The fundamental role of the mm-VLBI in understanding the emission mechanisms in flaring blazars

M. Orienti

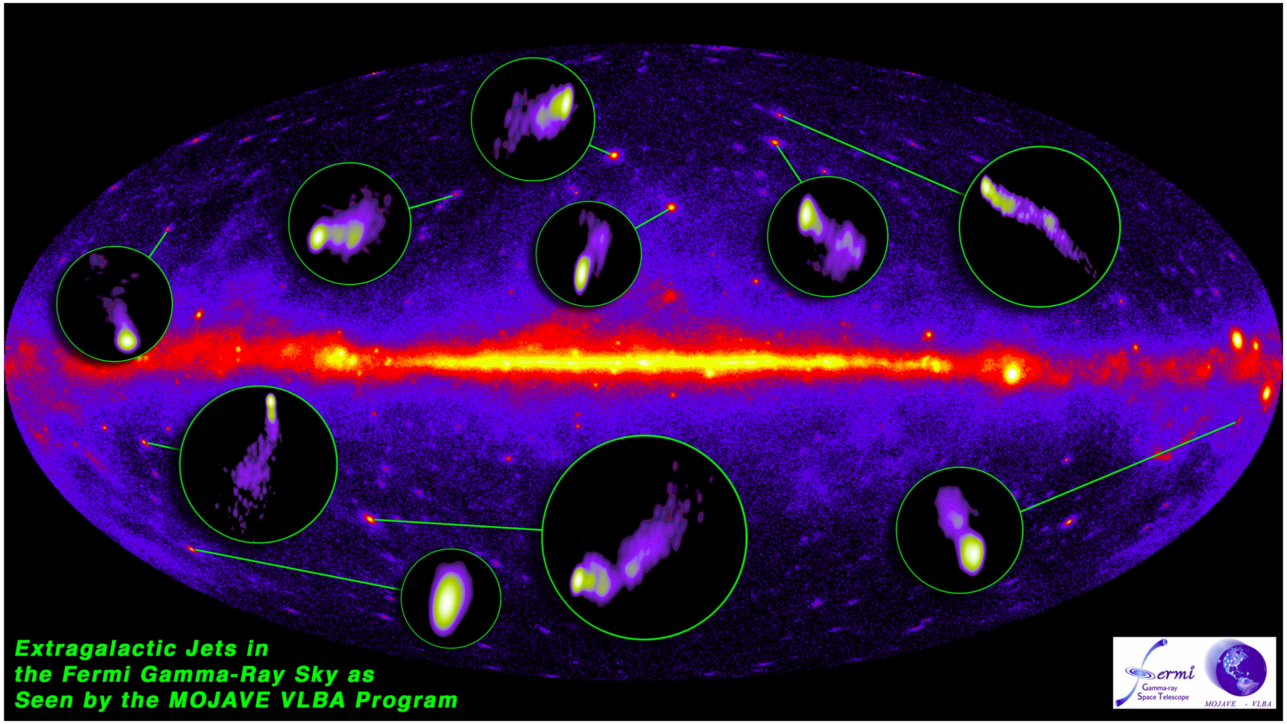
(Bologna University – INAF-IRA)

M. Giroletti (INAF-IRA), F. D'Ammando (Perugia Un.), F. Schinzel (UNM),
J. Kataoka (Waseda Un.) on behalf of the *Fermi*-LAT collaboration
L. Fuhrmann (MPIfR), G. Giovannini (INAF-IRA), H. Nagai (NAOJ),
D. Dallacasa (Bologna Un.)

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

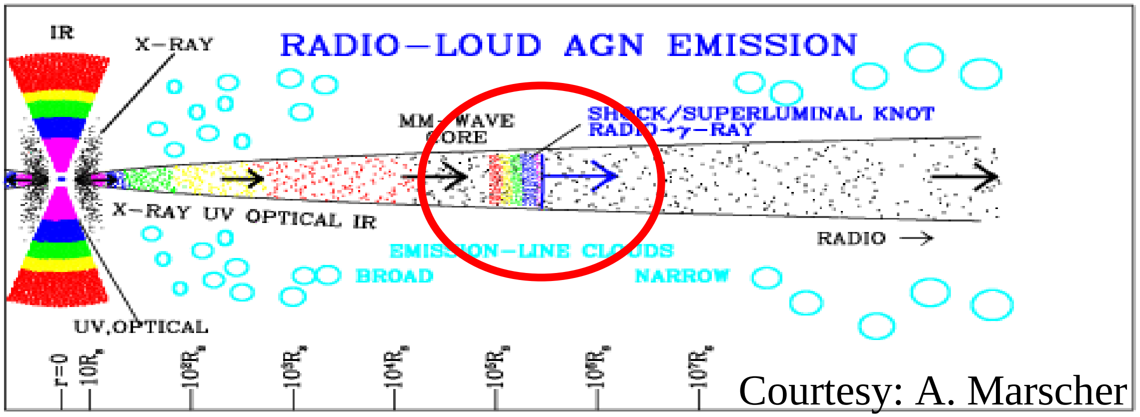
Savolainen+ 2010, Lister+ 09, Kovalev+ 2009

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 do jets consist of?
- What is the “jet-base”?
- .....

Why mm/sub-mm observations?

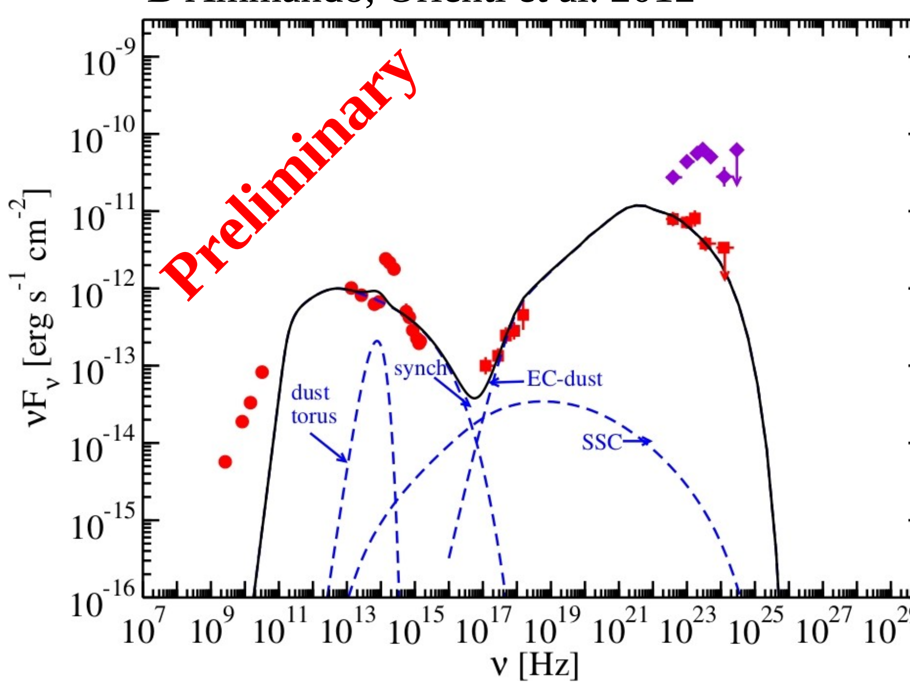


Courtesy: A. Marscher

- Radio cm-band highly self-absorbed
- Discriminate the emission models at low energies

- Quasi-simultaneous mm/sub-mm and γ-ray flares due to less severe opacity effects
- Possibility to study the various stages of shock evolution along the jet, i.e. formation, plateau, decaying
- Determining the distribution and strength of the magnetic field

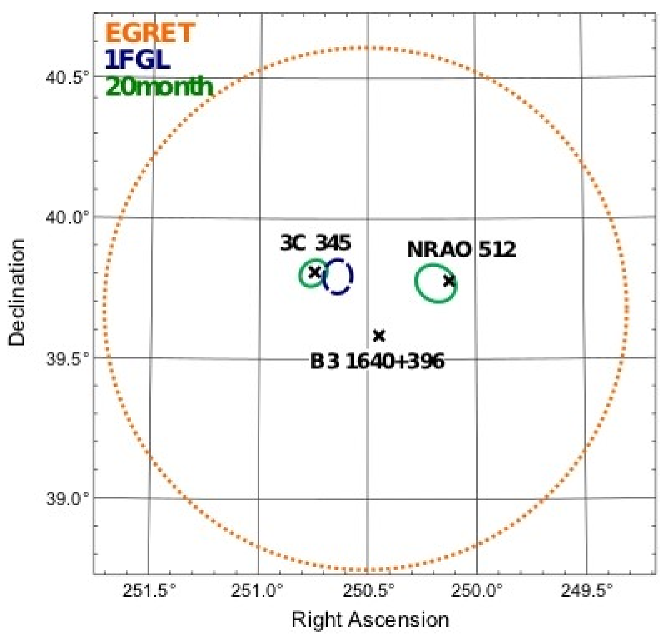
D'Ammando, Orienti et al. 2012



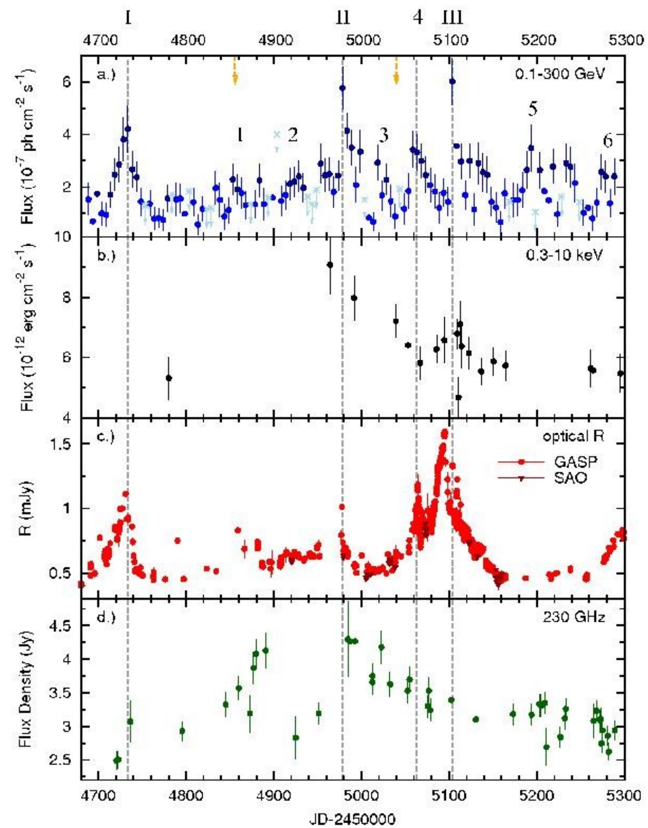
3C 345: a γ-ray emitter

The association of 3C 345 with a γ-ray source was difficult due to the presence of other 2 blazars close-by.

3C 345 was identified as a γ-ray emitter by Schinzel et al. (2011), in 2009 October thanks to the multiband correlated variability



Schinzel+ 2011



The variability at 230 GHz is close in time with the variability observed at higher energies. Opacity effects are less important than in the cm regime.

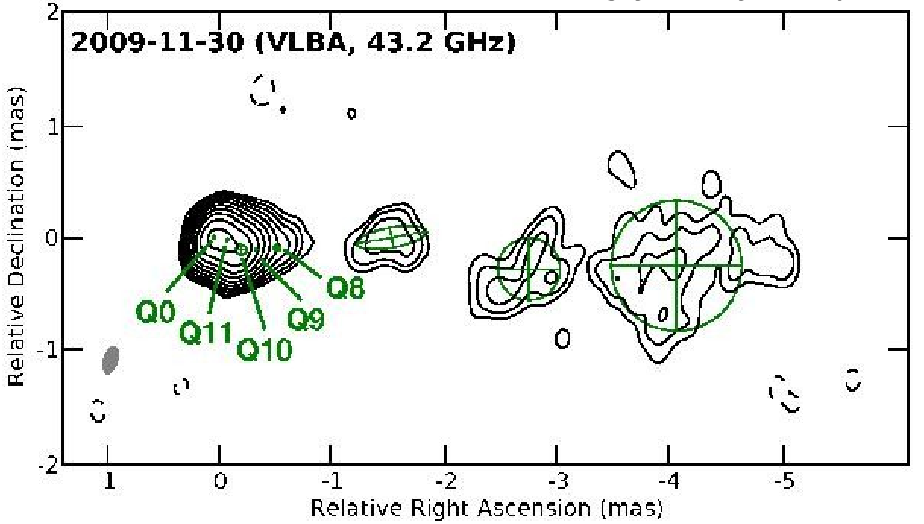
3C 345: pc-scale structure

In 7-mm images the source has a core-jet structure of ~5 mas in size

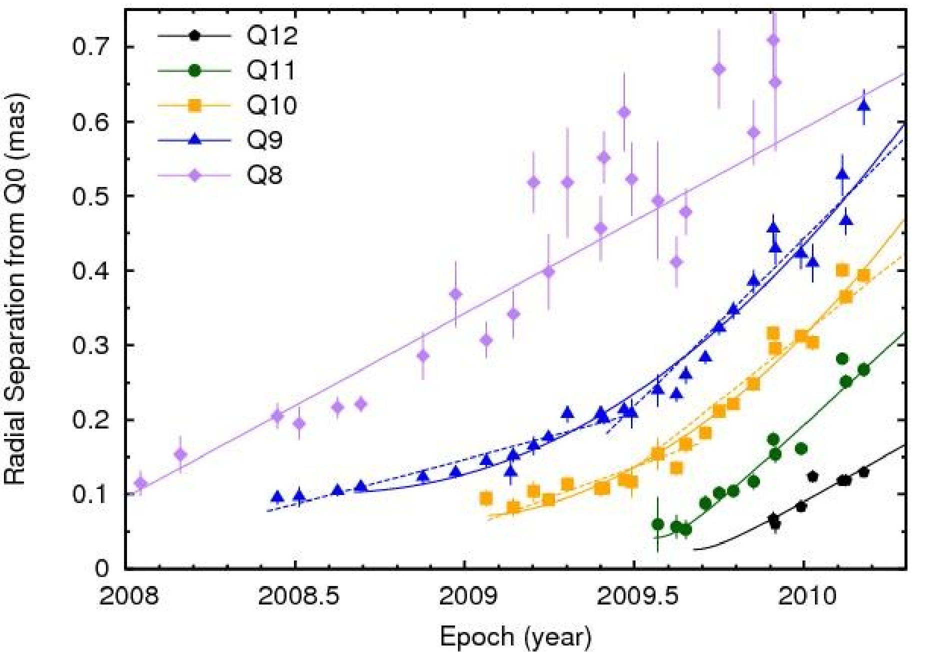
Many superluminal jet components are ejected from the nucleus with β_{app} ~ 9-15c

A stationary feature, a standing shock, is located at ~0.1 mas

Schinzel+ 2012



Schinzel+ 2012



Apparent acceleration seems to occur at 0.3 mas from the core

Radio emission is variable and dominated by the jet, which is likely the site of γ-ray emission

3C 345: GMVA observations

GMVA observations were carried out on 2005 Oct 14 and on 2008 May 8 as calibrator of Mrk 501 (see Giroletti's talk)

Antennas: 4 EU, 5 USA
No: Mh, Nl, Pt, Ov
Beam: 0.14x0.04 mas
34 scans of 1.5 min
Total observing time: 47 min
EU+USA obs time: 35 min
Averaging time 15: sec

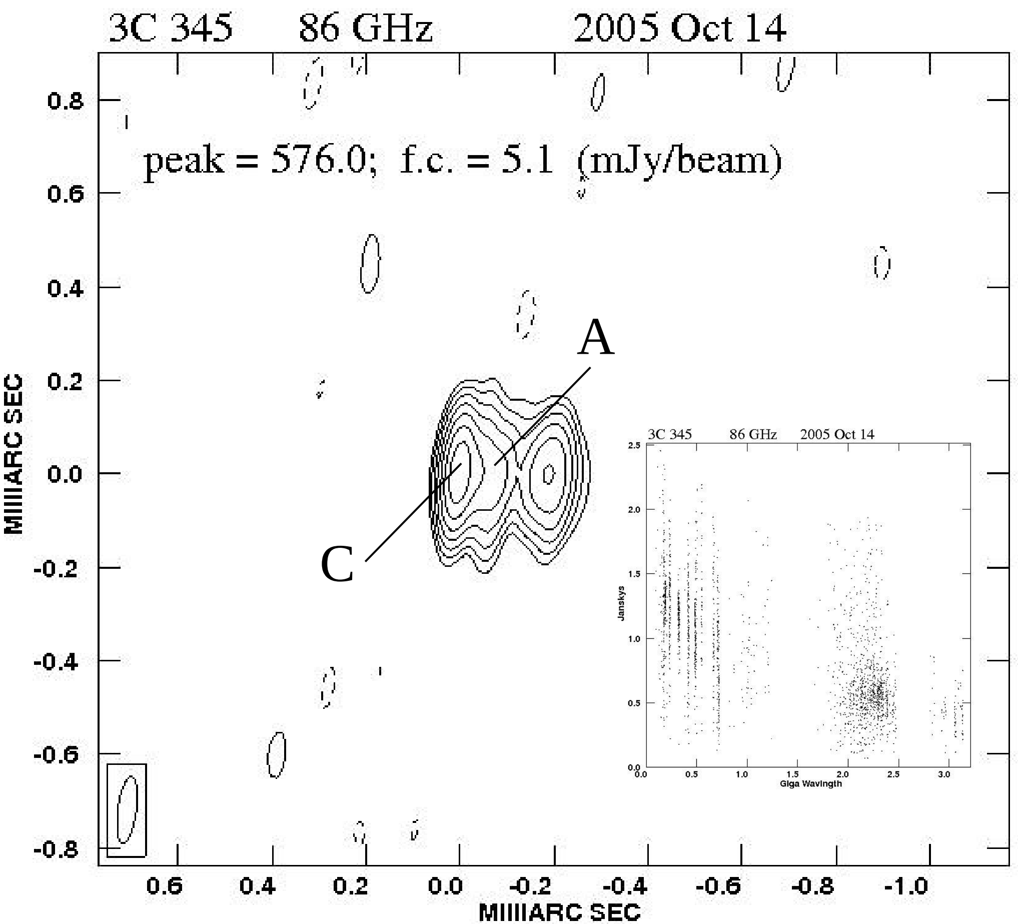
Size ~ 0.2 mas

S_{tot} = 1275 mJy

S_{core} = 525 mJy

A ~0.06±0.02 mas

We are looking into the 43-GHz central component with great details!



3C 345: GMVA observations

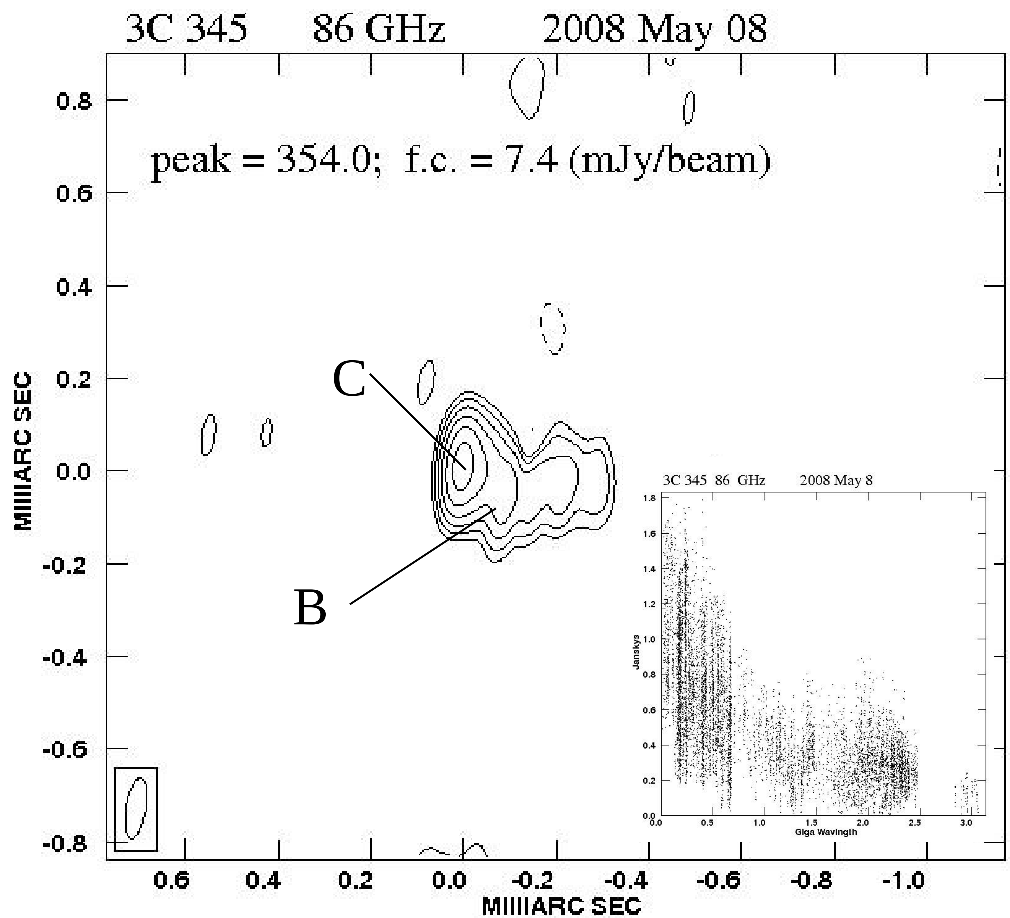
Antennas: **4 EU, 8 USA**
No: On, Pv
Beam: 0.13x0.04 mas
47 scan of 1.45 min
Total observing time: ~80 min
EU + USA obs time: ~40 min
Averaging time 10 sec

Size ~ 0.3 mas

S_{tot} = 845 mJy

S_{core} = 432 mJy

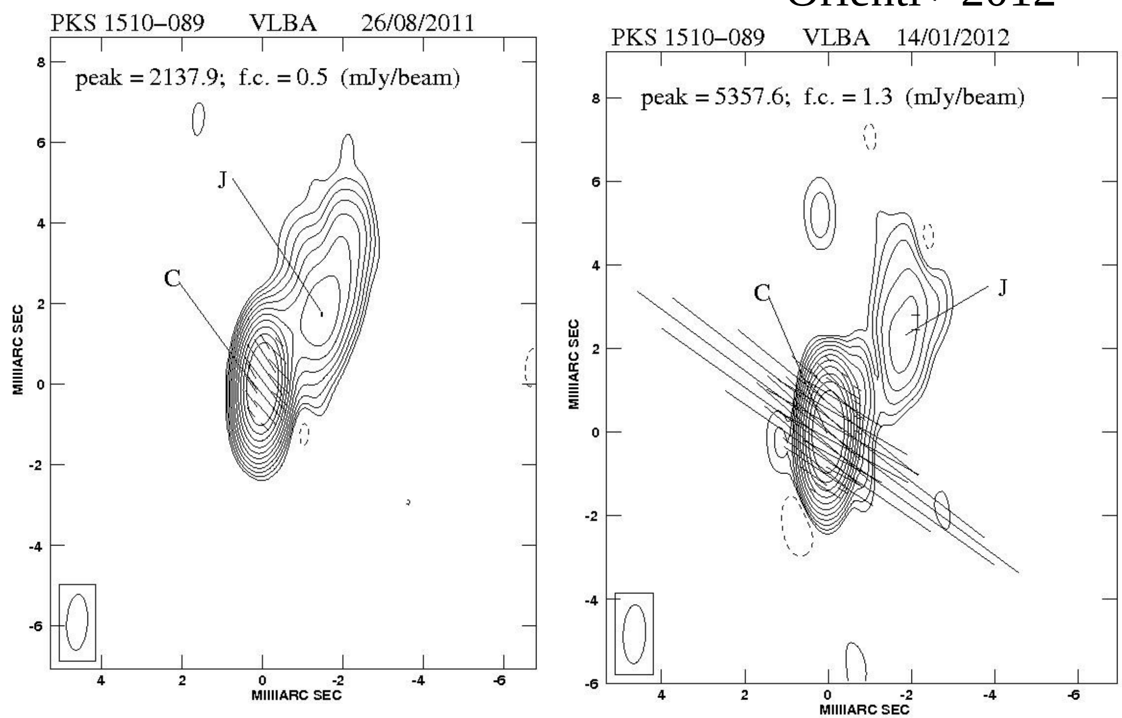
B ~0.08±0.02 mas



Multi-epoch 3-mm observations with adequate time sampling and high sensitivity would provide a unique opportunity to locate the γ-ray emitting site

The flaring blazar PKS 1510-089

Orienti+ 2012

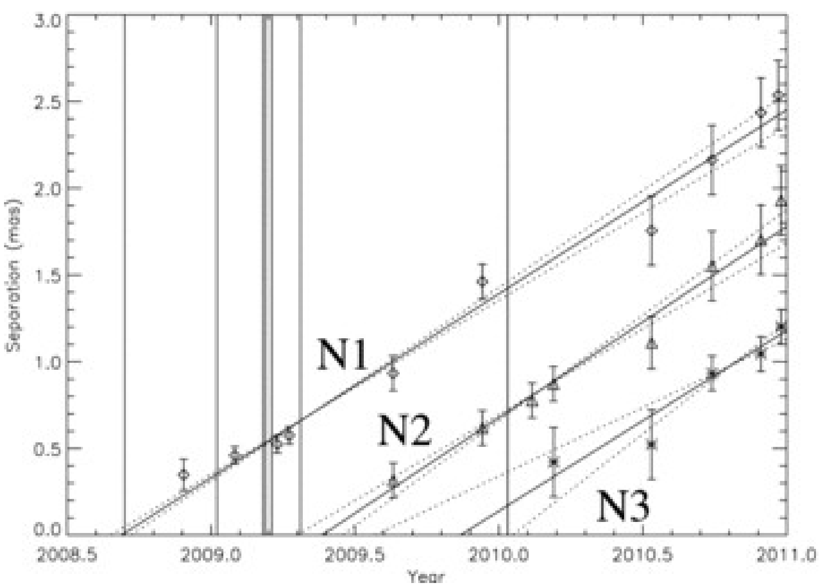


Core-jet structure with PA= -30°

Superluminal knots ejected roughly once per year with βapp ~ 15-25, close in time with a γ-ray flare

Highly variable across the entire e.m. spectrum

Orienti+ 2011

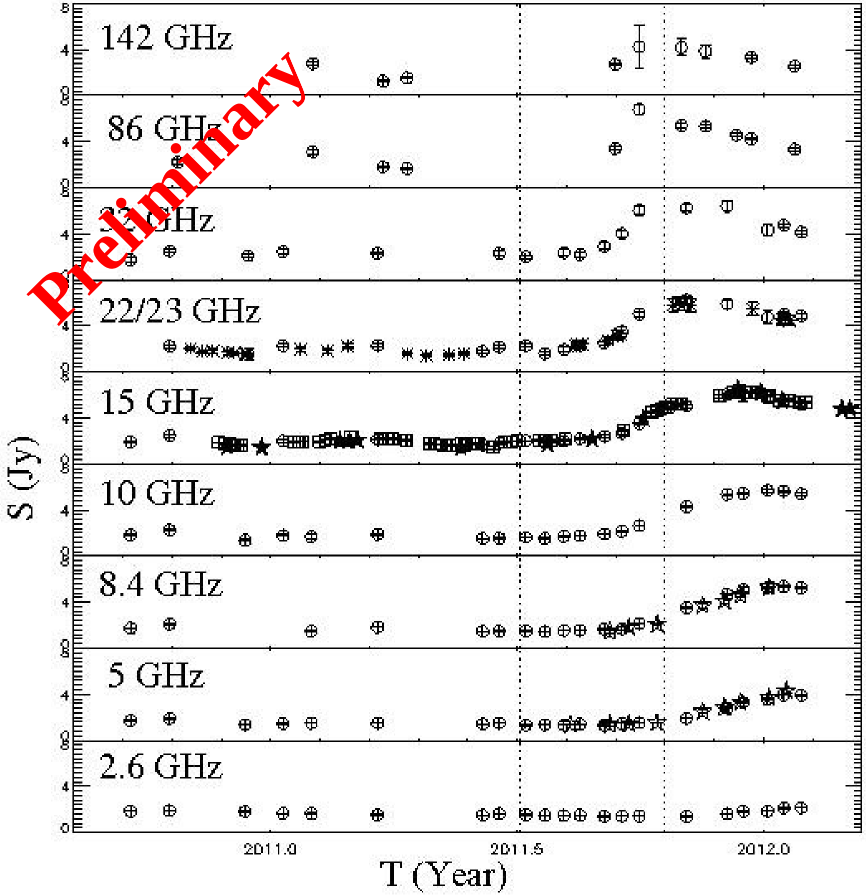


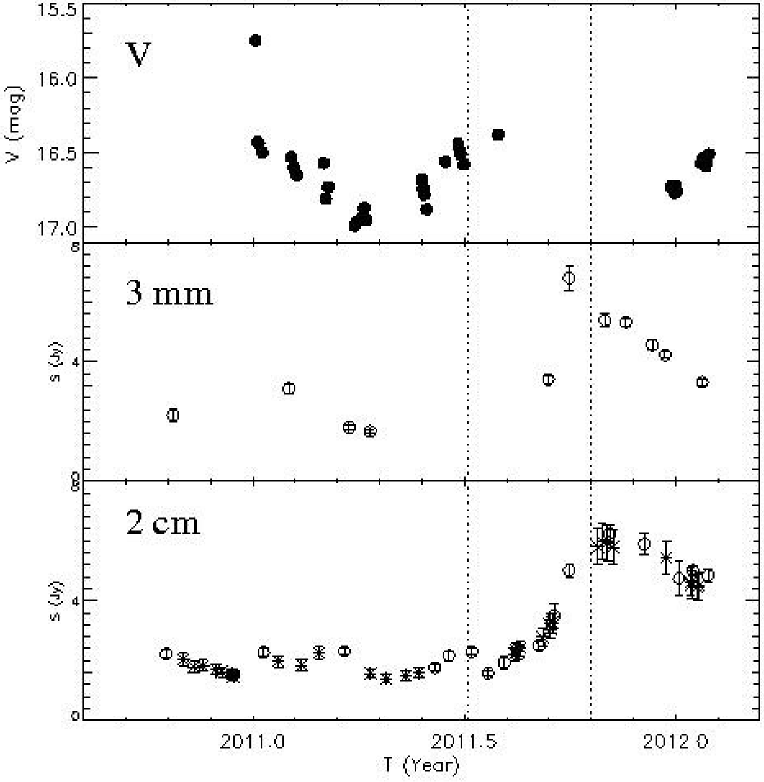
High variability levels in both optical and radio polarization

Possibility to study the magnetic field structure before and after strong γ-ray flares

Multifrequency variability

Orienti+ 2012

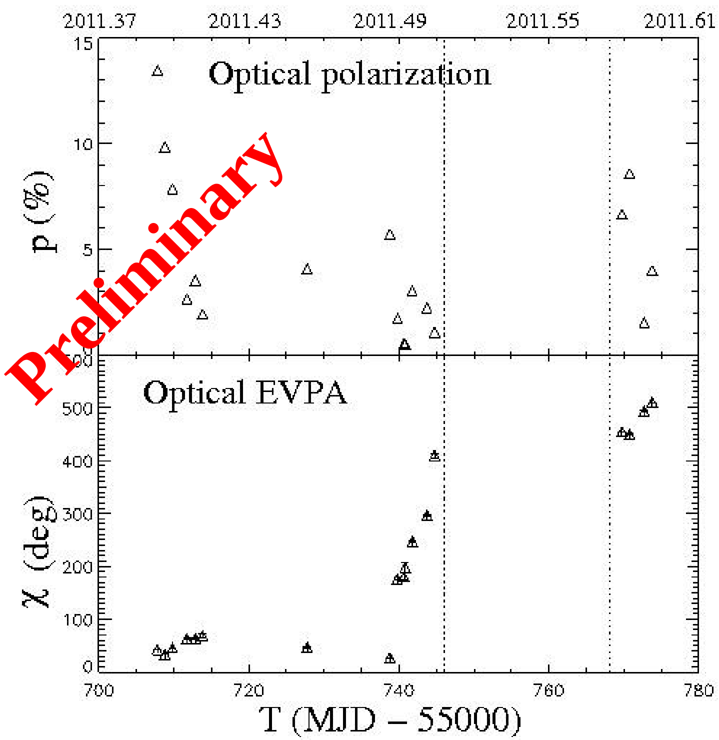




Observations in the mm regime are **less affected by opacity effects.** They can provide, without severe time-delay, crucial information on the possible connection between high and low energy emission

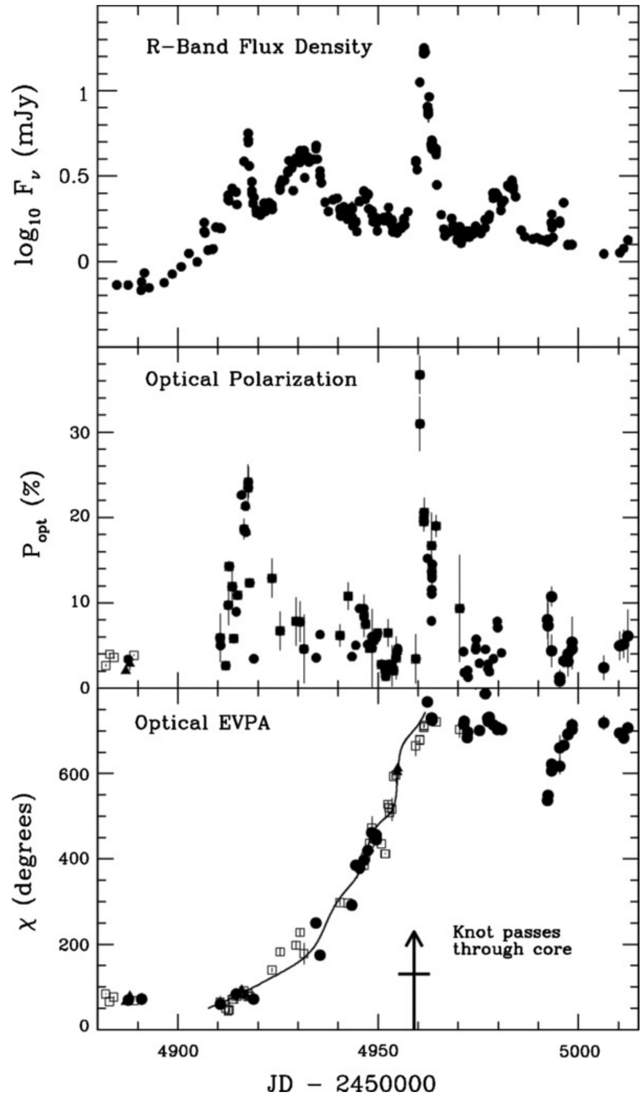
PKS 1510-089: polarization

Orienti+ 2012



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

Marscher+ 2010



Optical emission is not always dominated by synchrotron emission.

Follow-up in the mm regime may help in characterizing the long-term changes

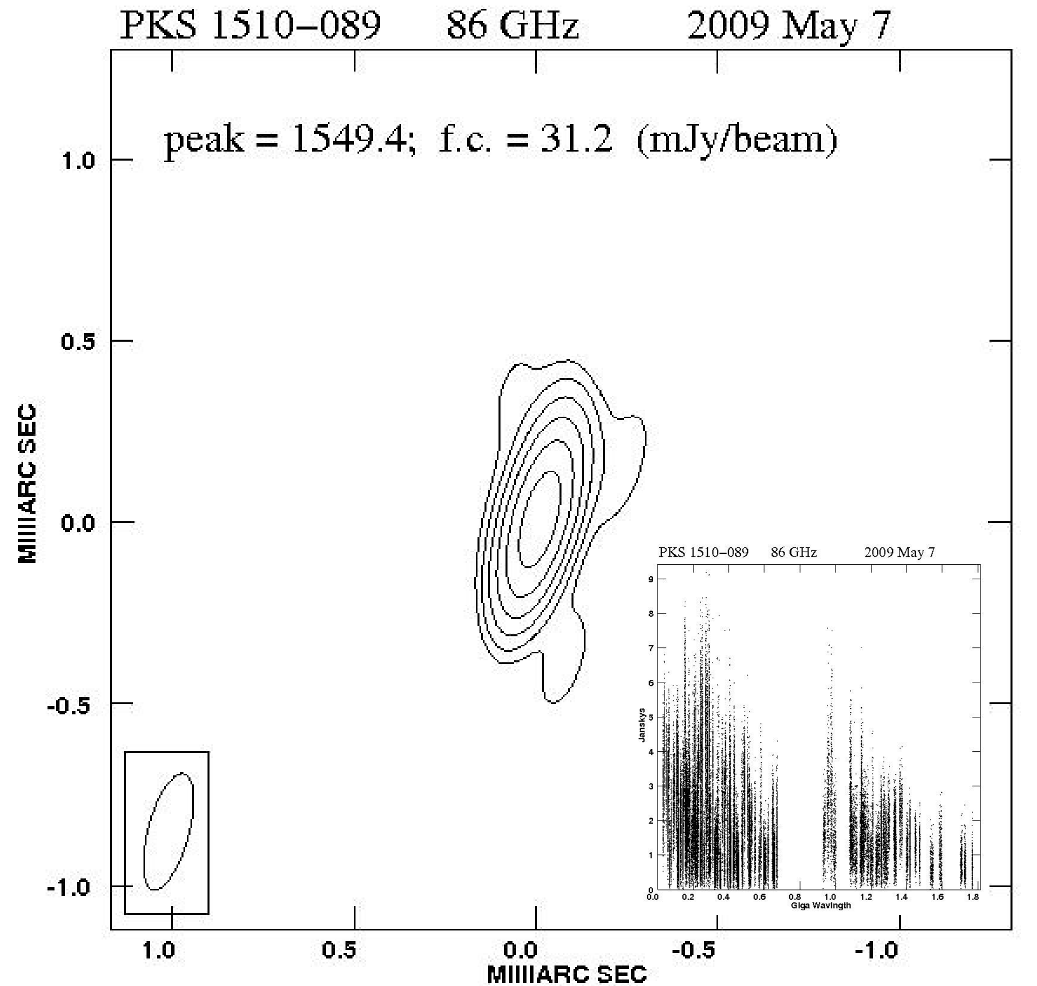
PKS 1510-089: GMVA observations

GMVA observations were carried out on 2009 May 7 as a calibrator source for the source B1502+106

Antennas: 4 EU, 10 USA
No: Mh
8 scans of 5 min
Beam: 0.34x0.10 mas
Total observing time: 40 min
EU+USA obs time: 0 min
Averaging time 4: sec
Problems in the amplitude calibration

S tot = 1750 mJy

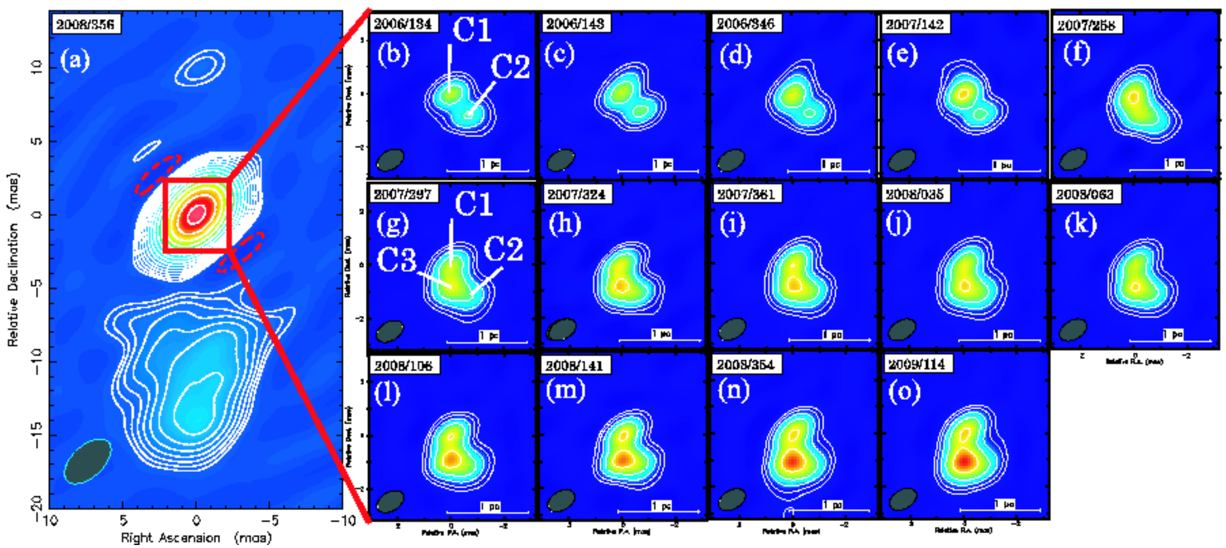
Unresolved structure



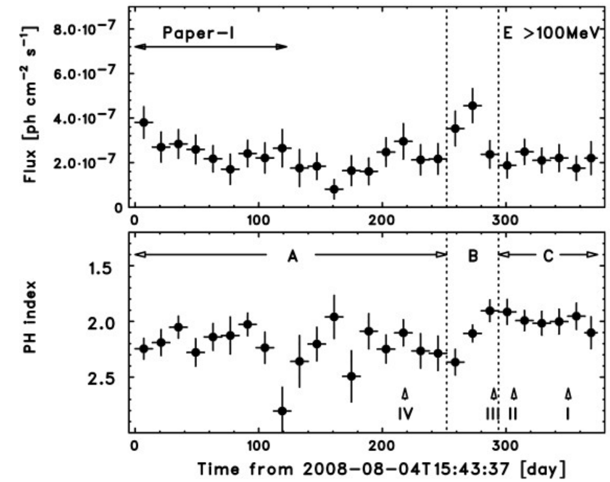
3C 84: a misaligned AGN

3C 84 was undetected by EGRET, while it was detected by *Fermi* with luminosity 10 times higher than EGRET upper limit, suggesting variability

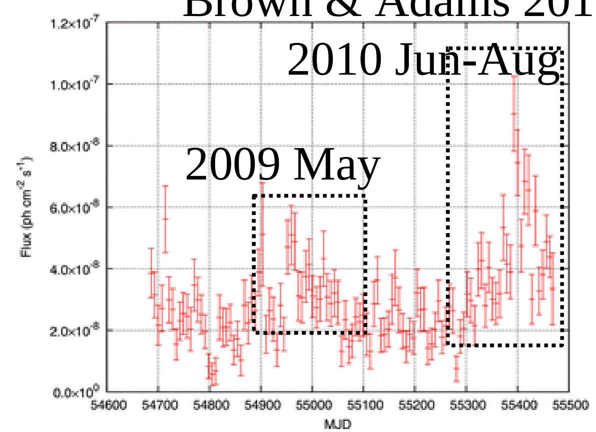
Nagai et al. 2010



Kataoka et al. 2010



Brown & Adams 2011

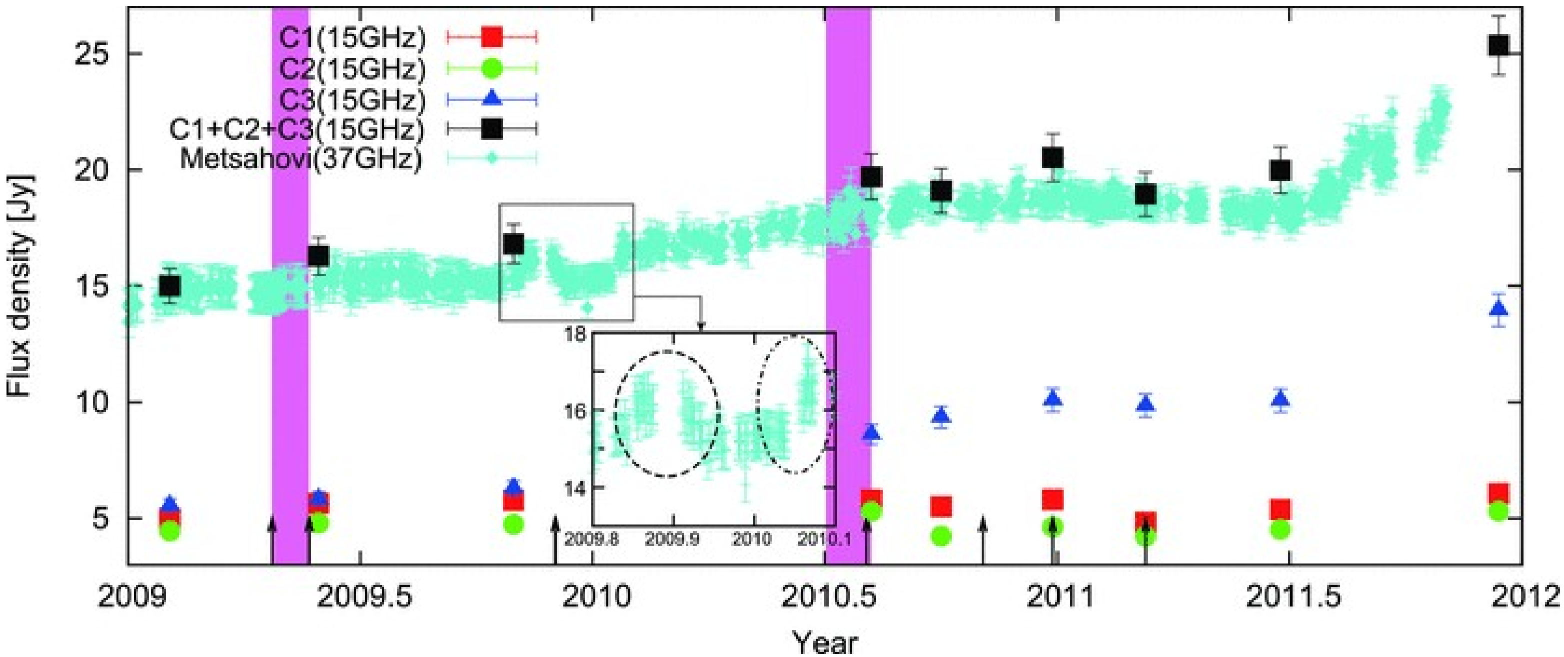


7mm VERA observations could identify the emission of a new jet component that dominates the radio emission

γ-ray emission originating within 1 pc region

3C 84: variability

Nagai, Orienti et al. 2012



- VHE emission detected by MAGIC after the 2010 γ-ray flare (Aleksic+11)
- No obvious correlation with the radio variability at 15 and 37 GHz
- Radio variability dominated by the jet component

Where is the region responsible for the γ-ray emission?

Conclusions

The advent of *Fermi* has provided a step forward in understanding the physics of jets. However, many aspects are still not understood...

Observations in the mm regime with high angular resolution are crucial for characterizing the **innermost region of the jet**

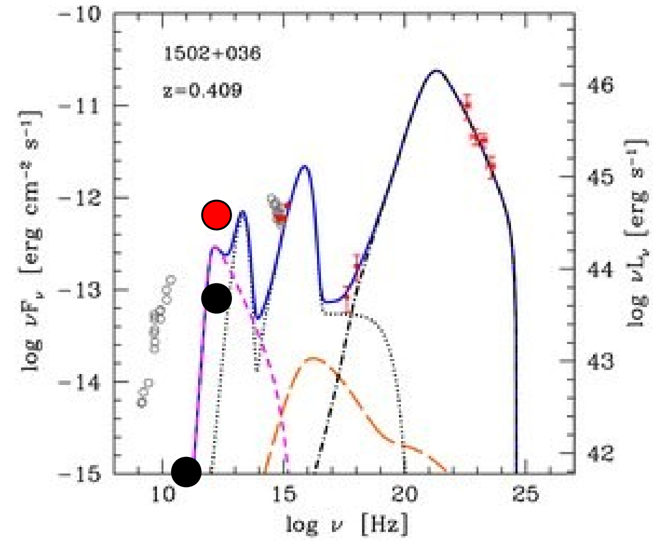
High-sensitivity and high-angular resolution observations at mm/sub-mm wavelengths will allow the **investigation of the low-energy part of the SED** that cannot be constrained by cm observation due to self-absorption

The mm regime is **not severely affected by the opacity** and short/absent time delay is expected with flares at higher energies

Monitoring of the polarized emission at mm/sub-mm wavelengths will provide information on **changes in the magnetic field** related to turbulence or shocks that may trigger the high-energy emission

ALMA and the VLBI

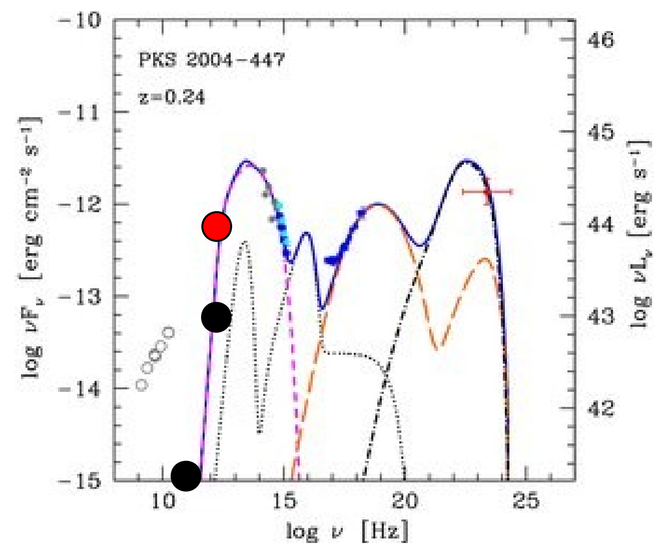
ALMA rms in 1 min: **0.2, 0.3, 0.6, 5.3 mJy/beam** at 100, 230, 345, and 675 GHz



Almost 2 orders of magnitude more sensitive!!!

Adequate sensitivity for study the SED

ALMA will observe in full polarization mode



But ALMA cannot go further than 5 mas!!

ALMA in a mm-VLBI network would reach ~10 μas and a baseline sensitivity of 10 mJy/beam

Excellent for unveiling the innermost region of the AGN!