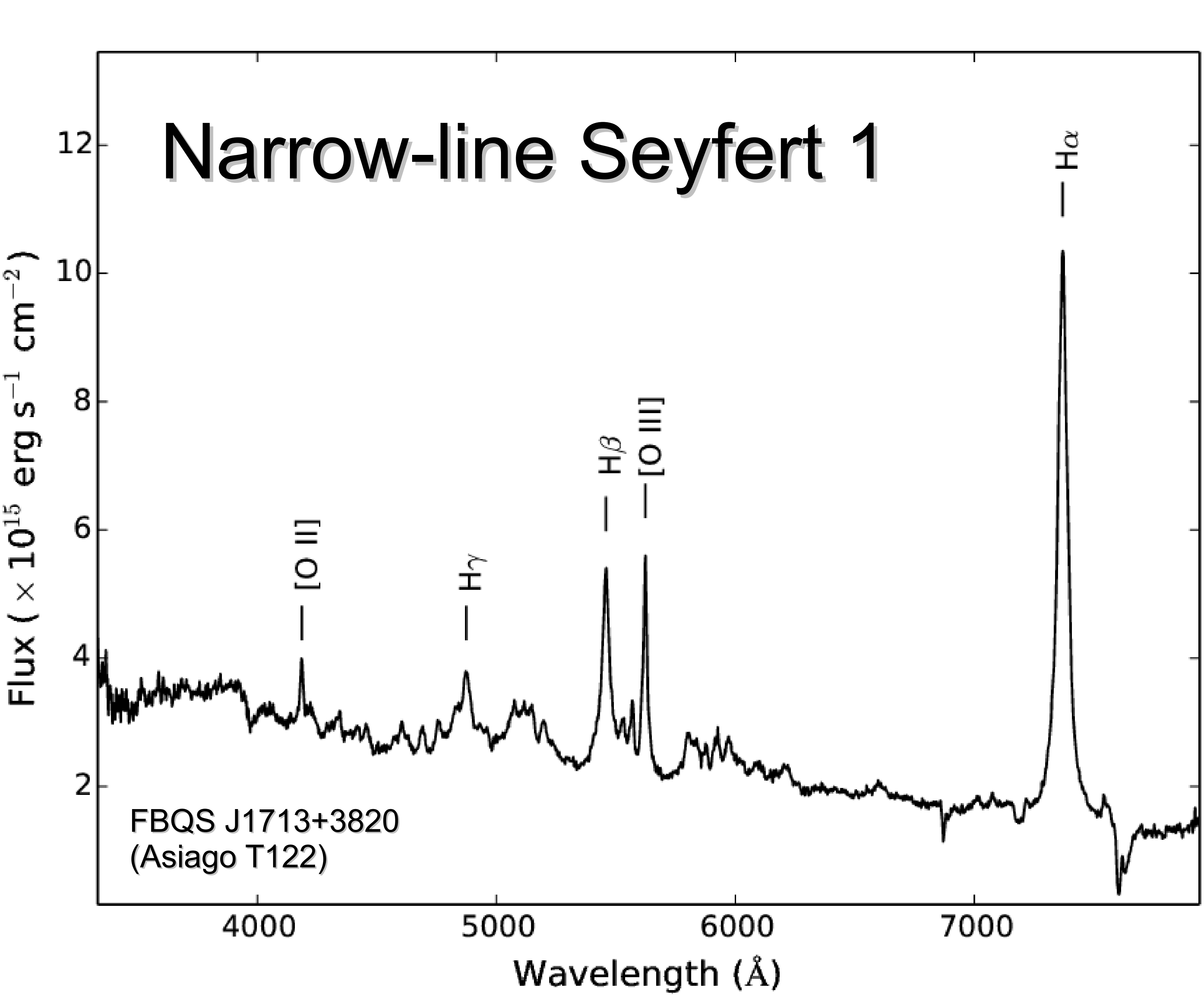
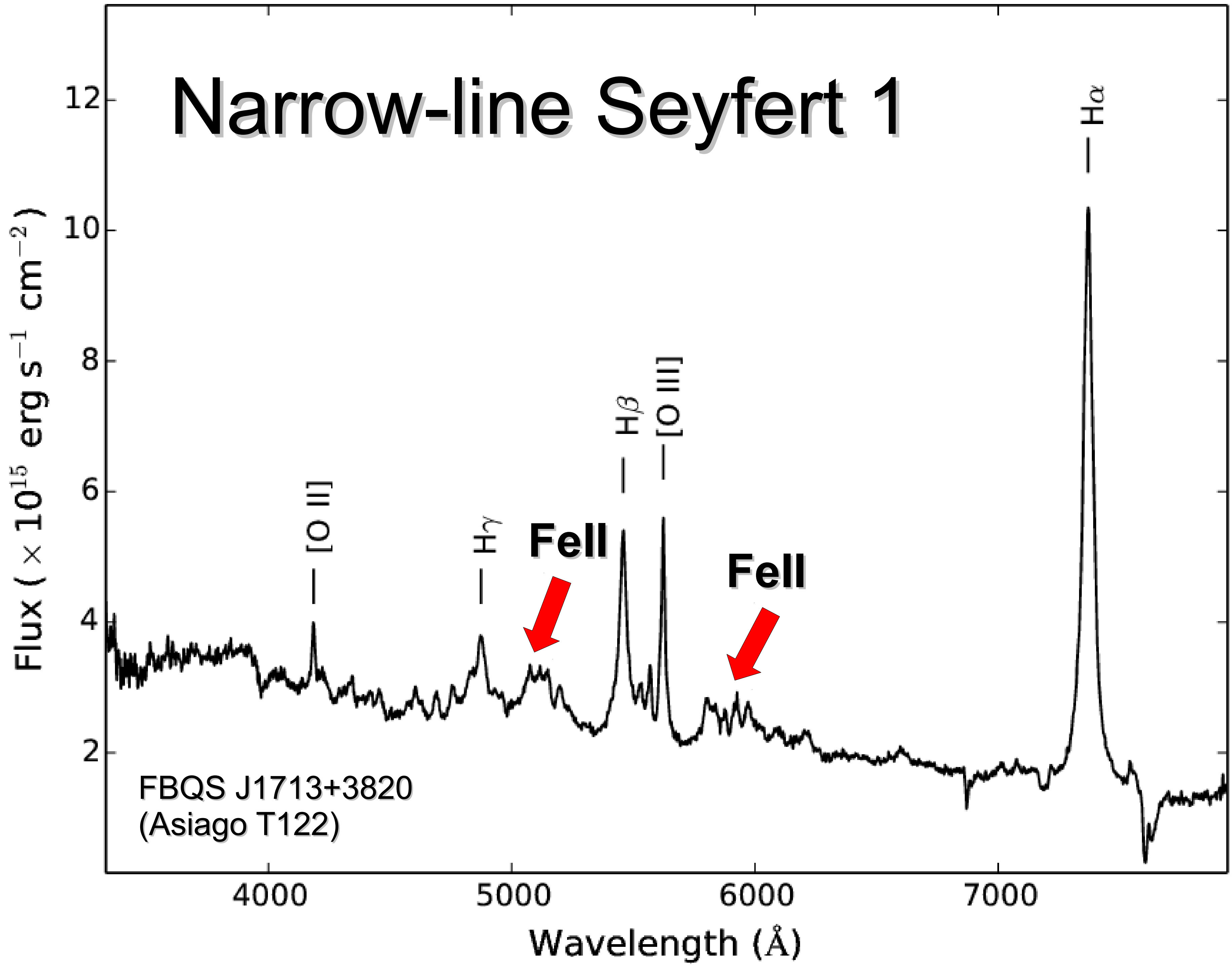
Parent population of flat-spectrum radio-loud narrow-line Seyfert 1 galaxies

Marco Berton

Dept. of Physics and Astronomy "G. Galilei"
University of Padova

Collaboration with L. Foschini (INAF-Brera), S. Ciroi (UniPD),
V. Cracco - G. La Mura - P. Rafanelli - M. Frezzato - E. Congiu (UniPD),
A. Caccianiga (INAF-Brera), B.M. Peterson - S. Mathur (Ohio State),
J.L. Richards - M.L. Lister (Purdue)


Narrow-line Seyfert 1
Hα
Hβ
[O III]
[O II]
Hγ
FBQS J1713+3820
(Asiago T122)
Flux (× 10^15 erg s^−1 cm^−2)
Wavelength (Å)
12
10
8
6
4
2
4000
5000
6000
7000


Narrow-line Seyfert 1
Flux (× 10^15 erg s^-1 cm^-2)
Wavelength (Å)
[O II]
Hγ
Hβ
[O III]
Hα
FeII
FeII
FBQS J1713+3820
(Asiago T122)
2
4
6
8
10
12
4000
5000
6000
7000

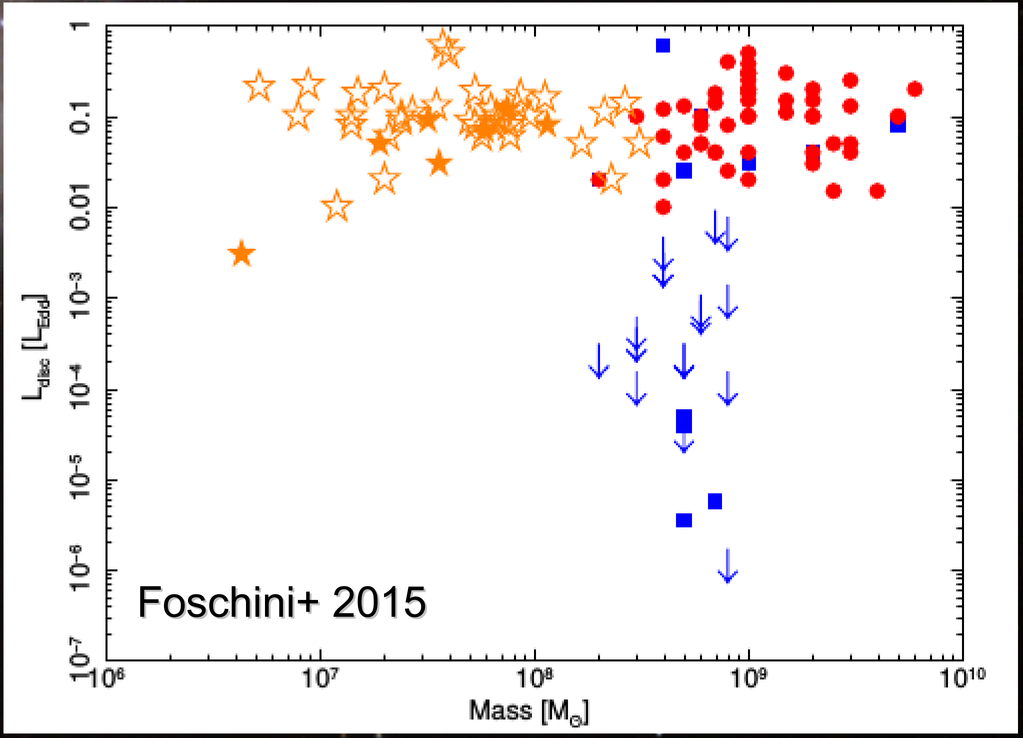
Flat-spectrum radio-loud NLS1s

7% of NLS1s are radio-loud (Komossa+ 2006), and some show blazar-like properties (Yuan+ 2008).

Fermi satellite detected γ-ray emission coming from them (Abdo+ 2009a), indicating a relativistic beamed jet.
To date they are 10 (and counting...), between z = 0.061 (Abdo+ 2009b) - 0.966 (Yao+ 2015).

These F-NLS1s might represent the low-mass tail of γ-ray AGN.
Young: CSS?

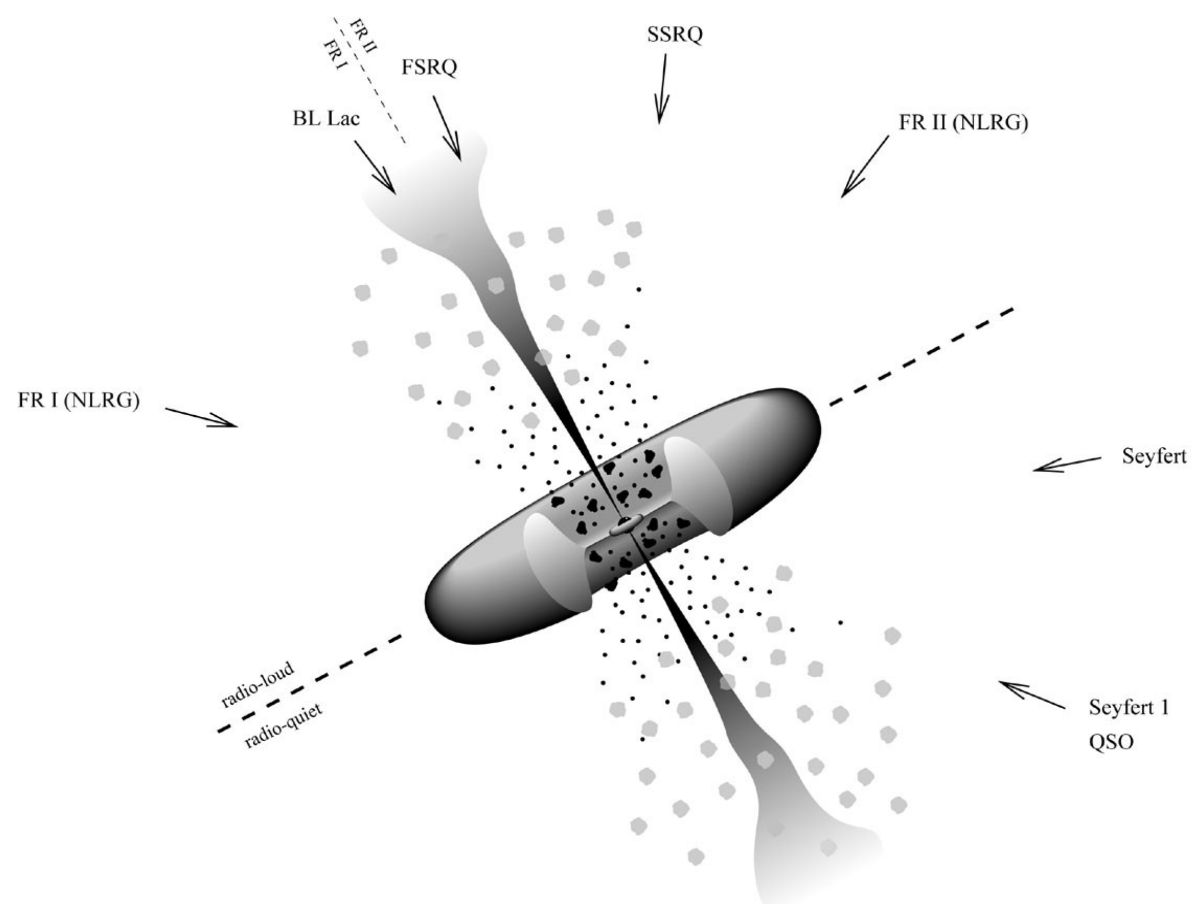
See Luigi Foschini's talk!



Parent population

How do beamed sources look like when randomly oriented?

Assuming Γ around 10, for 10 γ-ray emitting beamed sources, there should be >2000 misaligned sources...

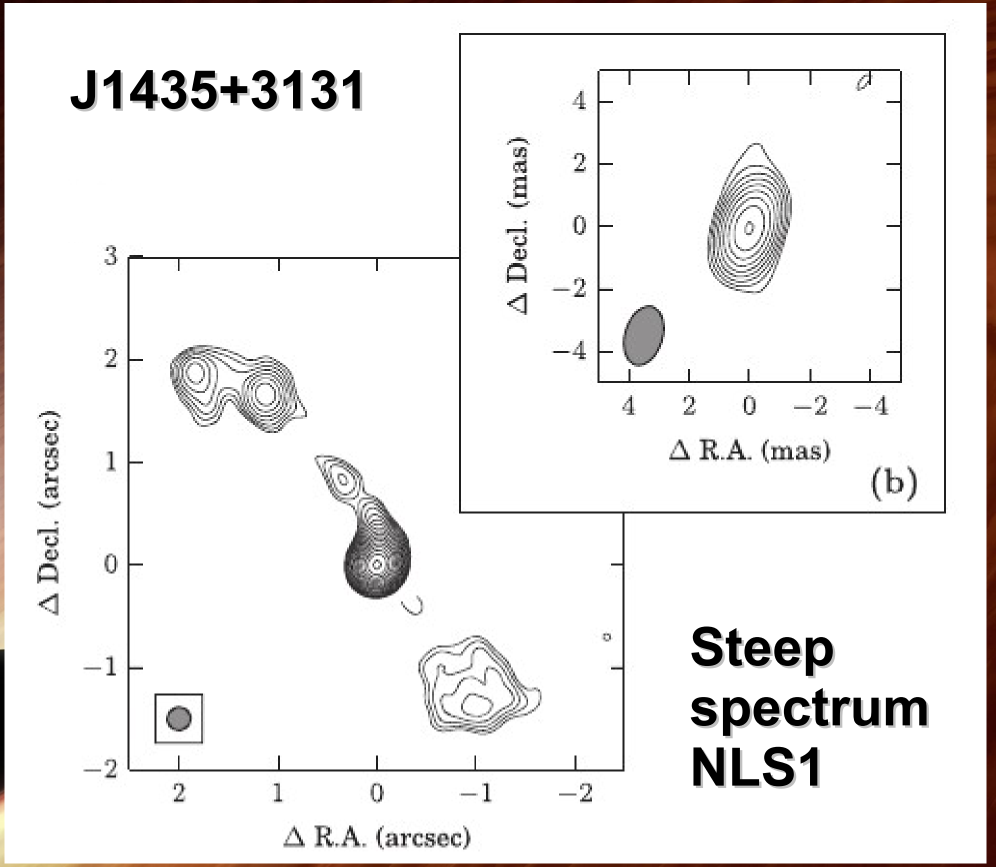


Hypotheses

1. ***S-NLS1s***

2. RQ-NLS1s

3. BLRG/NLRG



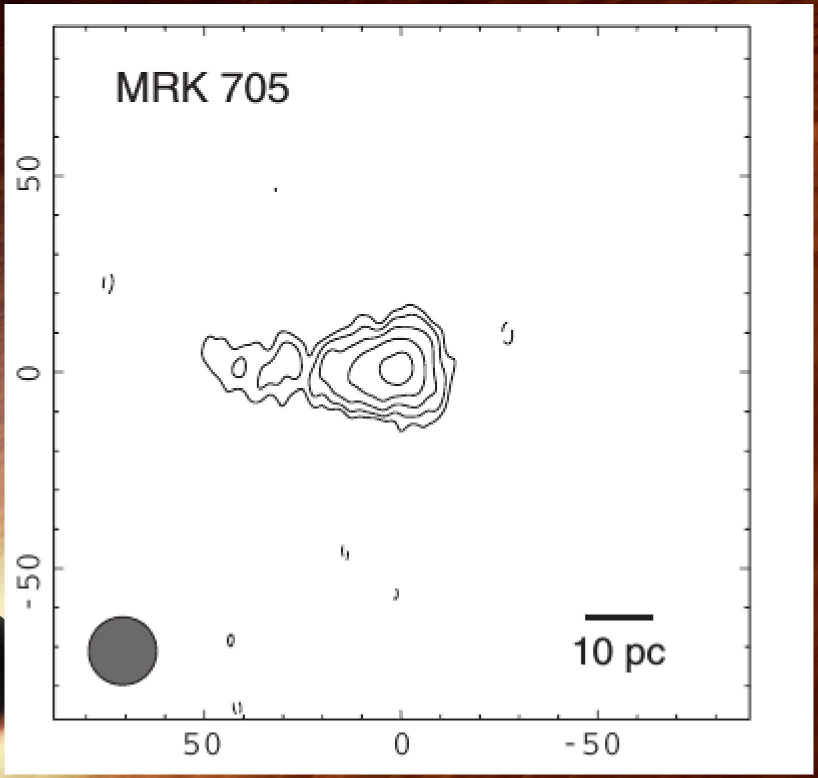
Richards & Lister 2015

Hypotheses

1. S-NLS1s

2. ***RQ-NLS1s***

3. BLRG/NLRG



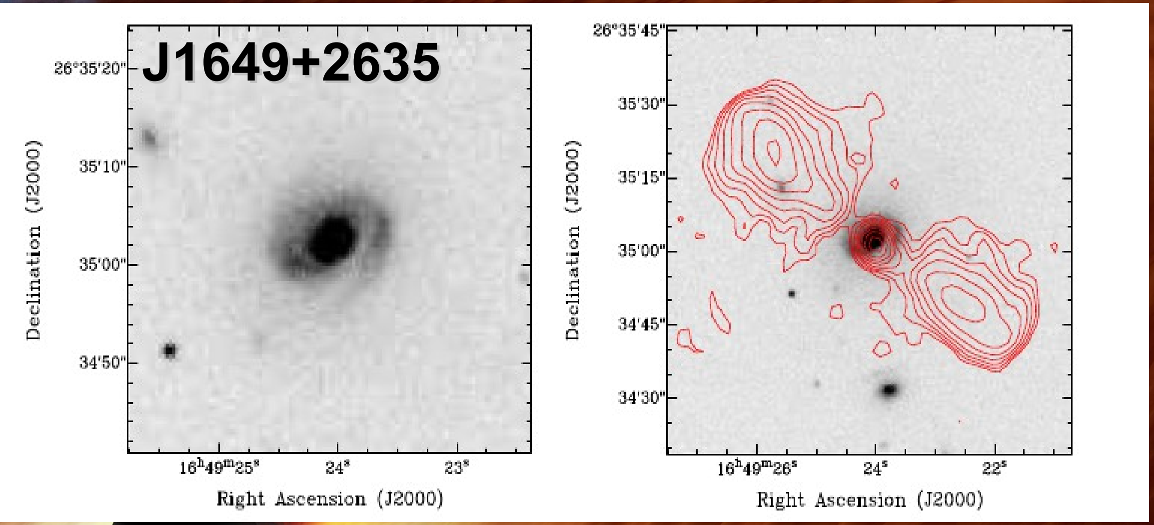
Doi+ 2013

Hypotheses

1. S-NLS1s

2. RQ-NLS1s

3. ***BLRG/NLRG***



Mao+ 2015

Black hole mass

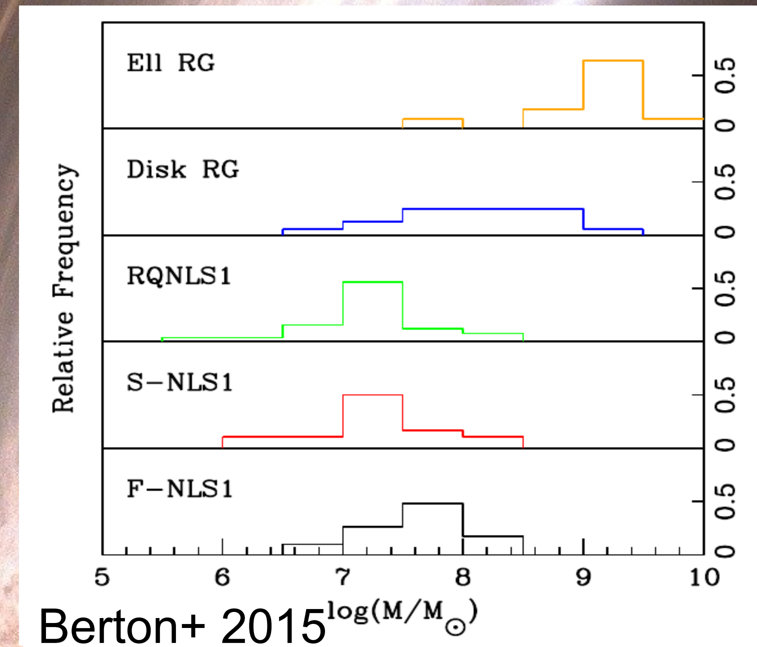
I analyzed optical spectra to derive the Hβ second-order momentum σ (type 1) or the stellar velocity dispersion (type 2). Then I calculated the black hole mass via:

$$M_{BH} = f\left(\frac{R_{\rm BLR}\sigma^2_{\rm H\beta}}{G}\right),$$

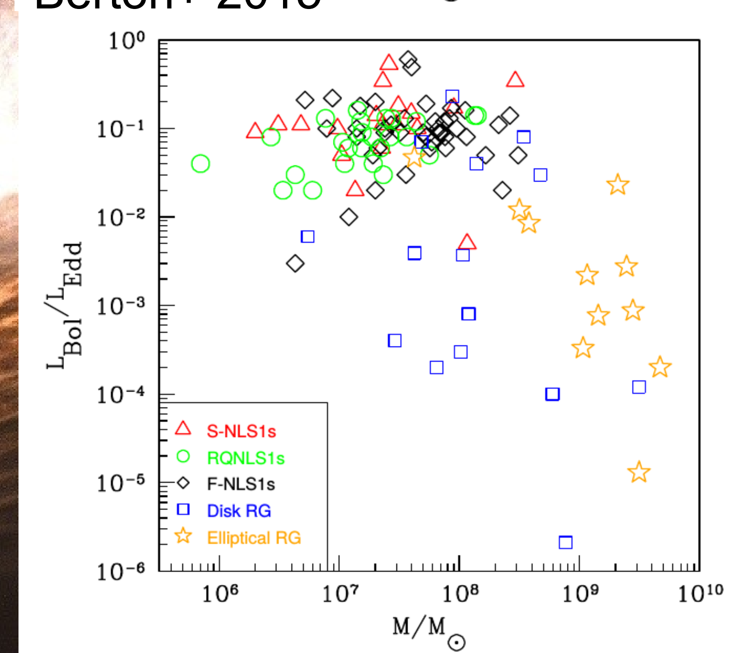
or

$$\log\left(\frac{M_{\rm BH}}{M_\odot}\right) = 8.49 + 4.38 \log\left(\frac{\sigma_*}{200\,{\rm km\,s^{-1}}}\right).$$

Lines are less affected by the jet contribution than the continuum, and σ is less biased than FWHM for black hole estimation (Collin+ 2006). We tested the populations via K-S test.



Berton+ 2015



Implications for the parent population

S-NLS1s are excellent parent population candidates, as expected.

Disk RGs are a good match in case of low black hole mass and high Eddington ratio. In particular, the best candidates are disk RGs with a pseudobulge.

RQNLS1s are not good candidates. Nevertheless, the non-thermal emission and the jet-like structures in some of them now lack of an explanation: a deeper investigation was needed.

Radio-quiet NLS1s

I selected two complete samples:

23 RLNLS1s (both steep and flat from Yuan+ 2008)

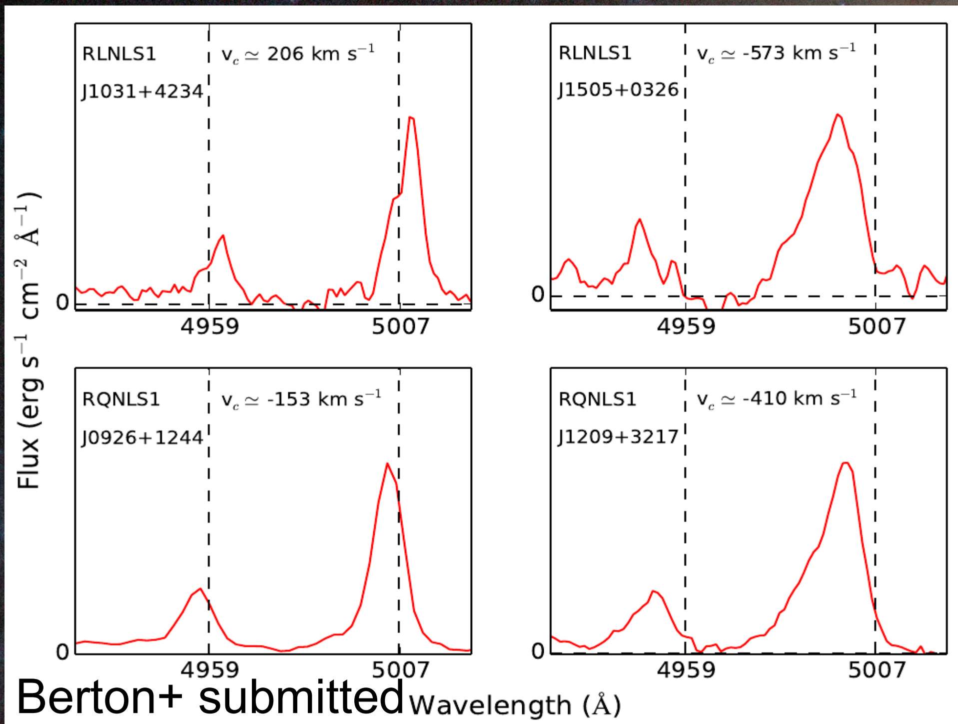
22 RQNLS1s (from Berton+ 2015)

When possible, the spectra were obtained from SDSS DR12. Those unavailable were observed with Asiago T122 telescope.

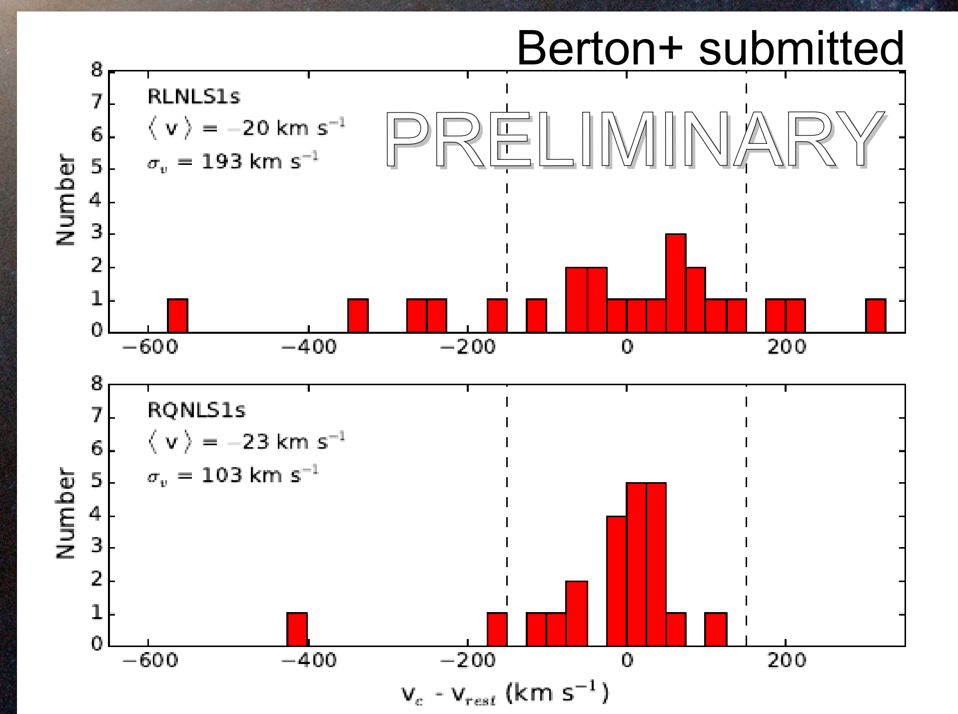
We looked for blue outliers, shifts in the [O III] lines interpreted as sign of a bulk motion in the narrow-line region (NLR).

Jet interaction?

Radio-quiet NLS1s

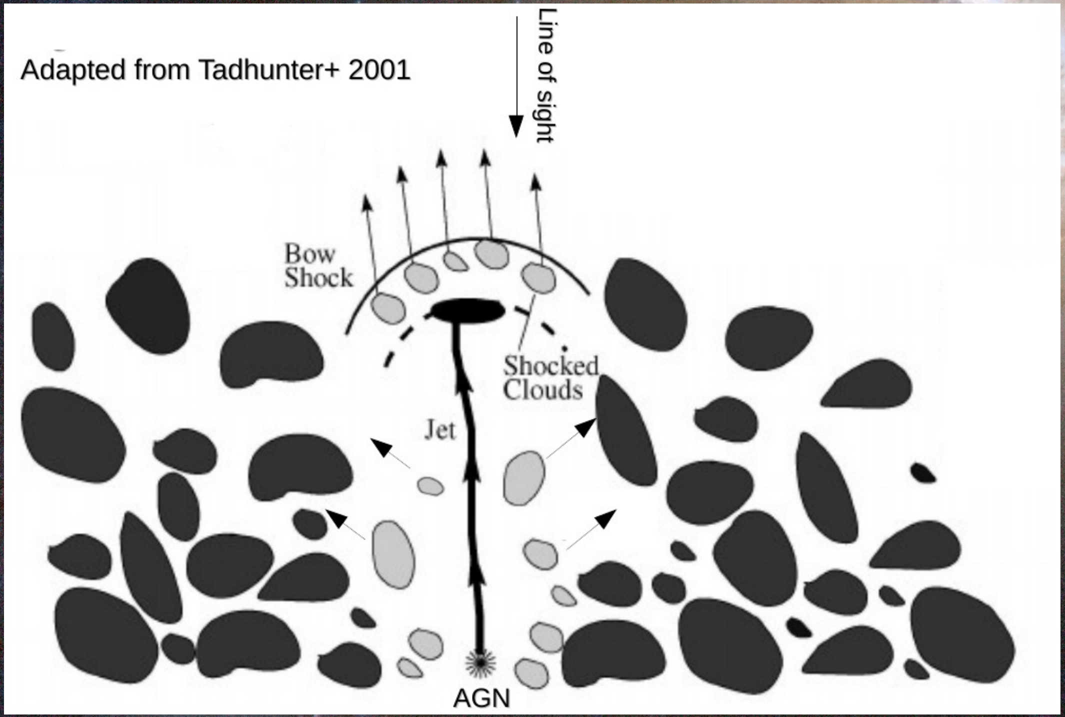


Blue outliers are more common among RLNLS1s, and even more common in γ-ray NLS1s.



The NLR in RLNLS1 is more perturbed than in RQNLS1s.

Radio-quiet NLS1s

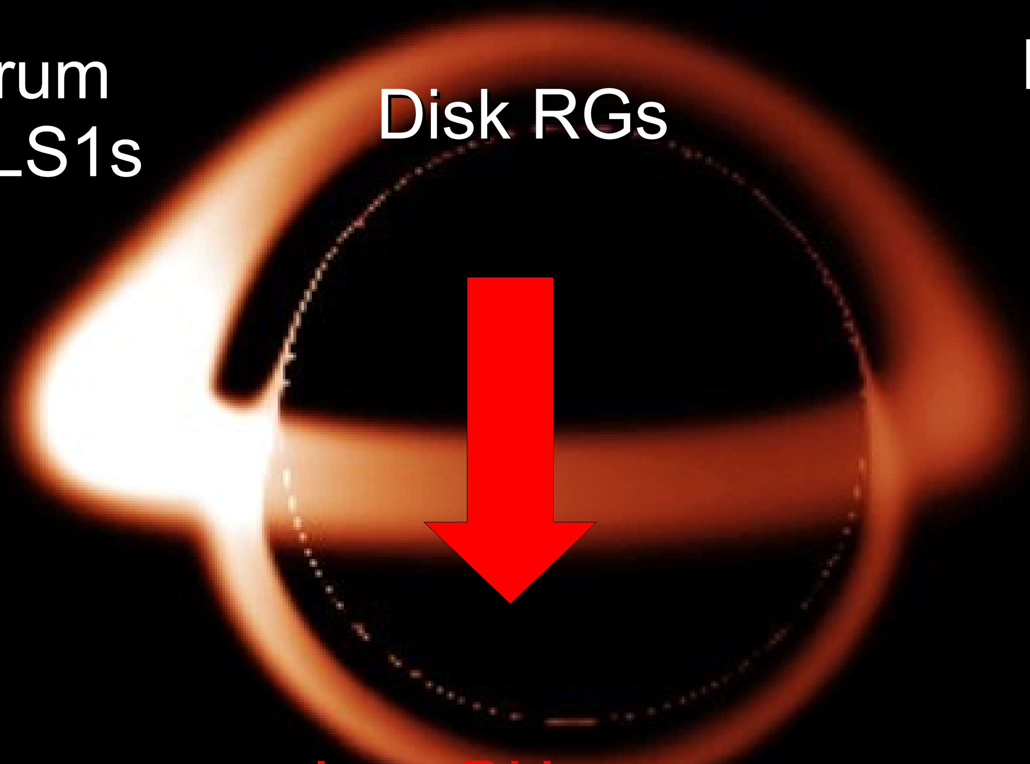


In RLNLS1s the jet is compact and it appears to interact with the NLR.

γ-ray NLS1s have a particularly turbulent NLR.

In RQNLS1s, the NLR is relatively unperturbed: possibly no jet at all!

The final solution to the parent population will likely come from...



Steep-spectrum radio-loud NLS1s → *OK*

Disk RGs → Low BH mass High Eddington

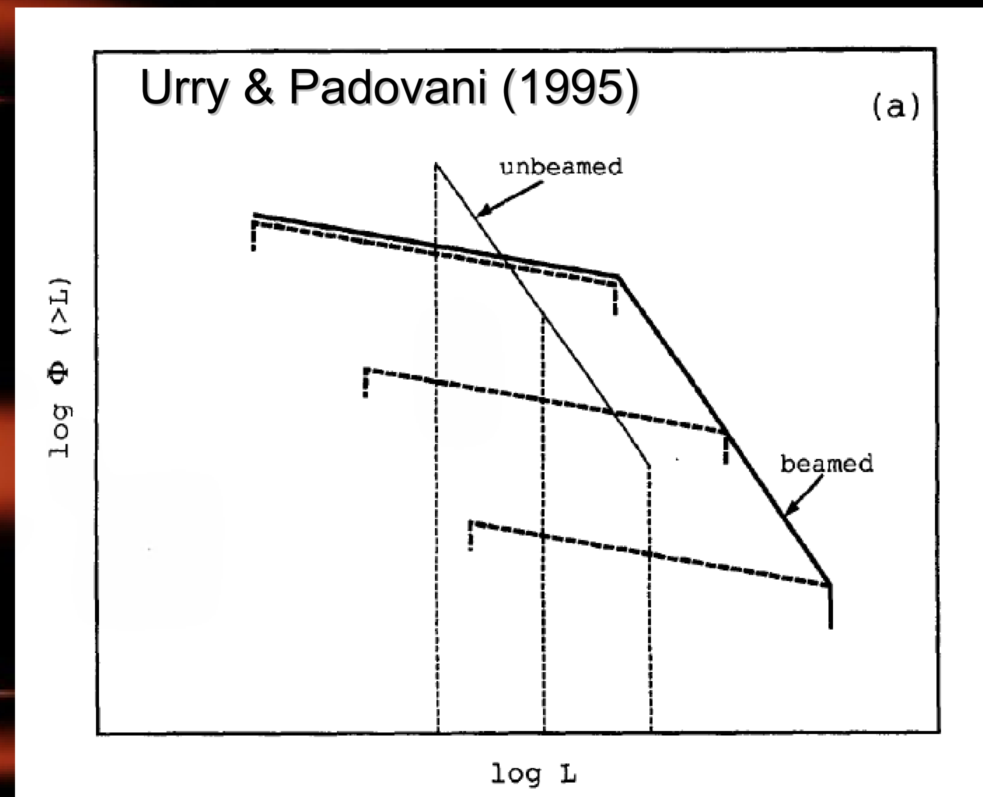
Radio-quiet NLS1s → No?

...radio luminosity functions

Luminosity function (LF) is the volumetric density of sources as a function of luminosity.

$$\Phi(L)\Delta L = \frac{4\pi}{A} \sum_{L_i \in (L \pm \Delta L/2)} \frac{1}{V_{max}(L)}$$

The LFs are useful to compare beamed and unbeamed populations: relativistic beaming can be added to unbeamed sources.
Urry & Padovani (1995) used them to investigate the parent population of blazars.



...radio luminosity functions

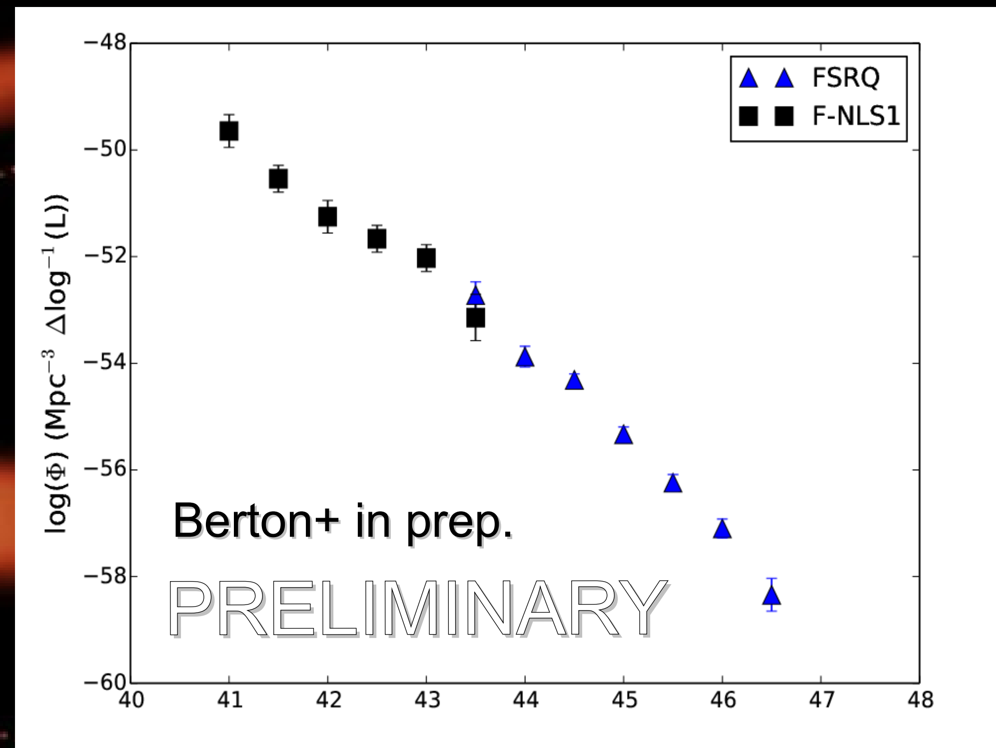
I built beamed sample and candidate samples. The LFs require complete samples.

RQNLS1s SDSS DR7
RLNLS1s Yuan+ 2008
Disk RGs Schawinski+ 2010

The samples are:

- 13 flat-spectrum RLNLS1s
- 10 steep-spectrum RLNLS1s
- 132 RQNLS1s
- 14 disk RGs

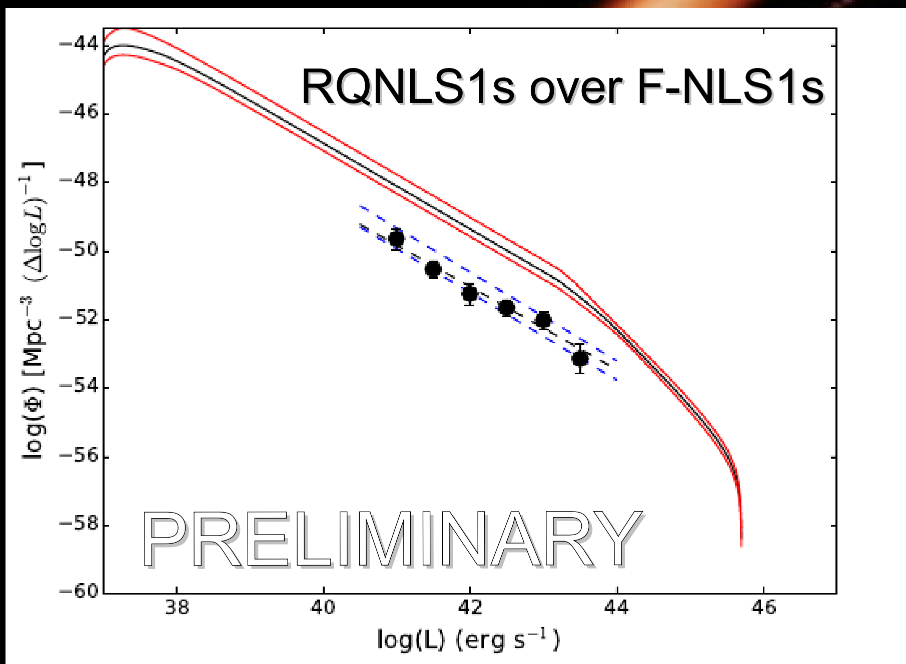
F-NLS1s + FSRQs

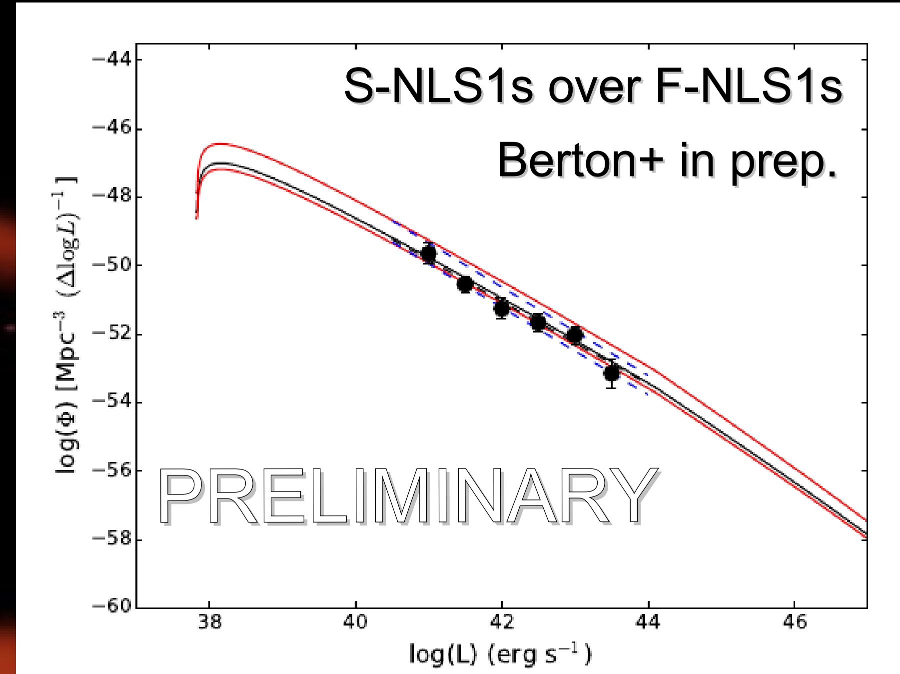


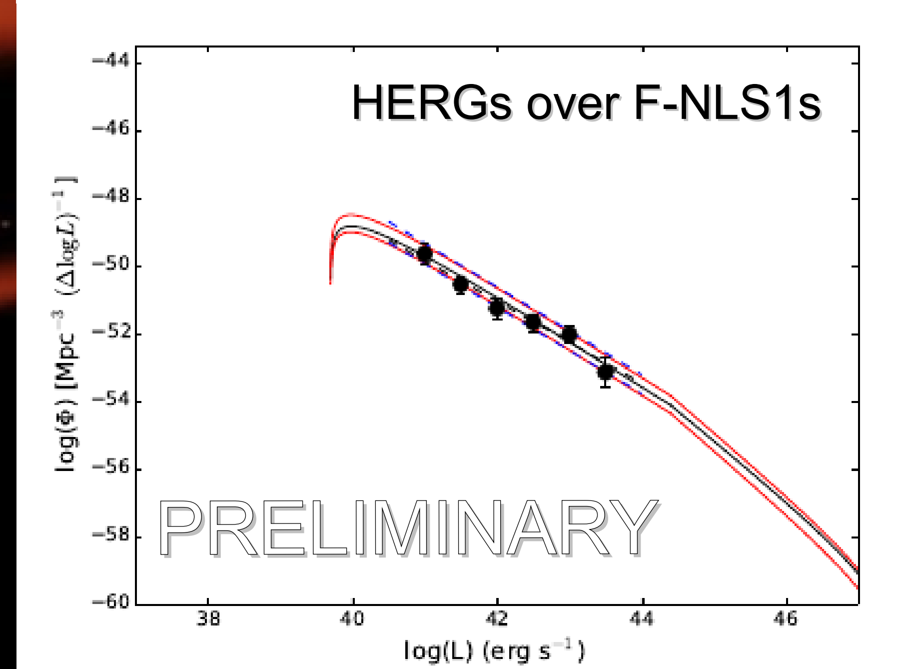
I am also comparing NLS1s with CSS high-excitation radio-galaxies (HERG), drawn from Kunert-Bajraszewska+ 2010. As a control sample, I used that of FSRQs of Urry & Padovani (1995).

...radio luminosity functions

By adding the relativistic beaming I can directly compare the parent candidates with the beamed population.







S-NLS1s and HERGs appear to be consistent with F-NLS1s, while RQNLS1s do not independently from the beaming parameters I used.

Conclusions

- Steep-spectrum radio-loud NLS1s are very likely part of the parent population
- Disk-hosted radio-galaxies with high Eddington ratio and low BH mass are good parent candidates
- Radio-quiet NLS1s, with some exception, do not probably belong to parent population
- CSS/HERGs are good candidates as both obscured and unobscured parent sources. Spectropolarimetry can be useful to investigate this relation.