EGRET AGN observed with INTEGRAL and XMM-Newton

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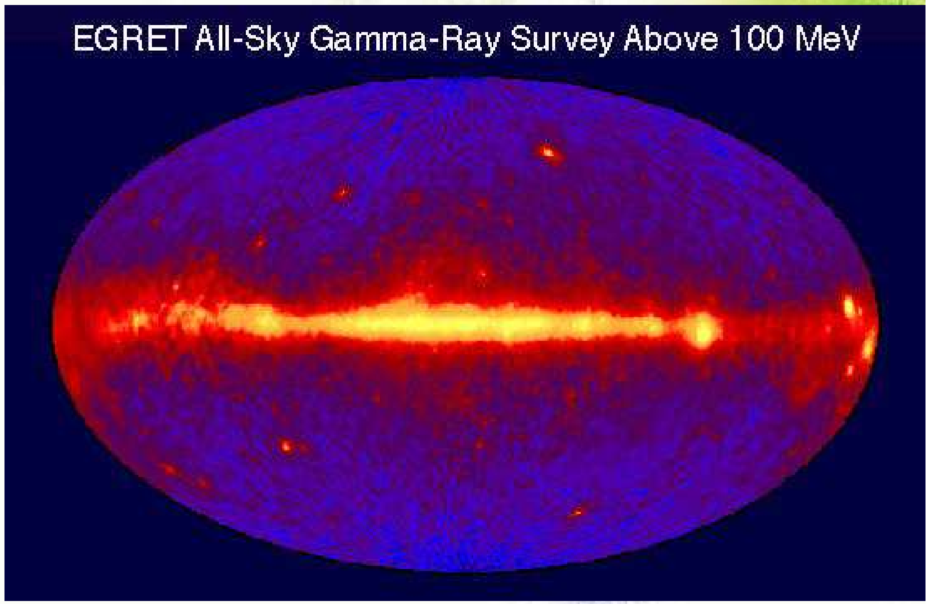
And many others…

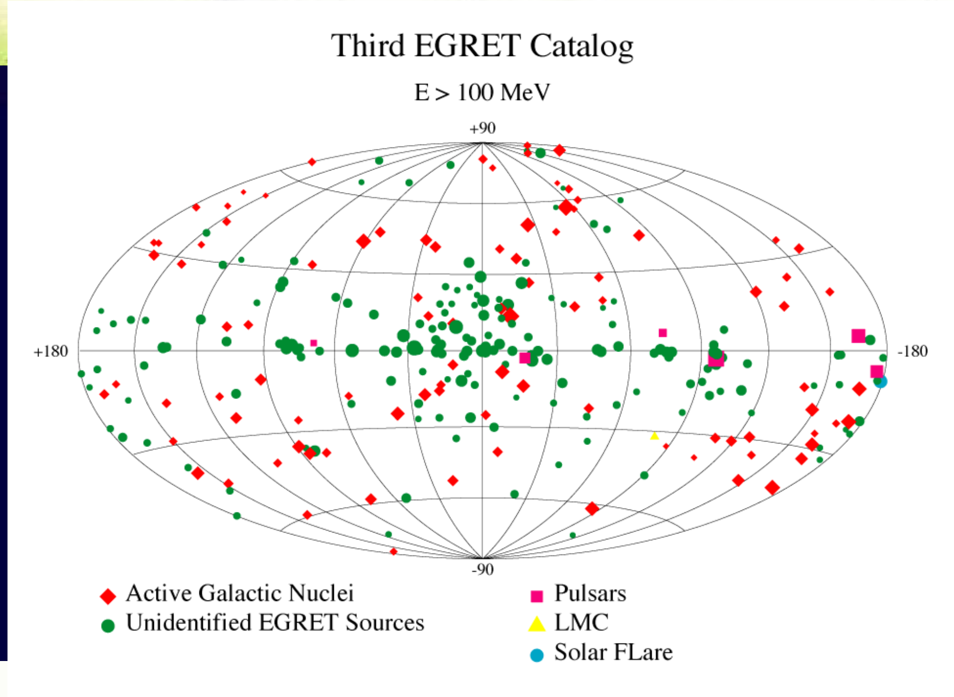
GLAST Collaboration Meeting
Blazar and other AGN Group Meeting
Stockholm (Sweden), 28 August 2006

A bit of history…

✓ **First detection** of γ-rays (50-500 MeV) from an AGN (3C 273) by ESA satellite *COS-B* (Swanenburg et al. 1978);

✓ Breakthrough with NASA satellite *CGRO/EGRET*, with 271 point sources detected at E>100 MeV (Hartman et al. 1999), 93 of them identified with **blazars** and 2 with **radiogalaxies**;



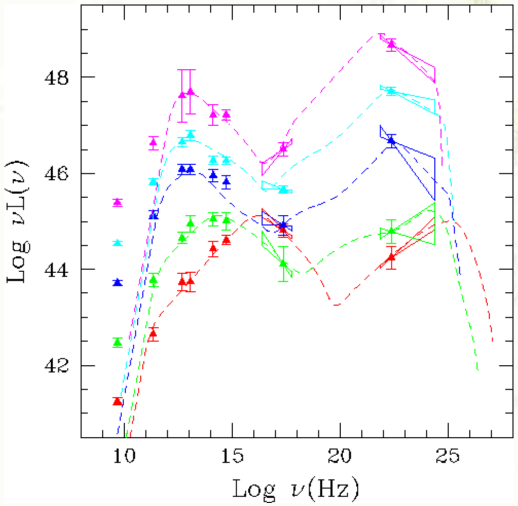


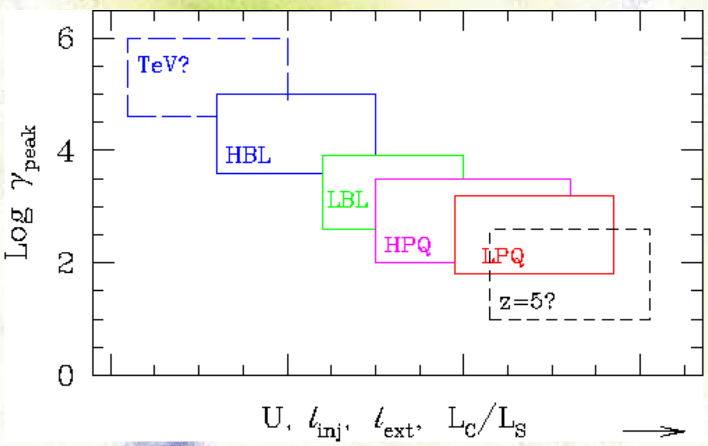
✓ γ-ray loudness strongly biased by EGRET sensitivity and non-uniform exposure map; **here we consider "γ-ray loud" an AGN detected by EGRET at E>100 MeV**;

A bit of what…

The **“blazar standard model”**: SMBH with a relativistic jet pointed toward the observer with small angles (<10°); the relativistic motion can account for negligible γ-ray attenuation.

The **“blazar sequence”** (Fossati et al. 1998; Ghisellini et al. 1998).





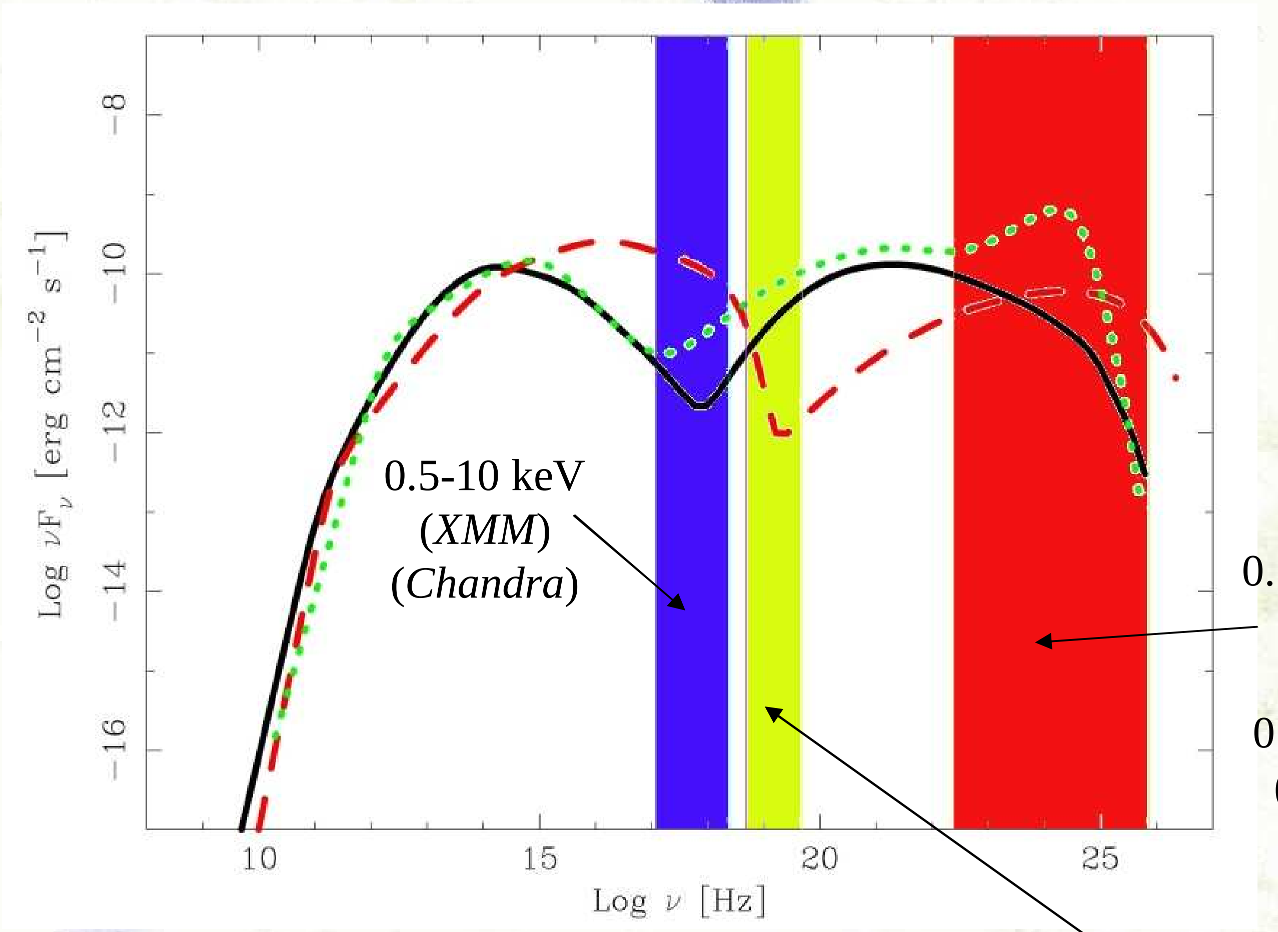
See, however, Padovani et al. (2003).

Open questions concerning the **physics** of γ–ray loud AGN: γ–ray generation mechanisms and places, dependence on viewing angle (link with radiogalaxies), composition of jets, disk-jet coupling, scaling laws for μquasar, and many more!

A bit of how…

Multiwavelength variability appears to be a key issue in understanding the blazar phenomenon: it should allow to gain insights on the geometry of the emitting region, acceleration/deceleration processes, test models (SSC, EC, others?), …

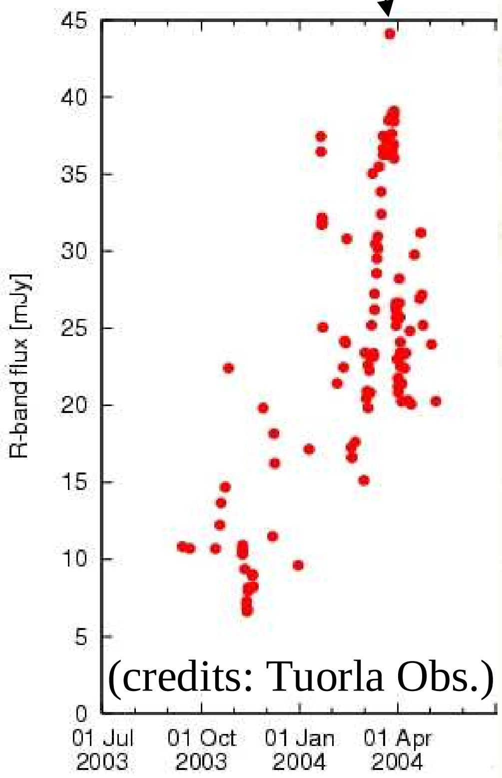
Multiwavelength variability: X-rays and hard X-rays energy bands are **crucial** in understanding the physics of γ-ray loud AGN.



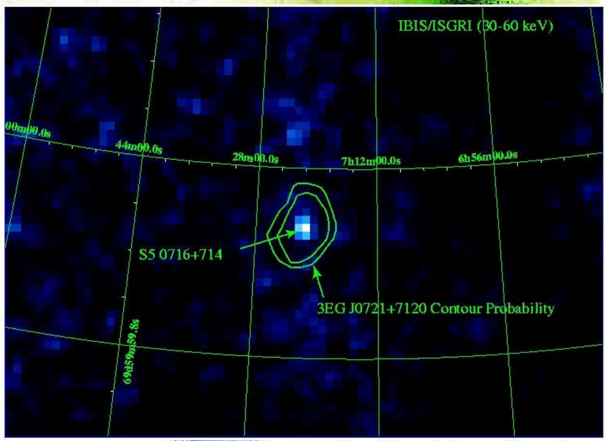
Continuous line: typical low frequency peaked BL Lac (LBL)
Dashed line: typical high frequency peaked BL Lac (HBL)
Dotted line: typical flat-spectrum radio quasar (FSRQ)

TOO activities to observe blazars in outburst: S5 0716+714

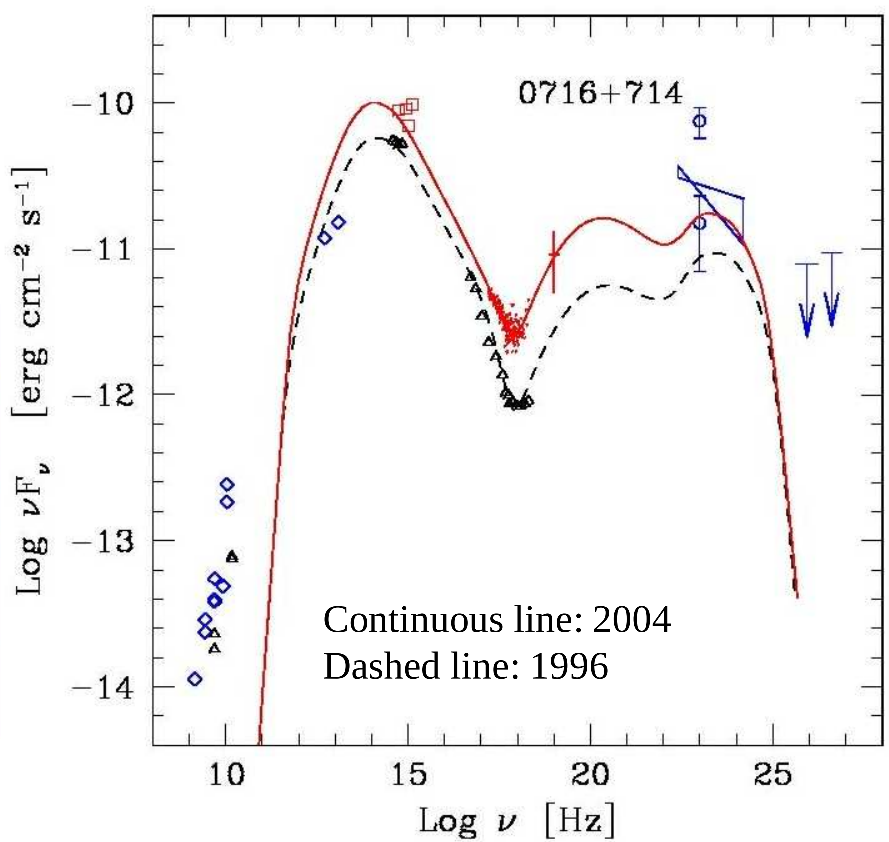
Optical outburst at the end of March 2004: **historical peak** recorded on 27 March 2004 with **R=12.1**! (Ostorero et al., in prep.)



Pian et al., 2005, A&A 429, 427



Model by Ghisellini, Celotti & Costamante (2002)



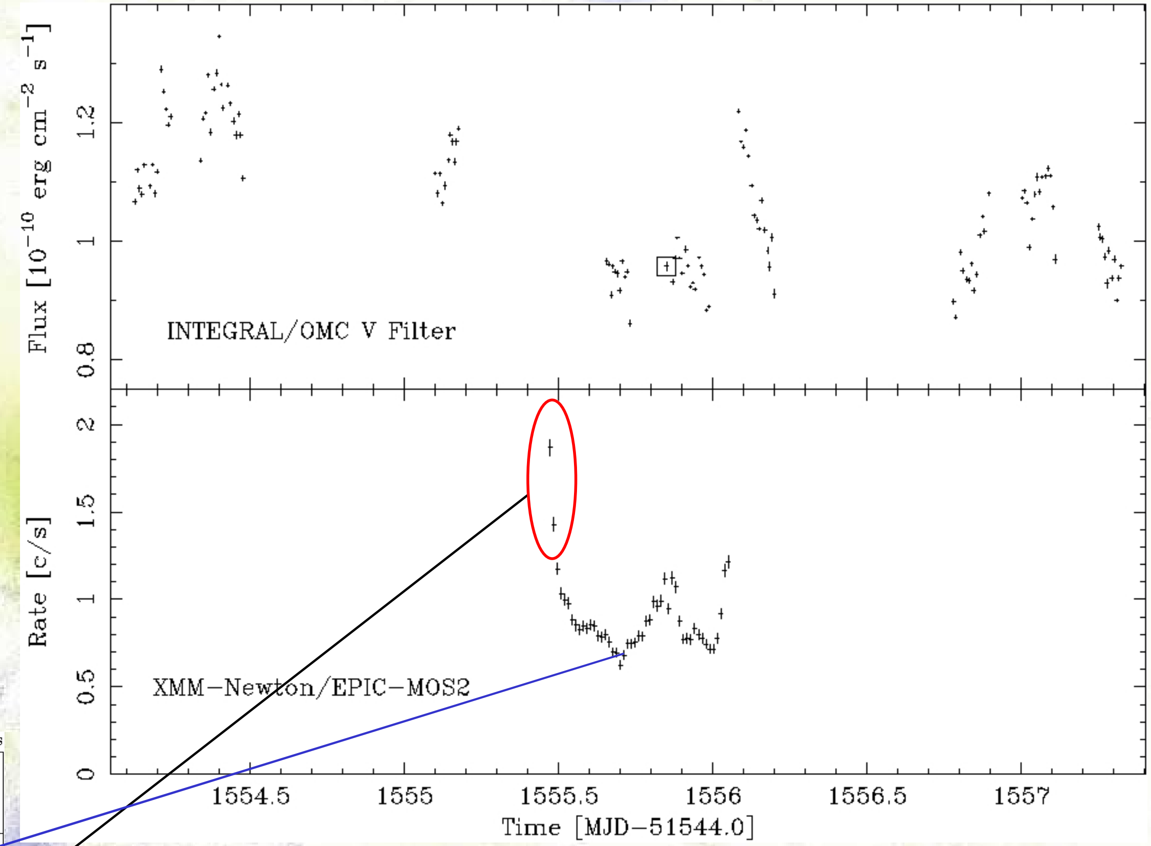
TOO with *INTEGRAL* (PI E. Pian; 2-7 April 2004; 280 ks) and *XMM-Newton* (PI G. Tagliaferri; 4-5 April 2004; 50 ks), but “too” late and the source was declining...

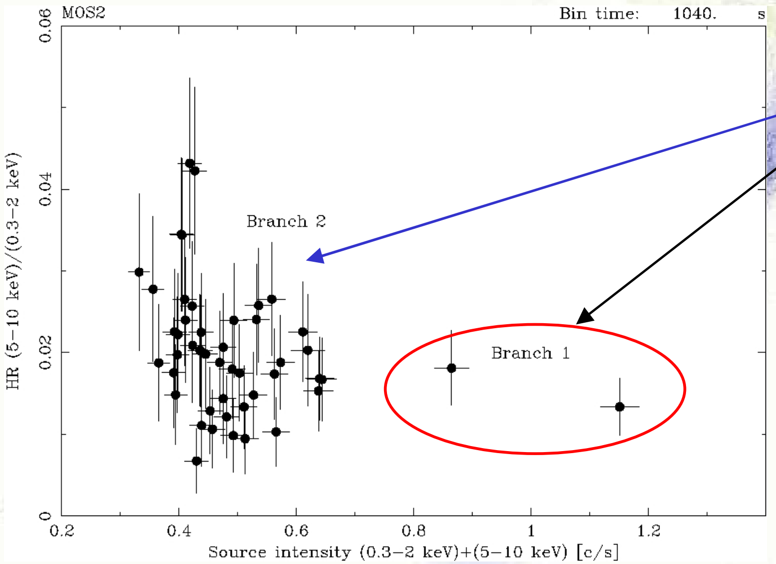
TOO activities to observe blazars in outburst: S5 0716+714

Long term variability (burst to quiescence; branch 1?):

➢ gradual decay afterburst probably due to escape of electrons from the processing regions or to a decrease of seed photons.

➢ from quiescence to outburst and viceversa (SED: 1996-2004): minor changes in the model parameters, except for the injected power (2.2×10^{42} erg/s in 1996; 4×10^{42} erg/s in 2004).



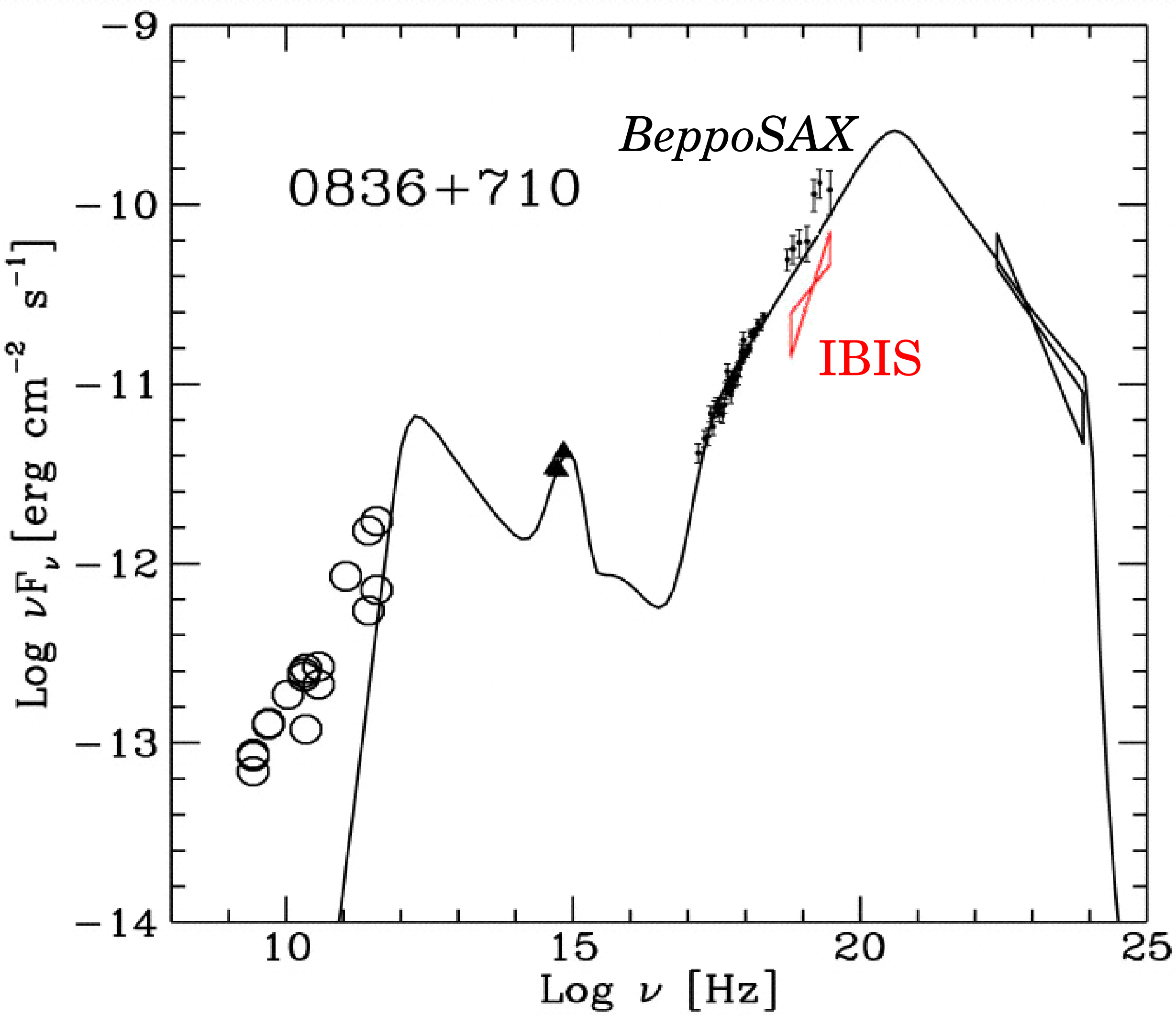


Short term variability (optical/X-ray flares; branch 2): probably due to changes in the slope of the electrons distribution.

Foschini et al., 2006, A&A 455, 871

TOO activities to observe blazars in outburst: S5 0836+710

Since the IBIS telescope has a large FOV of IBIS (29°×29°), it is possible to monitor simultaneously several sources. During the outburst of S5 0716+714, Pian et al. (2005) reported also the detection of **S5 0836+710**, that is "only" 6°.5 distant from the target source.

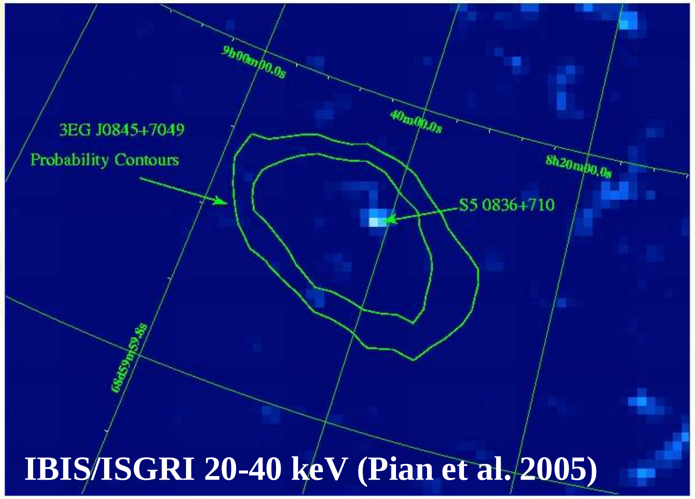


S5 0836+710 is a FSRQ at z=2.172.

BeppoSAX data from Tavecchio et al. (2000);

INTEGRAL/IBIS data from Pian et al. (2005).

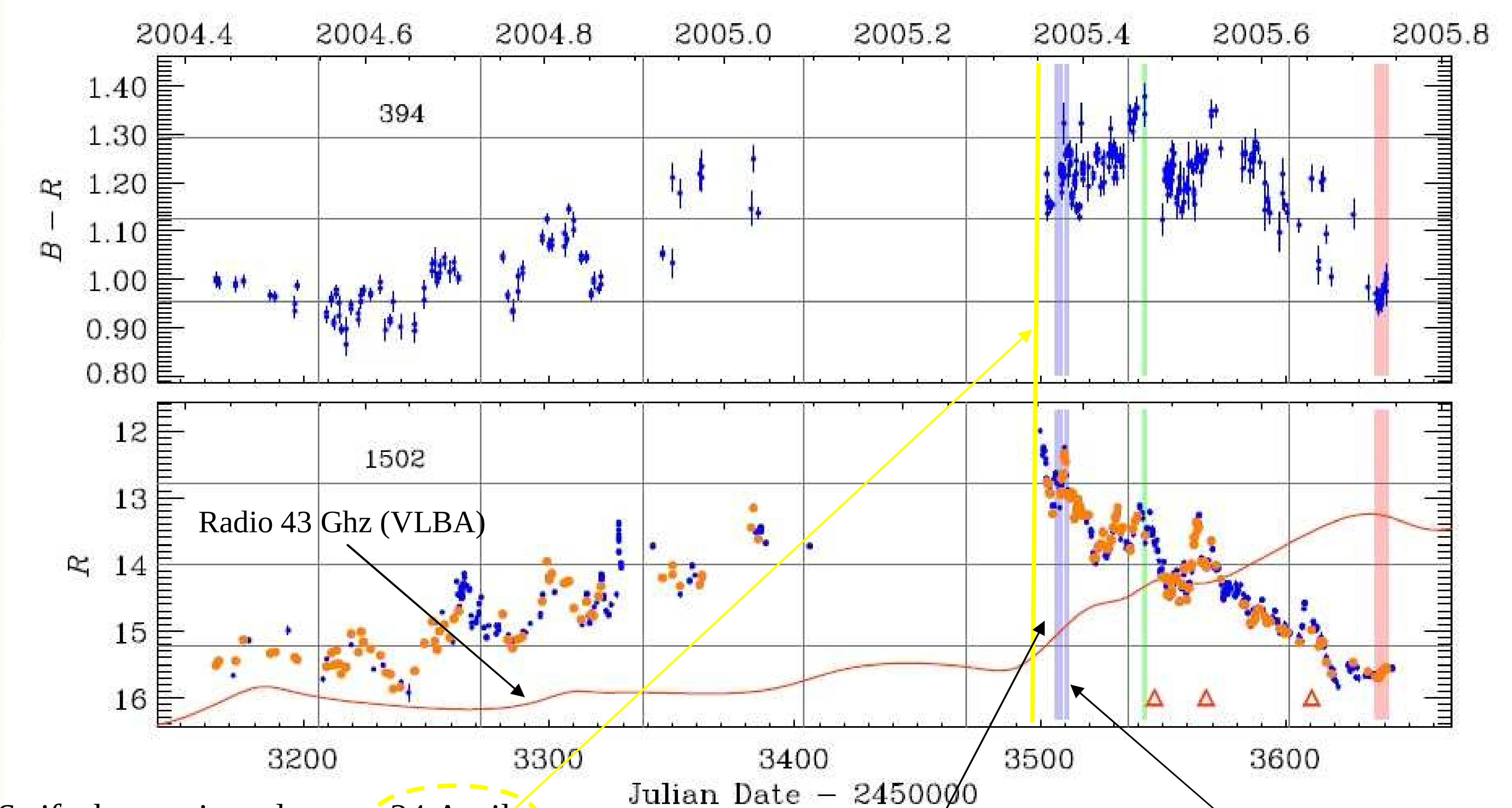
Γ≅1.3 in both observations, but the flux was a factor 3 lower during the INTEGRAL observation.



TOO activities to observe blazars in outburst: 3C 454.3

Long outburst of 3C 454.3 in April-May 2005.

Whole Earth Blazar Telescope campaign (Villata et al. 2006, A&A 453, 817)



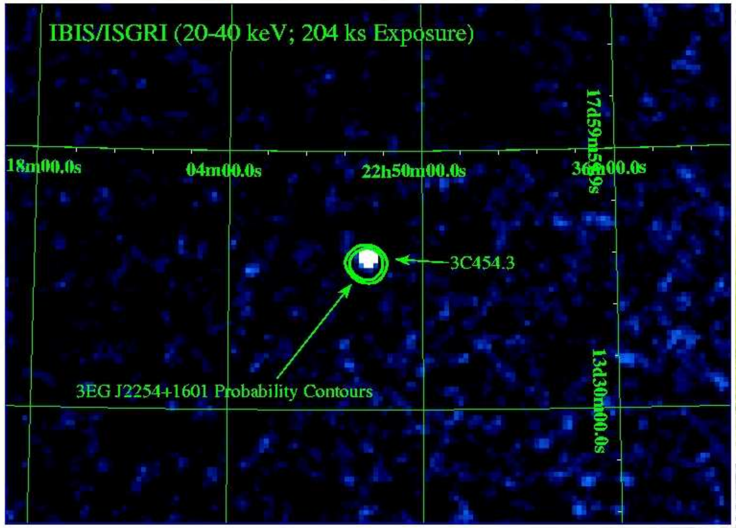
Swift observations done on 24 April, 11, 17, 19 May are reported in: Giommi et al., astro-ph/0606319

INTEGRAL (PI E. Pian) 15-18 May 2005

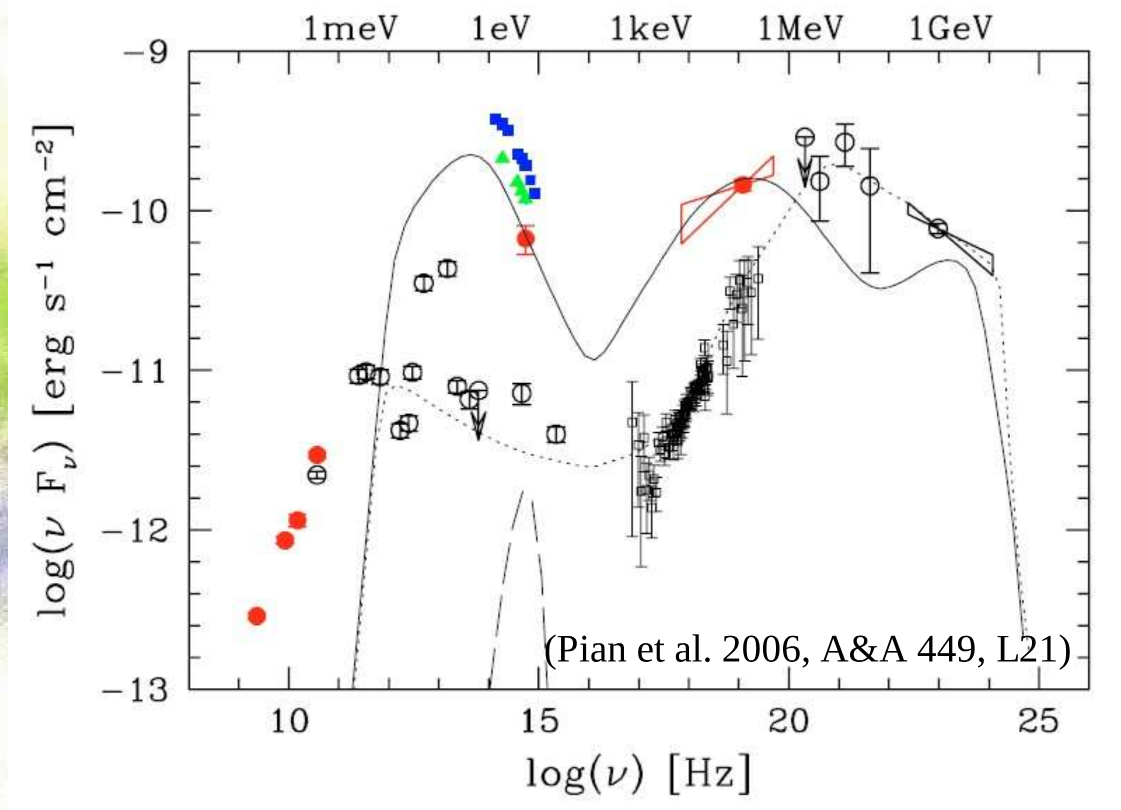
Chandra (PI F. Nicastro) 19-20 May 2005

TOO activities to observe blazars in outburst: 3C 454.3

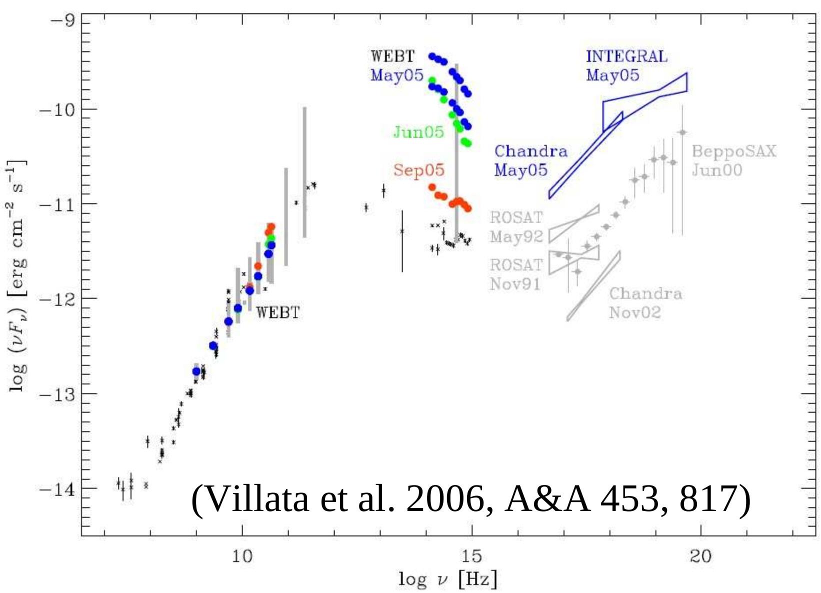
TOO with *INTEGRAL* (PI E. Pian)



Model by Ghisellini, Celotti & Costamante (2002)



(Pian et al. 2006, A&A 449, L21)



(Villata et al. 2006, A&A 453, 817)

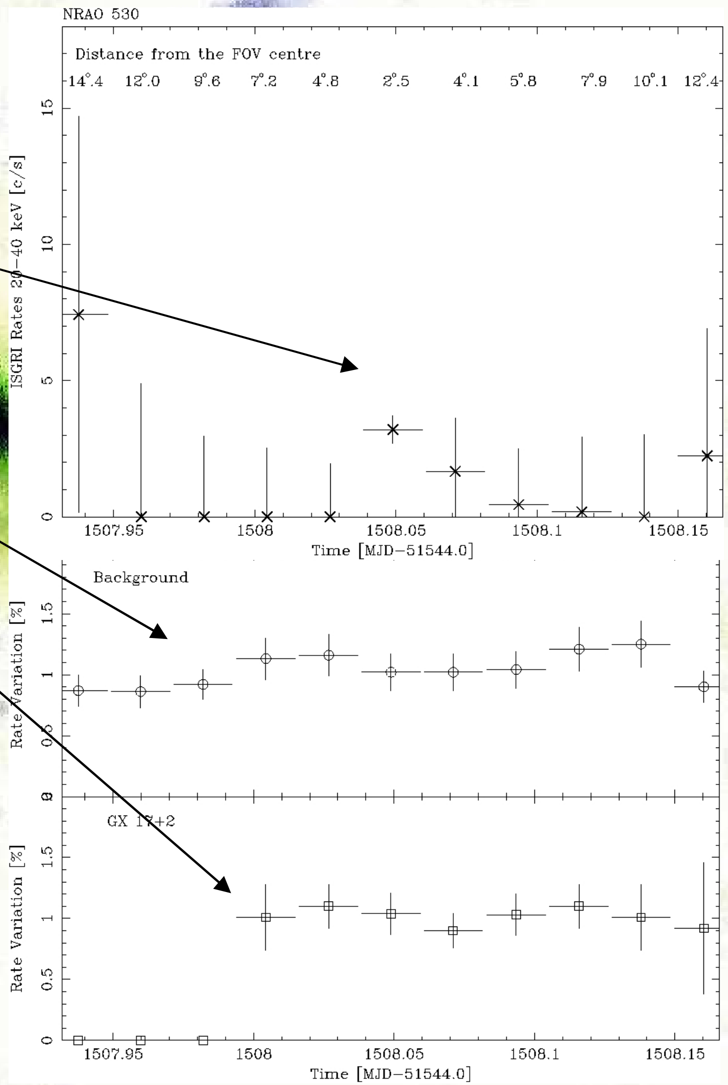
Studies on the **post-outburst** properties: the new **WEBT** campaign on 3C 454.3 with continuous radio to optical monitoring and three *XMM-Newton* pointings. See details at: http://www.to.astro.it/blazars/webt→campaigns

Search into public archives for lost outbursts: NRAO 530

Occurred on 17 February 2004 and detected serendipitously by IBIS/ISGRI on board *INTEGRAL* during the Galactic Centre Deep Exposure (GCDE).

Peak flux ≈ 2×10^{-10} erg cm^{-2} s^{-1} in the 20-40 keV energy band in a time scale of less than 1 hr.

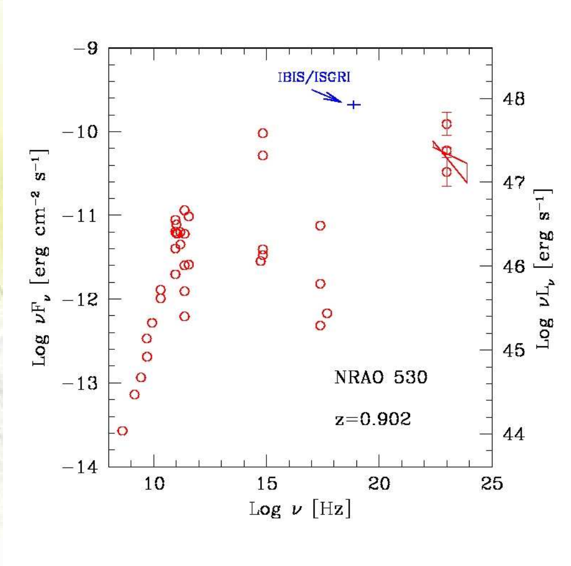
Background: stable
GX 17+2 (that has the ISGRI SPSF overlapping with NRAO530): stable



Two *Swift*/XRT (0.3-10 keV) snapshots show **no other X-ray sources** inside the 3 arcmin IBIS/ISGRI error circle.

Search into public archives for lost outburst: NRAO 530

- NRAO 530 is known to display strong and erratic variability: up to Δmag ≈ 3 at optical wavelengths (Pollock et al. 1979; Webb et al. 1988); up to a factor 6 in flux in the EGRET energy band (Mukherjee et al. 1997).
- **First event of this type** in the hard X-rays **(in a FSRQ)**, exceptional, but still consistent with the SED.



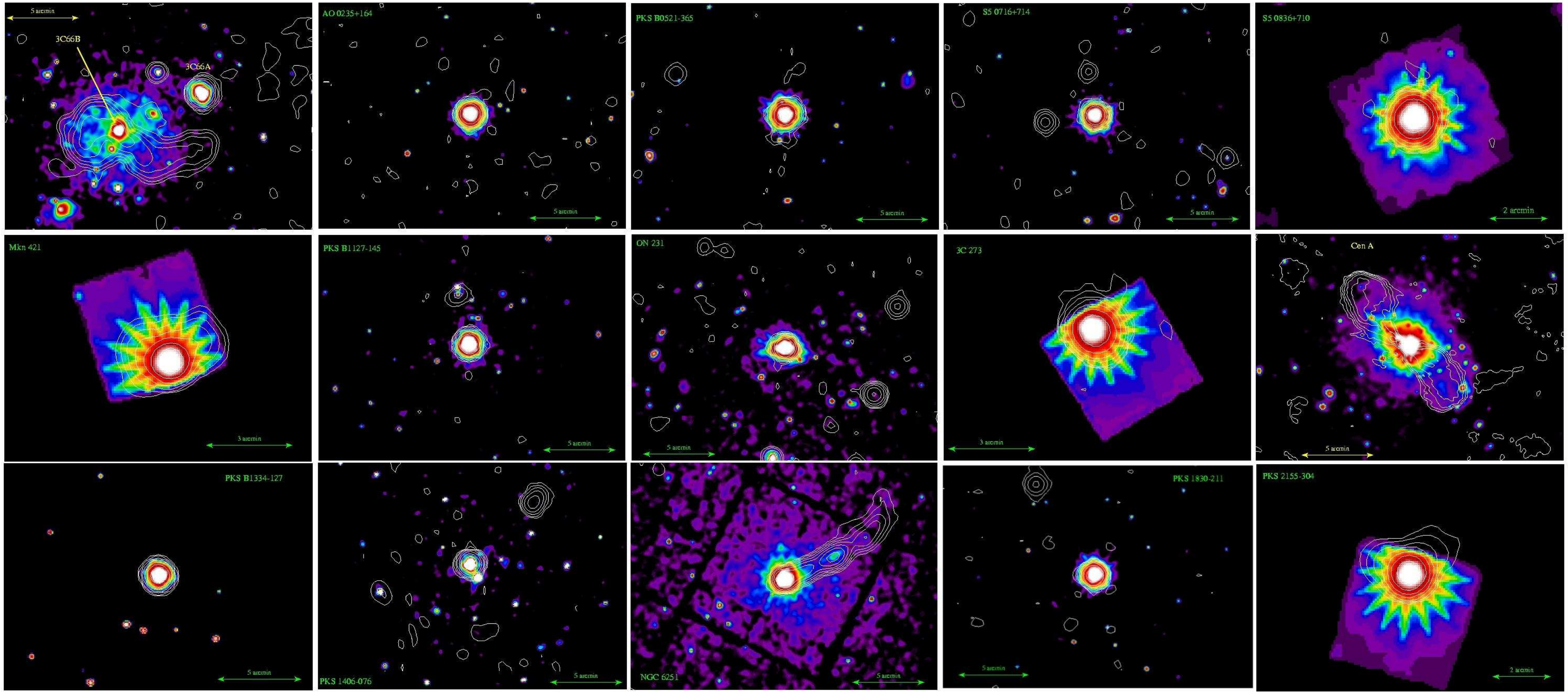
- Search for simultaneous or nearly simultaneous data at other wavelengths: only one **radio** observation at 2 cm (**MOJAVE Project**, Lister & Homan, 2005, AJ 130, 1389) performed on 11 February 2004 revealed a moderate increase of the **polarization**.
- Possible explanations: unsteadyness of the jet flow, that might be due to a single non stationary shock (e.g. Hughes et al. 1985) or to a collision of two relativistic plasma shells (internal shock, Spada et al. 2001). Anything else?

For more details: Foschini et al. 2006, A&A 450, 77

Studies on overall properties based on public archival data

Study of a sample of γ-ray emitting AGN (Foschini et al., 2006, A&A 453, 829 – Updated):

✓ 2 HBL (Mkn 421; PKS 2155-304)
✓ 4 LBL (3C66 A; AO 0235+164; S5 0716+714; ON 231)
✓ 8 FSRQ (PKS 0521-365; PKS 0537-286; S5 0836+710; PKS 1127-145; 3C 273; PKS 1334-127; PKS 1406-076; PKS 1830-211)
✓ 2 RG (Cen A; NGC 6251)



The XMM-Newton view of Gamma-Ray Loud AGN

Image courtesy of Luigi Foschini (INAF/IASF-Bologna, Italy)

European Space Agency

Studies on overall properties based on public archival data
Averages on best fits

Name (1)	N_H (2)	Γ/Γ_1 (3)	Γ_2 (4)	E_{break} (5)	N_H (2)	Γ/Γ_1 (3)	Γ_2 (4)	E_{break} (5)
0219 + 428	Gal.	$2.91^{+0.12}_{-0.08}$	$2.23^{+0.10}_{-0.09}$	1.3 ± 0.2	Gal.	2.22 ± 0.06	–	–
AO 0235 + 164	Gal.	2.33 ± 0.04	2.1 ± 0.1	$3.3^{+0.7}_{-0.5}$	Gal.	2.0 ± 0.1	–	–
PKS 0521 – 365	Gal.	1.95 ± 0.03	1.74 ± 0.03	$1.5^{+0.3}_{-0.2}$	Gal.	1.74 ± 0.02	–	–
PKS 0537 – 286	$2.6^{+1.2}_{-0.7}$	$1.19^{+0.04}_{-0.02}$	–	–	$7.5^{+6.4}_{-5.5}$	$1.46^{+0.14}_{-0.13}$	–	–
S5 0716 + 714	Gal.	2.70 ± 0.02	$1.98^{+0.08}_{-0.09}$	$2.3^{+0.2}_{-0.1}$	Gal.	2.5 ± 0.2	1.8 ± 0.1	3.0 ± 0.4
S5 0836 + 710	14 ± 3	1.379 ± 0.007	–	–	78^{+55}_{-35}	1.31 ± 0.02	–	–
Mkn 421	Gal.	2.38 ± 0.09	2.7 ± 0.2	2.7 ± 1.0	Gal.	1.9 ± 0.2	2.3 ± 0.3	1.3 ± 0.8
PKS 1127 – 145	12^{+2}_{-1}	$1.40^{+0.08}_{-0.05}$	1.22 ± 0.06	$2.7^{+1.0}_{-0.8}$	Gal.	1.42 ± 0.05	–	–
ON 231	2.5 ± 0.6	2.77 ± 0.04	–	–	Gal.	2.58 ± 0.01	1.52 ± 0.06	2.8 ± 0.2
3C 273	Gal.	2.02 ± 0.08	1.67 ± 0.05	1.44 ± 0.08	Gal.	2.0 ± 0.1	1.603 ± 0.006	0.9 ± 0.3
Cen A	1523 ± 261	2.22 ± 0.06	–	–	Gal.	1.58 ± 0.03	–	–
PKS 1334 – 127	6.7 ± 0.9	1.80 ± 0.04	–	–	1020^{+90}_{-40}	$1.80^{+0.03}_{-0.04}$	–	–
PKS 1406 – 076	Gal.	1.59 ± 0.01	–	–	–	–	–	–
NGC 6251	14 ± 1	$2.11^{+0.08}_{-0.06}$	1.78 ± 0.07	$2.5^{+0.3}_{-0.4}$	–	–	–	–
PKS 1830 – 211	63 ± 1	1.00 ± 0.09	1.32 ± 0.06	3.5 ± 0.7	9 ± 1	1.79 ± 0.06	–	–
PKS 2155 – 304	1.69 ± 0.06	2.9 ± 0.1	–	–	194^{+28}_{-25}	1.09 ± 0.05	–	–
	Gal.	2.7 ± 0.1	2.94 ± 0.06	2.7 ± 0.7	Gal.	2.3 ± 0.1	2.8 ± 0.1	1.7 ± 0.2

XMM-Newton
2000-2005
(Foschini et al. 2006, A&A 453, 829)
Updated with PKS 0537-286 (FSRQ @ z=3.1)

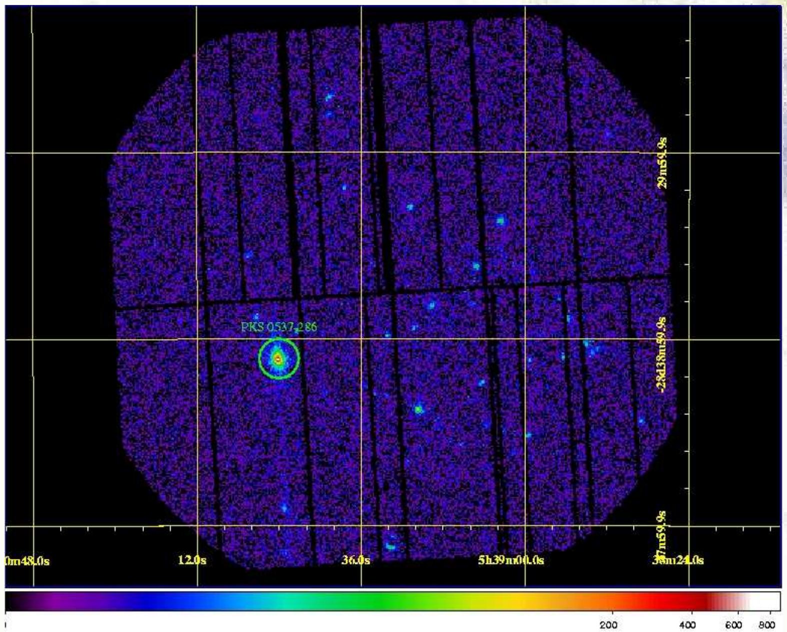
BeppoSAX 1996-2002
(Giommi et al. 2002; Donato et al. 2005)
Cen A: Grandi et al. (2003);
NGC 6251: Chiaberge et al. (2003); Guainazzi et al. (2003)
PKS 1830-211: Chandra+INTEGRAL, De Rosa et al. (2005).
PKS 0537-286: ASCA, Cappi et al. (1997)

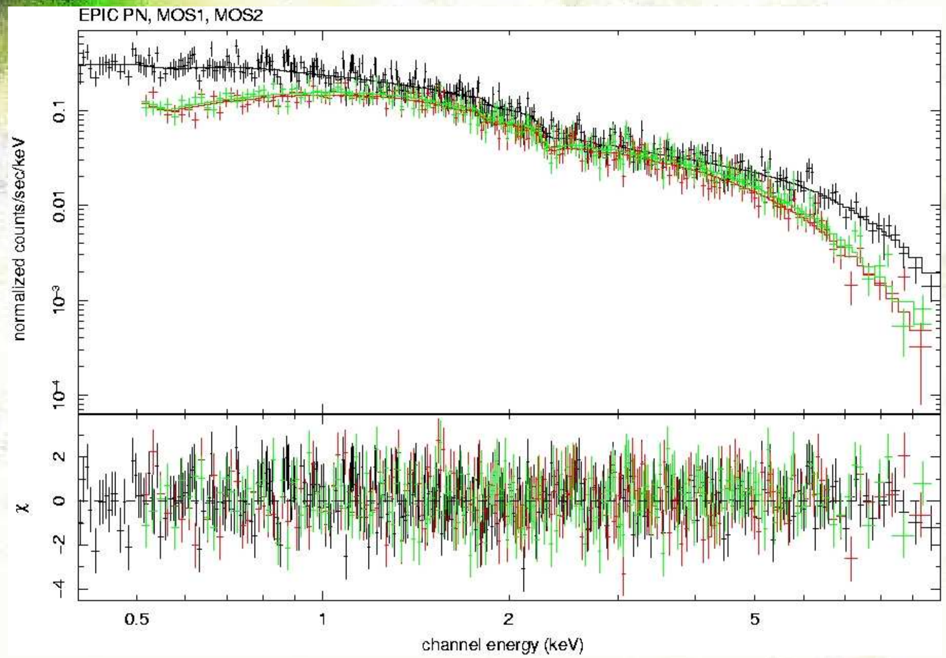
Studies on overall properties based on public archival data
Update with PKS 0537-286 (=3EG J0531-2940?)

PKS 0537-286 is a FSRQ at z=3.104 associated (low confidence) with 3EG J0531-2940 (Hartman et al. 1999; Sowards-Emmerd et al. 2004). Observed by XMM-Newton in 2005, but with 8.7´ distance from the centre of the FOV (it was not the on-axis source). Data public since 30 June 2006.

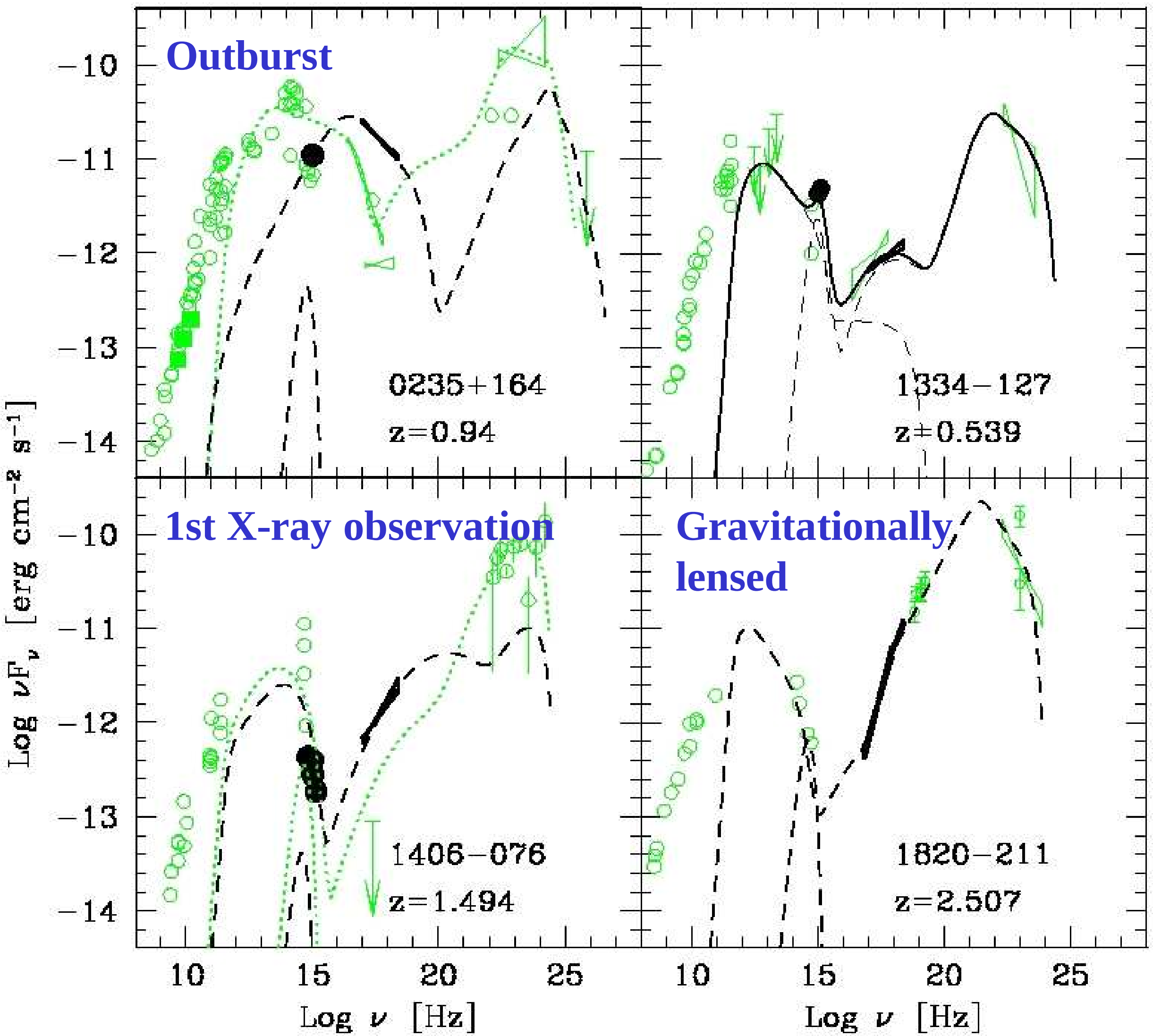
Best fit: single power law with $\Gamma=1.19$ and absorption consistent with the Galactic column.
Flux 0.4-10 keV = 6.12×10^{-12} erg cm^{-2} s^{-1}.

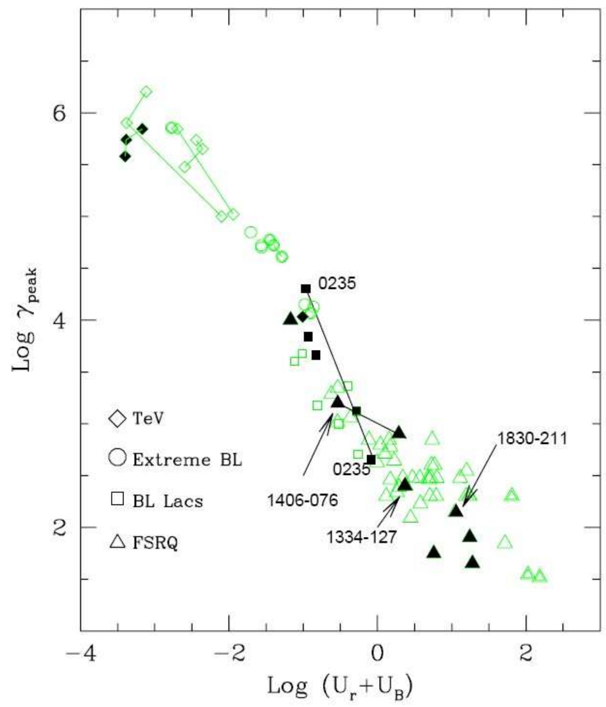
Previous observation done in 1994 with ASCA (Cappi et al. 1997) indicated a softer spectrum with $\Gamma=1.46$ and lower flux 2.63×10^{-12} erg cm^{-2} s^{-1}.





Studies on overall properties based on public archival data
New or peculiar SED with respect to Ghisellini et al. (1998)

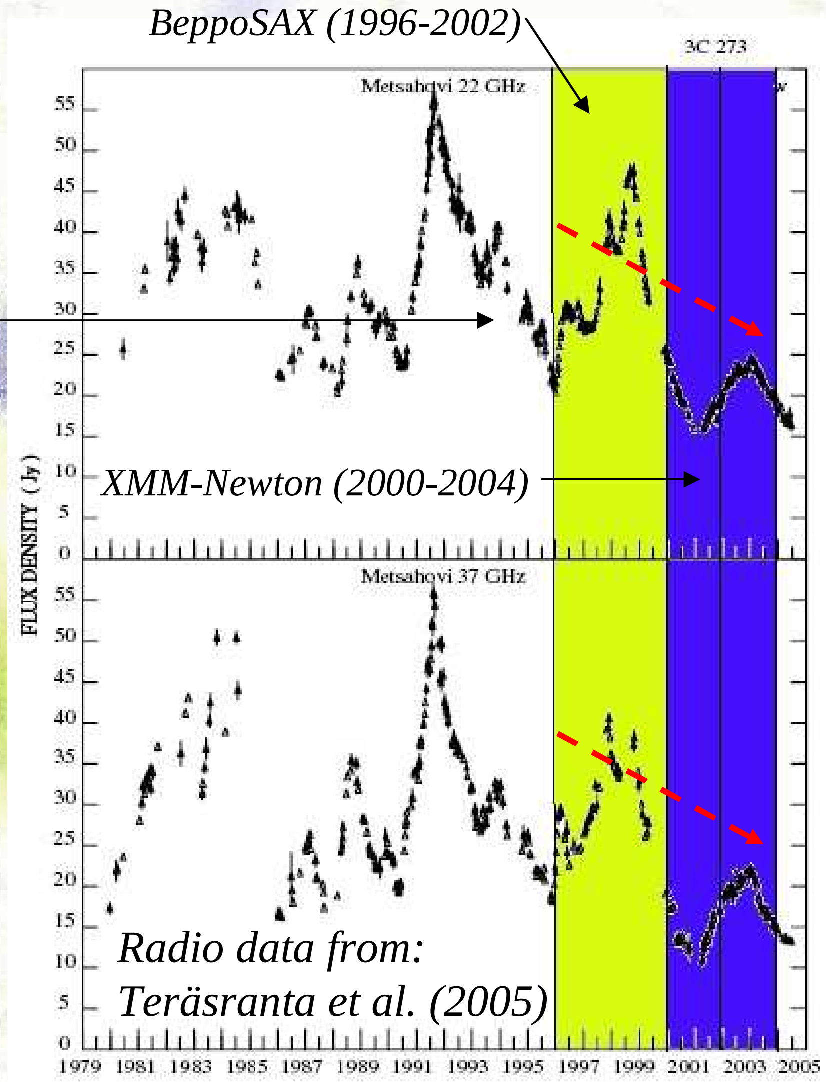




Studies on overall properties based on public archival data

Grandi & Palumbo (2004, Science 306, 998) **first disentangled** the "thermal" and the "non-thermal" components in 3C273 by using *BeppoSAX* data.

Decreasing trend of the radio flux.



BeppoSAX vs XMM-Newton vs Radio:
increase of the average "thermal" component, indicated by an increase of the energy break in the broken power law model:

- E_{break}(*XMM-Newton*)=1.44±0.08 keV
- E_{break}(*BeppoSAX*)=0.9±0.3 keV

or – in the blackbody model – :

- kT(*XMM-Newton*)=143±6 eV
- kT(*BeppoSAX*)=54_{-4}^{+6} eV

(*BeppoSAX data from Grandi & Palumbo 2004*)

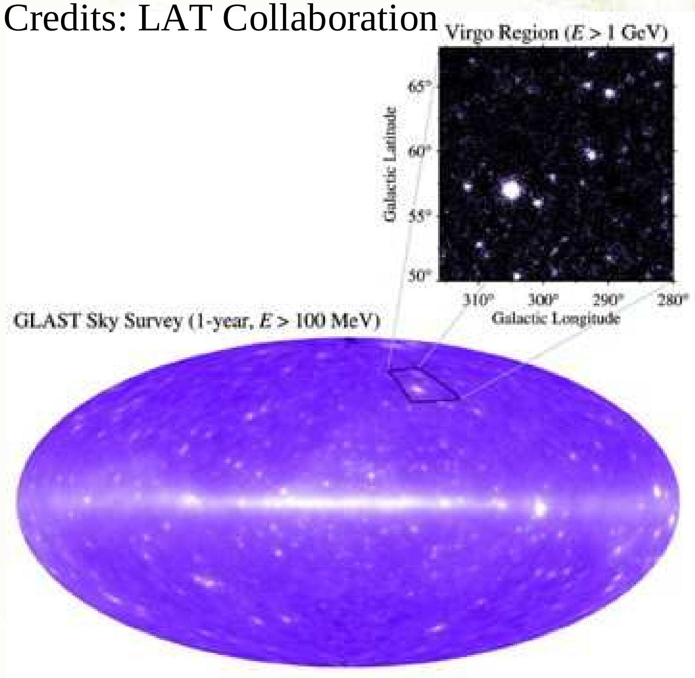
XMM-Newton data are **consistent** with (and support) the picture outlined by Grandi & Palumbo (2004).

Studies on overall properties based on public archival data
Jet viewing angle: from FSRQ to RG, with some biases…

Table 5. Parameters useful to understand γ–ray loudness. Columns: (1) Source name; (2) beaming factor δ; (3) observed flux in the 0.4 – 10 keV energy band [erg cm^{-2} s^{-1}]; (4) intrinsic luminosity in the 0.4 – 10 keV energy band [erg s^{-1}]; (5) Confidence of the EGRET detection (high > 95%; low < 95%).

Source (1)	δ (2)	F (3)	L (4)	Conf. (5)
3C 273	6.5 – 7	$\approx 10^{-10}$	$\approx 10^{46}$	high
NGC 6251	3.2 – 3.8	$\approx 10^{-12}$	$\approx 10^{43}$	low
PKS 0521 – 365	1.4 – 3	$\approx 10^{-11}$	$\approx 10^{42}$	low
Cen A	1.2 – 1.6	$\approx 10^{-10}$	$\approx 10^{41}$	high

Credits: LAT Collaboration

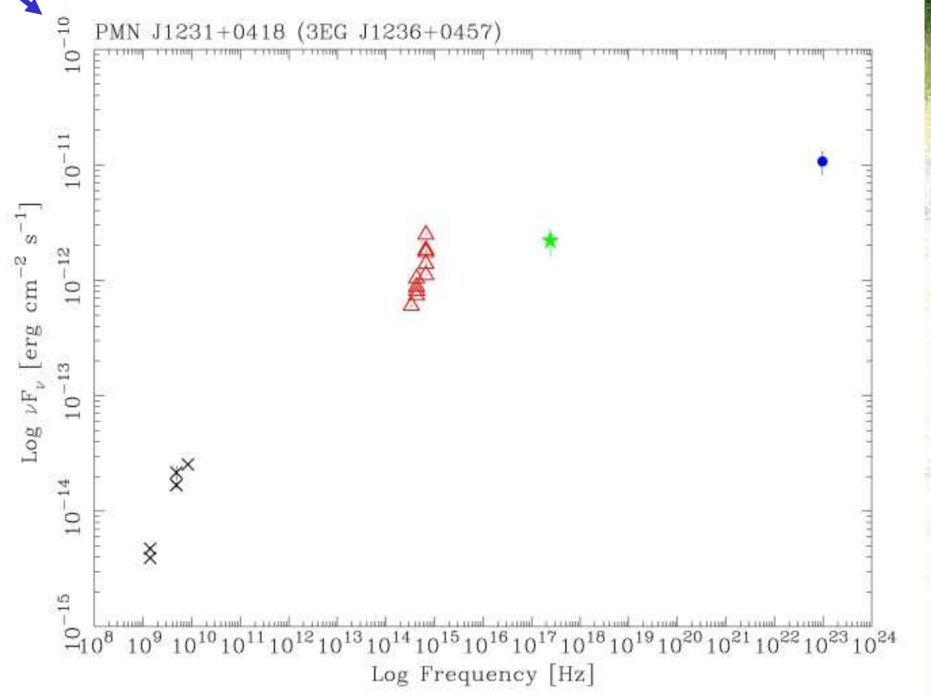


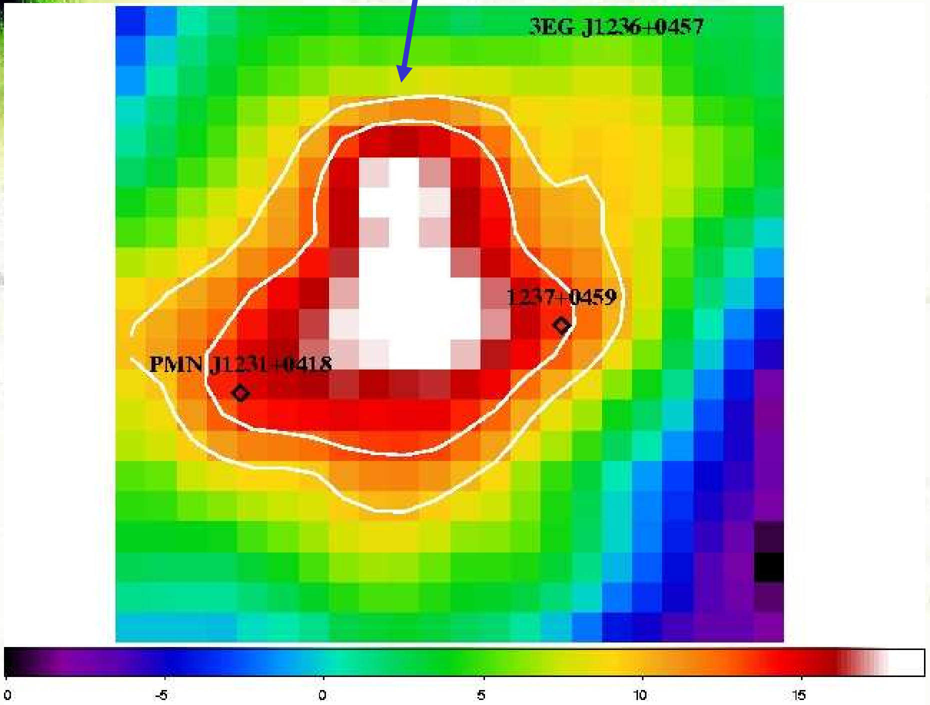
Differences in the detection due to instrument sensitivity and distance.

Waiting for ***GLAST/Large Area Telescope*** (improvement in sensitivity of two orders of magnitudes with respect to *CGRO/EGRET*) in order to have an unbiased definition of γ-ray loudness.

X-ray follow-up of new identifications: 3EG J1236+0457

• In the Third EGRET Catalog (Hartman et al. 1999), the source 3EG J1236+0457 was associated, with **low confidence**, with the blazar 1237+0459 (z=1.76).
• Sowards-Emmerd et al. (2003) proposed a **new association** with the FSRQ PMN J1231+0418 (z=1.03), but there was no X-ray observation at all to date.
• Now, we have found the **first X-ray detection** in the *XMM-Newton Slew Survey* (Read et al. 2005): in an exposure of 8.7 s, the EPIC-PN flux in the 0.2-12 keV energy band was 0.83±0.27 c/s. Here is the **first SED** with the X-ray detection (star point).
• Given the position of the two counterparts inside the EGRET probability contours, perhaps 3EG J1236+0457 is the **sum** of the γ-ray emission **of both blazars**…



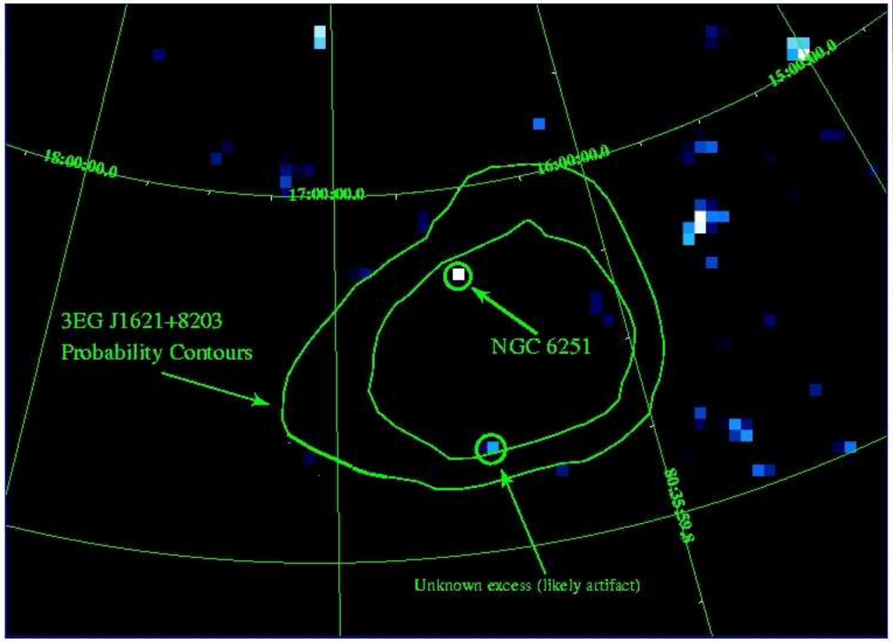


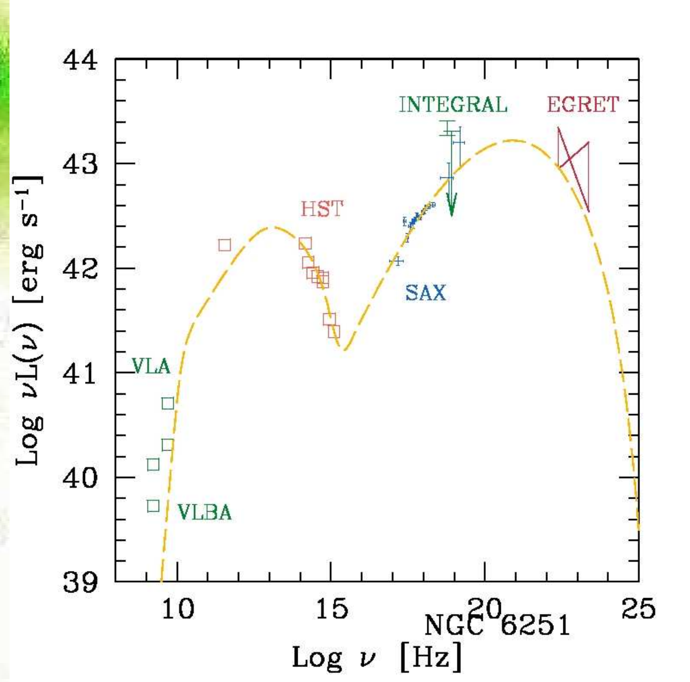
INTEGRAL AO Observations: 3EG J1621+8203 = NGC 6251

✓ Mukherjee et al. (2002, ApJ 574, 693) **first proposed** the association of 3EG J1621+8203 with the FRI radiogalaxy NGC 6251, based on X-ray (*ROSAT*, *ASCA*) observations that covered most (but not all) of the EGRET probability contours.

✓ *INTEGRAL* AO2 Observation of the **whole** EGRET probability contour (PI Foschini) revealed **only** NGC6251 inside the error contours, thus **supporting** the Mukherjee's findings.

✓ Faint detection (5σ) of NGC 6251, but **consistent** with the SED as modeled with a SSC.





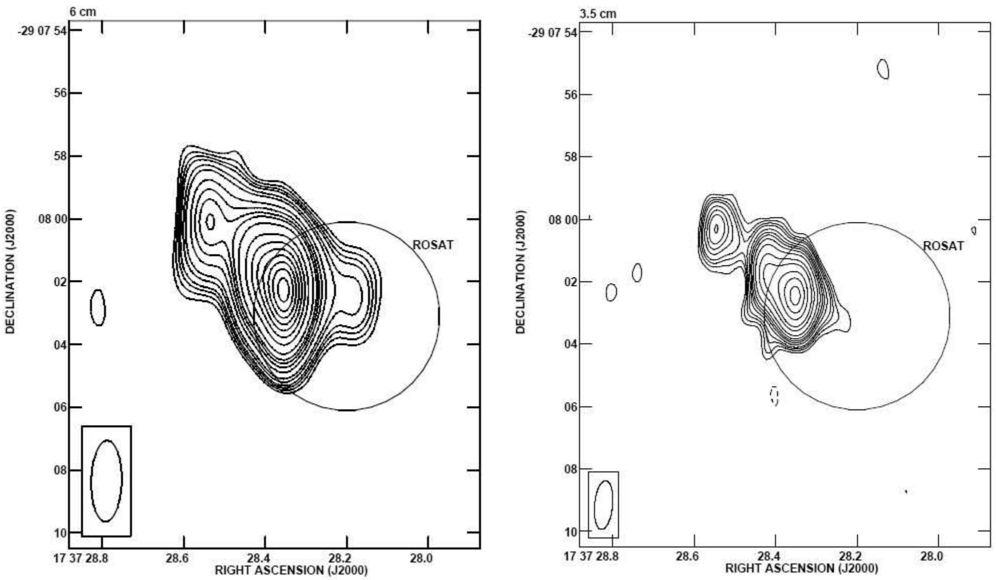
(for more details, see Foschini et al. 2005, A&A 433, 515)

INTEGRAL Core Programme:
The enigmatic case of 3EG J1736-2908 = GRS 1734-292?

➢ *INTEGRAL* observations around the Galactic Centre revealed **only one** source within the probability contours of 3EG J1736-2908, that is the nearby (*z=0.0214*) AGN GRS 1734-292 (Di Cocco et al. 2004, A&A 425, 89).

➢ Originally classified as Seyfert 1, it shows a clear **bipolar jet** at radio wavelengths, with an extension of about 5″ but weak flux (23 mJy @ 5 GHz) and spectrum $S_\nu \propto \nu^{-(0.75\pm0.03)}$ (Martí et al. 1998, A&A 330, 72).

➢ **If** this association will be **confirmed** by *GLAST*, then: how is it possible that a Seyfert can generate γ-ray photons with E>100 MeV? Or is this AGN correctly classified? Perhaps it is another radiogalaxy…



NVSS Radio 6 and 3.5 cm (Martí et al. 1998)