

Millimetre VLBI Monitoring of AGN with sub-mas Resolution

3C 454.3 as a typical example

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In collaboration with:

- ◆ Bonn: W. Alef, D.A. Graham, J. Klare, A. Kraus,
T.P.Krichbaum, A. Witzel, J.A. Zensus, *et al.*
- ◆ IRAM: M. Bremers, A. Greve, M. Grewing, *et al.*
- ◆ Onsala: R. Booth, J. Conway, F. Rantakyrö, *et al.*
- ◆ Haystack: S. Doeleman, R. Phillips, A.E.E. Rogers, *et al.*
- ◆ Metsähovi: P. Könönen, S. Urpo, K. Wiik, *et al.*
- ◆ VLBA: V. Dhawan, *et al.*

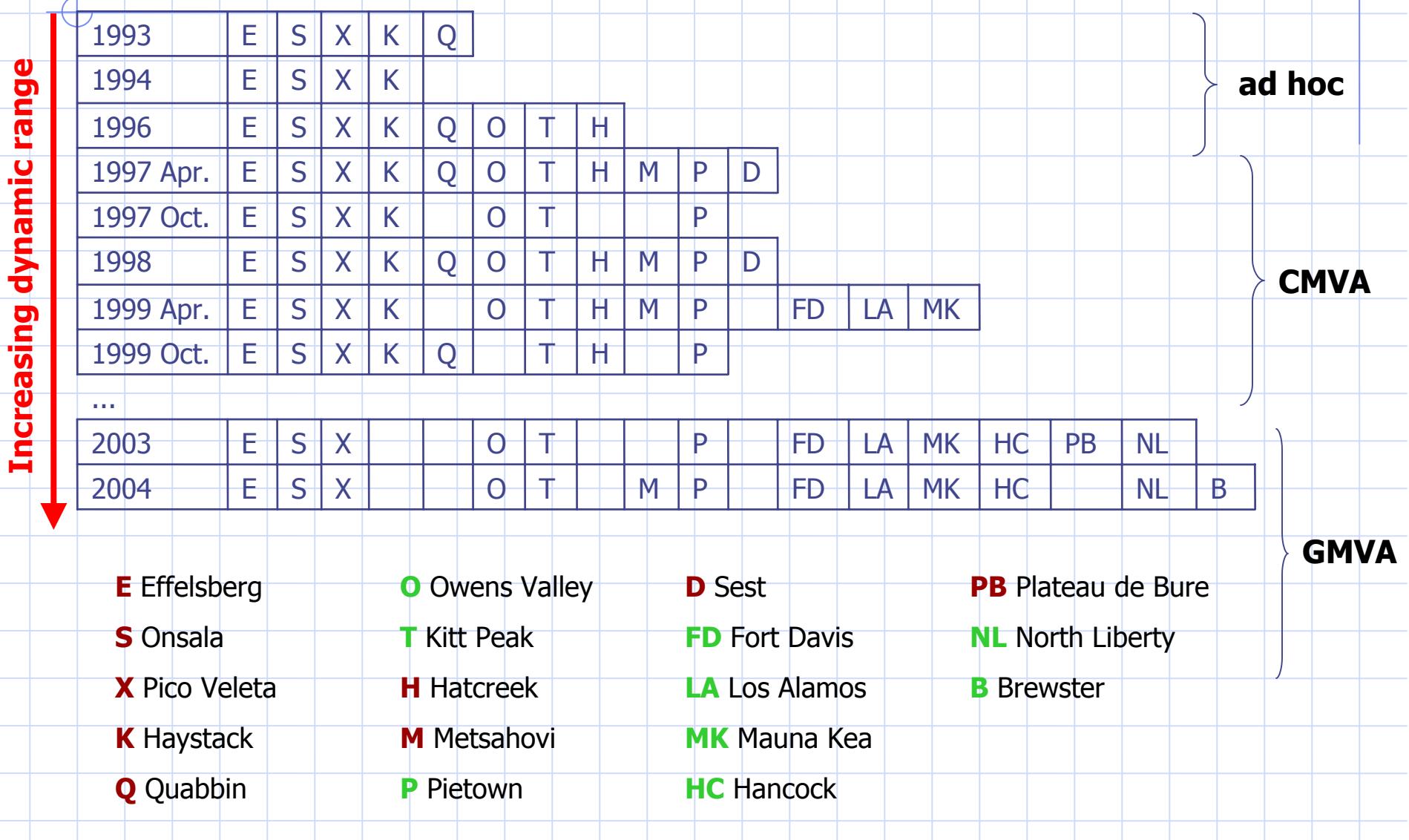
and also:

- S. Jorstad, A. Marscher,
- H. Teräsanta,
- H. Ungerechts,
- I. Agudo, M. Kadler,
- J.L. Gómez

Motivation

- ◆ Resolution $\sim \lambda/D \rightarrow$ go to shorter wavelengths
- ◆ Resolve the core structure of AGN
- ◆ Penetrate the opacity barrier by observations at shorter wavelenghts
- ◆ Facilitates study of jet components at their earliest stage of structural evolution

The Global 3mm VLBI campaigns



The Sample

	z	$S_{90\text{GHz}}$ [Jy]		z	$S_{90\text{GHz}}$ [Jy]
0234+285	1.213	5.0	3C 84	0.017	4.9
0420-014	0.915	4.0	3C 273B	0.158	19.4
0538+134	2.070	5.7	3C 274	0.004	4.3
0607-157	0.324	6.7	3C 345	0.594	4.6
0827+243	0.941	1.9	3C 454.3	0.859	6.7
1156+295	0.729	2.3	4C 39.25	0.698	5.6
1546+027	0.412	4.3	CYG A	0.056	0.8
1611+343	1.401	2.8	OJ 287	0.306	2.0
1633+38	1.807	2.1	CTA 102	1.037	4.1
2005+403	1.736	1.0	NRAO 150	unknown	4.5
2145+067	0.999	3.3	NRAO 512	1.666	12.8
2201+315	0.298	3.0	BL LAC	0.069	2.8

to be continued

3C 454.3

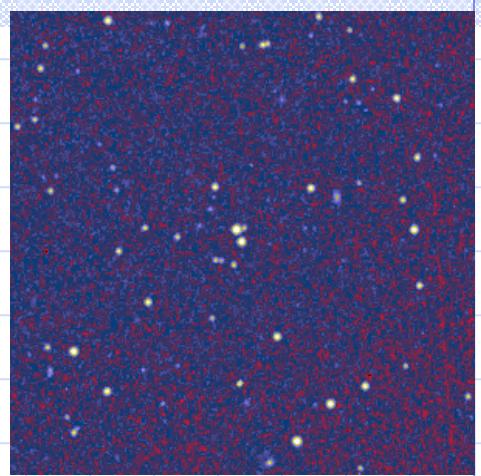
- ◆ OW, $V = 16^m$, $z = 0.859$
- ◆ 7.7 pc/mas
- ◆ Highly variable flux @ 3mm $\approx 2 - 15$ Jy
- ◆ Curved jet bending from P.A. = $-95^\circ \dots -45^\circ$
- ◆ Inner jet (< 3 mas) oriented mainly to the west
- ◆ Outer jet (> 3 mas) bends to the north
- ◆ Superluminal motion $\beta_{\text{app}} \approx 4-10c$ @ $r \leq 1$ mas
 $\beta_{\text{app}} \approx 8c$ @ $r \leq 2$ mas
 $\beta_{\text{app}} \approx 8-20c$ @ $r \geq 5$ mas

(Krichbaum *et al.*, 1996; Pauliny-Toth *et al.*, 1987 & 1998)

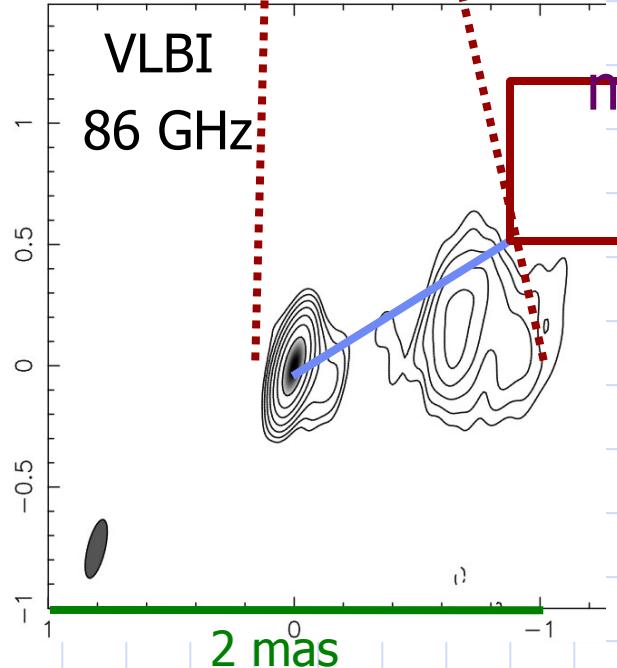
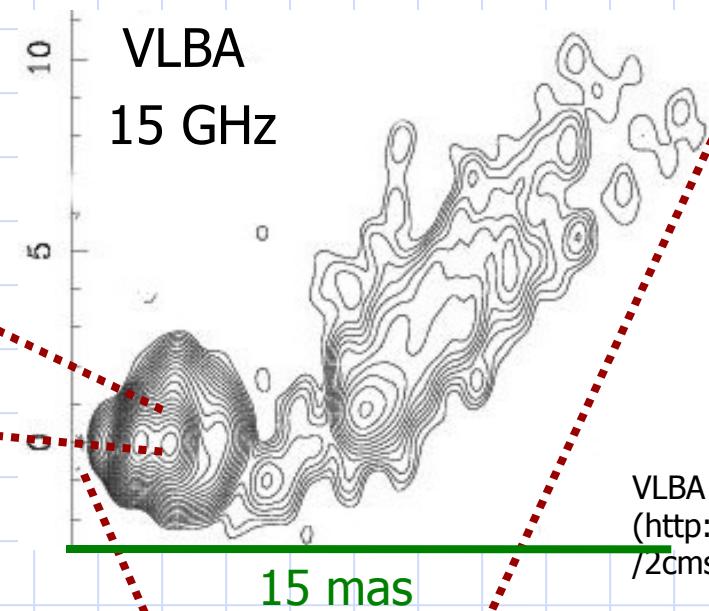
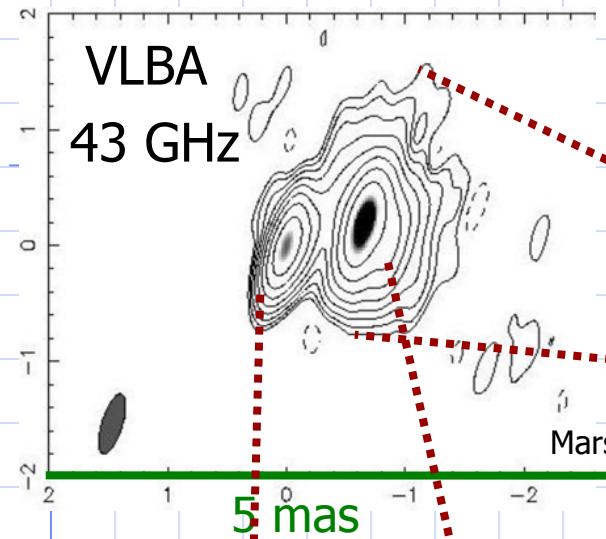
- ◆ Stationary component @ 0.6mas at 22GHz and 43GHz

(Jorstad *et al.*, 2001)

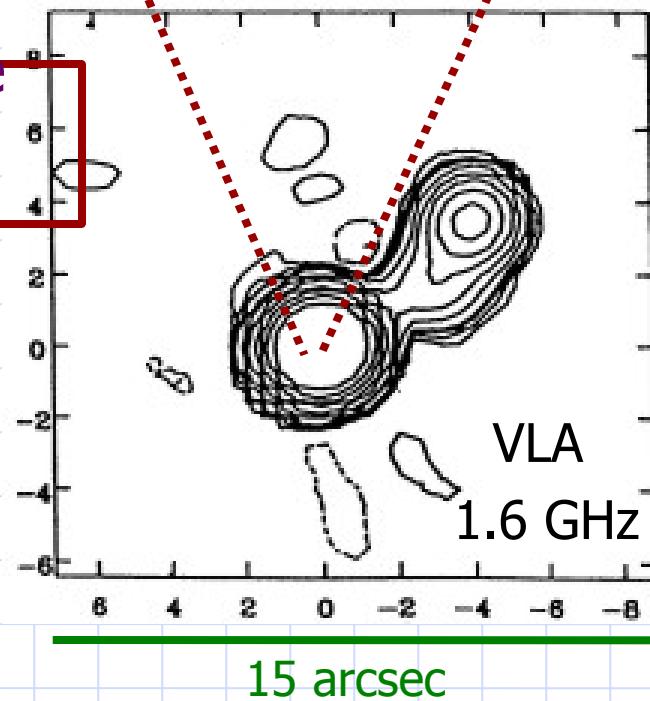
$$H_0 = 71 \text{ km s}^{-1} \text{ Mpc}^{-1}, \Omega_M = 0.27, \Omega_\Lambda = 0.73$$



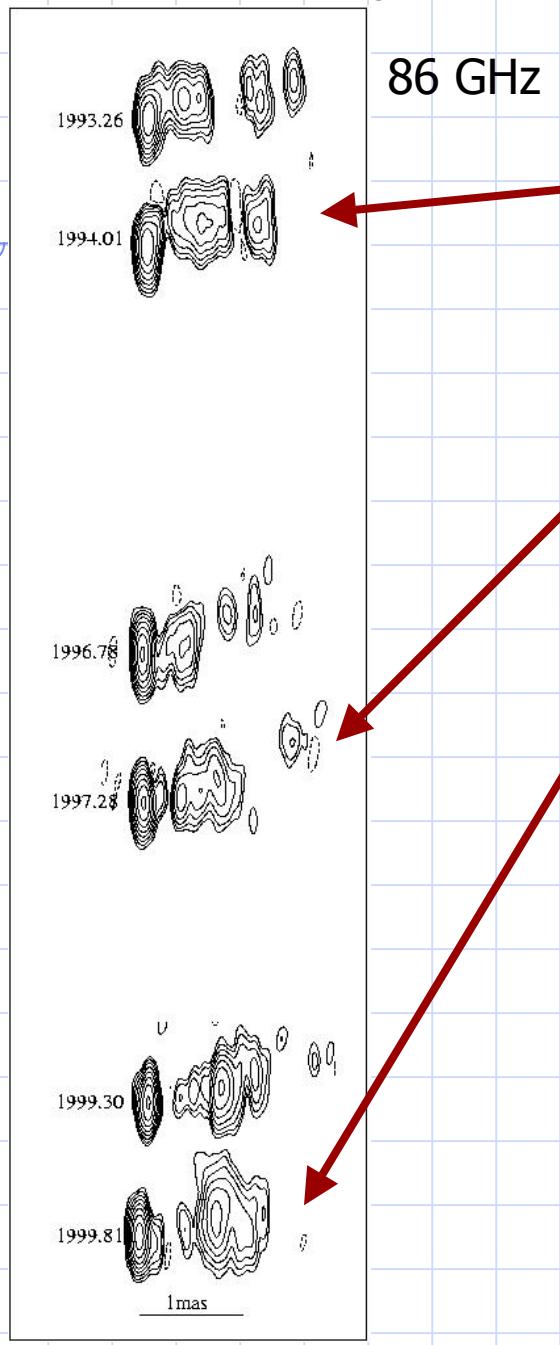
Millimetre VLBI Monitoring of AGN with sub-mas Resolution



max. core
size
0.5 pc



Millimetre VLBI Monitoring of AGN with sub-mas Resolution



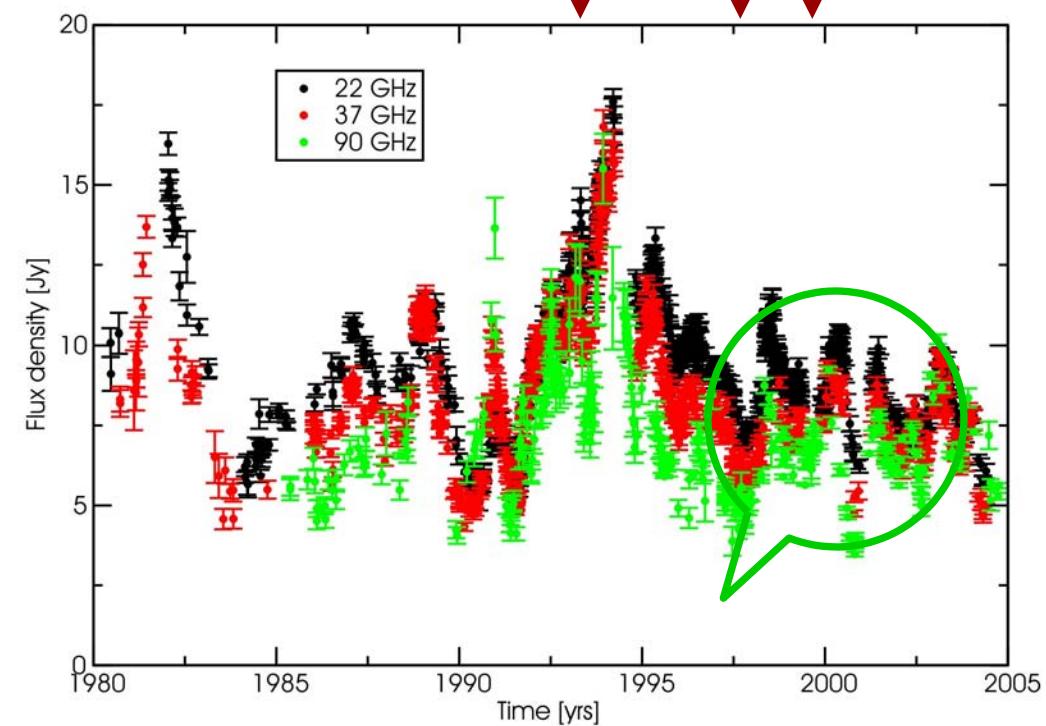
86 GHz

Component ejection at these epochs

1994.01

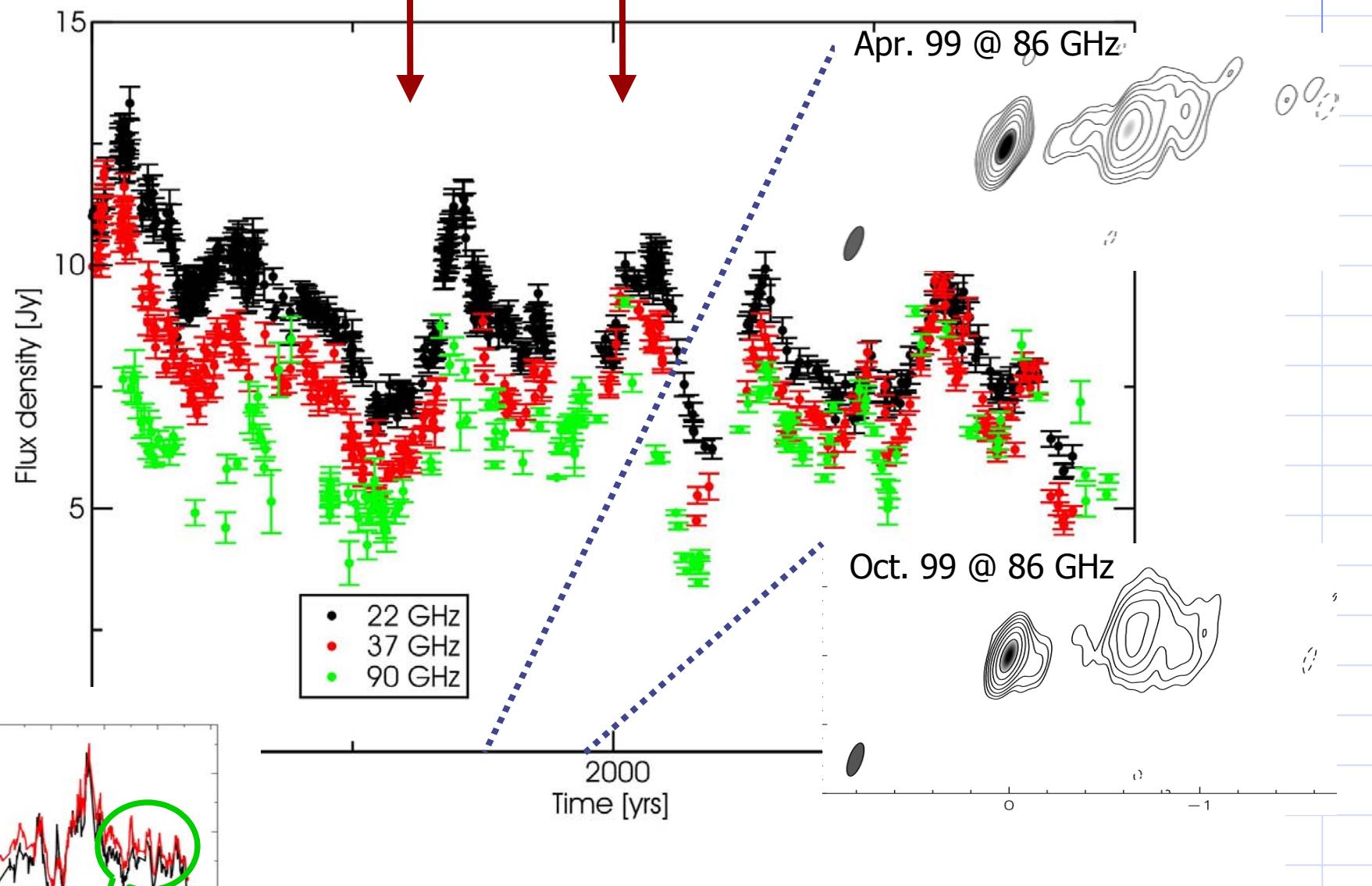
1997.28

1999.81



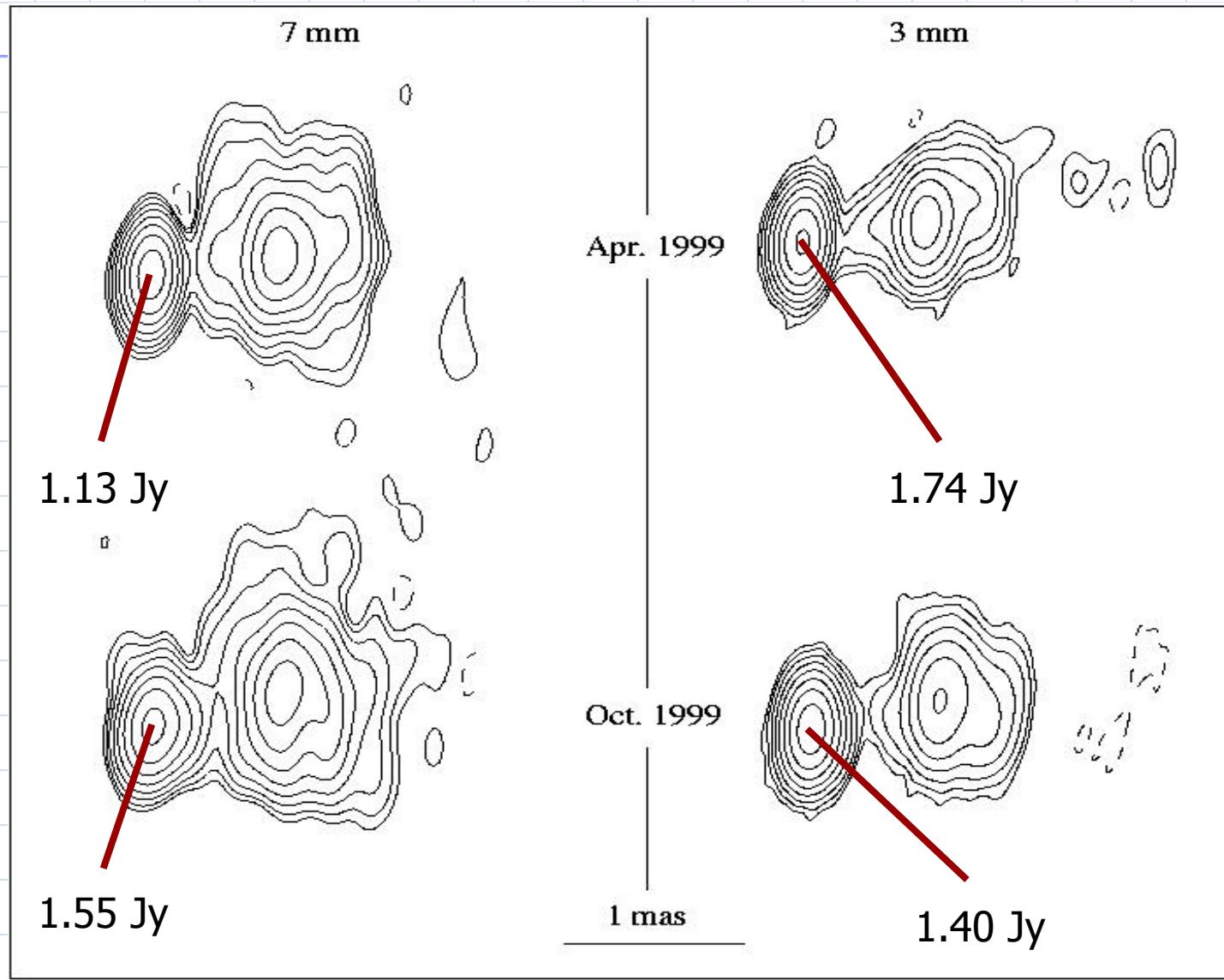
(Data: Metsähovi & IRAM)

3C 454.3 Flux @ 22 & 37 & 90 GHz



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3C 454.3 Maps @ 43 & 86 GHz



$$\alpha_{\text{CORE}} = 0.62$$

(inverted)

$$\alpha_{\text{JET}} = -0.04$$

(flat)

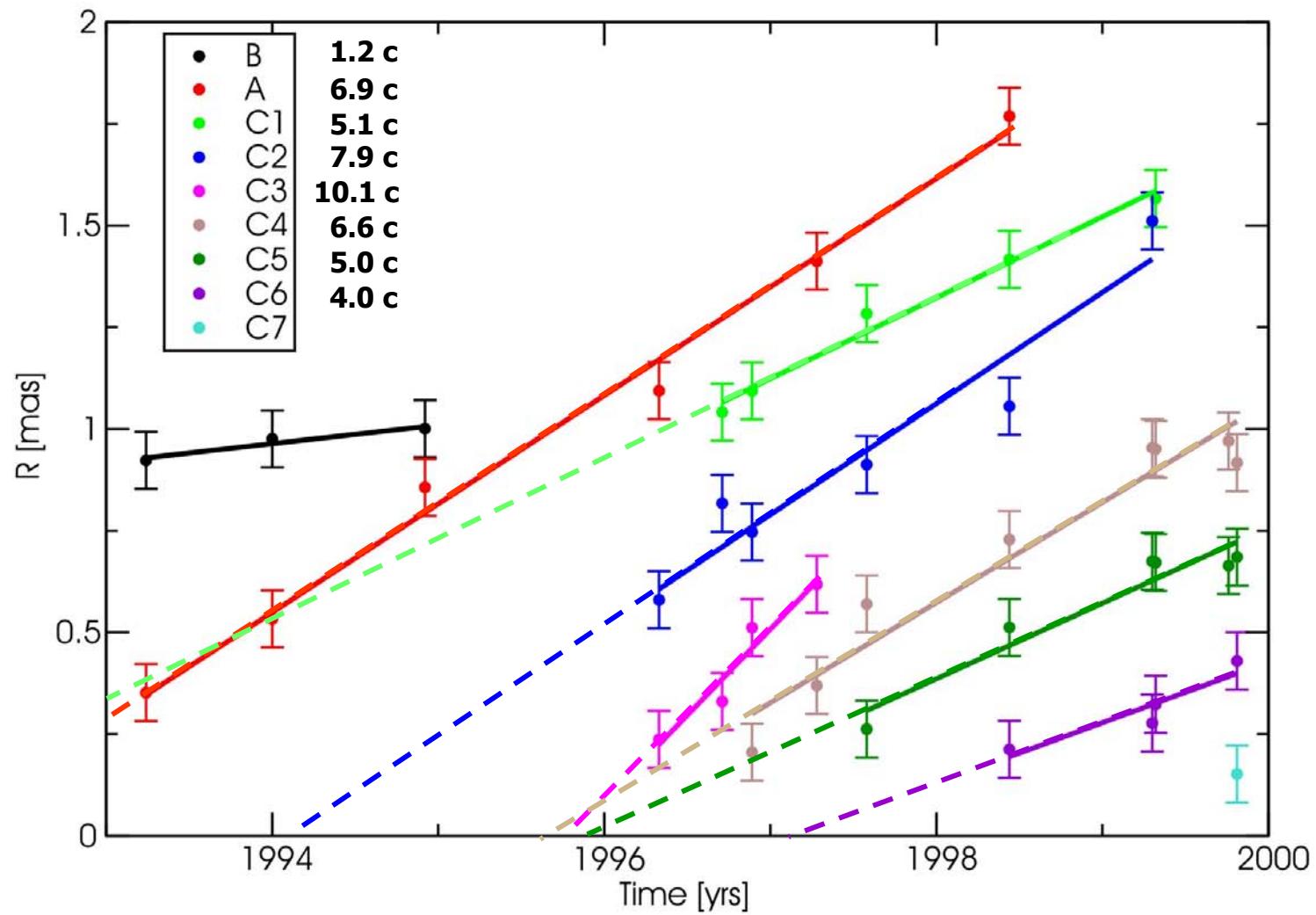
$$\alpha_{\text{CORE}} = -0.15$$

(steep)

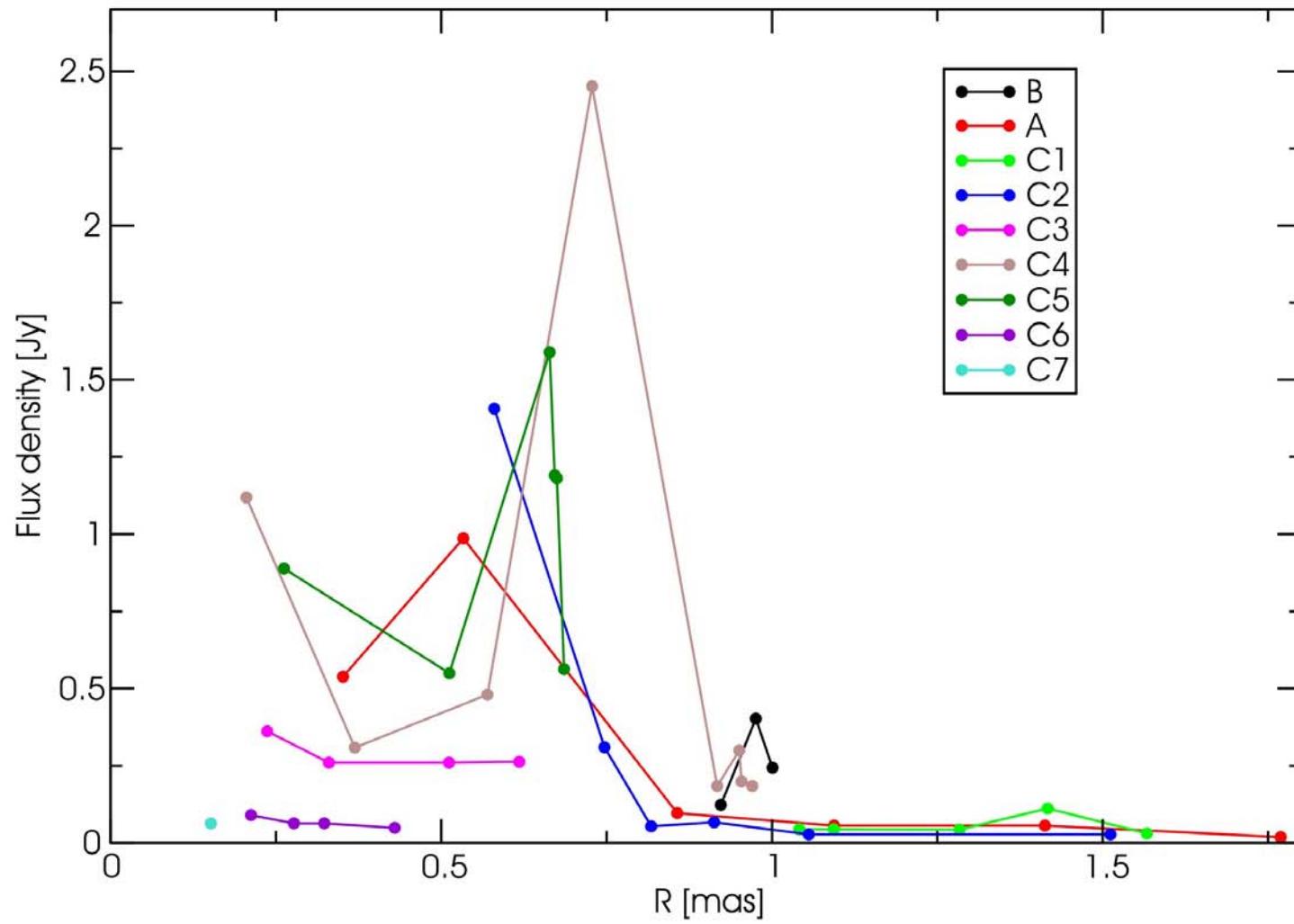
$$\alpha_{\text{JET}} = -0.95$$

(steep)

Component Identification



Flux vs. Distance



Summary & Outlook

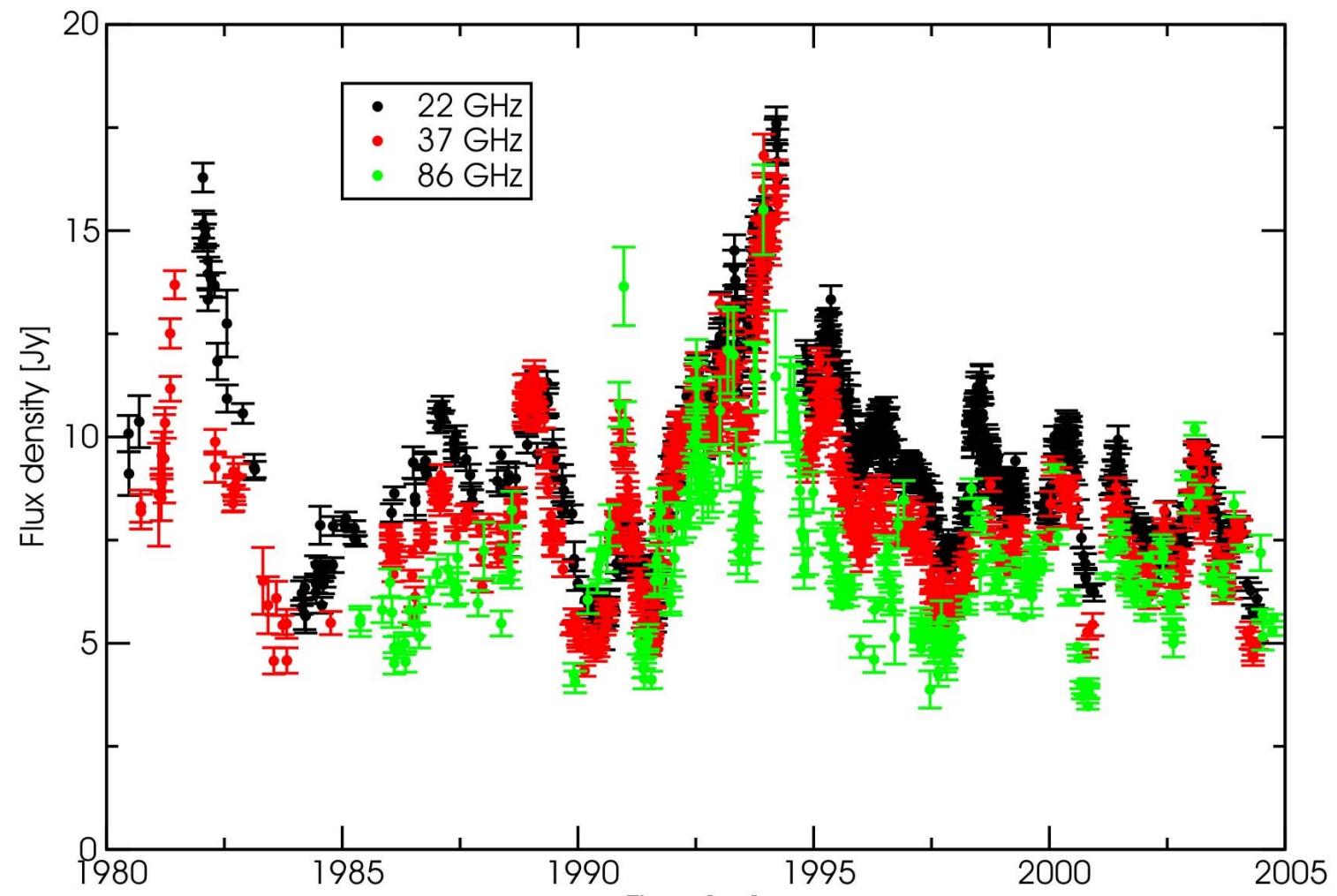
3mm VLBI

- ◆ μ -arcsec resolution of several AGN which show sub- and superluminal motion
- ◆ Finish the data reduction for the sample of AGN

3C 454.3

- ◆ Moving components with different velocities ($\beta_{app} \approx 4\text{-}20c$)
- ◆ At 0.6mas core distance all components brighten as they move through this region (explains previously claimed stationarity)
- ◆ Several new components appear near the core and appear correlated with flares seen in the 22-90 GHz band
- ◆ Complete the kinematic picture with further cm- and mm-VLBI monitoring.

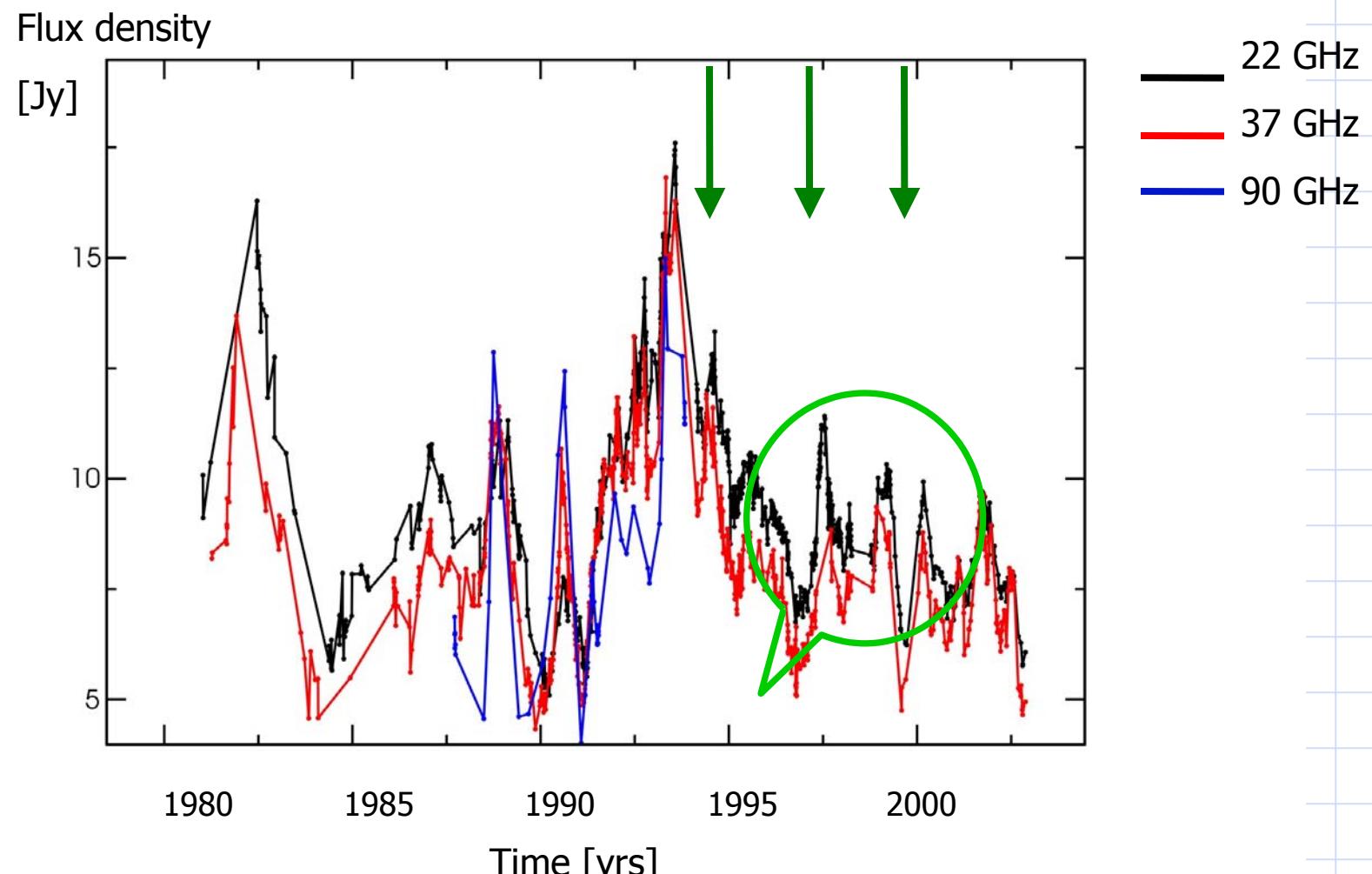
3C 454.3 Flux @ 22 & 37 & 86 GHz



(Data: Metsähovi & IRAM)

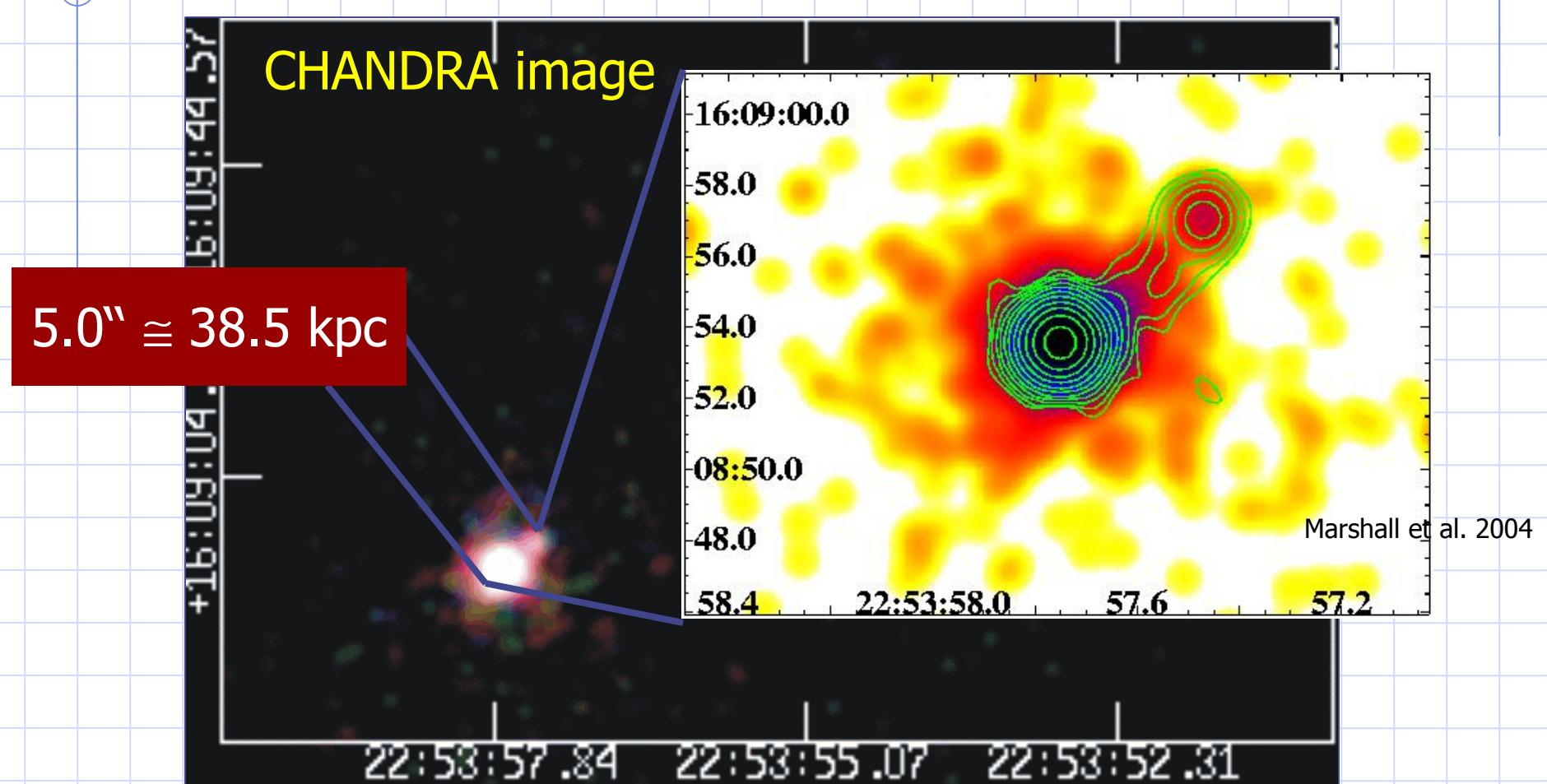
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3C 454.3 Flux @ 22 & 37 & 90 GHz



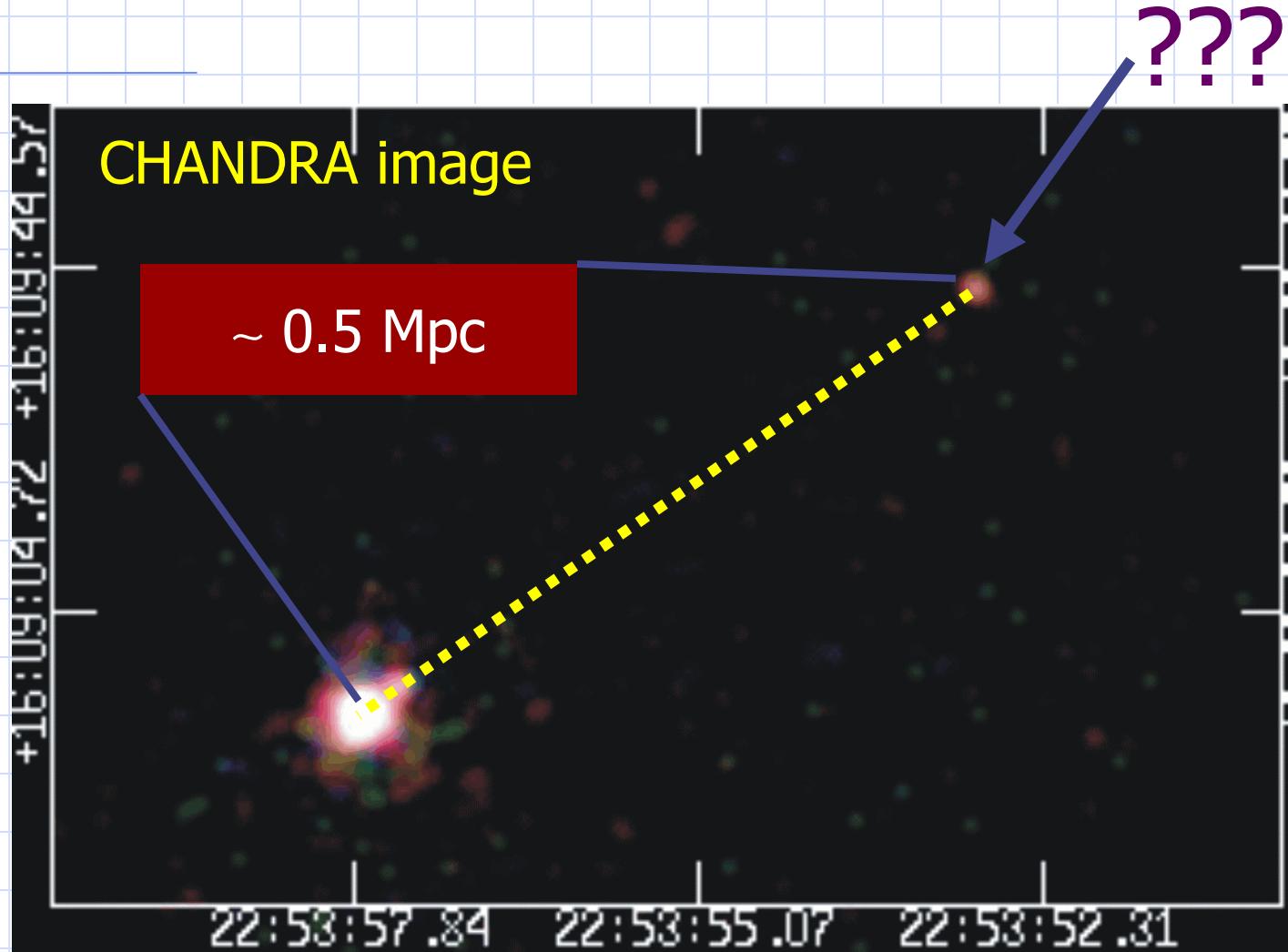
(Data: Metsähovi & IRAM)

3C 454.3 in X-rays



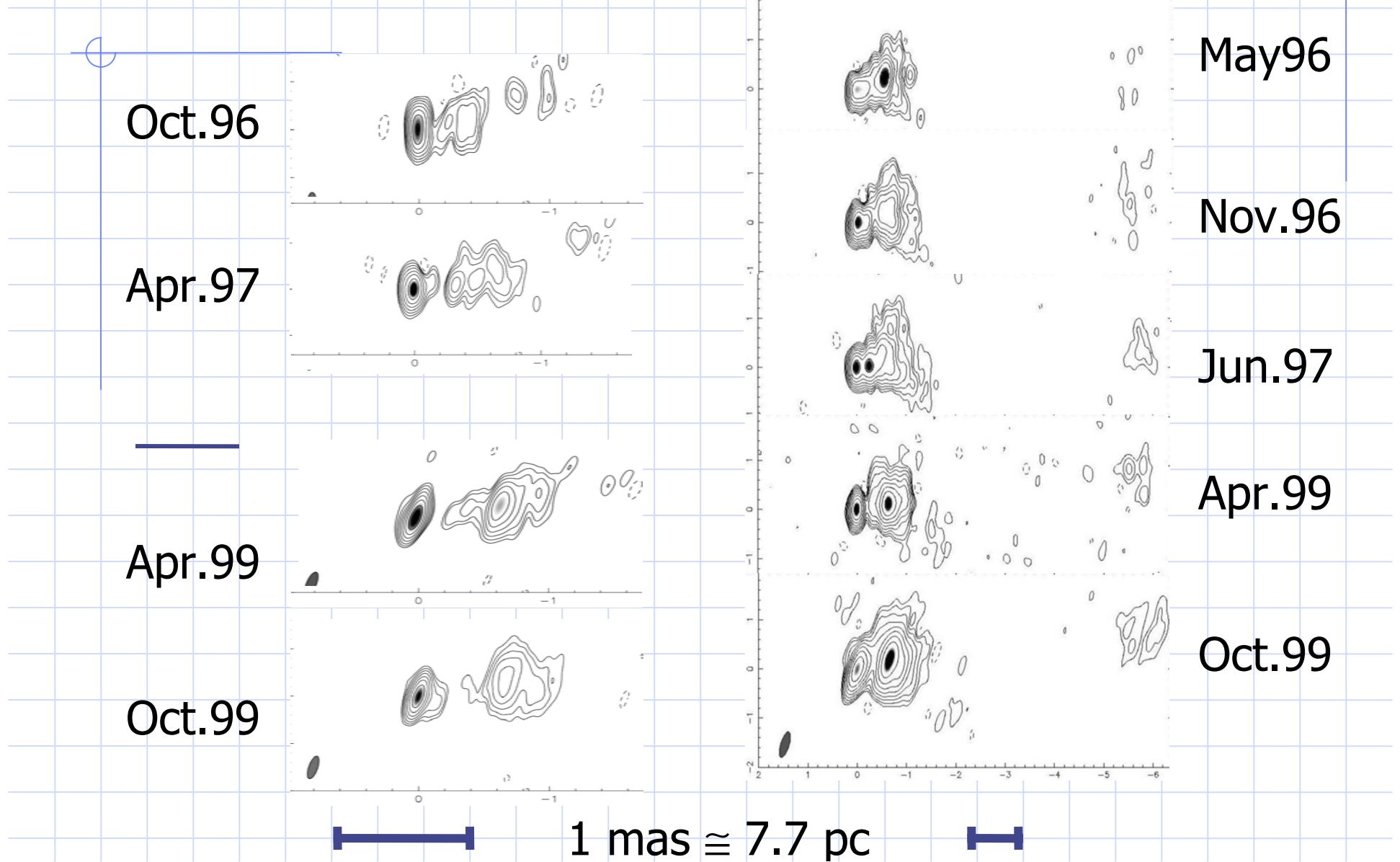
Red: 0.2-1.5 keV, Green: 1.5-2.5 keV, Blue: 2.5-8 keV

3C 454.3 in X-rays



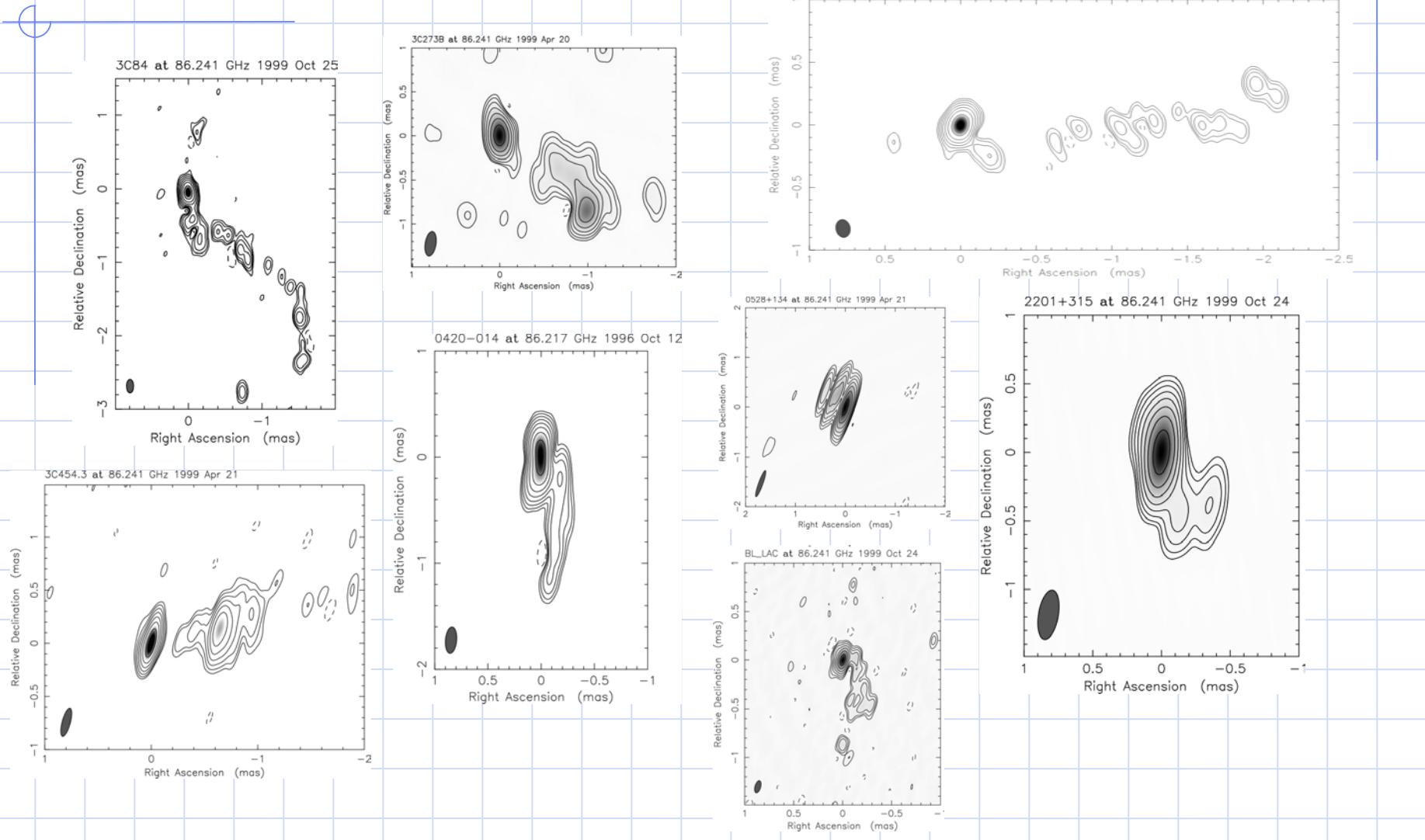
Red: 0.2-1.5 keV, Green: 1.5-2.5 keV, Blue: 2.5-8 keV

Epochs of 3C 454.3

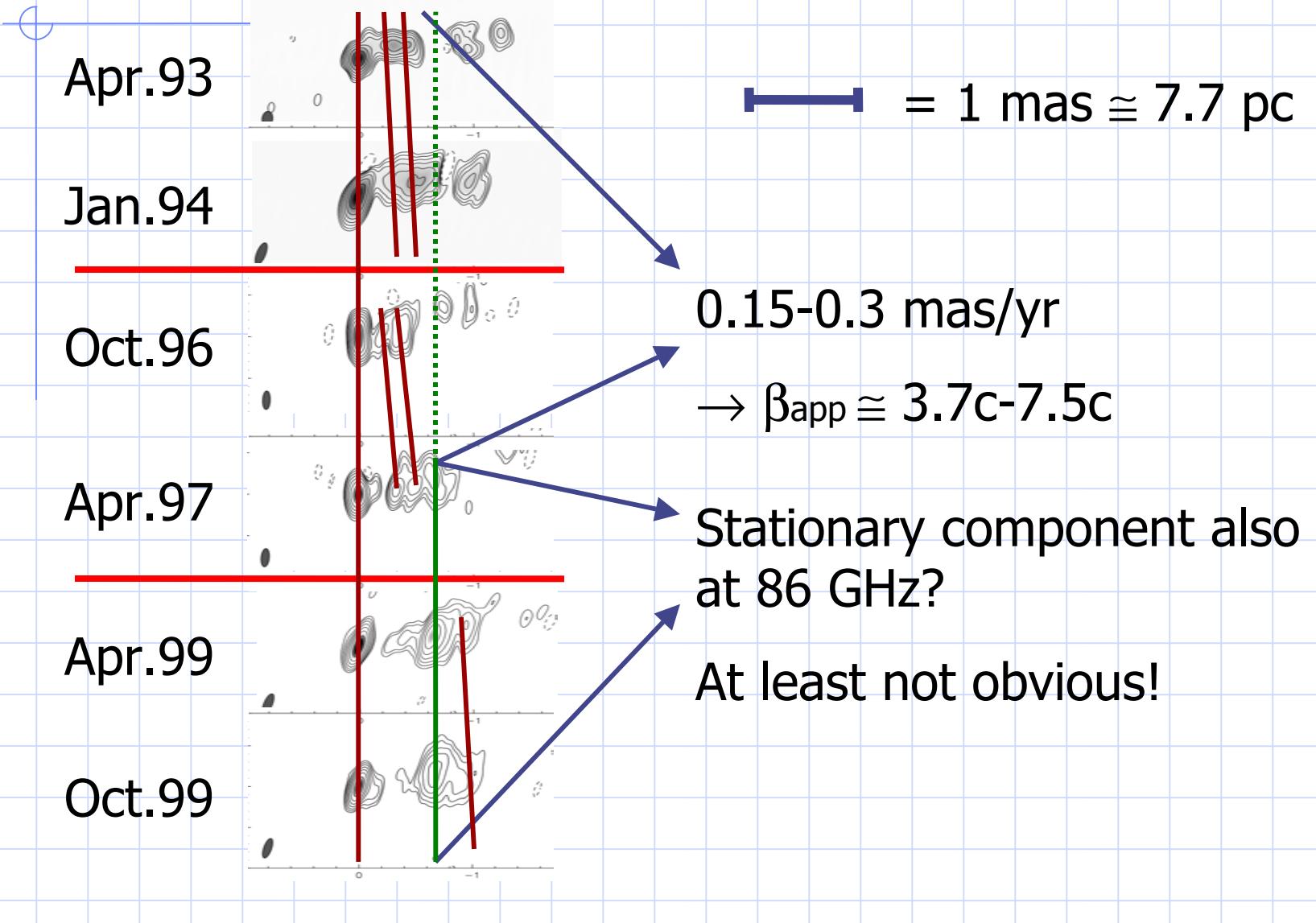


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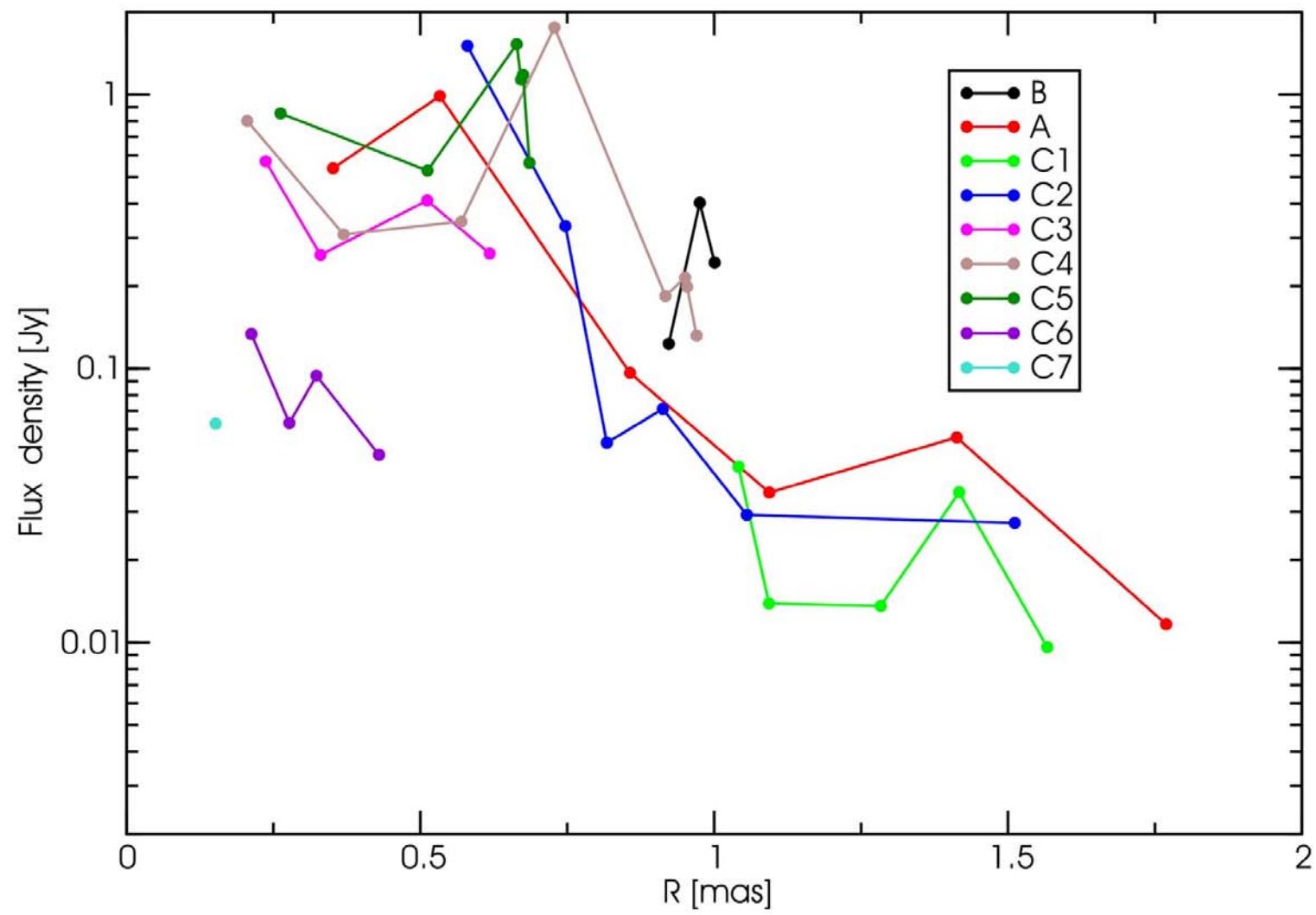
The μ -arcsec view of AGN



6 epochs of 3C 454.3 @ 86 GHz



Flux vs. Distance



Component Identification

