The growth of supermassive black holes in bulges and elliptical galaxies

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Outline

Work with two main observables:

1. M_{Bulge}
2. σ

Outline

- Sample Selection
- Image Decompositions
- The M_{Bulge}-σ Relation for Ellipticals and Bulges
  - Implications for the M_{BH}-σ and M_{BH}-M_{Bulge} relations
- Black Hole Demographics
  - Total BH mass density, BH mass distribution and budget
- Conclusions

Gadotti (2009 MNRAS 393, 1531)
Gadotti & Kauffmann (arXiv:0811.4299)

Sample Selection

Database:

- *g*,*r*,*i* images from SDSS

HWHM ~ 750 pc

Criteria:

- $0.02 \leq z \leq 0.07$ (not too far, not too close – typical z: 0.05)
- $M_* \geq 10^{10}\ M_{Sun}$ (no dwarves – typical mass: MW)
- $b/a \geq 0.9$ (face-on galaxies, avoids dust, projection etc.)
- 3375 galaxies

Visual inspection to remove:

- not truly face-on
- ongoing interactions, mergers
- overly faint or irregular
- images not suitable (bright stars, close to edge, duplicates etc.)
- galaxies smaller than 8" in diameter (25 *g*-mag arcsec^{-2})

Final sample: 963 galaxies (407 AGN, mostly type 2)

Sample Selection

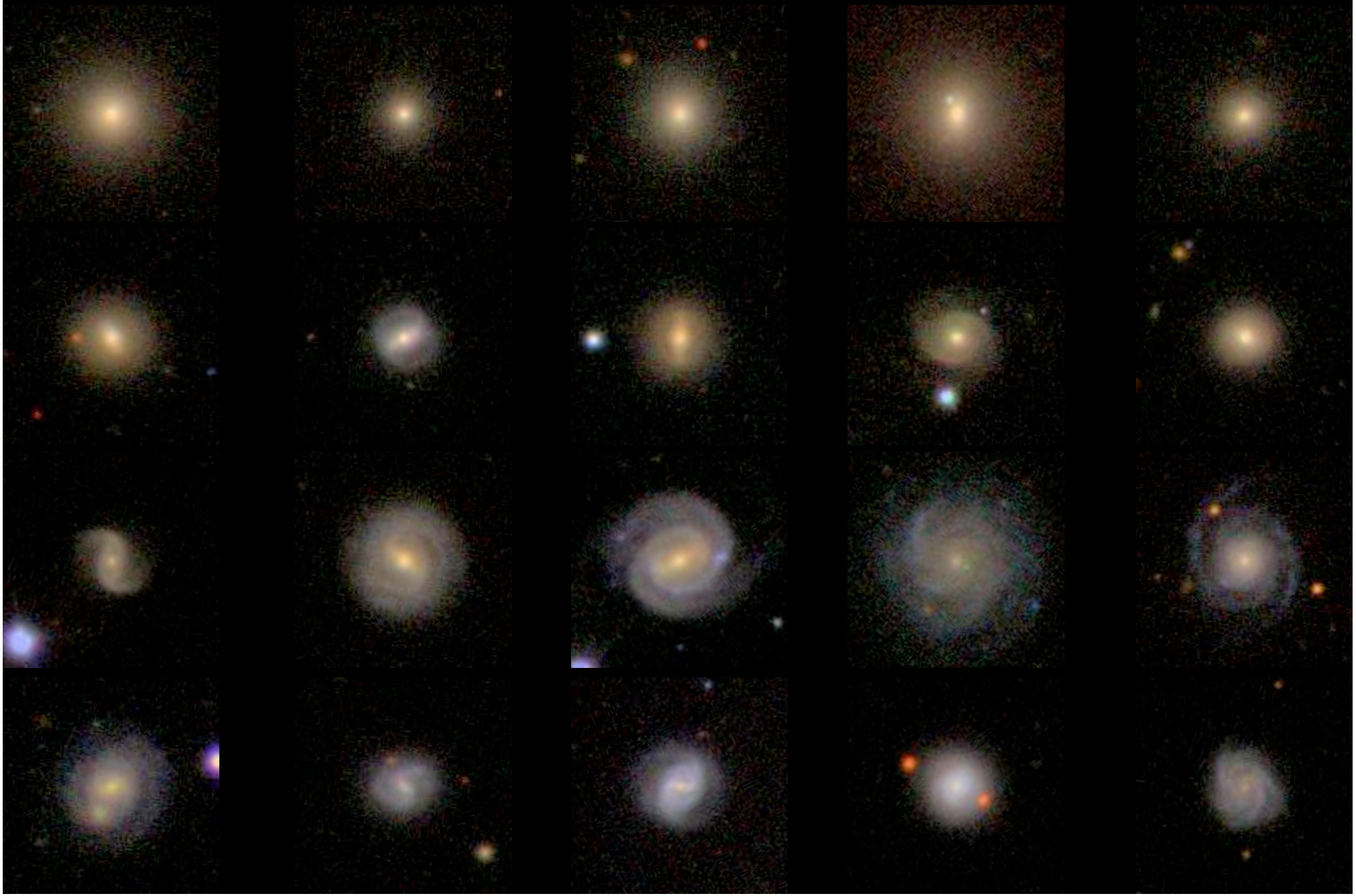

Image Decompositions

BUDDA v2.1 (de Souza et al. 04, Gadotti 08):

- 2D fitting using generalized ellipses (Athanassoula et al. 90)
- exponential disk (Freeman 70)
- Sérsic bulge (Sérsic 68)
- Sérsic bar

$$\left(\frac{|x|}{a}\right)^c + \left(\frac{|y|}{b}\right)^c = 1$$

Parameters:

- disk: μ_0, h
- bulge: μ_e, r_e, n
- bar: $\mu_{e,Bar}$, $r_{e,Bar}$, n_{Bar}, L_B, c, ε
- B/T, D/T, Bar/T
- M_*: from total luminosity, g-i color and relation between g-i and M/L from Kauffmann et al. (07)

$$\mu_d(r) = \mu_0 + 1.086 r/h$$

$$\mu_b(r) = \mu_e + c_n \left[\left(\frac{r}{r_e}\right)^{1/n} - 1\right]$$

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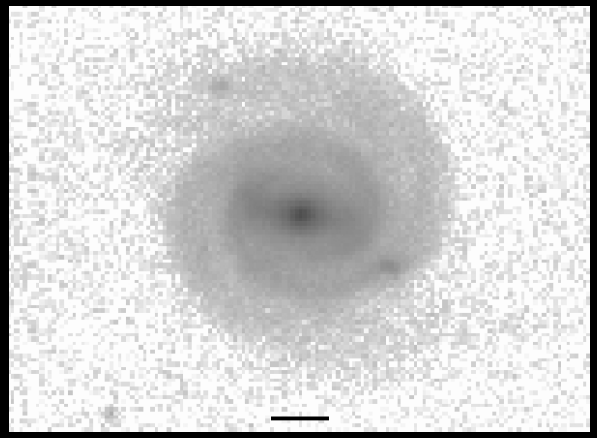
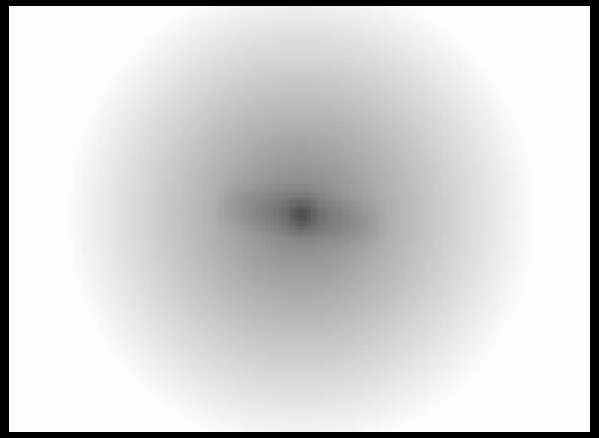
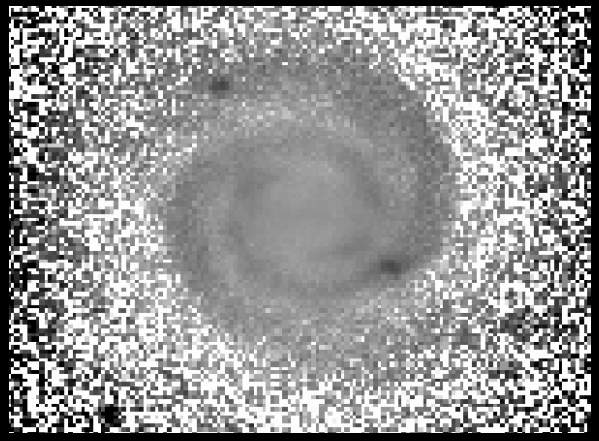
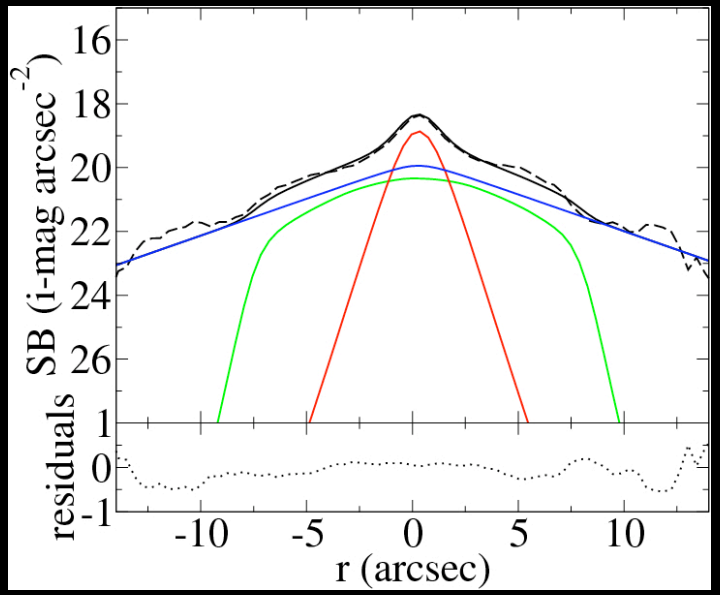
Image Decompositions







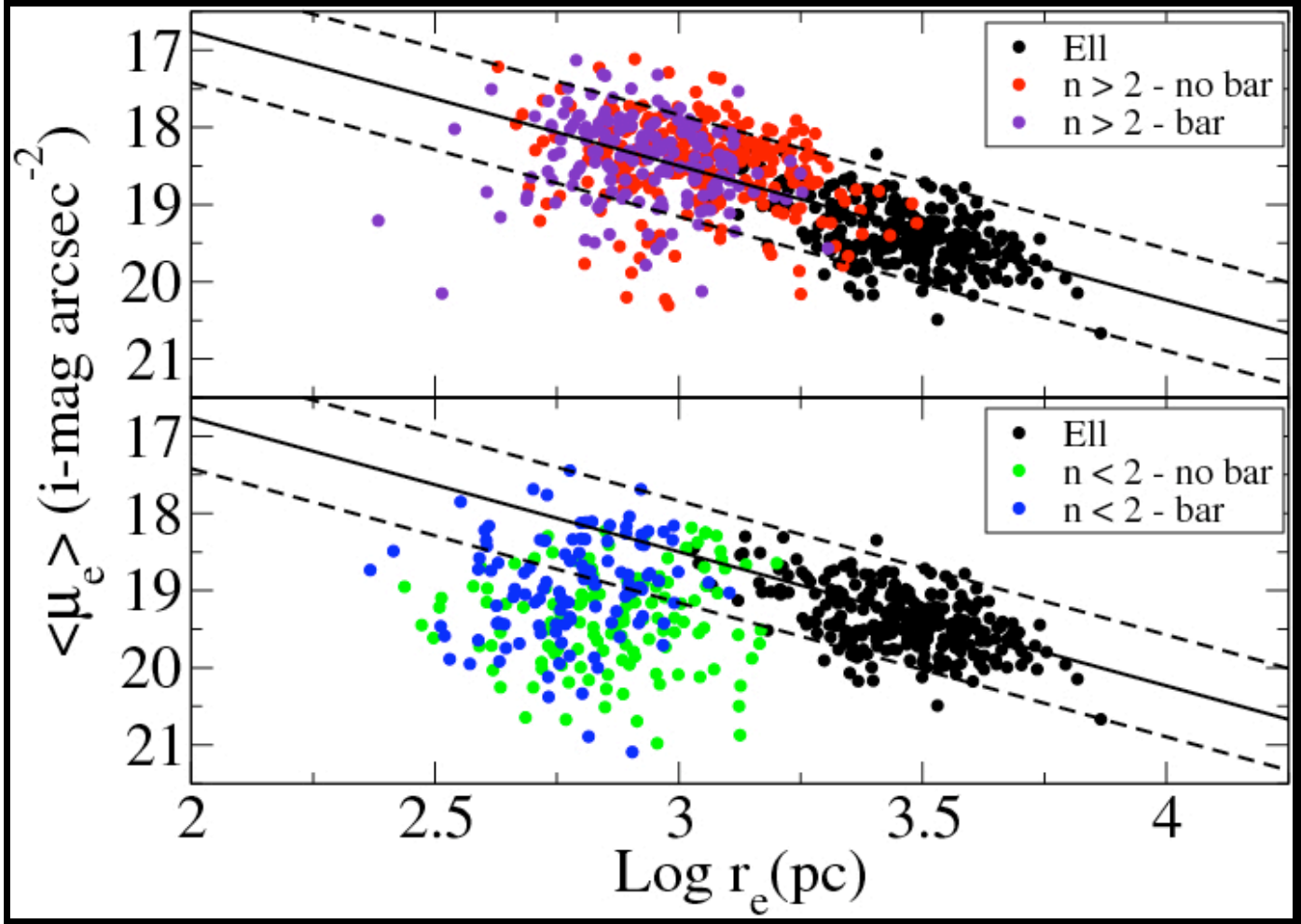


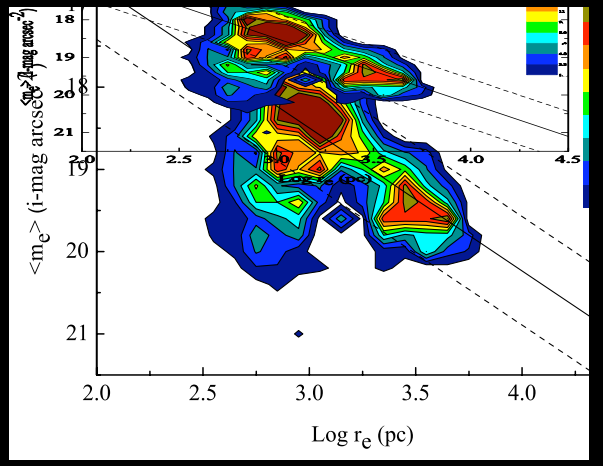
- Bar has to be modeled (Gadotti 08)!
- AGN light can be neglected
- All results available at

http://www.mpa-garching.mpg.de/~dimitri/buddaonsdss/buddaonsdss.html

Identifying Pseudo-Bulges

Ellipticals and classical bulges follow Kormendy (77) relation, but pseudo-bulges seem not to (Carollo 99, Kormendy & Kennicutt 04, Fisher & Drory 08)

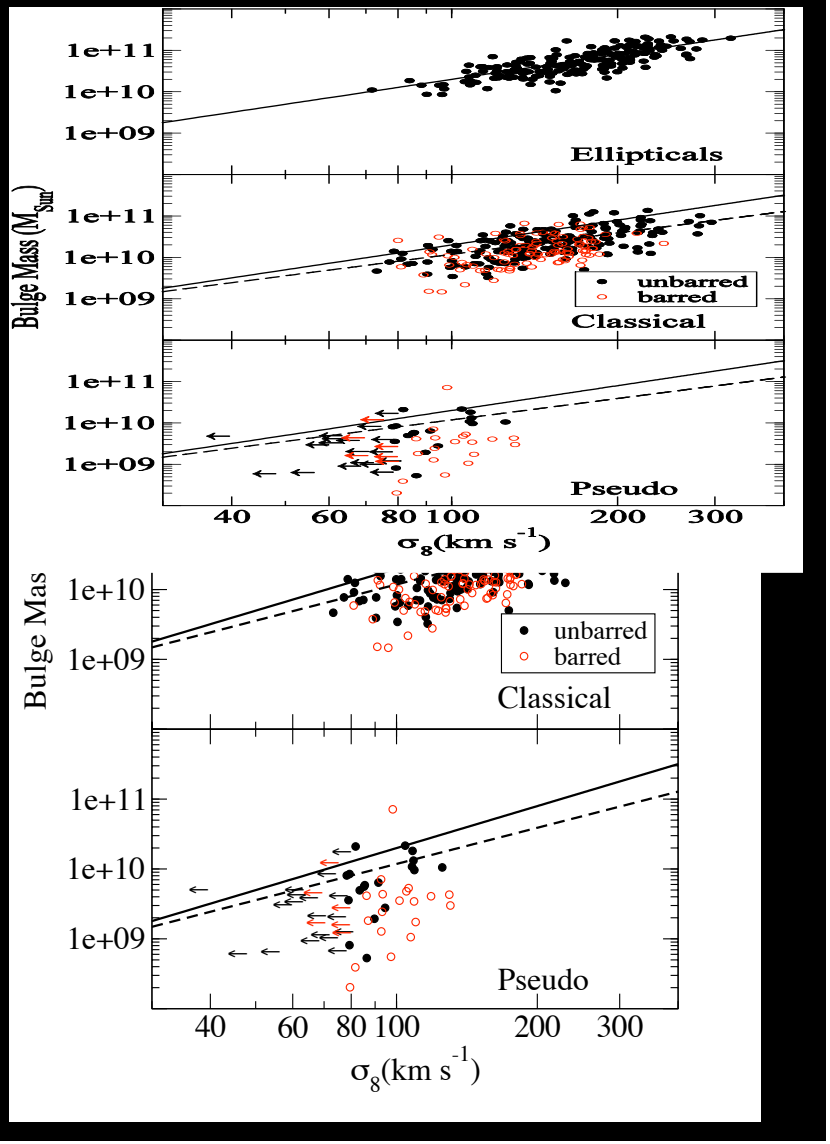




Disc-like bulges, not box/peanut bulges

The M_{Bulge}-σ relation

- difference between ellipticals and classical bulges is a 3σ result
- some SDSS σ values are upper limits (those below 70 km/s)
- deviation of pseudo-bulges seems to be mostly due to barred galaxies



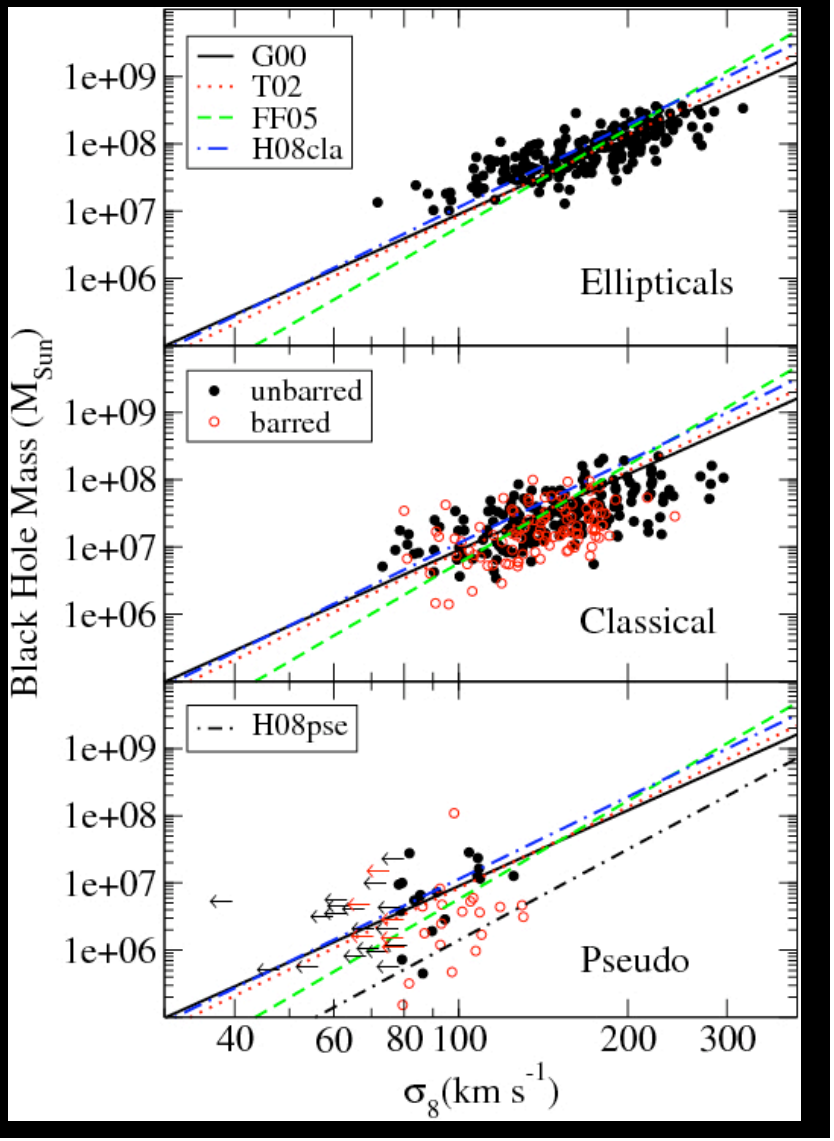
The M_{BH}-σ relation

- using M_{BH}-M_{Bulge} from Häring & Rix (04)

- G00: Gebhardt et al. (00); T02: Tremaine et al. (02); FF05: Ferrarese & Ford (05); H08cla: Hu (08 - classical); Hu08pse: Hu (08 - pseudo)

- There cannot be single M_{BH}-M_{Bulge} *and* M_{BH}-σ relations

- again (obviously!) deviation of pseudo-bulges is mostly due to barred galaxies (see also Graham 08, Graham & Li 09)



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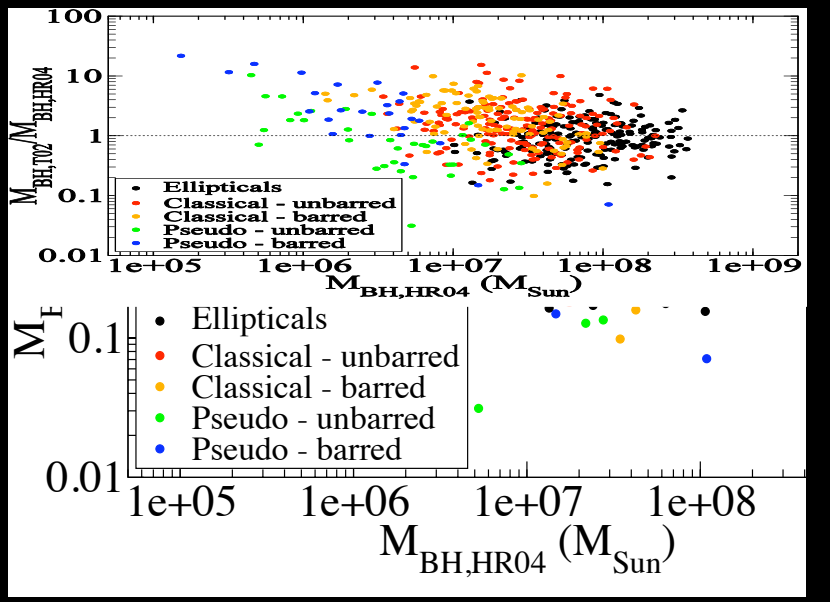
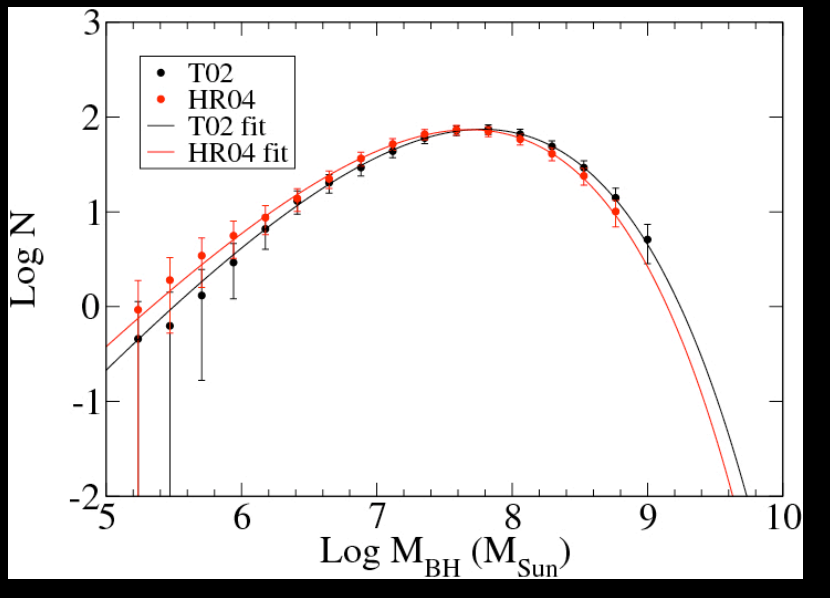
Total Black Hole Mass Density and Distribution at z ~ 0

- total BH mass density is 25-55 per cent larger using M_{BH}-σ compared to M_{BH}-M_{Bulge} (Tremaine et al. 02)

- scatter taken into account

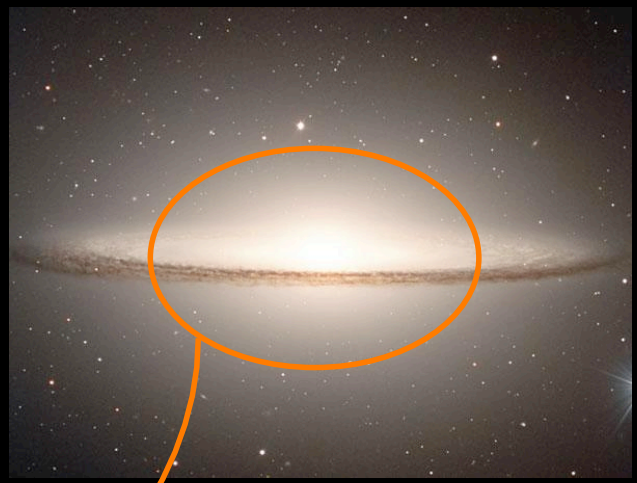




The Black Hole Mass Budget at z ~ 0
(For galaxies with $M_* \geq 10^{10}\ M_{Sun}$)

• using M_{BH}-M_{Bulge} from Häring & Rix (04):

• ~ 55% in elliptical galaxies



• ~ 41% in classical bulges

• ~ 4% in pseudo-bulges

Conclusions

(or what you should take with you)

1. There is evidence of different M_{Bulge}-σ relations for ellipticals and bulges.

2. There can not be single M_{BH}-M_{Bulge} *and* M_{BH}-σ relations for ellipticals and bulges.

Different back hole growth modes?

3. Deviation of pseudo-bulges from the M_{Bulge}-σ relation seems to be caused by bars.

Perhaps barred galaxies have to be treated differently…