OUTFLOWS IN BLAZARS

Claudia M. Raiteri
INAF-Osservatorio Astrofisico di Torino, Italy

Collaborators:
Massimo Villata & Maria Isabel Carnerero (INAF-Osservatorio Astrofisico di Torino)
Jose A. Acosta Pulido (IAC, Tenerife, Spain),
Stefano Vercellone & Patrizia Romano (INAF-Osservatorio Astronomico di Brera)

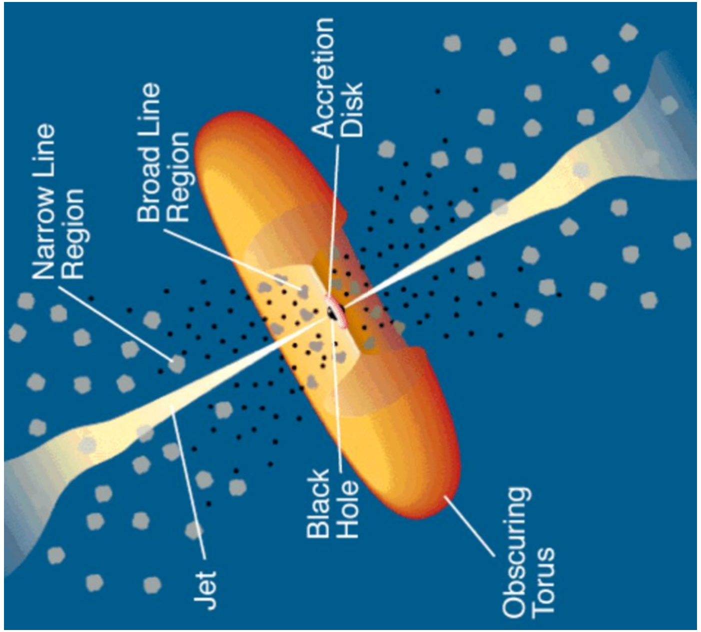
BLAZAR = AGN with one jet pointing toward us

Jet emission affected by relativistic effects that depend on the **Doppler factor** $\delta = [\Gamma(1-\beta\cos\theta)]^{-1}$

where $\Gamma = (1-\beta^2)^{-1/2}$ bulk Lorentz factor, β=v/c plasma velocity

θ viewing angle

smaller θ = stronger beaming



Urry & Padovani 1995, PASP, 107, 803

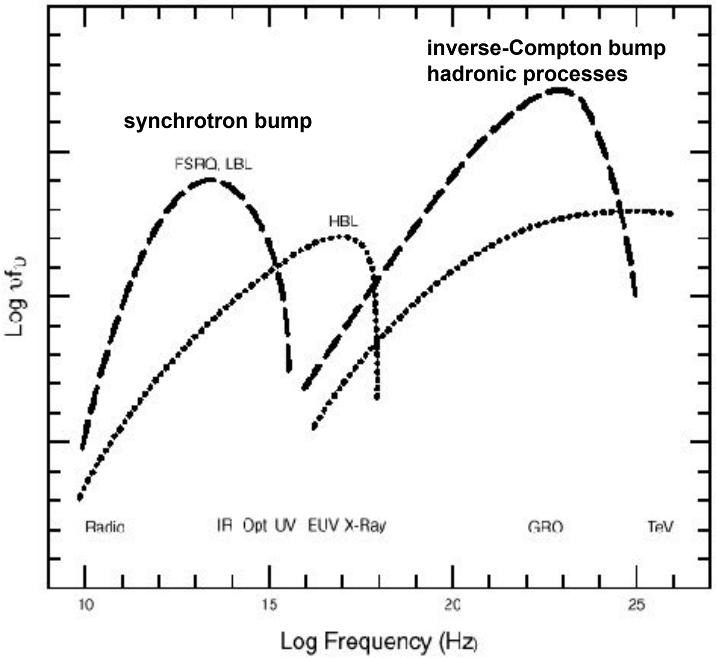
Consequences of Doppler beaming:

- flux relativistically enhanced $F_\nu(\nu) = \delta^{n+\alpha} F'_{\nu'}(\nu)$
- blue-shift of emitted frequencies $\nu = \delta\, \nu'$ prevailing over cosmological redshift
- shortening of variability timescales $\Delta t = \Delta t'/\delta$

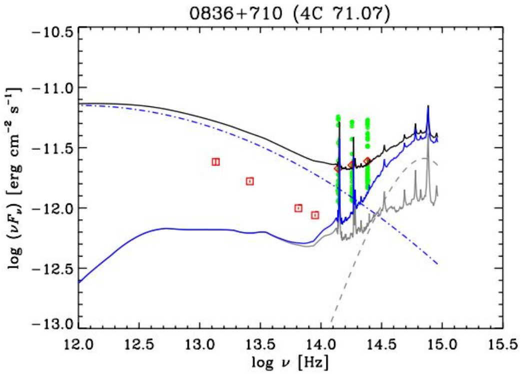
➪ **Blazars appear as luminous and very variable sources across the whole electromagnetic spectrum**

Blazar Spectral Energy Distribution (SED)

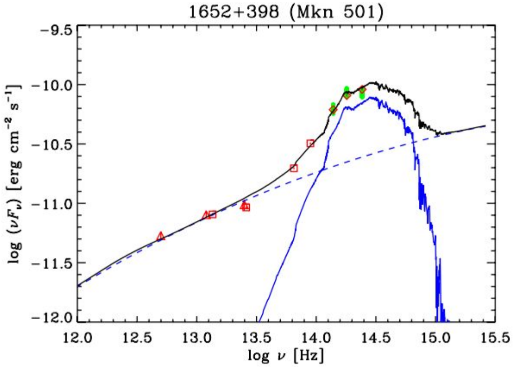
Jet emission



FSRQs
(flat-spectrum radio quasars):
strong emission lines from nuclear region;
low-energy peaked;
(big and little blue bumps)



BL Lacs
(BL-Lacertae-type objects):
weak or no emission lines;
low or high-energy peaked;
(host galaxy)



Raiteri et al. 2014, MNRAS, 442, 629

Aim of the work: disentangle the beamed non-thermal jet emission from the unbeamed thermal emission from the quasar core and study their properties

Target: FSRQ 4C 71.07 (0836+710)

Method:

Massive 2-year broad-band monitoring campaign by the Whole Earth Blazar Telescope (WEBT)

- \+ Swift (UV and X-rays) and Fermi (gamma rays)
- \+ Optical (WHT, NOT) and near-IR (TNG) spectra

Whole Earth Blazar Telescope

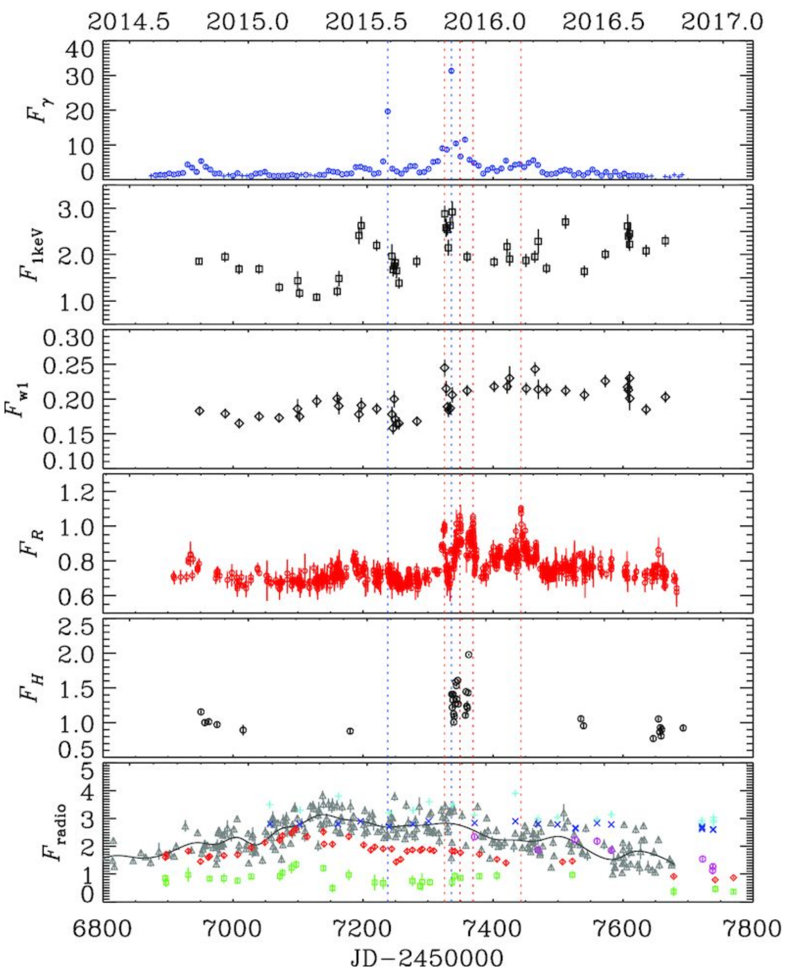
https://www.oato.inaf.it/blazars/webt

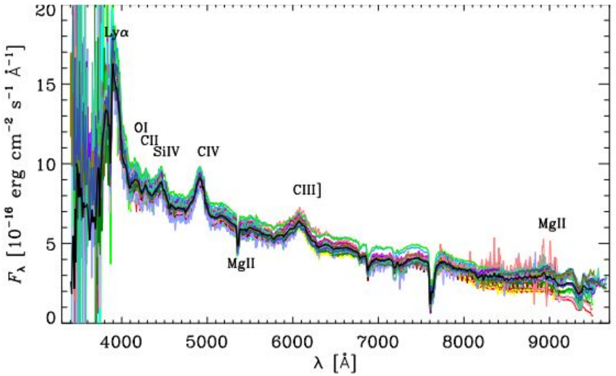
Wide International Collaboration born in 1997 to monitor bright blazars in a continuous way thanks to the distribution in longitude of its members.

Mainly optical, but also radio and near-IR photometry and polarimetry.

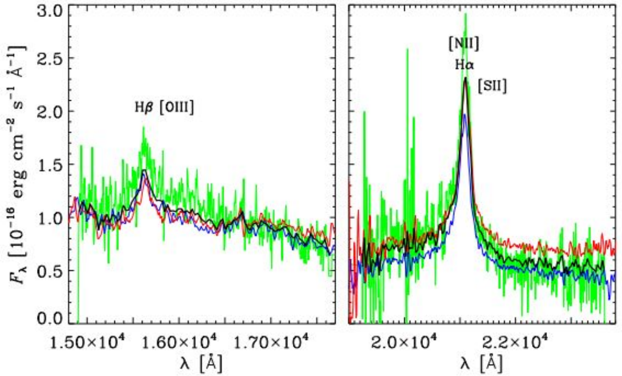
Multifrequency light curves dominated by jet emission variability

Complex correlation between bands



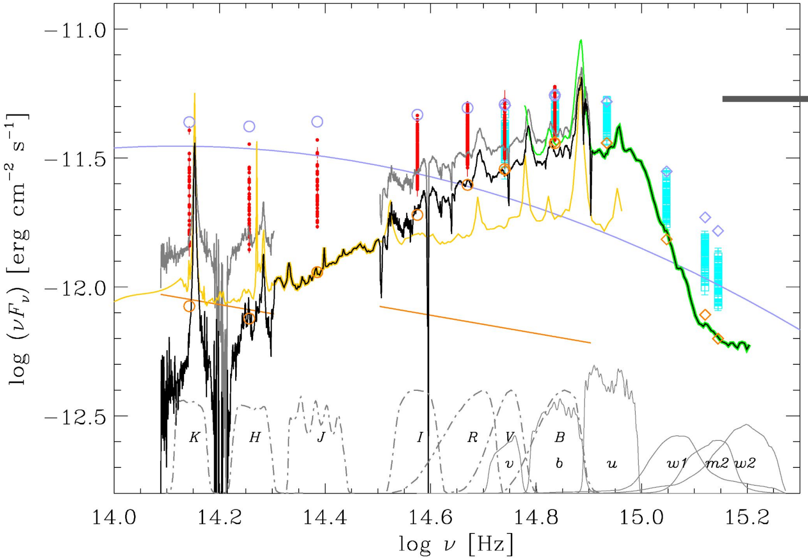


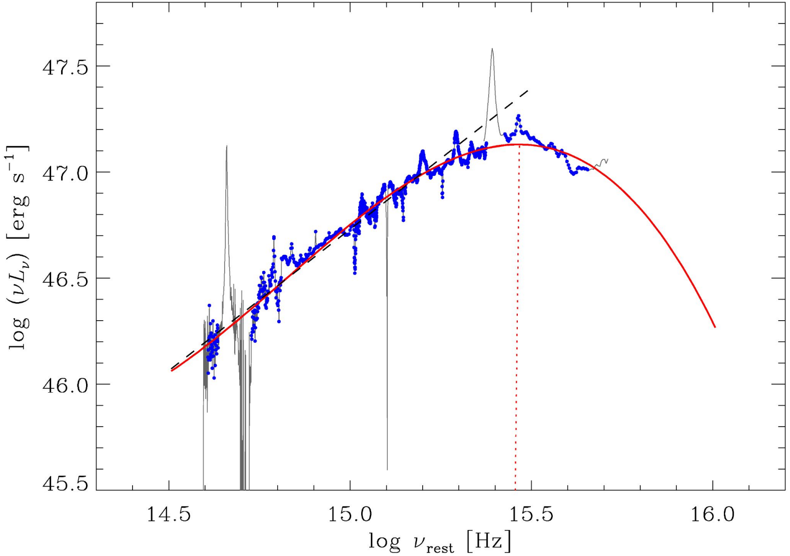
24 optical spectra



3 near-infrared spectra

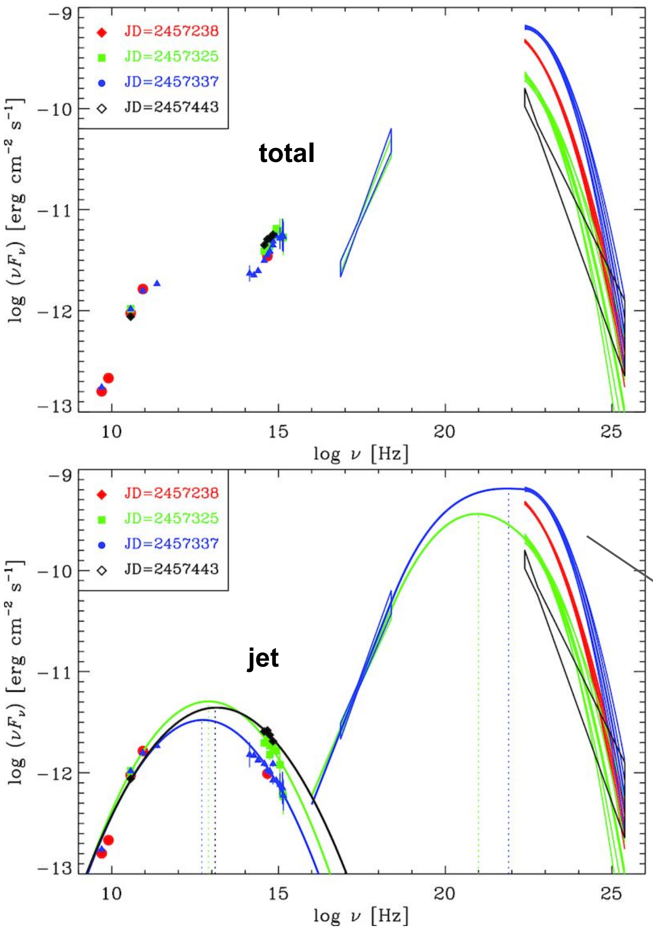
Separation between the jet and quasar core emissions





Bolometric disc luminosity

L(disc)=2.45×10^{47}erg/s



Jet beamed emission: luminosity

Bolometric jet luminosity

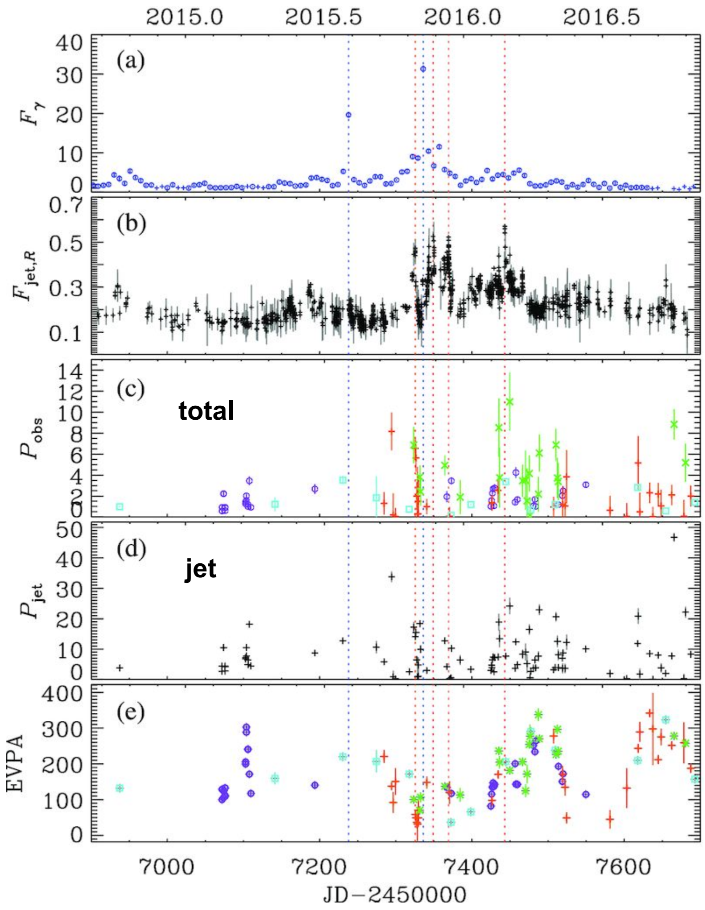
L(jet)=9.42×10^{49} erg/s

98.5% from the high-energy bump

Compton dominance

Jet beamed emission: polarimetric behaviour

= behaviour of the magnetic field in the jet emitting region



Observed polarization degree must be corrected for the dilution effect by the thermal nuclear emission to get the jet value
P(obs,max)=11%
P(jet,max)=47%

Rotations of the polarization angle in both directions

No clear correlation of polarization with flux

Presence of turbulence in the emitting region

Quasar core:

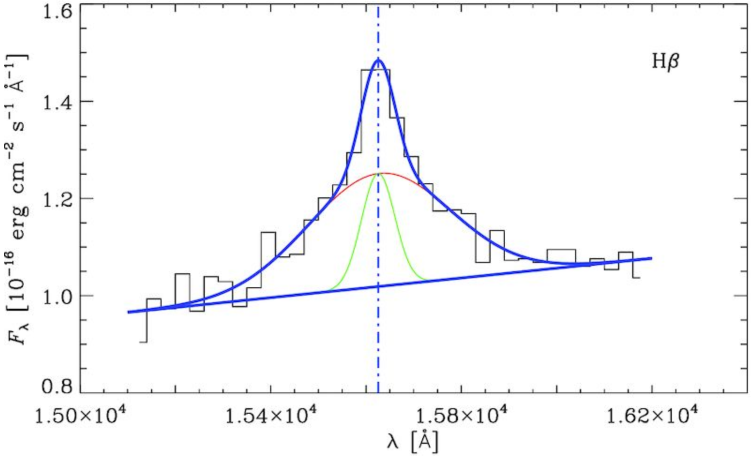
determining the systemic redshift

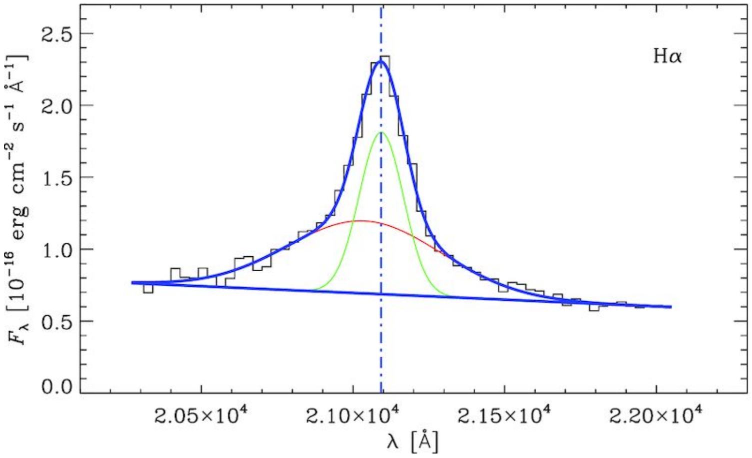
No narrow emission lines

⇨ systemic redshift estimated from Hβ and Hα

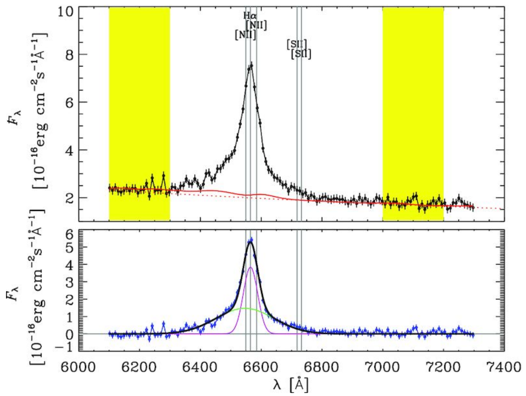
z=2.2130±0.0004

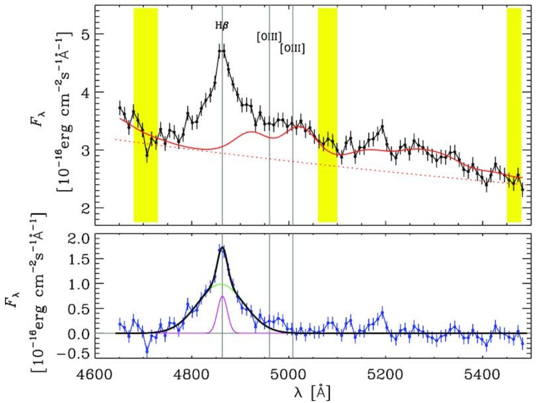
Uncertainty estimated through Monte Carlo simulations

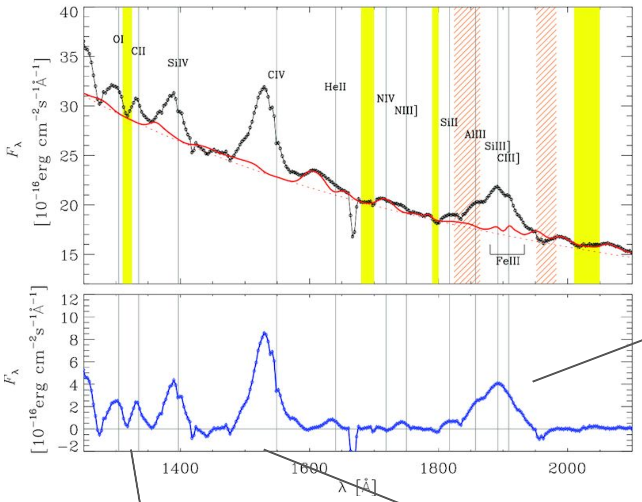




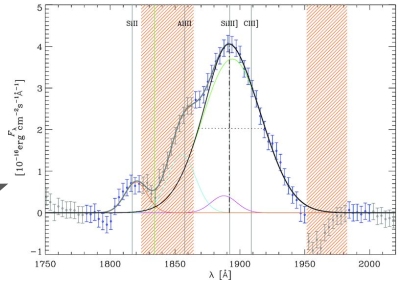
Quasar core: nuclear properties

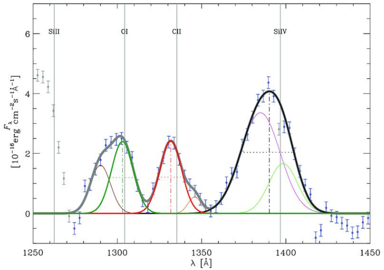


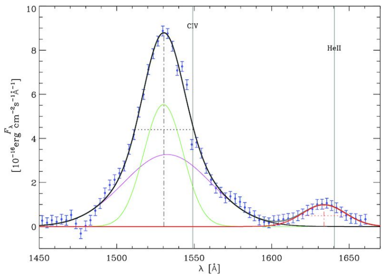




Strong blueshift of high ionisation lines ⇨ **OUTFLOW**







M(BH)=(2.0±0.7)×10^9 M☉

L(Edd)=2.49×10^{47}erg/s

L(disc)/*L*(Edd) ≈ 1

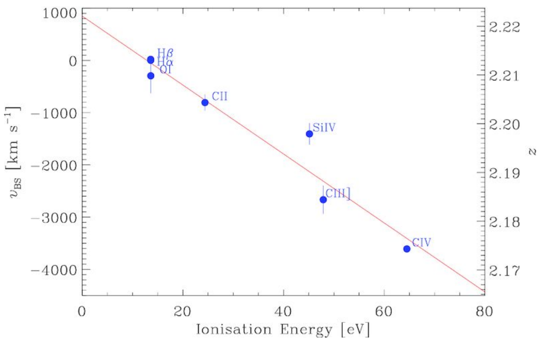
R(BLR)~2 light years

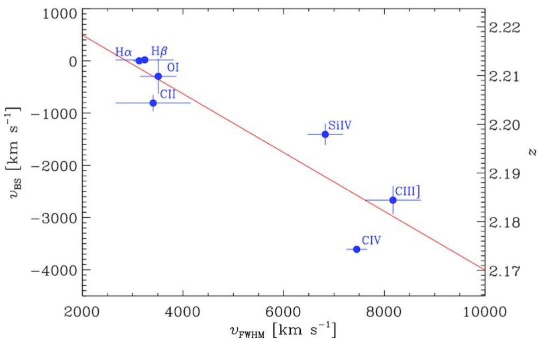
L(BLR)=(1.52±0.14)×10^{46}erg/s

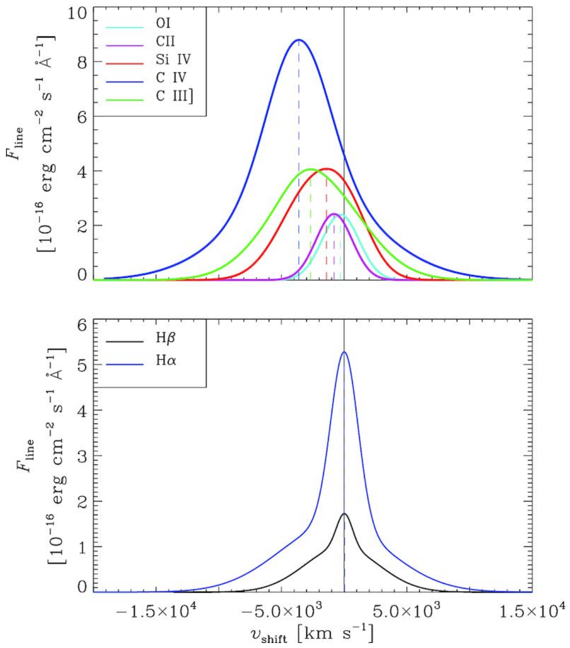
One of the most luminous blazar cores

Quasar core: nuclear properties

The blueshift and FWHM increase with ionizing energy
➩ the outflow is also responsible for the line broadening (disc face-on)

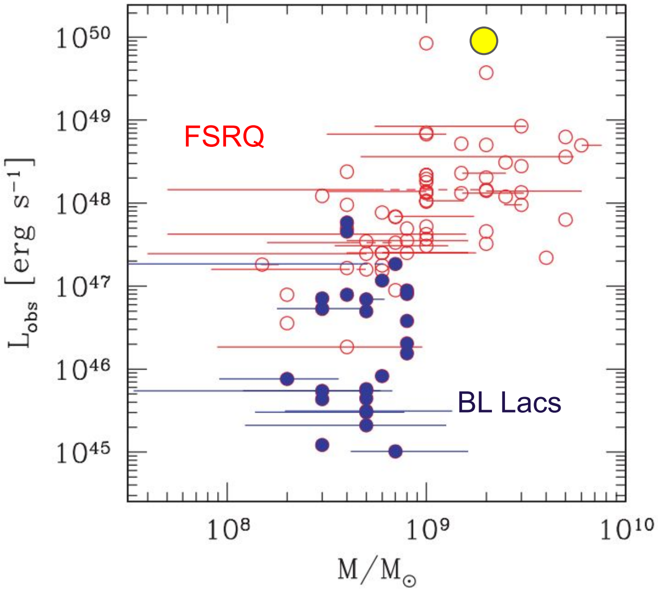




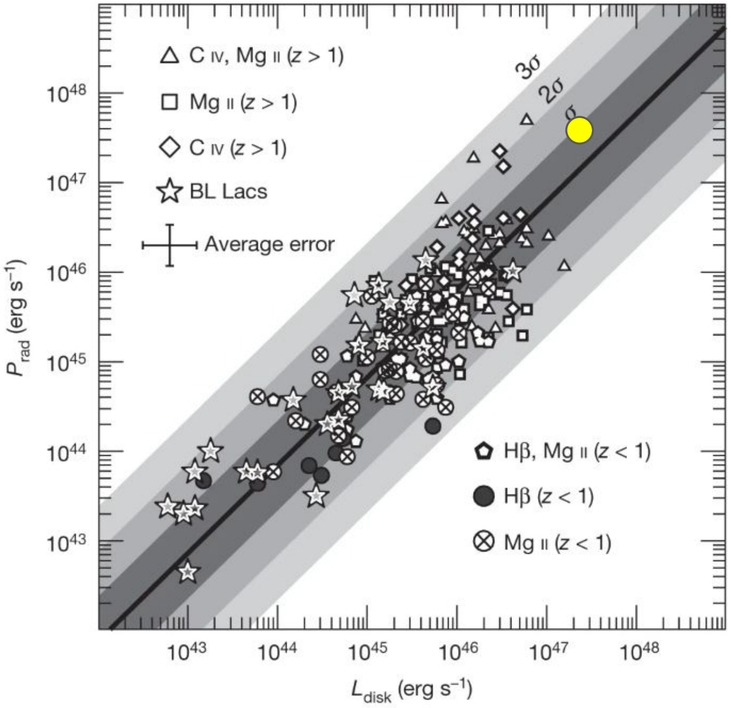


The BLR is stratified and strongly affected by ionized winds, whose velocity decreases going from the inner regions, where the high-ionization lines are produced, to the outer regions, from which the low-ionization lines come from.

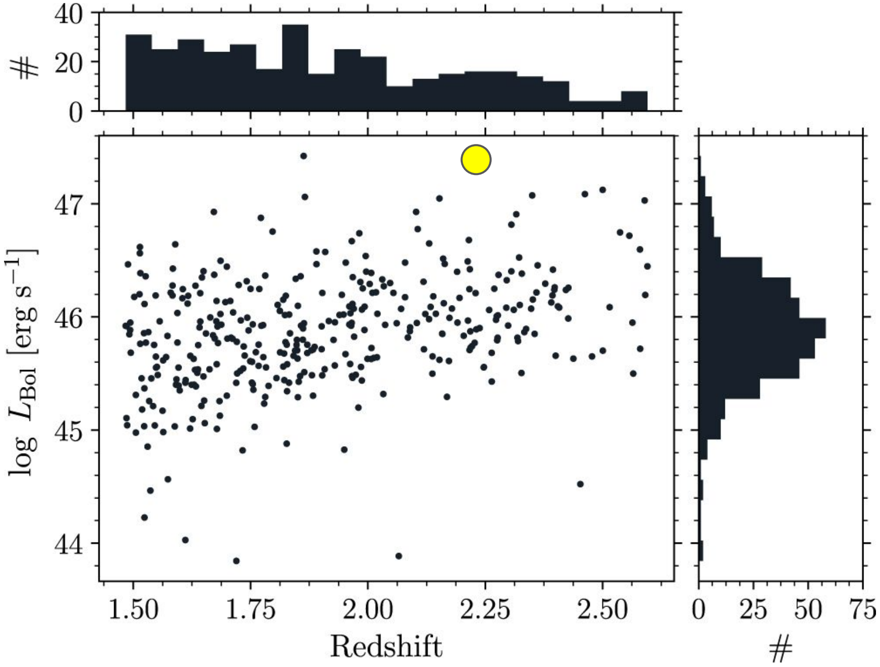
Comparison with other works on blazars



Observed bolometric luminosity produced by the jet versus BH mass (*Ghisellini et al 2010, MNRAS 402, 497*)

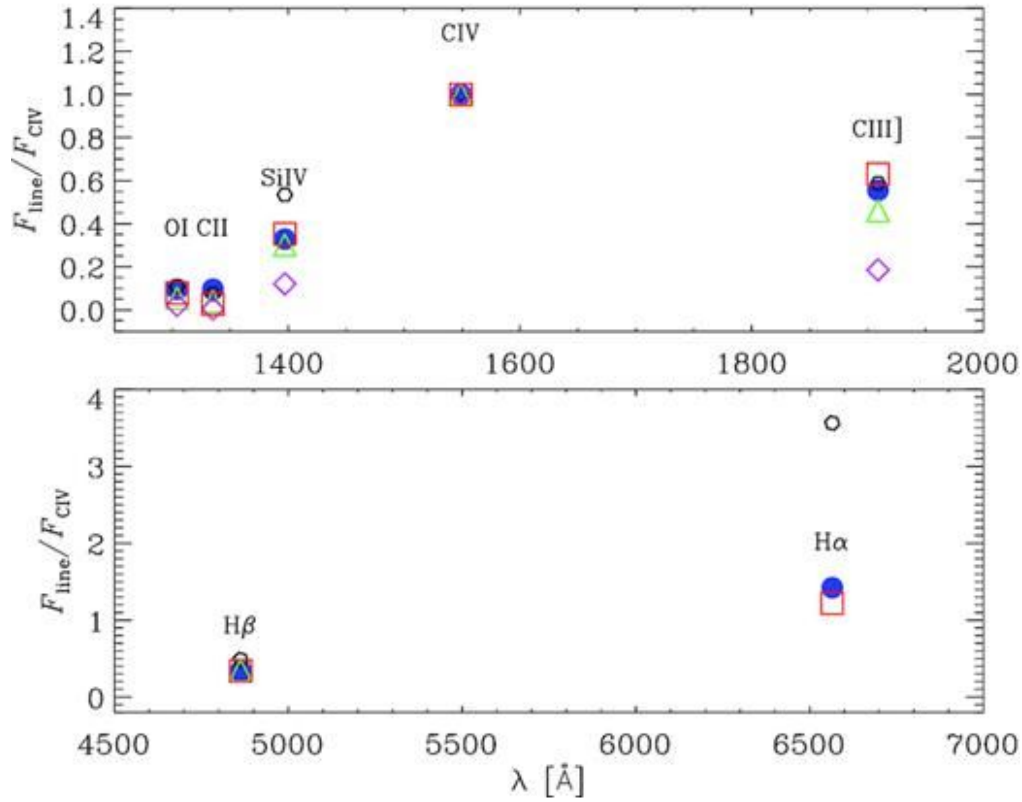


Radiative jet power ~2 L(jet)/Γ^2 versus disc luminosity (*Ghisellini et al. 2014, Nature 515, 376*)



Comparison with other works on quasars

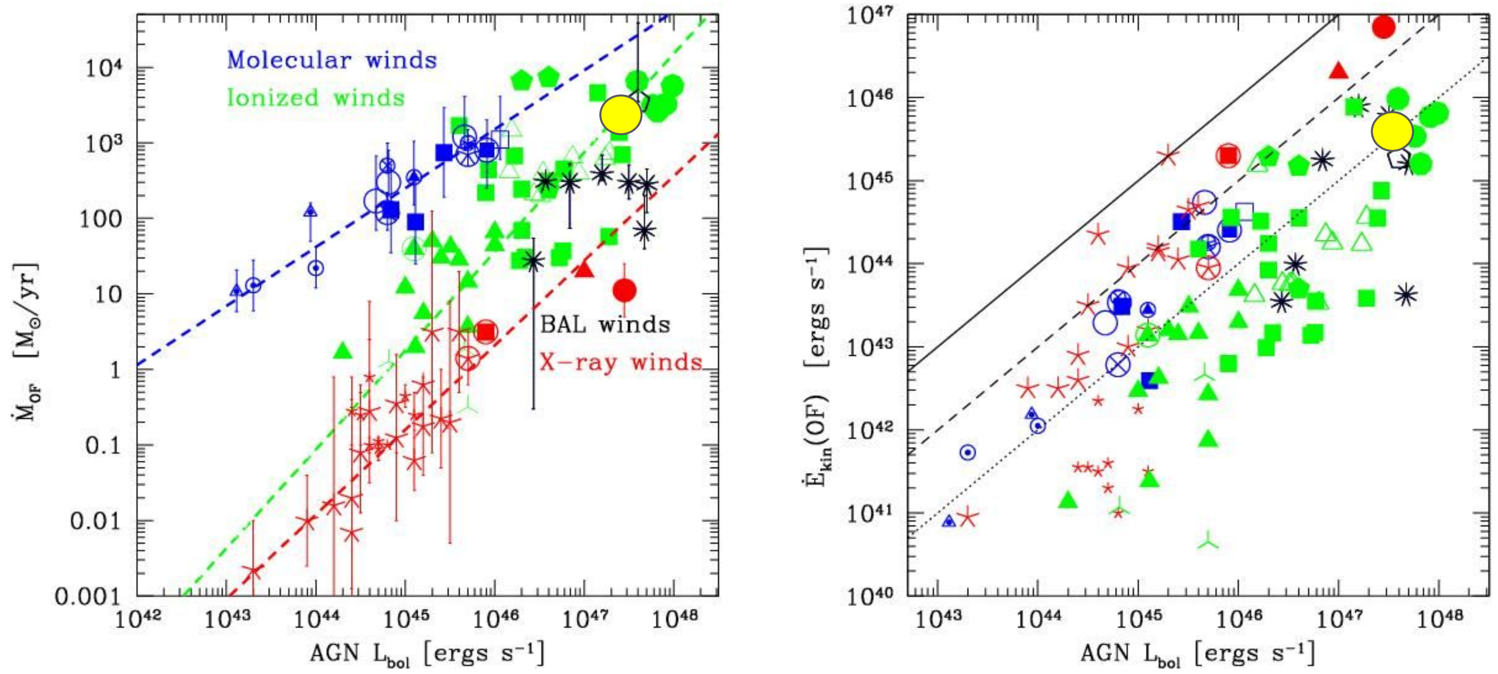
362 quasars from the SDSS Reverberation Mapping Project (*Sun et al. 2018, ApJ 854, 128*)



Comparison with other works on quasars

Line flux ratios with respect to C IV in 4C 71.07 (blue dots) and in various composite quasar spectra:
Cristiani & Vio (1990, black hexagons),
Francis et al. (1991, green triangles),
Zheng et al. (1997, magenta diamonds),
Vanden Berk et al. (2001, red squares).

Comparison with other works on AGN



Wind mass outflow rate (left) and wind kinetic power (right) versus AGN bolometric luminosity (*Fiore et al. 2017, A&A 601, A143*)

Further details in

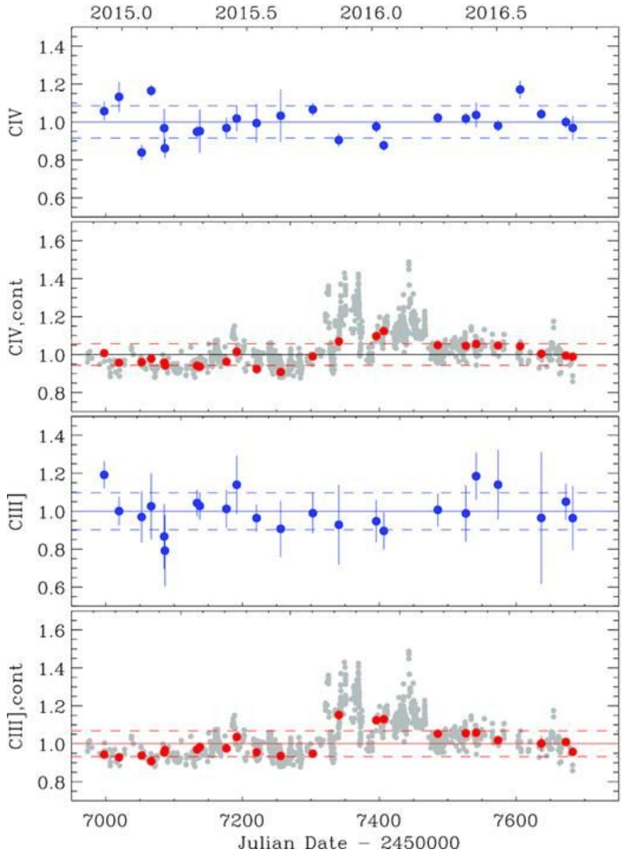
Raiteri et al. 2019, MNRAS, 489, 1837
Raiteri et al. 2020, MNRAS, 493, 2793

Work in progress

New optical spectra at Gemini and SOAR telescopes of a sample of FSRQ-type bright blazars at z~2 obtained in the framework of a Fermi proposal (PI: Michela Negro) to look for outflows in blazars and study their properties.

THANK YOU!

Optical spectroscopic monitoring



Jet not affecting the BLR