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# The search for super-massive black holes in UCDs - Tracers of the assembly history of a Galaxy Cluster

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in collaboration with:  
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# What are ultra-compact dwarfs (UCDs)?

- ❖ more massive ( $>2e6$ ) and brighter and GCs ( $M_V < -10$ )
- ❖ more compact than dwarf galaxies of the same mass ( $M > 10^6$ )

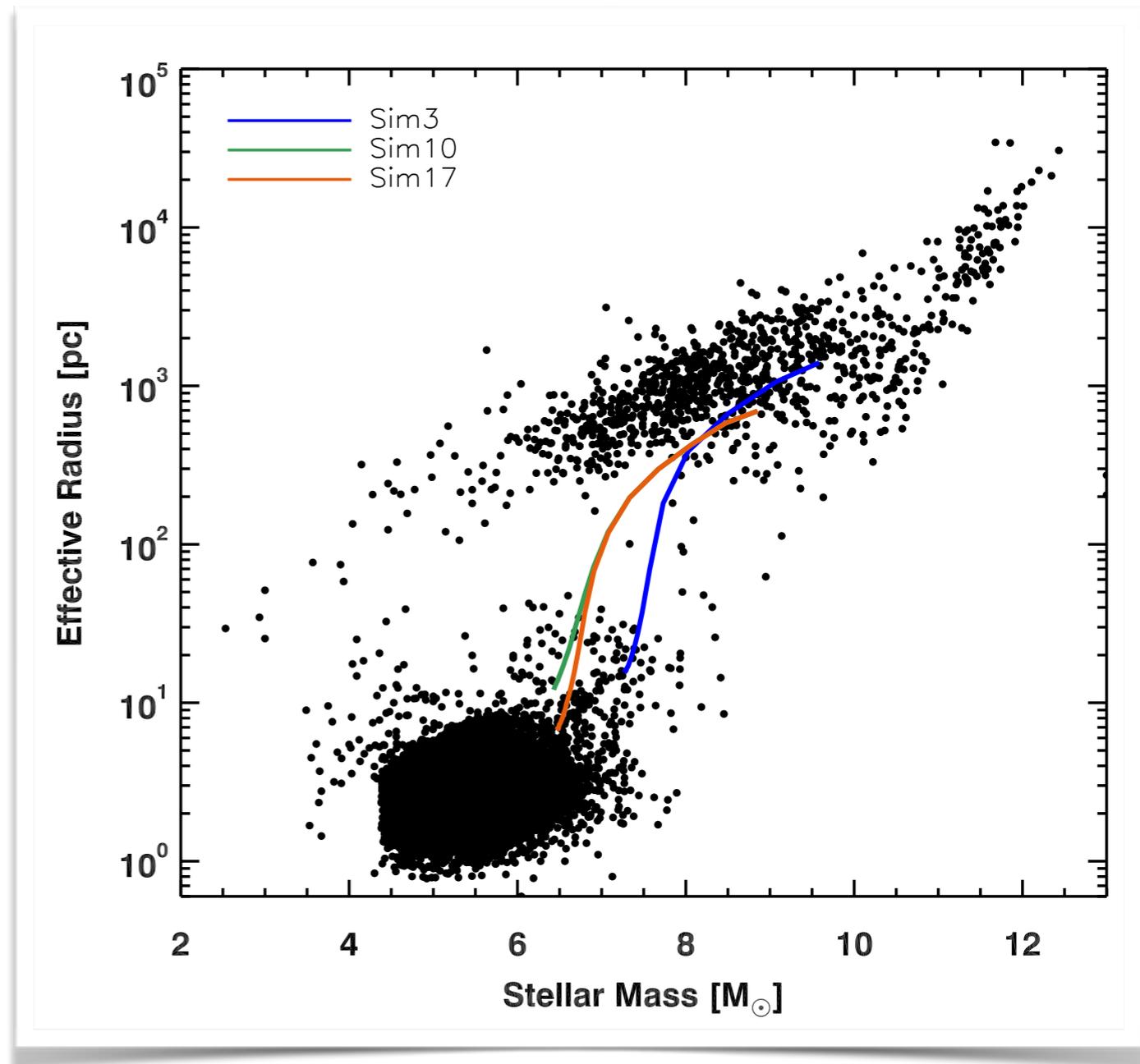


Omega Cen with its  $\sim 10$  million stars considered the lower mass limit of UCDs

# What is the nature of UCDs?

Two main physical formation channels:

1. They are the high mass end of the GC luminosity function
2. The nuclei of stripped dwarf Elliptical galaxies
  - ❖ If a fraction of UCDs are stripped dE nuclei some should contain Super-massive Black Holes!



# Which UCDs are the former nuclei of Galaxies?

❖ Inflated dynamical masses of high-mass UCDs

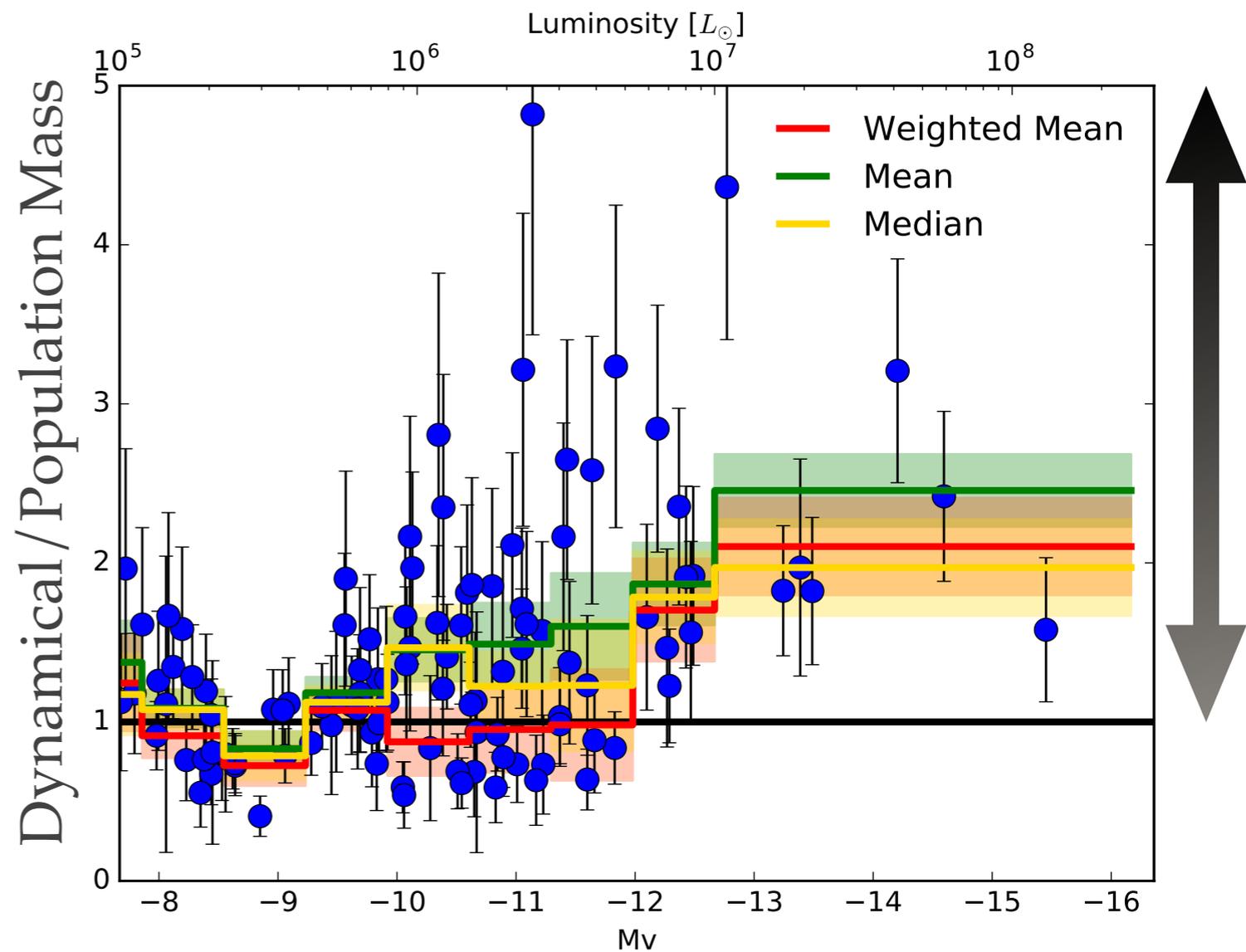
Possible explanations:

-> Dark Matter

-> IMF variations

-> SMBH in their centers!

**SMBH direct confirmation  
that a UCD is a stripped  
galaxy nucleus**

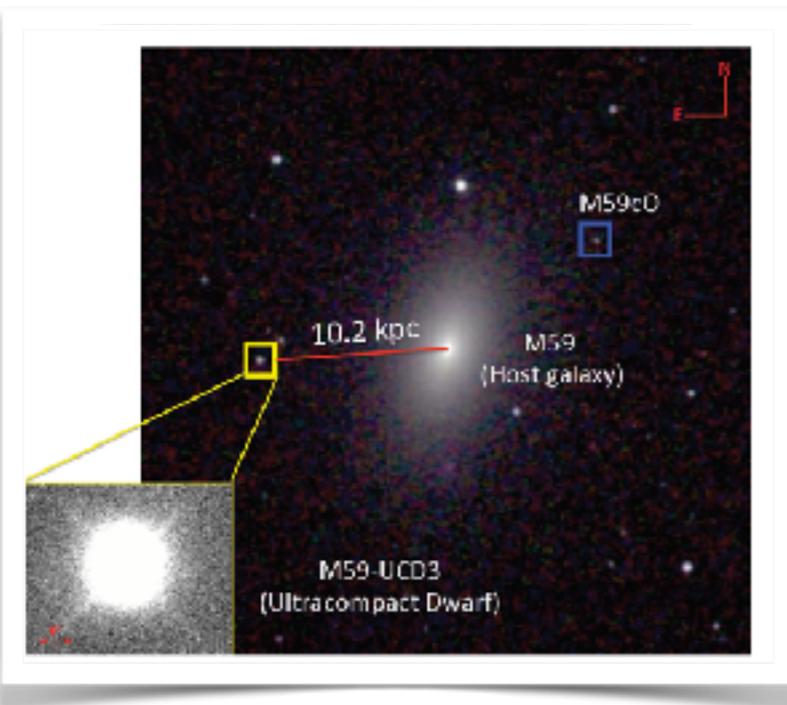


Voggel et al. in prep

# Measuring the BH mass: resolving the sphere of influence dynamically

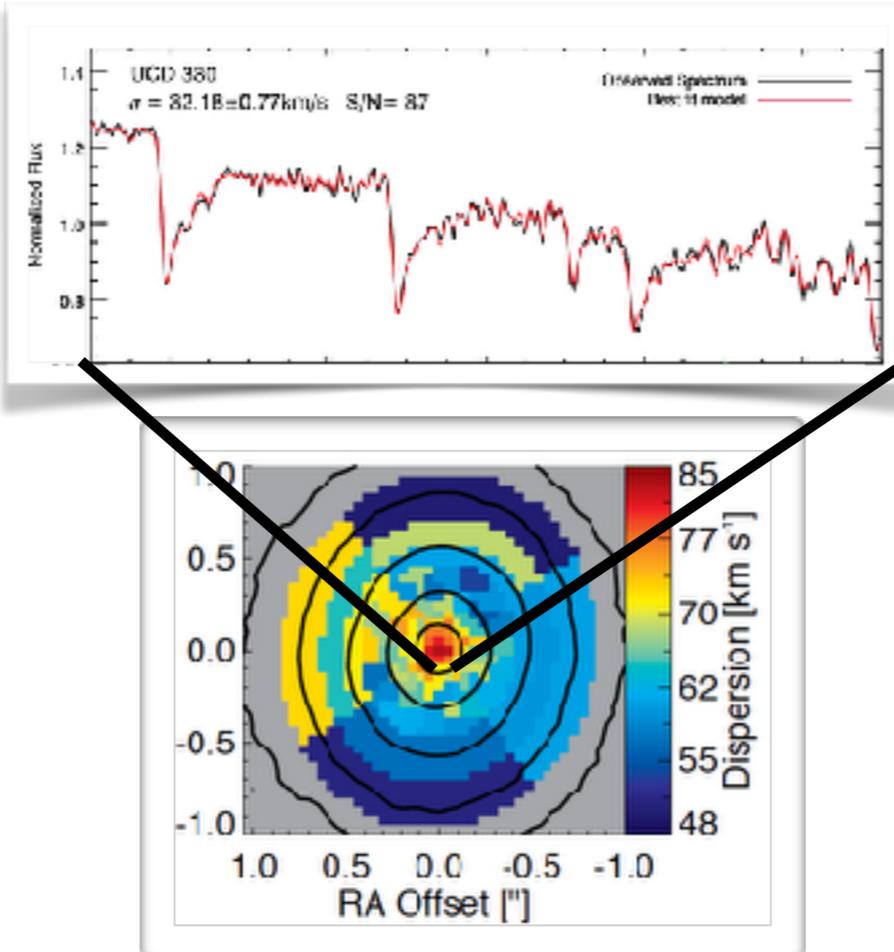
## 1.) Mass Model:

HST imaging -> Multi-Gaussian Expansion  
Mass model



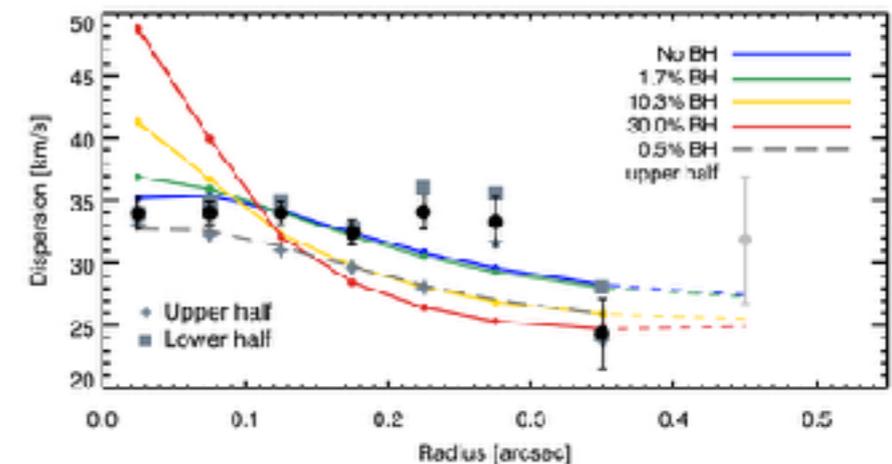
## 2.) Kinematic Data:

2D kinematical map of the CO band heads at 2.3 $\mu$ m, with AO resolving the central 0.1'' sphere of influence

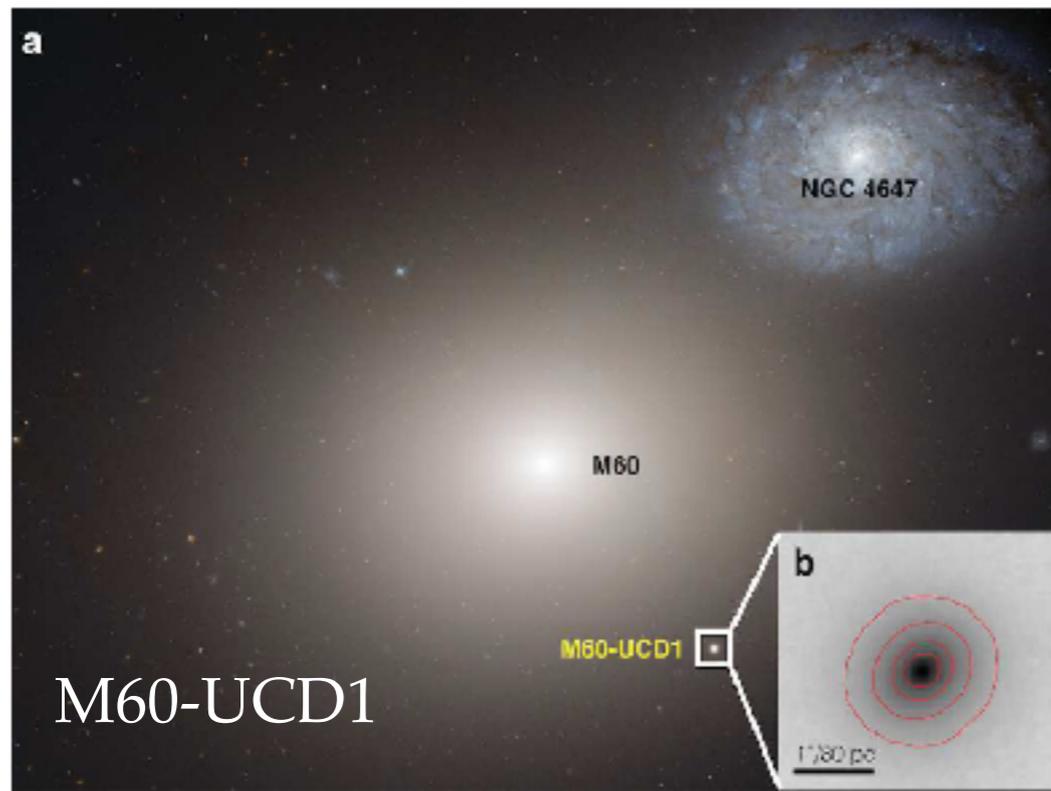


## 3.) JAM Models:

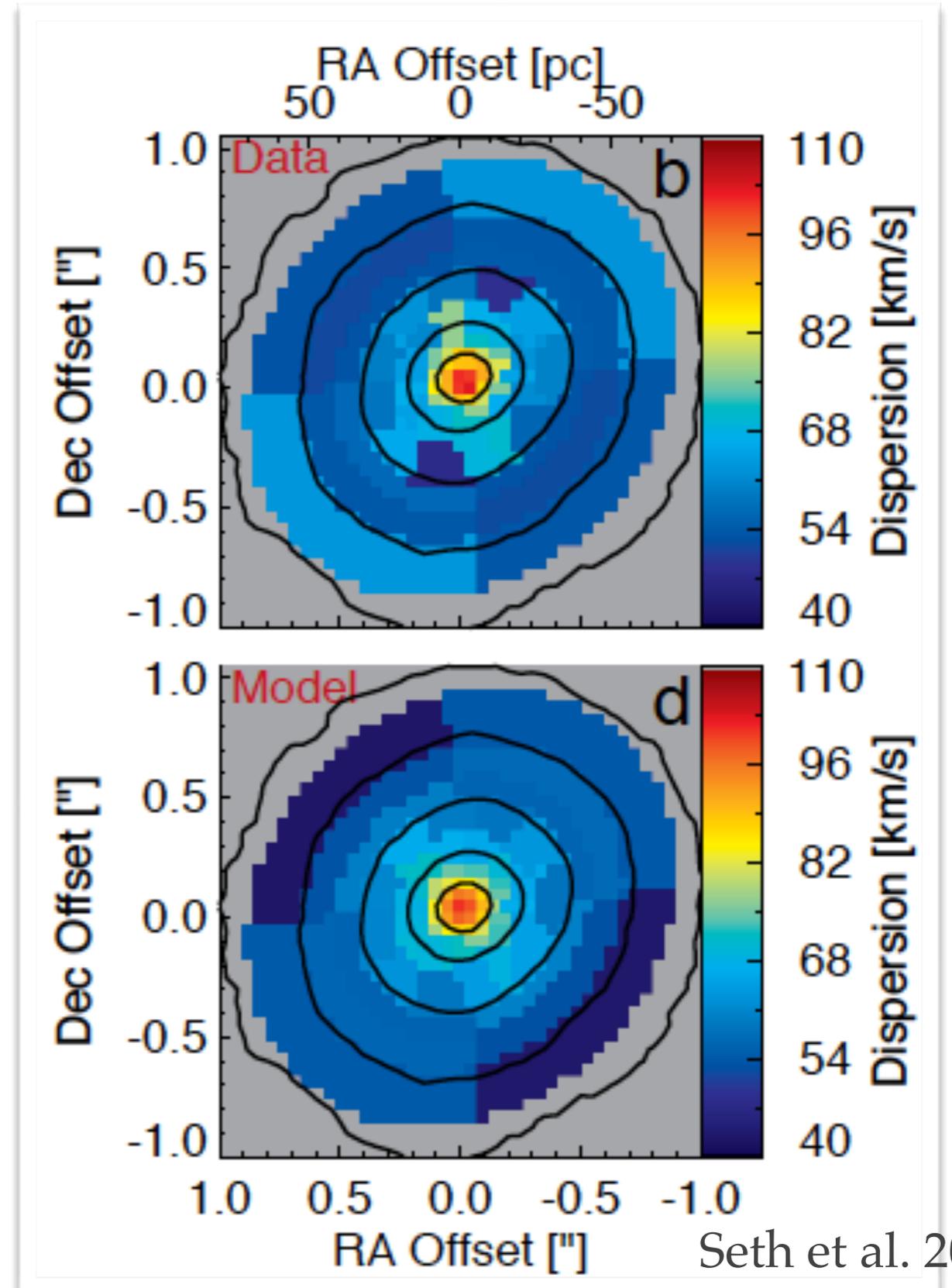
Dynamical Jeans anisotropic models with different BH masses



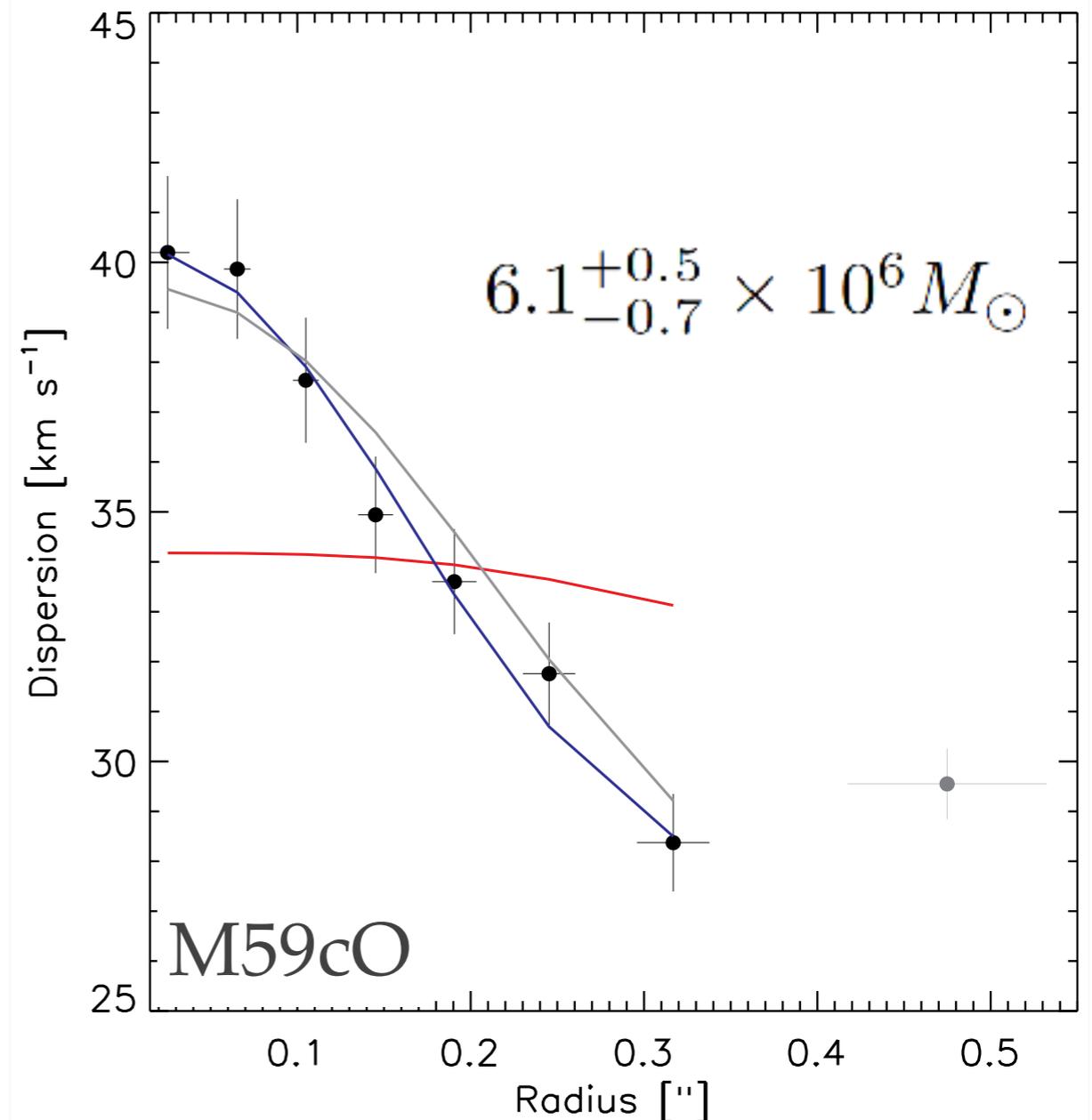
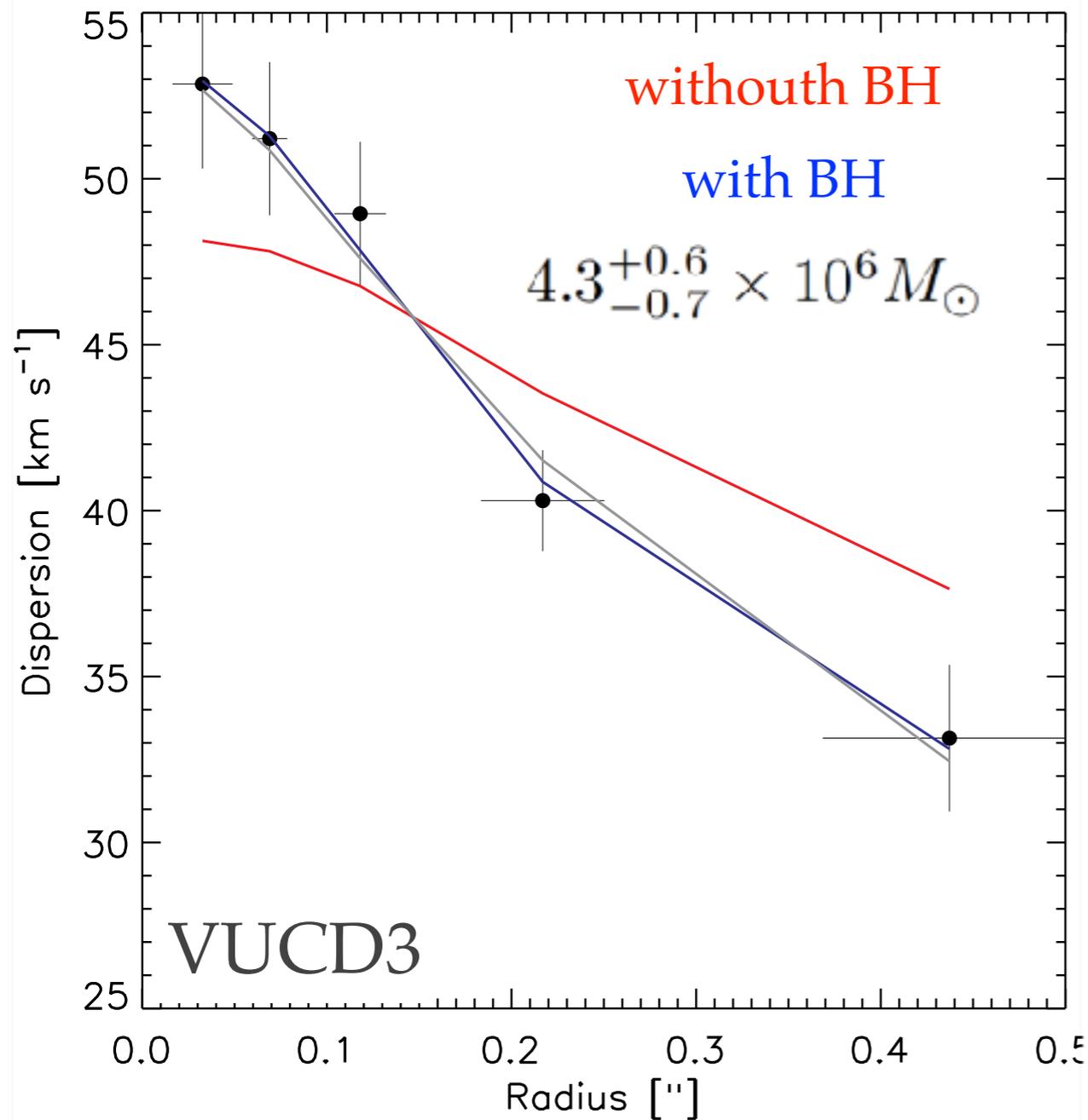
# First Super-massive black hole in a UCD



- ❖ SMBH of  $M=2 \times 10^7 M_{\odot}$ .
- ❖ SMBH Makes up 15% of UCD mass weather
- ❖ -> Inferred mass of progenitor galaxy:  $10^{10} M_{\odot}$ .

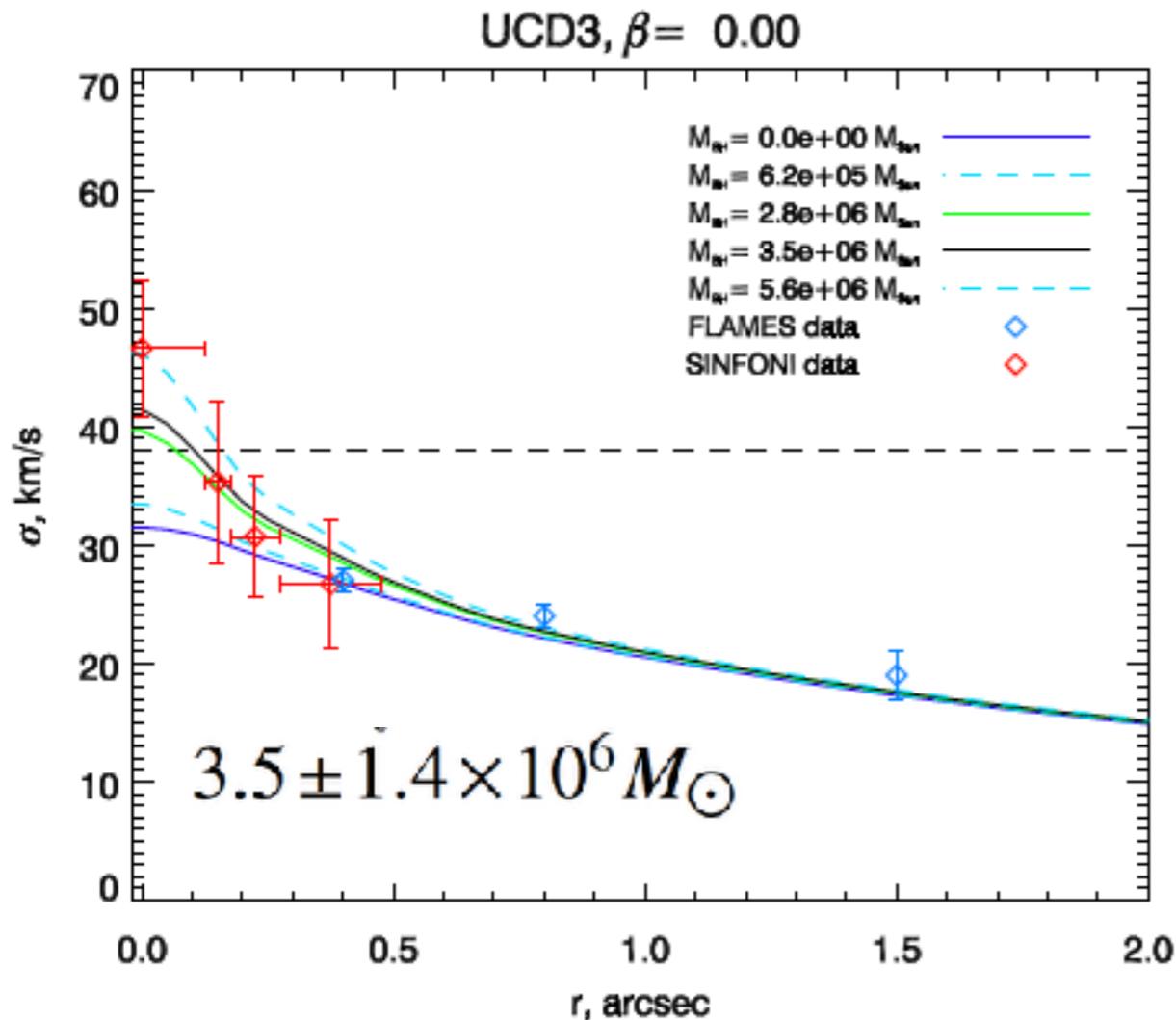


# Since then 4 new UCDs with SMBHs

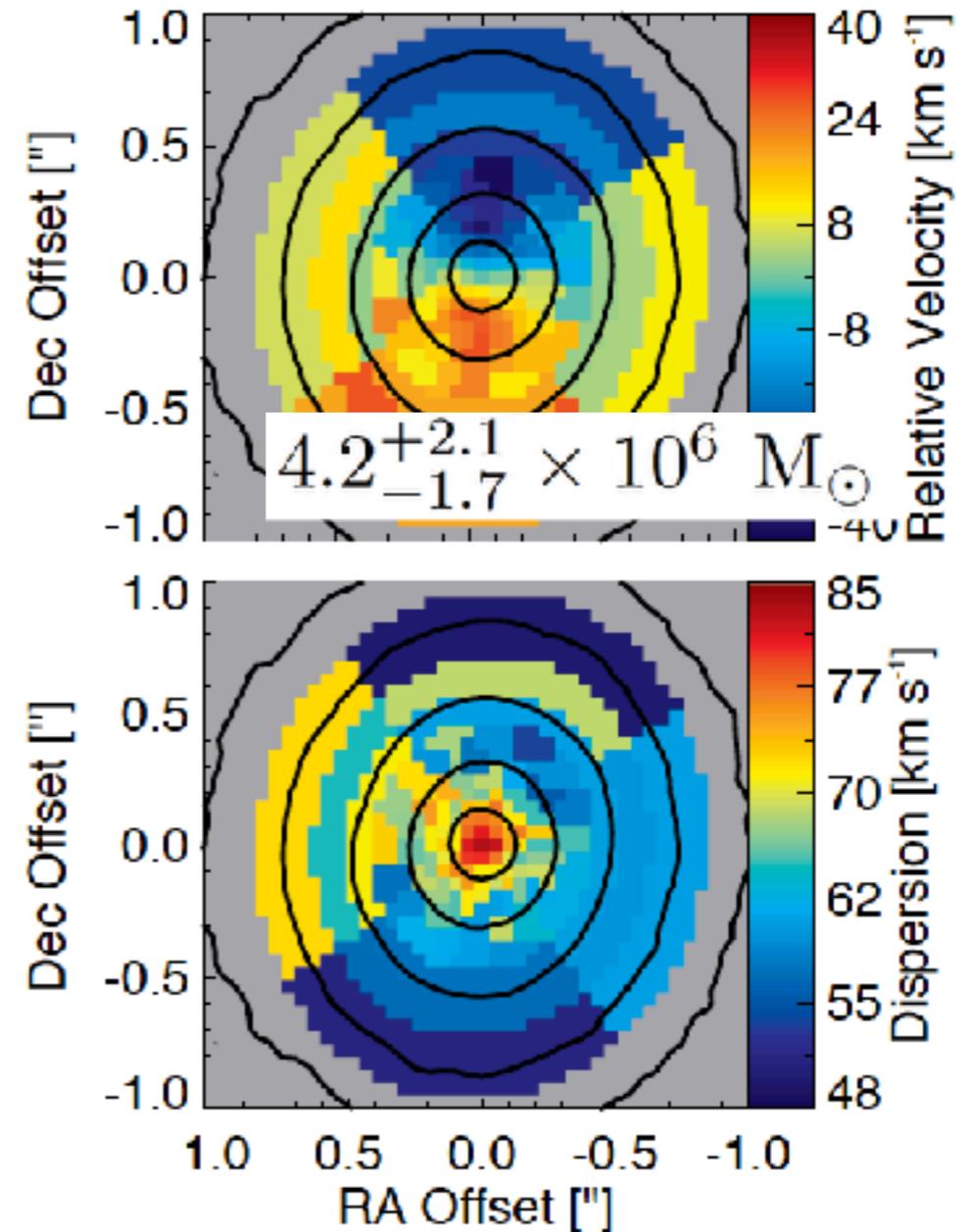


# Since then 4 new UCDs with SMBHs

Fornax UCD3  
Afanasiev et al. 2018



M59-UCD3  
Ahn et al. 2018



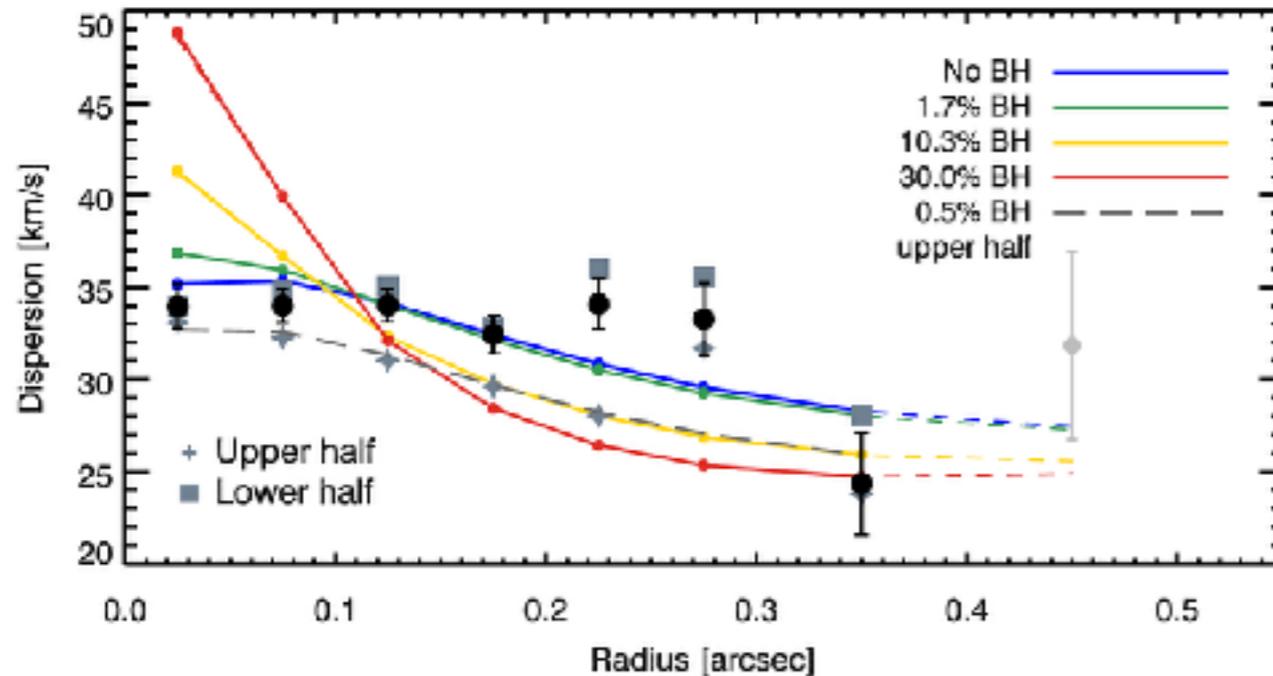
# Do low mass UCDs also host BHs?

- ❖ All 5/5 massive UCDs were found to host a SMBHs in their center.
- ❖ Question remains whether also lower mass UCDs  $< 10^7 M_{\text{sun}}$  host SMBHs as these are much more common
- ❖ Two targets in CenA with an integrated elevated M/L ratio



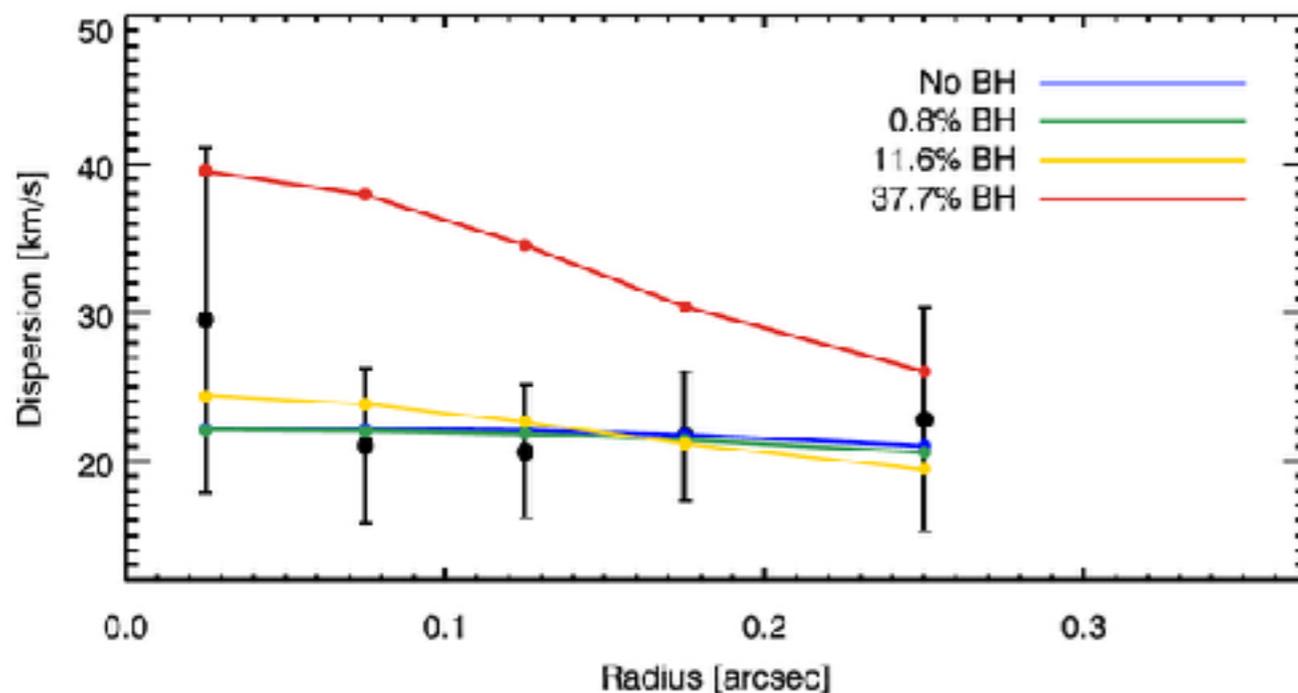
Voggel et al. 2018

# Two low mass UCDs in CenA



UCD330

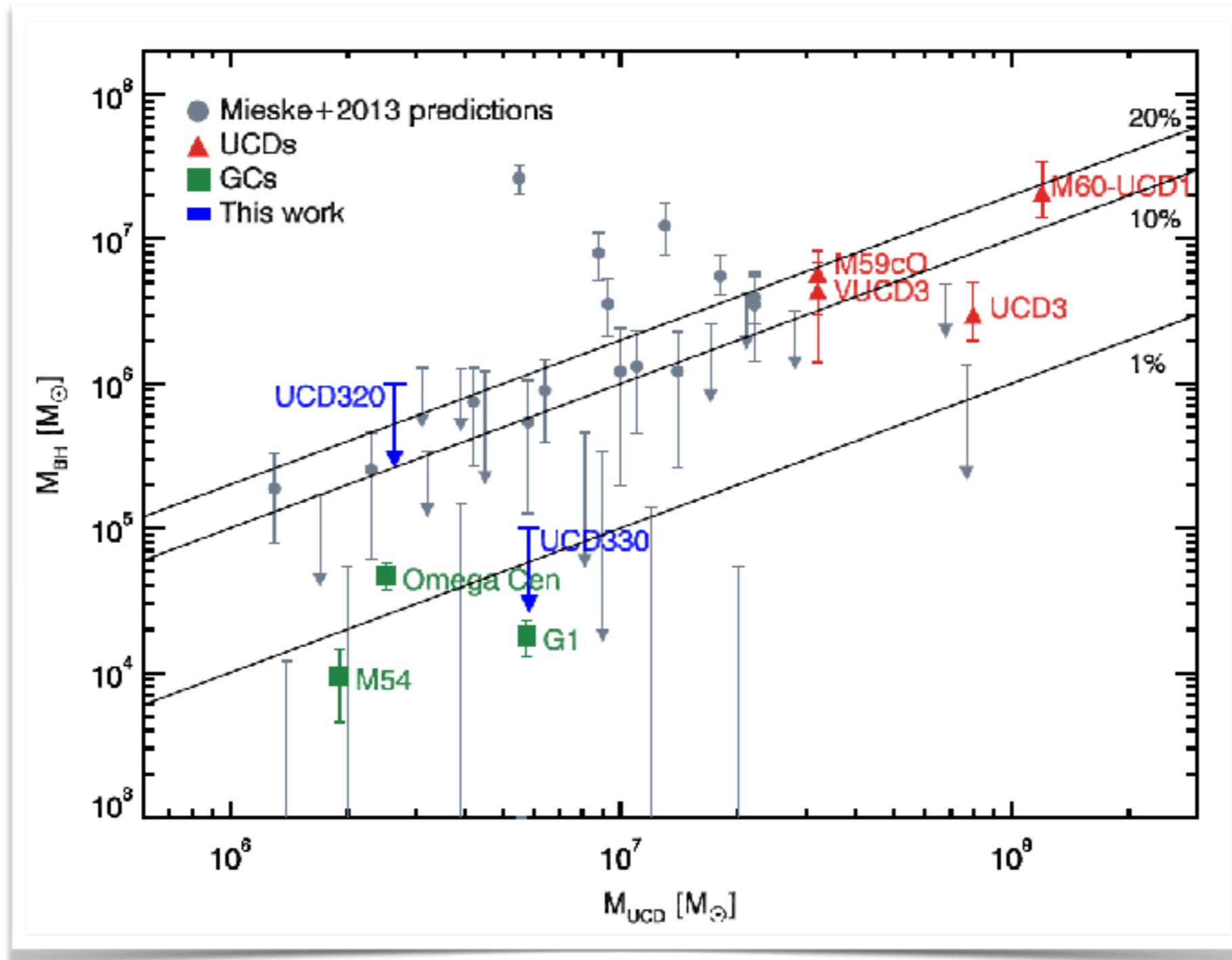
Upper limit for a SMBH of  $M < 1e5$



UCD320

Upper limit for a SMBH of  $M < 1e6$

# The Nucleus mass vs. black hole mass scaling relation

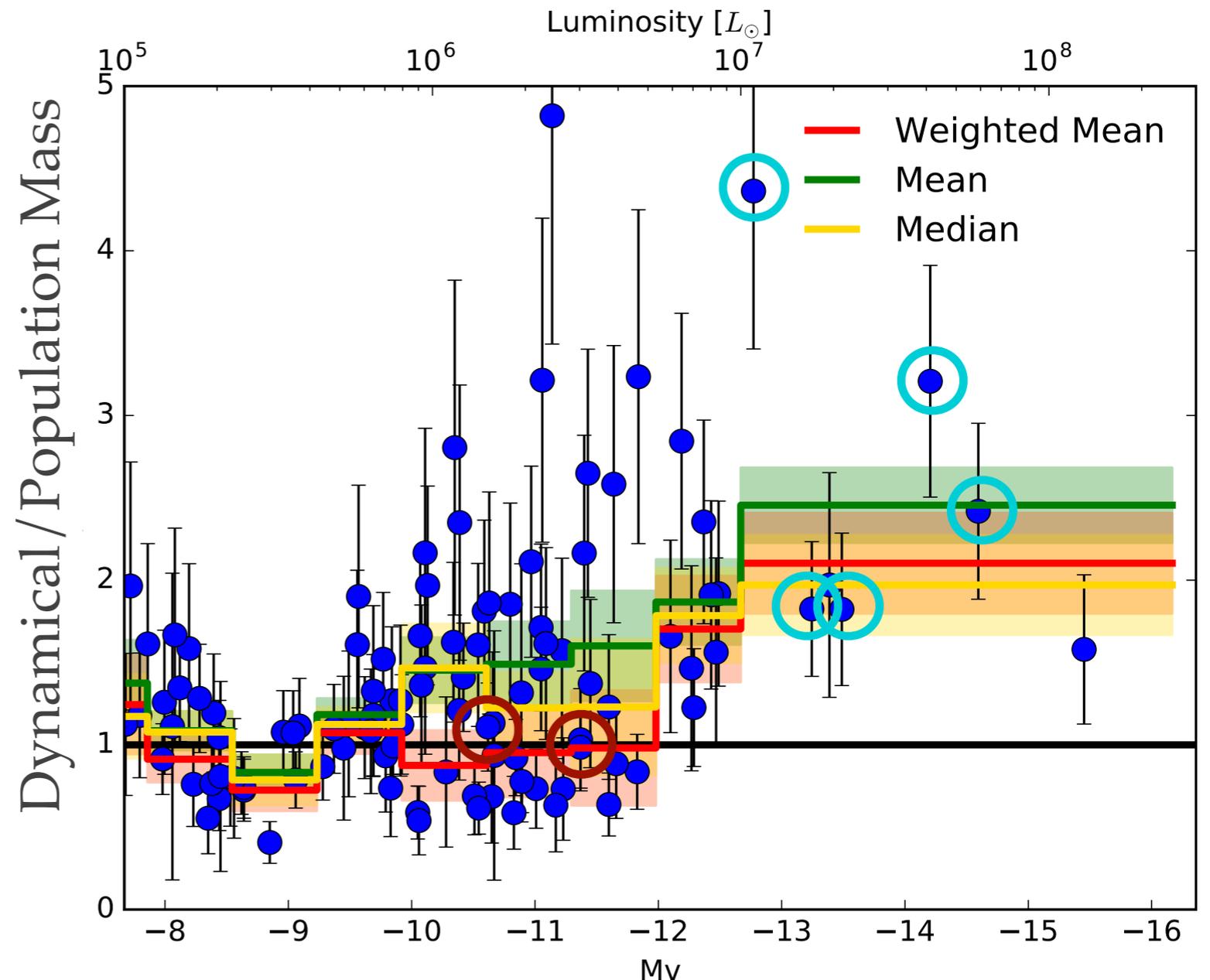


Now that we have found so many UCDs that are stripped Nuclei with “hidden” SMBHs:

How can they be useful for the big picture?

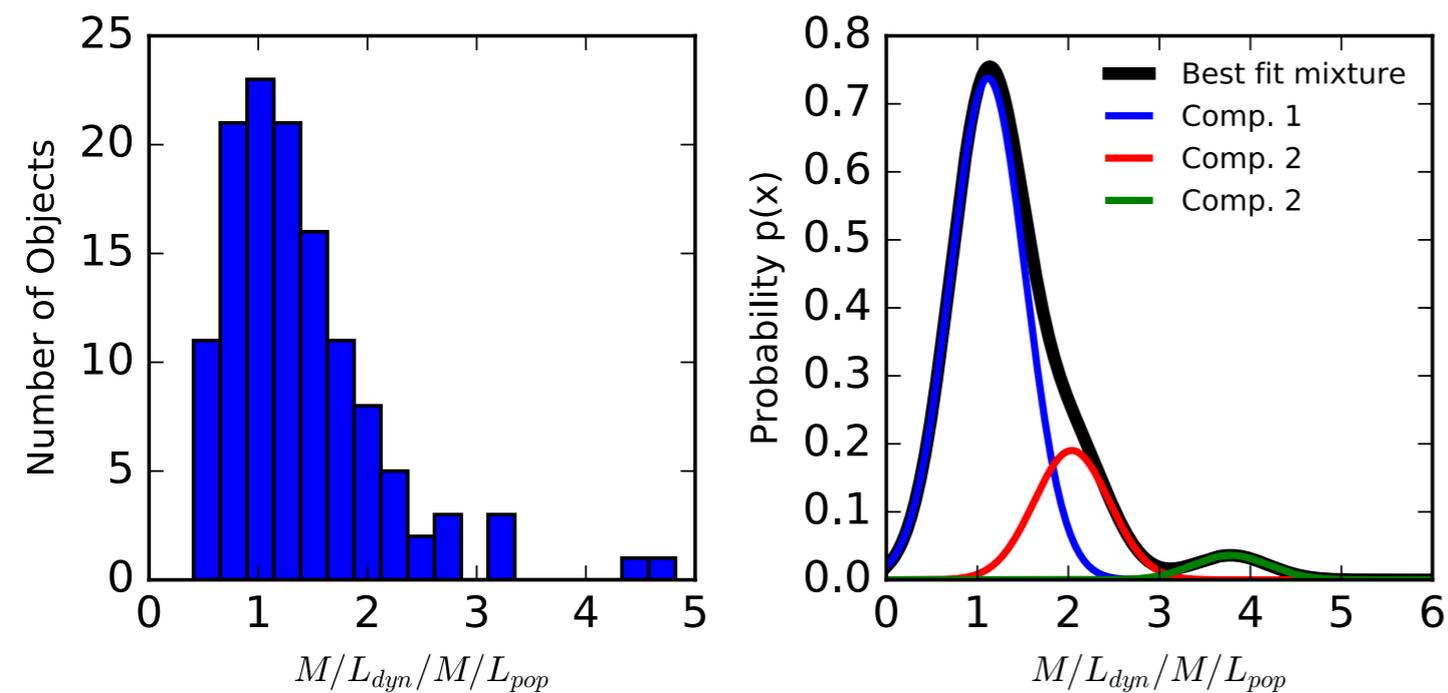
# Inflated dynamical Mass = Nucleus?

- ❖ All UCDs with SMBHs in their center have inflated dynamical masses!
- ❖ Measuring an overall dynamical mass MUCH easier than full adaptive optics resolved kinematics
- ❖ -> Using M/Ls as a proxy for which is a stripped nuclei



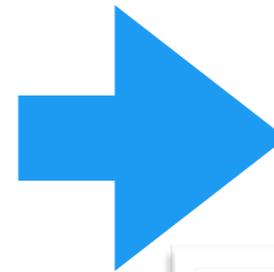
# Using inflated masses to estimate the SMBH occupation fraction of UCDs

Gaussian Mixture modelling to estimate the probability of each object belonging to the elevated category

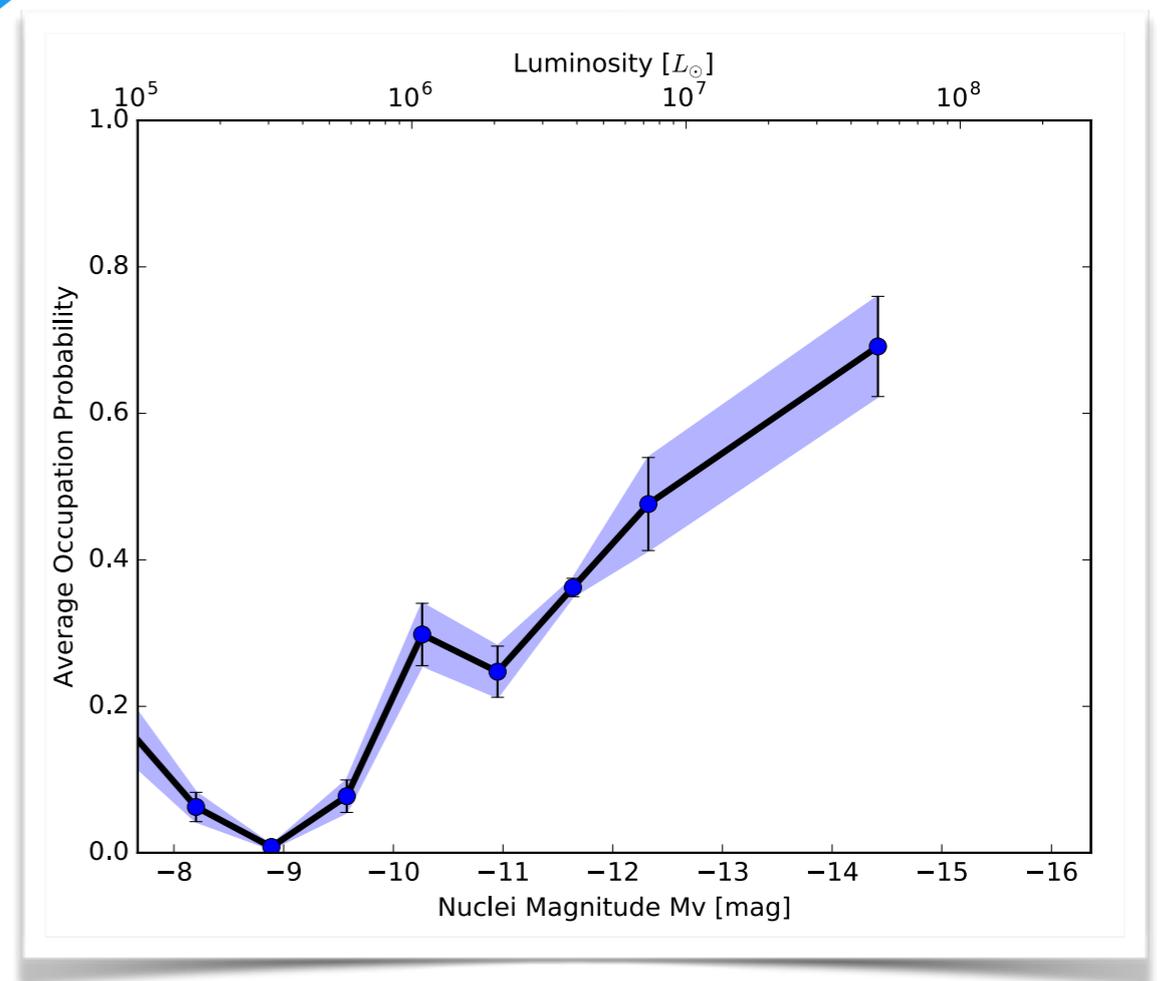
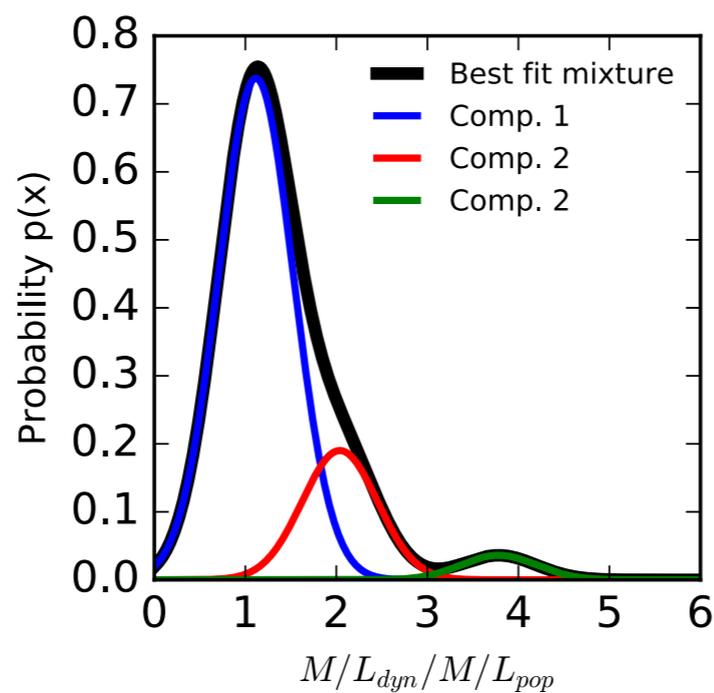
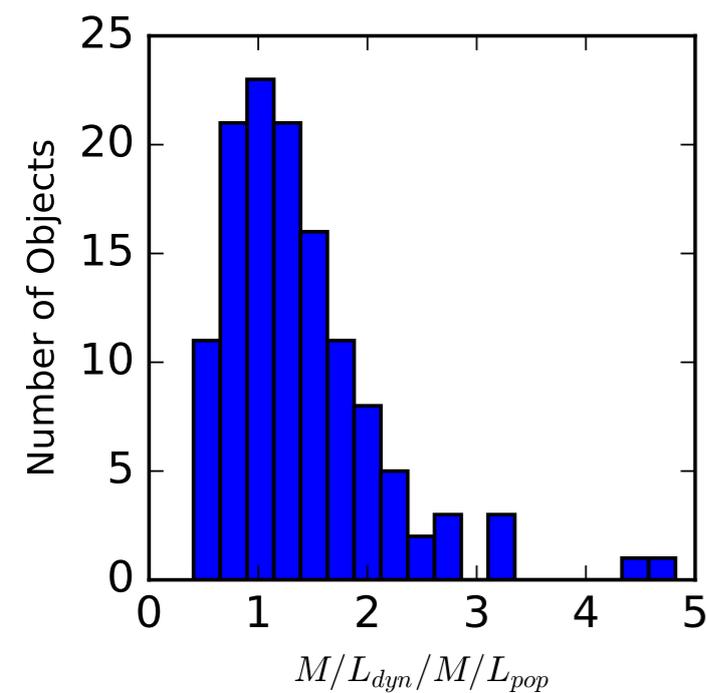


# Using inflated masses to estimate the SMBH occupation fraction of UCDs

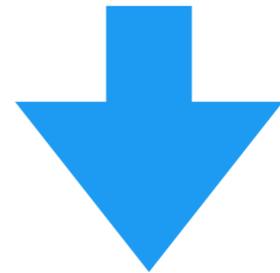
Gaussian Mixture modelling to estimate the probability of each object belonging to the elevated category



Average probability per magnitude bin



Hidden SMBHs in UCDs should be common! First estimate is that relic Nuclear Clusters are almost as common (50-100%) than current nuclei of Galaxies.



UCDs have the potential to be a unique direct tracer of the past merger history of a Galaxy Cluster!

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# So how does that connect to LIGO&LISA?

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- ❖ **Event Rate estimates based on SMBHs do not account for “hidden” SMBHs in Nuclei that have been Stripped from their Galaxies!**

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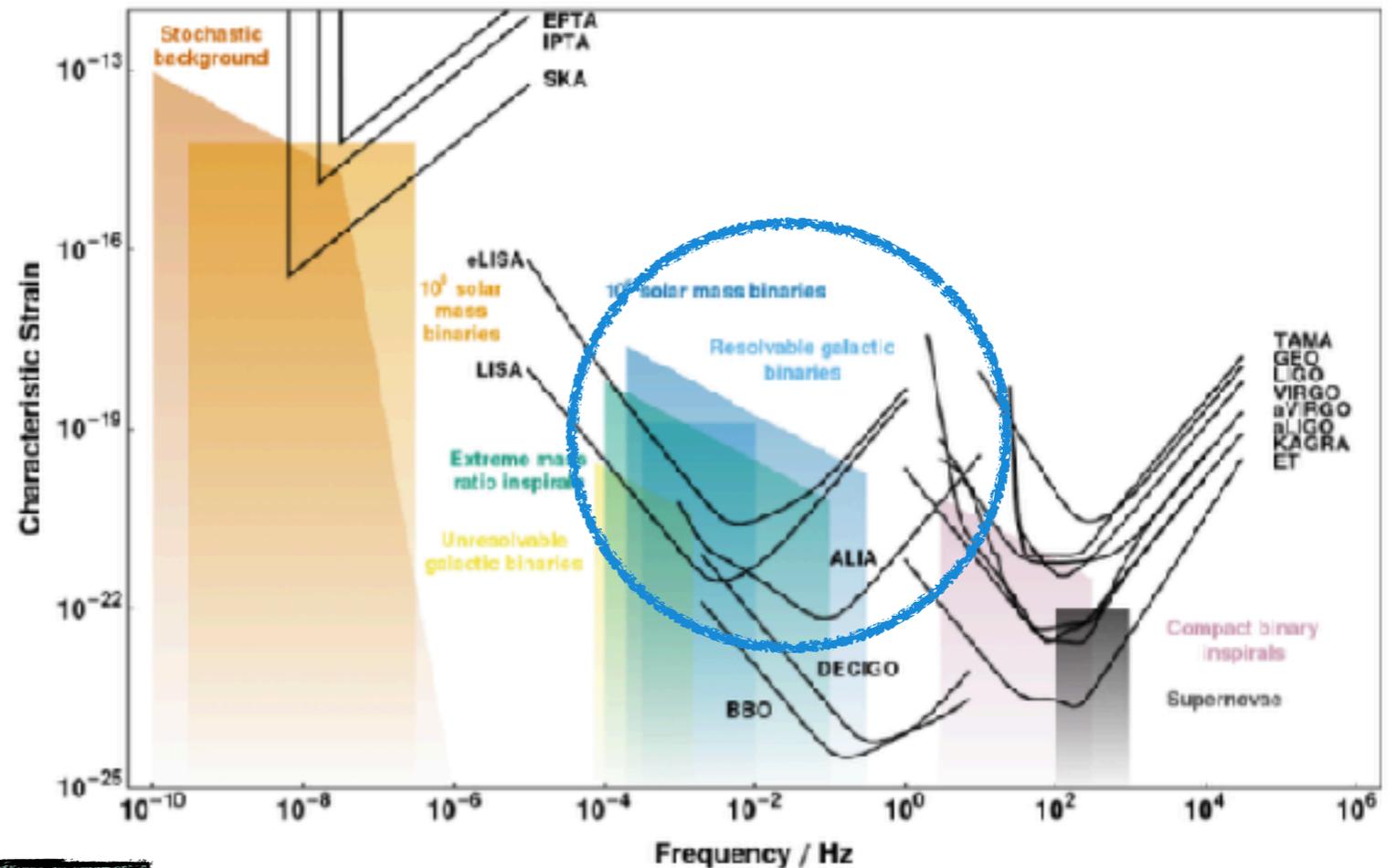
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Potential Increase of  
Tidal Disruption Events

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1

Potential Increase of Tidal Disruption Events

2

SMBH-SMBH and SMBH-BH merger rates significantly higher (see Alexander Rasskazovs talk)

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# Future

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1. 22h of SINFONI time accepted to observe 3 more UCDs in CenA
2. Limited by amount of bright enough UCDs. With ELT sized telescopes and IFU instruments like HARMONI.
3. Can access SMBH dynamics out to 100Mpc compared to 20Mpc now!

