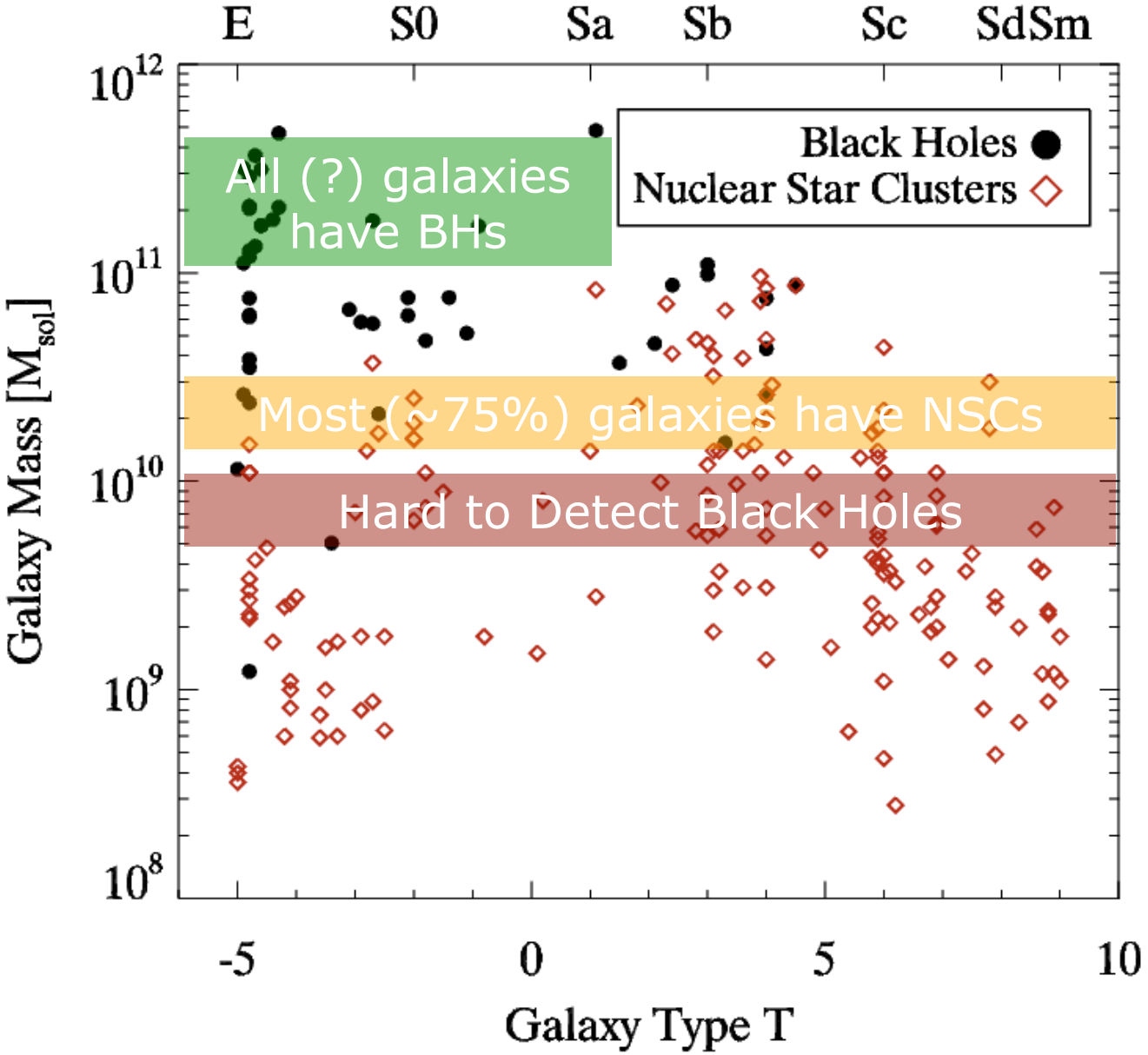
Nuclear Star Clusters and Black Holes

Nadine Neumayer

TU München /Excellence Cluster
'Origin and Structure of the Universe'

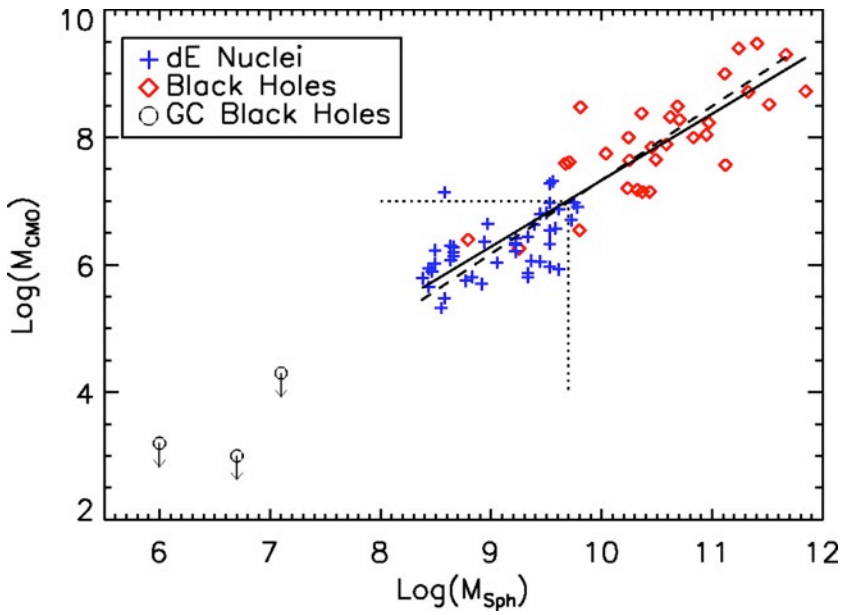
Anil Seth (CfA), Jakob Walcher (AIP), Aaron Barth (Irvine),
Torsten Böker (ESTEC), Hans-Walter Rix (MPIA Heidelberg),
Michele Cappellari (Oxford)



Data from: Böker+ 2002, Côté+ 2006, Carollo+ 1998-2002, Seth+ 2006, 2008a, Gültekin 2009

Nadine Neumayer

Motivation



Wehner & Harris 2006

- Nuclear star clusters follow the same mass scaling relation as BHs
  (Wehner & Harris 2006, Rossa et al 2006, Ferrarese et al 2006, Graham & Driver 2007, Erwin & Gadotti 2010)
- Some NCs host an AGN…
  (Filippenko & Ho 2003, Satyapal et al. 2007, Seth et al. 2008)

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NGC 4395 / SDSS

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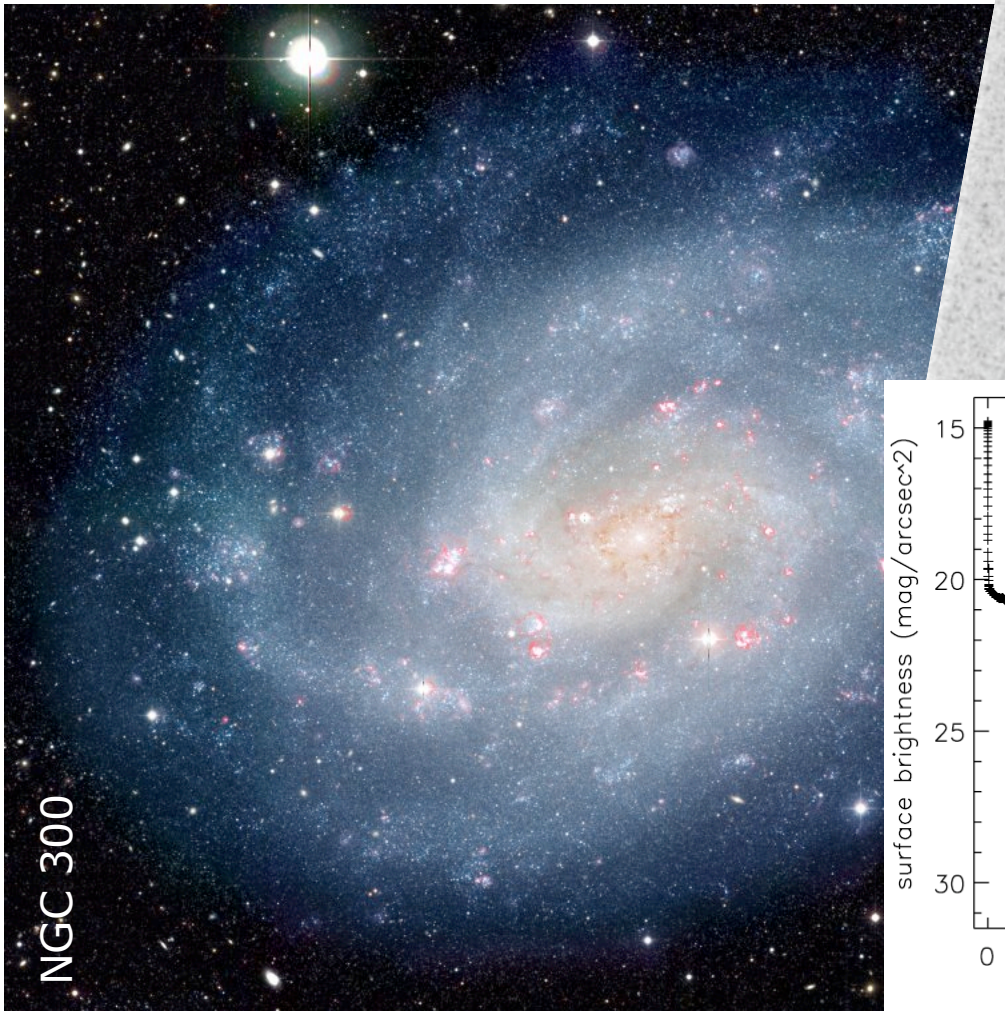
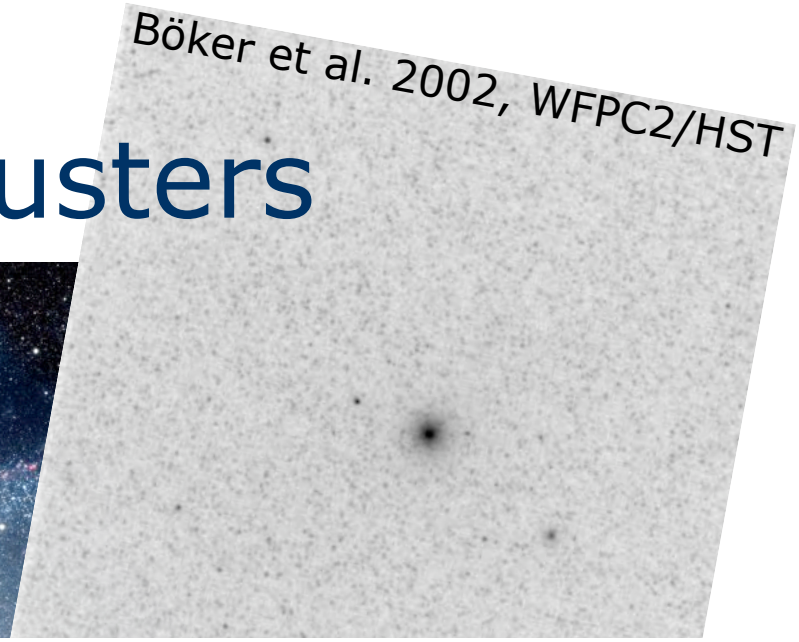
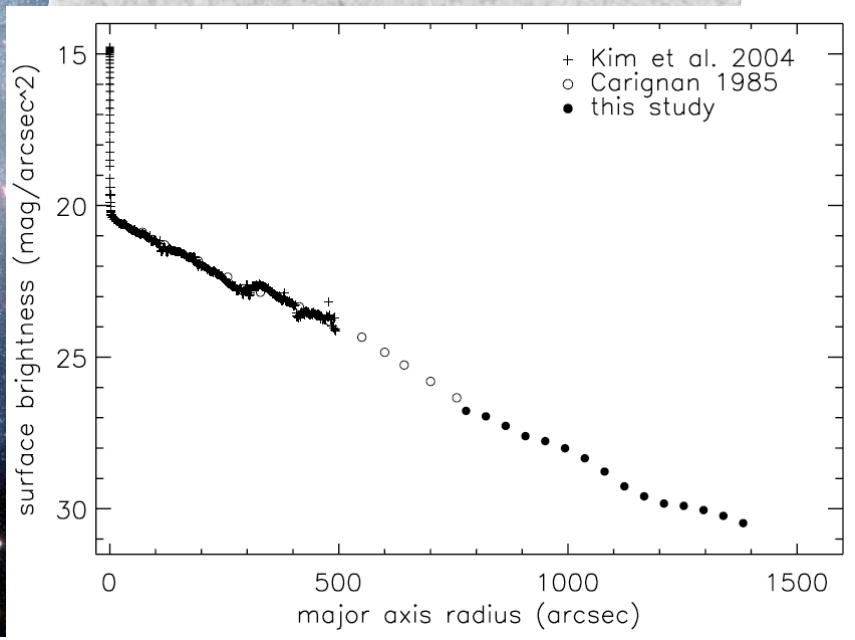
Galactic Centre / Spitzer / S. Stolovy

- Nuclear star clusters follow the same mass scaling relation as BHs (Wehner & Harris 2006, Rossa et al 2006, Ferrarese et al 2006, Graham & Driver 2007, Erwin & Gadotti 2010)
- Some NCs host an AGN… (Filippenko & Ho 2003, Satyapal et al. 2007, Seth et al. 2008)
- …or quiescent black hole
- The assembly history of NCs is visible through their stellar populations

Nuclear Star Clusters

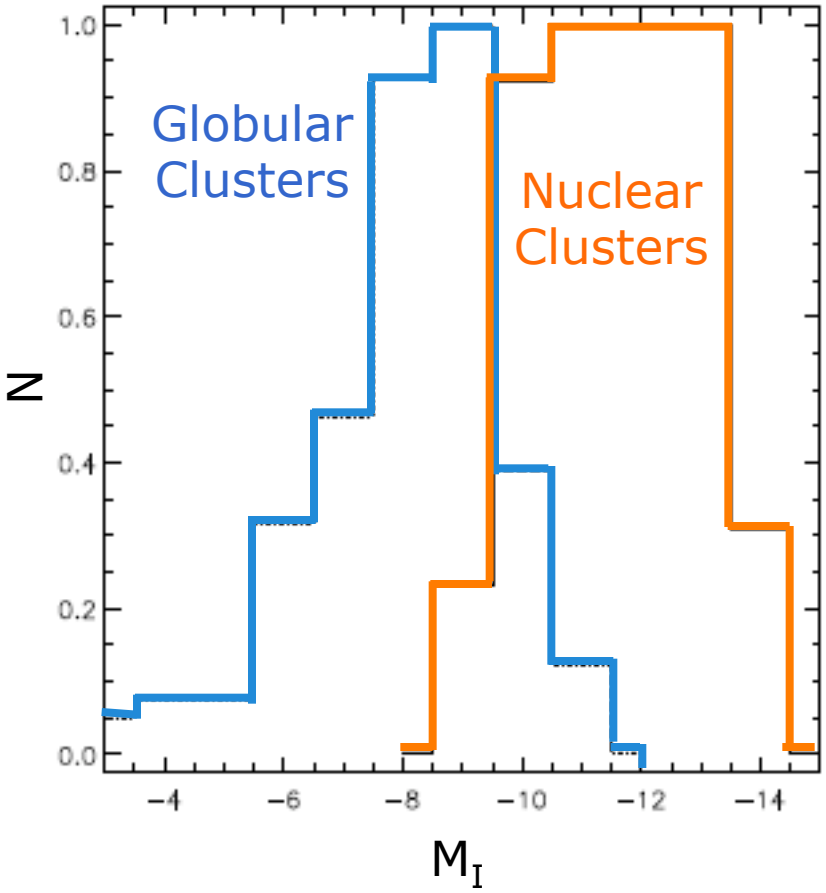






Bland-Hawthorn et al. 2005

Nuclear Cluster Properties



Böker et al. 2004

Compared to Globular Clusters:

- similar size (r_{eff} ~ 5pc)
- brighter (M_I ~ -12)
- more massive ($10^7 M_\odot$)

Walcher et al. 2005

present in ~75% of late type spirals and dwarf ellipticals

Böker et al. 2002; Coté et al. 2006

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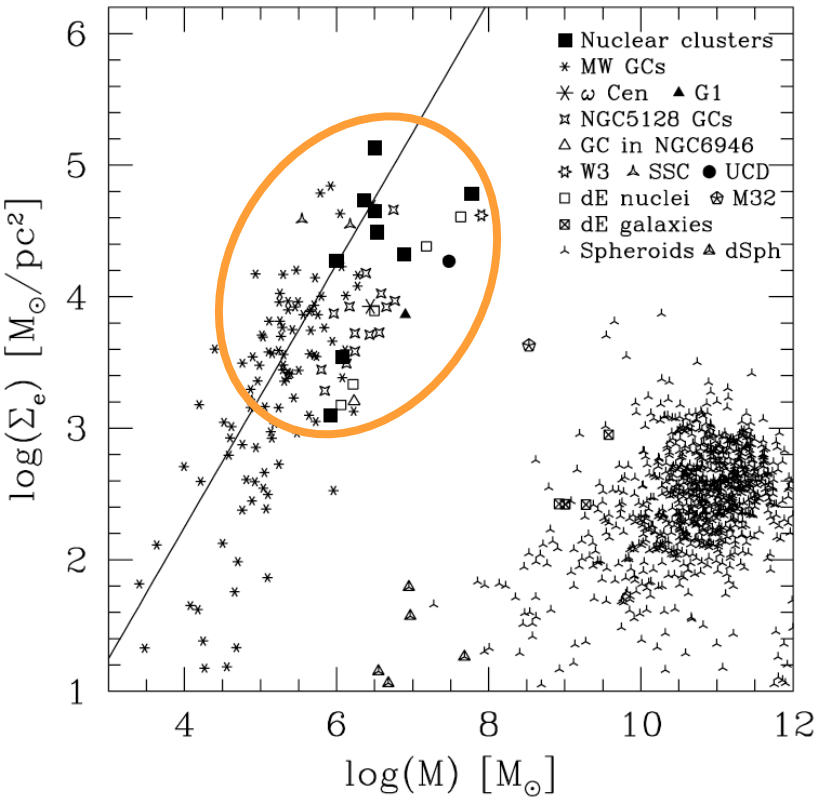

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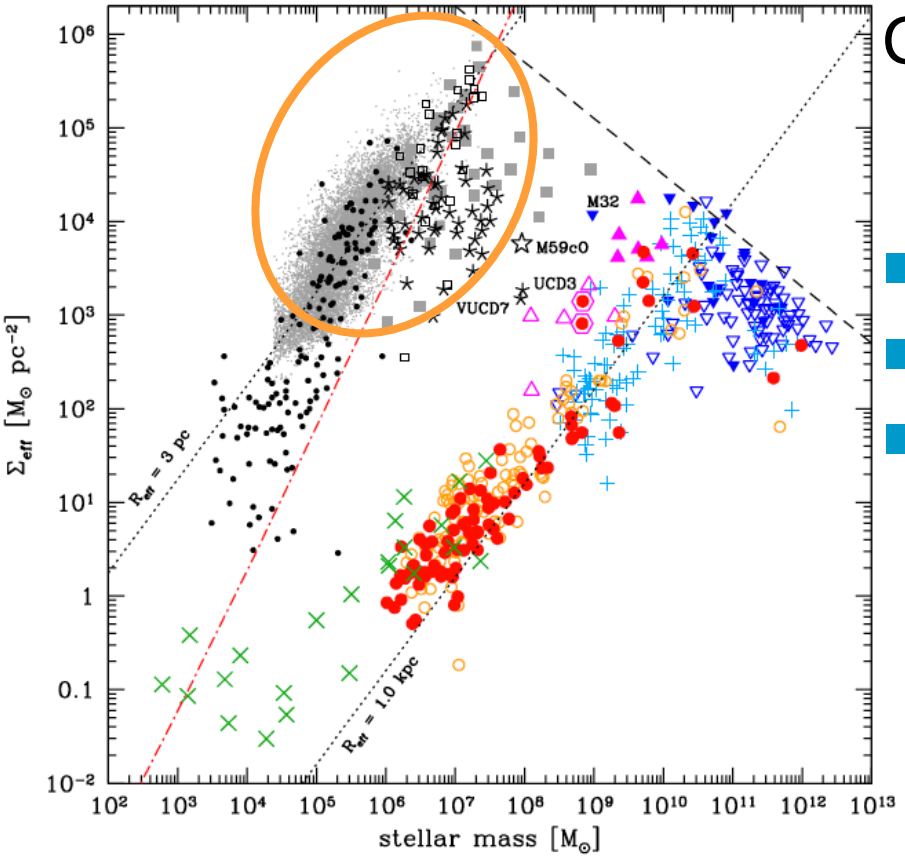

Misgeld & Hilker 2011

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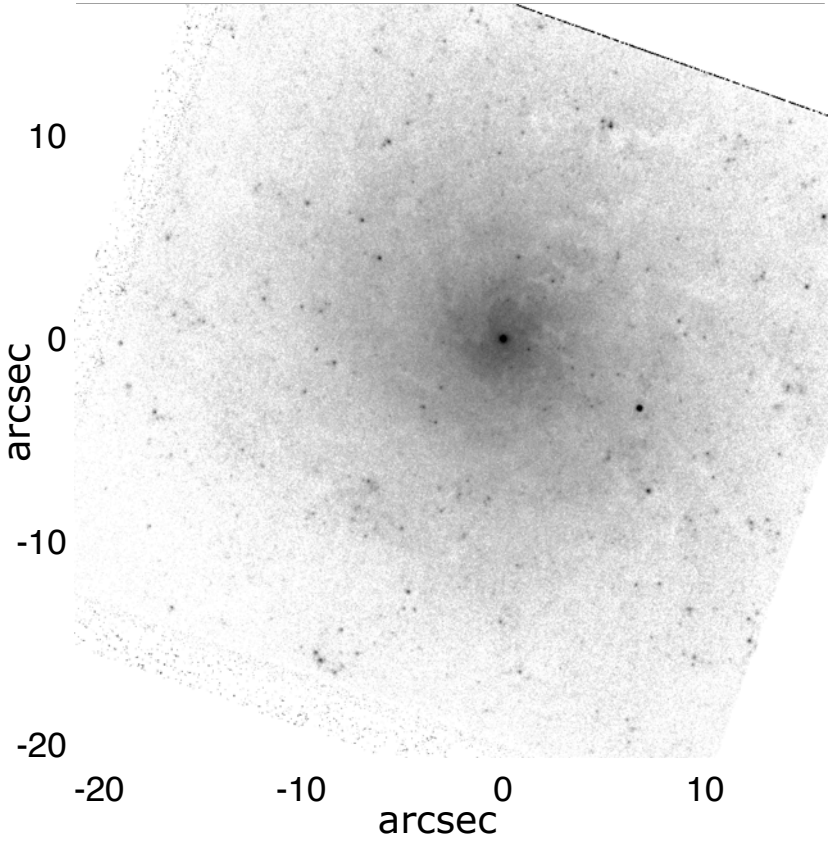

Neumayer et al. 2011

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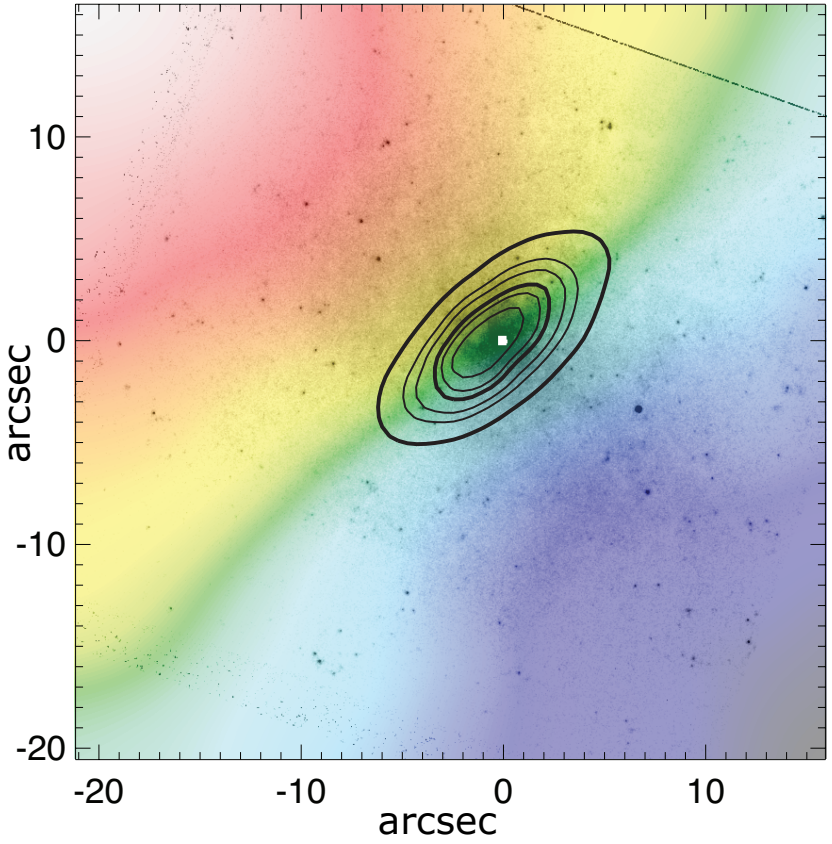

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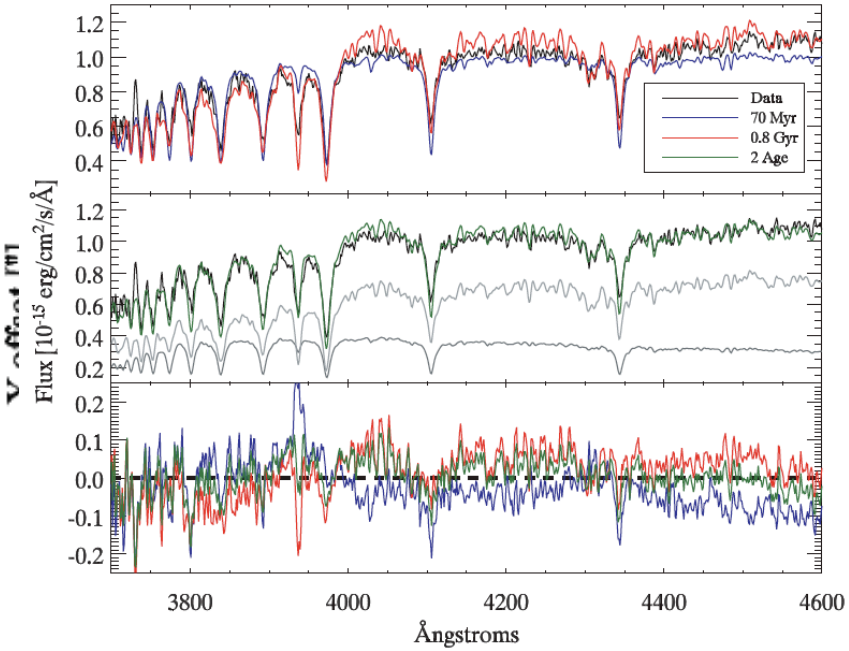
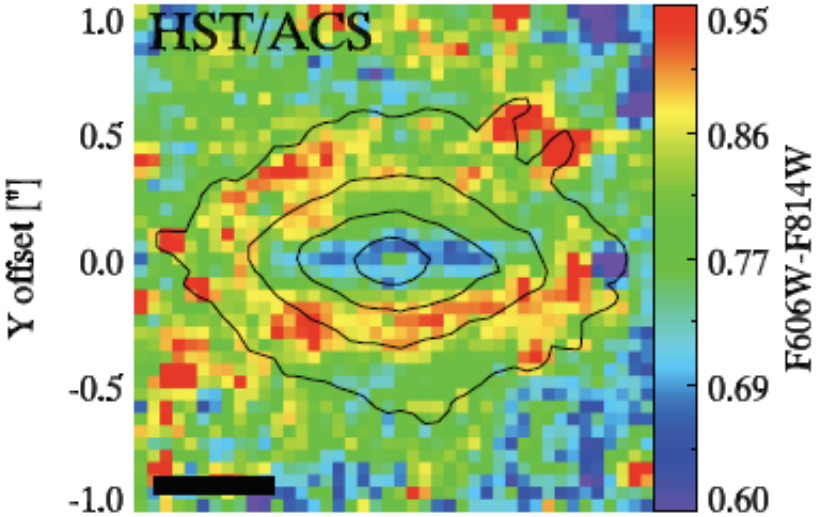


- NCs have multiple stellar populations (Walcher et al. 2006, Rossa et al. 2006, Seth et al. 2006)
- Show distinct components: old/red spheroid and young/ blue disk (Seth et al. 08b)
- Both rotate

➔ Properties hint towards in-situ formation

Nuclear Cluster Properties



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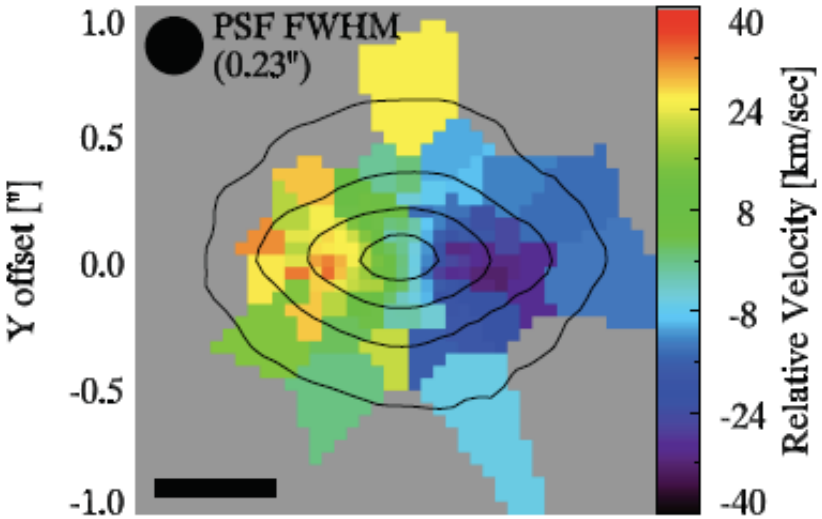

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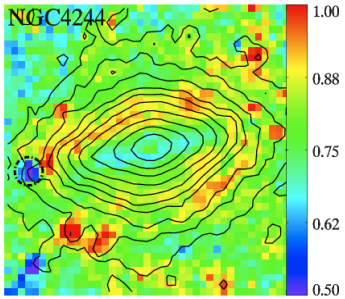
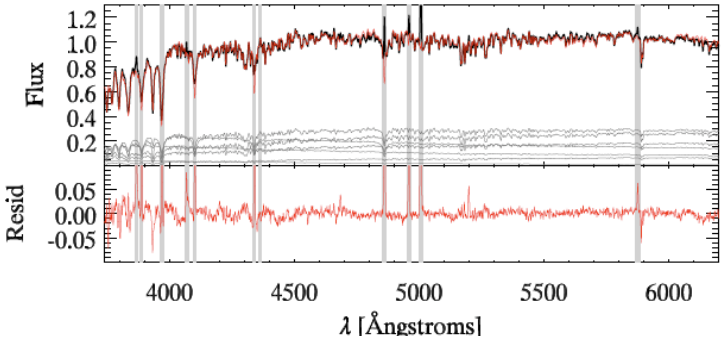
Formation of Nuclear Clusters

1) Morphology



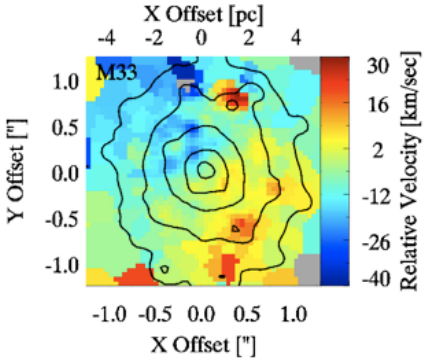
HST Imaging

2) Stellar Populations



Optical Spectra

3) Kinematics



Adaptive Optics Integral Field Unit spectra from NIFS/Gemini & SINFONI/VLT

Understanding the connection between BHs & NCs

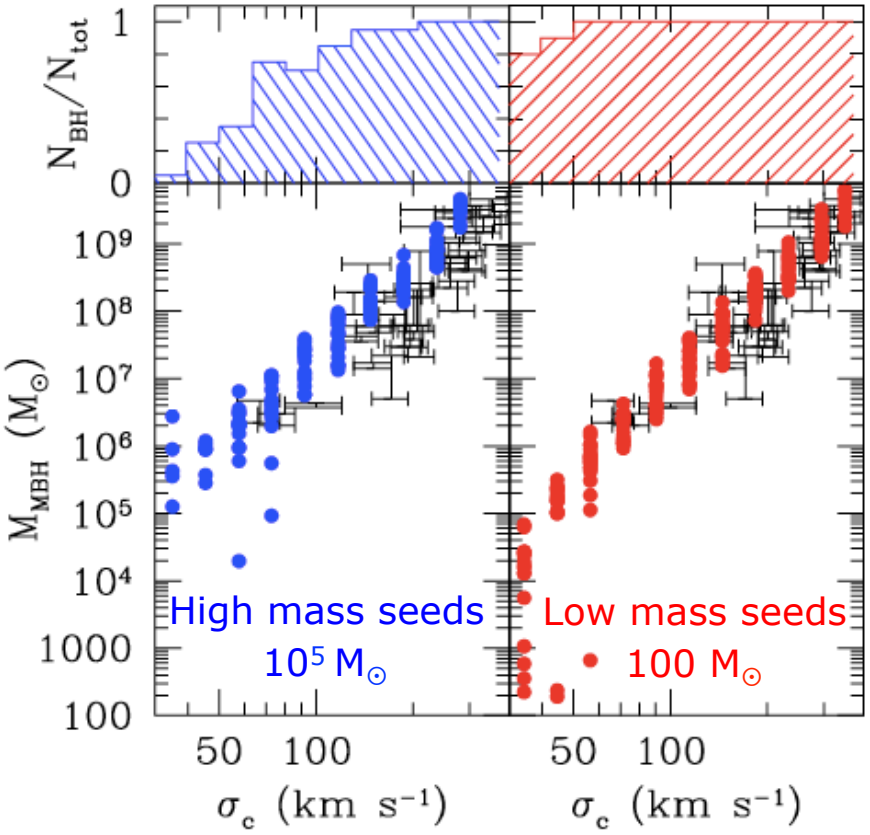
- Does NC formation result in BH formation?
  (e.g. Portegies Zwart et al. 2004)
- Or are both fed from the same events?
  (e.g. Hopkins & Quartaert 2010)

Our approach:

➢ Nuclear Clusters have observable histories

➢ Finding Black Holes inside Nuclear Clusters

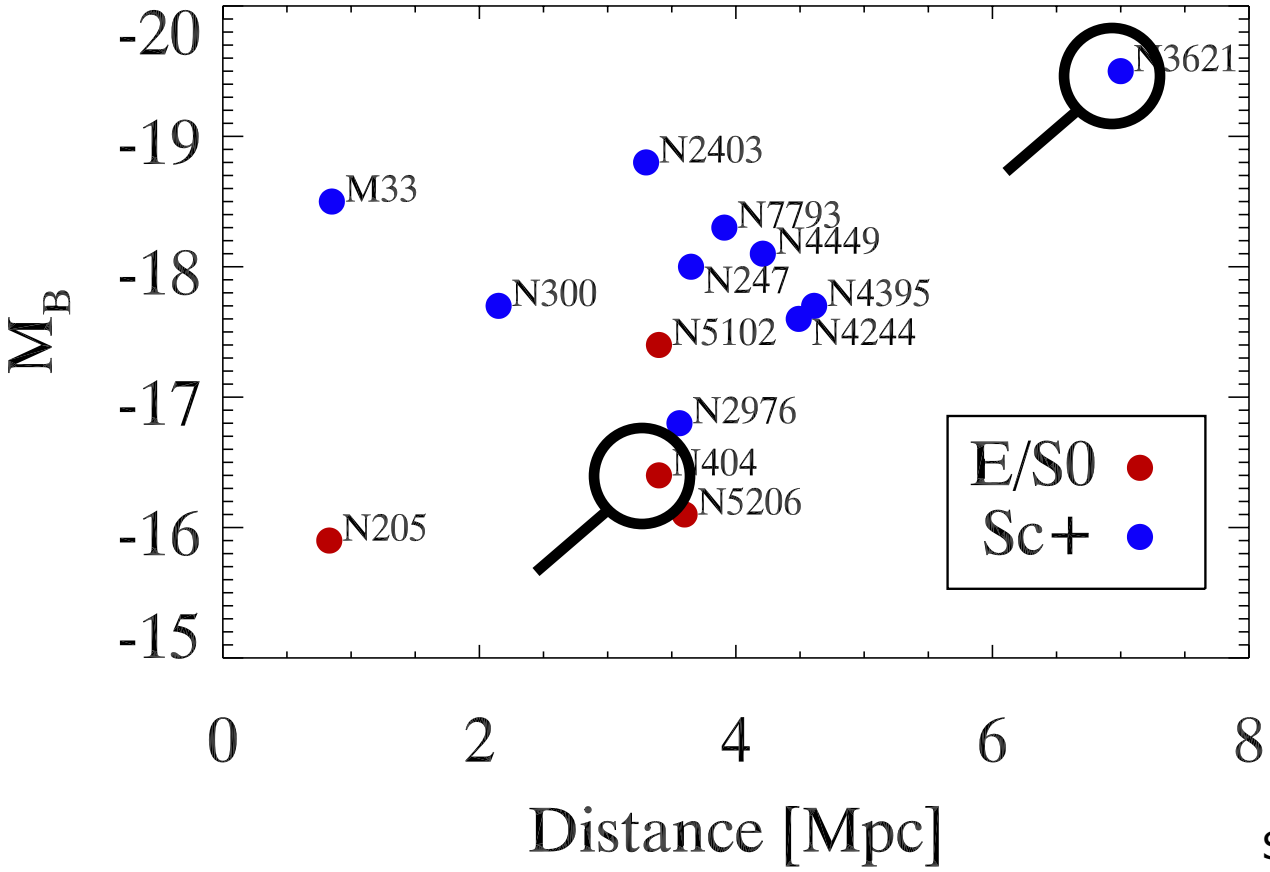
Clues to black hole formation?



- Low mass BHs may help to elucidate the early formation history of black holes

Volonteri, Lodato & Natarajan 2008

The Nearest Nuclear Clusters



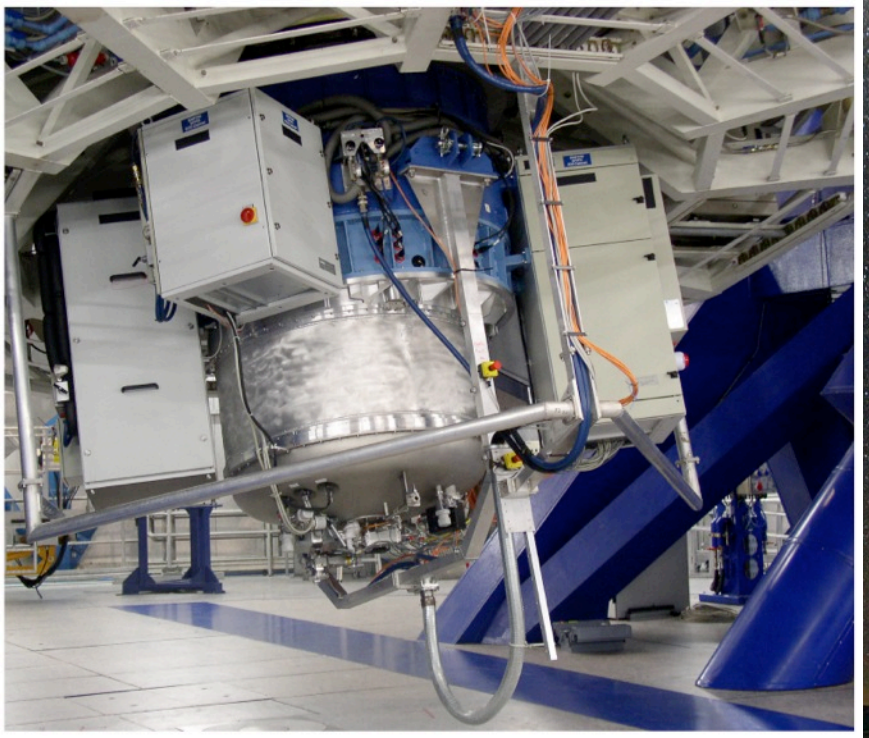
Seth/Neumayer

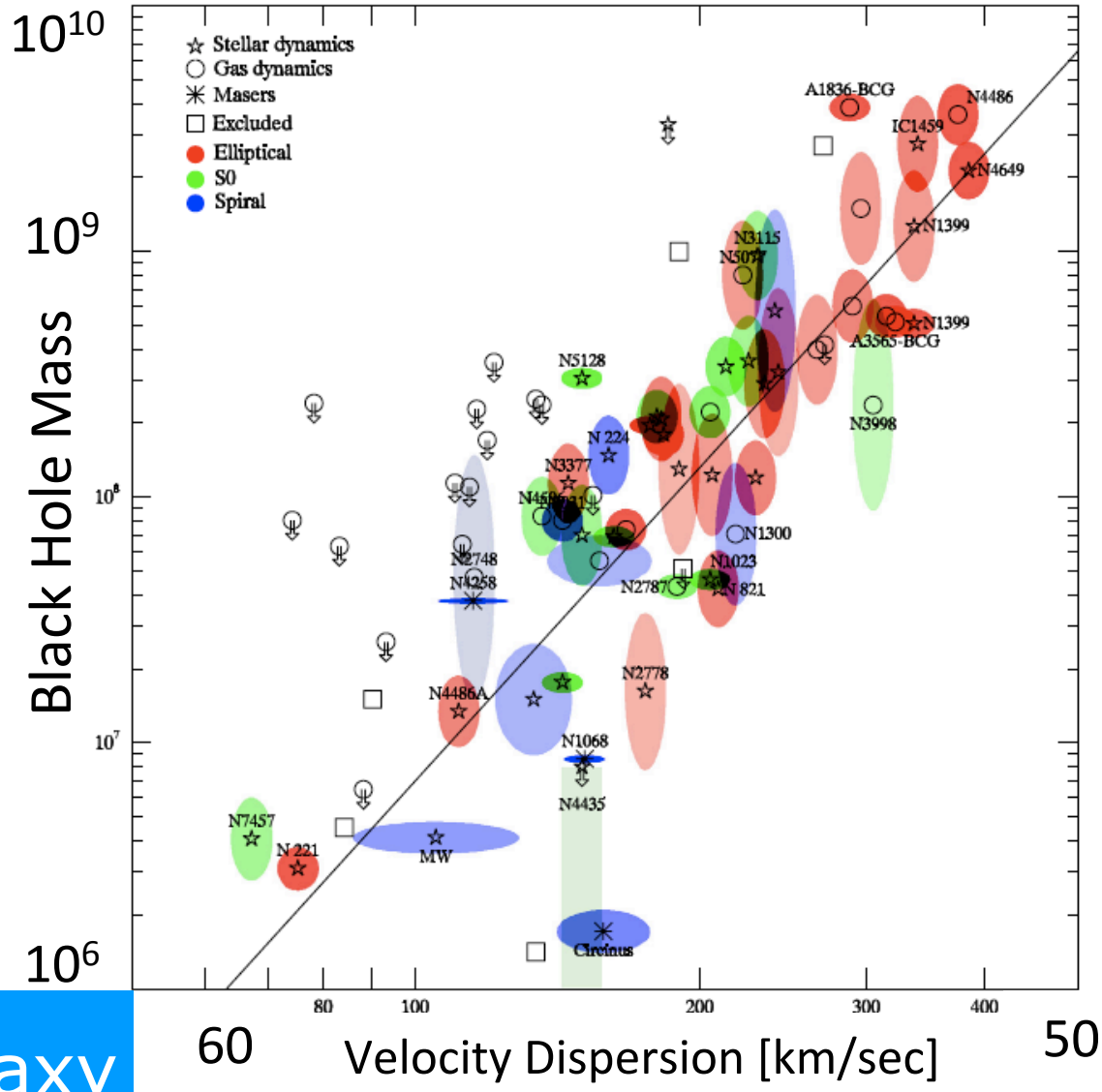
NIFS/GEMINI

Combines IFU with adaptive optics

SINFONI/VLT

IFU with adaptive optics

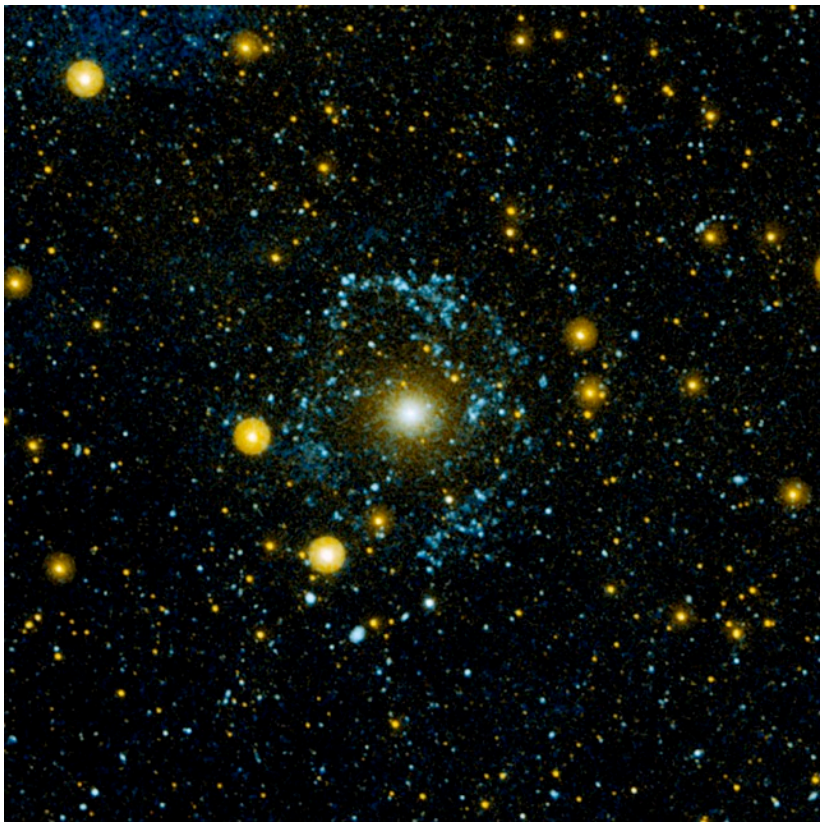




Our Galaxy Sample

Gültekin+ 2009

Close look at NGC 404

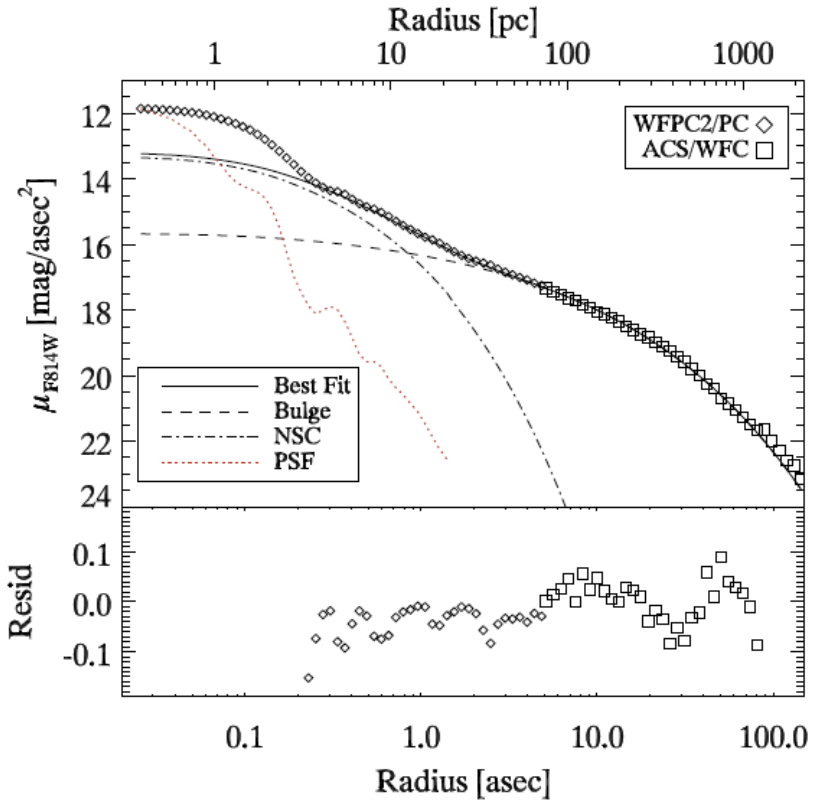


GALEX Thilker et al. 2010

- Nearest S0 galaxy
  D=3Mpc, σ=35km/s
- Some evidence for an accreting black hole:

✔ LINER like nucleus (Ho+ 1997)
✔ compact X-ray source (Eracleous+ 2002)
✔ High excitation lines in Mid-IR (Satyapal+ 2004)
✔ variable UV emission (Maoz+ 2005)
✔ compact dust emission (Seth+ 2010)

Dynamical black hole detection



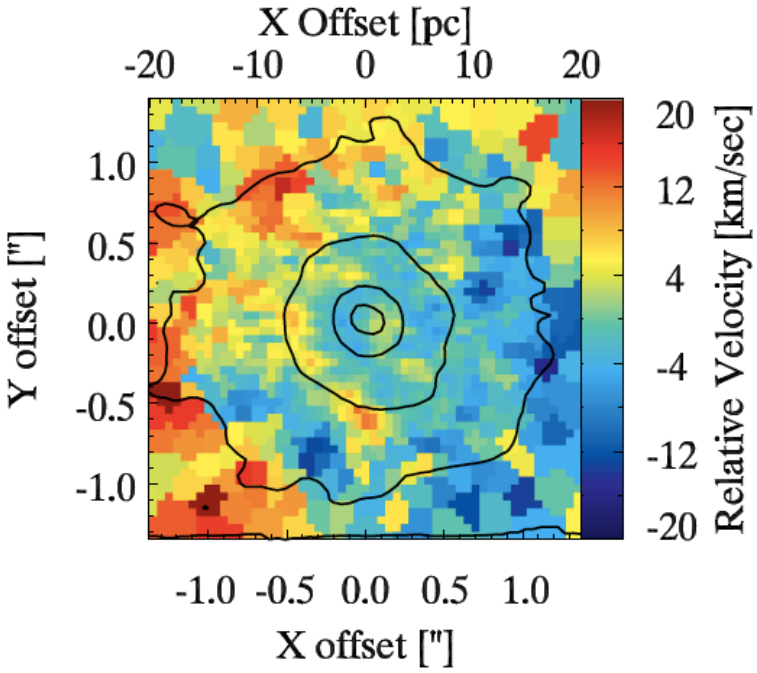
Ingredients:

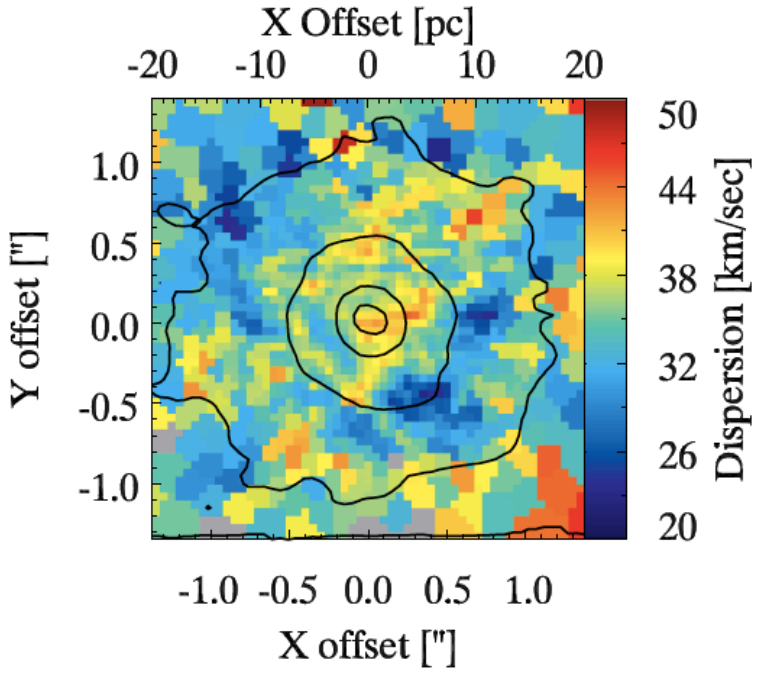
1) Stellar Mass Profile
   - Luminosity Profile
   - Mass-to-light ratio

2) Dynamical Tracer

Seth, Cappellari, Neumayer et al. 2010

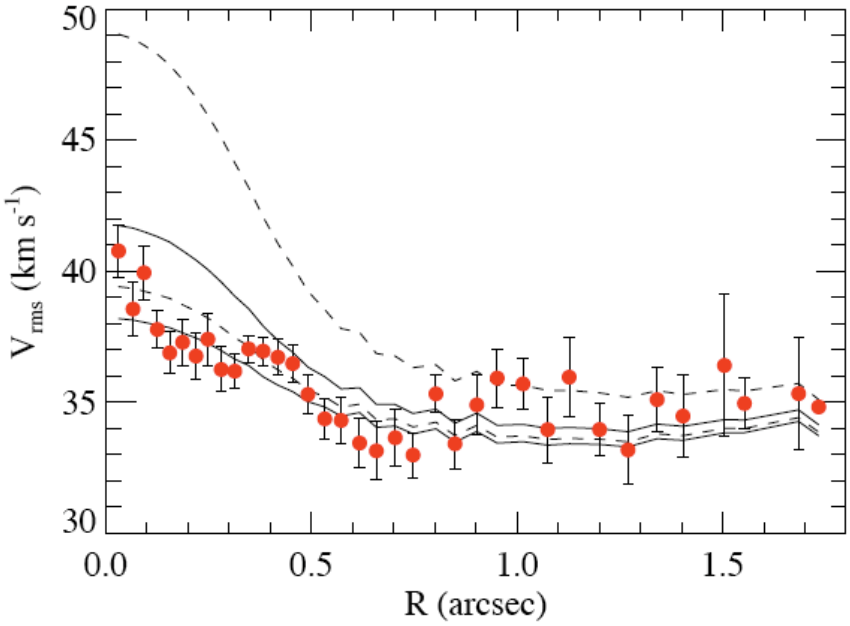
NGC404 - Stellar Kinematics



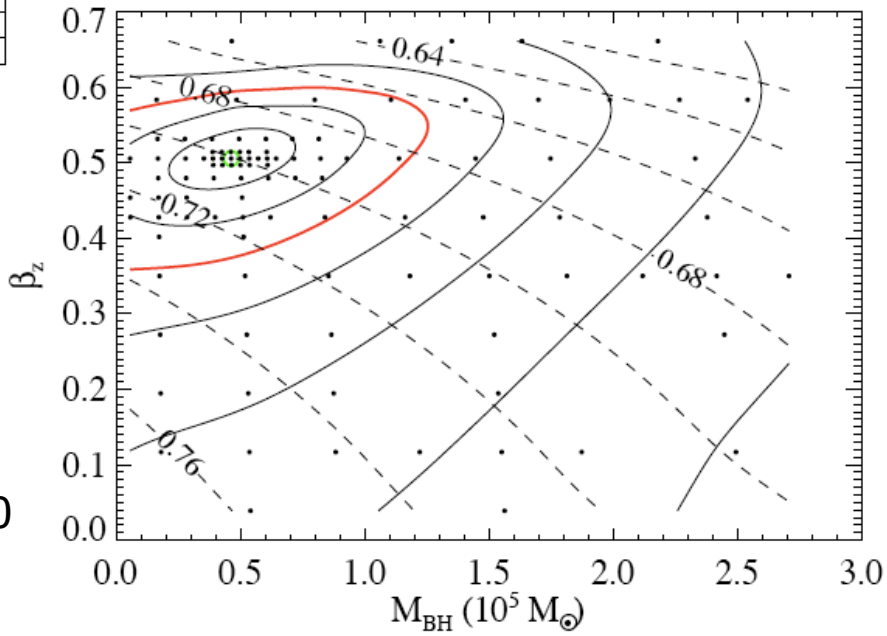


Seth, Cappellari, Neumayer et al. 2010

NGC404 - Stellar Kinematic Model

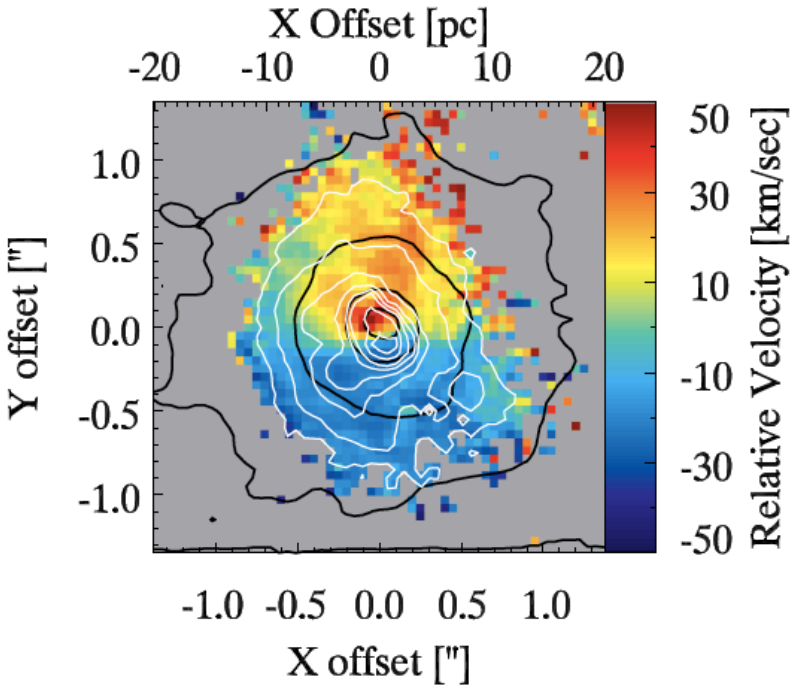


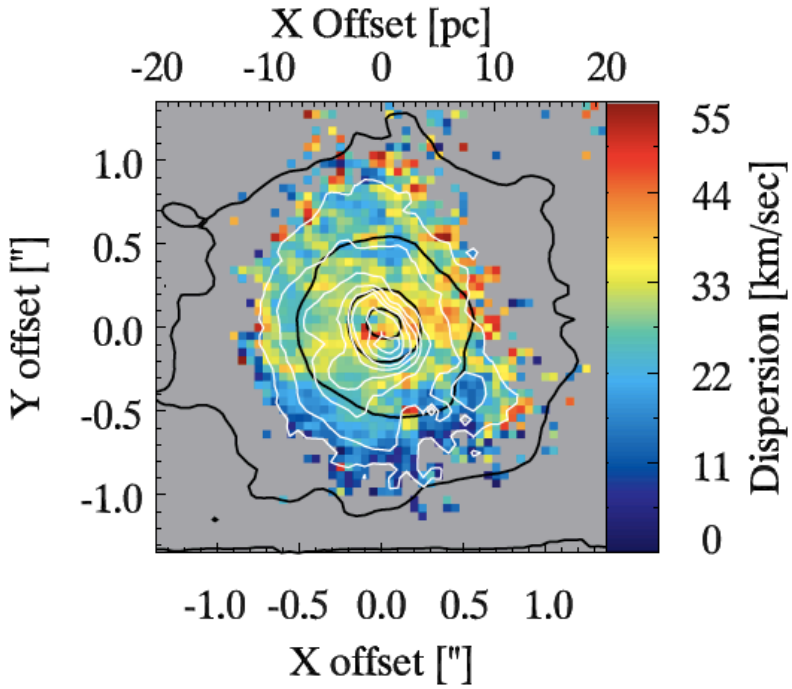
- Jeans anisotropic model
  - Fit M_{BH}, β_z, M/L
  - $M_{BH} < 1 \times 10^5\ M_\odot$ (~ $0.5 \times 10^5\ M_\odot$)



Seth, Cappellari, Neumayer et al. 2010

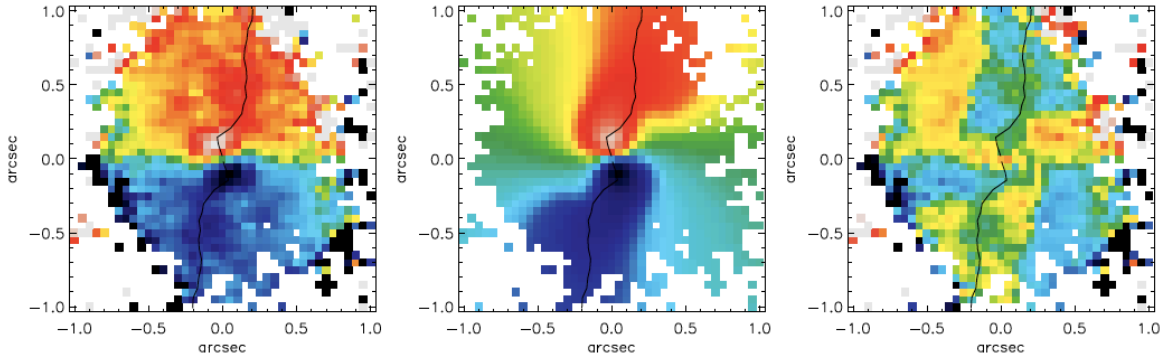
NGC404 - H_2 Gas Kinematics

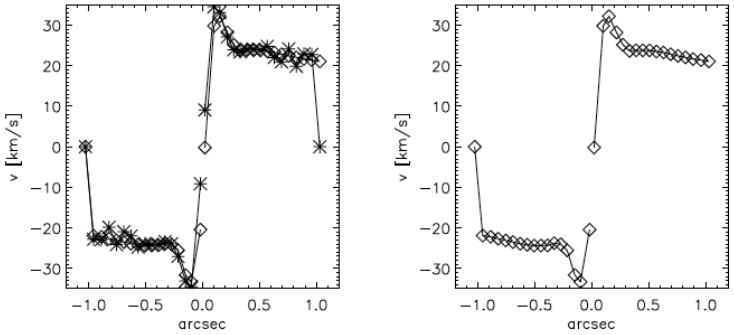




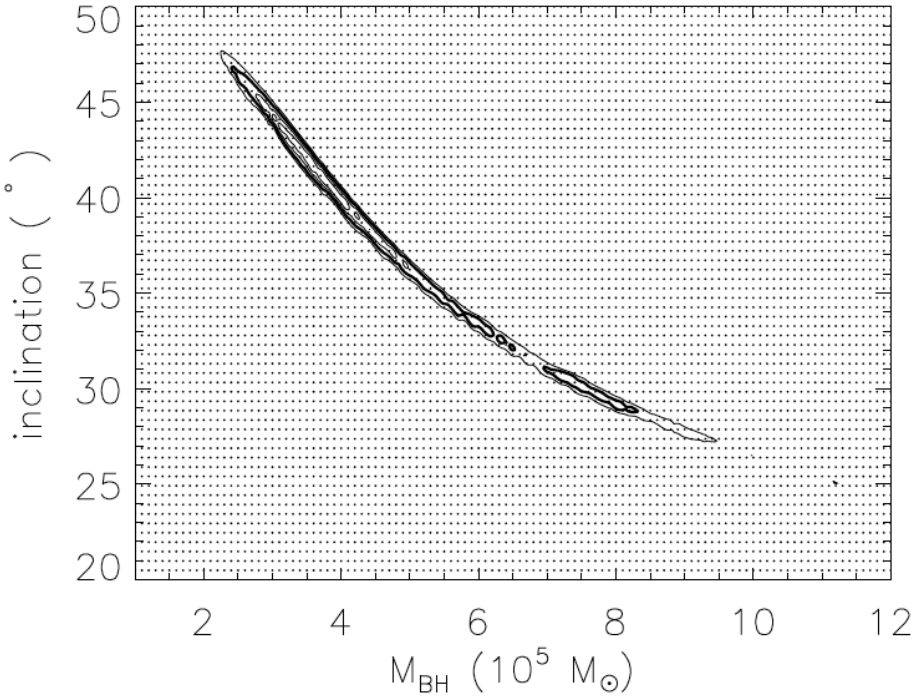
Seth, Cappellari, Neumayer et al. 2010

NGC404 – Gas Kinematic Model

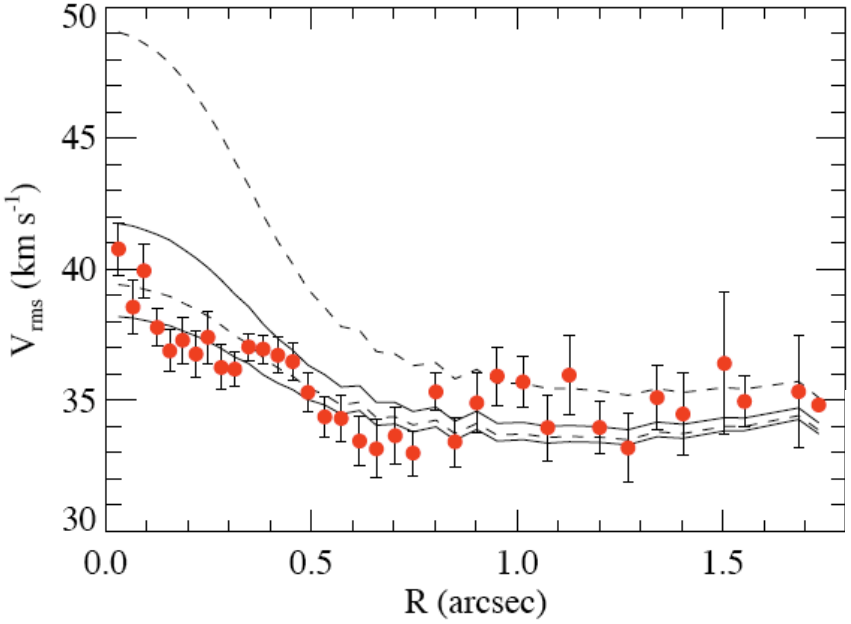




- $M_{BH} \sim (4.5 \pm 3) \times 10^5\ M_\odot$
  - Degeneracy due to $v_{rot} \sim \sqrt{M_{BH}} \times \sin(i)$
- Inclination i~37°±10°



Stellar Kinematic Model



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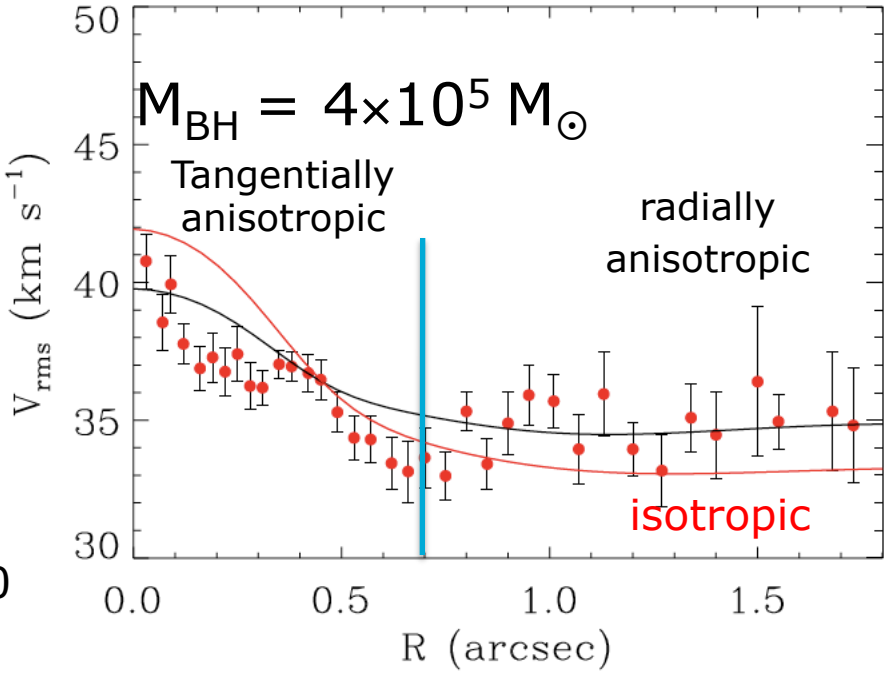

Seth, Cappellari, Neumayer et al. 2010

NGC 3621 - Sd galaxy

- Bulge-less spiral

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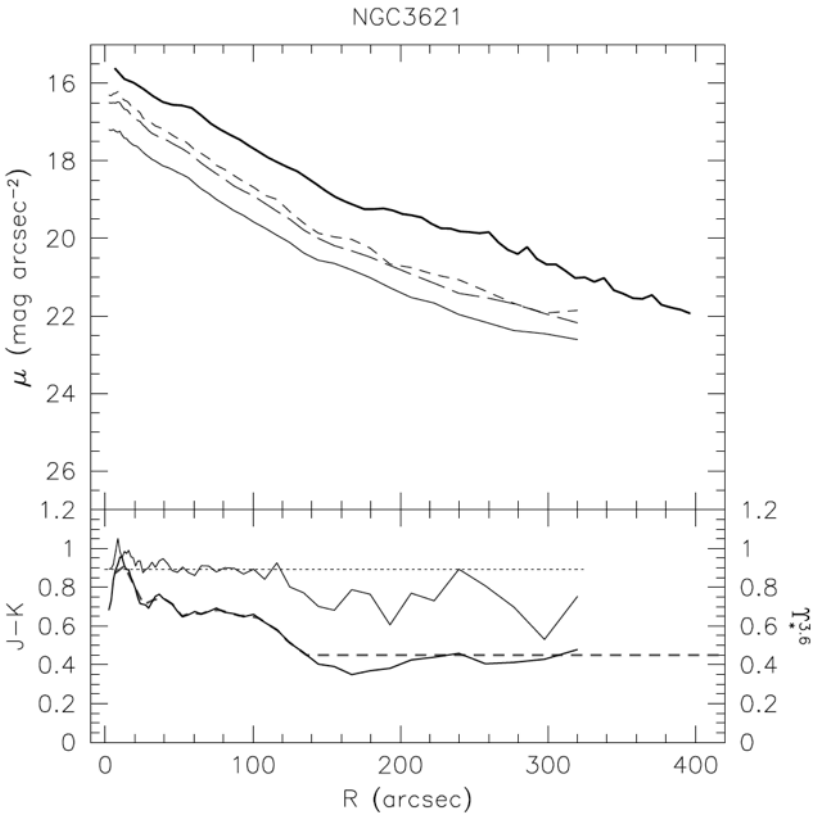

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2MASS de Blok et al. 2008

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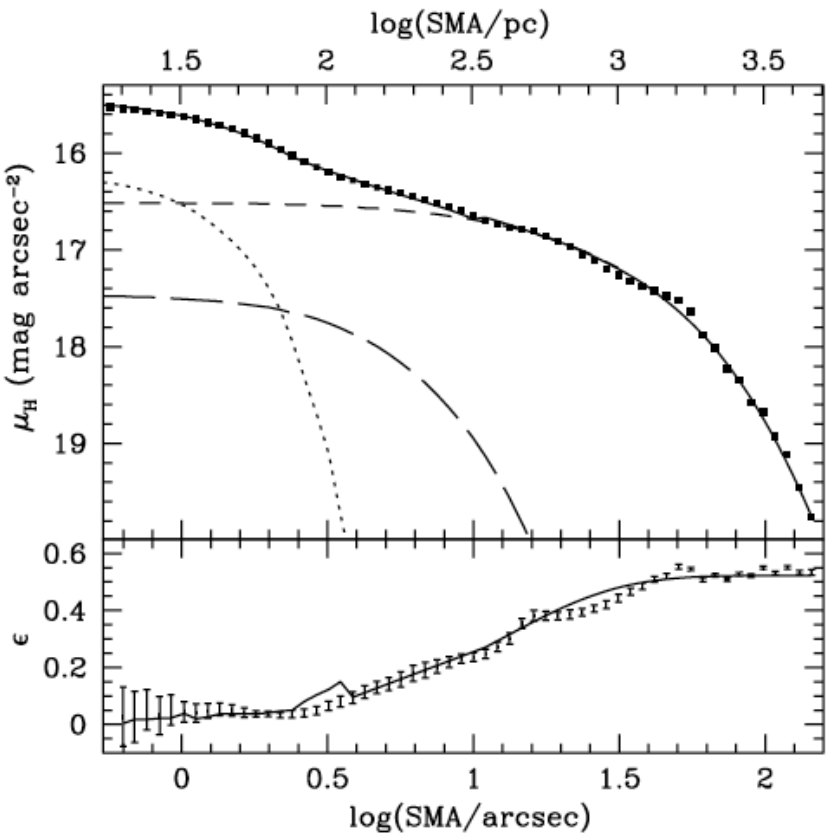

Barth et al. 2009

- Bulge-less spiral
- hosts nuclear cluster…

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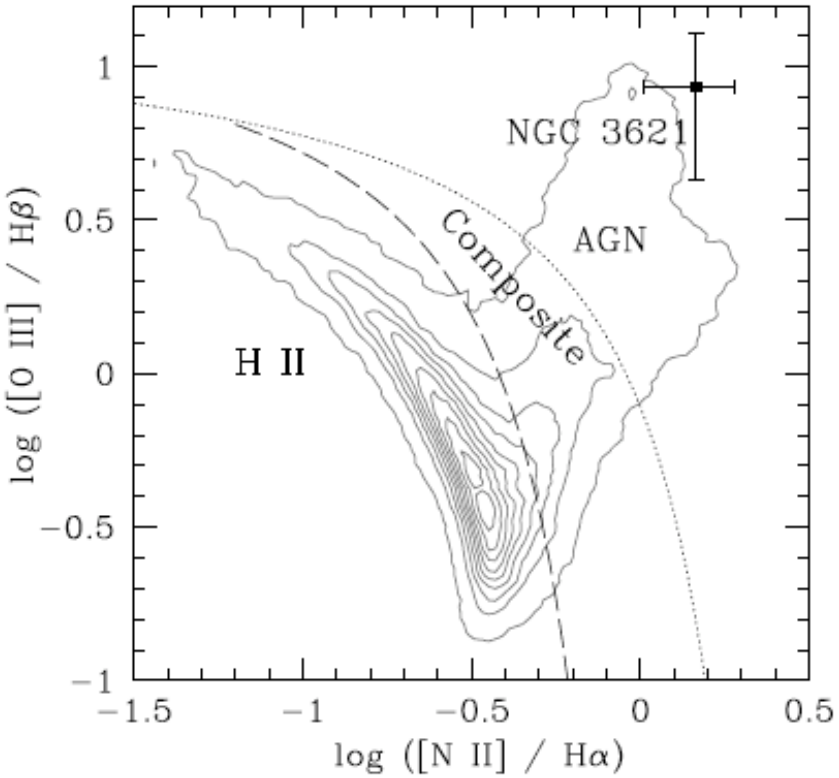
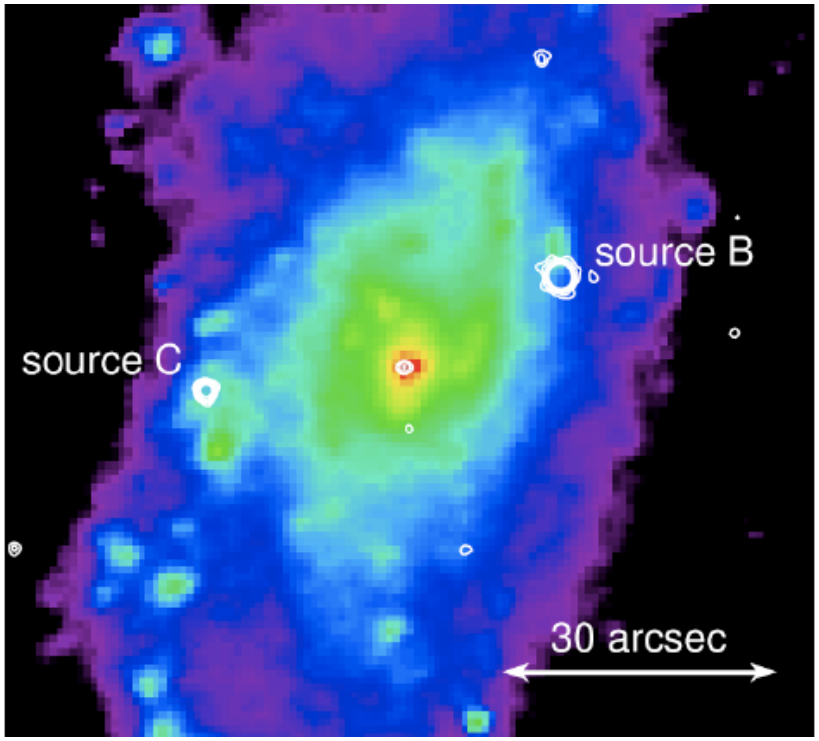


Barth et al. 2009

- Bulge-less spiral
- hosts nuclear cluster…
- …plus detected AGN
  - in MIR (Satyapal et al. 2007)

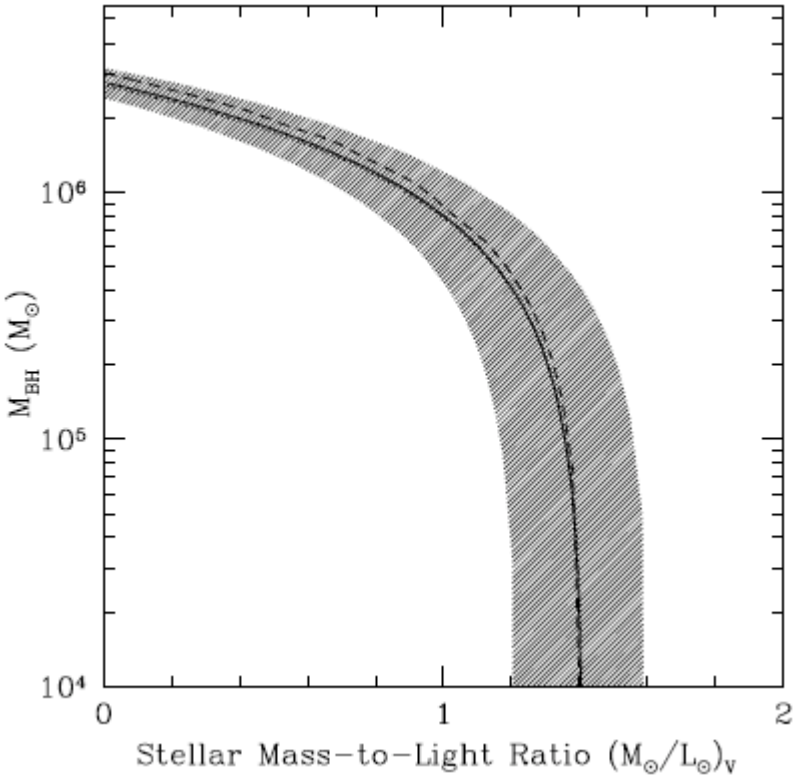
NGC 3621 - Sd galaxy



Gliozzi et al. 2009

- Bulge-less spiral
- hosts nuclear cluster…
- …plus detected AGN
  - in MIR (Satyapal et al. 2007)
  - and X-rays (Gliozzi et al. 2009)
- $M_{BH} > 2 \times 10^4 M_\odot$

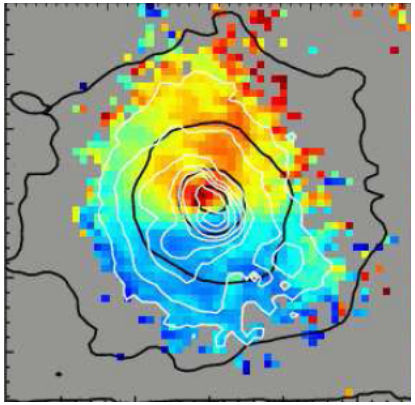
NGC 3621 - Sd galaxy

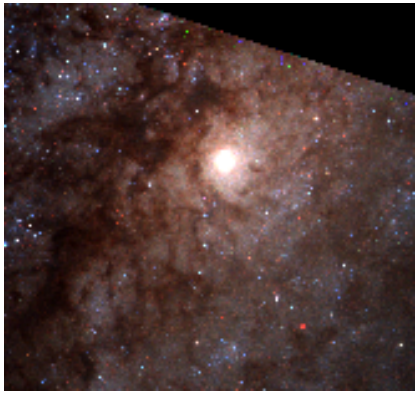


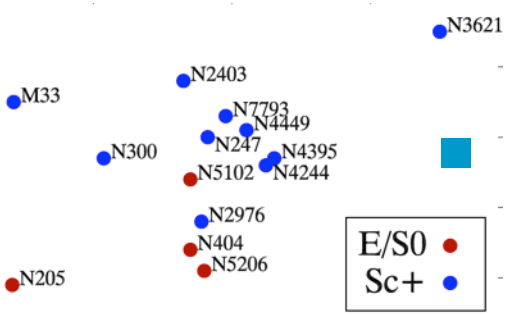
Barth et al. 2009

- Bulge-less spiral
- hosts nuclear cluster…
- …plus detected AGN
  - in MIR (Satyapal et al. 2007)
  - and X-rays (Gliozzi et al. 2009)
- $M_{BH} > 2\times10^4\ M_\odot$
- $M_{BH} < 3\times10^6\ M_\odot$
- SINFONI data resolve the cluster
- Can dynamically detect $M_{BH} \sim 3\times10^5\ M_\odot$

Summary







- Nuclear star clusters are common
- They co-exist with black holes
- Mixed evidence for a black hole in NGC404
- Detection of a black hole in NGC3621
- More to come!