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QSO HOST GALAXY LUMINOSITY AND [O III] LINE WIDTH AS A SURROGATE FOR STELLAR VELOCITY DISTRIBUTION

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Supermassive black holes in galactic nuclei show a close relationship between the black hole mass $M_{\rm BH}$ and the luminosity L and stellar velocity dispersion σ_* of the host galaxy bulge. Probing these relationships at high redshift may shed light on the link between the formation of the galactic bulge and central black hole, but direct measurements of σ_* at high redshift are difficult. We show that [O III] line widths provide a useful surrogate for σ_* by comparing $\sigma_{\rm [O\ III]}$ with the value of σ_* predicted by the Faber-Jackson relation for QSOs with measured host galaxy luminosity. Over a wide range of AGN luminosity, $\sigma_{\rm [O\ III]}$ tracks σ_*, albeit with considerable scatter. [O III] line widths are narrower by 0.1 dex in radio-loud QSOs than in radio-quiet QSOs of similar $L_{\rm host}$. In low redshift QSOs, the ratio of star formation rate to black hole growth rate is much smaller than the typical ratio of bulge mass to black hole mass.

Nelson & Whittle (1995, 1996) made a comparison of bulge magnitudes, [O III] line widths, and σ_* in Seyfert galaxies, finding on average good agreement between σ_* and $\sigma_{\rm [O\ III]} \equiv$ FWHM([O III])/2.35. However, direct comparisons of $\sigma_{\rm [O\ III]}$ with σ_* have generally been limited to lower luminosity AGN, and it is important to evaluate the substitution of $\sigma_{\rm [O\ III]}$ for σ_* at higher QSO luminosities. Here we do this by studying the Faber-Jackson relation (Forbes & Ponman 1999; Kormendy & Illingworth 1983) for a sample of quasars for which host galaxy luminosities are available.

Host galaxy magnitudes for ellipticals, and bulge magnitudes for spiral hosts were taken from the literature and from our own unpublished measurements (see Bonning et al. 2005 for details). The [O III] line width, continuum luminosity, and broad Hβ width were measured from spectra from Marziani et al. (2003) and McLure & Dunlop (2001). We assume a cosmology with $H_0 = 70$ km s^{-1} Mpc^{-1}, $\Omega_{\rm M} = 0.3, \Omega_\Lambda = 0.7$.

Our results for host magnitude ($M_{\rm host}$) and $\sigma_{\rm [O\ III]}$, plotted in Figure 1, agree in the mean with the Faber-Jackson relation. Intrinsic scatter is ~ 0.13 dex in $\sigma_{\rm [O\ III]}$, sufficient to obscure the expected increase in $\sigma_{\rm [O\ III]}$ over our limited range of $M_{\rm host}$. However, Figure 2 shows a clear increase in $\sigma_{\rm [O\ III]}$ with σ_* over a much wider range of AGN luminosity, using objects for which σ_* is directly measured or inferred from $L_{\rm host}$ or $M_{\rm BH}$.

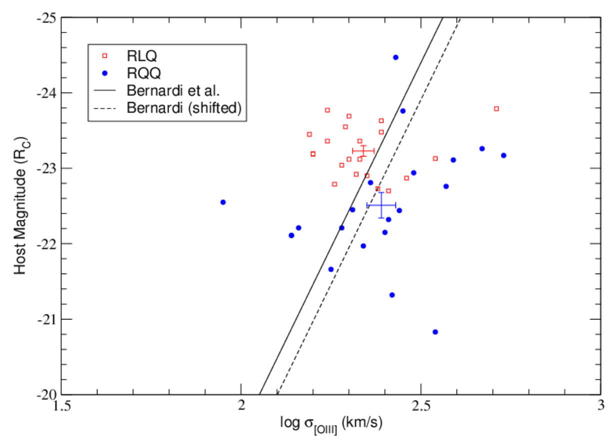

Fig. 1. The above plot shows the sample of quasars for which we have host galaxy bulge magnitudes ($R_{\rm Cousins}$) and $\sigma_{\rm [O\ III]}$. The straight line is the Faber-Jackson relation measured by Bernardi et al. (2003); the dashed line is the same relation with log σ displaced by 0.05 (see Bonning et al. 2005). The crosses indicate the mean values and errors of the mean, the RL being above and to the left of the RQ mean. (From Bonning et al. 2005)

Our RL objects have, on average, narrower [O III] lines than the RQ objects, for a given $L_{\rm host}$. A similar RL - RQ offset has been observed in the $M_{\rm BH} - \sigma_{\rm [O\ III]}$ relation for QSOs by Shields et al. (2003) and by Bian & Zhao (2004). The latter suggested that geometrical effects in RLQ might affect the observed Hβ widths or continuum luminosity,

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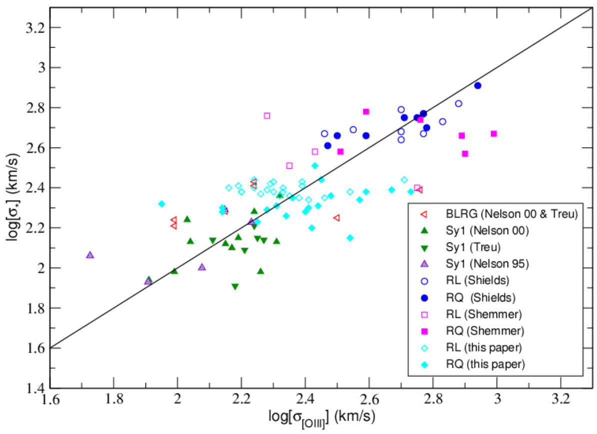

Fig. 2. Plot of $\sigma_{[\mathrm{O\ III}]}$ v σ_* (measured or inferred) for our data sample and others. QSOs from this paper have σ_* calculated from their host luminosity via the Faber-Jackson relation. The broad line radio galaxies (BLRG) and Seyferts (see legend) have directly measured σ_*. High luminosity QSOs from Shields et al. (2003) and Shemmer et al. (2004) have σ_* calculated from the M_{BH} – σ_* relation (Tremaine et al. 2002). (From Bonning et al. 2005)

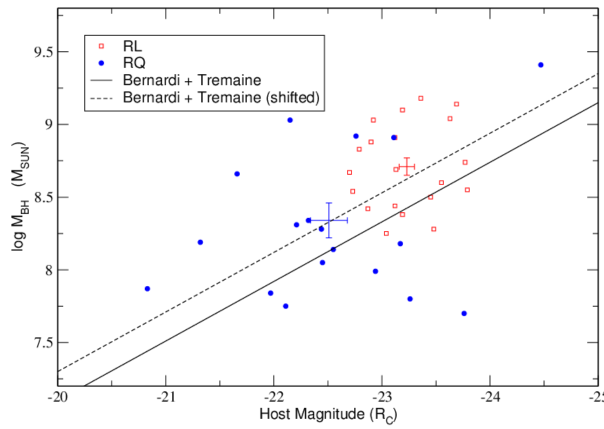

Fig. 3. M_{BH} versus M_{host} for the same objects as Figure 1. It can be seen that the RL objects are not offset from the RQ objects in relation to the normal M_{BH} – M_{host} trend. (From Bonning et al. 2005)

used to derive M_{BH} (Shields et al. 2003). However, a comparison of M_{BH} with M_{host} (Figure 3) shows no significant offset of RL objects relative to the expected slope. This suggests that narrower $\sigma_{[\mathrm{O\ III}]}$ for RL objects is responsible for the RL-RQ offset, and not any systematic effect involving M_{BH}.

The proportionality of black hole mass and bulge mass, $M_{\mathrm{BH}} \approx 0.0013 M_{\mathrm{bulge}}$ (Kormendy & Gebhardt 2001) raises the question of whether black hole growth and bulge growth occur simultaneously. The average bolometric luminosity of our RQQ ($L \approx 10^{45.7}$ erg s^{-1}) corresponds to an accretion rate $\dot{M} \approx 1\ M_\odot\,\mathrm{yr}^{-1}$ for an efficiency $L \approx 0.1\dot{M}c^2$. The corresponding star formation rate is $\sim 700\ M_\odot\ \mathrm{yr}^{-1}$ to maintain the black hole – bulge relationship. Such rates are observed in some ULIRGs but not in the PG QSOs of our sample. Ho (2005) finds that star formation is supressed in PG QSOs, despite abundant molecular gas. Star formation in PG QSOs is far less than required to maintain detailed balance between bulge and black hole mass. However, the main growth of the black hole at higher redshifts may involve more nearly simultaneous star formation and bulge growth.

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