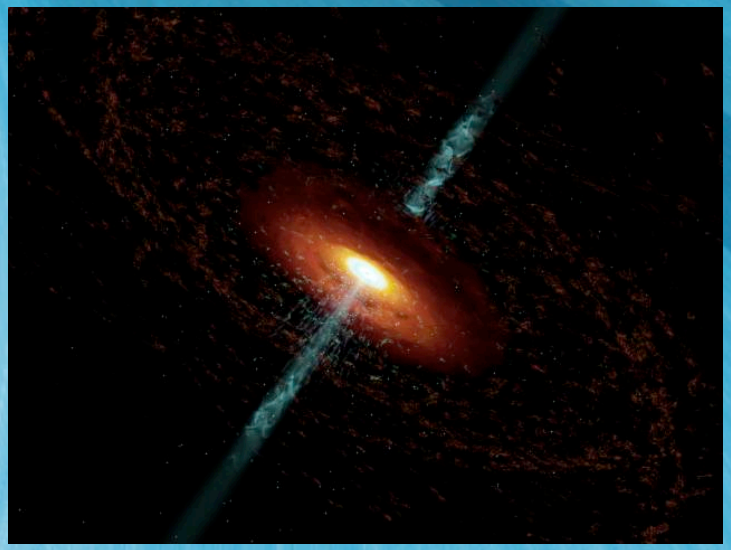
VLBA mm monitoring



Svetlana Jorstad

Collaborators:
A. Marscher , M. Aller, I. McHardy, M. Tornikoski, H. Teräsranta
B.T. Balonek, V. Larionov, V. Hagen-Thorn, G. Tosti, H. Miller

Our current programs of VLBA mm-monitoring

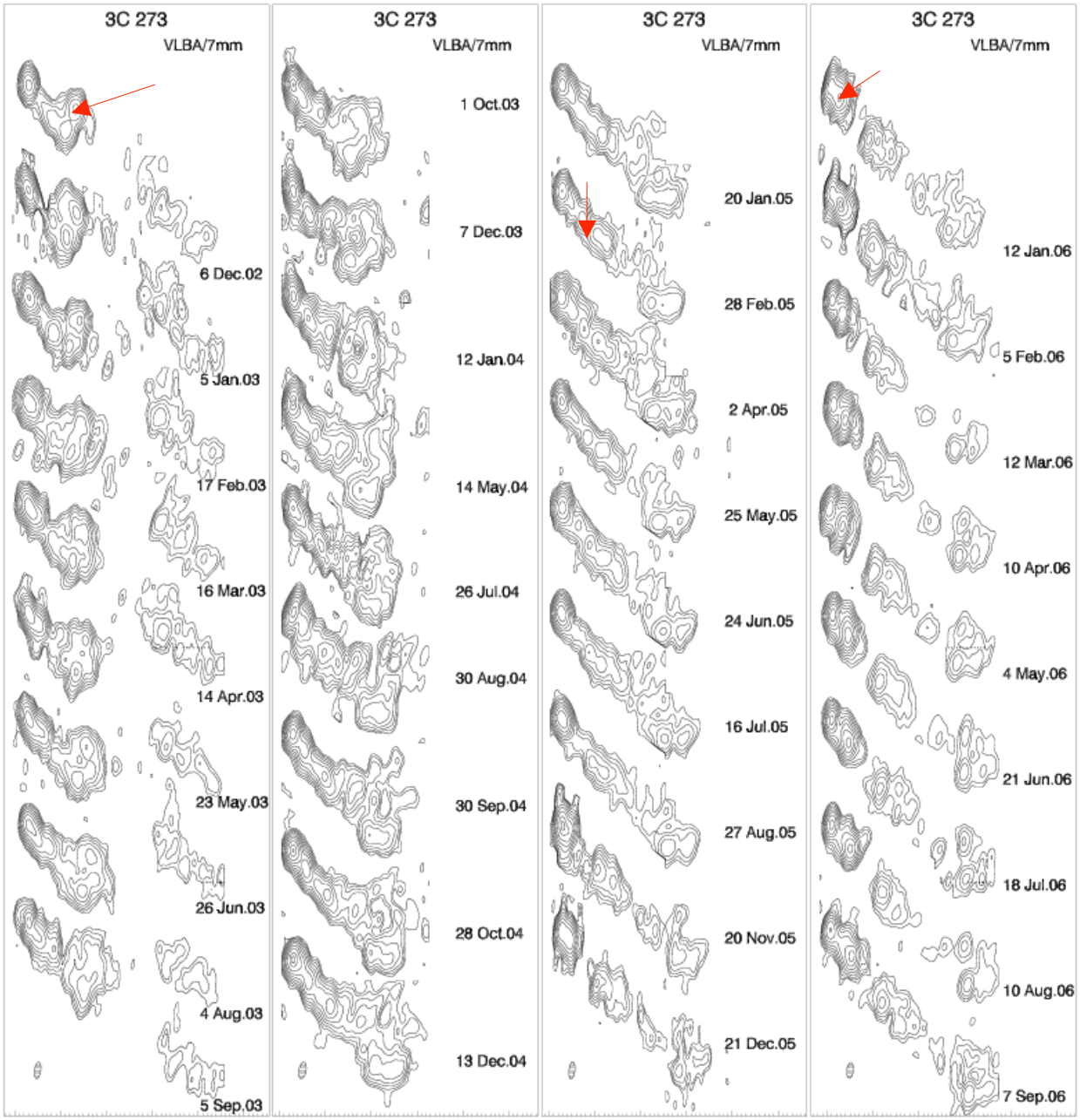
VLBA-high energy monitoring

7mm VLBA (monthly) + long-term (2-20keV) RXTE (2-3 times per week):
3C273 3C279 1510-089 BL Lac 3C111 3C 120

Polarization monitoring

Starting in March 2005
7mm VLBA (monthly) + R-band Lowell Observatory
Crimea Observatory
(2-3 times per month)
CTA26 3C 111 0420-014 OJ287 1156+295 3C279
1510-089 BL Lac CTA102 3C446 3C454.3

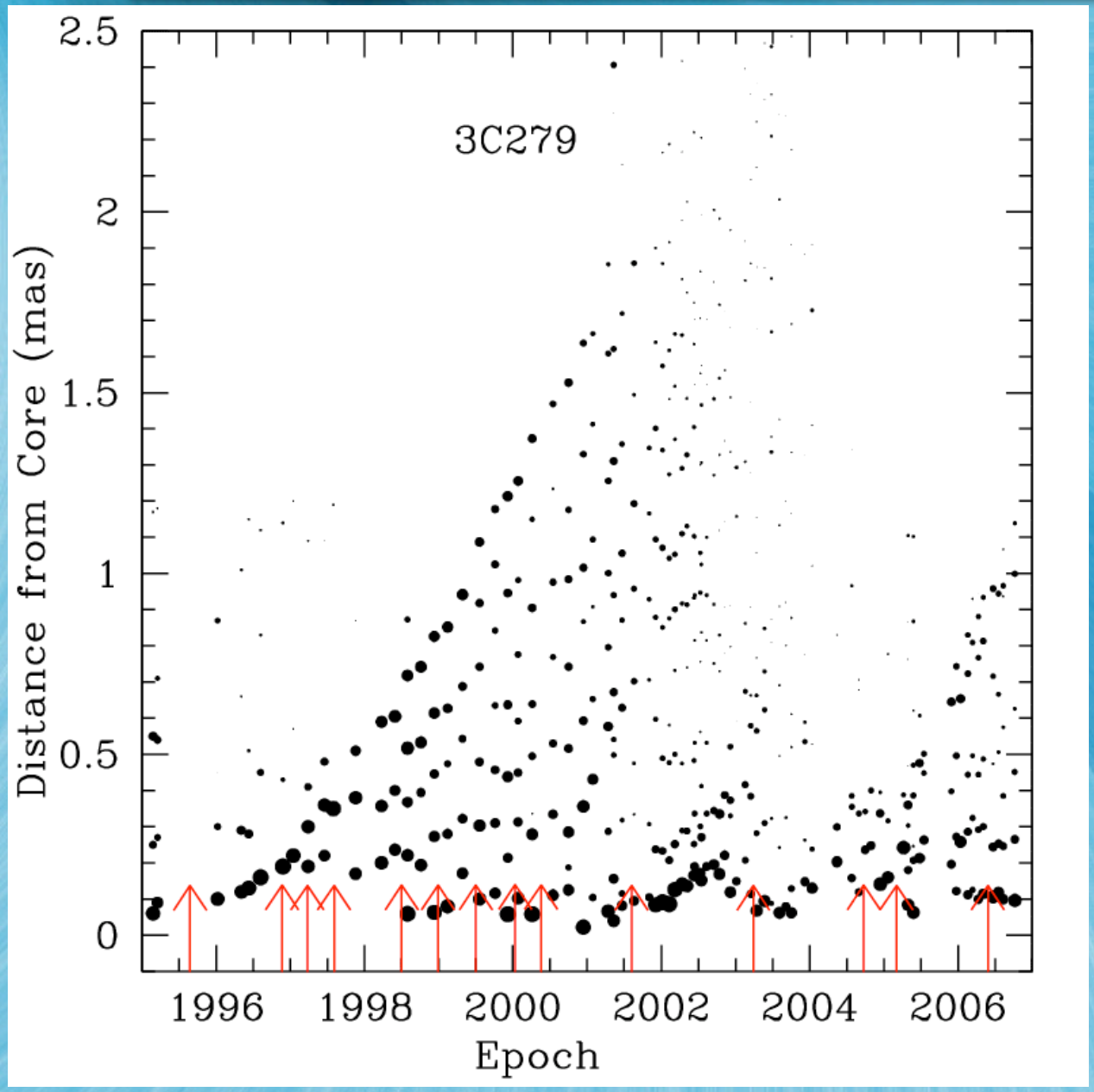
VLBA mm-monitoring



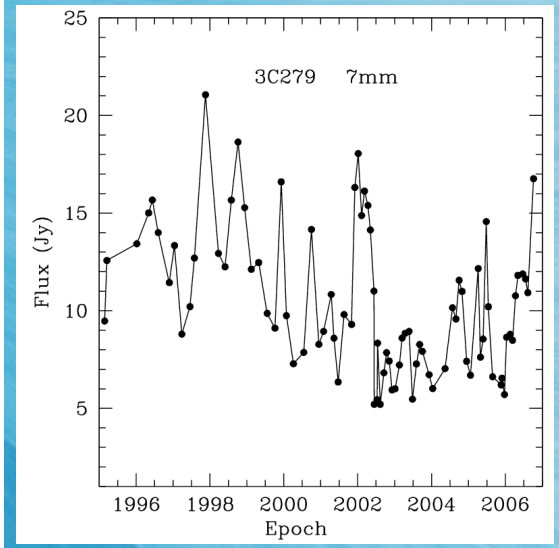
- Short timescale of the variability ≤ 2-3 week
- Fast separation of knots from the core
- Different trajectories of components.
- Some moving knots are brighter than the core
- Trailing components
- Jet bending
- Compact knots and diffuse features

Contours are in factors of 2 starting at 11 mJy/beam. The restoring beam is 0.38×0.14 mas at PA=-9°.

High and Low States of Activity in the Inner Jet of the Quasar 3C 279

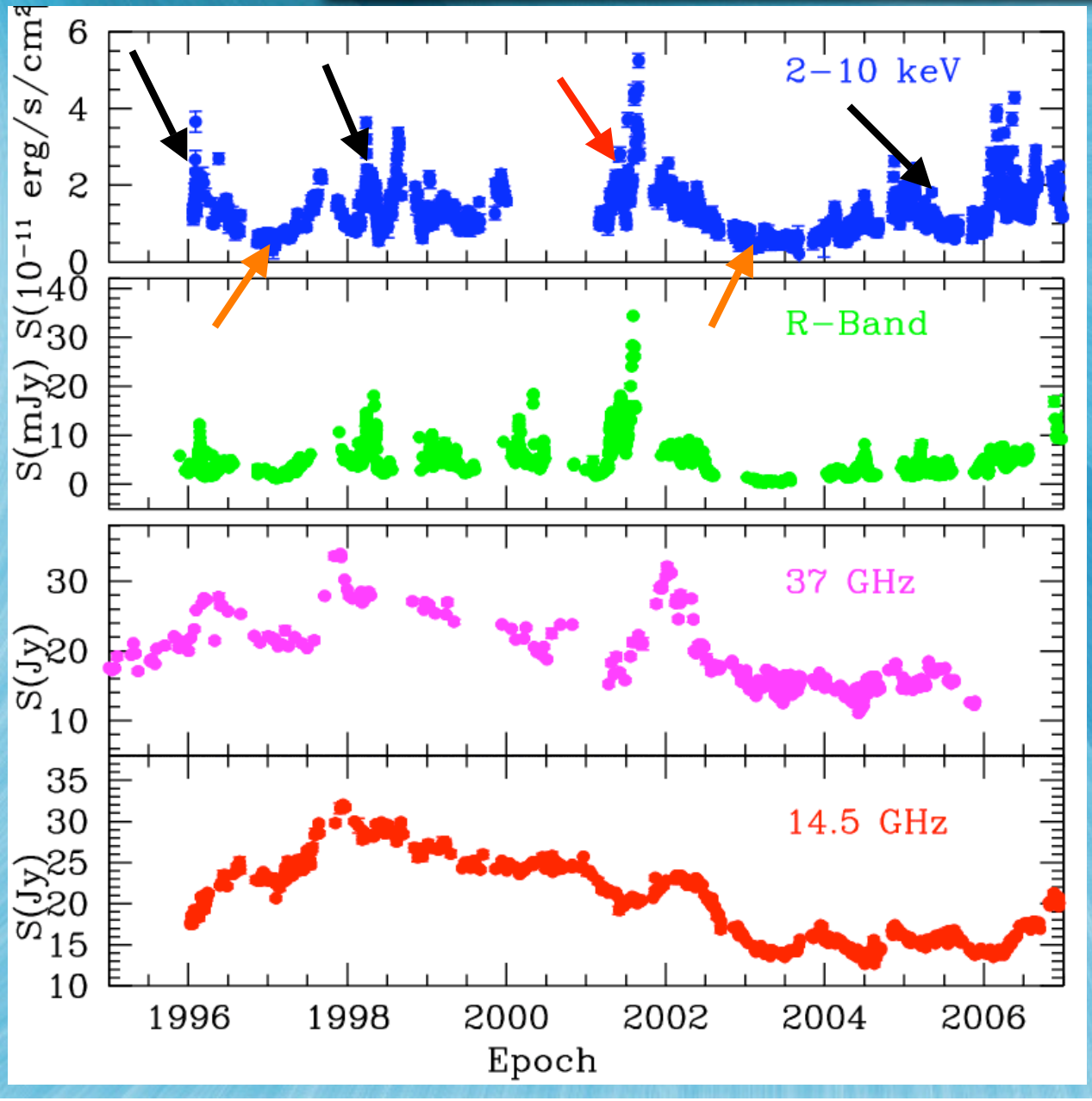


7mm Core Light Curve



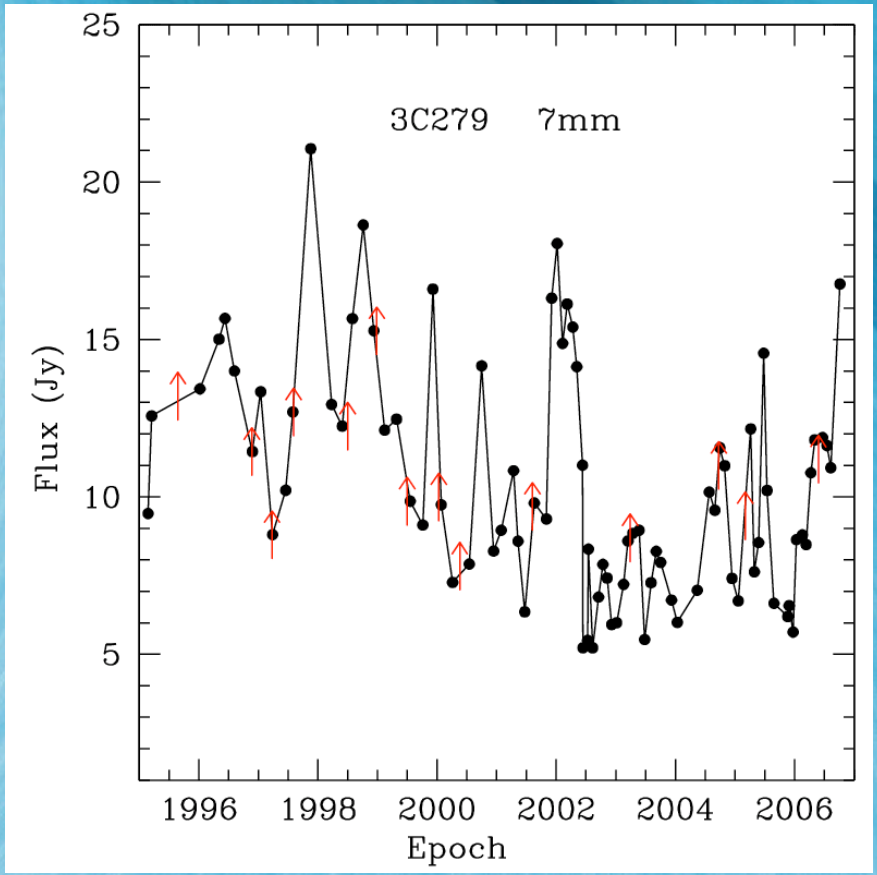
Wehrle et al. 2001
Lister, Marscher, & Gear 1998
Jorstad et al. 2001
Jorstad et al. 2005

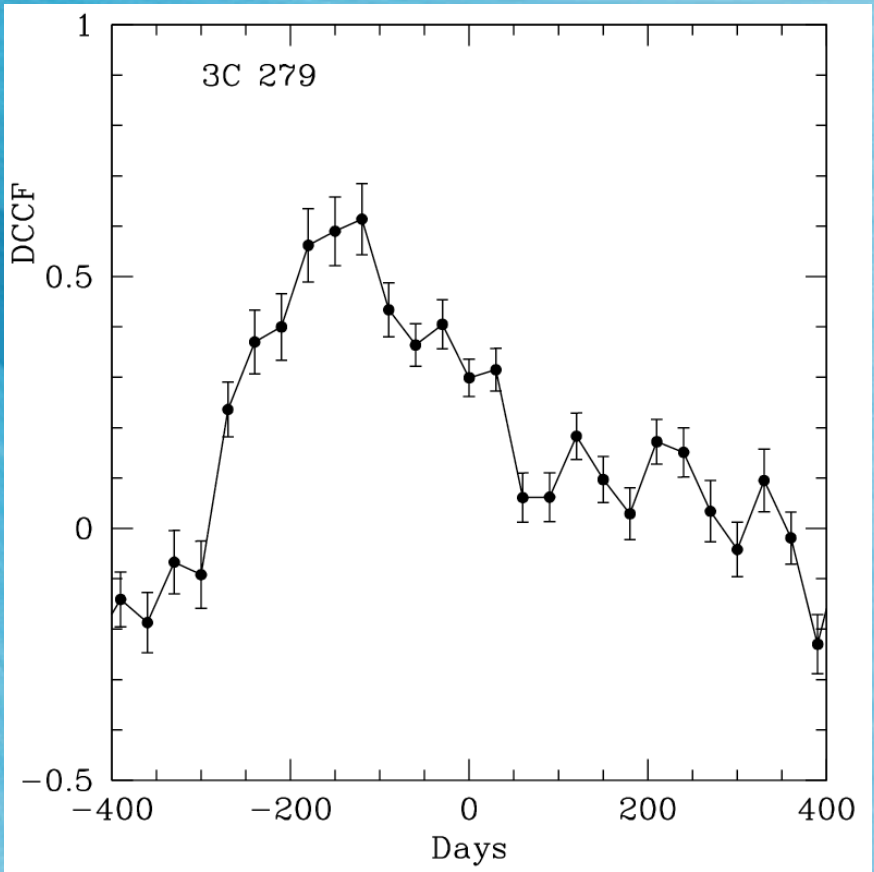
Multiwavelength Light Curves



- High activity in 1996, 1997.5-2000, & 2004-2006
- The strongest flare in 2001
- Quiescent state in 1997 & in 2003

Correlation between X-ray Flux and Core Brightness

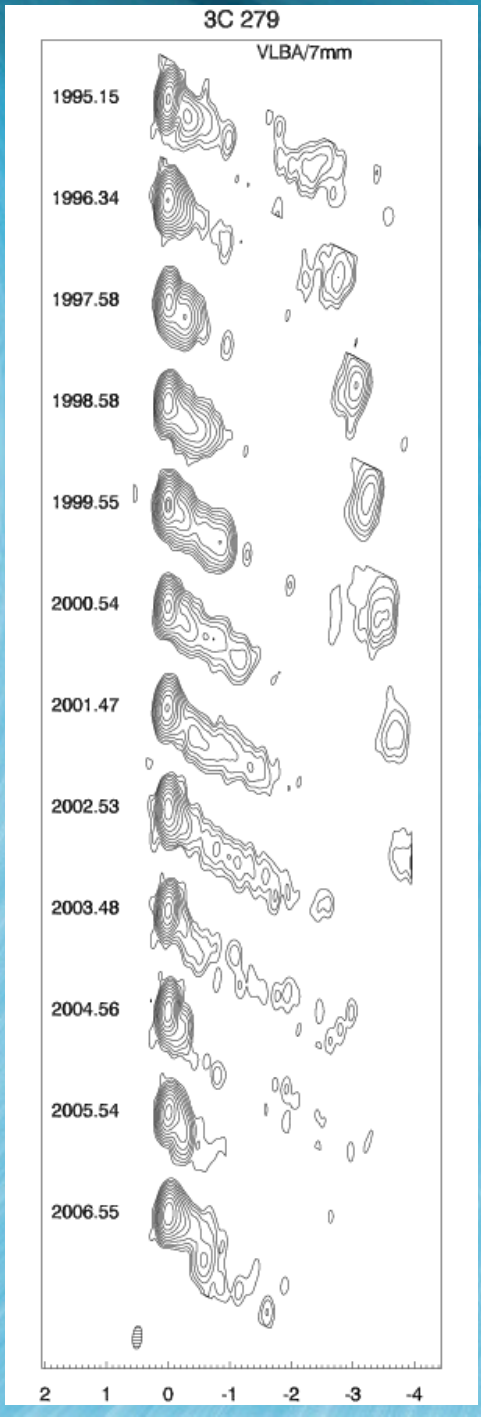


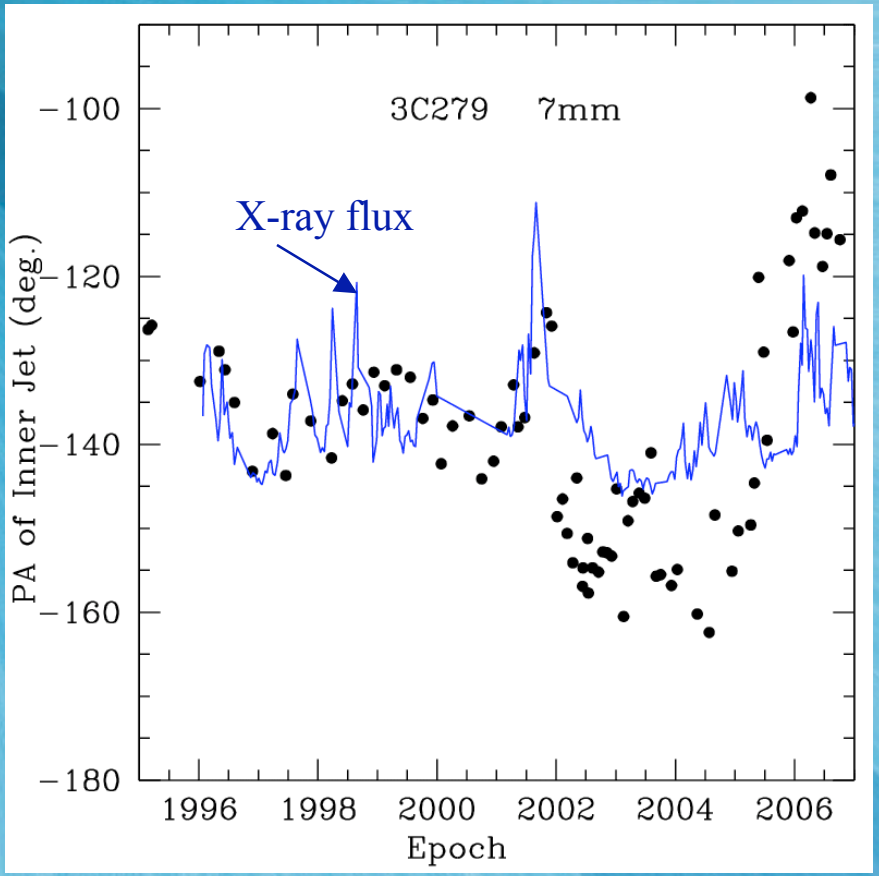


The ejections precede the peaks of the core flux by 90±50 days

X-rays lead the core flux variations by $120\ ^{+80}_{-20}$ days

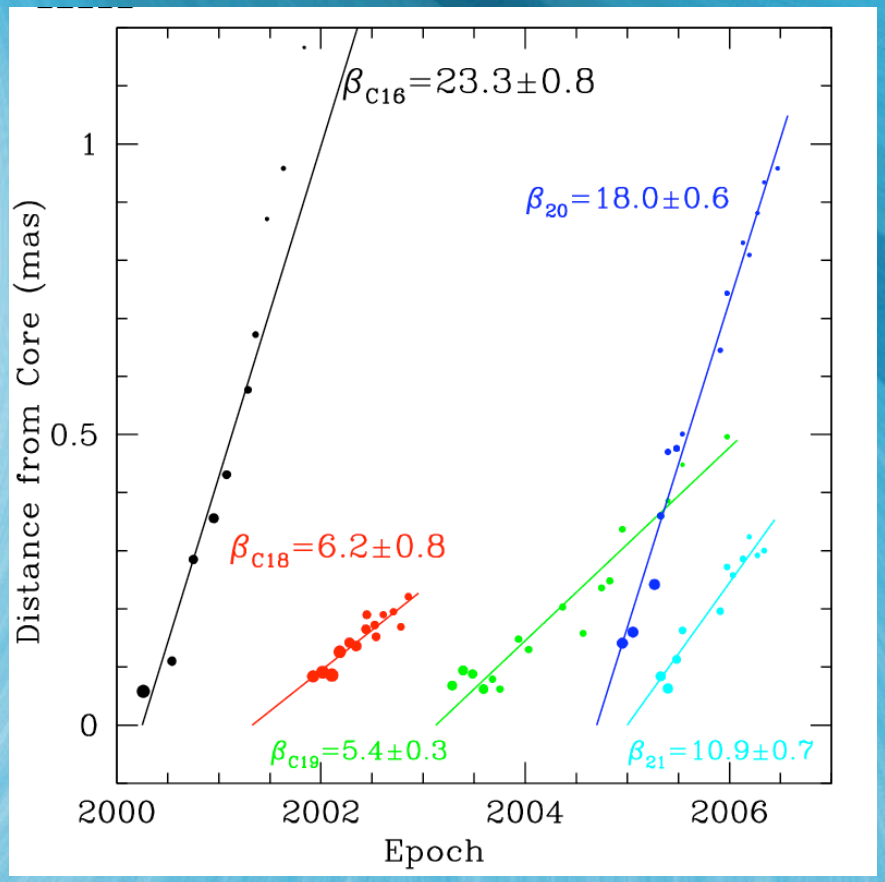
Jet Direction

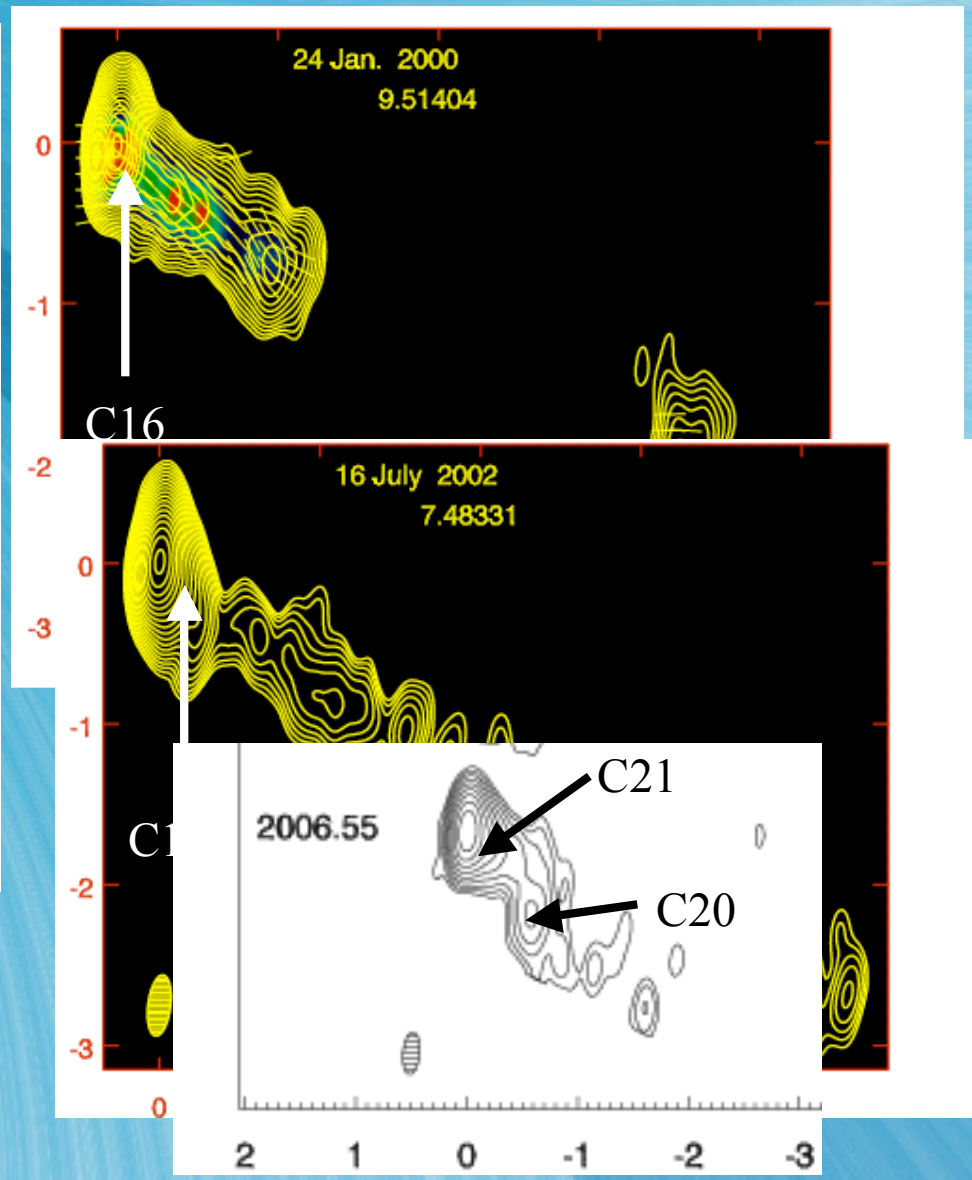




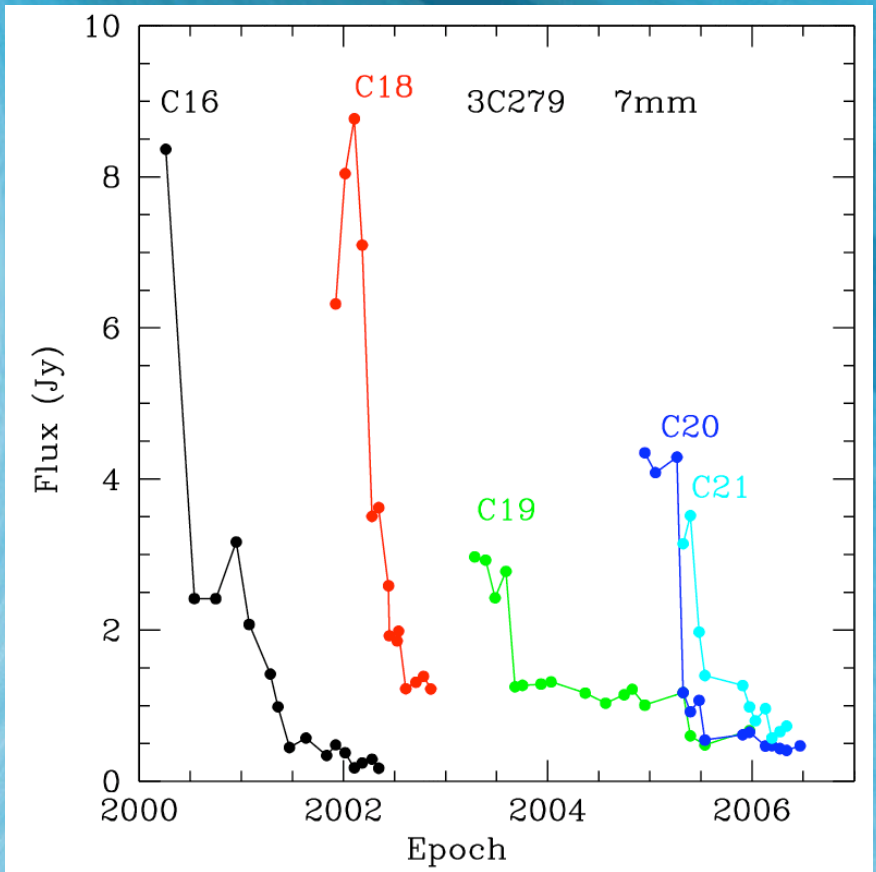
S_{peak} =17 Jy/beam, beam=0.38×0.14 mas^2
at PA=-5° . The lowest contour is 20 mJy/beam.

Superluminal Motion





Deriving of Jet Parameters



Jorstad et al. 2005

I. $\beta_{app} = \beta \sin\Theta_o / (1 - \beta\cos\Theta_o)$

$\beta = \sqrt{1 - \Gamma^{-2}}$

II. $\delta = \Gamma^{-1}(1 - \beta\cos\Theta_o)^{-1}$

Time Scale of Variability
Burbidge, Jones, & O'Dell
1974, ApJ , 193, 43

$\Delta t_{var} = dt/\ln(S_{max}/S_{min})$

Variability Doppler Factor

$\delta_{var} = aD/[c\ \Delta t_{var}\ (1+z)]$

D - luminosity distance

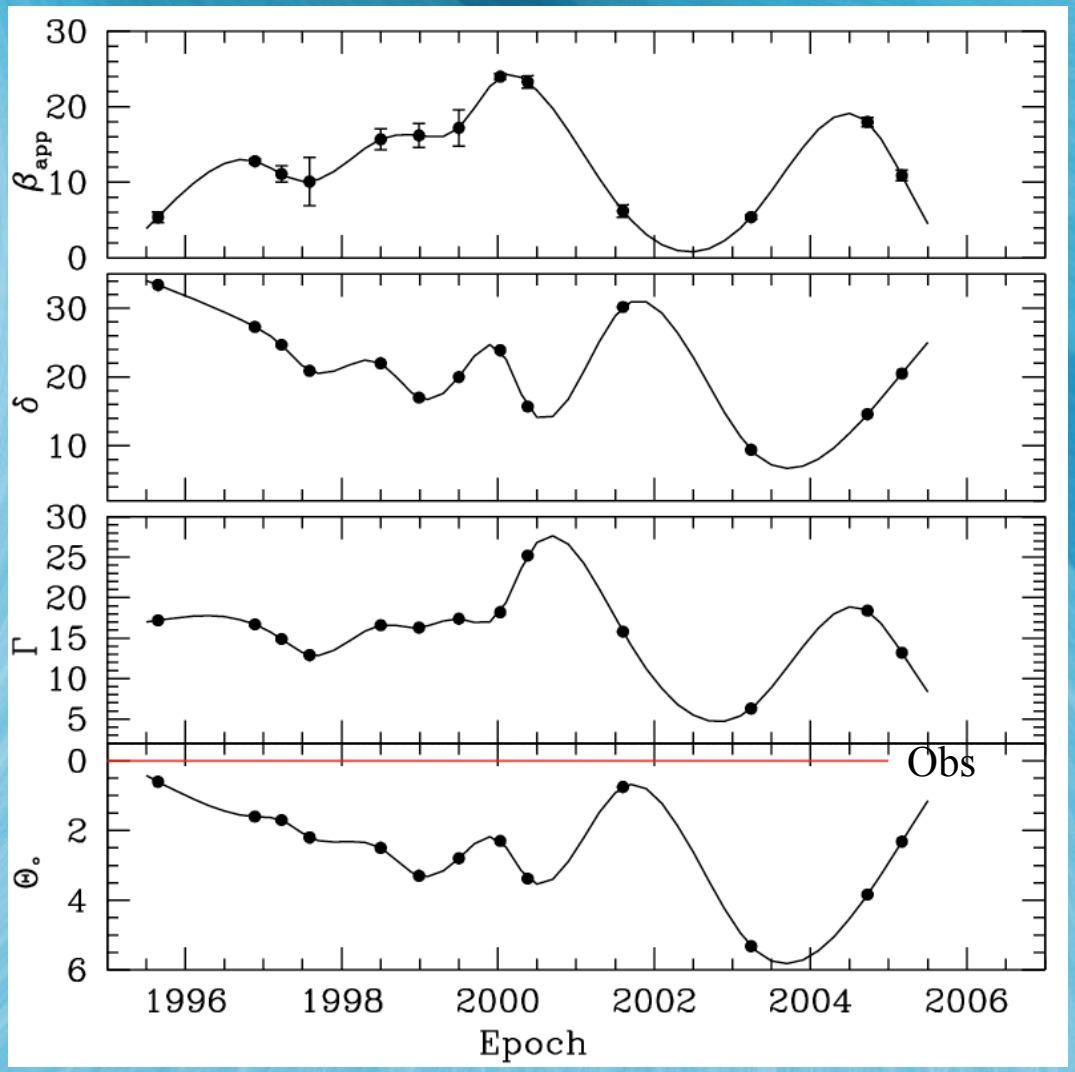
a =1.6s

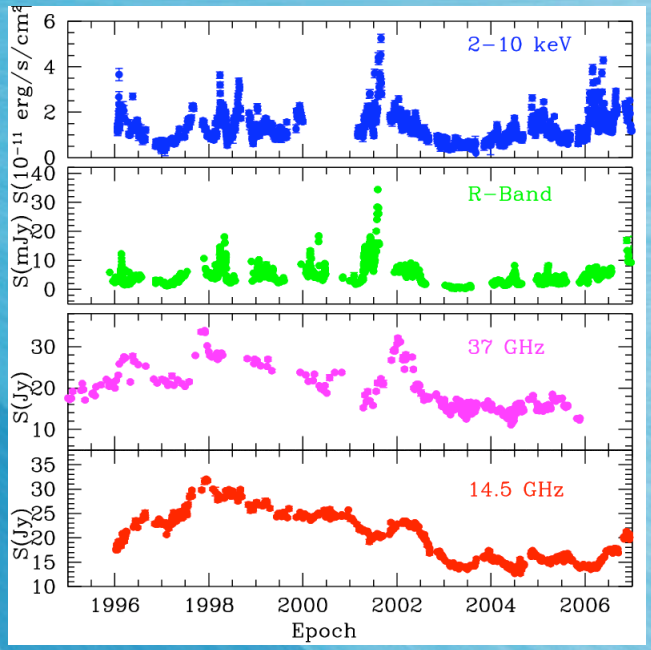
s - VLBI size of component

c - speed of light

z - redshift

Parameters of the Jet in the Quasar 3C 279





During a high activity period:
$\Gamma \approx 17$, $\Theta_o \approx 2^o$, $\delta \approx 20$
During the strong 2001 flare:
$\Gamma \approx 15$, $\Theta_o \approx 0.6^o$, $\delta \approx 30$
During a quiescent state:
$\Gamma \approx 5$, $\Theta_o \approx 6^o$, $\delta \approx 10$

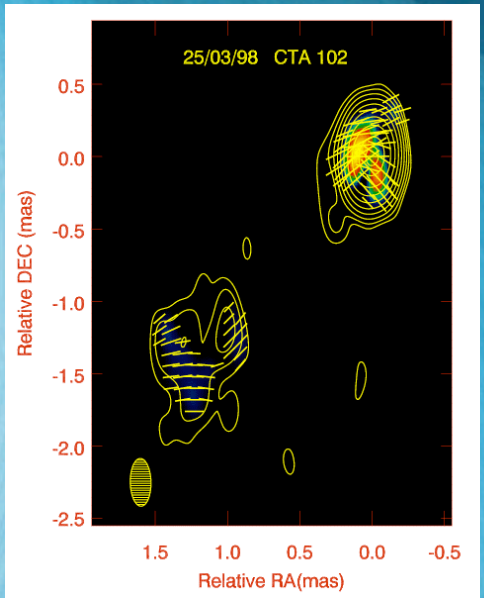
VLBA mm monitoring in the GLAST era

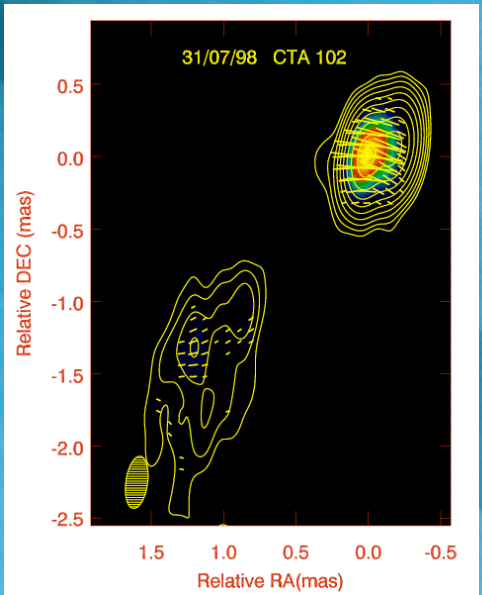
1. Monthly monitoring of a sample of ~35 EGRET blazars at 43GHz

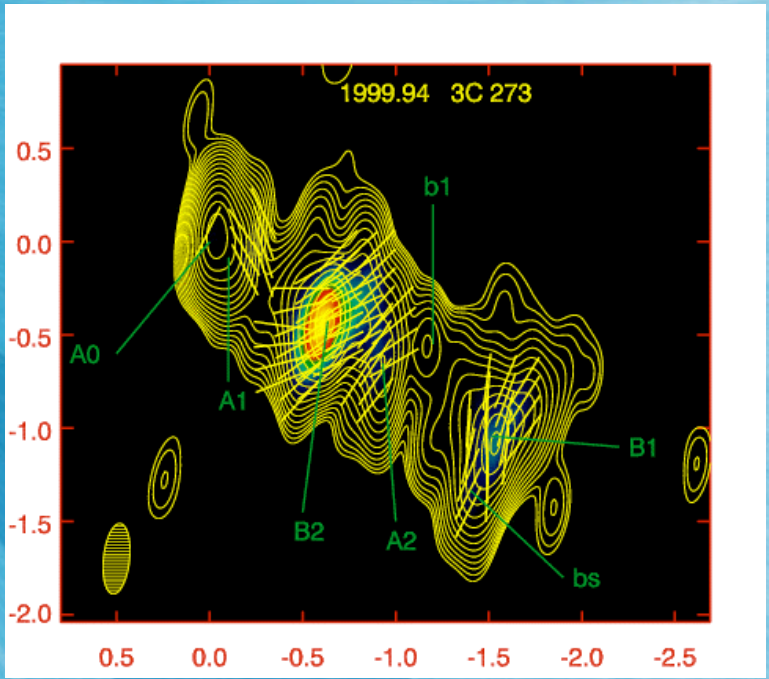
Source	Type	z	RA(J2000)	DEC(J2000)	S_{43GHz}(Jy)	V[1]	Pol(%)[2]
0202+149	Q	0.405	02 04 50.4139	+15 14 11.043	1.0	20.9	3.2 (1)
0234+285	Q	1.213	02 37 52.4056	+28 48 08.990	1.5	18.9	11.3 (1)
0235+164	BL	0.94	02 38 38.9301	+16 36 59.275	1.0	16.0	15 (2)
0336−019	HPQ	0.852	03 39 30.9377	−01 46 35.803	2.5	17.5	19 (1)
0420−014	HPQ	0.914	04 23 15.8007	−01 20 33.064	3.5	17.8	19 (3)
0440−003	HPQ	0.844	04 42 38.6607	−00 17 43.418	0.7	18.5	13 (1)
0458−020	HPQ	2.286	05 01 12.8098	−01 59 14.255	1.3	19.5	4.7 (2)
0528+134	HPQ	2.06	05 30 56.4167	+13 31 55.150	4.0	20.5	4 (3)
0716+714	BL	0.3	07 21 53.4484	+71 20 36.363	0.4	11.0	12.5 (2)
0735+178	BL	0.424	07 38 07.3937	+17 42 18.998	0.5	15.5	14 (1)
0836+710	HPQ	2.172	08 41 24.3652	+70 53 42.173	2.0	16.5	1.1 (1)
0851+201	BL	0.306	08 54 48.9000	+20 06 30.641	1.2	15.0	30 (4)
0954+658	BL	0.368	09 58 47.2451	+65 33 54.818	0.6	15.3	19 (5)
1127−145	Q	1.18	11 30 07.0525	−14 49 27.387	1.0	16.9	1.3 (1)
1156+295	HPQ	0.729	11 59 31.8339	+29 14 43.827	1.5	15.6	9.2 (2)
1219+285	BL	0.102	12 21 31.6905	+28 13 58.500	0.3	15.5	30 (6)
1222+216	Q	0.435	12 24 54.4583	+21 22 46.388	1.0	17.5	–
1226+023	Q	0.158	12 29 06.6997	+02 03 08.598	10	12.5	0.5(3)
1253−055	HPQ	0.536	12 56 11.1665	−05 47 21.523	20	15.0	39 (3)
1406−076	Q	1.494	14 08 56.4811	−07 52 26.665	0.7	18.4	–
1510−089	HPQ	0.361	15 12 50.5329	−09 05 59.828	2.5	15.5	4 (3)
1606+106	Q	1.226	16 08 46.2031	+10 29 07.776	1.0	18.5	–
1611+343	Q	1.400	16 13 41.0642	+34 12 47.908	5.0	17.5	1.6 (2)
1622−253	Q	0.786	16 25 46.8916	−25 27 38.326	2.5	18.7	2.8 (1)
1622−297	Q	0.815	16 26 06.0208	−29 51 26.970	3.0	20.5	–
1633+382	HPQ	1.814	16 35 15.4929	+38 08 04.500	1.0	17.0	2.6 (1)
1641+399	HPQ	0.593	16 42 58.8099	+39 48 36.993	8.5	16.0	38 (3)
1730−130	Q	0.902	17 33 02.7057	−13 04 49.547	10.0	18.5	–
1739+522	HPQ	1.375	17 40 36.9778	+52 11 43.407	0.7	18.5	4 (5)
2223−052	HPQ	1.404	22 25 47.2592	−04 57 01.390	3.0	18.0	2.4 (2)
2230+114	HPQ	1.037	22 32 36.4089	+11 43 50.904	2.5	16.5	9.5 (3)
2251+158	HPQ	0.859	22 53 57.7479	+16 08 53.560	6.0	16.0	6.2 (3)

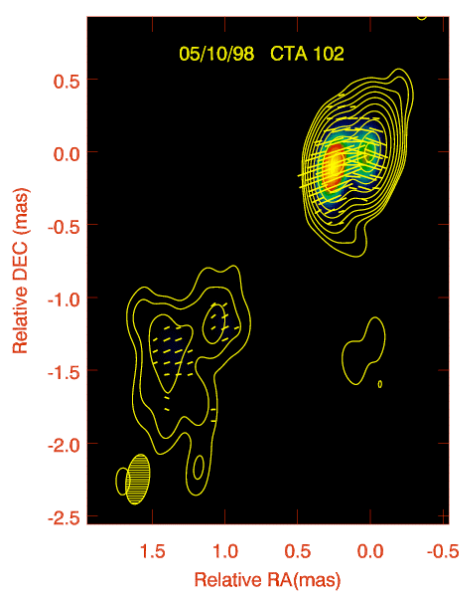
- Time sequences of images
  → apparent motions (usually superluminal)
  → sites of flux increase/decrease
- Ultra-high resolution: subparsec for low-*z* objects, parsecs for high-*z* (angular resolution ~ 0.1 milliarcsec at 43 GHz)
- Time of ejection and light curves of superluminal components
- Total and polarized intensity maps along with modelling parameters of jet components will be posted at our website: www.bu.edu/blazars/

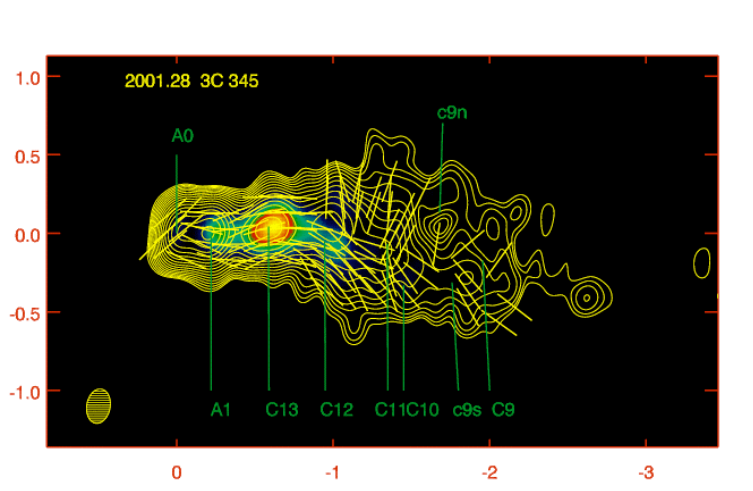
Polarization Maps of Quasars



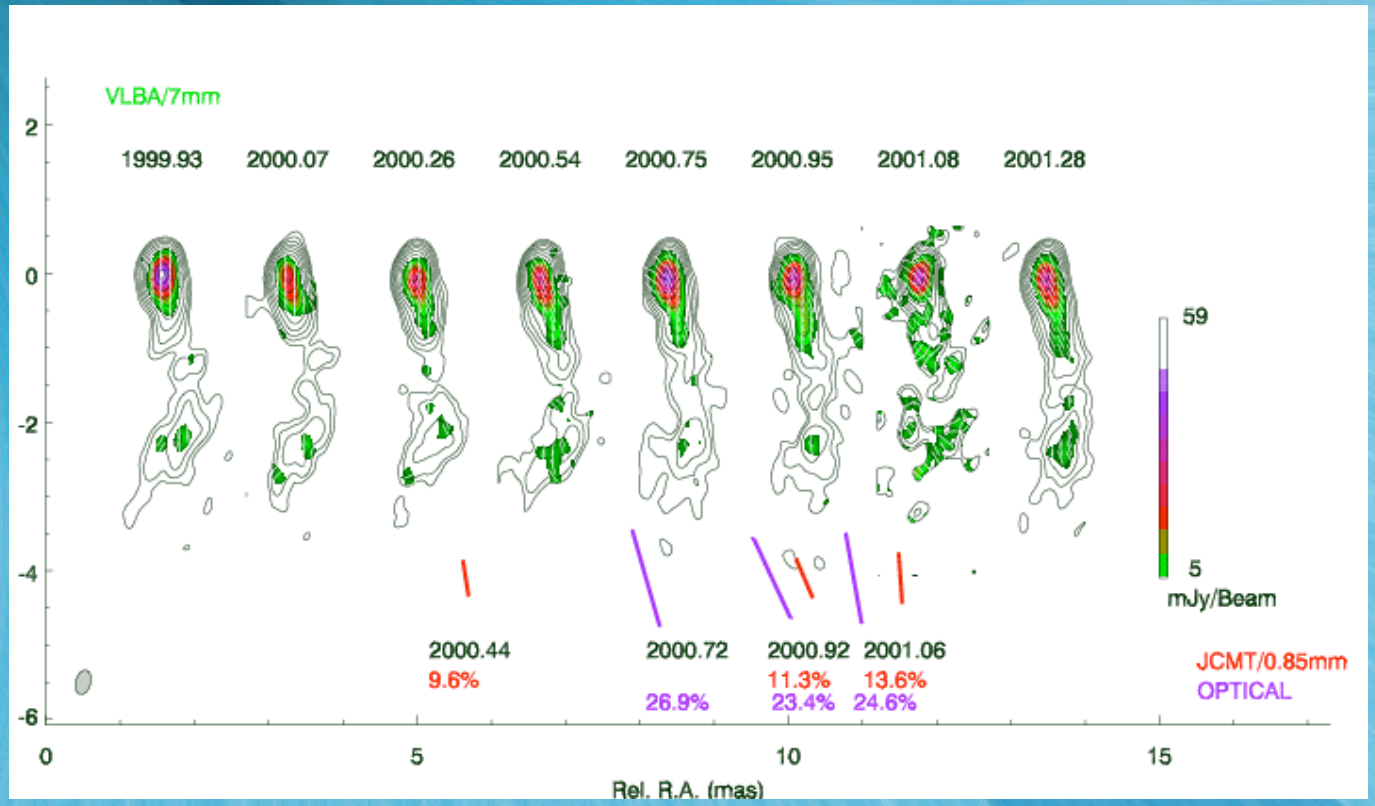








Polarization Maps of BL Lac Objects



- Identification of components across epochs
- Orientation of magnetic field
- Degree of ordering of magnetic field
- Changes in magnetic field structure

Multiwavelength Monitoring

- X-ray fluxes & spectral index: RXTE (3C279, 3C273 1510-089, 3C111, 3C120, BL Lac)
- Radio fluxes & polarization:
- UMRAO database - 4.5, 8, & 14.5 GHz
- Metsähovi database - 37 & 22 GHz
- IRAM - 90 & 230 GHz, perhaps SMA
- CARMA calibration data - 90 & 230 GHz
- Near-IR/optical total flux:
  Liverpool Telescope, Lowell Obs., U. Nebraska, Perugia U., Crimean Astrophys. Obs., many others