Using a Novel Methodology to Constrain the Supermassive Black Hole-Galaxy Coevolution and Analysis of the Selection Bias

UNIVERSITY OF CALIFORNIA SANTA CRUZ

SIP SCIENCE INTERNSHIP PROGRAM

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Introduction

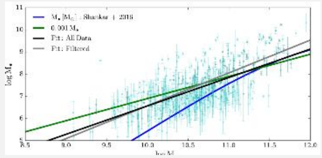
The impact that supermassive black holes (SMBHs) can have on their surrounding host galaxies is profound yet still poorly understood. In fact, the why, how, and when black holes alter the evolutionary pathways of their host galaxies remain as some of the major questions in astronomy. One of the most important results is the discovery that the masses of the central SMBHs are well correlated with the properties of their host galaxies, especially with the bulge properties. This suggests that the formation of the galactic central black hole and the bulge are intimately correlated and that the relationship between SMBHs and their host galaxies is the key to understanding galaxy formation. In this work, we analyze over 500 distinct galaxies with individual measurements of black hole mass, stellar velocity dispersion, and stellar mass. We report preliminary scaling relations for the SMBH mass-velocity dispersion and SMBH-stellar mass relationships. We also present preliminary estimations of the redshift evolution of the SMBH mass function derived based on these scaling relations. Finally, we present a simple model in which we measure the history of formation of black holes and galaxies.

Methods

Compared to previous studies that have derived the evolution of SMBHs based on empirical estimates from the stellar mass abundance of galaxies, we took the liberty of using the novel methodology of a convolution method as the basis of our research. This general method allows us to construct black hole masses not based solely on one galaxy property but on a large variety of galaxy properties. In doing so, we establish a fair standard to see how the velocity dispersion and stellar mass methods compare in SMBH-galaxy coevolution, especially in evolution at high redshifts.

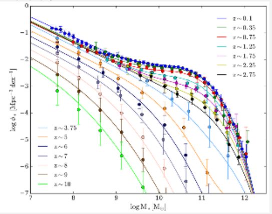
$$\phi_p(p) = \int_0^\infty P(p|q)\phi(q)dq$$

Stellar Mass:



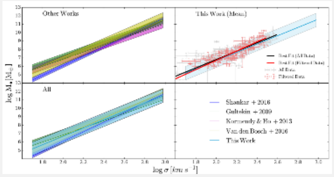
Stellar Mass - Black Hole Mass

×



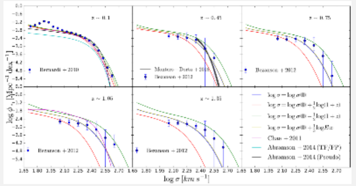
Stellar Mass Number Density

Velocity Dispersion:



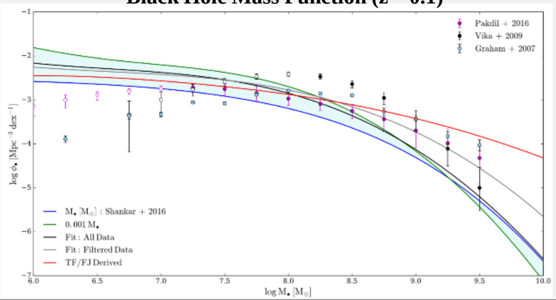
Velocity Dispersion – Black Hole Mass

×



Velocity Dispersion Density

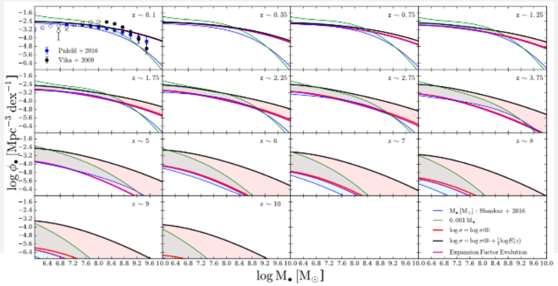
Black Hole Mass Function (z ~ 0.1)



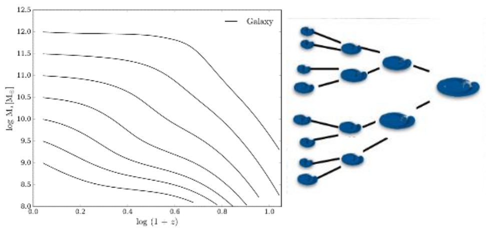
Results

We use black hole mass functions derived from velocity dispersions and total stellar masses to begin interpreting our results. Comparison with previous inferences show that our SMBH MF are in good agreement with the literature, so we construct mass growth plots. We infer the Stellar and Black Hole mass growth by using their corresponding number densities. We assume that Stellar and Black Hole mass mergers do not contribute significantly to the growth.

Black Hole Mass Density

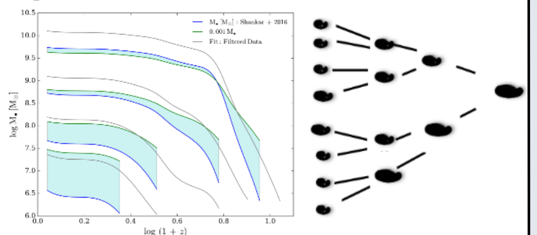


Mass Growth Comparison



Reality   Illustrative

Stellar Mass Growth Representations



Reality   Illustrative

Black Hole Mass Growth Representations

Discussion

The speculated reasoning for the causes of the coevolution of galaxies and their black holes follows the timeline of a galaxy's star formation rate. When a galaxy first forms in the early universe, it has rapid star formation as there are vast amounts of gas available. Massive stars explode as supernovae, ejecting dust and gas that is pulled back in and cycles back through the galaxy, to be reused to form more stars. The next portion of the evolution comes where the black hole reaches a peak mass and ejects all of the aforementioned dust and gas from the galaxy. Reaching that peak mass activates the SMBH and the galactic winds produced by the black hole prevent the dust and gas from reforming into stars. Additionally, our results confirm properties that we observe in galaxies today.

Conclusions and Future Work

In our paper, we sought to study the coevolution between galaxies and SMBHs over a broad history of cosmic time. Using our convolution method, we compared the stellar mass and velocity dispersion methods of constructing the BHMF and found further evidence of a SMBH-galaxy coevolution. Finally, we began questioning the bias outlined in the Shankar paper. In the future, we plan to evaluate the coevolution with more galaxy properties, compare galaxy morphologies, and as we receive more data, further investigate the bias.

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