Galaxies and supermassive black holes in the local universe: the Velocity Dispersion Function and Black Hole Mass Function

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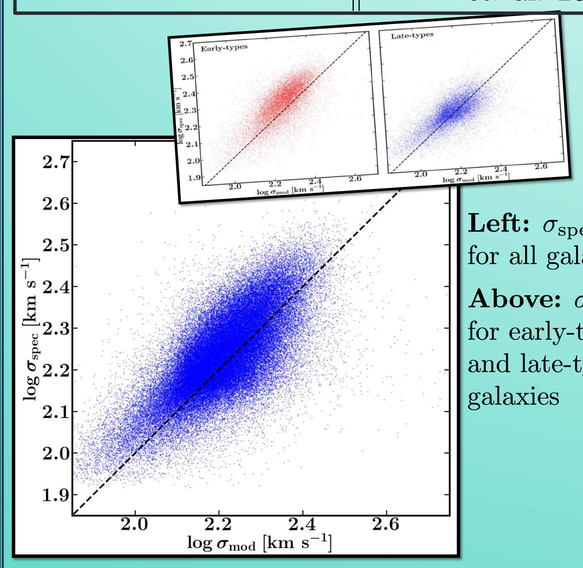
Objectives

1. **Determine the Velocity Dispersion Function (VDF) of galaxies at $0.01 \leq z \leq 0.1$ in SDSS from a sample complete for all velocity dispersions σ**
2. **Determine the Black Hole Mass Function (BHMF) for these galaxies**

We use two definitions of σ:

$\sigma_{\rm spec}$	$\sigma_{\rm mod}$
Observed σ from SDSS spectroscopy	σ inferred from stellar mass, effective radius, and Sersic index (Bezanson et. al. 2011)



Left: $\sigma_{\rm spec}$ vs. $\sigma_{\rm mod}$ for all galaxies

Above: $\sigma_{\rm spec}$ vs. $\sigma_{\rm mod}$ for early-type (left) and late-type (right) galaxies

→ $\sigma_{\rm spec}$ systematically higher than $\sigma_{\rm mod}$

$\Longrightarrow$ $\sigma_{\rm spec}$ may include rotational of a velocity of a galaxy!

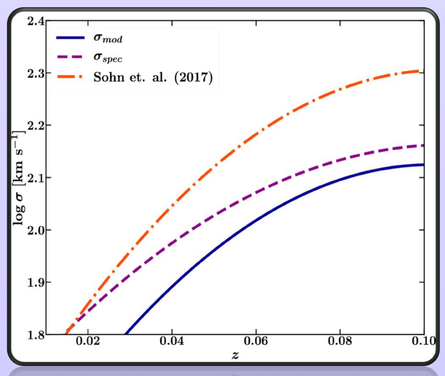
Data

- Velocity dispersions from Portsmouth group (Thomas et. al. 2013); SDSS DR12
- Stellar masses from MPA-JHU group (Brinchmann et. al. 2004)
- Effective radii and Sersic indices from NYU VAGC (Blanton et. al. 2005)
- Galaxy type classifications (early/late) from Galaxy Zoo (Lintott et. al. 2008)

Completeness

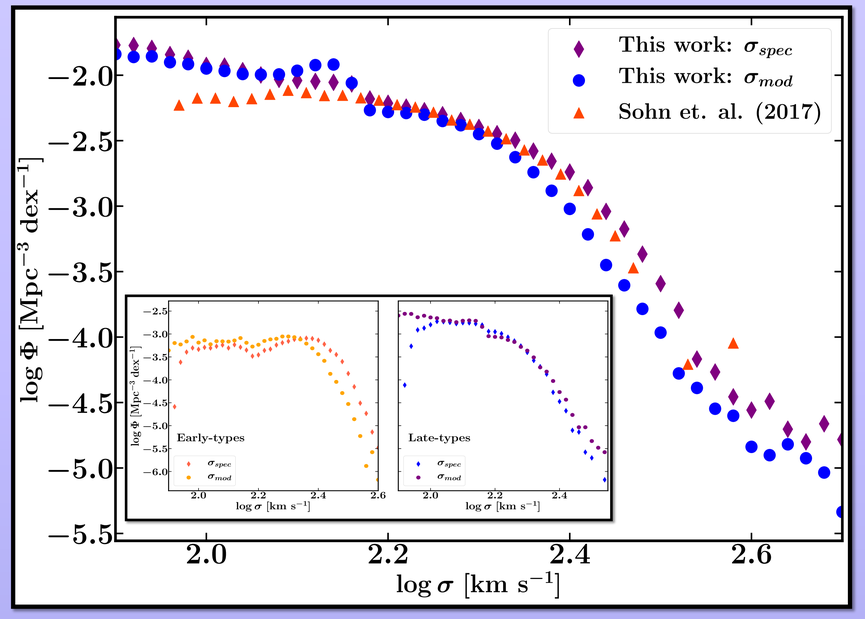
- We select galaxies for which σ is greater than the σ-completeness limit at that redshift
- ~ 118000 galaxies in the complete $\sigma_{\rm spec}$ sample and ~ 105000 galaxies in the complete $\sigma_{\rm mod}$ sample

Right: σ-completeness limit as a function of redshift for the $\sigma_{\rm spec}$ sample (purple), $\sigma_{\rm mod}$ sample (blue) and Sohn et. al's (2017) sample of quiescent galaxies.



The VDF

Each galaxy was weighed by the max. volume in which it could be found ($1/V_{max}$ method).

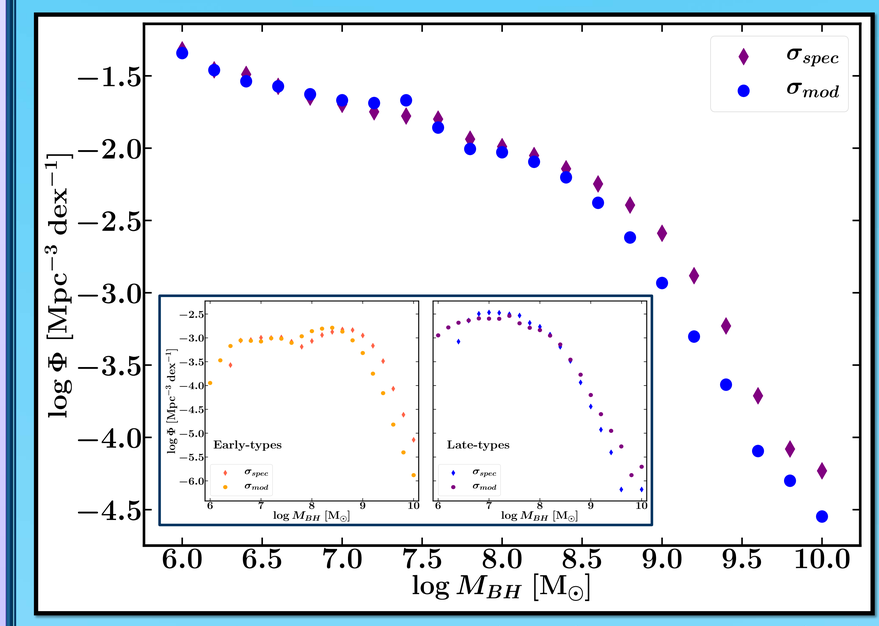


Above: VDF from our $\sigma_{\rm spec}$ sample (purple) and $\sigma_{\rm mod}$ sample (blue)
Inset: VDF for early-type (left) and late-type (right) galaxies

- VDF slowly declining up to $\log\sigma \sim 2.3$, rapid decline at $\log\sigma \gtrsim 2.4$
- $\sigma_{\rm spec}$ and $\sigma_{\rm mod}$ VDFs similar; $\sigma_{\rm mod}$ VDF slightly lower
- Early-types dominate high σ distribution, late-types dominate low σ distribution

The BHMF

Assuming each galaxy contains a central SMBH, we convert σ to a black hole mass, M_{BH}, using van den Bosch's (2016) $M_{BH} - \sigma$ relation, then use $1/V_{max}$.



Above: BHMF from our $\sigma_{\rm spec}$ sample (purple) and $\sigma_{\rm mod}$ sample (blue)
Inset: BHMF for early-type (left) and late-type (right) galaxies

- BHMF declines slowly for low mass SMBHs, and rapidly for $M_{BH} \gtrsim 10^{8.5}$ M$_\odot$
- Lots of low-mass SMBHs ($M_{BH} \lesssim 10^{7}$ M$_\odot$), very few high mass ones ($M_{BH} \gtrsim 10^{9}$ M$_\odot$)
- Early-types host more massive SMBHs than late-types.

SMBH mass density

We find the present day mass density:

$$\rho_{BH} = \left(2.71^{+0.55}_{-0.43}\right) \times 10^5 \ \mathrm{M}_\odot \ \mathrm{Mpc}^{-3}$$

→ Matches density observed from high-z AGN relics, with avg. radiative efficiency $\epsilon \sim 0.07 - 0.1$

$\Longrightarrow$ accretion primary mode of SMBH growth

References: 1) Bezanson, R., et al. 2011, ApJ, 737, L31, 2) Thomas, D., et al. 2013, MNRAS, 431, 1383, 3) Brinchmann, J., et al. 2004, MNRAS, 351, 1151, 4) Blanton, M. R., et al 2005, AJ, 129, 2562, 5) Lintott, C. J., et al. 2008, MNRAS, 389, 1179, 6) Sohn, J., et. al. 2017, ApJ, 845, 73, 7) Van den Bosch, R. C. E., 2016, ApJ, 831, 134