Blazars
&
INTEGRAL

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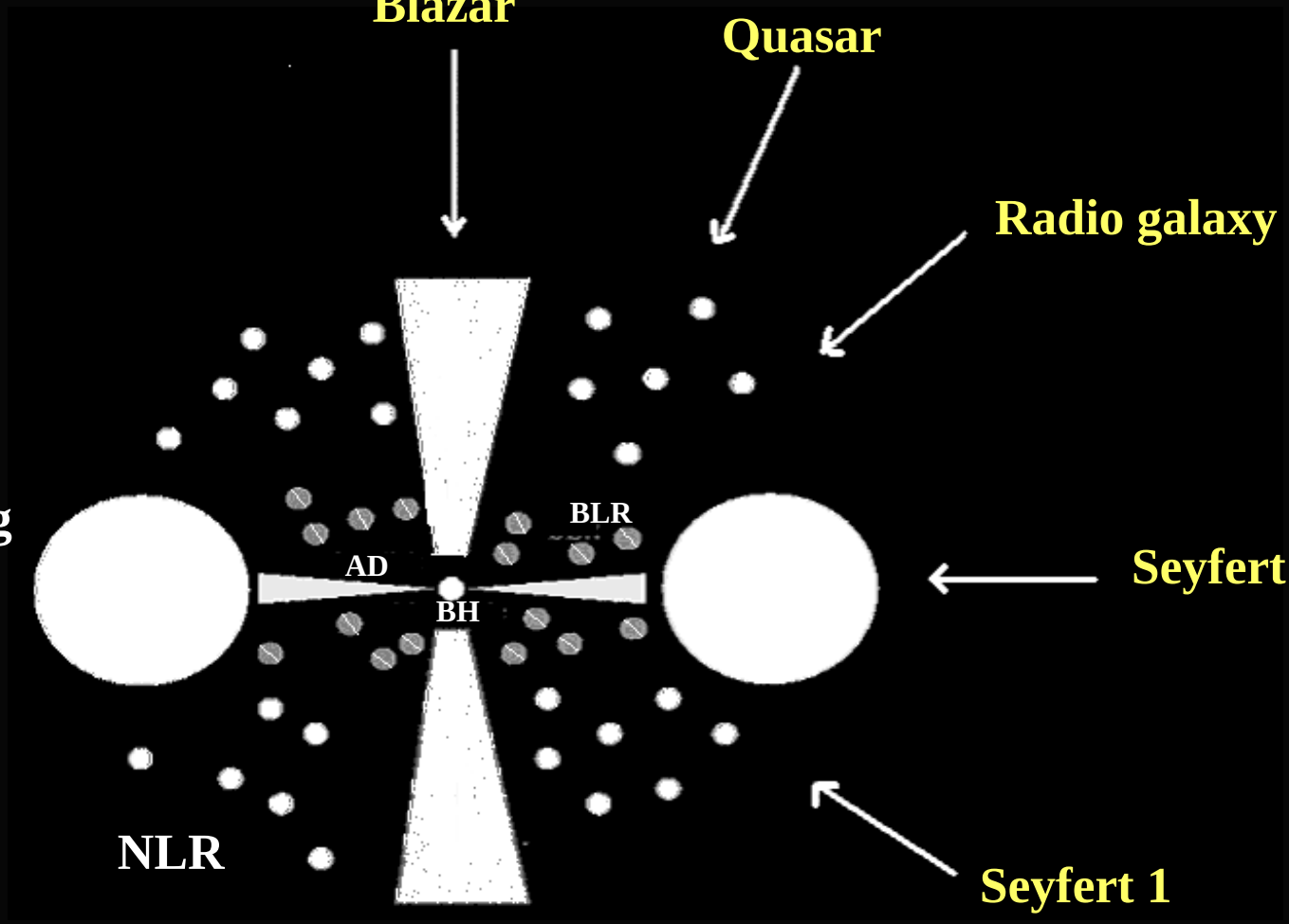
- **Blazars - the most extreme class of active galaxies, powerful and variable**
- **observed in all wavelength bands - from radio through VHE gamma frequencies**
- **maximum spectral output and largest variability often at gamma ray energies**
- **66 blazars identified as sources of >100 MeV emission by EGRET oboard CGRO (Hartman et al. 1999)**
- **6 blazars identified as VHE gamma sources (>350 GeV) by Čerenkov telescopes**
- **suitable targets for INTEGRAL especially during active states (flares)**

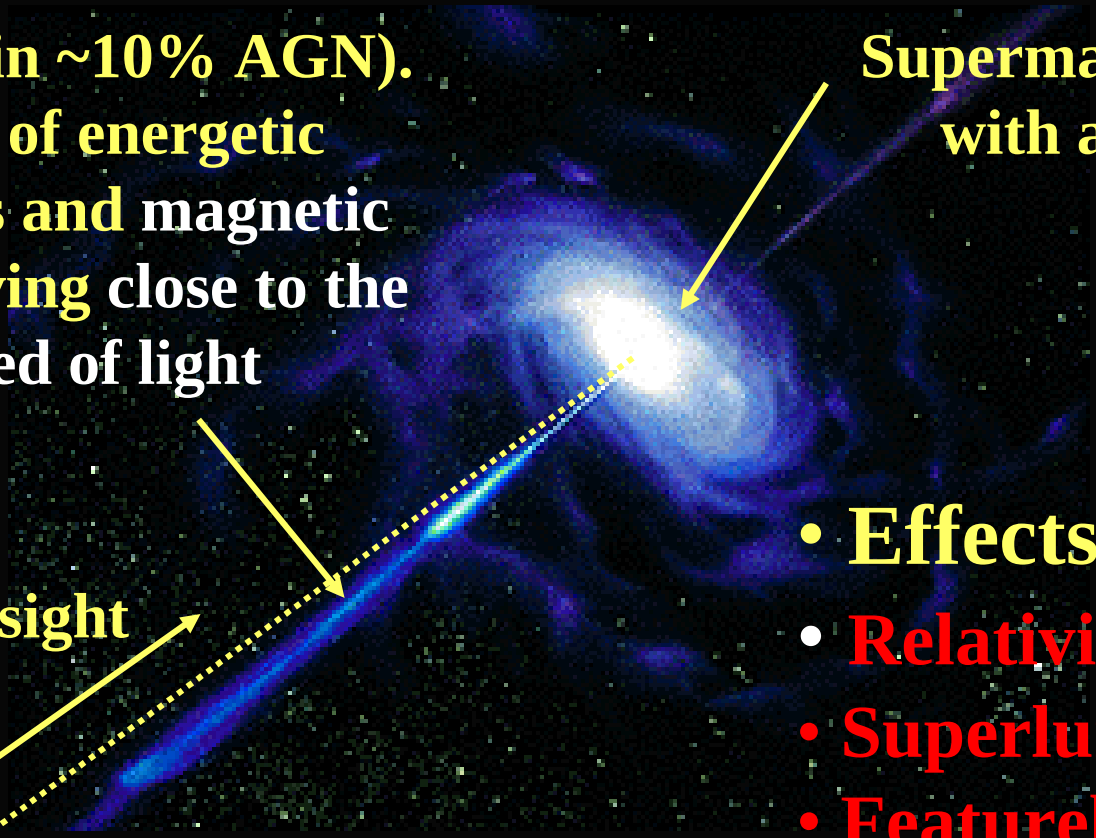
Blazars & AGN unification

Blazar = a class of Active Galactic Nuclei (AGN)

Unification model for AGN



Blazars & their powerful jets



Jet (within ~10% AGN). Beam of energetic particles and magnetic field moving close to the speed of light

Supermassive black hole with accretion disc

Line of sight

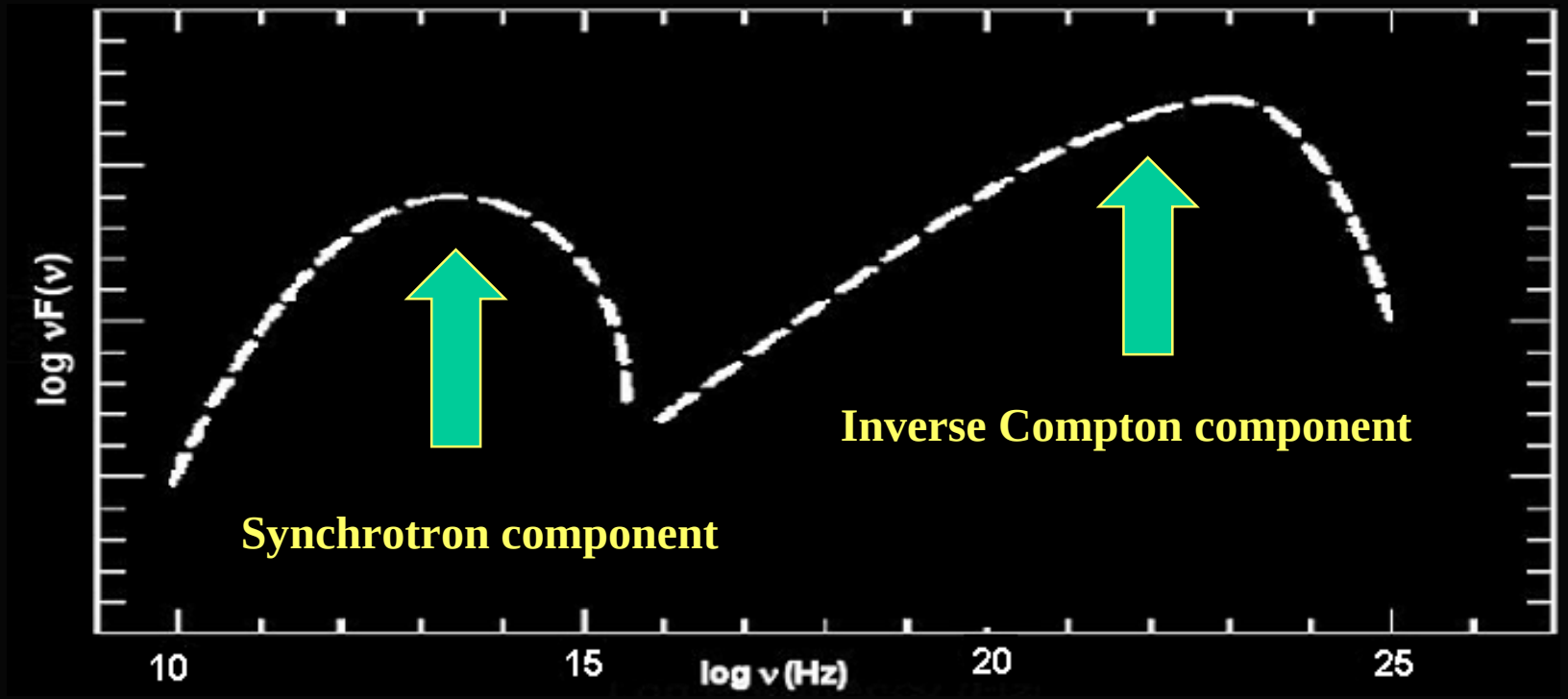
Blazar observer

- Effects of the jet:
- Relativistic beaming
- Superluminal motion
- Featureless continuum
- Gamma rays
- Rapid variability
- High luminosity

Blazars & their non-stellar spectra continuum emission

- **the widest range of all AGN**

from radio to gamma TeV, νF(ν) representation - two broad spectral components



Blazars in the GPS

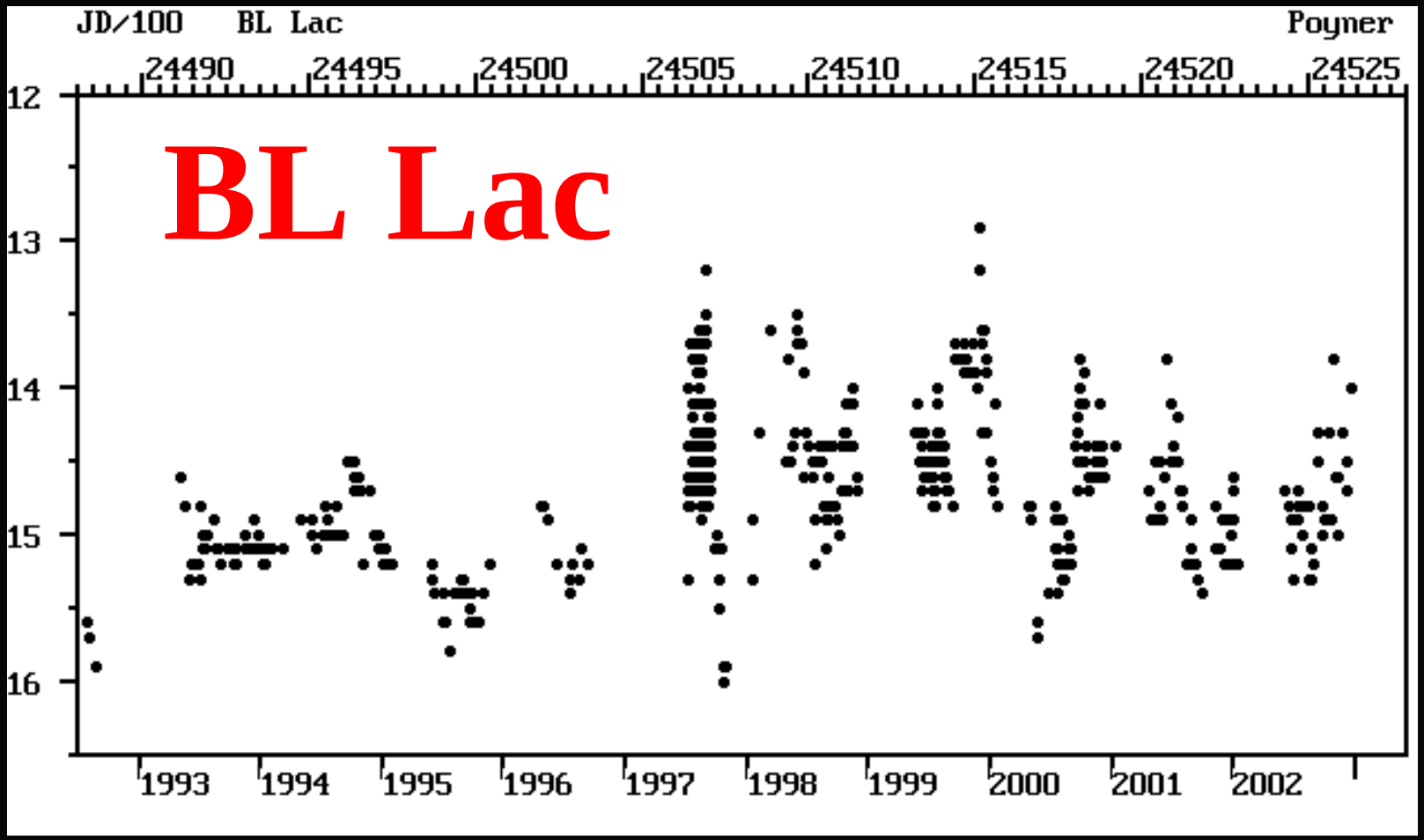
- **GPS zone usually neglected by extragalactic astronomers due to heavy obscuration**
- **in optical, ~20% of the sky obscured by our Galaxy**
- **INTEGRAL allows detectability of up to few mCrabs in the most exposed regions**

Blazars & Integral

Seven blazars V>17 mag identified in galactic scans of Integral

1ES 0647+250 ”A secret object”
PKS 0823-223 no gamma from EGRET, grav. lensing candidate
1ES 2344+514 TeV gamma ray source, very close
8C 0149+710 BL Lac candidate?
4C 47.08 ”A secret object”
87GB 02109+5130 poorly understood blazar, TeV candidate
BL Lac The prototype ☺

Object	z	optical	gamma	X-rays	radio
1ES 0647+250	z=0.20	V=15.3	TeV candidate	ROSAT & Einstein source	0.08 Jy at 5 GHz
PKS 0823-223	z=0.91	V=16.2	not detected by EGRET	?	0.78 Jy at 5 GHz
1ES 2344+514	z= 0.044	V= 15.5	TeV gamma ray source	large variability, spectral changes	0.23 Jy at 5 GHz
8C 0149+710	z=0.022	V=15.5	?	ROSAT	0.64 Jy at 5 GHz
4C 47.08	z=0.475	V=17.0	?	ROSAT	?
87GB 02109+5130	z=0.049	V=16.5	TeV candidate?	ROSAT	0.29 Jy at 5GHz
BL Lac	z=0.069	B=12.5 - 16 polarization	variable/outbursts	both comp. detected	2.94 Jy at 5 GHz, polar.



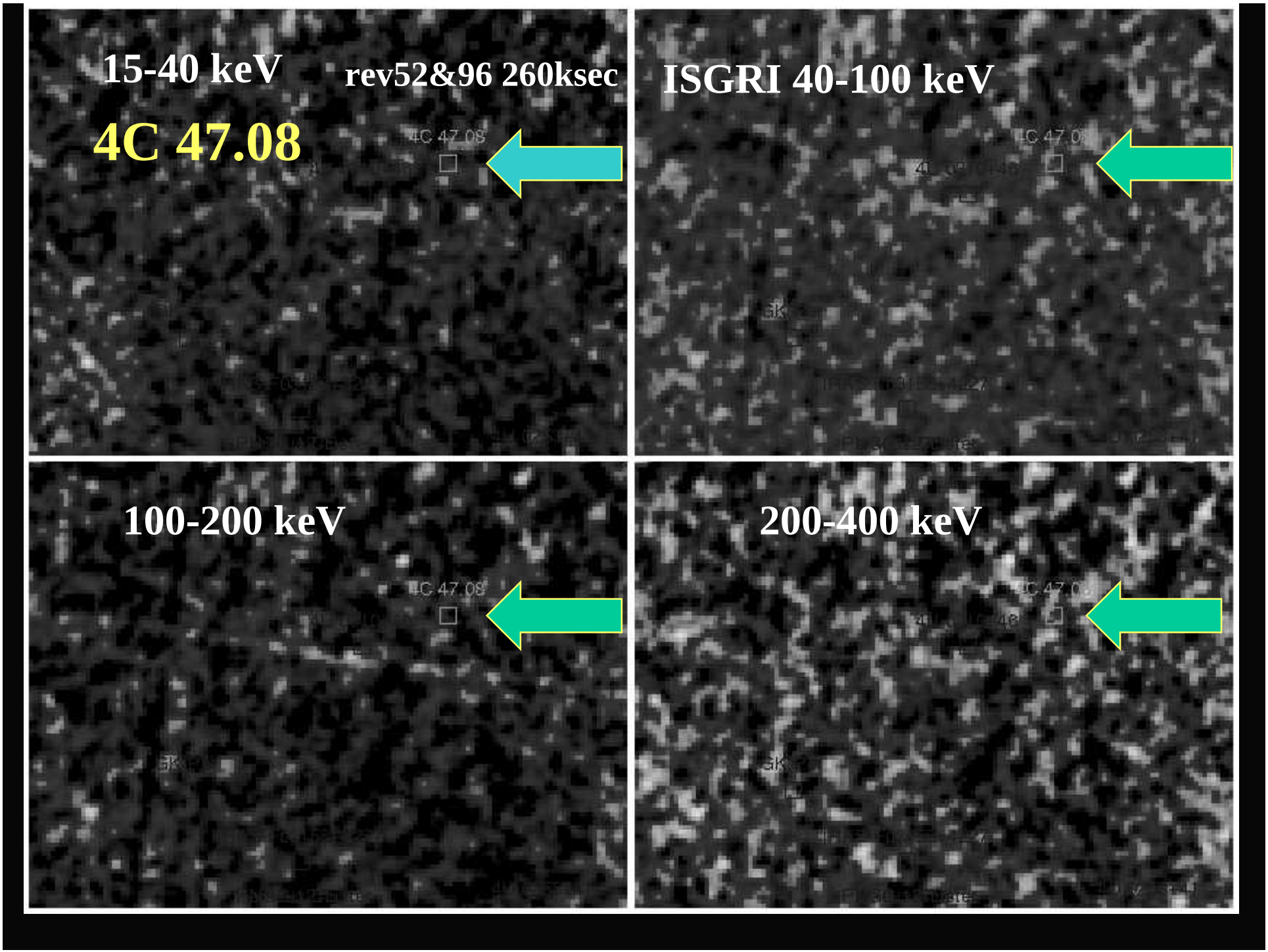
Violent optical variability of BL Lac on a long time time scale

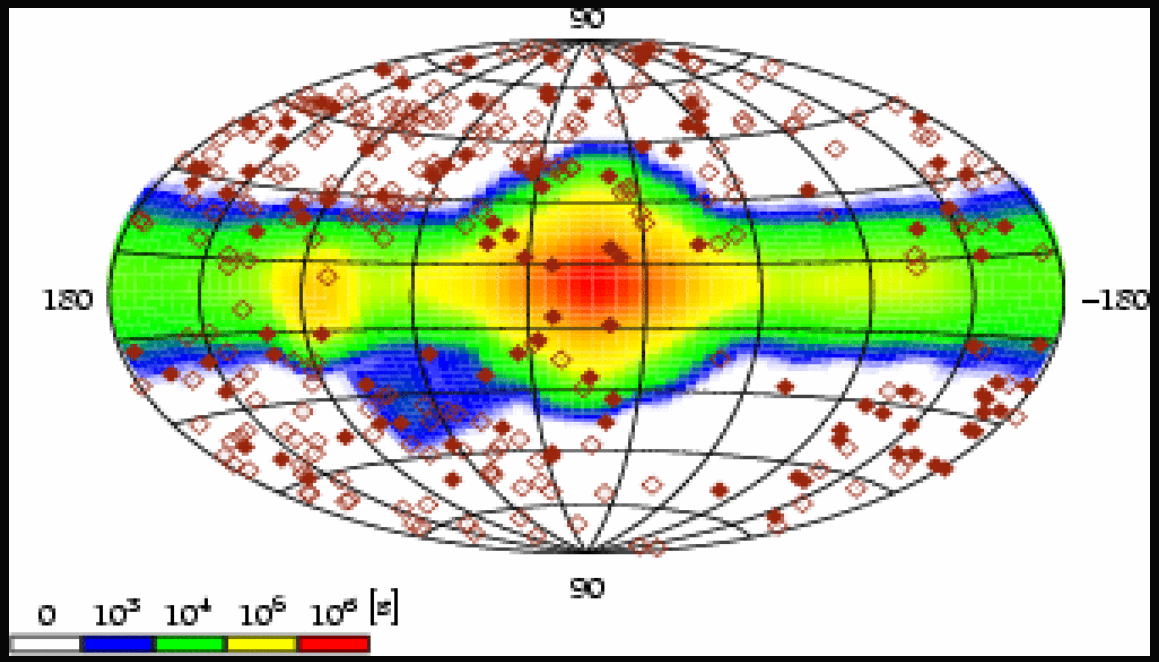
good candidate to be detected at flaring

BL Lac is well studied .... but

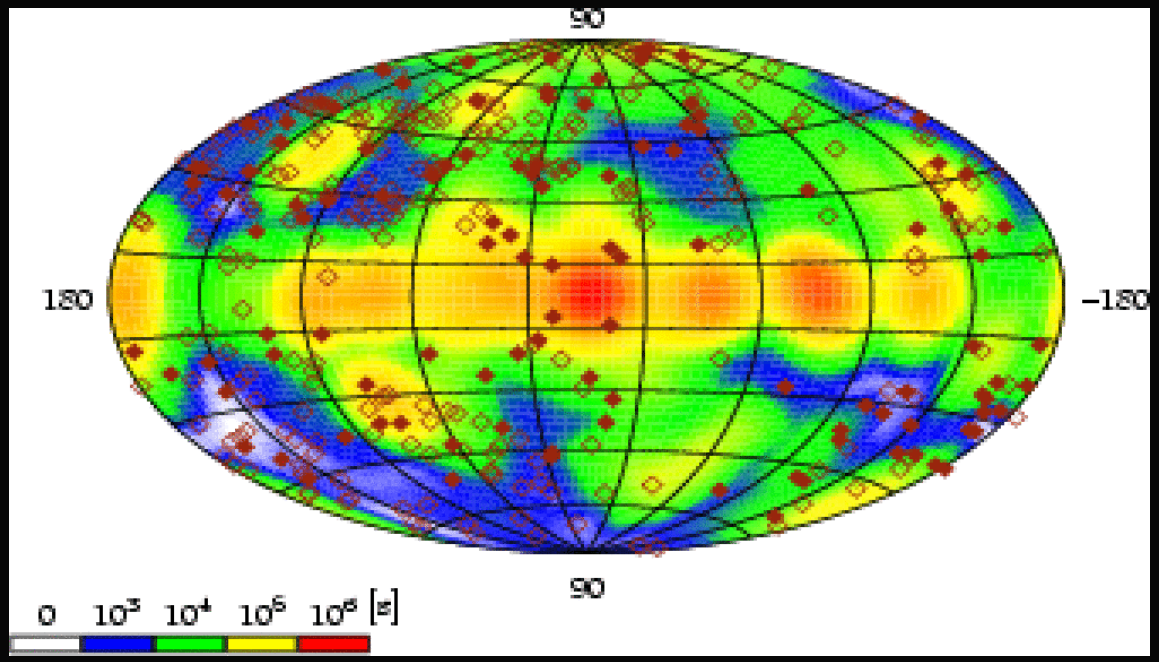
Most of the GPS blazars are poorly investigated and poorly understood and

The study with Sonneberg Observatory Archival Plates reveals that most of these objects are optically variable, hence a gamma ray variability can be expected


15-40 keV
rev52&96 260ksec
4C 47.08
ISGRI 40-100 keV
100-200 keV
200-400 keV



IBIS total exposure times for blazars, CP data, rev 1-250



IBIS total exposure times for blazars, all data, rev 1-250

Most observed blazars, CP (rev 1-250) + public (AO-1)

id	name	ra	decl	scws	sec
287	3EG J1800-3955	18:02:42	-39:40:01	961	1780516
288	3EG J1832-2110	18:33:00	-21:36:00	832	1497432
59	QSO B0637-7513	06:35:46	-75:16:16	489	1101254
357	NRAO 530	17:33:02	-13:04:49	480	791004
52	QSO B0528+134	05:30:56	13:31:55	454	1245729
315	QSO B1622-297	16:26:06	-29:51:27	366	563387
314	QSO B1622-253	16:25:46	-25:27:38	362	630769
140	J1242+3440	12:41:41	34:40:31	311	835312
318	QSO B1908-202	19:11:09	-20:06:55	307	481383
134	QSO B1225+3145	12:28:24	31:28:37	296	806857
131	QSO B1218+304	12:21:21	30:10:37	258	723653
317	QSO B1741-0348	17:43:58	-03:50:04	258	450219
302	QSO B1229-0207	12:32:00	-02:24:04	255	737799
362	J191744.8-1921	19:17:44	-19:21:31	248	393979
128	QSO B1215+303	12:17:52	30:07:00	246	697787
147	QSO B1308+328	13:10:28	32:20:43	244	534738

Most observed blazars in AO (rev 1-250)

id	name	ra	decl	SW	sec
125	B1206+416	12:09:22	41:19:41	114	404490
126	QSO B1207+39	12:10:26	39:29:09	113	402477
283	3C 445	22:23:49	-02:06:12	96	347728
288	3EG J1832-2110	18:33:00	-21:36:00	75	149156
135	3C 273	12:29:06	02:03:08	73	209863
130	QSO B1217+023	12:20:11	02:03:42	73	209327
145	B1255+244	12:57:31	24:12:40	65	139014
302	QSO B1229-0207	12:32:00	-02:24:04	56	161087
287	3EG J1800-3955	18:02:42	-39:40:01	55	101139
26	B0224+014	02:27:13	01:35:23	51	178909
147	QSO B1308+328	13:10:28	32:20:43	50	110191
52	QSO B0528+134	05:30:56	13:31:55	45	135653
303	QSO B1243-072	12:46:04	-07:30:46	41	120673
144	3C 279	12:56:11	-05:47:21	38	114465
335	RX J0227.2+02	02:27:16	02:02:00	38	133162
314	QSO B1622-253	16:25:46	-25:27:38	36	64280

NRAO530 (1730- 130)

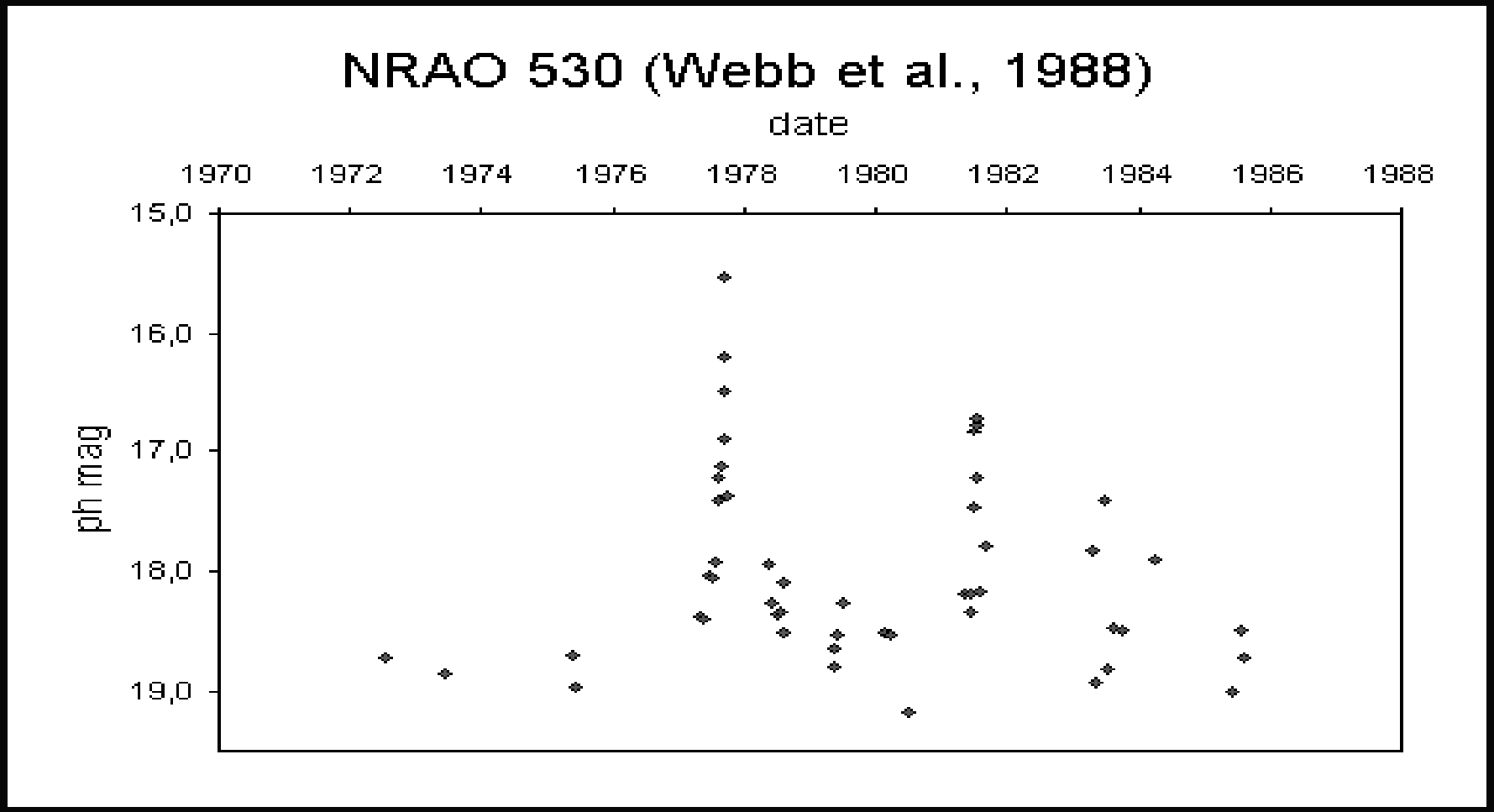
- a well known OVV in the GPS
- m (B) = 18.5 mag (Whelch and Spinrad 1973)
- z = 0.902 (Junkkarinen 1984)
- The source is detectable from radio to γ-ray
- ROSAT ~1.84 × 10 -6 Jy at 1.3 keV

(Brinkmann et al. 1994)

- EGRET ~4.6 × 10 -11 Jy at 2.55 GeV

(Fichtel et al. 1994; Thompson et al. 1995).

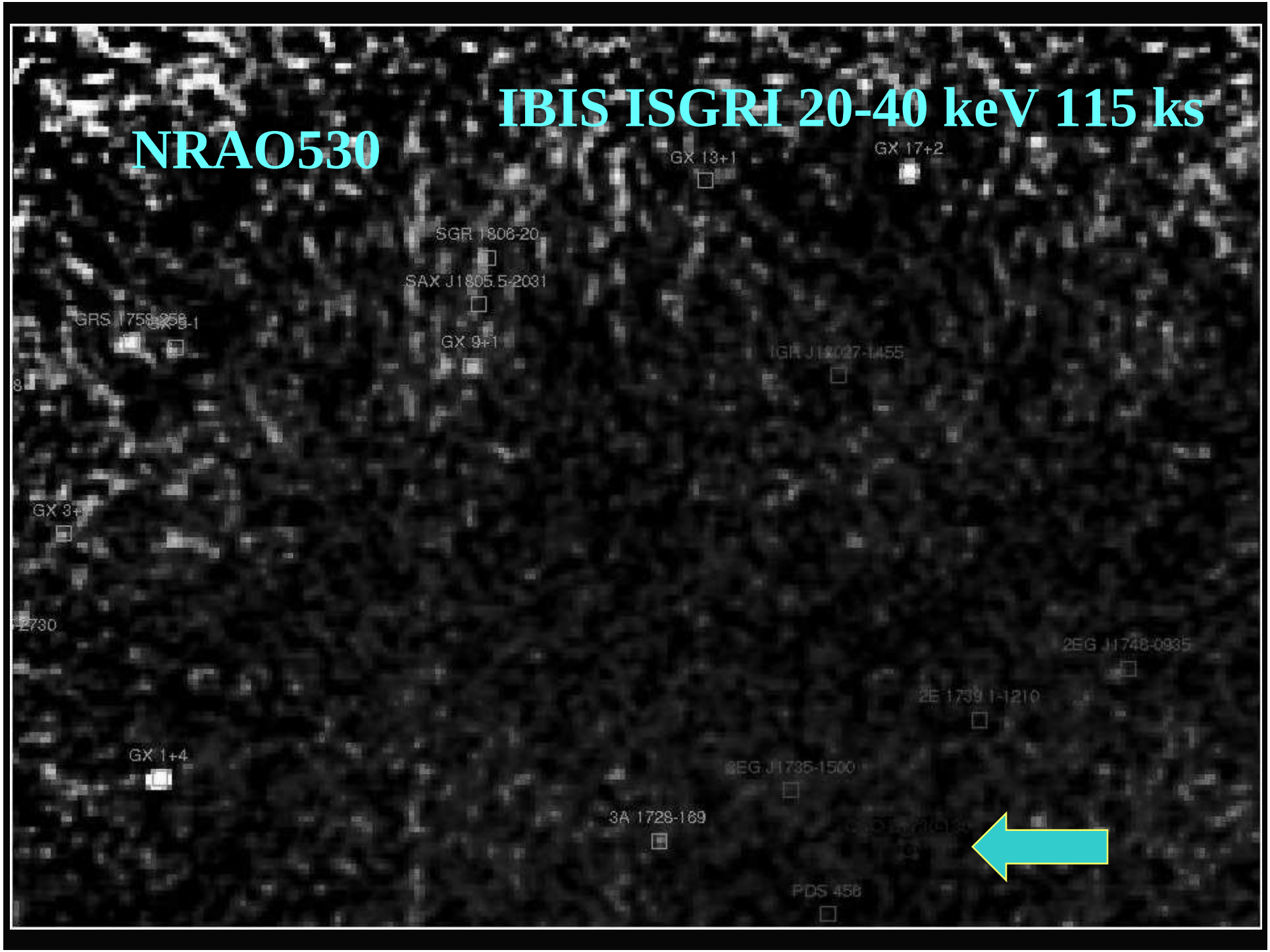
- **the object is known to exhibit prominent and sharp optical flares with very large amplitude**
- **good candidate for detection by IBIS during these flares (not predictable)**
- **so far no evidence of detection by IBIS & JEM-X**



Historical optical light curve of NRAO530

The source exhibits rare but large amplitude optical flares (Δm~ 4 mag)

Optical R band good tracer for the HE activity of blazars (CGRO experience, Collmar (2004)) - gamma flares can be expected


NRAO530
IBIS ISGRI 20-40 keV 115 ks
GX 13+1
GX 17+2
SGR 1806-20
SAX J1805.5-2031
GRS 1758-258
GX 9+1
GX 3+1
2730
2EG J1748-0935
2E 1739.1-1210
GX 1+4
3EG J1735-1500
3A 1728-169
PDS 456

- **example of blazar with violent optical activity (4 mag within 1 month)**
- **in flare, the object is expected to be much brighter also in gamma**
- **the role of optical monitoring and ToO program - the flare can be recognized by optical monitoring with small (D ~50 cm) telescopes**

Conclusion - blazars in GPS

- no positive detection by HE instruments onboard INTEGRAL yet (except marginal detection of 1ES 0647+250 and the newly confirmed PKS1830-211)
- the targets quiet level is still below the sensitivity threshold of the instruments
- positive detection may be possible in the future as:
  - there will be more cumulative time available
  - the probability to see a blazar during a flare (and hence much brighter) will also increase with time

The AO-2 ToO blazar observation No. 220049 by Pian et al.

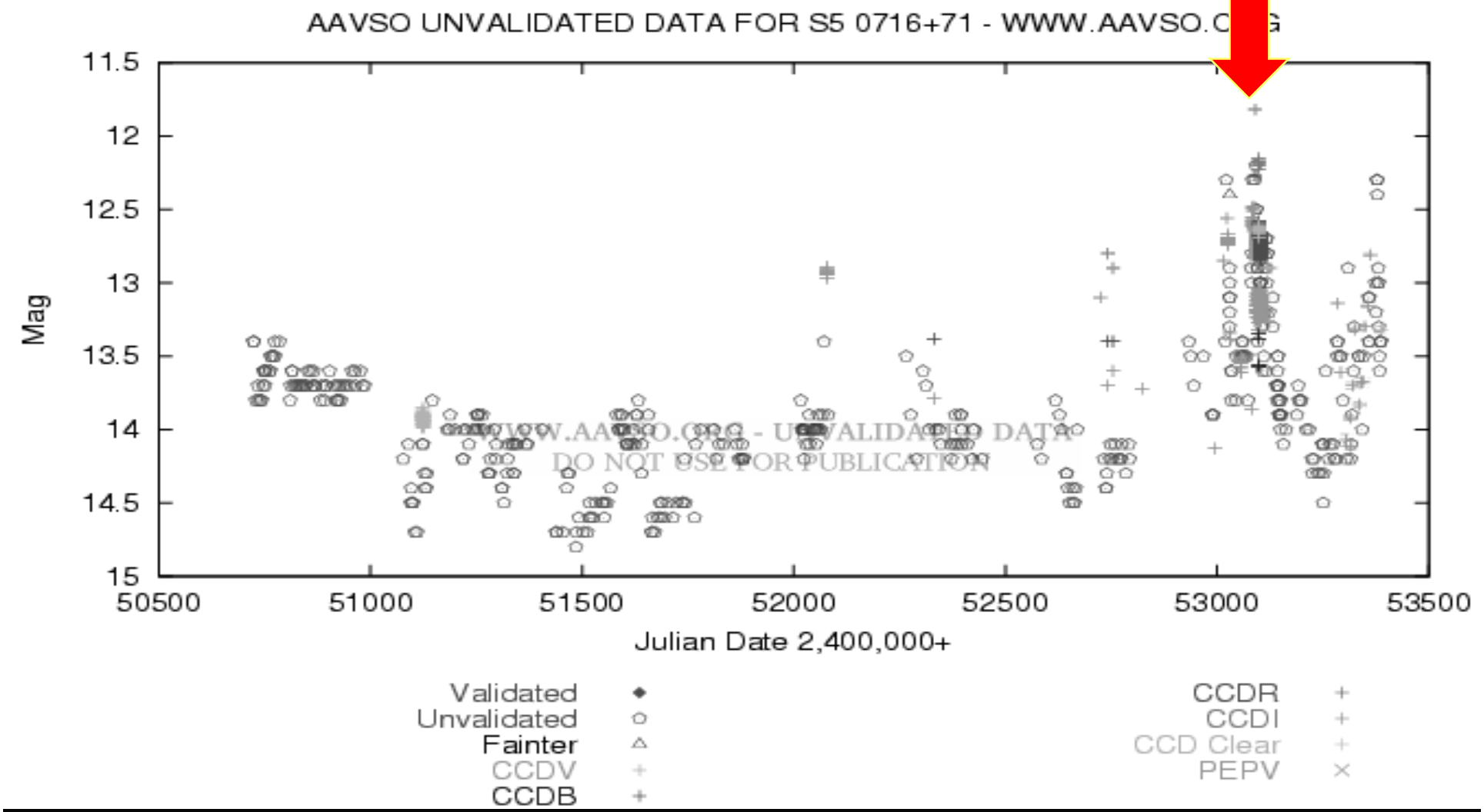
- optical and/or X-ray monitoring (RXTE ASM &h others) of flaring activity of a large list of blazars
- or, alternatively, soft gamma-ray monitoring by INTEGRAL itself (serendipitous detection of a flaring blazar in the IBIS FOV)
- ToO INTEGRAL observation activated meeting the "trigger criteria" (major flaring event)
- coordinated with XMM Newton ToO program

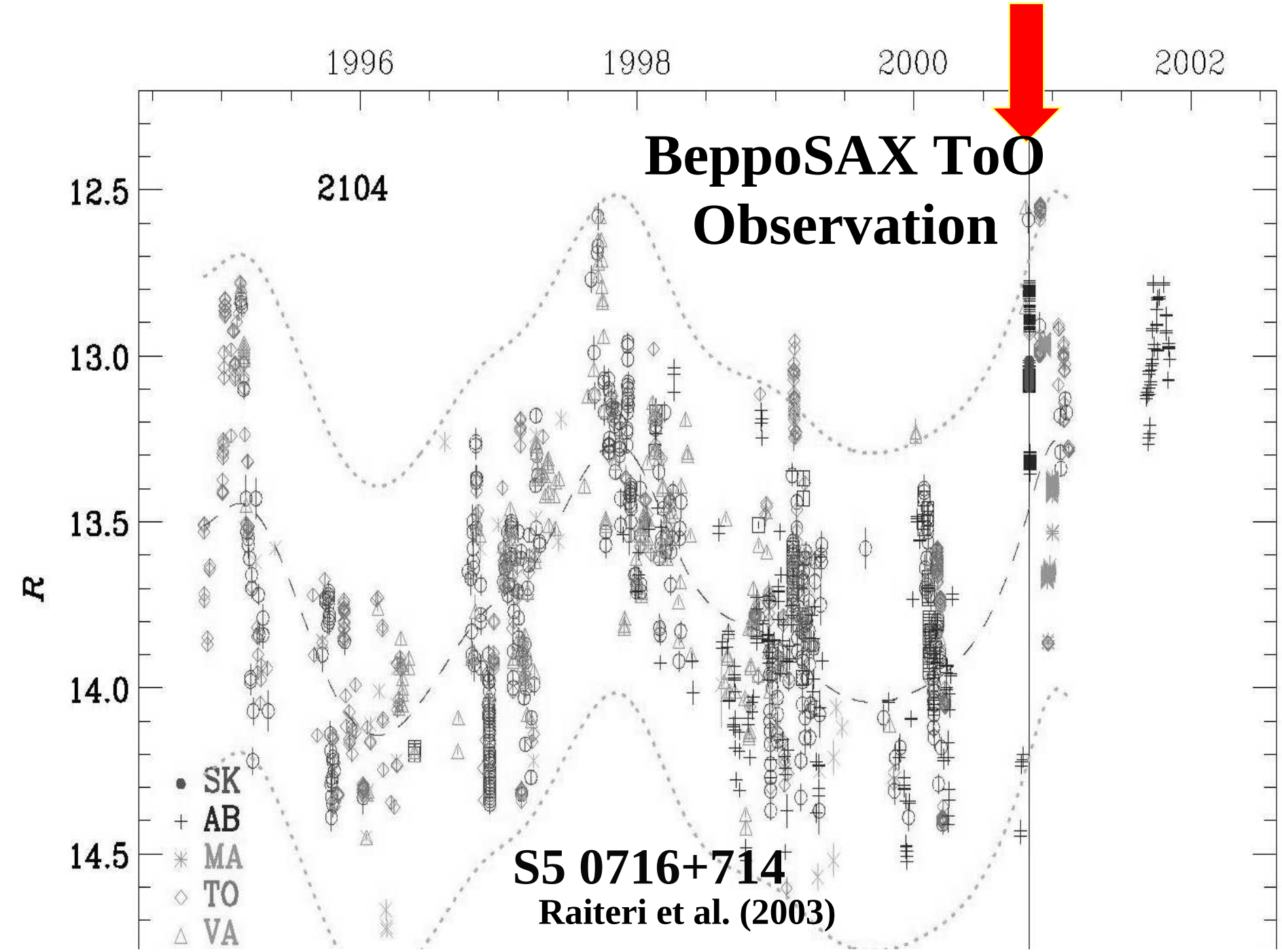
Blazar S5 0716+714

- a BL Lac object
- monitored at radio and optical wavelengths by Whole Earth Blazar Telescope (>40 telescopes, Villata et al. 2004)
- ToO triggered by optical activity - 2 outbursts up to the extreme level of R =12.1 mag (historical maximum, light increase by 1 mag in 2 weeks and 2 magnitudes in 4 months)
- ToO performed 2003 April 2-7

- **INTEGRAL observation: S5 0716+714 detected only by IBIS ISGRI at 4.5 sigma, 30-60 keV band, for a count rate of 0.11 counts/s (exposure 280 ksec). No signal above 60 keV. Better detected at the beginning (decline) ... the useful exposure reduced to 84 ksec**
- **No detection in IBIS/PICsIT, SPI and JEM-X (less than 292, 6 and 6 mCrab)**
- **observed at somewhat higher (2x) gamma-ray state when in Oct 2000 (BeppoSAX ToO, Tagliaferri et al., 2003) (R=12.5 versus 12.1)**
- **low signal/noise ratio - no intra-orbit variability study possible, - no spectrum extraction possible**

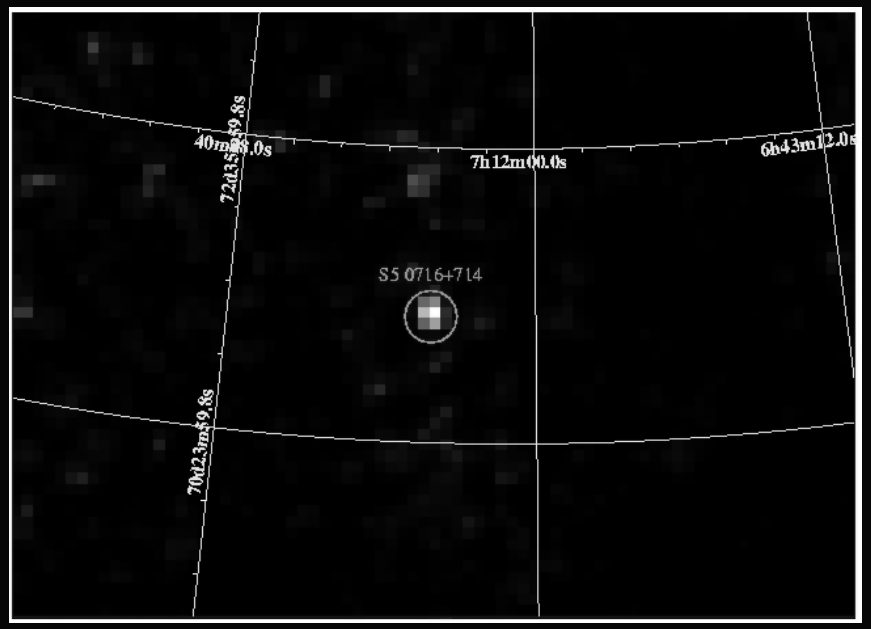
INTEGRAL ToO Observation




1996
1998
2000
2002
12.5
13.0
13.5
14.0
14.5
R
2104
BeppoSAX ToO
Observation
SK
AB
MA
TO
VA
S5 0716+714
Raiteri et al. (2003)

- **Other extragalactic sources observed in the IBIS FOV (19 x 19 deg at hallf response) - 3 additional AGNs with higher significance than the main blazar target**
- **these 3 AGNs were observed up to 100 keV**
- **no intra-orbit variability study possible**
- **spectrum extraction possible**
- **S5 0836+710 (high z blazar of the FSRQ sub-class) : single power law spectrum**
- **Mkn 6 (bright Seyfert): single power law spectrum**
- **Mkn 3 (bright Seyfert): broken power-law with cutoff at >50 keV**

The target and the three additional AGNs in the IBIS FOV (30-60 keV)



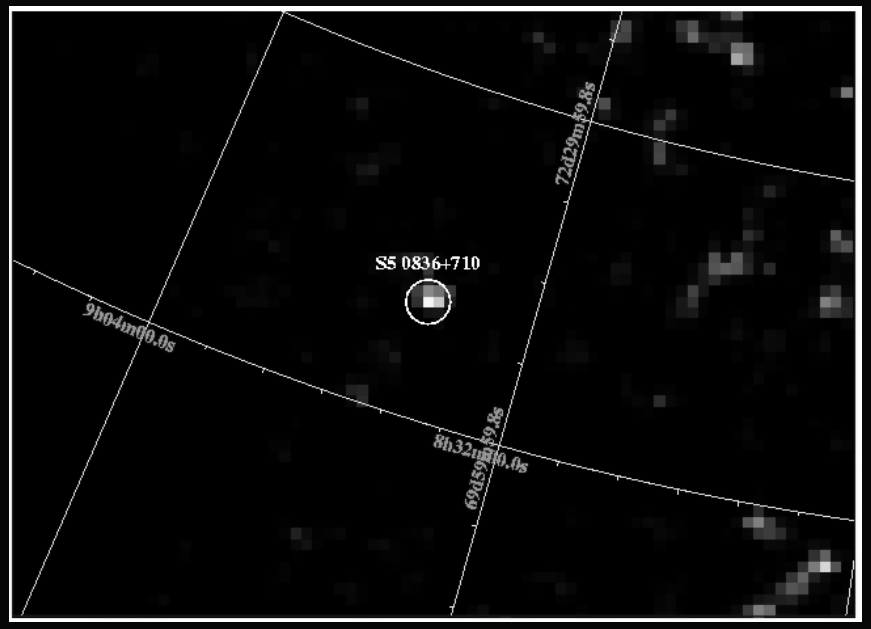


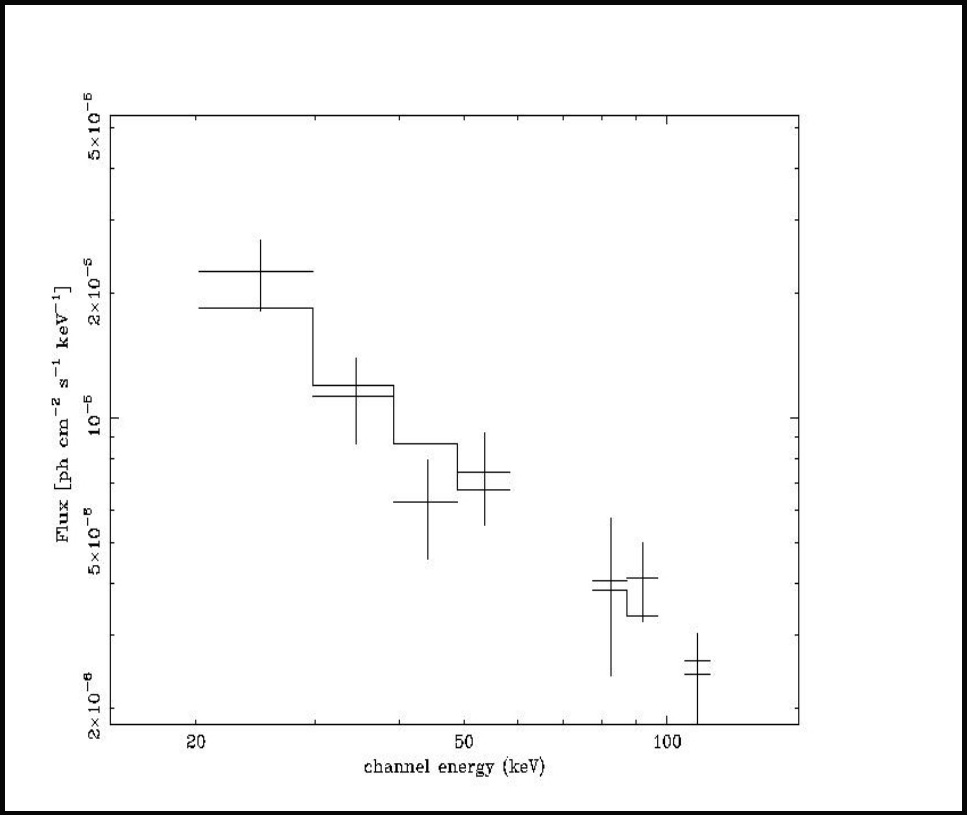
Table 1. Sources detected in the IBIS/ISGRI field of S5 0716+714

Object	AGN Type	z	CR[a]	Flux[b]	Range[c]	Γ_1^d	Γ_2^d	E_b^e	χ^2	d.o.f.	Γ_{PDS}^f
S5 0716+714	BL Lac	...	0.36 ± 0.07^g	3.1	30-60	...	...	...	...	...	$1.6 \div 2.0$
S5 0836+710	FSRQ	2.172	0.54 ± 0.05	4.6	20-100	1.3 ± 0.3^h	...	...	4.1	5	1.31 ± 0.03
Mkn 6	Sy 1.5	0.019	0.49 ± 0.06	4.6	20-100	$1.5^{+0.5}_{-0.4}$	...	...	3.7	3	1.8 ± 0.2
Mkn 3	Sy 2	0.013	0.82 ± 0.05	7.4	20-100	1.3^i	> 2.5	80 ± 20^h	2.5	3	1.8 ± 0.1

[a] IBIS/ISGRI count rate in the detection energy range (Col. 6), in counts s^{-1}.
[b] Fitted flux in the detection energy range (Col. 6), in 10^{-11} erg s^{-1} cm^{-2}. Calibration uncertainties are $\sim$10%.
[c] Energy interval to which count rates (Col. 4) and fluxes (Col. 5) are referred, in keV.
[d] Photon index: $f_E \propto E^{-\Gamma}$.
[e] Break energy, in keV.
[f] Photon index measured with the *BeppoSAX* PDS at previous epochs.
[g] Uncertainties on the count rates are 1σ.
[h] Uncertainties on the photon indices and break energy are 1.6σ.
[i] Γ_1 has been frozen to the index of the single power-law which best fits the spectrum below 100 keV, $\Gamma = 1.3 \pm 0.4$.

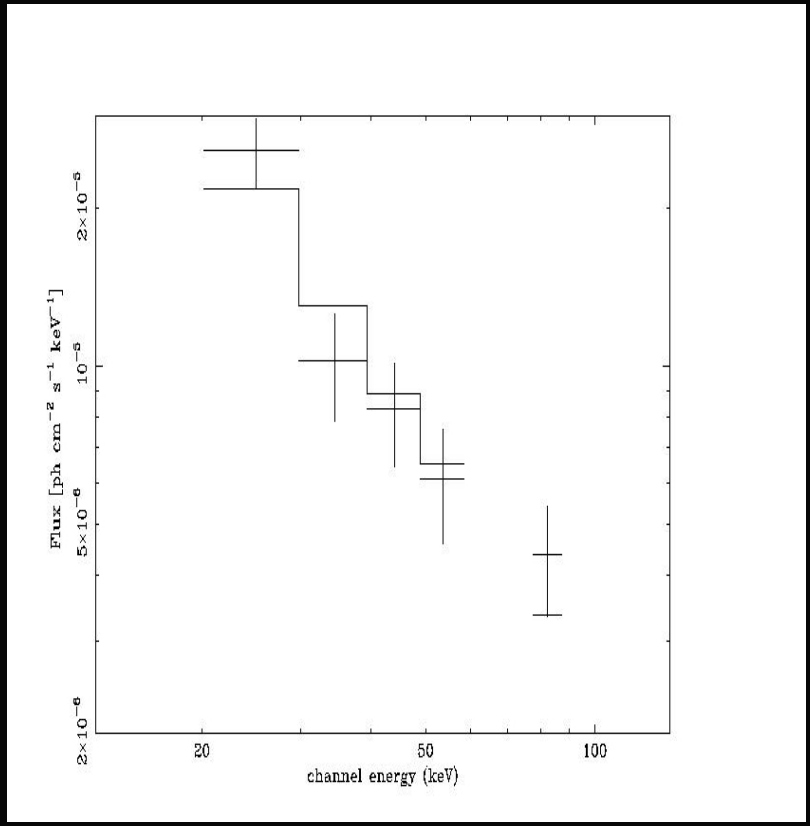
(Pian et al., 2005)

S5 0836+710



single power law spectrum Γ~1.3

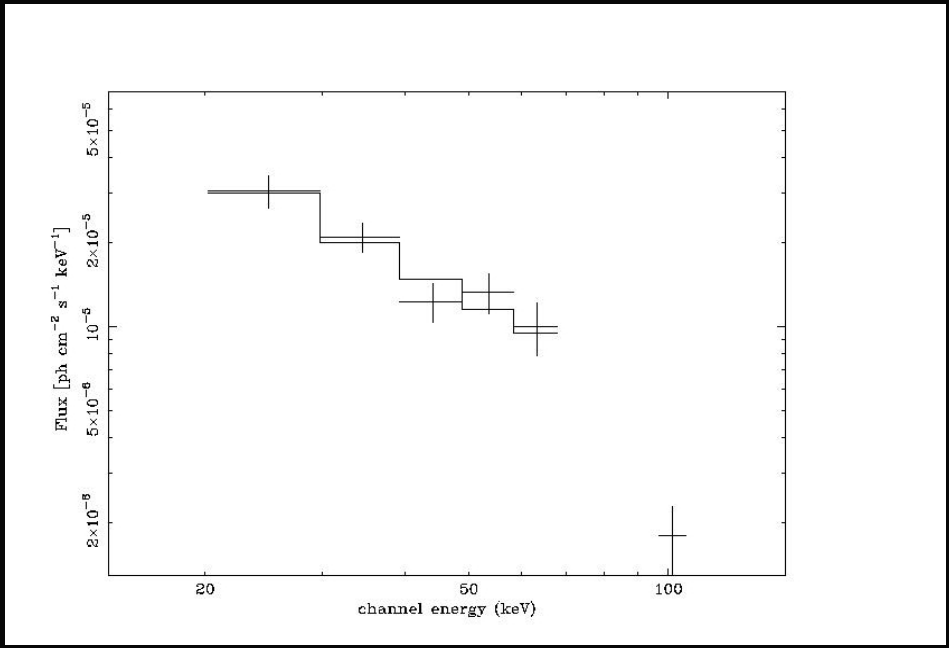
Markarian 6



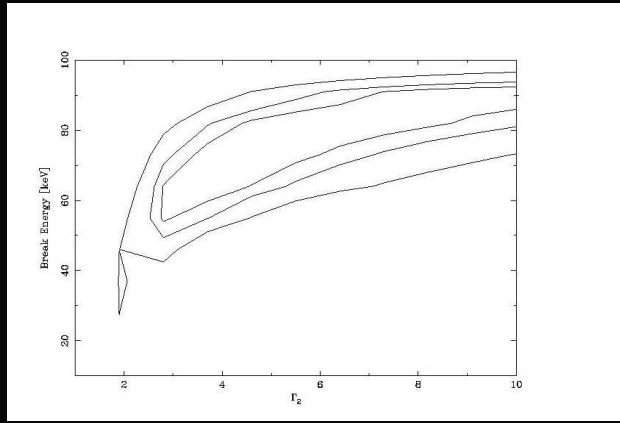
single power law spectrum Γ~1.5

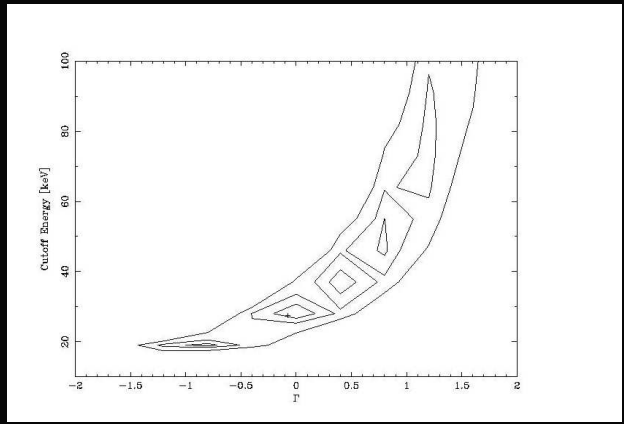
Hints for a break or cutoff in Markarian 3

IBIS/ISGRI spectrum



Broken power law





Power law with high energy cutoff

Conclusion - the AO blazar observation

- **with relatively short exposures the INTEGRAL is efficient tool to study bright AGNs at high Galactic latitudes**
- **importance of HE instruments with large FOV and good angular resolution**

Further INTEGRAL observations of blazars

- **3C 279 within AO-1 by Collmar et al. in a deep low-activity state (faintest R mag in 10 years, 3 mag fainter than average)**
- **PKS1830-211 confirmed as a blazar by INTEGRAL CP (Bassani et al., 2004) ... broad band energy spectrum confirms the blazar nature (low-energy - MeV - peaked or red blazar). One of farthest objects detected so far by INTEGRAL (z=2.5)**
- **S5 0716+714 AO-1 observation by Wagner et al. (in optically active state, results not yet published)**

INTEGRAL and high redshift Universe

detection of two high z blazars (S5 0836+710 at z=2.17 and PKS 1830-21 at z=2.51) - the most distant objects seen by INTEGRAL so far - INTEGRAL can also play a role in investigation of high z Universe

Acknowledgement. This study was supported by ESA Prodex 14527.

The End