The TANAMI Program
Southern-Hemisphere AGN on (Sub-)Parsec Scales

Cornelia Müller

Dr. Karl Remeis Observatory Bamberg & ECAP, FAU Erlangen/Nürnberg, JMU Würzburg

in collaboration with

M. Kadler, R. Ojha, J. Wilms & the TANAMI Team

FERMI and JANSKY - November 10th, 2011
Tracking Active Galactic Nuclei with Austral Milliarcsecond Interferometry

- bimonthly VLBI monitoring of extragalactic jets south of $\delta = -30^\circ$ since 2007
- simultaneous dual-frequency observations at 8.4 & 22.3 GHz
- dual-freq. observations with LBA, NASA's DSN, Hartebeesthoek
- additional 8.4 GHz monitoring with GARS, TIGO & Warkworth
Source Selection

- Initially: hybrid radio & γ-ray selected sample of southern extragalactic jets
  - γ-ray loud sub-sample based on EGRET results
  - Flux limited radio loud subsample

→ New Fermi/LAT detected sources continuously added
→ Initially 43, currently 79 sources
Multiwavelength Approach

- contemporaneous high resolution VLBI monitoring at 8 & 22 GHz
  → evolution of simultaneous spectral index maps at pc scales

TANAMI images: simultaneous 8.4 & 22.3 GHz, spectral index map (Kadler et al. in prep.)

more about PKS 0208-512 in J. Blanchard’s talk!
in addition to dual-frequency VLBI monitoring…

- *Fermi/LAT*
- pointed observations with *RXTE*
- *Swift* survey program
- optical program with *Rapid Eye Mount* (REM, INAF)
- flux density monitoring with ATCA
- Ceduna-Hobart Interferometer (CHI)

→ time evolution of simultaneous SEDs
→ SED modeling by NRL & University of Würzburg

quasi-simultaneous SED of PKS 2142-75
→ see M. Dutka’s poster
First Results

http://pulsar.sternwarte.uni-erlangen.de/tanami/pubs

- Ojha et al. 2010: first 8.4 GHz-epoch paper
- first-ever VLBI images for some of newly added Fermi-bright sources
- contributions to simultaneous broadband SEDs of several sources
• contributions to LAT-publications: PKS 1454-354, SED paper, Cen A core, ...

• TANAMI-1FGL-analysis (led by M. Böck):
  - 55/75 sources LAT-detected
  - all 8 BL Lacs but only 24/32 Quasars (75%)
  - similar result as for MOJAVE
  - upper limits on γ-ray fluxes for TANAMI sources not detected by LAT
  - 2 new detections beyond 1FGL

• high resolution observations of the γ-ray bright galaxy Centaurus A ...

More information:
http://pulsar.sternwarte.uni-erlangen.de/tanami
- four 8.4 GHz observations
- one simultaneous 22.3 GHz epoch
- closest AGN: $d \sim 3.8$ Mpc
  $\Rightarrow 1 \text{ mas} \equiv 0.018 \text{ pc}$

$\left( u, v \right)$-coverage for Cen A
$\Rightarrow \alpha \approx \left( 0.4 \times 0.7 \right) \text{ mas at 8.4 GHz}$
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\((u, v)-\text{coverage for Cen A}\)
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First dual-frequency images of Cen A:

→ Resolve innermost mas-scale jet into discrete components at both frequencies
→ Well collimated jet at P.A. $\sim 50^\circ$ with opening angle $\lesssim 12^\circ$
→ Study spectral changes at sub-parsec scales
High resolution spectral index map
Core shift of $\Delta \alpha_{rel} = -0.25\,\text{mas}$
$\Delta \delta_{rel} = -0.2\,\text{mas}$
Inverted spectrum in core region
Remarkable flat spectrum over inner few mas of jet
Multiple optically thick emission regions

What are the productions sites of the $\gamma$-rays?

(SED of Cen A core emission)

- quasi-simultaneous + archival data
- LAT accuracy $\sim 0.1$°
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(SED of Cen A core emission

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$\rightarrow$ Constraints on emission models of broadband SEDs

$\rightarrow$ Multiple possible regions of high energy emission

(Abdo et al. 2010)
Cen A Jet Kinematics at Sub-parsec Scales

Tingay et al. 2001

C. Müller et al. 2011, in prep.
Cen A Jet Kinematics at Sub-parsec Scales

Tingay et al. 2001

C. Müller et al. 2011, in prep.
- complex substructure
- stationary component at $\sim 3.5$ mas
- jet widening & flux decrease at $\sim 23$ mas
mean apparent jet speed $v_{\text{app,mean}} \approx 2.7 \text{ mas/yr} \approx 0.16c$

moderate peak-flux variability

differential motion: fastest component with $v_{\text{app}} \approx 4 \text{ mas/yr}$
For whole TANAMI sample:

- First spectral index maps and kinematics for all sources
- Joint Fermi analysis
- Studies on individual sources
- New telescopes: Katherine (Northern Territory), ASKAP & Yarragadee (Western Australia)

For Cen A:

- Proper motion analysis for jet and counterjet
- Evolution of spectral index
- Provide key parameters for broadband emission models
• TANAMI is the *only* large VLBI monitoring program of southern AGN
• bimonthly, simultaneous dual-frequency observations
• complementary multiwavelength observations

• Cen A: best-ever image of an AGN jet
• sub-parsec scale spectral index map
• multiple possible production sites of $\gamma$-rays