Blazar nuclei in Radio-Loud Narrow-Line Seyfert 1?

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Key Questions

Radio-loud vs radio-quiet AGN: is there anything in the middle?

What is radio loudness? Emission from jet or other? Are there relativistic jets in NLSy1 RL?

Hints to understand/improve the blazar sequence?

Hints to understand/improve the AGN unified model?

Hints to search for connections with Galactic Black Holes?

Definition of Blazar

- **Blazar** is term derived from the contraction of **BL Lac** and **Quasar**, proposed by Ed Spiegel in 1978.

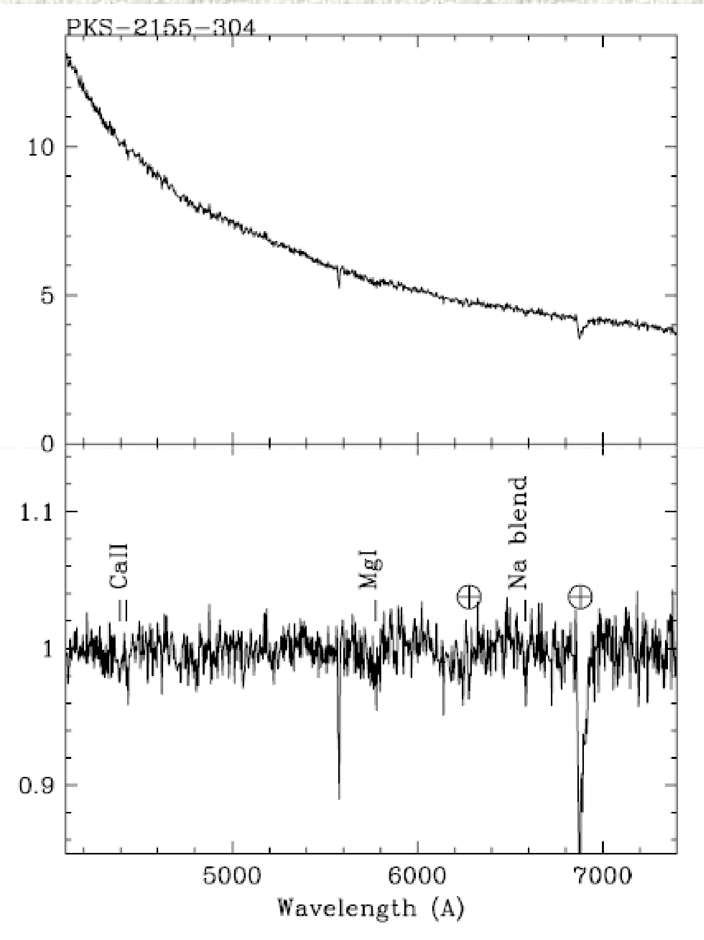
- Spiegel's intuition was correct as found in 1998 by G. Fossati, L. Maraschi, A. Celotti, A. Comastri, G. Ghisellini with the discovery of the **blazar sequence**.

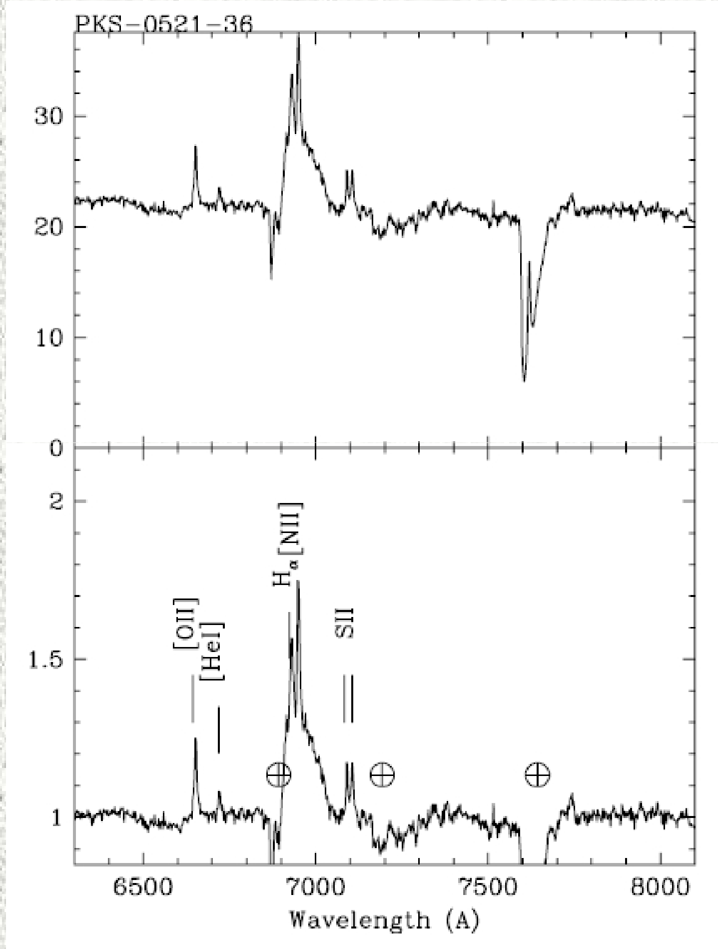
- Blazar SED are characterized by a double-humped shape:
  - **low-energy peak** due to synchrotron emission of relativistic electrons;
  - **high-energy peak** is thought to be due to inverse-Compton emission.

- **Sequence**: low-power blazars (BL Lac Obj) have peaks at energies greater than high-power blazars (Quasars).

Optical Spectra of Blazar

(spectra from Sbarufatti et al. 2006 with ESO 3.6 m and NOT 2.5 m)



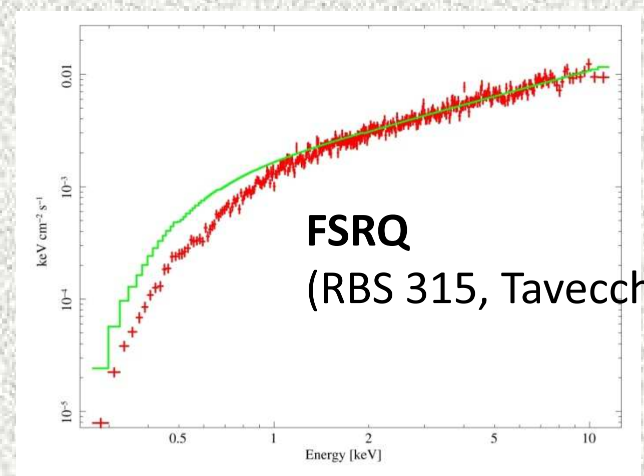


BL Lac Objects:
almost featureless continuum
(lines EW < 5 Å)

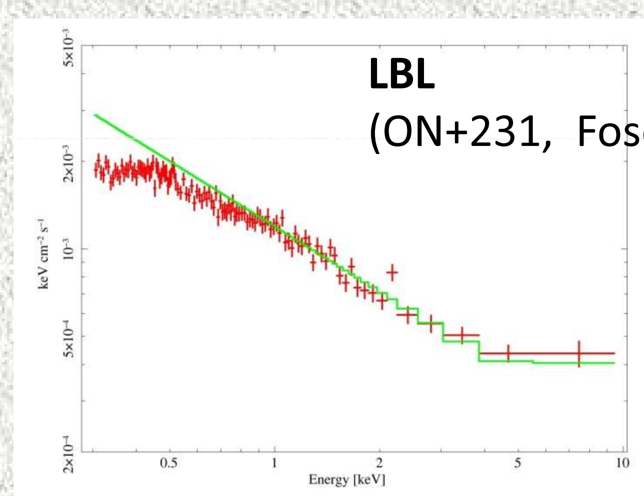
Quasars:
strong and broad emission lines

X-ray spectra of Blazar

(XMM-Newton)



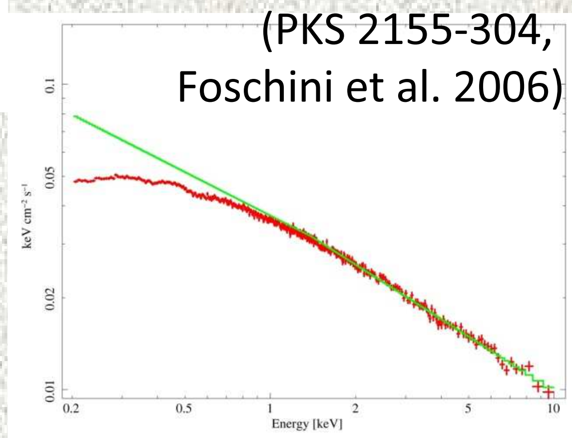
FSRQ
(RBS 315, Tavecchio et al. 2007)



LBL
(ON+231, Foschini et al. 2006)

High-Luminosity;
Low Frequency
Synchrotron Peak

Low-Luminosity;
High Frequency
Synchrotron Peak

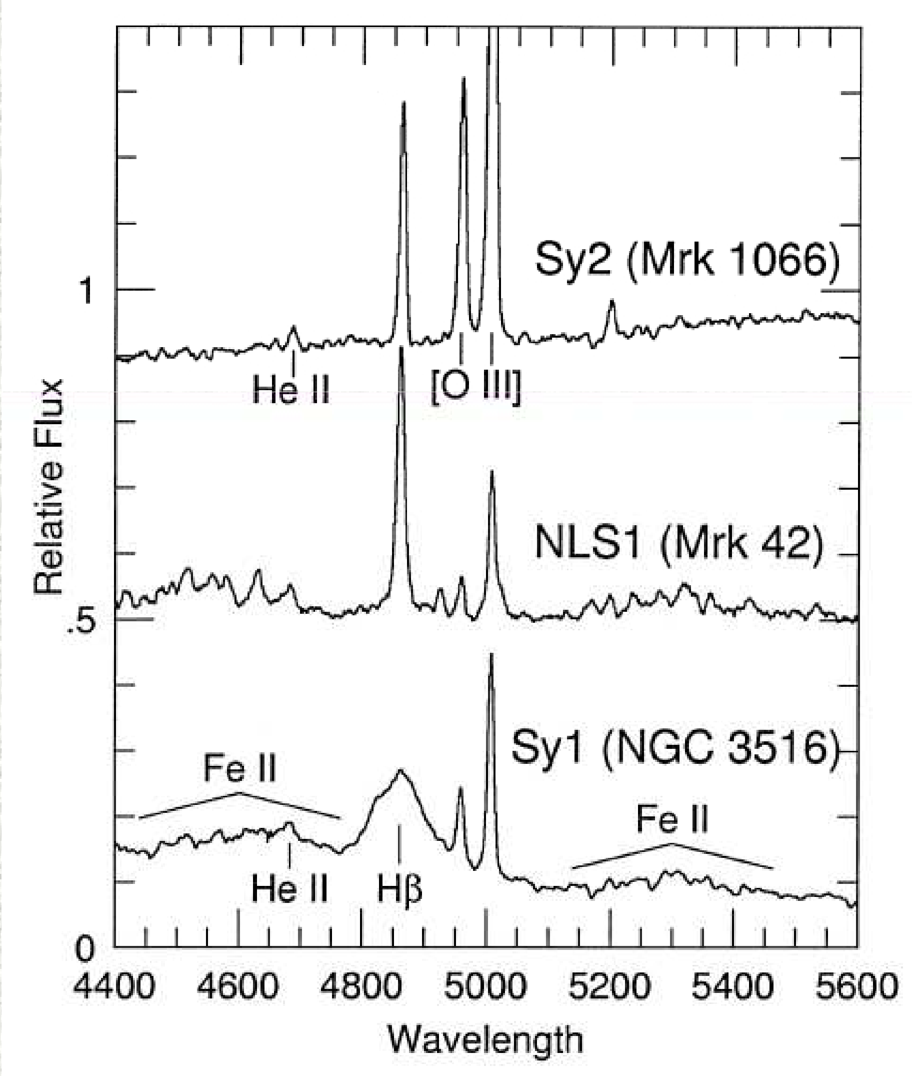


HBL
(PKS 2155-304,
Foschini et al. 2006)

Definition of
Narrow-Line Type 1 QSO/Seyfert

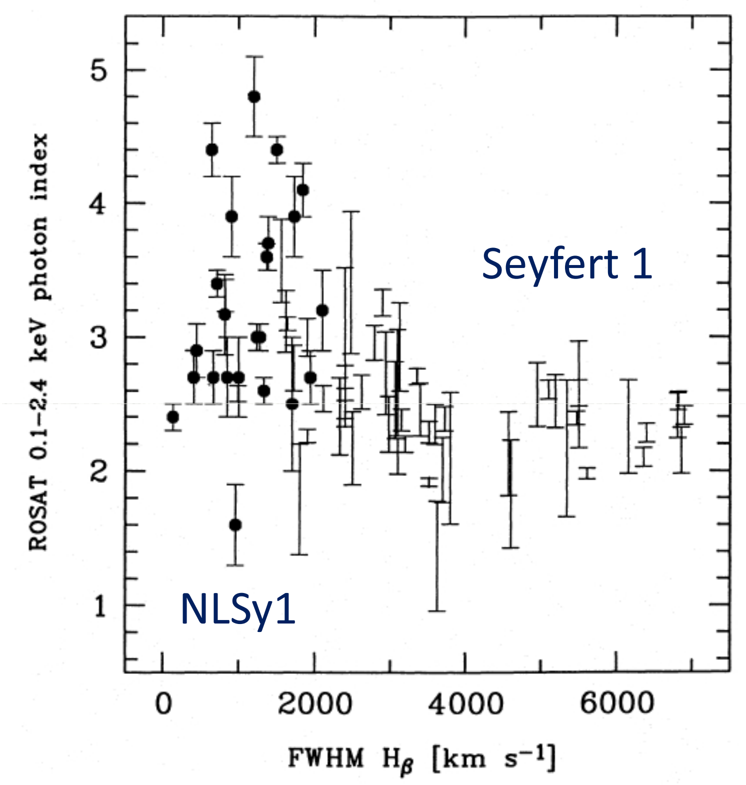
Optical spectra:

q Narrow permitted lines only slightly broader than the forbidden lines;
q [OIII]/Hβ < 3, unlike what is observed in Seyfert 2;
q FWHM(Hβ) < 2000 km/s;
q Fe II bump;



(from Pogge 2000)

Definition of Narrow-Line Type 1 QSO/Seyfert



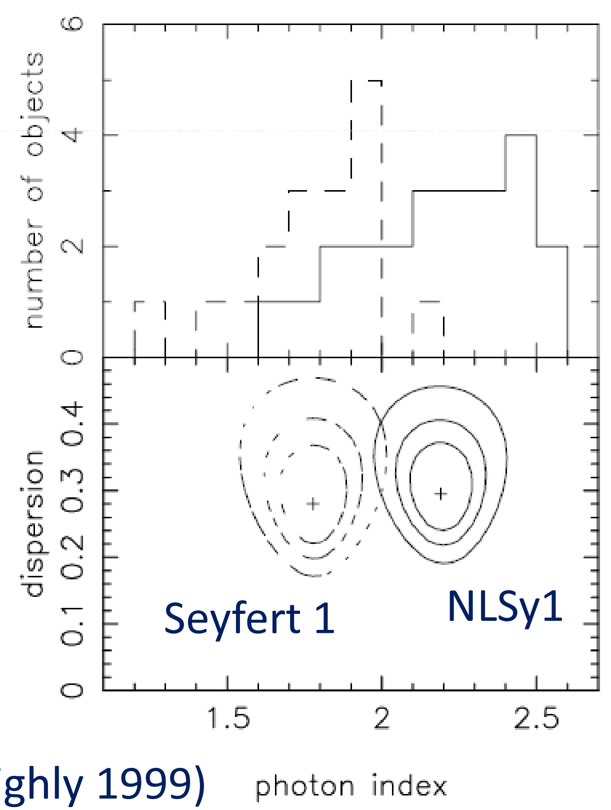
(from Boller et al. 1996)

X-ray Properties:

- Strong and rapid variability;
- Steeper spectra compared to Seyfert 1: 2.2 vs 1.8

Accretion close to Eddington rate?

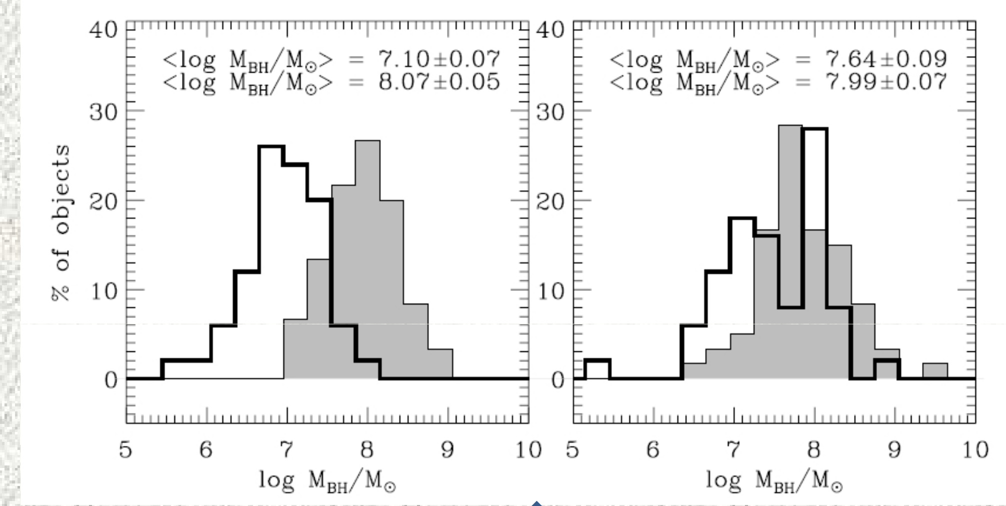
Lower masses?



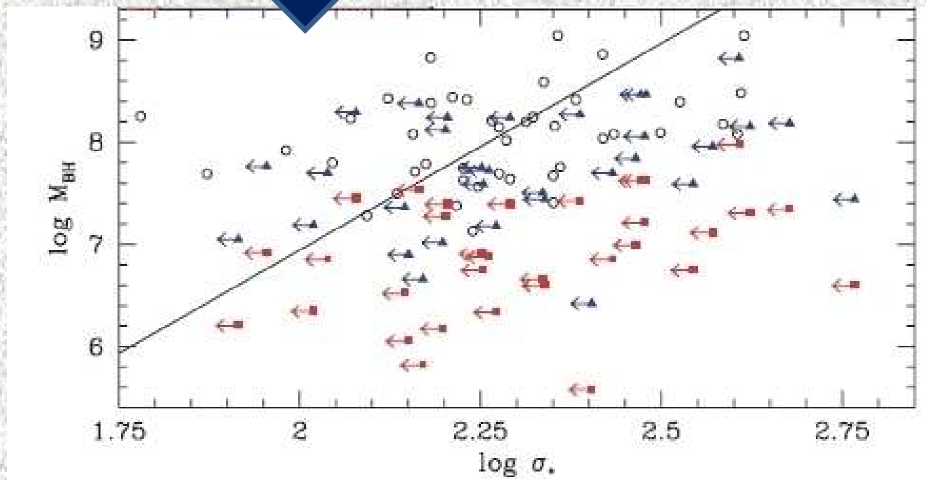
(from Leighly 1999)

NLSy1 Masses

Several authors pointed out that the characteristics of NLSy1 (steep spectra, extreme variability, …) can be explained by considering **lower masses of the central BH** and high accretion rate (e.g. Grupe & Mathur 2004).



Recently, Decarli et al. (2008) suggested instead that NLSy1 can have normal Sy1 masses, if we take into account a **disk-like** (instead of a isotropic) broad-line region.



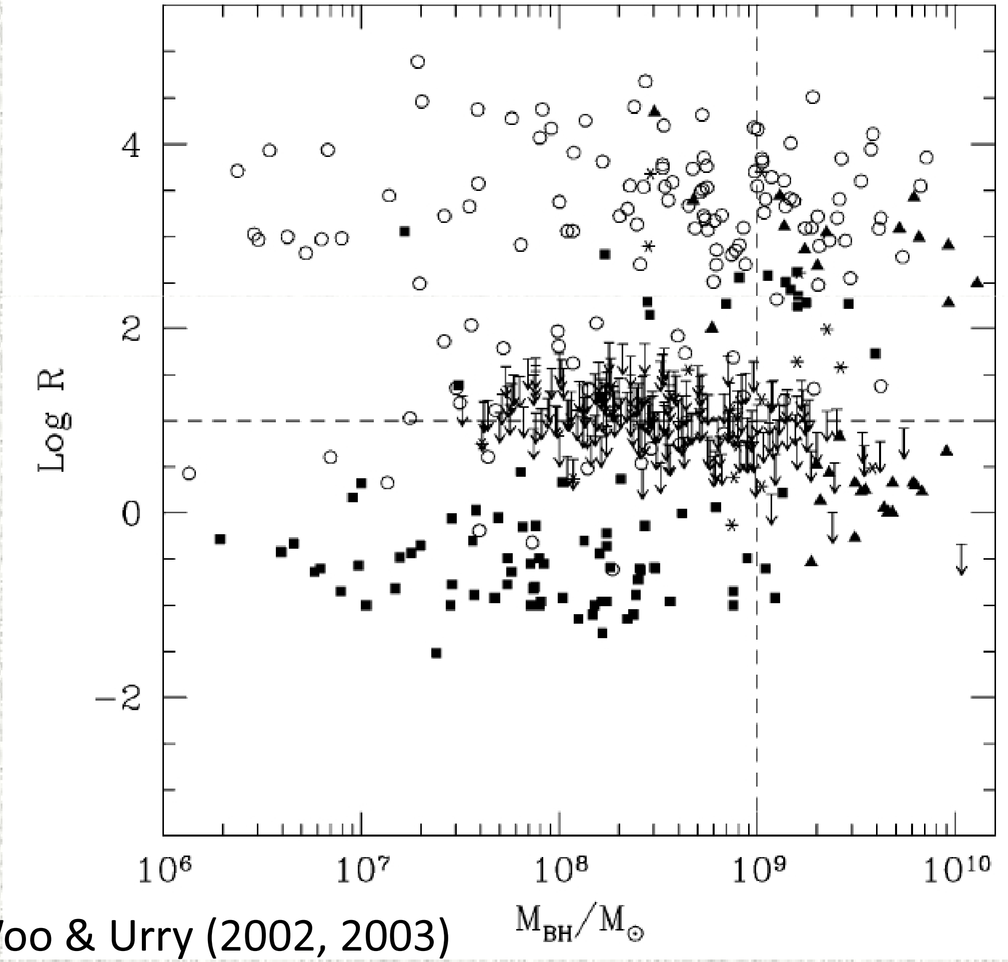
Also Marconi et al. (2008), independently and with a different method, suggested that if the **radiation pressure** is considered, again the masses are normal.

NLSy1 Masses: is really a problem?

Franceschini et al. (1998) and other researchers suggested that radio-quiet AGN have lower masses with respect to radio-loud AGN. **Laor (2000)** measured even a threshold of ≈10^9M❤ for an AGN to be radio-loud.

However, **Oshlack et al. (2002)** and **Woo & Urry (2002)**, with much larger samples, found no dicotomy, i.e. **the radio loudness is independent on the central black hole mass.**

The radio loudness **must** be independent on the mass of the central BH, otherwise microquasars would **not** exist!



Woo & Urry (2002, 2003)

Radio-quiet vs Radio-loud

General framework

- Radio-loudness R defined as $S_{5\ GHz}/S_B > 10$ (Kellermann et al. 1989) ; other definitions, less affected by contributions from the host galaxy are available (radio vs UV or X-rays);

- 15-20% of AGN are radio-loud (Urry & Padovani 1995);

- Radio-loud AGN include blazars and radiogalaxies, depending on the observing angle; the remaining radio-quiet AGN include Seyferts, QSO, Narrow-line Seyfert/QSO 1;

- **BUT about 6-7% of NLSy1/QSO1 are radio-loud!**

- **Why?**
  - Wrong classification?
  - Is there any physical reason?
  - Link with radio-loud AGN?
  - Other?

SDSS/FIRST Survey

by Yuan et al. arxiv 0806.3755

q Study of NLSy1 RL from SDSS and FIRST, with R(1.4 GHz)>100 [R(5 GHz) > 50]: it resulted in 23 sources (**optically selected** from SDSS);

q **Radio (FIRST):** compact and unresolved sources with flat spectra;

q **Optical (SDSS):** continuum bluer than NLSy1 RQ;

q **X-ray (RASS):** detection rate higher than NLSy1 RQ;

q Some objects resemble to HBL, with synchrotron peak in UV/X-rays; perhaps, the HFSRQ population proposed by Padovani?

Sample selection

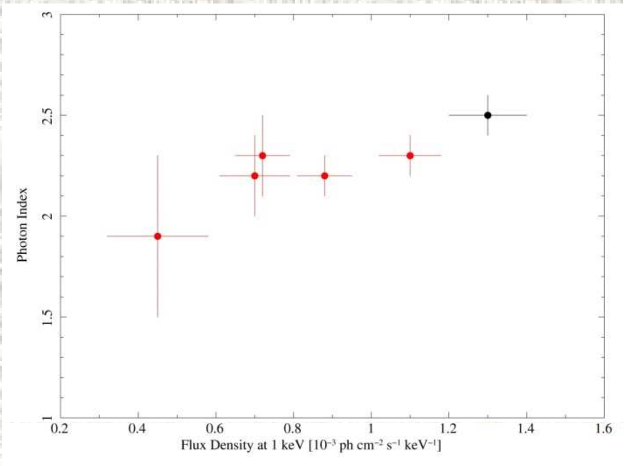
- **Main sources** of NLSy1/QSO1 Radio-loud:
  - Zhou H. Y. & Wang T. G., 2002, Chin. J. Astron. Astrophys. 2, 501
  - Komossa S. et al., 2006, AJ 132, 531
  - plus some papers on specific sources (e.g. 2MASX J0324+3410 a.k.a. 1H 0323+342, Zhou et al., 2007, ApJ 658, L13)

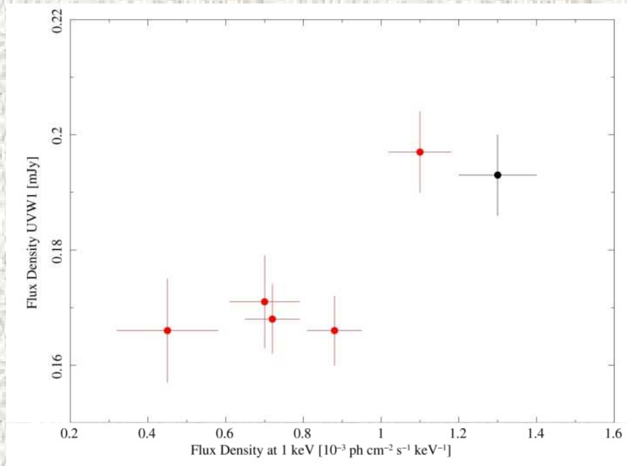
- Cross-correlation with **Swift** and **XMM-Newton** archives;
  - **XMM-Newton:**
    - PKS 0558-504 (z=0.1372);
    - B3 1702+457 (z=0.0604);
    - MS 1346.2+2637 (z=0.918388);
    - PKS 2004-447 (z=0.24);
  - **Swift:**
    - 1H 0323+342 (z=0.061);
    - RGB J1629+401 (z=0.271946);
    - RX J0134.2-4258 (z=0.238);
    - RX J2314.9+2243 (z=0.1692);
    - SDSS J172206.03+565451.6 (z=0.425583);

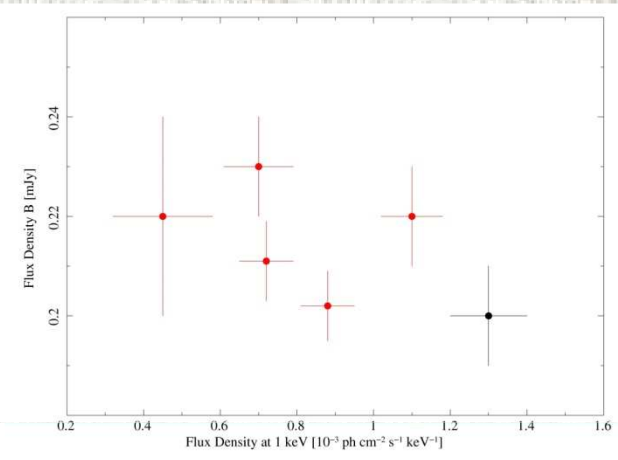
- This will allow us to have **simultaneous** optical/UV/X-ray data to build SEDs

RGB J1629+401

(z=0.272, R=35-182, flat radio spectrum)







Red points: single power law; **Black point:** broken power law

Γ-Flux: steeper when higher, but for high flux the spectral shape shows a break;

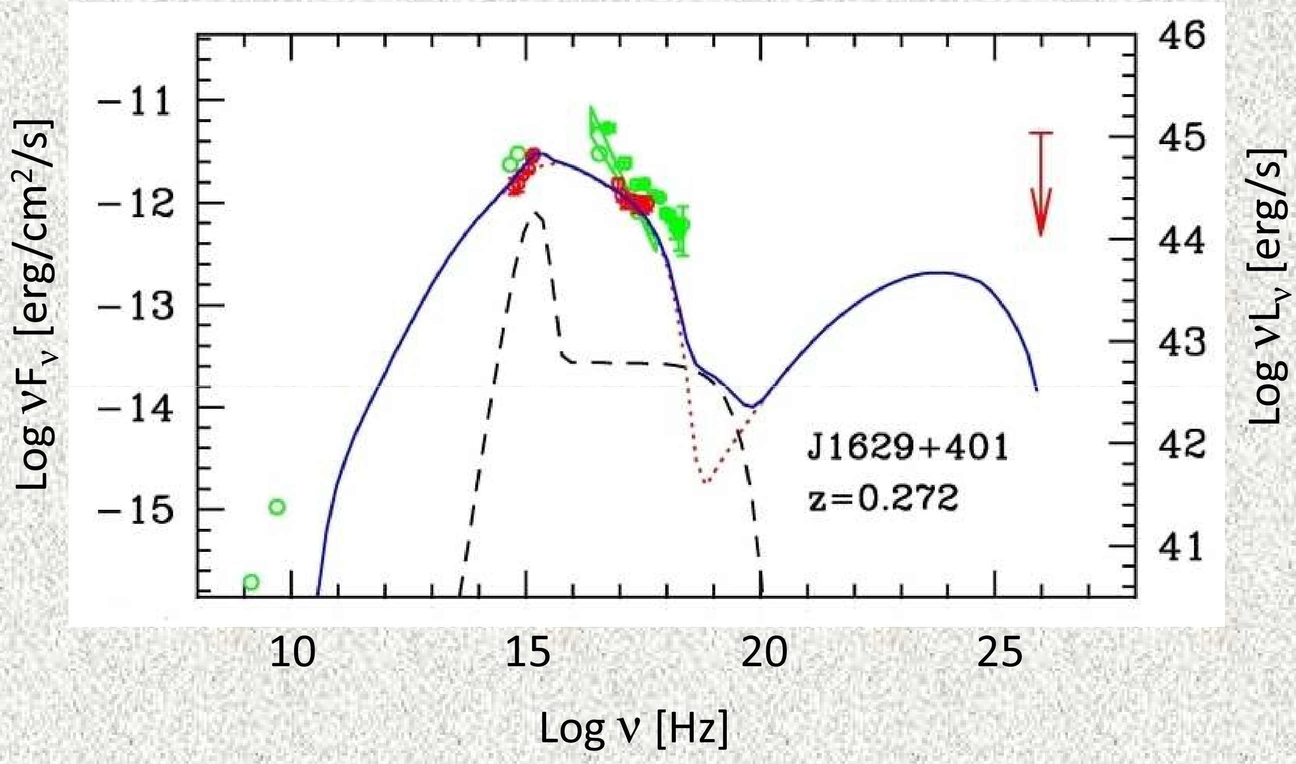
UVW1 (2634 Å)/X-ray: for high X-ray flux, there is high UVW1 flux;

B (4329 Å)/X-ray: high X-ray flux corresponds to low B flux;

Compare with classical NLSy1 Radio-Quiet (at the end of the presentation)

RGB J1629+401

(z=0.272, R=35-182, flat radio spectrum)

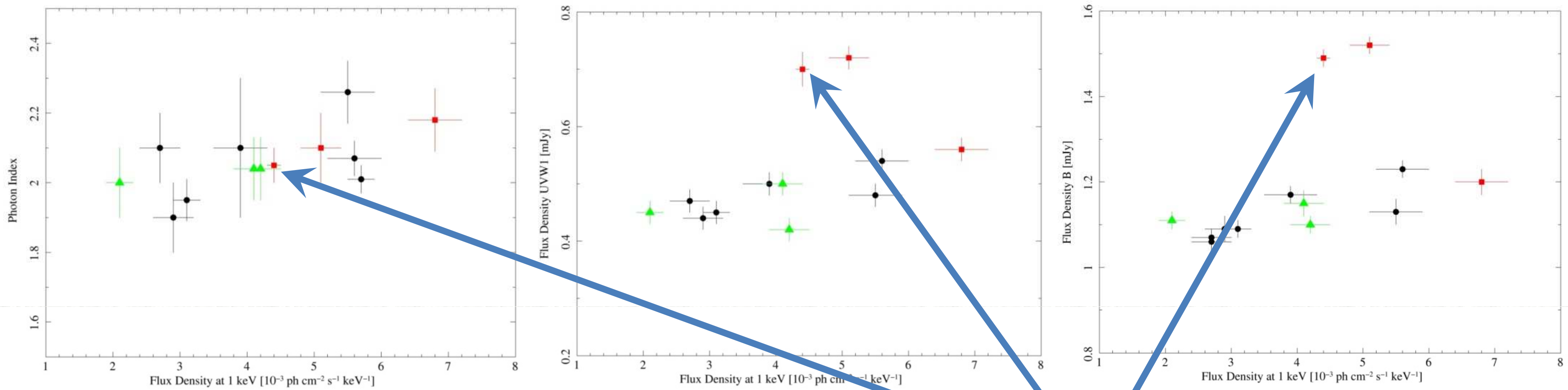


The *Swift* data can be modeled with SSC/EC model (Ghisellini, Celotti & Costamante 2002) with Γ=10, B=1.5 G, and viewing angle 4°.

More details in Maraschi et al. (2008, arXiv:0802.1789) and Maraschi et al. (in preparation).

1H 0323+342

(z=0.061, R=38-151, flat and polarized radio spectrum)

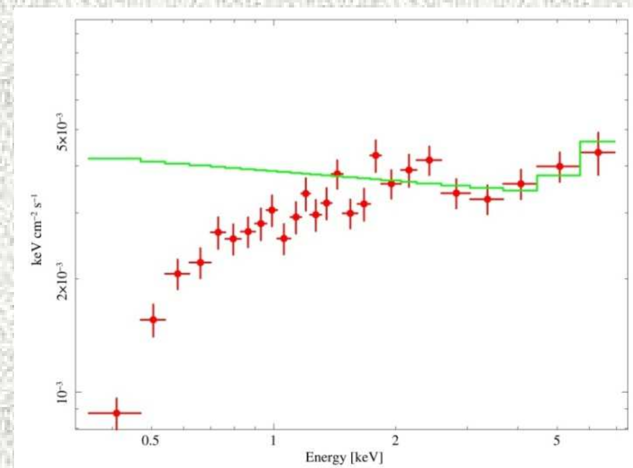


Swift XRT and UVOT:

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

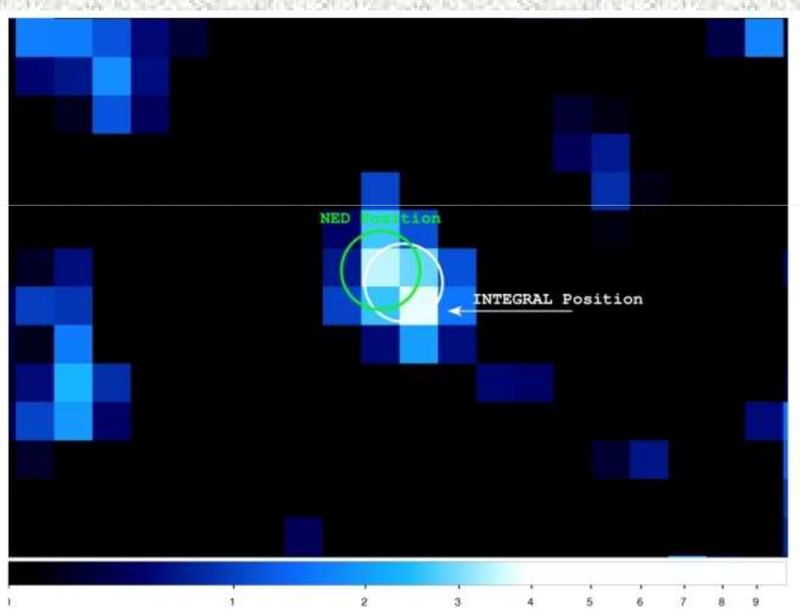
Green triangles: $\Gamma \approx 2$, hints of features in the spectrum; (no clear link; perhaps it is simply due to lack of statistics);

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



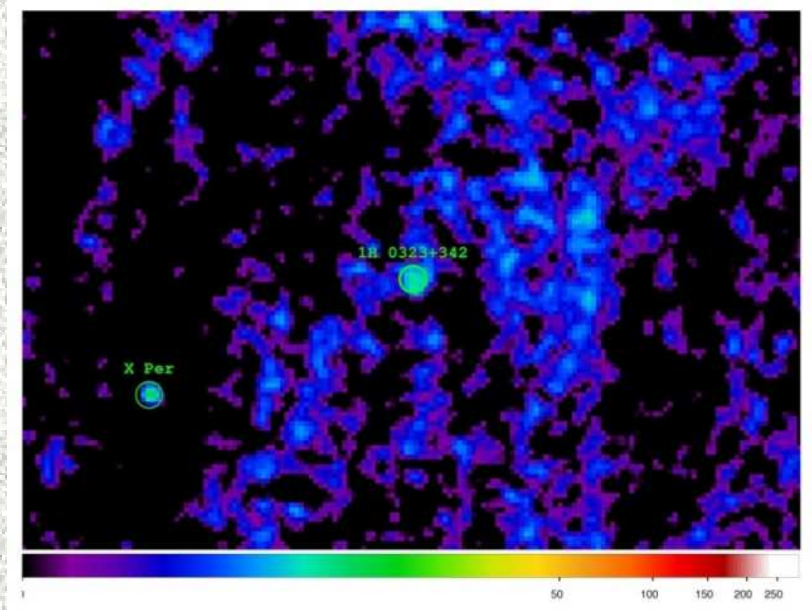
1H 0323+342
(z=0.061, R=38-151, flat and polarized radio spectrum)

Detections at hard X-rays with INTEGRAL/ISGRI (Krivonos et al. 2007, Bird et al. 2007, Malizia et al. 2007), but they consider it as a “normal” Seyfert. Nobody thought at radio-loudness or to the anomaly of a hard X-ray detection in a NLSy1.



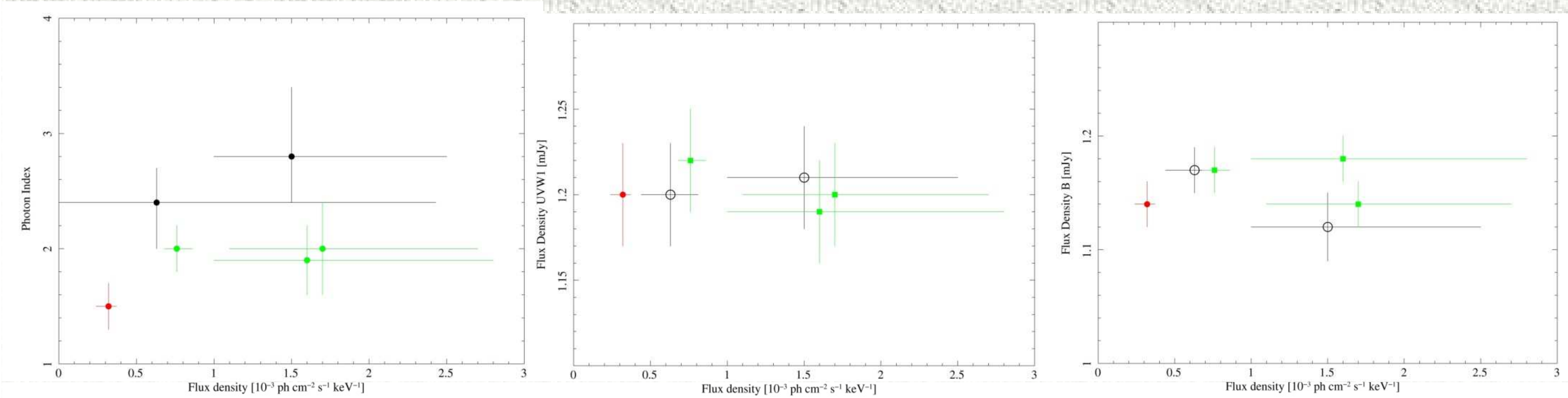
INTEGRAL/ISGRI (exp ≈ 200 ks):
20-40 keV ≈ 2.5 mCrab
40-100 keV < 2.6 mCrab
Faint, Soft

Strong variability!



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

RX J0134.2-4258
(z=0.238, R=36-178)



Green points: single PL, high flux, steep spectrum ($\Gamma \approx 2$), hints of low-energy flattening or broken pl with $\Gamma_{soft} < \Gamma_{hard}$;

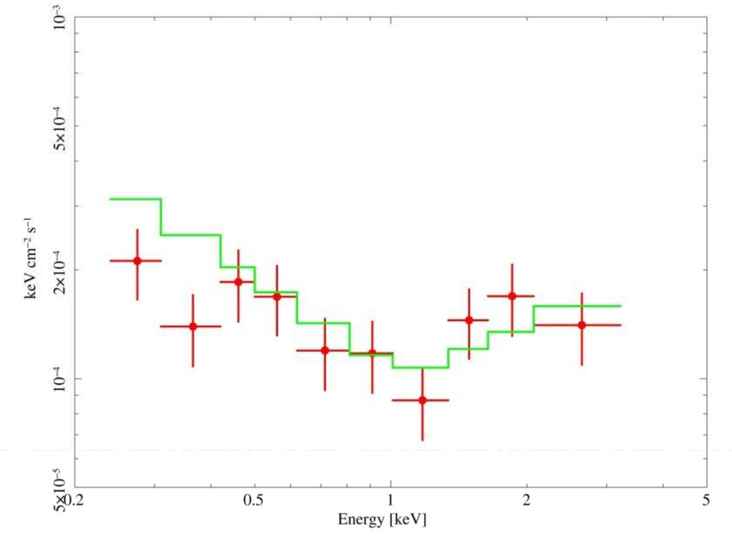
Red points: hard spectrum ($\Gamma = 1.5 \pm 0.2$) and moderately low flux;

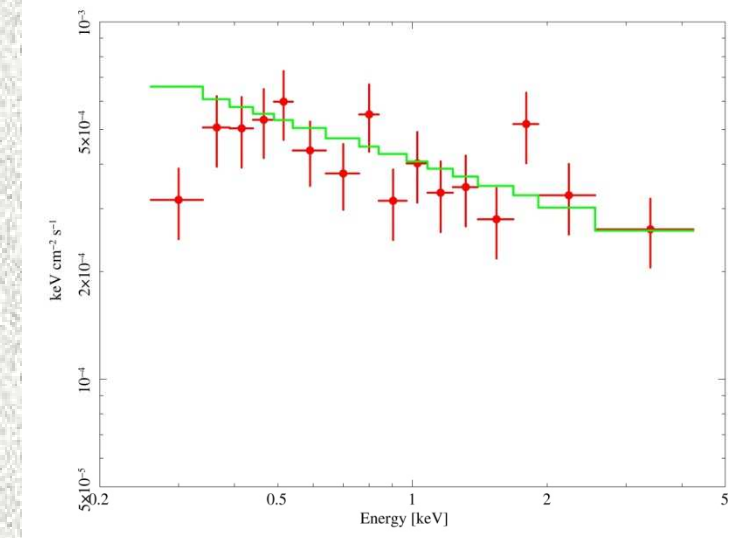
Black points: very steep spectrum ($\Gamma \approx 2.4$-2.8), hint of a warm absorber (redshifted Oxygen absorption edge at 0.58 keV);

Timescales of days. Strong spectral changes already noted by Grupe et al. (2000) and Komossa et al. (2000) with ROSAT and ASCA.

SDSS J172206.03+565451.6

(z=0.425583, R=70-773)





OBS 1 (June 23, 2007)

Γ_{soft} = 2.8 (+0.7, -0.4);

Γ_{hard} = 1.5 (+0.5, -0.6);

E_{break} = 1.0 ± 0.4 keV;

Flux [0.2-10 keV] =

= $(1.0\pm0.1)\times10^{-12}$ erg cm^{-2} s^{-1};

Flux [UVW2, 2030 Å] =

= $(8.9\pm0.2)\times10^{-2}$ mJy

OBS 2 (July 4, 2007)

Γ = 2.4 ± 0.1

Flux [0.2-10 keV] =

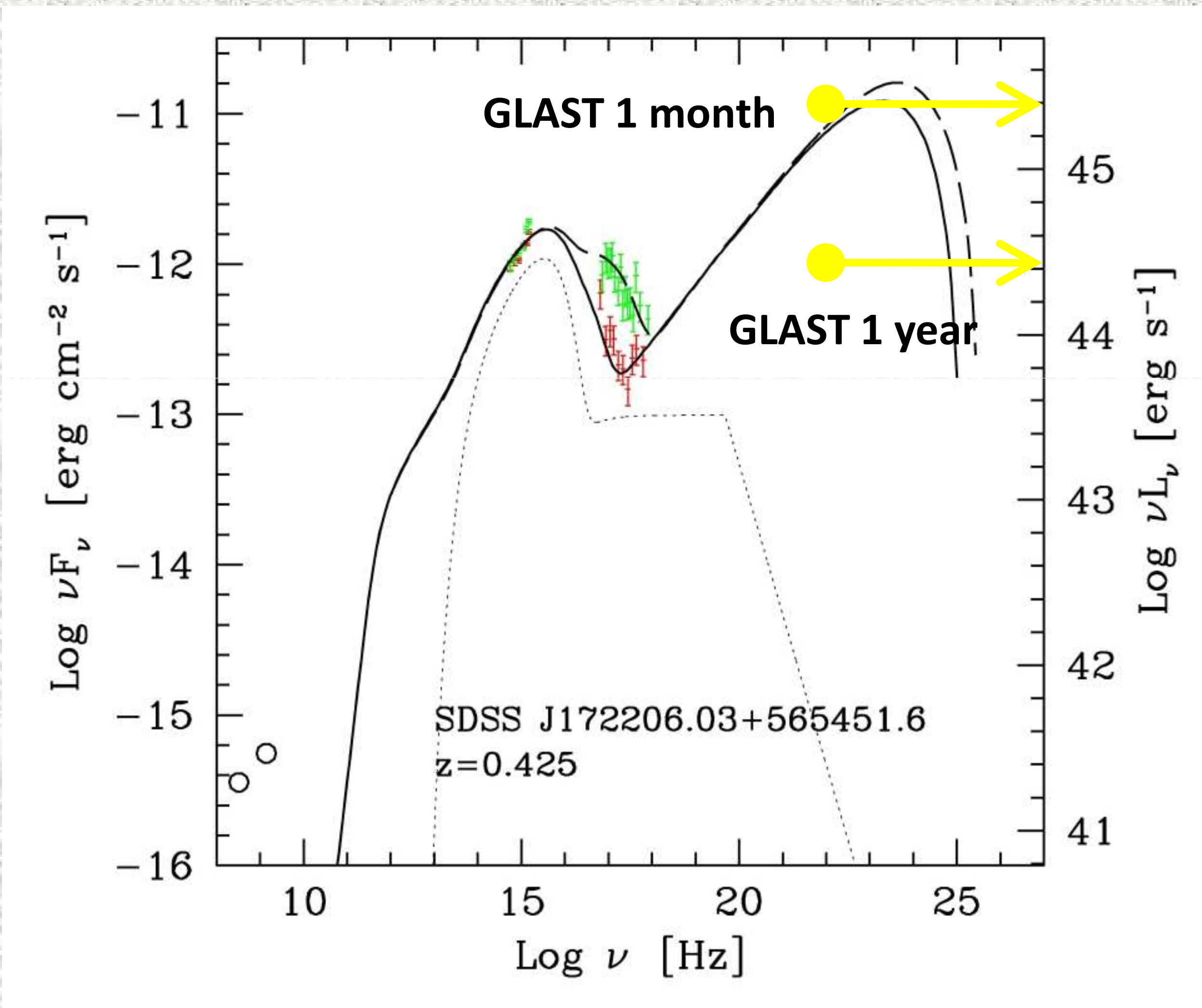
= $(1.9\pm0.2)\times10^{-12}$ erg cm^{-2} s^{-1};

Flux [UVW2, 2030 Å] =

= $(10.4\pm0.3)\times10^{-2}$ mJy

SDSS J172206.03+565451.6

(z=0.425583, R=70-773)



SSC model (see Maraschi & Tavecchio 2003) can fit *Swift* data:

"High-state"

R = 2.3×10^{15} cm

B = 2 Gauss

δ= 4

γ_{min} = 10

γ_{break} = 1.5×10^4

γ_{max} = 4×10^4

n_1 = 2

n_2 = 3.6

"Low-state"

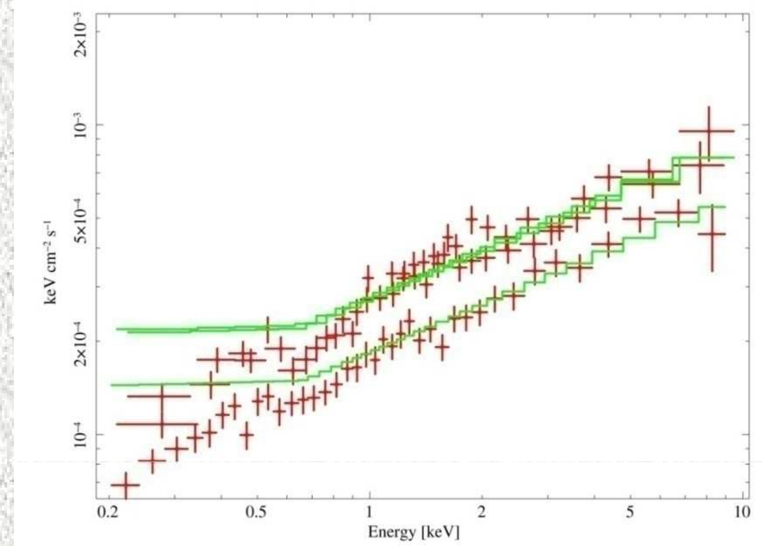
The same as above, but with:

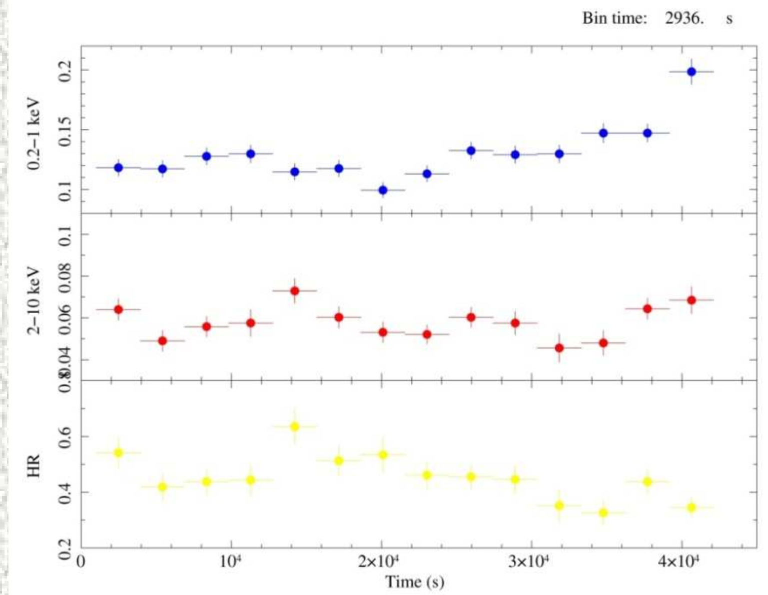
γ_{max} = 1×10^5

n_2 = 3.2

PKS 2004-447

(z=0.24, R=1710-6320, Radio: CSS/GPS)





Analyzed in detail by **Gallo et al. (2006)** with a MW campaign from radio to X-rays.

XMM-Newton data reanalyzed here.

X-ray spectrum:

Γ_{soft}=2.0±0.2 Γ_{hard}=1.49±0.03

E_{break}=0.66±0.08 keV

Flux 0.2-10 keV = 1.5×10^{-12} erg cm^{-2} s^{-1}

X-ray Variability:

0.2-1 keV: RMS (16±4) %

2-10 keV : negligible, RMS < 8 % (3 σ)

Two different components!

Soft excess typical of NLSy1, but Γ_{hard} unusually hard.

Soft excess unusual for CSS (cf Guainazzi et al. 2006).

Similar to FSRQ, both in spectrum and variability?

Other sources

(no more studied)

- **B3 1702+457 (z=0.0604, R=11):** classical Seyfert with complex spectrum (lines)

- **MS 1346.2+2637 (z=0.918388, R=6-18):** classical Seyfert with complex spectrum (lines)

- **RX J2314.9+2243 (z=0.1692, R=8-18):** Two Swift pointings, but one with not sufficient statistics. The average X-ray spectrum is well fitted with a broken power-law: Γ_{soft} = 1.5 ± 0.2; Γ_{hard} = 2.2 ± 0.3; E_{break}= 1.5 ± 0.5 keV; Flux [0.2-10 keV] = 2.3×10^{-12} erg cm^{-2} s^{-1}. No changes in the optical/UV.

Other sources

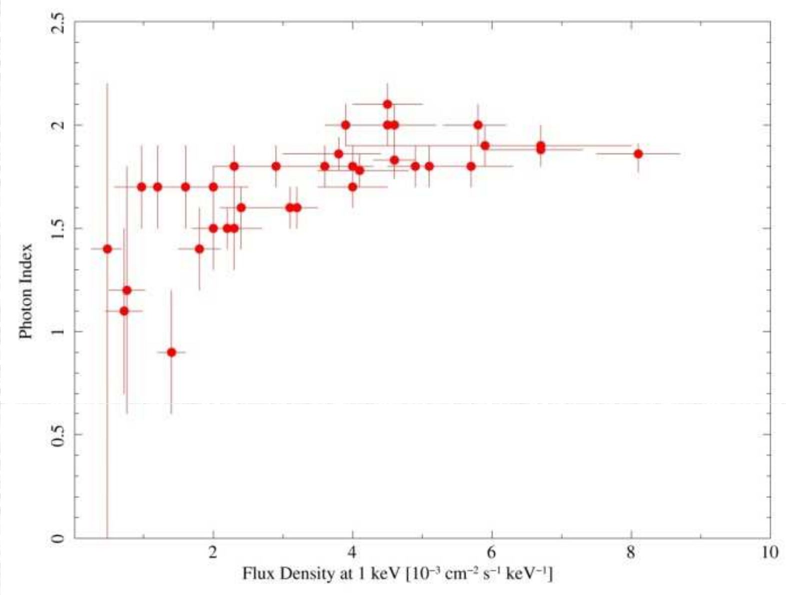
(not reported here, but studied)

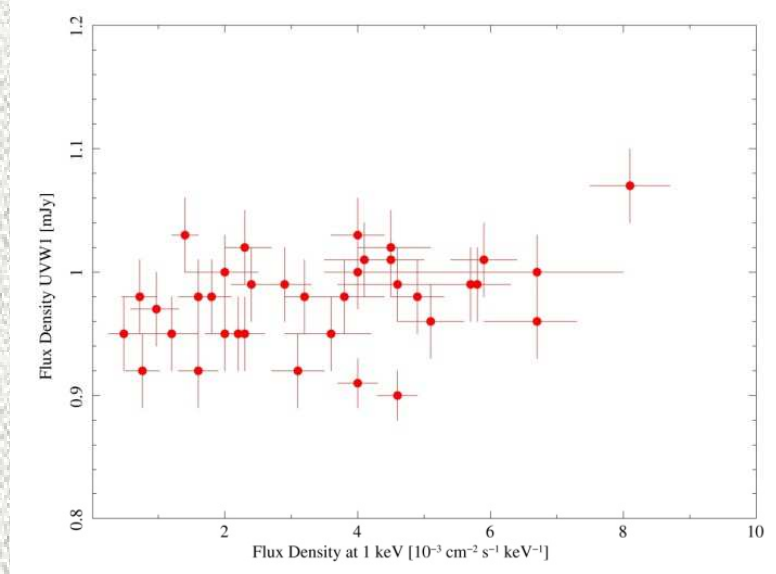
- **PKS 0558-504 (z=0.1372, R=15-35):** extensively studied by Gliozzi et al. (2001, 2007), also with long-term monitoring campaigns (RXTE). Main conclusions are that:
  - if jet dominated, it is similar to 3C 273, although the jet appears to be a bit strange;
  - if corona dominated, it is similar to a GBH in intermediate state;

- Long MW campaign, designed by Gliozzi, should begin in September 2008.

A template of NLSy1 Radio Quiet

Mkn 766 (z=0.012929)

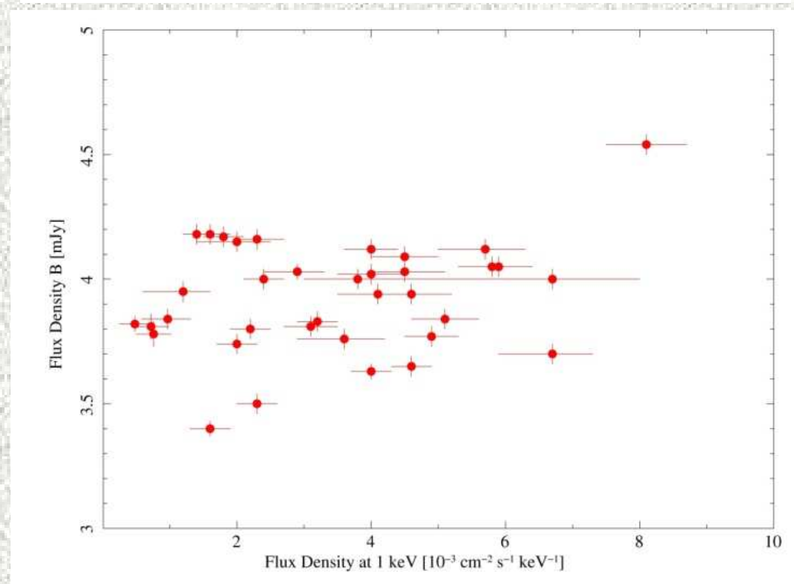




Γ-Flux: steeper when higher;

UVW1/X-ray: no evident correlation;

B/X-ray: no evident correlation;



A template of FSRQ

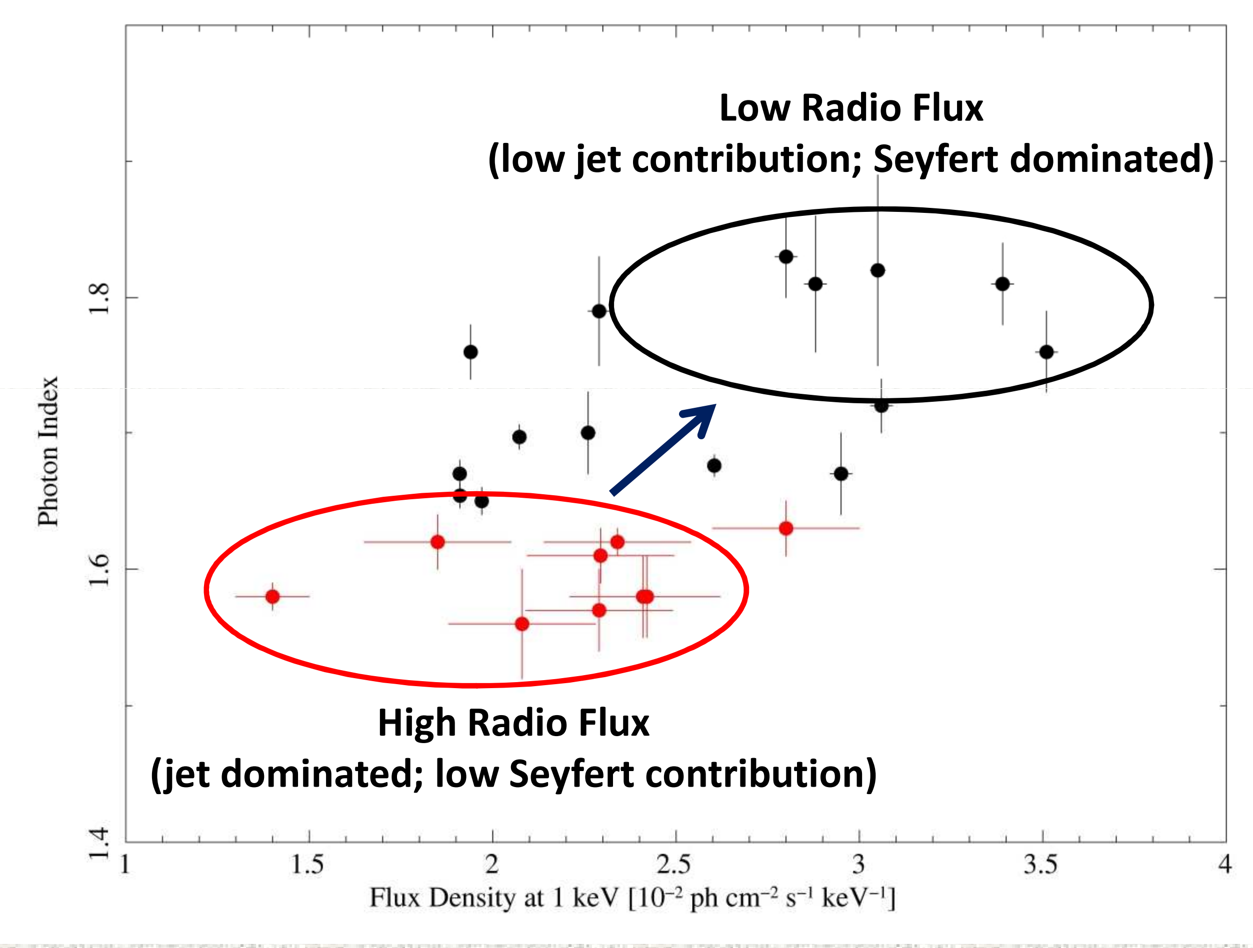
3C 273 (z=0.158, jet viewing angle ≈10°)

Black points: XMM-Newton observations from Foschini et al. (2006);

Red points: BeppoSAX observations from Grandi & Palumbo (2004)

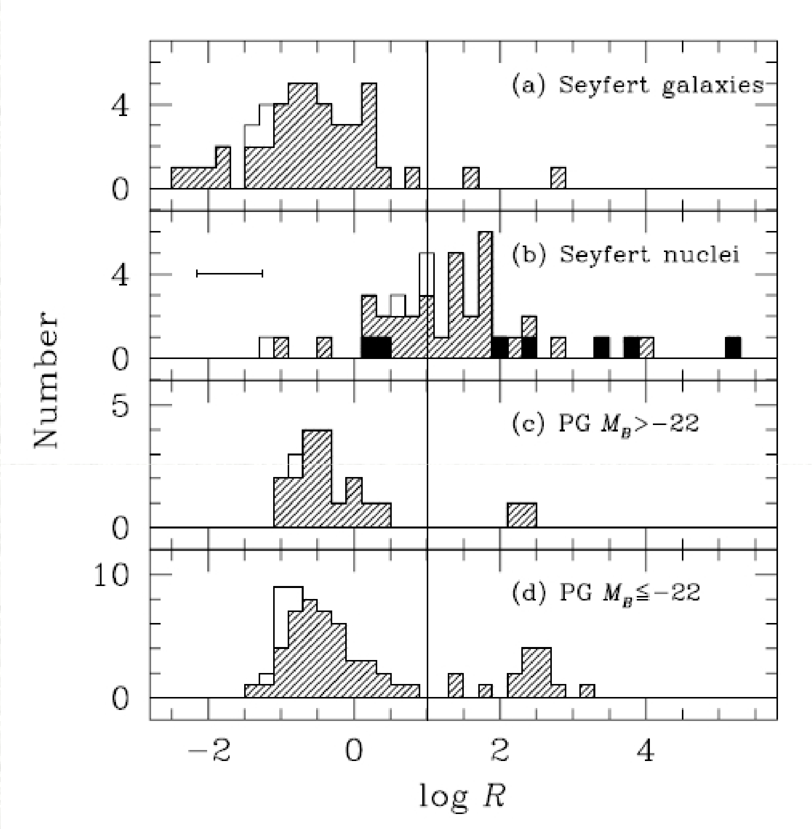
Γ-Flux: steeper when brighter, although the photon index is generally harder than that of NLSy1 RL.

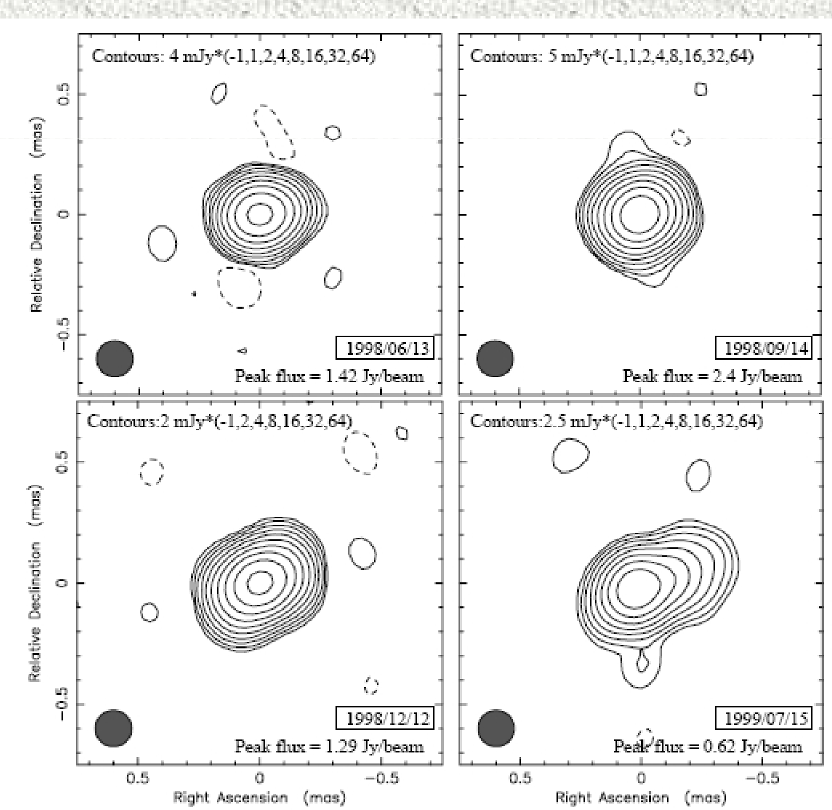
Timescale over years (1996-2004).



Radio-quiet vs Radio-loud: Caveat

- **Ho & Peng (2001)** have shown that radio and optical emission in Seyferts can be biased by the host galaxy contribution. After having properly subtracted this part, about 60% of the Seyferts in the analyzed sample change into **radio-loud**!





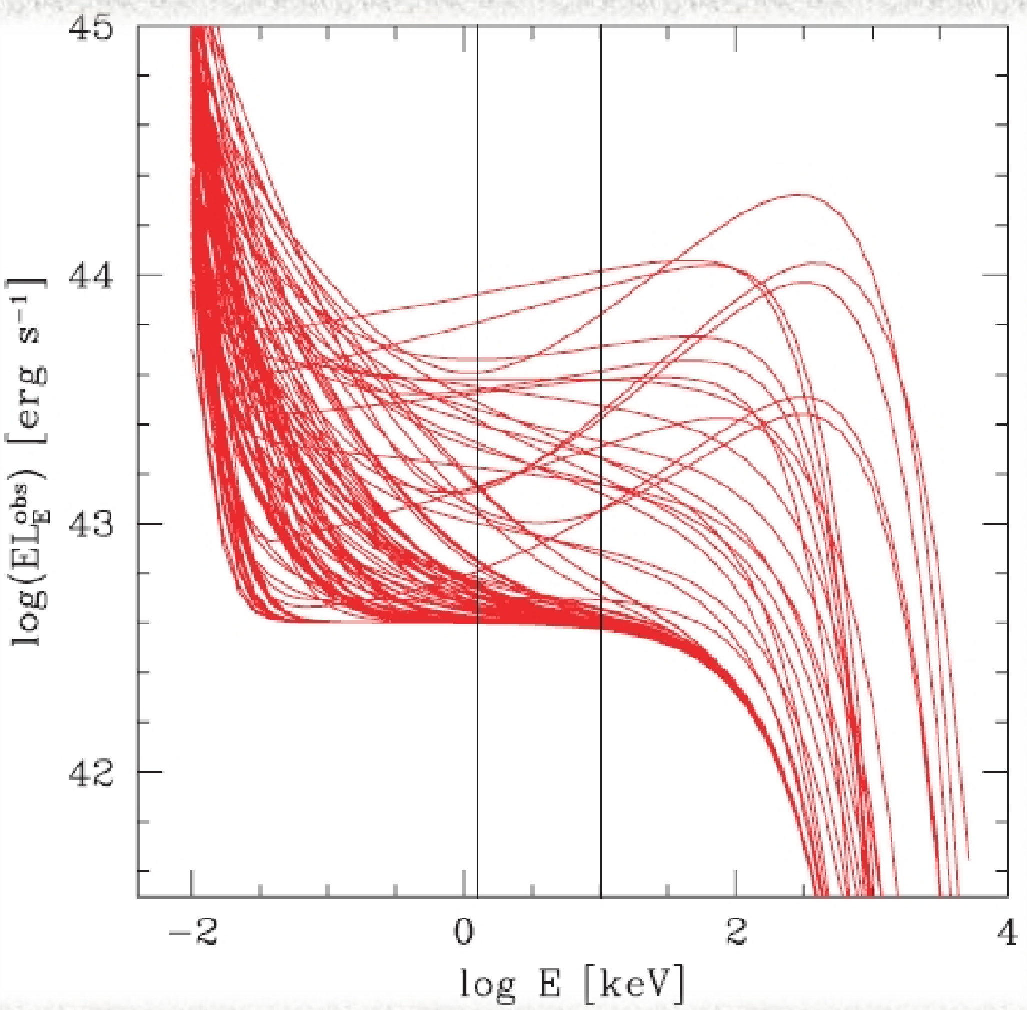
- **Brunthaler et al. (2000)** discovered the first superluminal jet in a “radio-quiet” Seyfert, with speed 1.25c.

Aborted/Launched Jet Scenario

The observed variability properties can fit the **aborted jets** scenario proposed by Ghisellini et al. (2004). Here it is shown an example of time-dependent simulated spectrum of an aborted jet, by assuming thermal Comptonization model by Titarchuk & Mastichiadis (1994).

This scenario has been proposed for NLSy1 RQ, but we note that it can be applied also for NLSy1 RL by adding that – sometimes - **the jet is lauched**.

[1-10 keV]



Ghisellini et al. (2004)

Conclusions

- NLSy1 Radio-Loud is something like a **“doggy-bag”** with some objects showing hints of blazar-like behaviour and some other objects, which are similar to classical Seyferts. There is need of extensive MW campaigns to monitor spectral and flux changes

- Blazar-like NLSy1 RL appears to be **similar to FSRQ seen at large angles (e.g. 3C 273)**, but it would be necessary to study the optical emission line variability to better assess this similarity.

- **Time behaviour is the key to understand these objects**: the most interesting cases show sometimes Seyfert behaviour and sometimes Blazar-like behaviour. A **hypothesis** is that sometimes the jet is aborted and sometimes is lauched.

- The **radio loudness**, as a “static” parameter, is not useful. It would be better to use R = R(t), i.e. a time-dependent radio loudness.

- Need of high-energy detections (we hope for **GLAST**) to confirm jet component.