TXS 0506+056 & IC-170922A

Modeling of multiwavelength data

The role of external radiation fields

Fabrizio Tavecchio

INAF-OAB

Outline

BL Lac as electromagnetic emitters

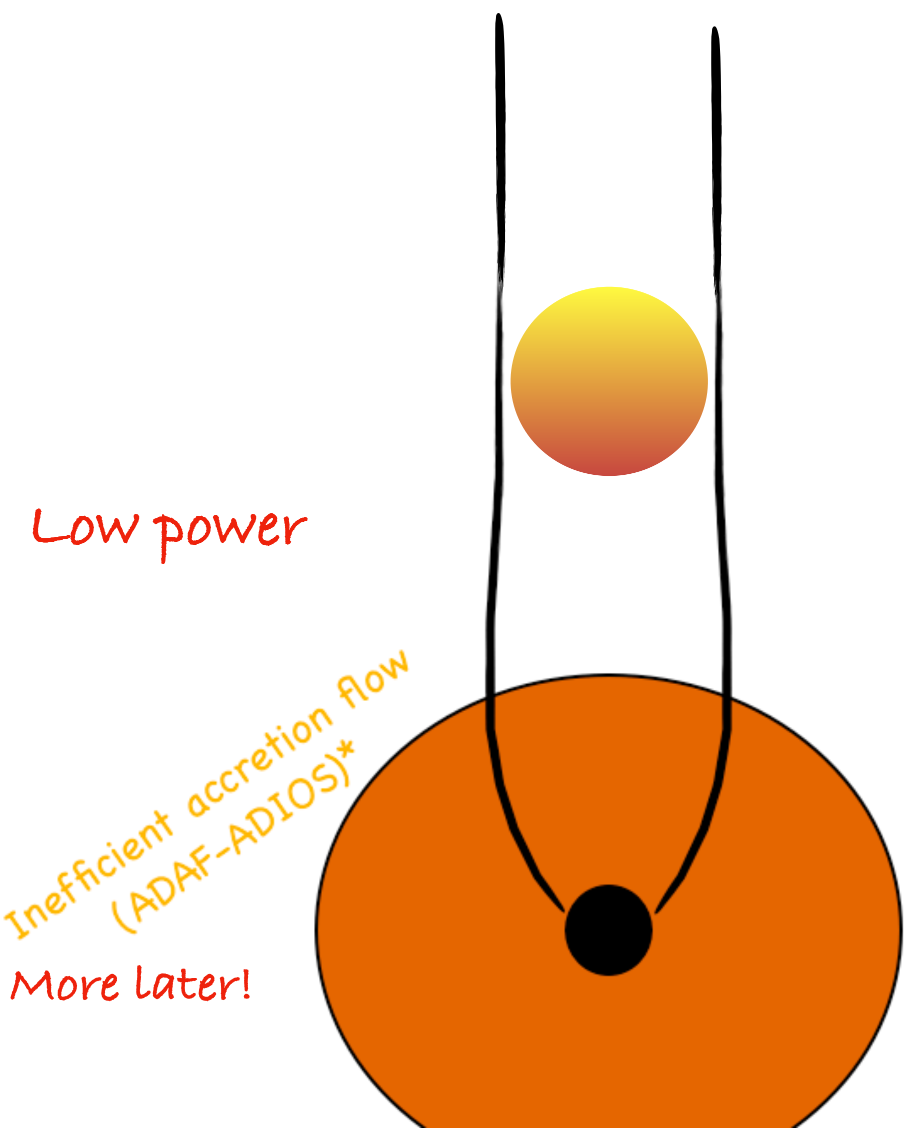
External sources of soft photons

Spine-sheath (MAGIC Coll 2018)

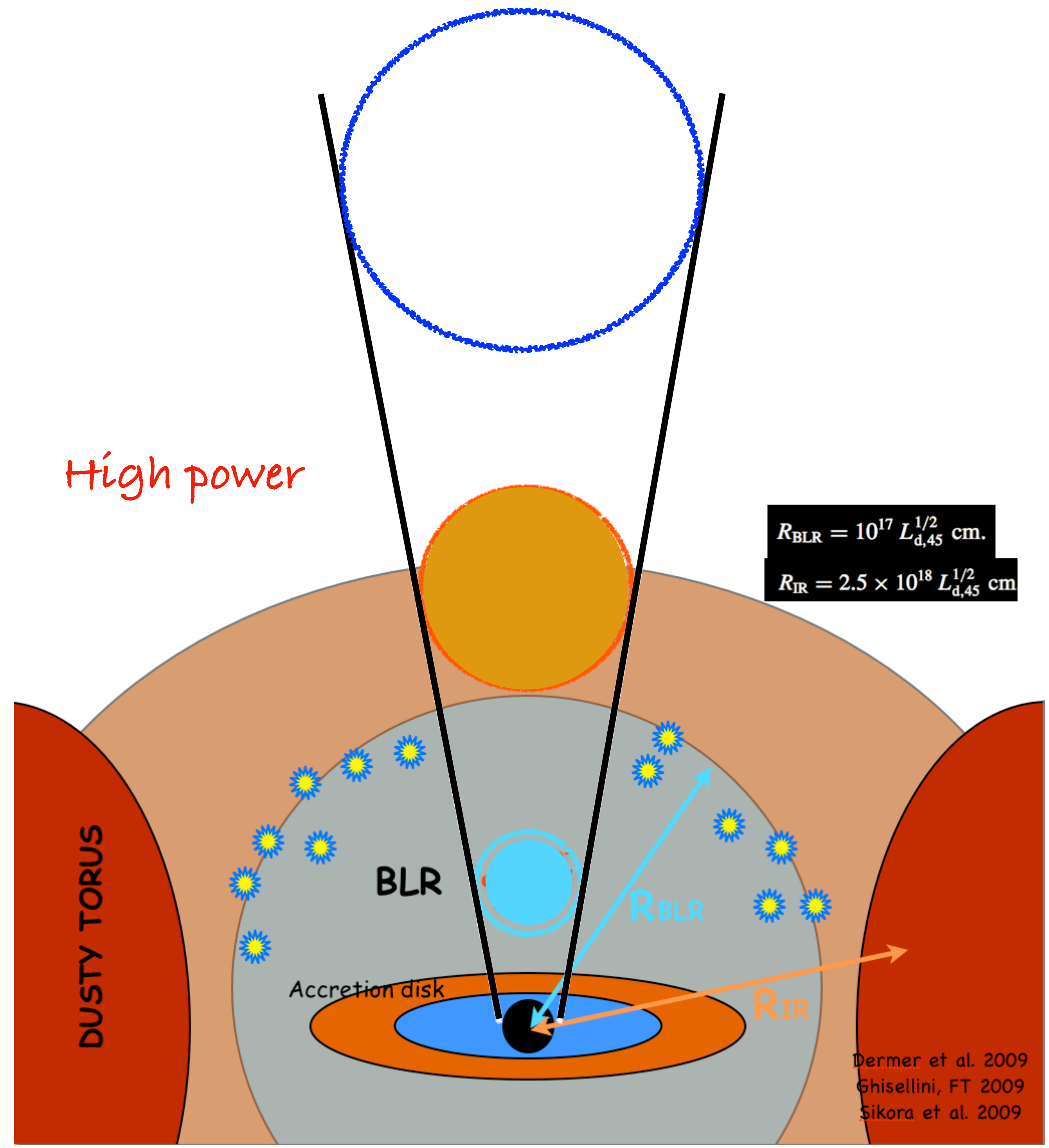
Accretion flow (Righi et al. 2018)

Blazars

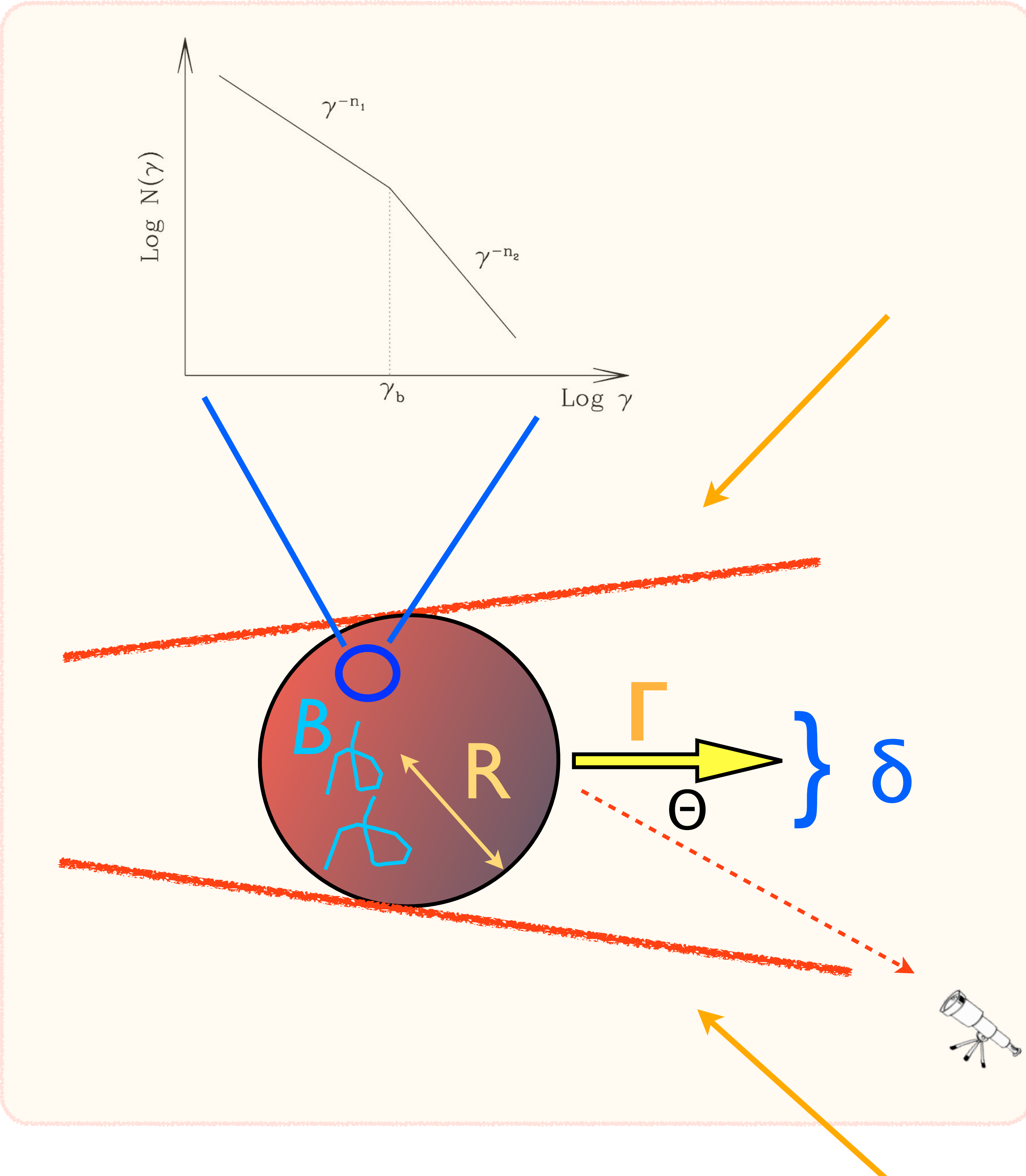
BL Lacs: "naked" jets



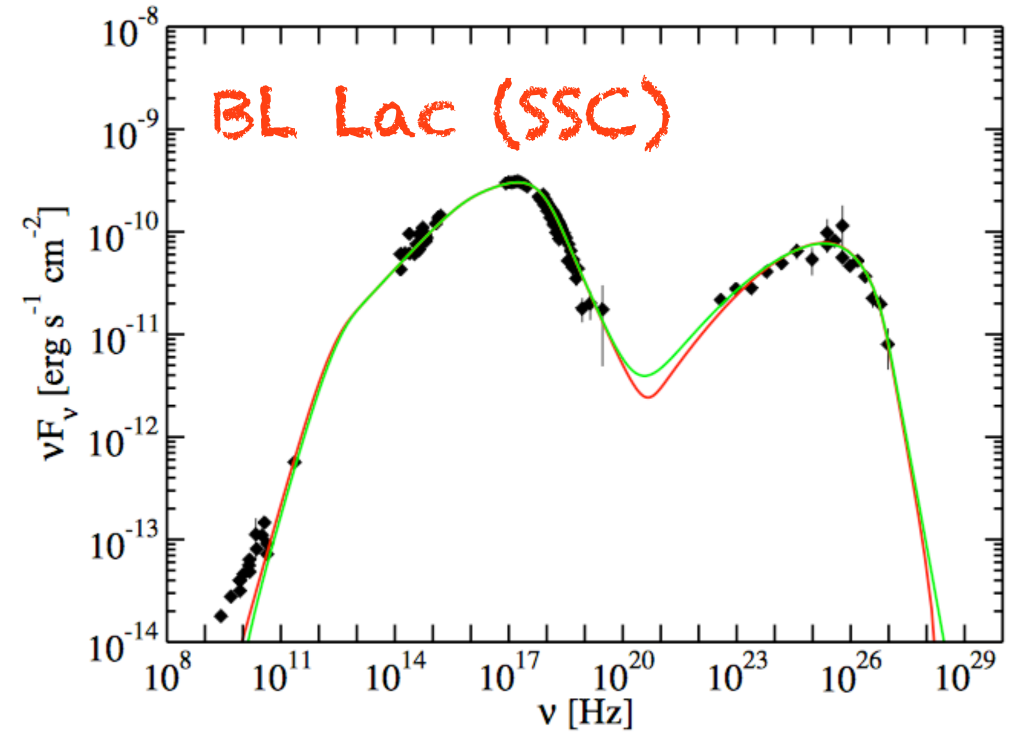
FSRQ: "dressed" jets



One-zone models

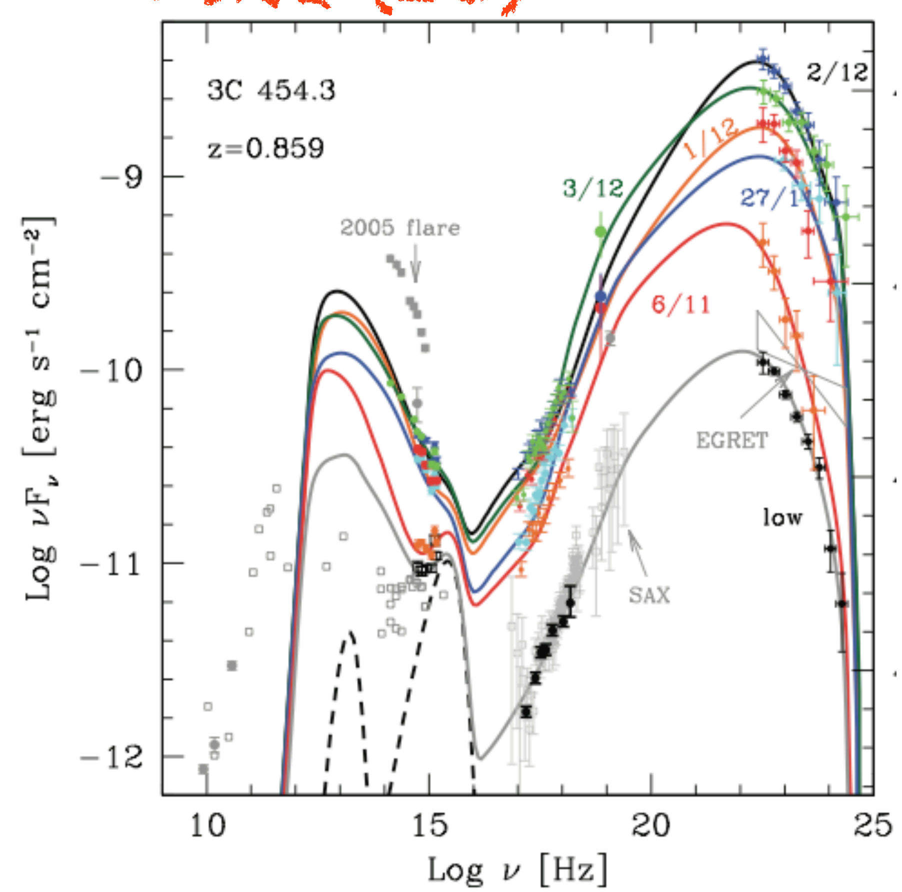


Abdo et al. 2011

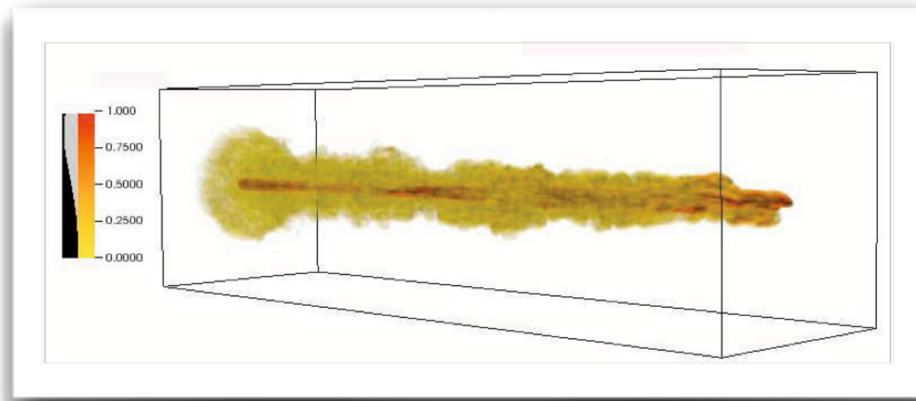


FSRQ (EC)

Bonnoli et al. 2011

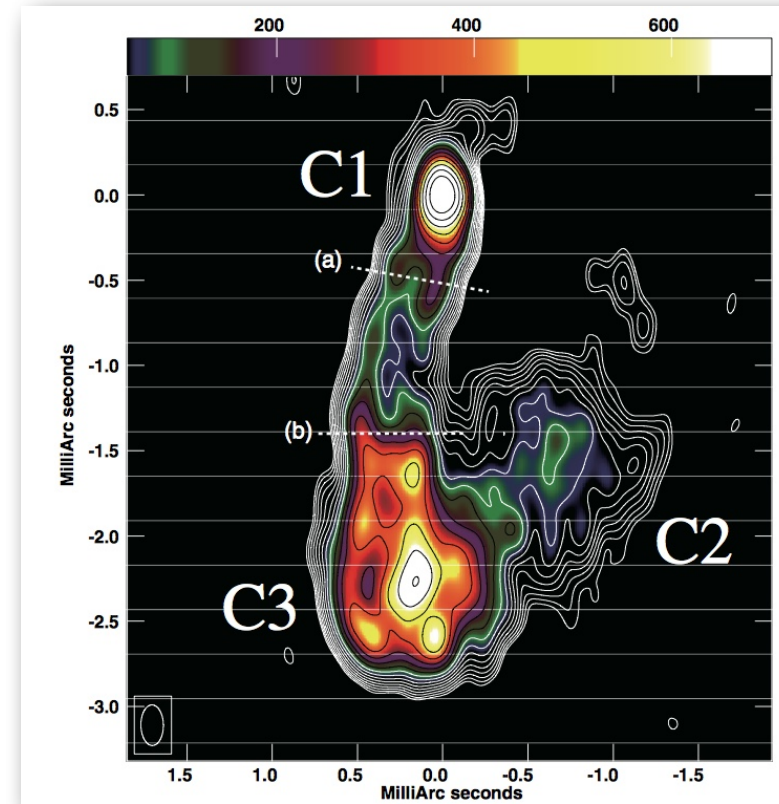


Structured jets in BL Lacs



Simulations predict spine-layer structure

Entrainment/instability e.g. Rossi et al. 2008
Acceleration process e.g. McKinney 2006



Limb brightening

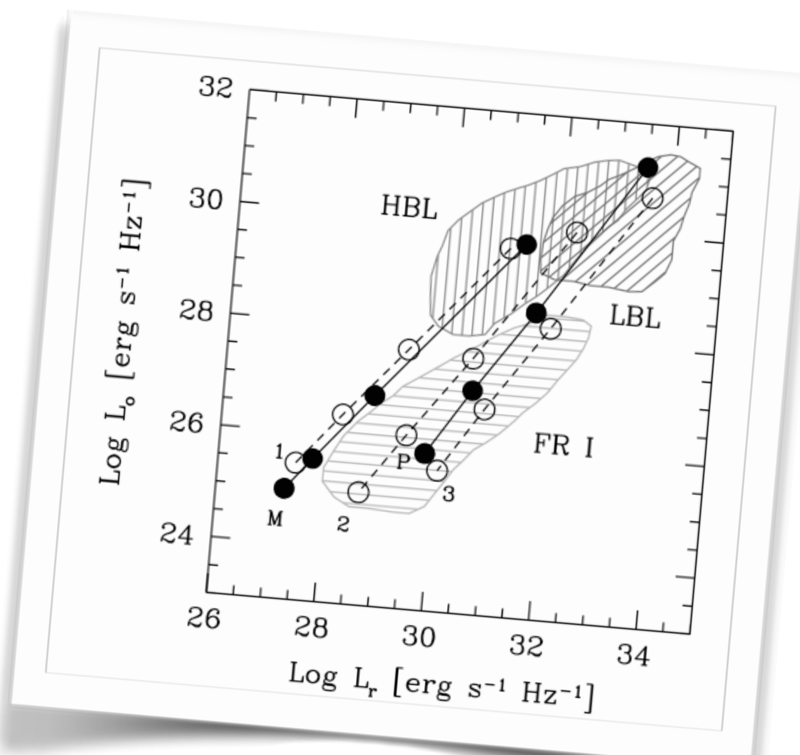
Mkn 501, Mkn 421, M87, NGC 1275

Laing 1996
Giroletti et al. 2004
Piner & Edwards 2014
Nagai et al. 2014

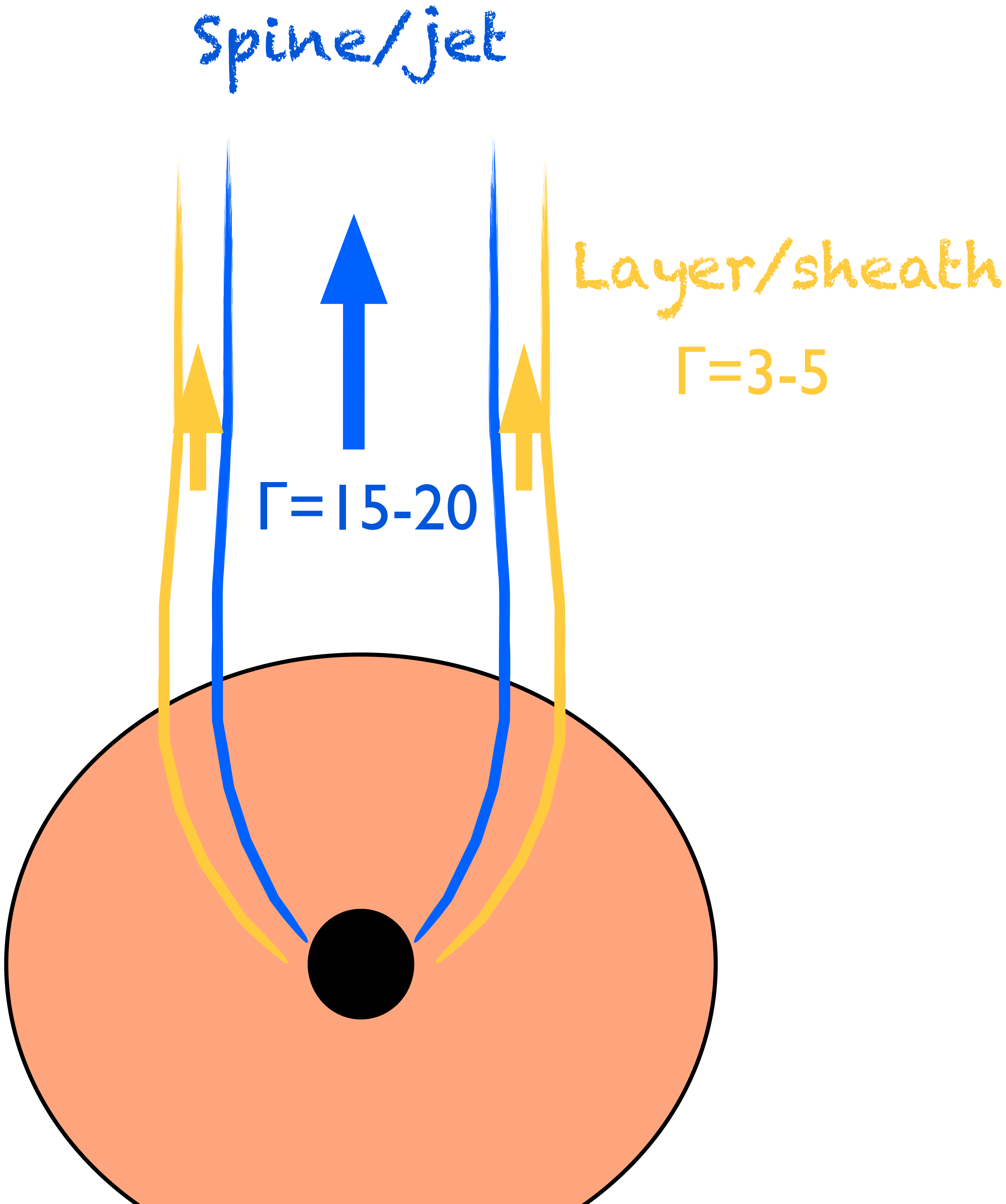
Pushkarev et al. 2005
Clausen-Brown 2011
Murphy et al. 2013

Unification requires velocity structures

Chiaberge et al. 2000
Meyer et al.
Sbarrato et al. 2014



Structured jets in BL Lacs

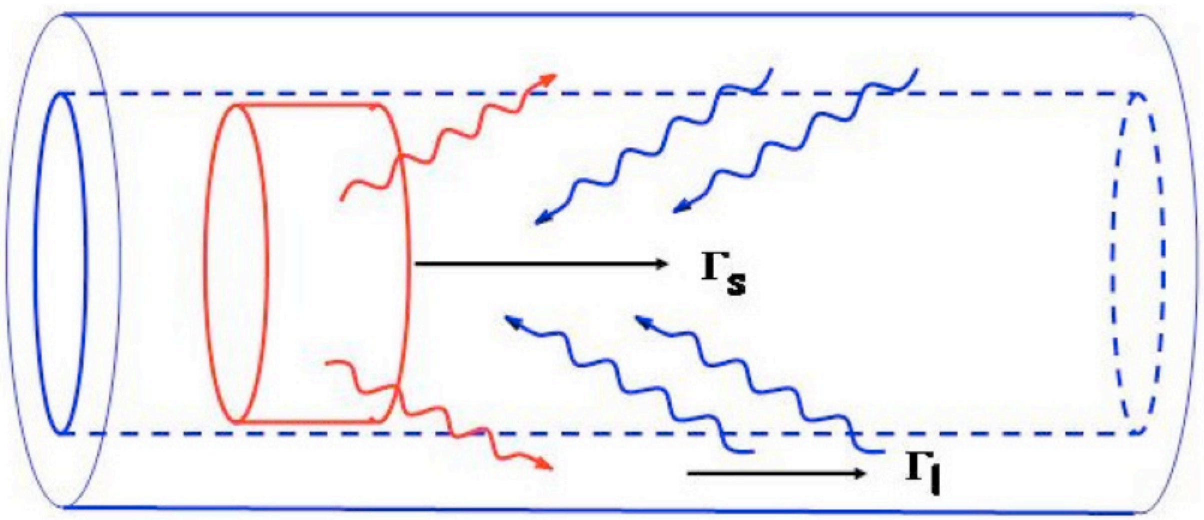


Ghisellini, FT and Chiaberge 2005
FT and Ghisellini 2008

Structured jets

$$\Gamma_{\rm rel} = \Gamma_{\rm s}\Gamma_{\rm l}(1 - \beta_{\rm s}\beta_{\rm l})$$

$$U' \simeq U\Gamma^2_{\rm rel}$$



★ The spine "sees" an enhanced u_{rad} coming from the layer

Rates of processes involving soft photons are enhanced w.r.t. to the one-zone model

Both IC and neutrino emission!

Structured jets

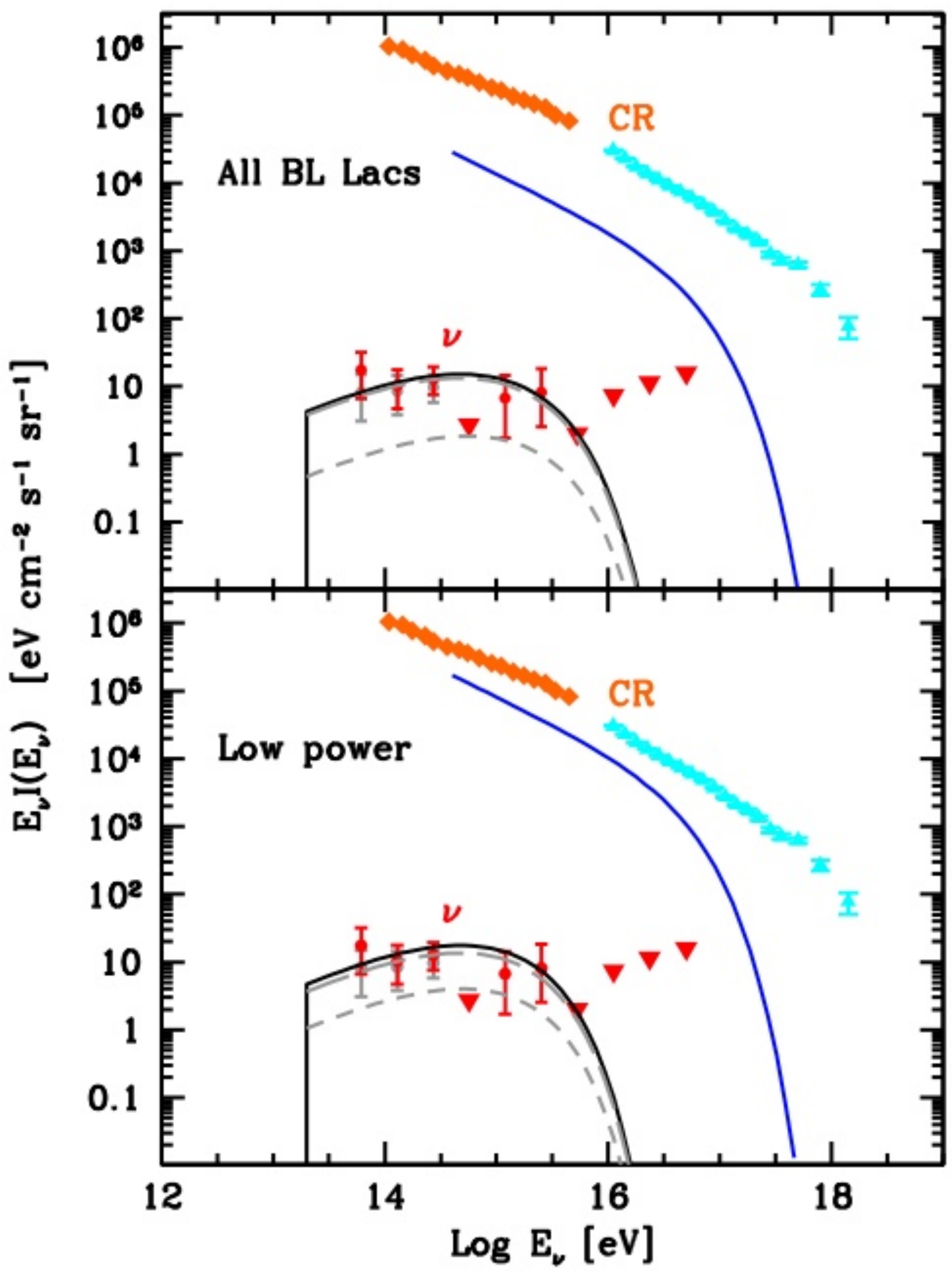
$$L_\nu \approx \frac{3}{8} f_{p\gamma} L_p$$

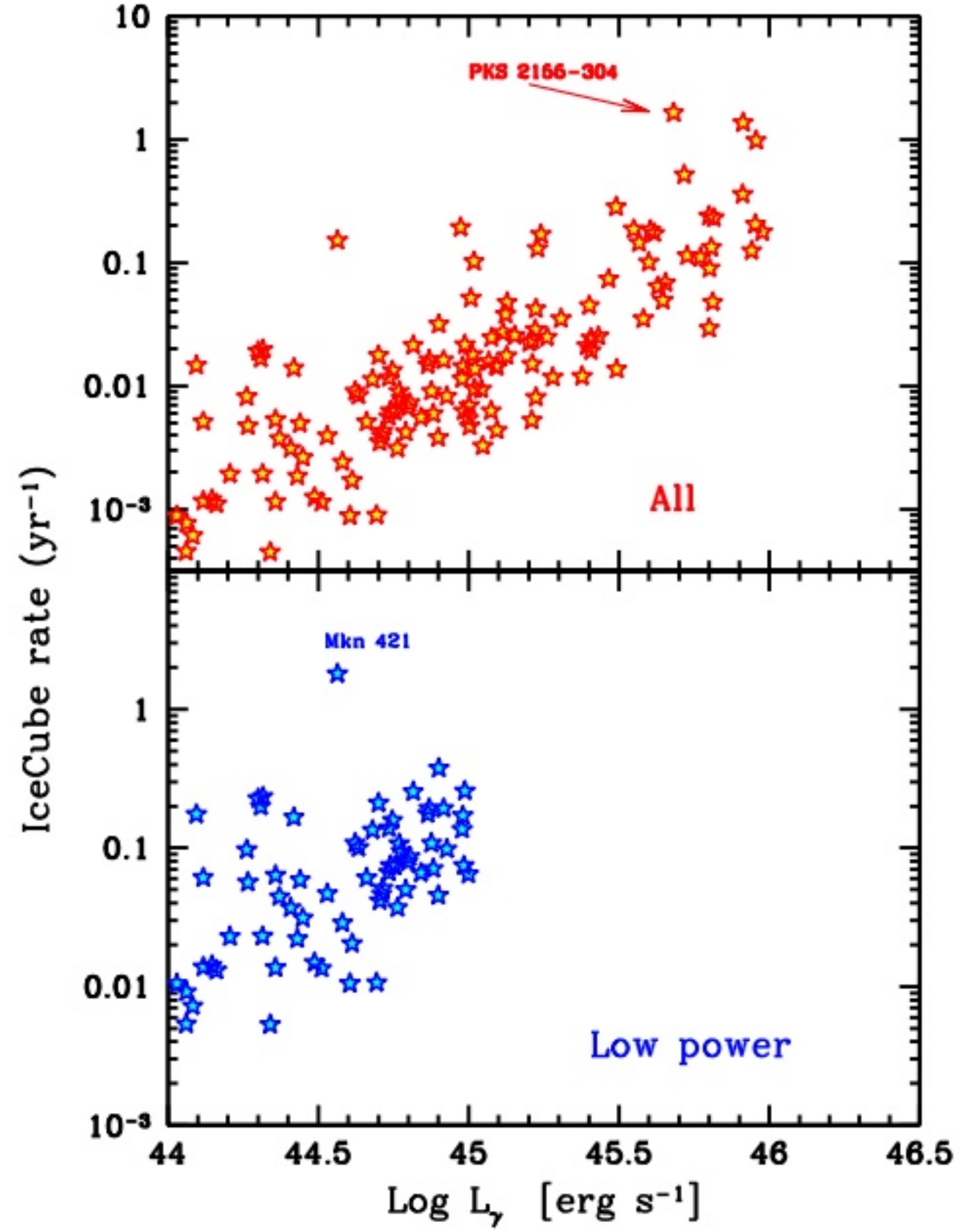
$$f_{p\gamma} \propto n_{soft}$$

Increased target density

⇒ Reduced proton luminosity

Neutrinos from BL Lacs?





Tavecchio et al. 2014, 2015
Righi FT, Guetta 2017

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2017 september 22

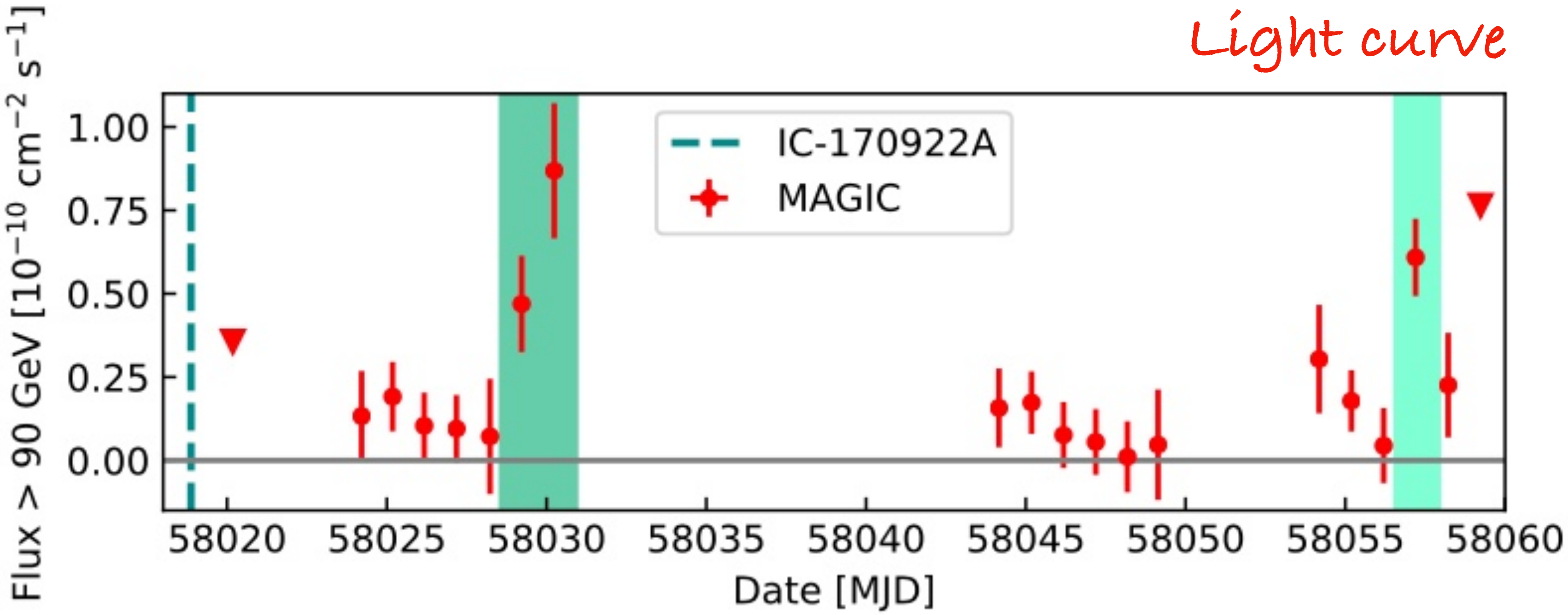
One-zone models

See dedicated talks!

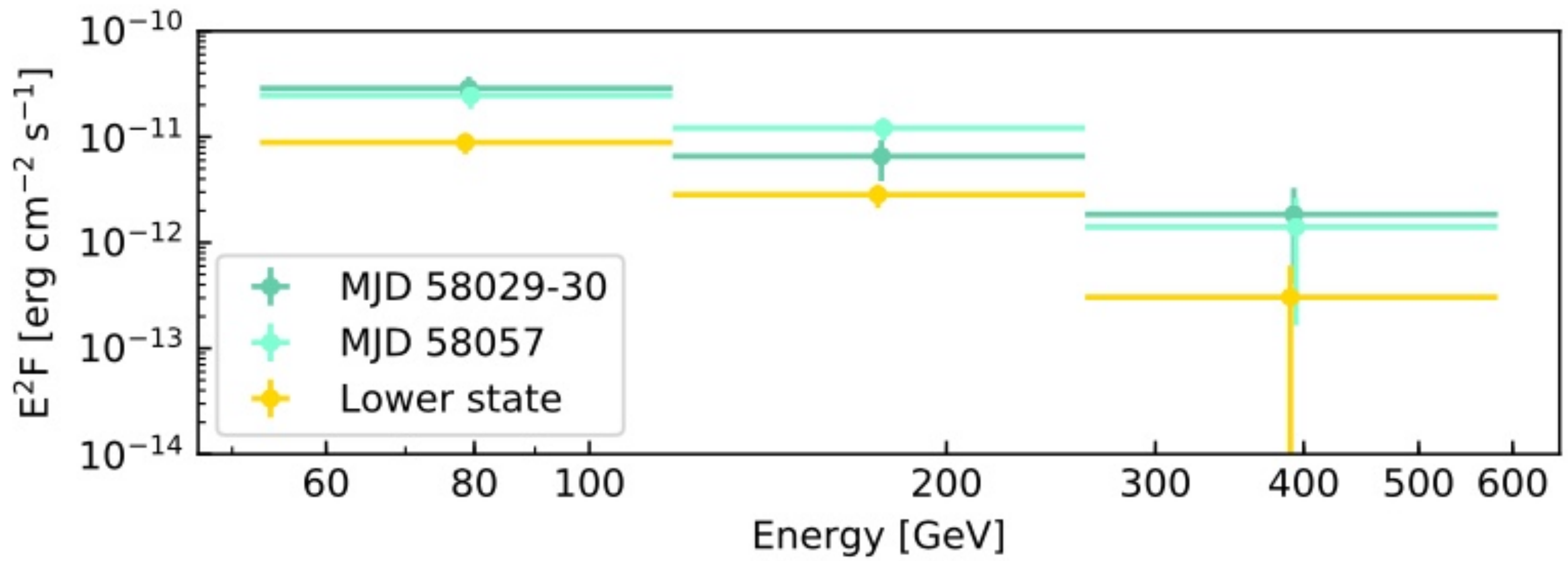
The MAGIC data

MAGIC Coll. 2018

Light curve



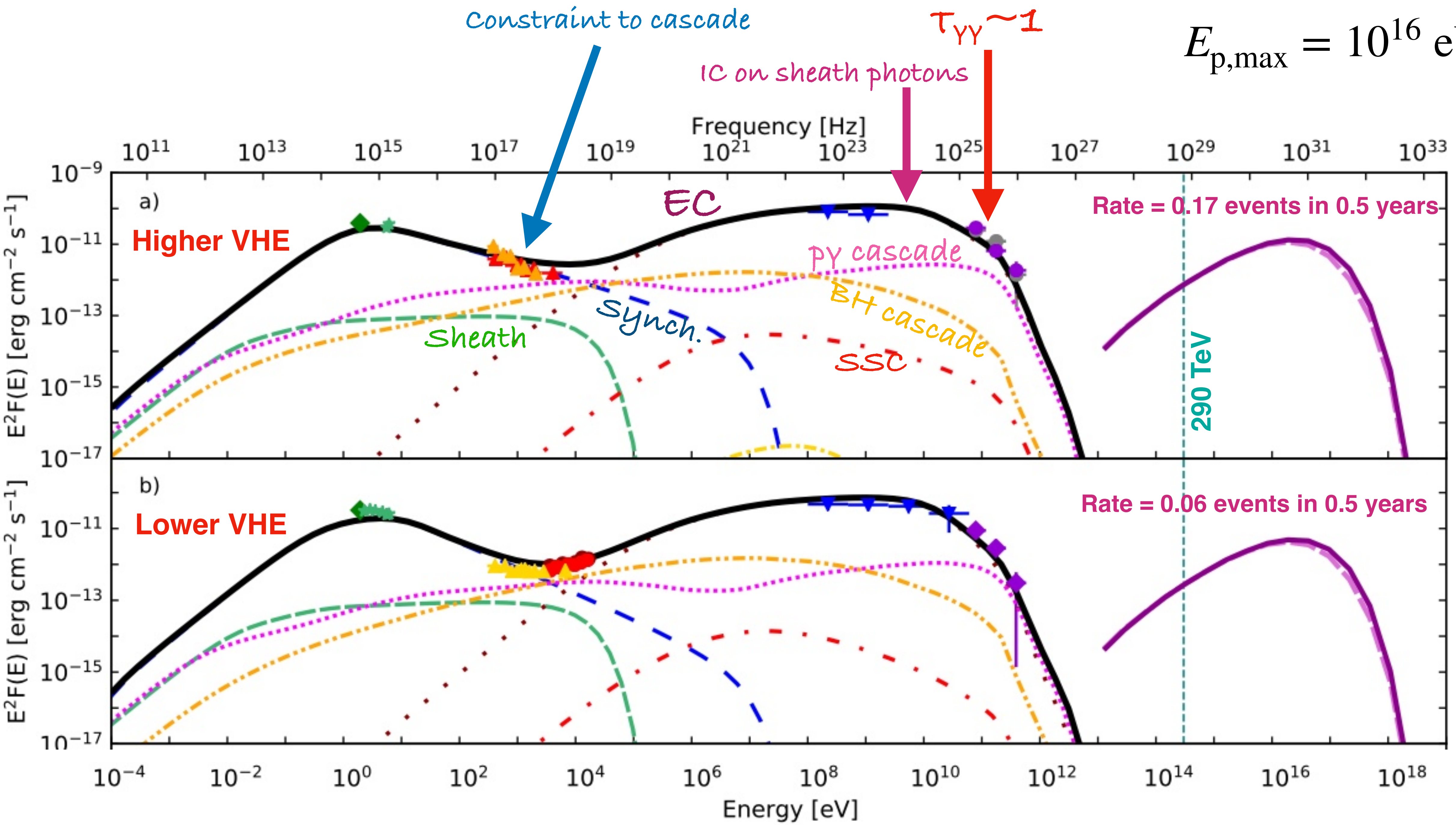
Spectra



Jet-sheath model

MAGIC Coll. 2018

$E_{\rm p,max} = 10^{16}$ eV



Jet-sheath model

MAGIC Coll. 2018

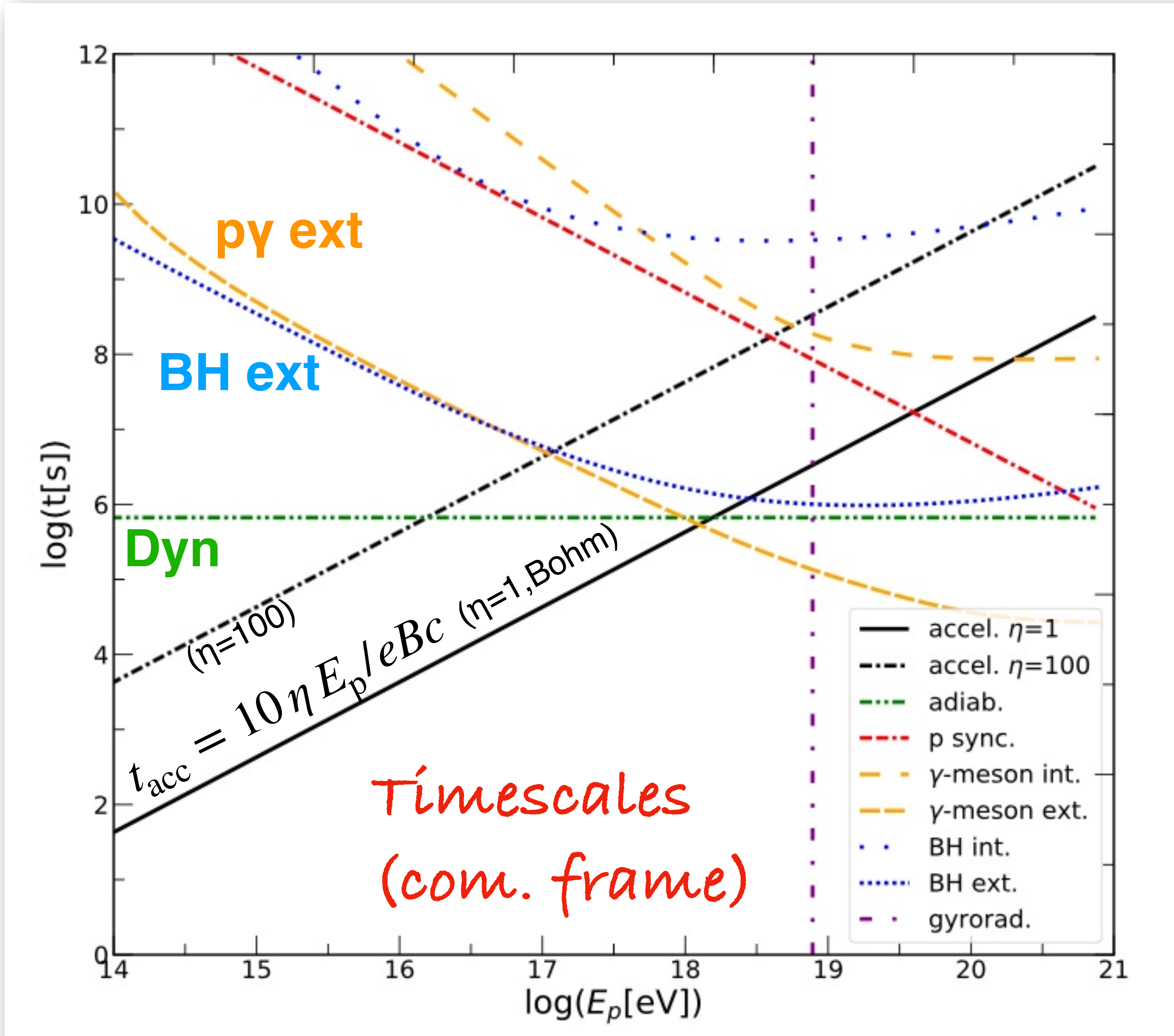
Table 3. Parameters for the jet-sheath model for $E_{\rm p,max}=10^{16}$.

State	MJD 58029-30	Lower VHE
B [G]	2.6	2.6
$E_{\rm min}$ [eV]	3.2×10^8	2.0×10^8
$E_{\rm br}$ [eV]	7.0×10^8	9.0×10^8
$E_{\rm max}$ [eV]	8×10^{11}	8×10^{11}
n_1	2	2
n_2	3.9	4.4
U_e [erg cm^{-3}]	4.4×10^{-4}	3.6×10^{-4}
U_B [erg cm^{-3}]	0.27	0.27
U_p [erg cm^{-3}]	1.8	0.7
P_e [erg s^{-1}]	2×10^{42}	1.6×10^{42}
P_p [erg s^{-1}]	8×10^{45}	3×10^{45}
P_B [erg s^{-1}]	1.2×10^{45}	1.2×10^{45}

$$P_j \approx 4 \times 10^{45} - 10^{46}\ \mathrm{erg\ s^{-1}}$$

Jet-sheath model

MAGIC Coll. 2018

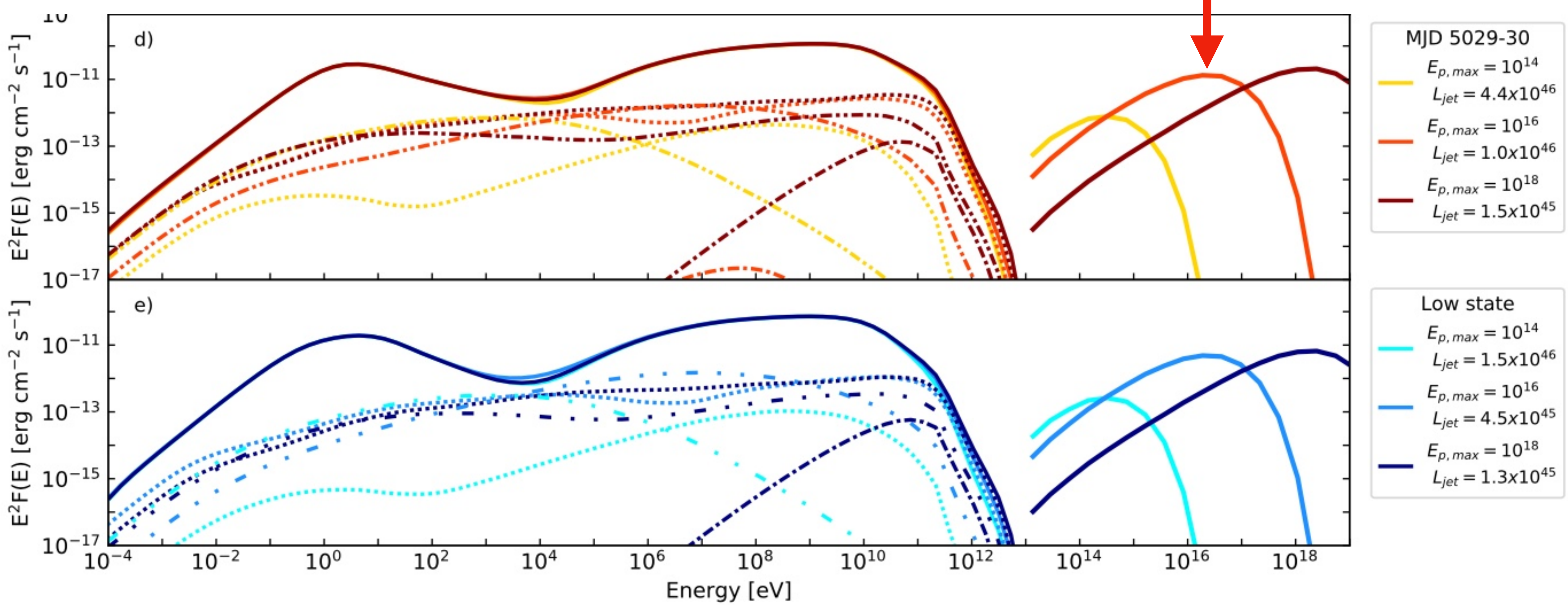


Jet-sheath model

MAGIC Coll. 2018

Effect of maximum proton energy

Constrained by cascade flux in X-rays



Larger Ep —> Lower neutrino rate at 300 TeV

Any role for the accretion flow?

Low-luminosity AGNs (including BL Lacs and the parent FRI radiogalaxies) are thought to be powered by an accretion flow with quite small accretion rate

e.g., Rees et al. 1982, Yuan et al. 2003, Di Matteo 2003

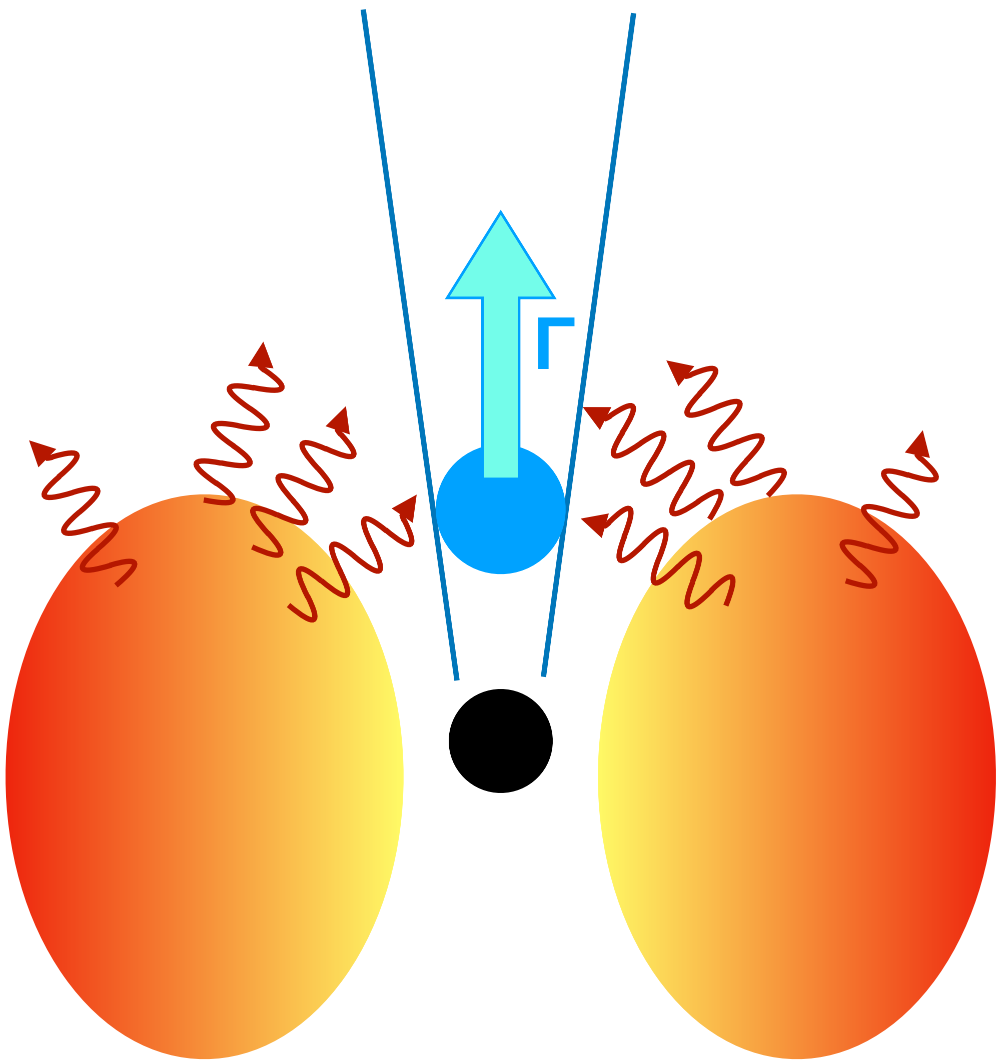
e.g., Ghisellini et al. 2009, 2011, Meyer 2013 for blazars

$$\dot{m} < \alpha^2 \approx 10^{-2}$$

Two-temperature flow (Tp>>Te)
Geometrically thick H~R ("spherical-like")
Optically thin
Outflow?

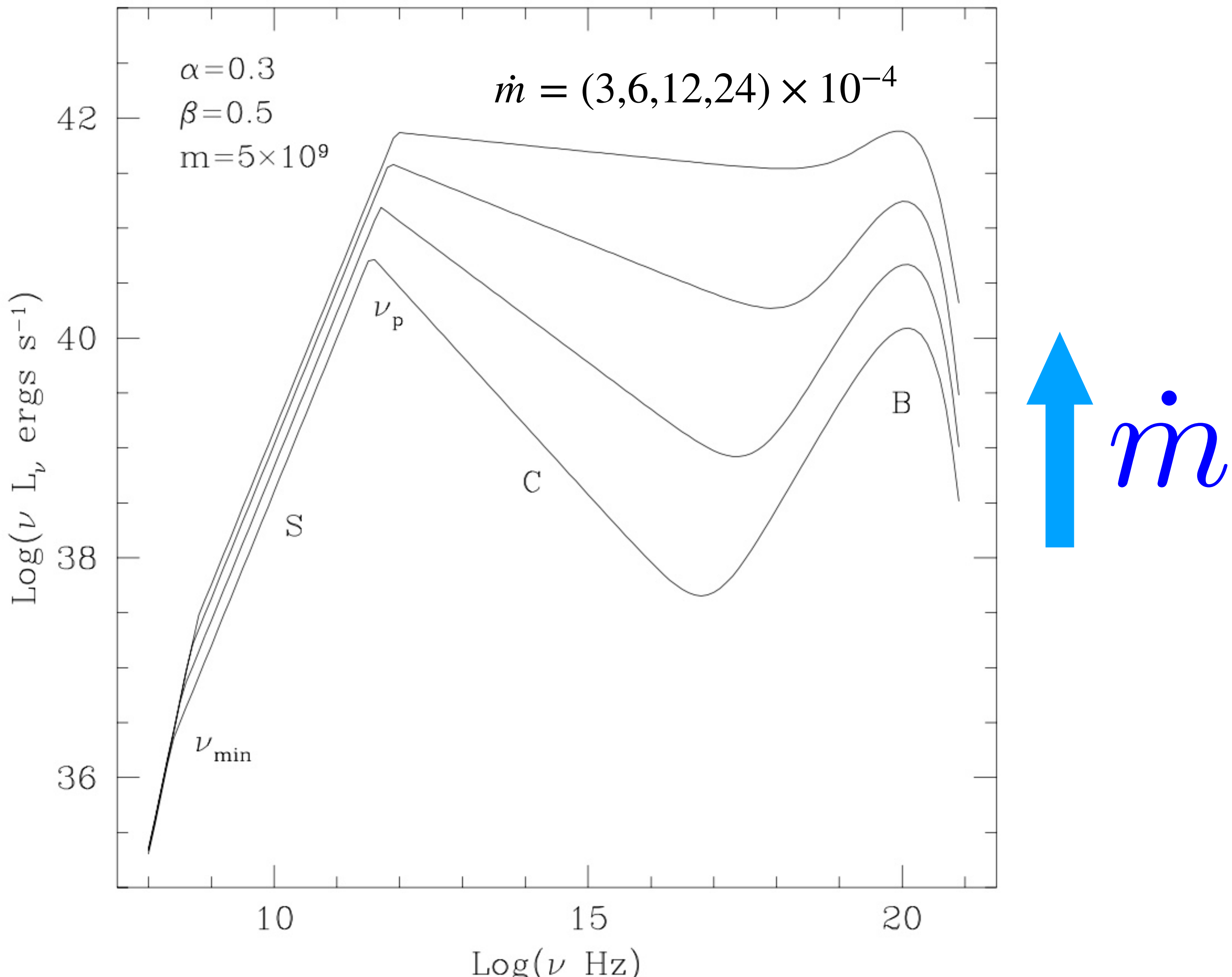
Ichimaru 1977, Rees et al. 1982, Narayan & Yi 1994, Blandford & Begelman 1999

Any role for the accretion flow?



ADAF spectra

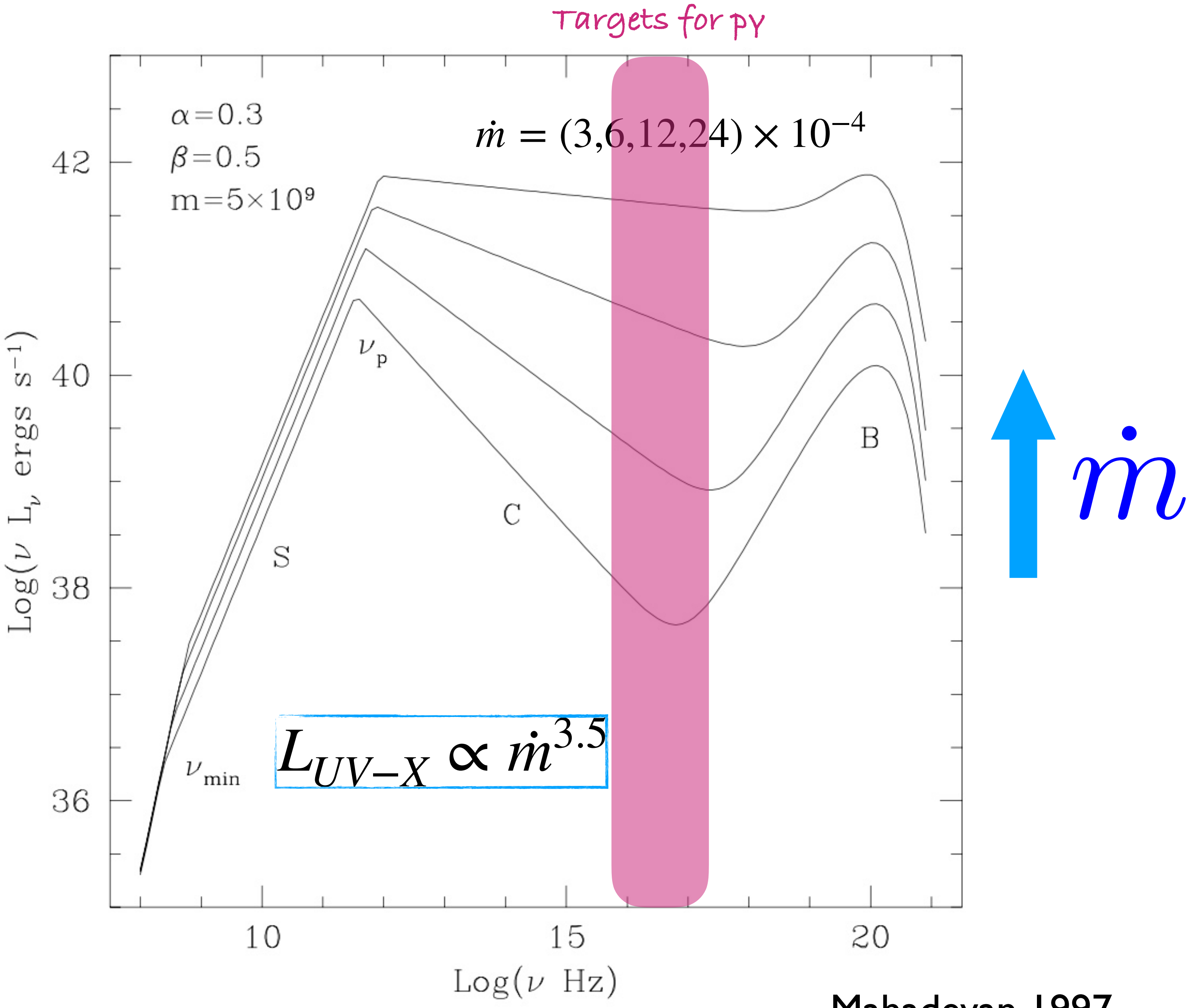
Advection dominated accretion flow



Mahadevan 1997

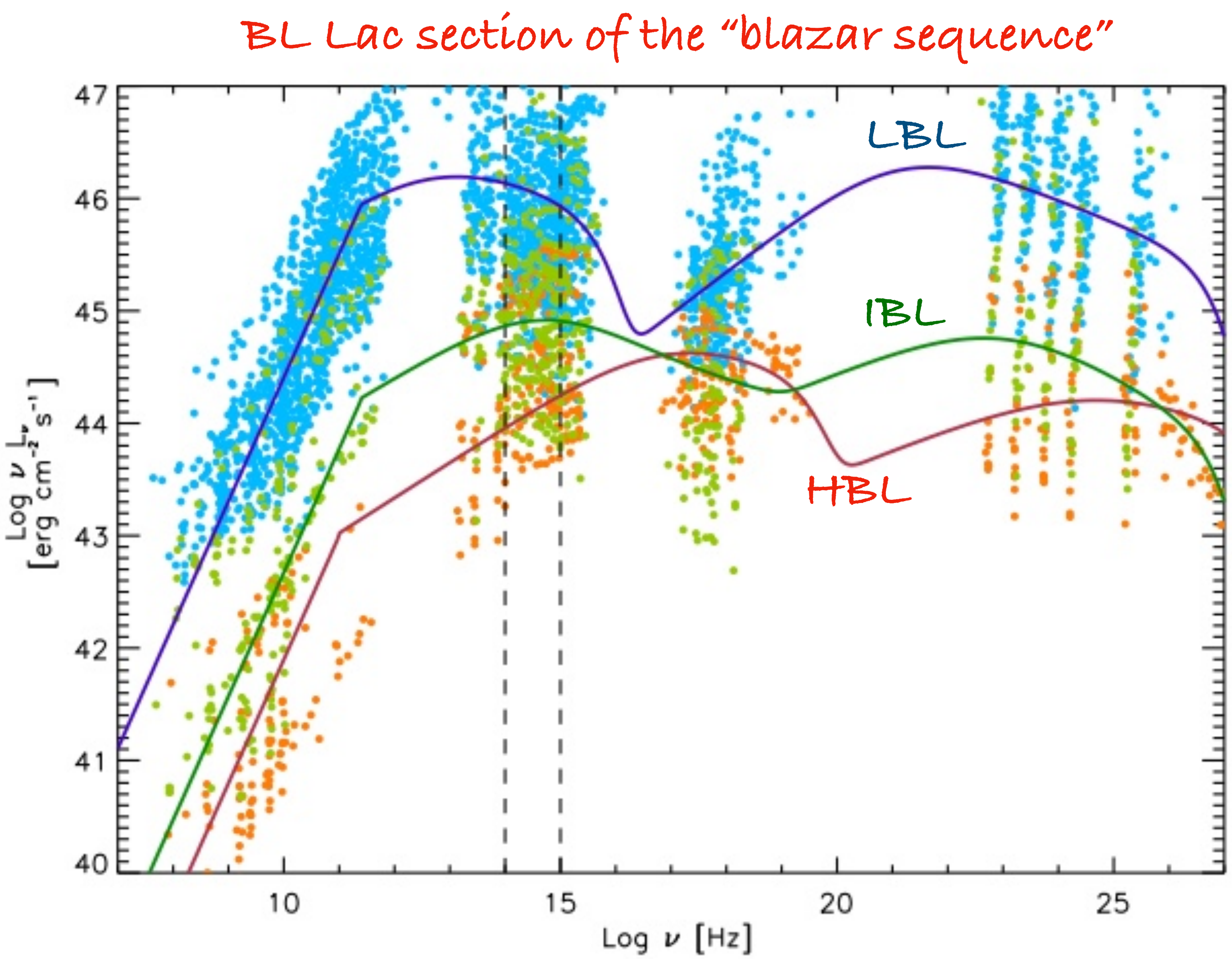
ADAF spectra

Advection dominated accretion flow



Mahadevan 1997

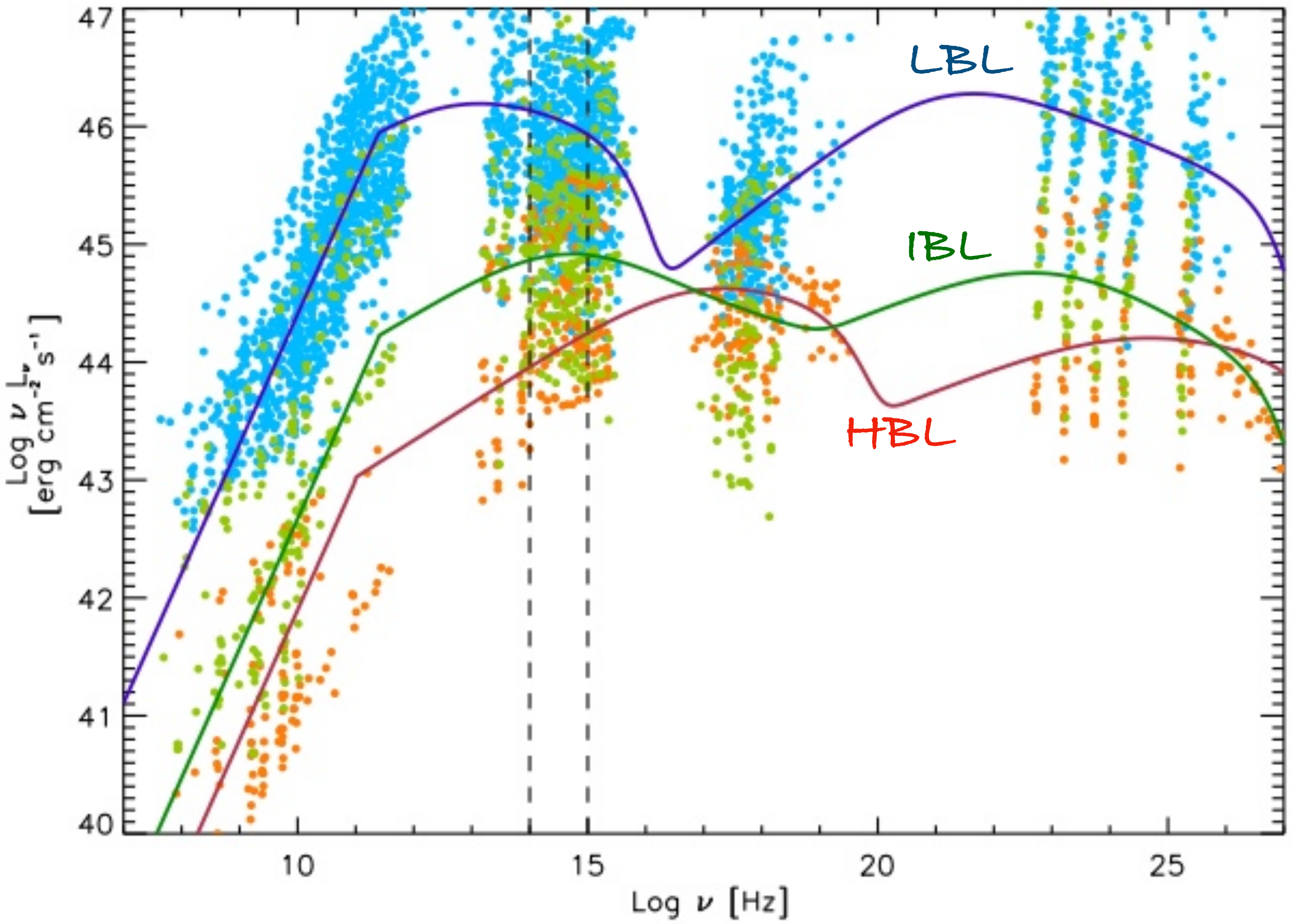
ADAF spectra



Righi, FT, Inoue et al. 2018

ADAF spectra

BL Lac section of the "blazar sequence"



$$P_{\rm rad} = \eta_{rad} P_{\rm jet}$$

$$P_{rad} \approx \frac{L_{rad}}{\Gamma^2}$$

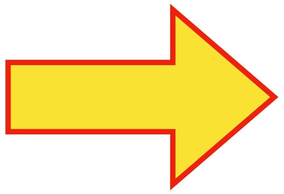
Nemmen et al. 2012
Celotti & Ghisellini 2008
Ghisellini et al. 2010

$$\eta_{\rm rad} \approx 0.1$$

$$P_{\rm jet} \simeq \eta_j \dot{M} c^2$$

$$\eta_{\rm j} \approx 1$$

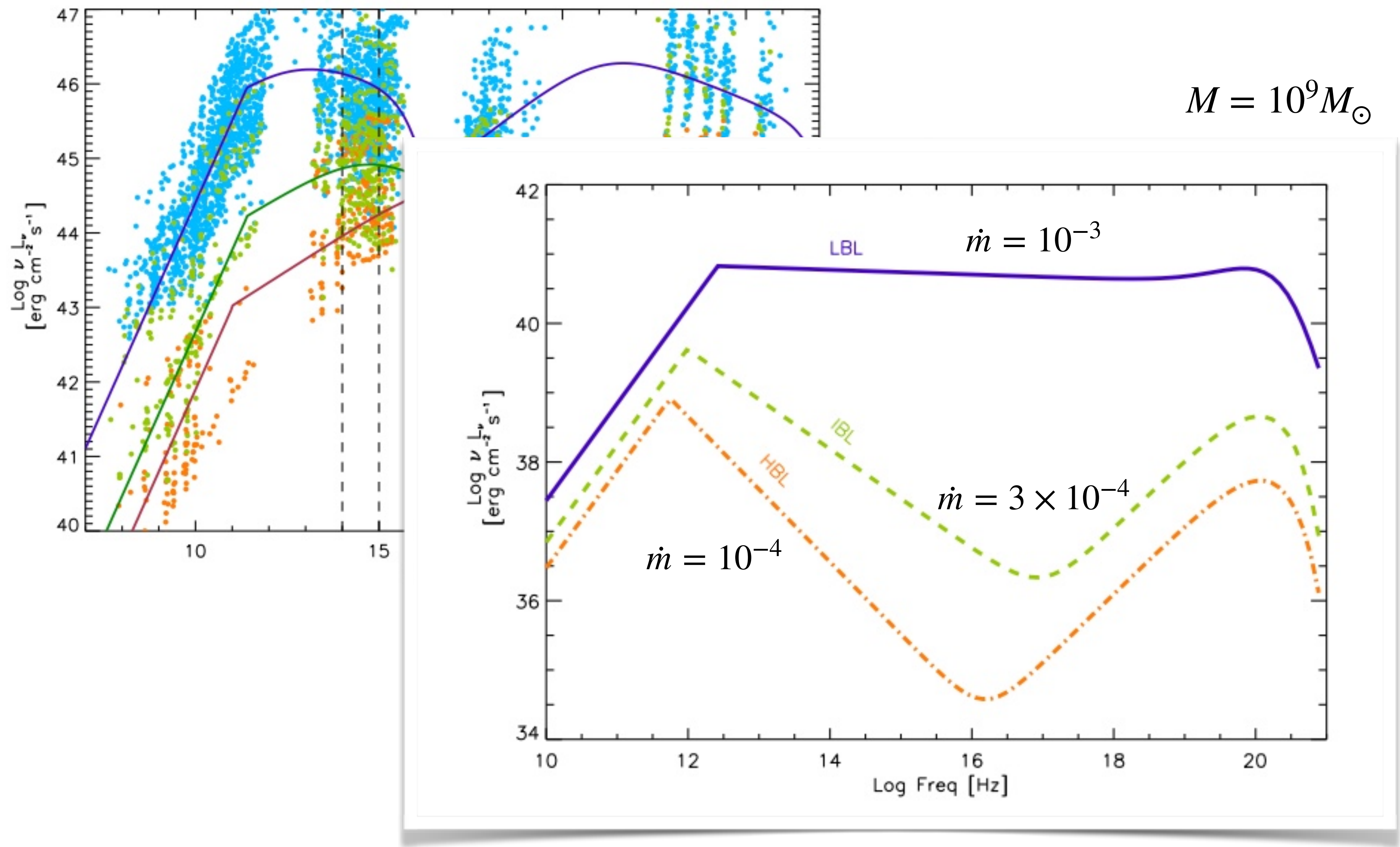
Ghisellini et al. 2010, 2014



$$\dot{m} = \frac{P_{\rm rad}\eta_{acc}}{L_{\rm Edd}} \frac{\eta_{rad}}{\eta_j}$$

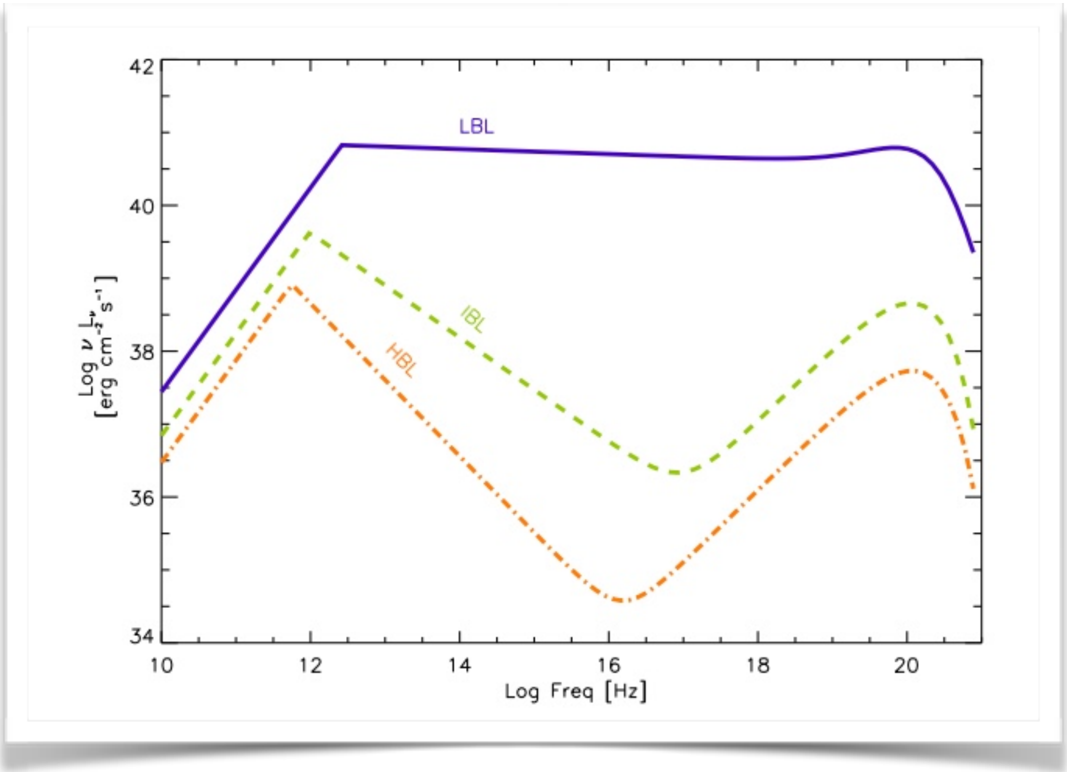
Righi, FT, Inoue et al. 2018

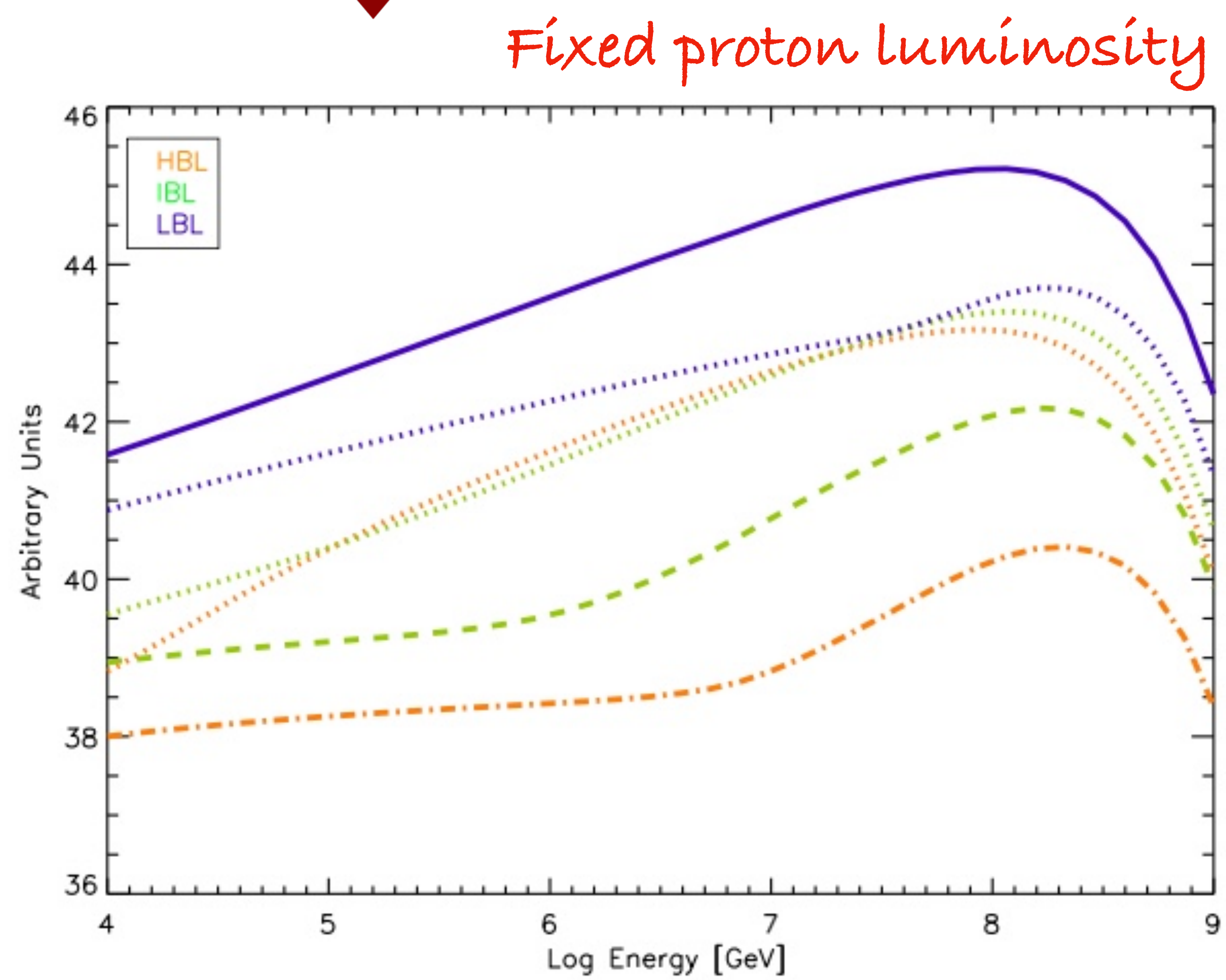
ADAF spectra



Righi, FT, Inoue et al. 2018

Neutrino emission

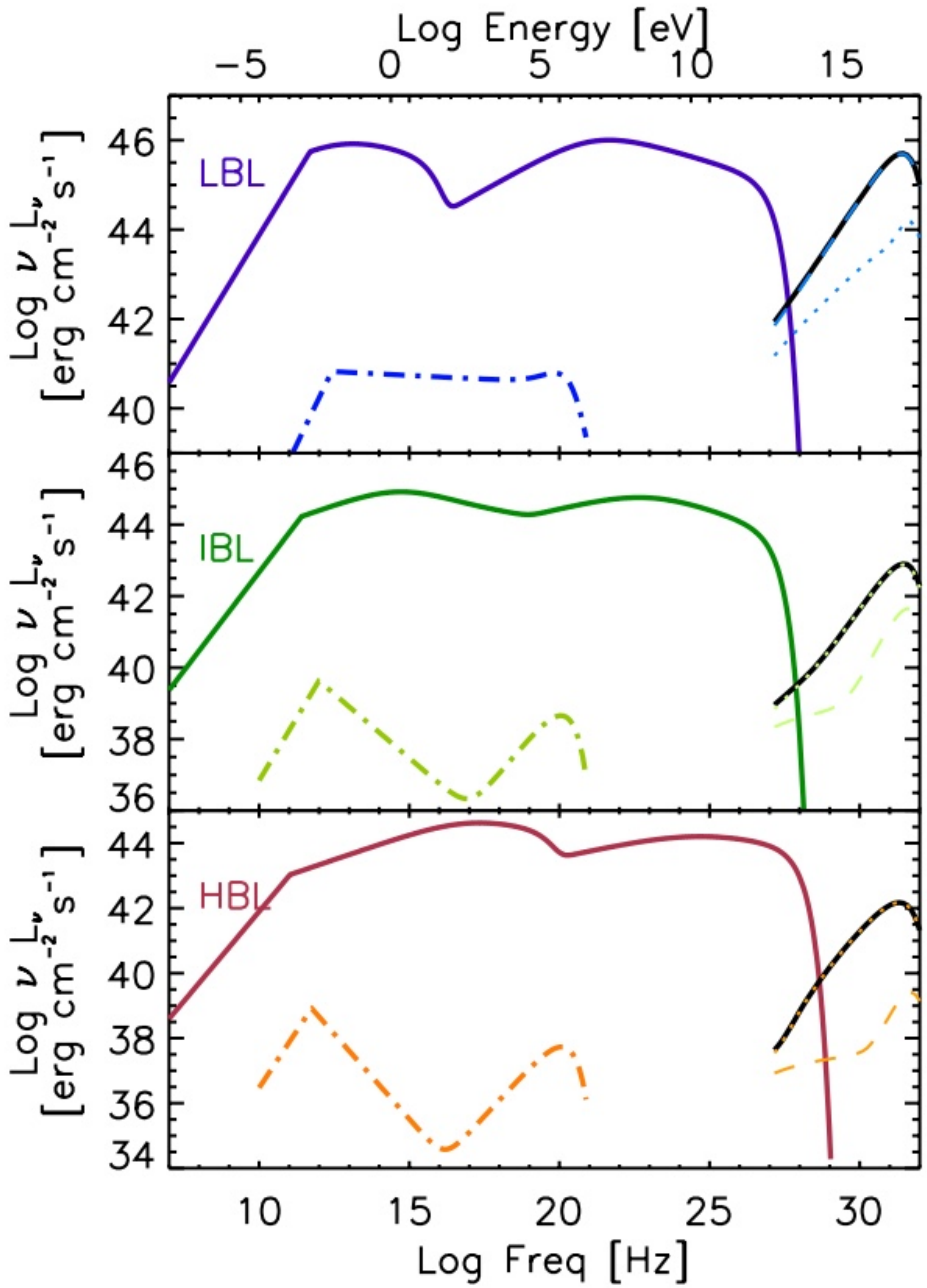




The external field is important for LBL only!

Righi, FT, Inoue et al. 2018

Neutrino emission



$L_p \propto P_{jet}$

$\dot{m} = 10^{-3}$

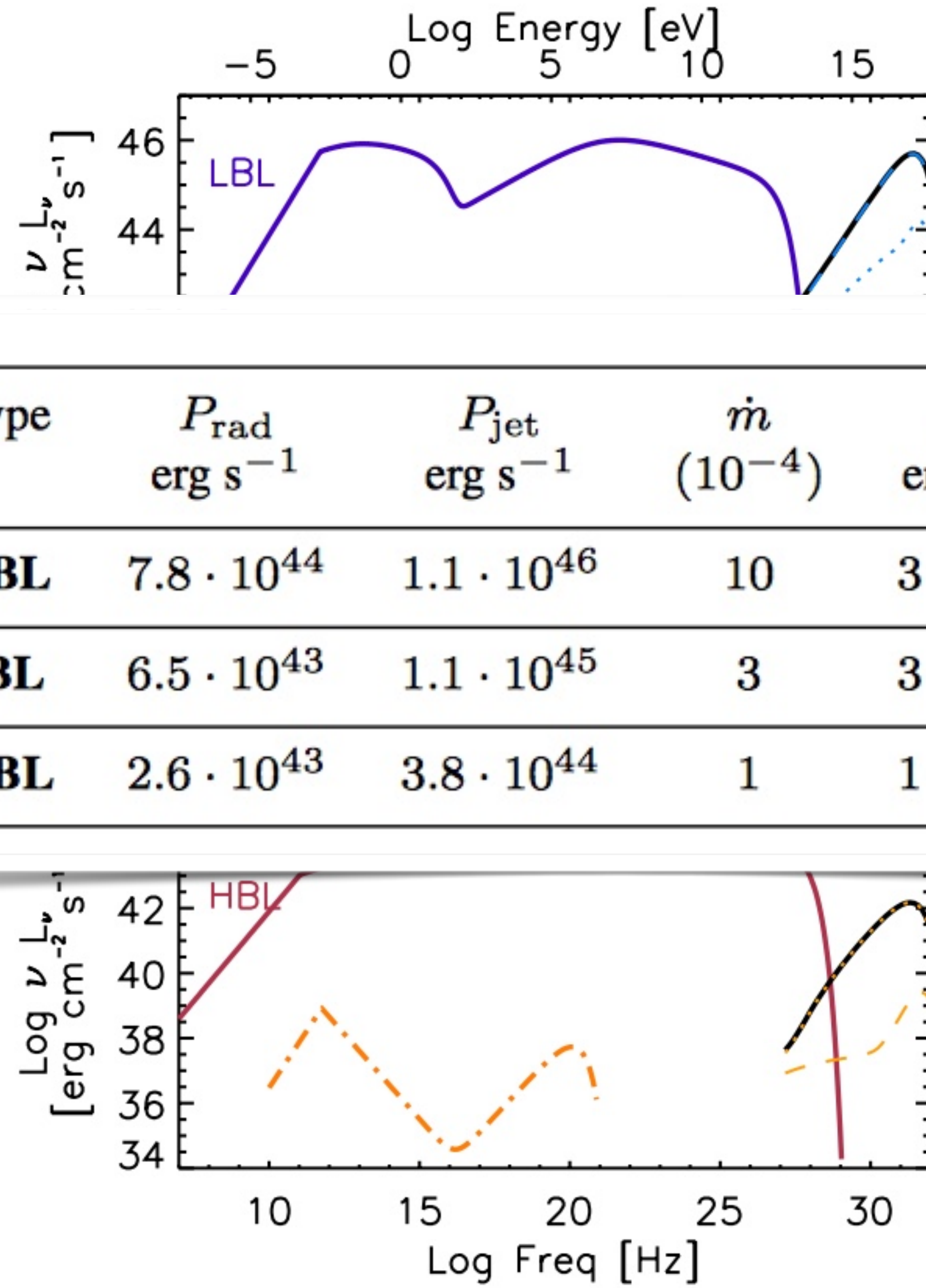
$\dot{m} = 3 \times 10^{-4}$

$\dot{m} = 10^{-4}$

Righi, FT, Inoue et al. 2018

Neutrino emission

$$L_p \propto P_{jet}$$



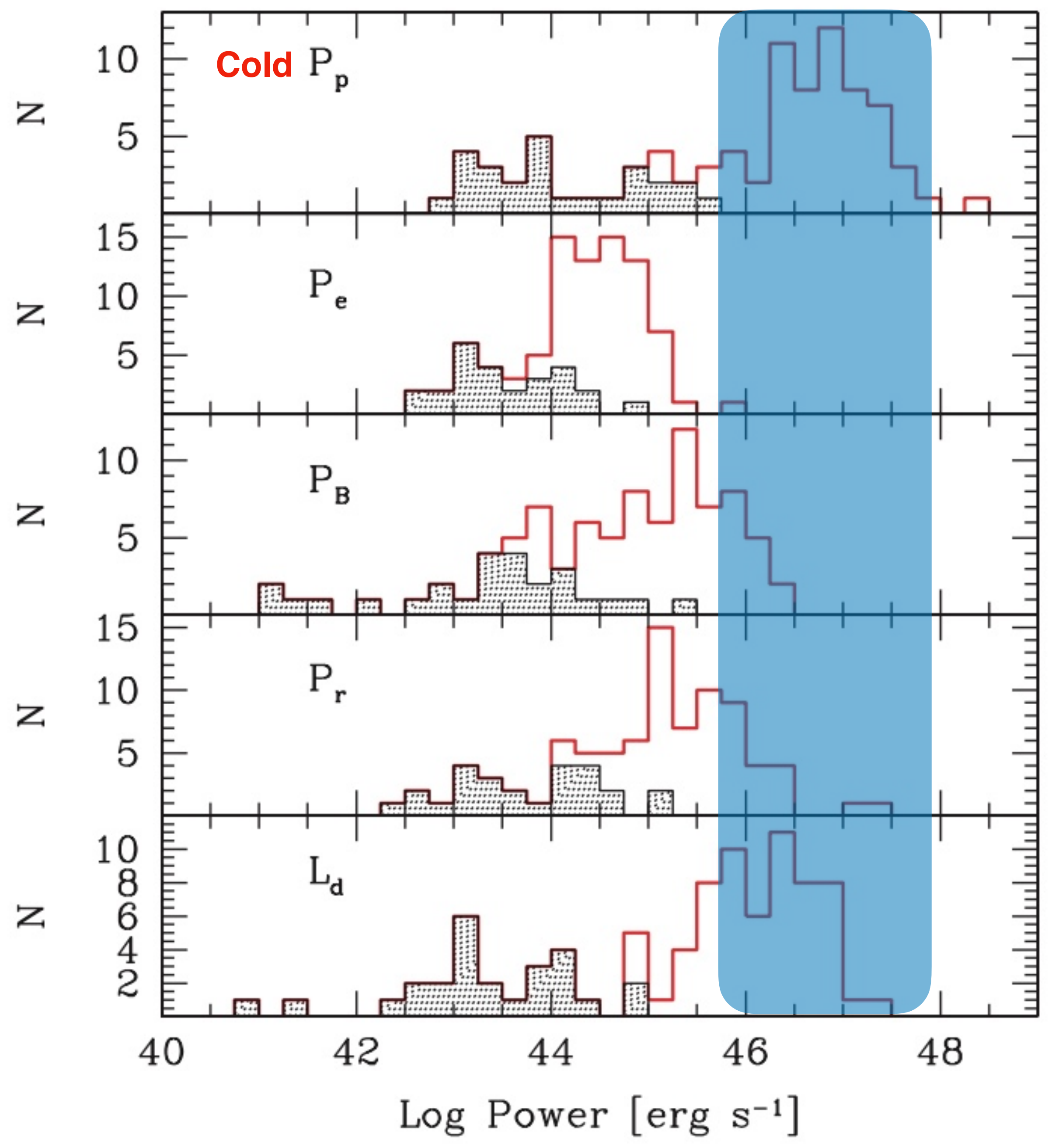
$\dot{m} = 10^{-3}$

Type	$P_{\rm rad}$ erg s^{-1}	$P_{\rm jet}$ erg s^{-1}	$\dot{m}$ (10^{-4})	$L'_{\rm p}$ erg s^{-1}	R_{ν_μ} 7 yr
LBL	$7.8 \cdot 10^{44}$	$1.1 \cdot 10^{46}$	10	$3 \cdot 10^{45}$	1
IBL	$6.5 \cdot 10^{43}$	$1.1 \cdot 10^{45}$	3	$3 \cdot 10^{44}$	$3 \cdot 10^{-5}$
HBL	$2.6 \cdot 10^{43}$	$3.8 \cdot 10^{44}$	1	$1 \cdot 10^{44}$	$9 \cdot 10^{-6}$

$\dot{m} = 10^{-4}$

Righi, FT, Inoue et al. 2018

Jet power



Take home messages

The astrophysical setting is relevant! Environment could play an important role

External photons can help to keep the jet power below 10^{47} erg/s

Fits allow us to fix several parameters in a self-consistent way

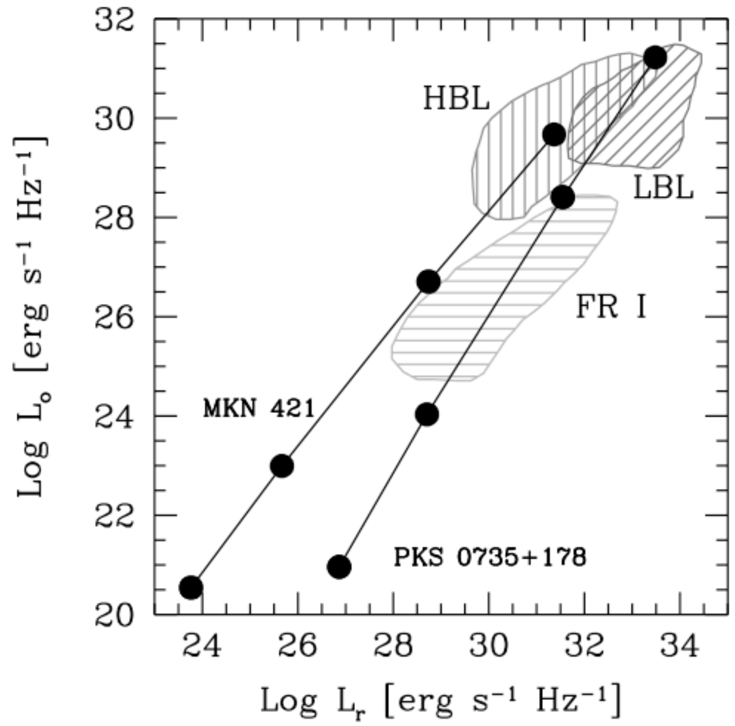
Further modeling/investigations are required

Thank you!

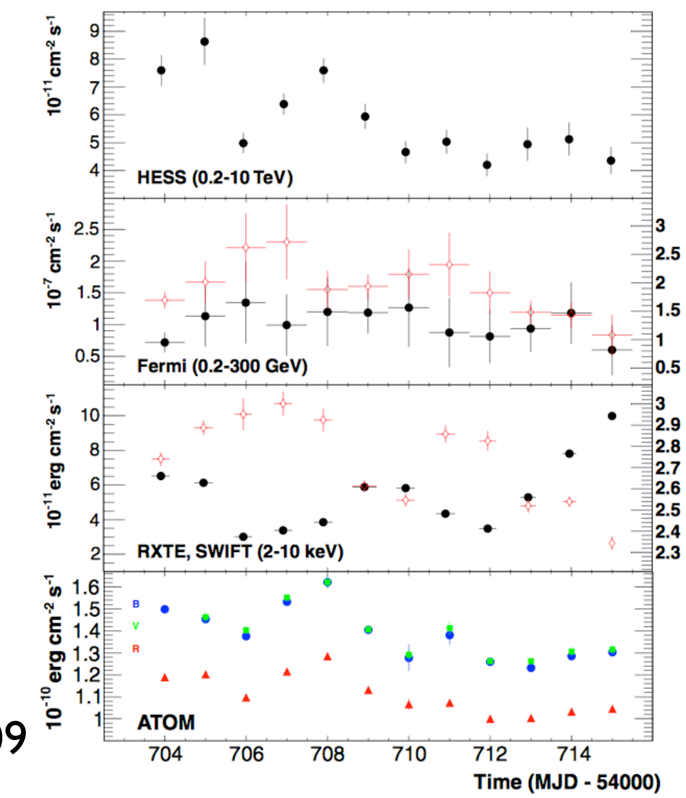
Some problems with BL Lacs

Unification

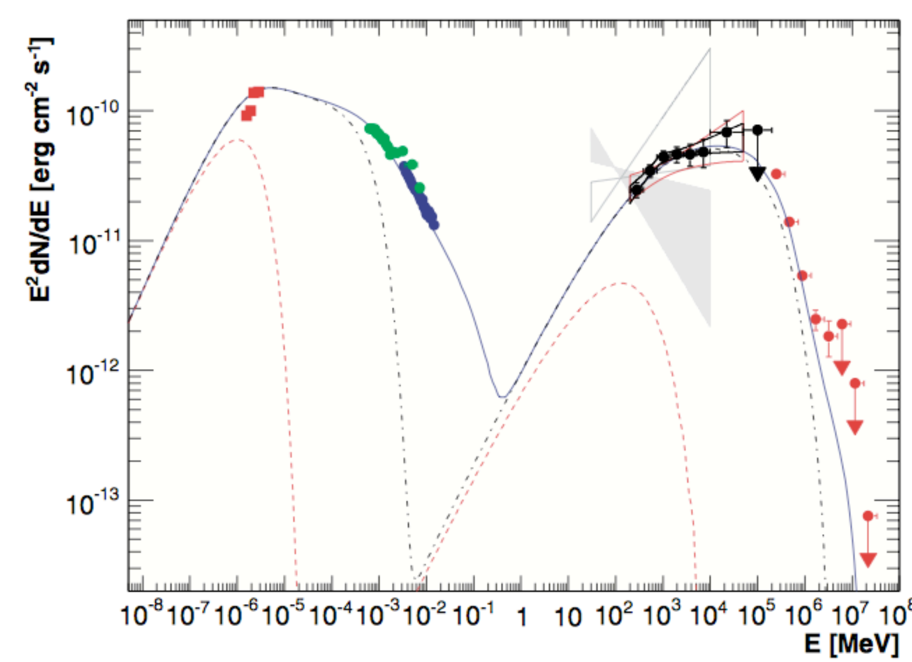
Chiaberge et al. 2000
Meyer et al. 2011
Sbarrato et al. 2014
Georganopoulos & Kazanas 2004
Henry & Sauge' 2006



X-ray/TeV connection

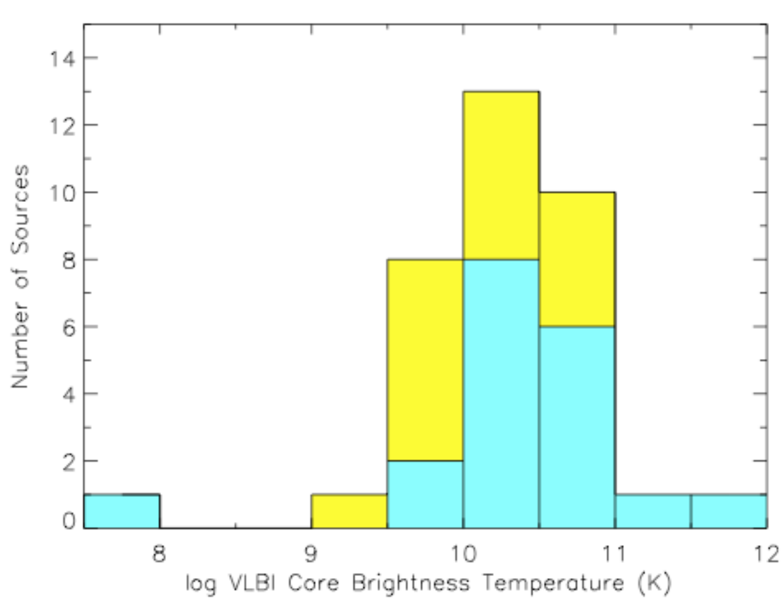


Aharonian et al. 2009
Aleksic et al. 2015



Velocity discrepancy

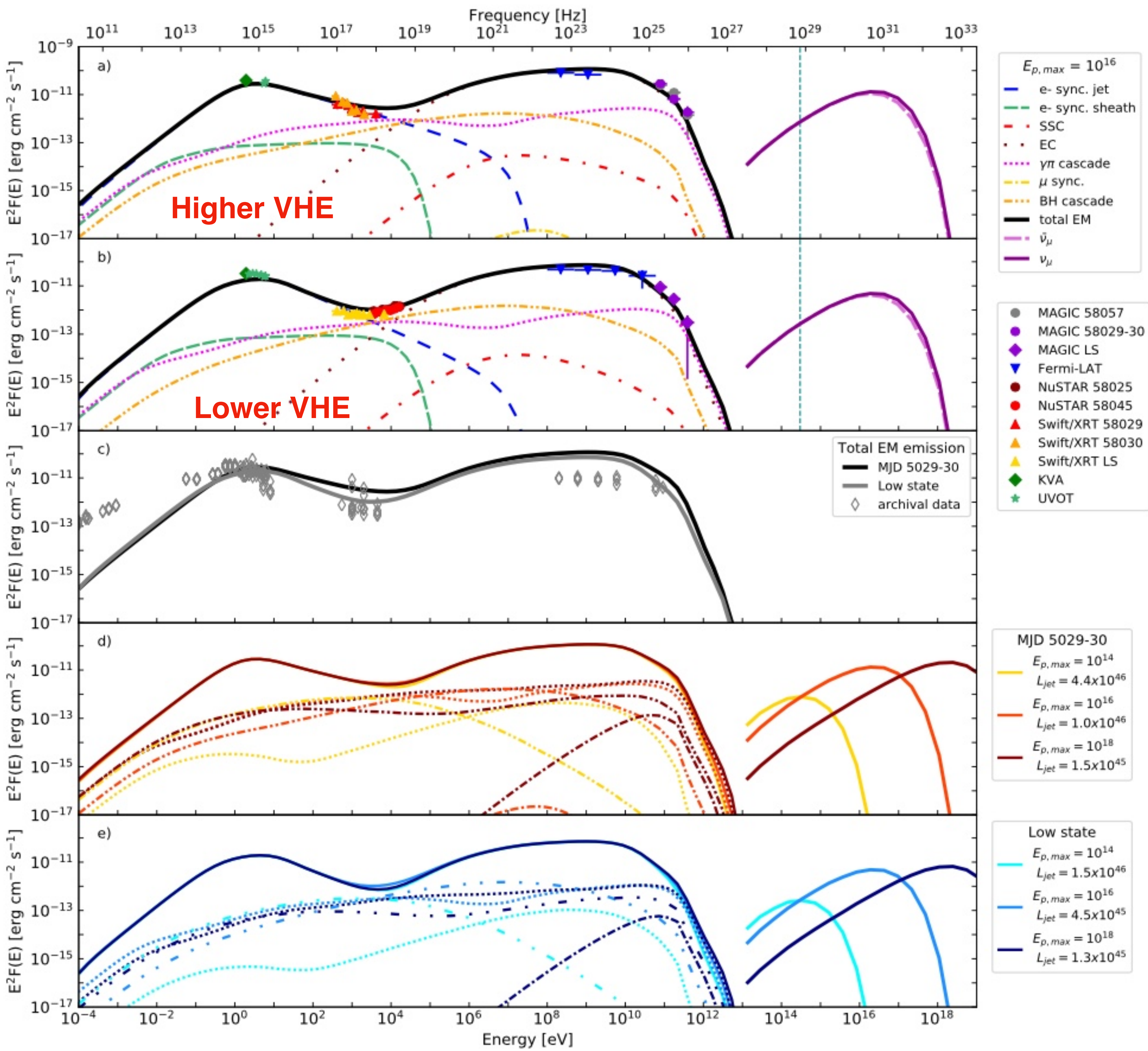
Contraddiction between large delta and small (v<c) VLBI apparent speeds and brightness T



Piner & Edward 2004, 2014
Georganopoulos & Kazanas 2004

Jet-sheath model

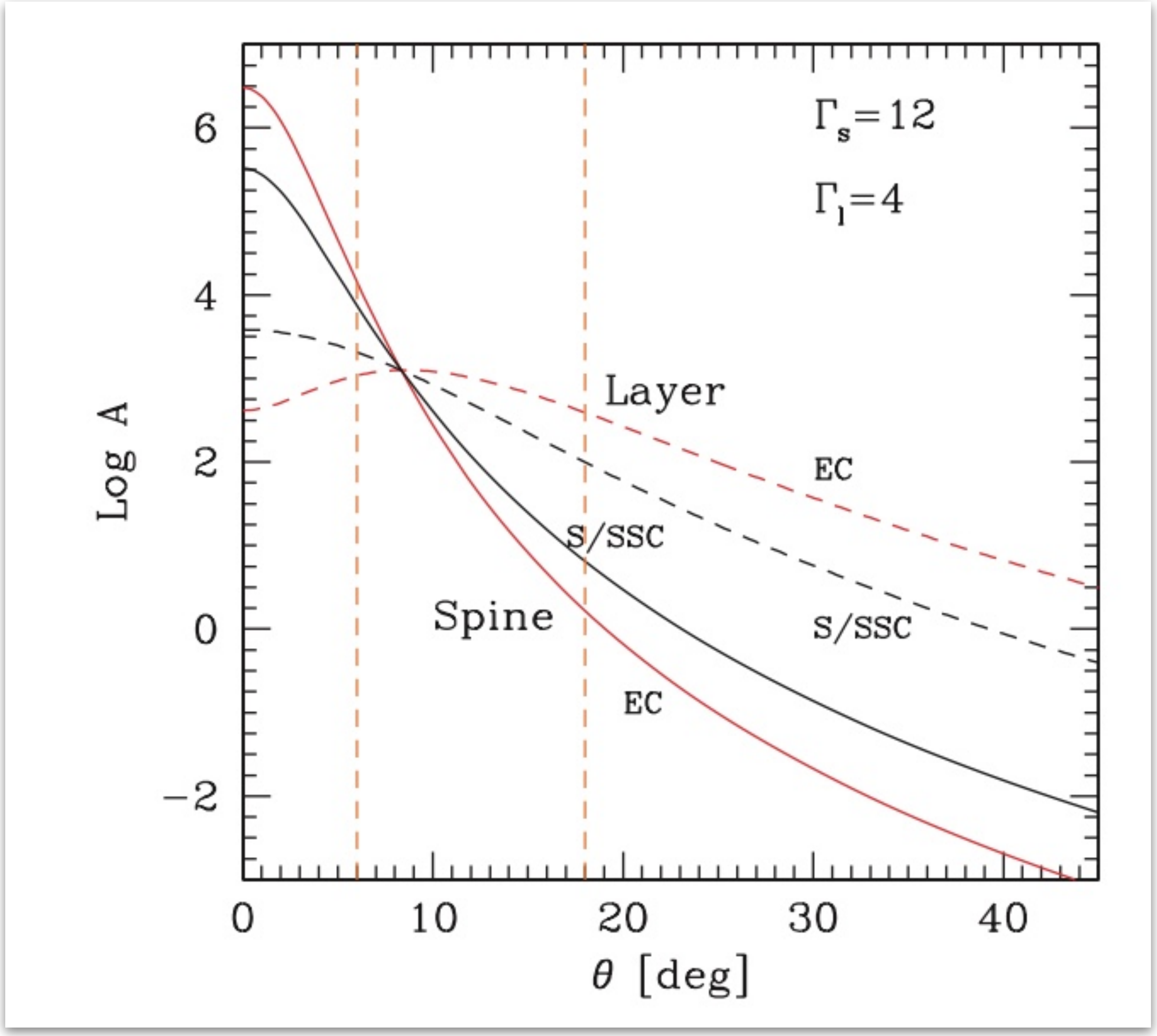
MAGIC Coll. 2018



Structured jets

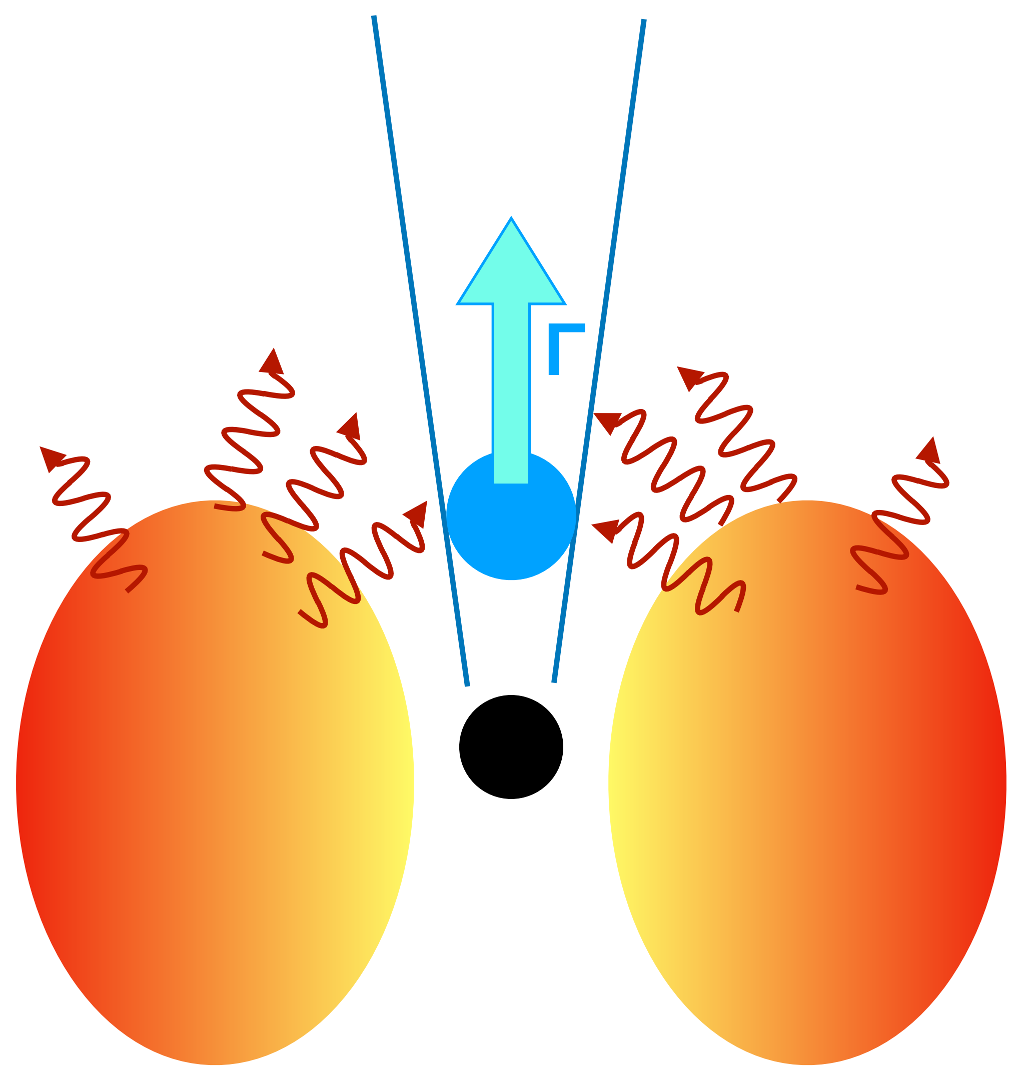
"Dermer effect"

Dermer 1995

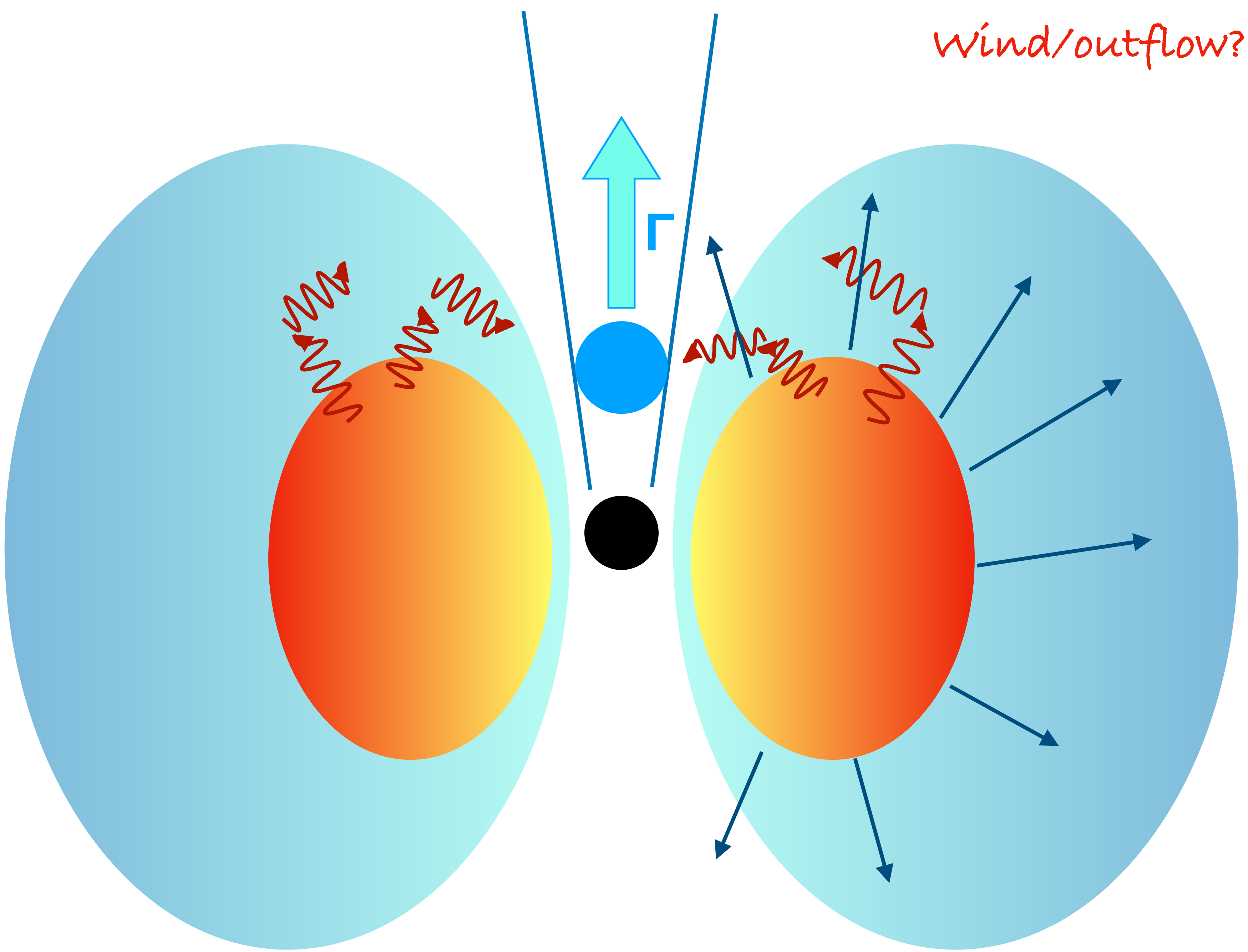


Tavecchio and Ghisellini 2008

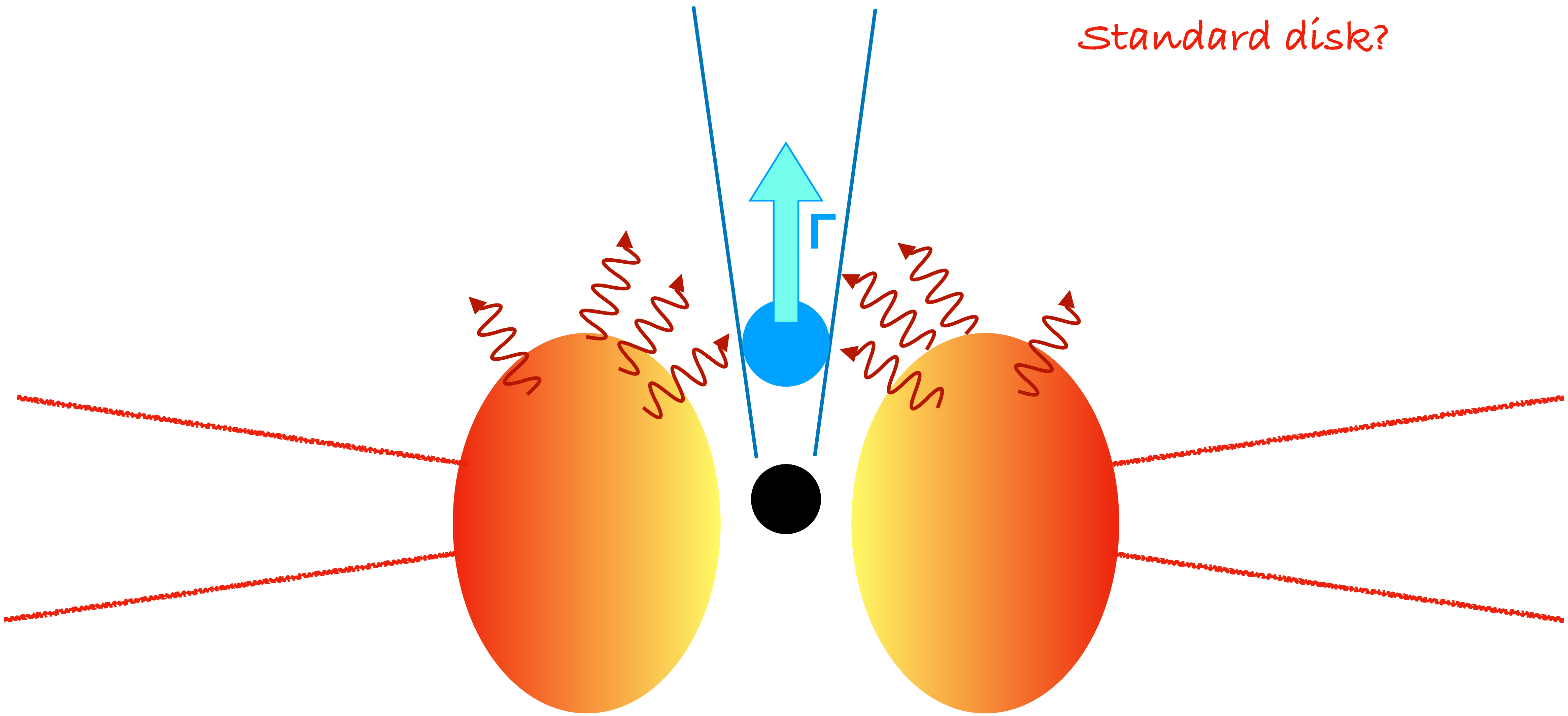
Caveats & Complications



Caveats & Complications



Caveats & Complications



Caveats & Complications