The Gamma-ray Activity of the high-z Quasar 0836+710

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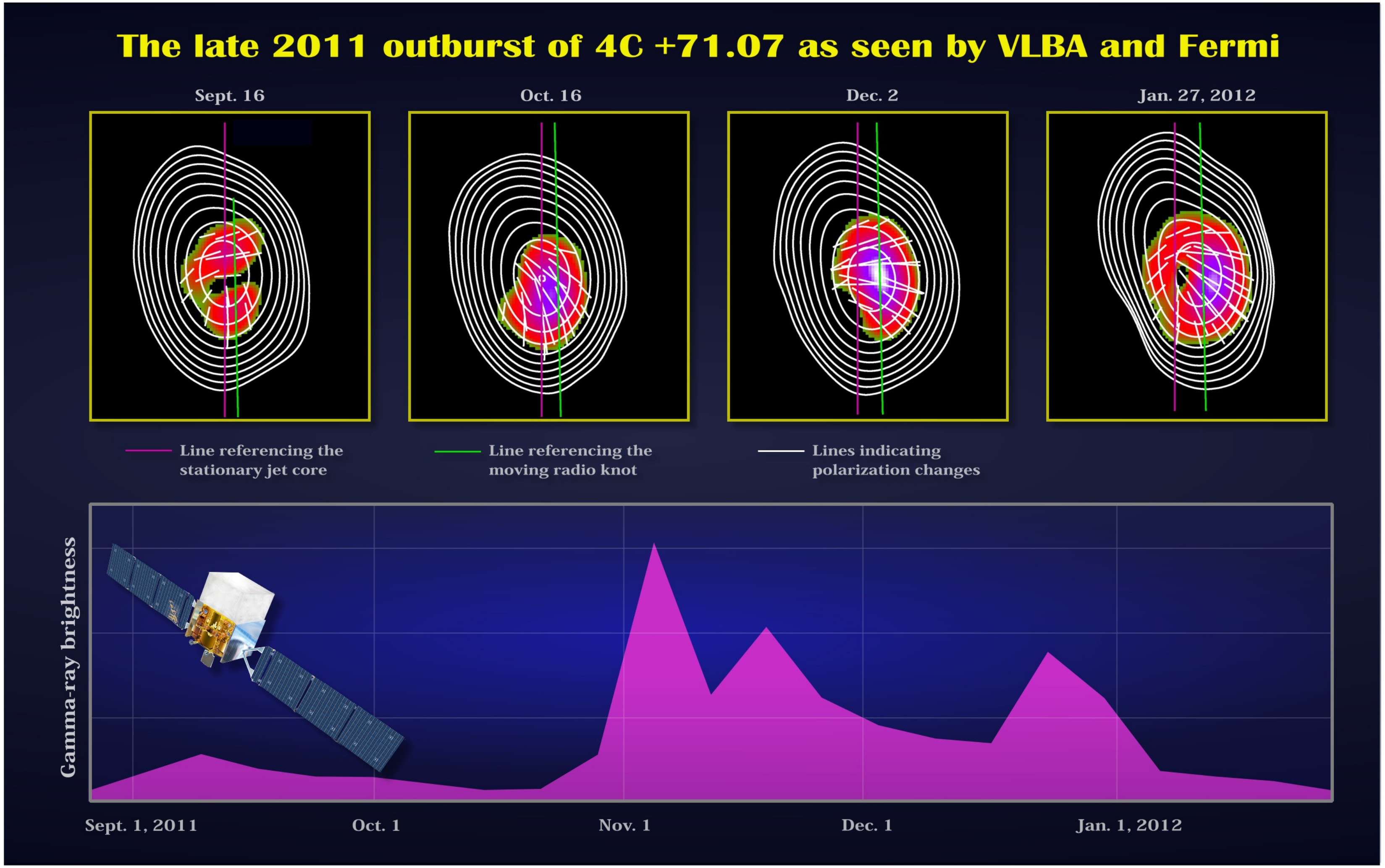

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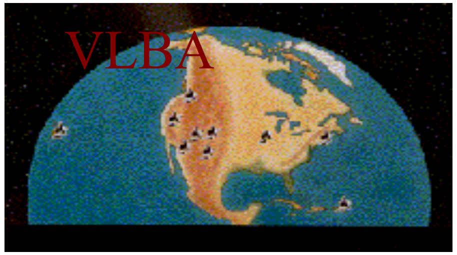
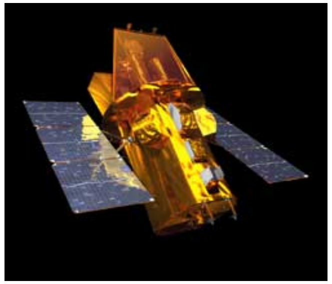
Cahill Center for Astronomy & Astrophysics: Talvikki Hovatta in behalf of the OVRO collaboration

Telescopes



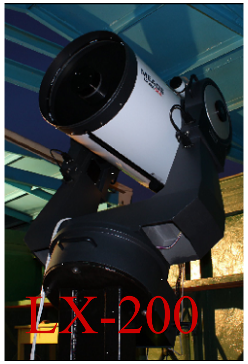
Fermi LAT



Swift XRT & UVOT

RXTE

SUZAKU

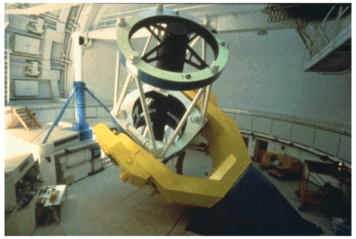


St.Petersburg, Russia

Canary Island, Spain

Flagstaff, AZ USA

Crimea, Ukraine

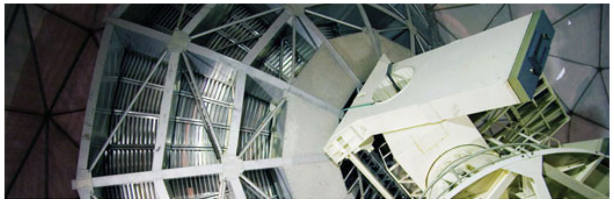


Calar Alto

Almería, Spain

Effelsberg, Germany

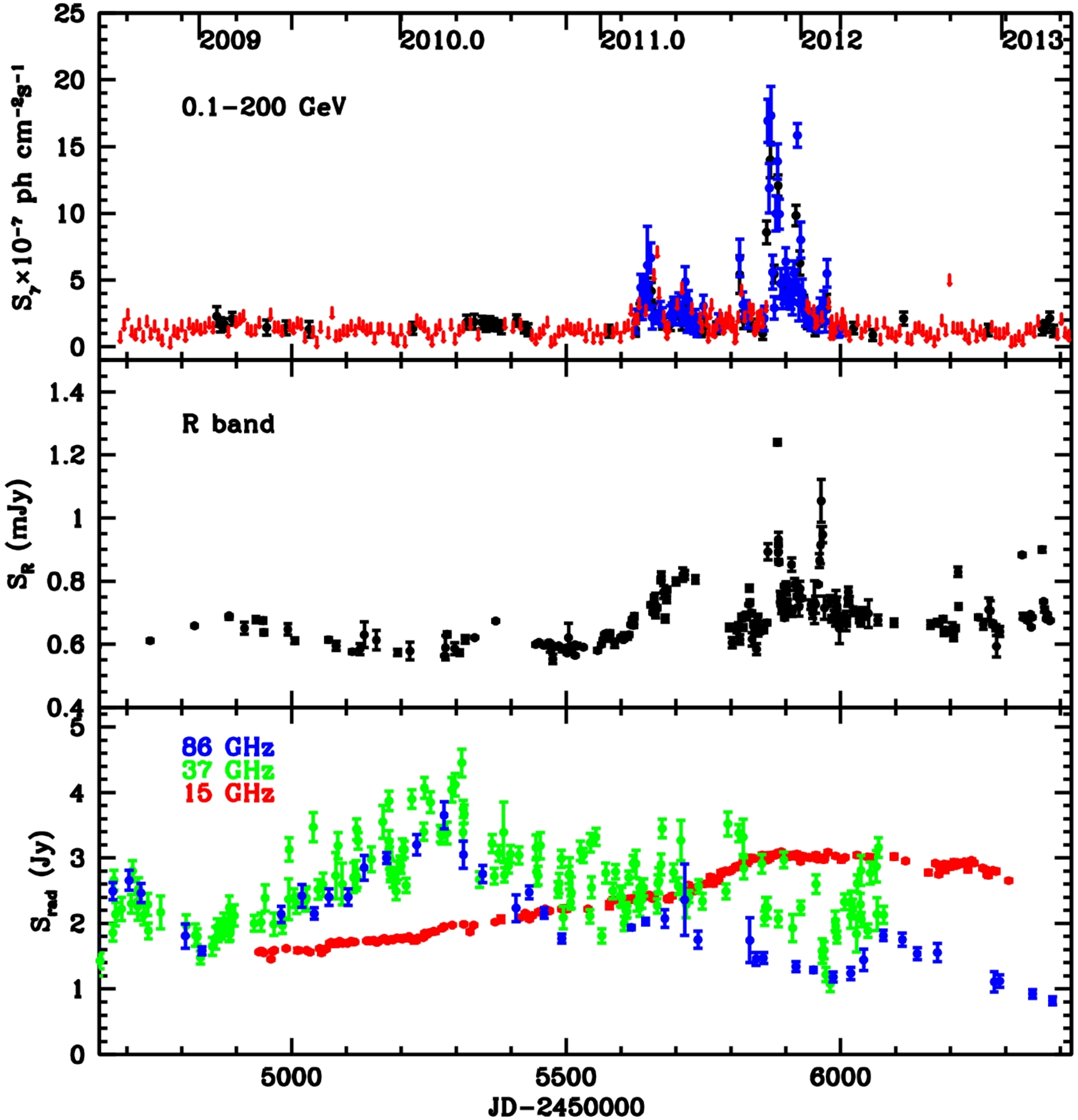
Mauna Kea, Hawaii



Metsähovi Obs., Finland

OVRO, CA USA

Outline



I. Multi-Frequency behavior of the quasar 0836+71 (4C +71.07), z=2.178

1. Gamma-ray Outburst

2. X-ray variability

3. Optical emission properties

II. Parsec Scale Jet Evolution

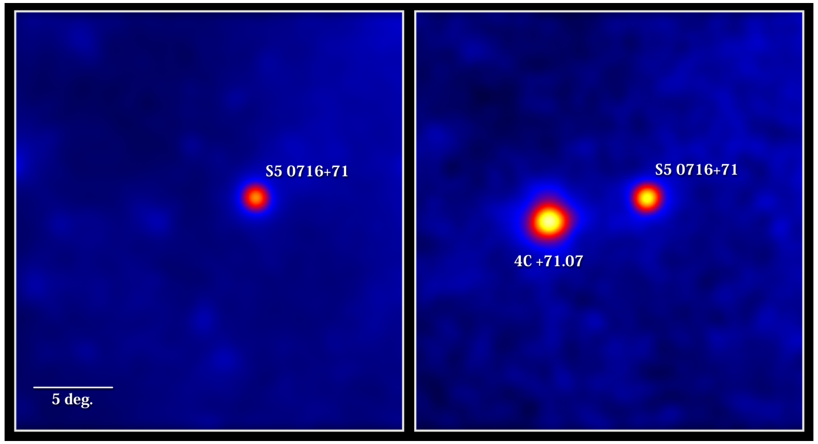
1. Jet Kinematics

2. Optical Polarization and Polarization in the Jet

3. Radio light curves

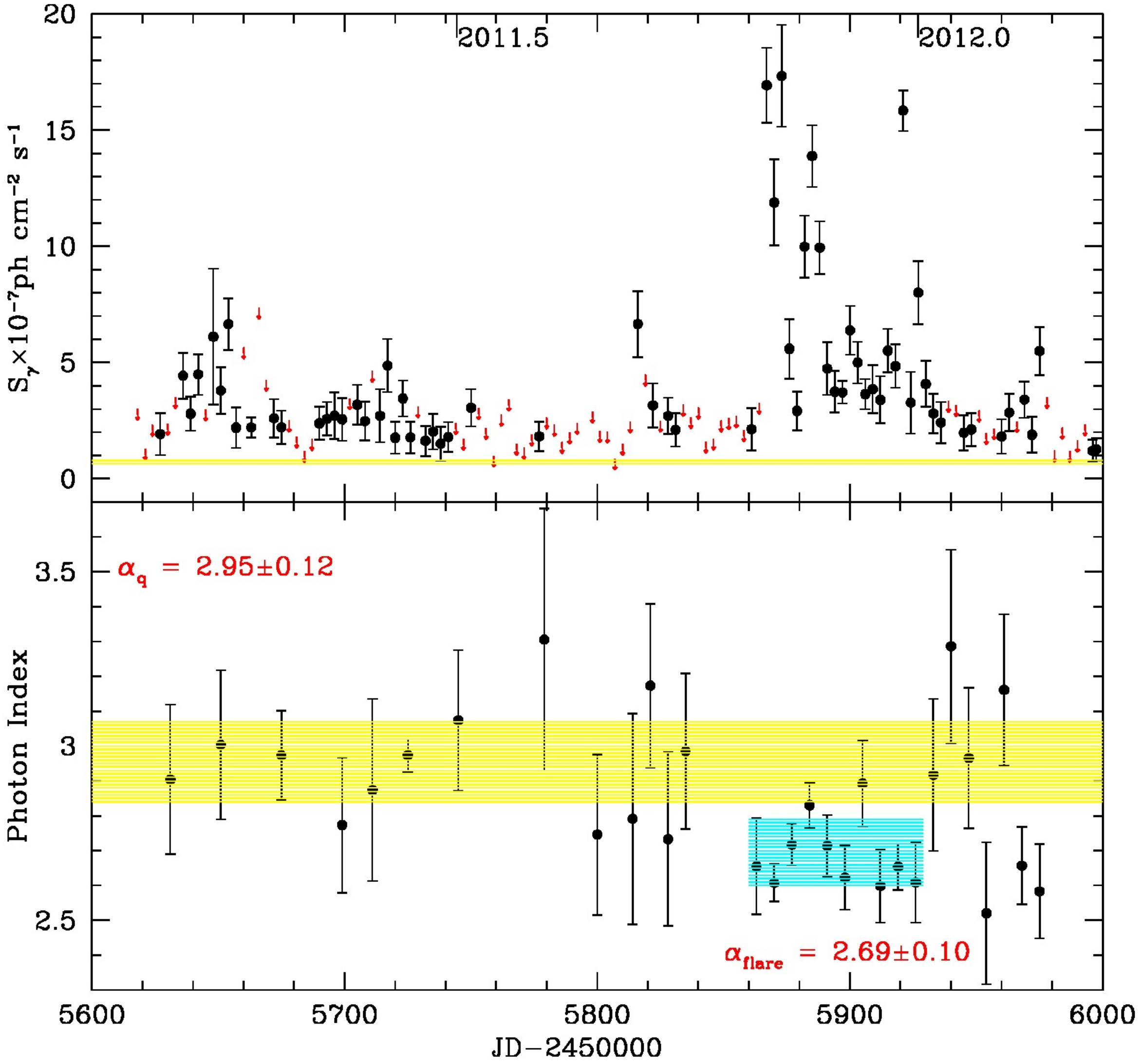
III. SEDs

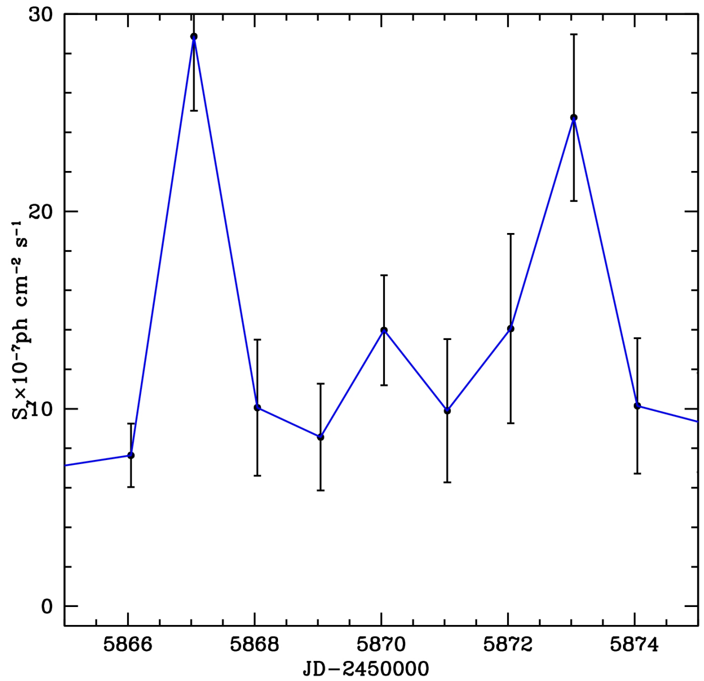
VI. Discussion & Conclusion



November, 2010 1 November, 2011

The Gamma-Ray Outburst





$T_\gamma^{start} \sim 5626$ *(5 March 2011)*

$S_\gamma^{max} = (28.9 \pm 0.38)\times 10^{-7}\ ph/cm^2/s$

$S_{2FLG} = (1.8 \pm 0.7)\times 10^{-8}\ ph/cm^2/s$

$T_\gamma^{max} = 5867.047$ *(1 November, 2011)*

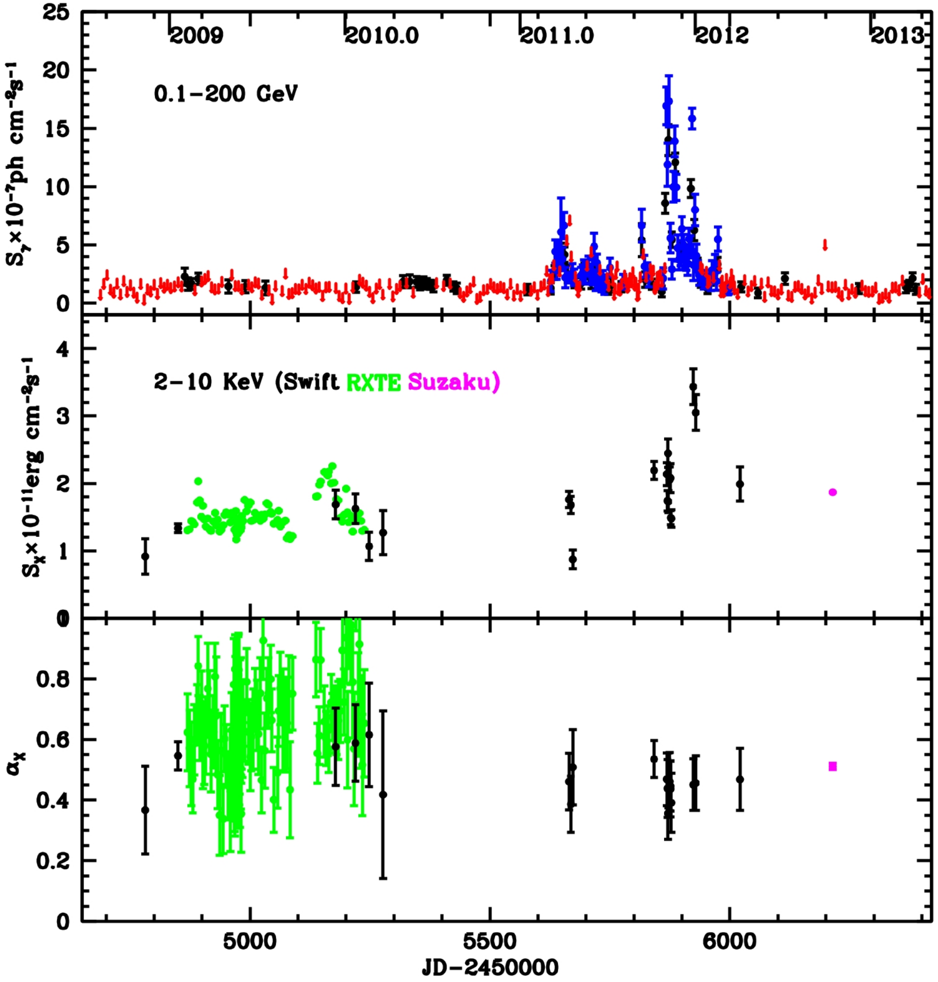
$\tau_\gamma^{min} = 10.6hr$ *(doubling time)*

$f = 3.78$ *in 18.1 hr*

$L_\gamma = (1.09 \pm 0.16)\times 10^{49}\ ergs/s$

$D_L = 17.875\ Gpc$

X-Ray Variability



$N_H = 2.9\times10^{20}\ cm^{-3}$ (Kalberla et. 2005)

$S_x^{max} = (3.43 \pm 0.27)\times10^{-11}\ ergs/cm^2/s$

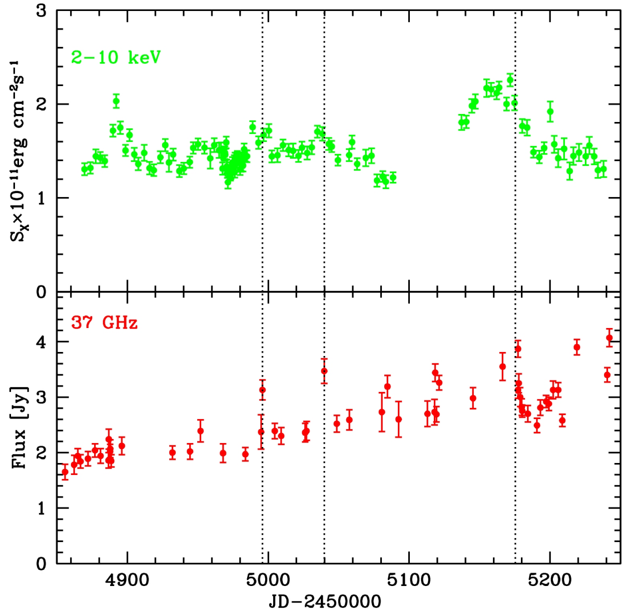
$T_x^{max} = 5923.4855\ (T_\gamma^{max} = 5867.0473)$

$\tau_x^{min} = 13hr\ \ f=1.4$:

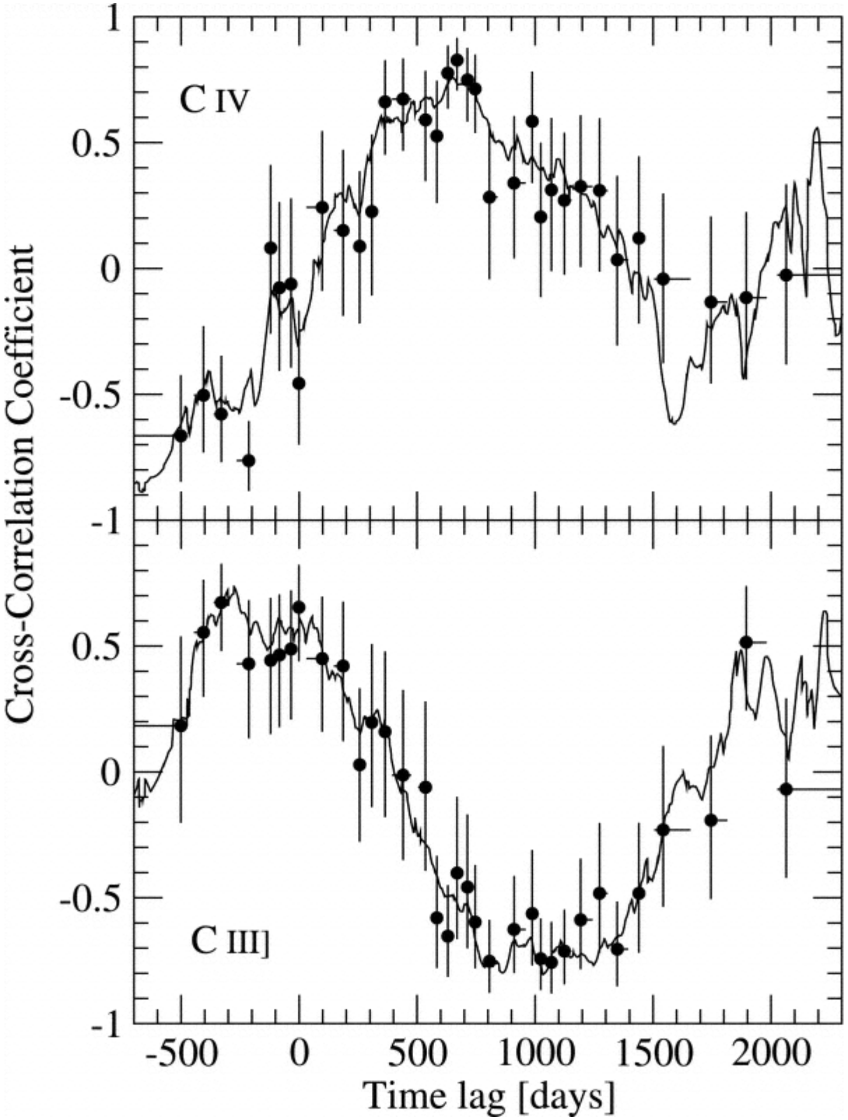
$5876.1276\ \ (2.08 \pm 0.22)\times10^{-11}\ ergs/cm^2/s$

$5876.6658\ \ (1.49 \pm 0.10)\times10^{-11}\ ergs/cm^2/s$

$L_x = (1.23 \pm 0.10)\times10^{48}\ \ ergs/s$



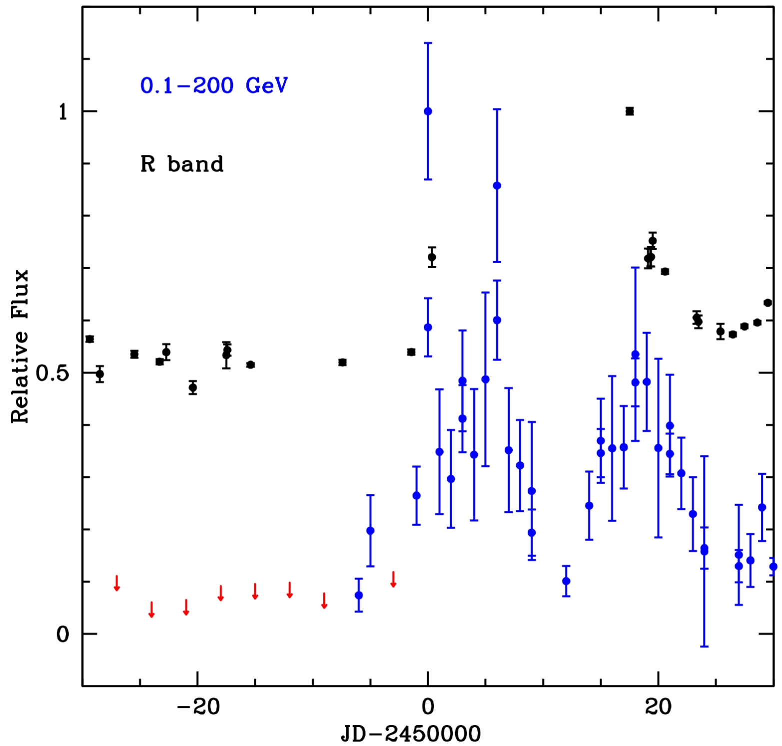
Optical Properties I

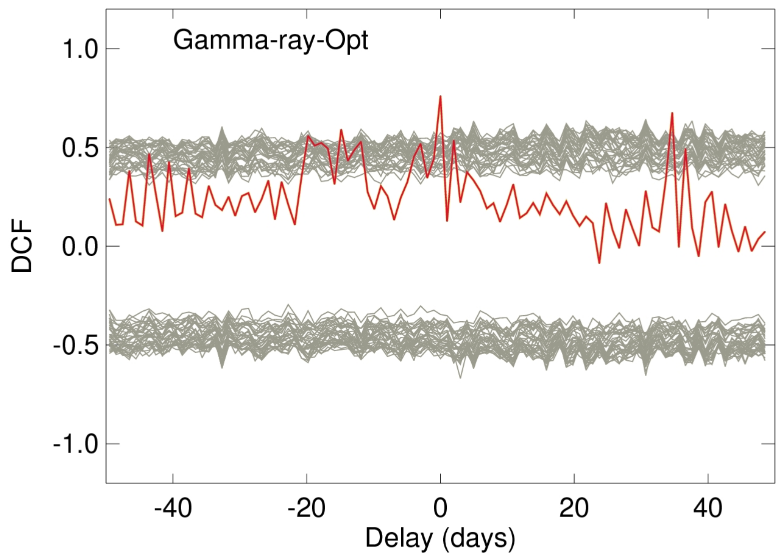


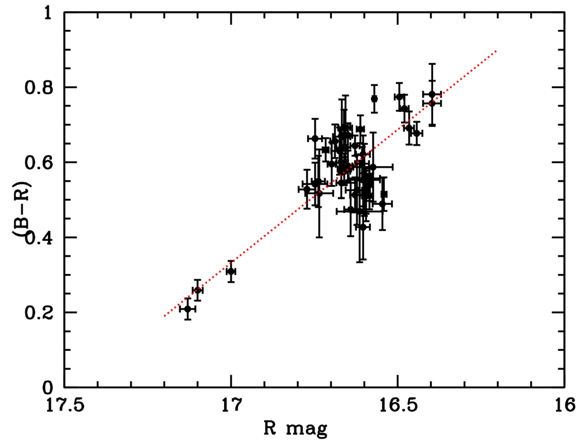
Kaspi et. al 2007:
$S_{CIV} = (2.36 \pm 0.57) \times 10^{-14}$ *ergs/cm²/s*
$FWHM_{CIV} \sim 9700$ *km/s*
Time Lag: 595 (+85,-110)days
188 (+27,-37)days
$M_{BH} \sim 2.6 \times 10^{9} M_{sun}$
λL_{λ} *(1350Å)* $= (1.12 \pm 0.16) \times 10^{47}$ *ergs/s*
$L_{disk} \sim 3.6 \times 10^{47}$ *ergs/s*
$L_{bol}/L_{Edd} \sim 0.9$
From CIV FWHM and UV luminosity
Vestergaard & Peterson (2006)
$M_{BH} \sim 1.8 \times 10^{10} M_{sun}$

Cross-correlation function between the continuum and the emission lines CIV and CIII]

Optical Properties II







$S_X^{max} = 1.239 \pm 0.009$ *mJy*

$T_X^{max} = 5884.565$ ($T_\gamma^{max} = 5867.0473$)

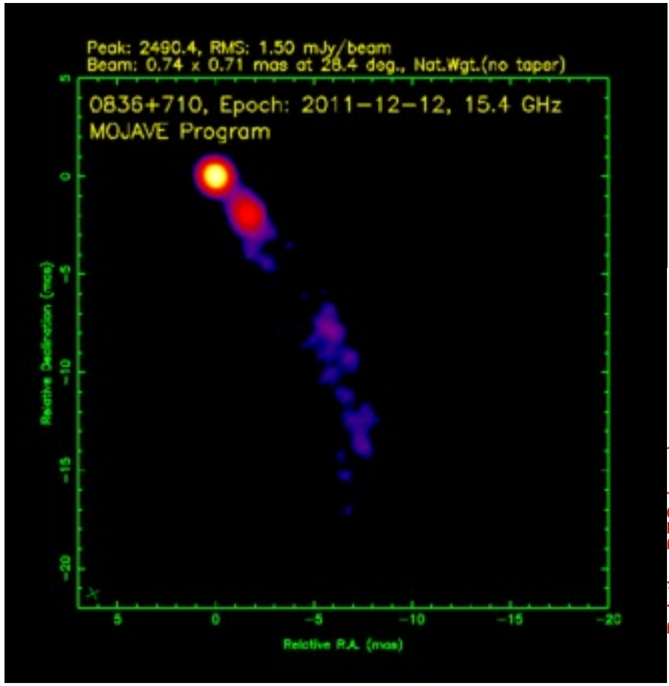
$\tau_X^{min} = 1.56$ *day* $f = 1.4$:

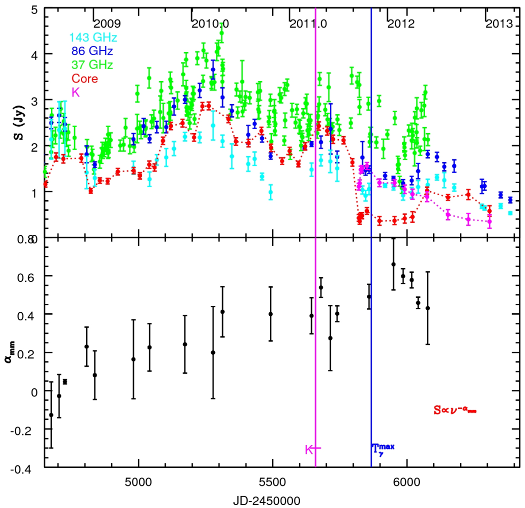
RJD: 5884.565 - 5886.156

Method of separation thermal and synchrotron components: Hagen-Thorn et al. #25

Parsec Scale Jet of the Quasar 0836+714

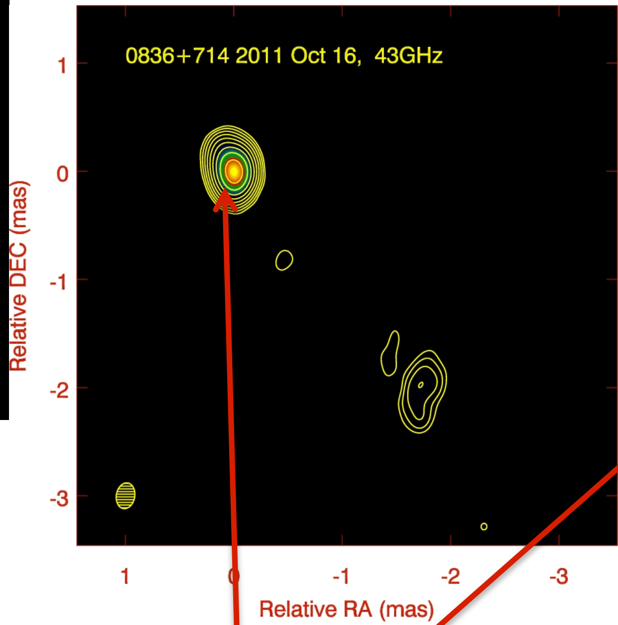
2 cm



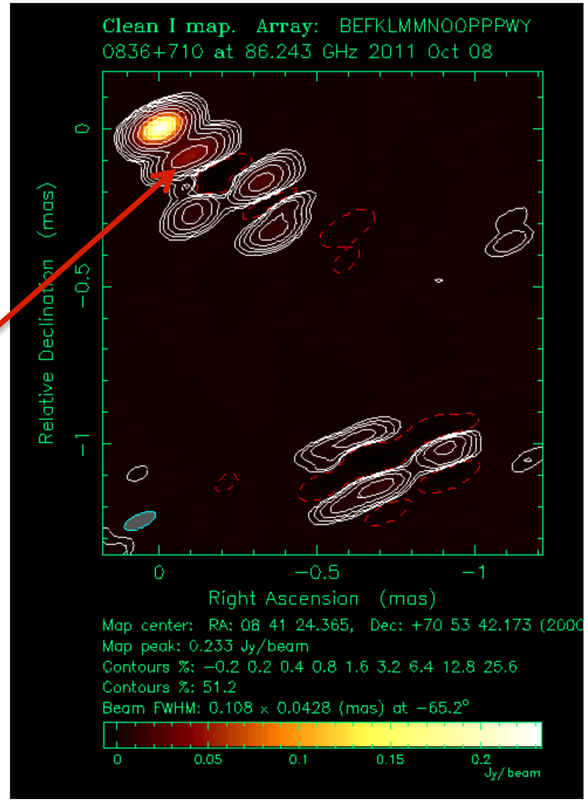


1 mas = 8.39pc

7 mm

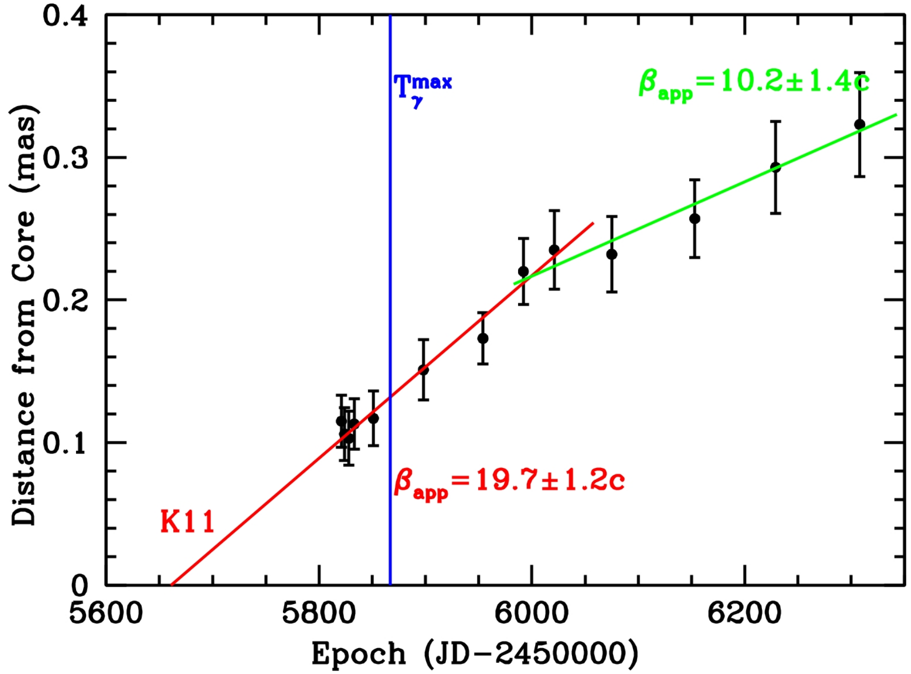


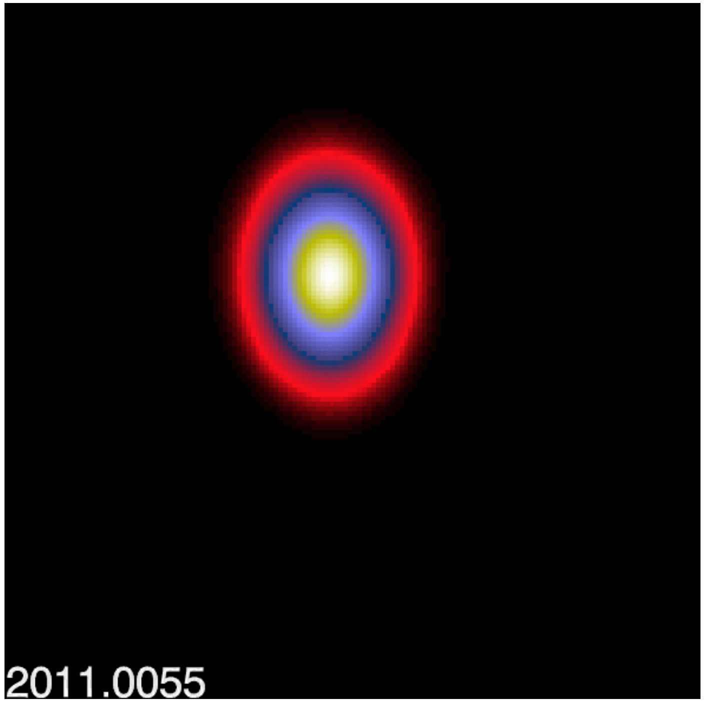
3 mm

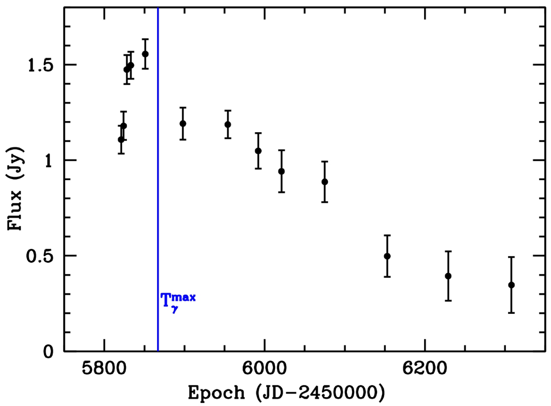


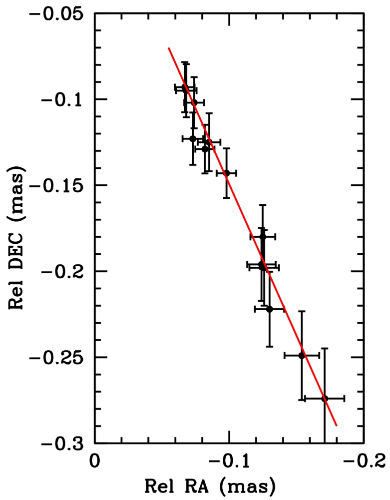
K11

Parsec Scale Jet Kinematics









K11:

$\mu = 0.234 \pm 0.014 mas/yr$

$T_o = 2011.27 \pm 0.02$

$\beta_{app} = 19.7 \pm 1.2c$

$\Gamma \sim 19.8$ ($\Gamma_{slow} \sim 12$)

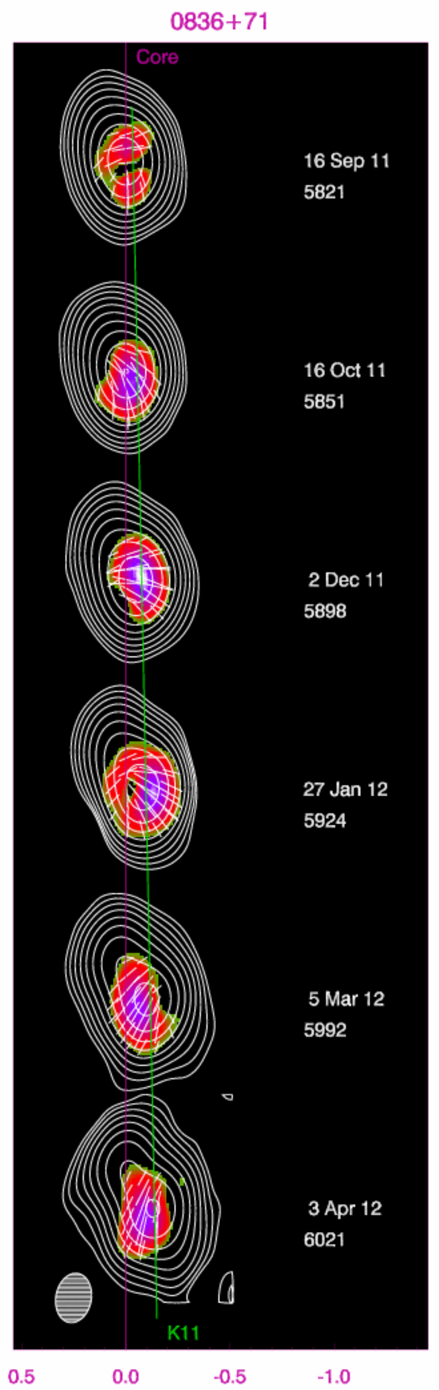
$\delta \sim 21.3$

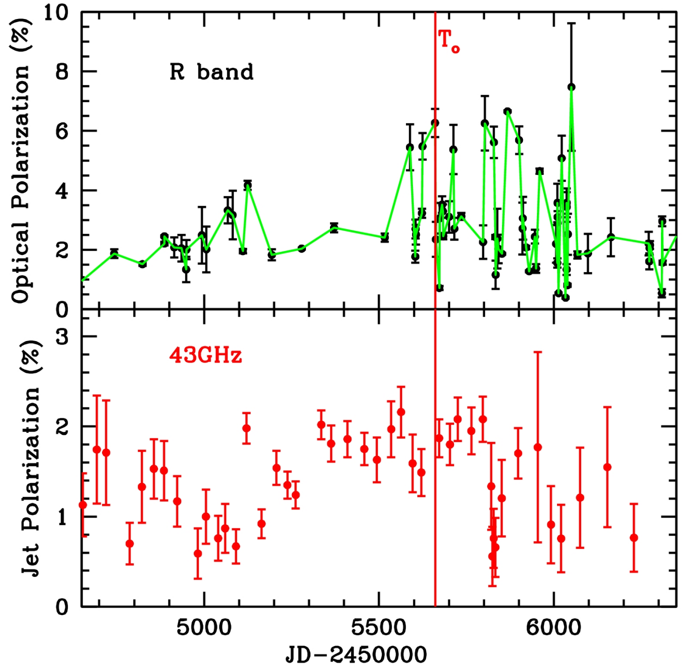
$\Theta_o \sim 2.7^o$

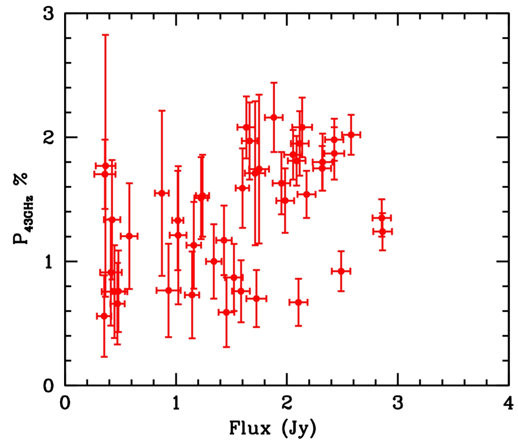
$\tau_{var} \sim 0.7yr$

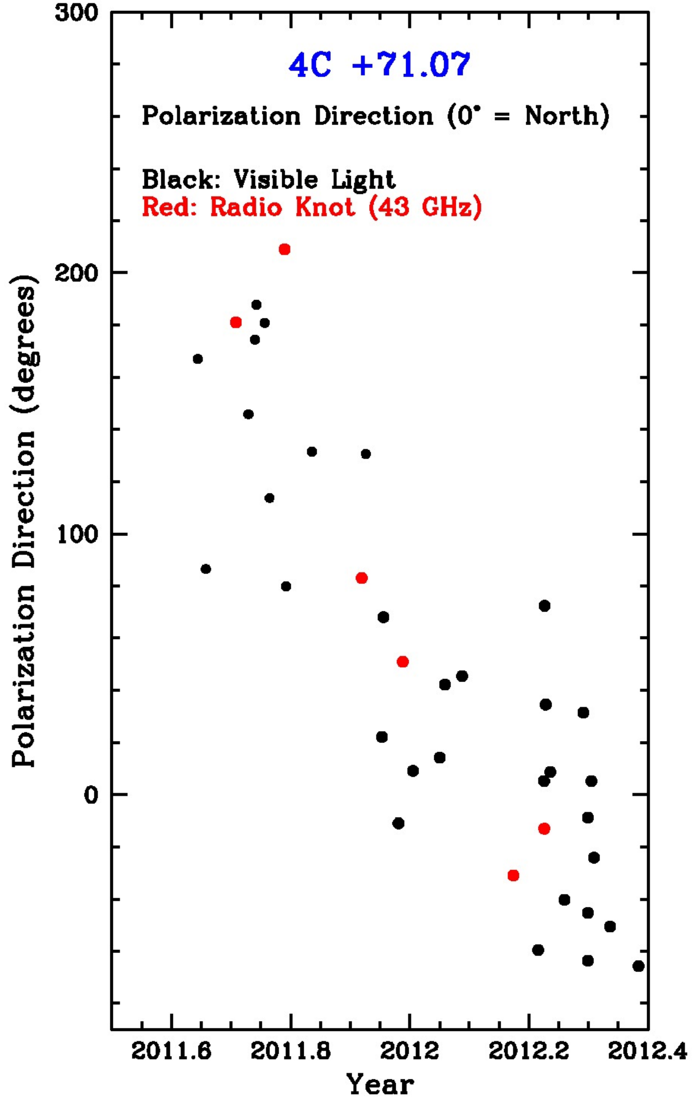
$a \sim 0.08mas$

Optical Polarization & Polarization in the Inner Jet



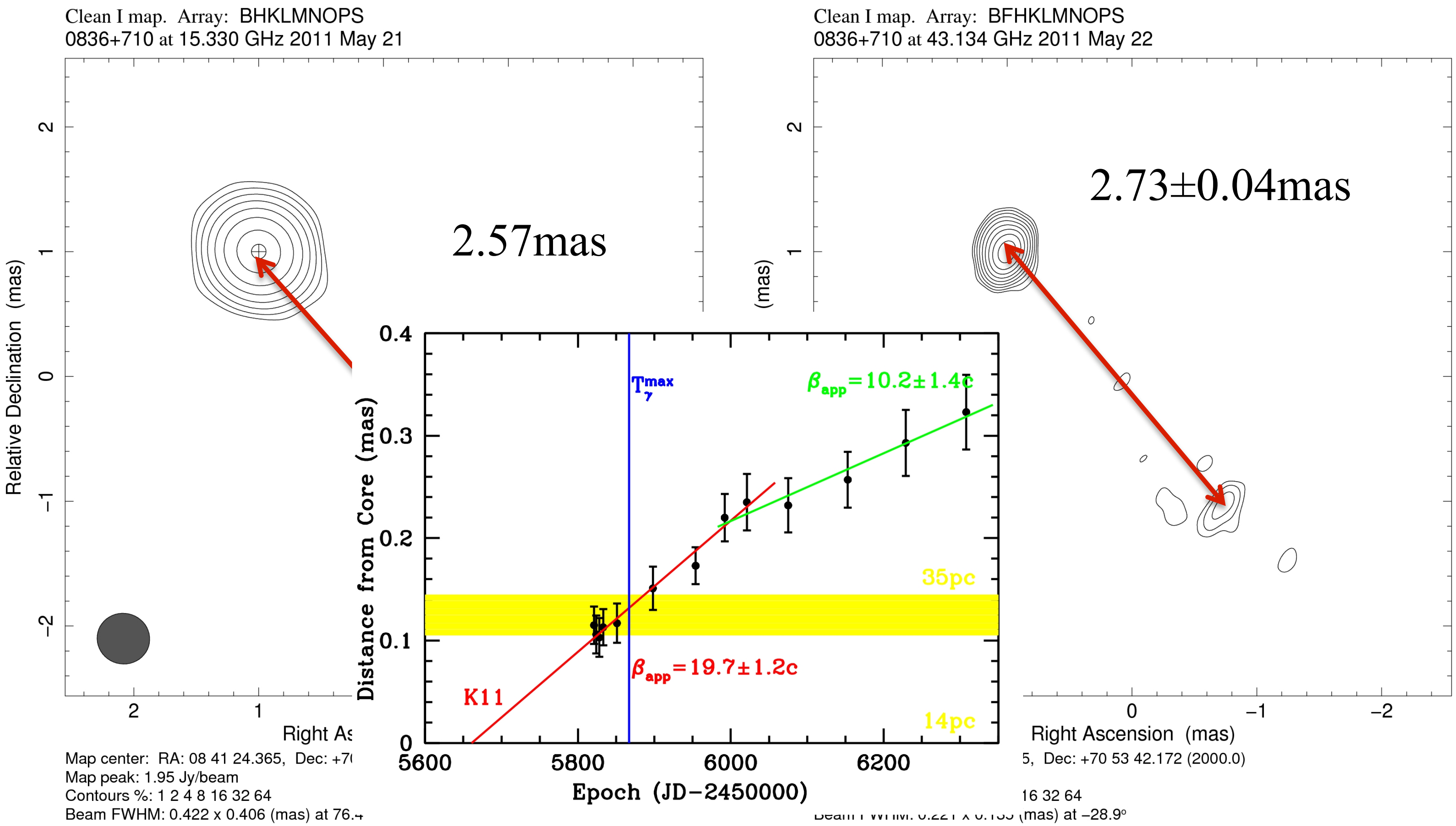






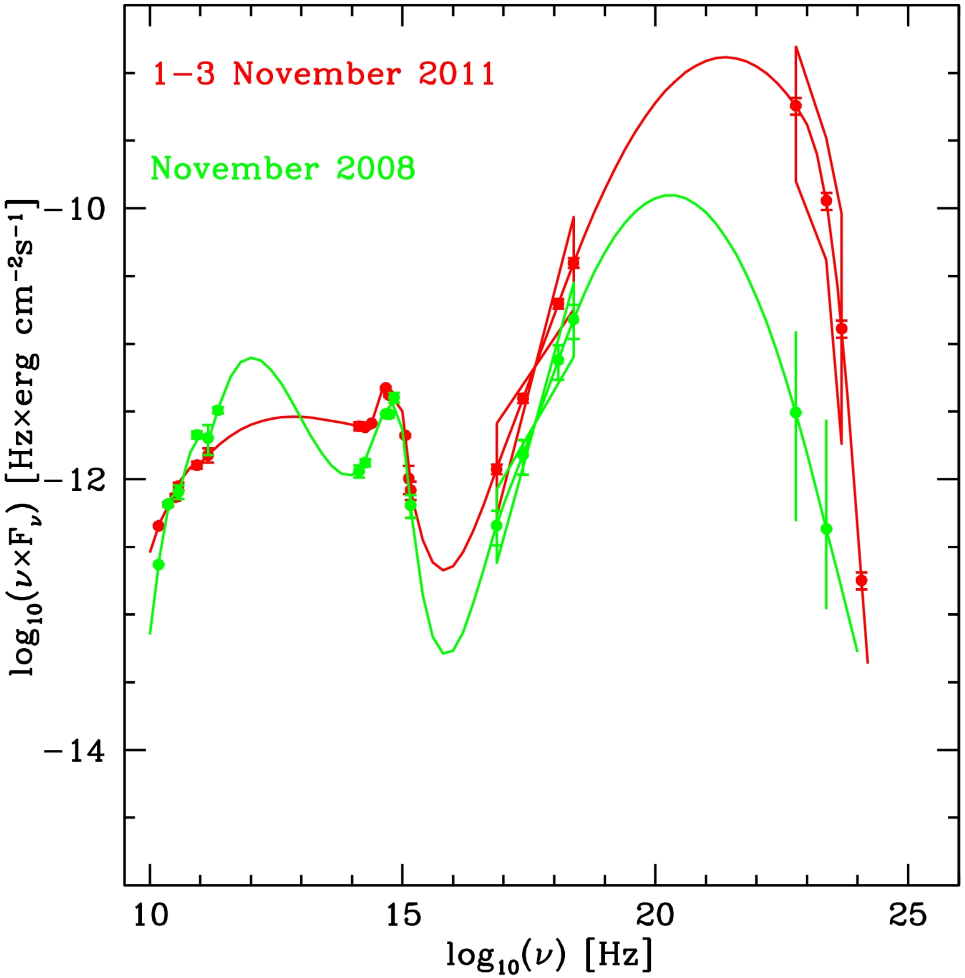
Larionov et al. 2013 ApJ

43GHz-15GHz Core Shift



Pushkarev et al. 2012: a distance from the BH to the 15 GHz Core ~42.5pc
a shift between the 15 and 43 GHz Cores ~ 0.16mas

Spectral Energy Distribution



Z=2.178

$L_\gamma = (1.09 \pm 0.16)\times 10^{49}$ ergs/s

$L_{disk} \sim 3.6 \times 10^{47}$ ergs/s

$L_X = (1.23 \pm 0.10)\times 10^{48}$ ergs/s

$L_{SSC} \sim L_X$

$L_{SYN} \sim 5.4 \times 10^{47}$ ergs/s

$\tau_{var,,obs} \sim 0.5$ day

$\Gamma \sim 19.8$

$\delta \sim 21.3$

Chatterjee, Nalewajko, & Myers 2013 ApJ, submit:

r – distance of γ-ray outburst with respect to BH

θ – opening angle of the jet

$\Gamma = f1\ (r,, \theta)$

$\Gamma = f2\ (r,\ L_{SSC},\ q)$

q-Compton dominance parameter

$q = L_\gamma / L_{SYN}$; $\xi \sim 0.3$

$$r = 2\Gamma^4 (\delta/\Gamma)^2 \,[1/3\, (L_{SSC}/L_{SYN})(\xi L_{disk}/L_\gamma)]^{1/2}\, [c\tau_{var,,obs}/(1+z)] = 15.8 \text{ pc}$$

Conclusions

1. The quasar 0836+71 had an active γ-ray state from March 2011 to March 2012, with the highest flux on November 1, 2011 when the γ-ray luminosity reached $(1.09 \pm 0.16)\times10^{49}$ ergs/s
2. The start of the γ-ray activity coincides with the appearance of the superluminal knot in the parsec scale jet with $\Gamma\sim20$. The peak of the γ-ray emission occurred within the brightest state of the knot, and the γ-ray outburst stopped as the knot decelerated to $\Gamma\sim12$.
3. Optical polarization behavior reveals a connection with properties of the mm-wave core region when the knot was within 0.3 mas of the core.
4. The γ-ray variations correlate with optical variations without a measurable delay.
5. We connect the active γ-ray state with the superluminal knot propagating down the jet from the mm-wave core located ~14 pc from the central engine.

Morozova et al. # 33

Troitsky et al. # 34

SAVE the VLBA!!!!