

# The survey for new AGN candidates within the field of Fermi unassociated gamma-ray sources

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## Abstract!

### Aim.

- ① Verification of "Blazar Sequence" with taking account of faint Blazars
- ② Discovery of new AGN type with gamma-ray emission

### Method.

Survey for AGNs within the field of Fermi unassociated gamma-ray sources by e-VLBI Observations.

### Result.

We detected 29 radio sources with high-brightness temperature.

### Discussion.

We estimated kinds of detected sources as possible. In this poster, we used spectral index, WGS and correlation diagram.

## Introduction!

### < Blazar >

Blazar is sub-class of Active Galactic Nuclei (AGNs) with relativistic jets pointing almost along the line of sight.

### < Blazar's SEDs >

Blazar's SEDs have two humps (Fig. 1). Left humps are emitted by synchrotron emission and right humps are emitted by Inverse-Compton scattering.

Anti-correlation between  $\nu_{\text{peak}}^{\text{syn}}$  and  $L_{\text{peak}}^{\text{syn}}$

⇒ **Blazar Sequence** (Fossati et al. 1998)

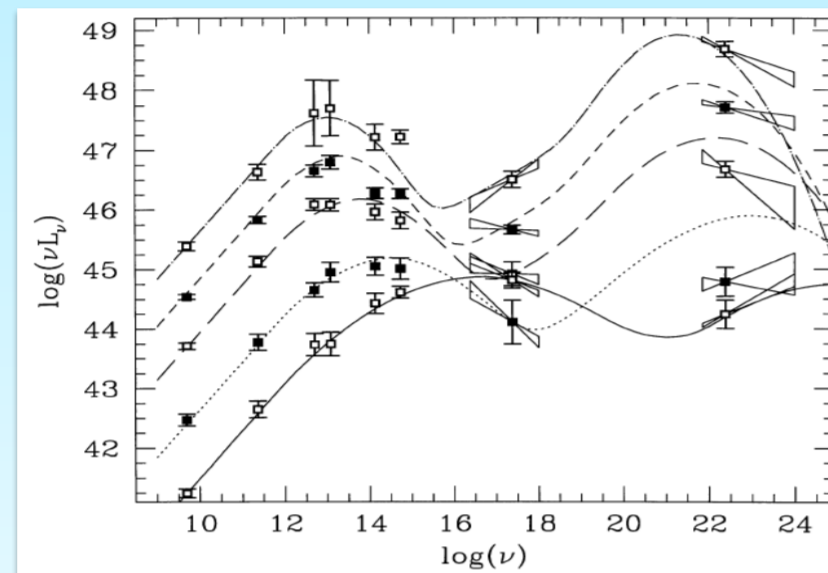


Fig.1 Blazar's SED [1]

## But !!

This characteristic is discovered among bright blazars at radio !!

Is "Blazar Sequence" caused by Selection bias?

It is needed to verify "Blazar Sequence" with taking account of faint blazars at radio.



## Observation!

### < Sample selection >

To search for faint blazars, we focused on Fermi 2<sup>nd</sup> Catalog [3]. This catalog lists 1873 gamma-ray sources detected by Fermi Large Area Telescope (LAT) in first two years. In listed gamma-ray sources, 127 sources were identified and 1171 sources have a possible counterpart within the positional error. These 1298 gamma-ray sources contain 806 blazars and most of such blazars are located at high galactic latitude. Therefore, it is expected to be a lot of blazars in 575 unassociated sources located at high galactic latitude.

⇒ We search for blazar candidates from unassociated sources in Fermi 2<sup>nd</sup> catalog

① We applied two criteria for unassociated sources in Fermi 2<sup>nd</sup> catalog. Criteria

- Dec > -30°
- |G-Lat| > 5°

In this process, we get 231 gamma-ray sources.

② We selected all radio sources located within the positional error of gamma-ray sources obtained process ① based on NVSS [5] and FIRST [6].

Sample : 1211 radio sources

※ We have observed 845 radio sources.

### < Observations >

In our observations, we used e-VLBI with Yamaguchi - Tsukuba baseline. Details of Our Observations are shown in tab. 1 and antennas used in our observations are shown in fig. 2.

Tab.1. Parameters of our observation

Parameters	Values
On-source time for each source [s]	180
SEFD <sub>γ</sub> [Jy]	286
SEFD <sub>r</sub> [Jy]	324
Observation frequency [GHz]	8.192 ~ 8.704
Bandwidth [MHz]	512
Observation epoch	2012 December 1, 2, 3, 8, 24

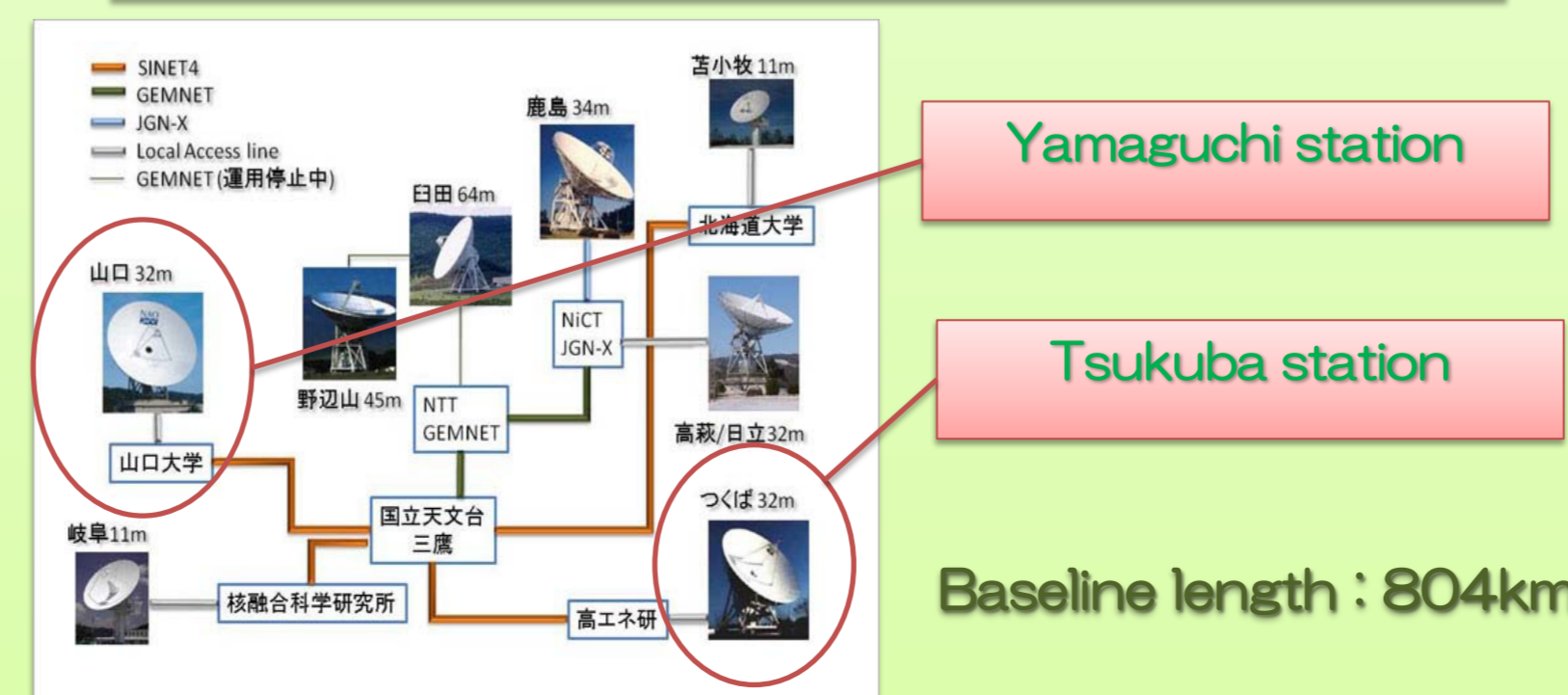


Fig. 2. Array of Japanese VLBI Network [7]

## Result

We could detect 29 sources!!!

### < Detected sources >

We detected 29 radio sources in our observations. Tab. 2 shows 2FGL name, Radio name, flux density observed by our observations, uv-length, brightness temperature of those. The brightness temperature is lower limit because we here assume to be the fringe spacing depending on each uv-length..

Tab 2. Detected sources.

Gamma Name (2FGL)	Radio name	Flux density	uv-length	brightness temperature
		8.6GHz [mJy]	[Mλ]	[×10 <sup>6</sup> K]
2FGL J0102.2+0943	J0102+0944	12.4	22.51	3.69
2FGL J0158.4+0107	J0158+0101	20.7	22.40	6.10
2FGL J0158.6+8558	J0152+8602	23.5	21.77	6.55
2FGL J0226.1+0943	J0226+0937	158.6	20.52	39.28
2FGL J0227.7+2249	J0227+2248	32.7	18.62	6.67
2FGL J0307.4+4915	J0307+4915	184.0	22.48	54.68
2FGL J0332.1+6309	J0331+6308	19.7	22.51	5.87
2FGL J0440.5+2554c	J0440+2604	9.3	20.48	2.29
2FGL J0600.9+3839	J0601+3838	90.5	22.03	25.83
2FGL J0723.9+2901	J0723+2859	60.5	22.24	17.59
2FGL J0923.5+1508	J0923+1505	14.9	22.34	4.37
2FGL J1016.1+5600	J1015+5551	102.6	22.39	30.26
2FGL J1208.6-2257	J1208-2248	23.4	19.20	5.08
2FGL J1208.6-2257	J1209-2254	20.7	20.91	5.31
2FGL J1254.2-2203	J1254-2208	61.5	20.58	15.33
2FGL J1502.1+5548	J1502+5554	42.1	21.52	11.48
2FGL J1548.3+1453	J1548+1452	32.8	21.79	9.17
2FGL J1612.0+1403	J1611+1410	62.9	22.48	18.69
2FGL J1614.8+4703	J1615+4703	16.3	22.48	4.85
2FGL J1704.3+1235	J1704+1234	41.7	22.47	12.38
2FGL J1730.8+5427	J1731+5428	6.6	20.96	1.70
2FGL J1738.9+8716	J1737+8717	27.7	22.20	8.02
2FGL J1835.4+1349	J1835+1348	121.3	21.11	31.78
2FGL J1844.3+1548	J1844+1546	27.3	20.37	6.67
2FGL J1950.3+1223	J1949+1225	14.6	14.56	1.83
2FGL J2107.8+3652	J2108+3655	60.7	20.79	15.43
2FGL J2133.9+6645	J2133+6647	22.1	20.86	5.65
2FGL J2227.8+0051	J2227+0044	16.3	22.20	4.73
Fermi J1418+3541 <sup>※</sup>	J1418+3542	77.3	18.01	14.74

※ This source is not listed in Fermi 2<sup>nd</sup> catalog but newly detected source by LAT [14].

# Discussion

## < WISE Gamma-ray Strip ( WGS ) >

Detected sources are considered to be AGNs because of their high brightness temperature. But we could not determine which types of AGNs these sources were with only flux density. Therefore, to estimate types of detected sources as possible, we used a method introduced in Massaro et al. (2012)<sup>[12]</sup>.

The simply explanation of that is shown here. This method uses WISE Gamma-ray Strip( WGS ), which is the region described by gamma-ray emitting blazars in WISE color-color space. First, we calculate parameter  $s$  which shows if sample sources belong to WGS. Second, We applied thresholds introduced in Massaro et al ( 2012 ) to parameter 's' and estimate which sample sources are blazars. Vertical and horizontal lines of Fig. 5. show colors calculated from WISE data and quadrilateral show WGS of BL Lacs ( blue ) or FSRQs( red ). Parameter  $s$  of BL Lac and FSRQ are  $s_b$  and  $s_f$  respectively. By this method, 7 sources are possible to be BL Lacs and 2 sources are possible to be FSRQ.

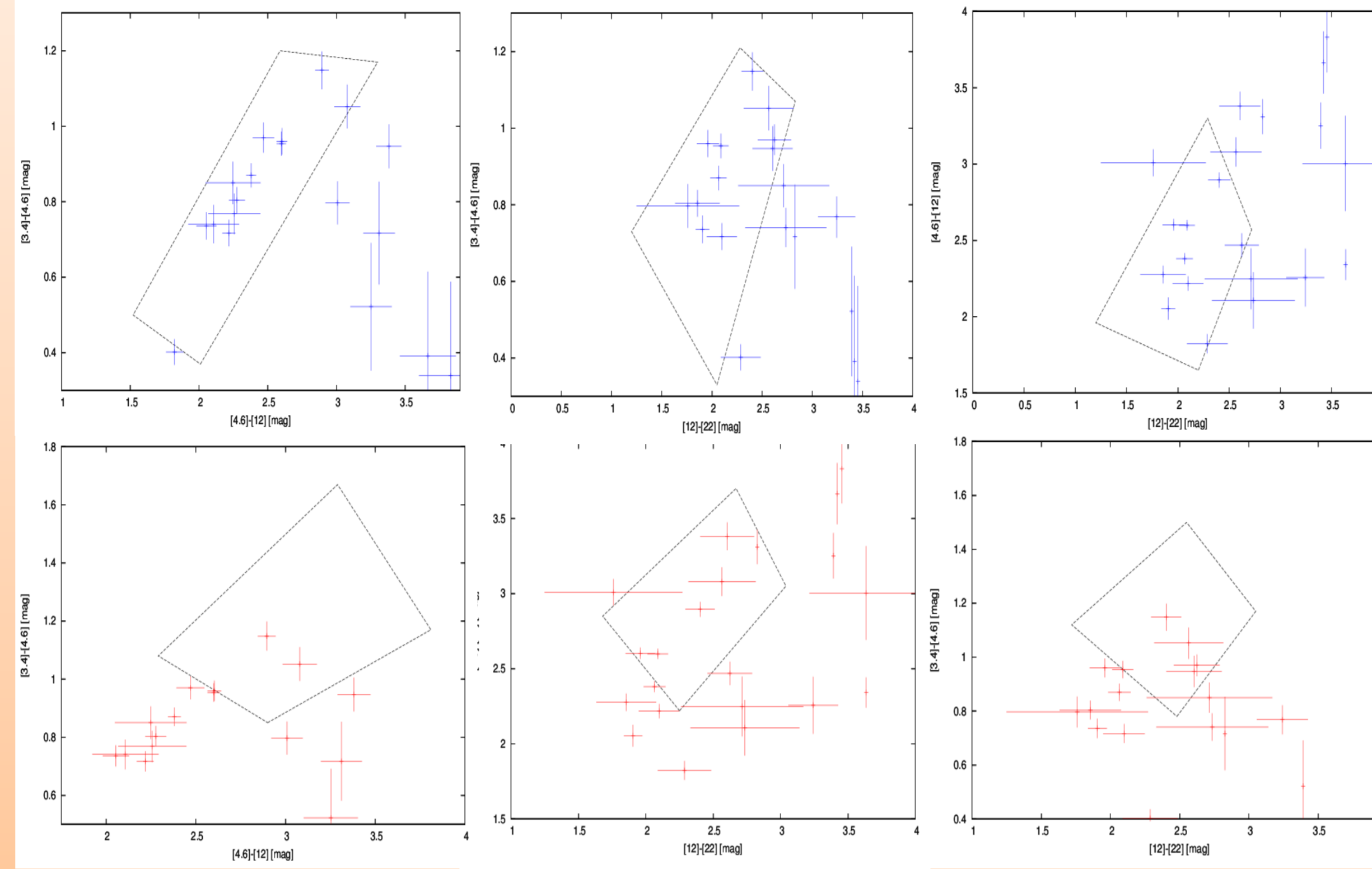


Fig. 5. Color - color 2D projection of detected sources. Upper panels and lower panels show WGS of BL Lacs objects and FSRQs, respectively.

**7 sources are identified as BL Lacs !!**  
**2 sources are identified as FSRQ !!**  
 ( By Massaro way )



## < Correlation diagram >

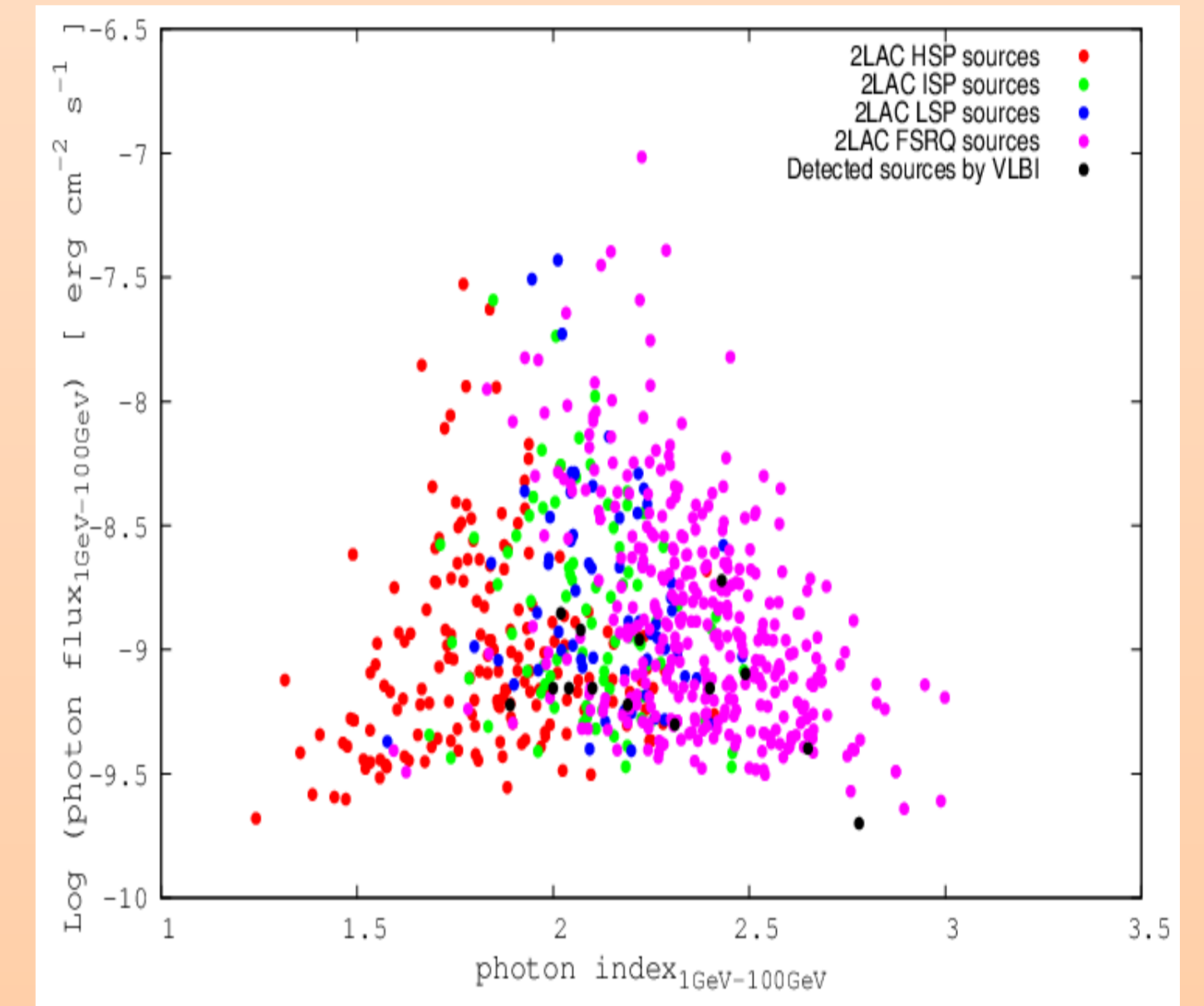
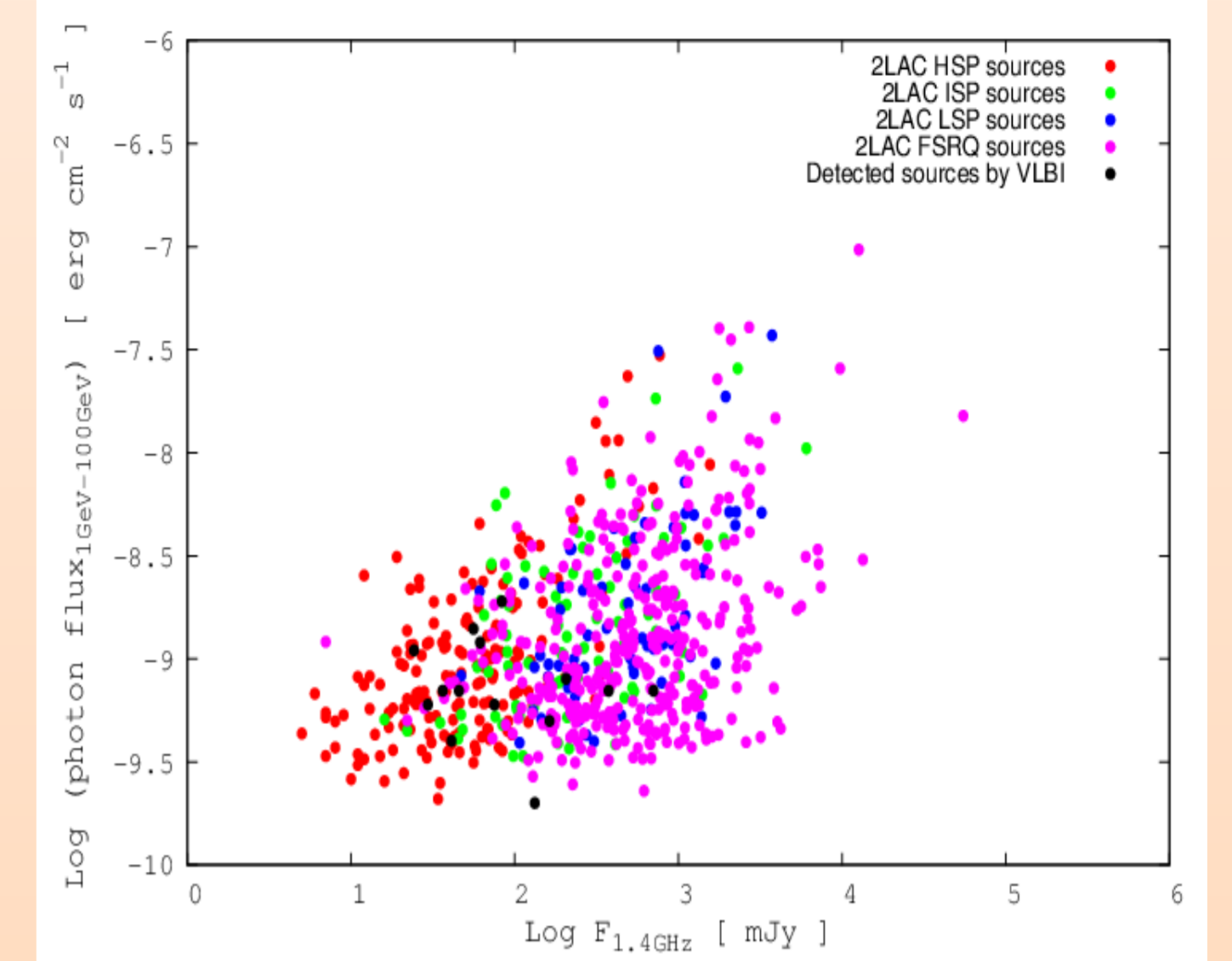


Fig. 4. Correlation diagram. Left panel show photon flux from 1 GeV to 100 GeV vs. radio flux density at 1.4GHz. Right one show flux from 1 GeV to 100 GeV vs. Photon index from 1 GeV to 100 GeV.

We compared the correlation diagram of detected sources with the one of 2LAC<sup>[13]</sup>. Trend of left panel show that detected sources are possibly high synchrotron peaked ( HSP ) BL Lacs. On the other hand, that of right panel show detected sources are possibly FSRQs. This trend possibly show that detected sources are different trend from 2LAC blazars.



## < Spectral index >

We conducted follow-up observations of 6 detected sources at S-band, X-band and U-band by VLBA. In this poster, we show the estimated indices of 6 sources in Tab. 3. We estimated the spectral indices by using peak flux densities at three bands. Here, we convoluted  $5 \times 5$  mas beam with each clean image maps because ,at S-band, the beam size is too large to detect jet component and we must adjust beam size to that of S-band. In Tab. 3, Each column show radio name, NVSS flux density, observed flux density by e-VLBI, VLBA flux density and estimated spectral indices by our observation and VLBA observation, respectively. 5 out of 6 sources are expected to be possible blazar because the spectrum at 2 -15 GHz is flatter than the spectral index of typical blazar ( $\sim 0.3$ ), which possibly show the possibility of beaming effect at jet of AGN.

Furthermore, we show also the images of J0307+4915 in Fig.4 as an example of sources having jet component. The images show jet component in the northeast direction.

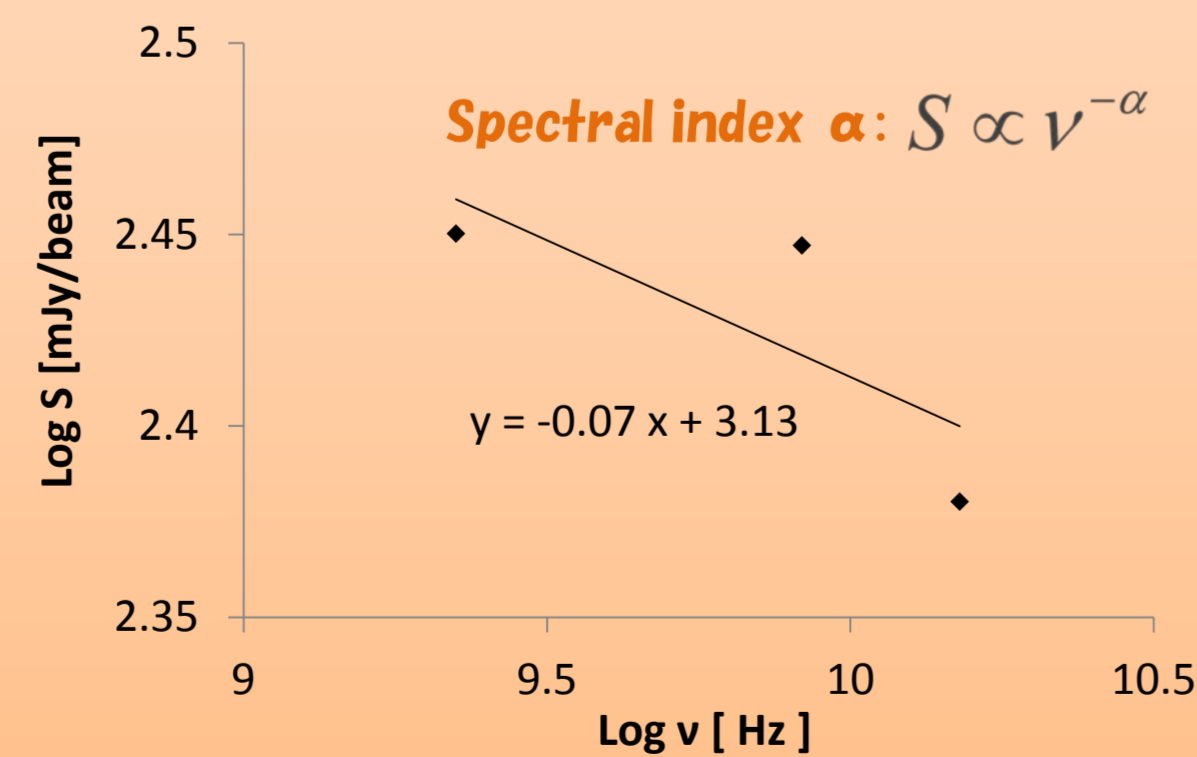


Fig. 3. Spectrum of J0307+4915 at 2 - 15 GHz.

Tab. 3. The estimated spectral indices of 6 sources

Radio Name	Flux density [mJy]		Flux density [mJy/beam]			$\alpha$	
	1.4GHz	8.4GHz	2.3GHz	8.4GHz	15.2GHz	1.4GHz-8.4GHz	VLBA
NVSS J022613+093726	374.6	158.6	202	67	31	0.48	0.96
NVSS J022744+224834	45.6	32.7	20.5	34.90	46.60	0.19	-0.43
NVSS J030727+491510	56.0	184.0	282	280	240	-0.66	0.07
NVSS J060102+383828	704.0	90.5	45.7	59.7	59.10	1.14	-0.15
NVSS J072354+285930	36.3	60.5	63.6	79.7	71.3	-0.29	-0.08
NVSS J101544+555100	132.5	102.6	47.8	43.5	37	0.14	0.12

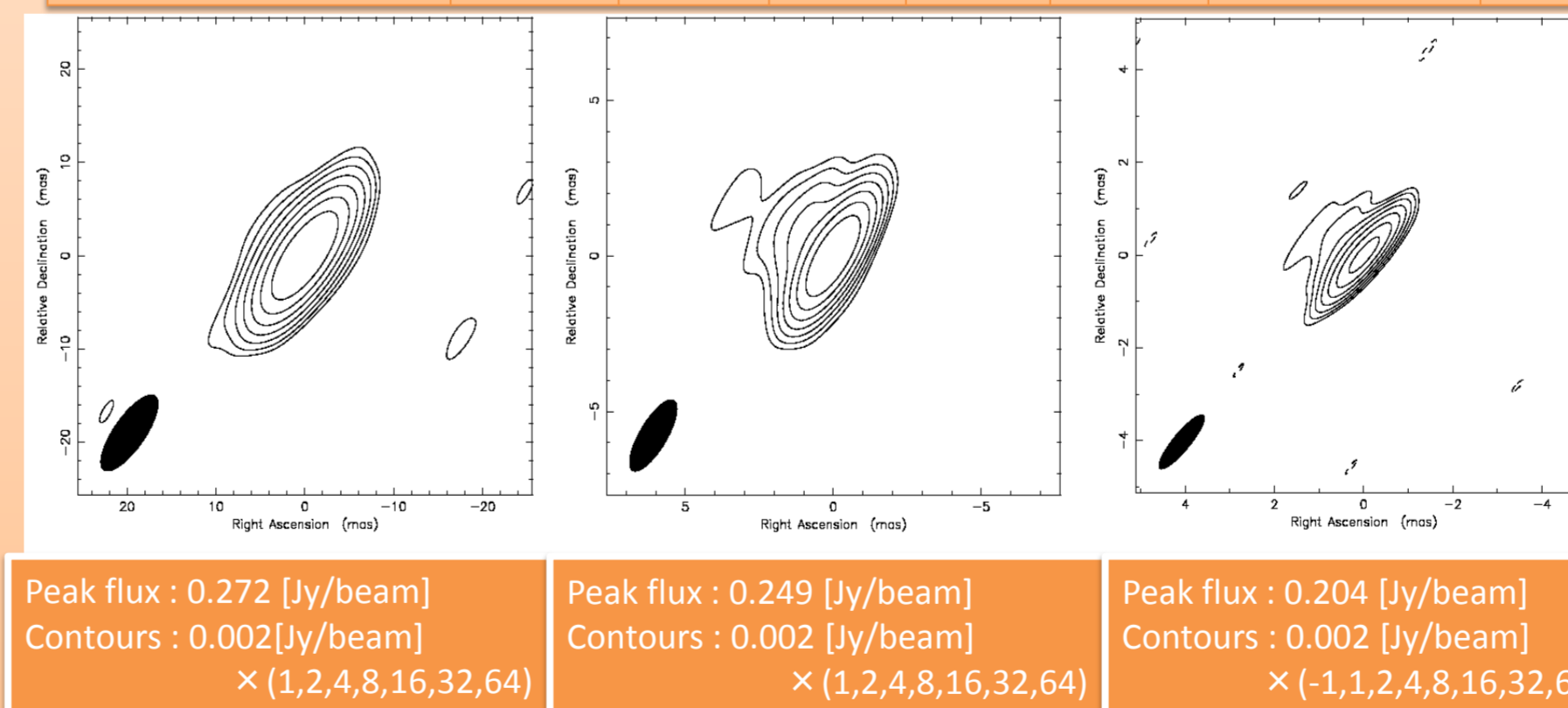


Fig. 4. VLBA images of J0307+4915 at S-band(left), X-band(center) and U-band(right), respectively. Image rms is about 2 [mJy] at all bands and synthesized beam sizes are  $9.7 \times 3.4$  [mas],  $2.6 \times 0.9$  [mas] and  $1.5 \times 0.37$  [mas], respectively.

## Future Processing

• Observations of the rest of radio samples ( 366 sources )

• Optical spectroscopic observations and estimation of distance to detected sources.