



# The most massive galaxies and black holes

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Single and Double Black Holes in Galaxies  
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August 23, 2011

## Collaborators

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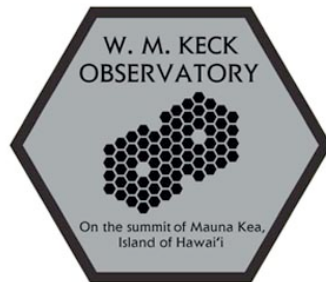
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Jeremy Murphy

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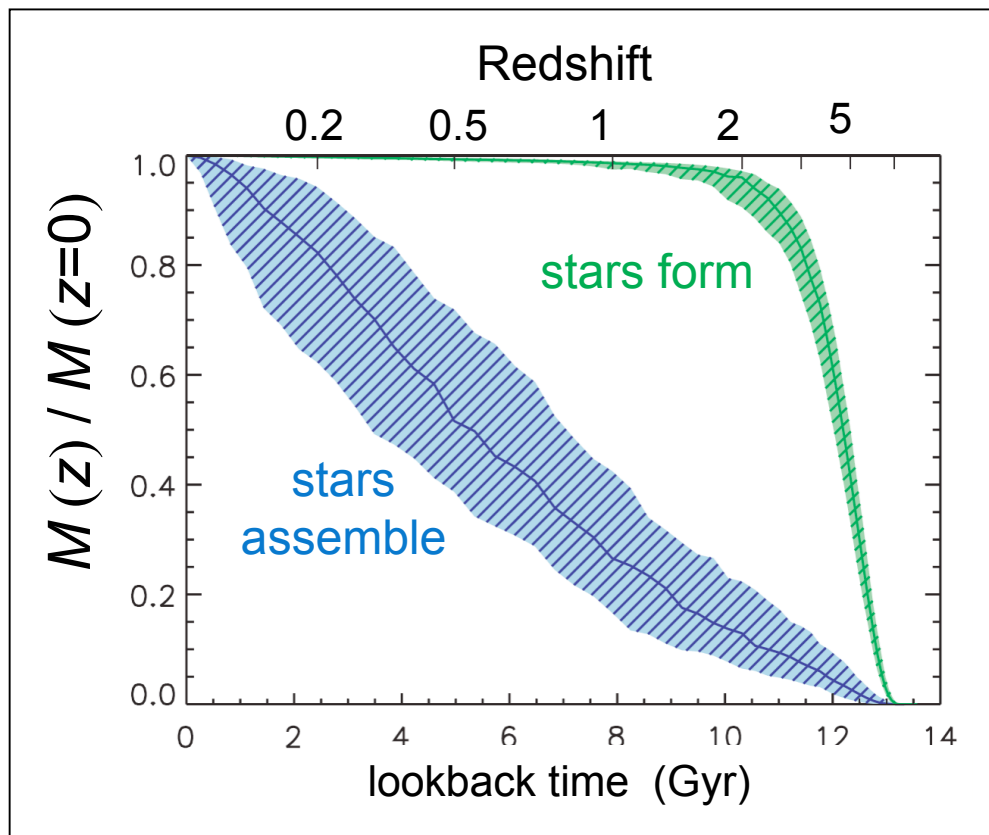
Scott Tremaine

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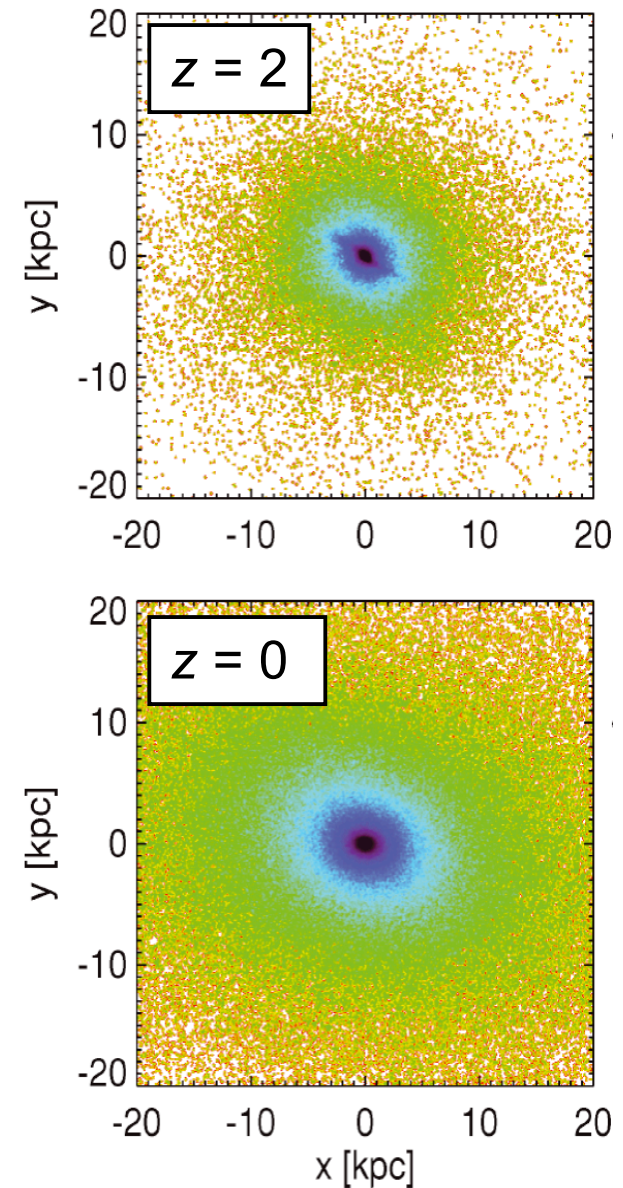


# Building massive ellipticals

De Lucia & Blaizot 2007

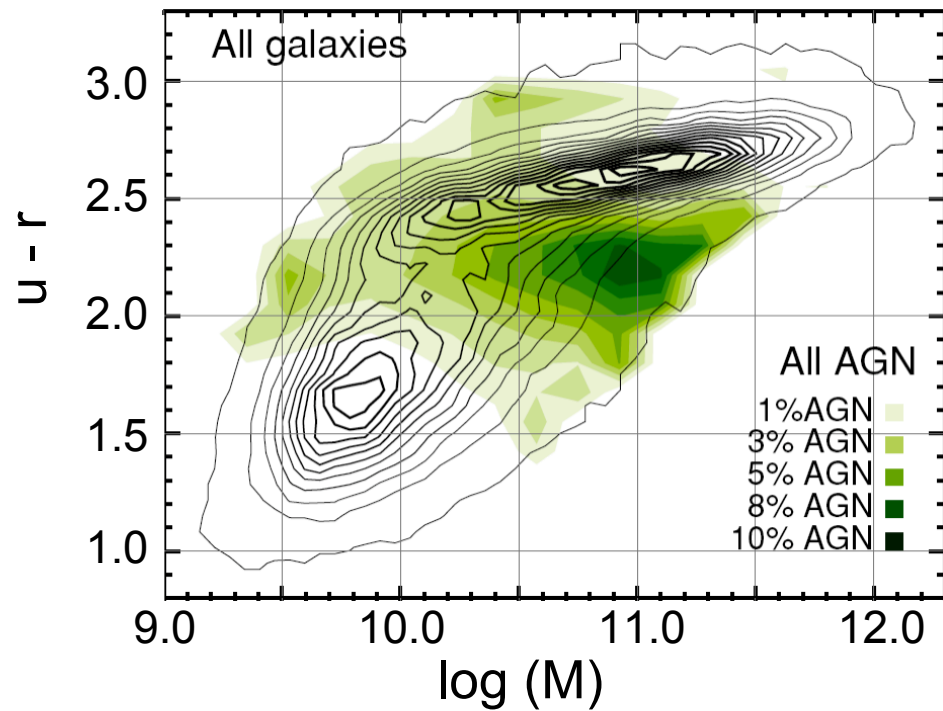


Hopkins et al. 2010

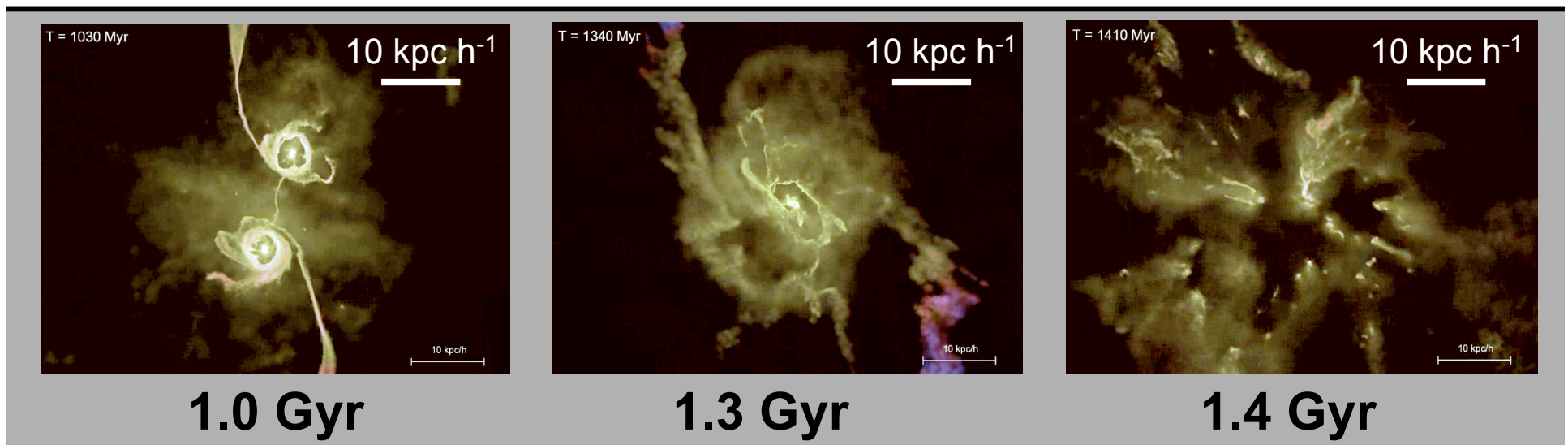


# BH growth and regulation

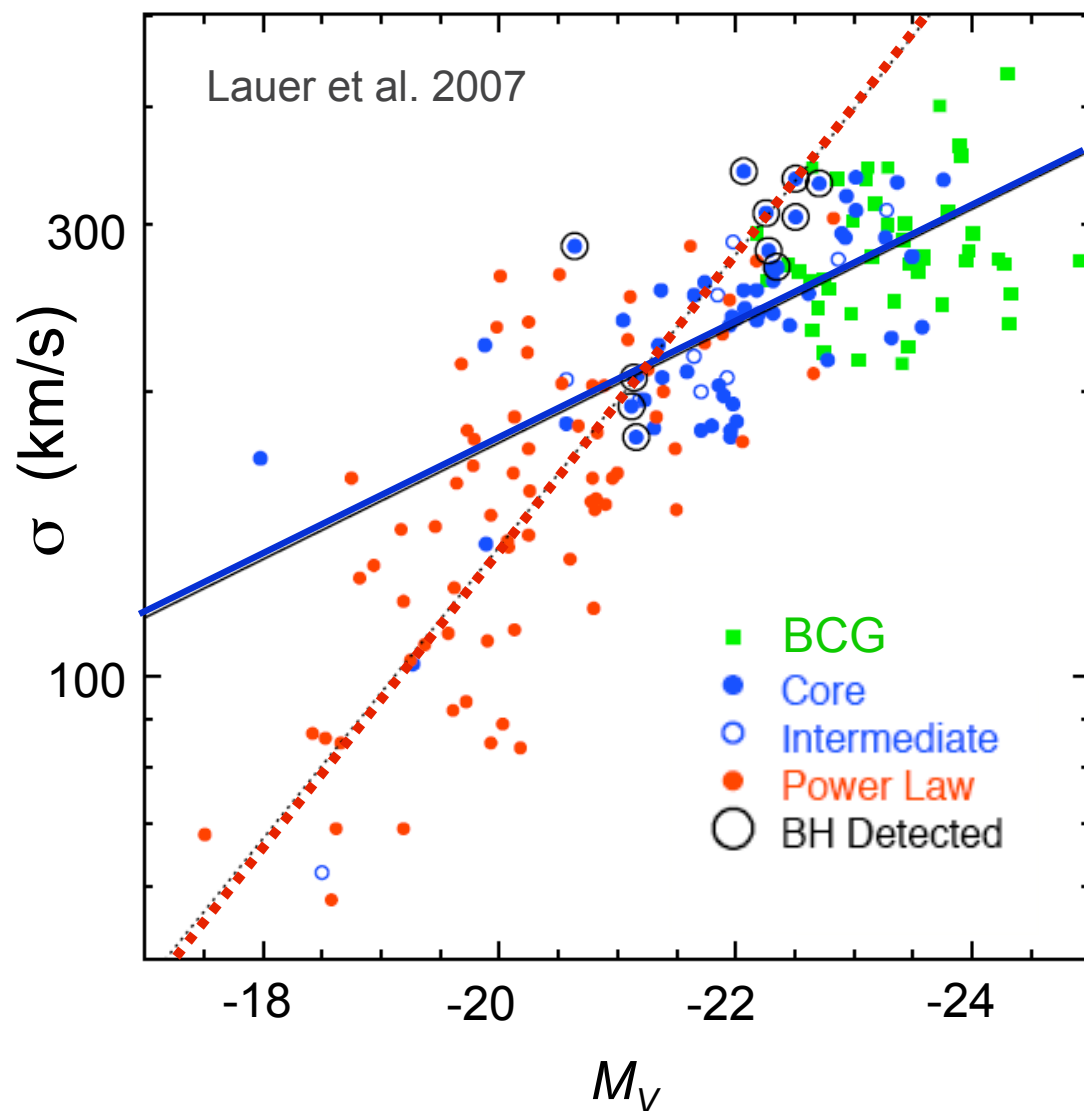
Schawinski et al. 2010



Di Matteo et al. 2005



# A break in $L - \sigma$



cores:  $L \propto \sigma^{6.5}$

cusps:  $L \propto \sigma^{2.6}$

Lauer et al. 2007

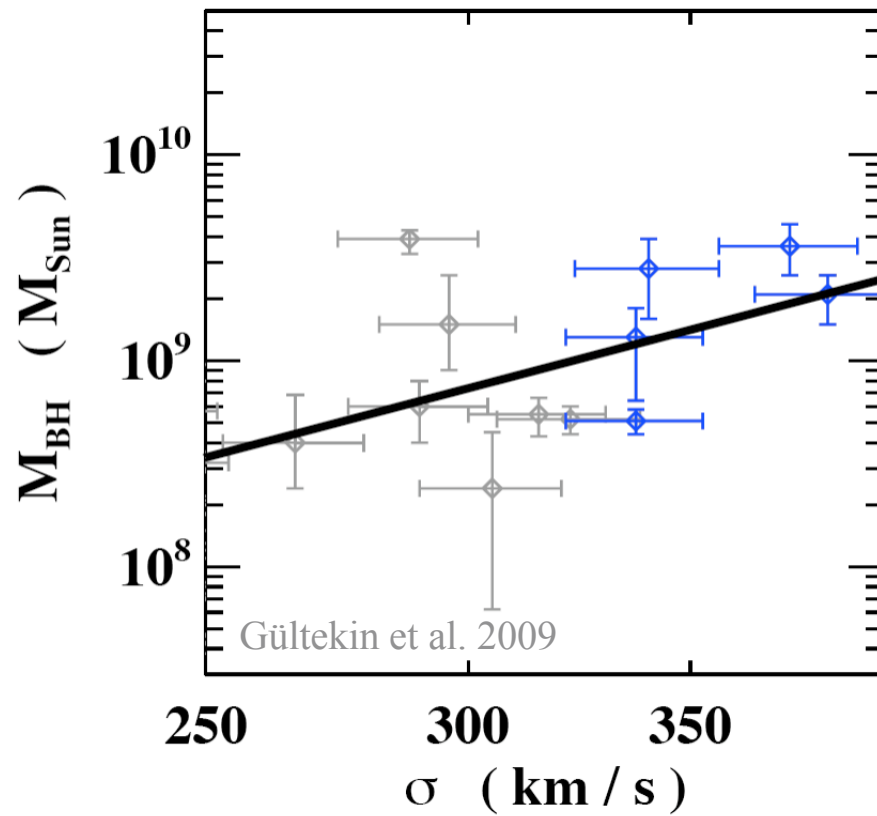
BCGs:  $L \propto \sigma^{5.3}$

non-BCGs:  $L \propto \sigma^{3.9}$

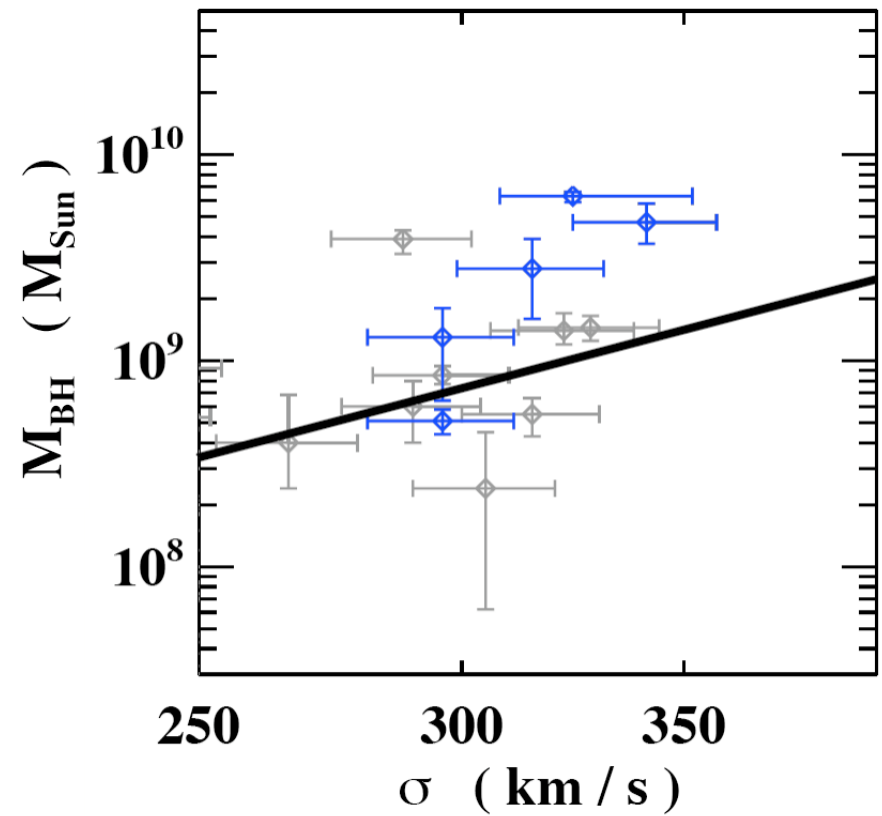
von der Linden et al. 2007

# $M_{\bullet} - \sigma$

2009



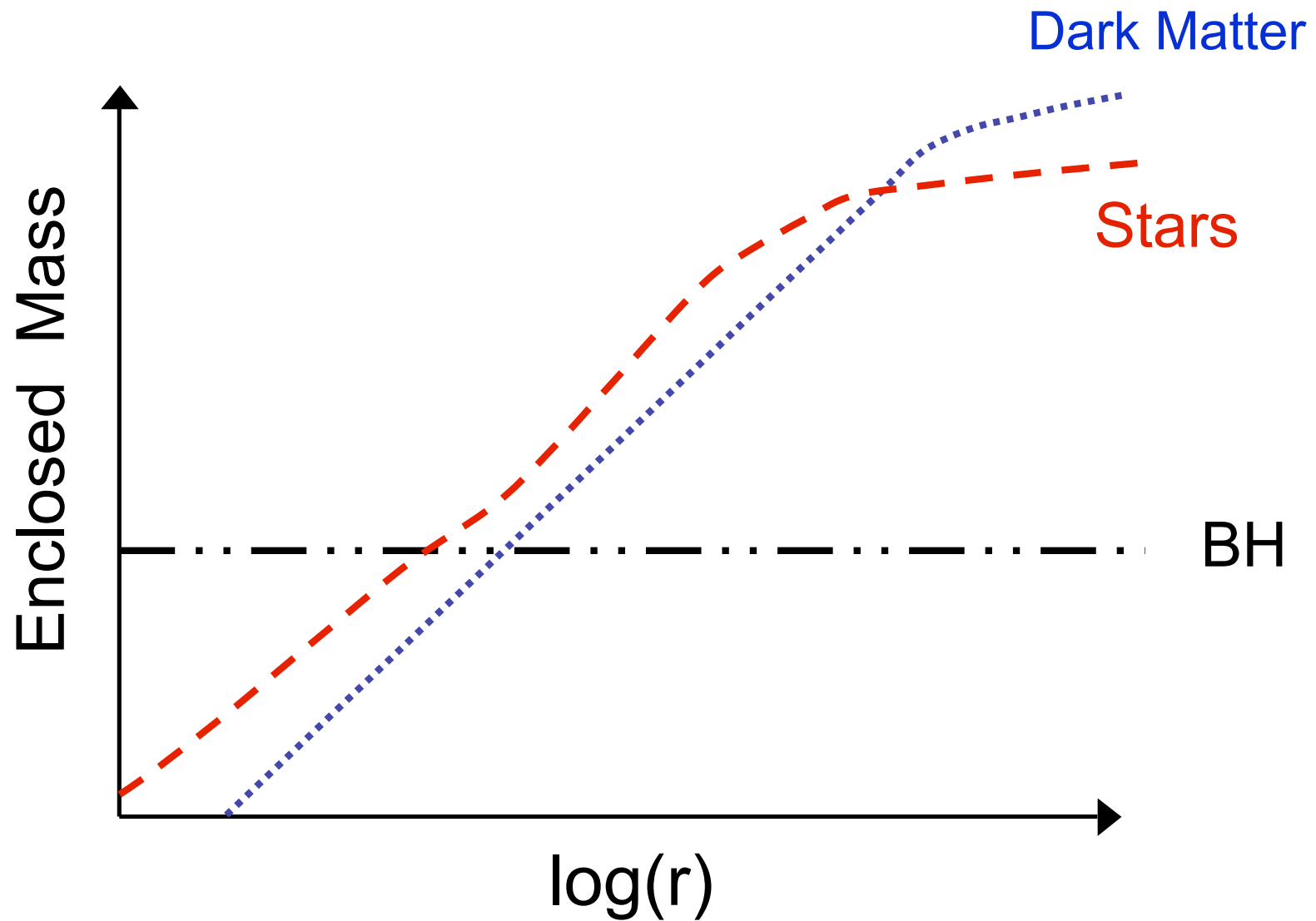
2011



## Surveying $M_{\bullet}$ in BCGs

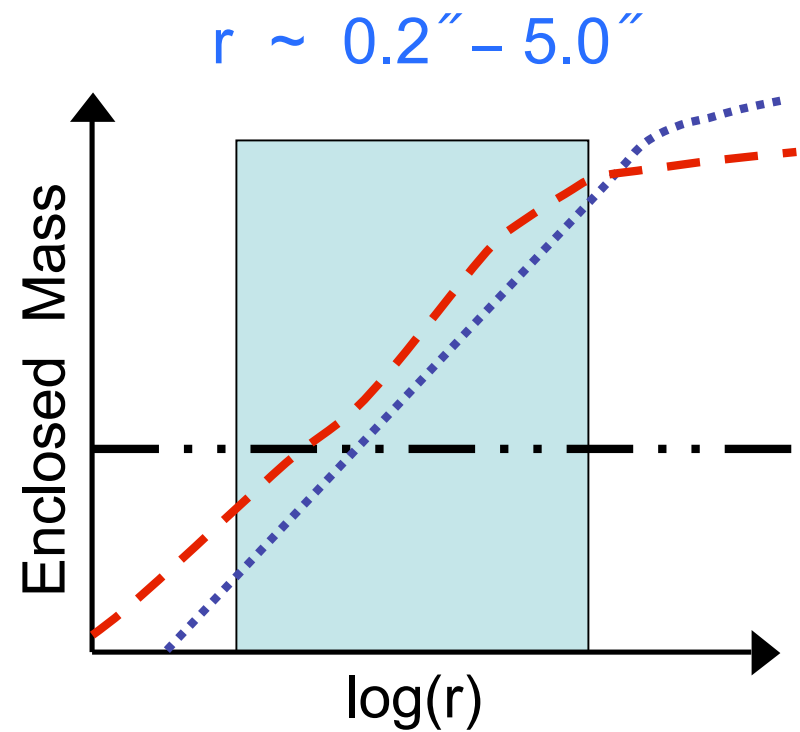
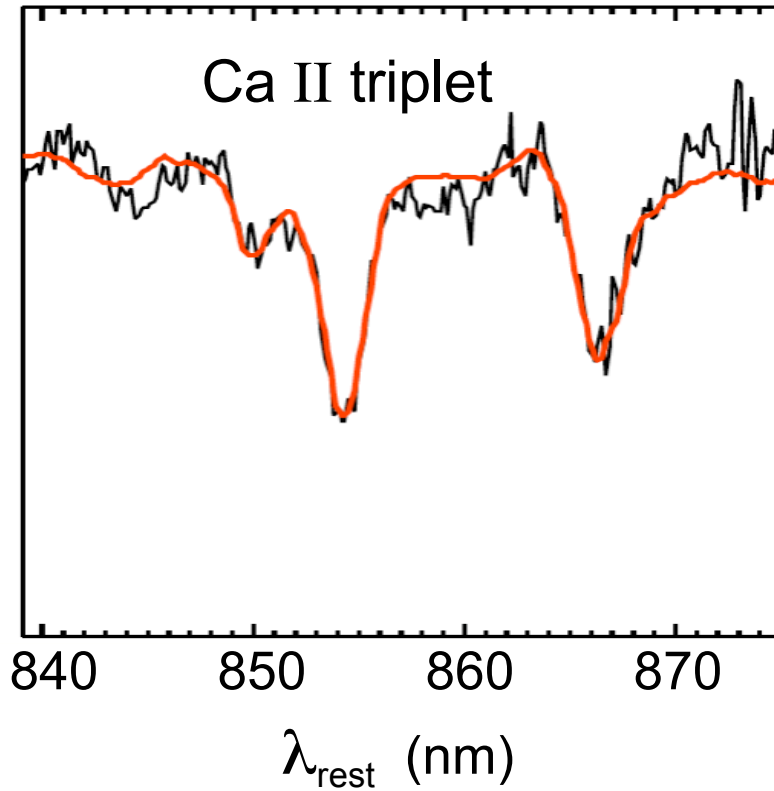
- Integral-field spectroscopy from Gemini, Keck, and McDonald observatories
- Stellar kinematics from  $\sim 0.1''$  to  $\sim 40''$   
(50 pc - 20 kpc)
- Stellar orbit models measure  $M_{\bullet}$ , stellar M/L, dark matter halo
- Current sample: 3 BCGs with  $M_{\bullet}$   
6 more BCGs observed

# Probing different mass components

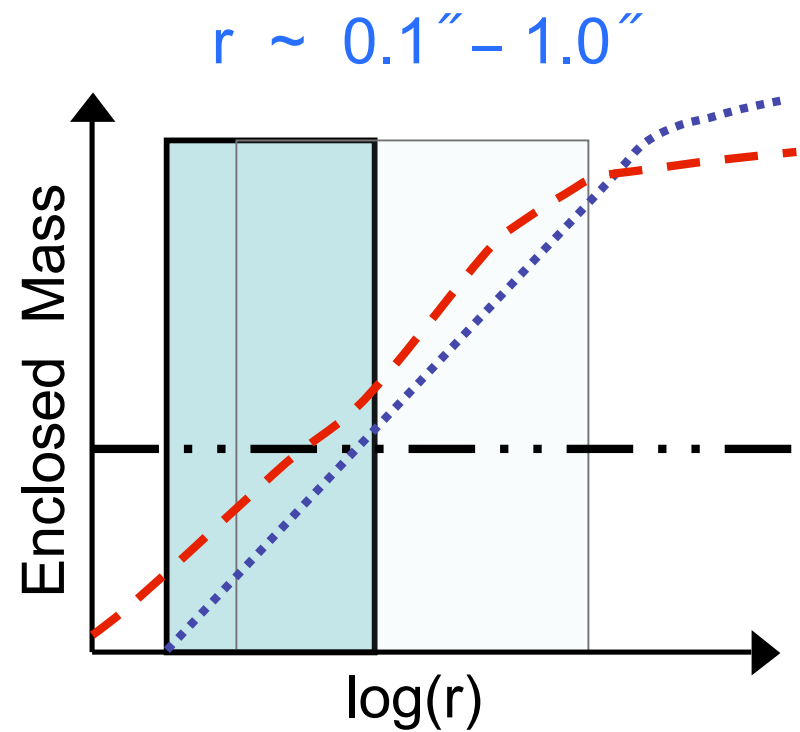
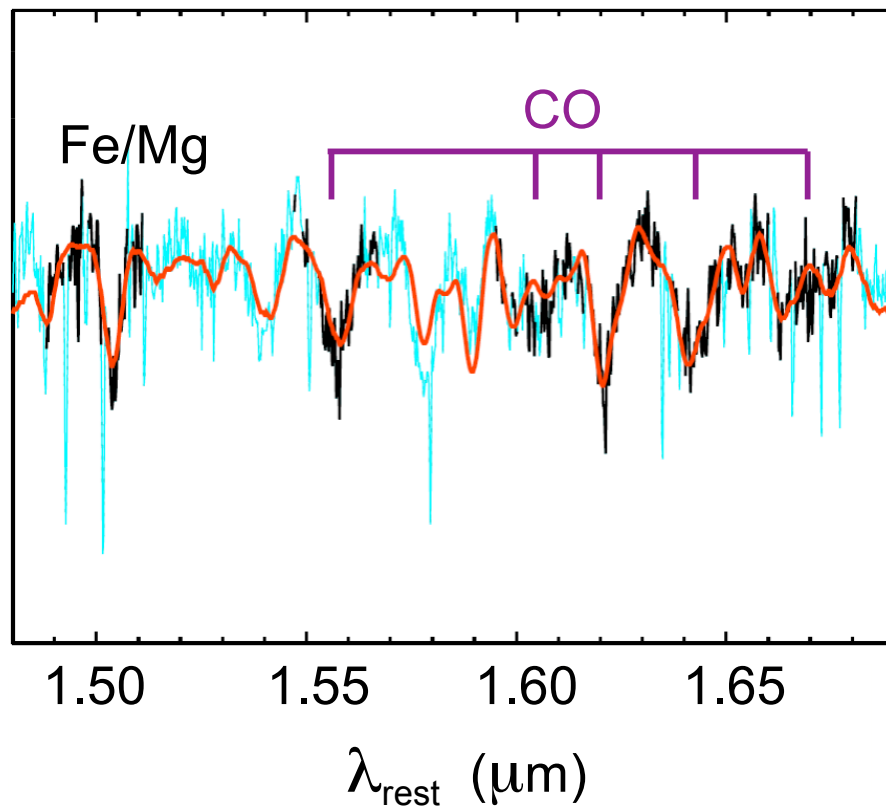




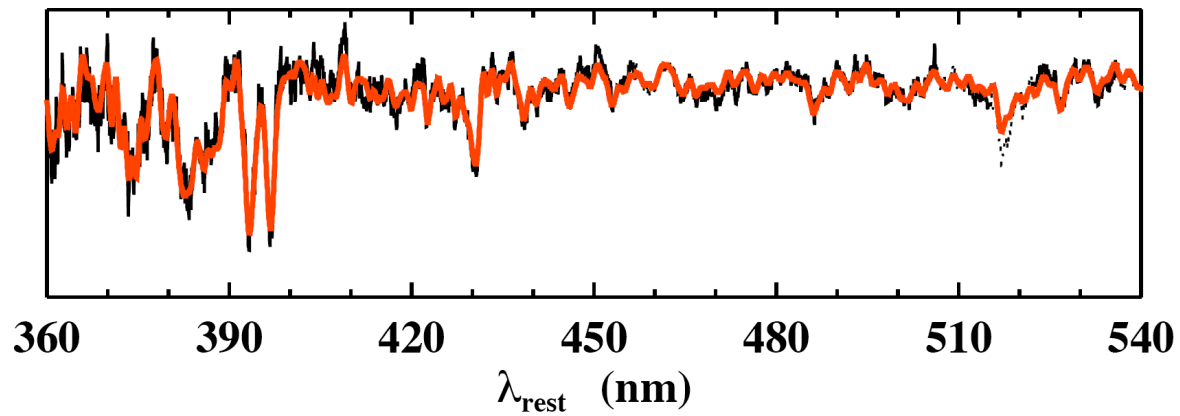
# GMOS IFU



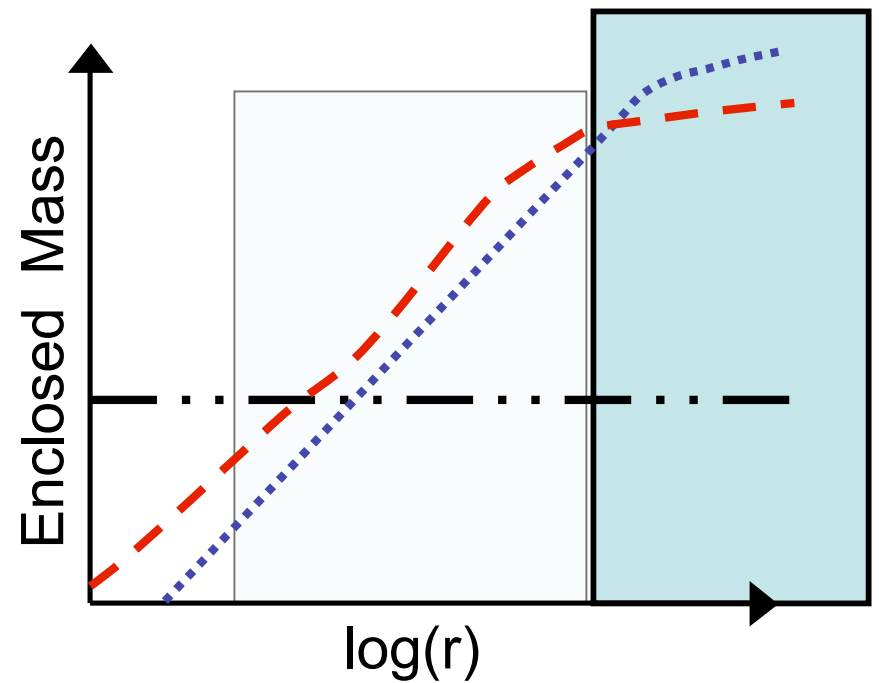
# Adaptive Optics data



# Large radius data



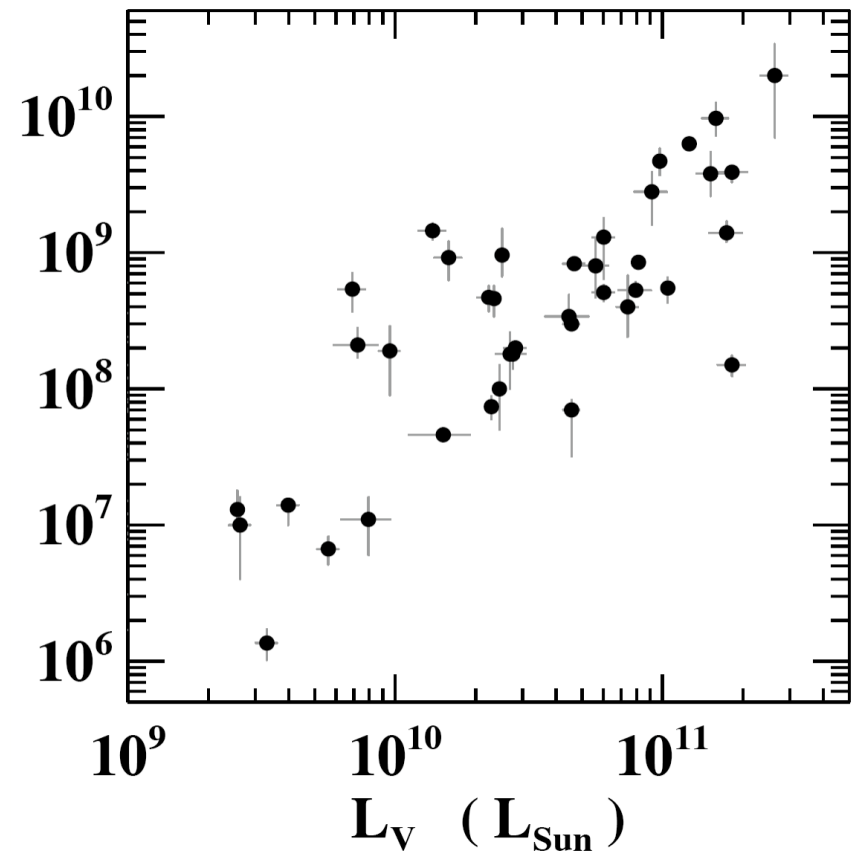
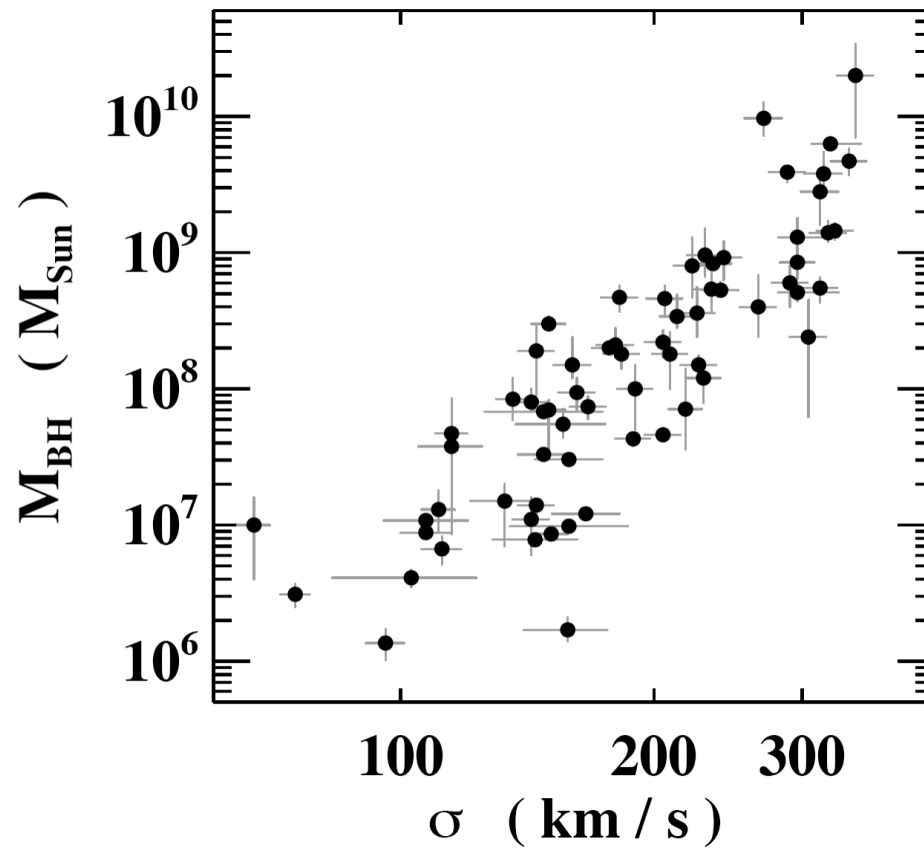
$r \sim 5'' - 40''$



# Scatter at high $\sigma$ , $L$

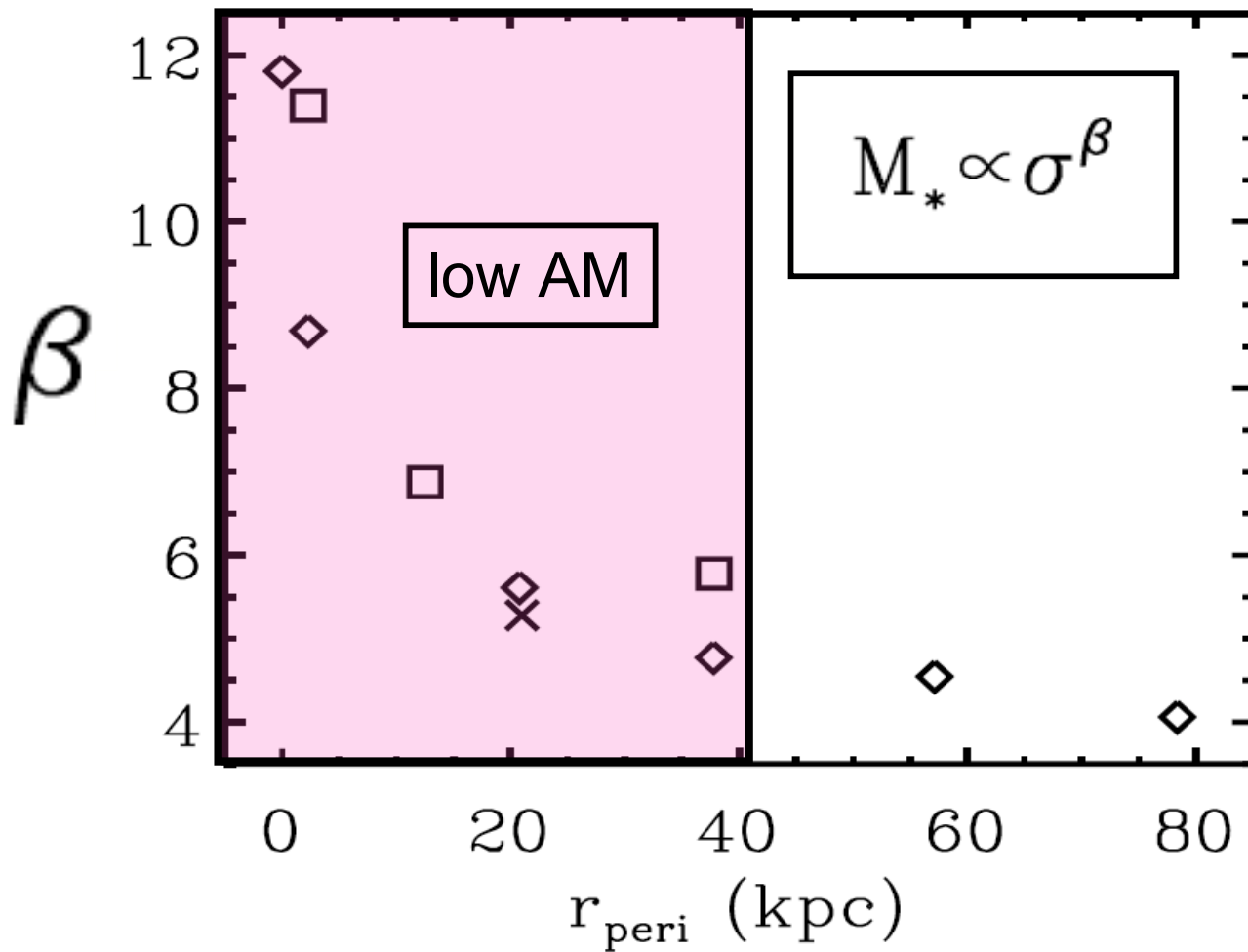
$M_{\bullet} - \sigma$

$M_{\bullet} - L$



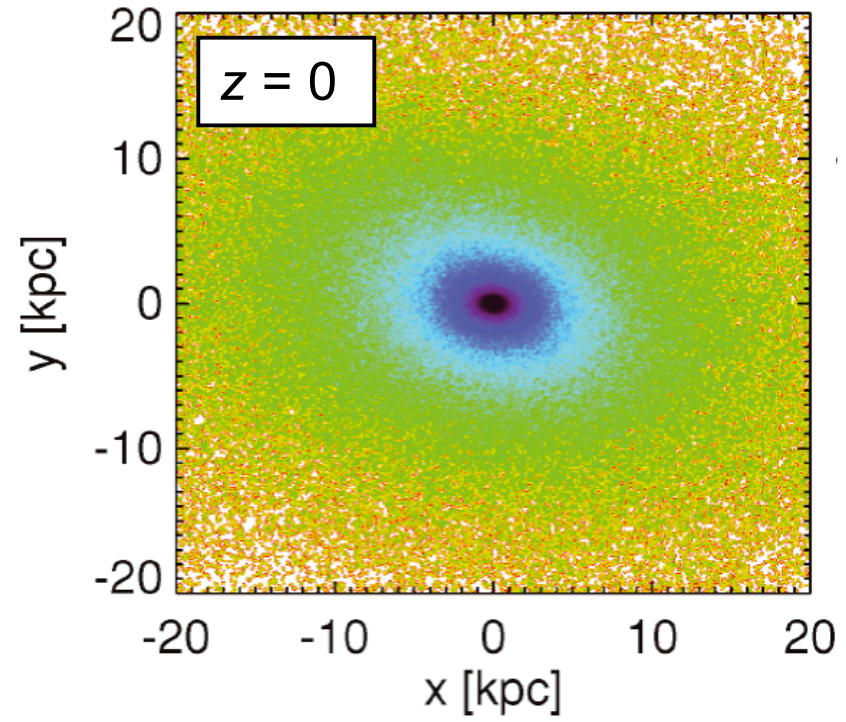
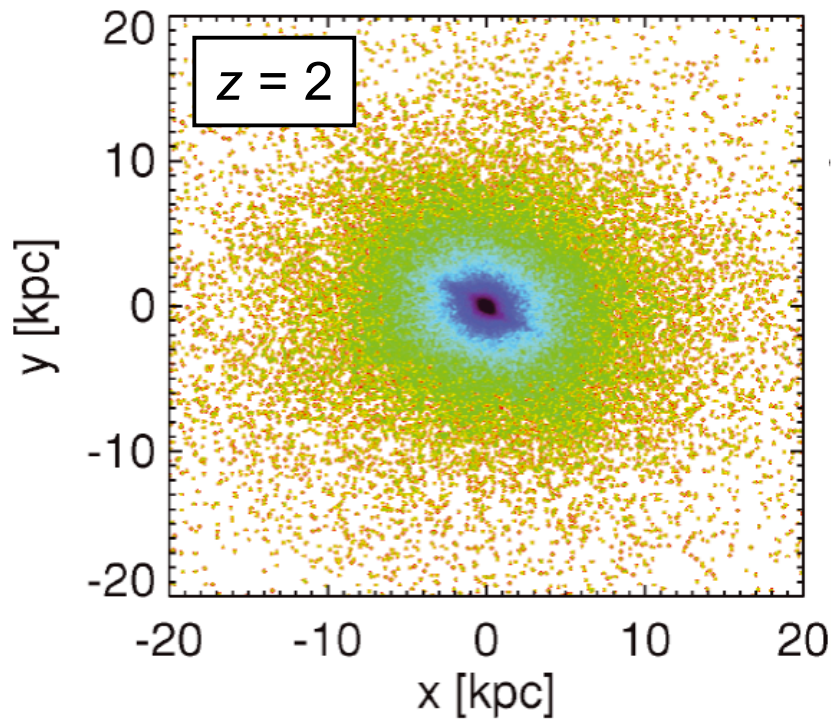
# Radial mergers along filaments

Bolyan-Kolchin et al. 2006



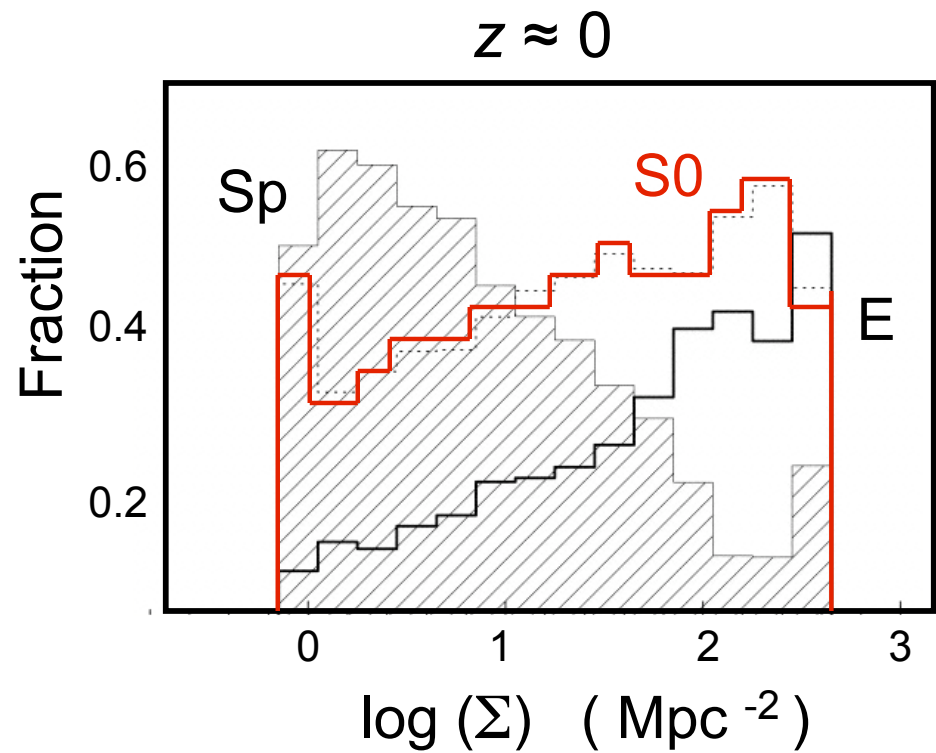
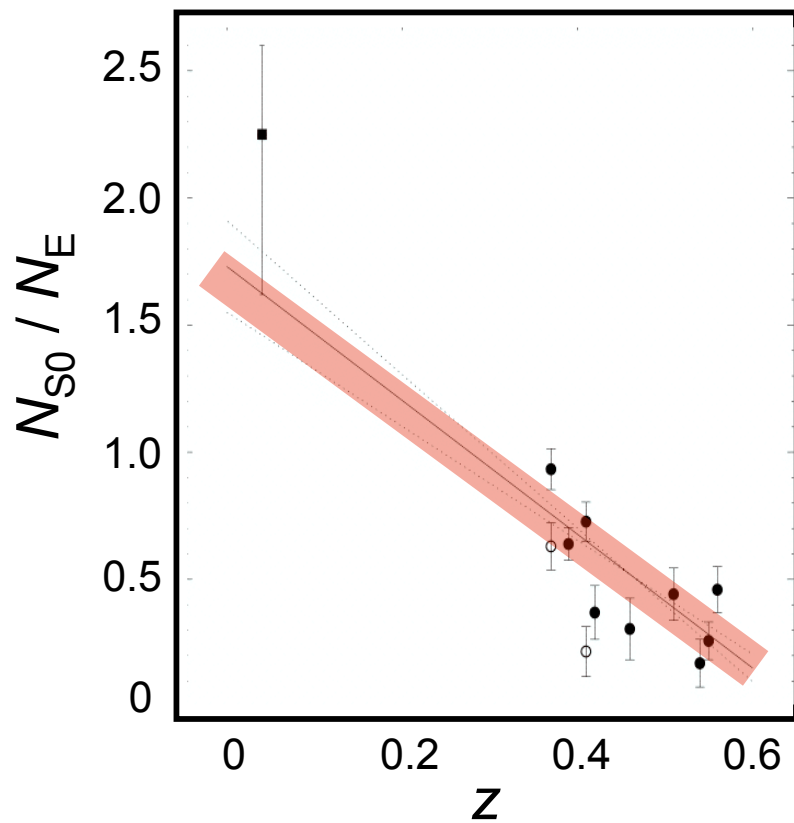
# Core - envelope growth

Hopkins et al. 2010

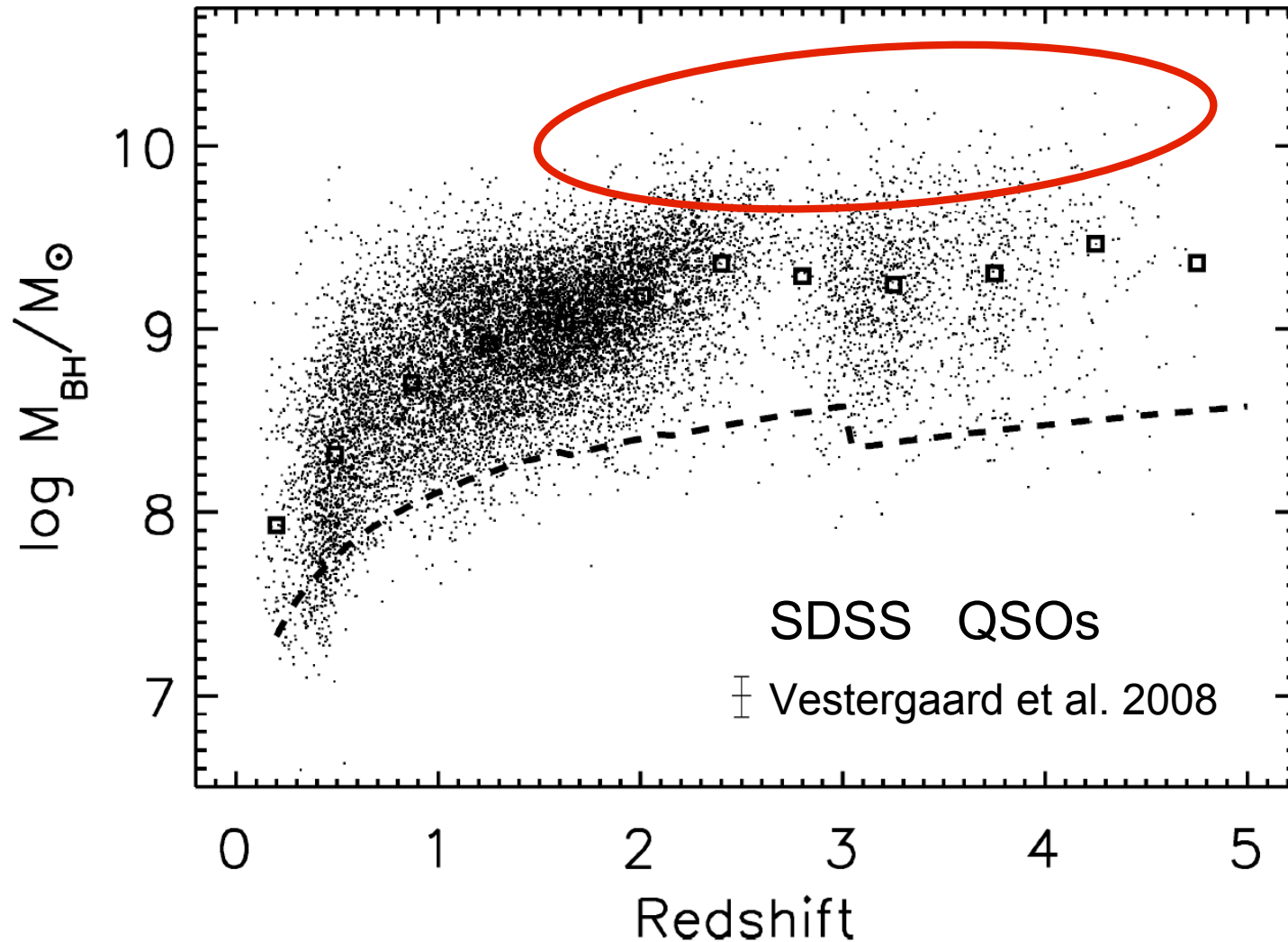


# Low $M_{\text{bulge}} / M_{\text{total}}$

Dressler et al. 1997



# Early accretion to $M_{\bullet} \sim 10^{10} M_{\odot}$





# Questions

- How do wet vs. dry mergers drive galaxy and black hole growth ?
- Do the high-mass ends of  $M_{\bullet}$ - $\sigma$  and  $M_{\bullet}$ - $L$  show upward curvature or high scatter in  $M_{\bullet}$  ?
- How can scatter in  $M_{\bullet}$  increase for systems dominated by dry merging ?
- Which processes of galaxy and black hole growth depend strongly on environment ?