Evolution of the Black Hole - Bulge Relationship in QSOs

Gregory A. Shields
U. Texas Austin

ABSTRACT

Quasars afford an opportunity to study the evolution of the black hole - bulge relationship, using the broad emission lines to estimate M_{BH}. Results using AGN narrow emission lines as a surrogate for stellar velocity dispersion σ_* suggest some increase in M_{BH} at a given σ_* at $z \sim 1$. CO line widths indicate that at $z \sim 4$ to 6, giant black holes exist in undersized galaxies. The largest QSO black holes violate the standard M_{BH} - σ_* relationship.

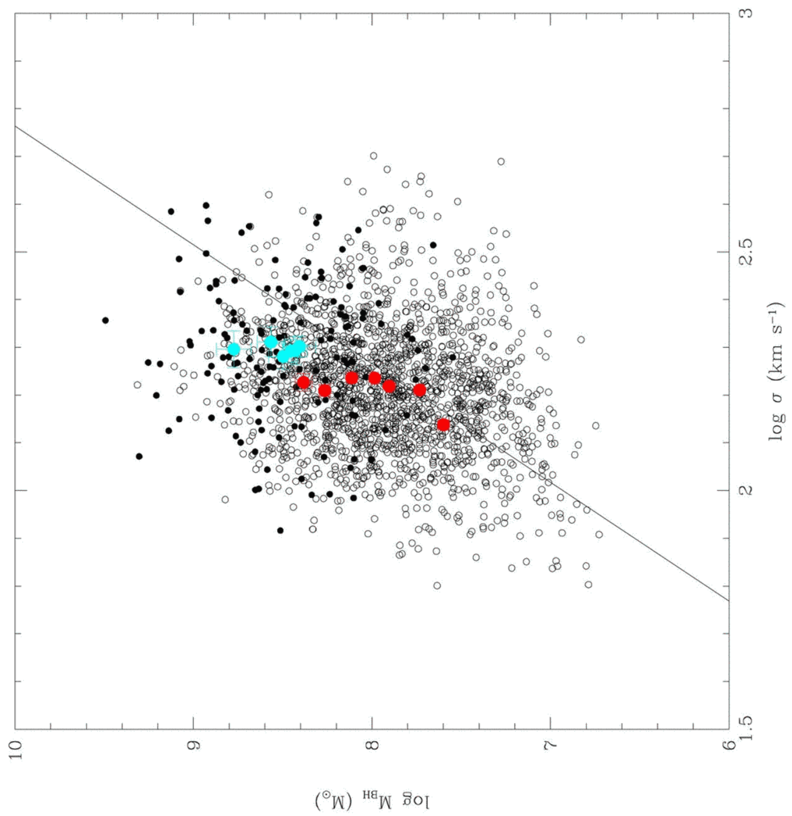
M_{BH} - σ Relationship in AGN

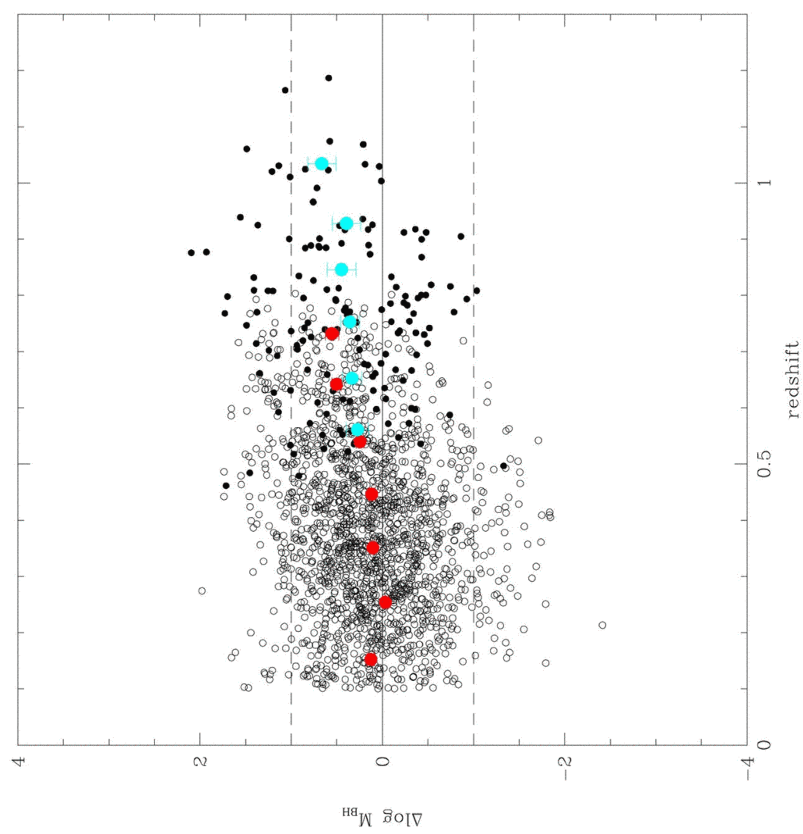
- Reverberation mapping gives BLR radius, scales as $R \propto L^{0.5}$ to $L^{0.7}$ (e.g., Kaspi et al. 2000, 2005; Bentz et al. 2006)
- Width of Hβ, Mg II, C IV gives $M_{BH} = (10^{7.69} M_{\odot}) v_{3000}^{2} L_{44}^{0.5}$
- Width of [O III] λ5007 line is indicator of σ (Nelson & Whittle 1996, Nelson 2000, Boroson 2003, Bonning et al. 2005): $\sigma_* =$ FWHM of [O III] / 2.35. Needs confirmation for luminous QSOs.
- Study $M_{BH} - \sigma_*$ relationship (Ferrarese & Merritt 2000; Gebhardt et al. 2000; Tremaine et al. 2002):
  $M_{BH} = (10^{8.13} M_{\odot})(\sigma_*/200)^{4.02}$

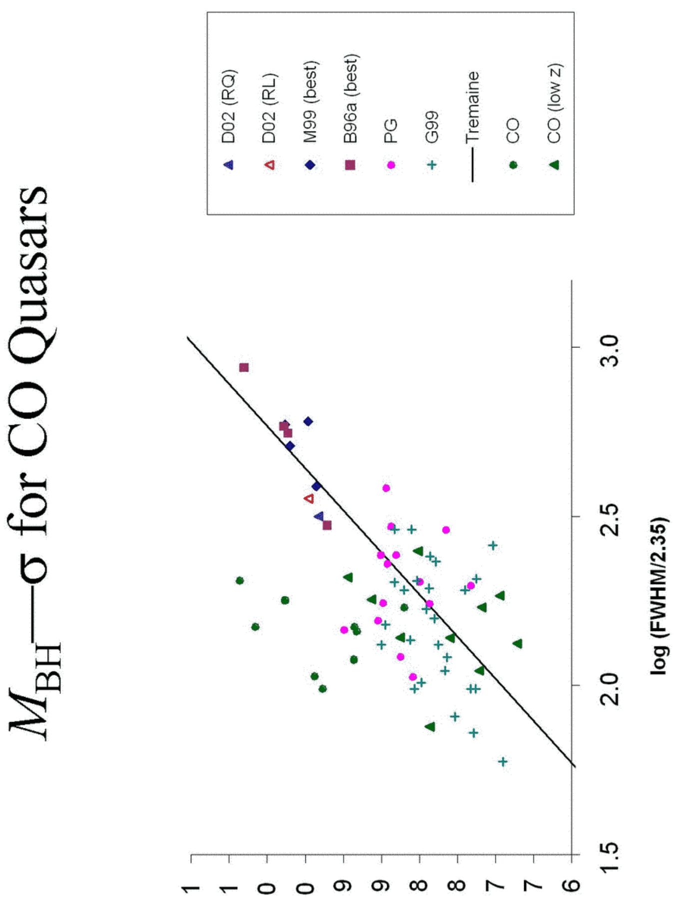
Evolution of $M_{BH} - \sigma_*$

- Shields et al. (2003) find little change at z ~ 2 based on [O III] widths, for large BH in luminous QSOs.
- Salviander et al. (2006 submitted) find a 0.3±0.3 dex increase in M_{BH} at given σ_* at z ~ 1 using [O III] and [O II] for SDSS QSOs. Selection effects important.
- Peng et al. (2005) find BH mass 3 - 6 times too large for host mass using lensed QSOs at $z \sim 2$.
- Borys et al. (2005) find black holes much *smaller* than expected for stellar mass in SMGs at $z \sim 2$.
- Shields et al. (2006) use width of CO radio lines as surrogate for σ. At z > 4, giant black holes occur in QSOs with narrow CO lines suggesting modest galaxies.
- Can one get tight $M_{BH} - \sigma_*$ if black hole grows first?

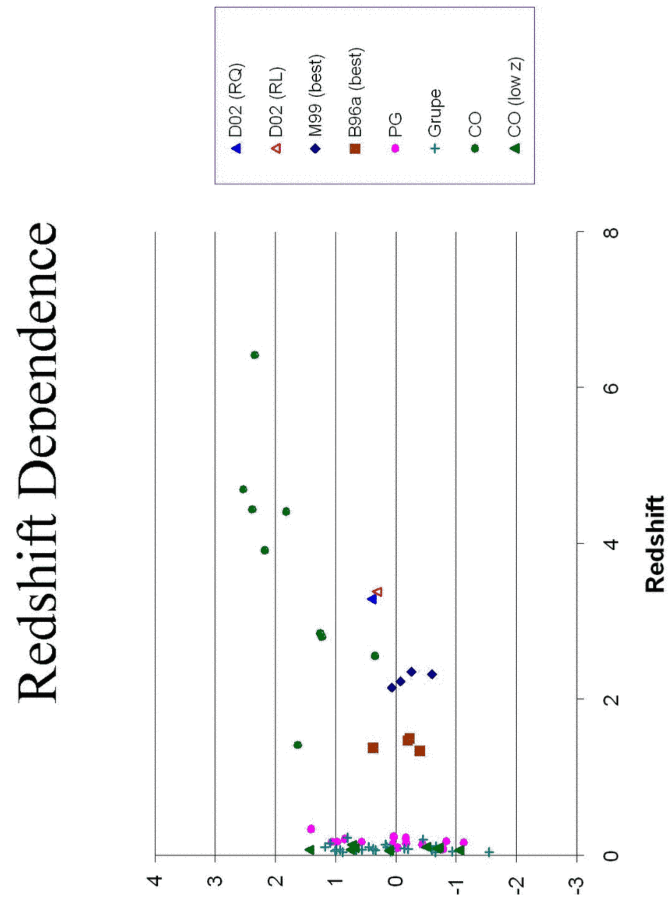
Salviander et al (2006) submitted







M_{BH}—σ for CO Quasars
D02 (RQ)
D02 (RL)
M99 (best)
B96a (best)
PG
G99
Tremaine
CO
CO (low z)
log (FWHM/2.35)
1.5
2.0
2.5
3.0
11
11
10
10
9
9
8
8
7
7
6



Redshift Dependence
D02 (RQ)
D02 (RL)
M99 (best)
B96a (best)
PG
Grupe
CO
CO (low z)
Redshift
0
2
4
6
8
4
3
2
1
0
-1
-2
-3

Host Galaxies of the Largest Black Holes

- Masses of QSO black holes from broad emission line widths call into question the normal M_{BH} - bulge relationship (Netzer 2003; Wyithe & Loeb 2003).
- Most QSOs at redshift ~2 with $\nu L_{\nu}(5100\ \text{Å}) > 10^{46.6}$ erg s^{-1} have $M_{BH} > 5$ billion $M_{\odot}$. These masses are based on broad emission-line widths and are supported by the Eddington limit.
- QSO luminosity function gives ~6 such QSOs per comoving Gpc^{3}. For a QSO lifetime of 50 million years, and a QSO epoch lasting 3 billion years, there should be $\sim 10^{2.3}$ Gpc^{-3} former host galaxies with $M > 10^{12.4}\ M_{\odot}$ and $\sigma > 500$ km s^{-1} by local relationships.

- Nearest such BH should be ~100 Mpc from earth, corresponding to largest cluster galaxies such as NGC 6166. These have $\sigma_{*} \sim 350$ km/s but luminosity is commensurate with BH *if* cD halo is included (see Lauer et al. 2006).