Fermi Gamma-ray Space Telescope

The multi-frequency behaviour of Blazars

Based on data from Fermi, Swift + many other observatories

Paolo Giommi
Italian Space Agency, ASI and

N. Mazziotta, E. Cavazzuti, S. Colafrancesco,
S. Cutini, D. Gasparrini, C. Monte, S. Raino',
A. Tramacere

On behalf of the LAT collaboration
and many other multi-frequency collaborators

Quasi simultaneous high quality SEDs for 48 LBAS blazars

- A sample oriented approach -

- Data from Fermi, Swift, Effelsberg, OVRO, RATAN, TANAMI-VLBI, GASP-WEBT collaboration, VLT-VISIR, Spitzer, AGILE
- Fermi data integrated during the first three months of operations: 4 August to 31 October 2008.
- Quasi-simultanaous multi-frequency data taken in the interval May 2008 January 2009.
- Archival multi-frequency data (radio to TeV)
- Representative of the entire LAT Bright AGN Sample (LBAS)

See S. Cutini's Poster for more details

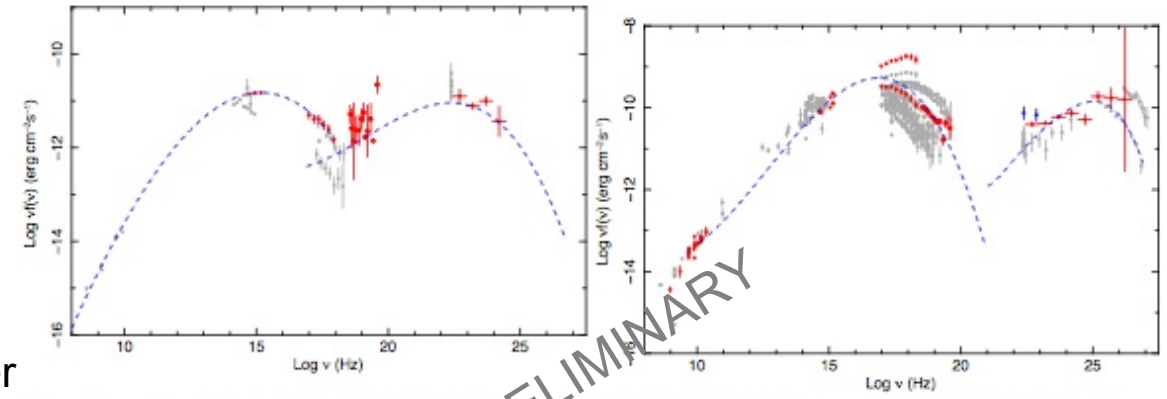


Fig. 15.— The SED of 0FGL J1058.9+5629 = GB6 J1058+5628 (left) and of 0FGL J1104.5+3811 = Mkn 421 (right)

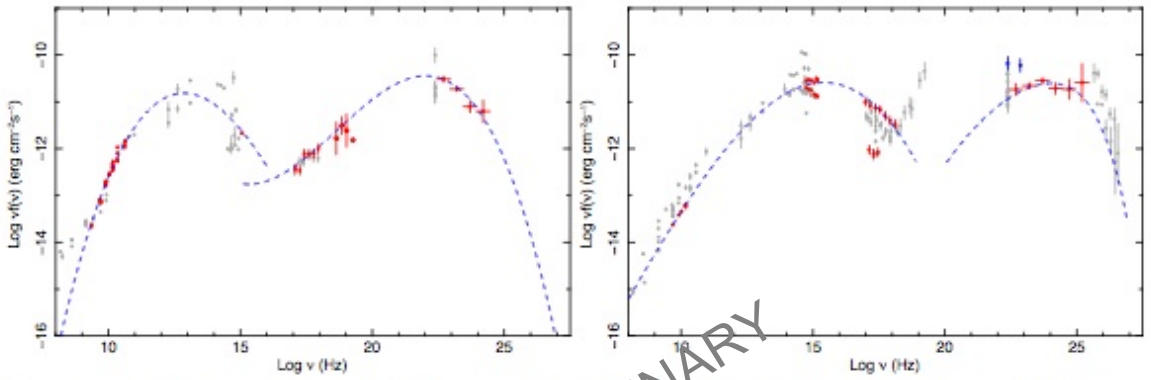


Fig. 16.— The SED of 0FGL J1159.2+2912 = 4C29.45 (left) and of 0FGL J1221.7+2814 = ON231= W Comae (right)

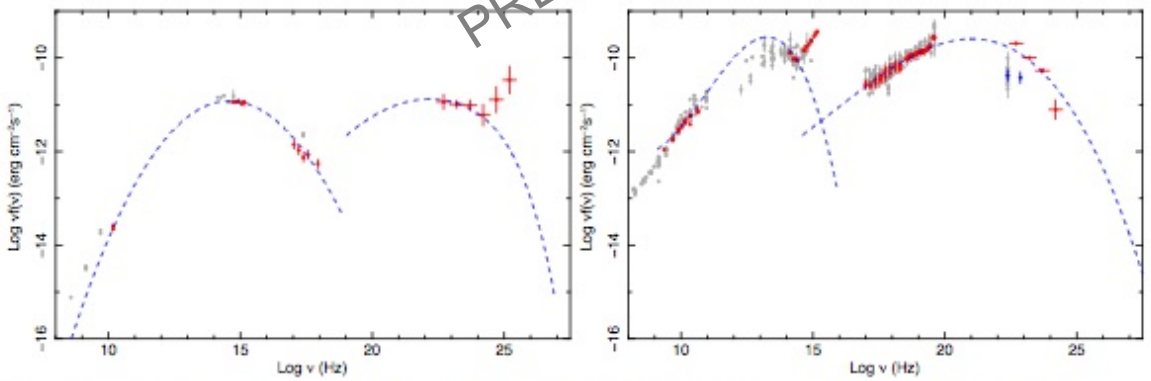
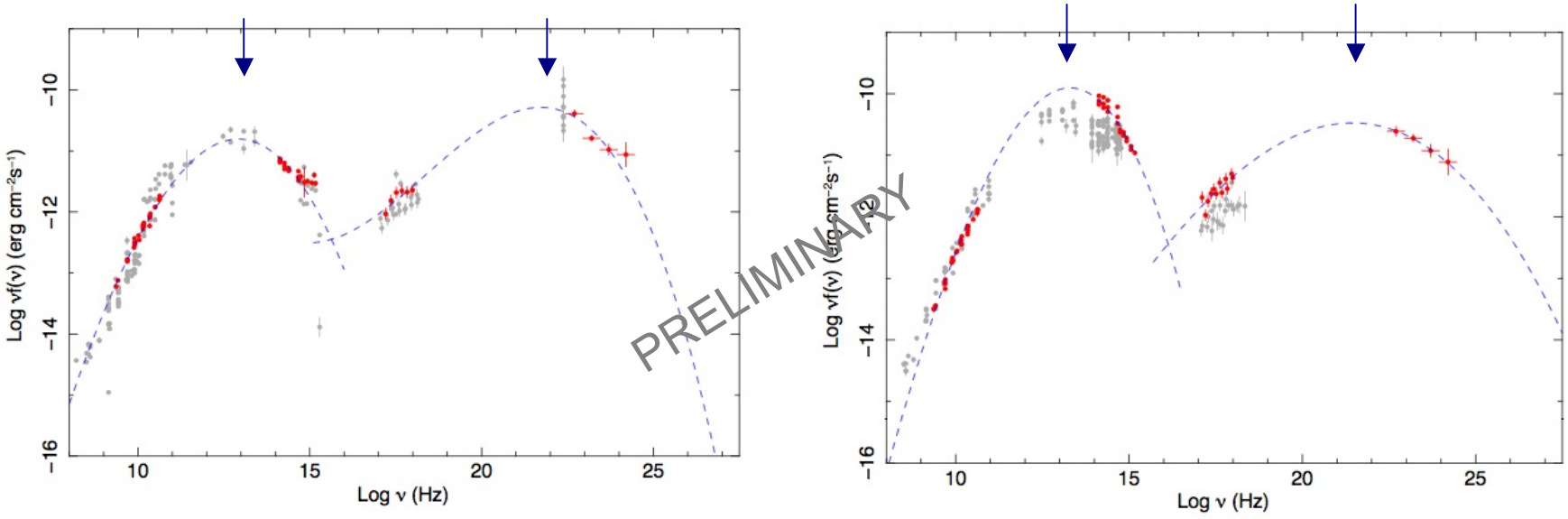


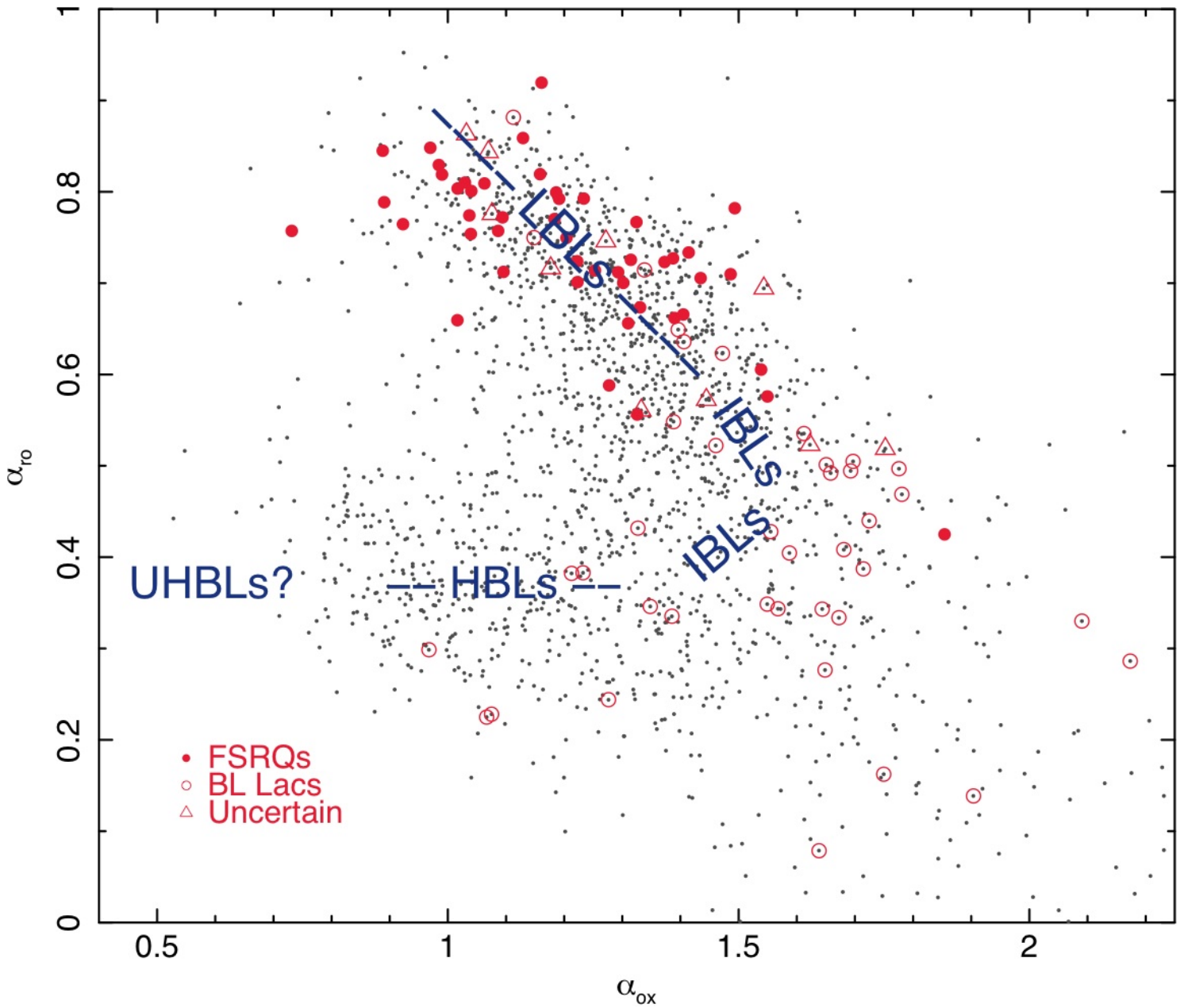
Fig. 17.— The SED of 0FGL J1248.7+5811 = PG 1246+586 (left) and of 0FGL J1229.1+0202 = 3C273 (right)

The synchrotron/invC peak frequencies ν_{peak} and intensities ν_{peak} $f(\nu_{peak})$

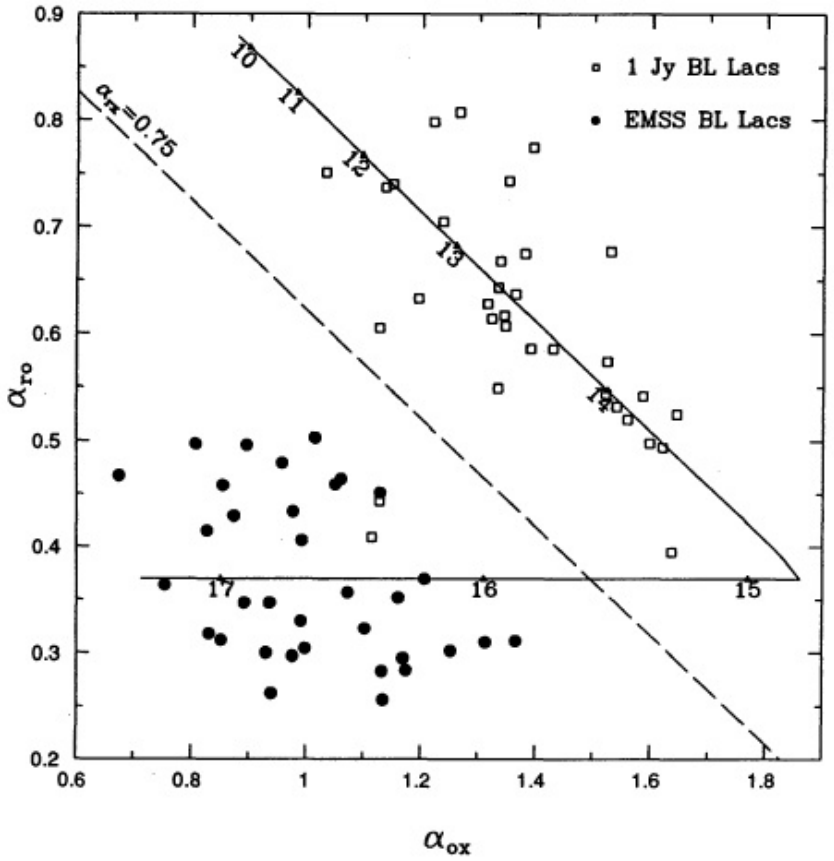
Measured from the 48 SEDs using
3rd degree polynomial functions



See S. Cutini's poster for details


1
0.8
0.6
0.4
0.2
0
0.5
1
1.5
2
α_{ro}
α_{ox}
LBLs
IBLs
IBLs
UHBLs?
HBLs
FSRQs
BL Lacs
Uncertain

A method to derive ν^{S}_{peak} and ν^{S}_{peak} f(ν^{S}_{peak}) form α_{ox} and α_{ro}



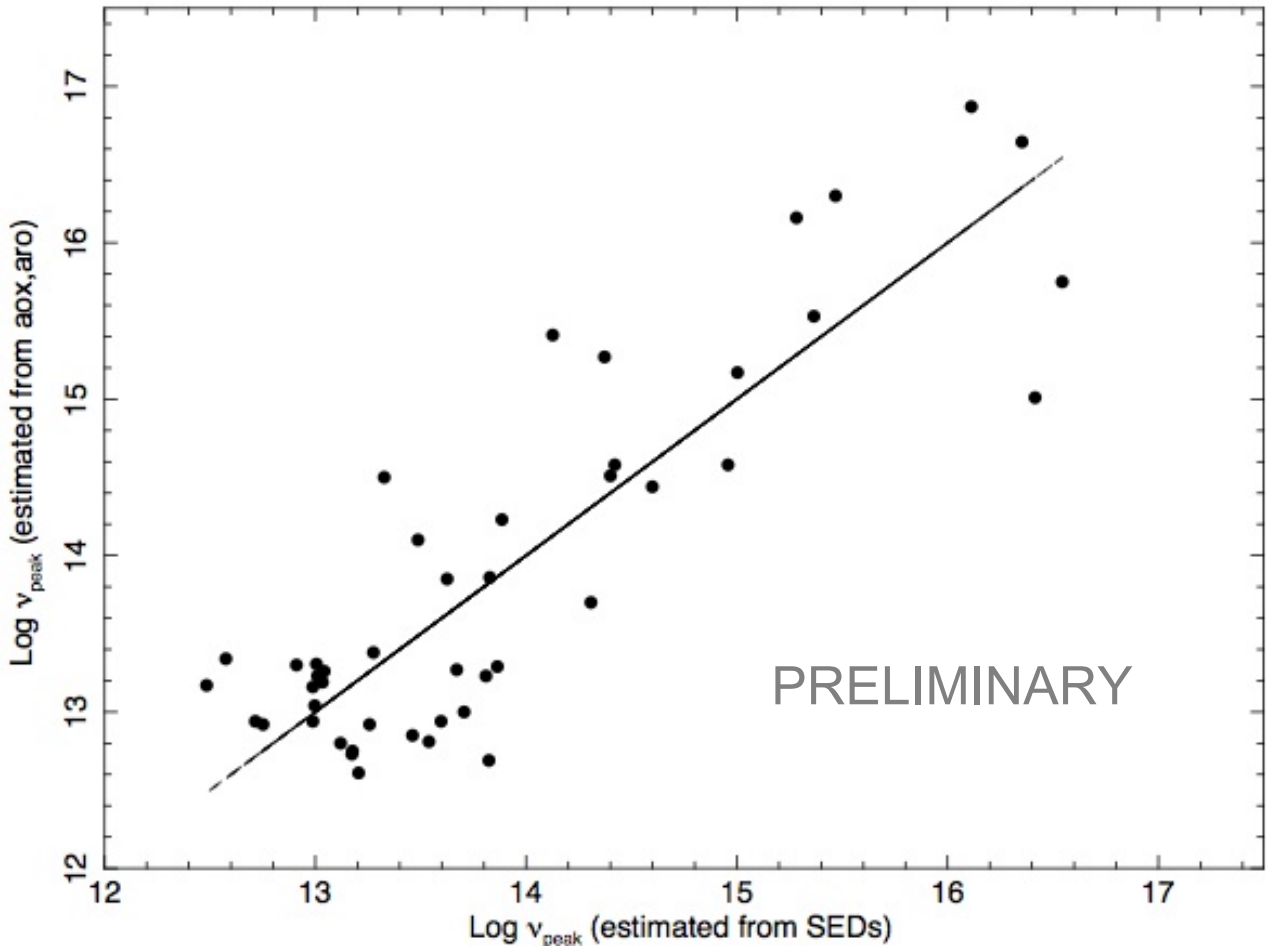
A "calibrated" version of the method of
Padovani & Giommi (1995)

The position of a blazar in the α_{ox} - α_{ro} plane is determined by the synchrotron peak energy

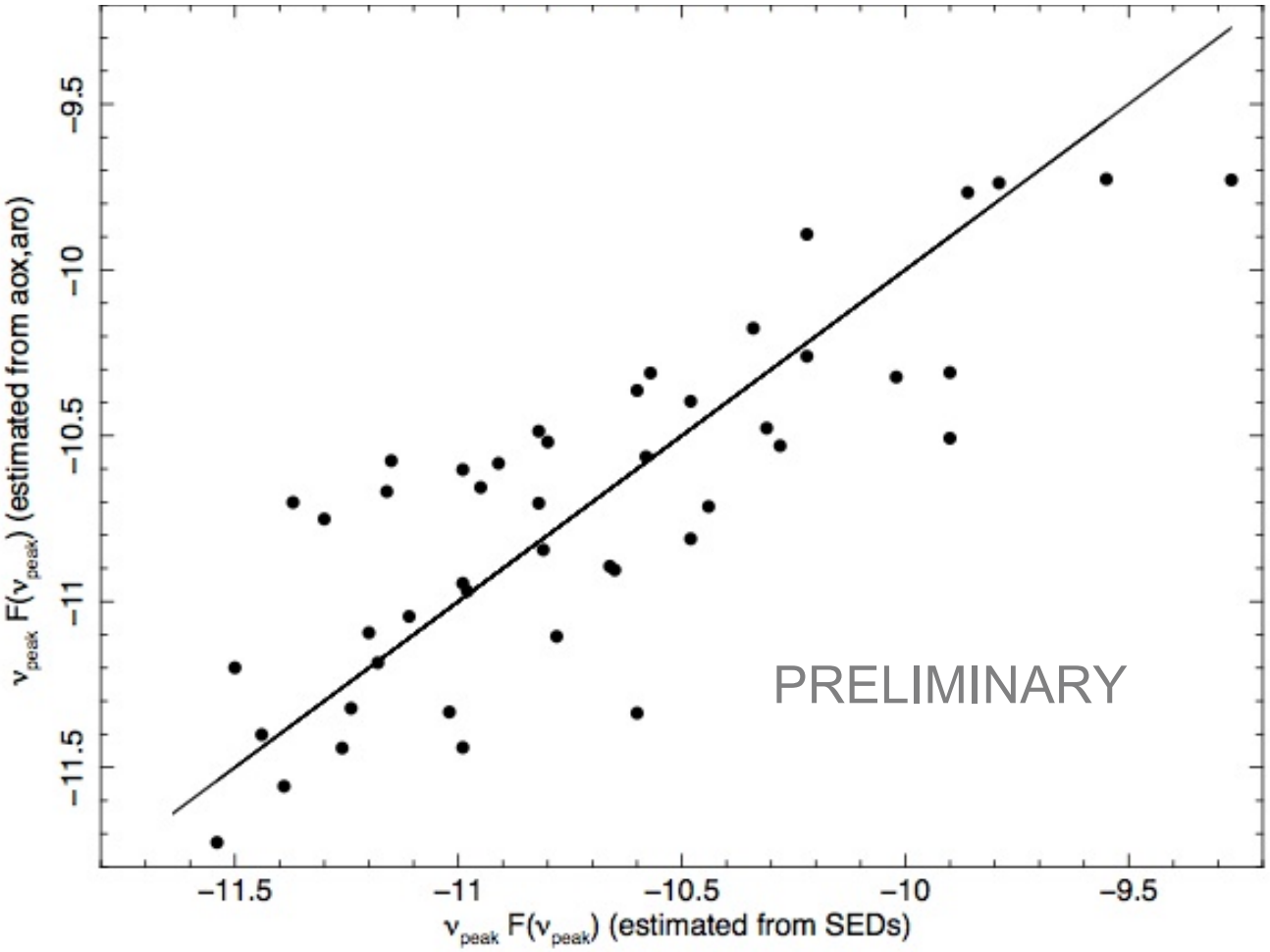
Paodvani & Giommi 1995, ApJ, 444, 567

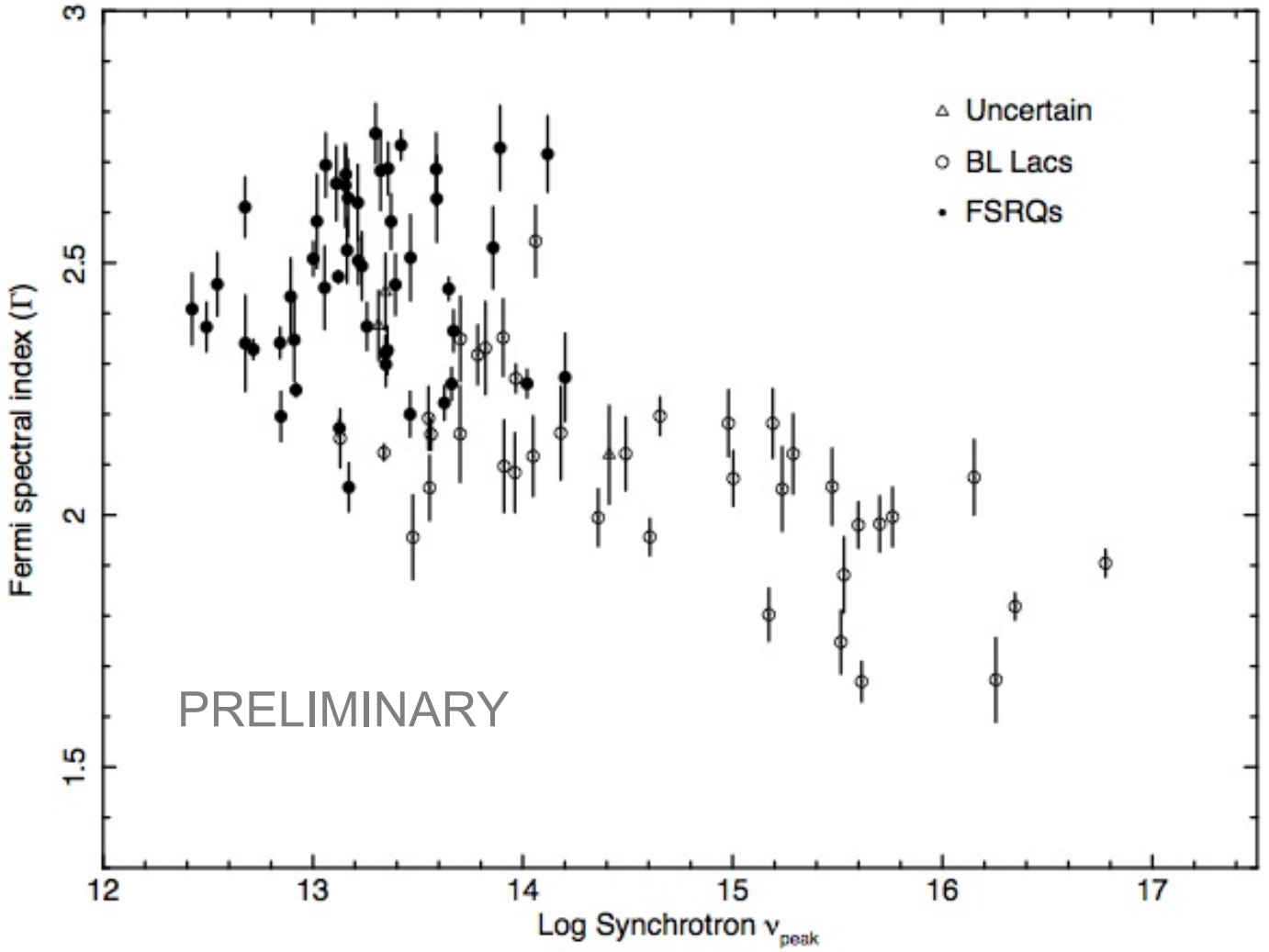
$$\mathrm{Log}(\nu_{peak_S}) = \begin{cases} 13.85 + 2.30X & if \quad \mathrm{X} < 0 \text{ and } \mathrm{Y} < 0.3 \\ 13.15 + 6.58Y & \text{otherwise} \end{cases}$$

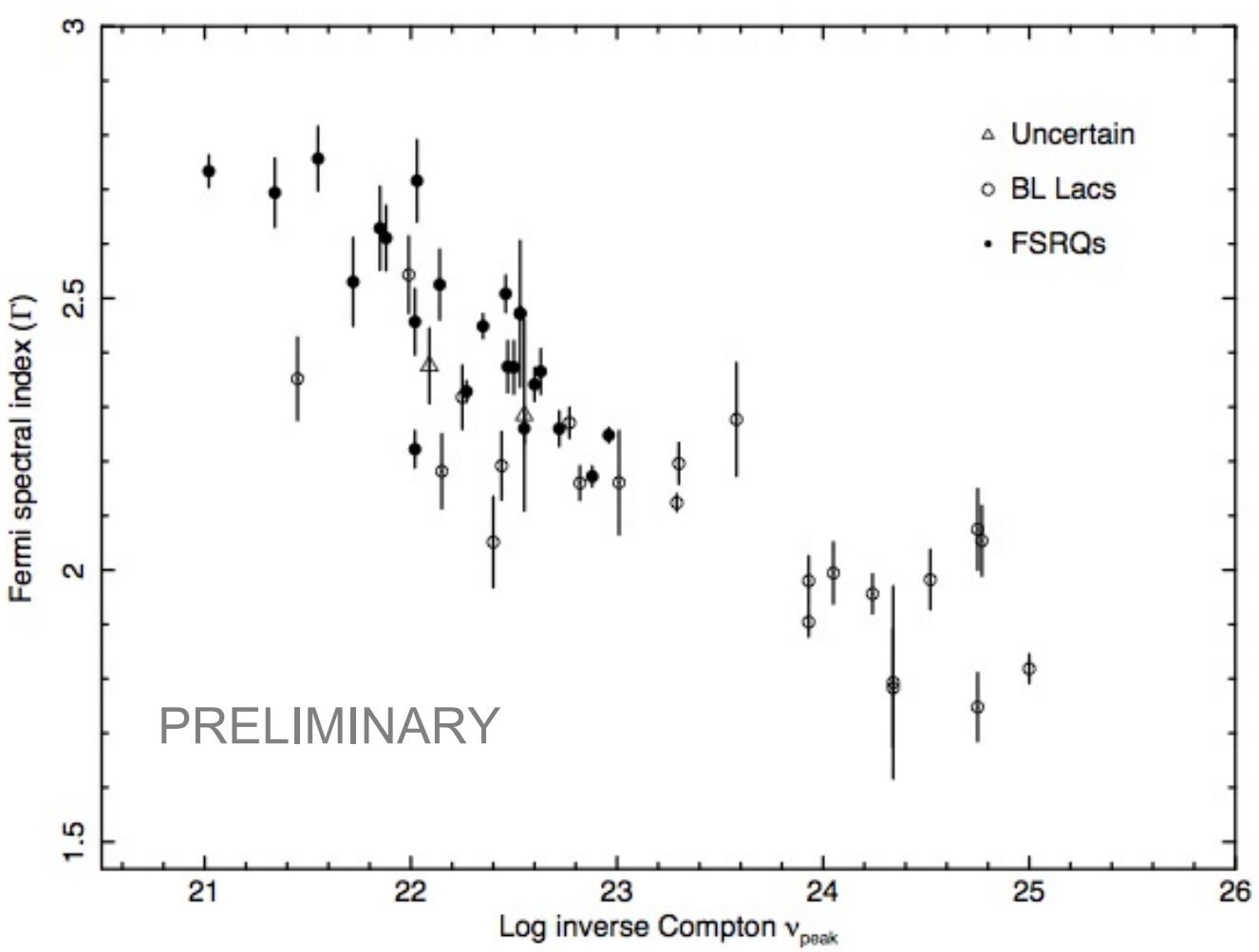
where $\mathrm{X} = 0.565 - 1.433 \cdot \alpha_{\mathrm{ro}} + 0.155 \cdot \alpha_{\mathrm{ox}}$ and $\mathrm{Y} = 1.0 - 0.661 \cdot \alpha_{\mathrm{ro}} - 0.339 \cdot \alpha_{\mathrm{ox}}$

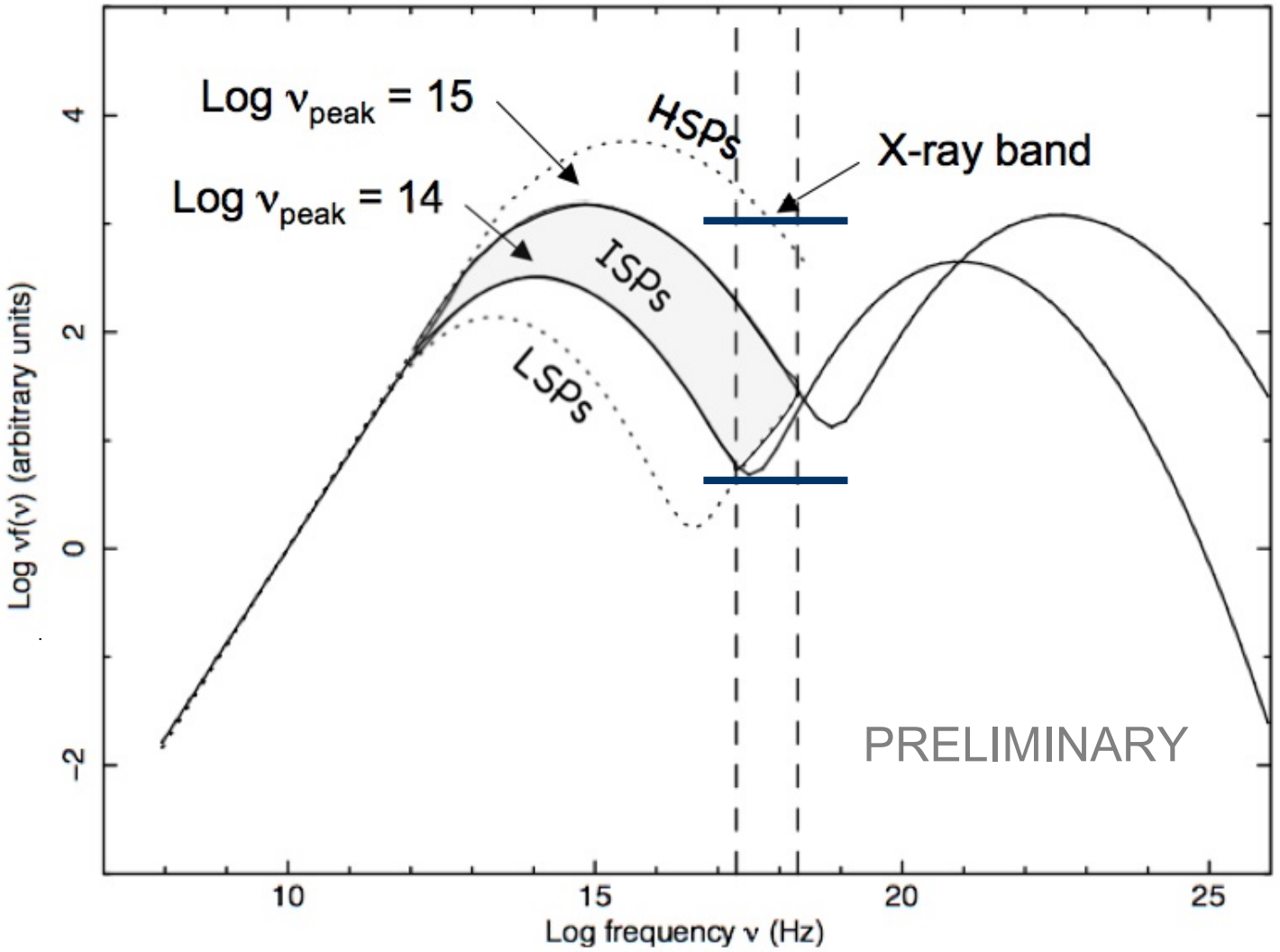


$$\mathrm{Log}(\nu_{peak_S} F(\nu_{peak_S})) = 0.5 \cdot \mathrm{Log}(\nu_{peakS}) - 20.4 + 0.9 \cdot \mathrm{Log}(\mathrm{Rflux}),$$




Uncertain
BL Lacs
FSRQs
PRELIMINARY
Fermi spectral index (Γ)
Log Synchrotron ν peak
1.5
2
2.5
3
12
13
14
15
16
17


Uncertain
BL Lacs
FSRQs
PRELIMINARY
Fermi spectral index (Γ)
Log inverse Compton ν_{peak}
1.5
2
2.5
3
21
22
23
24
25
26


Log ν_{peak} = 15
Log ν_{peak} = 14
HSPs
ISPs
LSPs
X-ray band
PRELIMINARY
Log νf(ν) (arbitrary units)
Log frequency ν (Hz)
4
2
0
−2
10
15
20
25

γ-ray vs radio/μ-wave selected samples

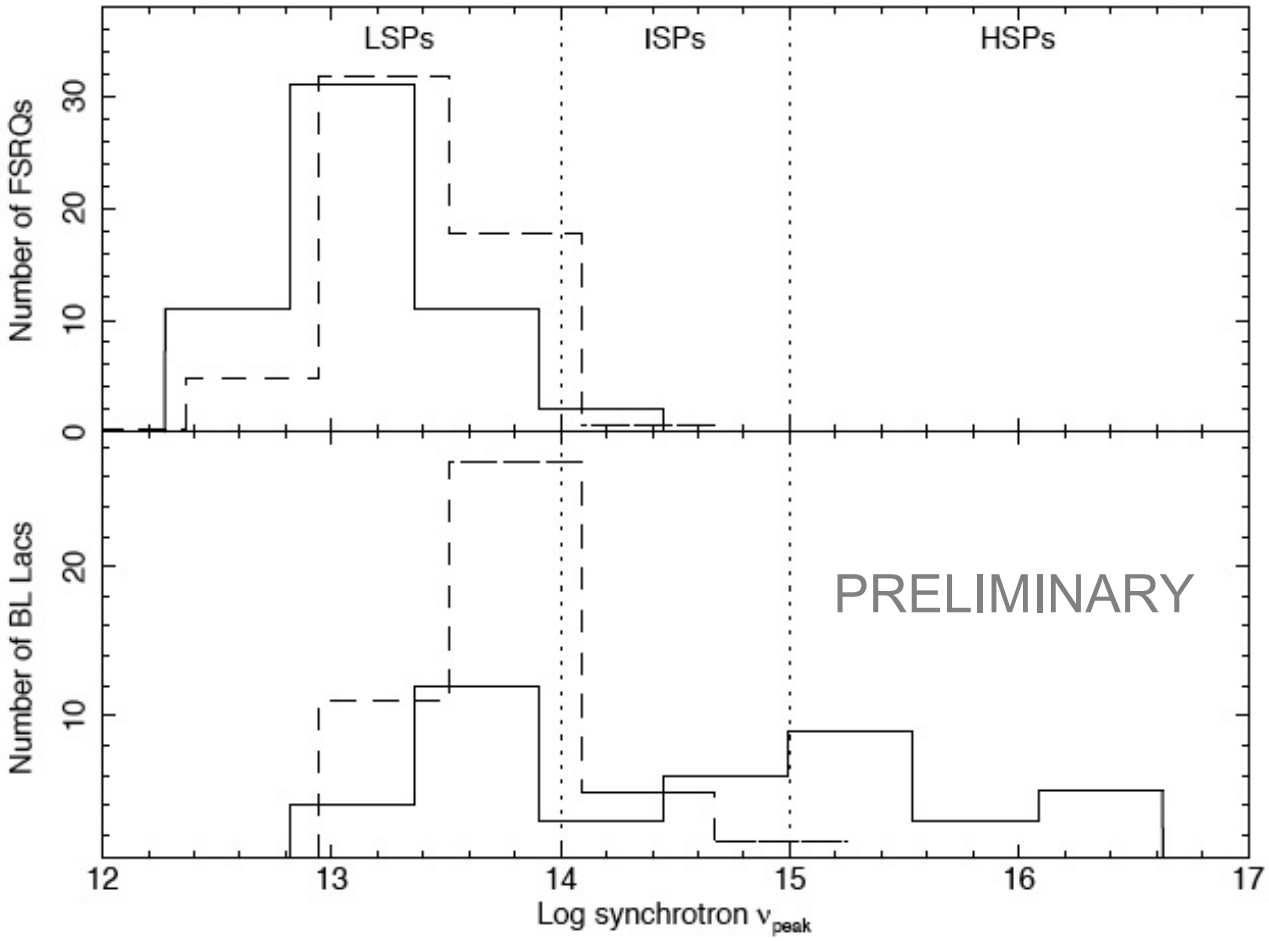


Fig. 31.— The distribution of synchrotron peak energy for the sample of LBAS FSRQ (solid line, top panel) and BL Lacs (solid line, bottom panel) compared to that of microwave selected blazars listed in the WMAP foreground sources catalog (dotted histograms) . The WMAP counts have been scaled to match the LBAS sample.

γ-ray vs x-ray selected samples

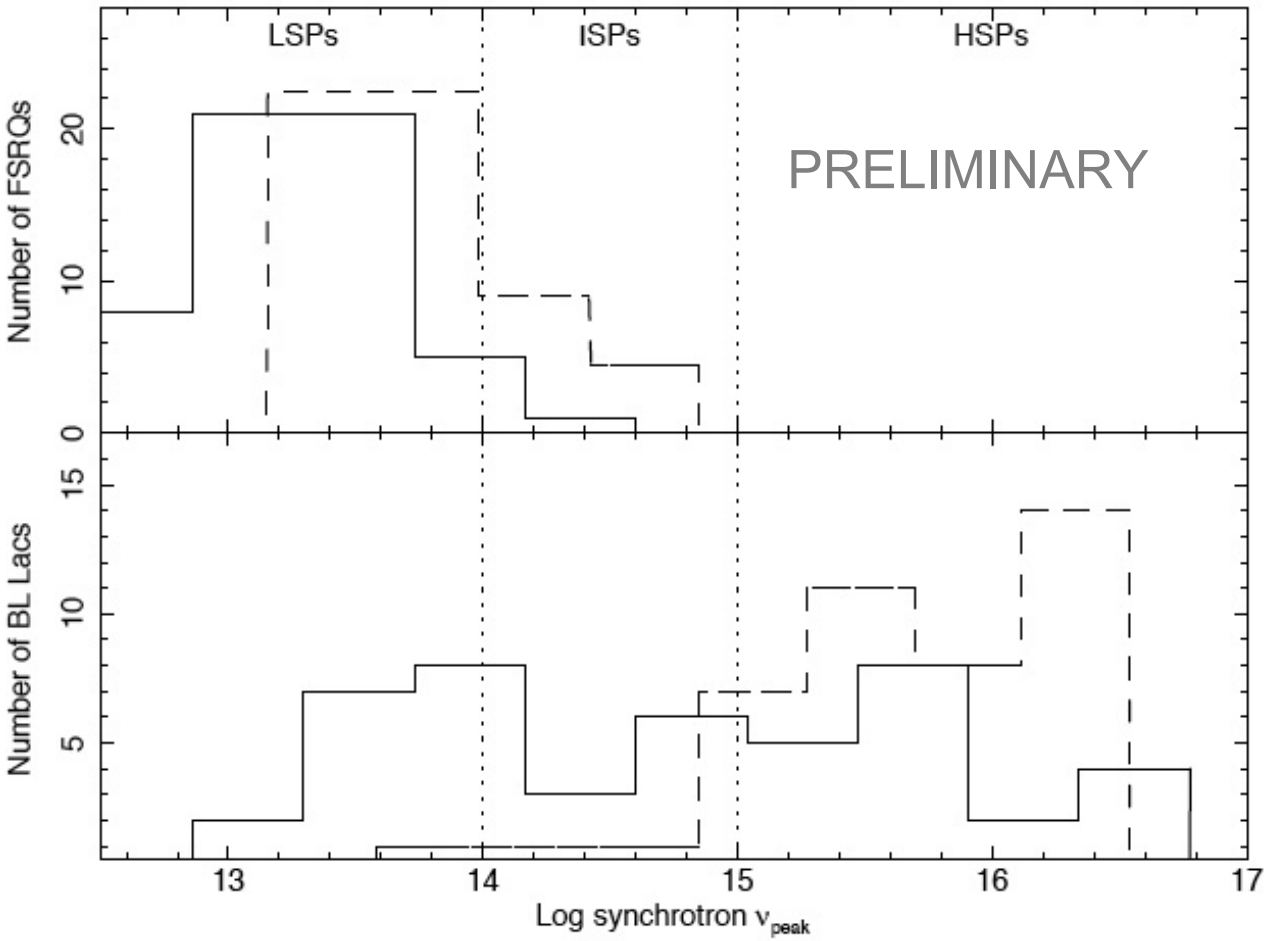
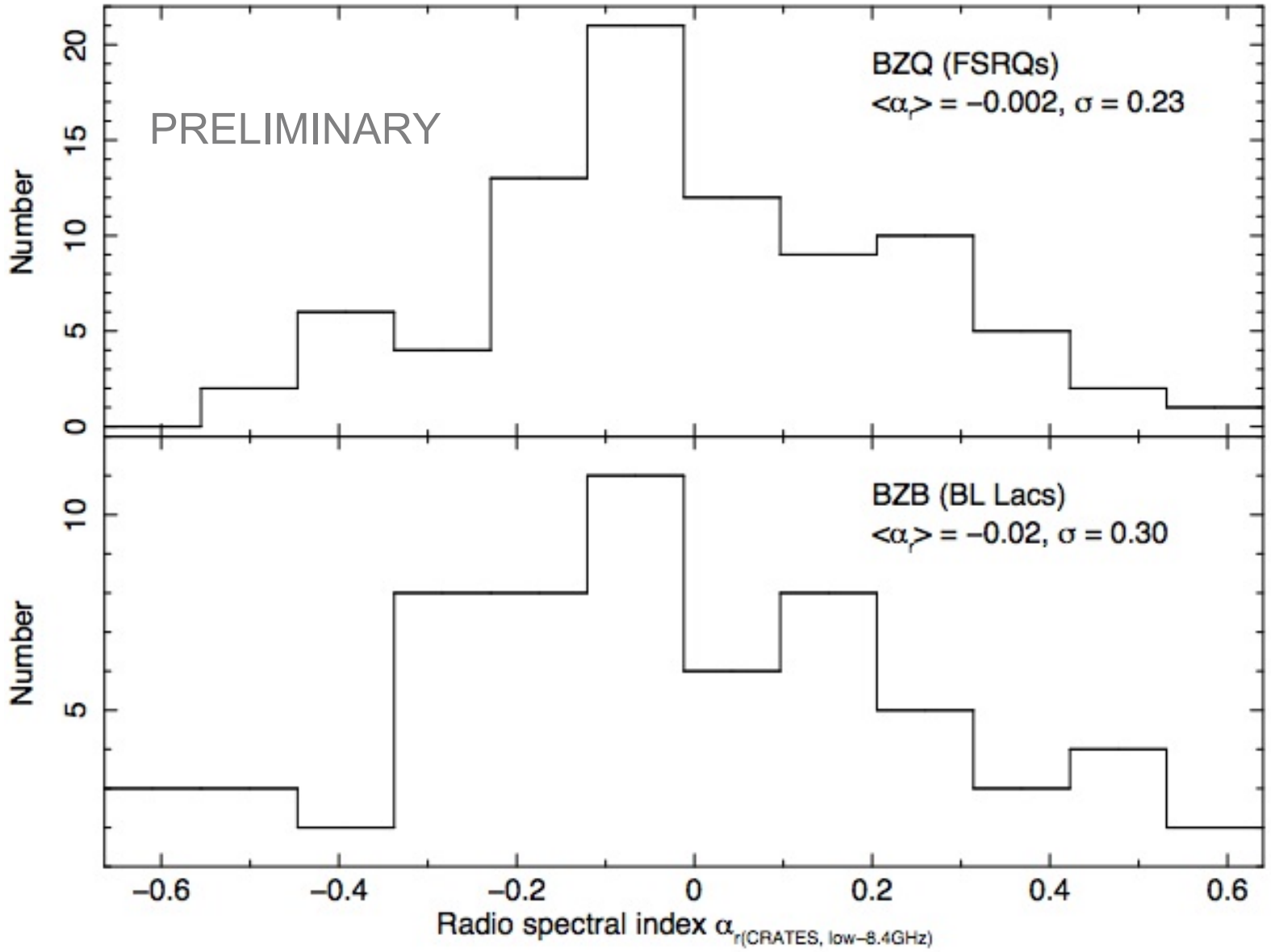
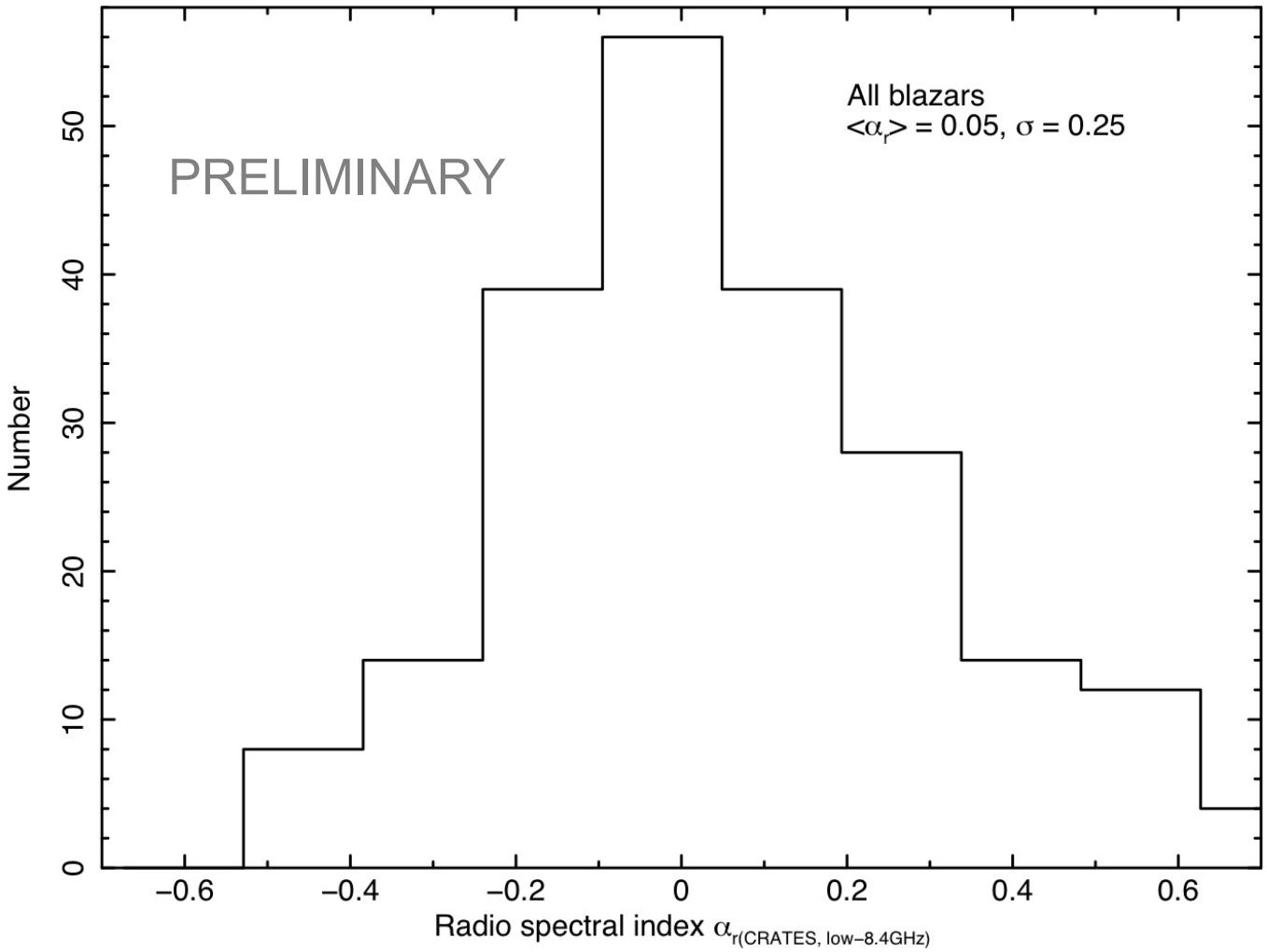


Fig. 32.— The distribution of synchrotron peak energy for the sample of LBAS FSRQ (solid line, top panel) and BL Lacs (solid line, bottom panel) compared to that of the sample of X-ray selected blazars of the *Einstein* Extended Medium Sensitivity Survey (EMSS, dotted histograms). The EMSS counts have been scaled to match the LBAS sample.

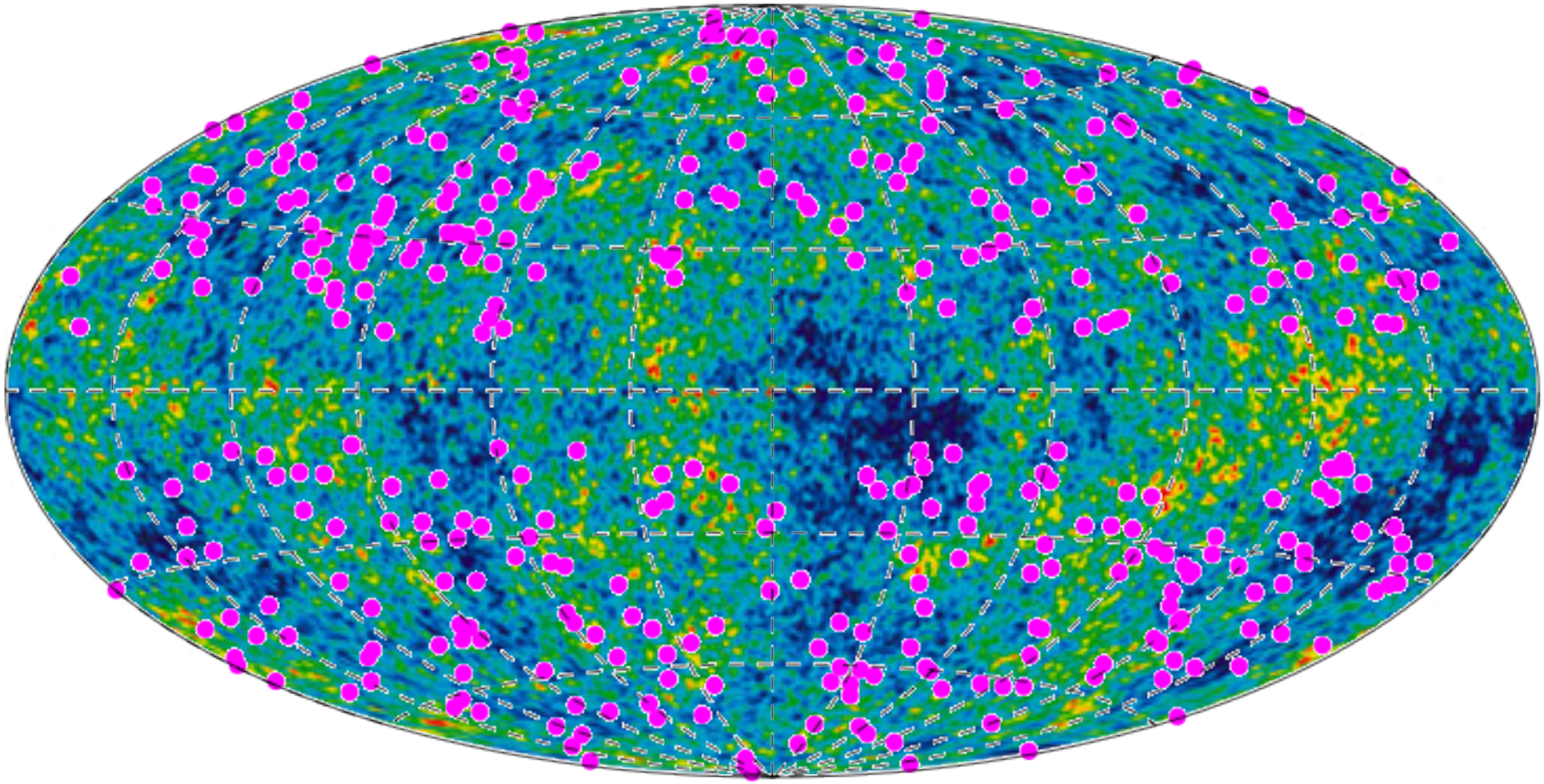
Fermi LBAS


PRELIMINARY
BZQ (FSRQs)
<α_r> = −0.002, σ = 0.23
BZB (BL Lacs)
<α_r> = −0.02, σ = 0.30
Number
Number
0
5
10
15
20
5
10
−0.6
−0.4
−0.2
0
0.2
0.4
0.6
Radio spectral index α_r(CRATES, low−8.4GHz)

WMAP-5yr foreground Blazars

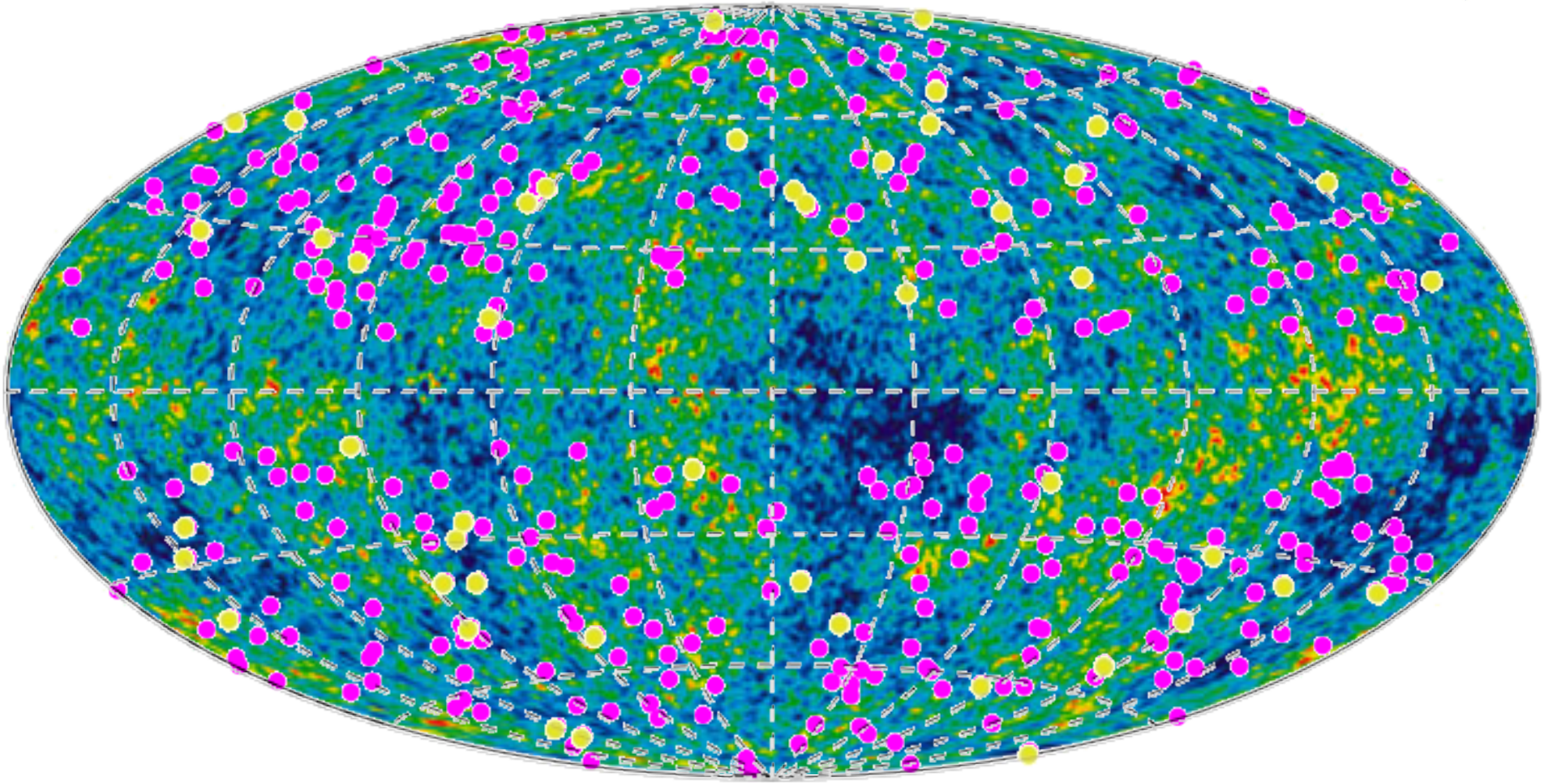


γ-ray vs radio/μ-wave selected samples



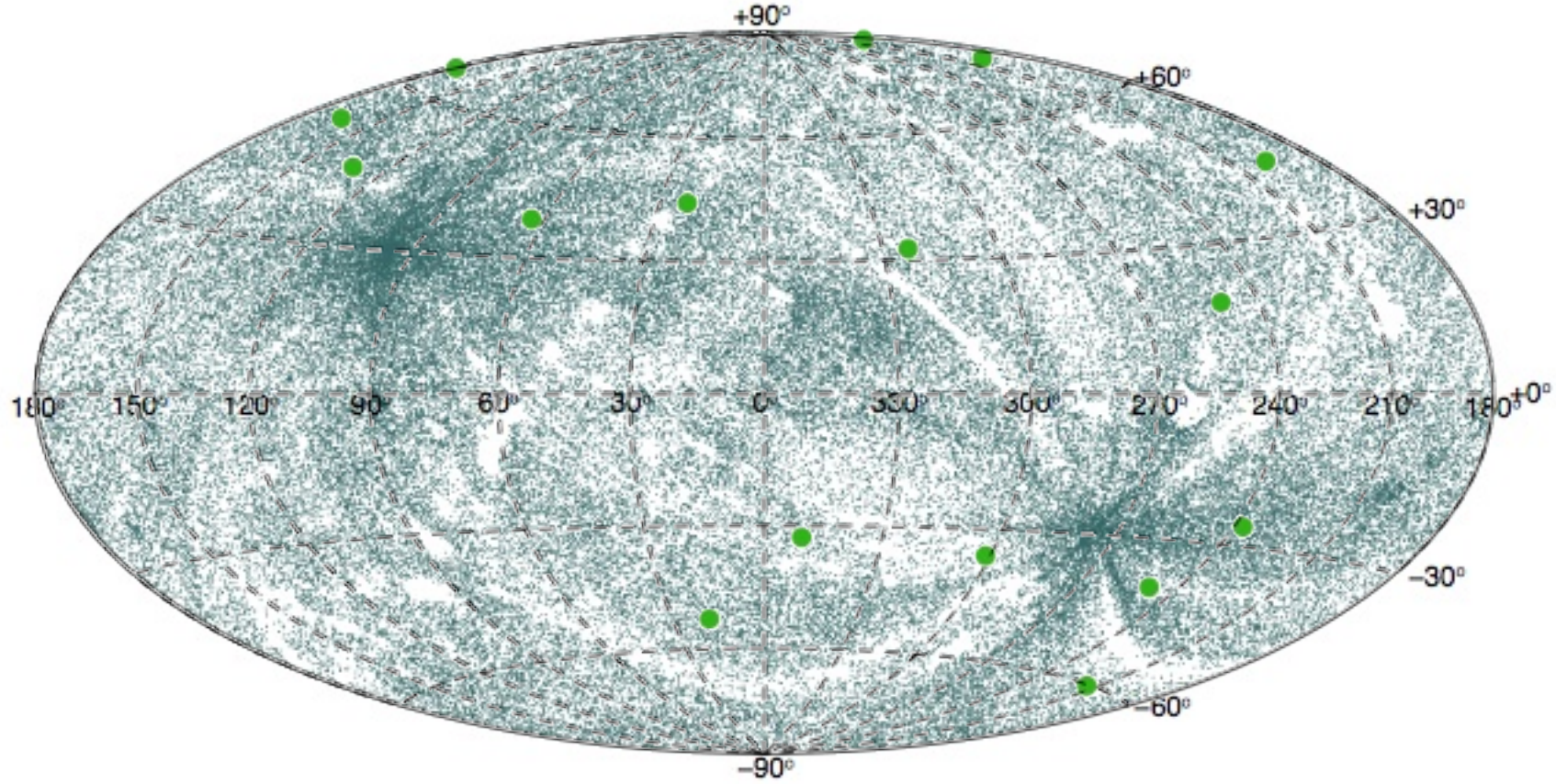
WMAP-5yr data

γ-ray vs radio/μ-wave selected samples



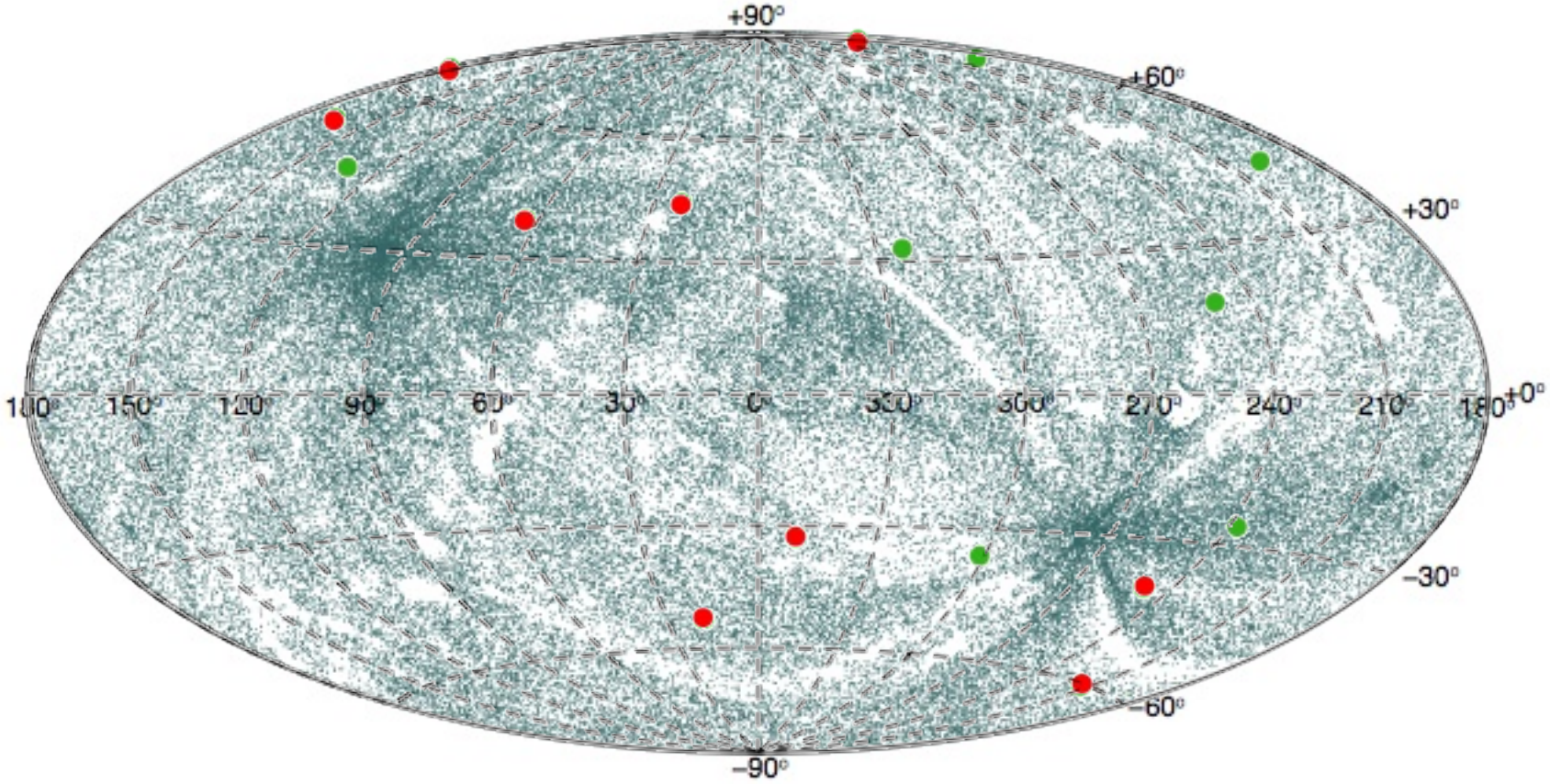
WMAP-5yr data

γ-ray vs x-ray selected samples

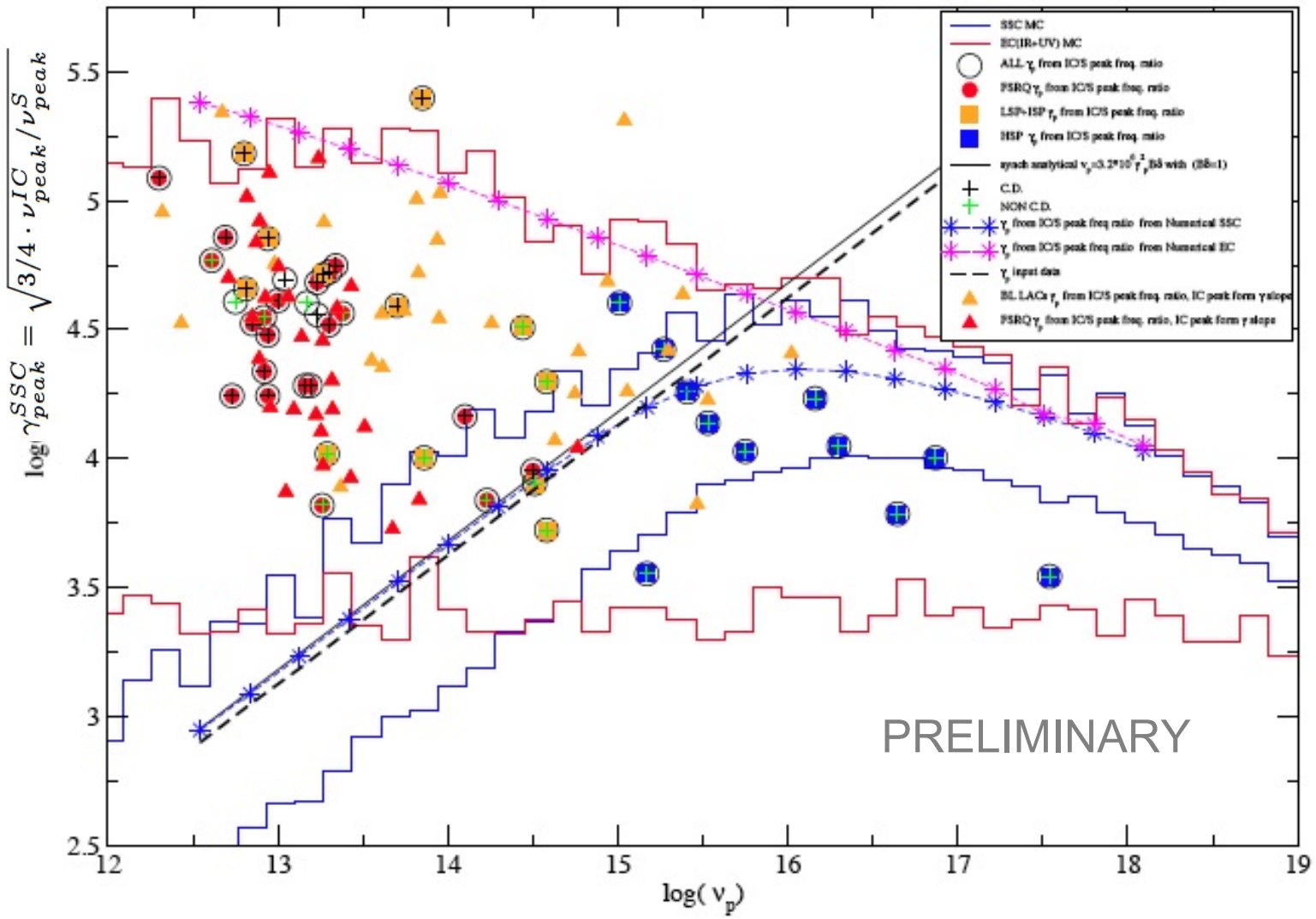


ROSAT All Sky Survey

γ-ray vs x-ray selected samples



ROSAT All Sky Survey


SSC MC
EC(IR+UV) MC
ALL γ_p from IC/S peak freq. ratio
FSRQ γ_p from IC/S peak freq. ratio
LSP+ISP γ_p from IC/S peak freq. ratio
HSP γ_p from IC/S peak freq. ratio
synch analytical $\nu_s=3.2*10^6\gamma_p^2\delta B$ with ($\delta B=1$)
C.D.
NON C.D.
γ_p from IC/S peak freq ratio from Numerical SSC
γ_p from IC/S peak freq ratio from Numerical EC
γ_p input data
BL LACs γ_p from IC/S peak freq. ratio, IC peak form γ slope
FSRQ γ_p from IC/S peak freq. ratio, IC peak form γ slope
$\log \gamma_{peak}^{SSC} = \sqrt{3/4 \cdot \nu_{peak}^{IC}/\nu_{peak}^{S}}$
$\log(\nu_p)$
PRELIMINARY

Conclusions-1

- We have assembled high-quality quasi-simultaneous SED of 48 LBAS blazars. This subset is representative of the entire LBAS
- All Fermi bright blazars have broad-band spectral properties similar to radio and X-ray selected blazars (double bump SEDs, same area of aox-aro plane, but no UHBLs… so far)
- We have estimated the syncrhotron and "iC" peak energy and intensities for all 106 sources in the sample.
- The distribution of synchrotron and "i-Compton" ν_{peak} distributions are very different for FSRQs and BL Lacs.
  - FSRQs ν^{S}_{peak} values range between $10^{12.5}$ Hz and $10^{14.5}$ Hz
  - BL Lacs ν^{S}_{peak} values range between 10^{13} Hz and 10^{17} Hz
- There is a strong correlation between both ν^{S}_{peak}, ν^{iC}_{peak} and the gamma-ray spectral slope
- The overabundance of HBL (HSP) BL Lac is a selection effect similar to what experienced in the X-ray band

Conclusions-2

- HBL (HSP) BL Lacs radiate close to the predictions of simple one-zone SSC models
- Over 50% of known HSP BL Lacs (fr > 300 mJy) are detected as bright Fermi sources.
- LBAS FSRQs and LBL/LSP BL Lacs (all LSPs) emit much more gamma-rays than predicted by SSC, requiring additional mechanism (e.g. EC, or multiple components)
- However, only ~13% of FSRQs brighter than 500 mJy in the Bzcat or in WMAP-5yr catalogs are detected in LBAS, despite having similar properties (same redshift, Vmag, ν^{S}_{peak} distributions etc). It is therefore possible/probable that the majority of FSRQs actually radiate not too far from simple SSC.