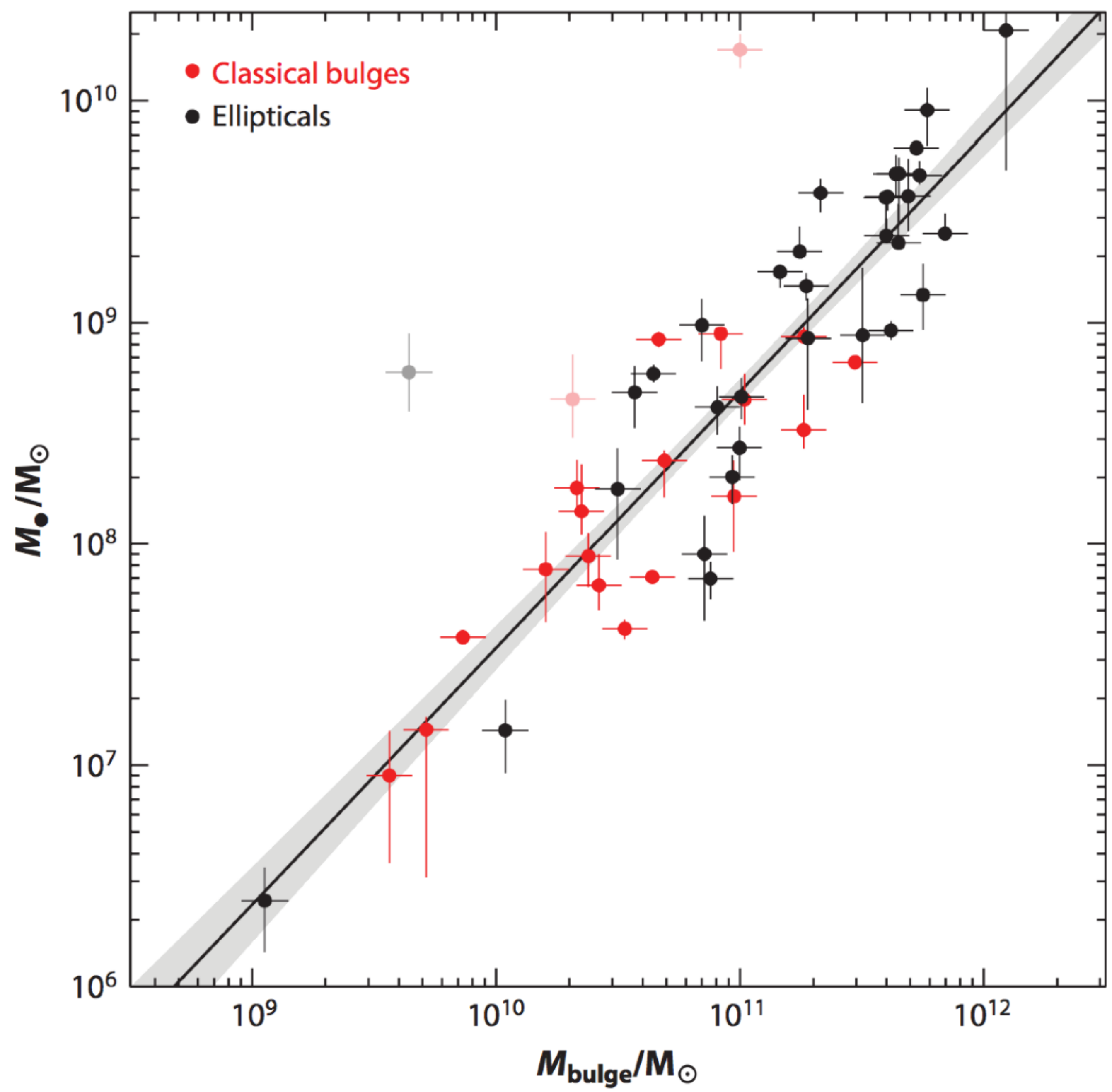
Exploring High-z Black Hole - Bulge Relations With Semi-Analytics

Madeline Marshall

with Stuart Wyithe & Simon Mutch

Black Hole - Host Relations

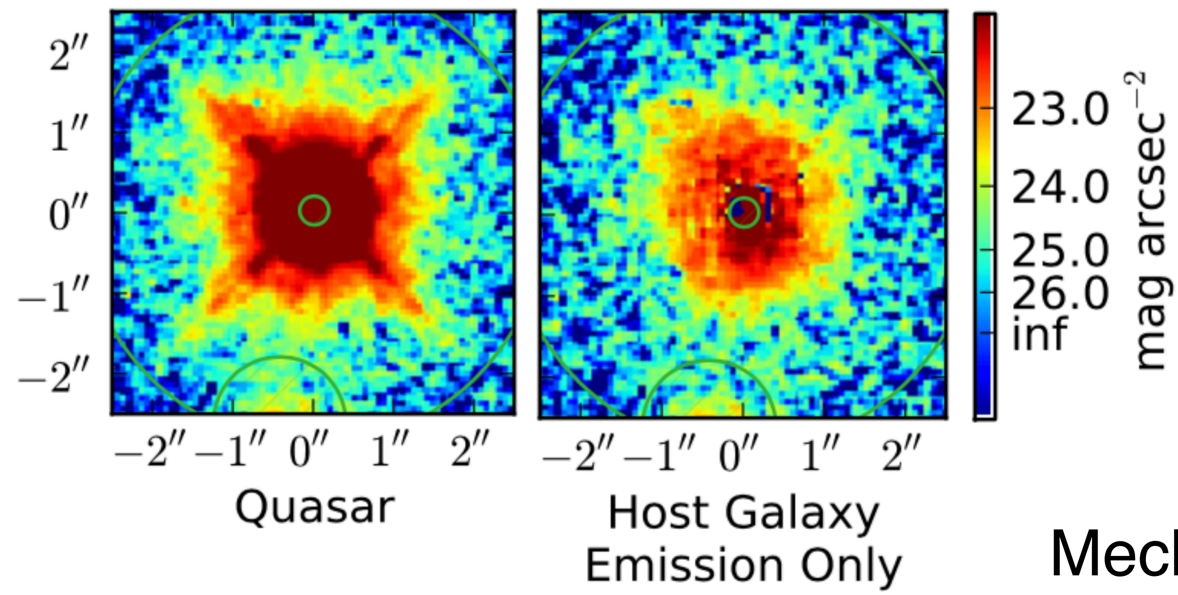
- Correlations between black holes and hosts at low redshift
- To understand, need to study at high redshift



Kormendy & Ho (2013)

High Redshift Quasar Hosts

- High-z quasar hosts are hard to detect



Mechtley et al. (2016)

- Haven't detected any z~6 hosts in rest-frame UV or optical
- We're observing two z~6 quasars with JWST, so developing models while we wait

MERAXES

Semi-Analytic Model

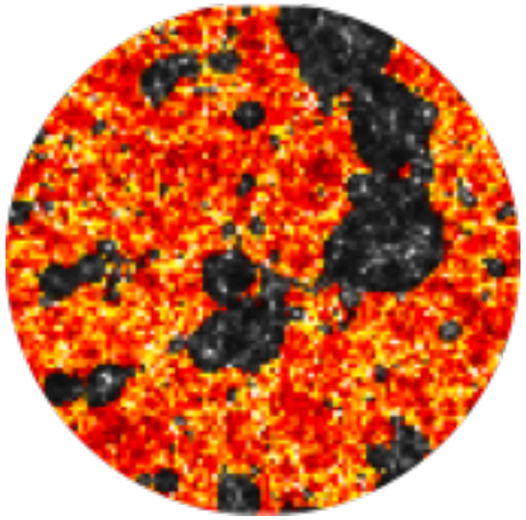
(Mutch et al. 2016)

- Semi-analytic model designed for studying galaxy formation during epoch of reionization
- Add galaxies to dark matter haloes from N-body simulations

	Tiamat	Tiamat-125-HR
Redshift Range	$z = 35 - 2$	$z = 35 - 0$
Time Cadence	11.1 Myr per snapshot to $z = 5$	
Box Size	$(100\ \mathrm{Mpc})^3$	$(184\ \mathrm{Mpc})^3$
Particle Mass	$3.89\times10^6\ M_\odot$	$1.77\times10^8\ M_\odot$

MERAXES

Semi-Analytic Model
(Mutch et al. 2016)



- Models physical processes:
  - Baryonic infall
  - Gas cooling
  - Star formation (density-dependent prescription)
  - Metal enrichment
  - Supernova feedback
  - AGN feedback
  - Reionization
  - …

MERAXES

Black Hole Growth

(Qin et al. 2017)

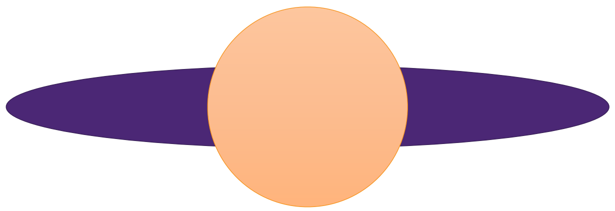
- Seed black holes in all galaxies, $10^3\,M_\odot$
- “Radio-mode” hot gas accretion:
  - Bondi–Hoyle accretion rate
  - Eddington-limited
- “Quasar-mode” cold gas accretion:
  - Due to galaxy mergers
  - Or disc instabilities (NEW)
  - Eddington-limited
- Black hole coalescence during galaxy mergers

MERAXES

Bulge Growth

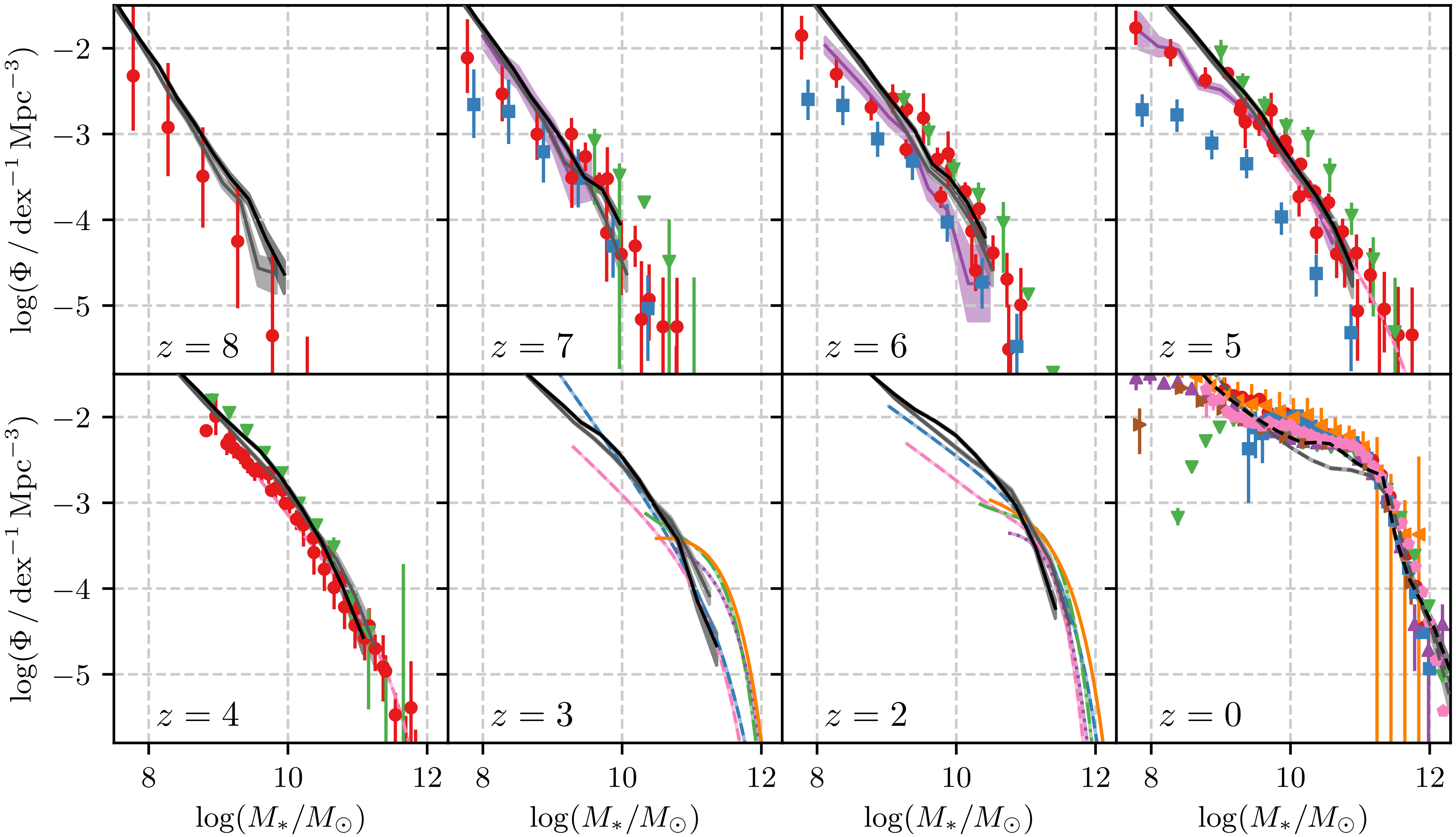
(New, analogous to Tonini et al. 2016)

- Galaxy mergers:
  - In major mergers, remnant is a bulge
  - In minor mergers, mass of secondary's stars sent to bulge
- Disc instabilities:
  - $M_{\rm disk} > \frac{V_{\rm disk}^2 R_{\rm scale}}{G}$
  - Enough disc material is sent to bulge such that it becomes stable
  - Get a starburst, with stars added to bulge



Calibration

Stellar Masses



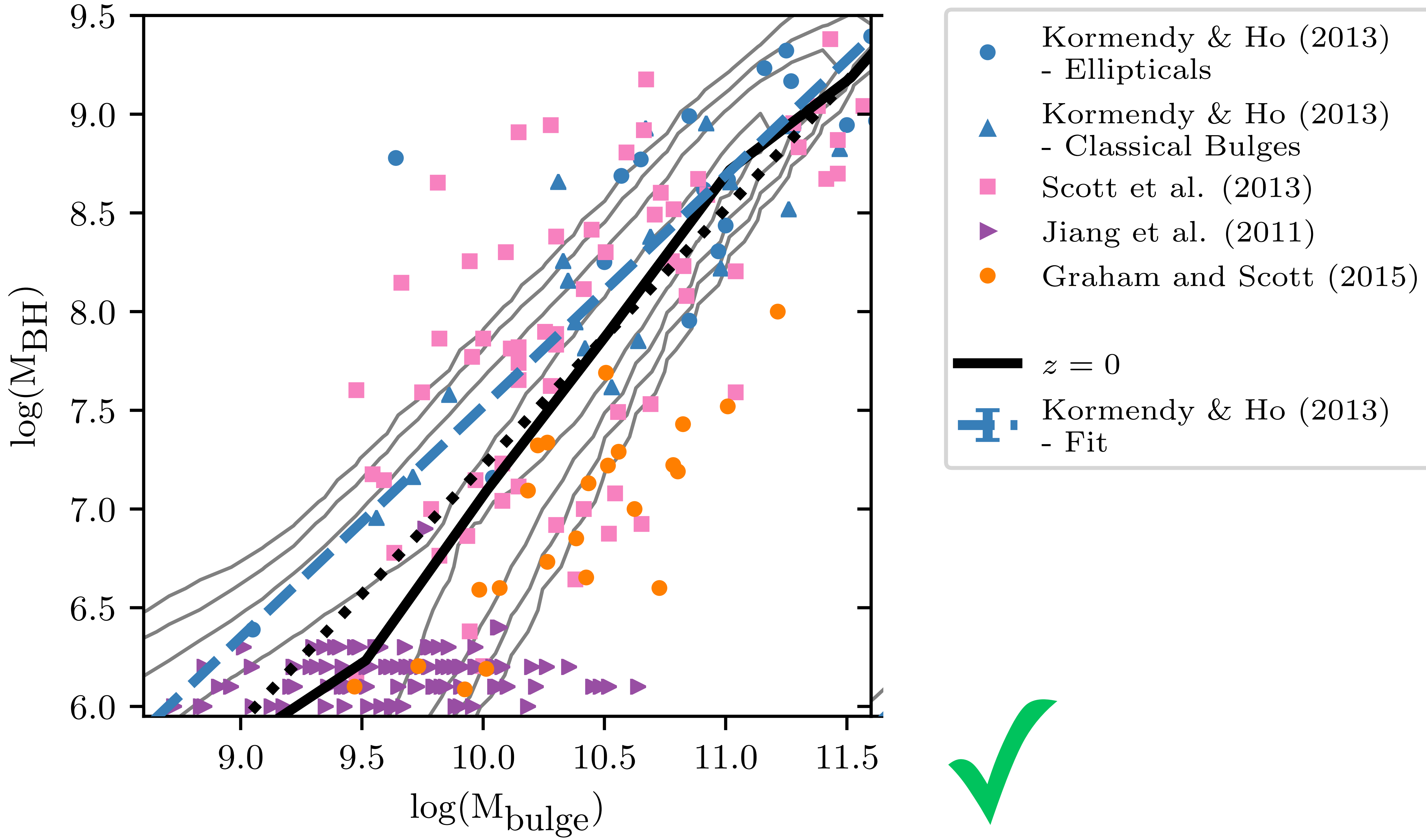
Model

Observations

✓

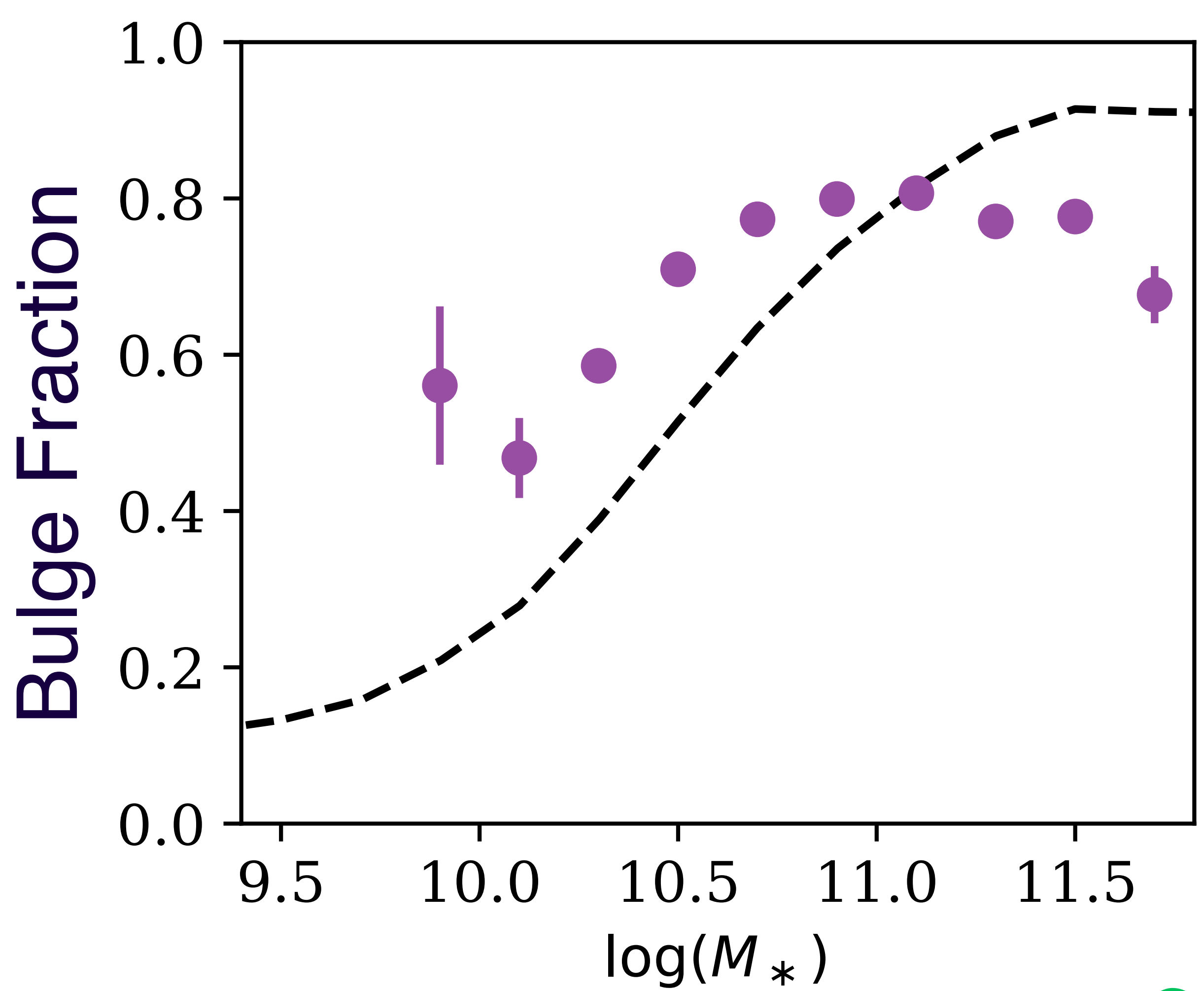
Calibration

Black Hole - Bulge Relation



Verification

Bulge Masses

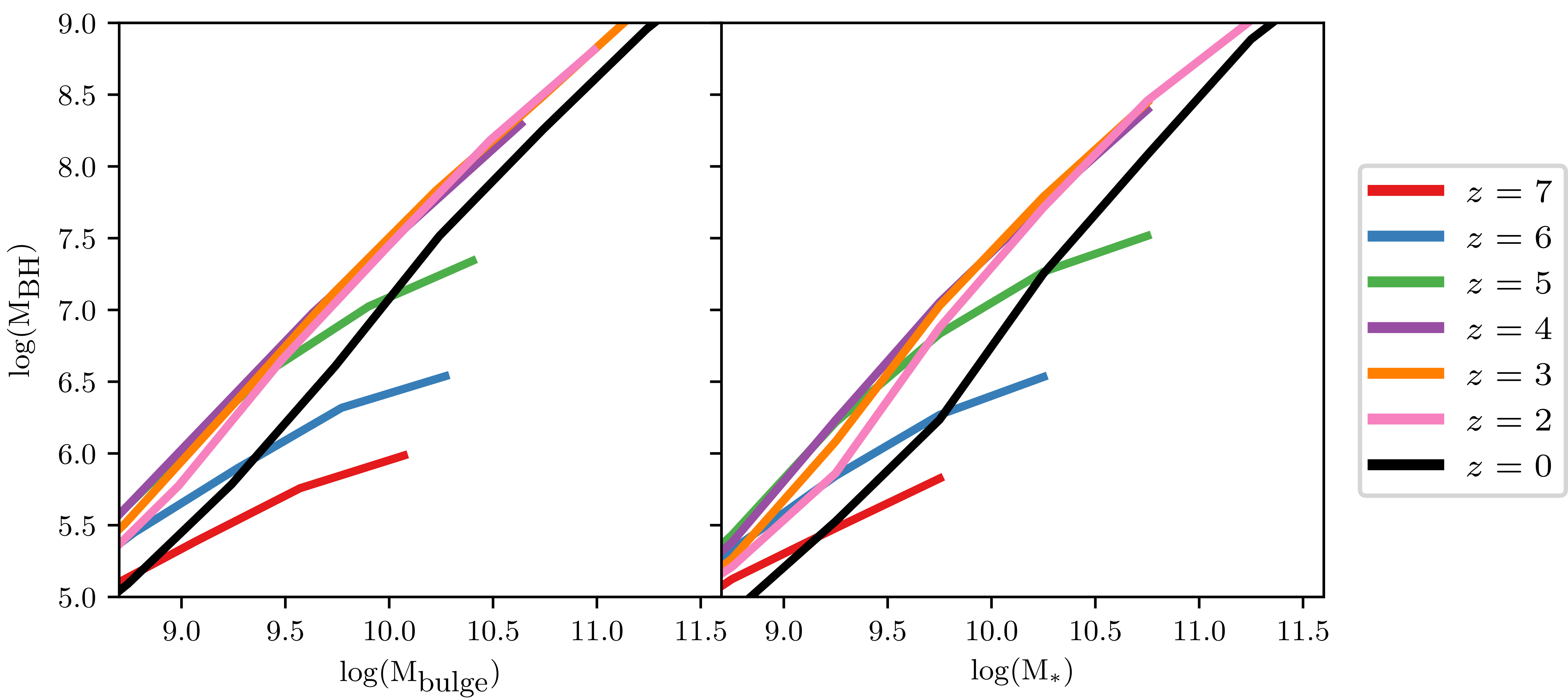


Model

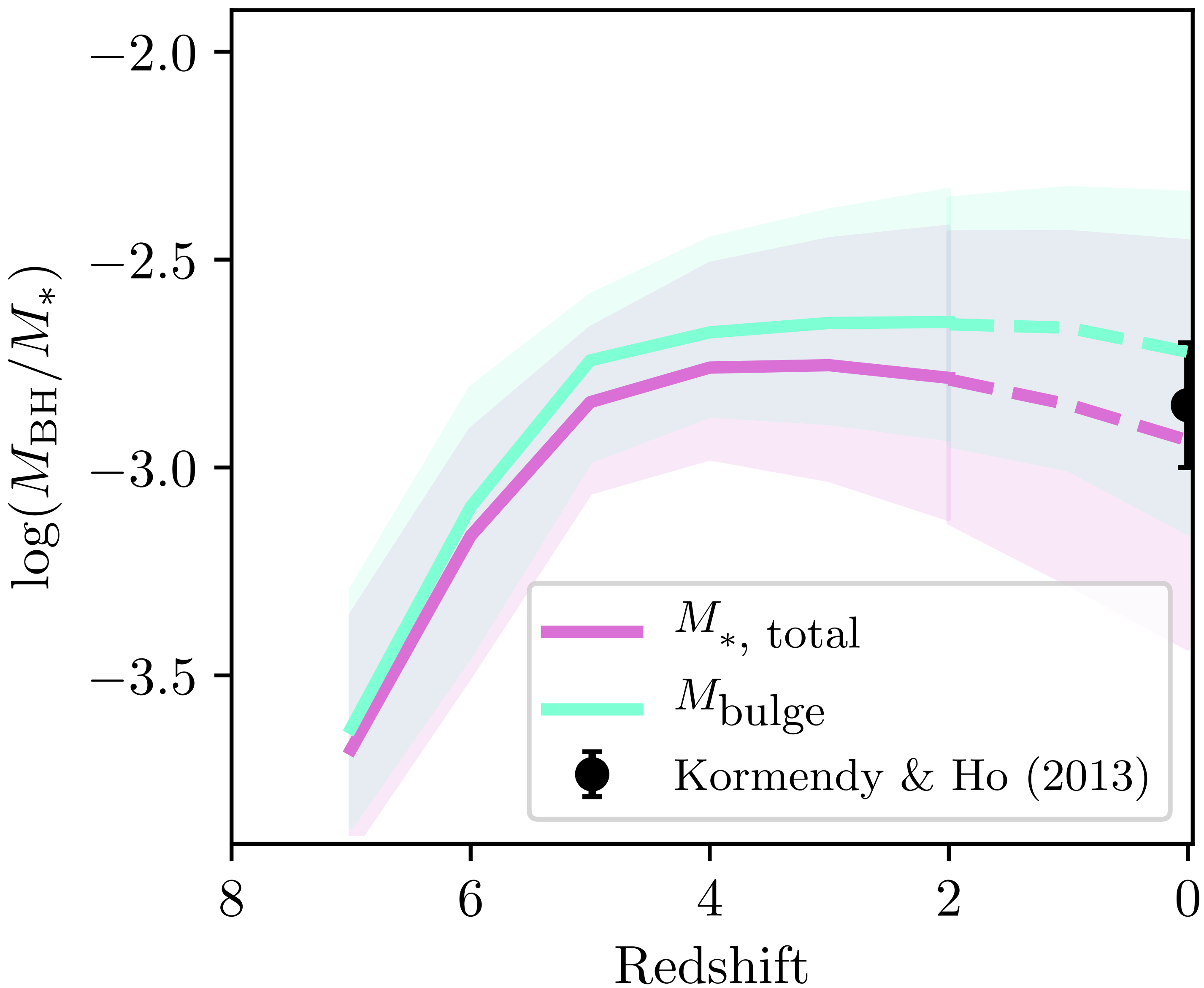
SDSS Observations (Thanjavur et al. 2016)

- Also verified with:
  - Stellar mass - disc size relation ✓
  - Stellar mass - star formation rate relation ✓
  - High-z UV galaxy luminosity function ✓
  - High-z AGN luminosity functions ✓

Black Hole - Host Mass Relations

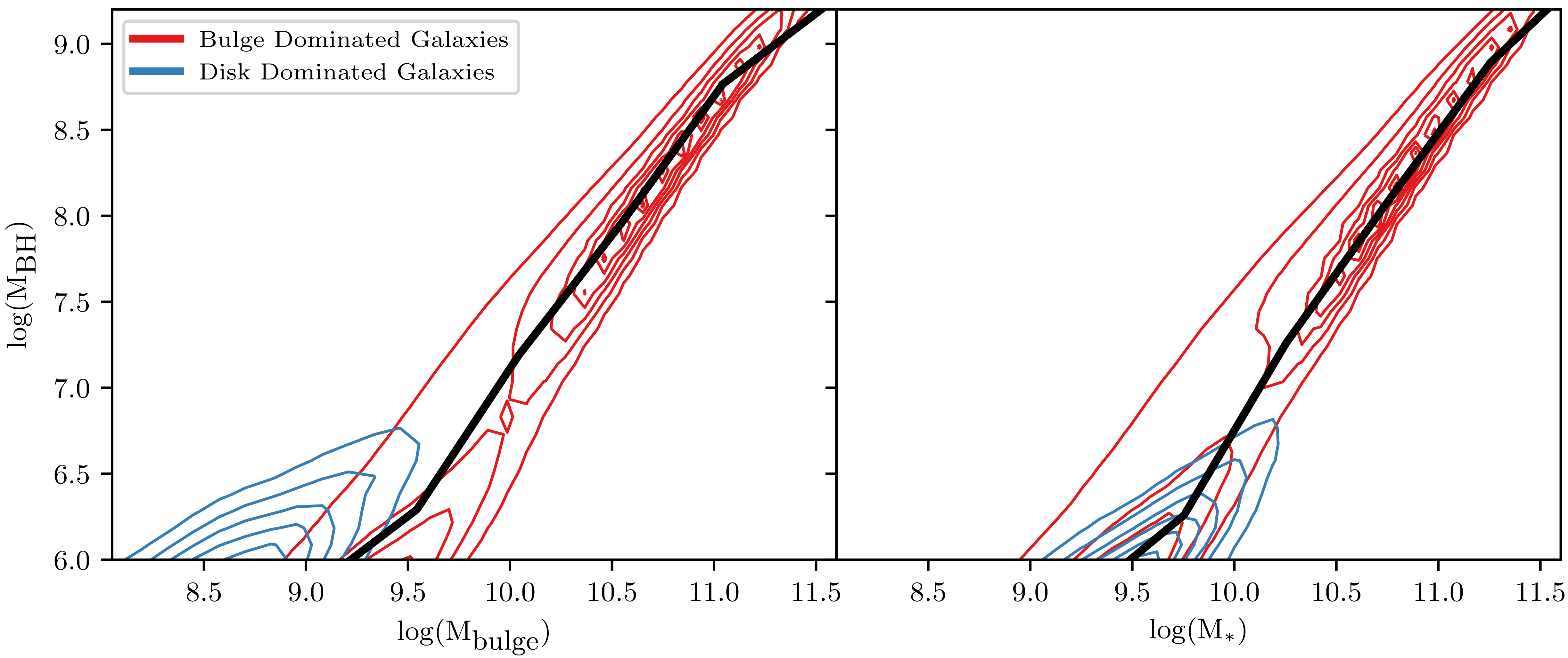


Black Hole - Host Mass Relations



- Very little evolution for z<5
- Get smaller black holes for same size galaxy at z>5

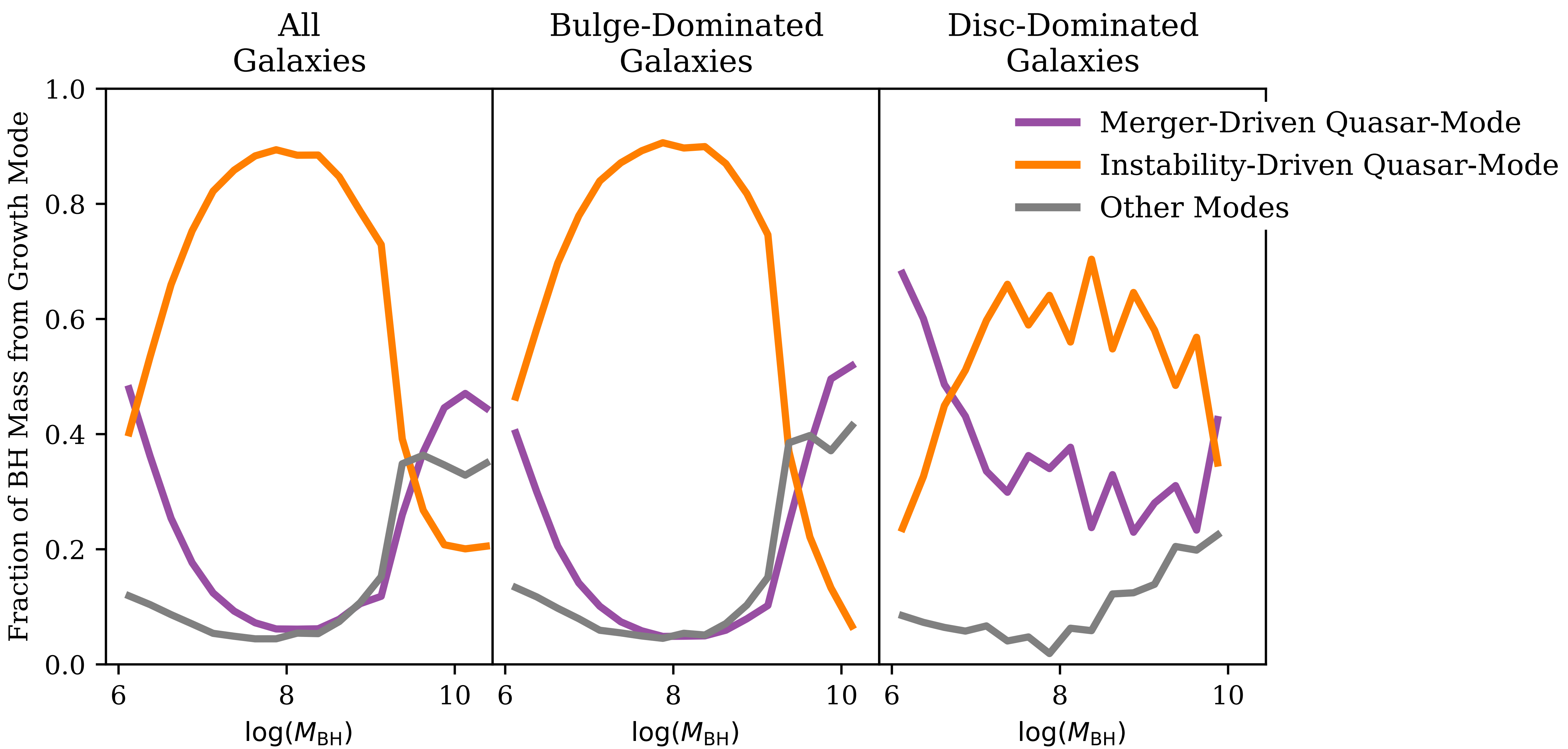
Morphological Dependence



- Disc dominated galaxies offset from black hole-bulge but not black hole-stellar relation

  [See also Simmons et al. (2017) observations and Martin et al. (2018) simulations, for example]

Morphological Dependence



- Relative significance of growth modes different for bulges and discs

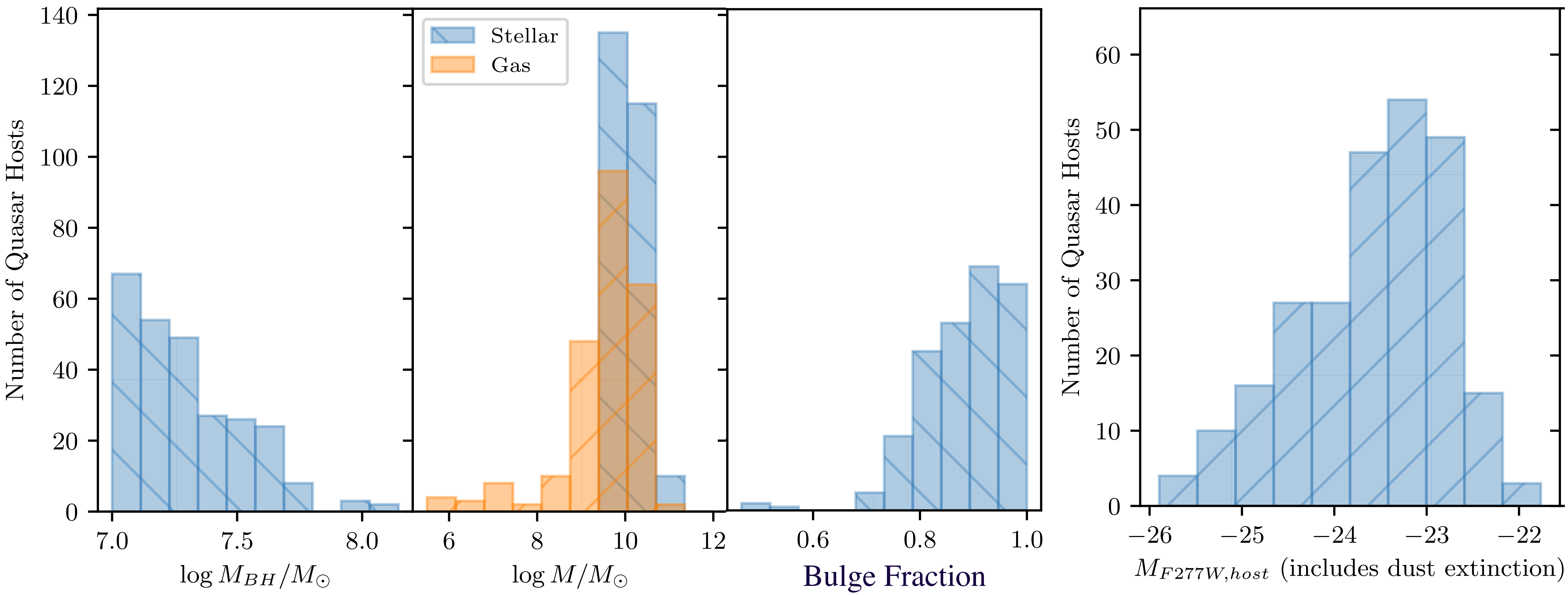
Morphological Dependence

- Bulges grow more during disc instabilities (ΔBulge ~ 6ΔBH) than minor mergers (ΔBulge ~ 3.1-3.7ΔBH)

- Both modes grow the total stellar mass by the same amount in proportion to the black hole growth

Black holes formed by either growth mechanism will lie on the M_{BH}-M_* relation

High-z Quasar Hosts



- z = 5 quasar hosts are:
  - Mostly bulge-dominated
  - Have gas and stellar masses around ~10^{10} $M_\odot$
  - Can observe in ~100s in JWST imaging, if no quasar light

CONCLUSIONS

- We haven’t detected high-z quasar hosts in the optical/near-IR, yet
- Need to make models to estimate their properties & the evolution of the black hole - host relations
- Will try to confirm this using JWST

Madeline Marshall