The Role of Massive Black Holes in Romulus25 Dwarf Galaxy Evolution

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Introduction

The role of massive black holes (BHs) in the evolution of dwarf galaxies is only now becoming possible to probe via both simulations and observations. It is currently unclear how black holes form, grow, and affect their environment within dwarf galaxies. If BHs play a significant role in dwarf galaxy evolution, we expect to find similar indicators of their presence that are seen in massive galaxies.

We analyze how black holes form, grow, and affect their host dwarf galaxy ($M_{star} < 10^{10}$) in the Romulus25 cosmological hydrodynamic simulation. We study BH - host scaling relations (M_{BH} - M_{star}), host structural relations (M_{star} - M_{vir}; Σ_e - M_{star}), and BH - host energetics.

Simulation Properties

The physics in Romulus25 make it uniquely suitable for studying BHs in dwarf galaxies in a cosmological context. Romulus25 contains a statistical sample of low-mass galaxies in a cosmological volume, run to redshift $z = 0$.

Romulus25 properties:

- $(25\ \mathrm{cMpc})^3$ uniform volume w/ periodic boundary conditions
- 250 pc spatial resolution
- Particle mass: $m_{DM} = 3.39 \times 10^5\ M_\odot$, $m_{star} = 2.12 \times 10^5\ M_\odot$

Black hole seeding based on environment:

- Gas metallicity, $Z < 3 \times 10^{-4}$
- Gas density threshold, $n_{BH} = 15 \times n_\star$
- Temperature, T = 9500 - 10,000 K

Black hole physics:

- Dynamical friction sub-grid prescription
- Rotationally supported, Eddington-limited Bondi accretion
- Thermal BH feedback
- Mergers within 2 softening lengths

References

Reines & Volonteri (2015) ApJ, 813, 82
Schramm & Silverman (2013) ApJ, 767, 13

Acknowledgements

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Poster, additional plots, and data available
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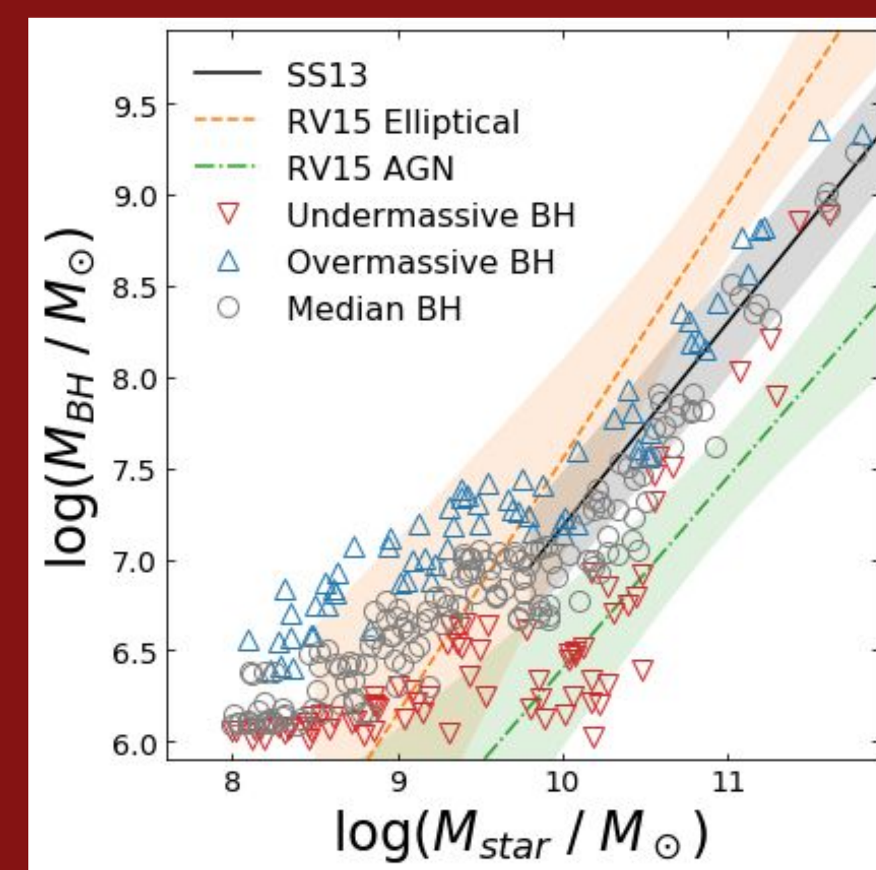
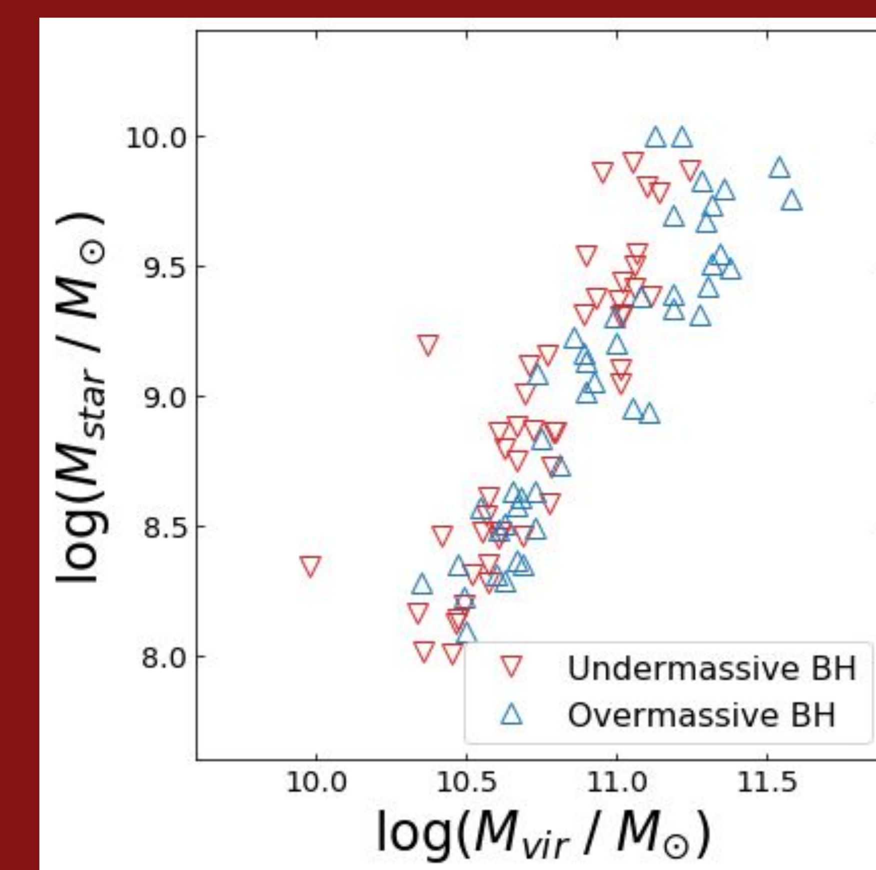
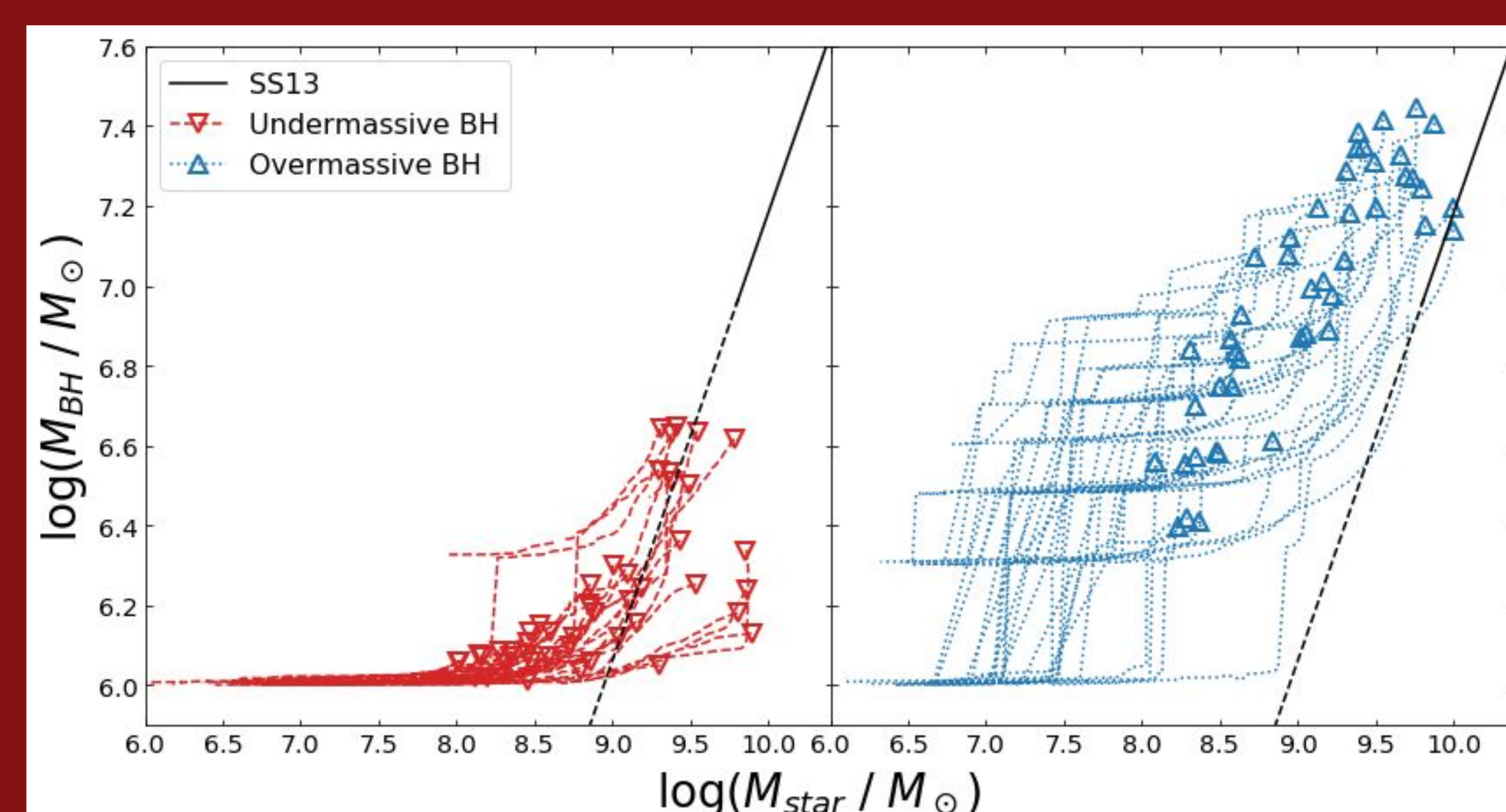
"Overmassive black holes can **suppress star formation** in Romulus25 **dwarf galaxies** via **feedback**."



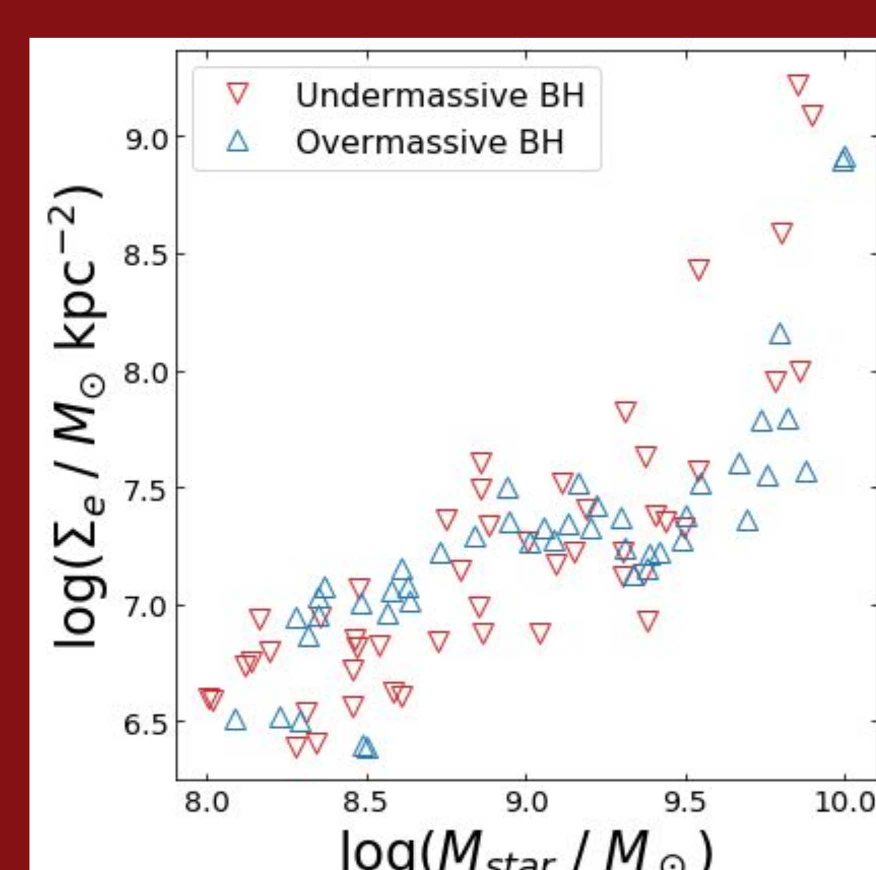
[1] BH Mass - Stellar Mass



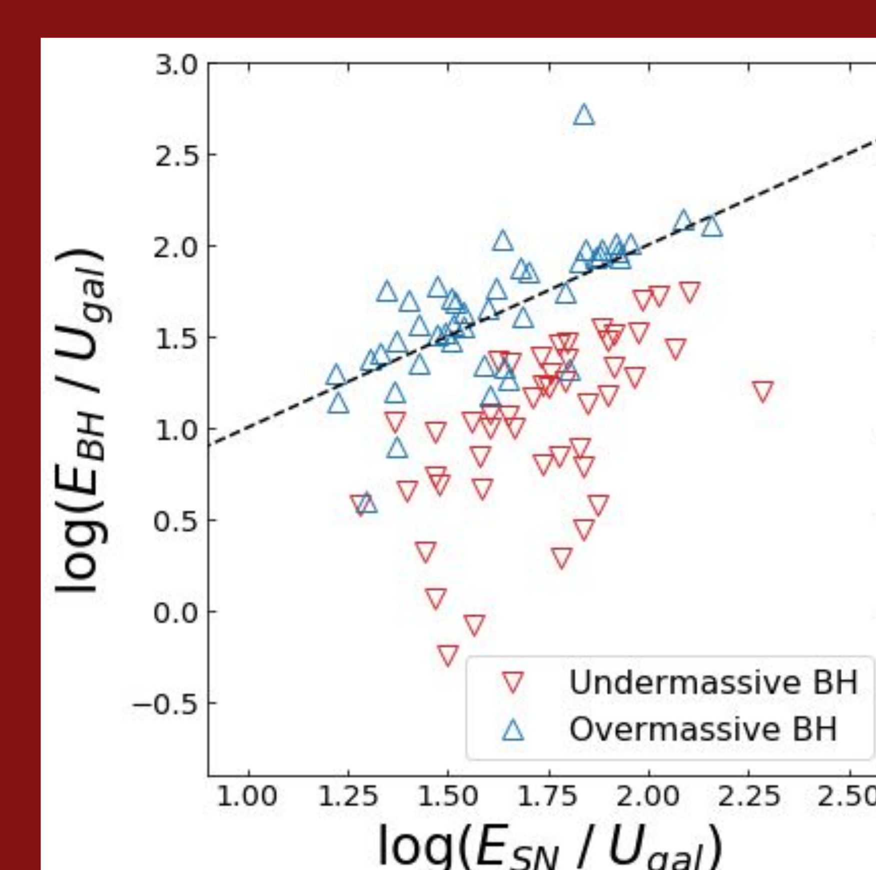
[2] Stellar Mass - Halo Mass



[3] BH Mass - Stellar Mass Evolution



[4] Central Density - Stellar Mass



[5] BH Energy - SN Energy

Results

We restrict our sample to contain only central halos (no subhalos), only dwarf galaxies below $M_{star} < 10^{10}\ M_\odot$, and galaxies containing a central BH within the central 2 kpc.

[Figure 1] *Black hole mass - stellar mass relation* at $z = 0$ compared with observations from Reines & Volonteri (2015) [RV15] and Schramm & Silverman (2013) [SS13]. Shaded regions indicate 1σ uncertainties in measurements. Galaxies below $M_{star} < 10^{10}\ M_\odot$ exhibit a large amount of scatter in M_{BH} that is not seen in higher mass galaxies. We categorize each BH by M_{BH}:

- Overmassive BHs = 75th percentile
- Undermassive BHs = 25th percentile
- Median BHs = 25th—75th percentile

[Figure 2] *Stellar mass - halo mass relation* for dwarf galaxies at $z = 0$. Hosts of overmassive BHs above $M_{star} > 10^9\ M_\odot$ tend to exhibit lower M_{star} than expected for their M_{vir}.

[Figure 3] *Dwarf galaxy time evolution along the M_{BH} - M_{star} relation*. The dashed portion represents the linear extrapolation of the SS13 relation. Hosts of undermassive BHs grow their stars before growing their central BH. Hosts of overmassive BHs instead grow their BH through mergers and accretion before growing their stars.

[Figure 4] *Central stellar density - stellar mass relation* for dwarf galaxies at $z = 0$. Σ_e denotes the central surface density of stars within the effective radius. Hosts of overmassive BHs above $M_{star} > 10^9\ M_\odot$ sit on a relation with lower Σ_e than hosts of undermassive BHs.

[Figure 5] *Total energy injected by black holes vs supernovae* at $z = 0$ compared with the 1-1 relation. Each energy is scaled to the galaxy binding energy at the effective radius. Overmassive BHs are capable of injecting more energy into the surrounding interstellar medium than supernovae. Undermassive BHs instead fall below the relation.

Conclusions

- Central dwarf galaxies within Romulus25 may host a wide range of central BH masses.
- Overmassive and undermassive BHs grow at different times relative to the surrounding stars of the host galaxy.
- Hosts of overmassive BHs exhibit both lower stellar mass and lower central stellar density versus undermassive BH hosts, at a given halo mass.
- Hosts of undermassive BHs are dominated by energy injection via supernovae, while many hosts of overmassive BHs are dominated by BH feedback.
- Overmassive black holes suppress star formation in Romulus25 dwarf galaxies via feedback.

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