



Fermi
Gamma-ray Space Telescope



The Third LAT AGN Catalog (3LAC)

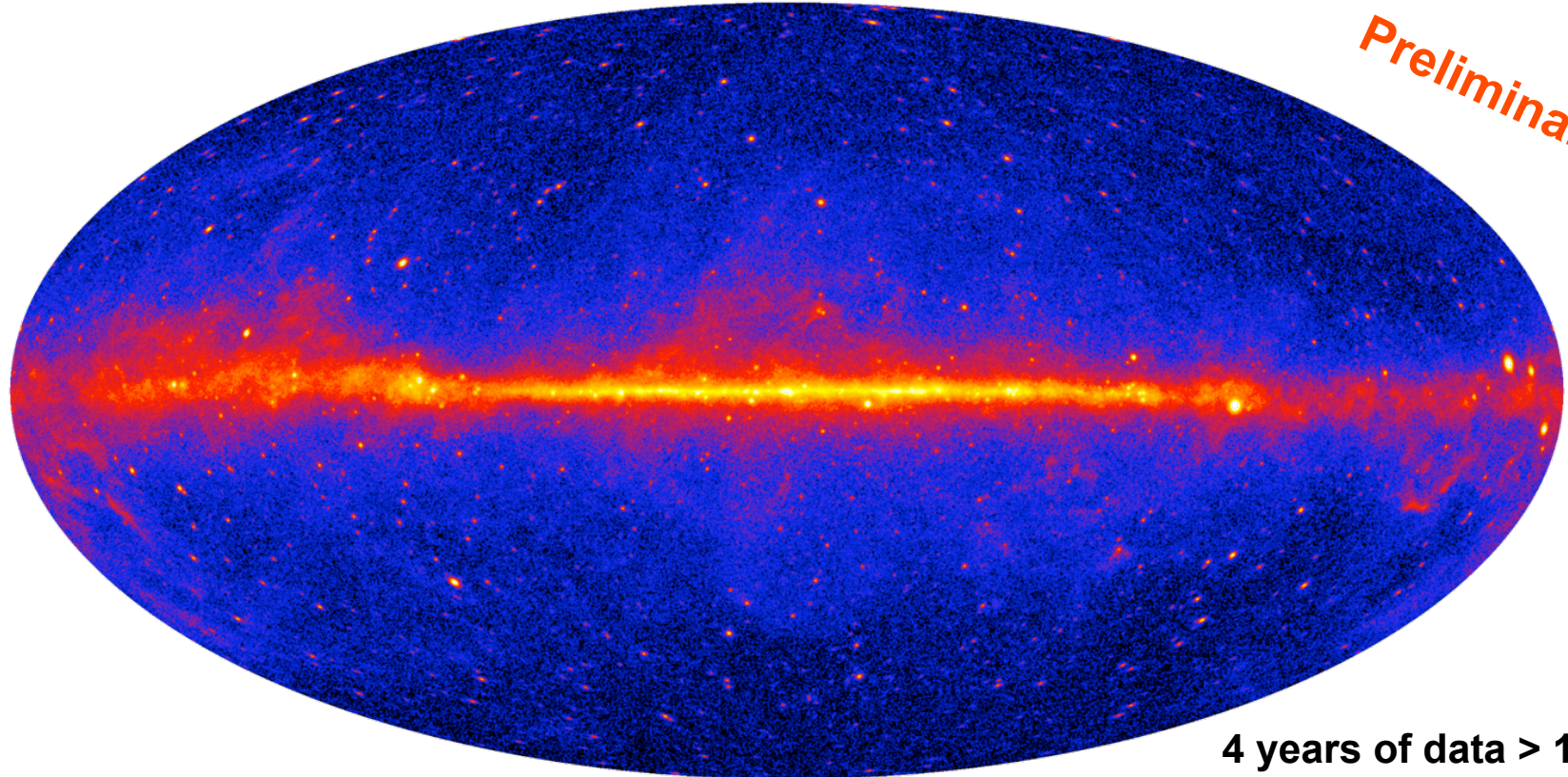
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D. Gasparrini on behalf of the Fermi-LAT
collaboration



Preliminary

4 years of data > 1 GeV

- 4 years, P7REP_SOURCE_V15, improved PSF
 - Front/Back handled separately (different isotropic and Earth limb)
 - Energy range 100 MeV - 300 GeV
- 3032 sources, 2192 at $|b| > 10^\circ$

Associations

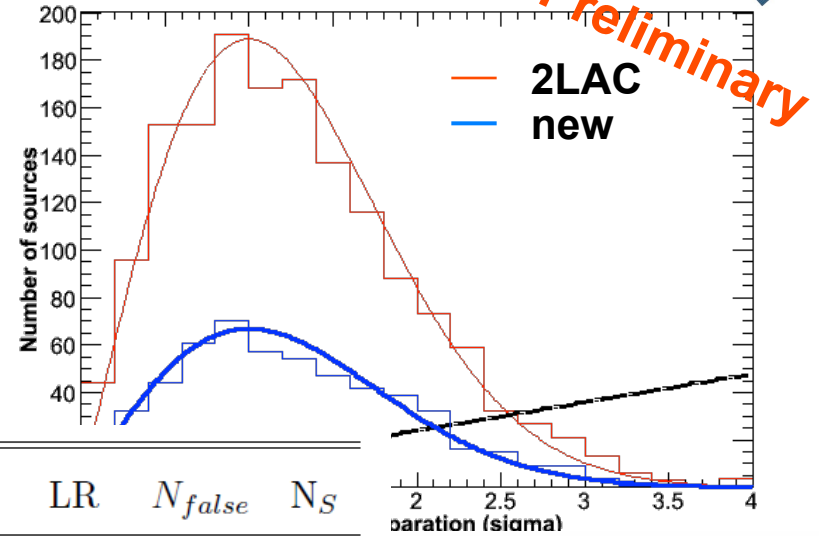


Two associations methods:

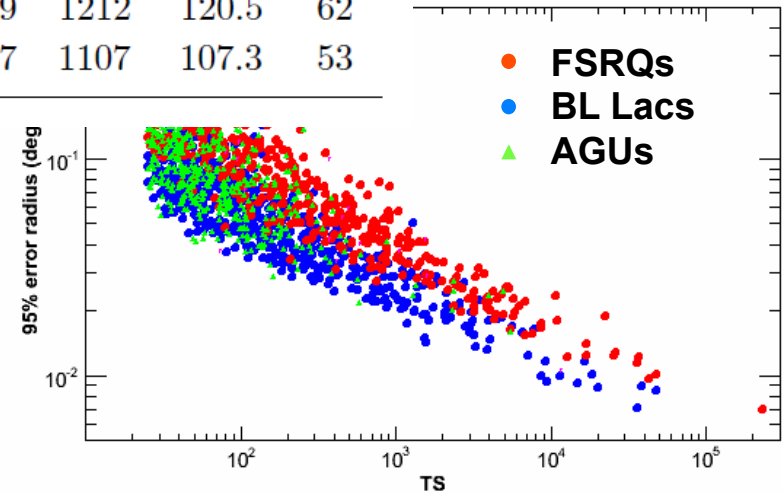
- Bayesian method
- Likelihood ratio (LR) method

Association probability > 0.8

$$N_{false} = \sum_i (1 - P_i)$$



Sample	Total	N_{false}	Bayesian	N_{false}	N_S	LR	N_{false}	N_S
All	1591	29.7	1529	34.5	379	1212	120.5	62
Clean Sample	1444	23.4	1391	17.5	337	1107	107.3	53



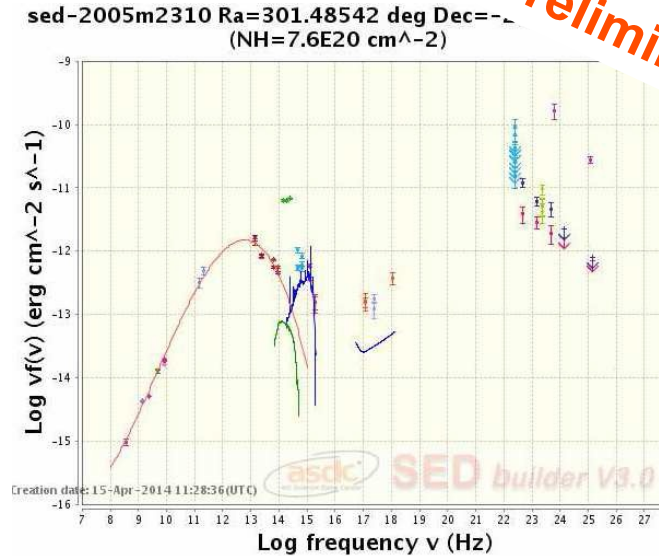
72% in common
False-positive rate < 2%

Classification



Two classification schemes:

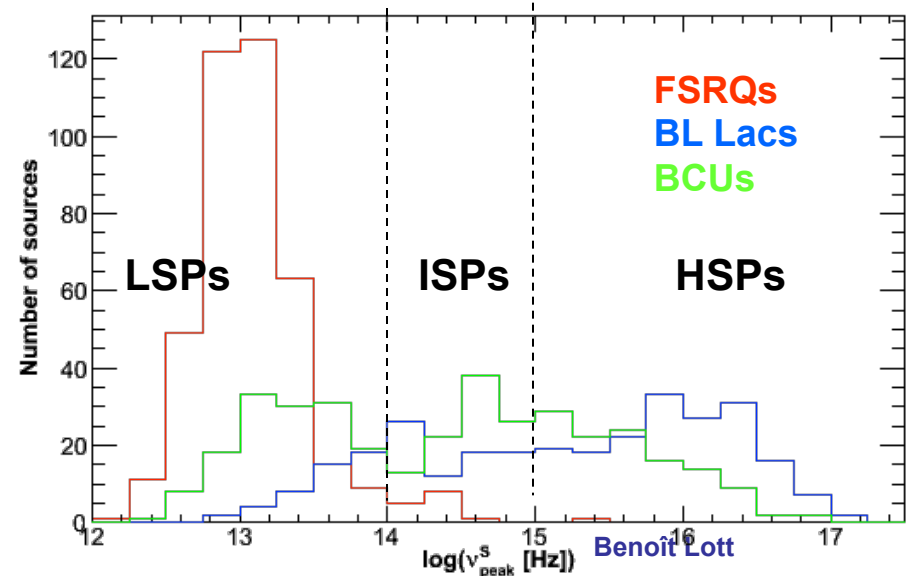
- **Optically-based (strength of broad lines): FSRQs, BL Lacs, BCUs (aka Blazar Candidates of Unknown type)**
- **SED-based: Low-, Intermediate-, High-Synchrotron-Peaked sources (LSPs, ISPs, HSPs resp.)**



2LAC: automatic SED fit

3LAC: manually-controlled SED fit by 20 « seeders » over 3 continents

B. Carpenter, C. Leto, D. Gasparrini, E. Torresi, E. Cavazzuti, F. Krauss, F. Schinzel, J. Perkins, J. Becerra Gonzalez, K. Sokolovsky, L. Fuhrmann, R. Ojha, R. Itoh, S. Buson, S. Cutini, S. Ciprini, T. Kawano, Y. Fukazawa, Y. Tanaka



2LAC vs. 3LAC tallies



Preliminary

3LAC: $|b| > 10^\circ$, 1563/2192=72% of all high-Galactic-latitude sources
Clean sample (CS): single associations, no analysis flags
Low-latitude sample

2LAC

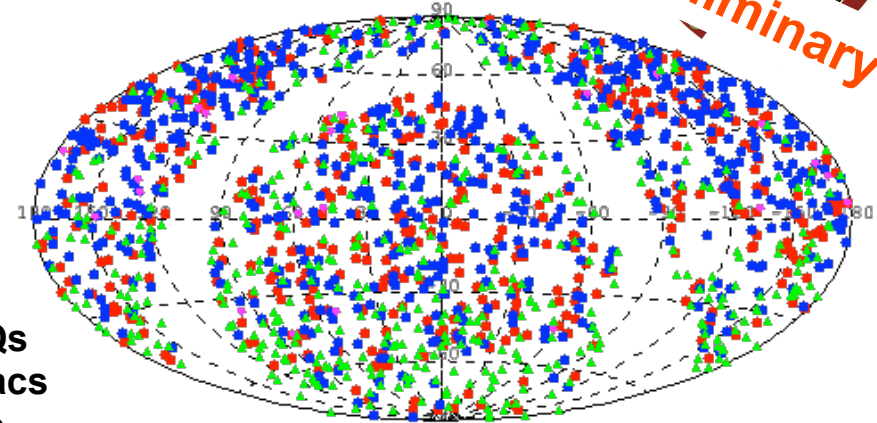
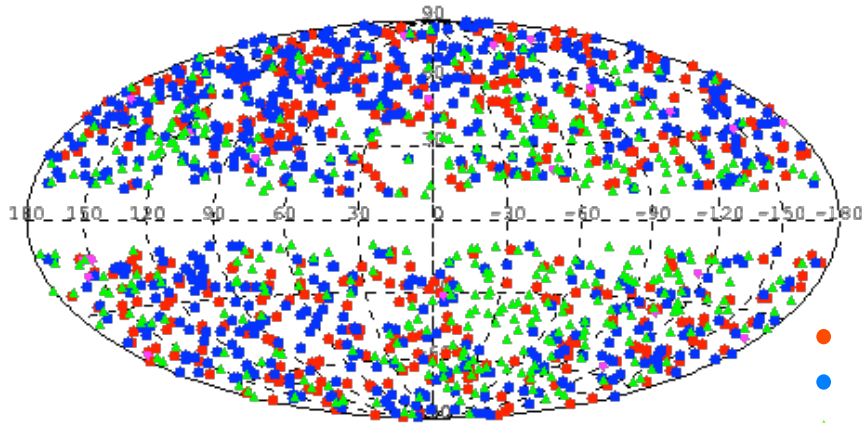
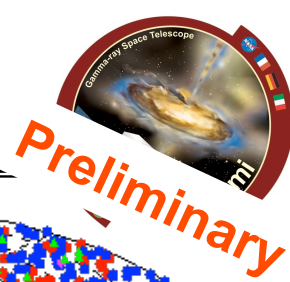
AGN type	Entire 2LAC	2LAC Clean Sample ^a	Low-lat sample
All	1017	886	104
FSRQ	360	310	19
... LSP	246	221	7
... ISP	4	3	2
... HSP	2	0	0
... no classification	108	86	10
BL Lac	423	395	16
... LSP	65	61	3
... ISP	82	81	3
... HSP	174	160	5
... no classification	102	93	5
Blazar of Unknown type	204	157	67
... LSP	24	19	10
... ISP	13	11	3
... HSP	65	53	13
... no classification	102	74	41
Other AGN	30	24	2

3LAC

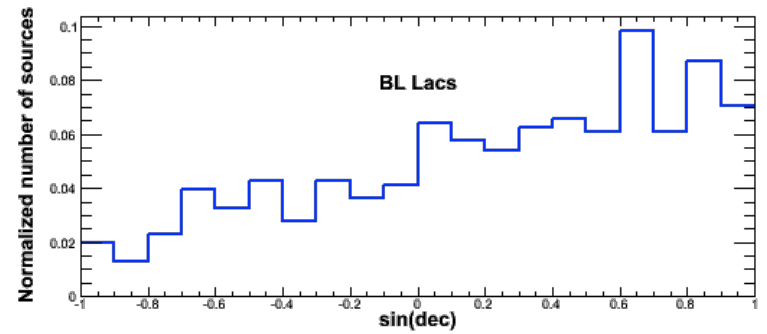
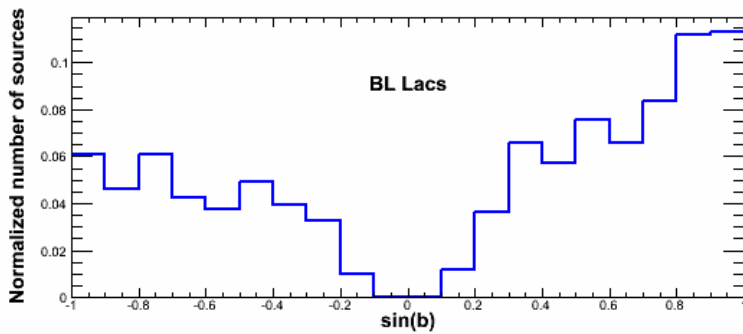
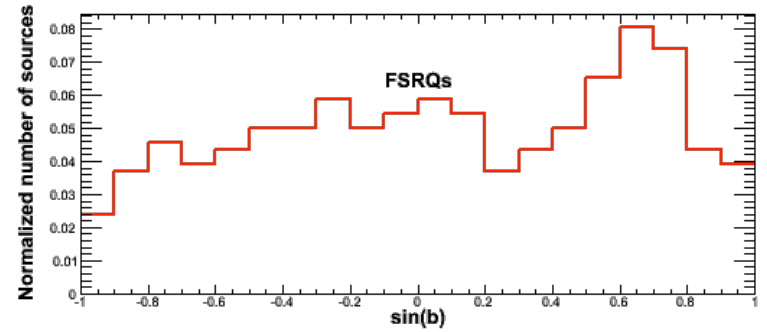
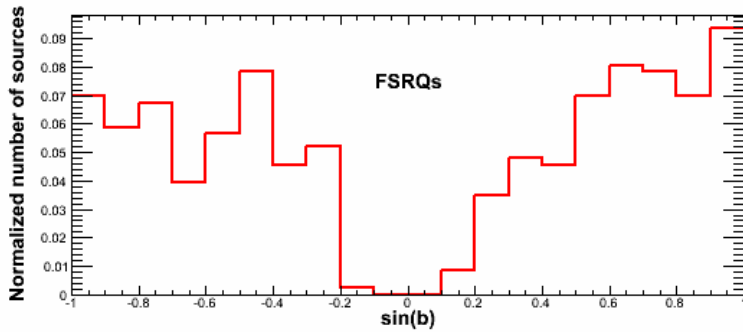
AGN type	Entire 3LAC	3LAC Clean Sample ^a	Low-latitude sample
All	1591	1444 +64%	182
FSRQ	467	414 +34%	24
... LSP	412	366	16
... ISP	47	42	3
... HSP	3	2	4
... no classification	5	4	1
BL Lac	632	604 +52%	30
... LSP	162	150	15
... ISP	178	173	4
... HSP	272	265	10
... no classification	20	16	1
Blazar of Unknown type	460	402 +164%	125
... LSP	198	164	54
... ISP	89	79	26
... HSP	120	118	39
... no classification	53	41	6
Other AGN	32	24	3

New varieties: Four high-redshift ($z > 1$) HSP-BL Lacs
Two HSP FSRQs

Sky loci



- FSRQs
- BL Lacs
- ▲ BCUs



Misaligned AGNs



Name	3FGL	2FGL	1FGL	Type	Photon index
NGC 1218	J0308.6+0408	...	J0308.3+0403	FRI	2.07±0.11
IC 310	J0316.6+4119	J0316.6+4119	...	FRI/BLL	1.90±0.14
NGC 1275	J0319.8+4130	J0319.8+4130	J0319.7+4130	FRI	2.07±0.01
For A	(J0322.5-3721)	J0322.4-3717	...	FRI	2.20±0.11
TXS 0331+391	J0334.2+3915	...	...	FRI/BLL?	2.11±0.17
TXS 0348+013	J0351.1+0128	...	...	SSRQ	2.43±0.18
3C 111	J0418.5+3813	...	J0419.0+3811	FR II	2.79±0.08
Pictor A	J0519.2-4542	...	...	FR II	2.49±0.18
PKS 0625-35	J0627.0-3529	J0627.1-3528	J0627.3-3530	FRI/BLL	1.87±0.06
3C 189	J0758.7+3747	...	...	FRI	2.16±0.16
4C +39.23B	J0824.9+3916	...	...	CSS	2.44±0.10
3C 207	J0840.8+1315	J0840.7+1310	J0840.8+1310	SSRQ	2.47±0.09
4C +39.26	J0934.1+3933	...	...	SSRQ	2.28±0.12
3C 264	J1145.1+1935	...	...	FRI	1.98±0.20
4C +04.40	J1205.4+0412	...	...	SSRQ	2.64±0.16
M87	J1230.9+1224	J1230.8+1224	J1230.8+1223	FRI	2.04±0.07
3C 275.1	J1244.1+1615	...	...	SSRQ	2.43±0.17
Cen A Core	J1325.4-4301	J1325.6-4300	J1325.6-4300	FRI	2.70±0.03
3C 286	J1330.5+3023	...	...	SSRQ/CSS	2.60±0.16
Cen B	J1346.6-6027	J1346.6-6027	...	FRI	2.32±0.01
3C 303	J1442.6+5156	...	...	FR II	1.92±0.18
NGC 6251	J1630.6+8232	J1629.4+8236	J1635.4+8228	FRI	2.22±0.08
3C 380	J1829.6+4844	J1829.7+4846	J1829.8+4845	SSRQ/CSS	2.37±0.04
Circinus	J1413.2-6518	(J1415.7-6520)	...	Seyfert	2.43±0.10
ESO 323-G77	...	J1306.9-4028	J1307.0-4030		
3C 120	...	...	...	FRI	
3C 407	...	J2008.6-0419	J2008.6-0419		
NGC 6951	...	...	J2038.1+6552		
NGC 6814	...	J1942.5-1024	...		

Preliminary

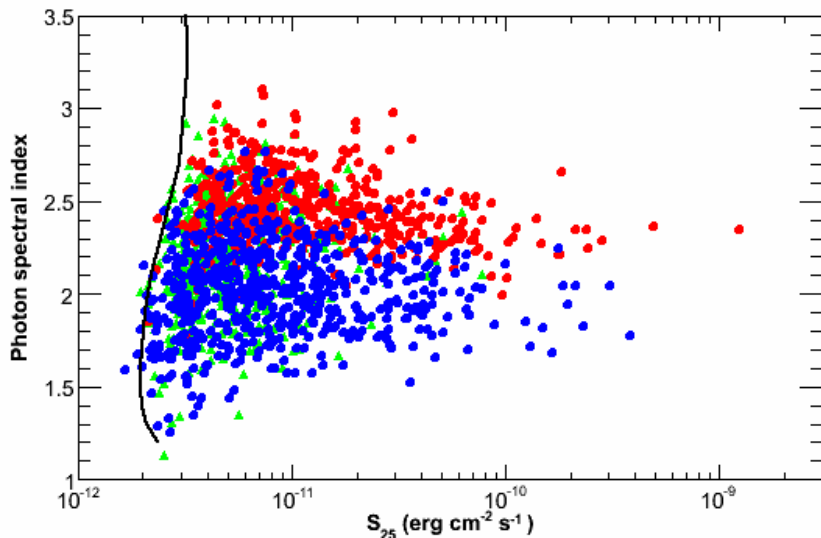
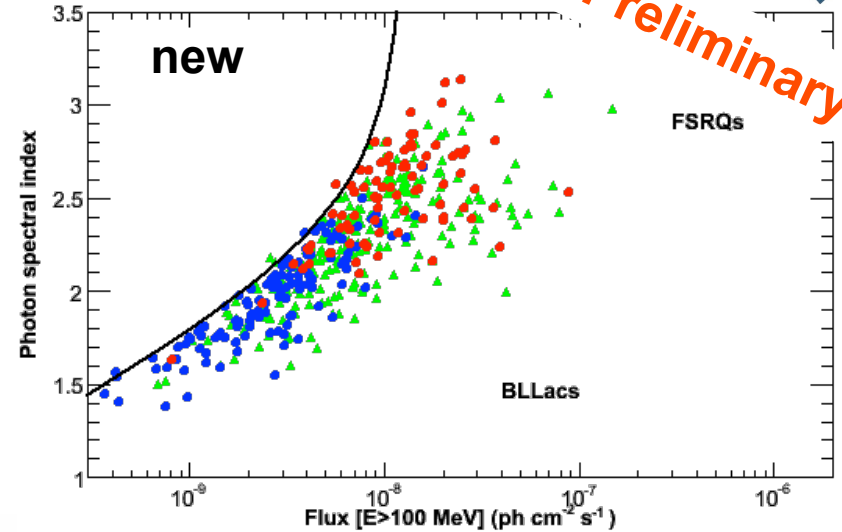
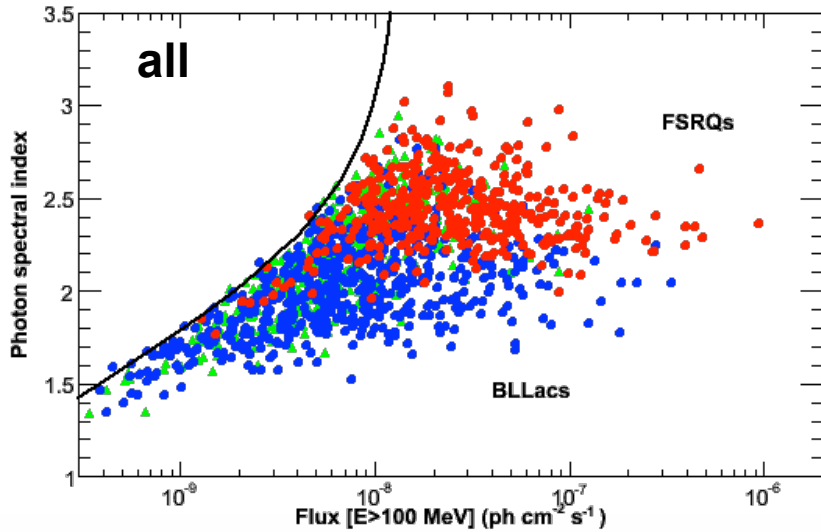
12 FRI
3 FR II
8 SSRQ or CSS

gone sources

+ five NLSy1

CSS: compact steep spectrum
SSRQ: steep-spectrum radio source

Spectral photon index vs photon/energy flux



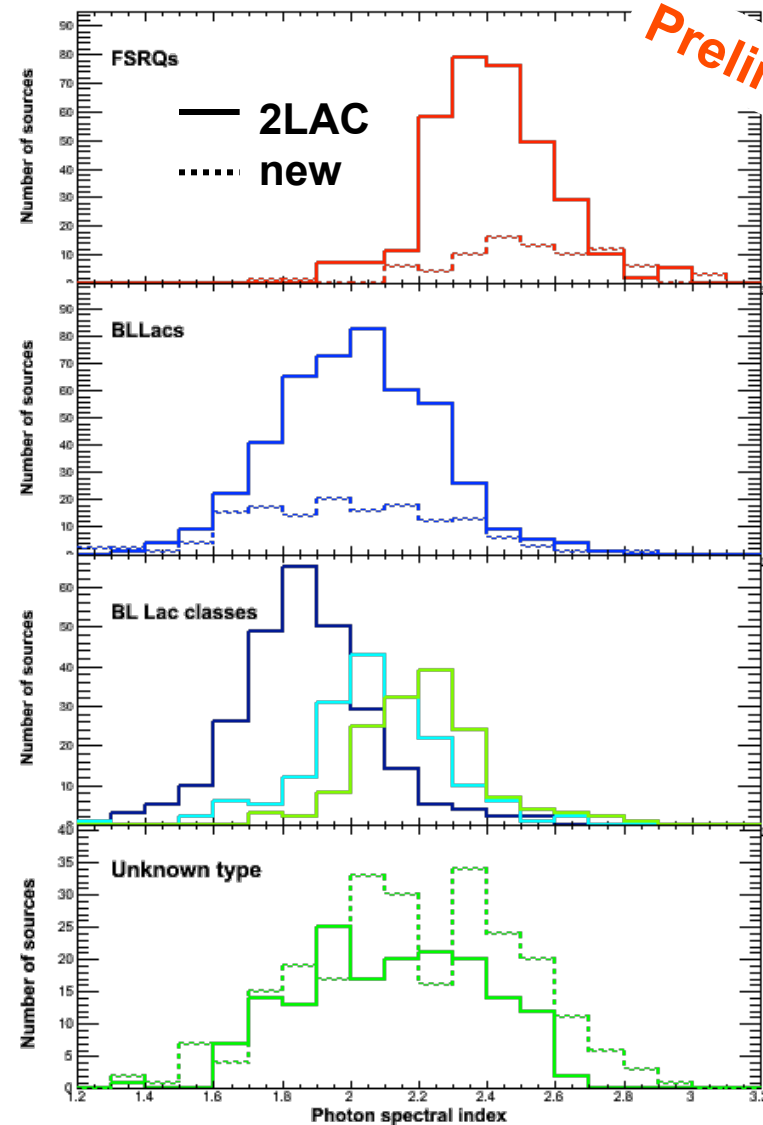
- FSRQs
- BL Lacs
- ▲ BCUs

**Strong bias in photon flux
but not in energy flux**

Photon spectral index



- Little overlap between FSRQs and BL Lacs
- New FSRQs slightly softer than 2LAC ones: ($\langle \Gamma \rangle = 2.53$ vs. 2.41)
- Not so for BL Lacs
- BCU spectral index distribution straddling the two classes' and extending beyond 2.5



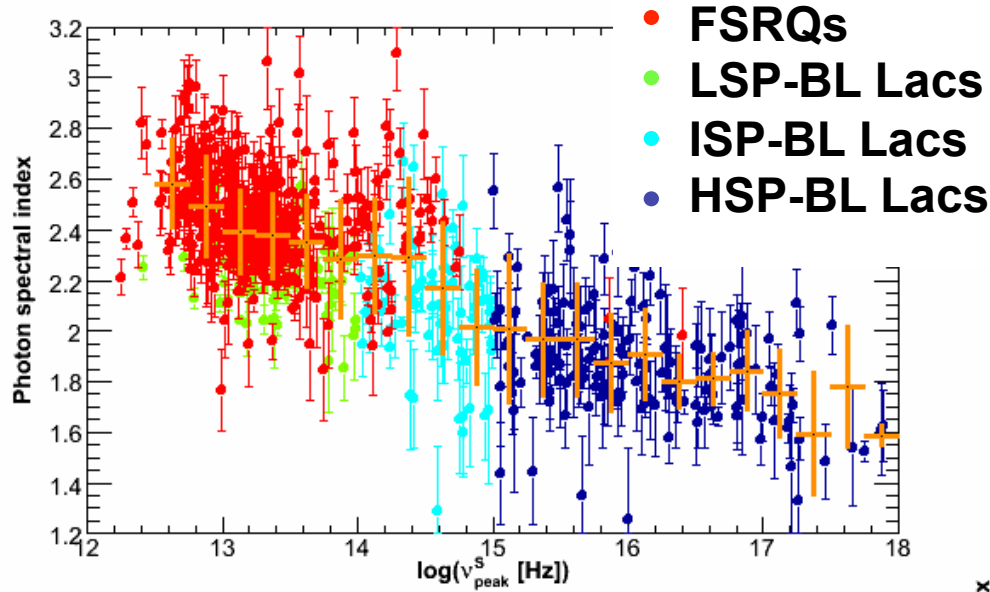
Preliminary

Photon spectral index vs ν_{peak}

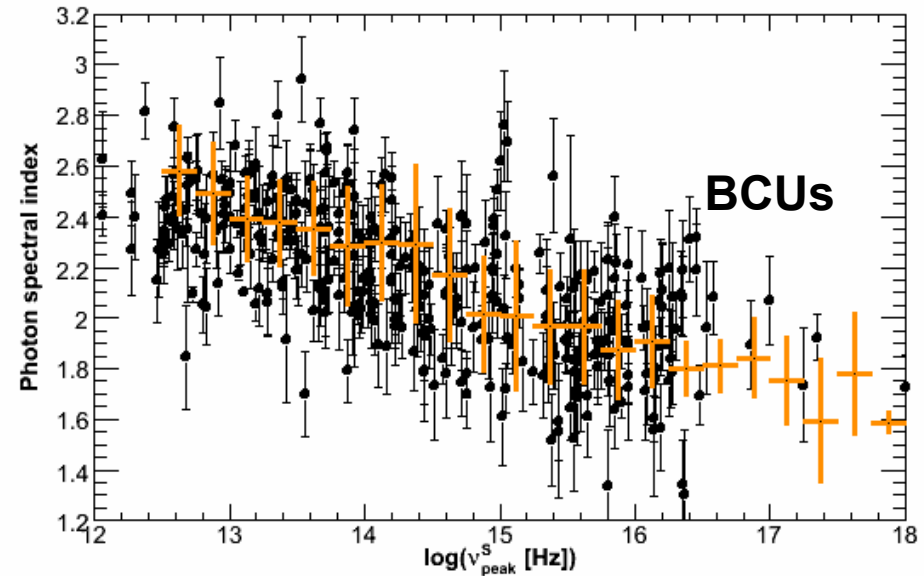
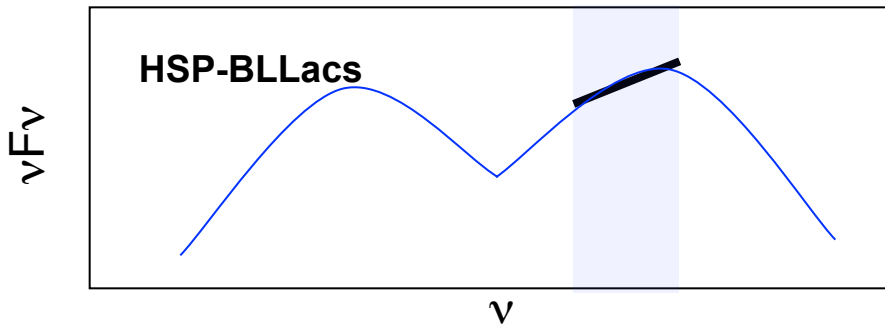


Preliminary

- Correlation between spectral hardness and ν_{peak} confirmed
- Same applies to BCUs



LAT range

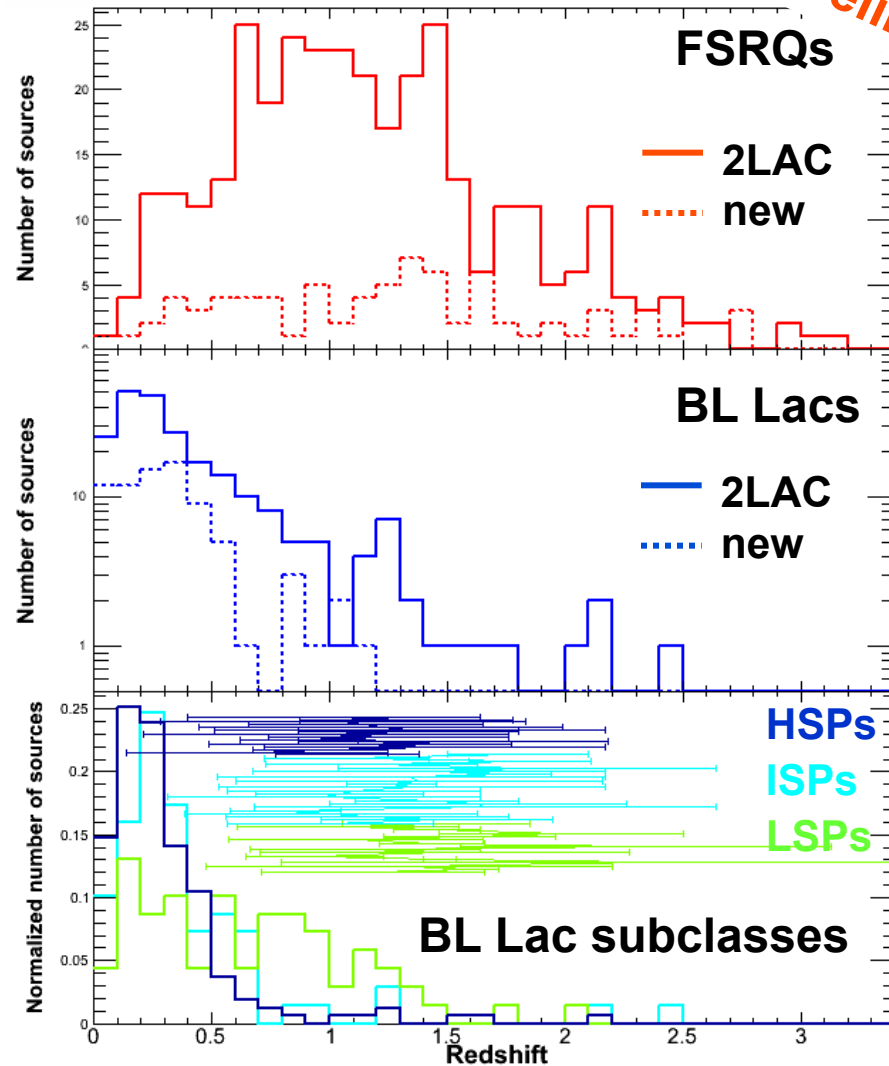


Redshifts



Preliminary

- slightly higher z for new FSRQs relative to 2LAC ones $\langle z \rangle = 1.33$ vs. 1.17
- maximum redshift still $z = 3.1$
- 295/604 BL Lacs have no measured redshifts (55%, 61%, 40%) for (LSPs, ISPs and HSPs)
- narrower z distribution for BL Lacs
- 134 constraints from Shaw et al. (2013)
- Redshift limits for BLLacs not compatible with measured redshifts: measured redshifts are biased low.

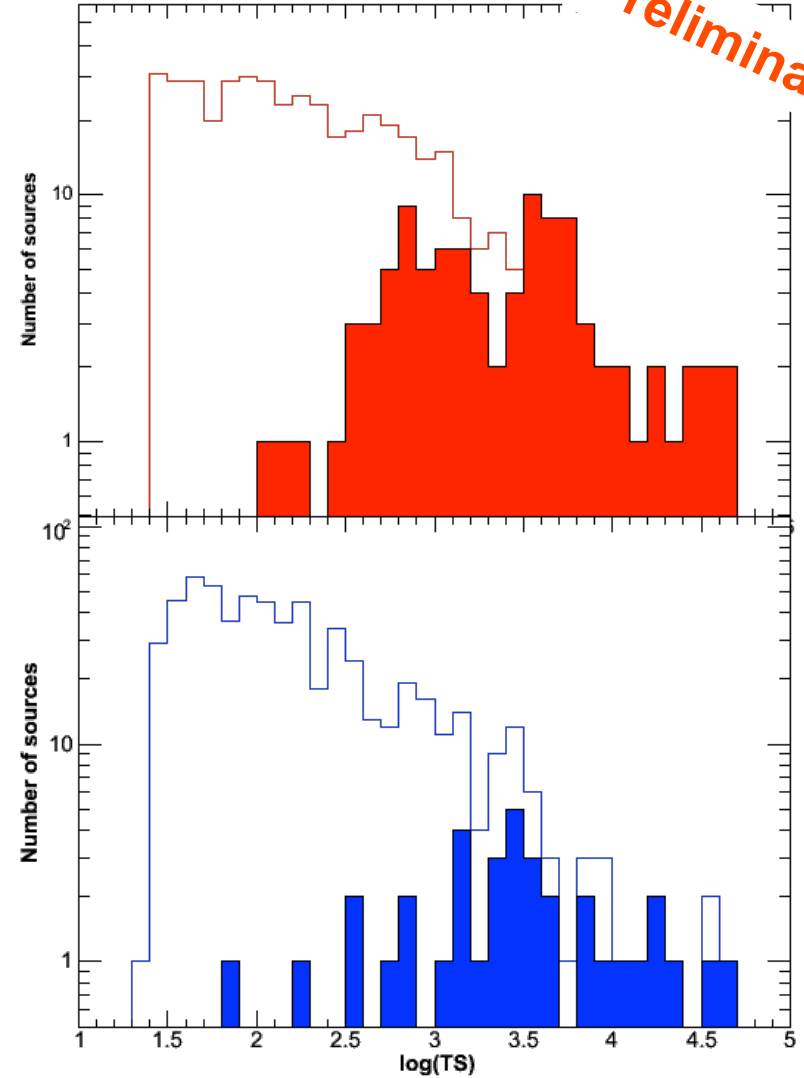
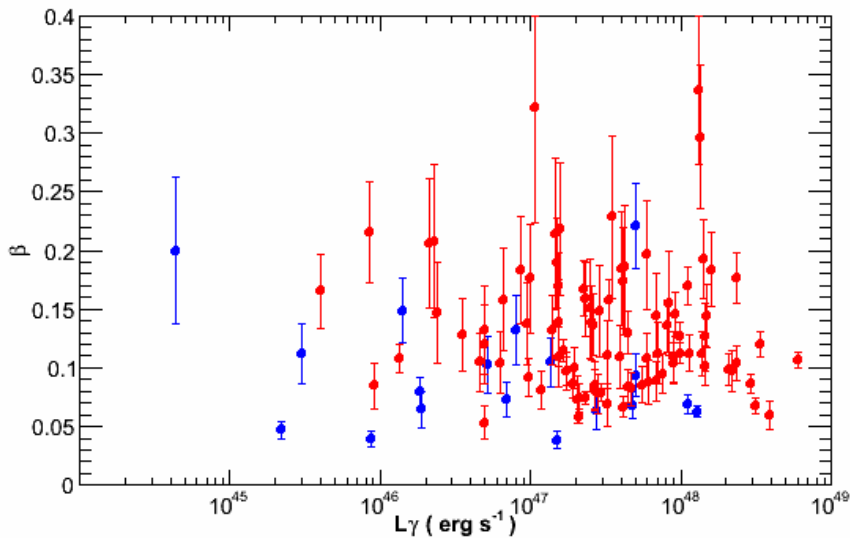
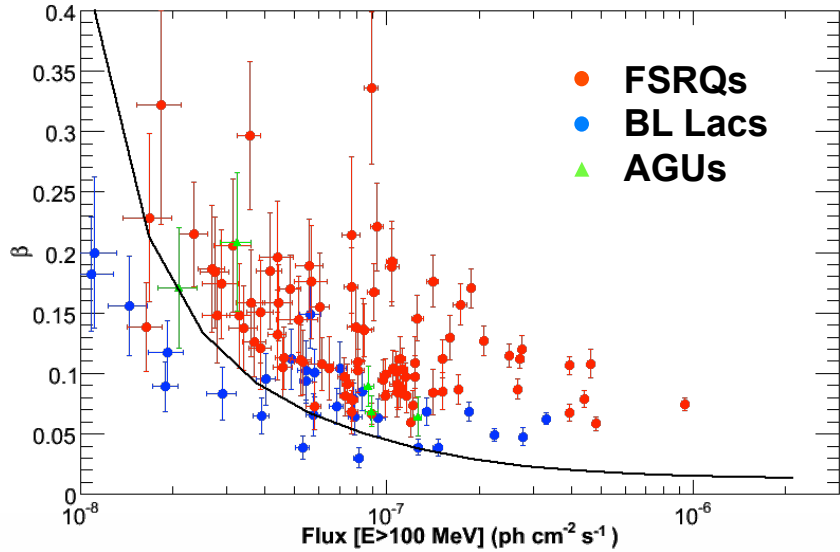


Spectral curvature



Preliminary

91 FSRQs (57 in 2LAC), 32 BL Lacs (12 in 2LAC) and 8 BCUs



Variability



Preliminary

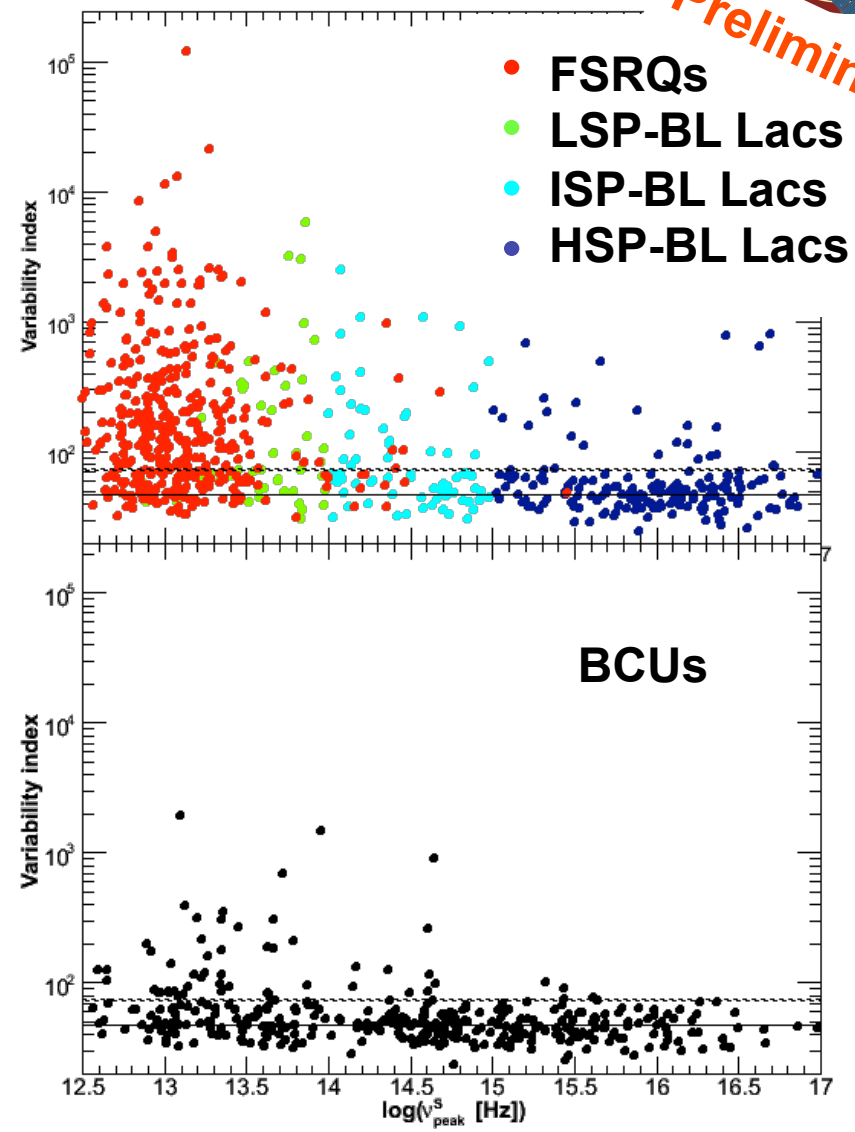
Variability index distributed as

a χ^2 with 47 d.o.f. for non-variable sources.

Fractions of sources showing significant variability

FSRQS: 69%
BL Lacs: 23 %
(39%, 23%, 15%) for (LSP, ISP,HSP)

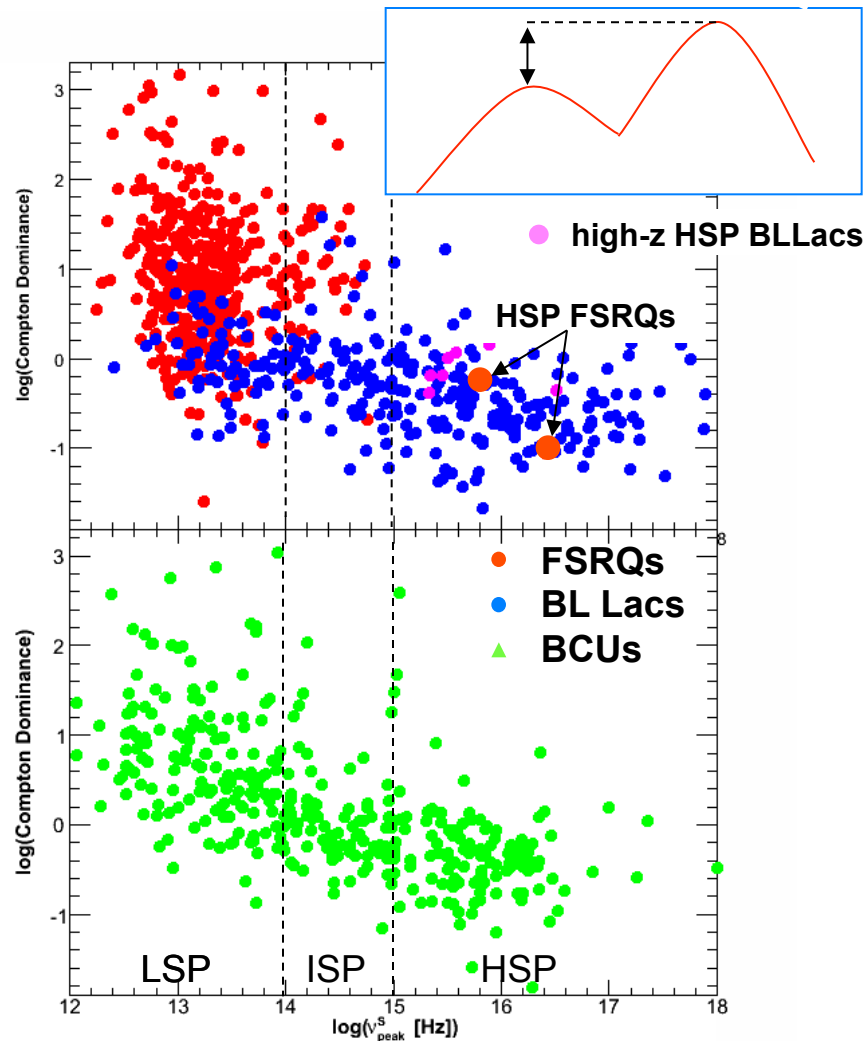
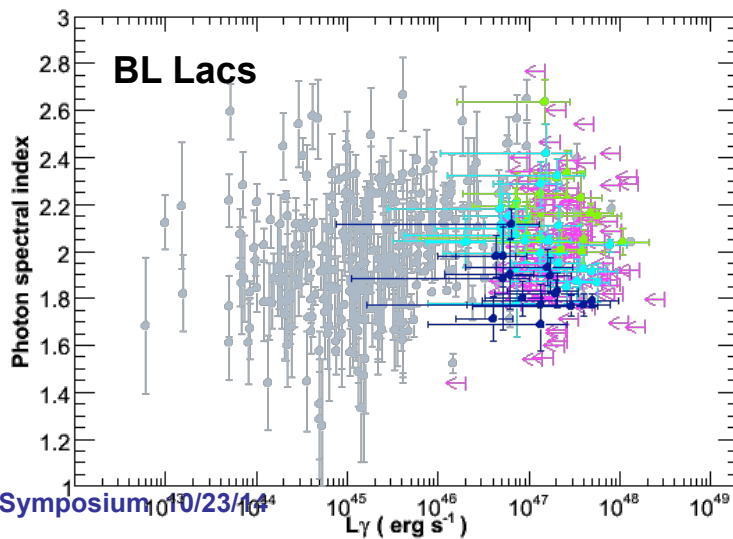
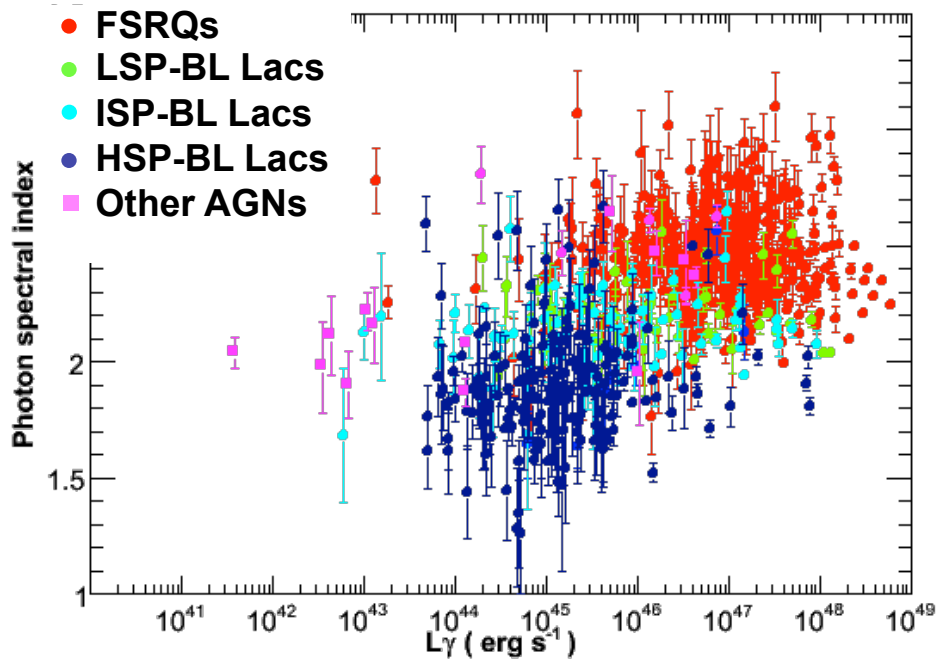
Monthly light curves to be extended beyond 48 months, *continuously updated and posted on the ASDC site*



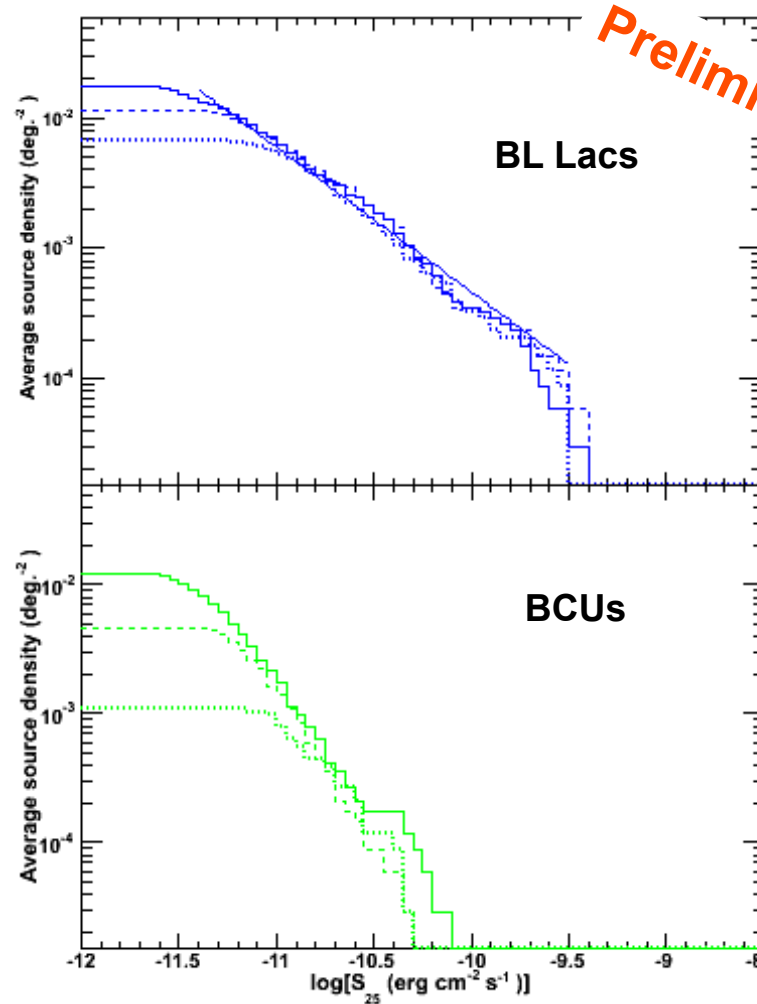
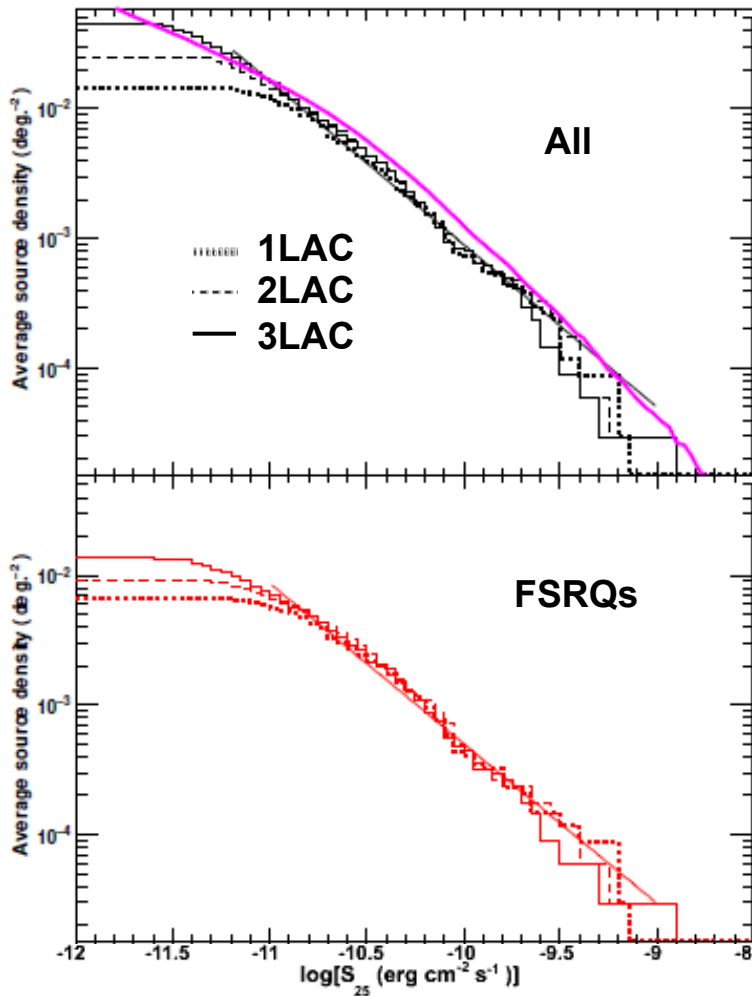
L_γ / Compton dominance



Preliminary



log N-log S

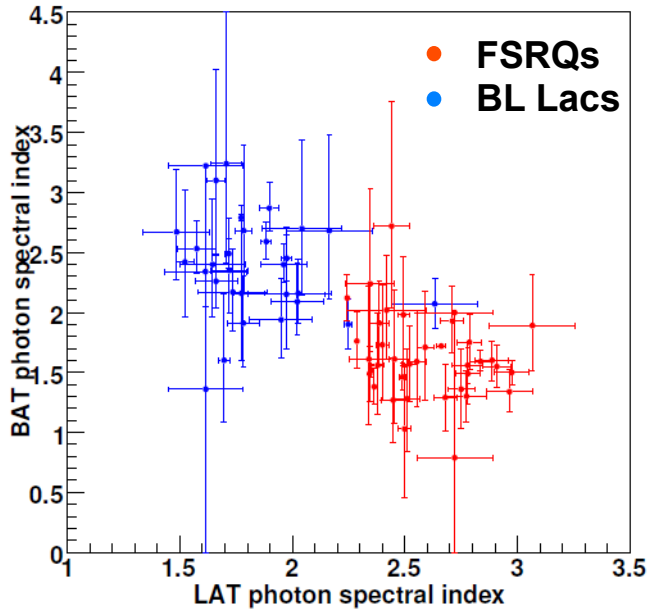


Contribution to diffuse gamma-ray background compatible with previous estimates

Connections with neighboring bands



- 85 3LAC sources in the Swift BAT 70-month survey
- only 9 BAT FSRQs and 7 BL Lacs missing in 3LAC



- 55 out of 56 TeV AGNs in 3LAC (*HESS J1943+213* missing)
- 28 found to be variable
- 96 3LAC AGNs in the V38 INTEGRAL Cat.

Table 10. Properties of the VHE AGN detected by the *Fermi* LAT.

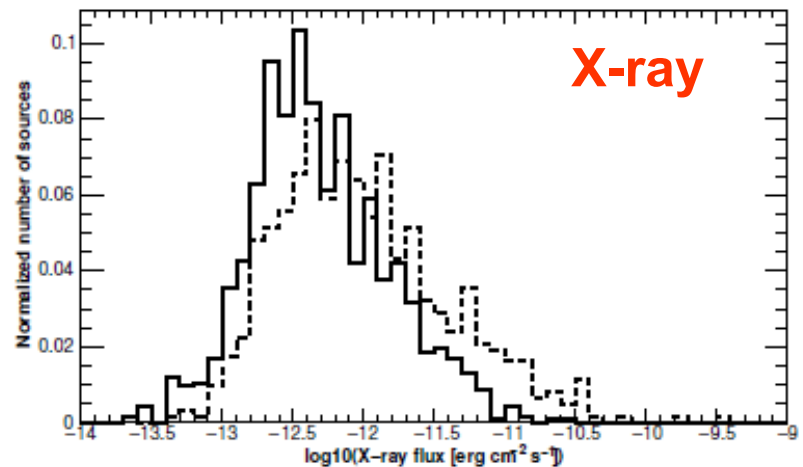
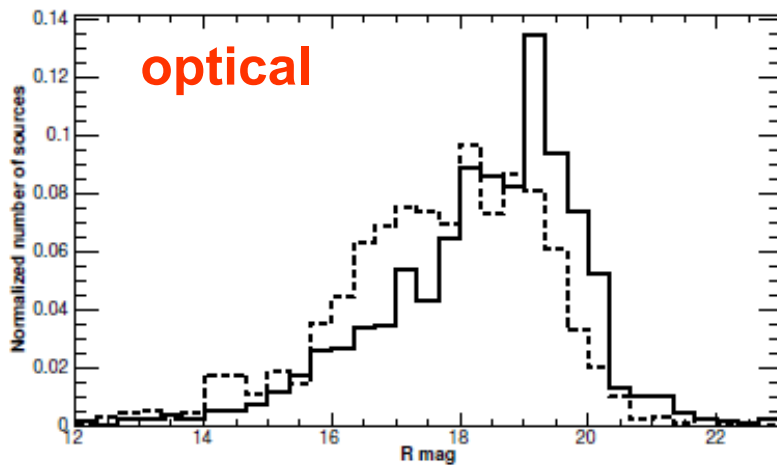
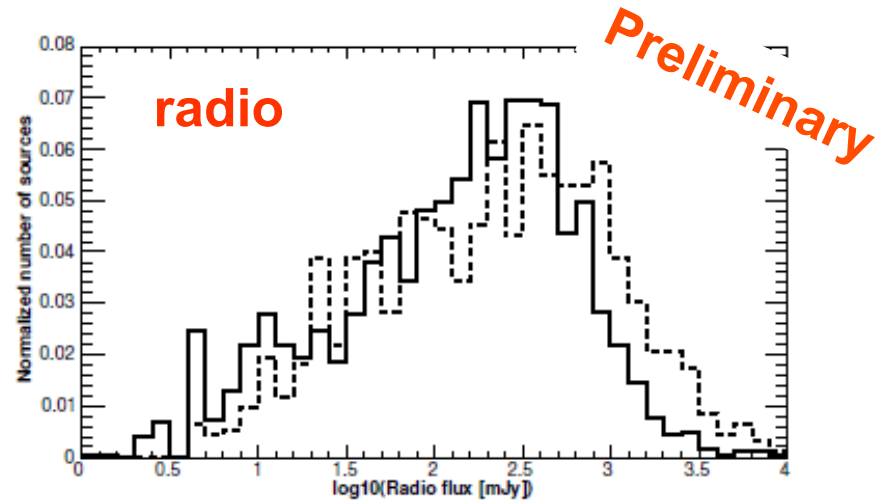
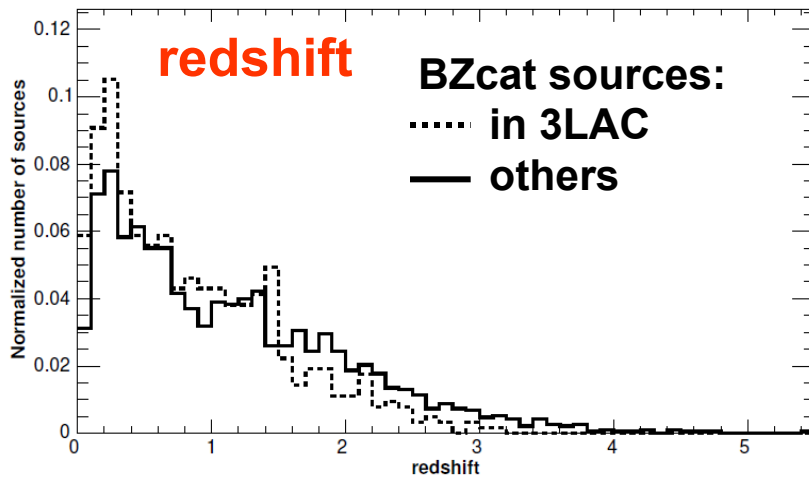
VHE Name	3FGL Name	Source Class	SED Type	Redshift	Spectrum Type ^a	3FGL/Int.
SHBL J001355.9-185406	J0013.9-1853	HL Lac	HSP	0.095	PL	---
KUV 00311-1938	J0033.6-1921	HL Lac	HSP	≥ 0.51	PL	H
RGB J0136+391	J0136.5+3905	HL Lac	HSP	---	PL	H
RGB J0152+017	J0152.6+0148	HL Lac	HSP	0.08	PL	Y
3C 66A	J0222.6+4301	HL Lac	ISP	$0.3347 < z < 0.41$	LP	Y
1ES 0229+200	J0232.8+2016	HL Lac	HSP	0.139	PL	---
PKS 0301-243	J0303.4-2407	HL Lac	HSP	0.26	PL	H
IC310	J0316.6+4119	Radio Gal	HSP	0.018849	PL	Y
RBS 043 ^b	J0319.8+1847	HL Lac	HSP	0.19	PL	Y
NGC1275 ^c	J0319.8+4130	Radio Gal	ISP	0.018	LP	Y
1ES0347-121	J0349.2-1158	HL Lac	HSP	0.188 (7)	PL	---
1ES 0414+009	J0416.8+0104	HL Lac	HSP	0.287	PL	Y
PKS 0447-439	J0449.4-4350	HL Lac	HSP	0.205	PL	Y
1ES 0502+675 ^d	J0508.0+6736	HL Lac	HSP	0.341	PL	Y
PKS 0548-322	J0550.6-3217	HL Lac	HSP	0.069	PL	H
1ES 0647+250	J0650.7+2503	HL Lac	HSP	---	PL	H
RGB J0710+591 (1H 0658+595?)	J0710.3+5908	HL Lac	HSP	0.125	PL	Y
SS 0716+714	J0721.9+7120	HL Lac	ISP	$0.2314 < z < 0.27$	LP	Y
1ES 0806+524	J0809.8+5218	HL Lac	HSP	0.138	PL	Y
RX J0847.1+1133 (RBS 0723)	J0847.1+1134	HL Lac	HSP	0.199	PL	---
1RXS J101015.9-311909	J1010.2-3120	HL Lac	HSP	0.143	PL	H
1ES 1011+496	J1015.0+4925	HL Lac	HSP	0.212	PL	Y
1ES 1101-232	J1103.5-2329	HL Lac	HSP	0.186	PL	Y
Markarian 421	J1104.4+3812	HL Lac	HSP	0.031	PL	Y
Markarian 180	J1136.6+7009	HL Lac	HSP	0.046	PL	Y
1ES 1215+303	J1217.8+3007	HL Lac	HSP	---	PL	Y
1ES 1218+304	J1221.3+3010	HL Lac	HSP	0.182	PL	Y
W Comae	J1221.4+2814	HL Lac	ISP	0.102	PL	Y
MS 1221.8+2152	J1224.5+2436	HL Lac	HSP	0.218	PL	---
4C+21.35	J1224.9+2122	FSRQ	LSP	0.435	LP	Y
MS7	J1230.9+1224	Radio Gal	LSP	0.0036	PL	Y
3C 279	J1256.1-0547	FSRQ	LSP	0.536	LP	Y
1ES 1312-423	J1314.7-4237	AGU (BL Lac?)	HSP?	0.105 (7)	PL	H
Centaurus A	J1325.4-4301	Radio Gal	---	0.0008 ^d (0.00183)	PL	Y
PKS 1424+240	J1427.0+2347	HL Lac	ISP	$z \geq 0.6$	LP	Y
H 1426+428	J1428.5+4240	HL Lac	HSP	0.129	PL	Y
1ES 1440+122	J1442.8+1200	HL Lac	HSP	0.163	PL	Y
PKS 1510-089	J1512.8-0906	FSRQ	LSP	0.36	LP	Y
APL1 ^e	J1517.6-2422	HL Lac	LSP	0.048	PL	Y
PG 1553+413	J1553.7+4111	HL Lac	HSP	$0.43 < z < 0.58$	LP	Y
Markarian 501	J1653.9+3945	HL Lac	HSP	0.0337	PL	Y
1H 1720+117	J1725.0+1152	HL Lac	HSP	---	PL	---
1ES 1727+502	J1728.3+5013	HL Lac	HSP	0.0554	PL	H
1ES 1741+196	J1743.9+1934	HL Lac	HSP	0.084	PL	H
1ES 1959+650	J2000.0+6509	HL Lac	HSP	0.047	PL	Y
PKS 2005-489	J2009.3-4849	HL Lac	---	0.071	PL	Y
PKS 2155-304	J2158.8-3013	BL Lac	HSP	0.116	LP	Y
BL Lacertae	J2202.7+4217	HL Lac	ISP	0.0686	LP	Y
B32247+381	J2250.1+3825	HL Lac	HSP	0.119	PL	Y
H 2356-309	J2359.3-3038	HL Lac	HSP	0.165	PL	Y
1ES J0033+595	J0033.9+5949	HL Lac	HSP	---	PL	H
VER J0521+211	J0521.7+2113	BL Lac	ISP	0.108	PL	L
VER J0648+152	J0648.9+1516	HL Lac	HSP	0.179	PL	L
MAGIC J2001+435	J2001.1+4352	HL Lac	ISP	---	PL	L
1ES 2344+514	J2342.0+5142	HL Lac	HSP	0.044	PL	E

Preliminary

Connection with BZCat



LAT-detected fraction: 24% (409/1707) for FSRQs, 44% (543/1221) for BL Lacs and 27% (59/221) for BCUs



Conclusions



The 3LAC represents a significant improvement over the 2LAC. It should be made public within a few weeks.

A master list of all LAT-detected AGNs is maintained at the ASDC web site, including those sources reported in previous catalogs and now missing in 3LAC.

Continuously updated monthly light curves extending beyond the 48 m-period will be posted at ASDC as well.

The 4LAC will use >5 years of data and will make use of improved IRFs (Pass 8). It will probably constitute another notable step forward.