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# TANAMI and RadioAstron observations of AGN

Phil Edwards  
7 August 2014

CSIRO ASTRONOMY & SPACE SCIENCE  
[www.csiro.au](http://www.csiro.au)





# TANA of PKS 1954-388

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# Outline

Co-authors

Some reminiscences

PKS 1954-388

ATCA monitoring

Previous VLBI observations

RadioAstron observation

Results

Conclusions

# Co-authors

The TANAMI team

R. Ojha, B. Carpenter, M. Kadler ++

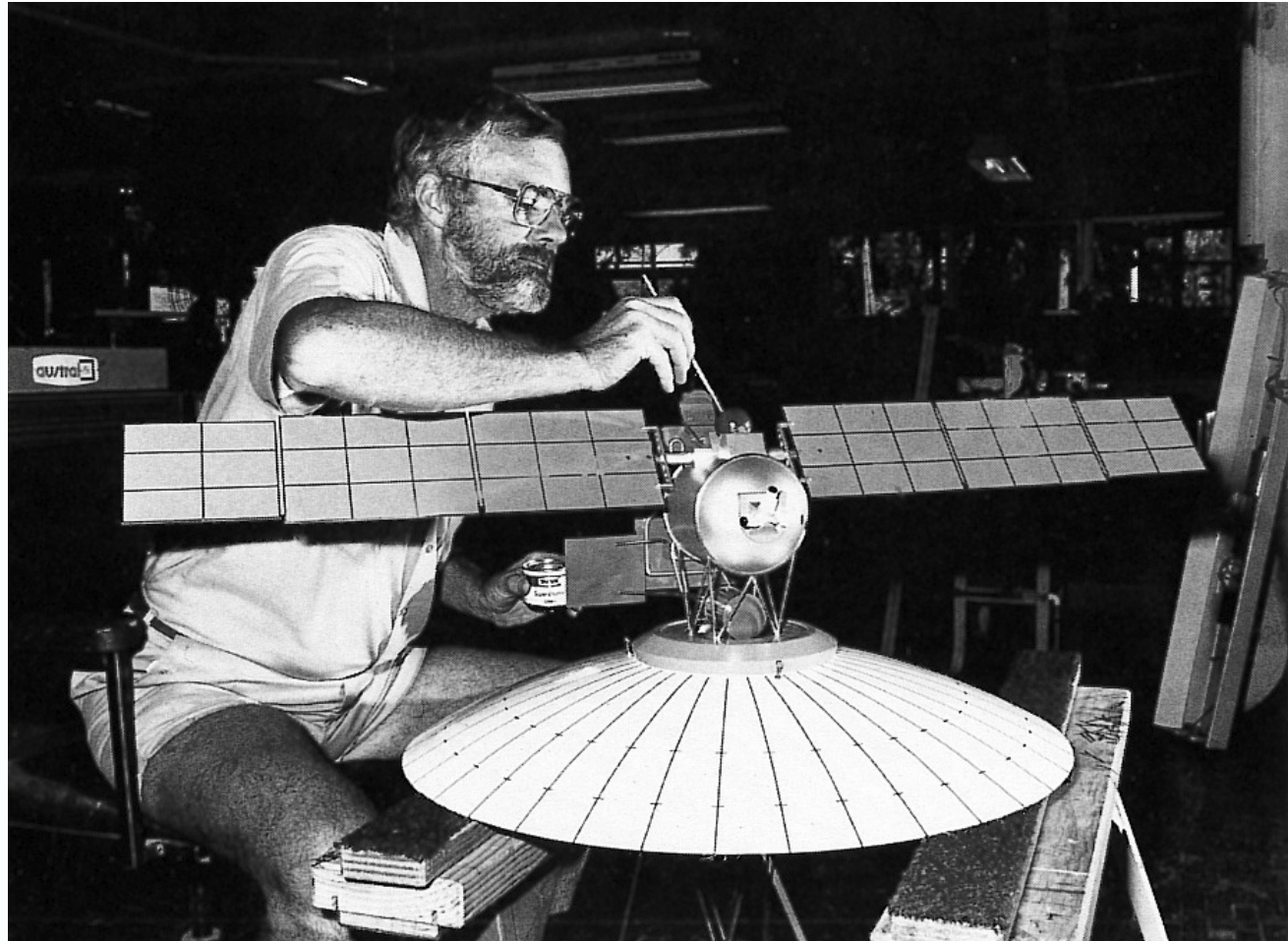
The RadioAstron AGN team

Y. Kovalev, P Voytsik, M. Lisakov +++

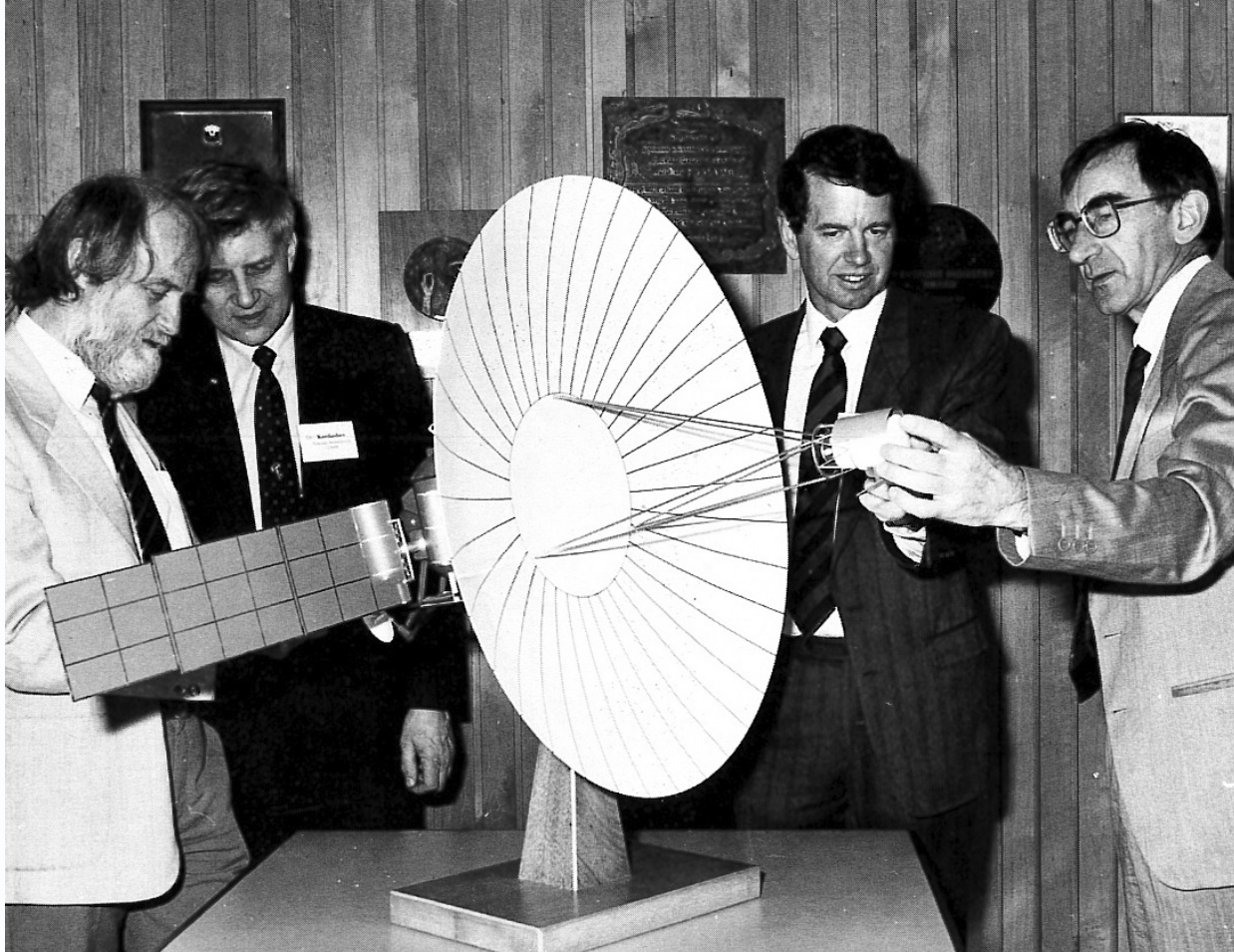
The LBA team

C. Phillips, J. Stevens, J. McCallum ++

# 23 years ago...



# 23 years ago...

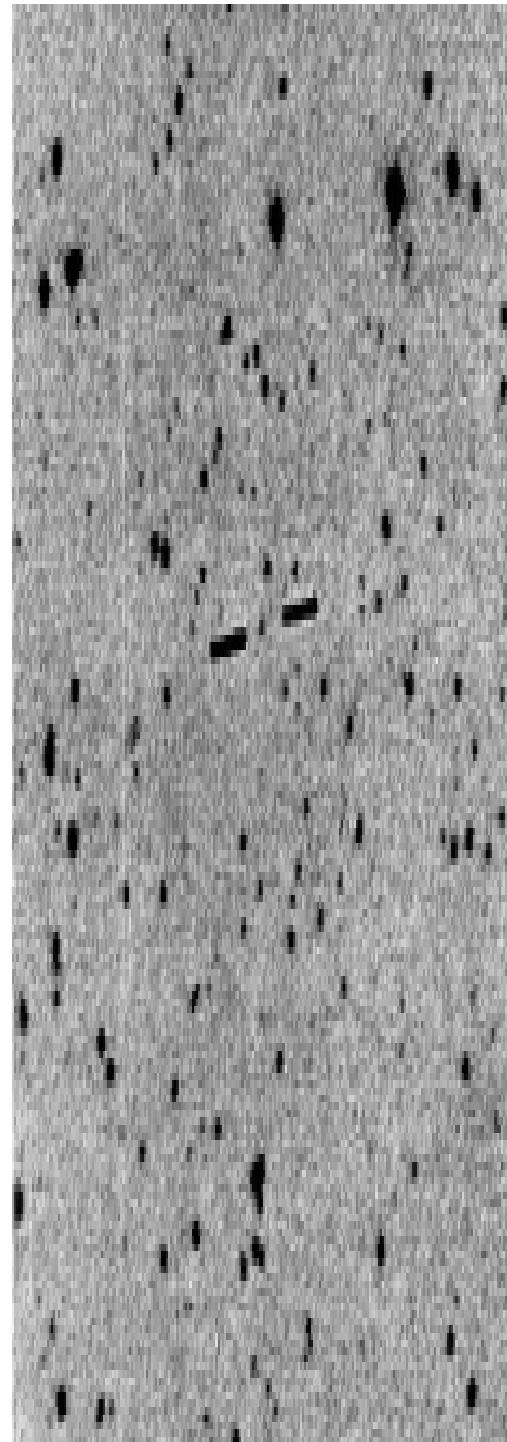


# 23 years ago...



# Identification

“Identifications of Southern  
Quasi-Stellar Objects”  
Shimmins, Bolton,  
Peterson, & Wall  
Ap. Letters 1971 vol. 8 p. 139



1954-388

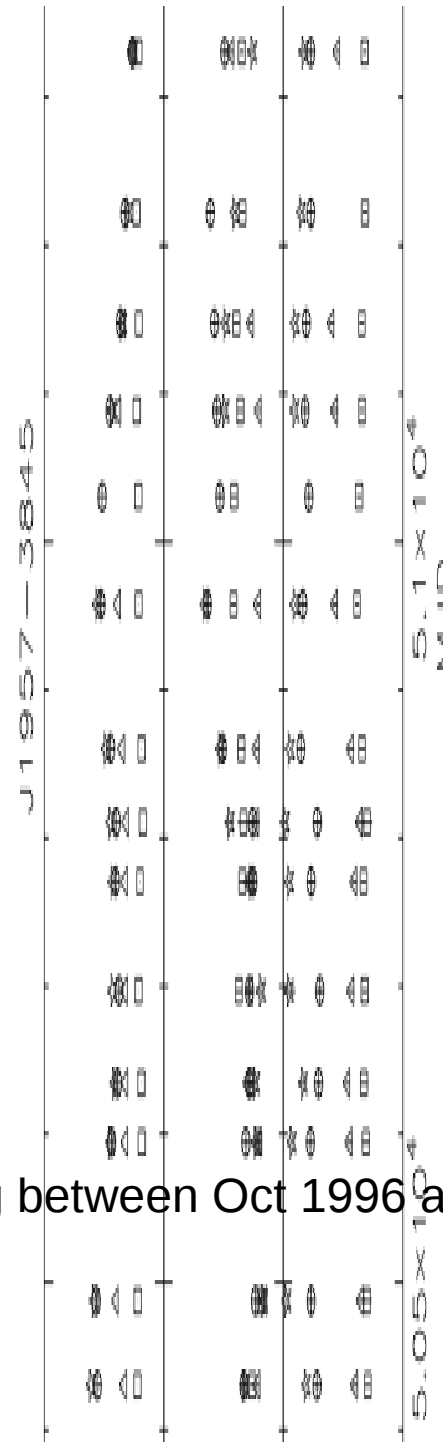
# PKS 1954-388

- $z = 0.63$  determined from AAT obs. by Browne et al. 1975
- “New blazars discovered by polarimetry” Impey et al. 1988 revealed optical polarisation of 11%
- Detected at X-rays by ROSAT (Brinkmann et al. 1994)
- Not detected by EGRET
- Oshlack et al. (2002) estimated  $M_{\text{BH}} = 4.3 \times 10^8 M_{\odot}$
- Detected by Fermi LAT (in 1FGL, 1LAC, 2FGL, 2LAC)
- Nolan et al. (2012) conclude  $< 1\%$  chance of being steady at gamma-ray energies

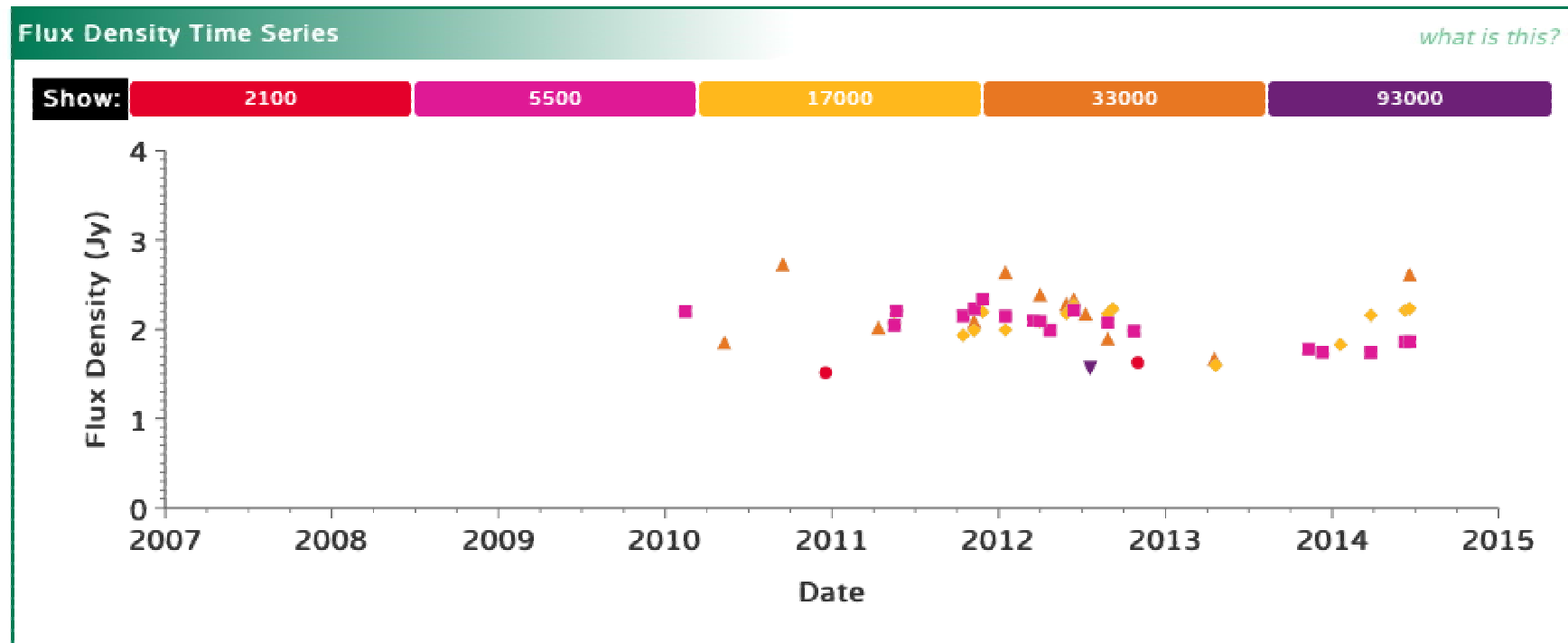
# ATCA monitoring (PASJ)

al. 2003

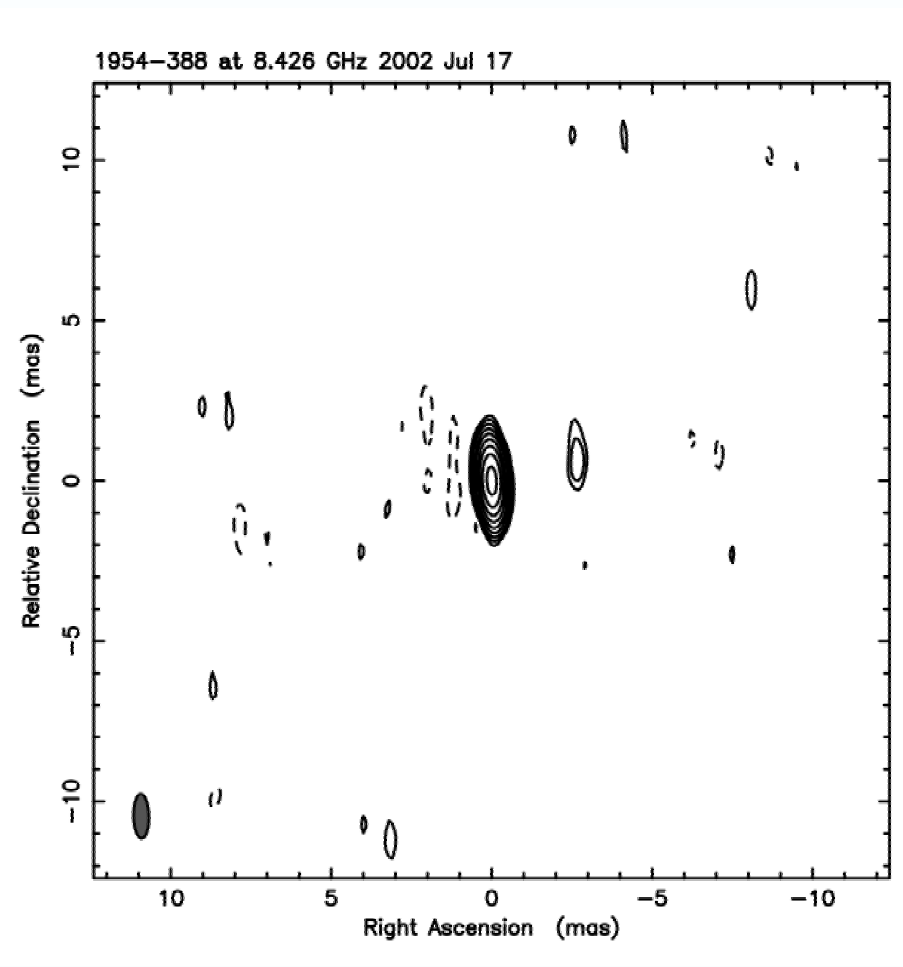
1.6, 2.3, 4.8 & 8.4 GHz monitoring between Oct 1996 and Feb 2000



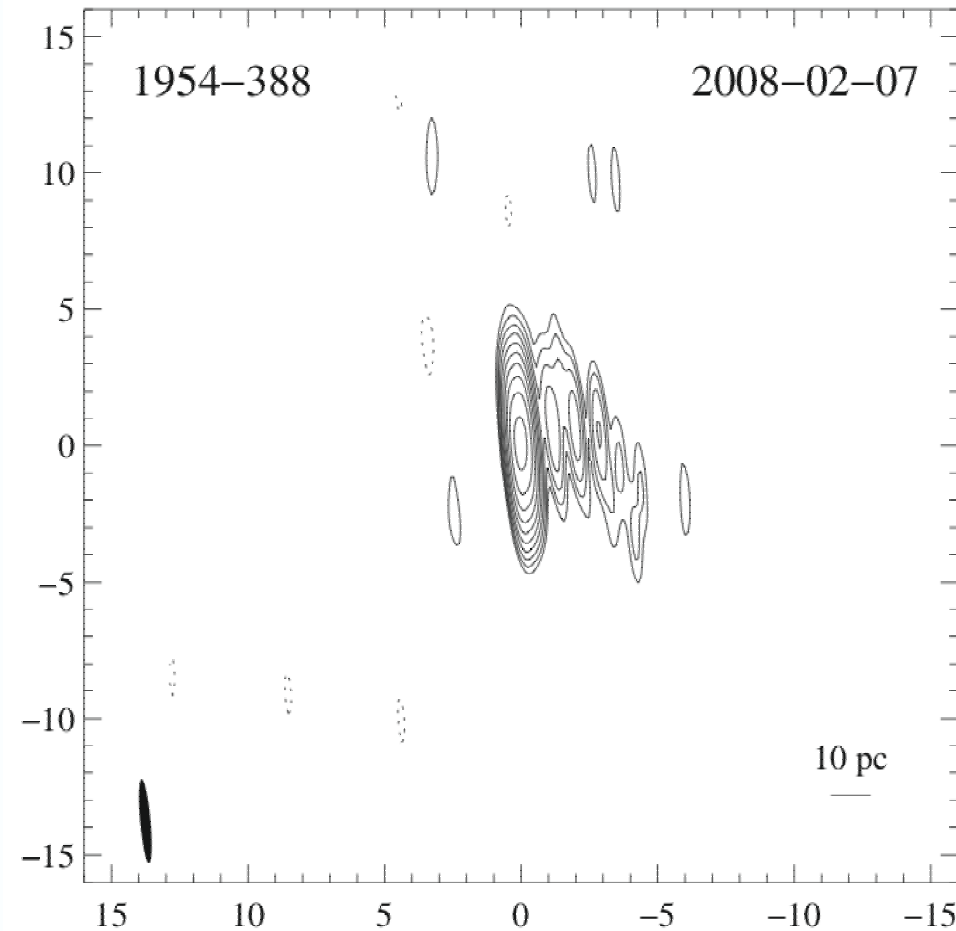
# ATCA flux density monitoring



# Ojha et al. 2004



# TANAMI image (Ojha et al. 2010)





# **TANAMI = Tracking Active Galactic Nuclei with Austral Milli-arcsecond Interferometry**

*With the floods of data that surveys provide, why name your project after a desert?*

**TANAMI =**  
**Tracking Active Galactic Nuclei with**  
**Austral Milli-arcsecond Interferometry**

**MOJAVE =**  
**Monitoring of Jets in AGN with VLBA**  
**Experiments**

# The TANAMI team

**Roopesh Ojha**  
Edwards

**Matthias Kadler**

James Lovell

Phil

Steven Tingay

Moritz Böck

Jay Blanchard

Roy Booth

Michael Dutka

Thomas Eberl

Alan Fey

Lars Fuhrman

Neil Gehrels

Hayo Hase

Faith Hungwe

Shinji Horiuchi

David Jauncey

Kenneth Johnston

Uli Katz

Matt Lister

Julie McEnery

Cornelia Müller

David Murphy

Chris Phillips

Tapio Pursimo

Jonathan Quick

John Reynolds

Eduardo Ros

Jamie Stevens

Greg Taylor

Dave Thompson

Gino Tosti

Tasso Tzioumis

Joern Wilms

Anton Zensus

Tobias Beuche

Bryce Carpenter

Christoph Grossberger

Annika Kreikenbohm

Felicia Krauss

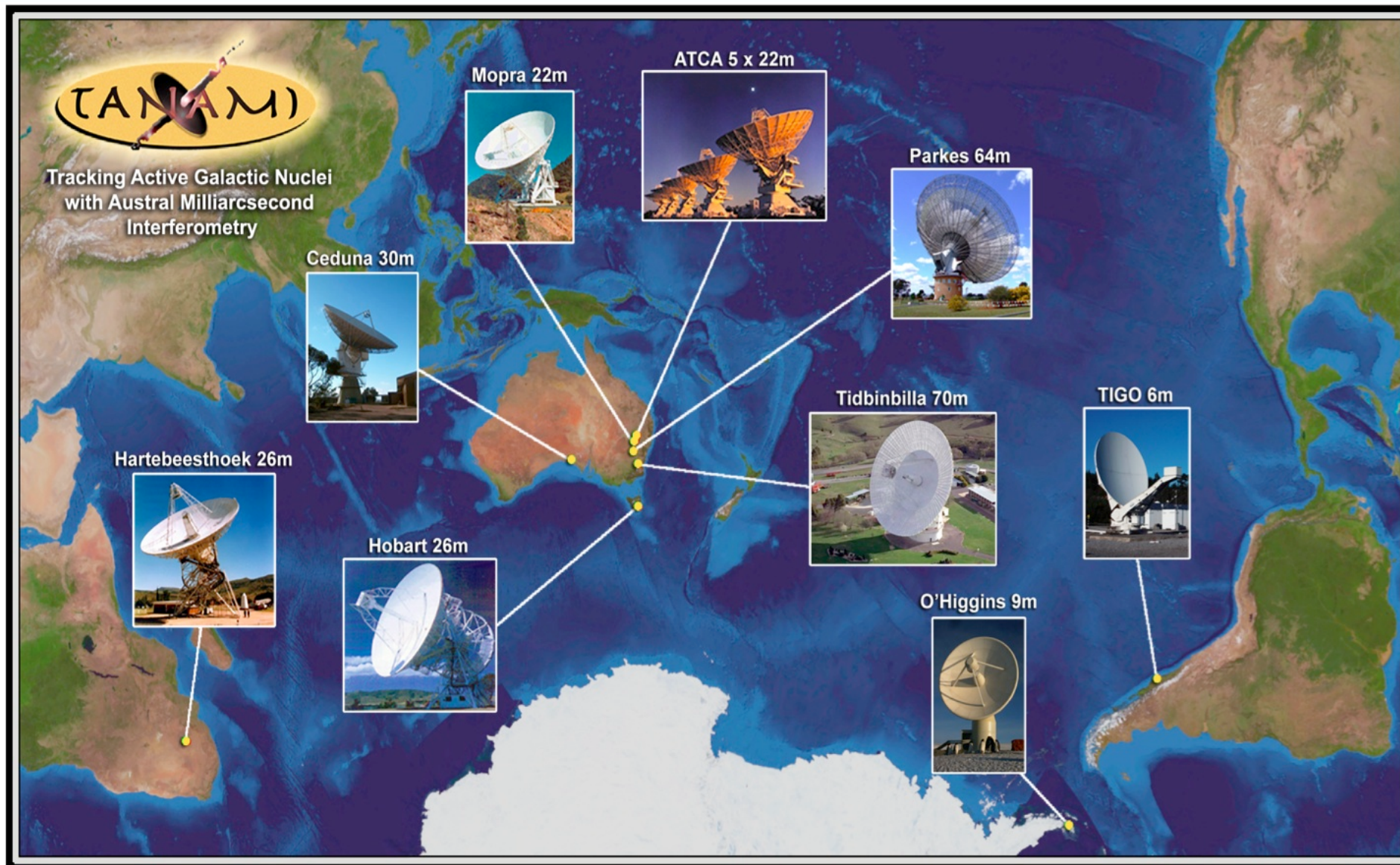
Marcus Langejahn  
Trüstedt

Christian Plötz

Robert Schulz

Jonas

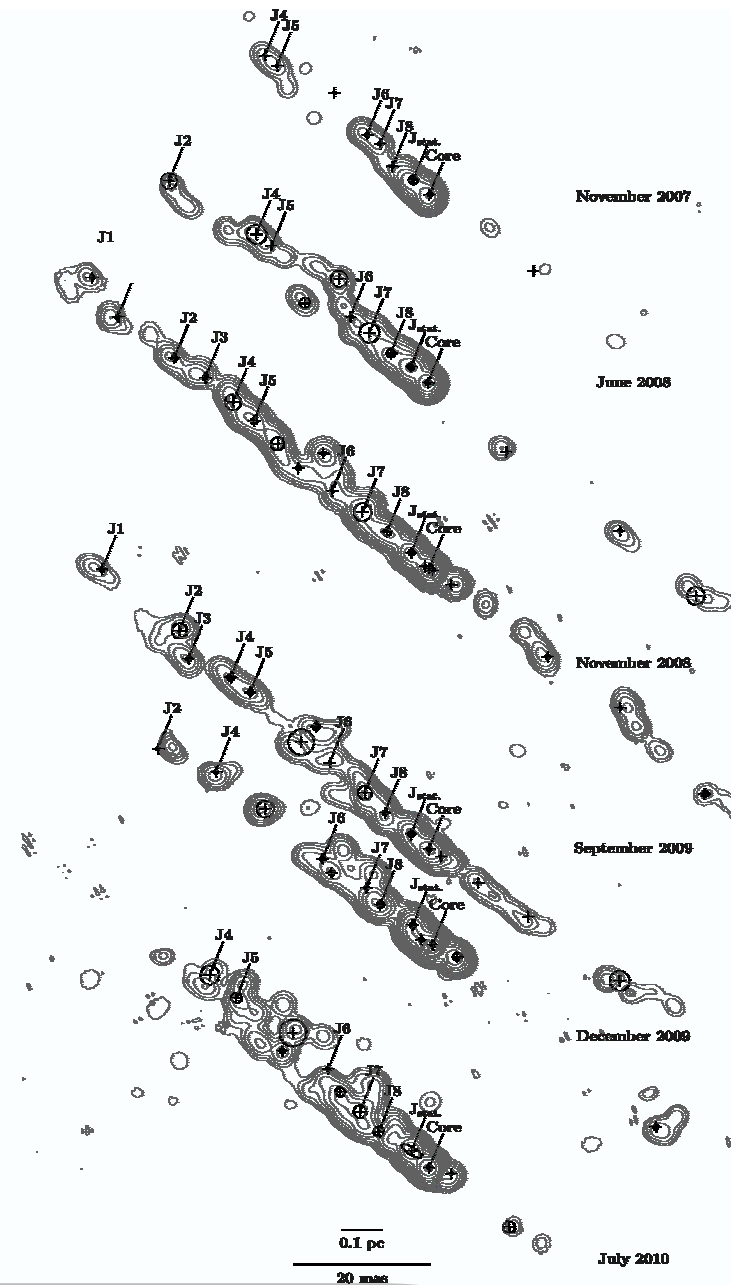




# Kinematics

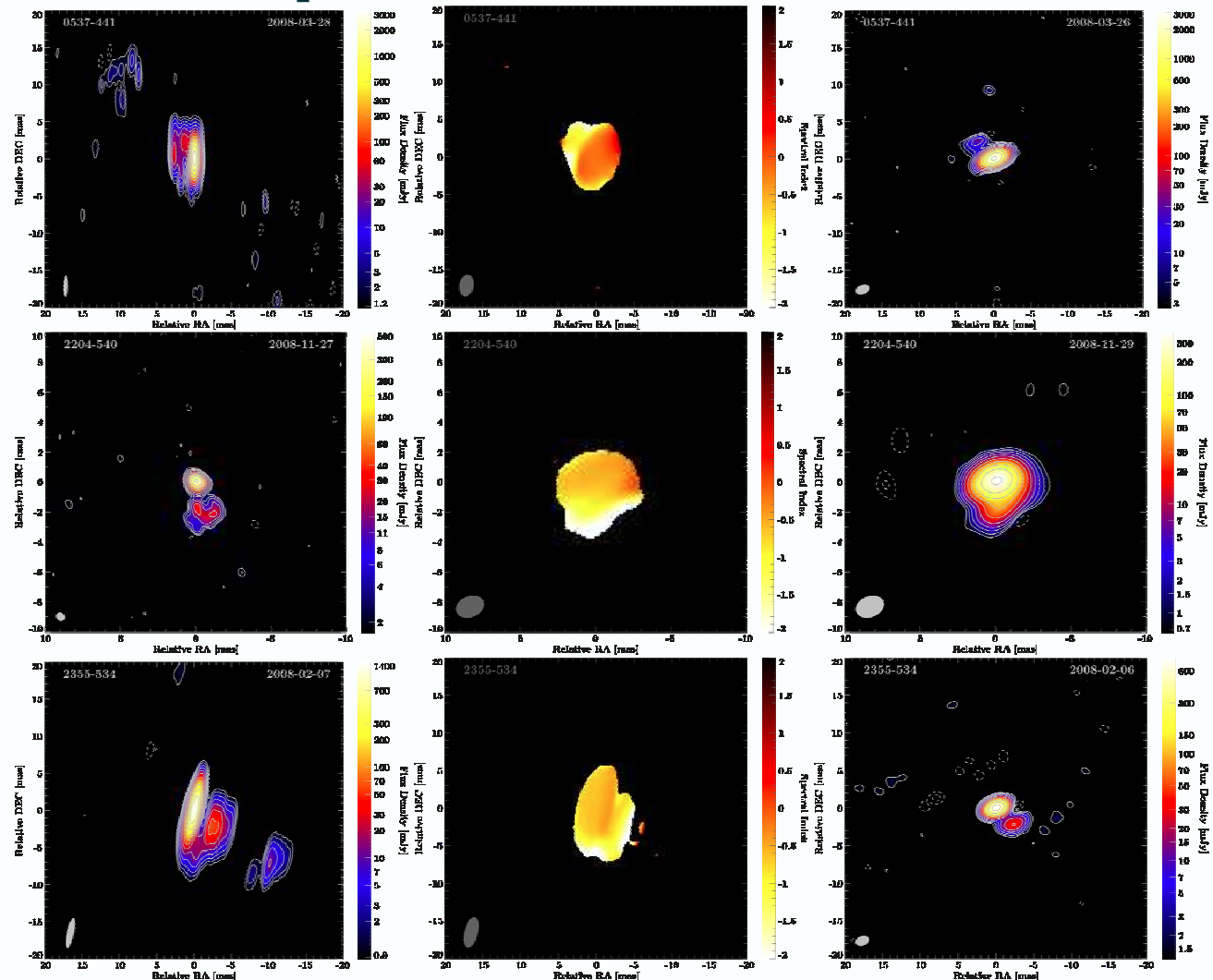
Multi-epoch observations allow component motions to be traced, and extrapolated back to determine ejection epoch.

Cen A (d~4Mpc) allows highest linear resolution studies of a jet.

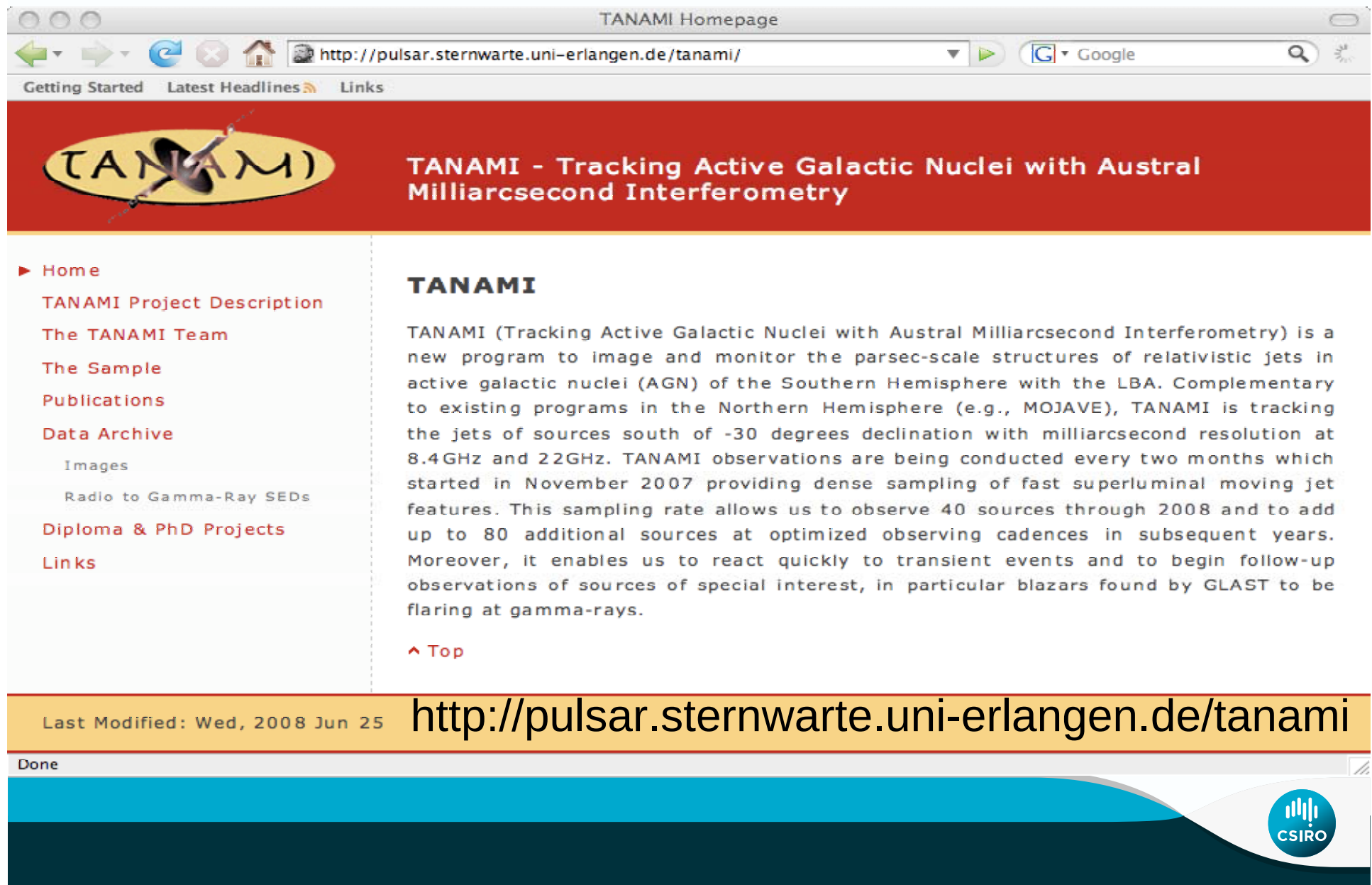


# Spectral Index Maps

Contemporaneous VLBI observations at 8 & 22 GHz allow the spectral index variations across the source to be mapped. From top to bottom: PKS 0537–441, PKS 2204–540, & PKS 2355–534. Spectral indices are derived where the flux densities at 8 GHz and 22 GHz both exceed the  $3\sigma$ -noise level.



# For more information...



The screenshot shows a web browser window titled "TANAMI Homepage". The address bar displays the URL <http://pulsar.sternwarte.uni-erlangen.de/tanami/>. The browser's navigation bar includes "Getting Started", "Latest Headlines", and "Links". The main content area has a red header with the TANAMI logo (a yellow oval with "TANAMI" and a radio telescope dish) and the text "TANAMI - Tracking Active Galactic Nuclei with Austral Milliarcsecond Interferometry". Below the header, the left sidebar contains a list of links: Home, TANAMI Project Description, The TANAMI Team, The Sample, Publications, Data Archive, Images, Radio to Gamma-Ray SEDs, Diploma & PhD Projects, and Links. The main text area, titled "TANAMI", describes the project as a new 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 mentions that TANAMI is tracking the jets of sources south of -30 degrees declination with milliarcsecond resolution at 8.4 GHz and 22 GHz, and that observations started in November 2007. A "Top" link is provided at the bottom of the main text. The footer of the browser window shows "Last Modified: Wed, 2008 Jun 25" and the URL <http://pulsar.sternwarte.uni-erlangen.de/tanami>. The browser's status bar at the bottom indicates "Done" and features the CSIRO logo.

TANAMI Homepage

<http://pulsar.sternwarte.uni-erlangen.de/tanami/> Google

Getting Started Latest Headlines Links

**TANAMI** - Tracking Active Galactic Nuclei with Austral Milliarcsecond Interferometry

► Home

TANAMI Project Description

The TANAMI Team

The Sample

Publications

Data Archive

Images

Radio to Gamma-Ray SEDs

Diploma & PhD Projects

Links

**TANAMI**

TANAMI (Tracking Active Galactic Nuclei with Austral Milliarcsecond Interferometry) is a new program to image and monitor the parsec-scale structures of relativistic jets in active galactic nuclei (AGN) of the Southern Hemisphere with the LBA. Complementary to existing programs in the Northern Hemisphere (e.g., MOJAVE), TANAMI is tracking the jets of sources south of -30 degrees declination with milliarcsecond resolution at 8.4 GHz and 22 GHz. TANAMI observations are being conducted every two months which started in November 2007 providing dense sampling of fast superluminal moving jet features. This sampling rate allows us to observe 40 sources through 2008 and to add up to 80 additional sources at optimized observing cadences in subsequent years. Moreover, it enables us to react quickly to transient events and to begin follow-up observations of sources of special interest, in particular blazars found by GLAST to be flaring at gamma-rays.

▲ Top

Last Modified: Wed, 2008 Jun 25 <http://pulsar.sternwarte.uni-erlangen.de/tanami>

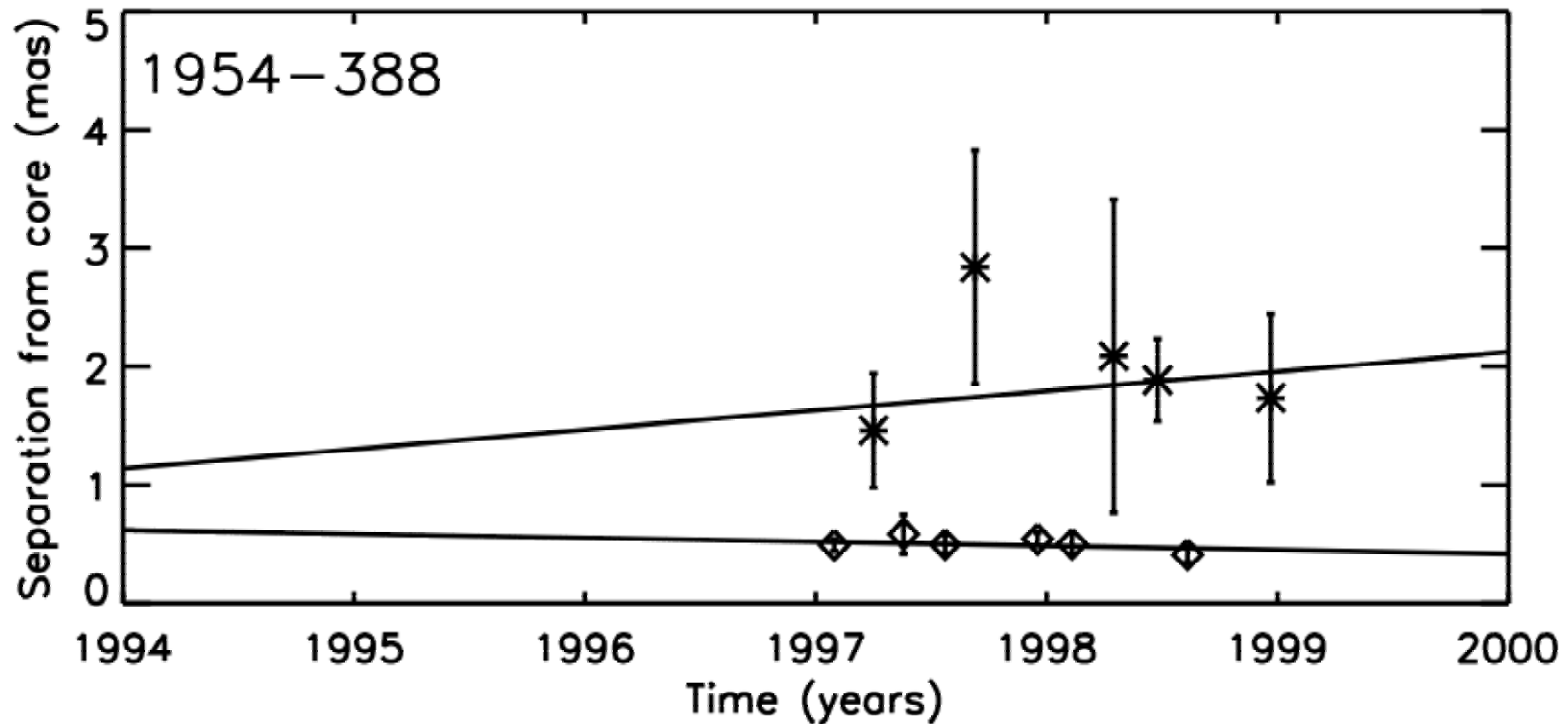
Done

CSIRO

# TANAMI results

- Analysis of the first epoch of TANAMI images (Ojha et al. 2010) found that 13 of 43 Fermi AGN observed at the first TANAMI epochs had source frame brightness temperatures in excess of  $10^{12}$  K, making them ideally suited to RadioAstron observations on baselines extending beyond several Earth diameters.
- These included PKS 0208-512, PKS 0454-463, PKS 0537-441 and PKS 1954-388
- More recent publications include *"TANAMI monitoring of Centaurus A: The complex dynamics within the inner parsec of an extragalactic jet,"* Muller et al. A&A in press (2014) arXiv:1407.0162
- *"TANAMI Blazars in the IceCube PeV Neutrino Fields,"* Krauss et al. 2014, A&A, in press
- *"The unusual multiwavelength properties of the gamma-ray source PMN J1603-4904,"* Mueller et al. 2014, A&A, 562, A4
- *"Multi-Wavelength Observations of PKS 2142-75 during Active and Quiescent Gamma-Ray States,"* Dutka et al. 2013, ApJ 779, 174

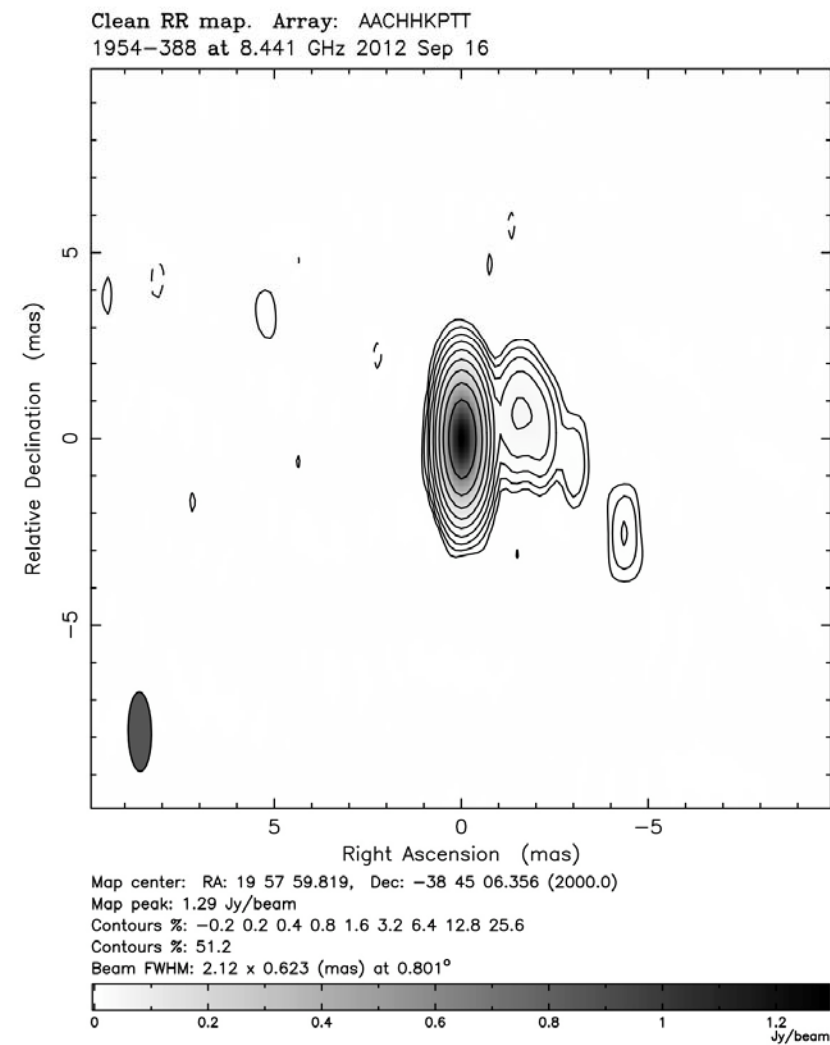
# RRFID analysis (Piner et al. 2007)



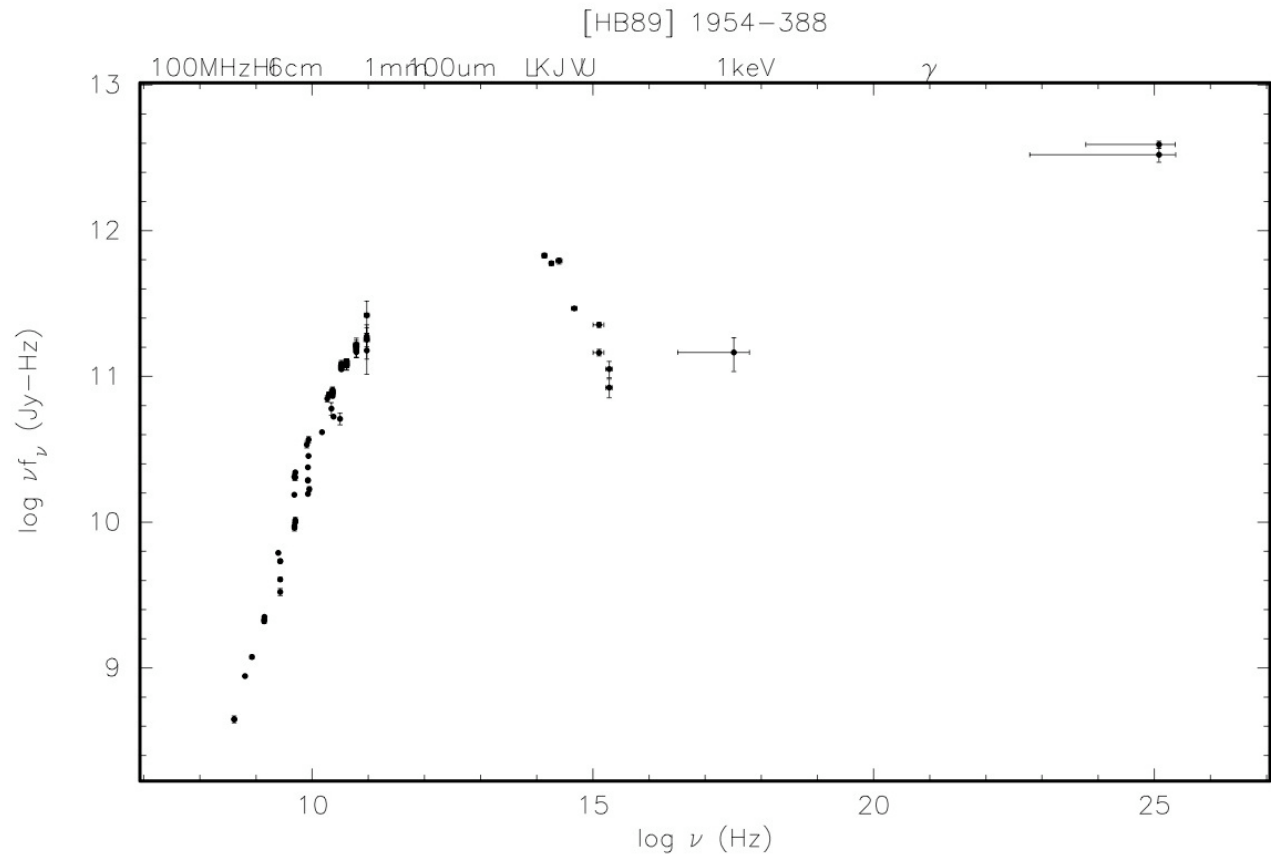
Apparent speeds of  $6 \pm 15c$  and  $-1.2 \pm 1.8c$ .

Revised by Piner et al 2010 to  $3.7 \pm 1.8c$  and  $3.7 \pm 1.0c$

# TANAMI Sep 2012



# Spectral Energy Distribution



NED Tue Jul 15 19:31:56 2014

# RadioAstron observation

Observational code: raes03br

LBA project: V475

Task: AGN fringe survey

2012 August 23 15:45-16:45 UT

Band: C and/or L

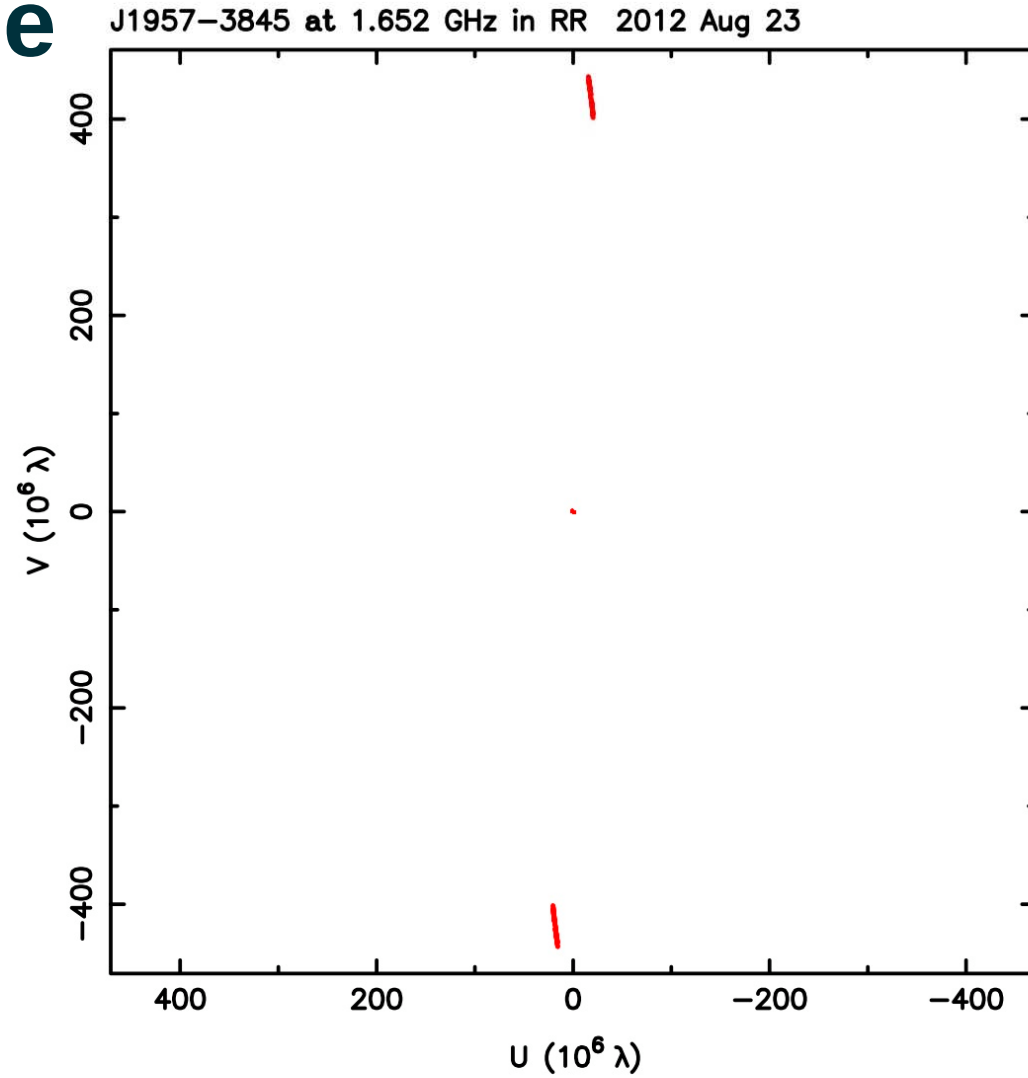
Source: 1954-388

Telescopes: LBA (Parkes, Mopra, ATCA?)

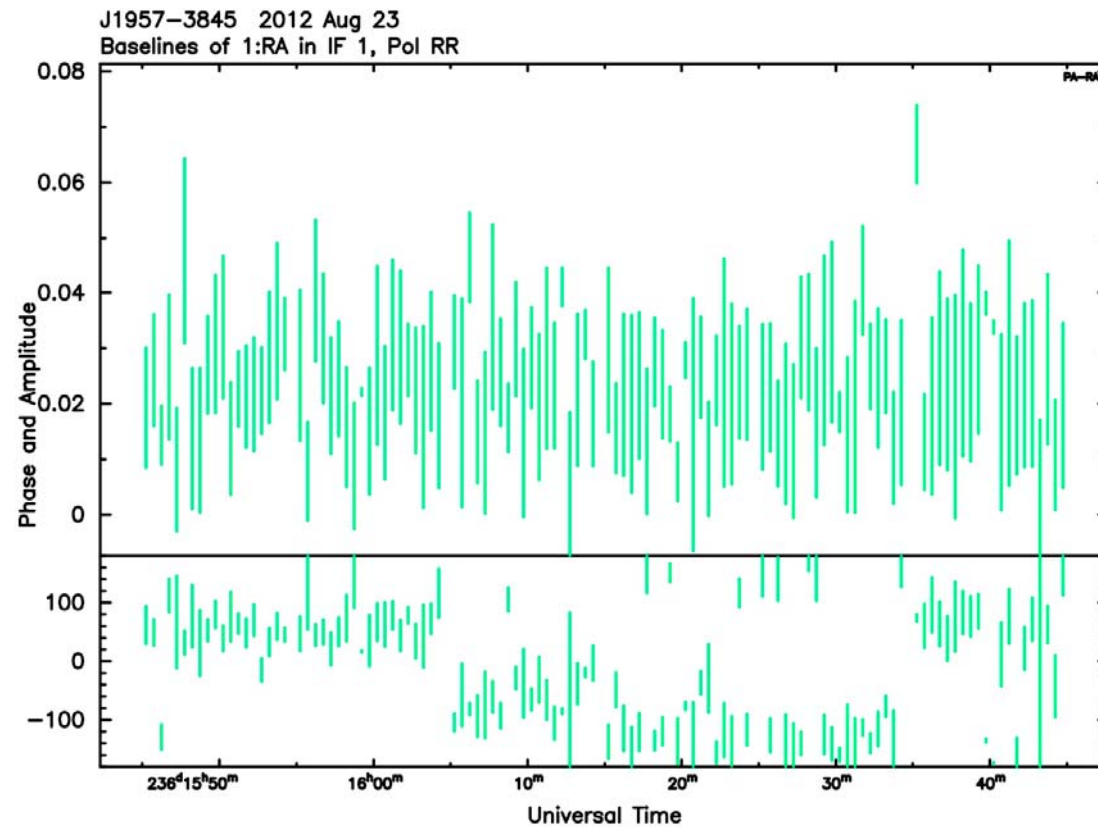
Comment: 5 E\_D

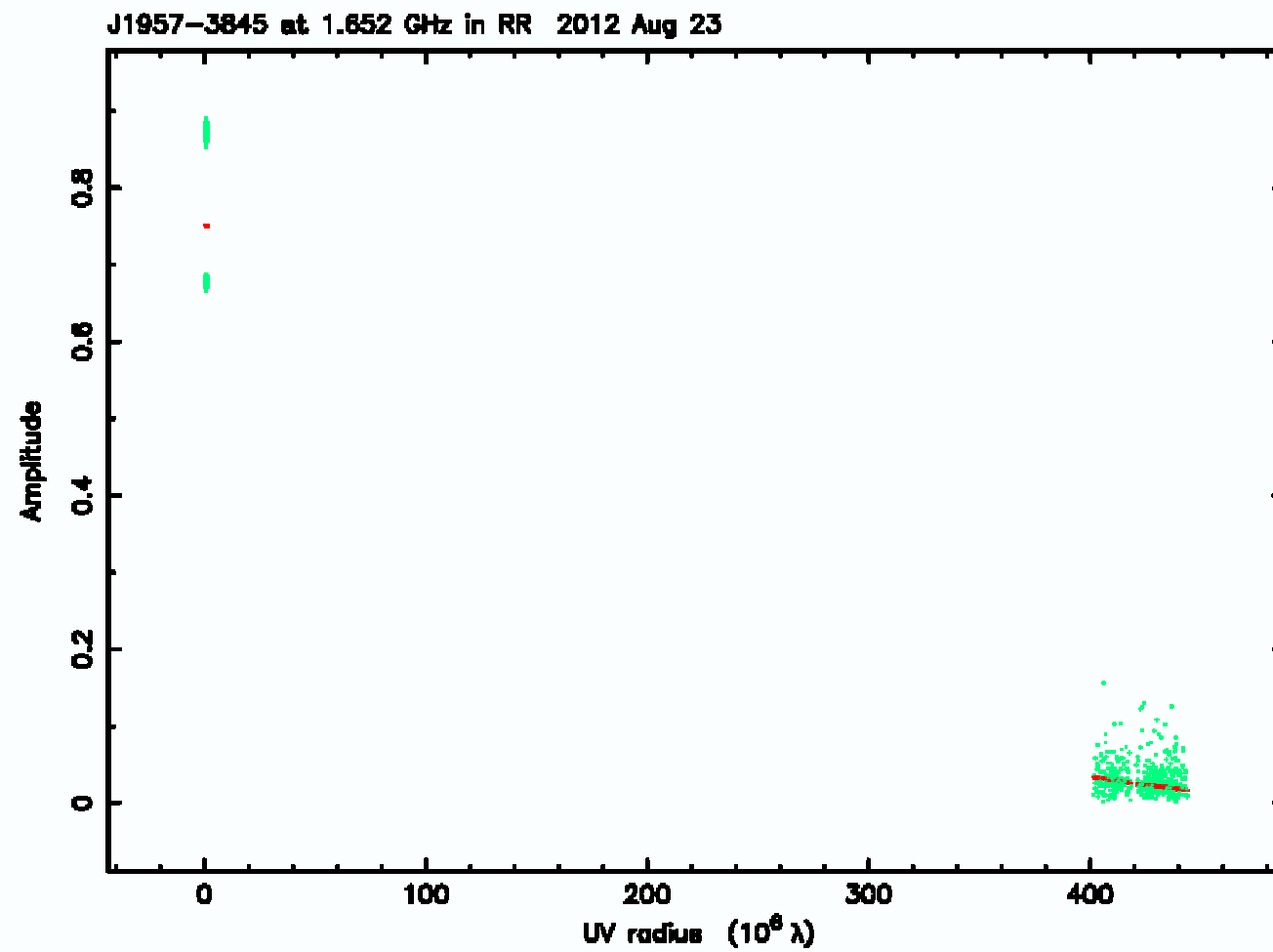
Pushchino tracking station used. Correlated at ASC correlator.

# (u,v) coverage



# Spektr-R to Parkes baseline





# Results

- Source is 0.75 Jy on Parkes-Mopra baseline, and  $\sim 0.03$  Jy on Earth space baselines
- Projected baseline of 420 M-lambda  $\sim 5.6$  Earth diameters
- Model-fit with single circular gaussian component with a flux density of 0.75 Jy and 0.48 mas axes (FWHM).
- For  $z=0.63$ , this yields a source frame brightness temperature of  $2.3 \times 10^{12}$  K
- As source lies at  $l = -29^\circ$ ,  $b = 1.5^\circ$ , would expect some scatter broadening in galactic ISM, so this is a lower limit on real  $T_B$

# Conclusions

- Successful RadioAstron detection in AGN Early Science program
- Minimal (u,v) coverage, but simple model-fit and  $T_B$  estimation
- RadioAstron has succeeded where VSOP was not able to...
- CSIRO budget cuts may impact the availability of Parkes in the future...
- The bottleneck in correlation of other RadioAstron + LBA observations has been in data transfer from CSIRO. This has recently been significantly improved
- Congratulations to the hard-working mission team for making this all possible!

# Thank you

**CASS/ATNF**

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**CSIRO ASTRONOMY AND SPACE SCIENCE**  
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