The TANAMI program:

Southern-Hemisphere VLBI Monitoring of Relativistic Jets in Active Galaxies

Matthias Kadler[1,2,3], R. Ojha[4,5], M. Böck[1], C. Müller[1], S. A. Richers[6], J. Wilms[1] & the TANAMI Collaboration

[1]Dr. Remeis-Sternwarte & ECAP — [2]CRESST/NASA Goddard Space Flight Center — [3]USRA — [4]United States Naval Observatory — [5]NVI — [6]University of Virginia

Abstract

TANAMI (Tracking Active Galactic Nuclei with Austral Milliarcsecond Interferometry) is a monitoring program to study the parsec-scale structures and dynamics of relativistic jets in active galactic nuclei (AGN) of the Southern Hemisphere with the Australian Long Baseline Array (LBA) and the trans-oceanic antennas Hartebeesthoek, TIGO and O'Higgins. TANAMI is a unique complement to other ongoing VLBI monitoring programs of AGN as it focuses on extragalactic sources south of −30 degrees declination with quasi-simultaneous dual-frequency observations at 8.4 GHz and 22.3 GHz every two months at milliarcsecond resolution. The initial TANAMI sample of 43 sources has been defined to include the most promising candidates for bright γ-ray emission expected to be detected by the LAT instrument on *Fermi*. Since November 2008, we have been adding new sources to the sample, which now includes the radio- and γ-ray brightest AGN of the Southern Hemisphere. The combination of VLBI and γ-ray observations is crucial to understand the broadband emission characteristics of AGN and the nature of relativistic AGN jets.

Table 1: The TANAMI-Array

Telescope	Diameter (meters)	Location
Parkes	64	Parkes, New South Wales
ATCA	5x22	Narrabri, New South Wales
Mopra	22	Coonabarabran, New South Wales
Hobart	26	Mt. Pleasant, Tasmania
Ceduna	30	Ceduna, South Australia
DSS43[a]	70	Tidbinbilla, ACT
DSS45[a]	34	Tidbinbilla, ACT
Hartebeesthoek[c]	26	Hartebeesthoek, South Africa
O'Higgins[b]	9	O'Higgins, Antarctica
TIGO[b]	6	Concepcion, Chile

[a]Operated by the Deep Space Network of the National Aeronautics and Space Administration
[b]Operated by Bundesamt für Kartographie und Geodäsie (BKG)
[c]Not available since September 2008

- Parsec-scale resolution monitoring of Southern-Hemisphere extragalactic jets
- Quasi-simultaneous observations at 8.4 GHz and 22.3 GHz at intervals of about 2 months
- VLBI observations are complemented by flux-density monitoring across the radio spectrum with ATCA, Hobart, Ceduna and Effelsberg telescopes
- Ceduna Hobart Interferometer (CHI) provides a 1700 km baseline for quick followup of flaring sources
- Multiwavelength correlated observations with *Swift* (optical/UV and X-ray through a dedicated *Swift* fill-in program), *INTEGRAL* (through an AO 8 key program in the PKS 2155−304 field), and *Fermi*/LAT (continuous all-sky monitoring)

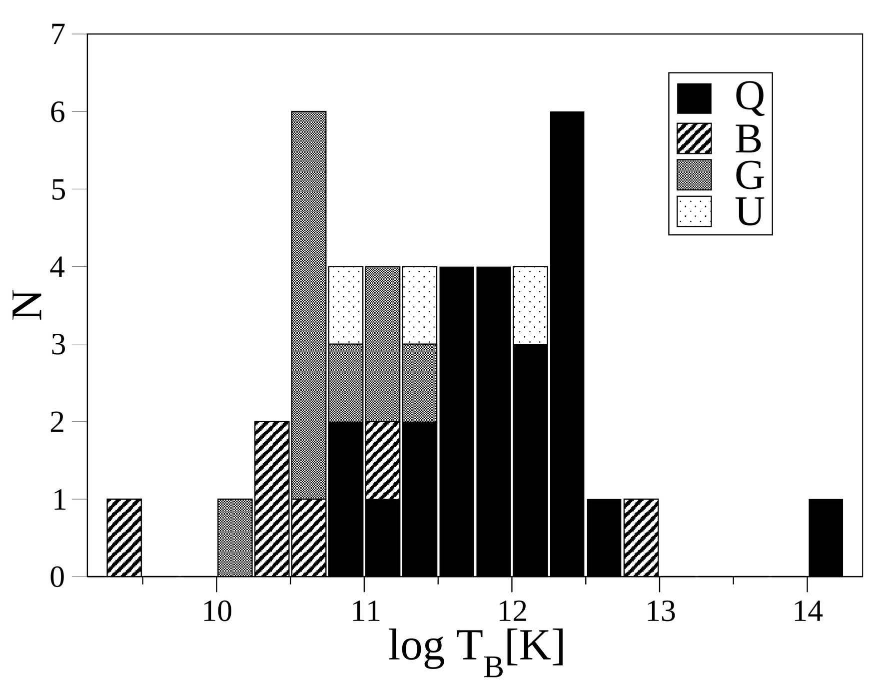

Figure 3: Distribution of core brightness temperature of all initial TANAMI sources with optical classification

First Epoch Results (based on LAT-3-month-list)

- 78% of LAT AGN Bright Sample (LBAS) sources have opening angles $\geq 30^\circ$, only 27% of non-LBAS sources do. Hence, either LBAS jets have smaller Lorentz factors(Γ) (beaming cones $\sim 1/\Gamma$) or LBAS jets are pointed closer to the line of sight.
- Redshift distribution of blazars in TANAMI sample (see Fig. 4) similar to those for LBAS and EGRET blazars. No difference in the radio- and gamma-ray selected subsamples.
- No significant difference between LBAS and non-LBAS luminosities. The five most distant and luminous TANAMI sources are not detected.
- No significant difference in brightness temperatures of LBAS and non-LBAS. 14 below equipartition, 30 below inverse Compton limit, putting about a third above this limit.

For more details, please see:
Ojha, R., et al. 2010, A&A (in press), arXiv:1005.4432

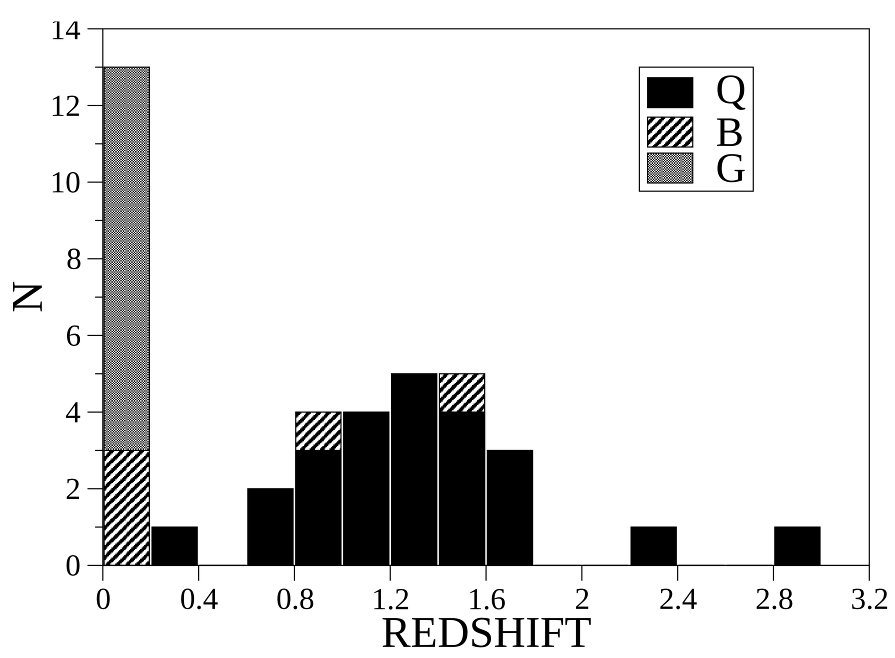

Figure 4: Redshift distribution of of all initial TANAMI sources with optical classification

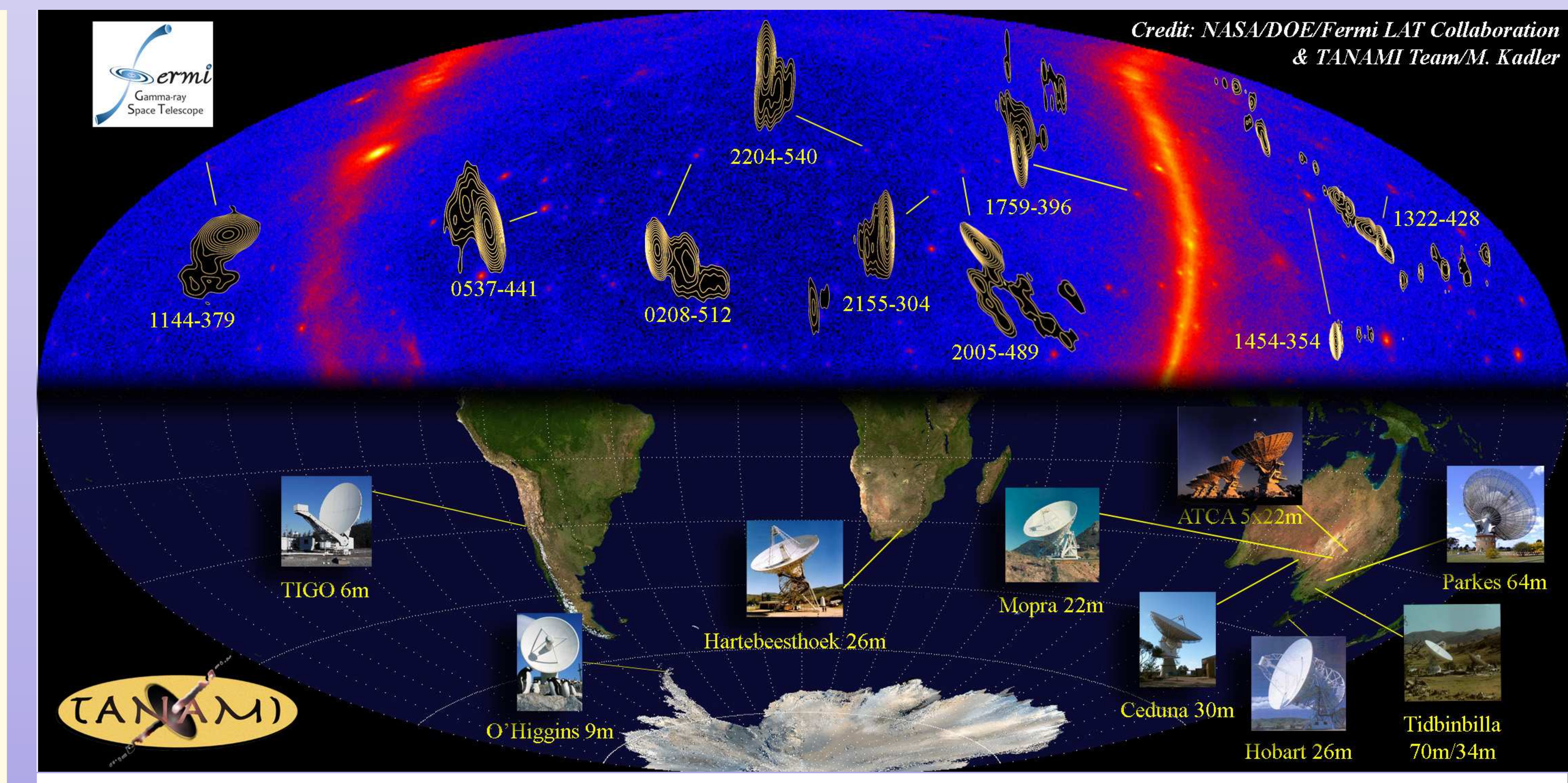

Fig.1: Collage showing the Southern Fermi/LAT γ-ray sky in the top half of this Aitoff projection (with South being up) and the Southern Hemisphere of the earth in the bottom with the positions of the radio telescopes of the TANAMI array indicated. Overlaid on the Fermi sky image are TANAMI radio images of the brightest extragalactic γ-ray sources. Note that South is up in the Fermi -ray image and that the scale of the radio jets is enhanced by a factor of $\sim$1000 compared to the γ-ray sources.

Figure 2: Simultaneous 8.4 GHz (left) and 22.3 GHz (right) images of selected TANAMI sources and the corresponding spectral index map (middle)

The core shift analysis for the spectral maps is done by using a cross-correlation method. The spectral index (defined as $F_\nu \sim \nu^{+\alpha}$) is calculated for the maximum value of the cross-correlation.

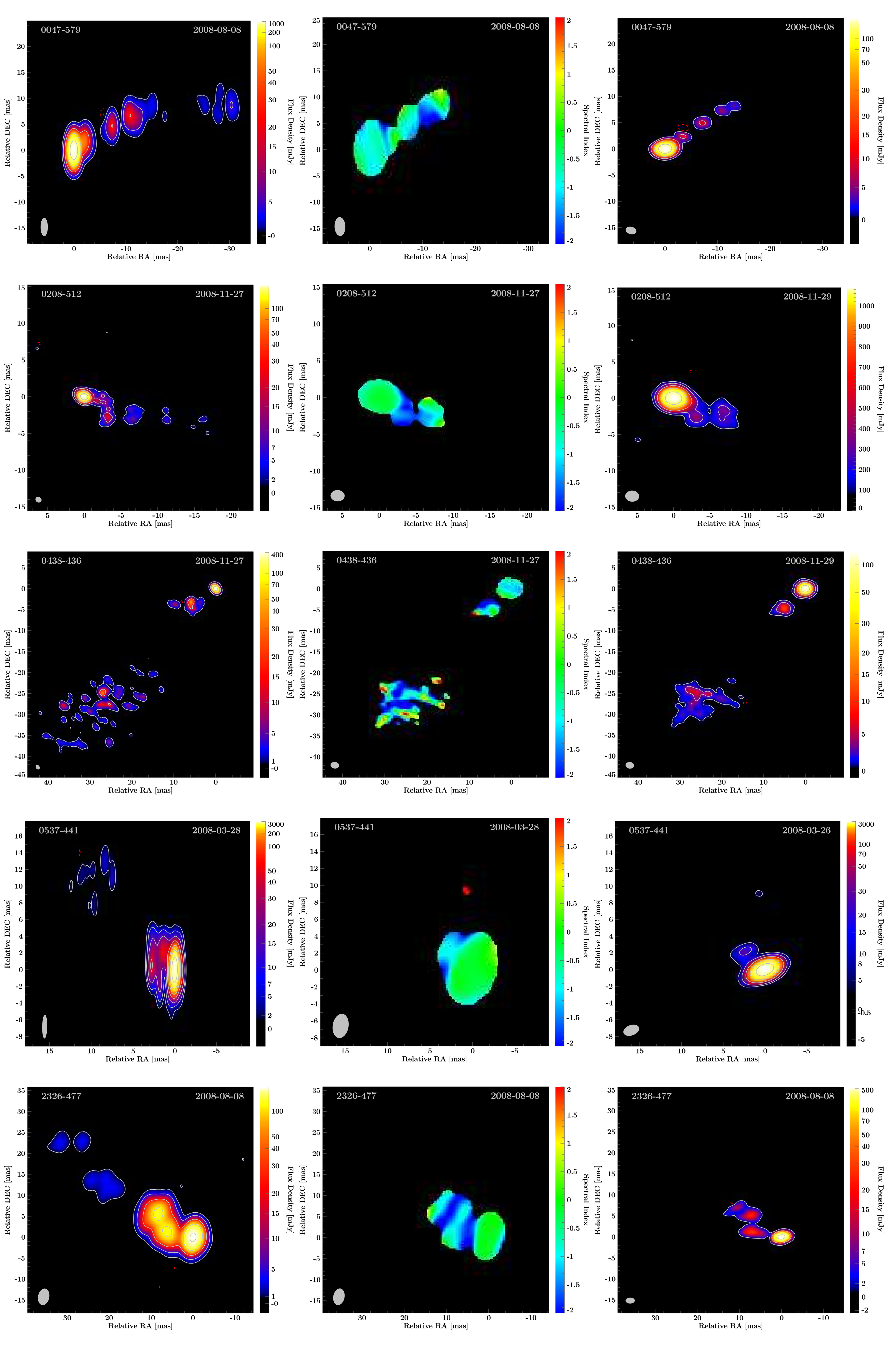

Table 2: Source List

IAU Name	Alt Name	LAT[a]	ID[b]	z
0047−579		Y	Q	1.979
0055−328		Y	U	-
0208−512		Y	B	0.99
0227−369		Y	Q	2.115
0244−470		Y	U	-
0302−623		Y	U	-
0308−611		Y	Q	1.48
0332−376		Y	U	-
0332−403		Y	B	1.445
0402−362		Y	Q	1.42
0405−385		Y	Q	1.285
0412−536		Y	U	-
0426−380		Y	Q	1.1120
0438−436		N	Q	2.863
0447−439		Y	B	0.2050
0454−463		Y	Q	0.8528
0506−612		N	Q	1.093
0516−621		Y	U	-
0518−458	PICTOR A	N	G	0.035058
0521−365	ESO 362−G021	Y	B	0.055338
0524−485		Y	U	-
0527−359		N	U	
0537−441		Y	Q	0.894
0625−354	OH−342	Y	G	0.054594
0637−752		Y	Q	0.653
0700−661		Y	U	-
0717−432		Y	U	-
0736−770		N	Q	
0745−330		N	U	
0812−736		Y	U	-
1057−797		Y	U	-
1101−536		Y	Q	
1104−445		N	Q	1.598
1144−379		Y	Q	1.048
1257−326		N	Q	1.256
1258−321	ESO 443- G 024	N	U	0.0170
1313−333		Y	Q	1.21
1322−428	CenA, NGC 5128	Y	G	0.001825
1323−526		Y	U	-
1325−558		Y	U	
1333−337	IC4296	N	G	0.012465
1344−376		Y	U	-
1424−418		Y	Q	1.522
1440−389		Y	U	0.0655
1454−354		Y	Q	1.424
1501−343		Y	U	-
1505−496		N	U	-
1549−790		N	G	0.1501
1600−445		Y	U	
1600−489		Y	U	
1606−667		Y	U	-
1610−771		Y	Q	1.71
1613−586		Y	Q	
1646−506		Y	U	
1714−336		Y	B	-
1716−771	NGC 6328	N	U	-
1718−649		N	G	0.014428
1733−565		N	G	0.098
1759−396		Y	Q	0.296
1804−502		N	Q	1.606
1814−637		N	G	0.06270
1933−400		Y	Q	0.965
1954−388		Y	Q	0.63
2005−489		Y	B	0.0710
2027−308	ESO 462−G 027	N	G	-
2052−474		Y	Q	1.489
2106−413		N	Q	1.058
2136−428		Y	B	-
2149−306		N	Q	2.345
2152−699	ESO 075−G 041	N	G	0.028273
2155−304		Y	B	0.116
2204−540		Y	Q	1.206
2326−477		N	Q	1.2990
2355−534		N	Q	1.01

[a] detected by *Fermi*/LAT, based on 1LAC (Abdo et al.,2010)
[b] optical counterpart, denoted as: (Q) quasar,(B) BL Lac object, (G) galaxy, (U) unclassified

Outlook

- Jet kinematics analysis of full sample now possible based first 3–5 source epochs
- Dynamic spectral index imaging based on multi-epoch dual-frequency imaging
- SEDs from correlated TANAMI, *Swift* and *Fermi*/LAT monitoring
- High resolution multi-epoch study of Cen A (see Poster by Müller et al.)

For more information, please contact Matthias.Kadler@sternwarte.uni-erlangen & rojha@usno.navy.mil or see http://pulsar.sternwarte.uni-erlangen.de/tanami