

# Il contributo del **Whole Earth Blazar Telescope (WEBT)** allo studio della variabilità` dei blazars



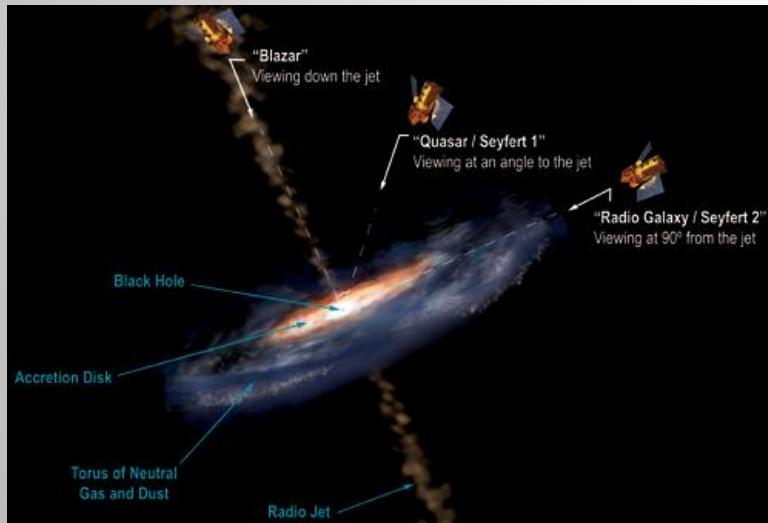
<https://www.oato.inaf.it/blazars/webt/>

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(INAF-Osservatorio Astrofisico di Torino)

# What is a blazar?

⇒ Active Galactic Nucleus (AGN) with one jet pointing toward us

- ⇒ relativistic effects that depend on the Doppler factor  $\delta = [\Gamma(1-\beta\cos\theta)]^{-1}$   
with  $\theta$  viewing angle and  $\Gamma = (1-\beta^2)^{-1/2}$  bulk Lorentz factor



## Blazar emission properties:

- flux relativistically enhanced
- blue-shift of emitted frequencies
- contraction of variability time-scales

## Blazar observed characteristics:

- unpredictable variability at all frequencies on all time-scales, from minutes/hours to months/years
- high polarization, with both the polarization degree P and angle (EVPA) very variable too

## Blazars come in different flavours:

FSRQs (flat-spectrum radio quasars) - strong emission lines

BL Lacs (BL-Lacertae-type objects) - weak or no emission lines

- Low-energy peaked BL Lacs (LBL)
- High-energy peaked BL Lacs (HBL)

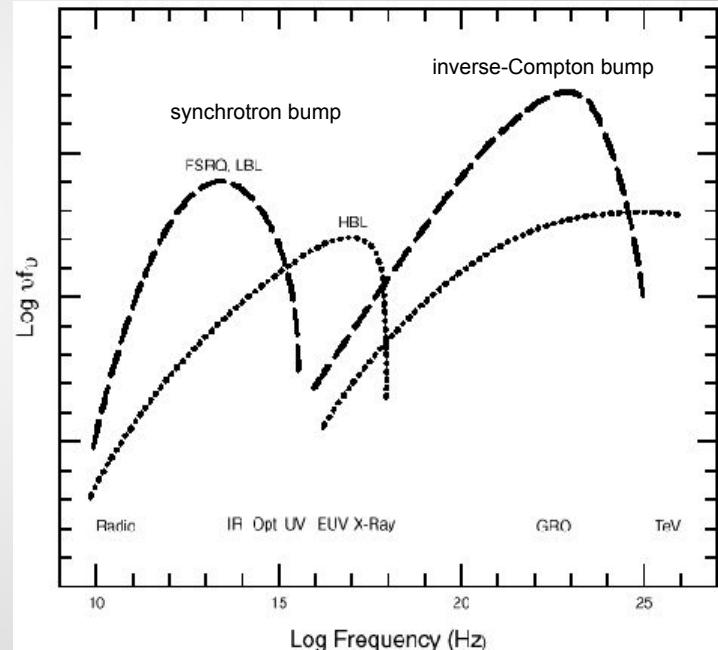
Their spectral energy distribution (SED) is dominated by non-thermal radiation from the jet

But in the optical different emission contributions

1. polarised synchrotron from the jet - very variable
2. accretion disc and broad line region (blue) - less variable
3. host galaxy (red) - not variable

Optical variability is attenuated in case 2. or 3. are strong

2. can dominate in high-redshift FSRQs
3. can dominate in low-redshift BL Lacs





## A brief outline of WEBT history



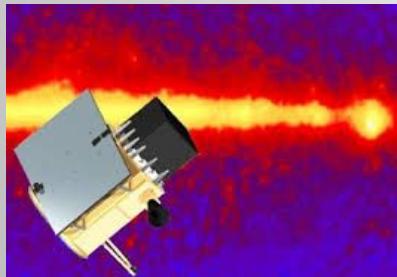
1991-2000 Compton Gamma Ray Observatory (CGRO)

⇒ The extragalactic  $\gamma$ -ray sky is full of blazars

1997 birth of the WEBT - John Mattox (BU, USA) President ⇒ support to the CGRO observations with continuous optical monitoring

2000 Massimo Villata (INAF-OATo, Italy) President ⇒ +radio+near-IR

WEBT multiwavelength campaigns on specific objects



2007 birth of the GLAST-AGILE Support Program (GASP) in view of the launch of the AGILE and Fermi  $\gamma$ -ray satellites

⇒ 14 (now 15) BL Lacs + 14 FSRQs continuously monitored





**Team:** ~ 200 observers; more than 150 telescopes

**AMERICA** (Argentina,Mexico,USA)

**ASIA** (China,India,Japan,Taiwan,Uzbekistan)

**EUROPE** (Bulgaria, Crimea, Finland, Georgia, Germany, Greece, Italy, Russia, Serbia, Spain)

In particular in **Italy today**:

Optical observations from INAF-OACT - Serra La Nave

Radio observations from INAF-IRA (Medicina+Noto+SRT, PI: N. Marchili)

Optical observations from University of Siena and high-level amateurs

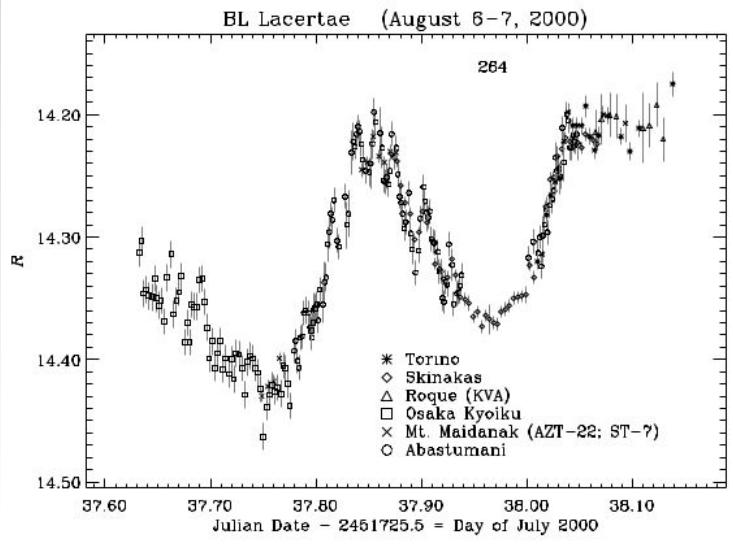
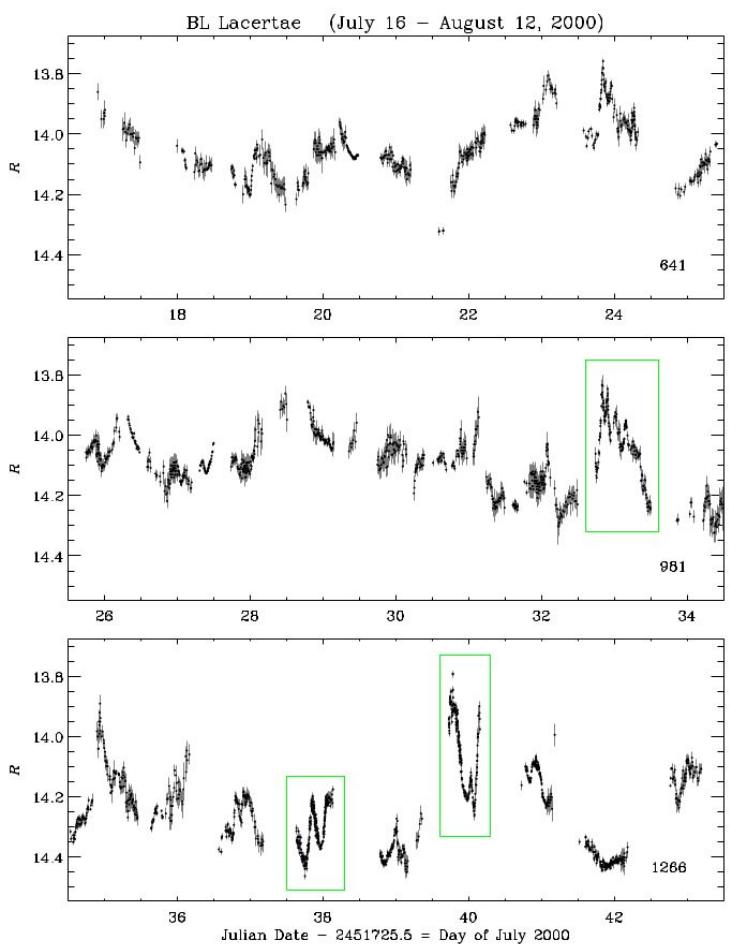
#### **Deliverables:**

- photometry + polarimetry + spectroscopy
- satellite GO observations: XMM-Newton, Swift, TESS
- archive, with data available after publication
- models to explain blazar variability
- 252 papers by the WEBT in the NASA ADS, 129 refereed, including 2 (3?) papers on Nature, 1 (2?) of which led by the WEBT

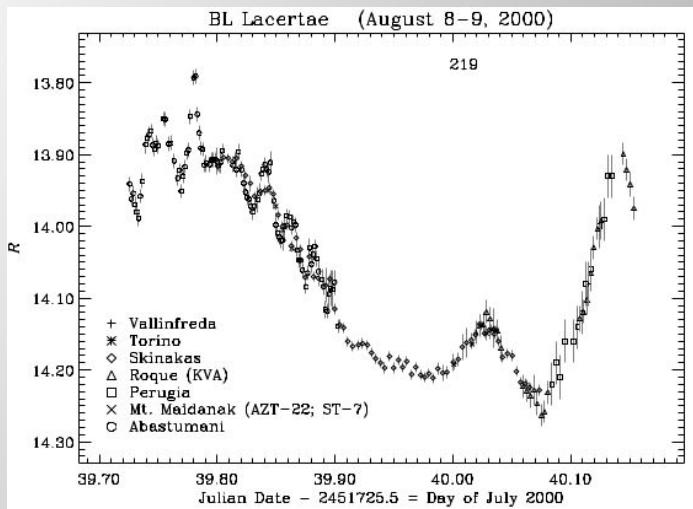
#### **Main collaborations:**

AGILE, Fermi, MAGIC

# Optical monitoring with exceptional sampling

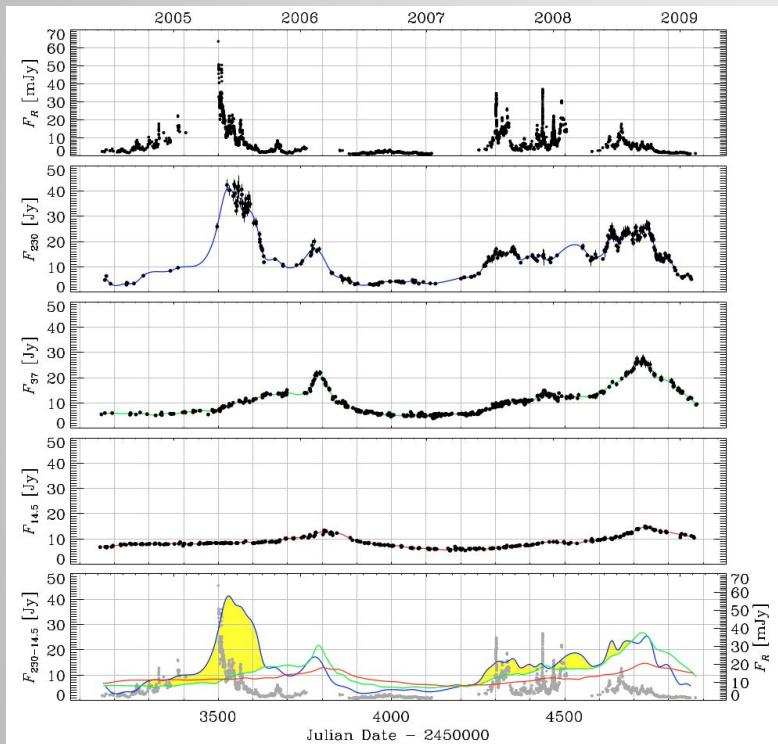


BL Lacertae,  
Villata et al. 2002  
(A&A, 390, 407)

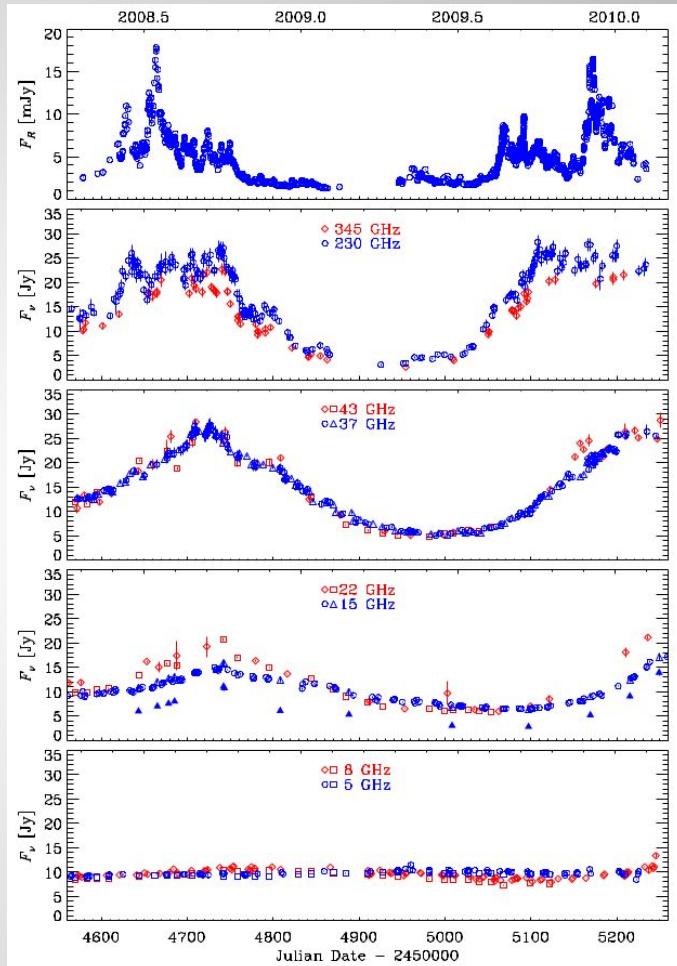


# Cross-correlation between bands: optical and radio

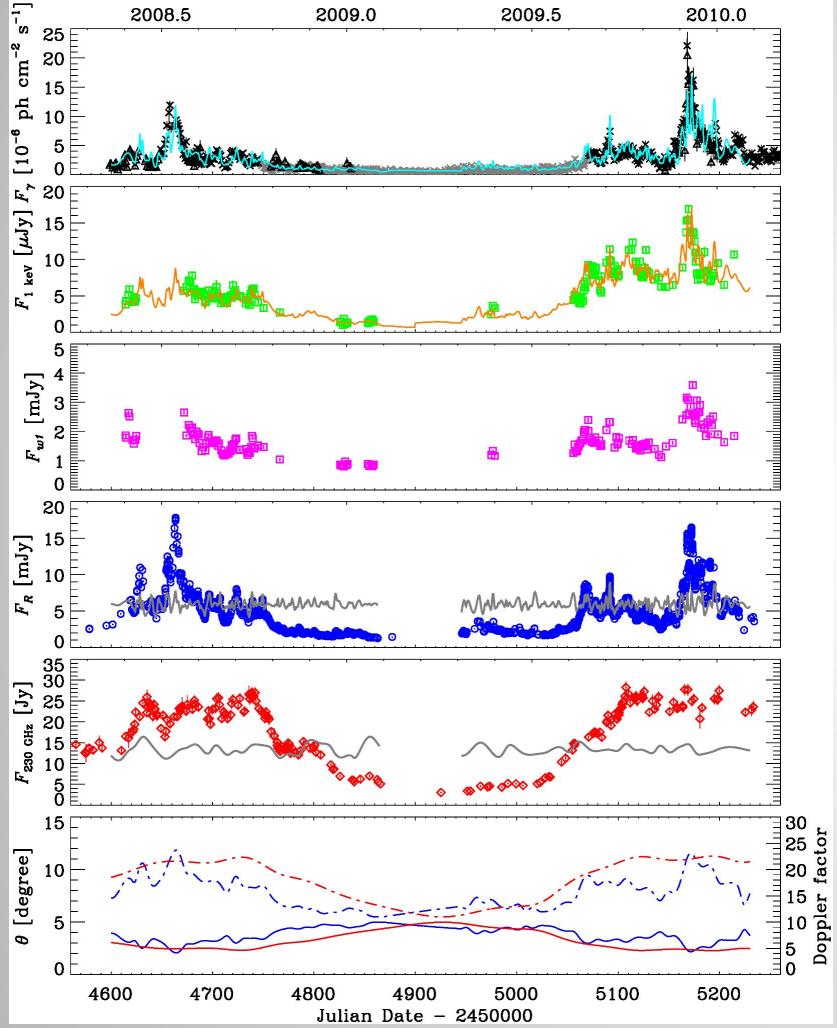
3C 454.3: “The Crazy Diamond”



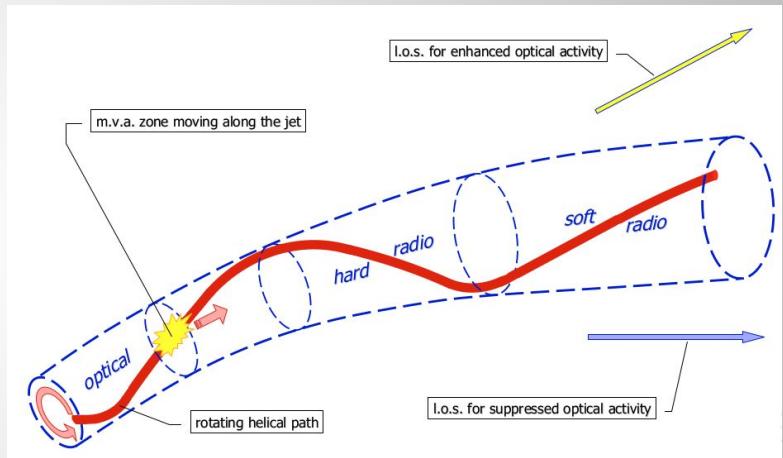
Villata et al. 2009, A&A, 504, L9



Raiteri et al. 2011, A&A, 534, A87

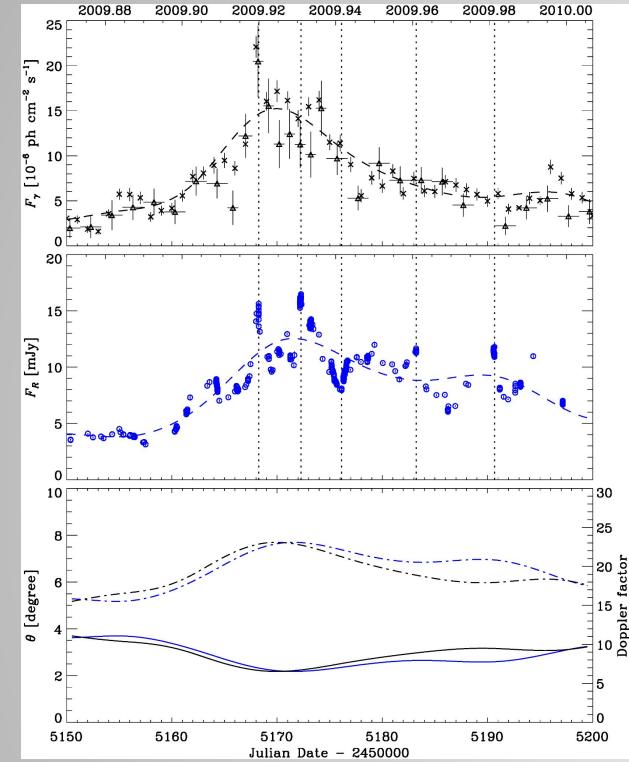


## Cross-correlation between bands: from radio to gamma-rays

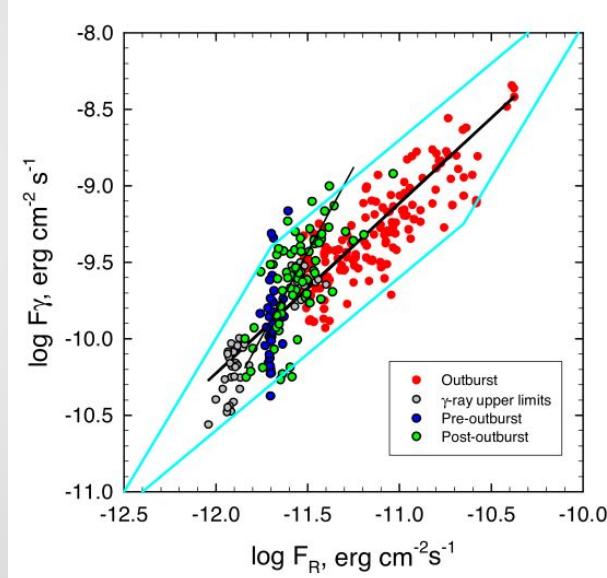
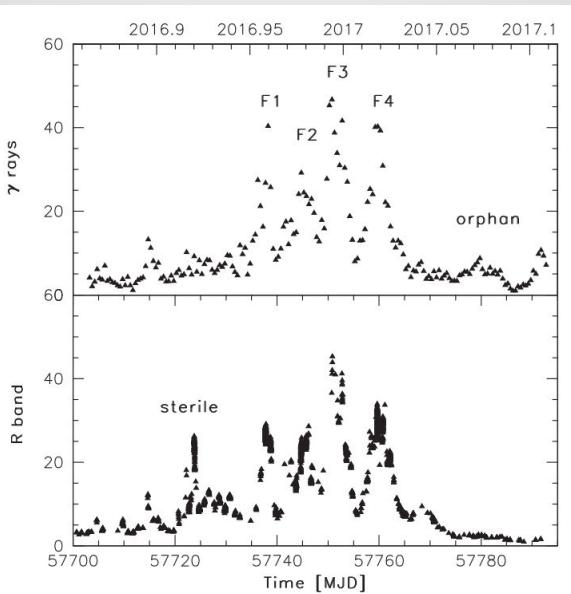


BL Lacertae, Villata et al. 2009, A&A, 501, 455

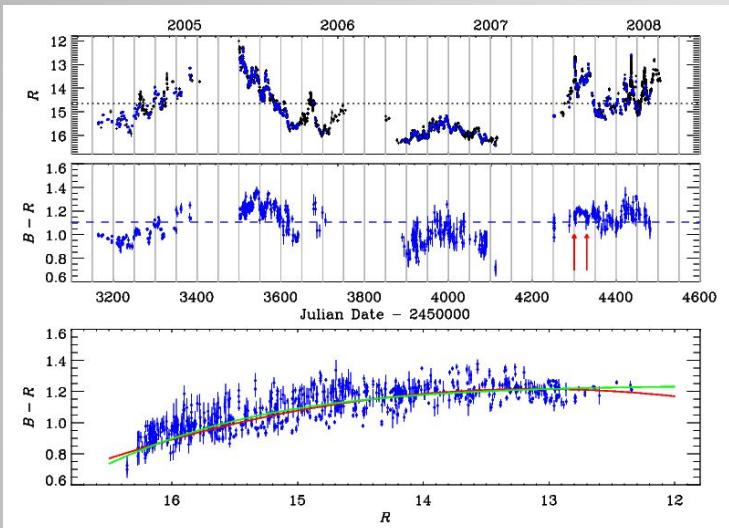
3C 454.3, Raiteri et al. 2011, A&A, 534, A87



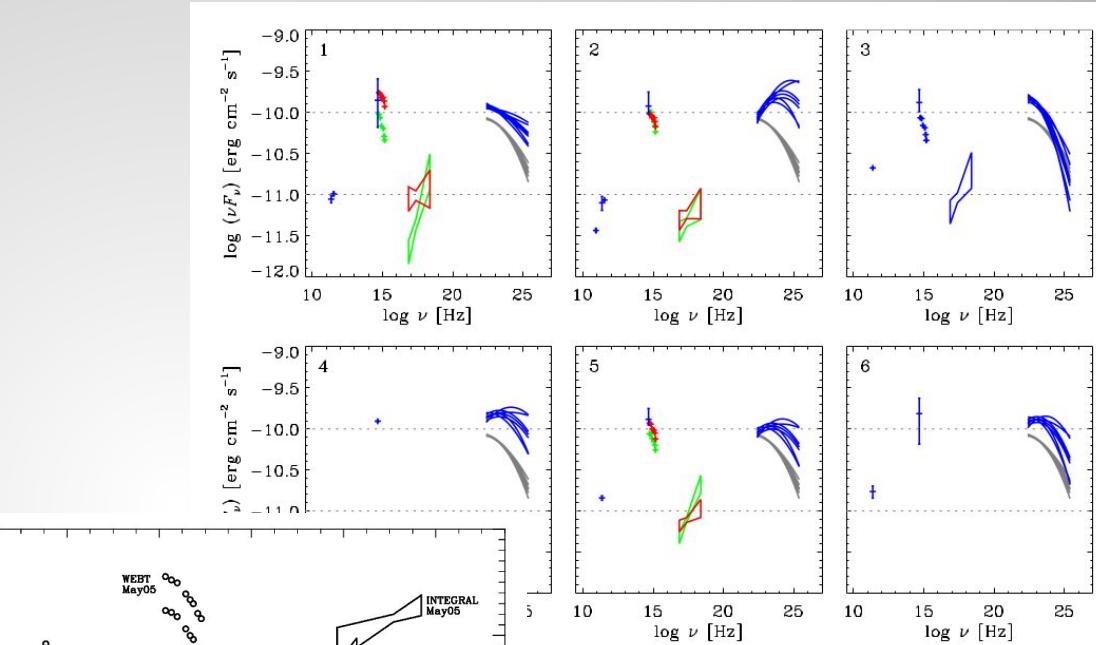
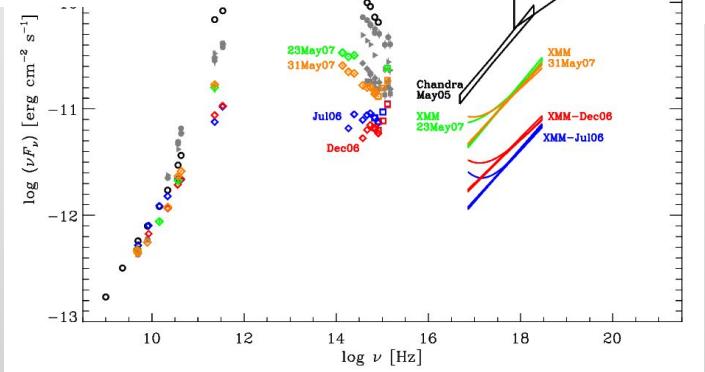
## Cross-correlation between gamma and optical



# Colour and spectral behaviour

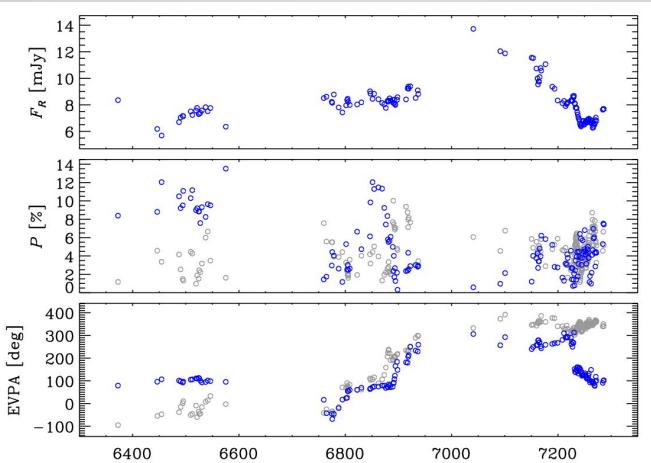
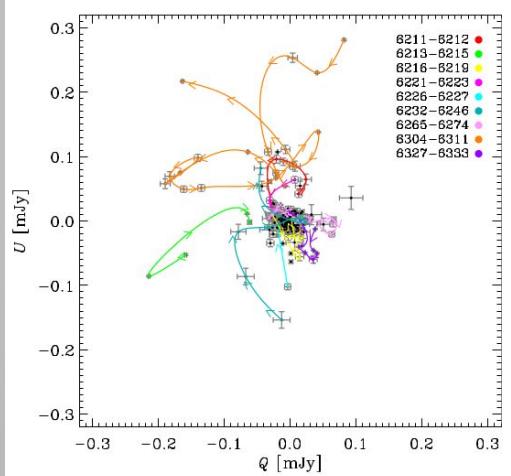


3C 454.3, Raiteri et al. 2008, A&A, 491, 755

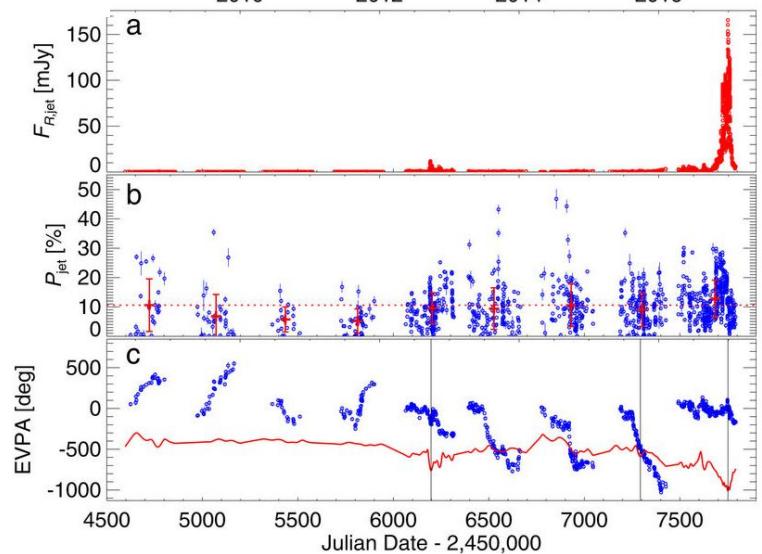


BL Lacertae, Raiteri et al. 2013, MNRAS, 436, 1530

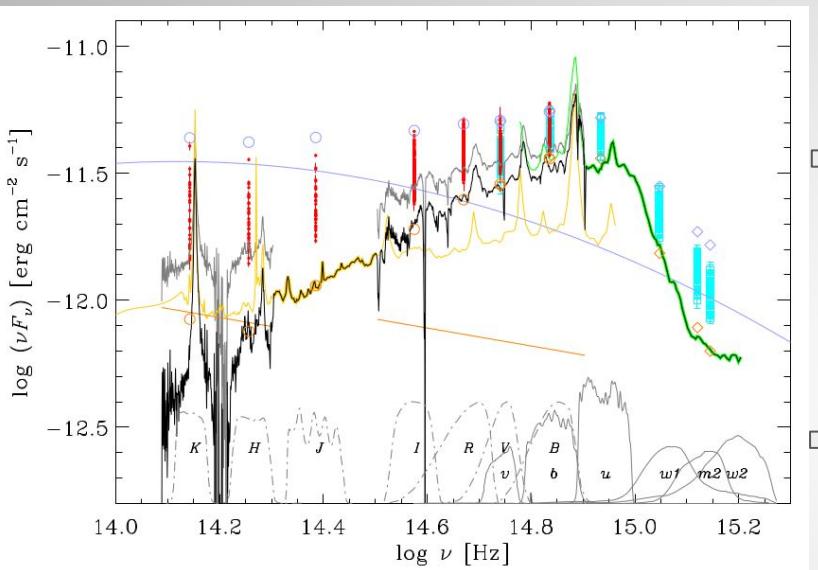
# Polarimetric behaviour



CTA 102, Raiteri et al. 2017,  
Nature, 552, 374



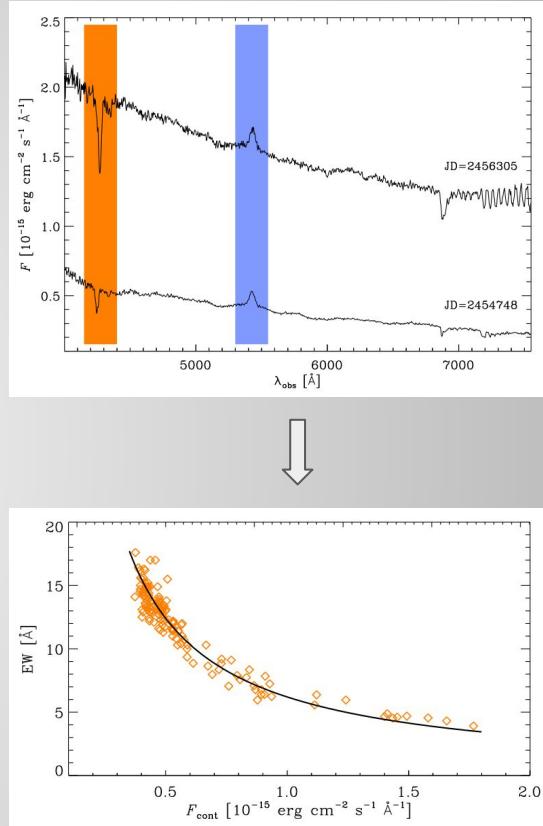
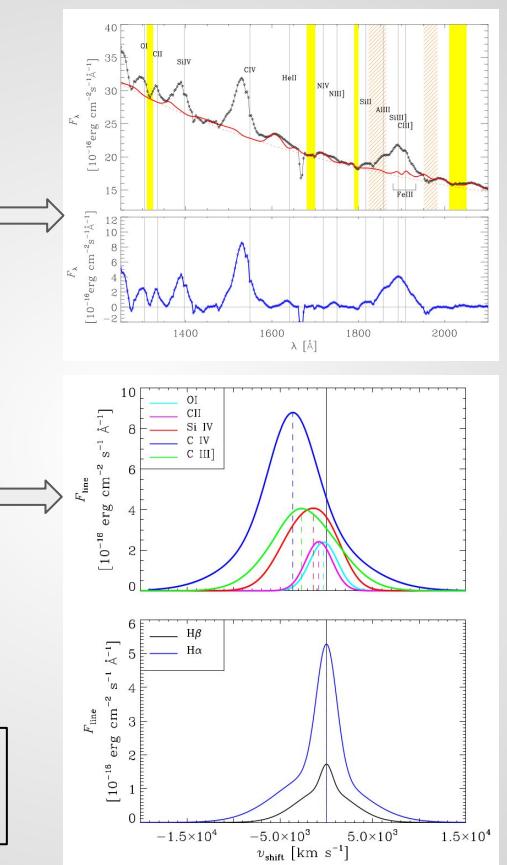
# Spectroscopic behaviour



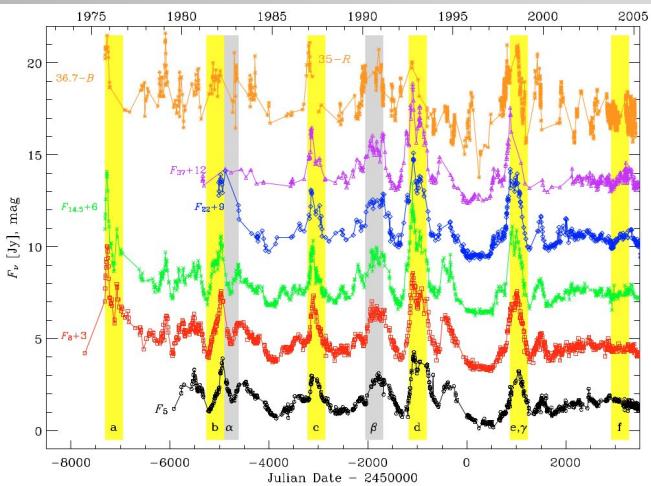
4C 71.07, Raiteri et al. 2019, MNRAS, 489, 1837

First evidence of outflow in a blazar!

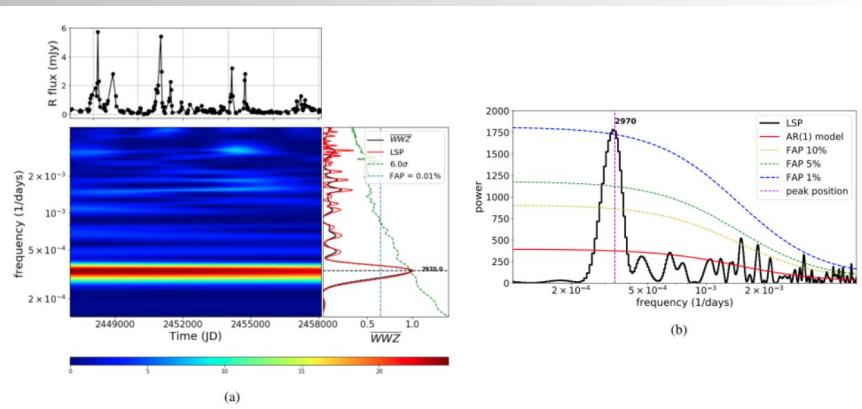
4C 71.07, Raiteri et al. 2020, MNRAS, 493, 2793



OJ 248, Carnerero et al. 2015, MNRAS, 450, 2677

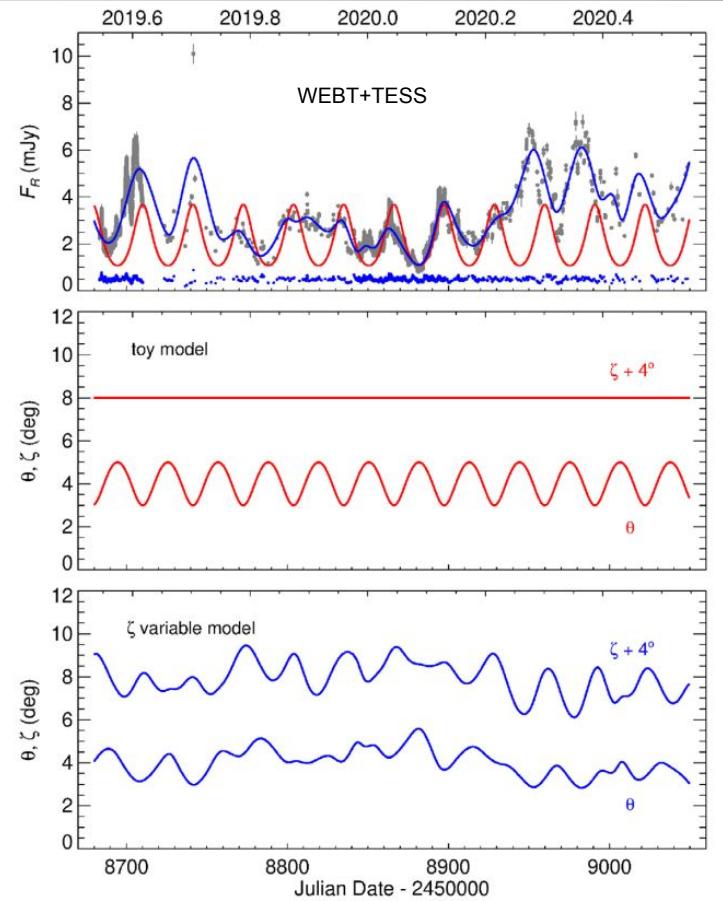


AO 0235+164, Raiteri et al. 2006, A&A, 459, 731



AO 0235+164, Roy et al. 2022, MNRAS, arXiv:2205.03586

## Search for quasi-periodic oscillations (QPO)



S4 0954+65, Raiteri et al. 2021, MNRAS, 504, 5629

## Blazar spectral variability as explained by a twisted inhomogeneous jet

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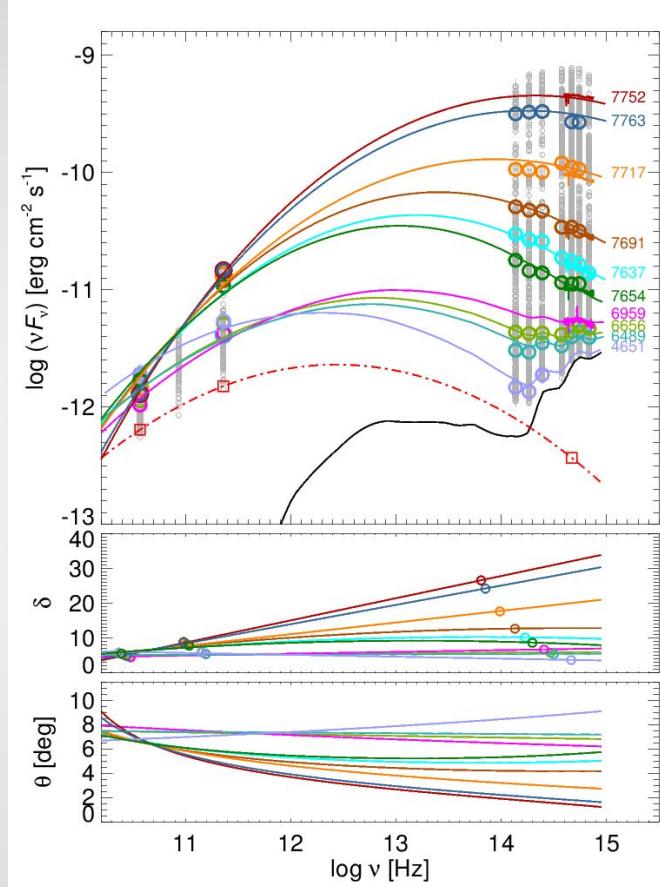
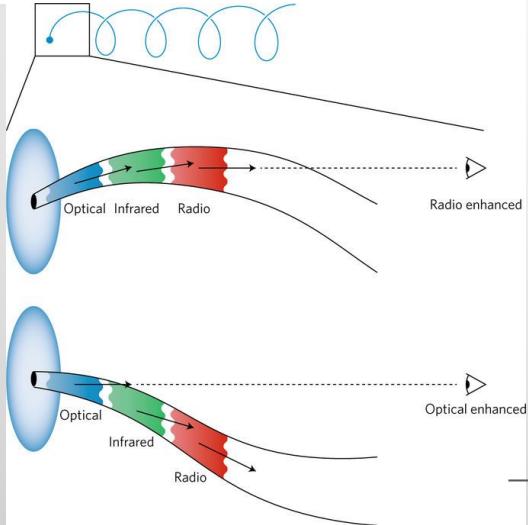
## Model

The jet is:

**inhomogeneous**: different frequencies emitted from different regions

**curved**: different regions have different viewing angles

**twisting**: the viewing angle varies in time because of internal (instabilities) or external (orbital motion, precession) reasons



**Leadership:** INAF-OATo dal 2000!

**Prospettive:** il numero di aderenti al WEBT e` in crescita, cosi` come le richieste di collaborazione! Tanti aspetti scientifici ancora da chiarire!



### **Finanziamenti:**

Sporadici, da contratti ASI-INAF e PRIN-INAF e fondi ricerca di base; nel 2003-2006 ENIGMA finanziato da Commissione Europea

Fatta richiesta di mini-grant per poter divulgare i risultati del WEBT in congressi e per poter invitare/visitare collaboratori

### **Criticita`:**

Massimo Villata (INAF-OATo) ora in pensione, anche se associato INAF con incarico gratuito di ricerca  
Maria Isabel Carnerero (INAF-OATo) assegnista Gaia

Necessaria una posizione TI come aiuto nello sfruttamento scientifico dei dati e, in prospettiva, come possibile erede della leadership.