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

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Blazars through Sharp Multi-Wavelength Eyes - Málaga (Spain). 30 May – 3 June, 2016.

Radio galaxies detected at γ-ray are very few (~2%)

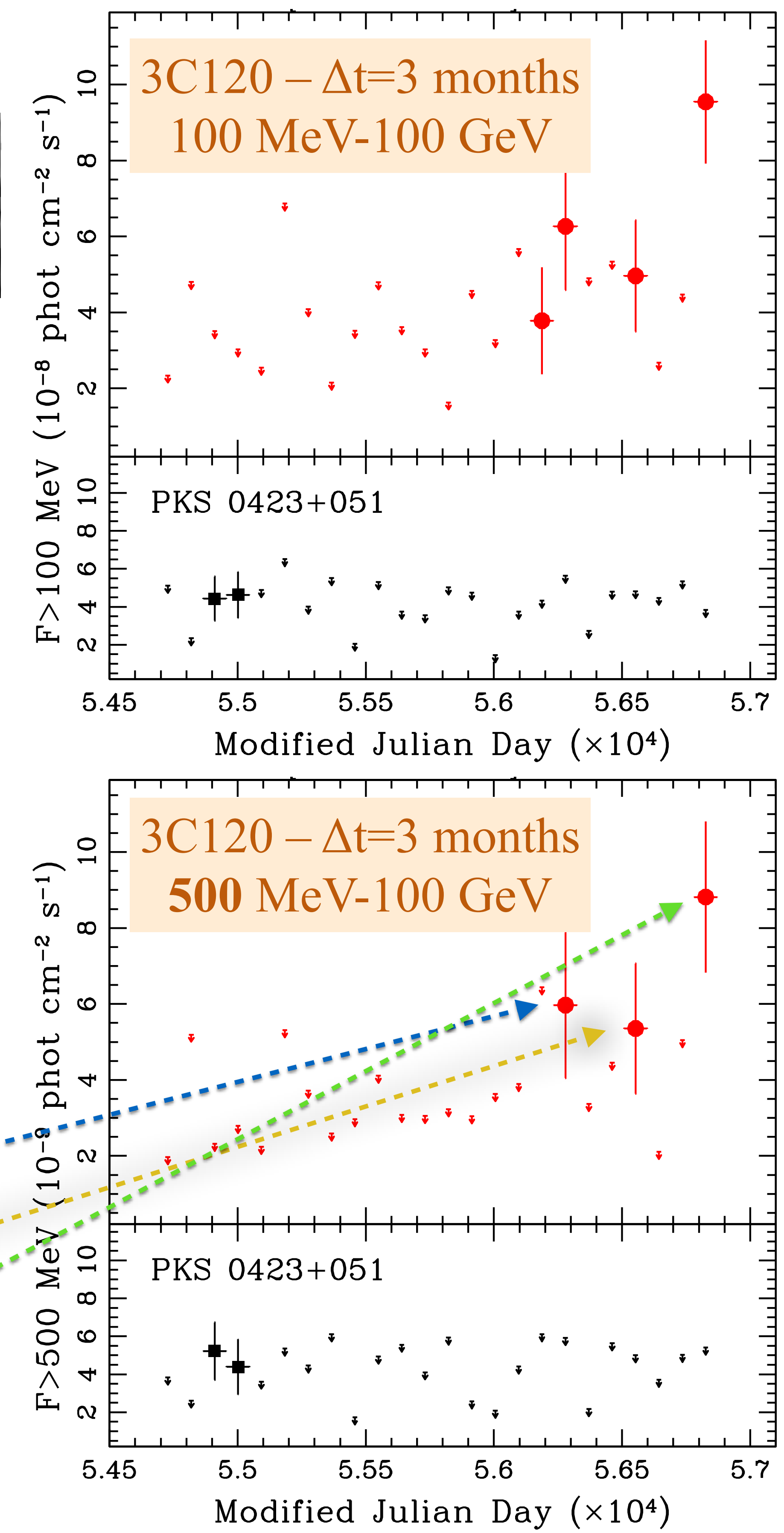
Fermi detected a bright γ-ray flare from the radio galaxy 3C120 on September 2014 (Tanaka et al. 2014)

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

Prolonged γ-ray activity between December 2012 and September 2014

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

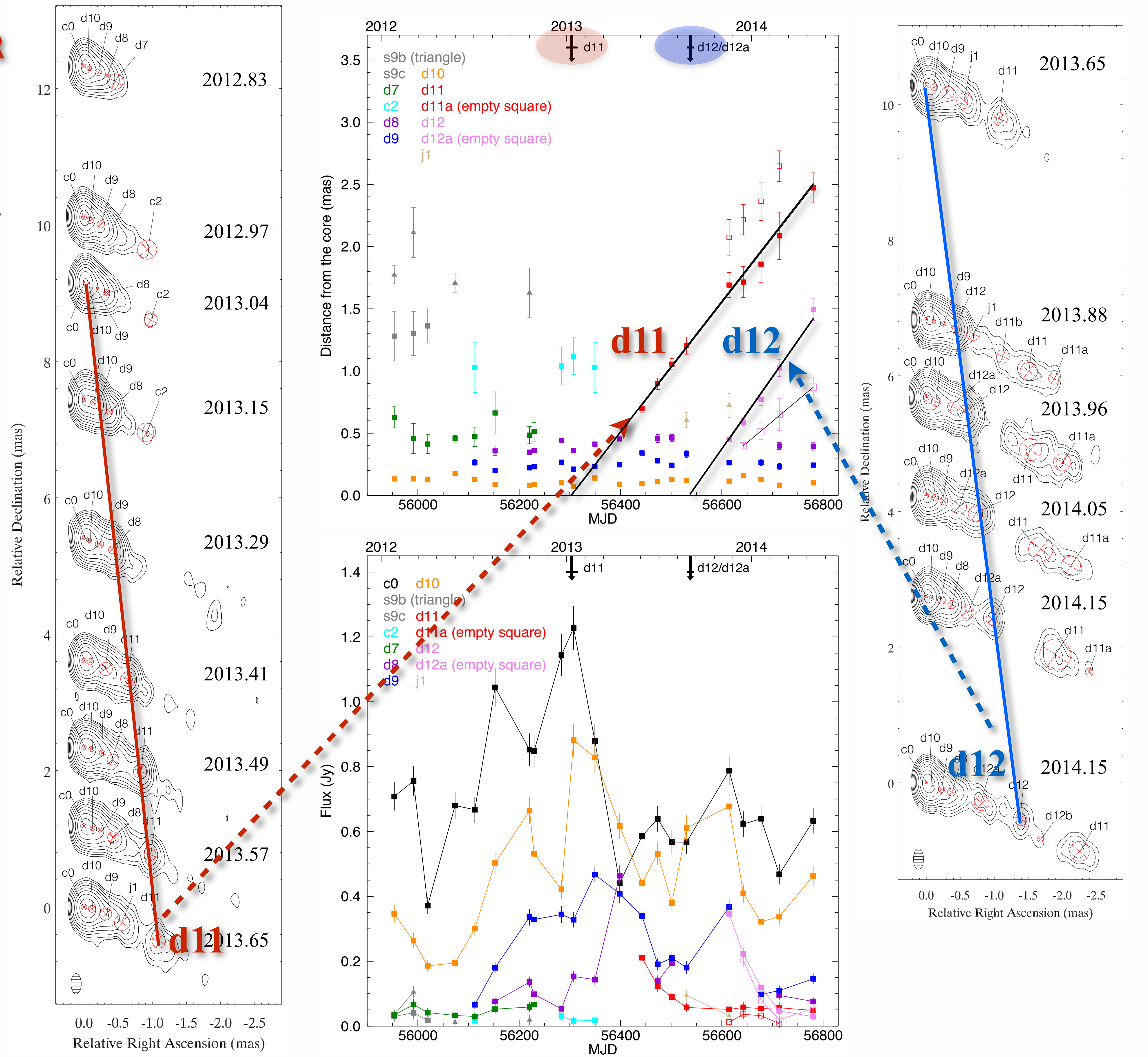


Casadio et al. (2015a)

VLBA-BU-BLAZAR

VLBA at 43 GHz

21 epochs between January 2012 and May 2014.



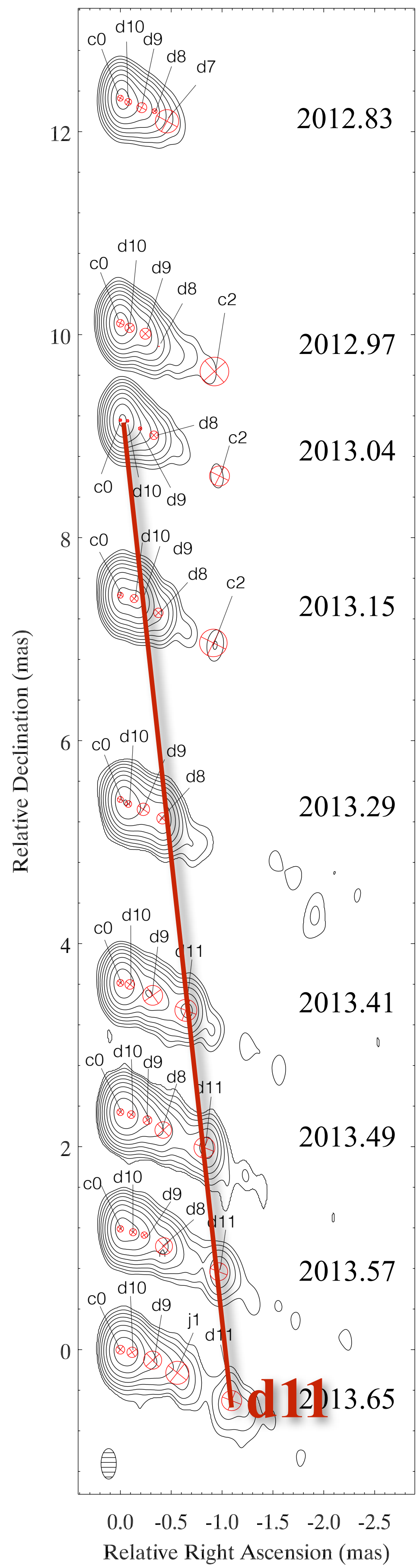
Casadio et al. (2015a)

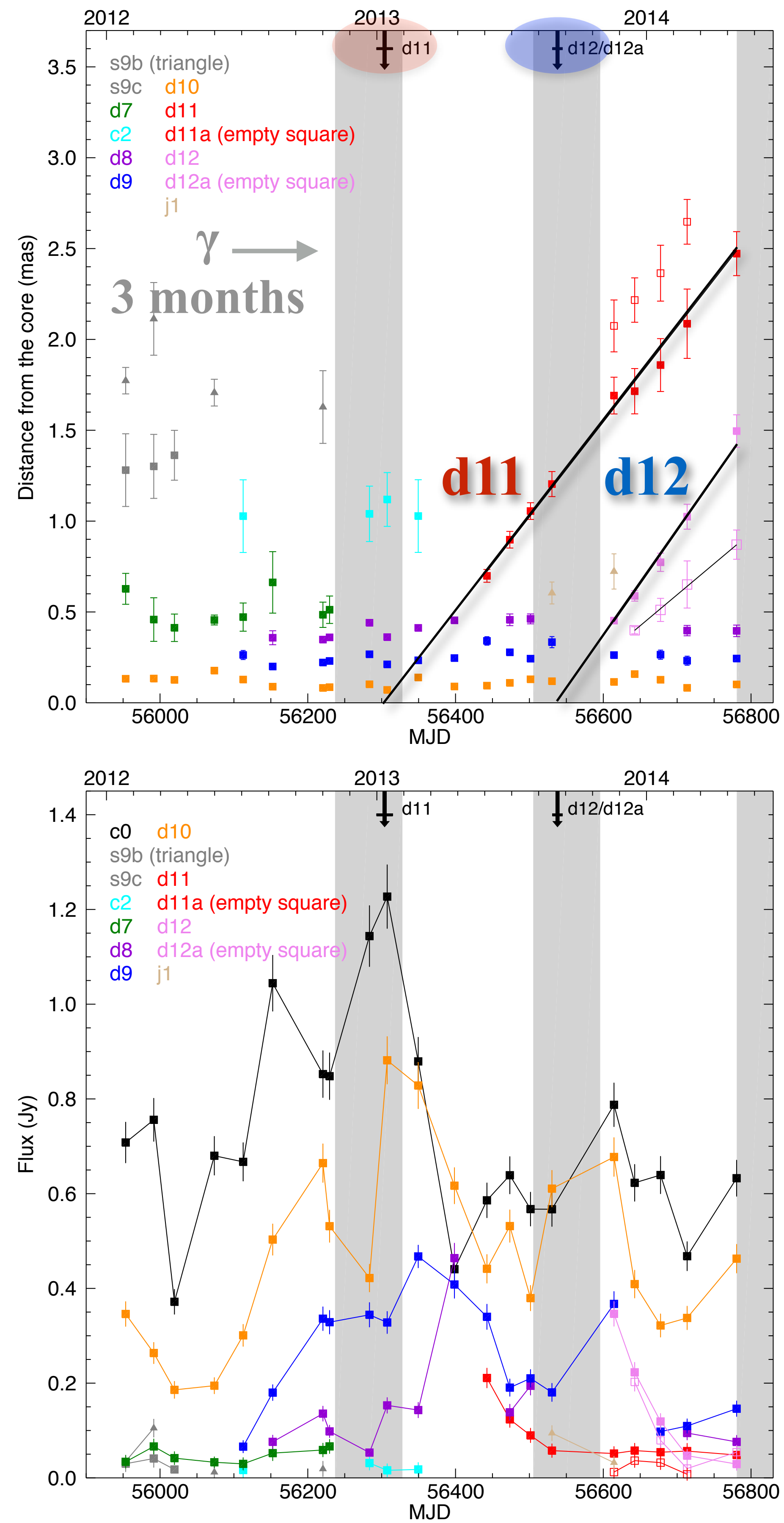
THE CONNECTION BETWEEN THE RADIO JET AND GAMMA-RAY EMISSION IN 3C120

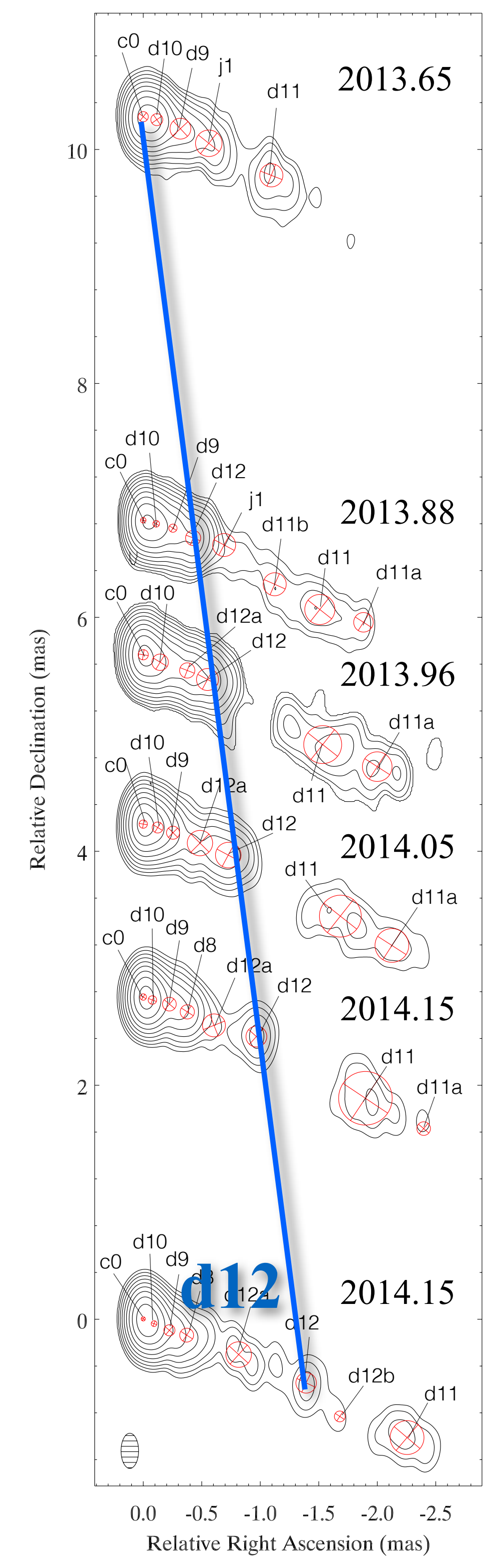
VLBA-BU-BLAZAR

(43 GHz)

January 2012 - May 2014







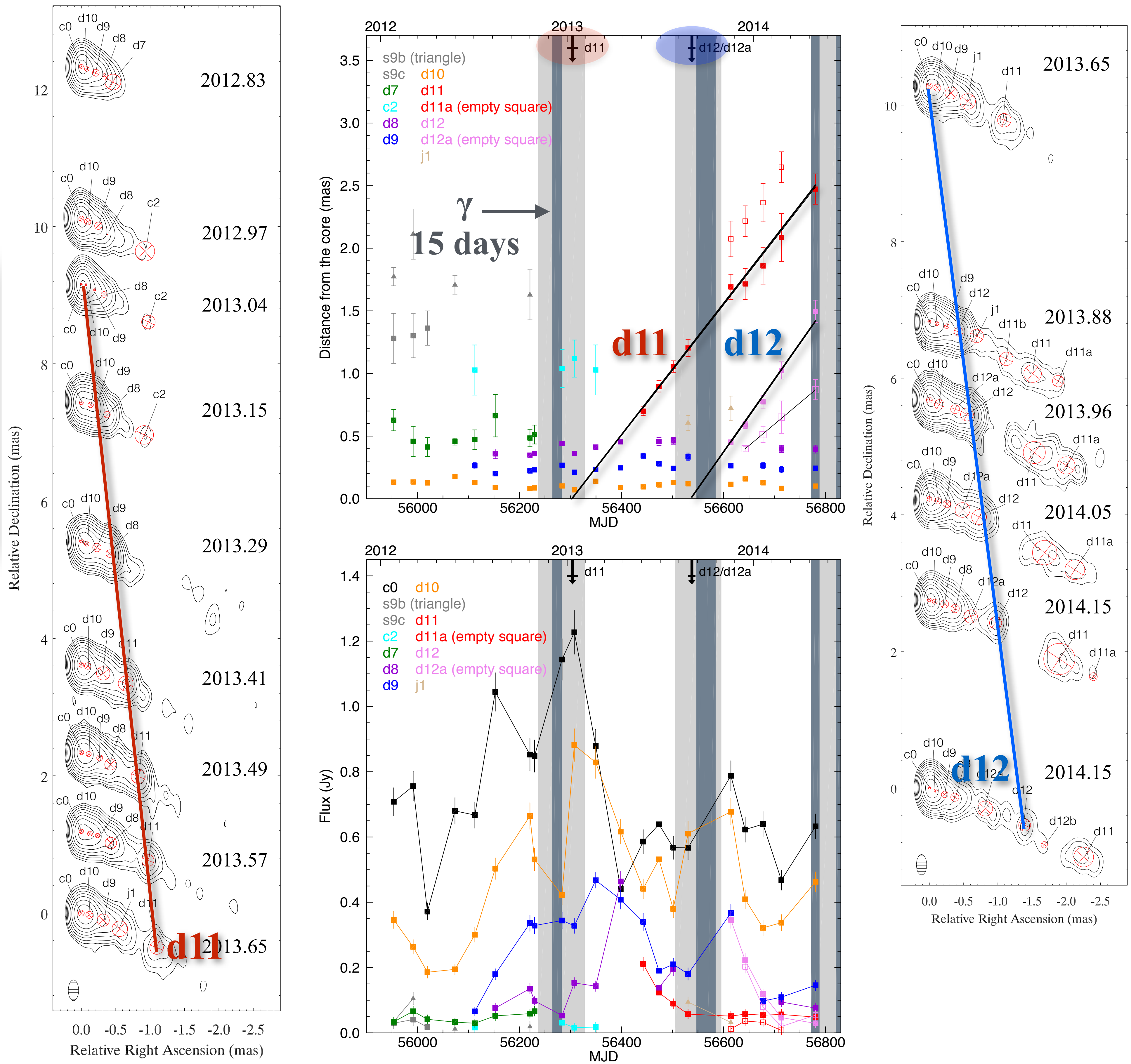
Casadio et al. (2015a)

VLBA-BU-BLAZAR

(43 GHz)

January 2012 - May 2014

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



Casadio et al. (2015a)

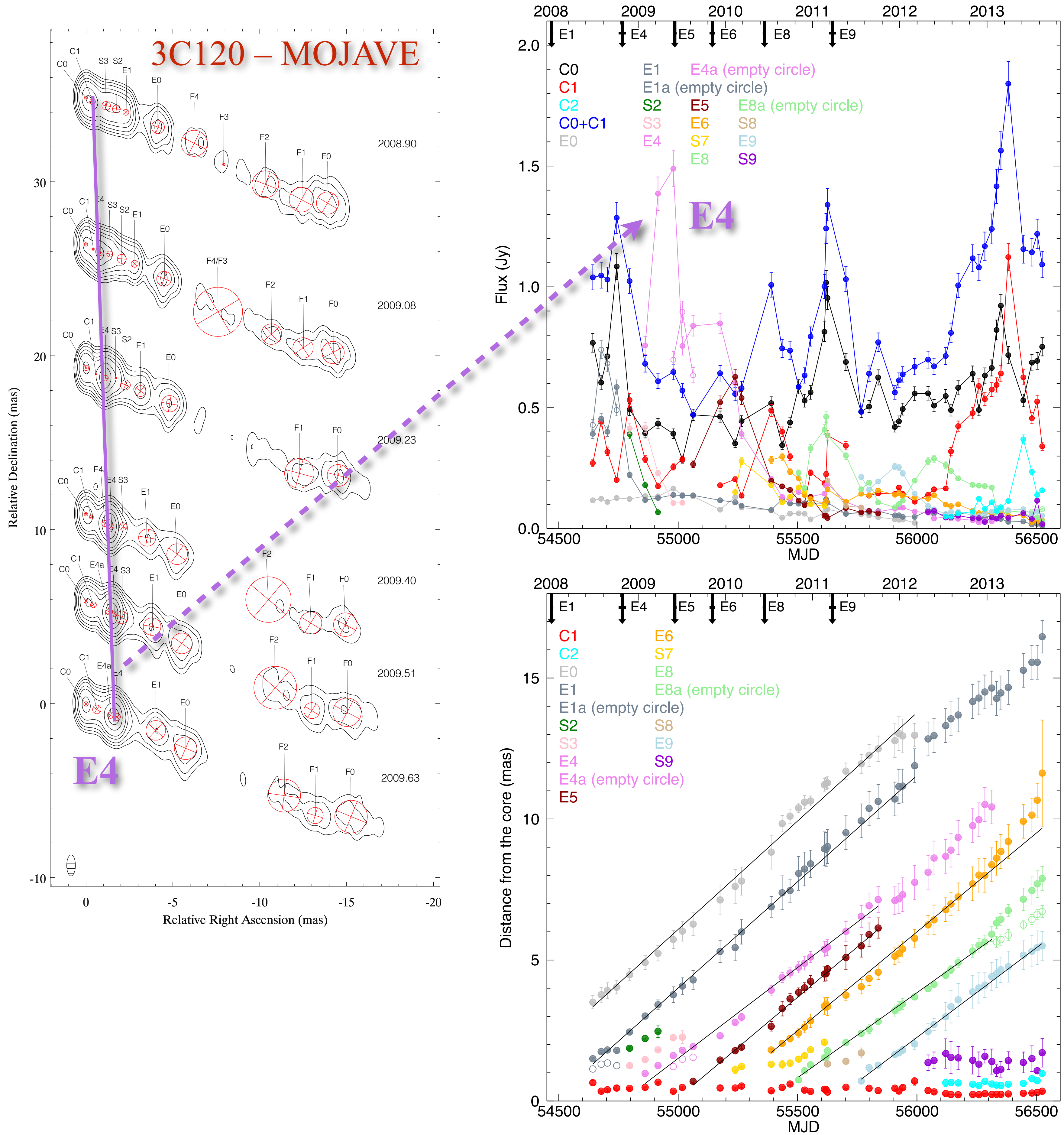
The connection between the radio jet and gamma-ray emission in 3C120

MOJAVE

(VLBA - 15 GHz)

46 epochs

January 2008 - August 2013



Casadio et al. (2015a)

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

MOJAVE

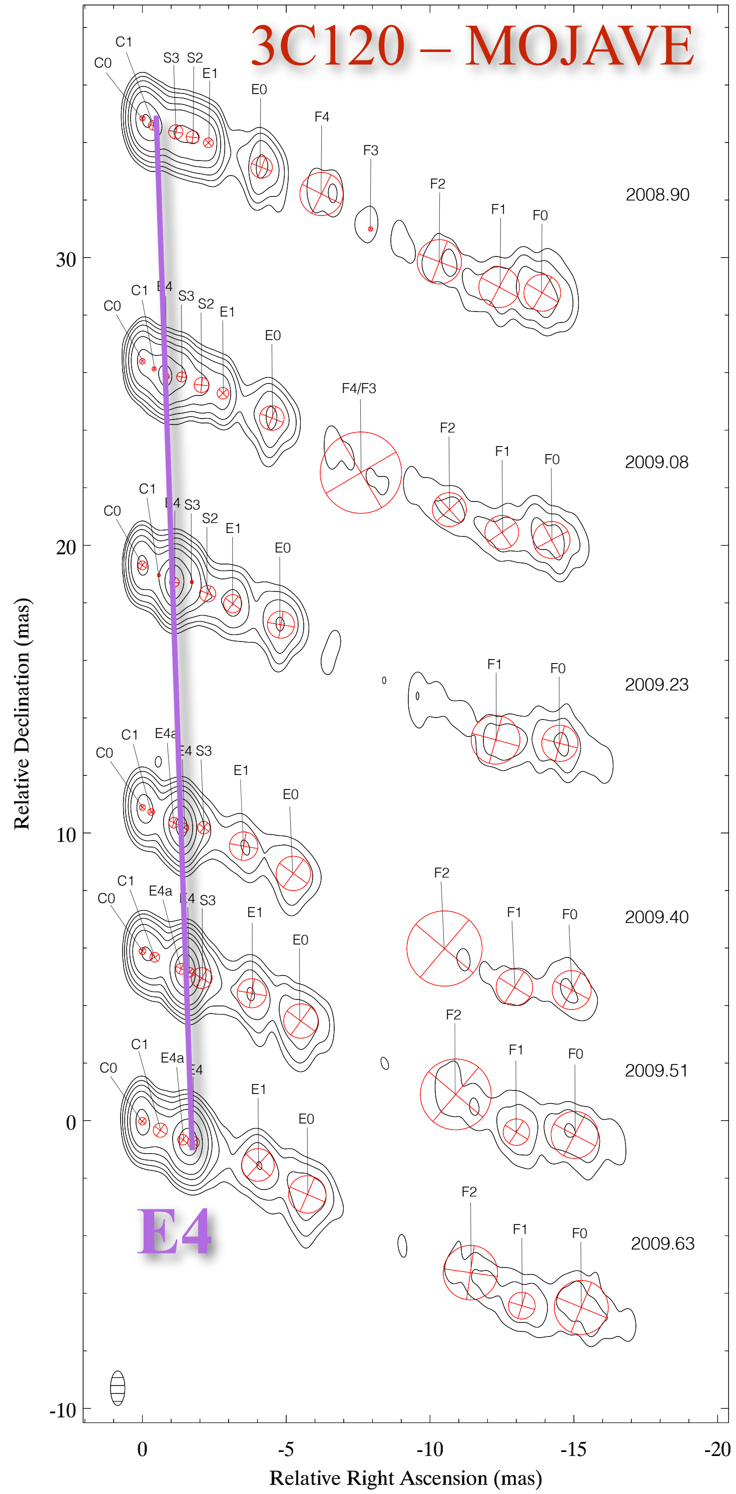
(VLBA - 15 GHz)

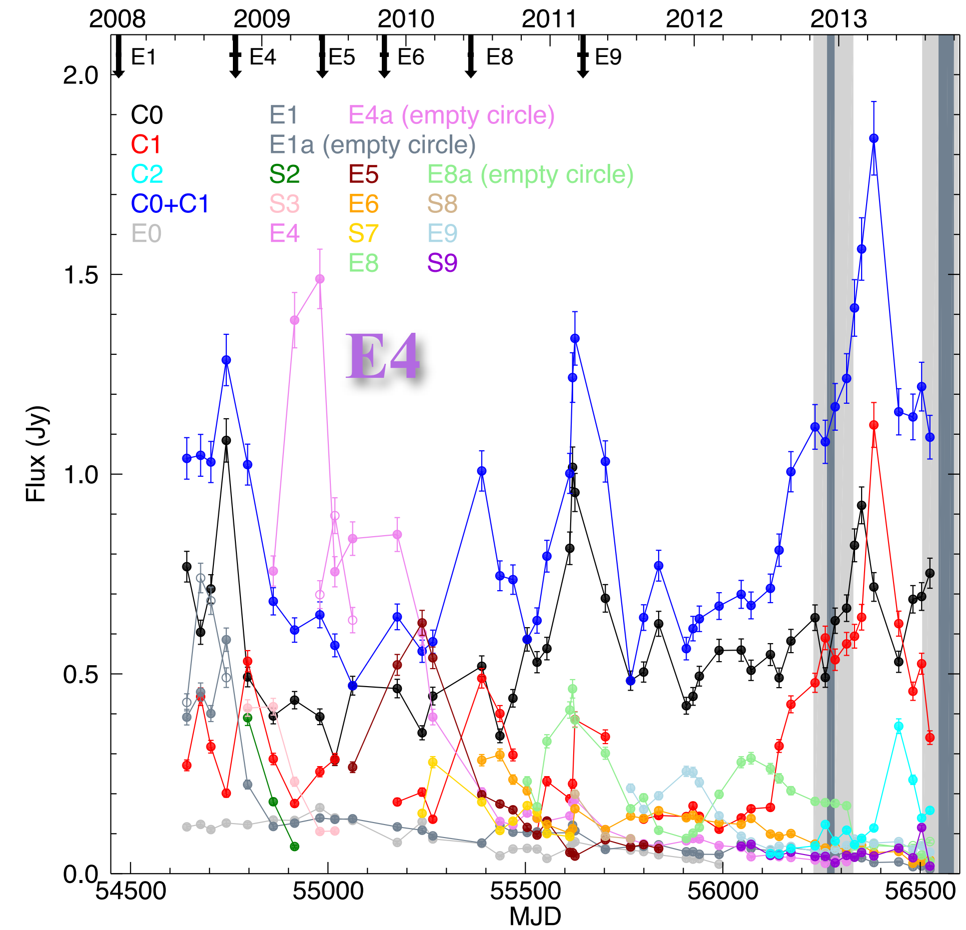
46 epochs

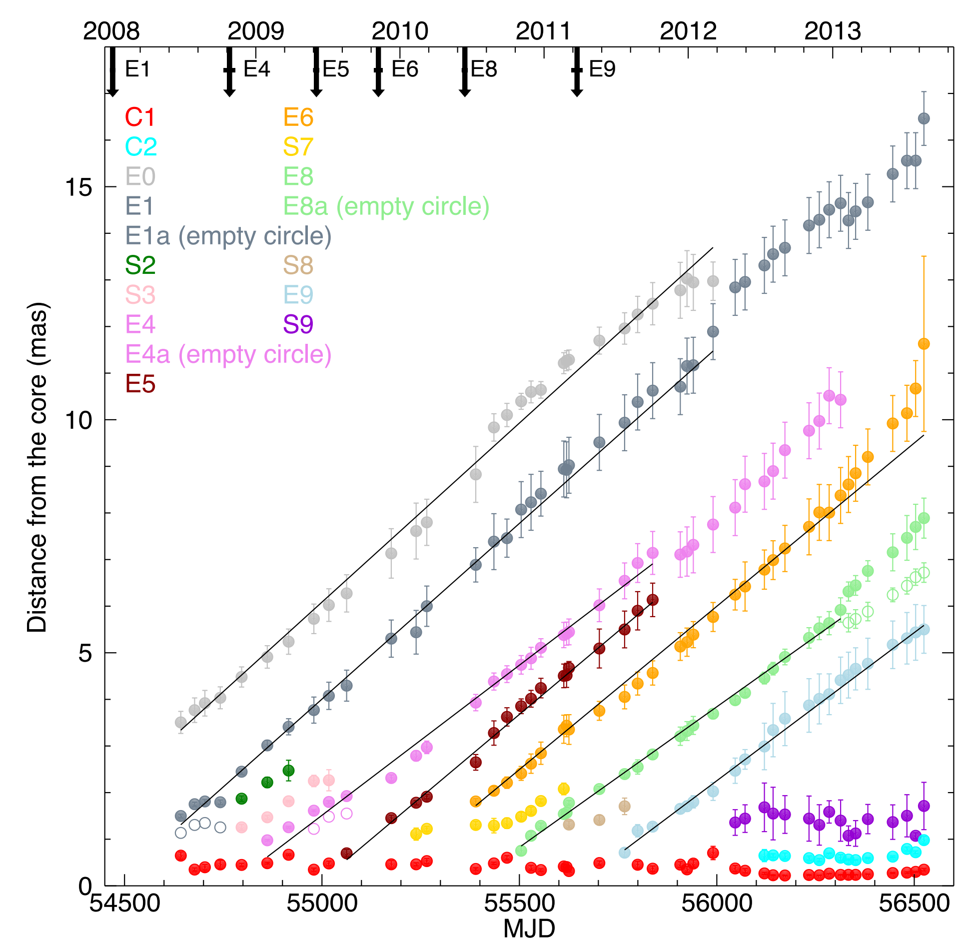
January 2008 - August 2013

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.







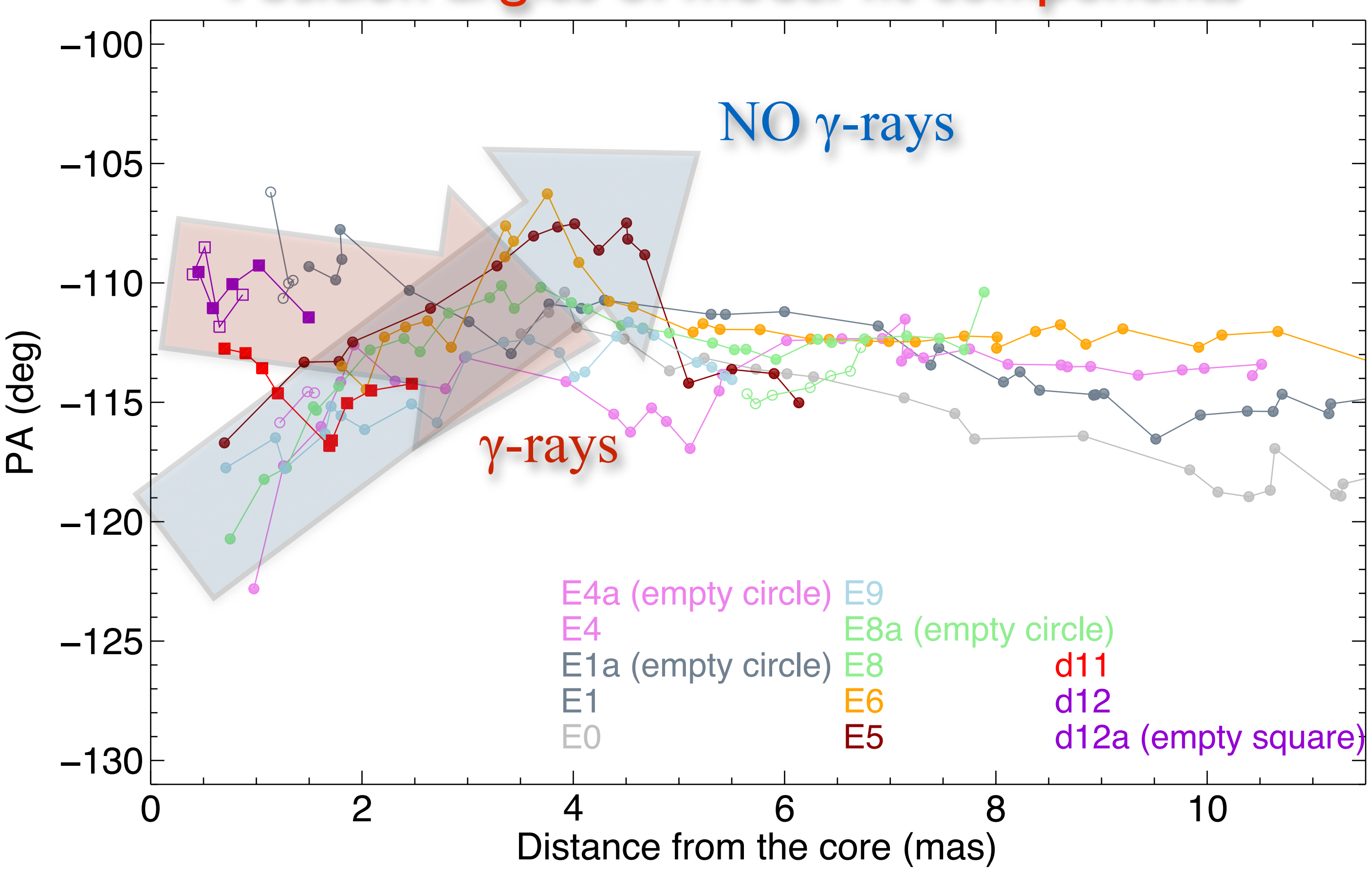
Casadio et al. (2015a)

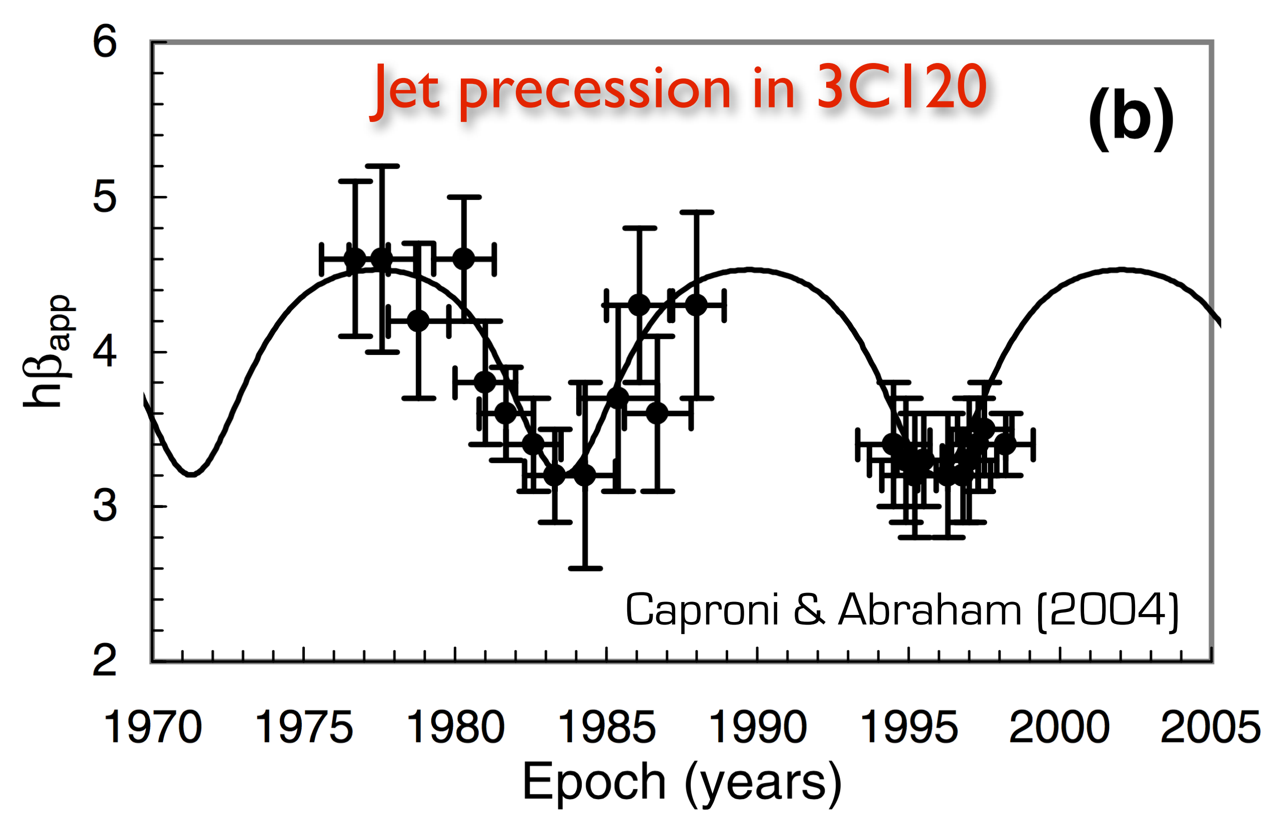
Components show a progressive decrease in apparent velocity in a time span of ~6.4 years, about half of the precessing period of 12.3 yrs estimated by Caproni & Abraham (2004).

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

Position angles of model-fit components





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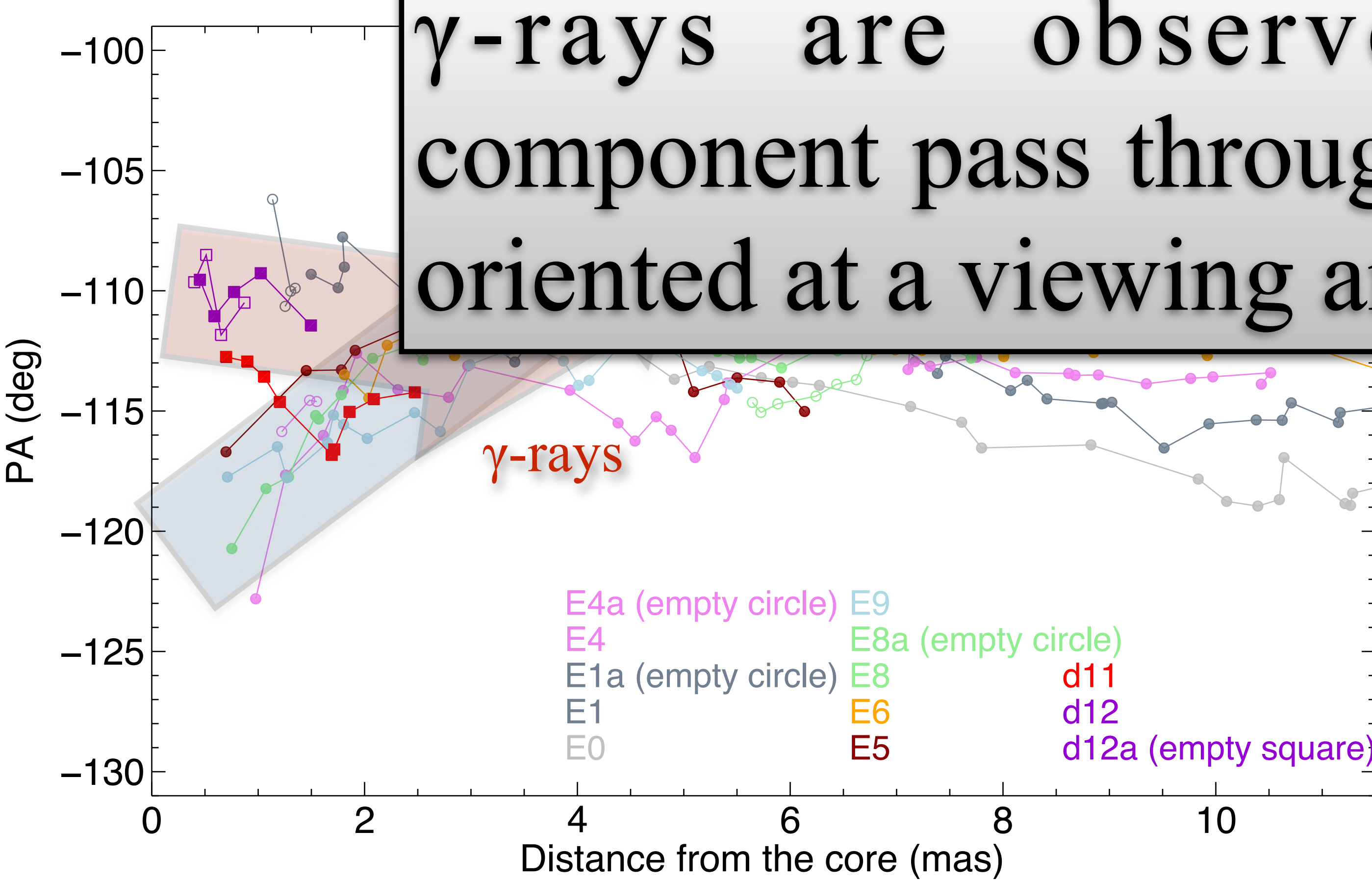
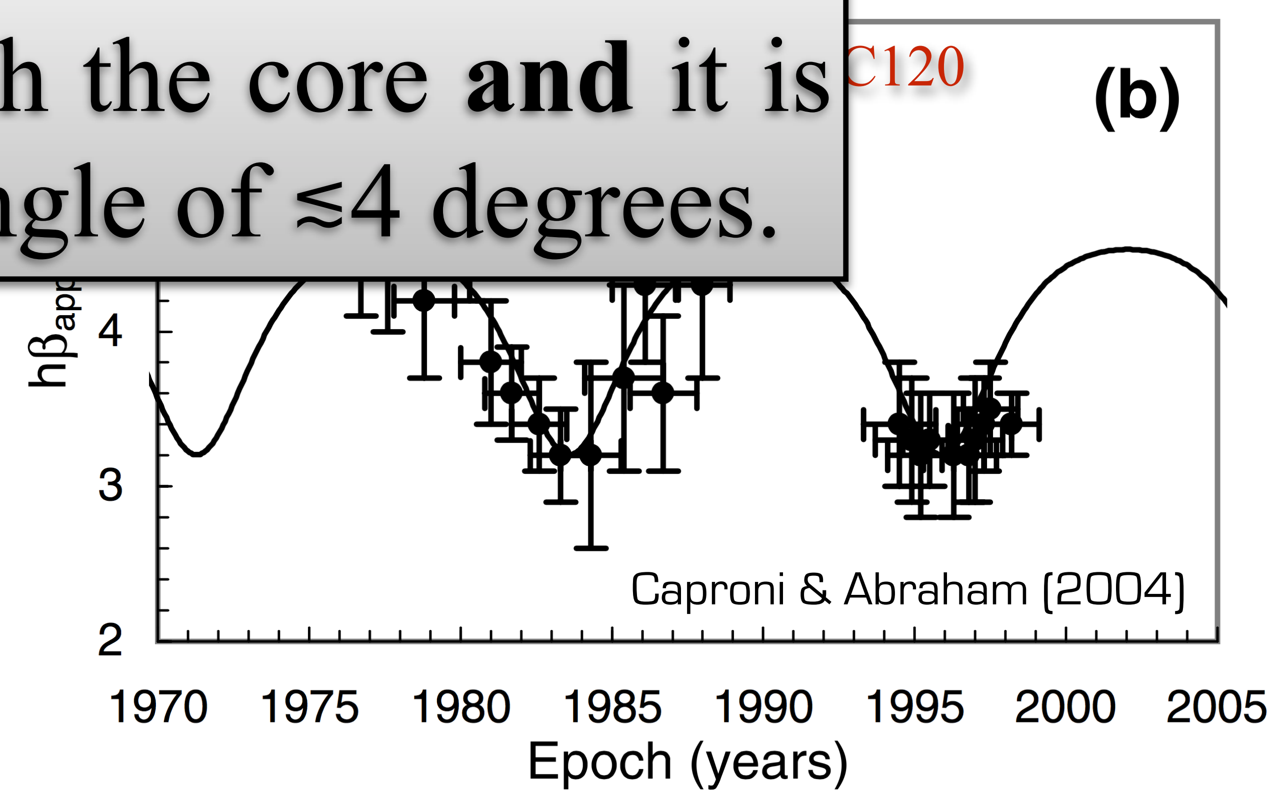
Furthermore, components are ejected at different position angles, suggesting that the variation in apparent velocity is due to a **change in viewing angle**.

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°, 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.

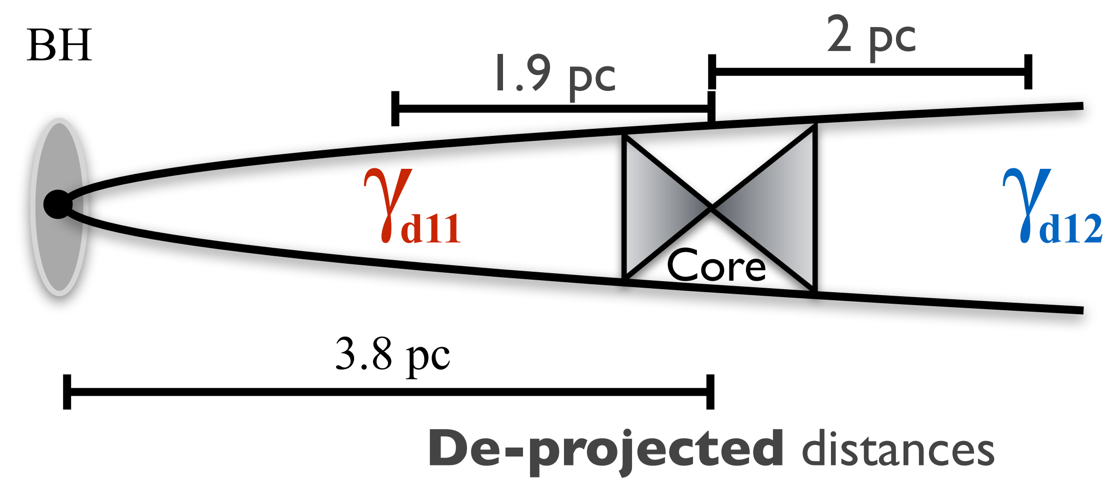




Casadio et al. (2015a)

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 v_{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°.

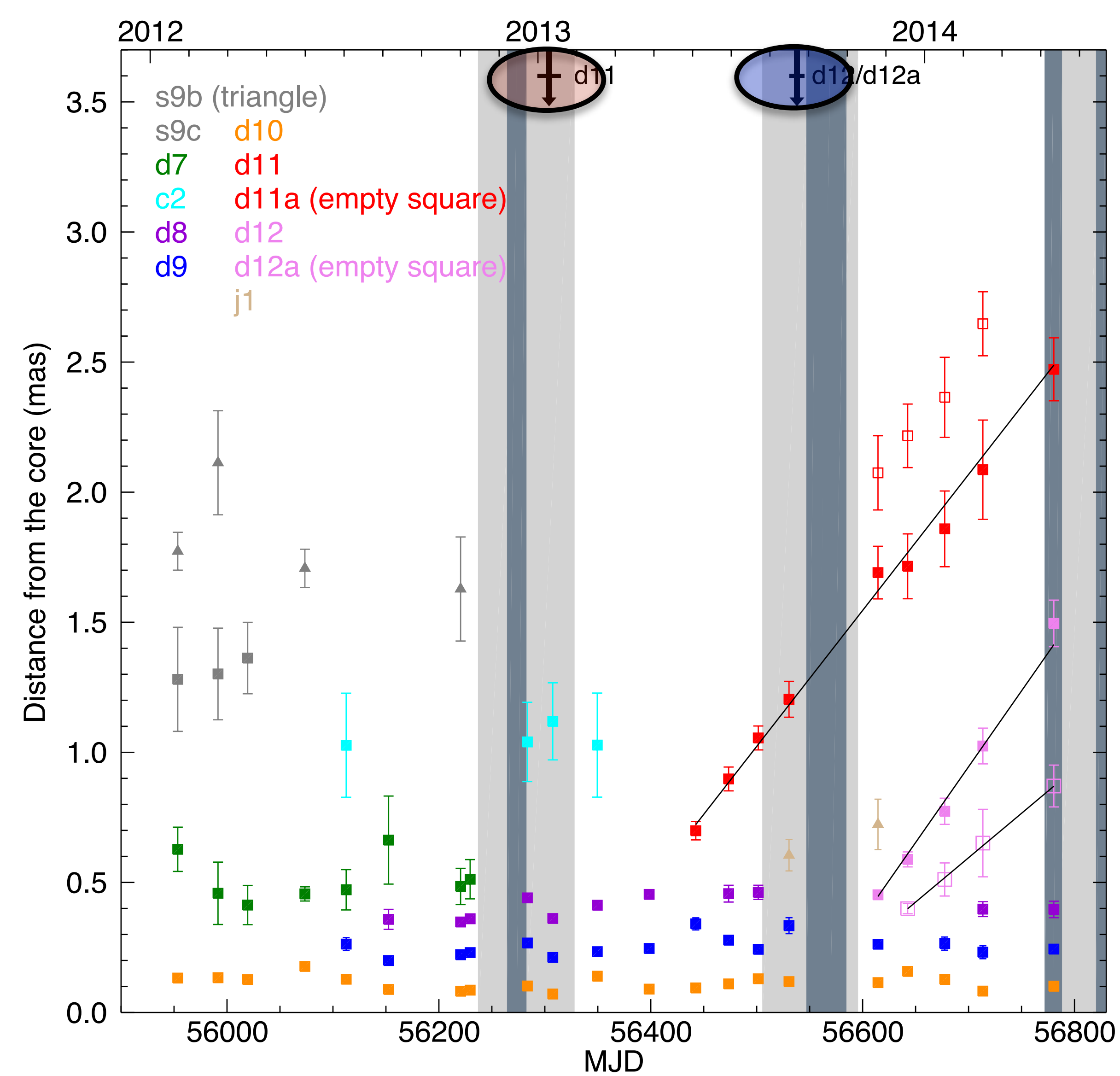


First γ-ray takes place 34 days (~1.9 pc de-projected) before component d11 crosses the core, or about half the BH-core distance.

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

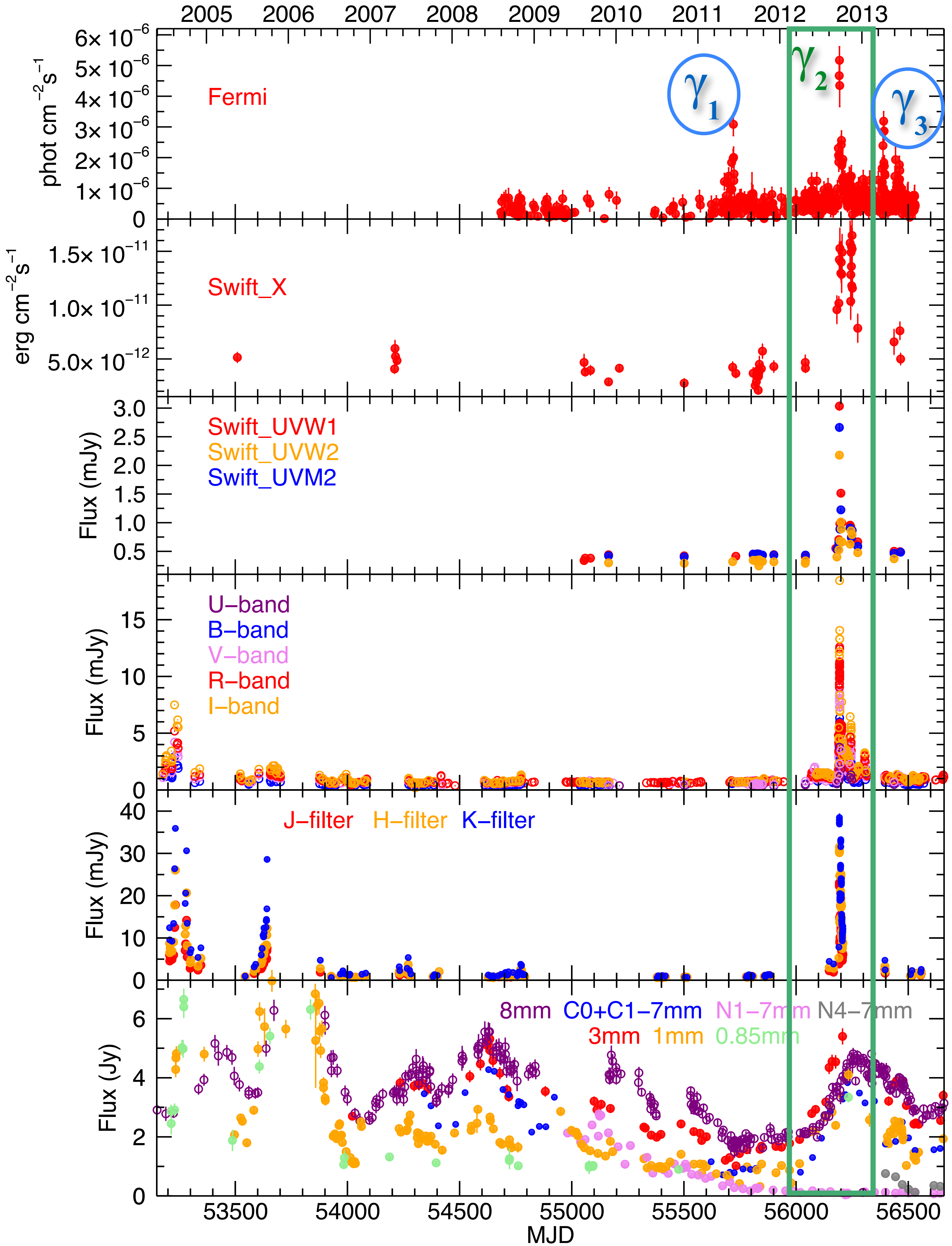
Hence, **γ-ray detections took place near the core, parsecs away from the BH.**

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



Multi-wavelength monitoring collecting *10 yrs* of data

(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 (Orphan flares)

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 all the other wavebands.**

Casadio et al. (2015b)

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

VLBA-BU-BLAZAR

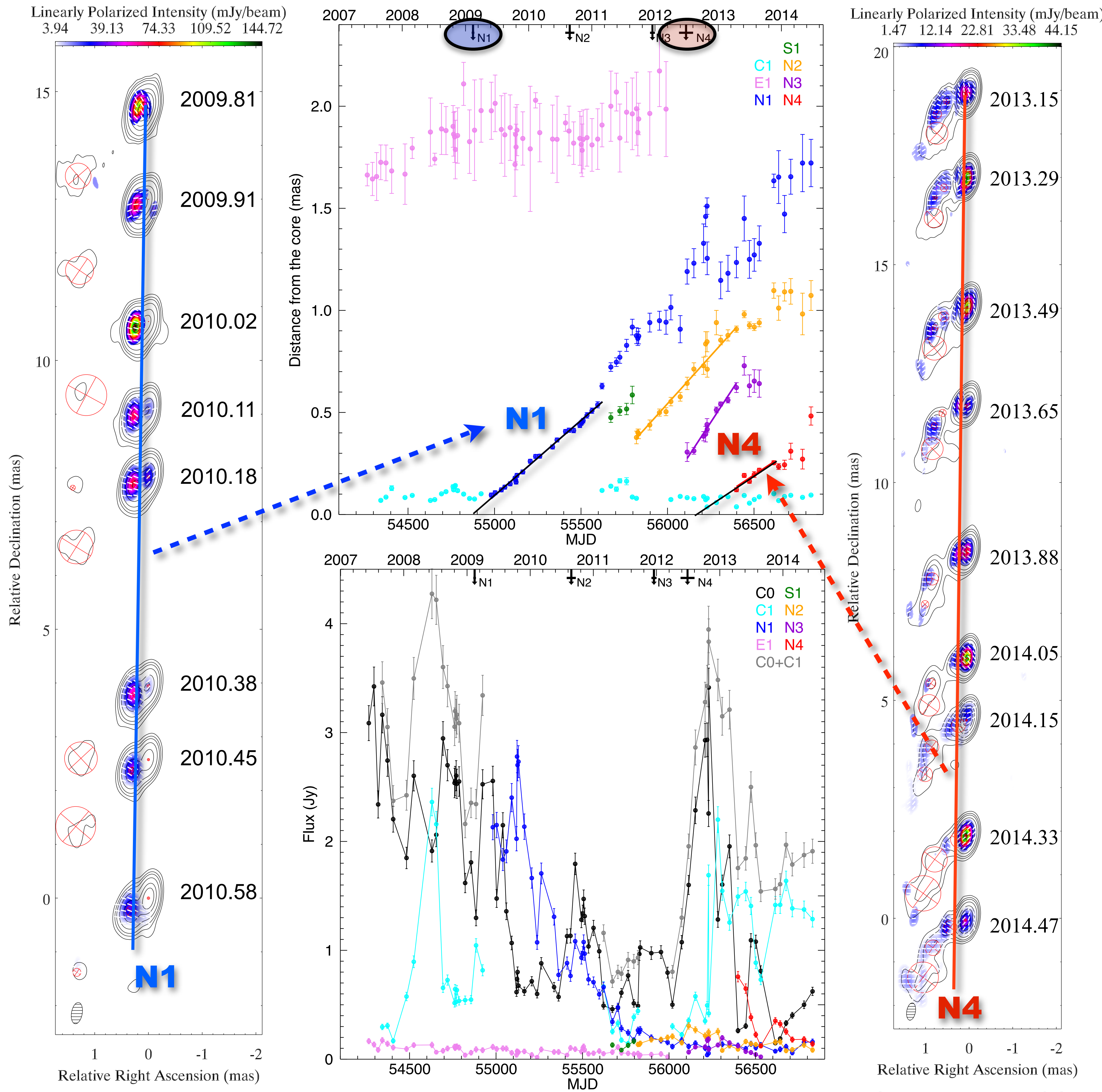
80 epochs

June 2007 - June 2014

Four main superluminal components and two *stationary features*, in agreement with previous studies (Jorstad et al., 2001,2005; Fromm et al., 2013):

C1 at ~ 0.1 mas

E1 at ~2 mas



Casadio et al. (2015b)

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

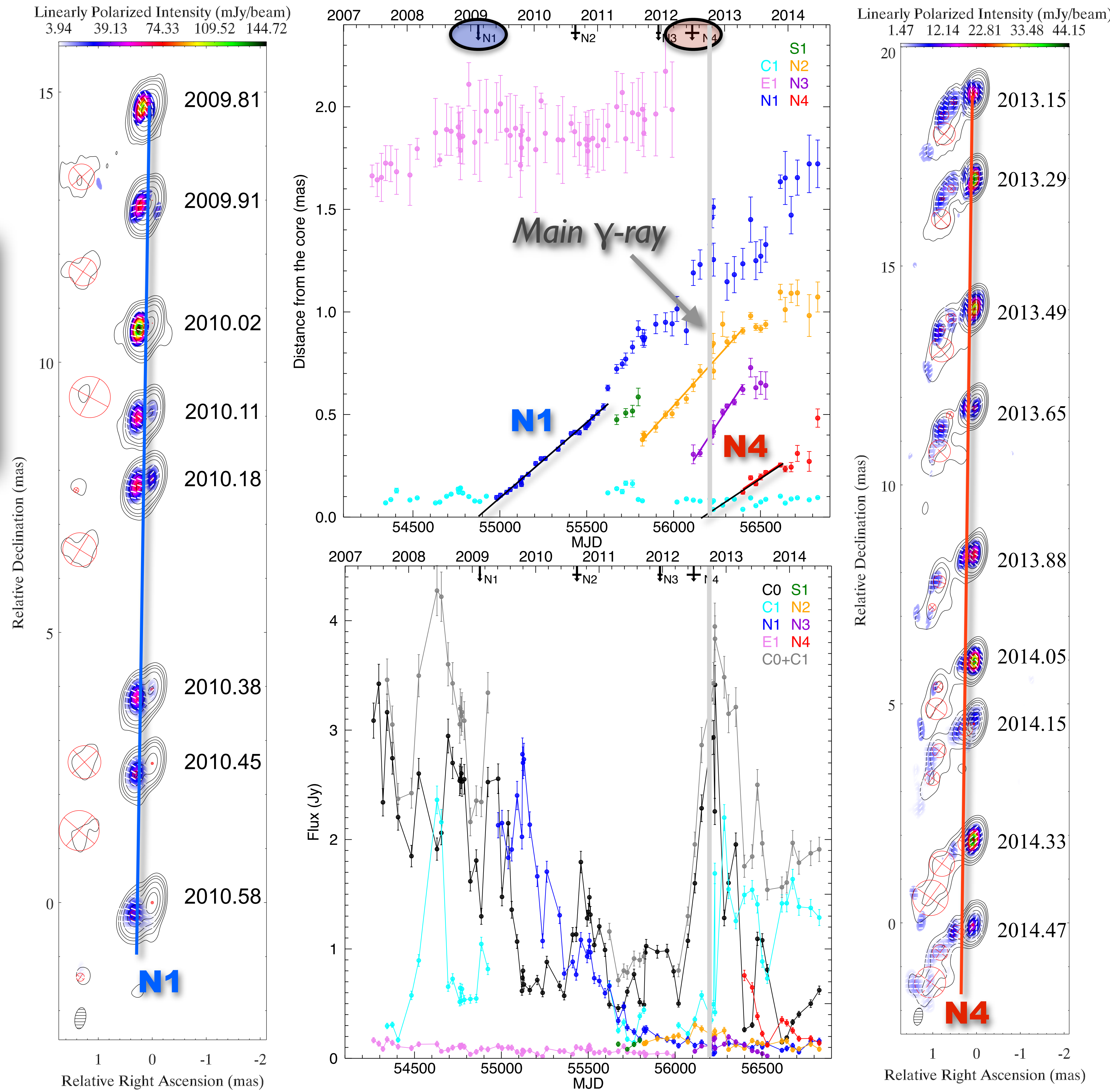
VLBA-BU-BLAZAR

80 epochs

June 2007 - June 2014

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

Strongest component N1 has no associated γ-ray flare.



Casadio et al. (2015b)

Progressive increase in δ_{var} with time due to a reorientation of the jet towards the observer.

Component N4 has the largest δ_{var} ever observed in CTA102, at θ_{var}=1.2º.

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)

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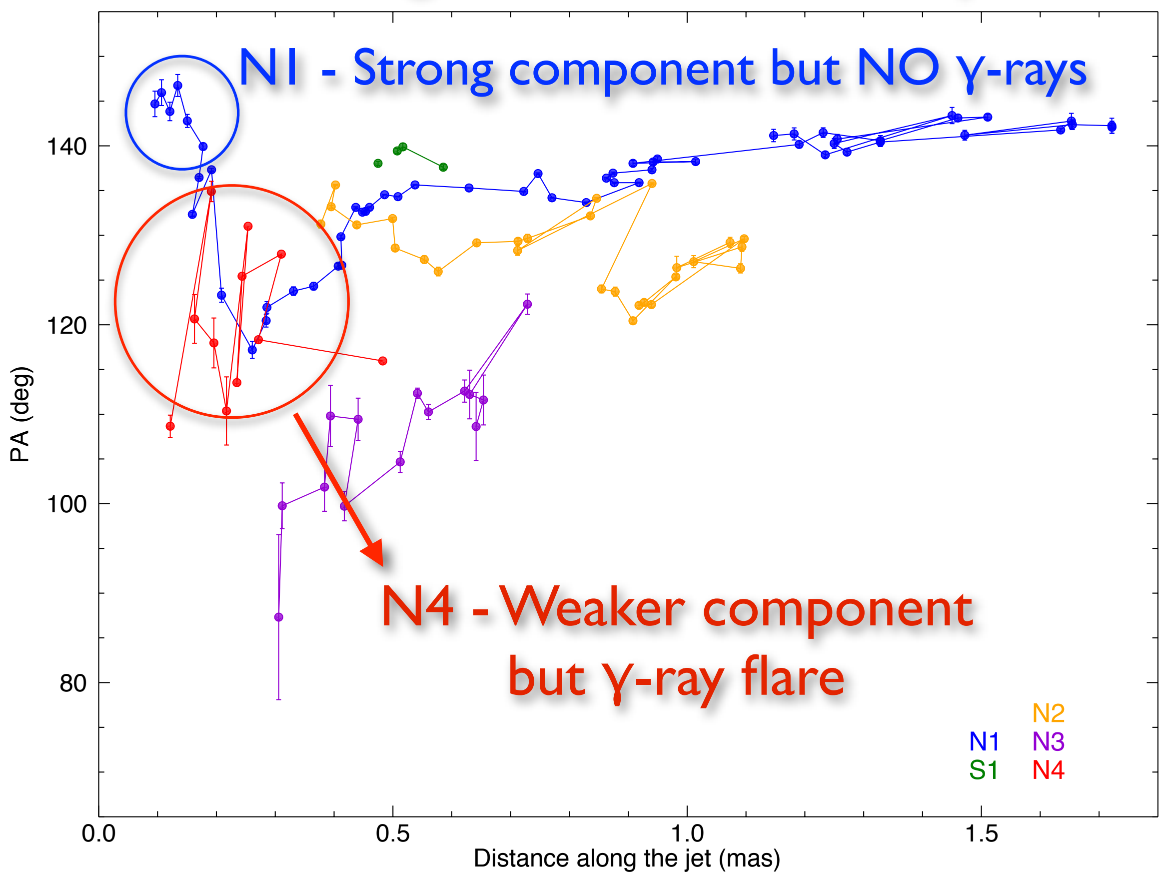
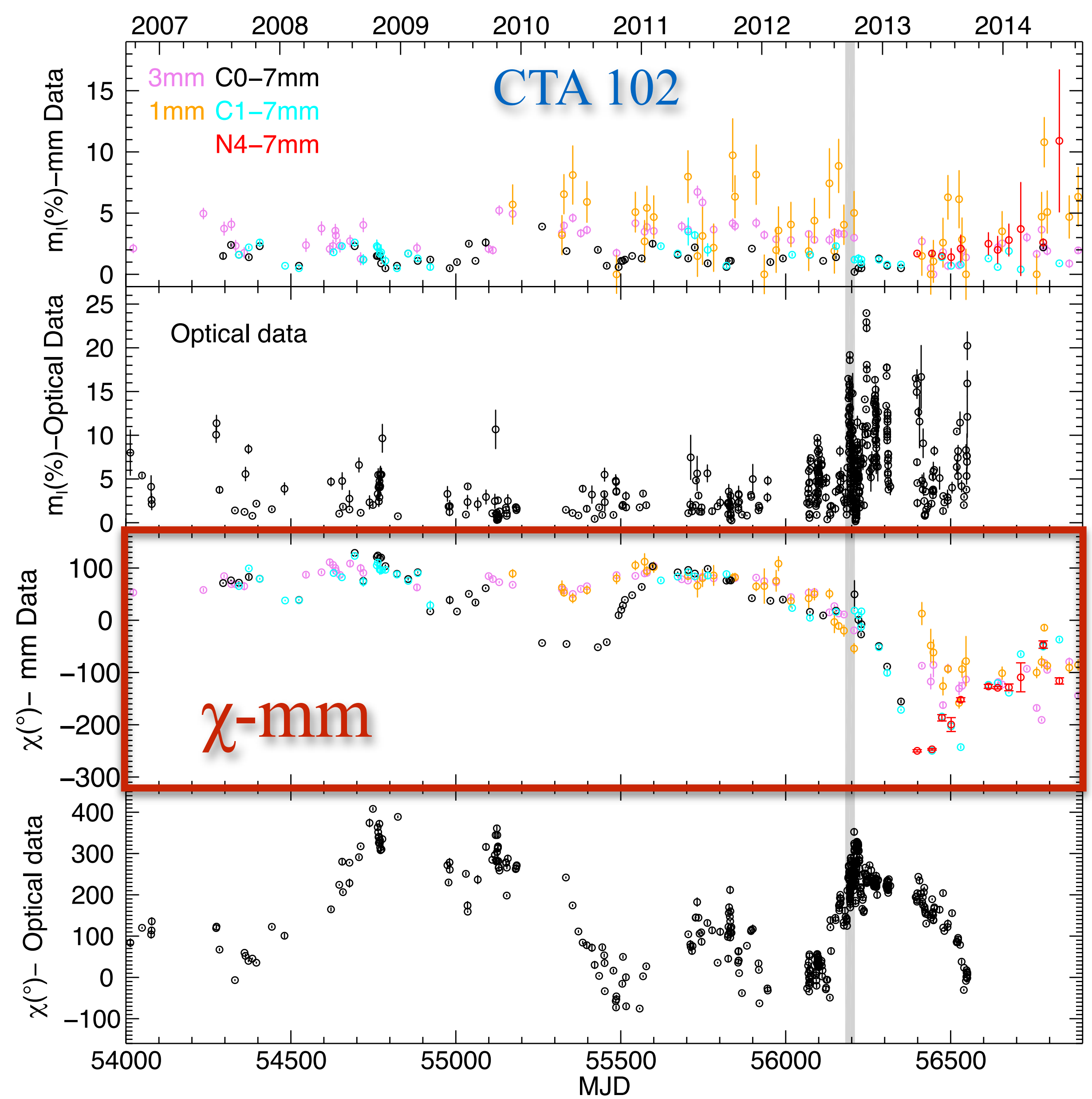
Position angles of model-fit components





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.

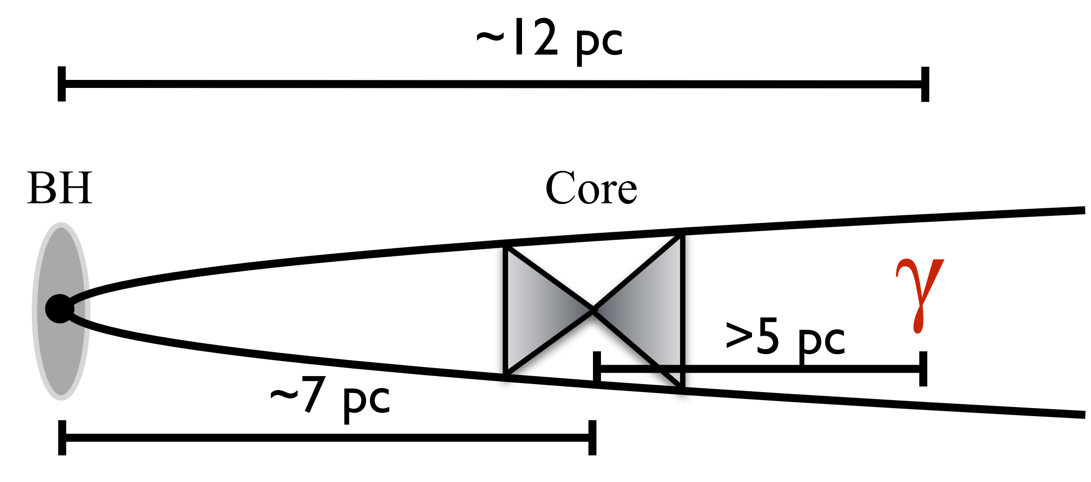
Casadio et al. (2015b)

The mm-VLBI core is located at a de-projected distance of ~7 pc from the BH (Fromm et al. 2015).

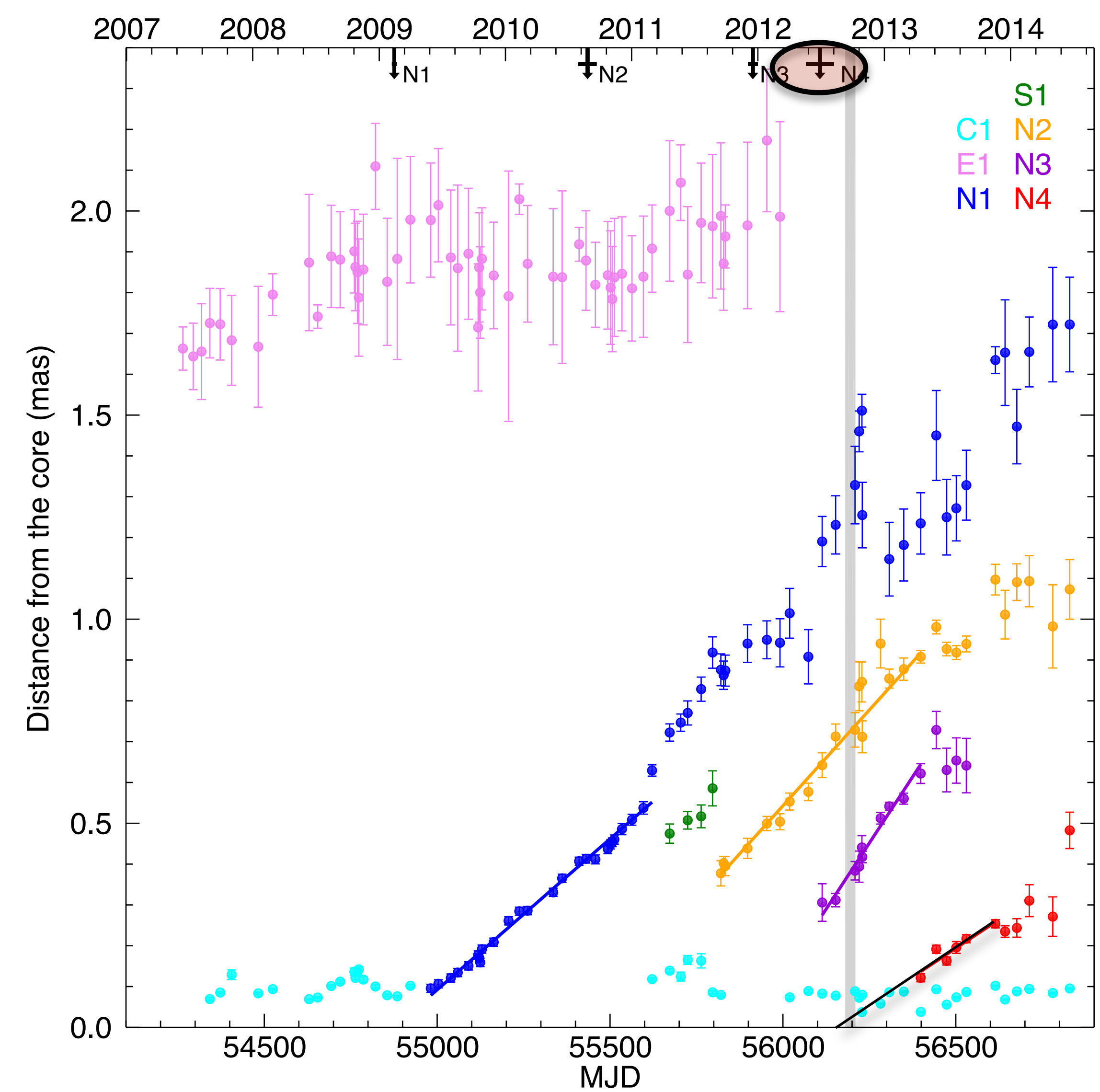
Main γ-ray flare in 2012.73 occurred 47 to 127 days *after* component N4 crossed the mm-VLBI core in 2012.49±0.11, or at a *de-projected* distance of > 5 pc from the core.

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.**



De-projected distances



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.
  (in agreement with MOJAVE's results - Pushkarev's talk)

- 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.