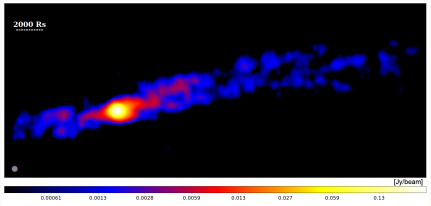



# A zoom into the jet launching region of the radio galaxy Cygnus A

Bia Boccardi, **Uwe Bach**, Thomas Krichbaum, et al.

June 15, 2018

Max-Planck-Institut fuer Radioastronomie, Bonn

References:

B. Boccardi, T.P. Krichbaum, U. Bach, et al. 2016a, A&A, 585, 33
B. Boccardi, T.P. Krichbaum, U. Bach, et al. 2016b, A&A, 588, 9

# Outline

Introduction

- About Cygnus A
- AGN Model

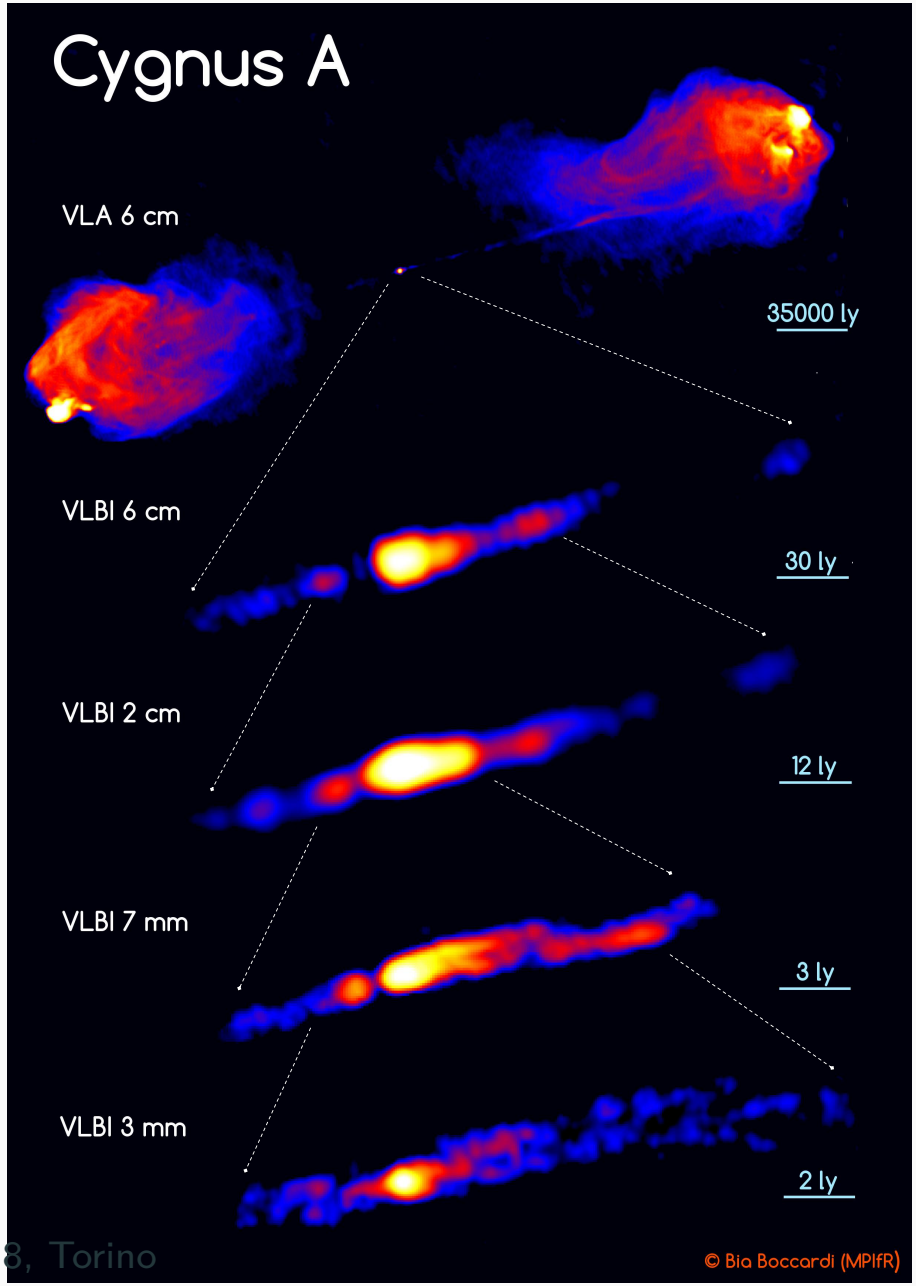
Observations, Results and Discussion

- Global VLBI at 86 GHz/3 mm (GMVA)
- Global VLBI at 43 GHz/7 mm
- Simplified view of the stratified jet in Cyg A

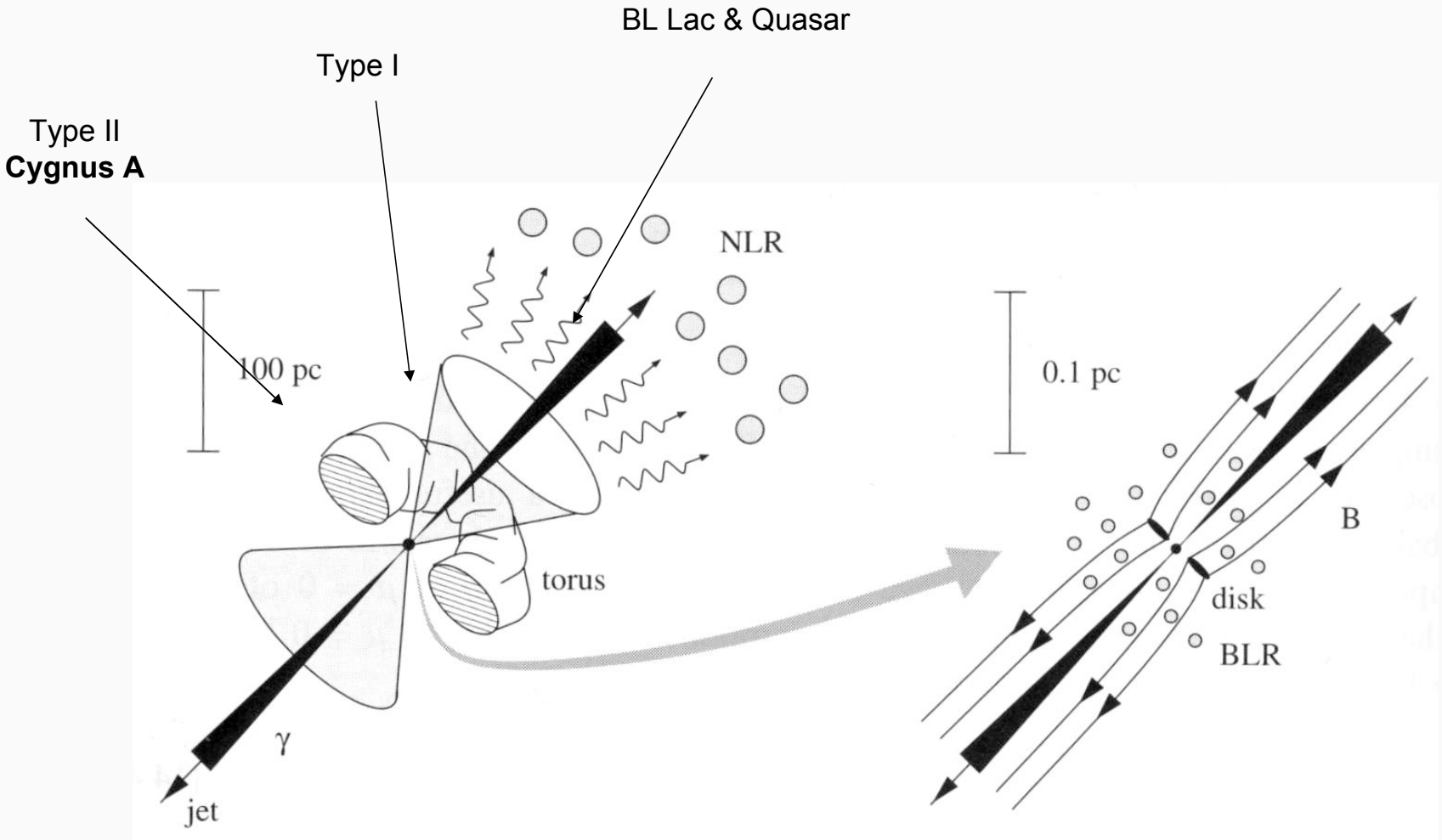
Summary

# About Cygnus A

- One of the first and strongest extra-galactic radio sources and a prototype for FRII radio galaxies
- Nearby, $z = 0.0561$ corresponding to 250 Mpc and a resolution of $1\,\mathrm{mas} \sim 1.1\,\mathrm{pc}$ and $0.1\,\mathrm{mas} \sim 400$ Schwarzschild radii ($R_\mathrm{s}$)
- Prominent two sided jets on parsec scales.
- Large viewing angle $\sim 75°$ $\rightarrow$ less relativistic effects



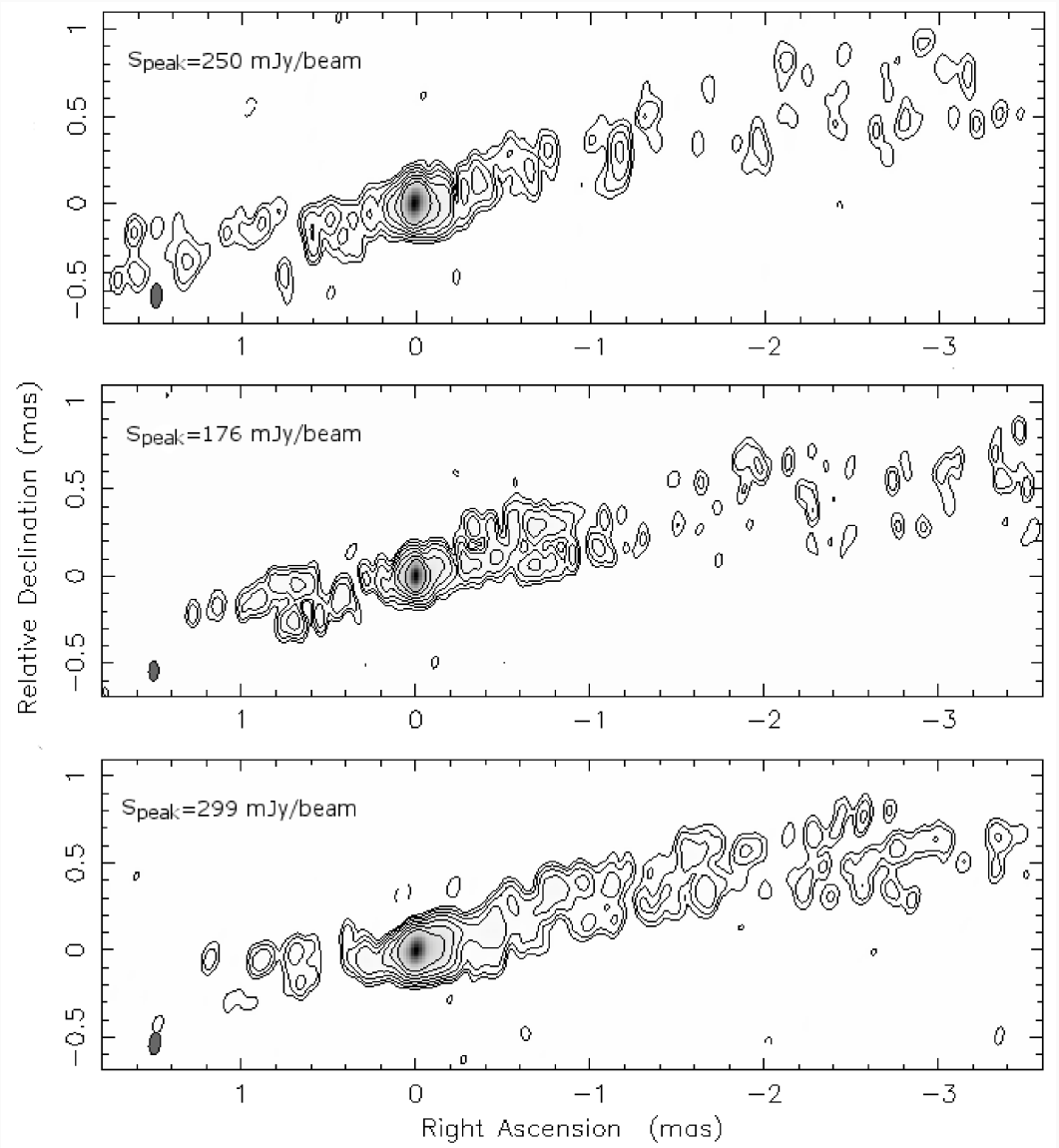
# AGN Model




**Peacock, Cosmological Physics (1991)**

# Global VLBI at 3 mm (86 GHz)

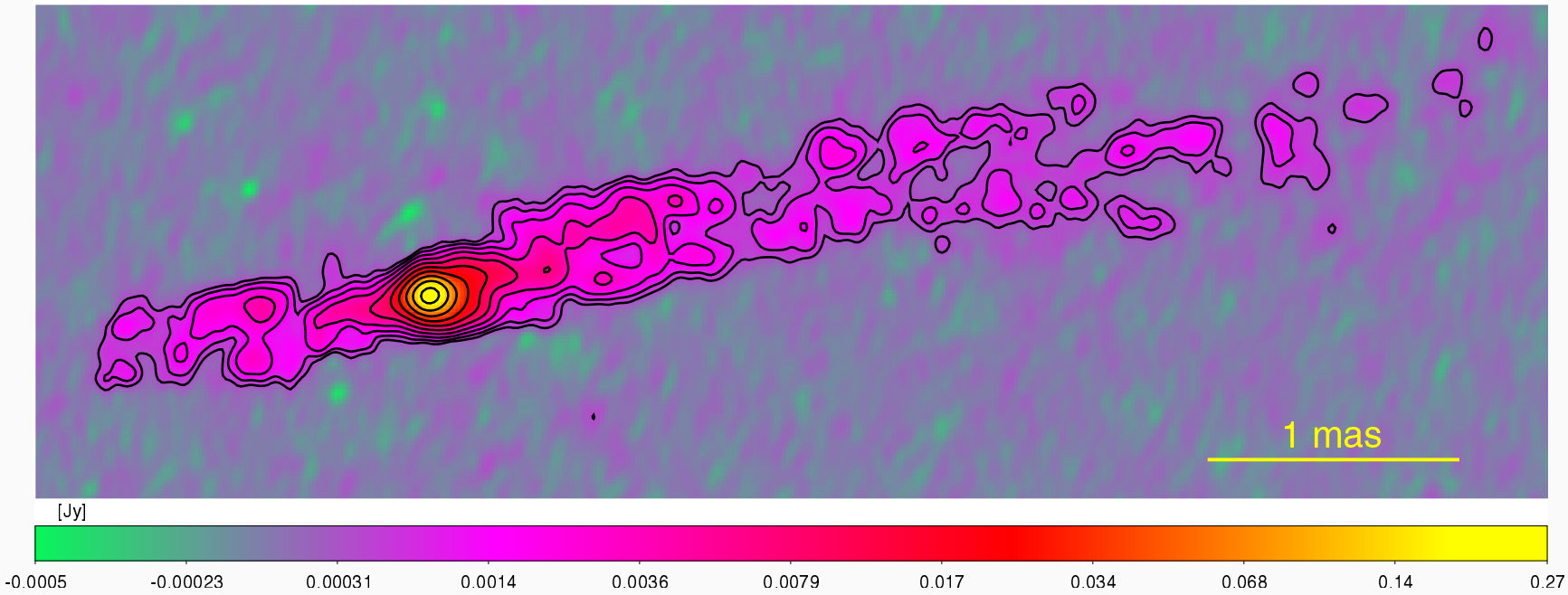
- GMVA observations from May 2009, Oct 2009 and May 2010
- Beam of $\sim 0.1 \times 0.05\,\mathrm{mas}$ $\rightarrow \sim 200\,\mathrm{R_s}$
- Peak flux varies around $\sim 250\,\mathrm{mJy/beam}$ noise level at $\sim 0.15\,\mathrm{mJy/beam}$




Boccardi et al. 2016b

# Global VLBI at 3mm (86 GHz)

Stacked image of Cyg A at 86 GHz combining all 3 GMVA observations from 2009-2010 restored with a circular beam of 0.1 mas.

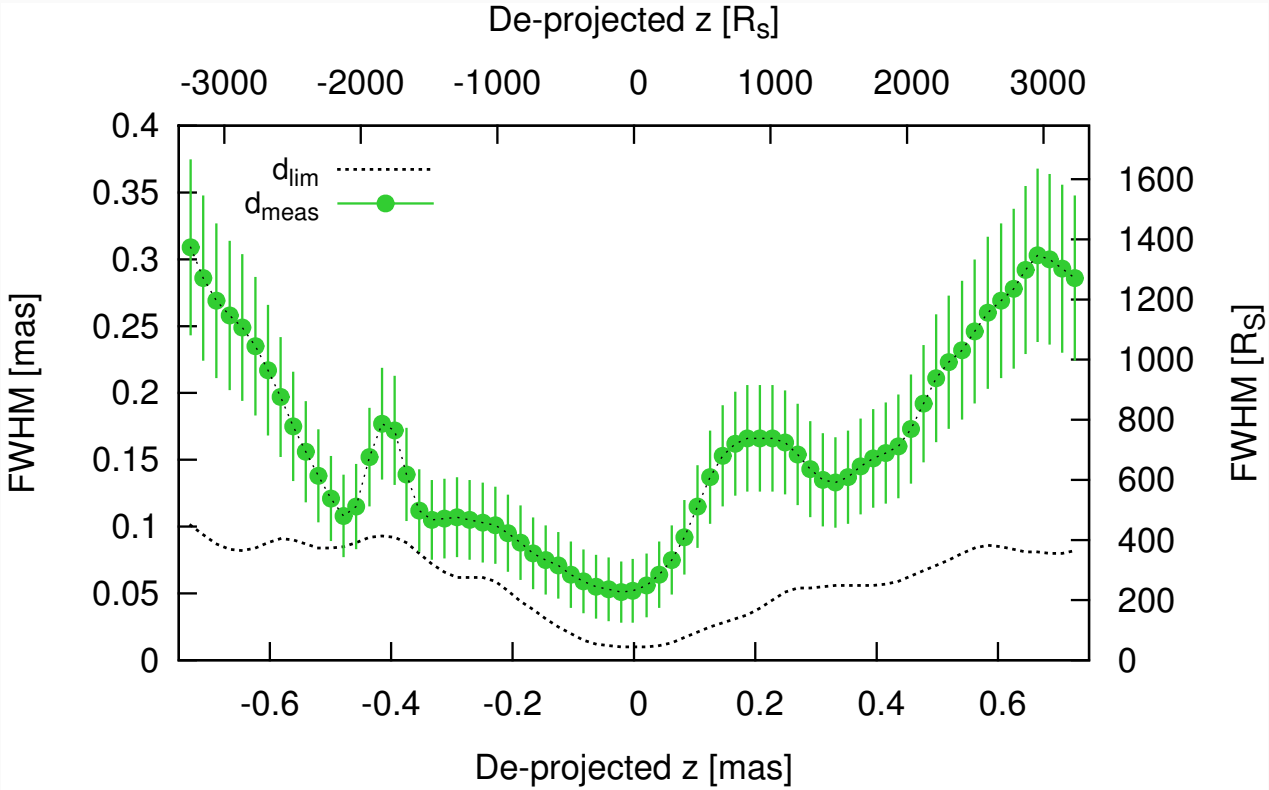


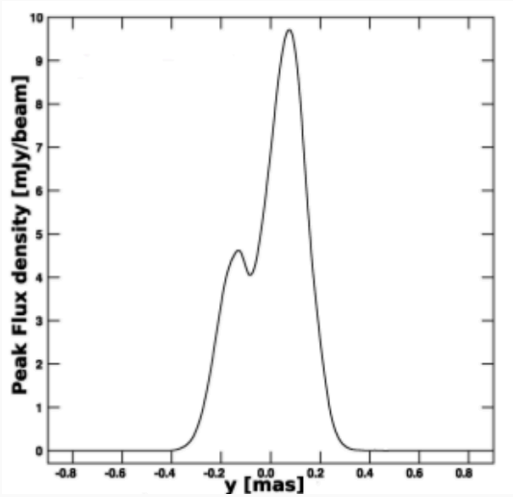

- Recovers more of the limb-brightened jet
- Lower noise level of $\sim 0.1\,\mathrm{mJy/beam}$

Boccardi et al. 2016b

# Jet width vs. distance from the core

Boccardi et al. 2016b

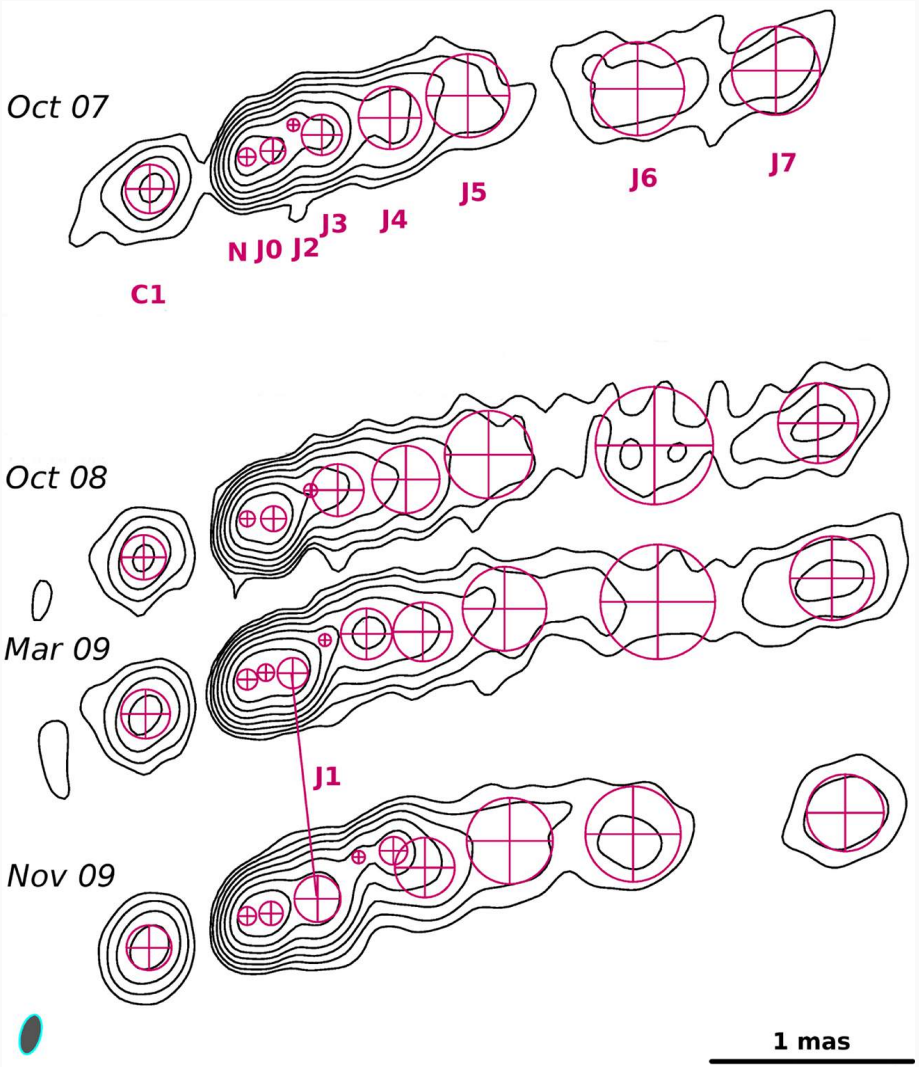


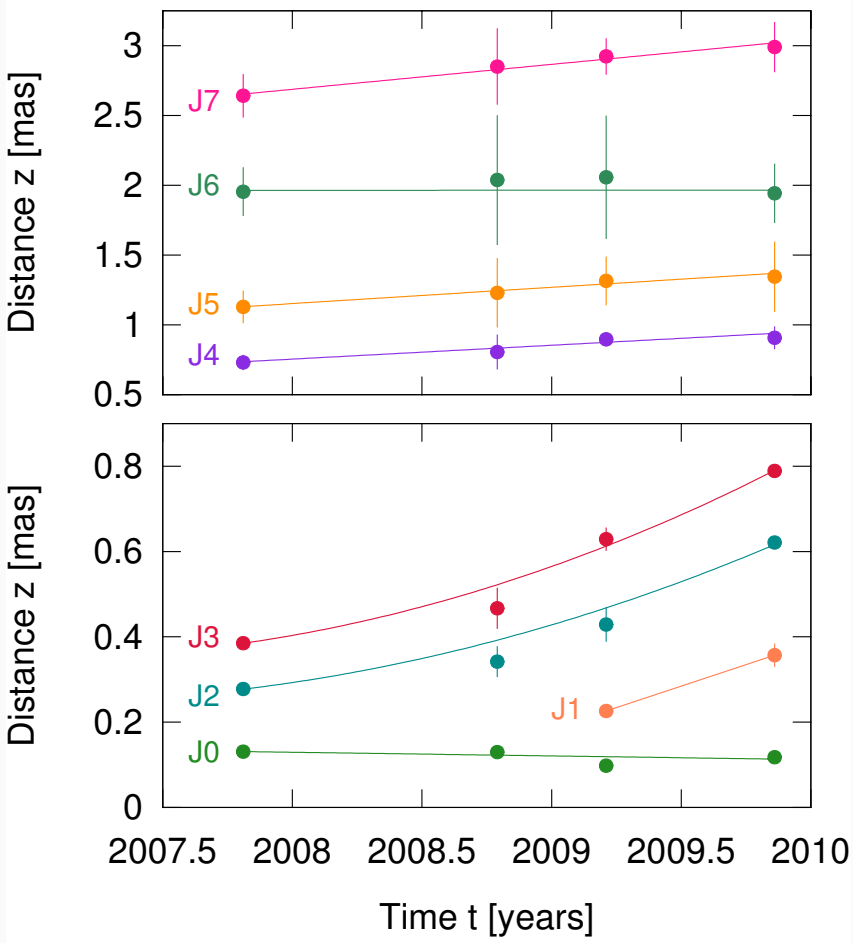




$\rightarrow$ the jet is transversally resolved! $d_{\rm min} = 51 \pm 22\,\mu{\rm sec} \sim 227 \pm 98\,{\rm R_s}$

# Global VLBI at 7mm (43 GHz)

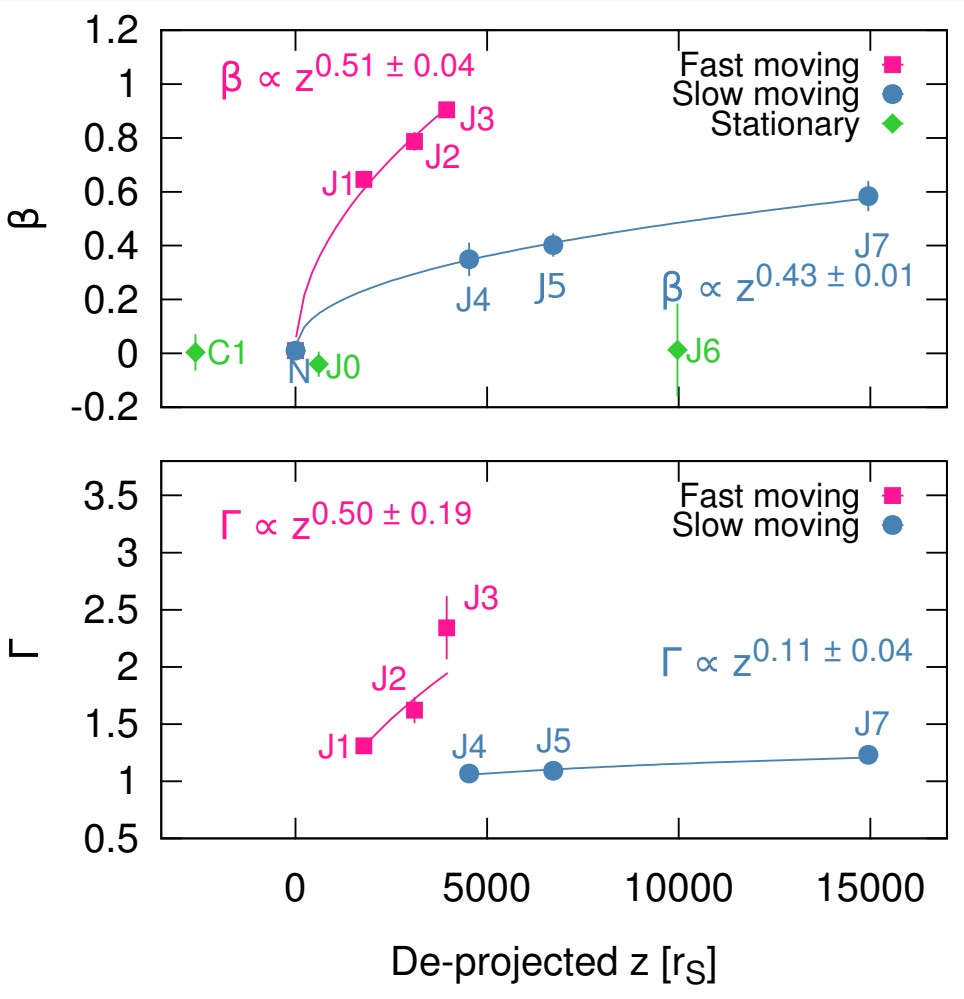
Jet kinematics from 7mm VLBI observations from Oct 2007 to Nov 2009

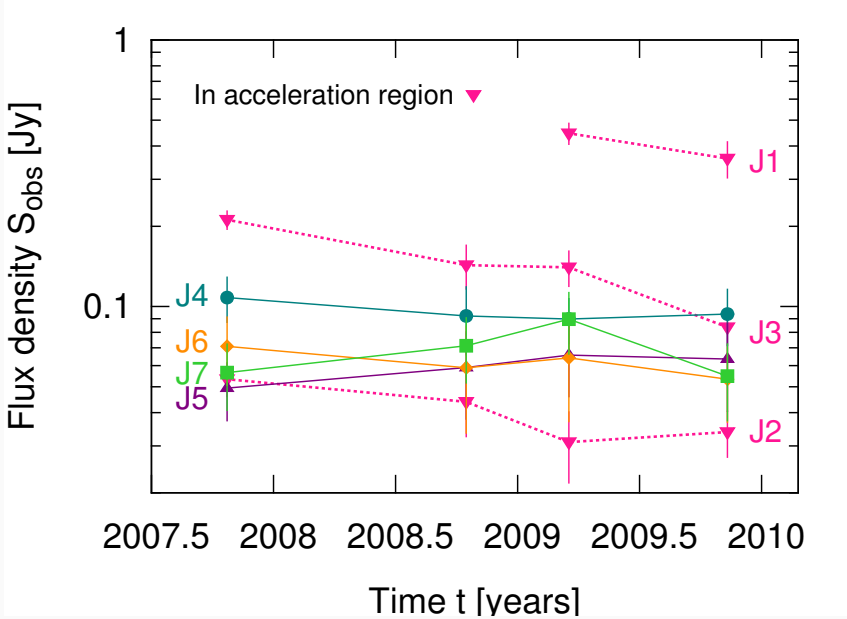



Boccardi et al. 2016a

# Jet kinematics



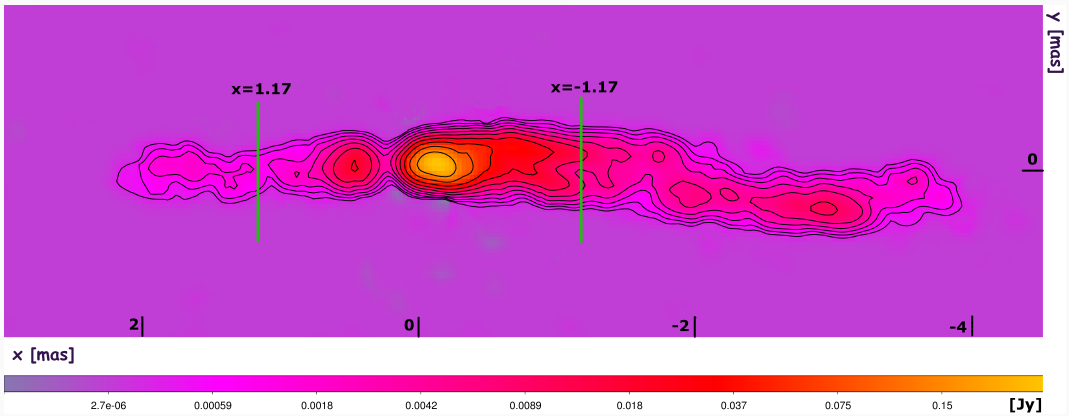

- Mildly relativistic
- Accelerating on parsec scales
- Stratified in Bulk speed

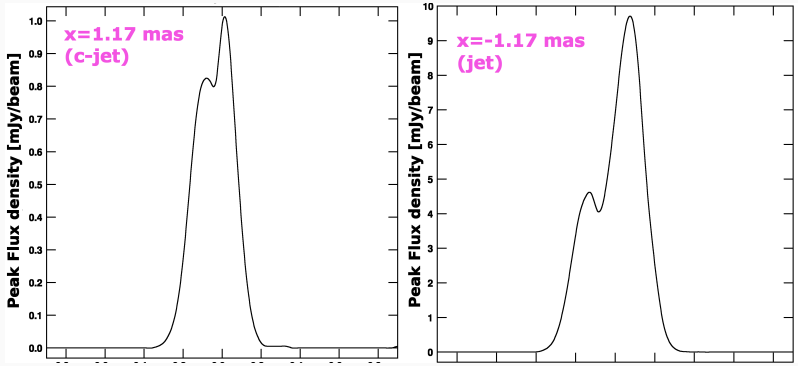
- Because of the large viewing angle, jet components will get fainter when they are faster.

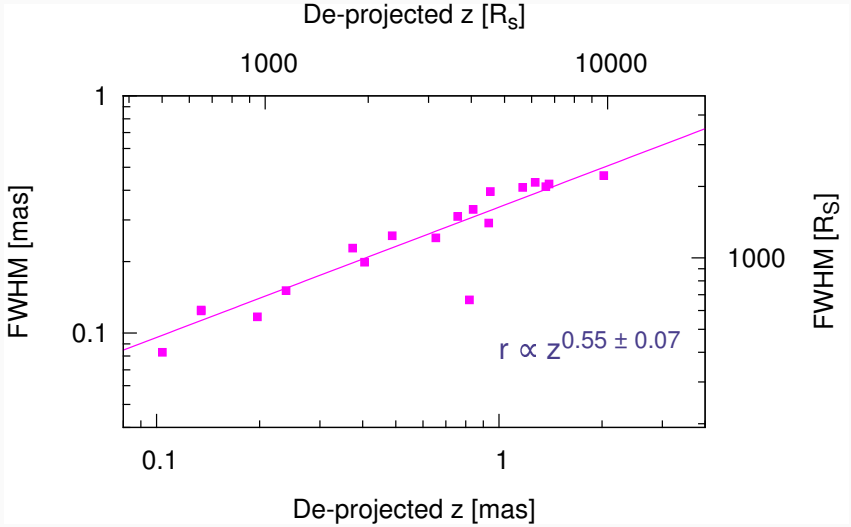


Boccardi et al. 2016a

# Stacked image of all 4 epochs



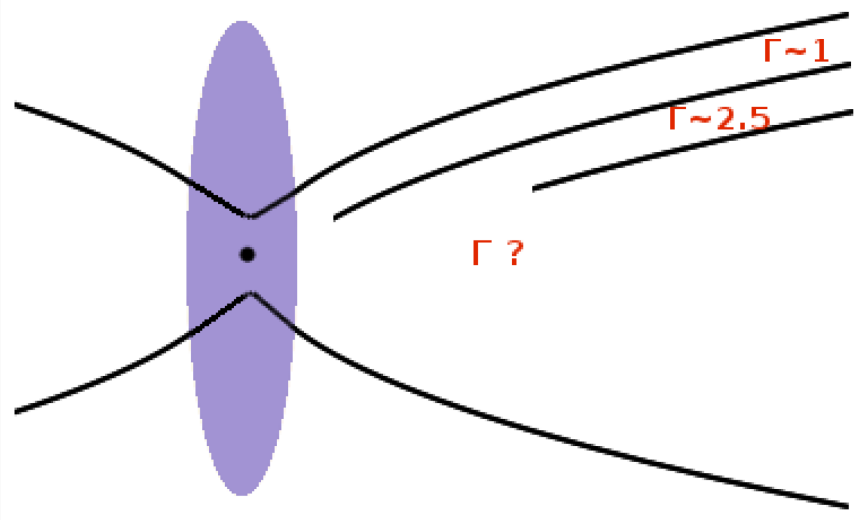

Jet width vs. distance from the core

→ limb brightened jet structure

→ parabolic shape with a mean opening angle, $\Theta \sim 5^\circ$

# Simplified view of the stratified jet in Cyg A

- Parabolically expanding
- Accelerating on scales of $10^3 - 10^4\ R_{\rm s}$
- Spine-sheath structure
- Even faster flow might exist
- On larger scales, at 5 GHz, the jet appears cylindrical (e.g. Carilli et al 1991




Boccardi et al. 2016a

# Summary

- Our VLBI studies indicate that the jet in Cygnus A is produced by a mildly relativistic and parabolically expanding disk wind
- Acceleration and shape are consistent with expectations from a magnetically-driven jet.
- Stratified jet structure and limb brightening of the flow suggests coexistence with a faster narrow spine (BH-driven?)
- To further constrain this picture:
  - Proposed RadioAstron observations at 22 GHz, providing a beam of up to 60 $\mu sec$
  - Proposed more sensitive GMVA (3 mm/7 mm) observations close in time to the RadioAstron dates

# Thank you!