

Powers and Magnetization of Blazar Jets

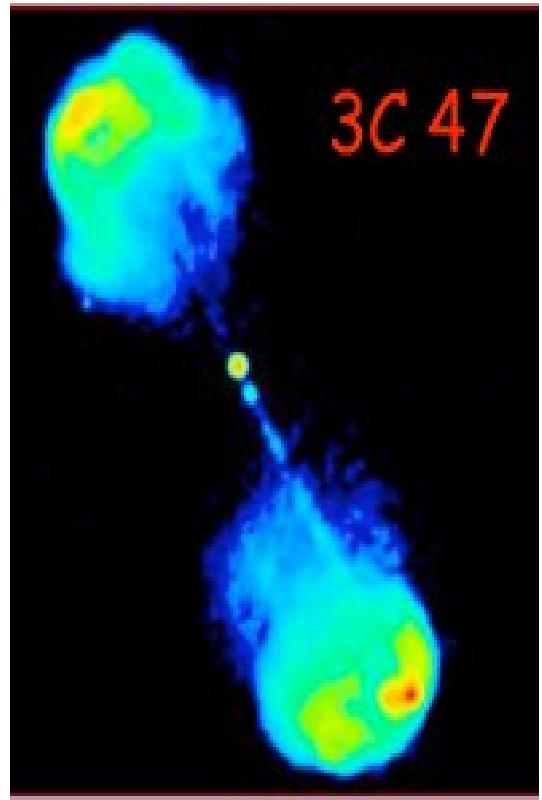
Marek Sikora

Nicolaus Copernicus Astronomical Center
Warsaw

Malaga, 30 May - 03 June 2016

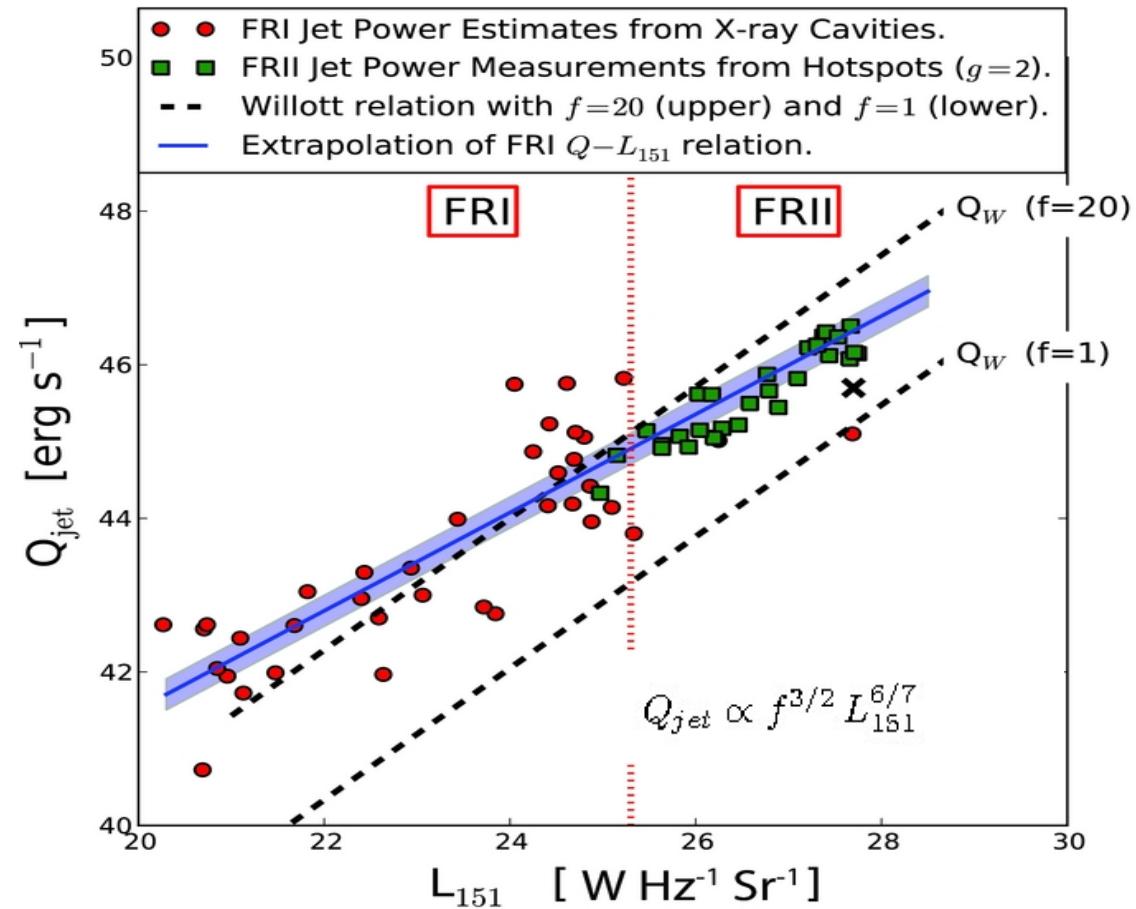
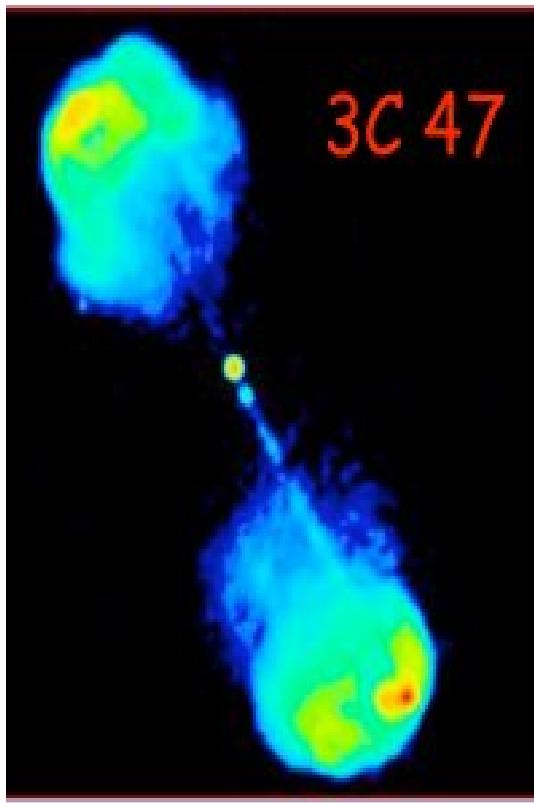
Powers

FRII



Rawlings & Saunders '91

FRII



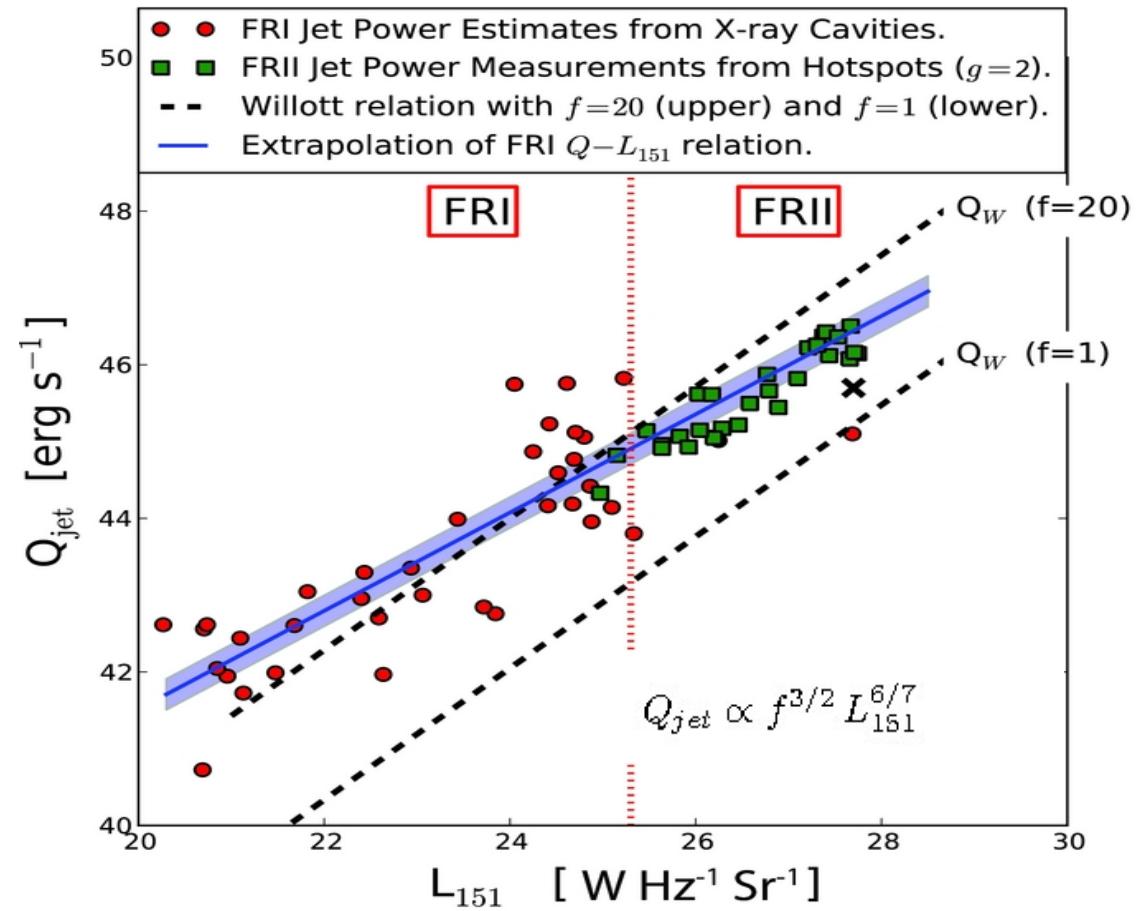
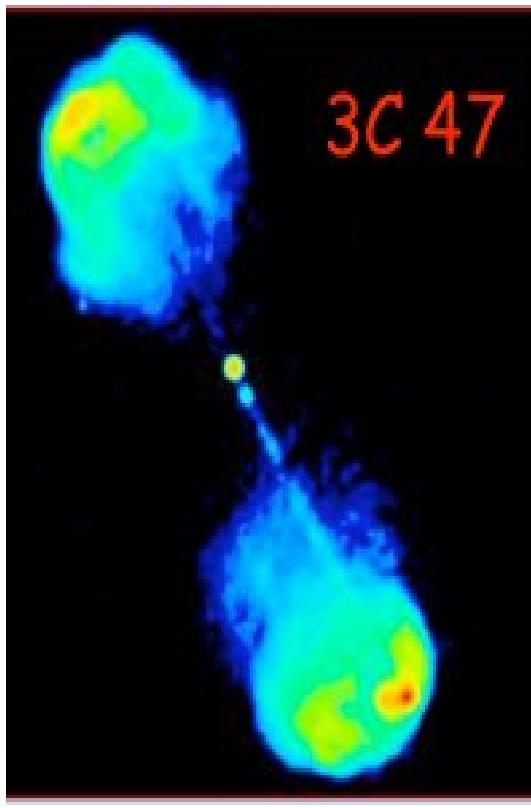
Rawlings & Saunders '91;

Willott et al. '99 (radio lobes);

Cavagnolo et al. '10 (X-ray cavities);

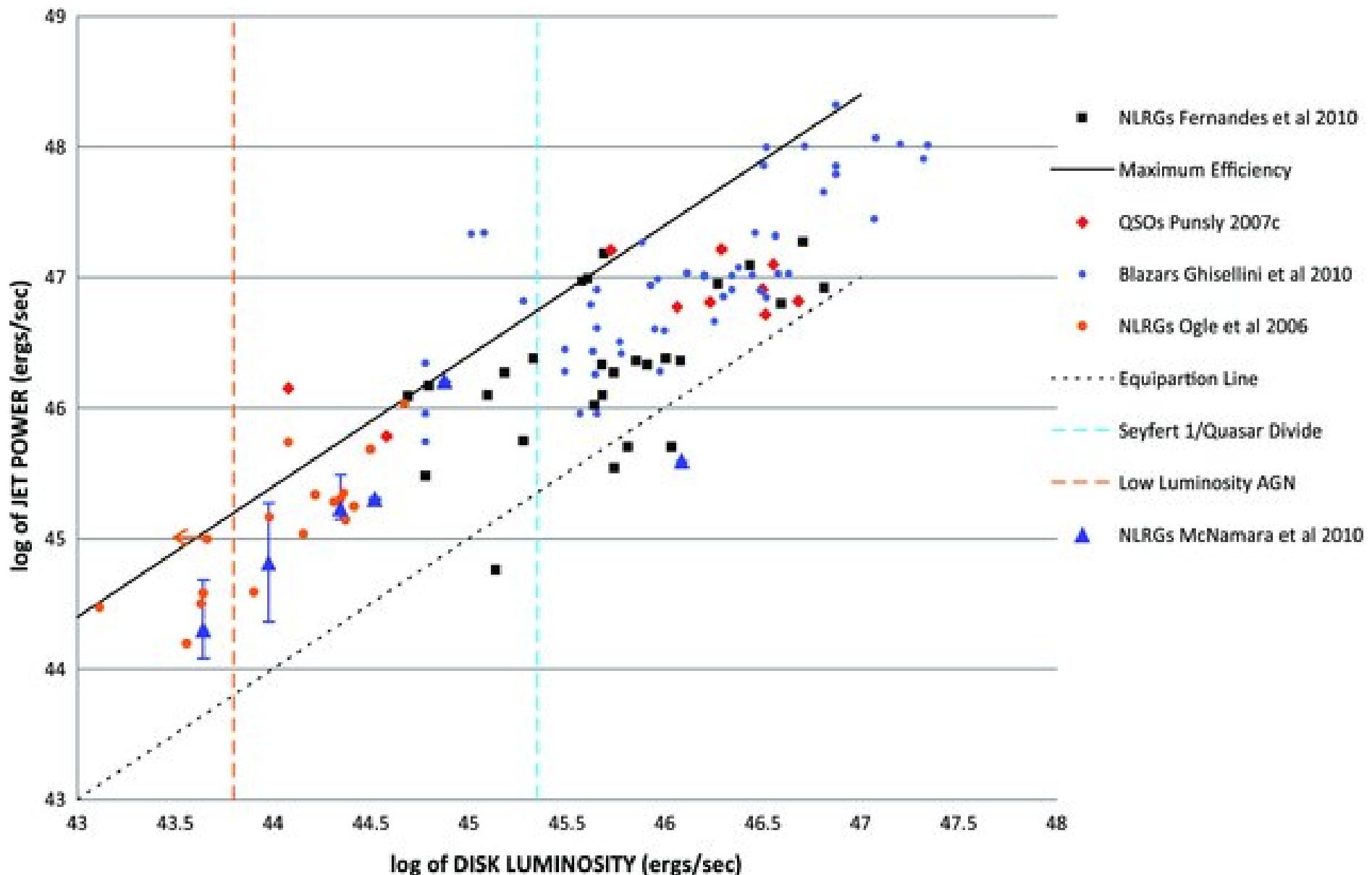
Godfrey & Shabala '13 (hot spots)

Godfrey & Shabala 2013

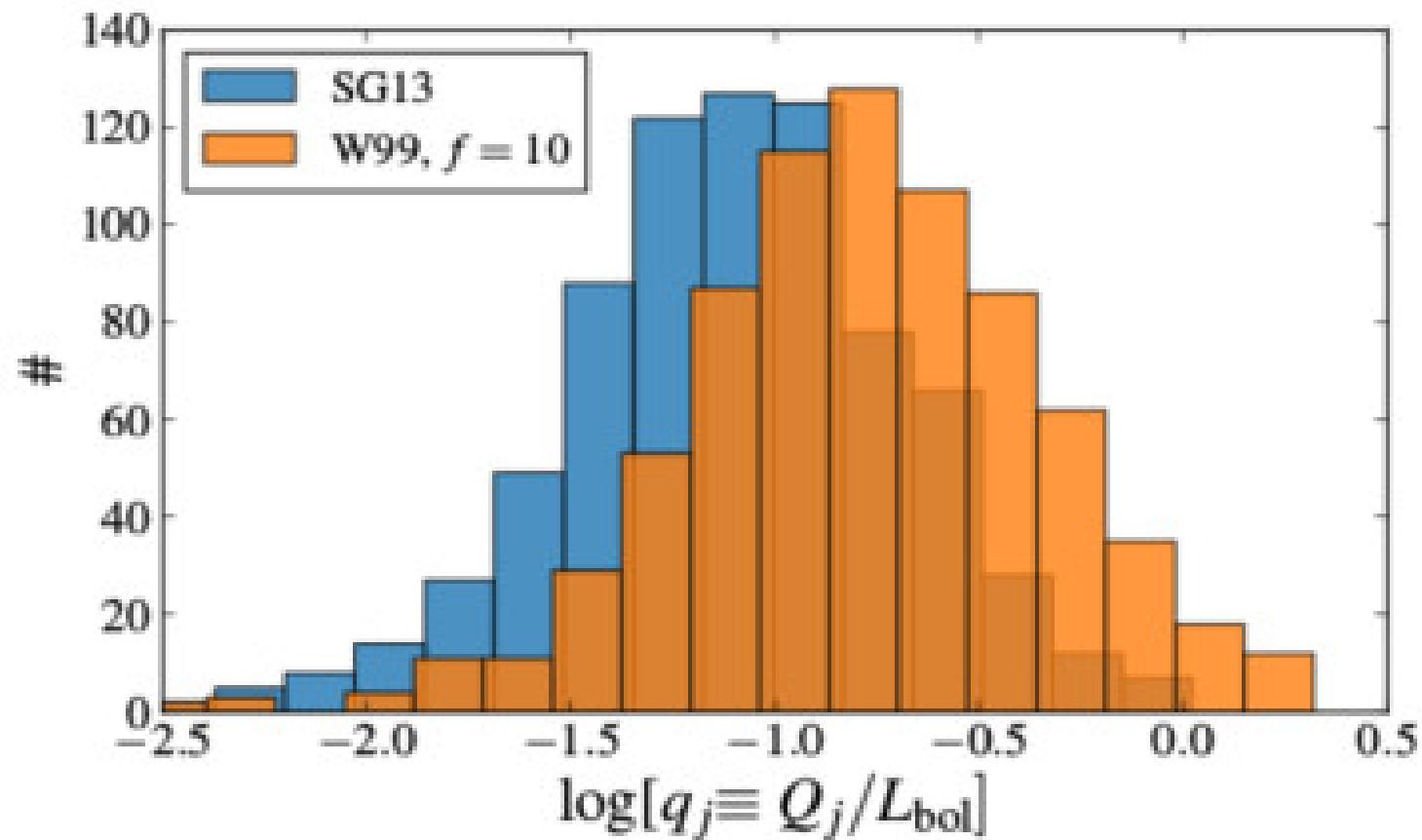


Rawlings & Saunders '91;
Willott et al. '99 (radio lobes);
Cavagnolo et al. '10 (X-ray cavities);
Godfrey & Shabala '13 (hot spots)
Ghisellini et al. '10 (blazar spectra);
Zamaninasabe et al. '14, and
Zdziarski et al. '15 (core-shifts)

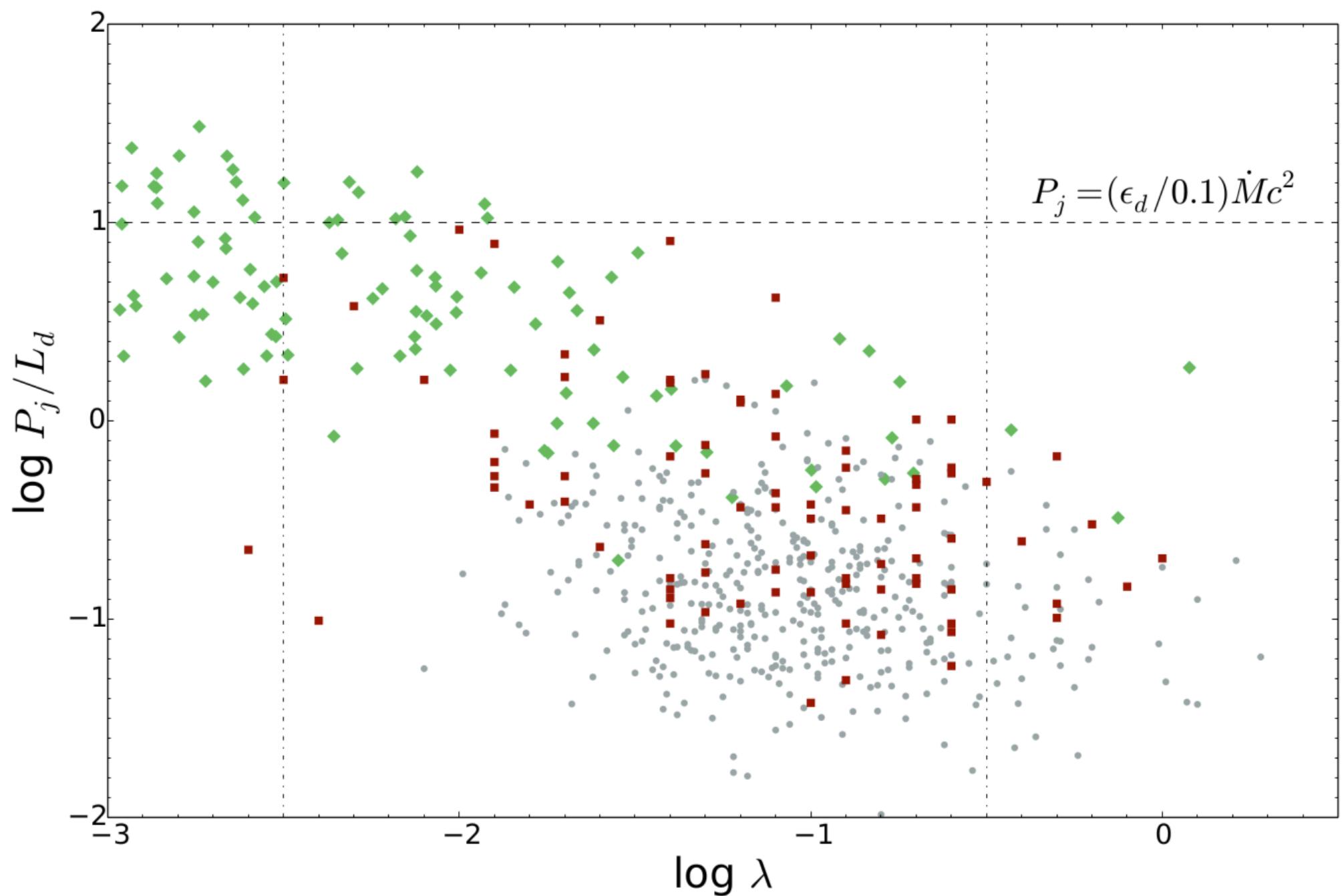
Godfrey & Shabala 2013



Punsly 2011



van Velzen & Falcke 2013

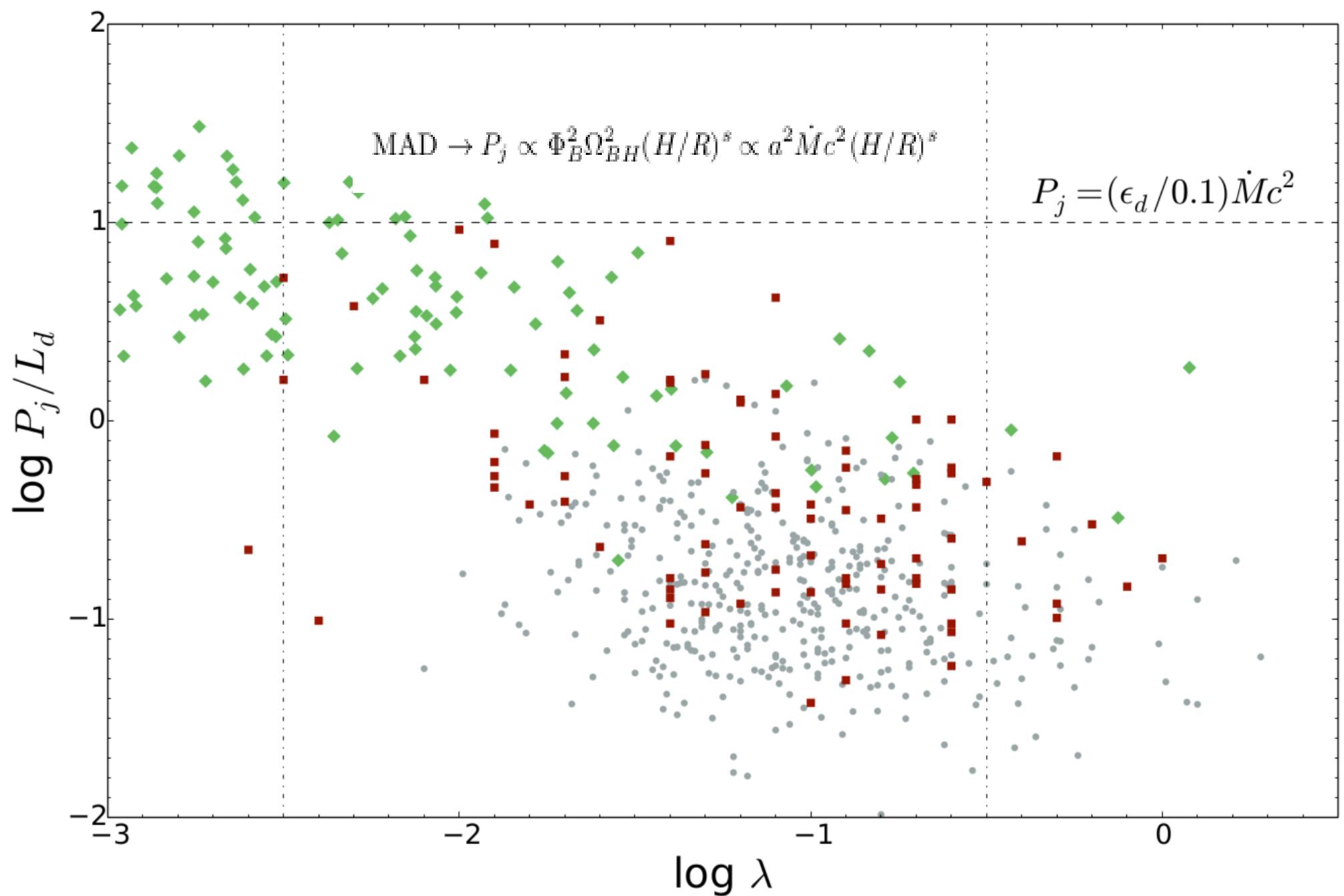


green diamonds – NLRG (Sikora et al. 2013)

red squares – BLRG + RLQ (Sikora et al. 2007)

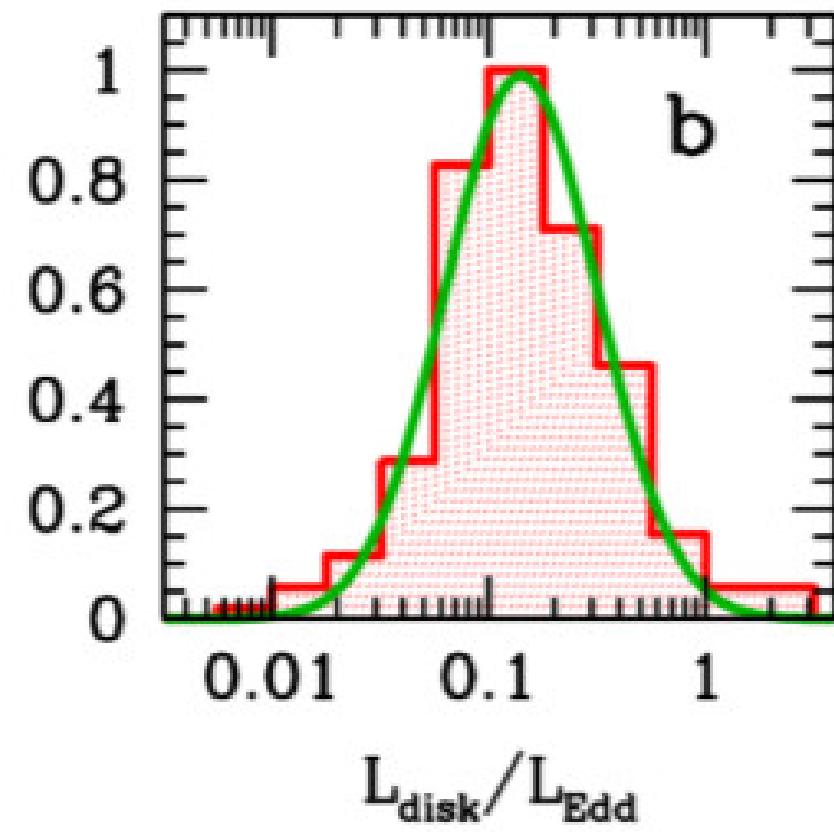
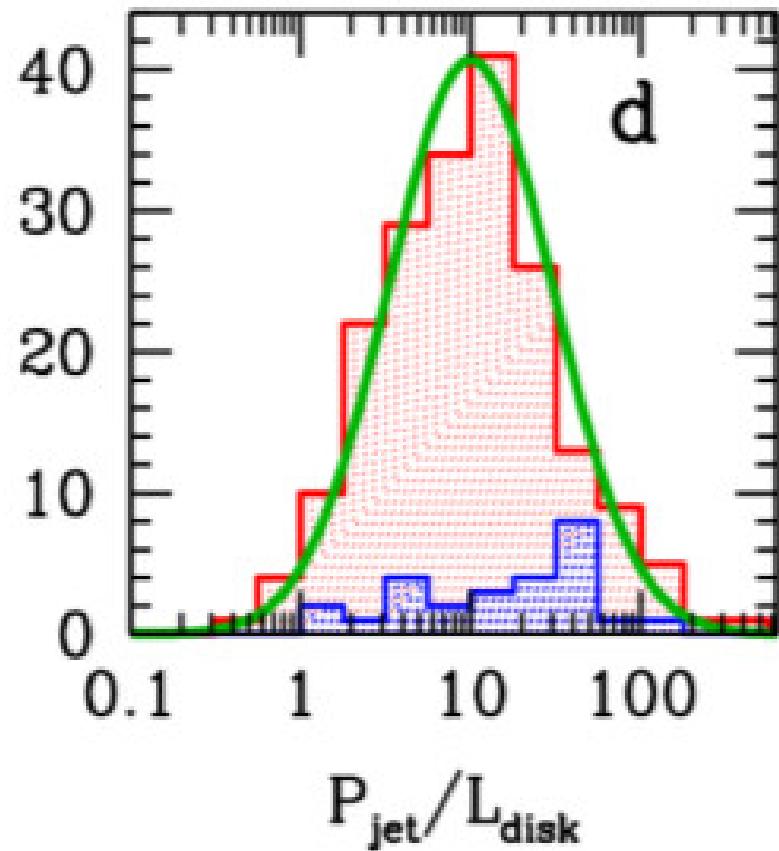
grey dots – FRII quasars (van Velzen & Falcke 2013)

Rusinek et al.
(in preparation)

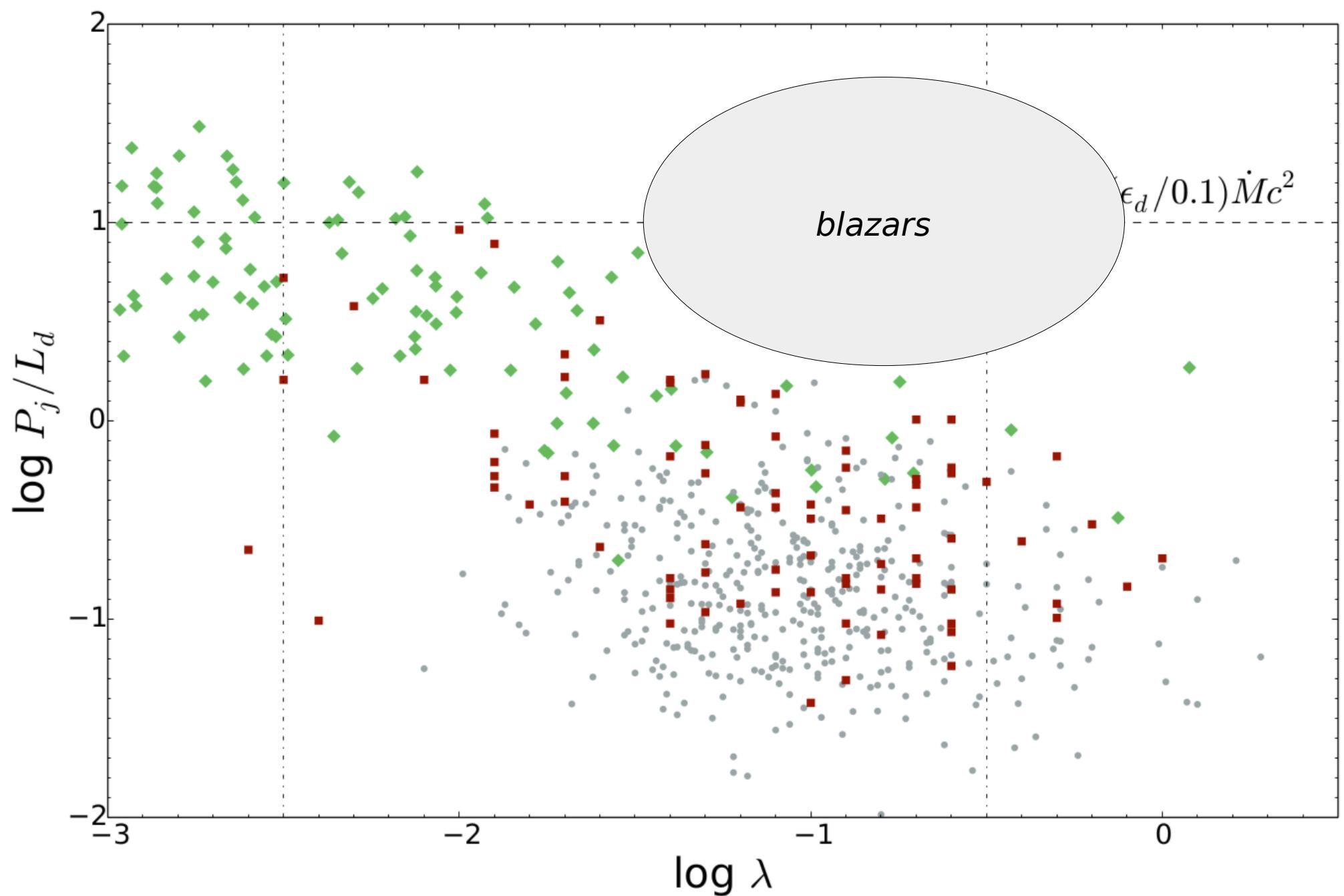


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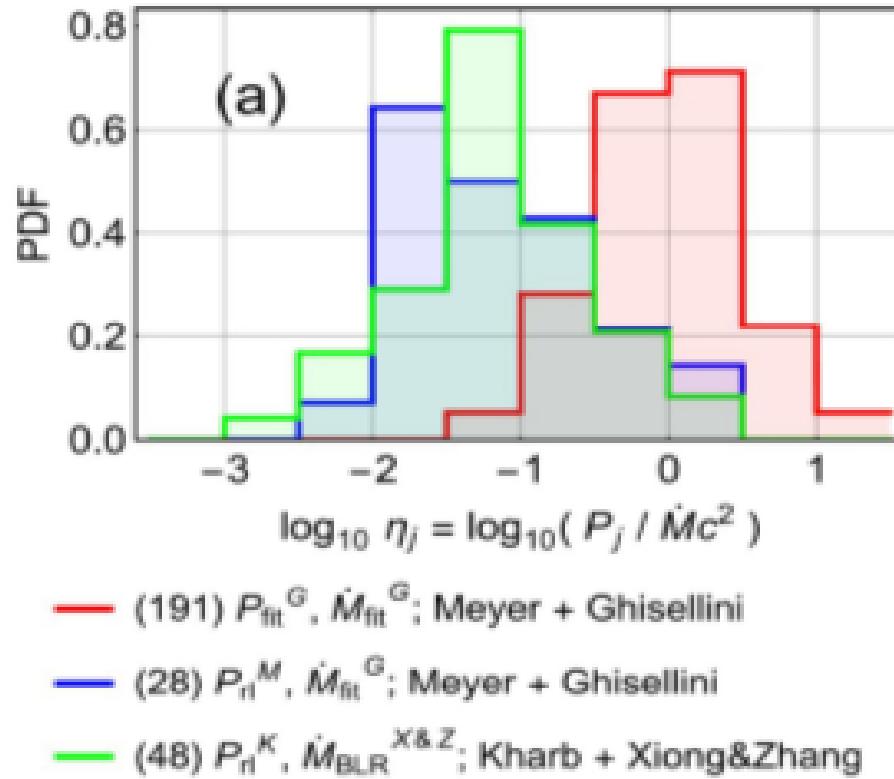
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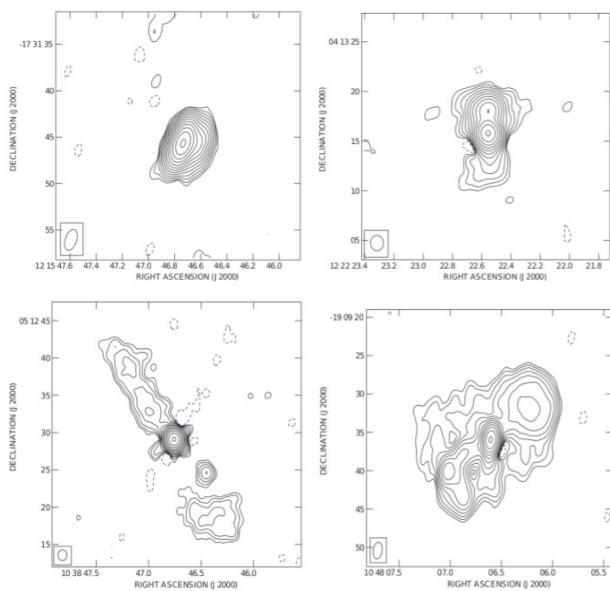
Ghisellini et al. 2014



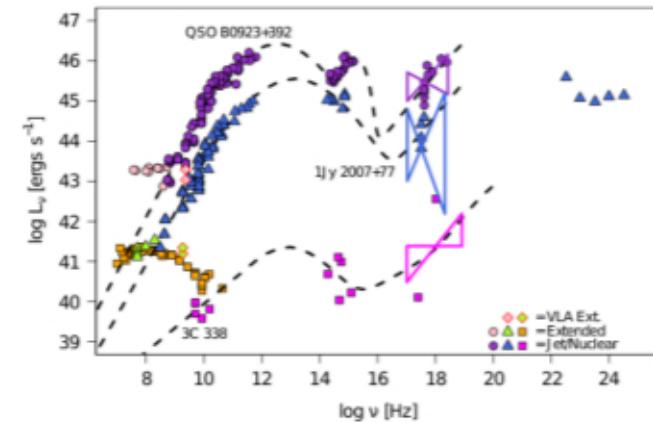
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Pjanka et al. (in preparation)



Kharb et al. 2010



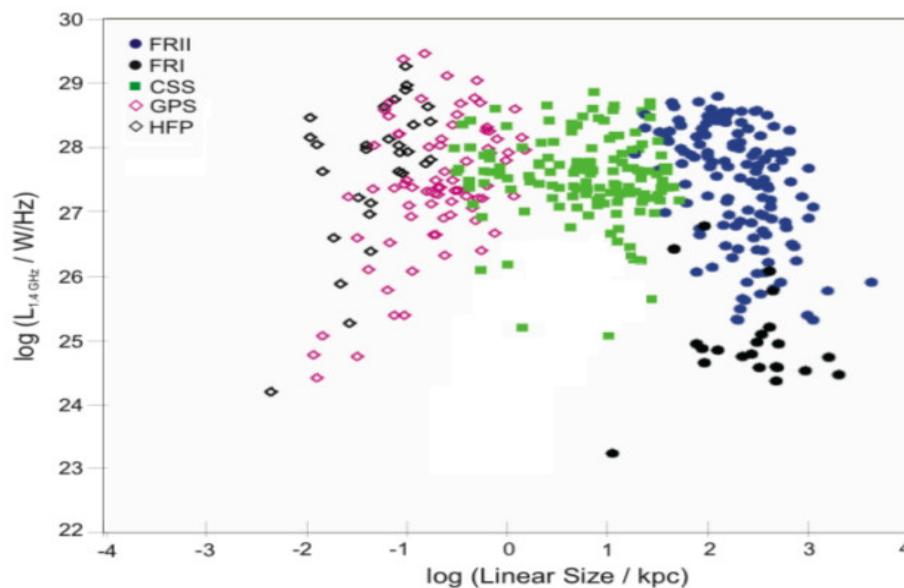
Meyer et al. 2011

Possible reasons for discrepancy between $P(\text{fit})$ and $P(\text{rl})$:

- jet energy losses during propagation (e.g. by the work done against the external medium by variable reconfinement shocks);
- overestimation of $P(\text{fit})$ (e.g. by assuming one zone model and zero pair content);
- underestimation of $P(\text{rl})$ (e.g. by assuming that jet production is steady);
- a significant fraction of blazars can be hosted by CSS, GPS and HFP (then the methods of spectral decomposition and core subtraction may lead to underestimation of the lobe flux).

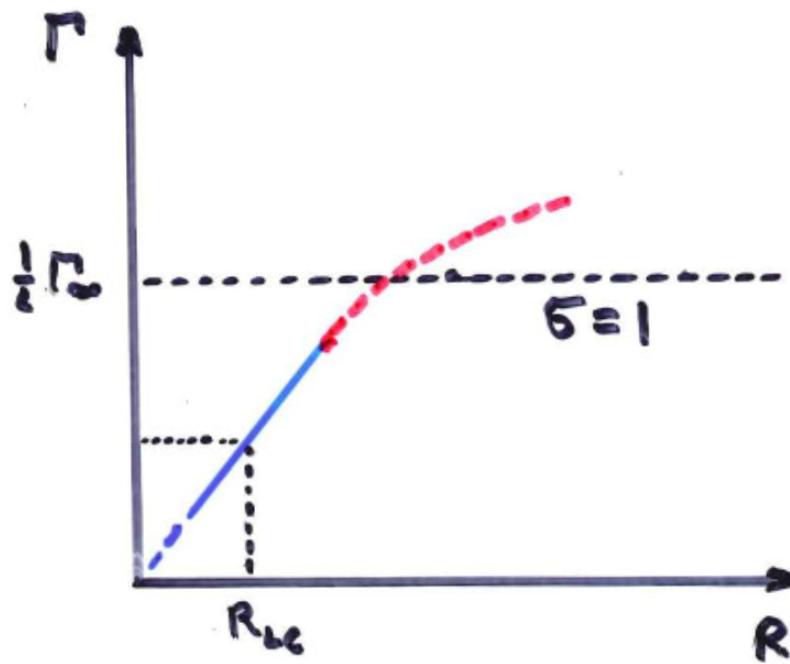
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*Kunert-Bajraszewska 2016
(An & Baan 2012)*

Magnetization

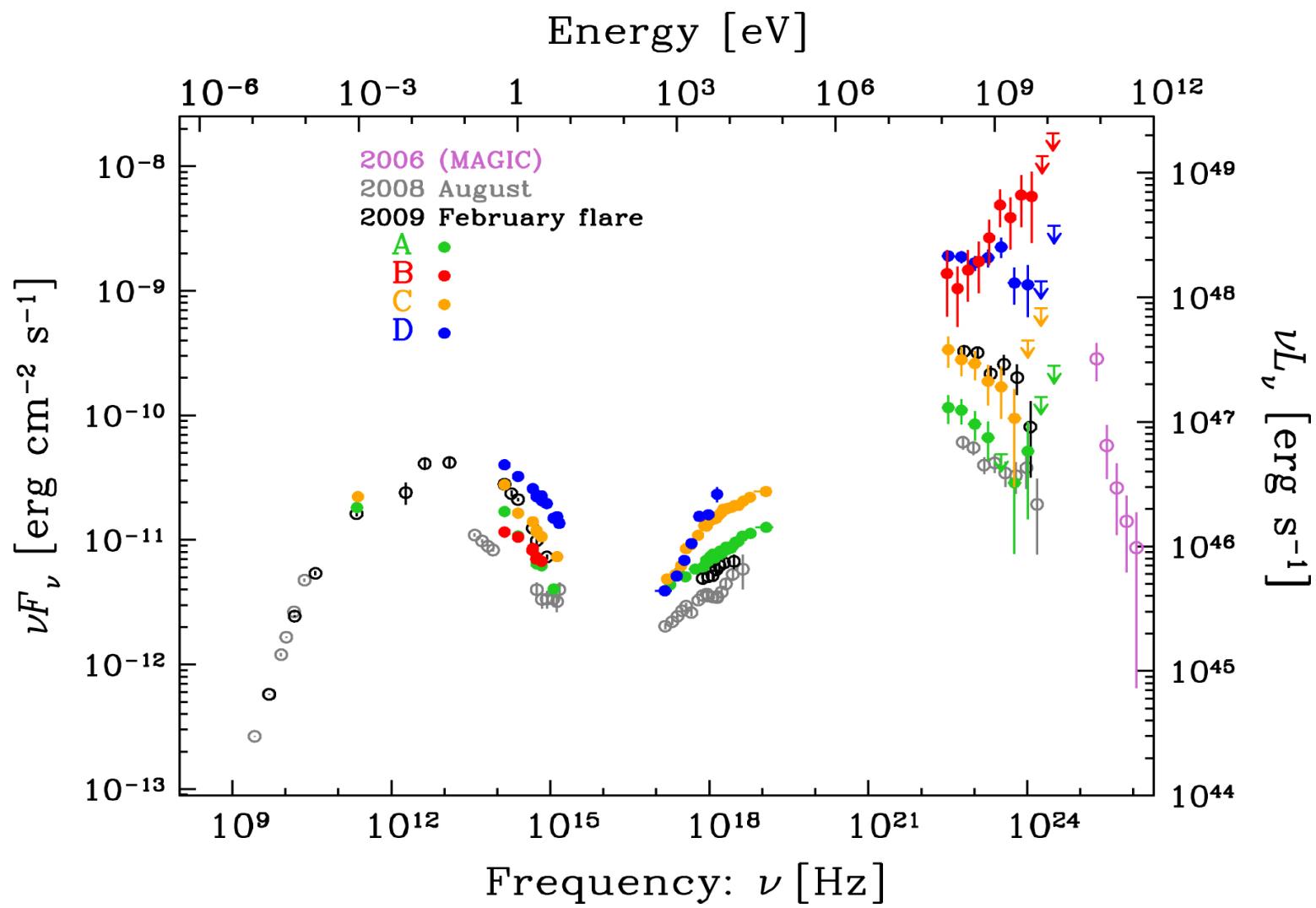


$$\delta \equiv \frac{P_B}{P_K}$$

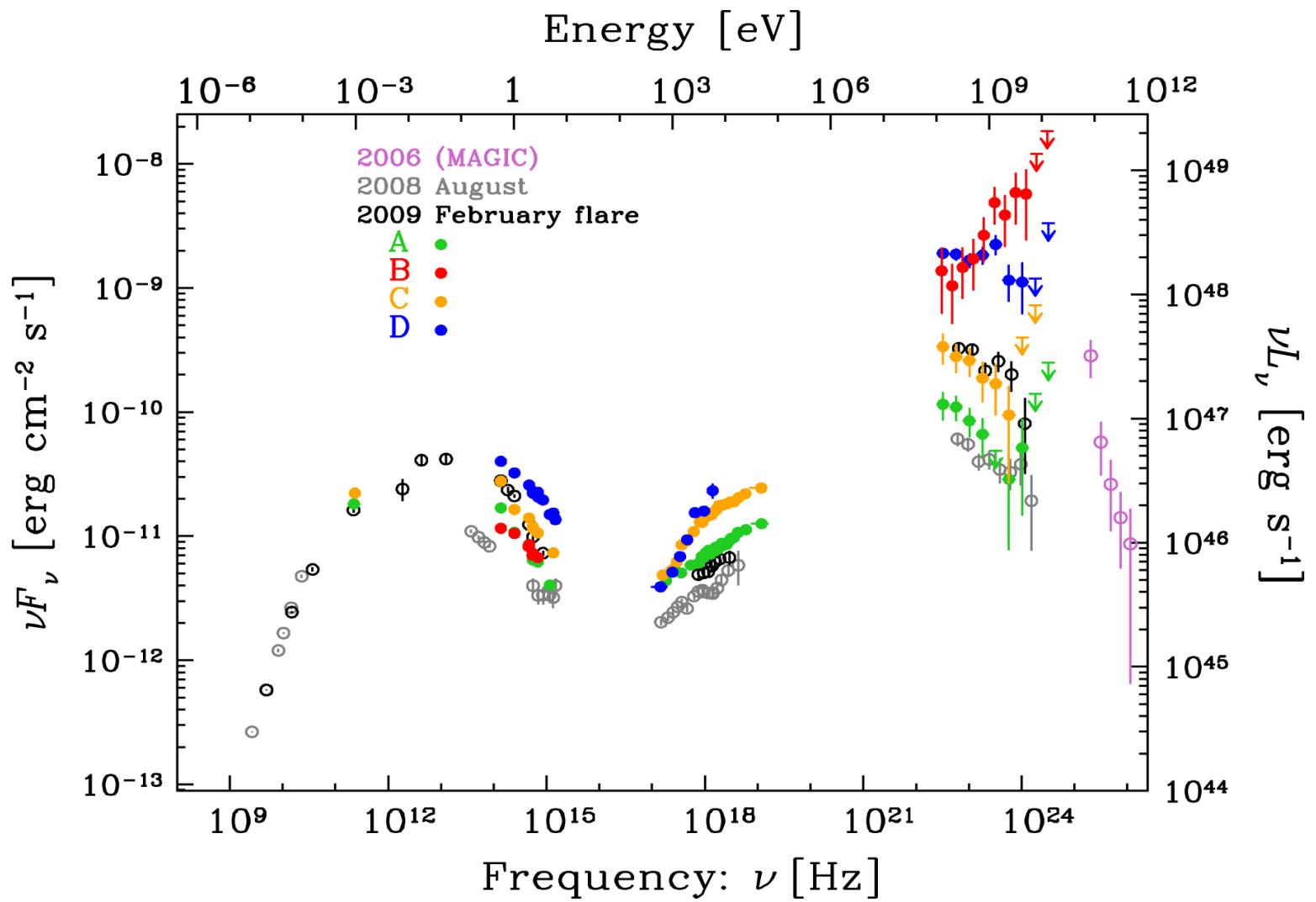
$$P_0 = \frac{P_J}{\dot{m}_c c^2}$$

$$P_J = P_B + P_K$$

Tchekhovskoy et al. '09;
Lyubarsky '10;
Komissarov '11

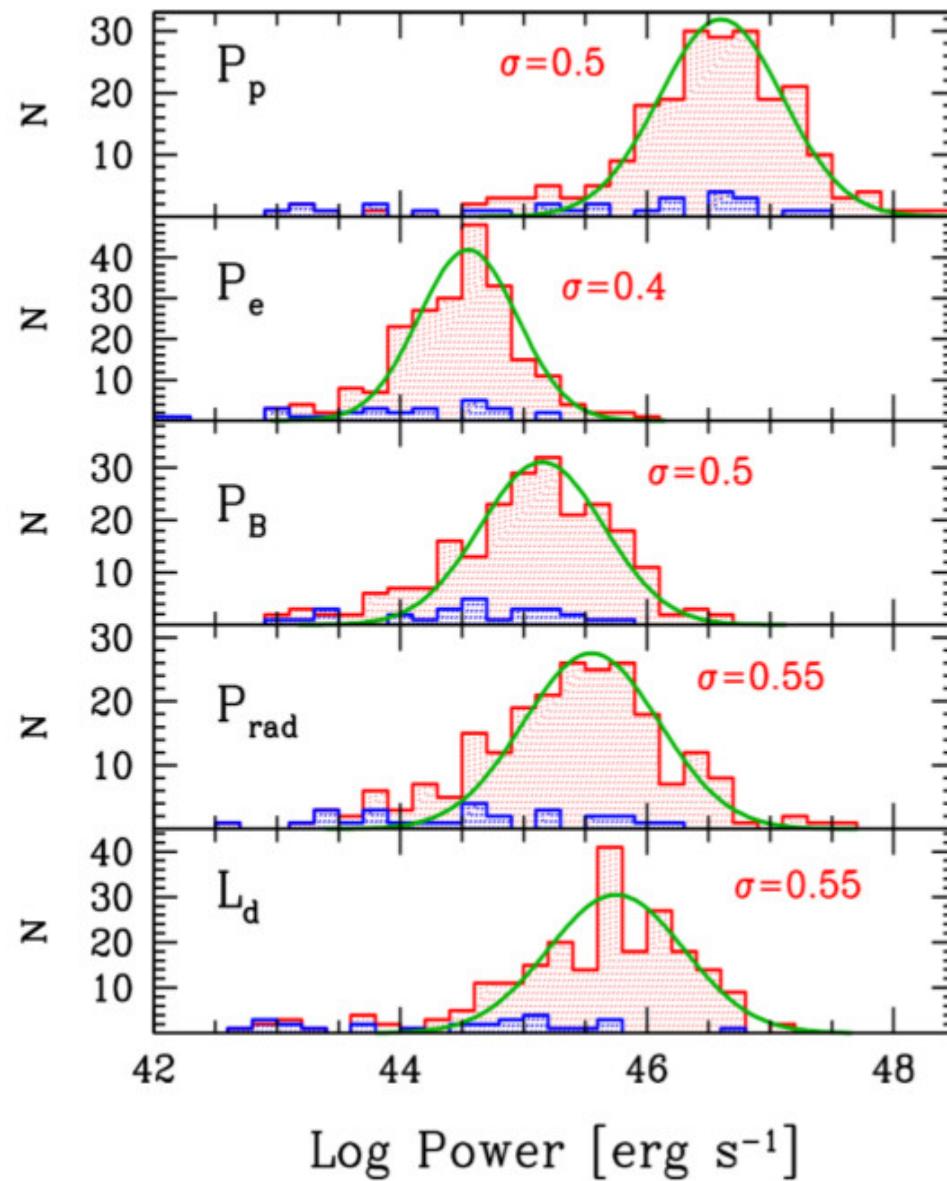


Hayashida et al. '15



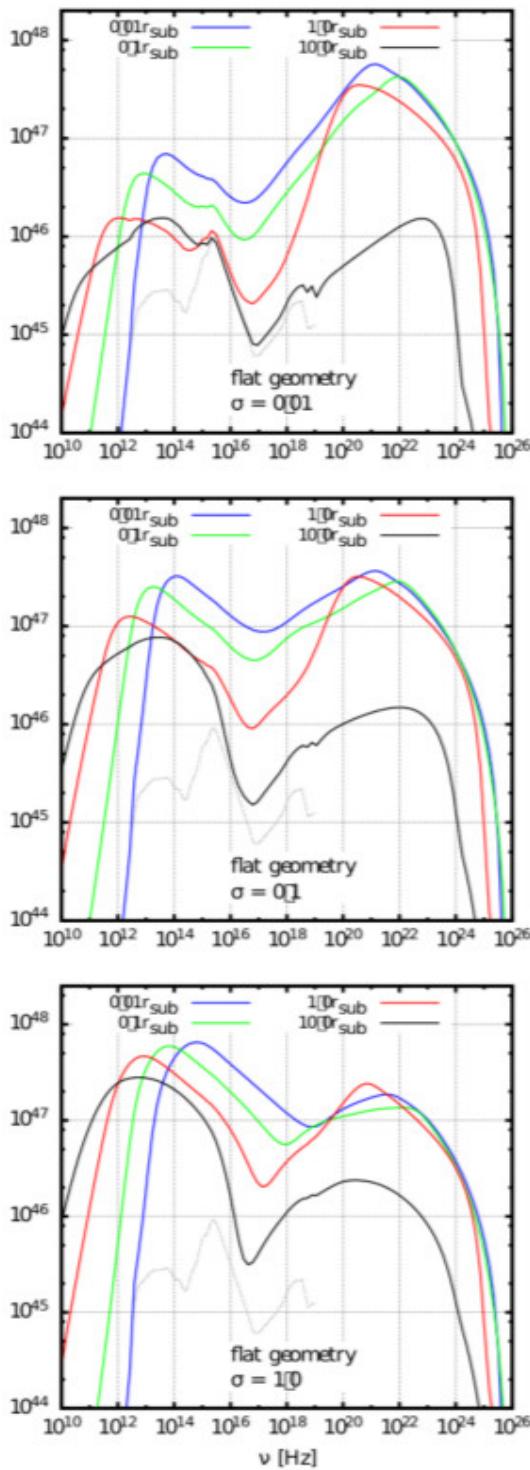
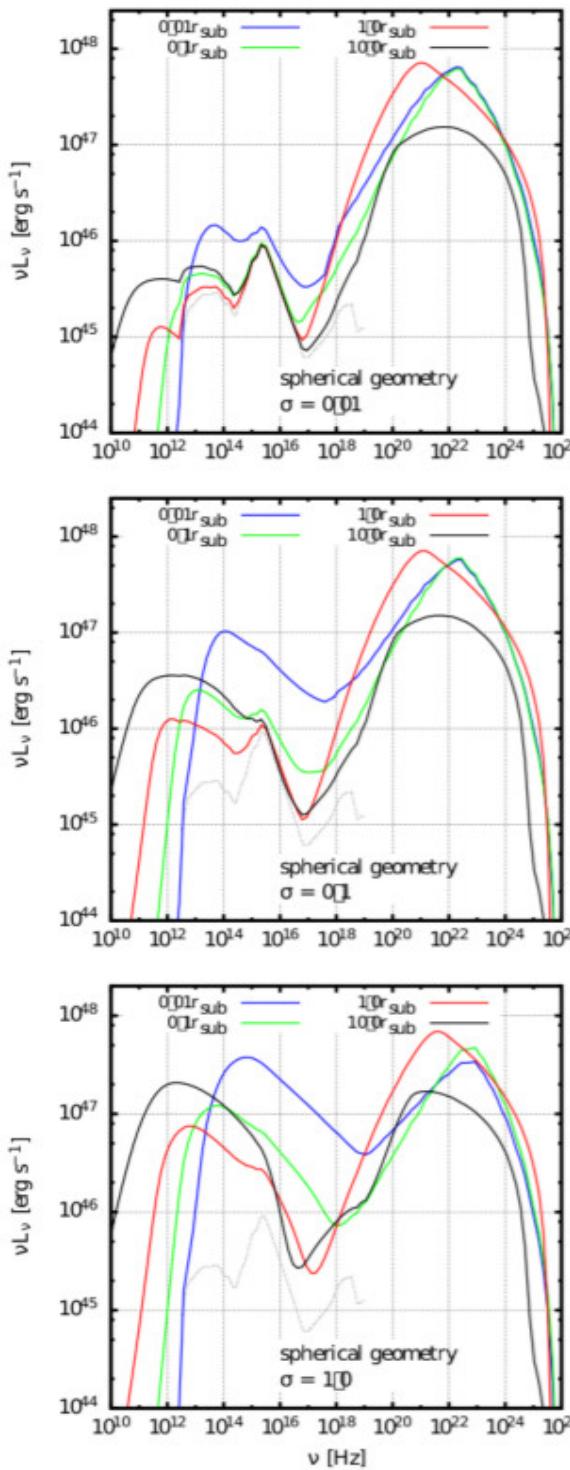
Hayashida et al. '15

$$CD \equiv \frac{L_{\gamma,peak}}{L_{syn,peak}} \sim \frac{1+\sigma}{\sigma} \frac{1}{\eta_j} (\zeta \Gamma^2)$$



$$\sigma \simeq \frac{P_B}{P_p} \simeq 0.04$$

Ghisellini et al. '14



$$L_d = 0.3L_{Edd}, \quad \epsilon_d = 0.1,$$

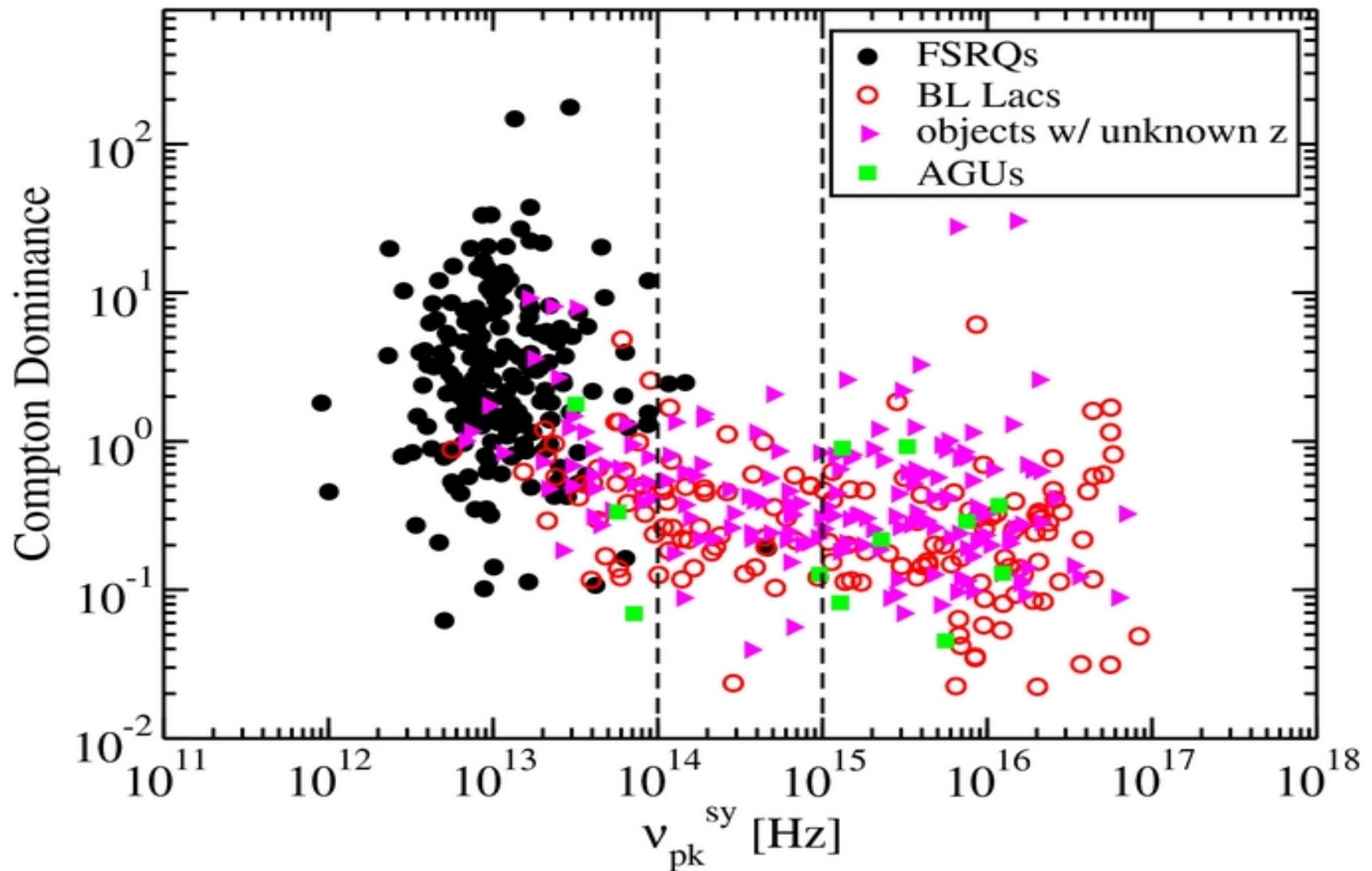
$$M_{BH} = 10^9 M_\odot, \quad \eta_j = 1,$$

$$\bar{\gamma}_{inj} = \frac{\eta_e \eta_{diss} P_j}{m_e c^2 N_e \Gamma},$$

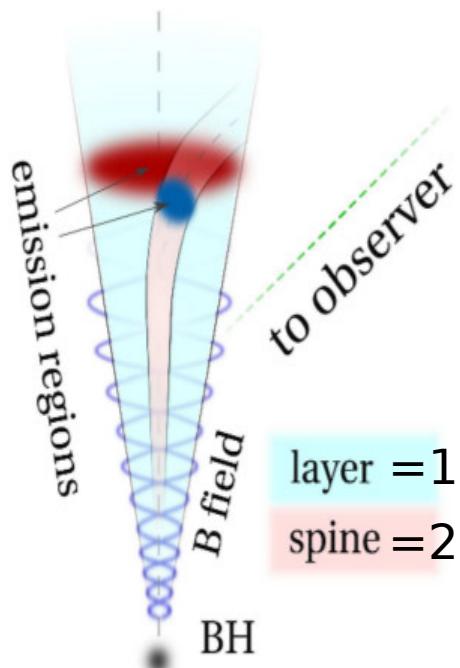
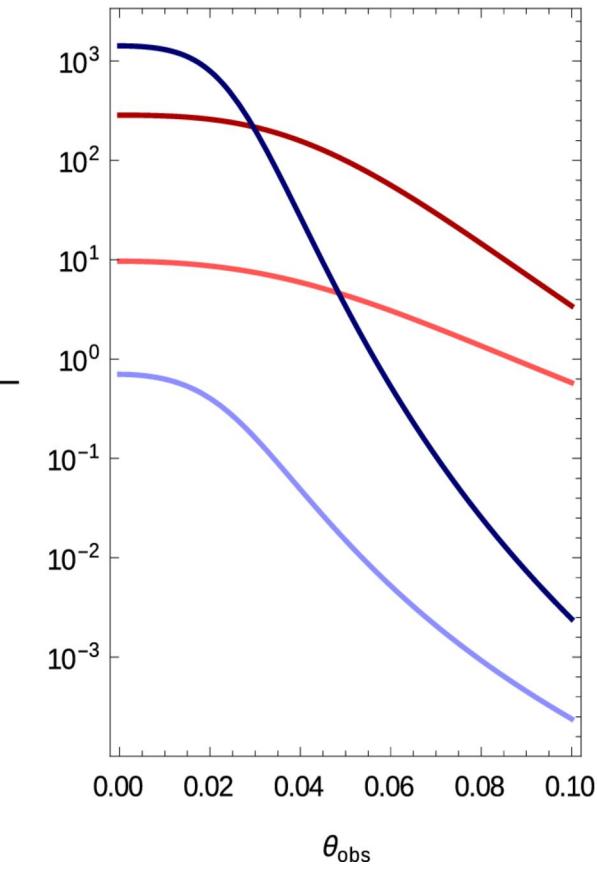
$$\eta_e = 0.5, \quad \eta_{diss} = 0.3,$$

$$\Gamma = 15, \quad n_e = n_p$$

$$p_1 = -1.0, \quad p_2 = 2.5$$



*Finke 2013 (see also Linford et al. '11;
Hovatta et al. '14; Lister et al. '15)*



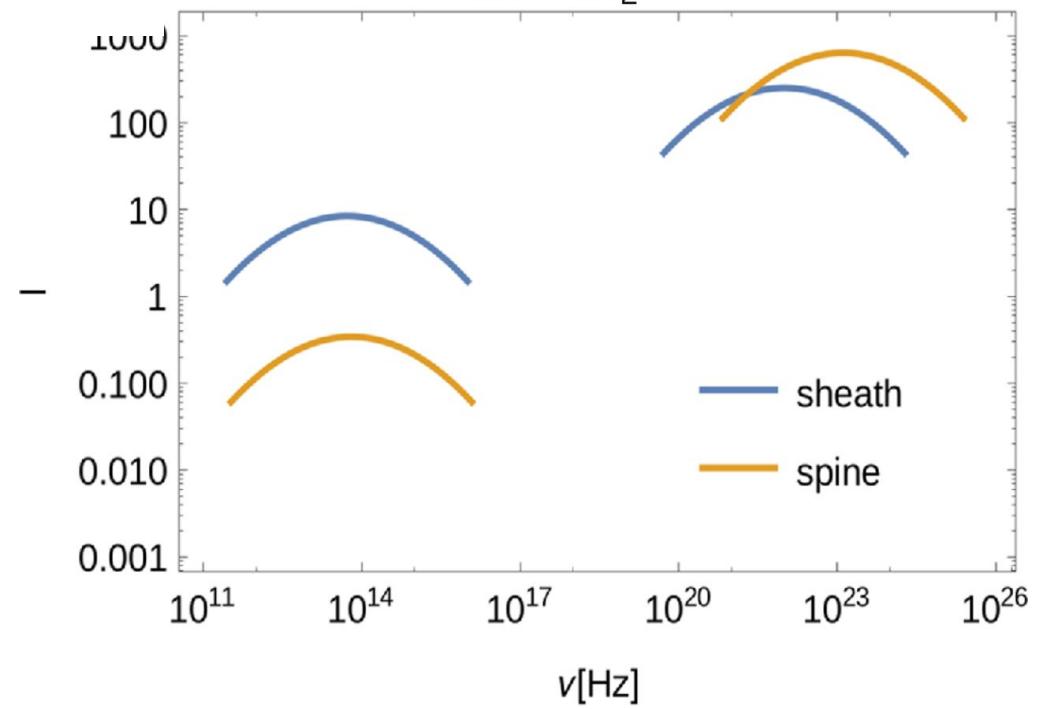
$$P_j \equiv P_{j,1} + P_{j,2} = L_d, \quad \partial P_j / \partial \Omega = \text{const},$$

$$P_{j,1} = P_{j,2}, \quad \theta_{j,2} = 1/\Gamma_2, \quad \Gamma_1 = 12, \quad \Gamma_2 = 48,$$

$$\eta_{diss} = \frac{\sigma_0 - \sigma}{1 + \sigma_0}, \quad \sigma_0 = 1, \quad \sigma = 0.25,$$

$$\bar{\gamma}_{inj} = \eta_e (\sigma_0 - \sigma) \frac{n_p m_p}{n_e m_e}$$

$$\theta_{\text{obs}} = 1/\Gamma_2$$



Sikora, Rutkowski & Begelman 2016

CONCLUSIONS

Studies of gamma-ray luminous blazars indicate that:

Jet powers in some quasars are comparable to accretion powers.

(Such powerful jets can be provided by the Blandford-Znajek mechanism involving rapidly rotating BHs immersed in strong magnetic fields confined by MADs.)

Conversion of jets from $\sigma_0 \gg 1$ to $\sigma < 1$ takes place within a distance range $r < 10^{4-5} r_g \sim (M_{BH}/10^9 M_\odot) \text{pc}$.

(Such a conversion can proceed via the differential collimation of poloidal magnetic surfaces, but may involve also reconnection of magnetic fields driven by MHD instabilities)

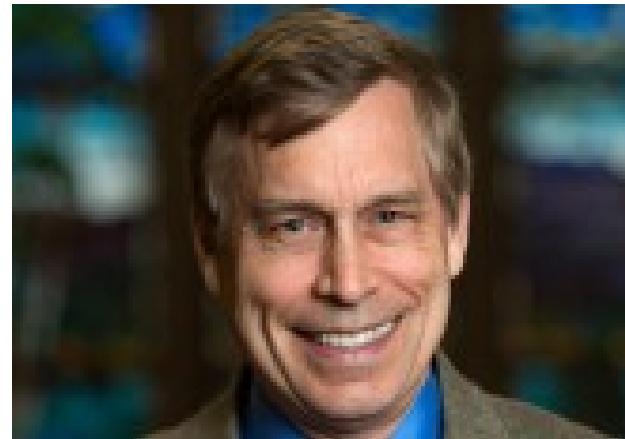


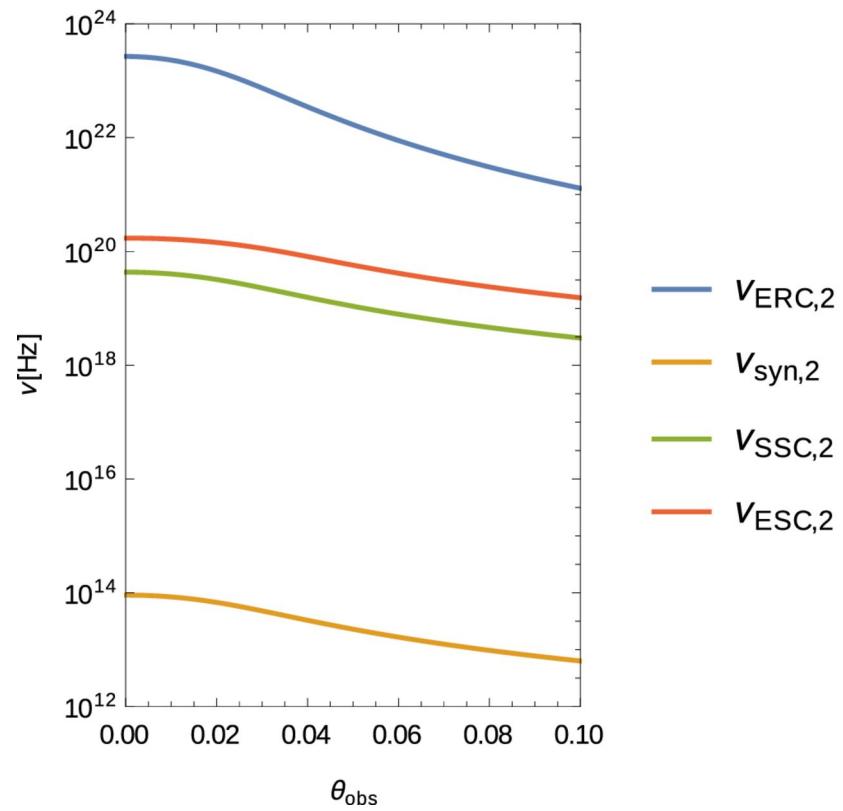
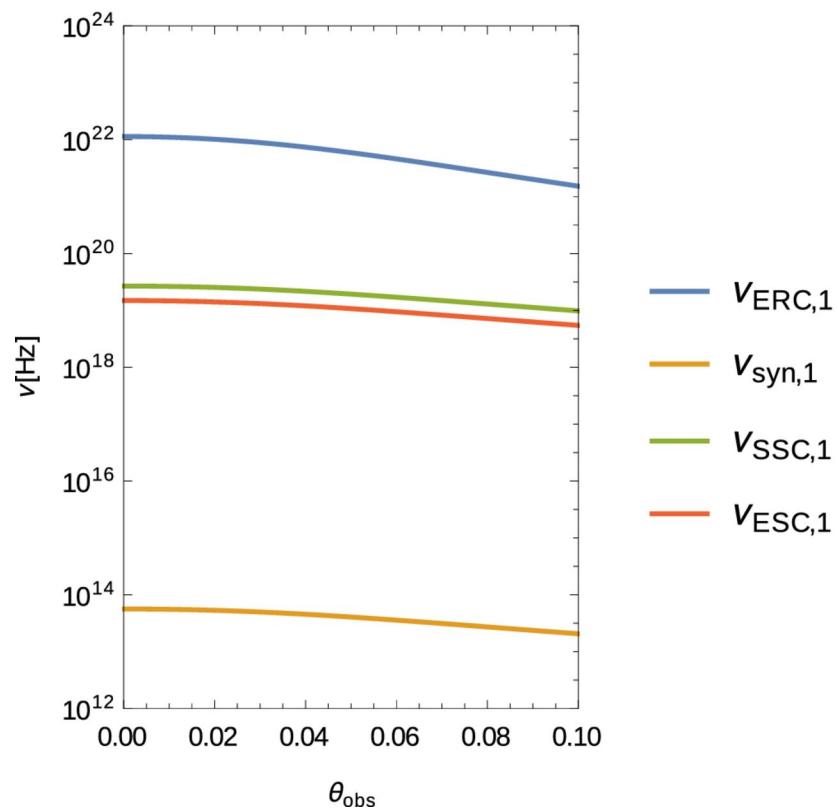


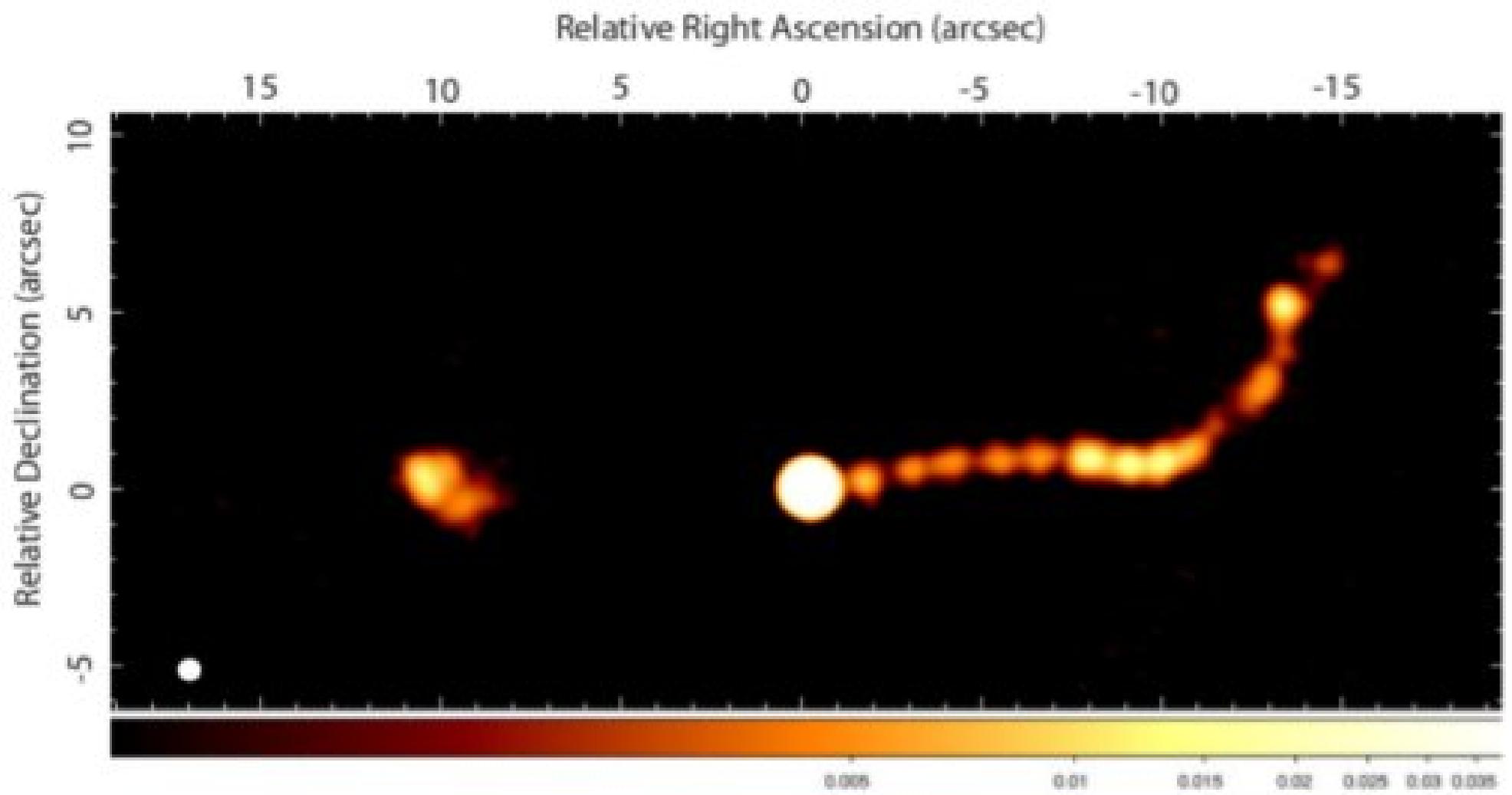
to

HAPPY BIRTHDAY

to

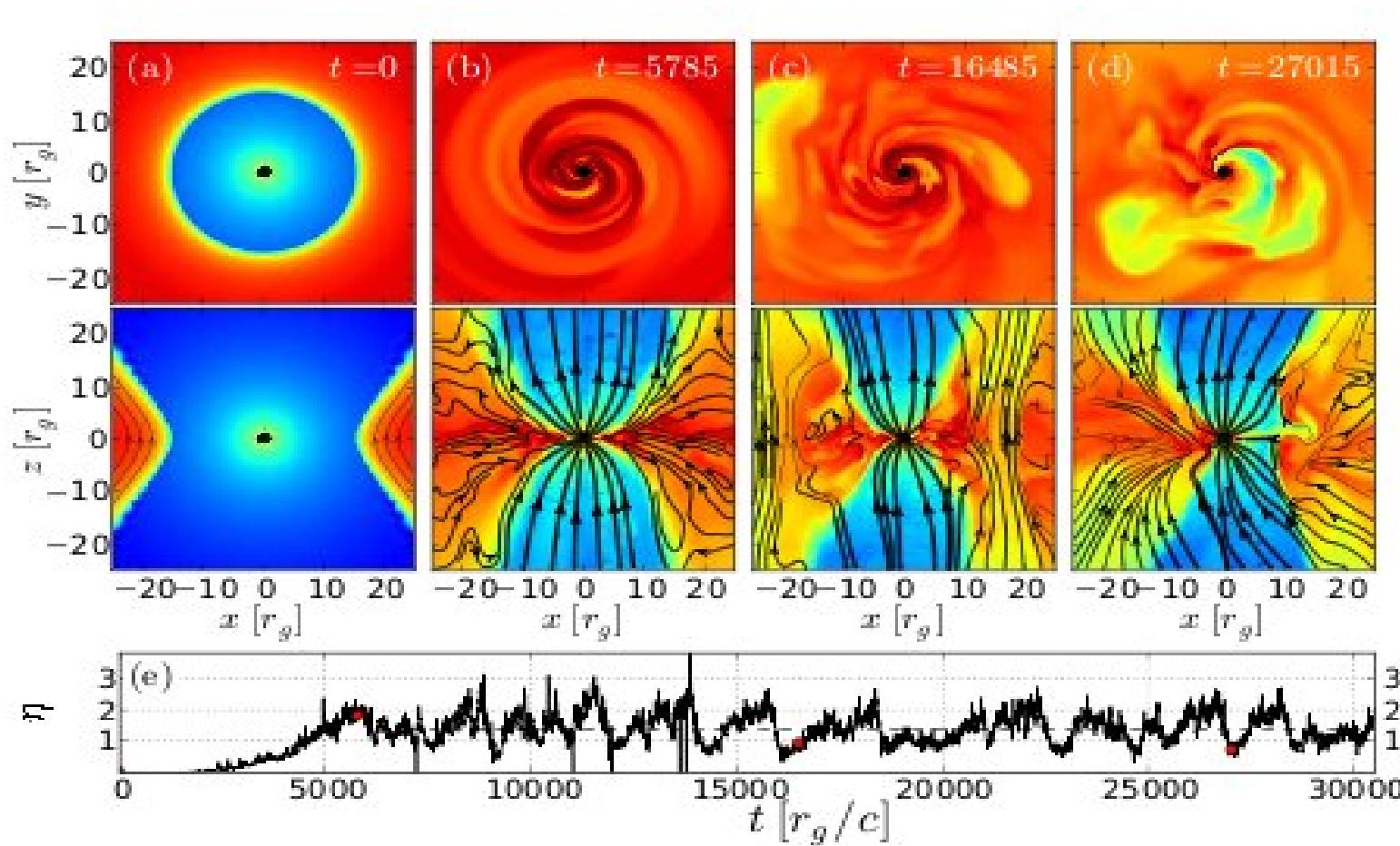






Godfrey, Lovell, Burke-Spolaor, et al. '12

Magnetically choked accretion flows



Narayan, McClintock & Tchekhovskoy '13

(Igumenshchev '08;
Punsly, Igumenshchev & Hirose '09;
McKinney, Tchekhovskoy & Blandford '12)