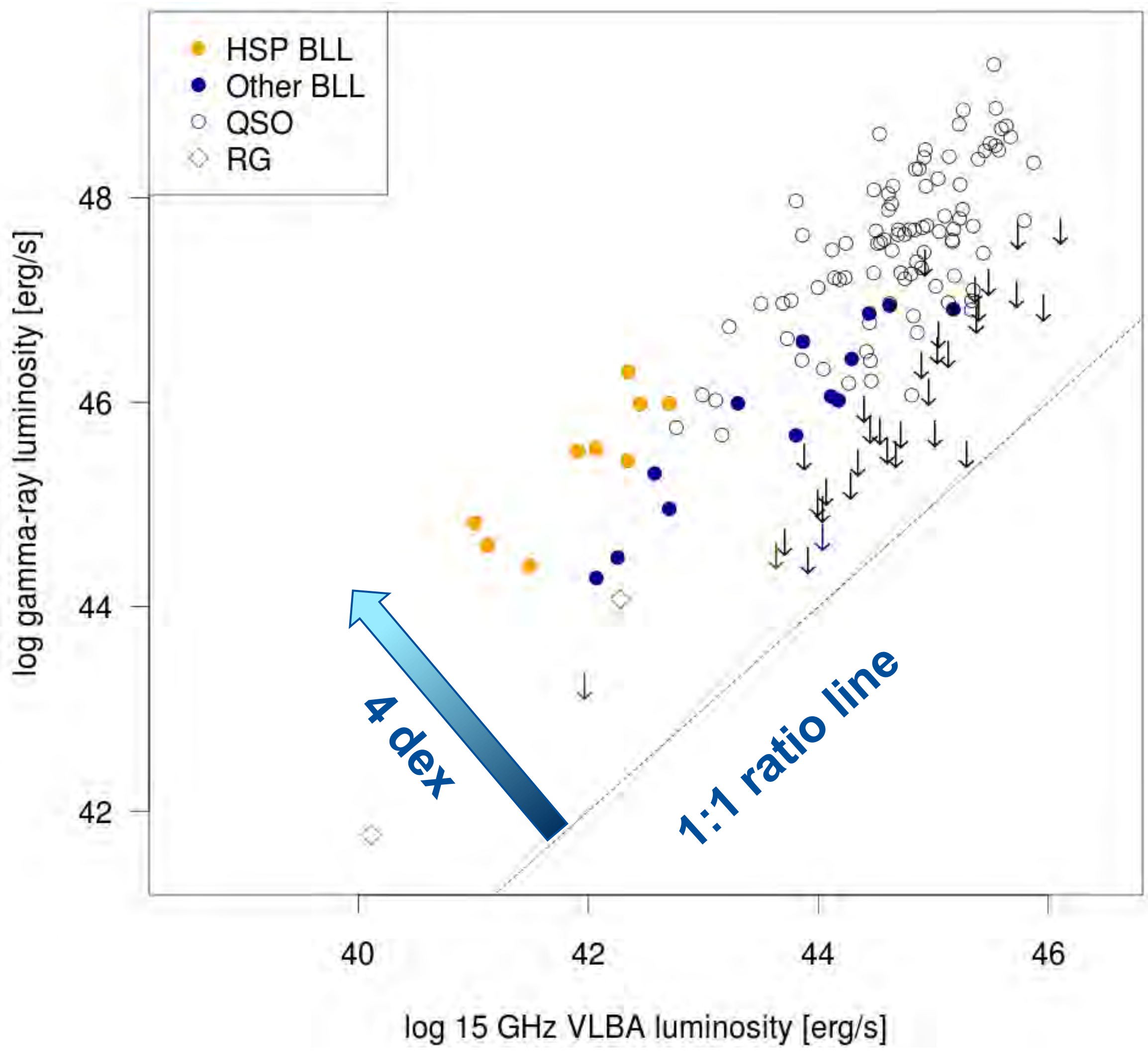


- **γ-ray selected blazars have an additional sub-population of low-redshift HSP BL Lacs that are intrinsically very bright in γ-rays**

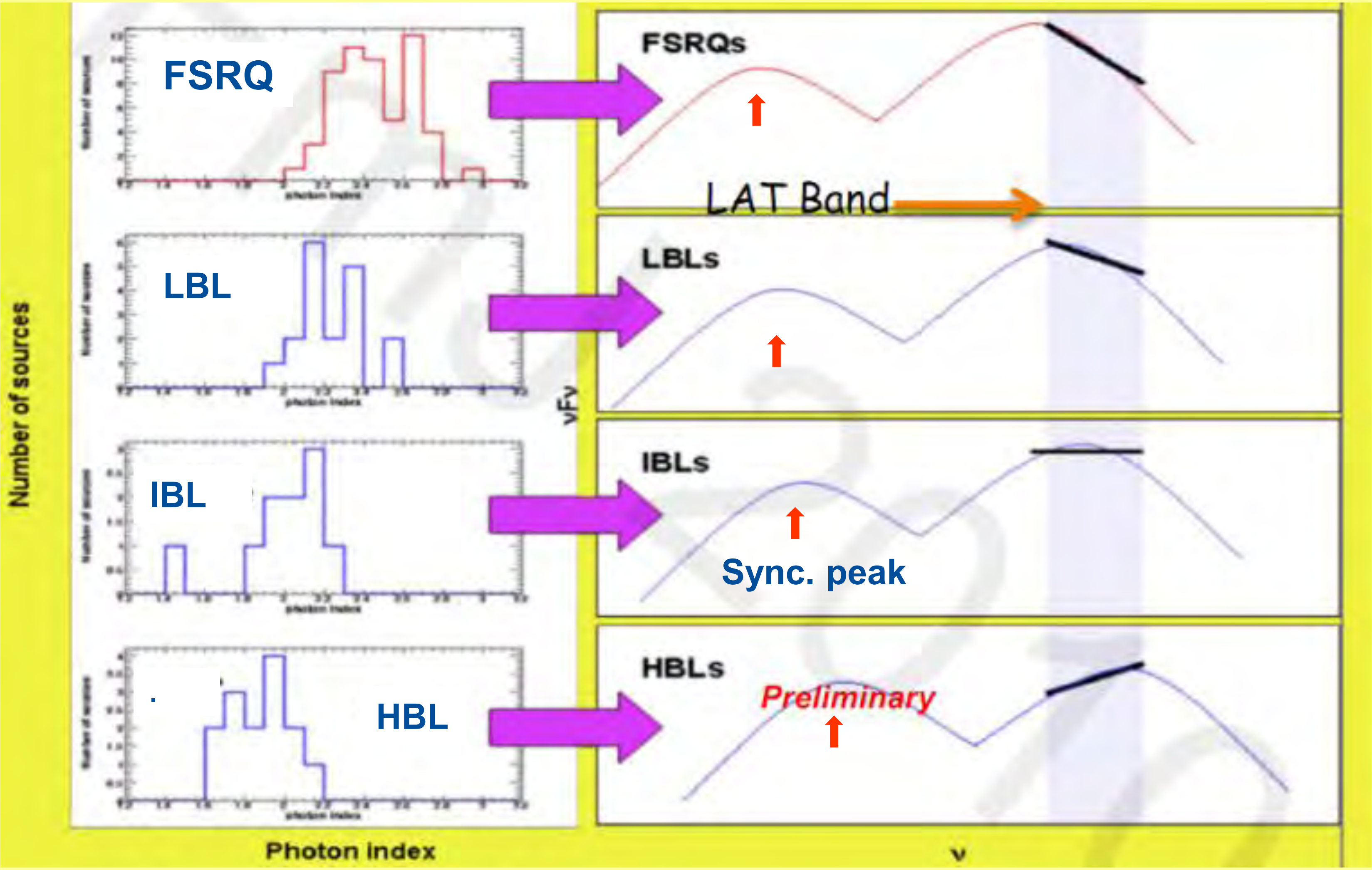
- **the brightest γ-ray and radio-selected quasars have similar redshift distributions.**

ɣ-ray Loudness

- **Define loudness as ratio of ɣ-ray to 15 GHZ VLBA radio luminosity**
- **Lowest luminosity BL Lacs (HSPs) all have high ɣ-ray loudness (due to SED peak location)**
- **LAT-non-detected AGNs all have low ɣ-ray loudness due to sample selection bias (omits radio-weak--ɣ-ray weak sources)**



Synchrotron peak: a key blazar parameter

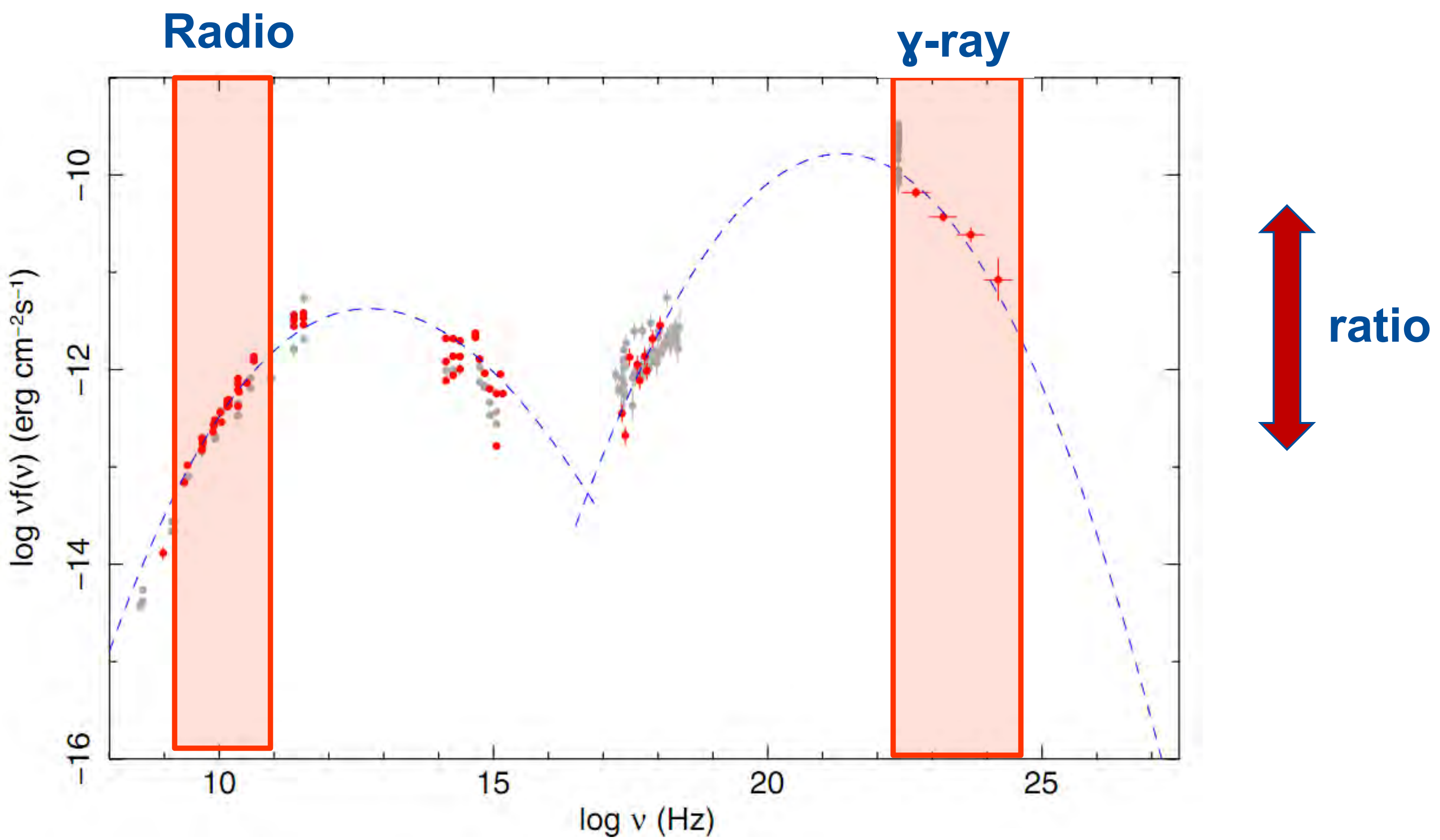


No HSP FSRQs discovered yet

Slide from Gino Tosti; FMJ 2010

γ-ray loudness and the Sync. peak

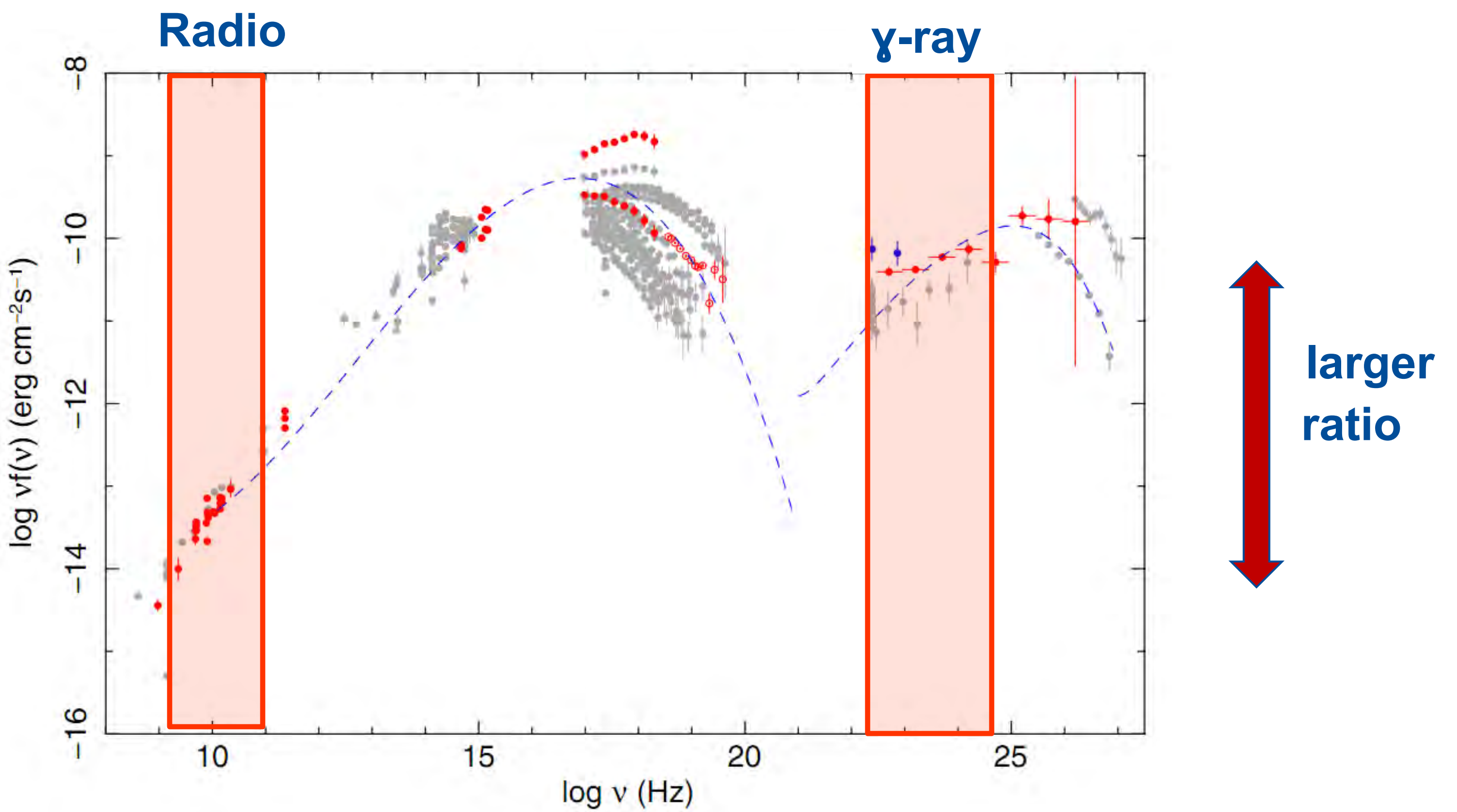
- **0528+134: Low-spectral peaked FSRQ at z=2**
- **Moderate apparent γ-ray to radio luminosity ratio**



Abdo et al. 2010, ApJ 716, 30

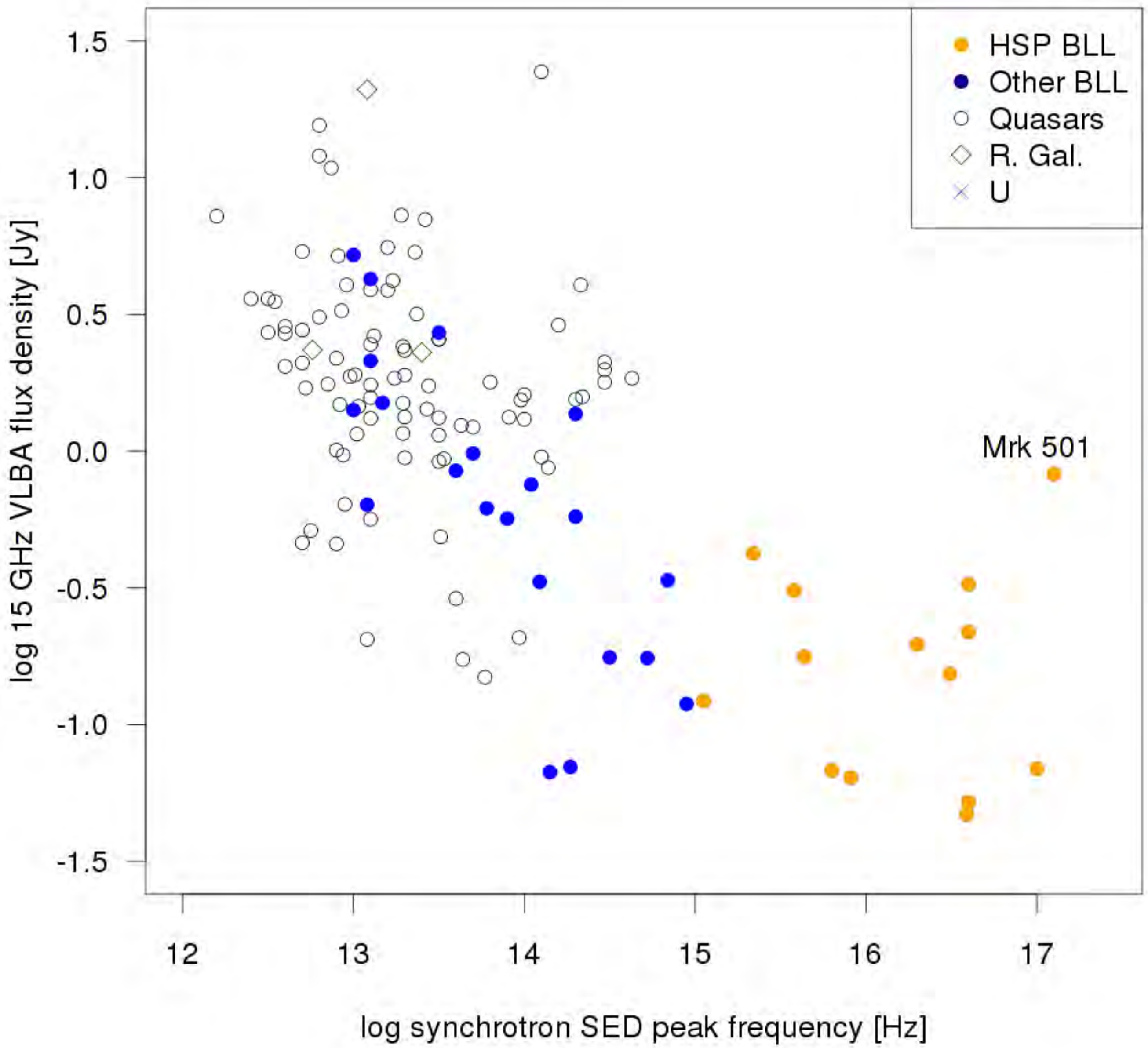
ɣ-ray loudness and the Sync. peak

- **Mk 421: High-spectral peaked BL at z = 0.033**
- **Larger apparent ɣ-ray to radio luminosity ratio**

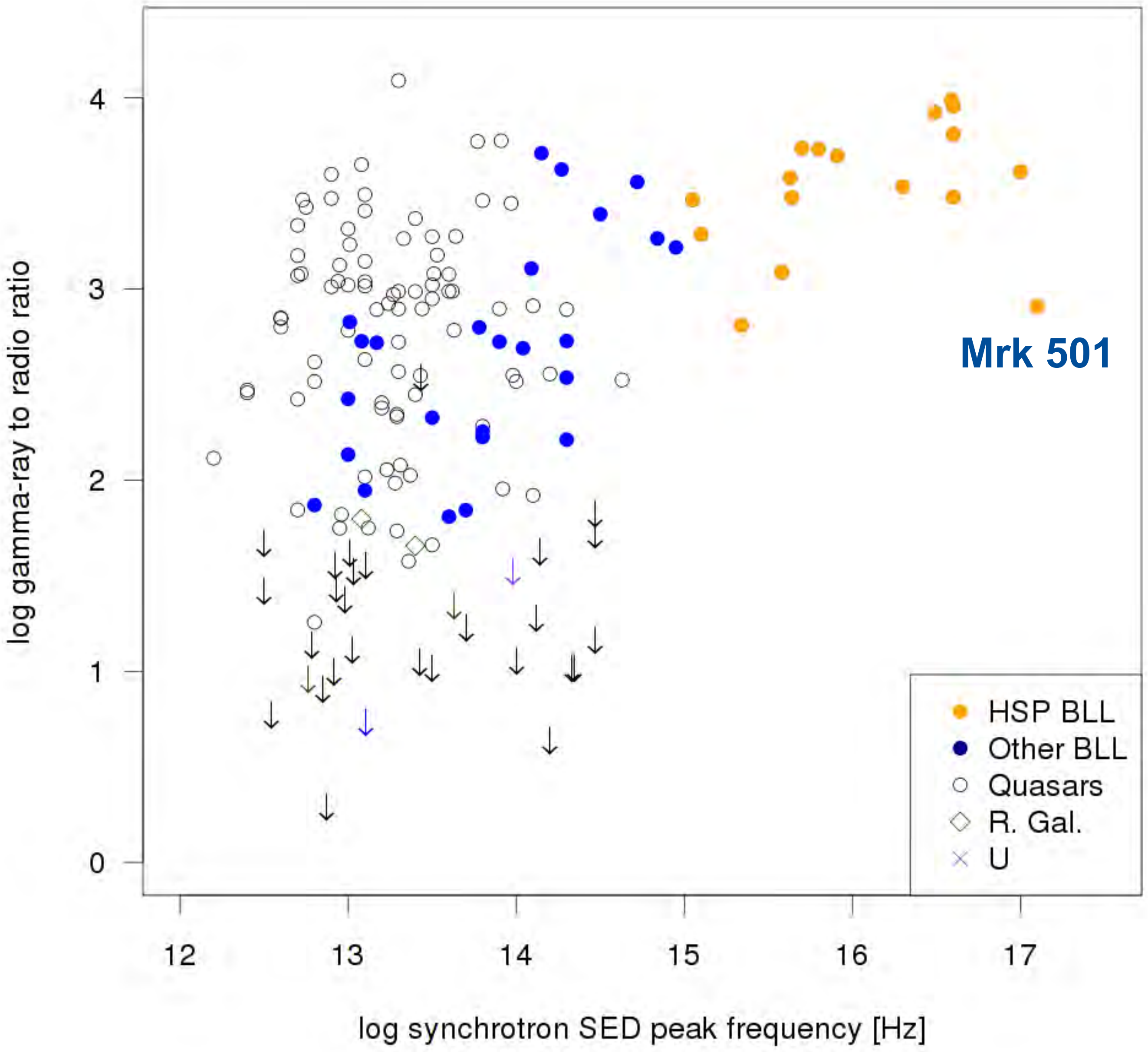


Abdo et al. 2010, ApJ 716, 30

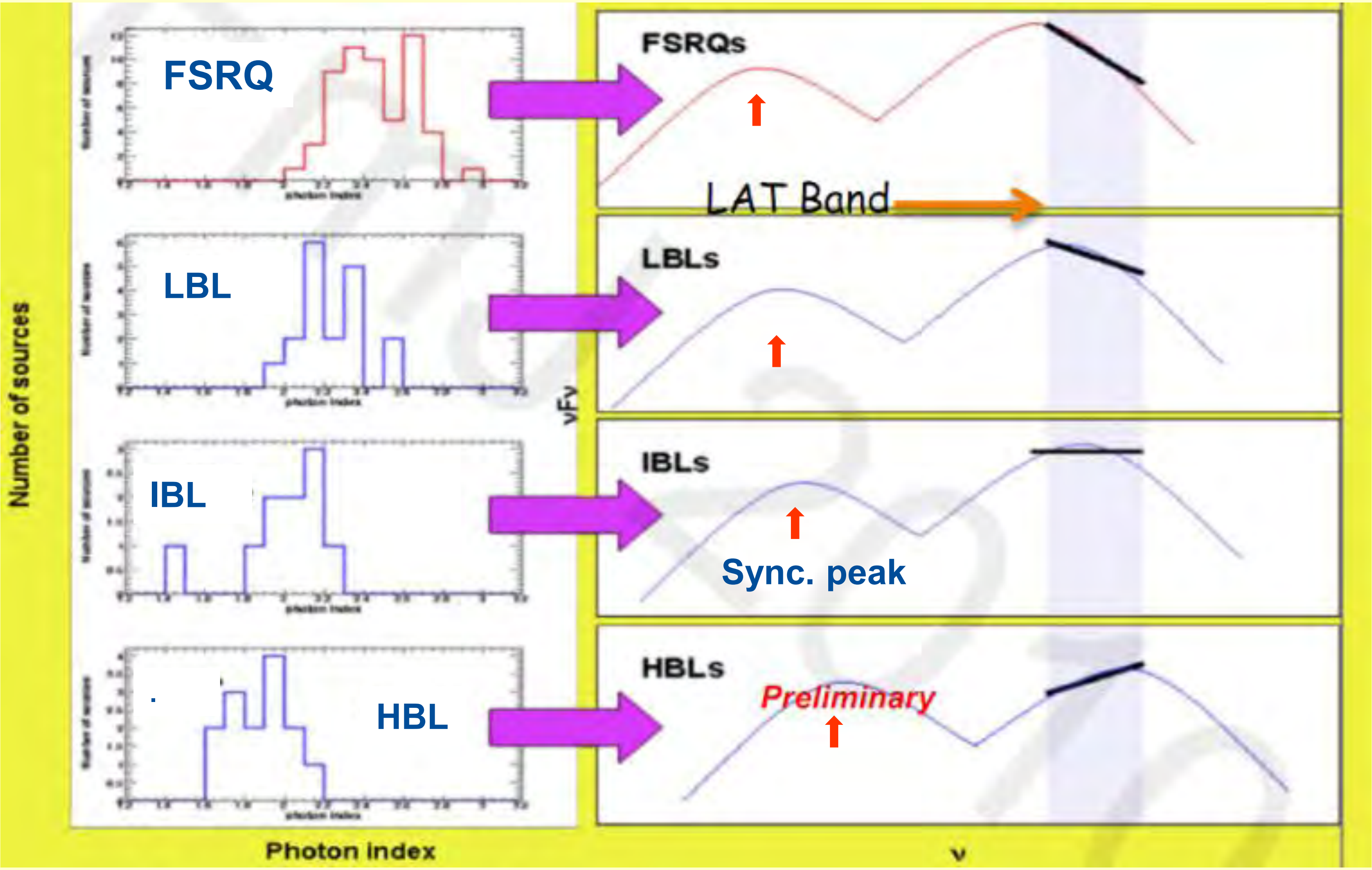
Pc-scale radio flux drops with increasing ν_{peak} for BL Lacs



ɣ-ray loudness increases with ν_{peak} for BL Lacs

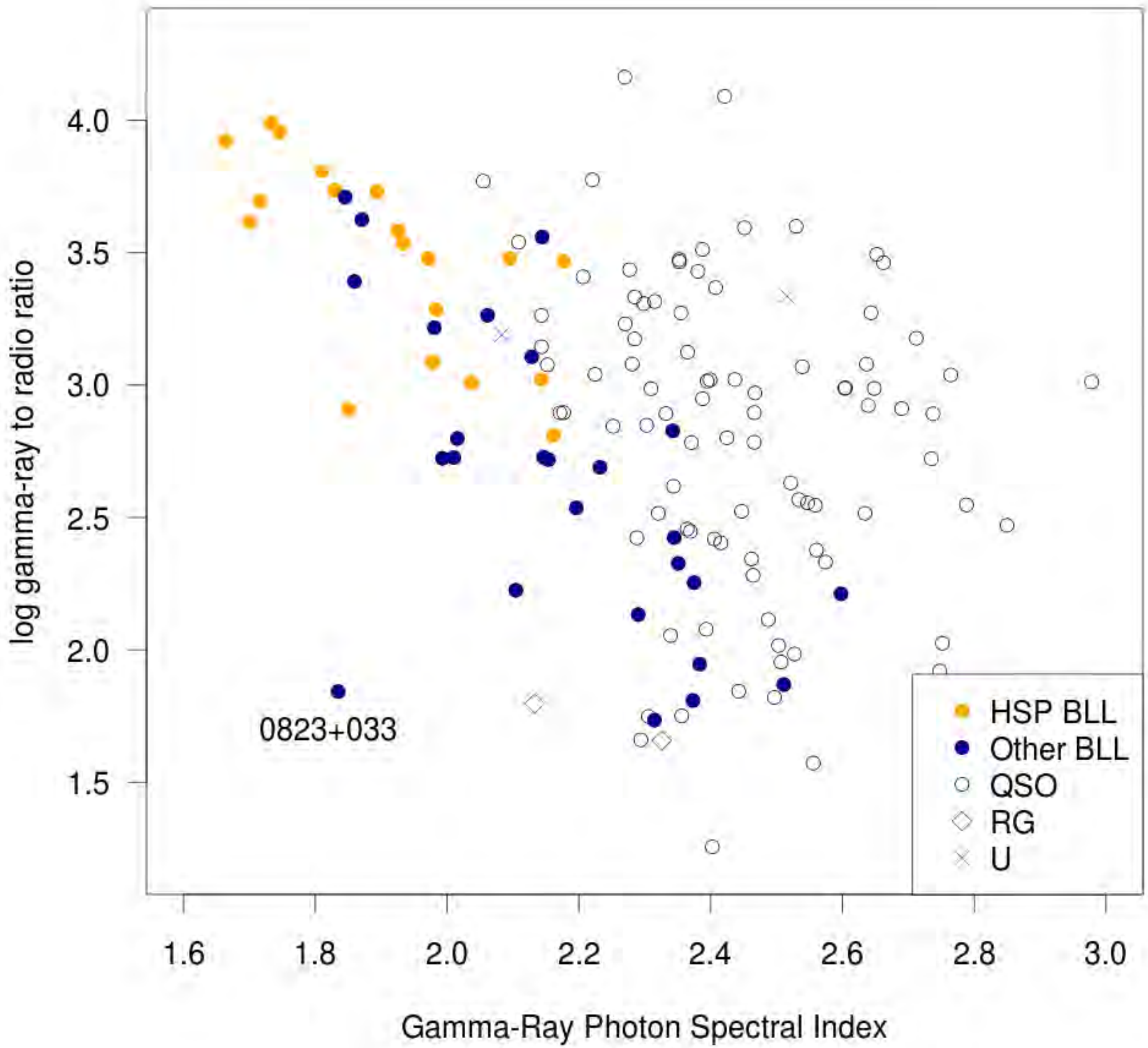


Synchrotron peak: a key blazar parameter



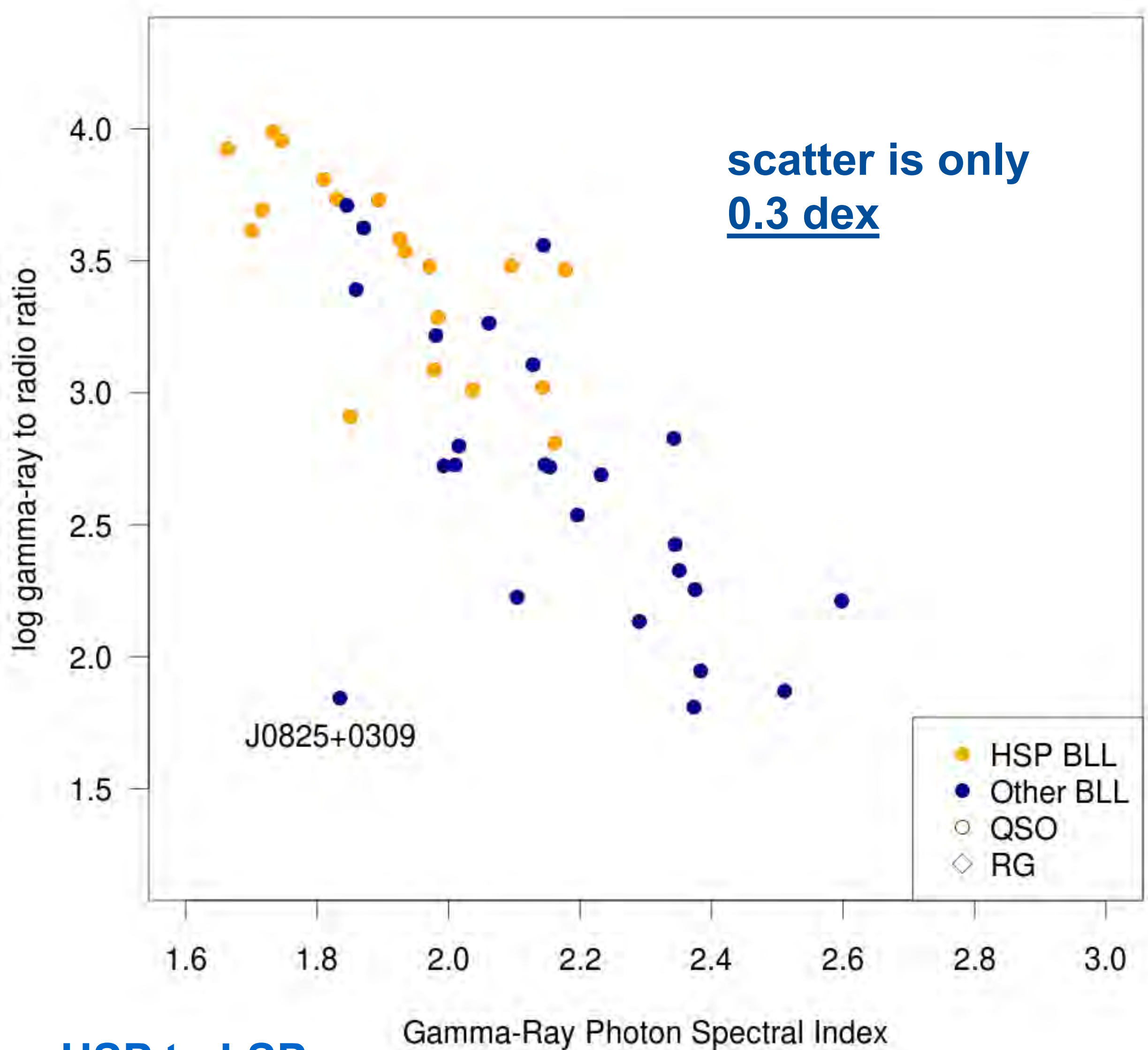
Slide from Gino Tosti; FMJ 2010

γ-ray loudness versus γ-ray hardness



ɣ-ray loudness versus ɣ-ray hardness (BLL only)

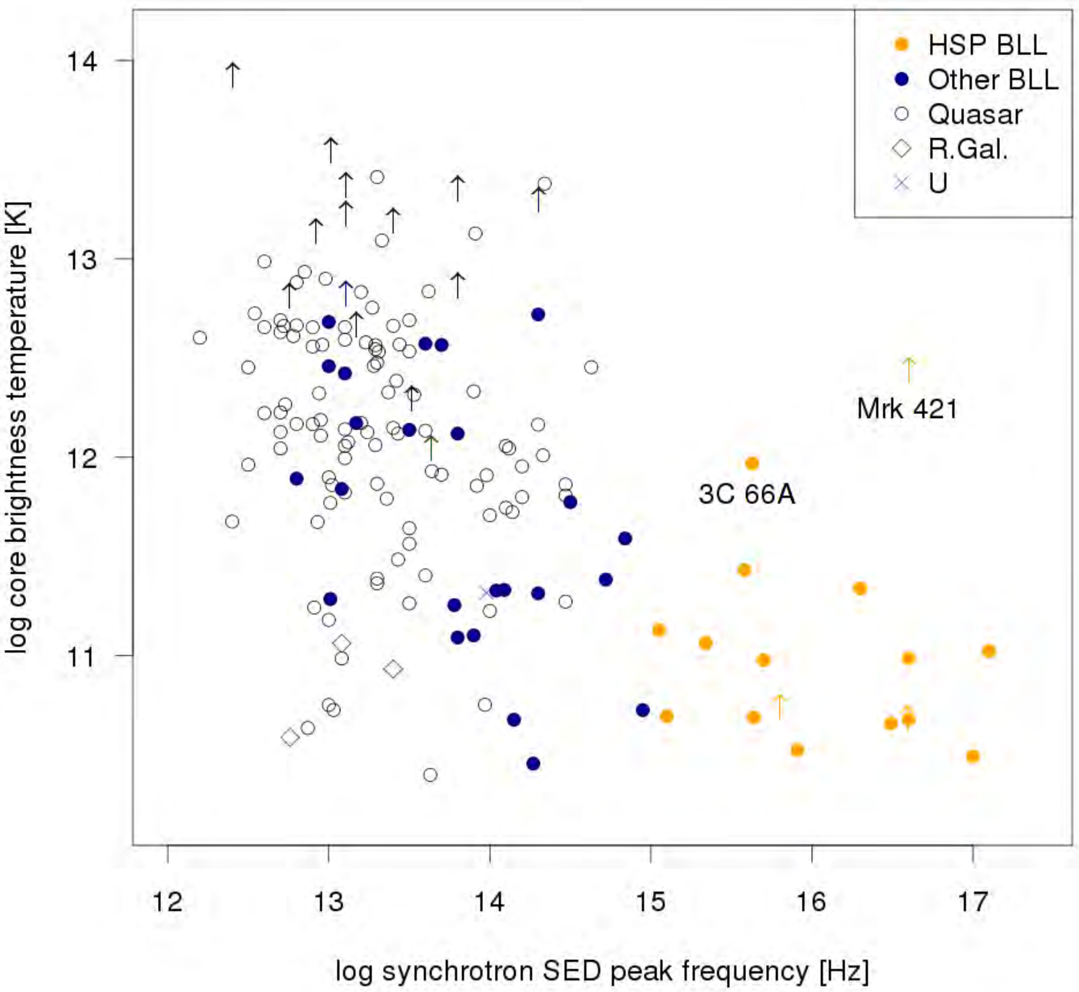
- **Photon index is well correlated with Compton peak location** ***(LAT team, ApJ 716,30)***
- **Should this trend exist if the ɣ-ray and pc-scale radio jet emission are fully independent ?**
- **BLL have lower avg. Compton Dominance values than FSRQ** ***(Giommi et al. arXiv:1108.1114)***



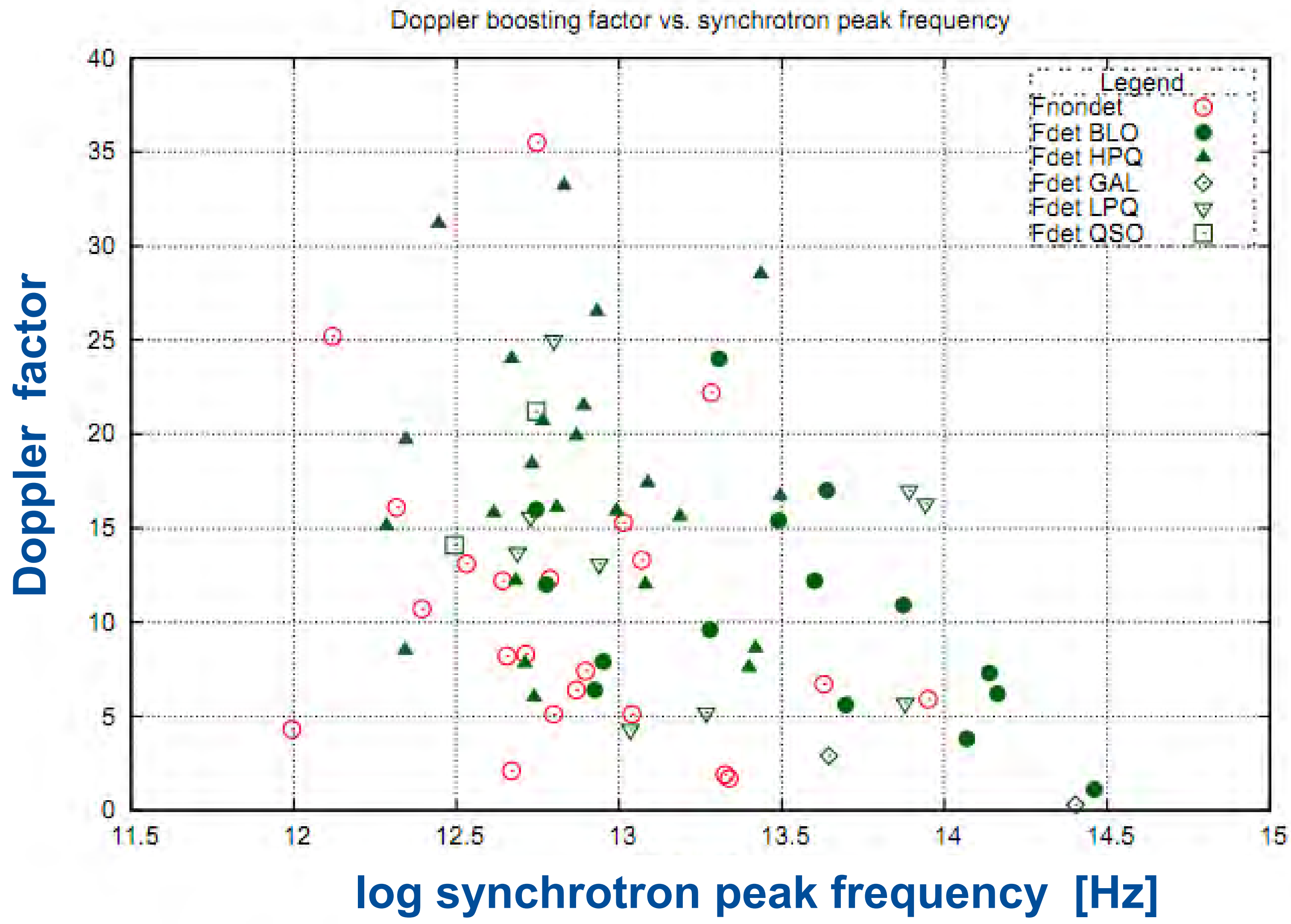
- **Trend is continuous from HSP to LSP**

Parsec-scale radio core compactness vs. ν_{peak}

- **Radio core compactness (brightness temperature) is strongly affected by beaming and jet activity level**
- **FSRQ show no trend at all between ɣ-ray loudness and core compactness, reflecting wide intrinsic range of these two properties**
- ***Low compactness level of HSP radio cores is suggestive of lower Doppler beaming factors***



▸ Variability Doppler factors: Tornikoski et al. 2011



Summary

- **Bright BL Lacs (but not FSRQ) display several trends:**
  - *ɣ-ray loudness positively correlated with synchrotron SED peak freq.*
  - *pc-scale radio emission correlated with high energy SED peak*
  - *in the radio, HSP BL Lacs **do not show** high compactness, high variability, high core linear polarization, or high superluminal speeds*

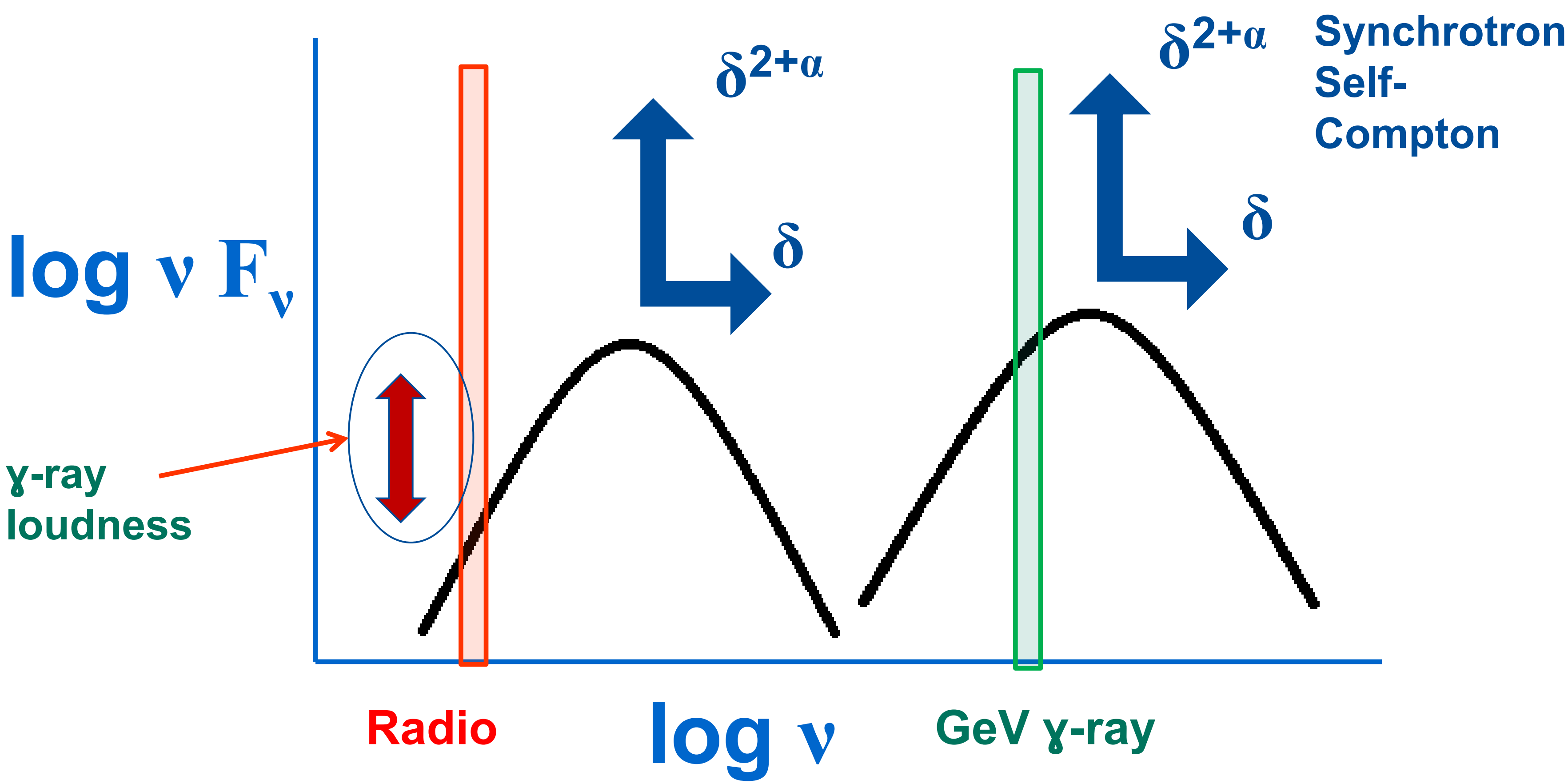
- **Radio/ɣ-ray correlations are suppressed in FSRQs because of wide range of Compton Dominance values**

- **Simplest current explanation for brightest BL Lacs:**
  - *lower Doppler factors for the HSPs*
  - *SSC origin of ɣ-rays favored over ECS*
  - *tightness of trends suggest a limited range of SED shape & Compton Dominance within the bright BL Lac population (needs further verification with high quality simultaneous SED data)*

Lister et al. 2011, ApJ 742, 27

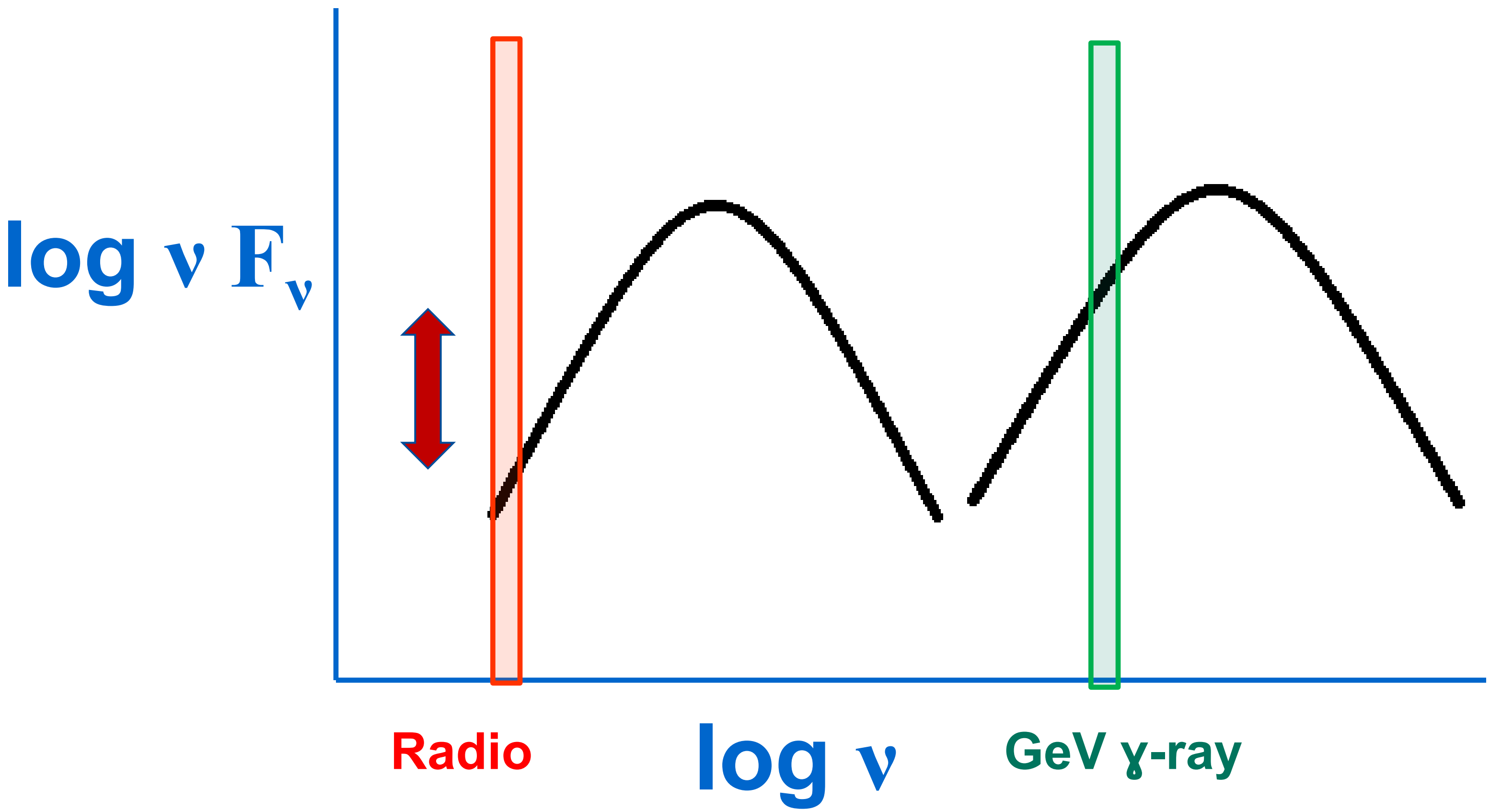
Backup slides

High-spectral-peaked blazar (unbeamed SED)



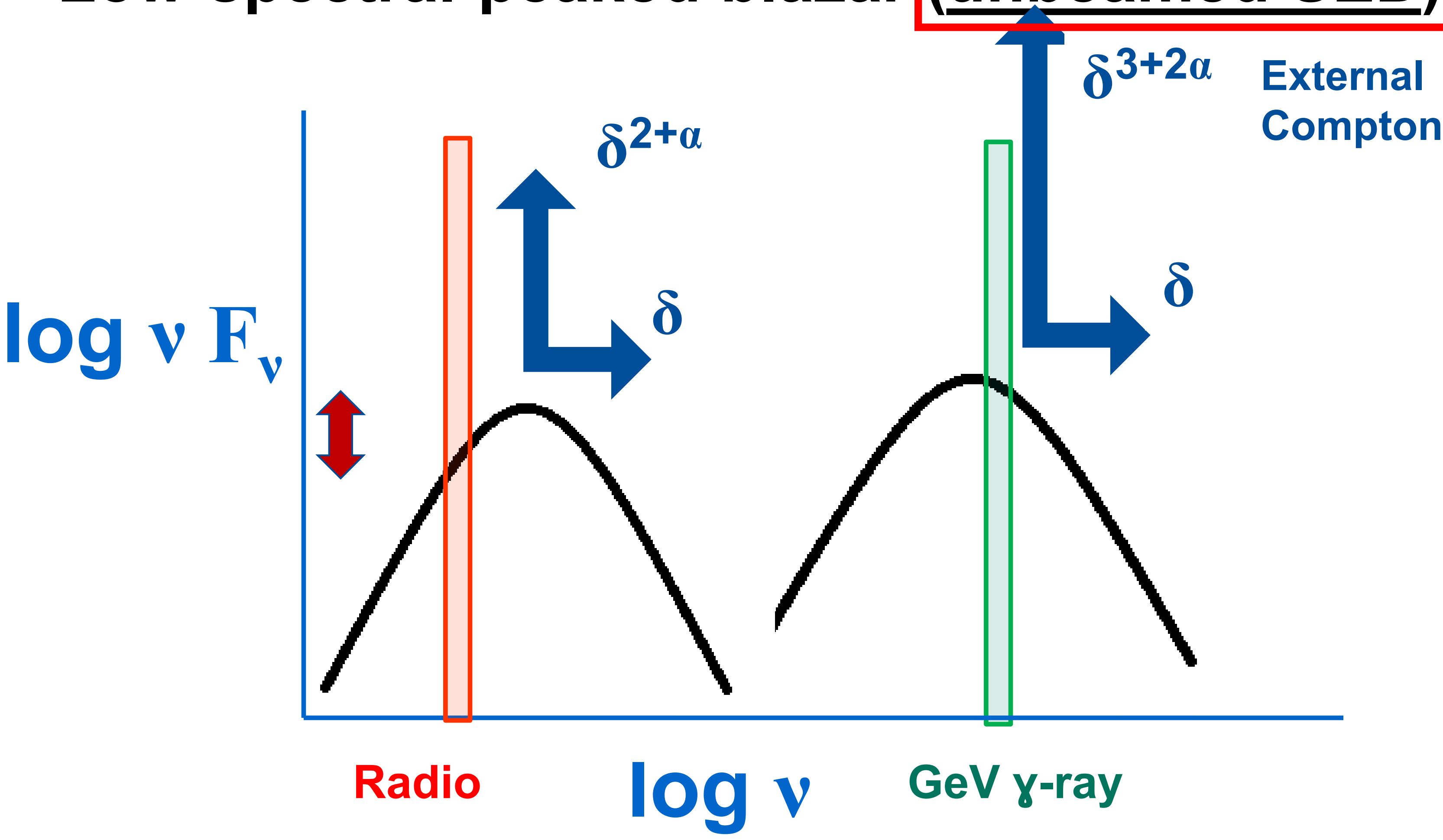
SSC model predicts similar change in both SED peaks when jet emission is beamed

High-spectral-peaked blazar (beamed SED)

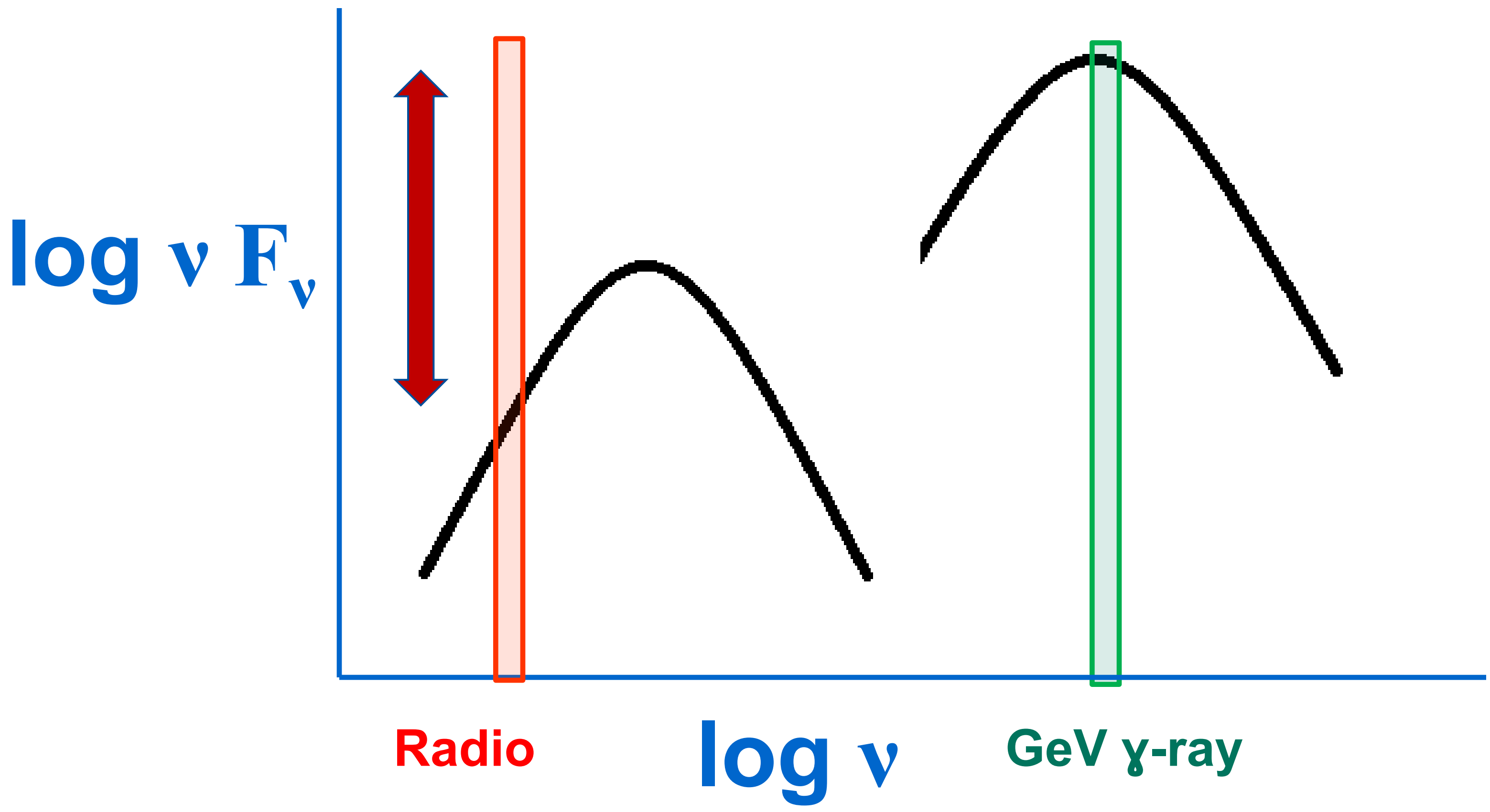


For the SSC model, γ–ray loudness is more affected by SED peak location than beaming (BL Lacs)

Low-spectral-peaked blazar (unbeamed SED)



Low-spectral-peaked blazar (beamed SED)

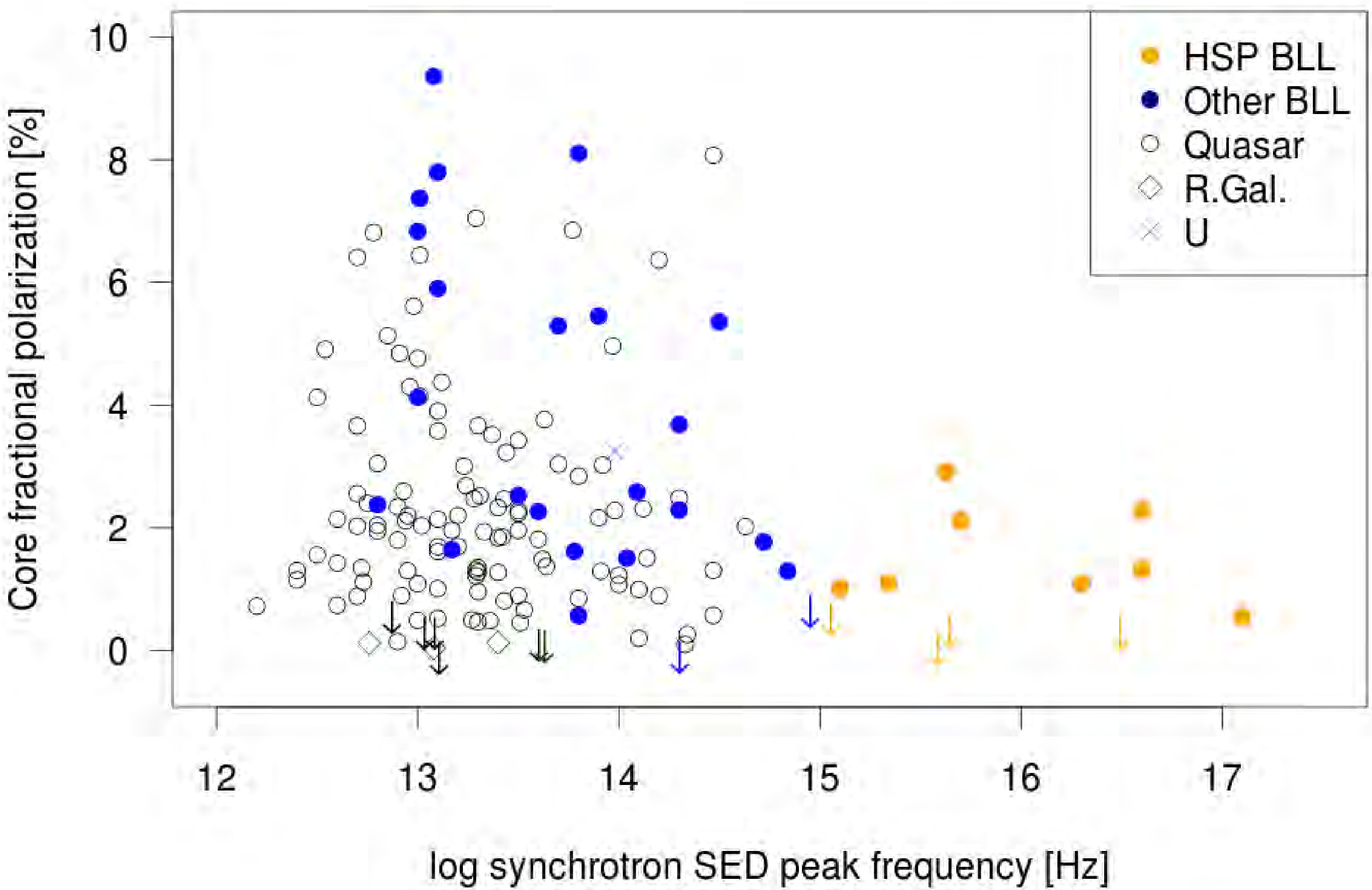


In the ECS model, γ–ray loudness is more strongly affected by beaming than SED peak location (FSRQ)

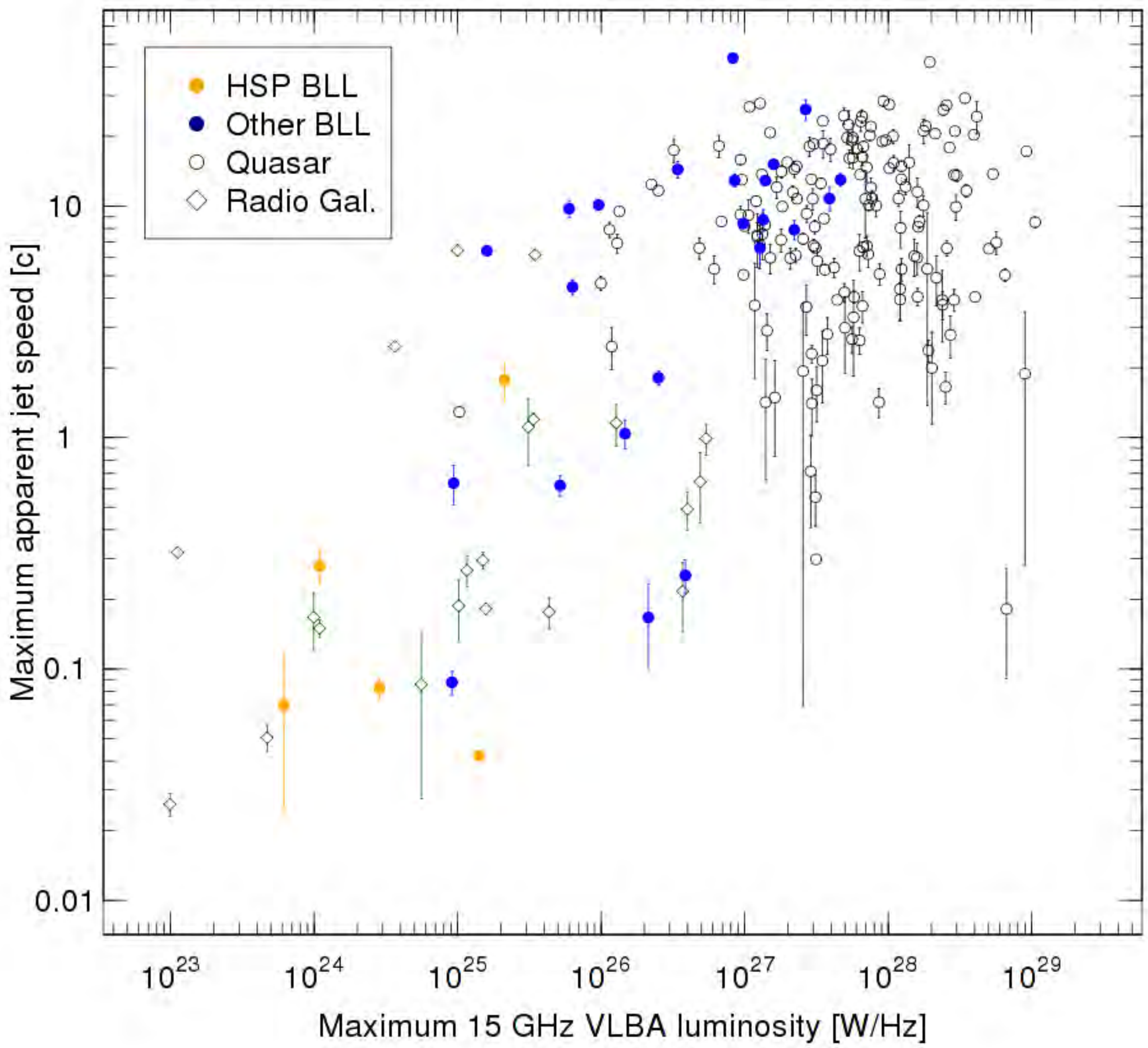
What's next:

- **Do these trends hold for weaker blazars?**
  - *Parsec-jet properties of all 1FGL AGN associations*
  - *8 GHz VLBI survey underway by Kovalev, Petrov, et al.*
- **Pc-scale jet speeds of HSP and low-luminosity AGN**
  - *MOJAVE-2 program underway*
- **Full SED information on brightest AGNs**
  - *Planck AGN survey*
  - *E. Meyer Ph.D. thesis*

VLBA core polarization vs. ν_{peak}

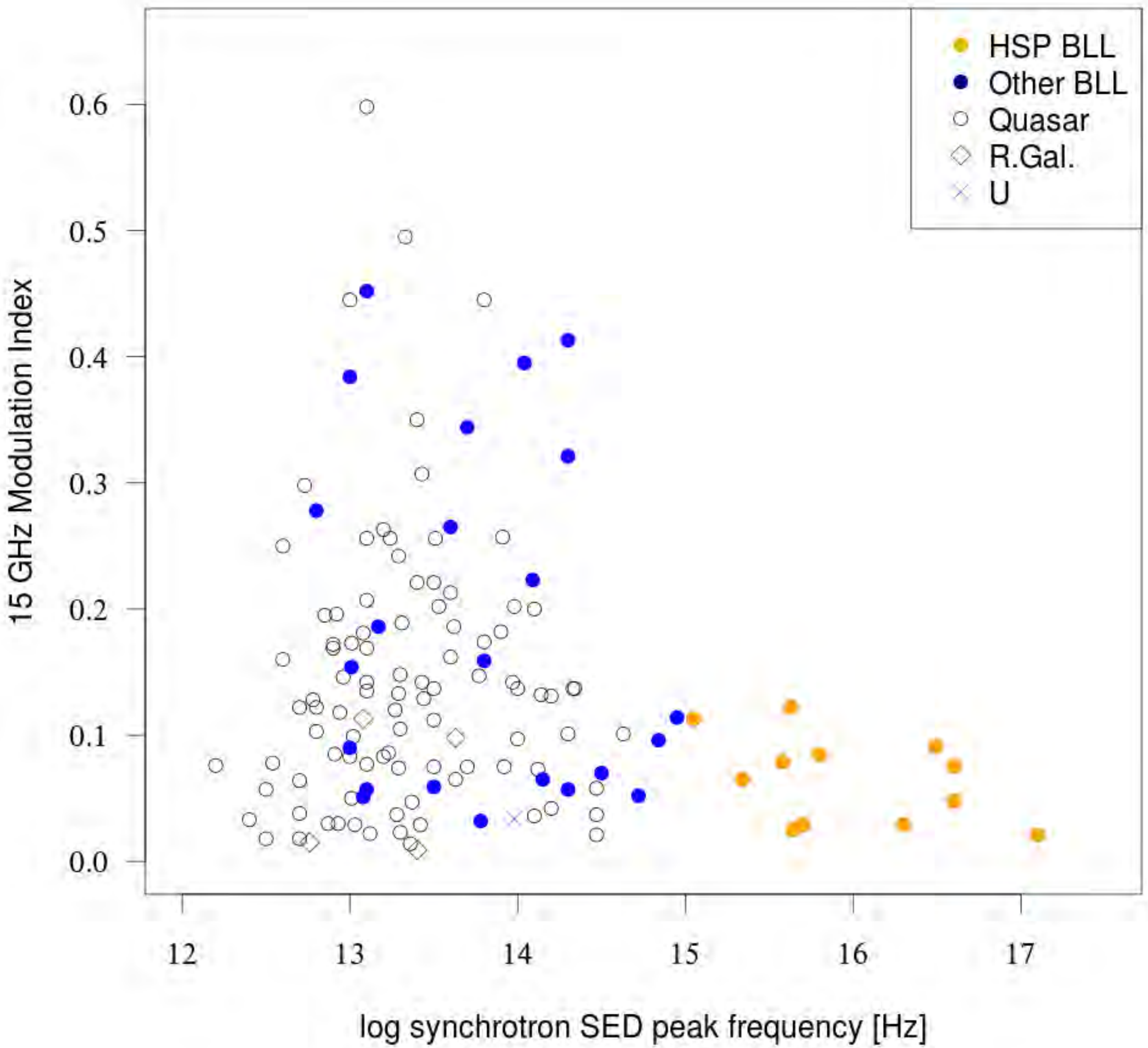


Jet speed vs. pc-scale radio luminosity



- **Lister et al., in prep.**

OVRO radio variability level versus ν_{peak}



Five factors determine γ-ray jet brightness:

↑ Relative Importance ↑

1. Intinsic jet speed
2. Viewing angle

→ Doppler factor

3. Location of synchrotron SED peak
4. Activity state of jet
5. Proximity to Earth

Predictions of the beaming model

A. External-photon Compton scattering models predict more beaming in gamma-rays than in radio regime

→ extra Lorentz transformation between jet frame and external seed photon frame (e.g., Dermer 1995)

→ may apply to flat spectrum radio quasars (FSRQ)

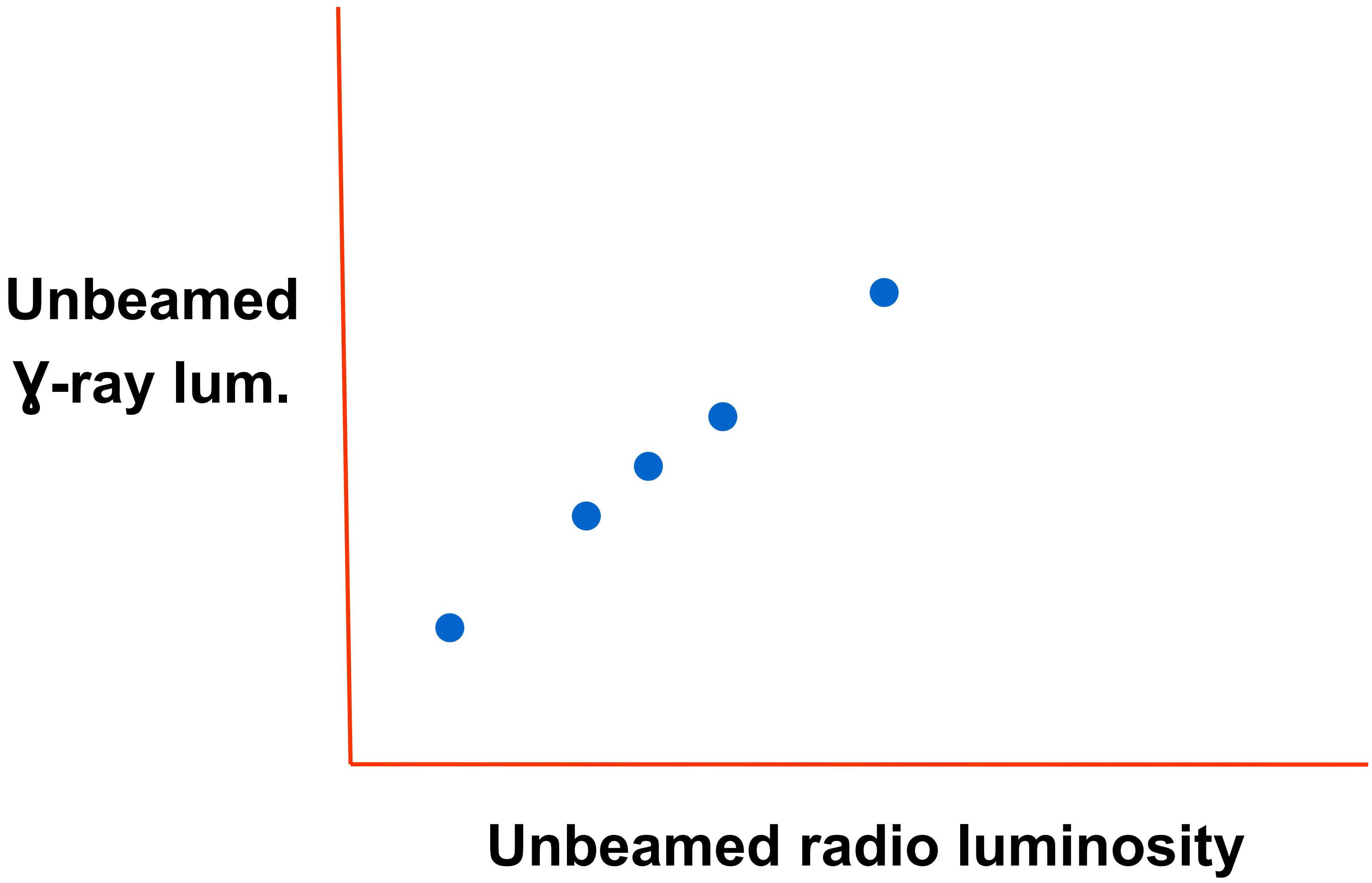
B. High-spectral peaked jets in gamma-ray samples:

→ intrinsically much brighter in gamma-rays

→ don't need to be as highly beamed as the low-peaked quasars

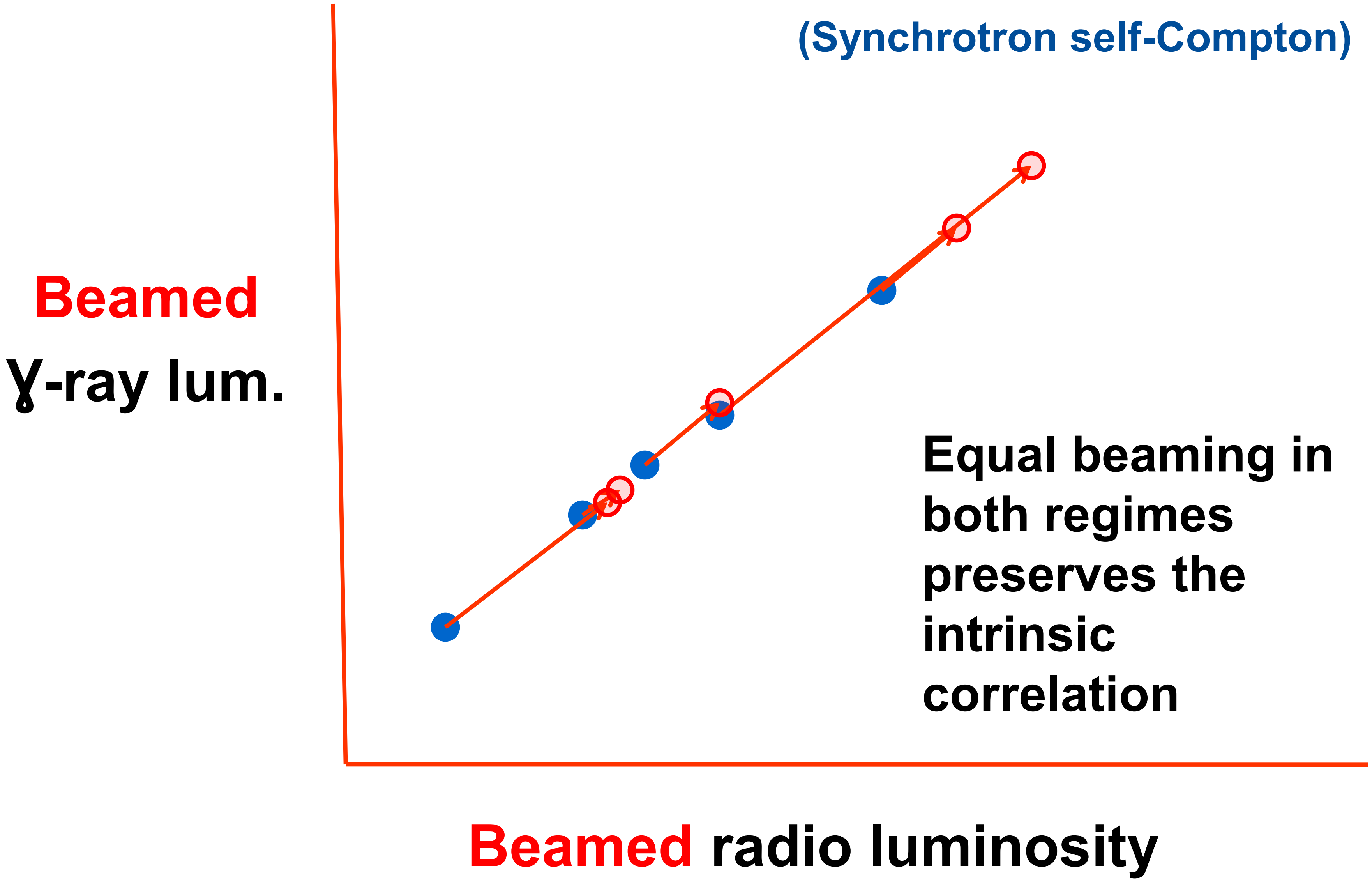
→ all HSPs are BL Lacs, where synchrotron self-Compton applies

Doppler beaming



Doppler beaming

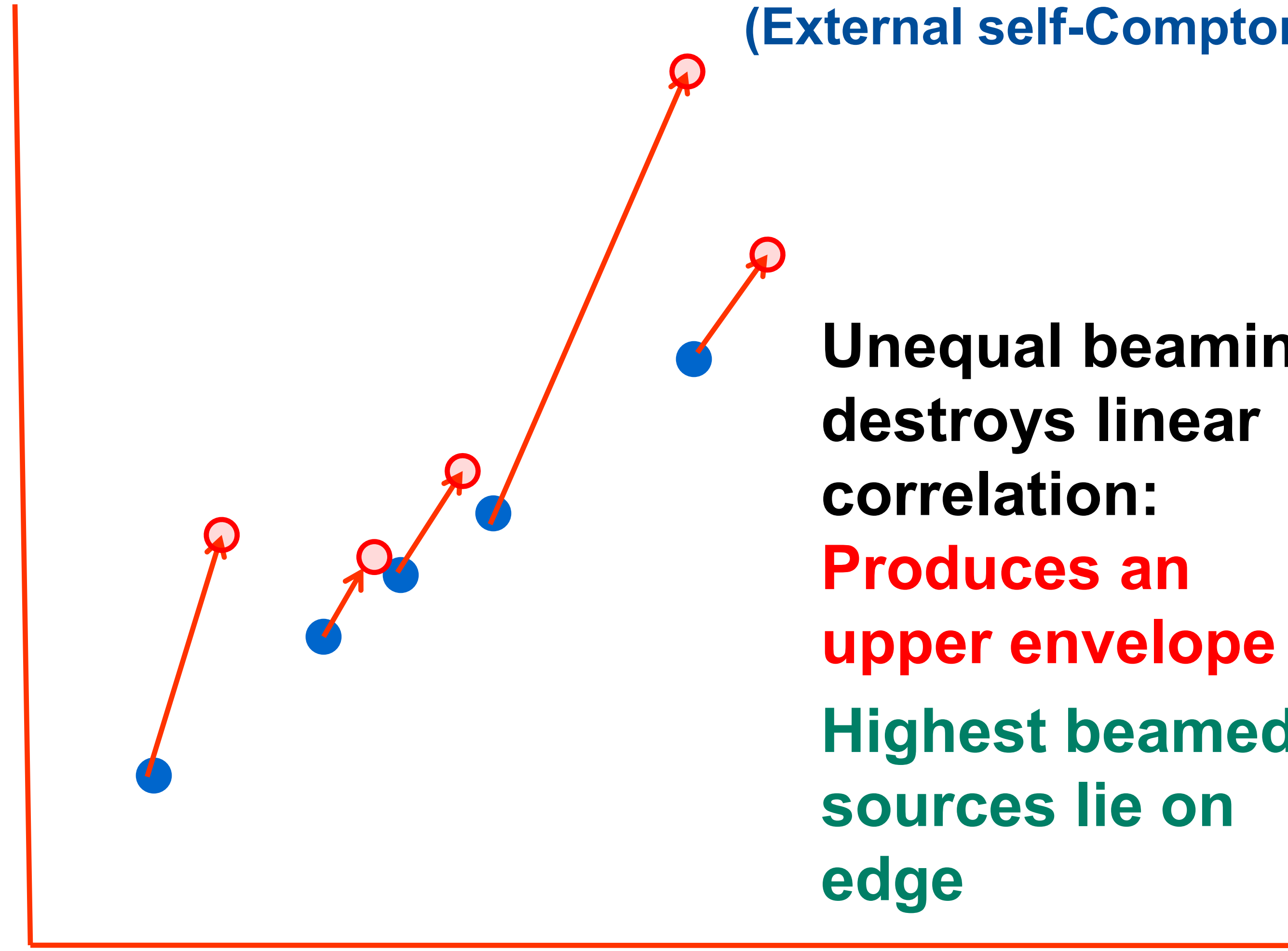
(Synchrotron self-Compton)



Equal beaming in both regimes preserves the intrinsic correlation

Doppler beaming

(External self-Compton)

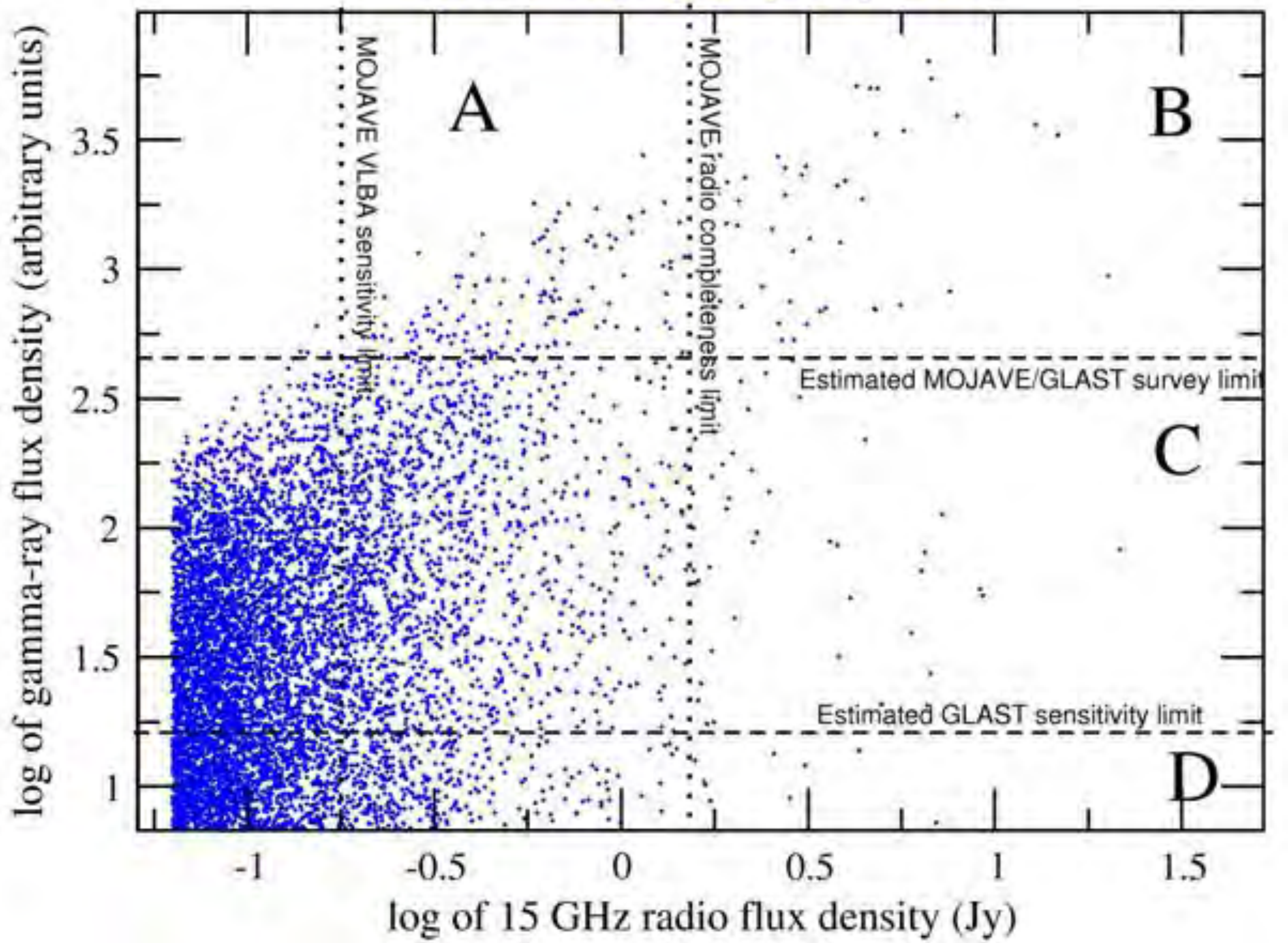


Unequal beaming destroys linear correlation:

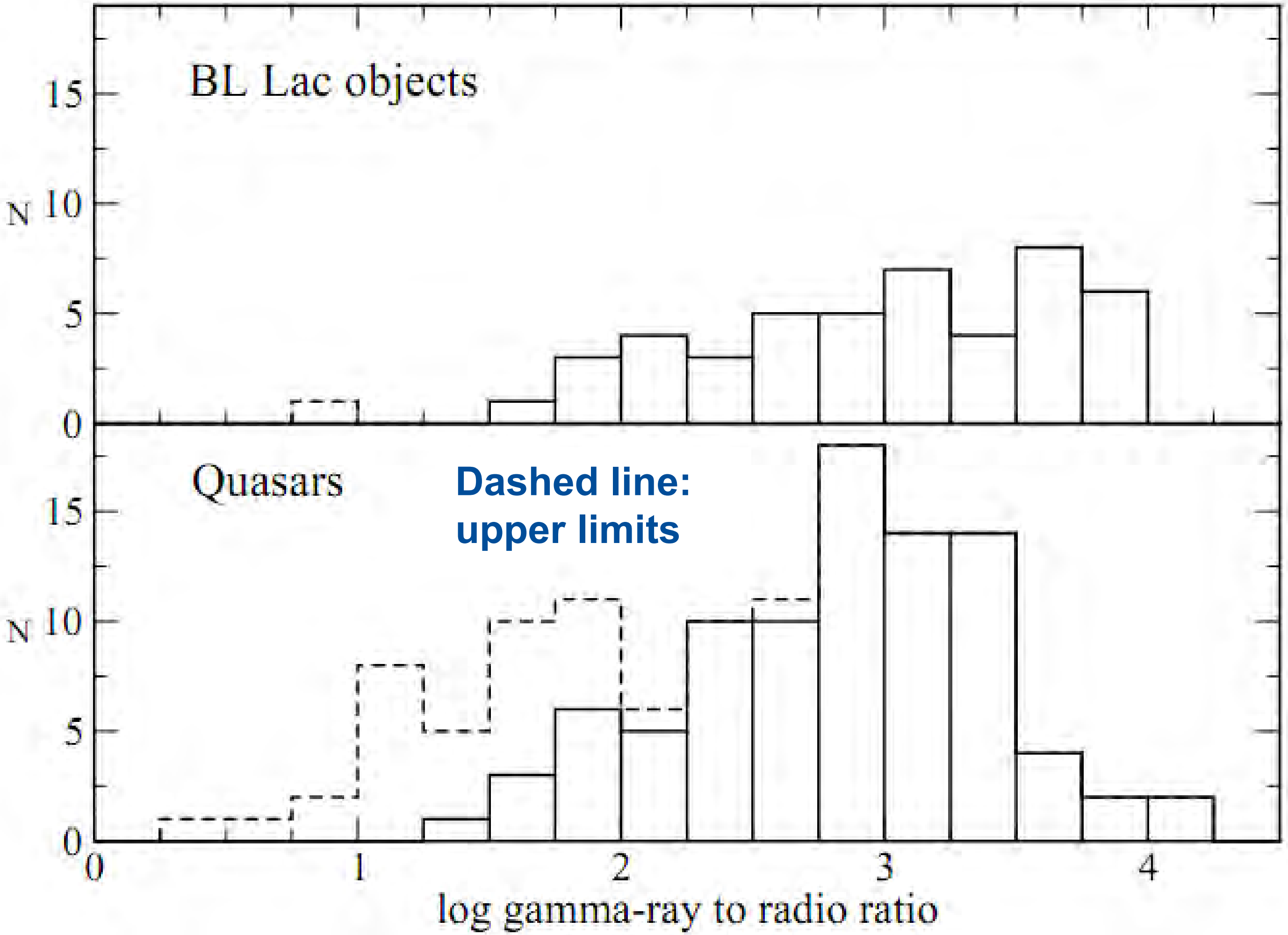
Produces an upper envelope

Highest beamed sources lie on edge

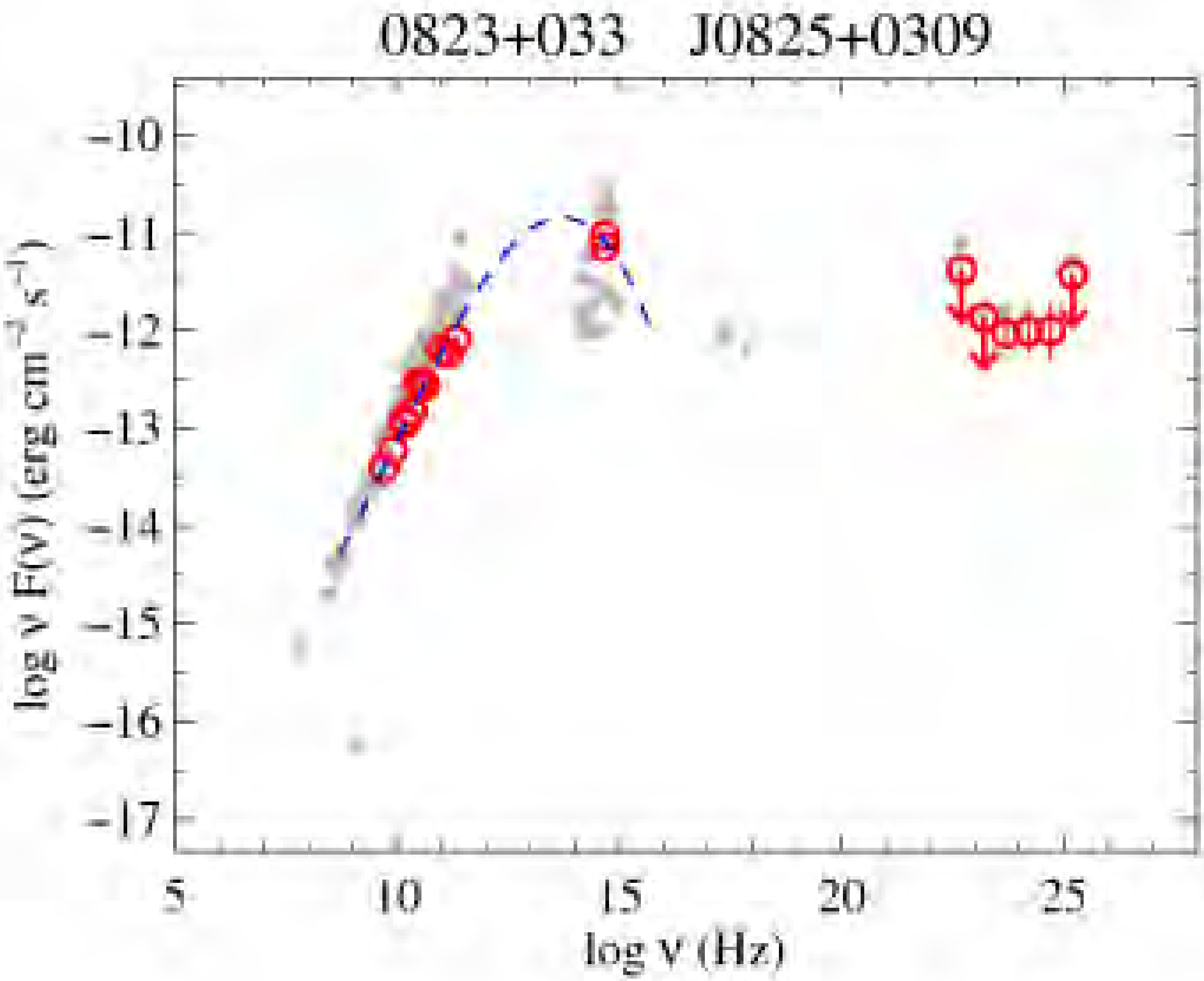
External Compton (ECS) model



Poster: Lister 2007, 1st Fermi Symposium



- → **Gamma-ray loudness spans at least 4 orders of magnitude in the brightest blazars**
- → **higher mean for BL Lacs vs. quasars**



0823+033 J0825+0309
log ν F(ν) (erg cm⁻² s⁻¹)
log ν (Hz)
−10
−11
−12
−13
−14
−15
−16
−17
5
10
15
20
25