The growth of supermassive black holes in bulges and elliptical galaxies

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Outline

Work with two main observables:

1. $M_{\text{Bulge}}$
2. $\sigma$
Outline

- Sample Selection
- Image Decompositions
- The $M_{\text{Bulge}} - \sigma$ Relation for Ellipticals and Bulges
  - Implications for the $M_{\text{BH}} - \sigma$ and $M_{\text{BH}} - M_{\text{Bulge}}$ 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

Criteria:
• $0.02 \leq z \leq 0.07$ (not too far, not too close – typical $z$: 0.05)
• $M_\ast \geq 10^{10}\ M_{\odot}$ (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 ($25\ g\text{-mag}\ arcsec^{-2}$)

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

Parameters:

- disk: $\mu_0$, h
- bulge: $\mu_e$, $r_e$, n
- bar: $\mu_{e,Bar}$, $r_{e,Bar}$, $n_{Bar}$, $L_B$, c, $\varepsilon$
- 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)

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

\[
\mu_d(r) = \mu_0 + 1.086r/h
\]

\[
\mu_b(r) = \mu_e + c_n \left[ \left( \frac{r}{r_e} \right)^{1/n} - 1 \right]
\]
• Bar has to be modeled \textit{(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

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The $M_{\text{Bulge}}$ - $\sigma$ relation

- difference between ellipticals and classical bulges is a $3\sigma$ result
- some SDSS $\sigma$ values are upper limits (those below 70 km/s)
- deviation of pseudo-bulges seems to be mostly due to barred galaxies
The $M_{BH}-\sigma$ 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 $M_{BH}-\sigma$ relations

- again (obviously!) deviation of pseudo-bulges is mostly due to barred galaxies (see also Graham 08, Graham & Li 09)
• total BH mass density is 25-55 per cent larger using $M_{\text{BH}}-\sigma$ compared to $M_{\text{BH}}-M_{\text{Bulge}}$ (Tremaine et al. 02)

• scatter taken into account
The Black Hole Mass Budget at $z \sim 0$
(For galaxies with $M_* \geq 10^{10} \, M_{\odot}$)

- $\sim 4\%$ in pseudo-bulges
- $\sim 41\%$ in classical bulges
- $\sim 55\%$ in elliptical galaxies

Using $M_{\text{BH}}-M_{\text{Bulge}}$ from Häring & Rix (04):
Conclusions
(or what you should take with you)

1. There is evidence of different $M_{\text{Bulge}} - \sigma$ relations for ellipticals and bulges.

2. There cannot be single $M_{\text{BH}} - M_{\text{Bulge}}$ and $M_{\text{BH}} - \sigma$ relations for ellipticals and bulges.

   Different back hole growth modes?

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

   Perhaps barred galaxies have to be treated differently…