Simultaneous NIR and Gamma-ray observations of southern Blazars

R. Nesci, (INAF-IAPS)
G. Tosti, (Universita' di Perugia)
T. Pursimo, (Nordic Optical Telescope)
R. Ojha, (NASA/GSFC)
M. Kadler, (Universitat Wurzburg)

The sample

We selected a sample of southern Blazars from the list of 75 sources monitored by the TANAMI project

http://pulsar.sternwarte.uni-erlangen.de/tanami/

The aim was to get optical-NIR monitoring with a sampling rate similar to the Radio one.

Observations were made with the REM 60 cm telescope at La Silla (Chile), operated by INAF, in the R,J,H,K bands.

The selection criteria was the apparent J magnitude of the sources, in order to be easily observable with REM.

We choose 22 sources, with J<16.0 in the 2MASS catalogue.

Only a few sources are in common with the similar SMARTS project of southern Blazars NIR-optical monitoring.

Source list

Name	2FGL name	Class	T	B	z	group
PKS0047-579	2FGLJ0049.7-5738	BZQ	Q	Q	1.797	3
PKS0208-512	2FGLJ0209.5-5229	BZB	B	U	0.999	2
PKS0332-403	2FGLJ0334.2-4008	BZB	Q	B	1.445	3
PKS0332-376	2FGLJ0334.3-3728	BZB	U	U		2
PKS0402-362	2FGLJ0403.9-3604	BZQ	Q	Q	1.417	3
PKS0447-439	2FGLJ0449.4-4350	BZB	B	B	0.107	1
PKS0454-463	2FGLJ0456.1-4613	BZQ	Q	Q	0.852	2
PKS0521-365	2FGLJ0523.0-3628	AGN	B	U	0.055	1
PKS0537-441	2FGLJ0538.8-4405	BZB	Q	B	0.894	1
PKS0625-354	2FGLJ0627.1-3528	RG	G	-	0.054	1
PKS0637-752	2FGLJ0635.5-7516	BZQ	Q	Q	0.653	2
PKS0700-661	2FGLJ0700.3-6611	BZB	U	U		2
PKS0812-736	2FGLJ0811.1-7527	BZB	U	-		3
PKS1144-379	2FGLJ1146.8-3812	BZQ	Q	U	1.048	2
PKS1325-558	2FGLJ1329.2-5608	AGU	U	-		3
PKS1424-418	2FGLJ1428.0-4206	BZQ	Q	Q	1.522	2
PKS1440-389	2FGLJ1443.9-3908	BZB	U	B	0.065	1
PKS1600-489	2FGLJ1603.8-4904	BZB	U	-		3
PKS1954-388	2FGLJ1958.2-3848	BZQ	Q	Q	0.965	2
PKS2005-489	2FGLJ2009.5-4850	BZB	B	B	0.071	1
PKS2136-428	2FGLJ2139.3-4236	BZB	B	B	>0.24	2
PKS2155-304	2FGLJ2158.8-3013	BZB	Q	B	0.116	1

The TANAMI Project

- TANAMI (Tracking Active Galactic Nuclei with Austral Milliarcsecond Interferometry) is a program to image and monitor the parsec-scale structures of relativistic jets in active galactic nuclei (AGN) of the Southern Hemisphere with the LBA.
- It is complementary to existing programs in the Northern Hemisphere (e.g., MOJAVE).
- TANAMI is tracking the jets of sources south of DEC -30 with milliarcsecond resolution at 8.4GHz and 22GHz.
- TANAMI observations started in 2007 and are being conducted every two months to provide dense sampling of fast superluminal moving jet features.
- TANAMI enables us to react quickly to transient events and to begin follow-up observations of sources of special interest, in particular blazars found by Fermi to be flaring at Gamma-rays.

Fermi-LAT

- Gamma ray monitoring of the sample was provided by the Fermi-LAT instrument.
- Weekly flux density averages in the whole instrument band (E>0.1 GeV) were built for each source to get its Gamma-ray light curve.
- Most of the sources were generally faint (1E-8 erg/cm2/s), near the detection limit, so that flux uncertainties are often large.

REM Monitoring

- Our monitoring lasted for one year (AOT 23 and 24 of REM).
- Exposure times were typically 150s in each JHK band.
- R-band images were often of poor quality for technical reasons.
- Best images were provided by the J filter.

Photometry

- Aperture photometry (2 arcsec radius) in the JHK bands were performed with IRAF/Apphot, using a sequence of several nearby stars form the 2MASS catalogue, possibly encompassing the magnitude of the target.
- A linear calibration relation was derived to transform the instrumental magnitudes into the 2MASS magnitudes scale: the slope of the fit was generally very near to 1.0.
- Error estimates was provided by the rms deviation of the reference stars with respect to the calibration line.

Detection groups

From the NIR observations, our sample of 22 sources was naturally divided into 3 groups:

1. bright sources with photometric errors in all three IR bands small enough to allow a meaningful color index measurement (below 0.05 mag, 7 sources);
2. sources bright enough to be measured but with larger errors, so that only a J-band light curve can reliably be obtained (9 sources);
3. sources never detected or unreliable (6 sources).

Physical classification:

Group 1: 5 BL Lac, 1 Unclassified (0521-365), 1 Radio galaxy (0625-354);

Group 2: 4 BL Lac, 5 QSO;

Group 3: 3 BL Lac, 2 QSO, 1 Unclassified.

Group 1: photometry

PKS	mean-J	range	sigma	2MASS	trend	Class
0447–439	12.68	12.2-13.1	0.39	13.89	increasing	B
0521–36	12.87	12.5-13.1	0.20	12.95	no	A
0537–441	13.21	12.5-14.0	0.42	13.23	no	B
0625–35	13.11	12.8-13.3	0.18	13.38	no	G
1440–389	13.62	13.2-14.0	0.28	13.66	wave	B
2005–489	12.20	11.9-12.5	0.22	11.35	decreasing	B
2155–304	11.93	11.4-12.2	0.29	11.40	decreasing	B

Group 1: colors

PKS	E(B-V)	N	slope REM	slope 2MASS	J-H;H-K mean	Class
0447-439	0.061	17	-0.47	-0.57	0.65;0.65	B
0521-36	0.169	12	-0.95	-0.94	0.75;0.85	A
0537-441	0.169	14	-0.96	-1.16	0.85;0.85	B
0625-35	0.288	11	-0.15	-0.46	0.65;0.45	G
1440-389	0.515	10	+0.02	-0.18	0.70;0.55	B
2005-489	0.241	11	-0.35	-0.34	0.65;0.75	B
2155-304	0.093	7	-0.49	-0.43	0.65;0.65	B

Assumed spectrum: F(nu)=A*nu**slope

Group 2: mags and colors

PKS	mean J	range	sigma	2MASS J	trend	2MASS slope	Class
0208-512	14.89	13.7-16.0	0.83	13.69	no	-1.14	B
0332-376	14.52	13.8-15.4	0.45	14.85	decr	-1.23	B
0454-463	15.80	15.2-16.4	0.39	15.38	decr	-0.50	Q
0637-752	14.52	14.0-15.0	0.26	14.85	no	-0.03:	Q
0700-661	14.18	14.0-14.6	0.18	13.60	no	-0.65	B
1144-379	15.70	13.6-15.5	0.44	15.66	no	-1.12	Q
1424-418	14.52	13.6-15.5	0.49	16.26	incr	-1.07	Q
1954-388	15.30	14.3-16.5	0.69	15.96	no	-1.05	Q
2136-428	14.18	13.8-14.5	0.21	14.57	no	-0.66	B

NIR overview

	Group 1	Group 2
Average J flux	like 2MASS	somewhat different from 2MASS
Spectral slope	like 2MASS	not measured
Variability range	~0.6 mag	>1.0 mag
Long-term trend	3/7 sources	3/9 sources
Flares	none	1 source

Variability index

For each source, and for each couple of consecutive observations, we computed a variability rate index, defined as

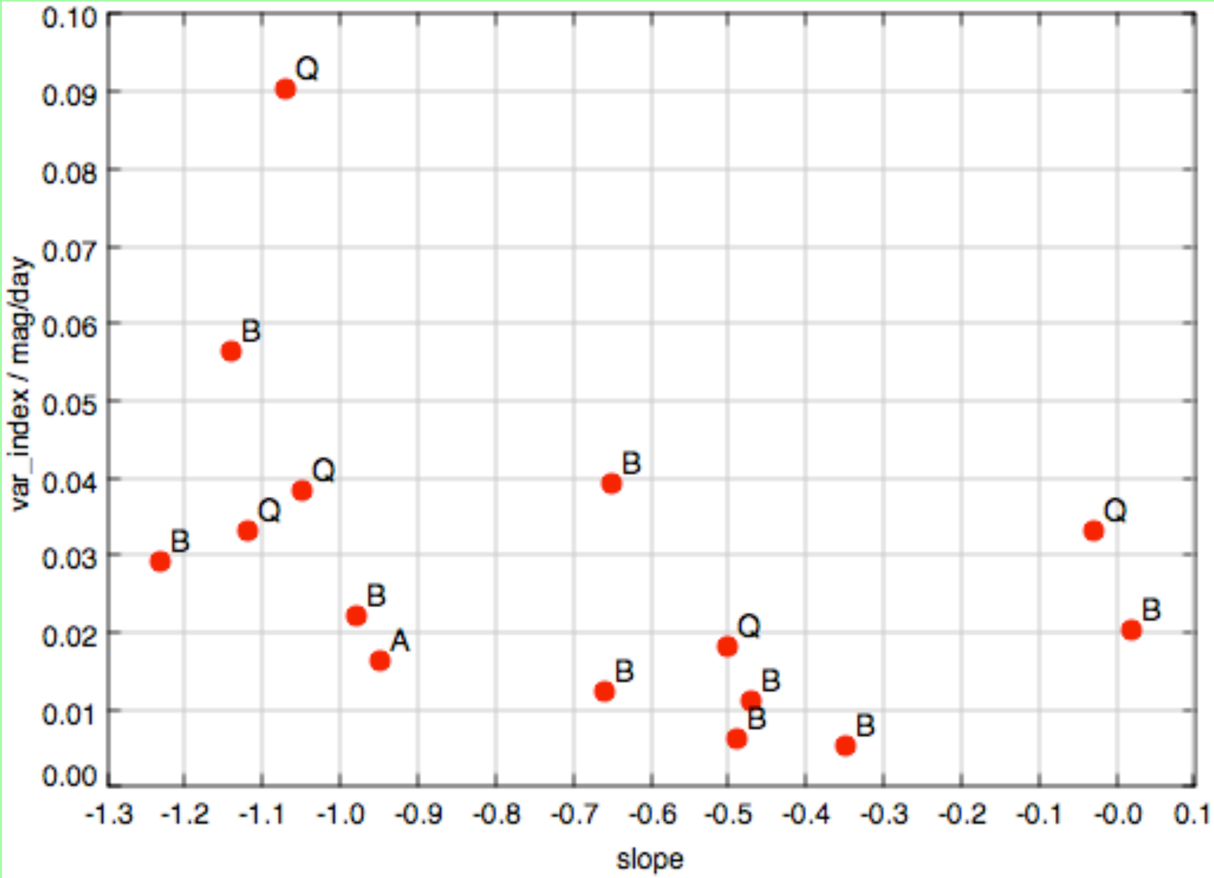
VR = Delta(Mag)/Delta(Time)

We assumed as representative of each source the second largest value of our monitoring.

The correlation between this index and the NIR spectral slope is interesting ….

BL Lacs are NOT more variable than FSRQ !

Variability index - NIR slope

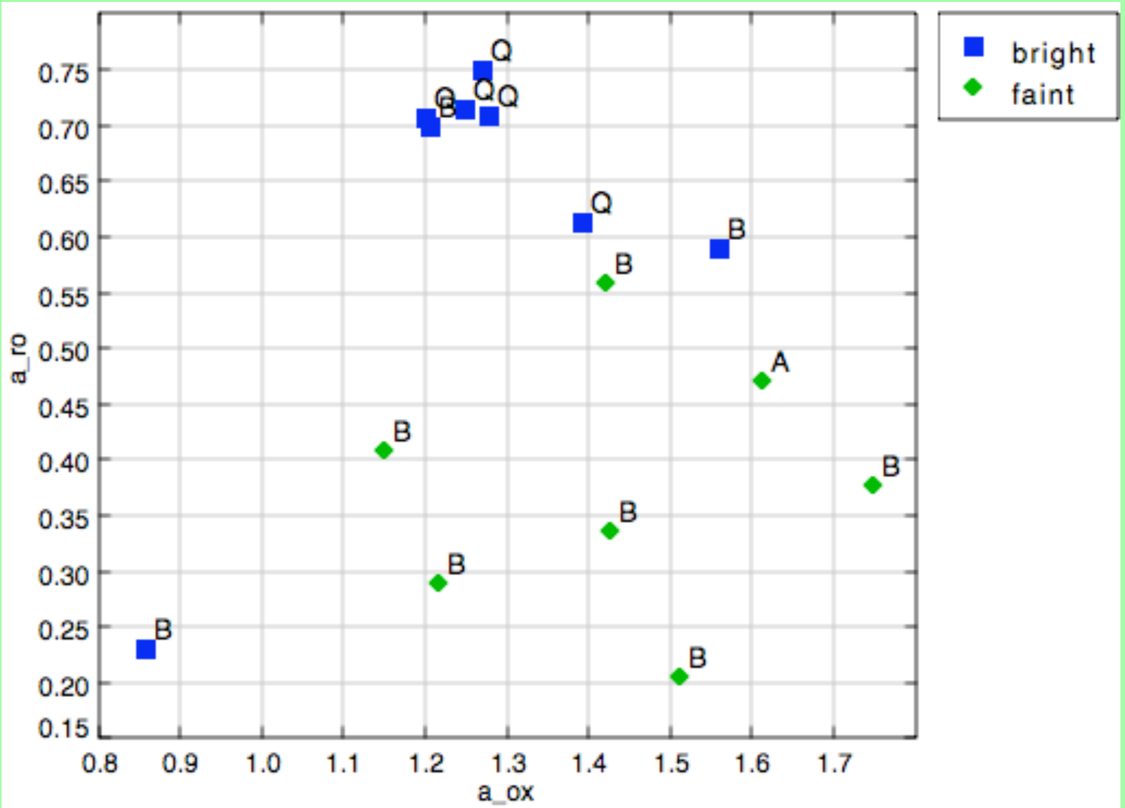


Most variables: Q=1424-418; B=0208-512

Why?

An explanation can be given by the well known alpha_ro alpha_ox diagram. Our BL Lacs are mostly in the region of HFP (or HBL), so that we observe them far from the peak of their SED, where variability is less pronounced.

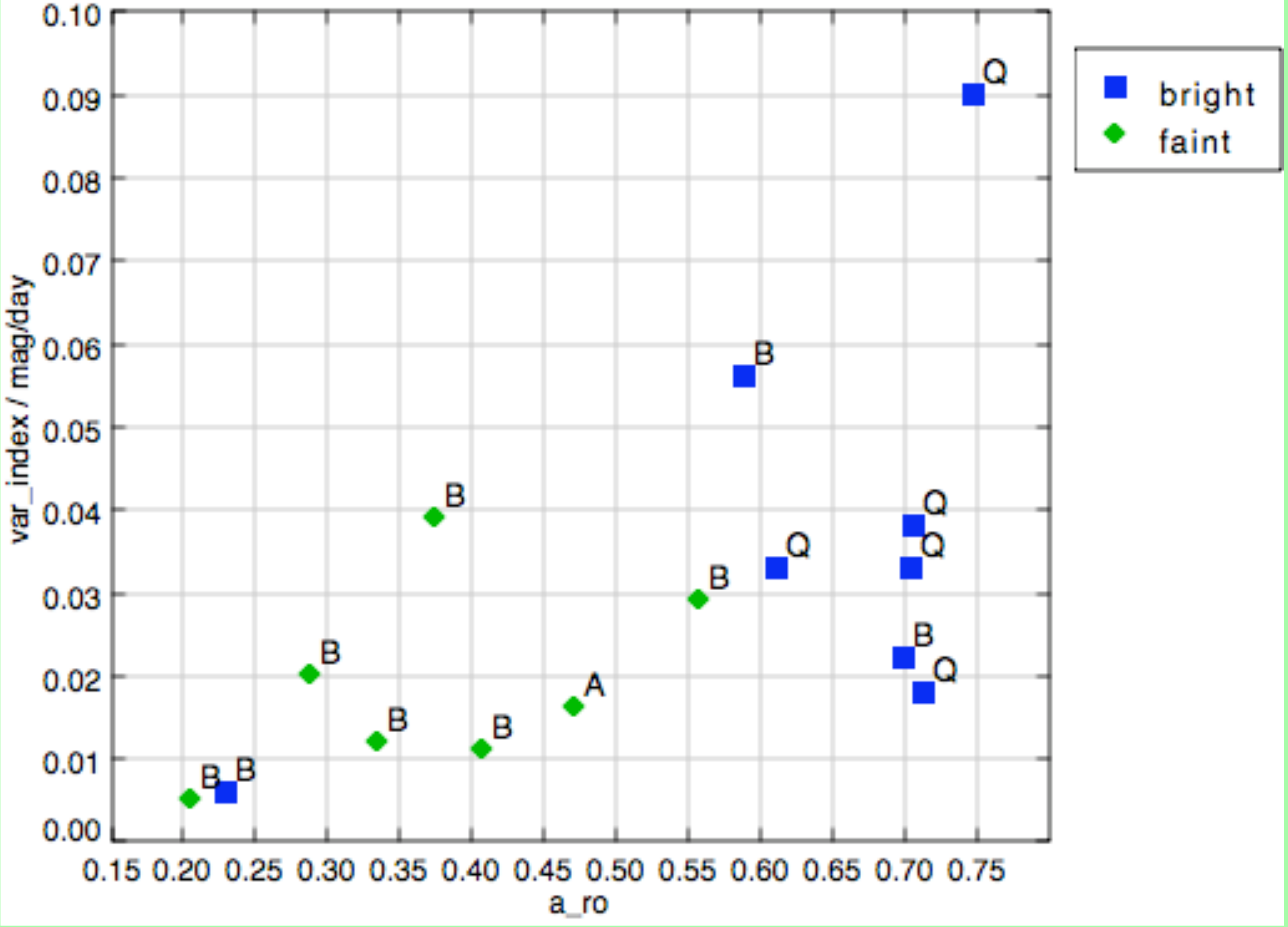
(bright and faint refer to Absolute magnitudes M_J<26)



FSRQ-BL Lac discriminator

- The alpha_ro, alpha_ox plot shows also that alpha_ro is a good discriminator between FSRQs and BL Lacs, the border value being around 0.60.
- A plot of the variability index vs alpha_ro confirms the previous indication, i.e. radio-loud sources in our sample (FSRQ) apparently vary more in NIR than our radio-faint (BL Lac) sources.

Alpha_ro, Variability index



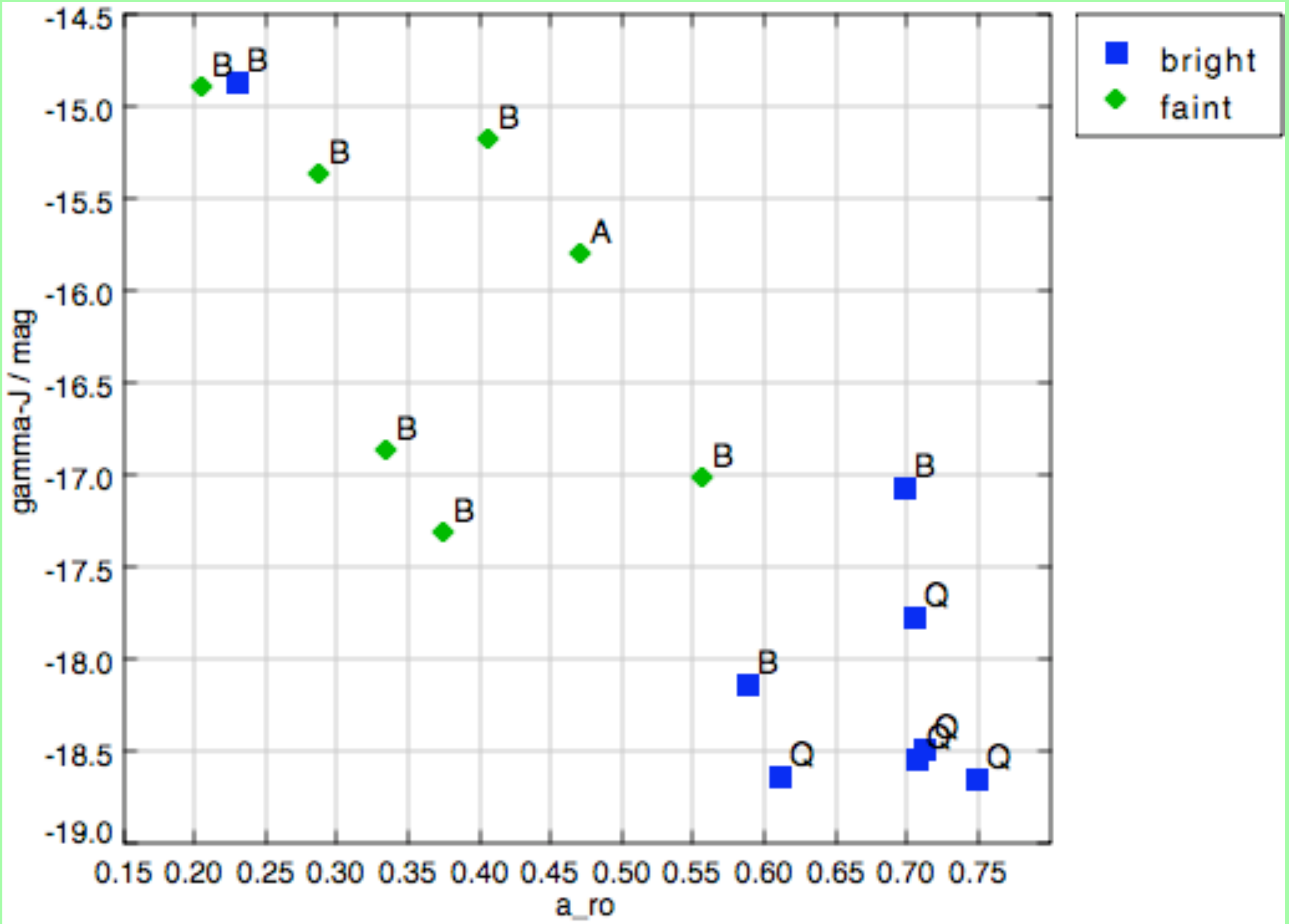
Gamma ray fluxes

- We derived weekly averages of the Gamma-ray flux for the 16 sources detected in the NIR, as well as their overall average value.
- The average Gamma-ray/NIR flux ratio in the sources of our sample covers a wide range of values, indicating the existence of gamma-ray loud and Gamma-ray faint sources.
- A nice correlation is apparent if the Gamma-ray/J-band flux ratio is plotted against the alpha_ro index.
- The correlation coefficient is -0.85 and BL Lacs are well separated from FSRQs, suggesting the existence of a physical sequence (FSRQs are typically more Gamma-loud).

Gamma/J flux ratio vs alpha_ro

Gamma faint

Gamma loud



Gamma-ray light-curves

Gamma-ray count rates (E>100 MeV) are converted into magnitudes via:

Mag = -2.5log(Count_rate)

Mag 18 = 6.3 E-8 ph/cm2/s

Mag 17 = 1.6 E-7 ph/cm2/s

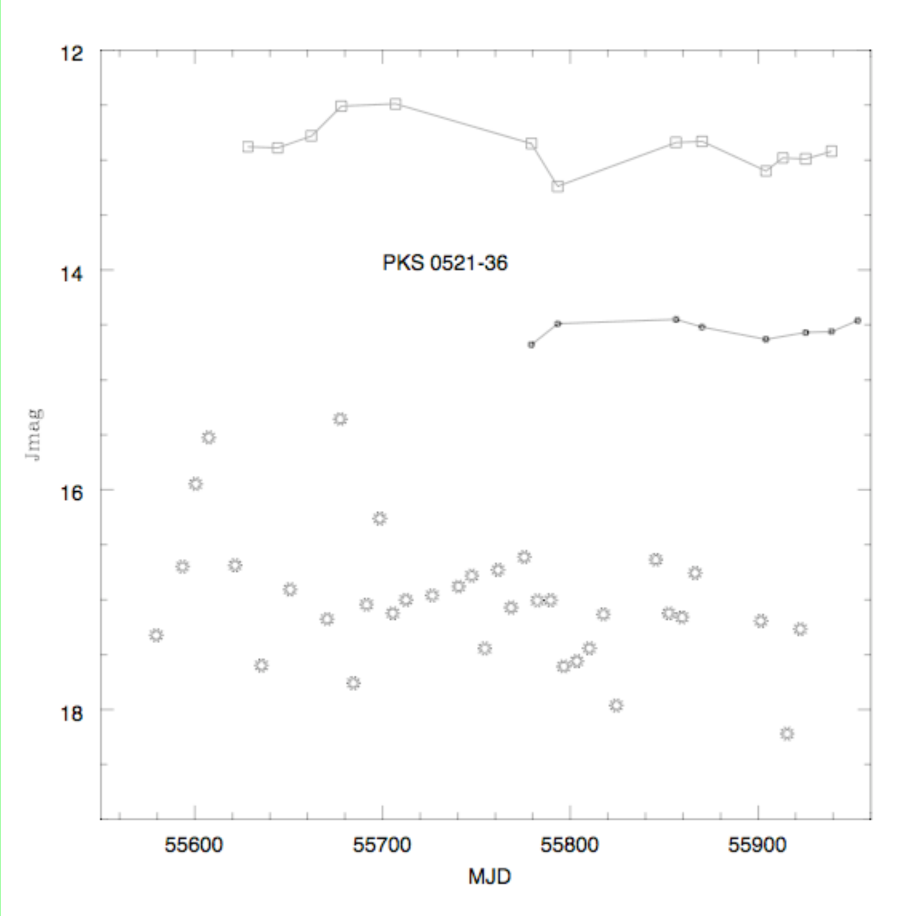
Mag 16 = 4.0 E-7 ph/cm2/s

Mag 15 = 1.0 E-6 ph/cm2/s

A typical light curve, large variability in Gamma, smaller in NIR;

the two Gamma flares have no clear NIR counterparts.

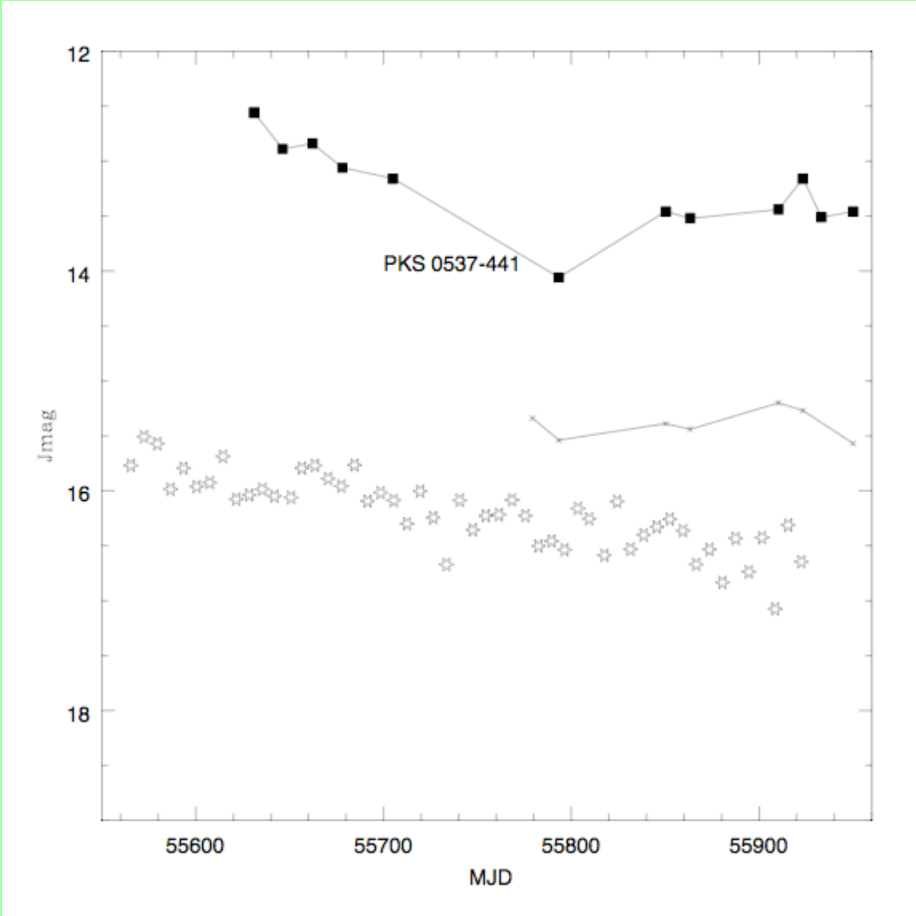
(0521 is unclassified A)



(For ease of comparison the NIR and Gamma-ray light curves are in magnitudes)

Discrepant light curve

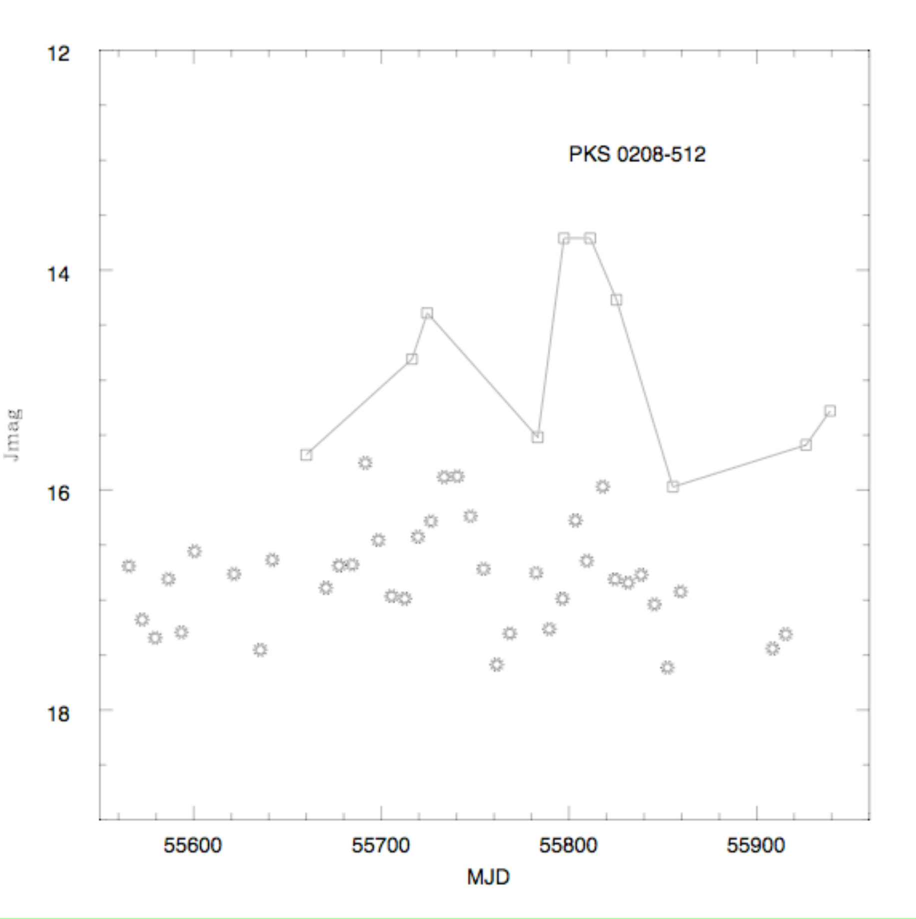
A discrepant case:
PKS 0537-441 (B)
monotonic in gamma,
non monotonic in J.



A Gamma-ray flare

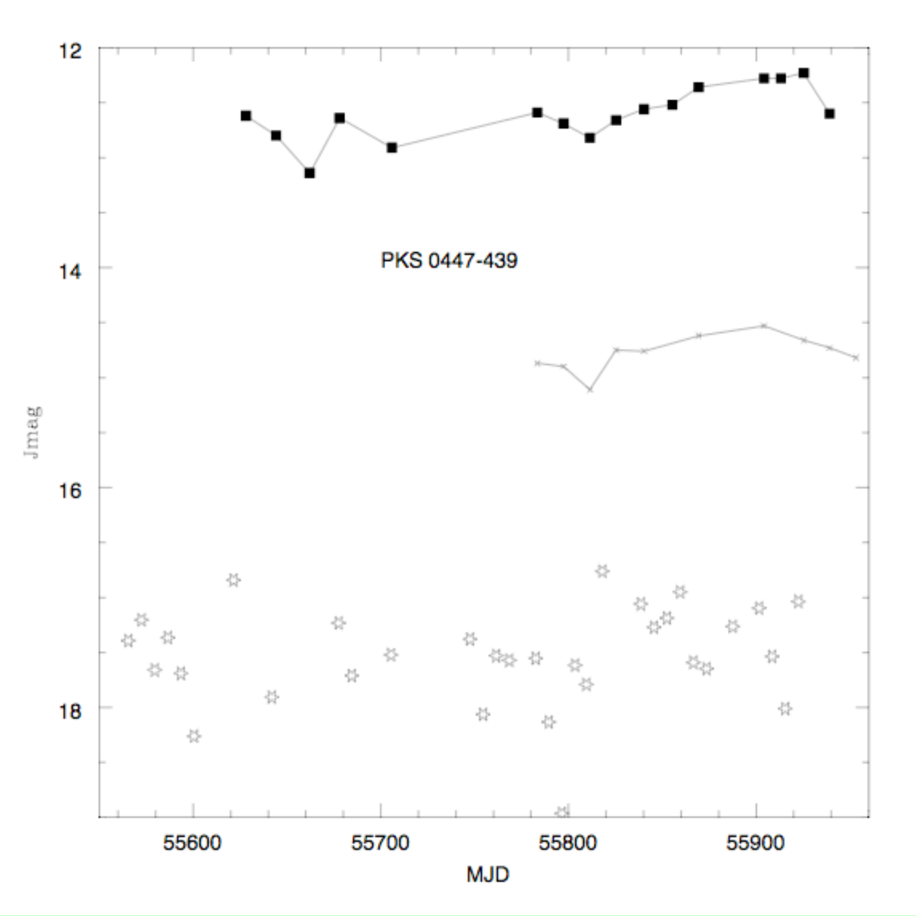
Our only case of simultaneous Gamma and NIR flare, PKS 0208-512, a gamma-loud source (Gamma-J ~ 2)

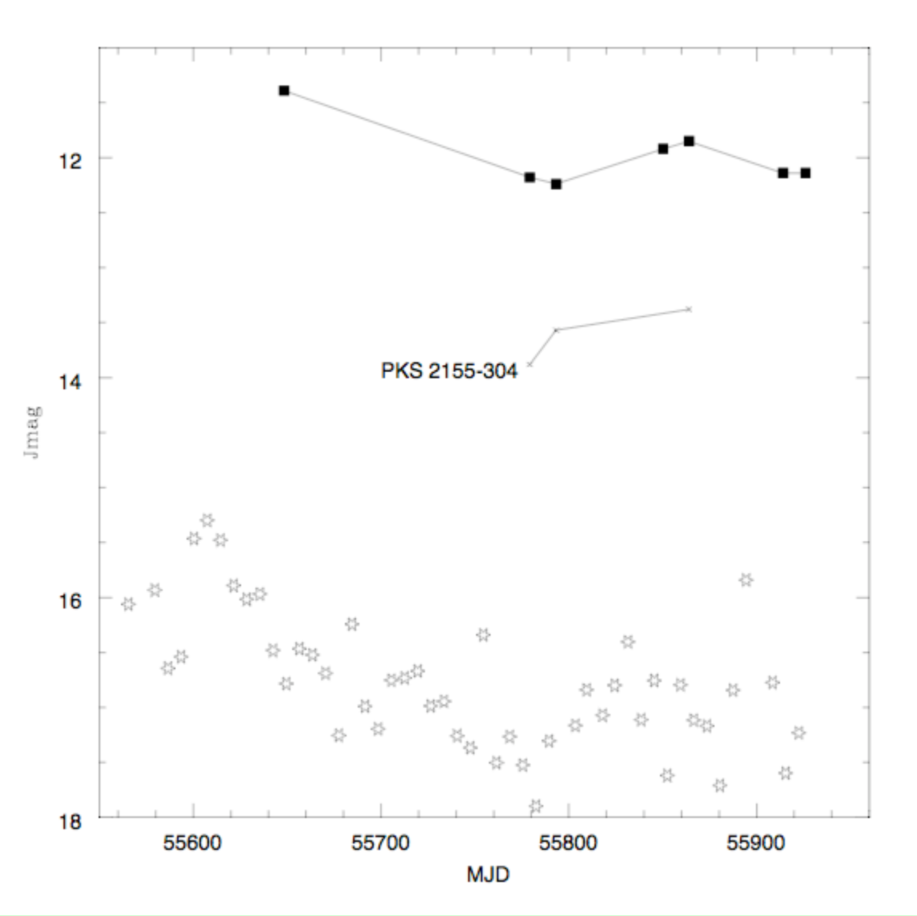
Classified as BL Lac



Other light curves

Parallel behaviours in Gamma and NIR, PKS 2155-304 and PKS 0447-439 (Delta-mag Gamma-J=5). Both classified as BL Lac





Summary

All the NIR detected (16) sources showed marked flux density variability, while the spectral slopes remained unchanged within our sensitivity limits. Steeper sources showed on average a larger variability.

FSRQ proved to be on average more rapidly variable than BL Lacs.

Half of the sources showed a regular flux density trend on a 1 year time scale, but do not show any other common property.

The alpha_ro index looks as a good proxy for the NIR spectral slope.

The Gamma-ray/NIR flux ratio showed a large spread, QSO being generally Gamma-loud and BLLac Gamma-faint, with a marked correlation with the alpha_ro index.

The agreement between Gamma-ray and NIR light curves is generally good for sources with good S/N ratios, suggesting a correlation between the two emission processes, but with some relevant exceptions.