Rapid polarisation variability in the core of 0716+714

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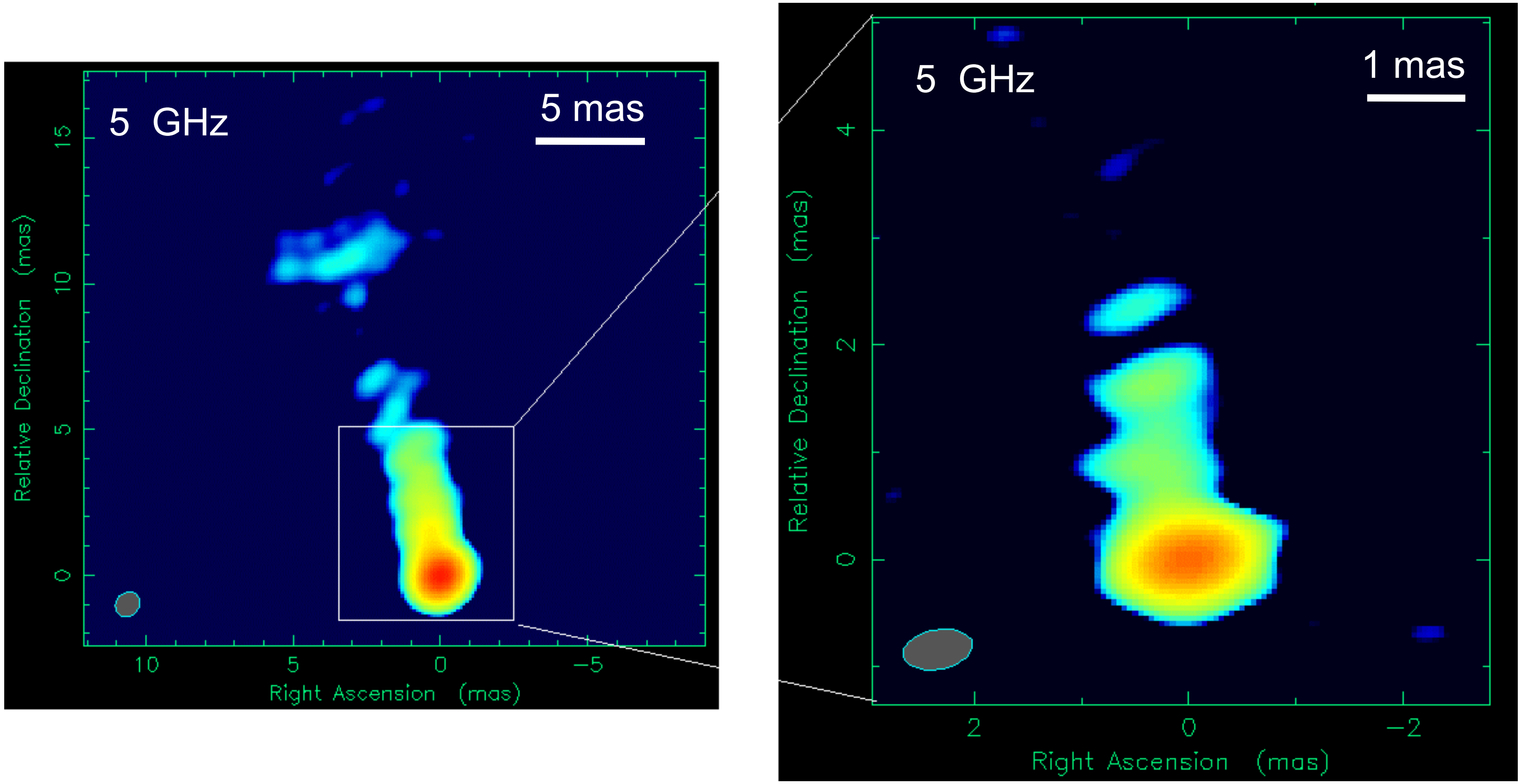
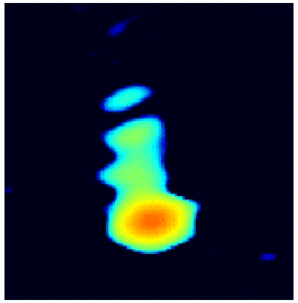


in collaboration with:
T.P. Krichbaum, E. Ros, A. Kraus, S. Britzen, A. Witzel and J.A. Zensus



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  - Kinematics of the jet in 0716+714 (long term variability).
  - VSOP.
- Space VLBI polarimetry of 0716+714 (short term variability)
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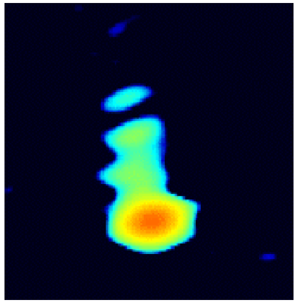
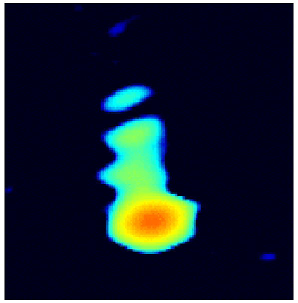


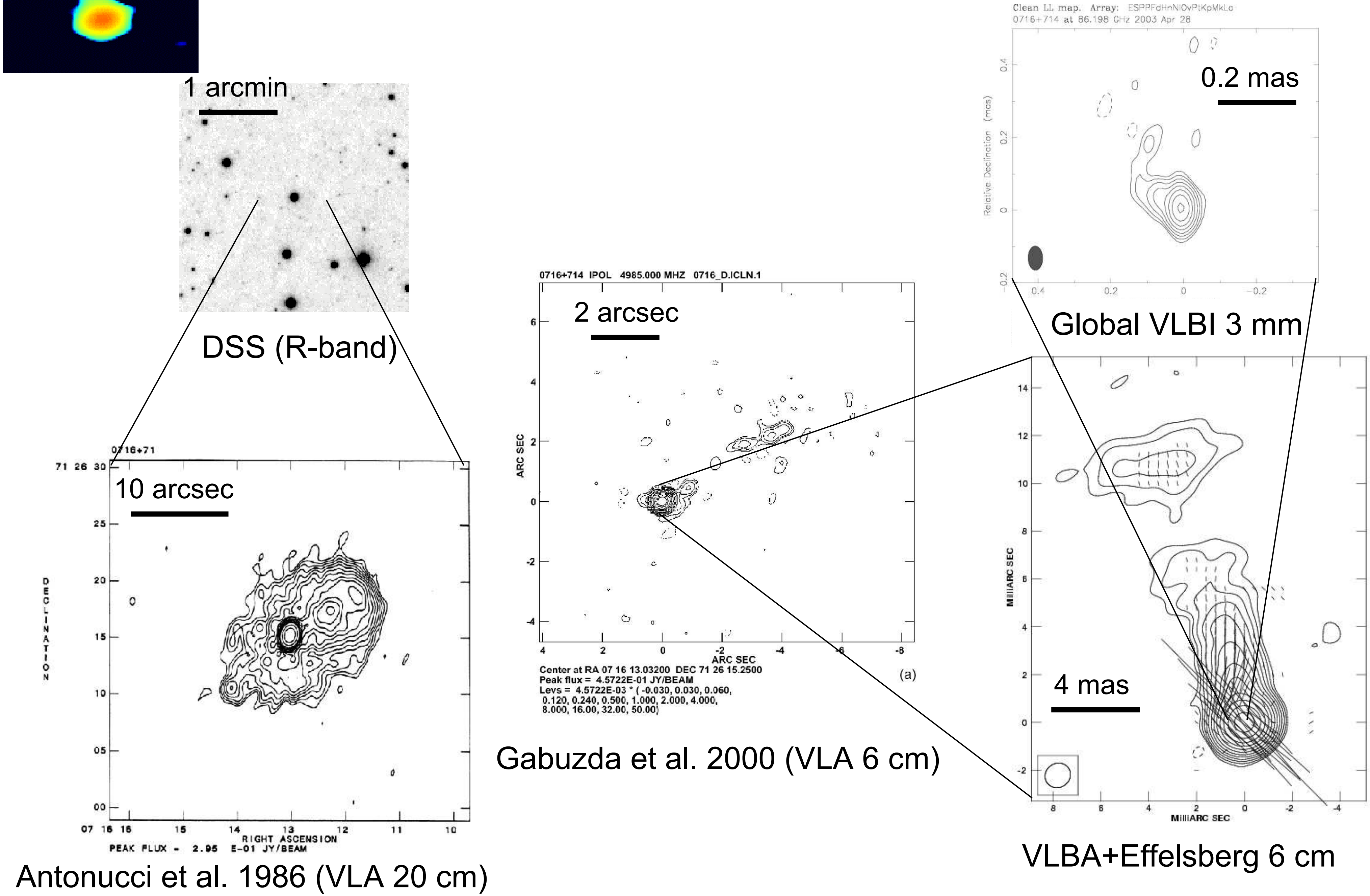
Why to observe 0716+714?

- Some facts:
  - S5 blazar (BL Lac).
  - Redshift not yet known (we use z=0.3 (Wagner et al. 1996)).
  - Very flat radio spectrum.
  - Extremely variable.
    - Intraday variable (IDV) in the radio bands (Witzel & Wagner 1995).
    - Correlated variability over wide ranges of the electromagnetic spectrum (Quirrenbach et al. 1991; Wager et al. 1996).
  - VLBI studies covering more than 20 years.
  - Misaligned jet.

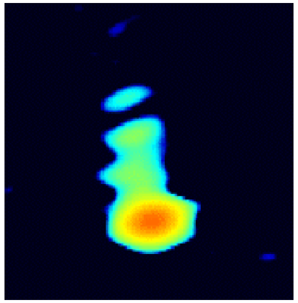
- Controversially discussed kinematics (0.5 c to 20 c).
- Part of the radio IDV is possibly intrinsic.

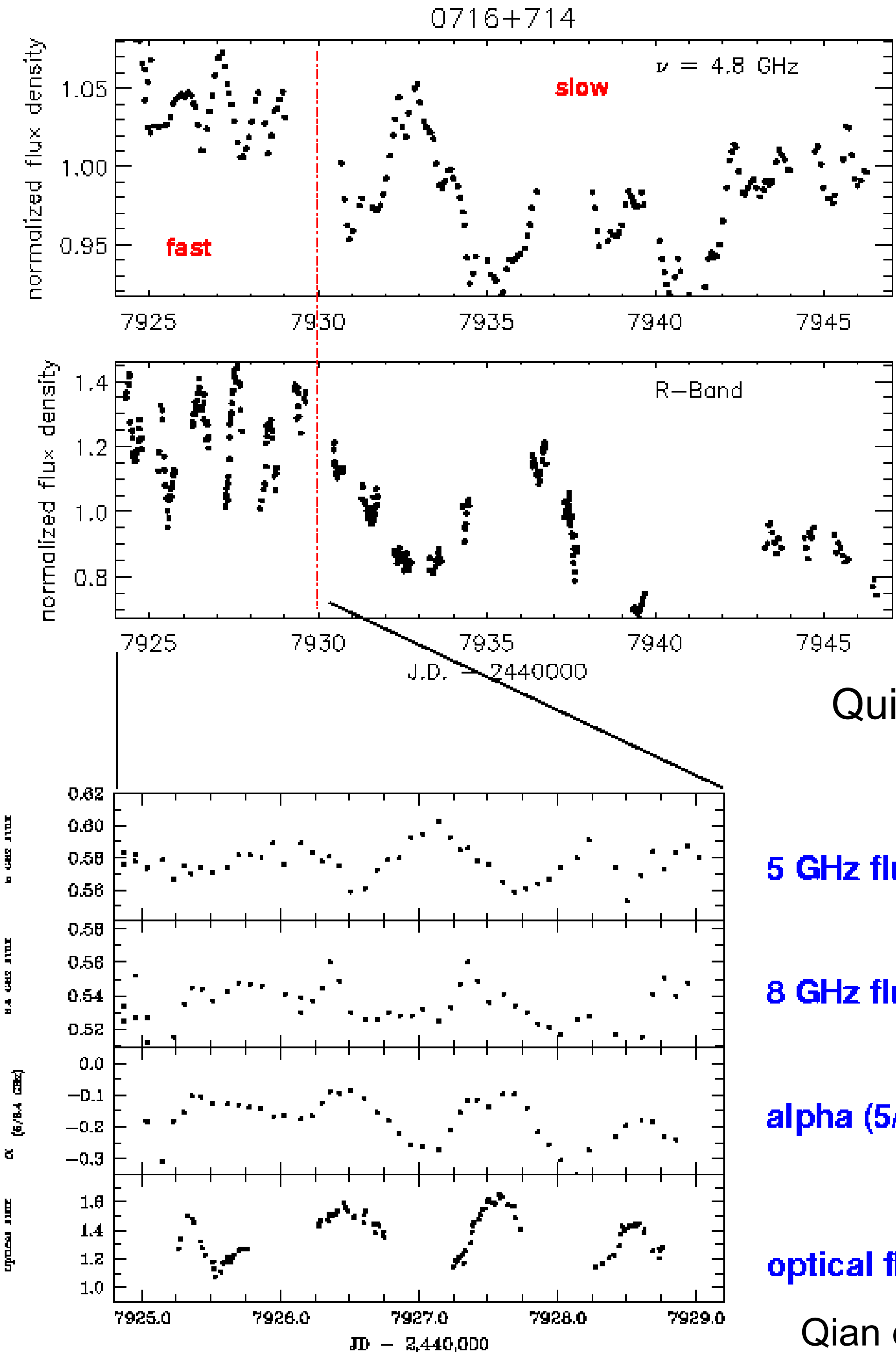


0716+714 on different scales



IDV in 0716+714





Brightness temperatures derived from radio IDV:

$T_b = 10^{15}$ K to 10^{17} K

Quirrenbach et al. 1991

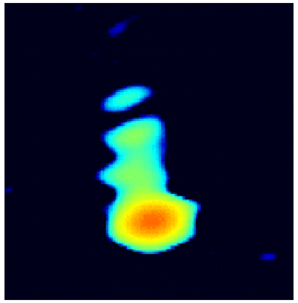
5 GHz flux

8 GHz flux

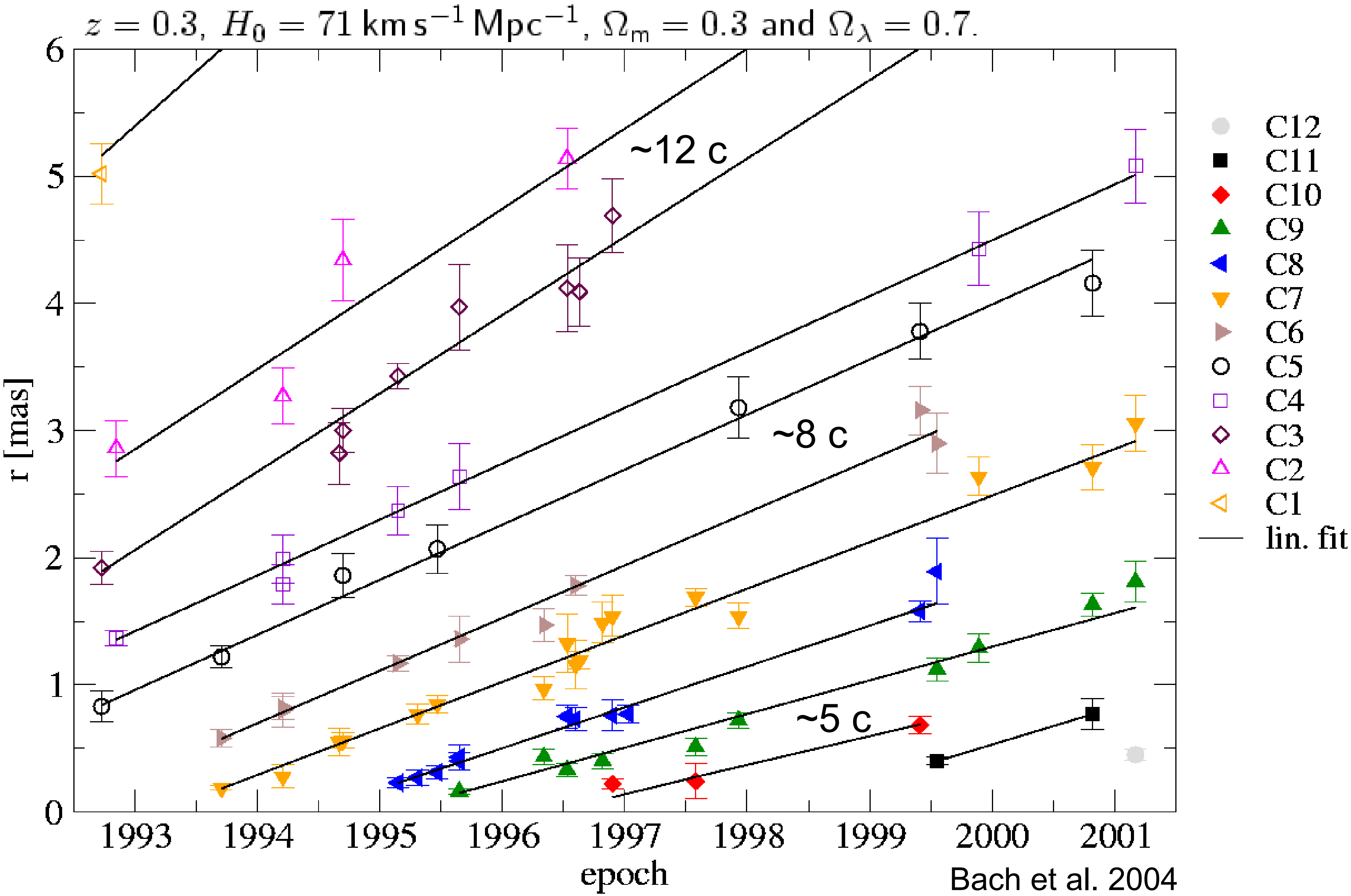
alpha (5/8 GHz)

optical flux

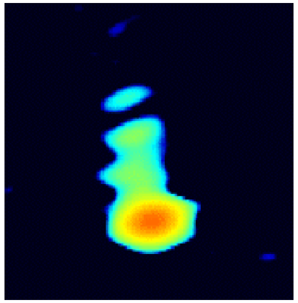
Qian et al. 1996, Wagner et al. 1996



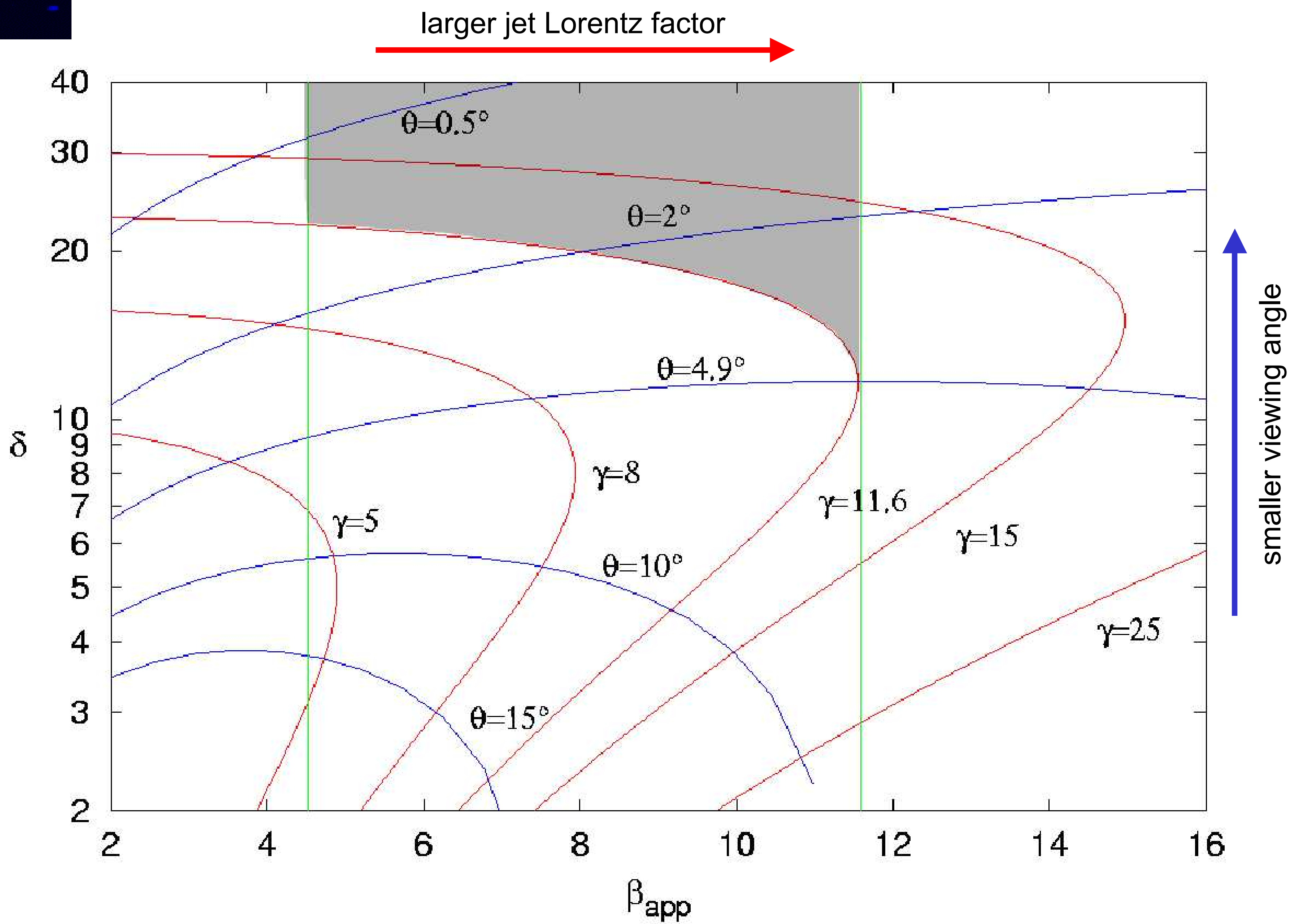
Jet kinematics

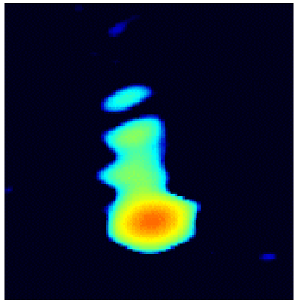


Bach et al. 2004



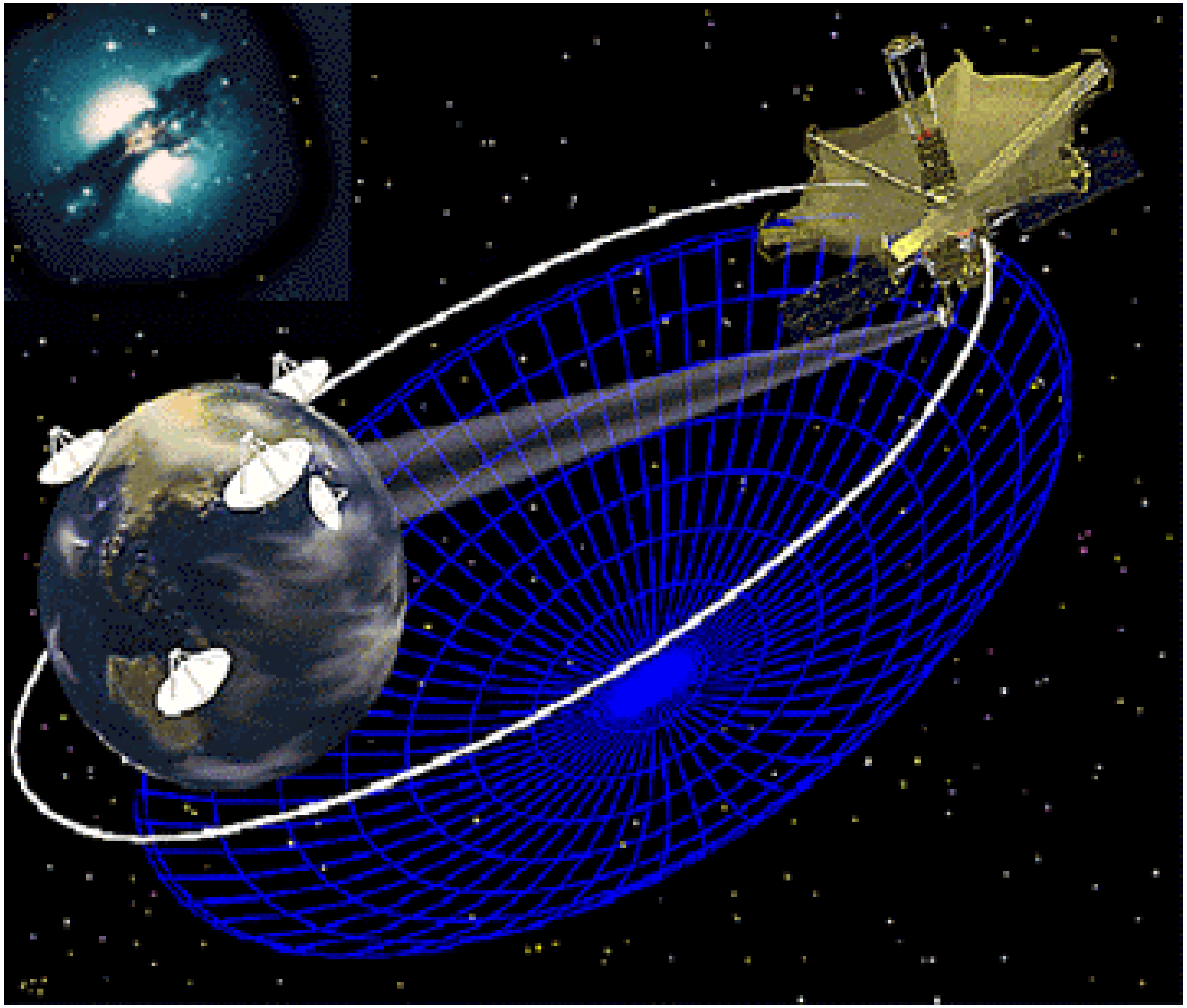
Doppler factor vs. apparent velocity



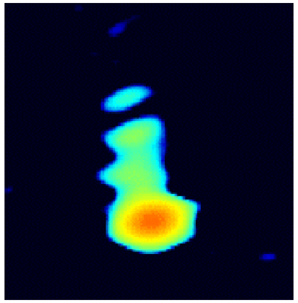


Space VLBI Observatory Programme

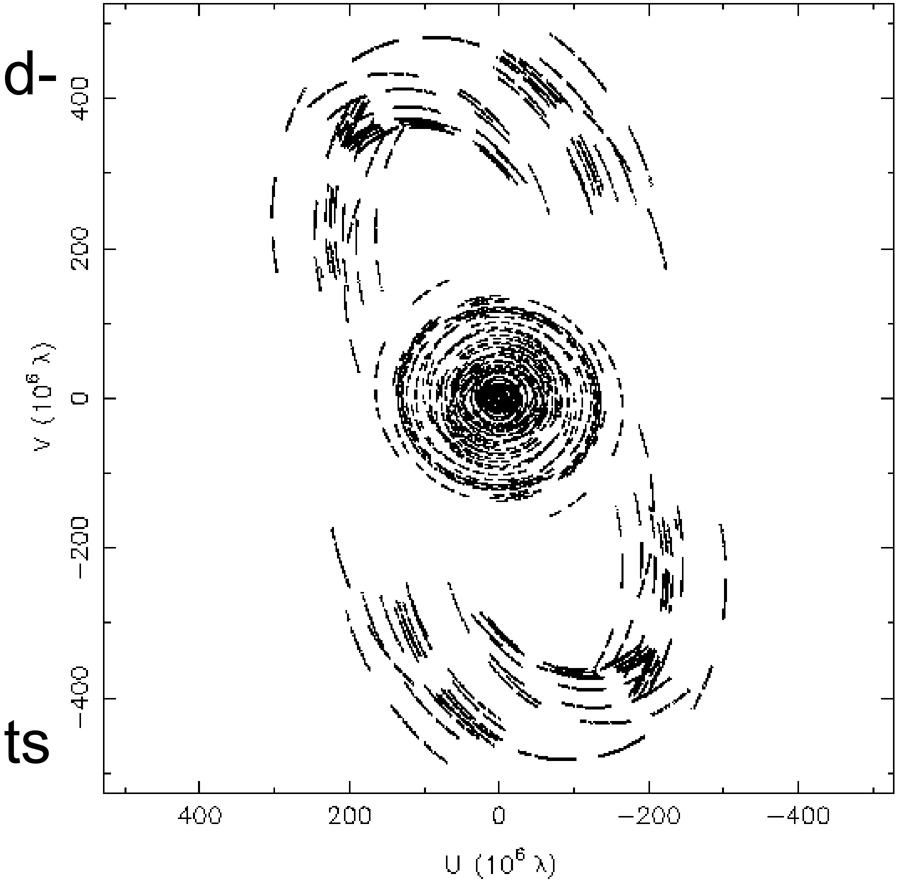
- HALCA Satellite:
  8 m radio telescope
- Max. baseline:
  Ground VLBI 10000 km
  VSOP 33000 km
- Resolution at 6 cm:
  VLBI 1.0 mas
  VSOP 0.3 mas
- At z=0.3:
  1 mas = 14.4 pc



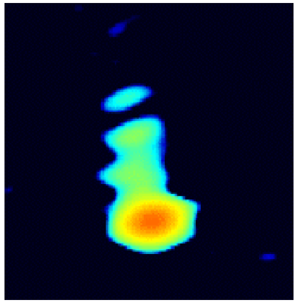
www.vsop.isas.ac.jp



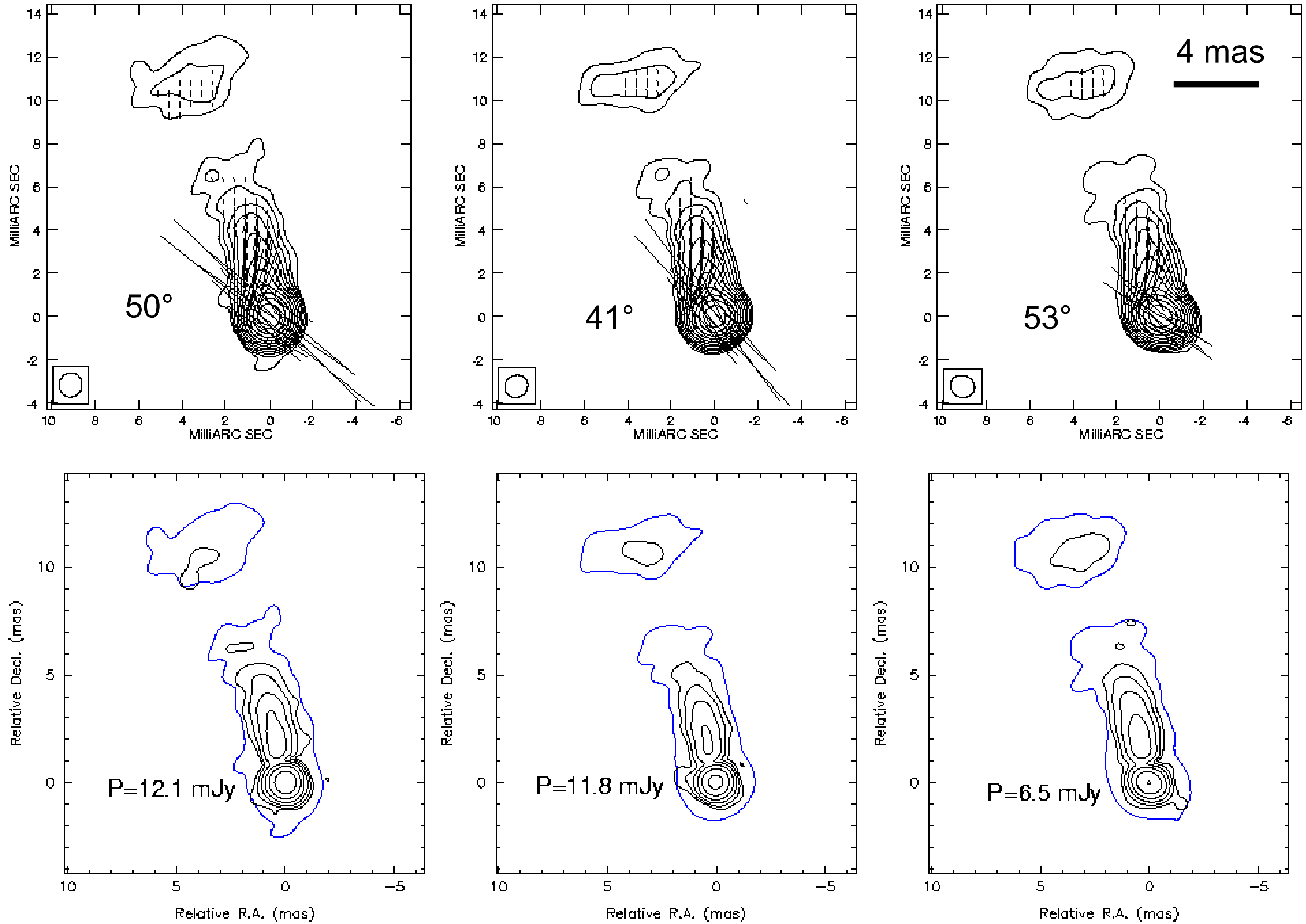
Observations



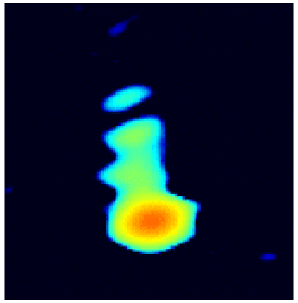
- 3 epochs at 5 GHz (16 h) with 11 ground-stations (VLBA, Effelsberg) and the HALCA satellite.
- Separations of 5 days and 1 day (Sep. 29, Oct. 4 & Oct. 6).
- Nearly identical uv-coverage.
- ~0.25 mas resolution at 5 GHz: ~4 times better than ground based VLBI.
- Simultaneous flux density measurements in Effelsberg.

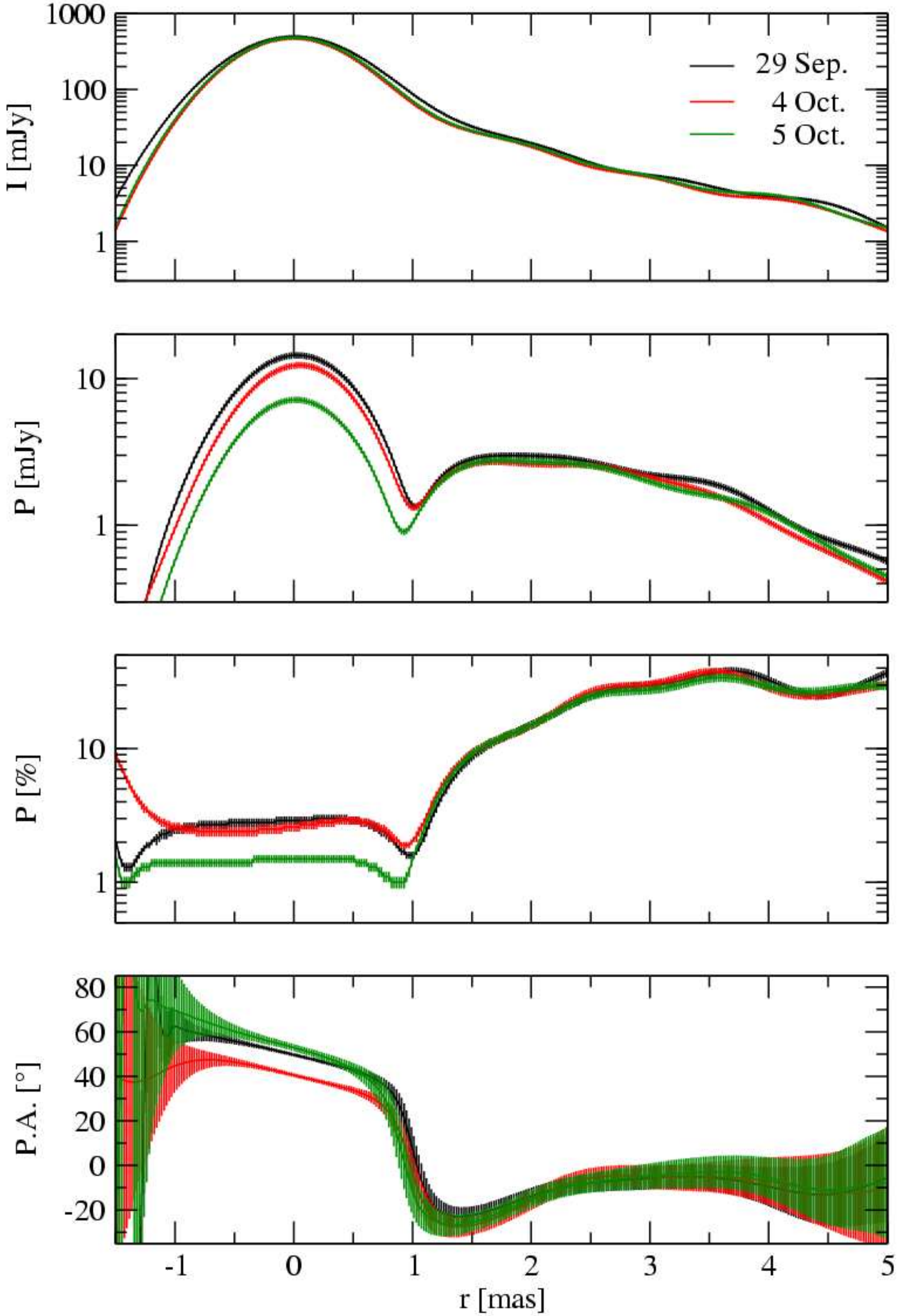


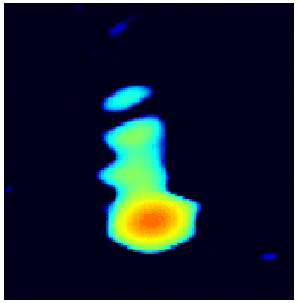
Ground-array Maps



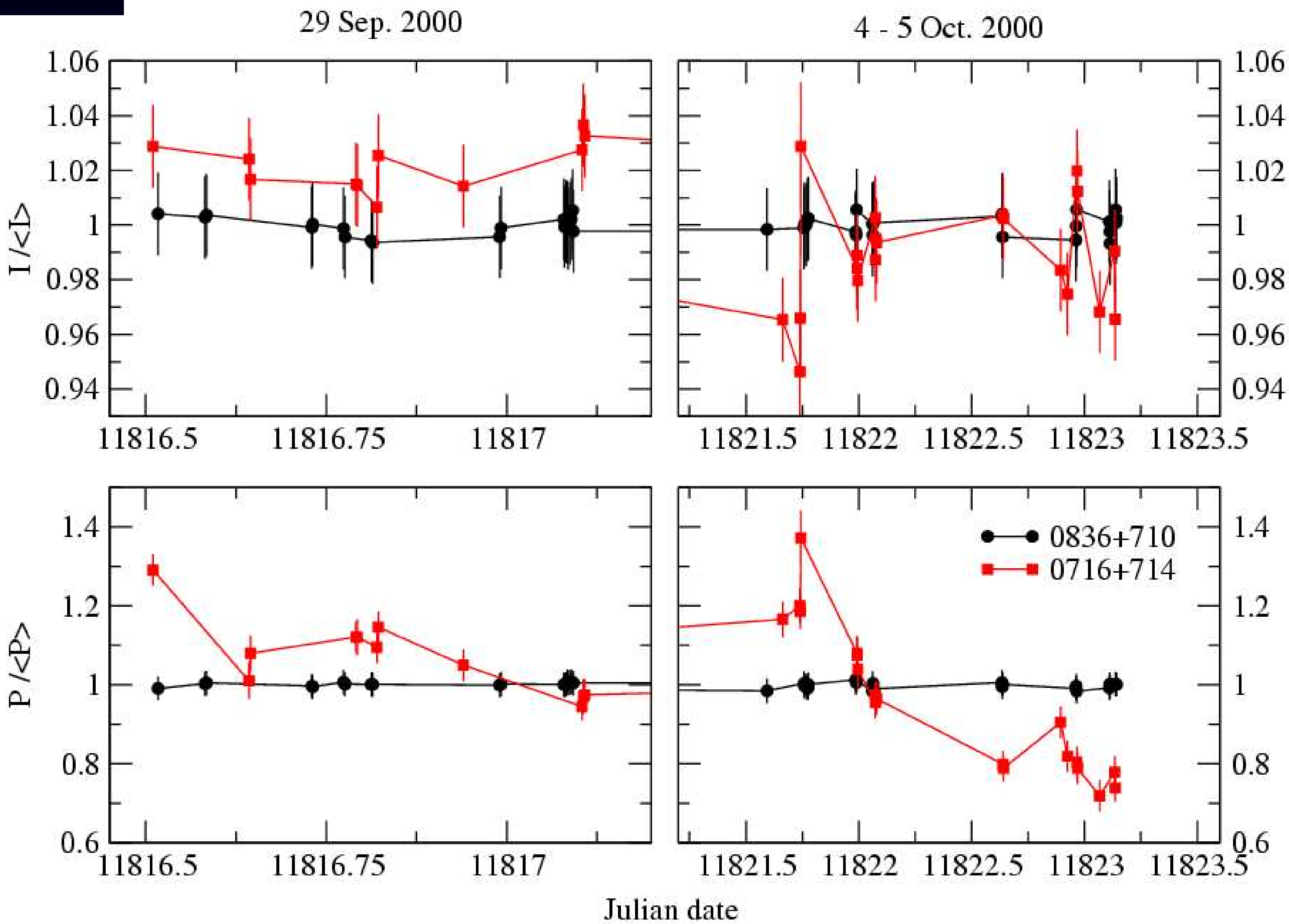
Ground-array Profile

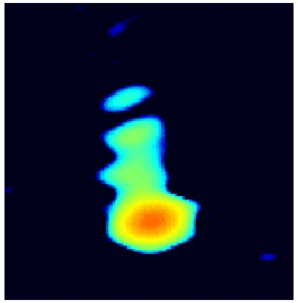






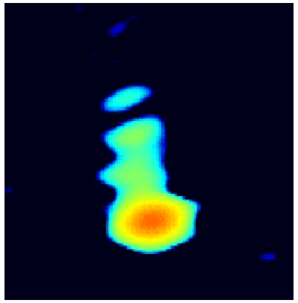
Effelsberg light-curve





VLBI vs. single dish

Array	Part	I [mJy]	P [mJy]	χ [°]
29 Sep 2000				
VLBI	Core	520.3 ± 26.9	12.1 ± 1.3	49.4 ± 4.1
	Jet	56.0 ± 4.7	7.4 ± 0.8	-10.8 ± 5.6
Eb		763.2 ± 6.9	21.4 ± 2.6	23.4 ± 2.1
4 Oct 2000				
VLBI	Core	499.3 ± 26.1	11.8 ± 1.3	40.7 ± 4.0
	Jet	54.8 ± 6.3	7.3 ± 0.8	-11.2 ± 7.8
Eb		735.7 ± 16.2	21.6 ± 2.6	18.6 ± 2.2
5 Oct 2000				
VLBI	Core	503.9 ± 25.4	6.5 ± 1.1	52.7 ± 5.2
	Jet	54.7 ± 6.0	7.5 ± 0.8	-9.5 ± 7.4
Eb		740.2 ± 14.6	15.7 ± 1.1	13.3 ± 2.5



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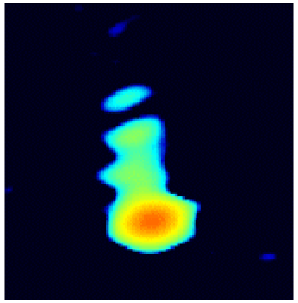

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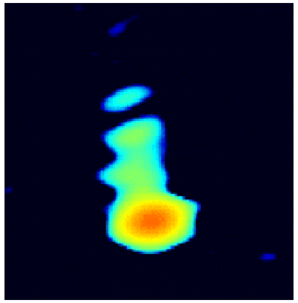
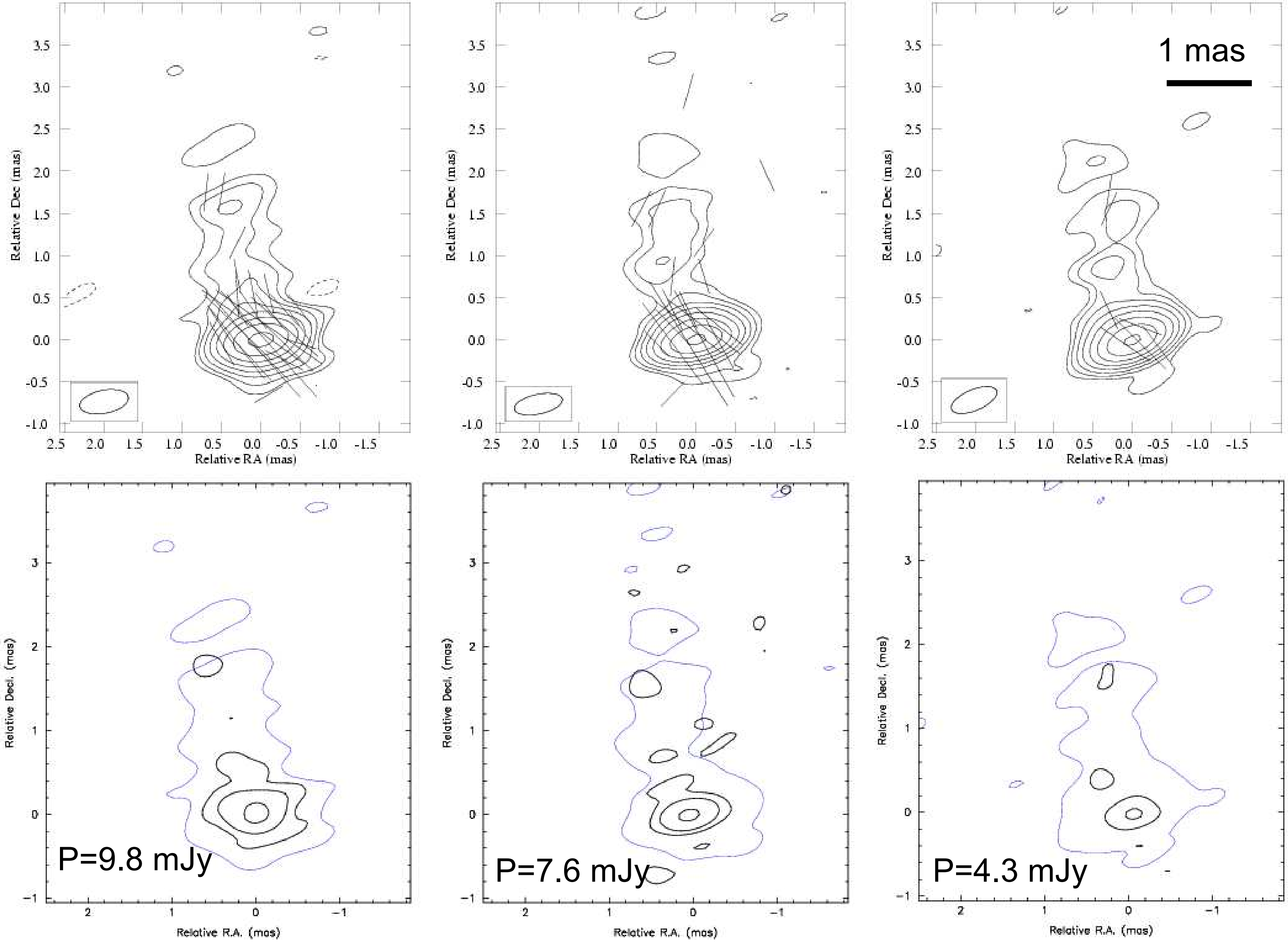
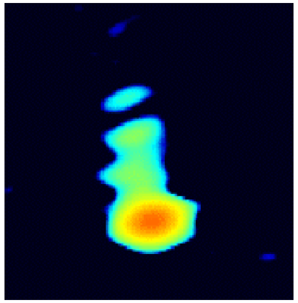
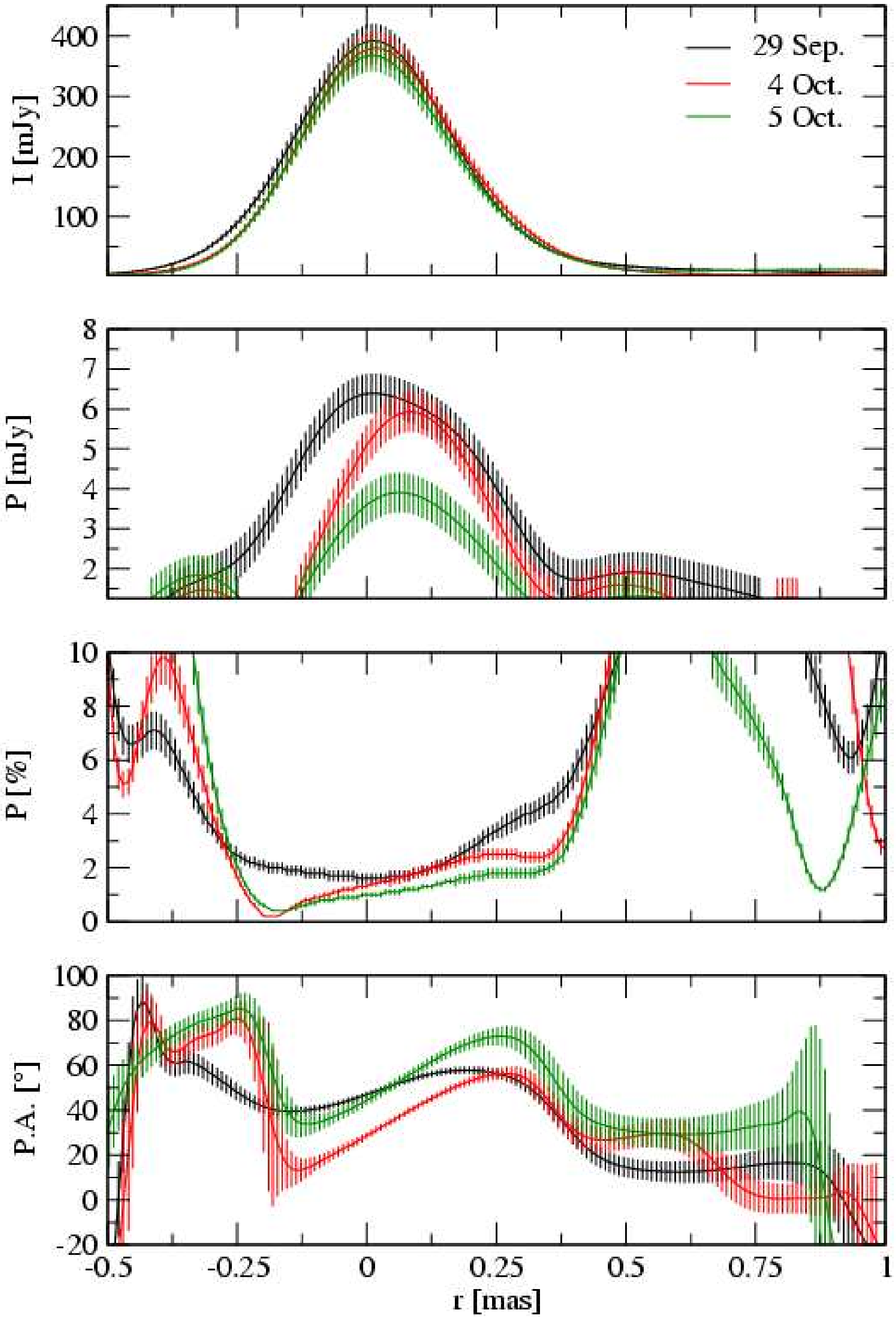


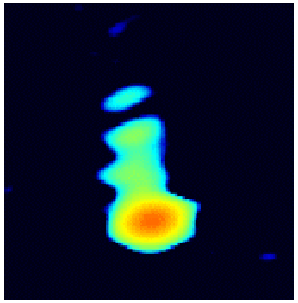
VSOP Maps


1 mas
Relative Dec (mas)
Relative RA (mas)
Relative Decl. (mas)
Relative R.A. (mas)
P=9.8 mJy
P=7.6 mJy
P=4.3 mJy

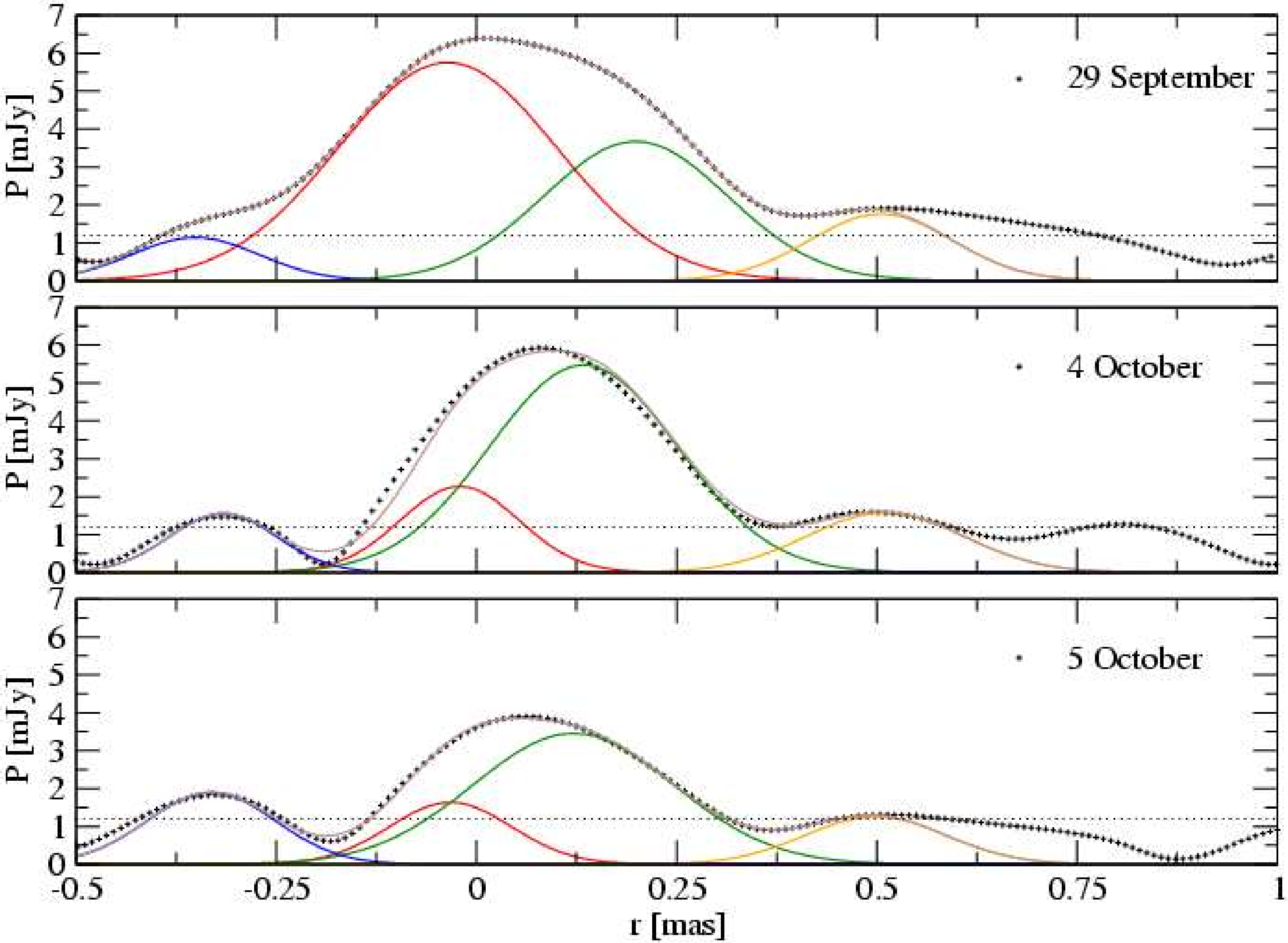
VSOP Profiles I





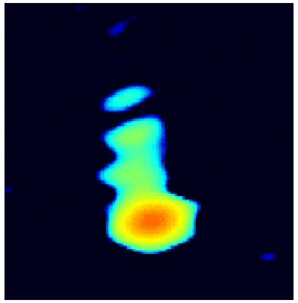


VSOP Profiles II

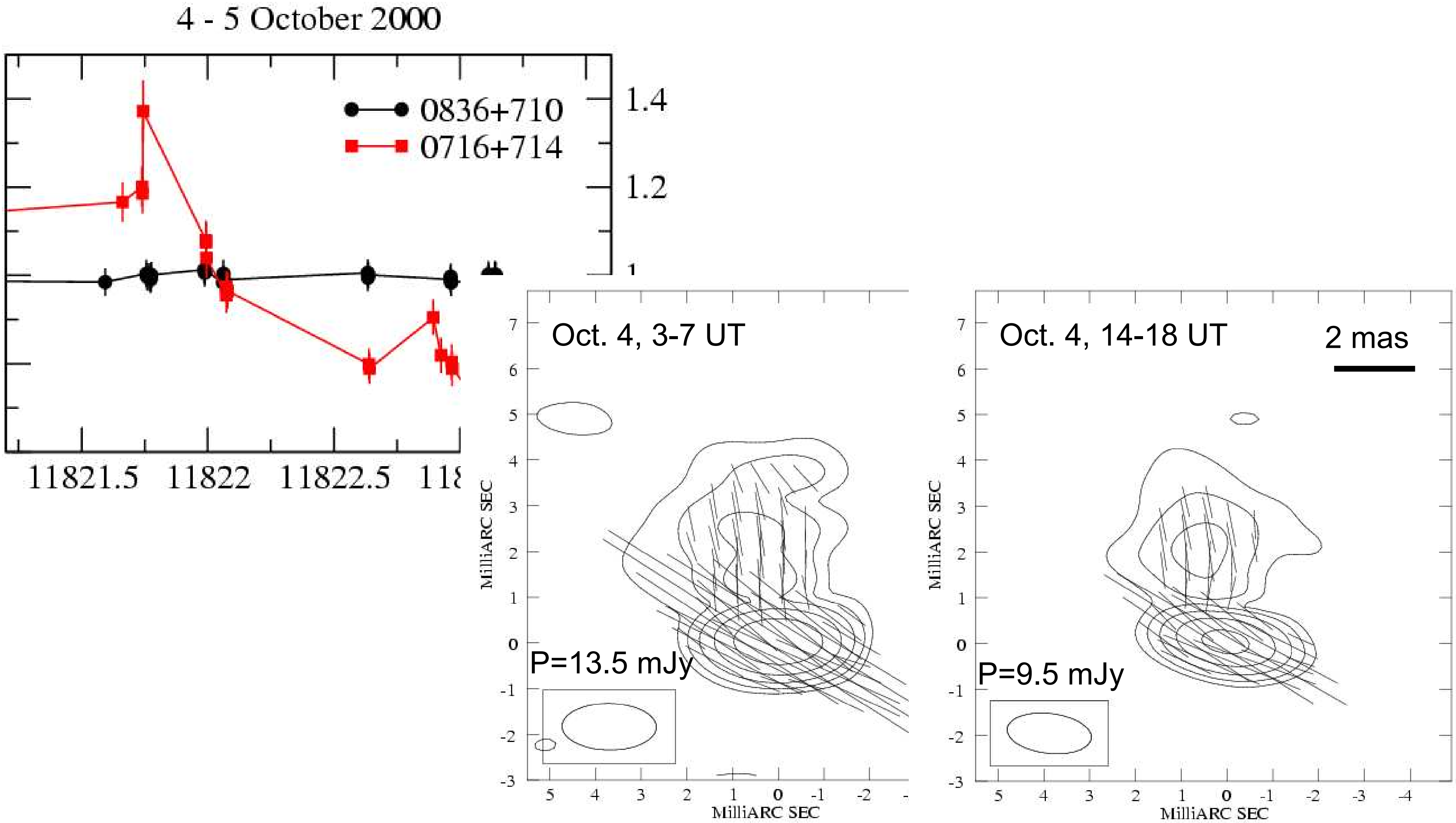


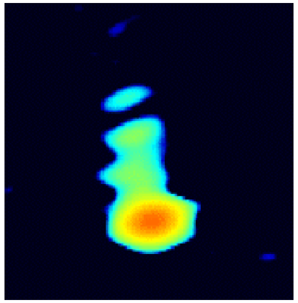
Sub-component size of ~80μas:

$T_b = 2 \times 10^{12}$ K



Variability on October 4





Brightness Temperature

$$T_\mathrm{b} = 1.86 \times 10^4 \; S \; \left(\frac{d_\mathrm{L}}{\nu \; t_\nu \; (1+z)^2} \right)^2$$

with

$$t_\nu = \frac{<S>}{\Delta S} \frac{\Delta t}{(1+z)},$$

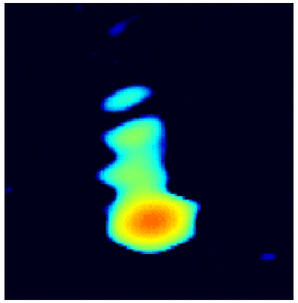
- Between October 4th and 5th ($<P>= 10.2\,\mathrm{mJy}$, $\Delta P = 3.2\,\mathrm{mJy}$ and $\Delta t = 24\,\mathrm{h} = 0.0027\,\mathrm{yr}$):

$$T_\mathrm{b} \approx \mathbf{3 \times 10^{15}}\,\mathrm{K}.$$

- On October 4th ($<P>= 11.5\,\mathrm{mJy}$, $\Delta P = 2.8\,\mathrm{mJy}$ and $\Delta t = 10\,\mathrm{h} = 0.0011\,\mathrm{yr}$):

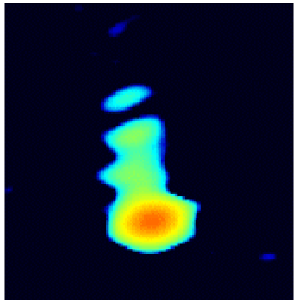
$$T_\mathrm{b} \approx \mathbf{10^{16}}\,\mathrm{K},$$

- Doppler factor of 14 to 22 are needed to reduce these values to the inverse-Compton limit of 10^{12} K.



Summary

- Measured speeds of 5 c to 16 c are atypically fast for a BL Lac object.
- Most likely jet parameters: γ > 16 and θ < 2°, which corresponds to a minimum Doppler factor > 22 (see also Bach et al. 2004).
- Jet magnetic field is perpendicular to the jet axis.
- Different orientation of electric vectors between core and jet:
    - Core is optically thick,
    - Jet bending in the inner core region.
- IDV:
    - Total intensity variations of ~5% during the observations.
    - Variations in linear polarisation of up to 30% in 10 h.
    - The IDV can be attributed to the VLBI-core.
    - No rapid variability in the jet.
    - VLBI-core is a composite of sub-components (< 0.1 mas) which corresponds to T_b= 2 x 10^{12} K.
    - Variability brightness temperatures of up to 10^{16} K require Doppler factors of ~25.



Future Prospects

- Test different jet models:
  - Precession (Binary black holes, warped disc)?
  - Helical jet?

- Resolving the sub-components in the core will help to distinguish between intrinsic and extrinsic effects:
  - Does they vary independently?
  - Does the E-vector rotate?
  - How changes the variability with frequency?

- Simultaneous broad band (radio to γ-rays) analysis of the variability can help to understand how the jet is launched and how fast it is. (WEBT, ENIGMA)