SMBH-Bulge-Relations

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Übersicht

- Super Massive Black Hole (SMBH) at the center of most galaxies
- SMBH resides in the bulge of its host galaxy
- SMBH mass $M_\bullet \sim 10^6 - 10^{10} M_\odot$

Introduction

Why study SMBH-Bulge relations?

- Not much known about Galaxy formation or evolution
- Not much known about SMBH formation or evolution either
- Correlation between SMBH and Galaxy (bulge) properties might further understanding
- (direct) gravitational influence of SMBH much smaller than bulge radius
  - relations must be caused by coevolution or -formation

- SMBH properties:
  - SMBH Mass $M_\bullet$
- Galactic bulge properties
  - (central) stellar velocity dispersion σ
  - bulge luminosity
  - bulge mass
  - etc.

Ferrarese, Merritt (2000)

- studied:
  - $M_\bullet - \sigma$ relation (first)
  - $M_\bullet - B_T^0$ relation

- used two samples:
    - 12 galaxies with "reliable" SMBH mass of kinematic measurements (Sample A)
    - 29 galaxies with less secure SMBH mass of fitting accretion disk models (Sample B)
- used mass errors of original papers
- suggest that some errors might be much larger
- used central velocity dispersion

Ferrarese, Merritt (2000)

Findings

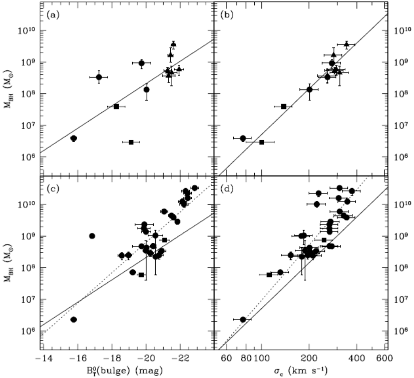

Figure: top row: Sample A, bottom row: Sample B

- poor fit for B_T^0
- tight relation for σ (in Sample A)

$$\log M_\bullet = 4.80(\pm 0.54) \log \sigma_c - 2.9(\pm 1.3) \tag{1}$$

- Sample B relation much less tight
    - SMBH masses of addition data lie systemetically above Sample A

Beifiori, Courteau, Corsini, Zhu (2011)

- studied:
  - $M_\bullet - \sigma$ relation
  - $M_\bullet - L_{bulge}$ relation
  - $M_\bullet - M_{bulge}$ relation
  - $M_\bullet - n$ relation (Sérsic shape index)
  - $M_\bullet - < \mu_{e,bulge} >$ relation (mean effective surface brightness)
  - $M_\bullet - L_{gal}$ relation
  - $M_\bullet - M_{gal}$ relation
- also tested if there is a *Fundamental Plane* by fitting two parameters

- used two samples:
  - 105 galaxies with SMBH mass obtained from *Hubble Space Telescope* archival spectra (Beifiori et al. 2009)
  - 49 galaxies with SMBH mass based on kinematics (Gültekin et al. 2009
  - 18 galaxies with SMBH mass from both measurements
- used 18 galaxies to compare both measurements
  - within 1σ to each other
  - use both for fits
- not all other properties are known for all galaxies

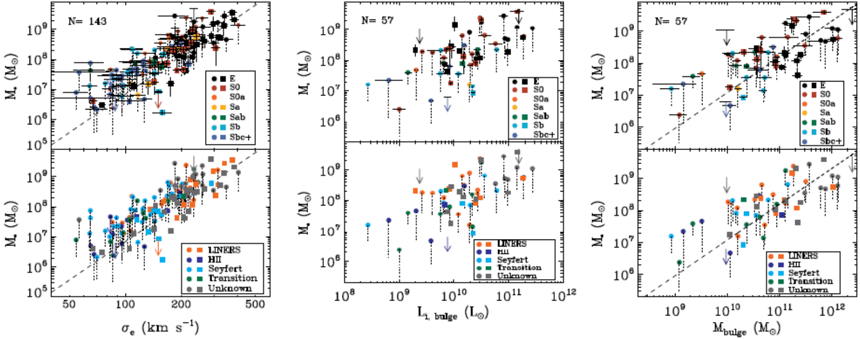

Figure: top row: morphological type, bottom row: nuclear activity

- relations given in the form

$$\log \frac{M_\bullet}{M_\odot} = \alpha + \beta \log \frac{x}{x_0} \quad (2)$$

x	N	α	β	ϵ	x_0
σ	143	7.99 ± 0.06	4.42 ± 0.30	0.44 ± 0.07	$200 km/s$
L_{bulge}	57	8.17 ± 0.22	0.79 ± 0.24	0.81 ± 0.13	$10^{11} L_\odot$
M_{bulge}	57	7.84 ± 0.12	0.91 ± 0.16	0.61 ± 0.08	$10^{11} M_\odot$

- $M_\bullet - \sigma$ relation
  - results consistent with previous measurements
  - upper limit changes zero-point
  - scatter slightly larger than expected
  - scatter larger for late-types, more late-types in data set
  - no significant difference between barred and unbarred galaxies
  - bulges and pseudo-bulges differ in slopes

- $M_\bullet - L_{bulge}$ relation
  - results consistent with previous measurements
  - scatter larger than $M_\bullet - \sigma$
  - strongly barred galaxies were excluded from sample
- $M_\bullet - M_{bulge}$ relation
  - results consistent with previous measurements
  - additional parameter: radius
  - scatter slightly larger than $M_\bullet - \sigma$

- inclusion of third parameter
  - tightest relation $M_\bullet - \sigma - r_{e,bulge}$
  - even that only slight improvement
- $M_\bullet - \sigma$ relation still fundamental

Lou, Jiang (2008)

- model galactic bulge as a
  - spherical
  - polytropic ($pV^n = C$)
  - fluid
- stellar velocity dispersion produces effective pressure
- pulled together by self-gravity

Lou, Jiang (2008)

- solved by self-similar static ansatz
  - observables invariant at x/t^n
  - needs an additional scaling index K
  - at very large timescales
- model dependent on two parameters n and K
- black hole mass defined by Schwartzschild-radius of enclosed mass

Lou, Jiang (2008)

- for positive mass $2/3 < n < 1$
- resulting relation:

$$M_\bullet = L \cdot \sigma^{1/(1-n)} \tag{3}$$

- L is dependent on n and constants
- model also reproduces $M_\bullet - M_{bulge}$ relation
- can not model pseudo-bulges, no spherical symmetry

Conclusion

- SMBH-galaxy relations might help understanding co-evolution
- tight $M_\bullet - \sigma$
  - even tighter depending on galaxy type
- other relations less tight
- only very slightly (if any) *Fundamental Plane*

Sources

- L. Ferrarese, D. Merritt; A Fundamental Relation between Supermassive Black Holes and Their Host Galaxies, The Astrophysical Journal Letters, Volume 539, Number 1, 3 August 2000, Pages L9
- A. Beifiori, S. Courteau, E. M. Corsini, Y. Zhu; On the correlations between galaxy properties and supermassive black hole mass, Monthly Notices of the Royal Astronomical Society, Volume 419, Issue 3, 21 January 2012, Pages 2497-2528
- Yu-Qing Lou, Yan-Fei Jiang; Supermassive black holes in galactic bulges, Monthly Notices of the Royal Astronomical Society: Letters, Volume 391, Issue 1, 1 November 2008, Pages L44-L48