On the radio and γ-ray connection at low and high redshift

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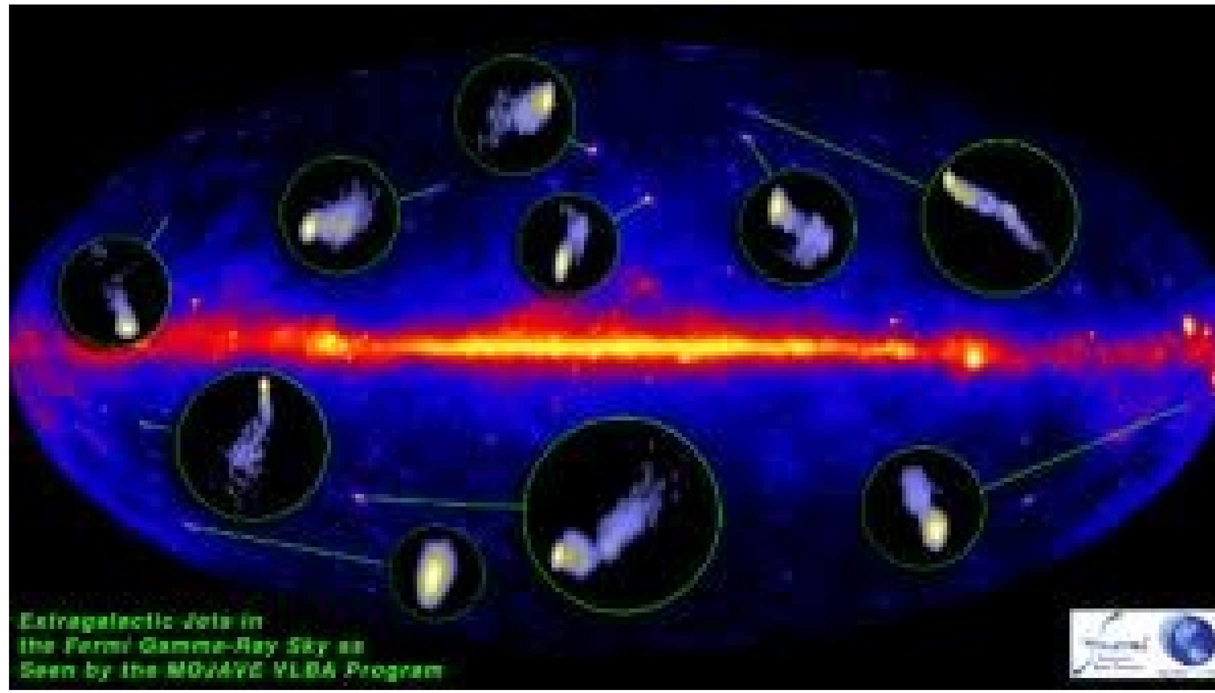
The extragalactic γ-ray sky

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

High energy emission

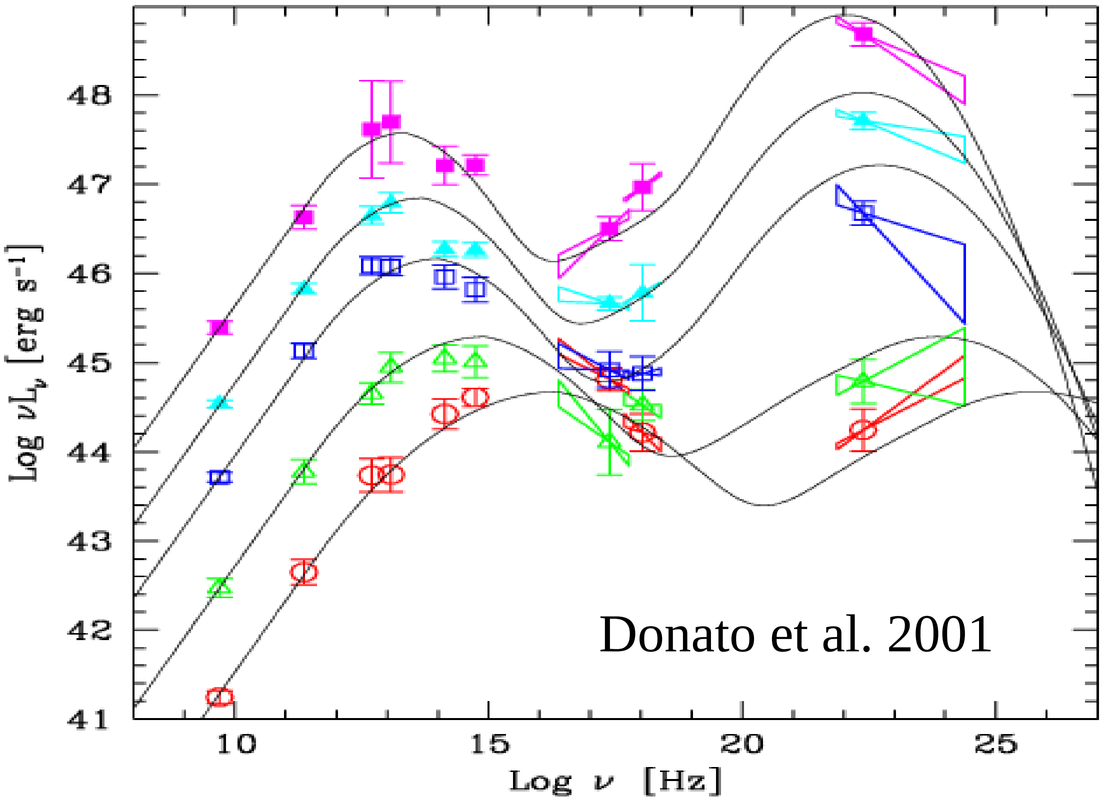
- Low energy: synchrotron

Relativistic electrons can scatter low energy photons

- High energy: inverse Compton

Seed photons:

- their own synchrotron photons (Synchrotron-self Compton)
- external photons from torus, disk, BLR... (External Compton)



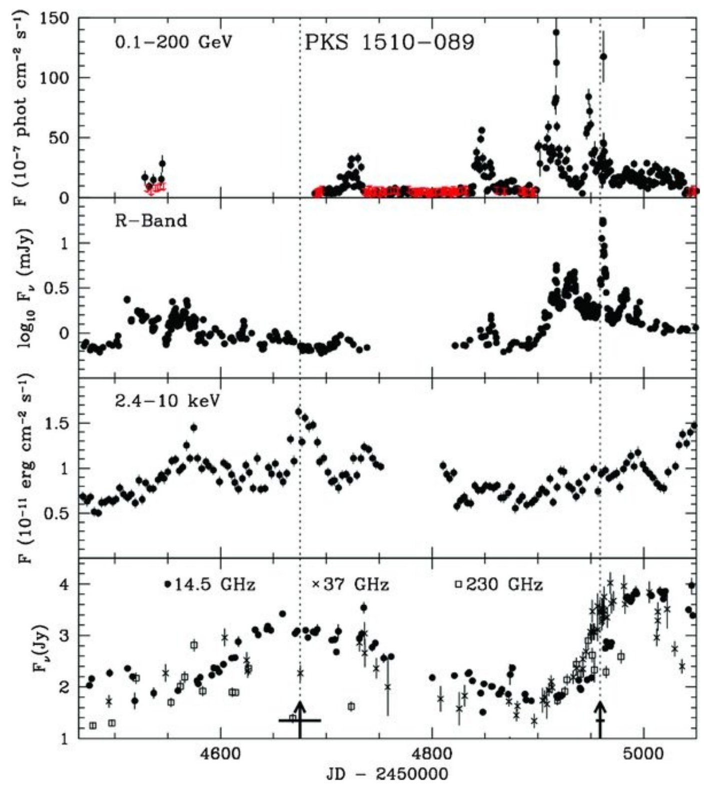
Derived from radio selected blazars by Fossati et al. (1998)

Time delay of the flare at different λ

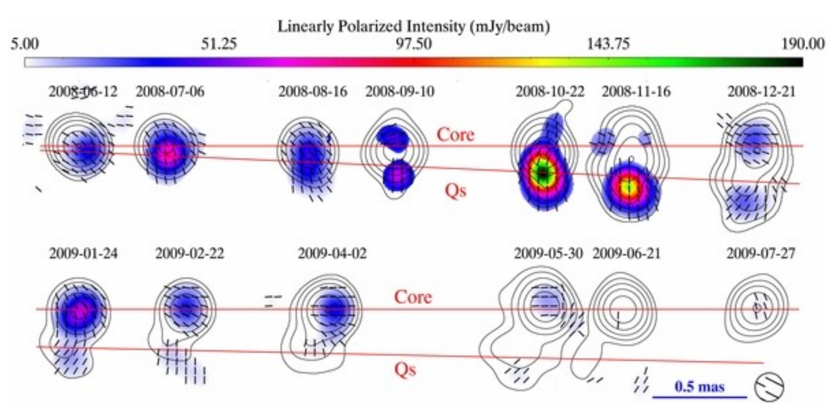
The peak of the flare in γ rays and at optical/mm is almost simultaneous.

In the radio band the variability is delayed due to opacity.

Strong mm flares seem to be related to the ejection of a superluminal plasmoid in the jet, i.e. a shock



PKS 1510-089
Marscher+10



0235+164
Agudo+11

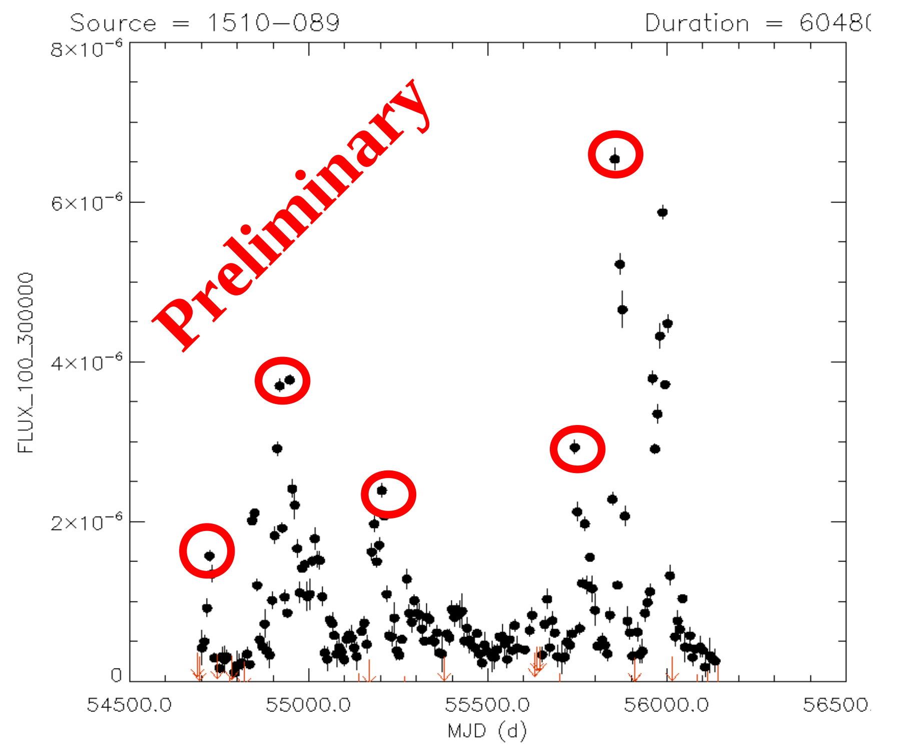
Some γ-ray flares at pc-scale distance from the SMBH?

Open questions

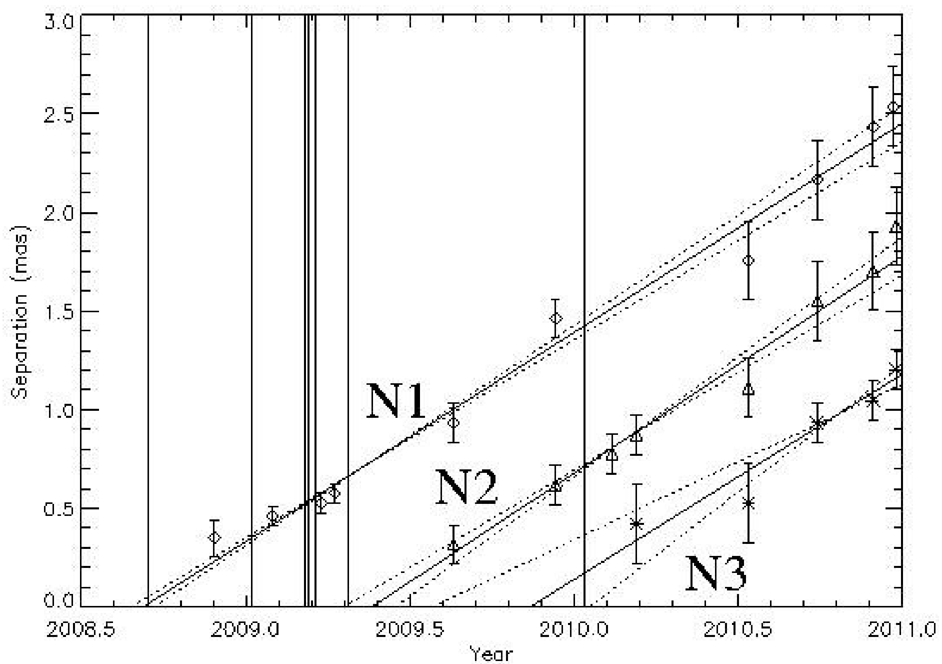
- How do jets form?
- What is the γ-ray emitting mechanism?
- Where is the region responsible for γ-ray emission?
- What do jets consist of?
- What is the "jet-base"?
- .....

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

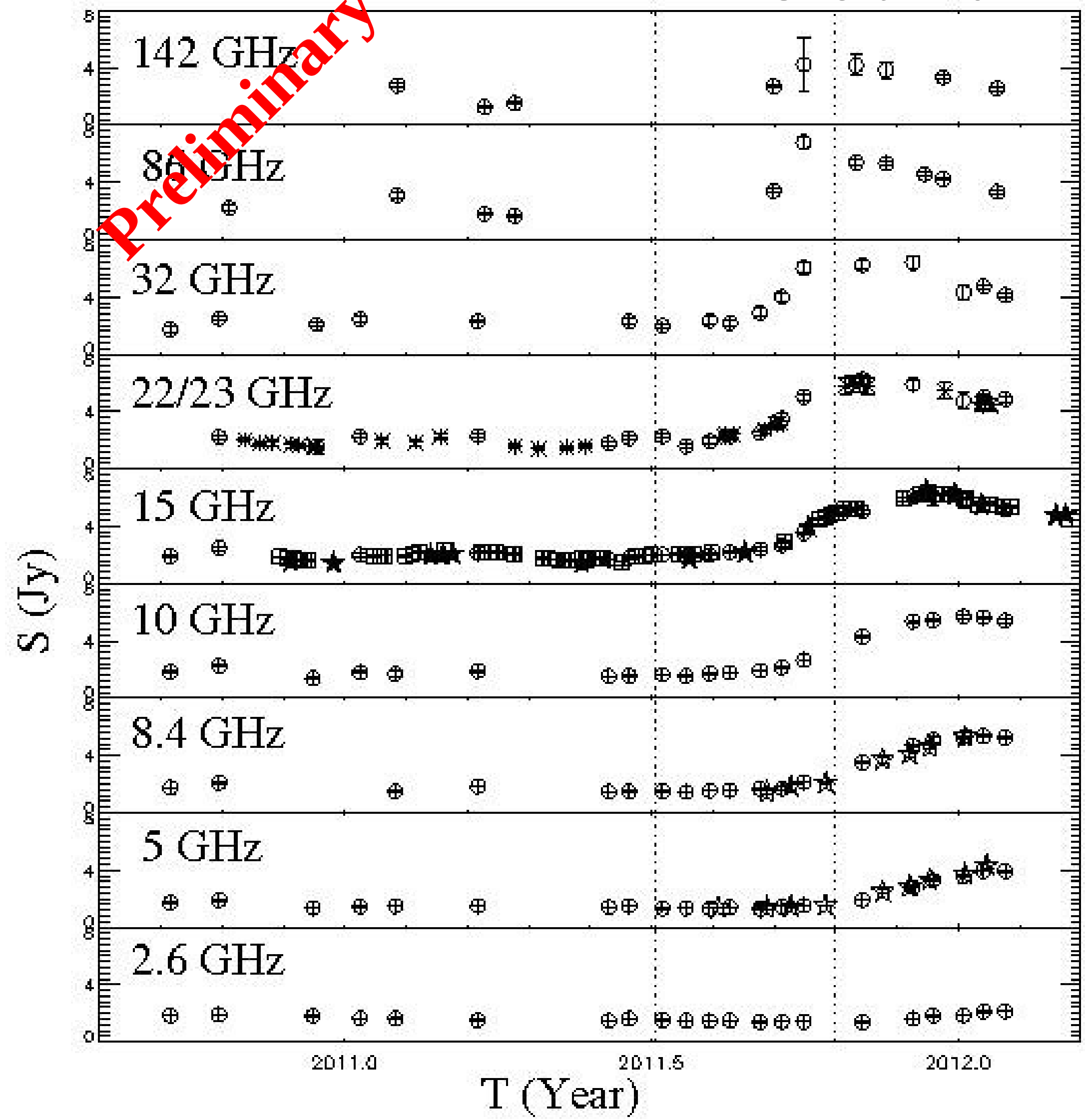
Multi-wavelength analysis

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.

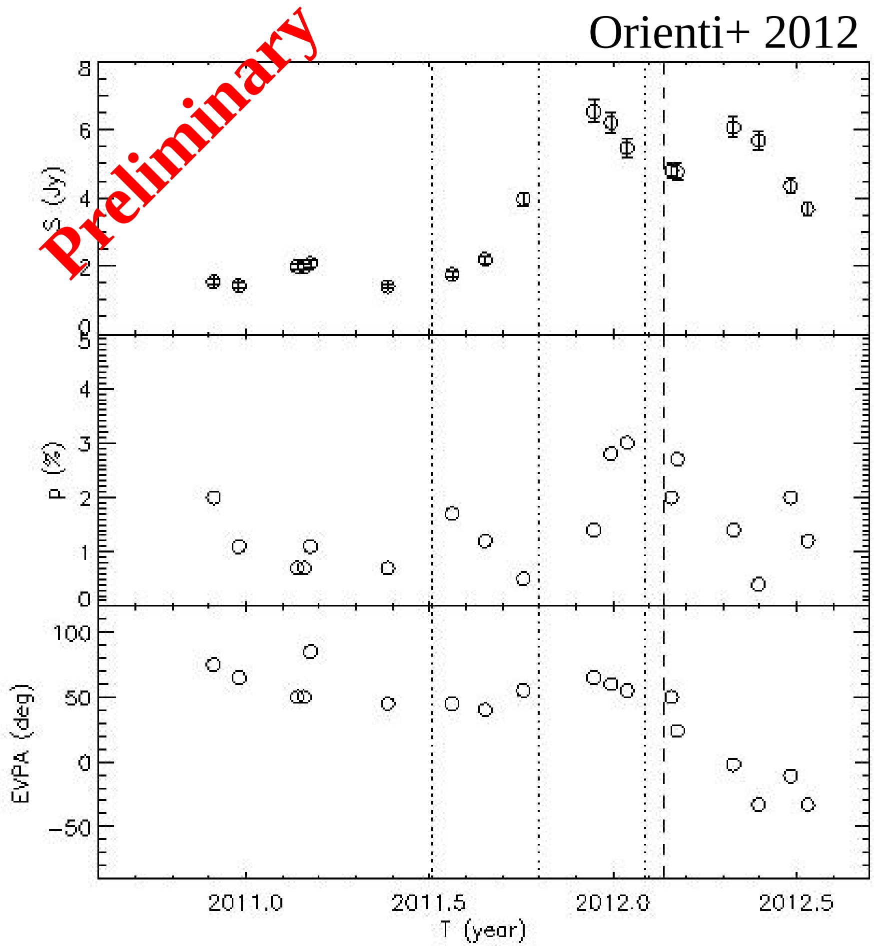
At decimeter wavelength (2.6 GHz), the flux density was still increasing on 2012 January.

Orienti+ 2012

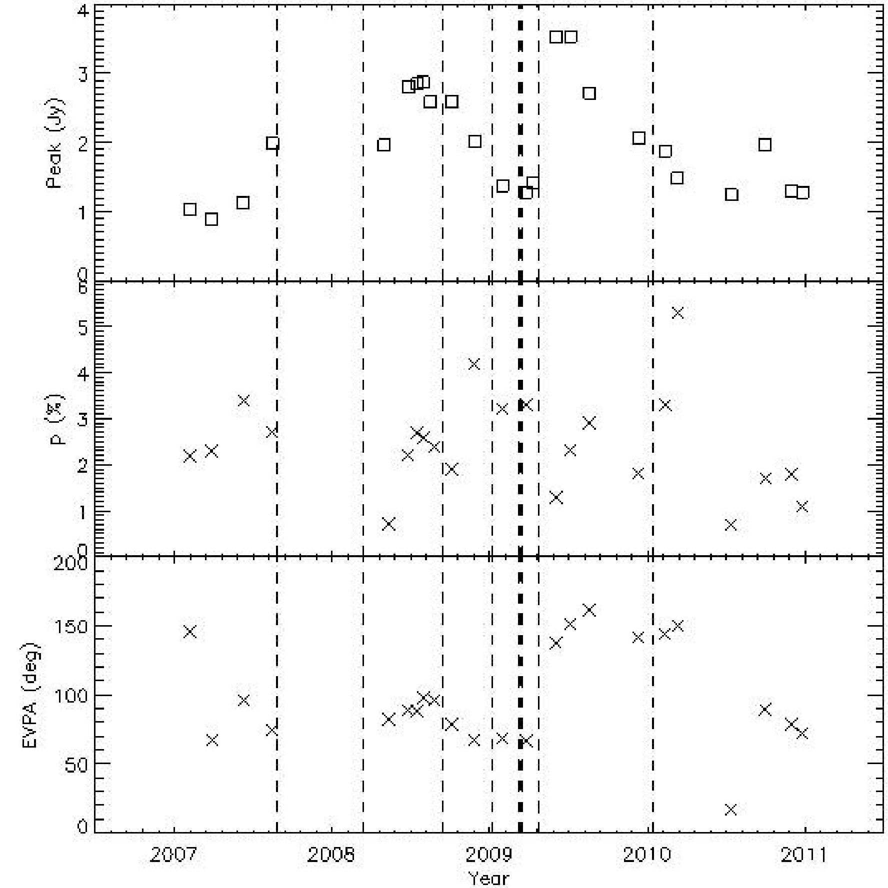


Parsec-scale properties

Orienti+ 2012



Orienti+ 2011

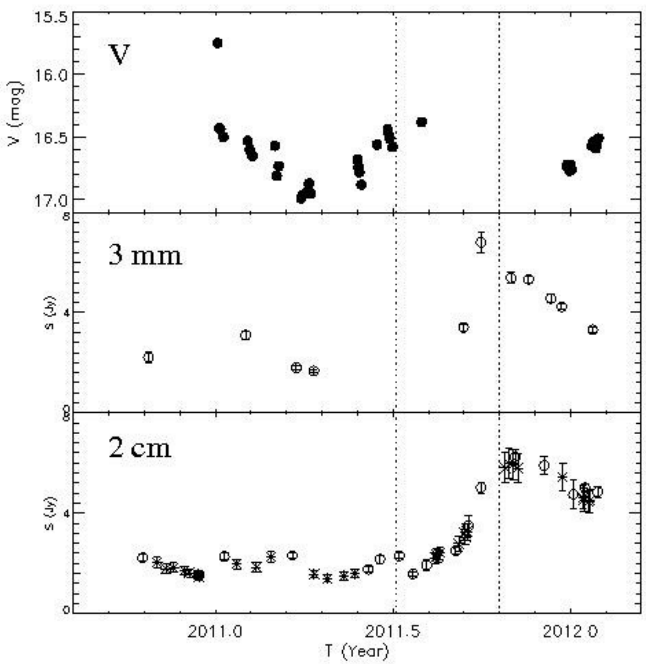


During different flares the polarized emission shows different behaviours:

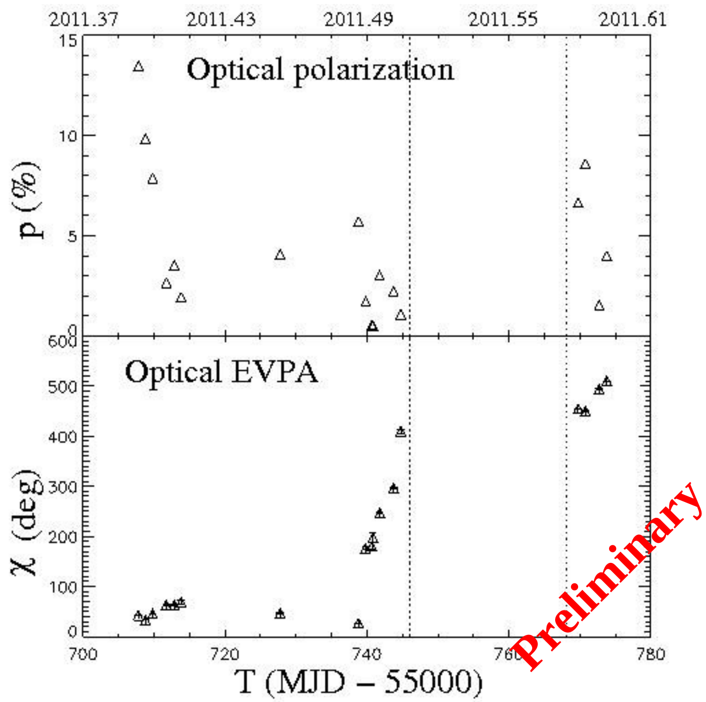
- After 2011 flares radio **EVPA changed of ~10°**;
- After April 2009 flare radio **EVPA rotated of 75°** at 15 ang 43 GHz;
- After **MAGIC VHE detection** in February 2012, radio **EVPA rotated of 60°**

Optical properties

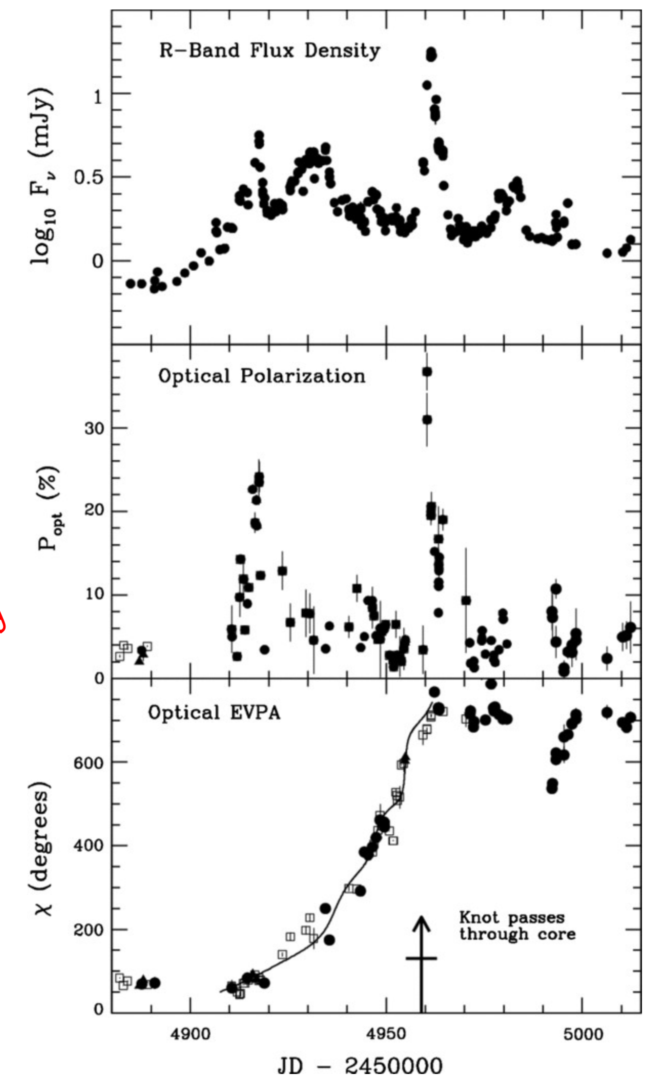
2011 January - 2012 January



May – July 2011



Marscher+ 2010



In April 2009 and July 2012 a large rotation of 720° and 380° of the optical EVPA culminates with the γ-ray flare, suggesting a co-spatiality of the γ-ray and optical emitting region.

An optical “orphan” flare was observed in January 2011

The origin of the γ-ray emission

The huge radio flare reached its maximum in the millimeter close in time with the γ-ray flare of 2011 October, suggesting a common emitting region. If the onset of the mm flare is a consequence of a shock propagating along the jet, it turns out that the γ-ray flare occurs off-nuclear:

$$\Delta r = \frac{\beta_{\rm app} c}{\sin\theta} \frac{\Delta t_{\rm obs}}{1+z}$$

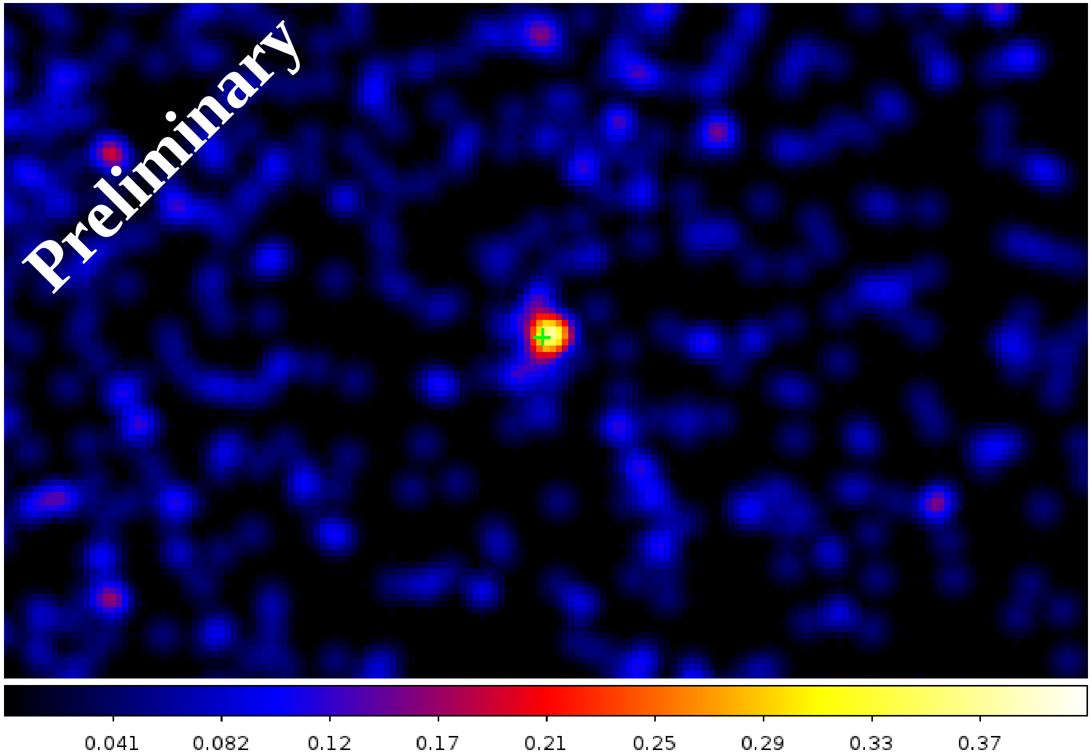
ΔT_{obs} = 40 days
β_{app} = 20.5c
θ = 3°

Δr_{proj} ~ 0.5 pc
$\Delta\theta$ ~ 0.1 mas
Δr ~ 10 pc

The July γ-ray flare may be due to a **first perturbation occurring in the central region opaque to the radio emission.** As it propagates it becomes visible at longer wavelengths. **As it passes through a standing shock a second γ-ray flare is produced**, while the shock becomes visible as a superluminal knot.

Why study TXS 0536+145?

- FSRQ at z=2.69
- **The most distant γ-ray flaring blazar observed so far**
- Detected in flare on 22 March 2012 by *Fermi*
- Not present in the 1LAC and 2LAC

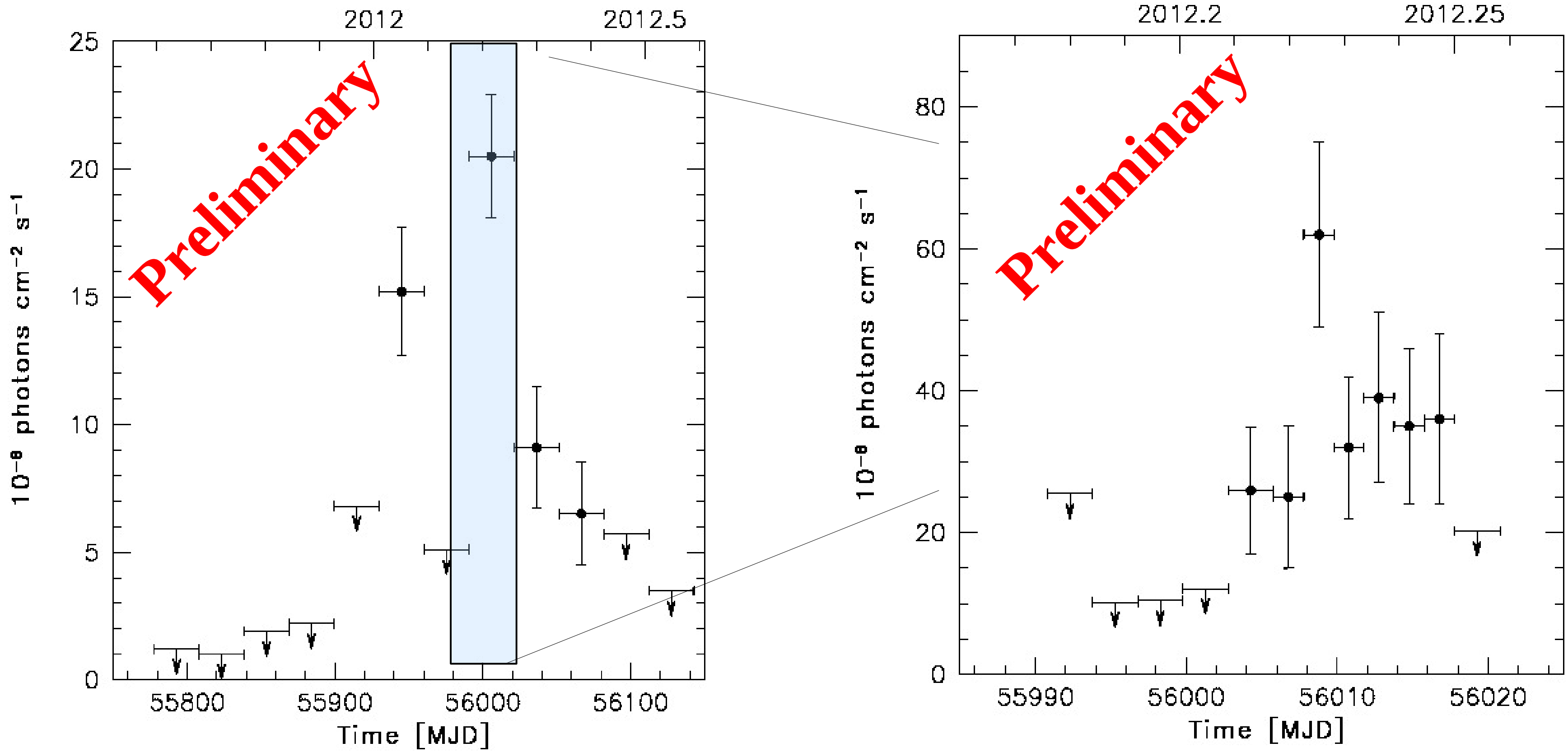


Energy range: 100 MeV – 100 GeV

Its high redshift allows us to set constraints on the EBL

The γ-ray flare

August 2011 – August 2012 | 4 March – 4 April 2012

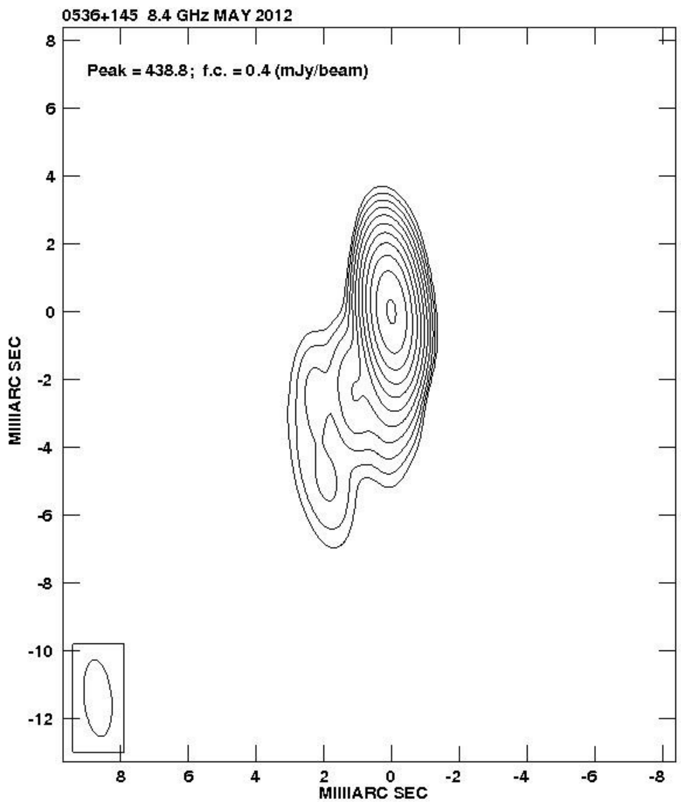


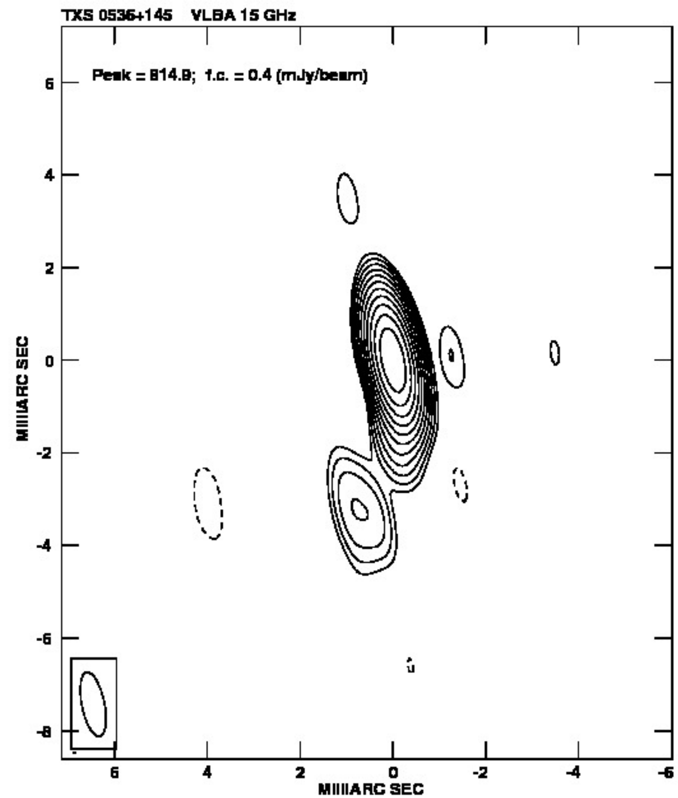
1-month time bins | 2-day or 3-day time bins

UL = TS < 10

Orienti, D'Ammando, Giroletti et al. In prep

Radio morphology





The γ-ray flare triggered multi-epoch VLBA and EVN observations at 8.4, 15, and 22 GHz to study the radio light curve and the possible ejection of a new jet component

Conclusions

- Strong γ-ray flares seem associated with the ejection of a new component

- Different flares may have different properties even in the same source

- The γ-ray emitting region might be a few parsec from the SMBH

- Large rotation of the polarization angle is observed close in time with γ-ray flares suggesting the co-spatiality of the emitting regions

- Monitoring campaigns with high resolution observations complemented with high-sensitivity polarimetric ALMA observations in the mm/sub-mm will provide important clues for better understanding the physics in relativistic jets