Compact radio-loud BAL QSOs

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The importance of quasar winds

Quasar outflows impact on:

see talks by
F. Nicastro,
P. Barai,
C. Tadhunter

- Growth of super-massive black holes
- Enrichment of the intergalactic medium
- Evolution of the host galaxy
- Cluster cooling flows
- Magnetisation of cluster and galactic gas
- Luminosity function of quasars

Wind as a *free parameter* with few observational constraints

How many?

Optically-selected

10 - 15% show BALs (1.7 < z < 3.4) e.g., Reichard et al. 2003

3 out of 6 at z > 4.9 QSOs show BALs Maiolino et al. 2004a

NIR-selected (less obscuration)

Higher fraction: >30% see poster by N. Maddox

Radio-selected:

Beginning of 90': 0% Radio-loud BAL QSOs

RL BAL QSOs from the FBQS [APM(O-E) < 2] ~ 10 %
Becker et al. 2000

Radio-Loud BAL QSOs [APM(O-E) > 2]: ~ 27 %
Carballo et al. 2006

Explanations for the BAL phenomenon

Two branches of models

- Unification by Orientation

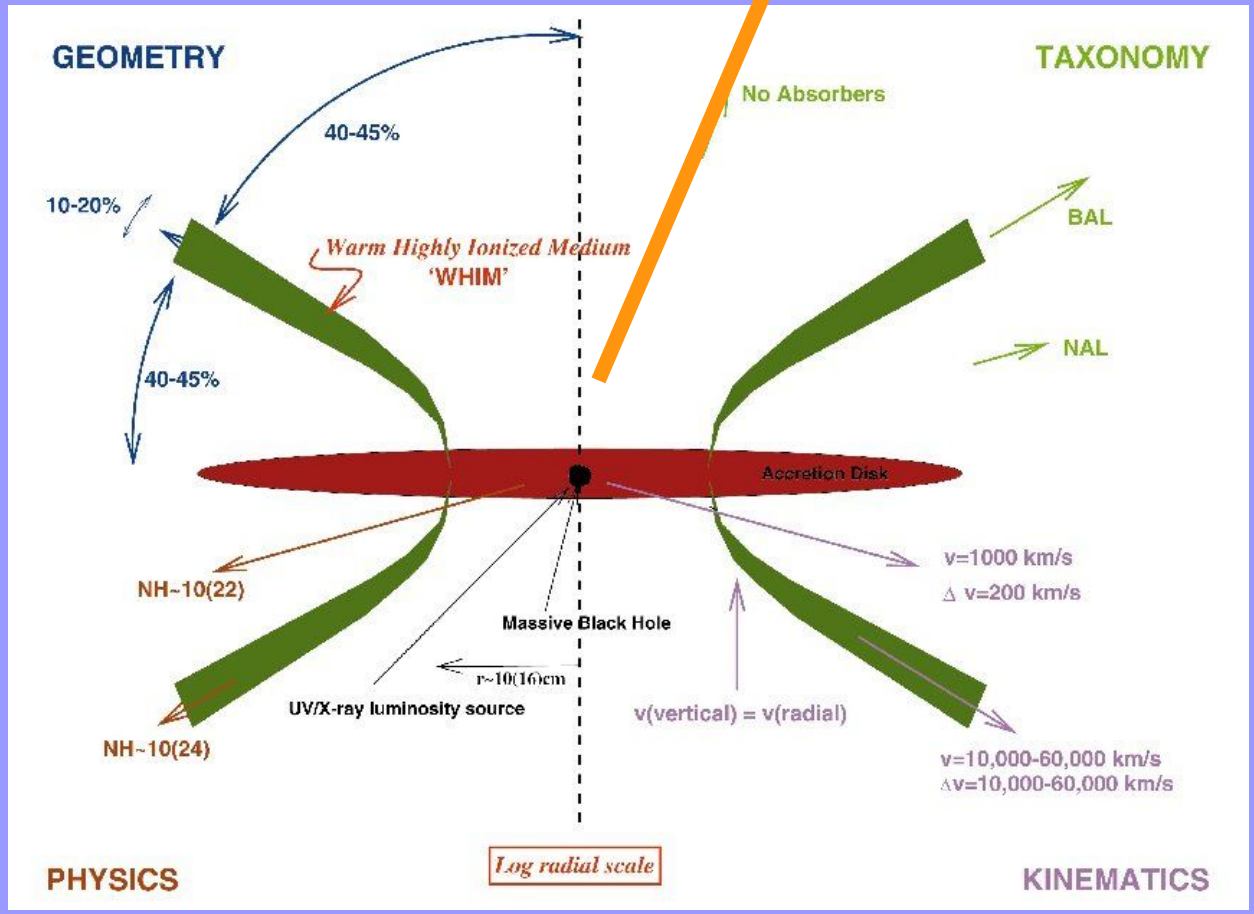
  "All quasars posses BAL outflows, so that the frequency of detection only translate to the rate at which our line of sight intercept the outflows"

- Unification by Evolution

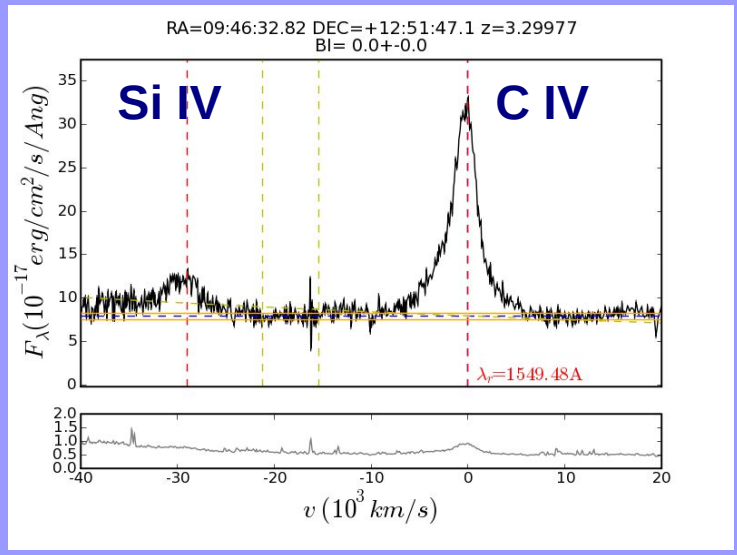
  "The rate of the BAL phenomenon is interpreted as a particular phase of the QSO's life"

Explanations for the BAL phenomenon

Orientation Scenario:



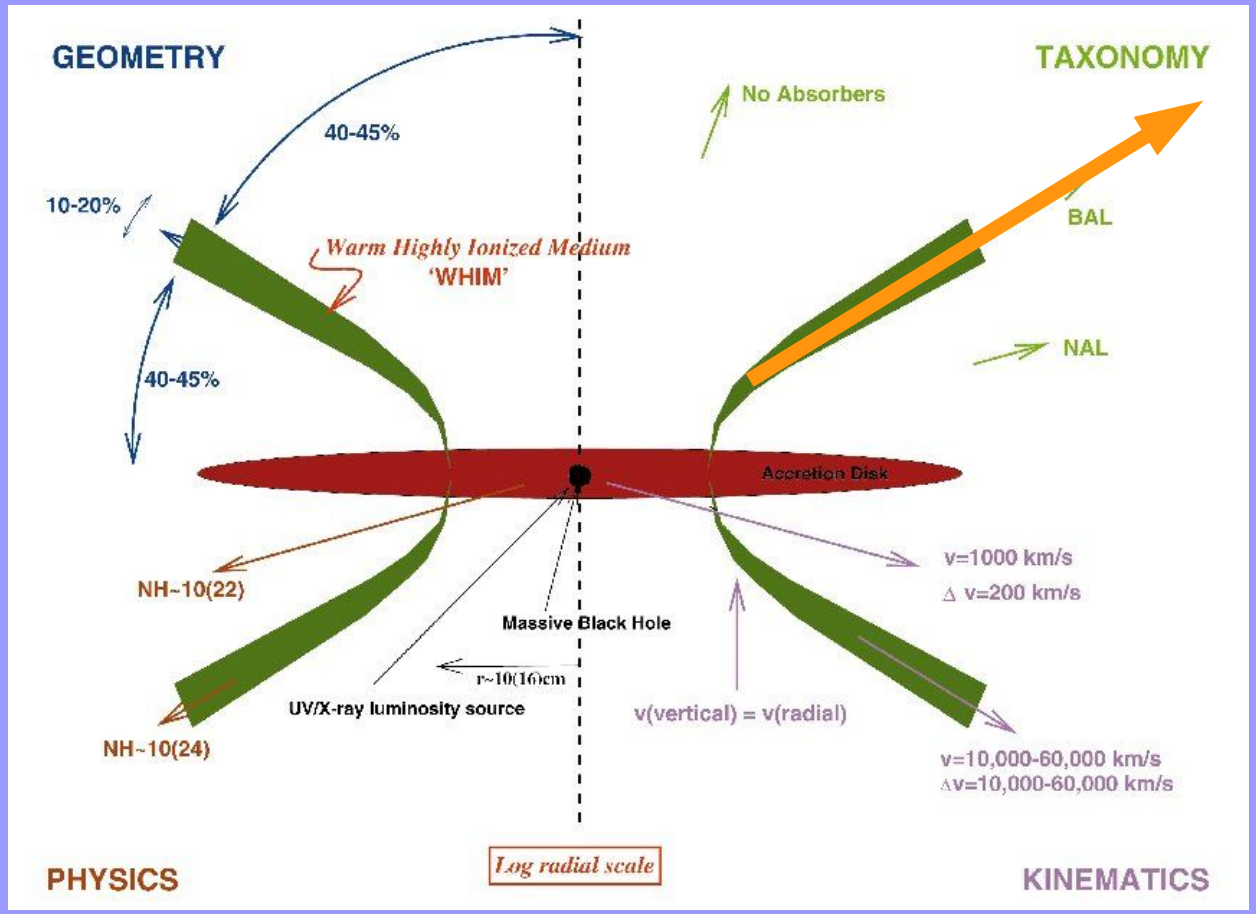
Elvis (2000)



Normal Quasar

Explanations for the BAL phenomenon

Orientation Scenario:



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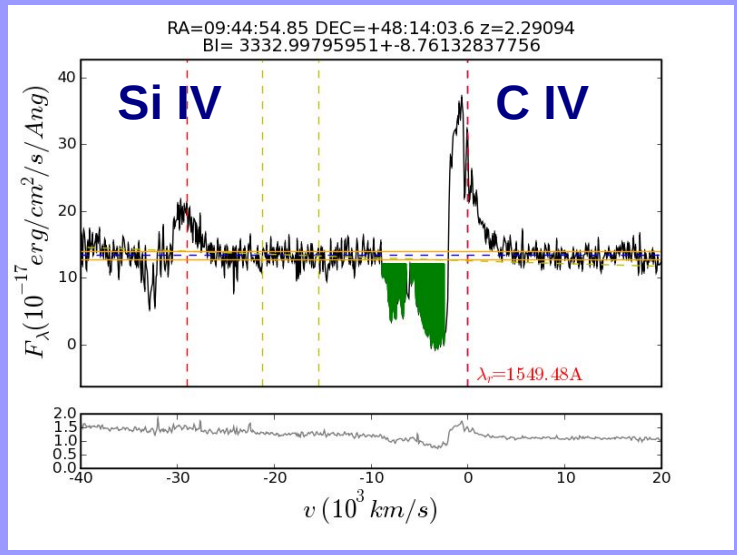
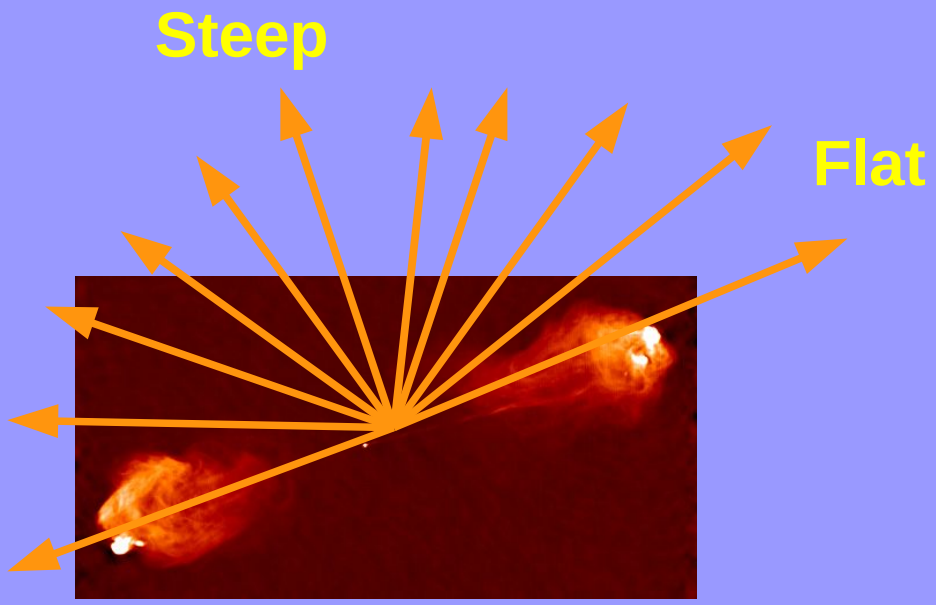


BAL features

Explanations for the BAL phenomenon

Orientation Scenario:



BUT...

Why RL BAL QSOs show a variety of radio spectral indices?

Becker et al. 2000
Montenegro-Montes et al. 2008

Why are there examples of RL BAL QSOs with FR2 morphology and at the same time examples of strongly beamed "polar" BAL QSOs?

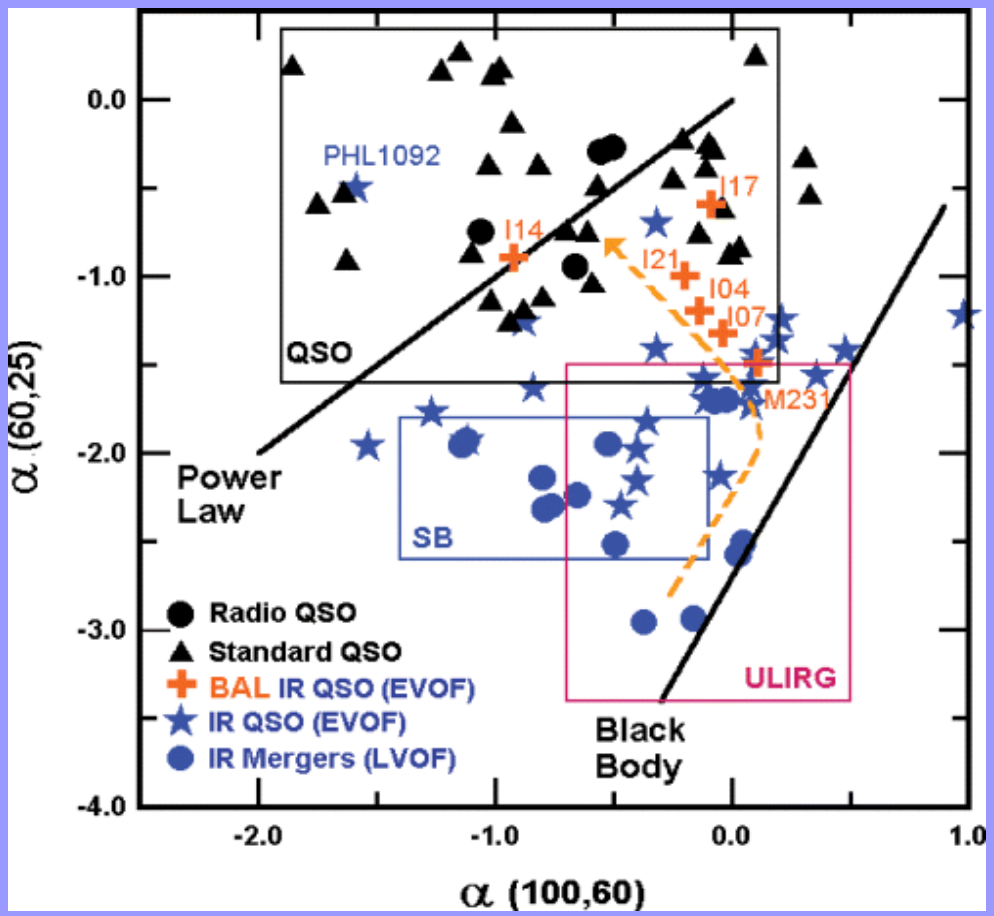
Gregg et al. 2006, Zhou et al. 2006,
Ghosh & Punsly 2007

Explanations for the BAL phenomenon

Evolutionary Scenario: Young or recently refueled quasars

Becker et al. 2000; Gregg et al. 2000, 2006;
Kunert-Bajraszewska & Marecki, 2007

} **Radio!**



Lípari & Terlevich 2006

Explanations for the BAL phenomenon

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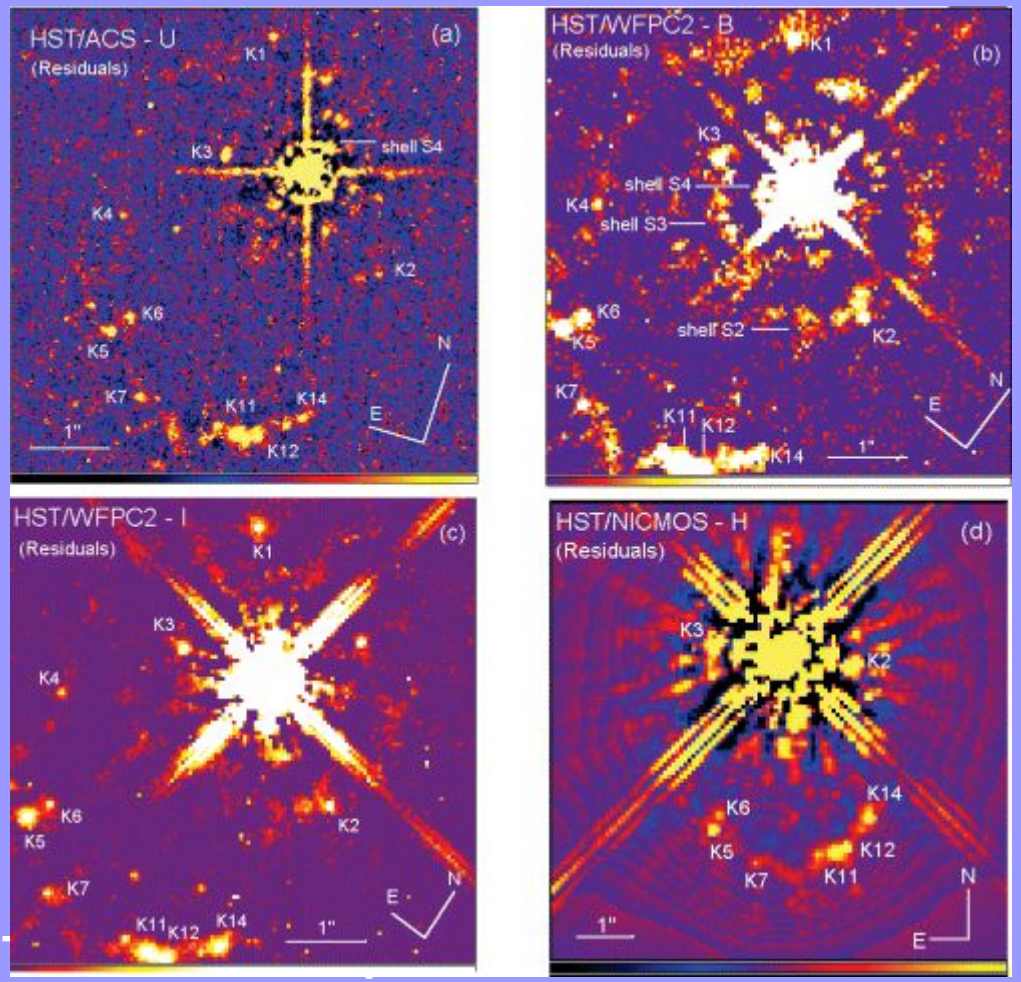


BUT...

Why similar mid-IR and mm properties?

Lewis, Chapman & Kuncic 2003
Willott, Rawlings, Grimes 2003
Priddey et al. 2007

Lípari et al 2005

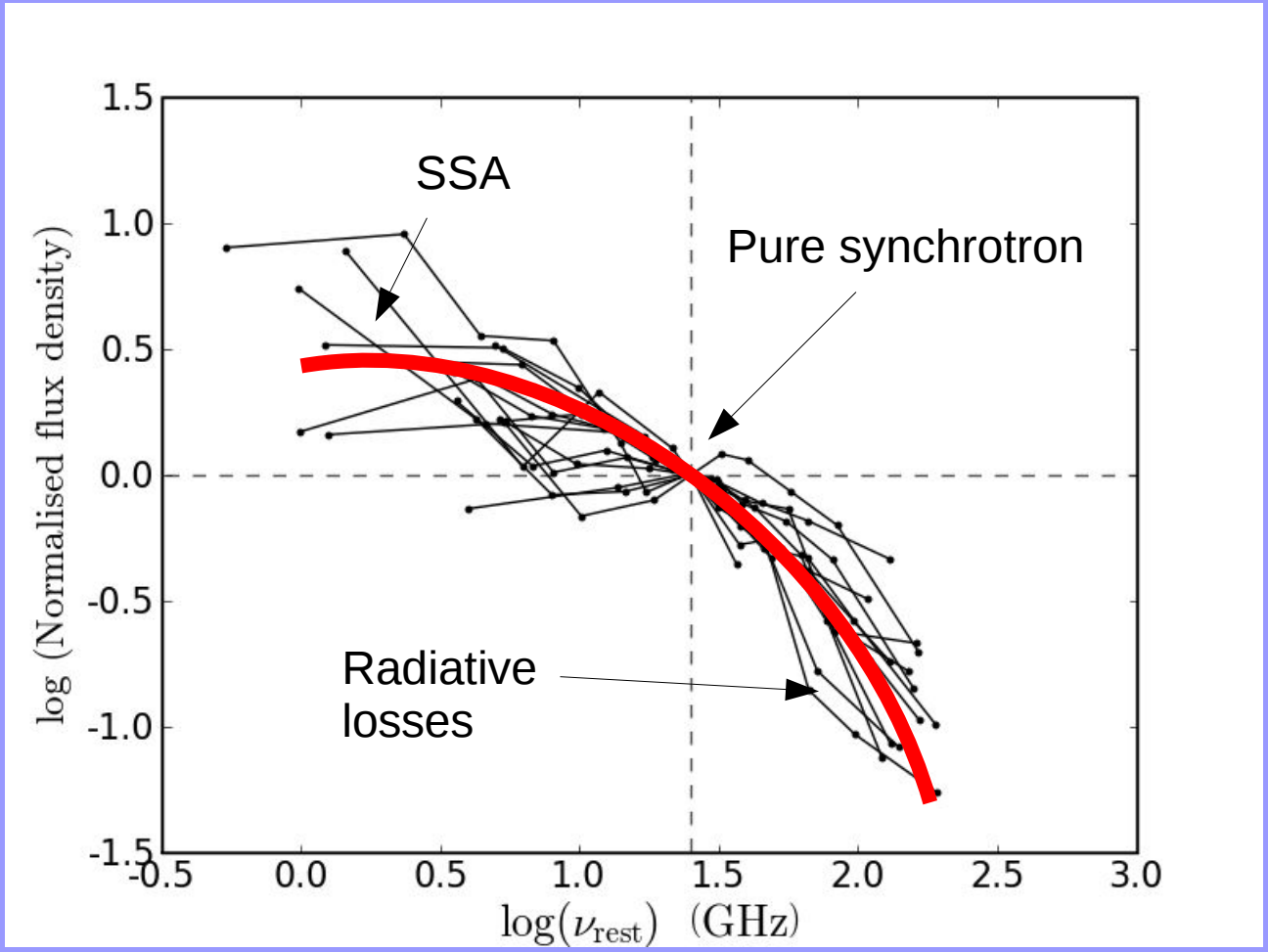
Radio properties of 15 BAL QSOs

- Radio spectra & polarisation properties
- Radio morphology
- Variability

Montenegro-Montes et al. 2008
MNRAS (accepted) (arXiv:0805.4746)

Radio spectra

Spectral shape: BAL QSOs have convex radio spectra



Variety of spectral indices

Flattening at low frequency: SSA, compact

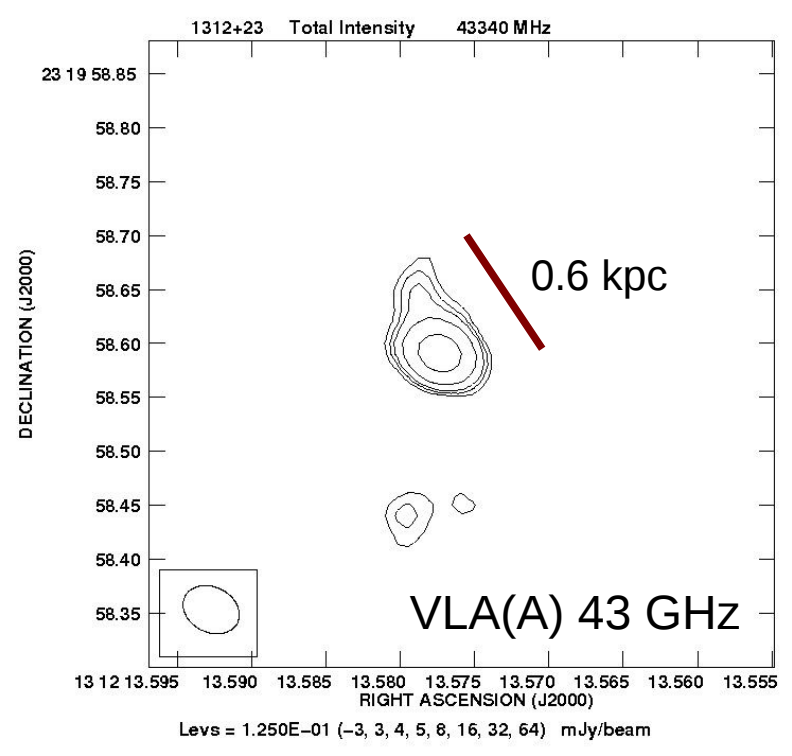
Spectra of typical CSS/GPS “young” radio sources

Morphology

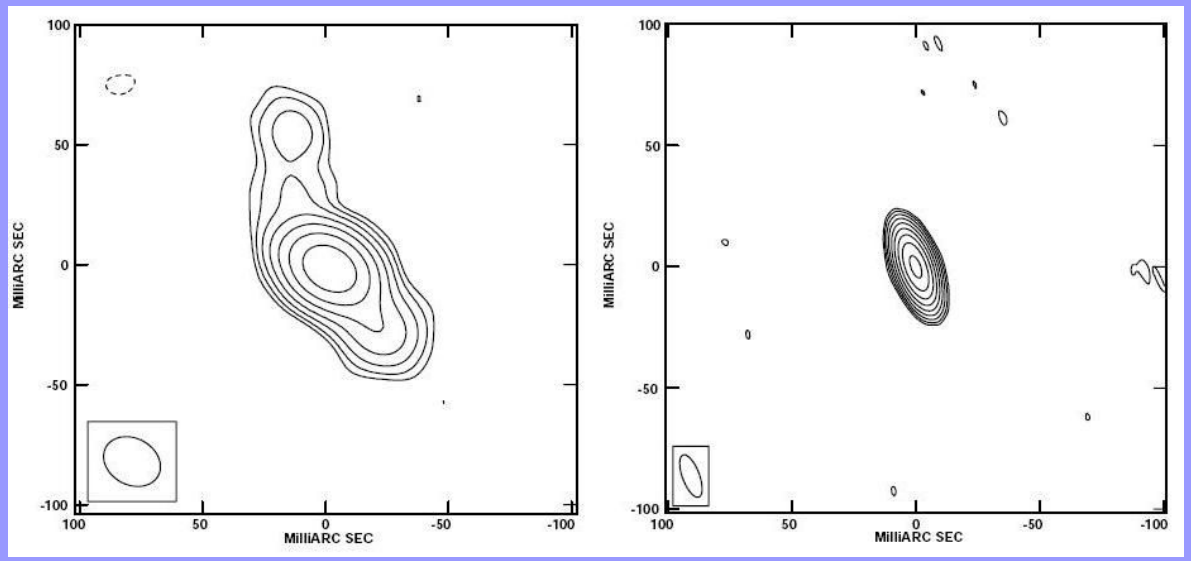
BAL QSOs are very compact radio sources

Most of 15 unresolved or slightly resolved with VLA(A)

Some VLBI observations in the literature



Montenegro-Montes et al 2008



EVN, 1.6 GHz Jiang, Wang & Wang, 2006

Radio properties of BAL QSOs

Variability (only 2 epochs):

1.4 GHz: FIRST – NVSS epochs, 14 objects

8.4 GHz: Becker et al. 2000 – This work, 5 objects

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

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

No strong variabilily for genuine GPS sources $Var_{\Delta S} << 3$

(Torniainen et al. 2005)

Source	Freq (GHz)	S_1 (mJy)	S_2 (mJy)	$Var_{\Delta S}$	σ_{Var}
0256−01	1.4	22.3±0.8 D	27.5 B	0.23	3.2
1213+01	1.4	27.5±0.9 D	22.9 B	−0.20	3.2
1312+23	8.4	12.6 A	19.4±0.2 A	0.54	10.3
1413+42	8.4	11.3 D	13.4±0.1 A	0.19	3.7
1603+30	8.4	18.1 A	22.1±0.3 A	0.22	4.2

Only 2 / 14 variable

3 / 5 variable

Radio properties of BAL QSOs

Polarisation: VLA @ 8.4 GHz sensible rms

10 / 15 unpolarised $m_{8.4} < 1\%$

5 / 15 significantly polarised $m_{8.4}$ (median) = 1.3 %

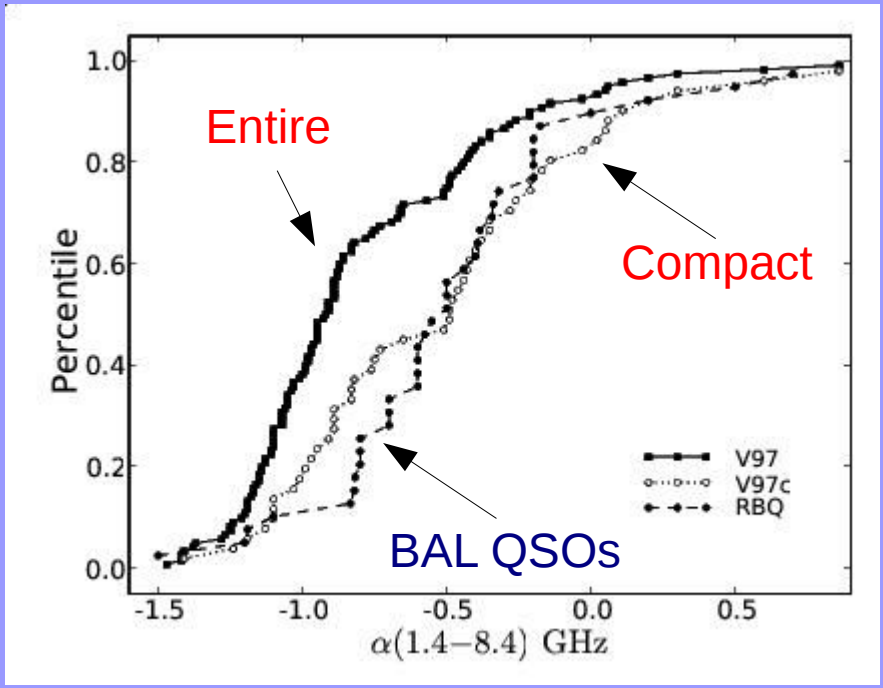
As a comparison, Stanghellini et al. (2003):

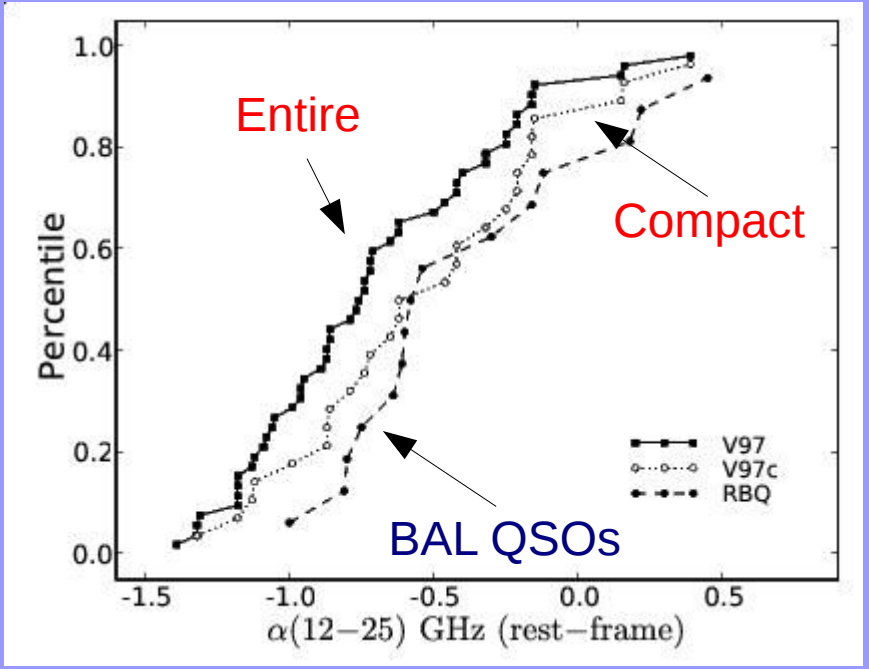
Flat-spectrum quasars: $m_{5\,GHz} = 1.8\ \%$
GPS quasars: $m_{5\,GHz} = 1.2\ \%$
GPS galaxies: $m_{5\,GHz} < 0.3\ \%$

Radio properties of BAL QSOs

Spectral indices: Test on orientation

BAL QSOs vs. non-BAL QSOs (B3-VLA, Vigotti et al. 1997)





Observer's frame Evolution! Rest frame

Conclusions

- Quite compact, ~ 50 mas ~ 0.5 kpc
- Some variable, but not too much
- Convex-peaked spectra (GPS)
- On average weakly polarised
- Same α distribution that non-BAL QSOs
- Many properties similar to GPS sources (young?)