Narrow Line Seyfert 1 galaxies and their multi-wavelength properties

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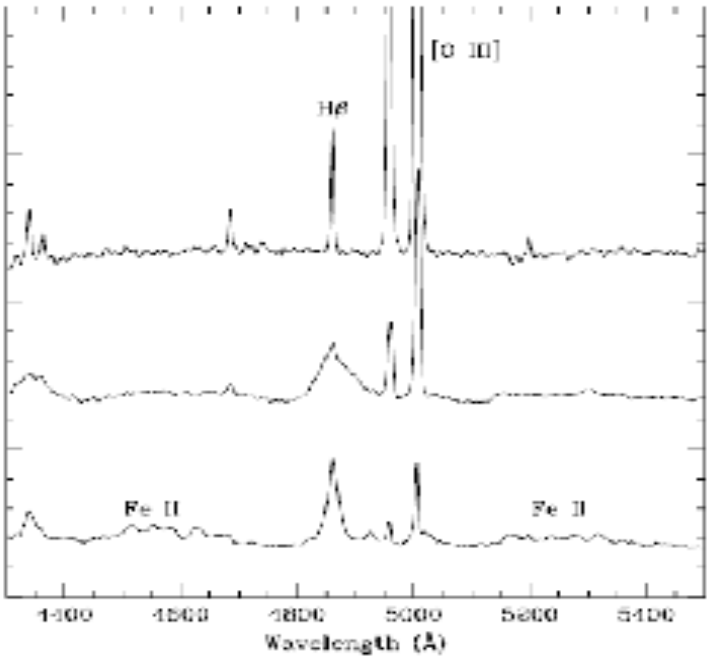
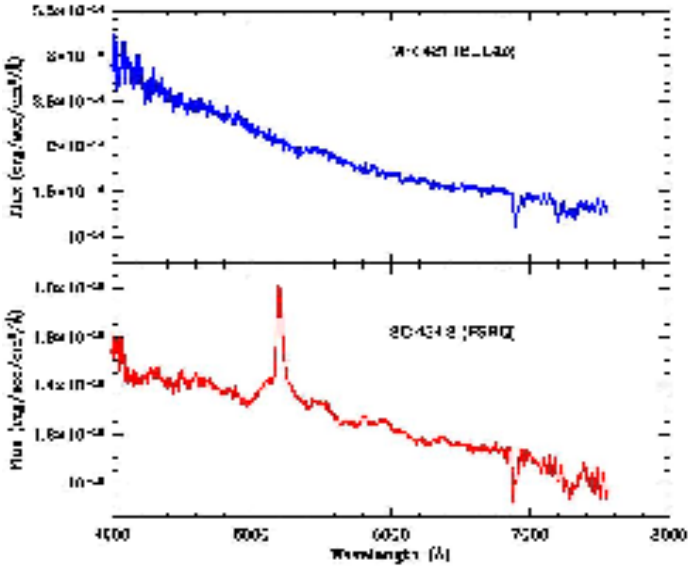
“ .... having given up on understanding AGNs, the community now focuses on the more modest goal of counting them”

R. Antonucci, 2013, Nature, 495, 165

Narrow Line Seyfert 1 galaxies

- FWHM < 2000 km /sec
- [O III]/Hβ < 3 (Osterbrock & Pogge 1985)
- Have Fe II lines
- Low mass black holes (10^6 – 10^8 $M_\odot$; Decarli et al. 2008)
- Soft X-ray excess & variability
- High accretion rate (0.1 – 1 Eddington; Boroson & Green 1992; Boller et al.1996)
- Spiral host, often with bars (Crenshaw et al. 2003; Deo et al. 2006)
- Generally high star formation activity (Sani et al. 2010)





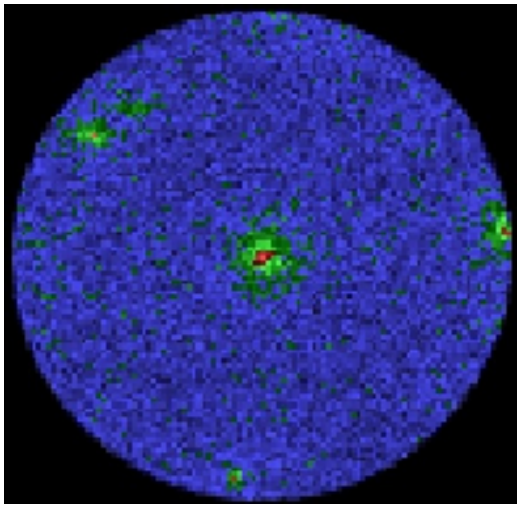
- Radio-loud (15%), Radio-quiet (85%)
- R-parameter: often used as a proxy for jet production
- Radio-loud (AGN with higher BH mass, $>10^8$ M, low accretion rates)
- Radio-quiet (AGN with low BH mass, 10^6 – 10^8 M, high accretion)
- NLSy1 galaxies have low BH mass and high accretion rates

INFERENCE: NLSy1 galaxies are radio-quiet AGN, and the young BH undergoing rapid growth via high accretion rate CANNOT produce relativistic jets

- Show radio-loud/radio-quiet dichotomy
- 7% are radio-loud compared to 15% in quasars

Narrow Line Seyfert 1 galaxies: *Fermi* era

- Radio spectra (blazars)
- Radio structure (blazars)
- Superluminal motion (blazars)
- Gamma-ray nature (blazars)
- Black hole mass (low v/s high)
- Host galaxies(spirals v/s ellipticals)



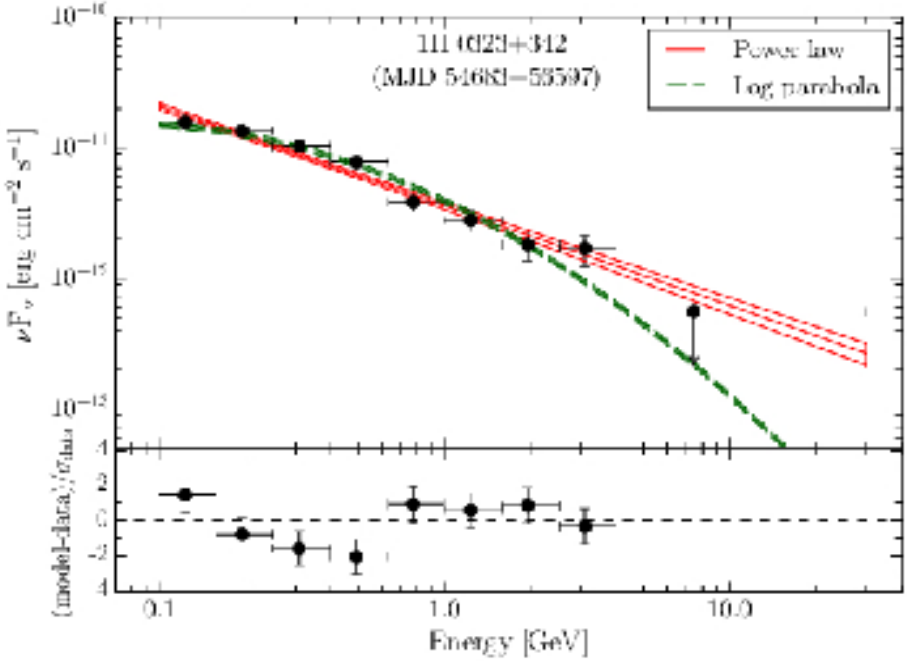
PMN J0948+0022
(Abdo et al. 2010)

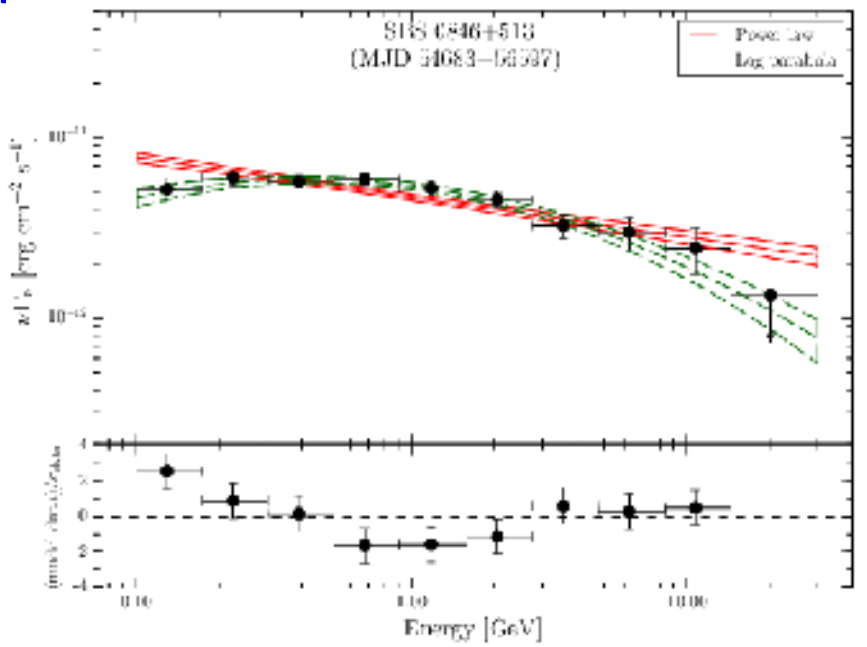
As of now 5 high confidence detections by Fermi

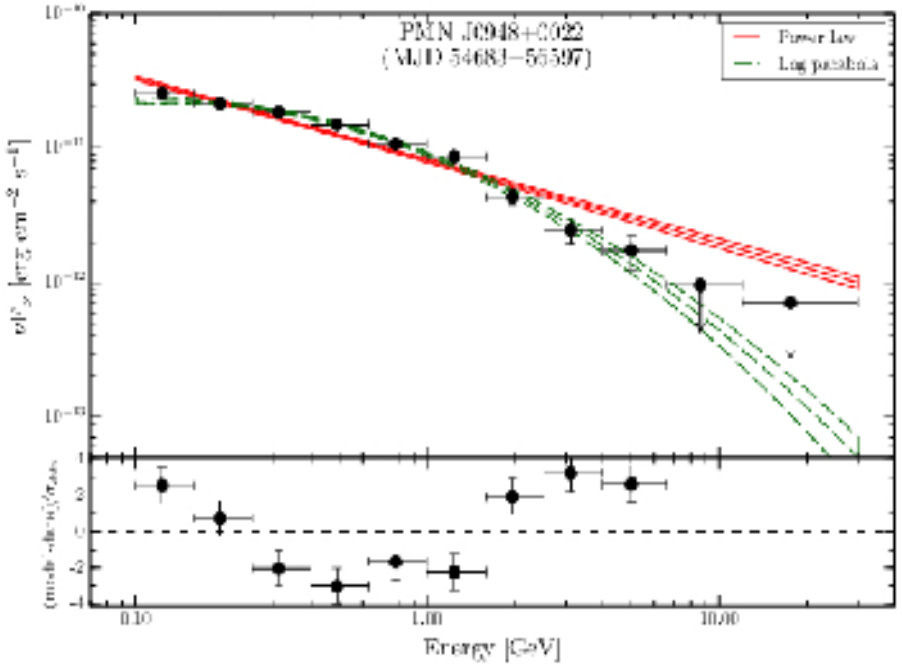
Strong optical polarization -> 18% (Ikejiri et al. 2011)

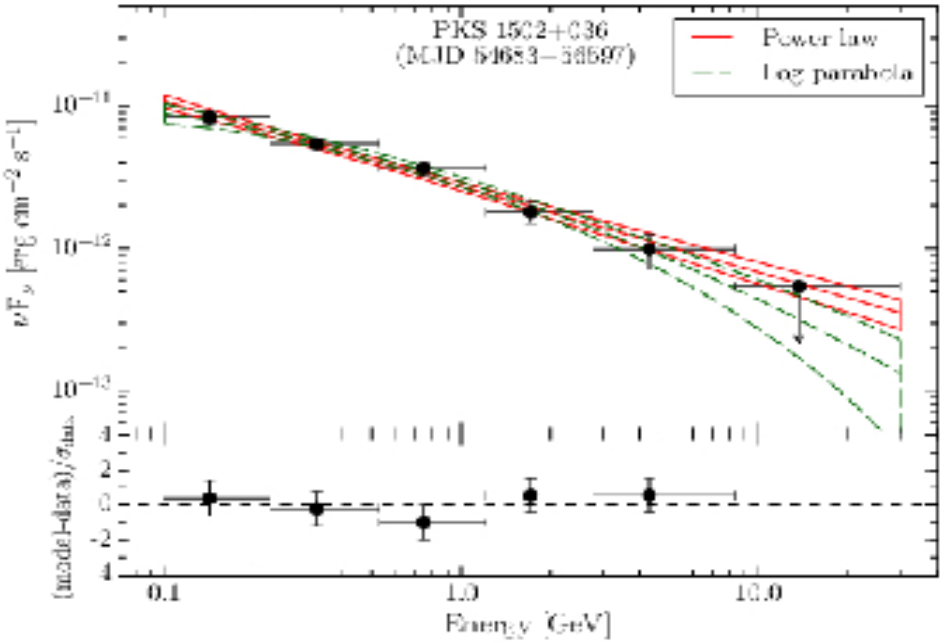
Confirms NLSy1 galaxies have jets similar to blazars (Elliptical – Jet paradigm)

Gamma-ray spectra



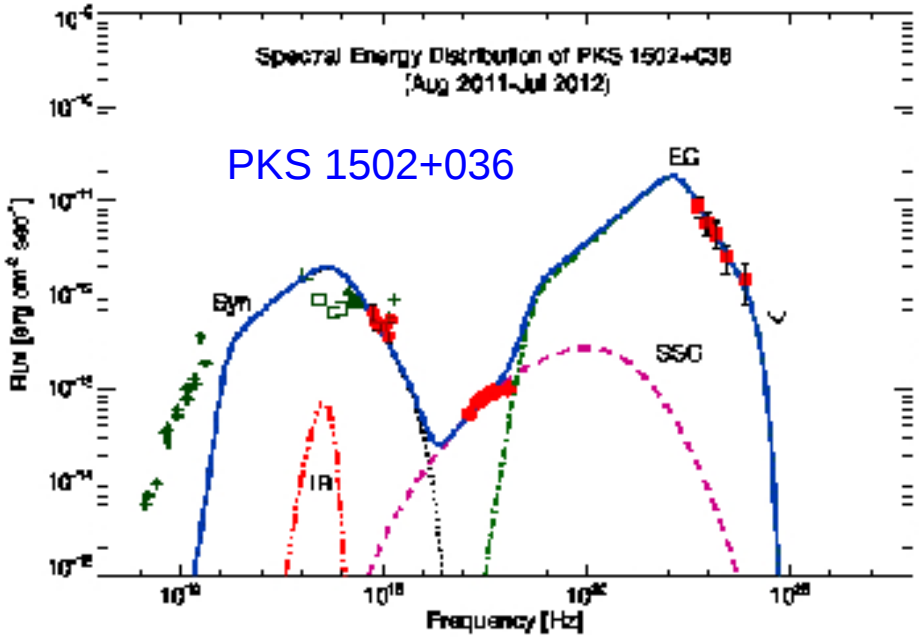


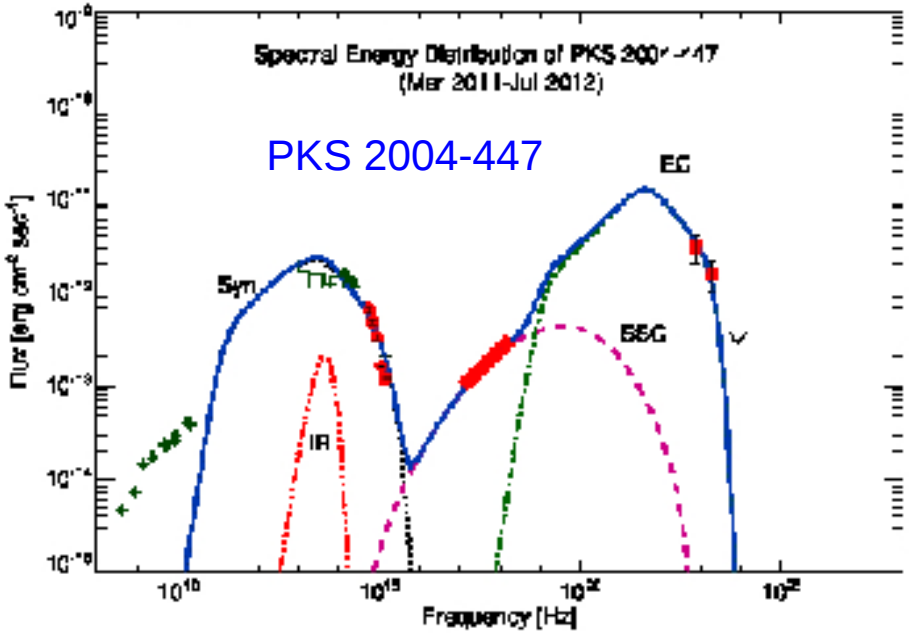




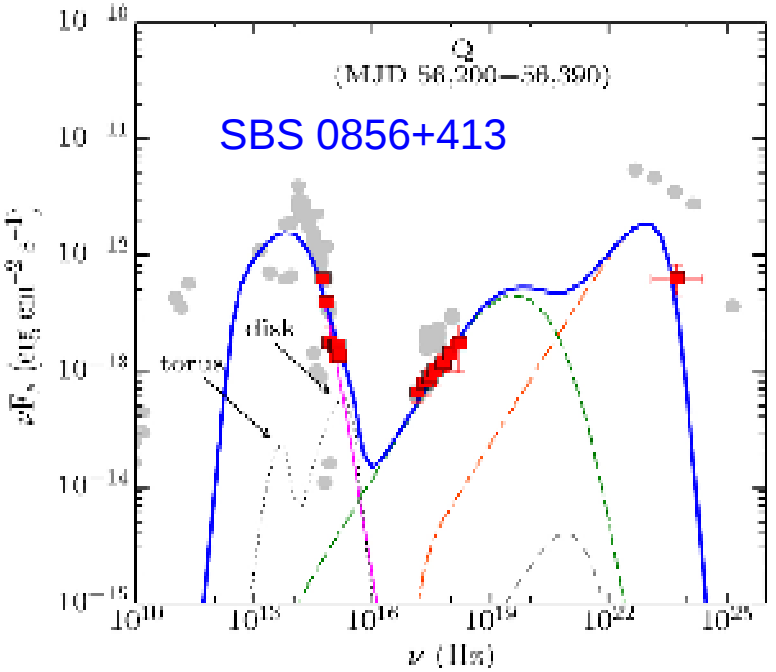
V. S. Paliya et al. 2015, AJ, 149, 41

Spectral energy distribution

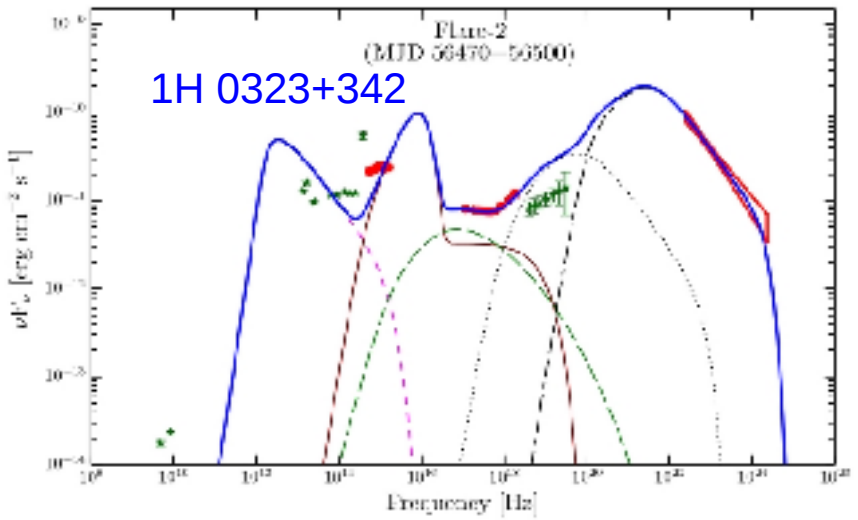




Paliya et al. . 2013, ApJ, 768, 52



Paliya et al. 2016, ApJ, 819, 121



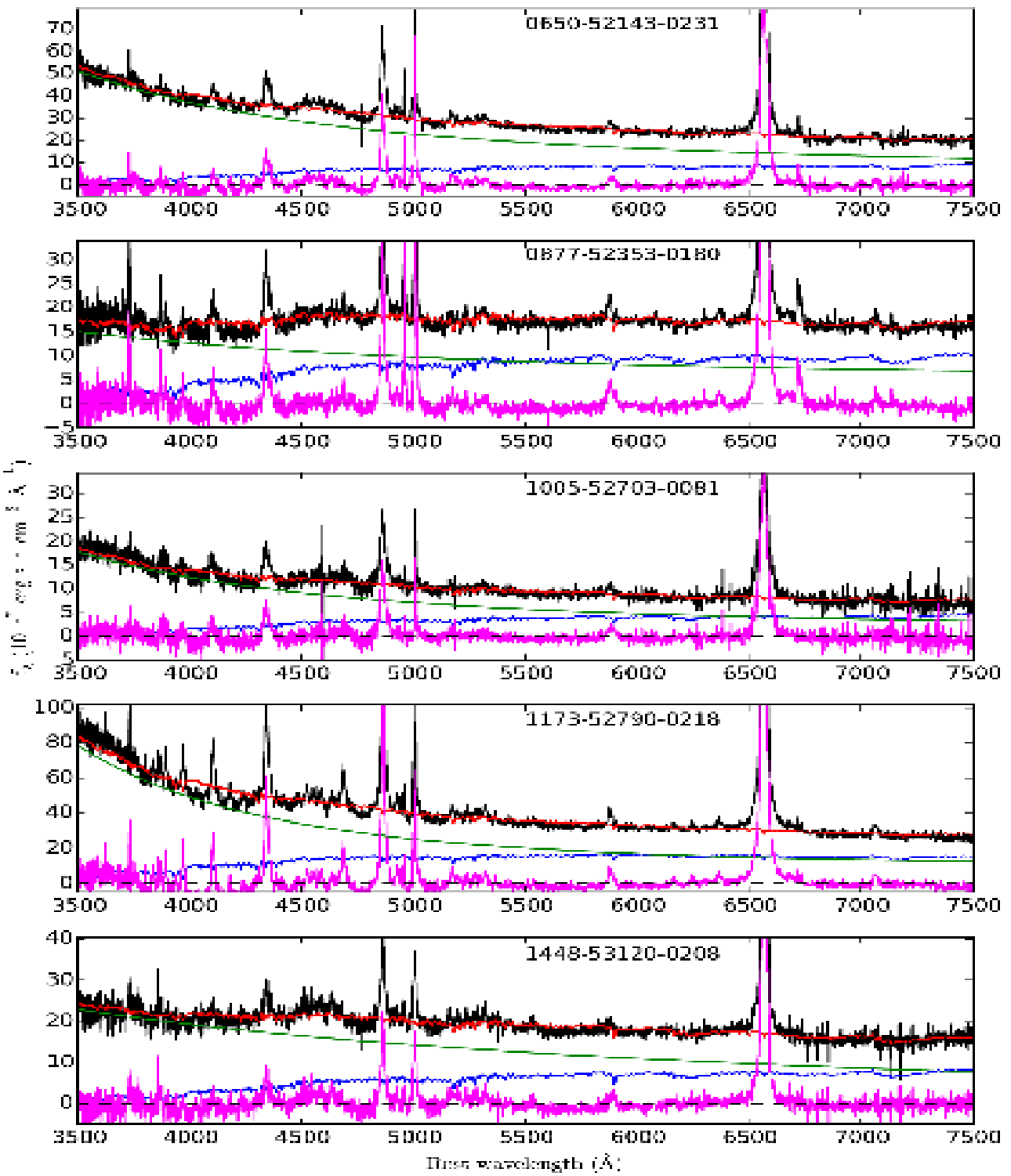
Paliya et al. 2014, ApJ, 789, 143

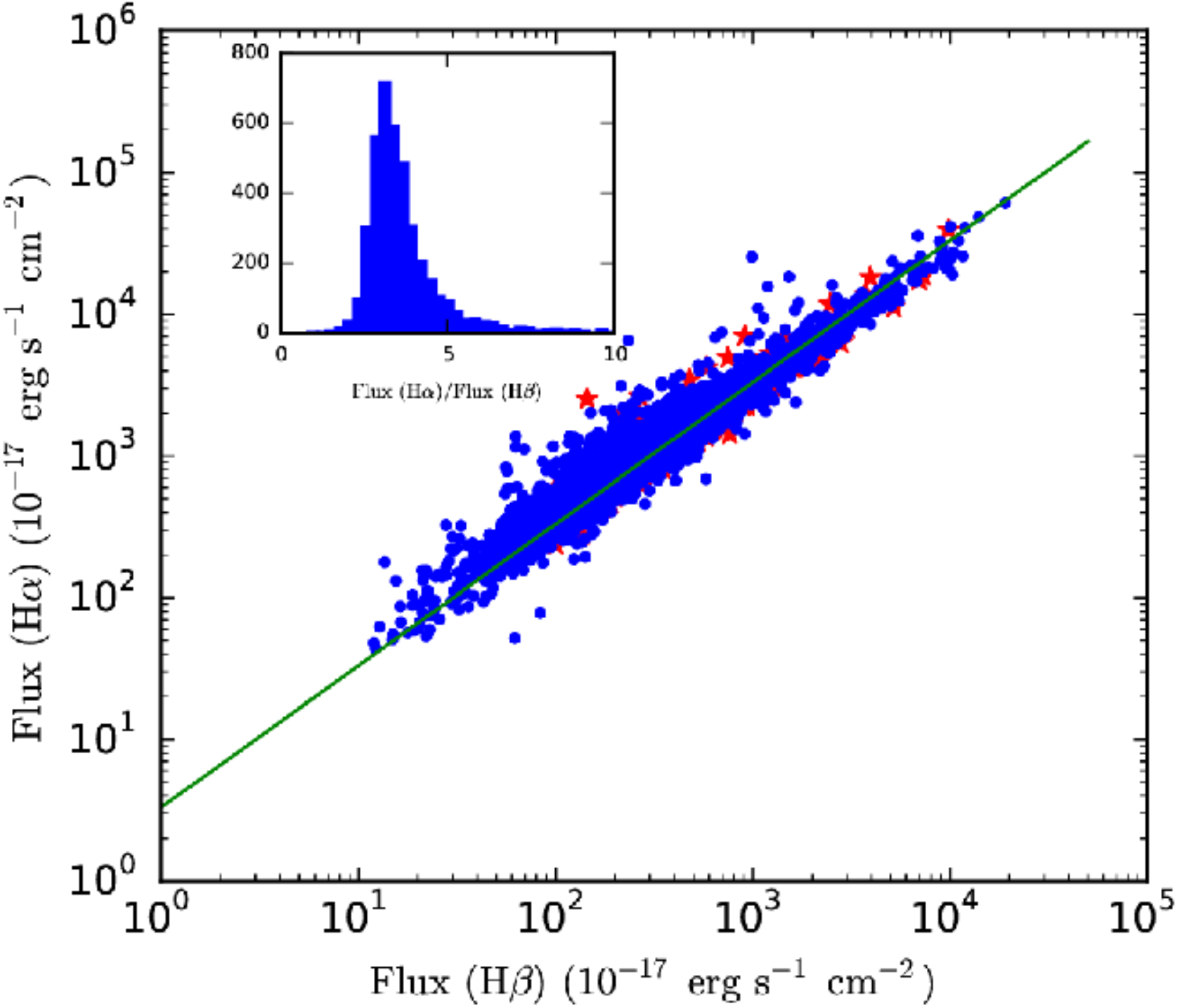
Open questions

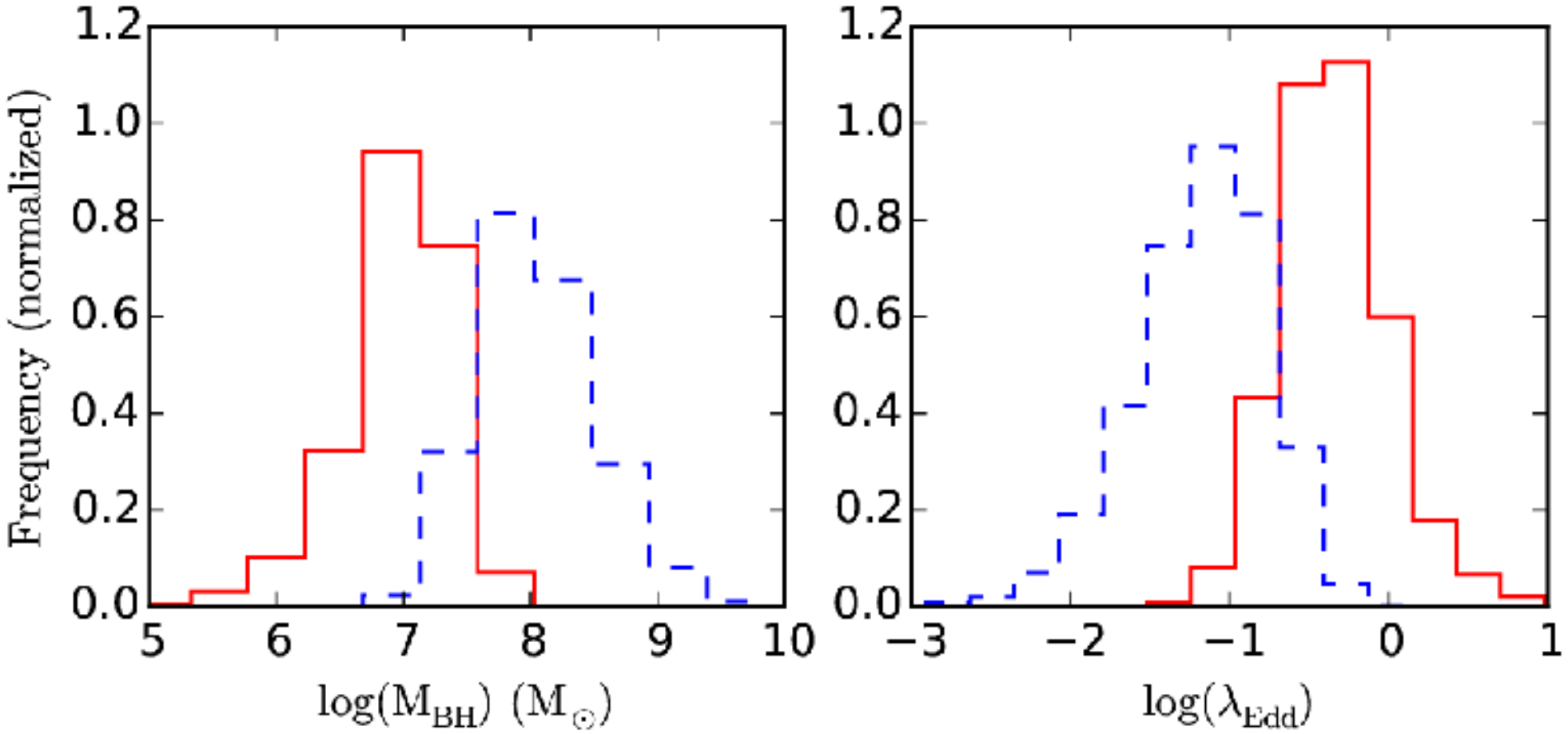
- Are gamma-ray loud NLSy1 galaxies elusive sources?
- Is it really true that NLSy1 galaxies have low mass black holes?
- Is it really true that NLSy1 galaxies are hosted by spiral galaxies?
- Whether NLSy1 galaxies conform to the same RBLR – Luminosity relation known for Seyferts and quasars?

Some of these questions can be addressed if we increase the number of known NLSy1 galaxies (The number known today is 2011 sources from Zhou et al. 2006)

- Selected all sources classified as “QSO” in DR12 with $z < 0.8$
- This resulted in 68,859 objects
- Spectra of all the 68,859 objects are fitted (host galaxy subtraction, AGN continuum, emission line) to get various parameters of the sources
- The flux of Hbeta is more than 3 sigma
- The width of the broad Hbeta is more than the narrow component
- FWHM of the broad Hbeta is narrow than 2200 kmsec
- The flux ratio of total O [III] to total H < 3

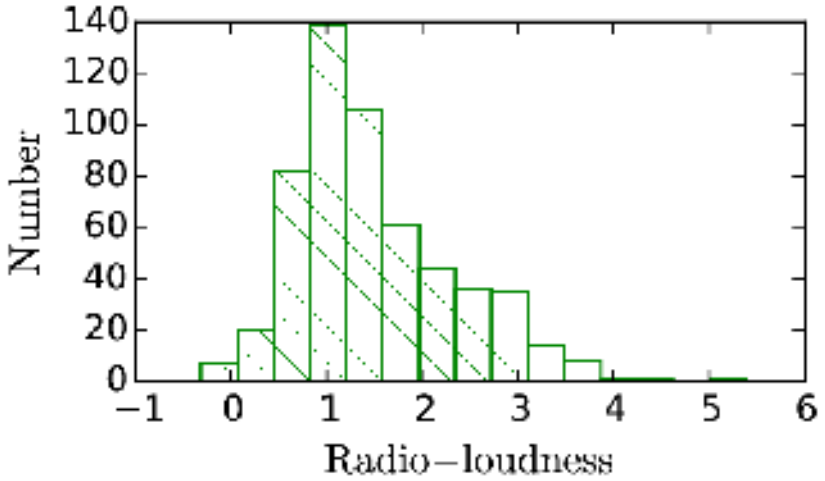

0650-52143-0231
0877-52353-0180
1005-52703-0081
1173-52790-0218
1448-53120-0208
Rest wavelength (Å)

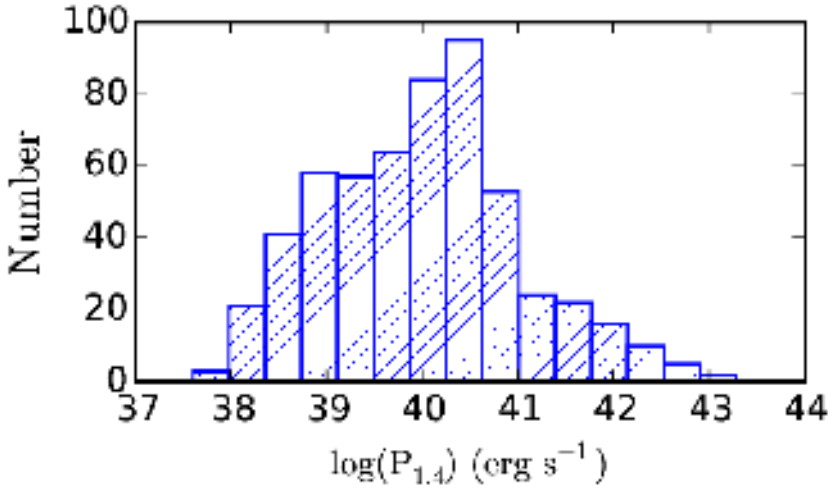

Flux (Hα) (10^{-17} erg s^{-1} cm^{-2})
Flux (Hβ) (10^{-17} erg s^{-1} cm^{-2})
Flux (Hα)/Flux (Hβ)

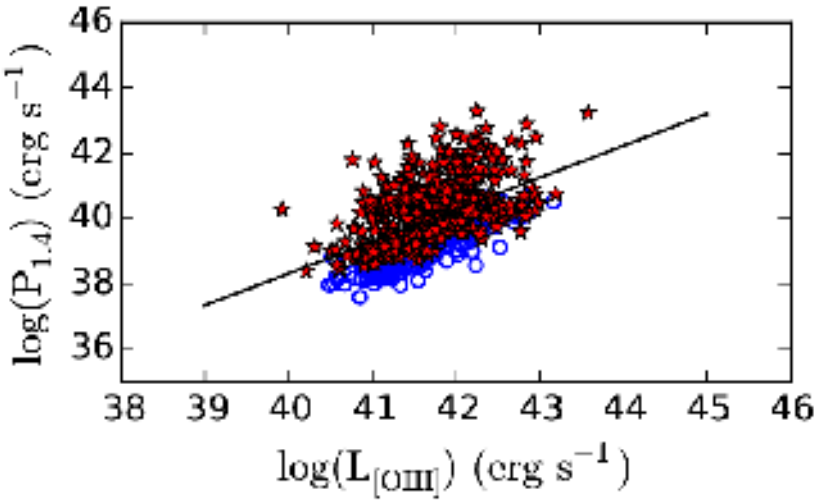


Rakshit et al. 2017, ApJS (under reivew)

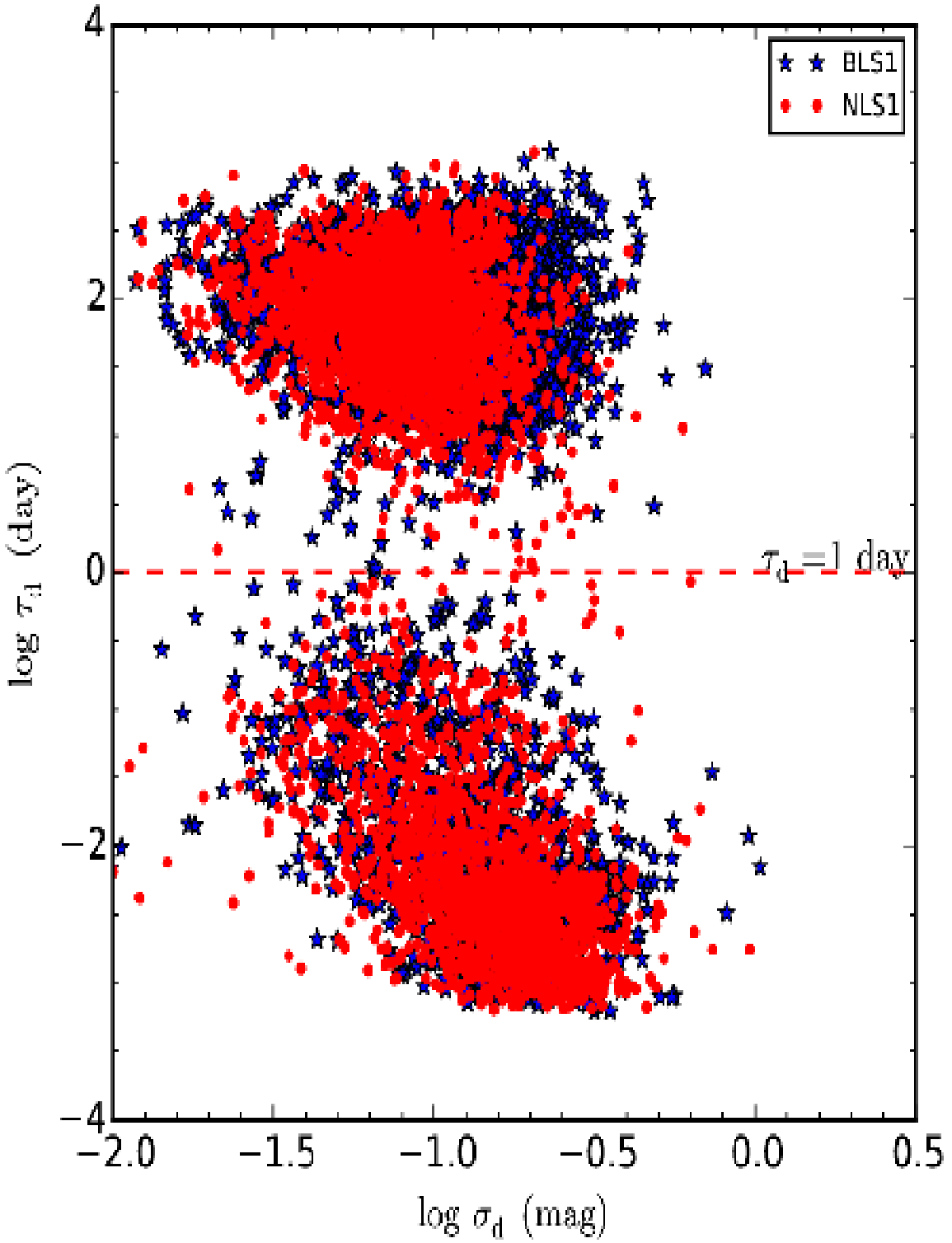
- What fraction of NLSy1 galaxies are radio-loud?
- Are there new gamma-ray emitting NLSy1 galaxies?
- What is the LTOV nature of NLSy1 galaxies?
- How do they compare with BLSy1 galaxies?



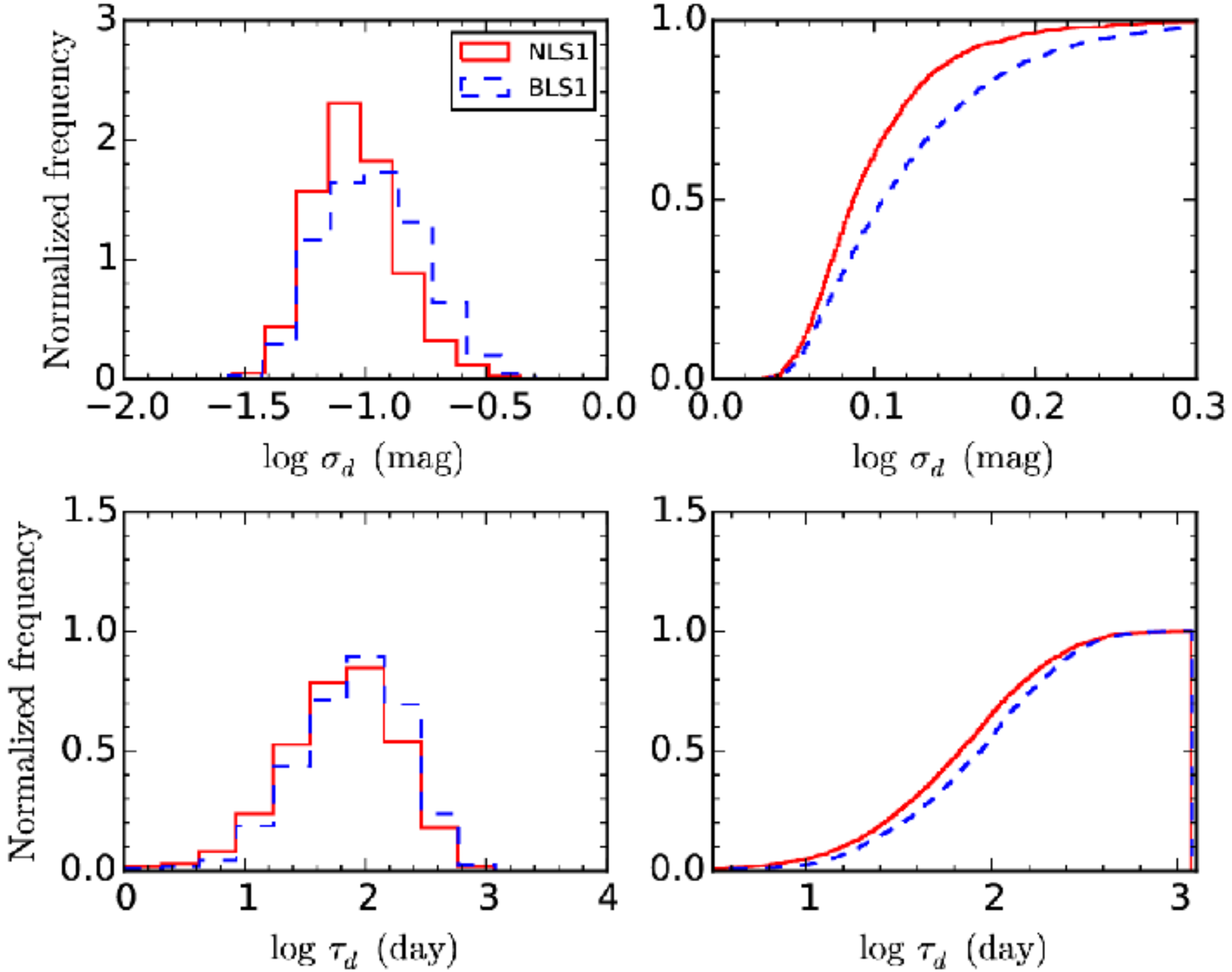


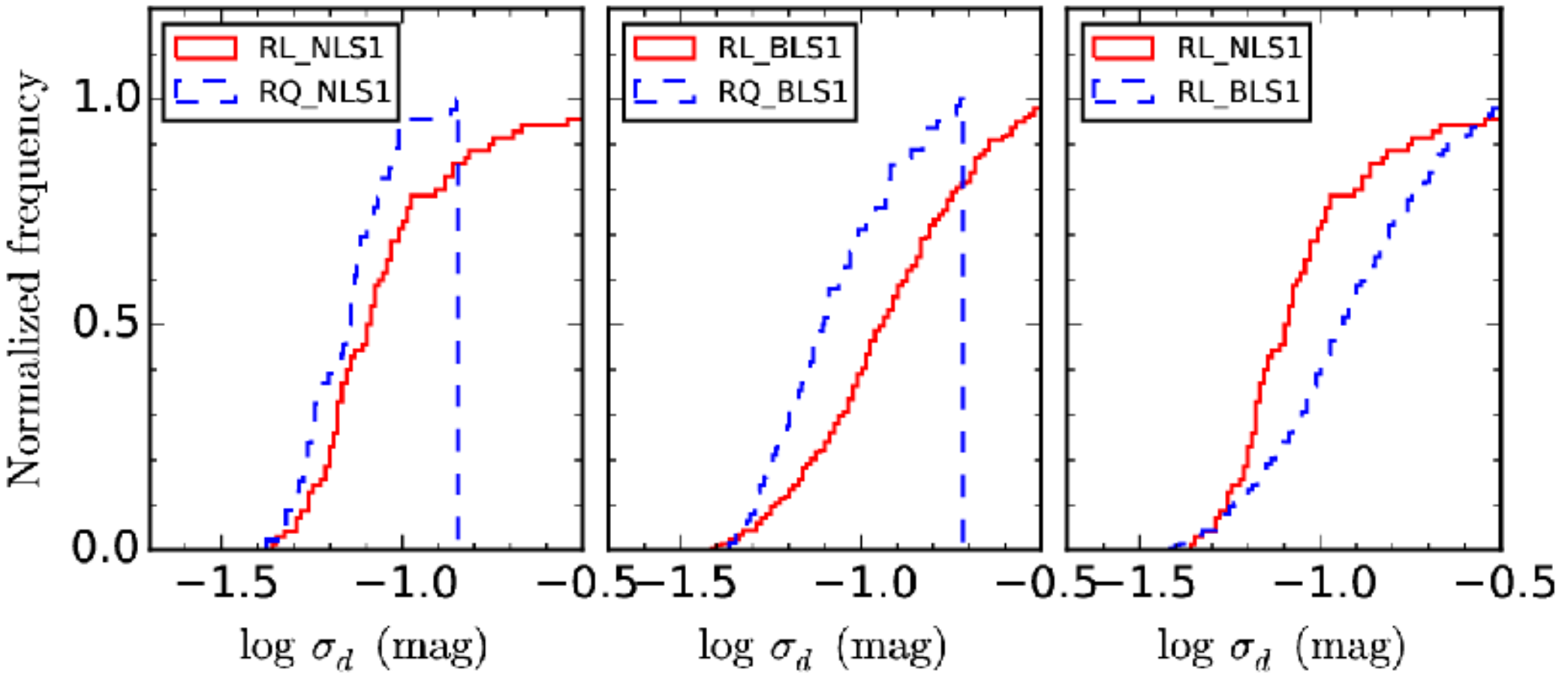


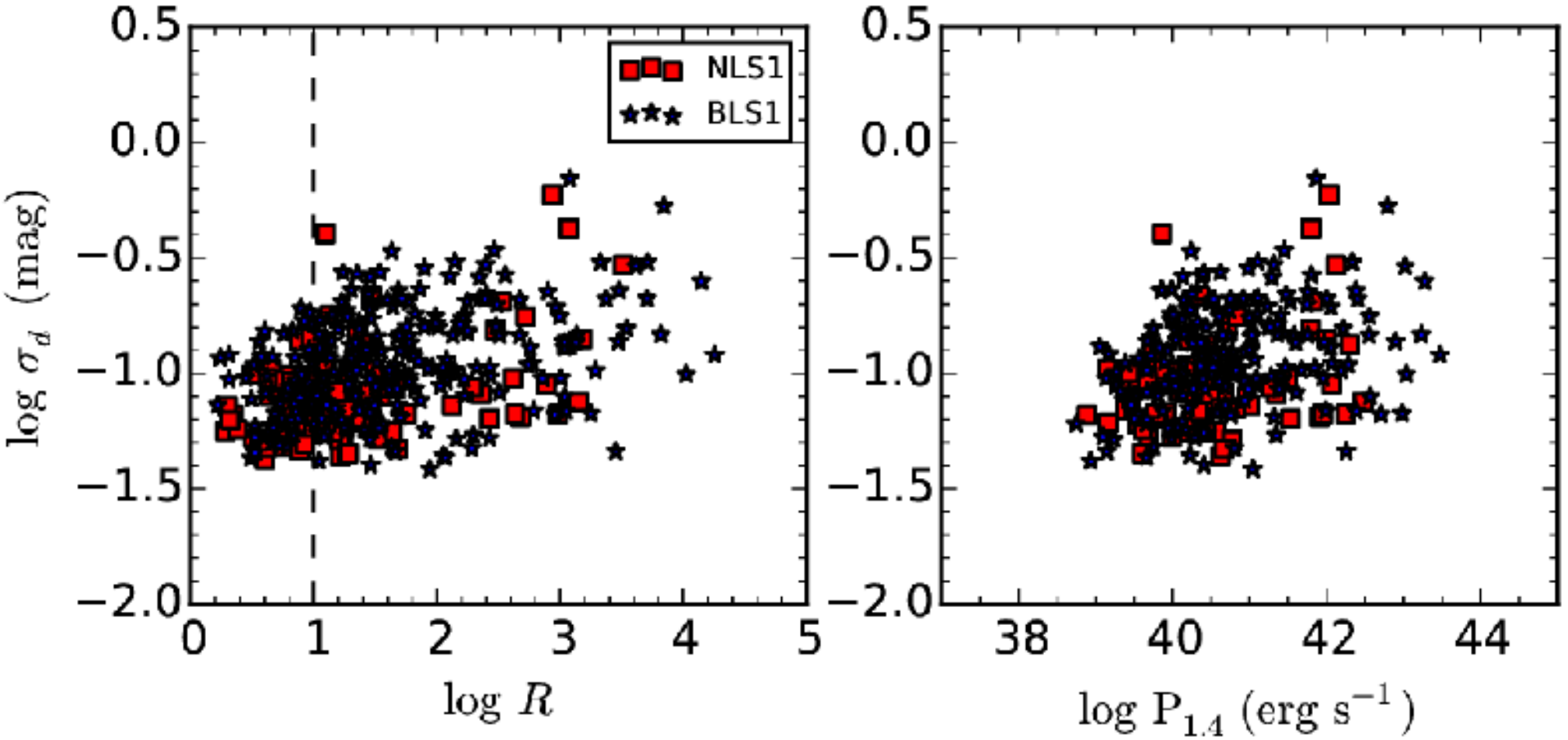
- Cross-correlated with FIRST
- About 5% are radio loud
- Less compared to the 15% we know for quasars
- Radio-loud/Radio-quiet dichotomy: not seen
- Focussing on very radio-loud sources (R > 100), 155 source
- Few promising candidates on gamma-ray emitting NLSy1 galaxies
- Expect to increase the number of gamma-ray emitting NLSy1 galaxies by a factor of about 5 (gamma-ray analysis in progress)



- NLSy1 = 11,101;
  BLSy1 = 14,894
- Cross-correlated with CRTS: NLSy1 = 9069;
  BLSy1 = 13,928
- More than 50 epochs:
  NLSy1 = 9063,
  BLSy1 = 13,831
- Must match in the L - z plane:
  NLSy1 = 5510,
  BLSy1 = 5510


NLS1
BLS1
Normalized frequency
log σ_d (mag)
log σ_d (mag)
Normalized frequency
log τ_d (day)
log τ_d (day)

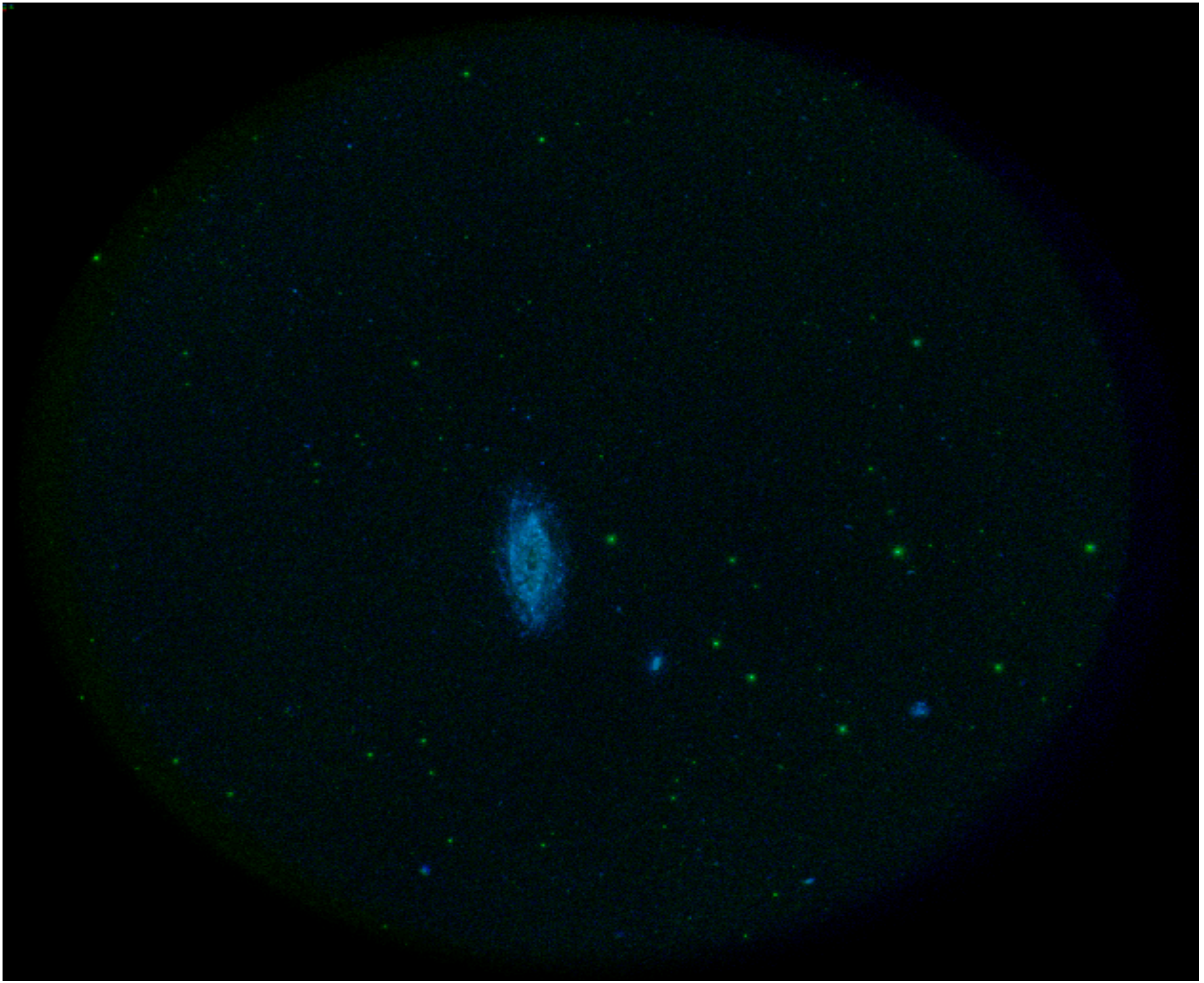

RL_NLS1
RQ_NLS1
RL_BLS1
RQ_BLS1
RL_NLS1
RL_BLS1
Normalized frequency
0.0
0.5
1.0
−1.5
−1.0
−0.5
log σ_d (mag)

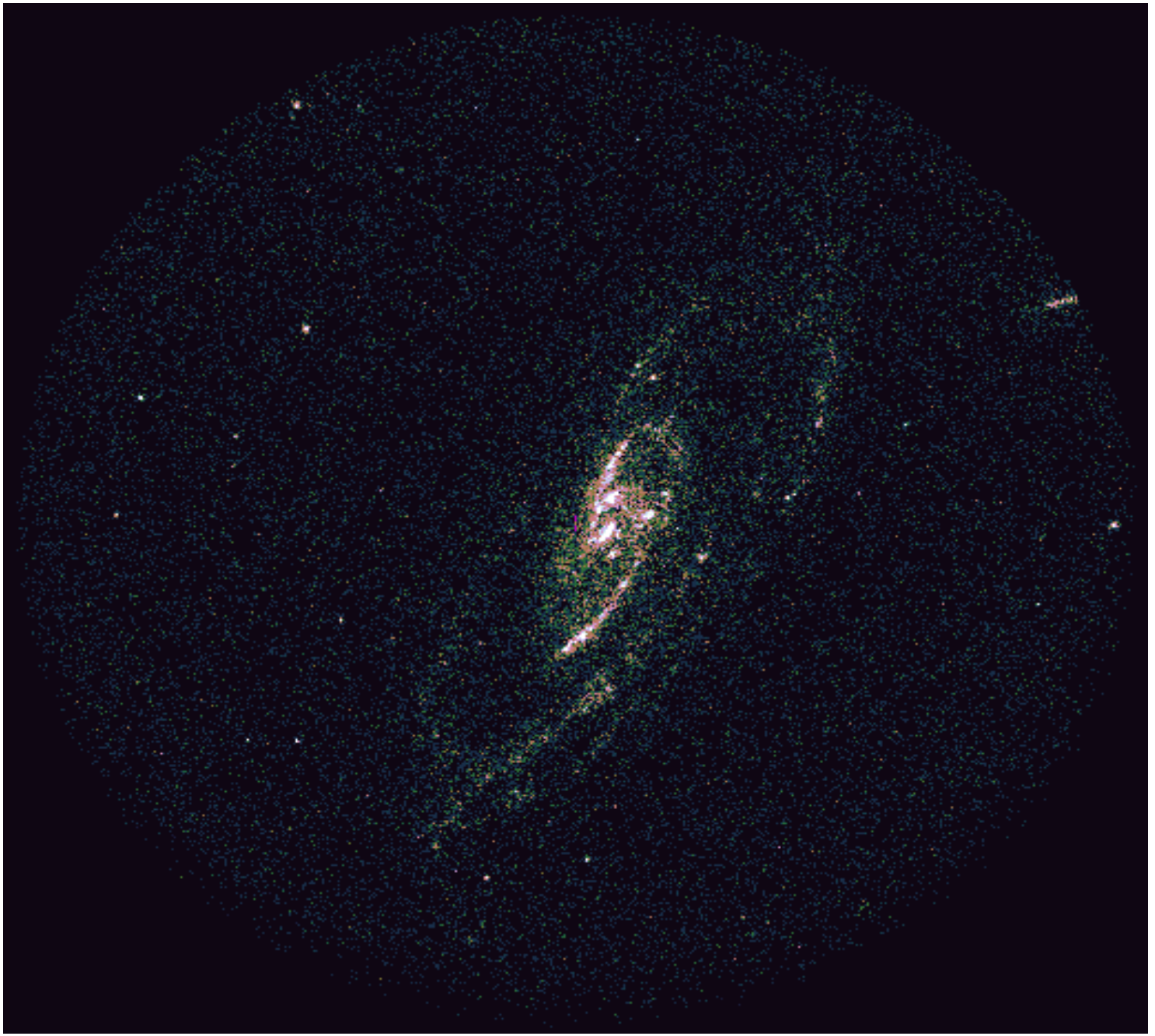


Rakshit et al. (2017, under preparation)

Summary

- We have arrived at a new catalog of NLSy1 galaxies containing about 10,000 sources. This is a five fold increase in the number known today
- About 5% of this are found to be radio-loud, compared to the 15% we know for quasars
- The apparent radio-loud/radio-quiet dichotomy is not seen
- About 150 of our sample are found to be very radio-loud
- Many are expected to be gamma-ray emitters
- In the long term NLSy1 galaxies are found to be more variable than BLNLSy1 galaxies
- Radio-loud sources are found to be more variable than radio-quiet sources
- Jets do play a role in the long term optical variability





Timing analysis