VLBA monitoring of Markarian 421 at 15 and 24 GHz during 2011

Presented by:

Rocco Lico

M.Giroletti, M.Orienti, G.Giovannini, Y.Y.Kovalev, A.Marscher, S.Jorstad, et al.

ACTIVE GALACTIC NUCLEI 10

Dall'orizzonte degli eventi all'orizzonte cosmologico

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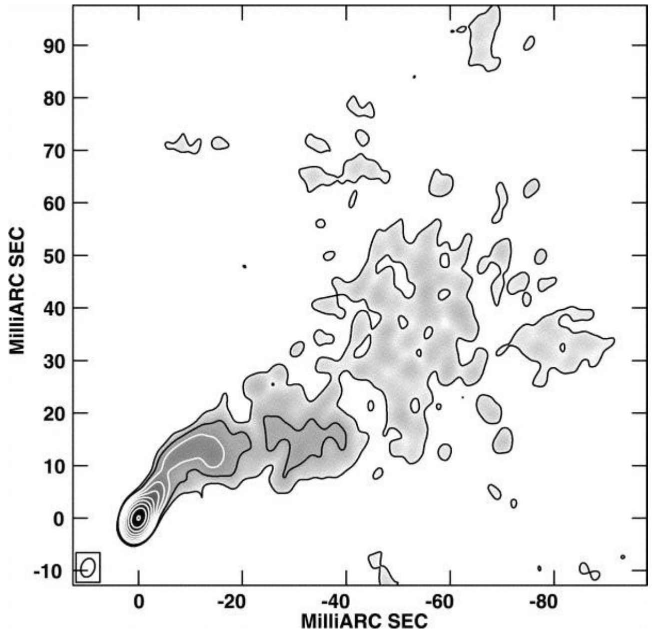
Markarian 421

Mrk421 is the nearest BL Lac of all those so far known: **$z = 0.031$**

1 mas corresponds to 0.59pc

$P_{15GHz} \sim 6.8 \times 10^{23}$ Watt/Hz

$D_{core} \sim 0.06\text{-}0.12$ mas ($\sim 1\text{-}2 \times 10^{17}$cm)



- HBL (High-frequency peaked BL Lac).
- Detected by EGRET.
- It is a bright Fermi source.

It shows a jet structure oriented in North-West direction, starting from the core and extending for several tens of mas.

It is the first extragalactic object revealed in TeV band

Data set

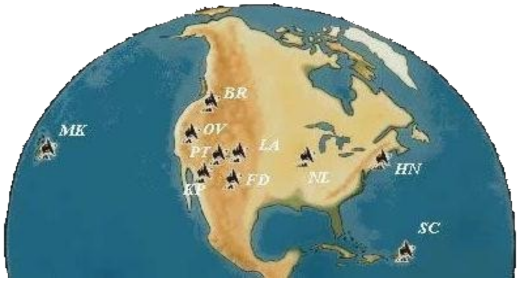
The source was observed once per month, throughout the entire 2011, for a total of 12 epochs at 15 e 24 GHz.

Main goals

- To make a detailed structural and physical analysis of the source on parsec scale: proper motion analysis, Doppler factor, flux density variations, spectral index.

VLBA

(Very Long Baseline Array)



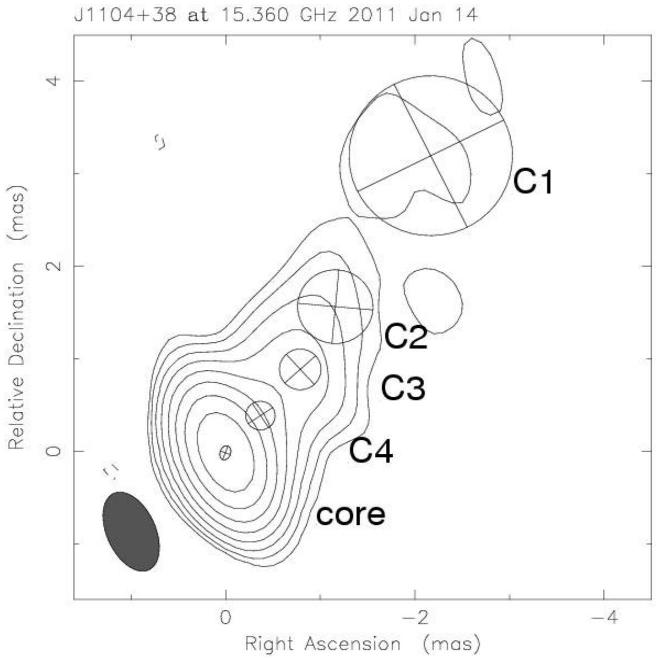
Multifrequency campaign

This study is part of an ambitious multifrequency campaign, with observations in:

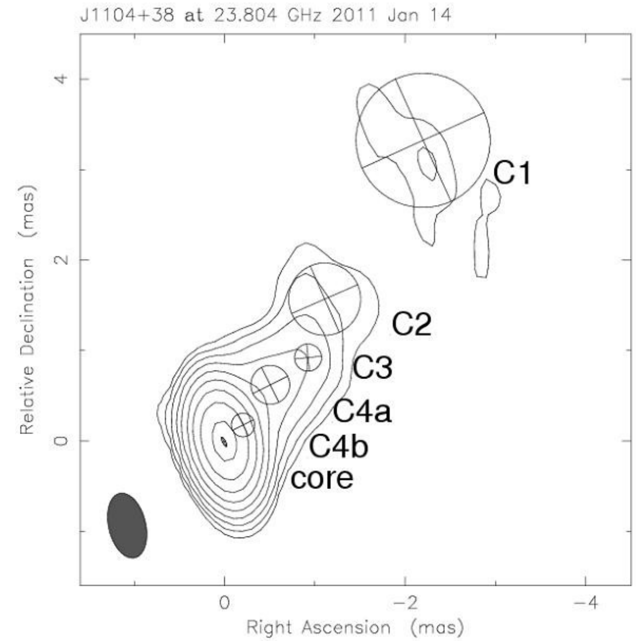
sub-mm (**SMA**), optical/IR (**GASP**), UV/X-ray (**Swift, RXTE, MAXI**), and γ rays (**Fermi-LAT, MAGIC, VERITAS**).

- Continuing Abdo et al. project (2011).

Maps



15GHz

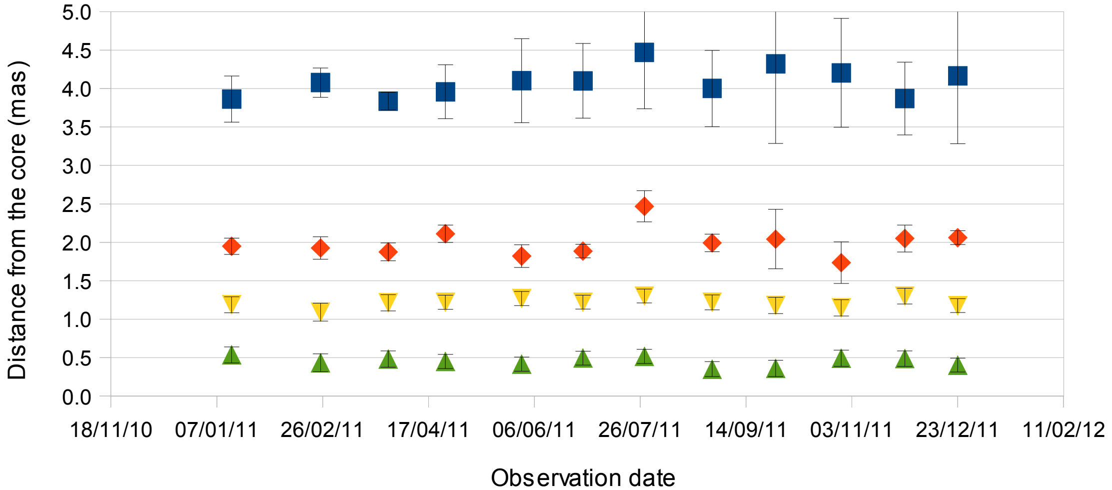


24GHz

- It shows a jet structure well defined and well-collimated emerging from a compact nuclear region.
- The **jet** is orientated in North-West direction (PA ~ -45°), and it extends over an angular distance of about 4.5 mas (for z=0.0311 it corresponds to about 2.67 pc).
- The **flux density** of nuclear region at 15 GHz is roughly 350 mJy, and it gradually decreases along the jet away.
- The angular **resolution** at 15 GHz is roughly 0.92mas x 0.54mas, while at 24 GHz i is roughly 0.58mas x 0.35mas.

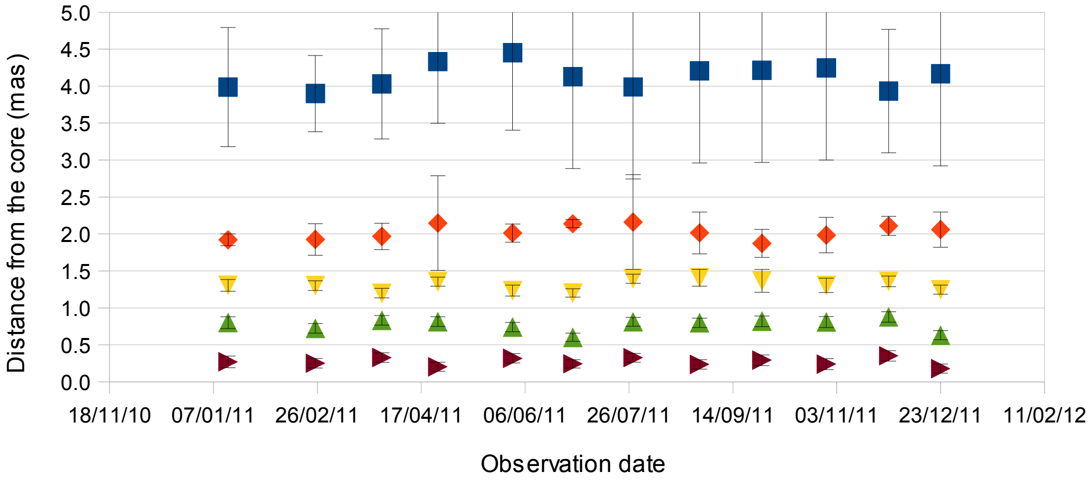
Structural analysis: modelfit

15GHz



- Data points occupy particular places in this plan, and this seems consistent with the identification of individual components.
- The identification is confirmed from flux density variation analysis.

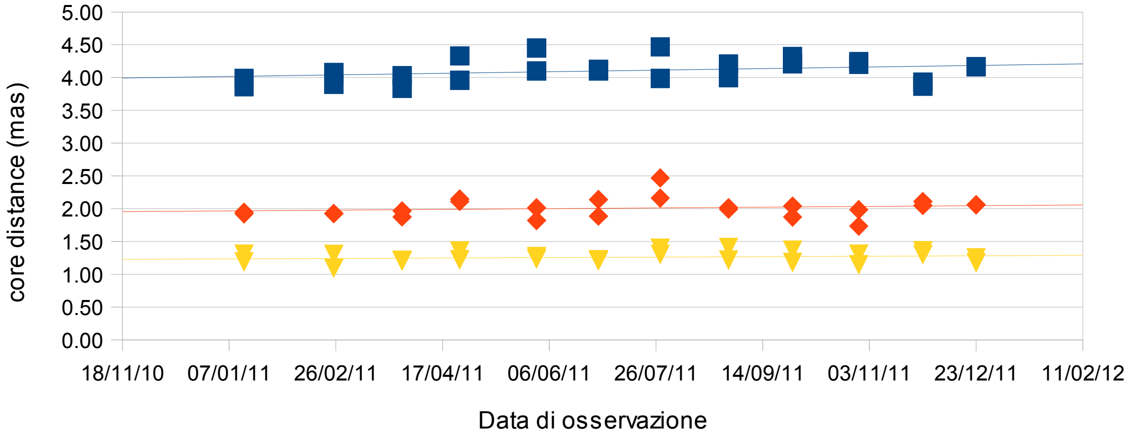
24GHz

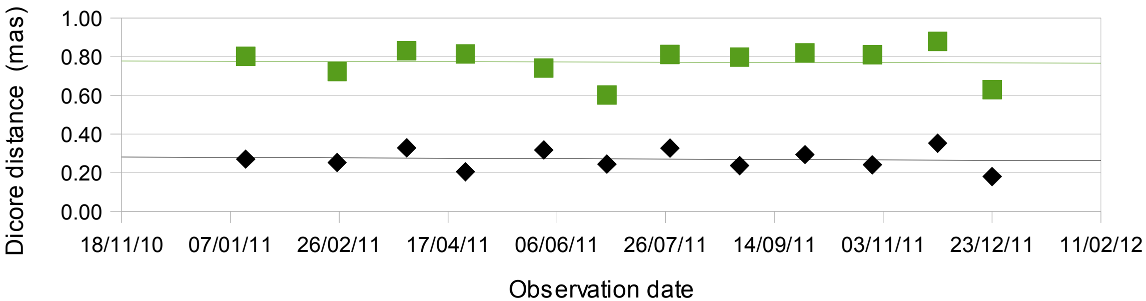


- The components cover an area of ~5mas (the closest to the core is at ~0.43 mas, the most distant is at ~4.6 mas).

All components appear essentially stationary.

Proper motion analisys





- Linear fit to the position versus time component by component.

Apparent speed	
Component	β_{app}
CI	0.3 ± 0.2
CII	0.2 ± 0.2
CIII	0.1 ± 0.1
CIVa	0.0 ± 0.2
CIVb	0.0 ± 0.1

NOT observed significant proper motions.

- Deceleration → **Doppler factor crisis**.
  - The jet axis lies at very **small angles** with the line of sight (**θ<1°**).
  - **Spine/Layer Model**.

θ and β limits from jet-counterjet ratio

$$\frac{B_J}{B_{cJ}} = R = \left(\frac{1+\beta cos\theta}{1-\beta cos\theta}\right)^{2+\alpha}$$

- B_J~24.41 mJy/beam (measured at 15 GHz on a component at ~1 mas from the core).
- B_{cJ}~0.17 mJy/beam (value provided by the map noise).

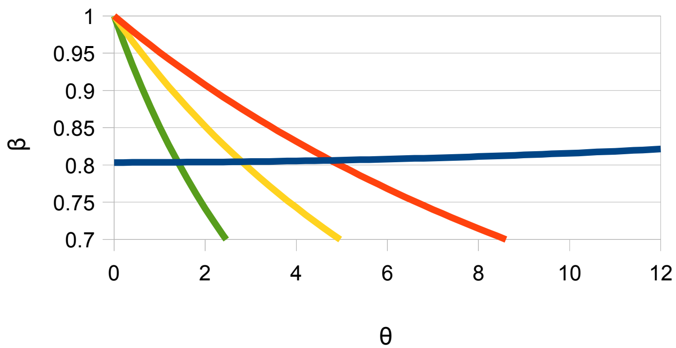
θ	β	β_{app}
0	0.803	0
2	0.804	0.14
4	0.805	0.29
6	0.808	0.43

We obtain **βcosθ > 0.8**

- By varying θ we obtain lower limits for β and also for β_{app}.

The previous values obtained for β_{app} are compatible with **θ~4.8 and β~0.81**, which yields **δ=3.0**

Relativistic radio jet with marginal effects of beaming



Summary

- **Relativistic radio jet** with marginal effect of beaming, that already at about 0.6 pc of projected distance from the core shows absence of proper motions, low flux density variability and steep spectral index.
- Radio images show us its outer surface (layer).
- Radiative losses are important.

- For the **core**, assuming **θ~4.8°** and **β~0.99,** we obtain **δ=14.11**.

$$P_c^{oss} = P_c^{intr} \times \delta_c^{2+\alpha}$$

For $\alpha \sim 0.36$ and $P_c^{oss} \sim 6.8 \times 10^{23}$ *Watt/Hz*

$$P_c^{intr} \sim 5.04 \times 10^{22} \; Watt/Hz$$

Unification Model for **BL Lac** objects with **FRI** type radiogalaxies.

Future prospects

- 43 GHz data available.

- We intend to combine our dataset with those of other works (e.g. Piner & Edwards 2005 or the MOJAVE survey, Lister et al. 2009) to increase the temporal coverage of the observations and obtain even tighter constraints over a longer time frame.

- Comparison with the other wavelengths.
    - Nature of the radiating particles.
    - Connection between the radio and γ-ray emission.
    - The location of the emitting regions.
    - Origin of the flux variability.

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