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SMBH mass function from velocity dispersion and luminosity

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Abstract. Black hole masses are tightly correlated with the stellar velocity dispersion of host galaxies, and slightly less-well correlated with the bulge luminosities. The $M_\bullet$-σ relation predicts fewer massive black holes than does the $M_\bullet$-L relation. This is because the L-σ in black hole samples currently available is inconsistent with that in the samples from which the distributions of L or σ are based. This suggests that current black hole samples are biased towards objects with abnormally large σ for their luminosities, and then the $M_\bullet$-σ and $M_\bullet$-L relations currently in the literature are also biased from their intrinsic values. Our analysis suggests that the bias in the $M_\bullet$-σ relation is likely to be small, whereas the $M_\bullet$-L relation is biased towards predicting more massive black holes for a given luminosity.

1. Introduction

Black holes masses $M_\bullet$ are observed to correlate strongly and tightly with the velocity dispersion of the surrounding bulge, and slightly less-well with the bulge luminosities. In this work we analyze the two relations by comparing the SMBH mass function derived from them.

2. Analysis

Our own fits to the two relations in the sample of Häring & Rix (2004) selecting early type galaxies are (Tundo et al. , 2007):

$\log(M_\bullet/M_\odot) = (8.21 \pm 0.06) + (3.83 \pm 0.21)\log(\sigma/\sigma_0)$ ($\Sigma_{M_\bullet|\sigma} = 0.22 \pm 0.06$ dex) ; $\log(M_\bullet/M_\odot) = (8.68{\pm}0.10)-(1.30{\pm}0.15)(M_r+22)/2.5$ ($\Sigma_{M_\bullet|M_r} = 0.34 \pm 0.09$ dex) ; $\sigma_0 = 200$ km/s^{-1}

We have transformed (see Fig. 1) the velocity dispersion function of Sheth et al. (2003) and the luminosity function of Blanton et al. (2003) augmented by the luminosity function of BCGs by Hyde et al. (2007) by coupling them with the above relations.

The L and σ based predictors should give the same result, so one of the relation may be uncorrect. The L-σ relation in the Häring & Rix (2004) sample is different from the one predicted in the Sloan Digital Sky Survey sample or the ENEAR sample (Bernardi , 2007) (see Figure 2).

$\log\sigma = (2.287 \pm 0.012) - (0.255 \pm 0.085)(M_r + 22)/2.5$ [SDSS]

$\log\sigma = (2.42 \pm 0.1) - (0.34 \pm 0.03)(M_r + 22)/2.5$ [H&R]

To account for this effect we made a mock catalog of the true joint distribution of $M_\bullet$, L and σ and measured the pairwise correlations

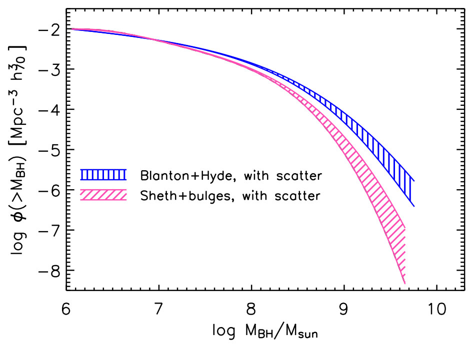

Fig. 1. σ-based and L-based cumulative mass function $\phi(> M_\bullet)$, from the distribution functions of Sheth et al. (2003), and Blanton et al. (2003) plus Hyde et al. (2007).

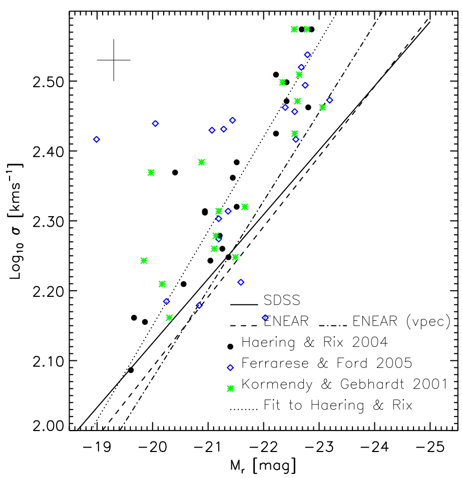

Fig. 2. Samples of early-type galaxies with measured black hole mass show a different L-σ behaviour respect to that predicted by other samples (SDSS, ENEAR). Different symbols refer to different local samples.

before and after applying the selection procedure to this joint distribution (Bernardi et al , 2007). In Figure 3 open diamonds show the objects in the original catalog, and the filled circles show the objects which survived the selection procedure. Dashed and solid lines show the slope of the relation before and after the selection. The relations in the selected sample are in good agreement with estimates of Tundo et al. (2007). The agreement is nontrivial: a change of 5% in the parameters of the model produce significative differences. Our simulations show that the slope of the $M_\bullet$-σ in the selected sample is not changed from its original value, whereas the $M_\bullet$-L is steeper. Estimates $\phi(M_\bullet)$ from $M_\bullet$-L relation and a L distribution may overpredict the true abundances of massive black holes.

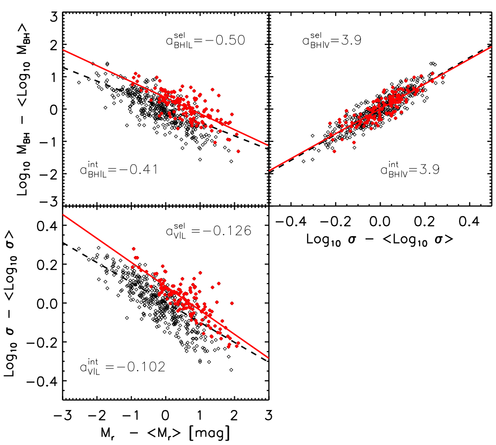

Fig. 3. Mock catalog reproducing the relations found in SDSS (open squares), and a selected sample that reproduce the biased relations observed in local $M_\bullet$ samples (filled circles). Bottom panel: L-σ. Upper panels: $M_\bullet$-σ and $M_\bullet$-L

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