Reorienting Our Perspective of Broad Absorption Line Quasars

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10/15/2011

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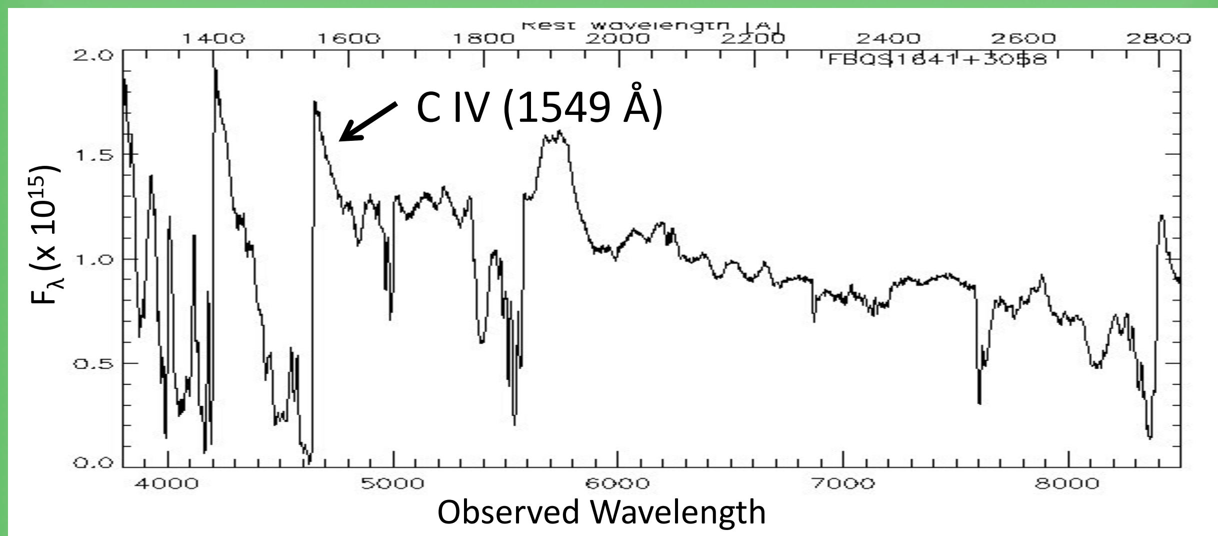
What are BAL Quasars?

- Quasars with wide, blueshifted absorption from ions like C IV, Si IV:



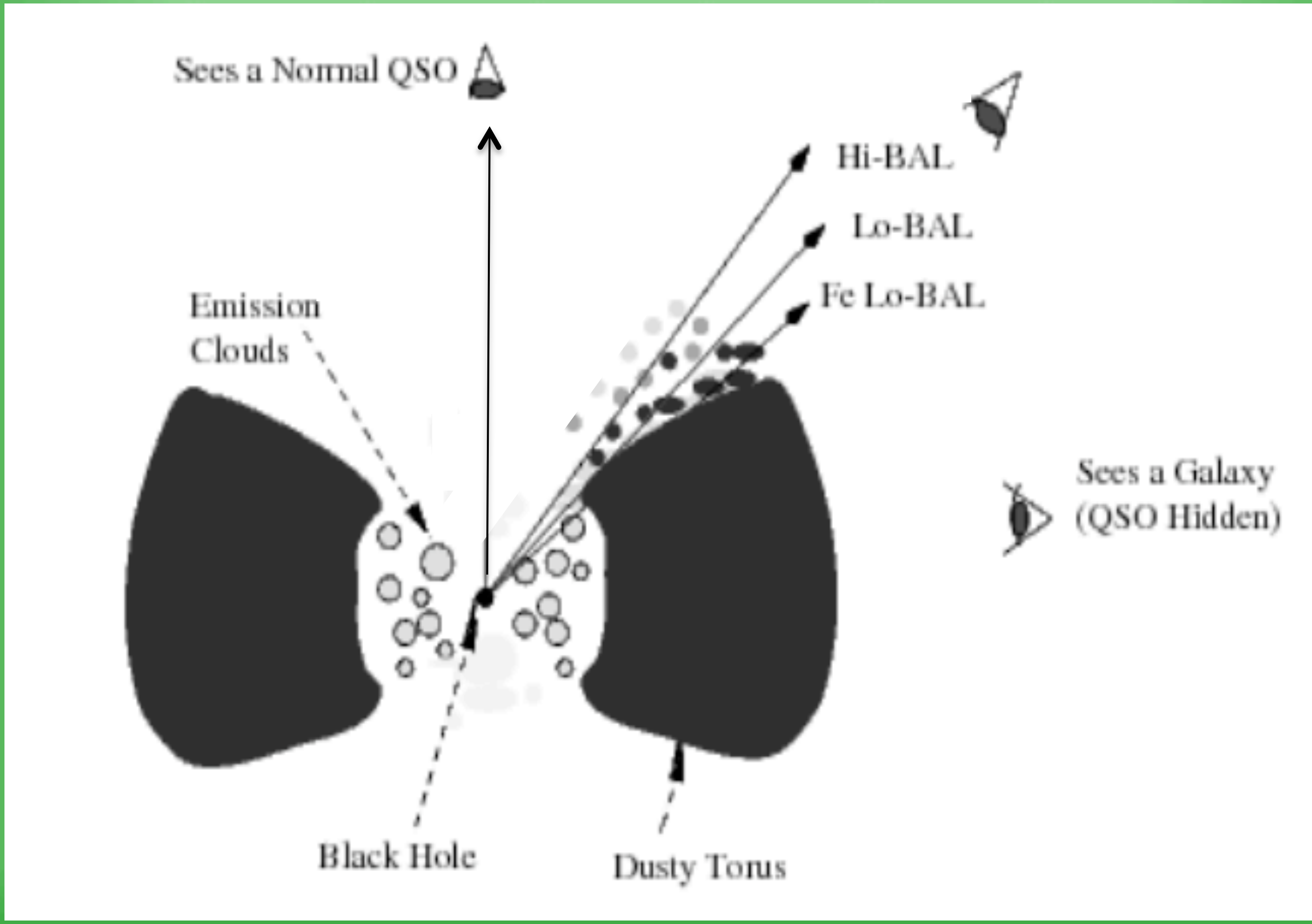
(DiPompeo et al. 2010)

- Seen in ~20% of optically selected quasar samples (at high enough z to see C IV), though the intrinsic fraction is likely much higher

- Indicate massive high velocity (few %c) outflows; the most extreme type of outflow identified in the optical/UV

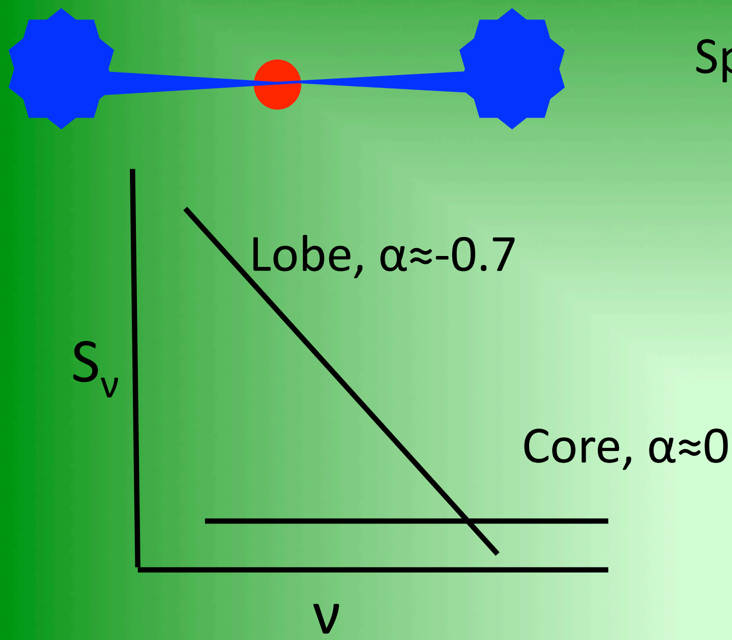
Explanations- Orientation

- Long suggested BAL quasars have a preferred line of sight. Analogous to other unified AGN schemes:



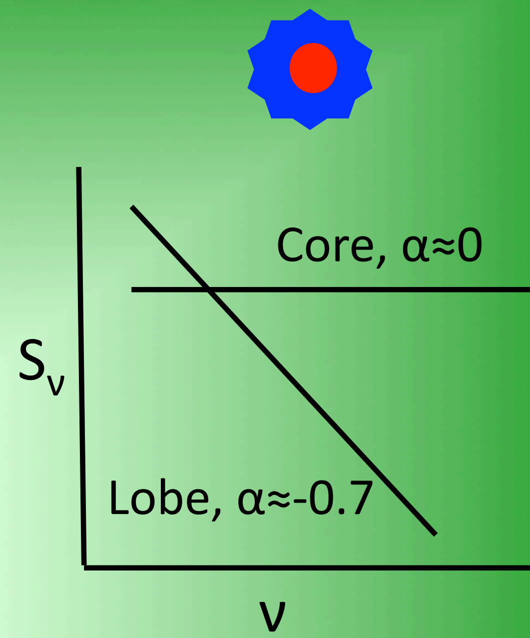
- How can we test this?

Explanations- Orientation



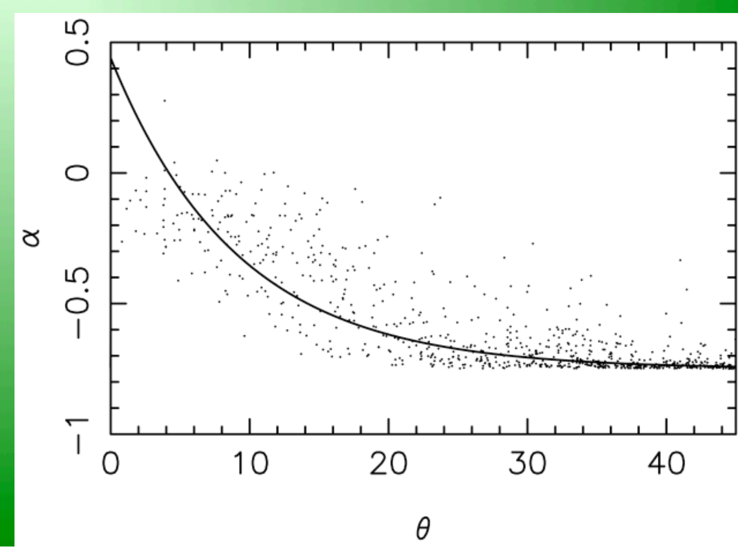
Spectral index, α:

$$f \propto \nu^{\alpha}$$



- Despite the large scatter, expect large samples of BALQSOs to show a difference in α from normal QSOs if they are indeed seen mostly edge-on

Fine et al. (2011)



Evolution?

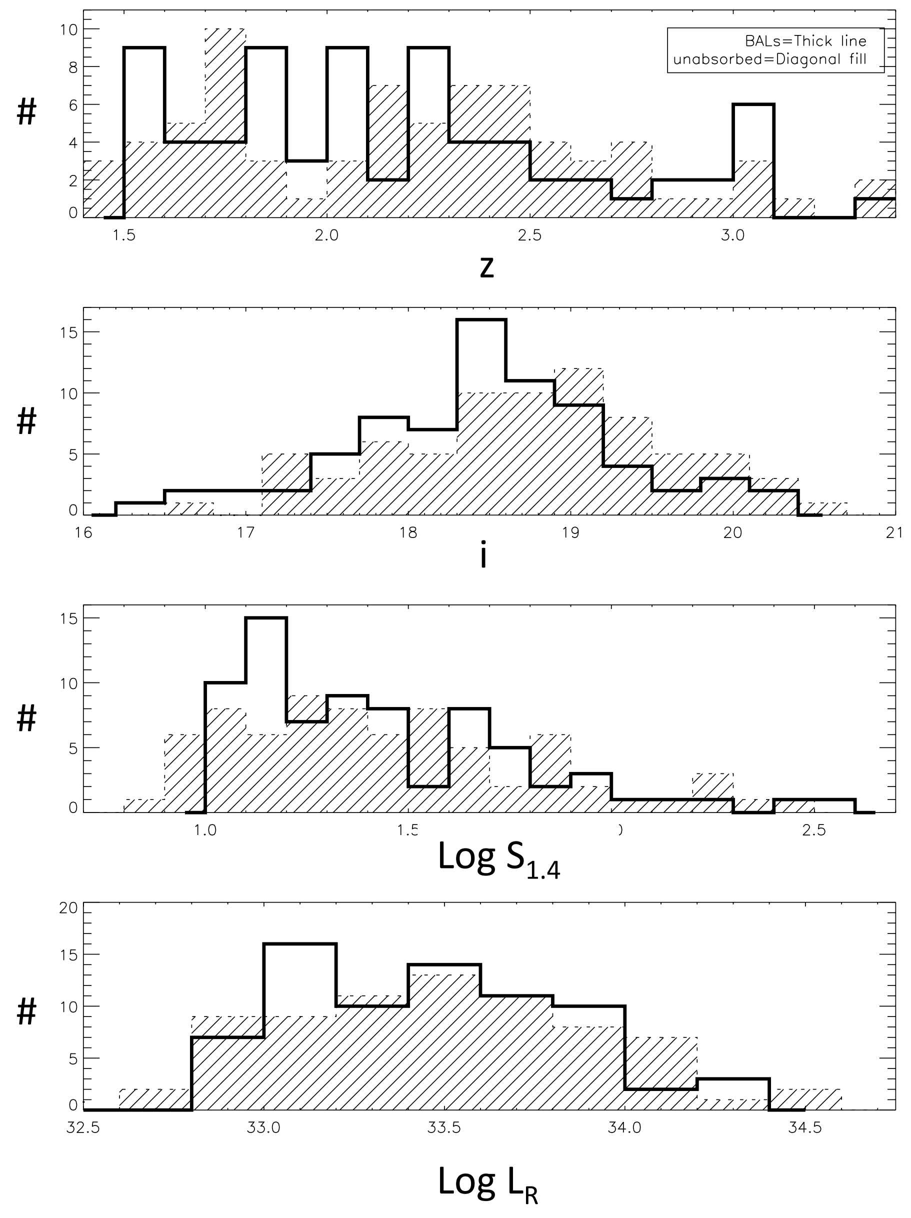
- No difference has yet been found in α distributions (Becker et al. 2000, Montenegro-Montes et al 2008, Fine et al. 2011). Samples have been small (~30 BALQSOs or less)
- "Polar" BALs (Zhou et al. 2006, Ghosh & Punsly 2007)
- Radio properties resemble CSS and GPS sources- these are likely progenitors of large radio sources

My Project- Radio Sample

- Built a sample of 74 radio-bright BALQSOs from FIRST (1.4 GHz) and SDSS (Gibson et al. 2009)

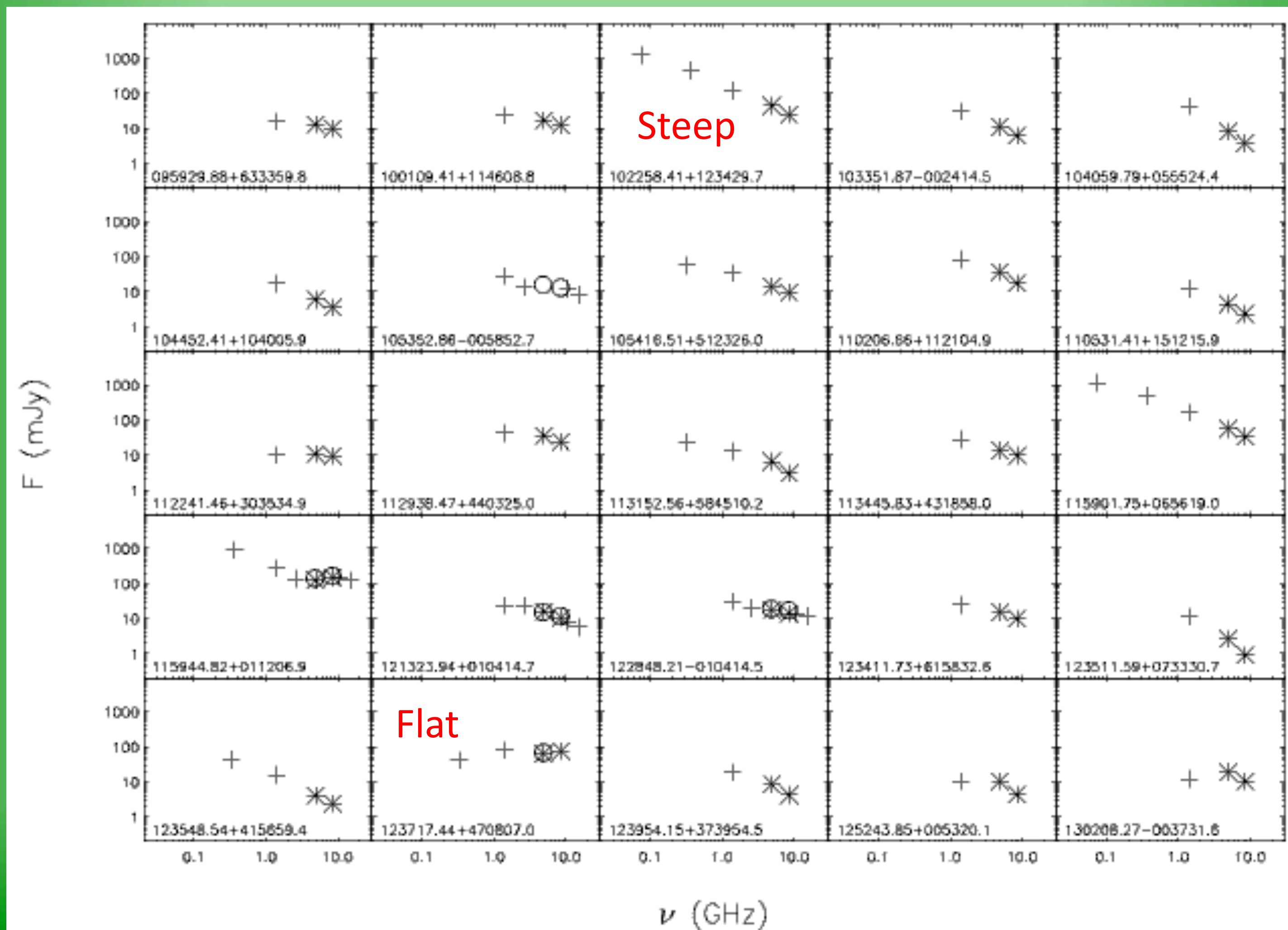
- Built a matched-pair comparison sample of 74 unabsorbed quasars

(DiPompeo et al. 2011, in press)



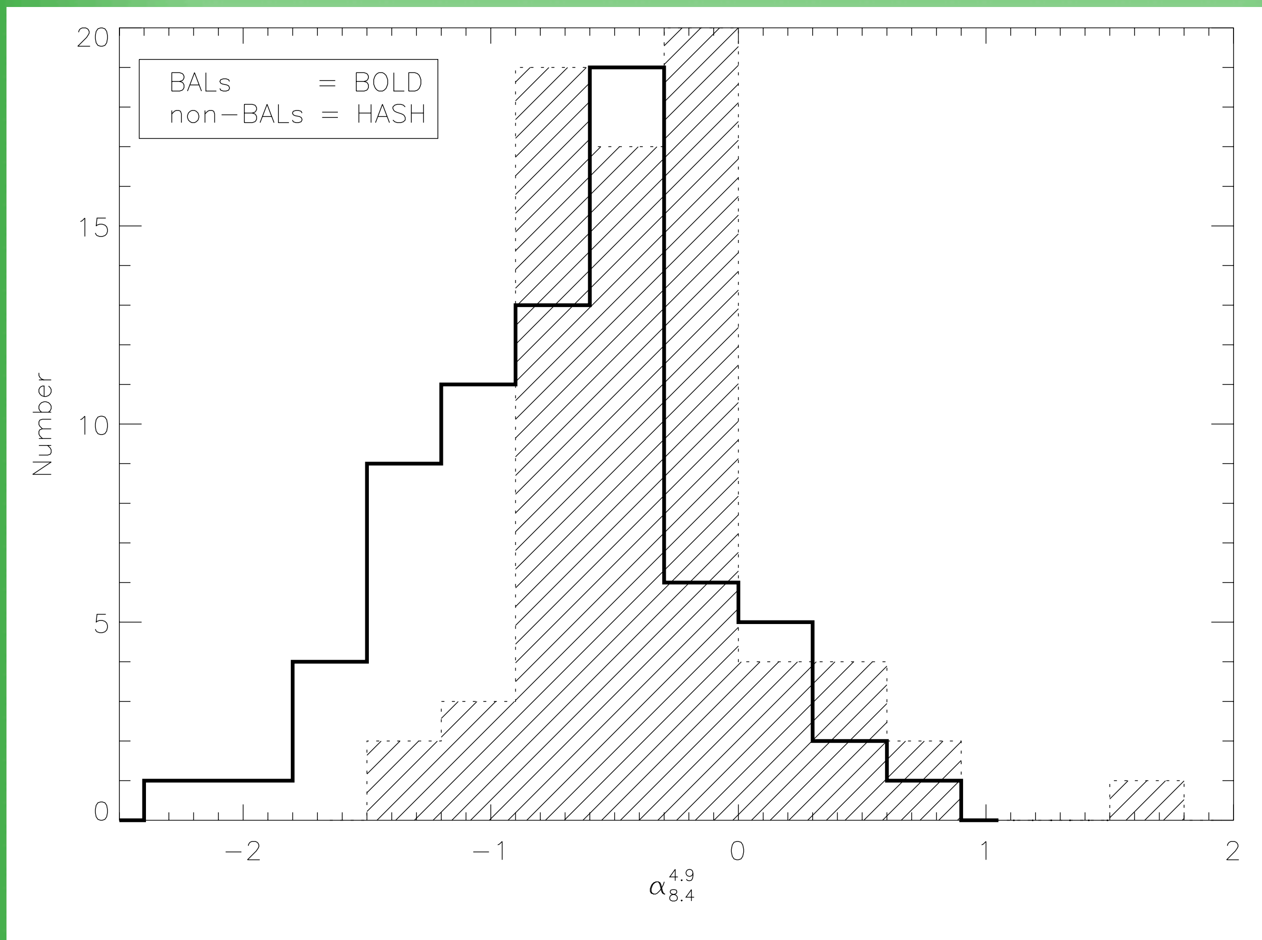
Radio Spectra

- ✧ Observed with the VLA/EVLA over 2 observing periods at 4.9 and 8.4 GHz. Simultaneous (with few exceptions)



First Results

- Do see a significant (~4σ) difference between BAL and non-BAL spectral index between 4.9-8.4 GHz

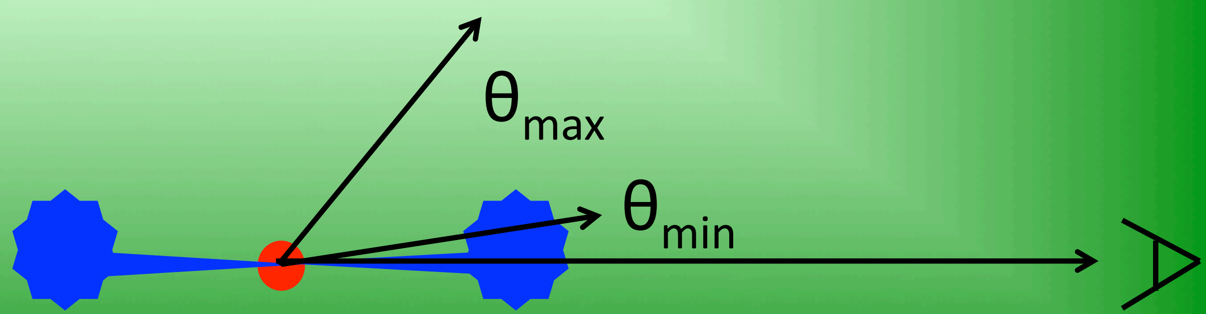


(DiPompeo et al. 2011, in press)

- Difference persists for several different measures of α

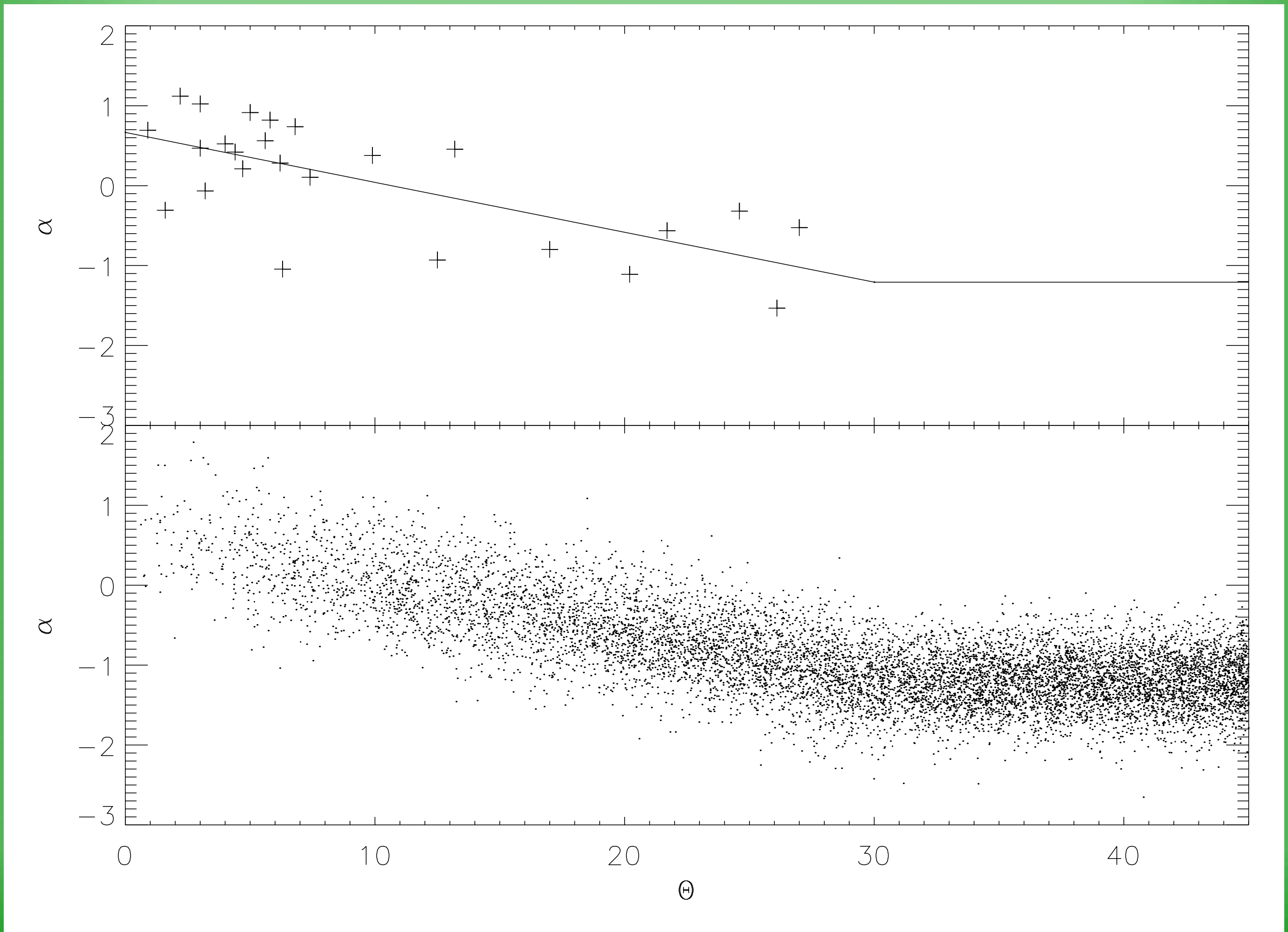
Quantifying Results- Modeling

- Utilize two different relationships between α and θ- observational and theoretical
- Simulate 74 objects with random bi-polar jet angles, compare α distribution to observations- repeat 10^5 times
- Vary allowed θ_{min}-θ_{max} to see which θ range best matches observation for each sample (i.e. $P_{KS}<0.05$)



Observational Model

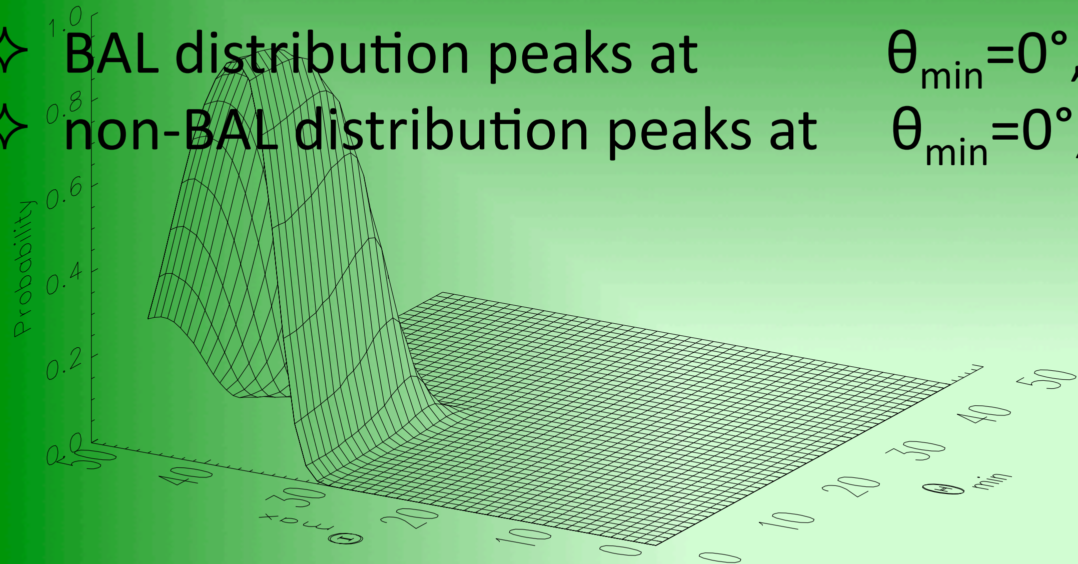
✧ Based on sample of Wills & Brotherton (1995)

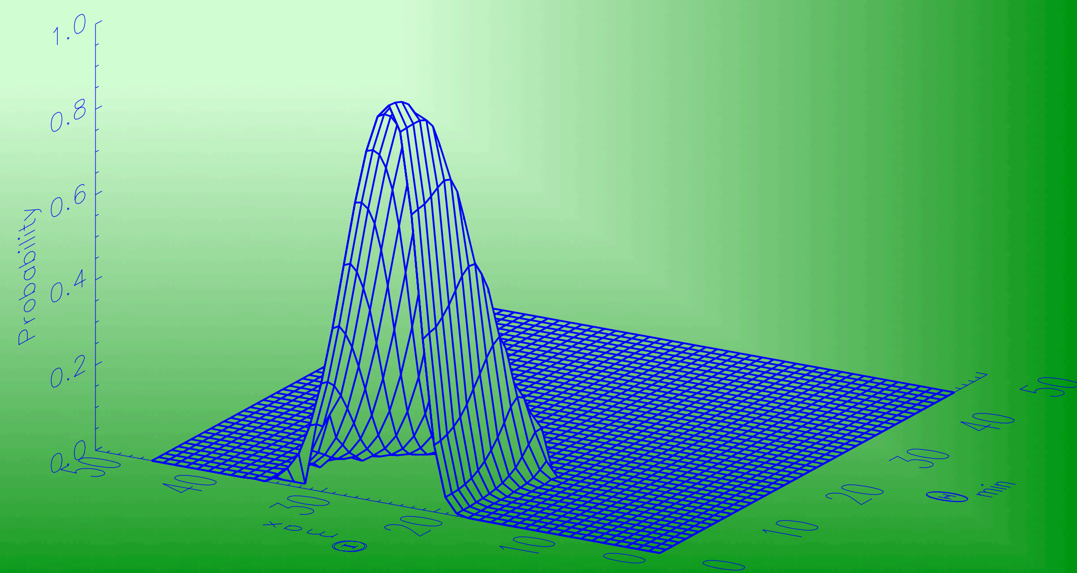


(DiPompeo et al. 2011, in press)

Model Results

- BAL distribution peaks at θ_{min}=0°, θ_{max}=37° (p=0.96)
- non-BAL distribution peaks at θ_{min}=0°, θ_{max}=24° (p=0.93)





Conclusions

- ✧ BAL quasars likely span a range of orientations, but do show a preference for steeper radio spectra
- ✧ Can explain this difference in α distribution by allowing BAL quasars to have viewing angles extending ~10° farther from the jet axis compared to non-BALs
- ✧ Orientation vs. Evolution is likely a false dichotomy- it could be both!
- ✧ Special thanks to Mike Brotherton, Carlos DeBreuck and ESO, and the Wyoming NASA Space Grant Consortium

First Results

✧ Difference persists when measuring index other ways

Measurement	n BAL	n non-BAL	D_{ks}	P_{ks}	Z_{rs}	P_{rs}
$\alpha_{8.4}^{4.9}$	72	72	0.347	0.0002	4.00	3.1×10^{-5}
$\alpha_{4.9}^{1.4}$	73	73	0.287	0.0036	3.18	0.0007
α_{fit}	73	74	0.322	0.0007	3.76	8.4×10^{-5}
c $\alpha_{8.4}^{4.9}$	63	56	0.337	0.0016	3.63	0.0001
c $\alpha_{4.9}^{1.4}$	63	57	0.342	0.0012	3.70	0.00011
c α_{fit}	63	58	0.394	0.0001	4.19	1.4×10^{-5}

✧ Matched-pair statistics give similar results

(DiPompeo et al. 2011, in press)