Gamma-ray Narrow-Line Seyfert 1 Galaxies

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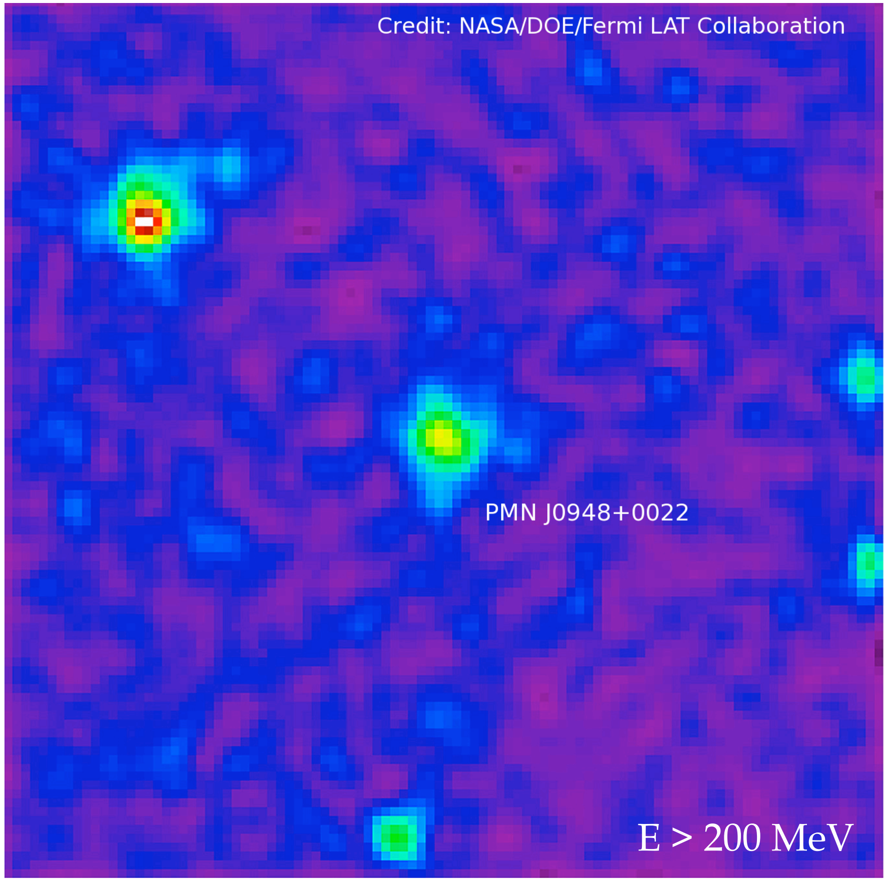
Narrow-Line Seyfert 1 Galaxies

FWHM	< 2000 km/s	Goodrich 1989
[OIII]/Hβ	< 3	Osterbrock & Pogge 1985
FeII	Yes ☞ No obscuration	Osterbrock & Pogge 1985
Mass Black Hole	10^6-10^8 $M_\odot$	Peterson, Mathur, Decarli, Marconi, Bentz, Denney, Vestergaard, Woo, Wandel,…
Accretion rate	0.1-1 Eddington	Boroson & Green 1992; Boller+ 1996
Host galaxy	spiral, mostly barred	Crenshaw+ 2003; Deo+ 2006
Star formation	Yes, high	Sani+ 2010
Age	Young, < Gyr	Grupe 1996, Grupe+ 1999, Mathur 2000, Mathur+ 2011, Orban de Xivry+ 2011
Radio	7% is radio-loud	Komossa+ 2006
γ rays	**YES! First detection by *Fermi* LAT Coll. in 2008 (see next slides)**	First (negative) attempt with *Whipple* at E > 400 GeV (Falcone+ 2004).

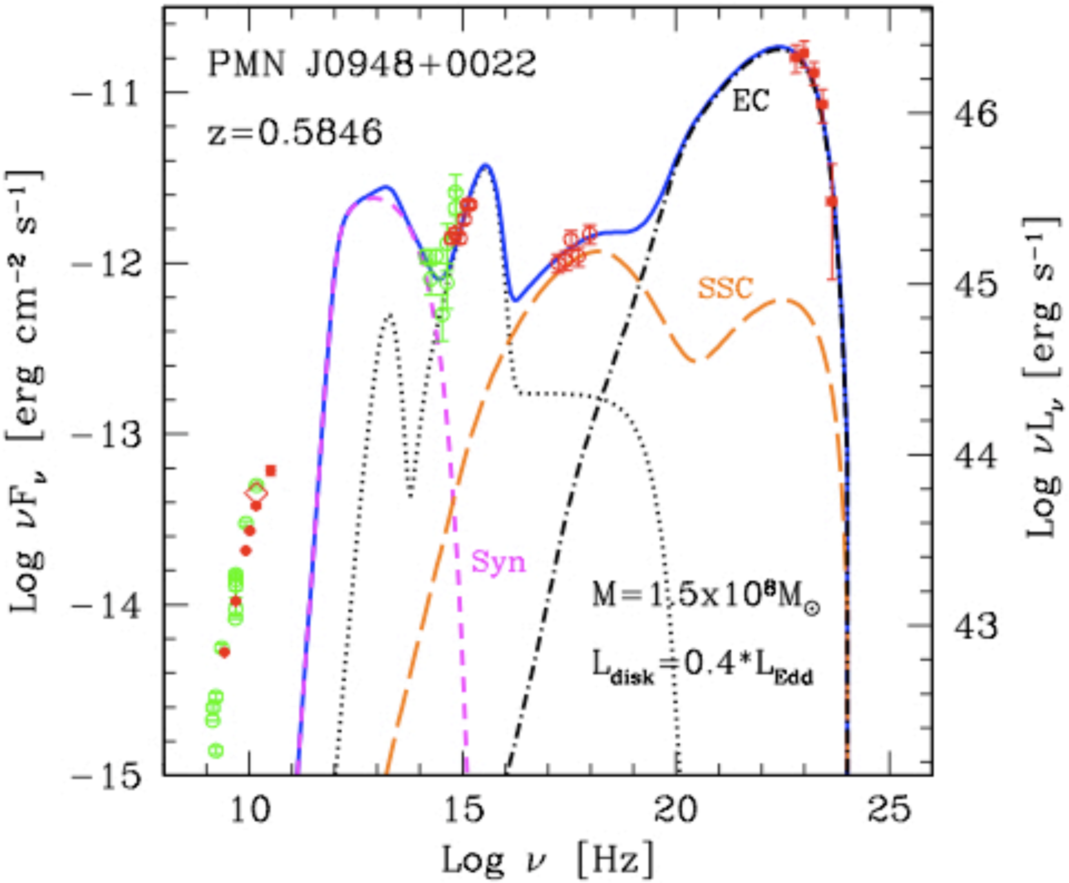
Discovery of GeV emission from NLS1s

PMN J0948+0022 a.k.a. SDSS J094857.31+002225.4 (0.5846)
The first NLS1 detected at high-energy γ−rays (LAT Coll. 2009a, 2010)

Already found to be radio-loud with flat spectrum and high brightness temperature by Zhou+ (2003)



17σ detection!

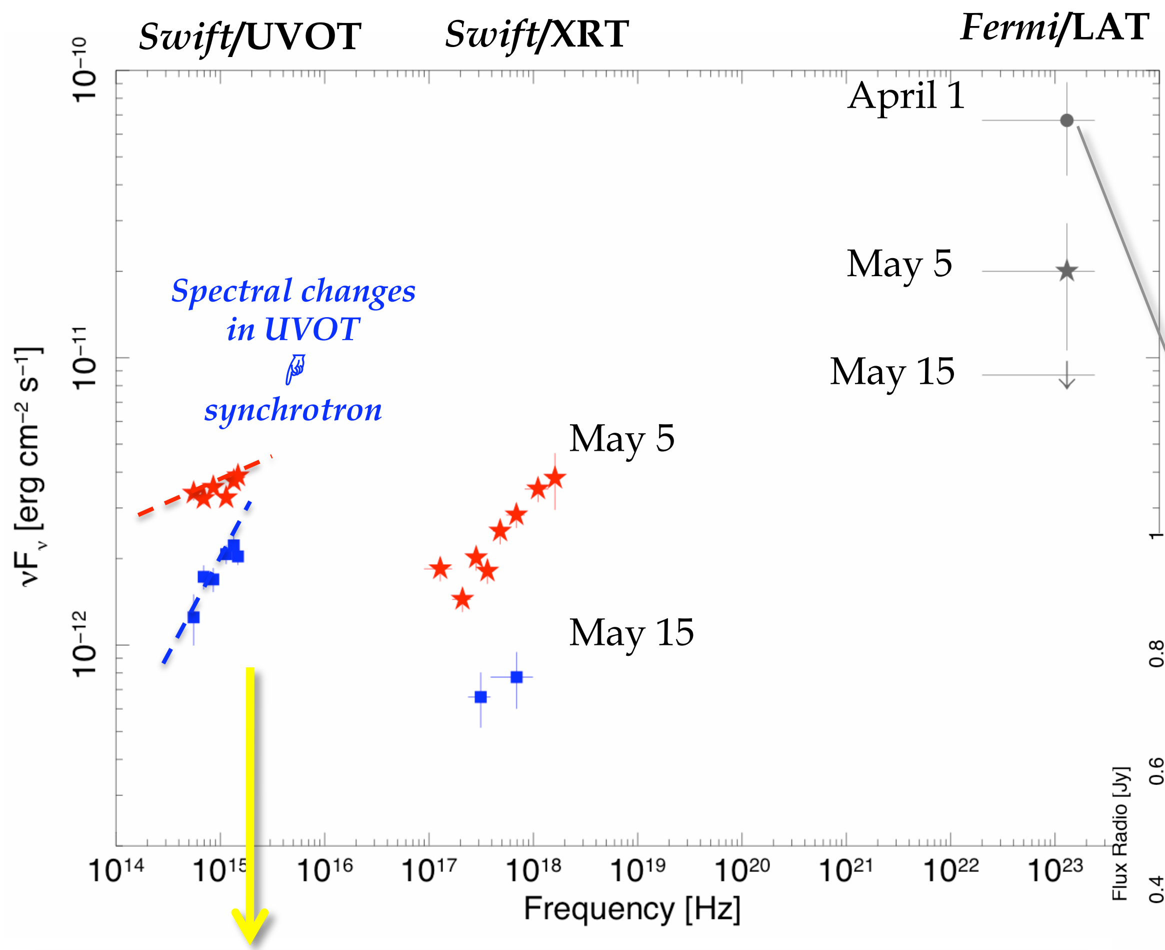


Model by Ghisellini & Tavecchio (2009)

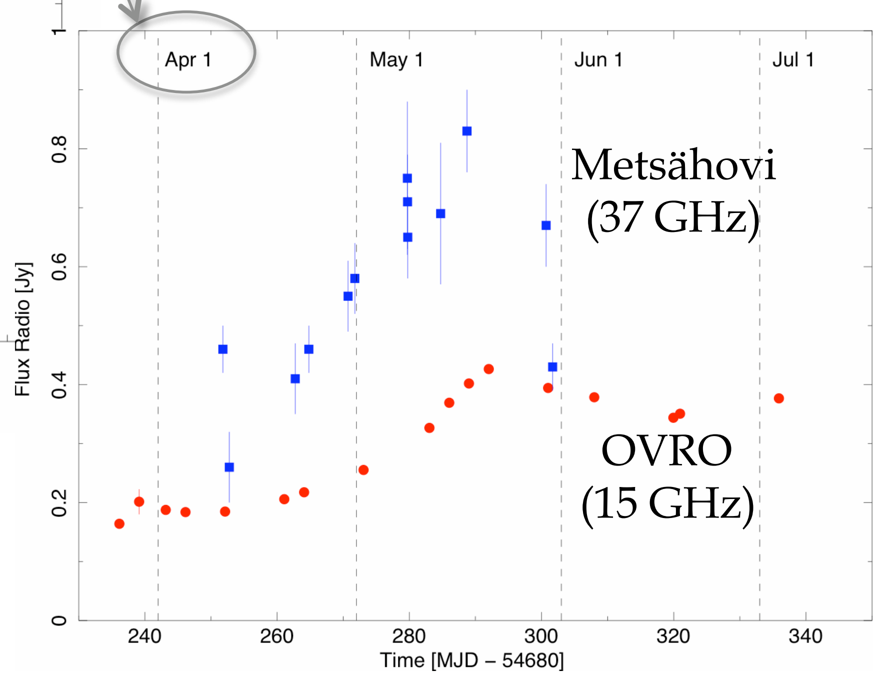
2009 MW Campaign

Observation of MW coordinated variability ☞ jet emission, confirmation of the association

LAT Coll. (2009b)



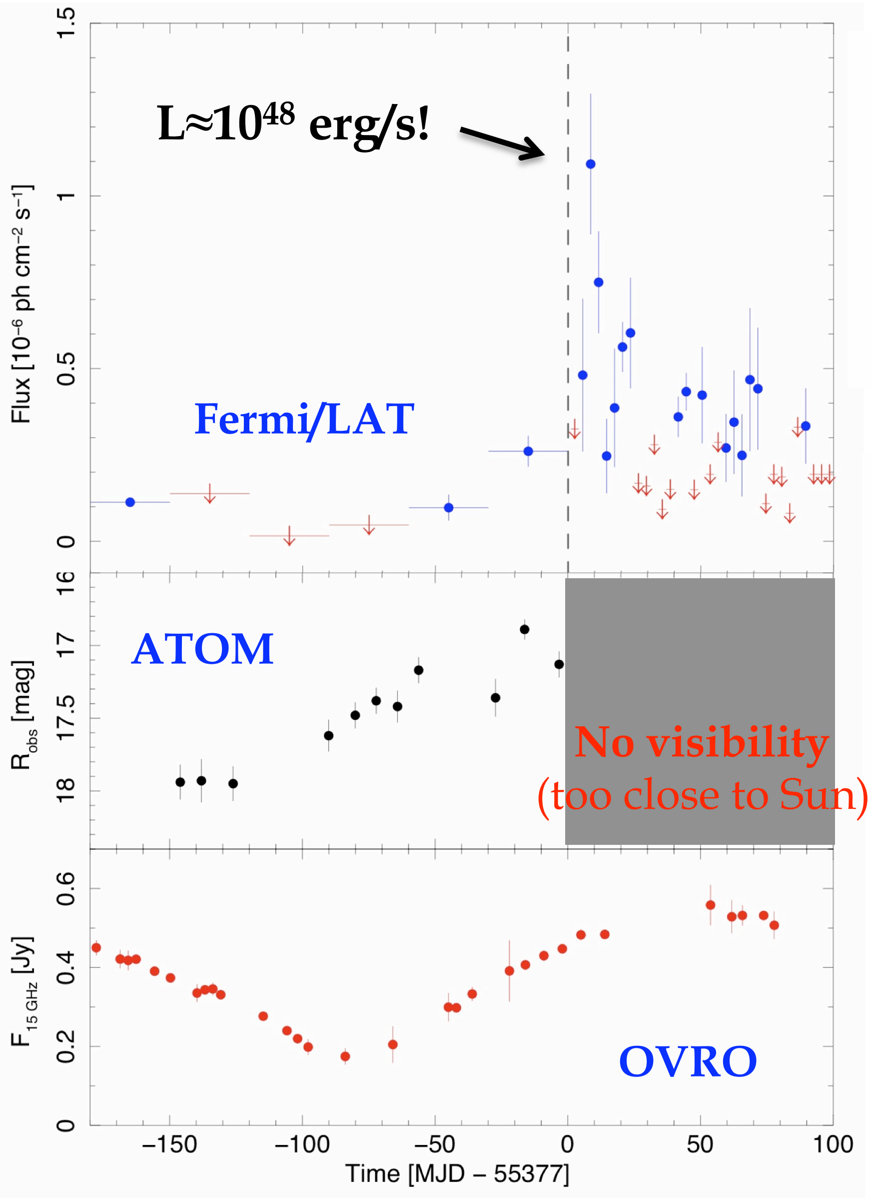
Radio peaks after 1.5-2 months

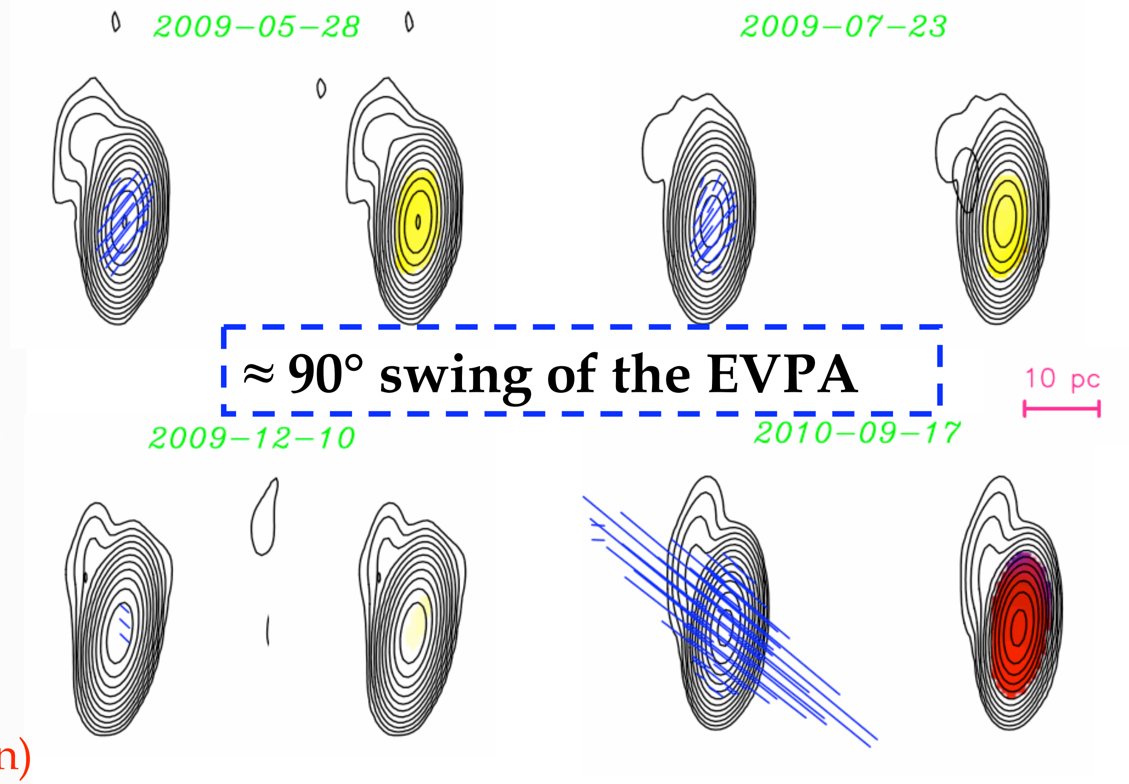


Strong synchrotron component confirmed by detection of optical (V) polarization (19%) with Kanata telescope (Ikejiri+ 2011)

2010 MW Campaign on PMN J0948+0022

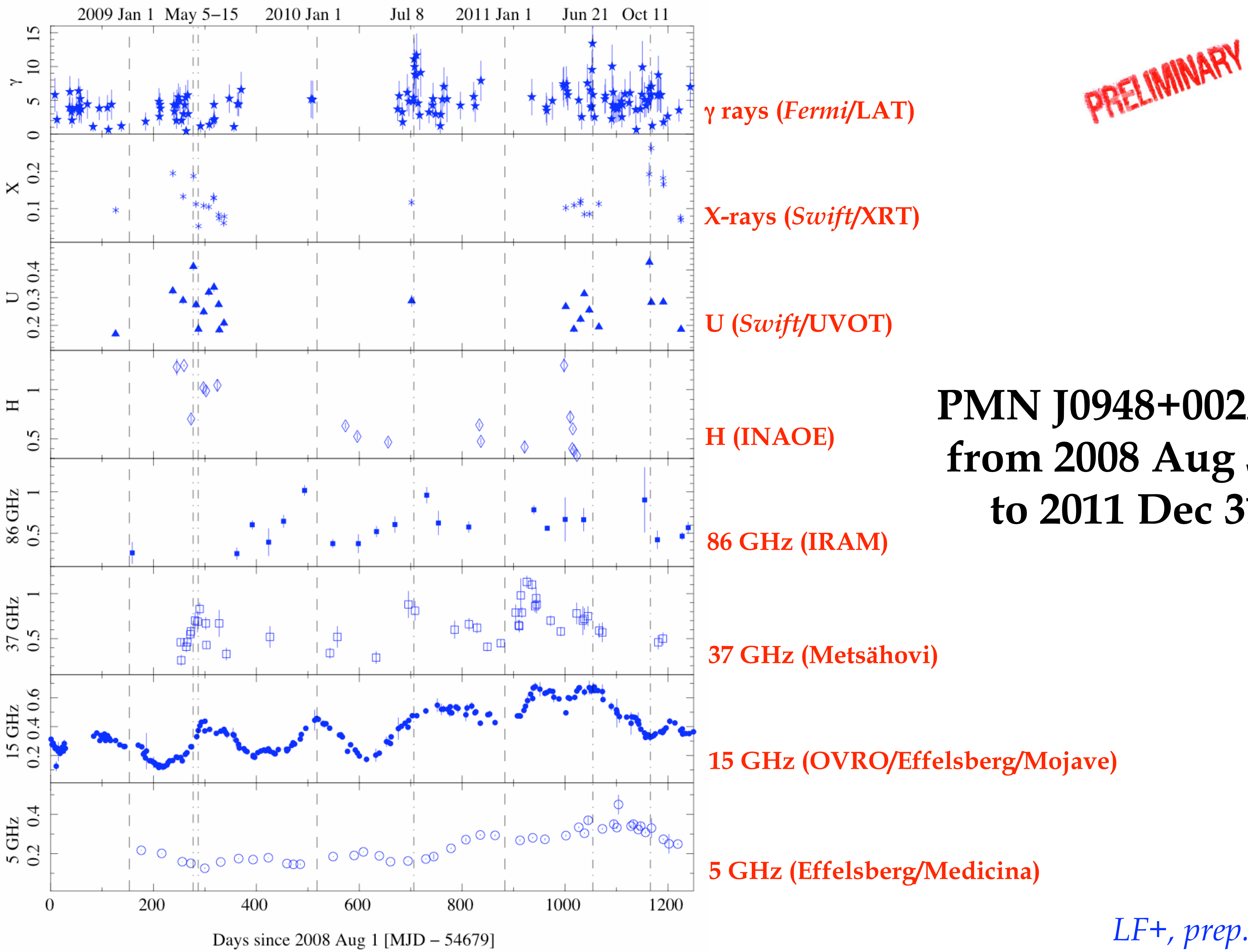
Triggered by the first γ-ray outburst (peak ≈ 10^{-6} ph cm^{-2} s^{-1} ➤ L ≈ 10^{48} erg/s!)





VLBA (2cm/15 GHz) – MOJAVE Project
(☞ http://www.physics.purdue.edu/MOJAVE/)

LF+ (2011)



PMN J0948+0022 from 2008 Aug 5 to 2011 Dec 31

LF+, prep.

Present status

PRELIMINARY

Sample of 50 radio-loud NLS1s from Komossa+ 2006, SDSS (Yuan+ 2008), FBQS (Whalen+ 2006), plus others individual sources (Grupe+ 2000, Oshlack+ 2001, Zhou & Wang 2002, Zhou+ 2003, Gallo+ 2006, Zhou+ 2007).

Results on 40 months of LAT data (ST 9.23.1; IRF 7):

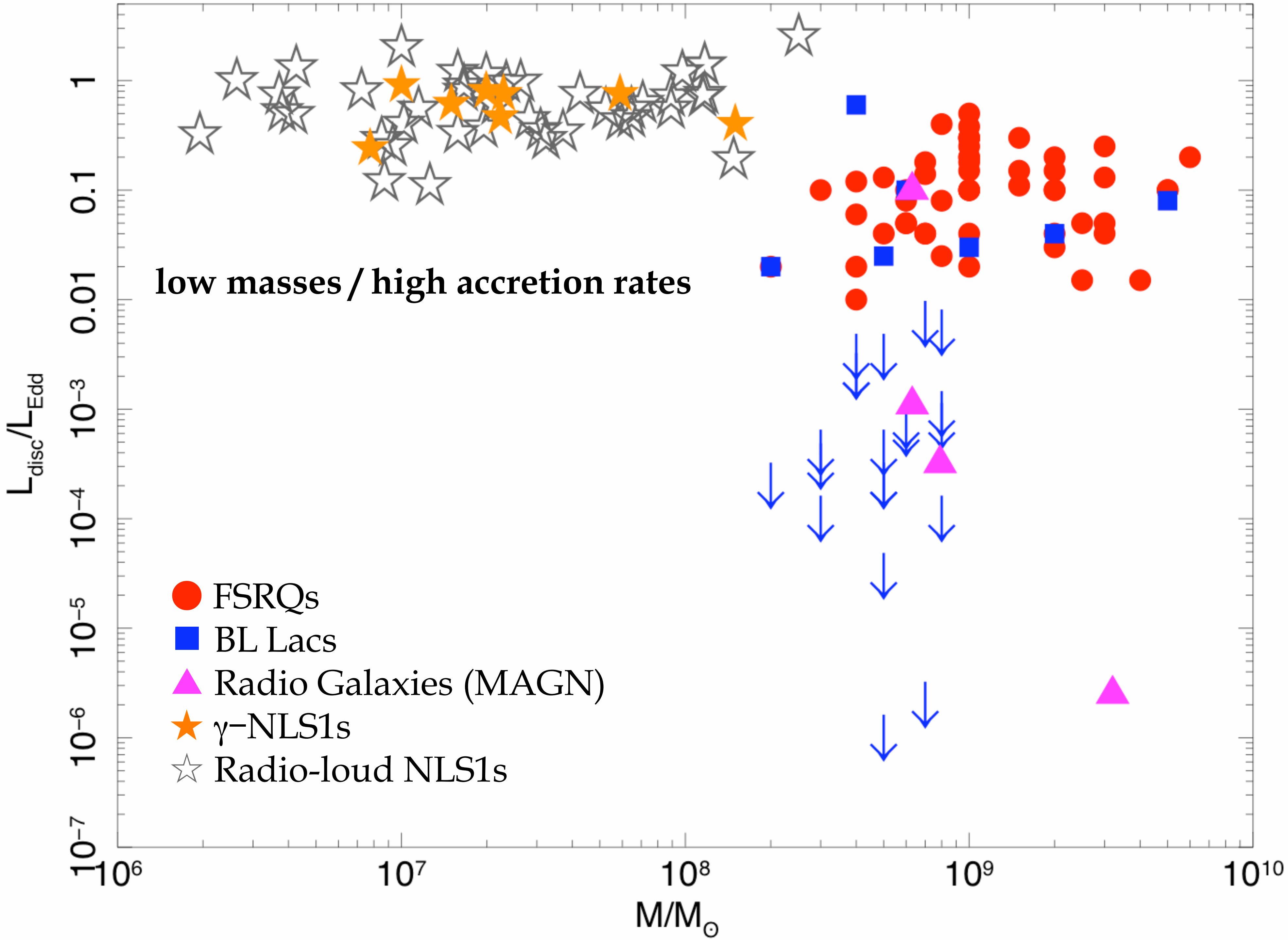
5 high-confidence detections (>5 σ):

- J0324+3410 (z=0.061) – 2FGL
- **J0849+5108 (z=0.584)**
- **J0948+0022 (z=0.585) – 2FGL**
- **J1505+0326 (z=0.409) – 2FGL**
- J2007-4434 (z=0.240) – 2FGL

3 low-confidence detection (3< σ <5):

- SDSS J080409.23+385348.8 (z=0.211) – Month time scale (4 σ)
- **SDSS J124634.65+023809.0 (z=0.363**) – (3.7 σ)
- **SDSS J163401.94+480940.2 (z=0.495)** – Month time scale (3.6 σ)

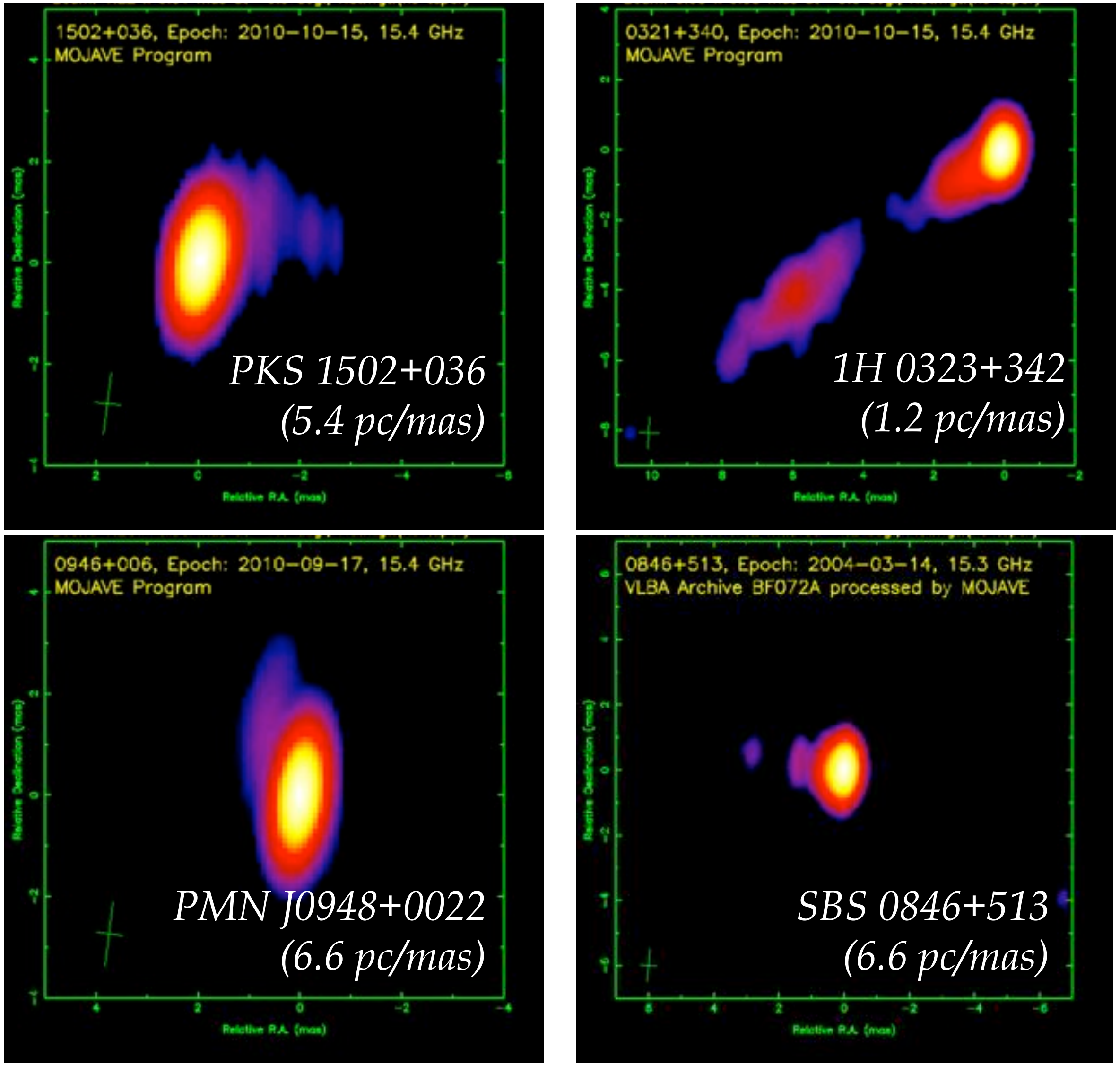
5 are from the flux-limited sample of 23 RL-NLS1s from SDSS (Yuan+ 2008) ☞ 22%



low masses / high accretion rates
FSRQs
BL Lacs
Radio Galaxies (MAGN)
γ−NLS1s
Radio-loud NLS1s
L_{disc}/L_{Edd}
$M/M_{\odot}$
1
0.1
0.01
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{6}
10^{7}
10^{8}
10^{9}
10^{10}

Radio morphology of γ-NLS1s:

very compact on pc scale



VLBA (2cm/15 GHz) MOJAVE Project (☞ http://www.physics.purdue.edu/MOJAVE/)

Search for the parent population

5-8 beamed NLS1 with Γ≈10

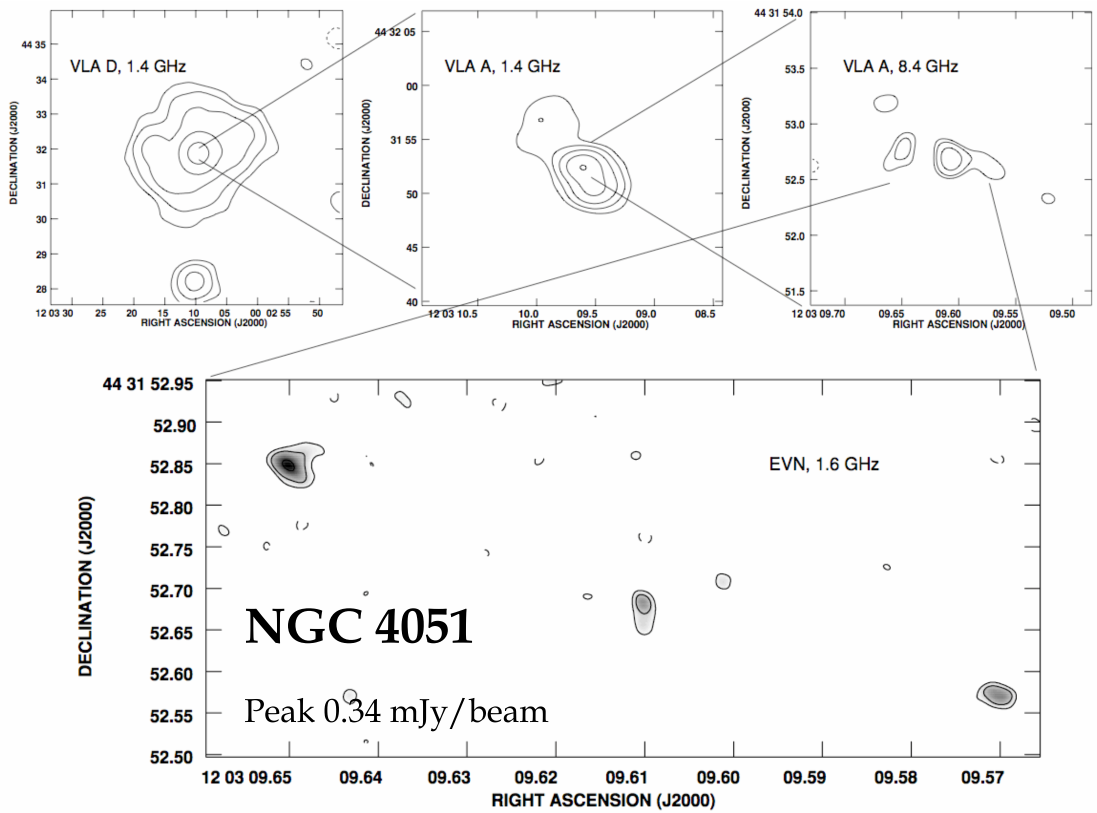
⬇

≈2Γ^2 unbeamed parent sources ≈ 1000-1600

Where are they? Three options:

Option 1: if the radio emission is so compact and negligible extended (isotropic) emission is present, then when the source is viewed at large angles, it could be a radio-quiet NLS1.

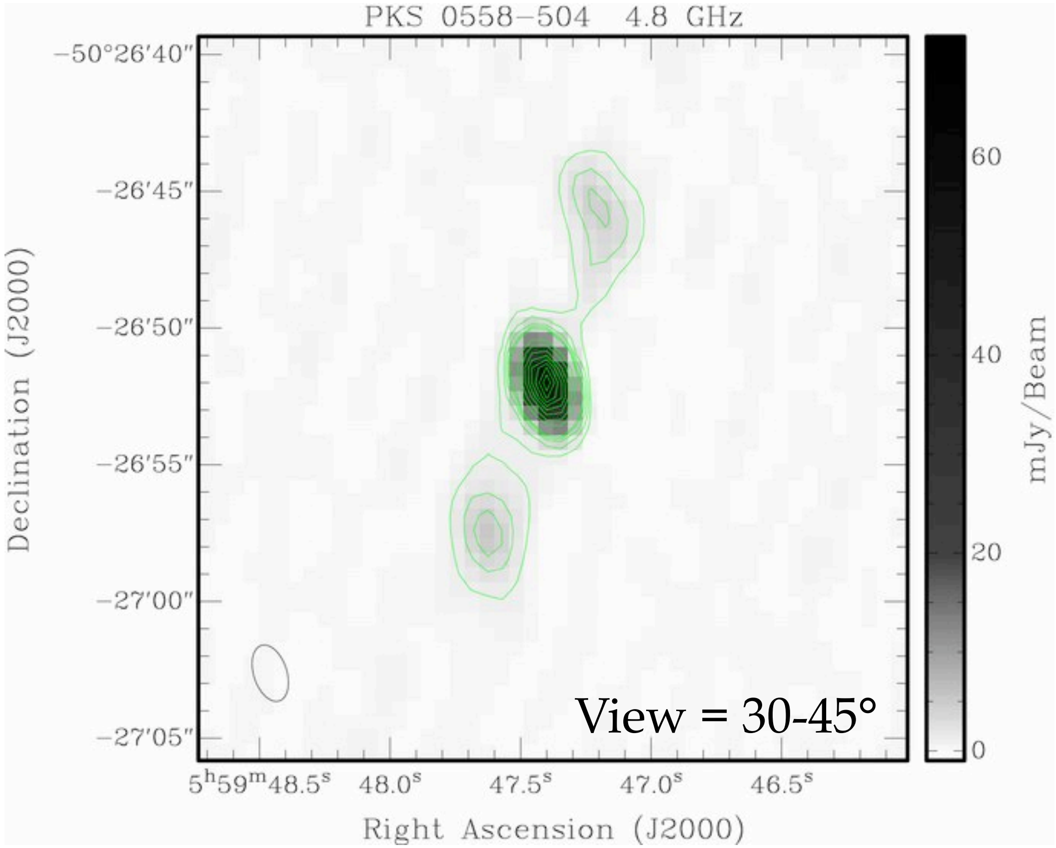
Giroletti & Panessa (2009) found some microJansky structures in radio-quiet NLS1s



Search for the parent population

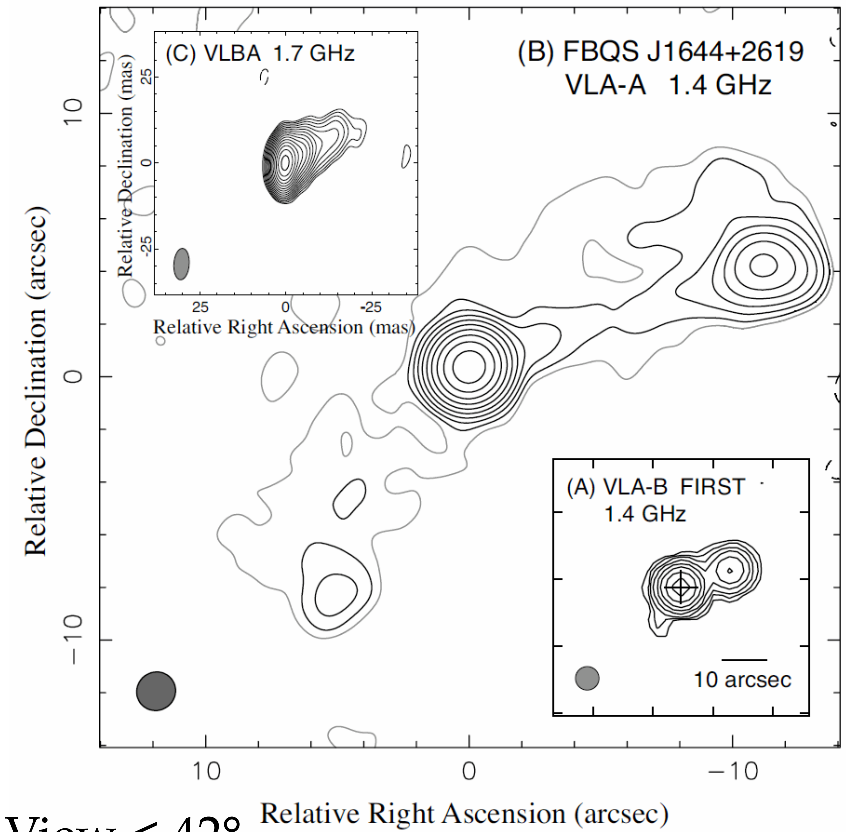
Option 2 (simplest): radio-loud NLS1s with jet viewed at large angles.

Gliozzi+ (2011)



Jet length 7″, 2.3 kpc/arcsec

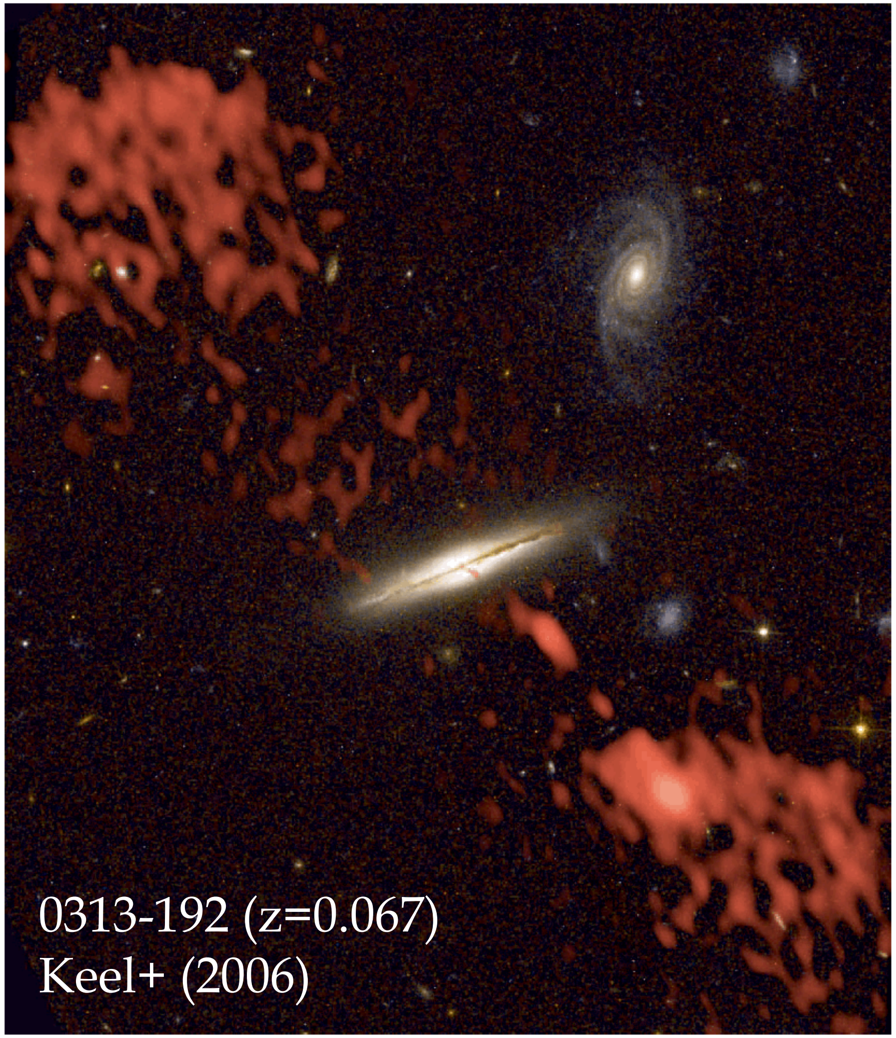
Doi+ (2012)



View < 42°

Jet length 12″, 2.4 kpc/arcsec

Search for the parent population



Option 3: search for broad-line radio galaxies hosted in spirals.

If the BLR is disk-like, when we observe pole-on the lines are narrow, but if we observe edge-on, the lines are broad as usual (Decarli+ 2008).

Some cases of RG in spirals are already available in literature, but they were not "seen": possible misclassification of E with S0, but also the opposite (bright S0 are classified as E).

Inskip+ (2010) in a sample of 42 radio sources (2Jy sample) found that **12%** are hosted in "disk" galaxies.

Parent population
Present status

PRELIMINARY

Sample of 22 radio galaxies from literature according to the three options previously outlined.

Results on 40 months of LAT data (ST 9.23.1; IRF 7):

3 high-confidence detections (>5 σ):

- Mkn 1501 (z=0.089) – Month time scale
- PKS 0336-177 (z=0.065) – 2FGL
- SDSS J141558.81+132023.7 (z=0.247) – 2FGL

3 low-confidence detection (3< σ <5):

- 3C 120 (z=0.033) – 4.9 σ – Not in FGL, but see the “misaligned” paper (LAT Coll. 2010)
- B2 0722+30 (z=0.019) – Month time scale – 3 σ
- SDSS J170441.37+604430.4 (z=0.372) – Month time scale – 3.7 σ

IC310, radio galaxy in S0: head-tail or jet? ☞ poster Eisenacher, talk Colin

Why γ−NLS1 are important?

Notes on the unification of jets at all scales

One more point of view

Compare more physical quantities (inferred from observations): mass, accretion rate, jet power (see LF 2011, 2012).

The sample:

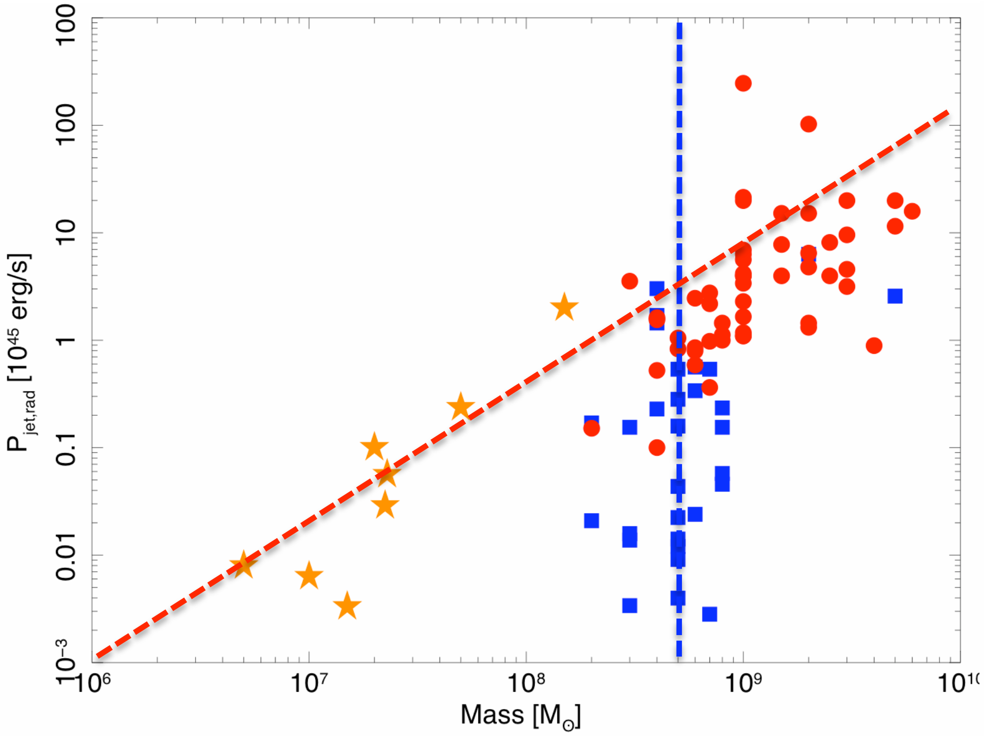
92 AGN:
53 FSRQs (data from Ghisellini+ 2010)
31 BL Lac Objects (data from Ghisellini+ 2010)
8 γ-NLS1s (data from LAT Coll. 2009c, LF 2011-2012) NEW!

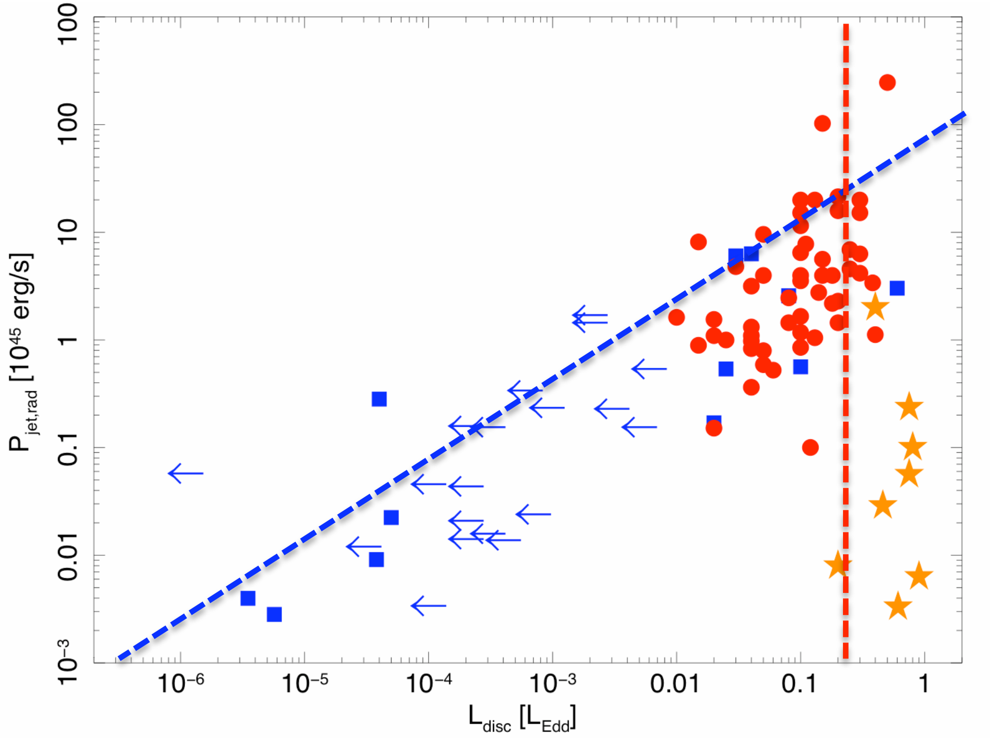
5 Galactic Binaries (GB, in different states; 80 points)
3 stellar mass BHs (data from Corbel+ 2003, 2008, Coriat+ 2011)
2 neutron stars (data from Migliari & Fender 2006, Miller-Jones+ 2010)

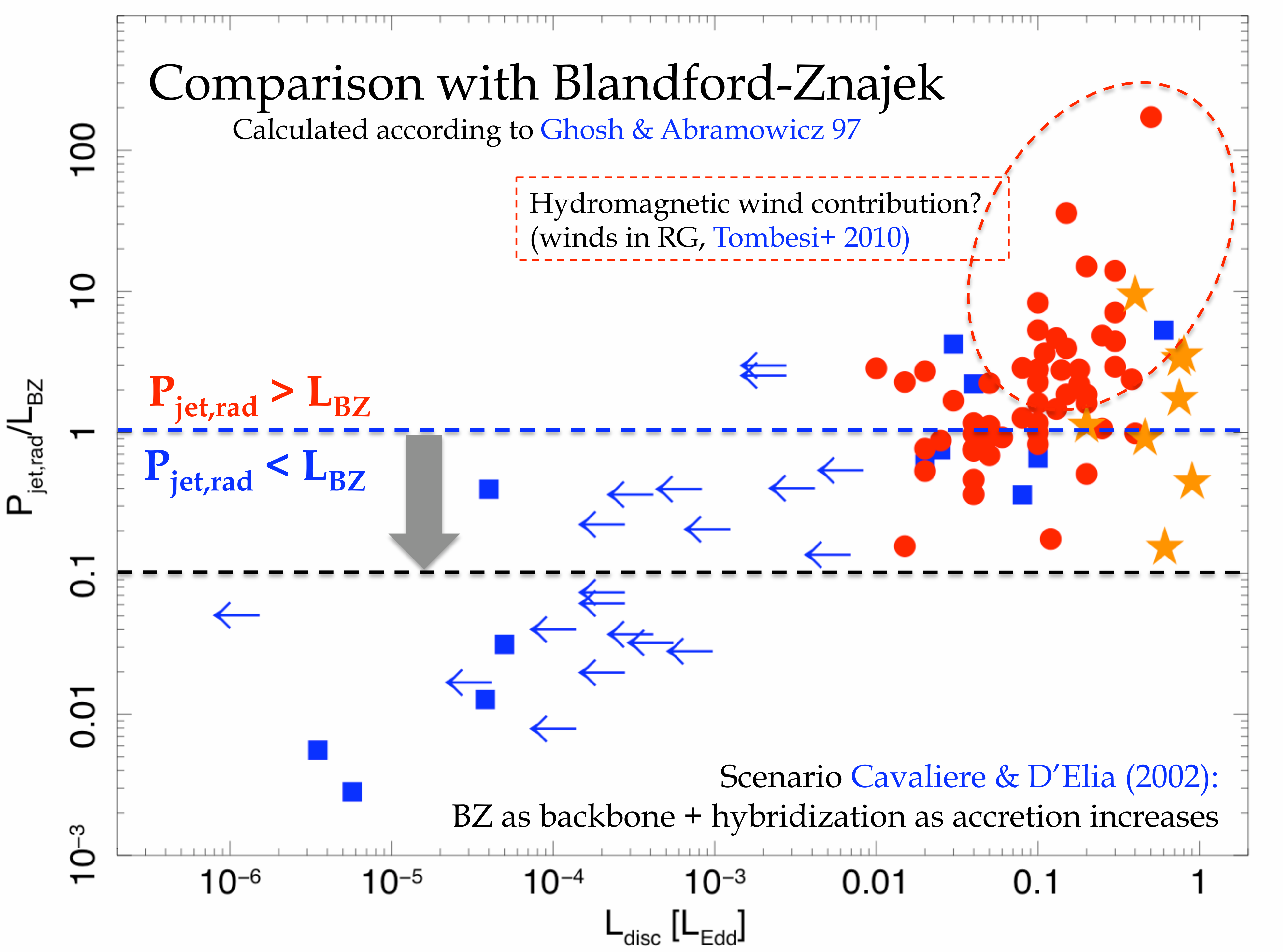
Jet as a function of mass and accretion rate: *two regimes?*

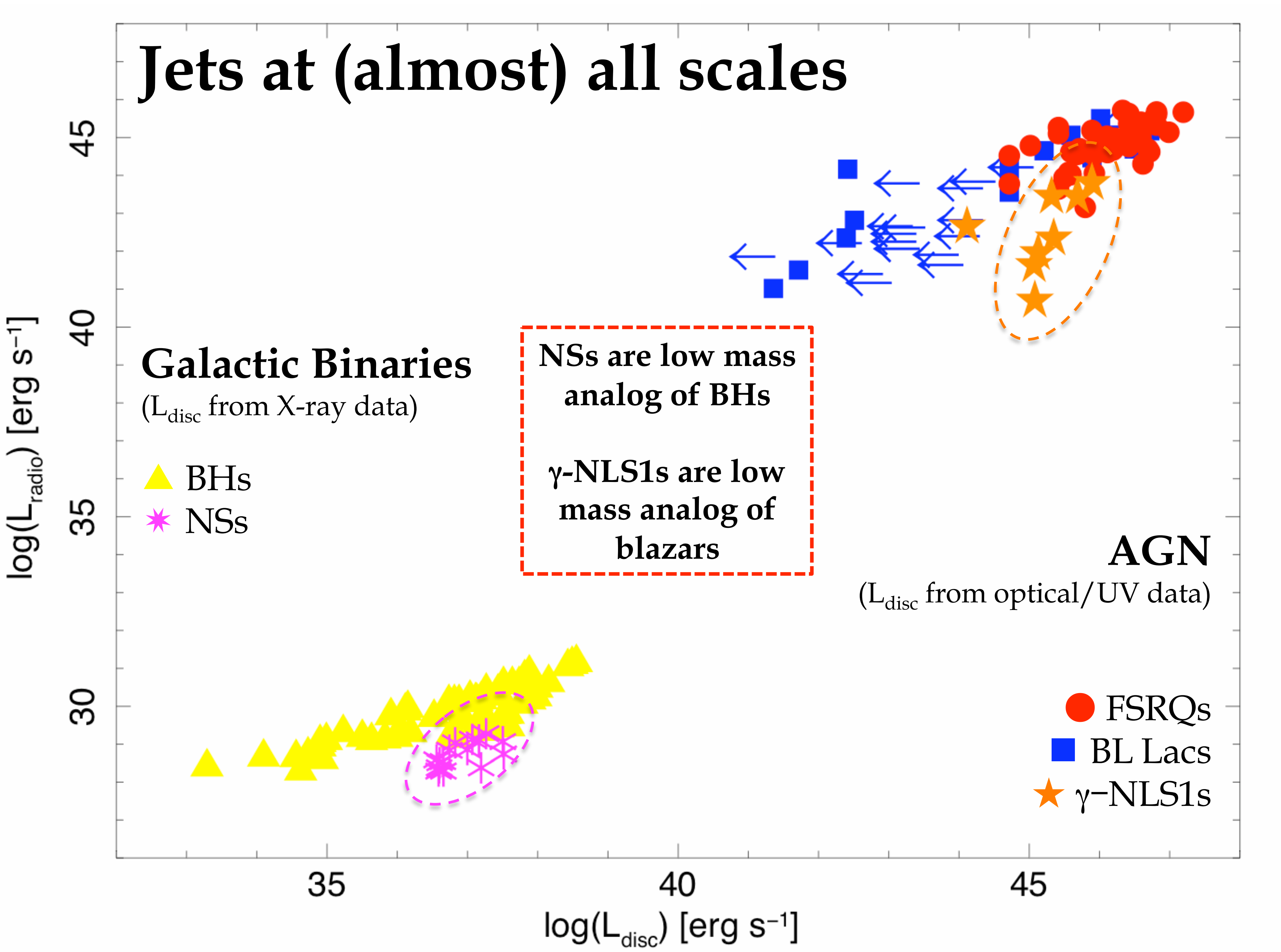
$$L_{\rm BZ}\ ({\rm erg\ s^{-1}}) = \begin{cases} 2.10^{44} M_8 (J/J_{\rm max})^2 & \textbf{RPD} \\ 8.10^{42} M_8^{11/10} \dot{m}_{-4}^{4/5} (J/J_{\rm max})^2 & \textbf{GPD} \end{cases}$$

Moderski & Sikora 96;
Ghosh & Abramowicz 97

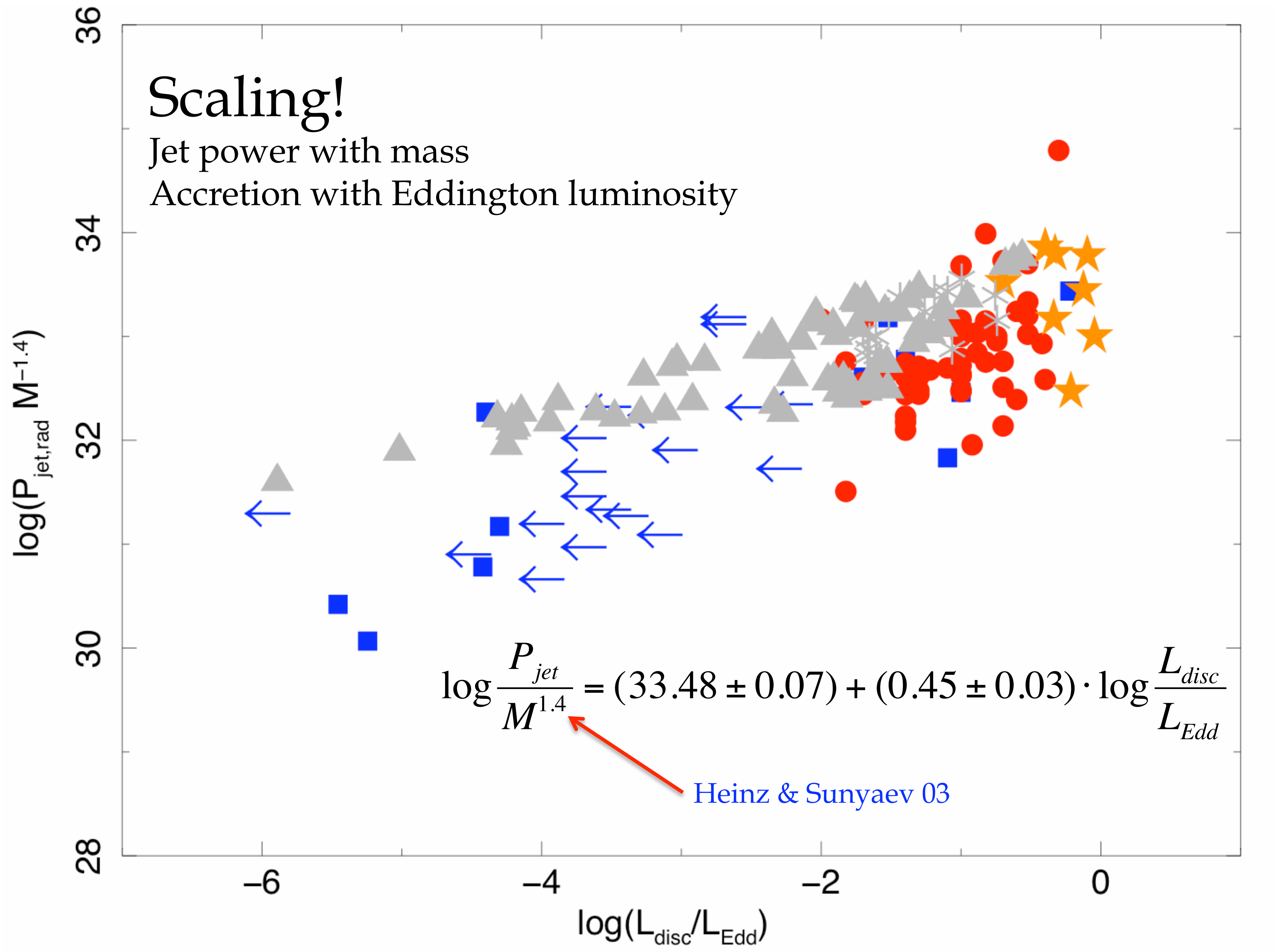





Comparison with Blandford-Znajek
Calculated according to Ghosh & Abramowicz 97
Hydromagnetic wind contribution?
(winds in RG, Tombesi+ 2010)
$P_{jet,rad} > L_{BZ}$
$P_{jet,rad} < L_{BZ}$
Scenario Cavaliere & D'Elia (2002):
BZ as backbone + hybridization as accretion increases
$P_{jet,rad}/L_{BZ}$
L_{disc} [L_{Edd}]
100
10
1
0.1
0.01
10^{-3}
10^{-6}
10^{-5}
10^{-4}
10^{-3}
0.01
0.1
1



Jets at (almost) all scales
Galactic Binaries
(L$_{disc}$ from X-ray data)
BHs
NSs
NSs are low mass analog of BHs
γ-NLS1s are low mass analog of blazars
AGN
(L$_{disc}$ from optical/UV data)
FSRQs
BL Lacs
γ−NLS1s
log(L$_{radio}$) [erg s^{-1}]
log(L$_{disc}$) [erg s^{-1}]
30
35
40
45


Scaling!
Jet power with mass
Accretion with Eddington luminosity
$\log \frac{P_{jet}}{M^{1.4}} = (33.48 \pm 0.07) + (0.45 \pm 0.03) \cdot \log \frac{L_{disc}}{L_{Edd}}$
Heinz & Sunyaev 03
$\log(P_{jet,rad}\ M^{-1.4})$
$\log(L_{disc}/L_{Edd})$
36
34
32
30
28
−6
−4
−2
0

Conclusions: Key Points

- **Radio-loud NLS1s** host a relativistic jet that can dissipate high power (with copious γ rays) at level of the most powerful quasars.
- We are now probing a **new parameter space** of AGN jets (low mass, high accretion, spiral host).
- There is increasing evidence that the jet/elliptical **paradigm** (☞ requirement on mass) was an observational **bias**.
- More support of **Livio's conjecture**: jet formation is always the same, while the **nearby environment** can determine how the dissipation occurs (i.e. how we can see it).
- The **unification of jets** at all scales is now possible (low masses in Galactic binaries, low masses in AGN).
- Still searching for ***The Universal Engine*** of Jets…

Web page g-NLS1s: http://tinyurl.com/gnls1s