Radio and γ-ray connection. Variability and polarization properties in relativistic jets

M. Orienti

(INAF-IRA)

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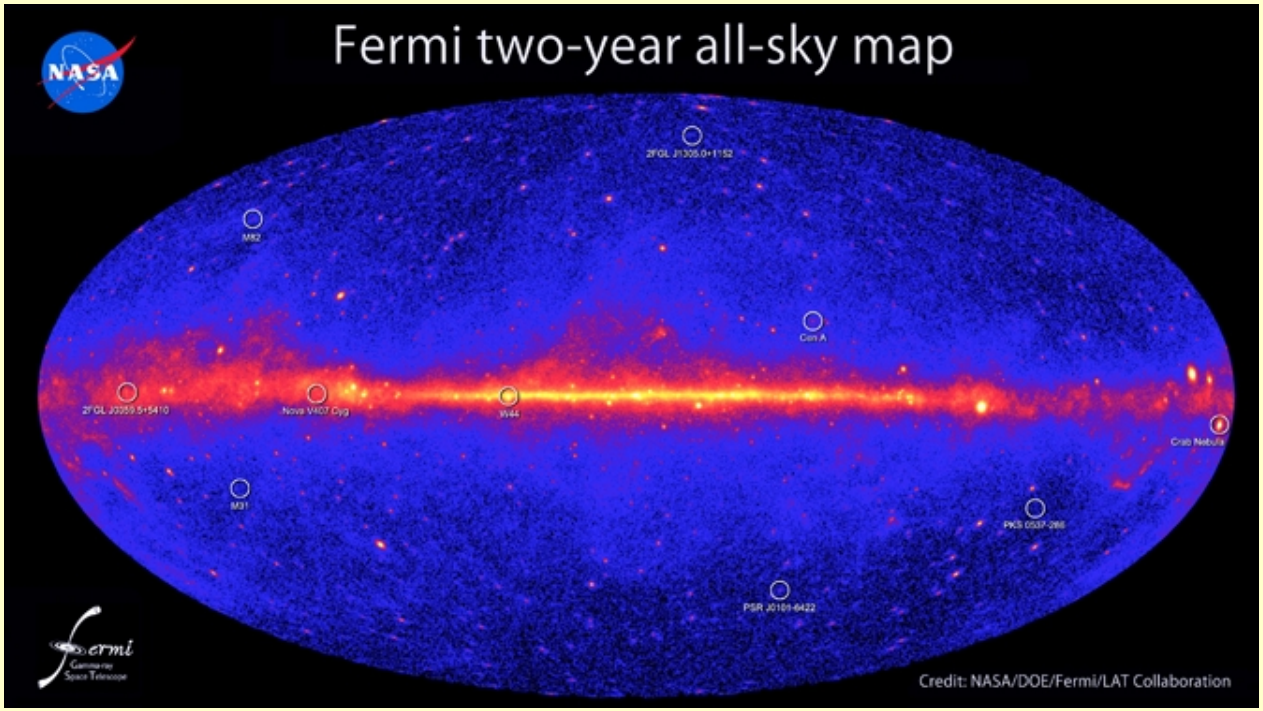
In collaboration with people involved in GENJI, OVRO, FGAMMA, FERMI-LAT Collaboration

This research has made use of data from the MOJAVE database that is maintained by the MOJAVE team (Lister et al., 2009, AJ, 137, 3718)

The extragalactic γ-ray sky

In the 2LAC clean catalogue there are 886 extragalactic sources (Ackermann+2011):

- 862 (97%) blazars
  - 310 FSRQ
  - 395 BL Lac
- 26 (3%) other objects (4% in 1LAC)



Strong γ-ray emitters:

- High radio luminosity
- Fast apparent jet speed
- High variability Doppler

Savolainen+ 2010, Lister+ 09, Kovalev+ 2009

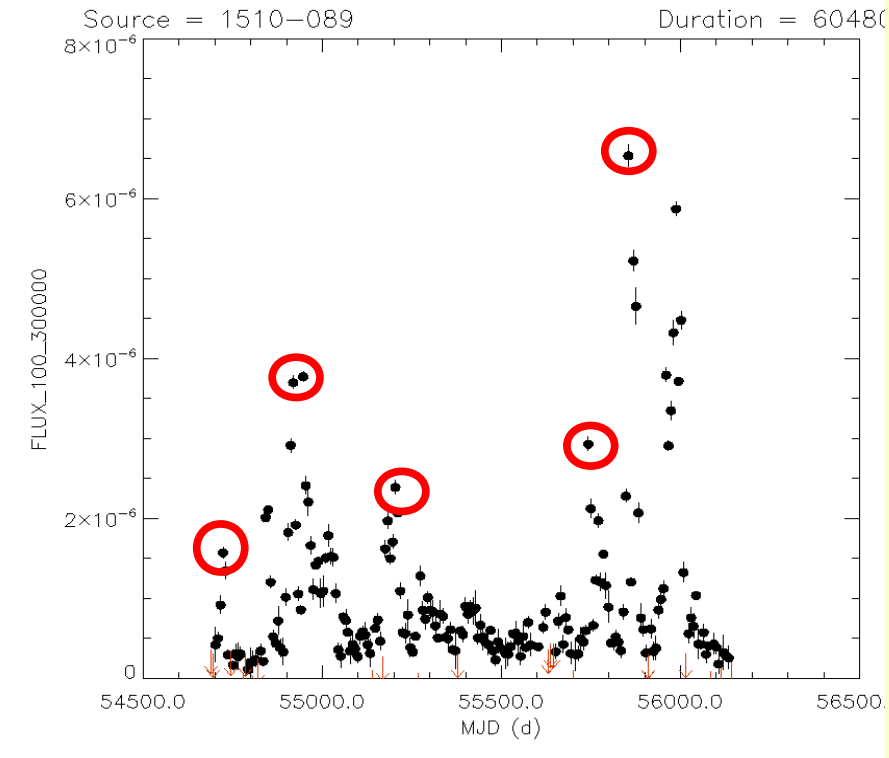
Extragalactic γ-ray sky dominated by radio-loud AGN

Open questions

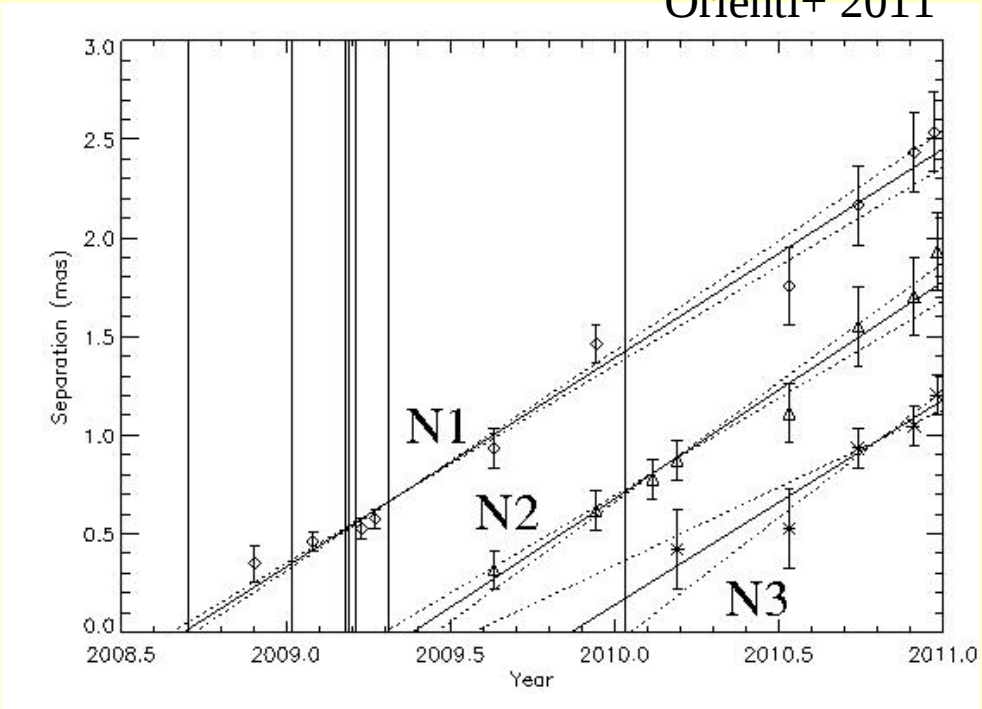
- How do jets form?
- What is the γ-ray emitting mechanism?
- Where is the region responsible for γ-ray emission?
- What is the “jet-base”?
- .....

Why study PKS 1510-089?

- FSRQ at z=0.361
- **Strong variability across the entire e-m spectrum**
- Highly superluminal jet components ejected close in time with a γ-ray flare
- **Detected at VHE (E>100 GeV)**



Orienti+ 2011

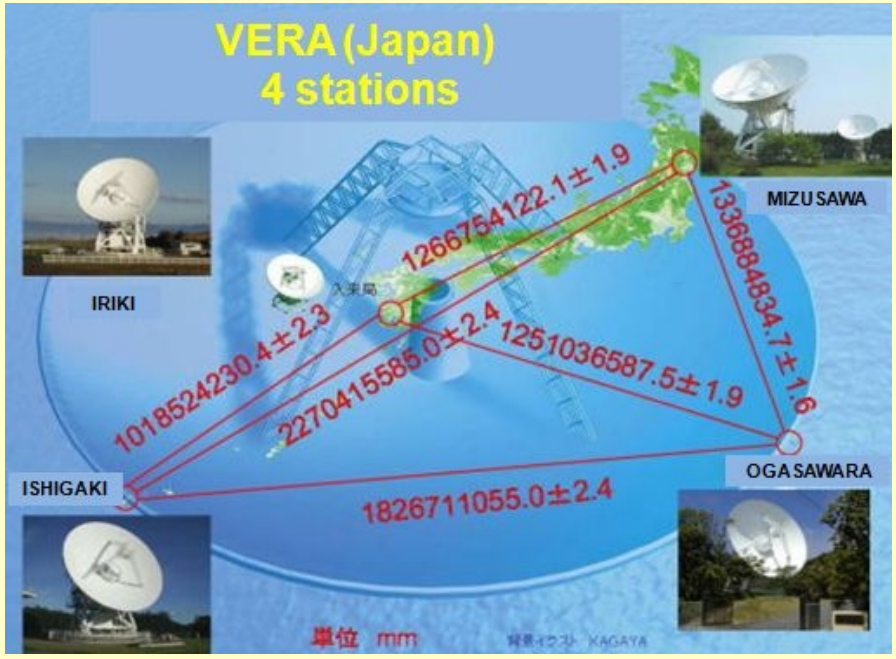


- High level of polarized emission in radio and optical bands
- **Large rotation of the EVPA** close in time with γ-ray flares

Radio follow up

Single-dish obseravtions:

- **Medicina observations at 5 and 8 GHz**
- **40-m OVRO observations at 15 GHz**
- **F-GAMMA data from 2.6 to 142 GHz**



High resolution:

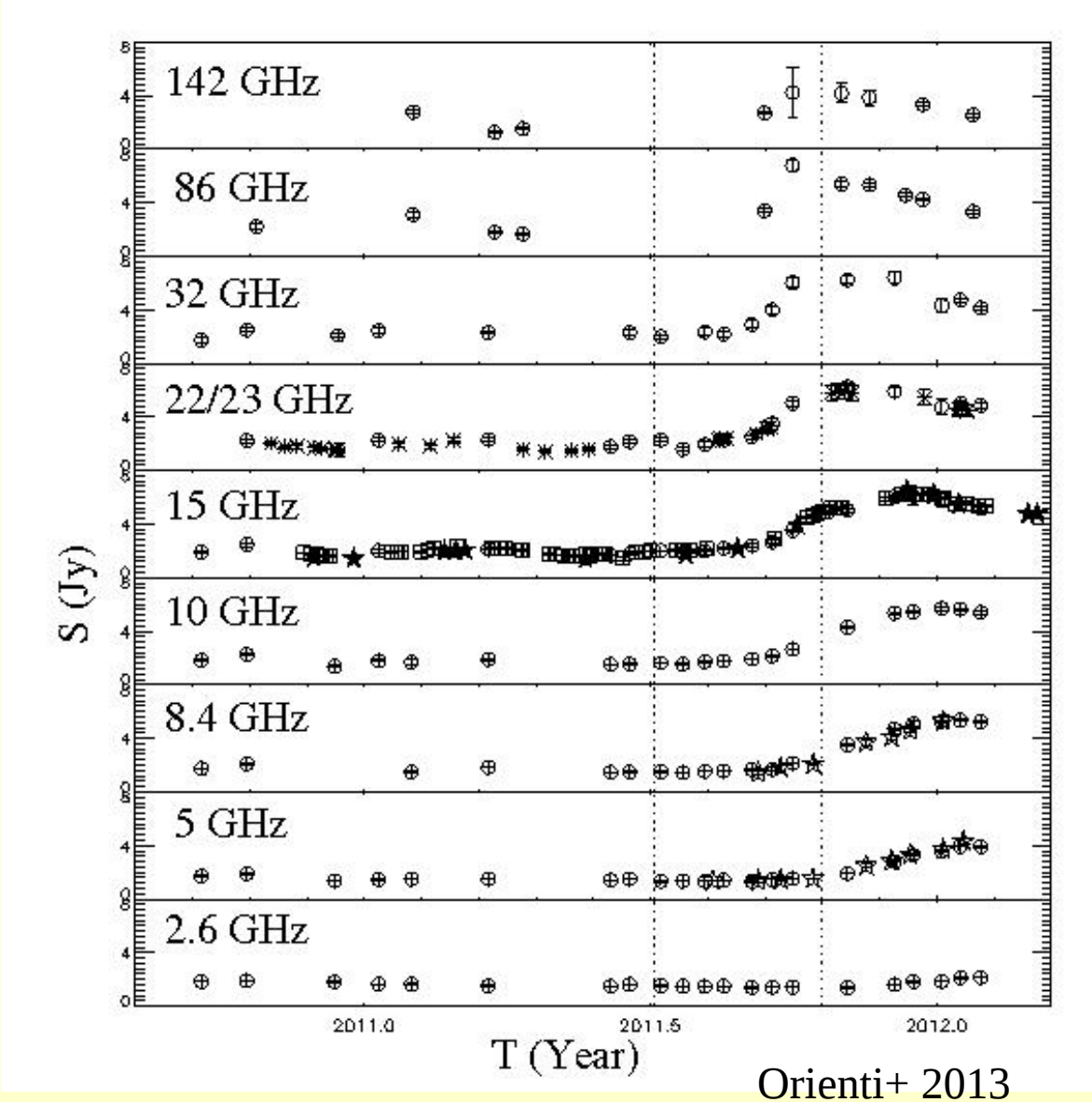
- **MOJAVE data at 15 GHz**
- **VERA observations at 22 GHz**

Multiwavelength analysis

The peak flux density is not simultaneous at the various frequencies due to opacity effects.

In the millimeter regime the maximum occurs at the end of September, although the sparse time coverage does not allow an accurate estimate.

At decimeter wavelength (2.6 GHz), the flux density was still increasing on 2012 January.



Orienti+ 2013

Proper motion

Component A:

v= (34.7±0.7)c

T_0~ 2010.20

γ-ray flare: Jan 2010

Component B:

v= (27.5±2.4)c

T_0~ 2011.9

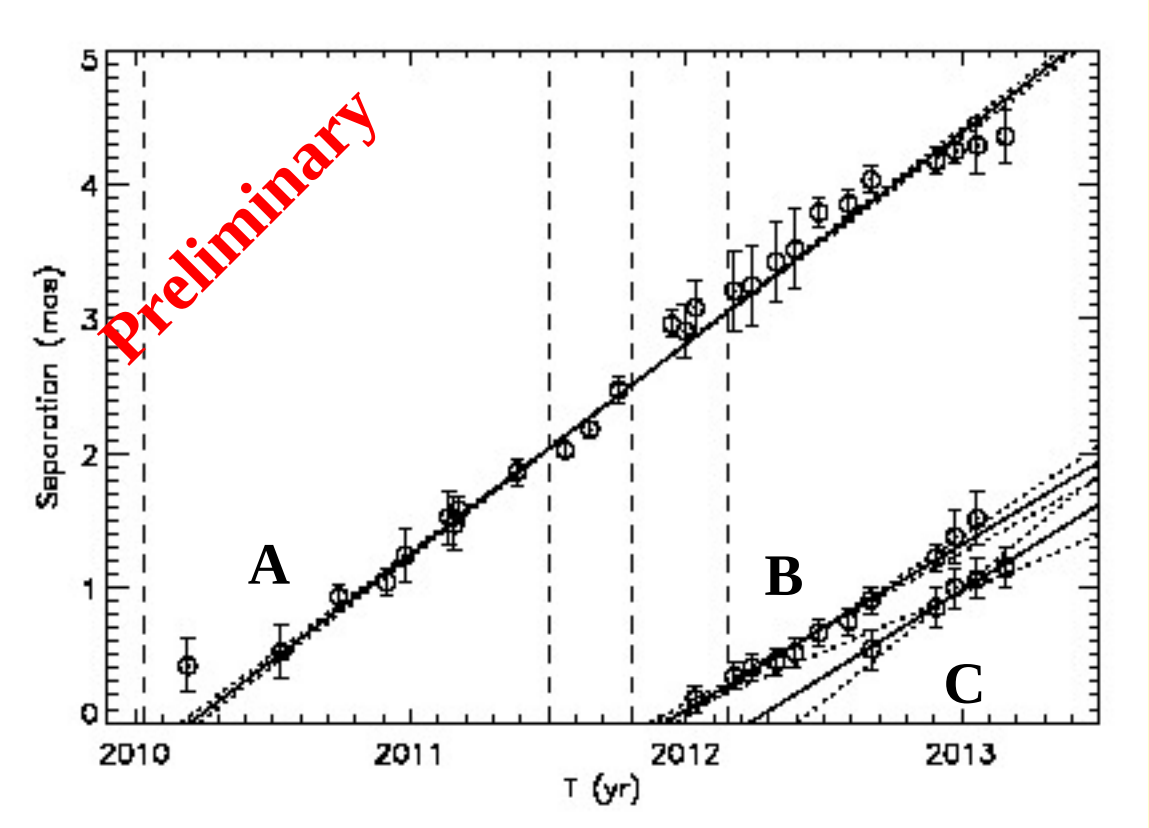
γ-ray flare: Oct 2011

Component C:

v= (28.5±8.9)c

T_0~ 2012.20

γ-ray & VHE flare: Feb 2012

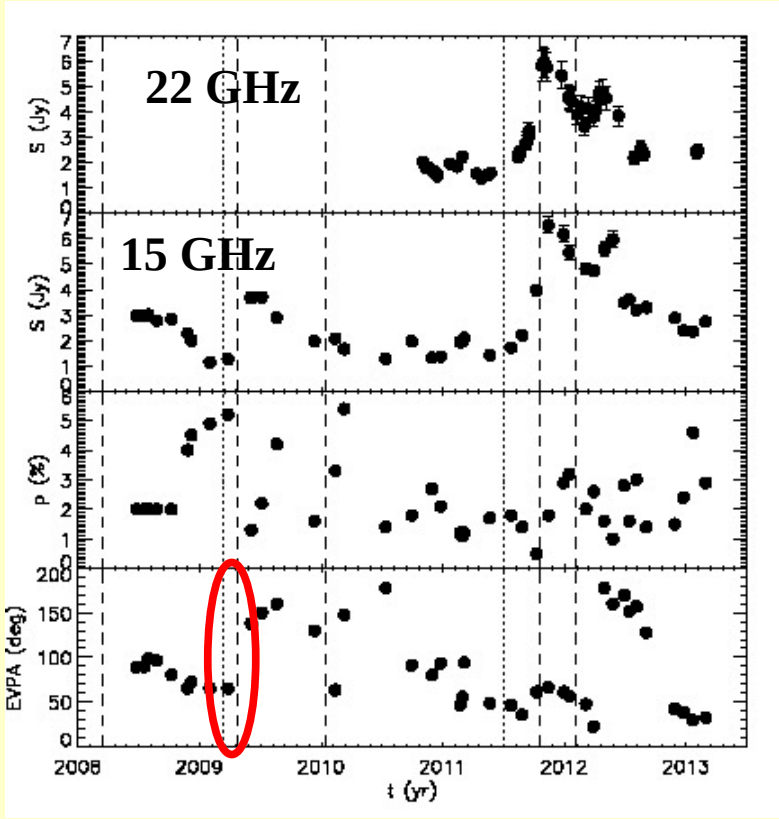


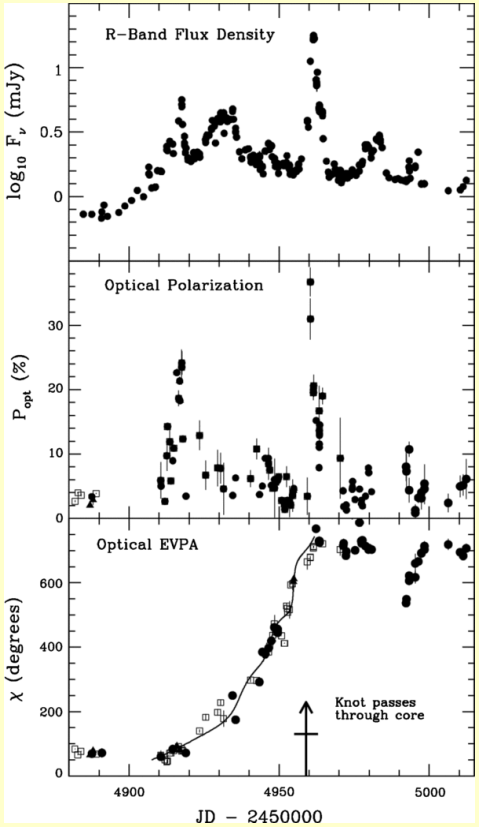
No obvious component ejected close in time to the July 2011 flare

Polarization: core component I

A: April 2009

- Strong γ-ray and optical flare;
- VHE detection (HESS; Abramowski+13);
- Optical EVPA rotates of ~720°
- Radio EVPA flips of ~70°
- Ejection of new superluminal jet component with v~24c;



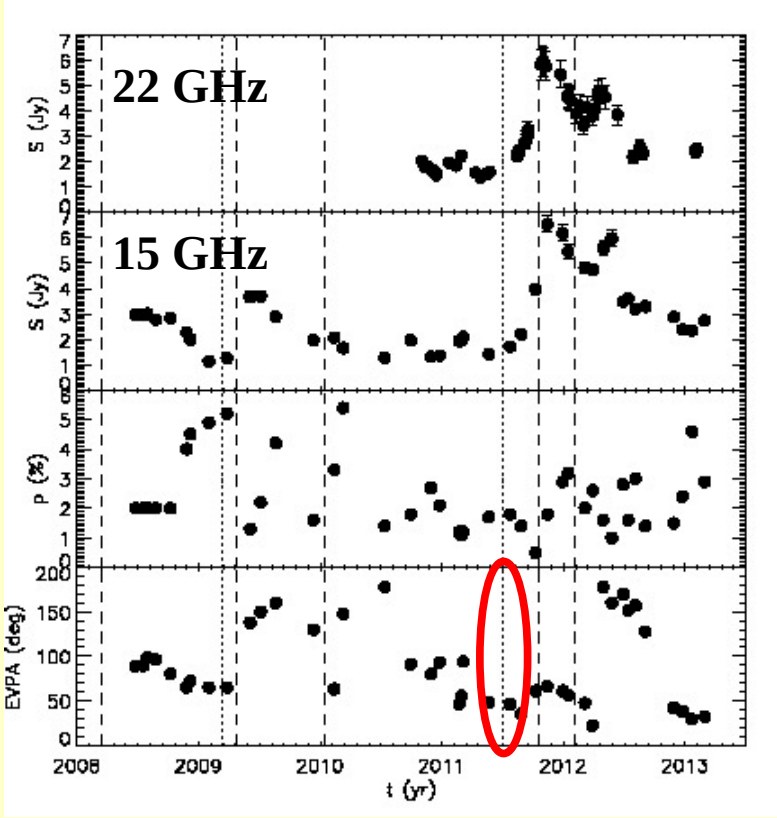


Marscher+10

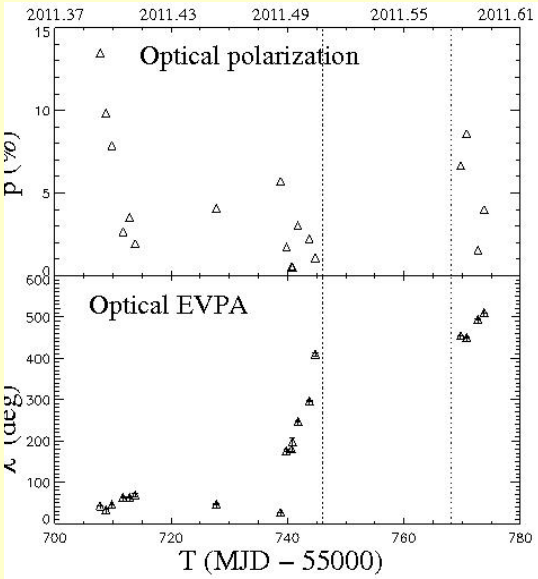
Polarization: core component II

B: July 2011

- Strong γ-ray flare;
- Optical EVPA rotates of ~380°
- No significant radio variability
- No changes in radio EVPA
- No ejection of superluminal blobs;



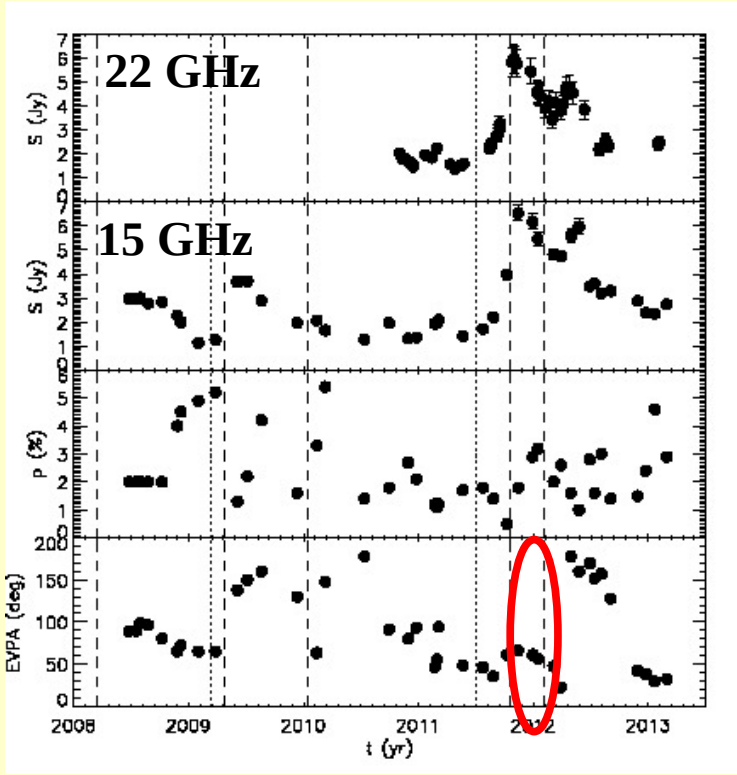
Orienti+13



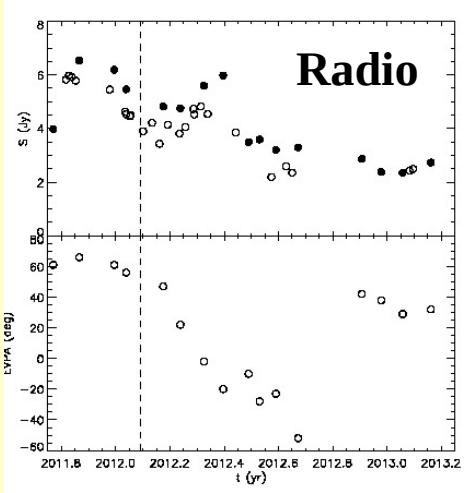
Polarization: core component III

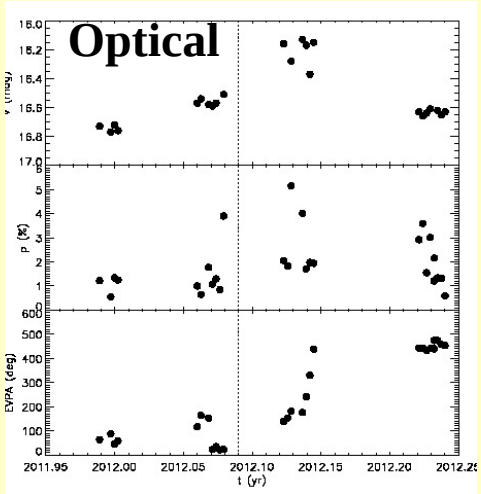
C: February 2012

- Strong γ-ray flare;
- VHE detected by MAGIC (Cortina 2012);
- Optical EVPA rotates of ~330°
- Rotation of the radio EVPA of ~80° in 2 months.
- Ejection of a new component with speed ~28c



Orienti+ in prep





Steward observatory

Polarization: jet components

A component:

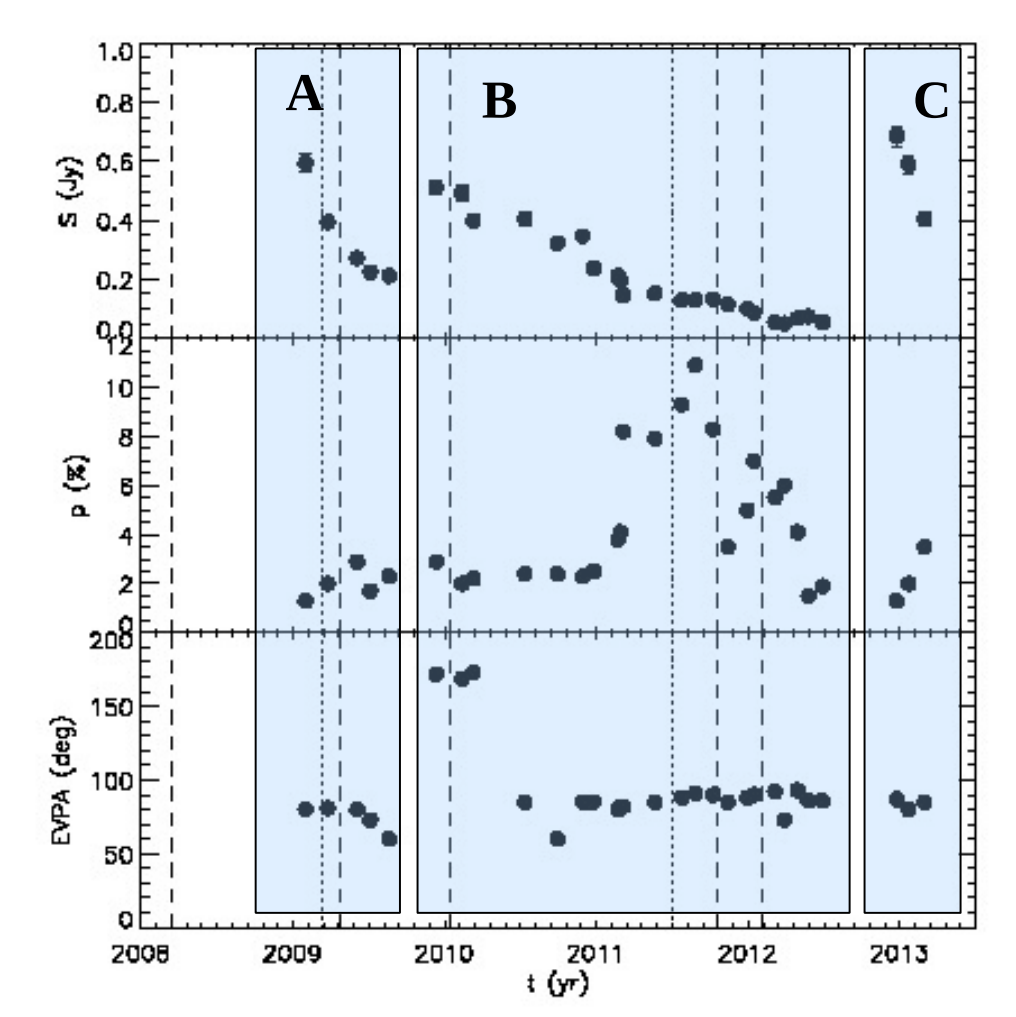
Ejection time ~ 2008 September
Flux density decreases with time

B component:

Ejection time ~ 2009 April
Flux density decreases with time,
Polarized flux density almost constant, but fractional polarization increases above 10%

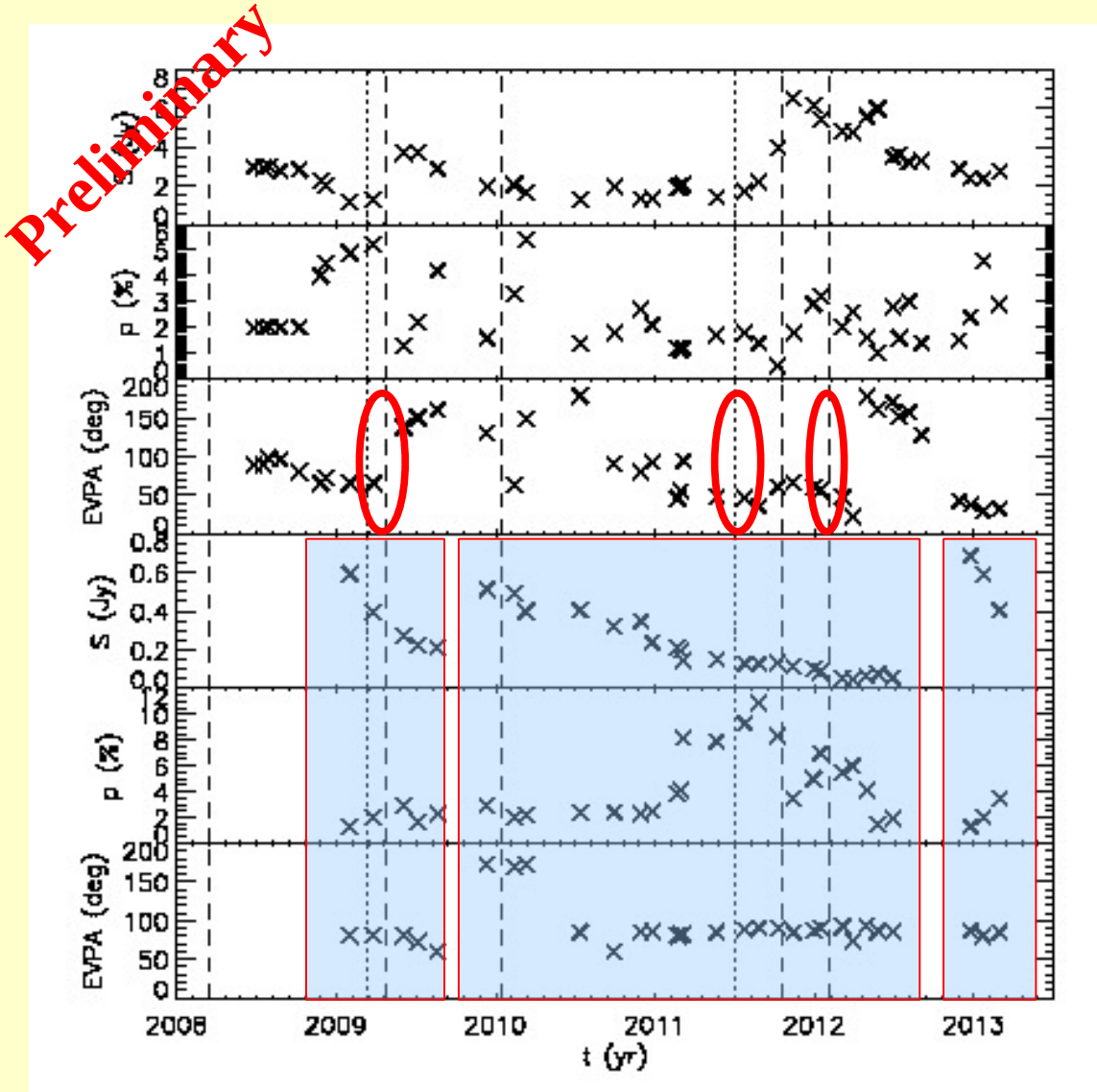
C component:

Ejection time ~ 2011 October
Flux density decreases with time



Polarization angle roughly constant

Polarization properties



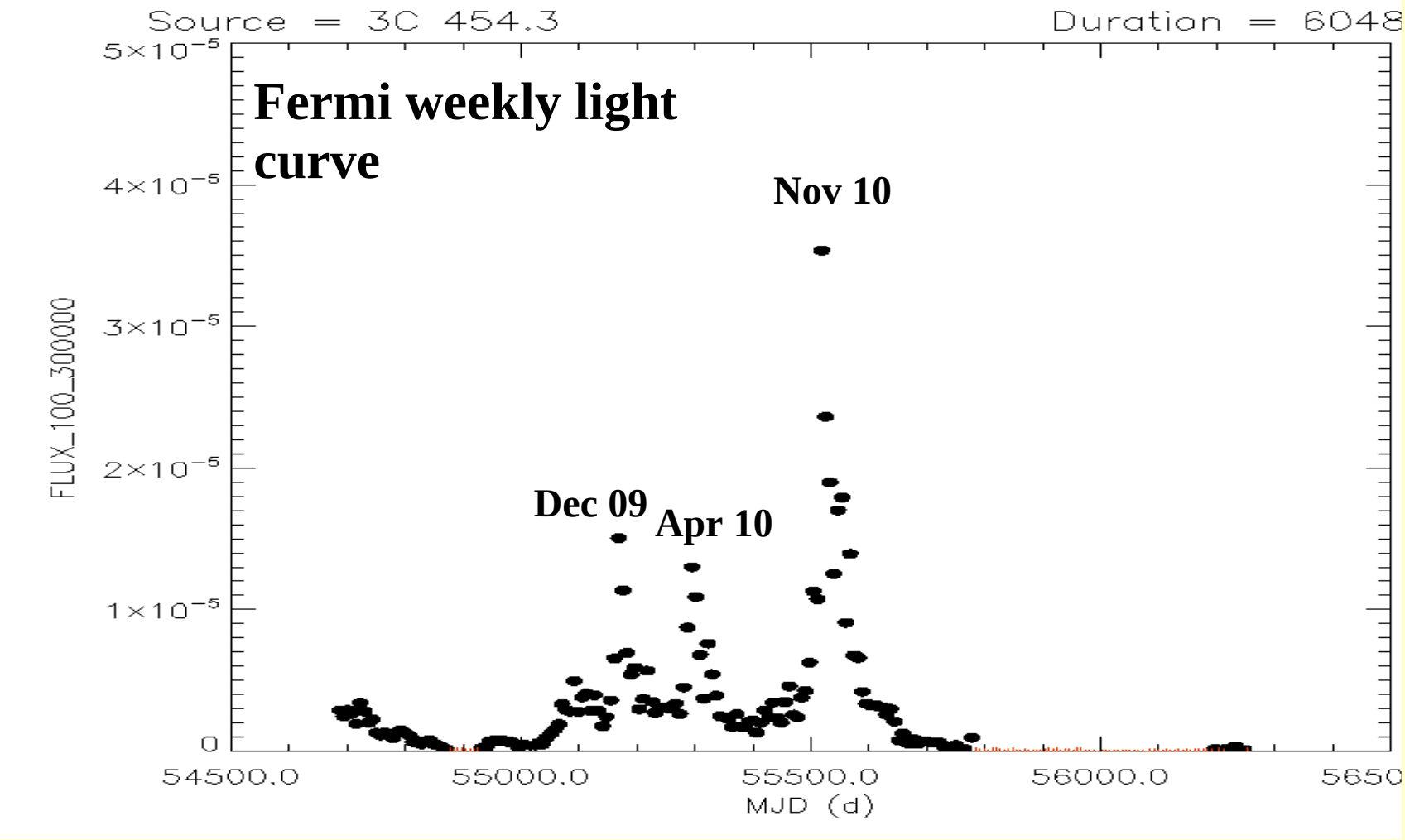
Core component

- No clear trend is observed in the polarization properties
- Fractional polarization <6%
- 70° EVPA rotation after 2009 flare, detected also by HESS at VHE
- EVPA rotation starting after 2012 flare detected by MAGIC at VHE

Jet components

- Properties change as the blob evolves (adiabatic losses)
- Fractional polarization up to 10%
- EVPA almost constant
- Main jet H dominates on the individual blob?

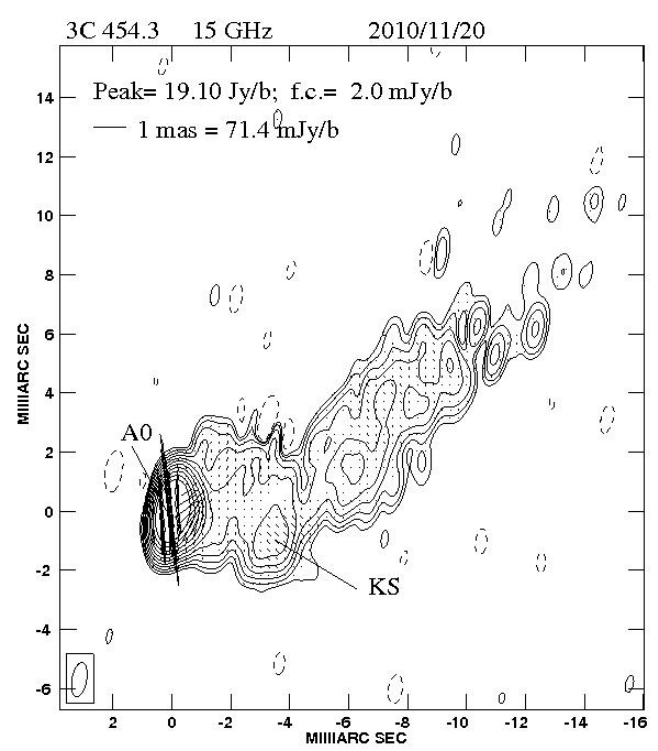
3C 454.3: γ-ray light curve

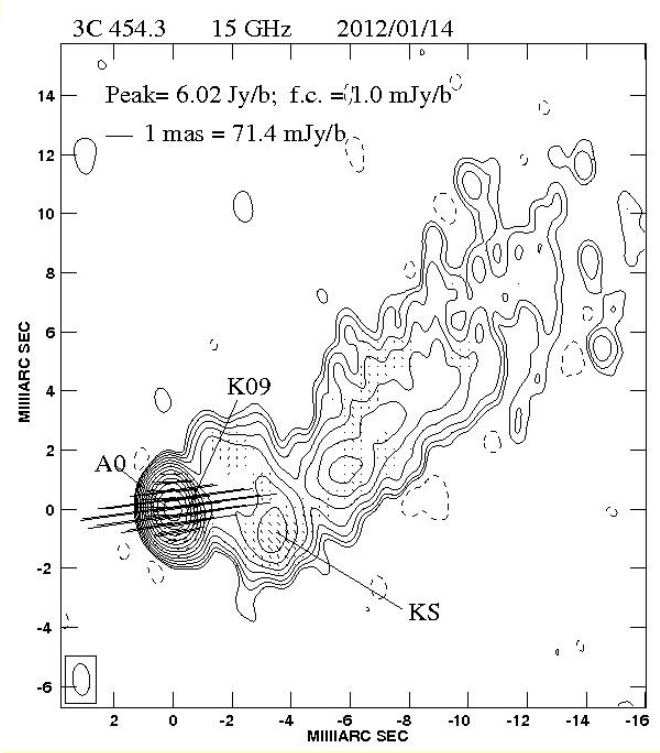


3C 454.3 was the most active blazar in gamma rays during the first 3 years of Fermi operation, now is sleeping…an ideal candidate to investigate the radio and gamma rays connection!

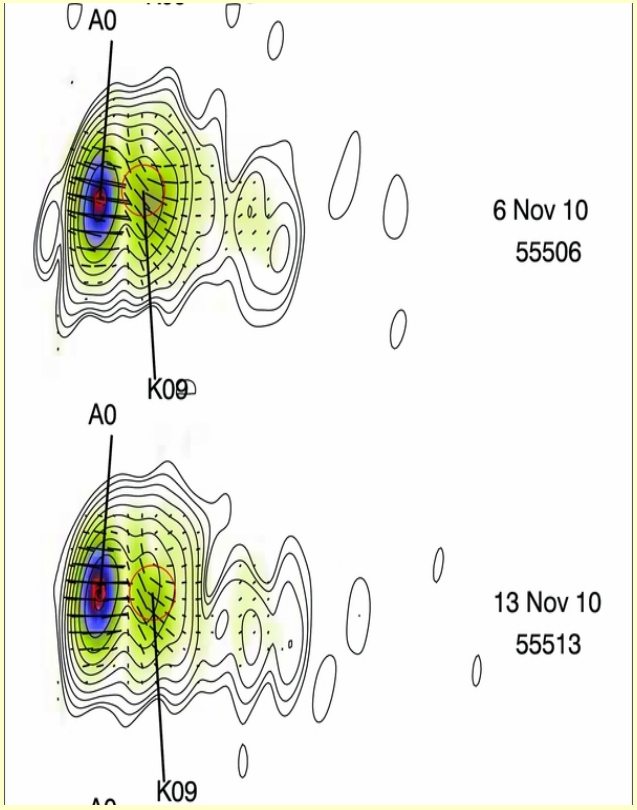
Parsec-scale morphology

Orienti+ in prep.



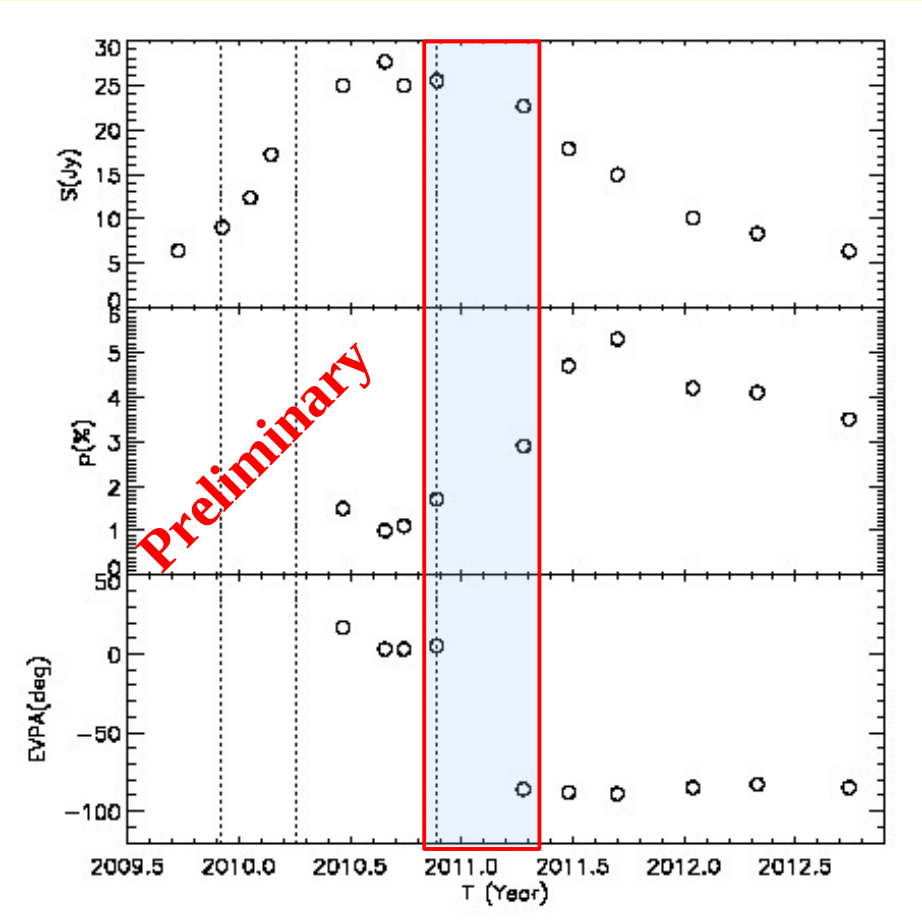


Wehrle+12

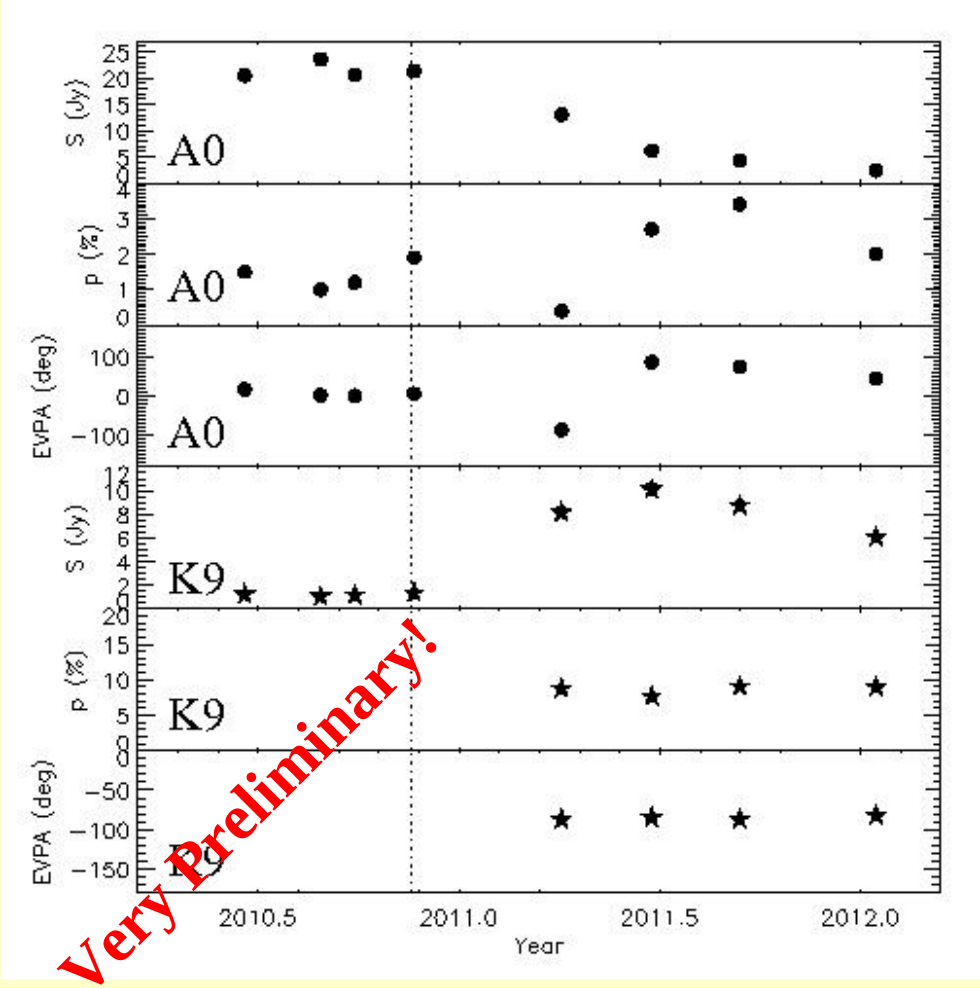


K9: $\beta_{app} = 9.2 \pm 0.6$

Pc-scale radio light curve



Change in core polarization properties



High energy emitting region

The location of the high-energy emission is still under debate:

Different flares may be produced in **different regions**

AGN region → July 2011 flare in PKS 1510-089

AGN region → November 2010 flare in 3C454.3

JET region → November 2010 flare in 3C454.3

JET region → October 2011 flare in PKS 1510-089

The **main mechanism** and the **seed photons** at the basis of high-energy emission may vary **depending on the location** of the flare region

AGN region → **UV/optical photons from disk/BLR**

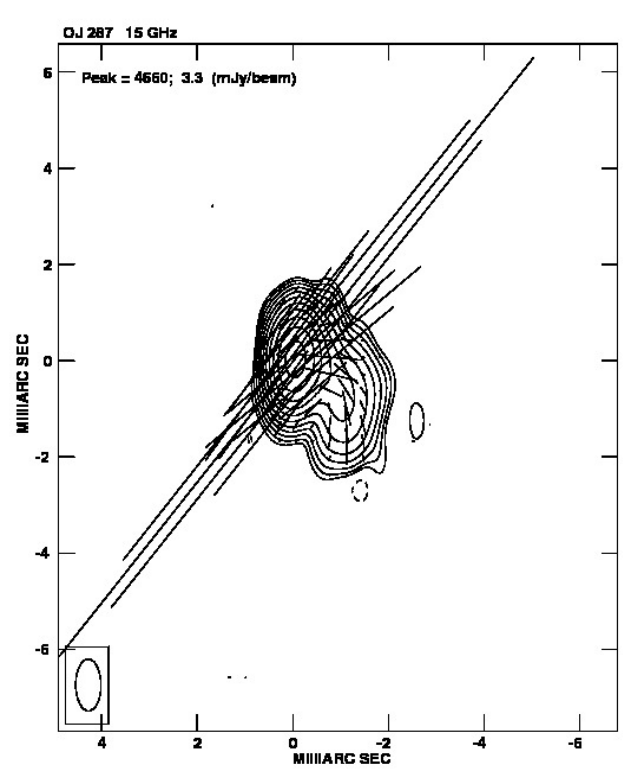
AGN region → **SSC/external synchrotron photons**

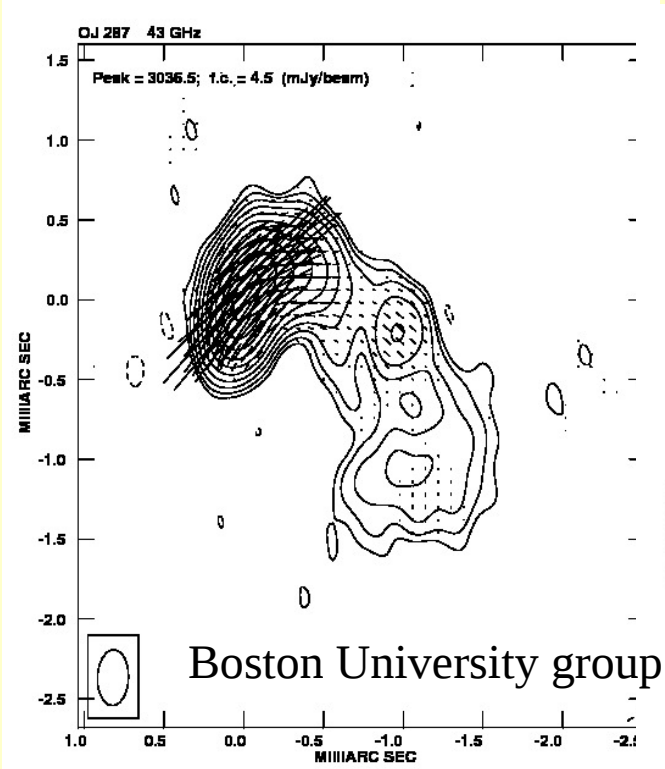
JET region → **SSC/external synchrotron photons**

JET region → **IR photons from dusty torus**

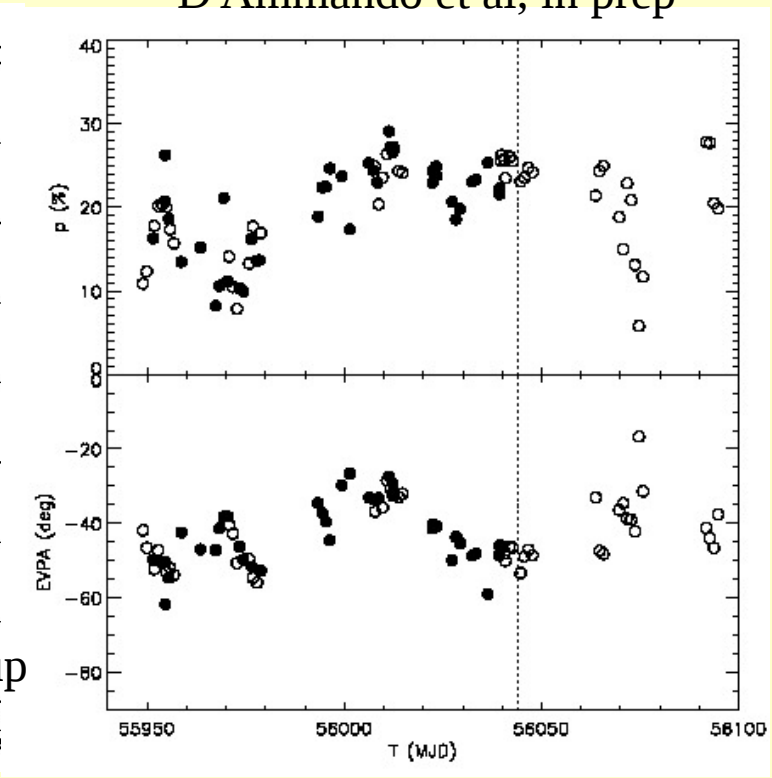
A “boring” case: OJ 287

D'Ammando et al, in prep



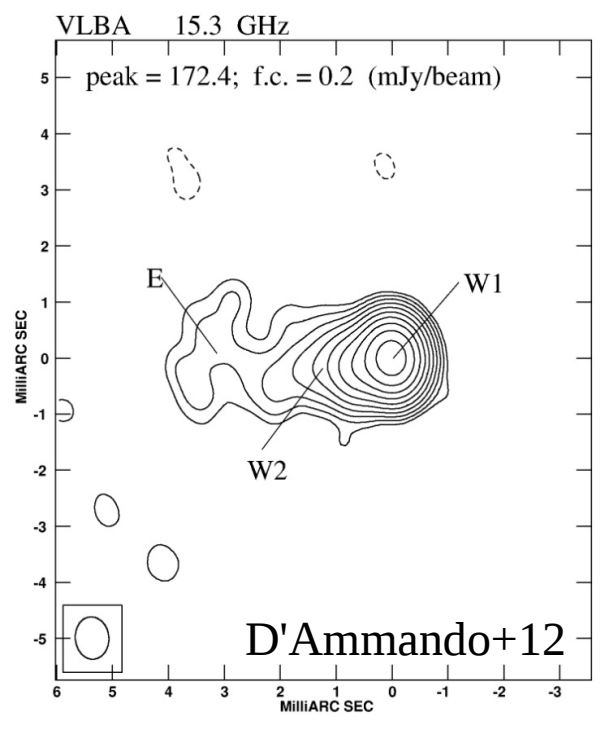


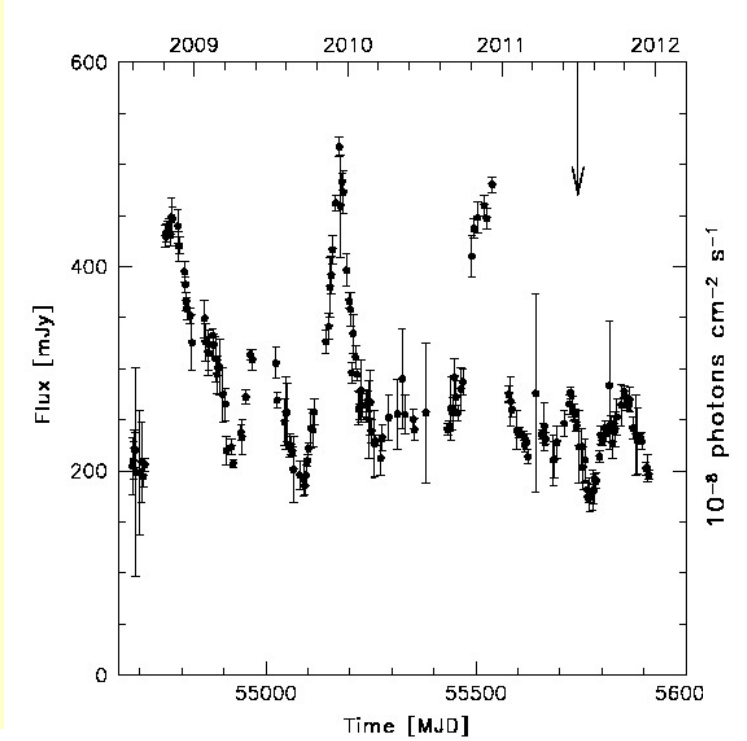
Boston University group

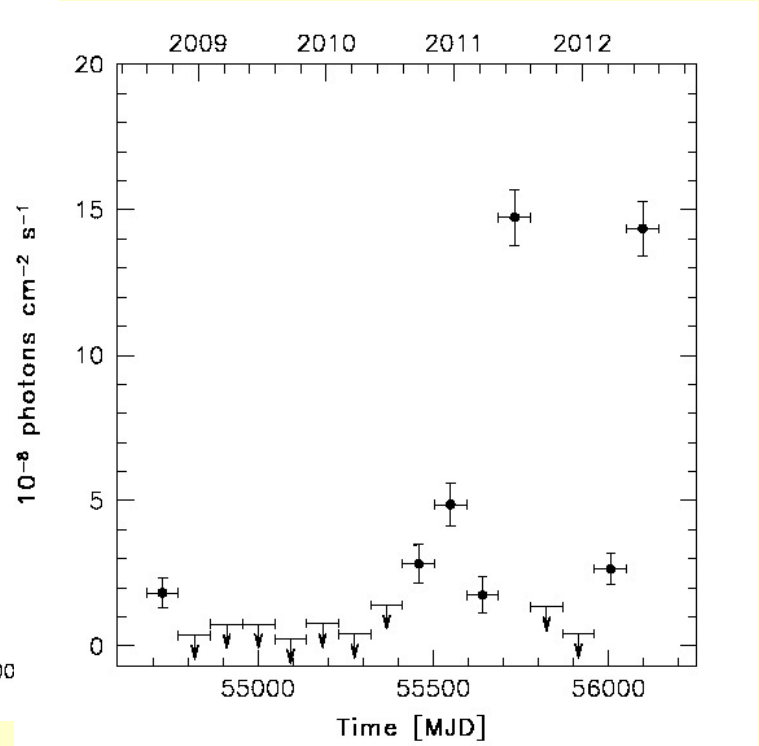


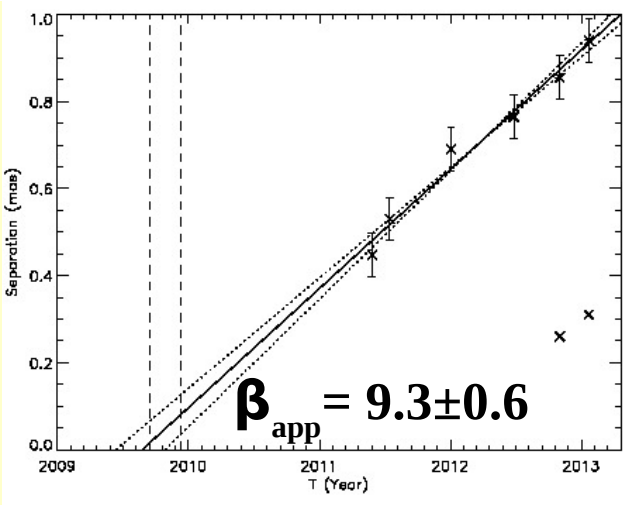
EVPA without significant changes. It is about ~-40° from radio up to optical band

SBS0846+513: relativistic jet in NLSy1









No clear γ-ray flare detected close in time with the ejection of a new jet component.

See D'Ammando's talk

Summary

The γ-ray flares may not show the same observational characteristics at different wavelength:

- Not all the γ-ray flares occurs close in time with the ejection of a blob

- The ejection of new jet components may not be associated with any γ-ray flare

- Large EVPA rotations in radio are not observed after each γ-ray flare

- 90° EVPA is observed first at high frequency and then at low frequencies: Opacity effects?

- In PKS 1510-089 the EVPA along the jet is almost constant suggesting that the magnetic field of the main jet structure dominates over the blob.

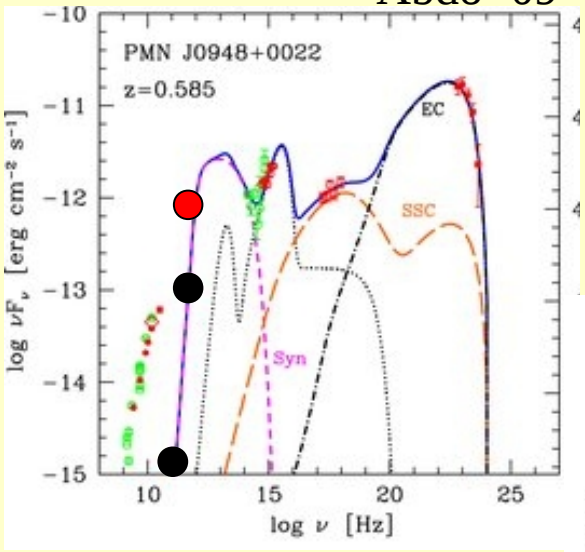
What about the future?...ALMA

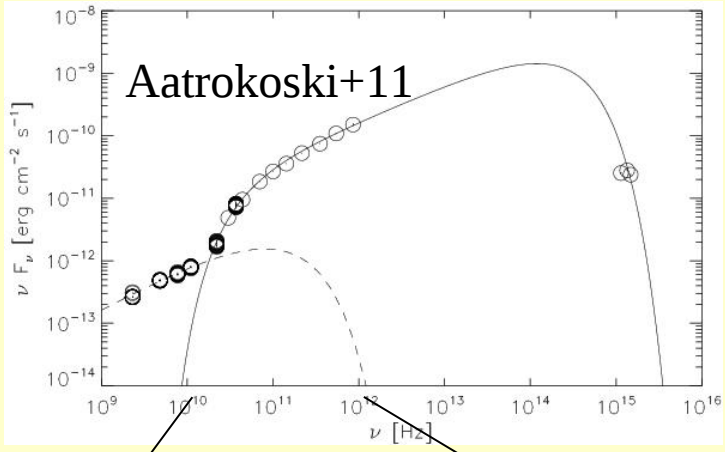
Planck 10σ is 0.25–1.0 Jy depending on the band. Only the brightest objects can be observed.

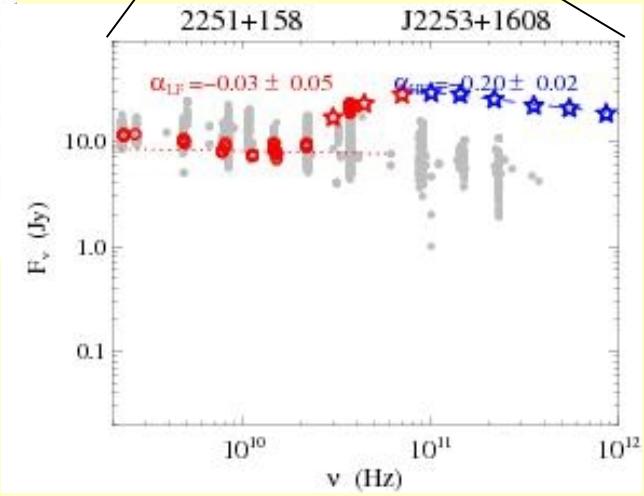
The majority of the radio sources are much fainter!!!

ALMA rms in 1 min: **~0.1, 0.3, 0.6, 5.3 mJy beam^{-1}** at 100, 230, 345, and 675 GHz

Abdo+09







Almost 2 orders of magnitude more sensitive and it provides full polarization information