Narrow-Line Seyfert 1 Galaxies

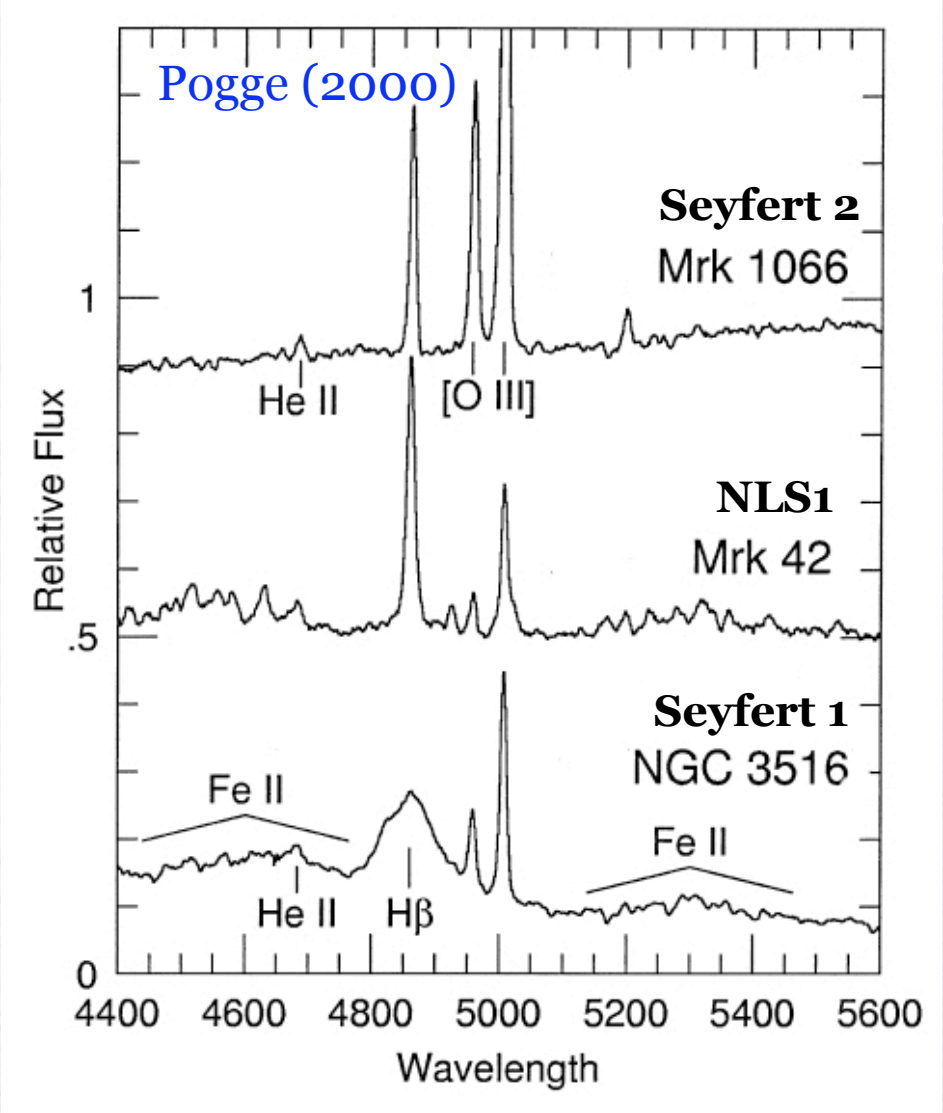
Luigi Foschini
INAF – Osservatorio Astronomico di Brera

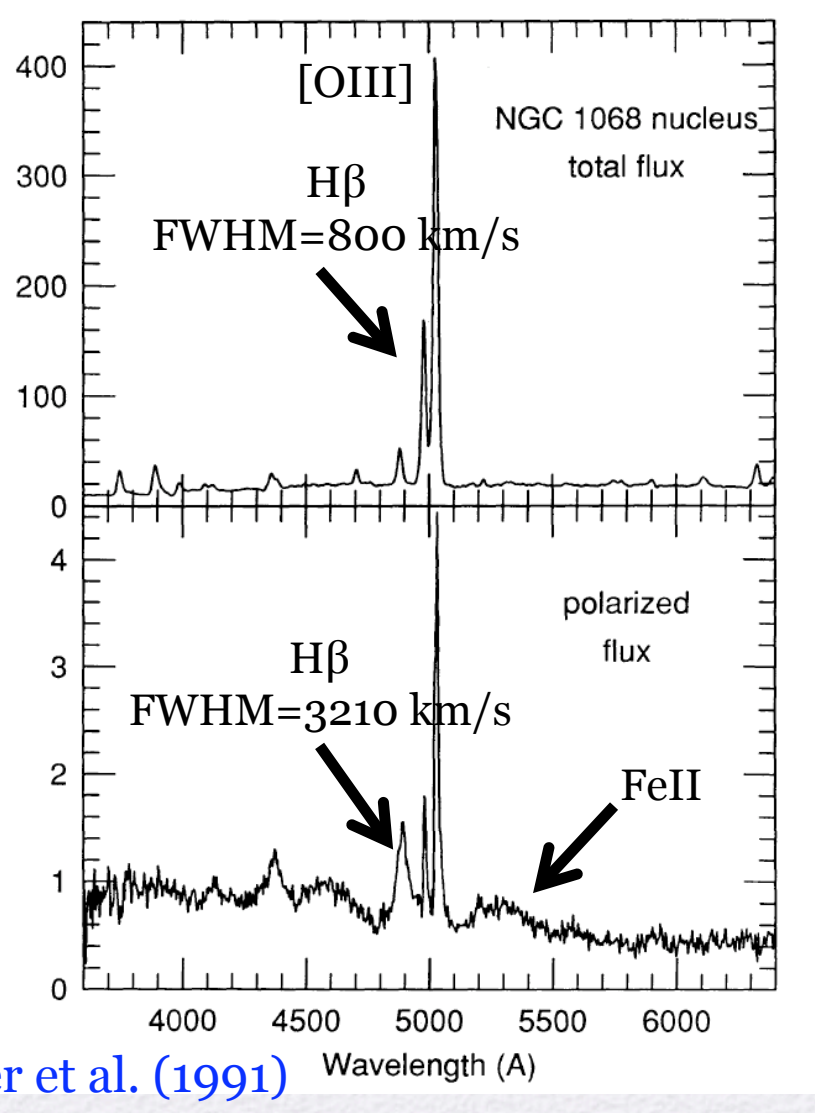
MeraTeV – 6 October 2011

Classification

Type 1:
Broad permitted lines
Narrow forbidden lines
Bump FeII
☞ direct view of BLR+NLR

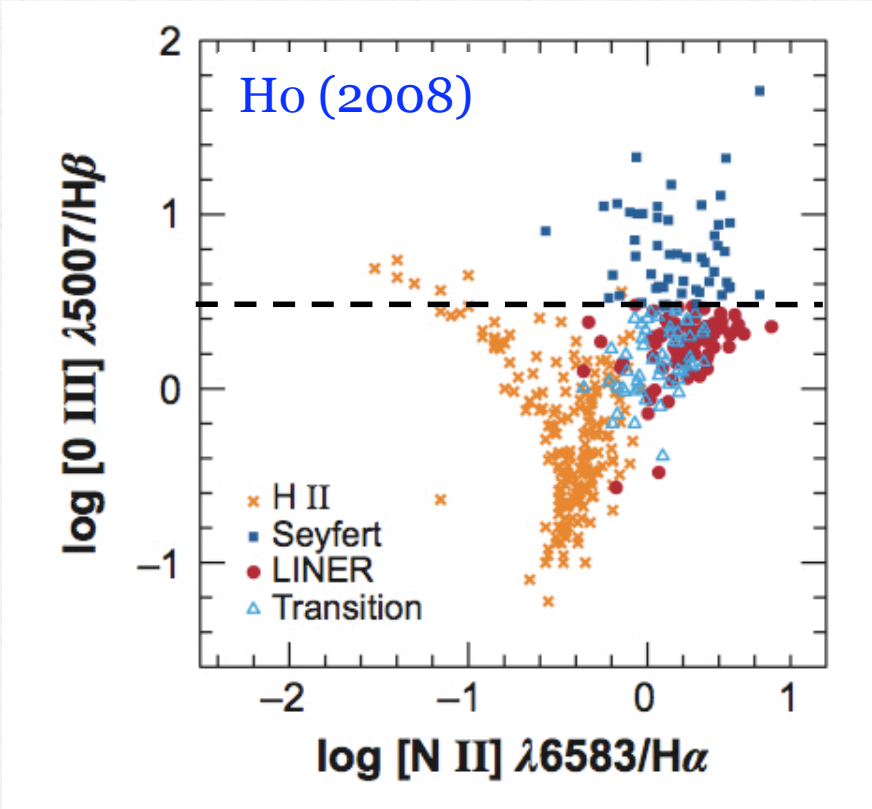
Type 2:
Narrow forbidden lines
Direct view of NLR only
BLR obscured
No FeII bump

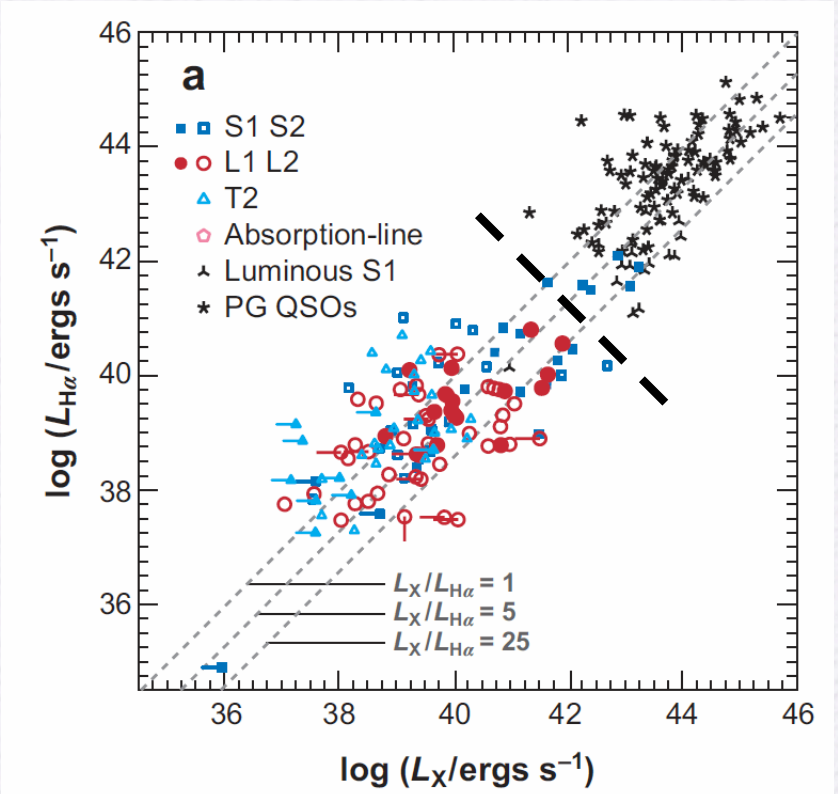




Miller et al. (1991)

Classification





Diagnostic diagrams
(Baldwin et al. 1981, Veilleux & Ostebrock 1987)

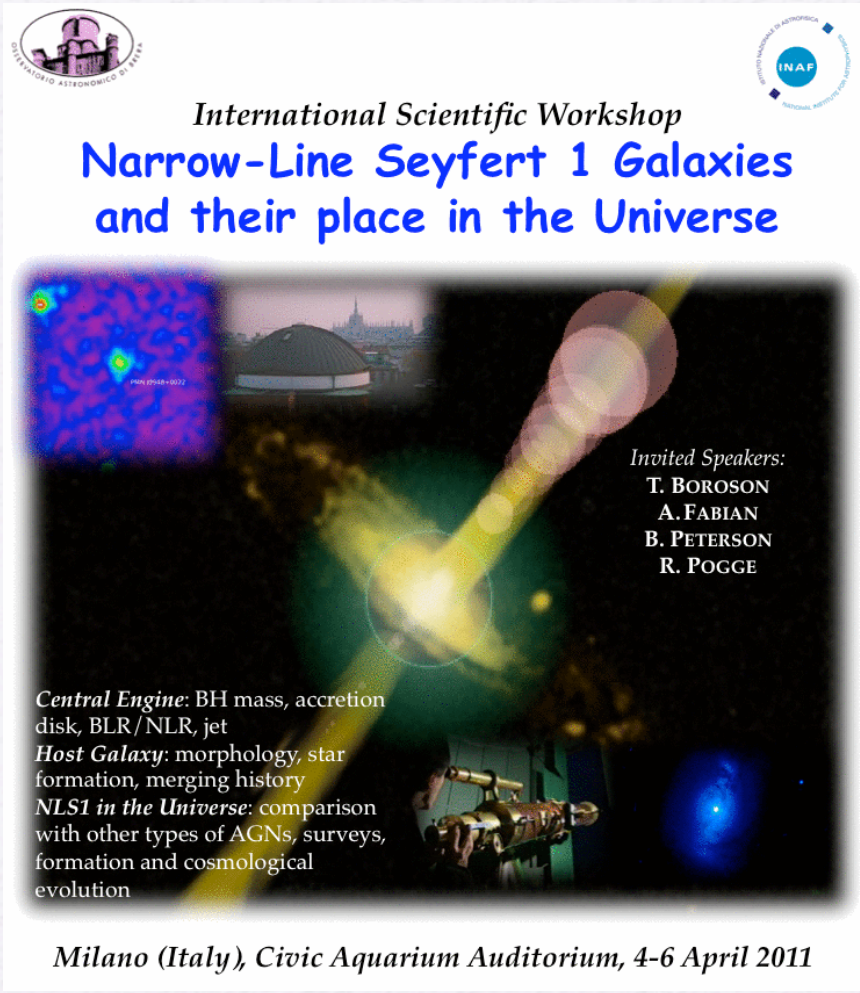
HII: starburst galaxies, no active nuclei (e.g. M82, NGC253).
Sometimes, there are also composite sources (AGN+SB, e.g NGC 1068)

What are NLS1s?

- Main observational characteristics:
  - FWHM(Hβ) < 2000 km/s; [OIII]/Hβ < 3; bump FeII (Osterbrock & Pogge 1985; Goodrich 1989)
  - **Oxymoron:** *the broad lines are narrower than usual…* ⇒ BLR different from other AGN (not due to obscuration! – bump FeII)
  - Generally hosted by **spiral barred galaxies** (e.g. Crenshaw et al. 2003; Deo et al. 2006)
  - Generally high **star forming** activity (Sani et al. 2010)

- Derived characteristics:
  - Relatively **low masses** (10^6-$10^8 M_\odot$ *vexata quaestio* ⇒ Peterson, Mathur, Decarli, Marconi, Bentz, Denney, Vestergaard, Woo, Wandel,…)
  - **high accretion** rates (0.1-1 Edd, Boroson & Green 1992; Böller et al. 1996)
  - possibly **young** AGN (e.g. Mathur et al. 2011, Orban de Xivry, Davies et al., 2011)

NLS1s: the view from Milano



What are NLS1s?

* Low BH mass tail of Seyferts?
* Intrinsically different AGN?

Proceedings on-line

http://pos.sissa.it/cgi-bin/reader/conf.cgi?confid=126

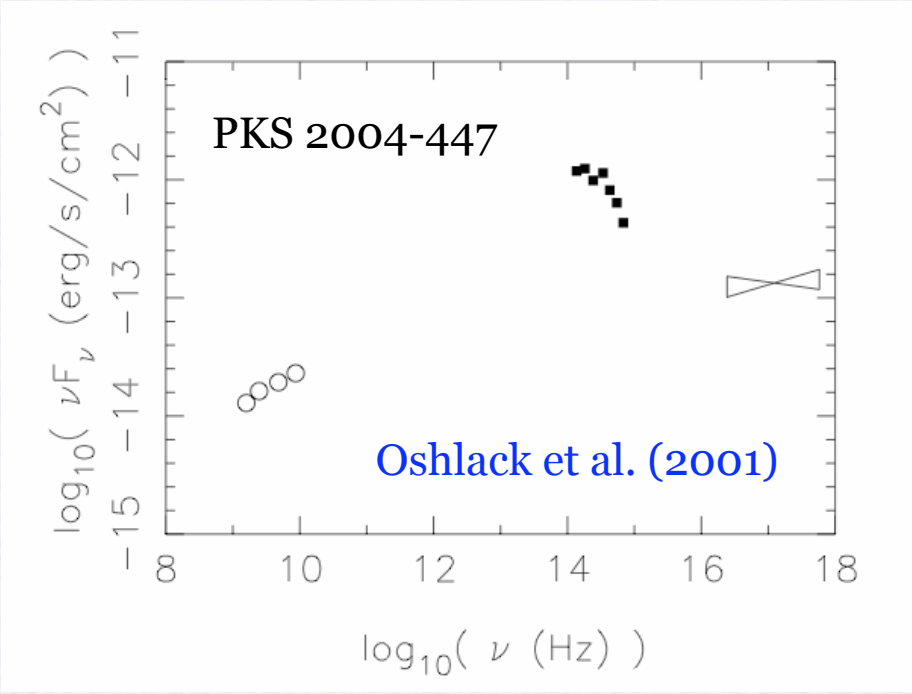
Radio-loud NLS1s?

Generally radio-quiet, but a small part is **radio-loud** (~ 7%, Komossa et al. 2006)

A few specific cases Remillard et al. (1986), Grupe et al. (2000), Oshlack et al. (2001), Zhou et al. (2003), Komossa et al. (2006); more in surveys: Whalen et al. 2006 (*FBQS*), Yuan et al. 2008 (*SDSS*)

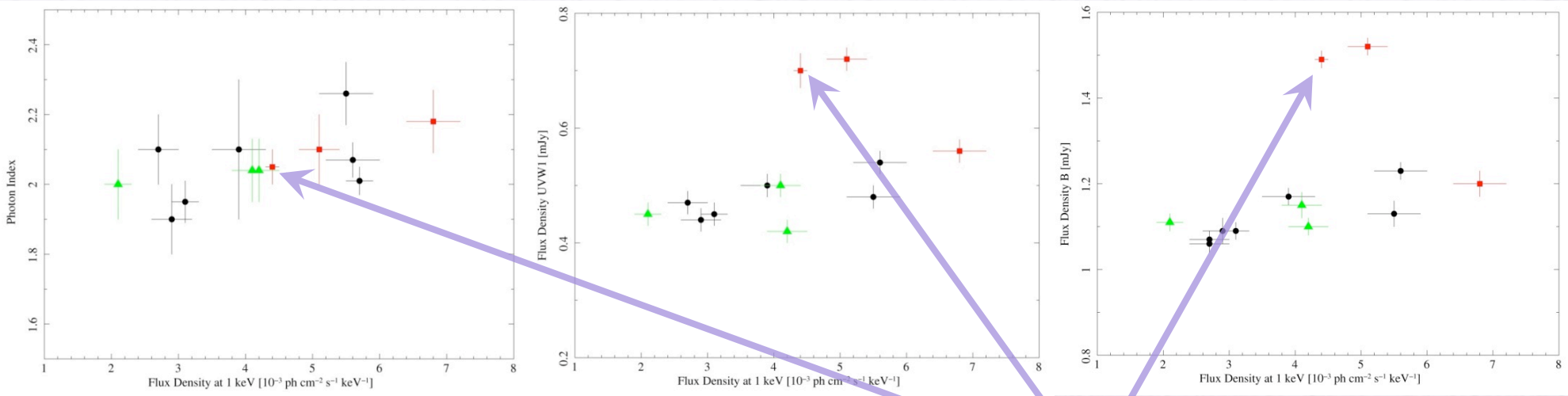
Often flat/inverted radio spectrum and high brightness temperature

Relativistic jet?



First (**negative**) attempt to detect NLS1s at very high-energy γ-rays (E > 400 GeV) with *Whipple* (Falcone et al. 2004).

Hints from X-rays

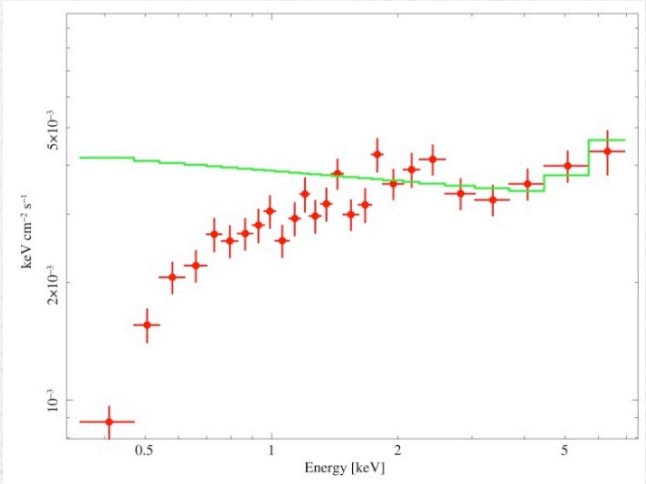


1H 0323+342 (z=0.061) - *Swift* XRT and UVOT

Red squares: hints of broken power-law, with $\Gamma_{soft} > \Gamma_{hard}$ (linked to high UV flux?)

Green triangles: $\Gamma \approx 2$, hints of features in the spectrum; (no clear link; perhaps it is simply due to lack of statistics);

Black points: single power-law, with $\Gamma \approx 2$;

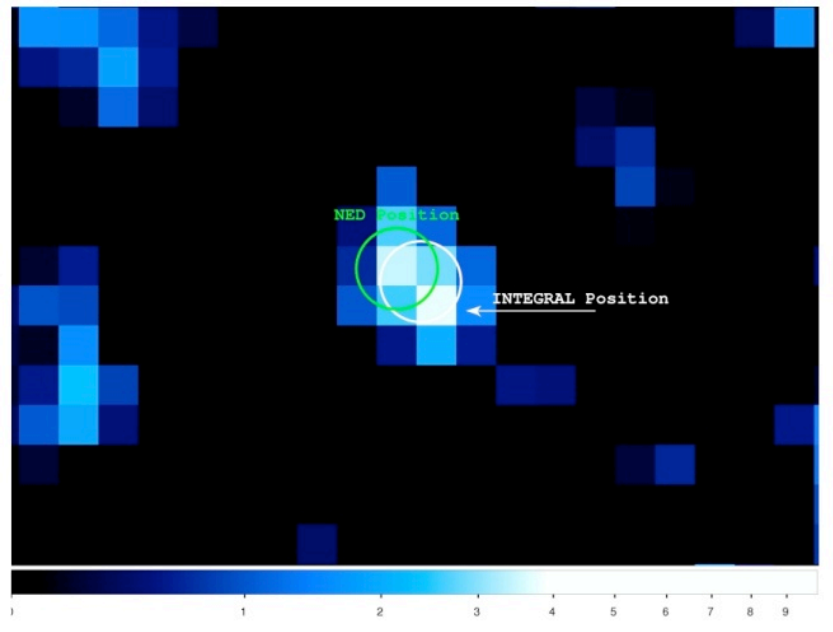


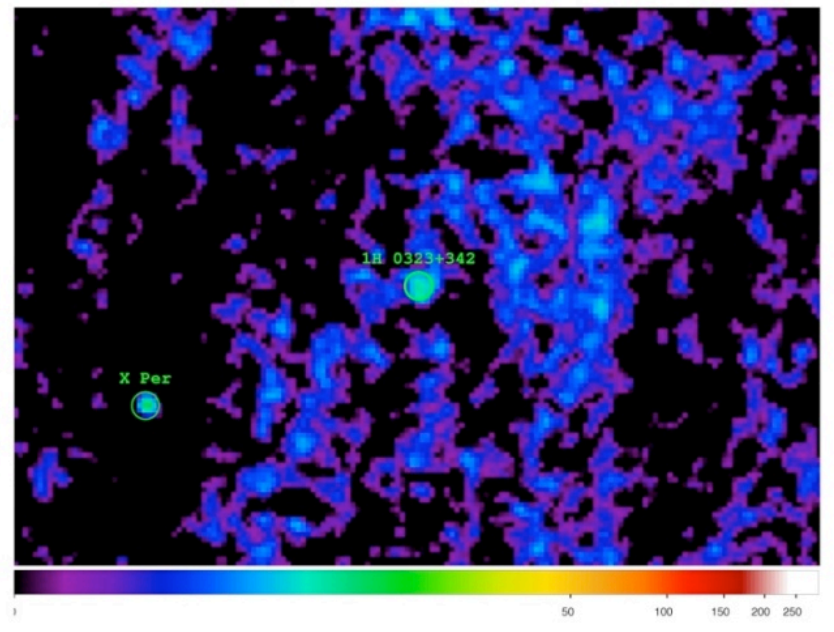
Foschini et al. (2009)

More hints from (hard) X-rays

Foschini et al. (2009)

1H 0323+342 (z=0.061)





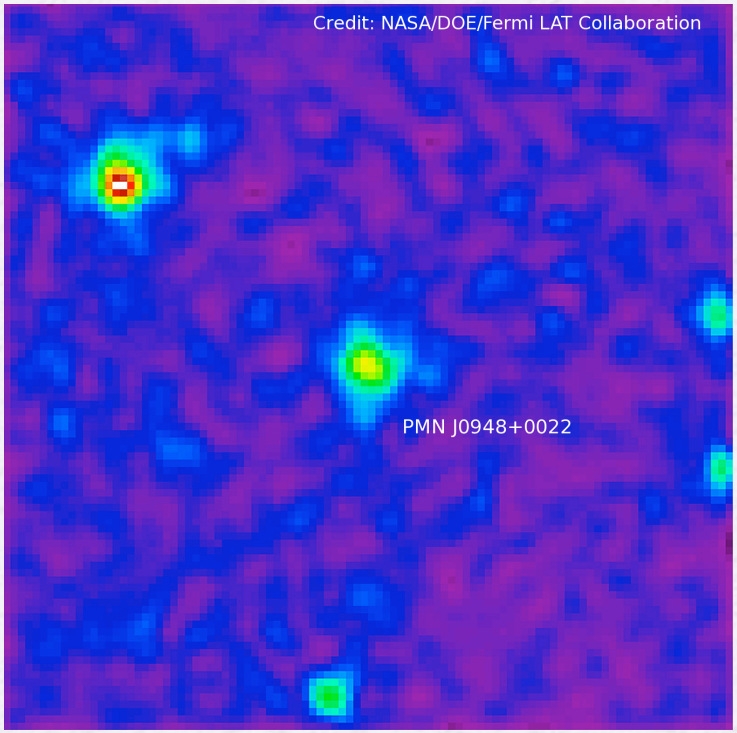
INTEGRAL/ISGRI (exp ≈ 200 ks):
20-40 keV ≈ 2.5 mCrab
40-100 keV < 2.6 mCrab
2004: Faint, Soft

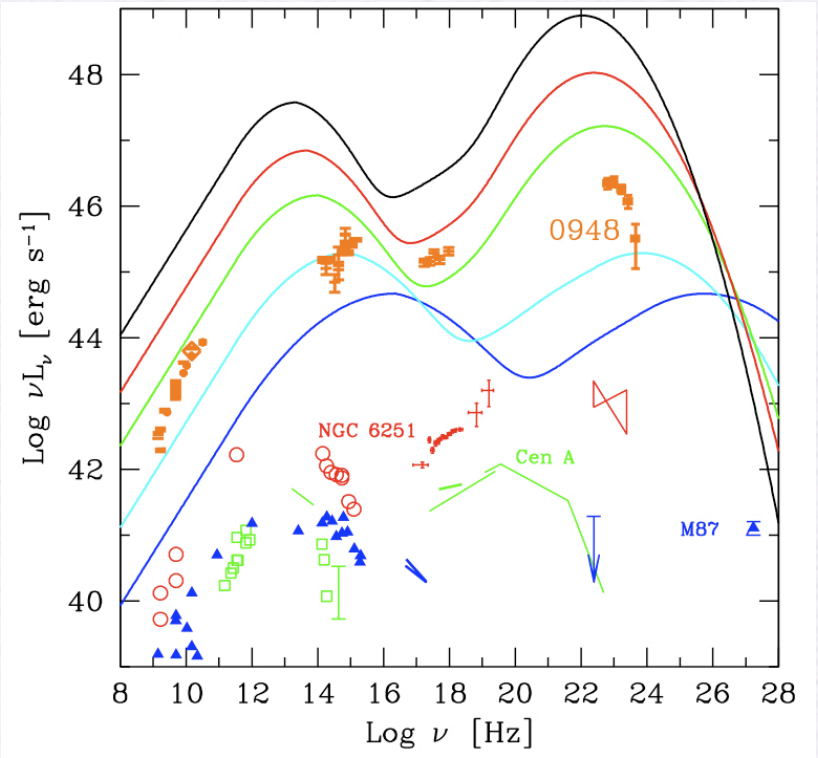
Flux and spectral variability!

Swift/BAT (exp ≈ 53 ks):
20-40 keV < 20 mCrab
40-100 keV ≈ 16 mCrab
2006-2008: High, Hard

Discovery of GeV γ rays from NLS1!

PMN J0948+0022 a.k.a. SDSS J094857.31+002225.4 (0.5846)
The first NLS1 detected at high-energy γ−rays (E > 100 MeV)

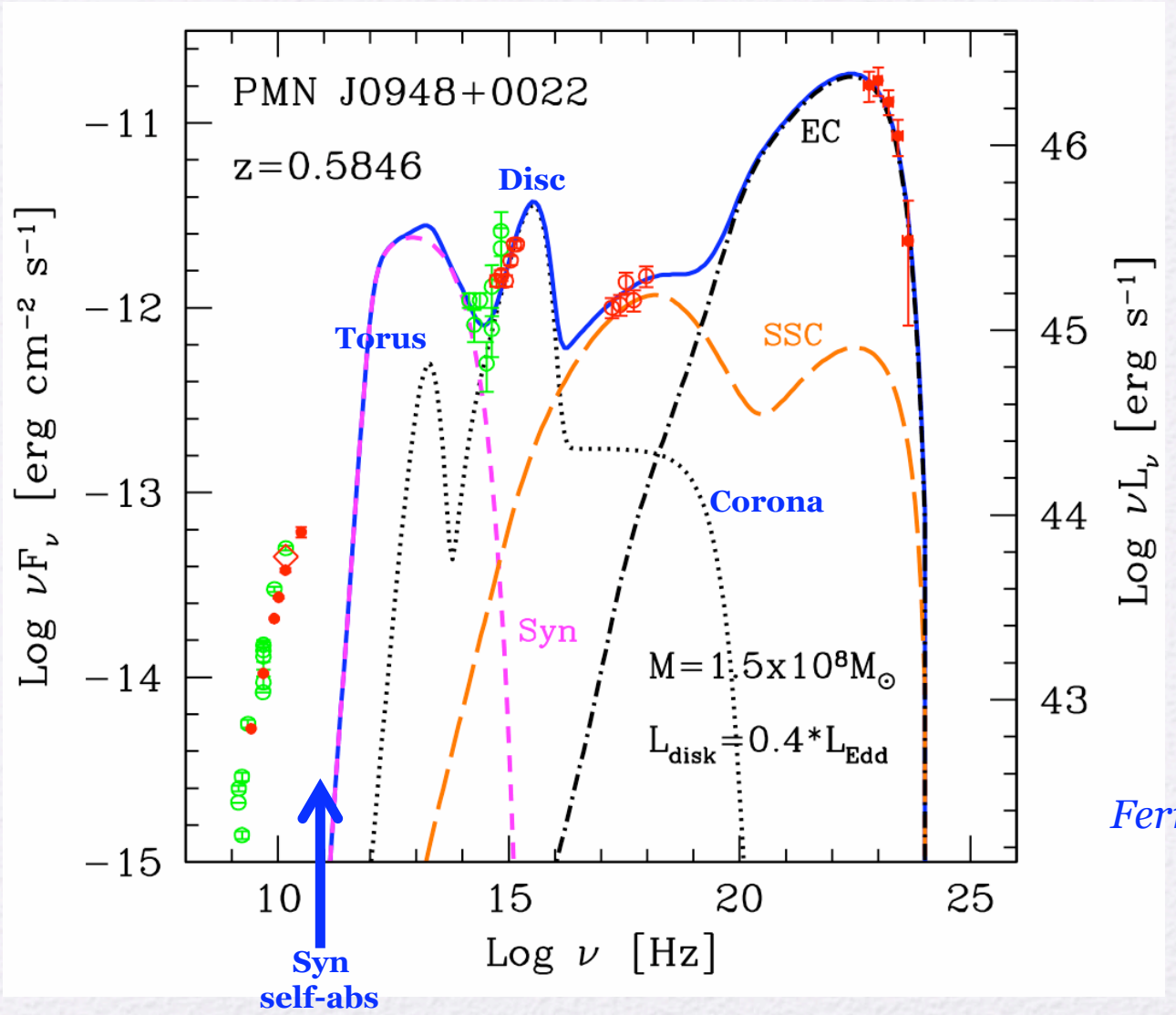




Already found to be radio-loud with flat spectrum and high brightness temperature by Zhou et al. (2003)

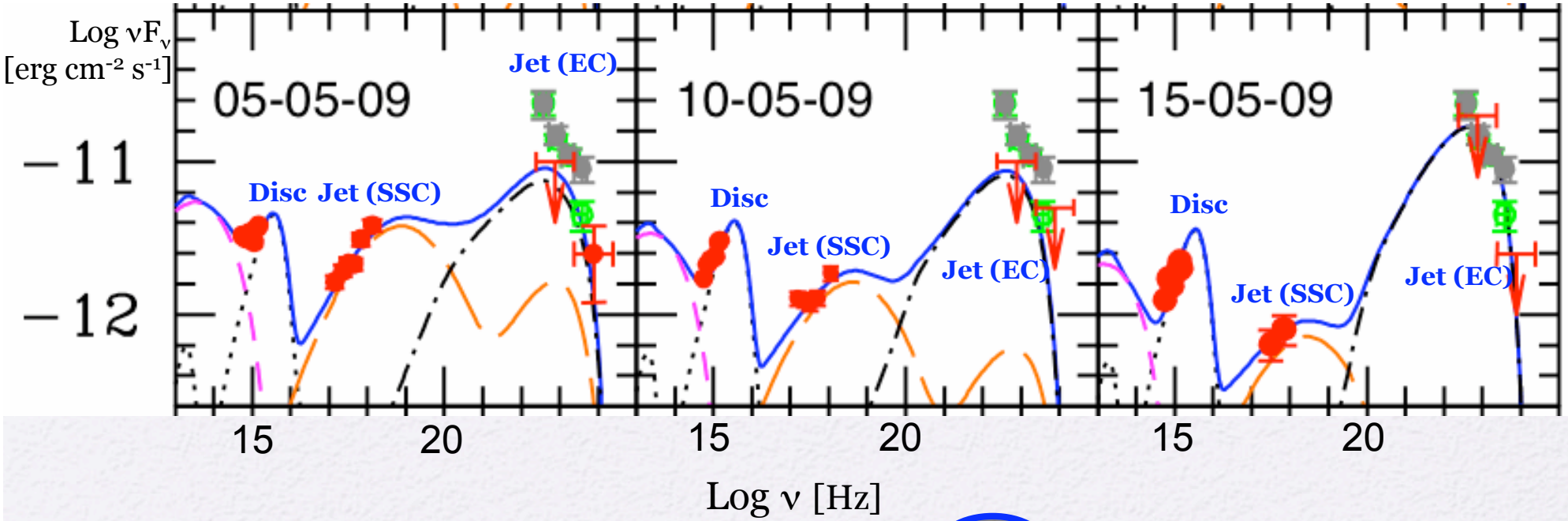
Fermi/LAT Coll. (Abdo et al.) 2009a
Fermi/LAT Coll. (Foschini et al.) 2010

Discovery of GeV γ rays from NLS1!



Fermi/LAT Coll. (Abdo et al.) 2009a

SED model described in detail in Ghisellini & Tavecchio (2009)

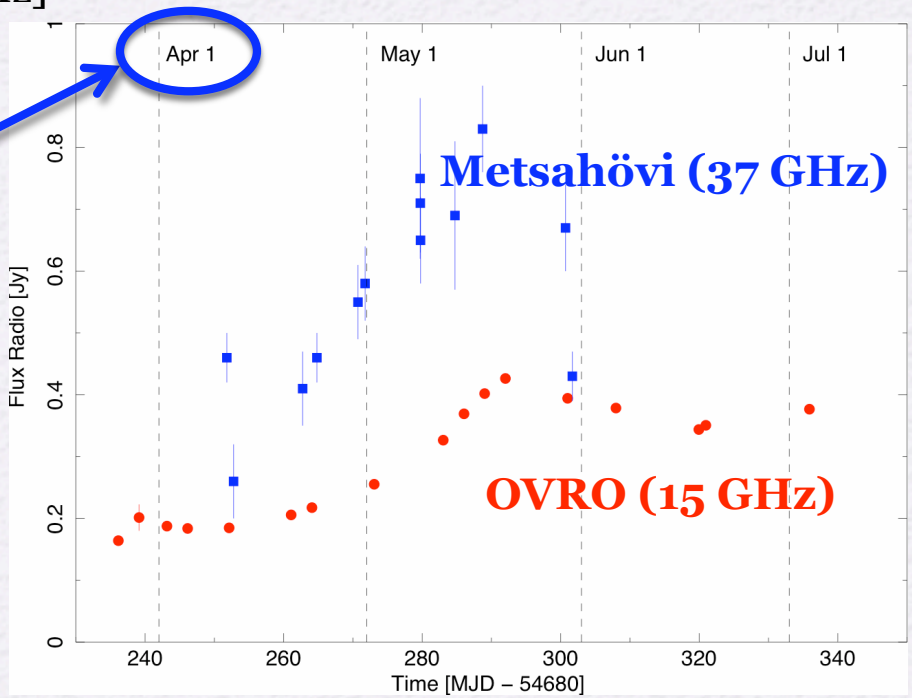


2009 MW Campaign on J0948+0022

γ-ray activity in early April 2009 (peak ≈ 4×10^{-7} ph cm^{-2} s^{-1}), drop of the MW fluxes, followed by an increase of radio emission after less than 2 months;

correlation between optical, X- and γ rays

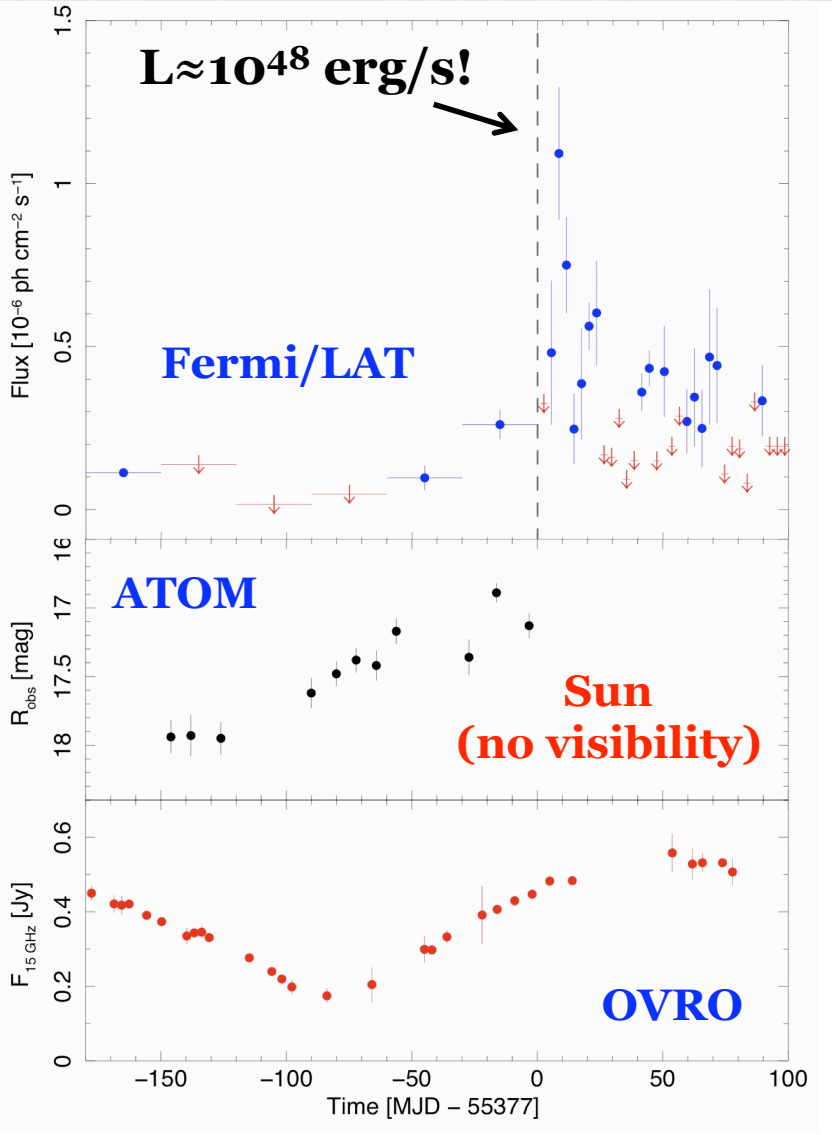
jet emission, confirmation of the association



NEW! Recently confirmed by detection of strong optical (V) polarization (19%) with Kanata telescope (Ikejiri et al. 2011)

Fermi/LAT Coll. (Abdo et al.) 2009b

2010 MW Campaign on PMN J0948+0022



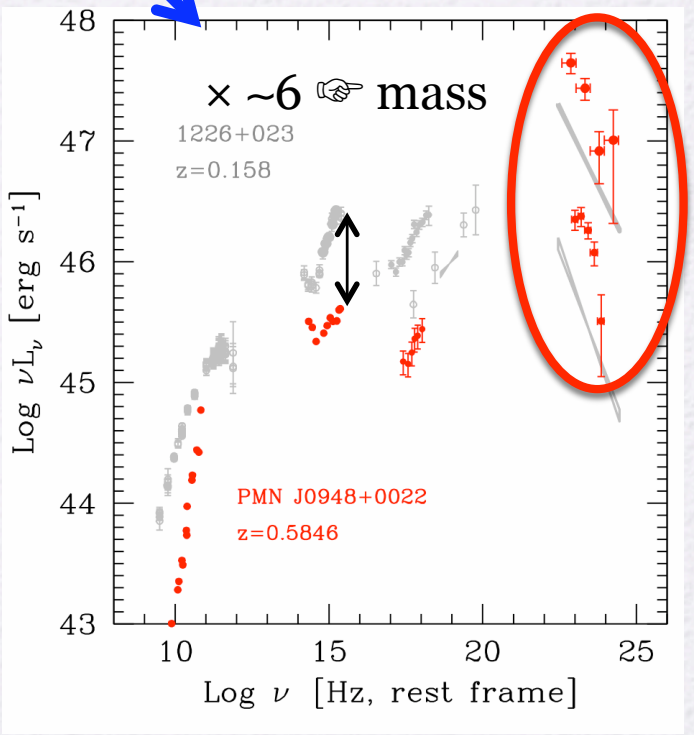
2010 July-September:

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

• Extreme power, when compared to the emission at other wavelengths.

Foschini et al. (2011)

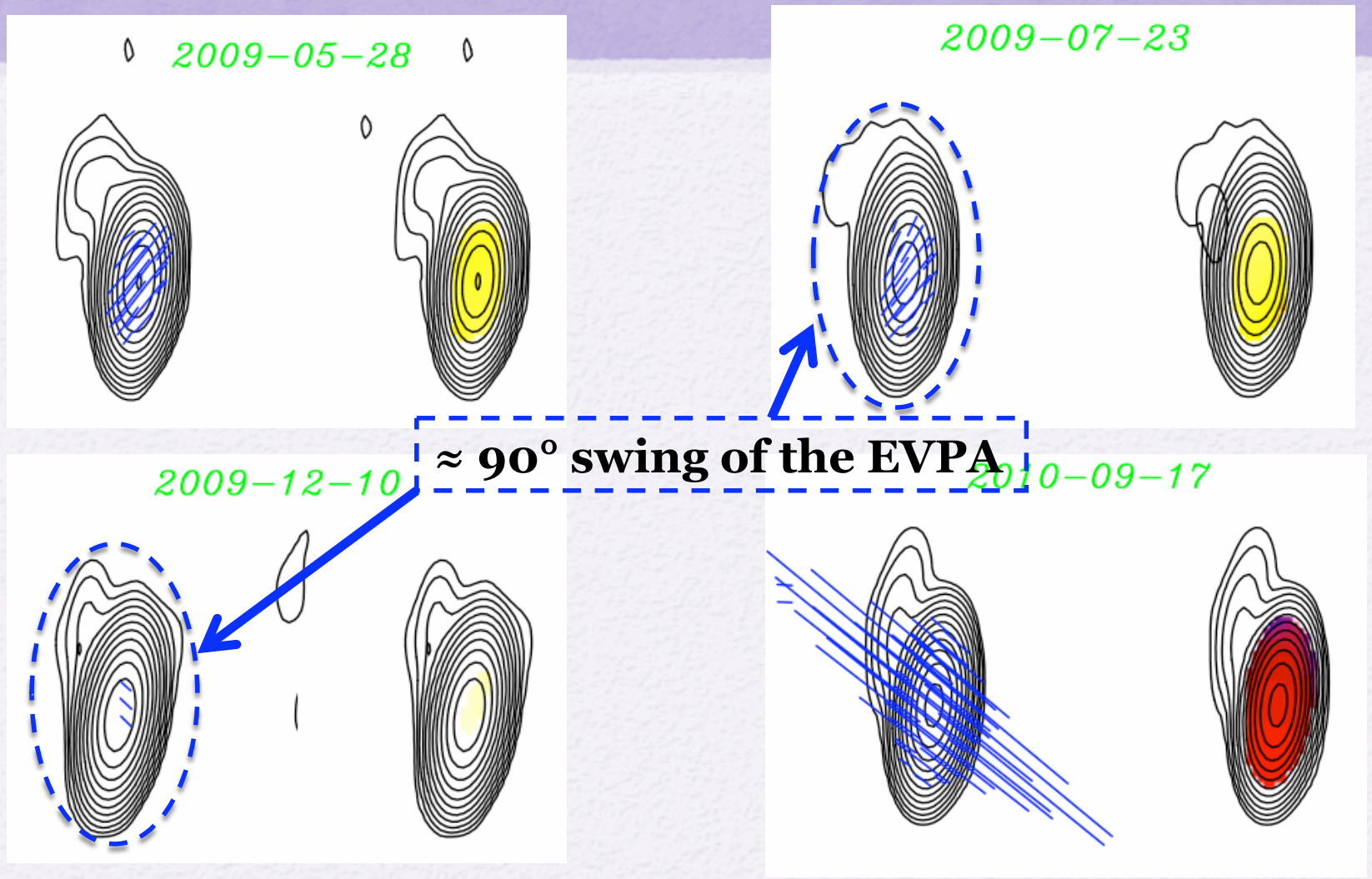
Small, but nasty!



10 pc

Radio morphology and polarization

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



Peak after γ burst

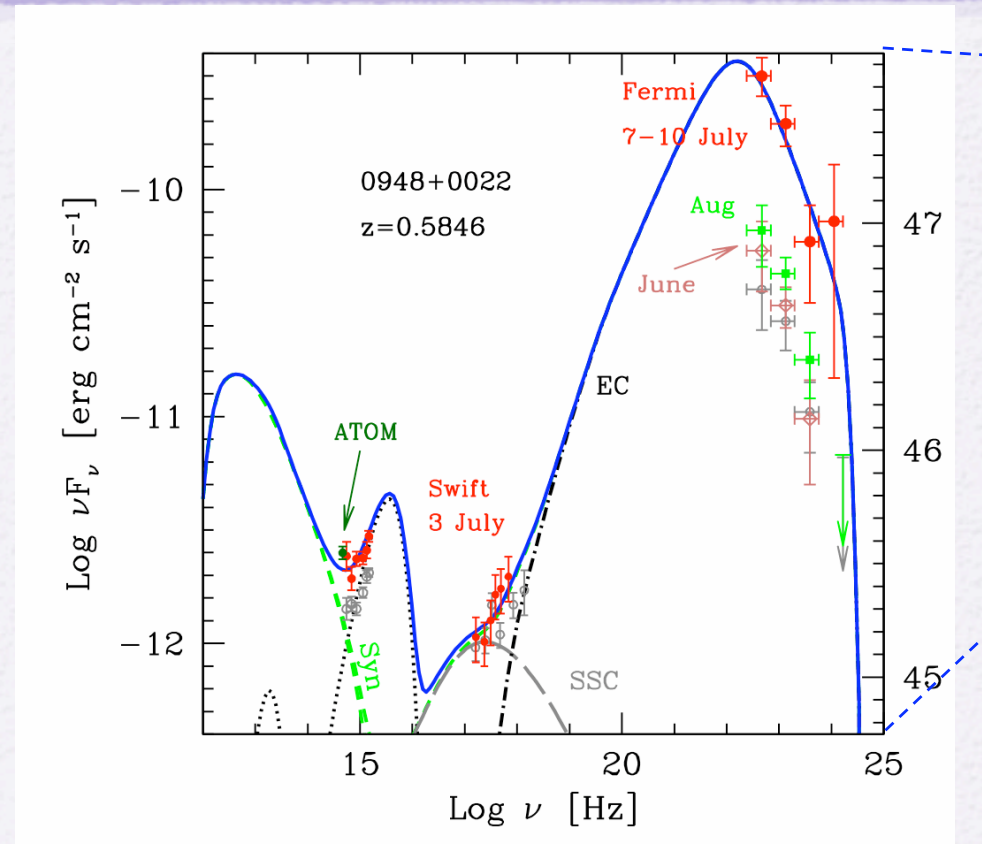
Similar to the 2008 outburst of the ***blazar*** PKS 1502+106

Fermi/LAT Coll. (Abdo et al.) 2010

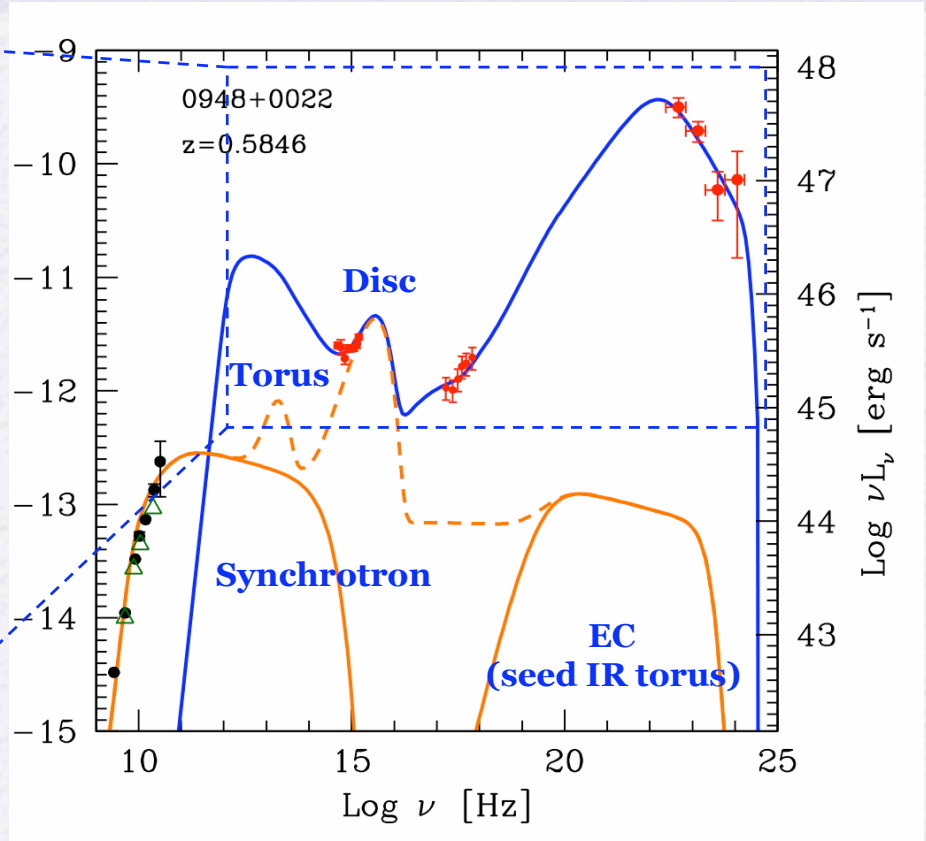
Foschini et al. (2011)

Spectral Energy Distribution (SED)

SED model described in detail in Ghisellini & Tavecchio (2009)



SED at the γ burst (7-10 July 2010) (blue model)



SED at the radio peak (Sept 2010) (orange model)

Foschini et al. (2011)

Typical relativistic jet
e.g. Blandford & Königl (1979)

Corona

Accretion disk

BLR

Molecular Torus

BH

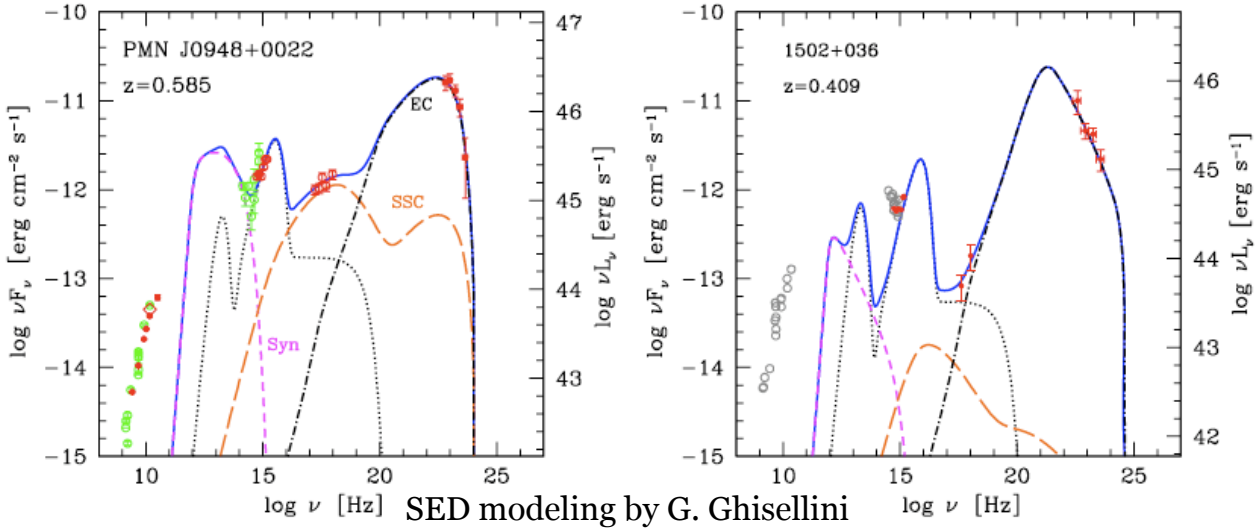
JET

Blue model:
compact blob
γ rays: high
Radio: opt. thick
R << 1 pc

< 2 months

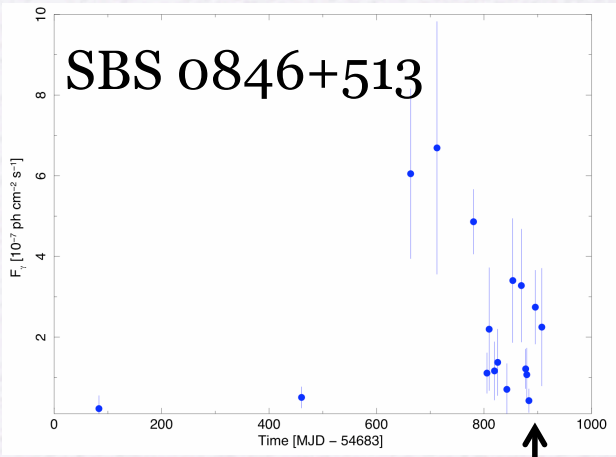
Orange model:
expanded and cooled blob
γ rays: low
Radio: opt. thin
R >> 1 pc

More γ-NLS1s …



SED modeling by G. Ghisellini

Fermi/LAT Coll. (Abdo et al.) 2009c



Foschini (2011a)

7 γ-NLS1s found to date in 30 months of data…

The search continues…

Detection still dependent on the activity of the source.

Host Galaxy of γ-NLS1s ...

Blazars and Radio Galaxies are hosted in ellipticals... ☞ Jet/Elliptical Paradigm

NLS1s are generally hosted in (barred) spirals

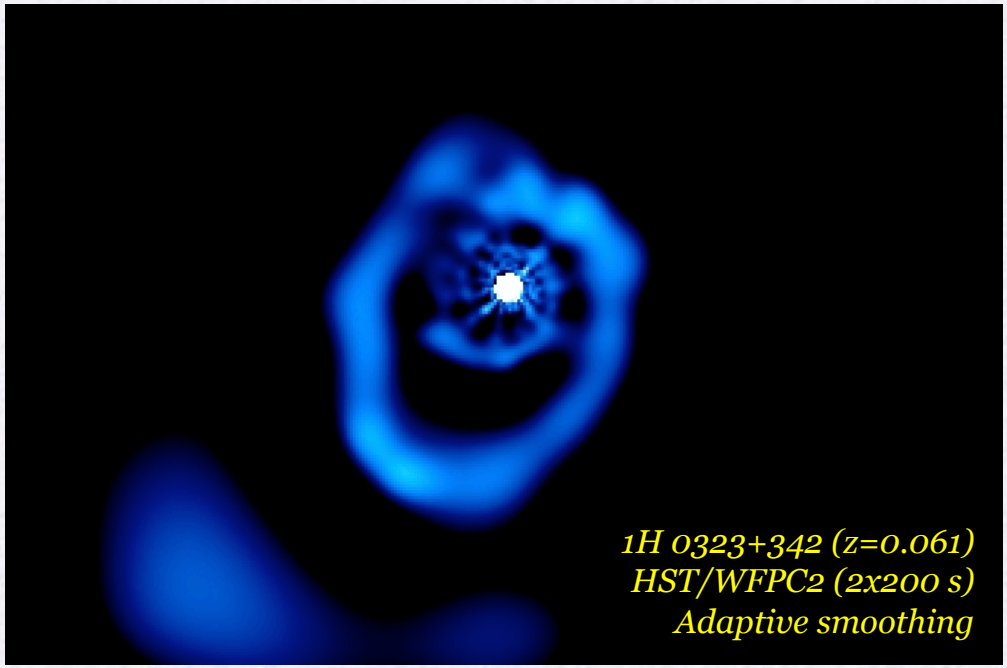
γ-NLS1s: one imaged with sufficient resolution (1H 0323+342) ☞ spiral arms!

Foschini (2011a)

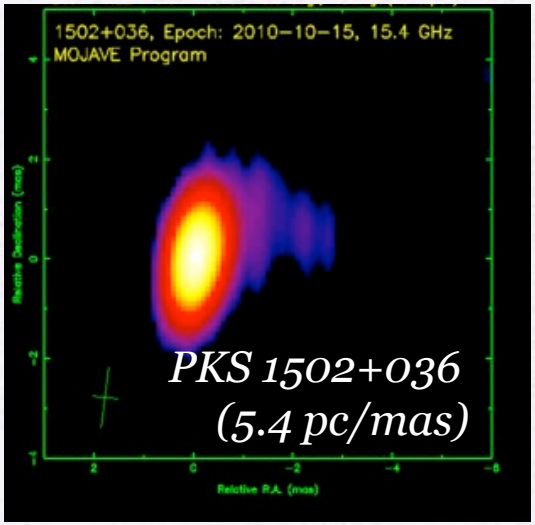
We need of more high-resolution observations!

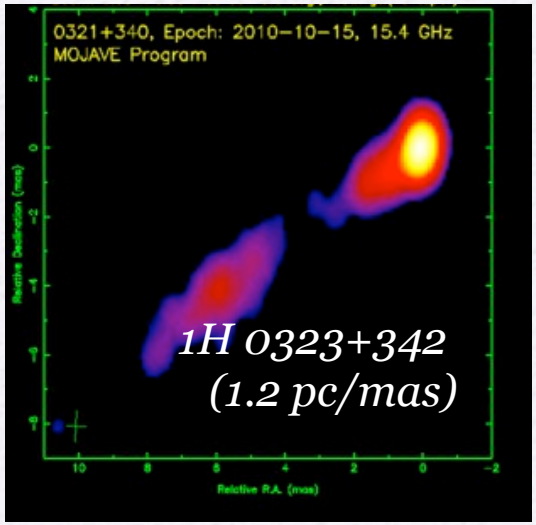
Zhou et al. (2007): spiral morphology

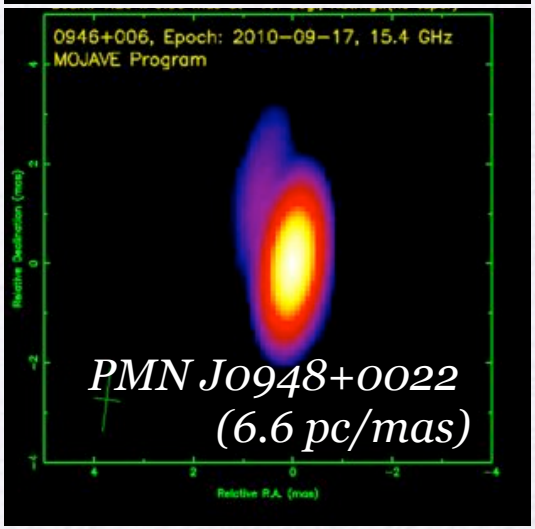
Anton et al. (2008): ring due to a recent merger

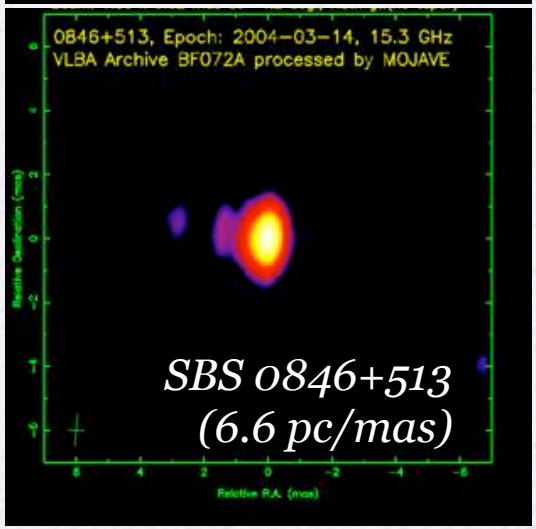


Radio morphology of γ-NLS1s …

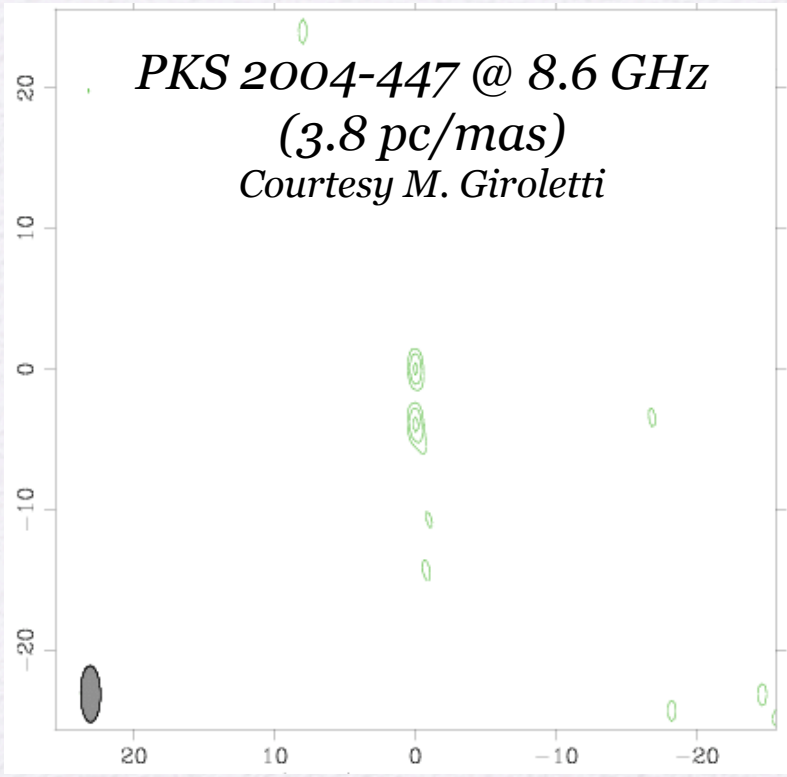




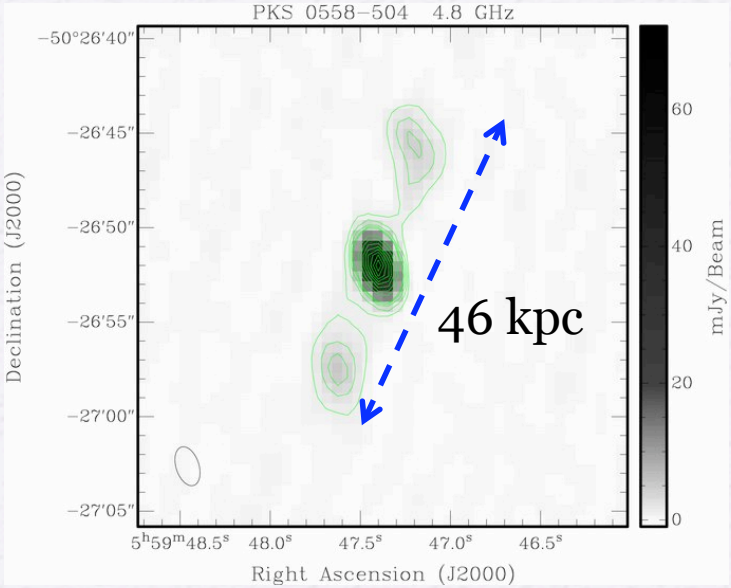




VLBA (2cm/15 GHz)
MOJAVE Project
(☞ http://www.physics.purdue.edu/MOJAVE/)



Search for the parent population: **radio galaxies in spirals**



7 γ-NLS1 with Γ≈10 ⇒ ≈ 700 NLS1 RG

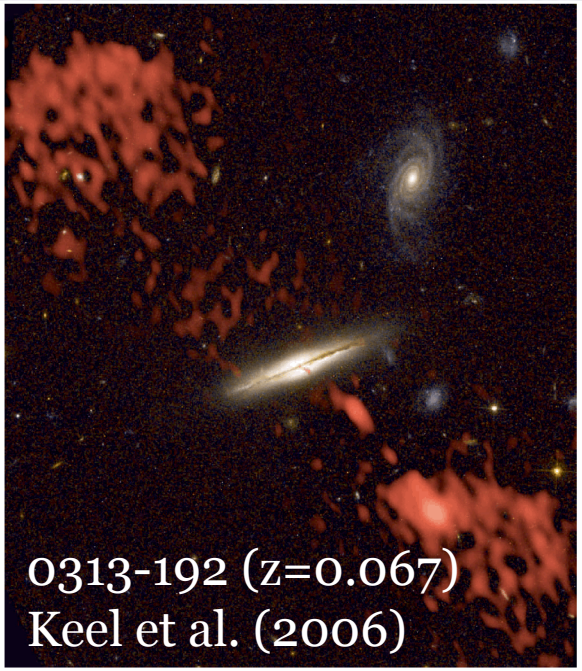
One found by Gliozzi et al. (2010), which is PKS 0558-504, but where are the others??

Should we search among NLS1 or among RG in spirals?

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).

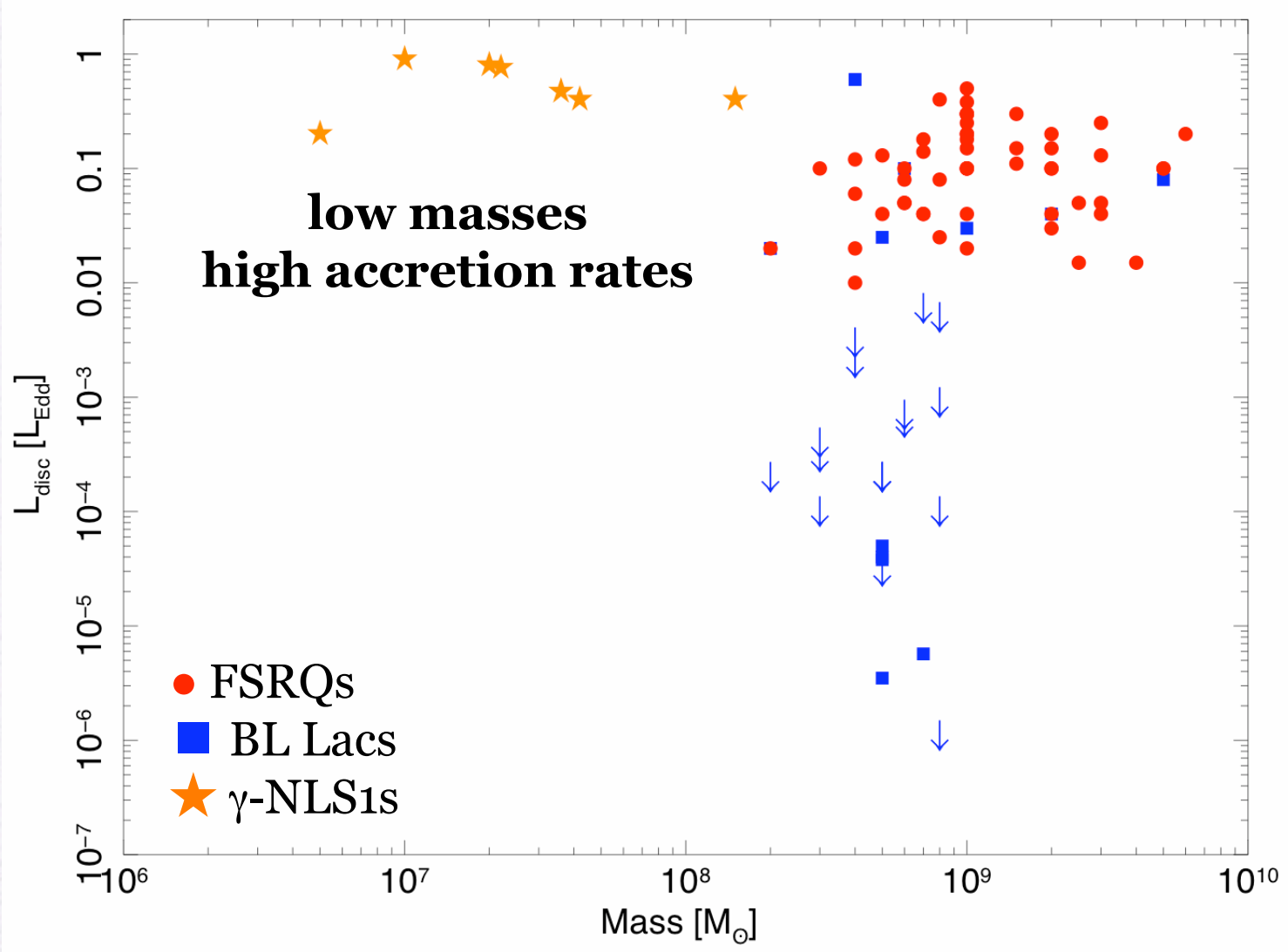
Some examples found (14), but checking for more sources...
2 γ-ray detections with *Fermi*: PKS 0336-177 (1LAC) and possibly PKS 1413+135 (under study); searching for more as data accumulate.

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



Implications on relativistic jets

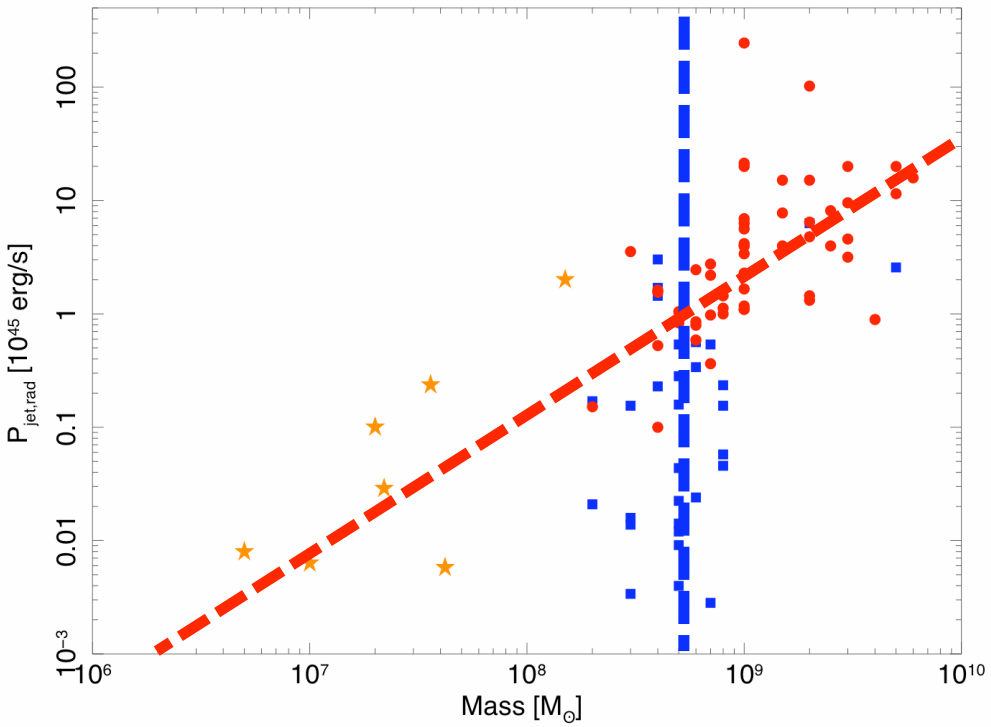
Foschini (2011b,c)

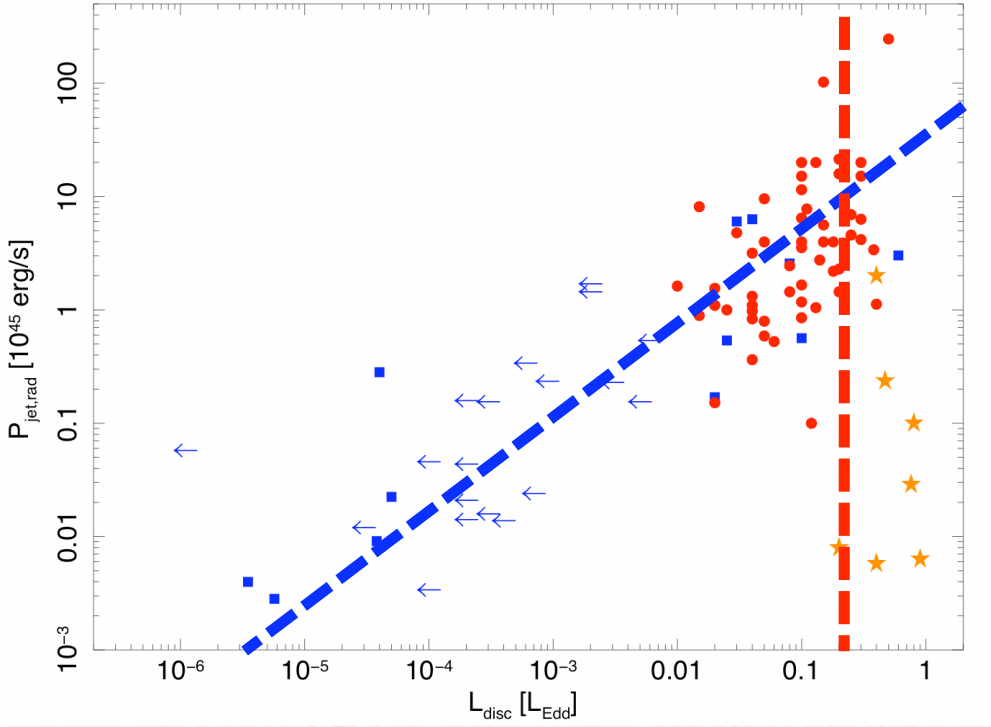


Jet as a function of mass and accretion rate: *two regimes?*

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

Moderski & Sikora 96;
Gosh & Abramowicz 97

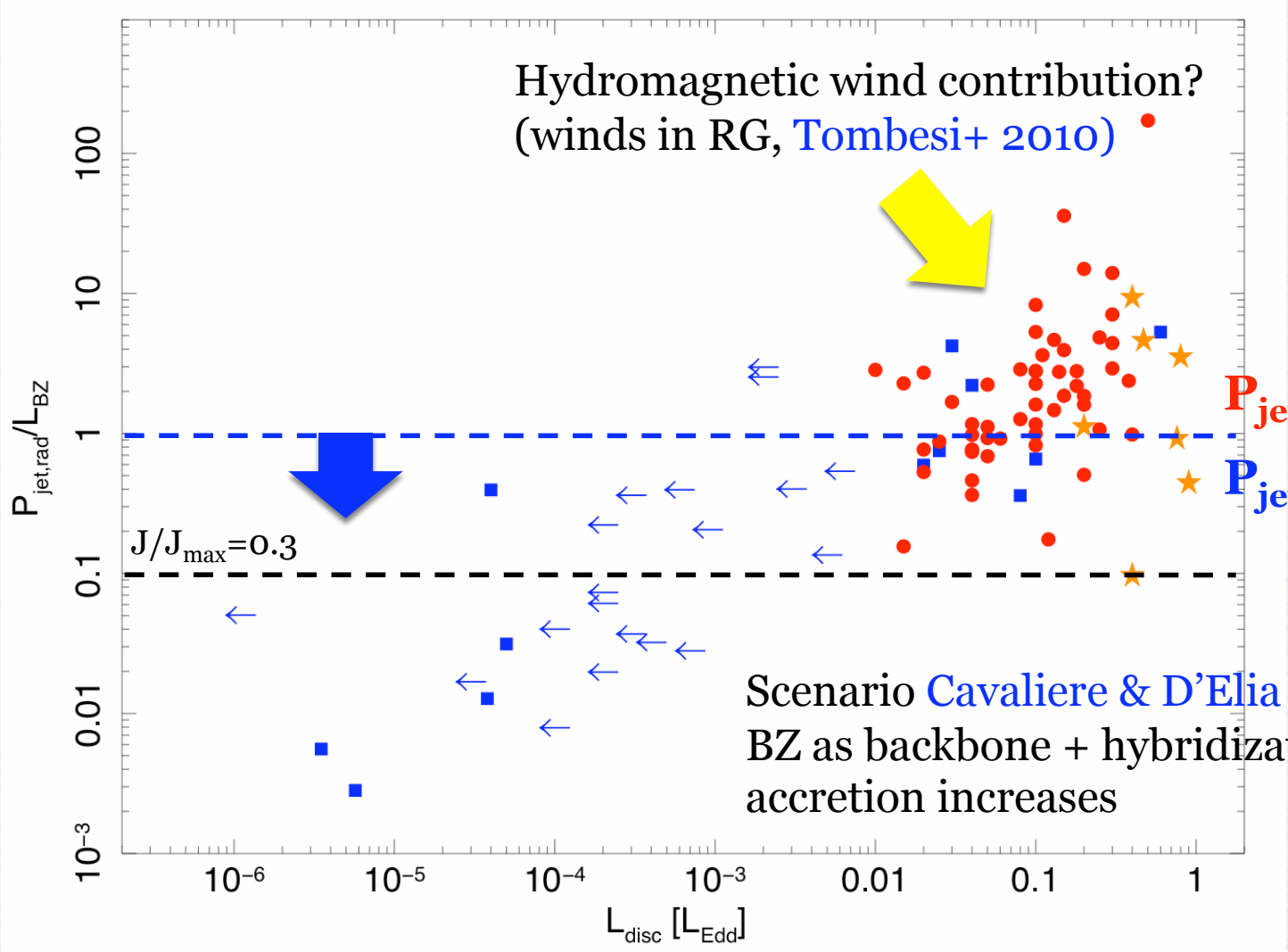




Foschini (2011b)

Comparison with Blandford-Znajek

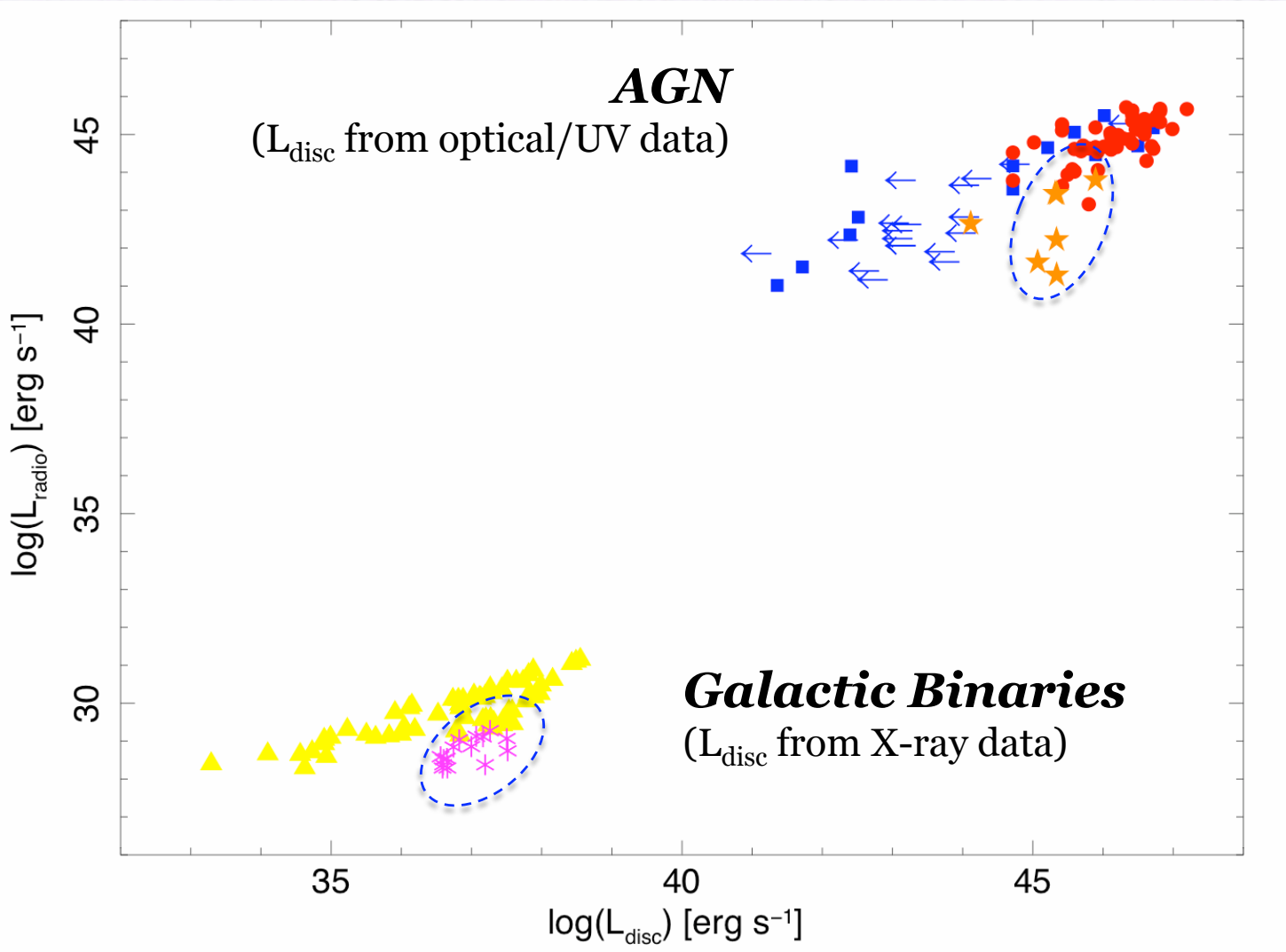
Calculated according to *Ghosh & Abramowicz 97*



Foschini (2011b)

Jets at all scales!

Observed data!



NSs are low mass analog of stellar mass BHs

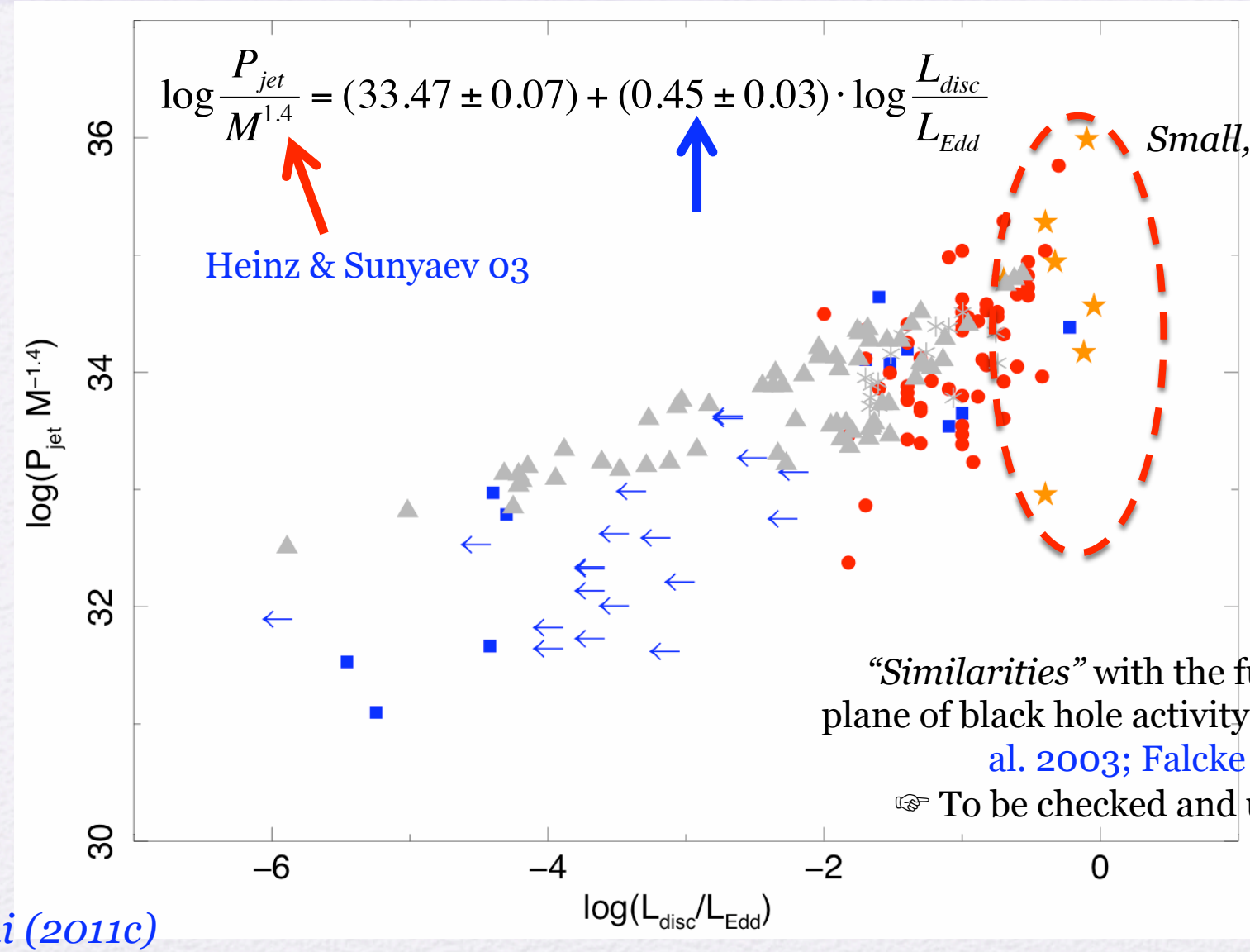
γ-NLS1s are low mass analog of blazars

- FSRQs
- BL Lacs
- γ-NLS1s
- BHs
- NSs

Foschini (2011c)

Scaling jet power with mass

Accretion with Eddington luminosity

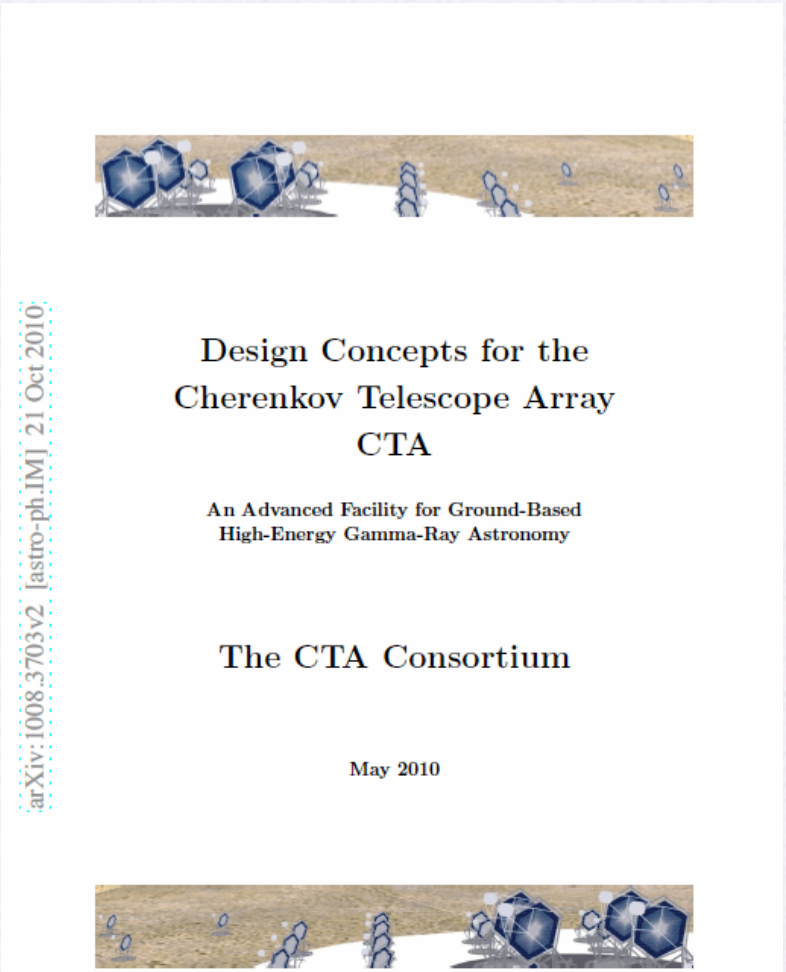


"Similarities" with the fundamental plane of black hole activity (Merloni at al. 2003; Falcke et al. 2004)

☞ To be checked and understood.

Foschini (2011c)

Perspectives for CTA

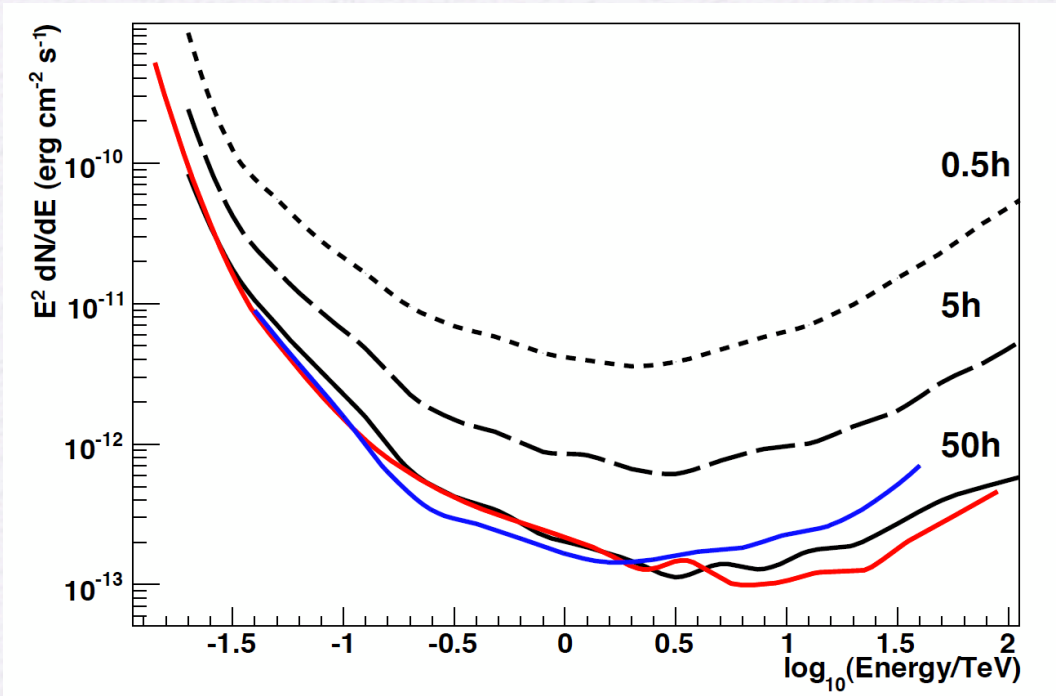


Design Concepts for the
Cherenkov Telescope Array
CTA

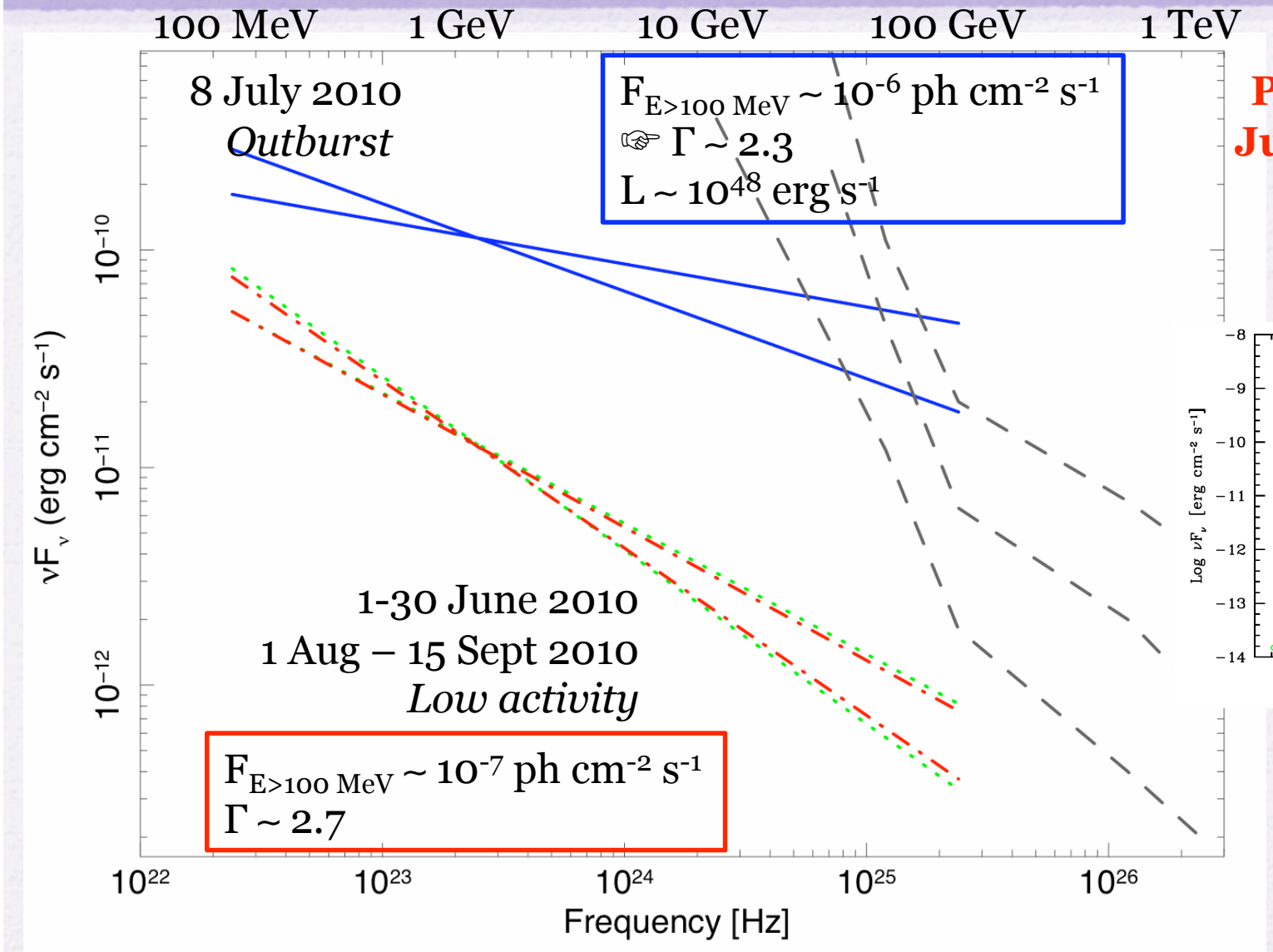
An Advanced Facility for Ground-Based
High-Energy Gamma-Ray Astronomy

The CTA Consortium

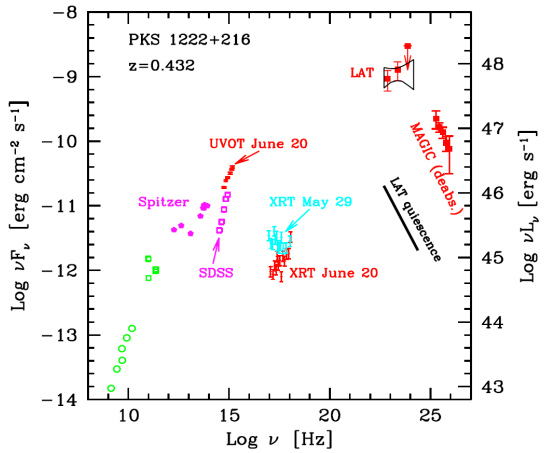
May 2010



Perspectives for CTA

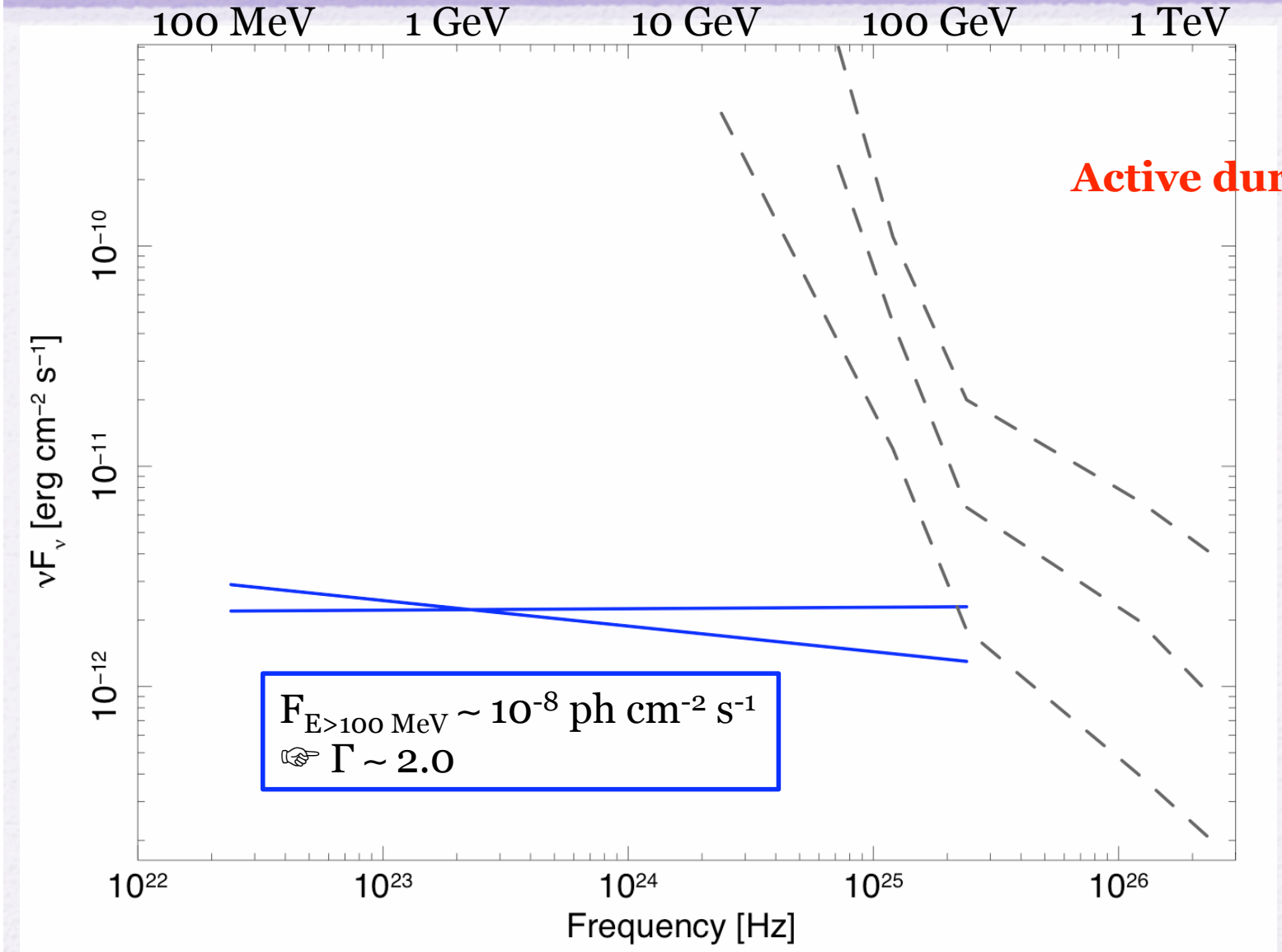


PMN J0948+0022
July 2010 Outburst



PKS 1222+216
Tavecchio et al. (2011)

Perspectives for CTA



SBS 0846+513
Active during the last year

Just a handful of γ-NLS1s discovered to date: does it matter?

No! The lesson from the history:

Satellite	Blazars observed
COS-B	1 (3C 273)
CGRO/EGRET	~ 10^2
Fermi/LAT	~ 10^3
Next one?	~ 10^4 ?

γ-NLS1s with *Fermi*/LAT are 7 to date and the number can increase depending on the activity of the source (e.g. SBS 0846+513).

Do we need a new improved satellite?

Final Remarks