On the jet properties of the gamma-ray loud AGNs

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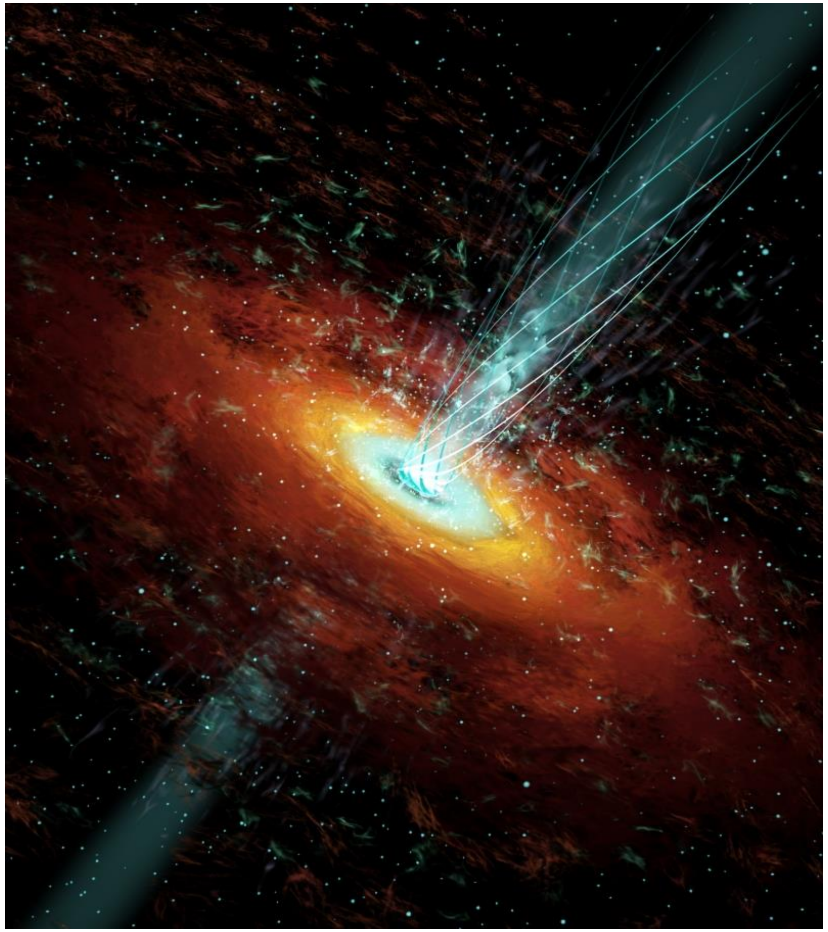
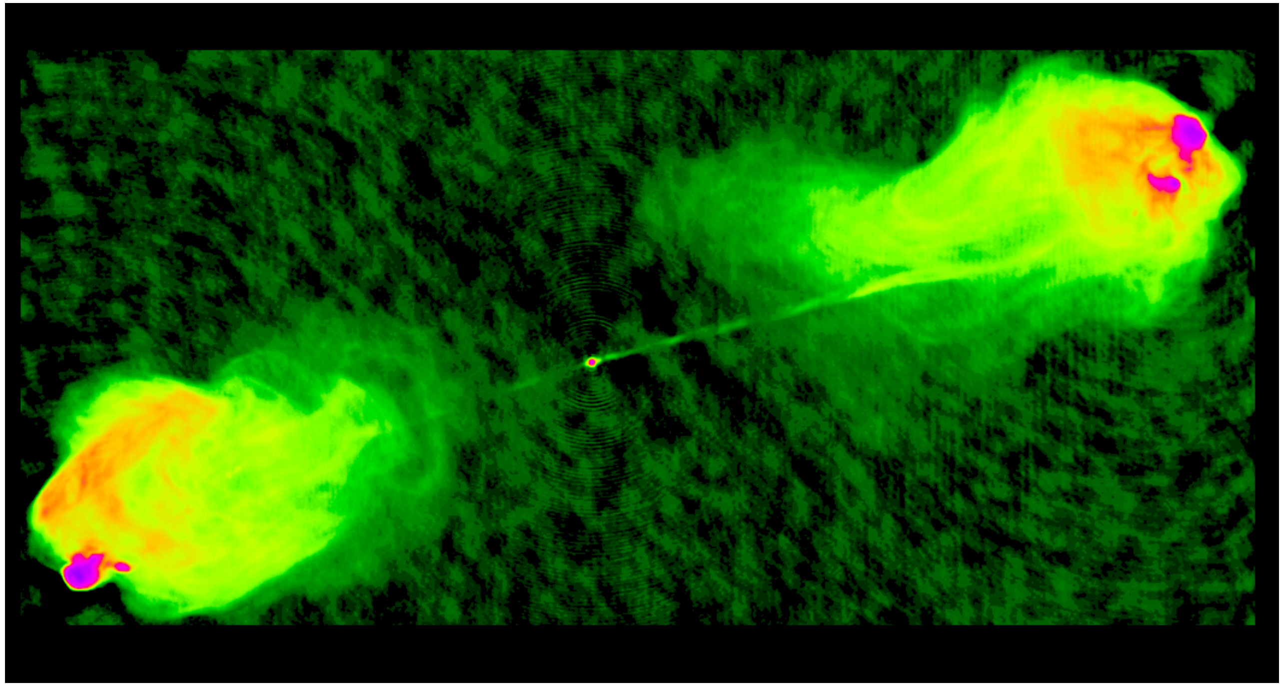
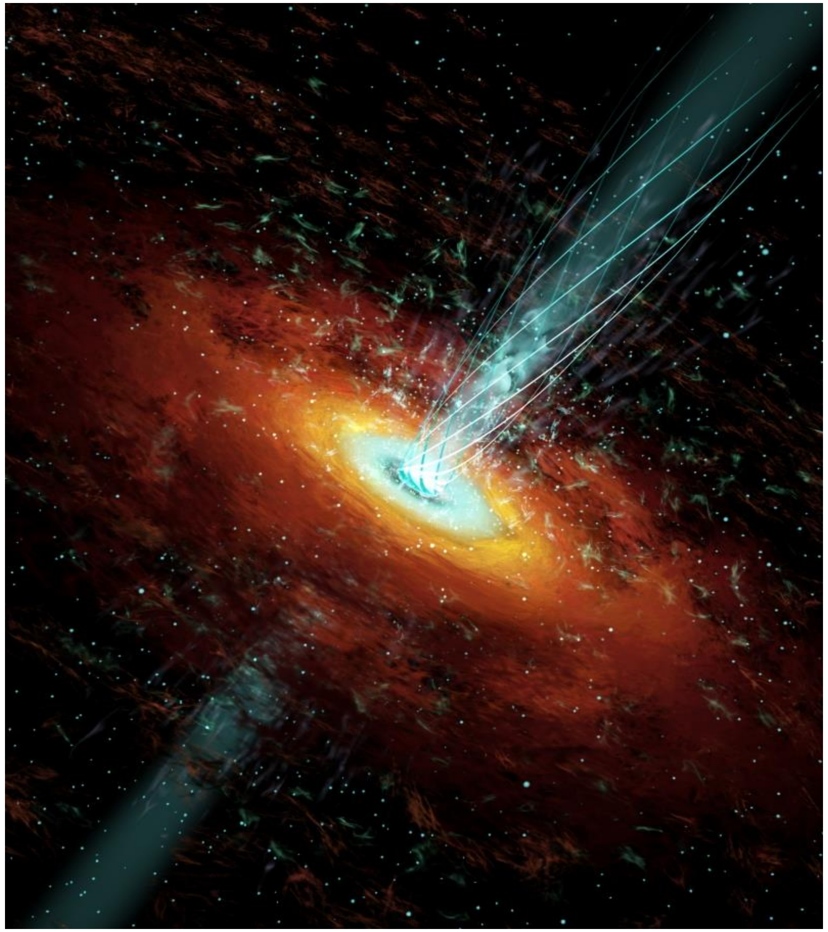
AGN - jet



- Accretion
- ~10%, relativistic jet



AGN - jet



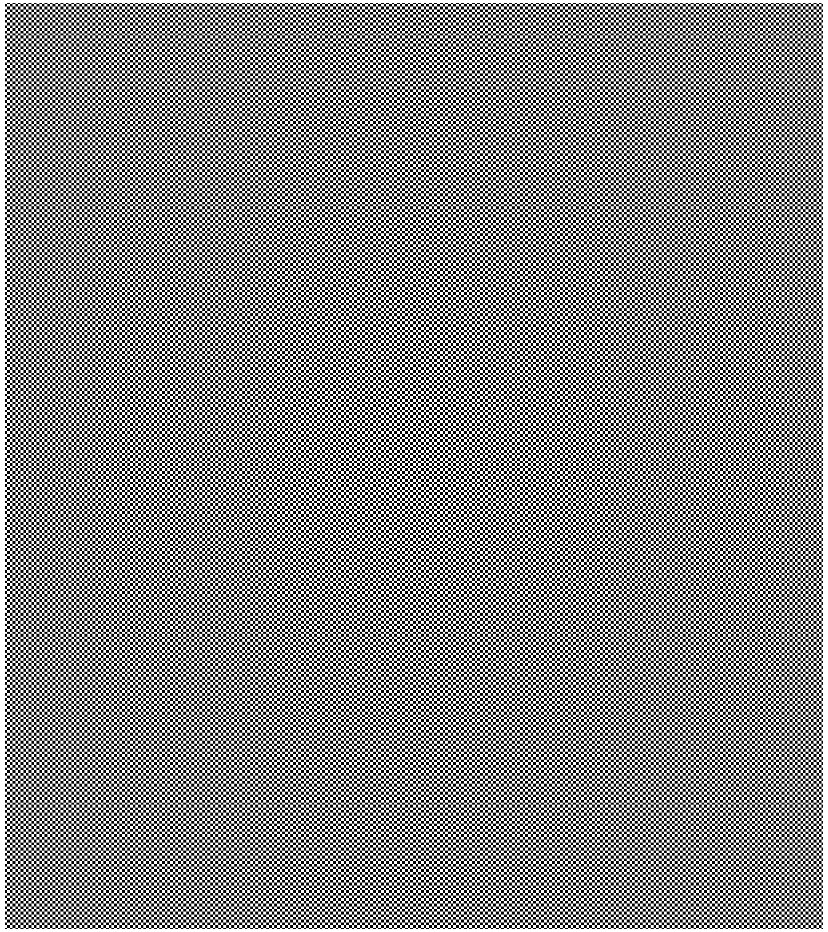
- jet formation, structure and collimation

  sub-pc - Mpc

- energy transport and dissipation

- particle acceleration and radiative process

AGN - jet

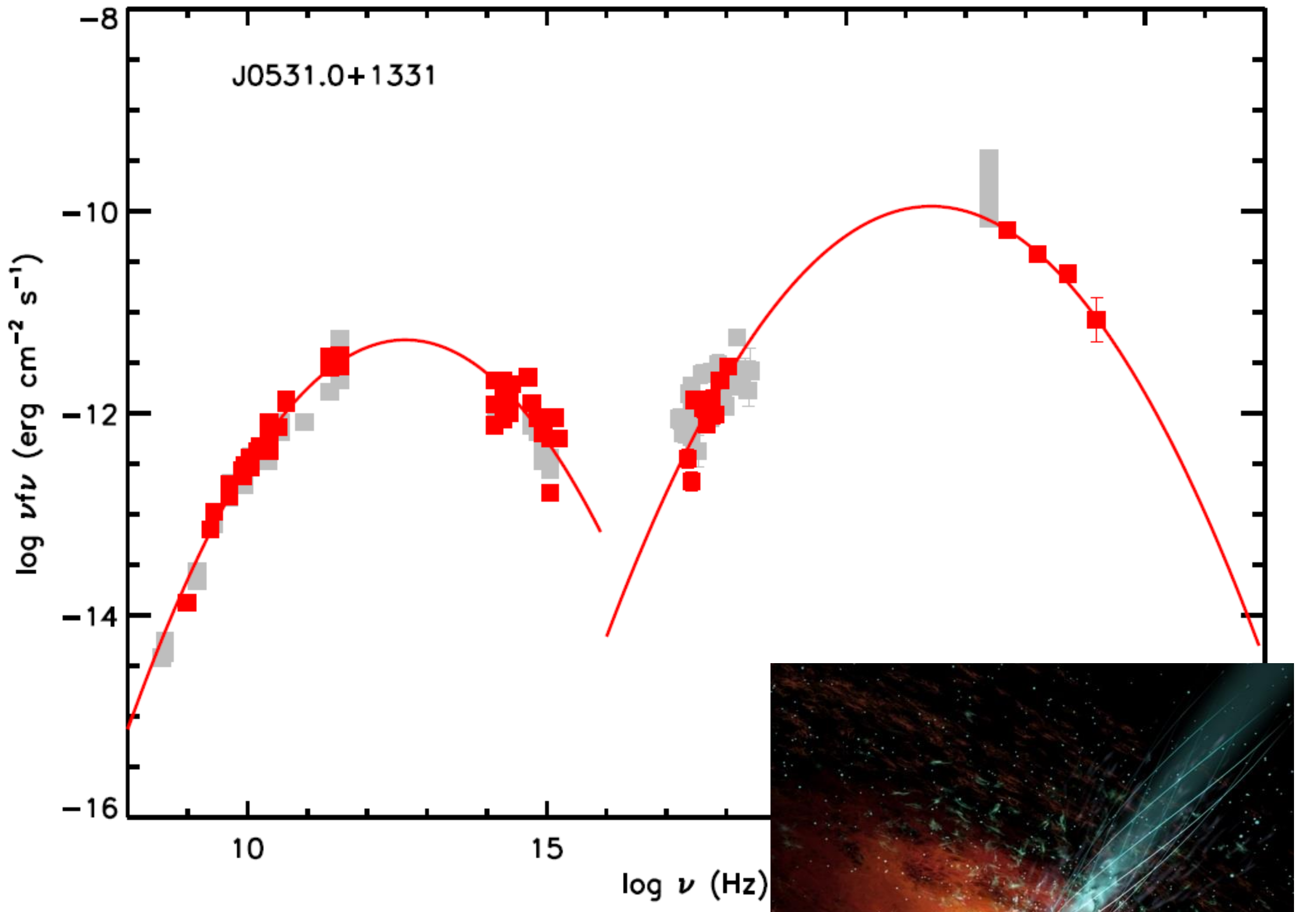


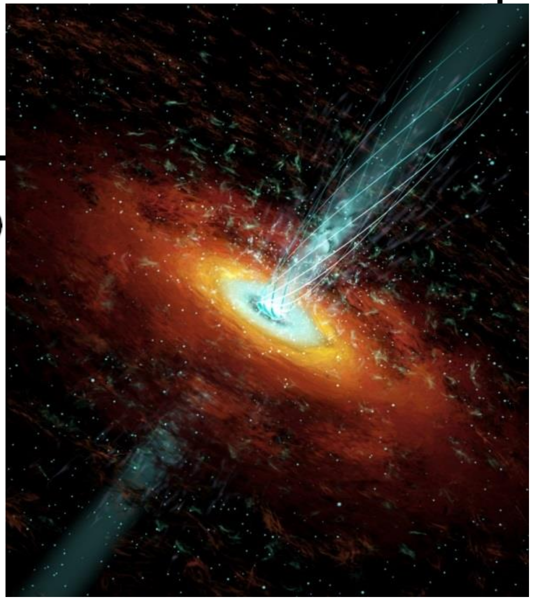
- jet formation, structure and collimation
- energy transport and dissipation
- particle acceleration and radiative process

AGN – jet – blazar

- Variability
- Polarization
- Broadband SED – gamma-ray
- SED modeling

Jet physical parameters: magnetic field, jet power...





I. Jet launching

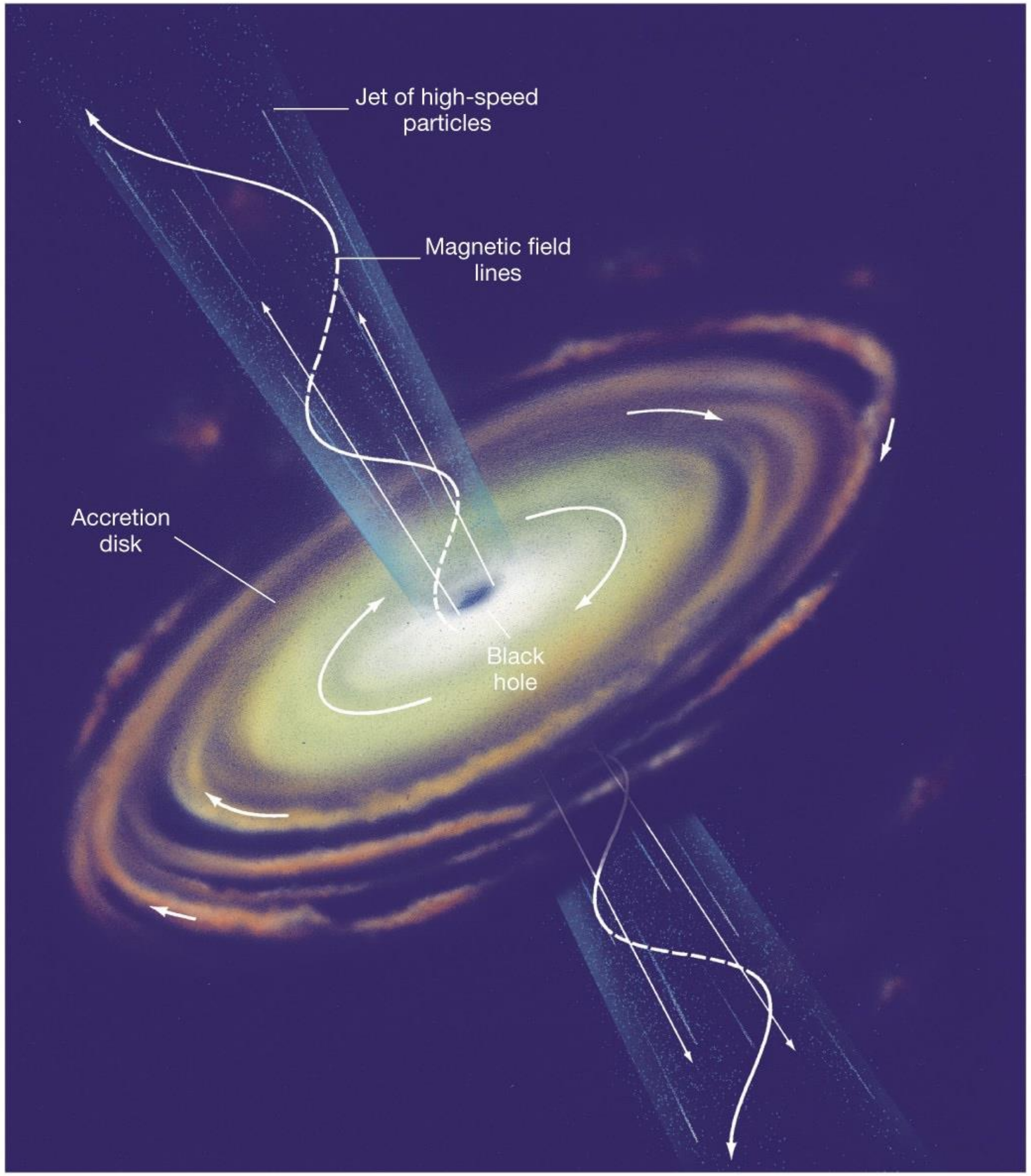
- Gravitational potential energy of accretion disk

  (BP mechanism, Blandford & Payne 1982)

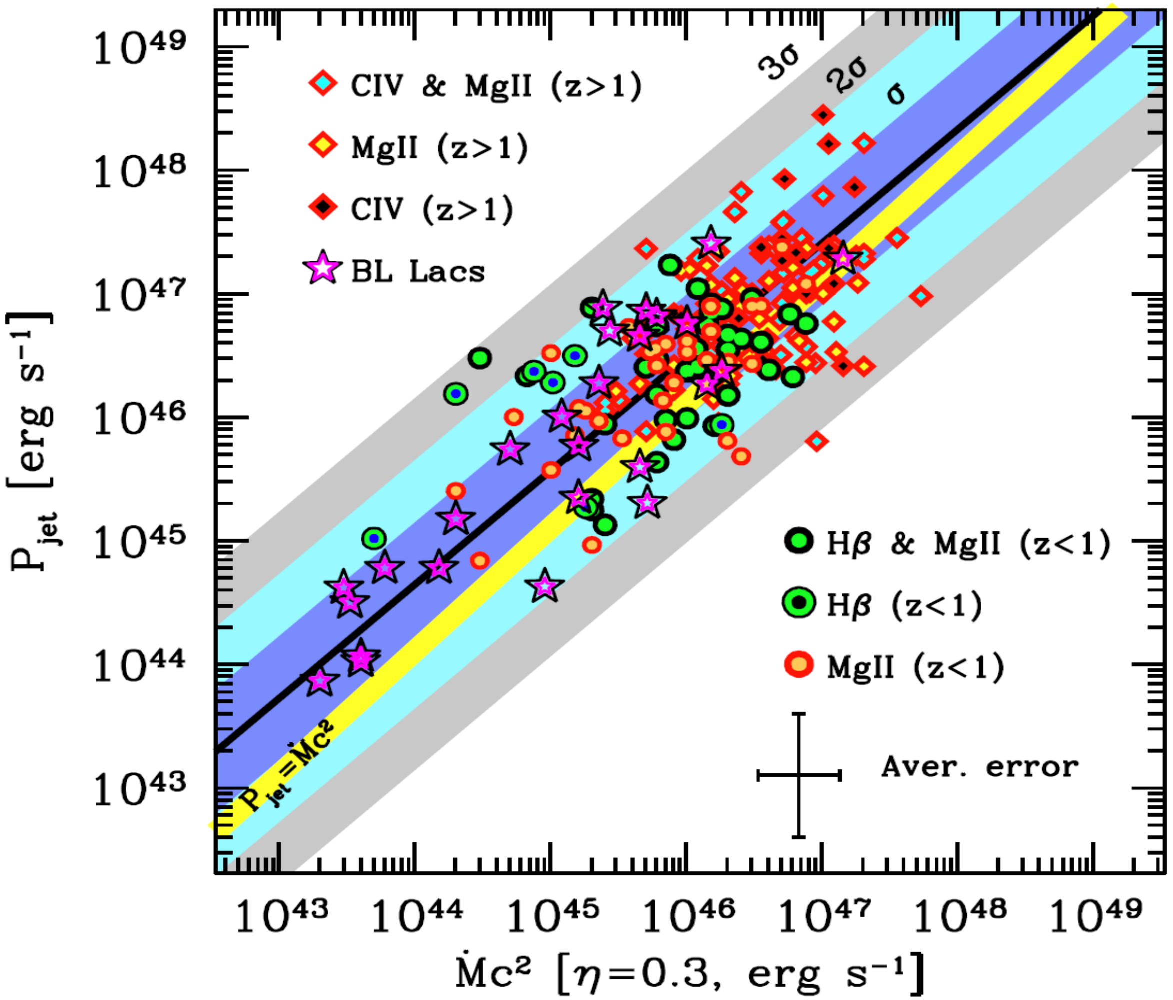
- Black hole spin energy

  (BZ mechanism, Blandford & Znajek 1977)

- Simulation/obervation



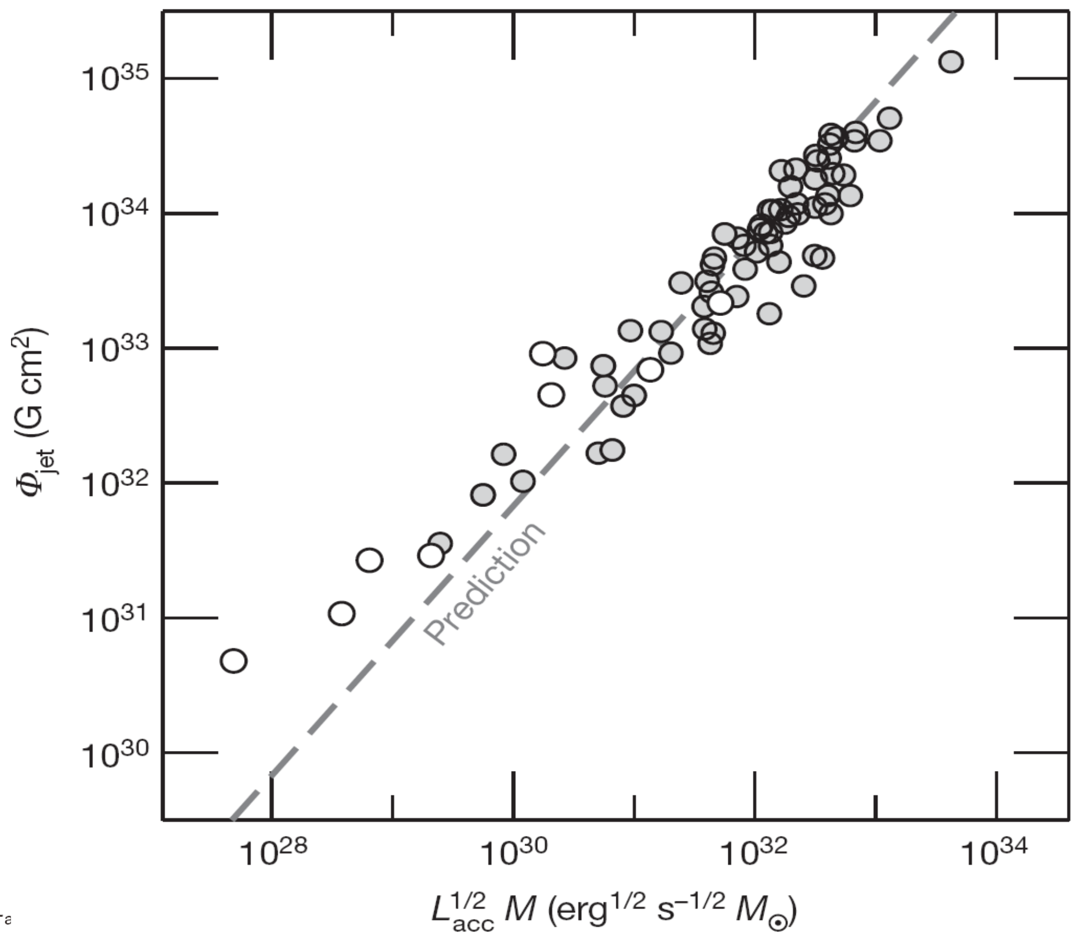
BZ: jet power – SED modeling

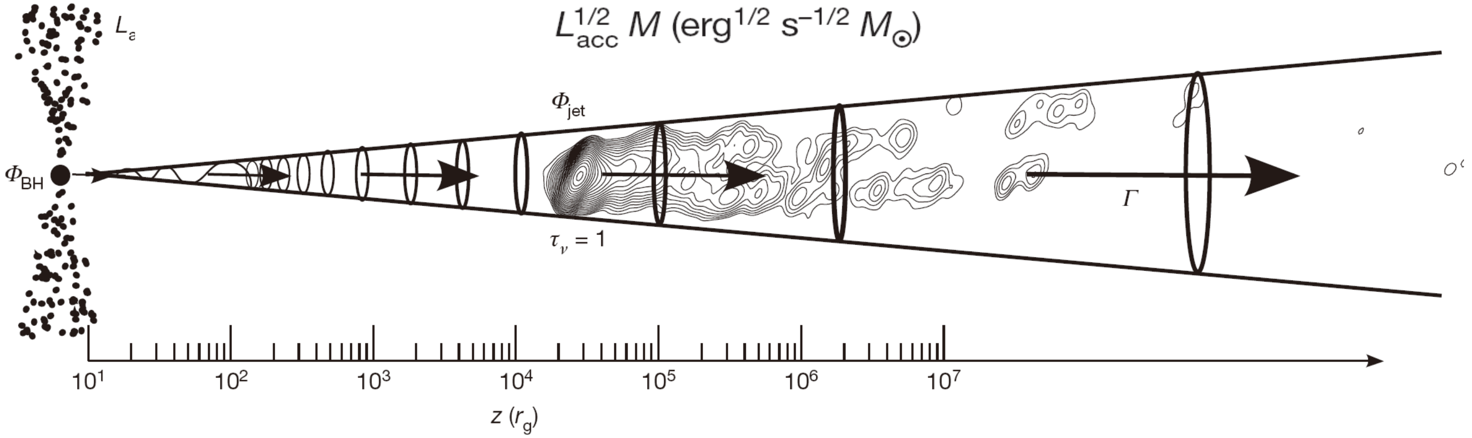


Ghisellini et al. 2014 Nature

BZ: magnetic flux

$$\Phi_{\rm jet} \approx 50\left(\dot{M} r_{\rm g}^2 c\right)^{1/2}$$





Zamaninasab et al. 2014 Nature

Jet vs. Disk

- 1392 gamma-ray AGNs

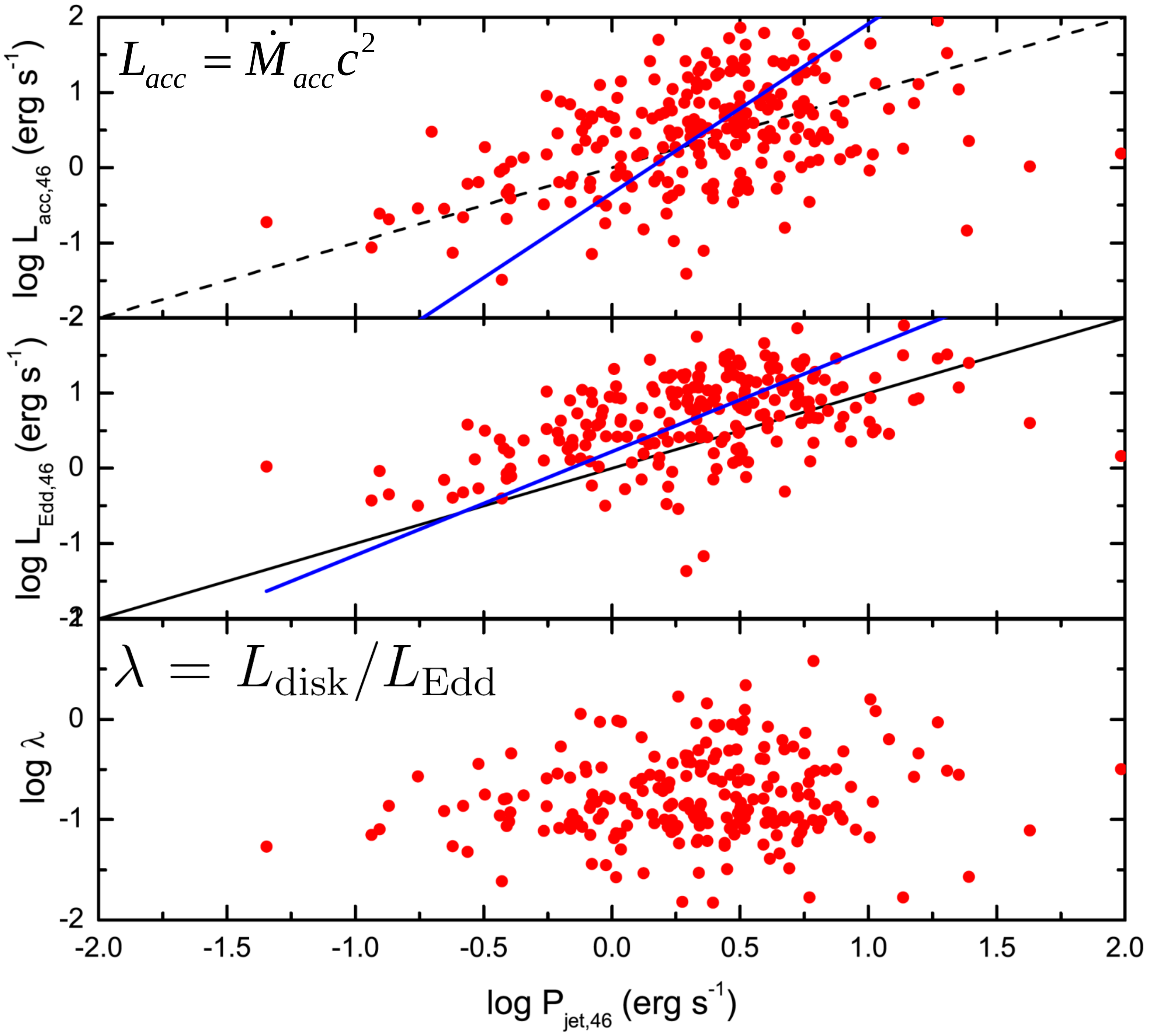
  observed luminosity (Fan 2016)

- 232 disk luminosity

  BLR

- BZ mechanism
- Independent of Eddington ratio

Chen 2018 ApJS



Jet vs. Disk

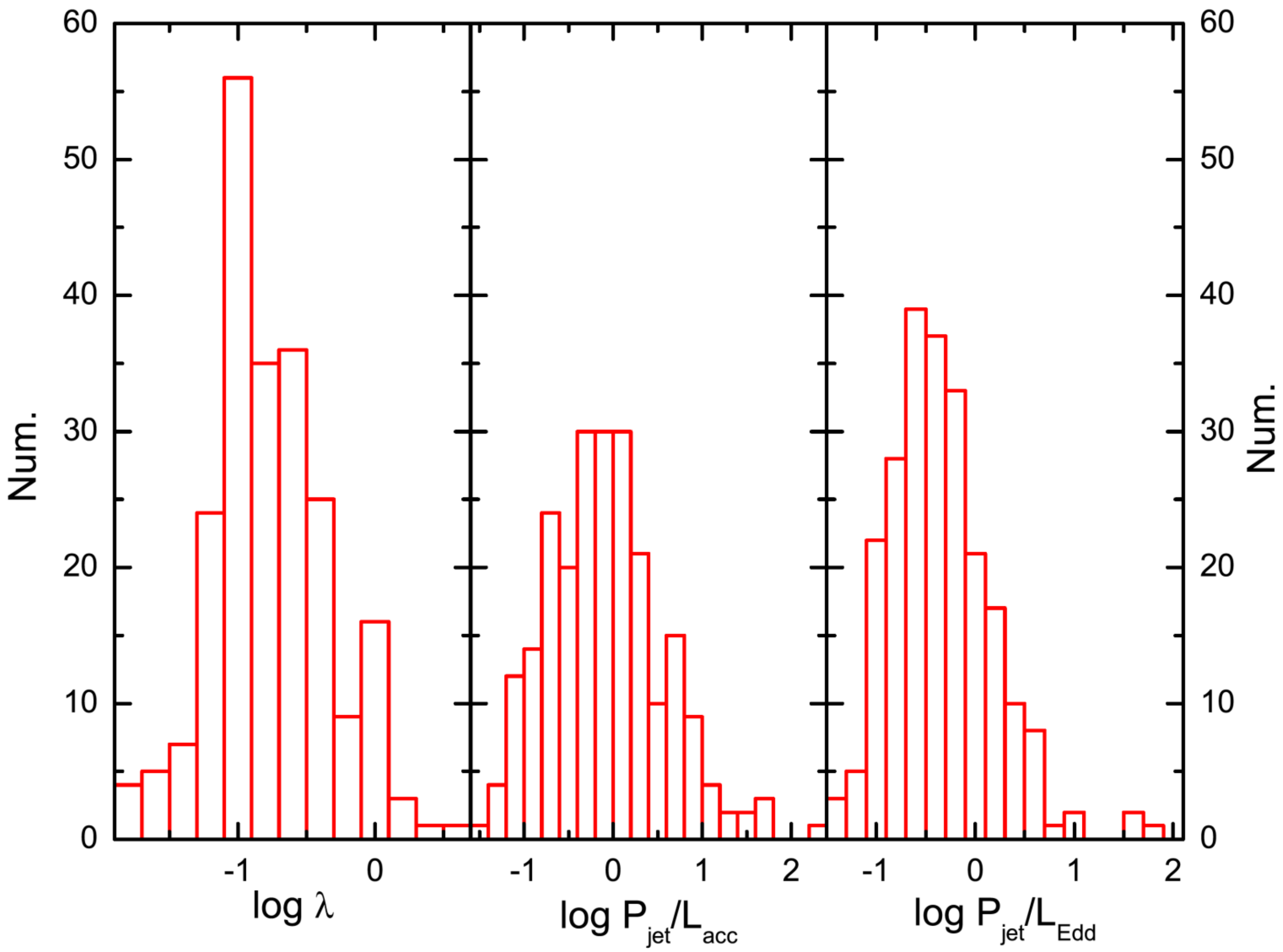
- Median values

$$P_{jet} / L_{acc} \sim 0.768$$

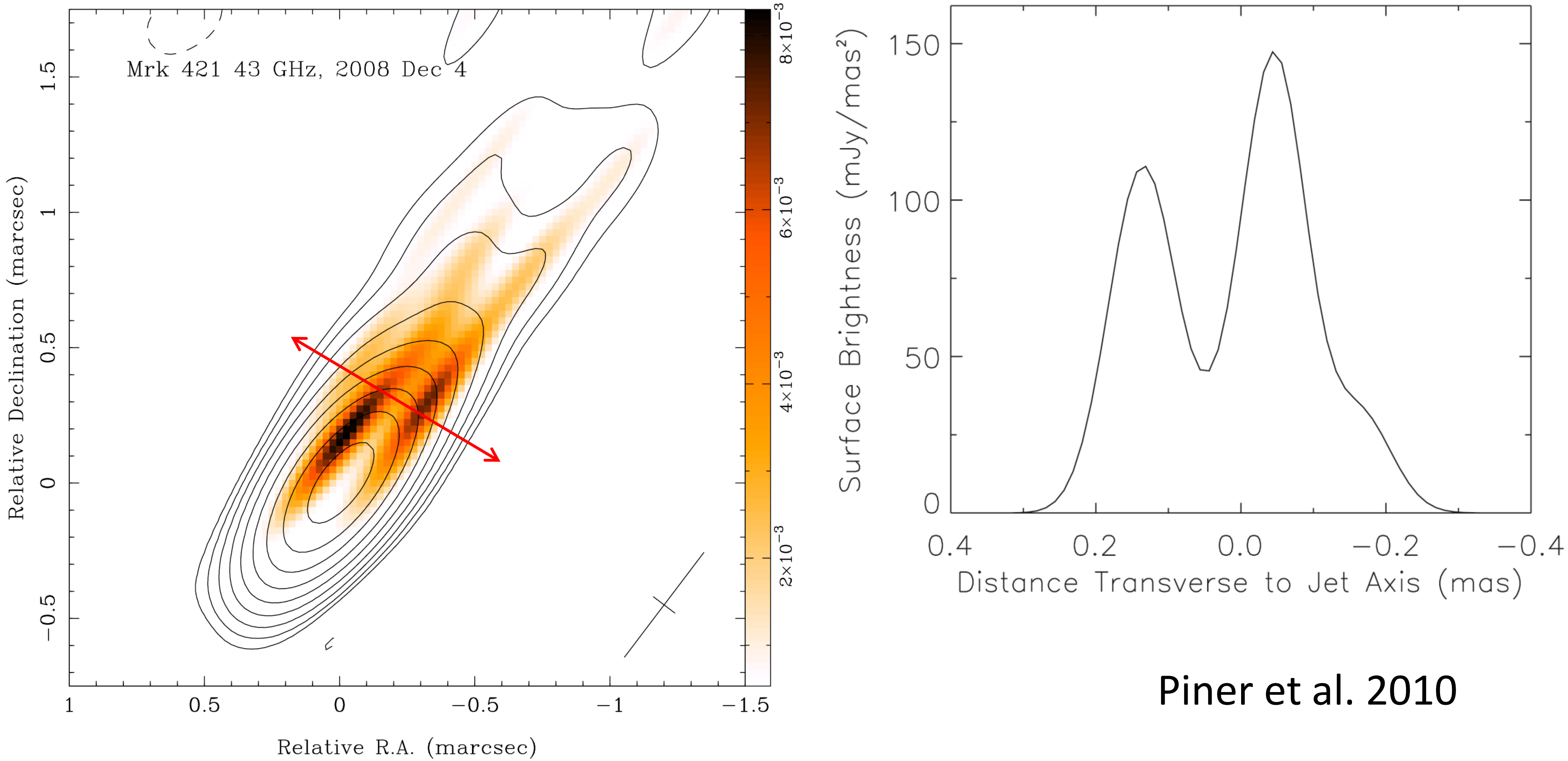
$$P_{jet} / L_{Edd} \sim 0.382$$

$$\lambda = L_{disk} / L_{Edd} \sim 0.148$$

- Standard disk can launch jet



II. Jet structure - limb brighten



Piner et al. 2010

Origin of structured jet

- Kelvin-Helmholtz instability, Lobanov & Zensus 2001
- layer from accretion disk and spine from black hole ergosphere, Mizuno et al. 2007; Meliani et al. 2010
- Magnetic tower jet, Kato et al. 2004; Li et al. 2006

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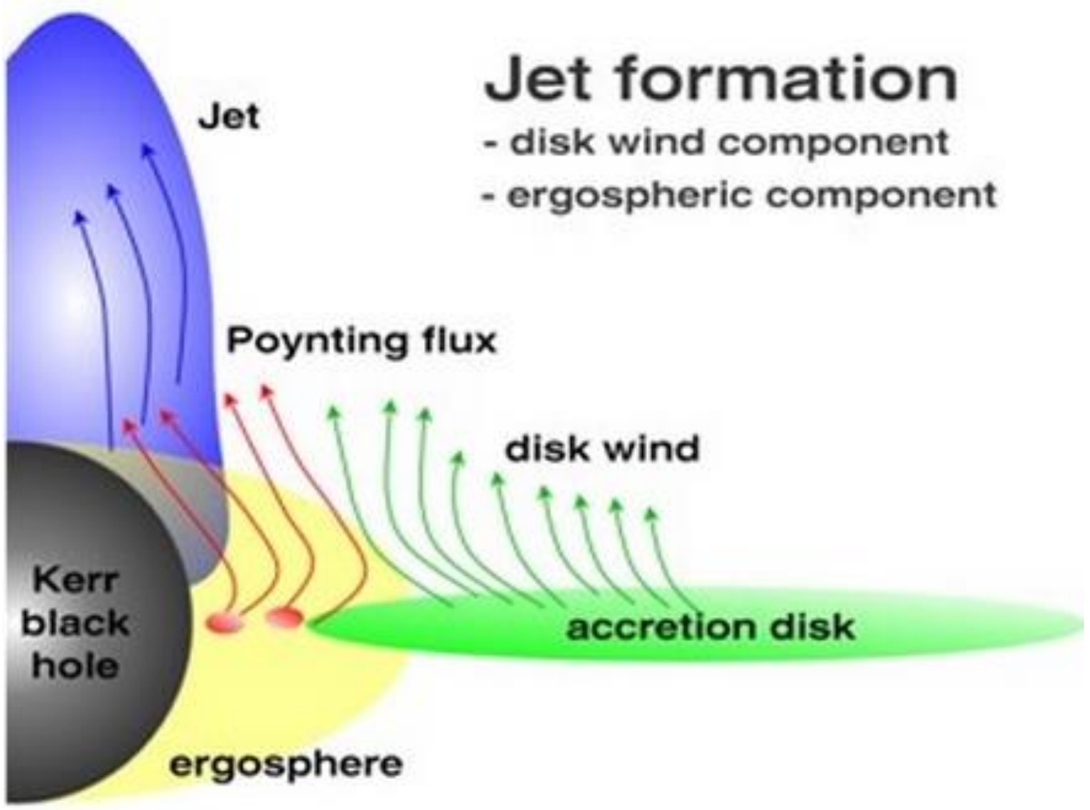

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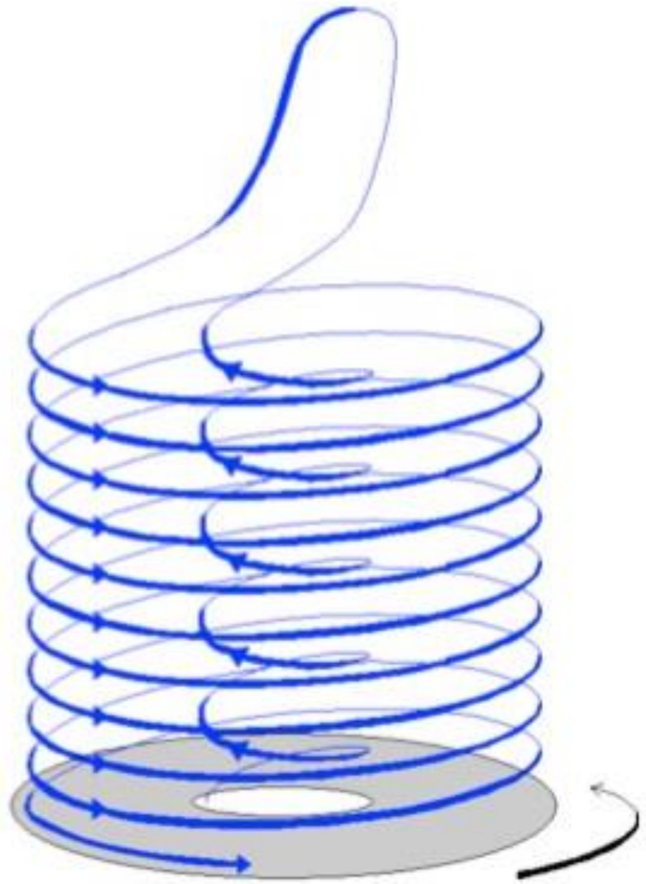


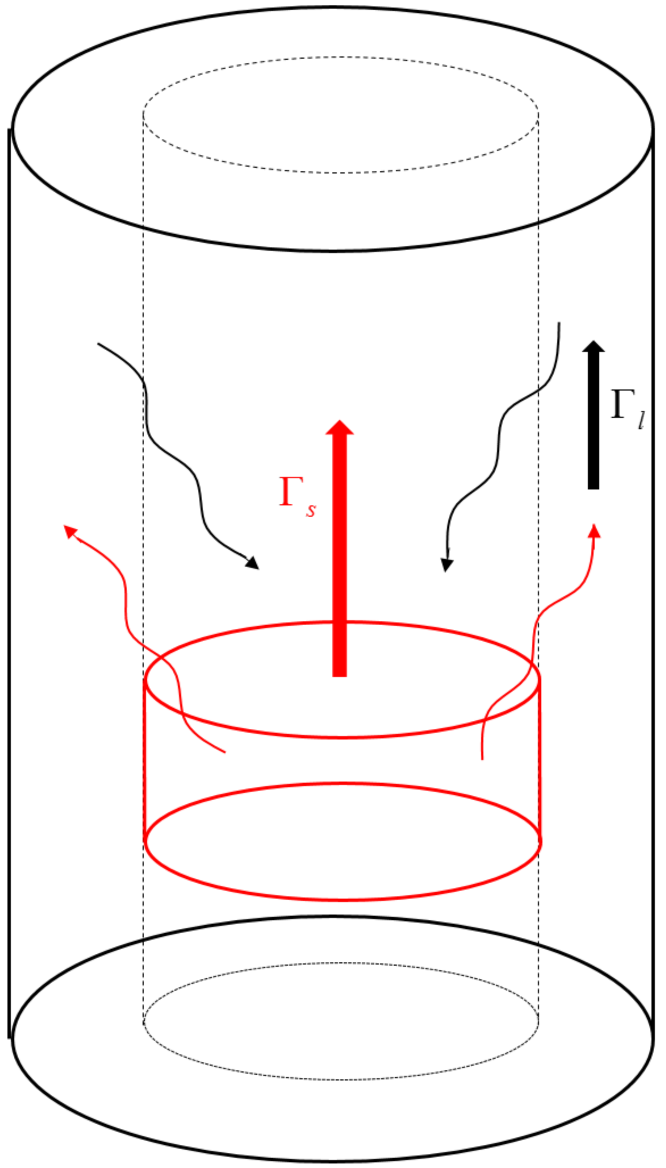
Structured jet

Spine vs. layer

$$\Gamma_{rel} = \Gamma_s \Gamma_l (1 - \beta_s \beta_l)$$

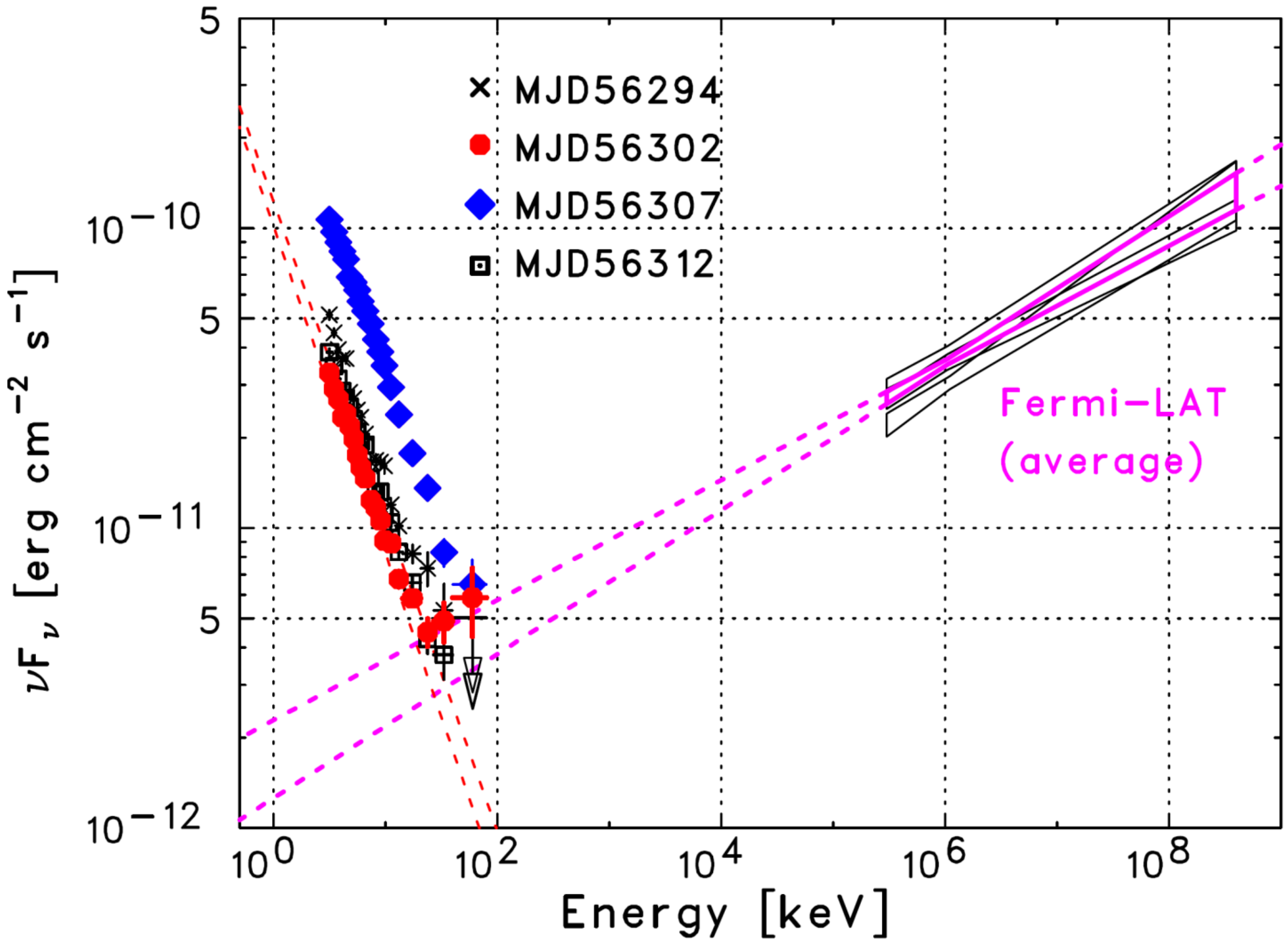
1. In the comoving frame of the layer, the radiation energy density $U_l'' = L_l''/[\pi(R_2^2 - R^2)c]$ (slightly different from that of Ghisellini et al. 2005, to make sure that the radiation energy density is in the same format as that in the spine). In the frame of the spine, this radiation energy density will be boosted to $U_l' = \Gamma_{rel}^2 U_l''$.
2. In the comoving frame of the spine, the radiation energy within the spine is assumed to be $U_s' = L_s'/(\pi R^2 c)$. The radiation energy density observed in the frame of the layer will be boosted by Γ_{rel}^2 but also diluted (since the layer is larger than the spine) by a factor $\Delta R_s''/\Delta R_l'' = (\Delta\ R_s'/\Gamma_{rel})/\Delta R_l''$.

blazar vs. radio galaxy



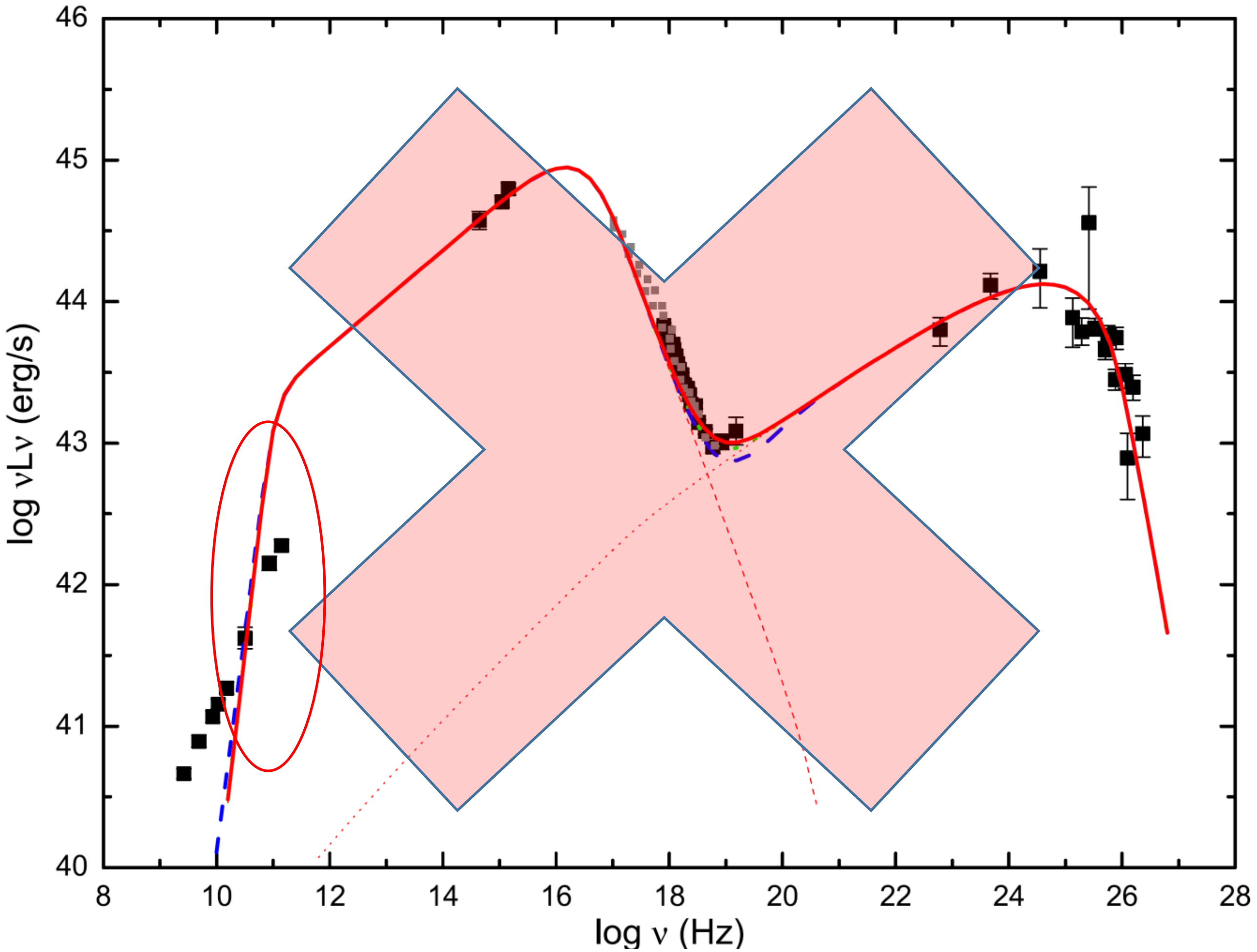
Chen 2017 ApJ

Mrk 421: GeV – X-ray



Kataoka & Stawarz 2016

One-zone modeling?



$\gamma_{\min} = 2, 20, 50$

Chen, 2017, ApJ

Mrk 421: structured jet

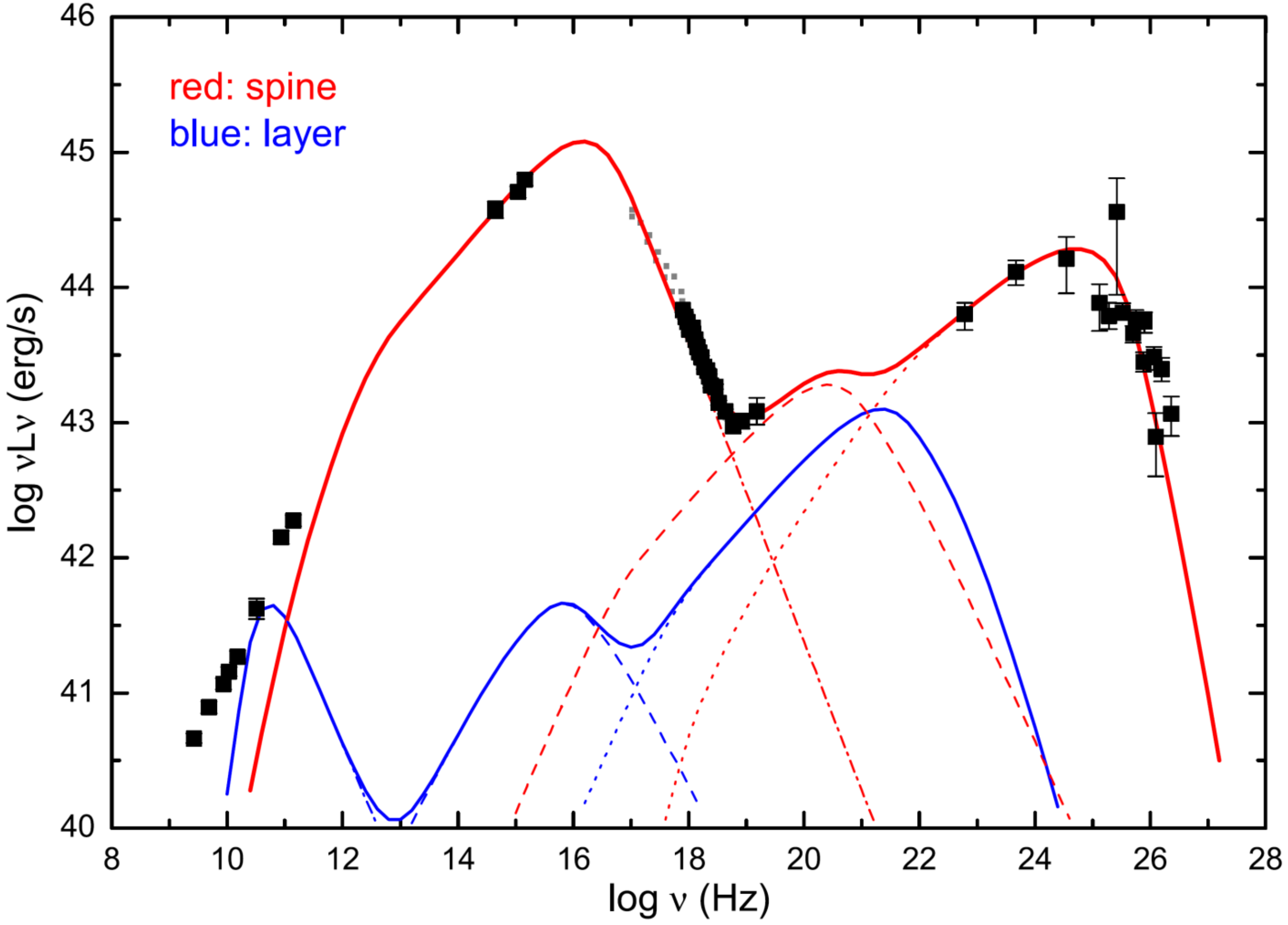
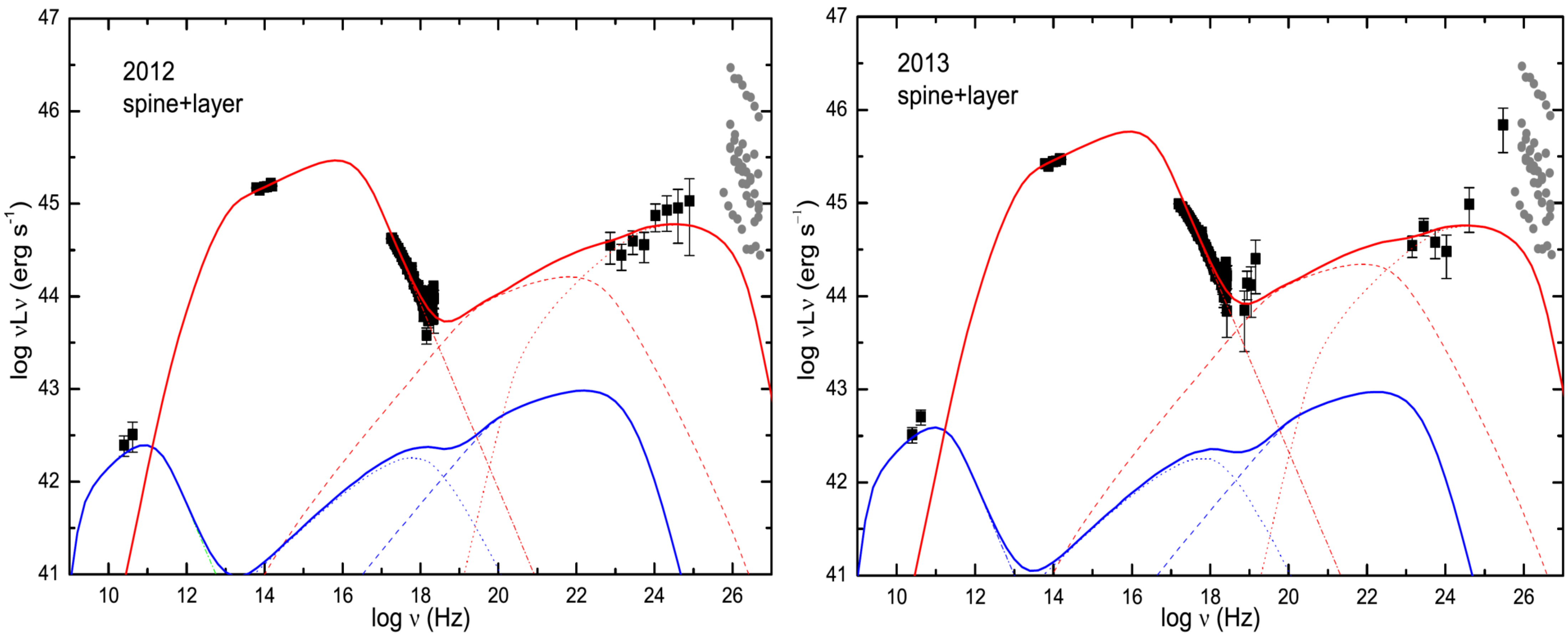


Table 1: The spine/Layer model parameters for Mrk 421.

	$\theta(^\circ)$	Γ	δ	B(Gs)	N_0	γ_0	γ_{min}	γ_{max}	p_1	p_2
Spine	2	21.4	27.5	0.23	996	29009	300	$100\gamma_0$	2.0	5.2
Layer	2	4.7	9.1	0.0087	593	326	2	$100\gamma_0$	1.0	5.0

Chen, 2017 ApJ

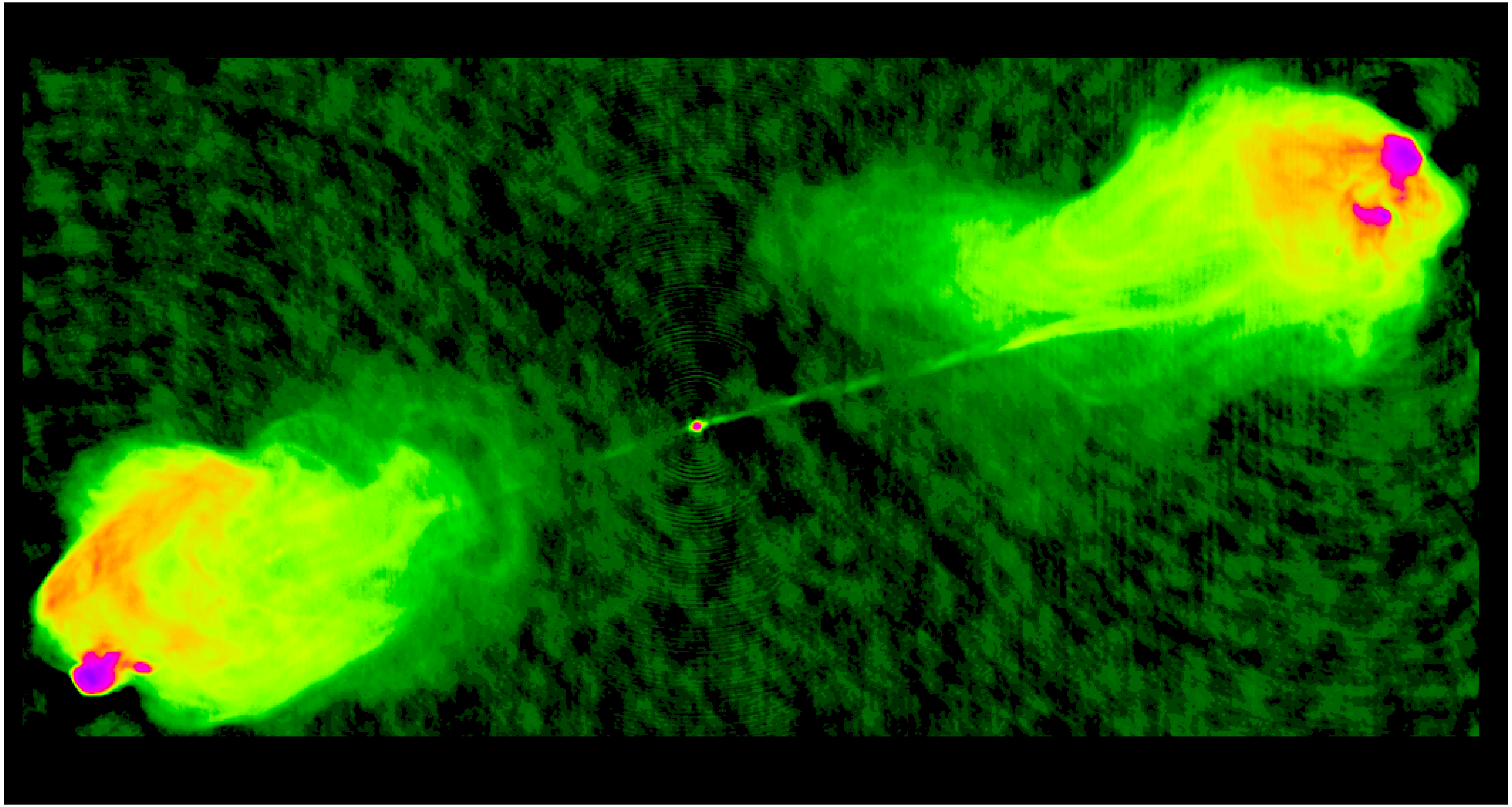
PKS 2155-304: structured jet



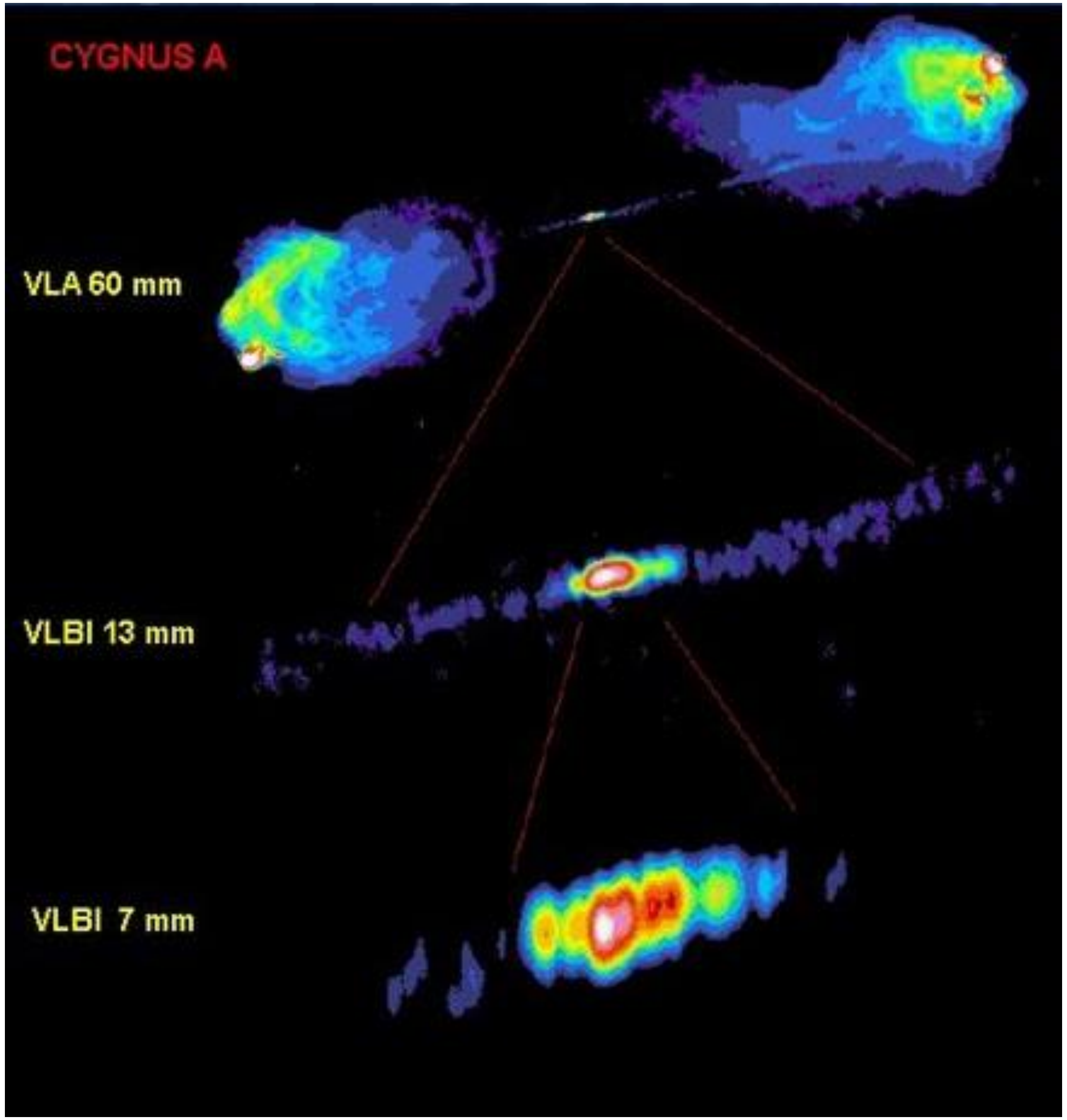
Gaur, Chen* et al. 2017 ApJ

Structured jet
through
Broadband SED: gamma-ray & X-ray

III. Jet energy transportation – Cygnus A



Jet energy transportation

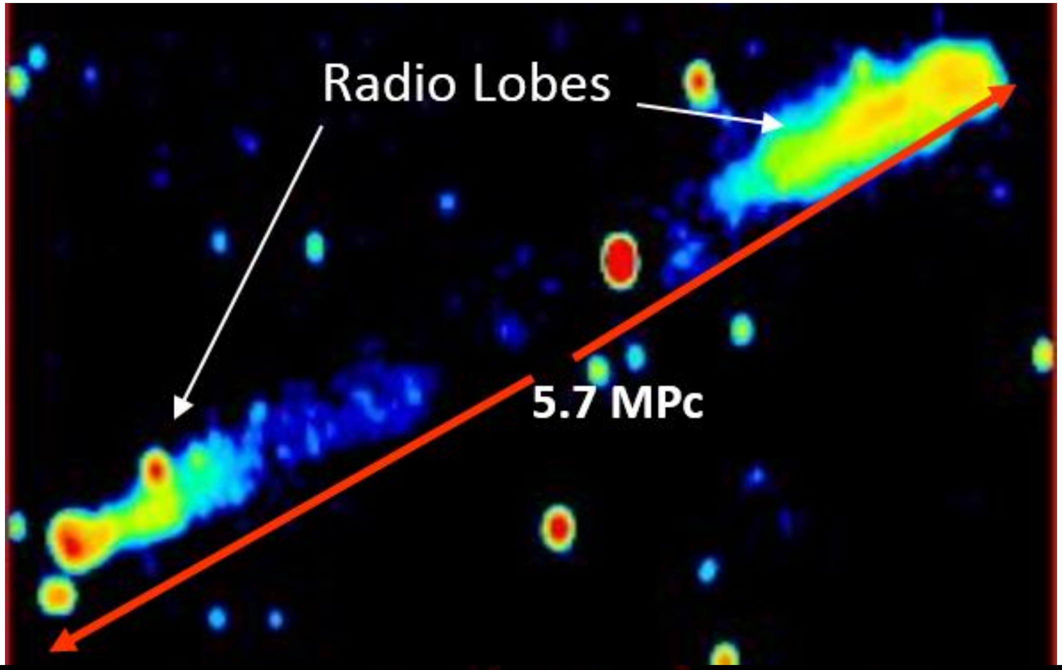


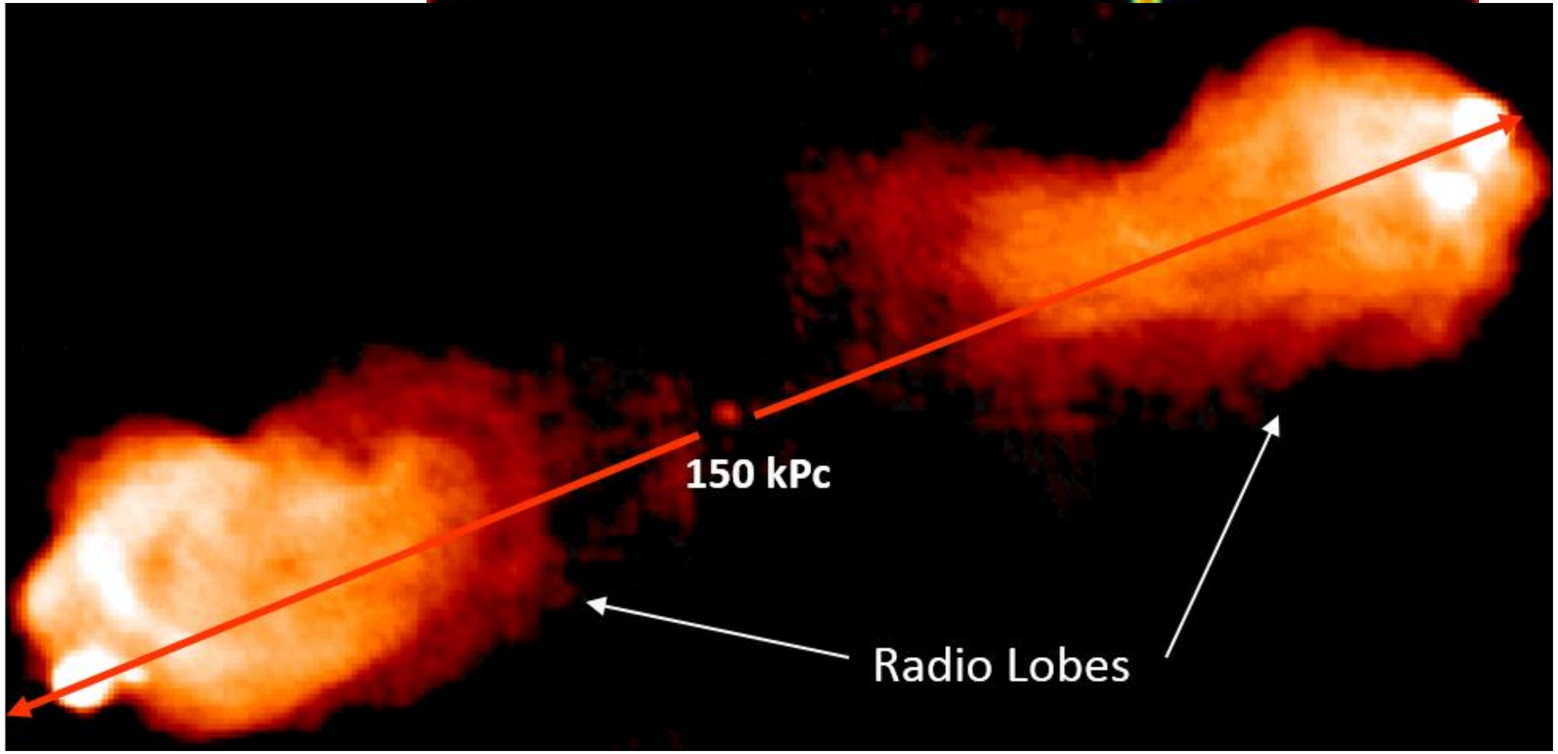
Jet energy transportation

- From core to large scale:

  how much left?

- What determine?

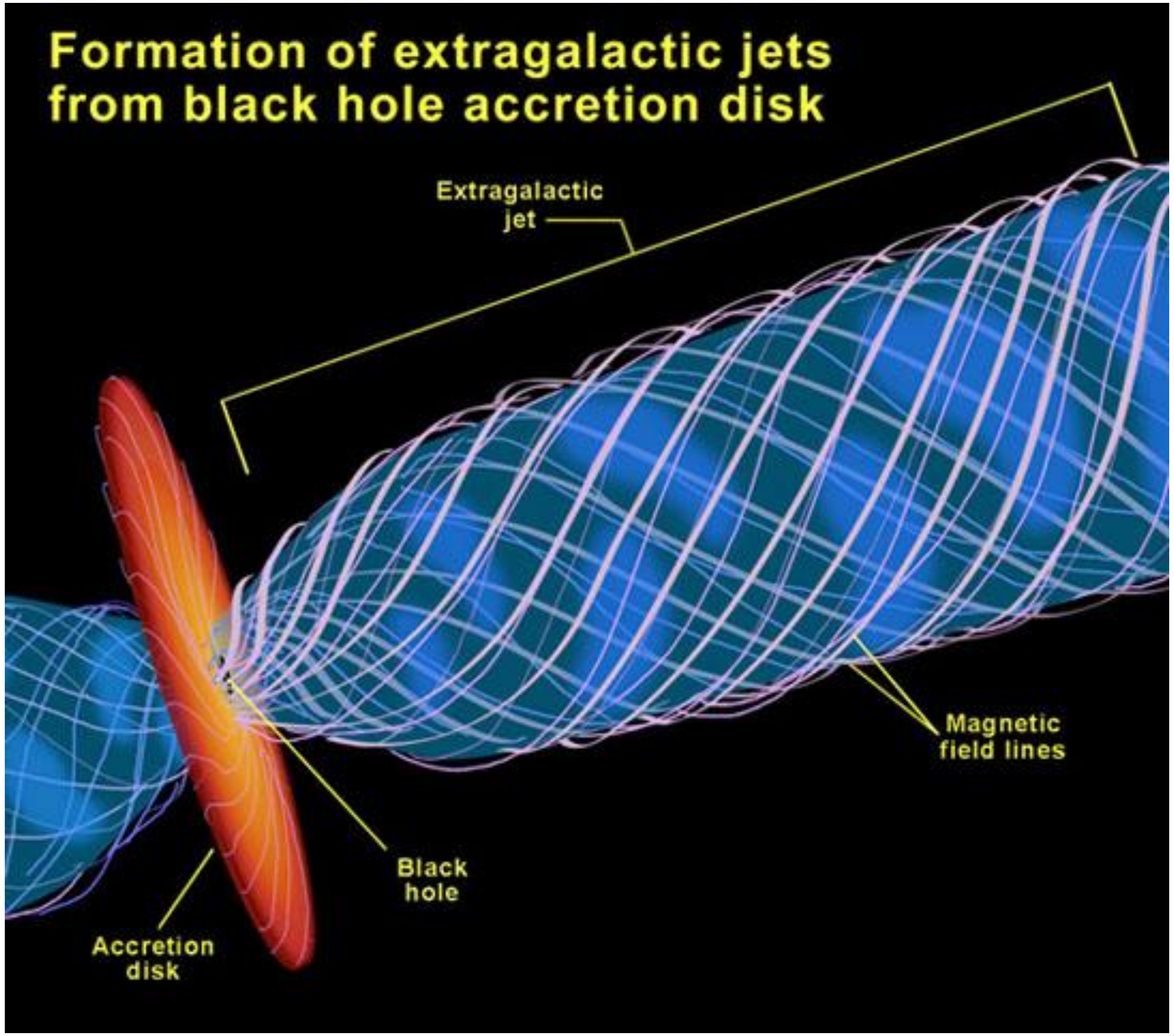




The role of magnetic field

- Jet launching
- Poynting flux
- Energy transportation
- Energy dissipation
- Particle acceleration
- Radiation

- Observation



Jet power: extended region

HCG 62

- X-ray cavity:

  kinetic jet power

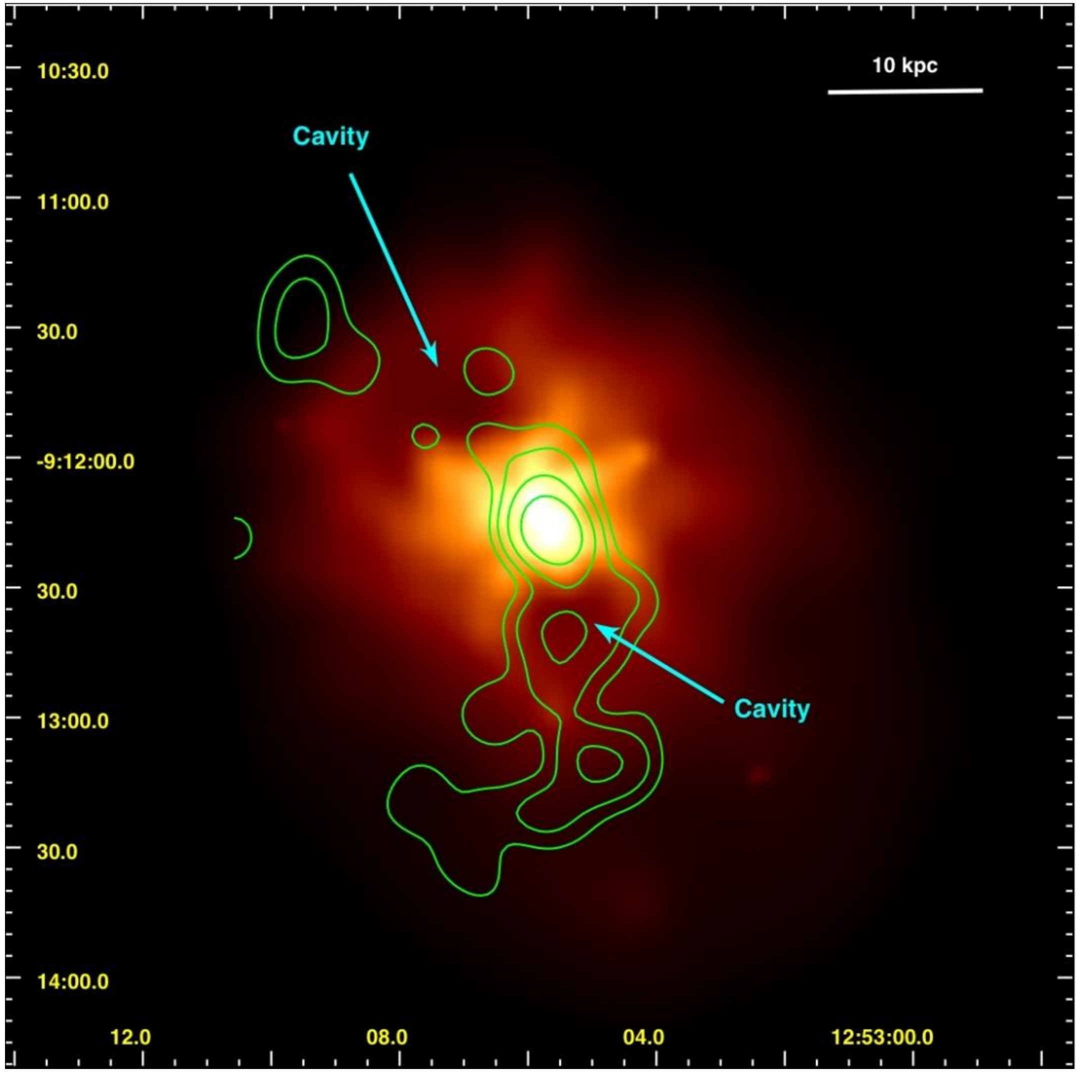
- Extended radio emissions

$$\log L_{\rm kin} = 0.64(\pm 0.09)\,(\log L_{300} - 40) + 43.54(\pm 0.12) \quad ({\rm erg\ s^{-1}}),$$

- Extended jet power

$$P_{jet,ext} = L_{kin}$$

Meyer et al. 2011



Jet energy transportation

- Jet power left

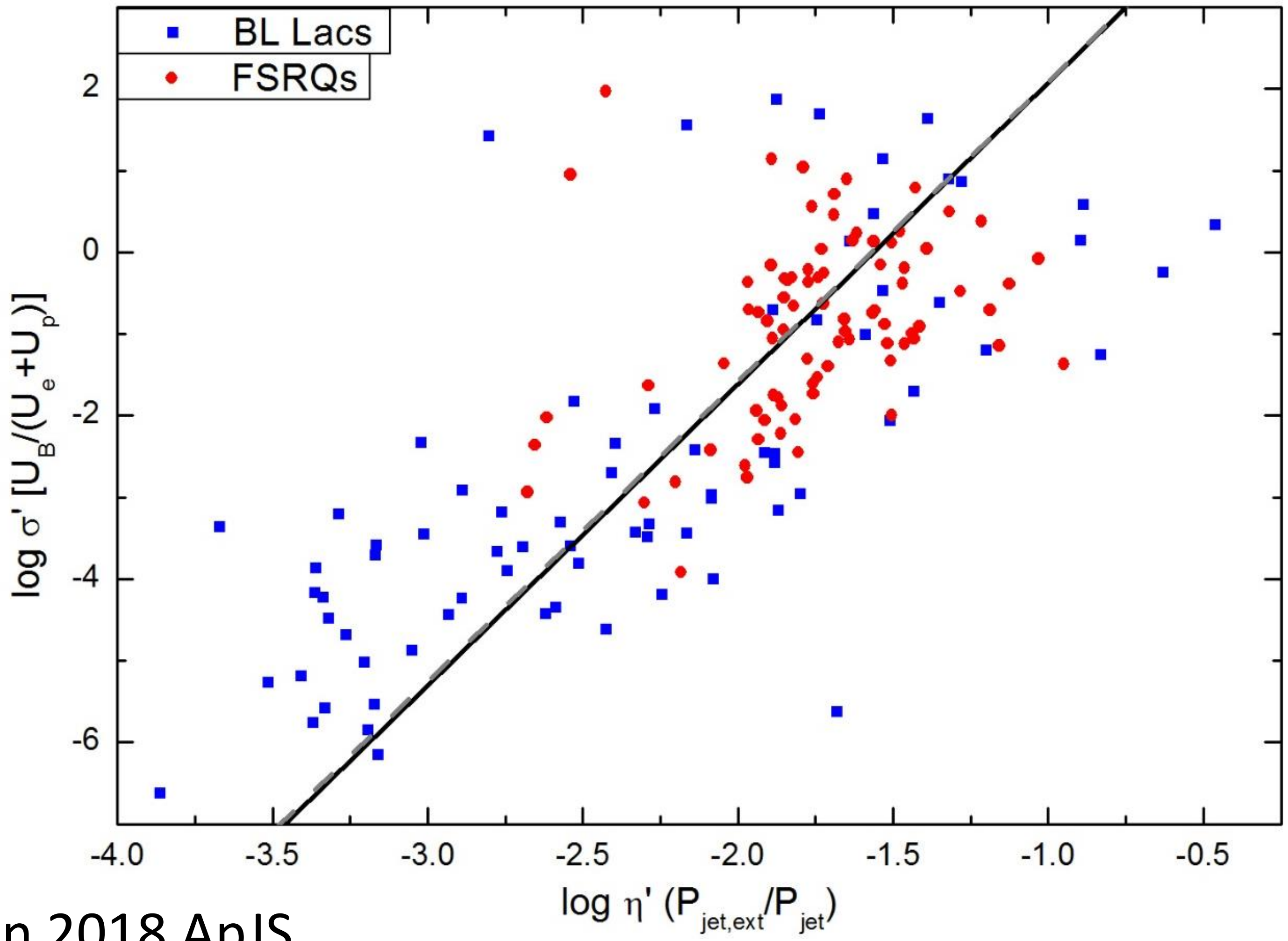
$$\eta' = \frac{P_{jet,ext}}{P_{jet}}$$

- Jet magnetization

$$\sigma' = \frac{U_B}{U_e + U_p}$$

- Chance properbility

$$p = 1.1 \times 10^{-25}$$



Chen 2018 ApJS

Jet energy transportation

- Jet power left

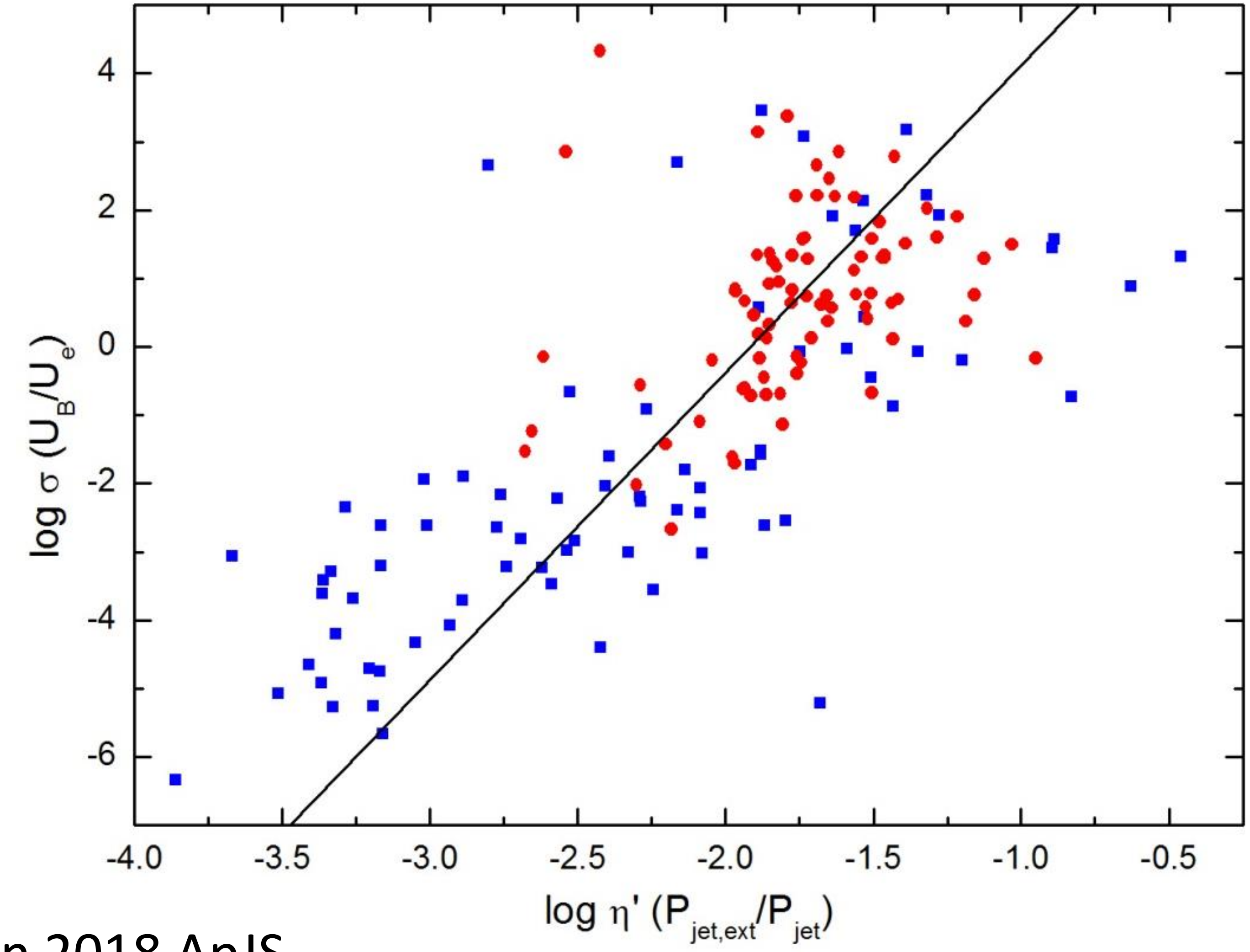
$$\eta' = \frac{P_{jet,ext}}{P_{jet}}$$

- Jet magnetization

$$\sigma = \frac{U_B}{U_e}$$

- Chance properbility

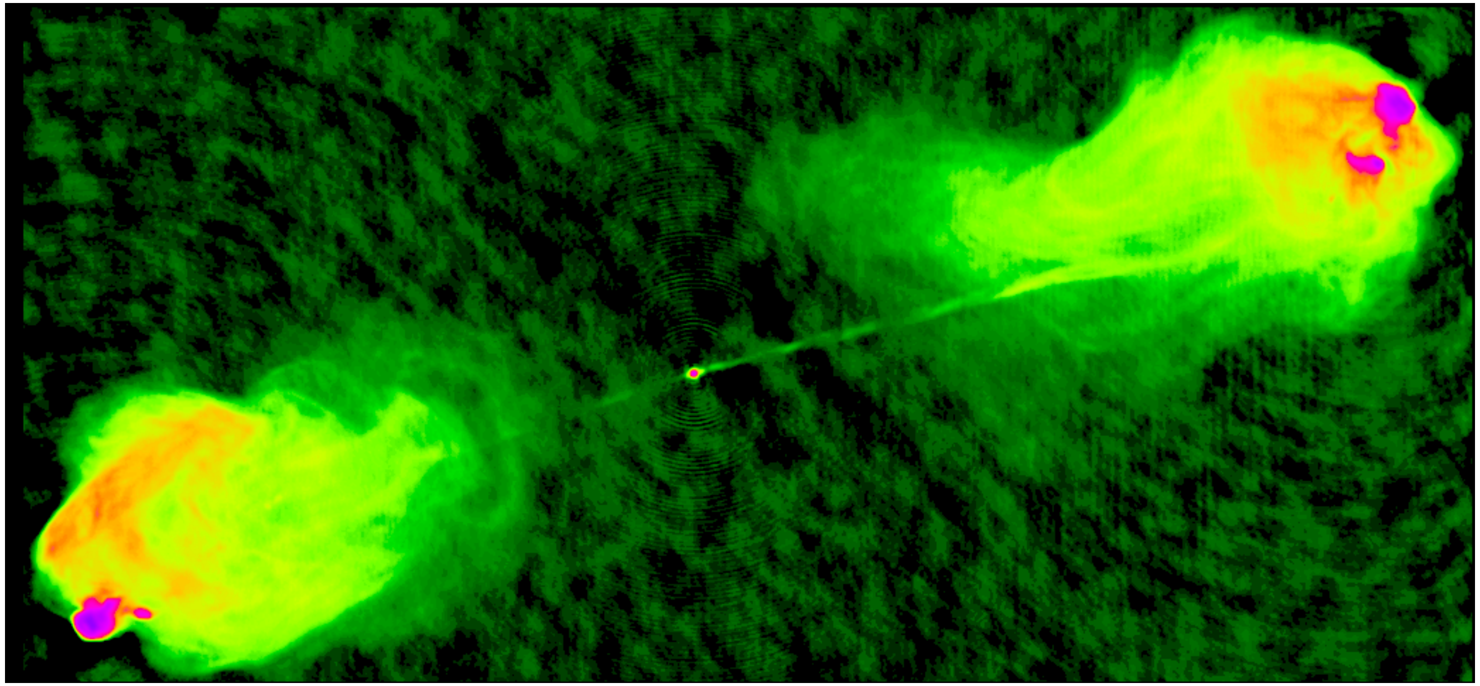
$$p = 4.7 \times 10^{-25}$$



Chen 2018 ApJS

First evidence (Chen 2018 ApJS) for jet energy transportation theory:

high magnetization jet more easily transport energy to large scale than low magnetization jet



Jet parameters of gamma-ray AGNs

Chen 2018 ApJS accepted, arXiv: 1803.05715

- 1392 jets
- 232 disk luminosity
- 159 extended jet power

- All parameters

gamma-ray/broadband SED vs. AGN jet

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Thanks!

gamma-ray/broadband SED vs. AGN jet