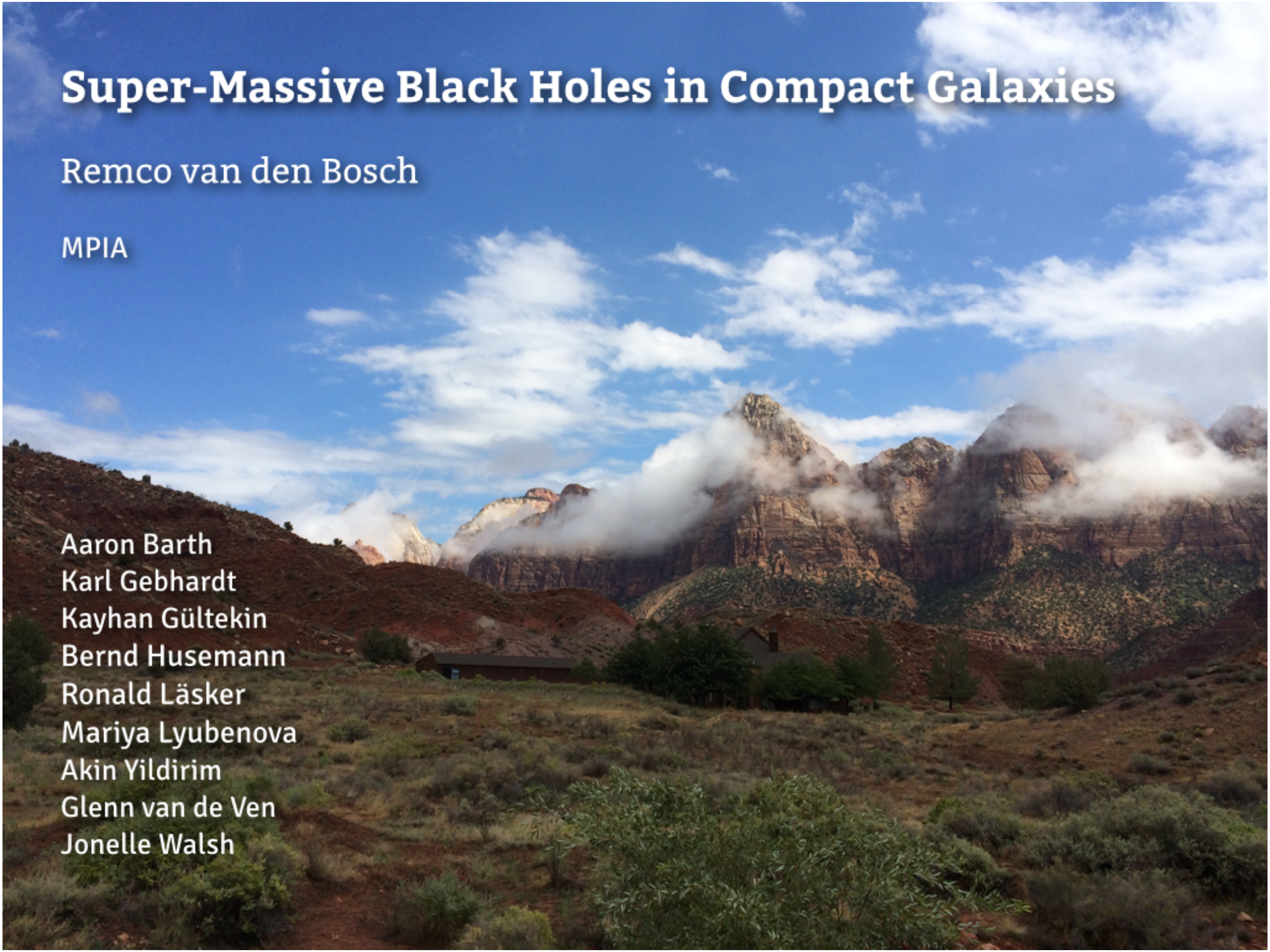
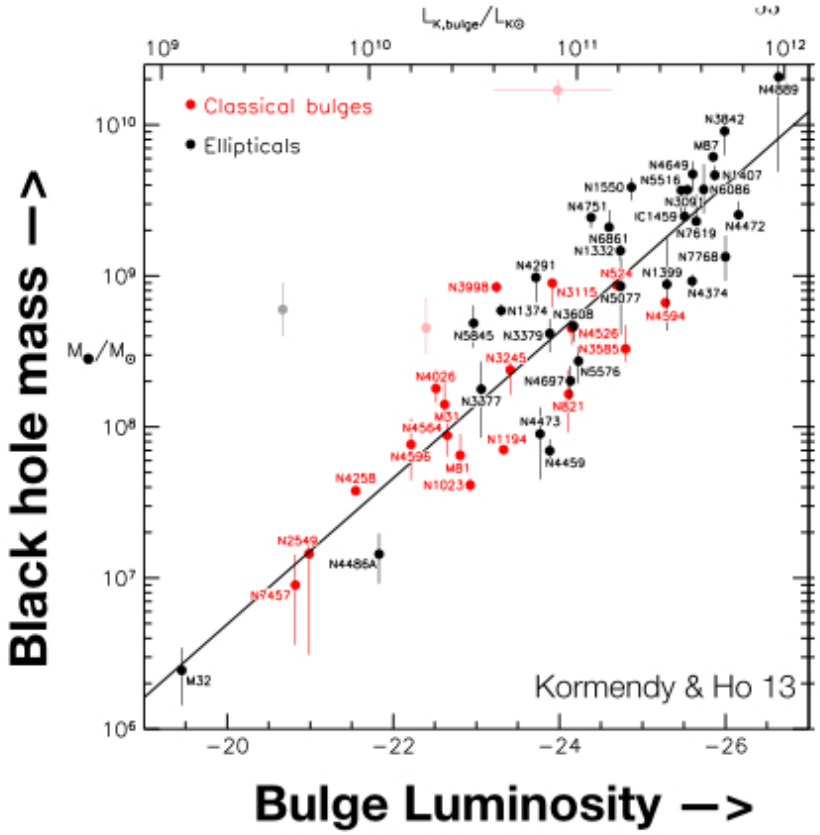

Super-Massive Black Holes in Compact Galaxies
Remco van den Bosch
MPIA
Aaron Barth
Karl Gebhardt
Kayhan Gültekin
Bernd Husemann
Ronald Läsker
Mariya Lyubenova
Akin Yildirim
Glenn van de Ven
Jonelle Walsh

DIRECT BLACK HOLE MASSES

- The direct black hole masses in nearby galaxies are the basis for all other BH mass estimates.
- Only ~80 have been measured to date.
- Requires high spatial resolution spectroscopy ELT (Do+14), ALMA Davis14)



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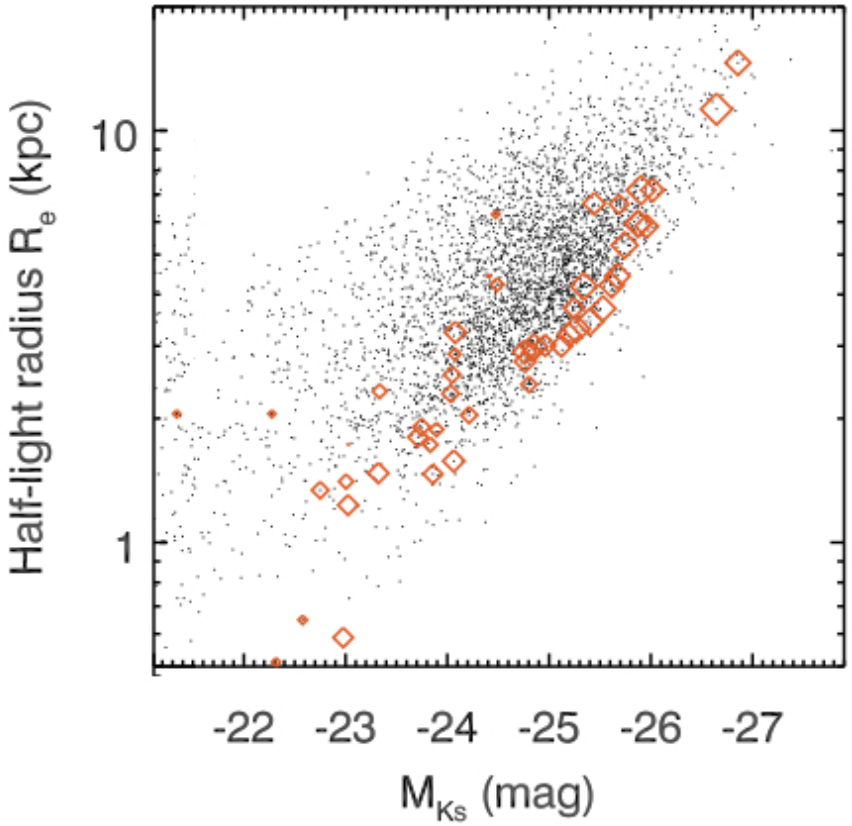

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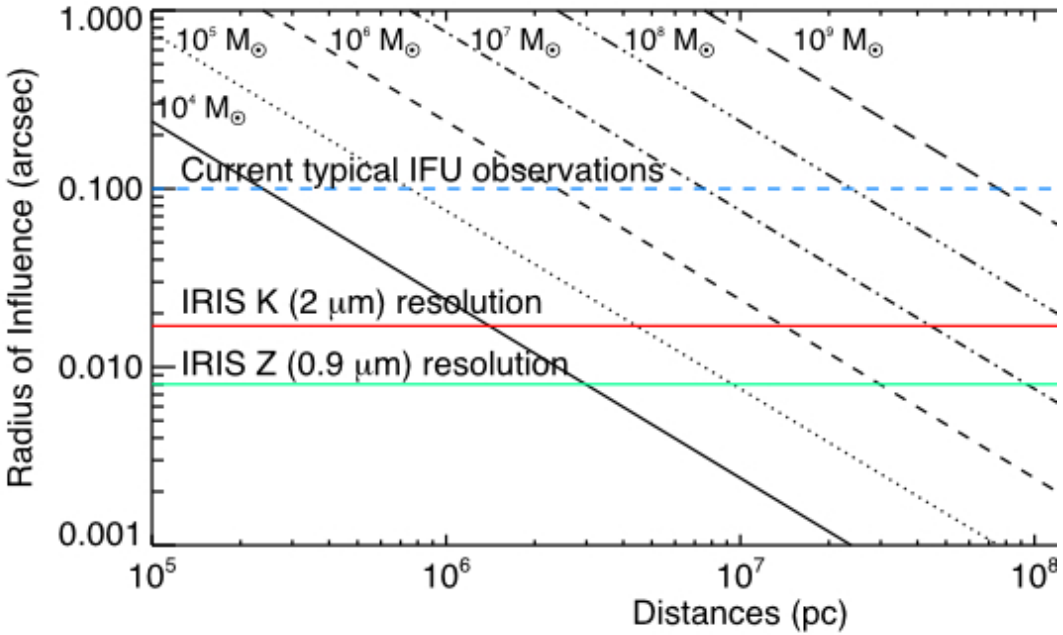
$$R_{soi} = \frac{GM_\bullet}{D\sigma^2} \propto \frac{\sigma^{2.2}}{D}$$



Do+2014

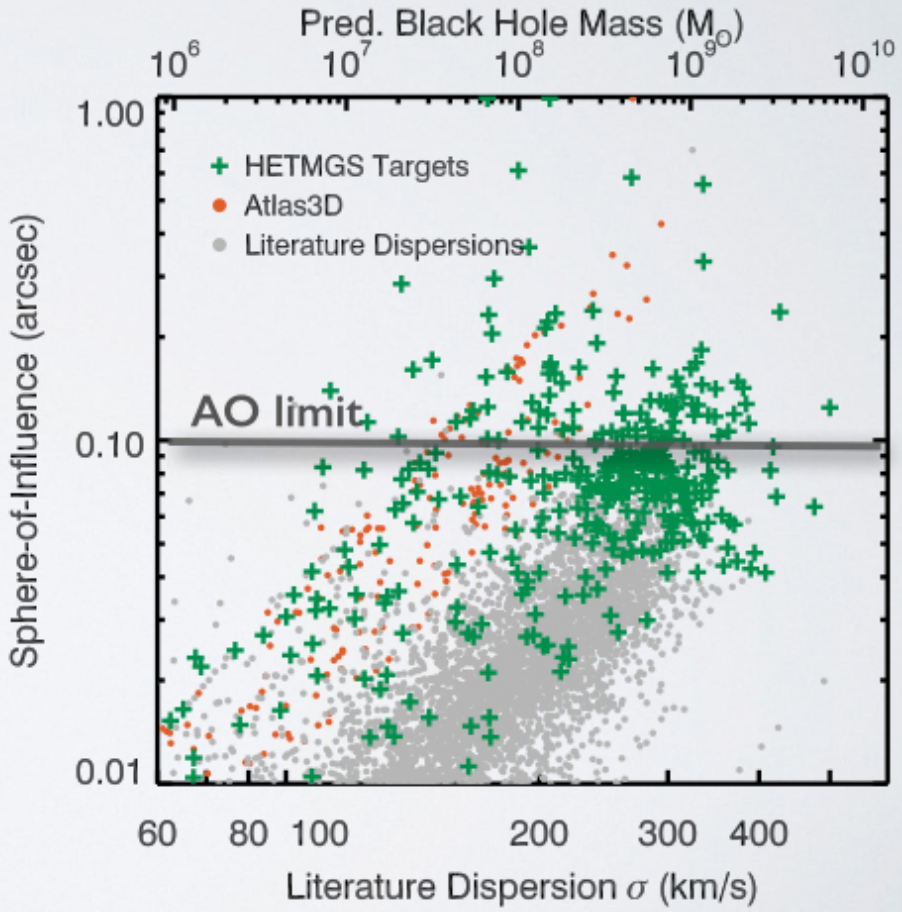
HET SURVEY

- Long slit spectra with the Marcario Low Resolution Spectrograph
- 4200-7400 AA, 106 km/s resolution, 1''x2.5' slit
- 1000 galaxies
- Distances less then ~140 Mpc
- Targeting the galaxies with the largest sphere of influences.
- Effectively probing the massive nearby galaxies

vdB+submitted

HET MASSIVE GALAXIES SURVEY

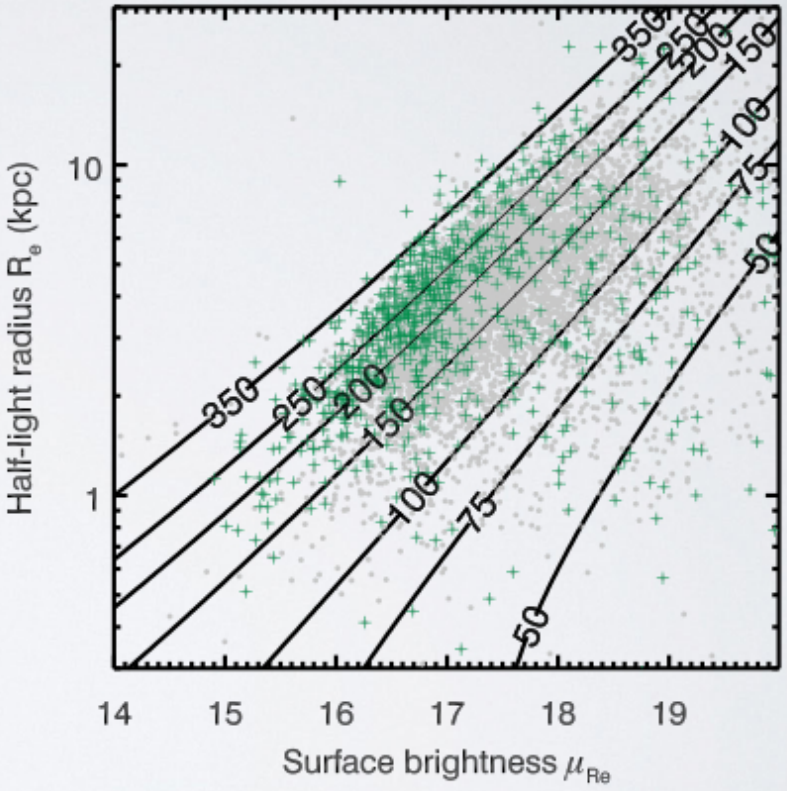
- **Select candidate galaxies using literature velocity dispersion from Hyperleda database**
- Predict black hole mass using M-sigma
- Few targets with SOI>0.1"
- Most nearby galaxies are not in SDSS



vdB+

2MASS FUNDAMENTAL PLANE

- **Sample across the face of the FP**
- Not all nearby galaxies have dispersions
- Predict dispersion:
  - 2Mass XSC (Jarret+00)
  - 2MRS Redshifts (Huchra+12)
  - Fundamental Plane (Dressler+87)
  - No selection on galaxy type
- Dispersion estimates accurate up to 0.09 dex



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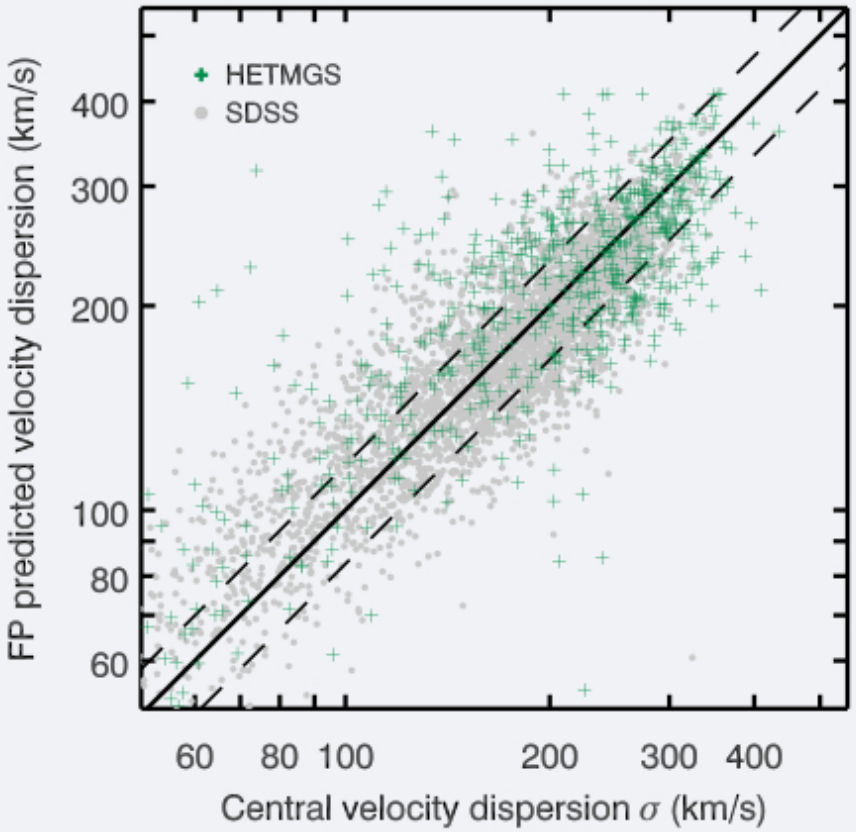
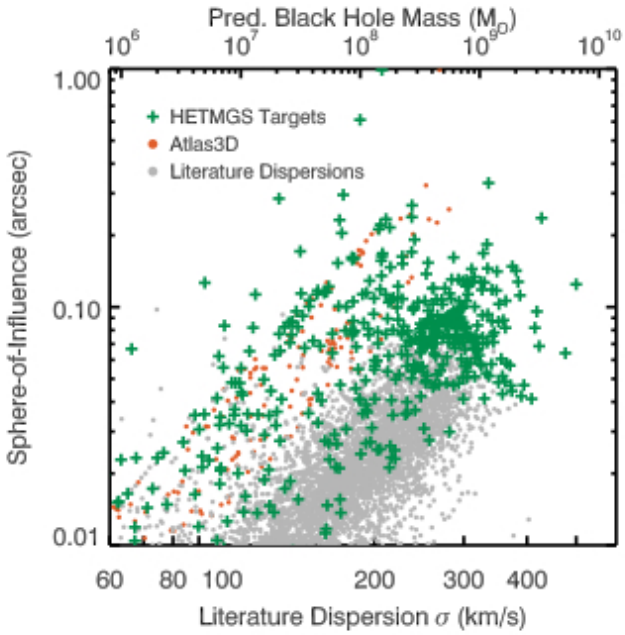
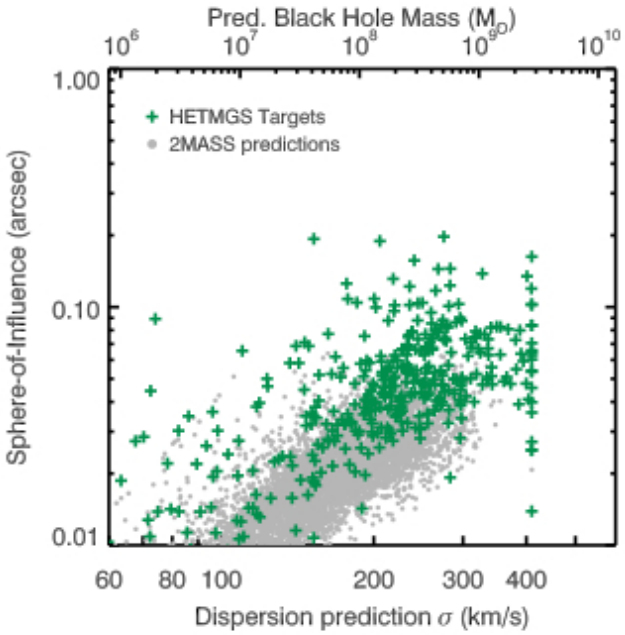


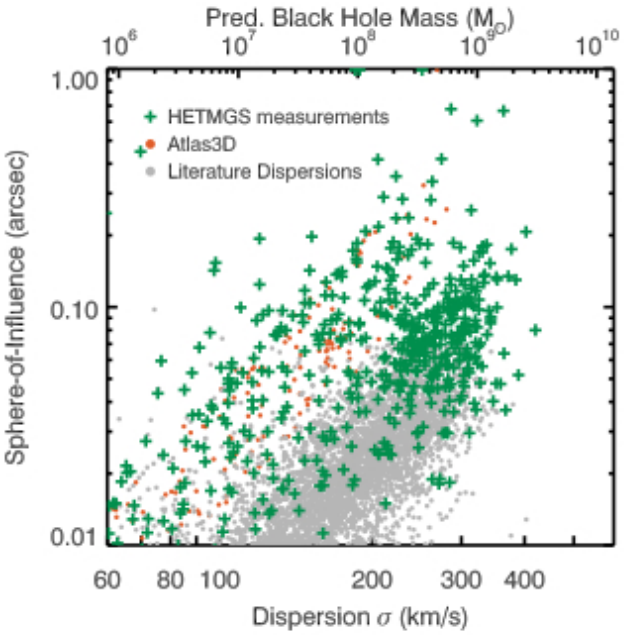
No literature dispersions



No literature dispersions

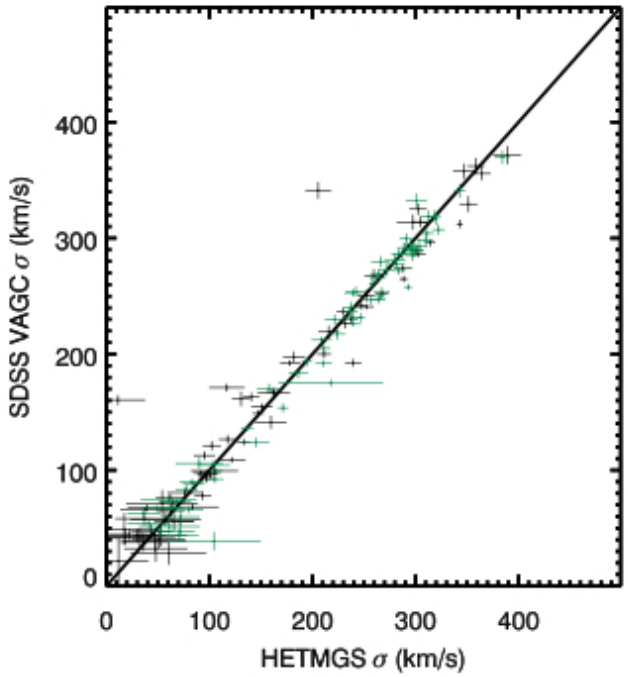


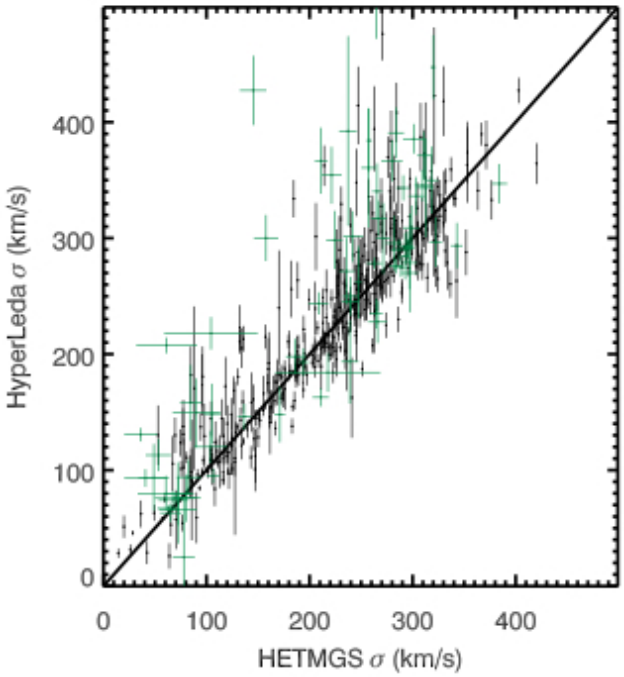
Final Survey

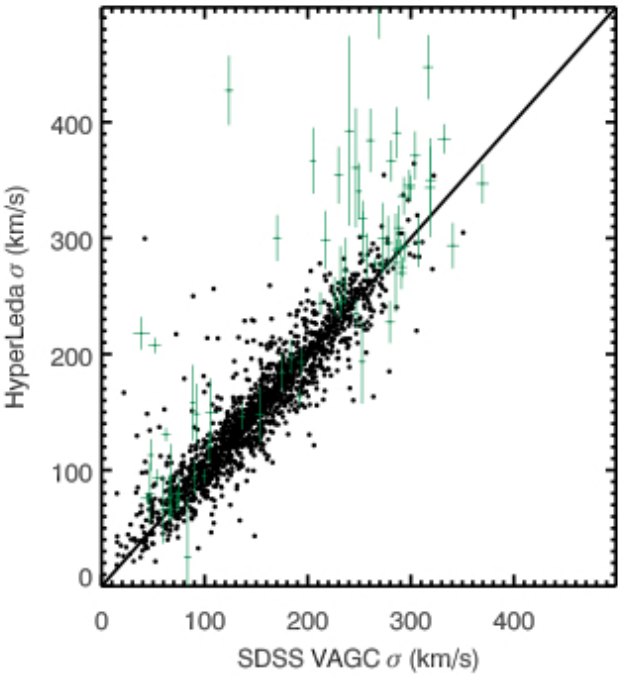


Survey completeness

vdB+

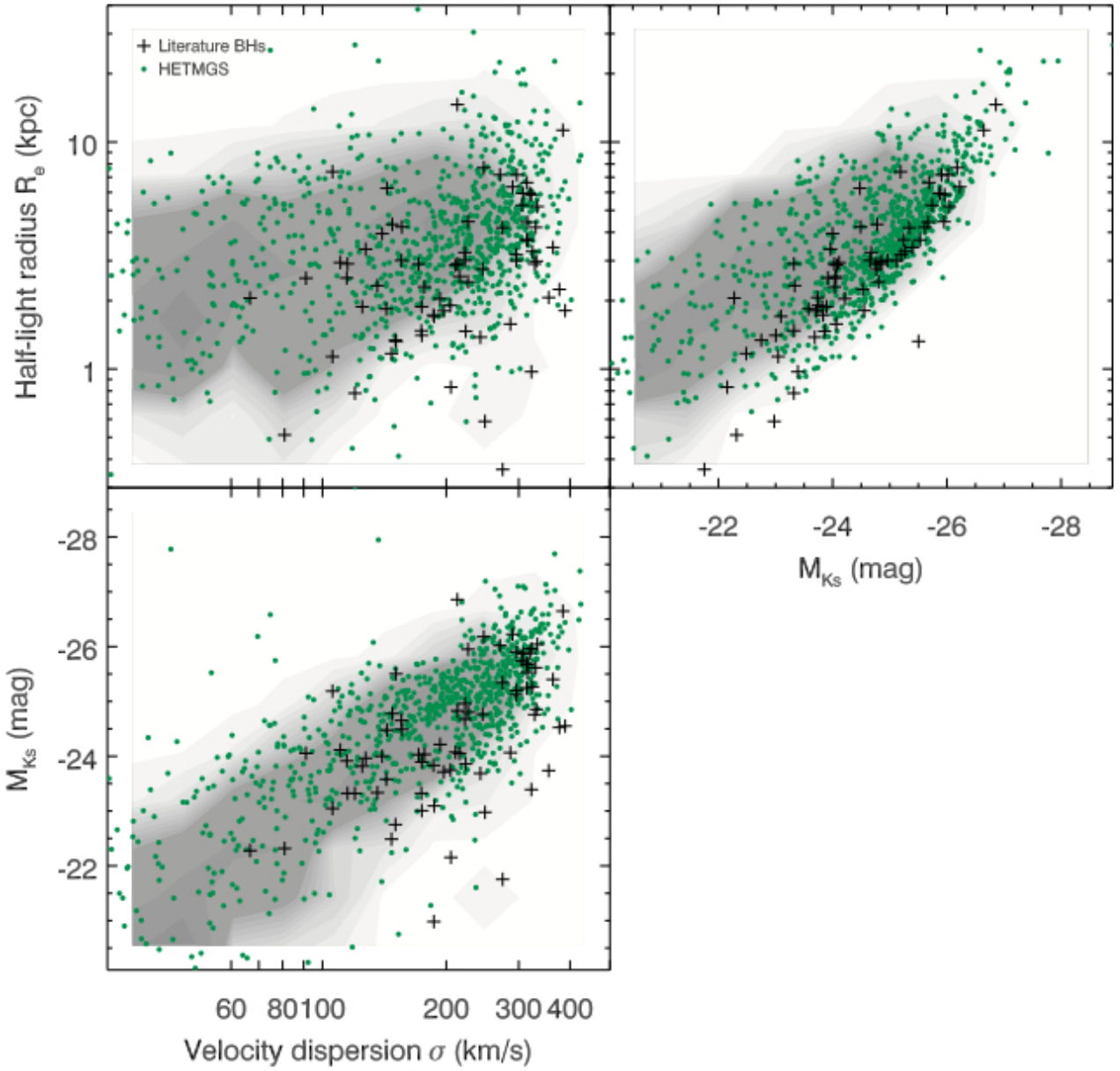






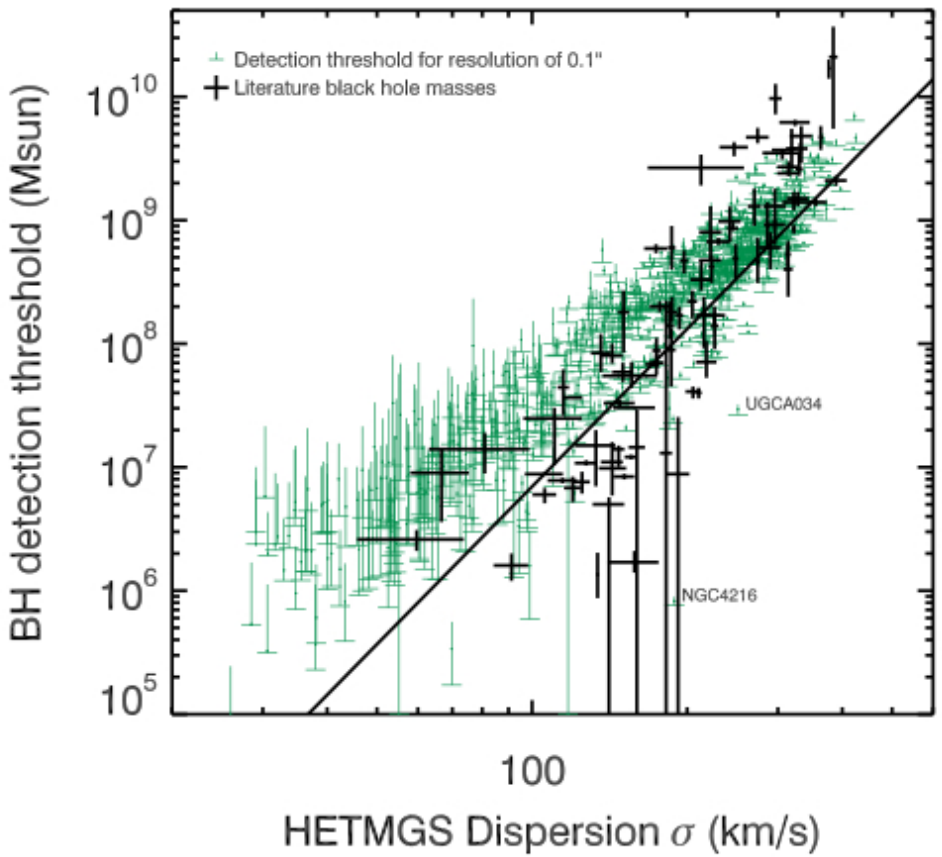
Dispersion comparison

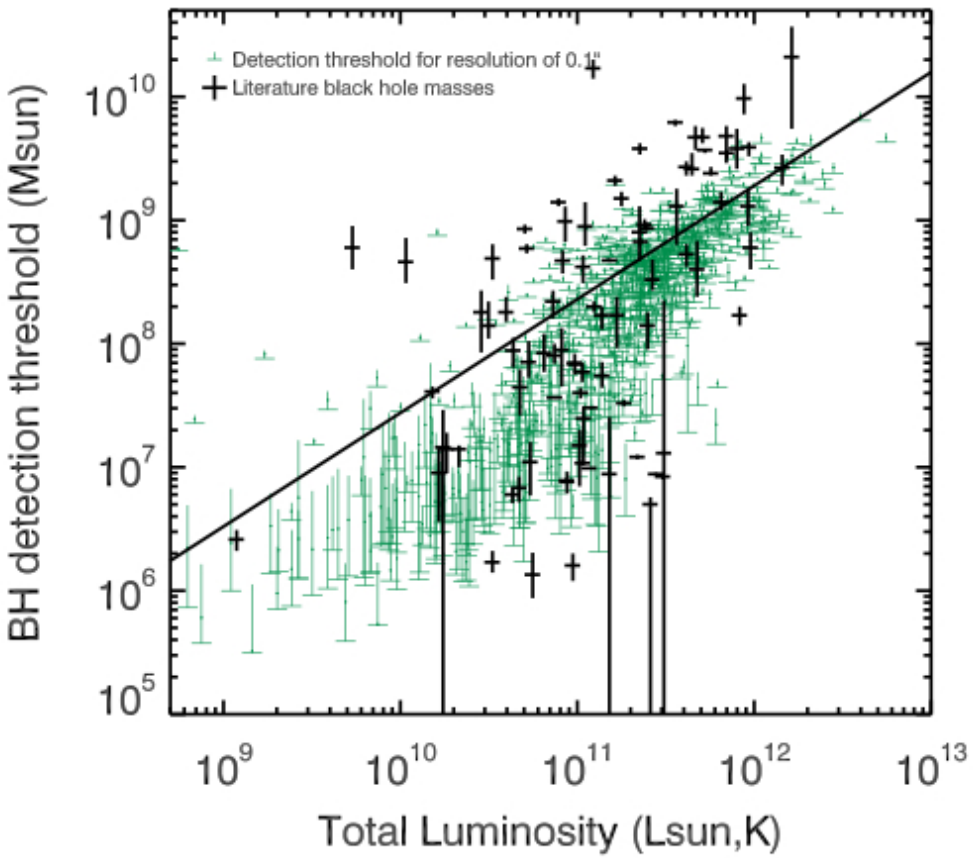
vdB+



Distribution of BH hosts

vdB+



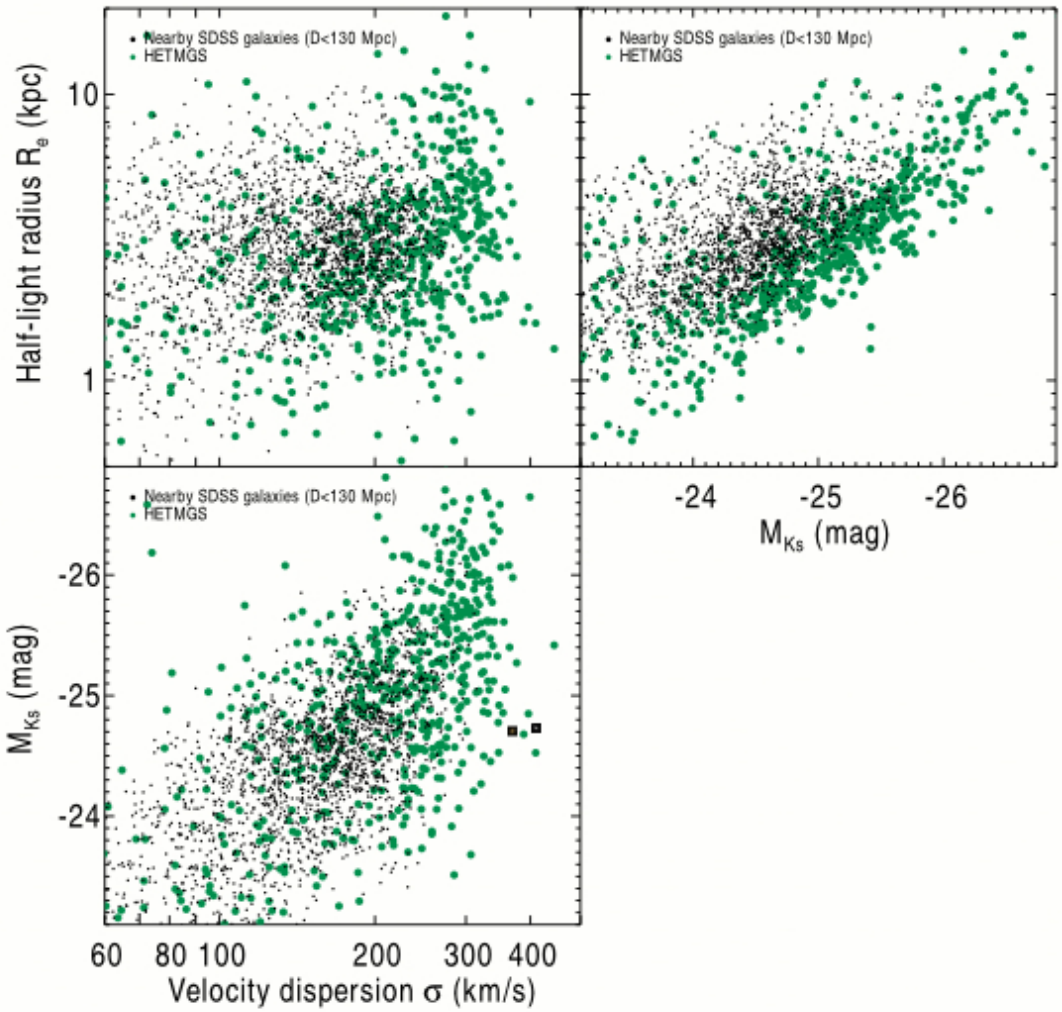


What can we expect?

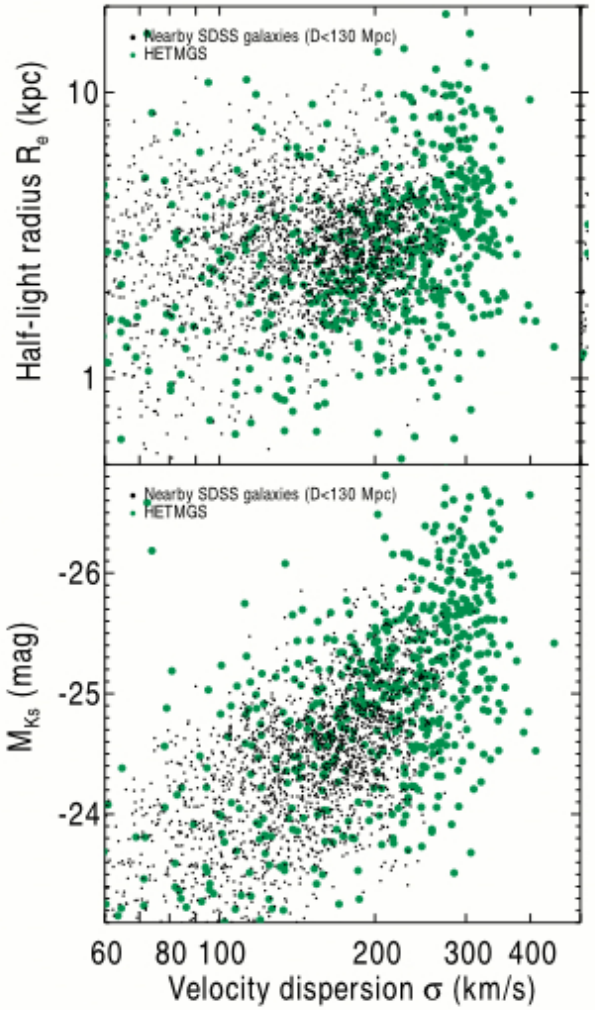
$$R_{soi} = \frac{GM_\bullet}{D\sigma^2}$$

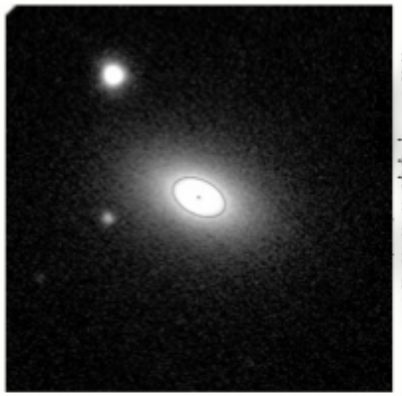
vdB+

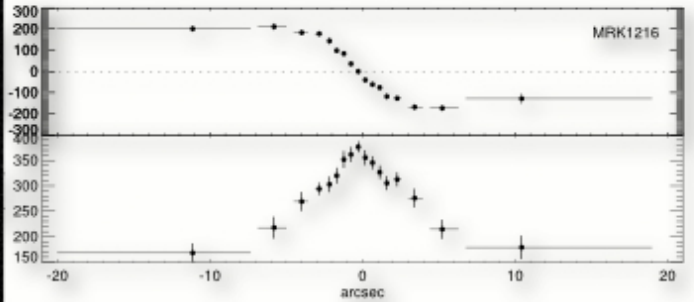
COMPACT GALAXIES

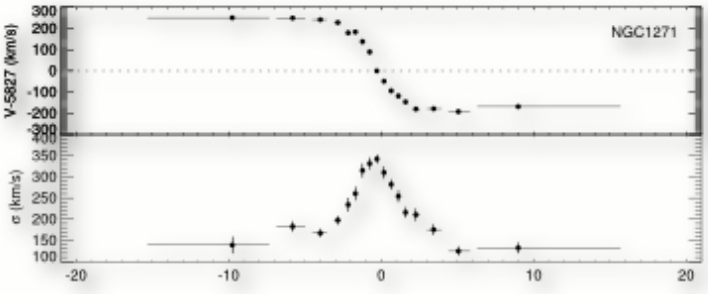


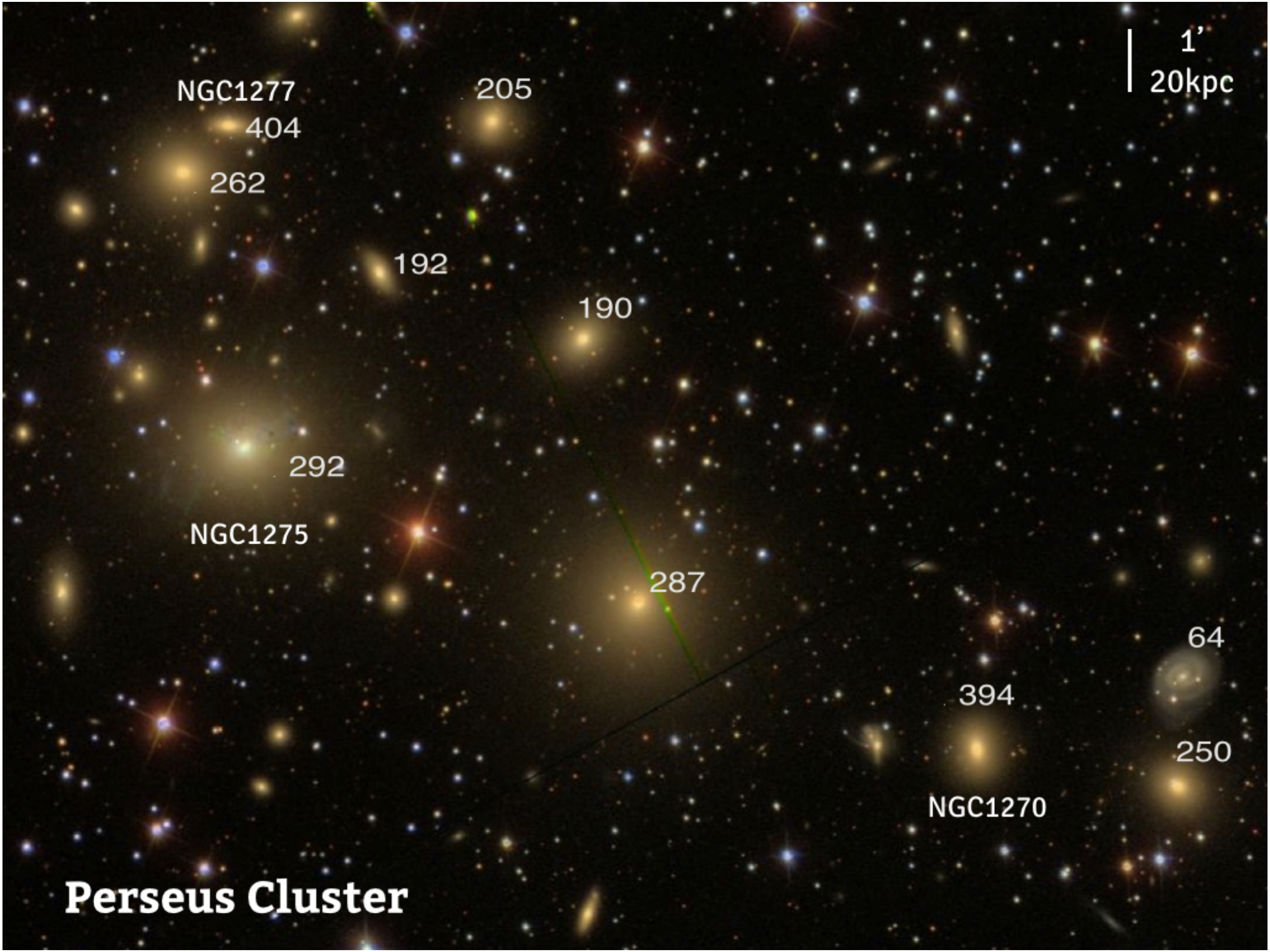
COMPACT GALAXIES



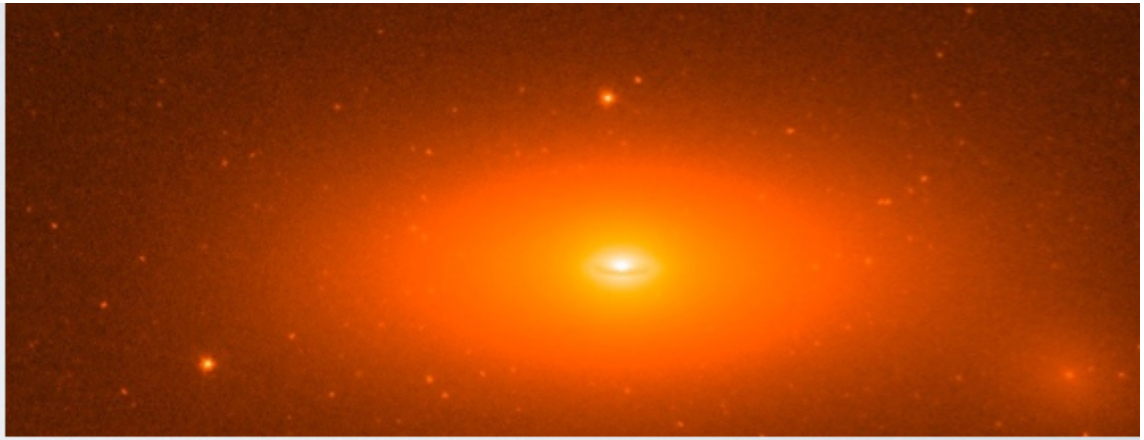


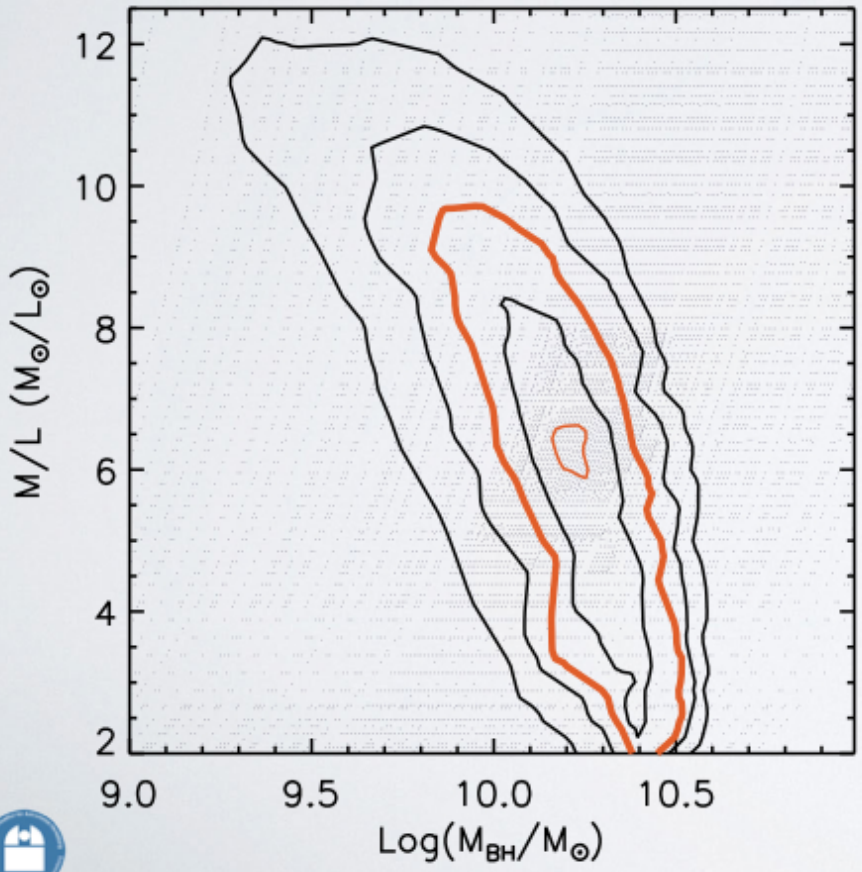


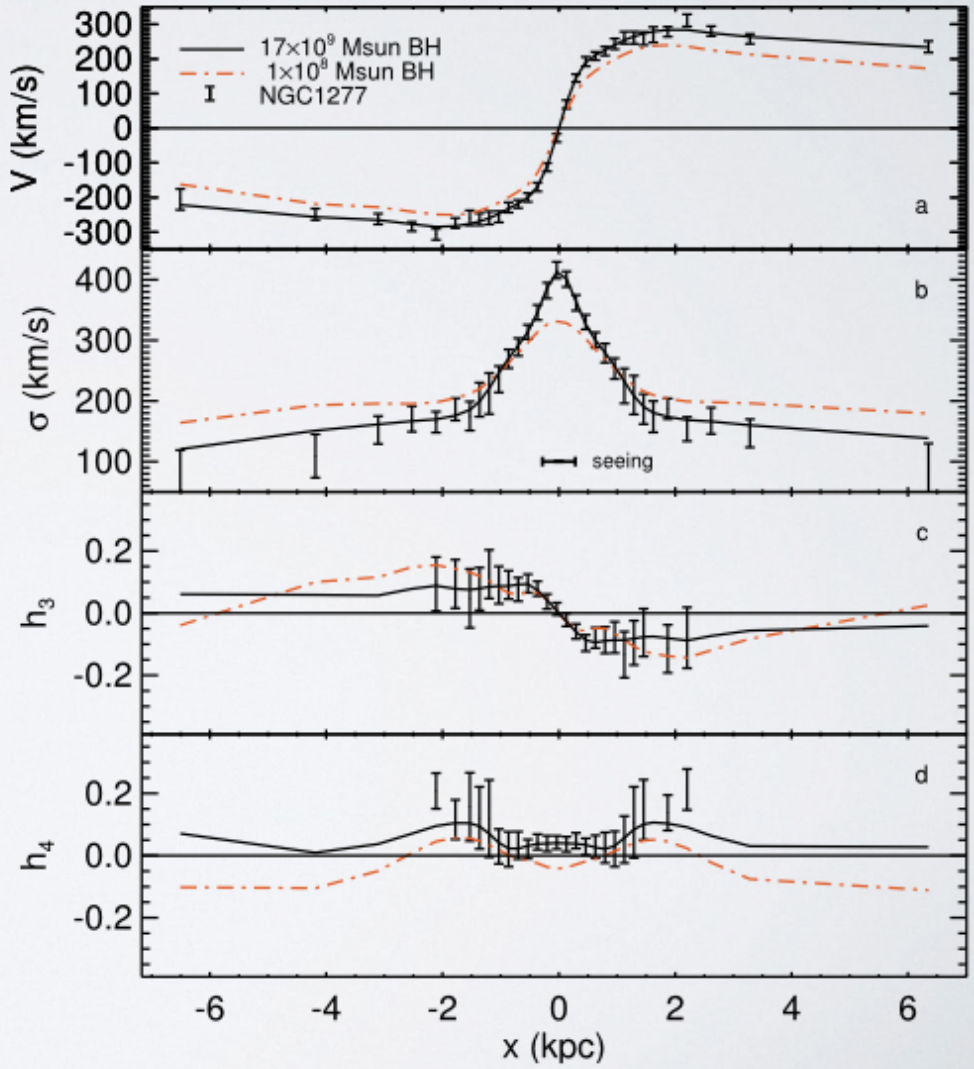



1'
20kpc
NGC1277
205
404
262
192
190
292
NGC1275
287
64
394
250
NGC1270
Perseus Cluster

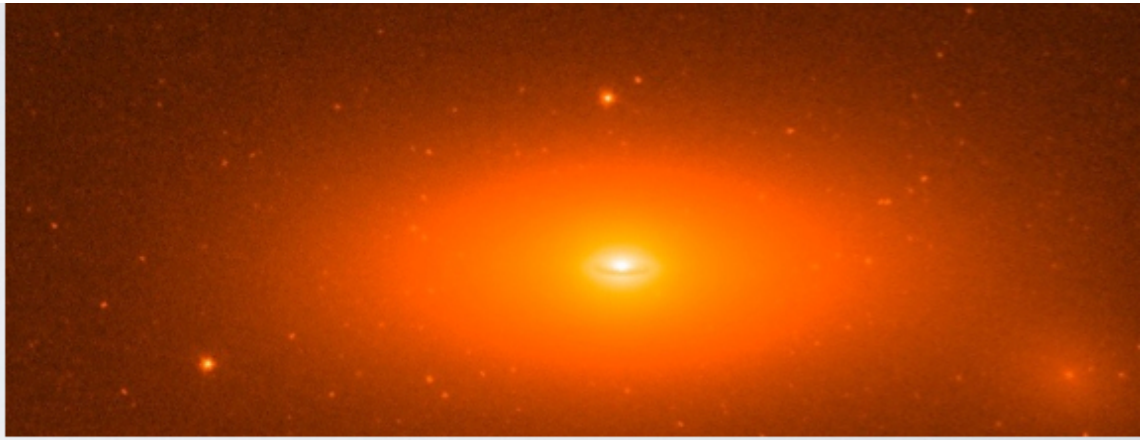
NGC 1277: A BIG BLACK HOLE IN A SMALL GALAXY

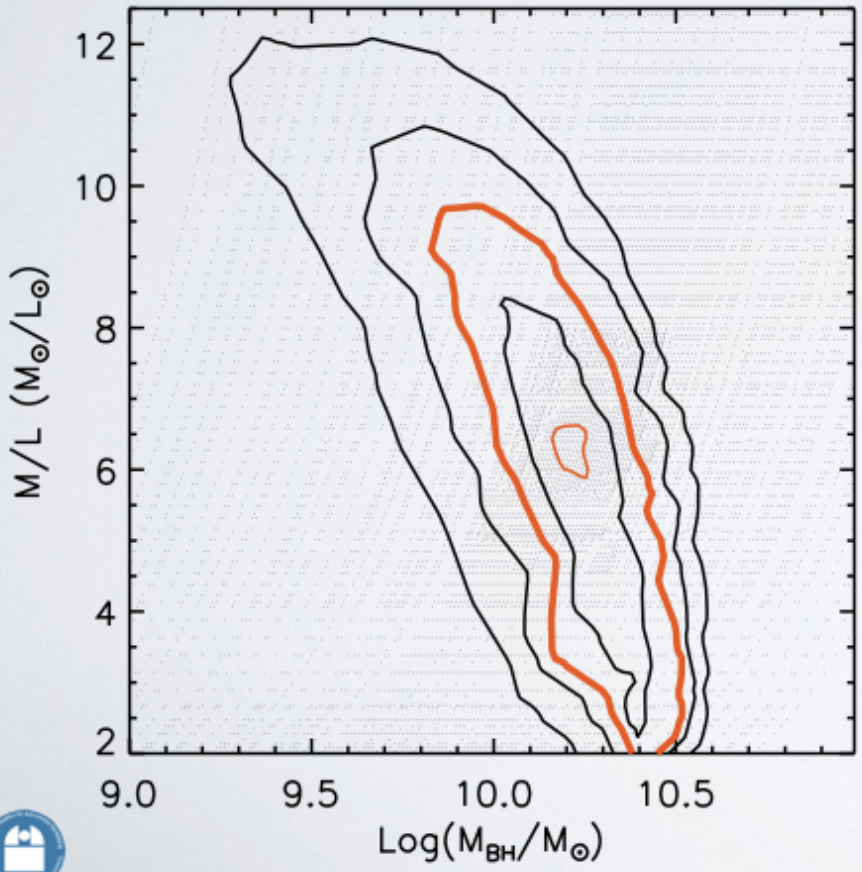


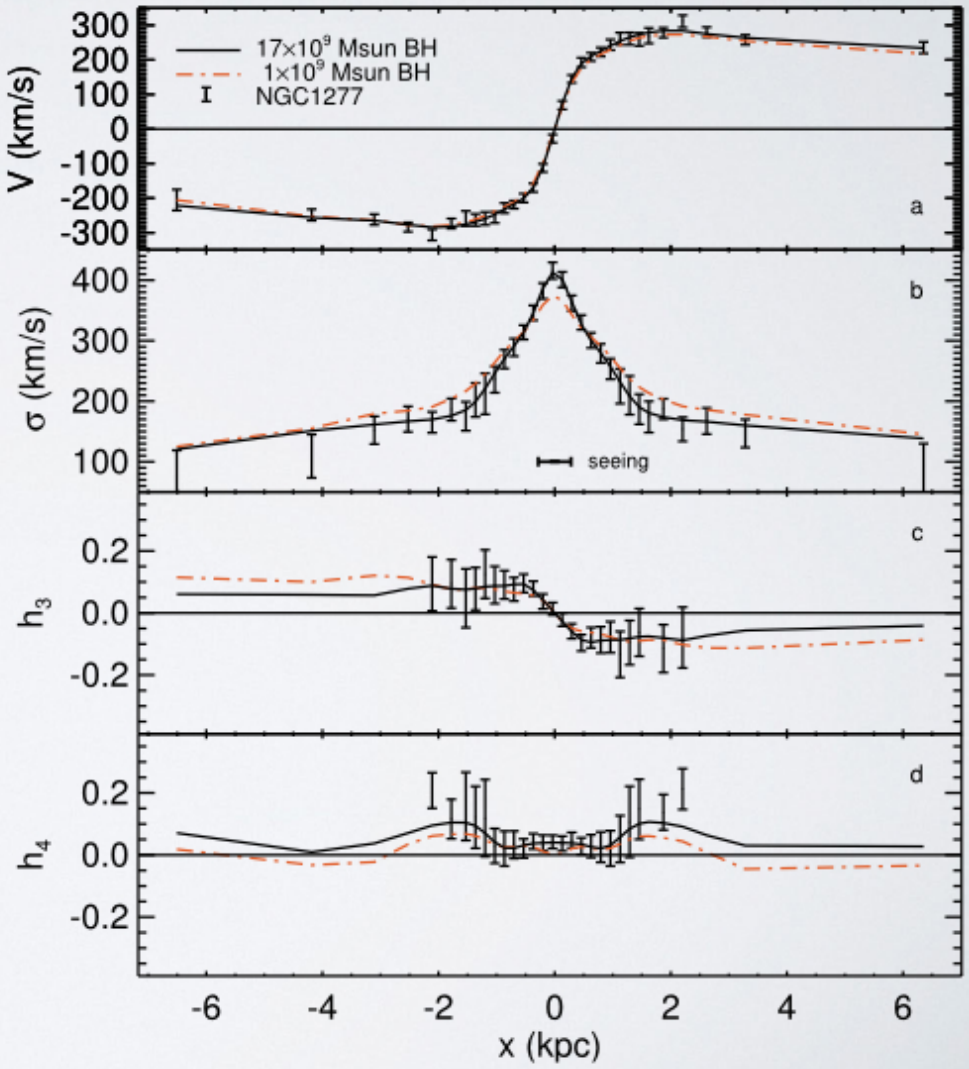




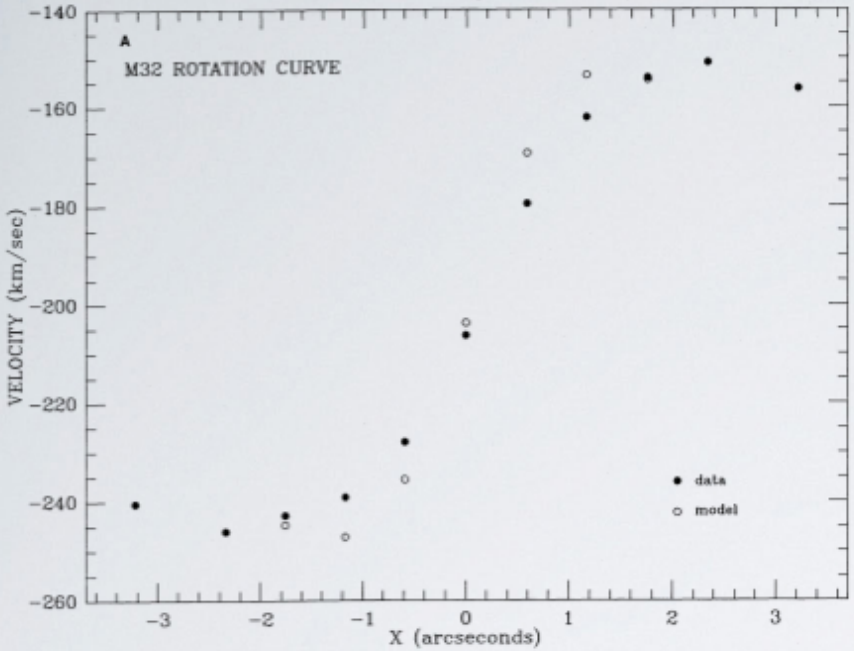
NGC 1277: A BIG BLACK HOLE IN A SMALL GALAXY

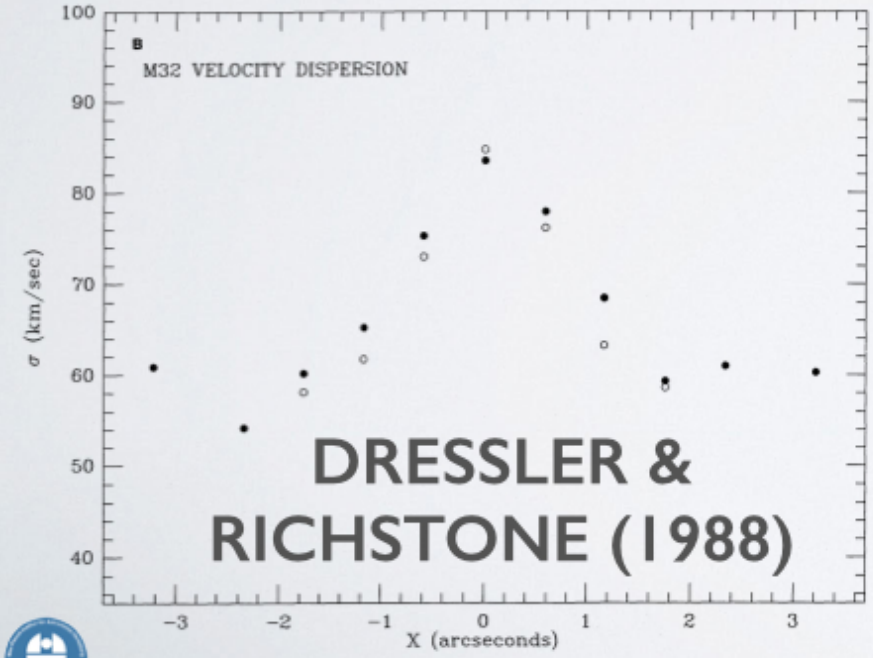




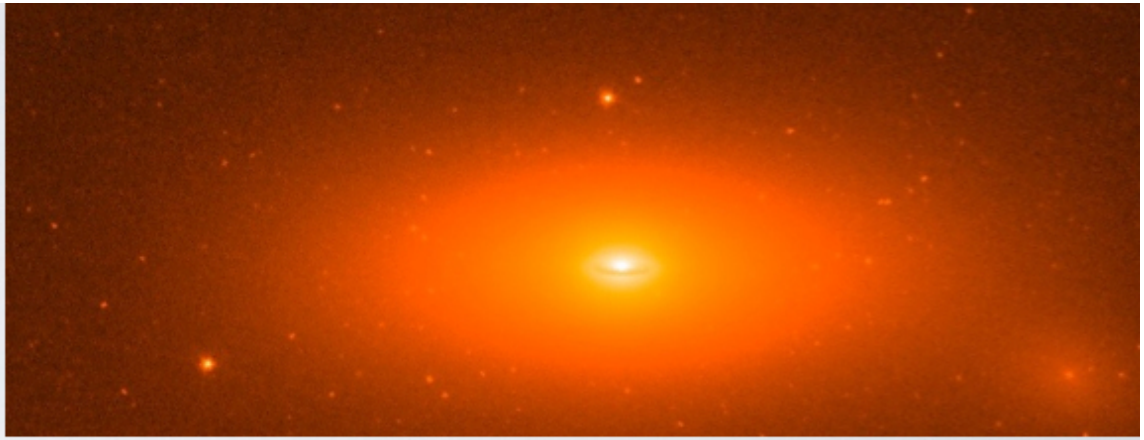


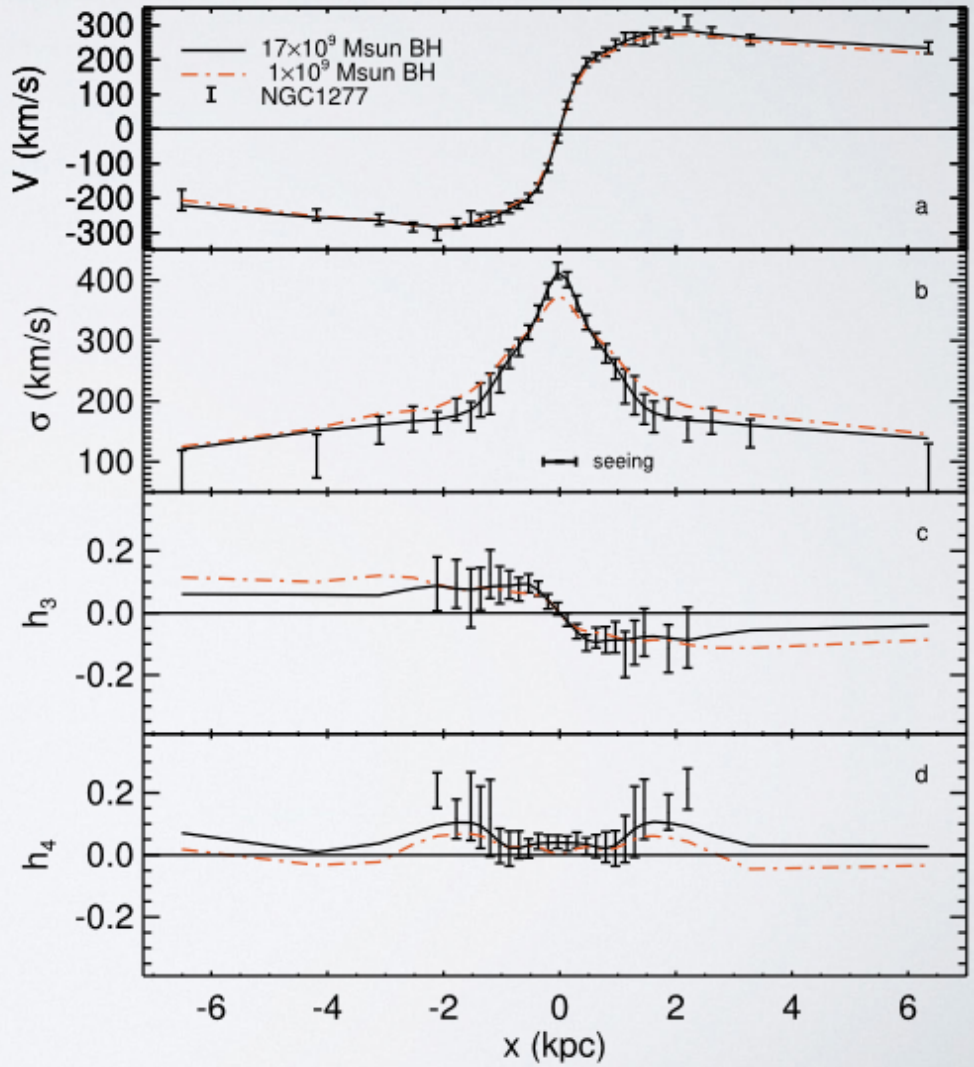
M32

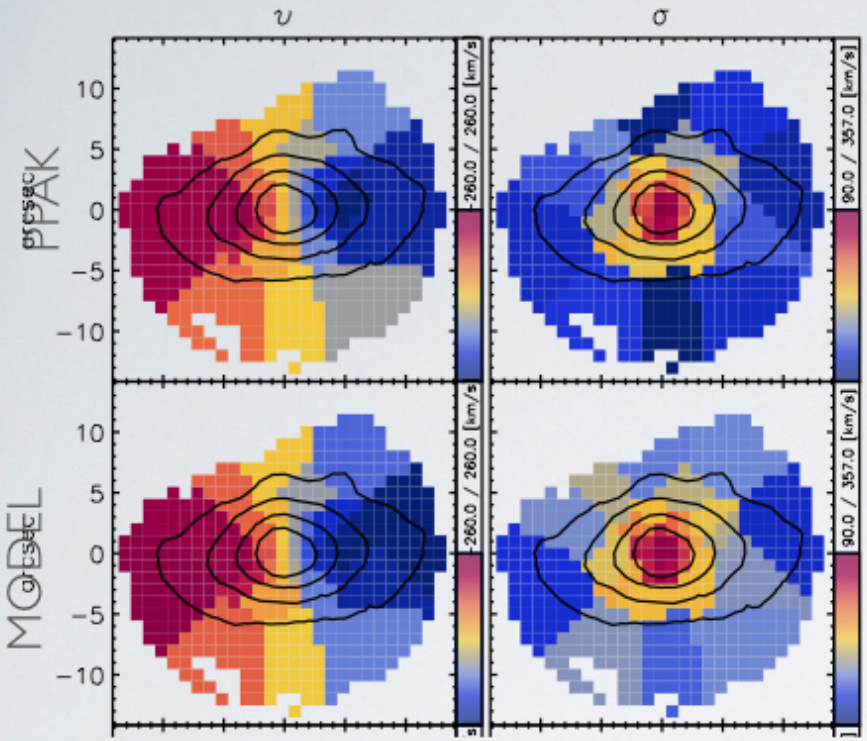


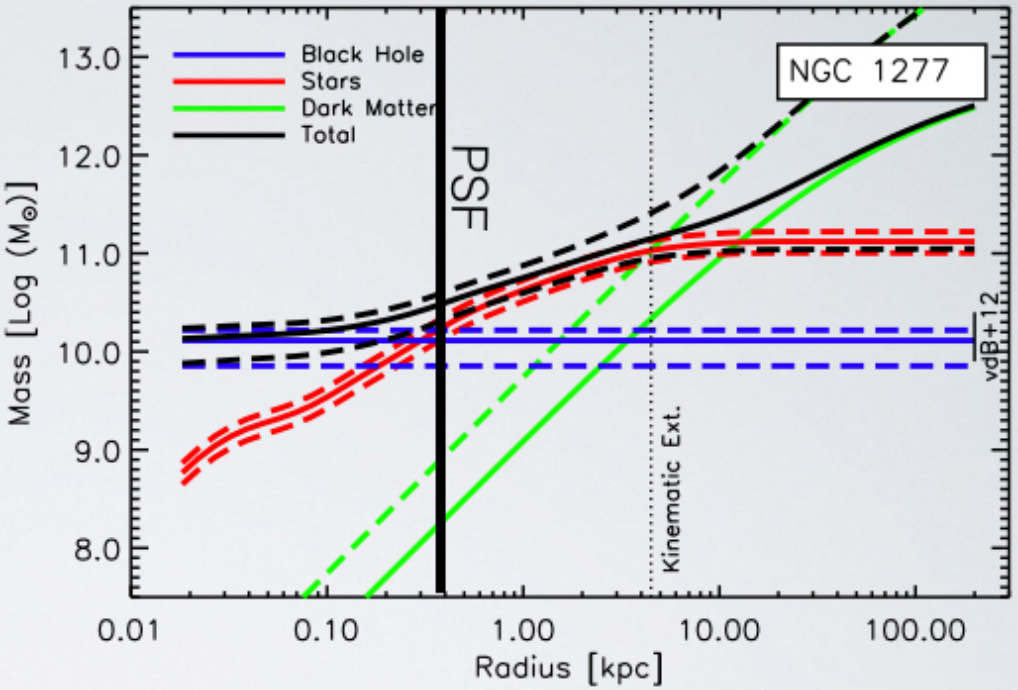


DRESSLER & RICHSTONE (1988)





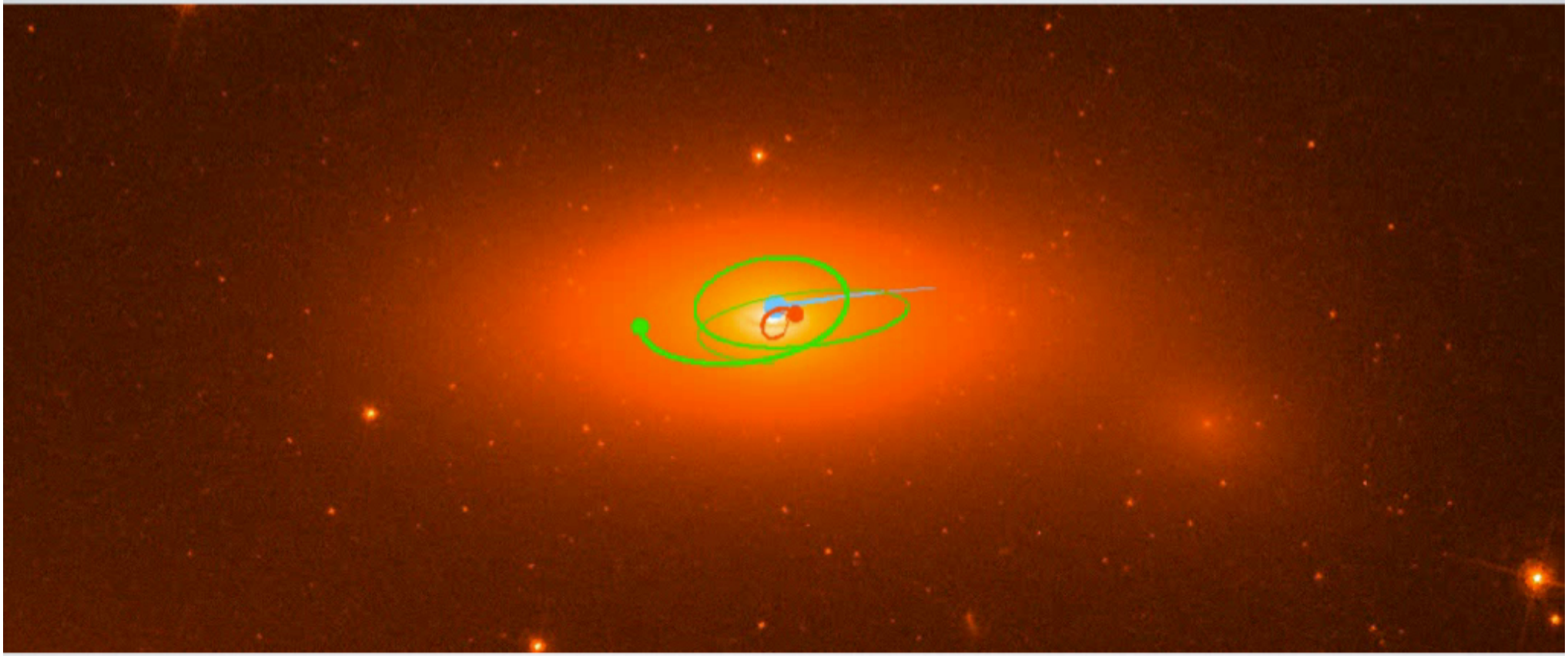




- PPAK IFU observations constrains the dynamical model and give a higher mass-to-light ratio and smaller black hole

Yildirim+

NGC1277 IS AN OLD DISK GALAXY



- No Classical Bulge, which implies no coevolution.
- Bottom heavy stellar populations (Emsellem 2013)
- stellar ages >10 Gyr. (Trujillo+2014)
- Chandra X-ray luminosity of 1e40 (Fabian et al. 2013), implies low accretion rate.
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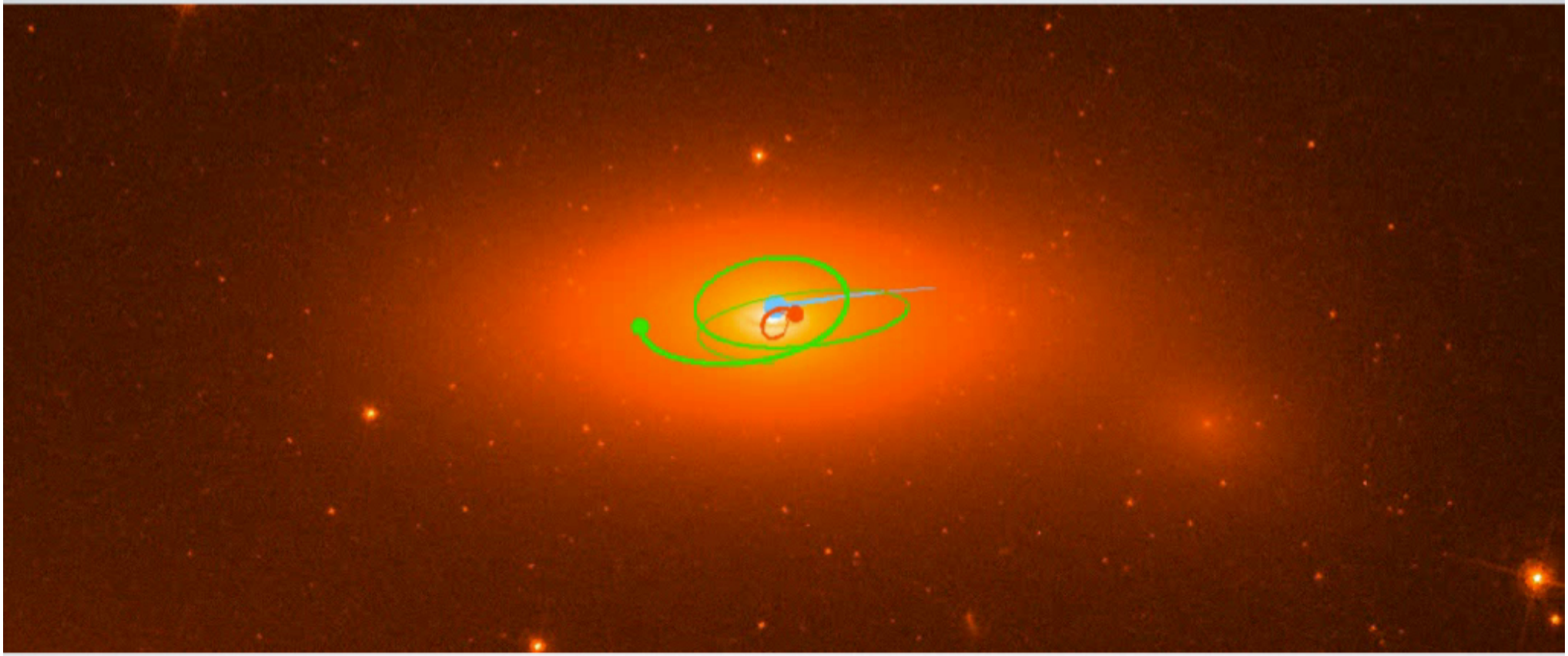

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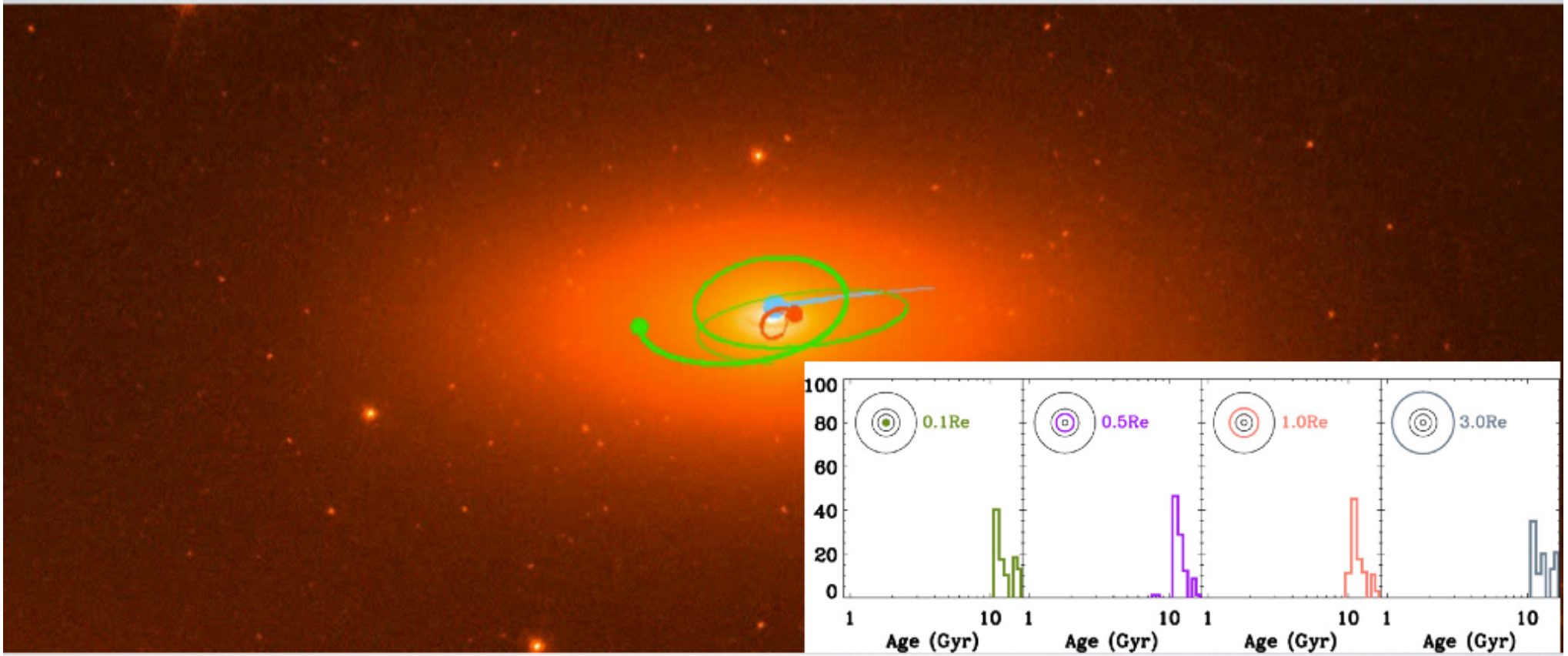

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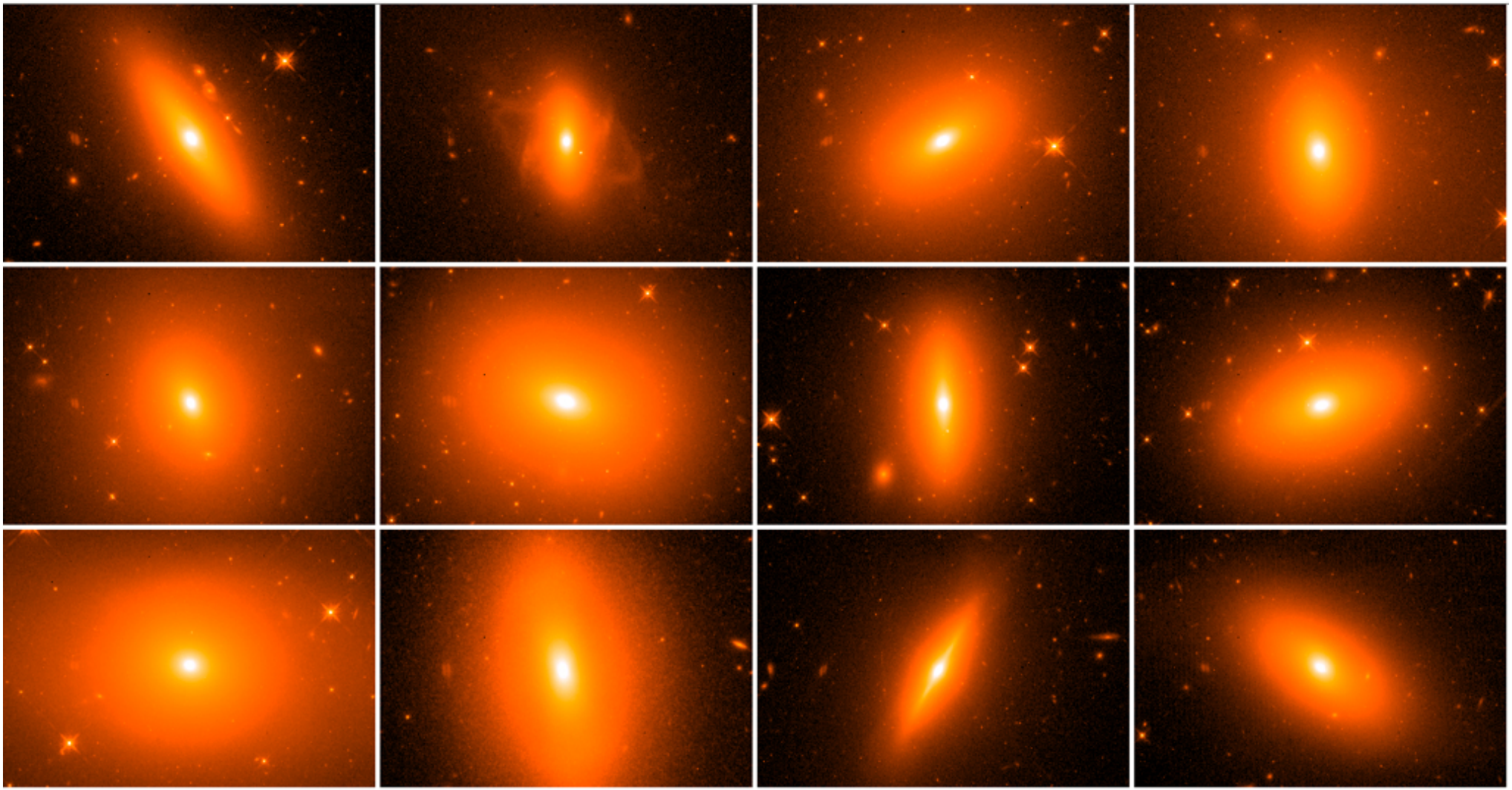
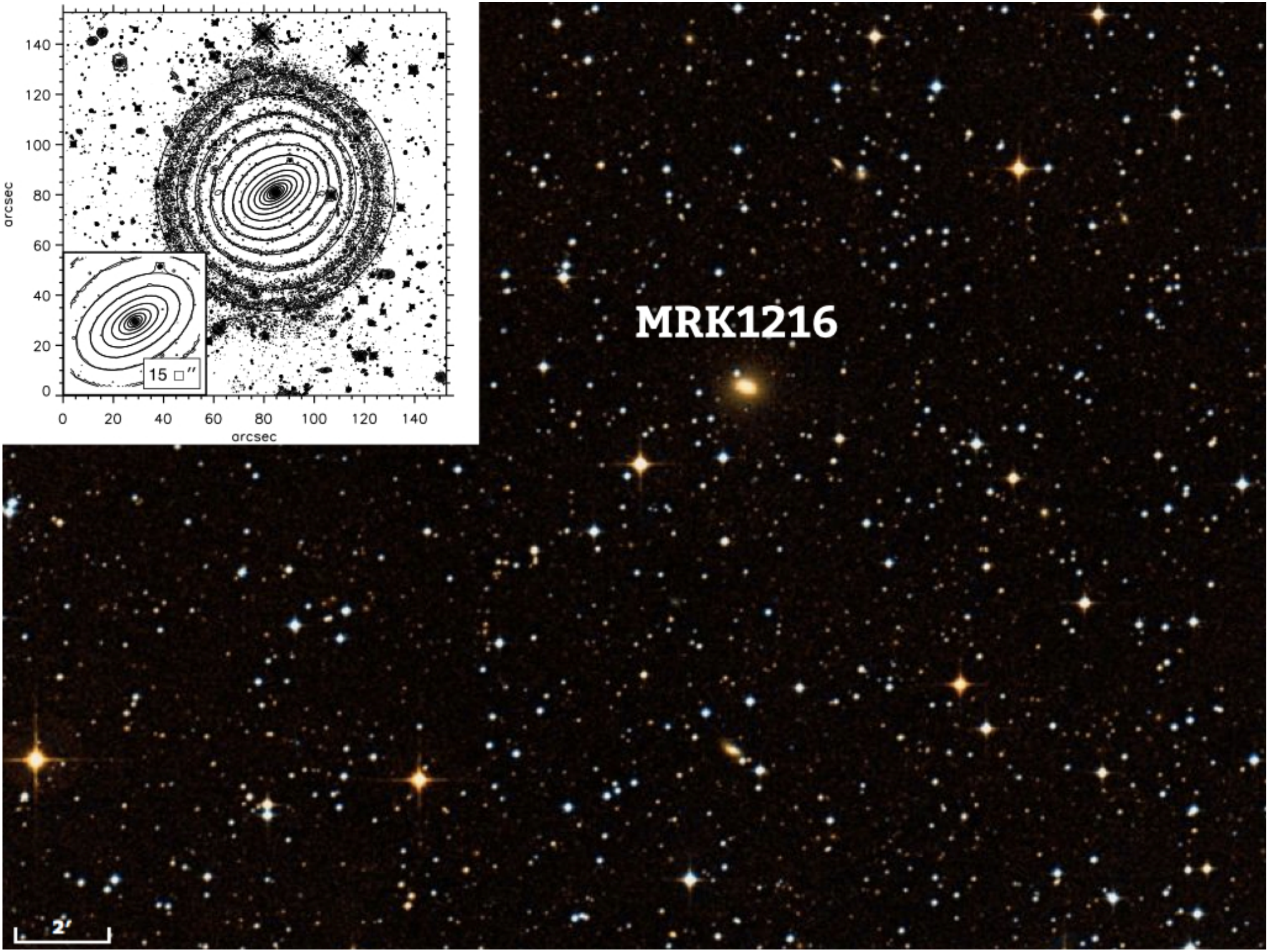
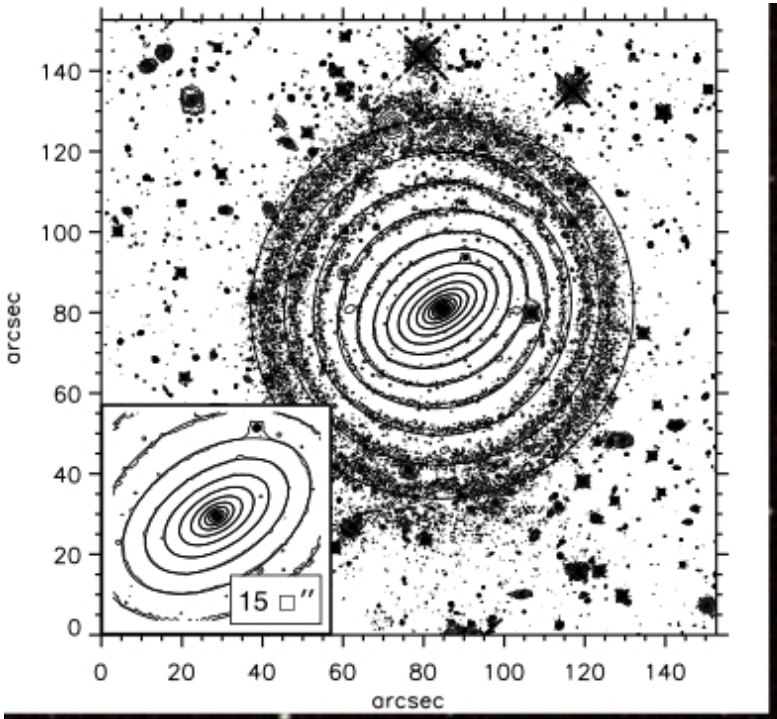
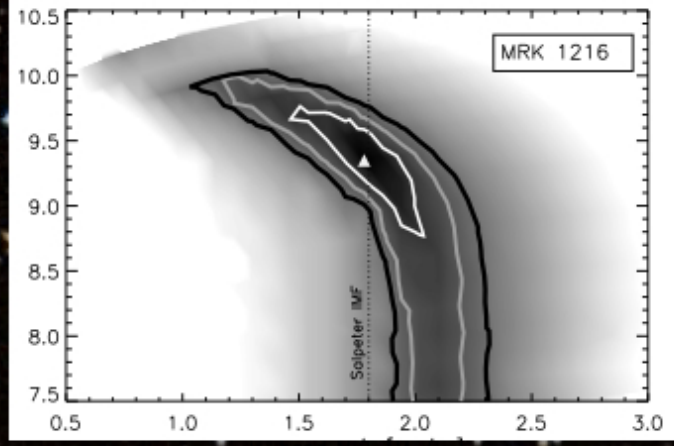
FOLLOW UP OF 17 COMPACTS WITH HST AND PPAK IFU



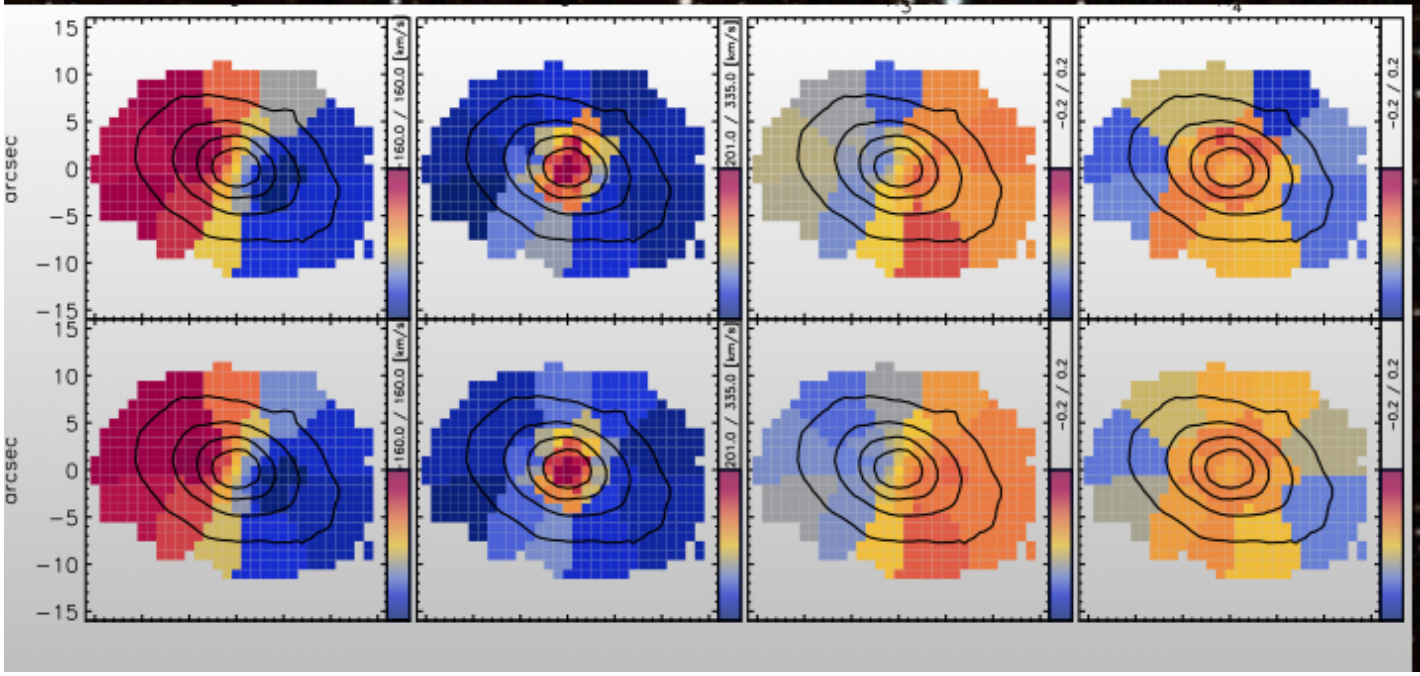

MRK1216
arcsec
arcsec
0
20
40
60
80
100
120
140
15 □″
2′



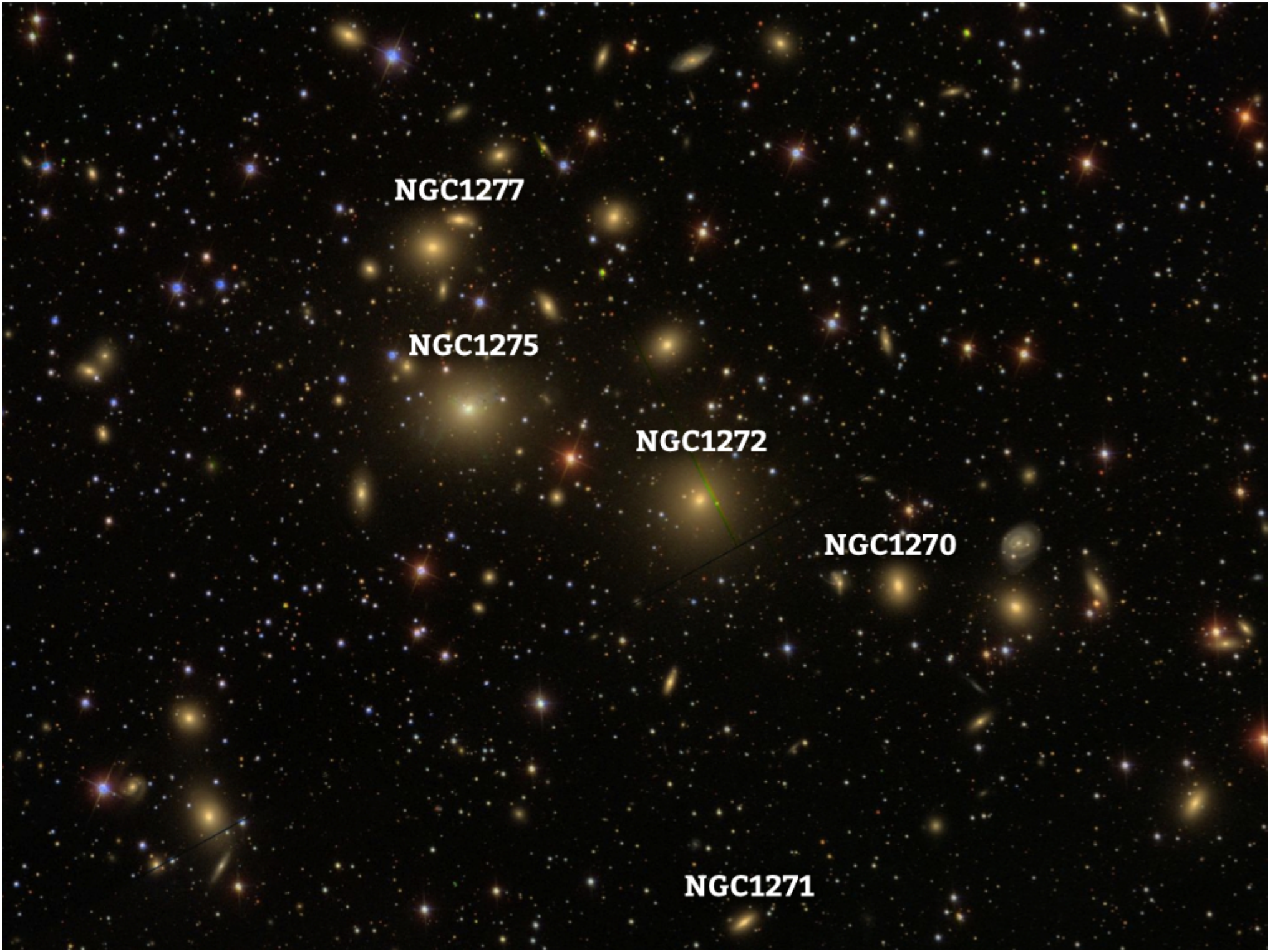


MRK1216

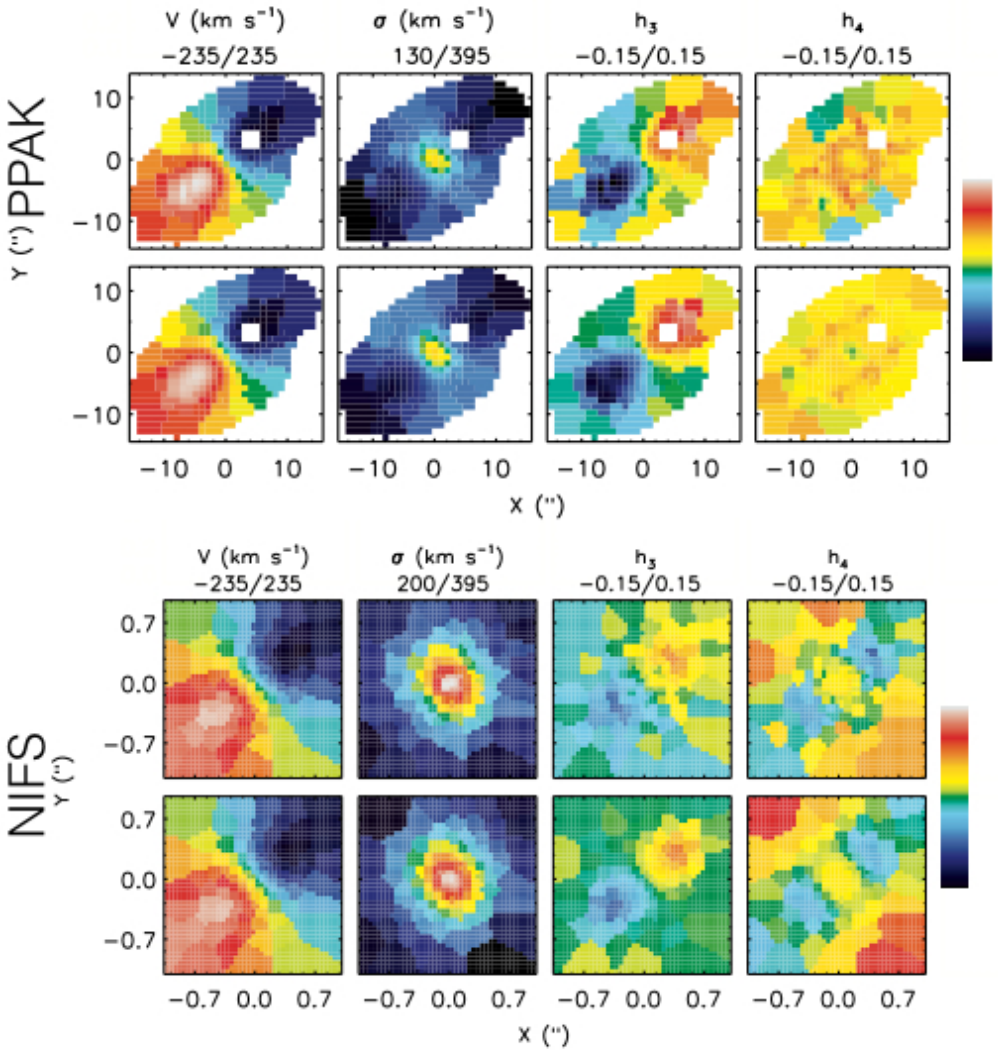
M/L$_H$



Yildirim+

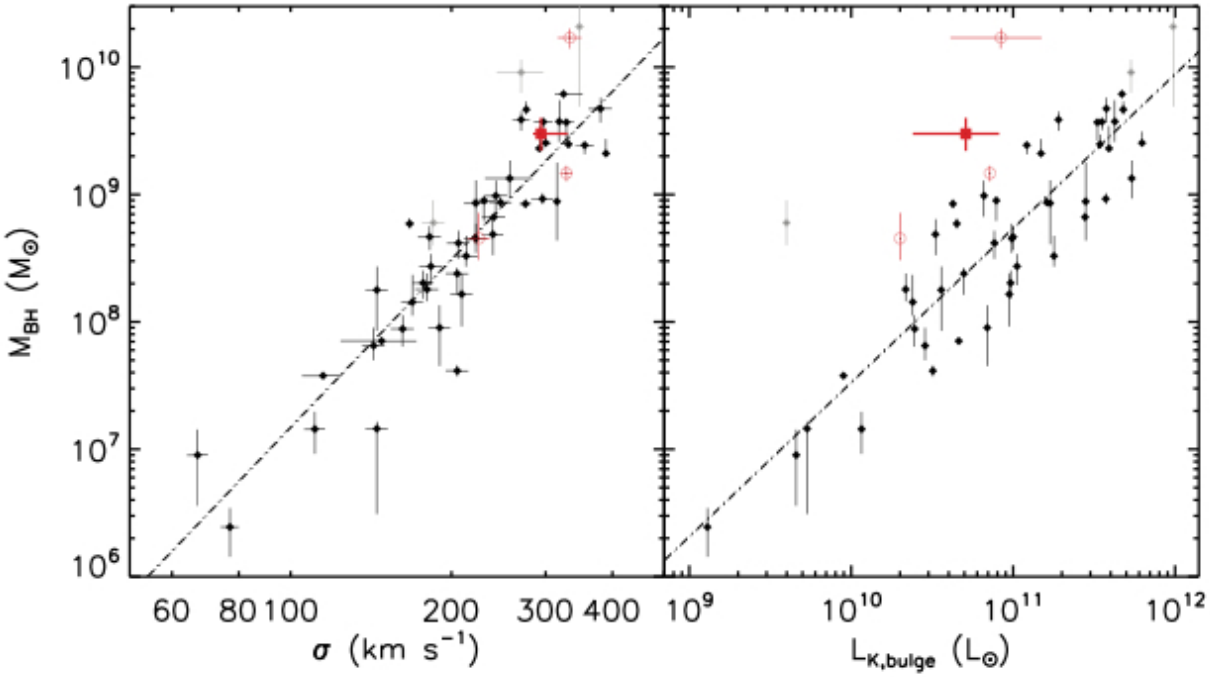

NGC1277
NGC1275
NGC1272
NGC1270
NGC1271

NGC1271 WITH PPAK AND NIFS



Walsh+

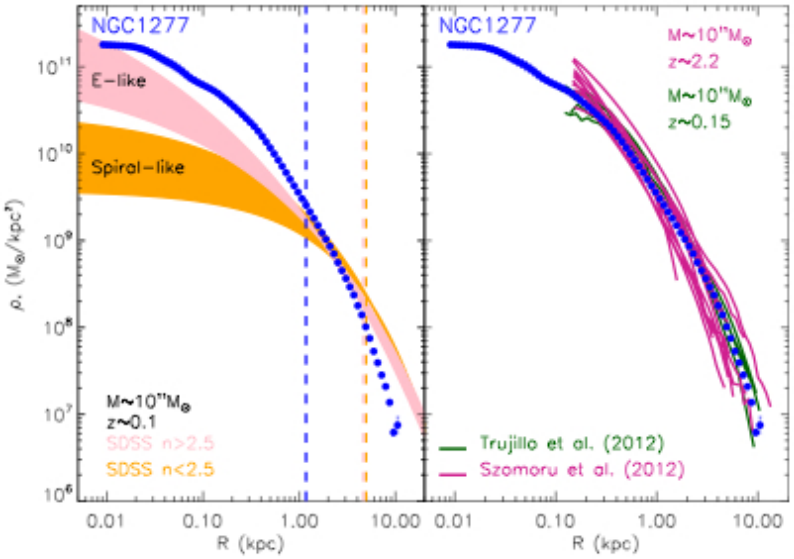
COMPACT GALAXIES



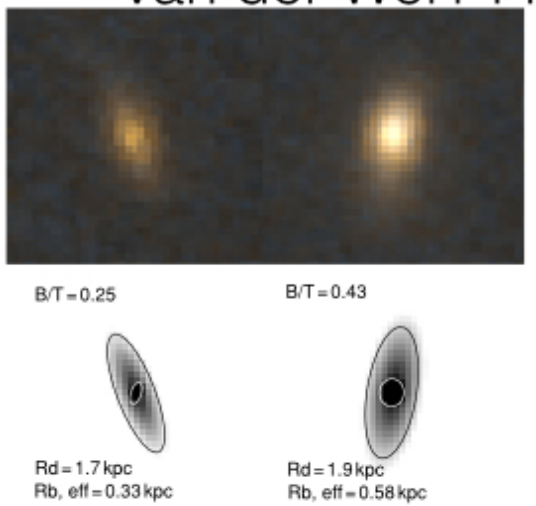
- Large lever on BH co-evolution

COMPACT GALAXIES

Trujillo+14

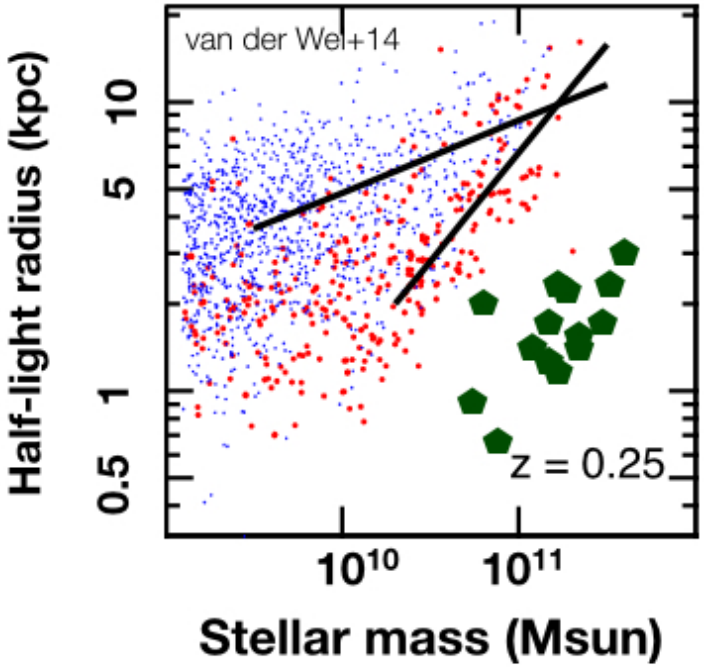


van der Wel+11



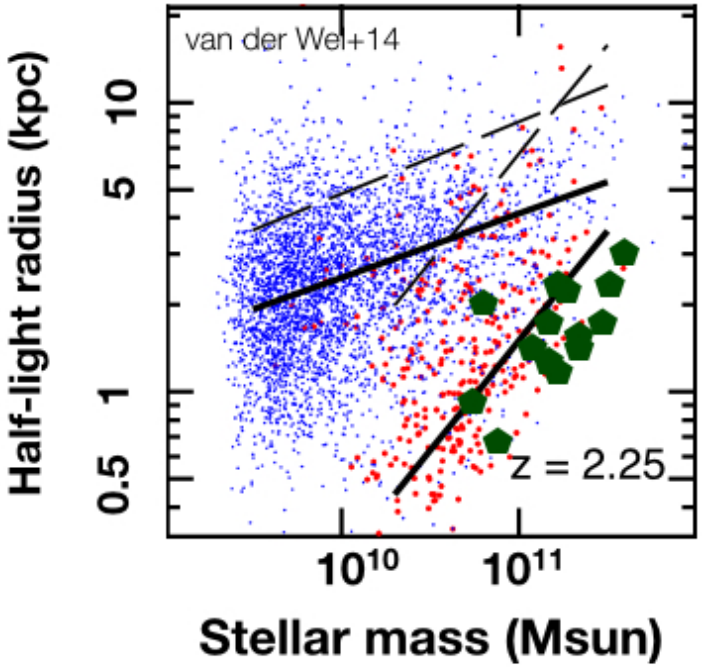
- Appear similar to z~2 passive galaxies

COMPACT GALAXIES



- Large mass-to-light ratios and hence bottom heavy IMF

COMPACT GALAXIES



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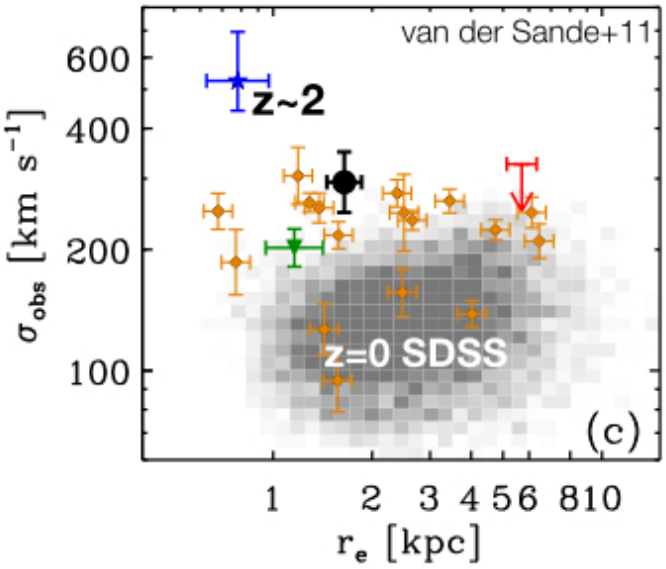
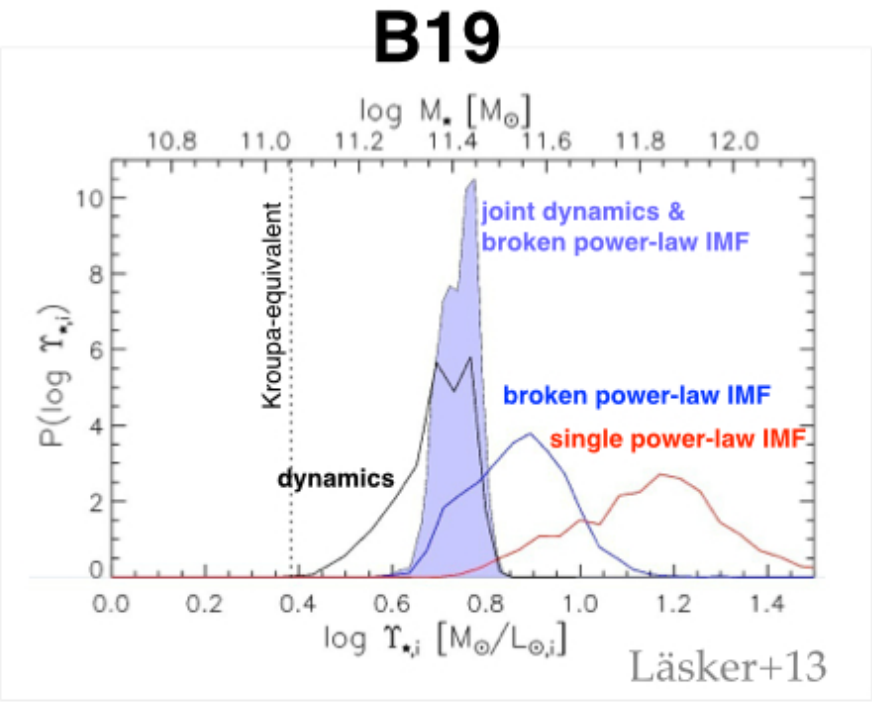
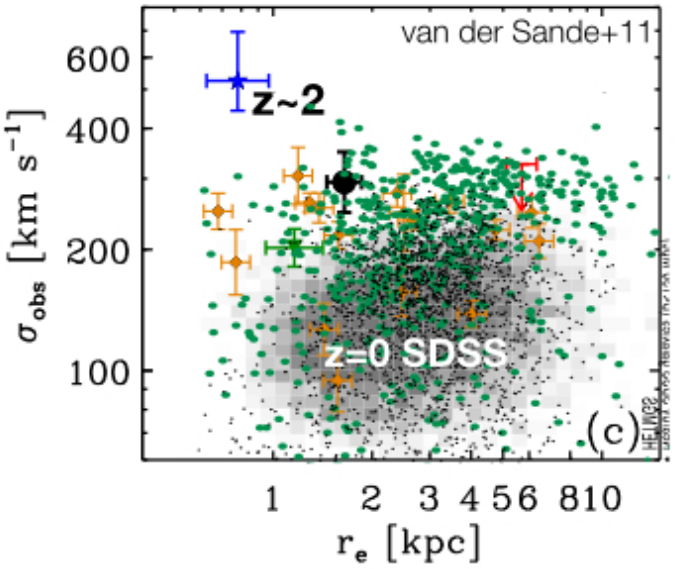
COMPACT GALAXIES



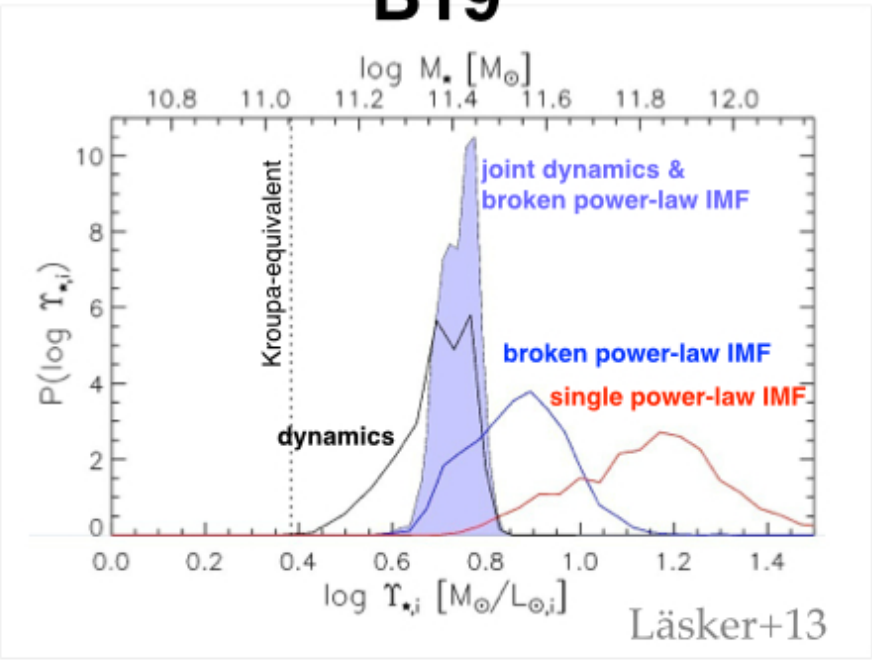


- Exist in SDSS too!

COMPACT GALAXIES



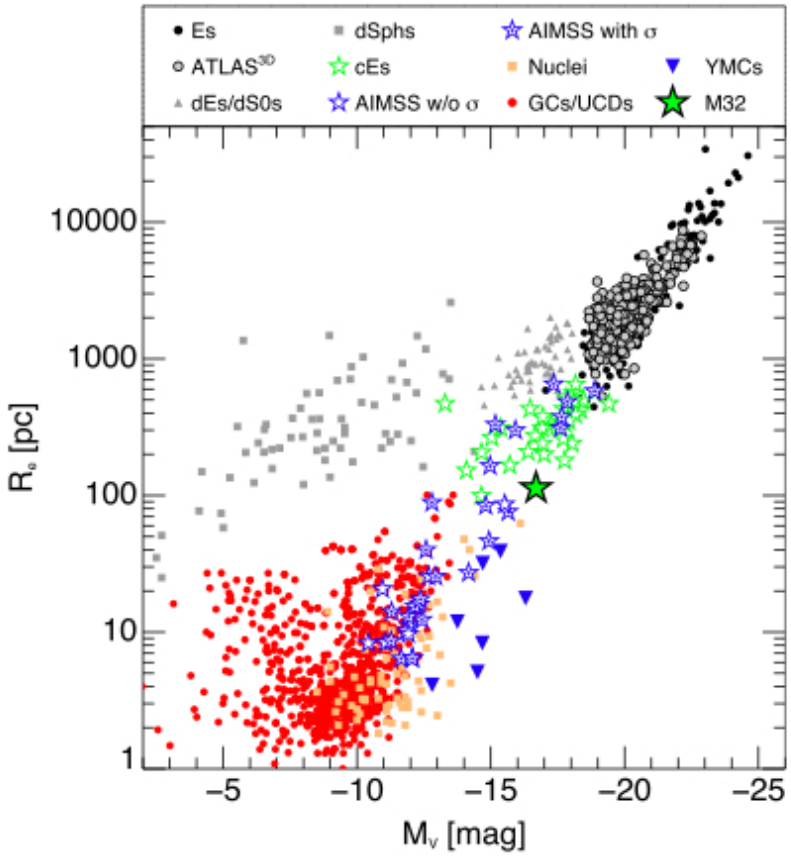
B19



- Exist in SDSS too!

Ultra Compact Dwarfs

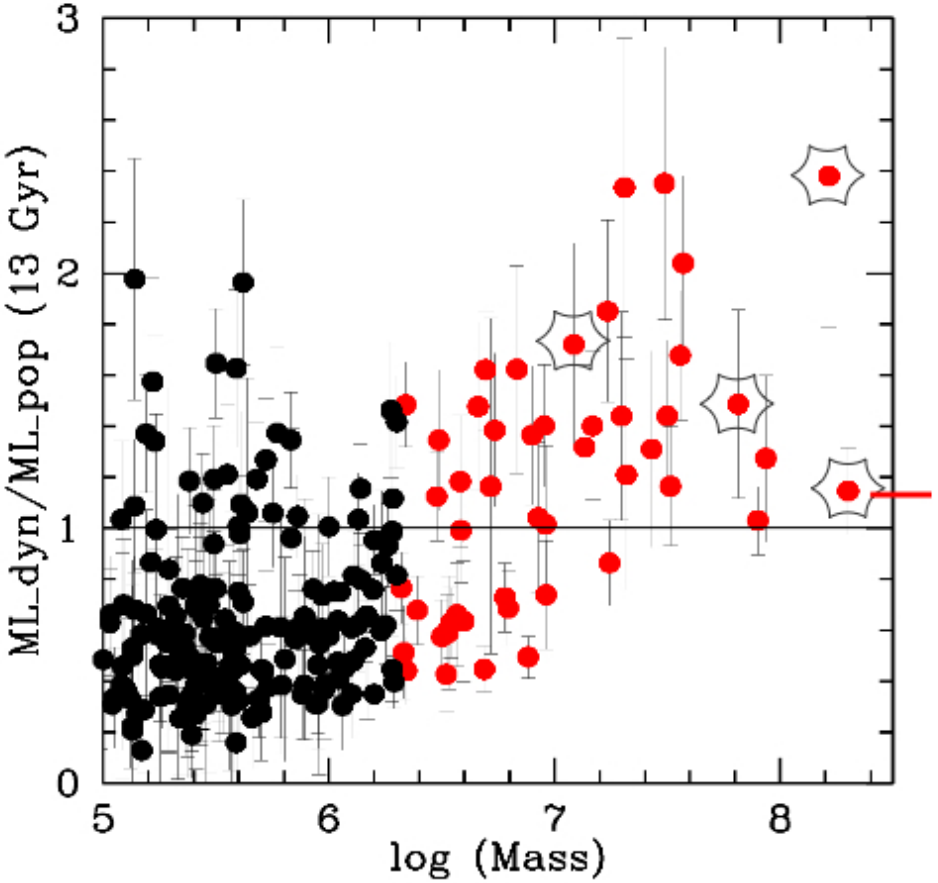
Big Globular Clusters or Stripped Galaxies?



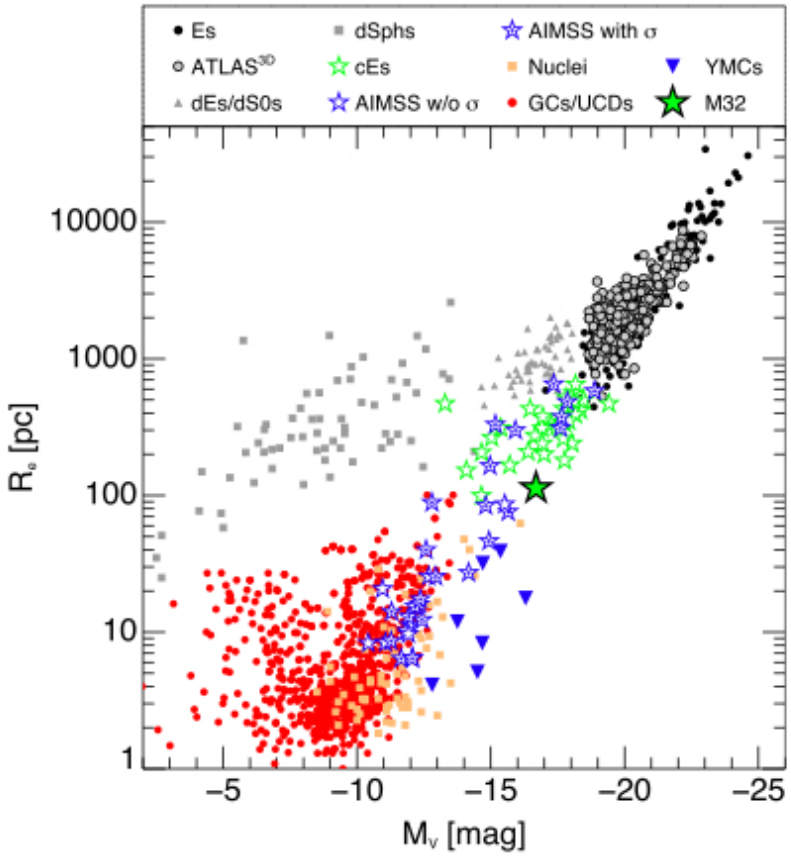
Norris+14

Ultra Compact Dwarfs

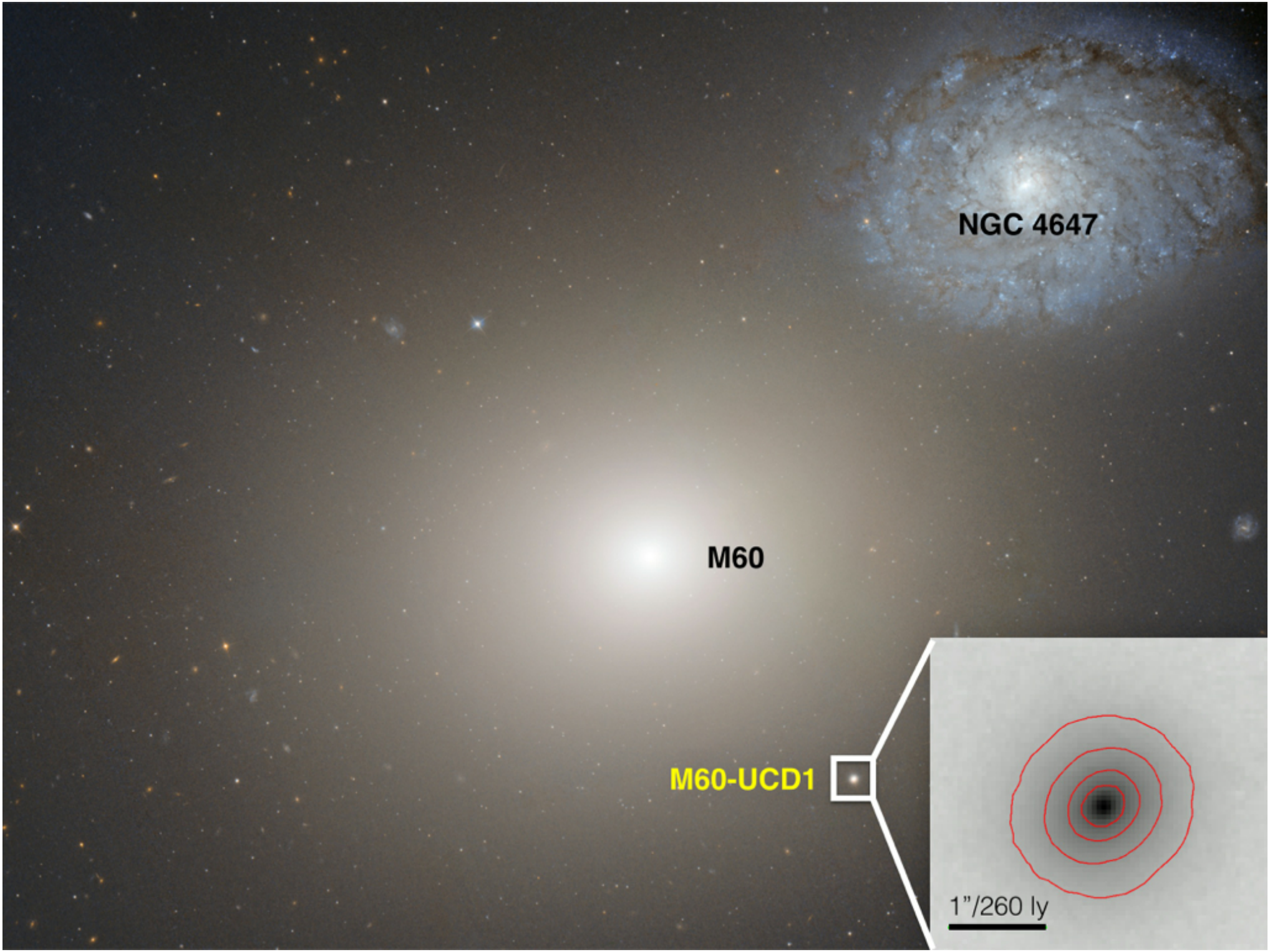
Big Globular Clusters or Stripped Galaxies?



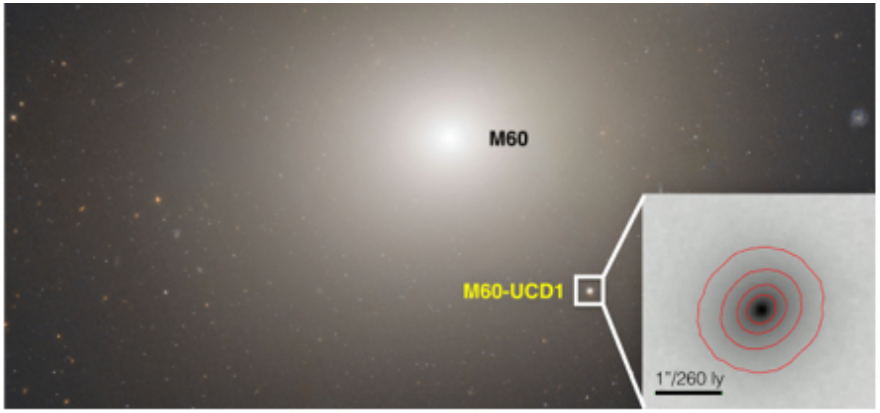
Mieske+

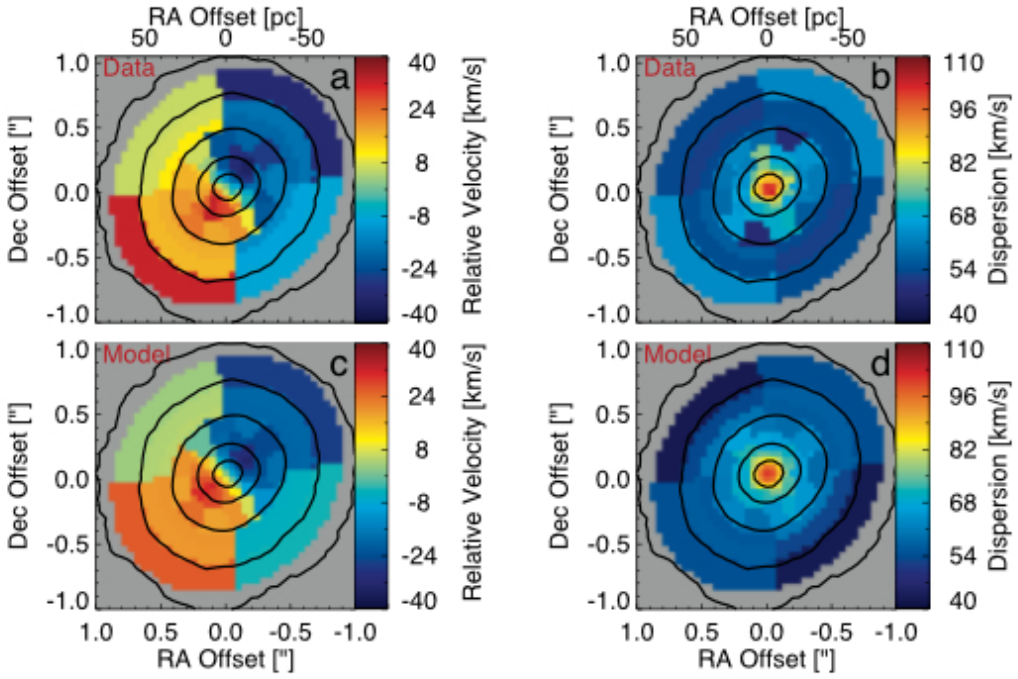


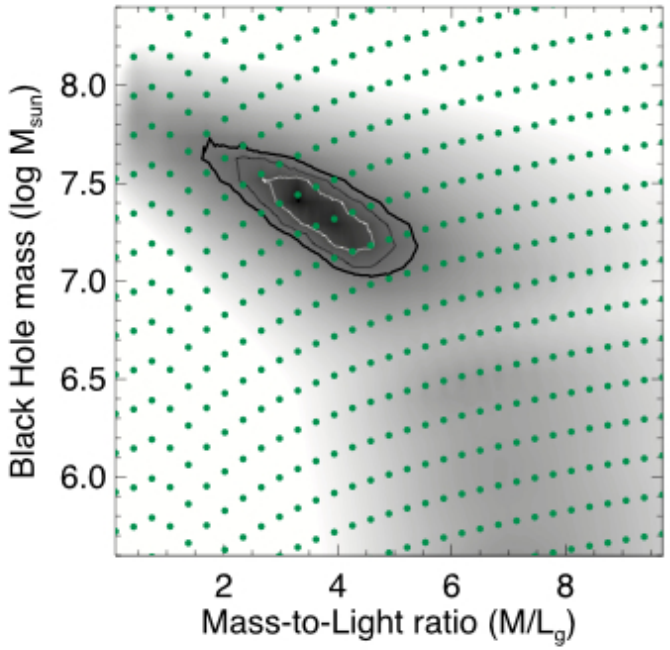
Norris+14


NGC 4647
M60
M60-UCD1
1”/260 ly

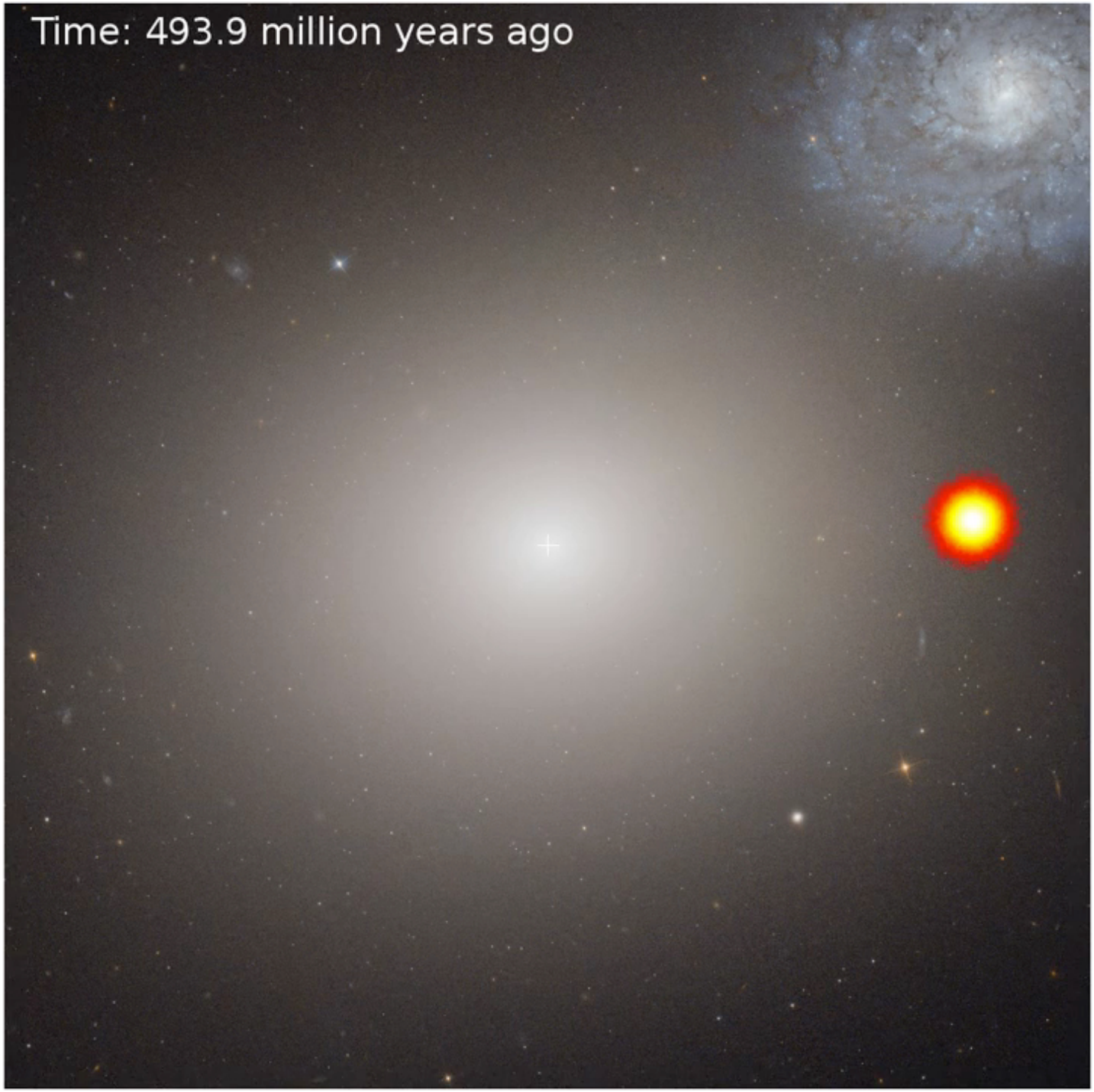
A super-massive black hole in an UCD







Seth,vdB+14


Time: 493.9 million years ago

CONCLUSIONS

- HET Massive Galaxy survey provides the necessary groundwork for future systematic black hole mass measurement campaigns.
- Compact Galaxies
  - Differentiate between different BH scaling relations
  - Appear very similar to z~2 passive galaxies
  - Have large stellar mass-to-light ratio, which implies bottom heavy IMFs.

Remco van den Bosch