Rapid Variability of AGN

Progress report on IDV related studies and observations

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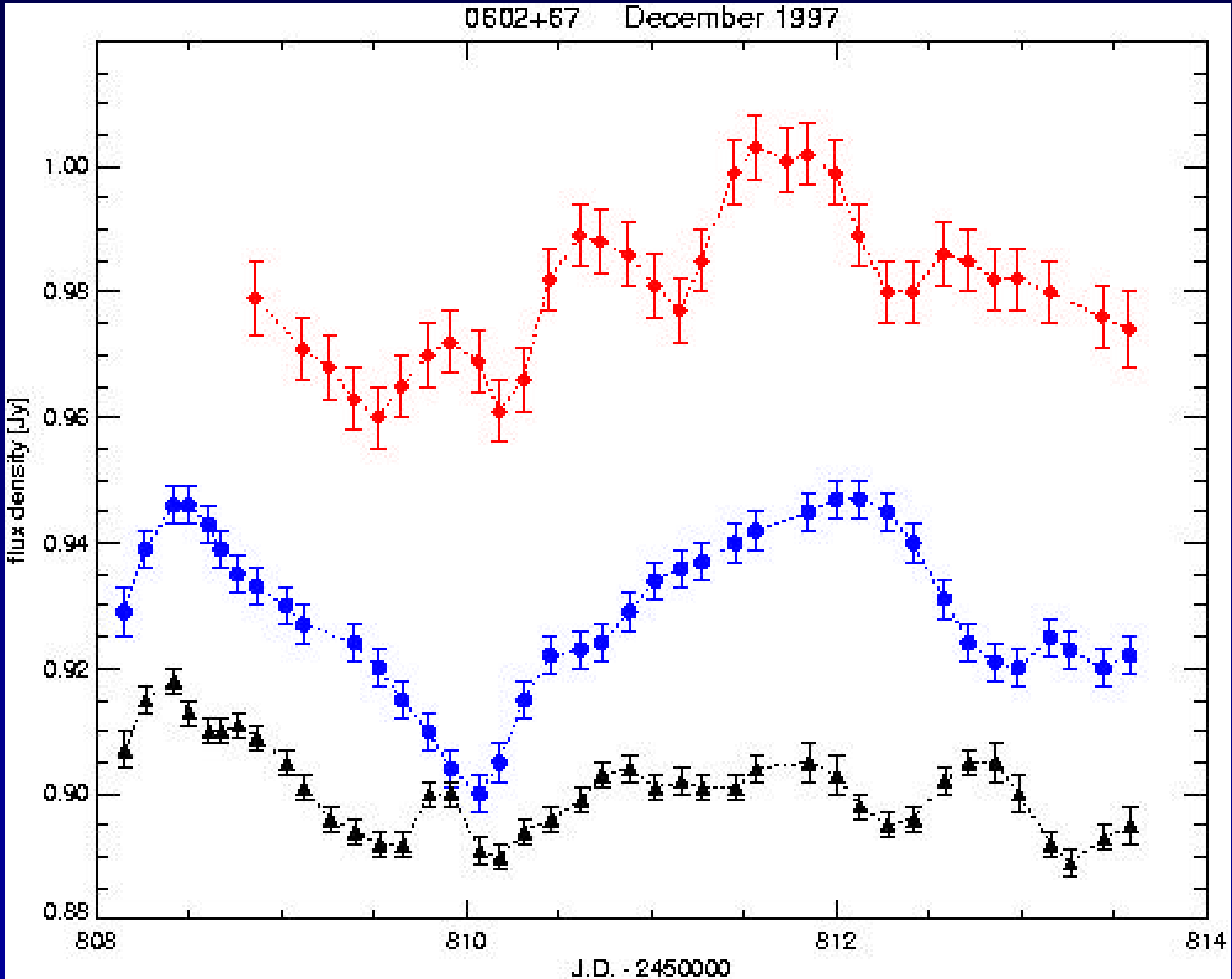
M. Kadler, J. Klare, A. Kraus, T.P. Krichbaum, E. Ros,

B.W. Sohn, A. Witzel, J.A. Zensus

A typical example of an IDV source (type II)



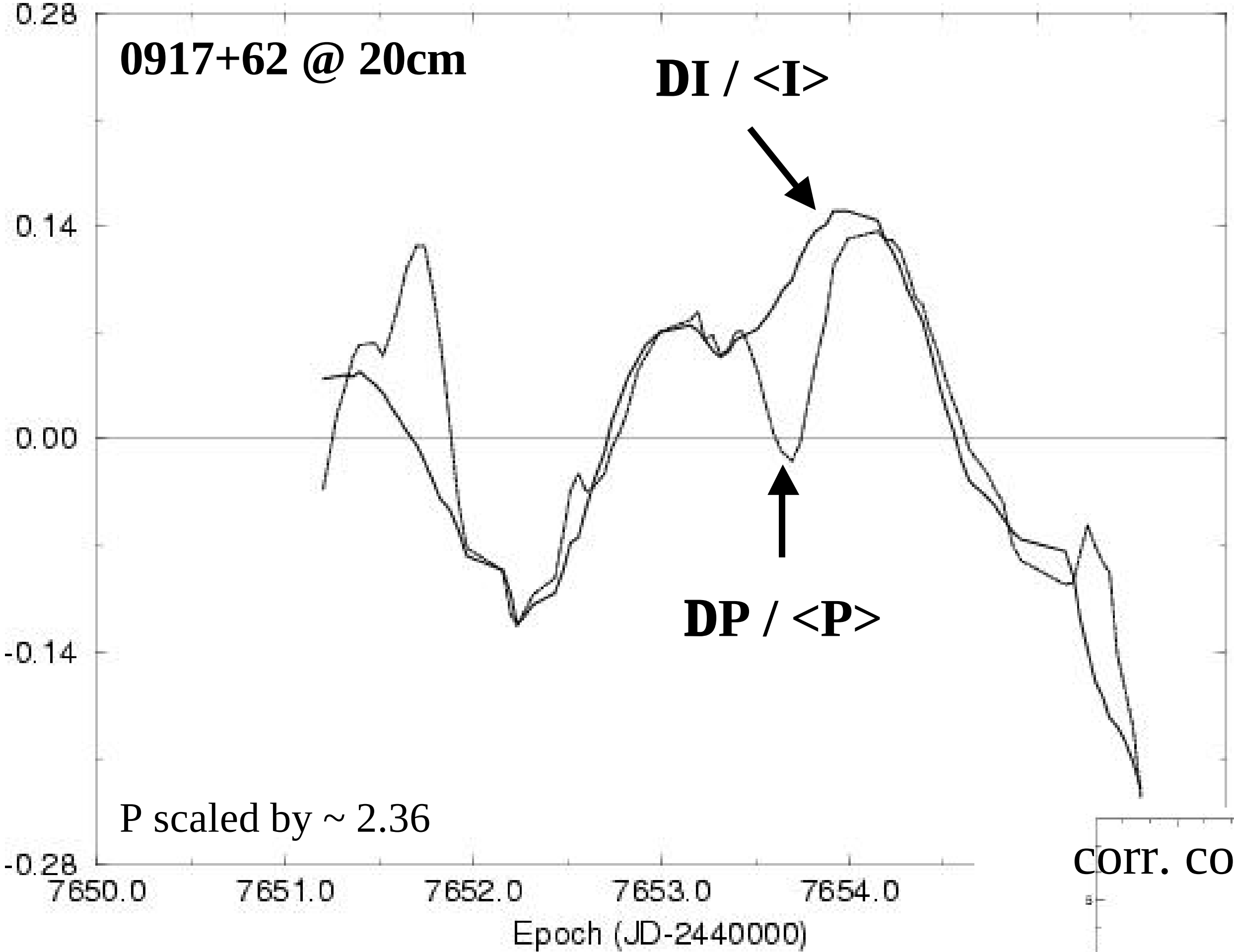
2.8 cm

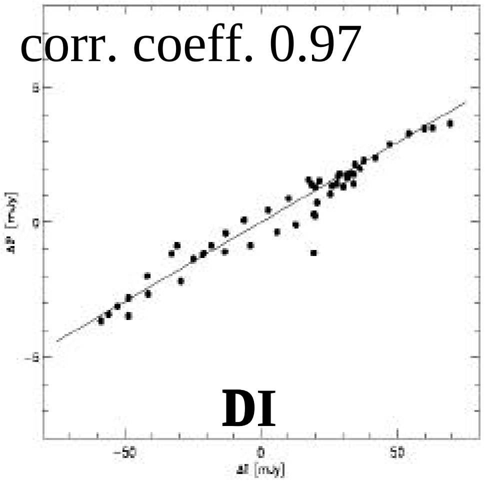
6 cm

11 cm

Kraus et al., AA, 2003

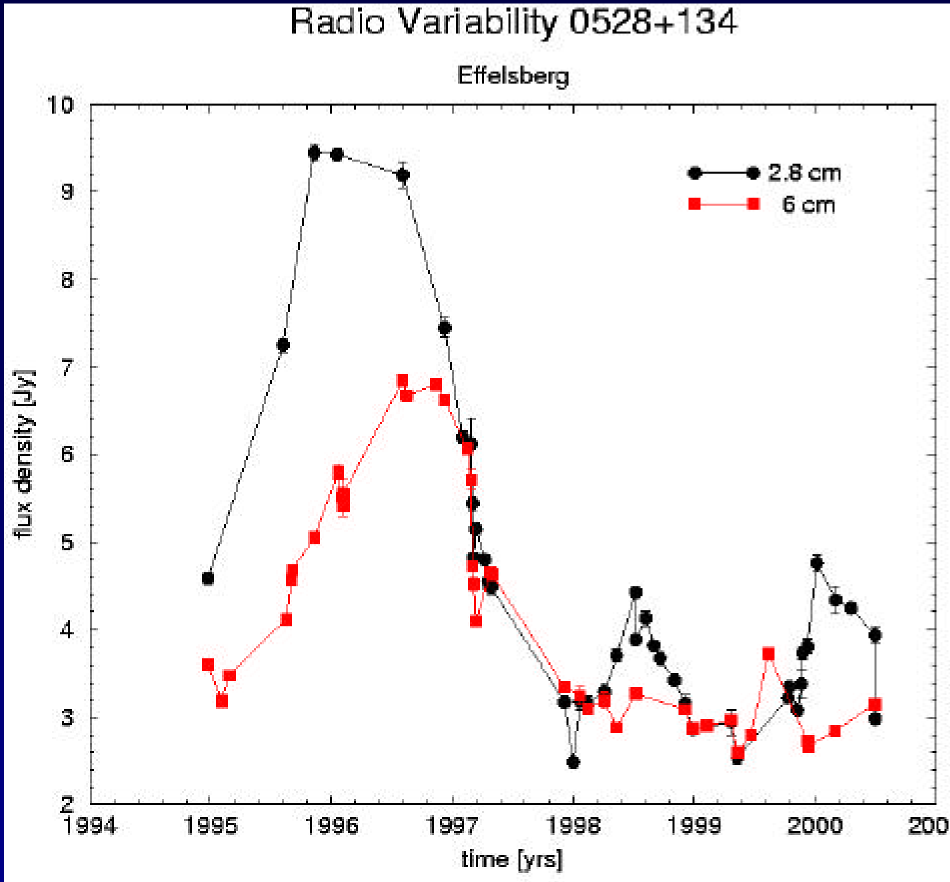
Polarisation and total Intensity are strongly correlated

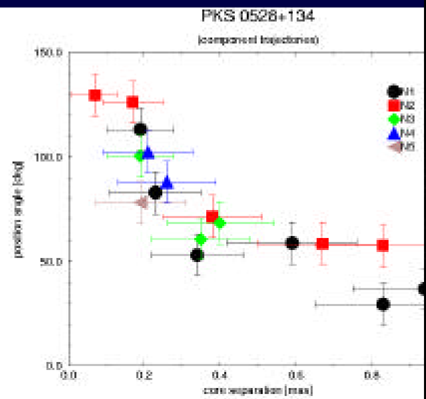


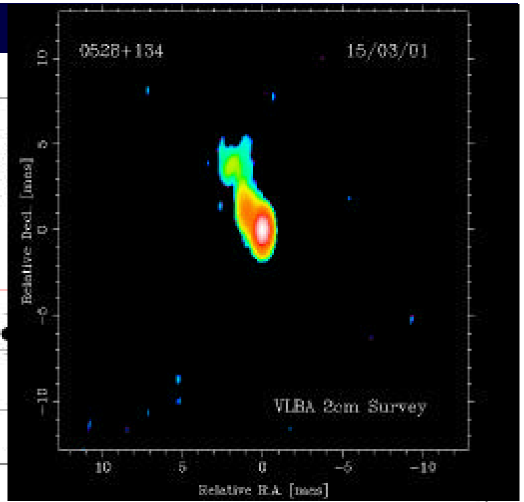


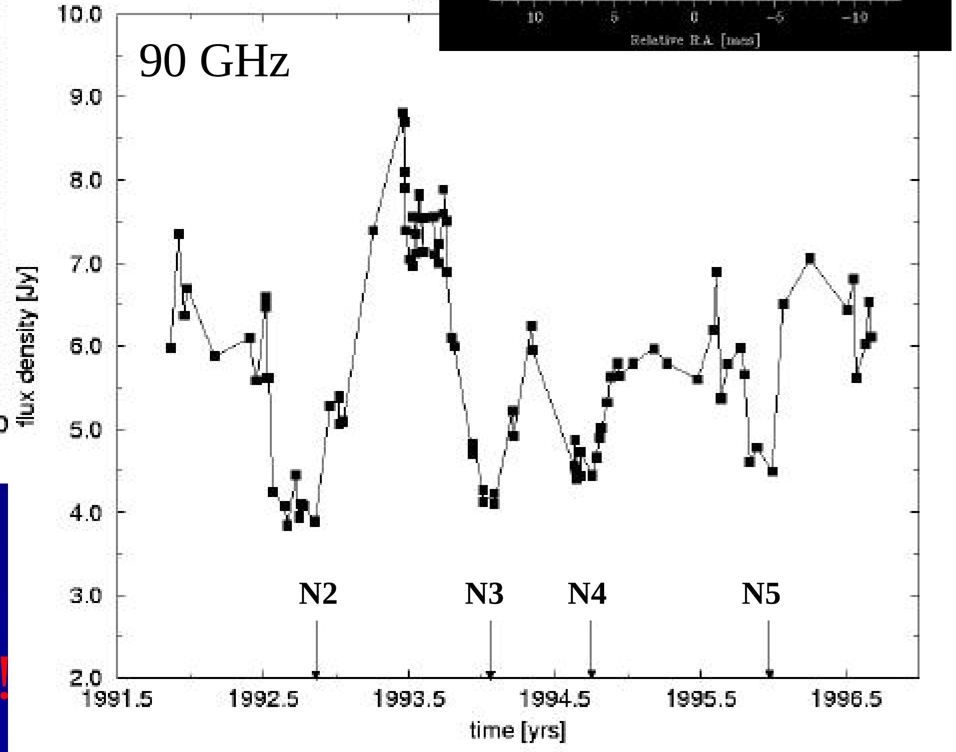
This proportionality implies that RISS might be at work. At shorter wavelength, however, we see correlations and anti-correlations between I & P !

Qian et al. 2001







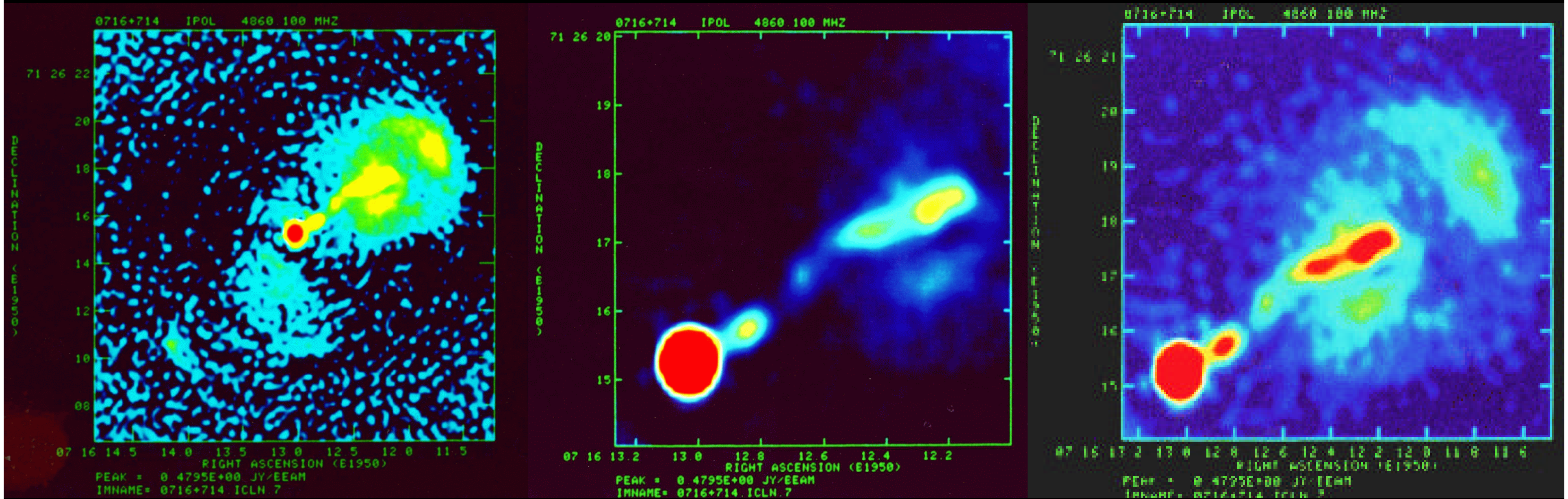


High T_B ($\leq 10^{16}$ K) is not exceptional!

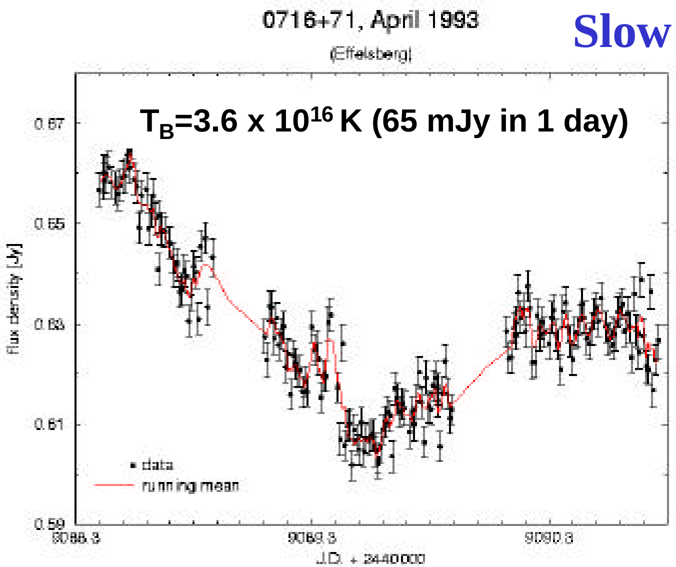
5 GHz: 2.7 Jy in 122 days $\rightarrow$ T_B = 1.7 x 10^{16} K, δ = 12

10 GHz: 4.4 Jy in 214 days $\rightarrow$ T_B = 2.0 x 10^{14} K, δ = 6

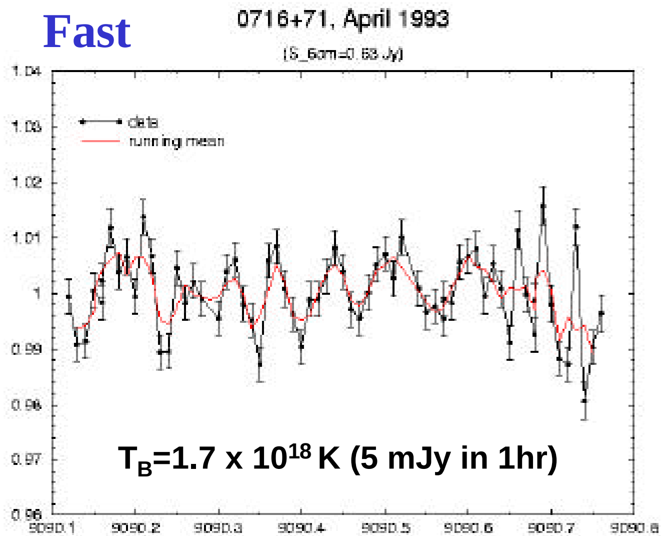
The Jet of the BL Lac S5 0716+714



Slow

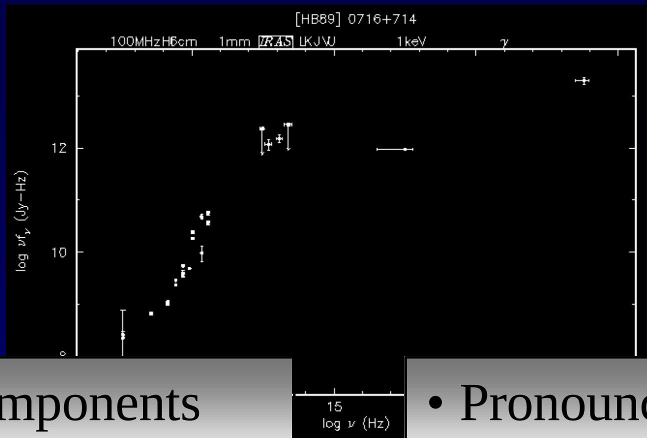


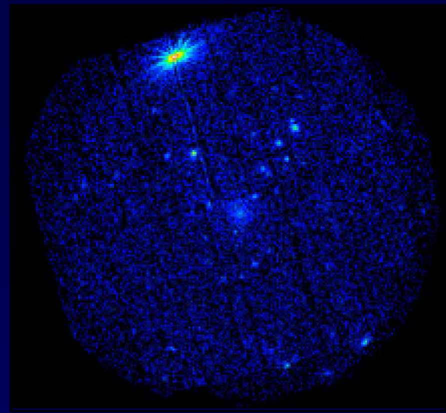
Fast



IDV in 0716+714

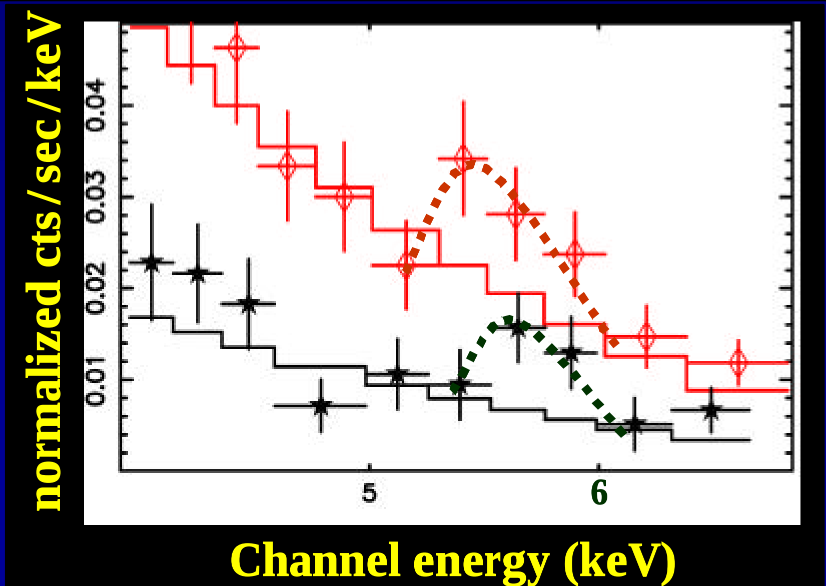
XMM-Newton observations of 0716+714

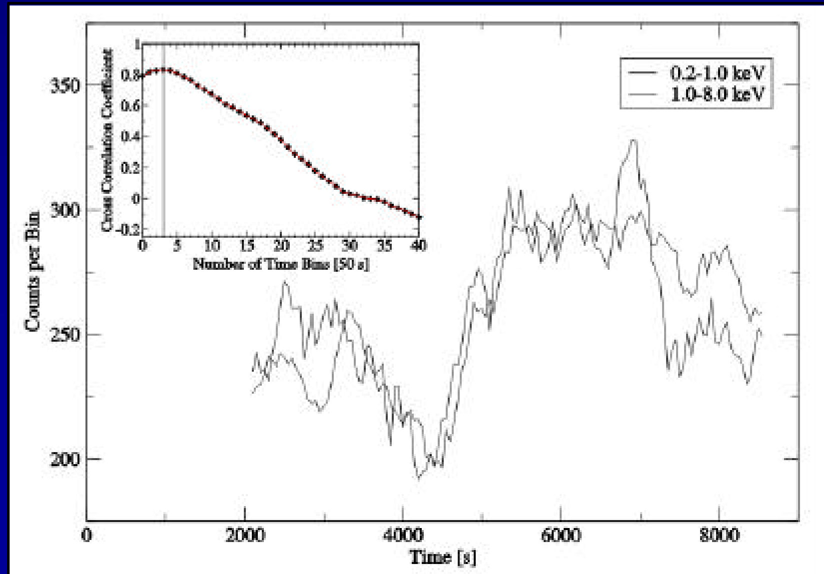




- Two distinct spectral components (synchrotron, IC)
- Tentative iron line detection: z = 0.1 (blue shifted or distance measure?)

- Pronounced and rapid (500 sec) X-ray variability in March 2002
- Soft Lag of ~150s
  ⇒ Cooling



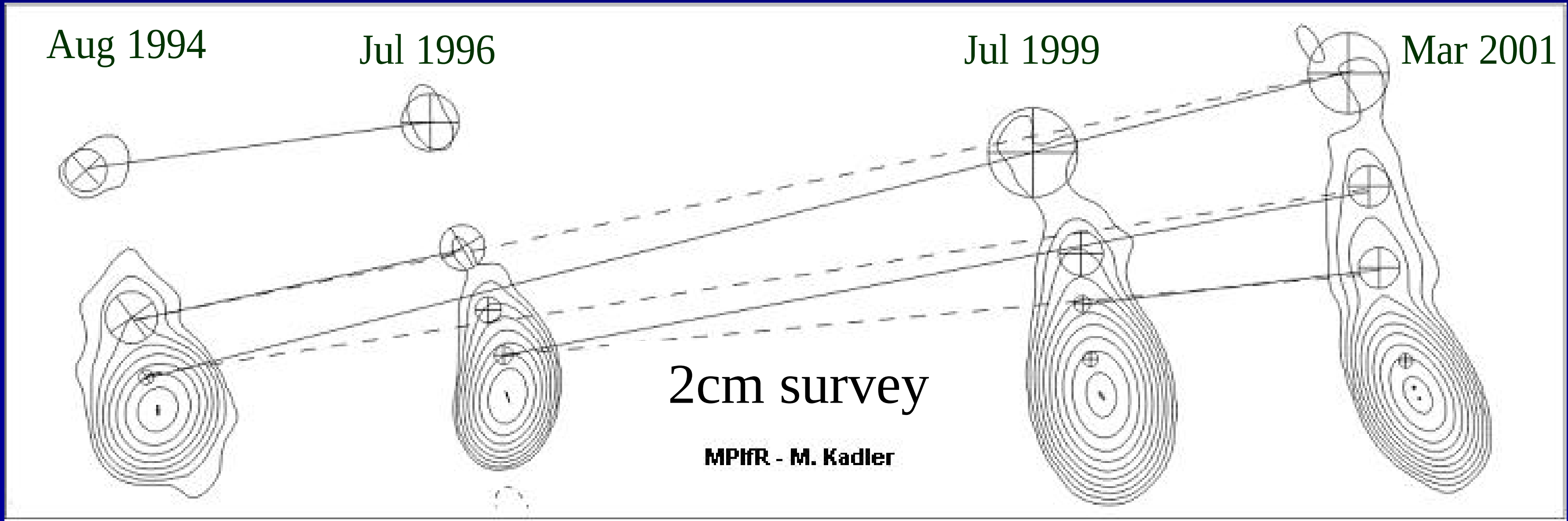


Kadler, Kerp, & Krichbaum 2004, A&A, submitted

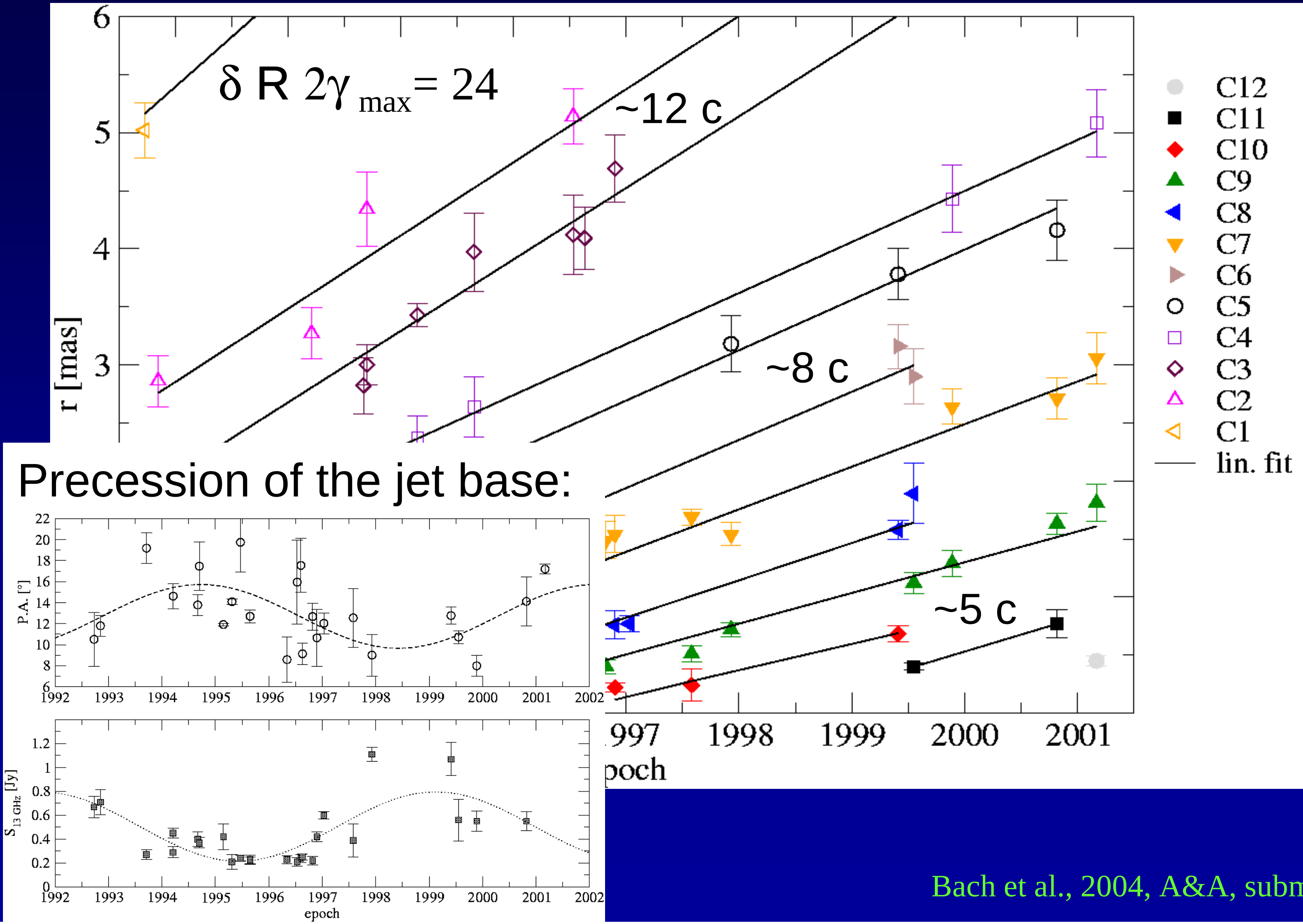
0716+714 – A Hard Nut to Crack

Improved knowledge on kinematics:

Witzel et al. (1988), Gabuzda et al. (1998):	Subluminal source
Jorstad et al. (2001):	0.9-1.2 mas/yr
Bach et al. (2003)	0.3-0.9 mas/yr
Kellermann et al. (2004, ApJ, in press):	~0.5 or ~0.3 mas/yr

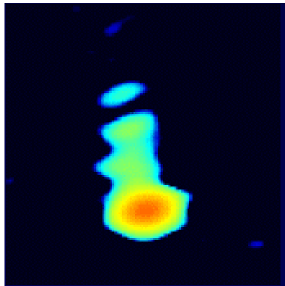


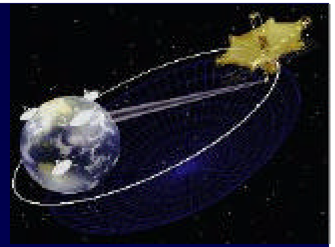
0716+714: 10 yrs of VLBI monitoring



Bach et al., 2004, A&A, submitted

Space-VLBI of 0716+714

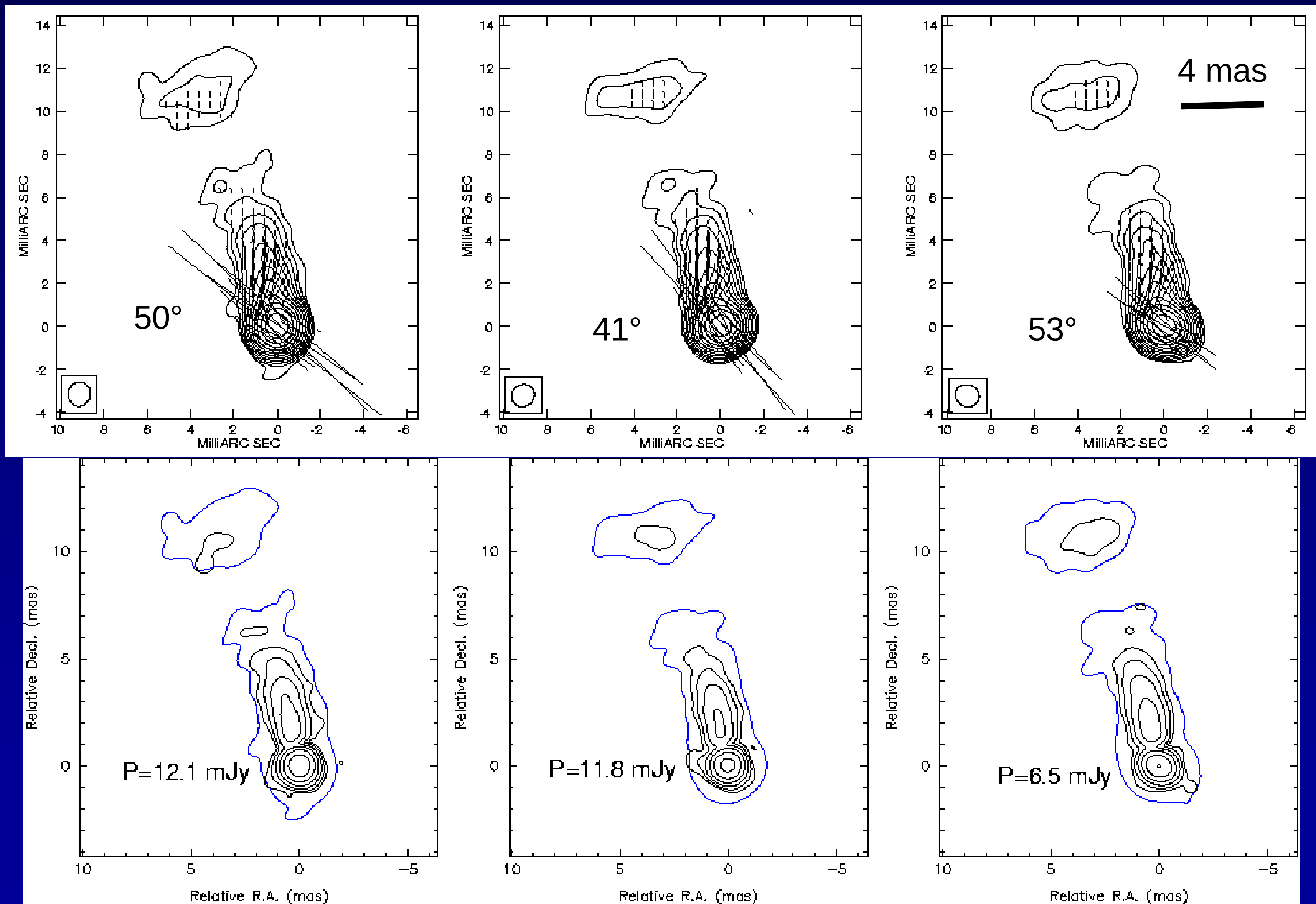




29. Sep. 2000 4. Oct. 2000 5. Oct. 2000

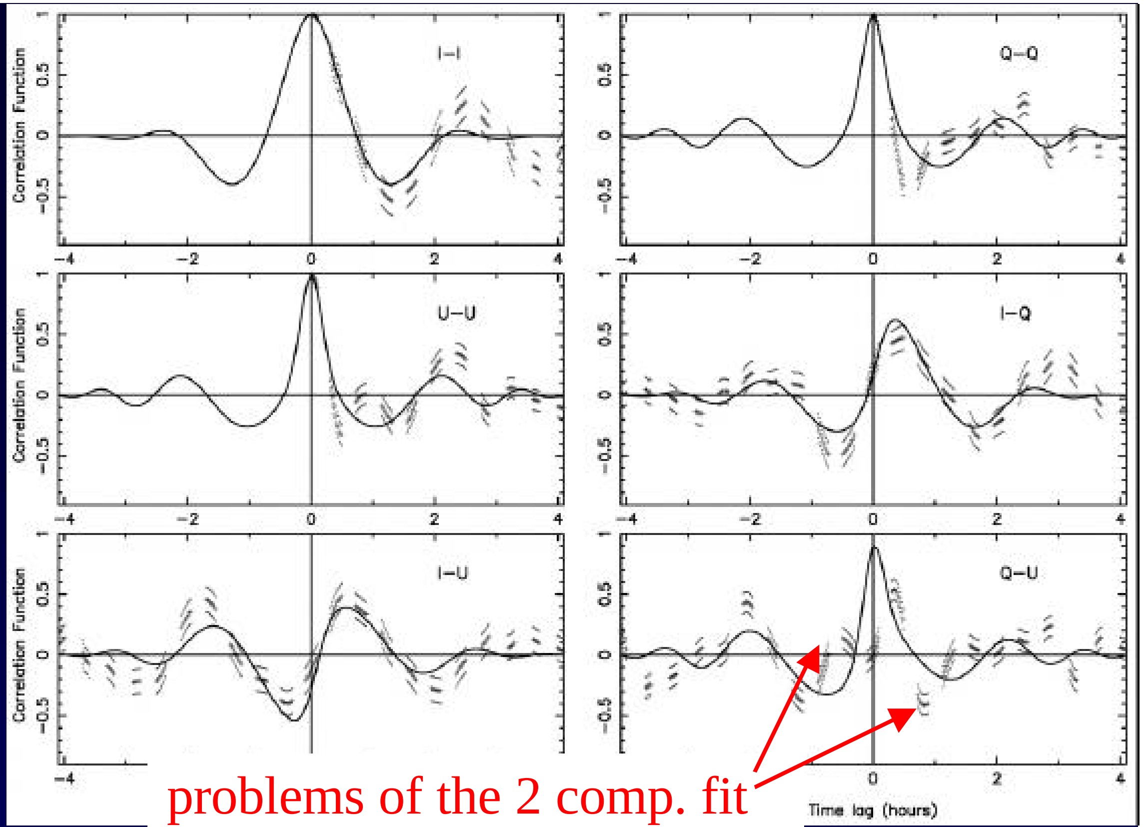
I

P



Bach et al., 2004

$$C_{II,t}(\tau) = \langle \Delta I(t) \Delta I(t+\tau) \rangle$$
$$C_{QQ,t}(\tau) = \langle \Delta Q(t) \Delta Q(t+\tau) \rangle$$
$$C_{UU,t}(\tau) = \langle \Delta U(t) \Delta U(t+\tau) \rangle$$
$$C_{IQ,t}(\tau) = \langle \Delta I(t) \Delta Q(t+\tau) \rangle$$
$$C_{IU,t}(\tau) = \langle \Delta I(t) \Delta U(t+\tau) \rangle$$
$$C_{QU,t}(\tau) = \langle \Delta Q(t) \Delta U(t+\tau) \rangle$$



PKS 0420-385:

2-3 strongly polarized components

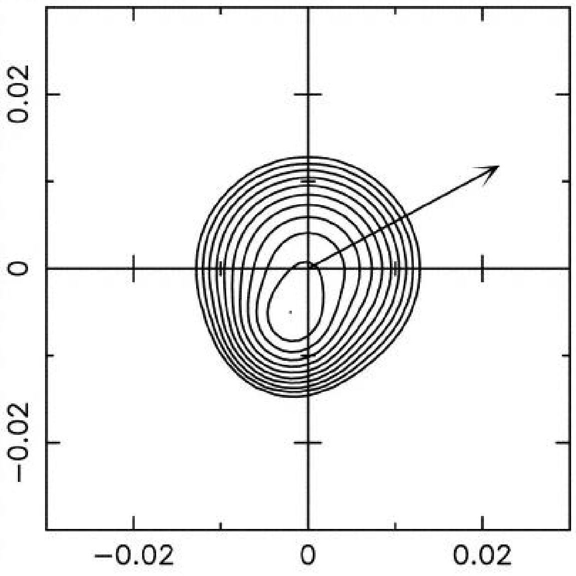
$T_B \sim 10^{13}$ K

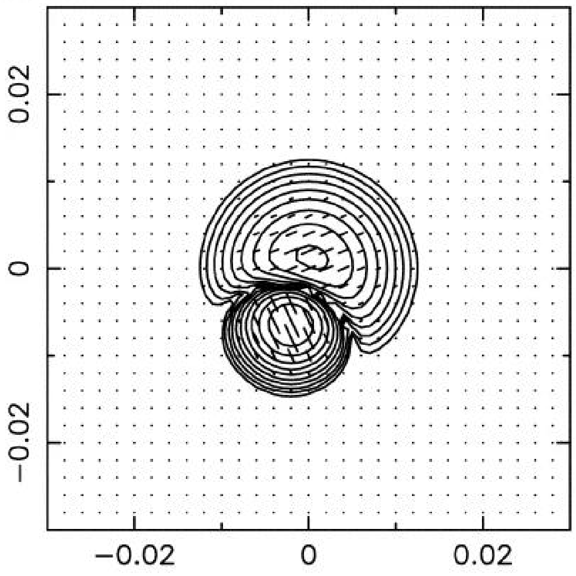
~a few 10 Üas offset

screen distance 25 pc

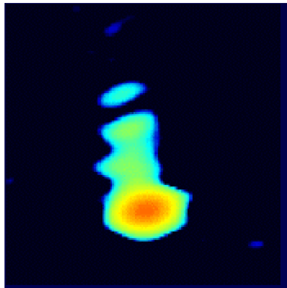
velocity 36 km/s

anisotropy 1:4

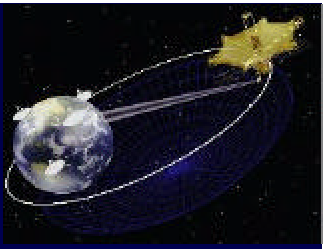




Rickett et al. 2002

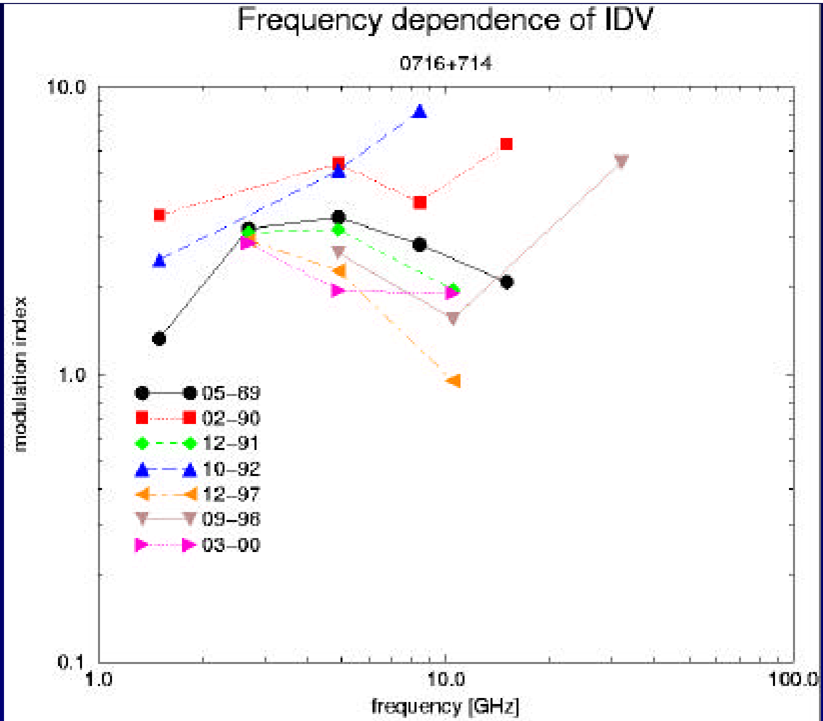


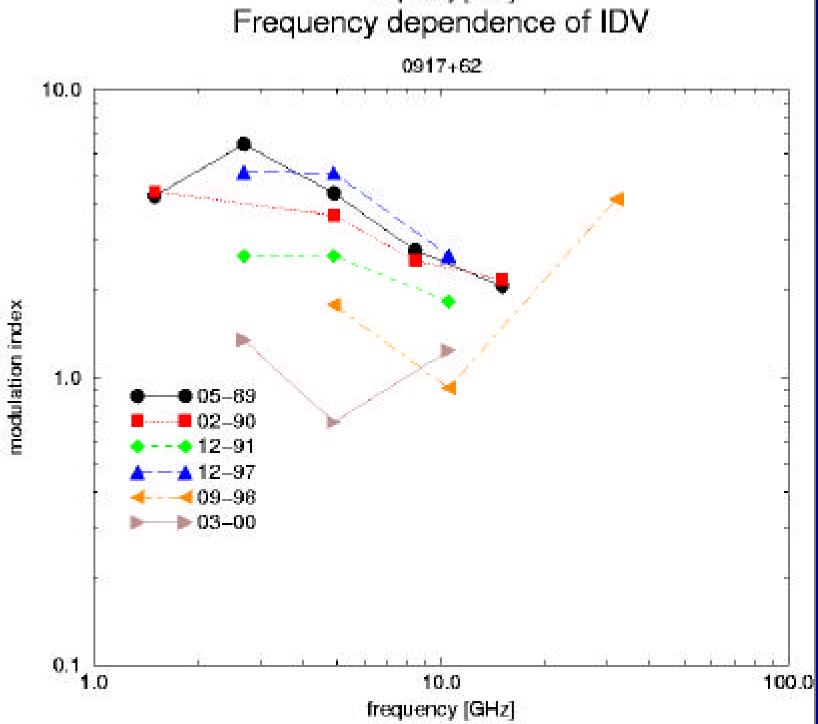
Intraday Variations of the VLBI core

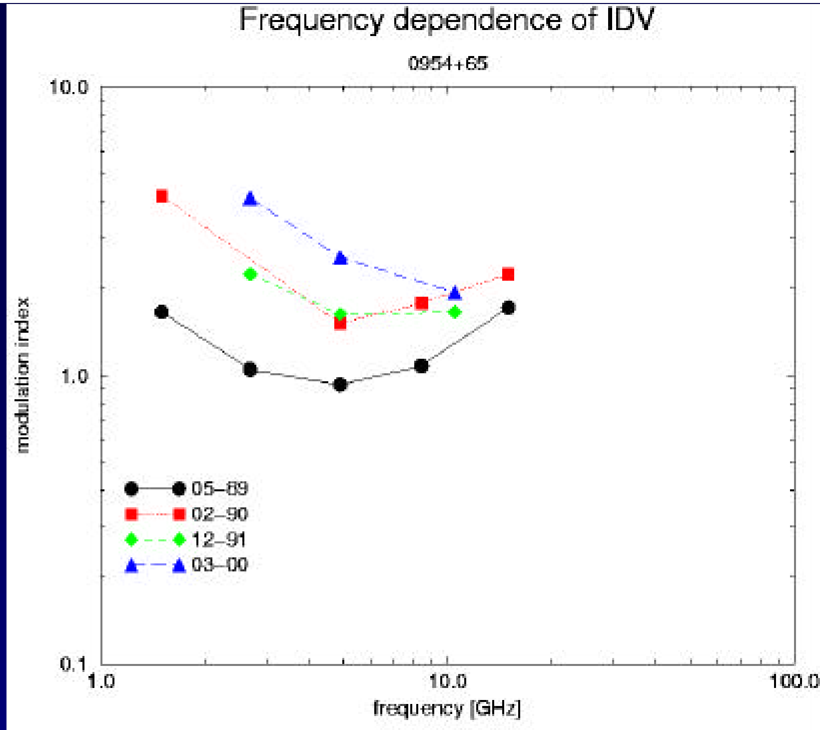


Array	Part	I [mJy]	P [mJy]	χ [°]
		29 Sep 2000		
VLBI	Core	520.3 ± 26.9	12.1 ± 1.3	49.4 ± 4.1
	Jet	56.0 ± 4.7	7.4 ± 0.8	-10.8 ± 5.6
Eb		763.2 ± 6.9	21.4 ± 2.6	23.4 ± 2.1
		4 Oct 2000		
VLBI	Core	499.3 ± 26.1	11.8 ± 1.3	40.7 ± 4.0
	Jet	54.8 ± 6.3	7.3 ± 0.8	-11.2 ± 7.8
Eb		735.7 ± 16.2	21.6 ± 2.6	18.6 ± 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

Bach et al., 2004







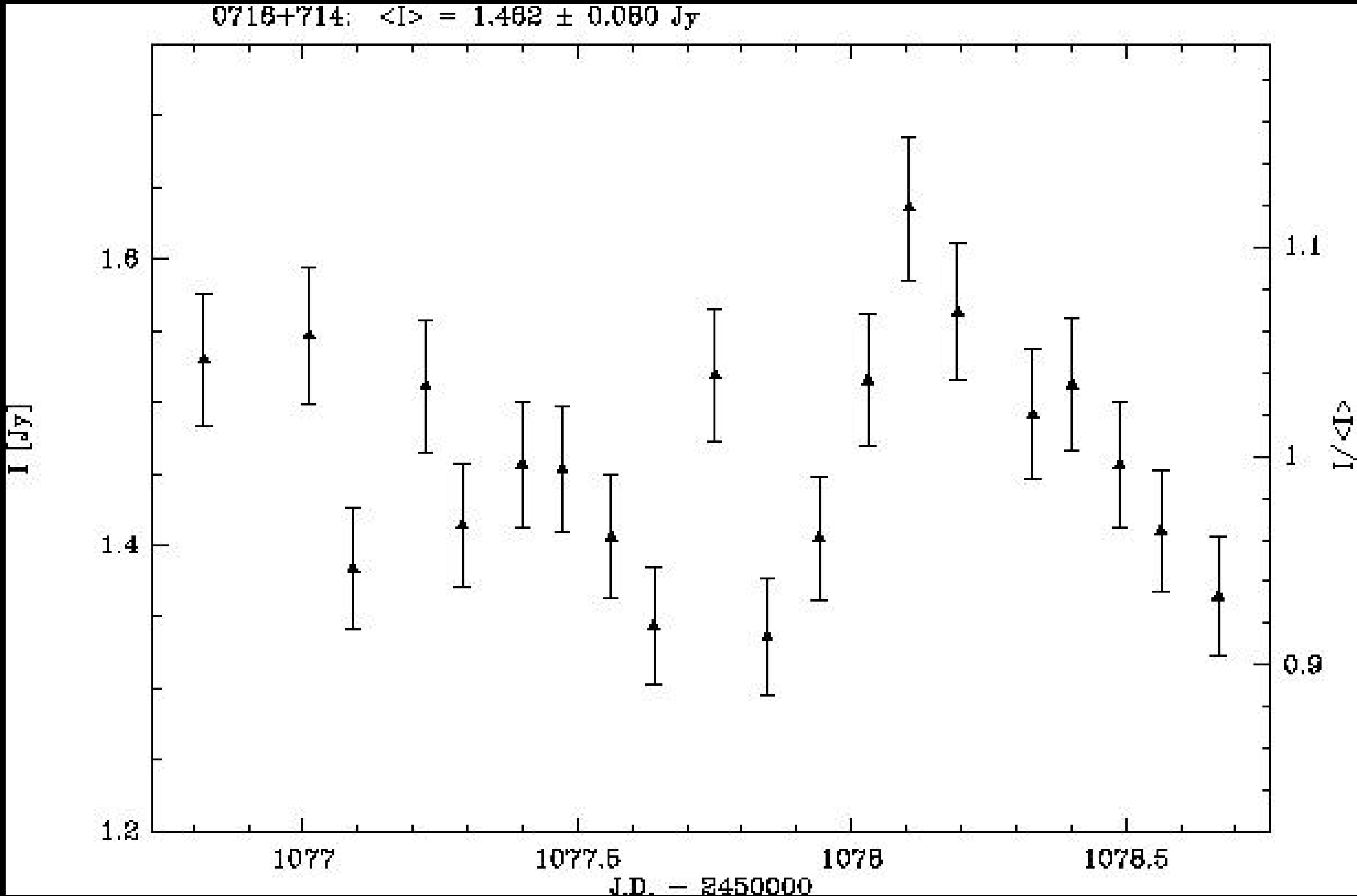
Modulation index plottet versus frequency:

- variable with time
- strongly varies between sources
- not simply related to strong or weak ISS

Krichbaum et al., 2002, PASA

100m RT Effelsberg

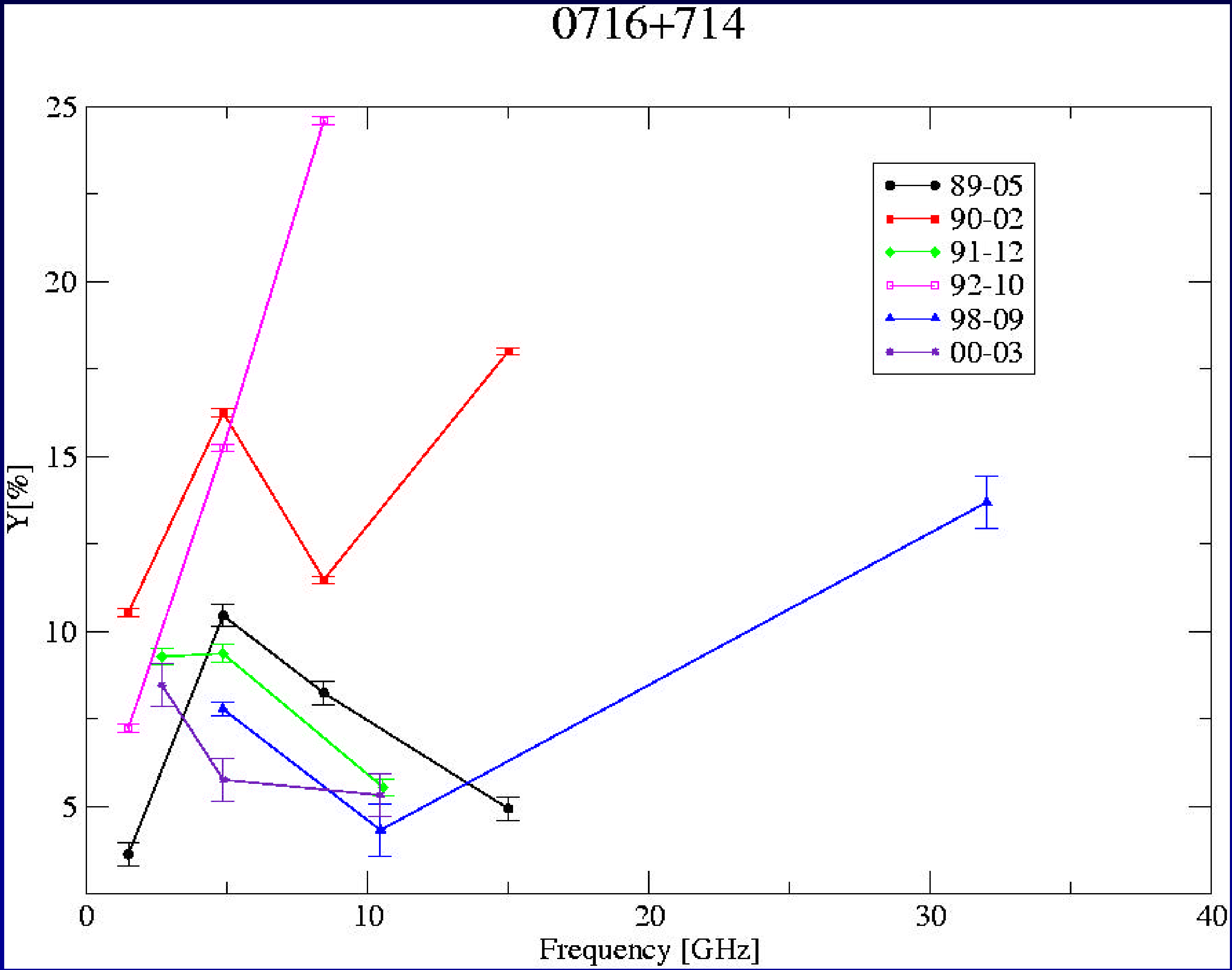
Kraus et al. 2002



IDV of 0716+714 at 9mm wavelengths, 20% flux change in 5 hrs

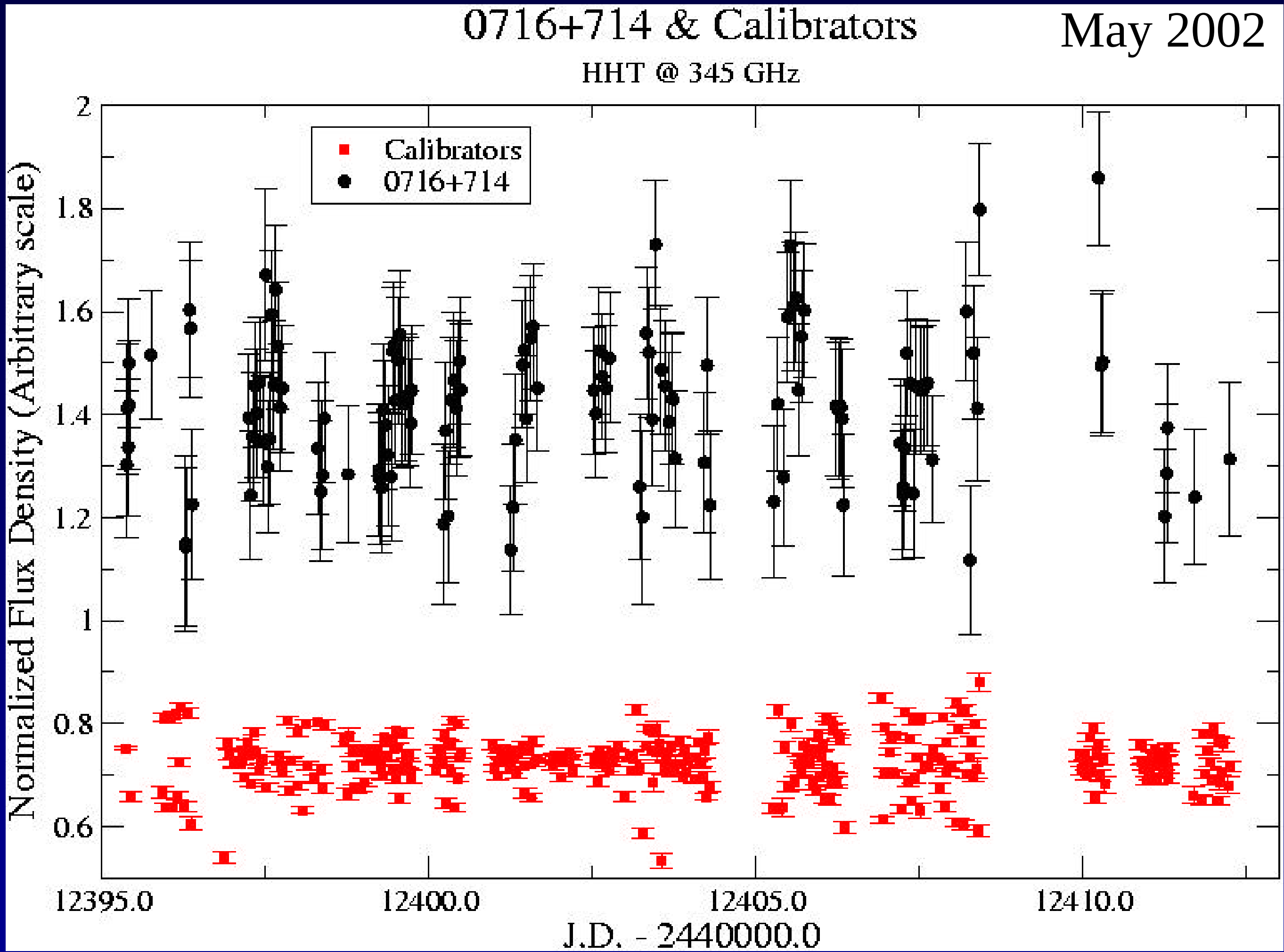
Krichbaum et al., 2002, PASA,

Kraus et al. 2003, A&A



IDV amplitude (Y) often increases with frequency

Krichbaum et al., 2002, and Cimo, PhD 2003



0716+714

m=0.15

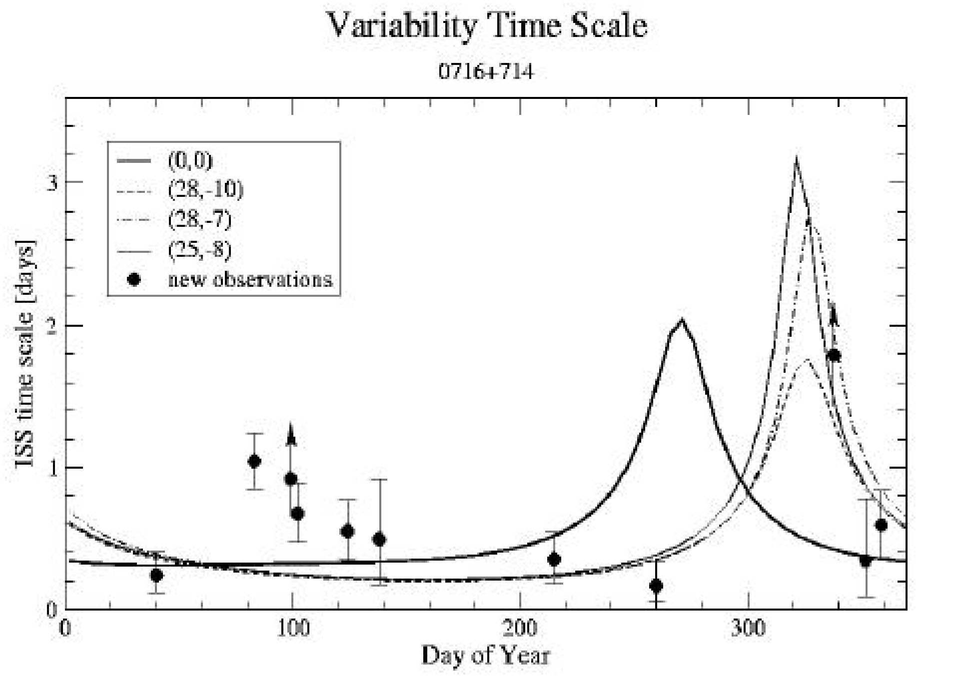
calibrators

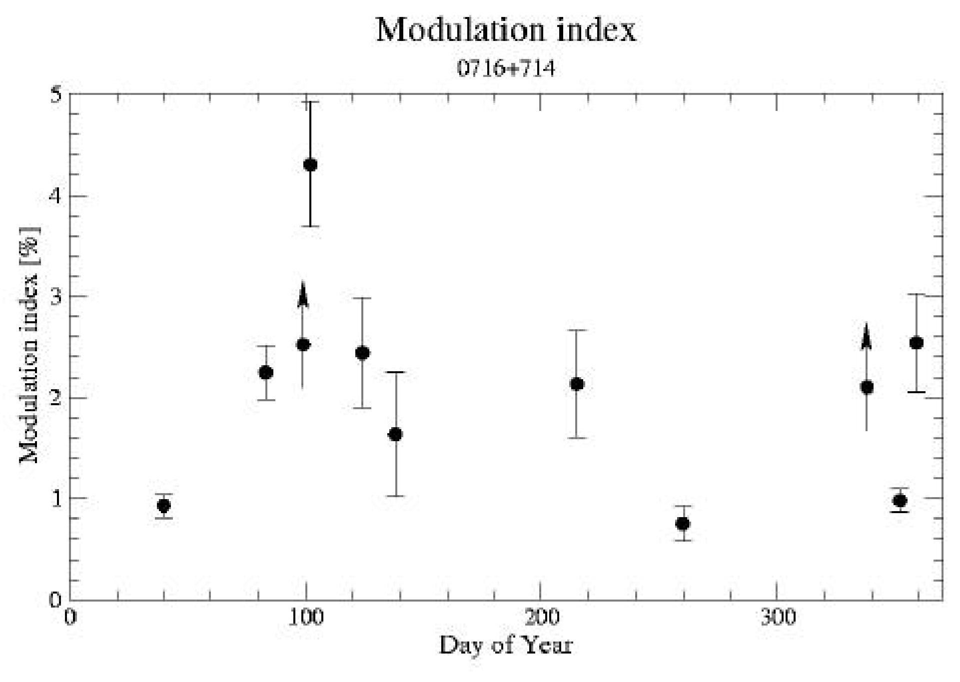
m=0.05

18 days

3σ detection of IDV in 0716+714 at 345 GHz

Cimo, PhD 2003





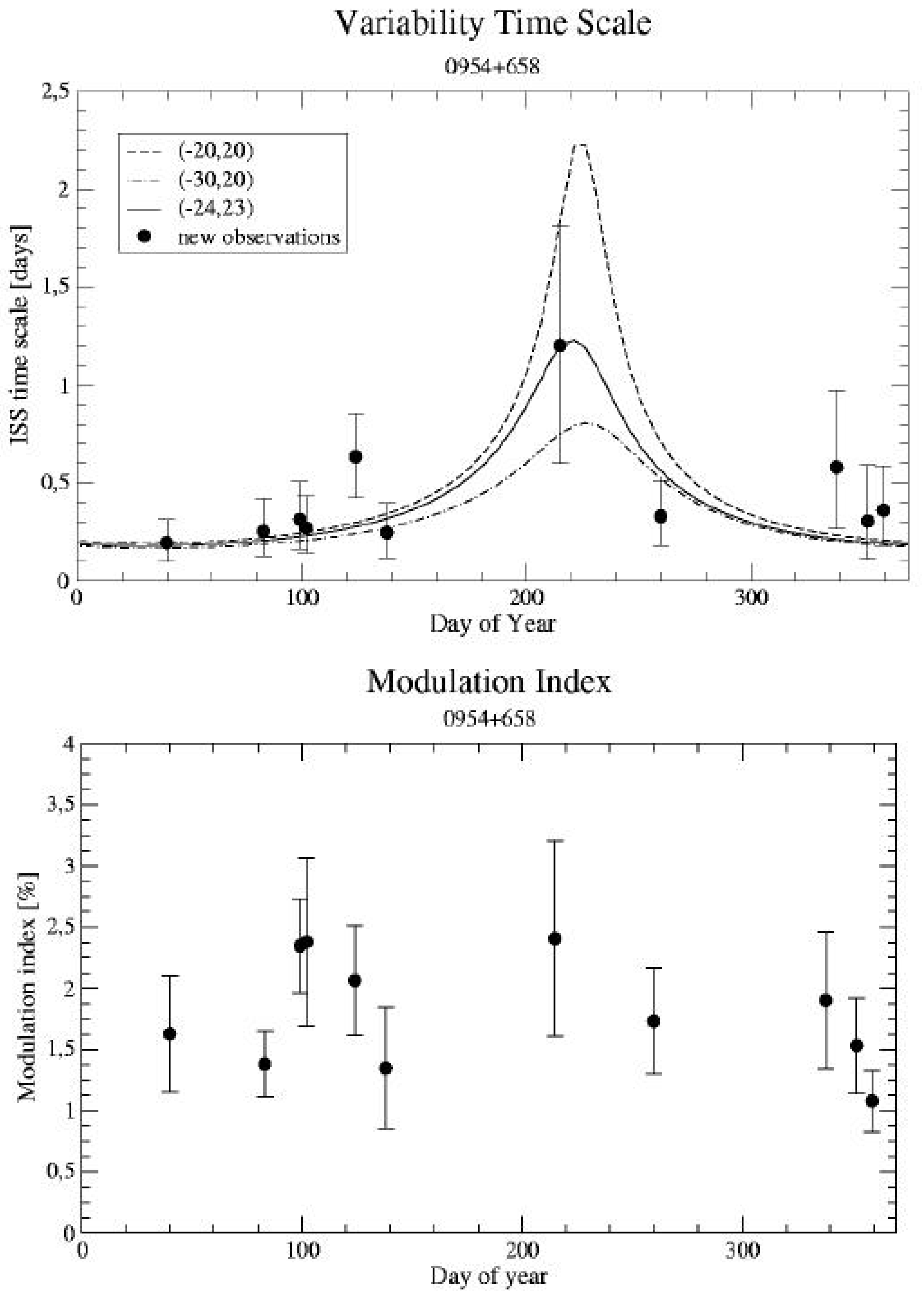
characteristic time vs. DOY

0716+714:

no evidence yet for annual modulation of IDV due to orbital motion

variability index vs. DOY

Fuhrmann, PhD 2004



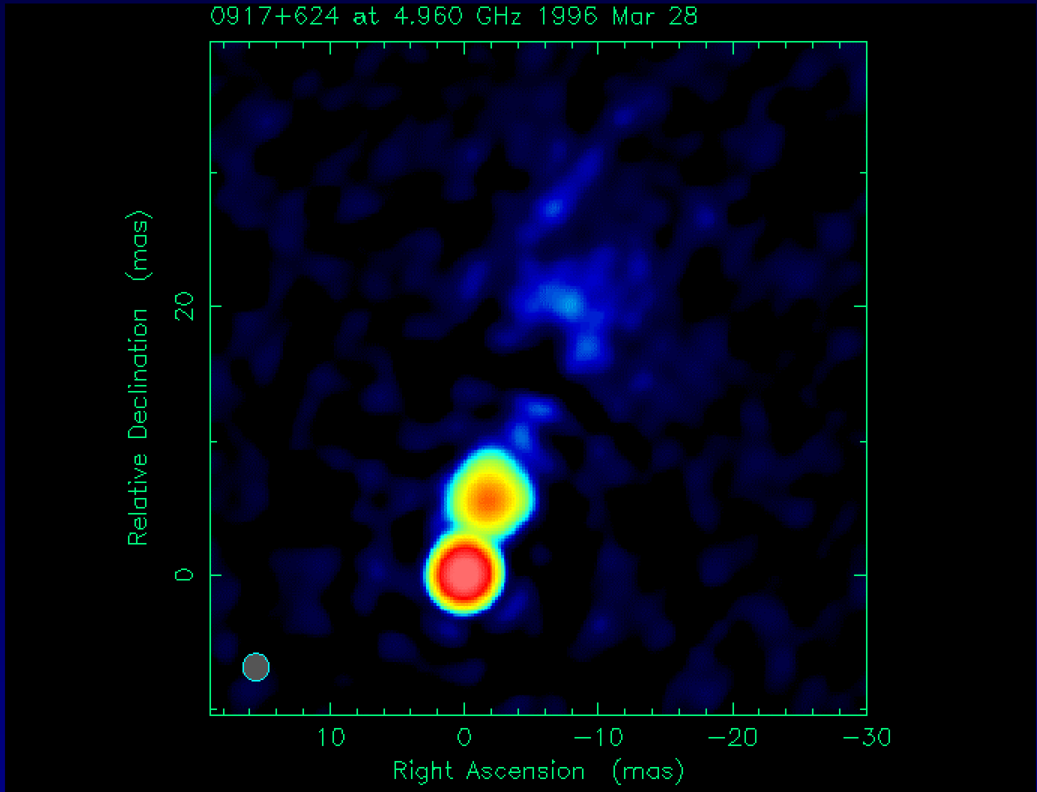
characteristic time vs. DOY

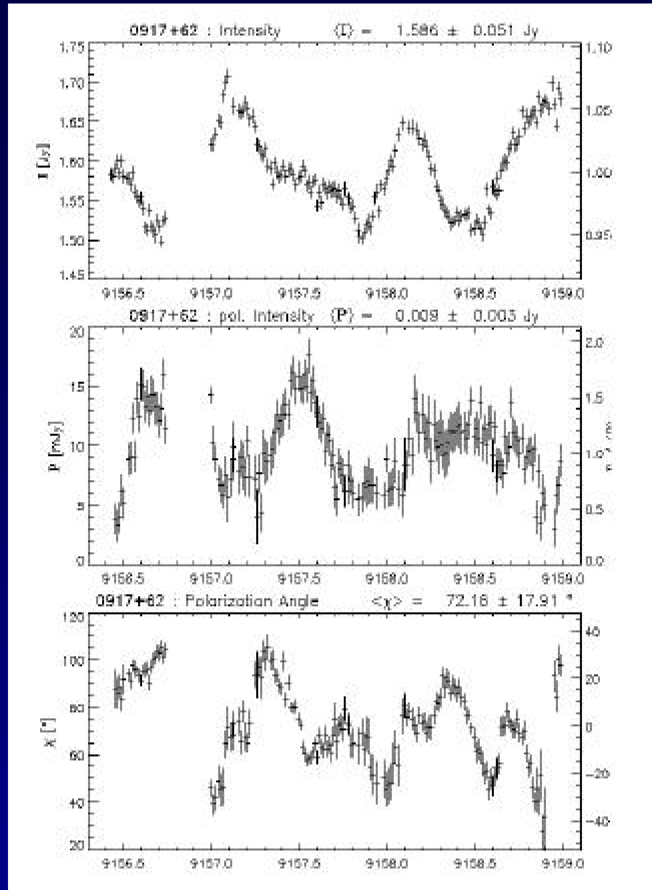
0954+658:

some evidence for annual modulation of IDV due to orbital motion

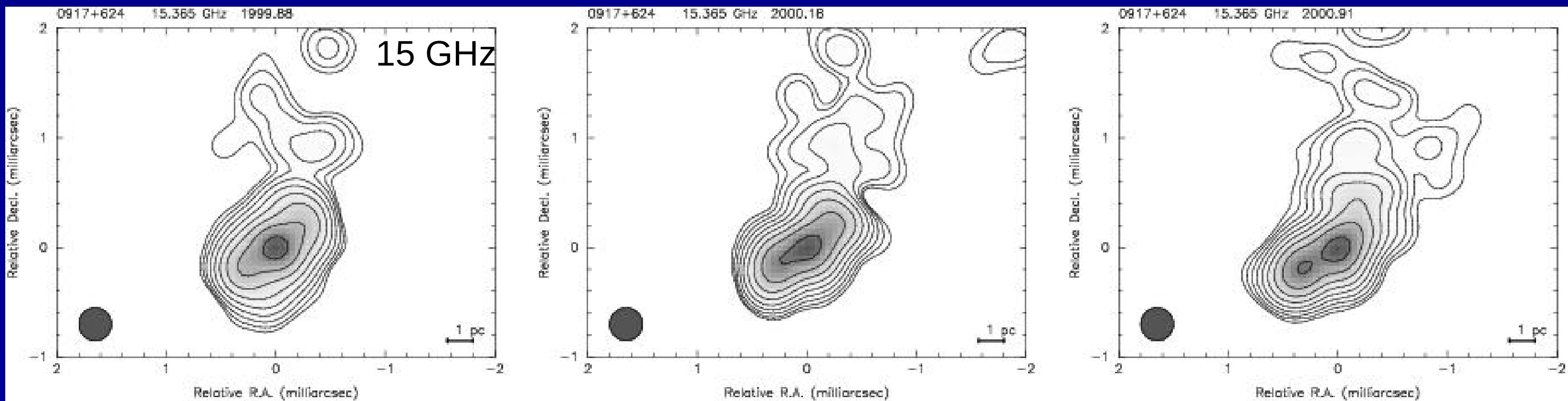
variability index vs. DOY

Fuhrmann, PhD 2004

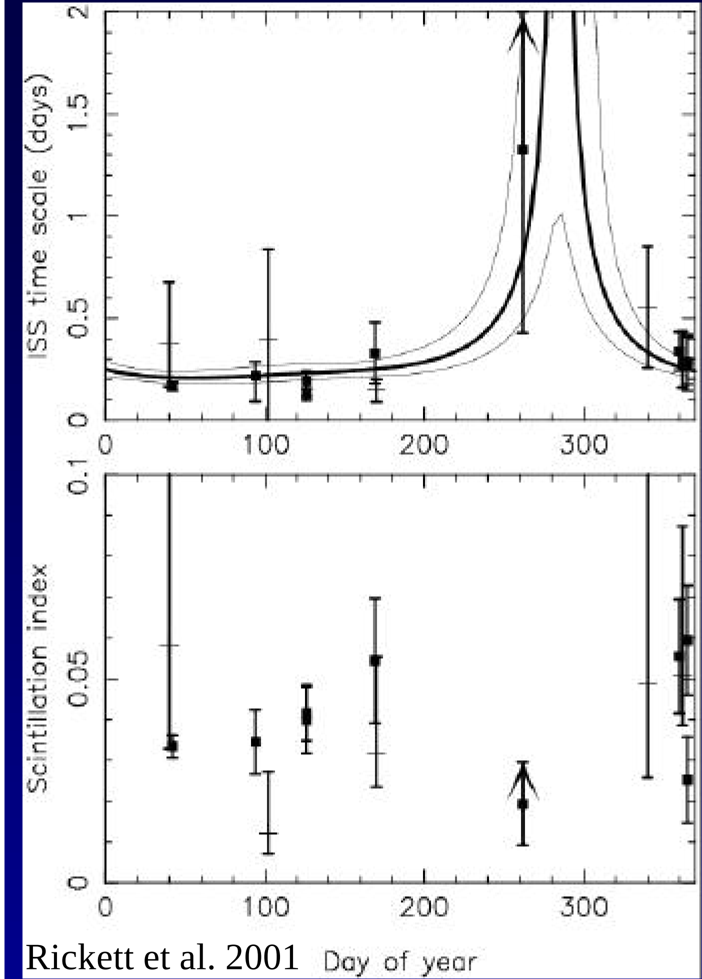




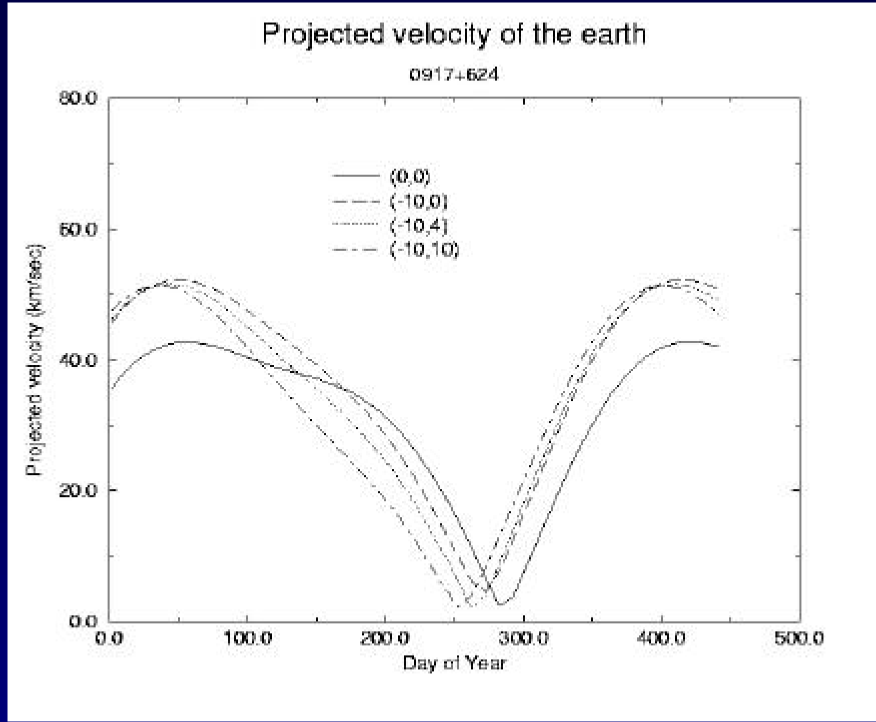
The IDV Quasar 0917+624



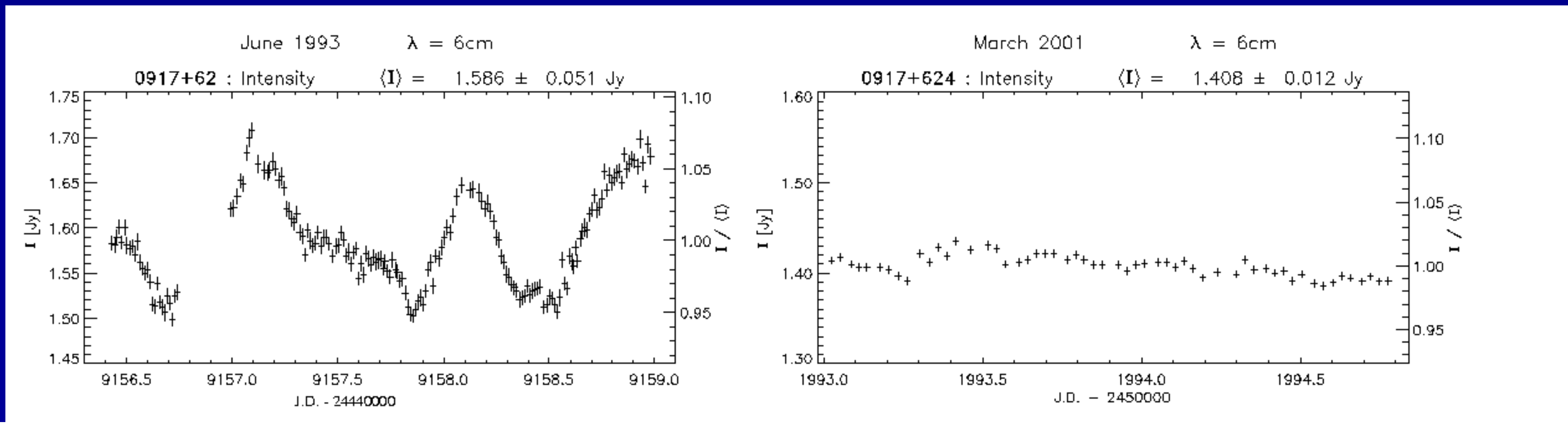
0917+624



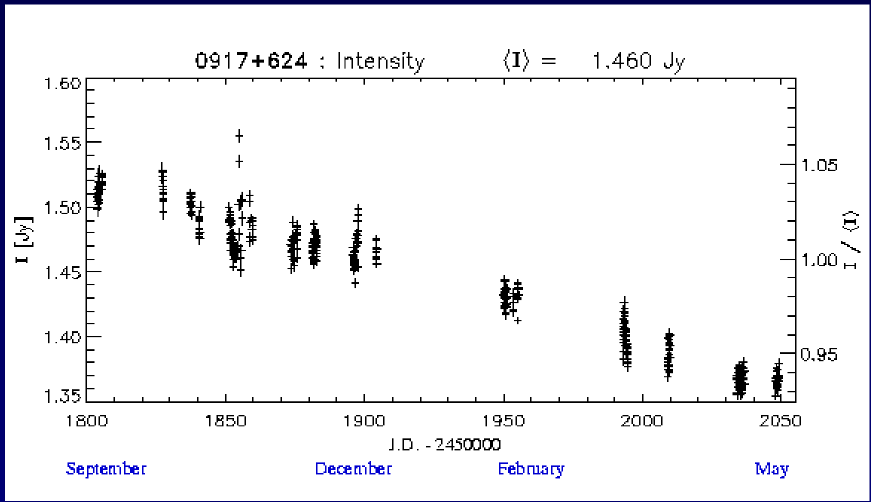
Rickett et al. 2001

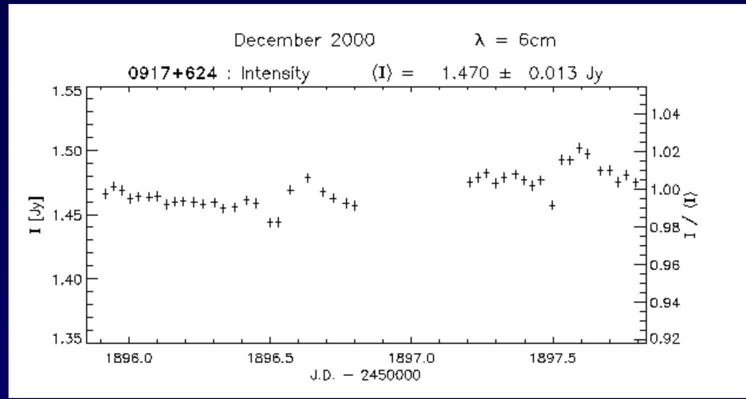


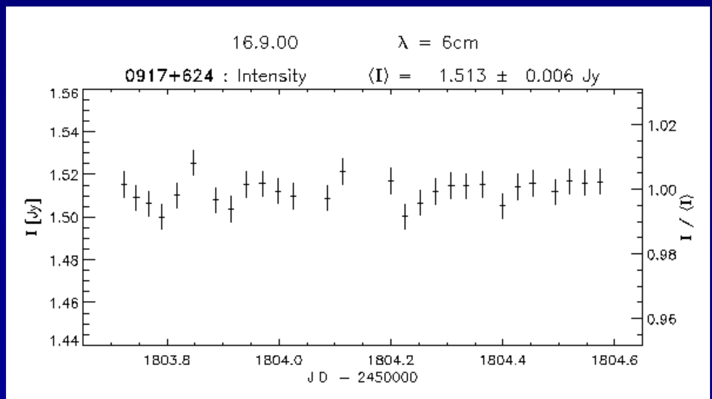
Published annual modulation due to orbital motion cannot be confirmed, since IDV stopped.

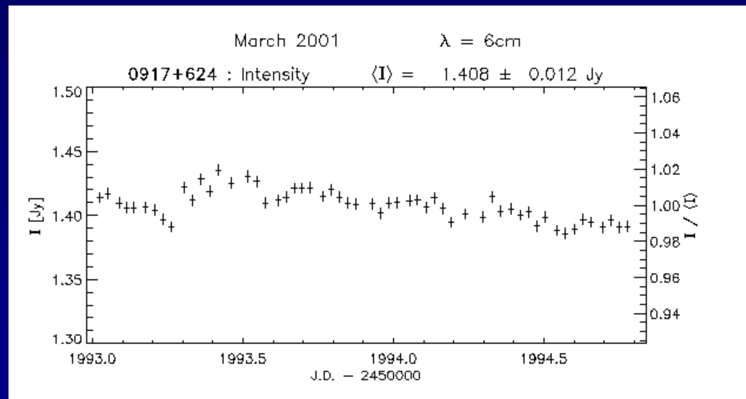


No IDV in 0917+624 since Sep. 2000

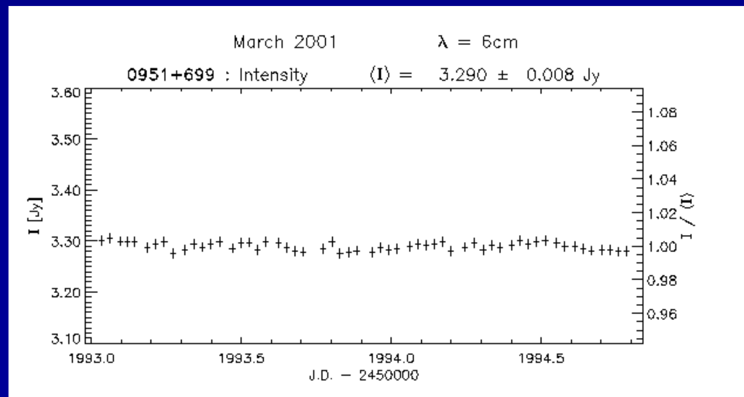




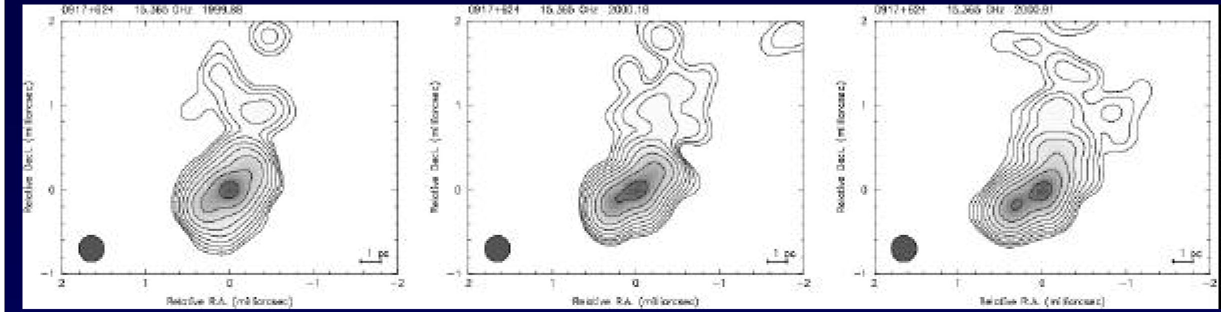


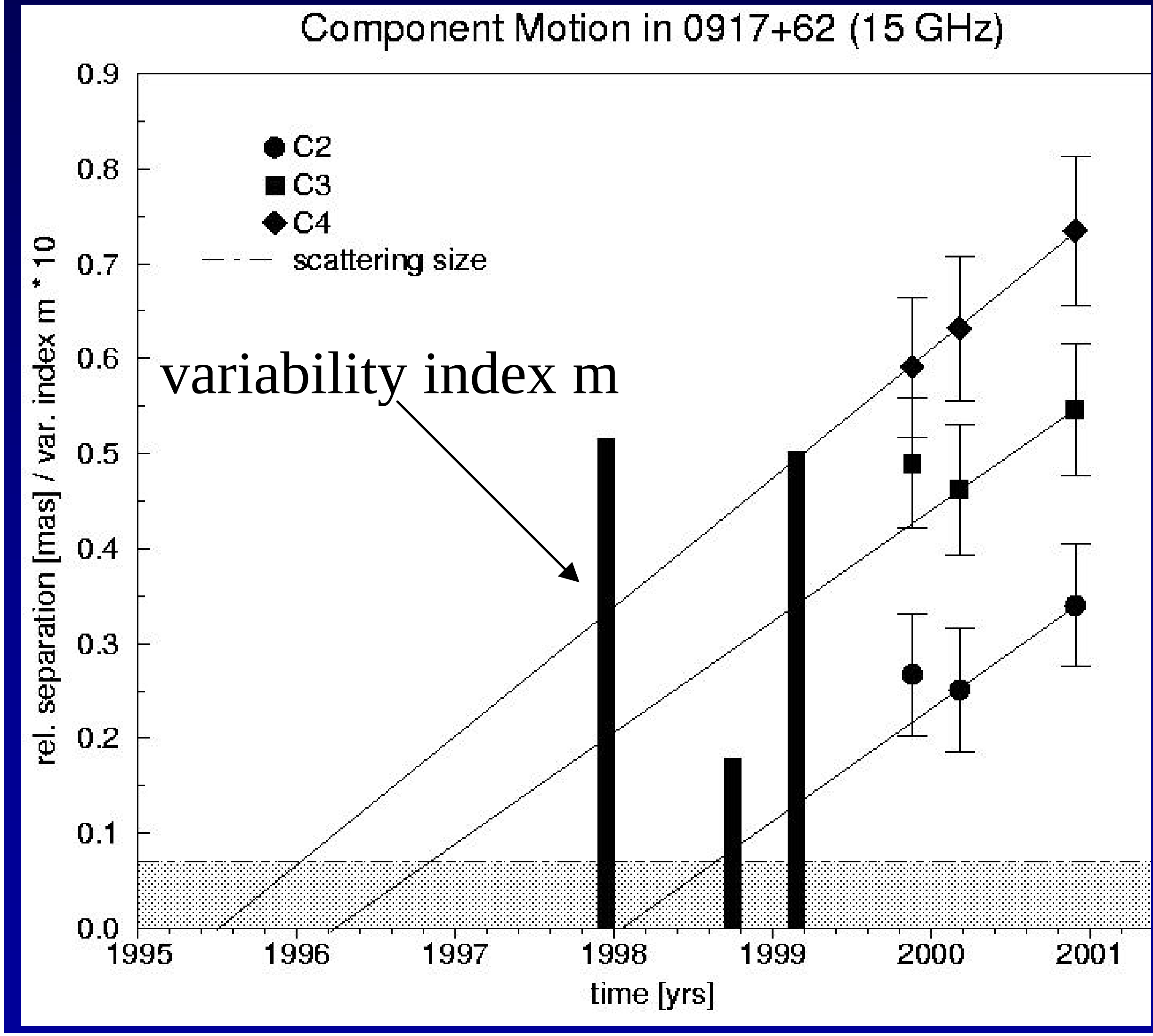


calibrator: typical accuracy < 0.5 % →



Fuhrmann et al., 2002

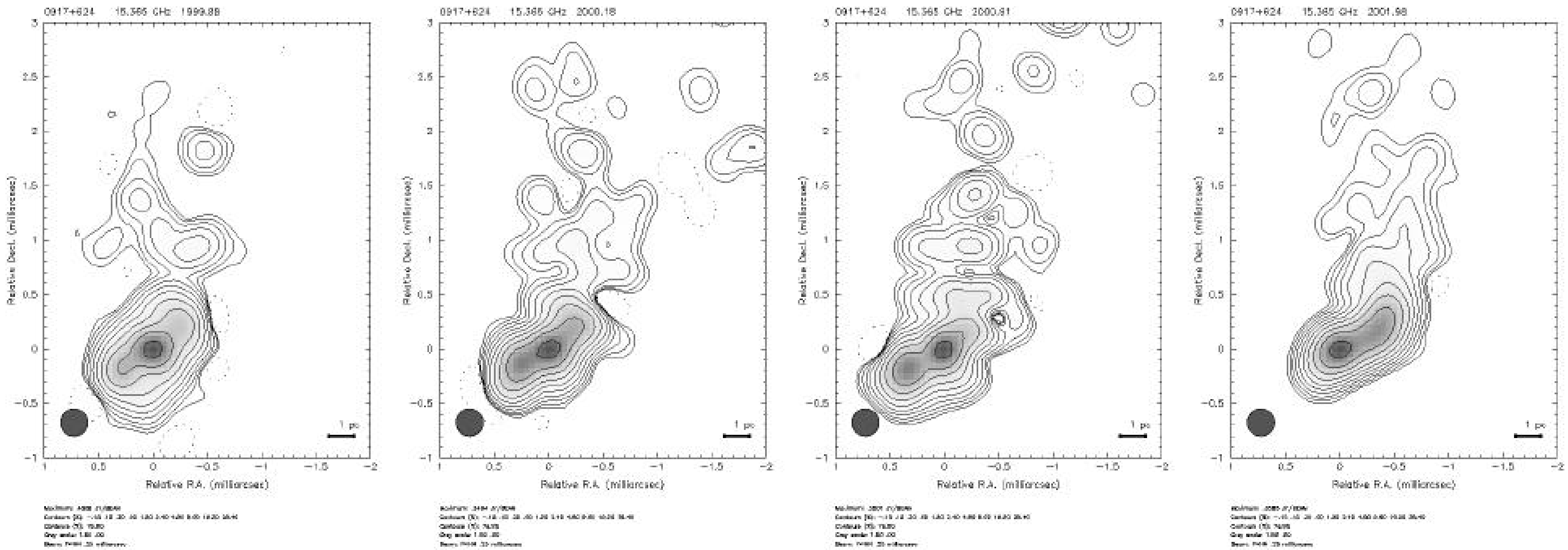


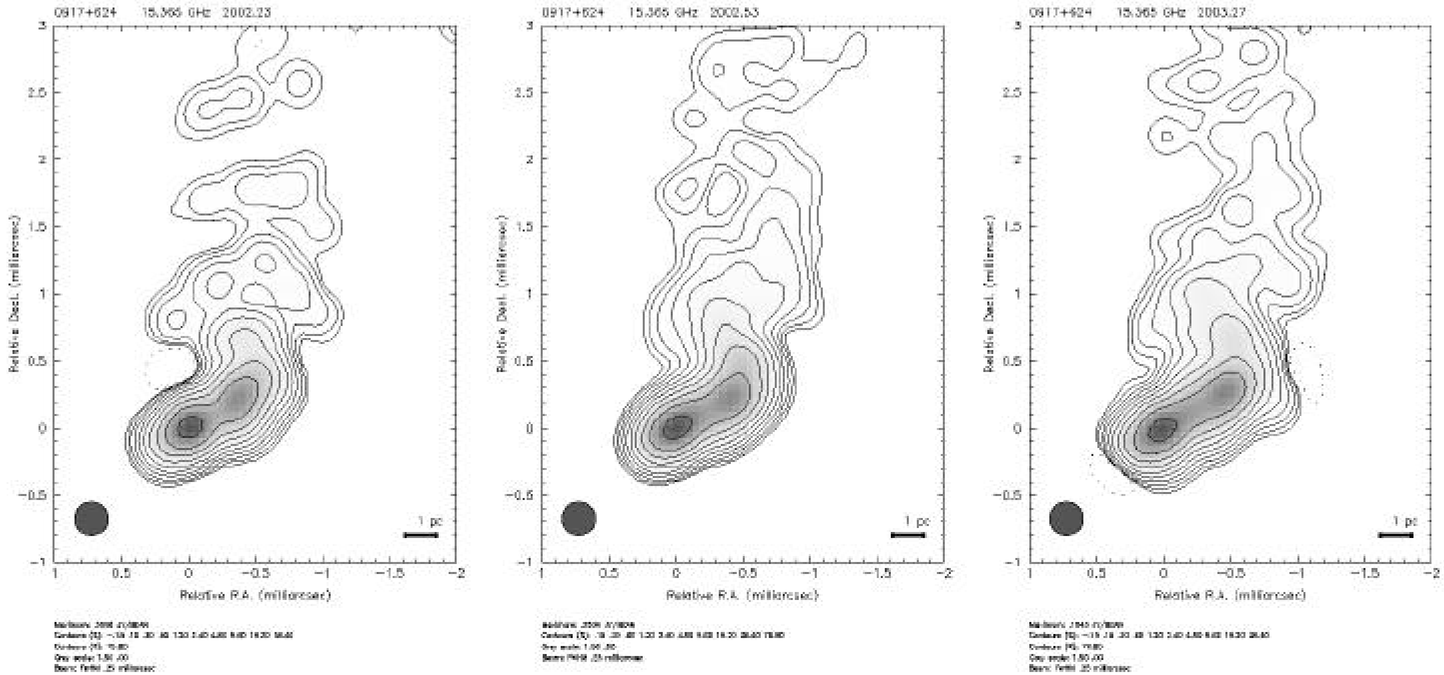


Hypothesis:

IDV should be affected from the time variable structure of the most compact regions in the source

Krichbaum et al. 2002, PASA 19, 14.



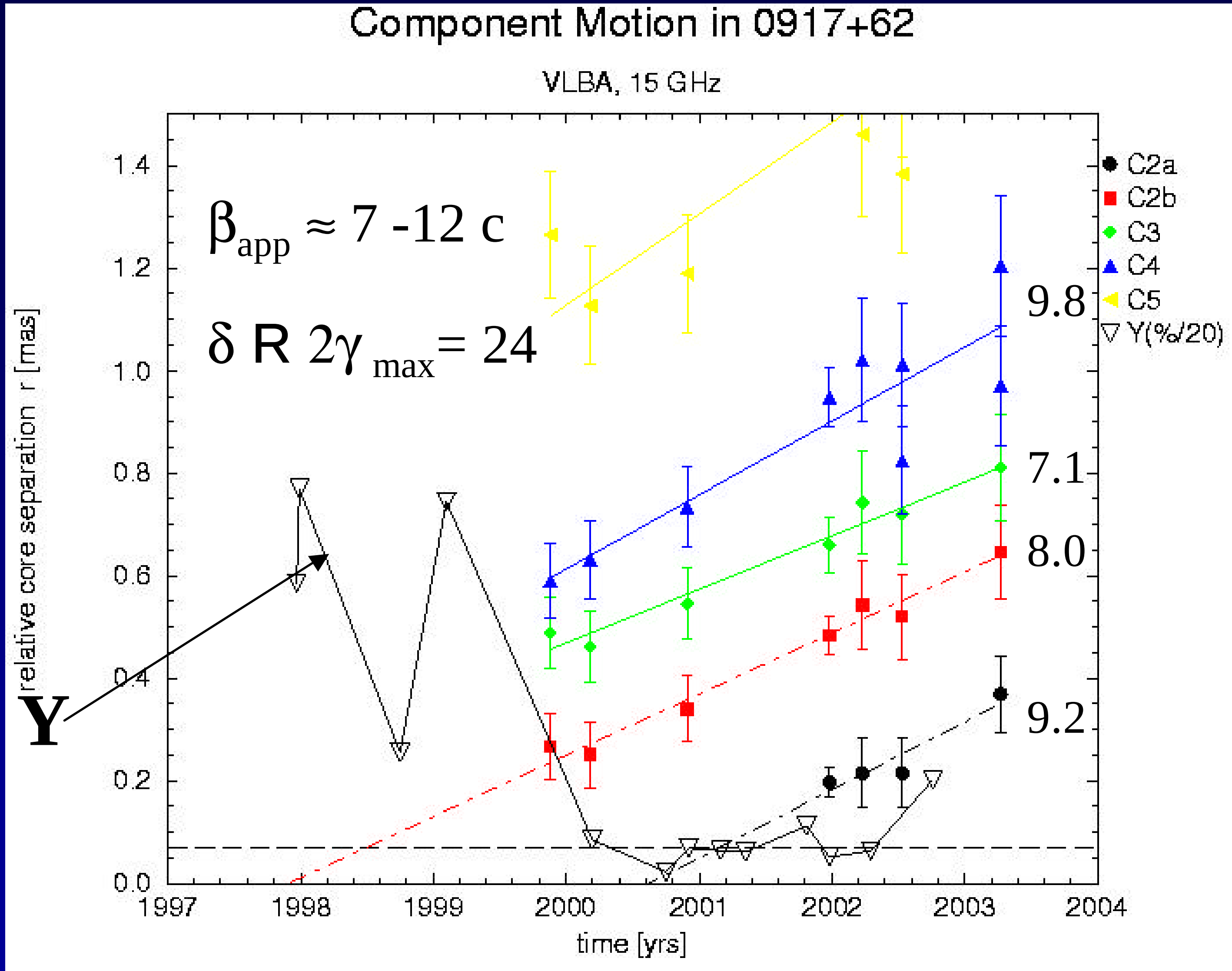


0917+624

1999 - 2003

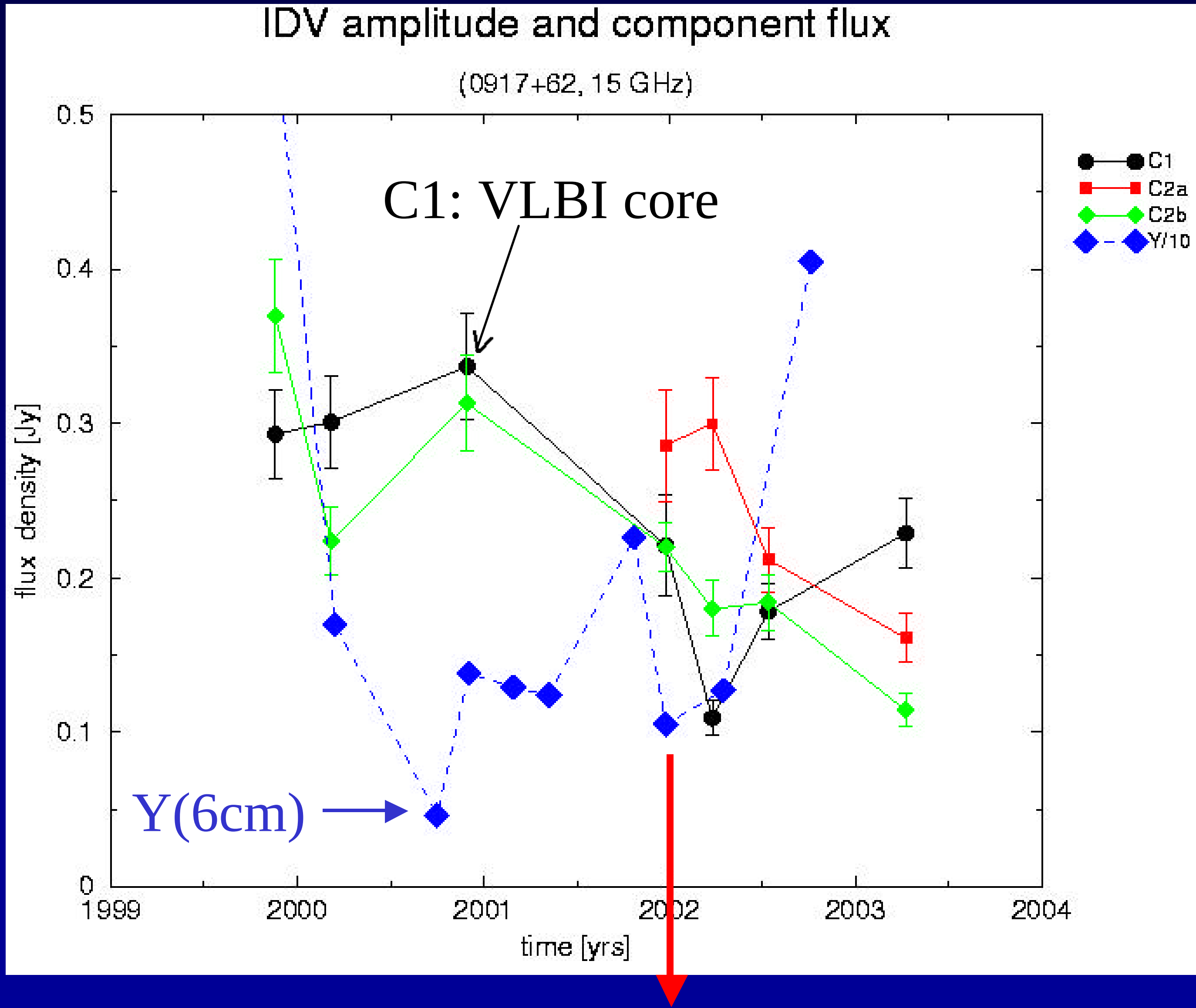
15 GHz

Multi-frequency VLBI monitoring of 0917+624

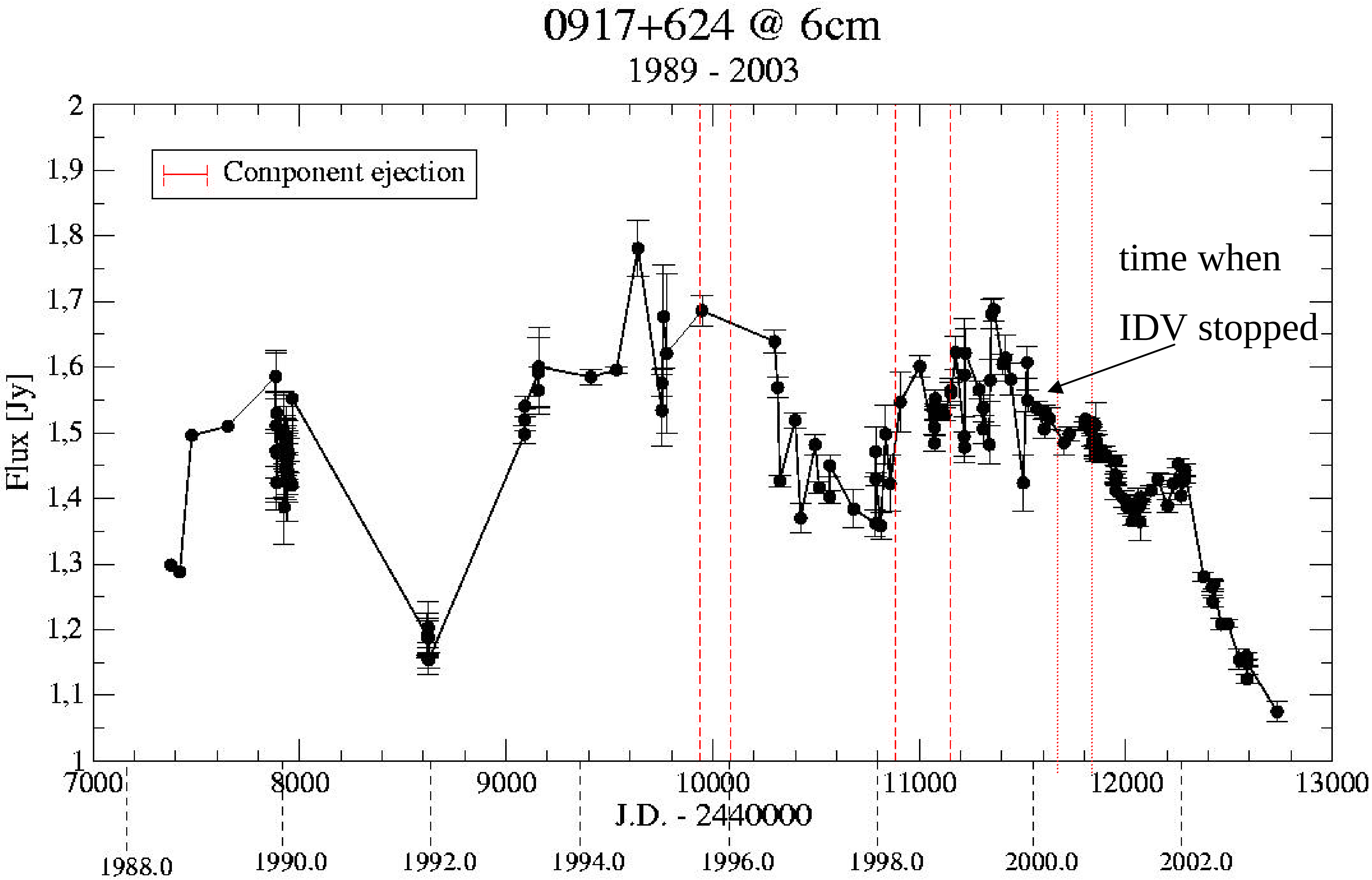


How does the jet evolution influence the IDV amplitude ?

Multi-frequency VLBI monitoring of 0917+624



Local minimum of Y in 2002 explained by new jet component ?



Total flux monitoring also showed change of IDV mode

Fuhrmann PhD, 2004

If IDV is due to ISS, then the size of the scintillating components must play an important role. Therefore:

Perform dense (daily) time sampled VLBI observations with highest possible angular resolution (high frequency VLBI, Space-VLBI)

Search for structural variability on sub-mas scales in core and jet

Expect more variability in polarisation than in total intensity

Obtain upper limit for jet speed and Doppler-factor

Determine brightness temperature of VLBI core (lower limit)

Experiments performed so far: 2007+77 (VSOP)

0716+71 (VSOP, VLBA+EB)

0954+65 (VSOP, VLBA+EB)

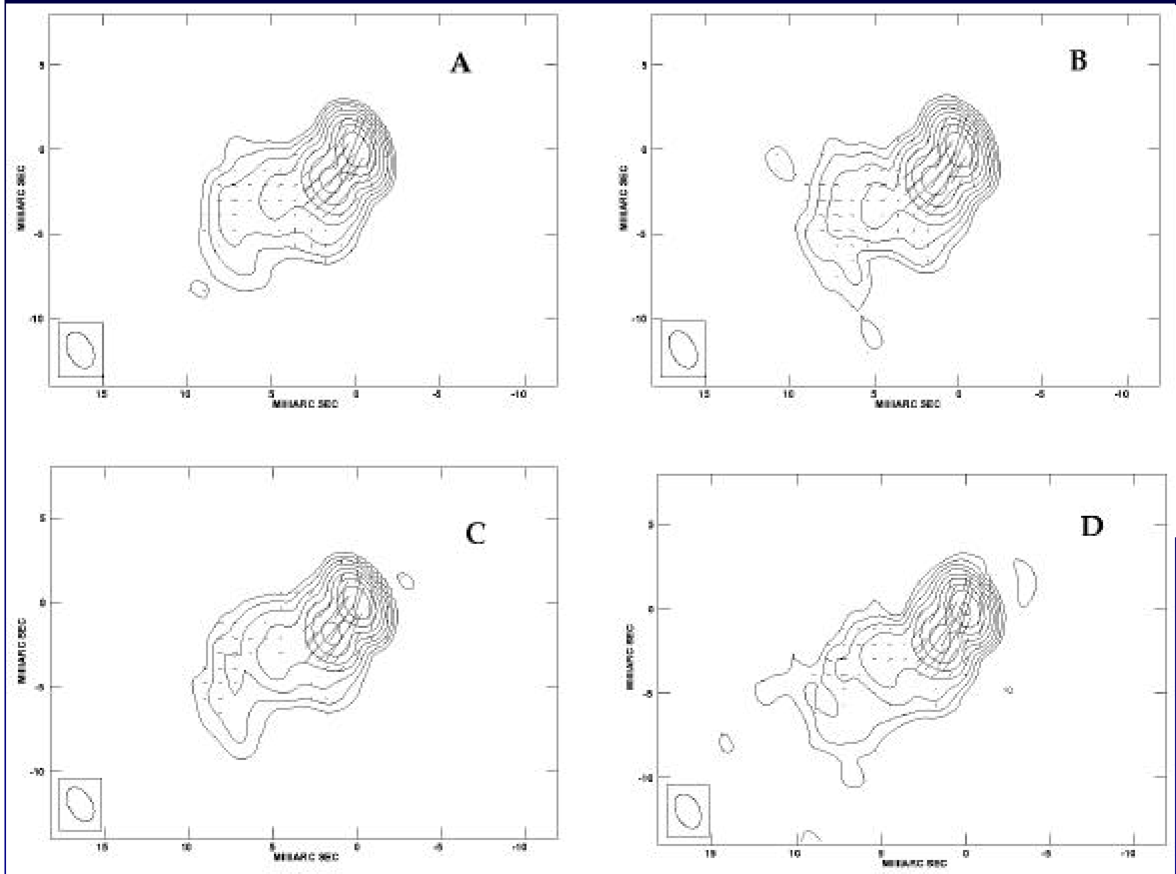
0917+62 (VLBA, VLBA+EB)

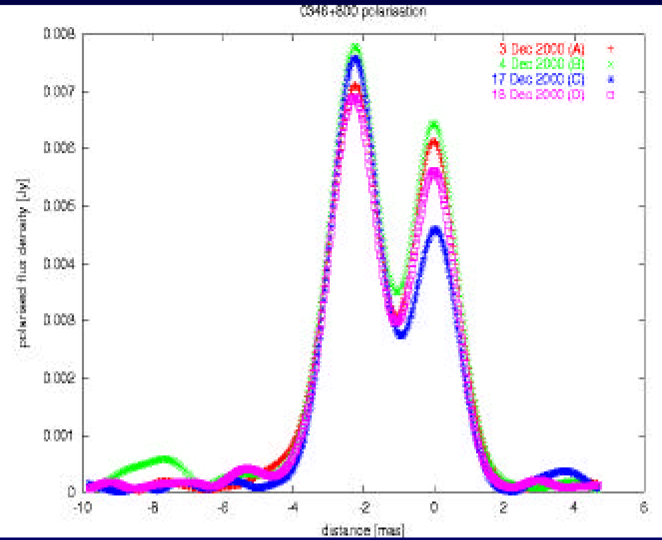
0346+80 (VLBA+EB)

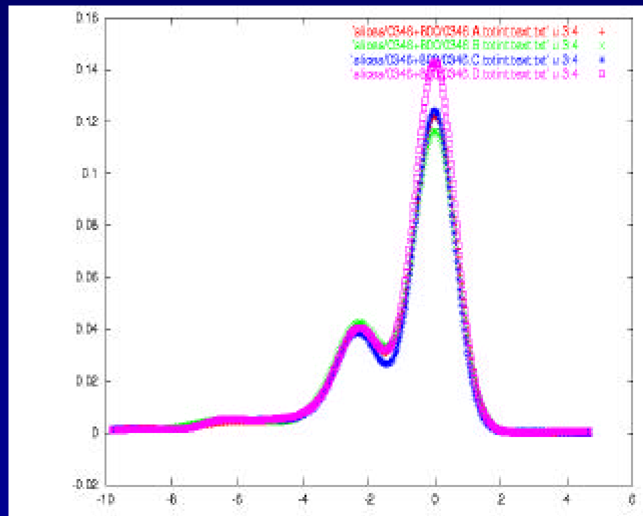
Summary of sources

Source	I_{var}	P_{var}	Chi-var	comment
0716+71	Continuous rise of 25 %	60% increase in P, connected to core of source	·Position angle swing of 40 deg from A to B (62 to 22). ·C & D EVPA is circa 20 deg.	·Variations in I are correlated with a rise in P in second epoch. ·In the last two epochs I&P anticorrelated. P flux density spurious.
0917+62	No changes in total flux (variations within 5%)	Polarisation constant in all epochs.	Polarisation angle is constant at around 40 deg.	No changes detected in the source.
0954+65	Variations of order of 8%. No detectable trend.	There seems to be a slight decrease in P in the last epoch (of the order of 20%) in the core.	15 deg change between A, B and C, D (106 deg to 120 deg)	Some slight changes, but not significant withing errors.
0346+80	Variations of the order of 15%	Variations also of the order of 15%. Most of the variations take place in the core.	Angle seems to get smaller towards the end. From −35 deg A&B to −25 deg C & D.	Changes observed mailny in polarisation. No trend is recognised..

Impellizzeri et al., in prep.







core: 10% variations in total intensity

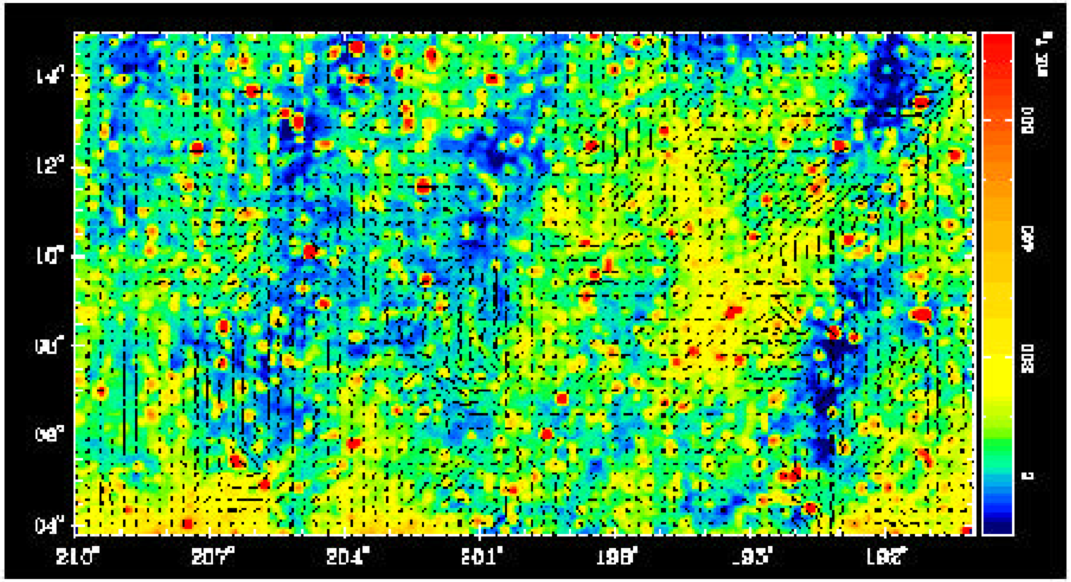
40% variations in polarization

10 degrees in EVPA

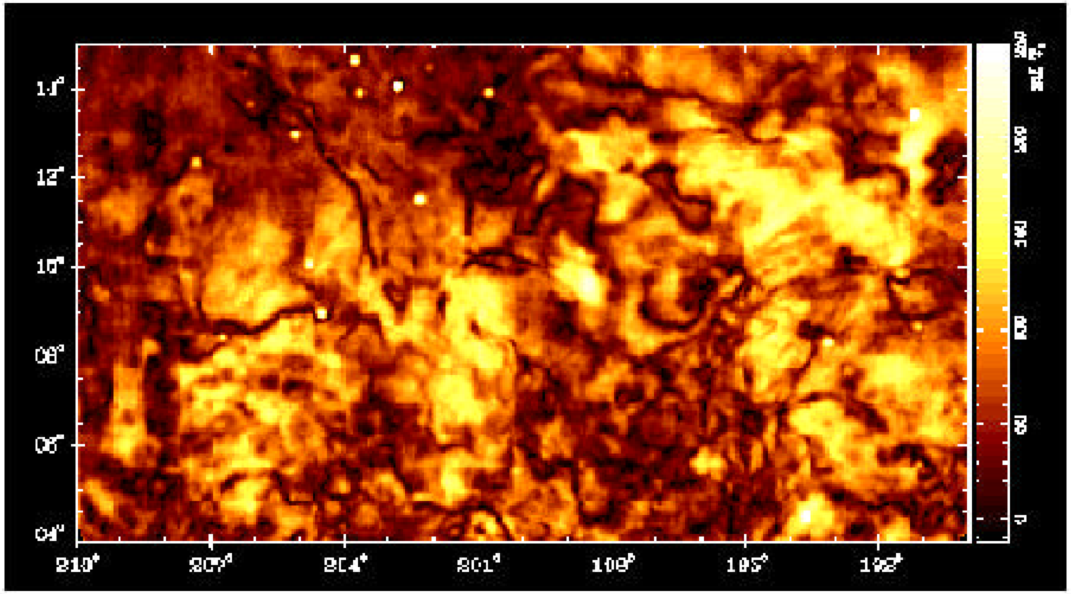
0346+800

Impellizzeri et al., in prep.

21 cm Effelsberg 100m RT



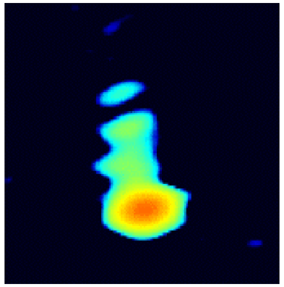
This is the total intensity image towards the Galactic anticenter. The Electric field vectors, proportional to the polarization intensity, are overlaid as bars.

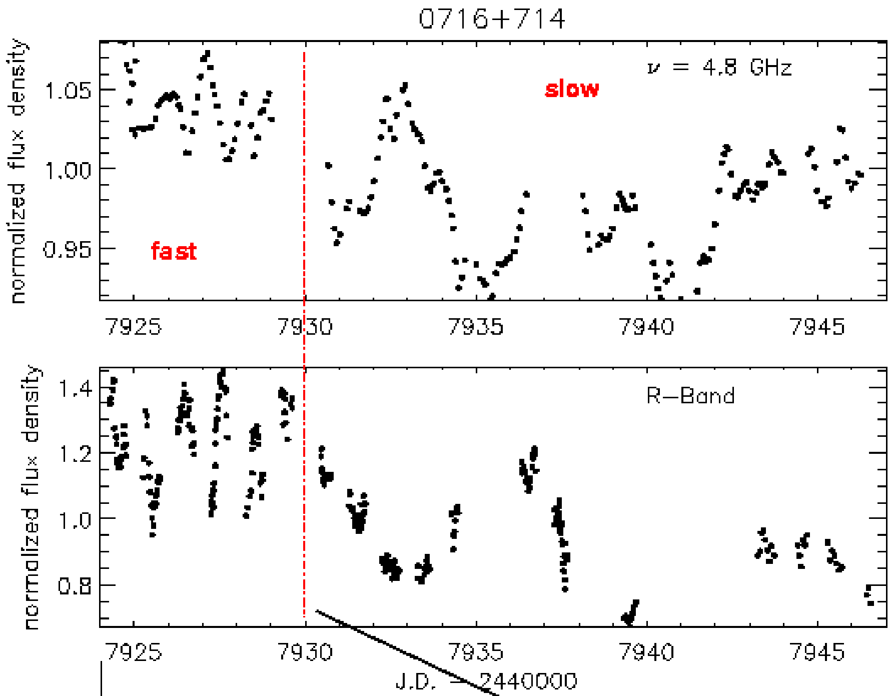


This is the polarized intensity image of the same region. Now compare the two images: the total intensity image shows a complete anticorrelation with the polarization intensity image!

Uyaniker et al. 1999

IDV in 0716+714

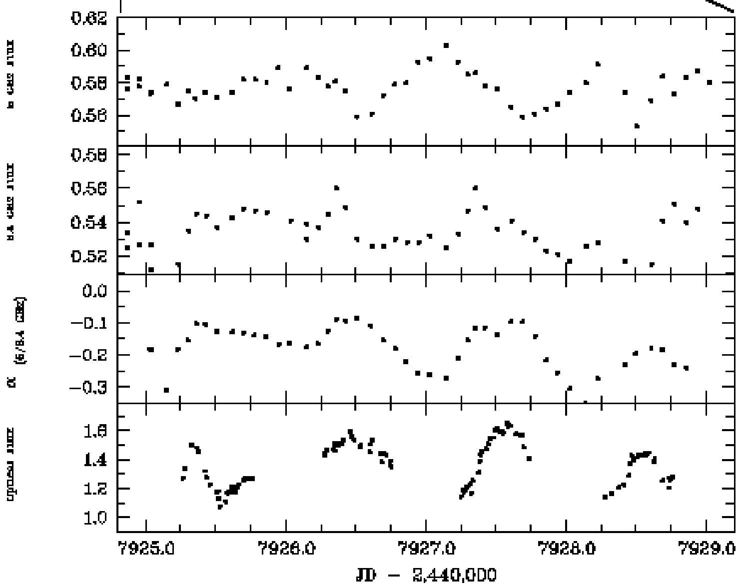




Brightness temperatures derived from radio IDV:

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

Quirrenbach et al. 1991



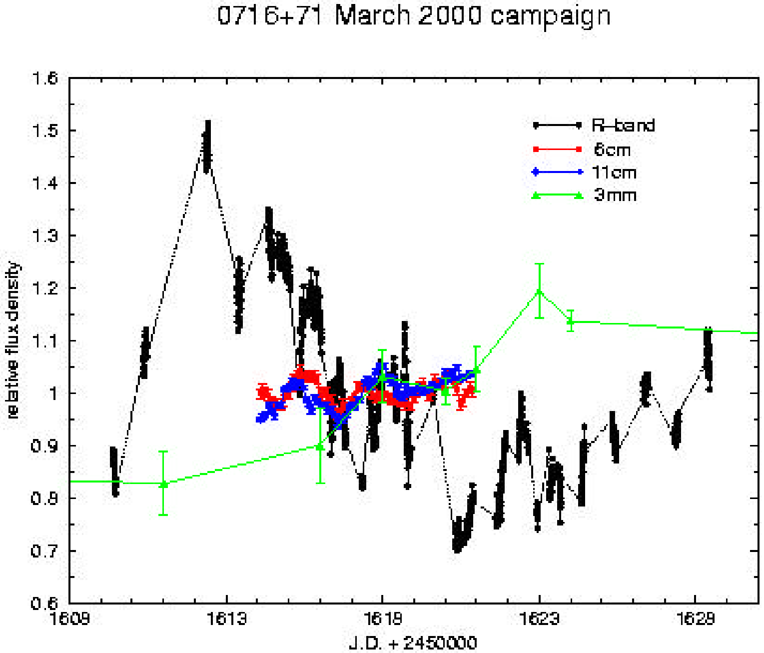
5 GHz flux

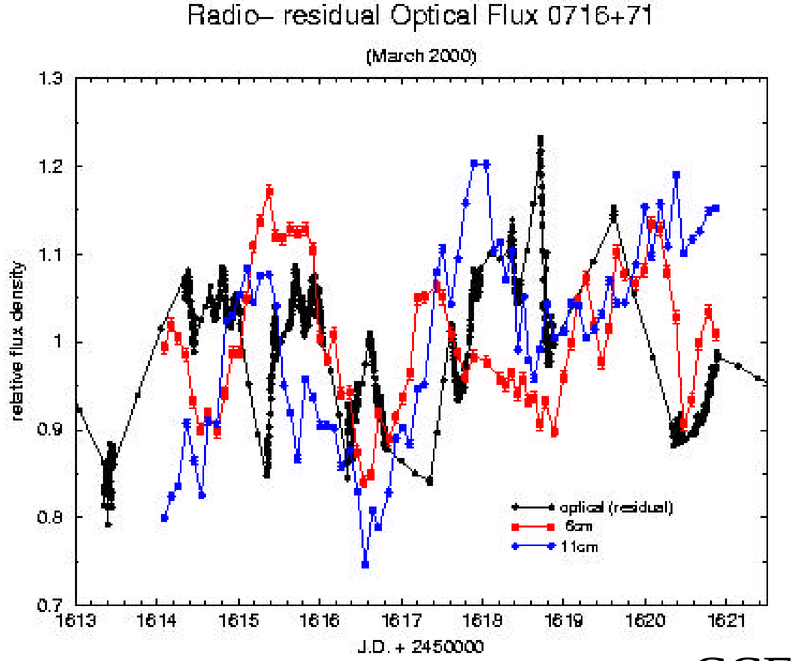
8 GHz flux

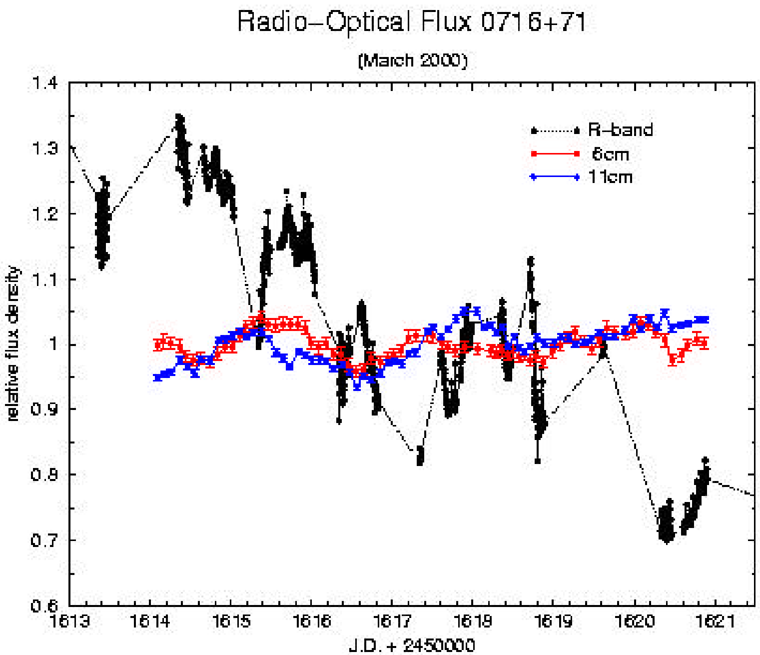
alpha (5/8 GHz)

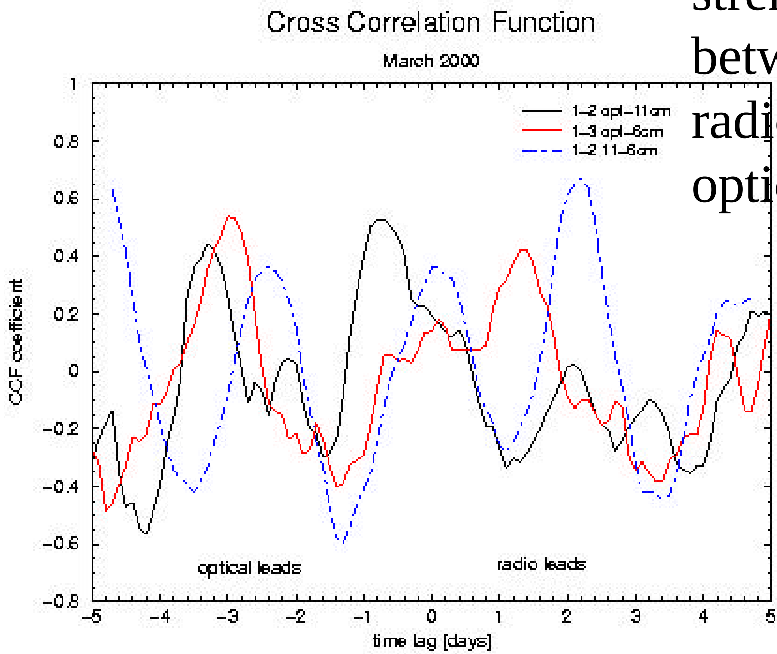
optical flux

Qian et al. 1996, Wagner et al. 1996









CCF has same strengths between radio-radio and radio-optical

A coordinated multi-frequency flux monitoring campaign of 0716+714 (INTEGRAL + ground telescopes)

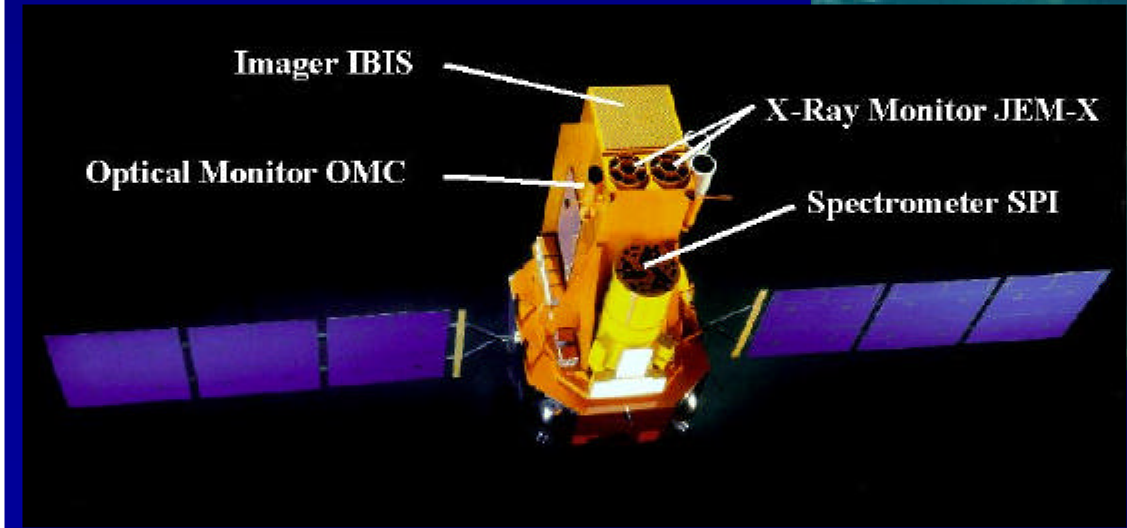
Nov. 11 – 18 , 2003

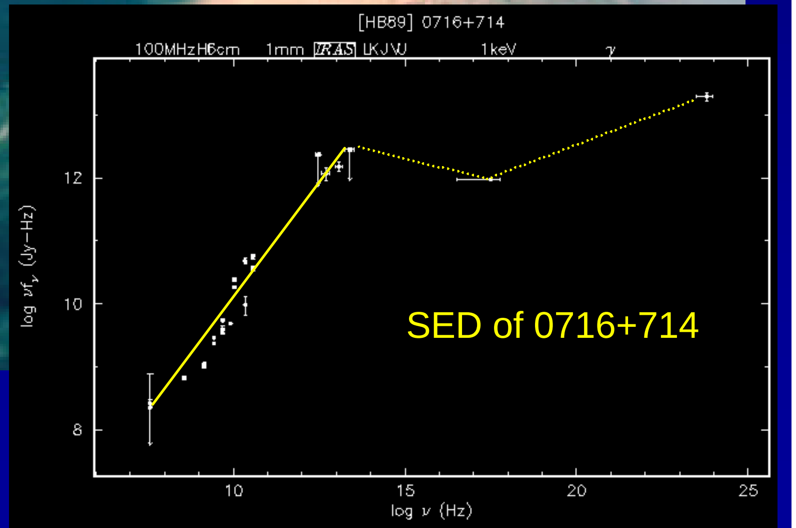
(500 ksec)

OMC V-band

JEM-X 3 – 35 keV

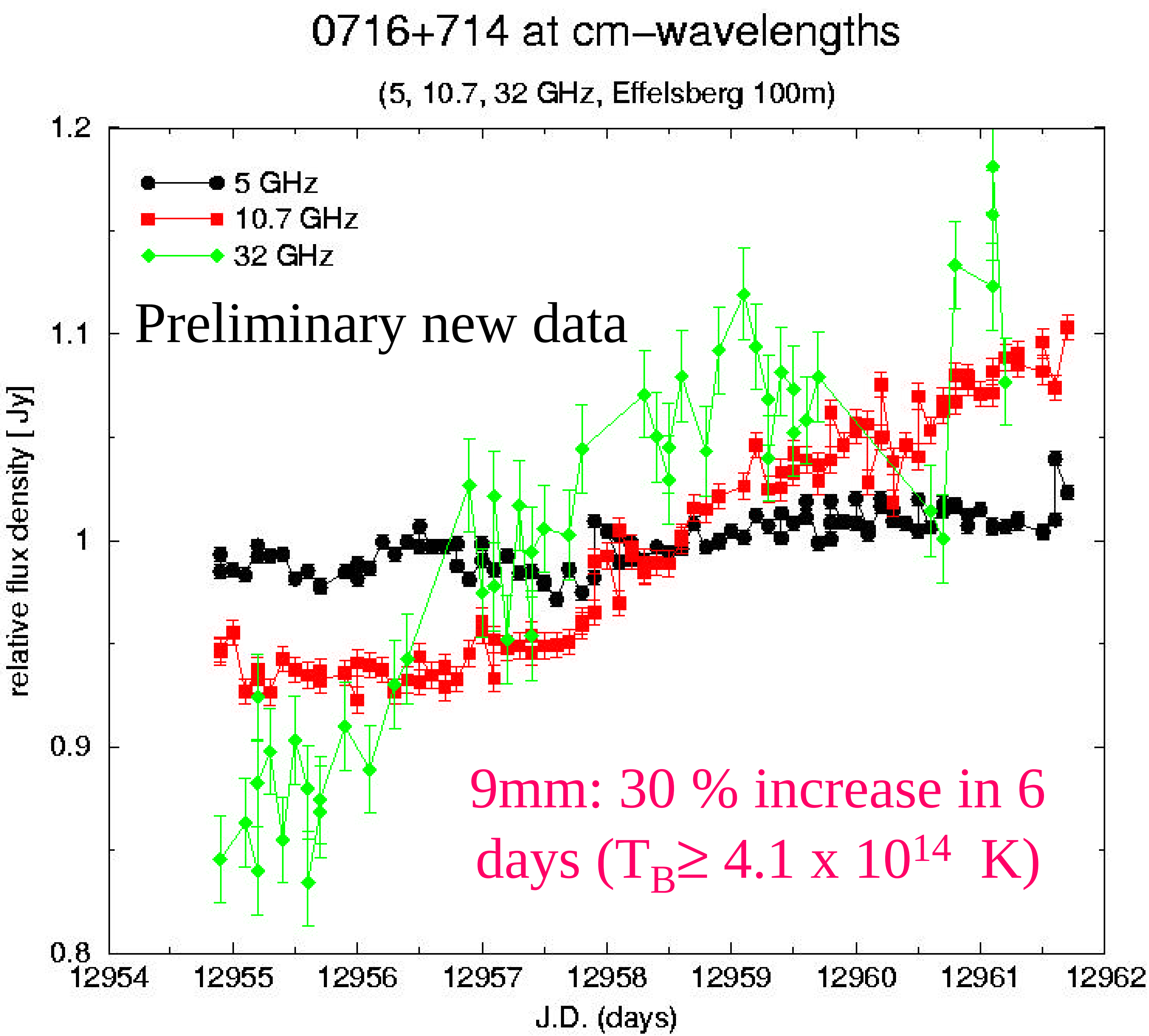
IBIS 15 keV – 10 MeV





Motivation for the INTEGRAL campaign

- disentangle between extrinsic and source intrinsic contributions to IDV
- violation of IC limit in radio bands should cause enhanced X-ray and Gamma-ray emission (Compton catastrophe)
- search for correlated variability from radio to Gamma-rays
- search for frequency dependence of the Doppler-factor
- search for electron/positron plasma


0716+714 at cm–wavelengths
(5, 10.7, 32 GHz, Effelsberg 100m)
5 GHz
10.7 GHz
32 GHz
Preliminary new data
9mm: 30 % increase in 6 days ($T_B \geq 4.1 \times 10^{14}$ K)
relative flux density [Jy]
1.2
1.1
1
0.9
0.8
12954
12955
12956
12957
12958
12959
12960
12961
12962
J.D. (days)

Conclusion

- Polarization IDV in VLBI cores detected for several sources , correlates with single dish measurements
- No IDV in secondary VLBI jet components
- High brightness temperatures also at mm-λ
- Annual modulation not detectable, if source structure varies on timescales of months to years

Need coordinated multi-frequency flux and polarisation monitoring over longer time ranges (months to years)!