Obituary

Leo Takalo

University of Turku,
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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

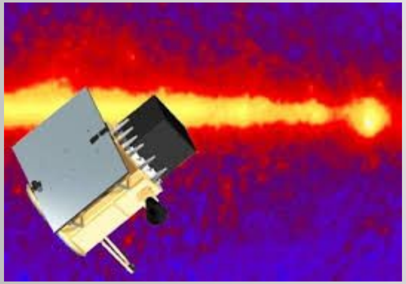
1991-2000 Compton Gamma Ray Observatory

➪ 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 θ

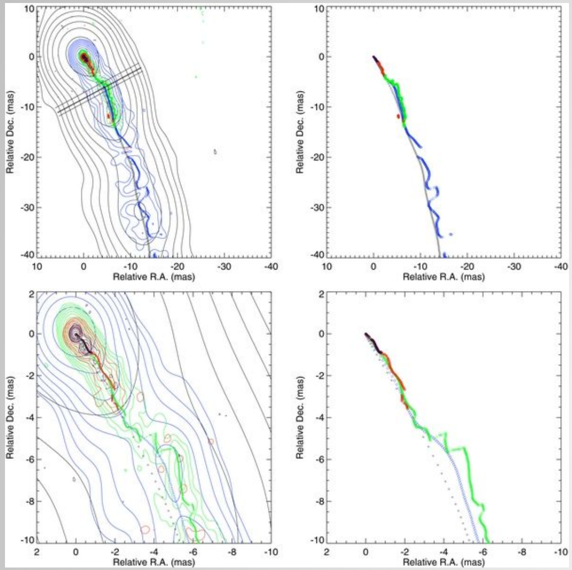
➪ variation of the DOPPLER BEAMING FACTOR δ

$\delta=[\Gamma(1-\beta\cos\theta)]^{-1}$ with $\Gamma=(1-\beta^2)^{-1/2}$ bulk Lorentz factor

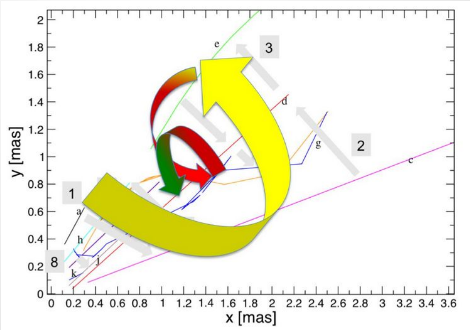
When δ increases:

- 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 $\Delta F \propto \delta^{2+\alpha}$

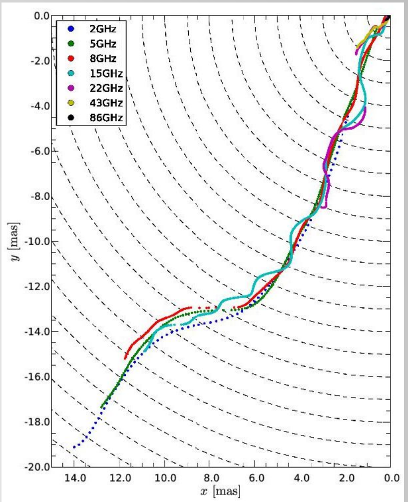
Observational hints



Perucho et al. (2012, ApJ, 749, 55)
"*Anatomy of helical extragalactic jets: the case of S5 0836+710*"

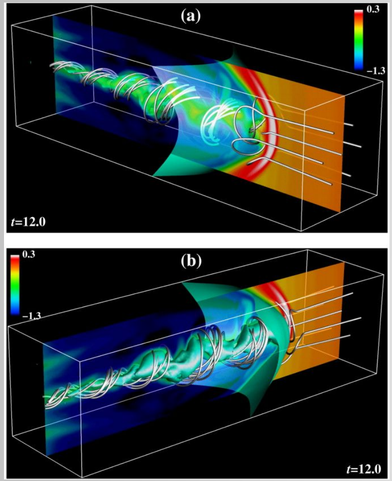


Britzen et al. (2017, A&A, 602, A29)
"*A swirling jet in the quasar 1308+326*"

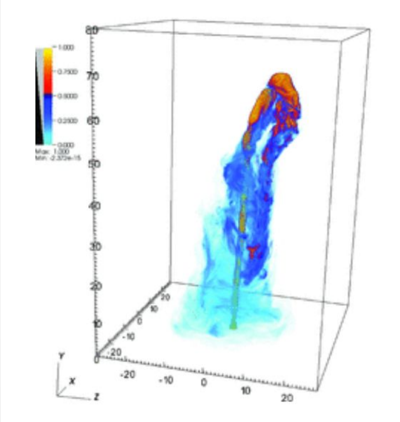


Fromm et al. (2013, A&A, 557, A105)
"*Catching the radio flare in CTA 102*"

Numerical hints

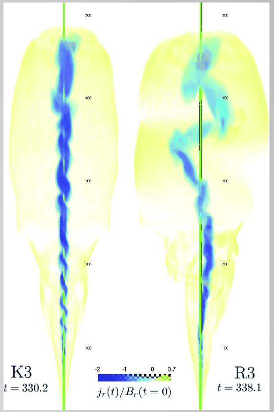


Nakamura et al. (2001, New Astronomy, 6, 61)
"*Production of wiggled structure of AGN radio jets in the sweeping magnetic twist mechanism*"

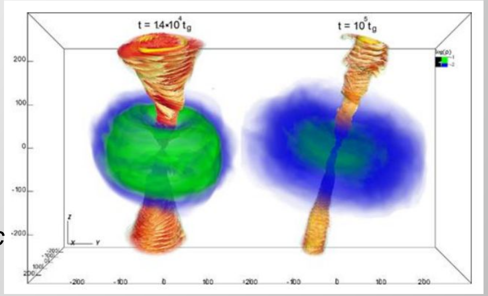


Mignone et al. (2010, MNRAS, 402, 7)
"*High-resolution 3D relativistic MHD simulations of jets*"

Moll et al. (2008, A&A, 492, 621)
" *Kink instabilities in jets from rotating magnetic fields*"



Liska et al. (2018, MNRAS, 474, L81)
"*Formation of precessing jets by tilted black hole discs in 3D general relativistic MHD simulations*"



But can we see the effects of Doppler factor changes in the blazar light curves?

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LETTER

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Blazar spectral variability as explained by a twisted inhomogeneous jet

C. M. Raiteri[1], M. Villata[1], J. A. Acosta-Pulido[2,3], I. Agudo[4], A. A. Arkharov[5], R. Bachev[6], G. V. Baida[7], E. Benítez[8], G. A. Borman[7], W. Boschin[2,3,9], V. Bozhilov[10], M. S. Butuzova[7], P. Calcidese[11], M. I. Carnerero[1], D. Carosati[9,12], C. Casadio[4,13], N. Castro-Segura[3,14], W.-P. Chen[15], G. Damljanovic[16], F. D'Ammando[17,18], A. Di Paola[19], J. Echevarría[8], N. V. Efimova[5], Sh. A. Ehgamberdiev[20], C. Espinosa[8], A. Fuentes[4], A. Giunta[19], J. L. Gómez[4], T. S. Grishina[21], M. A. Gurwell[22], D. Hiriart[8], H. Jermak[23], B. Jordan[24], S. G. Jorstad[21,25], M. Joshi[25], E. N. Kopatskaya[21], K. Kuratov[26,27], O. M. Kurtanidze[28,29,30,31], S. O. Kurtanidze[28], A. Lähteenmäki[32,33,34], V. M. Larionov[5,21], E. G. Larionova[21], L. V. Larionova[21], C. Lázaro[2,3], C. S. Lin[15], M. P. Malmrose[25], A. P. Marscher[25], K. Matsumoto[35], B. McBreen[36], R. Michel[8], B. Mihov[6], M. Minev[10], D. O. Mirzaqulov[20], A. A. Mokrushina[5,21], S. N. Molina[4], J. W. Moody[37], D. A. Morozova[21], S. V. Nazarov[7], M. G. Nikolashvili[28], J. M. Ohlert[38,39], D. N. Okhmat[7], E. Ovcharov[10], F. Pinna[2,3], T. A. Polakis[40], C. Protasio[2,3], T. Pursimo[41], F. J. Redondo-Lorenzo[2,3], N. Rizzi[42], G. Rodriguez-Coira[2,3], K. Sadakane[35], A. C. Sadun[43], M. R. Samal[15], S. S. Savchenko[21], E. Semkov[6], B. A. Skiff[44], L. Slavcheva-Mihova[6], P. S. Smith[45], I. A. Steele[23], A. Strigachev[6], J. Tammi[32], C. Thum[46], M. Tornikoski[32], Yu. V. Troitskaya[21], I. S. Troitsky[21], A. A. Vasilyev[21] & O. Vince[16]

CTA 102 (2230+114)

FSRQ @ z = 1.037

WEBT optical+near-IR+radio monitoring

In 2013-2017:

39 telescopes in 28 observatories

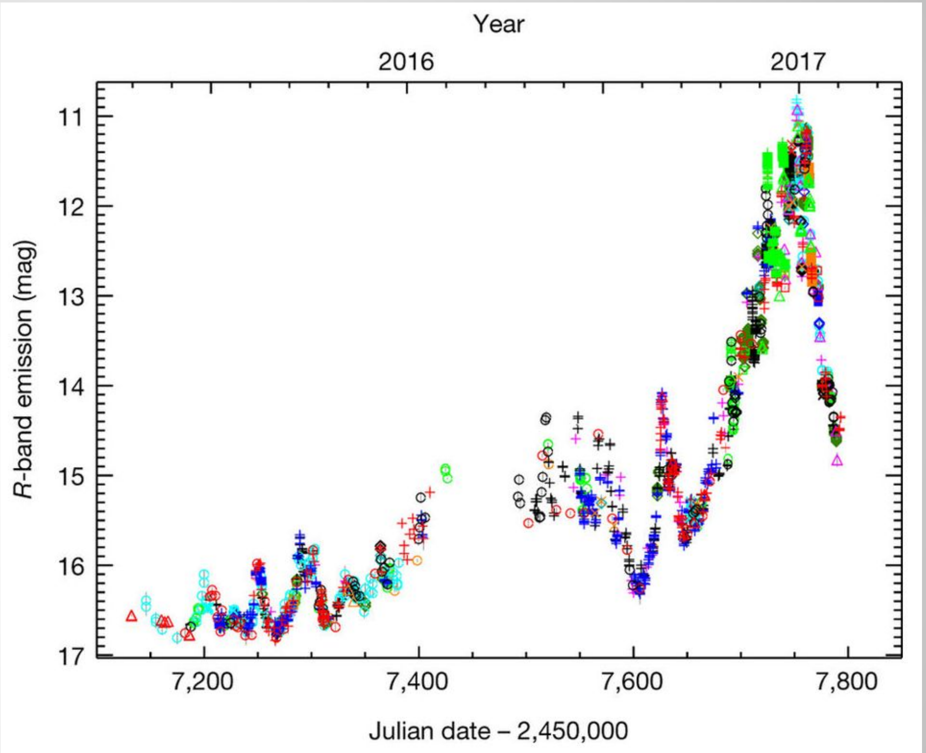
Late 2016: jump of 6-7 mag

Peak: 28 December 2016

➪ R = 10.82 ± 0.04

➪ log νL_ν = 48.12 (erg/s)

➪ unprecedented



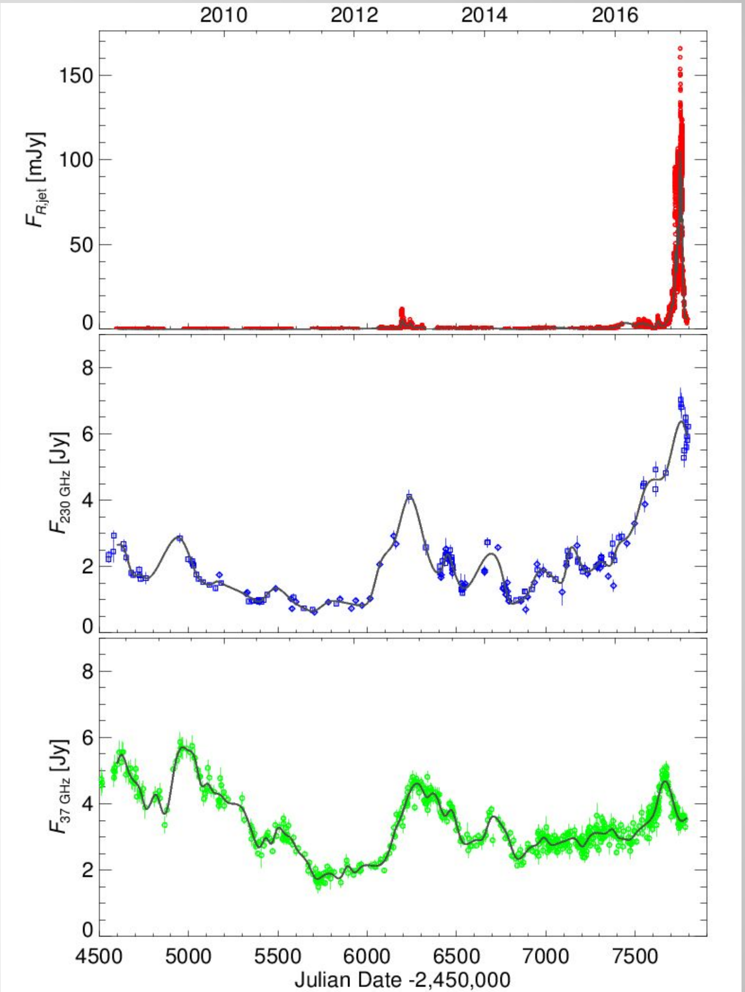
Optical, mm, and radio behaviour different

➪ coming from different jet regions

➪ the jet is inhomogeneous

Radio and mm changes smoother

➪ coming from more extended (outer) regions



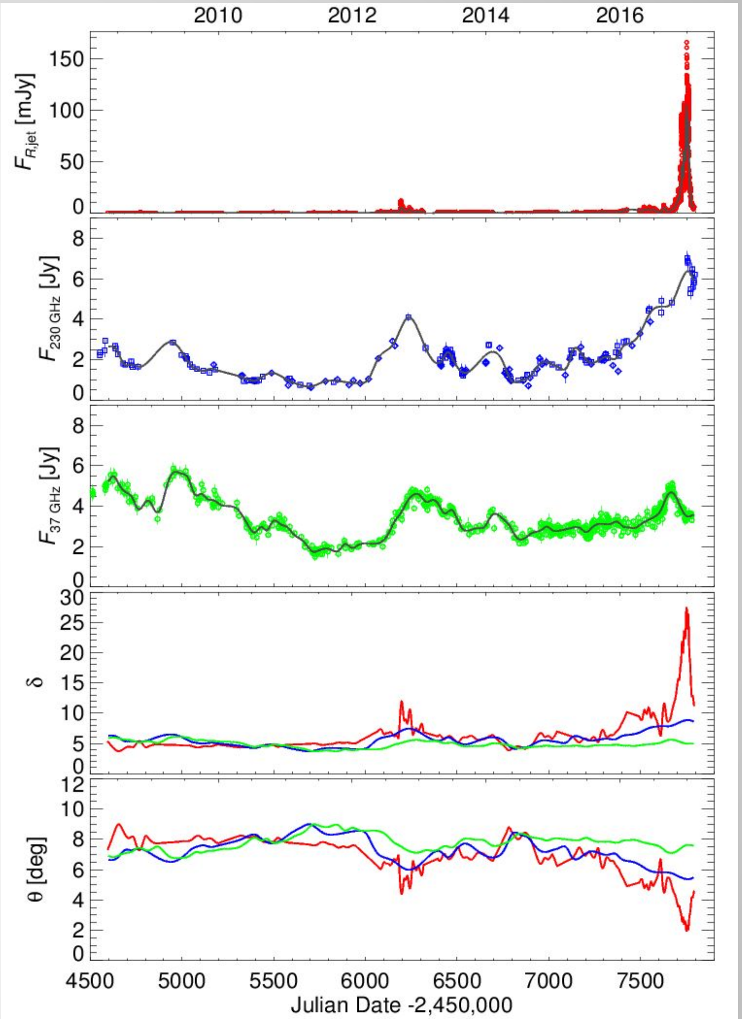
In optical, fast flares are more rapid and pronounced when the source is brighter

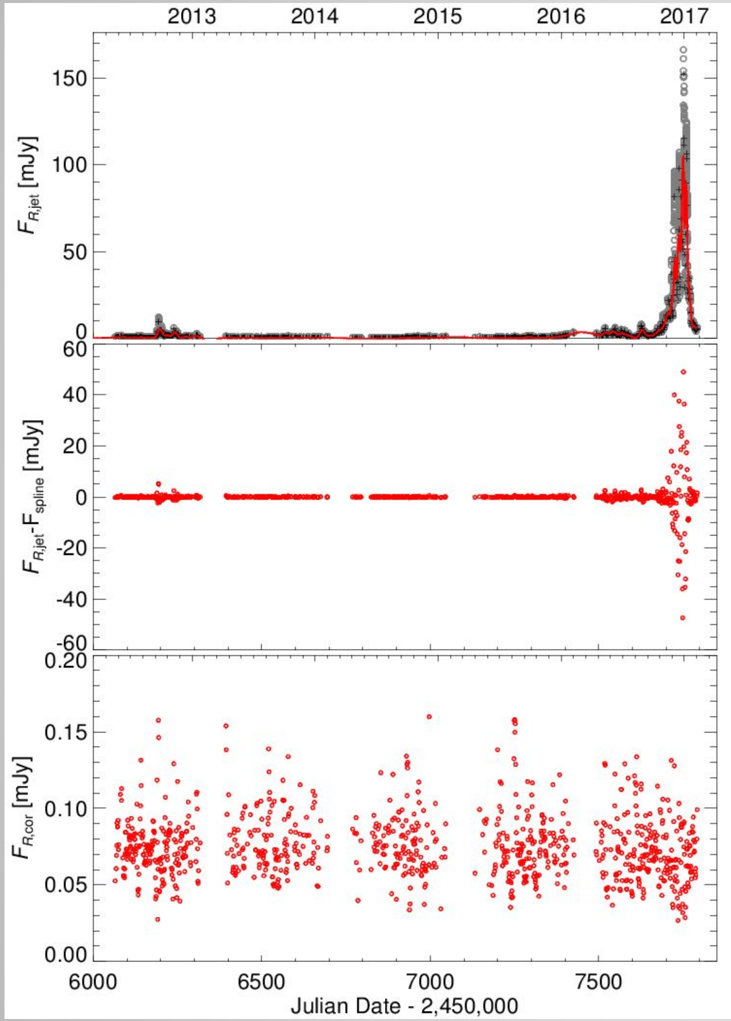
➪ Doppler beaming effect

Assume that long-term variability is due to changes of δ because of changes of θ

➪ From the long-term trends derive δ(t) and θ(t) at different ν

➪ the jet is curved and twisting



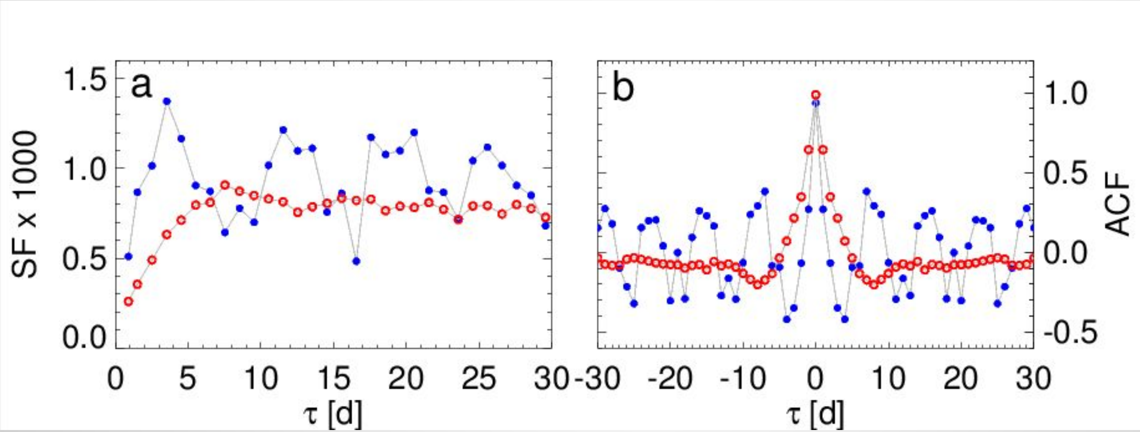


Verify increased variability amplitude for higher δ

Oscillations around the long-term trend represented by the spline

Small-amplitude fast variations due to intrinsic processes after correcting for δ(t)
(= fixed δ_{base})

Verify time contraction



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

➪ $\tau_{blue} = \tau_{red}/2$

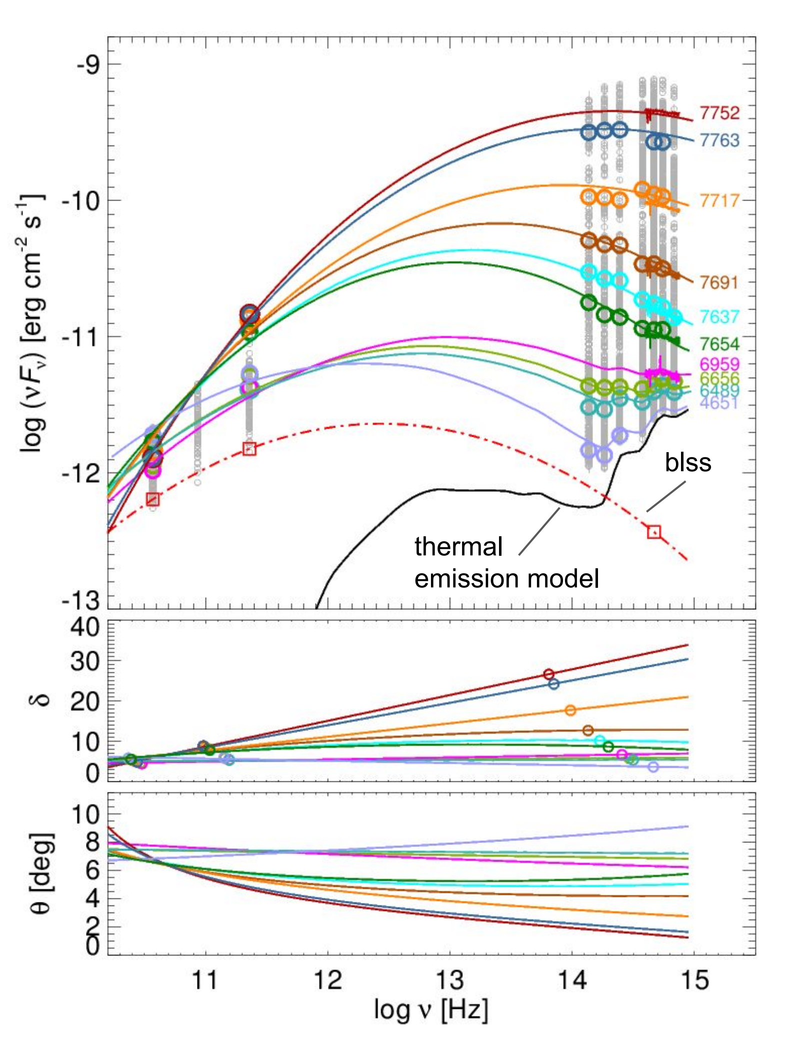
SED modelling

- build thermal emission model
- build a base-level synchrotron spectrum (blss)
- ∀ epoch build $\delta(\nu)$ and $\theta(\nu)$
- derive the predicted synchrotron SED as Doppler enhancement of the blss

\+ thermal emission model

= total SED to be compared with observed SED

➪ excellent reproduction of both flux level and spectral slope

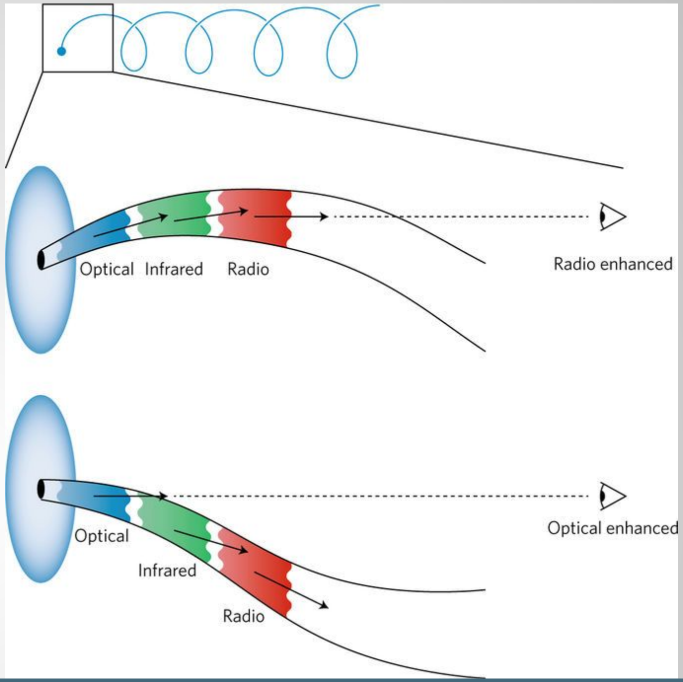


As a result the jet is:

- 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



news & views

NATURE ASTRONOMY, VOL 2, JANUARY 2018, 32-33

ACTIVE GALAXIES

A cosmic jet swinging our way

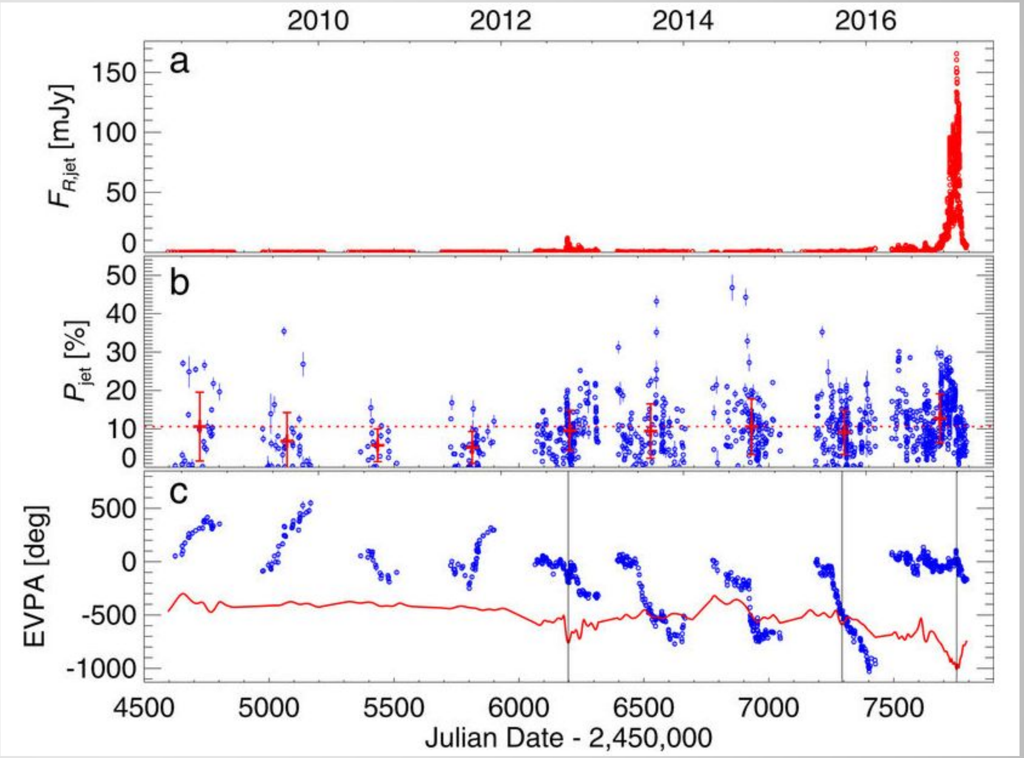
Long-term multi-wavelength monitoring of a jet from a supermassive black hole reveals that more intense periods of variability in brightness occur when the jet is pointed more directly at Earth, thereby strengthening the geometric interpretation of long-term changes in brightness.

Eileen T. Meyer

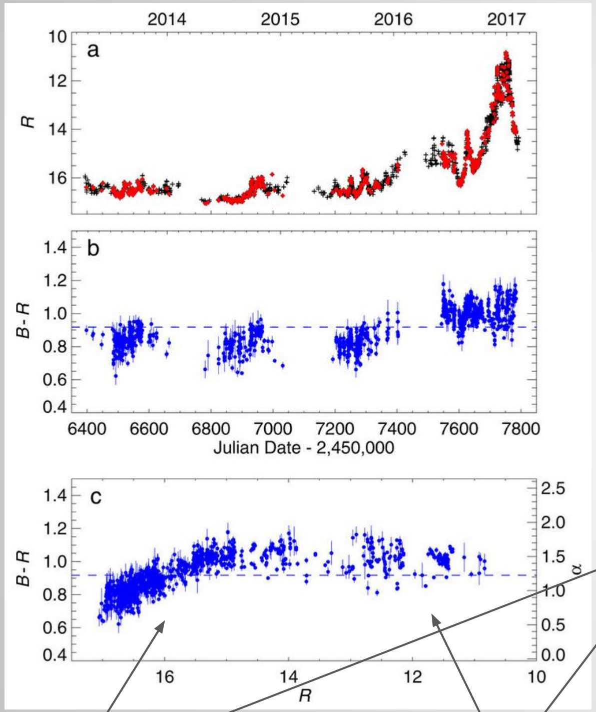
Thank you

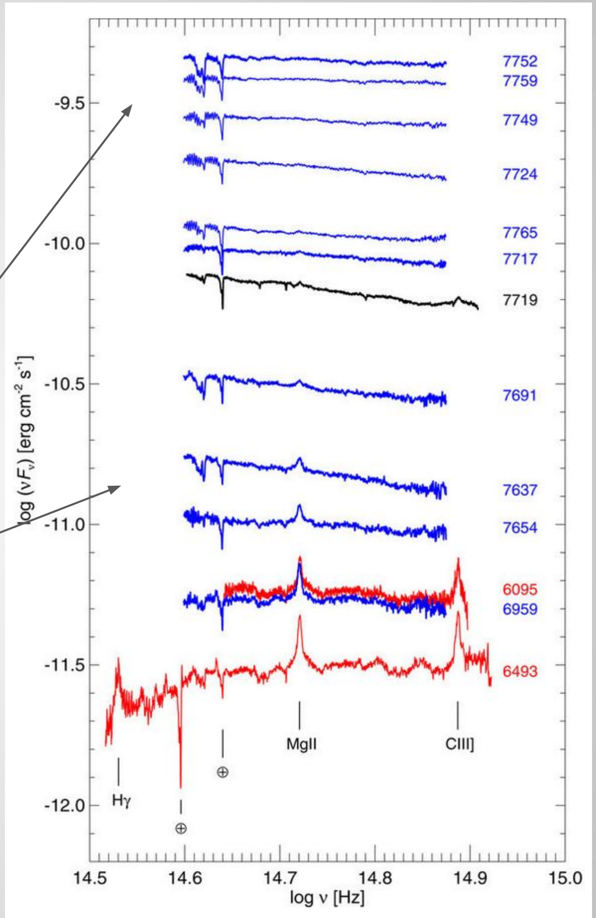
Polarization

- strong variability of P
- no correlation of P_{jet} with F_{jet}
- wide rotations of EVPA, both clockwise and anticlockwise
- coincidence of θ minima with fast changes or inversions of EVPA



Optical spectral changes





redder-when-brighter

~ bluer-when-brighter