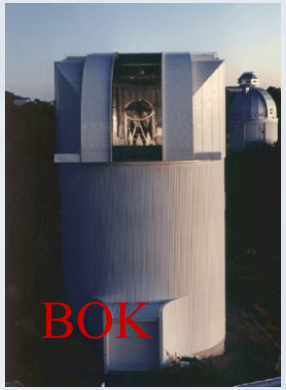
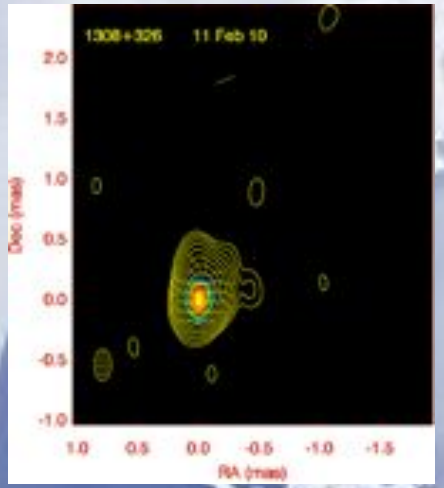
Evidence of a Strong Connection between Gamma-ray Outbursts and Events in the Millimeter-wave Core of Blazars.

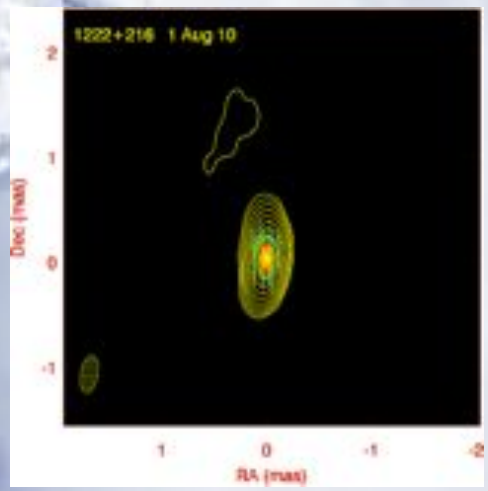
Svetlana Jorstad, Boston University

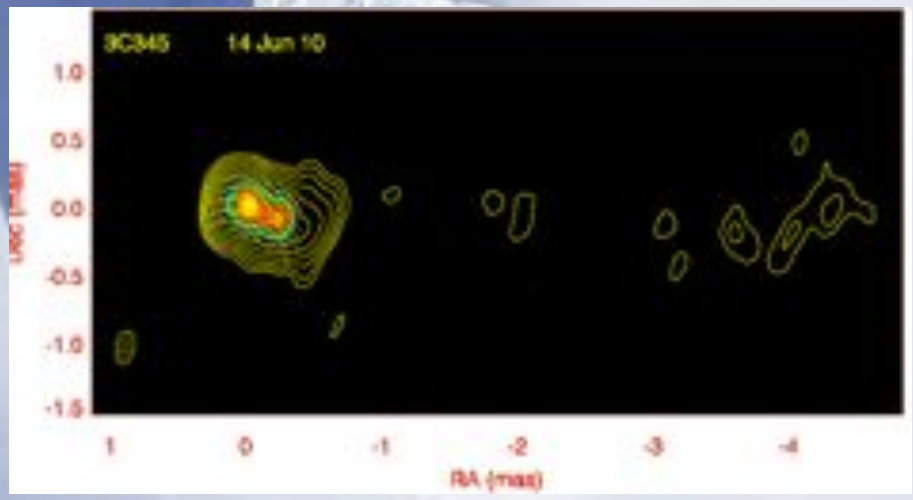


Boston University group
Alan Marscher et al.
St.Petersburg University group:
Valeri Larionov et al.
Instituto de Astrof´ısica de Andaluc´ıa group: Jose-Luis Gómez et al.
Steward Obs. group:
Paul Smith et al.
Abastumani Obs. group:
Omar Kurtanidze et al.
Mark Gurwell , CfA
Mets¨ahovi Radio Obs. group:
Merja Tornikoski et al.
Margo Aller & Hugh Aller , UMRAO
Ian McHardy, Southampton Univ., UK

Outline







I. From Gamma-Rays Outbursts to Parsec Scale Jets

1. 3C454.3 (z=0.859)

2. PKS 1510-089 (z=0.361)

3. 3C273 (z=0.158)

4. 0836+710 (z=2.17)

5. CTA26 (z=0.852)

6. BLLac Objects:

Agudo et al. #4.5 – AO0235+164

Larionov et al. #6.7 – S5 0716+714

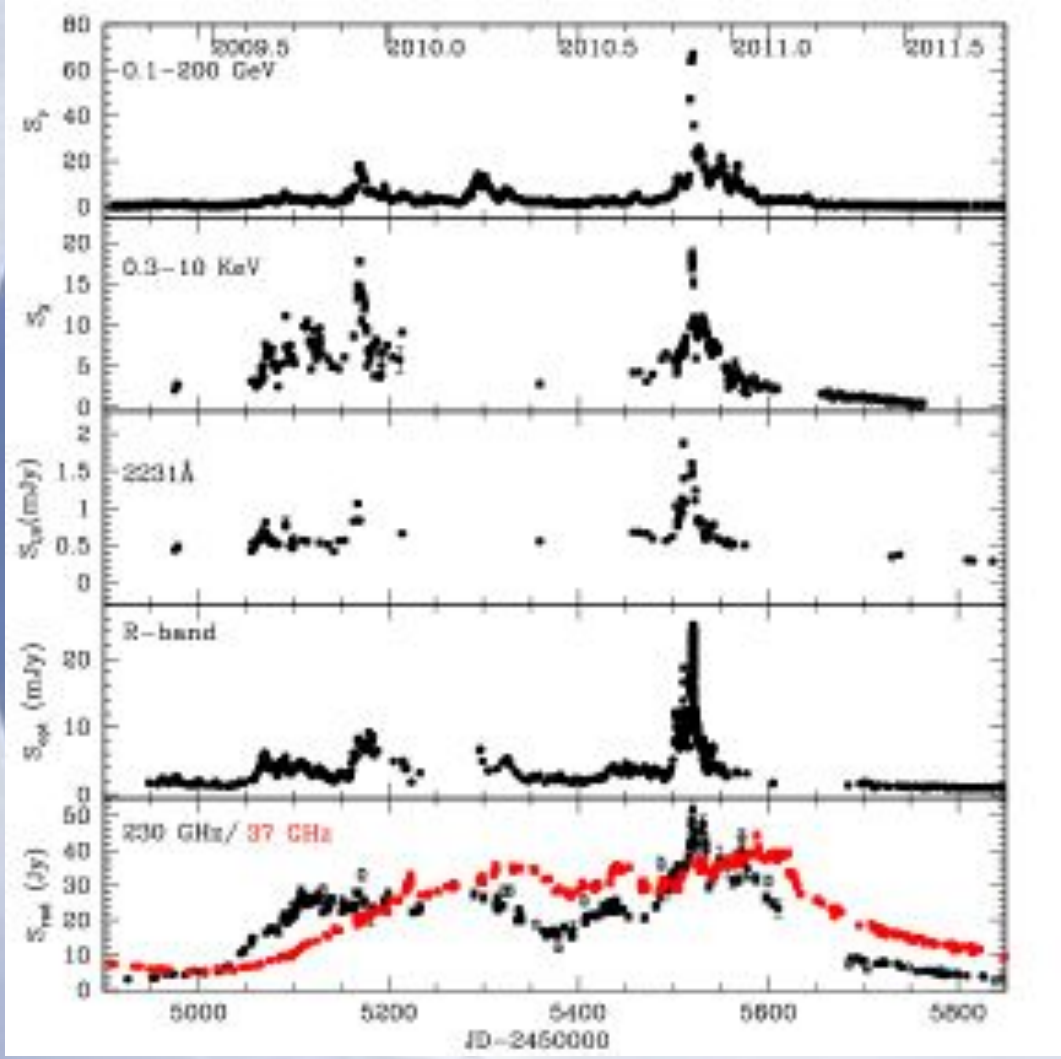
Marscher #1.6 – BL Lac

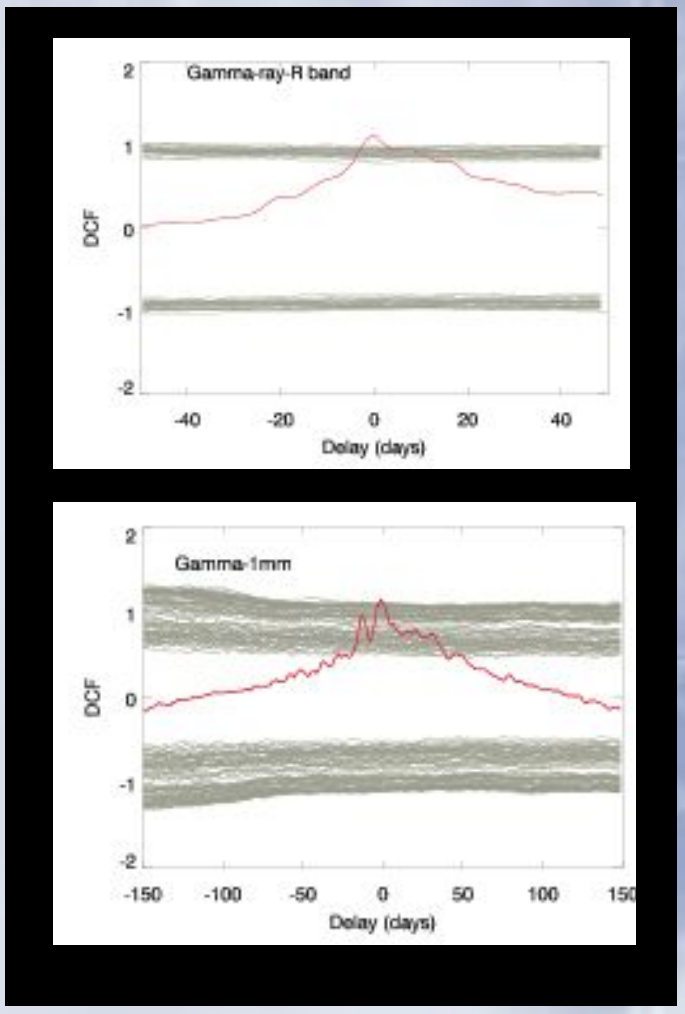
II. General Statistics

III. Conclusions

www.bu.edu/blazars/VLBAproject.html

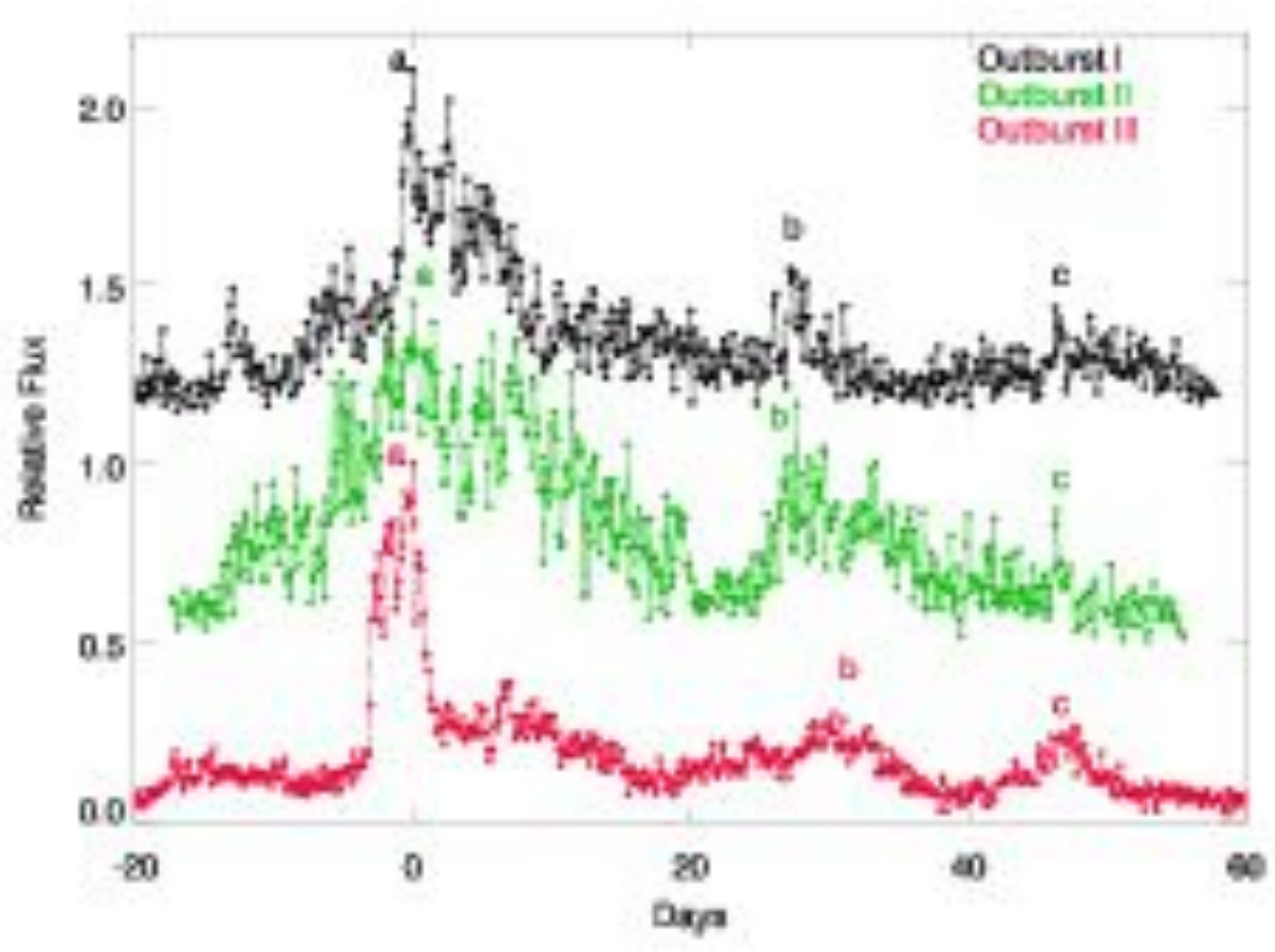
Multi-Wavelength Light Curves of the Quasar 3C454.3





Raiteri et al. 2011, A&A, 534, 87
Vercellone et al. 2011, ApJL, 736, L38
Wehrle et al. 2012, ApJ, 758, 72

Fine Structure of Gamma-Ray Outbursts



Normalization parameters of Gamma-Ray Light Curves

Outburst I:

T_{max} = 2 December 2009

$S_{max} = (2.4 \pm 0.2) \times 10^{-5}$ ph cm^{-2} s^{-1}

Outburst II:

T_{max} = 8 April 2010

$S_{max} = (1.6 \pm 0.1) \times 10^{-5}$ ph cm^{-2} s^{-1}

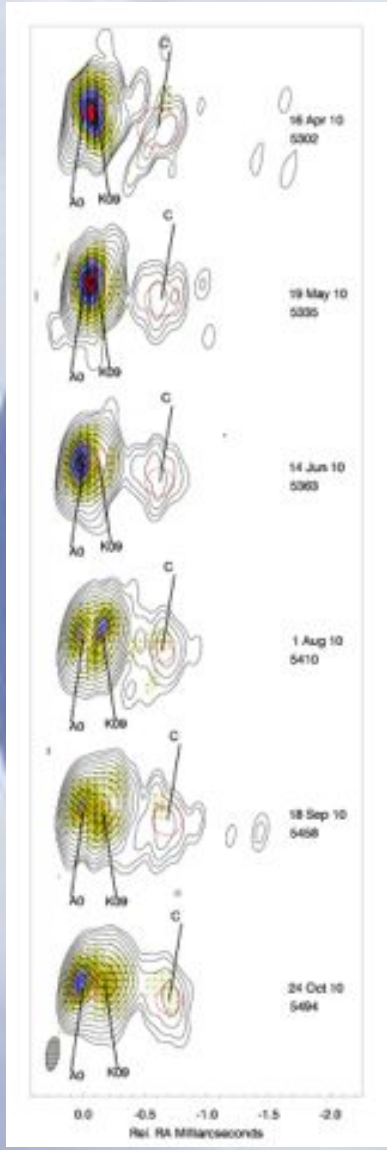
Outburst III:

T_{max} = 20 November 2010

$S_{max} = (8.4 \pm 0.4) \times 10^{-5}$ ph cm^{-2} s^{-1}

Ackermann et al. 2010, ApJ, 721, 1383
Abdo et al. 2011, ApJL, 733, L26

Kinematics of Parsec Scale Jet of 3C 454.3



Outburst I (K09):
$\mu = 0.21 \pm 0.02$ mas yr^{-1}
$\beta_{app} = (9.6 \pm 0.6)c$

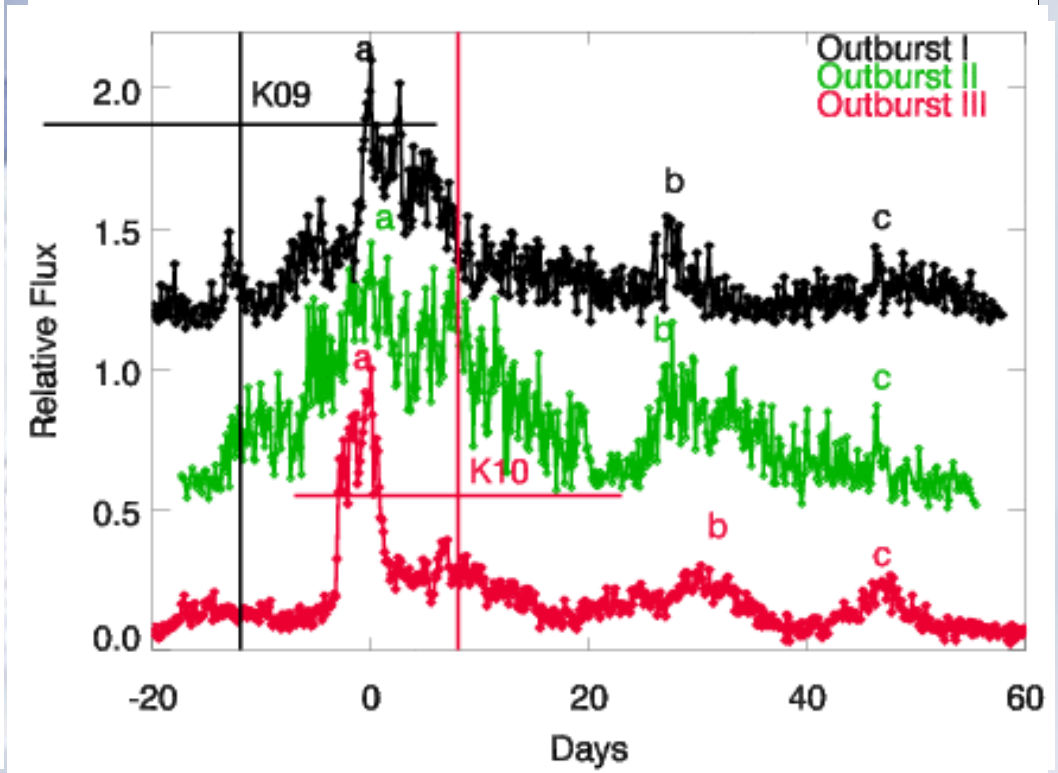
T_o = 10 Nov 2009±18 d

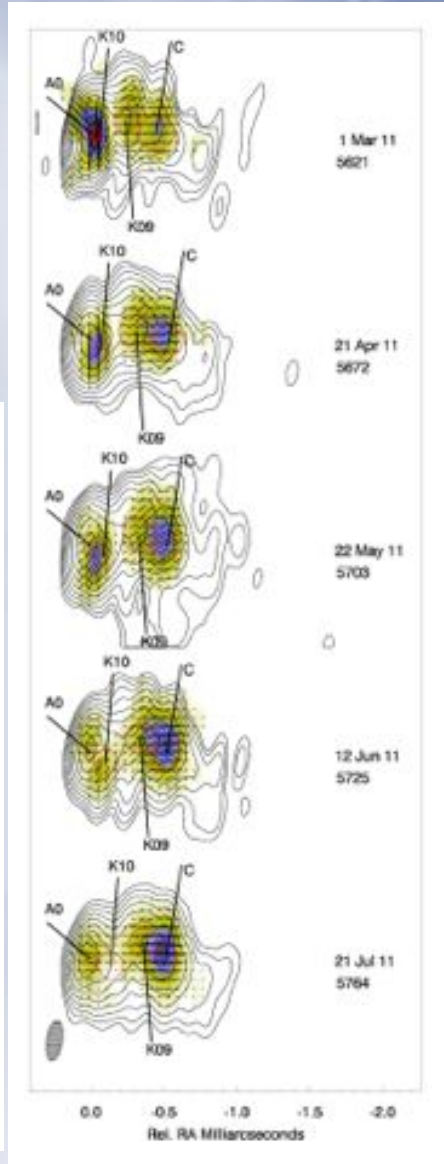
RJD: 5146±18

Outburst III (K10):
$\mu = 0.21 \pm 0.02$ mas yr^{-1}
$\beta_{app} = (8.9 \pm 1.7)c$

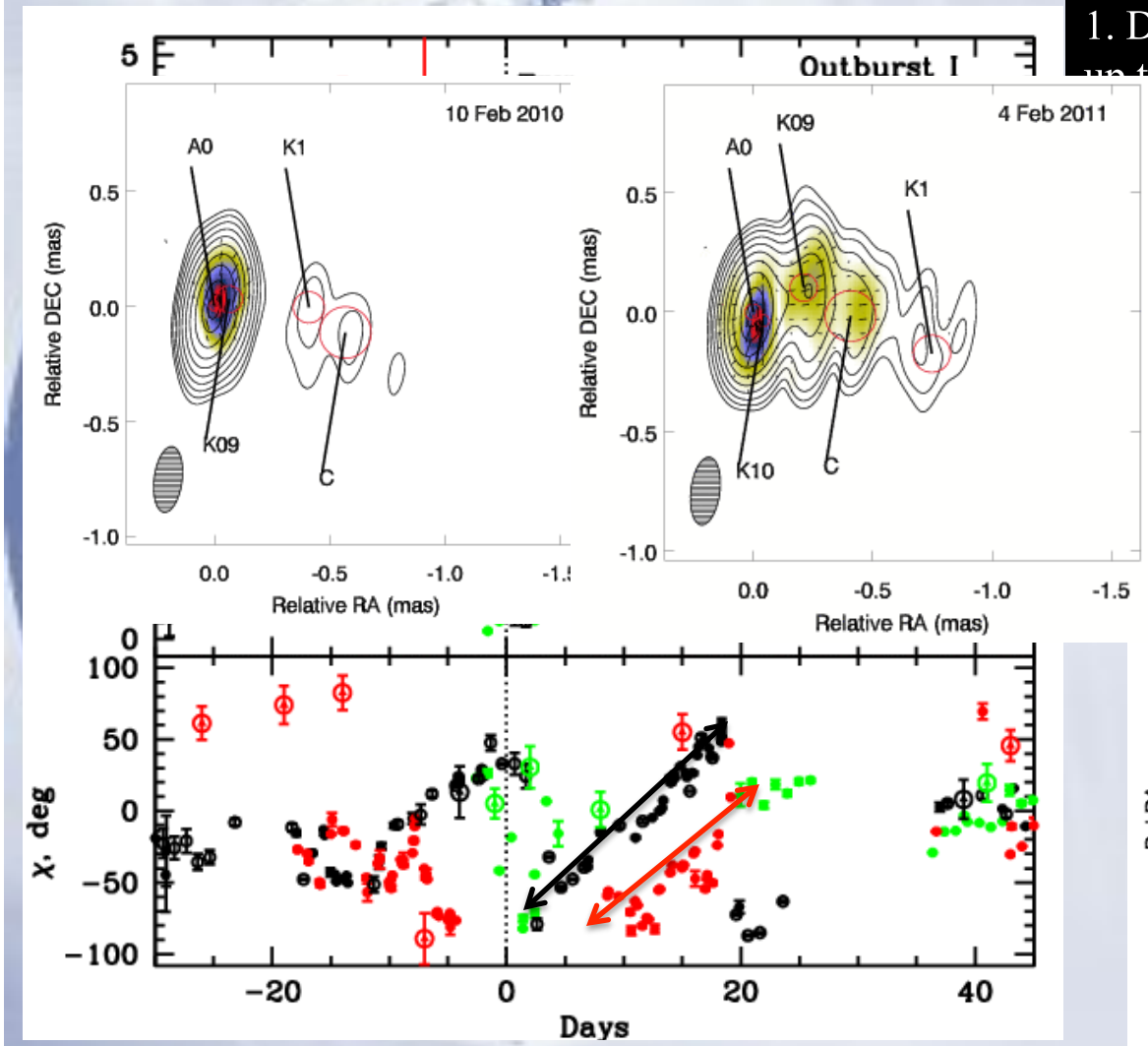
T_o = 13 Dec 2010±25 d

RJD: 55543±25

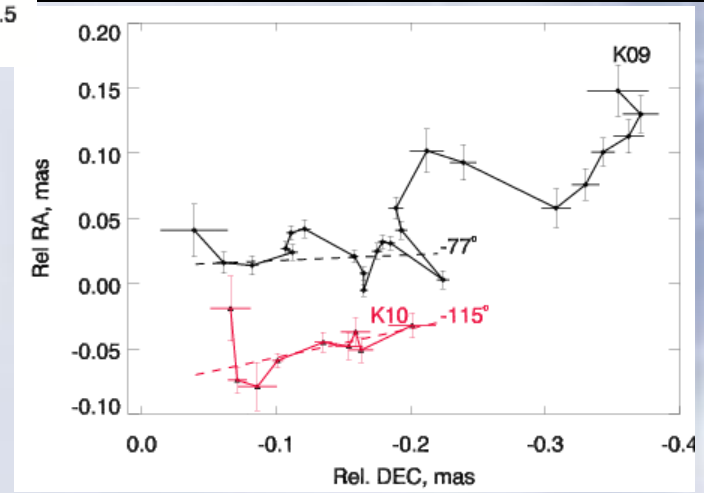




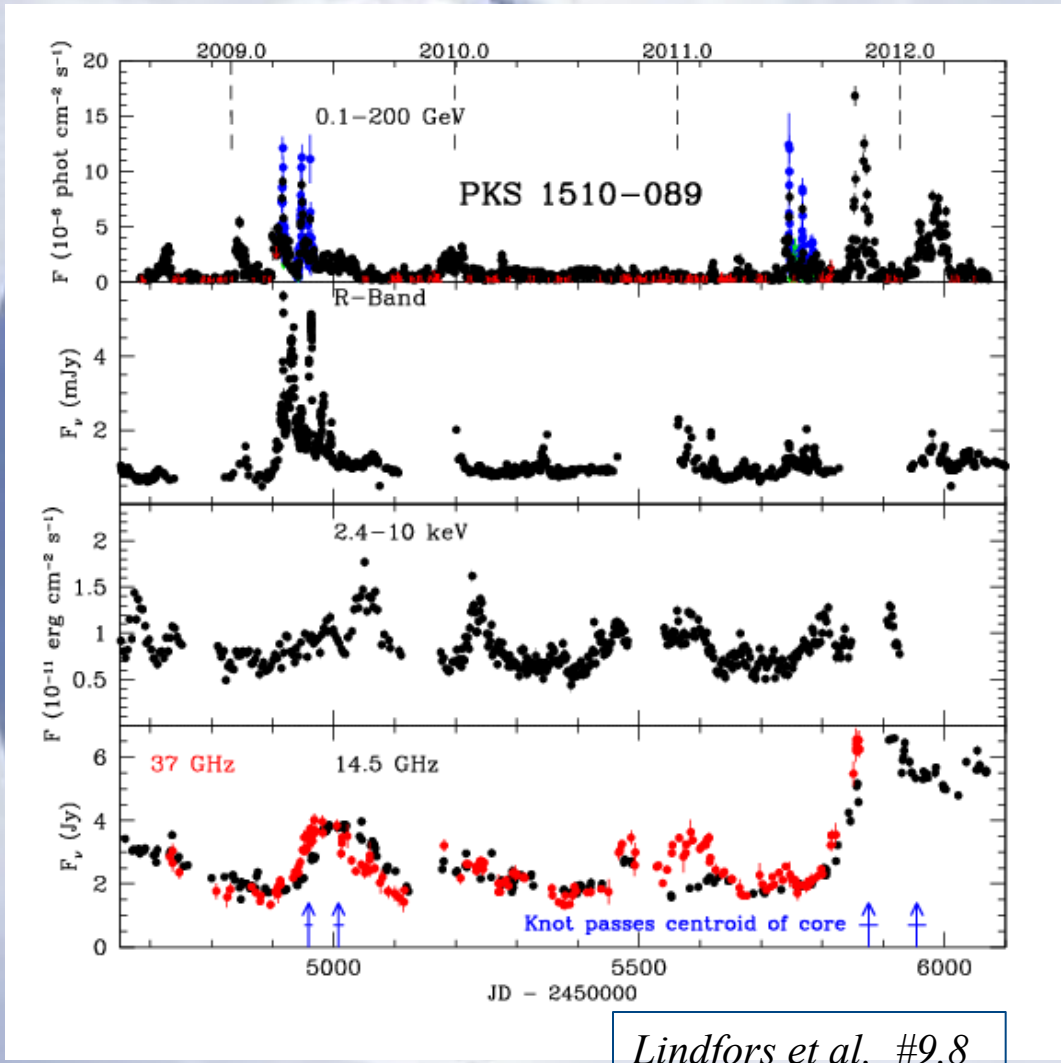
Comparison of Optical Polarization with Properties of Parsec Scale Jet of 3C 454.3



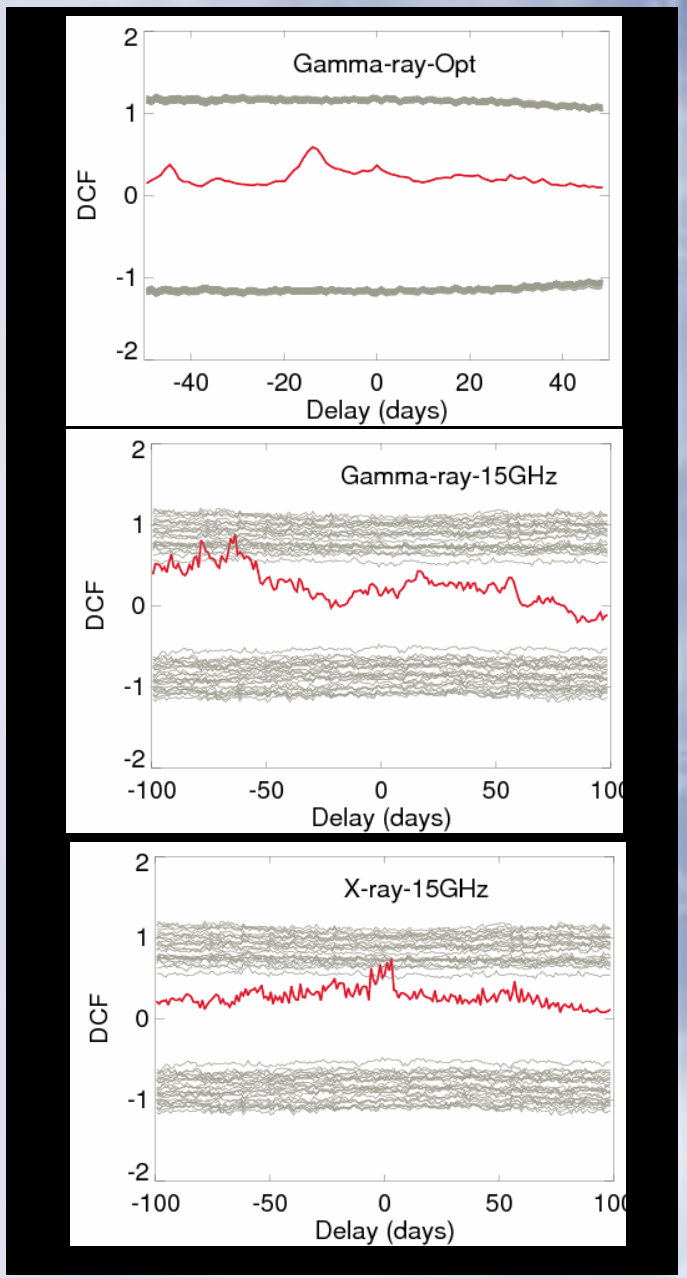
1. Degree of optical polarization increases
up to 30% (typical value of P_{opt} ~ 3-4%);
ical polarization data are supplemented
lata from Sasada et al. (2012, PASJ, 64,58)
egree of polarization in the core increases
o 5% (typical value of P_{core} ~ 1-2%).
t a γ-ray peak both P_{opt} & P_{cor} drop to 1%
$_{opt}$ rotates with the same speed after
$_{ax}$ during outburst I and III.
n the end of rotation:
~ χ_{core} ~ χ_{K09} ~ χ_{K10} ~perpendicular to jet



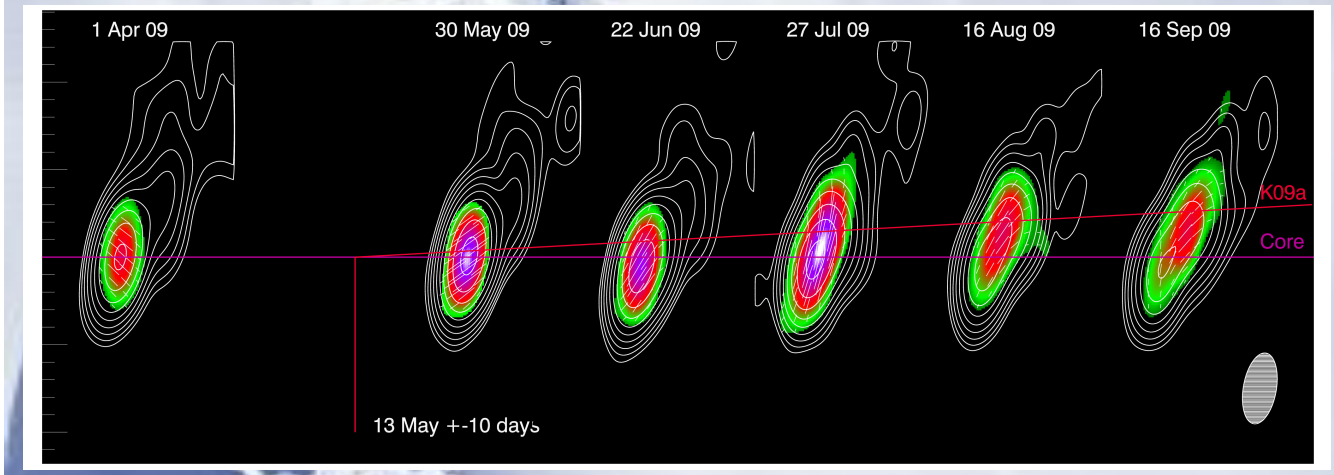
Multi-Wavelength Light Curves of the Quasar PKS1510-089

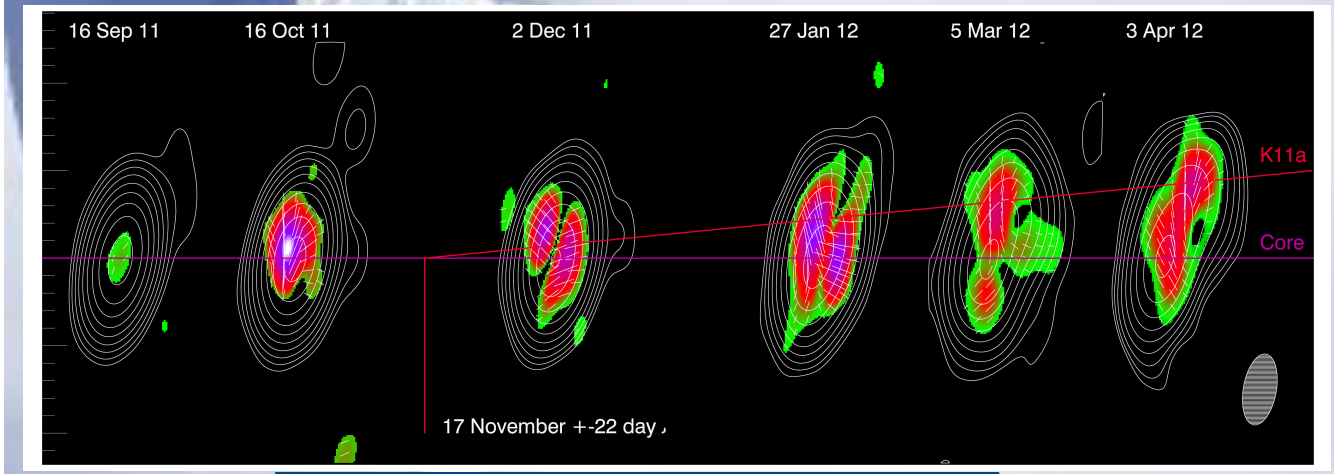


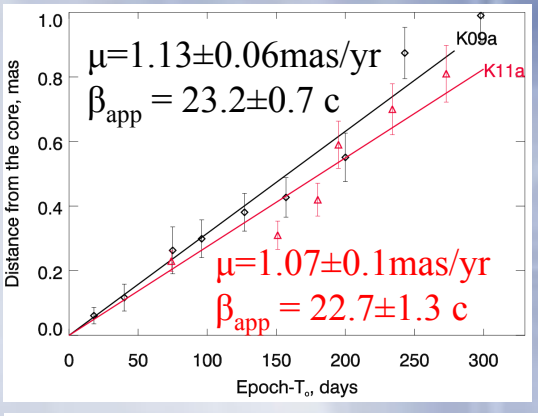
Lindfors et al. #9.8

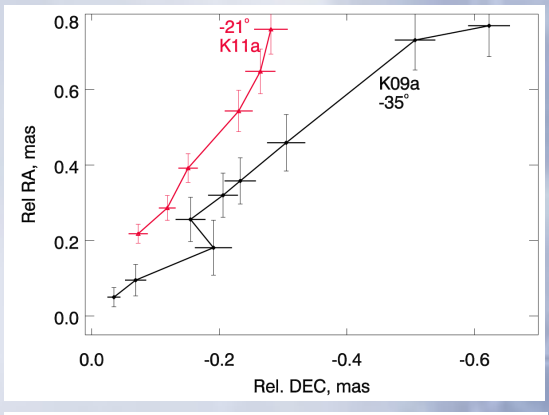


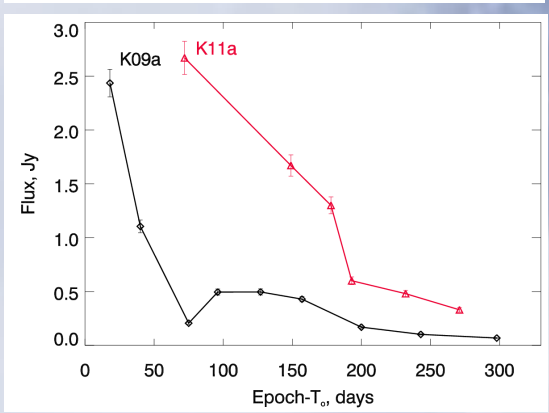
I. Kinematics of Parsec Scale Jet of PKS1510-089





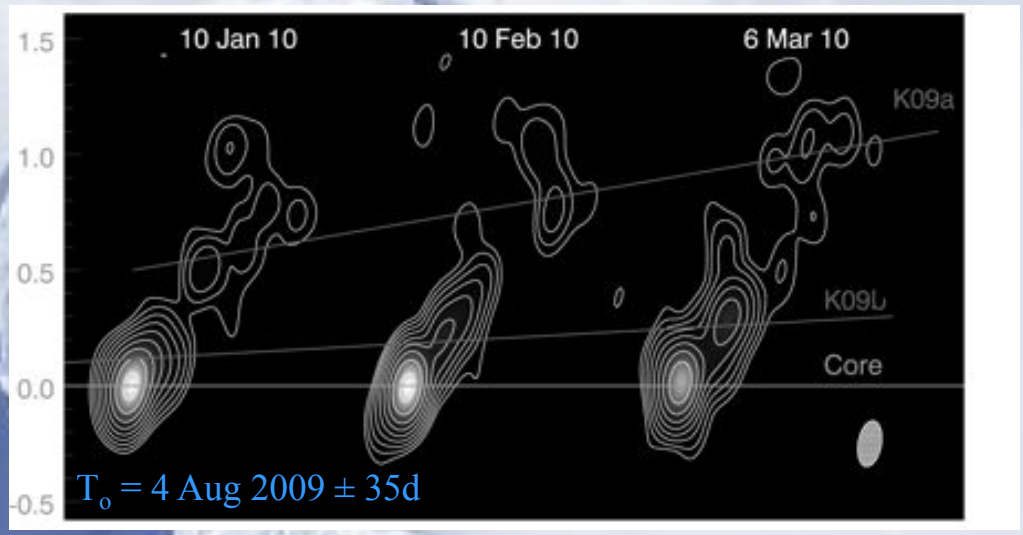


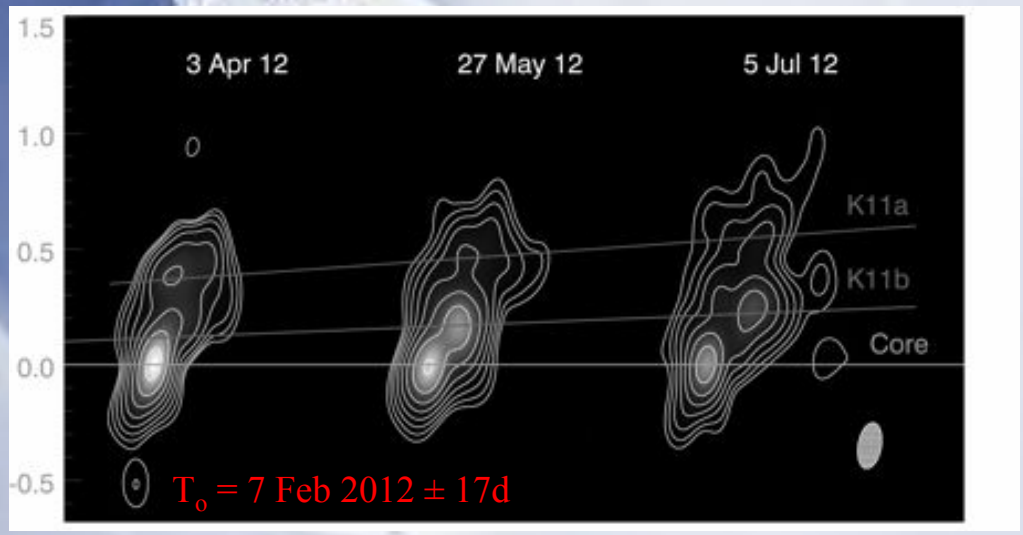


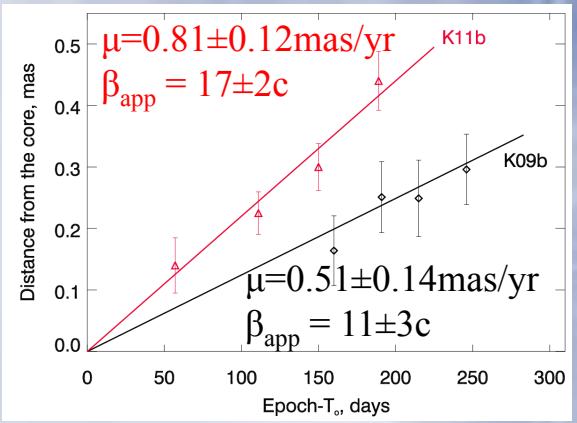


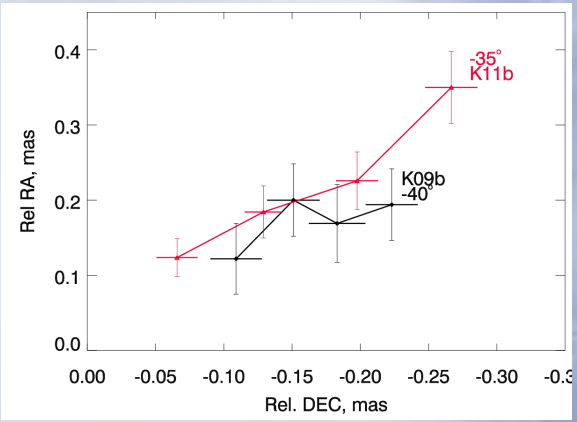
Marscher et al. 2010, ApJL, 710, L126
Orienti et al. 2012, arXiv:1210.4319

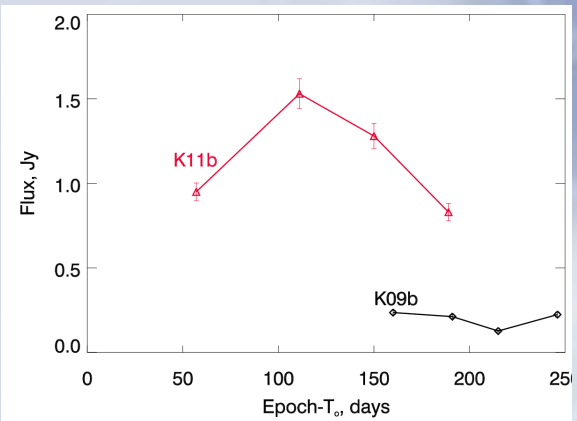
II. Kinematics of Parsec Scale Jet of PKS1510-089



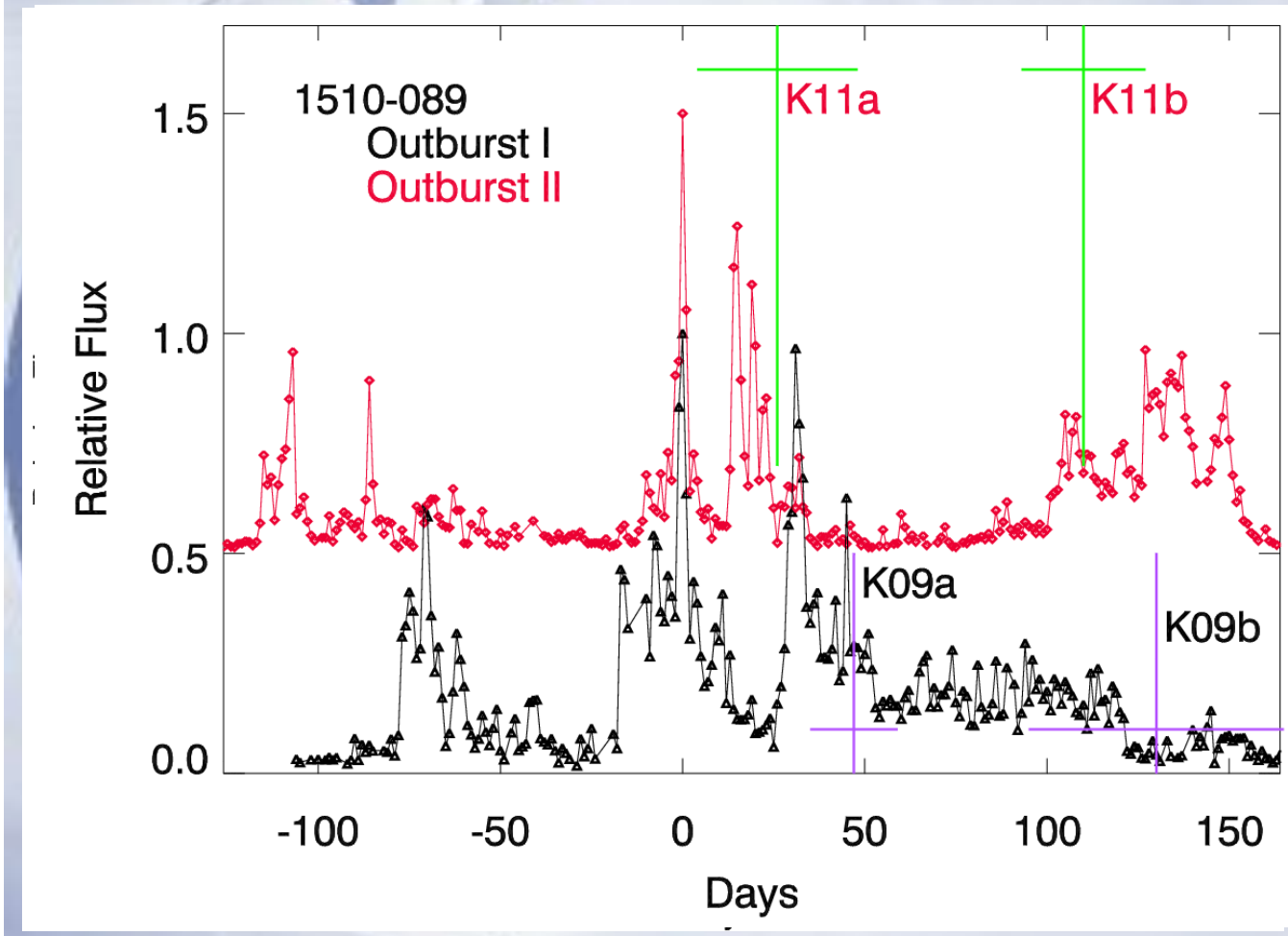








Properties of Knots vs. Gamma-Ray Light Curves



Normalization parameters of Gamma-Ray Light Curves

Outburst I:

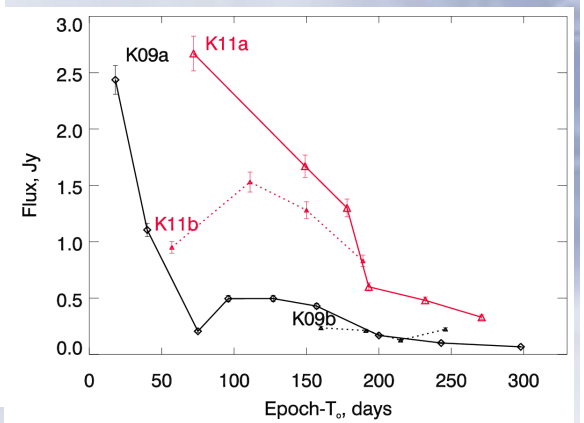
T_{max} = 27 March 2009 ± 0.5d

$S_{max} = (9.1 \pm 0.5) \times 10^{-6}$ ph cm^{-2} s^{-1}

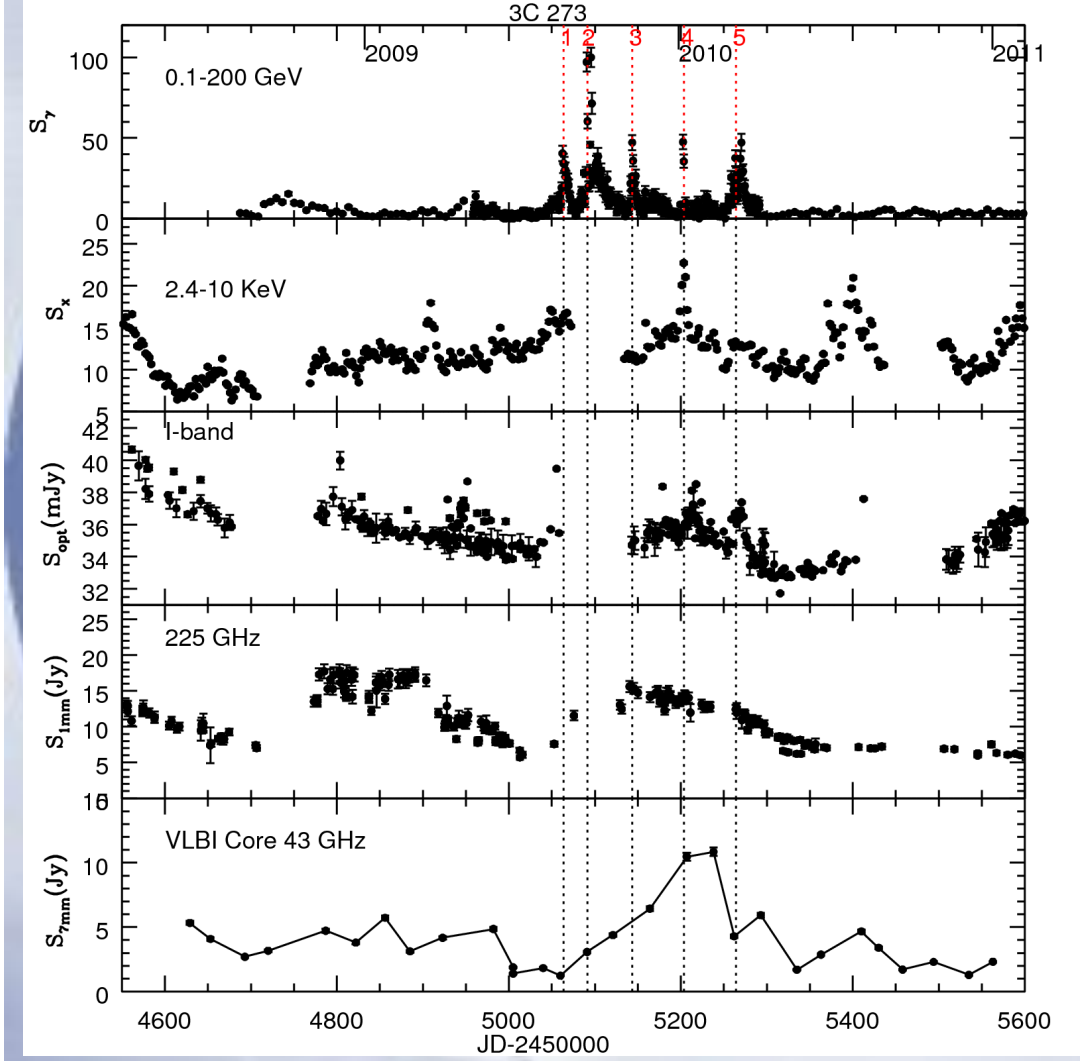
Outburst II:

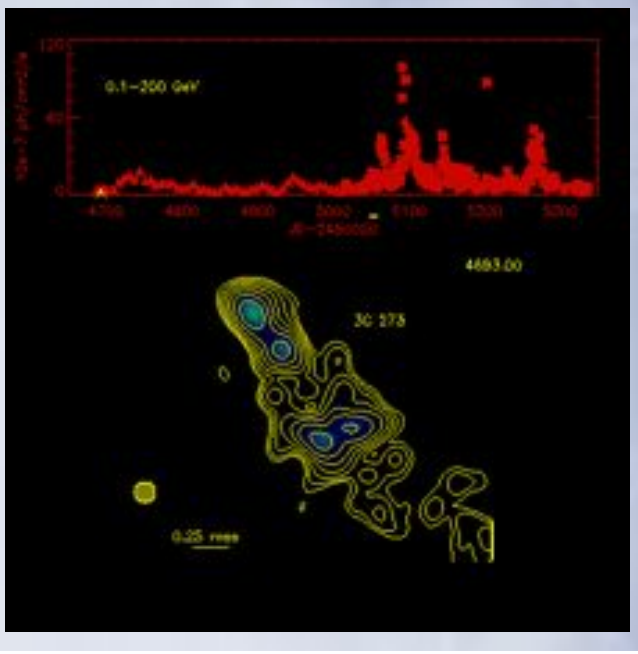
T_{max} = 20 October 2011 ± 0.5d

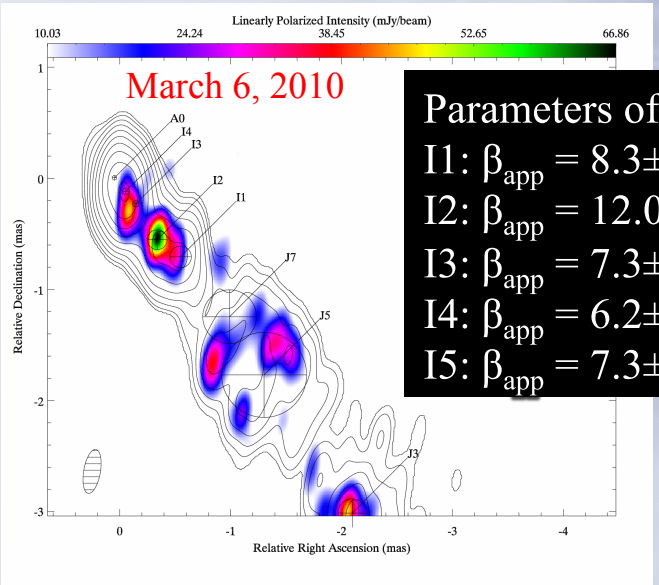
$S_{max} = (16.8 \pm 0.9) \times 10^{-6}$ ph cm^{-2} s^{-1}



Multi-Wavelength Light Curves and Jet Kinematics of the Quasar 3C 273







Parameters of Knots:

I1: β_{app} = 8.3±0.2 c

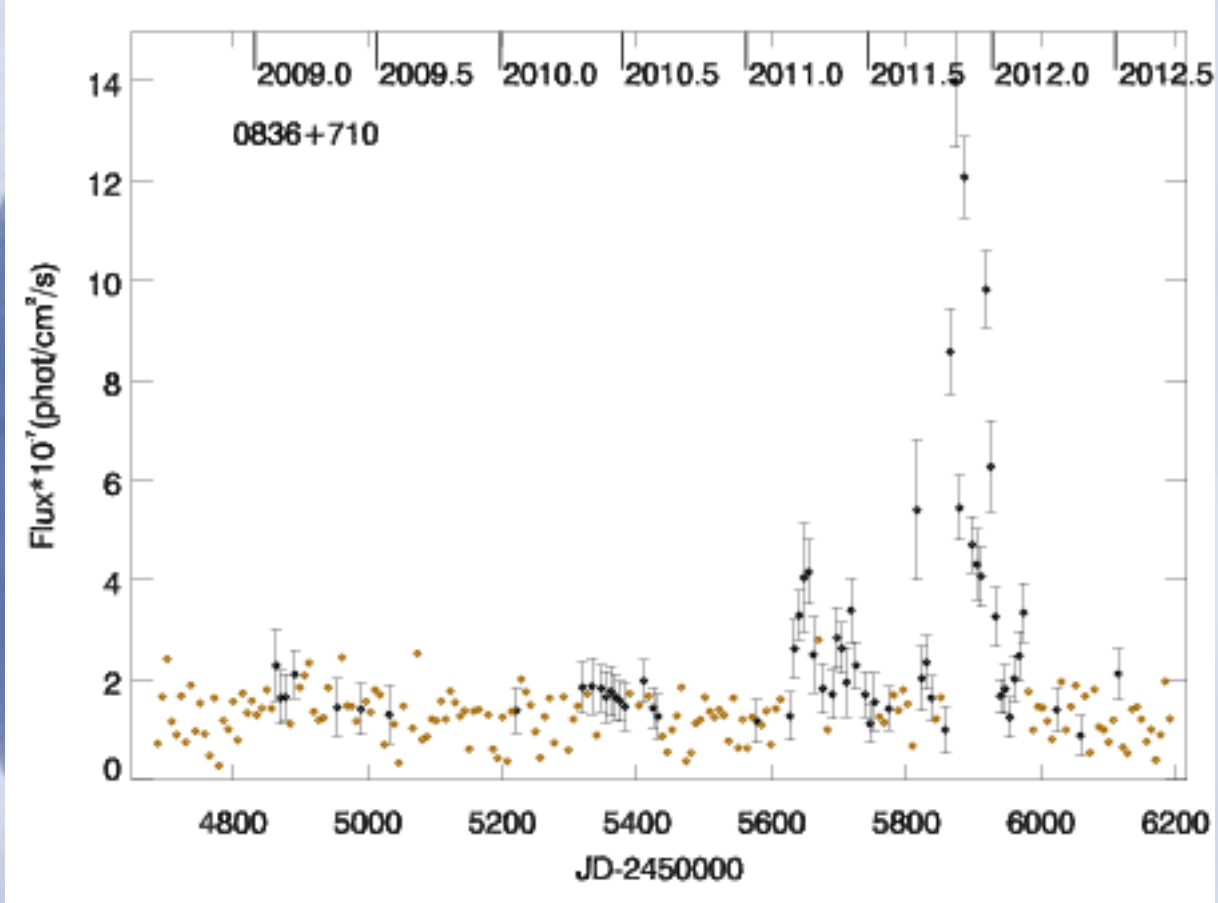
I2: β_{app} = 12.0±0.7 c

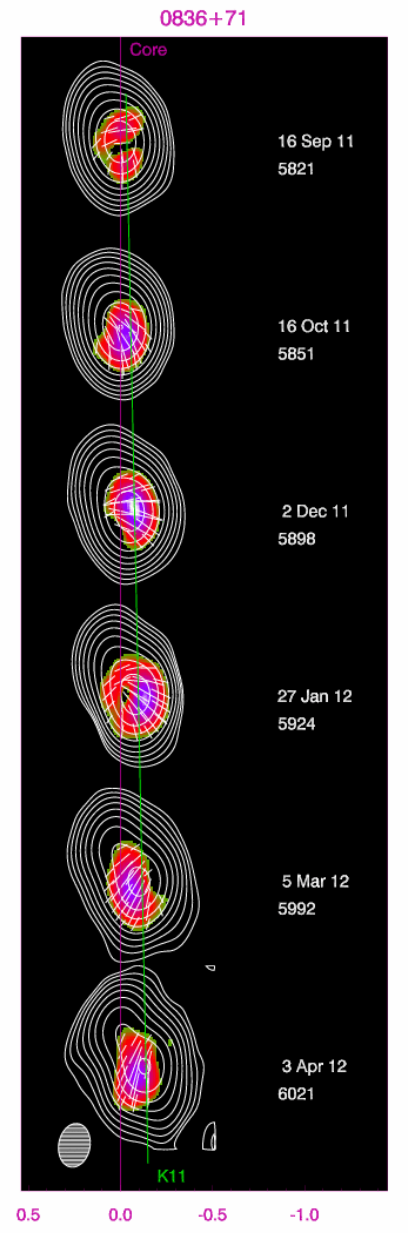
I3: β_{app} = 7.3±0.4 c

I4: β_{app} = 6.2±1.4 c

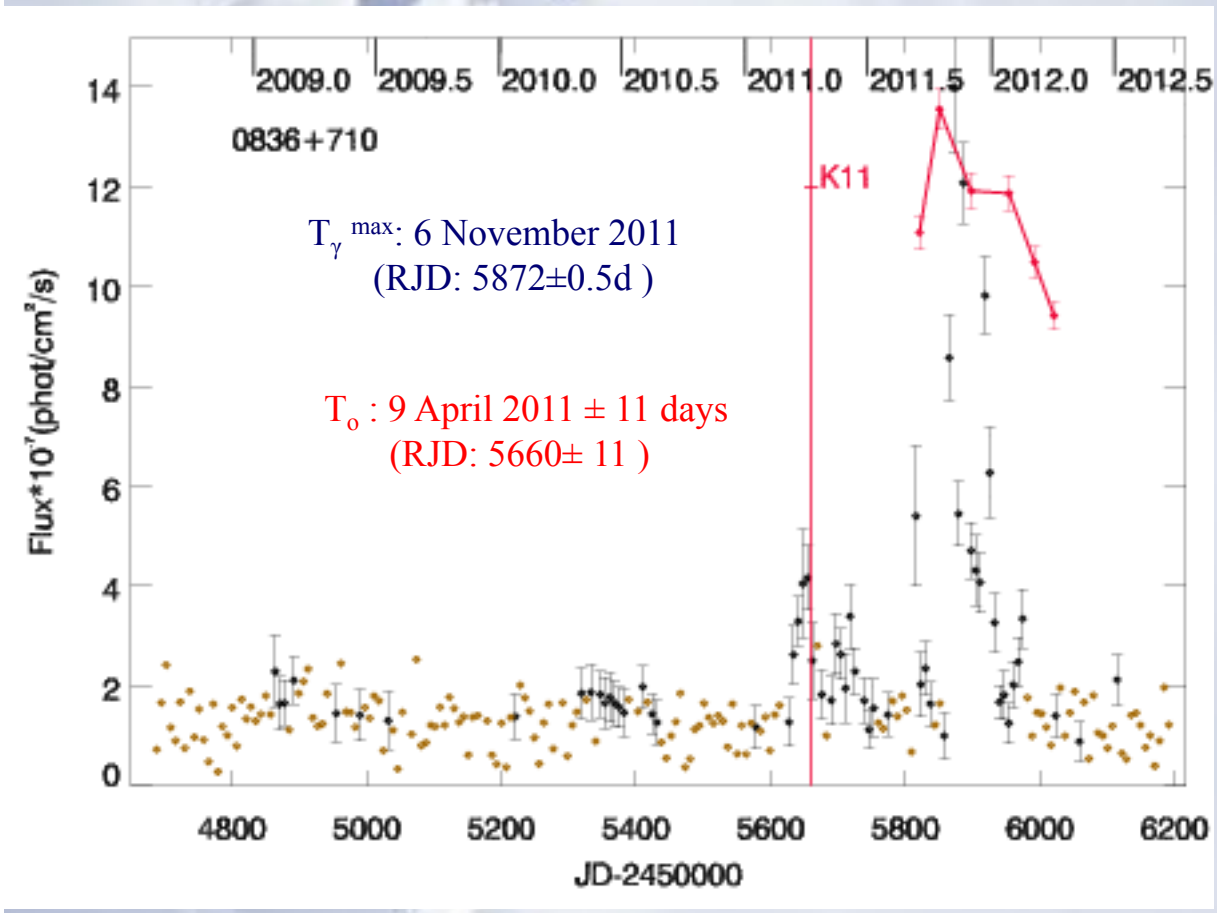
I5: β_{app} = 7.3±0.6 c

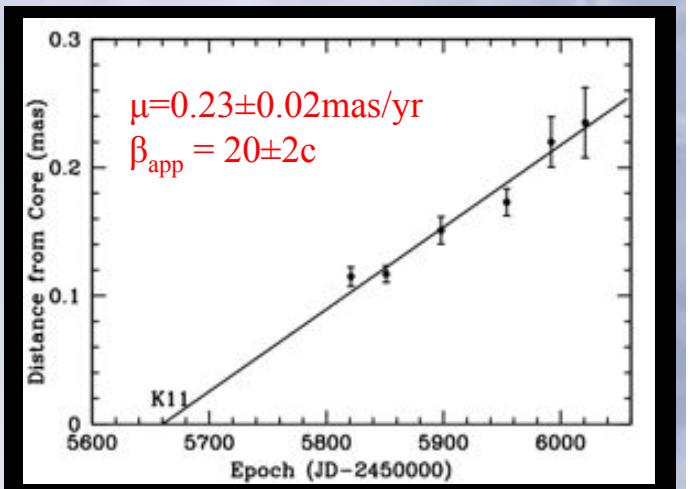
Comparison of Gamma-Ray Behavior with Parsec Scale Jet Activity in 0836+71

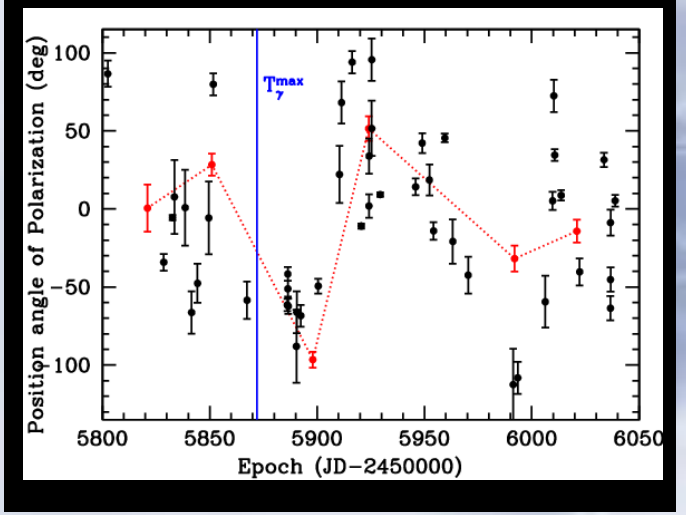




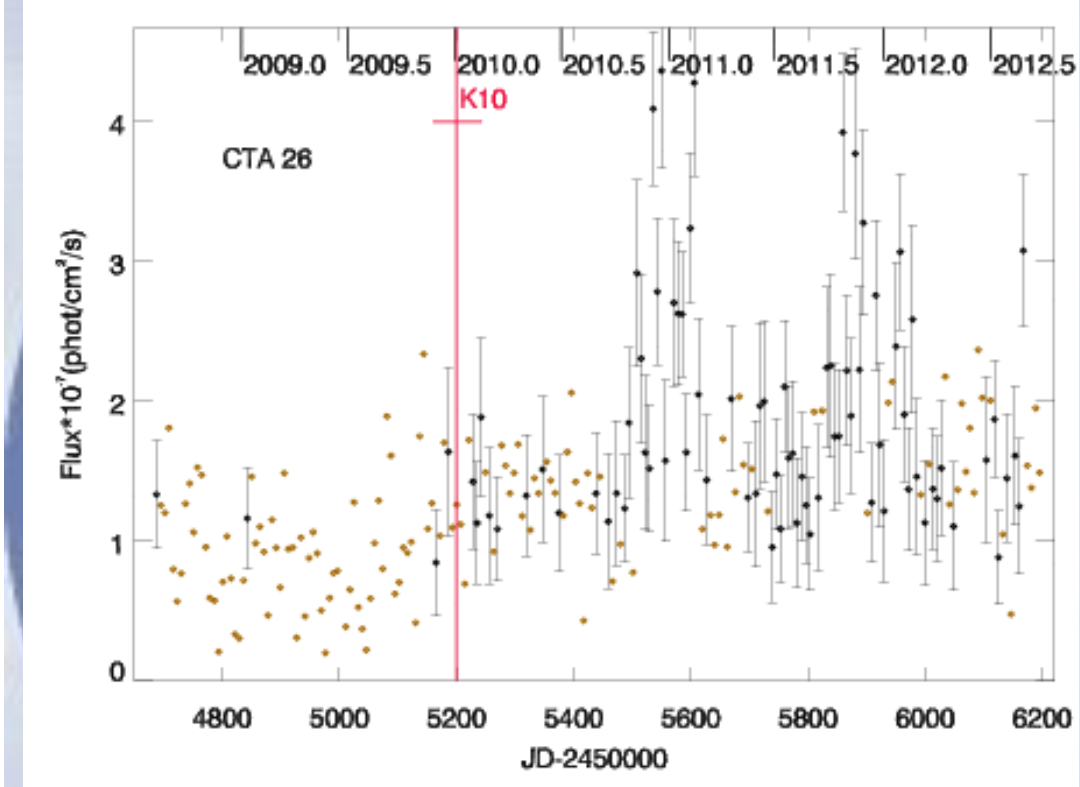
Connection of Gamma-Ray Behavior with Parsec Scale Jet Activity in 0836+71

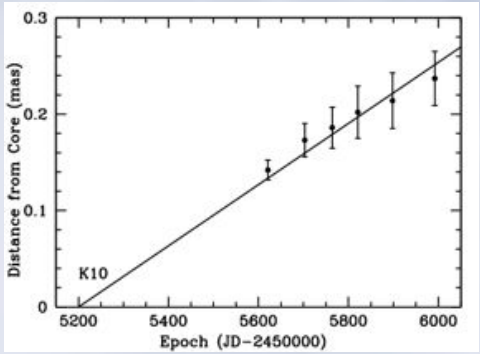




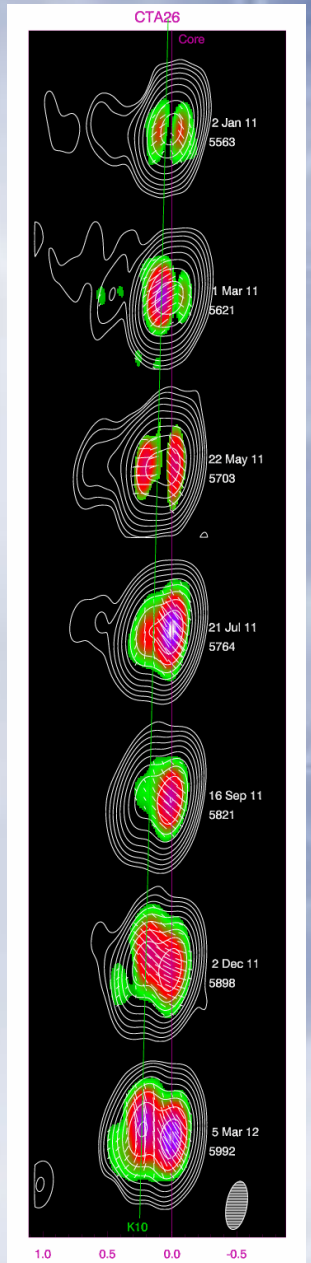


Comparison of Gamma-Ray Behavior with Parsec Scale Jet Activity in CTA26





μ=0.11±0.01mas/yr
β_{app} = 4.5±0.4c
T_o : 4 January 2010
RJD: 5200±36



T_γ^{max}: 20 December 2010 (RJD: 5550±0.5d)
S_{max} = (4.4±0.5)×10^{-7} ph cm^{-2} s^{-1}

General Statistics: Quasars

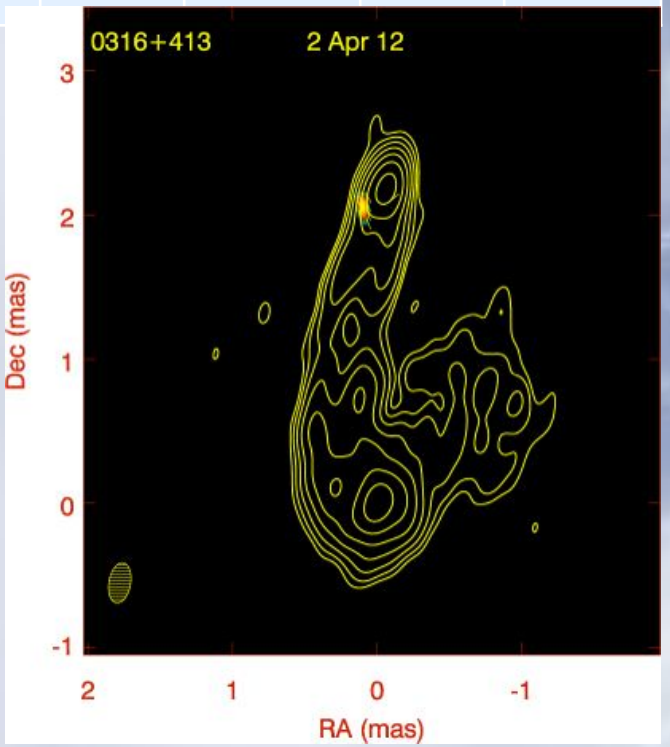
Source	Type	γ+jet	γ-jet	jet-γ
CTA26	Q	1	0	0
0420-014	Q	1	0	0
0528+13	Q	1	0	0
0827+24	Q	1	0	0
0836+71	Q	1	0	0
1127-14	Q	0	1	0
1156+29	Q	1	0	1
1222+21	Q	1	0	1
3C273	Q	4	1	1
3C279	Q	3	1	1
1406-07	Q	0	0	0
1510-08	Q	4	0	0
1611+34	Q	0	0	1

Source	Type	γ+jet	γ-jet	jet-γ
1622-29	Q	1	0	0
1633+38	Q	3	1	0
3C345	Q	3	0	1
1730-13	Q	1	0	0
CTA102	Q	0	1	1
3C446	Q	0	0	1
3C454.3	Q	2	1	0
Total	Q	28	6	8

General Statistics: BLLacs and Radio Galaxies

Source	Type	γ+jet	γ-jet	jet-γ
3C66A	BL	1	1	1
0235+16	BL	1	0	0
0716+71	BL	2	4	1
0735+17	BL	0	0	0
0829+04	BL	0	0	1
OJ287	BL	2	0	0
0954+65	BL	1	1	0
1055+01	BL	2	1	0
WCom	BL	4	1	1
1308+32	?	1	0	0
1749+09	BL	1	0	0
BLLac	BL	5	0	0
Total	BL	20	8	5

Source	Type	γ+jet	γ-jet	jet-γ
3C84	RG	0	1	1
3C111	RG	0	0	2
3C120	RG	0	0	1
Total	RG	0	1	4



Conclusions

1.We find that the majority, 73%, of γ-ray events coincide with an increase of flux in the 7 mm core and ejection of new superluminal knots.

-The coincidence rate is even higher for events with γ-ray flux $>10^{-6}$ ph cm^{-2} s^{-1} that are more common in the quasars.

- 86% of sources show simultaneous quiescent states at both γ-rays and mm-waves.

2. Multiple γ-ray outbursts in a given blazar display similar multi-waveband behavior.

3. Optical polarization behavior reveals a connection with properties of the mm-wave
core region when optical and mm-wave polarization is well sampled.

4.Our findings, along with the recent detection of the quasars 1222+216 and 1510-089 at TeV energies, favor the origin of high γ-ray states in blazars on parsec scales of relativistic jets, close to the mm-wave core.

Conclusions

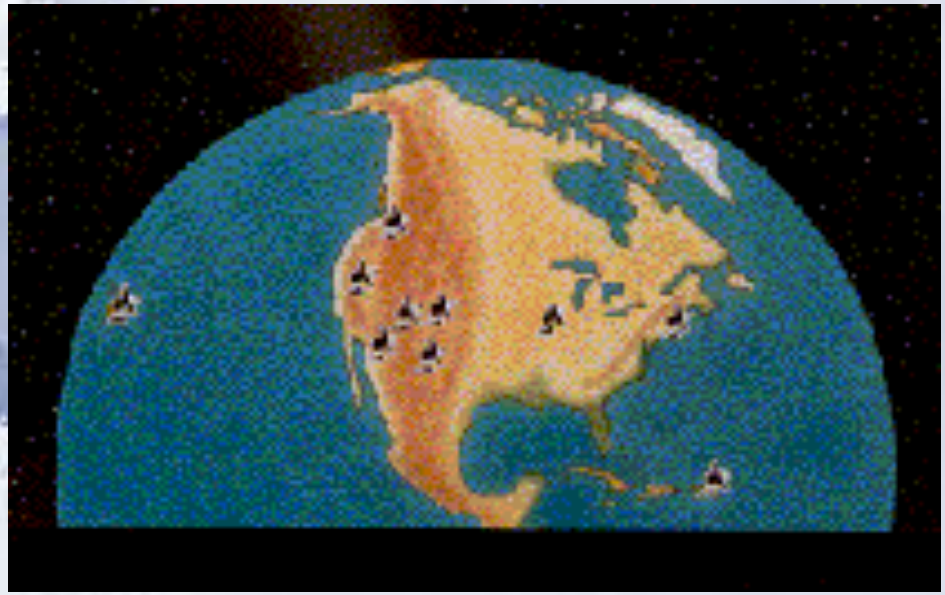
Localization of γ-ray outbursts on parsec scales is challenged by short timescales of γ-ray variability and a deficiency of external seed photons for the EC mechanism for γ-ray production, which is considered the most likely process for γ-ray production.

Our group is developing theoretical models to address these questions as well as to explain polarization behavior. Some of the models are presented at the Symposium:

a). A. Marscher #1.6 - a code, TEMZ, which calculates the non-thermal emission from turbulent plasma crossing a conical standing shock in a relativistic jet;

b).M. Joshi et al. #1.7 – an internal shock model in a relativistic jet;

c). V. Larionov et al. #6.7– a transverse shock moving in a relativistic jet with a helical magnetic field for modeling optical polarization behavior;

d). M. Malmrose et al. #6.1– measuring the properties of the dust torus in blazars.

SAVE the VLBA!!!!