Ultracompact Dwarfs as Stripped Galaxy Nuclei

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Collaborators

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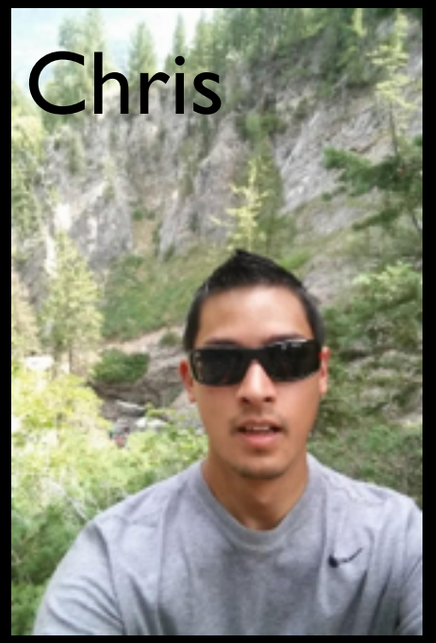
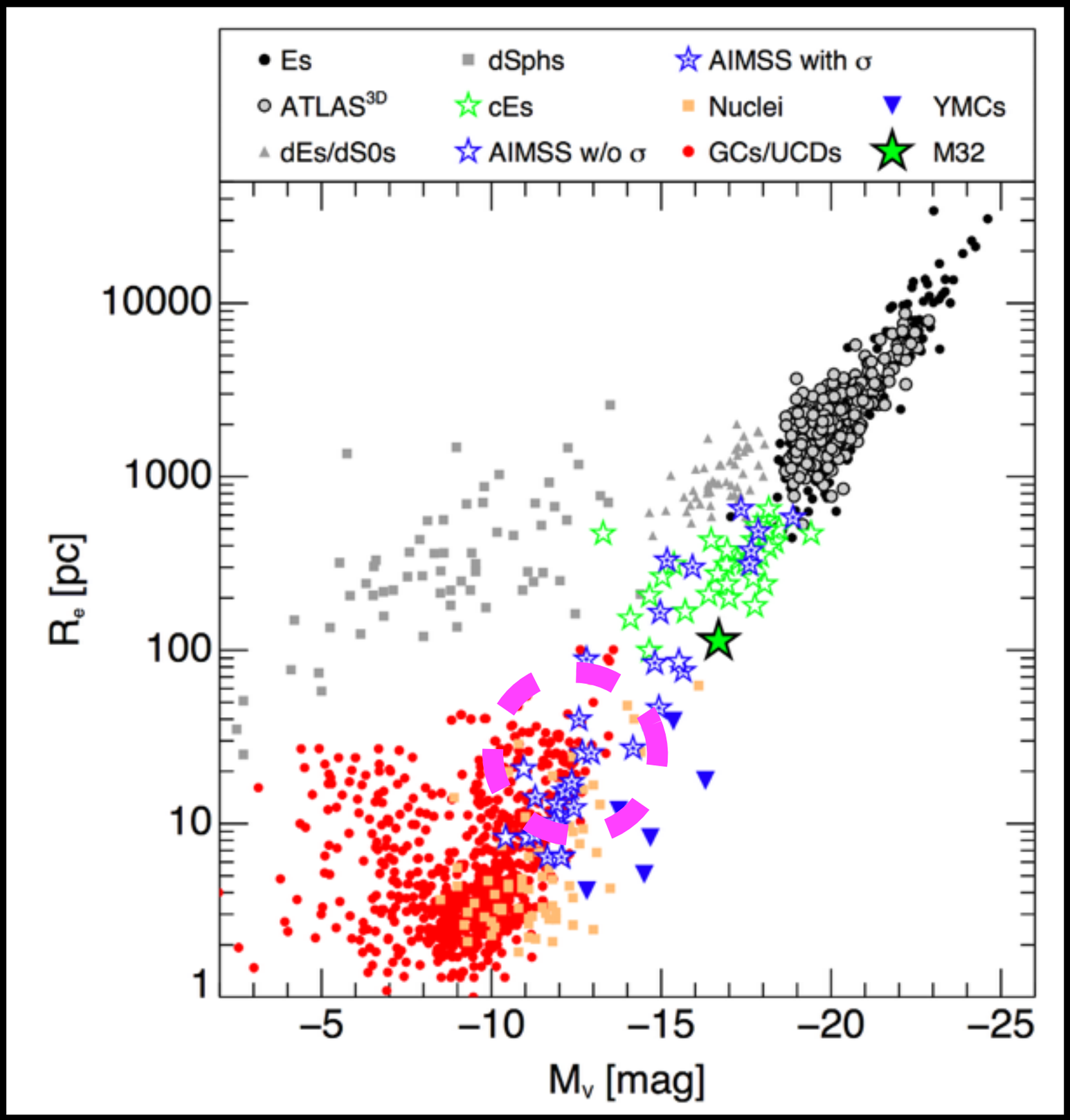


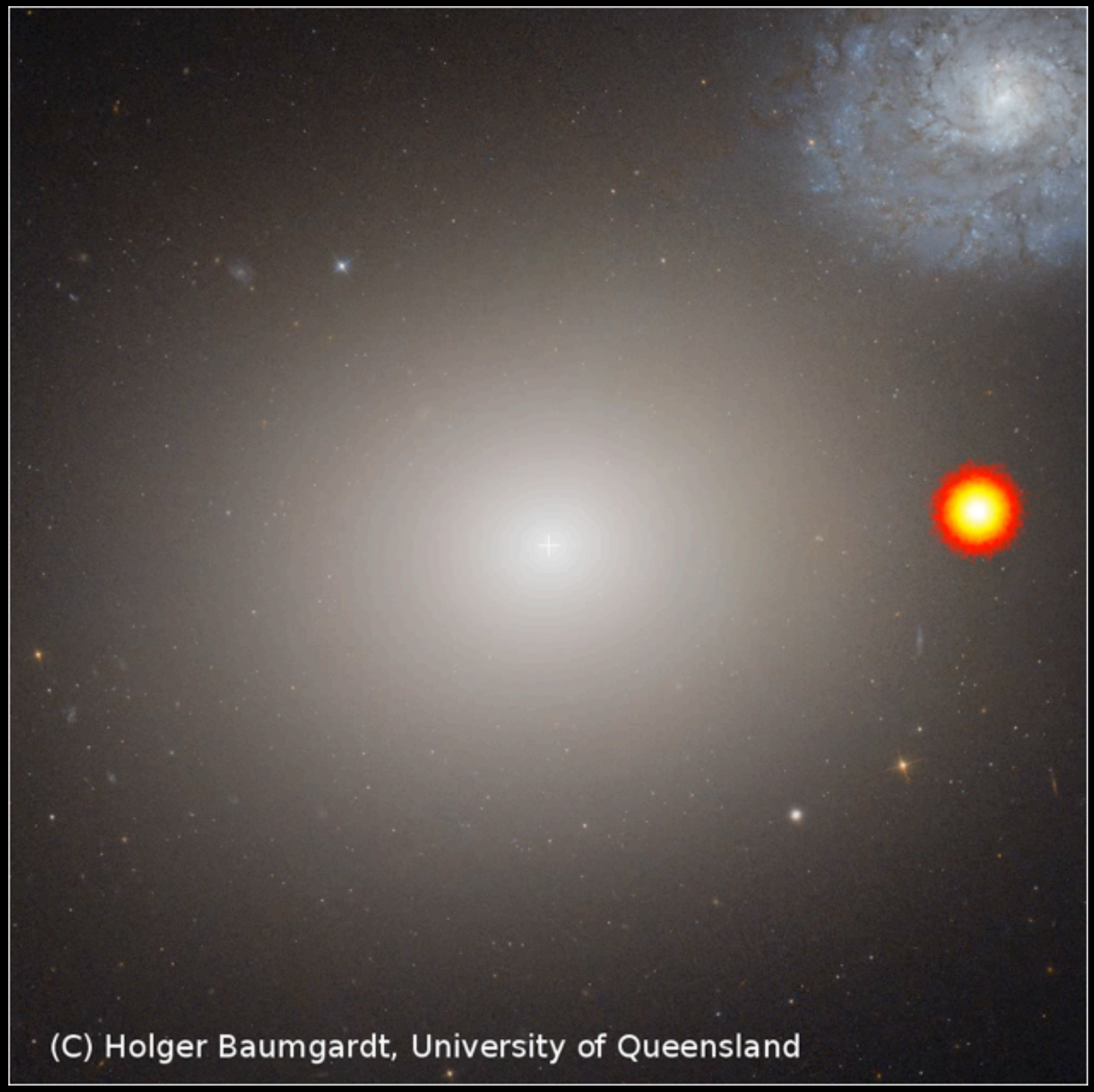


Norris+ 2014

UCDs in the size mass plane of (old) stellar systems

Overlap with GCs, galaxy nuclei & compact ellipticals.

When nuclei go rogue — UCDs

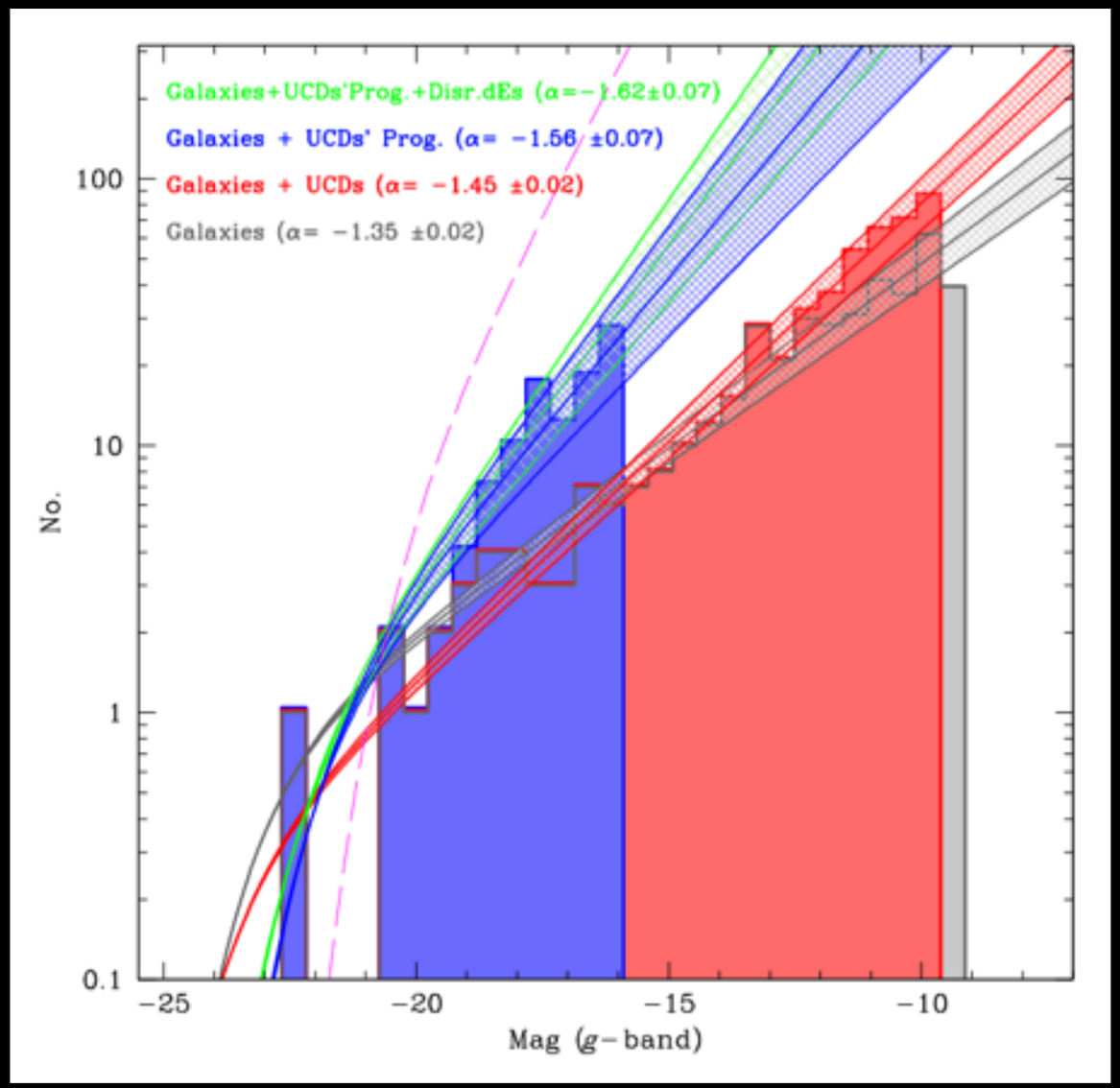


Made by Holger Baumgradt

Semi-analytic simulations suggest that above ~10^7 $M_\odot$ most are likely stripped nuclei (Pfeffer+ 2014, 2016)

M54, the Sagittarius Nucleus
A UCD in the making

UCDs are numerous

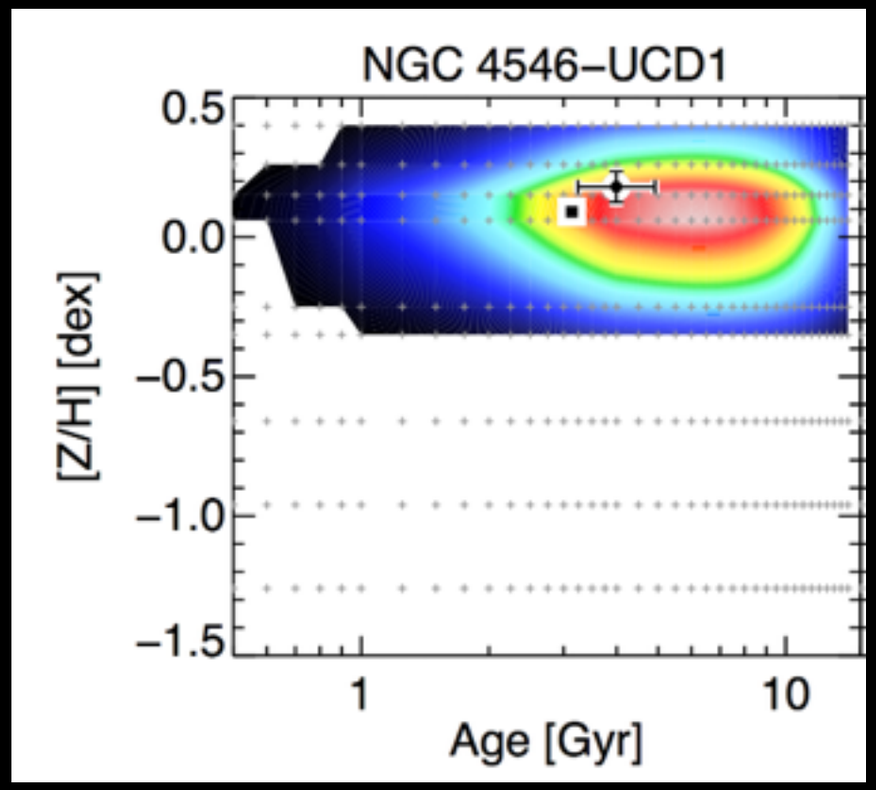


Ferrarese+ 2016

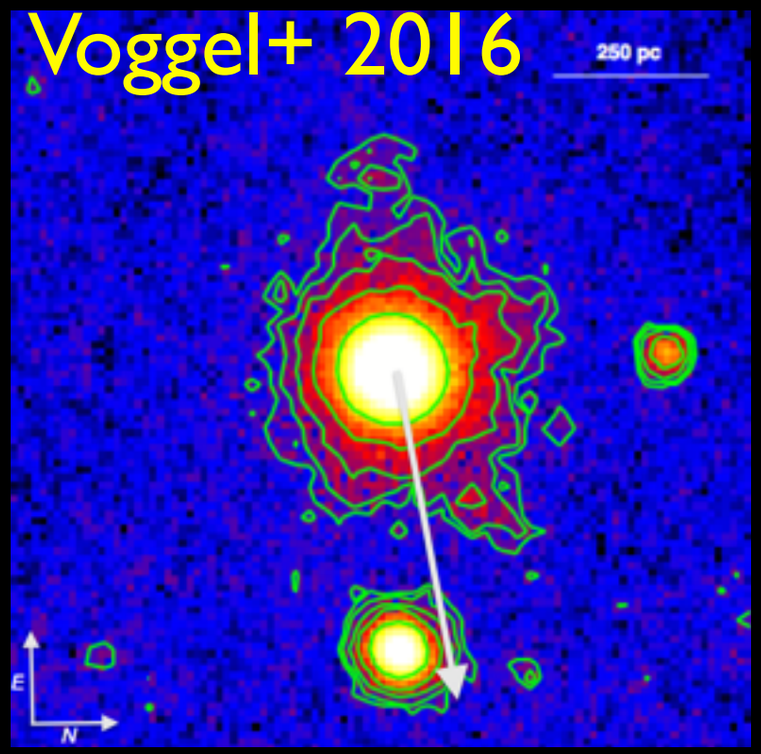
- For M_{star}~10^9 $M_\odot$ progenitors of UCDs likely outnumber present day galaxies in clusters.

- In local group, 19 globular clusters vs. 6 nuclei above 1.4x10^6 $M_\odot$

How do we know if they're nuclei?

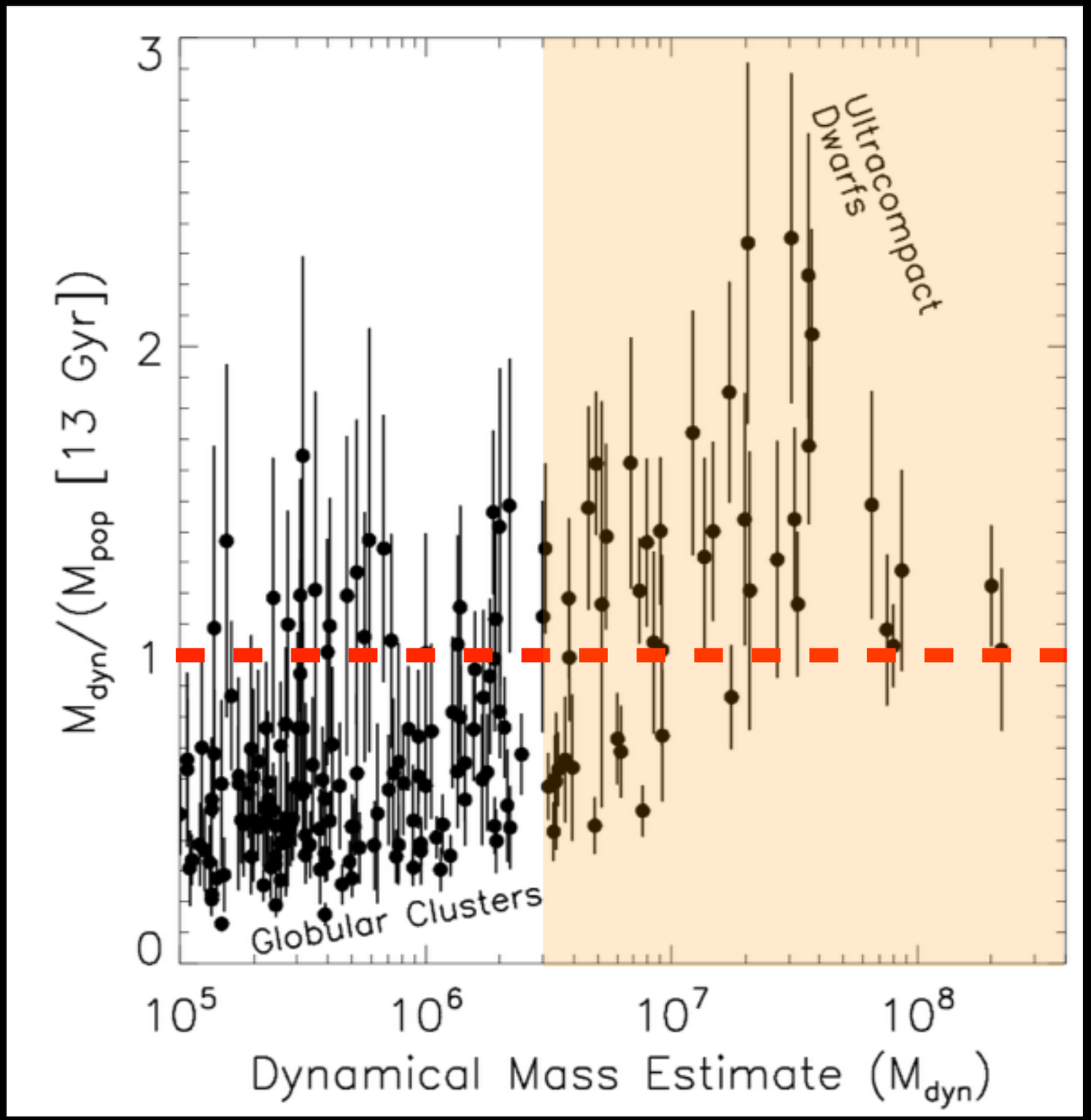


Norris+ 2015



- Extended star formation history (Norris+ 2015)
- Tidal features seen around a small fraction of UCDs/ GCs (Voggel+ 2016, Jennings+ 2015, Martini+ 2004)
- **High mass fraction black holes** (Mieske+ 2013)

UCDs are overweight



Adopted from Mieske+ 2013

- Integrated dispersions suggest a majority of objects above ~3×10^6 $M_\odot$ have larger dynamical masses than expected base on their stellar light.

High resolution kinematics required to separate the stellar mass from the BH.

NGC4647

Messier 60

M60-UCD1

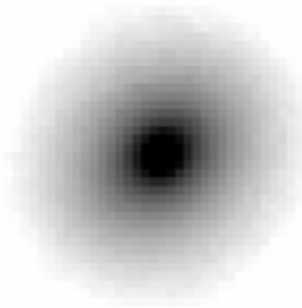
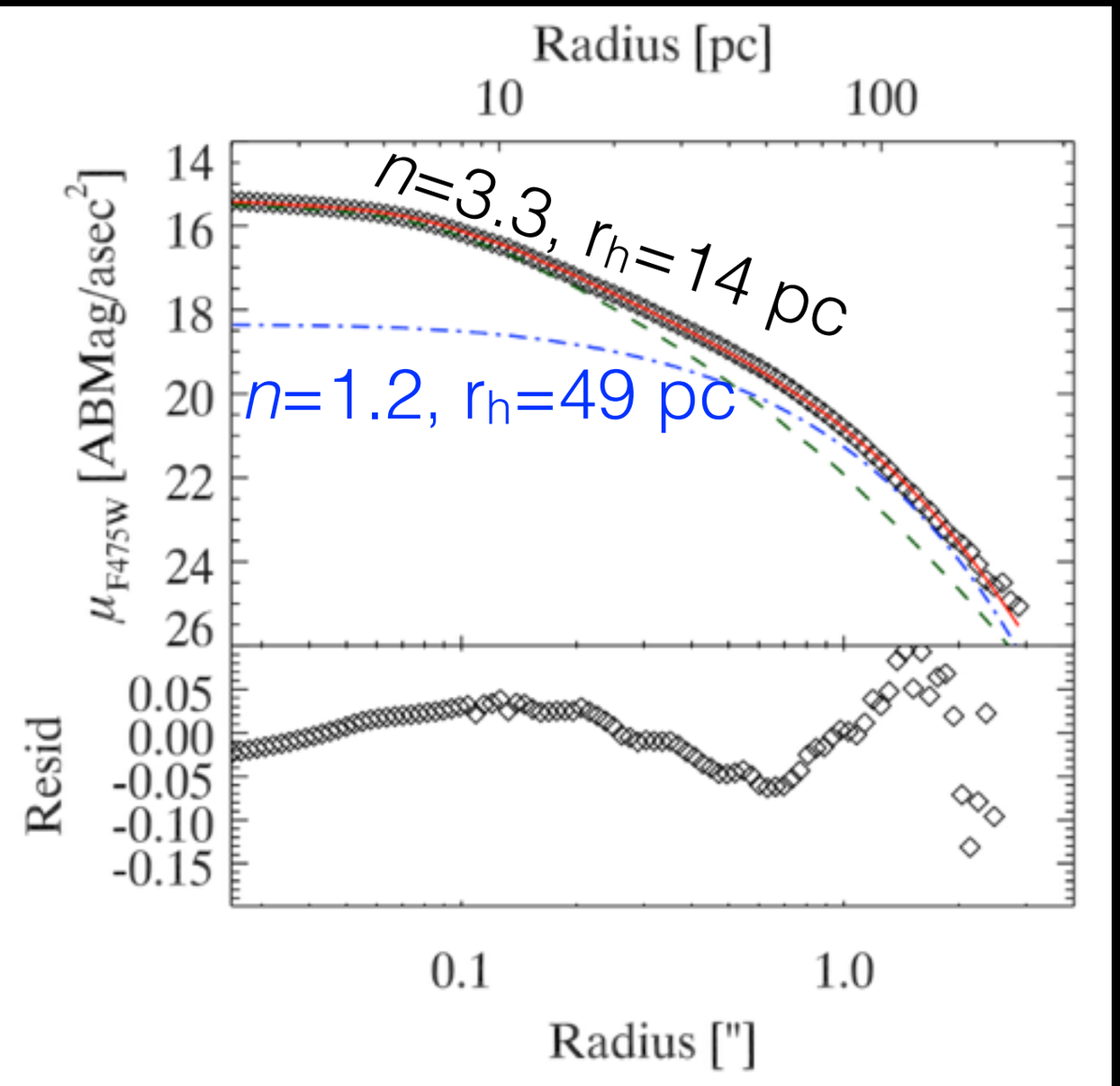


Image Credit: Hubble Heritage

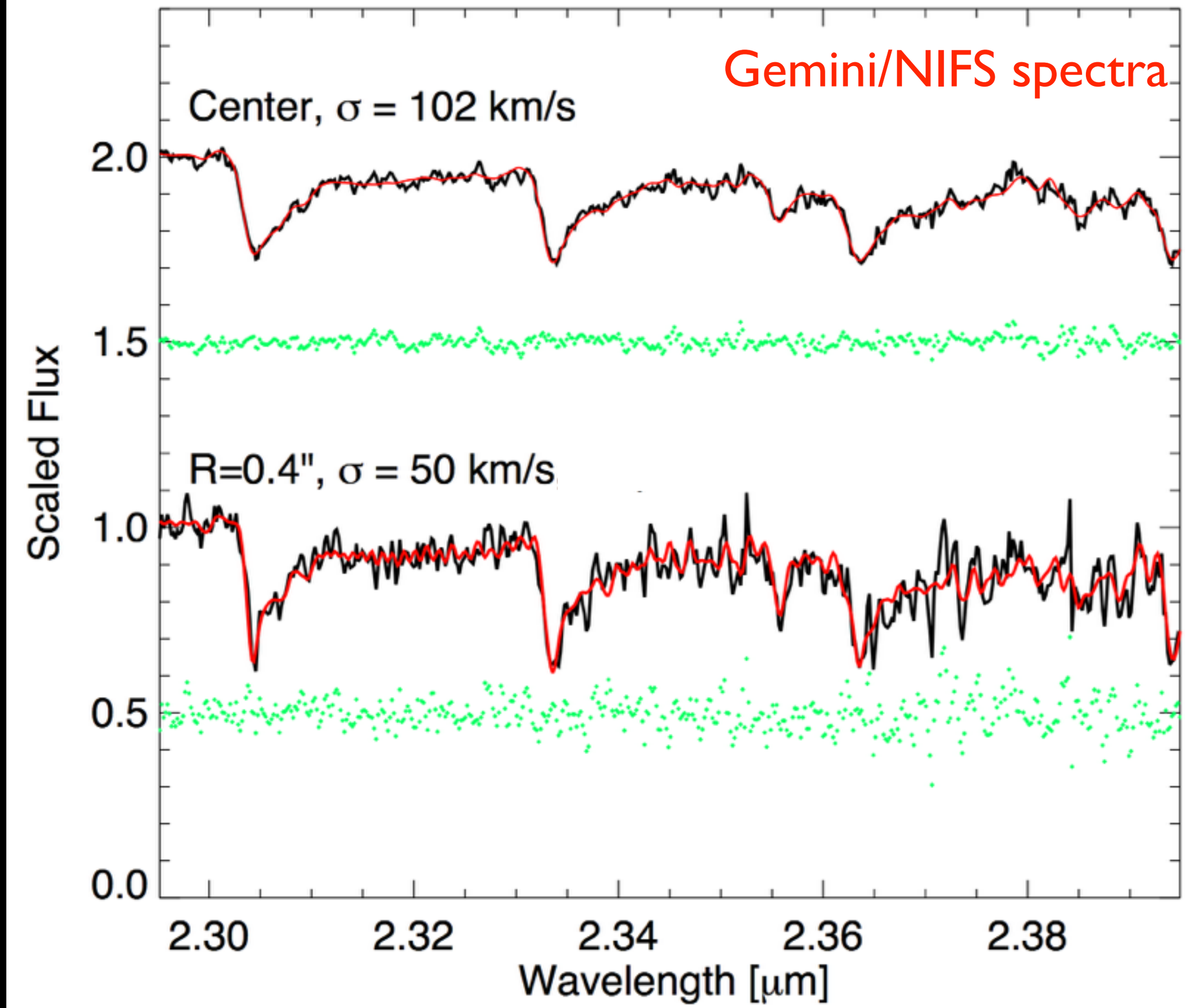
M60-UCD1 the "densest galaxy"



Strader, AS+ 2013

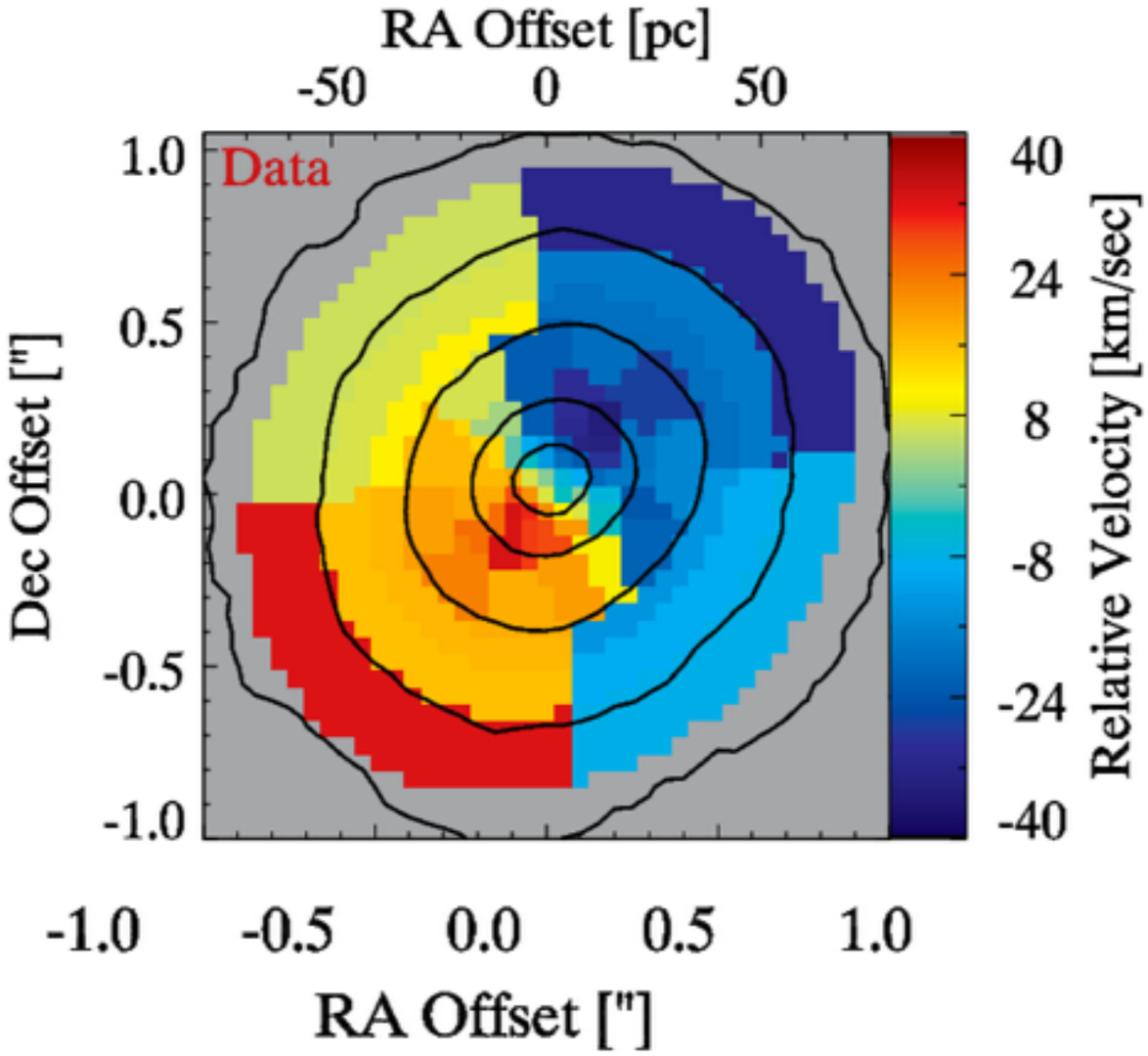
- Two Sérsic best fit
- R_h = 24 pc, L_V=4.1x10^7 $L_\odot$
- Integrated σ=68±5 km/s suggests 2x10^8 $M_\odot$
- Solar metallicity, old age, α-enhanced ([N/Fe]=+0.6)
- Variable X-ray source, L_X=1.3x10^{38} erg/s

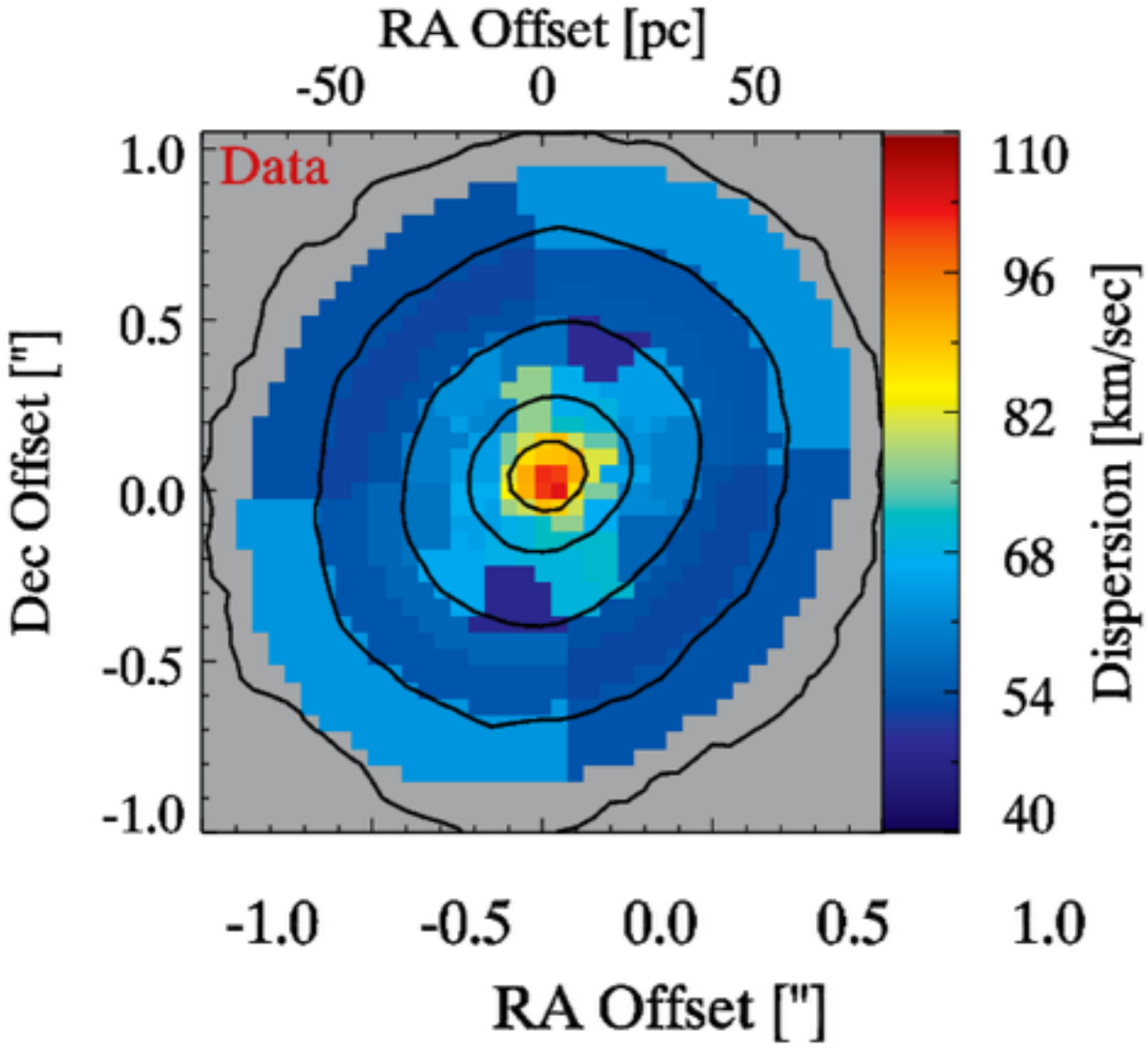
Gemini/NIFS spectra



Seth+ 2014

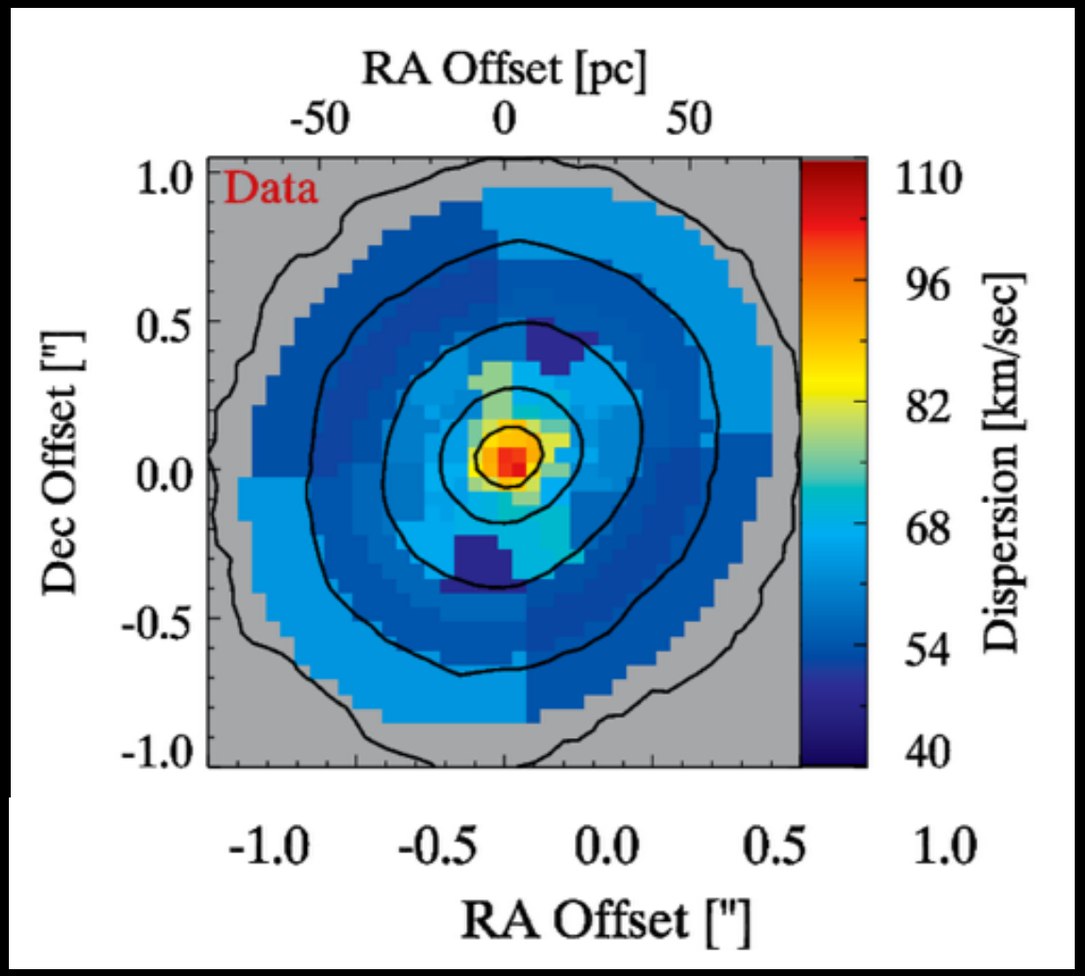
Stellar Kinematics



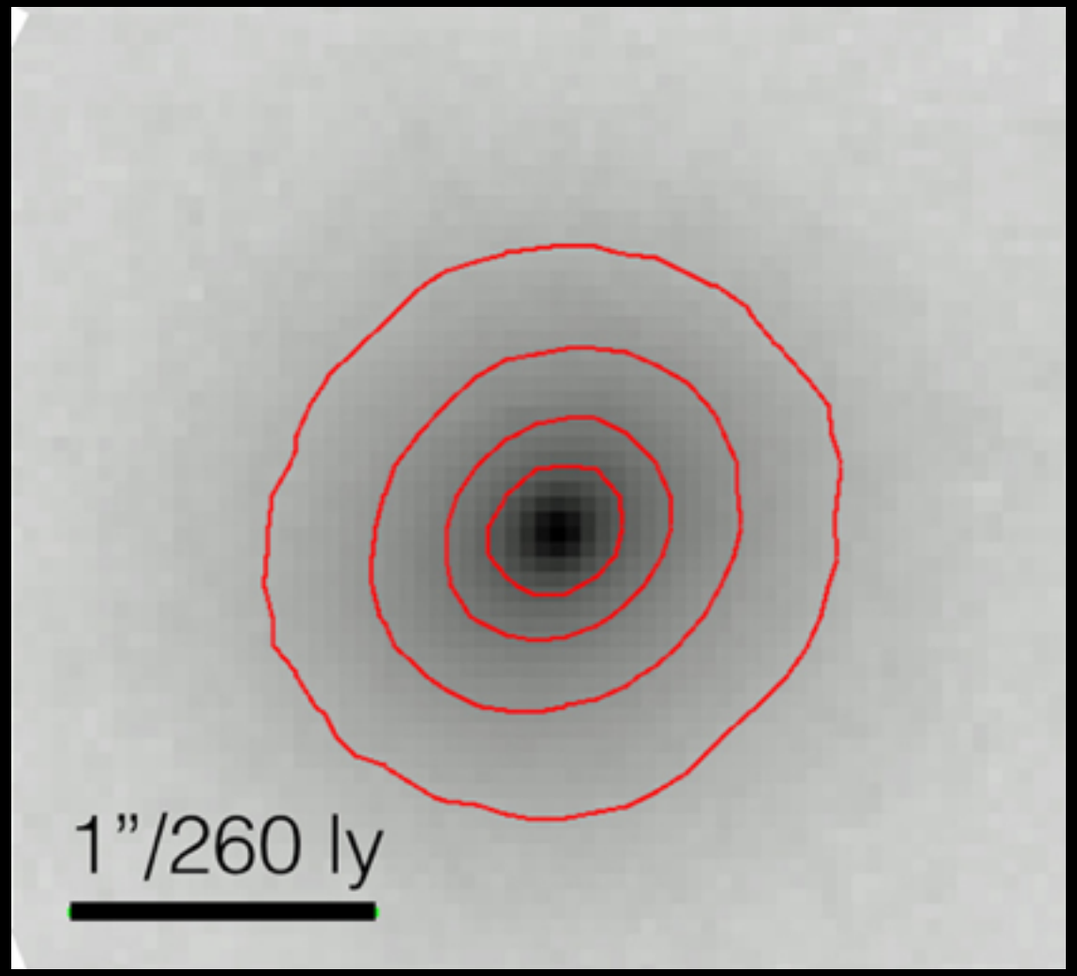


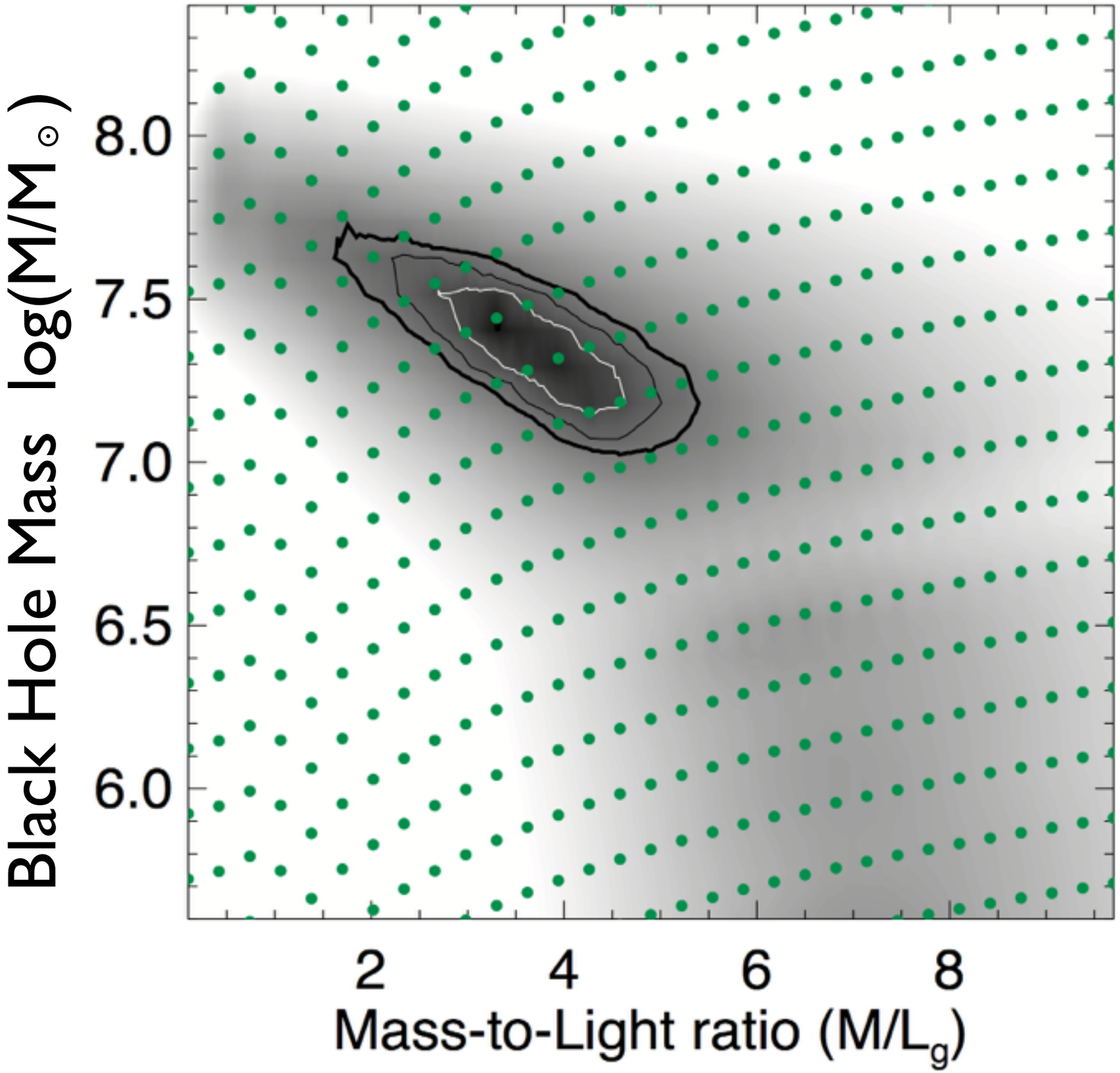
Measuring a BH mass

Motions of stars tell us how much mass is there



Hubble image tells us the distribution of stars





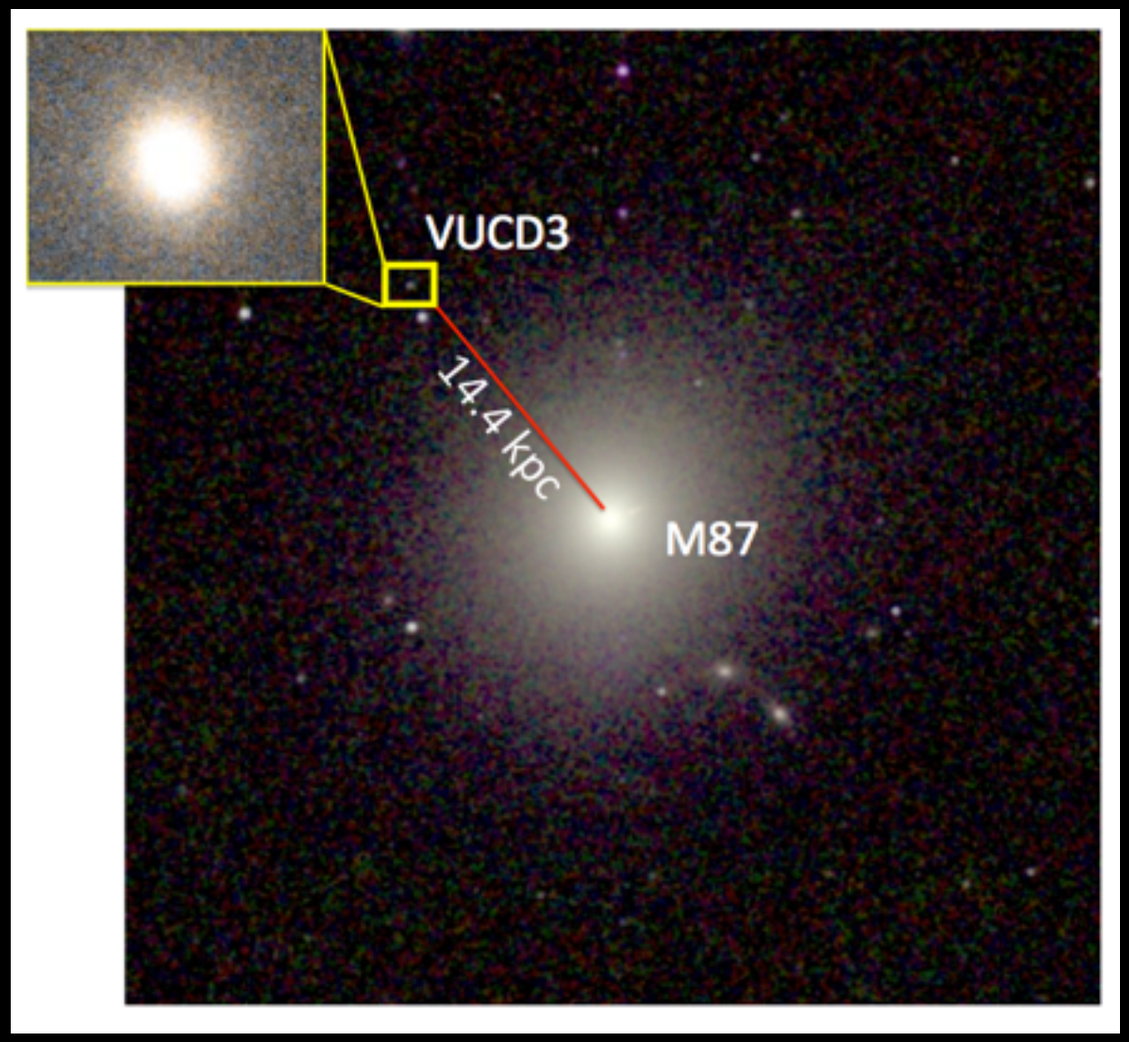
Schwazschild models (van den Bosch+ 2008,2010)

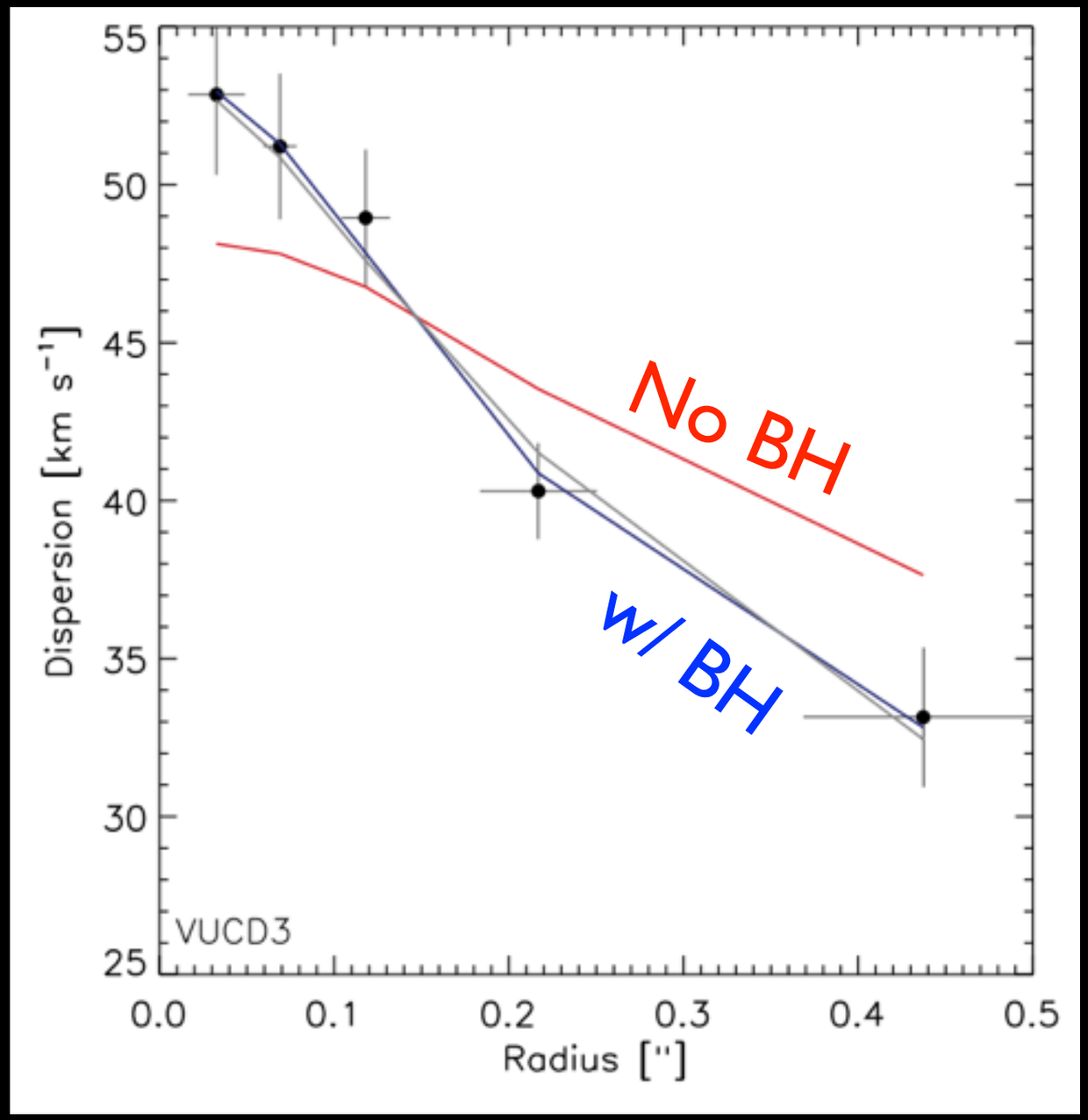
Best fit BH mass

$$2.1^{+1.4}_{-0.7} \times 10^7 \, \mathrm{M}_\odot$$

Best fit no BH model $\Delta\chi^2 = 20$ (>4σ)

M60-UCD1 is not unique: VUCD3

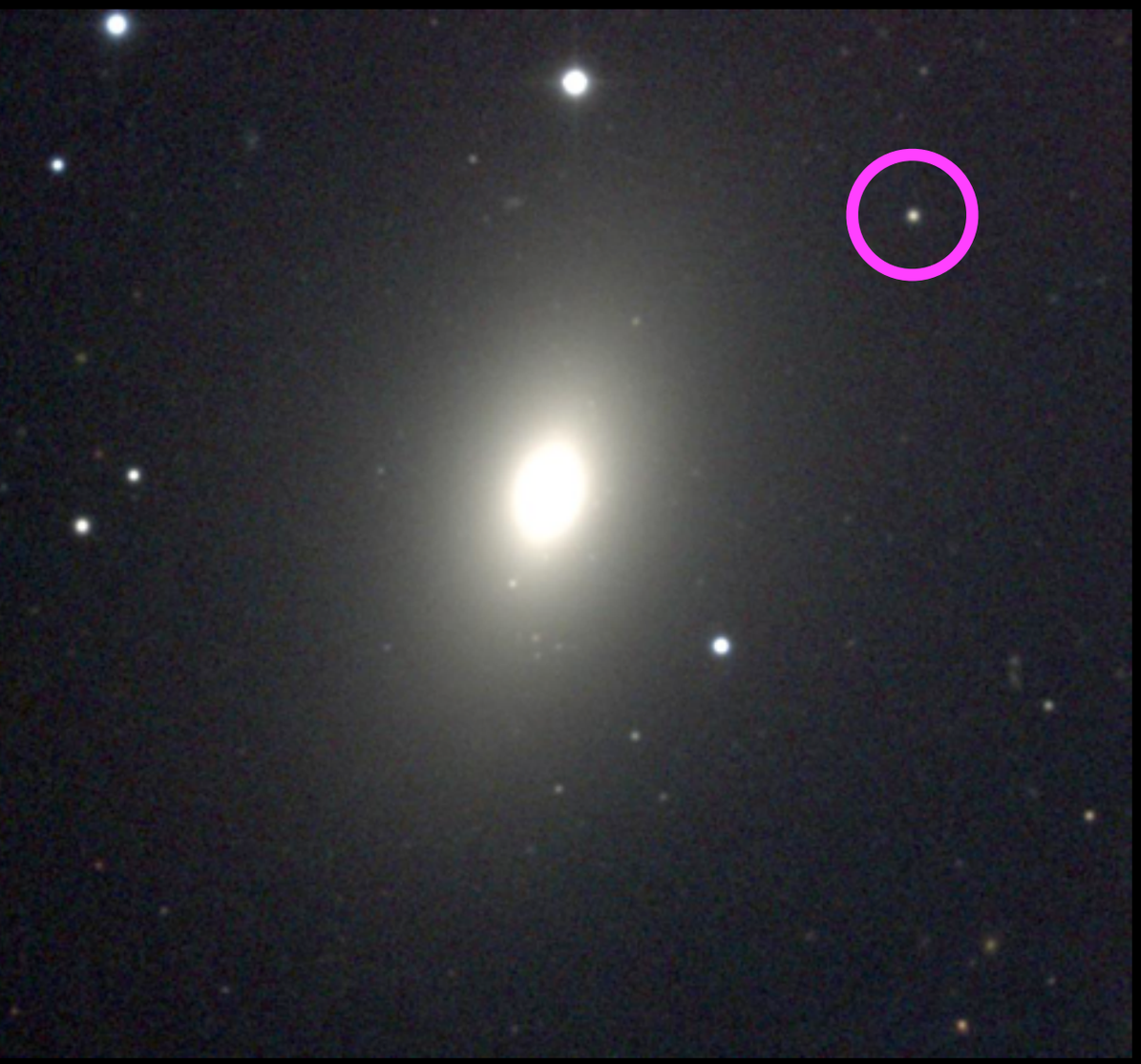




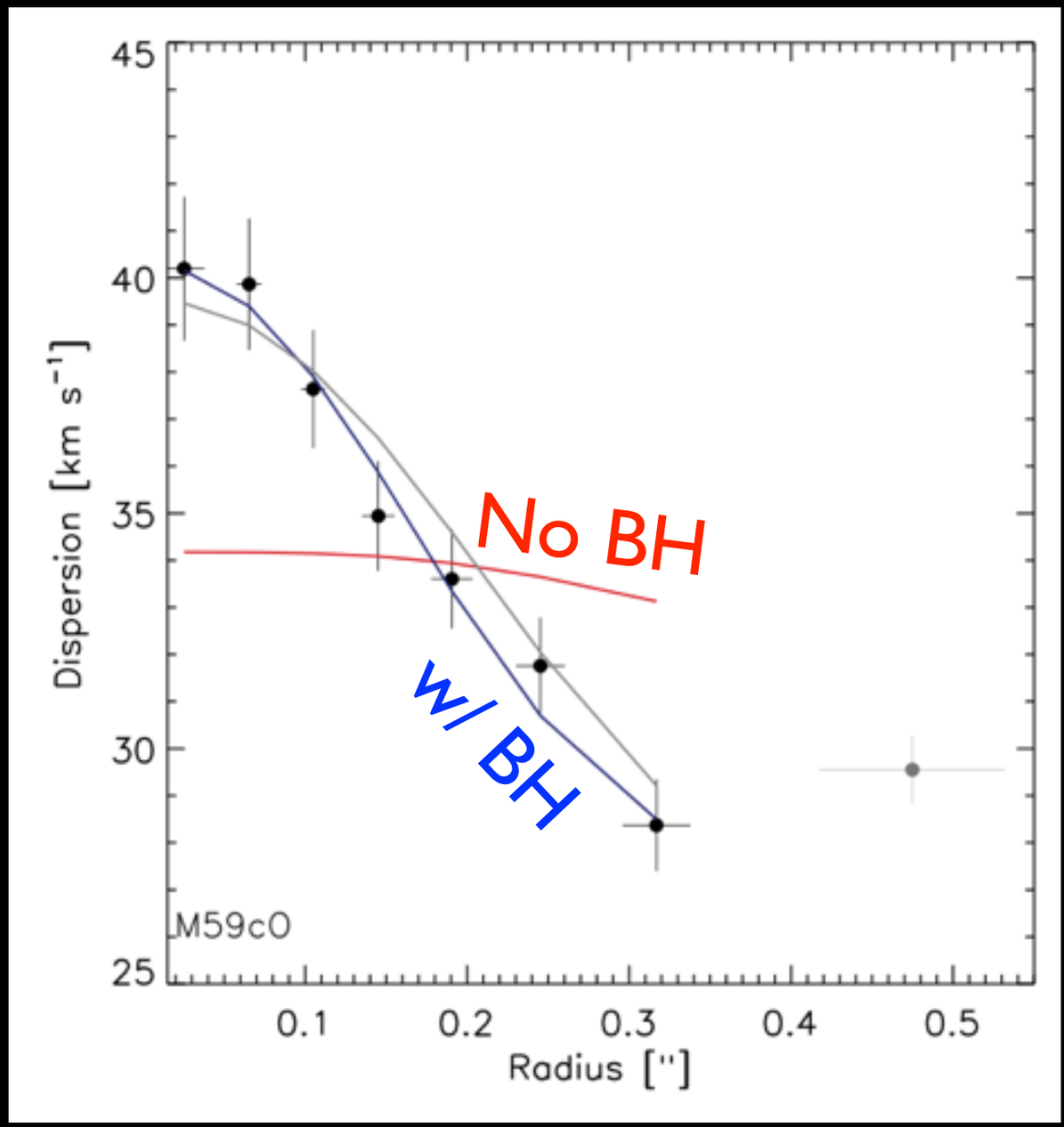
- BH mass 4×10^6 $M_\odot$
- Stellar mass 32×10^6 $M_\odot$

Ahn, AS+ *submitted*

M59cO

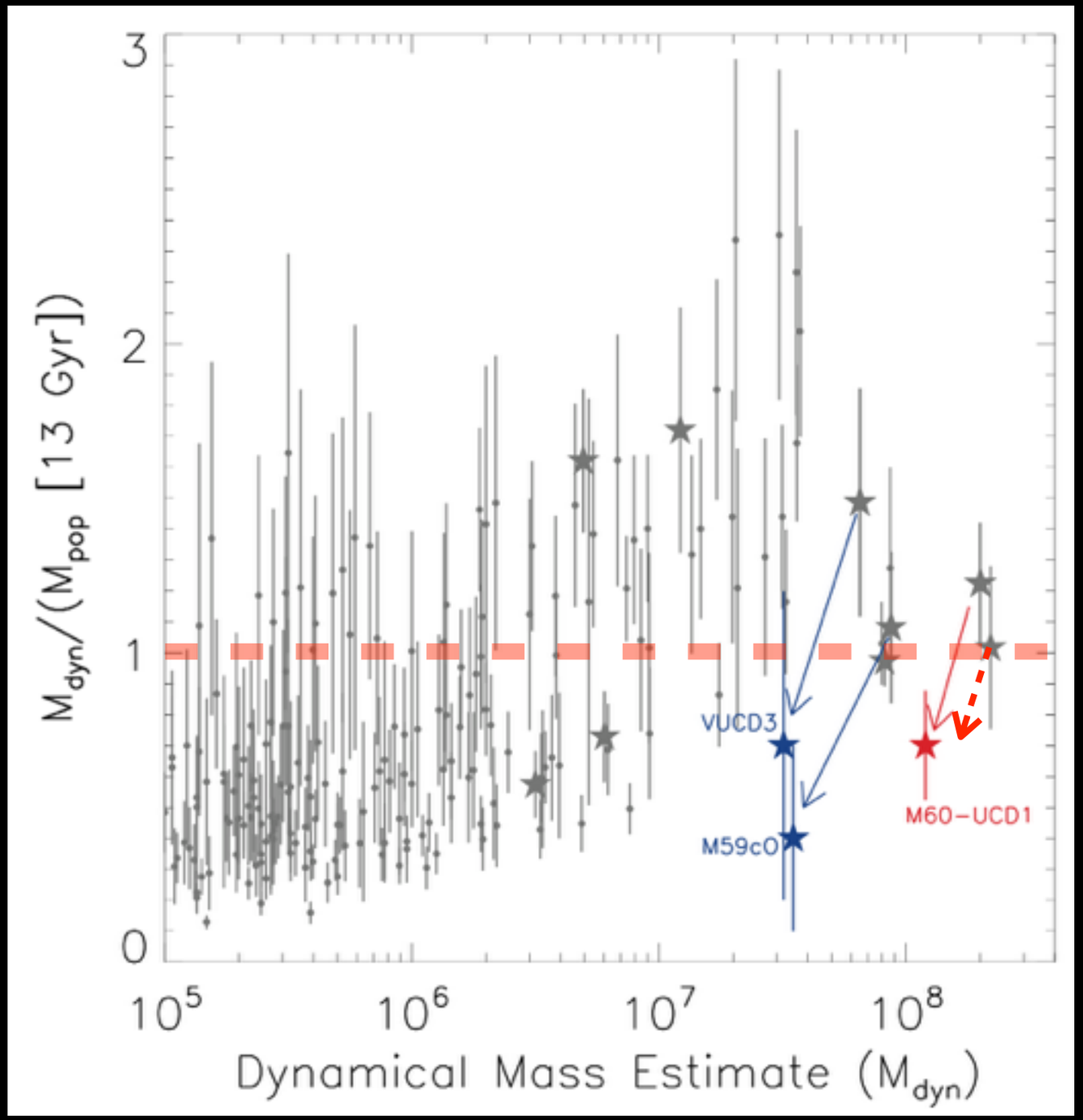


Ahn, AS+ *submitted*



- BH mass 6×10^6 $M_\odot$
- Stellar mass 35×10^6 $M_\odot$

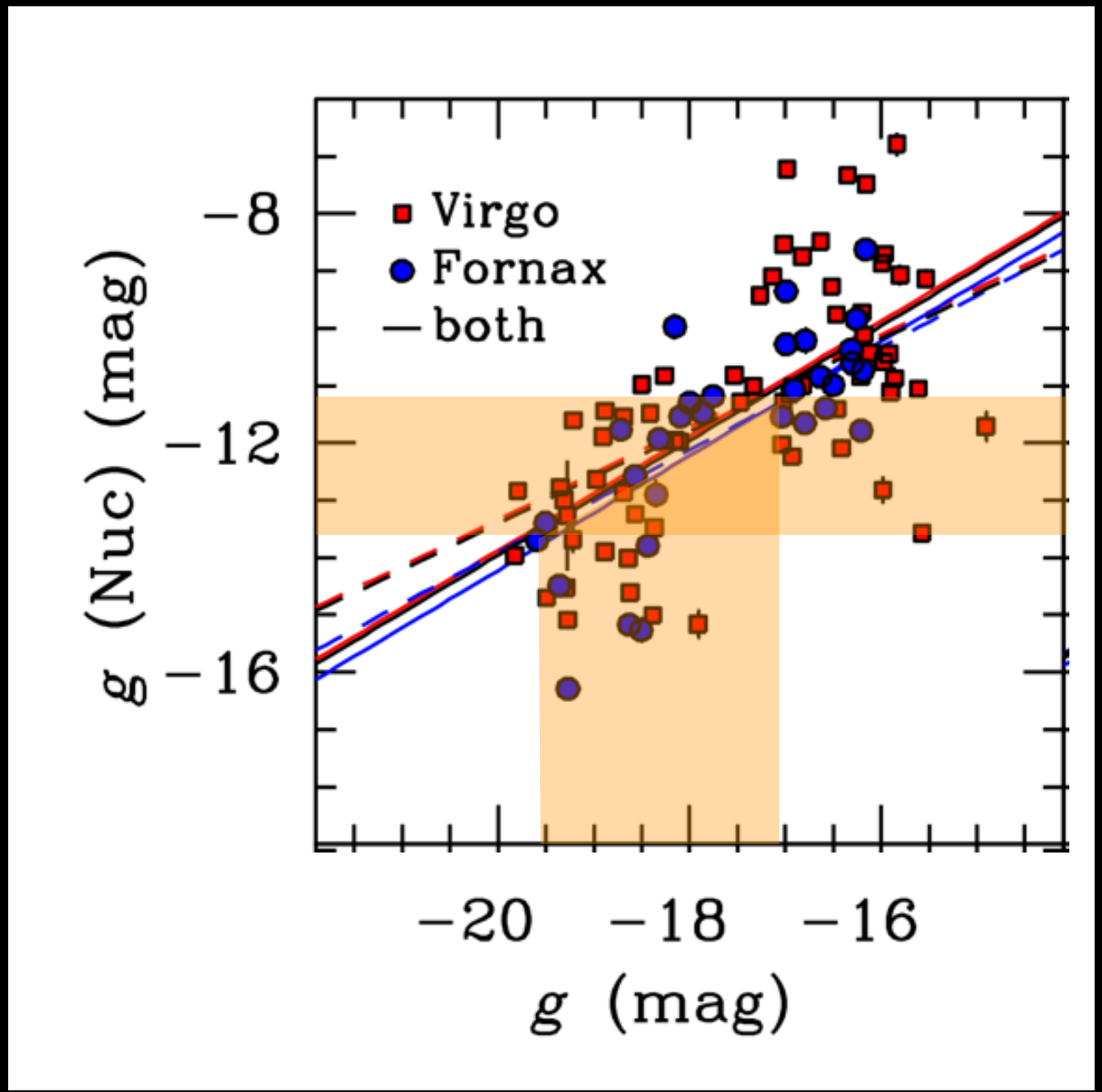
Tip of the iceberg?



Ahn, AS+ *submitted*

- Stellar mass in massive UCDs is not overweight! **Implies most UCDs have BHs.**
- Total number of UCD BHs depends critically on nature of lower mass UCDs and whether low mass galaxies have BHs (Karina Voggel)

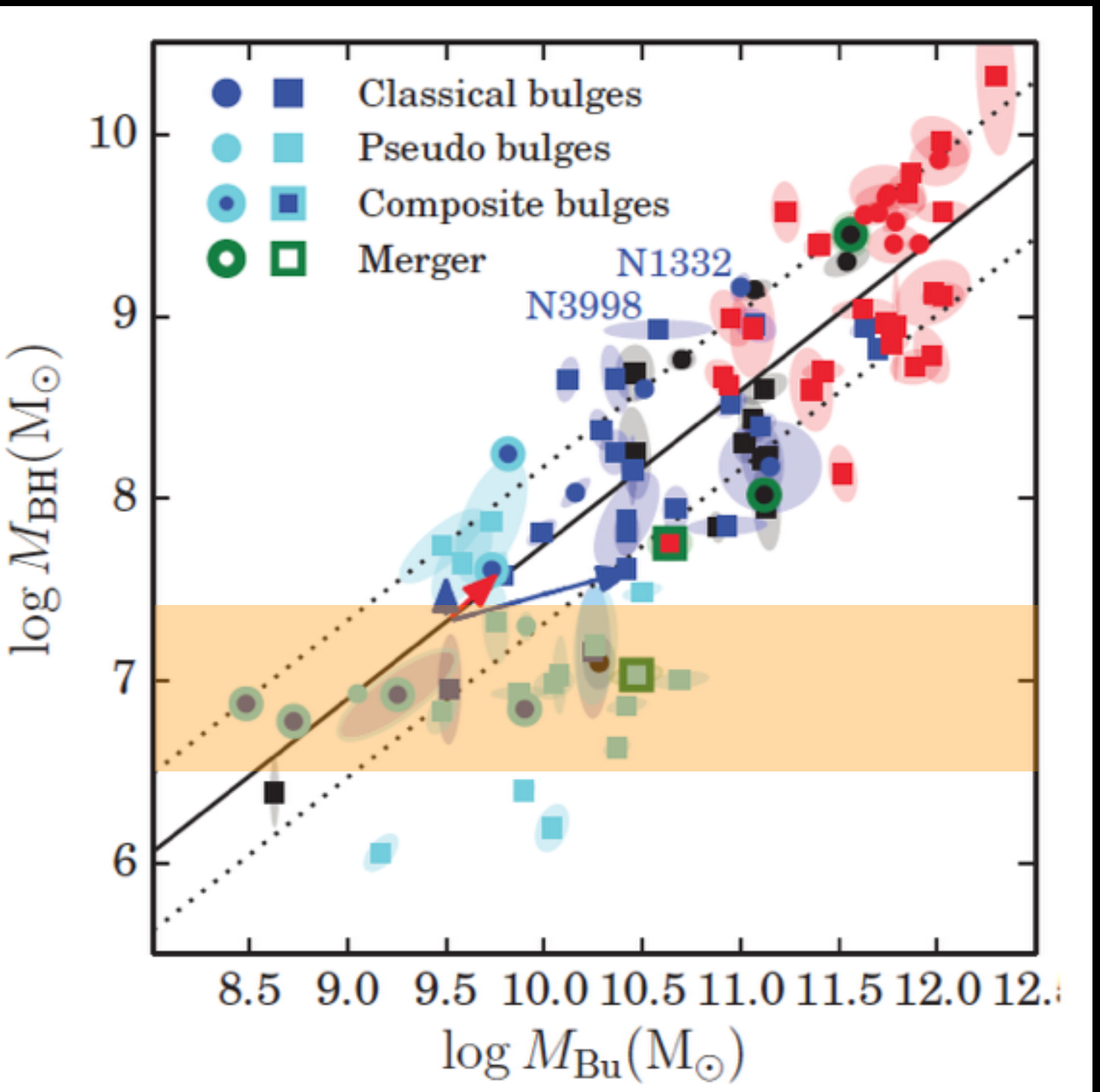
Host galaxies: Inner Components



- Assume inner components of UCDs are nuclear star clusters (Pfeffer+ 2013)
- Wide range of possible hosts, best matched by log(M)=9.5-10.3

Turner+ 2012

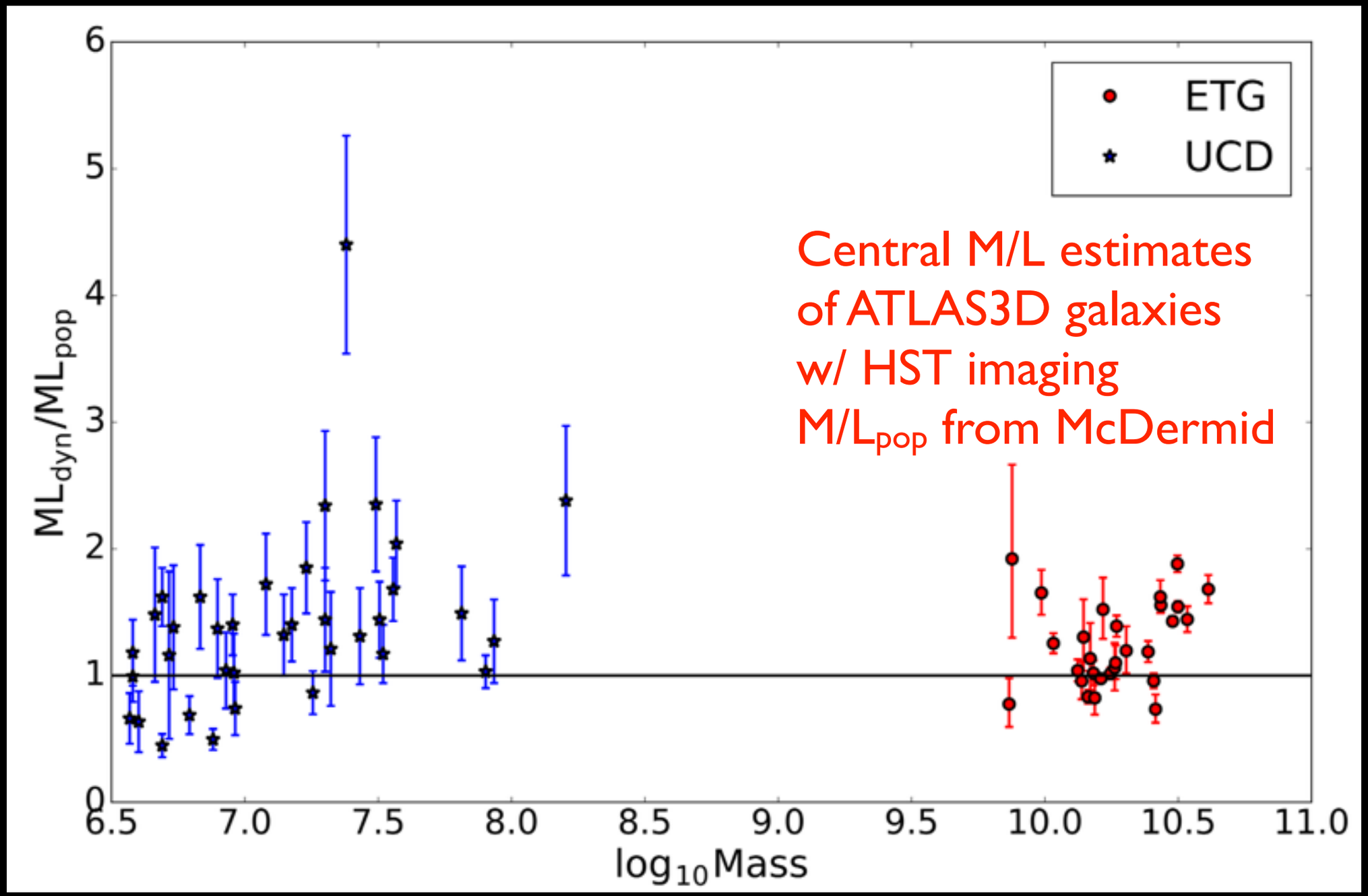
Host Galaxies: Black Holes



- Wide range of progenitor galaxy/bulge masses are possible
- Lower luminosity UCD measurements could probe IMBH range.
- Assuming early type progenitors, few measurements.

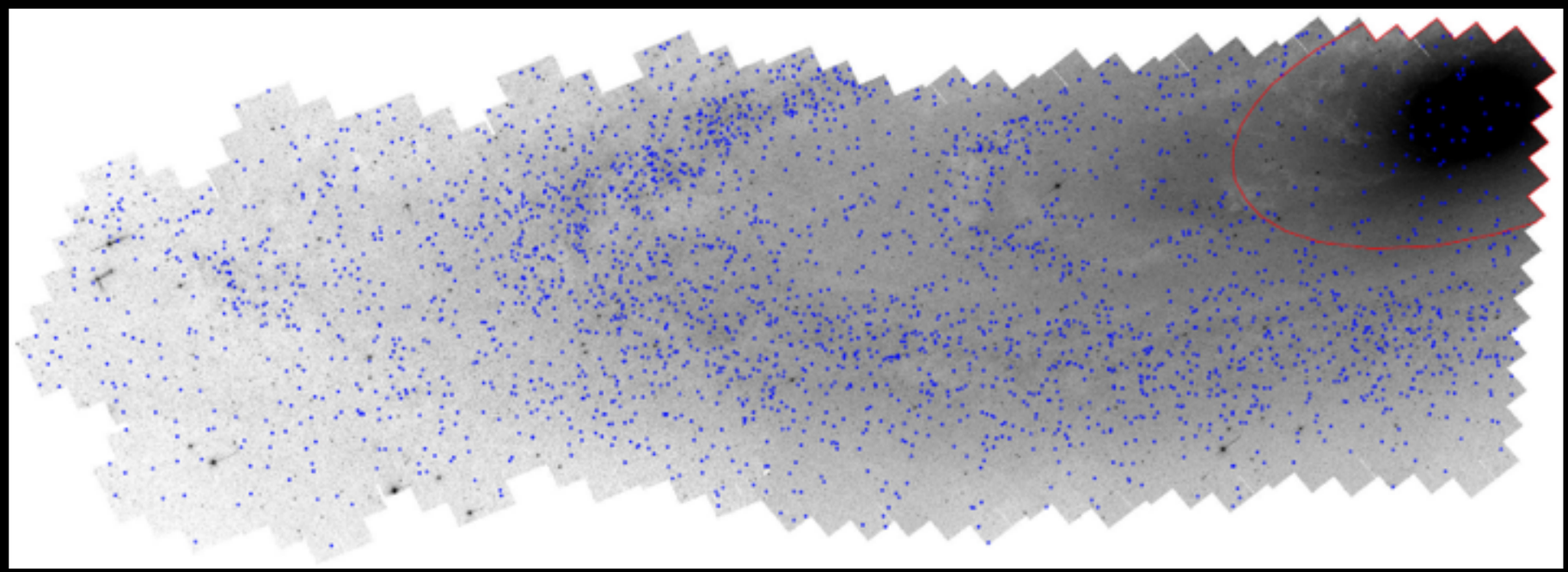
Saglia+ 2016

Early-Type Host Central M/Ls



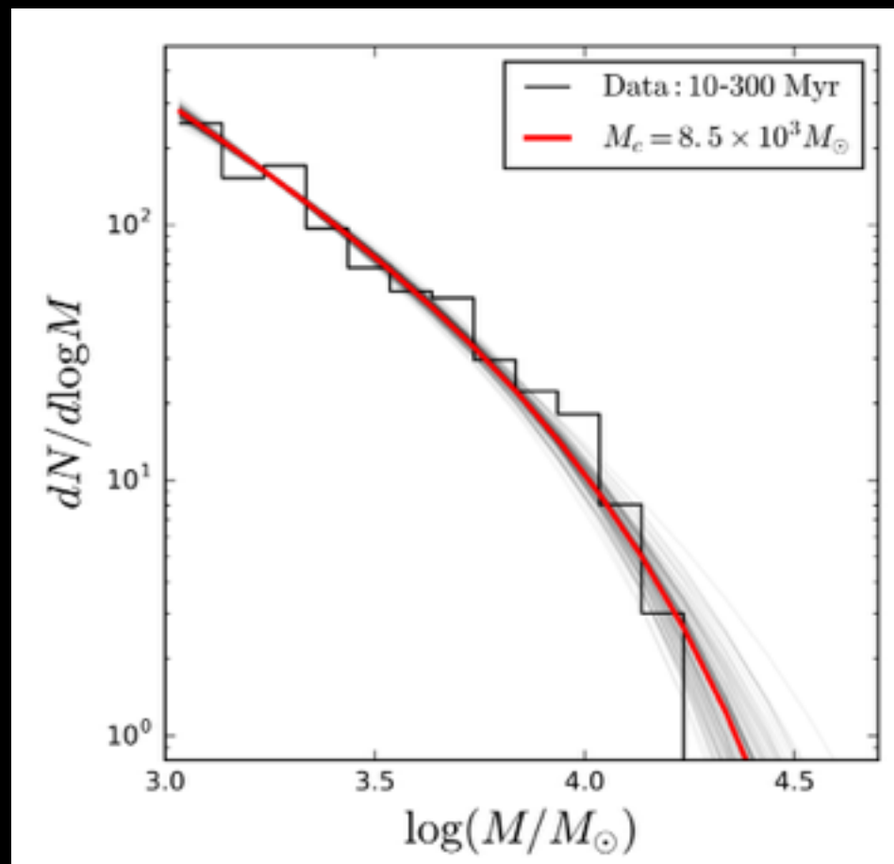
Pechetti+ *in prep*

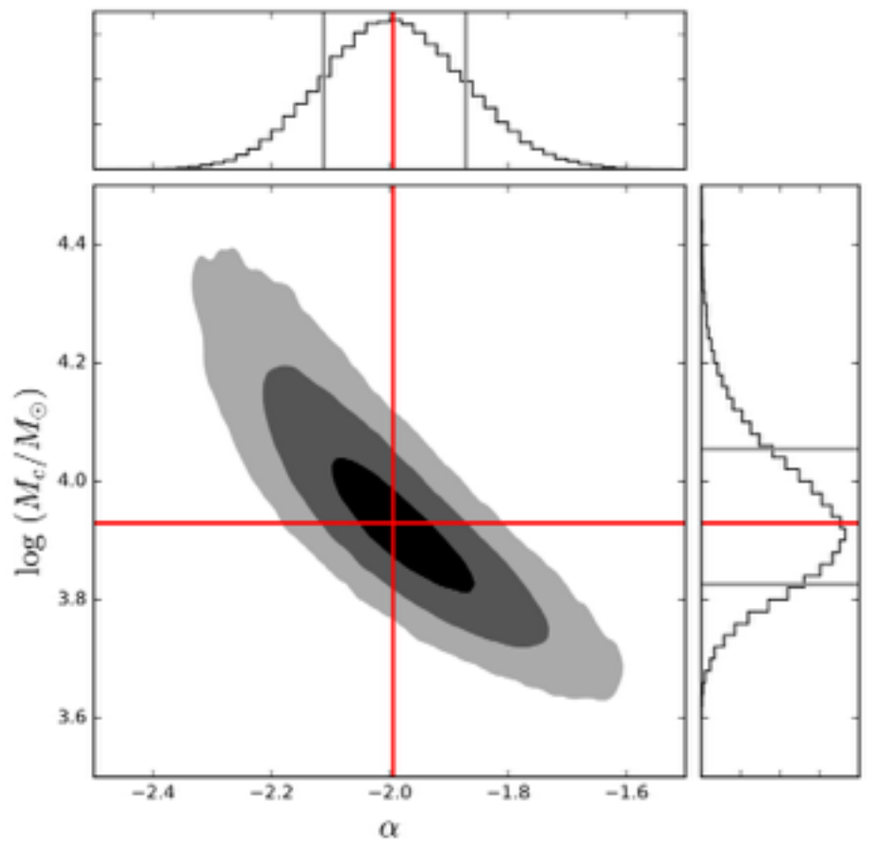
Aside: Cluster Mass Function

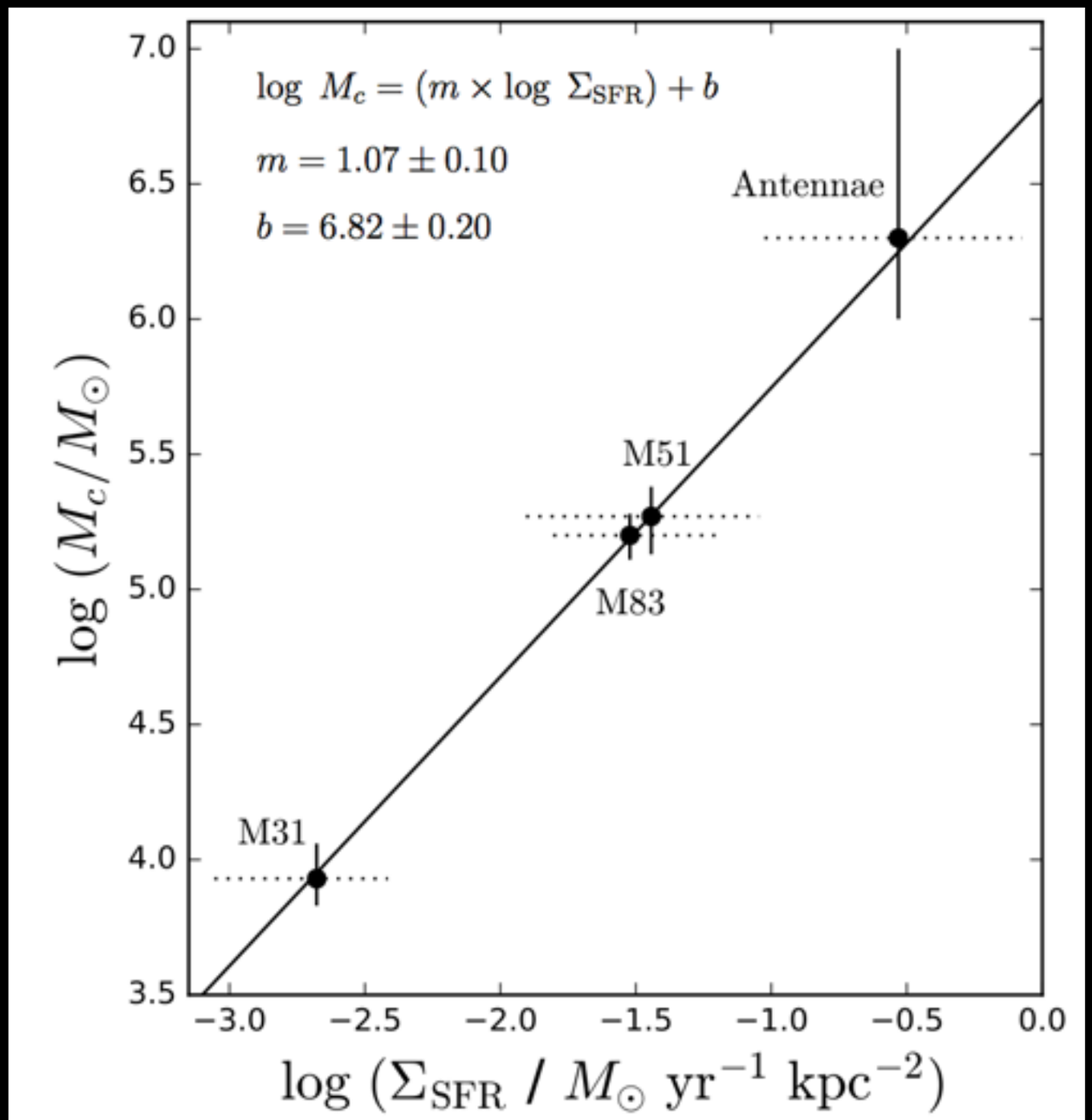


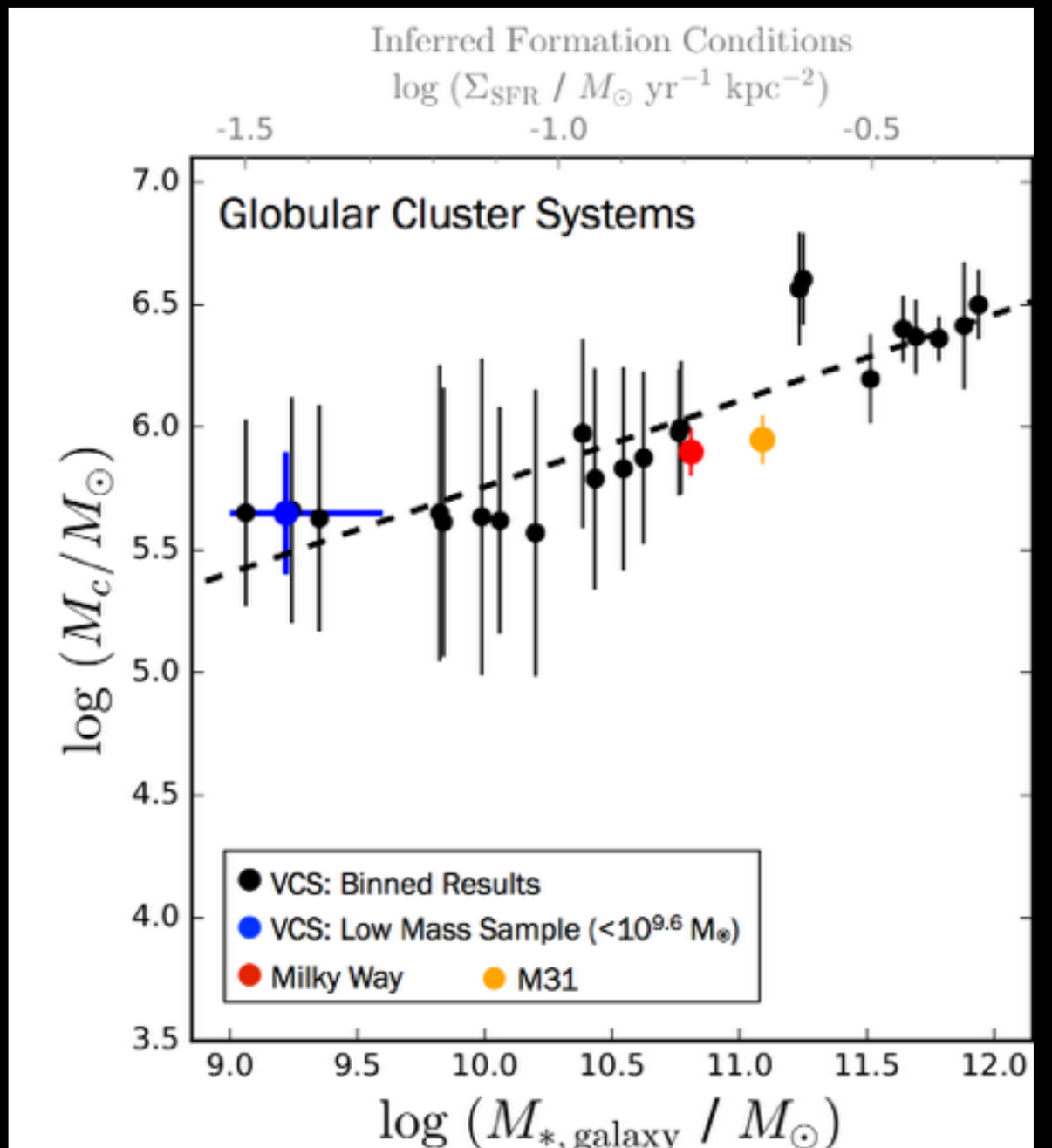
From PHAT: 840 young clusters above completeness limit in M31

Johnson, AS+ *submitted*

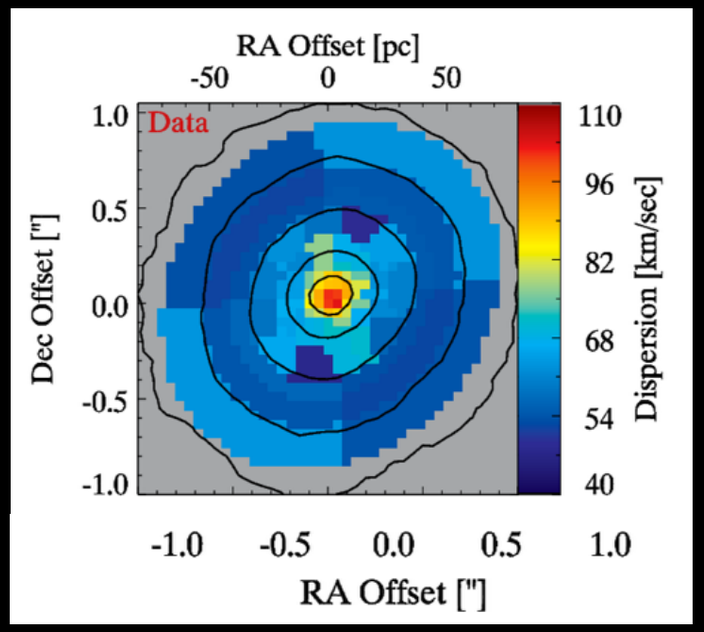


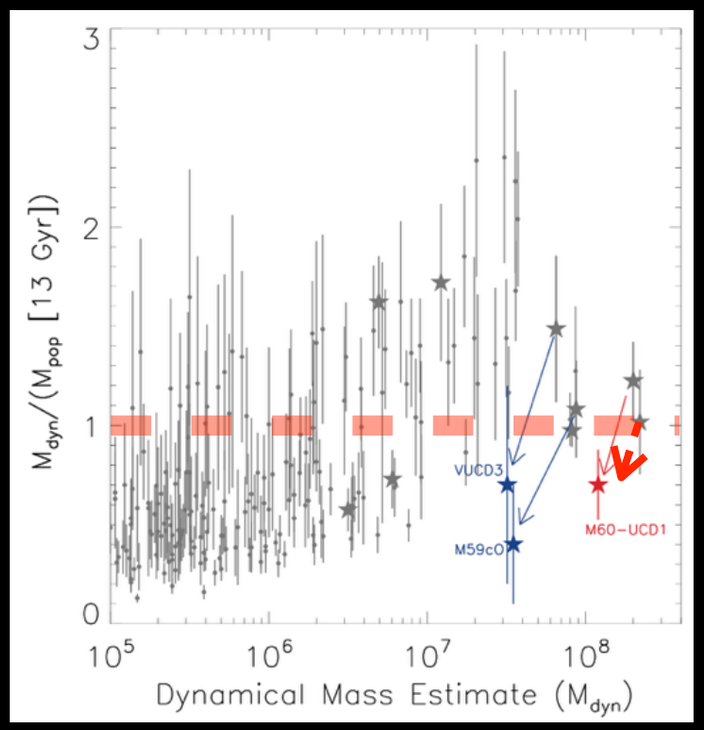



$\log\ M_c = (m \times \log\ \Sigma_{\rm SFR}) + b$
$m = 1.07 \pm 0.10$
$b = 6.82 \pm 0.20$
Antennae
M51
M83
M31
$\log\ (M_c / M_\odot)$
$\log\ (\Sigma_{\rm SFR}\ /\ M_\odot\ {\rm yr}^{-1}\ {\rm kpc}^{-2})$


Inferred Formation Conditions
$\log\ (\Sigma_{\rm SFR}\ /\ M_\odot\ {\rm yr}^{-1}\ {\rm kpc}^{-2})$
Globular Cluster Systems
VCS: Binned Results
VCS: Low Mass Sample (<$10^{9.6}$ $M_\odot$)
Milky Way
M31
$\log\ (M_c / M_\odot)$
$\log\ (M_{*,\,\rm galaxy}\ /\ M_\odot)$

Conclusions





- Black holes found in 4 high-mass ultracompact dwarfs. Lowest mass systems with supermassive BHs.
- Low stellar M/Ls in these systems suggest many UCDs likely host BHs.
- May be more stripped galaxies than present day systems; good place to study low mass BHs.