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

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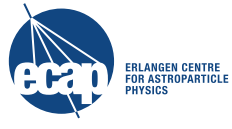
in collaboration with

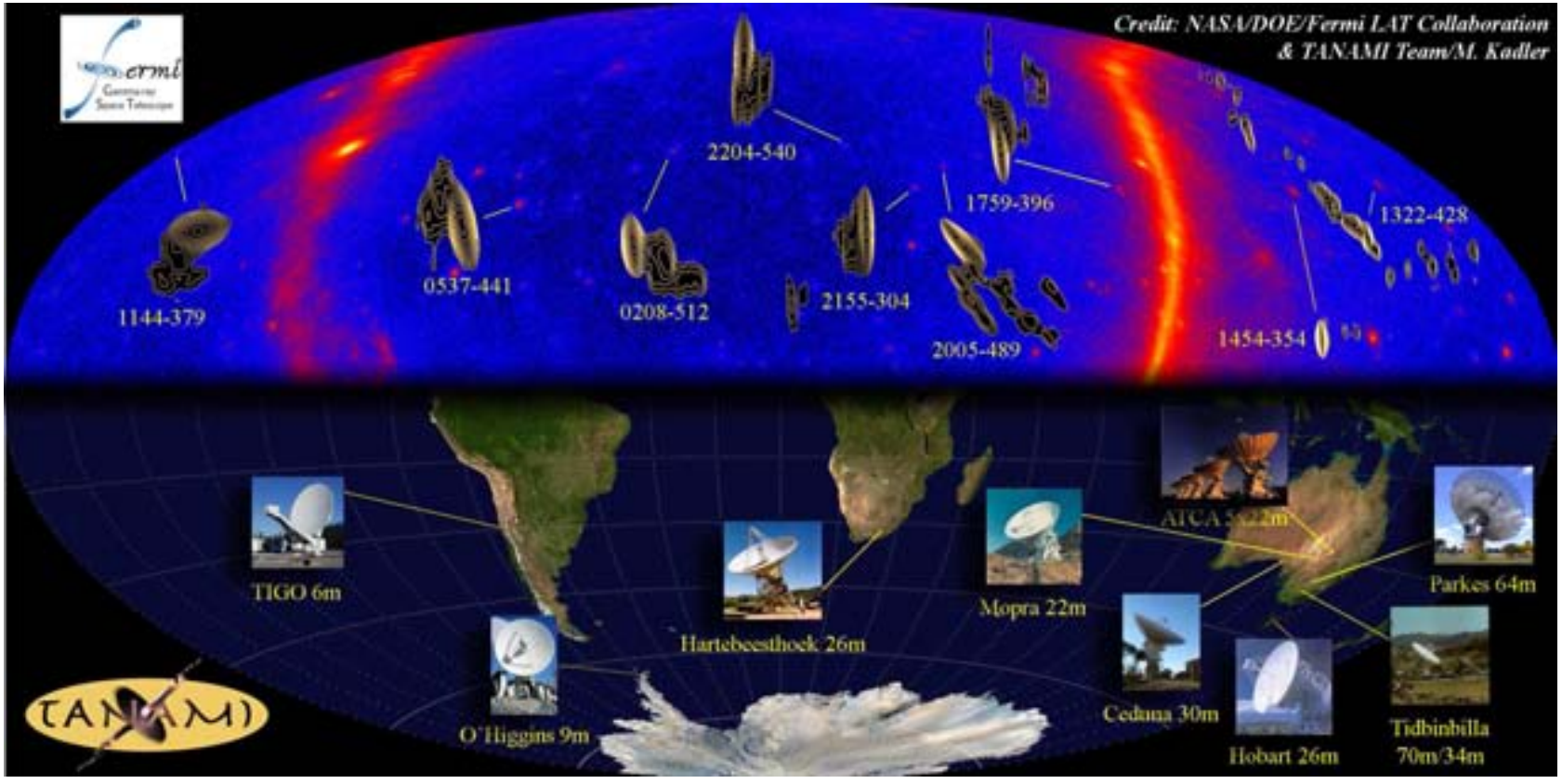
M. Kadler, R. Ojha, J. Wilms & the TANAMI Team

FERMI and JANSKY - November 10$^{\mathrm{th}}$, 2011



The TANAMI Program

Tracking **A**ctive **G**alactic **N**uclei with **A**ustral **M**illiarcsecond **I**nterferomerty

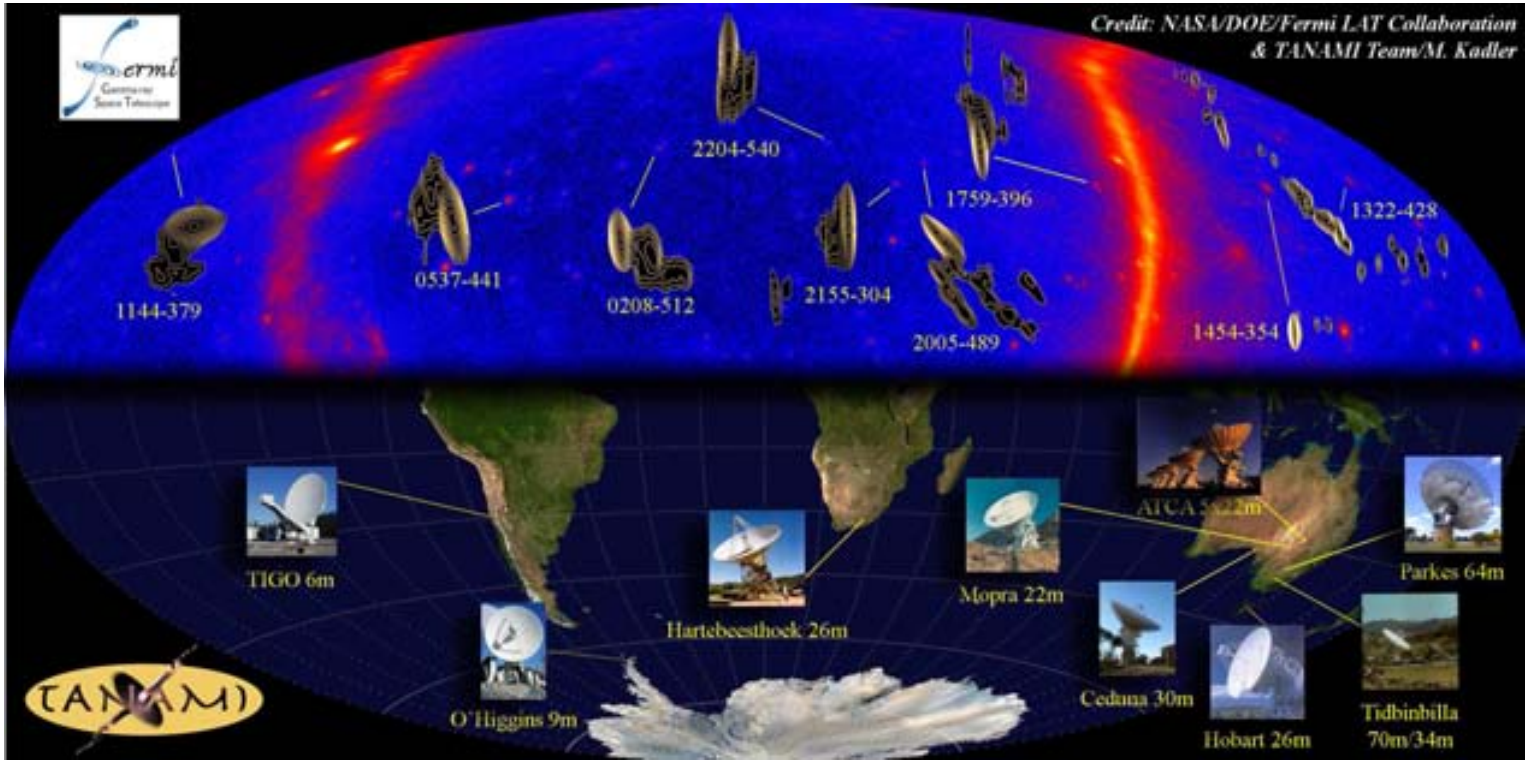


- bimonthly VLBI monitoring of extragalactic jets south of $\delta = -30^\circ$ since 2007
- simultaneous dual-frequency observations at 8.4 & 22.3 GHz

The TANAMI Array

- 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

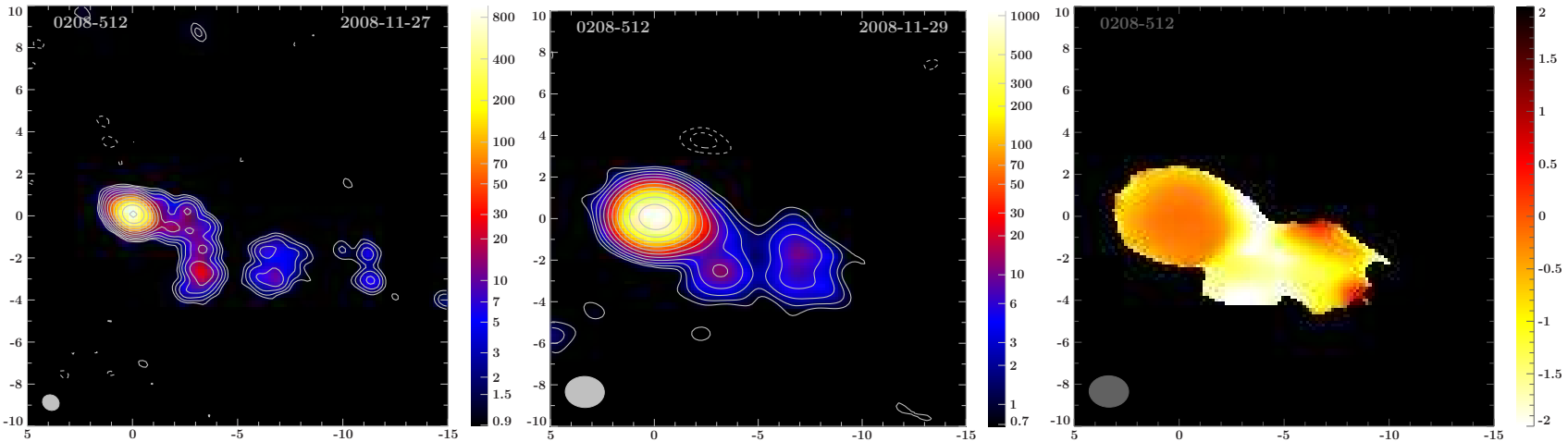
$\rightarrow$ new *Fermi*/LAT detected sources continuously added

$\rightarrow$ 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!

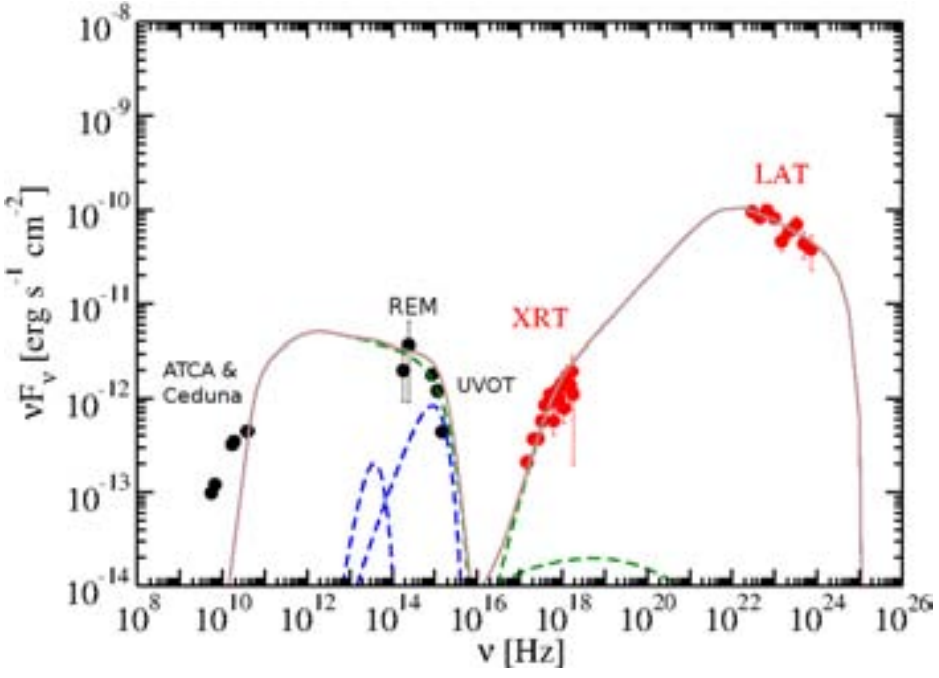
Multiwavelength Approach

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

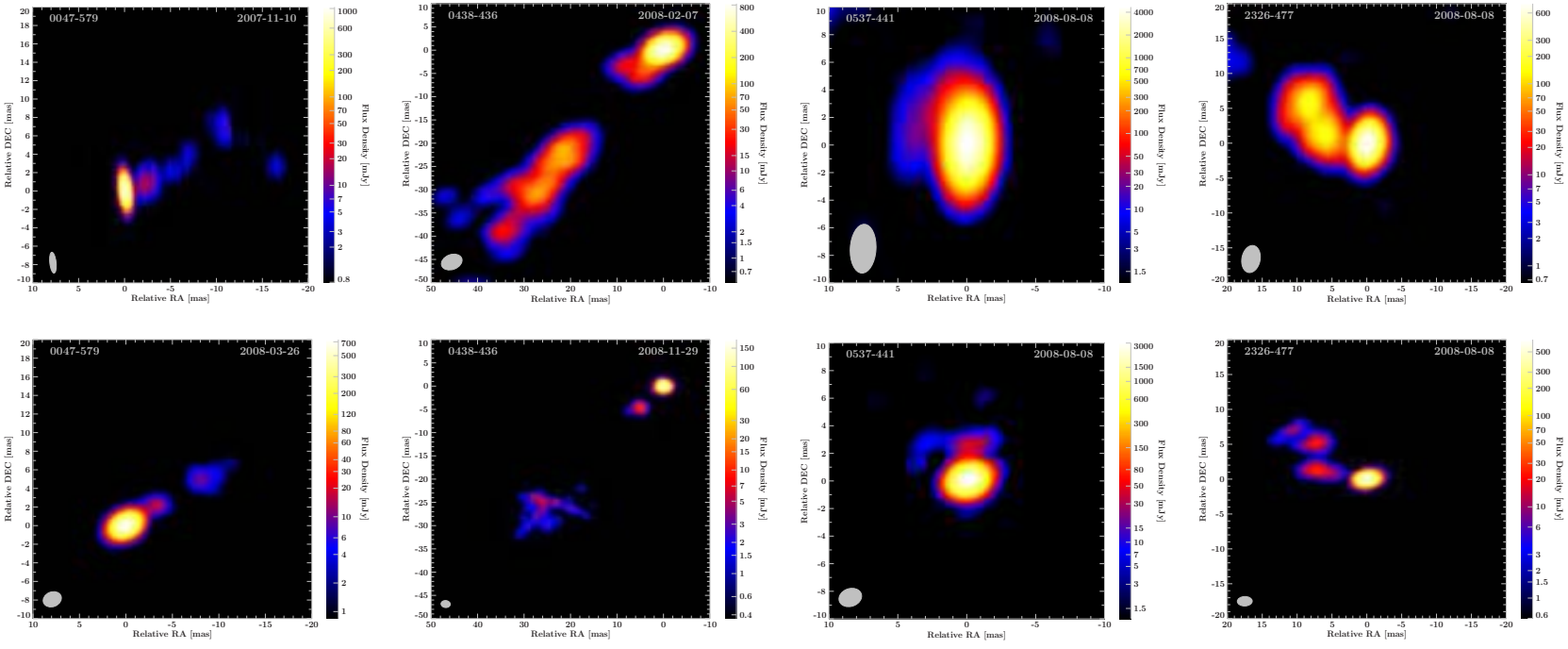


quasi-simultaneous SED of PKS 2142-75

→ see M. Dutka's poster

First Results

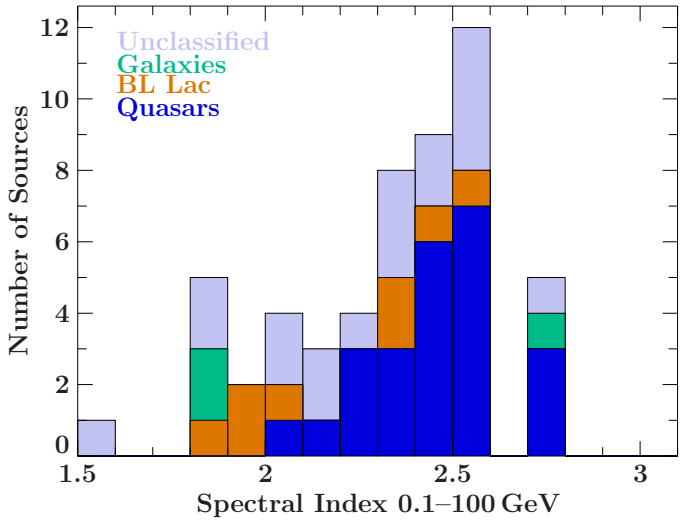
http://pulsar.sternwarte.uni-erlangen.de/tanami/pubs



- 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

First Results

- 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 ...



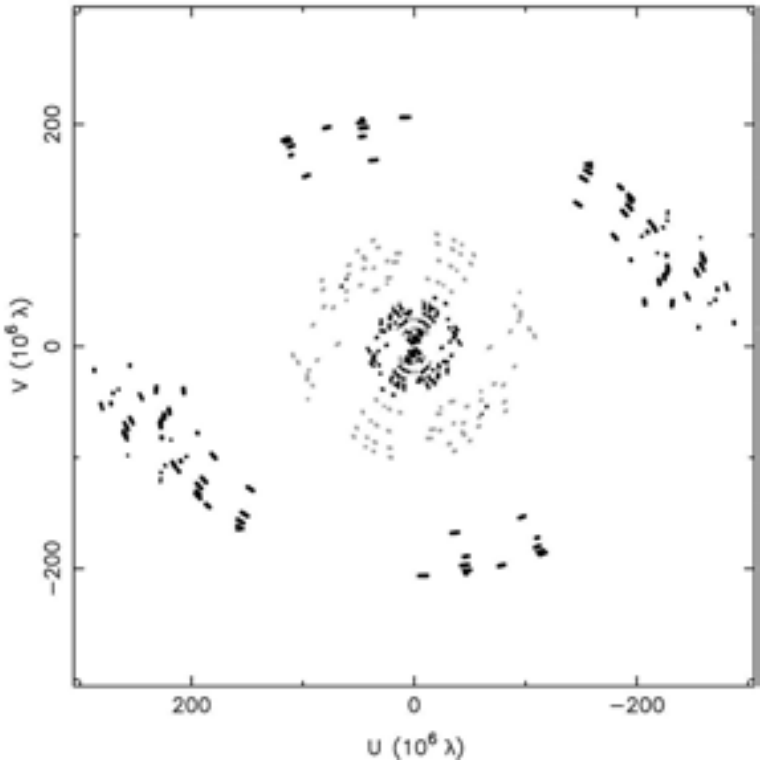
γ-ray spectral index distribution of TANAMI sources
(preliminary, M. Böck)

More information:

`http://pulsar.sternwarte.uni-erlangen.de/tanami`
Ojha et al. 2010, A&A, 519, A45

TANAMI observations of Centaurus A

- four 8.4 GHz observations
- one simultaneous 22.3 GHz epoch
- closest AGN: $\mathrm{d} \sim 3.8$ Mpc
  $\Rightarrow$ 1 mas $\widehat{=}$ 0.018 pc



(u, v)-coverage for Cen A
$\Rightarrow \alpha \approx (0.4 \times 0.7)$ mas at 8.4 GHz

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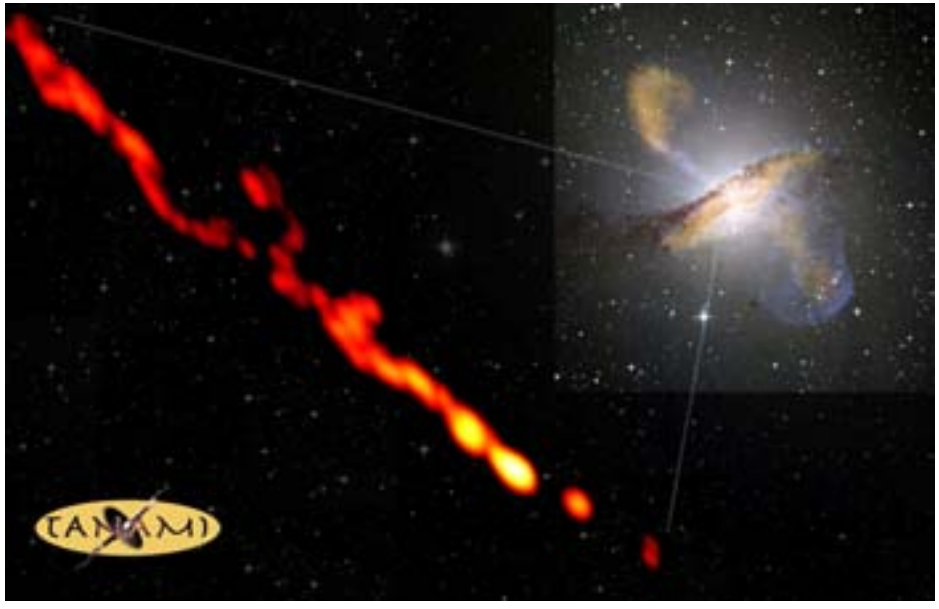

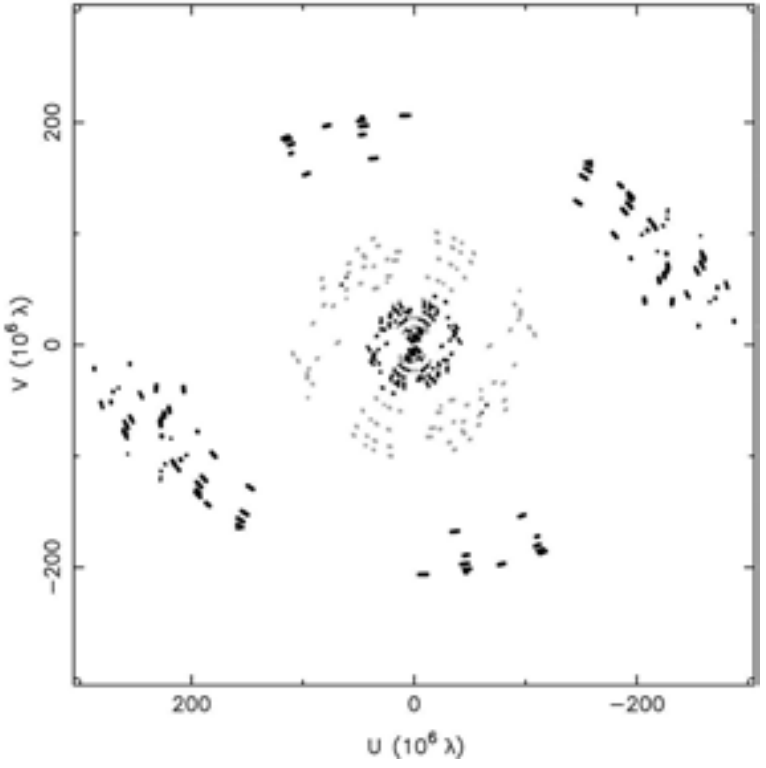

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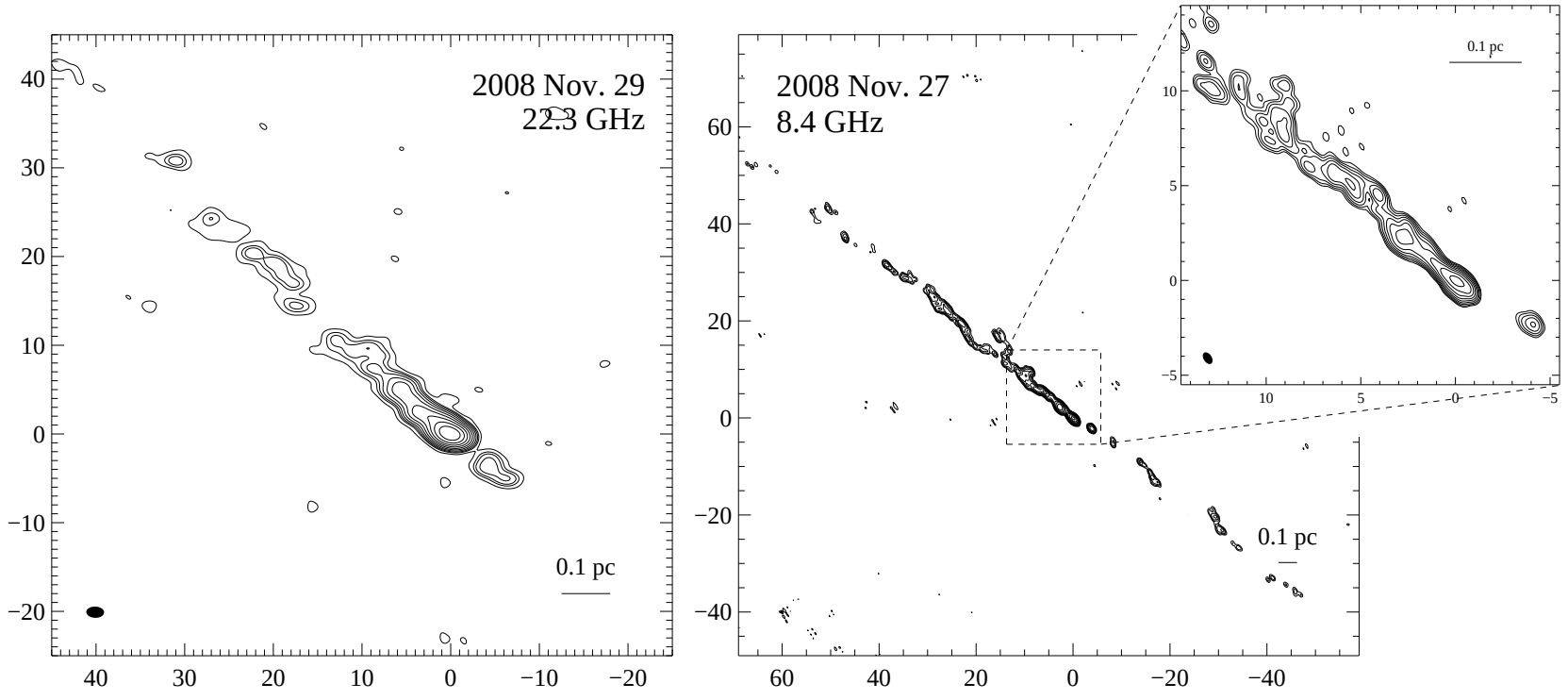
Simultaneous Dual-frequency Images of Cen A

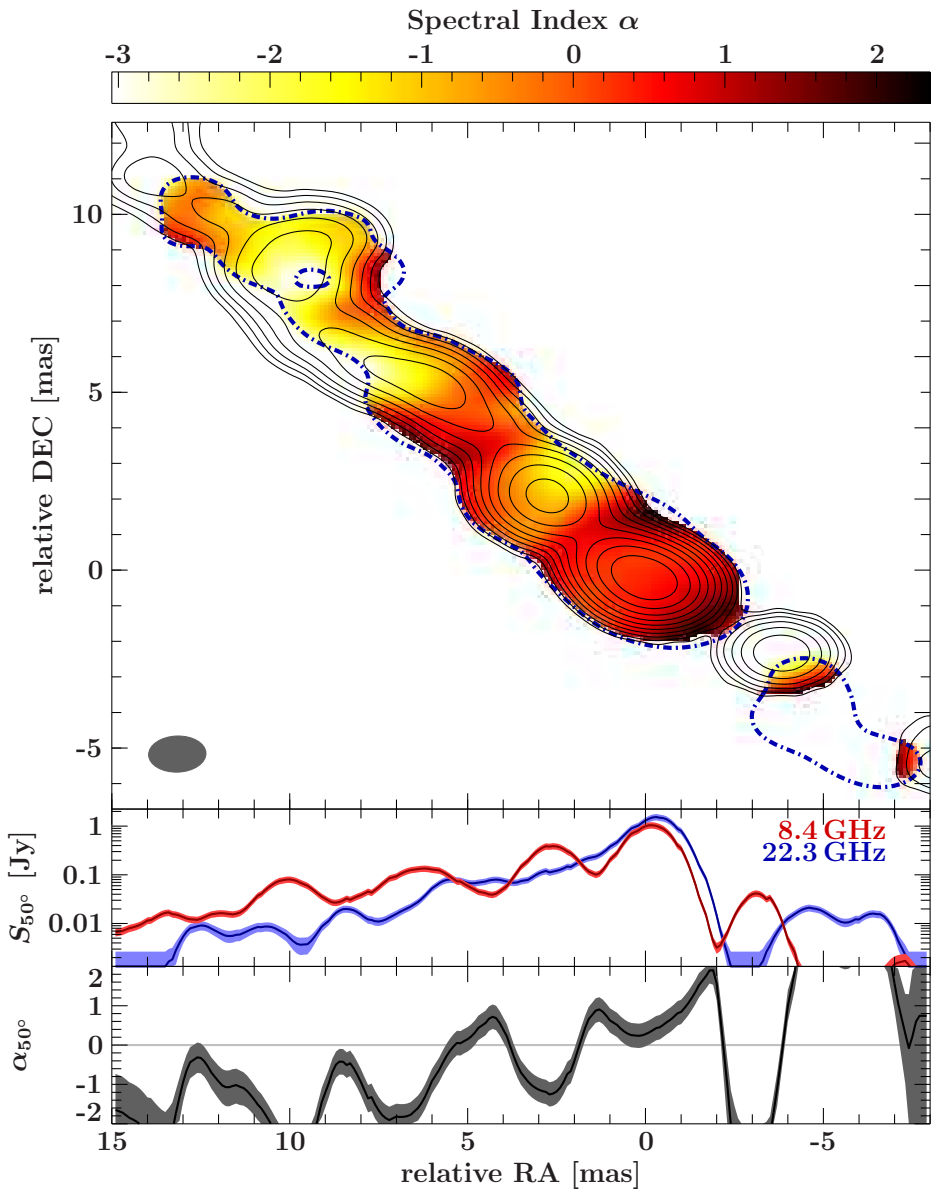


C. Müller et al. 2011, A&A, 530, L11

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

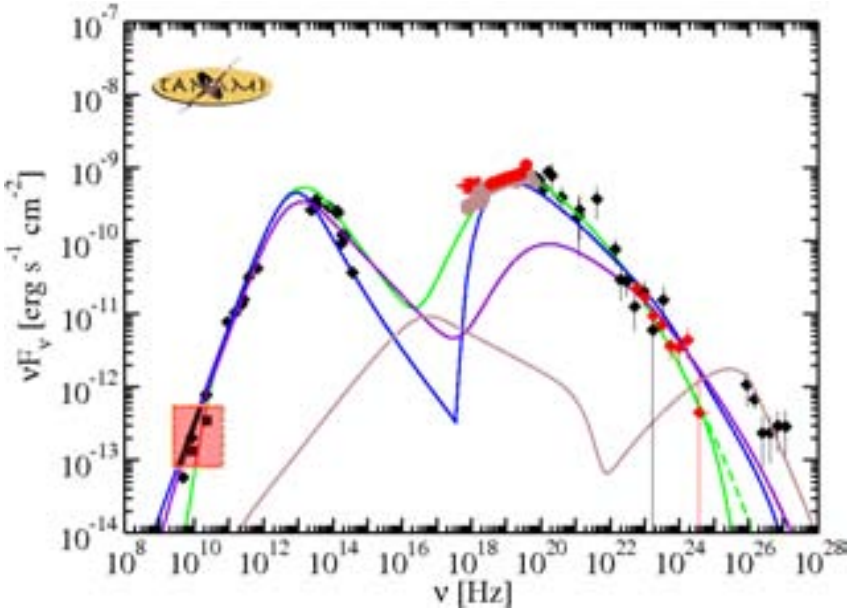
Spectral Index Map of Cen A's Sub-pc Scale Jet



C. Müller et al. 2011, A&A, 530, L11

- High resolution spectral index map
- Core shift of $\Delta\alpha_{rel} = -0.25\,\mathrm{mas}$ $\Delta\delta_{rel} = -0.2\,\mathrm{mas}$
- 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 γ-rays?



(Abdo et al. 2010)

SED of Cen A core emission

- quasi-simultaneous + archival data
- LAT accuracy $\sim 0.^\circ 1$

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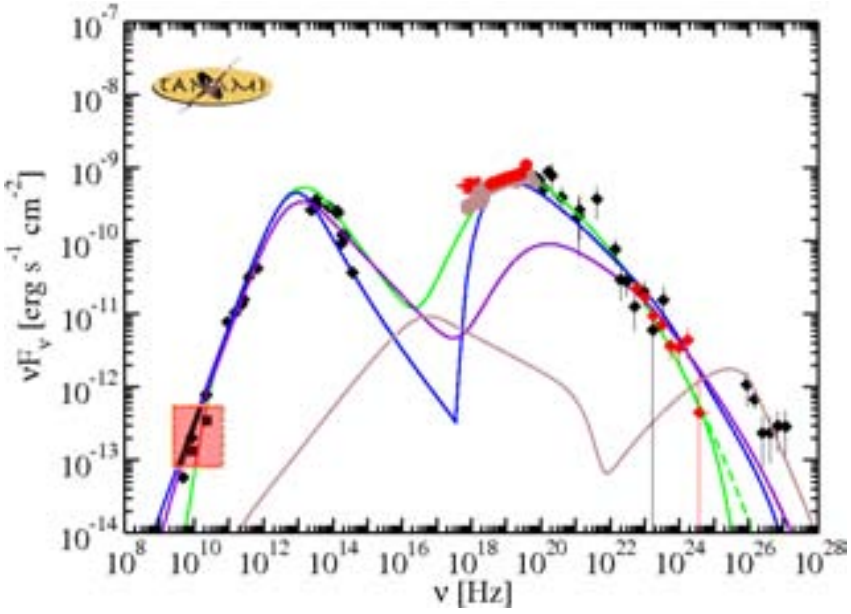

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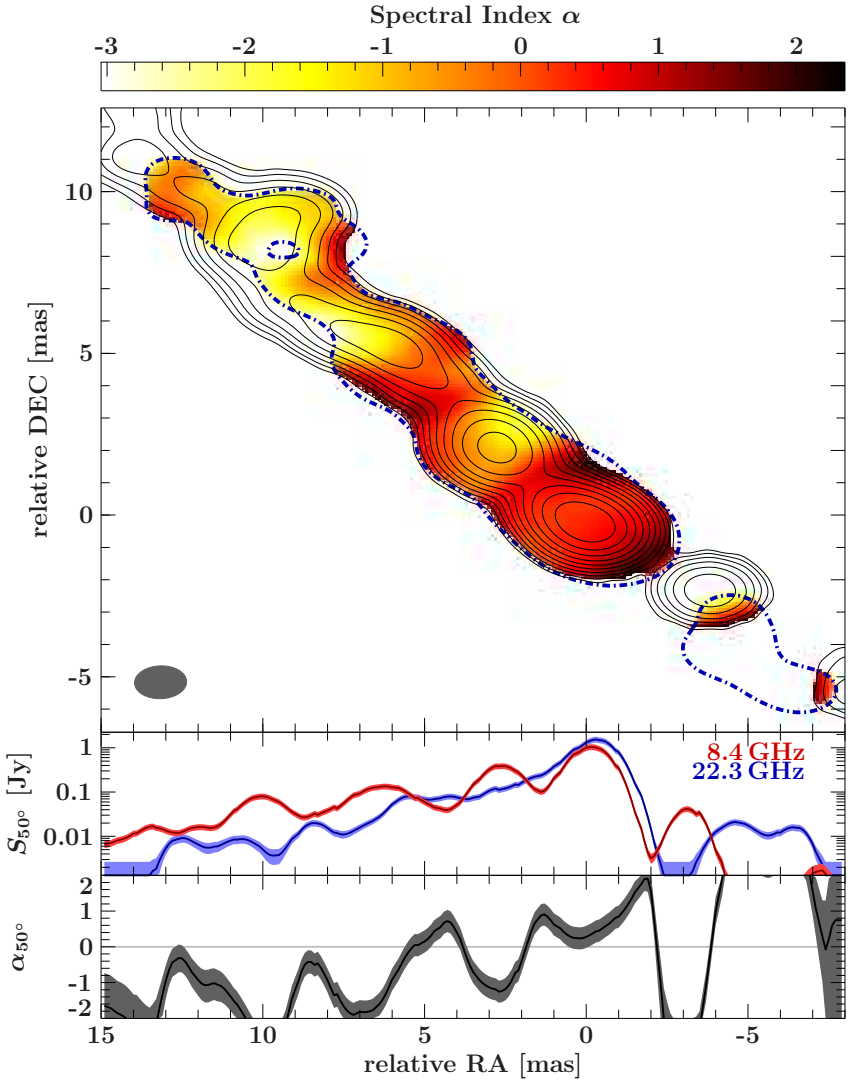
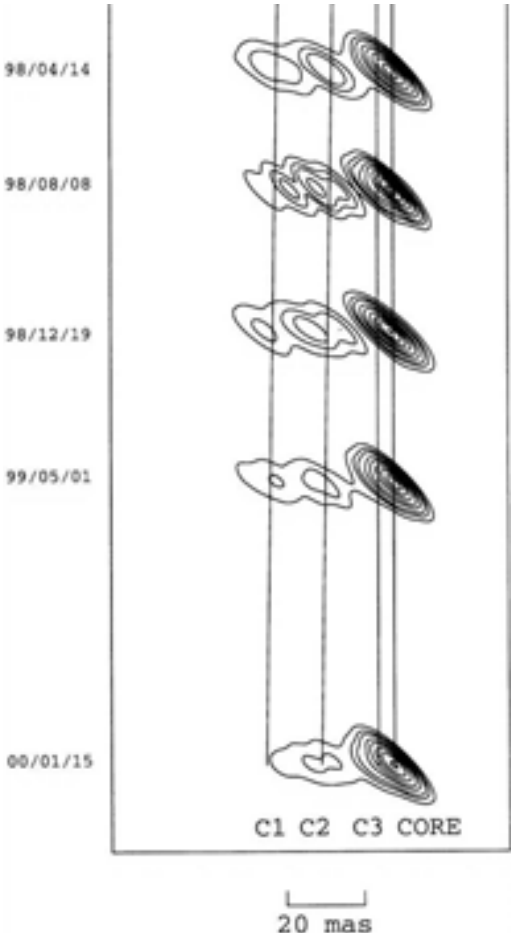
→ Constraints on emission models of broadband SEDs

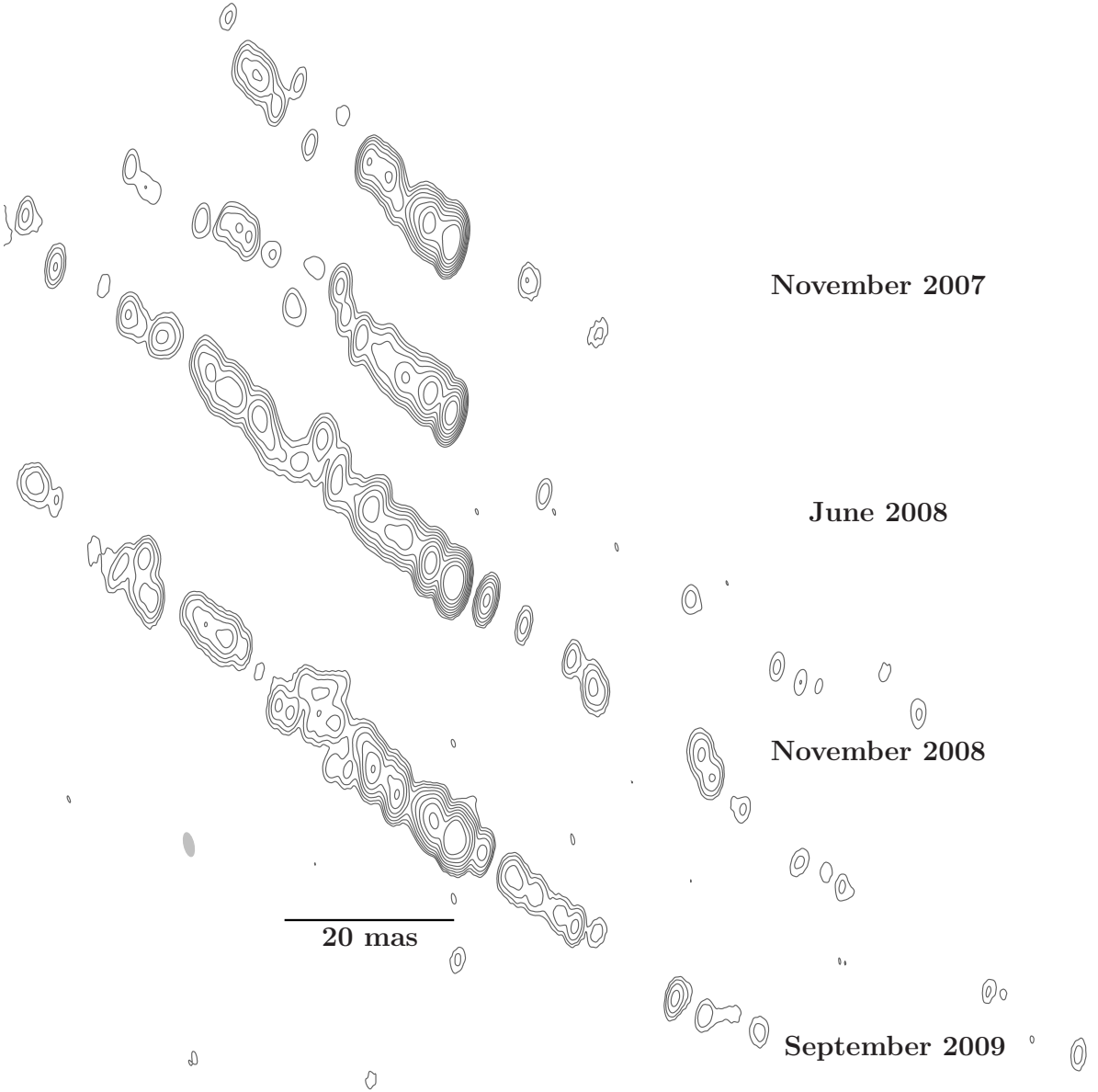


→ Multiple possible regions of high energy emission

Cen A Jet Kinematics at Sub-parsec Scales



Tingay et al. 2001



C. Müller et al. 2011, in prep.

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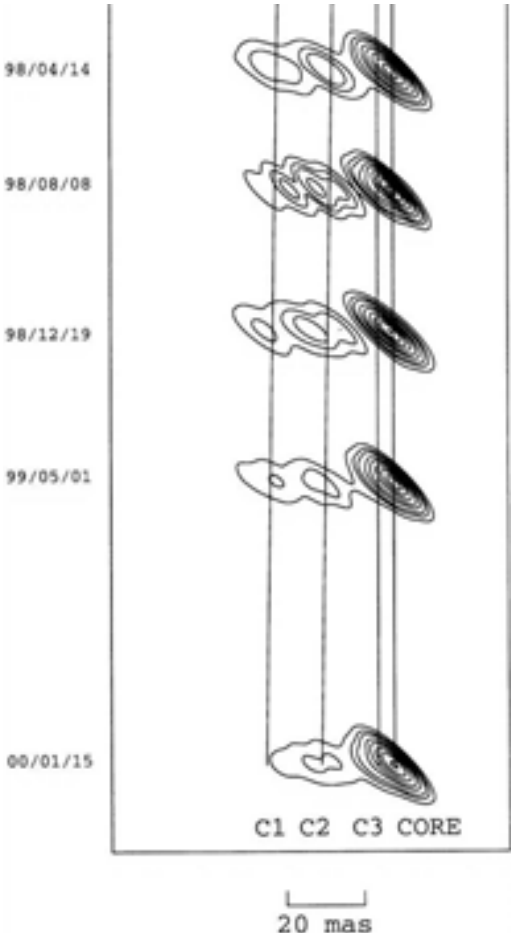

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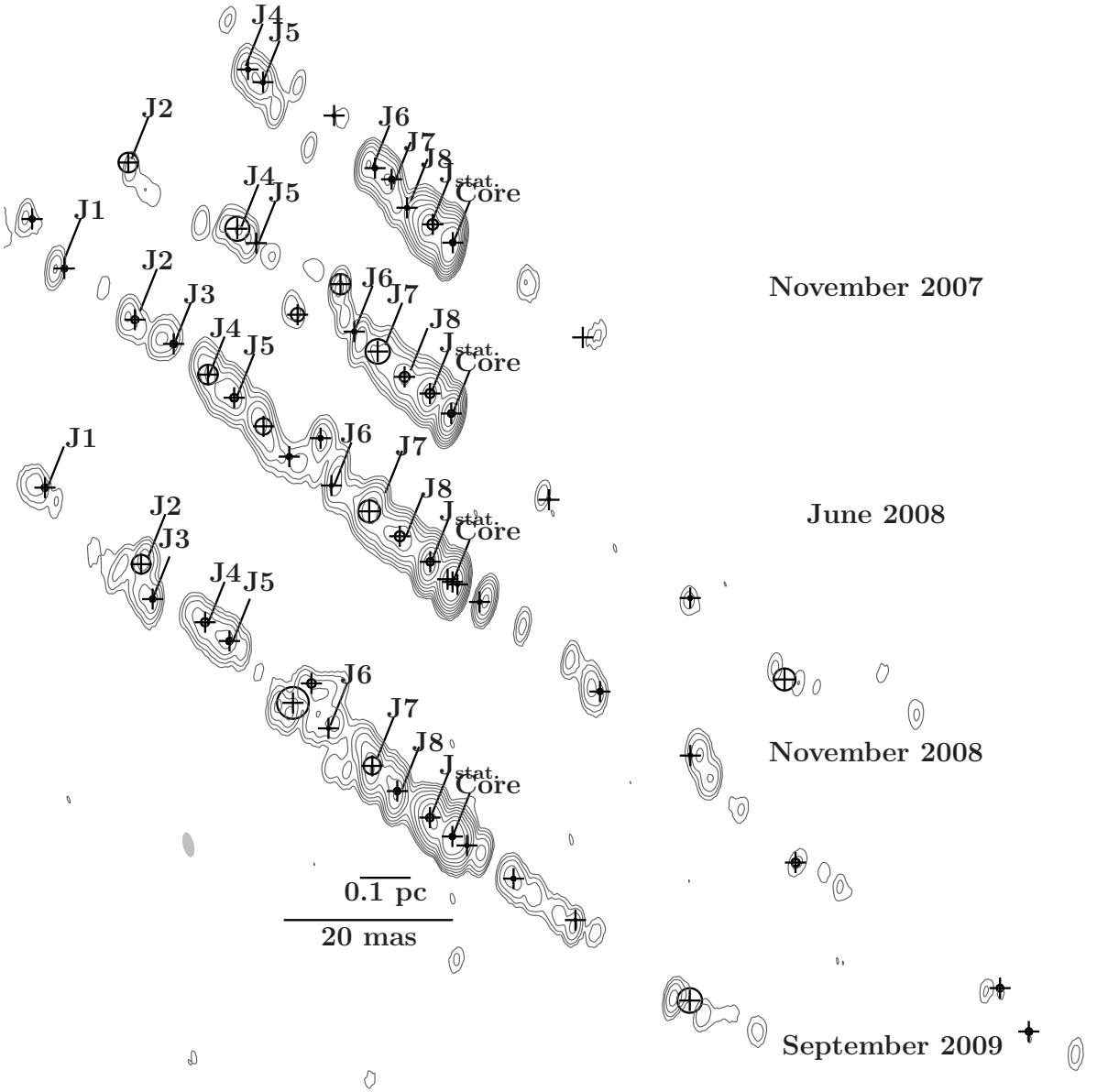

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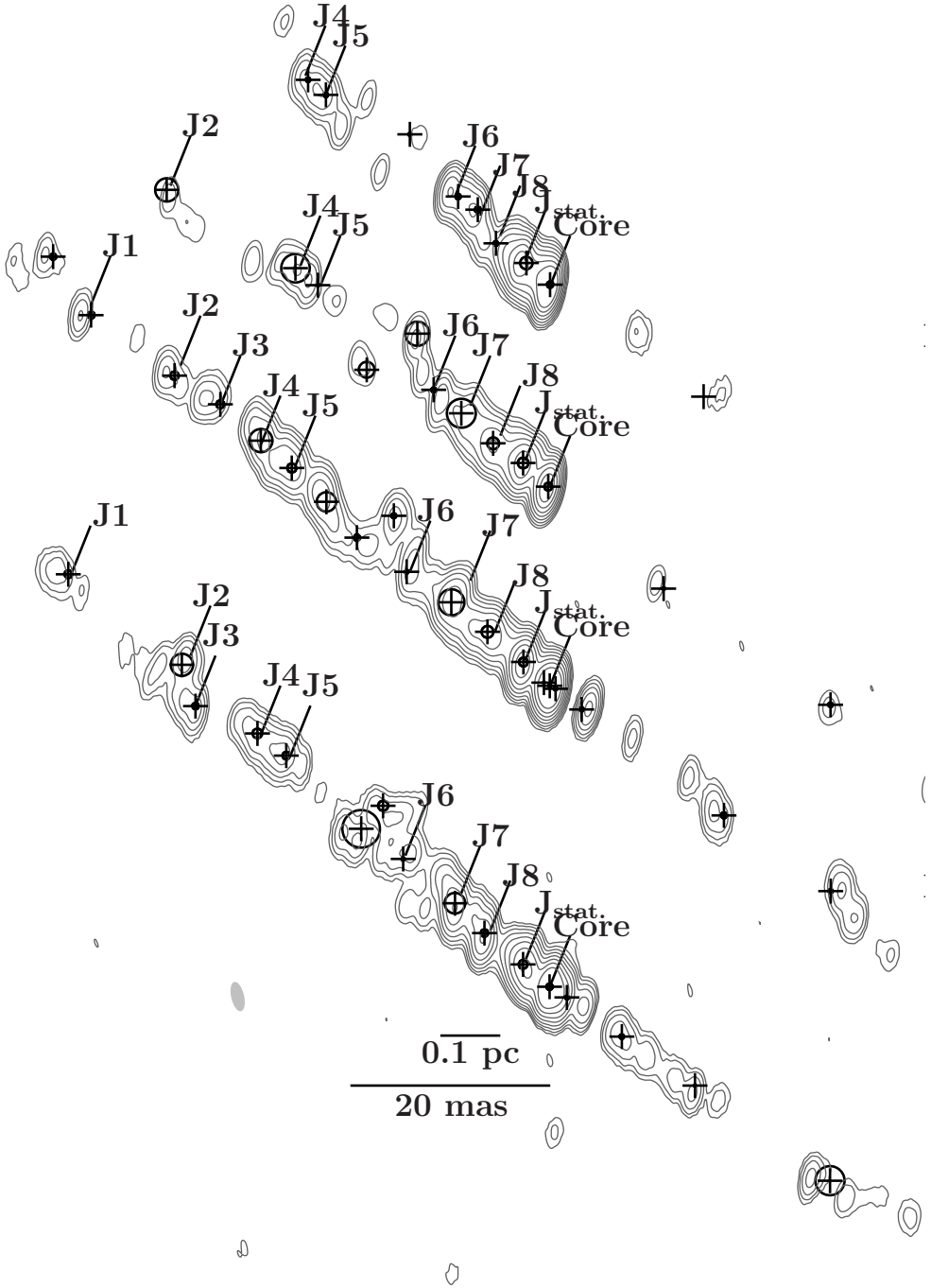
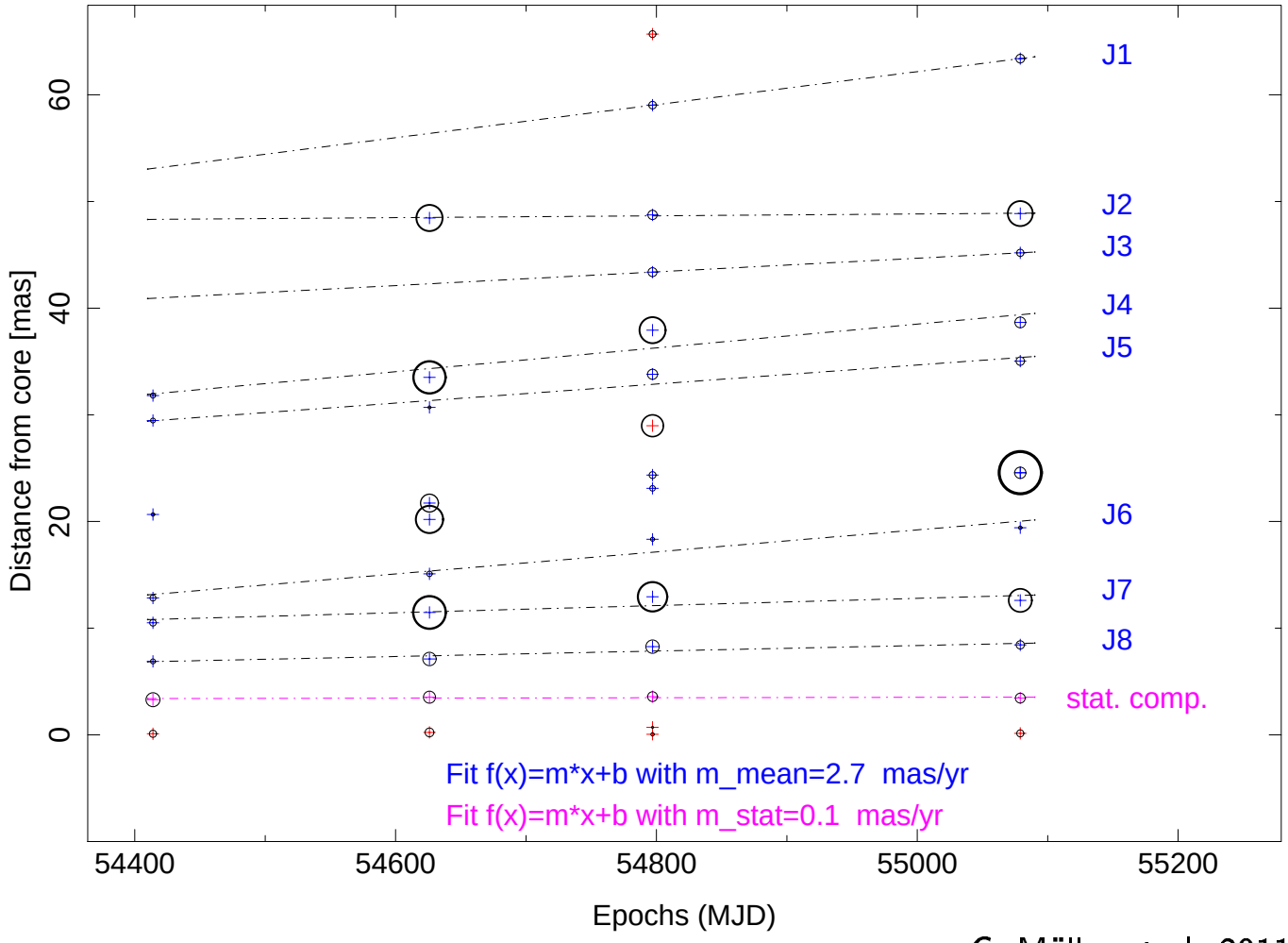
Cen A Jet Kinematics at Sub-parsec Scales

- complex substructure
- stationary component at ~ 3.5 mas
- jet widening & flux decrease at ~ 23 mas



Jet Kinematics



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- mean apparent jet speed $v_{\mathrm{app,mean}} \approx 2.7\,\mathrm{mas/yr} \approx 0.16c$
- moderate peak-flux variability
- differential motion: fastest component with $v_{\mathrm{app}} \approx 4\,\mathrm{mas/yr}$

Outlook

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

Summary

- 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 γ-rays