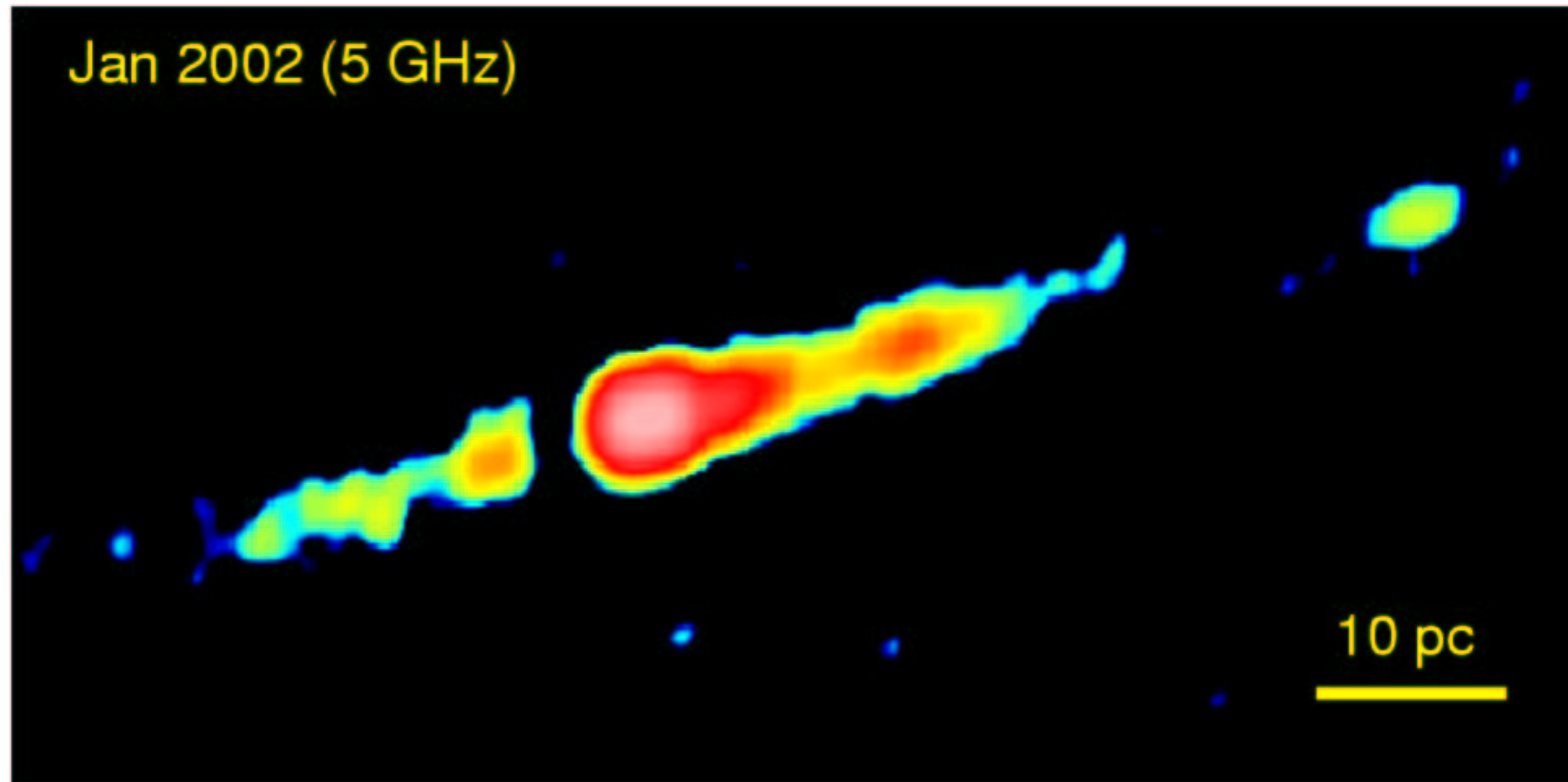


Multi-frequency & multi-epoch VLBI study of Cygnus A

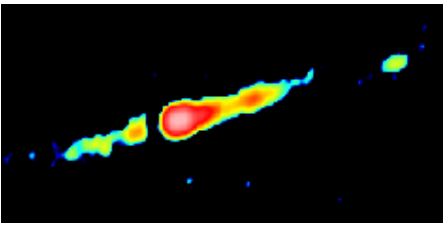
Uwe Bach



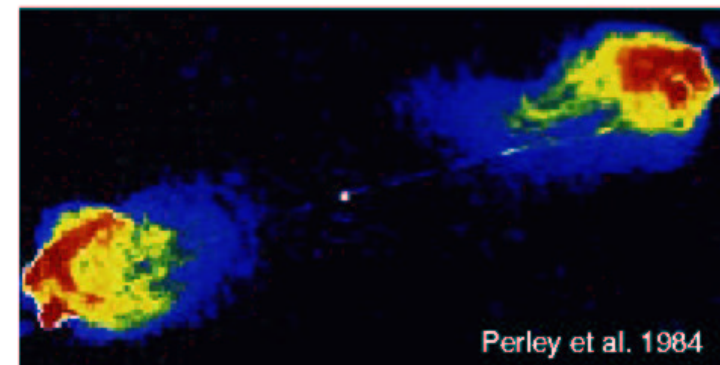
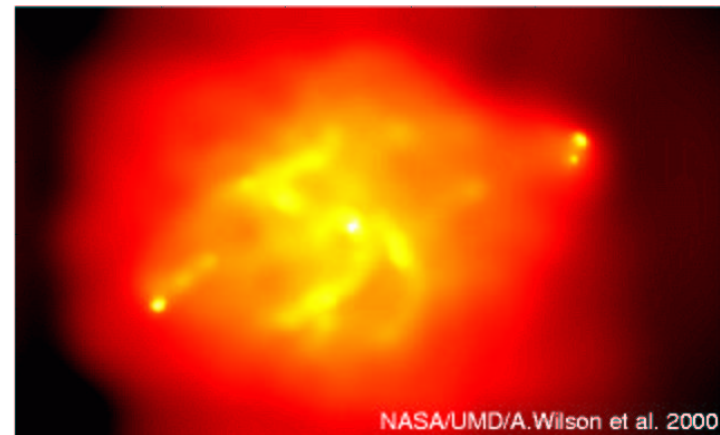
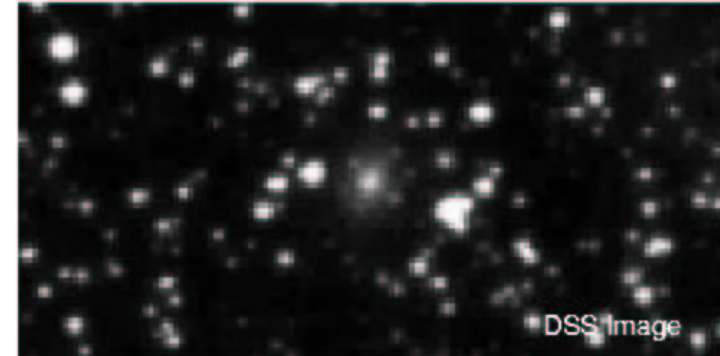
in collaboration with:

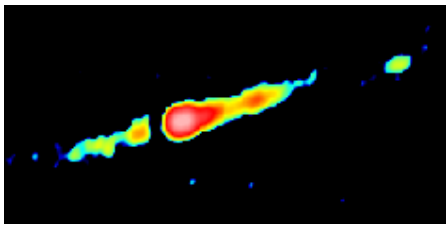
M. Kadler, T.P. Krichbaum, E. Middelberg, W. Alef, A. Witzel
and J.A. Zensus

About Cygnus A



- One of the first and strongest extragalactic radio sources
- Nearby: $z=0.0561$
- Huge dimension on the sky: $2'$
- Pronounced double structure with hot-spots and radio lobes
- Prototype for the FR II radio galaxies
- Test object for the standard model of radio galaxies and quasars





Motivation

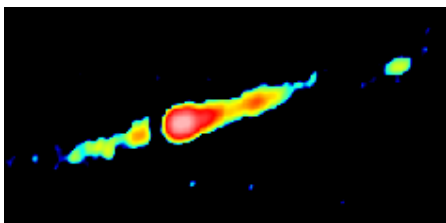
- No phase-referencing on the core of Cygnus A was done.
- Previous proper motion studies were done at lower frequencies (Carilli et al. 1994; Bach et al. 2002), except Krichbaum et al. 1998.
- Cygnus A is an ideal test object for jet theory and the unified scheme.

Our analysis is based on:

- Two multi-frequency epochs: 1996 at 15, 22, 43 GHz (VLBA+EB) and a phase-referencing in 2003 at 15 and 22 GHz (VLBA only)
- Two epochs at 15 GHz with VLBA+VLA1+EB in 2002

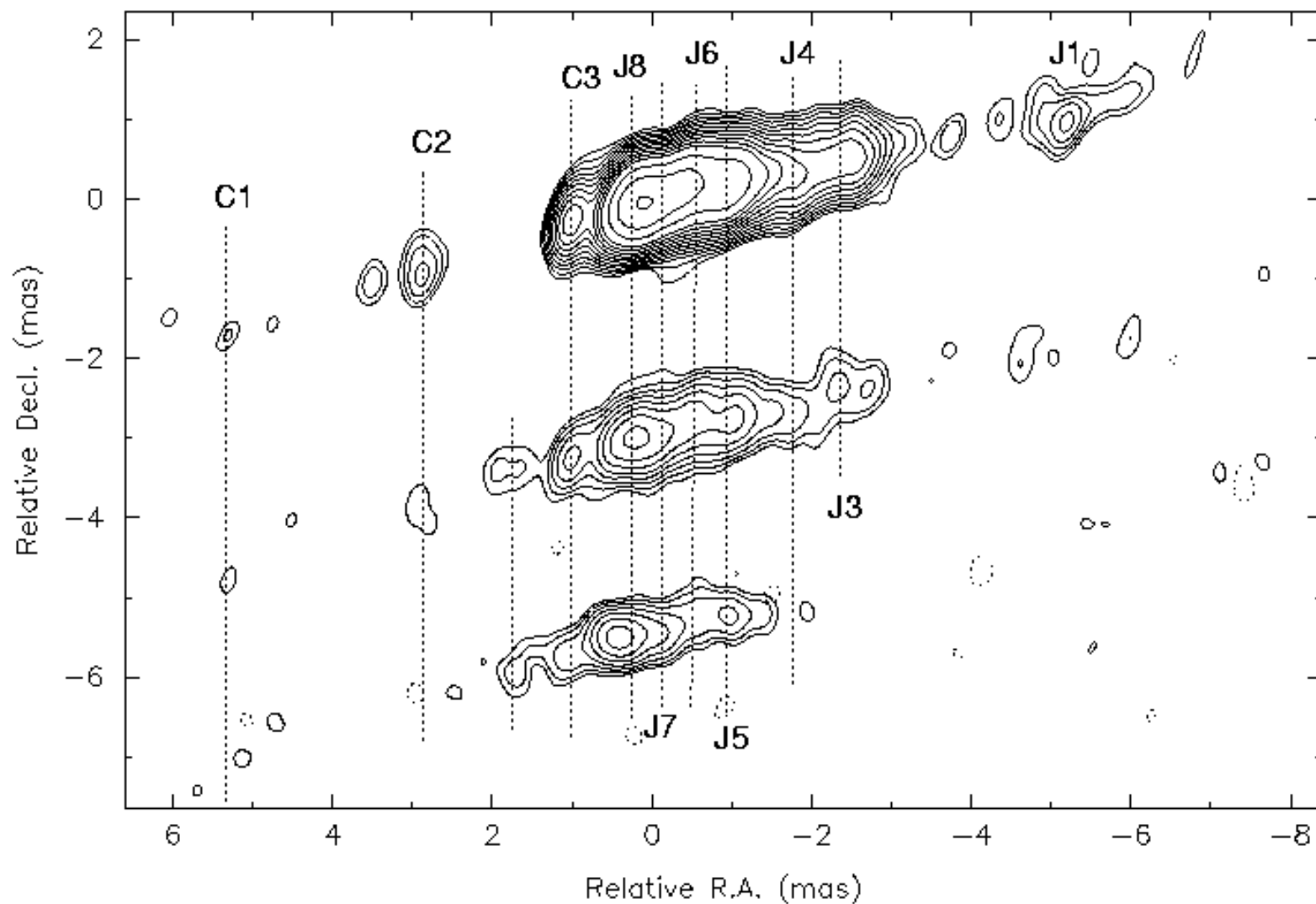
Complementary:

- 10 epochs from the VLBA 2cm Survey (Kellermann et al. 1998, AJ, 115, 1295; Zensus et al. 2002, AJ, 124, 662)

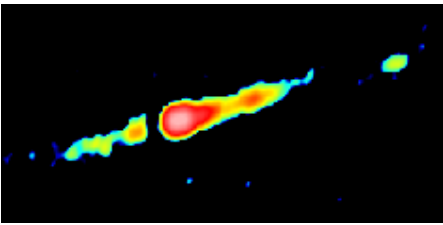


At different frequencies I

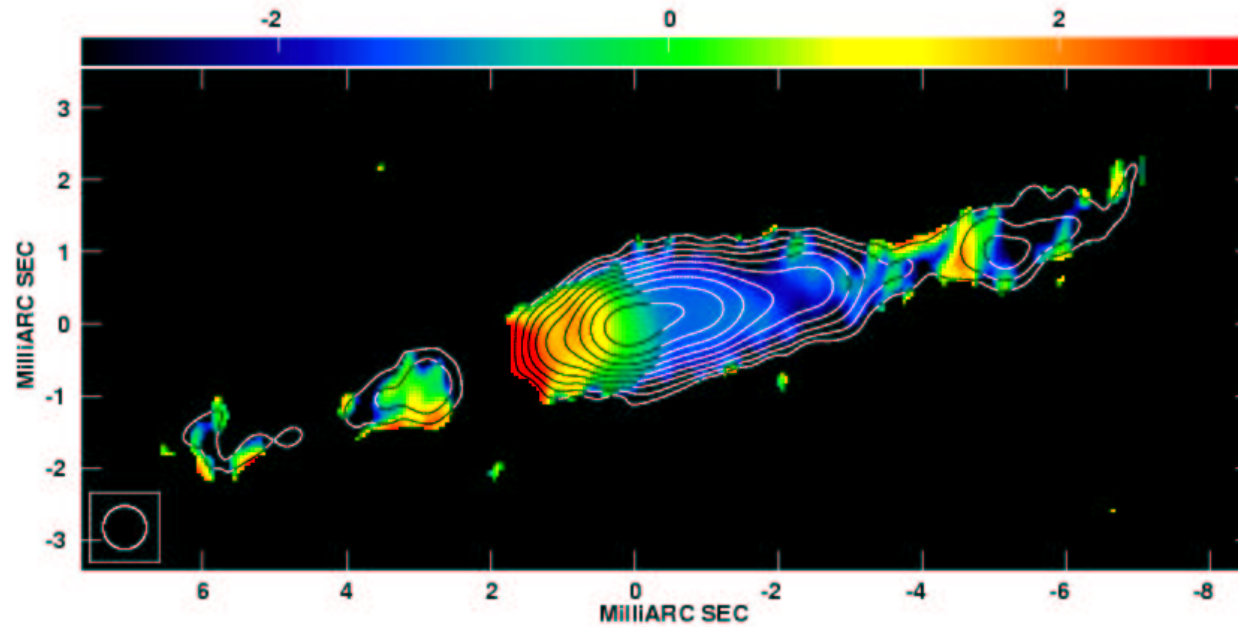
VLBI observations of Cygnus A at 2 cm, 1.3 cm and 0.7 cm
1996.72



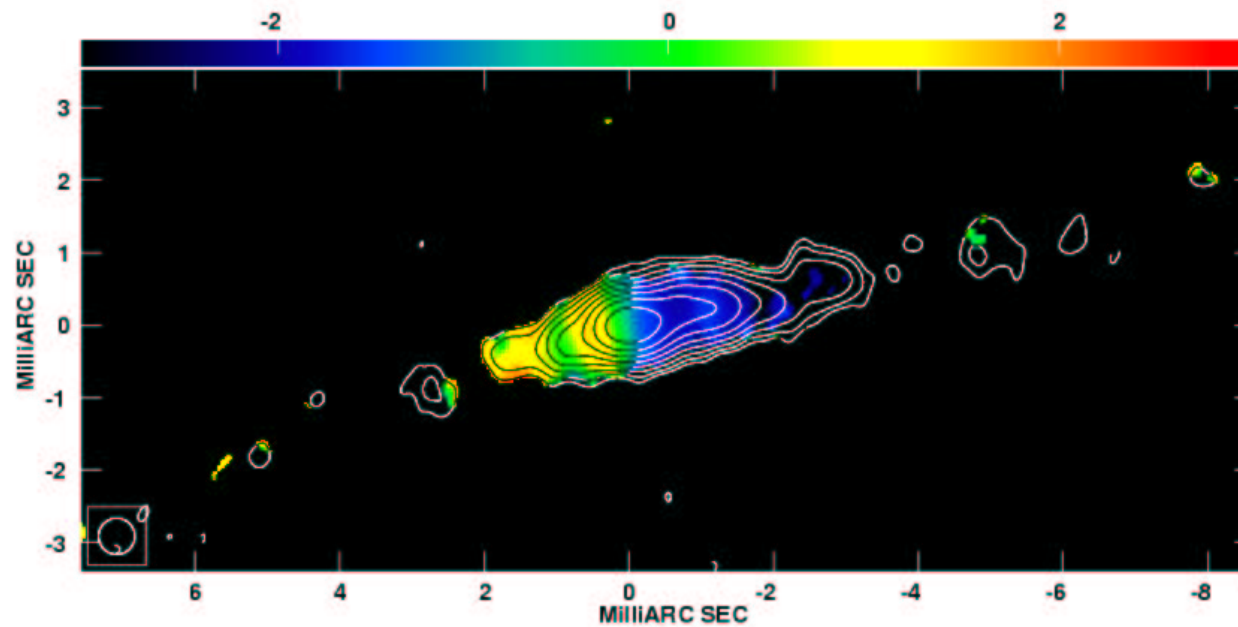
At different frequencies II

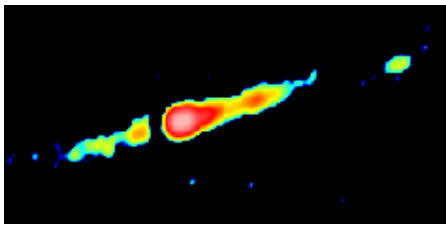


15/22 GHz



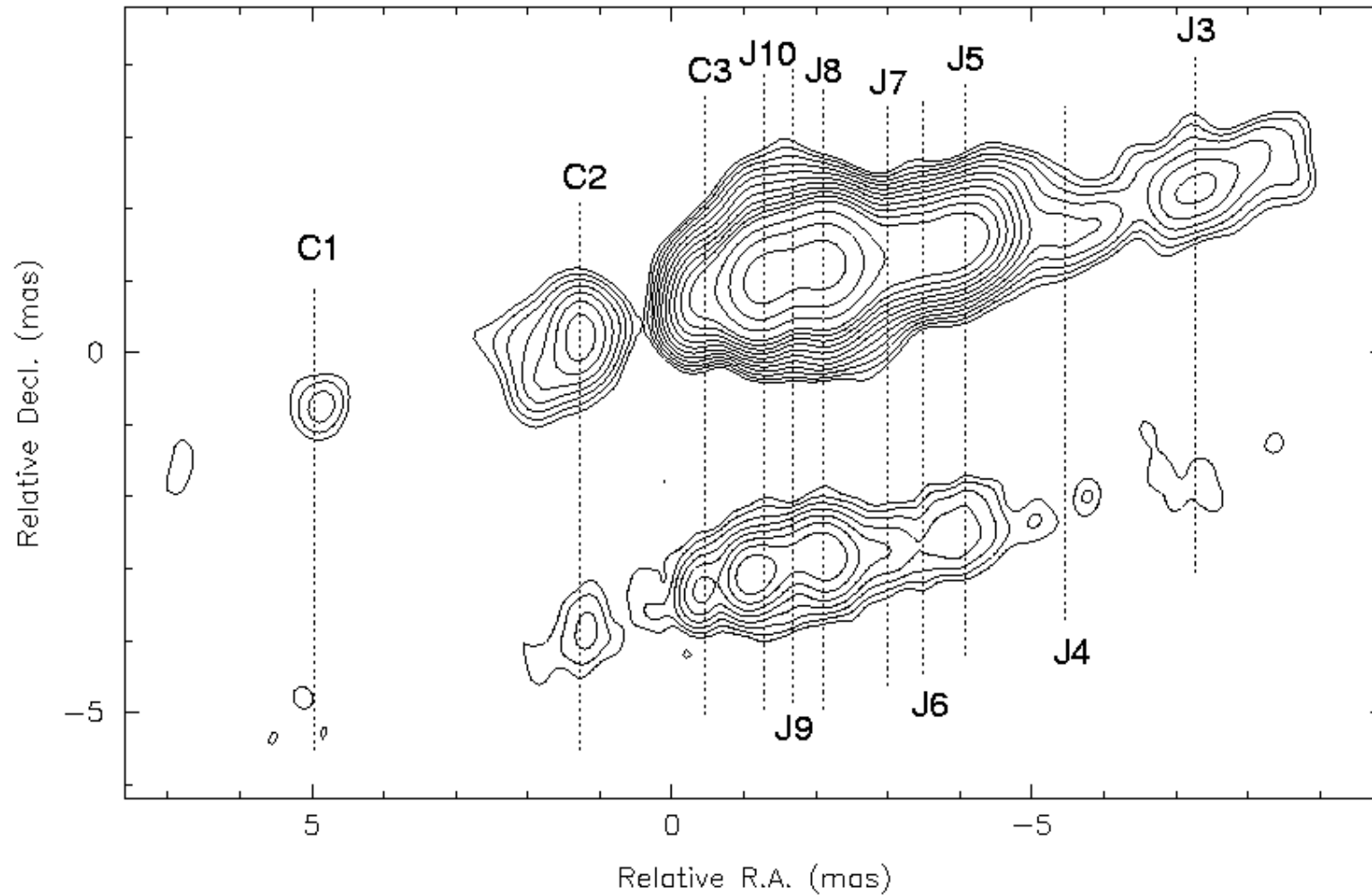
22/43 GHz



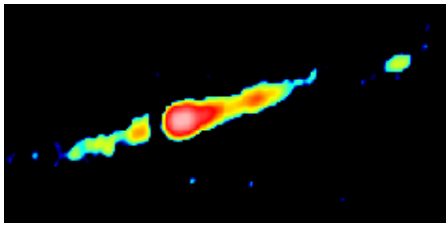


At different frequencies III

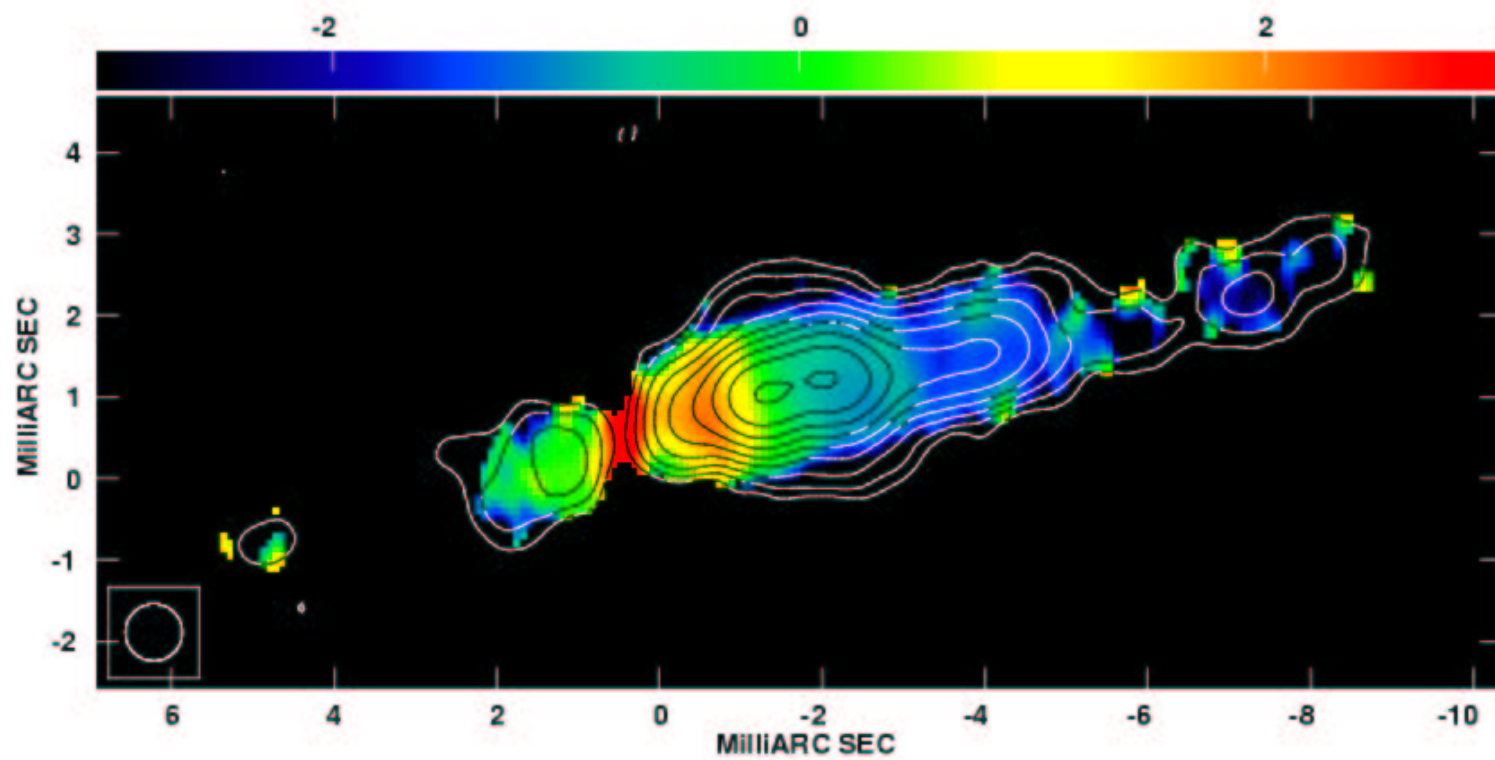
VLBA phase-referencing of Cygnus A at 2 cm and 1.3 cm
2003.04

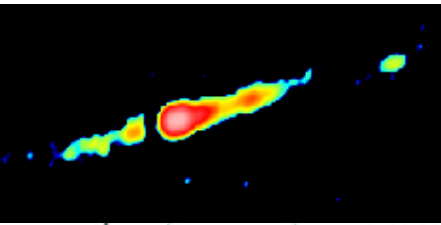


At different frequencies IV

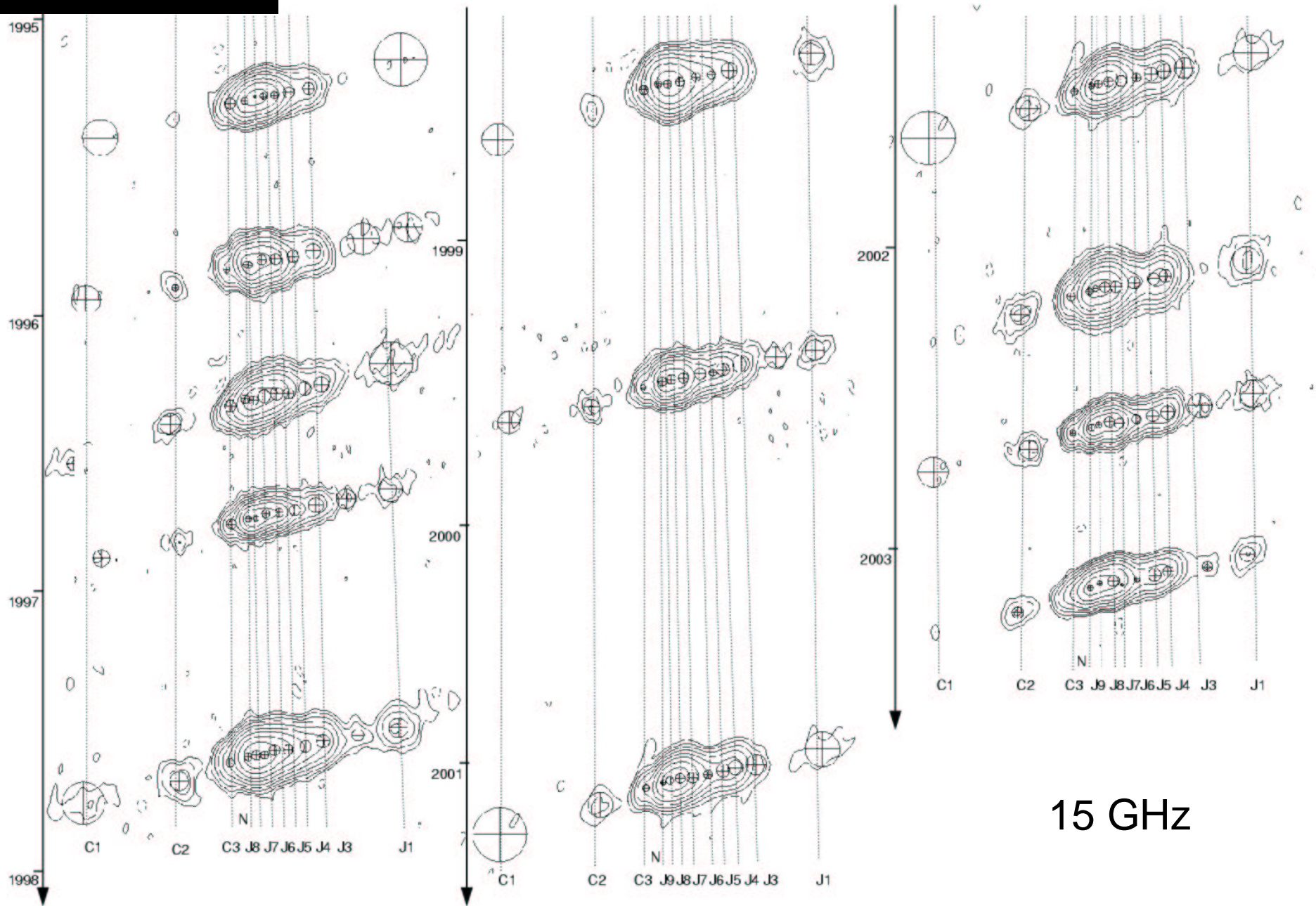


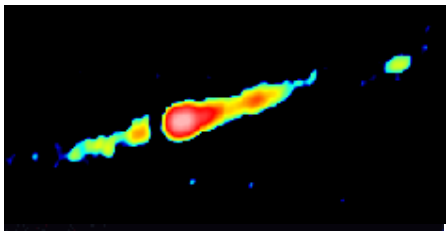
15/22 GHz



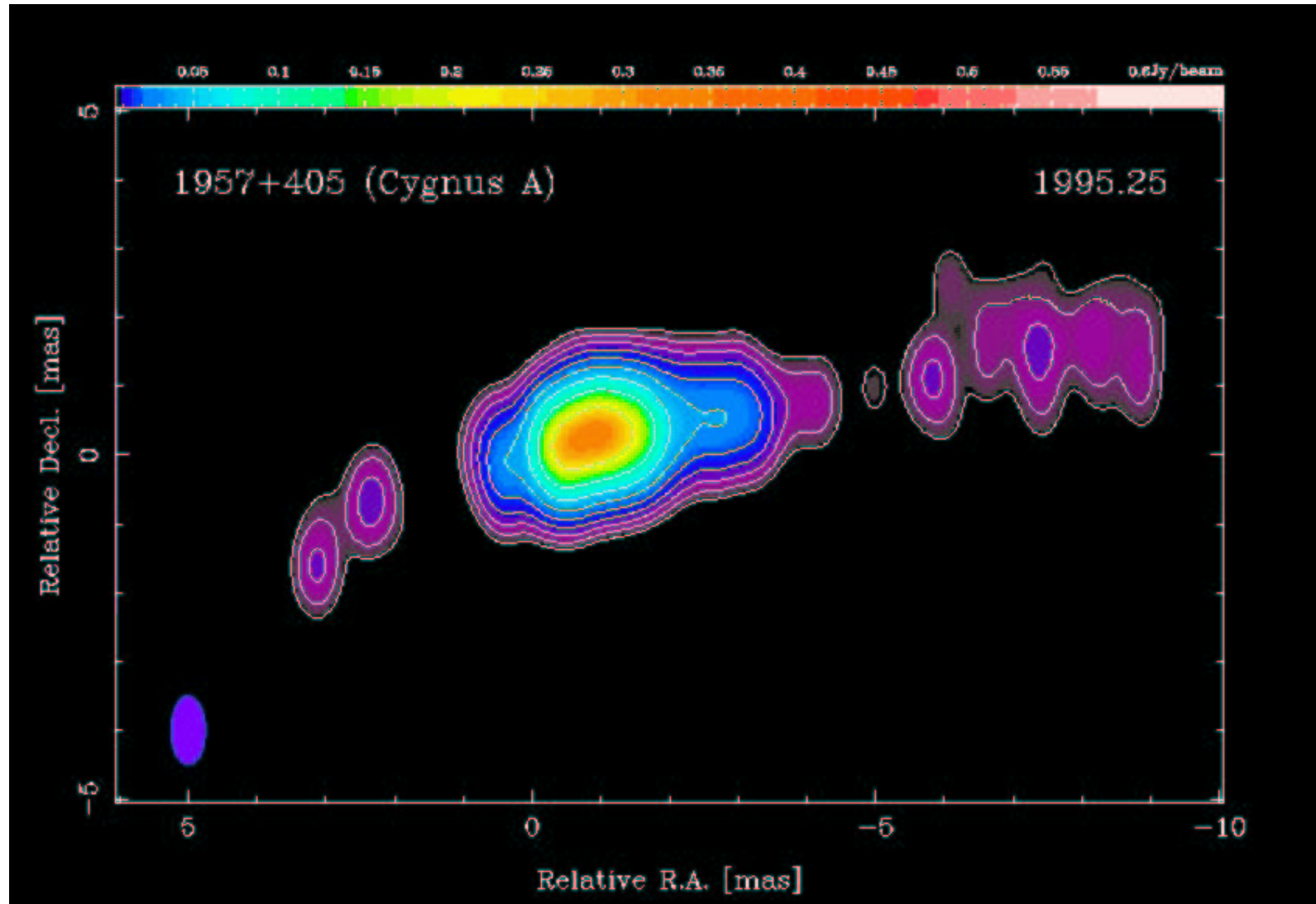


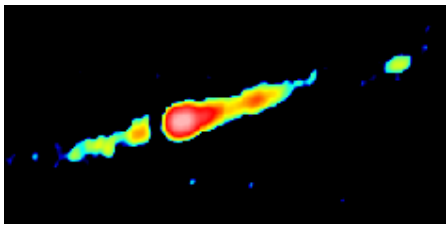
Component identification



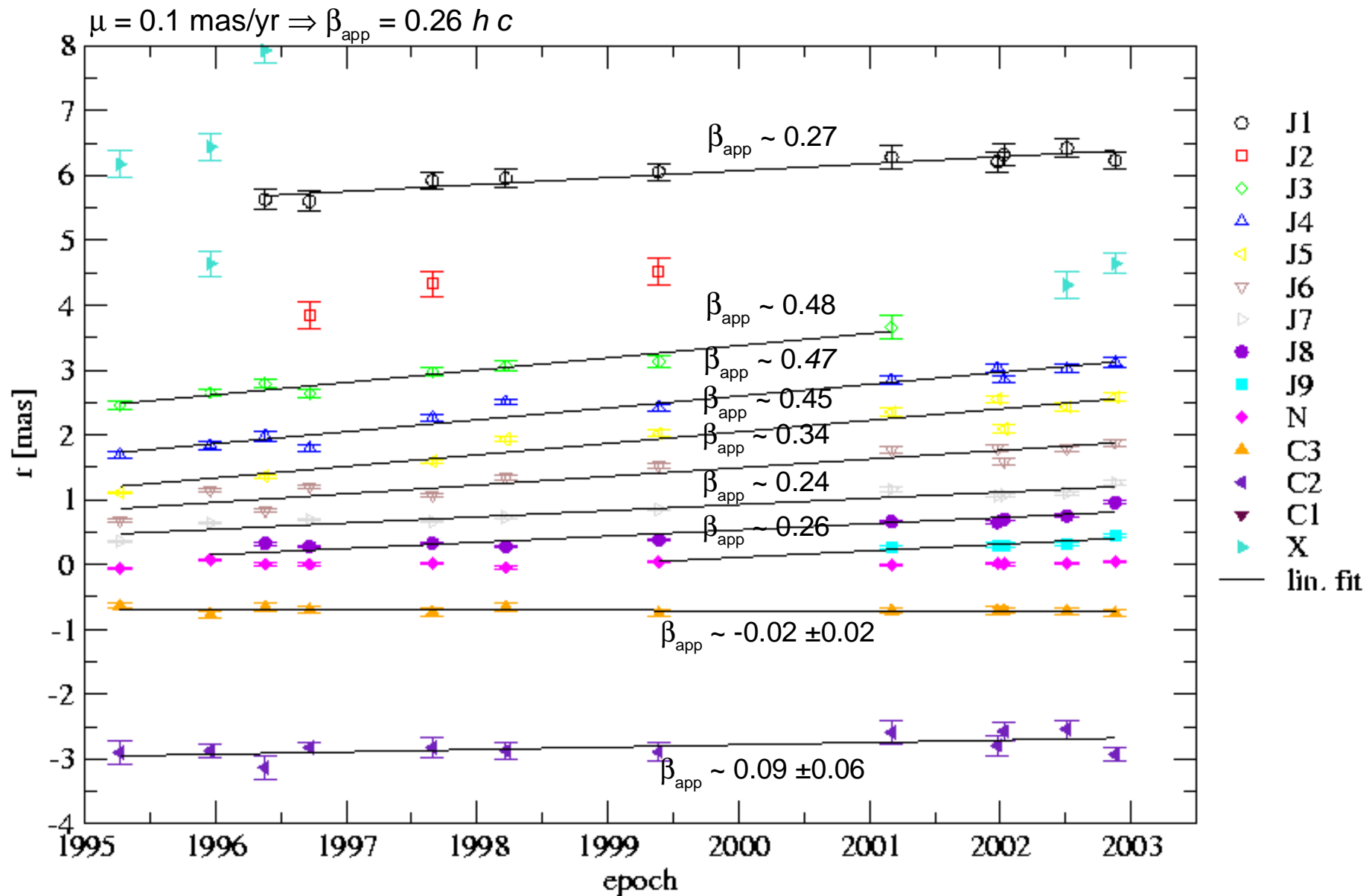


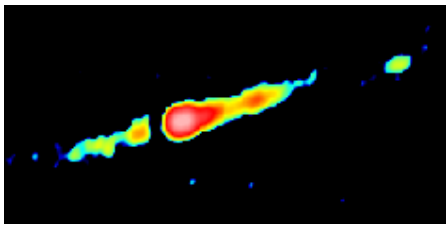
The Movie



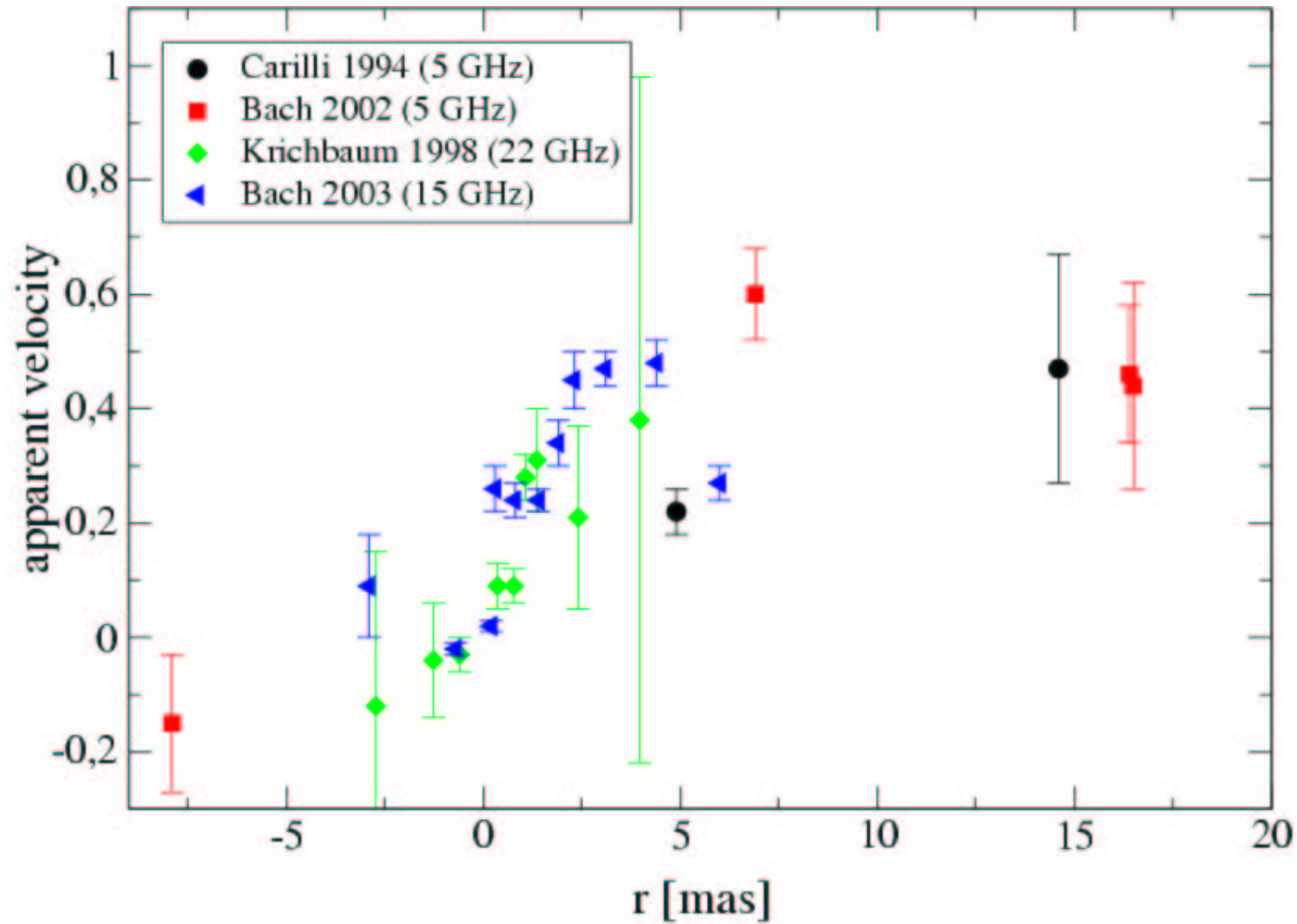


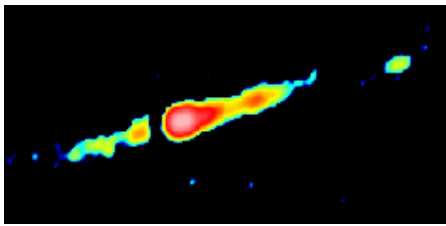
Proper motion I



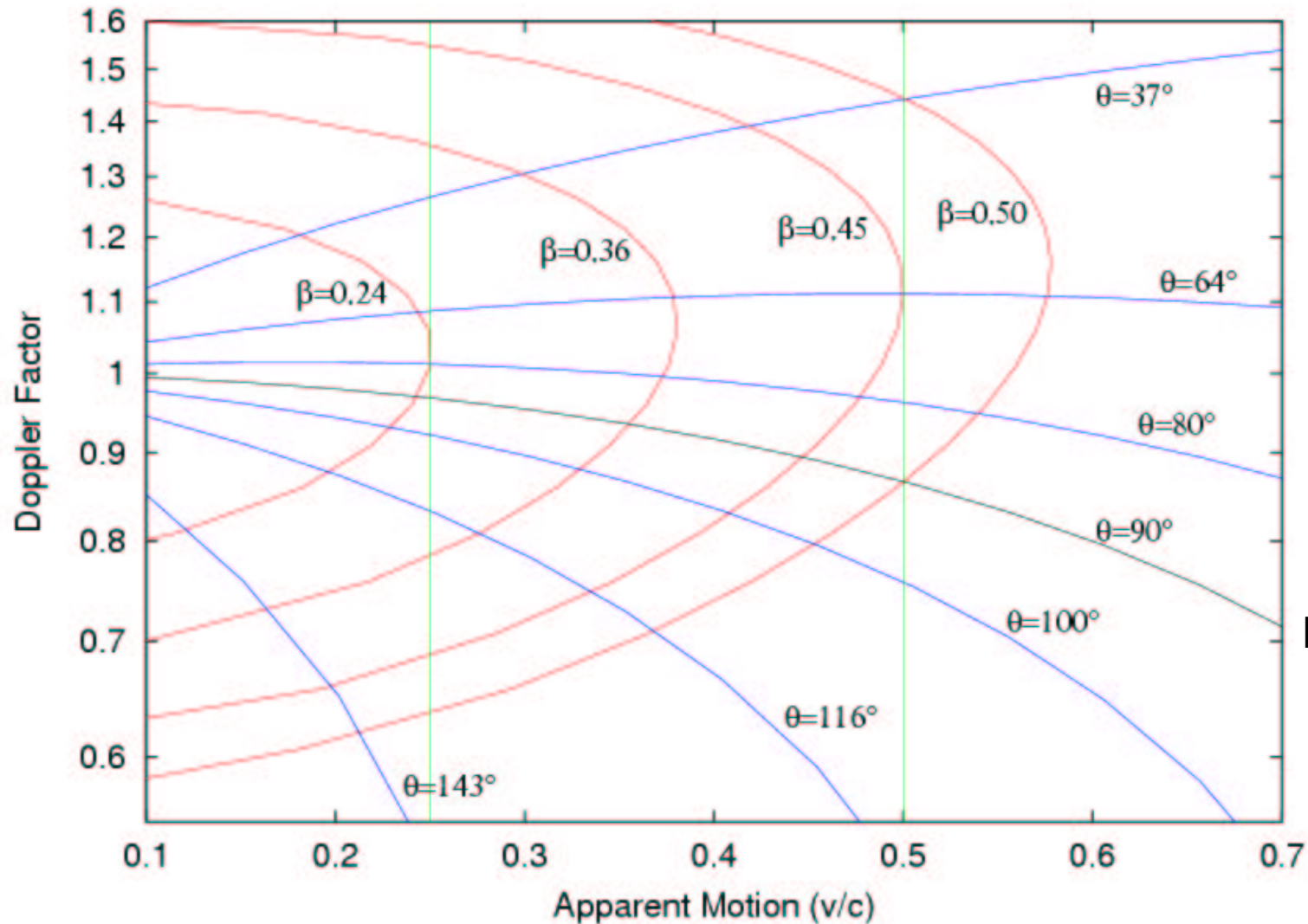


Proper motion II





Geometry and kinematics



Apparent jet-speed

$$\beta_{\text{app},j} = 0.5$$

Intrinsic jet-speed

$$\Rightarrow \beta_{\text{min}} = 0.45$$

$$\Theta = 64^\circ$$

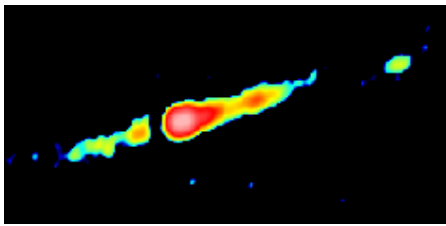
$$\Rightarrow \beta_{\text{max}} = 0.50$$

$$\Theta = 90^\circ$$

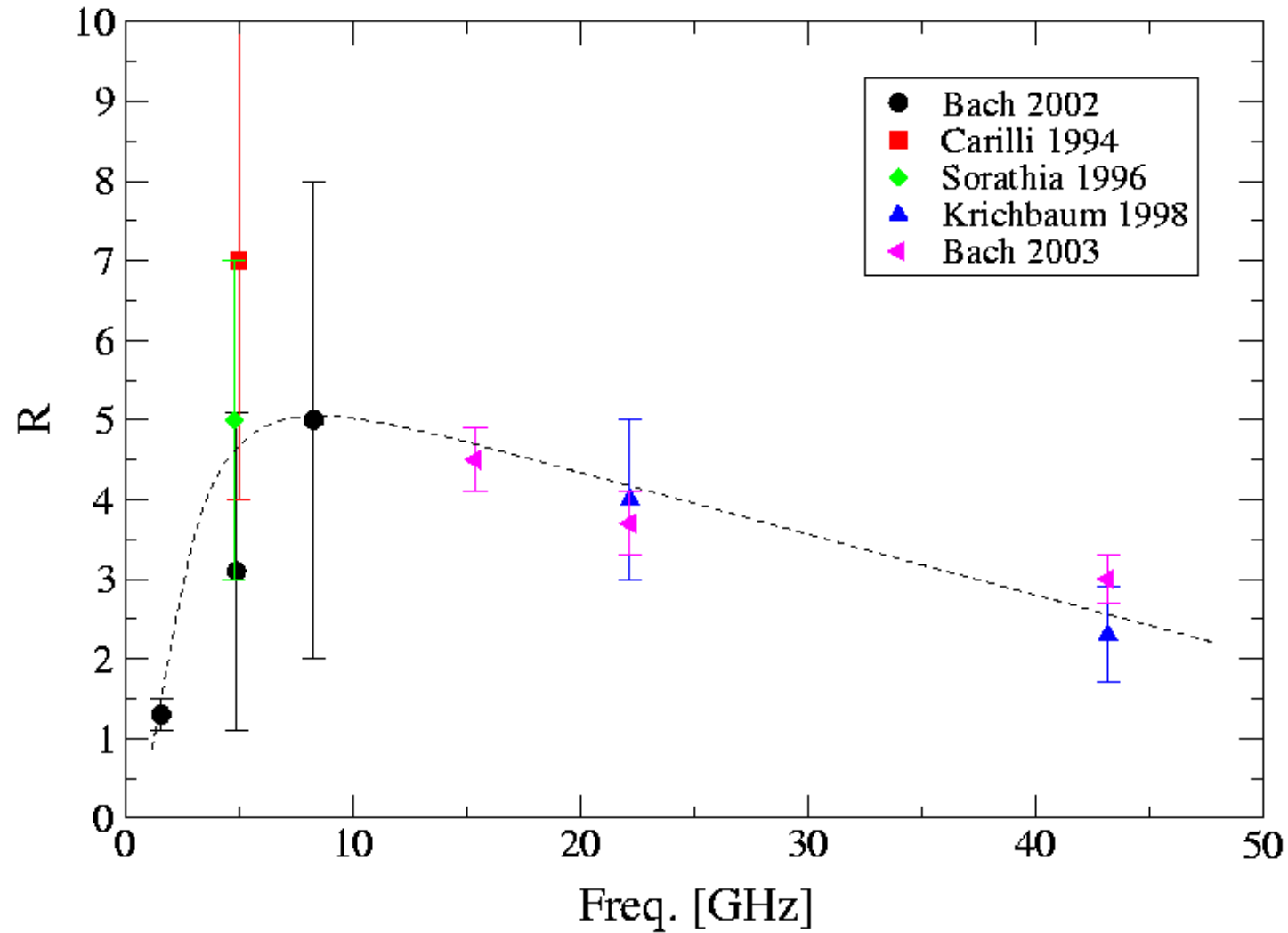
Expected counter-jet velocity

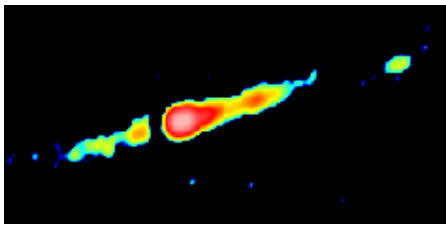
$$\Rightarrow \beta_{\text{app},cj} = 0.32 - 0.5$$

$$\Theta = 90^\circ - 116^\circ$$



Jet to counter-jet ratio





Summary

- We made the first multi-frequency phase-referencing of Cygnus A
 - The spectral indices and the frequency dependent jet to counter-jet ratio can be explained by an absorber around the core
 - We measured accelerated motion of up to $0.5 c$ in the jet but yet found no significant motion on the counter-jet side
 - Angle to the line of sight: $\theta > 65^\circ$
 - Discrepancy between the geometry and the non-detection of apparent motion in the counter-jet questions the symmetry of jet and c-jet
- We will continue our phase-referencing observations and will go to higher frequencies!