What is the origin of the black hole -bulge mass correlation?

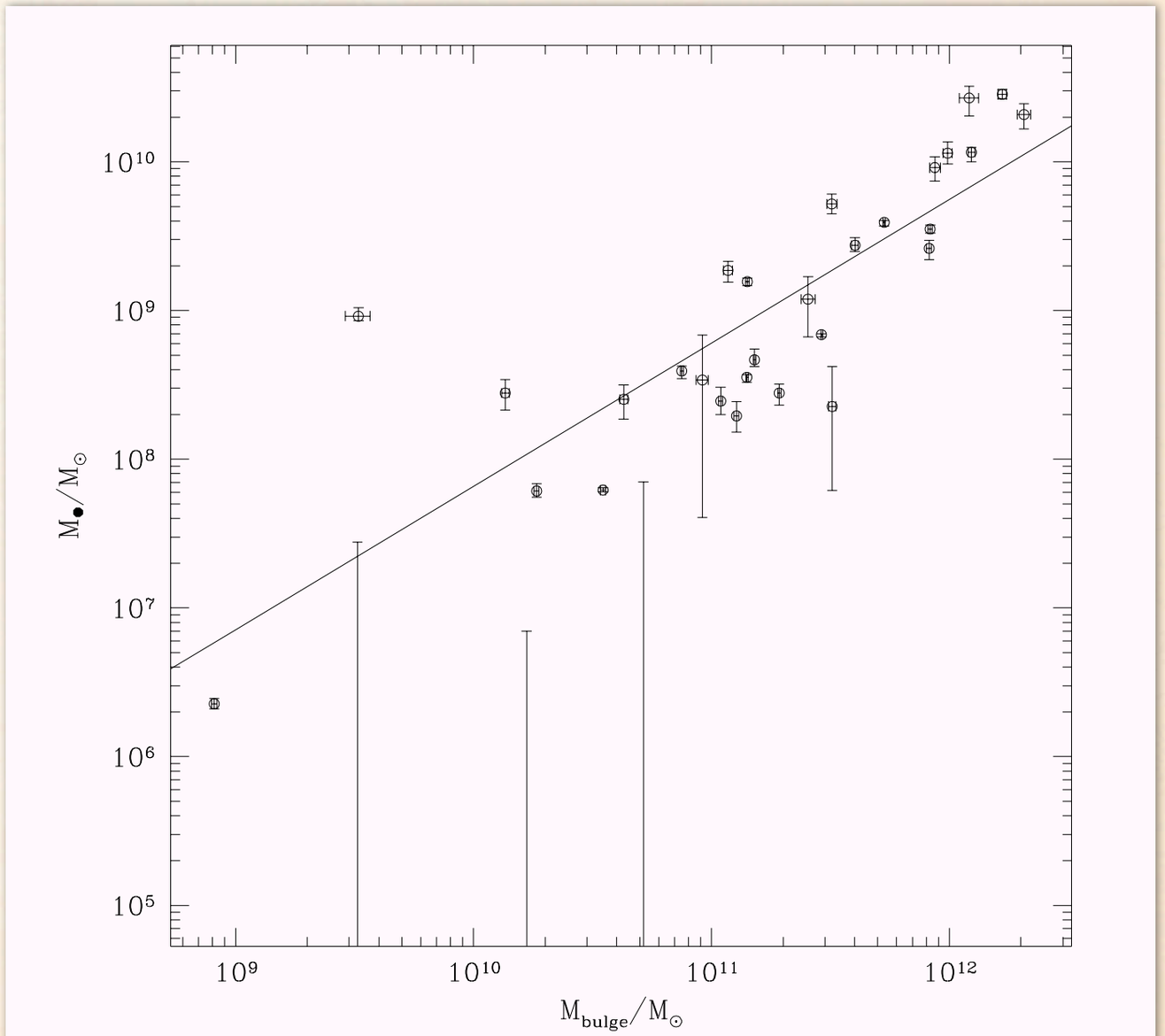
By Curtis McCully

OUTLINE

- What is the Black hole-Bulge mass correlation
- Observations
- Possible Theoretical Explanations

BH - BULGE MASS CORRELATION

- Magorrian Relation



- Plot from Magorrian et al. 1998

MOTIVATION

- BH has affects in galaxy formation much farther than is expected from its gravitation alone
- The radius of influence r_h can be defined as follows:

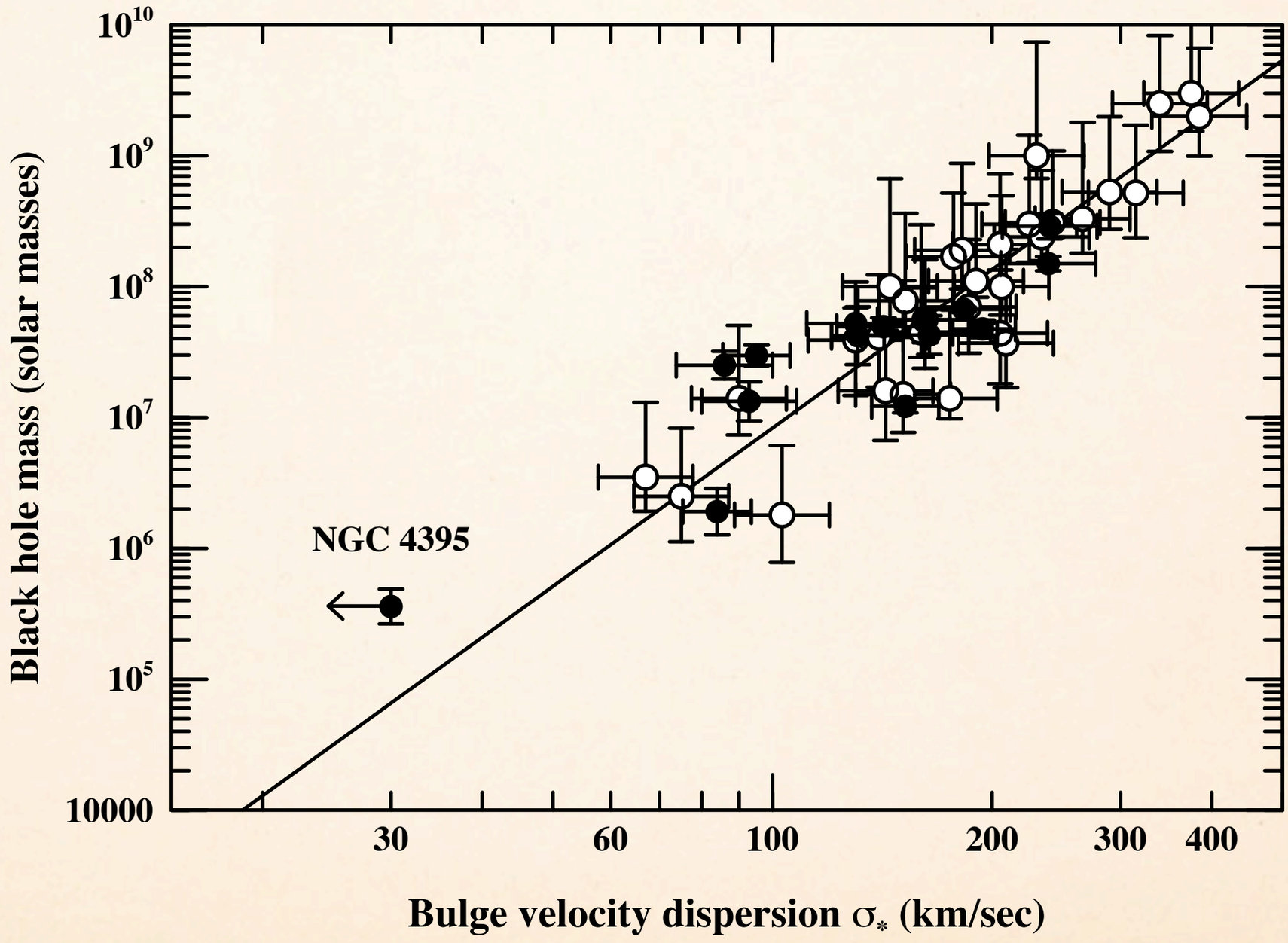
$$M(r < r_h) = 10 M_{BH}$$

- For Milky Way:
- $M_{Bulge} \approx 5 \times 10^{11} M_\odot \quad R_{Bulge} \approx 2 \text{ kpc}$
- $\Rightarrow \rho \approx 15 \frac{M_\odot}{pc} \qquad \Rightarrow r_h \sim 100 \text{ pc}$

OBSERVATIONS: USING $M - \sigma_\star$

- Virial Theorem: $2\langle T \rangle = \langle V \rangle$
- $\Rightarrow v^2 = \frac{GM}{R}$
- Velocity Dispersion $\sigma_\star \Rightarrow$ probe of the mass

REVERBERATION MAPPING



Peterson 2006

BLACK HOLE MASS OBSERVATIONS

- At low z: Use Reverberation mapping
- At higher z: BH mass from H_β width or Continuum velocity widths
- Can measure line widths for bulge mass estimates using the width of eg. [O III] for sigma

VELOCITY DISPERSION UNCERTAINTIES

Shen et al. 2008

VELOCITY DISPERSION UNCERTAINTIES

- [O III] not a perfect surrogate for sigma (Up to a factor ~ 5 uncertainty)

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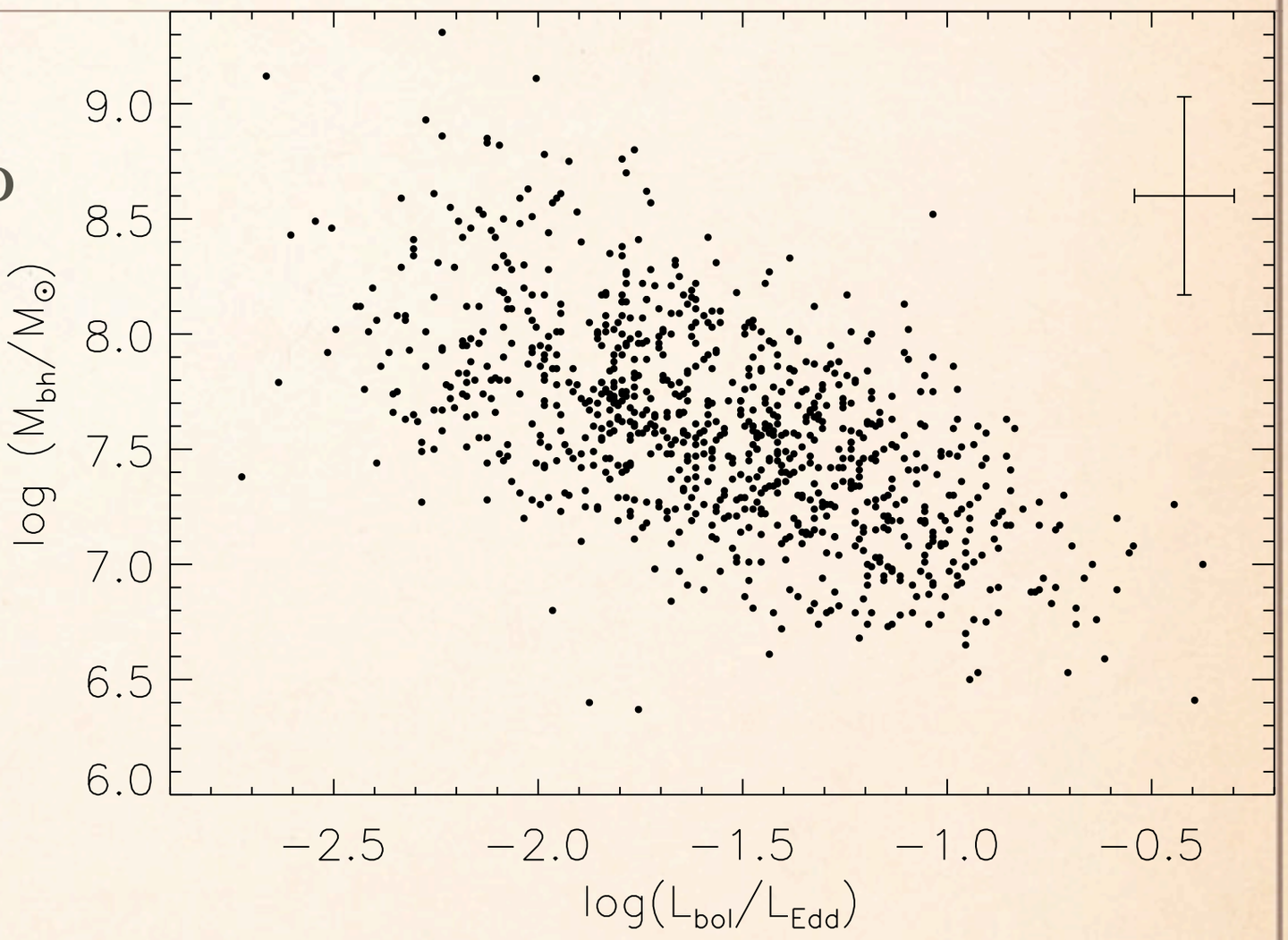
- L to R_{BLR} uncertainties
- Inversely correlated to Eddington ratio?



Shen et al. 2008

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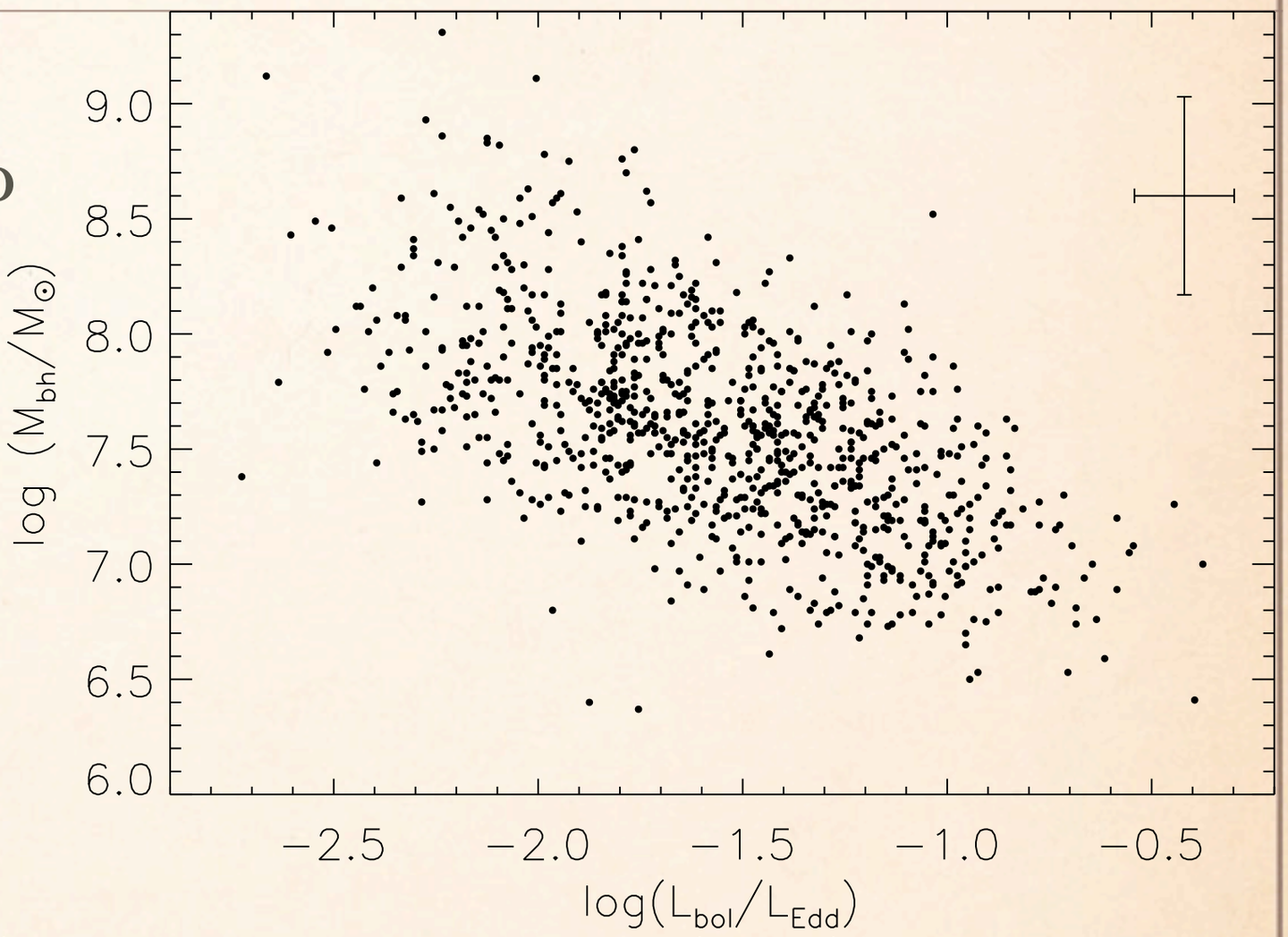
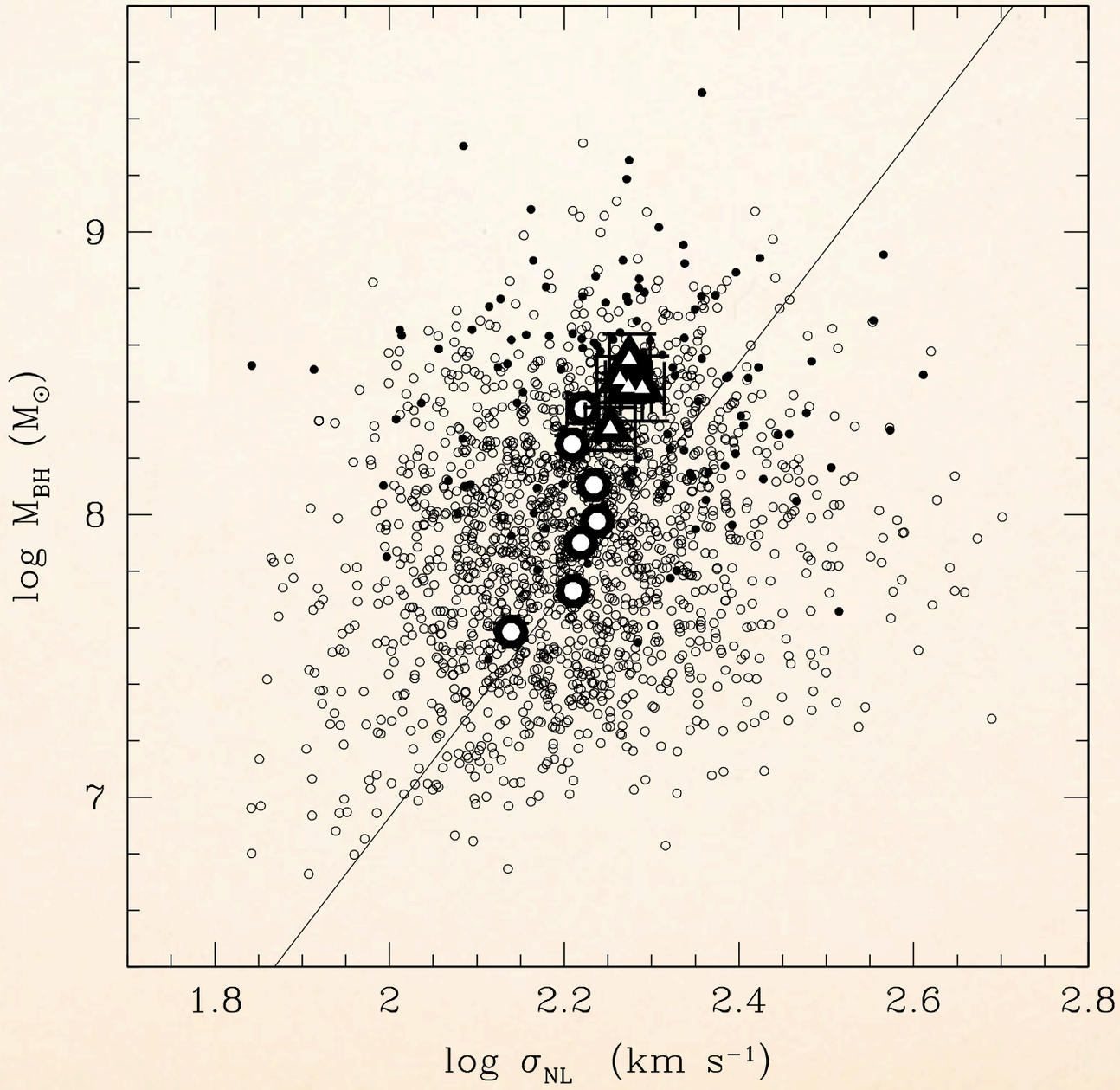


Uncertainties in $\sigma_\star$ and M_{BH} propagate to be the uncertainties in the inferred mass and therefore the Magorrian Relation.

Shen et al. 2008

MODERN RESULTS



- Salviander et al. 2007

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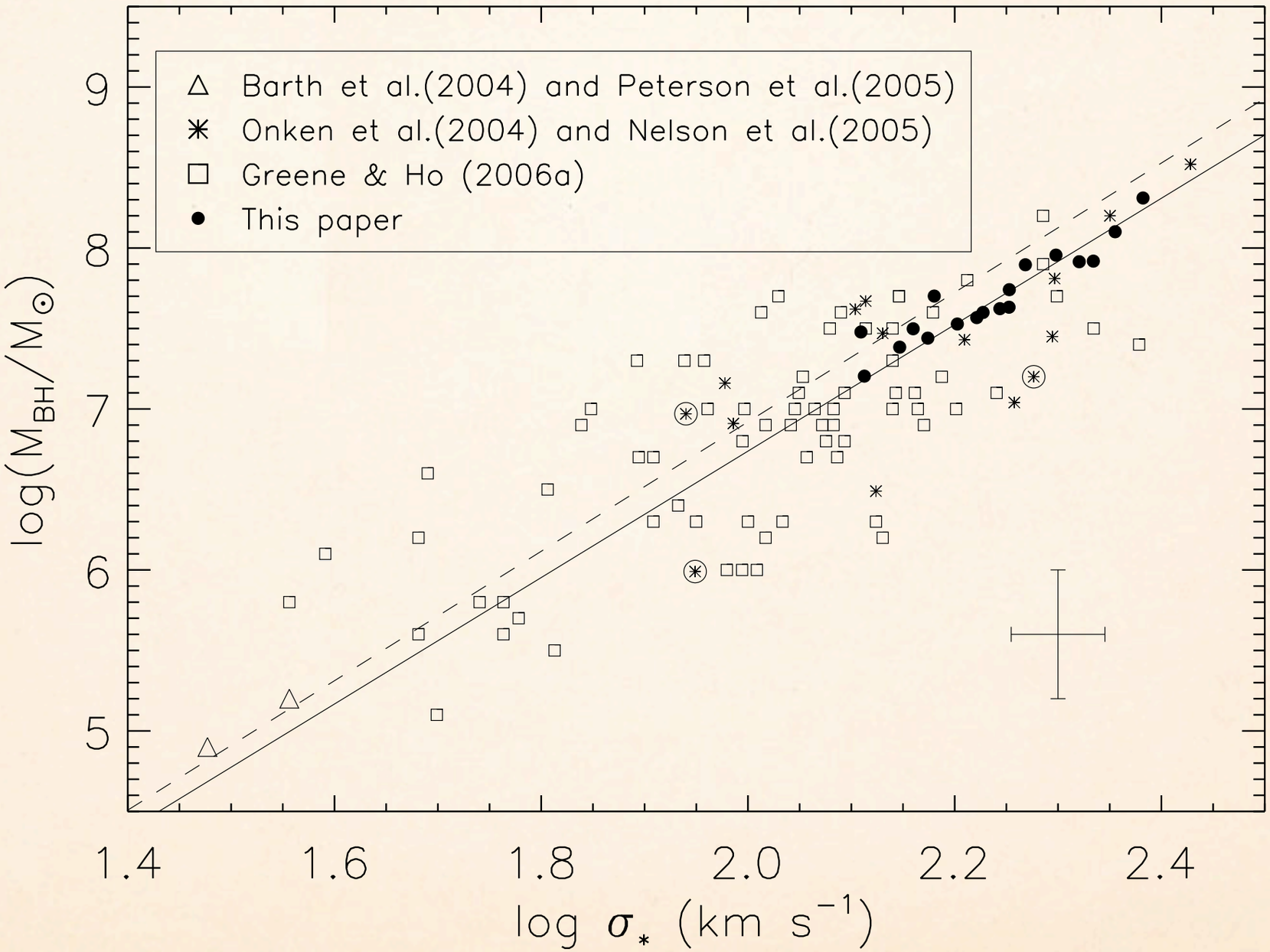
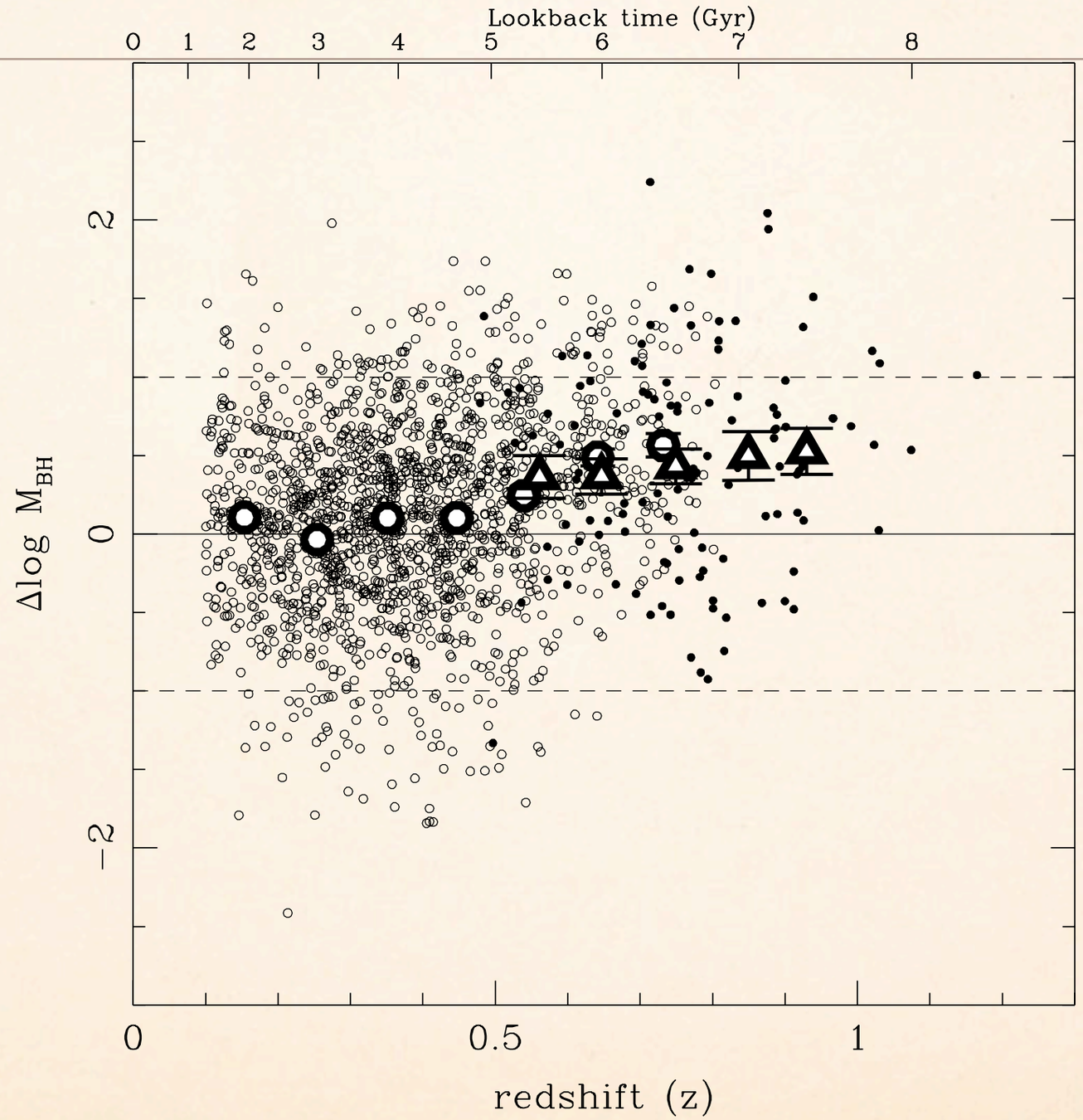


- Shen et al. 2008

EVOLUTION OF M-SIGMA RELATION



Salviander et al. 2007

FEEDBACK MODELS

- Self-regulated BH Growth
- Eddington Limited rapid BH growth
- Bulge and BH grow in tandem

- Begelman and Nath (2005)

ACCRETION MODELS

- Supercritical accretion rates create an outflow that forms a shell from a shock

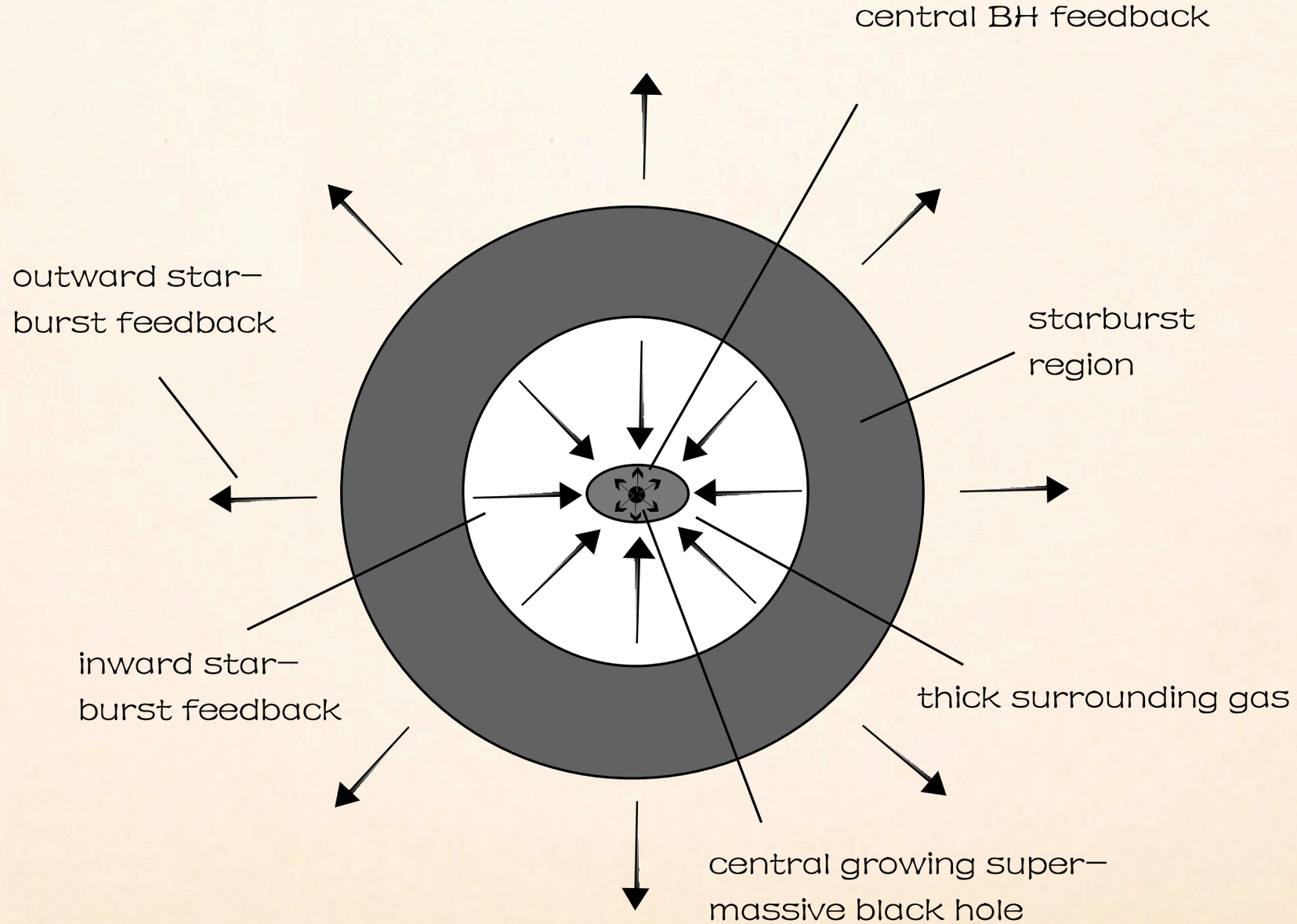
- As the BH accretes mass the velocity of the shell increases to reach sigma forming the $M - \sigma_\star$ relation

- Therefore, the $M - \sigma_\star$ relation only holds at the end of the formation of a galaxy

King (2003)

COMBINATION MODELS

- Star Formation Feedback (SNe and Radiation pressure)



- Xu et al. 2007

MODEL PREDICTIONS

- Feedback models predict that there should be no dependence on redshift and insensitive to dark matter halo (Begelman and Nath 2005)

- There could be redshift dependence in Accretion models (King 2003)

- There is predicted redshift dependence from the combination model and is dependent on an NFW dark matter profile (Xu et al 2007).

REFERENCES

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- Peterson, B. M. 2006, Memorie della Societa Astronomica Italiana, 77, 581
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- Shen, J., Vanden Berk, D. E., Schneider, D. P., & Hall, P. B. 2008, AJ, 135, 928
- Xu, B., Wu, X., & Zhao, H. 2007, ApJ, 664, 198

CONCLUSIONS

- There is a tight correlation between the Mass of the Central Black Hole and the Stellar Velocity Dispersion
- From the Virial Theorem we can use $\sigma_\star$ as a tracer of mass
- We find a tight correlation between the Mass of the Central Black Hole and the Mass of the Bulge: The Magorrian Relation
- This phenomenon is not well understood theoretically
- There are two main types of physical interpretations
  - Accretion models
  - Feedback models