Suzaku and Fermi observations of Gamma-ray bright Radio Galaxies : PKS0625-354 and 3C78

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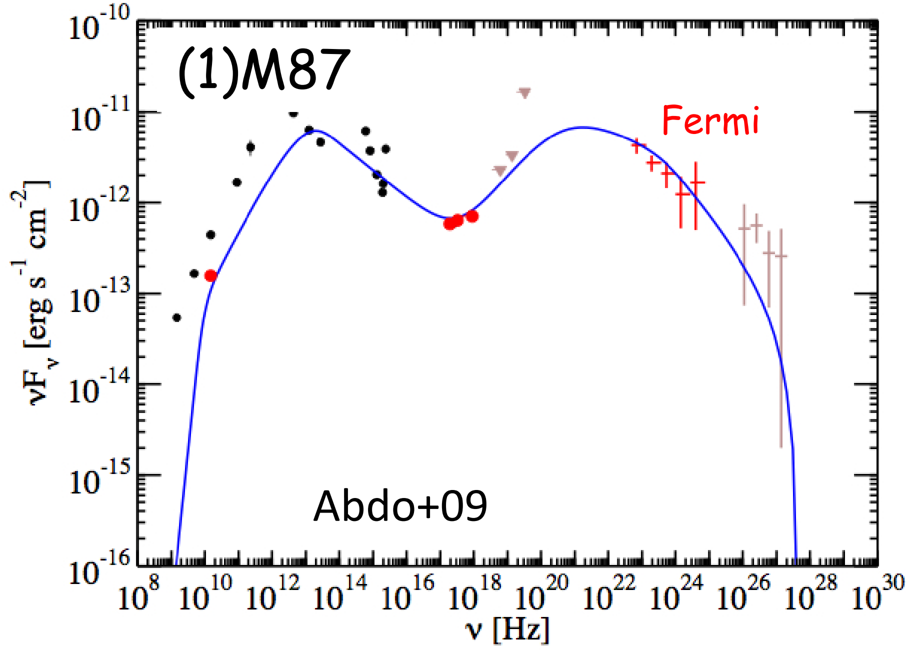
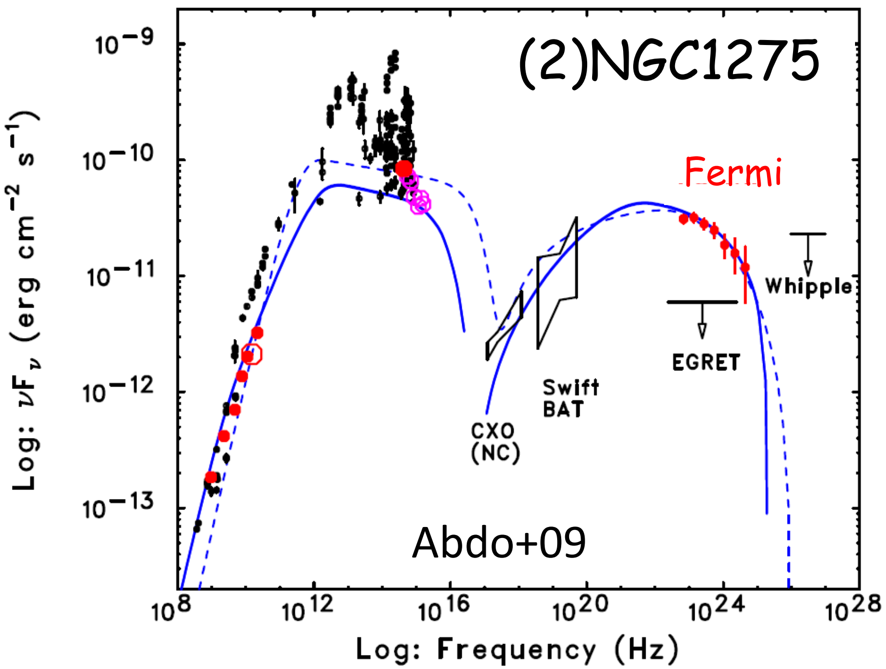
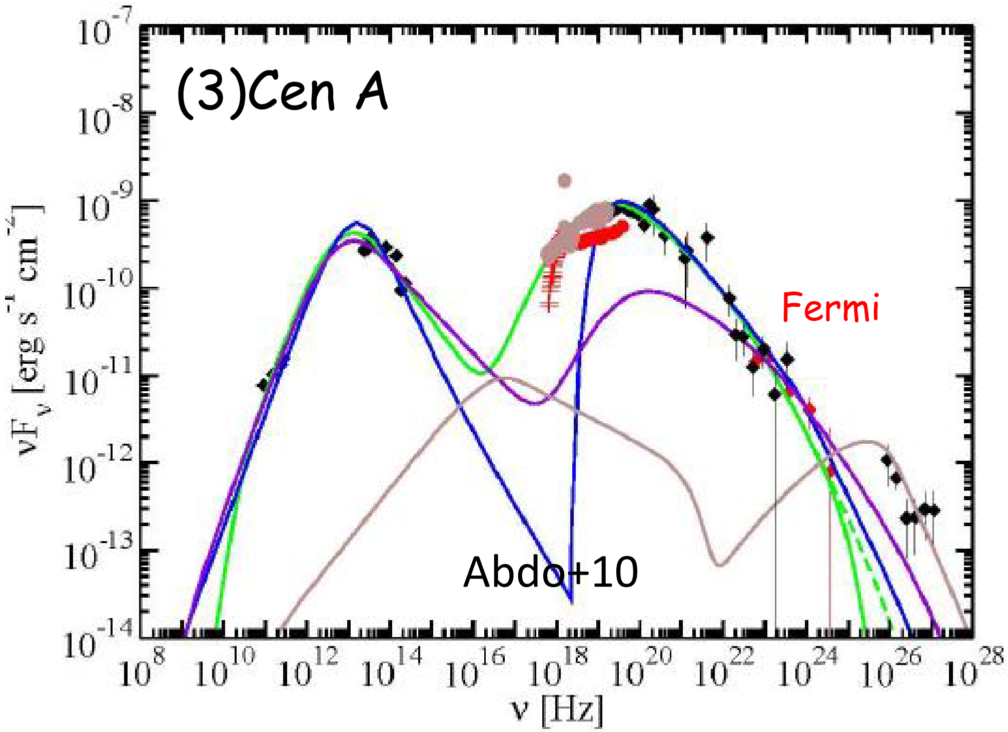
Fermi-LAT detected 11 radio galaxies during the 1st year.

However, inner jet emission has been detected mainly in the radio and GeV gamma-ray band for most objects, due to bright stellar and accretion disk components in the optical and X-ray band; SED of jet emission is unclear.

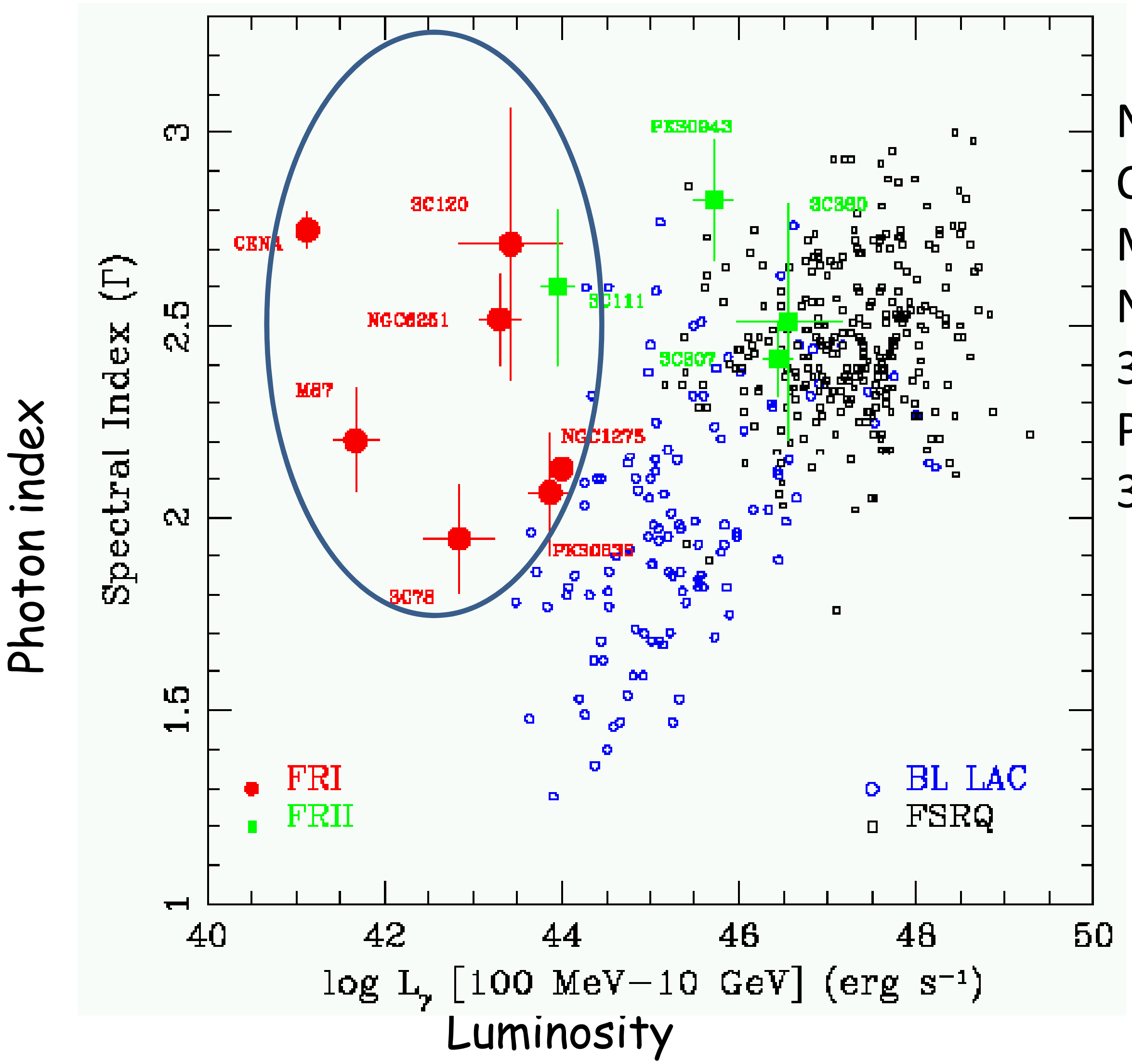
Thus, X-ray detection of jet is important for SED modeling.







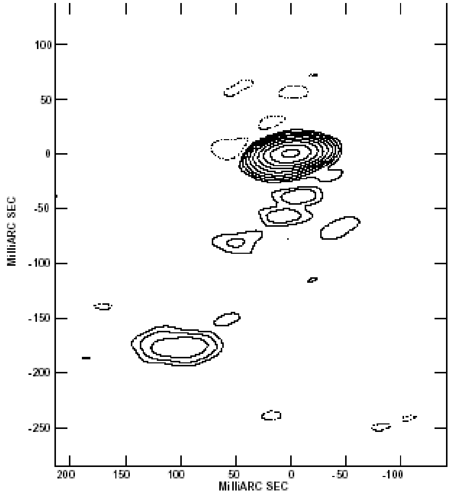
Abdo+10

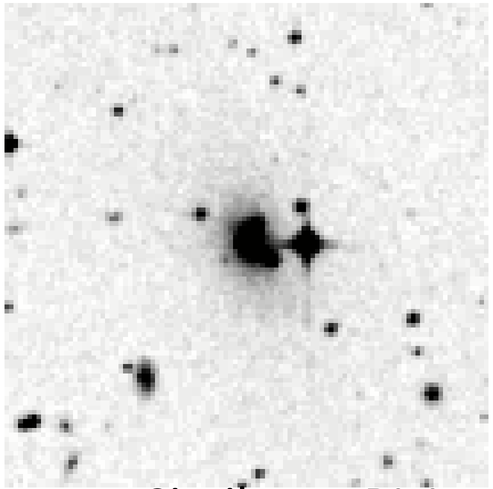


All objects were observed with Suzaku X-ray satellites.

NGC1275	Yamazaki+12
Cen A*	Fukazawa+11
M87	this work
NGC6251	Evans+11
3C120	Kataoka+07,11
PKS0625-354*	this work
3C78/NGC1218*	this work

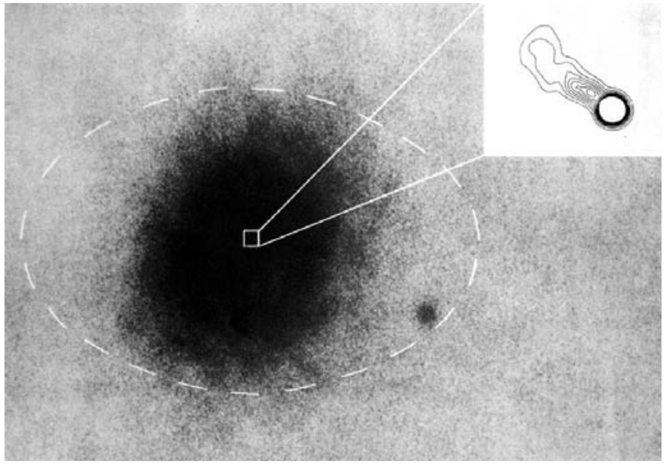
*: We are PIs.





Similar to BL Lac

PKS0625-354



3C78

	z	FR	class	Γχ	Lχ (log10)
3C78	0.029	I	Sy1	1.9±0.2	42.8
NGC1275	0.018	I	Sy2/NLRG	2.1±0.1	44.0
3C111	0.049	II	Sy1/BLRG	2.5±0.2	44.0
3C120	0.033	I	Sy1/BLRG	2.7±0.3	43.4
PKS0625-354	0.055	I	LINER	2.1±0.2	43.7
M87	0.004	I	Sy/NLRG	2.2±0.1	41.7
Cen A	0.0009	I	Sy2	2.5±0.1	41.1
NGC6251	0.024	I	Sy2	2.5±0.1	43.3

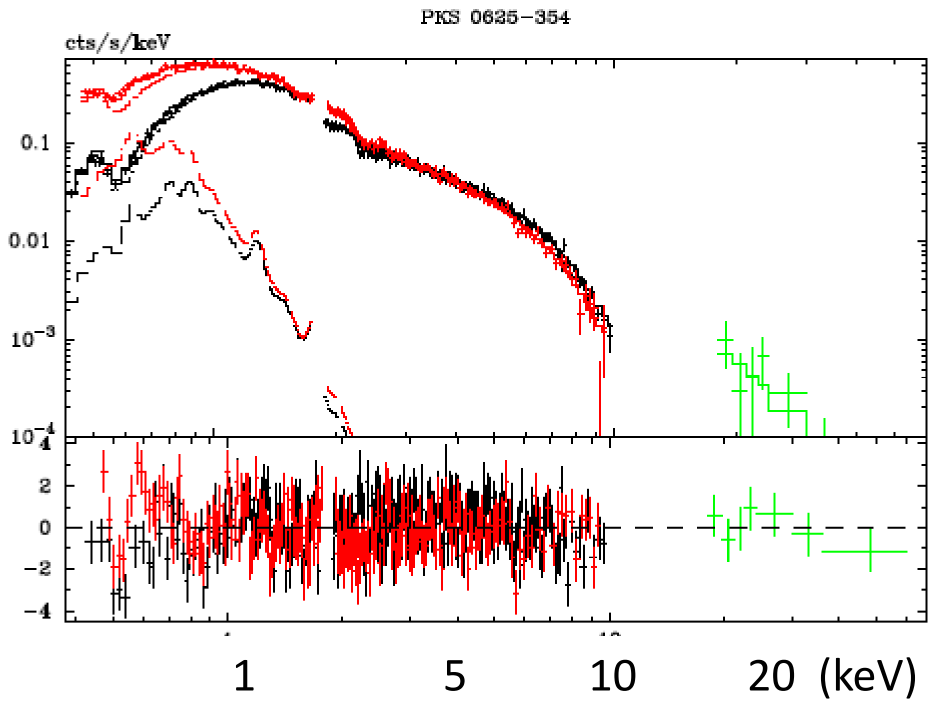
Here, we focus on the analysis of PKS0625-354 and 3C78

PKS0625-354 and 3C78

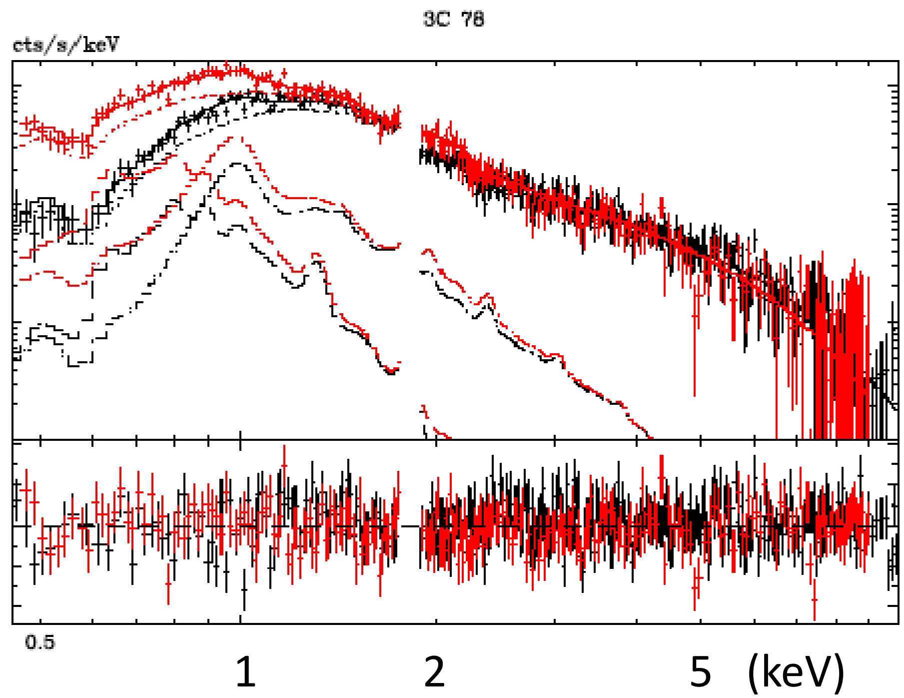
We observed these sources with Suzaku in 2011-2012.

Source	N_H 10^{20} cm^{-2}	kT keV	Z $Z_\odot$	$L_{0.5-10\,keV}$ 10^{42} erg s^{-1}	Γ_X	$L_{2-10\,keV}$ 10^{42} erg s^{-1}	EW eV	χ^2/d.o.f
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
PKS 0625−354	9±1 (6.36)	0.24±0.02	$0.3^{(f)}$	9.6	2.25±0.02	49	< 7	640/486
3C 78	14±2 (9.51)	0.29±0.04	$0.3^{(f)}$	1.0	2.32±0.04	2.0	< 75	572/567
		1.07±0.06	$0.3^{(f)}$					

PKS0625-354

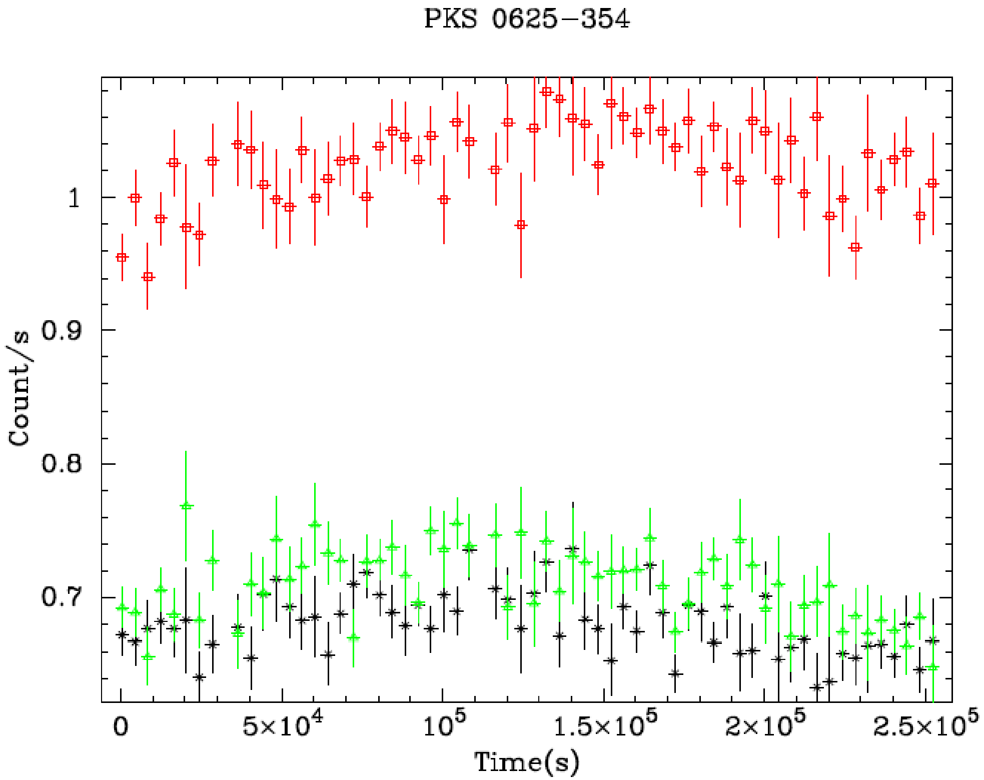


3C78

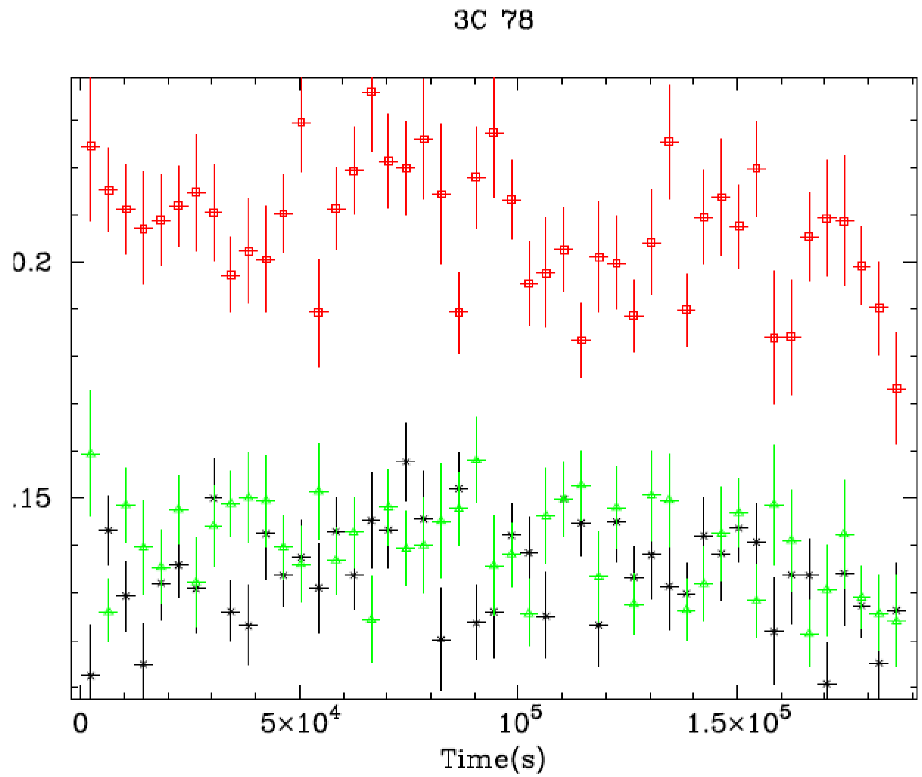


Suzaku X-ray light curve

PKS0625-354



3C78



Origin of X-ray Emission

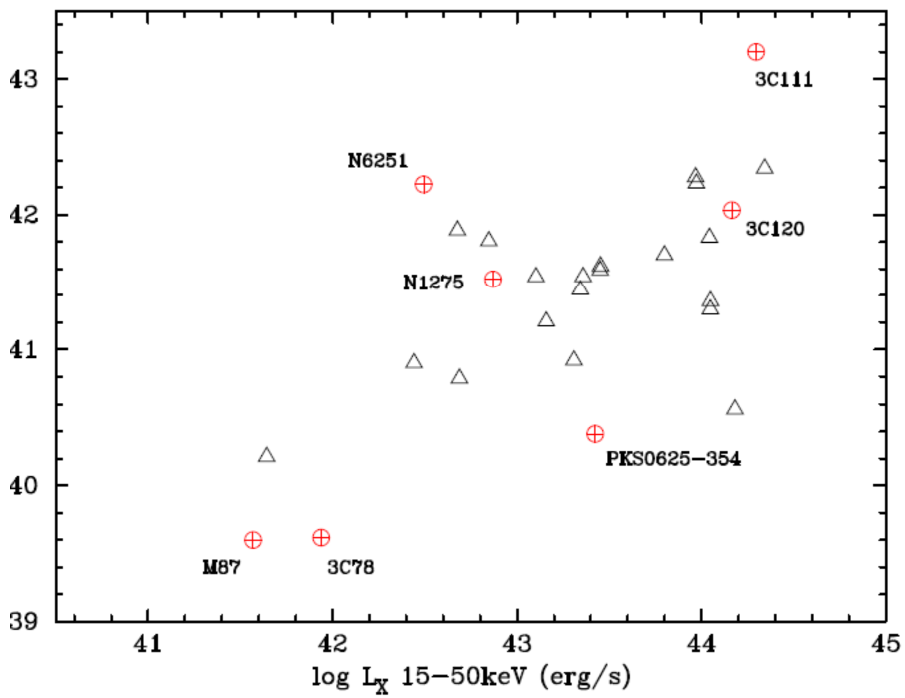
Fe-K line EWs of PKS0625-354, 3C78, M87, NGC6251 are smaller than those of typical Seyfert galaxies.

X-ray luminosity of PKS0625-354 is higher than that of typical Seyfert galaxies with a similar [O III] luminosity.

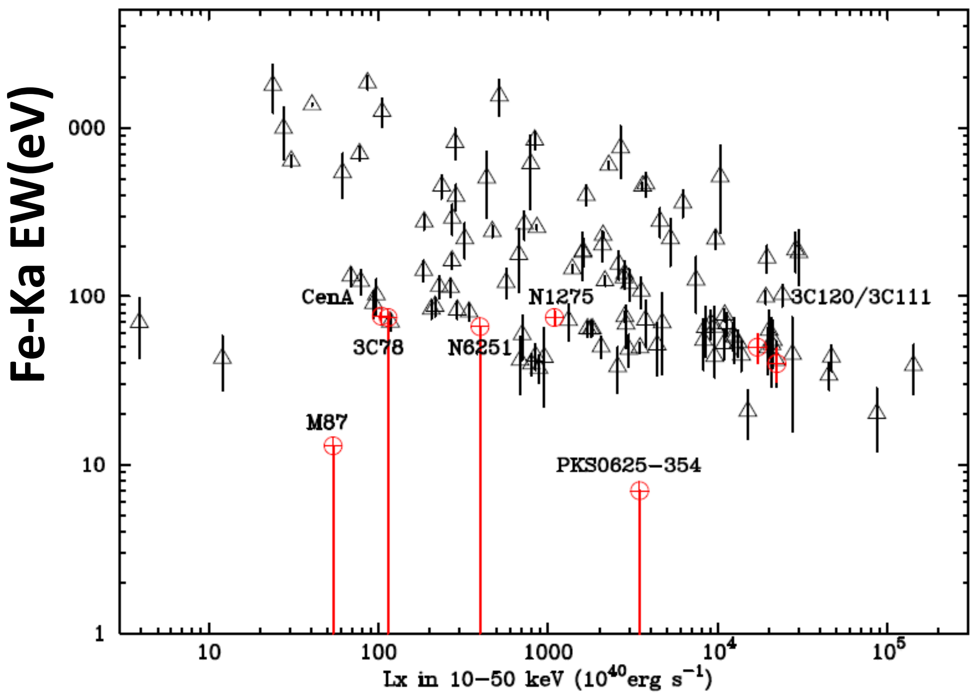
with Mulchaey+94, Winter+10

with Fukazawa+11

Log L O[III]



Log L x



Log L x

Origin of X-ray Emission

Source	Fe-K line	X-ray spectral index	X-ray variability	[O III] line	Type [ref.]
3C 78	jet	jet	inconclusive	jet	LERG [B10]
3C 84	disk/corona	inconclusive	inconclusive	disk/corona	HERG/LERG†
3C 111	disk/corona	inconclusive	inconclusive	disk/corona	HERG‡ [E00]
3C 120	disk/corona	inconclusive	inconclusive	disk/corona	HERG‡ [E00]
PKS 0625−354	jet	jet	inconclusive	jet	LERG [M14]
M 87	jet	jet	jet	jet	LERG [G13]
Cen A	disk/corona	inconclusive	jet	inconclusive	HERG [E04]
NGC 6251	jet	inconclusive	inconclusive	jet	LERG [E11]

X-ray emission of Low excitation radio galaxies (LERG) , which are considered to have a low mass accretion rate, is likely to be a jet origin.

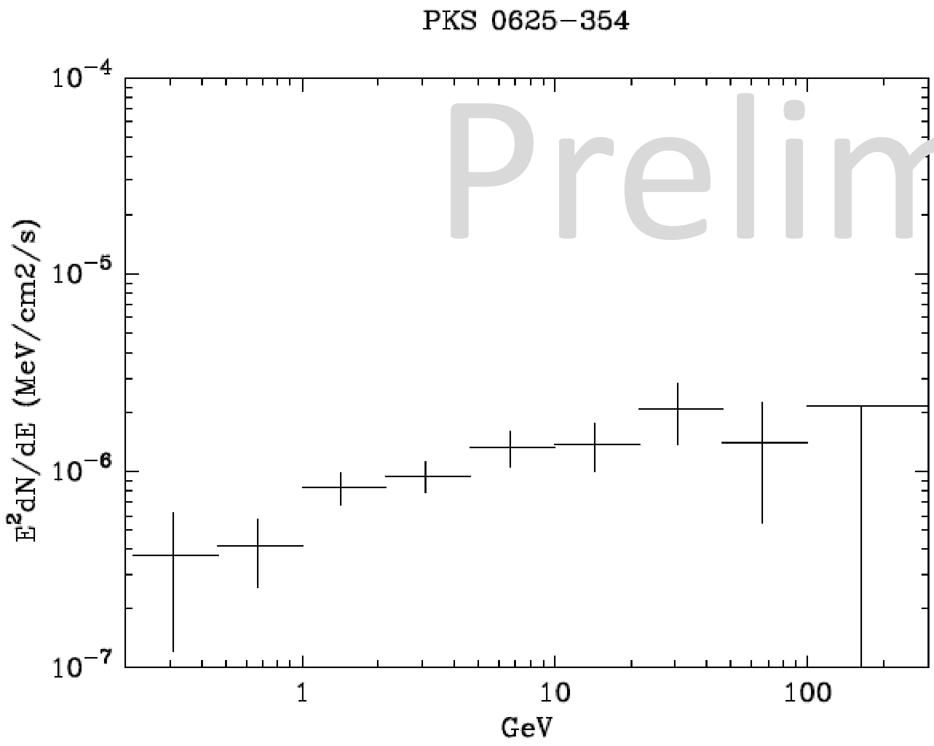
LAT Analysis with 5 years data

Science tools v9r32p5
2008.8 – 2013.08
P7REP_SOURCE_V15
Binned likelihood 12deg x 12deg region
0.2-300 GeV
2year Catalog + Galactic diffuse + Isotropic background (norm free)

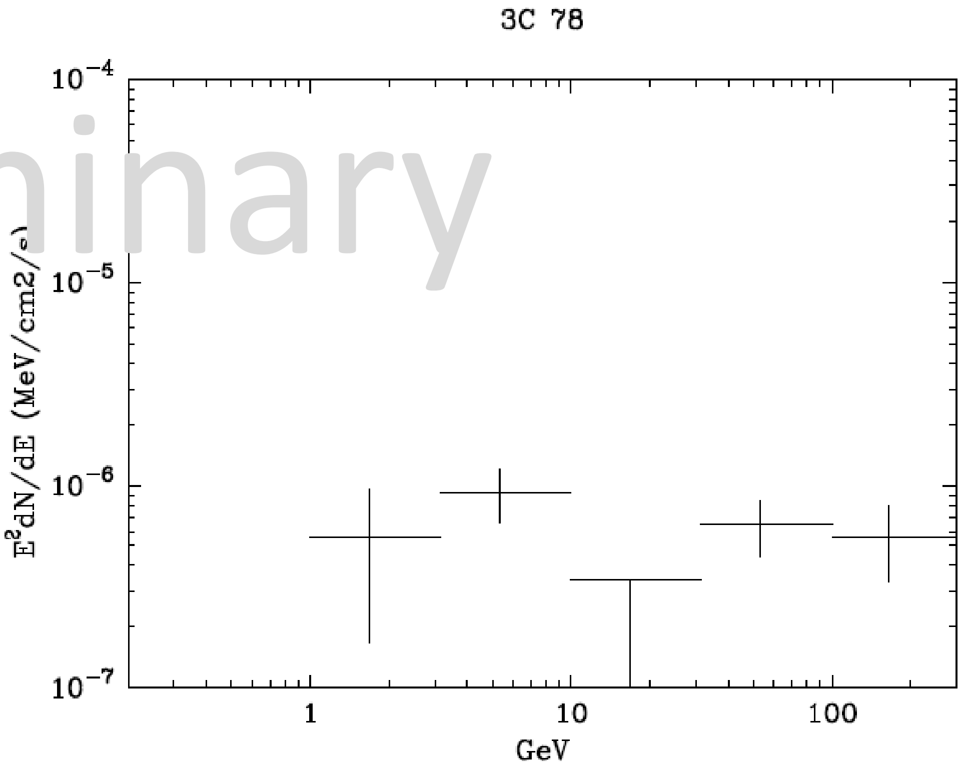
Fermi Gamma-ray Spectra

Source (1)	Γ_{HE} (2)	$F_{0.1-100\,GeV}$ (3)	TS (4)
PKS 0625−354	1.72±0.06	6.7×10^{-9}	403.2
3C 78	2.01±0.16	4.9×10^{-9}	61.3

PKS0625-354

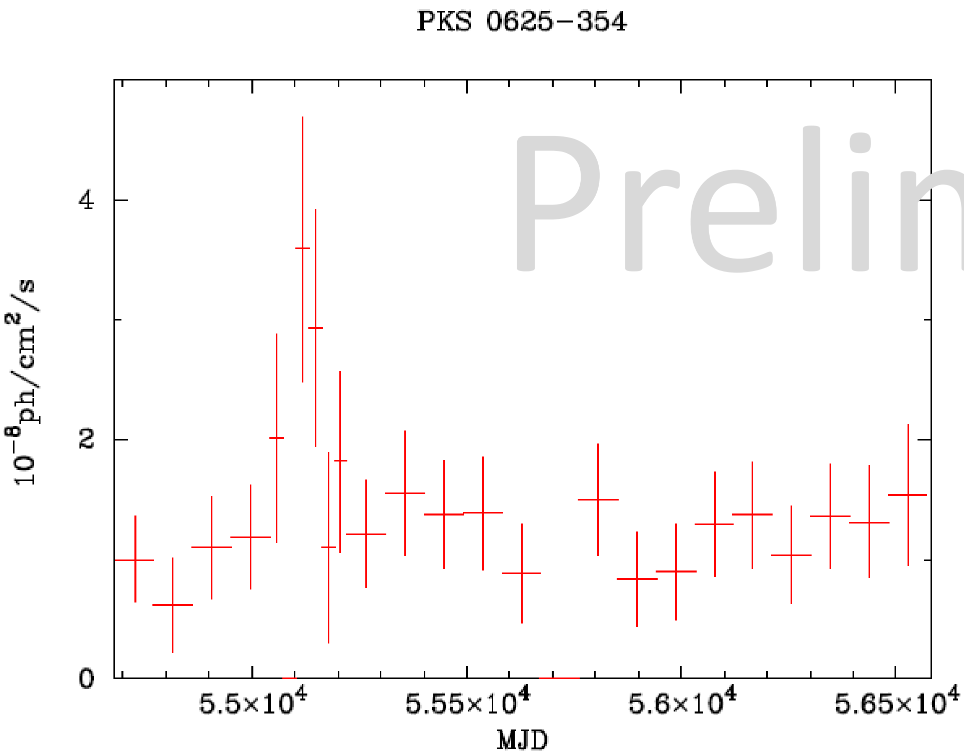


3C78

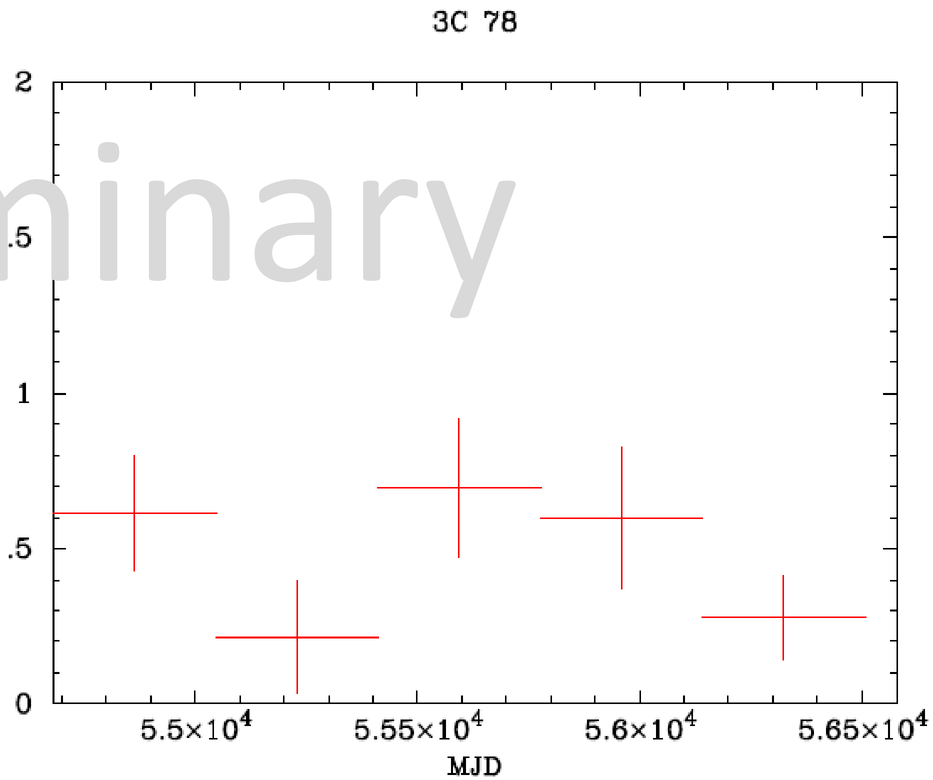


Fermi Gamma-ray Light curve

PKS0625-354



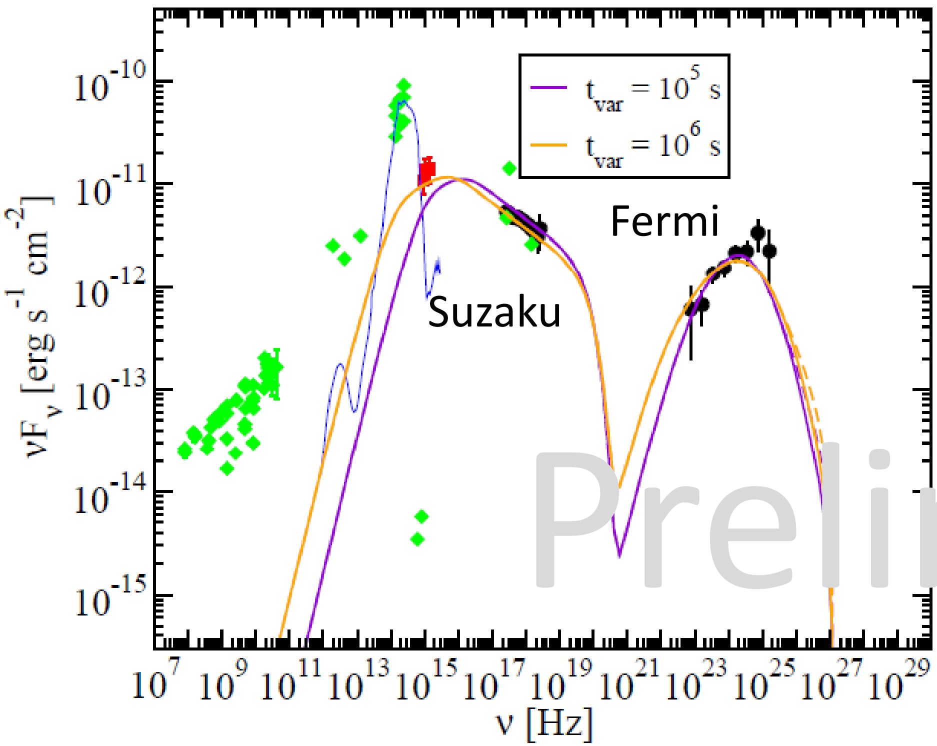
3C78



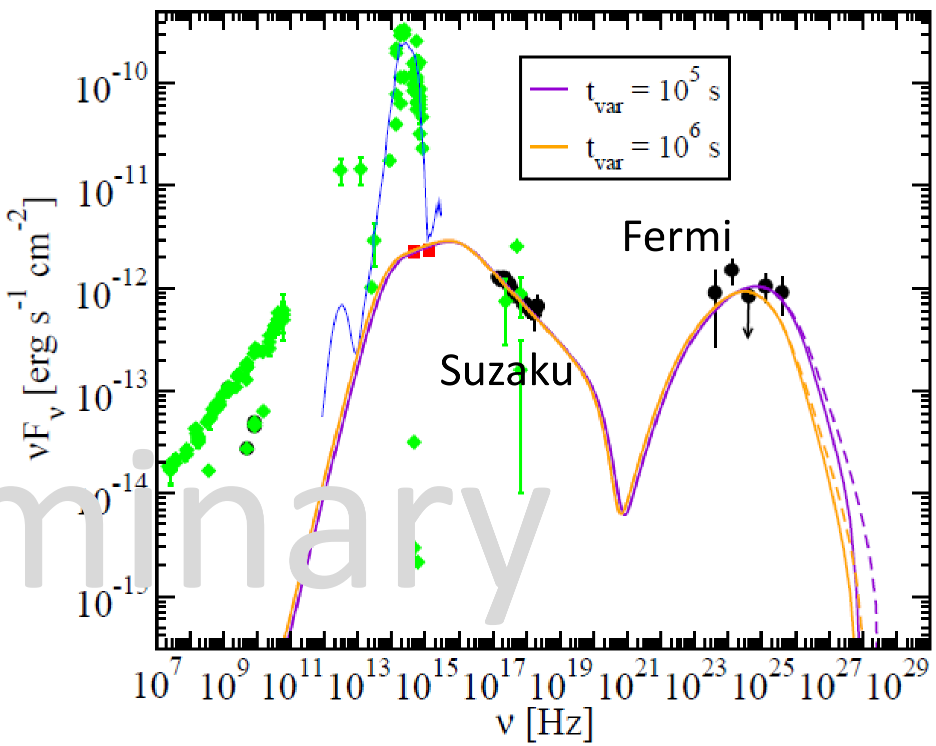
Preliminary

One-zone SSC modeling (Finke+08)

PKS0625-354



3C78(NGC1218)



SED fitting parameters ; Comparison with other radio galaxies

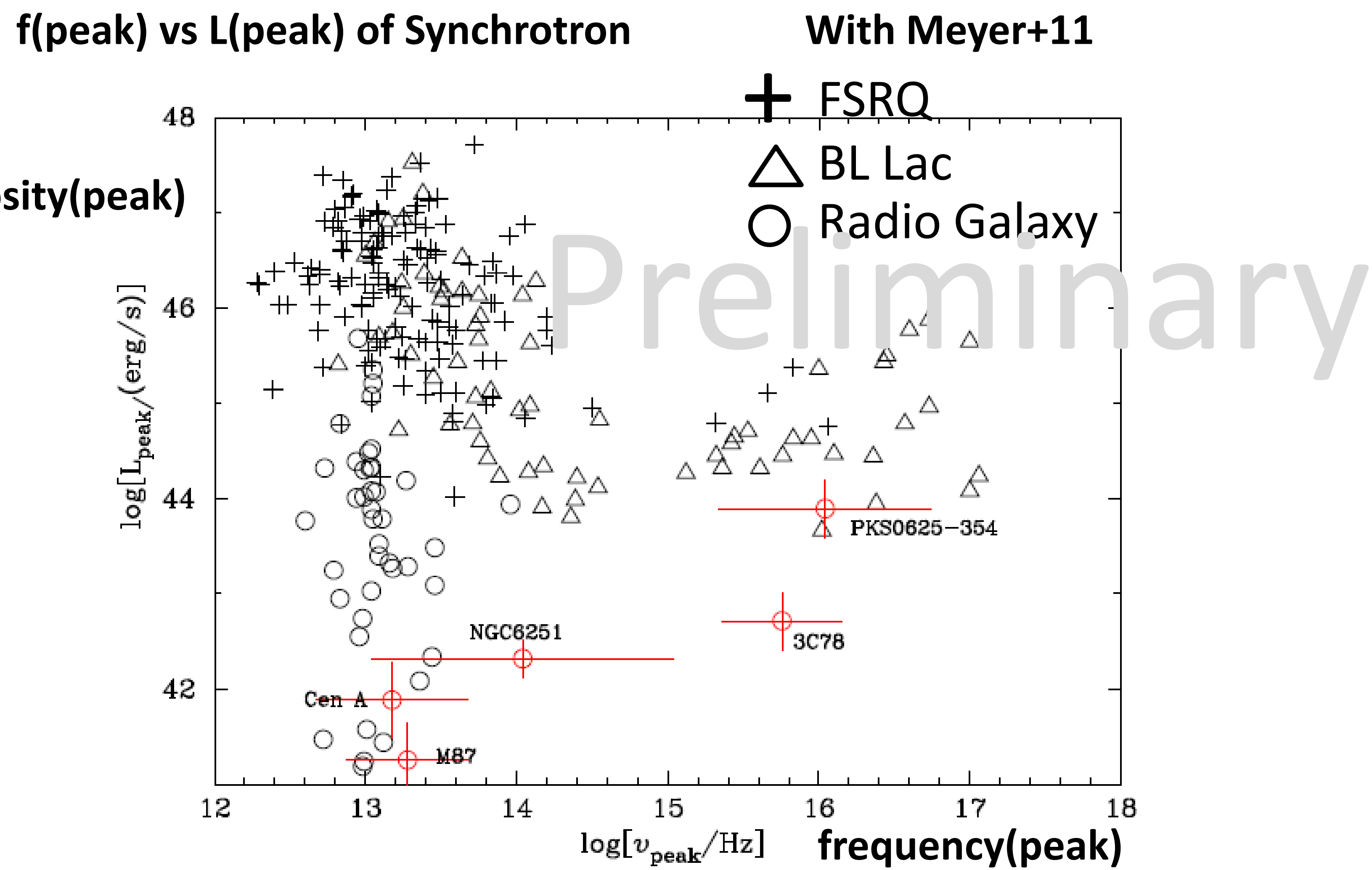
All the fittings were done by the one-zone SSC model (Finke+08)

Lower bulk Lorentz factors compared to those of typical blazars

	PKS 0625−354		3C 78		Cen A	M 87	NGC 1275	NGC 6251
Γ	5.8	5.7	2.93	5.75	7.0	2.3	1.8	2.4
δ	5.8	5.8	2.92	5.75	1.0	3.9	2.5	2.4
θ [deg]	10	19	20	20	30	10	25	25
B [G]	0.82	0.11	0.77	0.02	6.2	0.055	0.05	0.04
t_v [Ms]	0.1	1	0.1	1	0.1	1.2	30	1.7
R_b [10^{16} cm]	1.6	16	0.85	17	0.3	1.4	200	12
p_1	2.5	2.5	2.7	2.7	1.8	1.6	2.1	2.75
p_2	3.5	3.5	3.7	3.7	4.3	3.6	3.1	4.0
γ_{min}	6×10^3	6×10^3	1×10^3	1×10^4	3×10^2	1	8×10^2	250
γ_{max}	2×10^6	6×10^6	2×10^7	2×10^7	1×10^8	1×10^7	4×10^5	4.4×10^5
γ_{brk}	2.9×10^4	4.6×10^4	7.3×10^4	1.4×10^5	8×10^2	4×10^3	9.6×10^2	2.0×10^4
$P_{j,B}$ [10^{42} erg s^{-1}]	43	740	0.3	2.5	65	0.02	230	0.4
$P_{j,e}$ [10^{42} erg s^{-1}]	2	10	0.6	13	31	7	120	160

PKS0625-354 and 3C78: High-E peak radio galaxies

Outliers of Meyers' model which states the high-E peaked objects are only the most aligned jets.



Summary

We have presented Suzaku results of nearby Fermi-LAT detected low-power radio galaxies.
Based on the Fe-K and X-ray spectral slope, X-ray variability, and [O III] line strength, we argued for the jet origin of the observed X-ray emission in PKS0625-354 and 3C78.

We analyzed the 5-year s LAT data , derived their SEDs, and found that the bulk Lorentz factors of both objects are typical of those found from other LAT-detected FR-I radio galaxies, and lower than typically found for BL Lac objects.

The synchrotron peak frequencies for PKS0625-354 and 3C78 are unusually high for radio galaxies , and this seems at odds with the scenario outlined by Meyer+11, where high synchrotron pealed objects are the most aligned.