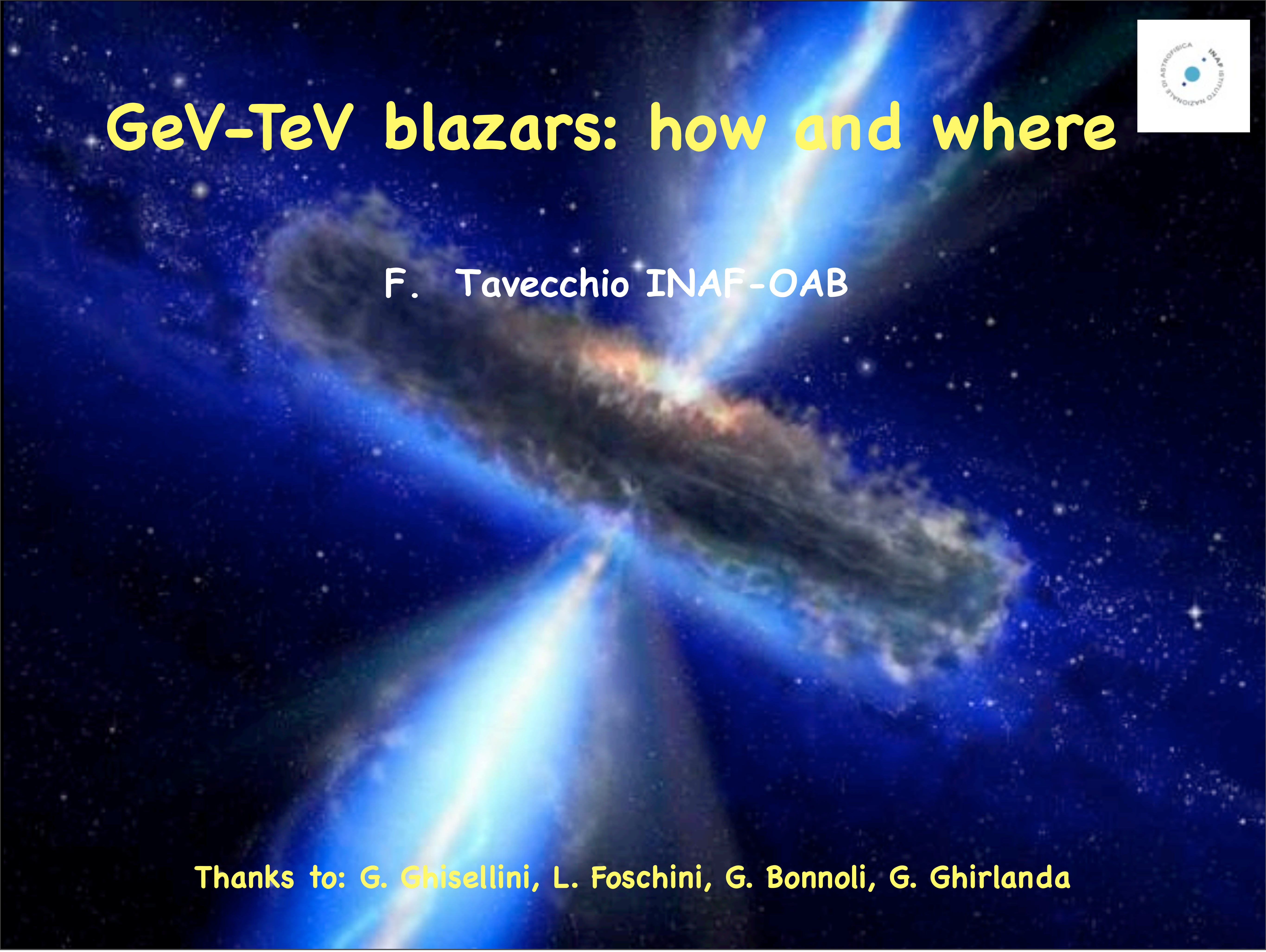
GeV-TeV blazars: how and where

F. Tavecchio INAF-OAB



Thanks to: G. Ghisellini, L. Foschini, G. Bonnoli, G. Ghirlanda

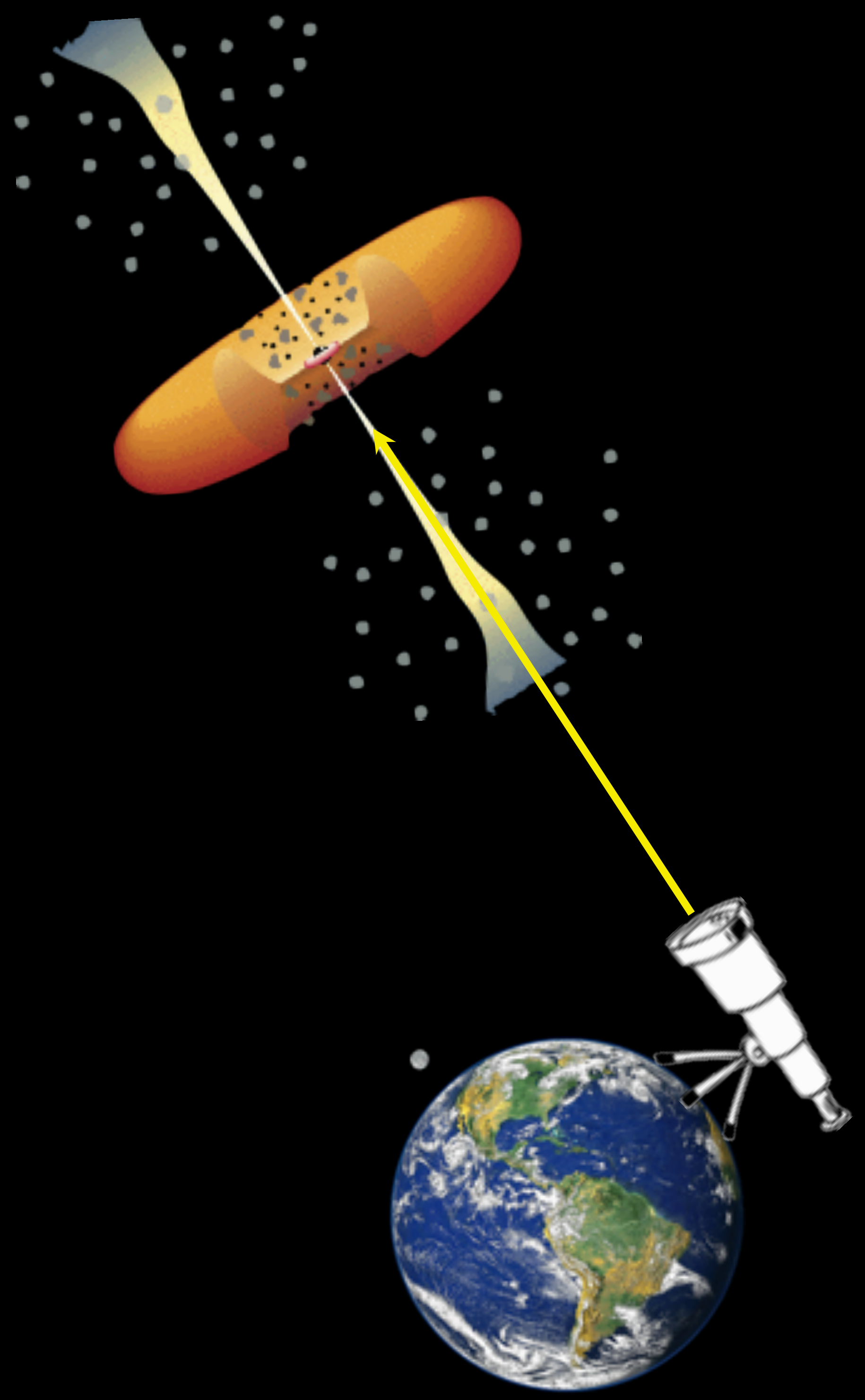
Outline

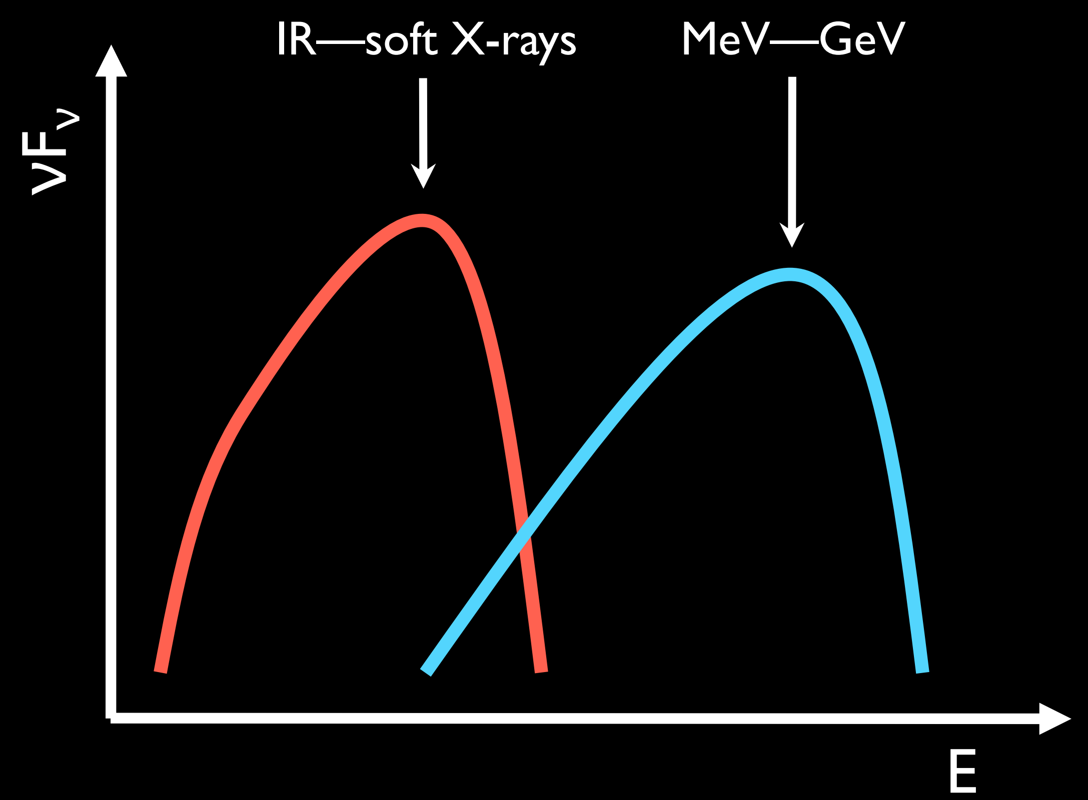
Blazars:

the "standard" view; the blazar sequence
jet-disk connection;
the location of the emitting region.

A benchmark case: 3C454.3

Blazars





Blazars

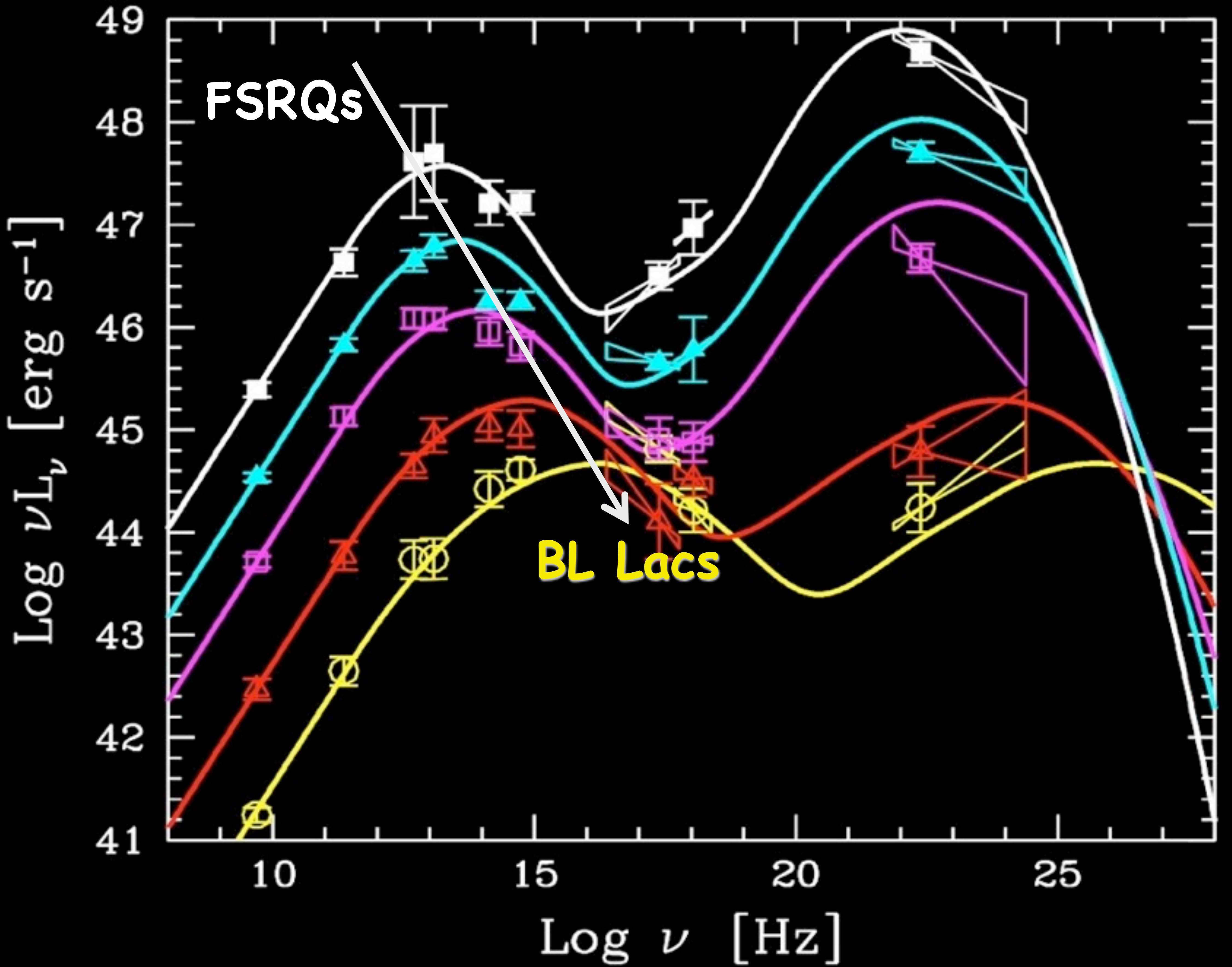
SED dominated by the relativistically boosted non-thermal continuum emission of the jet.

Two broad bumps:

Synchrotron and Inverse Compton in leptonic models.

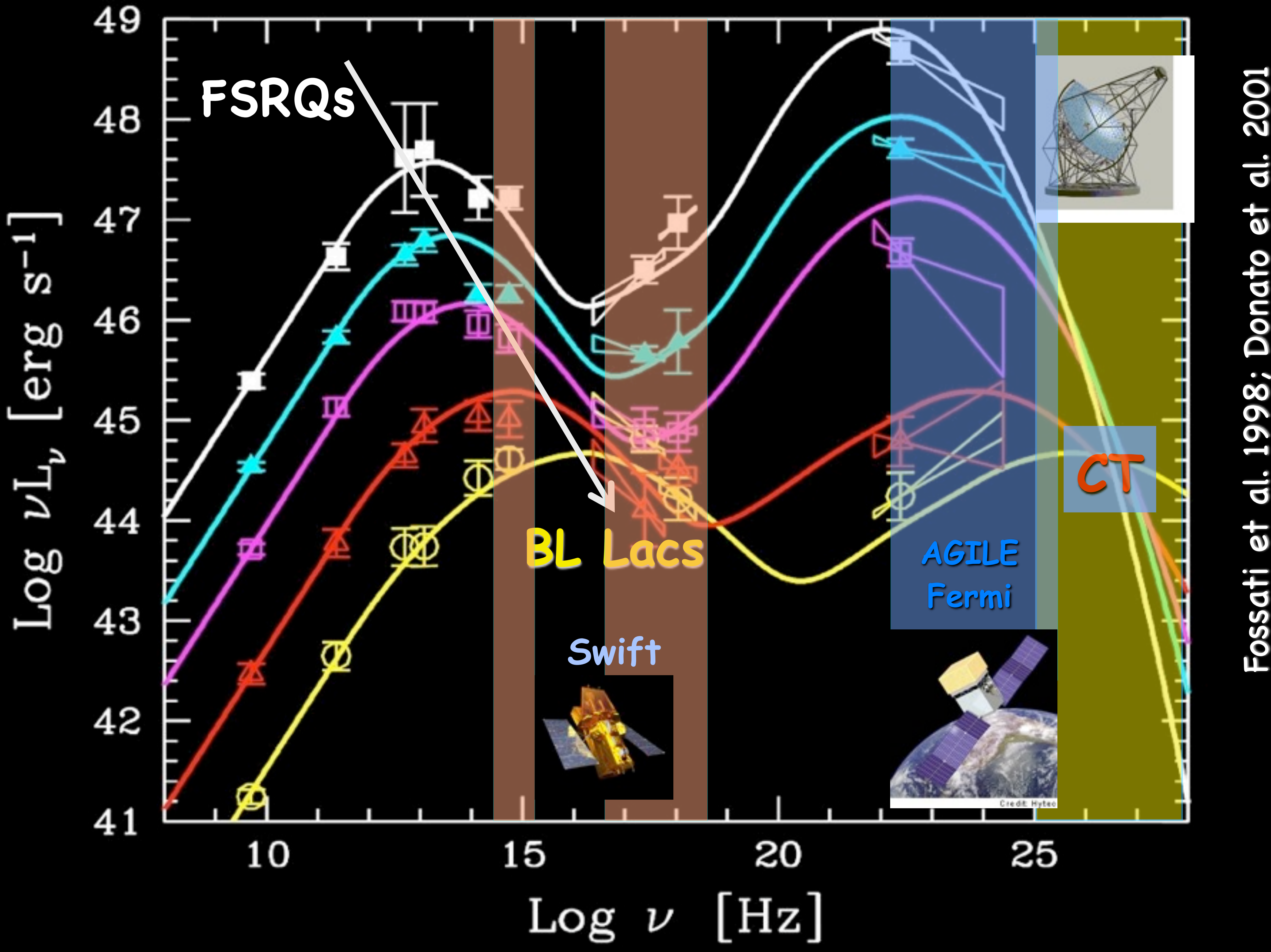
Also hadronic scenarios have been considered (e.g. Mannheim, Boettcher, Reimer).

The "blazar sequence"

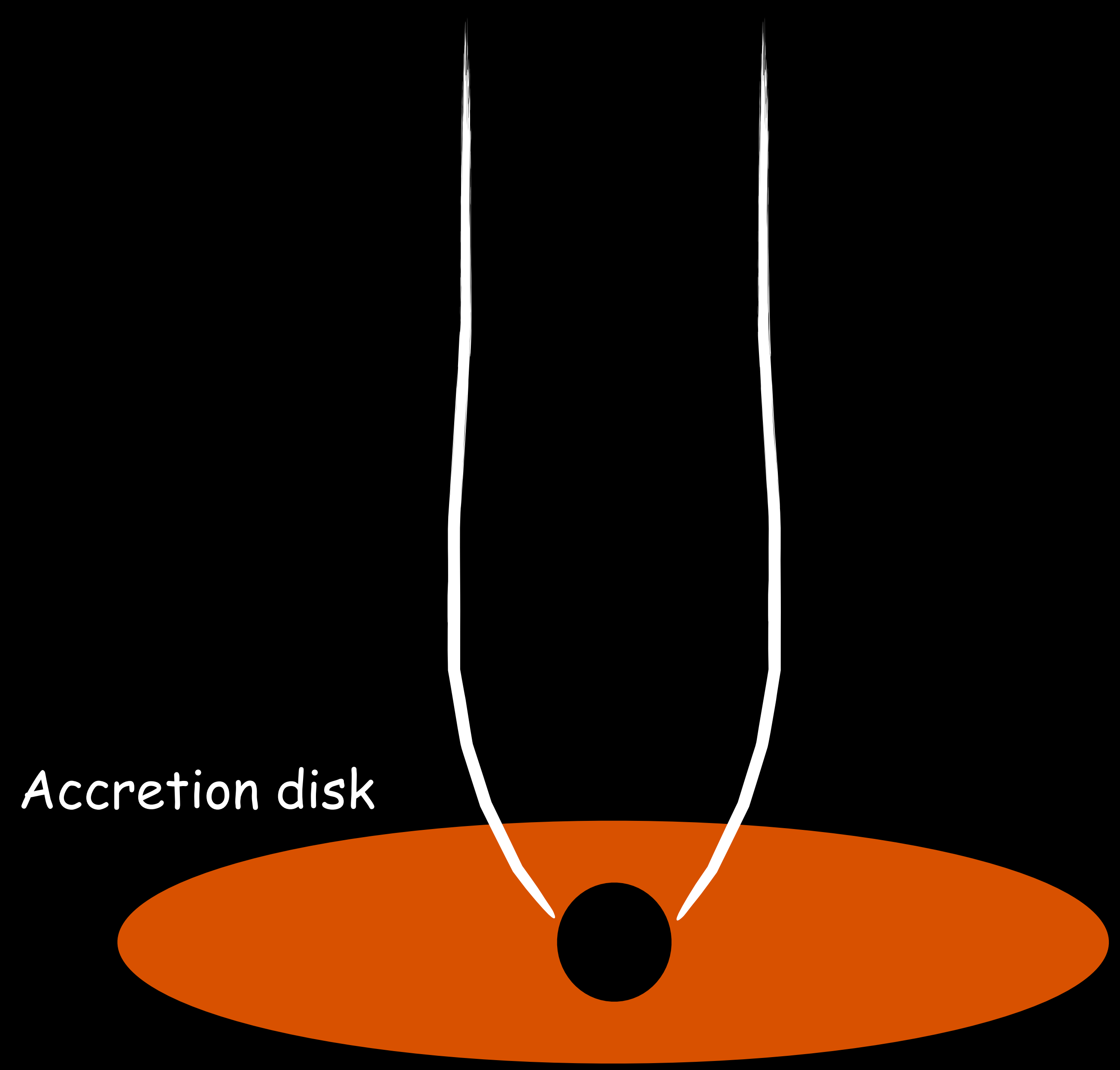


Fossati et al. 1998; Donato et al. 2001

The "blazar sequence"



FSRQs: the general scenario



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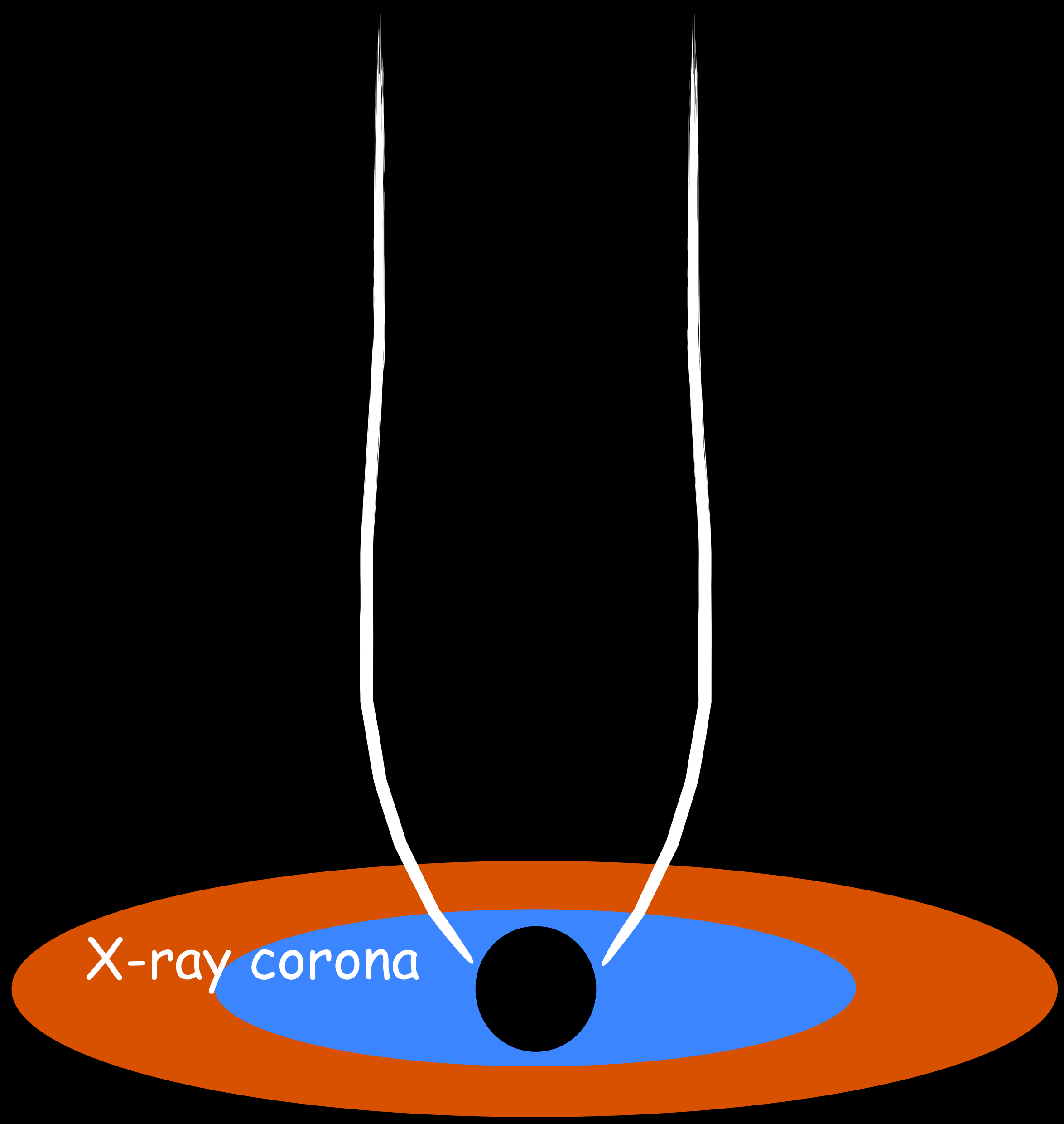

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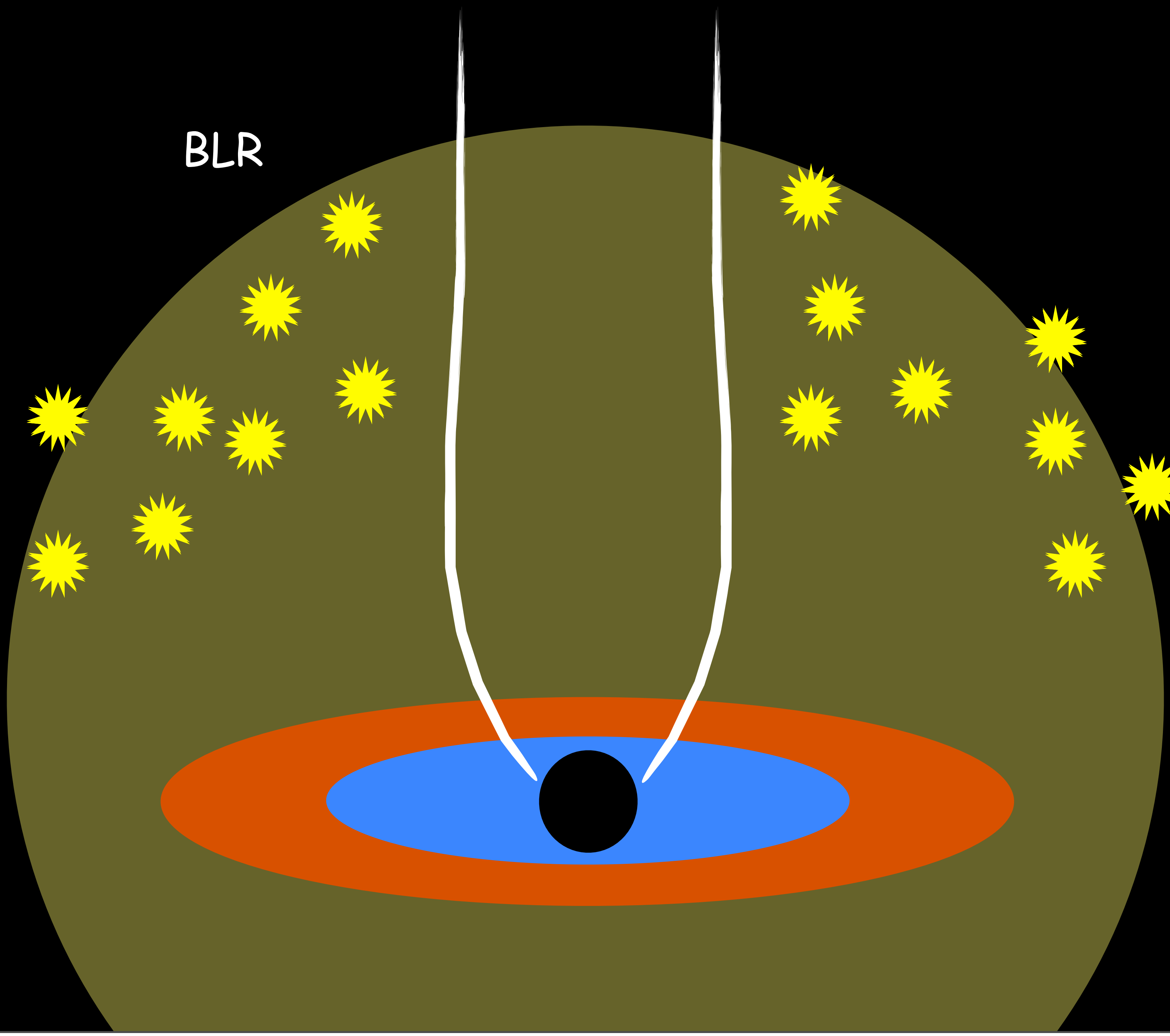

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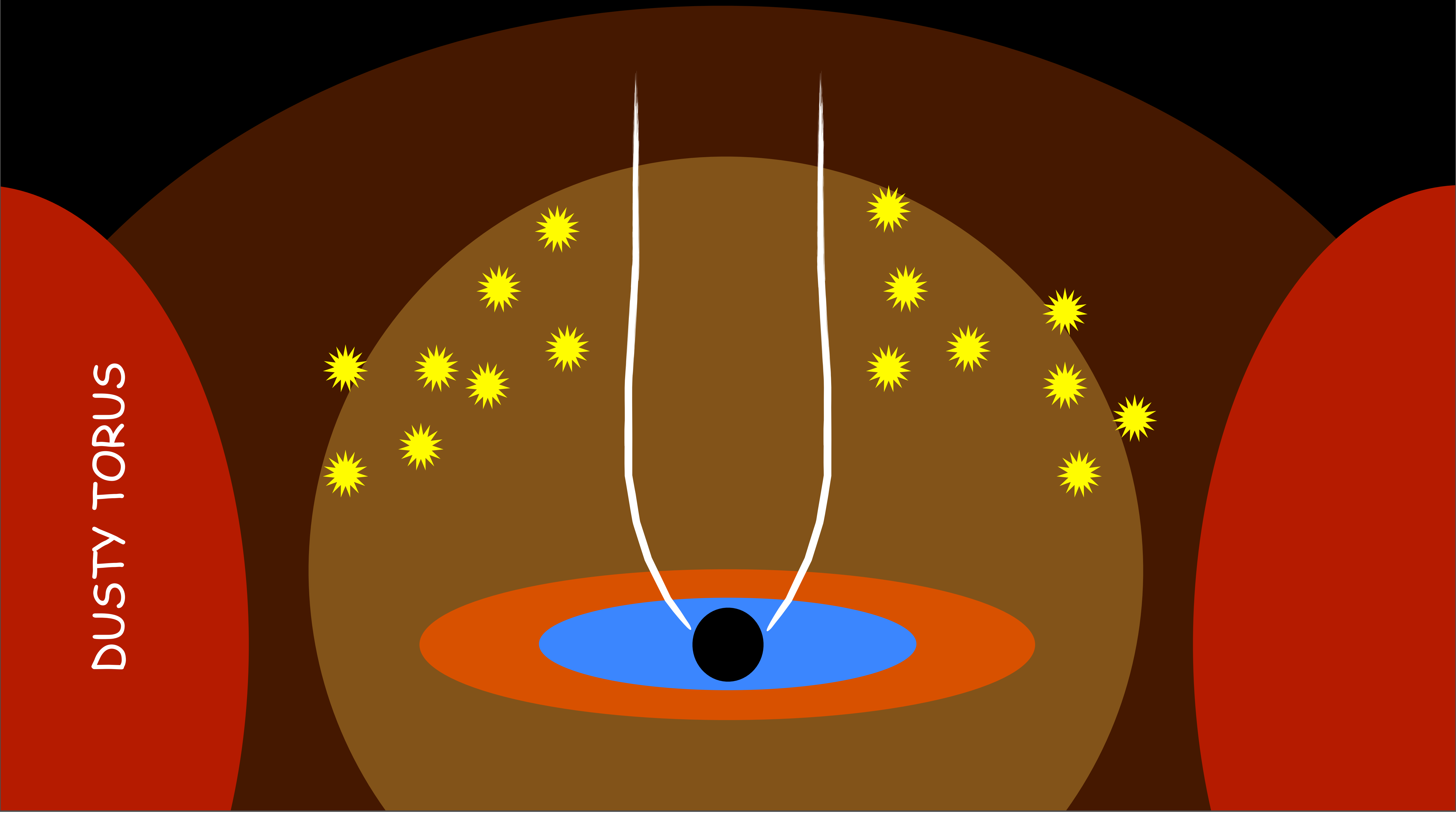
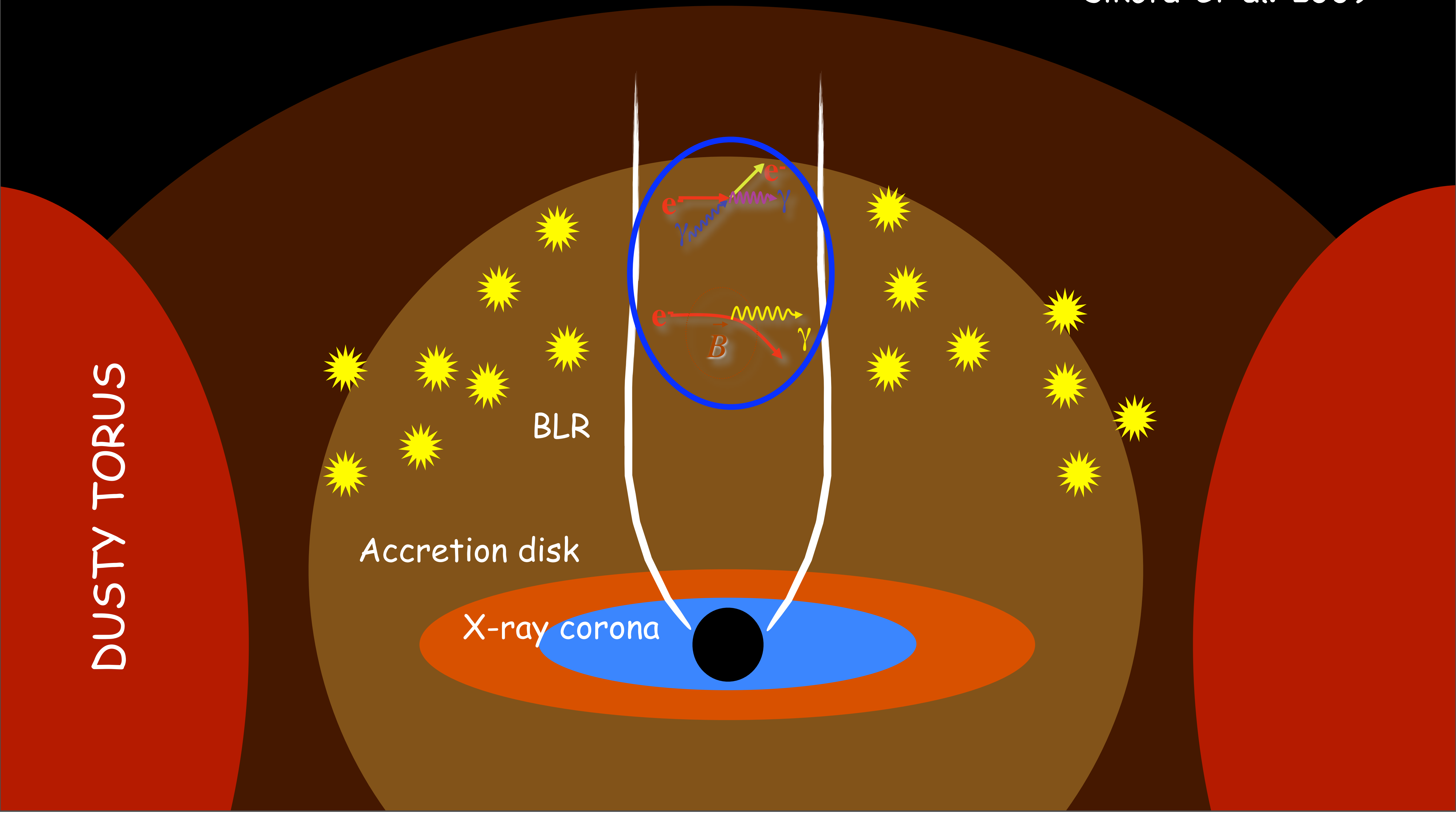


FSRQs: the "canonical" scenario

Dermer et al. 2009
Ghisellini, FT 2009
Sikora et al. 2009



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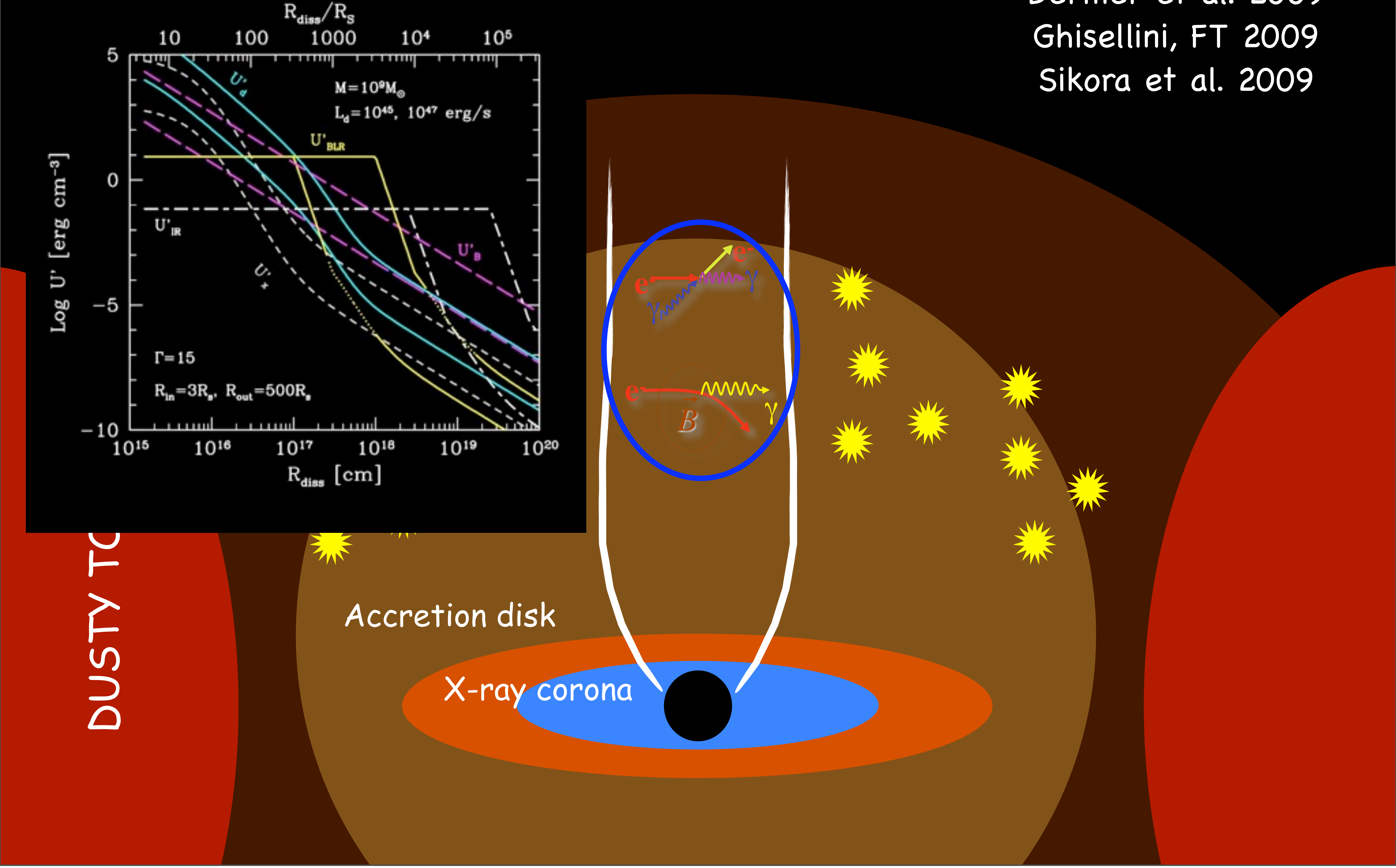

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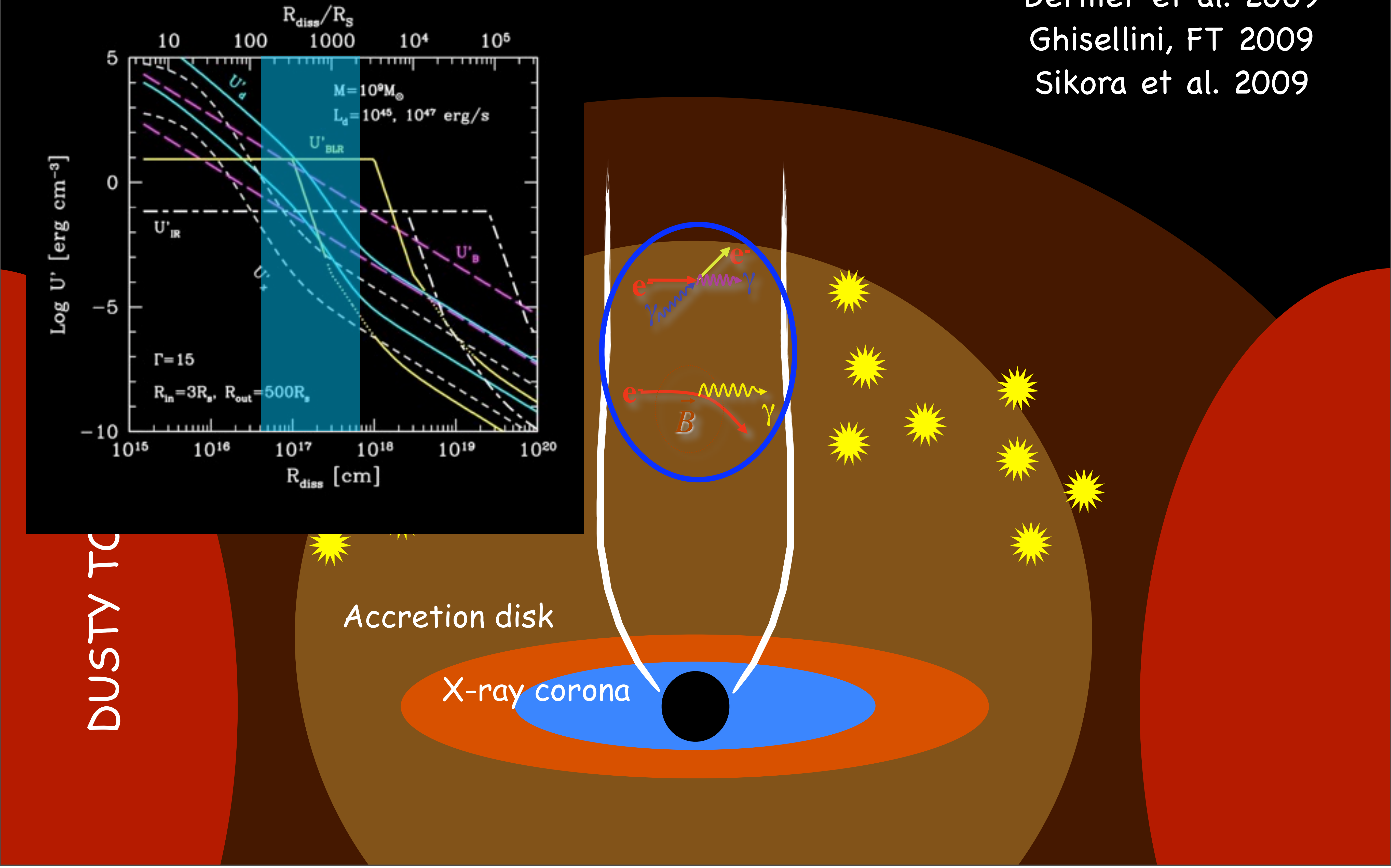
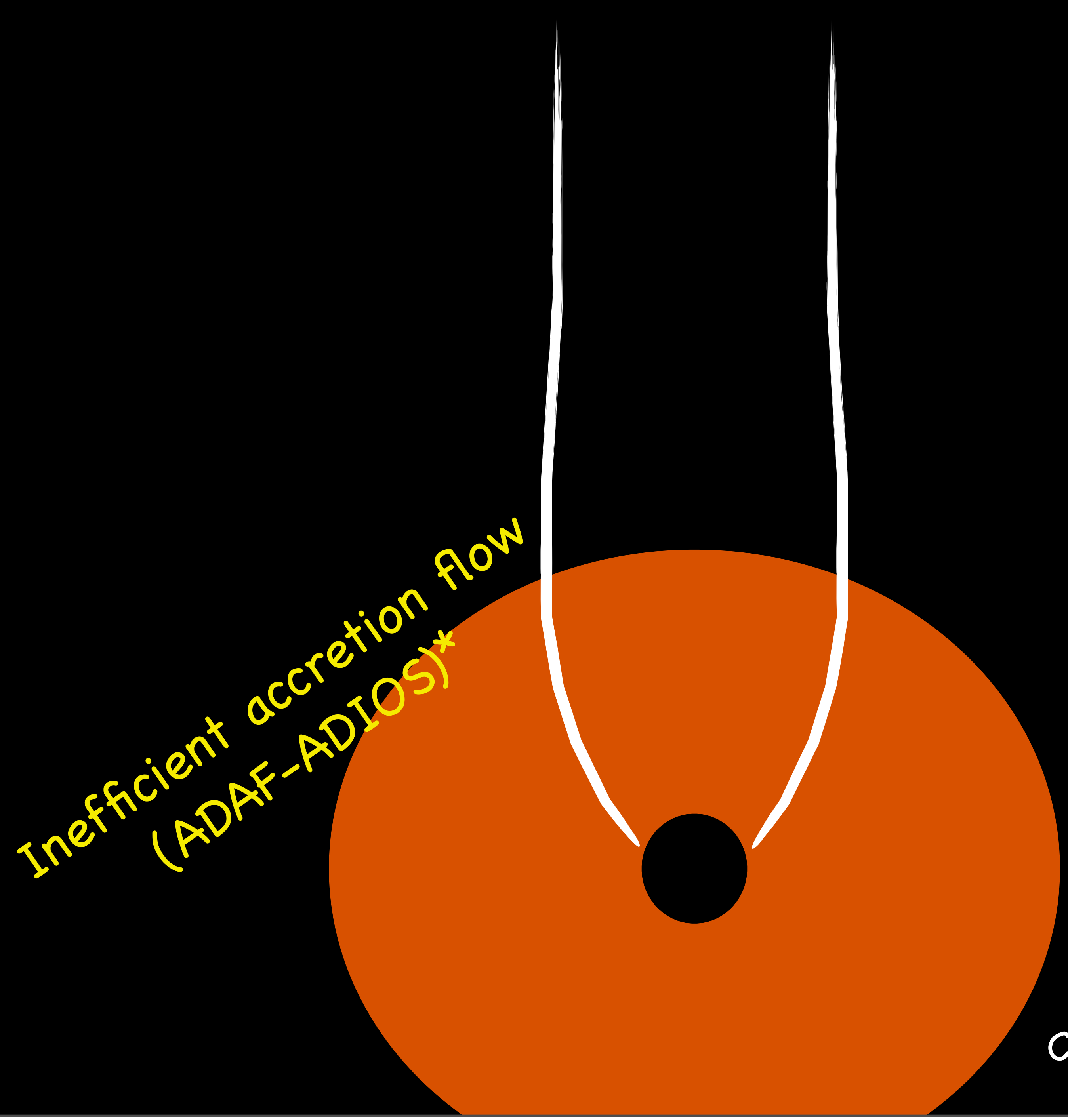
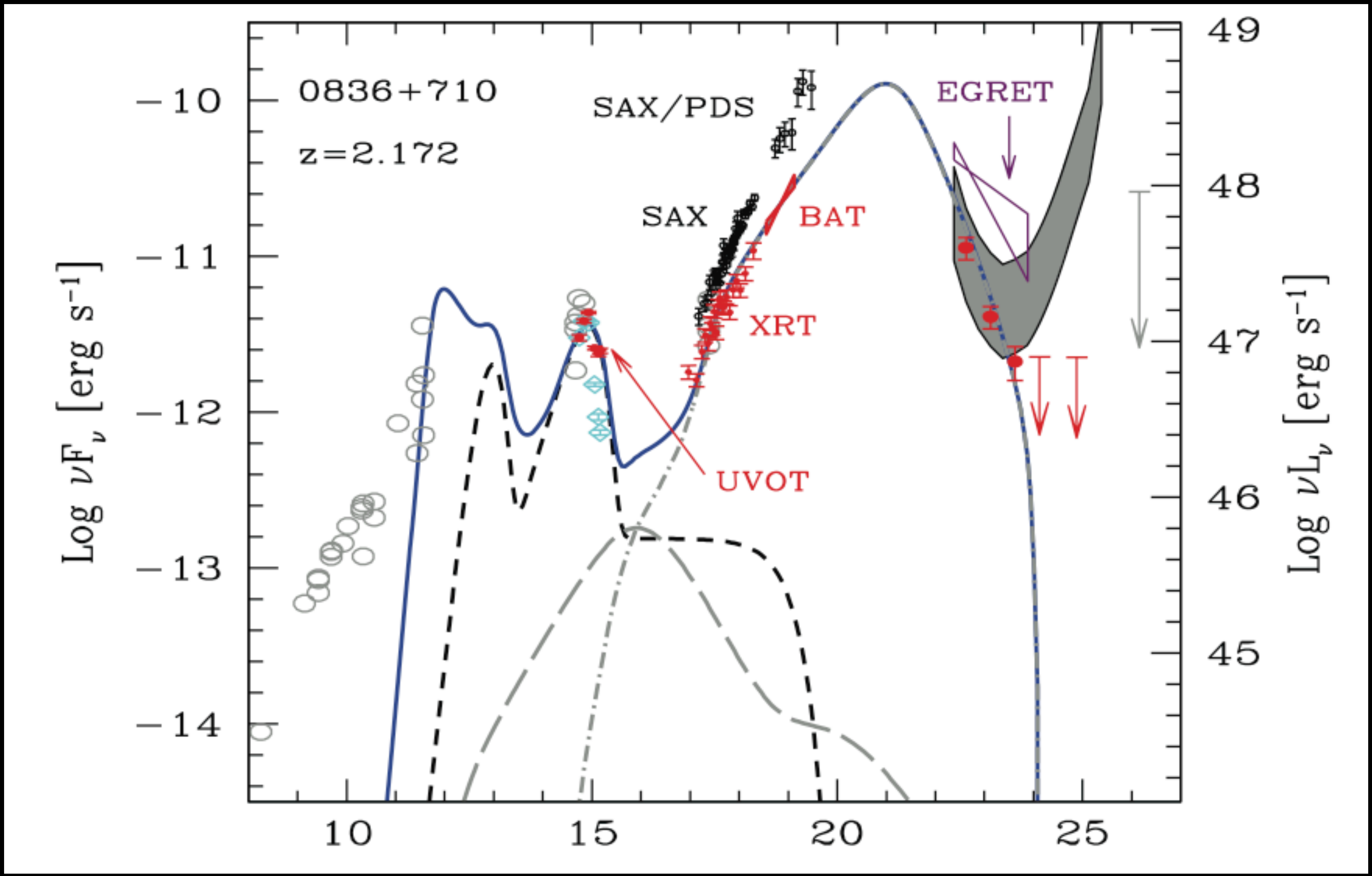


BL Lacs: “clean” jets



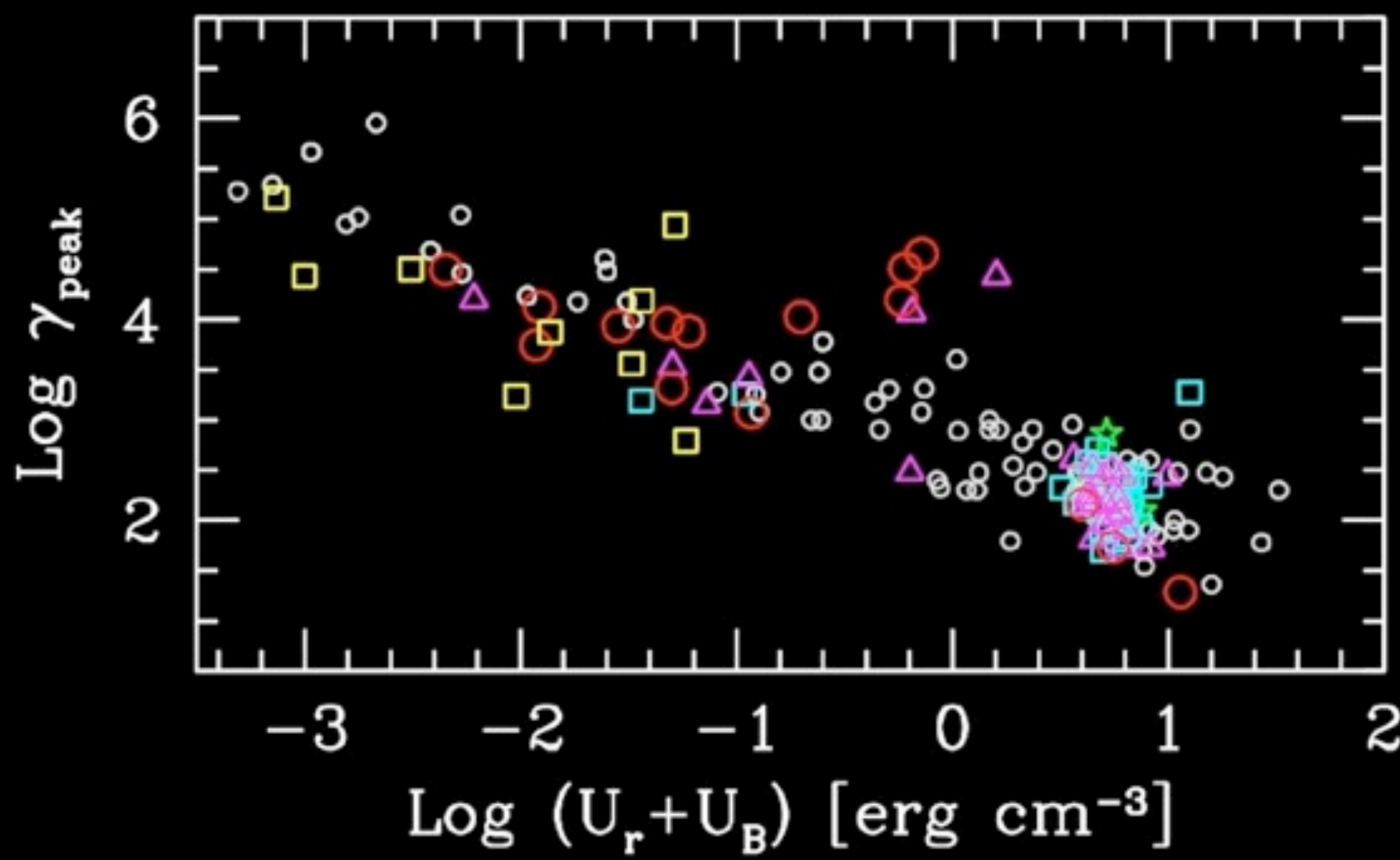
*but see Raiteri et al. 2009
Capetti et al. 2010 for BL Lac itself

Modeling: from data to physics



Log vFv [Hz]

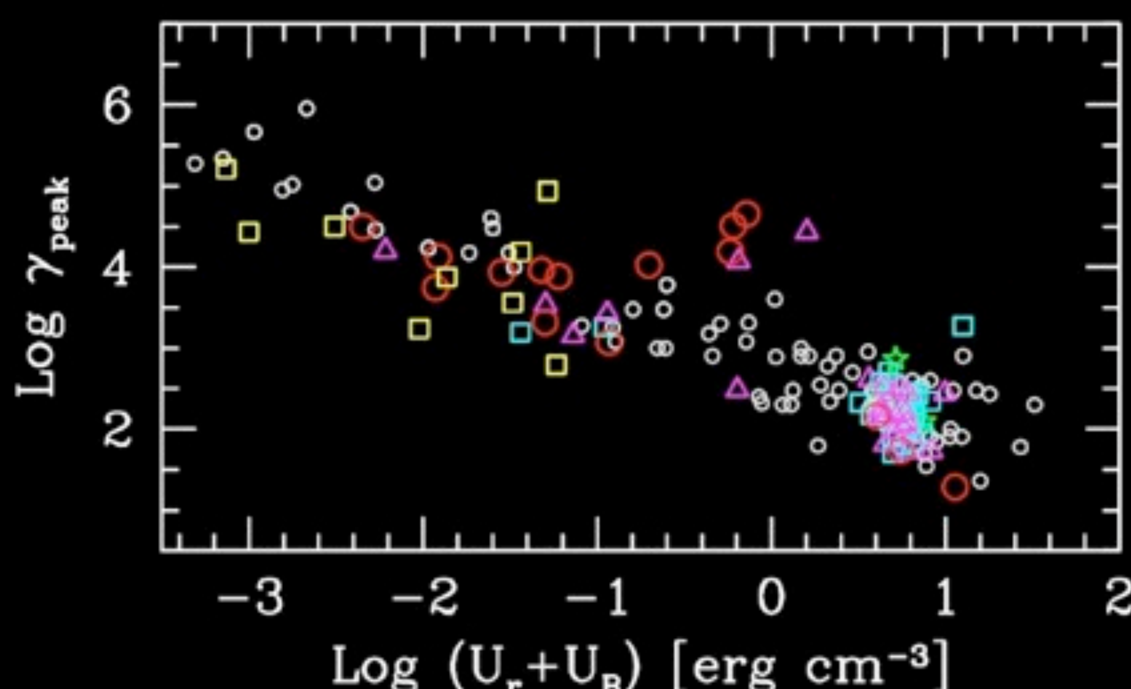
The physical sequence



Ghisellini, FT et al. 2010

The "cooling" paradigm

Energy of electrons emitting at the peak



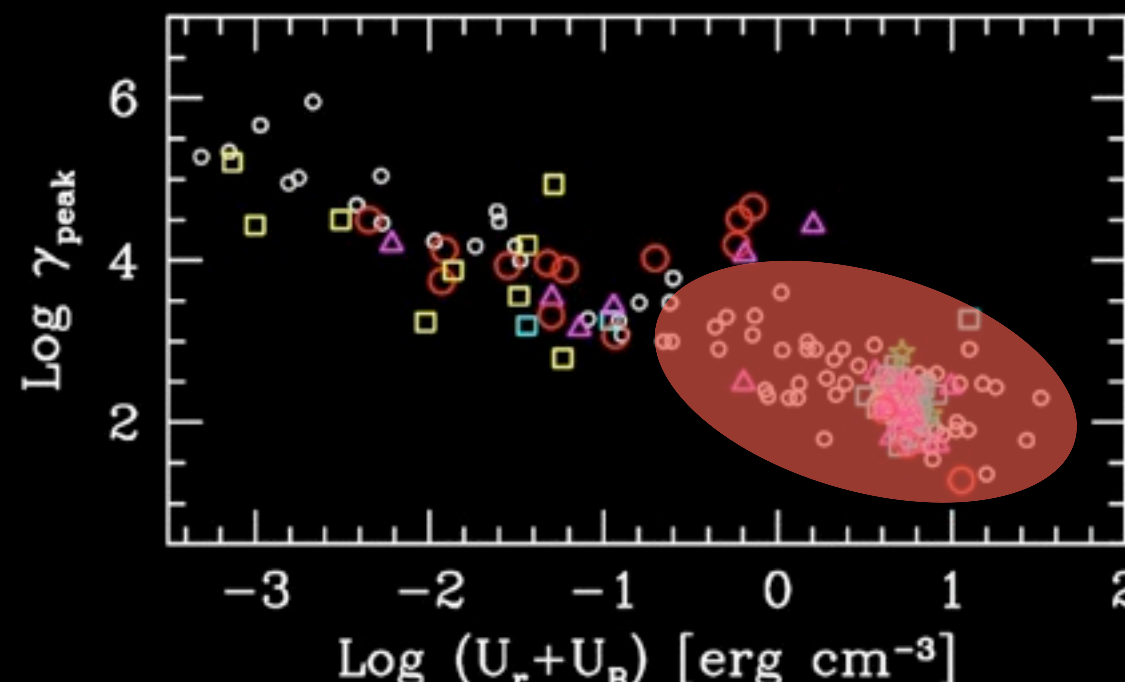
Ghisellini et al. 2010

Total en. density ≈ cooling rate

The "cooling" paradigm

FSRQs: strong cooling → low el. energy

Energy of electrons emitting at the peak



Ghisellini et al. 2010

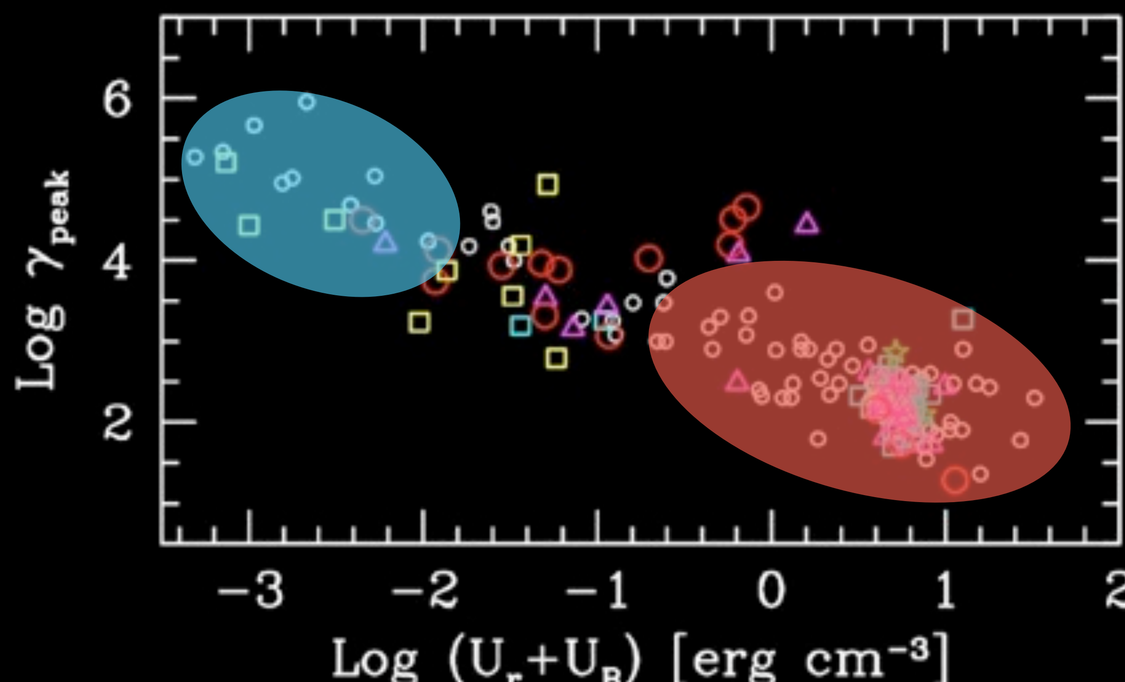
Total en. density ≈ cooling rate

The "cooling" paradigm

FSRQs: strong cooling → low el. energy

BL Lacs: weak cooling → high el. energy

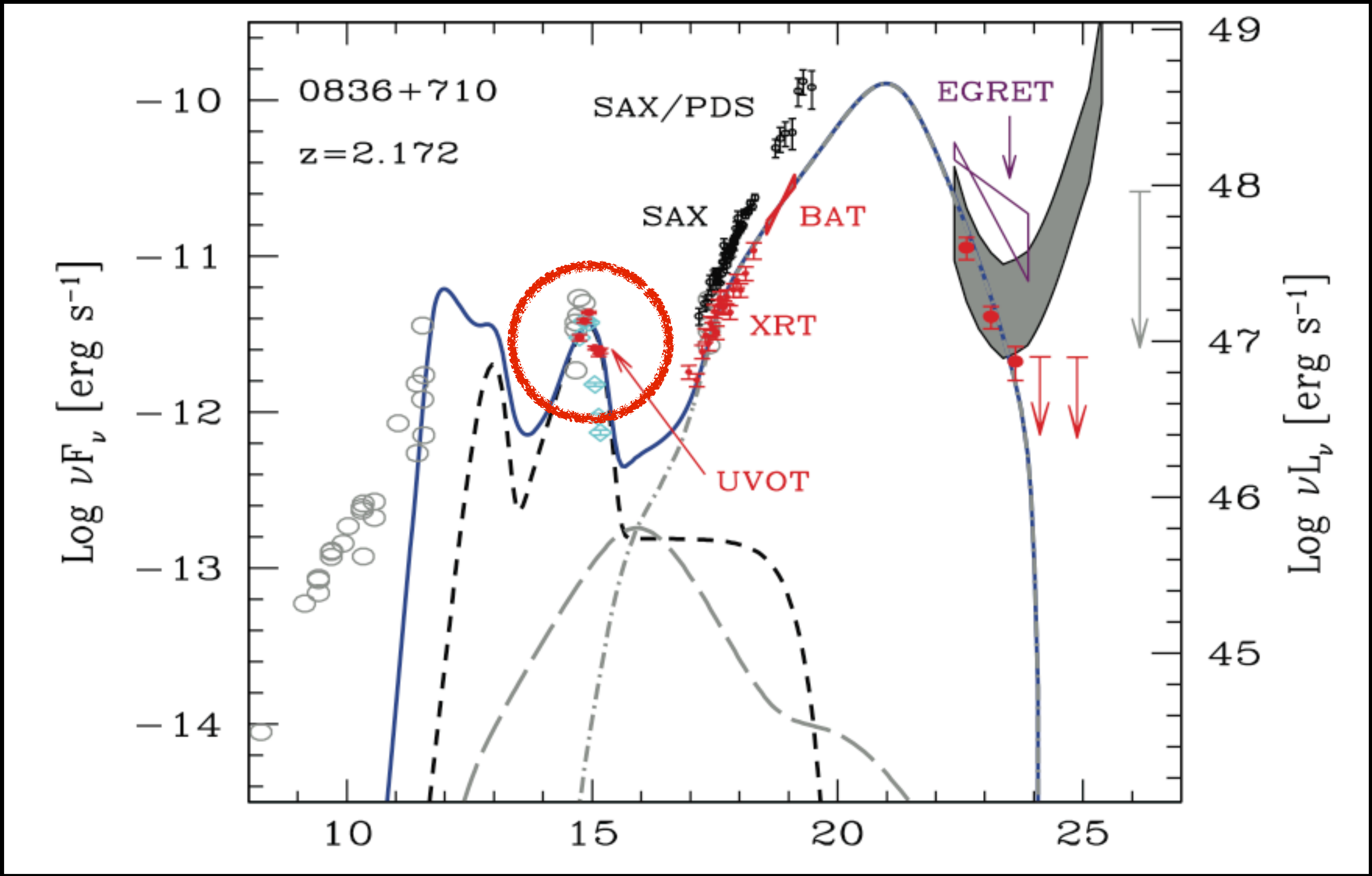
Energy of electrons emitting at the peak



Ghisellini et al. 2010

Total en. density ≈ cooling rate

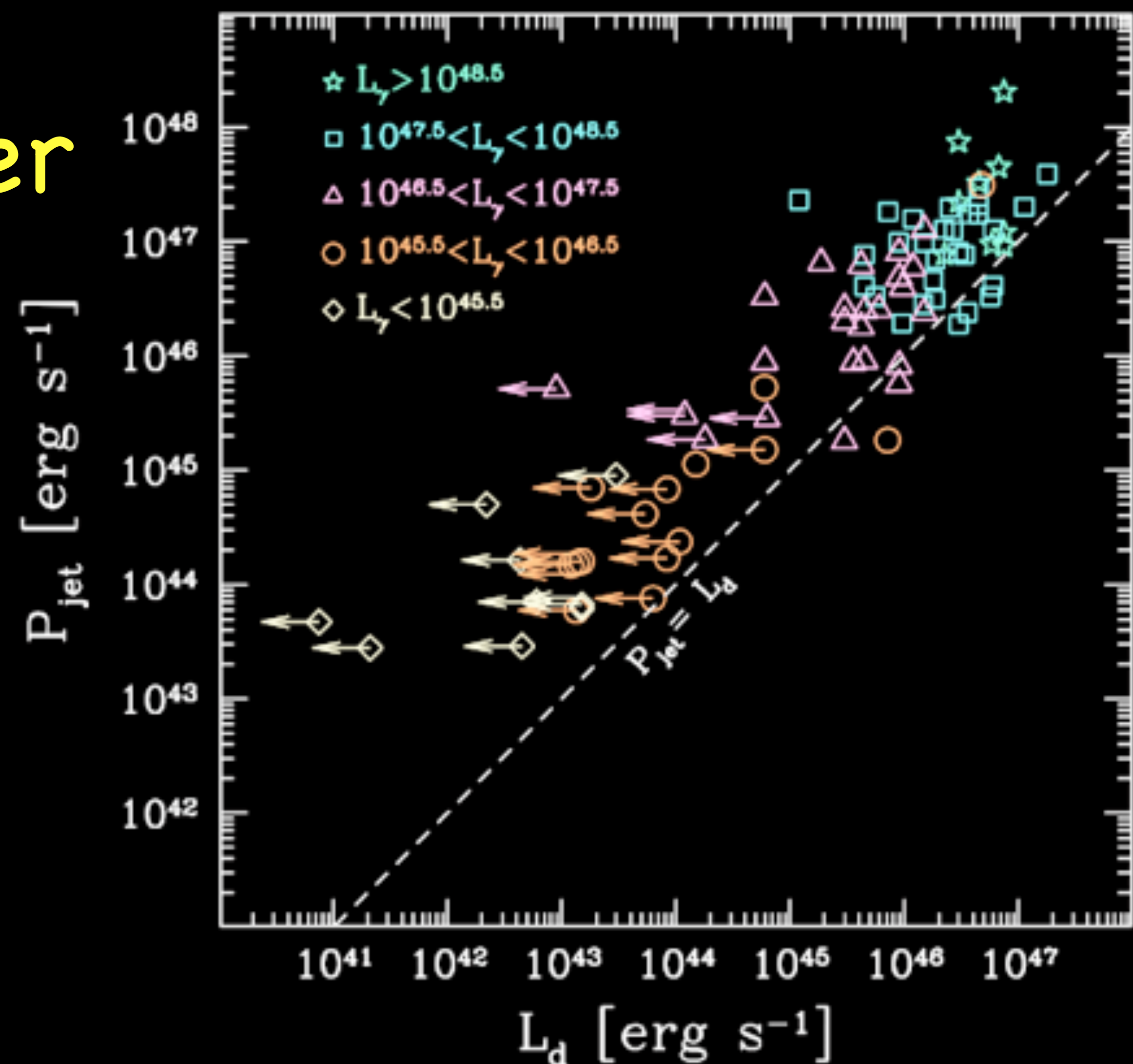
Accretion power!



Log ν [Hz]

Jet power vs accretion

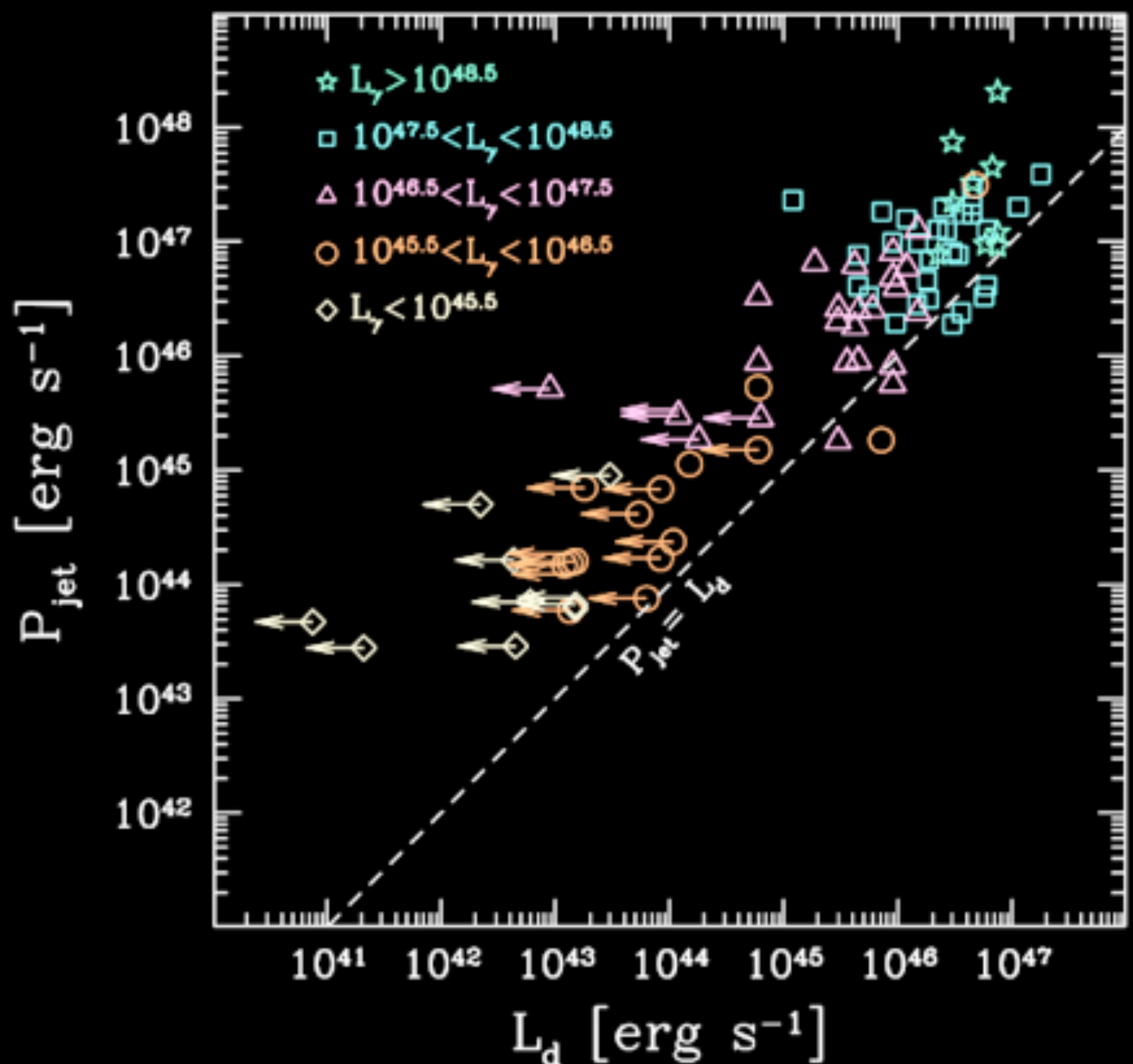
Jet power



Disk Lum.

Ghisellini, FT et al. 2010

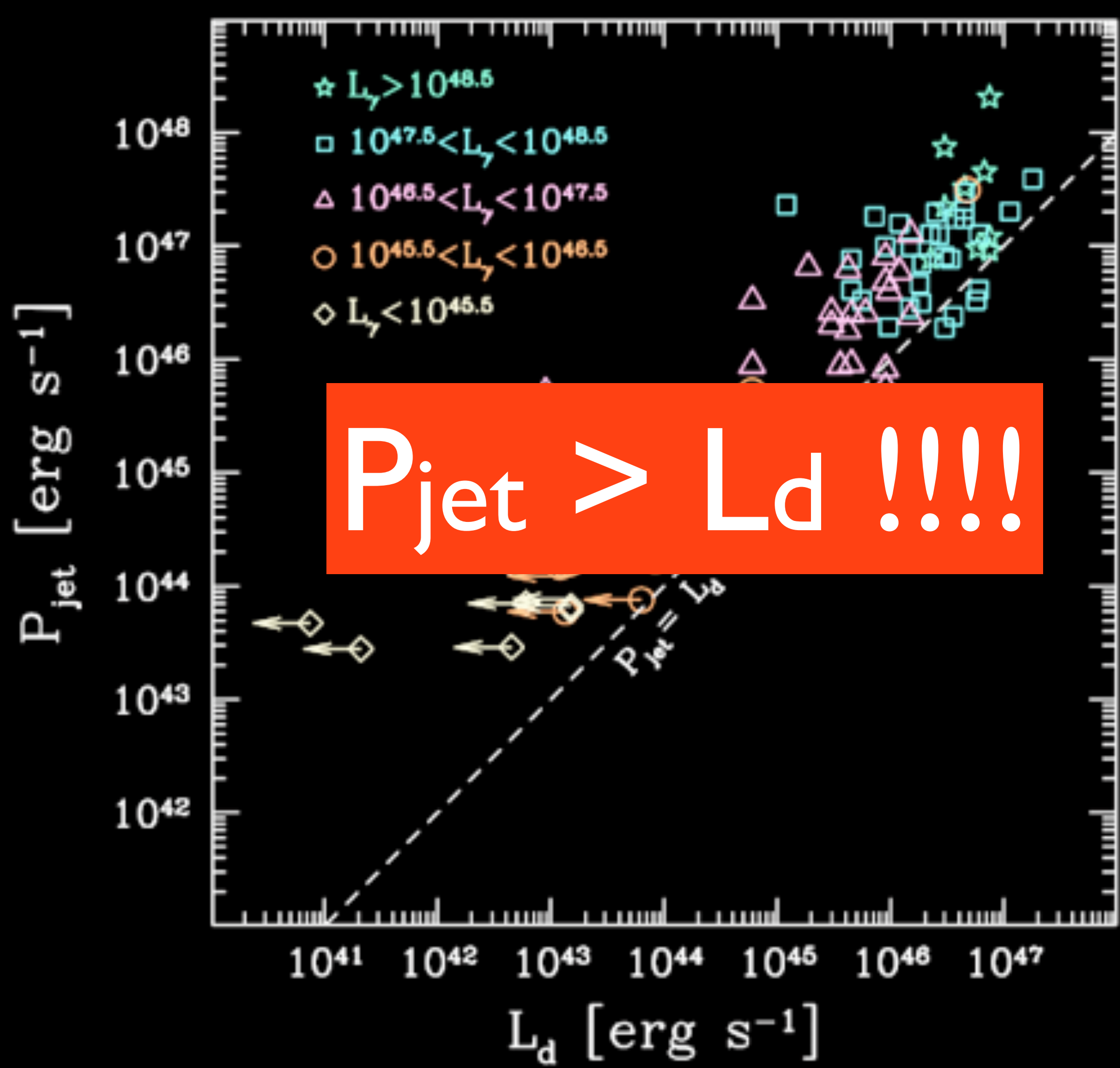
Jet power vs accretion



Sequence of accretion rate

Ghisellini, FT et al. 2010

Jet power vs accretion



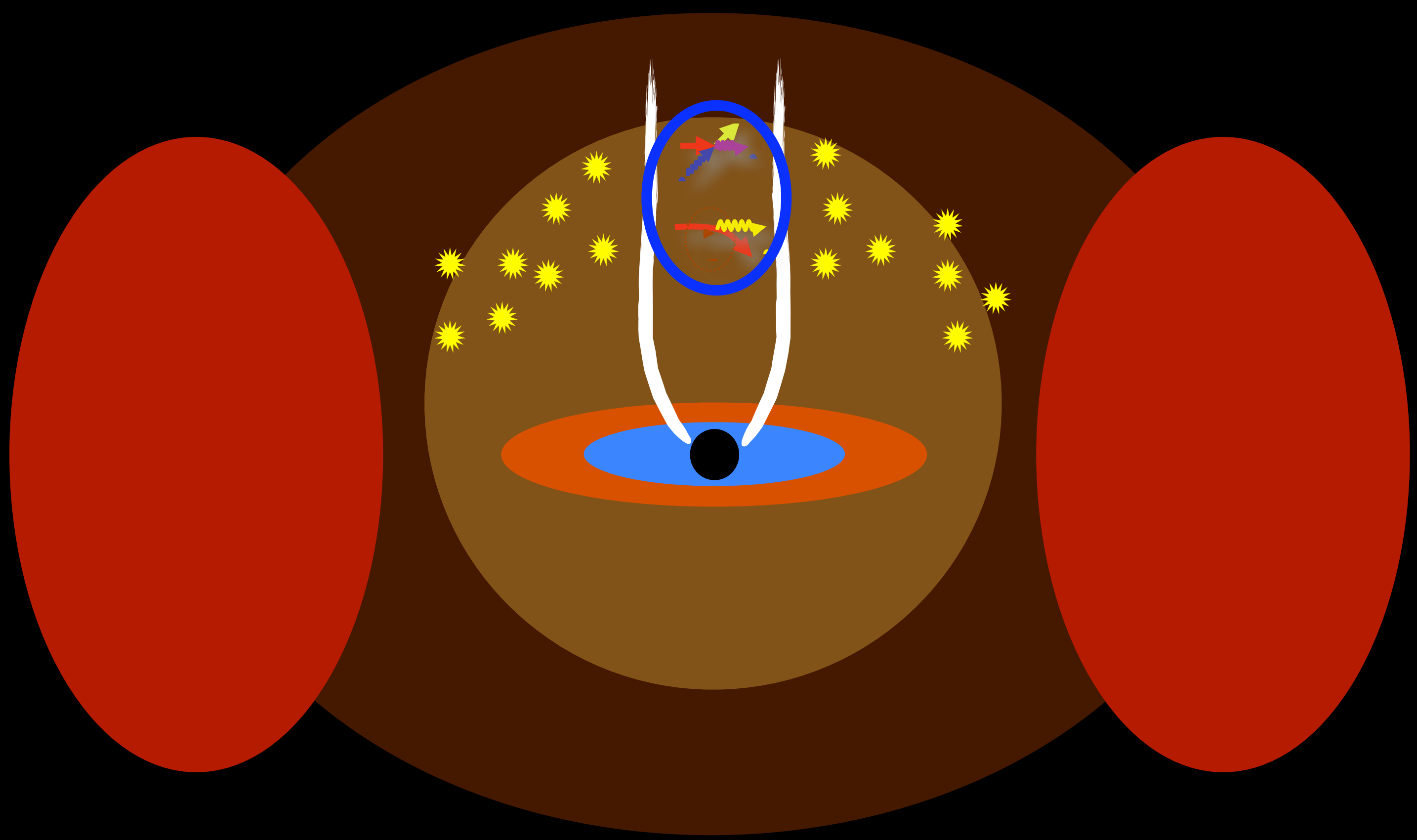
Acceleration/collimation mechanism?

B&Z able to produce enough power?

Ghisellini, FT et al. 2010

Localizing the emission region

Previous results assume distances < 0.1-0.3 pc



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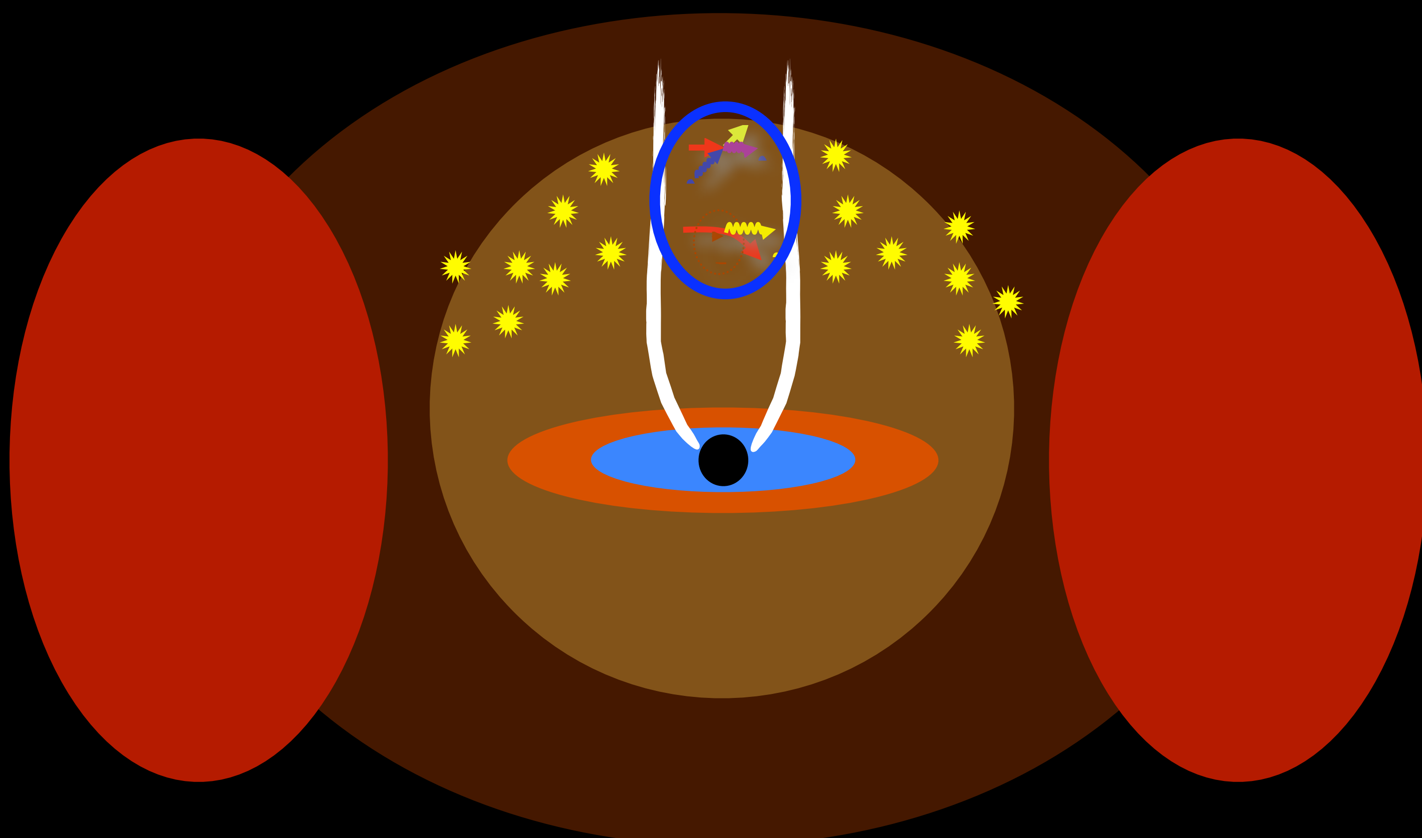
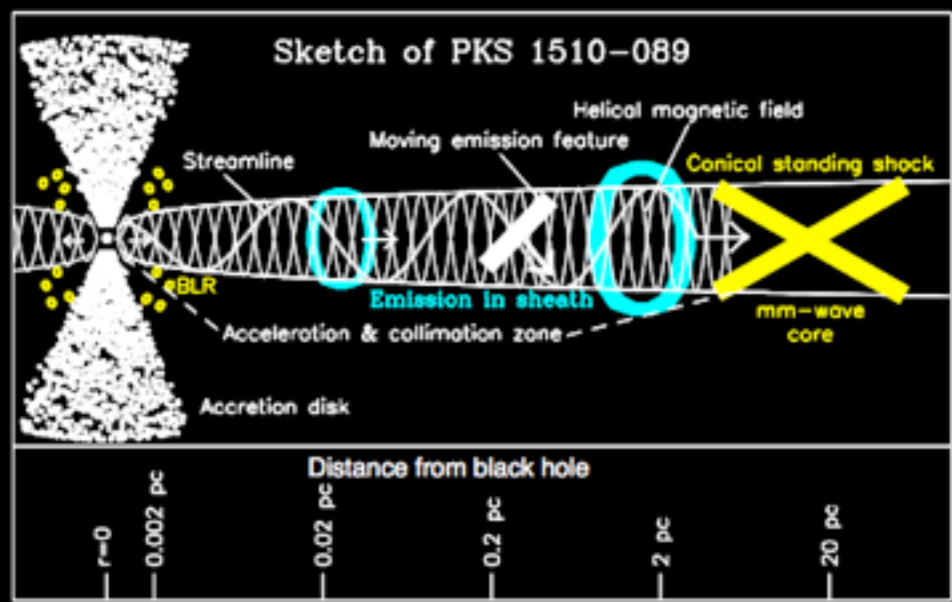


Marscher et al. 2010



But:

Sikora et al. 2009

Marscher et al. 2009, 2010

Lat Coll. 2010

~10-20 pc!

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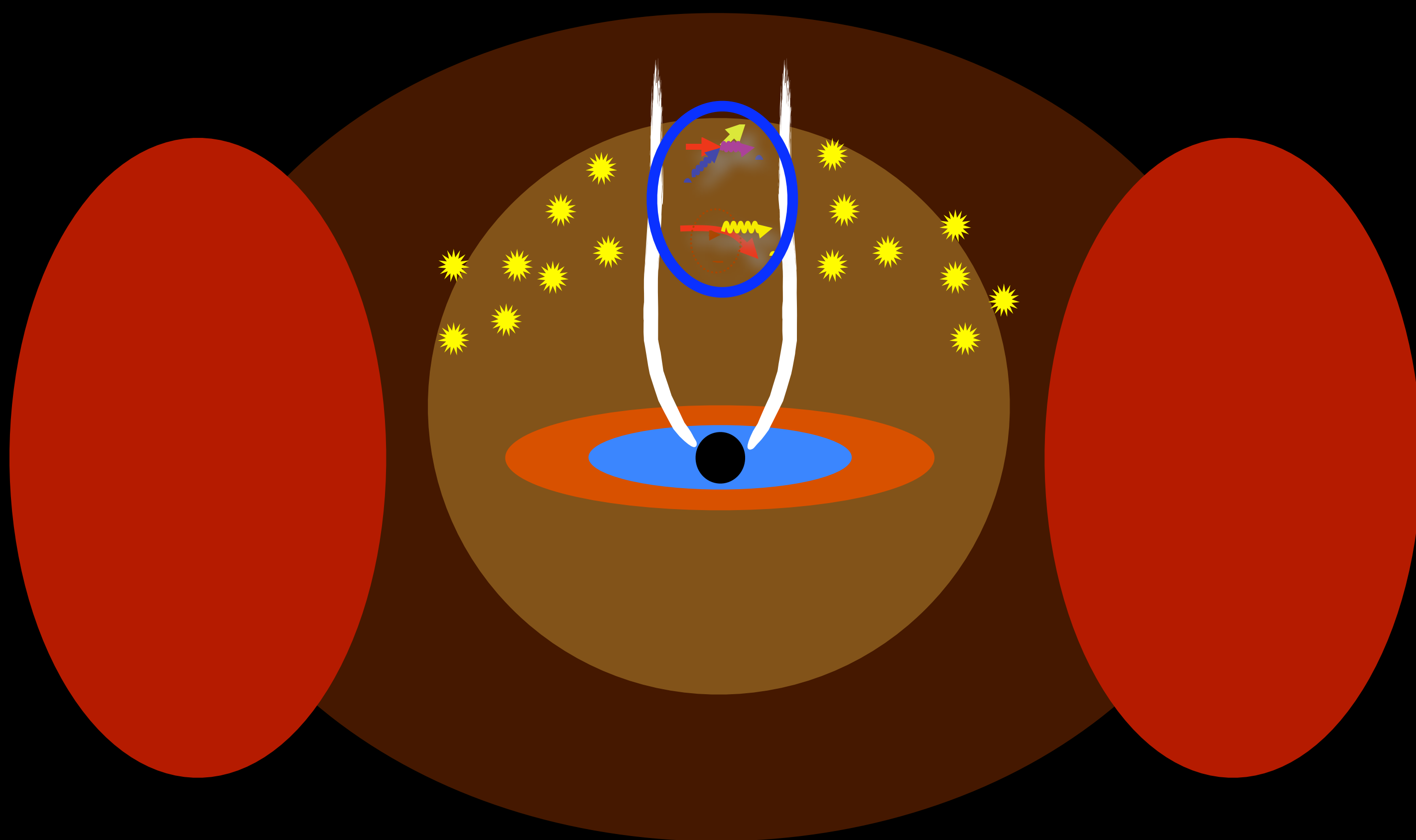

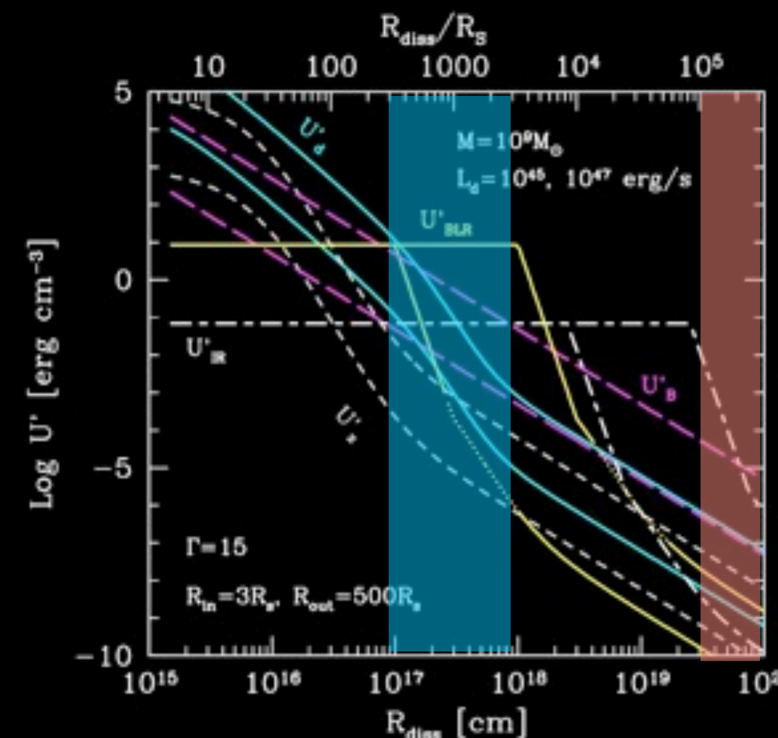

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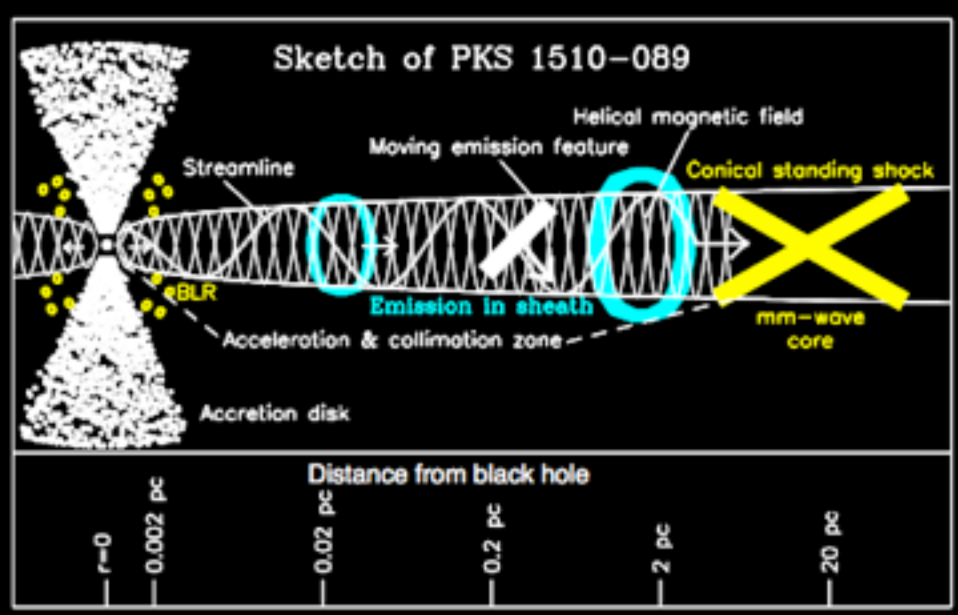
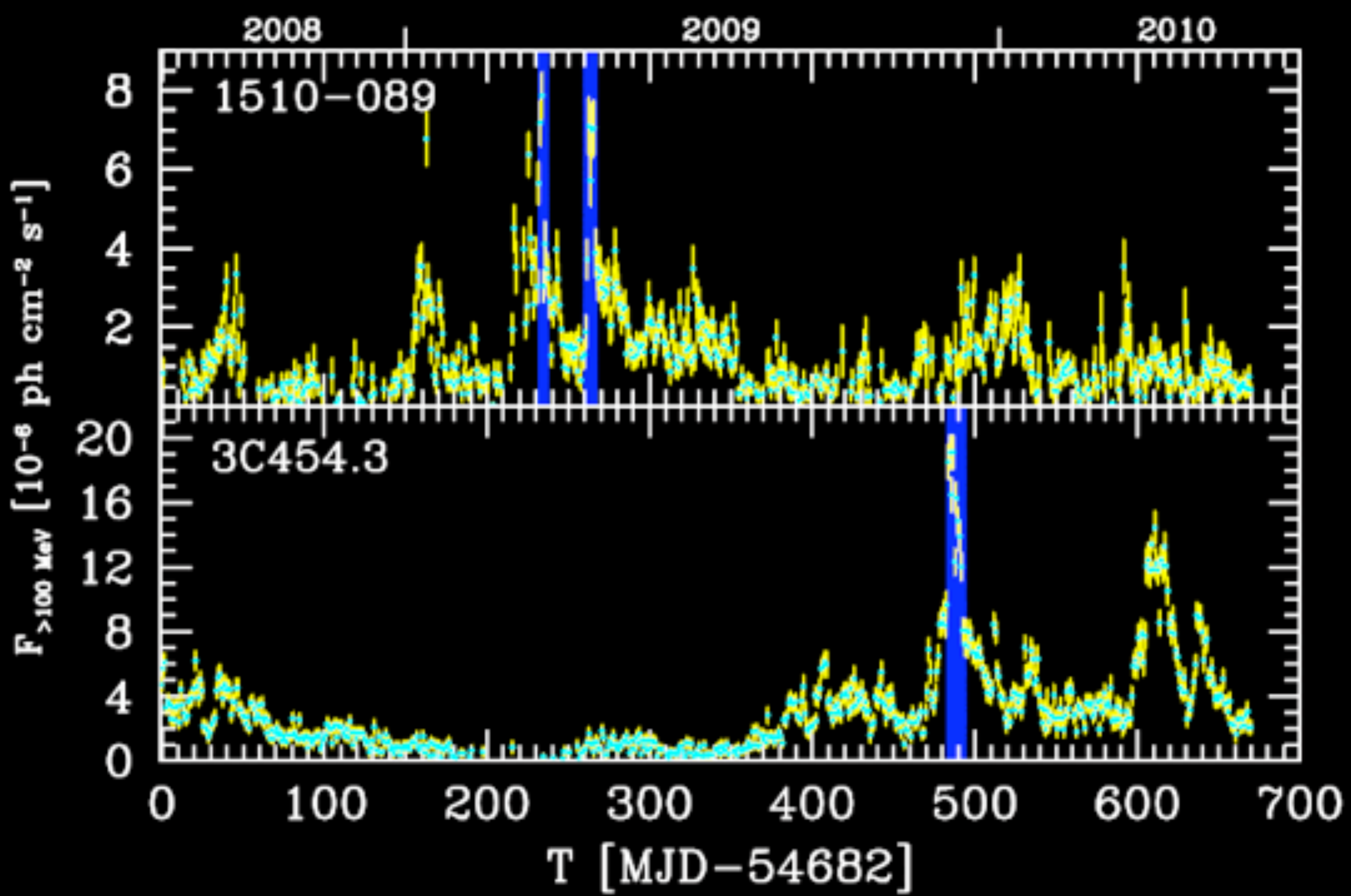


Rapid gamma-ray variability!

LAT lightcurve



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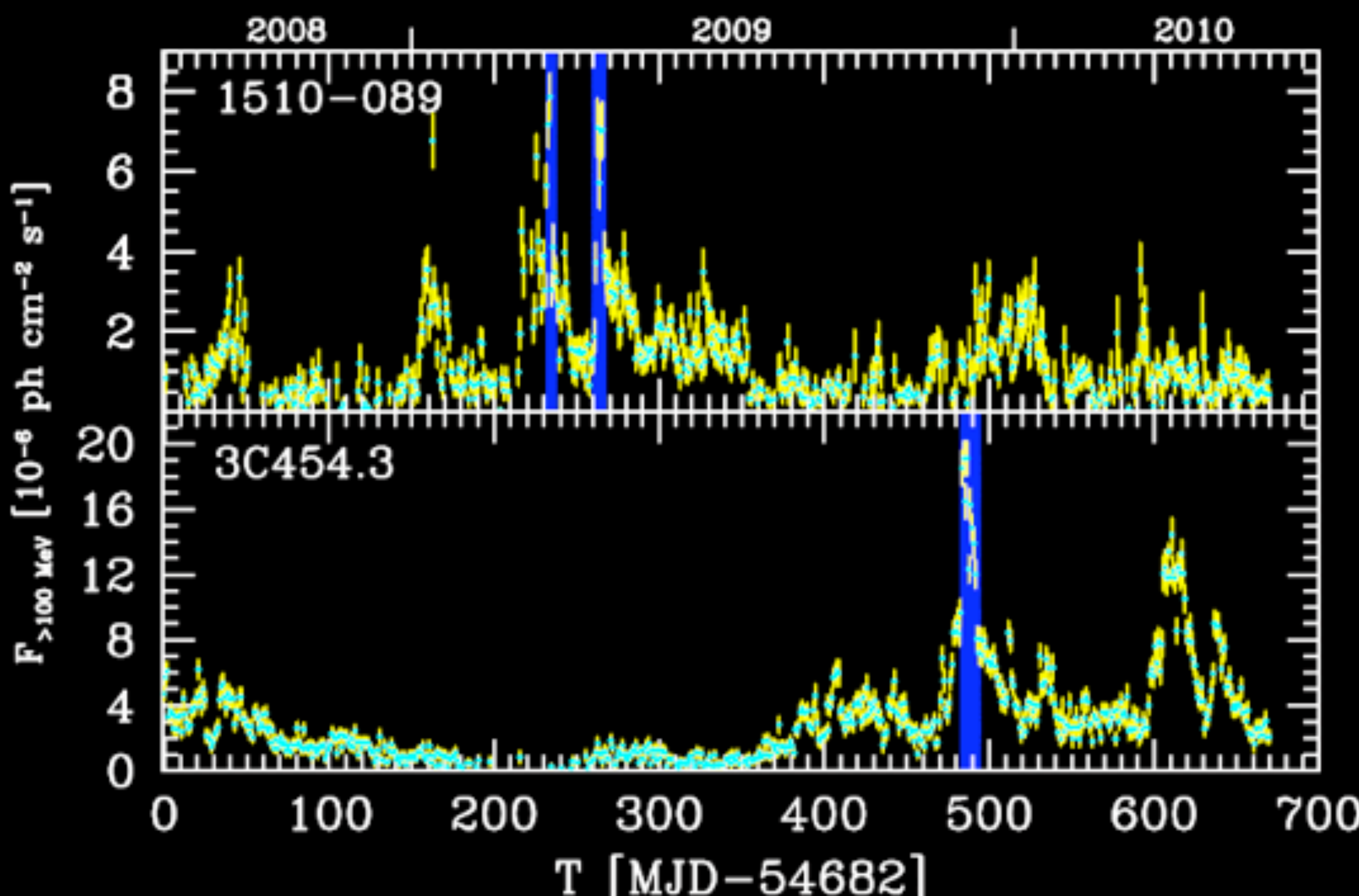

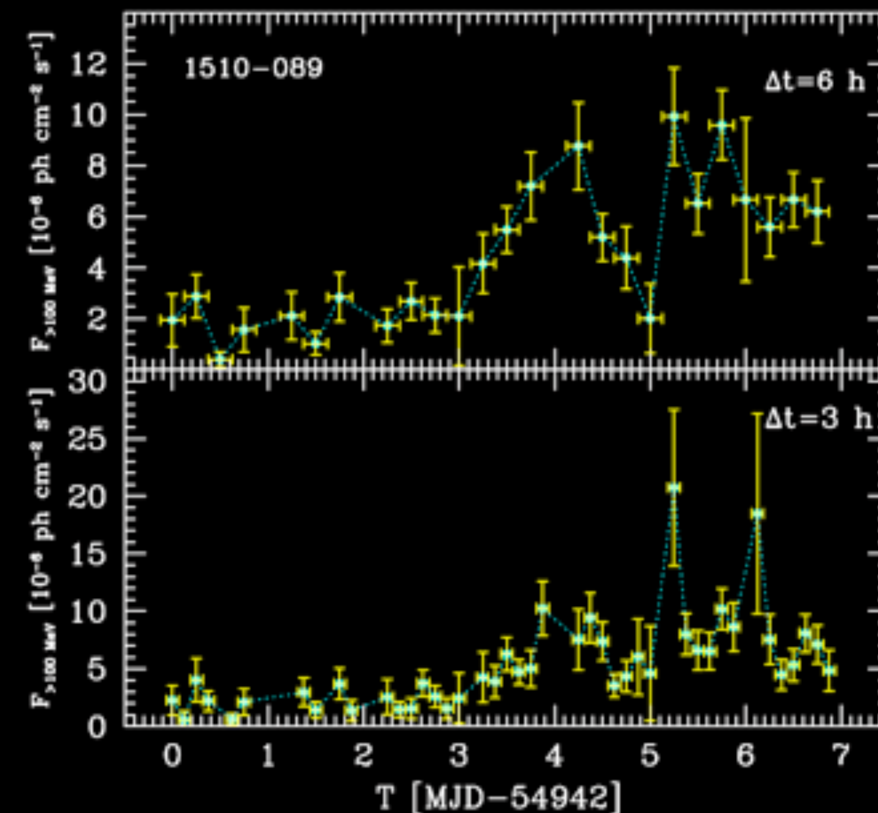

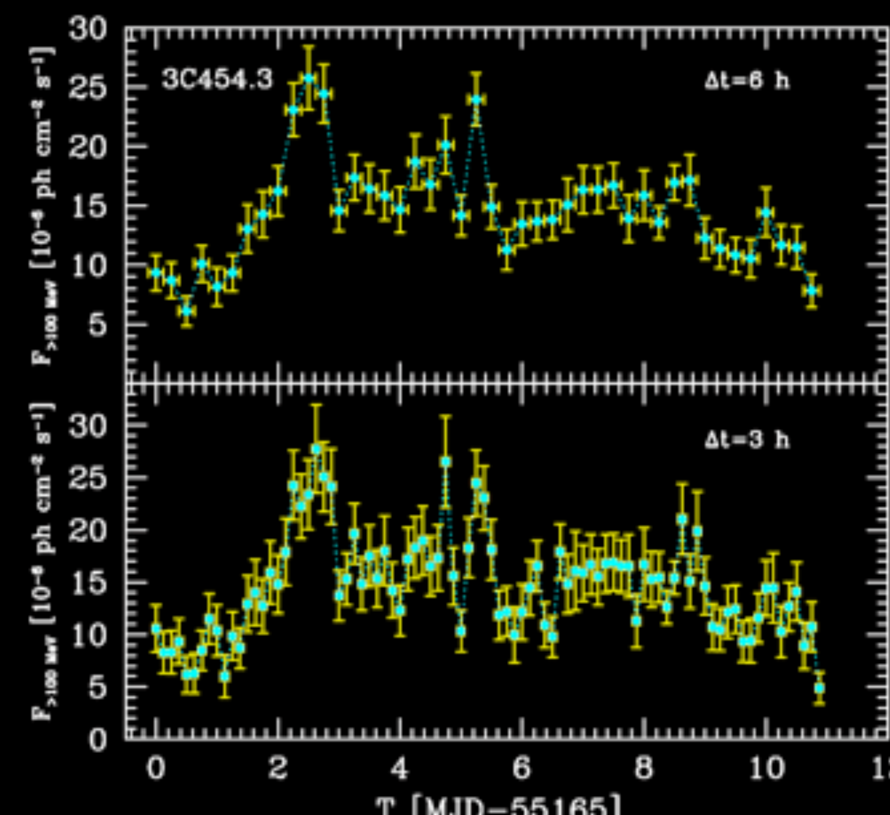

FT et al. 2010

See also Foschini et al. 2010

Abdo et al. 2010, arXiv:1007.0483 for 3C454.3

Rapid gamma-ray variability!

$$R < ct_{\rm var}\frac{\delta}{1+z} \simeq \frac{6.5\times10^{15}}{1+z}\left(\frac{t_{\rm var}}{6\,{\rm h}}\right)\left(\frac{\delta}{10}\right)\ {\rm cm}$$

IF $d \simeq \frac{R}{\theta_{\rm j}}$ Conical geometry

$$d < ct_{\rm var}\frac{\delta}{1+z}\theta_{\rm j}^{-1} \simeq \frac{6.5\times10^{16}}{1+z}\left(\frac{t_{\rm var}}{6\,{\rm h}}\right)\left(\frac{\delta}{10}\right)\left(\frac{\theta_{\rm j}}{0.1}\right)^{-1}\ {\rm cm}$$

i.e. inside the BLR

Doppler factor is not expected to be >> 30 (e.g. Abdo et al. 2010)

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i.e. inside the BLR

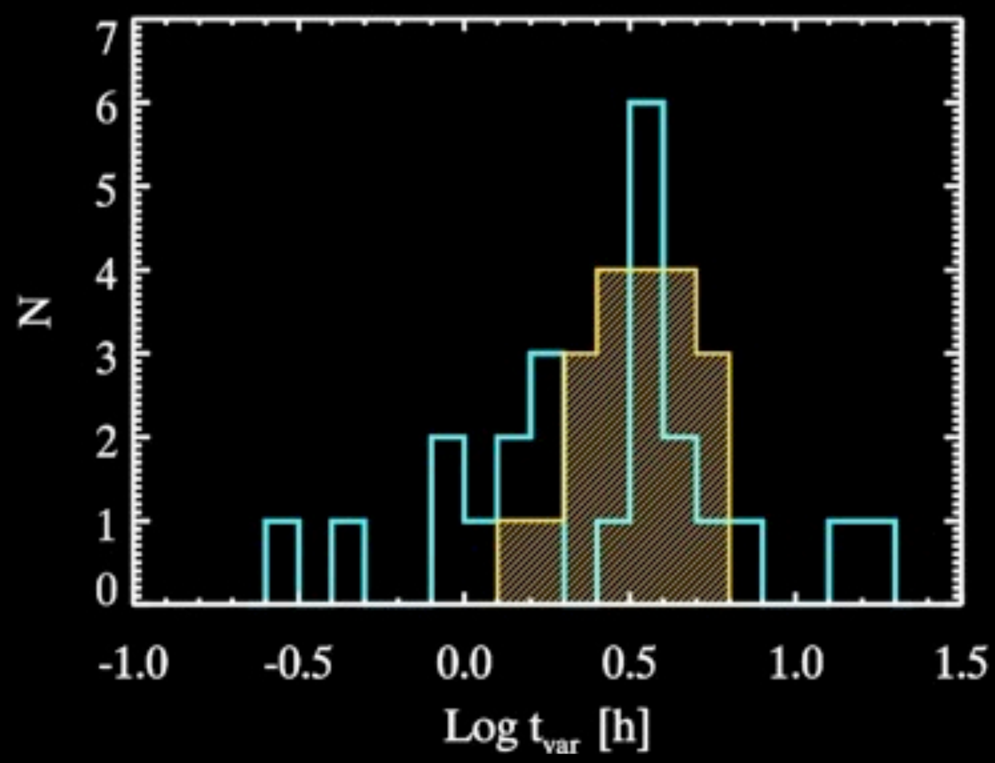
Doppler factor is not expected to be >> 30 (e.g. Abdo et al. 2010)

Very small collimation angle?
If d=20 pc

$$\theta_{\rm j} \simeq \frac{10^{-4}}{1+z}\left(\frac{t_{\rm var}}{6\,{\rm h}}\right)\left(\frac{\delta}{10}\right)$$

A similar problem: too rapid TeV variability in HBLs

BL Lac Detected in TeV
BL Lac not detected in TeV



FT et al. 2010

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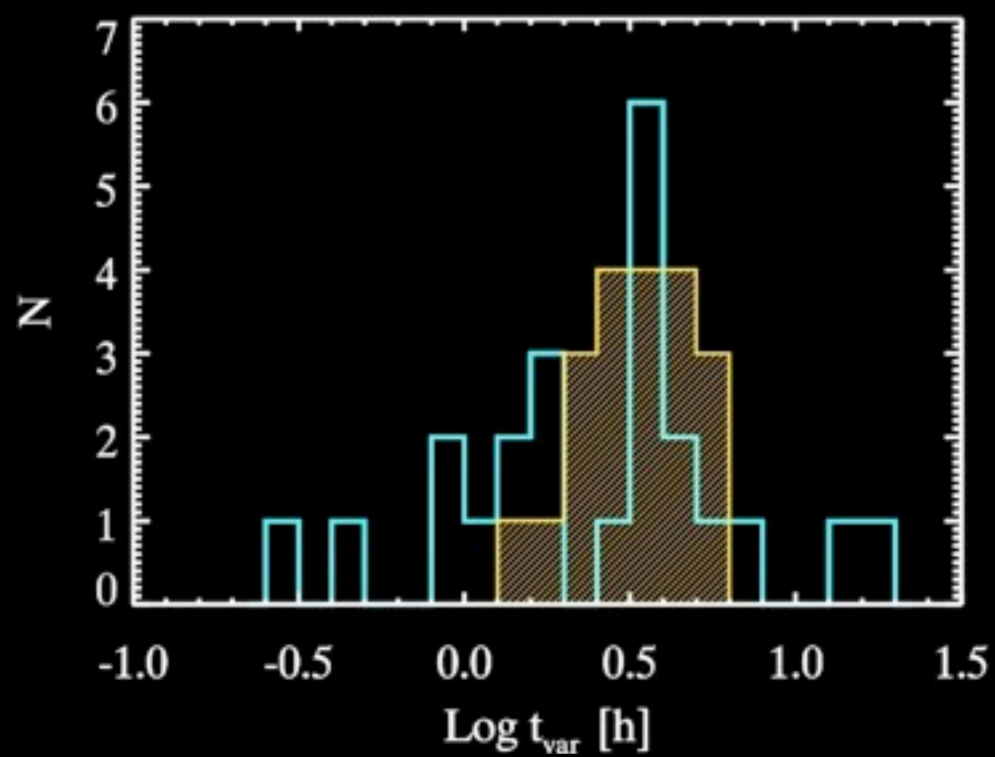
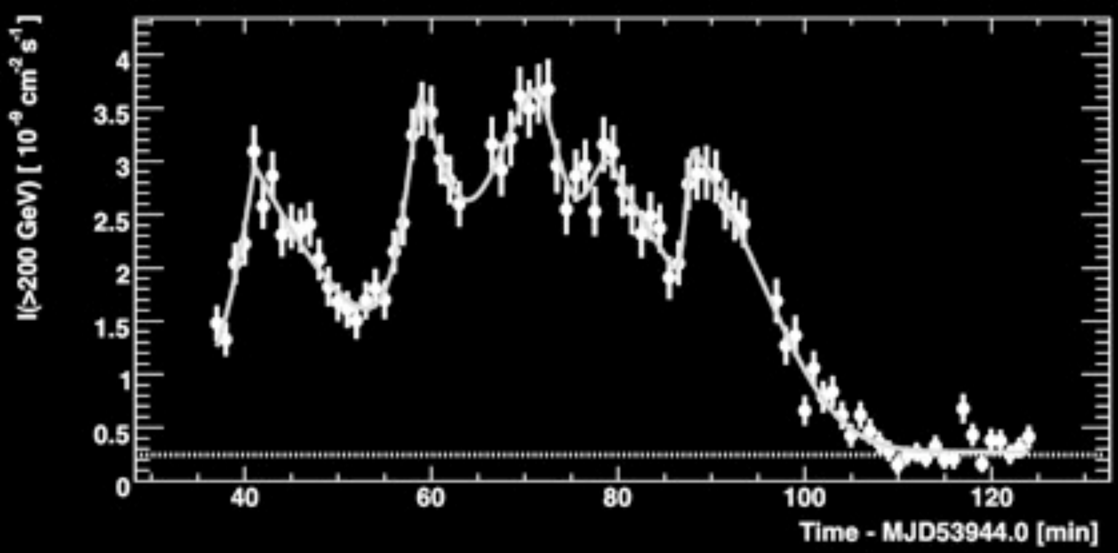


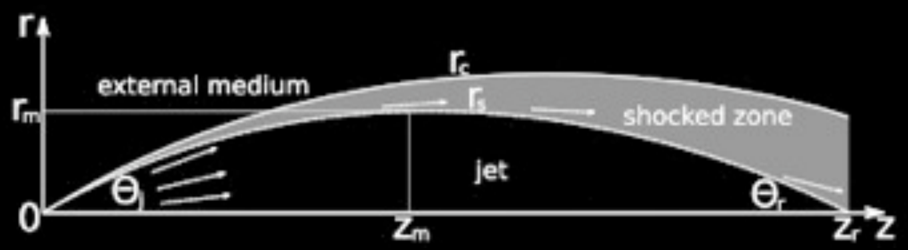
FT et al. 2010

PKS 2155-304 - HESS



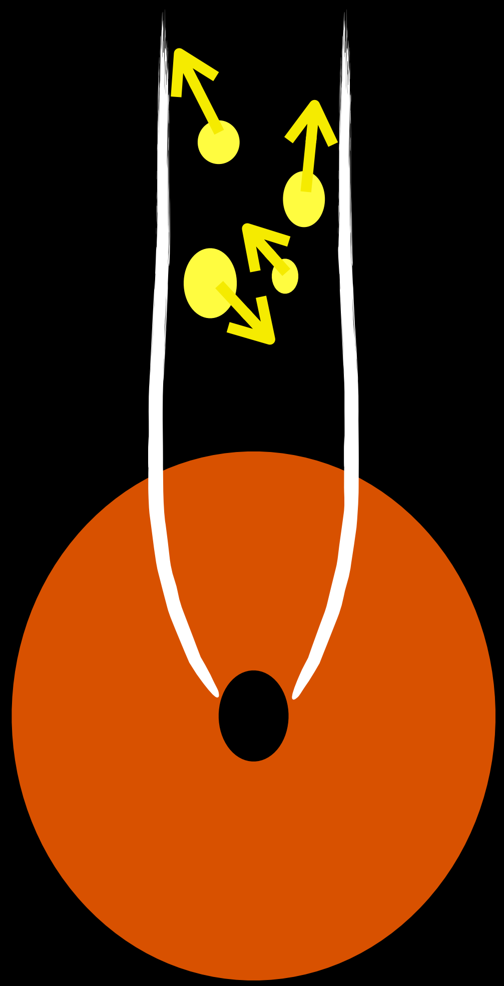
Ultrafast (~200 s) variability (Aharonian et al. 2007, Albert et al. 2007) needs major changes (e.g. Ghisellini et al. 2008, 2009, Giannios et al 2009, Neronov et al. 2008)

Possibilities to reconcile large d and rapid variability in BL Lacs (and FSRQs?)



Strong recollimation

e.g. Nalewajko & Sikora 2009
Bromberg & Levinson 2009



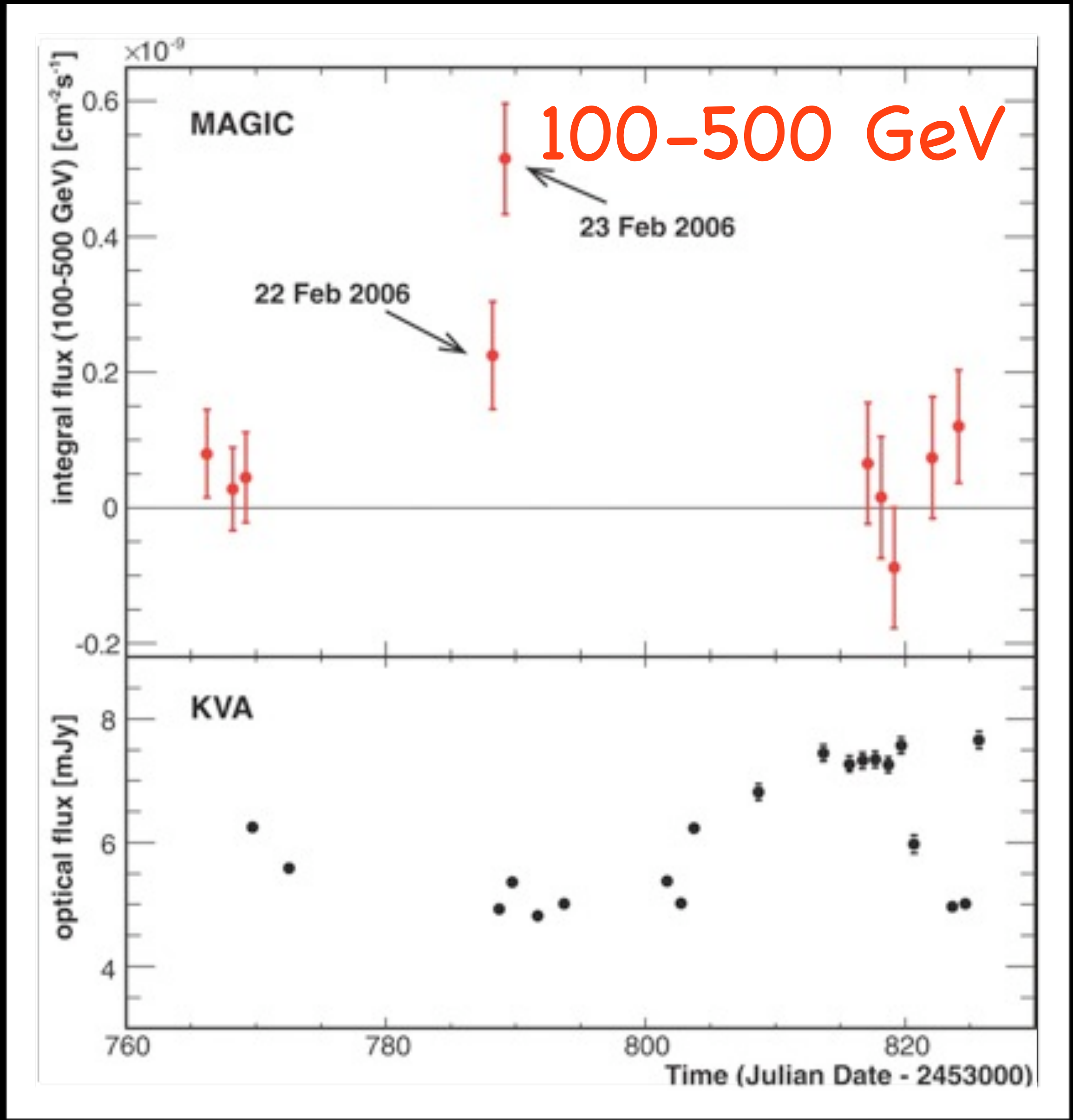
"Needles"

e.g. Ghisellini et al. 2008, 2009
Giannios et al 2009
Marscher & Jorstad 2010

VHE emission from FSRQs

3C279

Albert et al. 2008

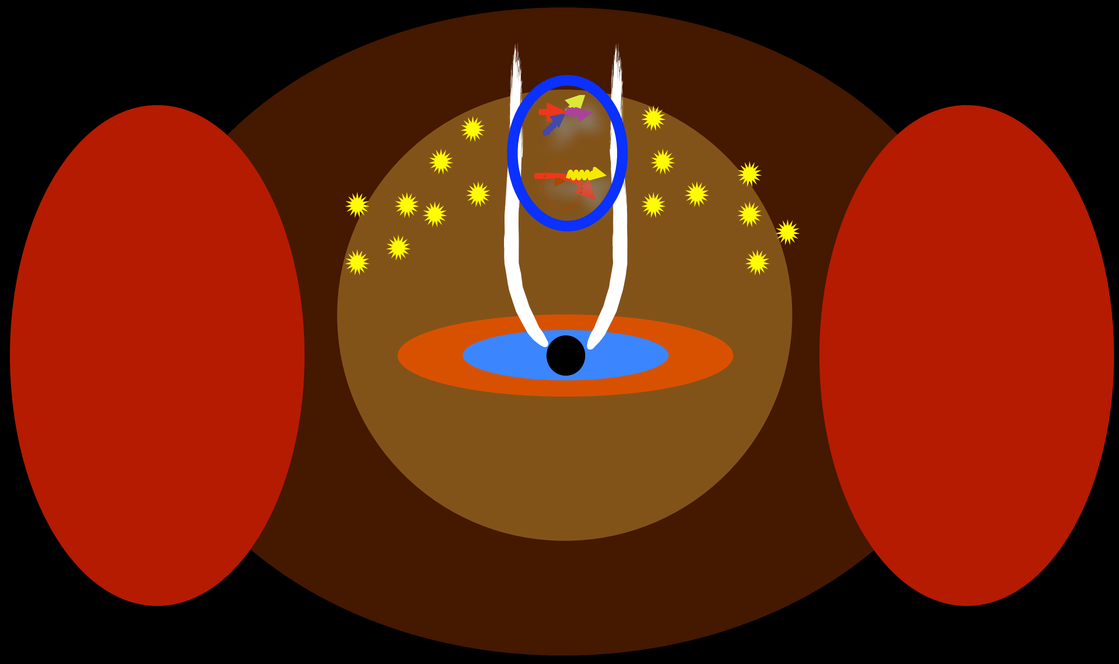


also :

Wagner 2010 for 1510-089 (HESS)

Mariotti 2010 for 1222+216 (MAGIC)

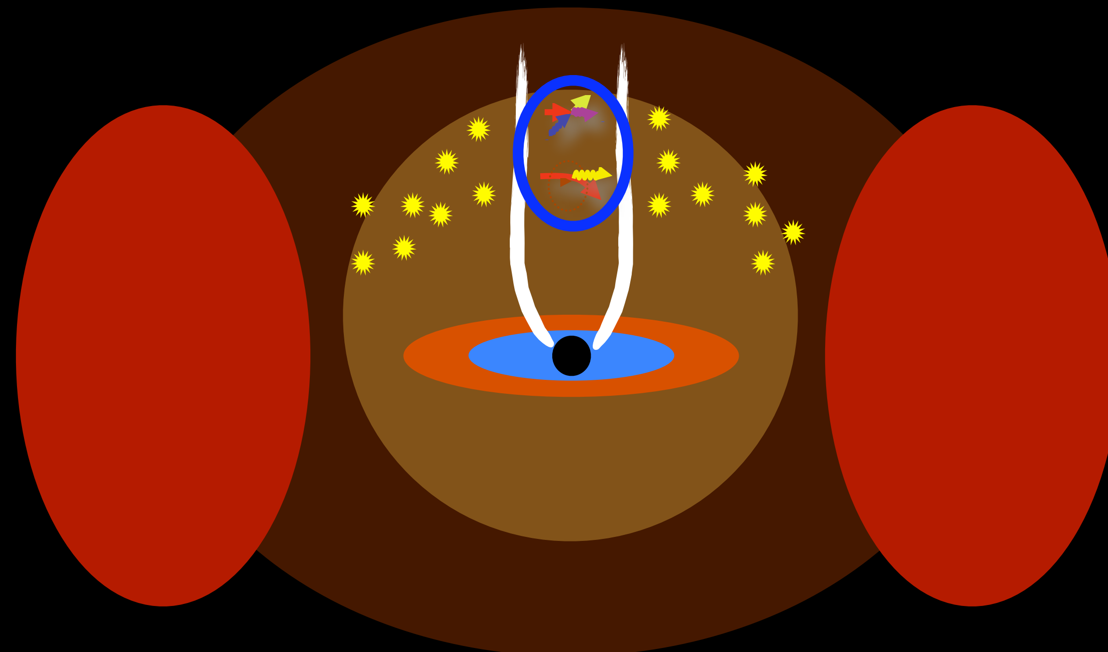
VHE emission from FSRQs? Difficult inside BLR!



Strong absorption
(E>30 GeV within BLR, E>1 TeV outside)
(e.g. Liu et al. 2008, Reimer 2007, FT & Mazin 2009)

Decline of the scattering efficiency
(e.g. Albert et al. 2008, FT & Ghisellini 2008)

VHE emission from FSRQs? Difficult inside BLR!



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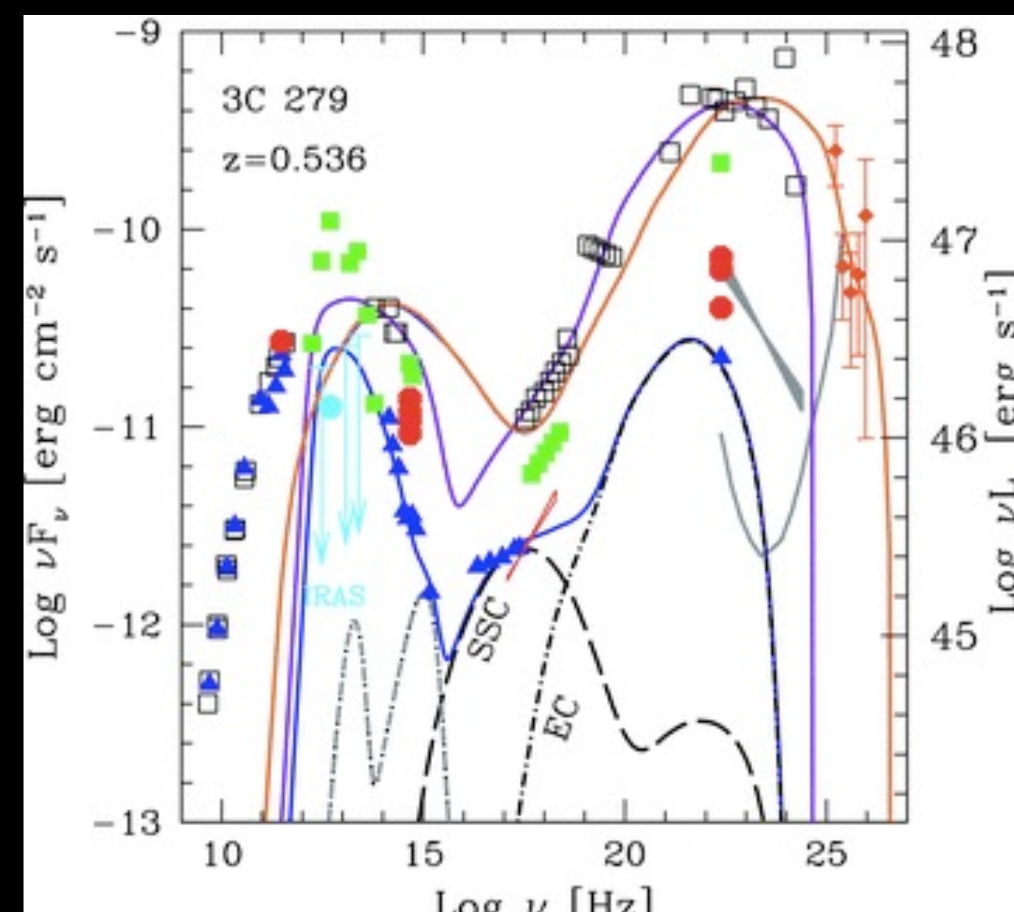
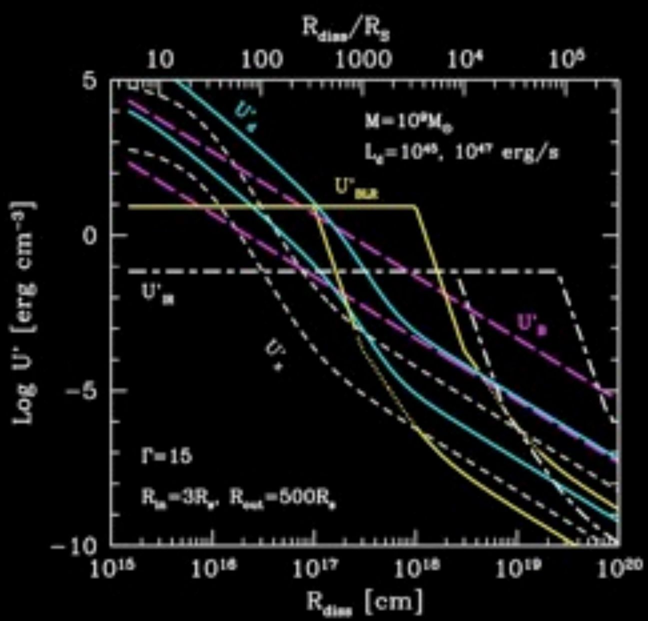
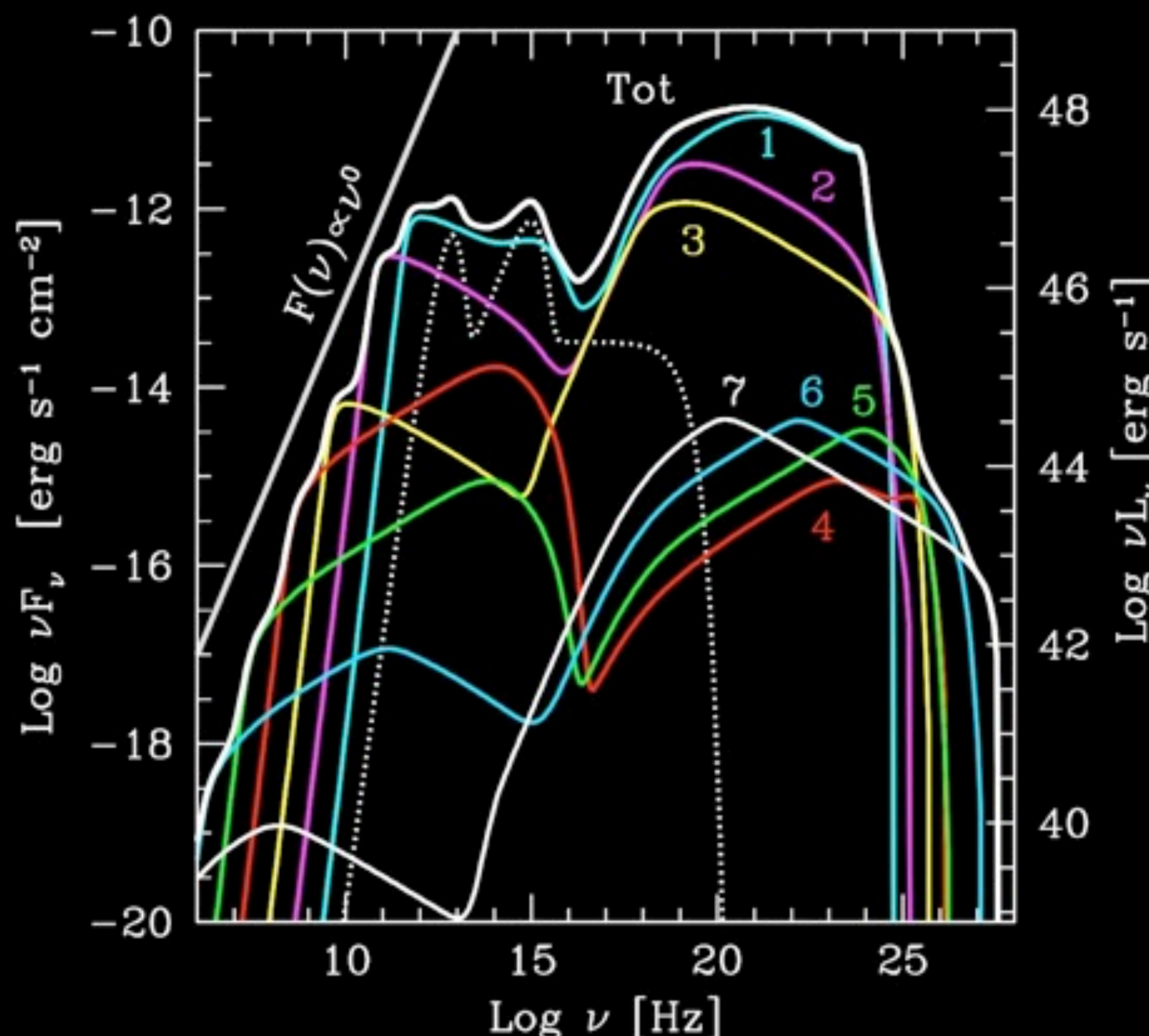


Both problems alleviated outside BLR (IR torus)

More than one region?

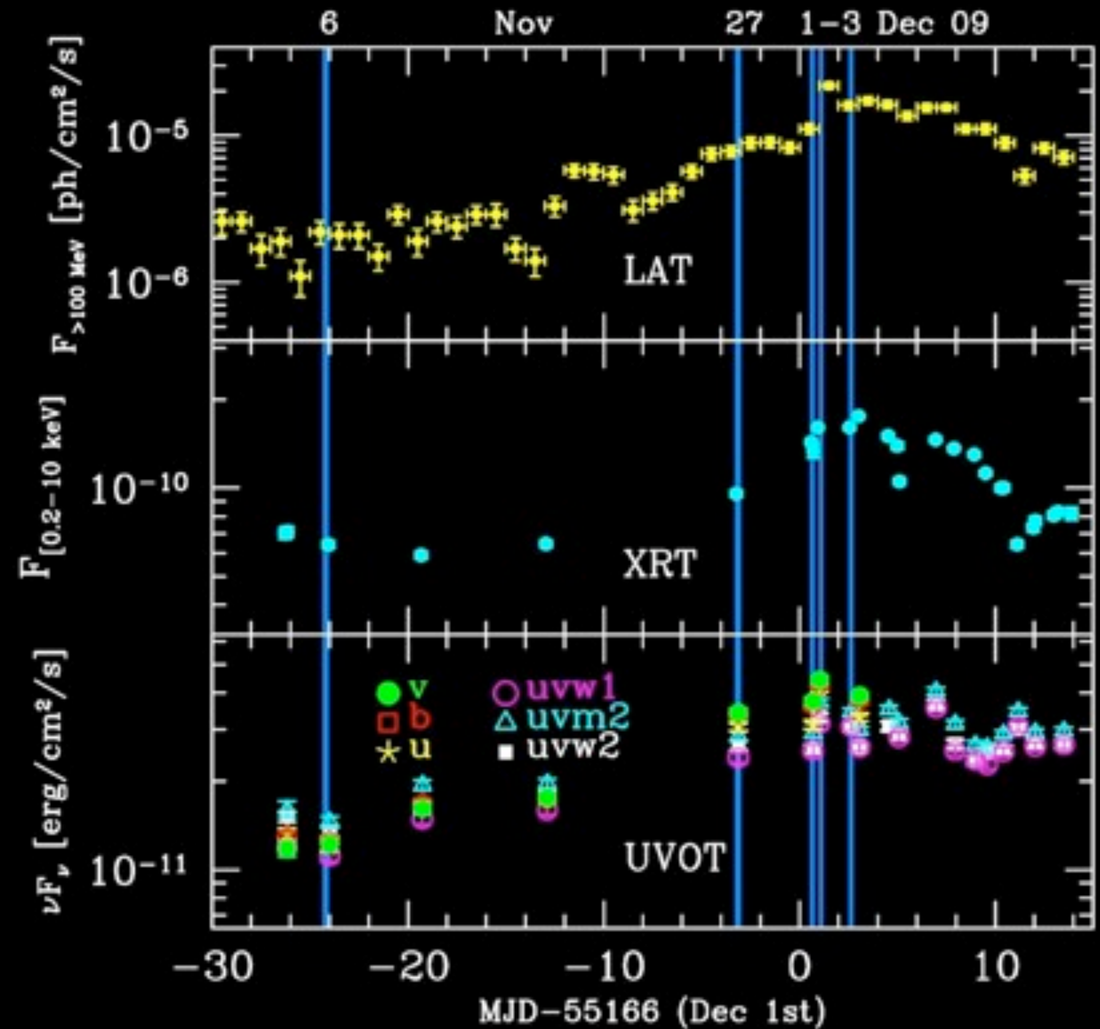


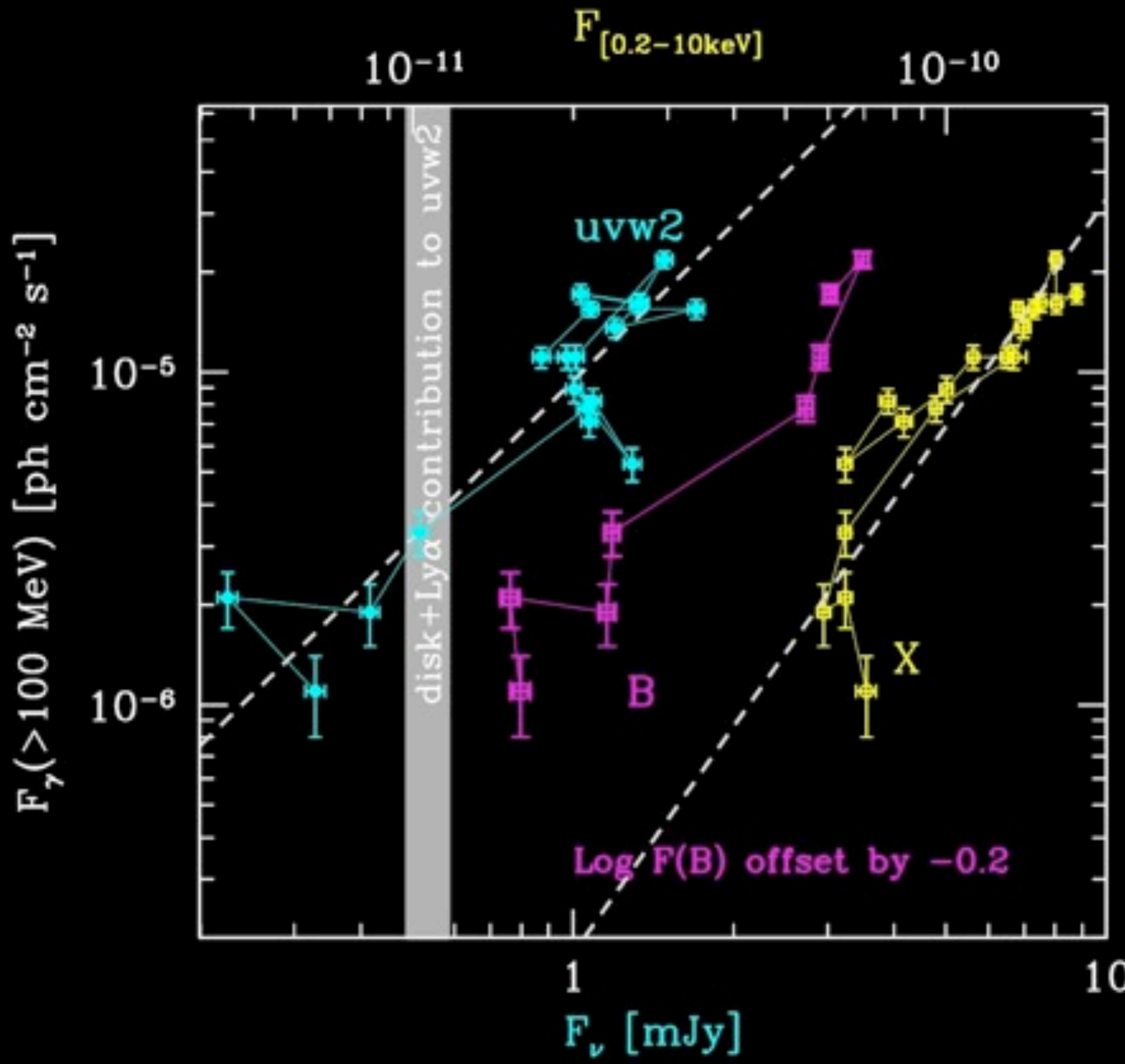


Different variability time-scales
at different energies (GeV: fast –TeV: slow)

No fast TeV variability (unless “needles”)

3C454.3: a benchmark case





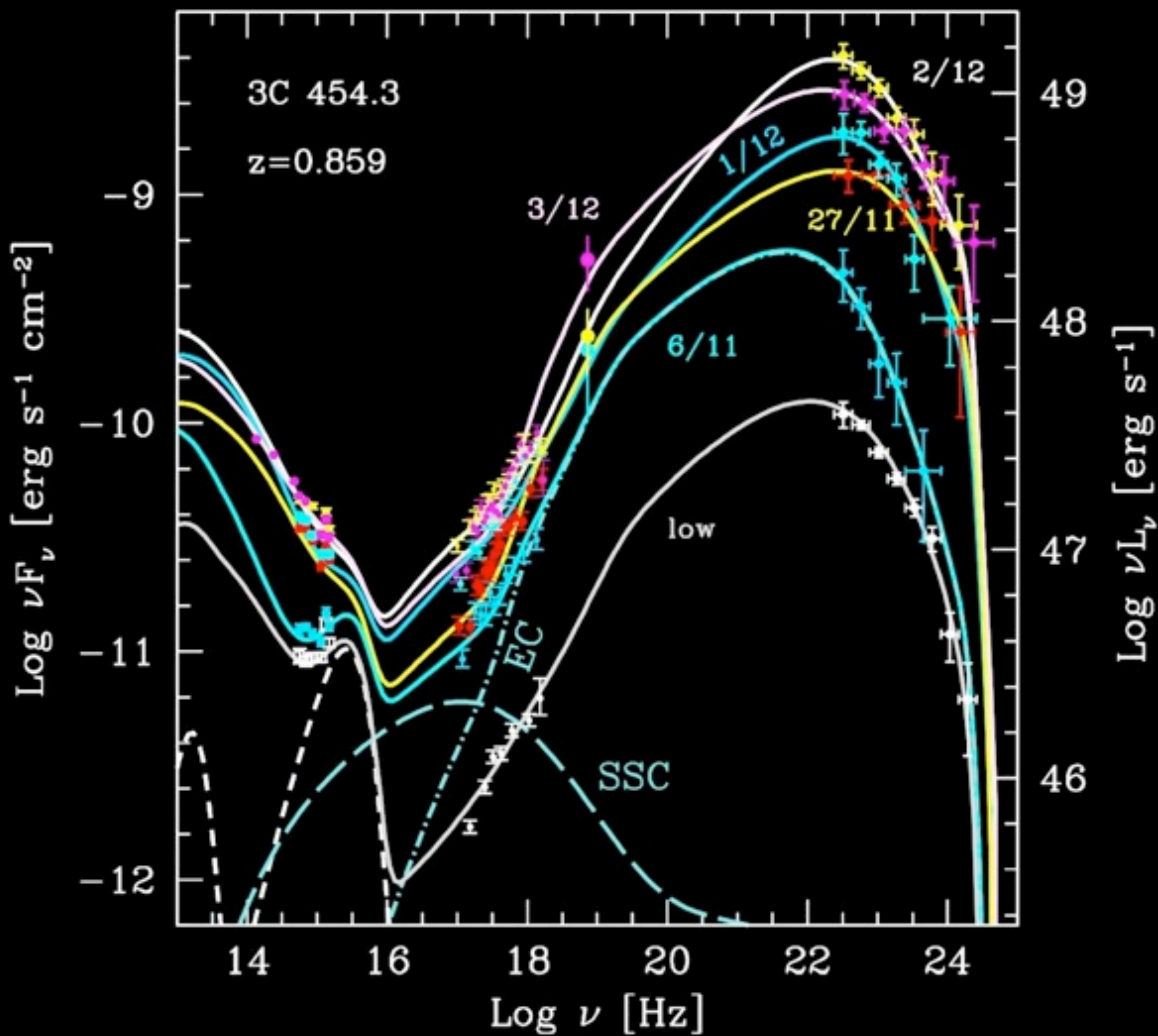
Correlation ⟶ **one zone**

F_{gamma} more than linear in F_{opt} and F_x

Also in PKS 1502+106 (Abdo et al. 2010)

Bonnoli et al. 2010

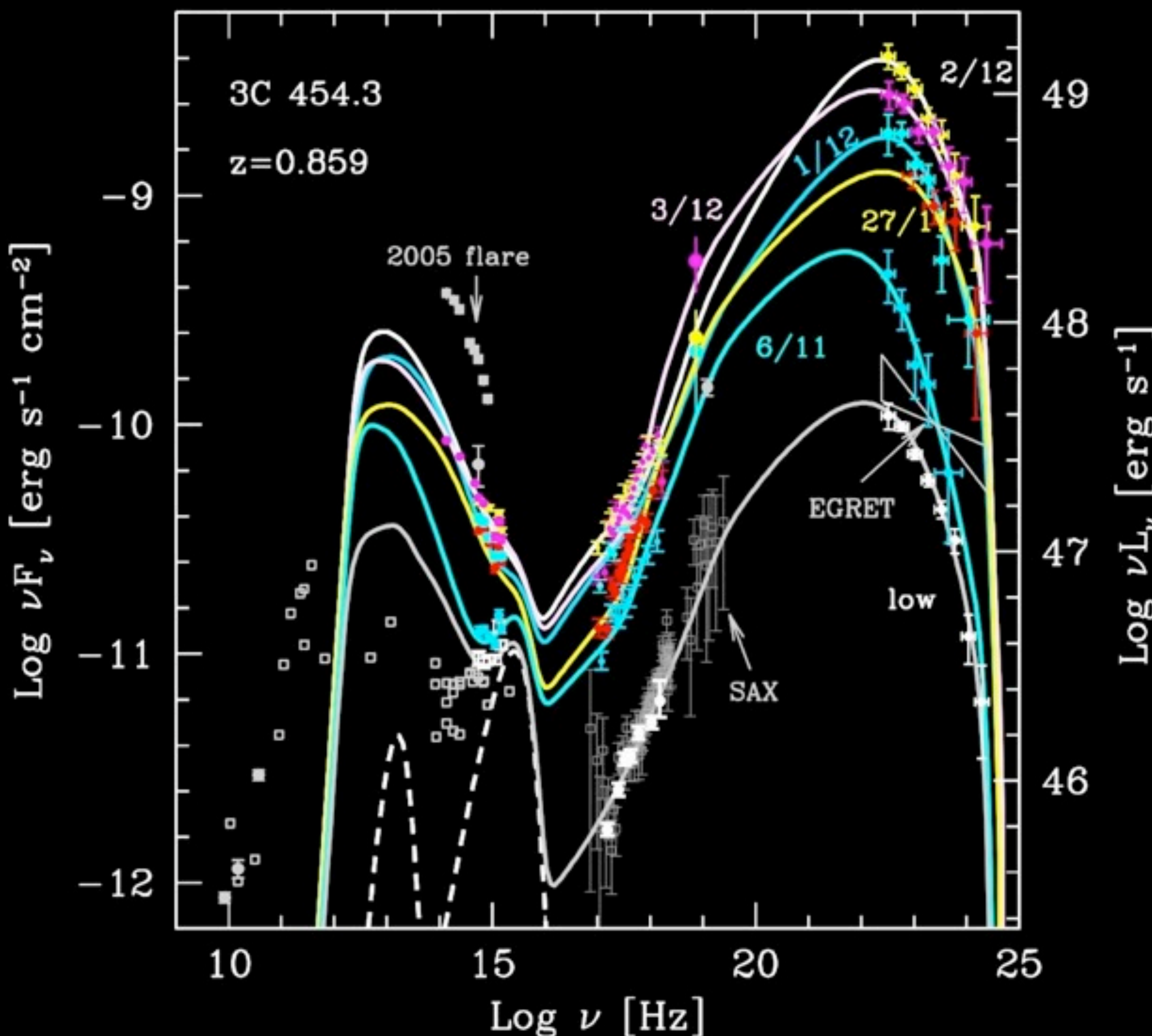
See also Abdo et al. 2010, arXiv:1007.0483



Large flux variations,
spectrum rather stable:

electron spectrum stable
similar physical conditions

Modeling of the SED with the "canonical" model



Bonnoli et al. 2010

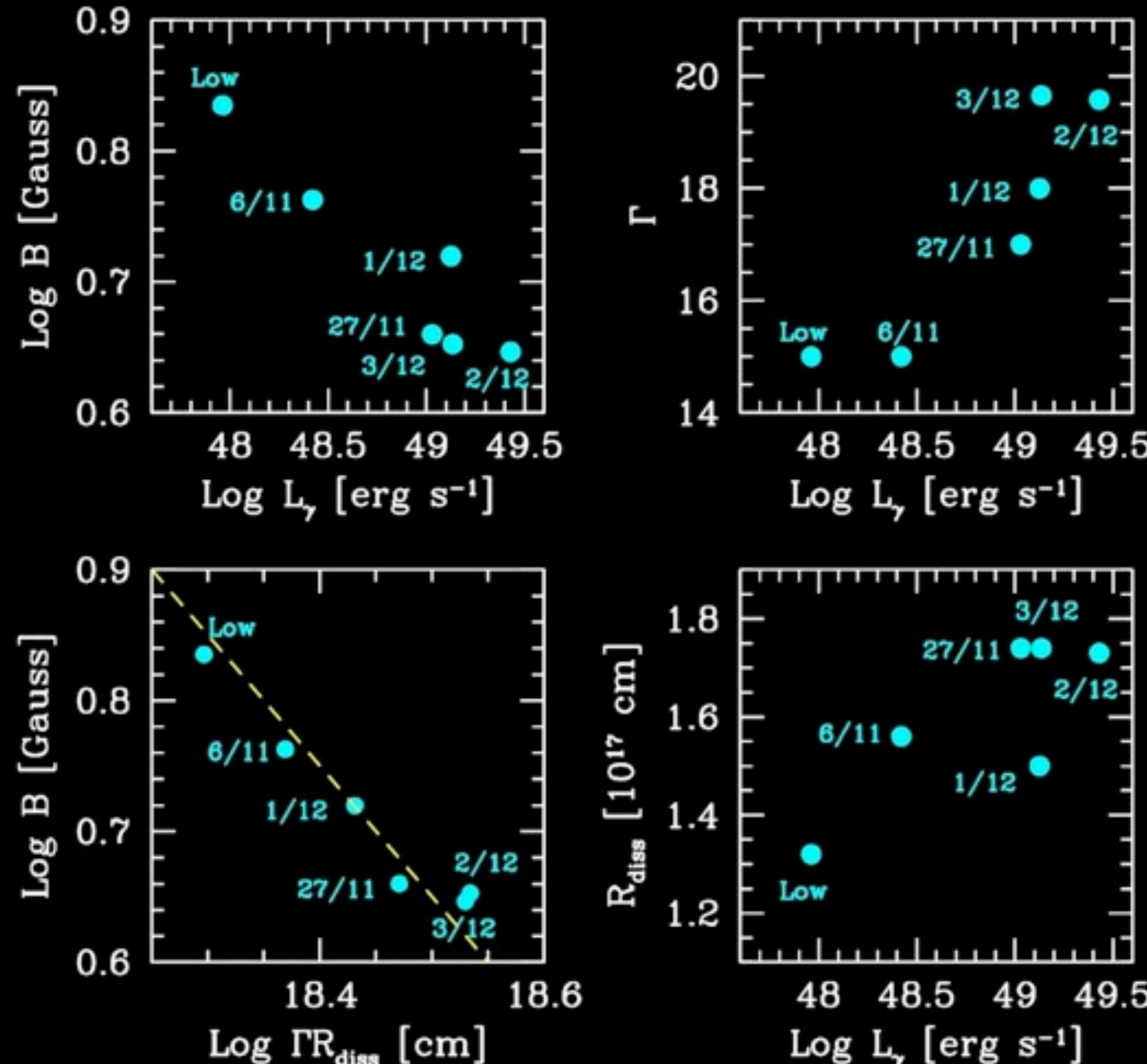
In syncro + EC frame :

- B must vary inversely to bolometric power

- Γ, R_{diss} correlate positively with L_γ

- $B \propto (\Gamma \cdot R_{diss})^{-1}$

- $P_B \propto (R_{diss} \cdot \Gamma \cdot B)^2$ (Poynting flux approx. constant at R_{diss})



In higher states, the emission originates at larger distance from the BH, with lower B and higher Γ

Summary

“Standard” model: gamma-rays through EC inside BLR in FSRQ

Rapid variability: gamma-rays produced <u>inside BLR</u> or
<u>very small emission regions at large distances</u>

TeV emission and GeV-TeV connection as a test

3C454.3: tracing the evolution of the emission zone