Blazar sequence: past, present, and future

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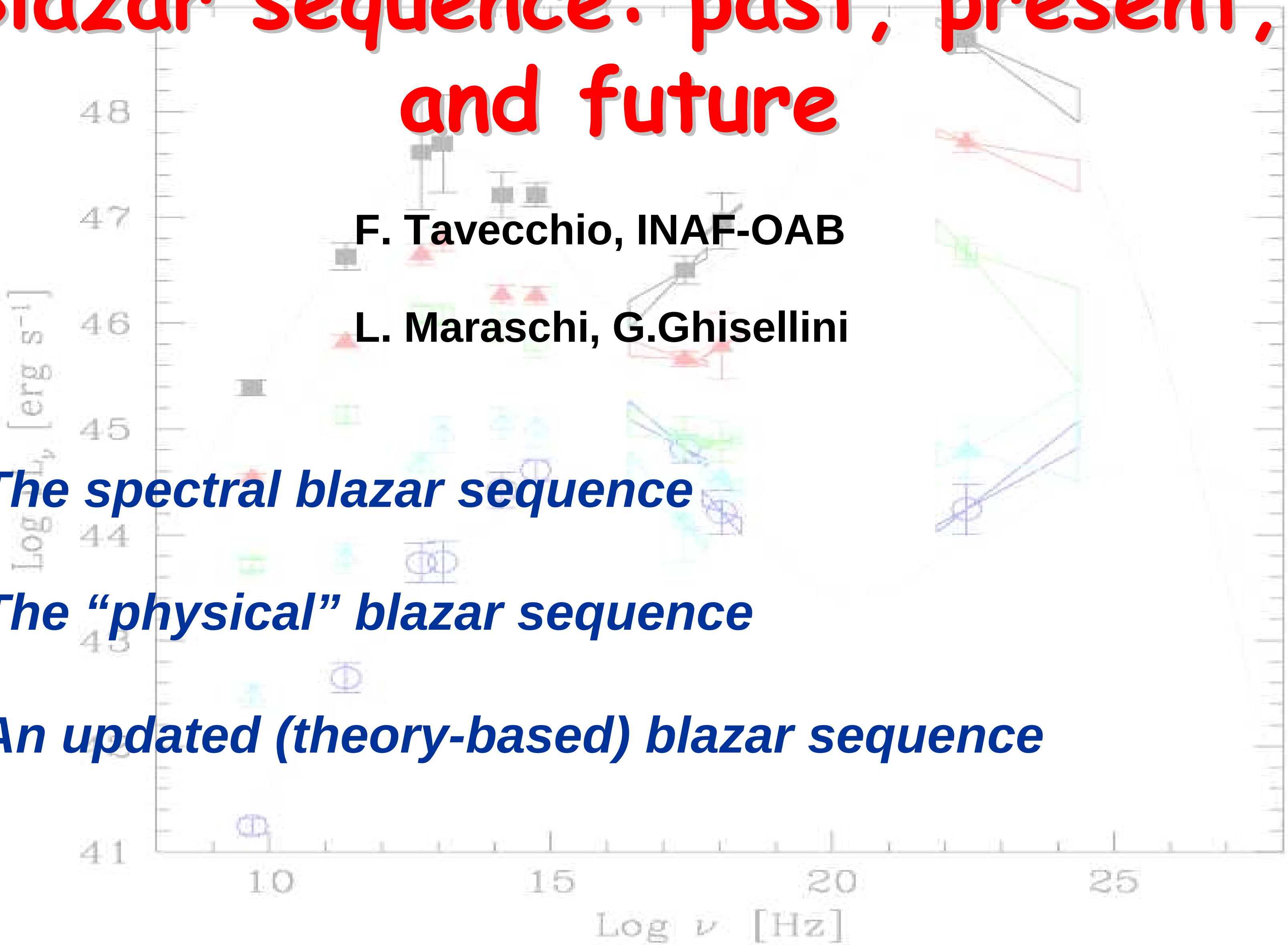
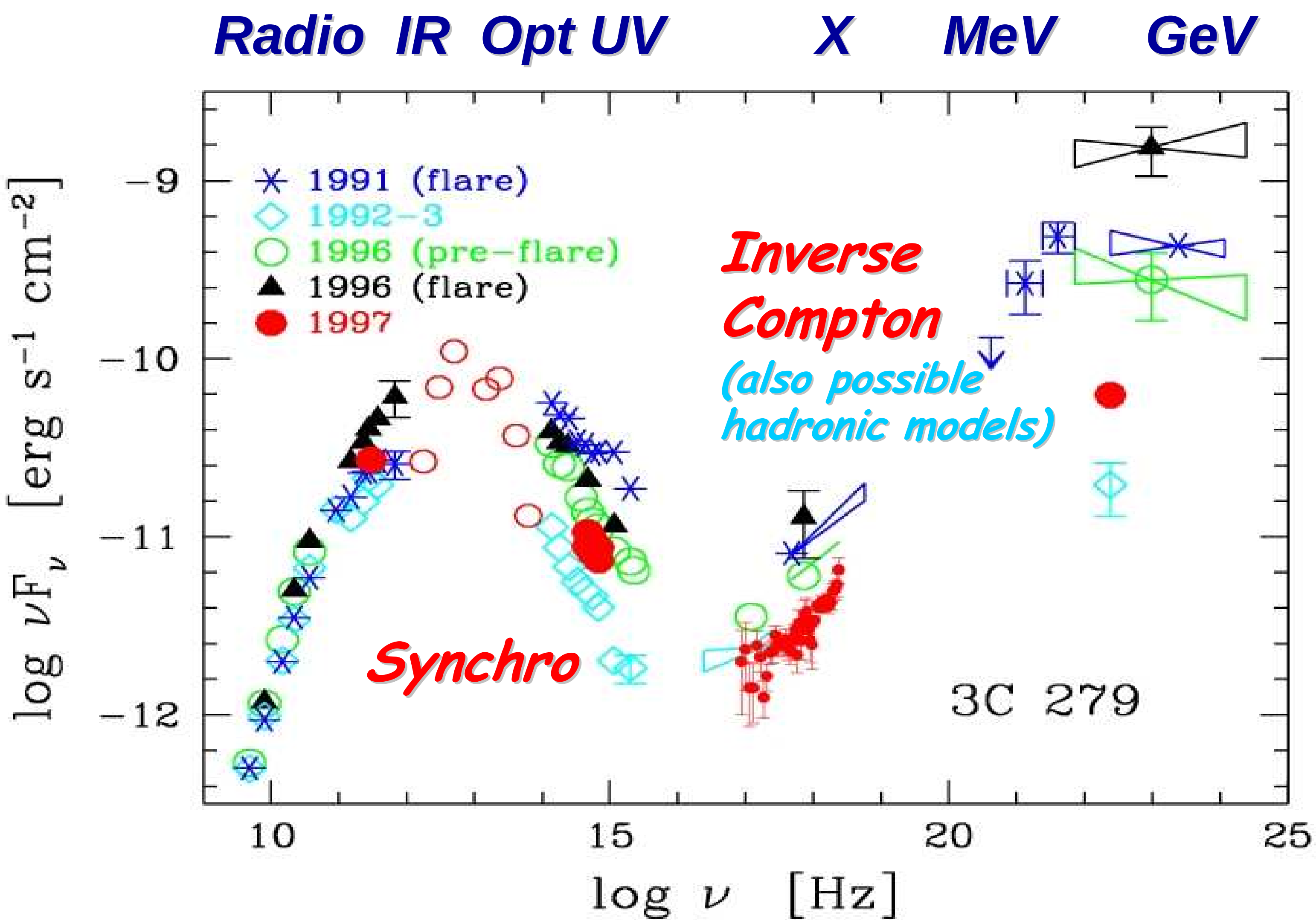
The spectral blazar sequence

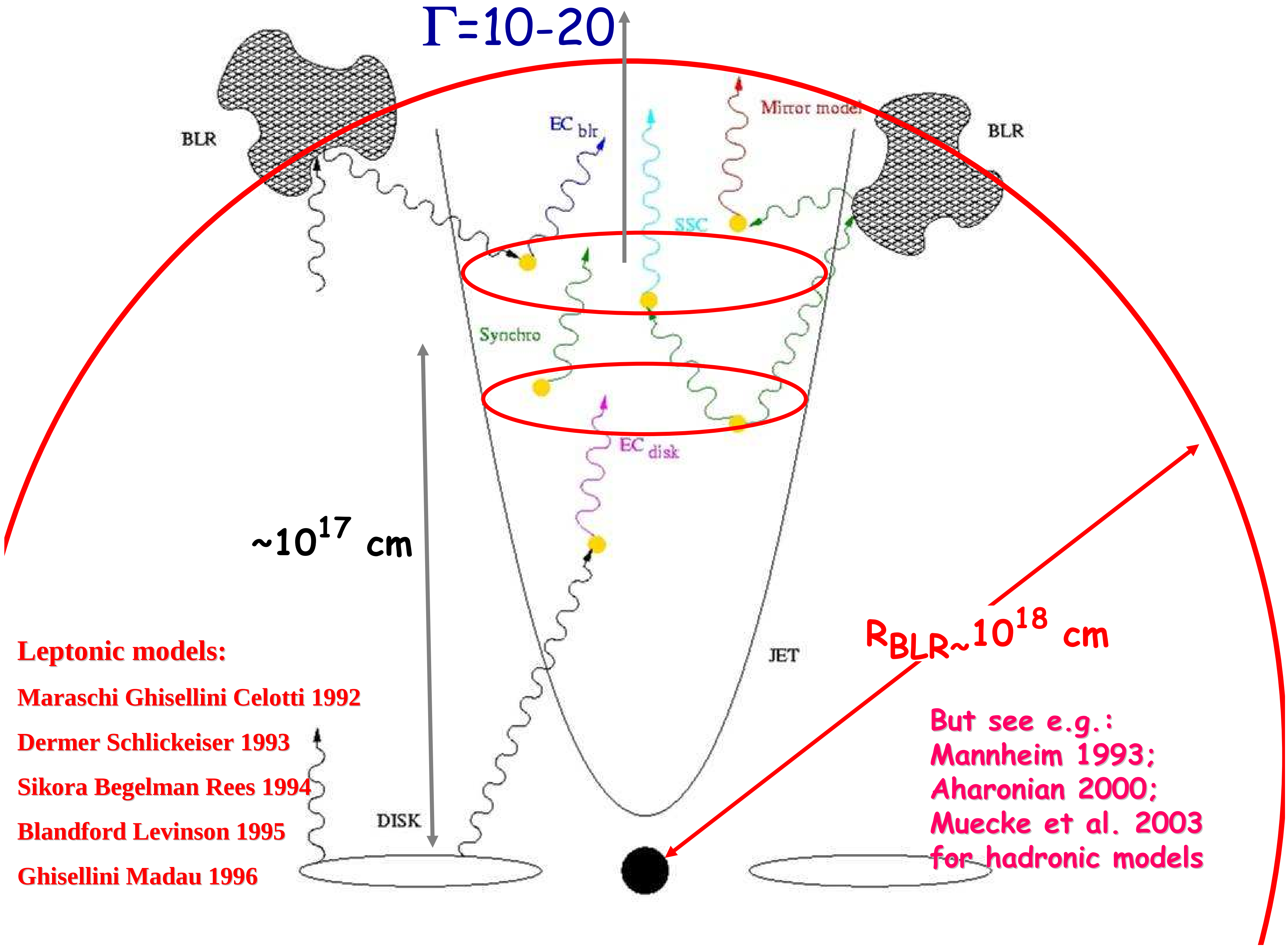
The "physical" blazar sequence

An updated (theory-based) blazar sequence



Blazars: Spectral Energy Distribution





Leptonic models:

Maraschi Ghisellini Celotti 1992

Dermer Schlickeiser 1993

Sikora Begelman Rees 1994

Blandford Levinson 1995

Ghisellini Madau 1996

But see e.g.:
Mannheim 1993;
Aharonian 2000;
Muecke et al. 2003
for hadronic models

3 samples of blazars (*Einstein slew survey, 1-Jy BL Lacs, 2-Jy FSRQs*)

Division into radio luminosity bins

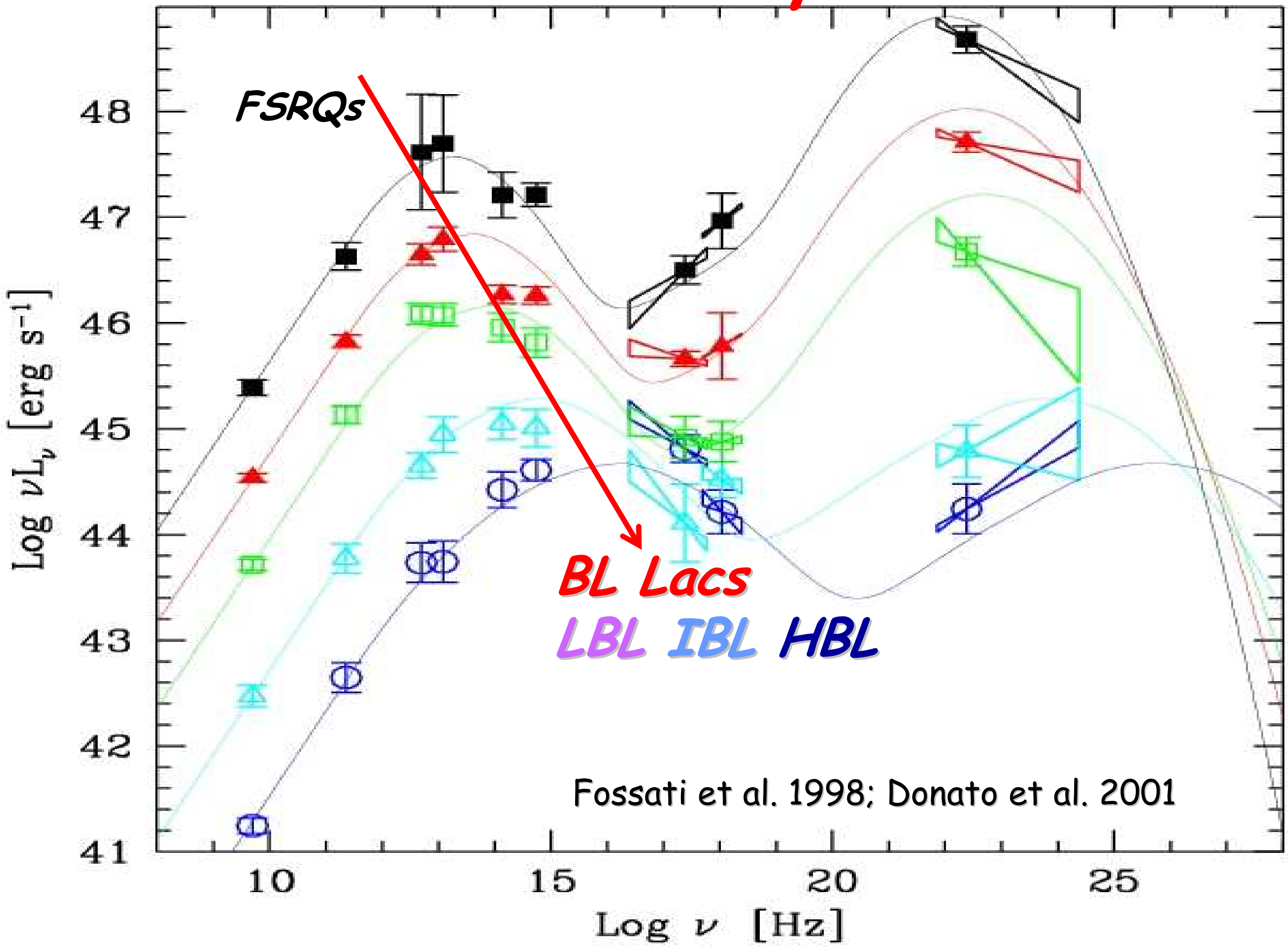
Average of luminosities in selected bands

⬇

Blazar (spectral) sequence

Fossati et al. (1998)

The "blazar sequence"



Some caveats

Samples:

3 “shallow” samples (2 radio, 1 X-rays). Total: 126 sources

Likely the most beamed and powerful sources.

Gamma-ray data biased?

Only 33 sources, mostly caught in flaring state

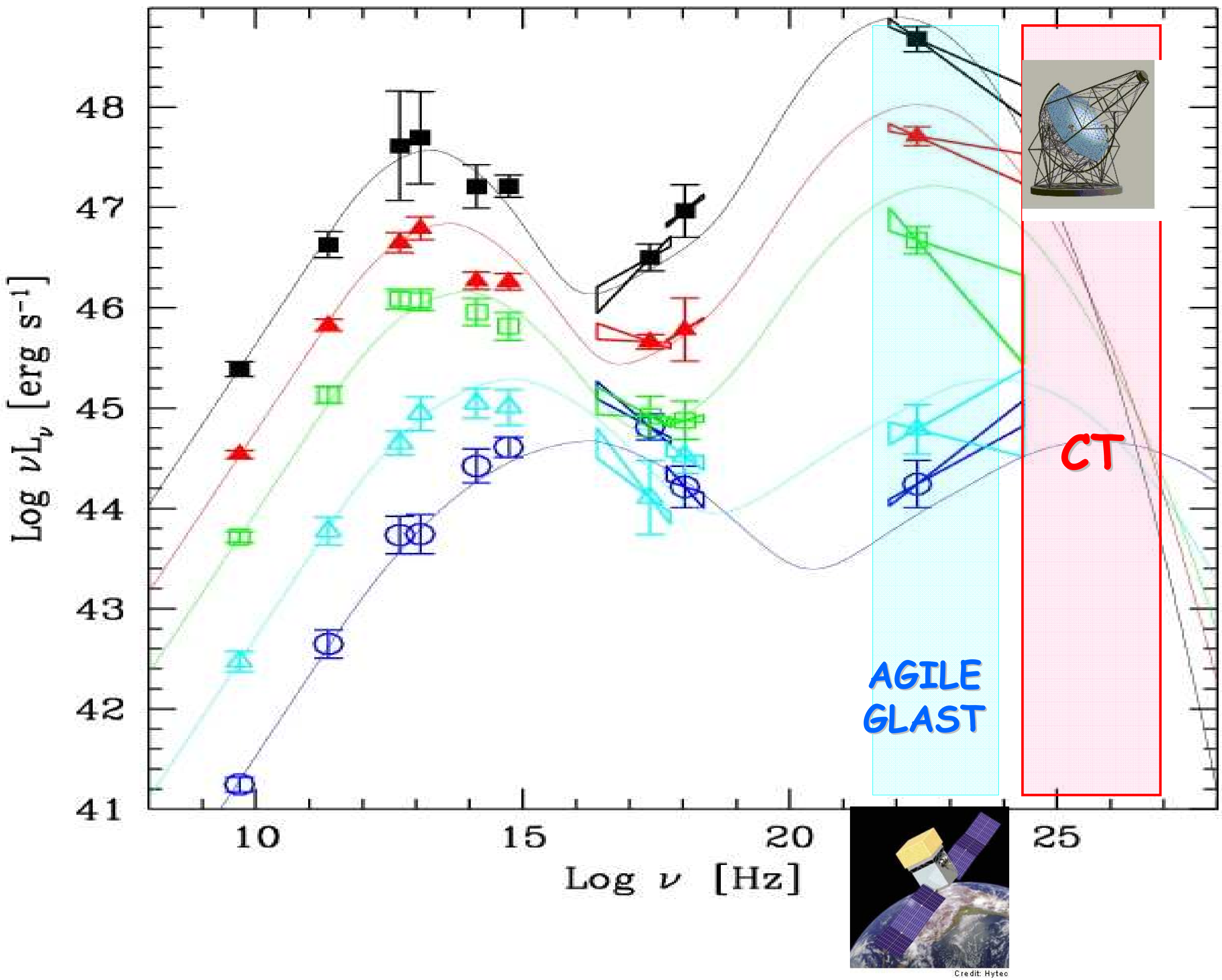
No TeV data (only two sources known in 1998!)

Blazars are extremely variable:

Only an average meaning!

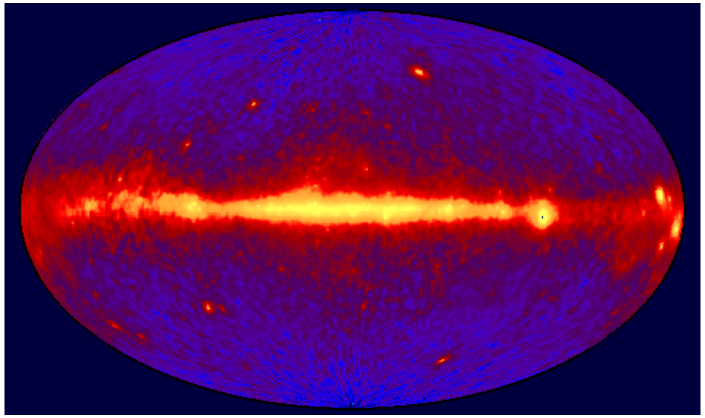
Simple consequences/predictions for γ-ray observations

1) GeV → FSRQs; TeV → BL Lacs



Log νL_ν [erg s^-1]
48
47
46
45
44
43
42
41
10
15
20
25
Log ν [Hz]
AGILE
GLAST
CT
Credit: Hytec

The extragalactic EGRET sky



3^{rd} EGRET Cat., Hartman et al. 1999
Revision in Nandikotkur at al. 2007

67 (high-conf.)+21 (low-conf.)

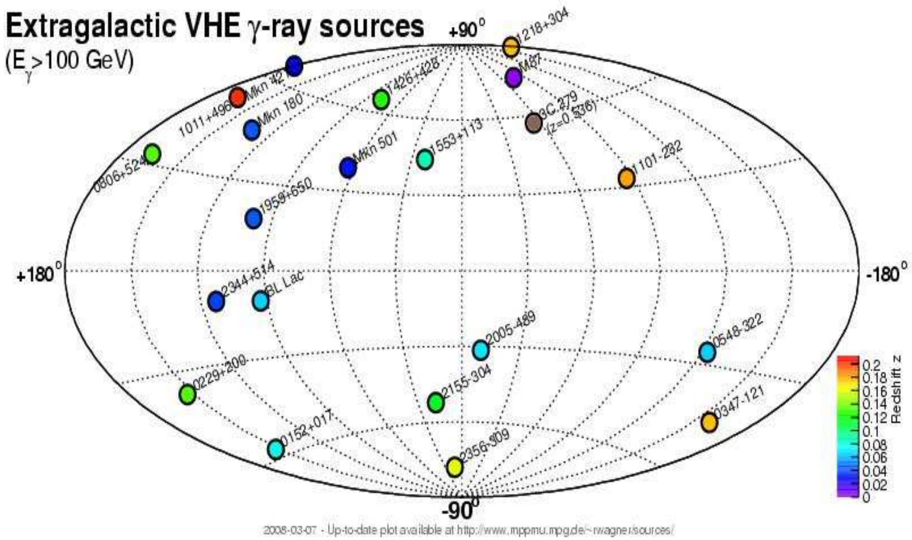
AGNs:

76 FSRQs

21 BL Lacs (17 LBL; 4 HBL)

The extragalactic VHE sky

20 BL Lacertae (18 HBL + 2 LBL)
1 radiogalaxy (M87, *16 Mpc*)
1 FSRQs (3C279, *z=0.536*)



Name	*Redshift*
Mkn 421	*0.03*
Mkn 501	*0.03*
1ES 2344+514	*0.044*
Mkn 180	*0.045*
1ES 1959+650	*0.047*
PKS 0548-322	*0.069*
BL Lacertae	*0.069*
PKS 2005-489	*0.071*
RGB 0152+017	*0.080*
ON231 (W Comae)	*0.102*
PKS 2155-304	*0.116*
H1426+428	*0.129*
1ES 0806+524	*0.138*
1ES 0229+200	*0.140*
H2356-309	*0.165*
1ES 1218+30	*0.182*
1ES 0347-121	*0.185*
1ES 1101-232	*0.186*
1ES 1011+496	*0.212*
PG 1553+113	*0.25-0.78*

Simple consequences/predictions for γ-ray observations

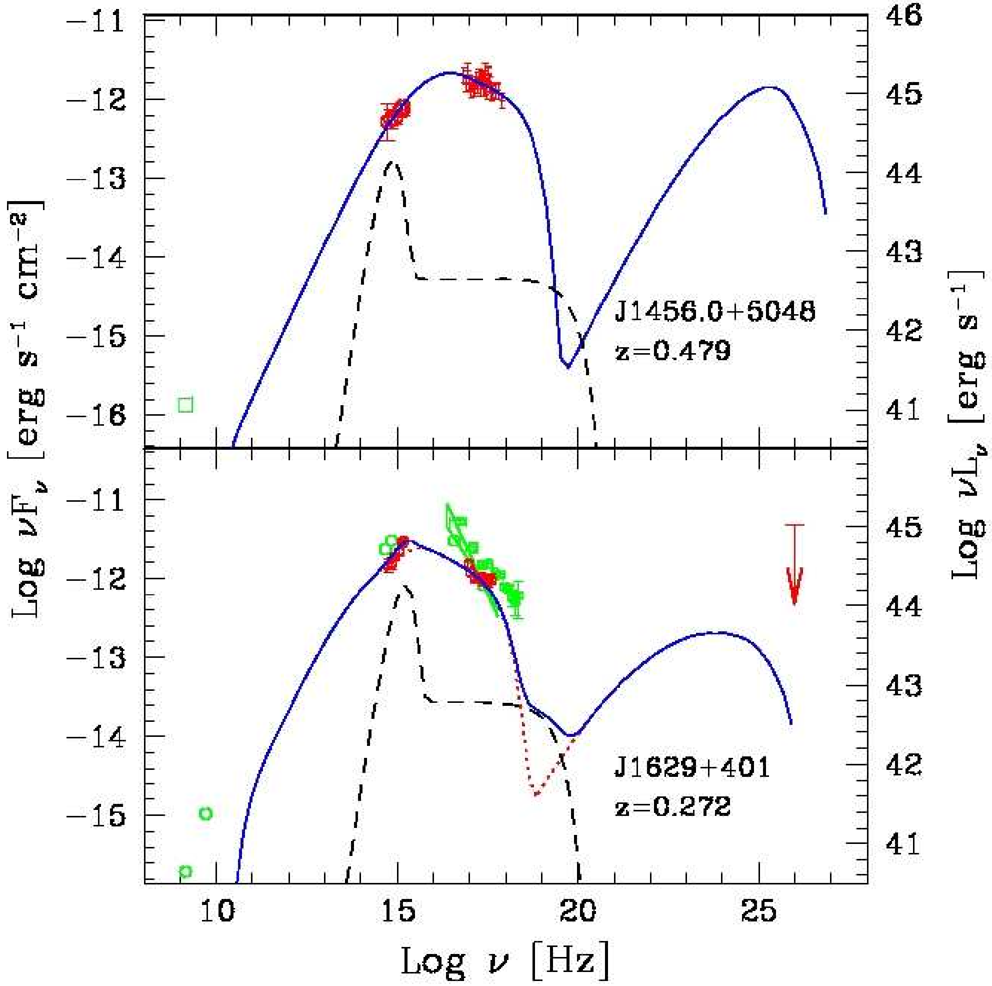
1) GeV → FSRQs; TeV → BL Lacs (possible bias?)

Simple consequences/predictions for γ-ray observations

1) GeV → FSRQs; TeV → BL Lacs (possible bias?)

2) No Blue powerful FSRQs -> no "TeV FSRQs"

Outliers?



Giommi 2008: a blue QSO

But weak lines -> BL Lac!

Padovani et al. 2002: a QSO

But only narrow lines -> NLSy1?

Small black hole

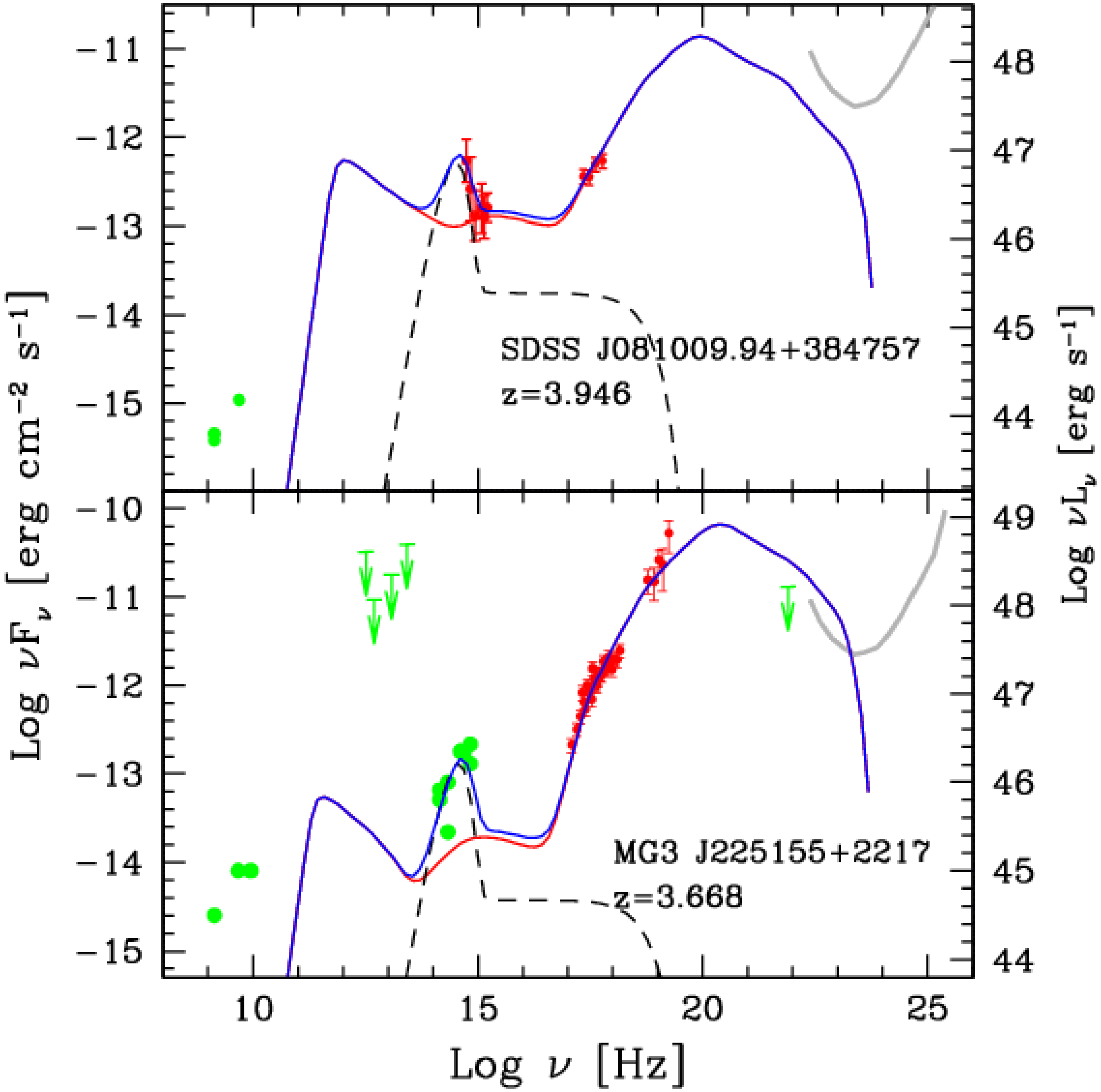
Maraschi et al. 2008

Simple consequences/predictions for γ-ray observations

1) GeV → FSRQs; TeV → BL Lacs (possible bias?)

2) No Blue powerful FSRQs -> no "TeV FSRQs"

3) Extremely powerful (high-z) FSRQs: not detected by EGRET, OK for Fermi



Maraschi et al. 2008

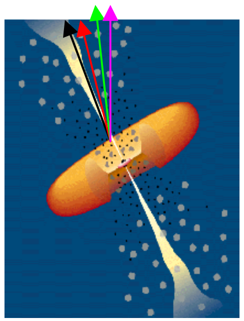
Simple consequences/predictions for γ-ray observations

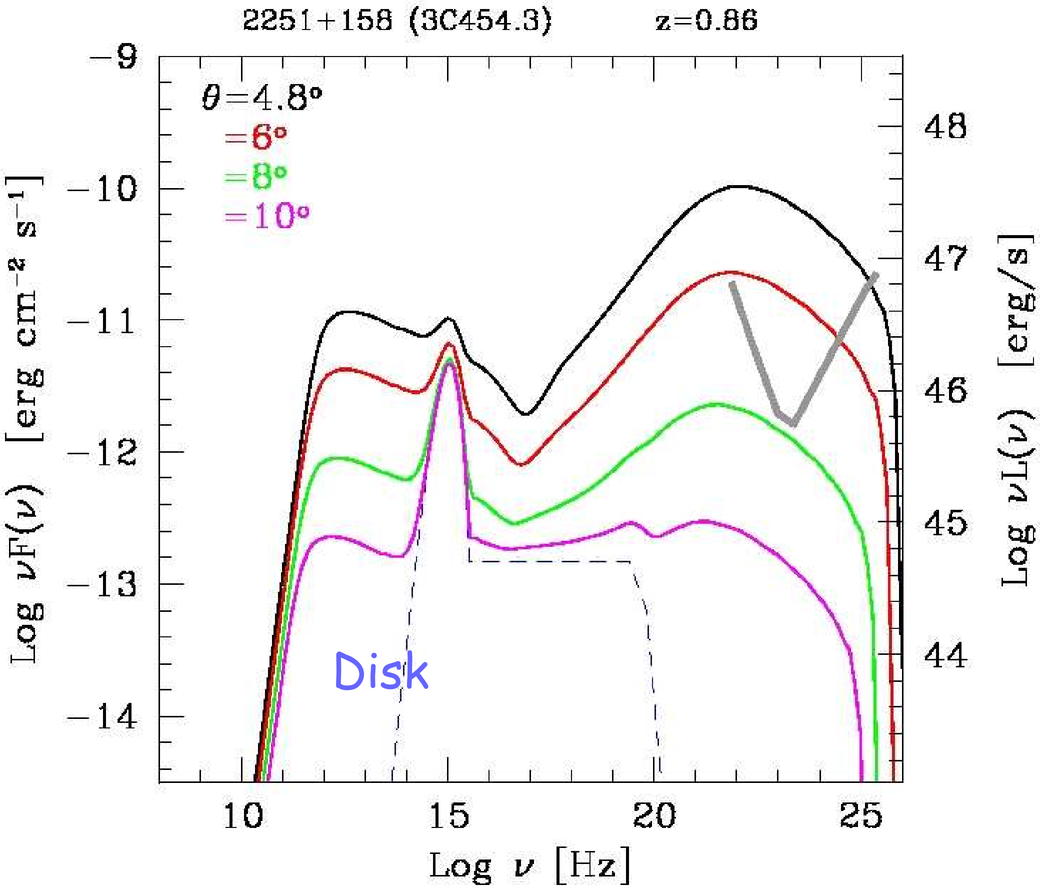
1) GeV → FSRQs; TeV → BL Lacs (possible bias?)

2) No Blue powerful FSRQs -> no "TeV FSRQs"

3) Extremely powerful (high-z) FSRQs: not detected by EGRET, OK for Fermi

4) Debeamed and intrinsically less powerful sources (more numerous!): low luminosity RED (GeV) blazars are expected: *Fermi*

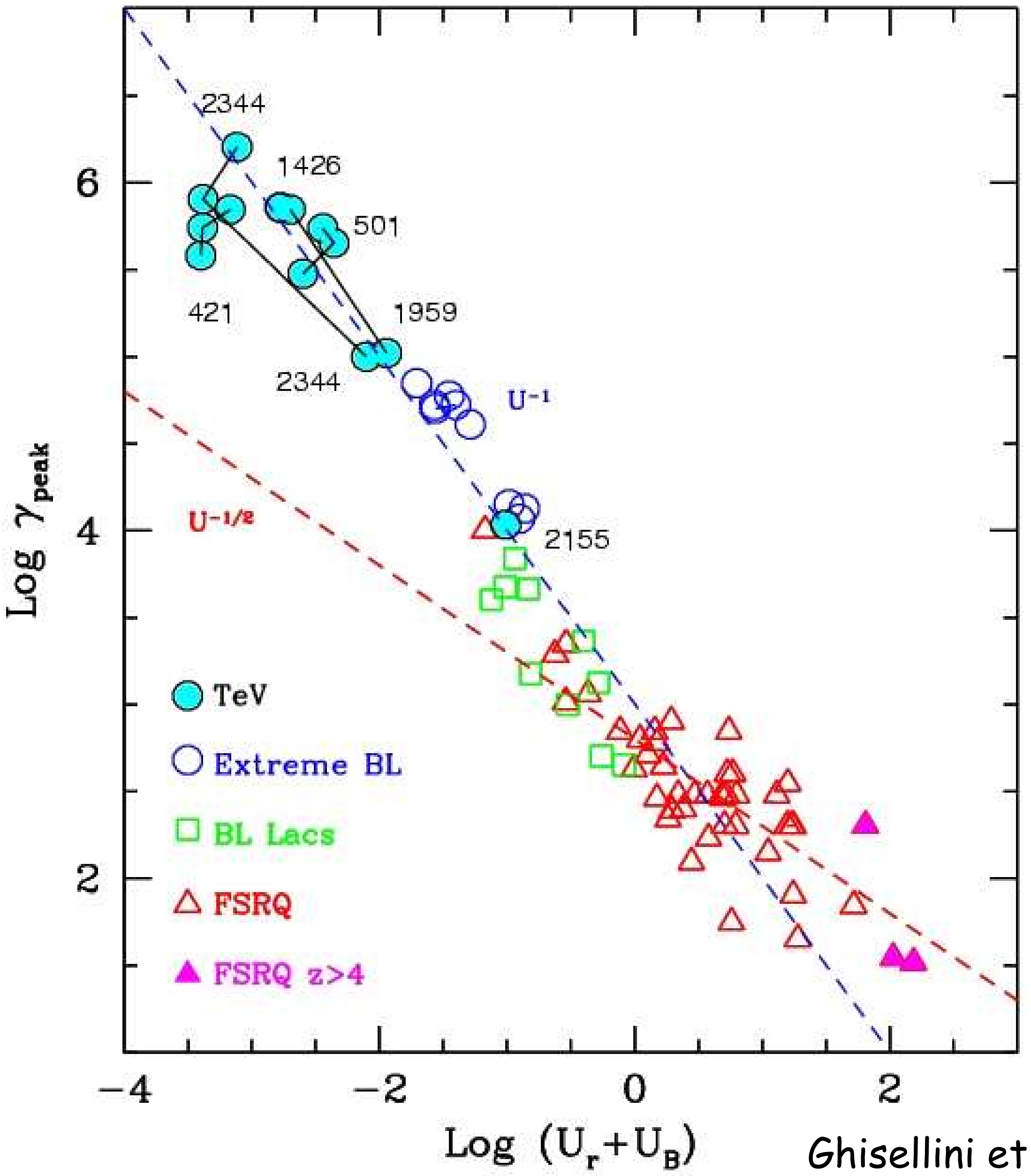




N(θ) dθ ~ sin θ dθ

See also Landt at al. 2008

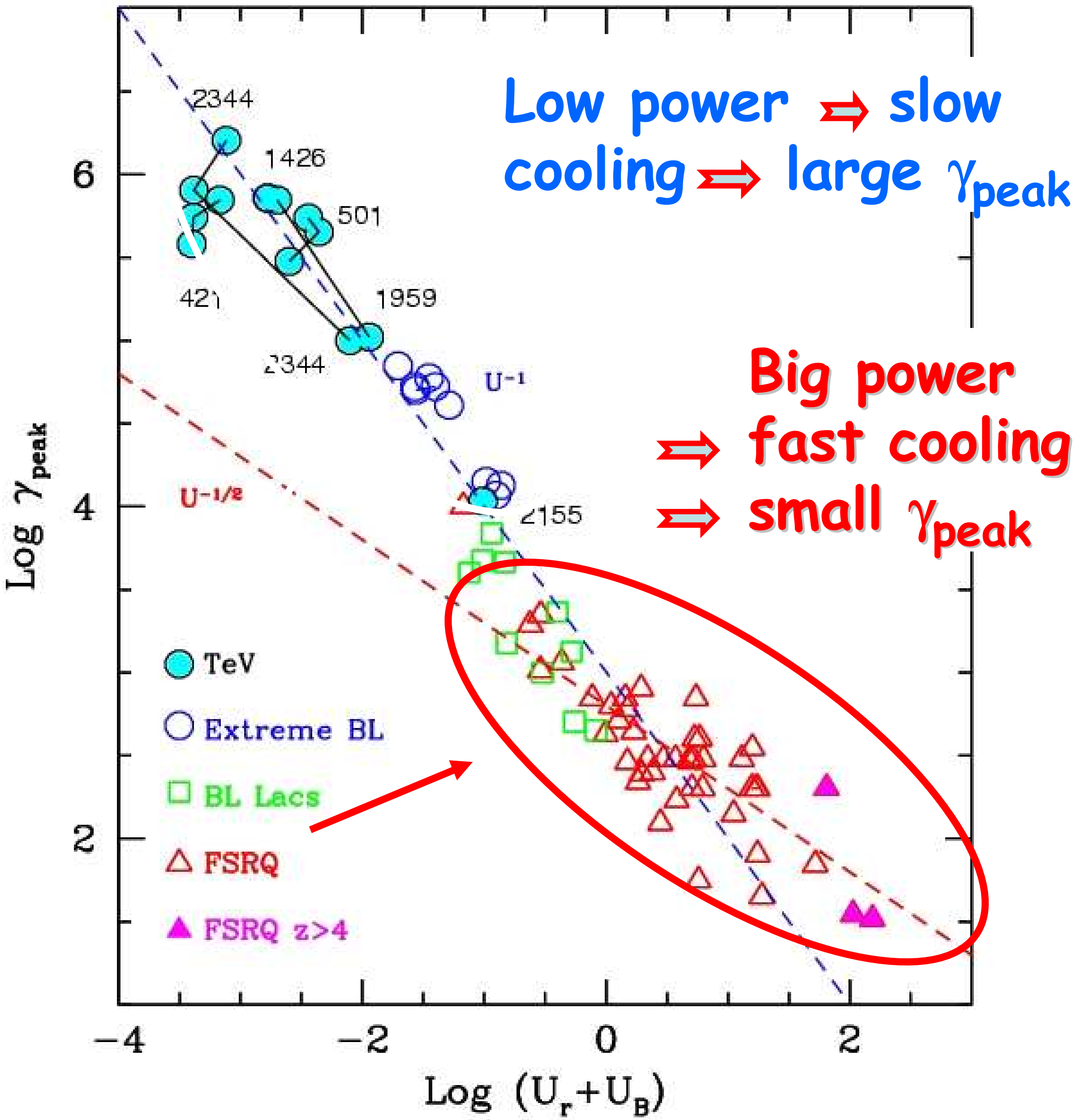
The physical sequence



Ghisellini et al. 1998, 2002

By modeling, we find physical parameters in the comoving frame.

γ_{peak} is the energy of electrons emitting at the peak of the SED



Low power ⇒ slow cooling ⇒ large γ_{peak}
Big power ⇒ fast cooling ⇒ small γ_{peak}
2344
1426
501
421
1959
2344
2155
U^{-1}
$U^{-1/2}$
TeV
Extreme BL
BL Lacs
FSRQ
FSRQ z>4
Log γ_{peak}
Log (U_r+U_B)
6
4
2
−4
−2
0
2

A new (theoretical) sequence

- Old one: based on 1 parameter: the observed luminosity
- Now: info on mass and accretion rate (spin? not yet)
- Info on jet power vs disk luminosity
- Info on location of dissipation: must be at some distance from BH. One zone is dominant (internal shocks?)

Ghisellini & Tavecchio 2008

The key ideas

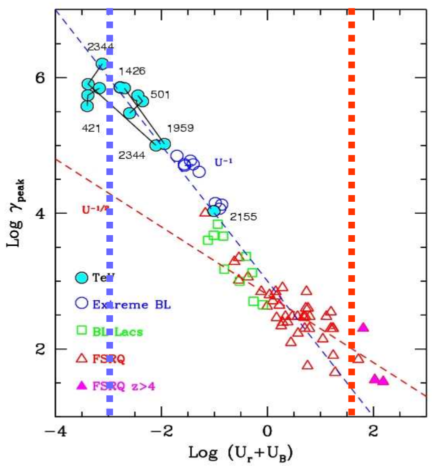
- R_{diss} proportional to M_{BH}
- R_{BLR} proportional to $(L_{disk})^{1/2}$
- For $L_{disk}/L_{Edd} < L_c \rightarrow$ no BLR (BL Lacs)
- $L_B = \varepsilon_B P_{jet}$
- $L_e = \varepsilon_e P_{jet}$
- γ_{peak} propto U^{-1}; $U^{-1/2}$

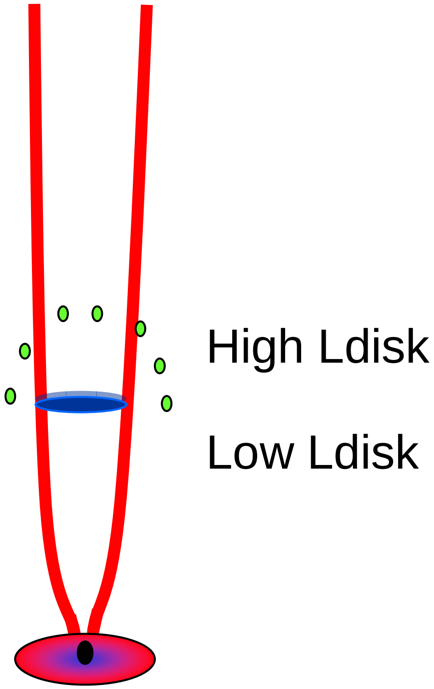
The key *ansatz*

- P_{jet} *always* proportional to $\dot{M}$

Simple consequences

- R_{diss} propto M; R_{BLR} propto $(L_{disk})^{1/2}$
  for large M, ~low L_{disk} → $R_{diss} > R_{BLR}$
- → Blue quasars!





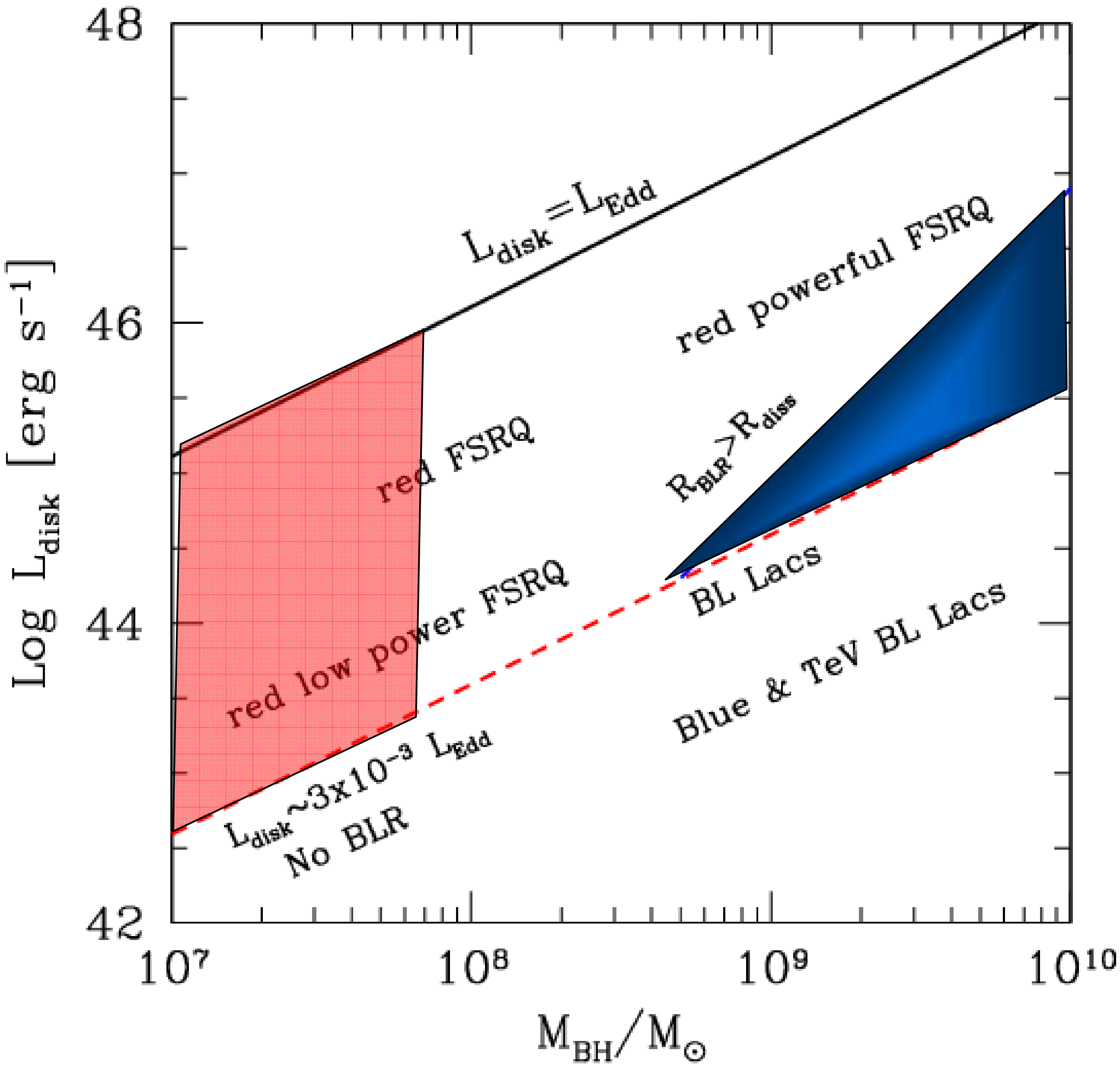
Simple consequences

R_{diss} propto M; R_{BLR} propto $(L_{disk})^{1/2}$
for large M, ~low L_{disk} → $R_{diss} > R_{BLR}$

- → Blue quasars!

Small M, small L_{jet}, large B

- → Low power, red quasars



48
46
44
42
Log L_{disk} [erg s^{-1}]
10^7
10^8
10^9
10^{10}
$M_{BH}/M_{\odot}$
$L_{disk}=L_{Edd}$
red powerful FSRQ
red FSRQ
$R_{BLR}>R_{diss}$
red low power FSRQ
BL Lacs
Blue & TeV BL Lacs
L_{disk}~3x10^{-3} L_{Edd}
No BLR

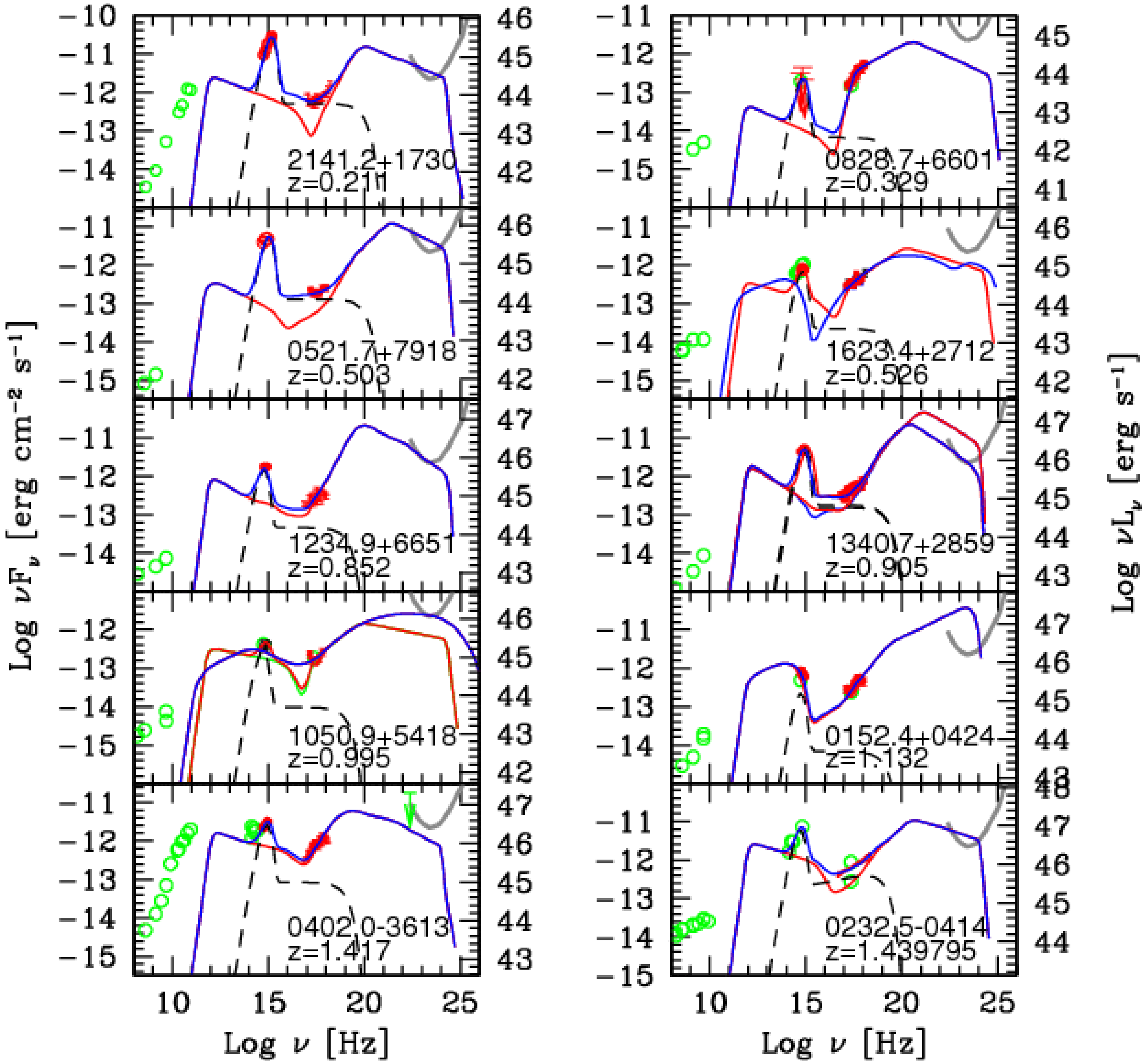
Conclusions

The spectral sequence still alive and healthy

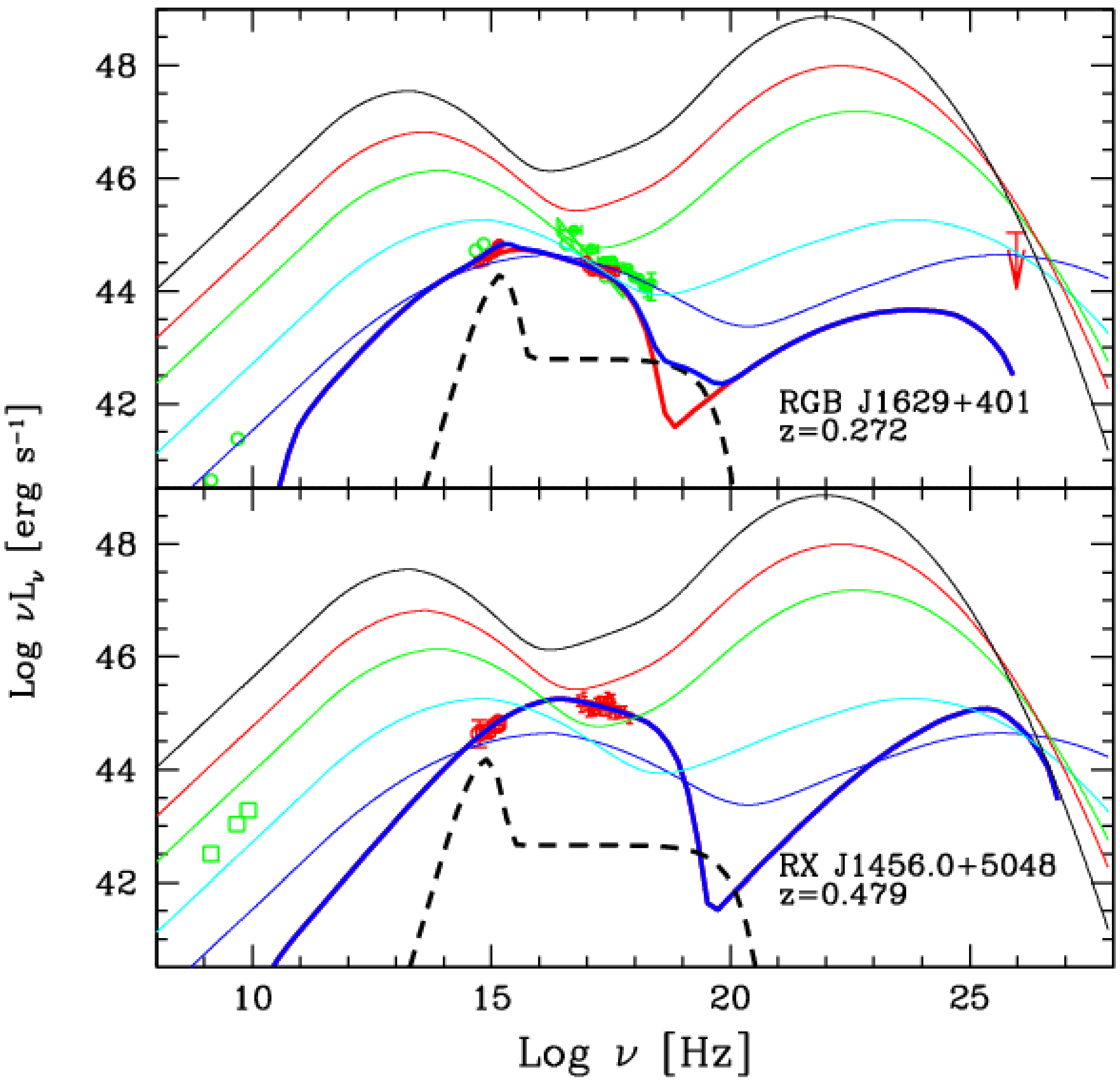
Prediction: a large number of misaligned and intrinsically less powerful sources

Updated (theoretical) sequence: (numerous) low power red and (rare) high power blue predicted (forbidden in the "classical" spectral sequence!)

Fermi is coming …



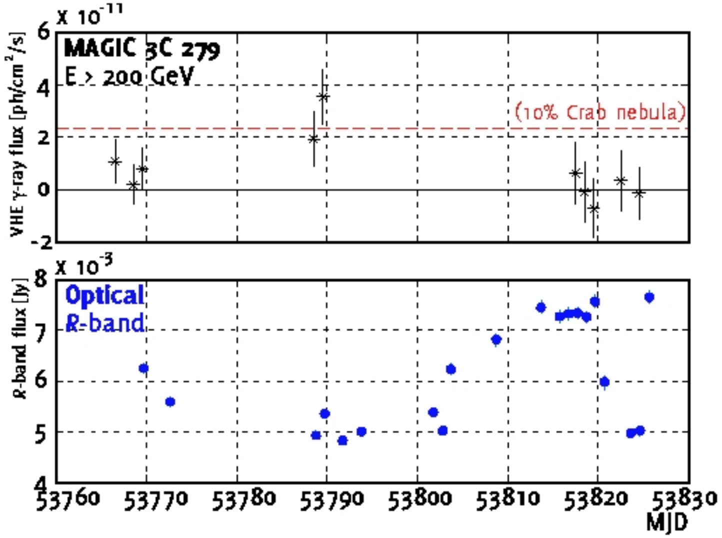
Maraschi et al. in prep

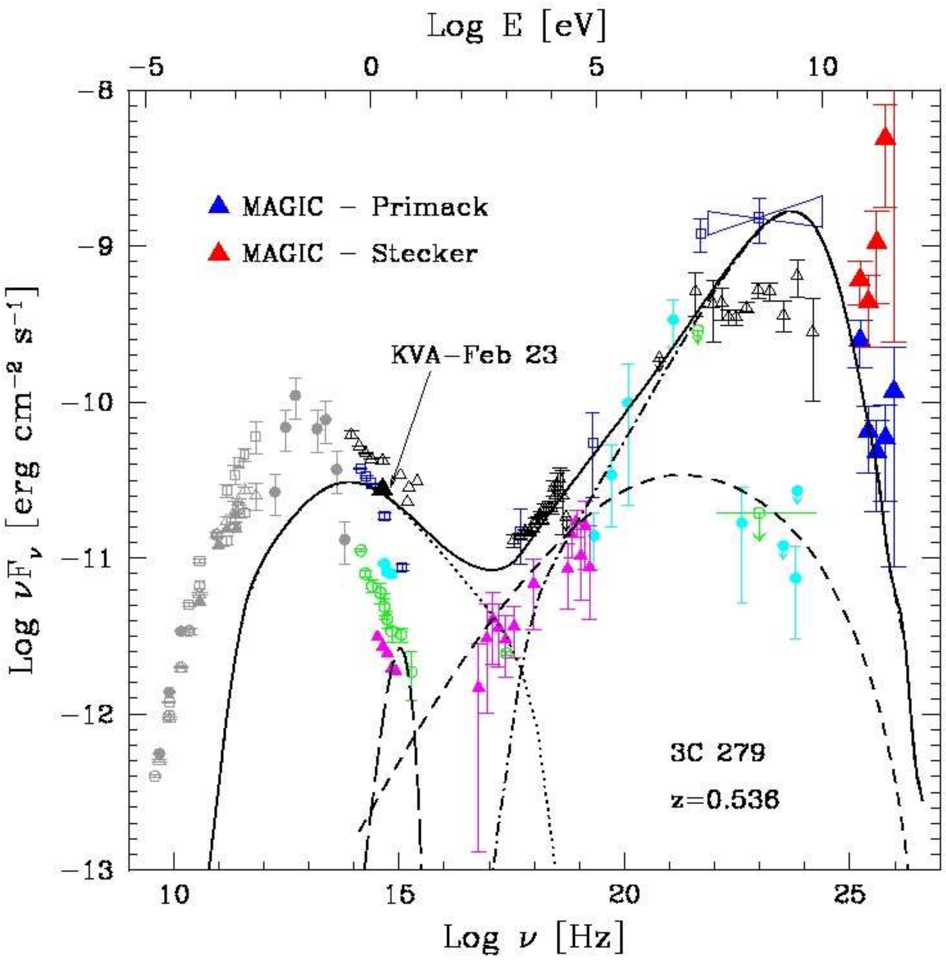


Log νL_ν [erg s^-1]
48
46
44
42
RGB J1629+401
z=0.272
48
46
44
42
RX J1456.0+5048
z=0.479
10
15
20
25
Log ν [Hz]

VHE emission of FSRQs

3C 279, z=0.536





Teshima et al. 2007

Costamante & GG 2002