Zooming into Centaurus A
Sub-parsec scale imaging with TANAMI

Astroteilchenschule 2011

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in collaboration with

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E. Ros & the TANAMI Team

ERLANGEN CENTRE FOR ASTROPARTICLE PHYSICS

Julius-Maximilians-
UNIVERSITÄT WÜRZBURG

Outline

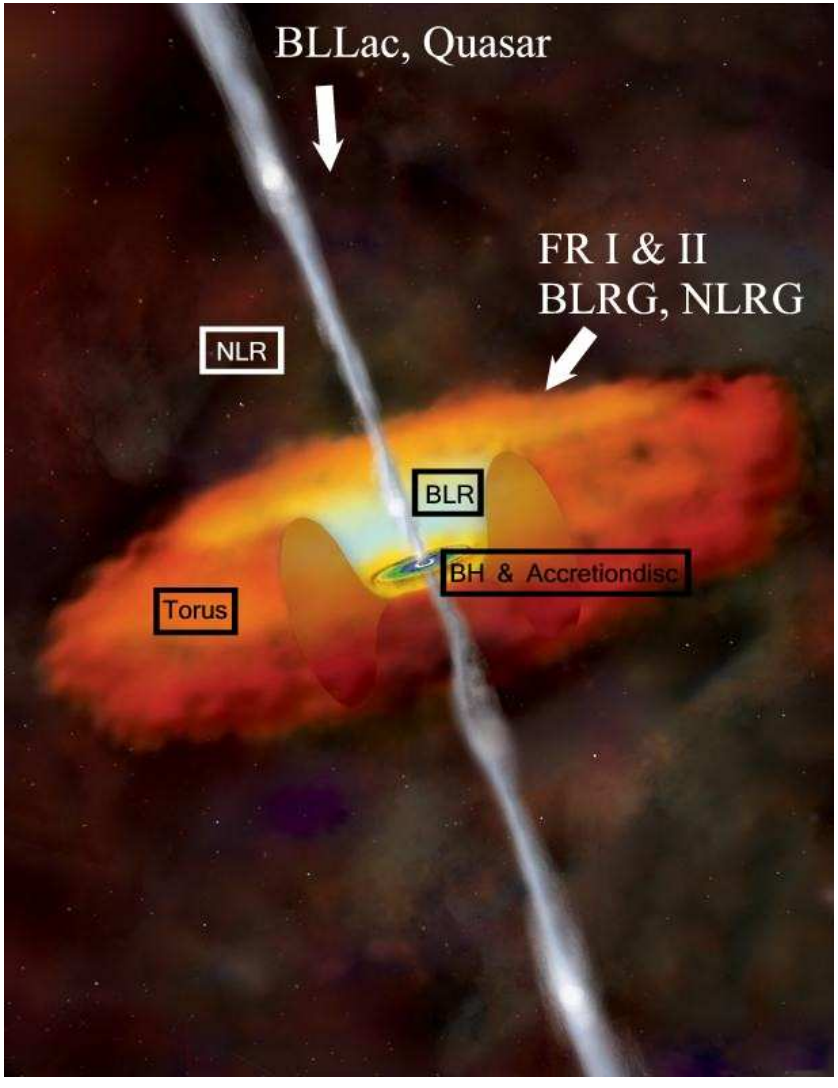
Friedrich-Alexander-Universität Erlangen-Nürnberg

Julius-Maximilians-Universität Würzburg

TANAMI

ECAP Erlangen Centre for Astroparticle Physics

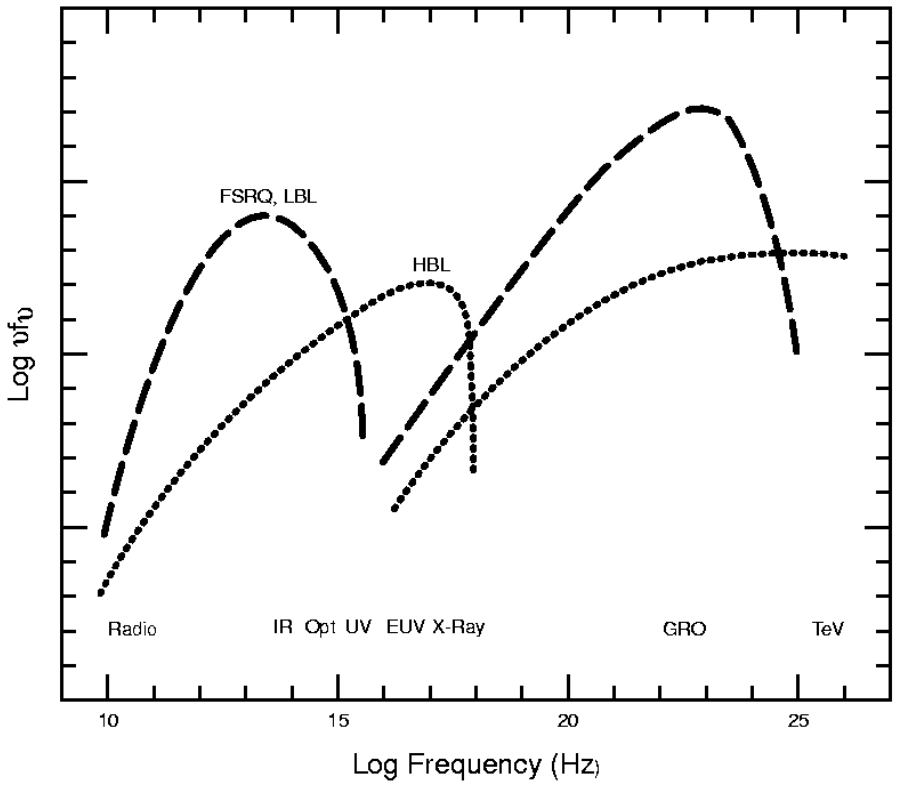
Radio-Loud AGN



Credit: NASA/CXC/M. Weiss

- Optical: $\sim 1000\times$ brighter than 'normal' galaxy
- Basic components: SMBH, NLR, BLR, Torus, Jet
- Unification scheme for AGN: dependence on viewing angle!

Blazar SED



Credit: `http://physics.gmu.edu/~rms/blazars/index.html`

- Jet dominates whole spectrum
- Double-humped: Synchrotron & Inverse-Compton peak

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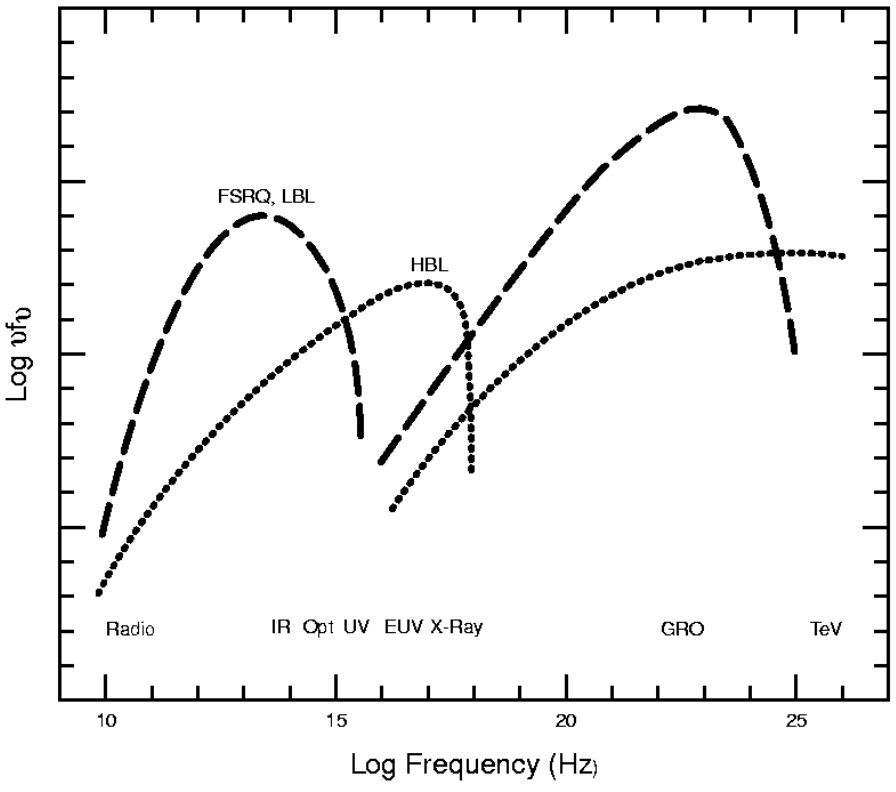

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$\rightarrow$ What are the emission mechanism in blazar jets?

$\rightarrow$ Where are γ-rays produced?

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Contemporaneous multiwavelength observations

$\rightarrow$ high spatial resolution: only possible in radio (**VLBI**)

$\rightarrow$ multiwavelength monitoring

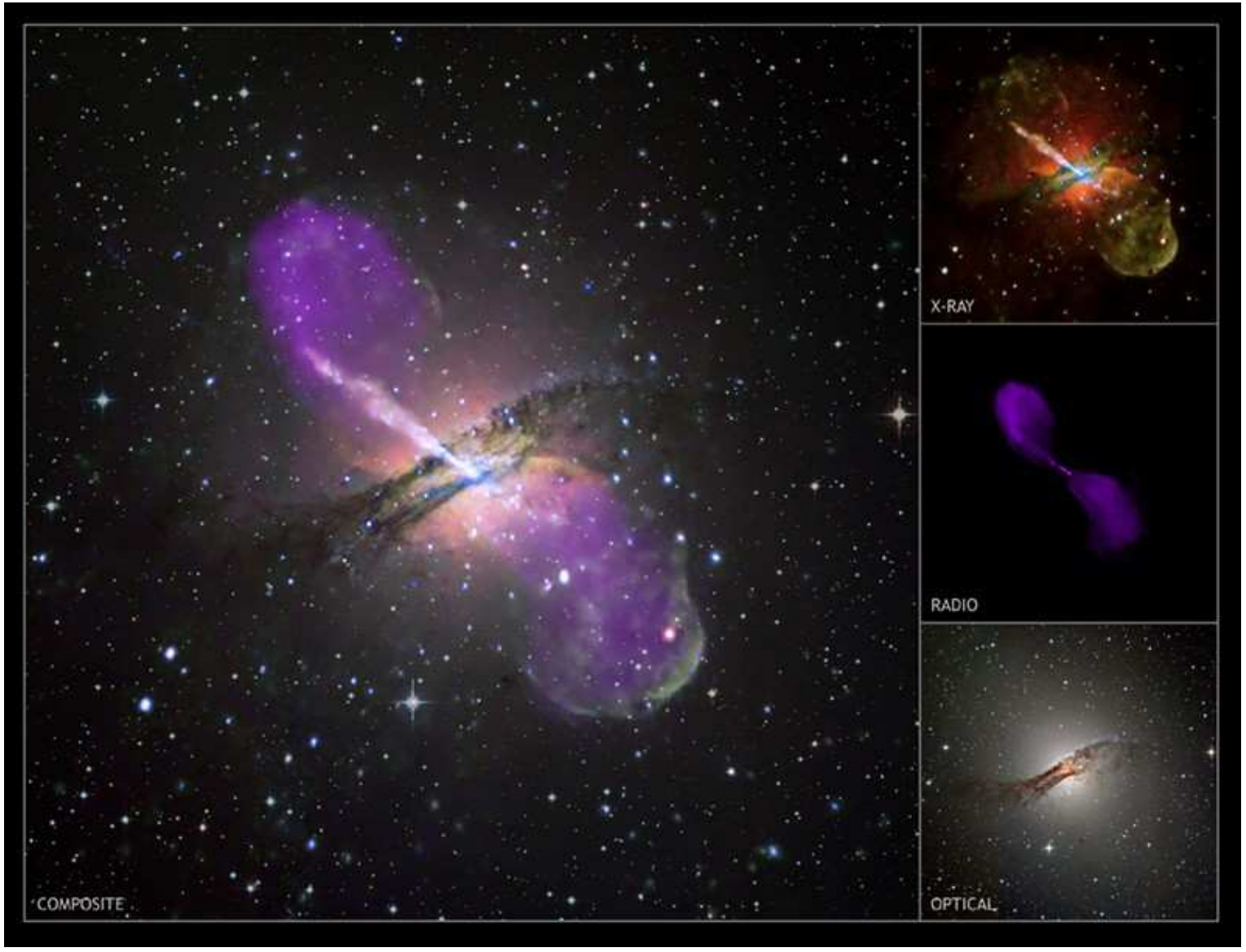
The TANAMI Program

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

Credit: J. Wilms/M. Kadler

- Southern Hemisphere VLBI array $\Rightarrow$ milli-arcseconds resolution!
- bimonthly VLBI monitoring of 75 jets south of $\delta = -30^\circ$ since 2007
- Simultaneous dual-frequency observations at 8.4 & 22.3 GHz

Perfect Laboratory: Centaurus A (NGC 5128)



Credit: NASA/NSF/ESO

closest radio-loud AGN: $\mathrm{d} \sim 3.8\,\mathrm{Mpc} \leftrightarrow 1\,\mathrm{mas} \mathrel{\widehat{=}} 0.018\,\mathrm{pc}$

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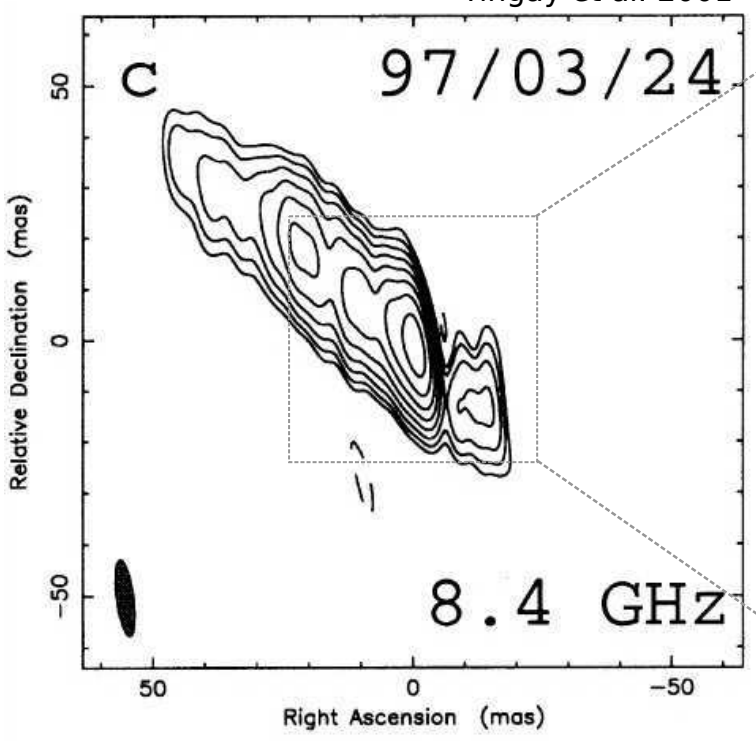
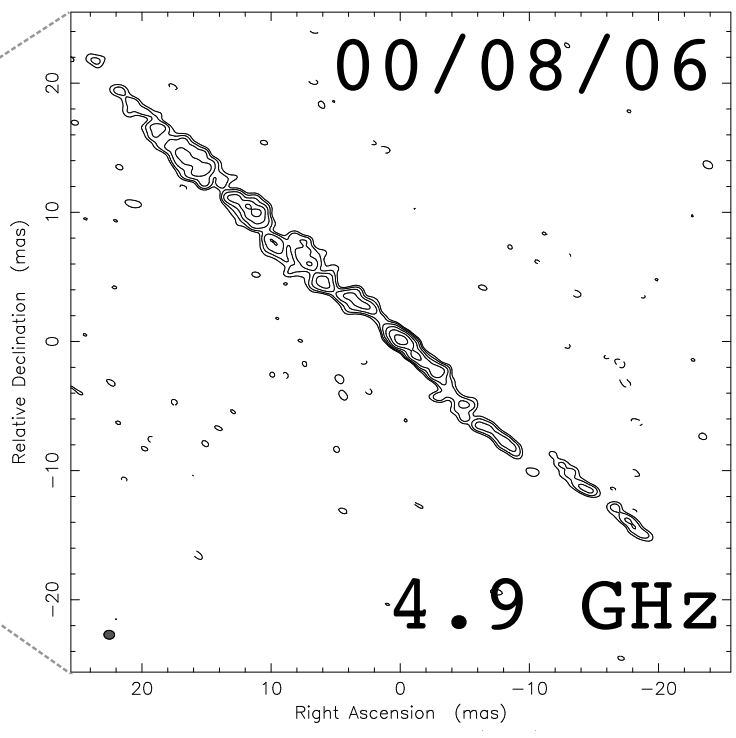
Previous VLBI observations of Cen A:

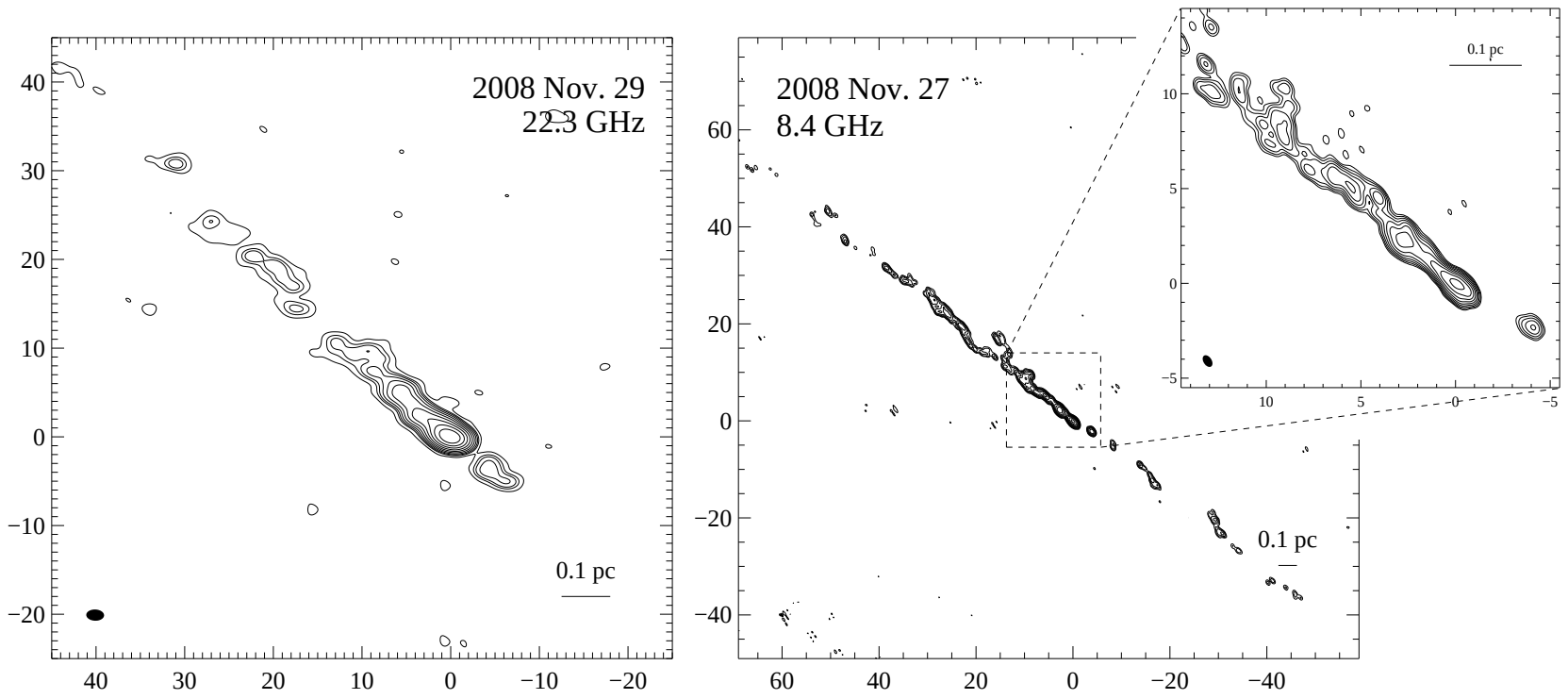
Tingay et al. 2001



Horiuchi et al. 2006



Simultaneous Dual-frequency Images of Cen A



C. Müller et al. 2011, A&A, 530, L11

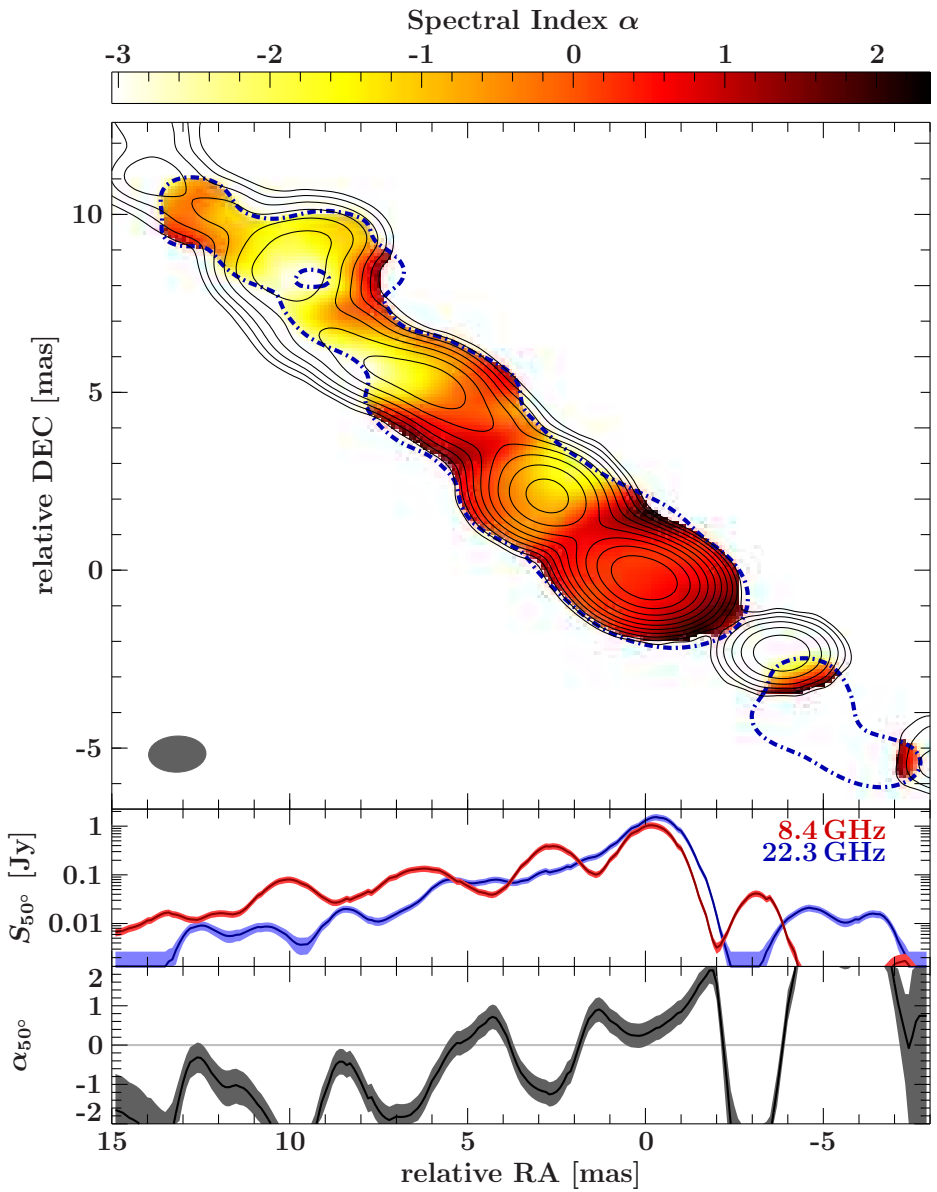
⇒ Highest resolution VLBI image of AGN jet ever made

→ Resolve discrete jet components down to scales of $\sim 3500\,\mathrm{AU}$

→ Study spectral changes at sub-parsec scales

→ Well collimated jet at P.A.$\sim 50^\circ$ with opening angle $\lesssim 12^\circ$

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



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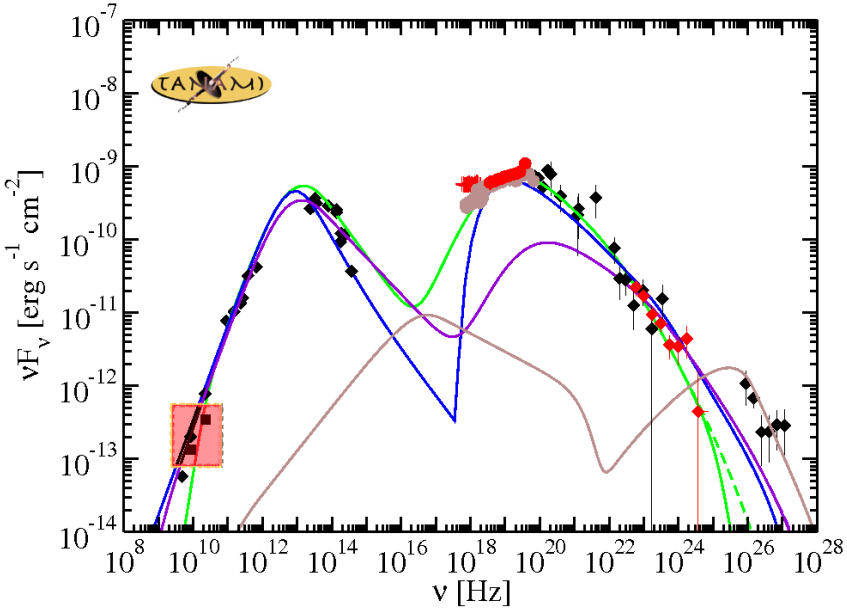
Spectral Index α

$S_\nu \sim \nu^{+\alpha}$

- High resolution spectral index map
- 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?



SED of Cen A core emission (Abdo et al. 2011)

- recent *Fermi*/LAT detection (γ-rays!)
- but: LAT accuracy $\sim 0^\circ.1$

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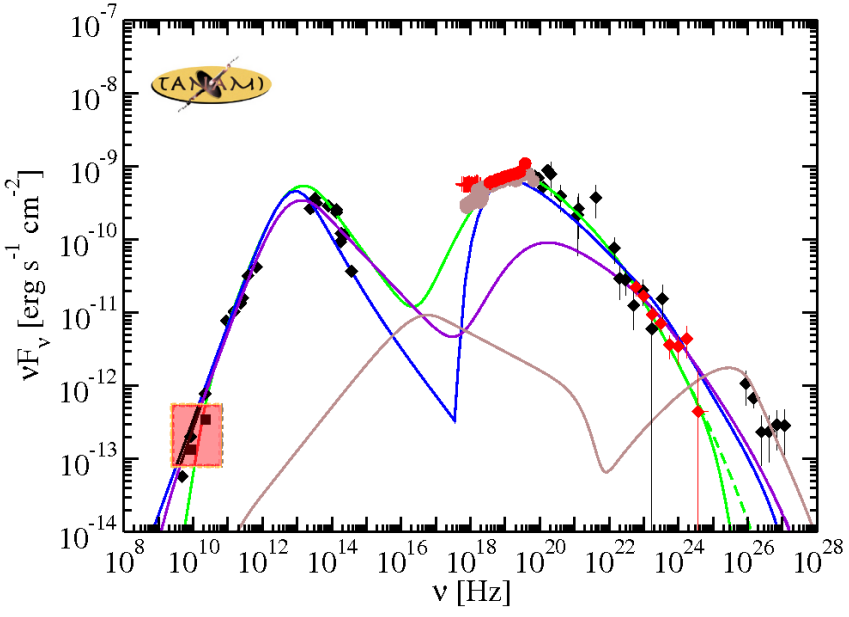

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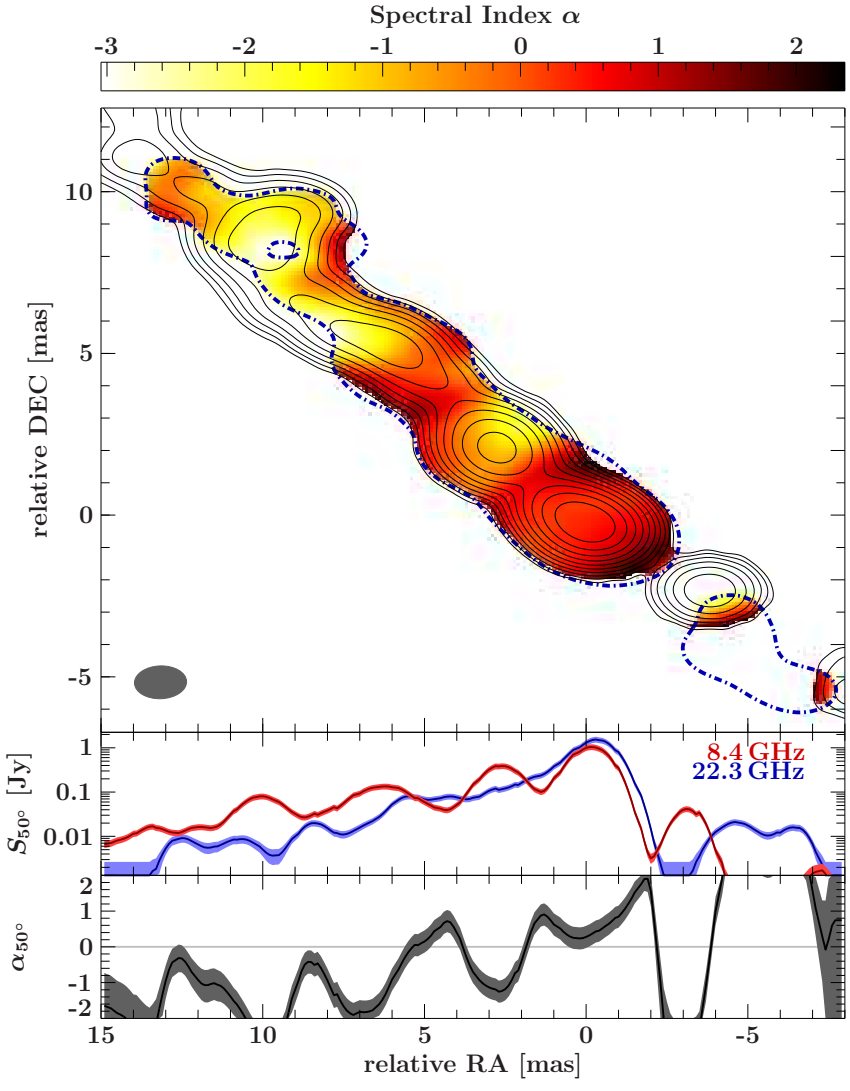

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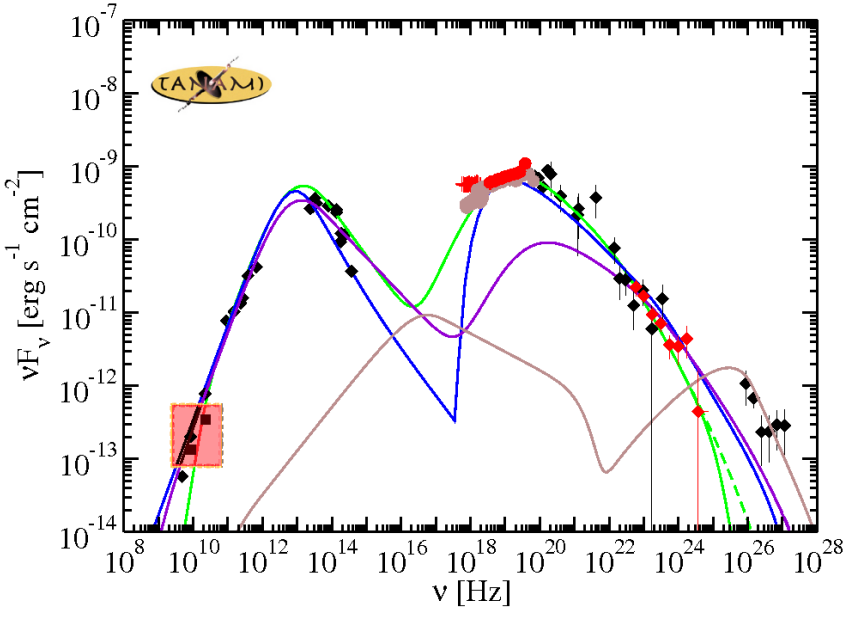

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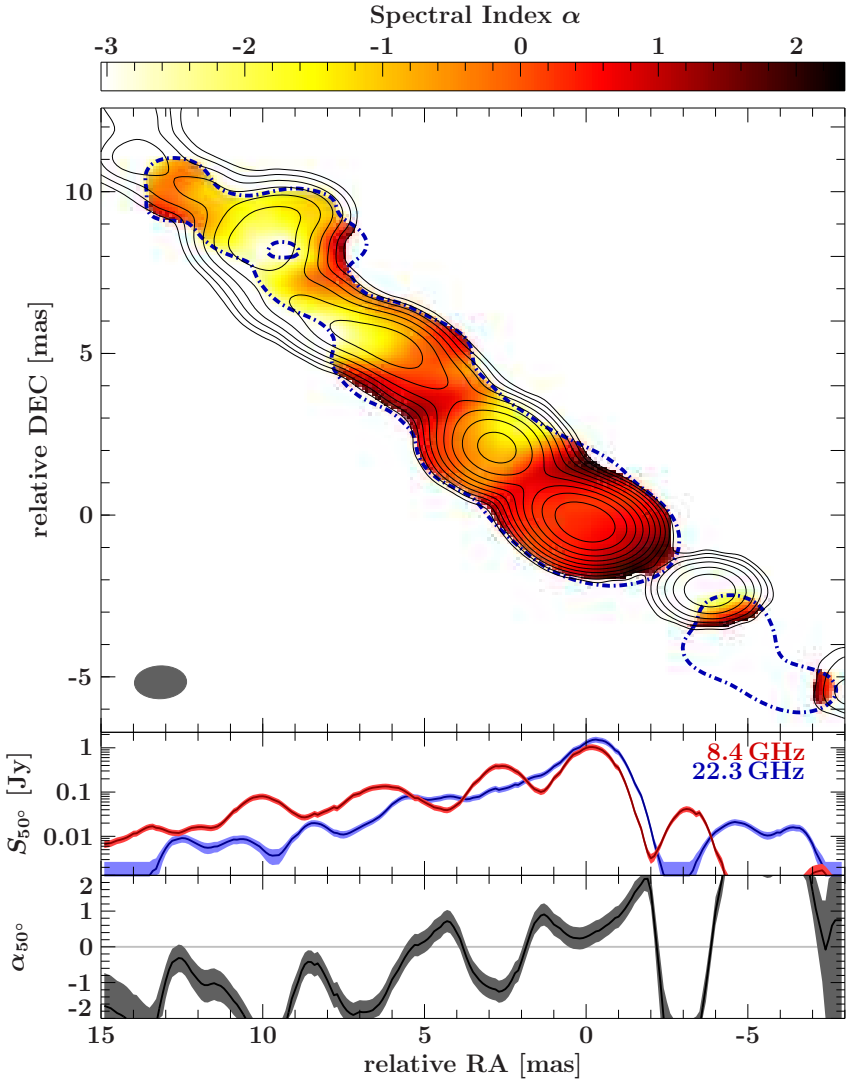

→ Multiple possible regions of high energy emission

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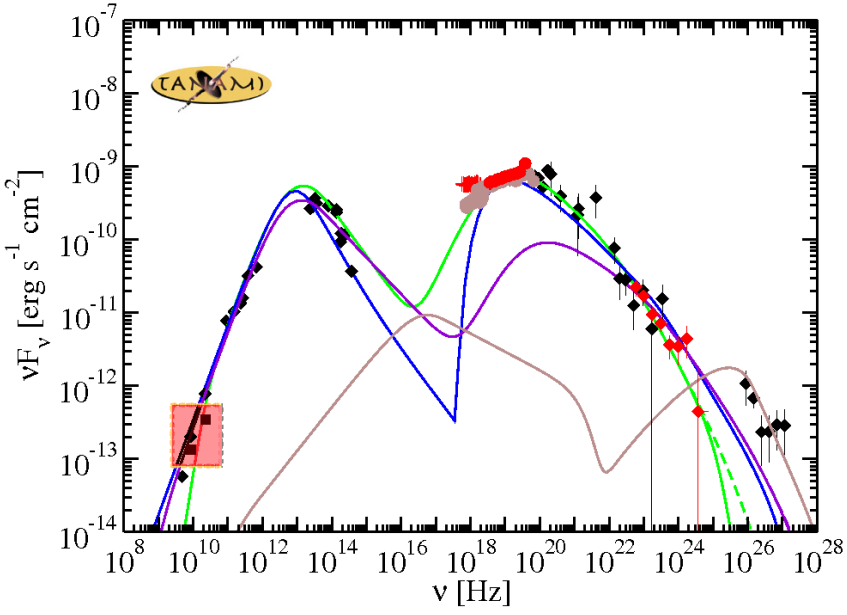
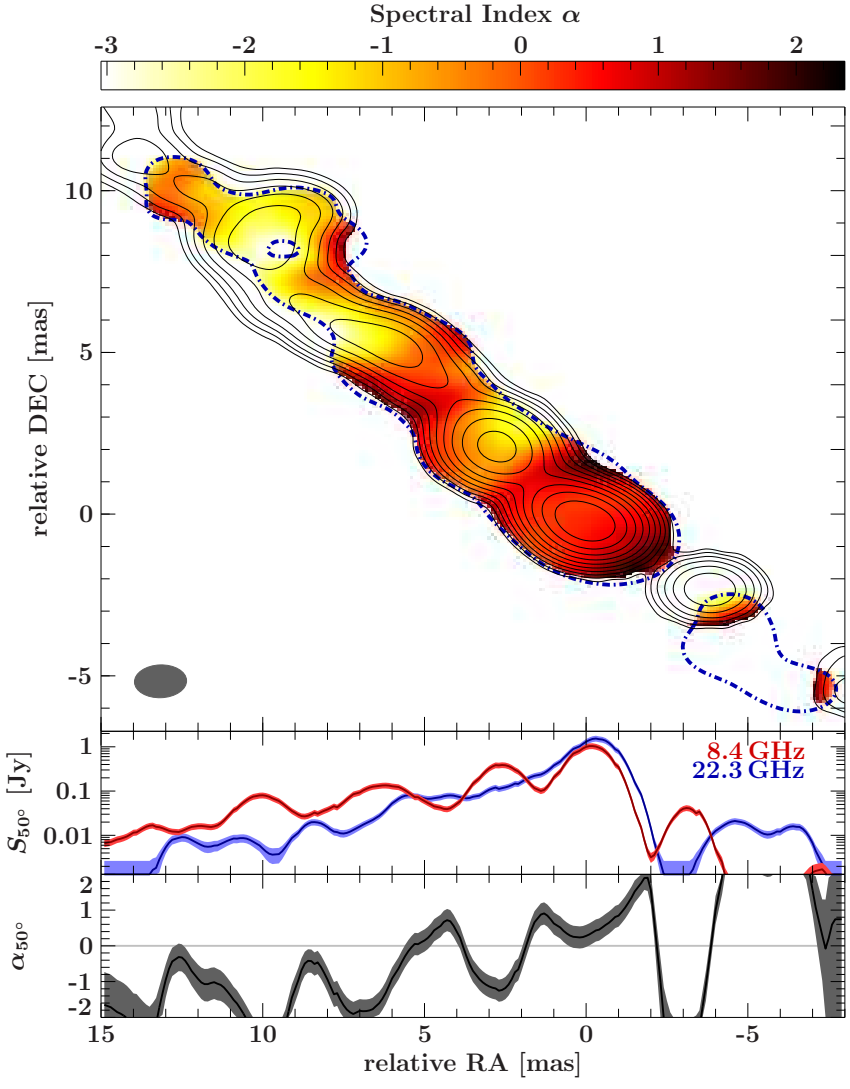


SED of Cen A core emission (Abdo et al. 2011)

→ Constraints on emission models of broadband SEDs



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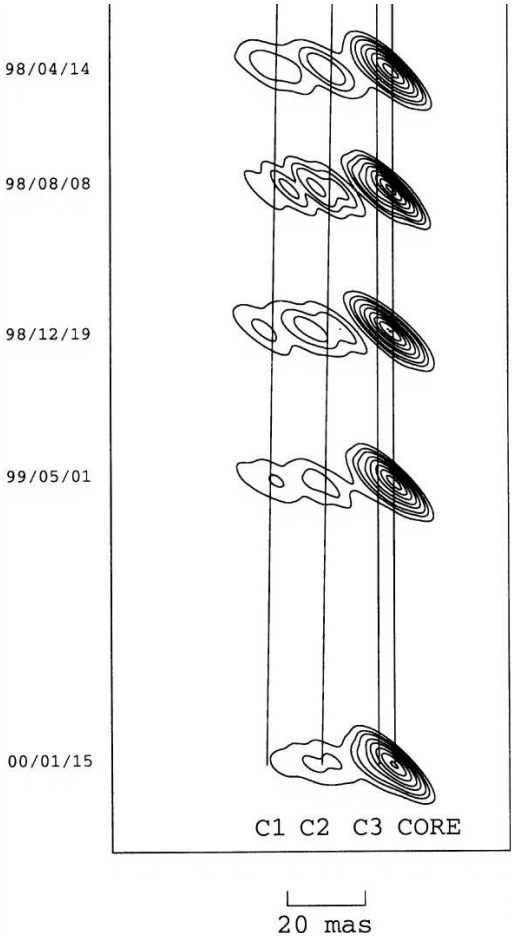
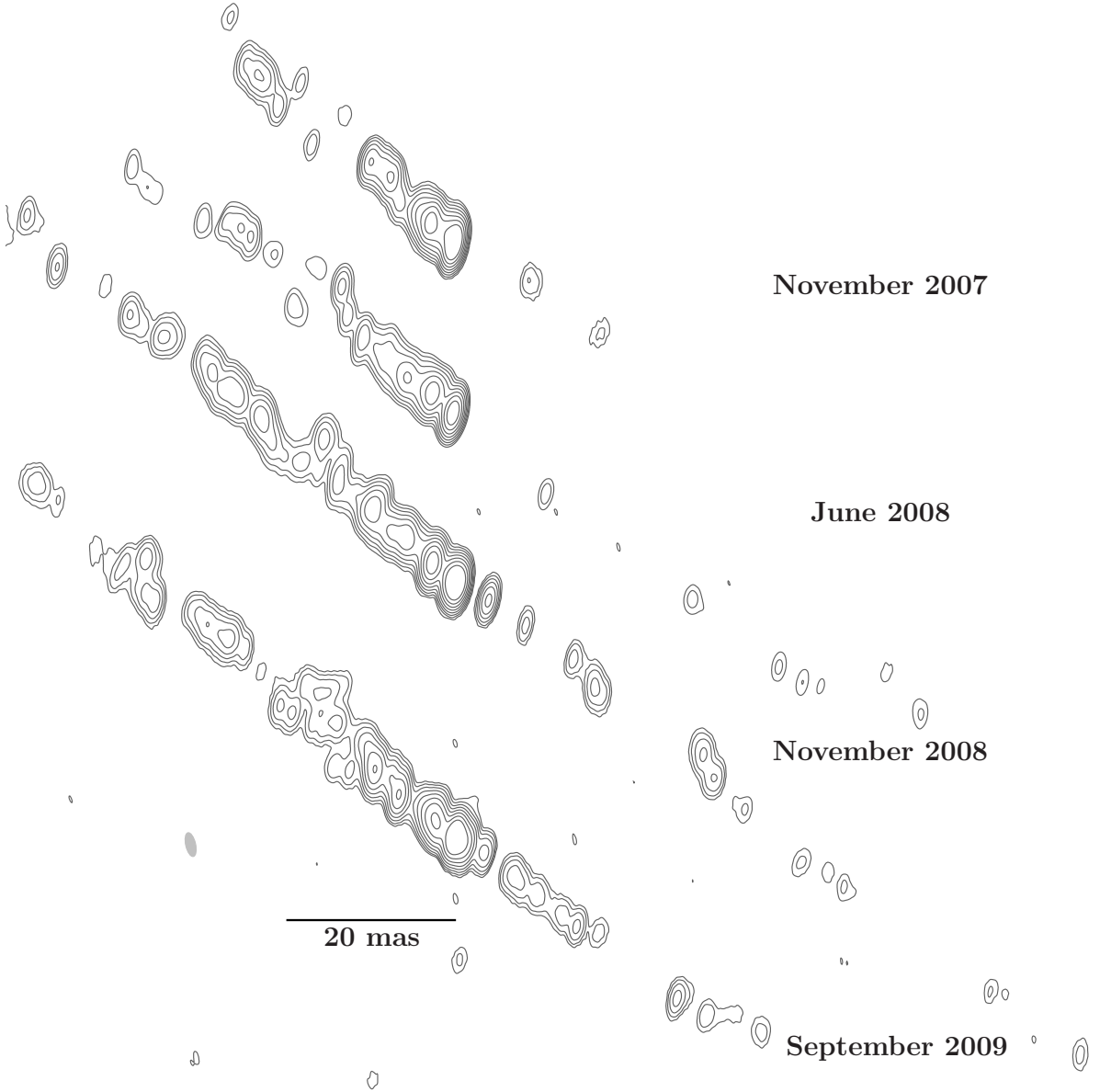
Cen A Jet Kinematics at Sub-parsec Scales



Tingay et al. 2001



C. Müller et al. 2011, in prep.

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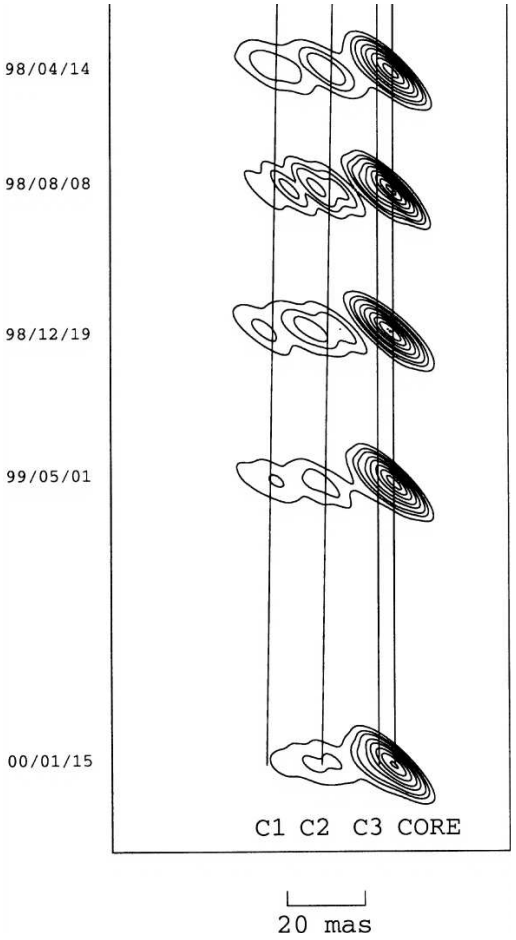

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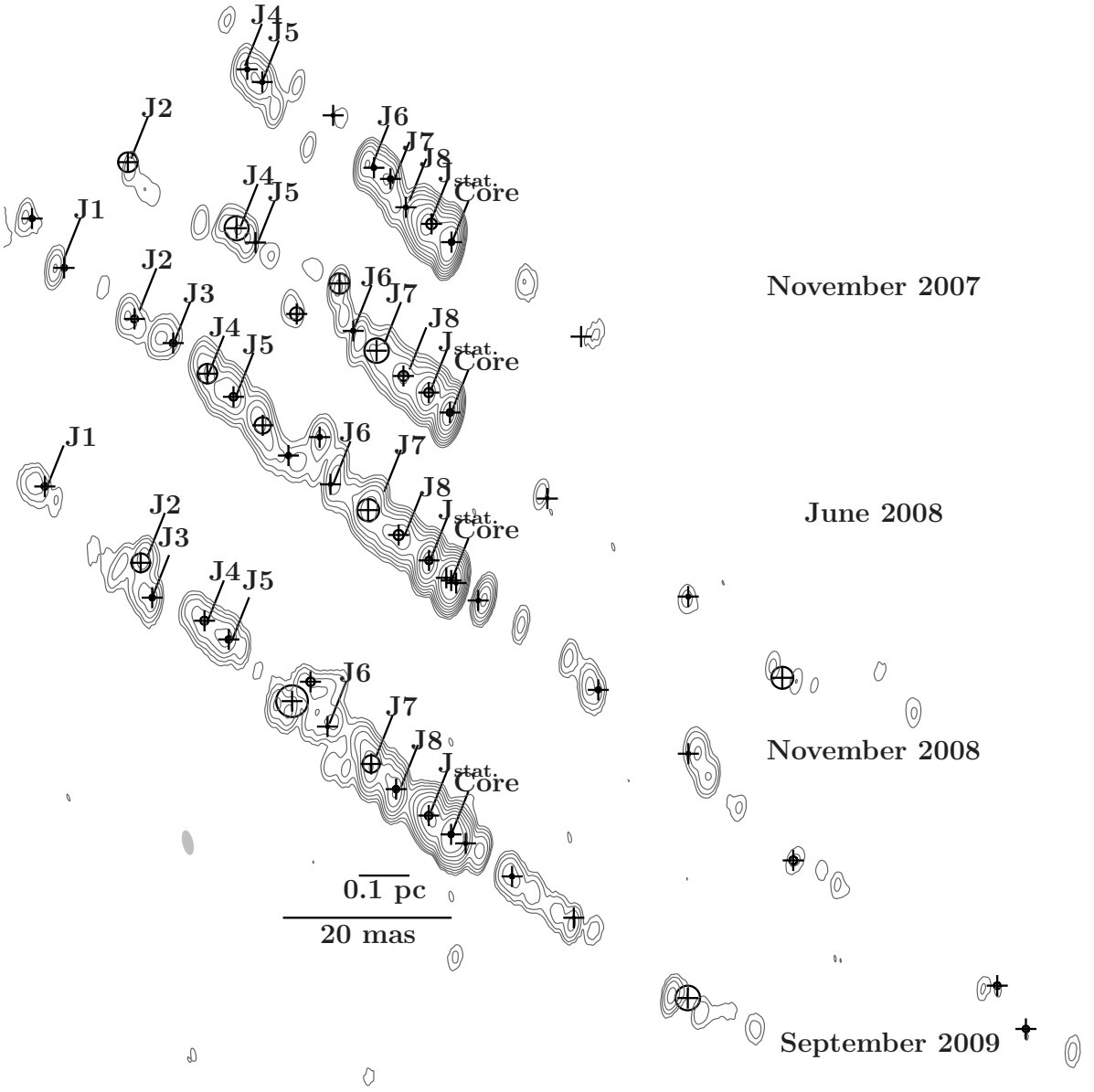
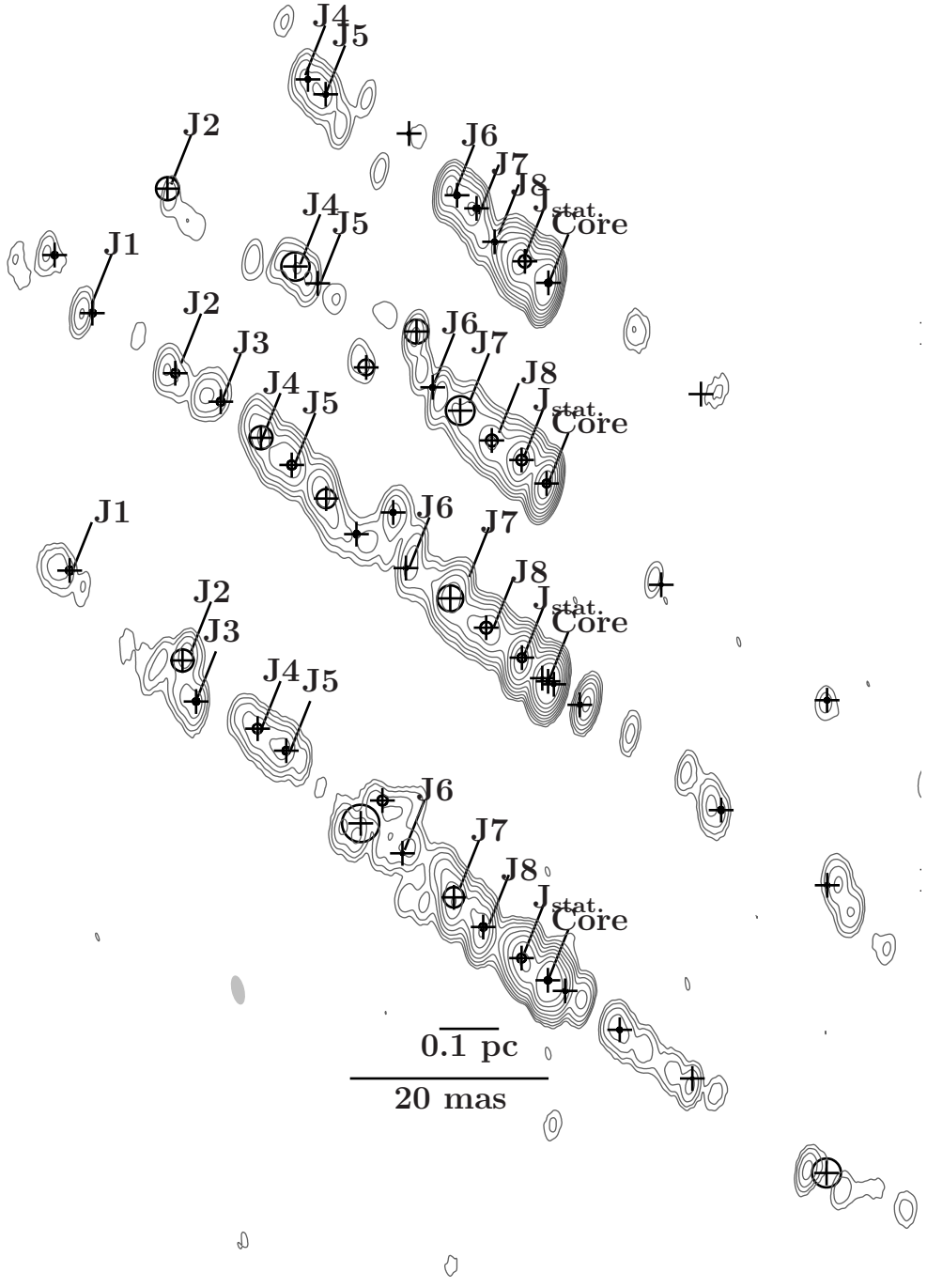


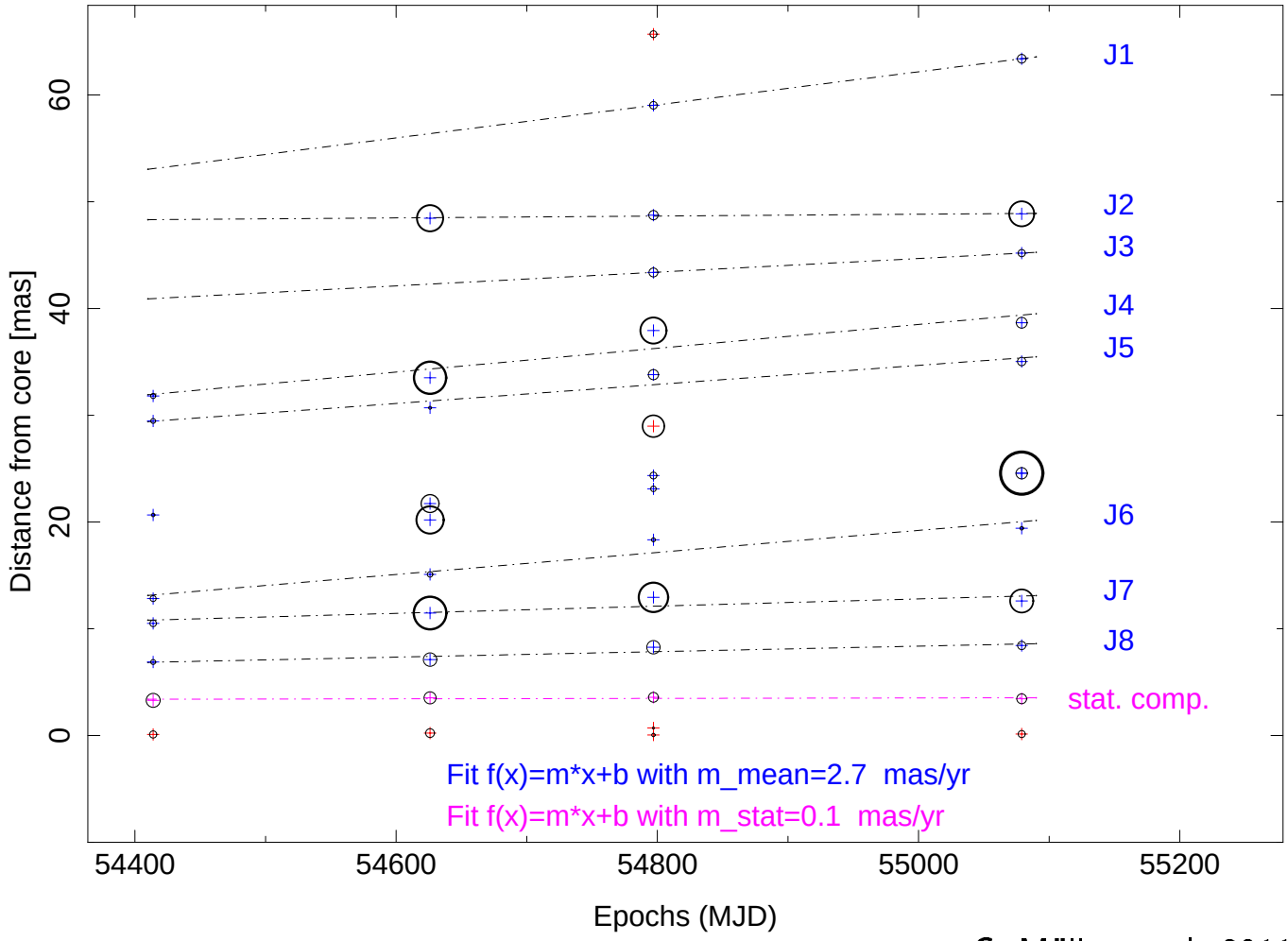
C. Müller et al. 2011, in prep.

Cen A Jet Kinematics at Sub-parsec Scales

- complex substructure
- stationary component at ~ 3.5 mas
- jet widening & flux decrease at ~ 23 mas
- similarity also to space-VLBI image



Apparent Jet Speed Analysis



C. Müller et al. 2011, in prep.

- 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 $v_{\mathrm{app}} \approx 4\,\mathrm{mas/yr}$

Conclusion & Outlook

- Cen A's jet was resolved down to scales of $\sim 0.018\,\mathrm{pc}$
  $\Rightarrow$ Highest resolution view of AGN jet ever made reveals complex substructure
- Spectral index map $\Rightarrow$ multiple possible origins of γ-rays

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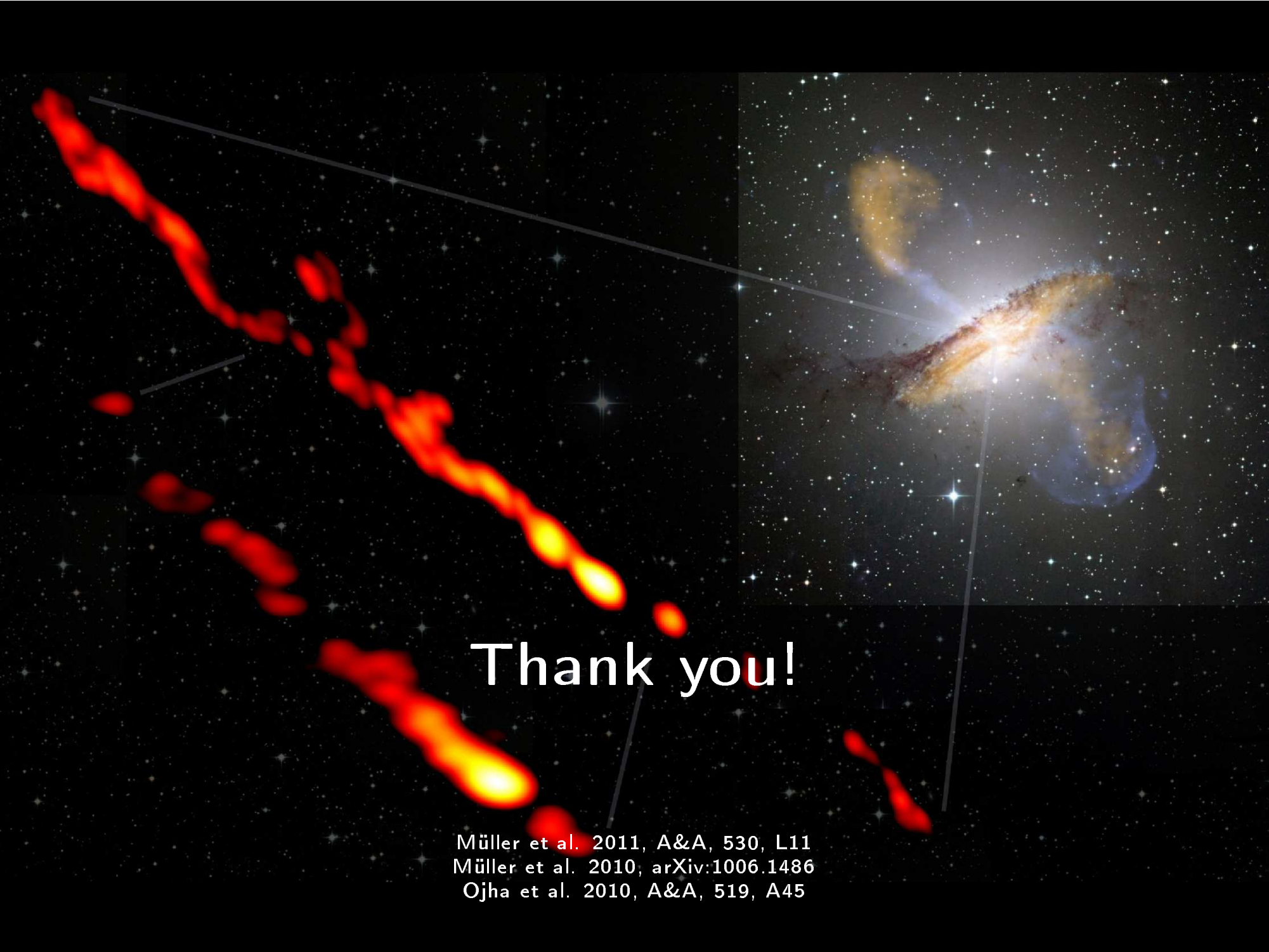
* Multi-epoch dual-frequency TANAMI monitoring of Cen A
  $\Rightarrow$ Evolution of spectral index
  $\Rightarrow$ Proper motion analysis for jet and counterjet
* Spectral and kinematical analysis of whole TANAMI sample
  $\Rightarrow$ Statistics, key parameters for jet broadband emission models



Thank you!

Müller et al. 2011, A&A, 530, L11
Müller et al. 2010, arXiv:1006.1486
Ojha et al. 2010, A&A, 519, A45