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Home

Blazars, the most extreme variety of active galactic nuclei (AGN) and the most luminous long-lived individual objects in the universe, continue to pose major astrophysical puzzles. This international conference will be devoted to recent progress in observational and theoretical aspects of blazars and advances in our understanding of the "big picture" of the blazar phenomenon.

Blazars radiate across the electromagnetic spectrum from radio to gamma-ray frequencies. Observations of

Topics to be discussed include:

- Jet formation, dynamics, and astrometry
- Probes of blazar jets with the finest angular resolution through EHT, mm-VLBI, and RadioAstron observations
- Multi-wavelength studies of blazars from theory and observations
- Magnetic fields and polarization
- Non-blazar AGN jets

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The connection between the radio jet and the γ-ray emission in the radio galaxy 3C120 and the blazar CTA102

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Fermi Symposium, Washington, November 9-13, 2015

The connection between the radio jet and gamma-ray emission in 3C120

We have analyzed Fermi-LAT data collected between August 2008 and August 2014.

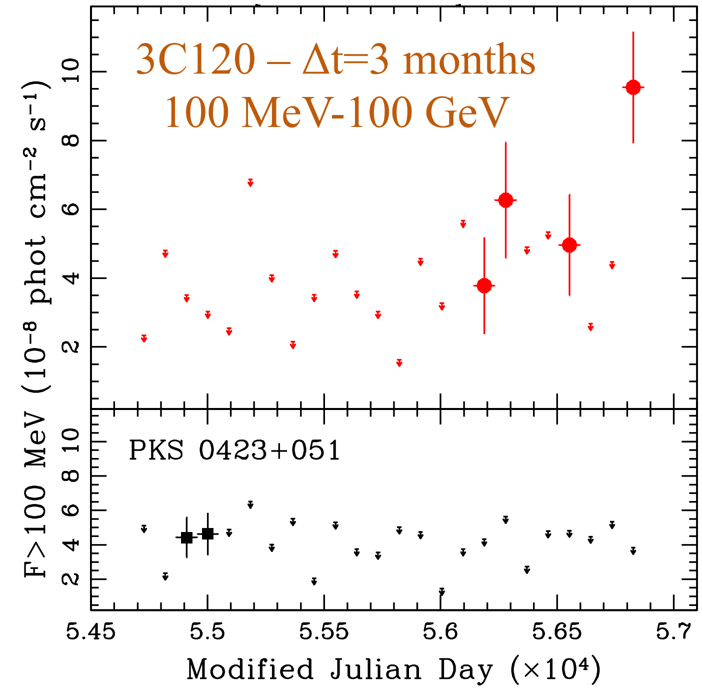
The light curve in the 100 MeV-100 GeV band and a bin size of 3 months shows four detections with TS>10.

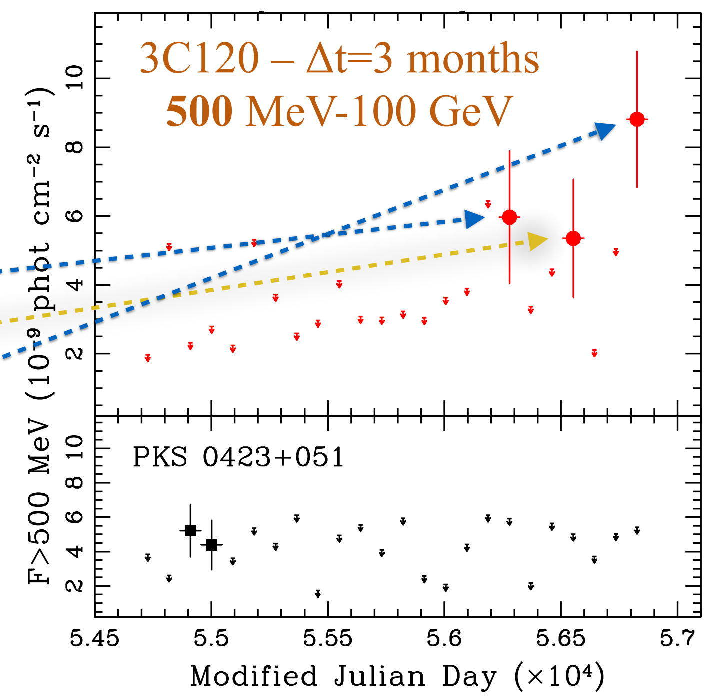
A FSRQ, PKS 0423+05, is located at ~1.6 degrees from 3C120. These sources are detected in different periods suggesting negligible mutual contamination.

The light curve with energy >500 MeV, with a PSF smaller than the separation between the two sources, confirms our detections and negligible contamination.

Detections in the energy range **500 MeV-100 GeV** with a bin size of **15 days**

MJD	Date	Flux	Err	TS
56264-56279	2012 Dec 03-2012 Dec 18	1.41	0.60	10.6
56549-56564	2013 Sep 14-2013 Sep 29	1.65	0.54	21.6
56564-56579	2013 Sep 29-2013 Oct 14	1.31	0.53	13.3
56774-56789	2014 Apr 27-2014 May 12	1.15	0.52	10.4
56819-56834	2014 Jun 11-2014 Jun 26	1.47	0.59	13.8
56924-56939	2014 Sep 24-2014 Oct 09	2.52	0.86	18.4



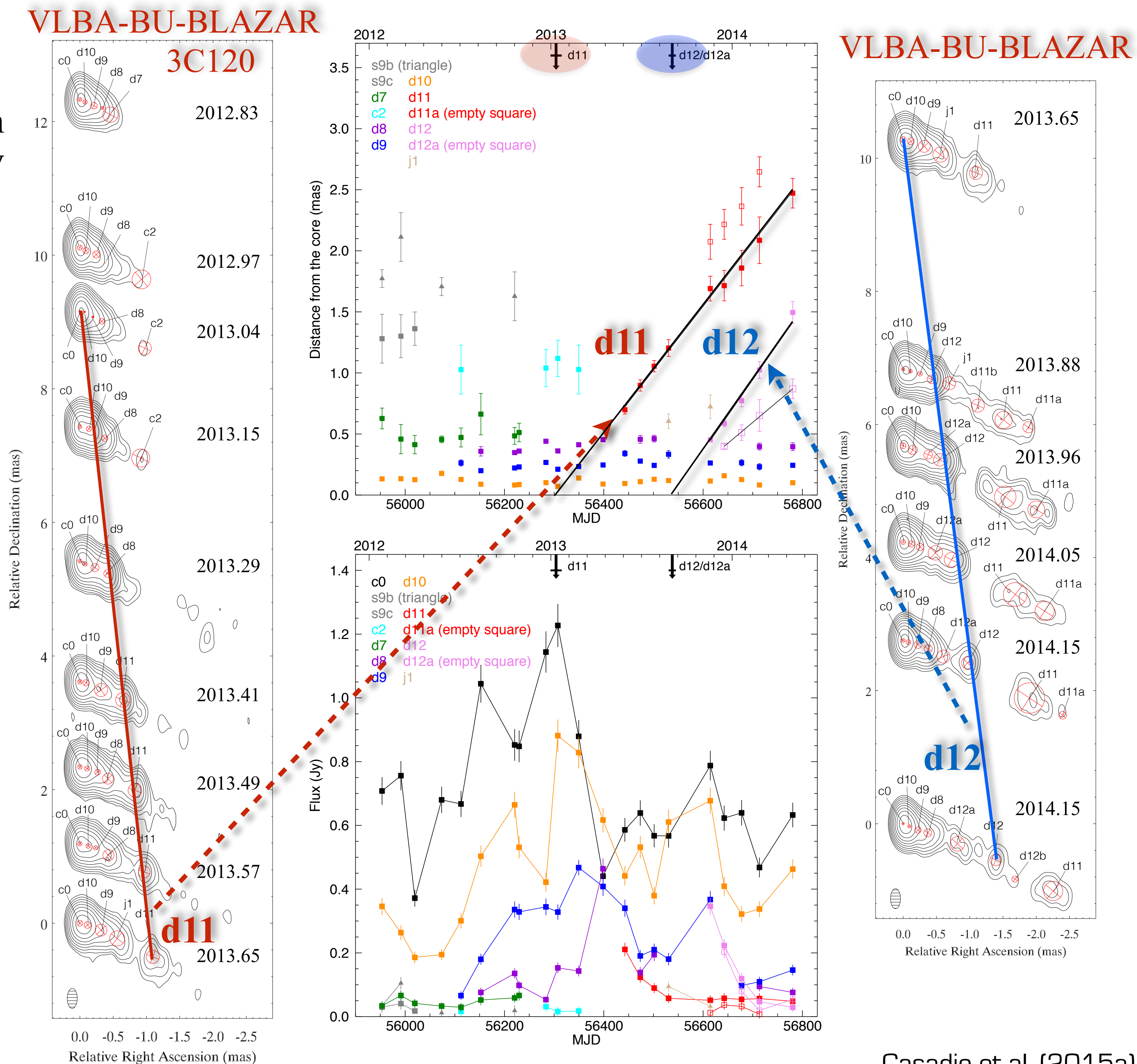


Casadio et al. (2015a)

The connection between the radio jet and gamma-ray emission in 3C120

VLBA-BU-BLAZAR

21 epochs between January 2012 and May 2014.



Casadio et al. (2015a)

THE CONNECTION BETWEEN THE RADIO JET AND GAMMA-RAY EMISSION IN 3C120

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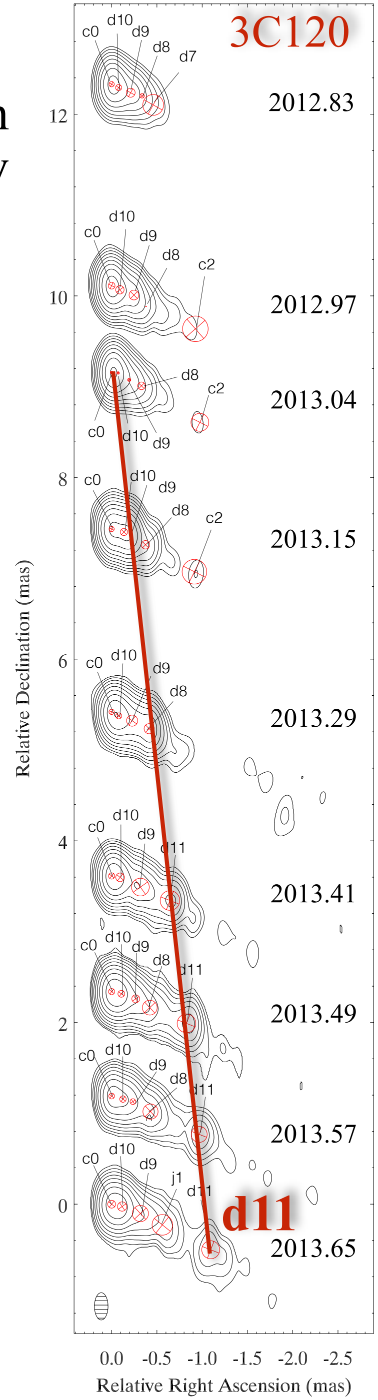
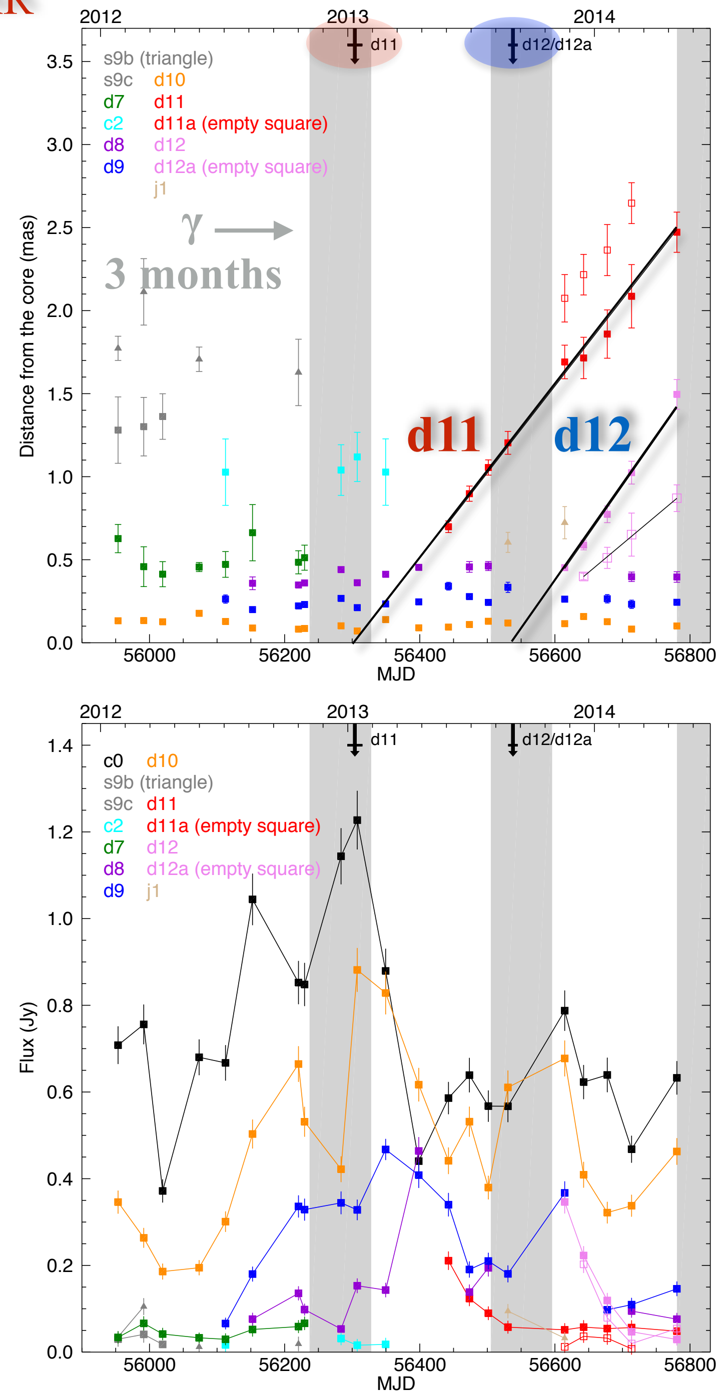
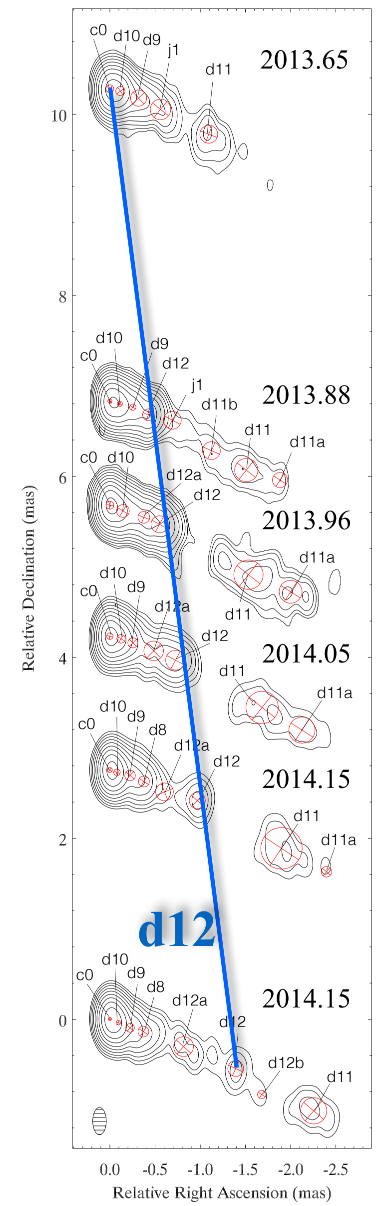




VLBA-BU-BLAZAR



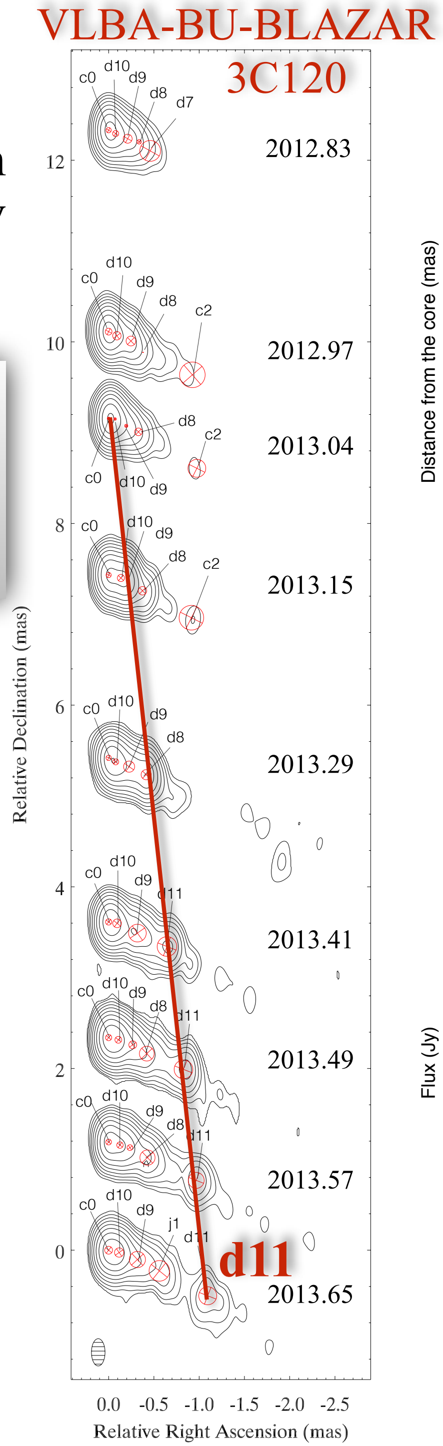
Casadio et al. (2015a)

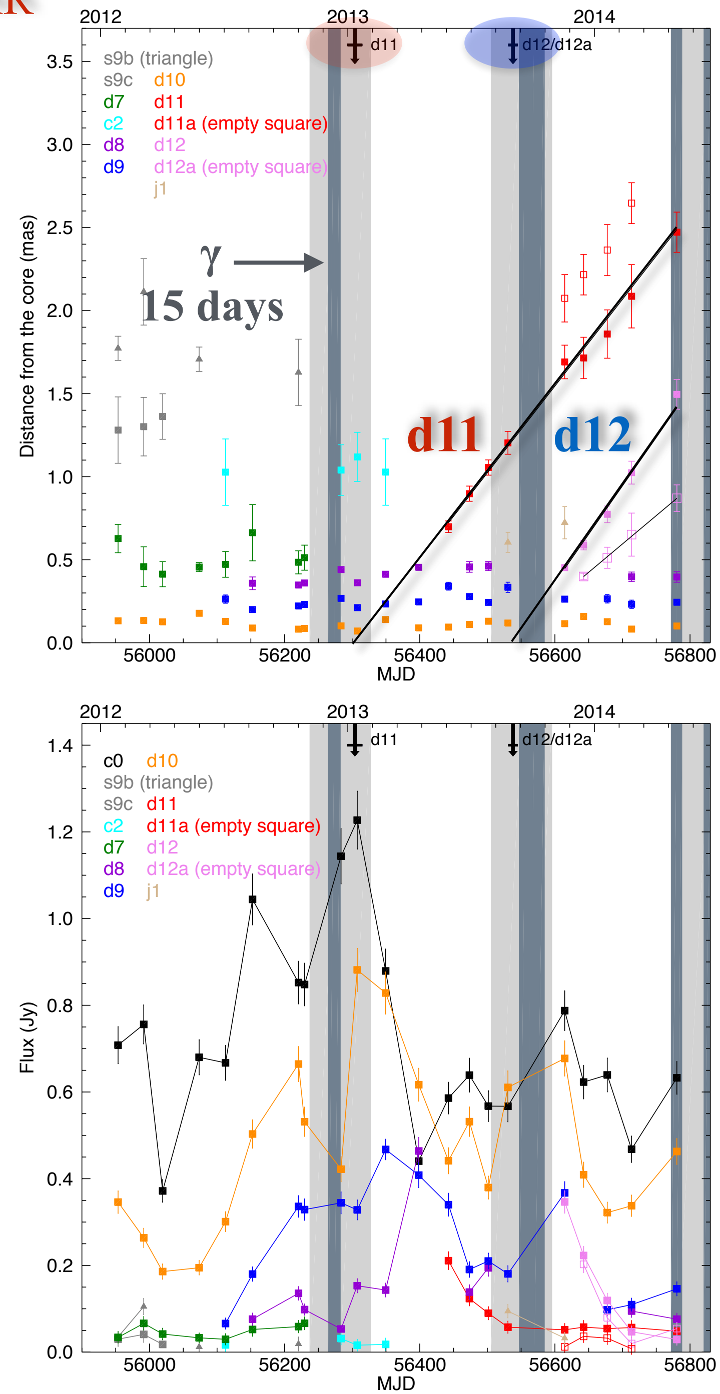
THE CONNECTION BETWEEN THE RADIO JET AND GAMMA-RAY EMISSION IN 3C120

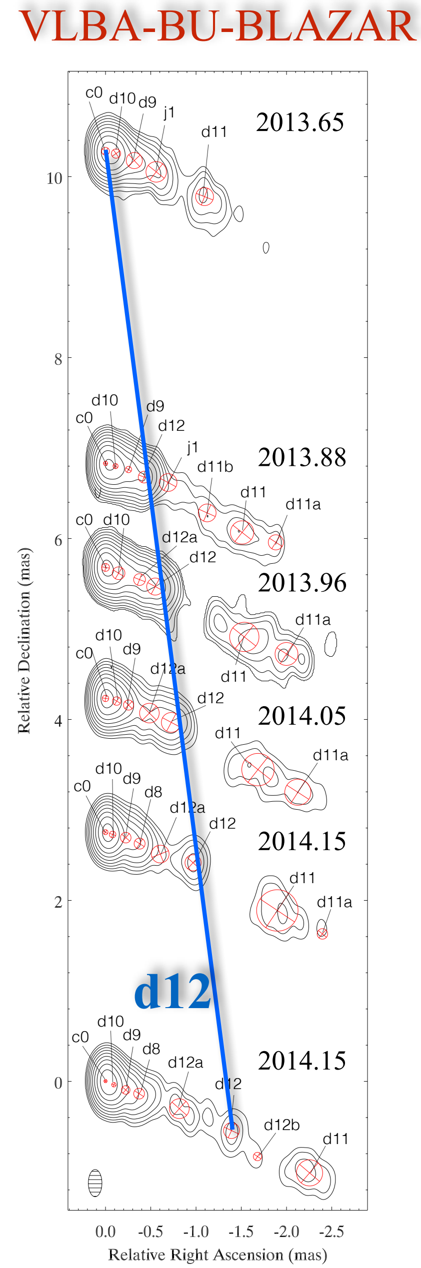
VLBA-BU-BLAZAR

21 epochs between January 2012 and May 2014.

γ-ray detections are ***always*** associated with the ejection of a new component.







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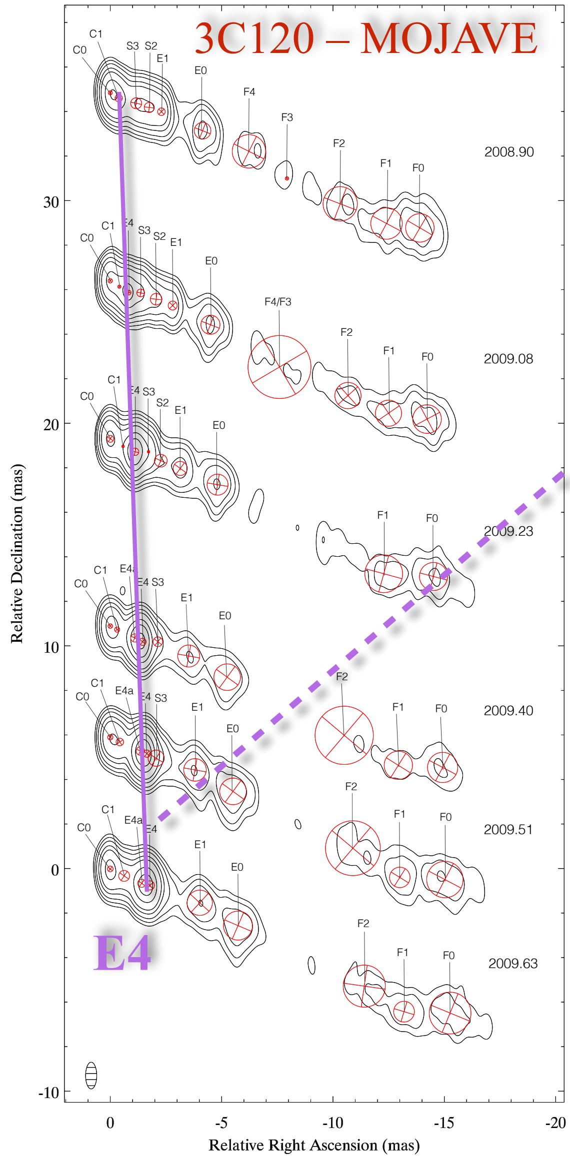
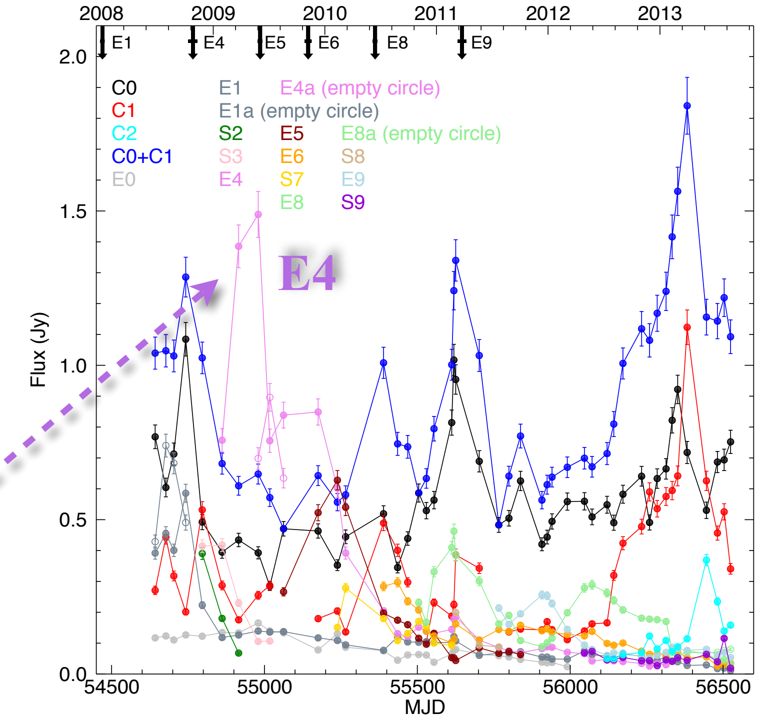
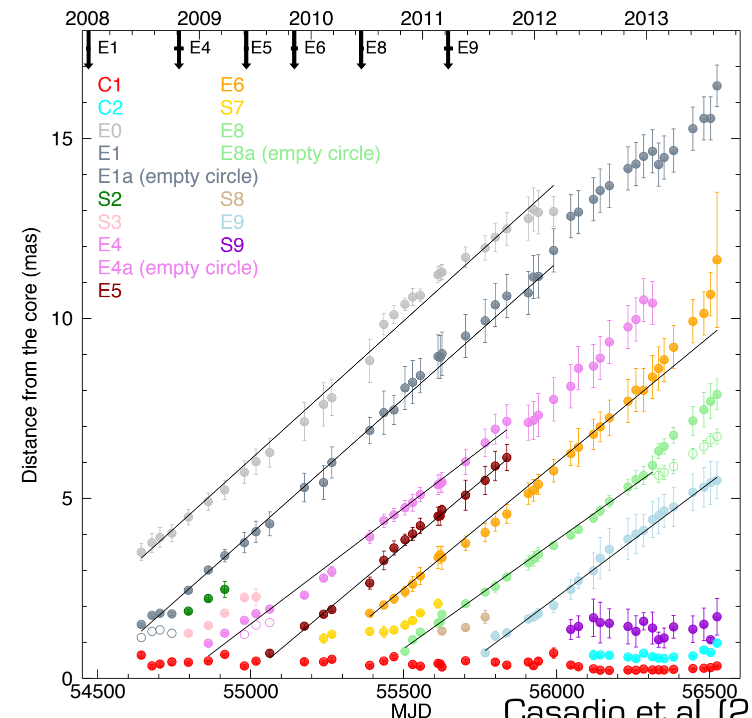


MOJAVE 15 GHz VLBA.

46 epochs between June 2008 and August 2013.





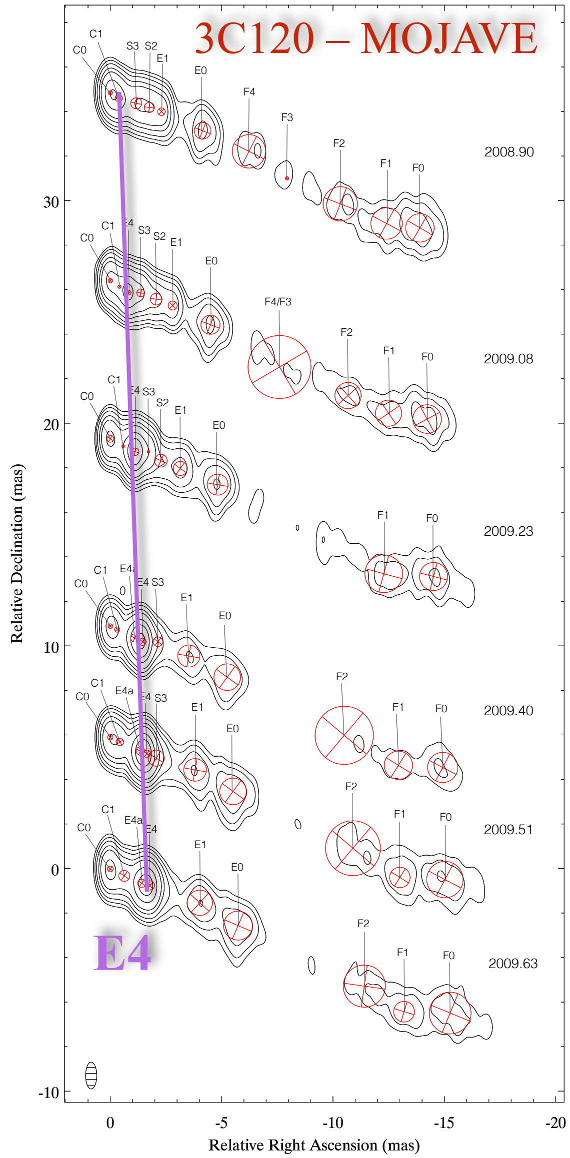
Casadio et al. (2015a)

VLBA-BU-BLAZAR

21 epochs between January 2012 and May 2014.

γ-ray detections are ***always*** associated with the ejection of a new component.

However, as seen for component E4, not all ejections lead to enhanced γ-ray emission.



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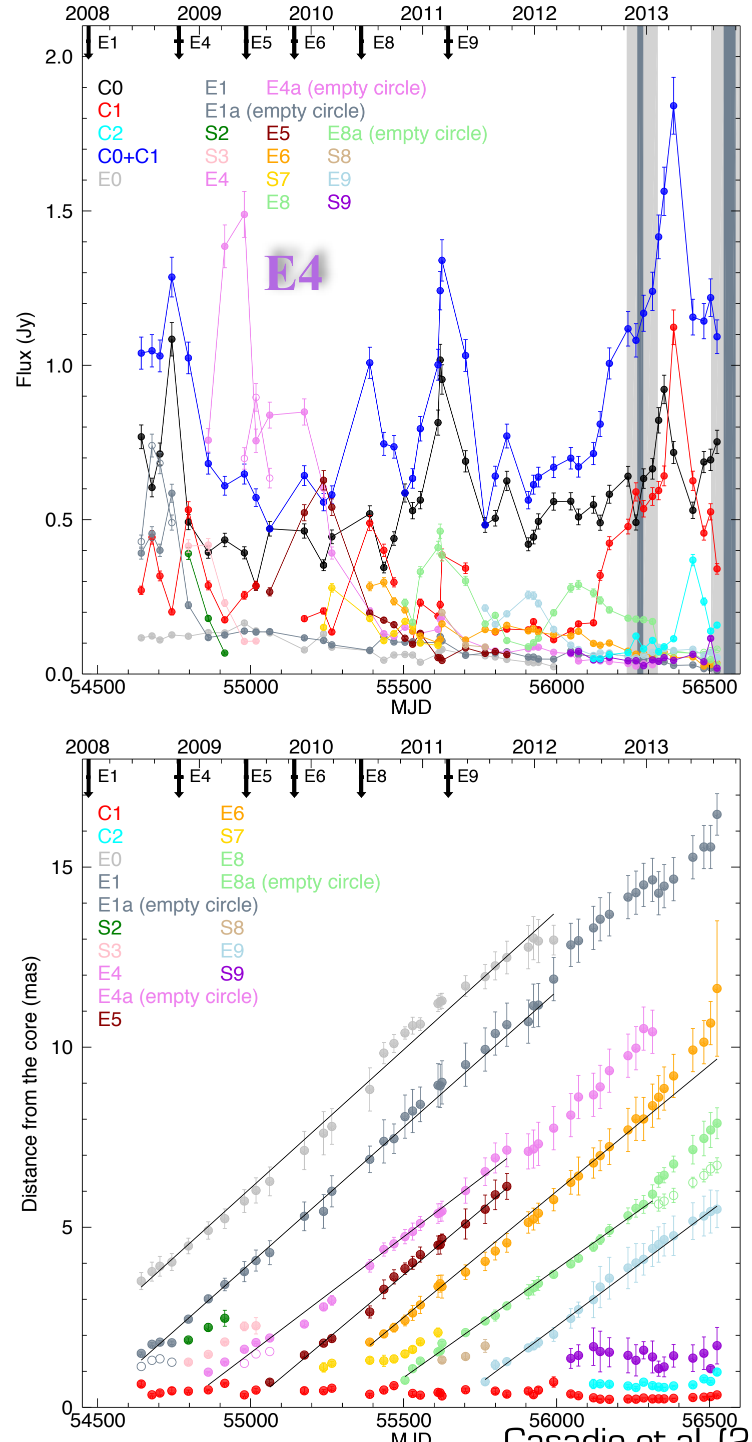


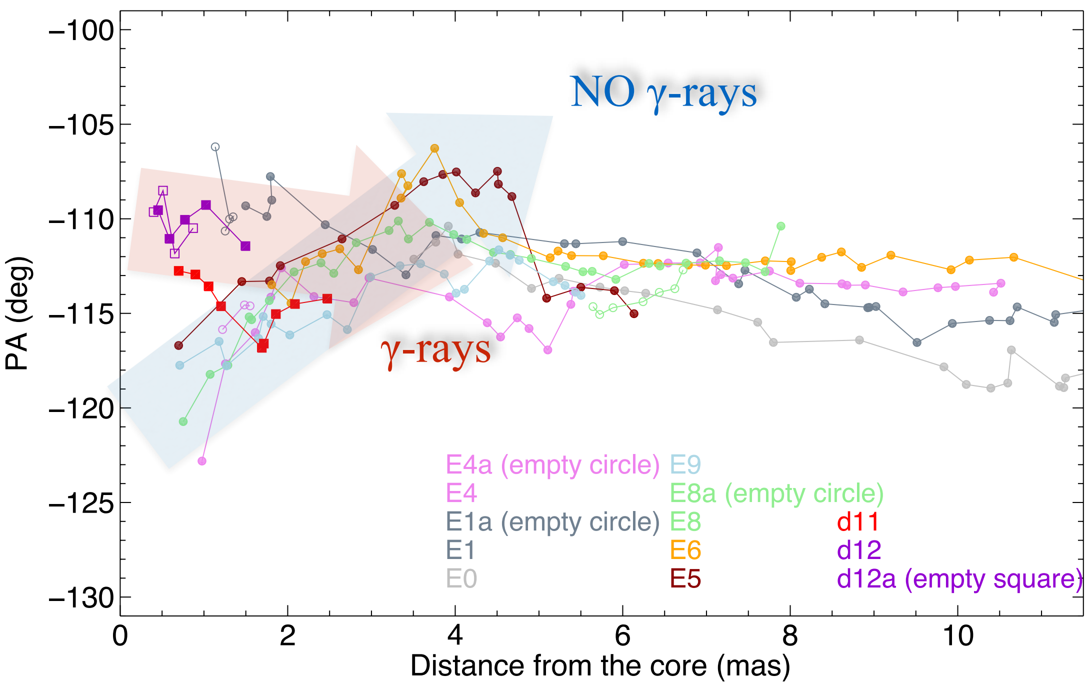
Casadio et al. (2015a)

The connection between the radio jet and gamma-ray emission in 3C120

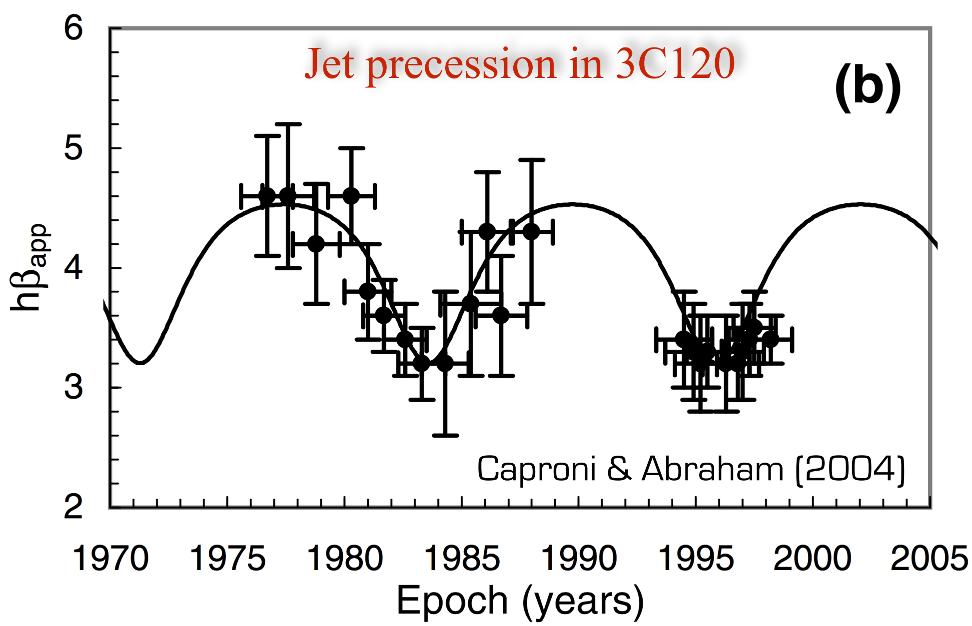
Components show a progressive decrease in apparent velocity in a time span of ~6.4 years, about half of the precessing period of 12.3 yrs estimated by Caproni & Abraham (2004).

Furthermore, components are ejected at different position angles, suggesting that the variation in apparent velocity is due to a change in viewing angle.

Name	T_{ej} (year)	μ (mas/yr)	β_{app}
VLBA 15 GHz			
E0	2007.29 ± 0.06	2.81 ± 0.05	6.21 ± 0.11
E1	2008.01 ± 0.02	2.76 ± 0.05	6.10 ± 0.11
E4	2008.82 ± 0.04	2.35 ± 0.05	5.19 ± 0.11
E5	2009.42 ± 0.02	2.60 ± 0.06	5.75 ± 0.13
E6	2009.85 ± 0.03	2.56 ± 0.05	5.66 ± 0.11
E8	2010.45 ± 0.02	2.20 ± 0.03	4.86 ± 0.07
E9	2011.23 ± 0.04	2.32 ± 0.09	5.12 ± 0.19
VLBA 43 GHz			
d11	2013.03 ± 0.03	1.91 ± 0.09	4.22 ± 0.22
d12	2013.67 ± 0.02	2.1 ± 0.2	4.7 ± 0.3



Casadio et al. (2015a)



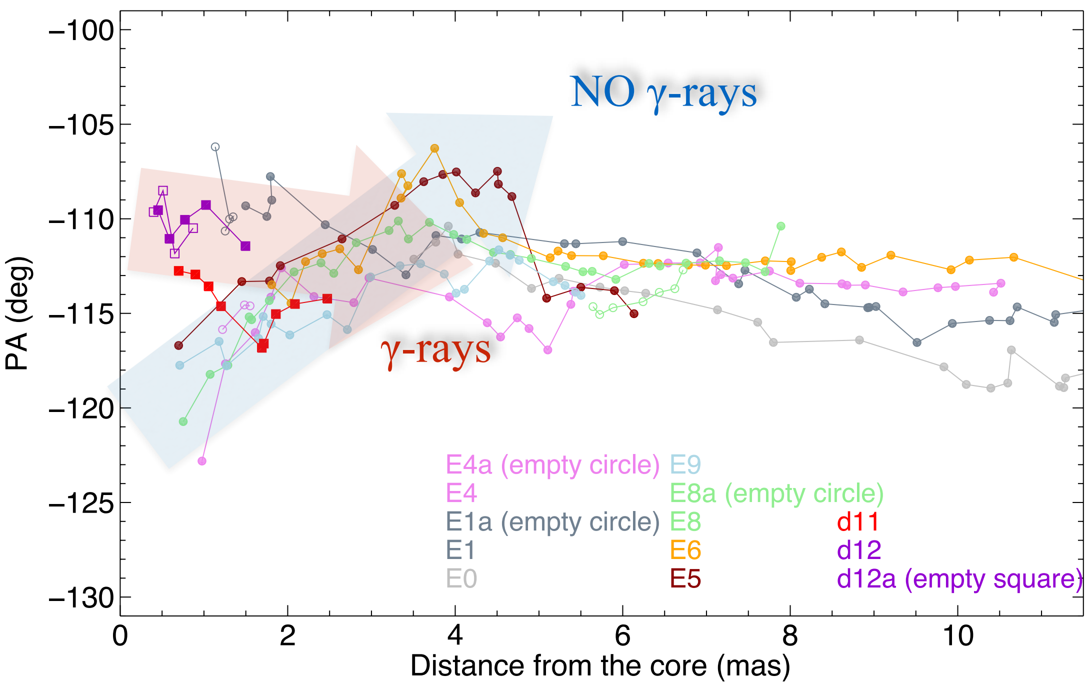
The connection between the radio jet and gamma-ray emission in 3C120

Components show a progressive decrease in apparent velocity in a time span of ~6.4 years, about half of the precessing period of 12.3 yrs estimated by Caproni & Abraham (2004).

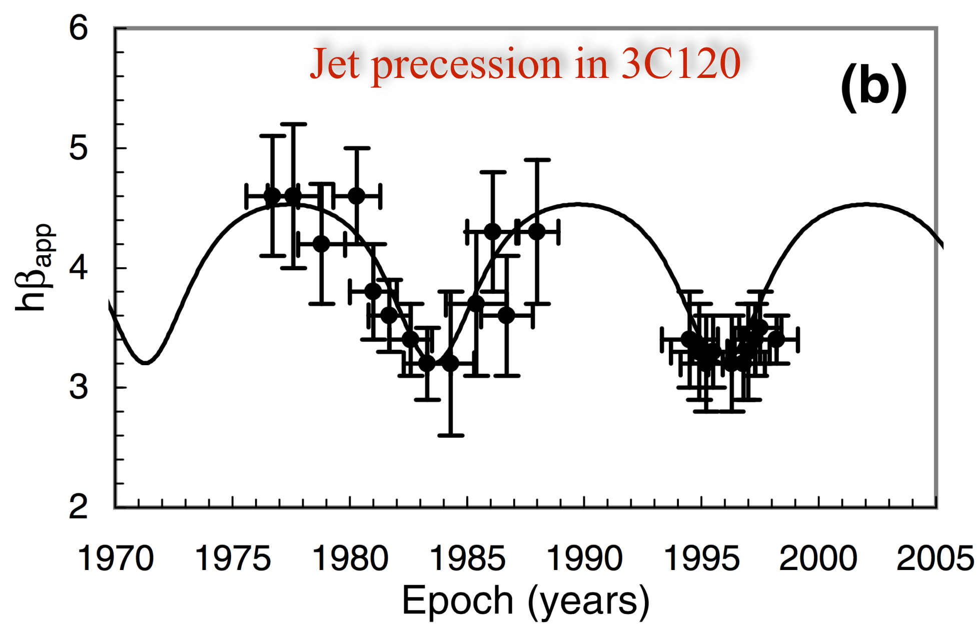
Furthermore, components are ejected at different position angles, suggesting that the variation in apparent velocity is due to a change in viewing angle.

From the observed apparent velocities, and minimizing the required reorientation of the jet, we estimate Γ=6.3, and a *change in viewing angle from θ=9.2 (component E0) to θ=3.6 degrees, when component d11 was ejected and a γ-ray emission is detected.* This implies a change in δ~6.2 (E0) to δ~10.9 (d11), leading to enhanced γ-ray emission.

γ-rays are observed when a new component pass through the core **and** it is oriented at a viewing angle of ≲4 degrees.



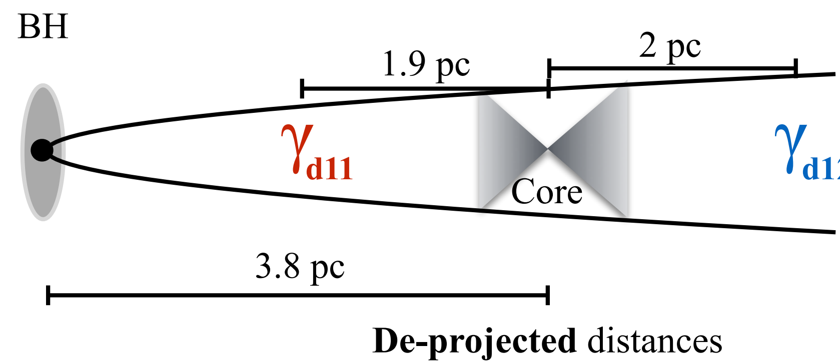
Casadio et al. (2015a)



Caproni & Abraham (2004)

Multi-wavelength observations have established a delay of ~66 days between X-ray dips and the ejection of new superluminal components (Marscher et al. 2002; Chatterjee et al. 2009).

For a mean β_{app}~2 mas/yr, this gives a separation between the BH and mm-VLBI core of ~0.24 pc, or ~3.8 pc *deprojected* with θ=3.6 deg.

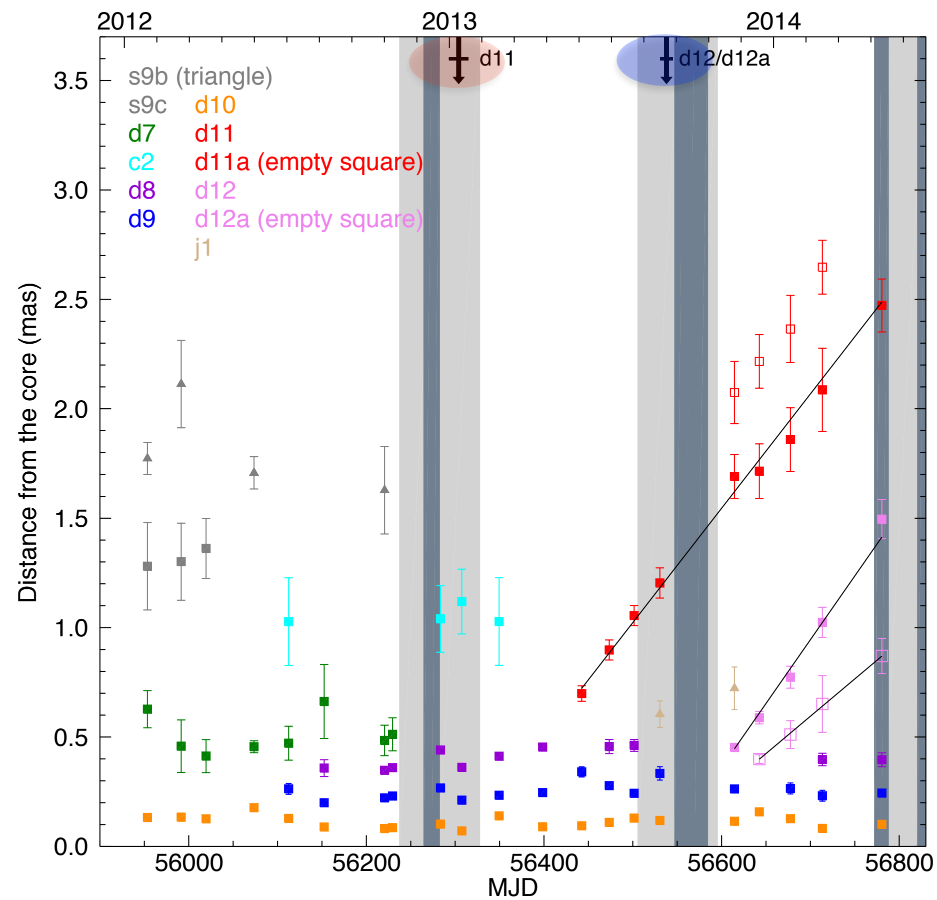


First γ-ray takes place 34 days (~1.9 pc de-projected) *before* component d11 crosses the core, or about half the BH-core distance.

Second γ-ray takes place 33 days (~2 pc) *after* component d12 crosses the core.

Hence, **γ-ray detections took place near the core, parsecs away from the BH.**

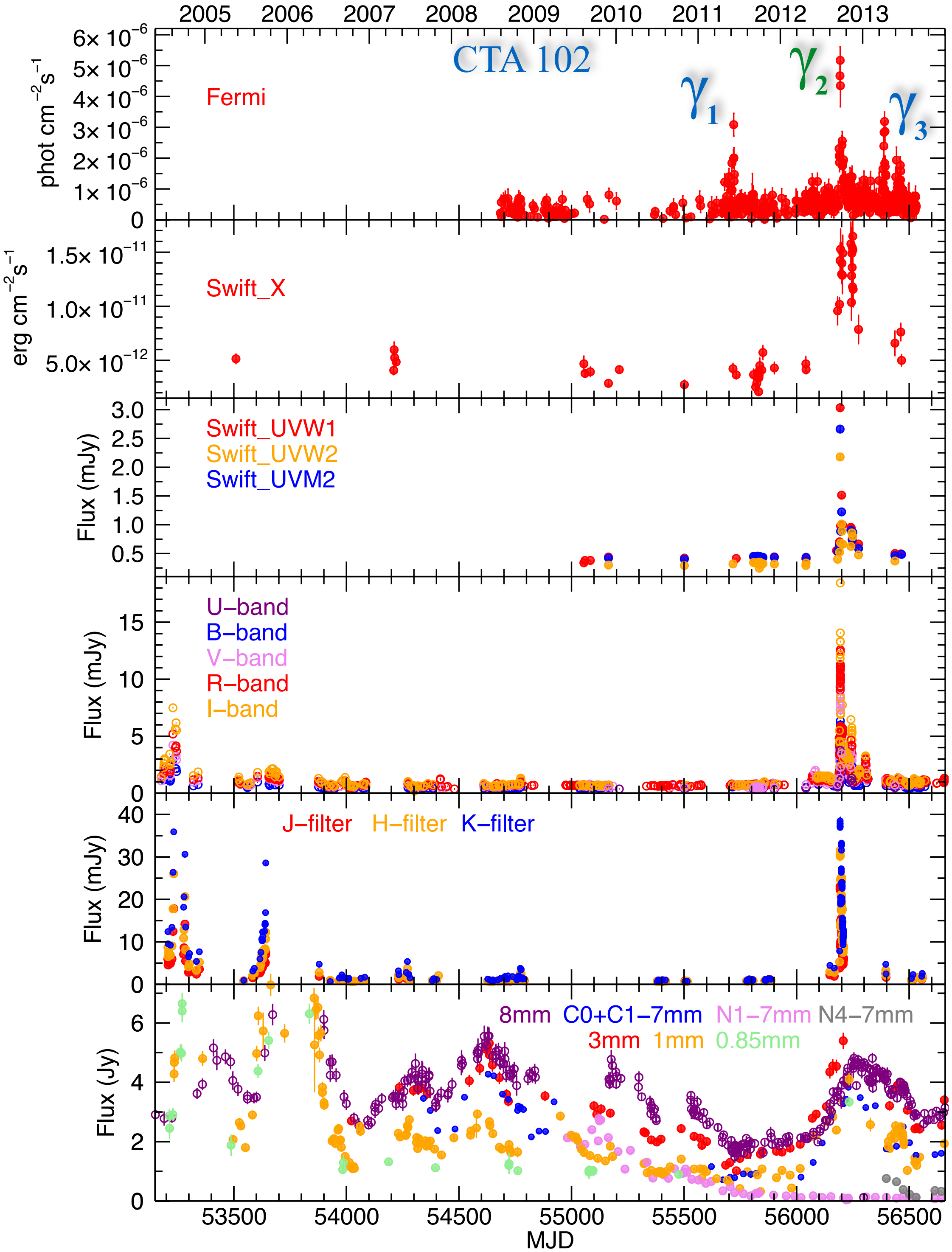
Estimated size for the BLR is ~0.03 pc (Grier et al. 2013; Kollatschny et al. 2014). This limits the amount of external photons from the BLR, suggesting **SSC as the γ-ray emission mechanism**, in agreement with other estimates (e.g., Tanaka et al. 2015).



Casadio et al. (2015a)

The blazar CTA102

A MWL study of the blazar CTA102 during a gamma-ray flare in 2012

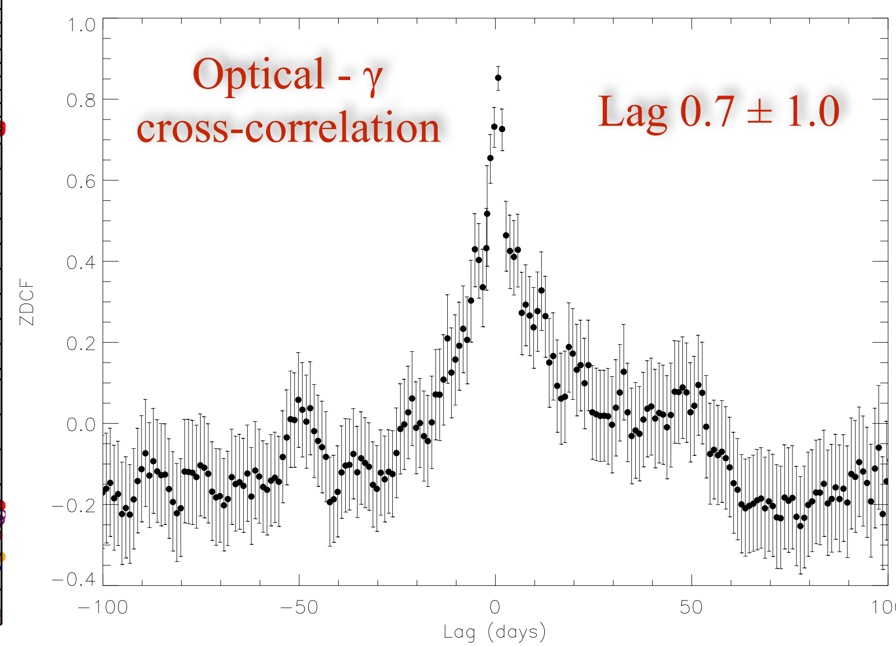


Multi-wavelength monitoring of the powerful blazar CTA 102 between June 2004 and June 2014.

Three γ-ray flares are observed between 2011 and 2013.

Flares in June 2011 and April 2013 (γ_1 and γ_3) have no counterparts at other wavebands.

Flare in September 2012 (γ_2) reached a peak of 5.2×10^{-6} ph cm^{-2} s^{-1} and was accompanied by *simultaneous* flares at other wavebands.



Casadio et al. (2015b)

A MWL study of the blazar CTA102 during a gamma-ray flare in 2012

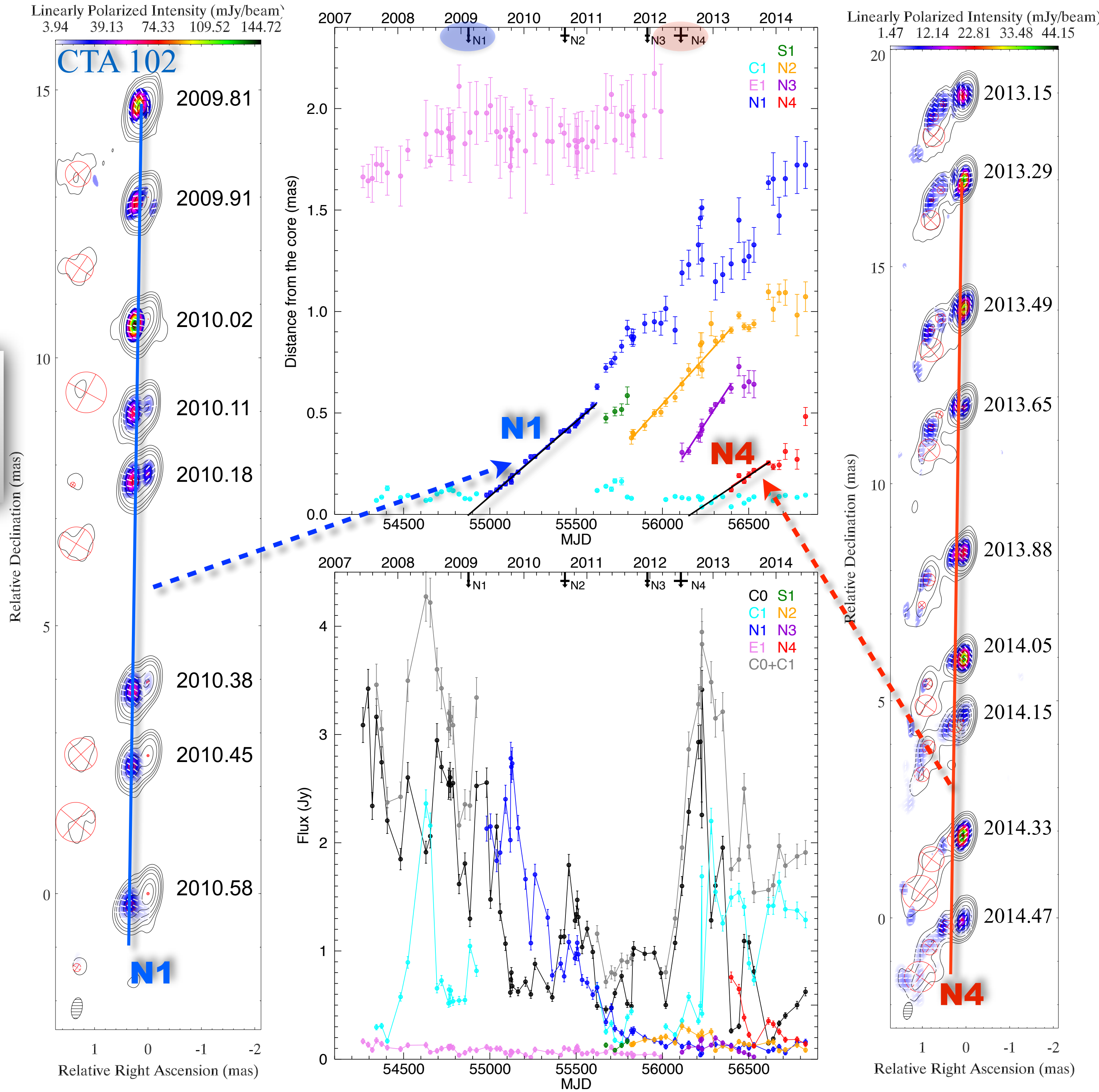
VLBA-BU-BLAZAR

80 epochs between June 2007 and June 2014.

Four main superluminal components and two stationary features.

Kinematics of Moving Jet Features

Name	N.Epoch	μ (mas yr^{-1})	β_{app} (c)	T_{ej} (year)
N1	26	0.27 ± 0.01	14.9 ± 0.2	2009.12 ± 0.02
N2	18	0.35 ± 0.01	19.4 ± 0.8	2010.65 ± 0.07
N3	10	0.49 ± 0.03	26.9 ± 1.8	2011.96 ± 0.07
N4	6	0.21 ± 0.02	11.3 ± 1.2	2012.49 ± 0.11



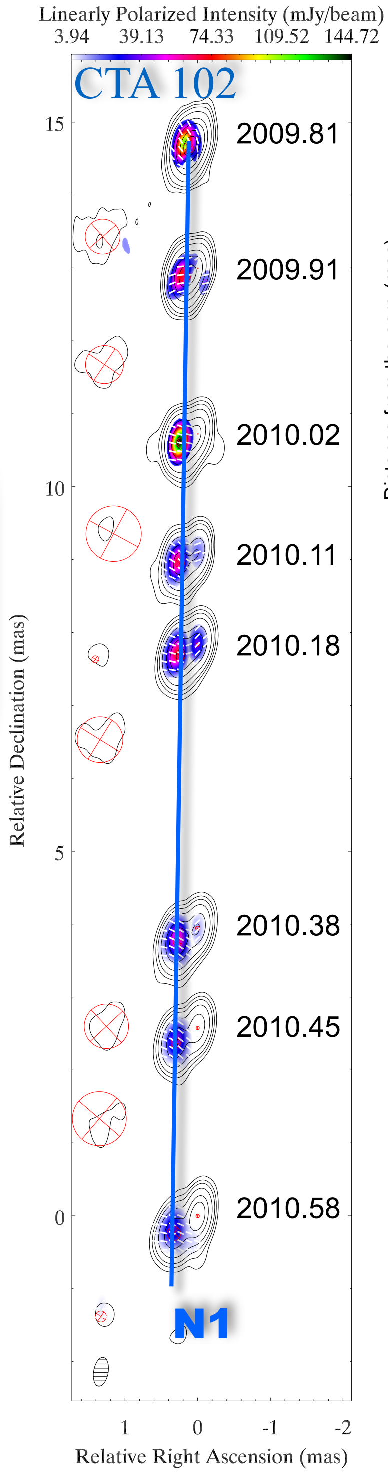
A MWL study of the blazar CTA102 during a gamma-ray flare in 2012

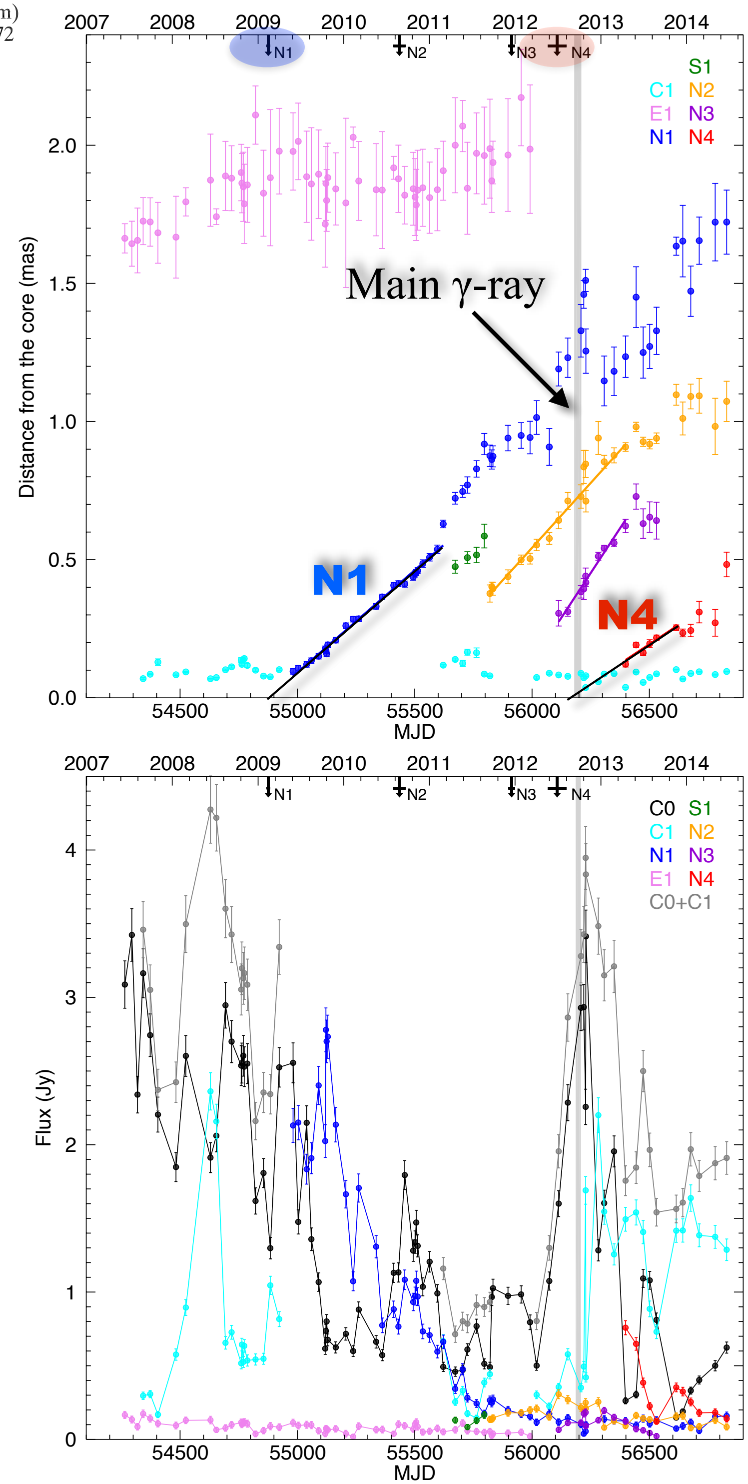
VLBA-BU-BLAZAR

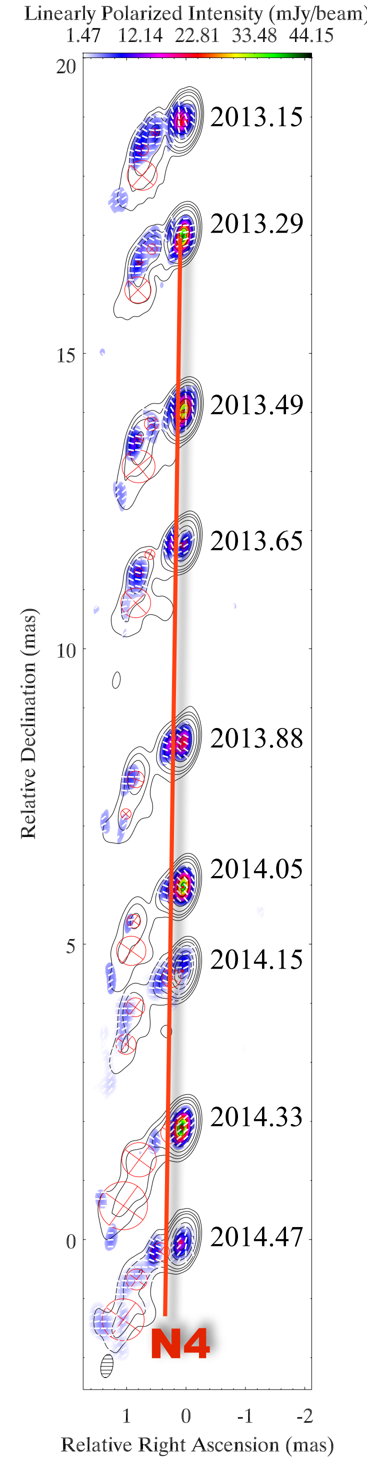
80 epochs between June 2007 and June 2014.

Four main superluminal components and two stationary features.

Main γ-ray outburst associated with a big core flare and ejection of N4.







A MWL study of the blazar CTA102 during a gamma-ray flare in 2012

VLBA-BU-BLAZAR

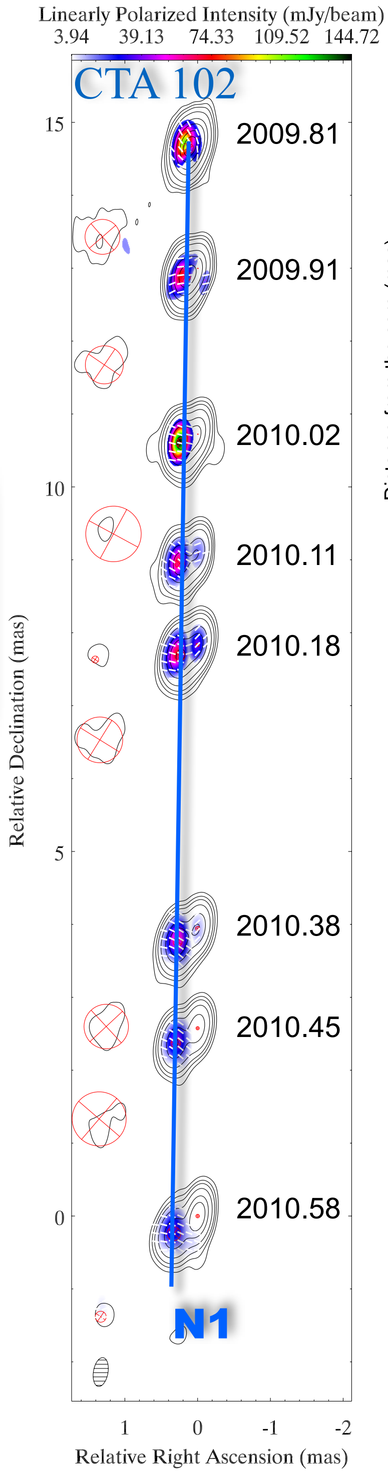
80 epochs between June 2007 and June 2014.

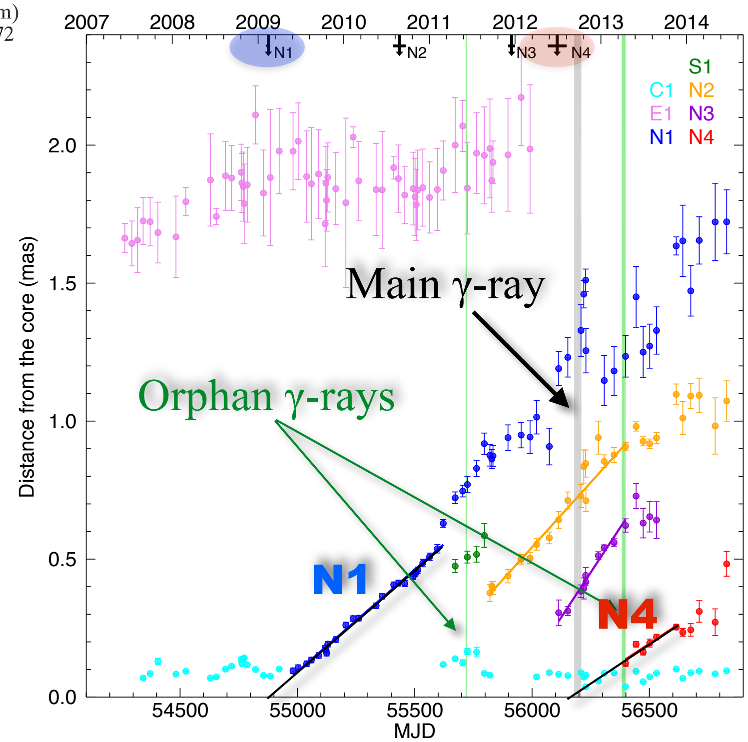
Four main superluminal components and two stationary features.

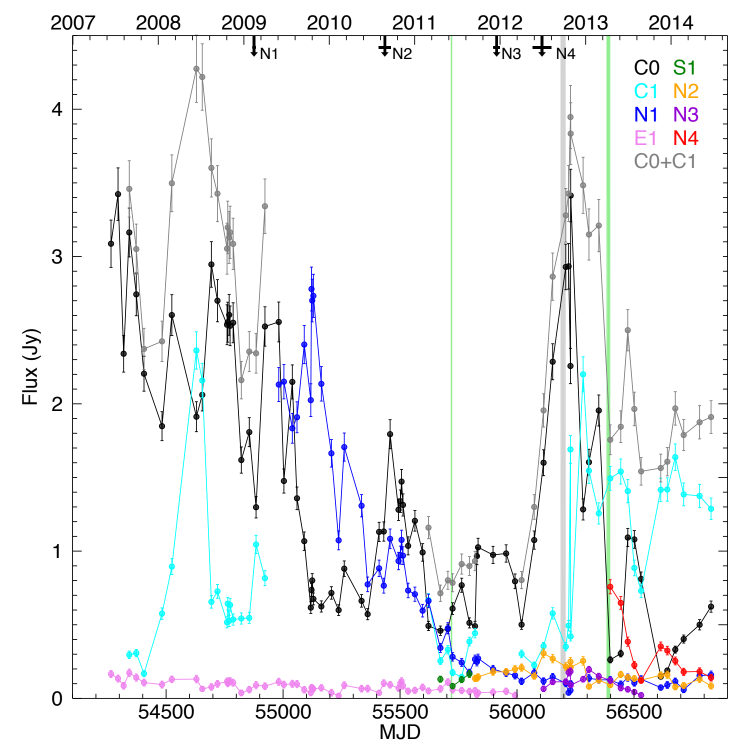
Main γ-ray outburst associated with a big core flare and ejection of N4.

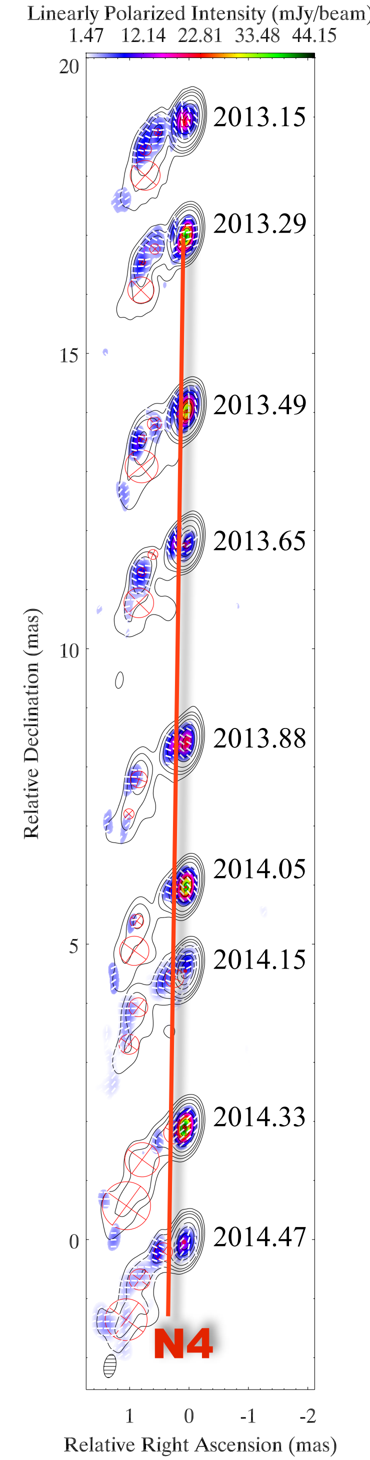
Second orphan γ-ray flare may be associated with the interaction of N4 and C1

Strongest component N1 has no associated γ-ray flare.









A MWL study of the blazar CTA102 during a gamma-ray flare in 2012

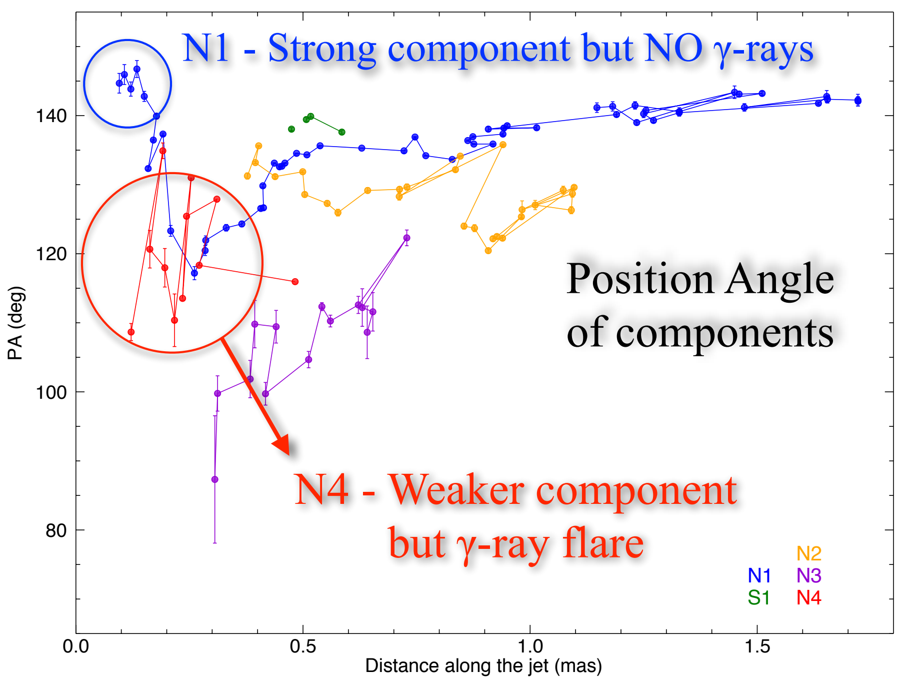
Estimated parameters for the main 4 components in the jet show a *progressive increase in δ_{var} with time* due to a *reorientation of the jet towards the observer.*

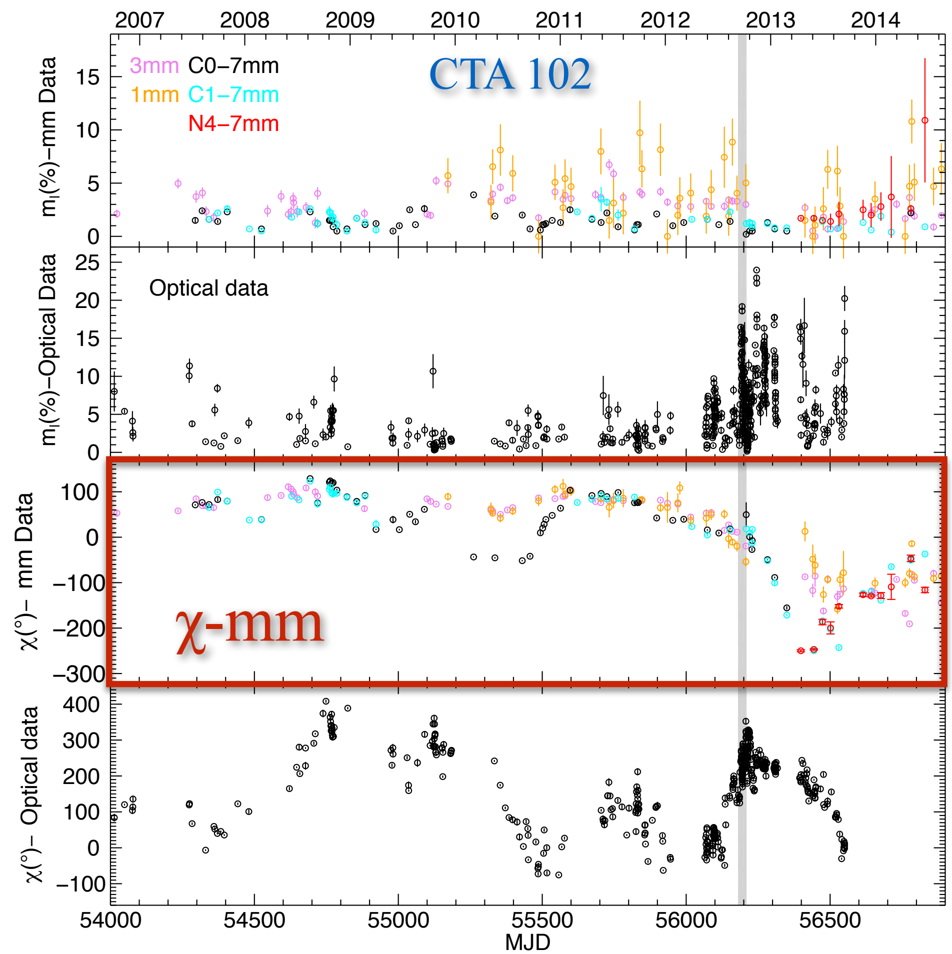
Component N4, associated with the main γ-ray flare, has the *largest δ_{var} ever observed in CTA102, at θ_{var}=1.2 deg.*

Progressive reorientation of the jet is also seen in the mm-wave EVPAs, followed by a faster rotation in mm-VLBI components after the γ-ray flare.

Physical Parameters of Moving Jet Features

Name	Δt_{var} (year)	a_{max} [a] (mas)	δ_{var} ↑	θ_{var} (°) ↓	Γ_{var}
N1	0.70	0.14	14.6	3.9	14.9
N2	1.12	0.33	22.4	2.5	19.6
N3	0.28	0.09	26.1	2.2	26.2
N4	0.20	0.08	30.3	1.2	17.3





Casadio et al. (2015b)

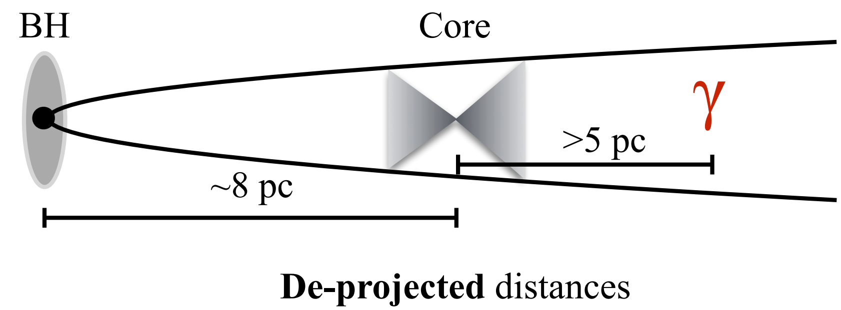
A MWL study of the blazar CTA102 during a gamma-ray flare in 2012

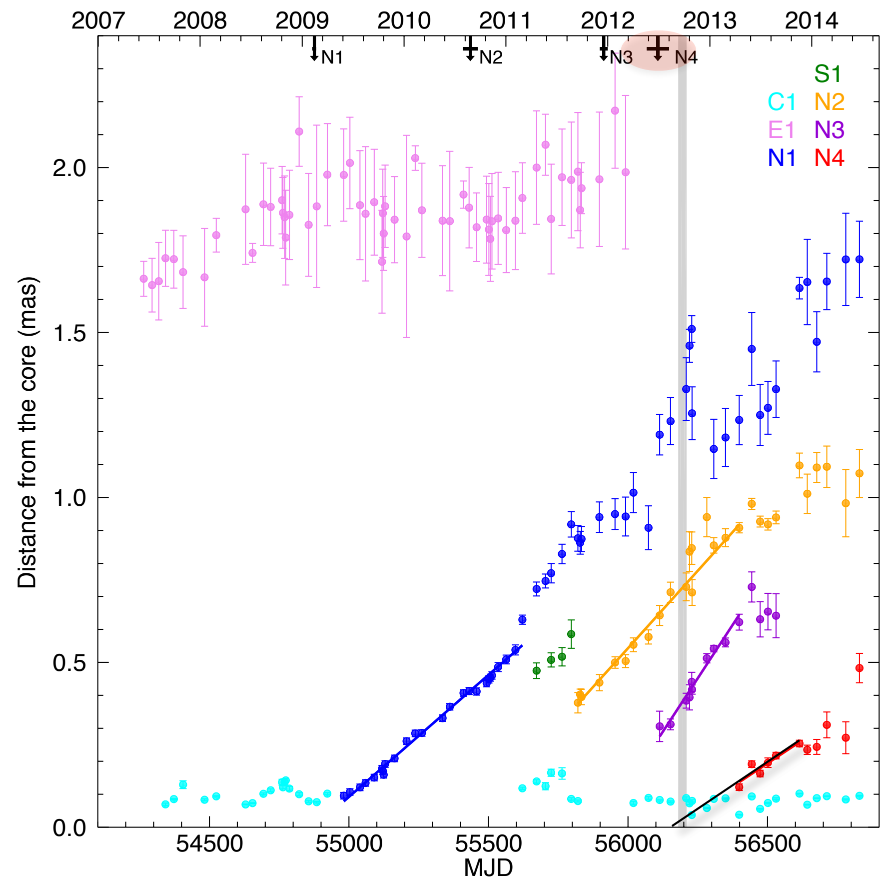
Opacity core-shifts have located the mm-VLBI at a deprojected distance of ~8 pc from the BH (Fromm et al. 2015).

Main γ-ray flare in 2012.73 occurred 47 to 127 days *after* component N4 crossed the mm-VLBI core in 2012.49±0.11, or at a *de-projected* distance of > 5 pc from the core.

Hence, **the γ-ray outburst took place more than 12 pc from the BH.**

At this location there should be no contribution of photons from the disk, BLR, or dusty torus, **suggesting SSC as the γ-ray production mechanism.**





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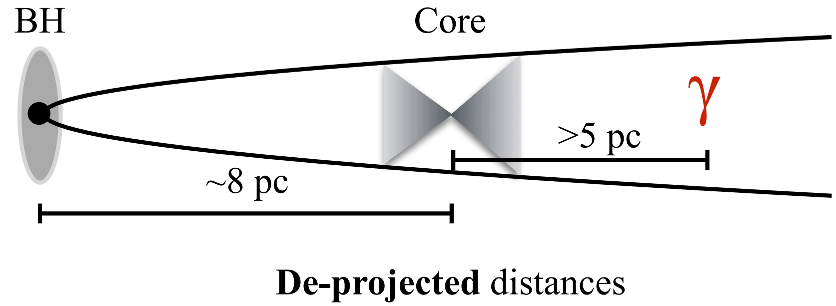
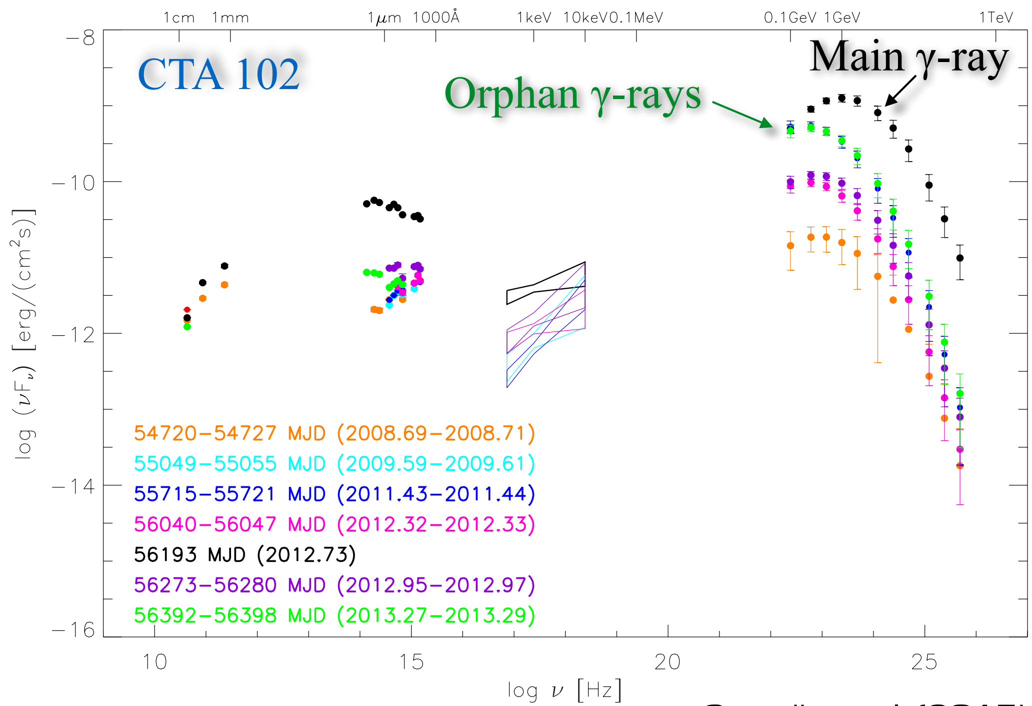
Only the main γ-ray flare displays a shift in the peak to higher frequencies, as expected for an increase in the Doppler factor.

The ratio of γ-ray to infrared (synchrotron) luminosity is ≲10, consistent with the SSC process.





Casadio et al. (2015b)

Summary

- Despite representing very different classes of AGN, the radio galaxy 3C120 and the blazar CTA102 have very similar properties during γ-ray events.
- The (MWL) γ-ray flares are associated with the passage of a new superluminal component through the mm-VLBI core.
- But not all ejections of new knots lead to γ-ray events. γ-ray events occurred only when the new components are moving in a direction closer to our line of sight.
- We locate the γ-ray dissipation zone a short distance from the mm-VLBI core, but parsecs away from the central black hole and BLR, suggesting SSC as the mechanism for γ-ray production.