Optical spectroscopic studies of BL Lac objects

Marco Landoni
PhD Student – Università degli Studi dell'Insubria

AGN X Edition – Rome September 2012

People of the collaboration

A.	Treves
R.	Falomo
J.	Kotilainen
R.	Scarpa
M.	Uslenghi
B.	Sbarufatti
R.	Decarli
E.	Liuzzo
A.	Veronesi
E. P.	Farina
M.	Landoni
M.	Barattini

Outline of the talk

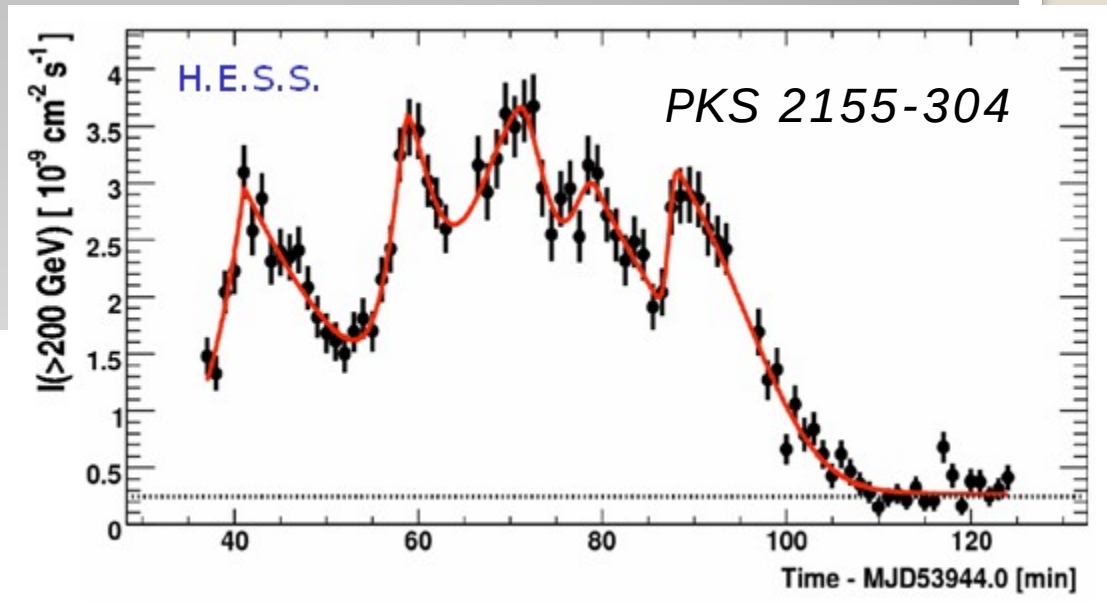
- General introduction to spectroscopic properties of BL Lac objects
- VLT Observational campaign of BL Lac – Determination of redshifts, lower limits and environment of BL Lac
- Emission mechanism and Optical Beaming Factor
- Conclusions

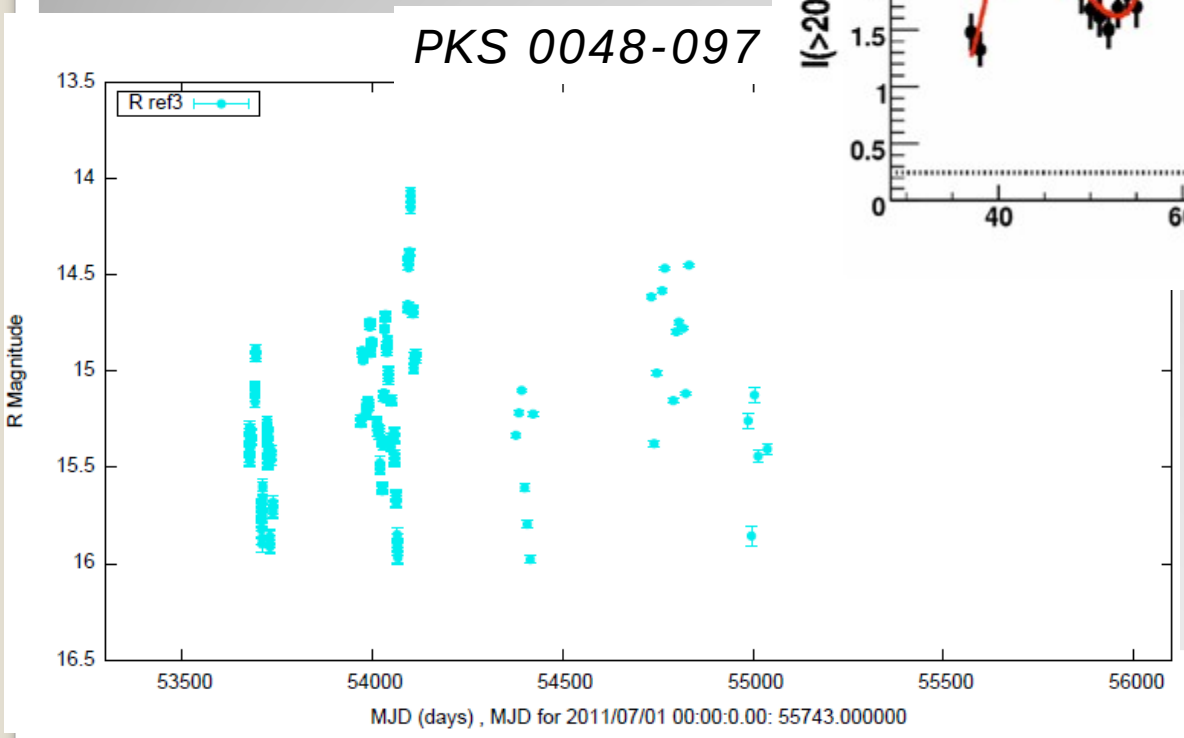
Optical properties of BLLac

- **Line less (E. W. ≤ 5 Å)**

- Polarized light
- Highly variable (in multiple band)
- Power-law spectral shape (3100 Å – 25.000 Å)

Variability (in multiple band...)





Spectra lines of BL Lac objects (when detected…)

Broad	Ly α (λ_0 = 1216) Balmer series transitions (e.g. Hα, Hβ) Mg II (λ_0 = 2800) C IV (λ_0 = 1550)
Host Galaxy	Emission [O II] (λ_0 = 3727) Absorption (H & K band of Ca II) G Band
Intervening	Mg II (λ_0 = 2800)
Our Galaxy	Ca II (λ_0 = 3934, λ_0 = 3968) Na I (λ_0 = 5892) *Diffuse Interstellar Bands (DIB)*

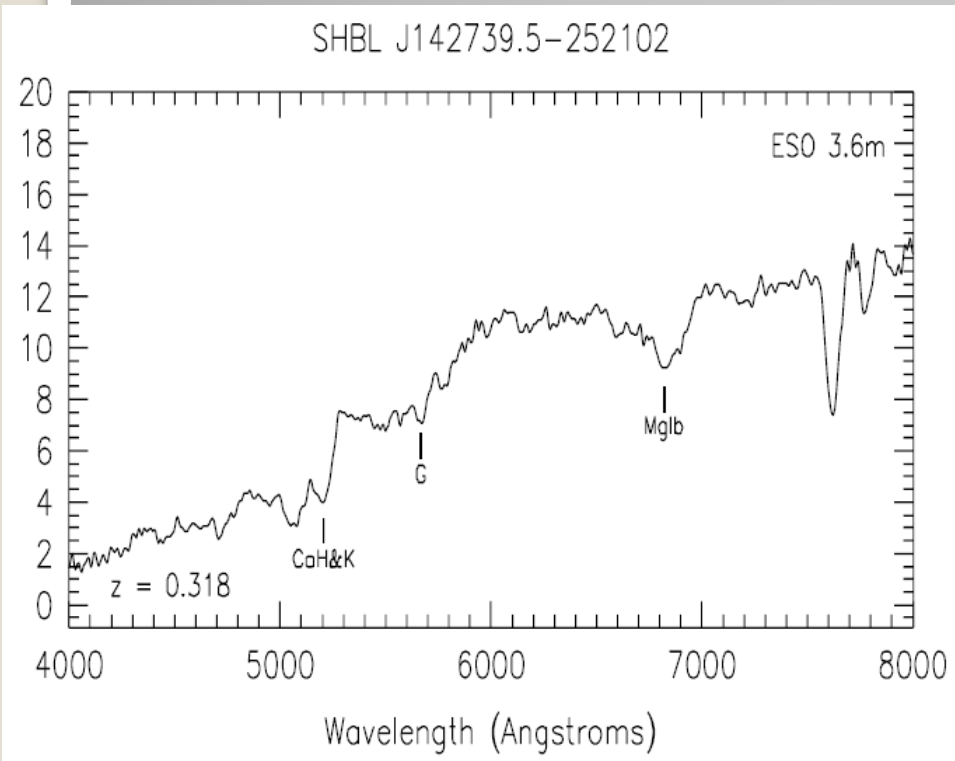
S/N Ratio

In order to detect very weak spectral features arising from the nucleus or from the thermal emission of its host galaxy, high signal-to-noise ratio spectra are required.

In the past, BL Lac were studied through 3mt class telescope limiting the maximum allowed magnitude and the S/N ratio of the collected spectra.

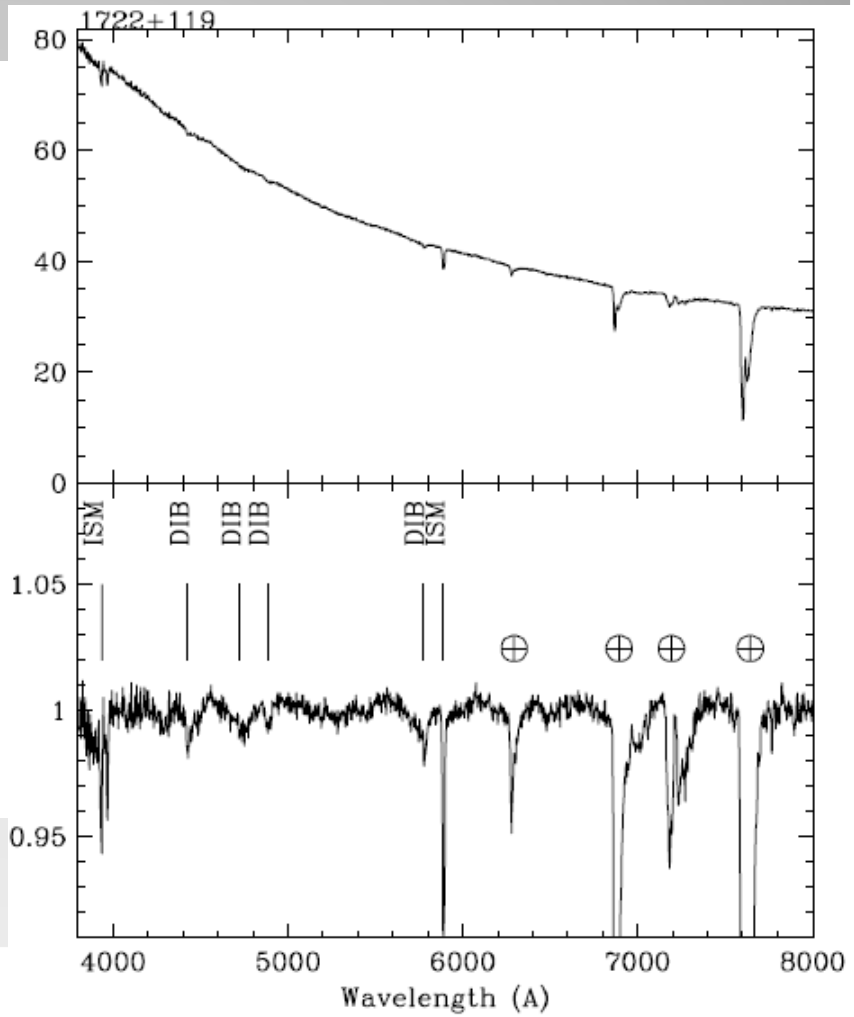
3mt vs 8mt telescopes

TNG / ESO 3.2m (S/N: 32)



Piranomonte et. al. 2008

FORS@VLT (S/N: 350)



Sbarufatti et. al. 2005

Observational Campaign @VLT

- BL Lac without redshift as from 3 mt telescope spectra candidates from Padovani and Giommi (1995) - Sedentary Survey from Giommi et. al. (1999 – 2005), etc.

- VLT UT 1..UT 4 300V+I grism (3800-8000 Å band) with 2.6 Å/pixel.

- 2003 – 2004 **3 RUNS (Sbarufatti et. al. 2005 2006)**
- 2006 **1 RUN (Sbarufatti et. al. 2009)**
- 2008 – 2009 **2 RUNS analyzed (see this talk)**

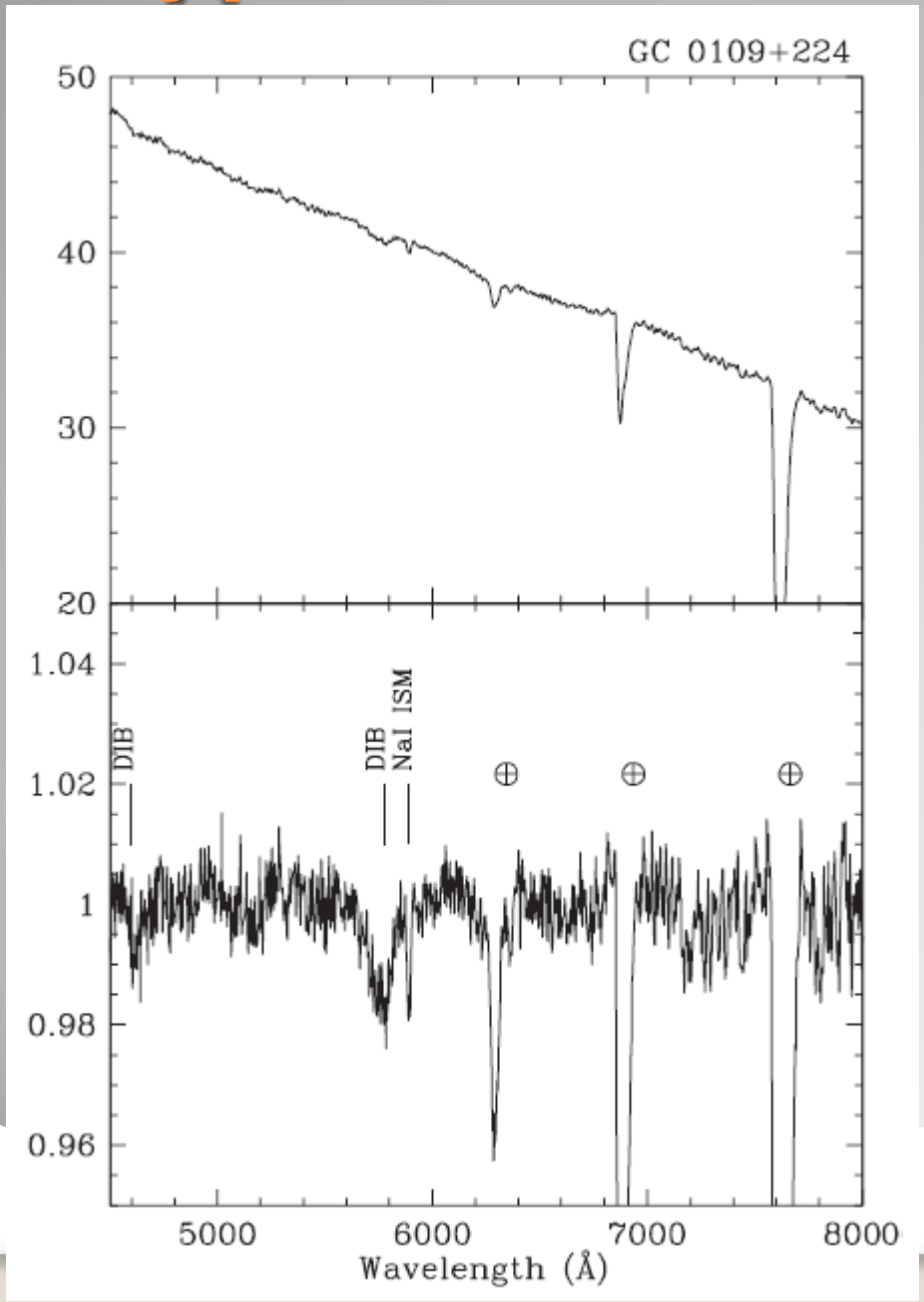
- **Spectroscopic database: http://www.oapd.inaf.it/zbllac/**

BL Lac @ Very Large Telescope

~ **75** BL Lac observed

- ~ 30 bad candidates, mostly *quasars* or *WD*
- 28 redshifts
- 41 lower limits on *z*

A typical lineless BL Lac



Average S/N: 200

EW min: 0.20 Å

R: 14.20

α: 0.85

z > 0.15

X – Shooter + VLT (UT2) - 2010

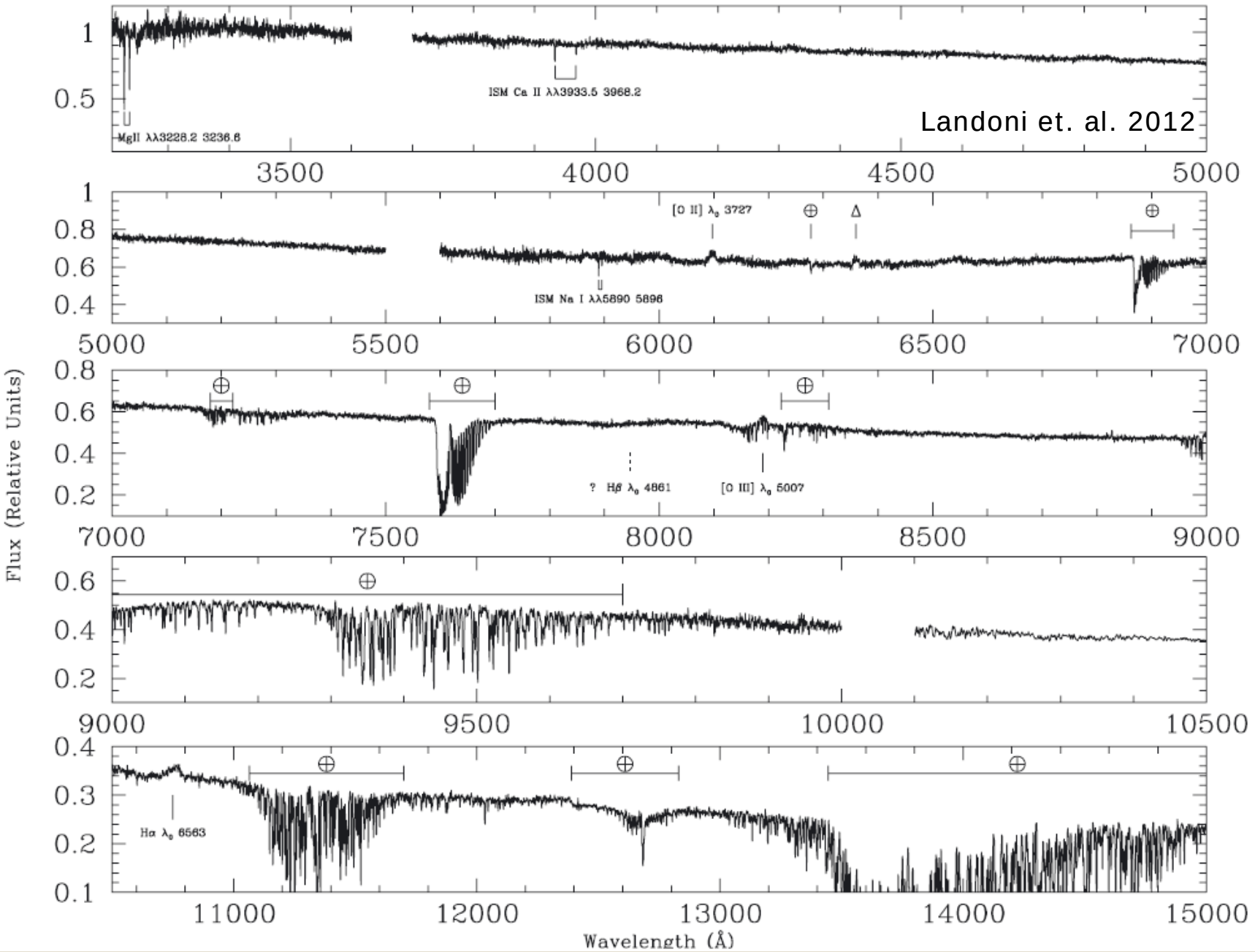
5 bright *lineless* BL Lac object observed

PKS 2254-204
H 1722+119
MH 2136-428
PG 1553+113
PKS 1349-439
PKS 0048-097

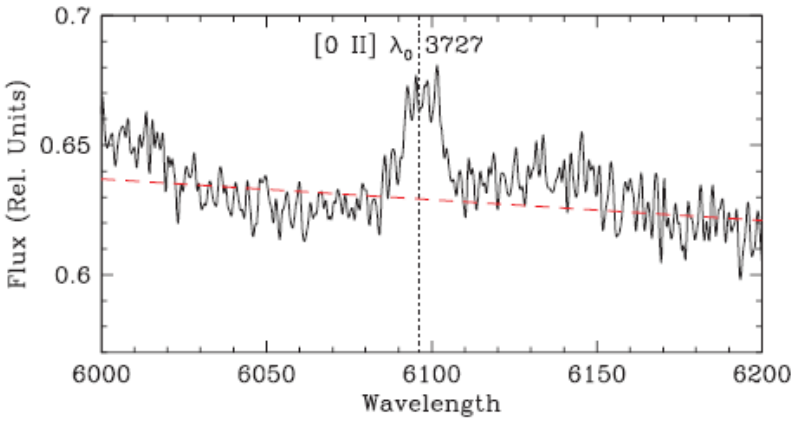
On the redshift of PKS 0048-097

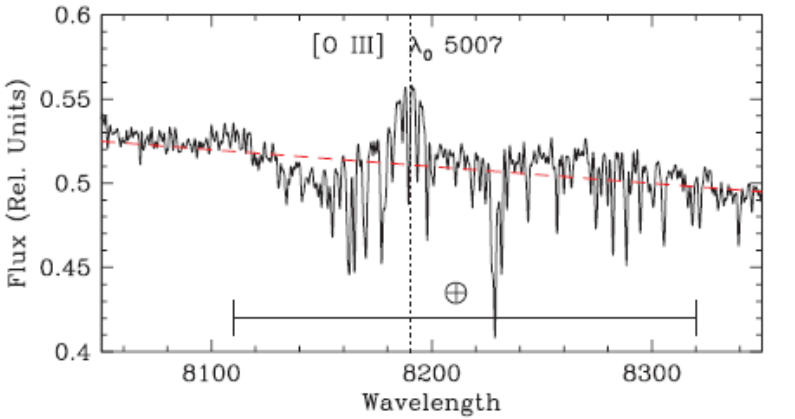
Date of Observation [a]	Seeing [b]	Channel [c]	Slit Width [d]	R [e]	t_{exp} [f]	N [g]	S/N [h]
05 Jul 2010	1.22	UVB	$1.6'' \times 11''$	3300	2720	4	34
		VIS	$1.5'' \times 11''$	5400	2460	6	32
		NIR	$1.5'' \times 11''$	3500	1440	6	28
18 Aug 2010	0.84	UVB	$1.6'' \times 11''$	3300	2720	4	24
		VIS	$1.5'' \times 11''$	5400	2460	6	24
		NIR	$1.5'' \times 11''$	3500	1440	6	24

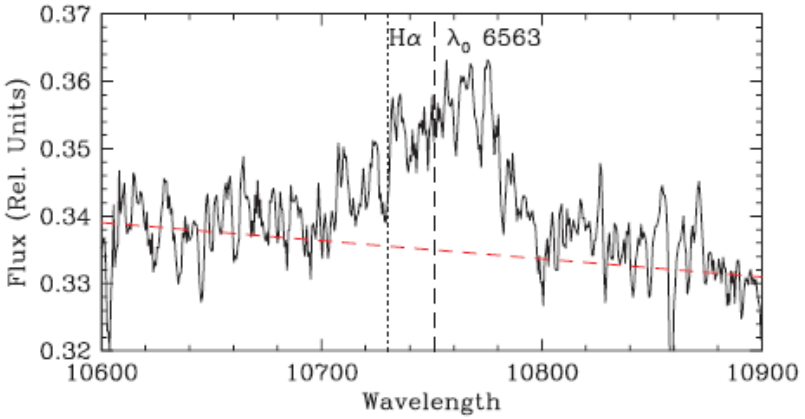
On the redshift of PKS 0048-097



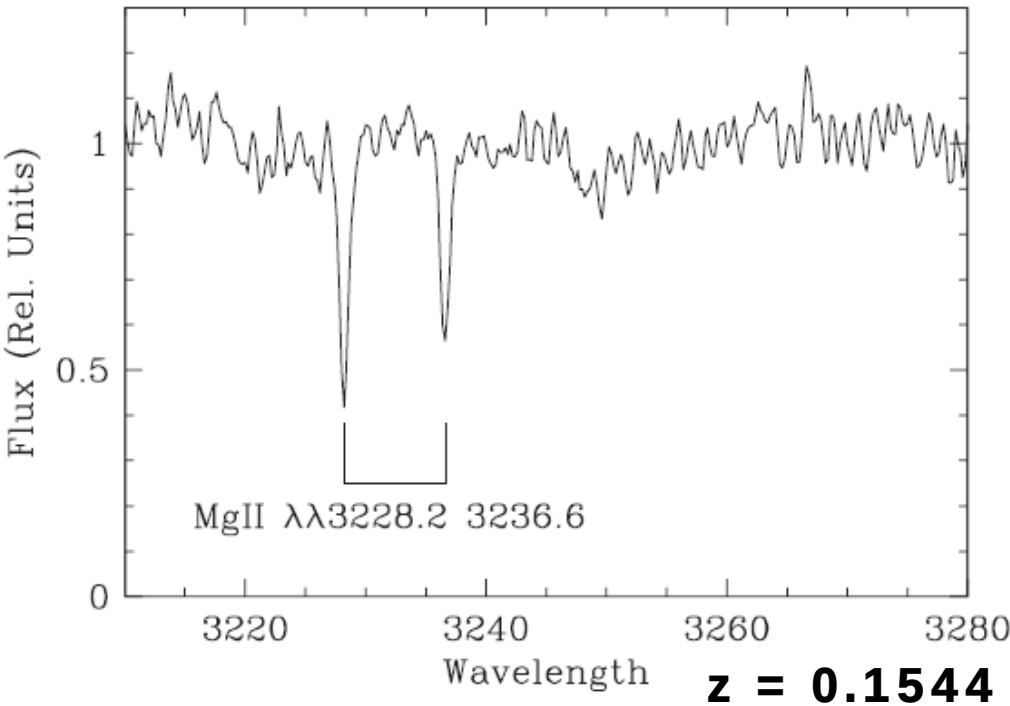
On the redshift of PKS 0048-097







z = 0.635

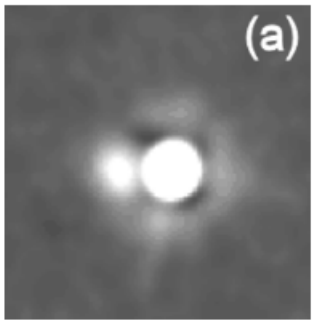


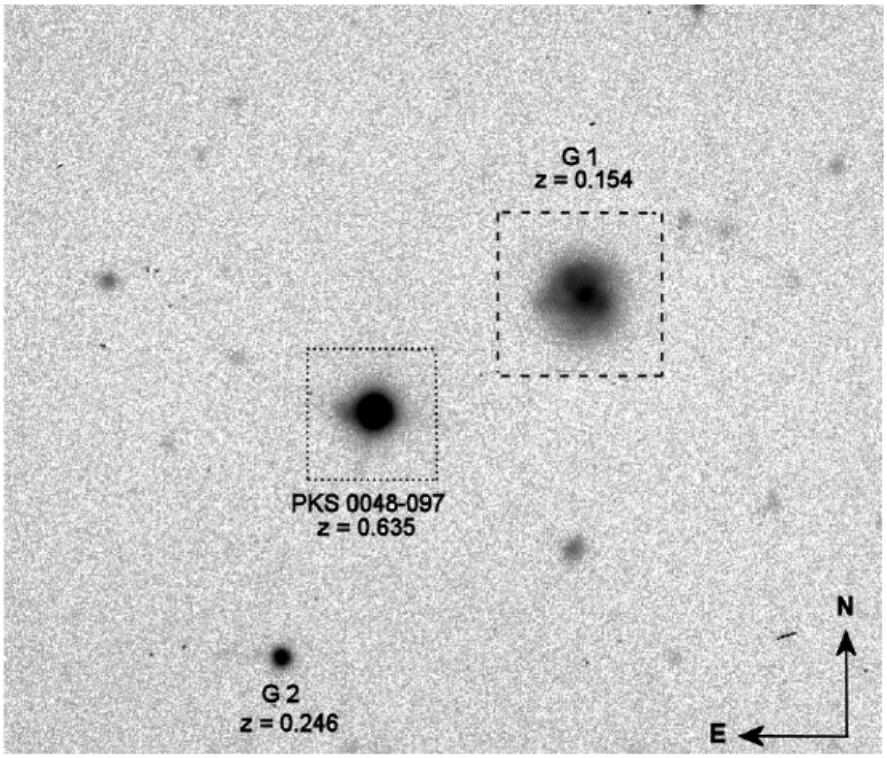
z = 0.1544

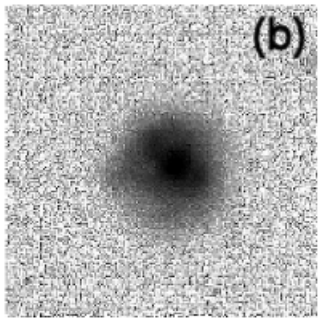
On the redshift of PKS 0048-097

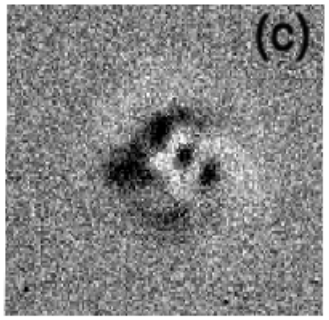
Line ID	Observed λ [Å]	z	Observed FWHM [km s^{-1}]	Observed EW [Å]	Notes
Mg II 2796.35	3228.20 ± 0.20	0.1544 ± 0.0001		0.59 ± 0.16	abs.
Mg II 2803.53	3236.60 ± 0.20	0.1544 ± 0.0001		0.45 ± 0.12	abs
[O II] 3727.40	6096.20 ± 1	0.635 ± 0.0004	680 ± 100	0.79 ± 0.39	em.
[O III] 5006.84	8189.20 ± 1	0.635 ± 0.0004	400 ± 100	0.92 ± 0.44	em. (polluted by telluric absorptions)
Hα 6562.80	10751.10 ± 5	0.638 ± 0.001	1900 ± 130	3.00 ± 1.20	em.

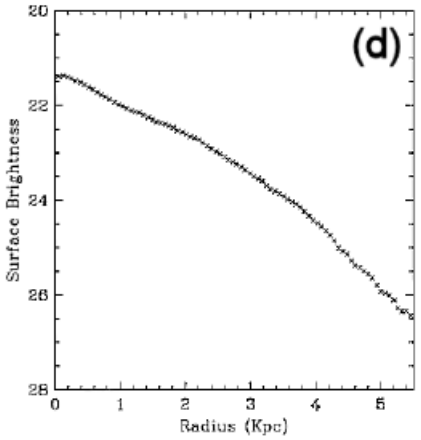
On the redshift of PKS 0048-097









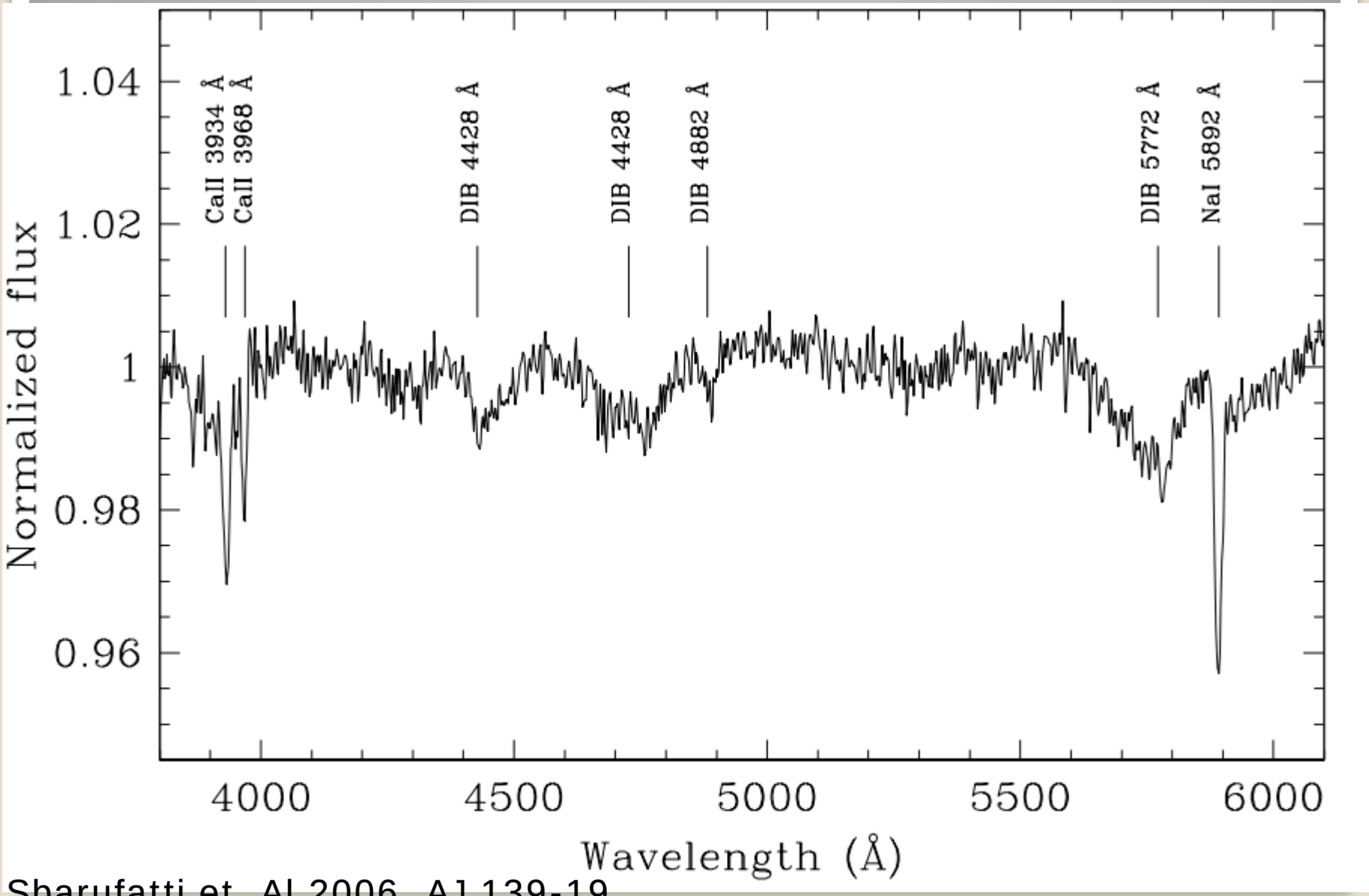


Latest run at FORS@VLT

- 33 objects observed spanning the period April 2008 – June 2008.
- 25 objects have been classified as BL Lac source
- 8 objects are typical Quasi Stellar Object

- **5** new redshift derived
- **20** new lower limits on z (see procedure in Sbarufatti et al 2005)

The average BL Lac spectrum



Sbarufatti et. Al 2006. AJ 139-19

Optical Beaming Factor

Contribution to the optical flux – Unified Model

- Host Galaxy
- Thermal continuum (disk)
- Broad lines
- Jet

ISOTROPIC

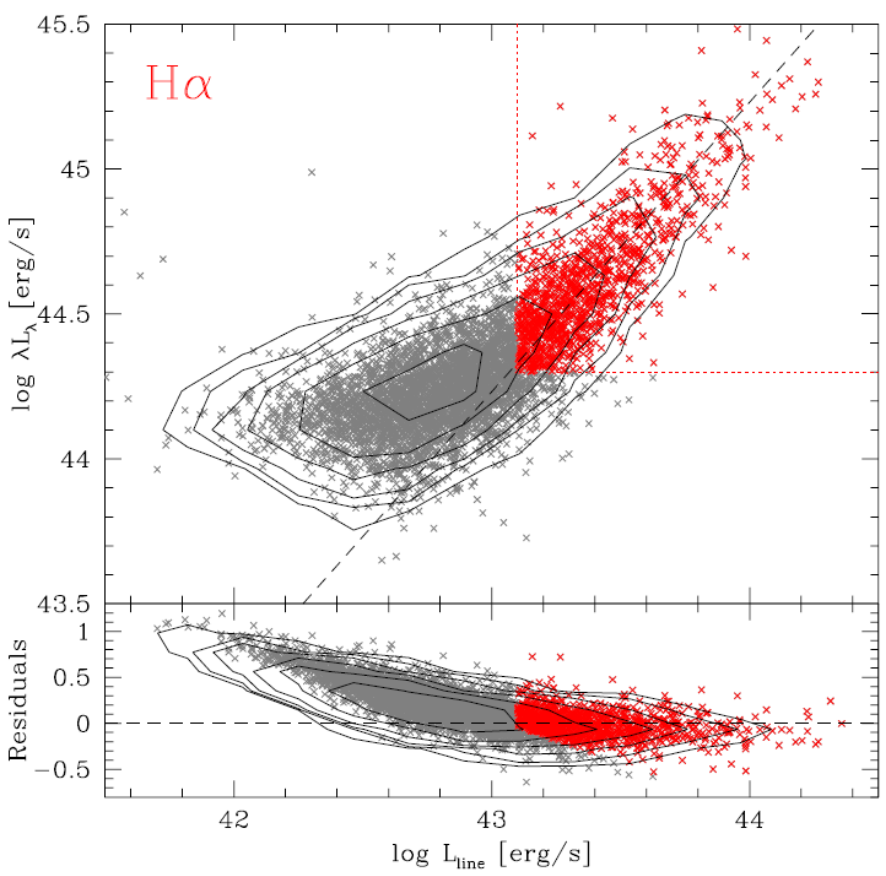
BEAMED

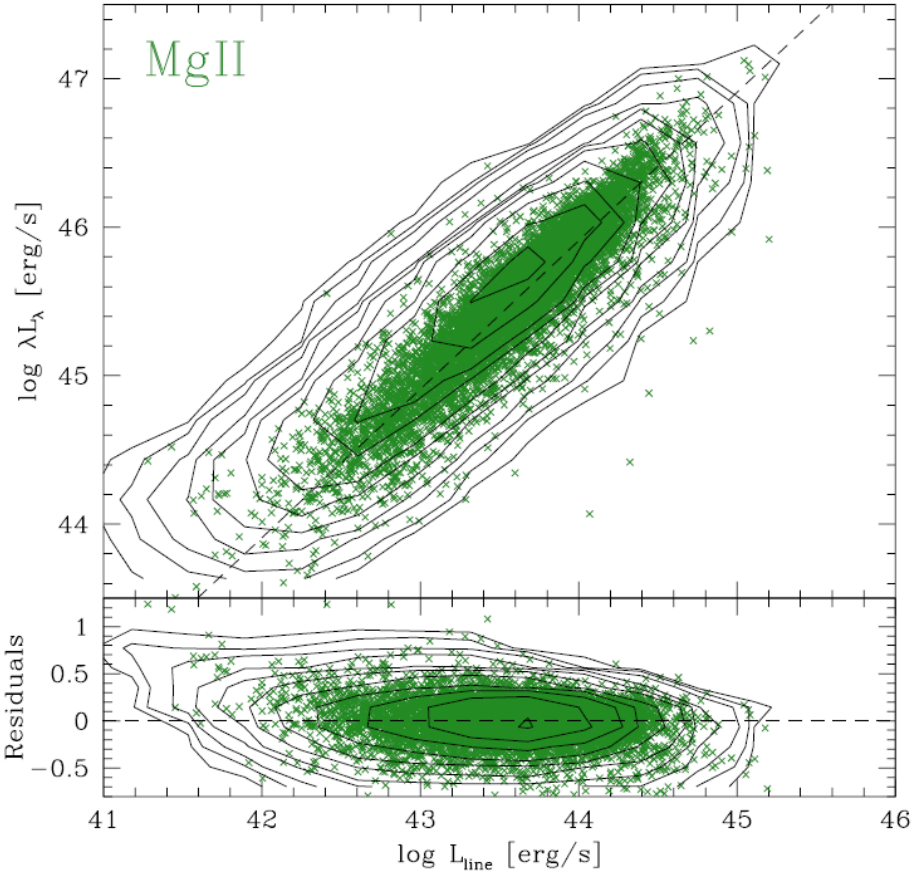
From the **Broad Lines** it is possible to infer to **Thermal Continuum**

$$BeamingFactor = \frac{Jet_{Luminosity}}{Thermal_{Luminosity}}$$

Thermal Luminosity

Decarli et.al 2010





$$\log \frac{\lambda L_\lambda(5100\mathring{A})}{L_{\rm line}({\rm H}\alpha)} = 1.23 \pm 0.14.$$

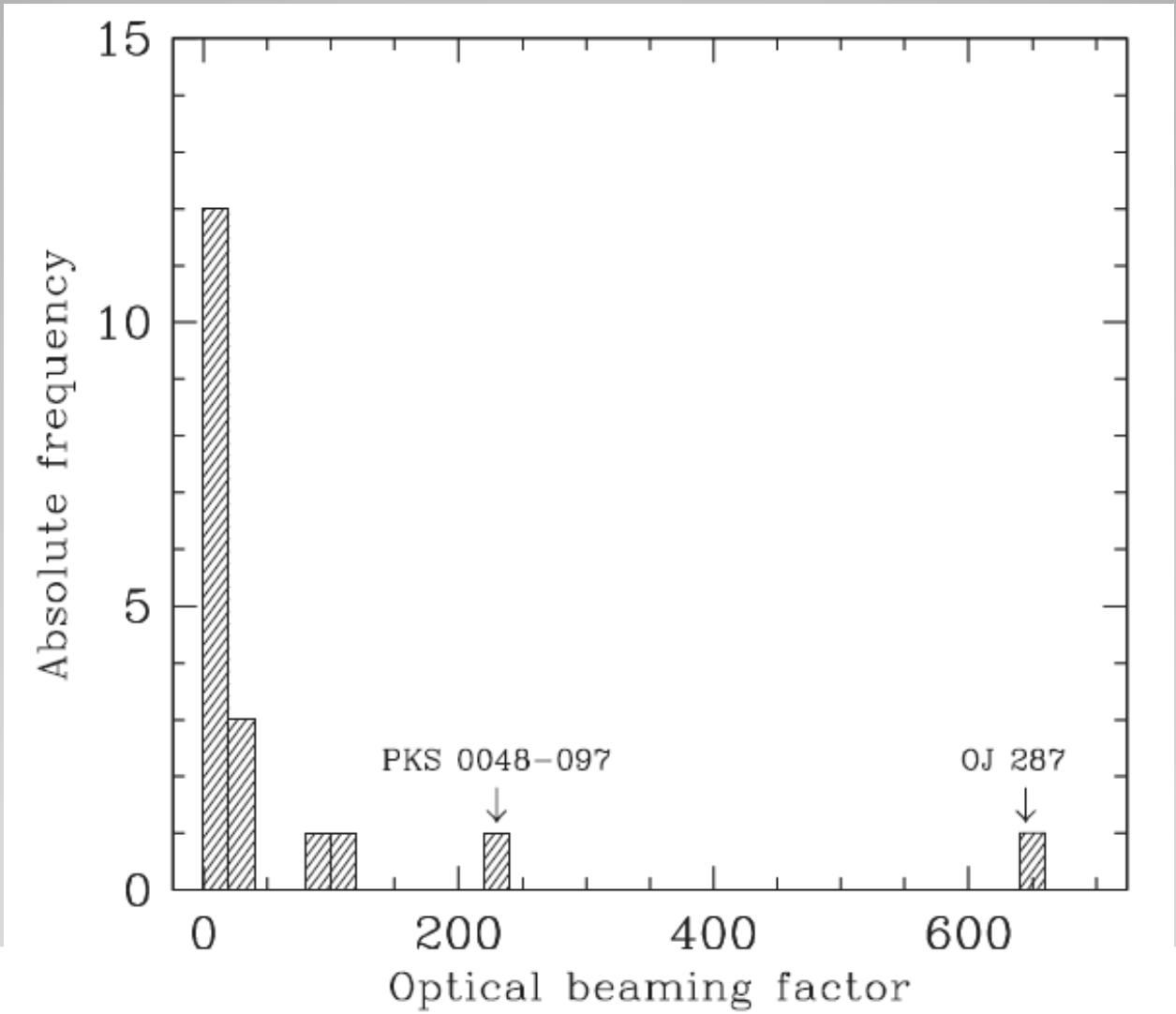
$$\log \frac{\lambda L_\lambda(3000\mathring{A})}{L_{\rm line}({\rm MgII})} = 1.91 \pm 0.26$$

BL Lac Beaming factors

Source	Beaming Factor
PKS 0048-097	**233**
PKS0403-132	1
PKS0405-123	25.10
PKS0420-014	19.95
PKS0426-380	12.30
PKS0521-36	57.54
OJ049	85.11
OJ287	**645.65**
3C 273	16.56
1249+174	1.35
3C279	43.65
PKS1519-273	104.71
4C1460	34.67
3C345	27.54
3C371	20.42
PKS2131-021	15.14
BL Lac	30.20
PKS2201+04	15.85
PKS2345-167	18.20

$$BeamingFactor = \frac{Jet_{Luminosity}}{Thermal_{Luminosity}}$$

BL Lac Beaming factor histogram



Conclusions

- The spectroscopic study of BL Lac objects in the optical band can provide useful information about:
  - Their distance (z) which is mandatory in order to understand their physics (Accretion and jet theory, TeV emission, EBL)
  - Their emission mechanisms in terms of thermal and/or non thermal emission (SC, SSC)
  - Their environment and LOS galaxy conditions (see e.g.the case of PKS 0048-097).