Super-Massive Black Holes in Compact Galaxies

Remco van den Bosch

MPIA

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WHY ARE THERE FEW BLACK HOLE MASS MEASUREMENTS?

- **MANY REQUIREMENTS FOR DYNAMICAL ESTIMATES:**

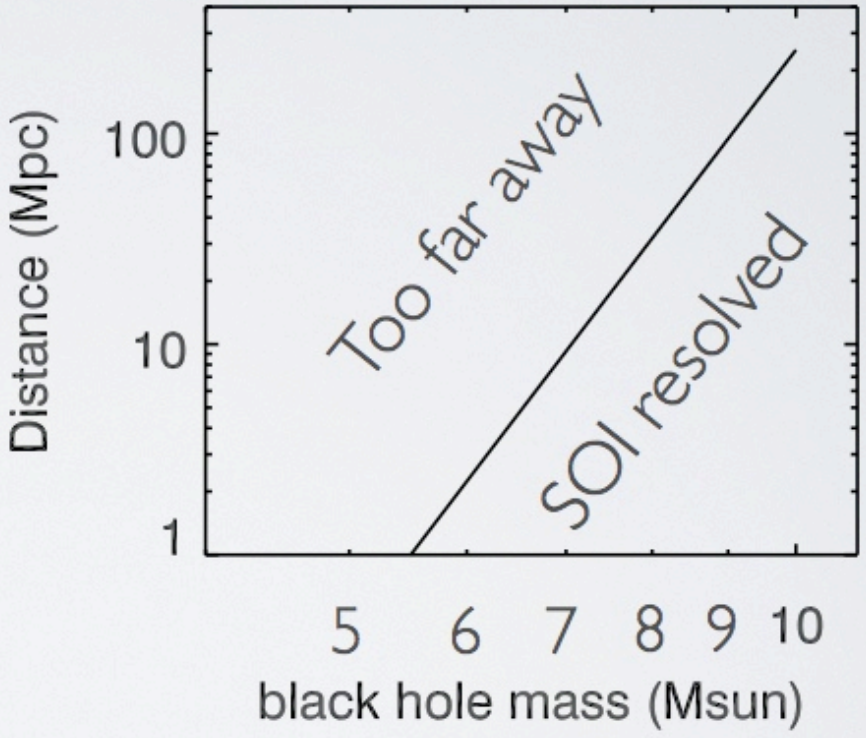
- Resolve the Sphere-of-influence

$$R_{soi} = \frac{GM_\bullet}{D\sigma^2} \propto \frac{\sigma^{2.2}}{D}$$

  Thus HST/STIS or AO. And few available targets

- Spatially resolved kinematics

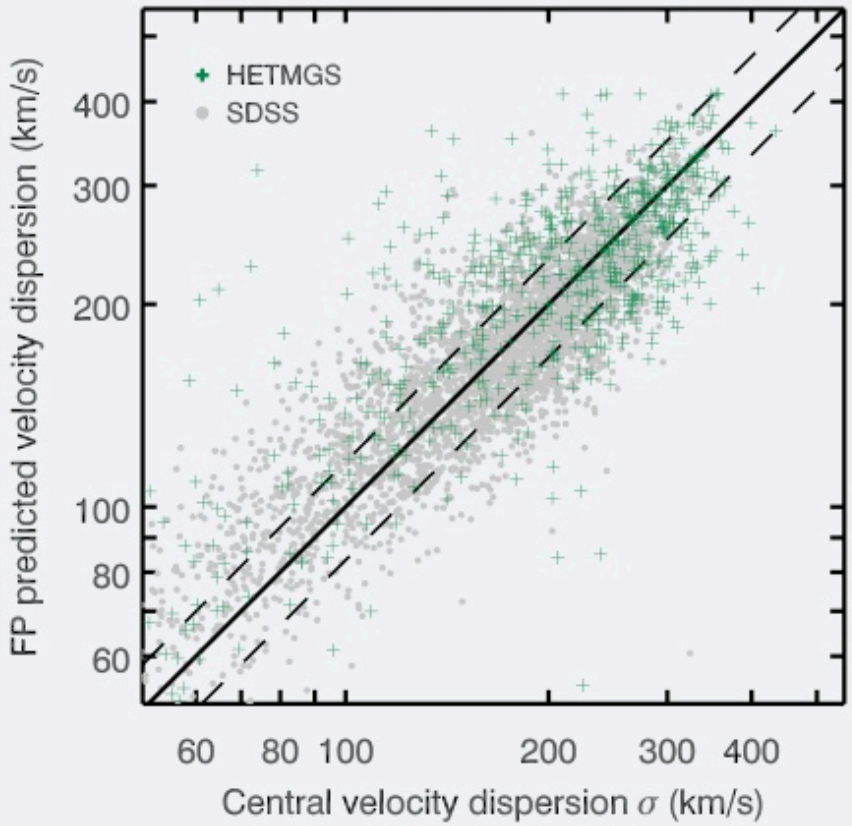
- High resolution photometry for stellar mass model

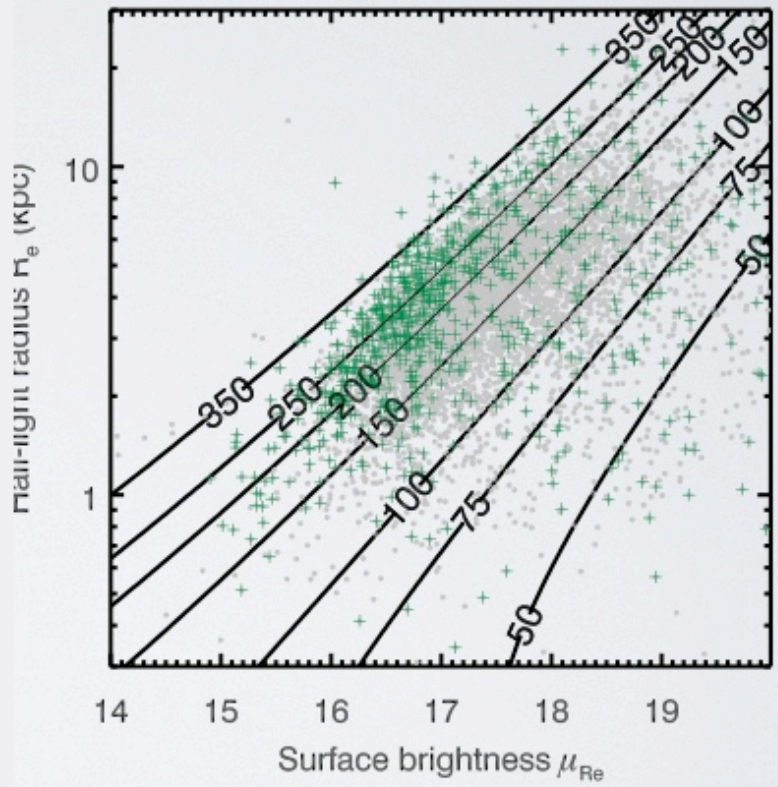


HET SURVEY

- Long slit spectra with the Marcario Low Resolution Spectrograph
- 4200-7400 AA, 180km/s resolution, 1''x2.5' slit
- 1000 galaxies observed to date
- Distances less then ~140 Mpc
- Effectively probing the most massive nearby galaxies

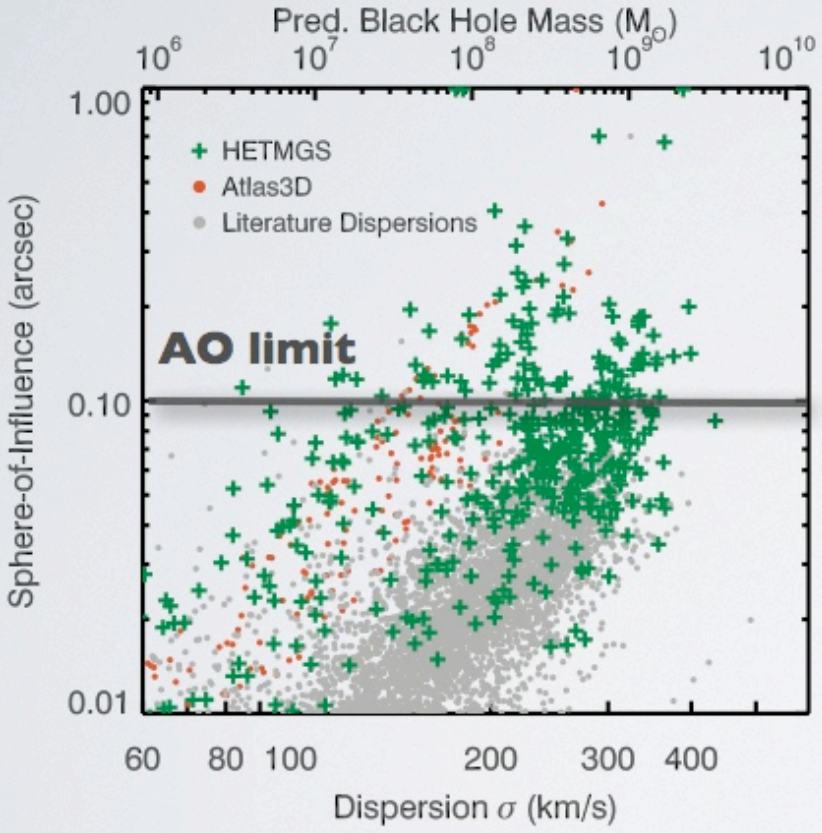
2MASS FUNDAMENTAL PLANE

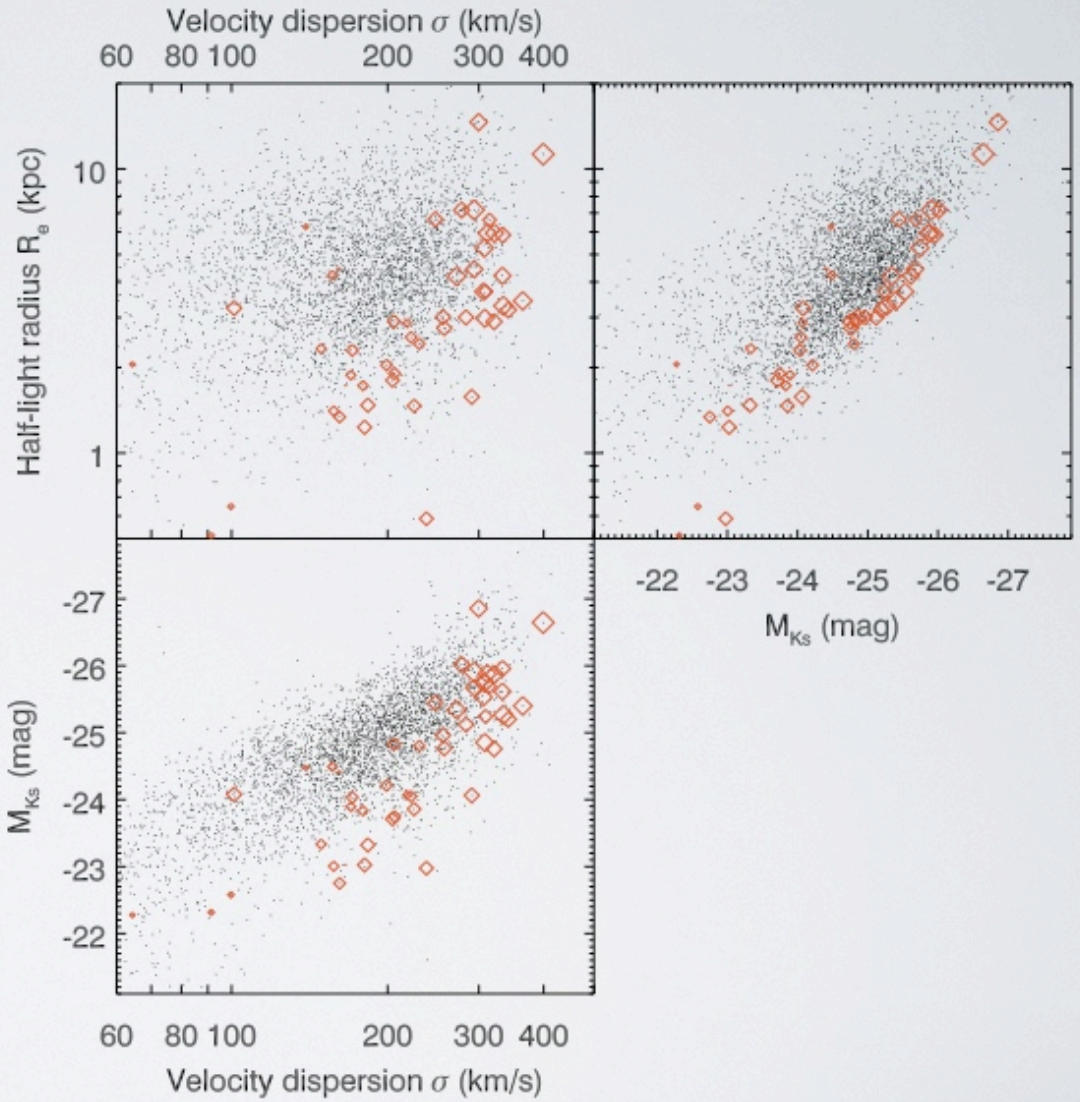




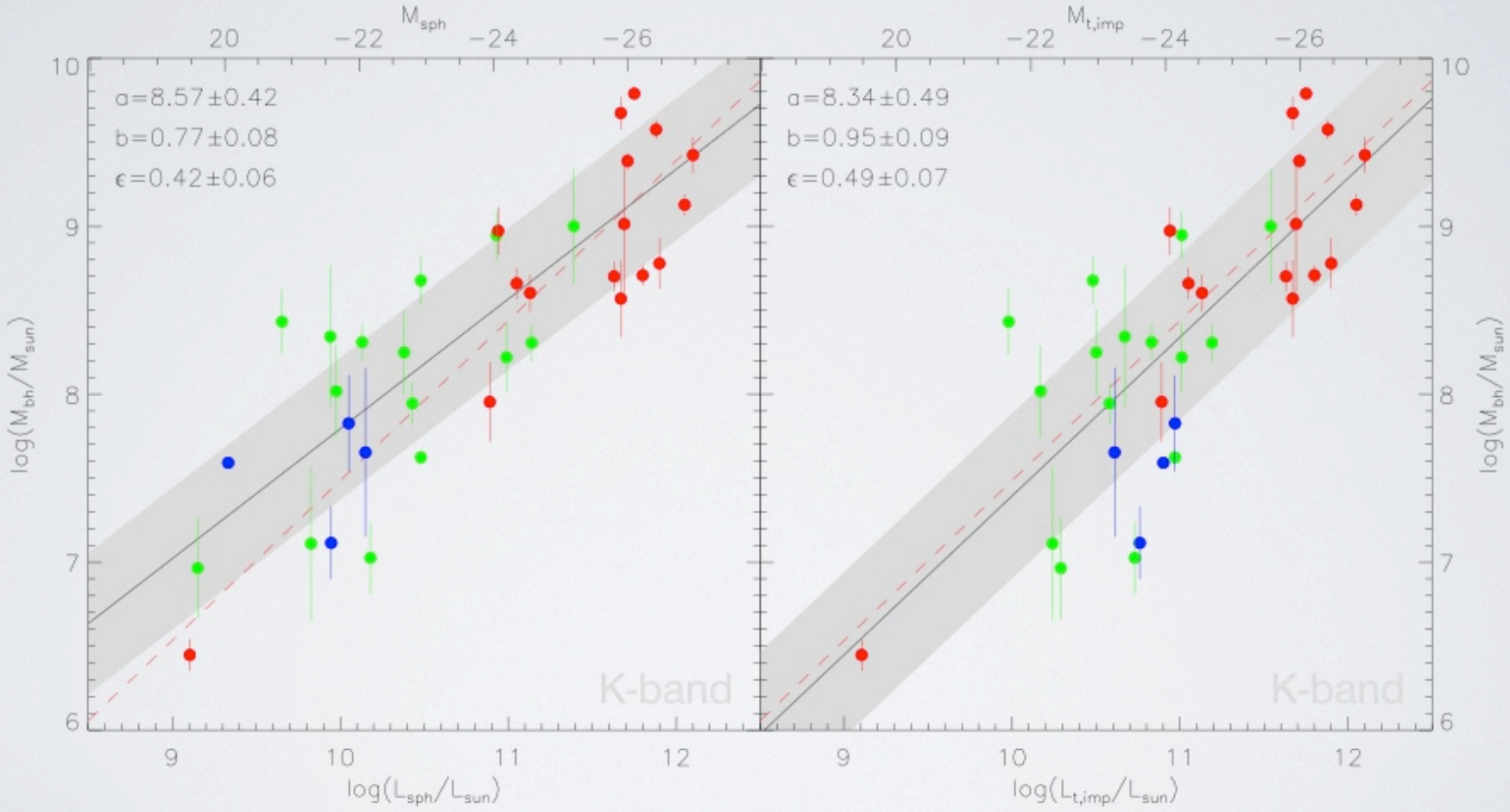
- **The fundamental plane (Virial Theorem) defines the relation between galaxy mass, size and velocity dispersion.**

GATEWAY TO MORE BLACK HOLE MASSES



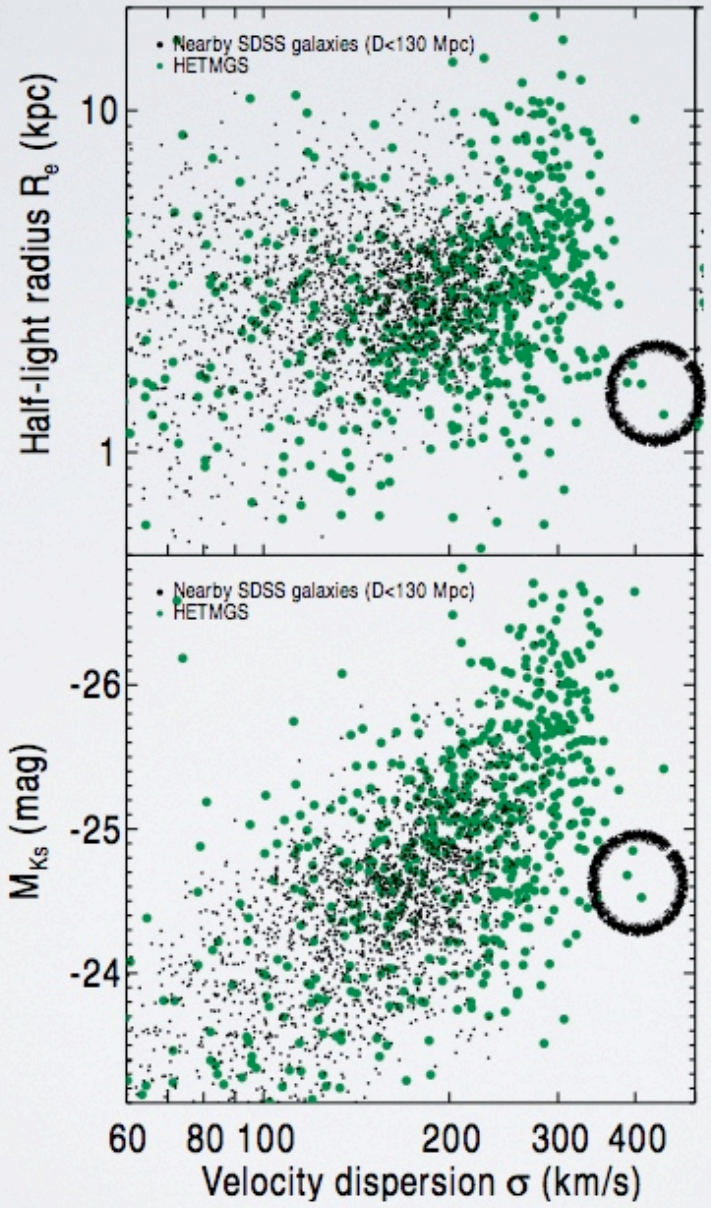


BULGE OR LUMINOSITY

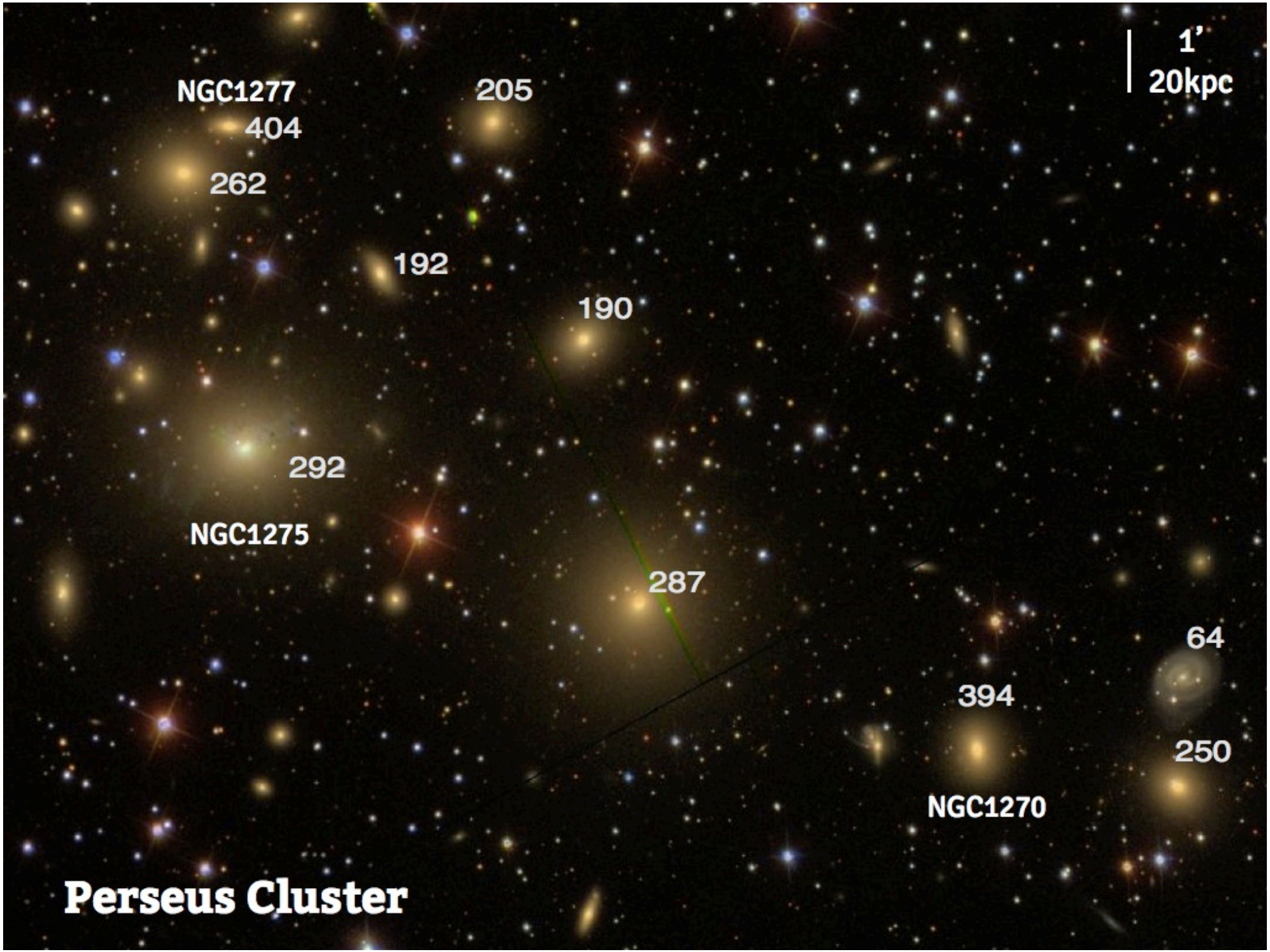


Läsker et al 2013 submitted

GALAXY PROPERTIES

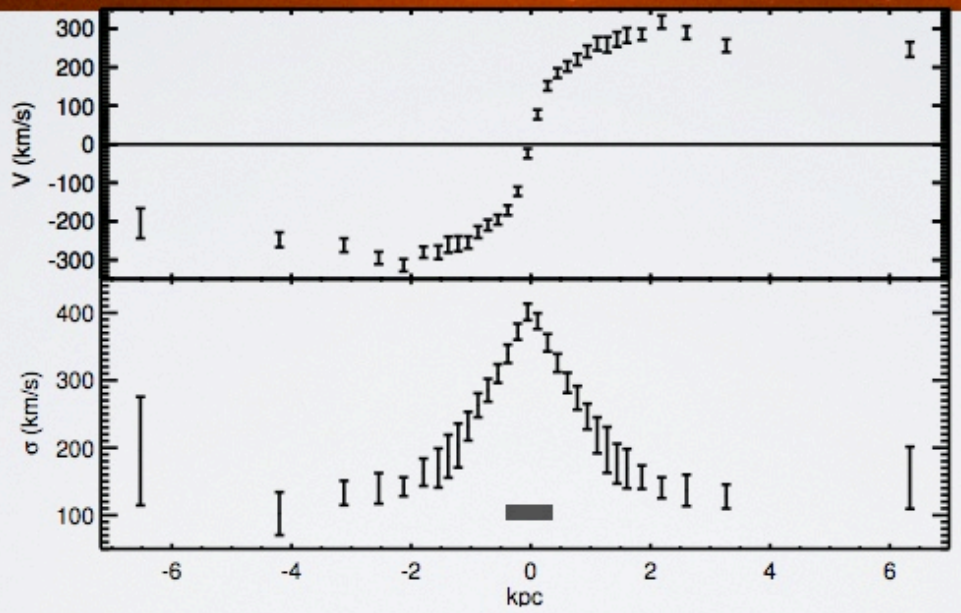



Perseus Cluster


1'
20kpc
NGC1277
205
404
262
192
190
292
NGC1275
287
64
394
250
NGC1270
Perseus Cluster

MEASURE BH MASS

VDB+2008, VDB+10



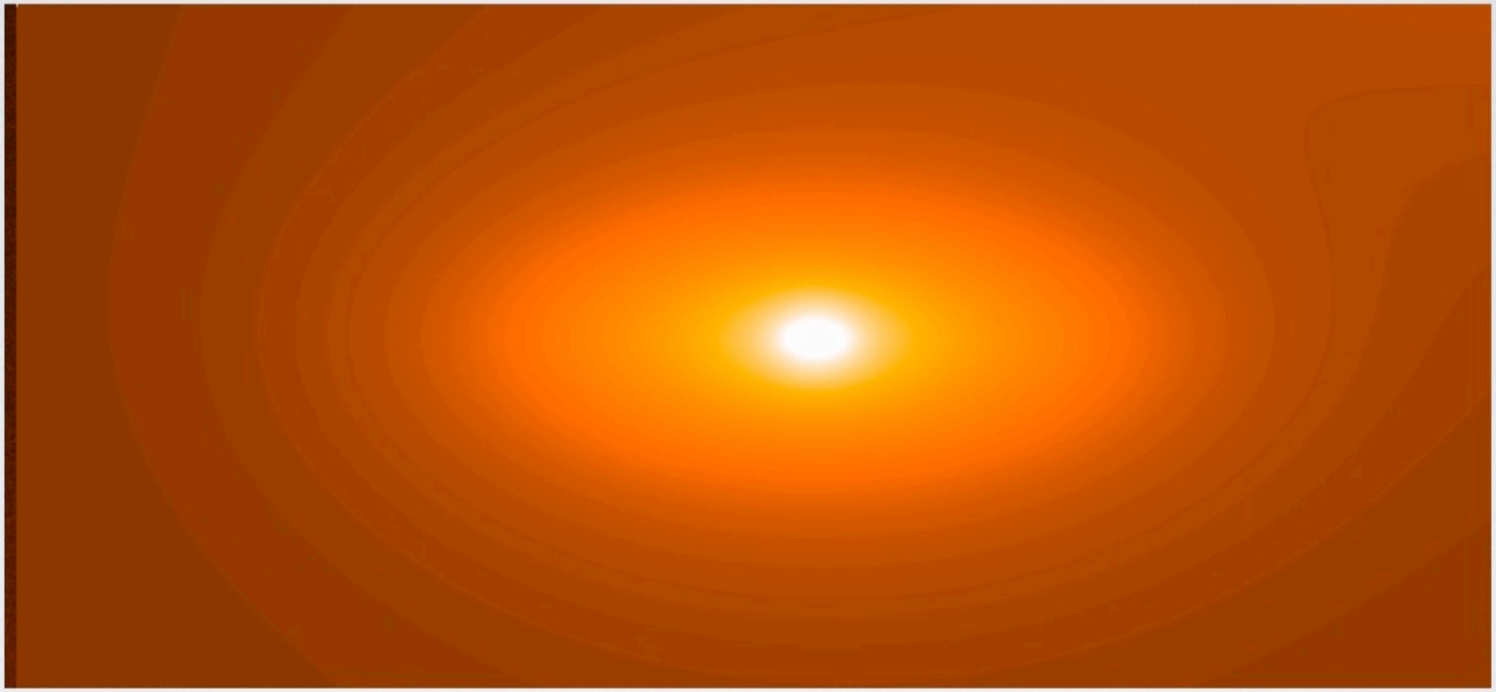
vdB+06, Cappellari+06 Shapiro+06, Cappellari +07, vdB+08, vdVen +08, Weijmans+09, vdBvdV09, vdBdZ10, Walsh+12, vdB+12, Breddels+13, Lyubenova +13, Lasker+13

Use orbit-based models to measure the mass distribution:

- Construct a trial potential, including stars, black hole, dark matter
- Integrate all types of orbits in trial potential
- Reconstruct the galaxy from orbits and at the same time fit the observed stellar kinematics
- Search over trial potentials to find optimal models

TRIAL POTENTIAL

Construct an analytical prescription consisting of 2D Gaussians, which then gets de-projected into 3D



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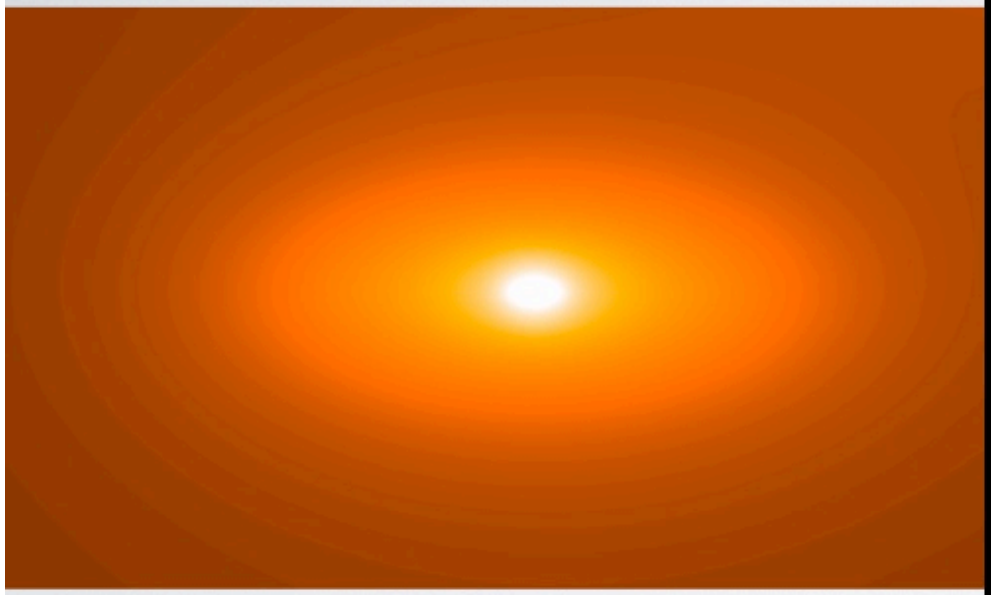
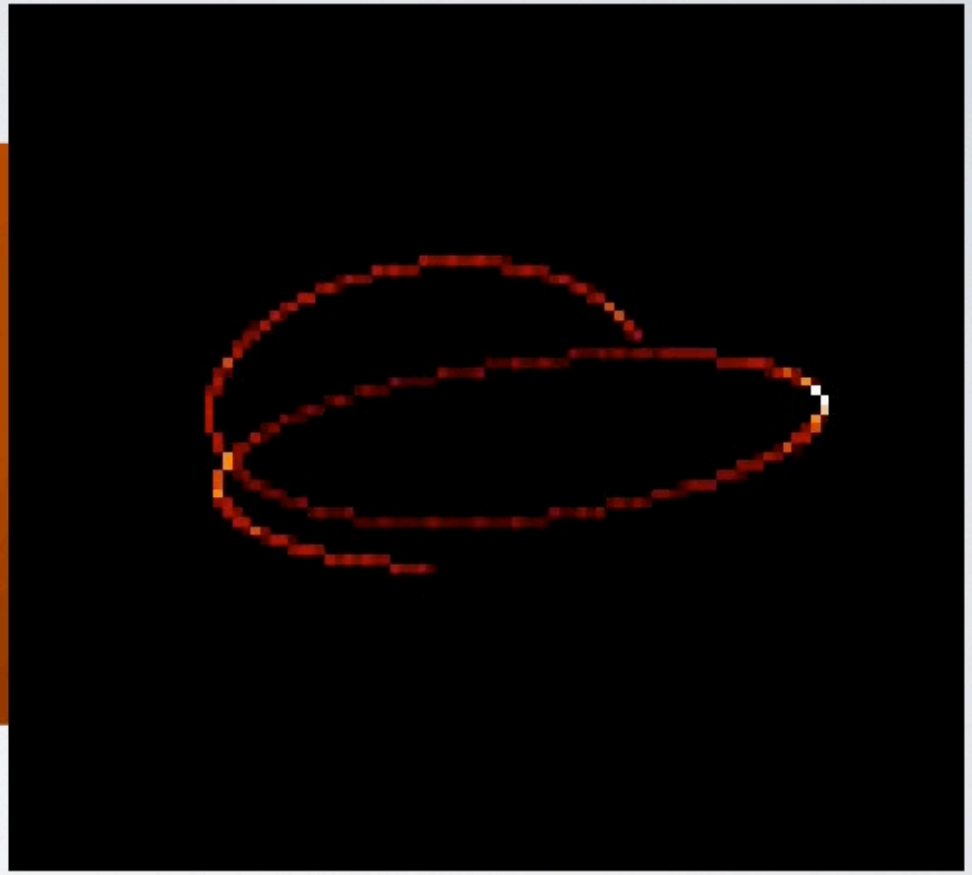
INTEGRATE ORBITS





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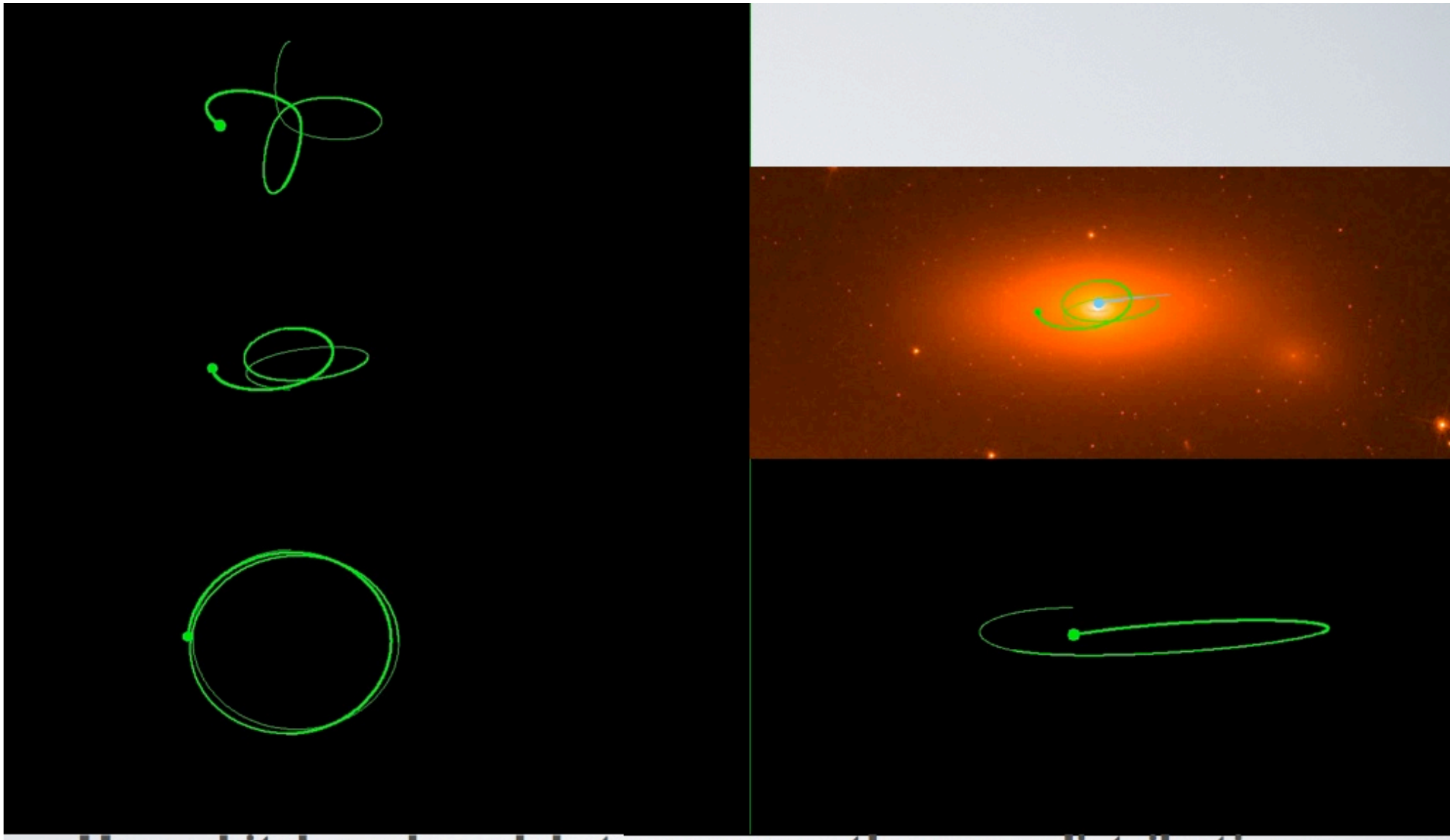

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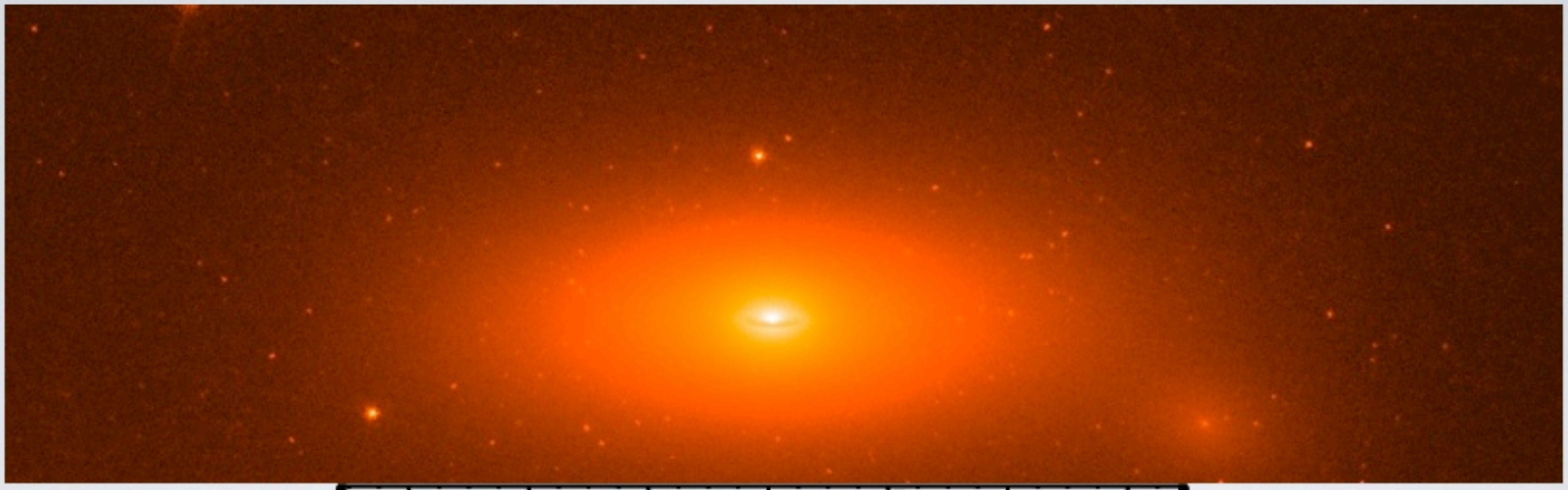

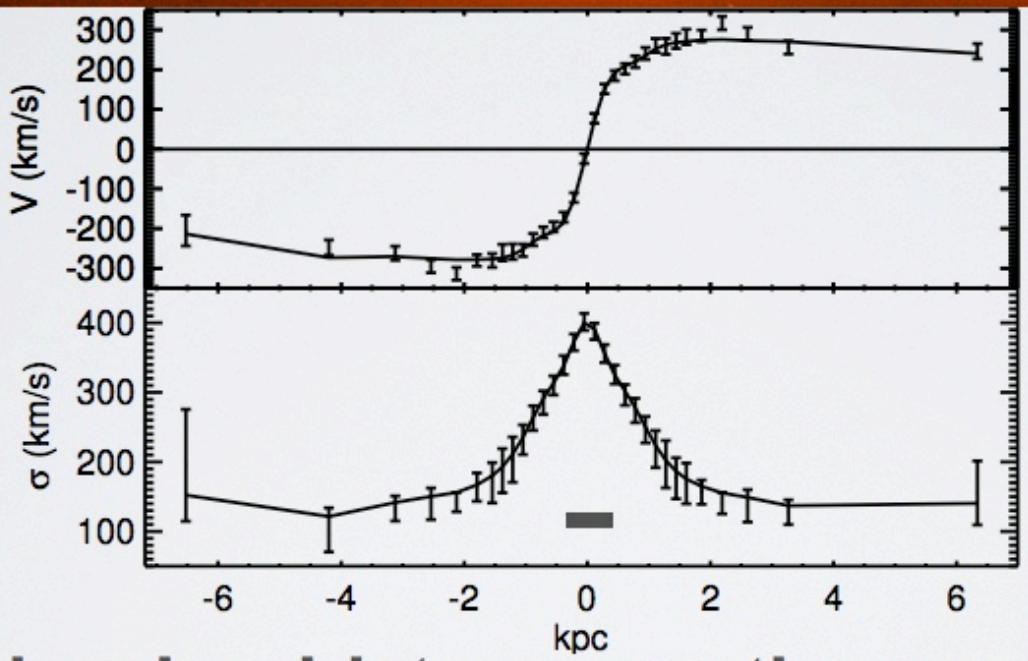

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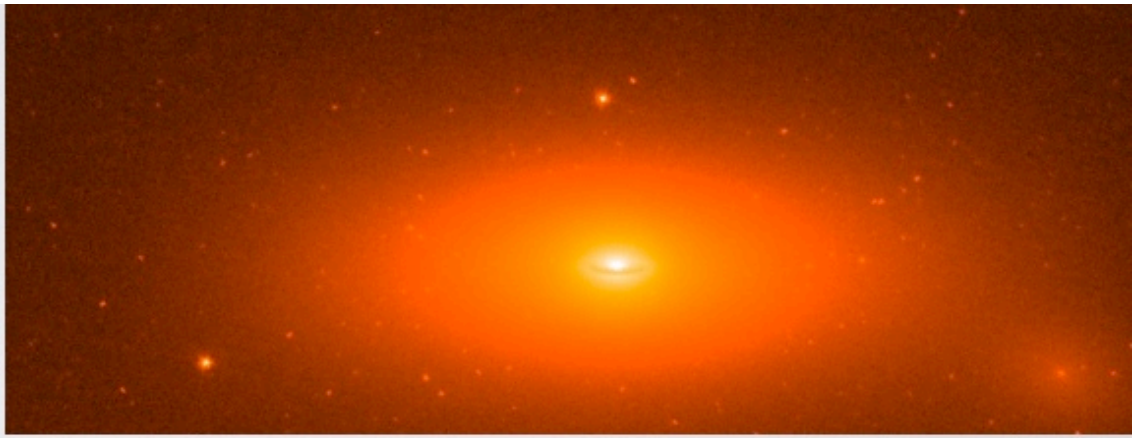
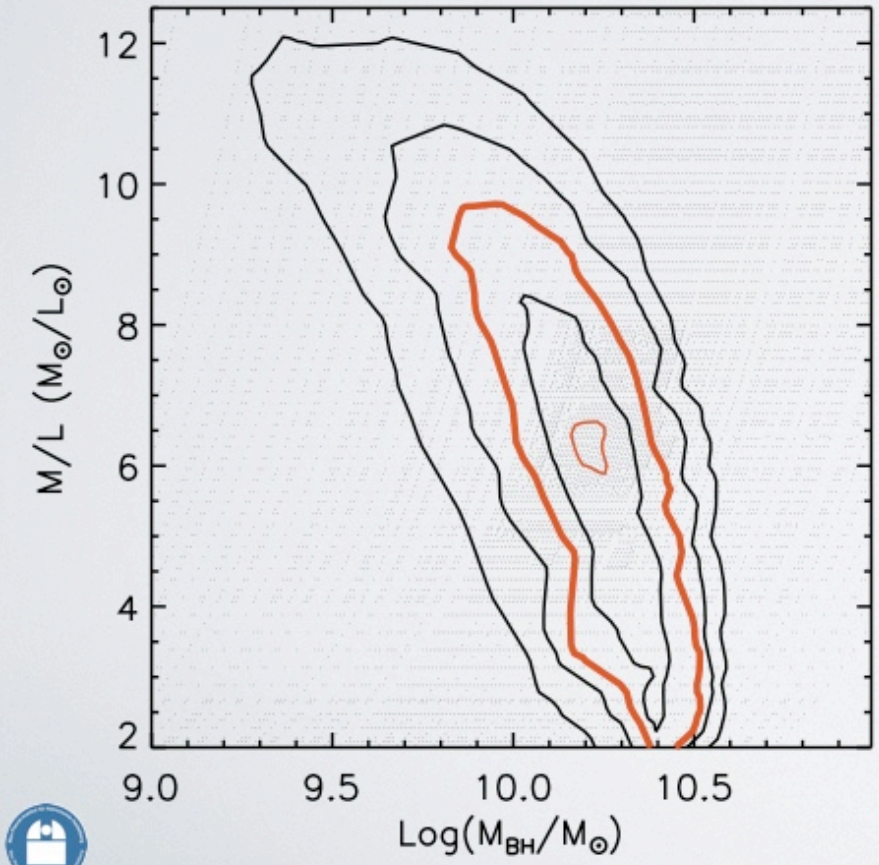
A BIG BLACK HOLE IN A SMALL GALAXY

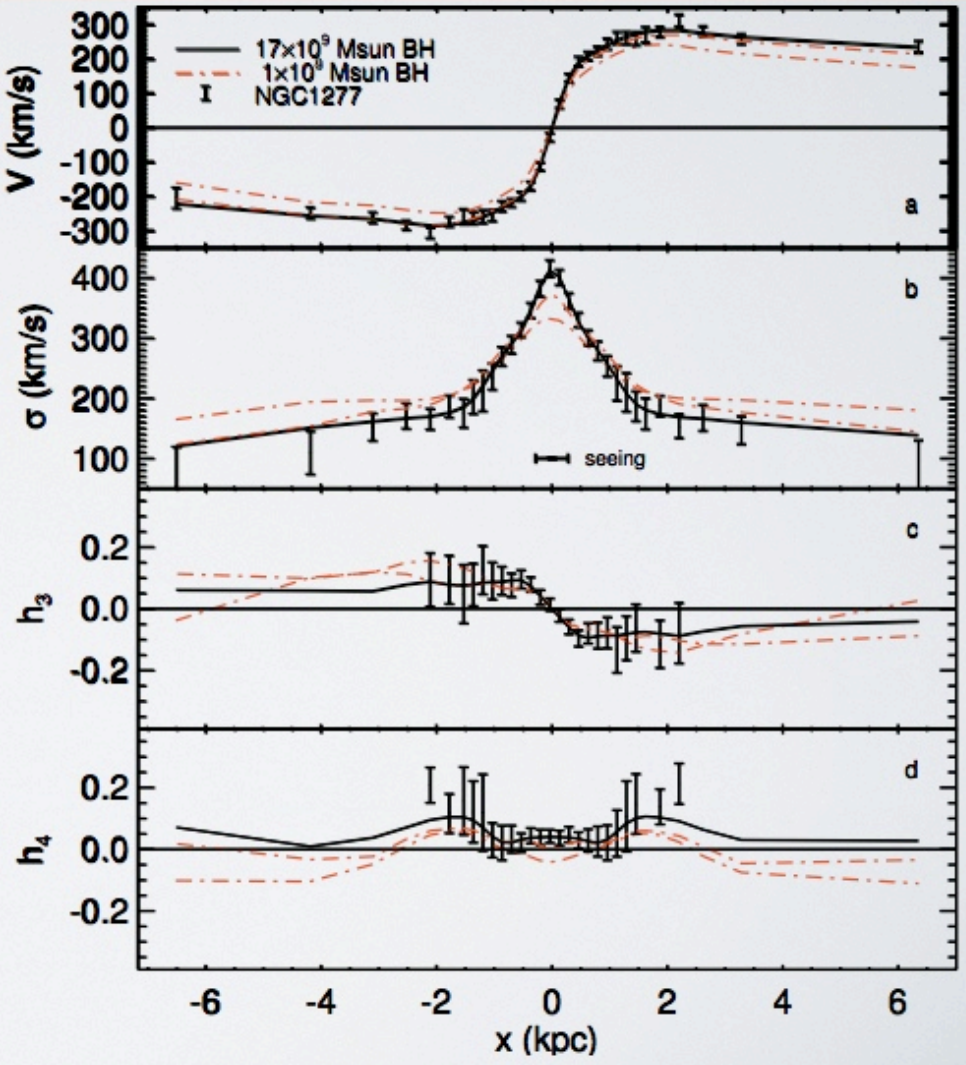
$$M_\bullet = 17 \pm 3 \times 10^9\,\mathrm{M}_\odot$$

$$M_\star = 1.2 \times 10^{11}\,\mathrm{M}_\odot$$

$$\sigma_e = 230 - 360\,\mathrm{kms}^{-1}$$

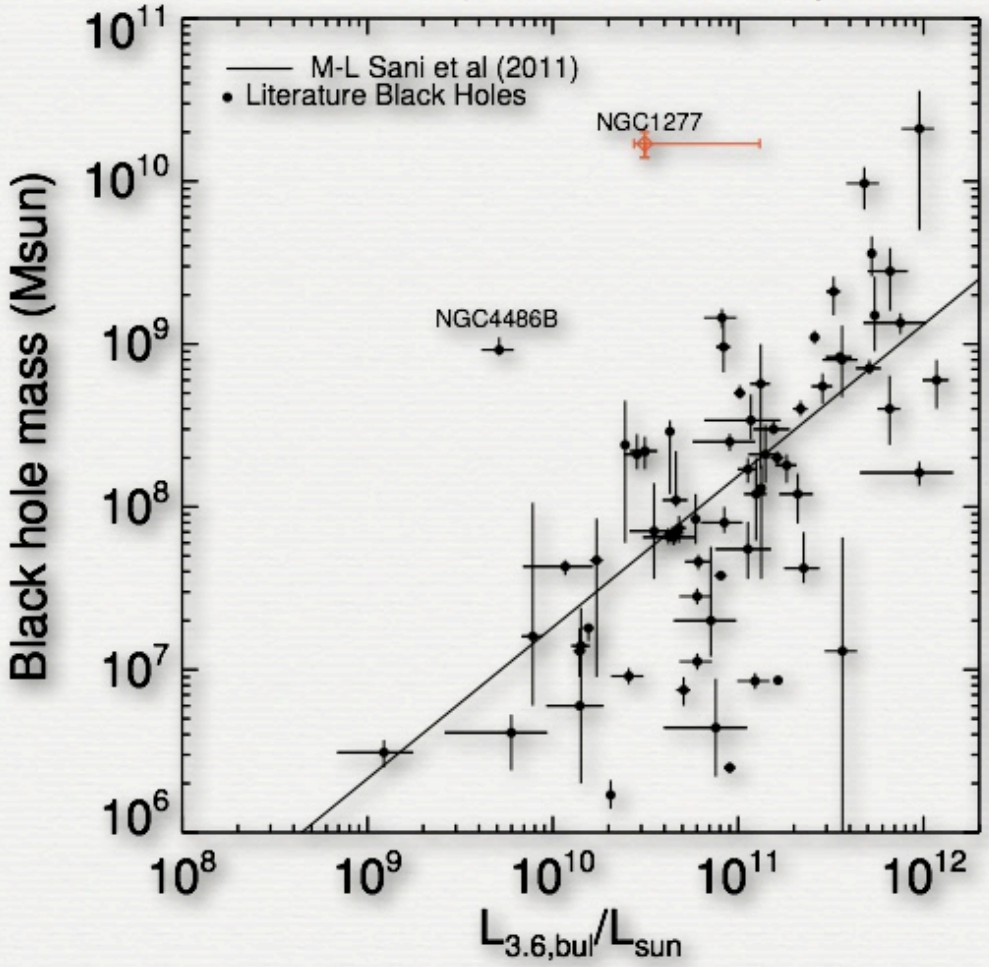






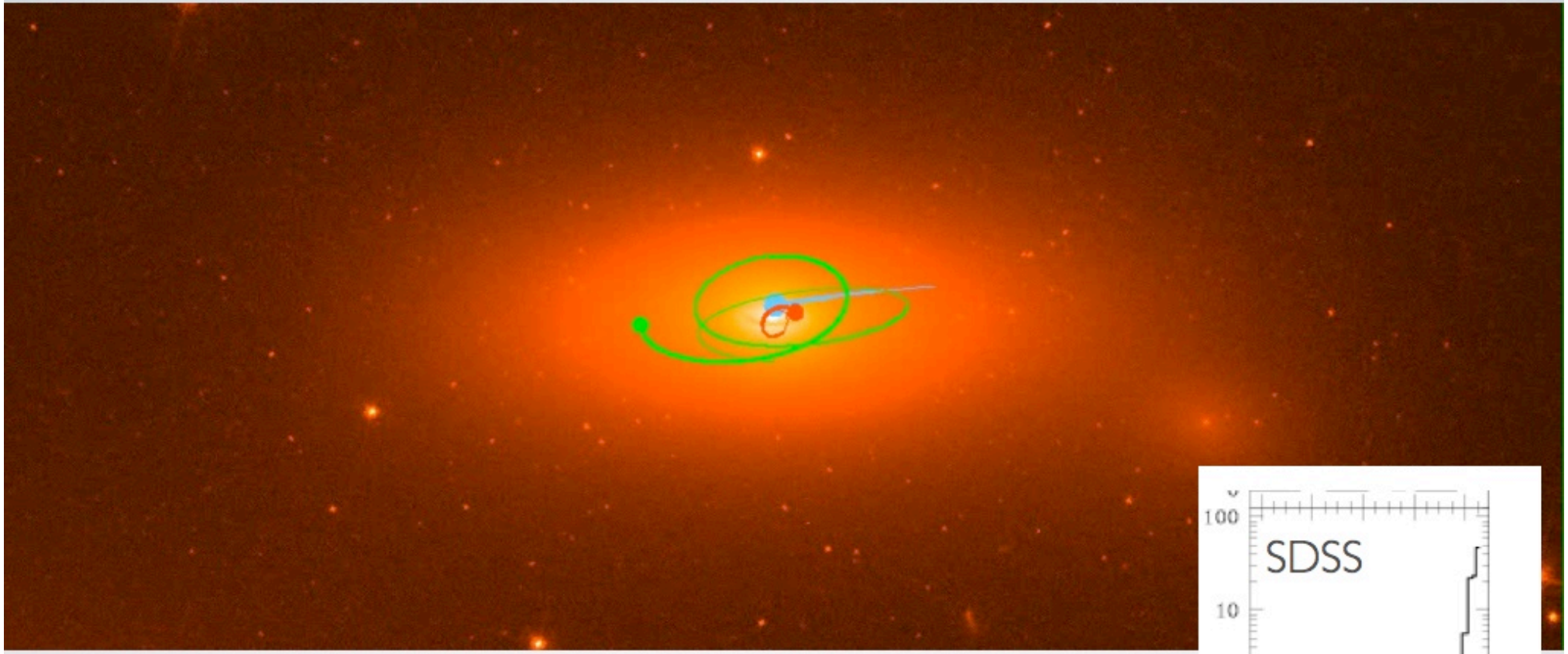
BLACK HOLE - BULGE RELATION

Also N4342, N4291 and N1332 (Rusli et al 2010)

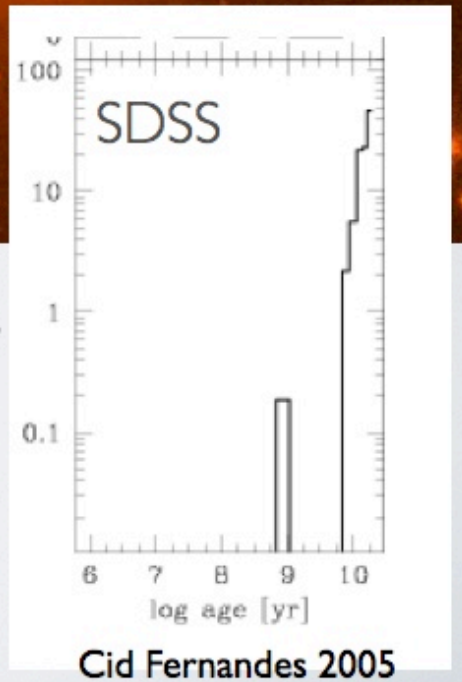


See also Sani et al. 2011, McConnel & Ma 2013, Gültekin 2011, Graham & Scott 1013, Kormendy & Ho 2013, Lasker 2013

NGC1277 IS AN OLD DISK GALAXY

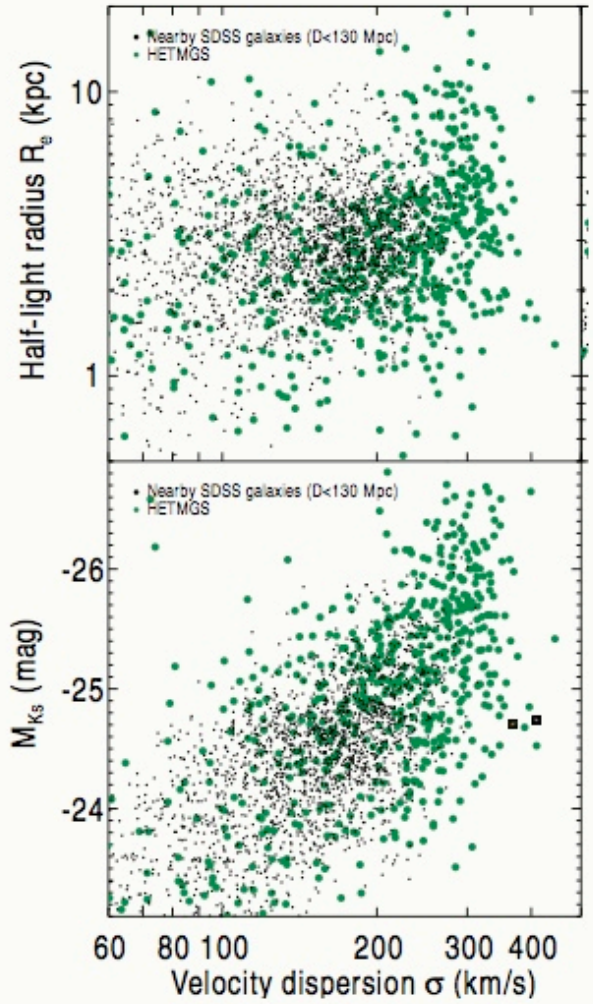


- No Classical Bulge, which implies no coevolution (Akos Bogdan)
- Bottom heavy stellar populations (Emsellem 2013, Lasker et al. 2013)
- Must have formed before z>5.
- Chandra Xray luminosity of 1e40 (Fabian et al. 2013), implies low accretion rate.
- That still leaves a lot of options: Cold streams (Di Matteo), Unstable disks (Bournaud), merger (Bonoli), direct collapse (Agarwal), Feedback (Fabian), Run-aways (Shields)



Cid Fernandes 2005

N1277 IS NOT ALONE



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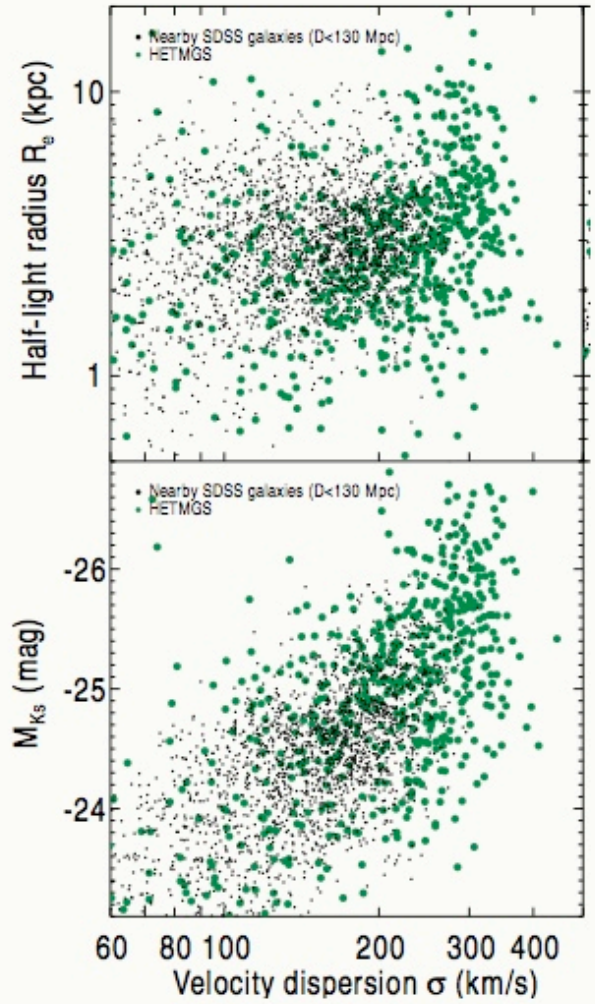
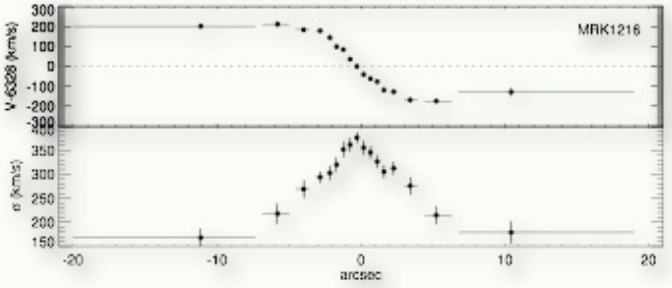
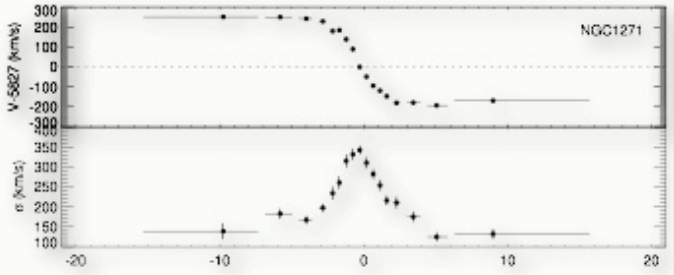


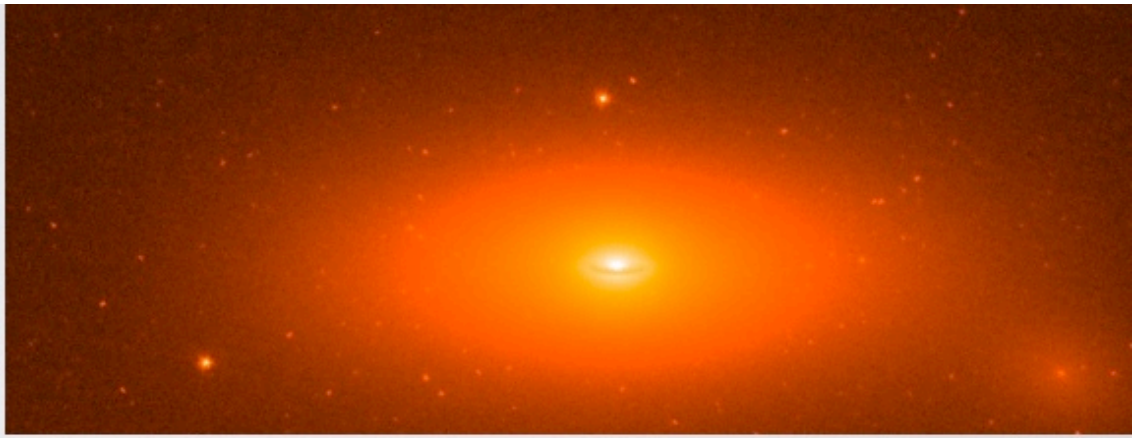


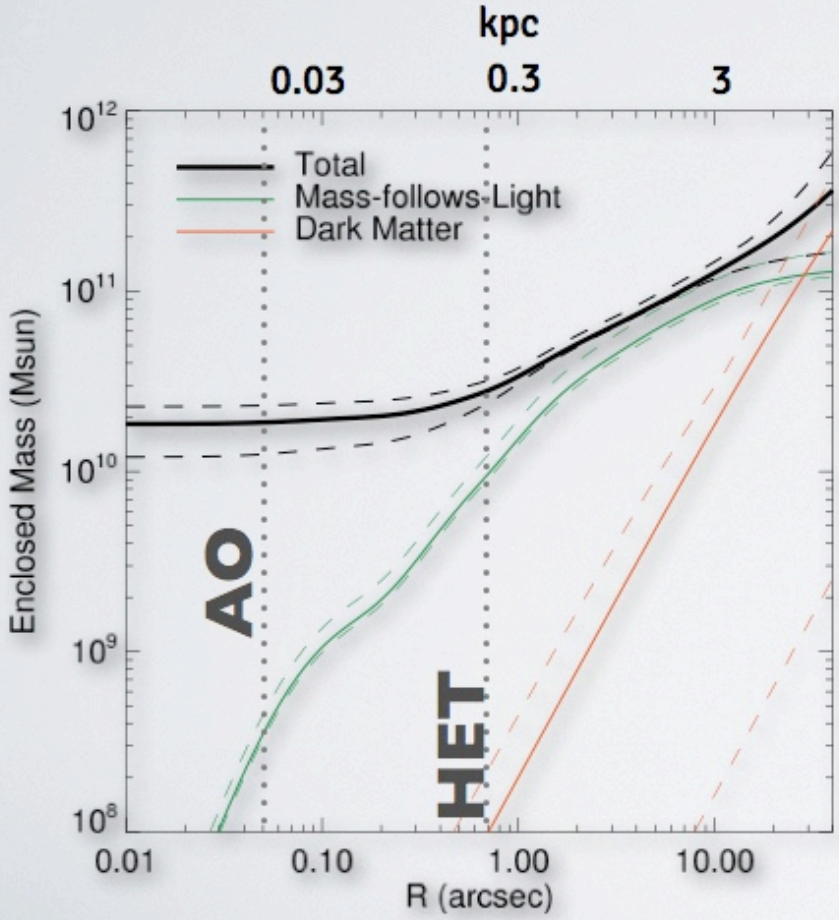


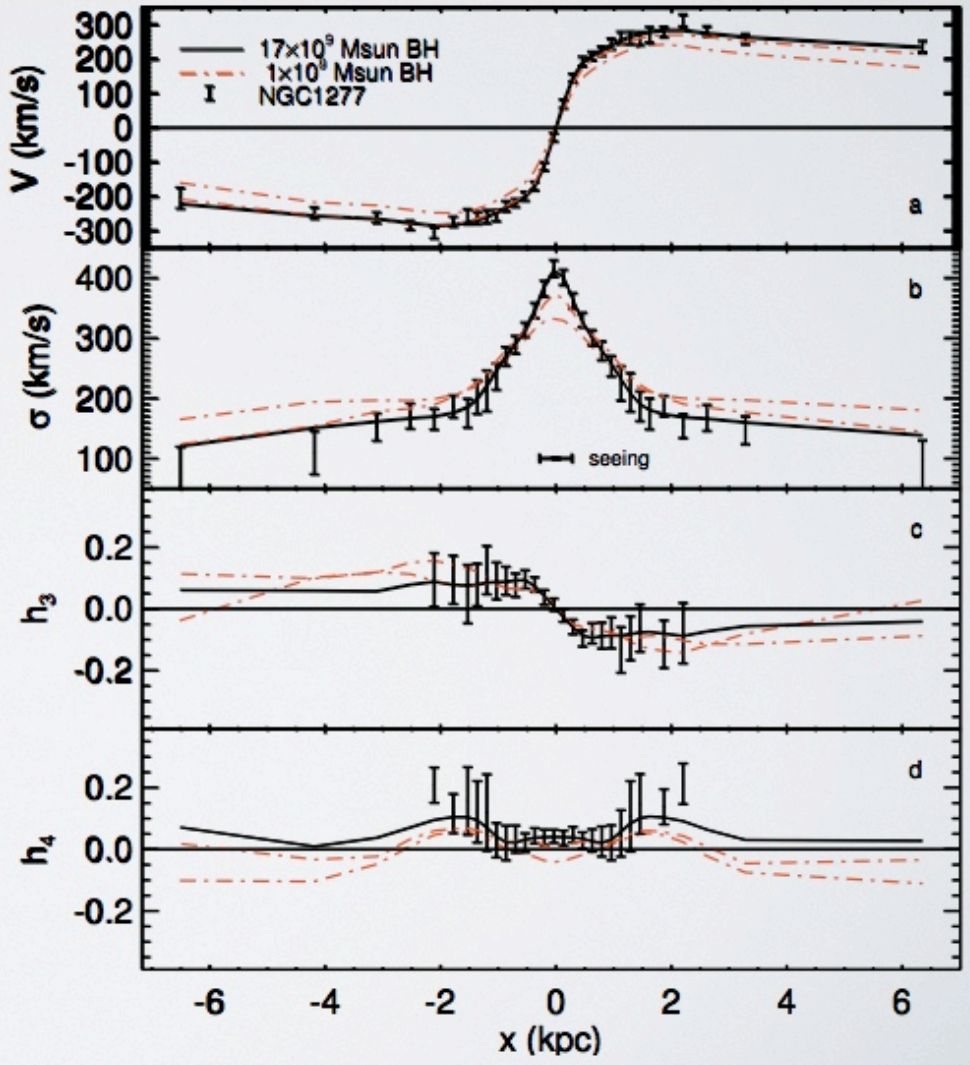
Also N4342 N4291 and N1332 (Rusli et al)


MRK1216
2′

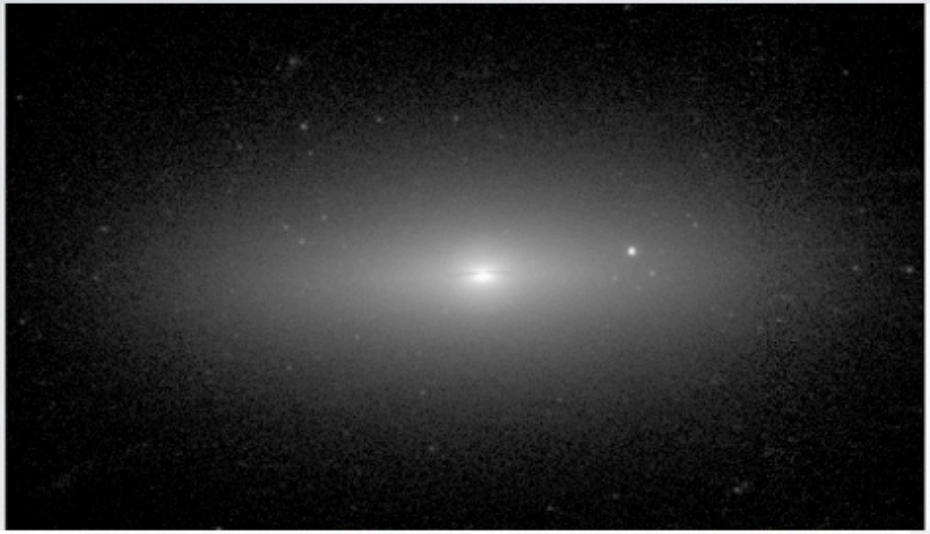
ULTIMATE PROOF REQUIRES ADAPTIVE OPTICS

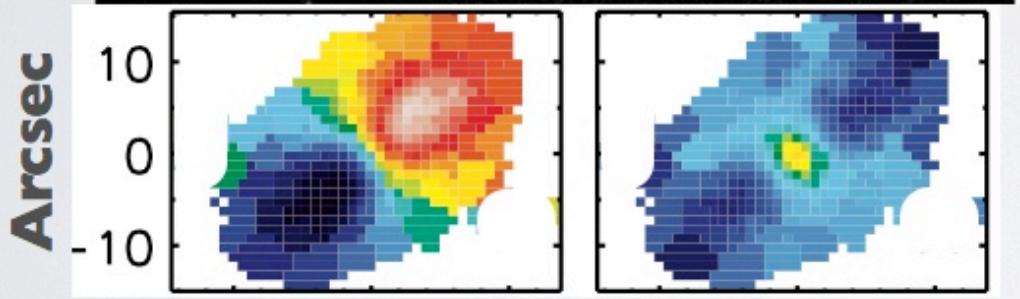


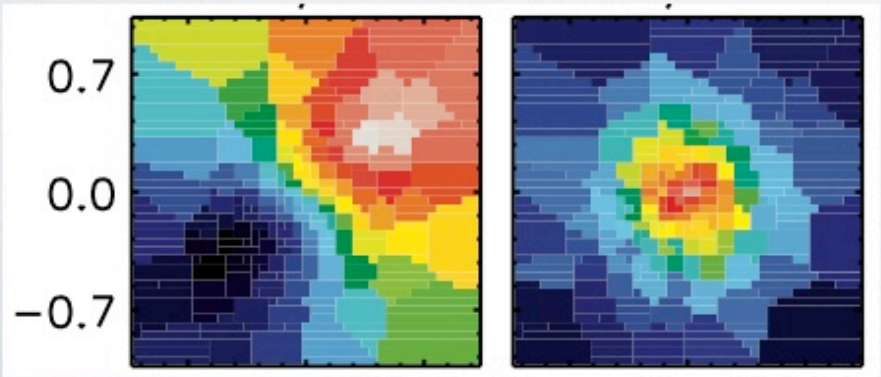




NGC1271



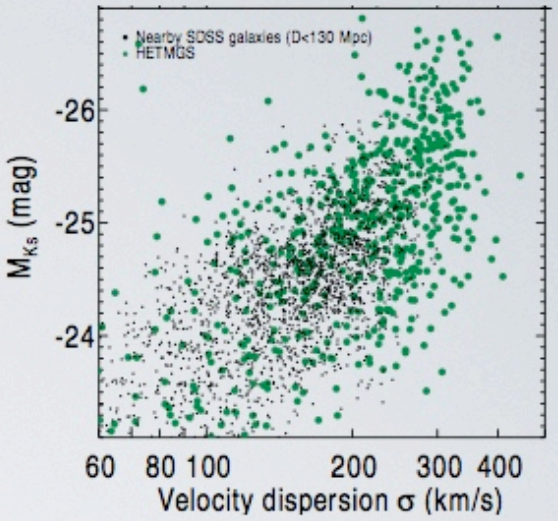




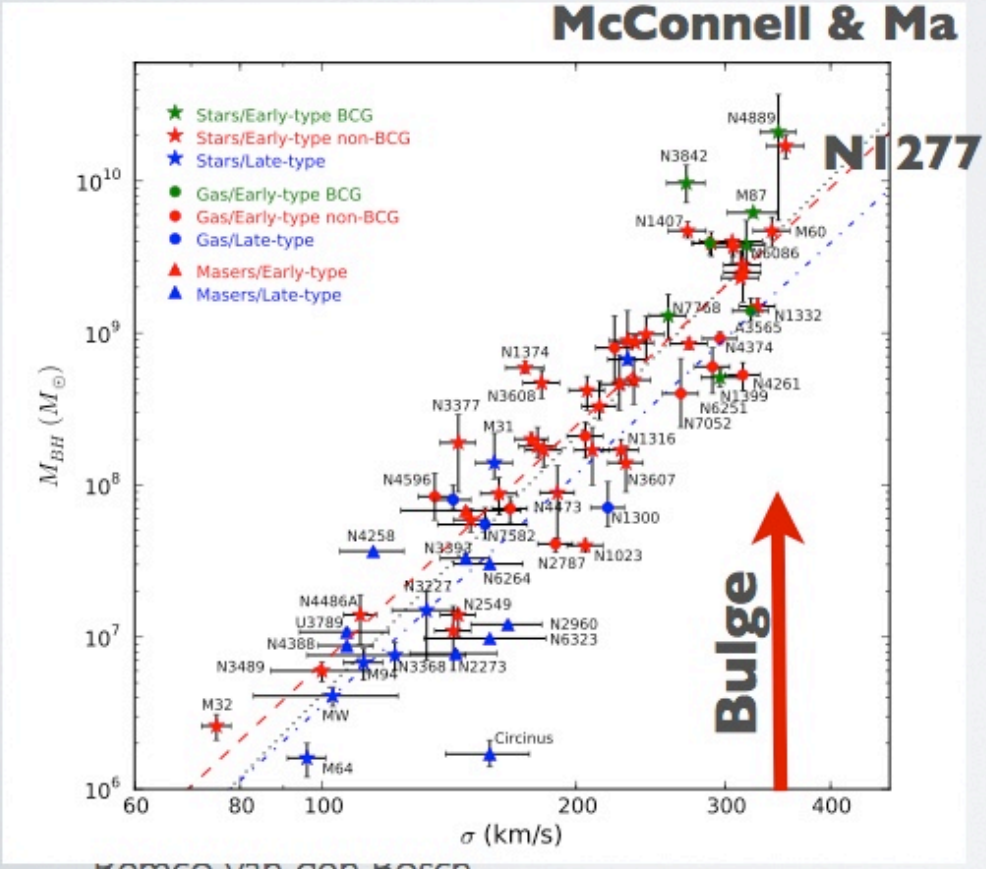
In these dense systems the potential of the different components overlap.

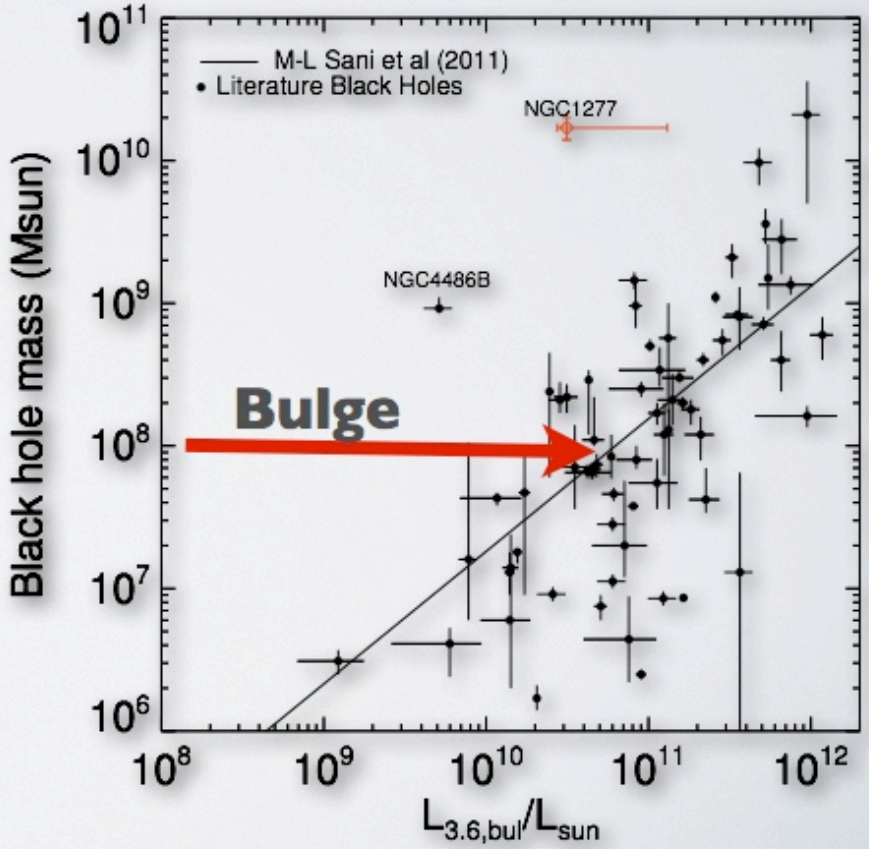
- HST imaging for stellar mass distribution (17, vdBosch)
- Large scale PPAK IFU observations for dark Halo (Yildirim)
- Adaptive Optics NIFS/ OSIRIS for the BH (~4 Walsh, N1277, Richstone)

Scaling relation make very different predictions.



What **is** a bulge?





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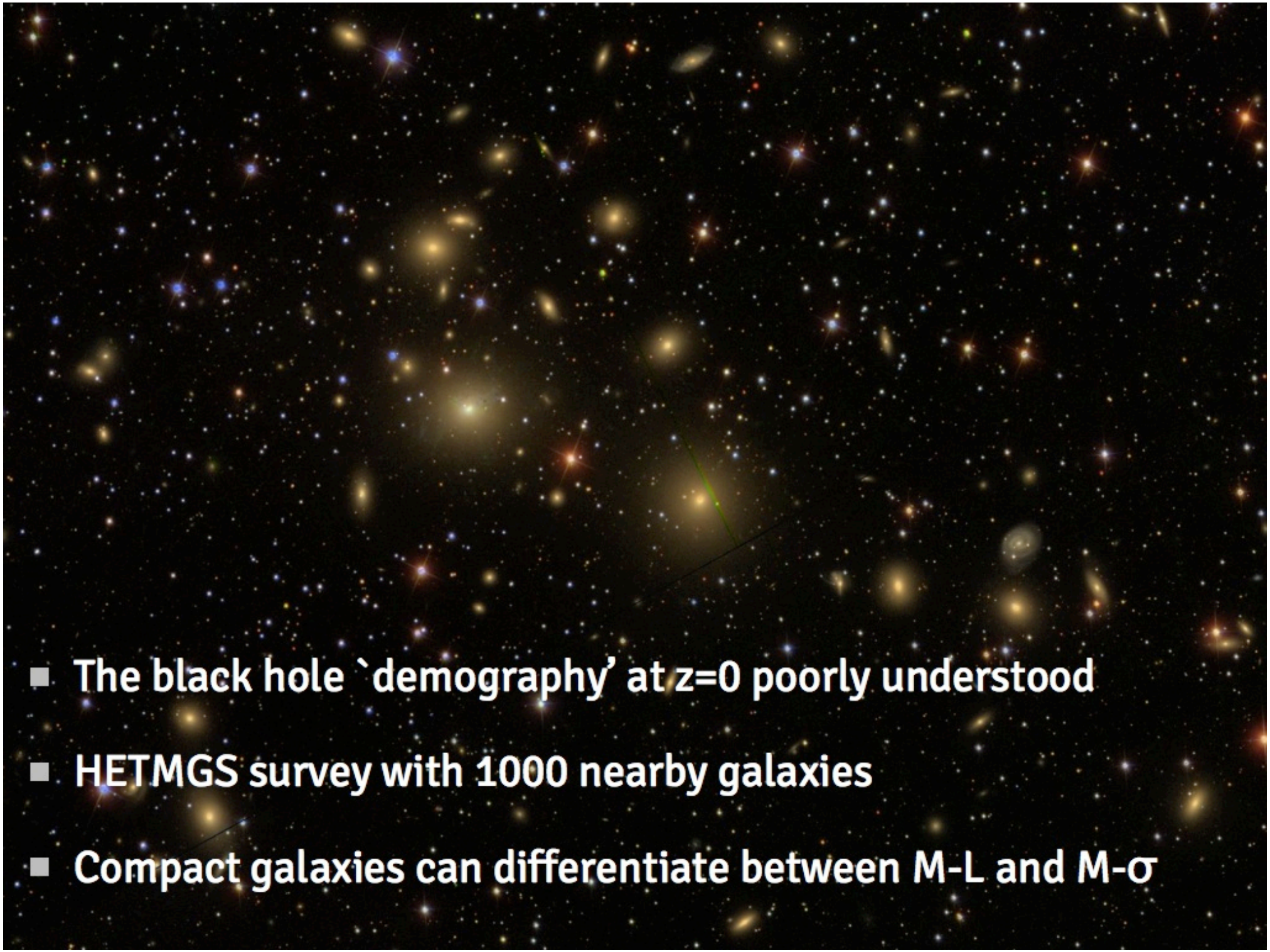
The black hole `demography' at z=0 poorly understood
HETMGS survey with 1000 nearby galaxies
Compact galaxies can differentiate between M-L and M-σ