Obituary

Leo Takalo
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MAGIC
Head of the OJ-94 Project
targeting OJ 287 periodicity

VI OJ-94 Annual Meeting
“Blazar monitoring towards the third millennium”
Torino, 19-21 May 1999
Twenty years of the Whole Earth Blazar Telescope

Claudia M. Raiteri & Massimo Villata
(INAF-Osservatorio Astrofisico di Torino)

for the WEBT Collaboration
http://www.oato.inaf.it/blazars/webt/
Some dates

1991-2000 Compton Gamma Ray Observatory

» Third EGRET Catalogue (20 MeV-30 GeV)

1997 WEBT birth - John Mattox (BU, USA) President ➔ continuous optical monitoring

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

WEBT MW campaigns on specific objects

2007 GLAST-AGILE Support Program (GASP)

» 14 BL Lacs + 14 FSRQs continuously monitored
Some information

~ 200 observers

~ 120 telescopes contributing to the WEBT campaigns (~100 optical + 9 near-IR + 10 radio)

- photometry + polarimetry + spectroscopy
- collaborations with other teams, in particular AGILE, Fermi, MAGIC
- archive data available one year after publication

~ 200 papers by the WEBT
GEOMETRICAL interpretation proposed in many WEBT works:

long-term VARIABILITY = variation of the VIEWING ANGLE $\theta$

$\Rightarrow$ variation of the DOPPLER BEAMING FACTOR $\delta$

$$\delta = \left[ \Gamma (1 - \beta \cos \theta) \right]^{-1} \quad \text{with} \quad \Gamma = (1 - \beta^2)^{-\frac{1}{2}} \text{bulk Lorentz factor}$$

When $\delta$ increases:

- flux density increases as $F_\nu (\nu) = \delta^{2+\alpha} F'_\nu (\nu)$ (for a continuous jet)
- variability time scale decreases as $\Delta t = \Delta t' / \delta$
- variability amplitude of intrinsic flux changes increases as $\Delta F \propto \delta^{2+\alpha}$
Observational hints

“Anatomy of helical extragalactic jets: the case of S5 0836+710”

“A swirling jet in the quasar 1308+326”

“Catching the radio flare in CTA 102”
Numerical hints


Nakamura et al. (2001, New Astronomy, 6, 61) “Production of wiggled structure of AGN radio jets in the sweeping magnetic twist mechanism”
But can we see the effects of Doppler factor changes in the blazar light curves?
Blazar spectral variability as explained by a twisted inhomogeneous jet

CTA 102 (2230+114)

FSRQ @ $z = 1.037$

WEBT optical+near-IR+radio monitoring

In 2013-2017:

39 telescopes in 28 observatories

Late 2016: jump of 6-7 mag

Peak: 28 December 2016

\[ R = 10.82 \pm 0.04 \]

\[ \log \nu L_\nu = 48.12 \] (erg/s)

unprecedented
Optical, mm, and radio behaviour different

tdowncoming from different jet regions

down the jet is inhomogeneous

Radio and mm changes smoother

downcoming from more extended (outer) regions
In optical, fast flares are more rapid and pronounced when the source is brighter

$\Rightarrow$ Doppler beaming effect

Assume that long-term variability is due to changes of $\delta$ because of changes of $\theta$

$\Rightarrow$ From the long-term trends derive $\delta(t)$ and $\theta(t)$ at different $\nu$

$\Rightarrow$ the jet is curved and twisting
Small-amplitude fast variations due to intrinsic processes after correcting for $\delta(t)$

Verify increased variability amplitude for higher $\delta$

Oscillations around the long-term trend represented by the spline

Small-amplitude fast variations due to intrinsic processes after correcting for $\delta(t)$

($= \text{fixed } \delta_{\text{base}}$)
Verify time contraction

Blue: $> \delta_{\text{max}}/2$    Red: $< \delta_{\text{max}}/2$

$t_{\text{blue}} = t_{\text{red}}/2$
SED modelling

- build thermal emission model
- build a base-level synchrotron spectrum (blss)
- ∀ epoch build \( \delta(v) \) and \( \theta(v) \)
- derive the predicted synchrotron SED as Doppler enhancement of the blss + thermal emission model = total SED to be compared with observed SED

\( \Rightarrow \) excellent reproduction of both flux level and spectral slope
As a result the jet is:

- inhomogeneous different frequencies emitted from different regions

- curved different regions have different viewing angles

- twisting/swinging/swirling/snaking/meandering/wiggling
  the viewing angle varies in time because of internal (instabilities) or external (orbital motion, precession) reasons
Polarization

- strong variability of $P$
- no correlation of $P_{\text{jet}}$ with $F_{\text{jet}}$
- wide rotations of EVPA, both clockwise and anticlockwise
- coincidence of $\theta$ minima with fast changes or inversions of EVPA
Optical spectral changes

redder-when-brighter  ~ bluer-when-brighter