Broad Absorption Line Quasars
from Radio to NIR band

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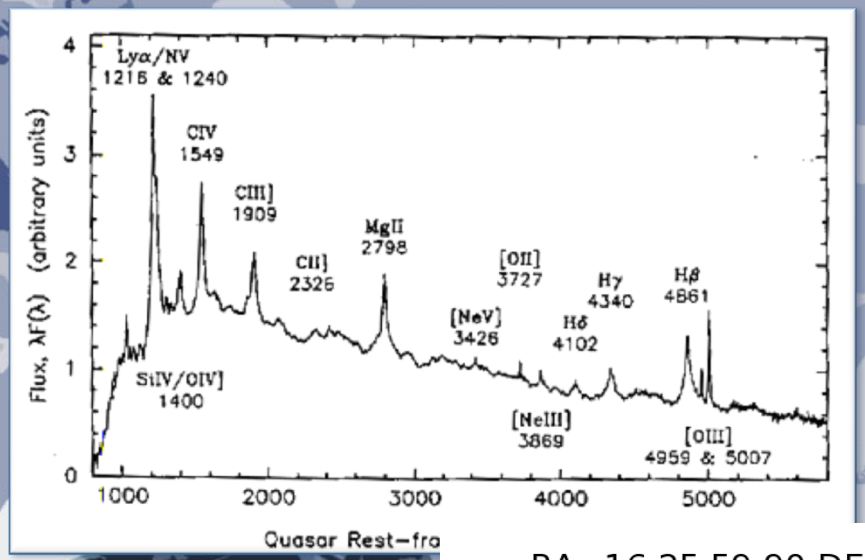
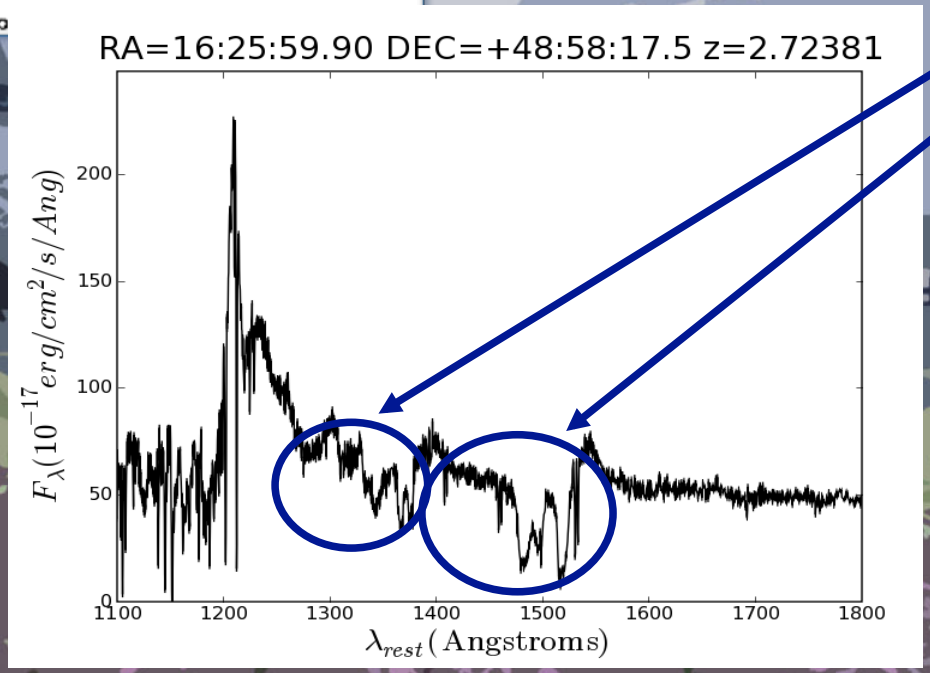
AGN 10: dall'orizzonte degli eventi all'orizzonte cosmologico
Roma, 10-13/09/2012





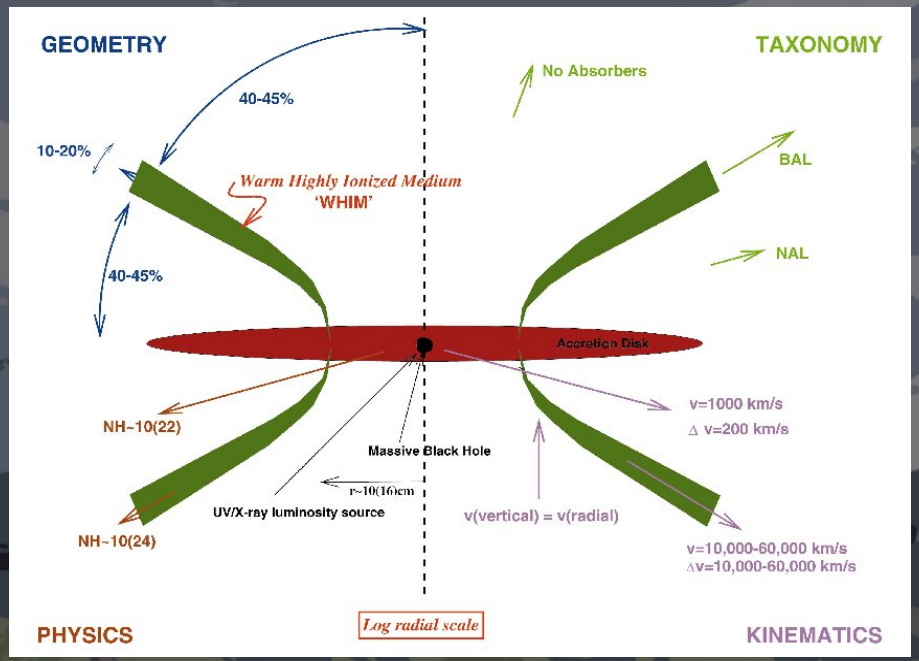
How many?
~20%

Broad absorption towards the blue wings of some UV emission lines, shifted up to ~ 0.2 c

- Most probably intrinsic
- Al III, Mg II, Si IV, C IV
- HiBALs, LoBALs, FeLoBALs.

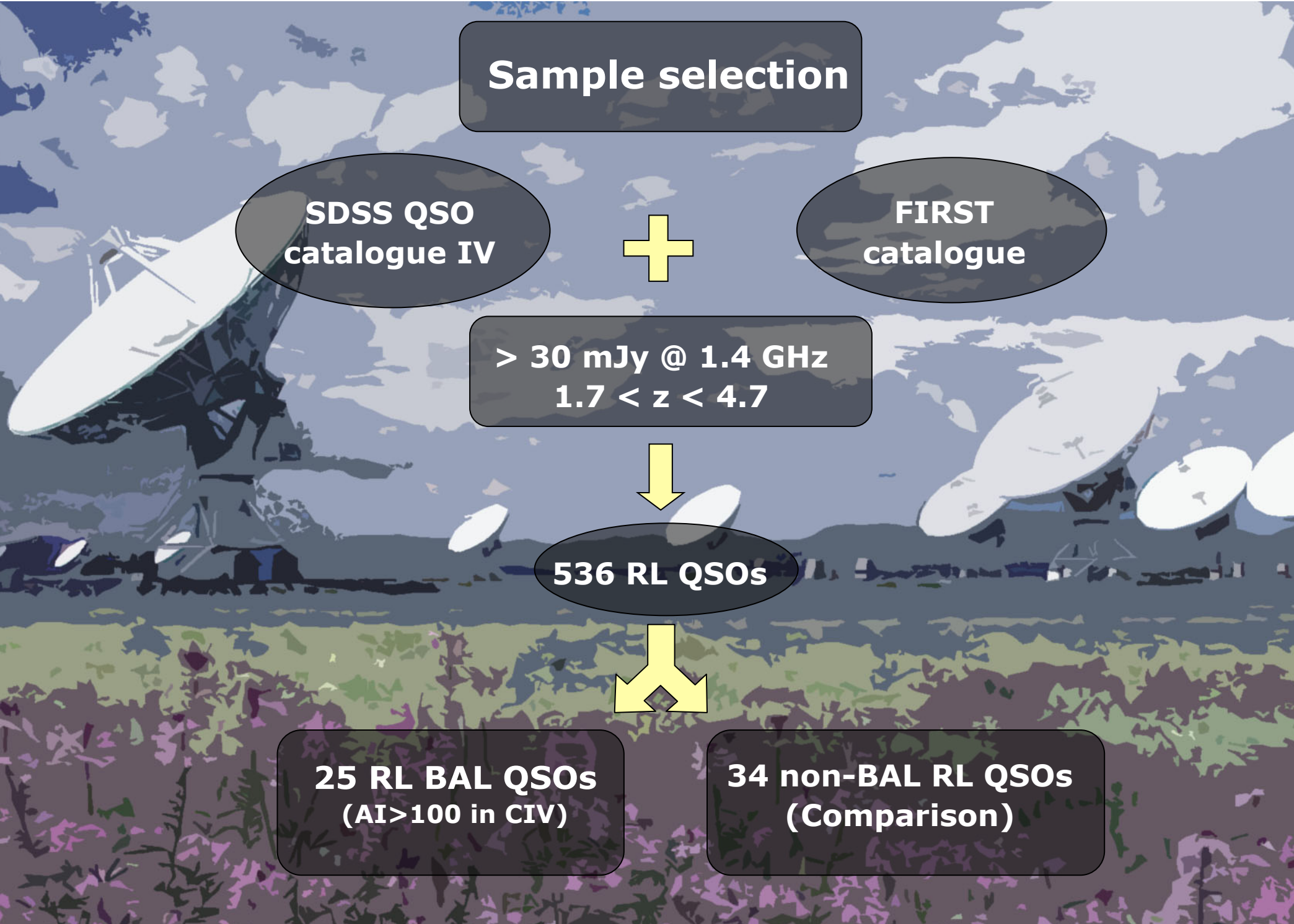
Explanations for the BAL phenomenon

1) Orientation Scenario



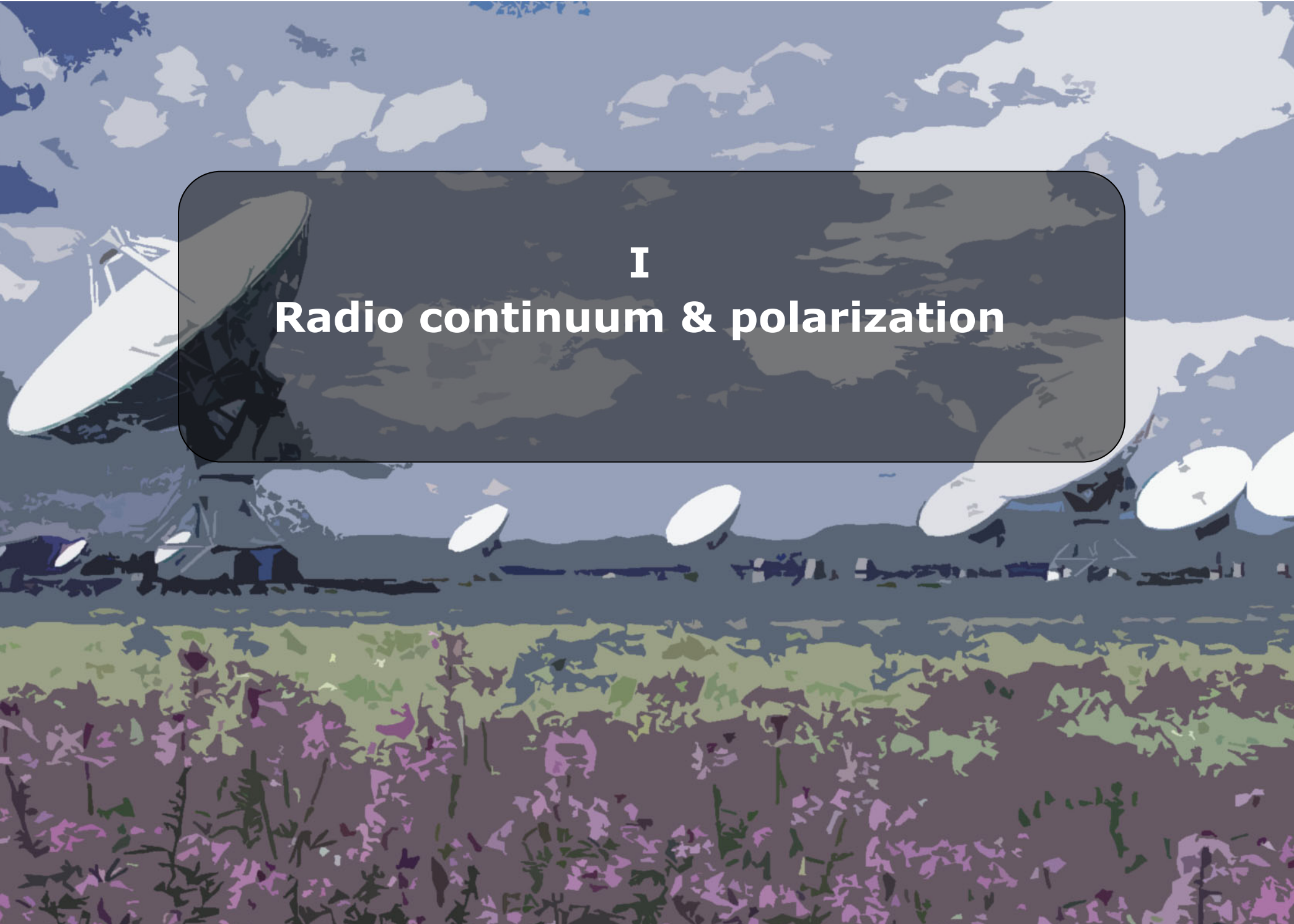
Elvis (2000)

2) Evolutionary Scenario: Young or recently refueled quasars
(Briggs et al. 1984; Lipari and Terlevich 2006)


Sample selection
SDSS QSO catalogue IV
FIRST catalogue
> 30 mJy @ 1.4 GHz
1.7 < z < 4.7
536 RL QSOs
25 RL BAL QSOs
(AI>100 in CIV)
34 non-BAL RL QSOs
(Comparison)

Observational campaign

- Radio continuum & polarization (Effelsberg, VLA, GMRT)
- Morphology & orientation (EVN, VLBA)
- Dust detection: (IRAM 30-m, APEX)
- Infrared spectroscopy: central BH mass estimation (TNG)



I
Radio continuum & polarization

Observations

Effelsberg 100-m dish

- Observations during 2007, 2008, 2009
- Polarisation and continuum at
  2.6, 4.8, 8.3, 10.4 GHz
- 25 RL BAL QSOs + 34 non-BAL QSOs

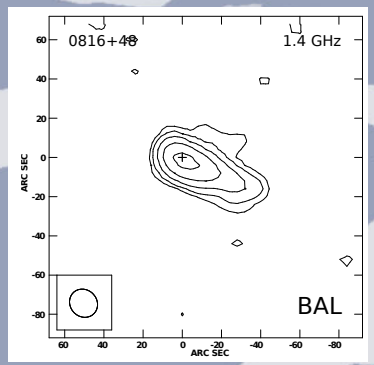
Very Large Array

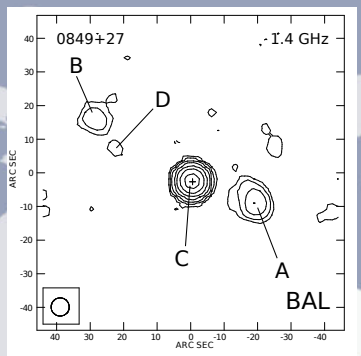
- Observations performed in July 2009
- Polarisation and continuum at
  1.4, 4.8, 8.4, 22, 43 GHz
- 25 RL BALs + 34 non-BAL QSOs

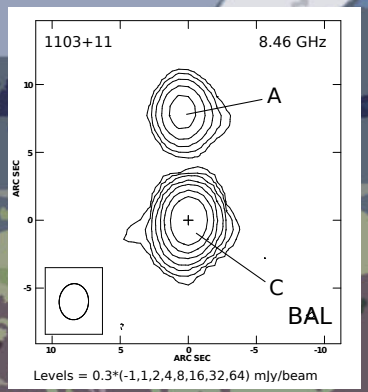
Results

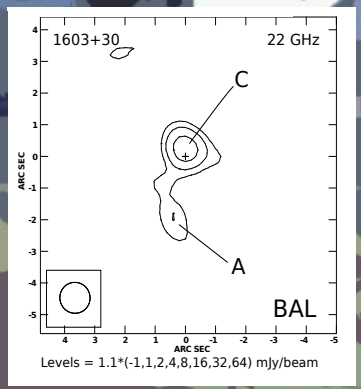
1) Morphology

- 8 resolved source with the VLA:
  4 BAL + 4 non-BAL QSOs (16% vs 12%)
- Linear sizes from 20 to 400 kpc for both
- Similar morphologies









Results

2) Variability

- Calculation of the flux-density variability (4.8 and 8.4 GHz; Var>20%; σ_{var}>4)
- 1 BAL vs 3 non-BAL QSOs present variability
- Results confirmed by the variability study of the RBQ sample (20% vs 14%)
  (Salerno et al. 2012, in prep.)
- Polar orientation is not preferred

$$Var_{\Delta S} = \frac{S_{max} - S_{min}}{S_{min}}$$

$$\sigma_{Var} = \frac{|S_2 - S_1|}{\sqrt{\sigma_1^2 + \sigma_2^2}}$$

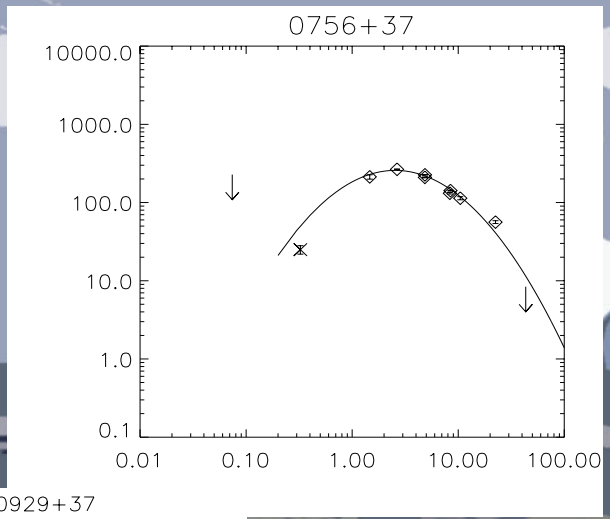
Results

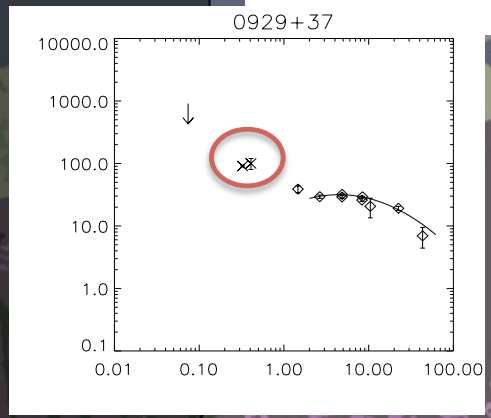
3) Fit of the spectra

- Both for non-BAL and BAL sample
- Determination of the peak frequency

  GPS: 32% BAL QSOs
  23% non-BAL QSOs

- Evidence of low-frequency components in some cases
  (12% BAL QSOs, 18% comparison QSOs)





Bruni et al. 2012a

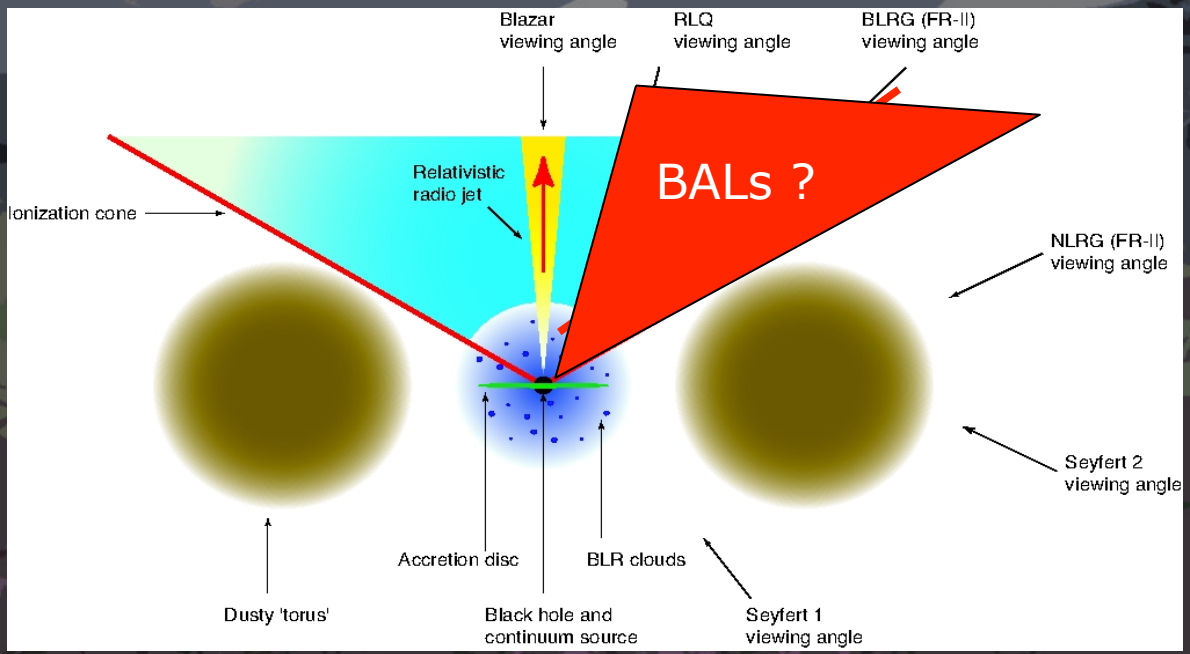
Results

4) Spectral characteristics

- Spectral index

  steep: 68% BAL QSOs
  50% non-BAL QSOs

- Wide range of orientations



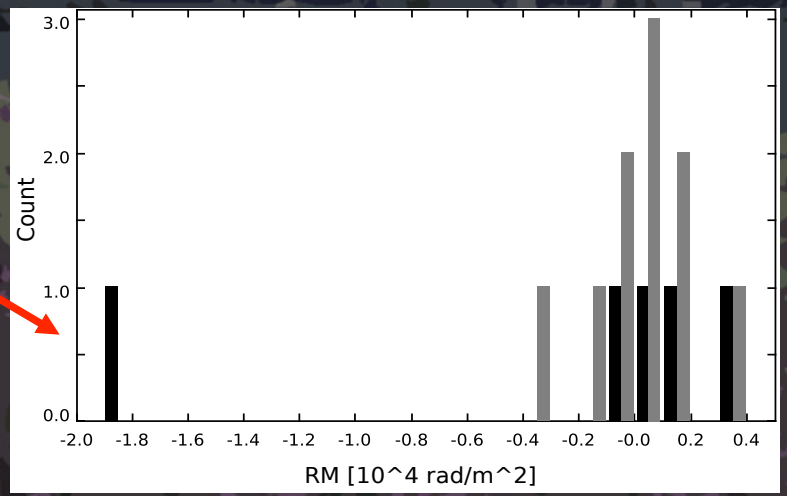
Results

5) Polarimetry

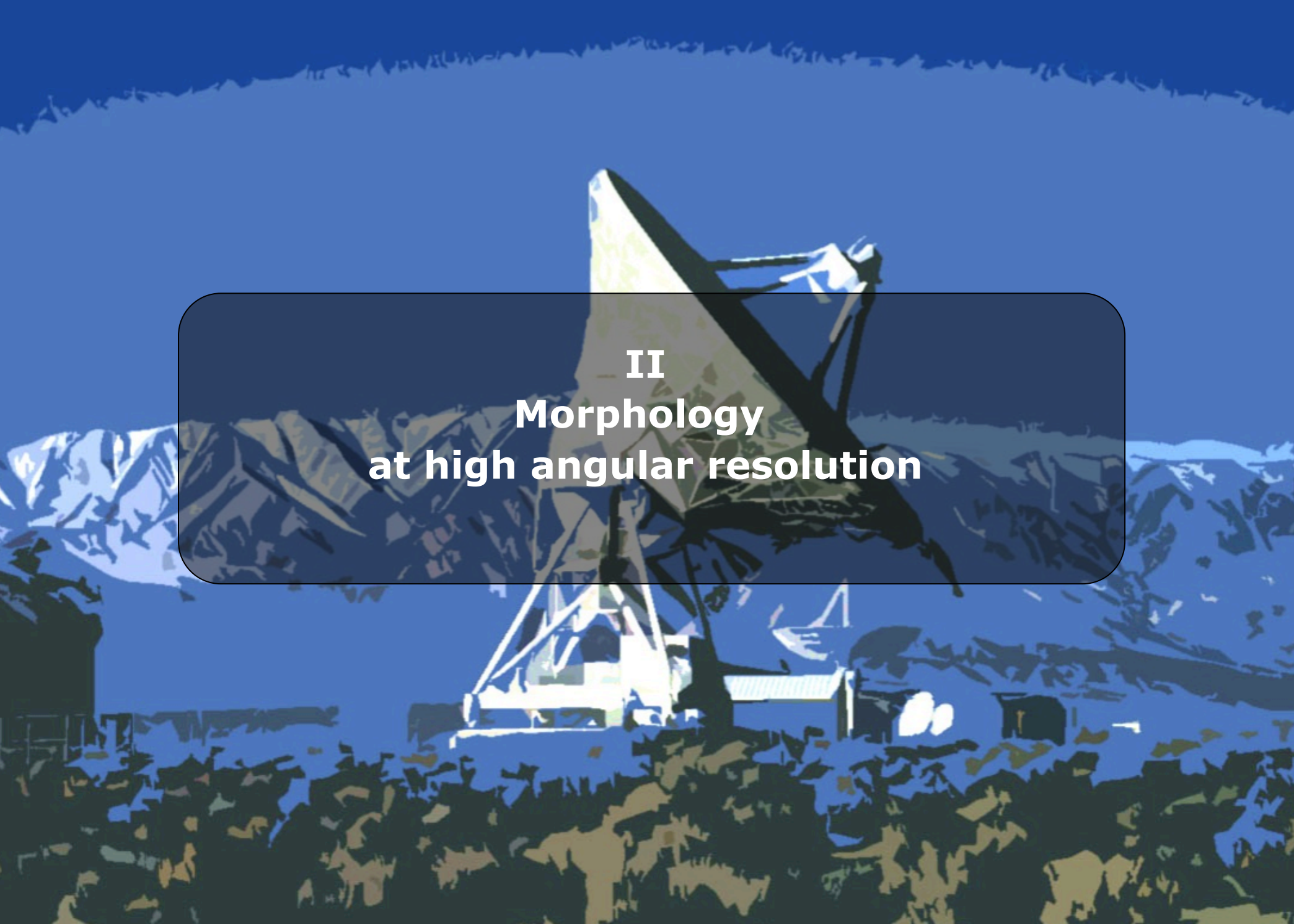
- Polarisation percentage ~ 1-10% Similar to non-BAL QSOs
- Rotation Measure 800<|RM|<3500 rad/m^2 , 1 outlier

$$RM = 8.1 \times \int (n_e \cdot B_{\parallel}) dL \quad [rad \cdot m^2]$$

Benn et al. (2005)
(-18350±570 rad/m^2)



Bruni et al. 2012a

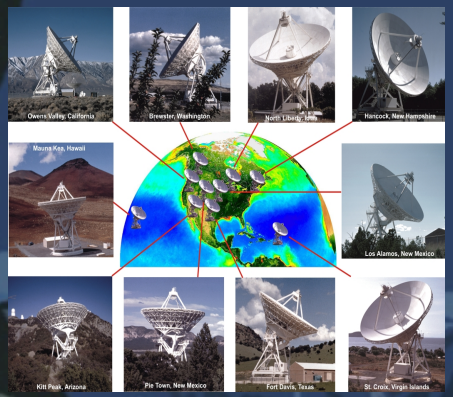


II
Morphology
at high angular resolution

VLBI observations

VLBA

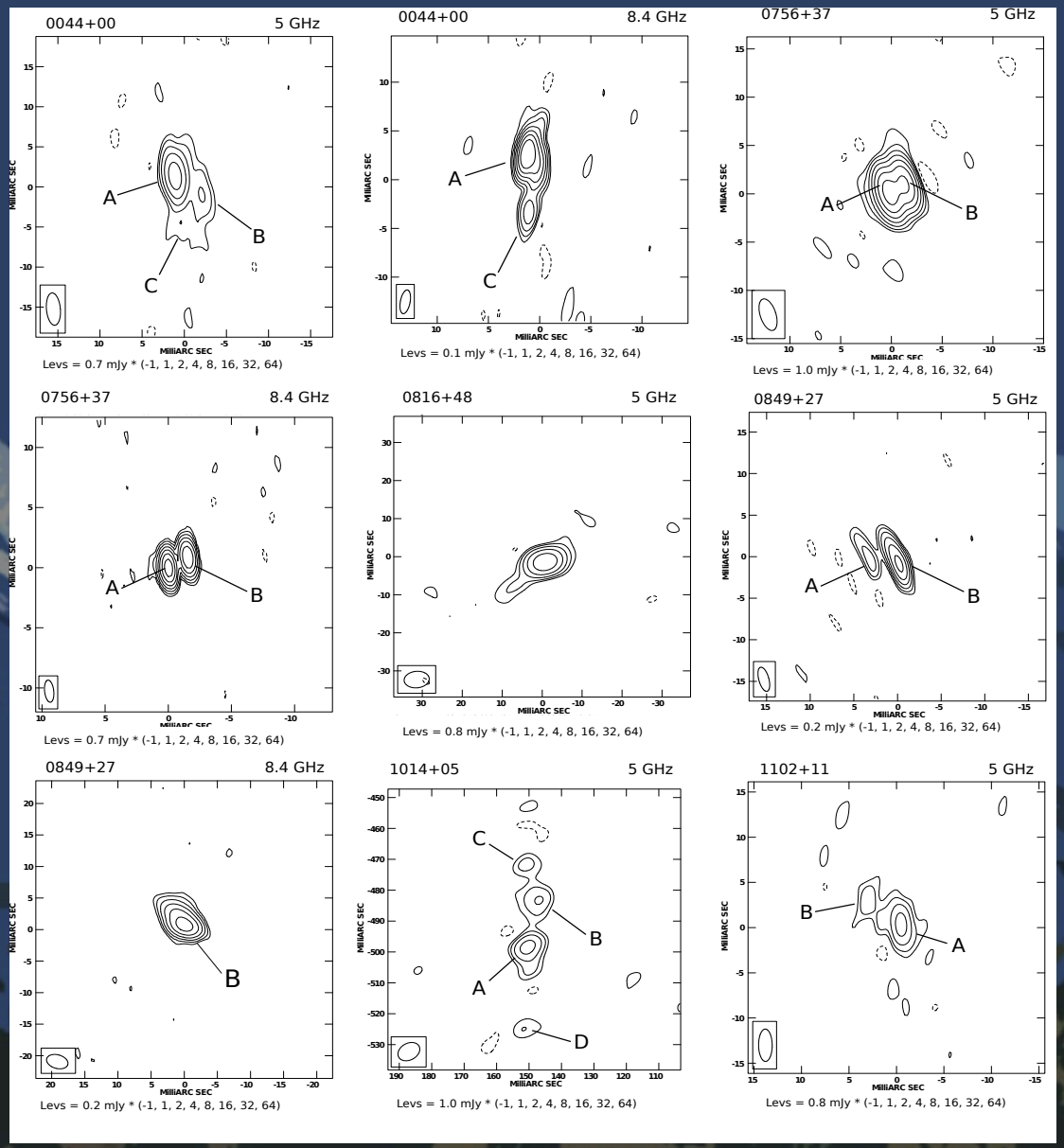
- First 6 brightest sources of the sample
- 4.8 and 8.4 GHz observations

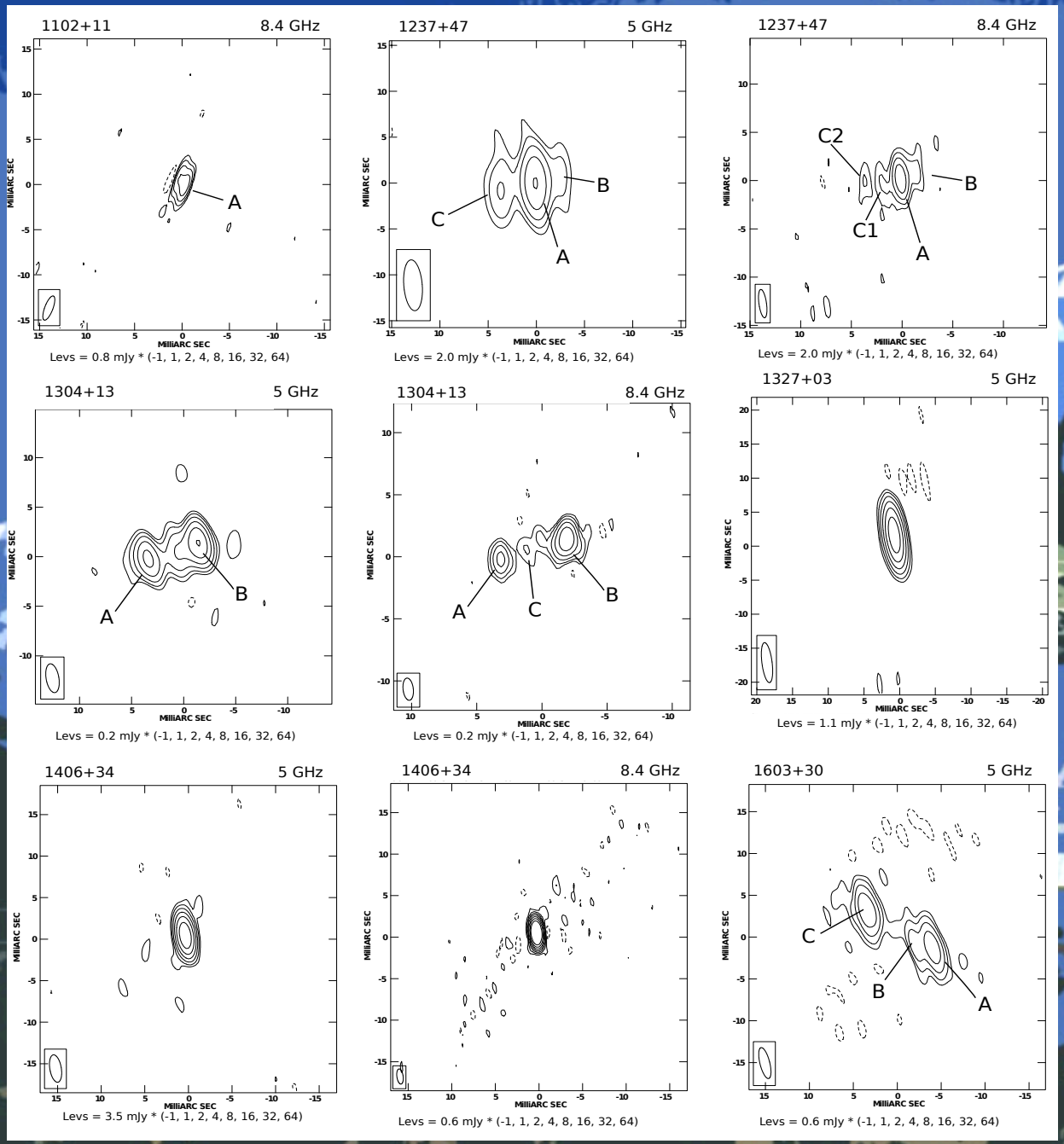


EVN

- Second 5 brightest sources of the sample
- 4.8 GHz observations

Results


0044+00
5 GHz
A
B
C
MilliARC SEC
Levs = 0.7 mJy * (-1, 1, 2, 4, 8, 16, 32, 64)
0044+00
8.4 GHz
A
C
MilliARC SEC
Levs = 0.1 mJy * (-1, 1, 2, 4, 8, 16, 32, 64)
0756+37
5 GHz
A
B
MilliARC SEC
Levs = 1.0 mJy * (-1, 1, 2, 4, 8, 16, 32, 64)
0756+37
8.4 GHz
A
B
MilliARC SEC
Levs = 0.7 mJy * (-1, 1, 2, 4, 8, 16, 32, 64)
0816+48
5 GHz
MilliARC SEC
Levs = 0.8 mJy * (-1, 1, 2, 4, 8, 16, 32, 64)
0849+27
5 GHz
A
B
MilliARC SEC
Levs = 0.2 mJy * (-1, 1, 2, 4, 8, 16, 32, 64)
0849+27
8.4 GHz
B
MilliARC SEC
Levs = 0.2 mJy * (-1, 1, 2, 4, 8, 16, 32, 64)
1014+05
5 GHz
C
B
A
D
MilliARC SEC
Levs = 1.0 mJy * (-1, 1, 2, 4, 8, 16, 32, 64)
1102+11
5 GHz
B
A
MilliARC SEC
Levs = 0.8 mJy * (-1, 1, 2, 4, 8, 16, 32, 64)



- 4 core-jet
- 2 doubles
- 3 symmetric
- 2 unresolved (18%)

- 10<LS<100 pc

Bruni et al. 2012b

Results

- 82% of sources are resolved at pc-scale
- Different morphologies imply different possible orientations
- Missing flux in some cases, possibly due to extended components.
- Linear sizes up to 200 kpc from previous VLA observations: not all sources are young/compact.

III
Dust detection

Observations

IRAM 30-m

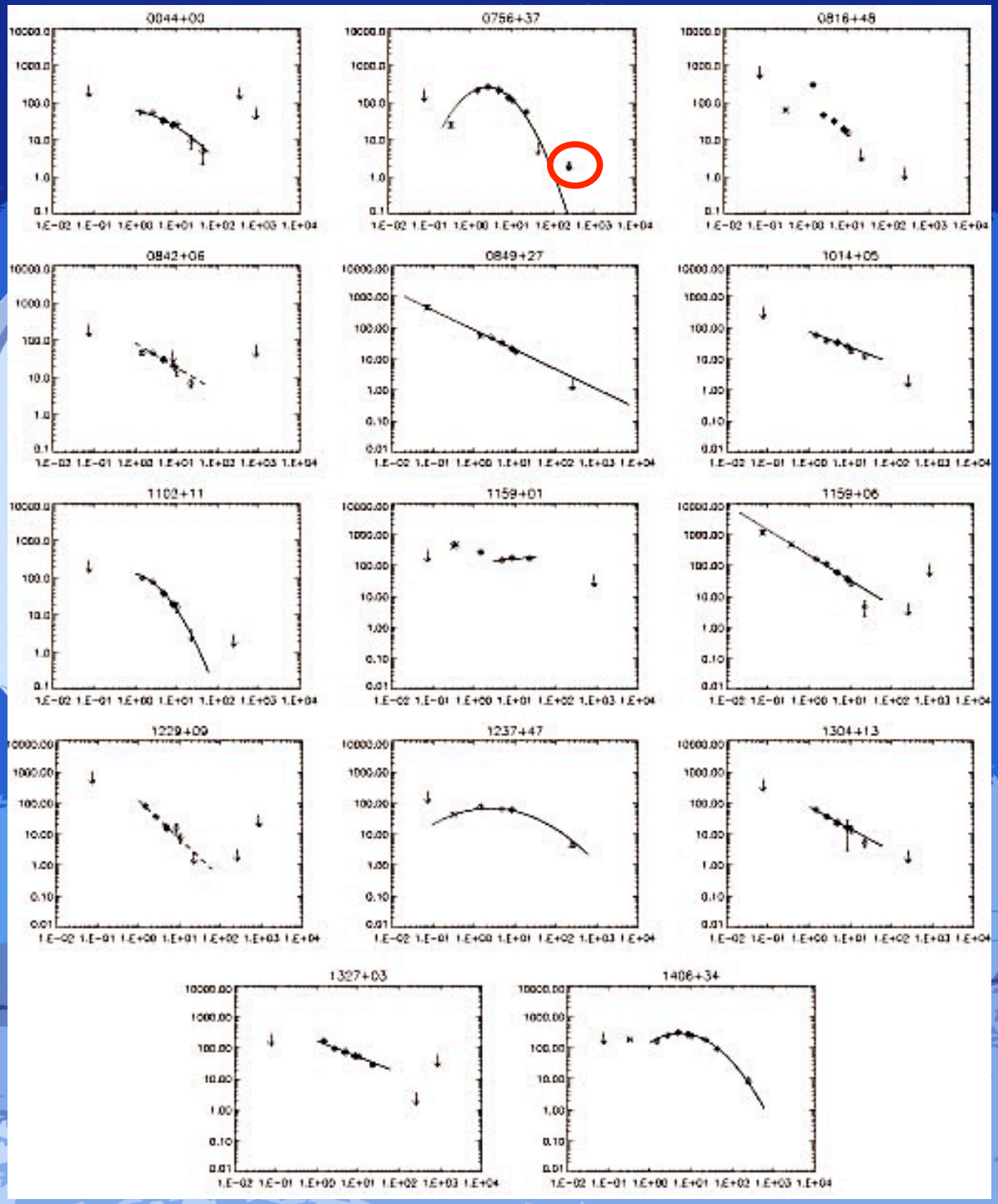
- Observations during 2010
- Continuum at 250 GHz
- 11/25 RL BAL QSOs

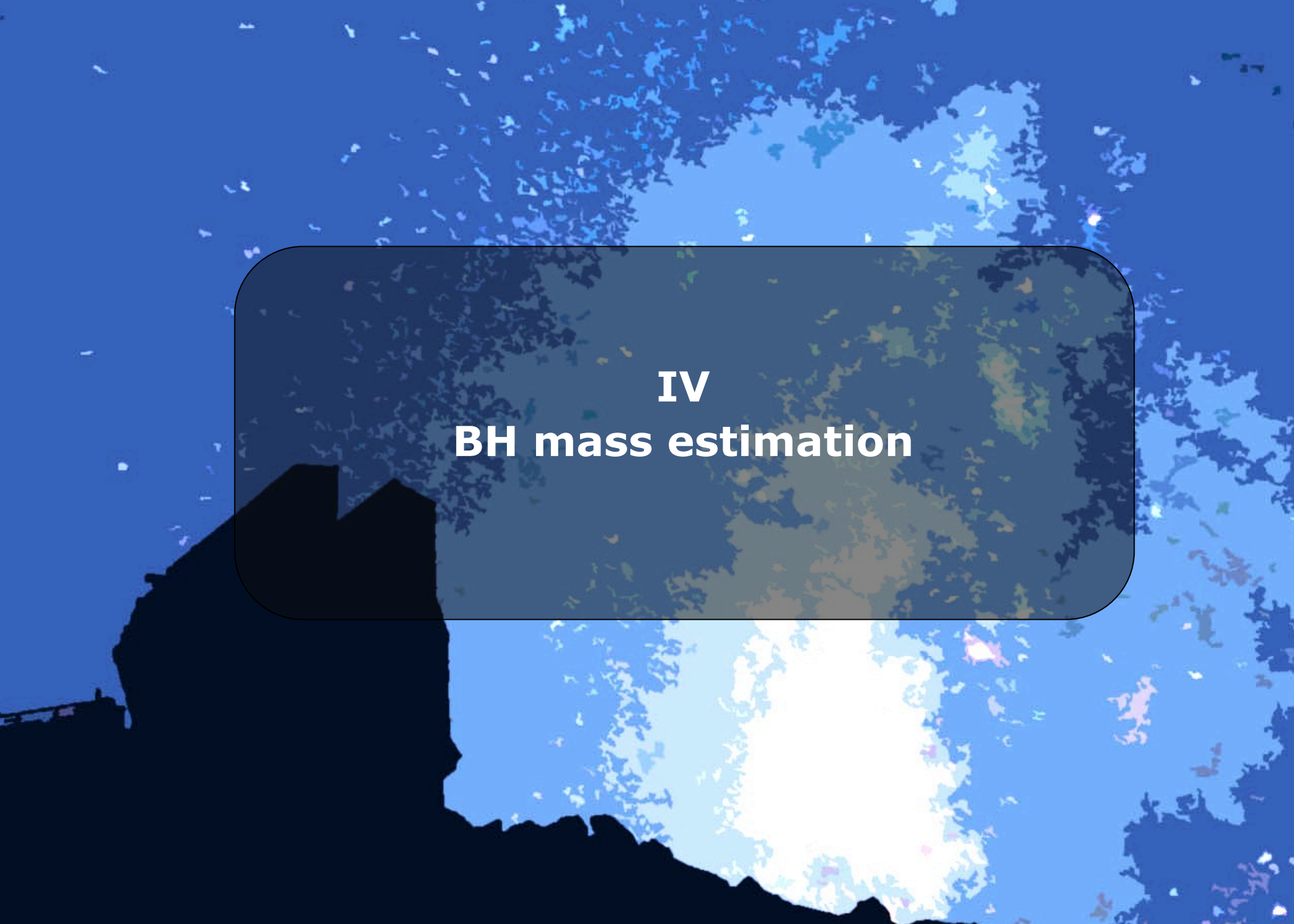
APEX

- Observations performed during 2010,
- scheduled for next fall
- Continuum at 850 GHz
- 6 equatorial sources of the sample (8/25)

- 7% with clear evidence of dust emission (1/14)
- 26% found from Omont et al. (2003) in the dust emission study of QSOs with z~2
- More statistic with new data (APEX)

Bruni et al. 2012b





IV
BH mass estimation

Why are RL BAL QSOs rare?

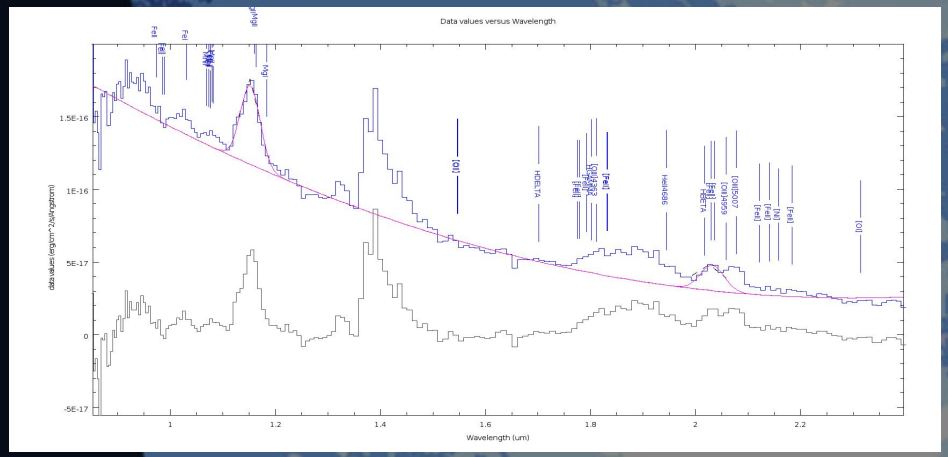
- BAL QSOs are 4 time less common among QSOs with R*>2 (Stocke et al. 1992)
- FR II BAL QSOs found by Gregg et al. (2006) with strong anticorrelation between Radio-Loudness and BAL strength

Evolutionary track?

BAL QSOs → RL QSOs

Infrared observations

- TNG spectroscopic observations of 21 RL + 23 RQ BAL QSOs optically bright (r<19)
- Low resolution (R~50)



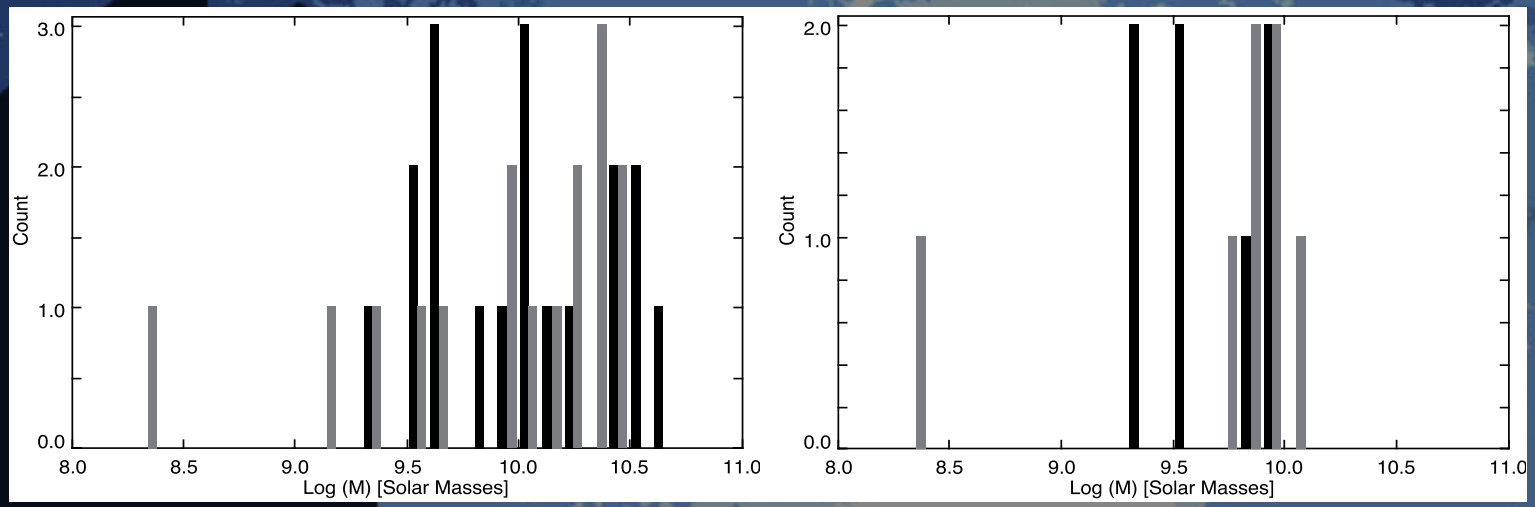
Mass of the BH from FWHM of MgII and H_β

$$M_{\rm BH}\ [M_\odot] = 10^{6.86}\left[\frac{\rm FWHM(MgII)}{1000\ km\ s^{-1}}\right]^2\left[\frac{\lambda L_\lambda(3000\,\text{Å})}{10^{44}\rm erg\ s^{-1}}\right]^{0.50}$$

Vestergaard et al. 2006

$$M_{\rm BH}\ [M_\odot] = 10^{6.91}\left[\frac{\rm FWHM(H\beta)}{1000\ km\ s^{-1}}\right]^2\left[\frac{\lambda L_\lambda(5100\,\text{Å})}{10^{44}\rm erg\ s^{-1}}\right]^{0.50}$$

Vestergaard & Osmer 2009



Eddington ratio and BLR radius

$$\frac{L_{bol}}{L_{Edd}} \approx 0.13 \left(\frac{\lambda L_\lambda (5100\,\text{Å})}{10^{44}\,\text{ergs}\,\text{s}^{-1}} \right)^{0.5}$$

Kaspi et al. 2000

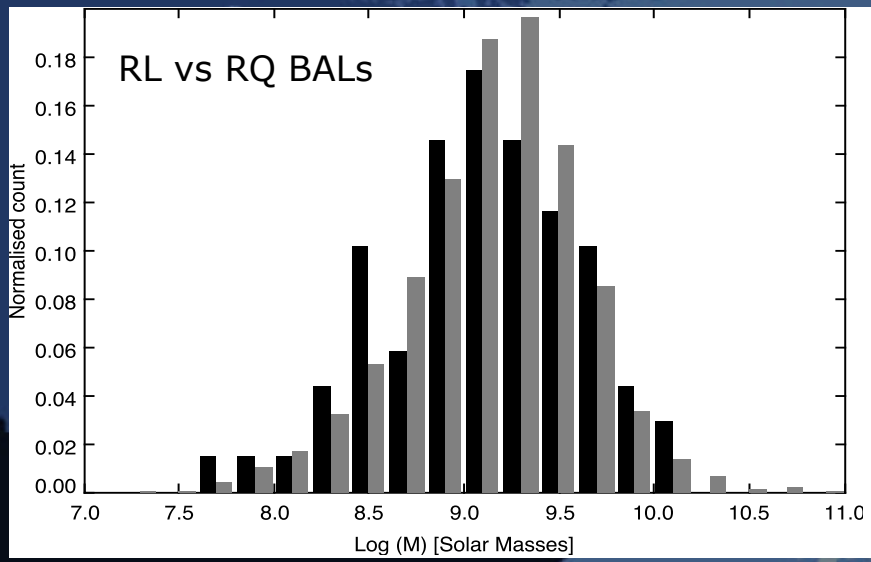
$$R_{BLR} = A \cdot \left[\frac{\lambda L_\lambda (5100)}{10^{44}\text{erg s}^{-1}} \right]^{0.5} \text{lt} - \text{days}$$

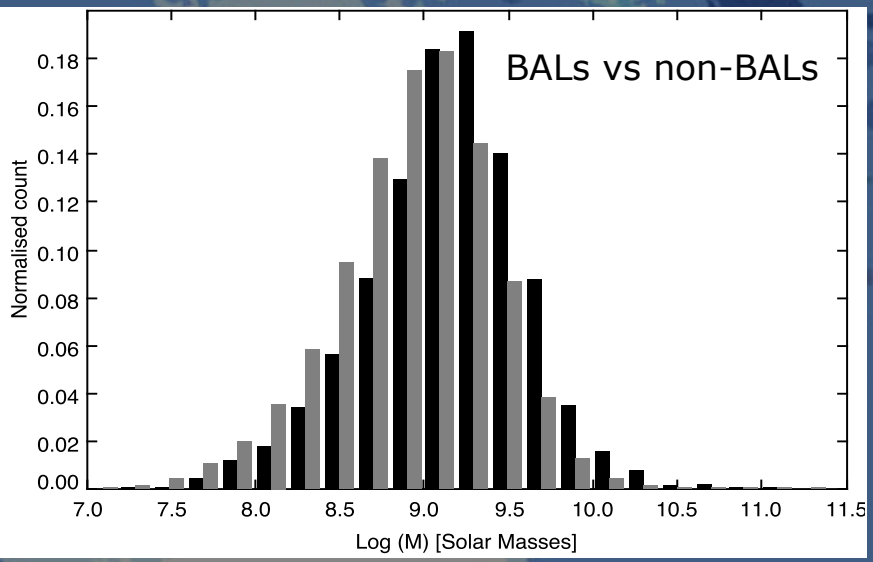
Kaspi et al. 2000, 2005
Bentz et al. 2006

- Similar values for Eddington ratios:
  1. all super-Eddington (selection effect)
  2. mean values of 2.52 vs 2.80
- Similar values for BLR: 481±142 vs 433±198 light-days

Results from the SDSS DR7 QSO catalogue

- 69 RL vs 3369 RQ BAL QSOs
- 3650 BAL vs 79650 non-BAL QSOs
- means within ±1 sigma for RL vs RQ BAL QSOs





Results from the SDSS DR7 QSO catalogue

Excess of super-Eddington objects among BAL QSOs:

13% vs 2%

BALs vs non-BALs

26% vs 13%

RL BALs vs RQ BALs

- High accretion rates required to trigger the BAL phenomenon?
- BH mass is not responsible for the rarity of RL BAL QSOs

Conclusions

- No particular orientation, only steep-spectrum majority
- Both GPS and low frequency peaked, old components in some cases
- Some resolved, different morphologies, sizes from ~10 pc to ~200 kpc
- No more dust-abundant than the QSO population (not so young)
- No higher BH masses than normal QSOs
- Tentative evidences of an excess of super-Eddington objects

Conclusions

The BALs are most probably produced by outflows, but:

① with different possible orientations (recollimated outflows?)

② Present in different evolutionary stages of the QSO

③ Probably as an intermittent phenomenon

BROAD ABSORPTION LINE DISAPPEARANCE ON MULTI-YEAR TIMESCALES IN A LARGE QUASAR SAMPLE

N. Filiz Ak[1,2,3], W. N. Brandt[1,2], P. B. Hall[4], D. P. Schneider[1,2], S. F. Anderson[5], R. R. Gibson[5], B. F. Lundgren[6], A. D. Myers[7], P. Petitjean[8], Nicholas P. Ross[9], Yue Shen[10], D. G. York[11], and D. Bizyaev[12], J. Brinkmann[12], E. Malanushenko[12], D. J. Oravetz[12], K. Pan[12], A. E. Simmons[12], B. A. Weaver[13]

Draft version August 7, 2012

ABSTRACT

We present 21 examples of C IV Broad Absorption Line (BAL) trough disappearance in 19 quasars selected from systematic multi-epoch observations of 582 bright BAL quasars ($1.9 < z < 4.5$) by the Sloan Digital Sky Survey-I/II (SDSS-I/II) and SDSS-III. The observations span 1.1–3.9 yr rest-frame timescales, longer than have been sampled in many previous BAL variability studies. On these timescales, $\approx 2.3\%$ of C IV BAL troughs disappear and $\approx 3.3\%$ of BAL quasars show a disappearing trough. These observed frequencies suggest that many C IV BAL absorbers spend on average at most a century along our line of sight to their quasar. Ten of the 19 BAL quasars showing C IV BAL disappearance have apparently transformed from BAL to non-BAL quasars; these are the first reported examples of such transformations. The BAL troughs that disappear tend to be those with small-to-moderate equivalent widths, relatively shallow depths, and high outflow velocities. Other non-disappearing C IV BALs in those nine objects having multiple troughs tend to weaken when one of them disappears, indicating a connection between the disappearing and non-disappearing troughs, even for velocity separations as large as 10000–15000 $\mathrm{km\,s^{-1}}$. We discuss possible origins of this connection including disk-wind rotation and changes in shielding gas.

Subject headings: galaxies: quasars: absorption lines

Thank you!

ALMA MATER STUDIORUM A.D. 1088

UC UNIVERSIDAD DE CANTABRIA

IFCA Instituto de Física de Cantabria

INAF ISTITUTO NAZIONALE DI ASTROFISICA

CSIC CONSEJO SUPERIOR DE INVESTIGACIONES CIENTÍFICAS

MANCHESTER 1824 The University of Manchester

VNIVERSITAT DE VALÈNCIA

NRAO

EUROPEAN VLBI NETWORK

MAX-PLANCK-GESELLSCHAFT

RadioNet

iram Institut de Radioastronomie Millimétrique

ESO