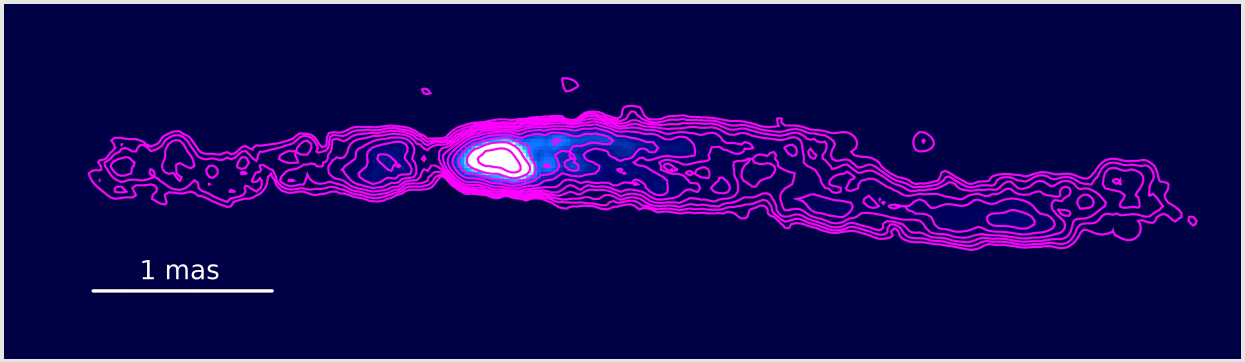
IMPRS astronomy & astrophysics Bonn and Cologne

Max-Planck-Institut für Radioastronomie

Bia Boccardi

MPIfR - Bonn

Stacked Global VLBI image of CygA at 7 mm



mm-VLBI observations of Cygnus A

(Collaborators: T.P. Krichbaum, U. Bach, V. Karamanavis, E. Ros, F. Mertens, J.A. Zensus)

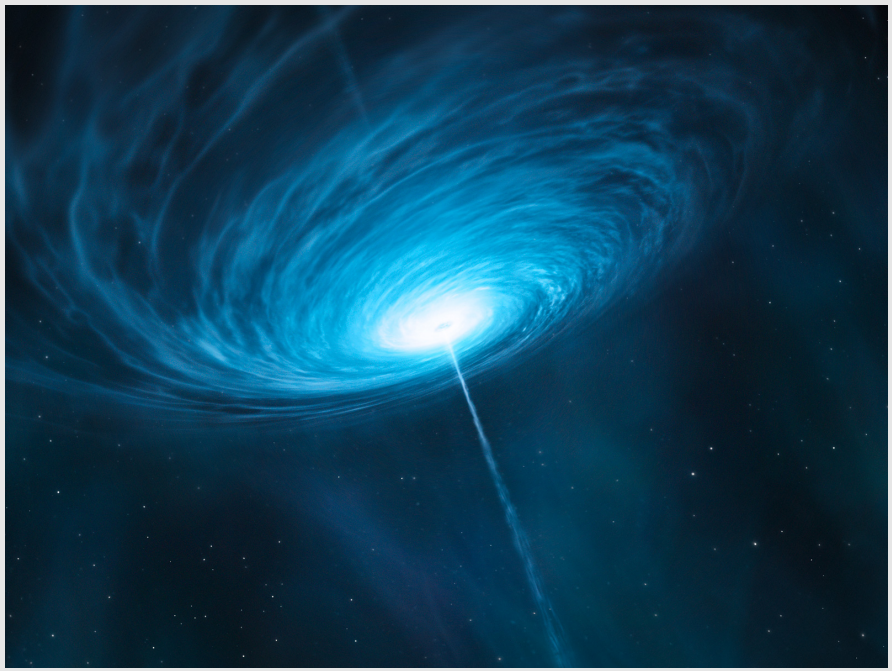
12th EVN Symposium - Cagliari, 7-10 October 2014

Relativistic jets - Open problems

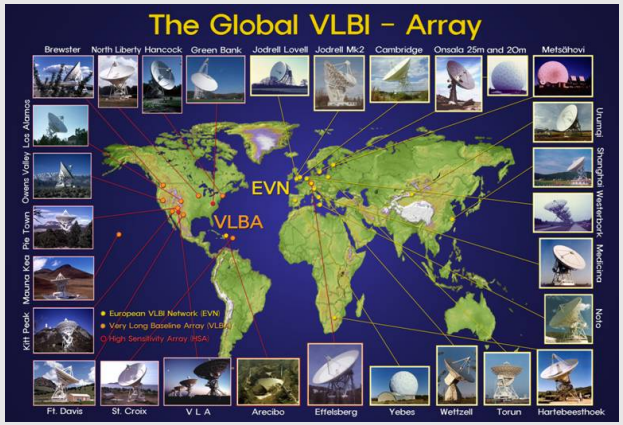
How are jets launched? Where and how are they accelerated? What is the collimation mechanism?

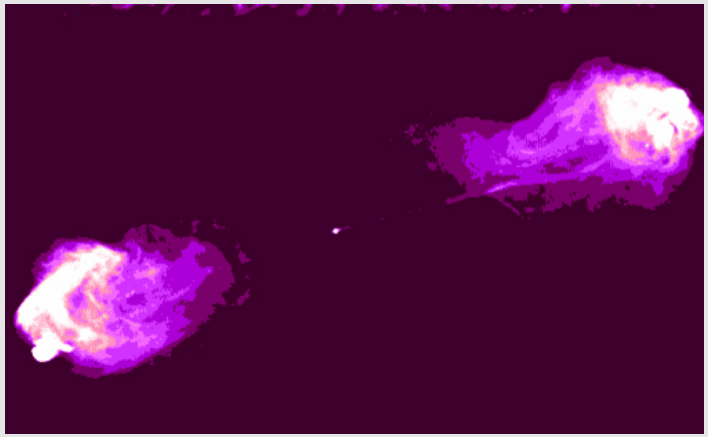
Models and simulations predict crucial processes to happen within ∼tens/hundreds R_S

Observational constraints still poor on these scales!



Why Cygnus A?



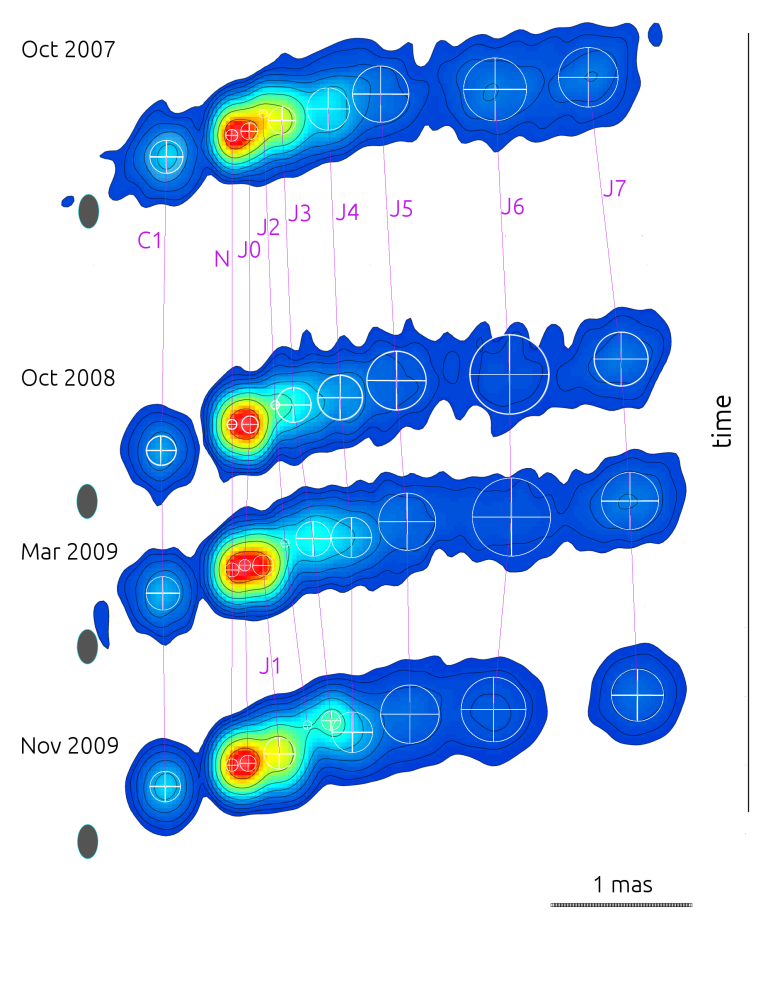


Observing Cygnus A with mm-VLBI: angular resolution down to $\sim$ **45** μ**as**
$\Rightarrow$ Linear scale: $\sim$ **48** milli-pc $\sim$ **200** $\mathbf{R_S}$!

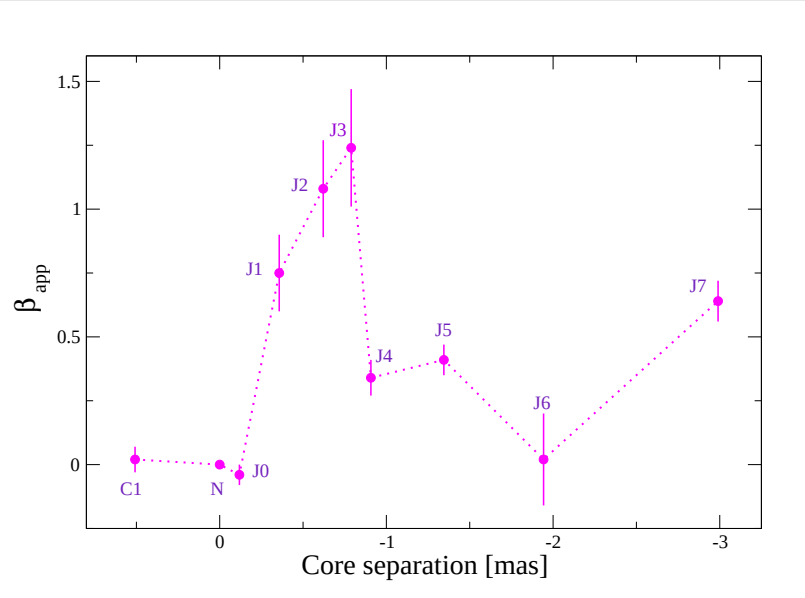
- Detailed imaging of emission regions which appear self-absorbed at longer wavelengths.
- **Transverse resolution of both jet and counter-jet!**
  $\Rightarrow$ study of collimation and stratification.

Kinematic analysis at 7 mm

Global VLBI observations at 7 mm
(VLBA,GBT,On,Nt,Eb,Yb)



- Acceleration in the inner 0.7 pc of the jet
- $\beta_{app}^{max} = 1.24 \pm 0.23 \Rightarrow \theta < 77°$
- Drastic drop of speed in the outer jet.
  Intrinsic deceleration?
- Counter-jet appears stationary.



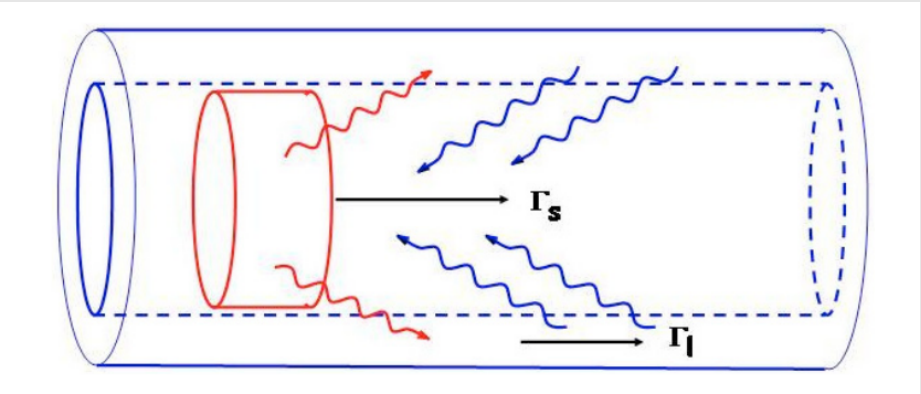
TRANSVERSE STRUCTURE IN RELATIVISTIC JETS

High resolution imaging ⇒

Jets are not homogeneous outflows, but show complex stratification and significant transverse motion!

Examples: M87, 3C84, Mrk 501, 3C273.

Observed limb brightening explained with spine+sheath structure of unclear origin...

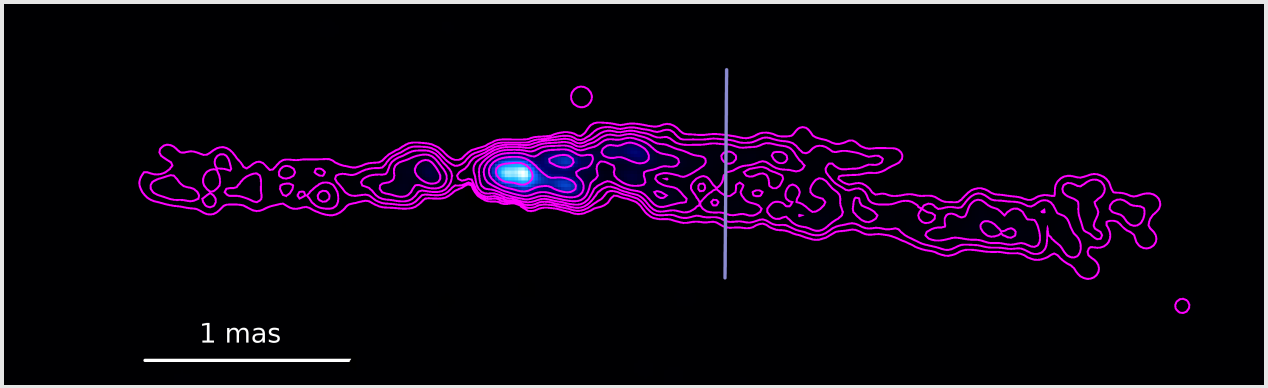


Ghisellini+ 2005

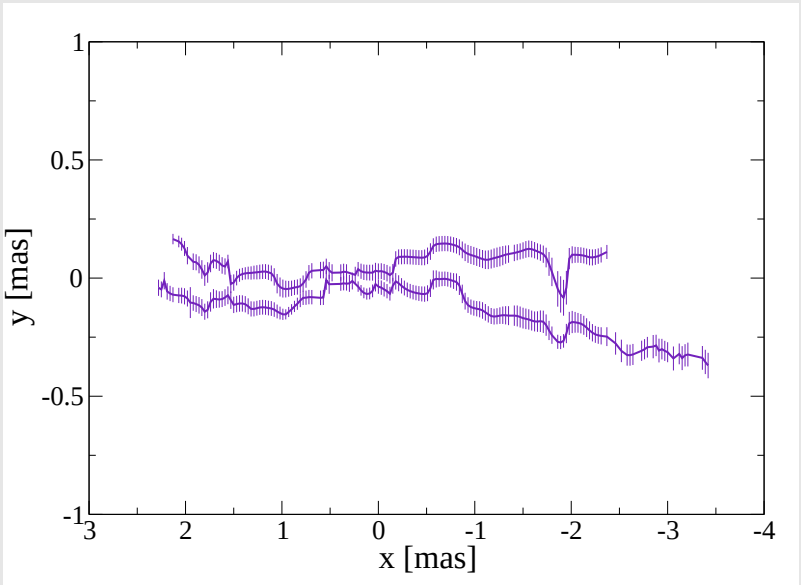
- Direct result of jet formation process: Blandford & Paine + Blandford & Znajek (e.g. Xie+ 2012)
- Kelvin Helmholtz instabilities (e.g Lobanov & Zensus 2001) or interaction of the walls of the jet with the ambient medium.

Ridge line study at 7 mm

7 mm map from November 2009, restored with beam FWHM of 0.1 mas

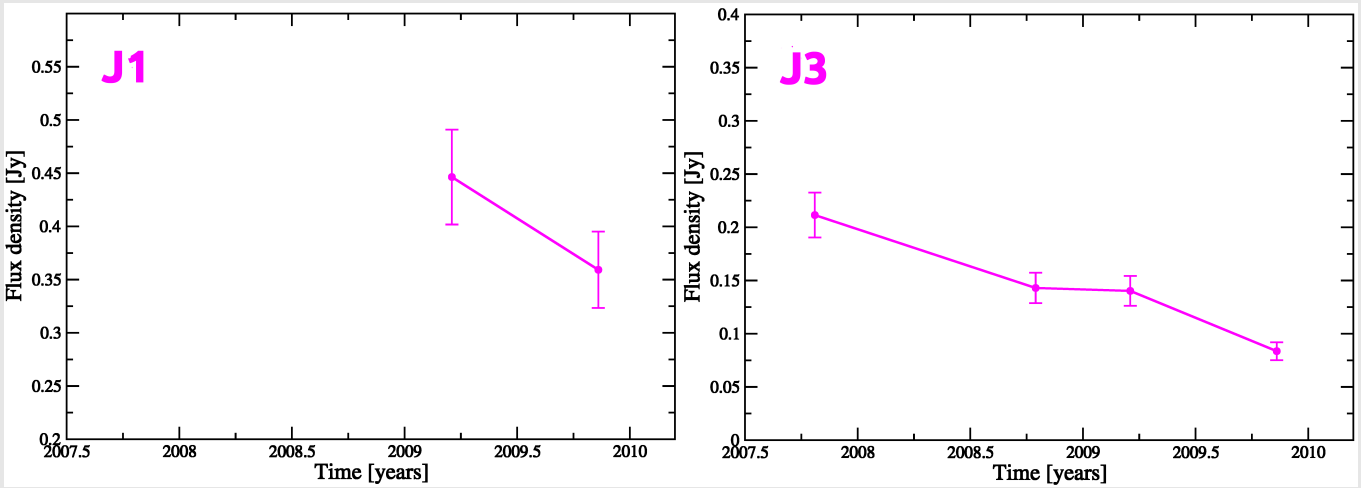


- Maps restored with circular beam of 0.15 mas FWHM.
- Sliced transversally pixel by pixel (every 0.03 mas).
- Gaussian fit of the double peaked intensity profiles.



Double ridge line structure present both in jet and counter-jet!

Apparent deceleration due to de-boosting of the spine?

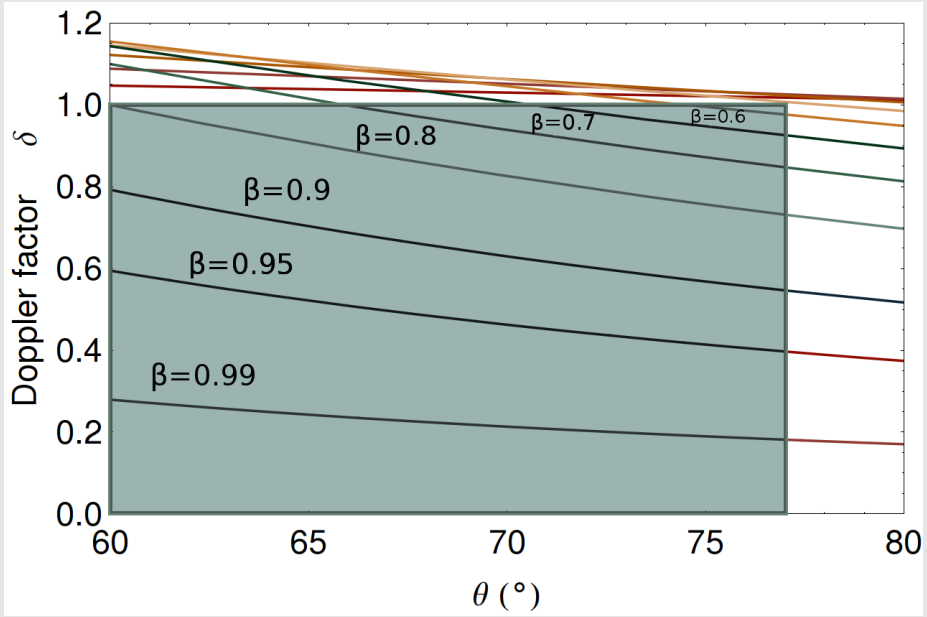


Flux density is decreasing during acceleration!

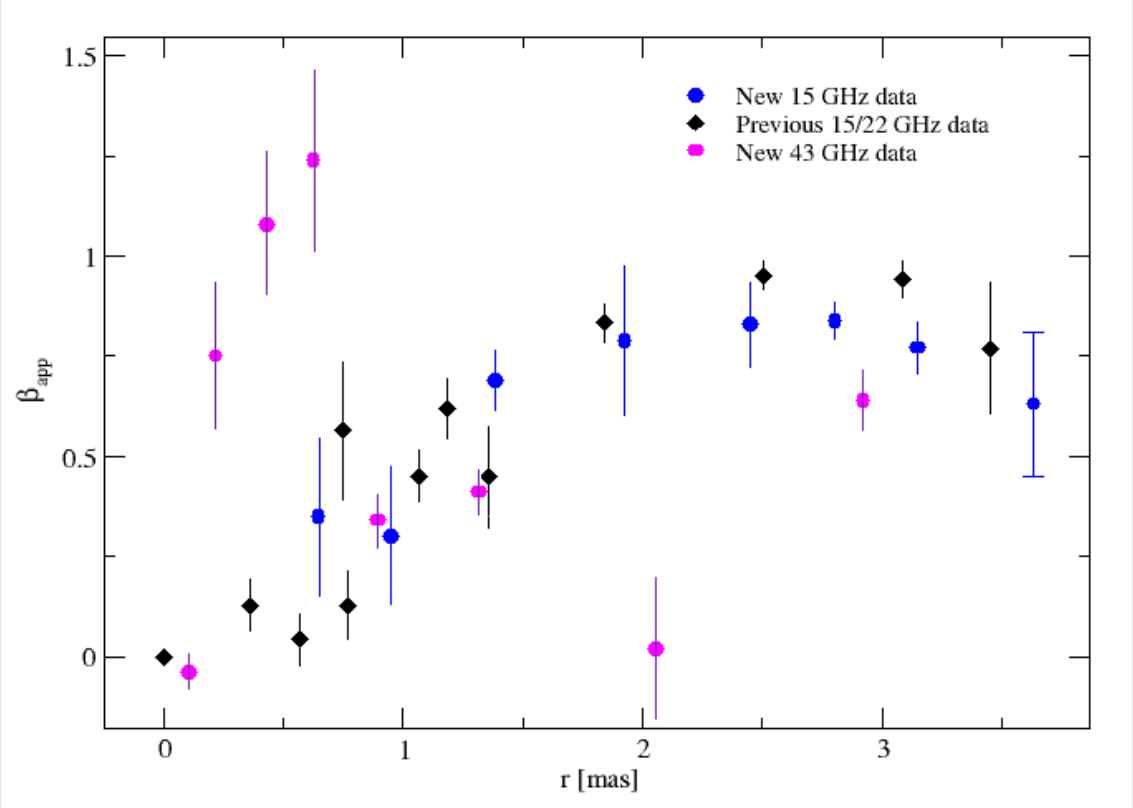
For $\theta = 75°$, the flow gets de-boosted ($\delta < 1$) when $\beta > 0.5$.

From the kinematics:

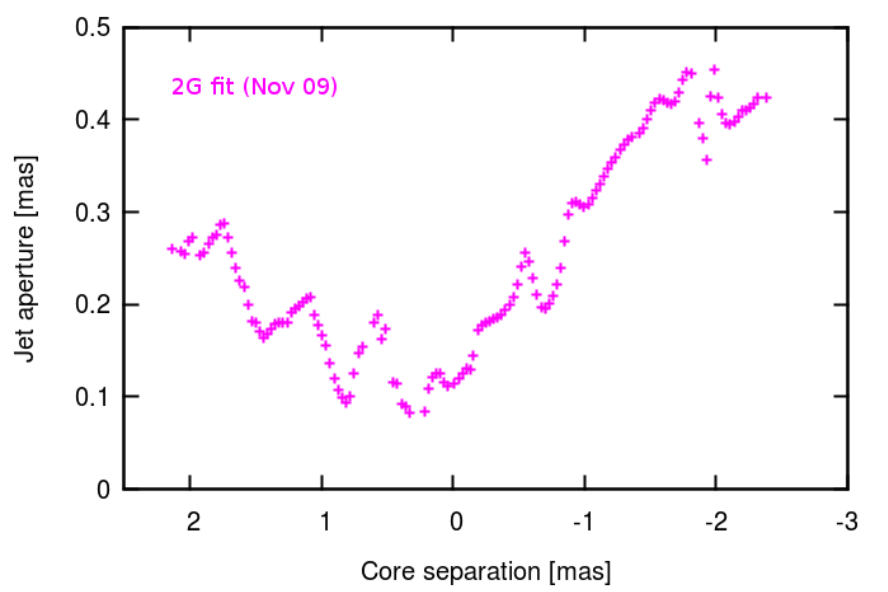
→ **De-boosting starts within the inner 0.3 pc of the jet.**

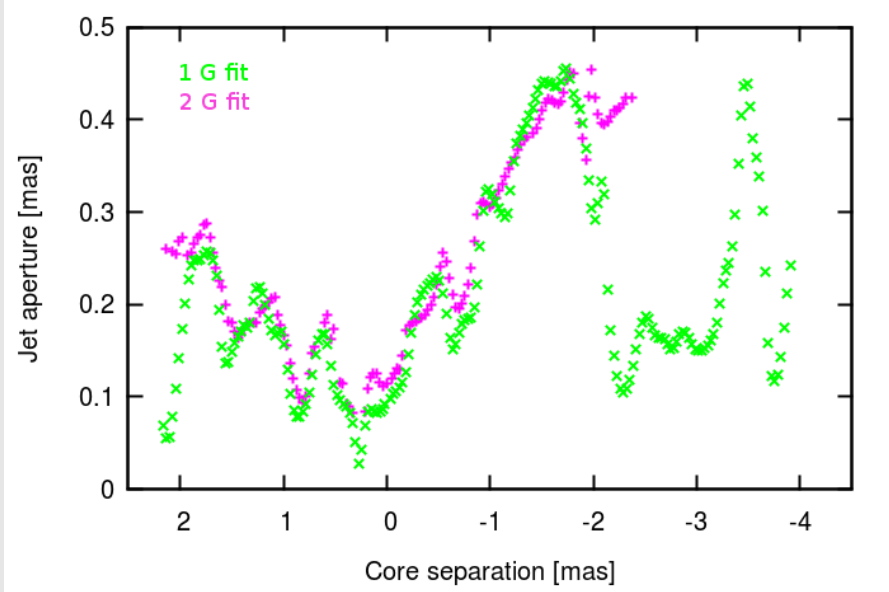


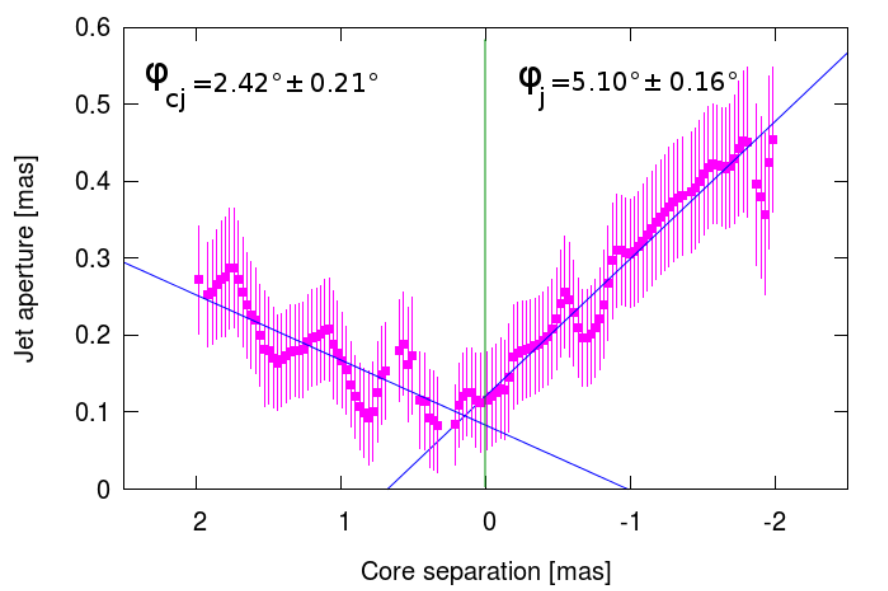
At lower frequencies?



Opening angle

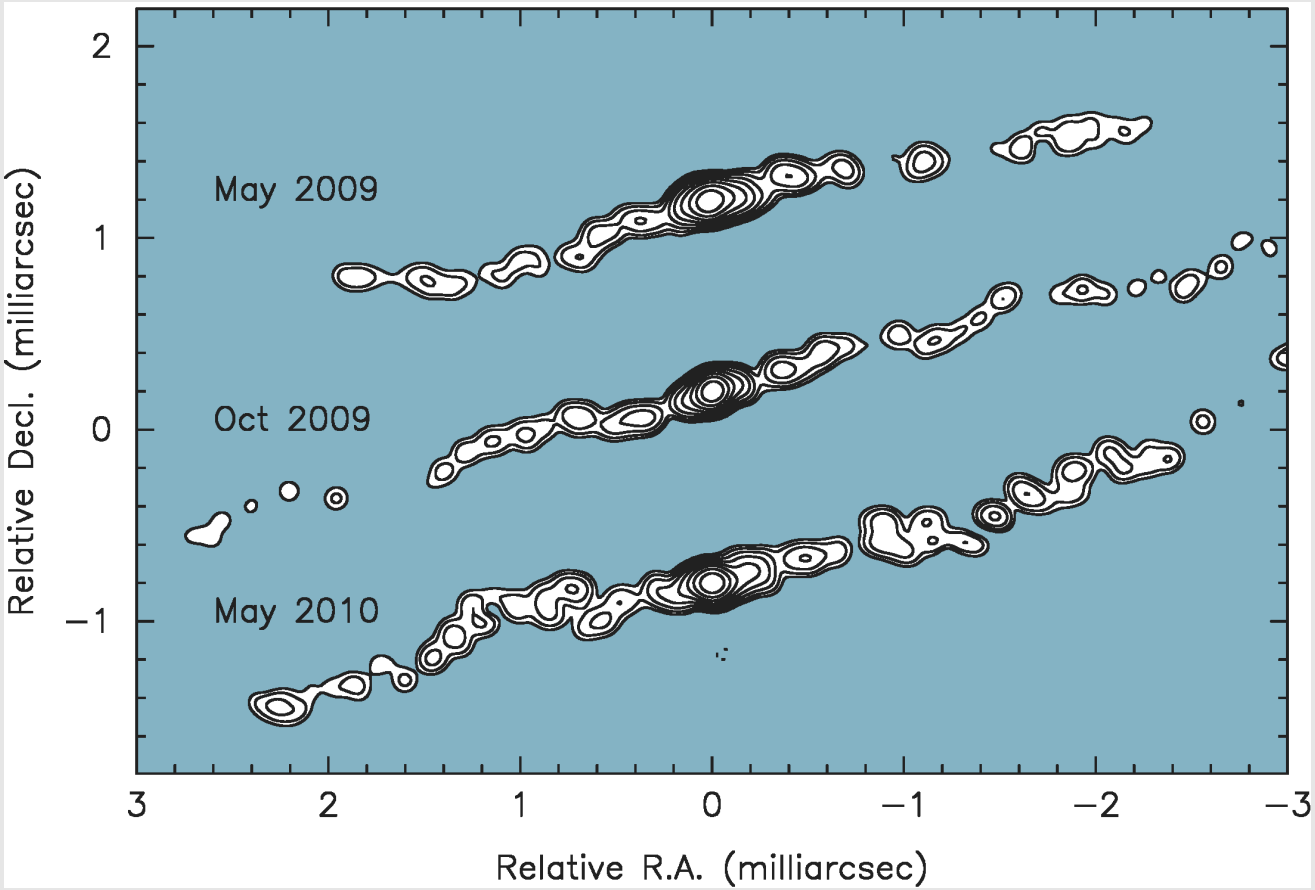






Are jet and counter-jet really intrinsically symmetric?

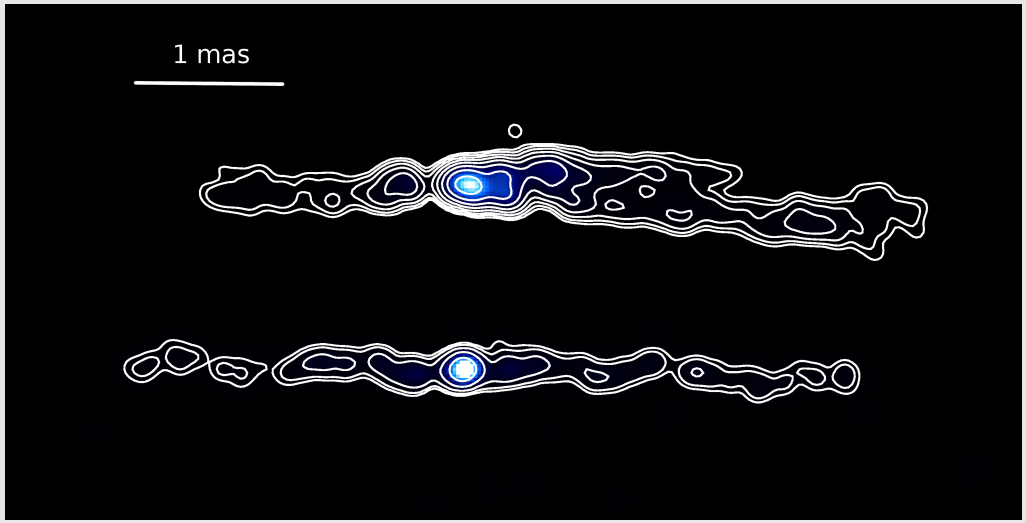
3 MM MAPS

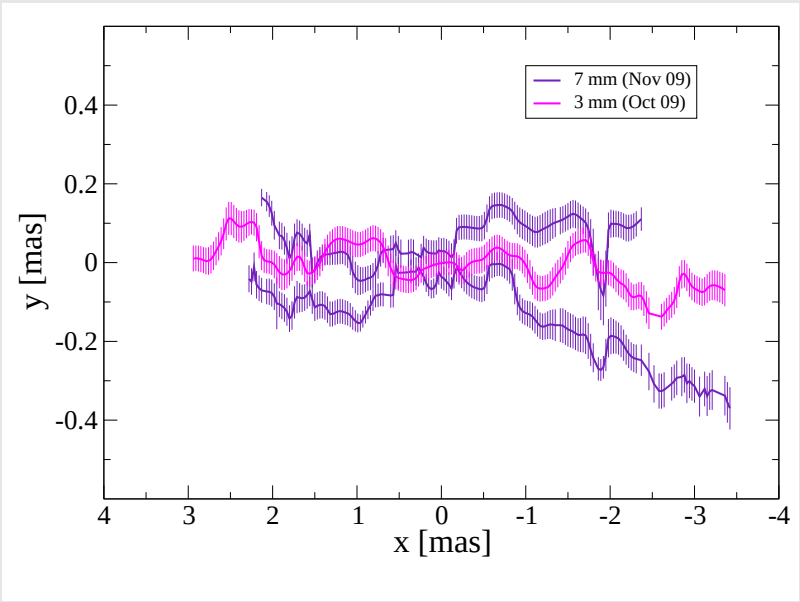

May 2009
Oct 2009
May 2010
Relative Decl. (milliarcsec)
Relative R.A. (milliarcsec)
2
1
0
−1
3
2
1
0
−1
−2
−3

TRANSVERSE STRUCTURE AT 3 MM

7 and 3 mm maps from November 2009 and October 2009, respectively.

Beam FWHM 0.15 mas





- A single Gaussian is seen at 3 mm.

Conclusions

- A faster part of the flow emerges when imaging the base of the jet at 7 mm. Its acceleration is on sub-parsec scale.
- Cygnus A shows a limb brightened structure, arising very close to the central engine → Direct result of jet formation process?
- Speeds measured in the outer jet and at lower frequency/resolution may reflect the speed of the slower layers.
- The apparent opening angle in jet and counter-jet is different → Intrinsic asymmetry?
- At 3 mm, a single ridge line is seen and it lies between the 7 mm rails.