Investigating the Blazar Sequence with the LAT

Benoît Lott

Science Goals: specific issues investigated with a few bright sources

Issue	Approach	Targets	Data (quality)
Jet structure/ composition: innermost part (ionic,e^+e^-,Poynting flux)	Search for "X-ray pre-cursors" to γ-flares, time delays (reveal e^+e^- content)	flaring bright blazars	soft X-ray, pre- to post-flare (~2 weeks, sample every 3 hrs)
Jet structure/ composition: γ-ray emitting part (pe^-,e^+e^-,B)	Identify operating radiation processes via broadband modeling with state-of-the-art emission models leptonic vs hadronic models?	bright variable FSRQs, LBLs	Simultaneous broadband SED + variable info (hysteresis, light curve, flare profiles)
	Estimate total jet luminosity: $U_{particle} + U_B + U_{kin,jet}$	blazars that are hard X-ray sources	hard X, soft γ–ray data
	Search for neutron-decay/cascade features	flaring bright QSOs, HBLs, radio galaxies	X and TeV; multi–λ at most highly variable synchrotron flares
Location of γ-ray production site	LE/HE cospatial/single zone? - measure lags of IR/opt/UV/X-ray/TeV to γ-rays	flaring HBLs	Simultaneous monitoring in IR/opt/UV/X-ray/TeV to temporally resolve flares
Location of energization site	$\tau_{\gamma\gamma}$ to set minimum distance of emitting region from black hole, and Γ_{bulk}	FSRQs	correlated X-ray
γ-ray flare production: importance of external photon fields	Measure of putative target photon fields (BLR, torus, accretion disk)	FSRQs, LBLs	BLR line strength during γ–activity
γ-ray flare production: relation to U_B dissipation	Modeling of correlated variability behavior between opt-GeV,X-TeV	flaring bright blazars	Simultaneous monitoring in IR/opt/UV/X to temporally resolve flare, long data trains
	Polarization behavior near LE-peak at time of γ-flare	bright QSOs with peak at IR/optical	Optical polarization at hour temporal resolution

Anita Reimer
Greg Madejski

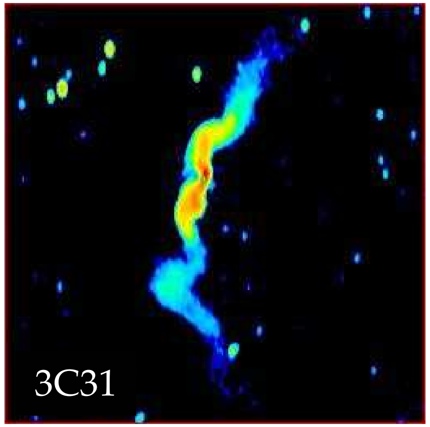
"Blazar Sequence": blazars as a population
long-term evolution of AGNs, history of galaxies
physical parameters driving this evolution?

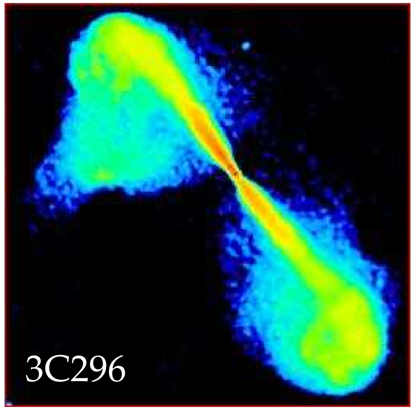
Radio-Loud AGNs

Elliptical or "disturbed" galaxies, exhibiting prominent radio lobes

Fanarov-Riley I

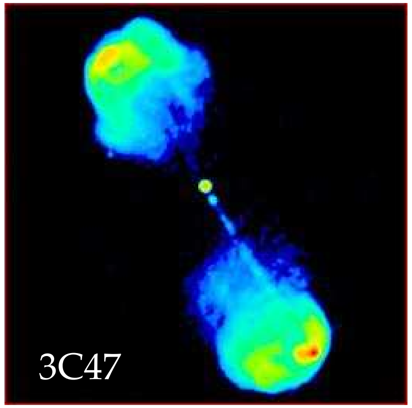
Emission peaks near the center
less–collimated jets, no hot spot
lower power (L_{radio} < 10^{42} erg/s)

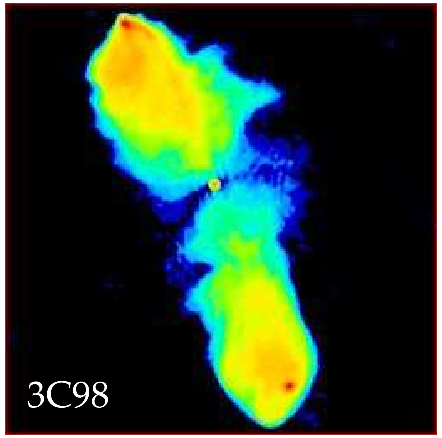




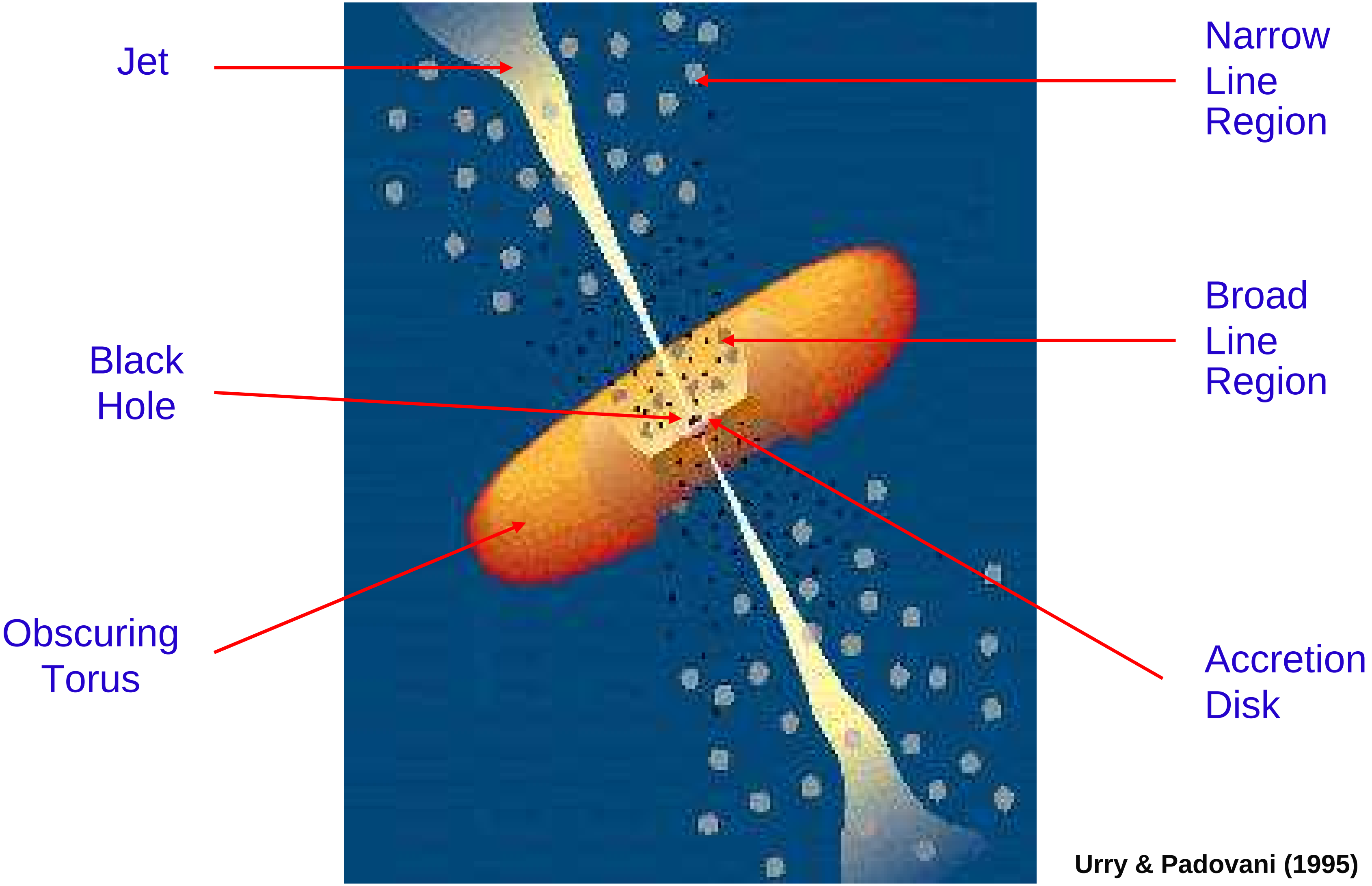
Fanarov-Riley II

Bright outer edges, hot spots
well–collimated jets, still relativistic in lobes,
high power: L_{radio} >10^{42} erg/s
emission lines 10 times brighter than FRI





Active Galaxy Nucleus



Urry & Padovani (1995)

Blazars

Relativistic jet aligned with the direction of sight!

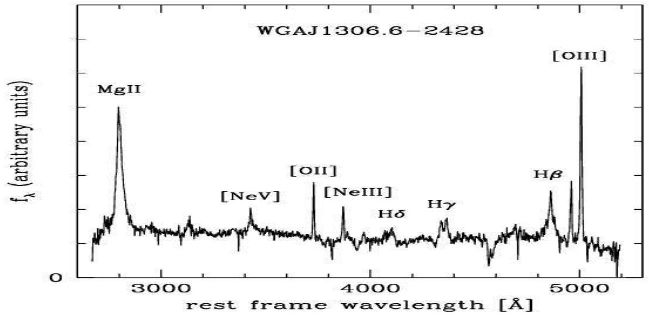
Two flavors: FSRQs and BLLacs

Common properties

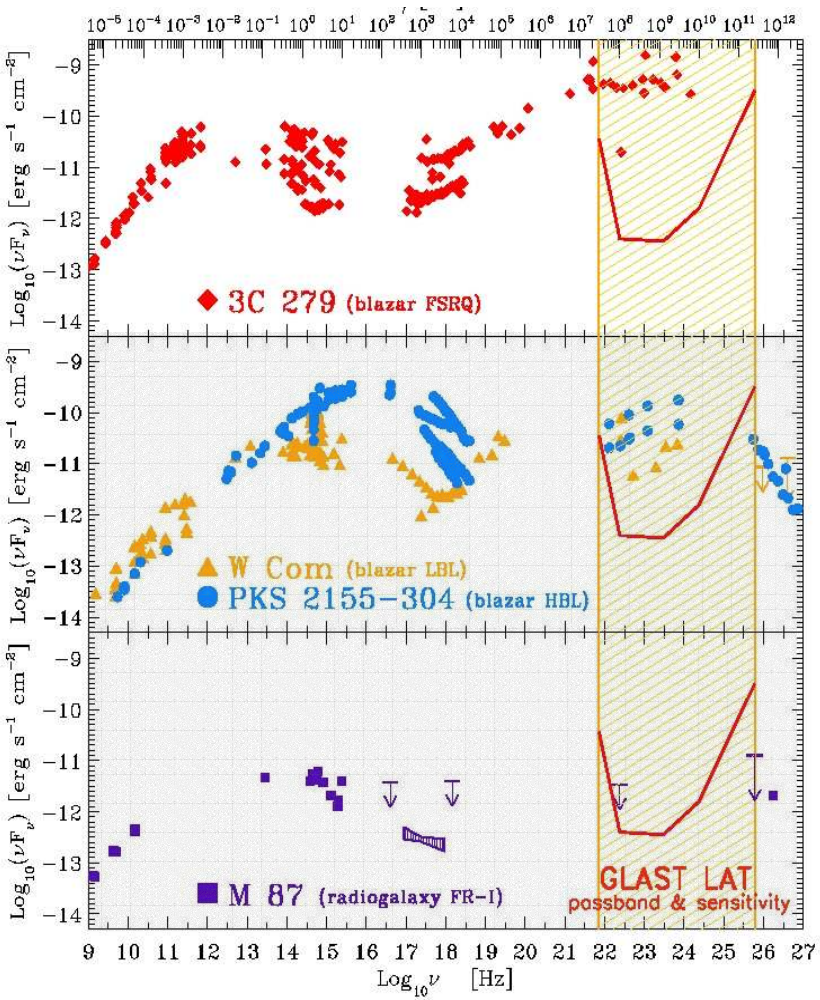
- Smooth, broad, non-thermal continuum (radio to γ-rays)
- Compact, flat-spectrum ($\alpha_r < 0.5$) radio sources ($f_{core} >> f_{extended}$)
- Rapid variability (high $\Delta L/\Delta t$), high and variable polarization ($P_{opt} > 3\%$)
- Superluminal motion
- Indication of "beaming": strong flux amplification
- Similar "two-hump" spectral energy distributions (SEDs)

FSRQs

- Defining property:
  strong emission lines ⇒ dense broad line region clouds (equivalent width EW >5 Å)



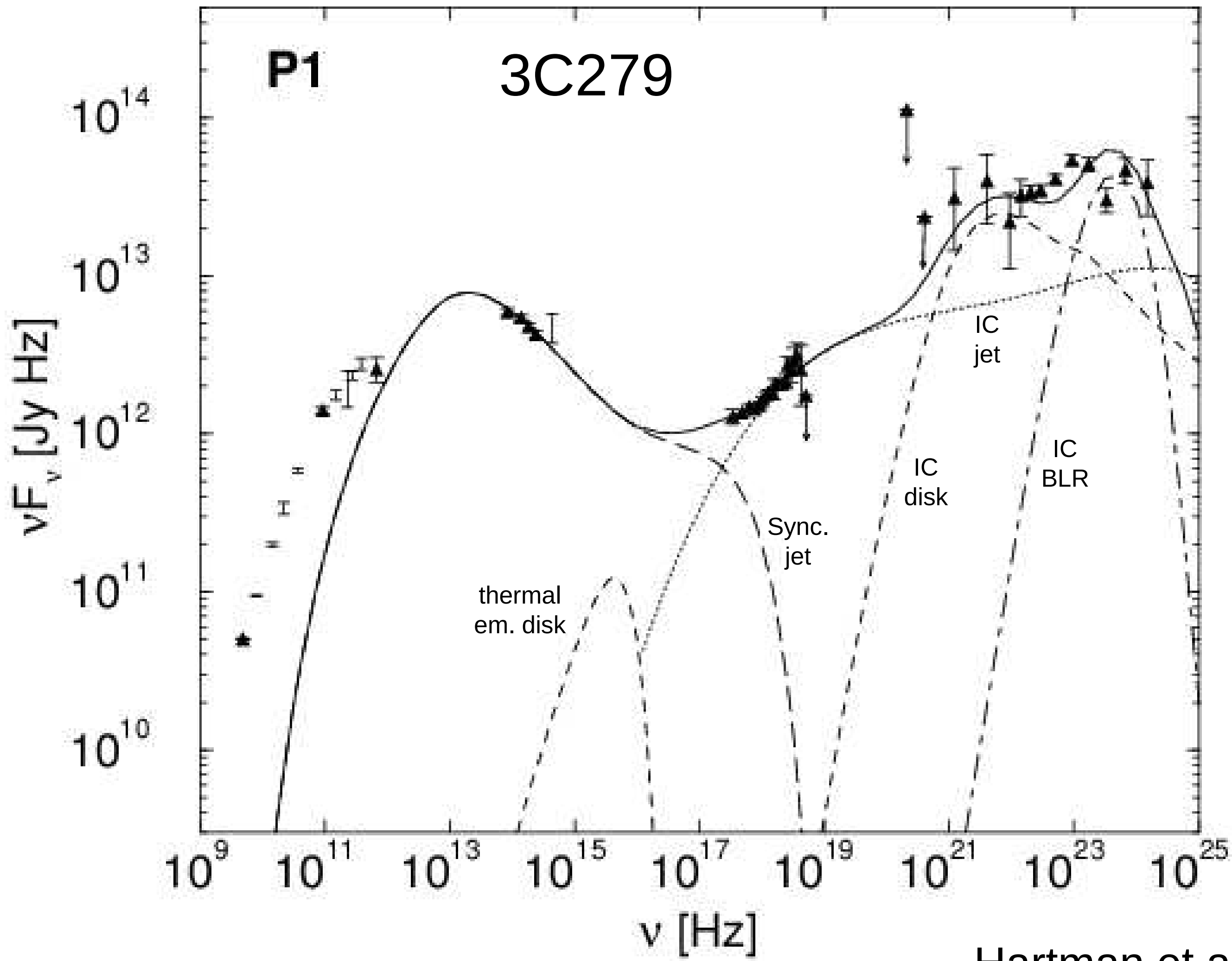
- Parent population: FR II
 (“Unification”, Urry and Padovani)
- High power (~$10^{46\text{-}48}$ erg/s)
- Low ν_{peak} (IR)
- Possible presence of a “Blue bump” (thermal emission from the disk)
- 46 FSRQs in 3EG catalog
  high redshift 0.1 < z < 2.3
- External Compton model (including external radiation fields) needed to account for the SEDs



Stefano Ciprini

3C279 SED

EGRET MW campaign

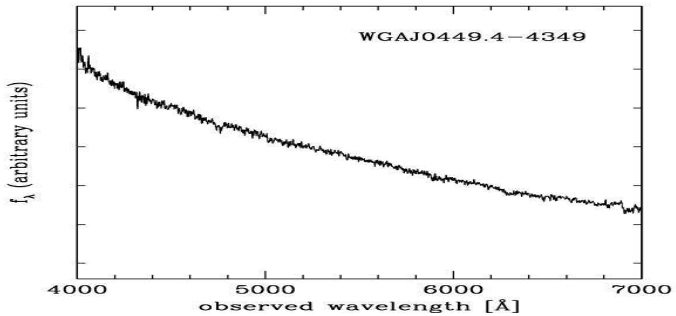


Hartman et al. 1999

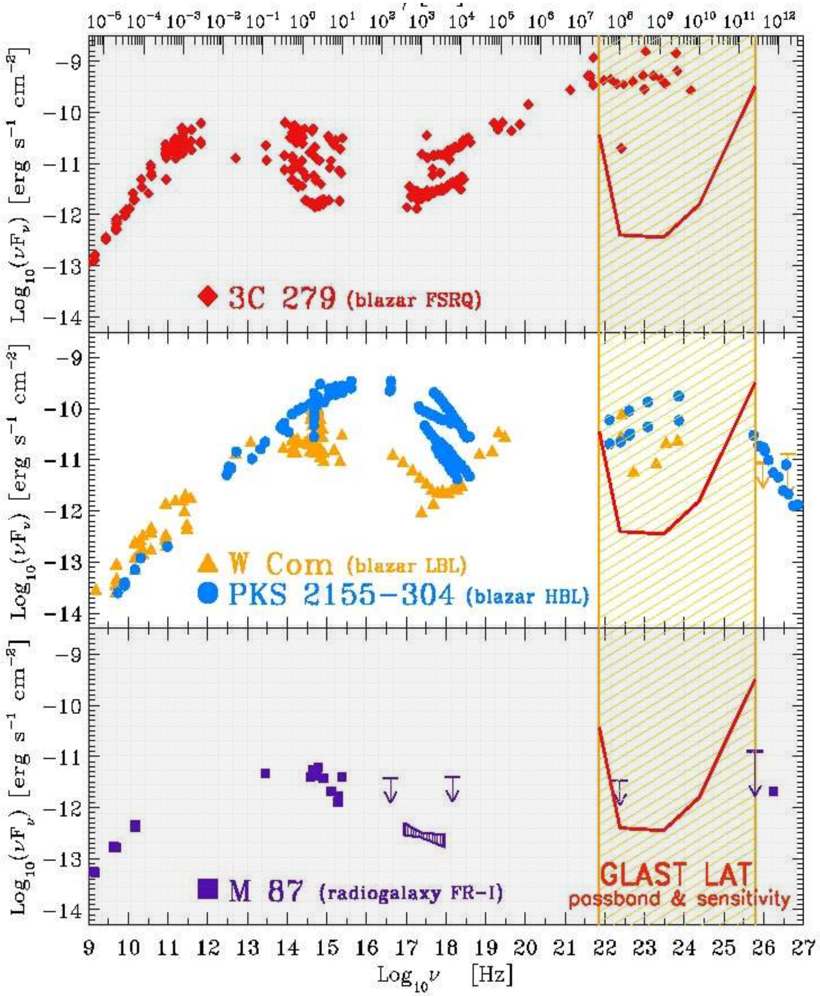
BLLacs

- Defining property:

nearly lineless (EW < 5 Å) ⇒ dilute surrounding gas



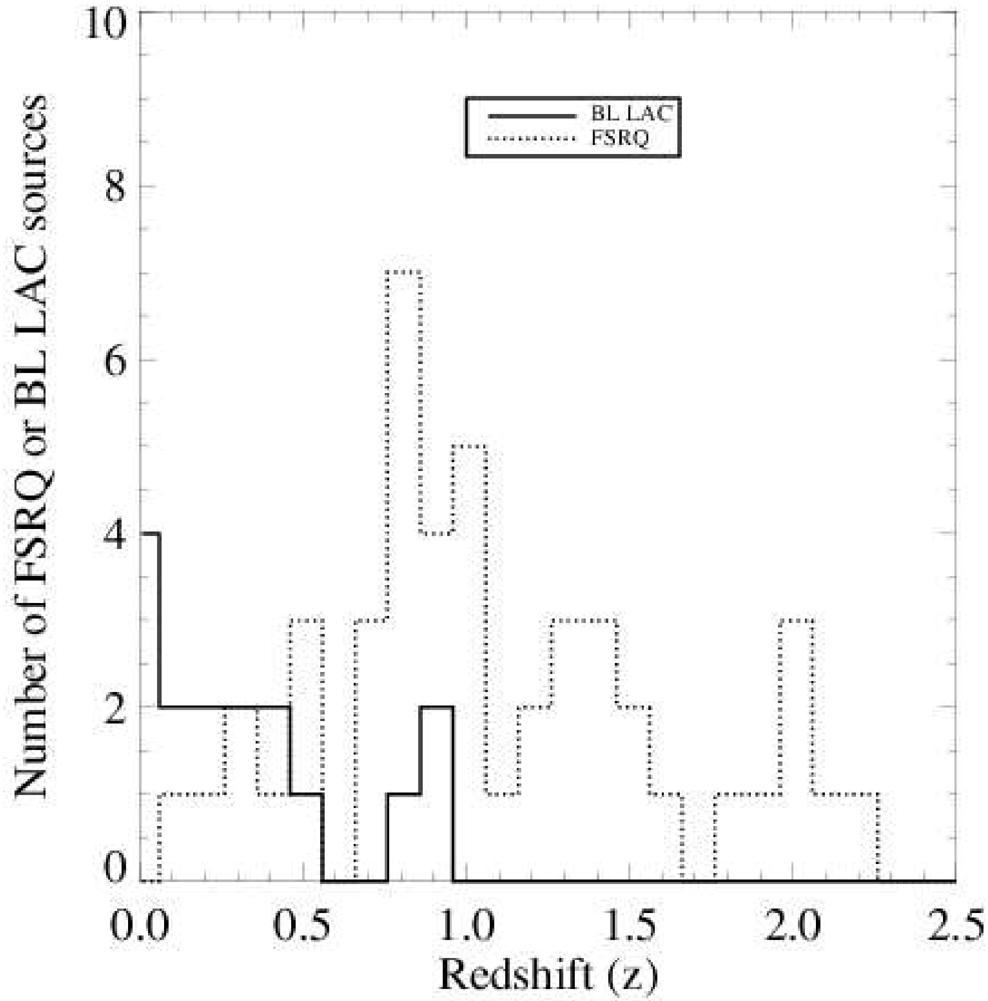
- "Low" power (~$10^{45\text{-}46}$ erg/s)
- Parent population: FR I ("Unification")
- Low ν_{peak} (Opt/IR): LBL
  High ν_{peak} (UV/X-rays): HBL (TeV)
- 14 BLLacs in 3EG catalog, 0< z < 0.9
- SSC models "mostly able" to reproduce SEDs



Classification of an object may change with time (ex: BLLac)

Stefano Ciprini

Redshift distribution for 3EG Blazars



Mukherjee et al. 1999

Candidate Gamma-Ray Blazar Survey

S. Healey,
R. Romani et al.

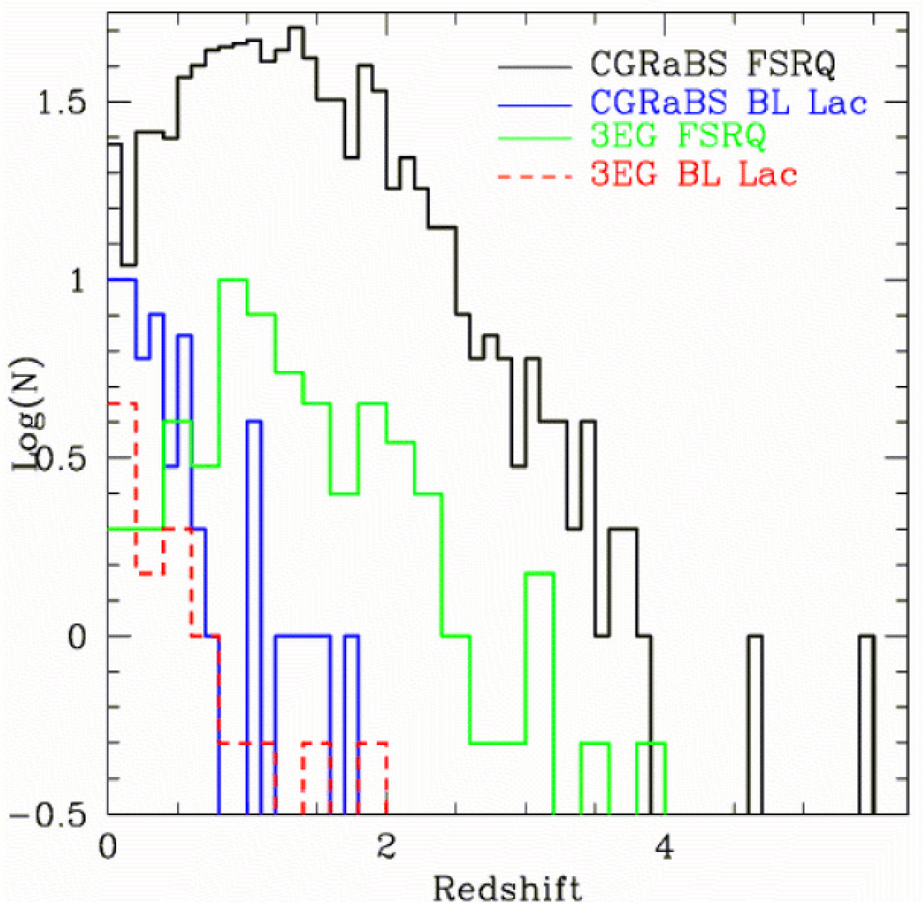
Radio + Optical Survey

Use FoM ($S_{8.4}$,α,S_X)

~ 1500 candidates

Redshift Distribution – FSRQ/BLL

- High-z tail…
- 3EG
  - 9 z>2.5
  - 5 z>3
- CGRaBS
  - 86 z>2.5
  - 30 z>3



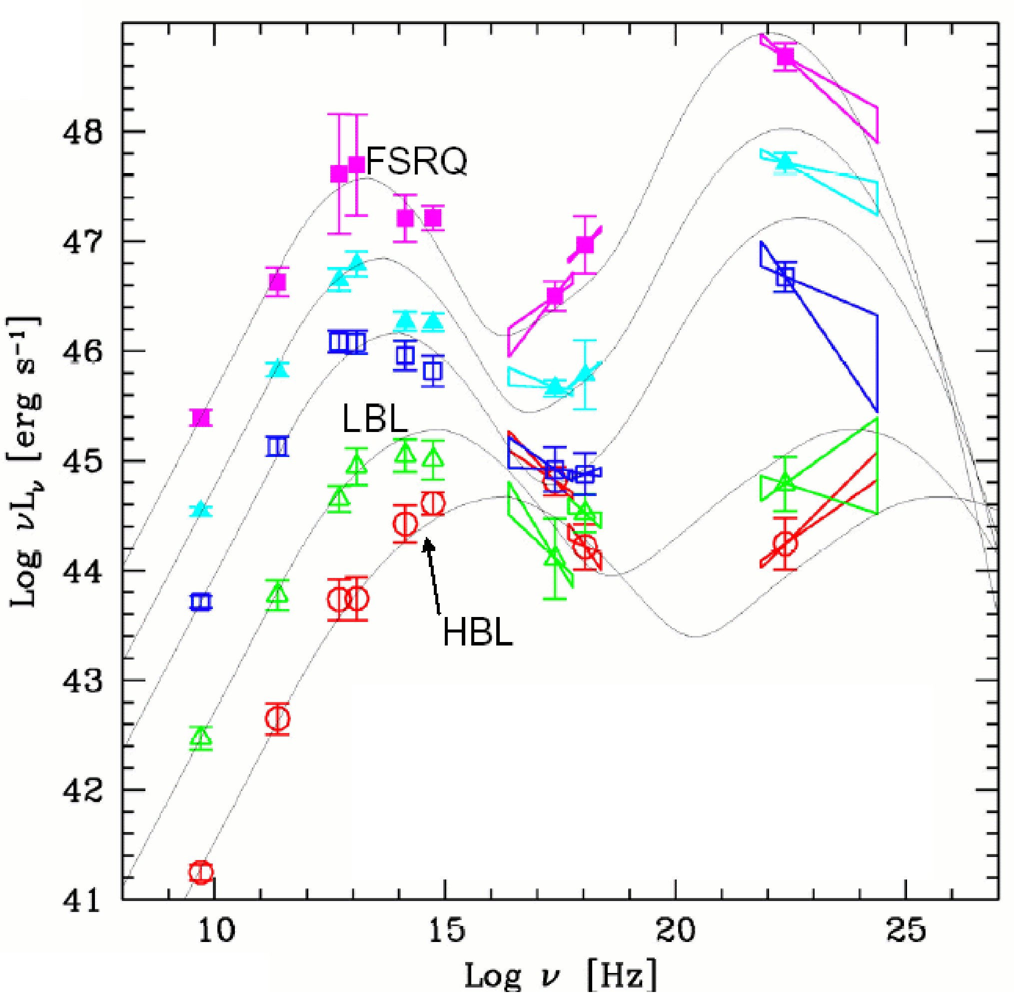
Blazar Sequence: « Grand Unification » (?)

Donato+ (2002) Fossati+(1998)

Average SEDs of blazars binned according to radio luminosity

126 blazars in total
28 with a spectral index measured by EGRET

- $\nu_{peak} \propto L^{-1}$
- ν_{HE} / ν_{LE} =cst
- $L_{HE} \propto L_{radio}$

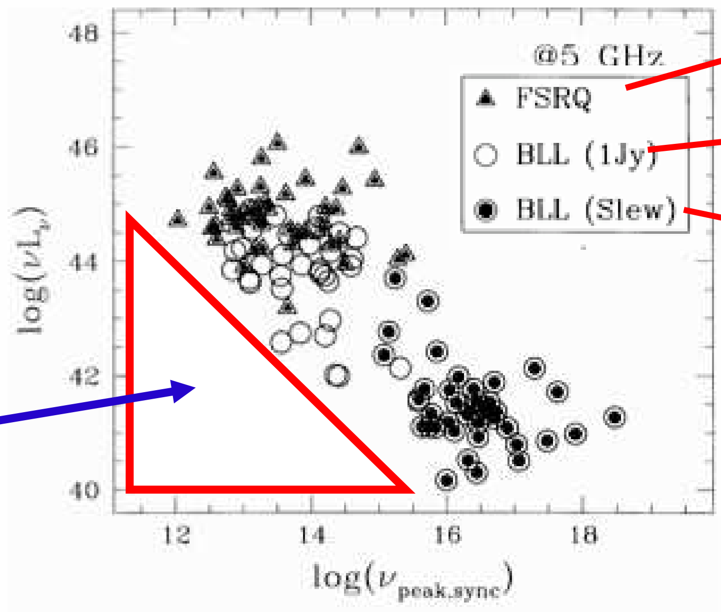


Blazar Sequence: Caveats

1) Small sample, data not taken simultaneously
Opposite trend observed in a flaring source: ν_{peak} might increase with luminosity.

2) No correction for attenuation due to Extragalactic Background Light in HBLs

3) Selection effects potentially present: only radio-selected FSRQs are included



2 Jy, radio-selected

1 Jy, radio-selected

Slew, X-ray-selected

disentangling jet flux from thermal flux from underlying galaxy is hard in this zone

The overall trend does not show up in the 3 samples taken individually.

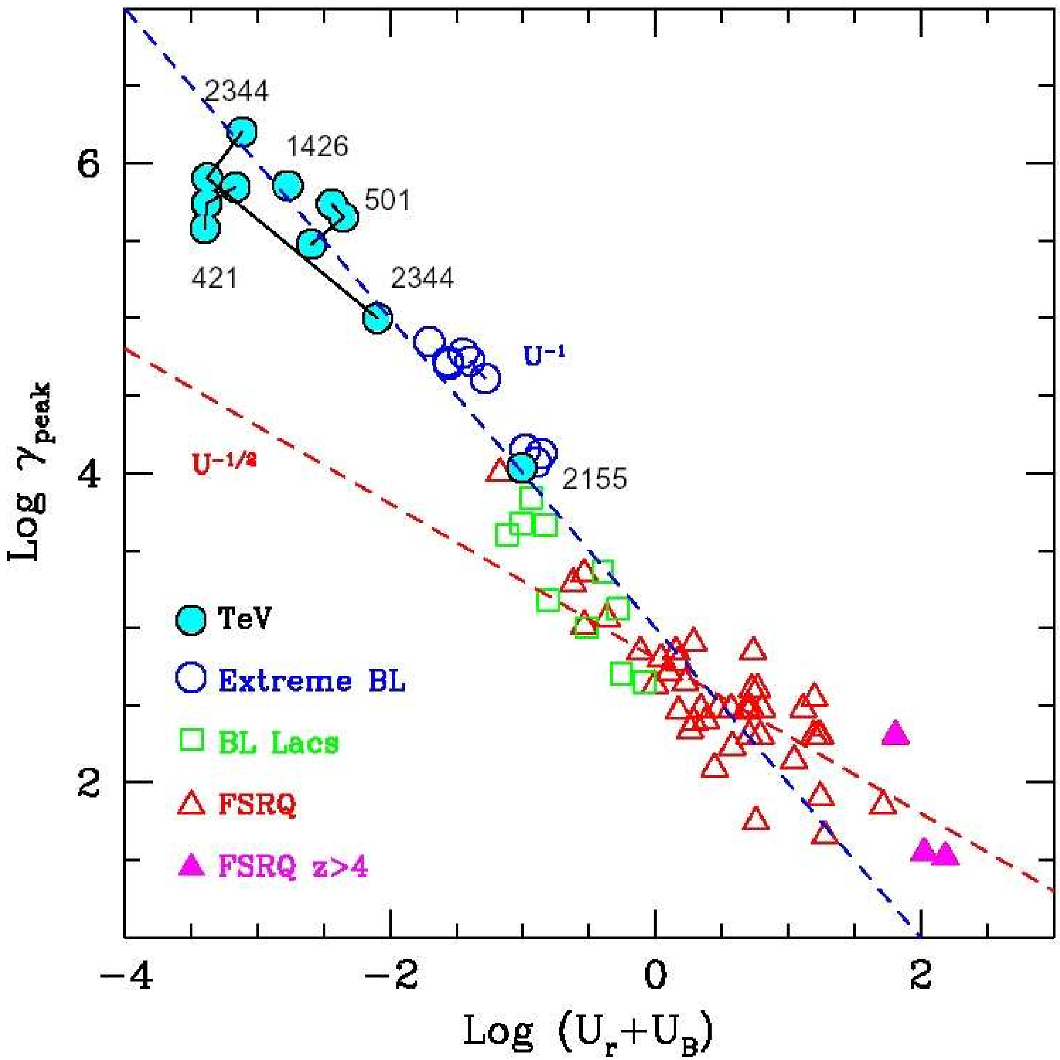
Driving parameter: radiation energy density (?)

$\nu_{peak} \propto B\delta\gamma^2_{peak}$

γ_{peak} for the electrons determined by the balance between acceleration and cooling processes (synchroton+IC)

Greater U_r : more cooling
→ lower γ_{peak}
→ greater L_{HE}

HFSRQs, if they exist, would not fit in this trend



Ghisellini et al. 2002

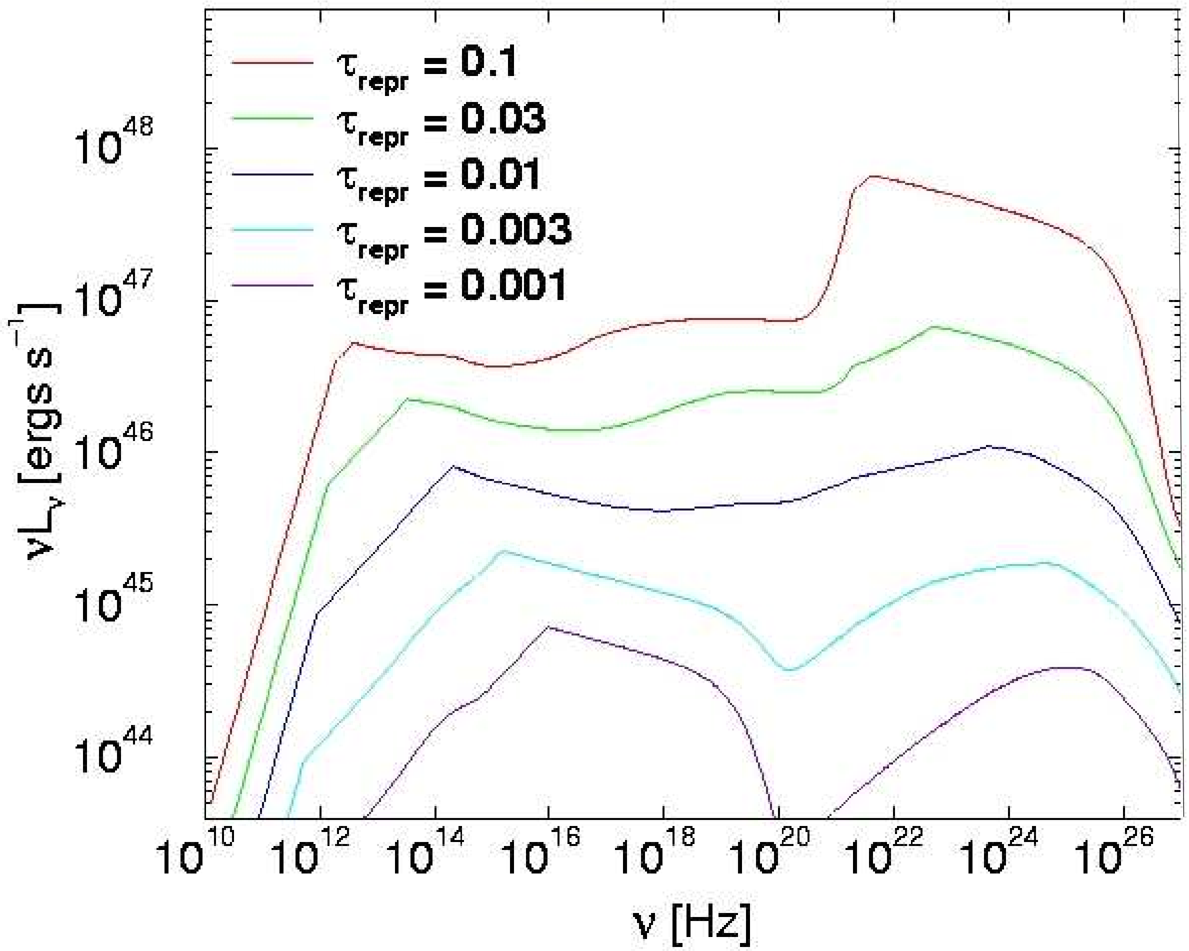
Evolutionary sequence

Other authors as well:
D'Elia & Cavaliere, Maraschi et al. Böttcher & Dermer 2002

Evolutionary link
FSRQ→ LBL→ HBL
via
reduction of the
accretion rate
$\dot{M}/M_{Edd}$
("1D- problem")

Consequence:
BH mass in BLLacs
should be greater than
in FSRQs.

Current data don't
confirm this trend.



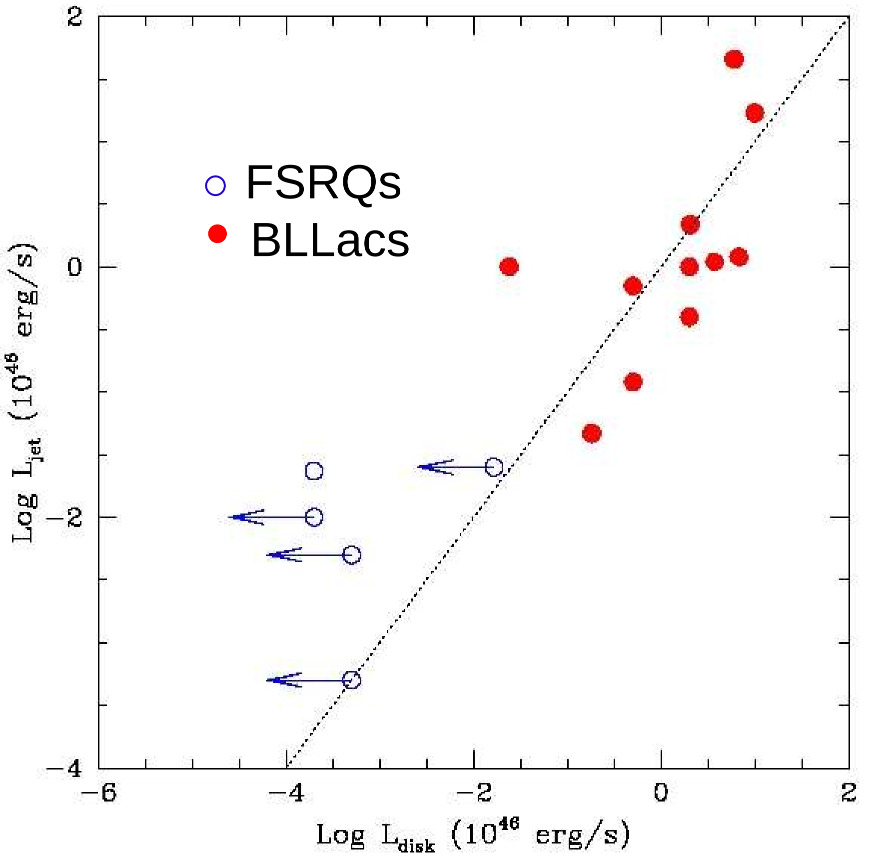
τ_{repr}= reprocessing optical depth (α L_{disk} in the model)

Disk luminosity

L_{jet} estimated by modeling the SEDs

L_{disk} estimated from Blue Bump or Boad Lines

Observation:
BLLac disks are underluminous as compared to FSRQs'.



Maraschi & Tavecchio 2003

Disk models

Standard “α” disk (Shakura & Sunyaev 1973): Geometrically thin, optically thick

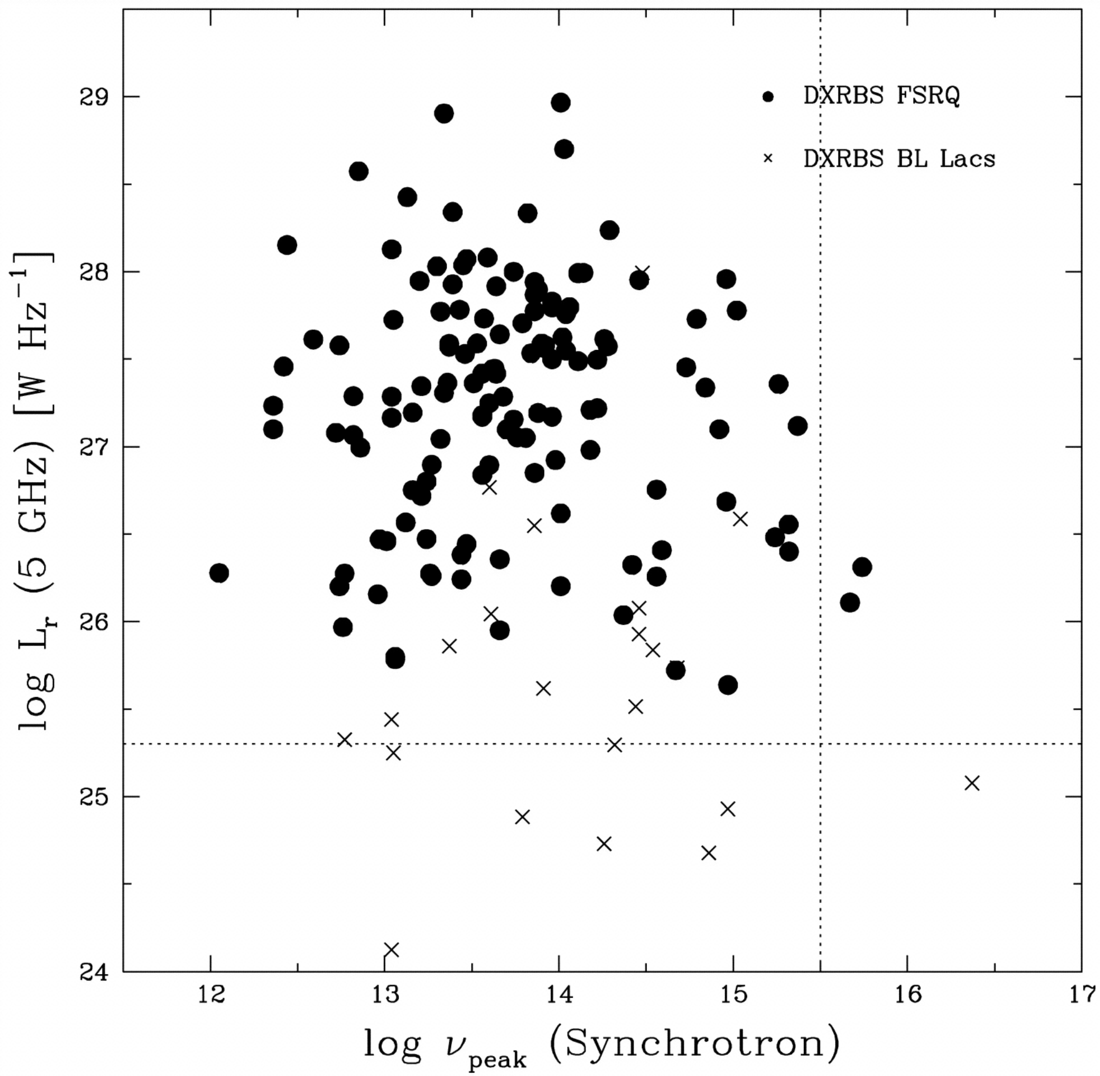
Low accretion rate, high temperature, low luminosity:
Heat energy generated by viscosity stored in gas, advected into the BH (not radiated)

ADAF (Advection-Dominated Accretion Flow, Narayan & Yi 1994)
ADIOS (Advection-Dominated Inflow-Outflow Solutions, Blanford & Begelman 1999, wind blows away part of the accreting mass)
Geometrically thick disk (gas “puffs up”)
Two-temperature plasma: $T_p >> T_e$ electrons cool efficiently, protons don’t

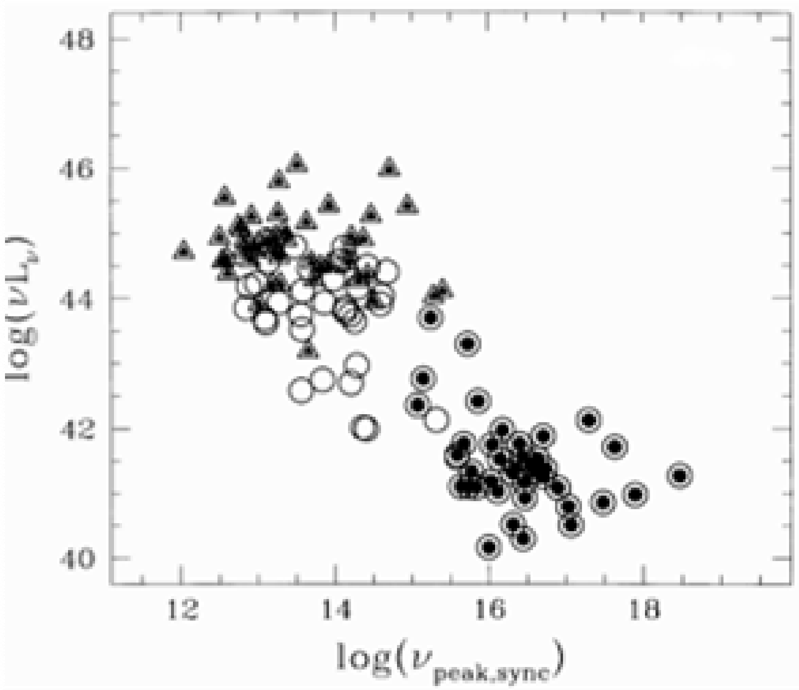
ADAF/ADIOS could be very common at low accretion rate (X-ray binaries, SgrA*) and present in BLLacs

ADAF/ADIOS offer favorable conditions for the launch of a jet:
- some particles are not bound (Bernouilli parameter is positive);
- a low radiation field is less likely to “quench” a jet via Coulomb-drag.

The Power – ν_{peak} correlation



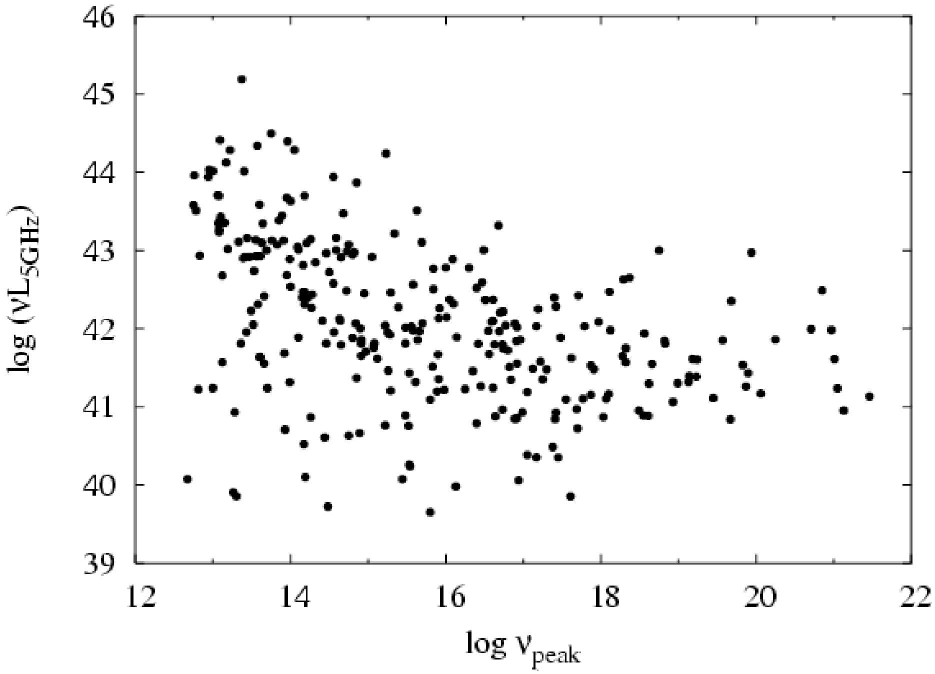
Deep X-Ray Radio Blazar Survey (**DXRBS**)
Padovani et al. (2003)



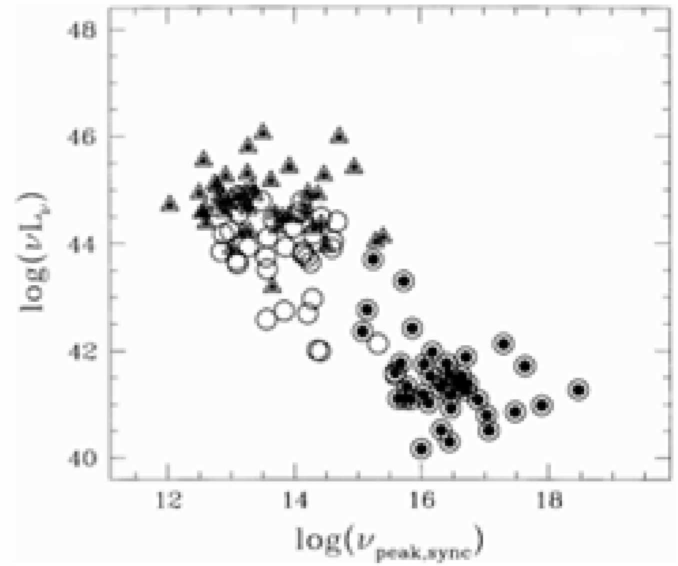
“No correlation, huge scatter, outliers”

From P. Padovani (Barcelona 2006)

New BLLac surveys



Nieppola et al. (2006)



Fossati et al. (1998)

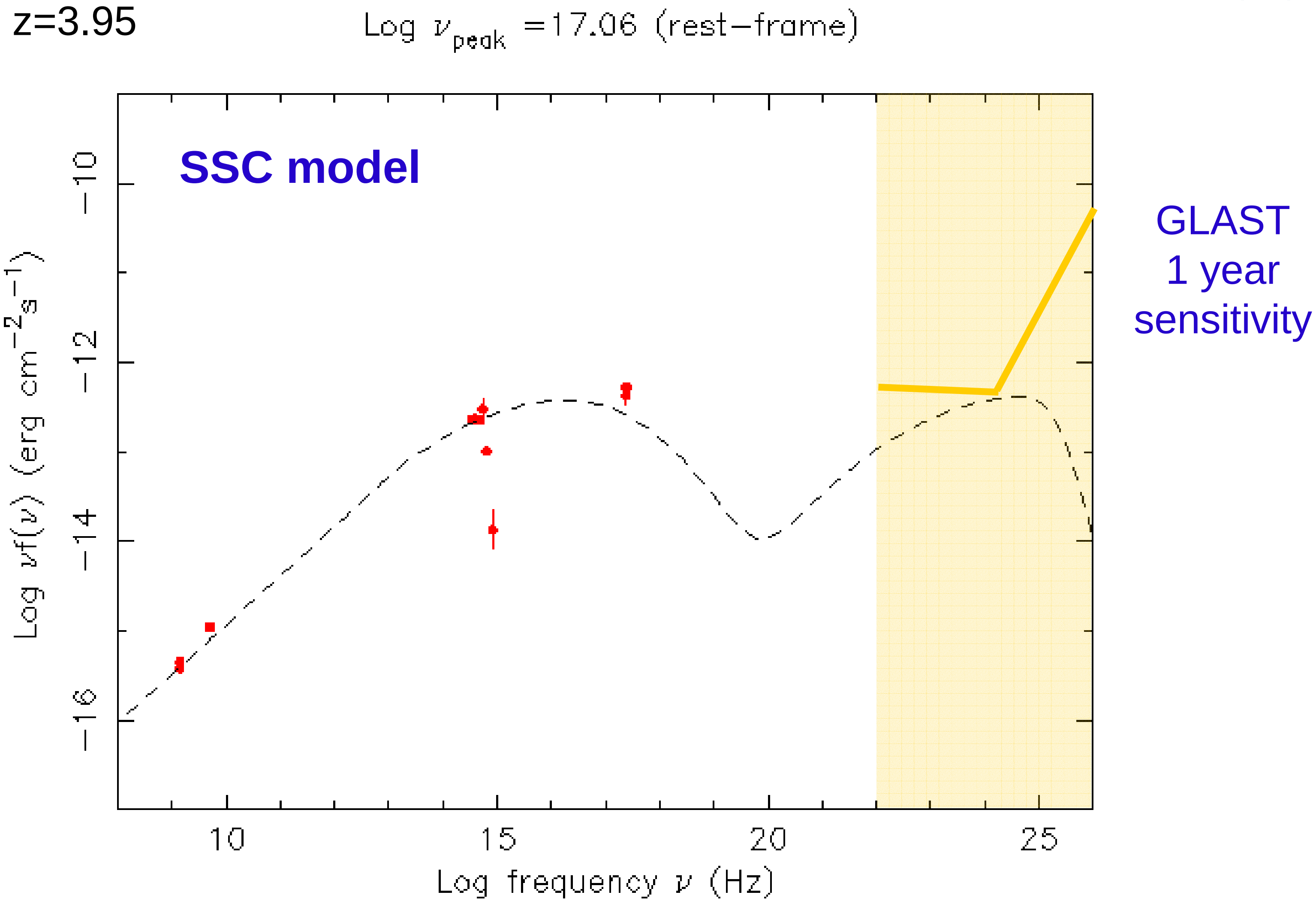
“This is the first time the SEDs of BL Lacs have been studied with a sample of over 300 objects. (…) On the grounds of our results we conclude that the blazar sequence scenario is not valid.”

From P. Padovani (Barcelona 2006)

The search for HFSRQs: ROXA J081009.9+84757.0

Giommi et al. in prep.

z=3.95



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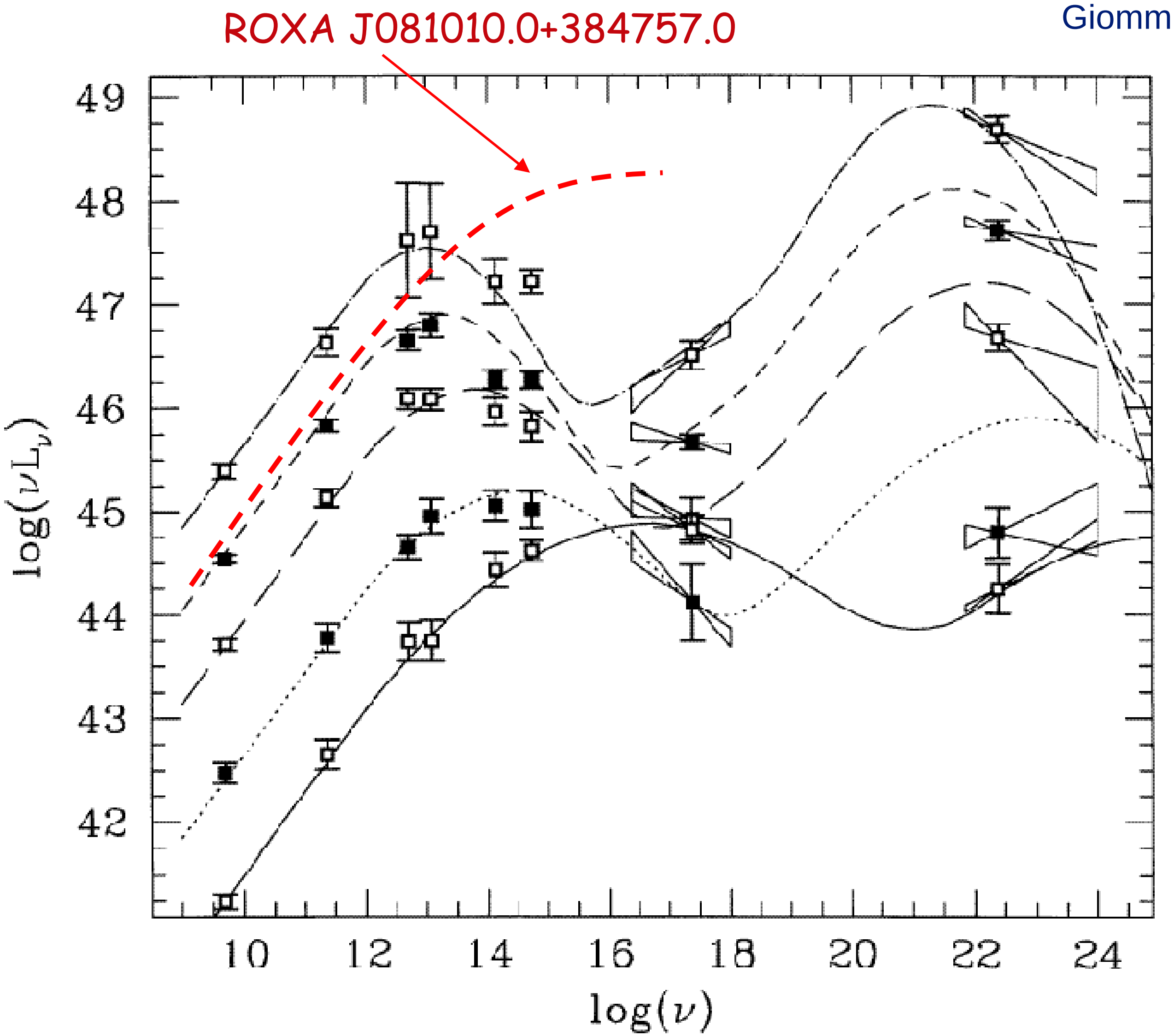
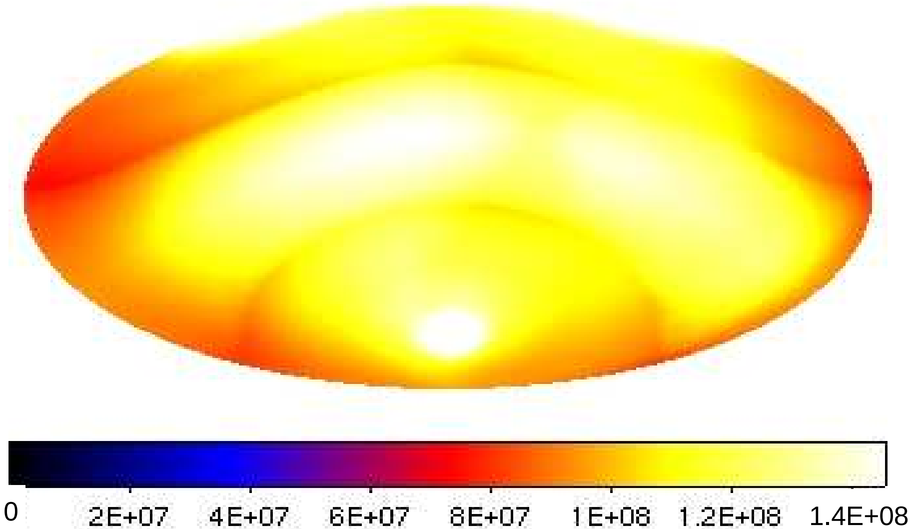
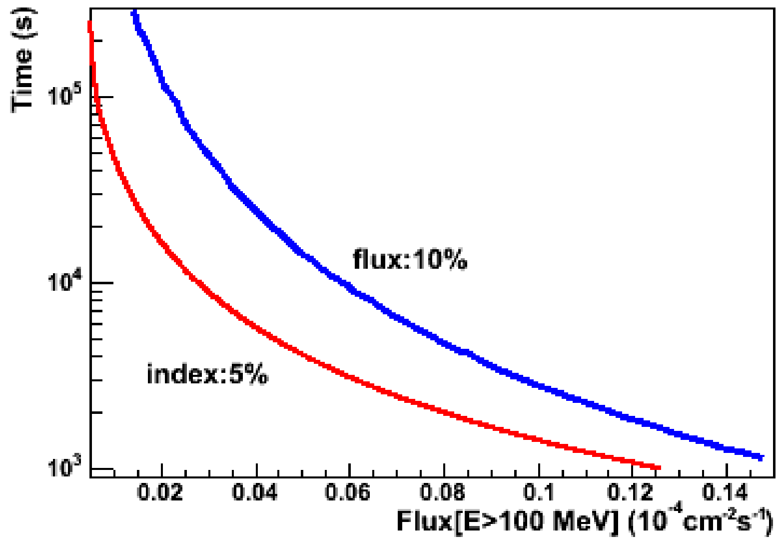


GLAST assets

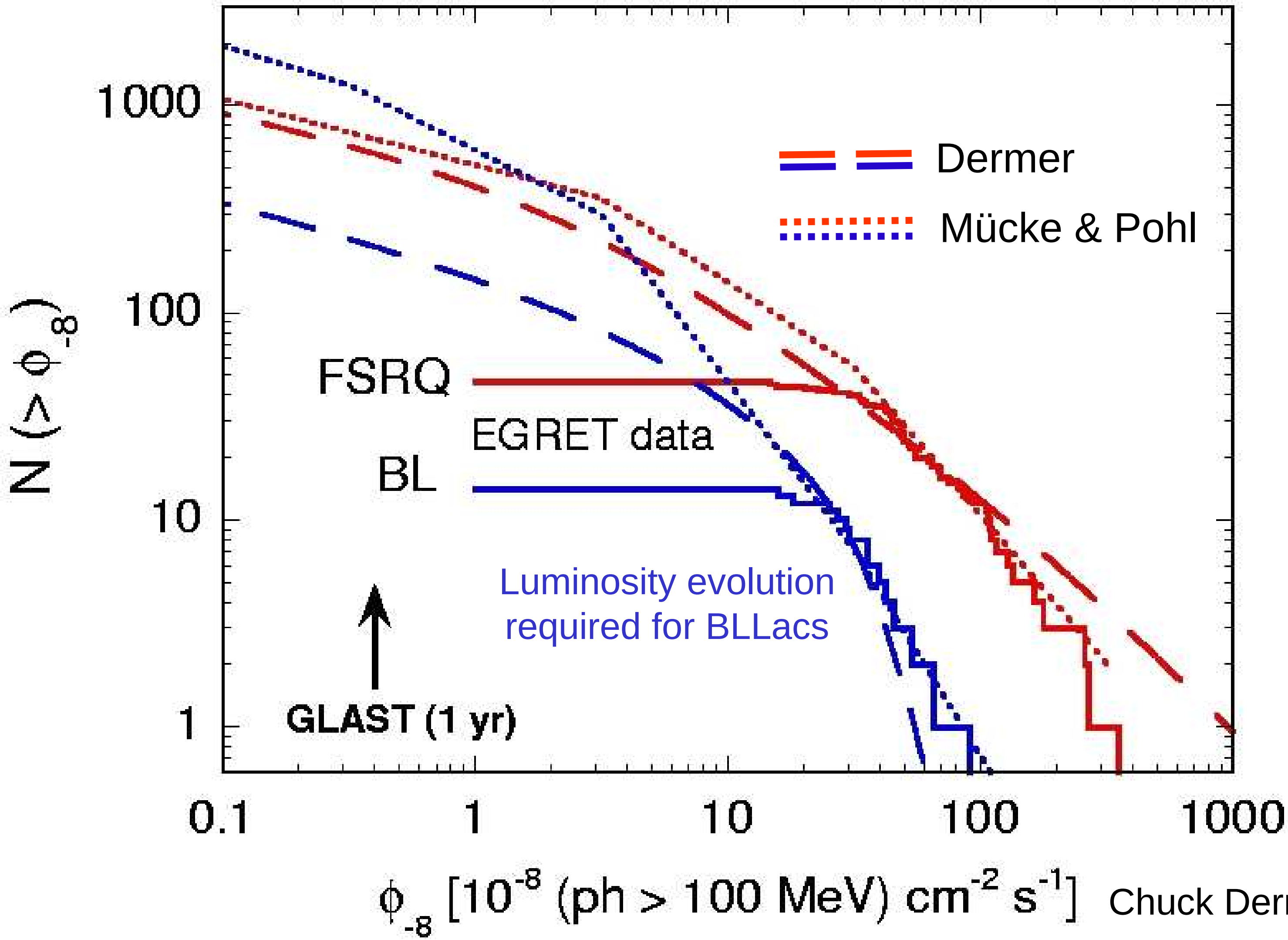
uniform exposure in survey mode
uniform sensitivity
good completeness of sample





“Short” sampling time
~ 20 minutes for bright flares

Blazar LogN-Log S



Chuck Dermer 2006