An alternative track of Black hole – galaxy co-evolution

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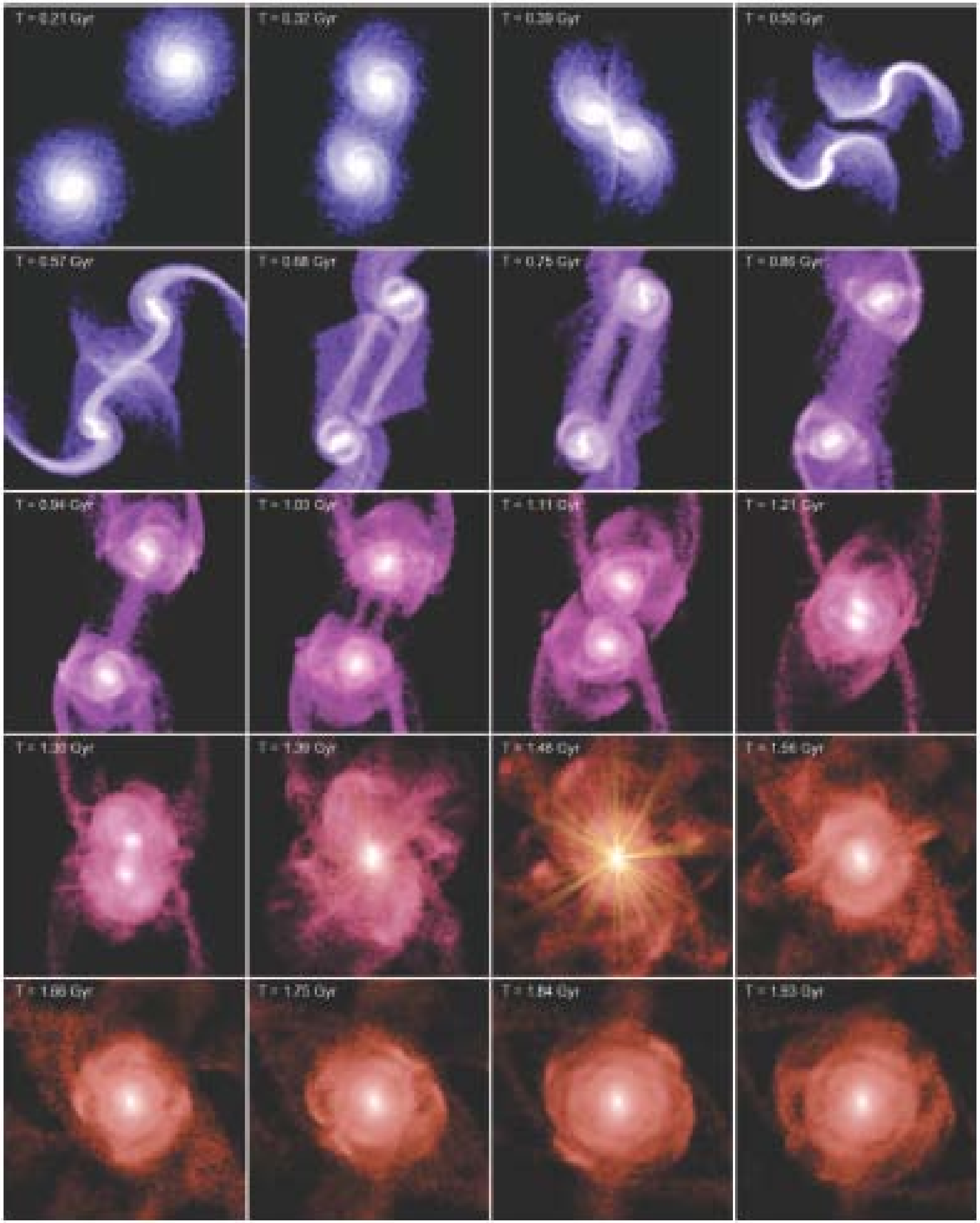
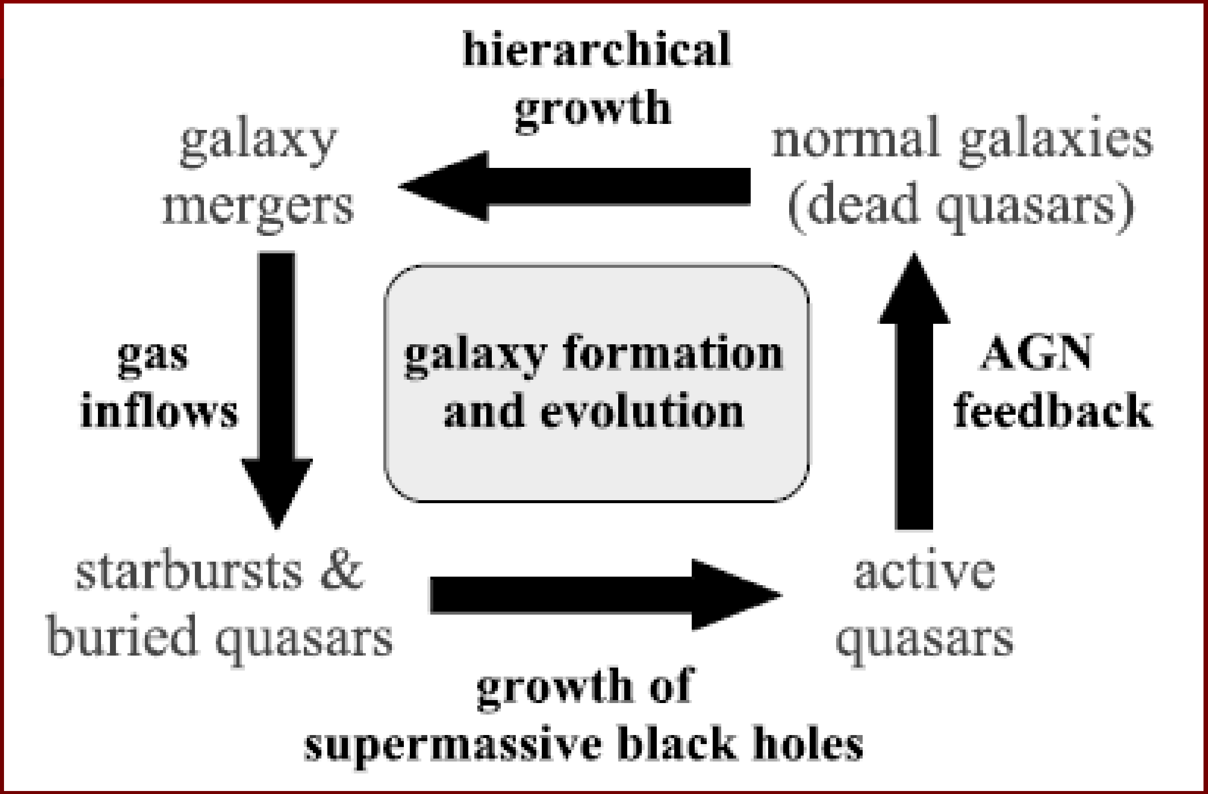
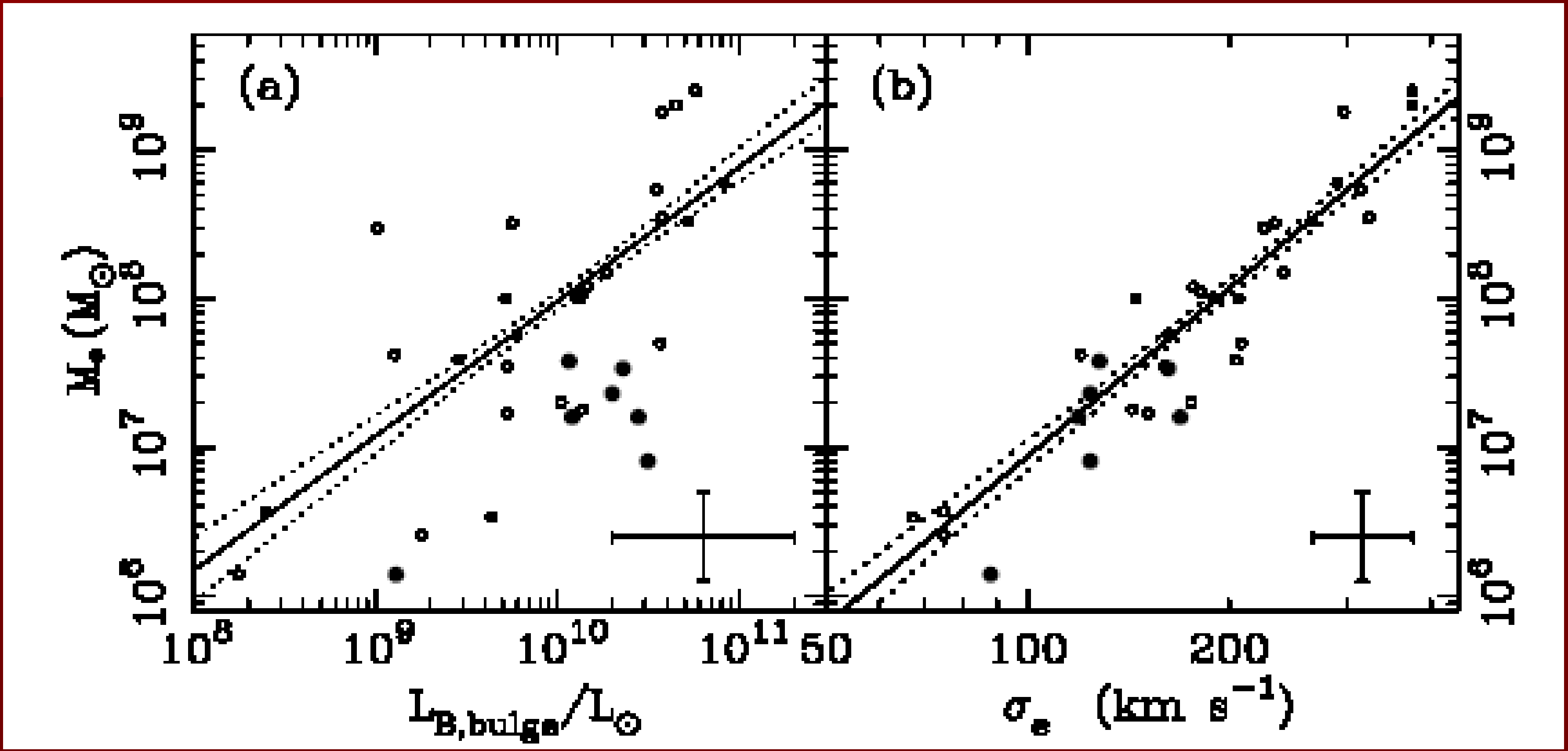


Hopkins+06


hierarchical growth
galaxy mergers
normal galaxies (dead quasars)
gas inflows
galaxy formation and evolution
AGN feedback
starbursts & buried quasars
active quasars
growth of supermassive black holes

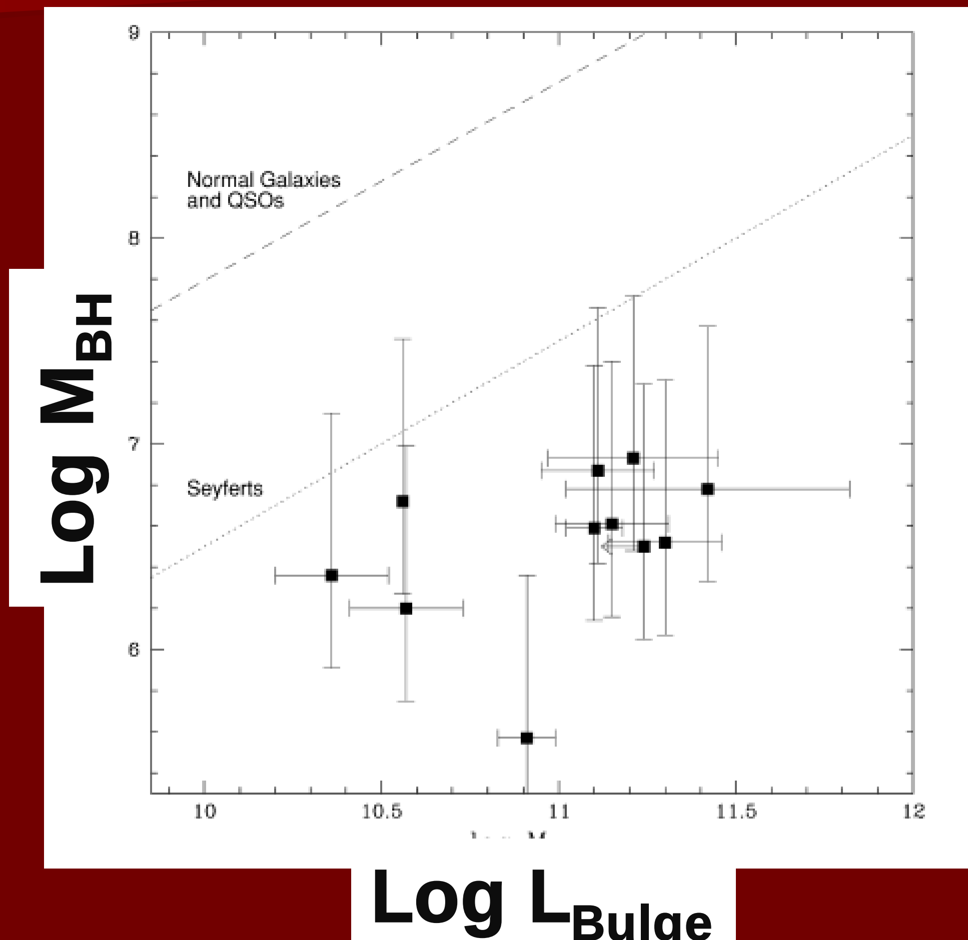
Black hole—Bulge relations



Gebhardt et al 2000, Ferrarese & Merritt 2000

Deviations from the BH—bulge relations

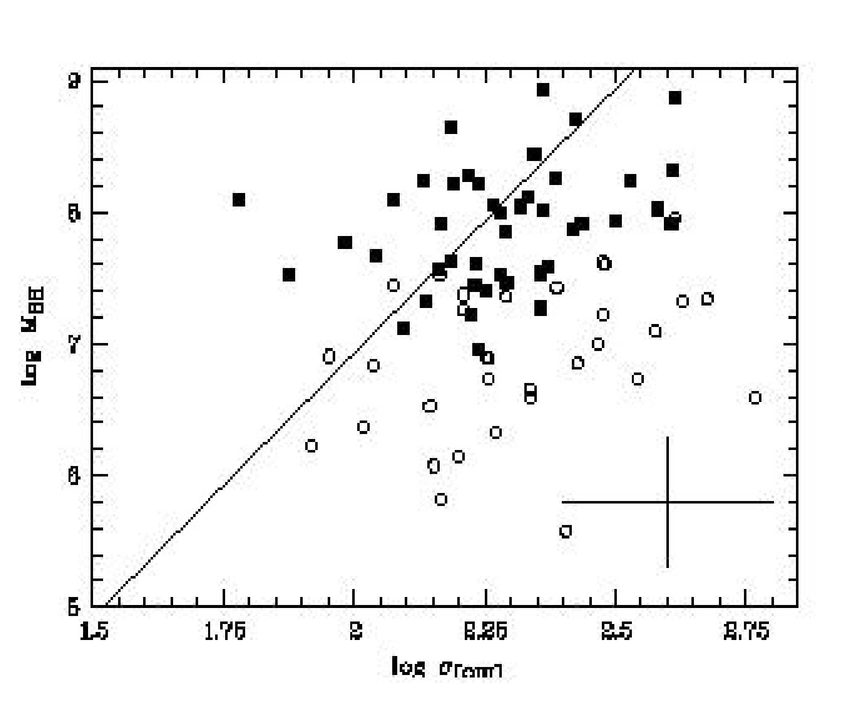
NLS1 do not lie on the M_{BH}—L_{bulge} relation



Mathur et al 2001

Locus of NLS1s on the M_{BH}--σ plane

- The M_{BH}--σ for normal galaxies and broad line Seyfert 1s is <u>not</u> followed by the narrow line Seyfert 1 galaxies.

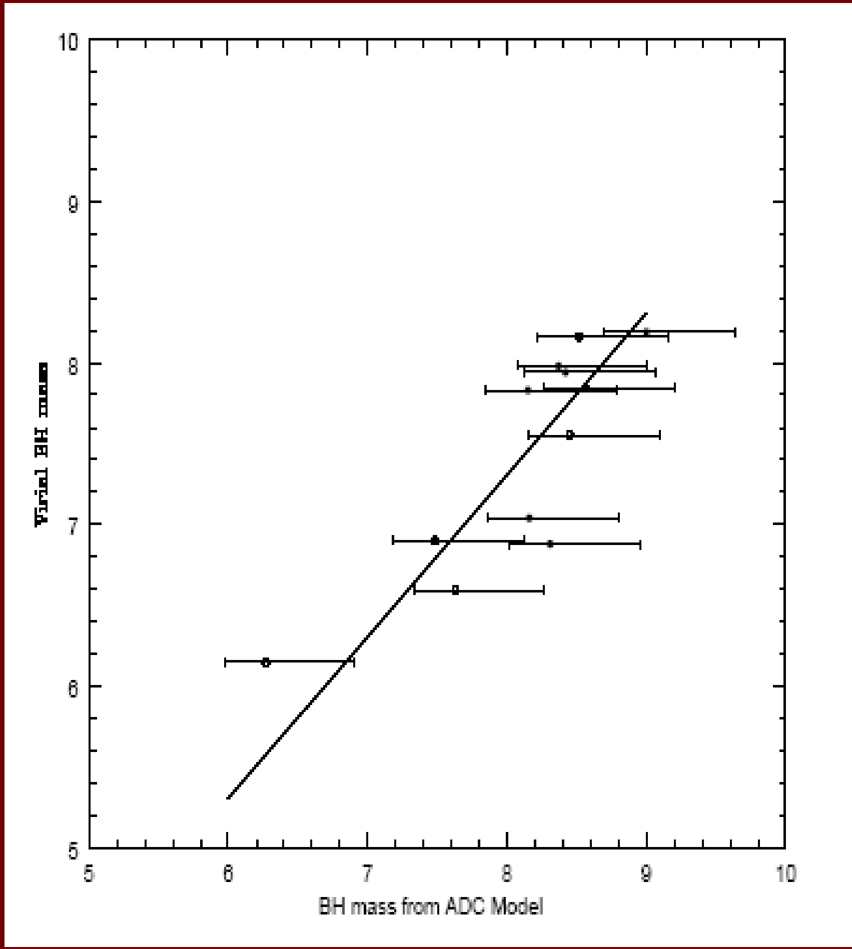


Grupe & Mathur 2004

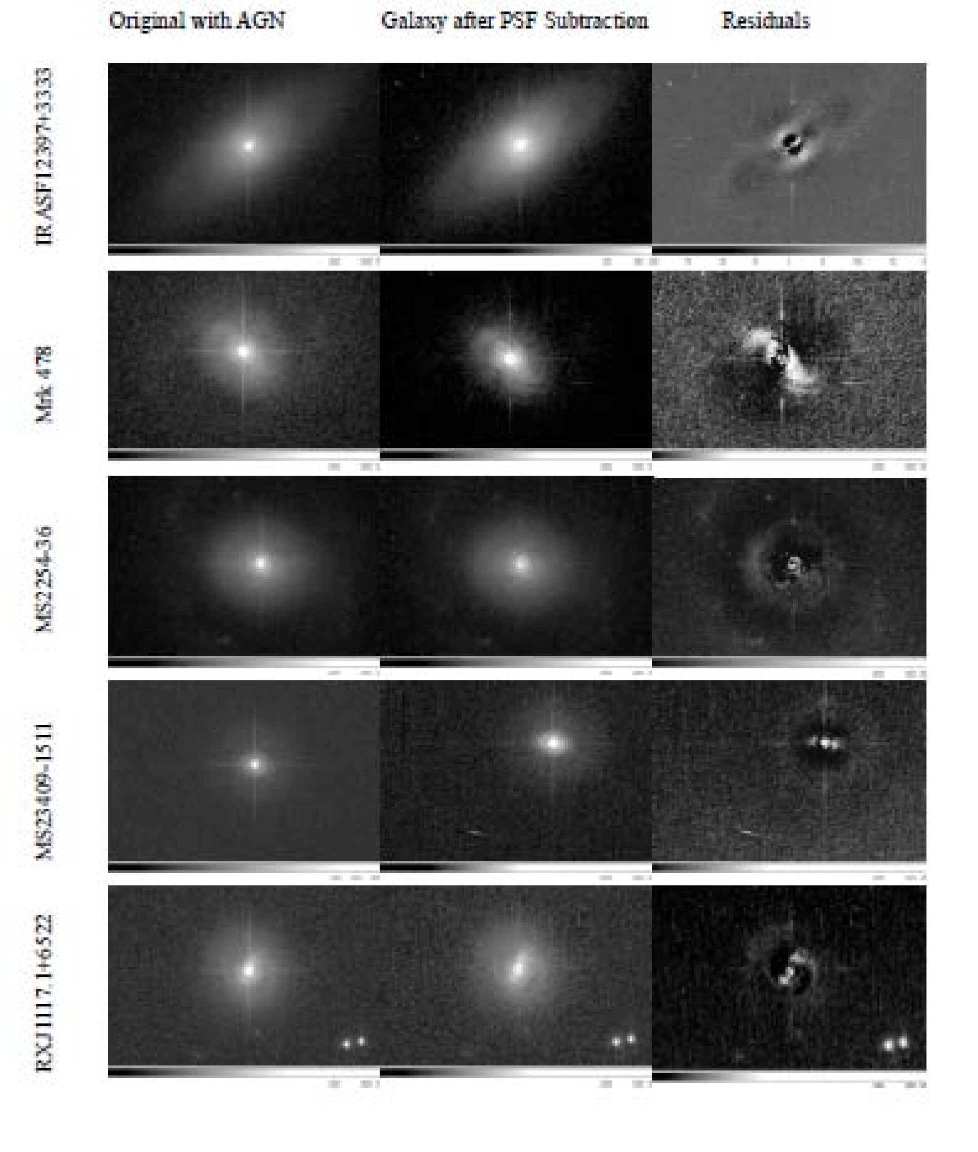
Mathur & Grupe 2005a,b

Independent methods of BH mass determination give same results

- BH mass from fits to SEDs. (Mathur et al 2001)
- BH mass from power spectrum analysis (Czerny et al 2001)
- Hβ width (GM04)
- *Same* method for both BLS1s and NLS1s

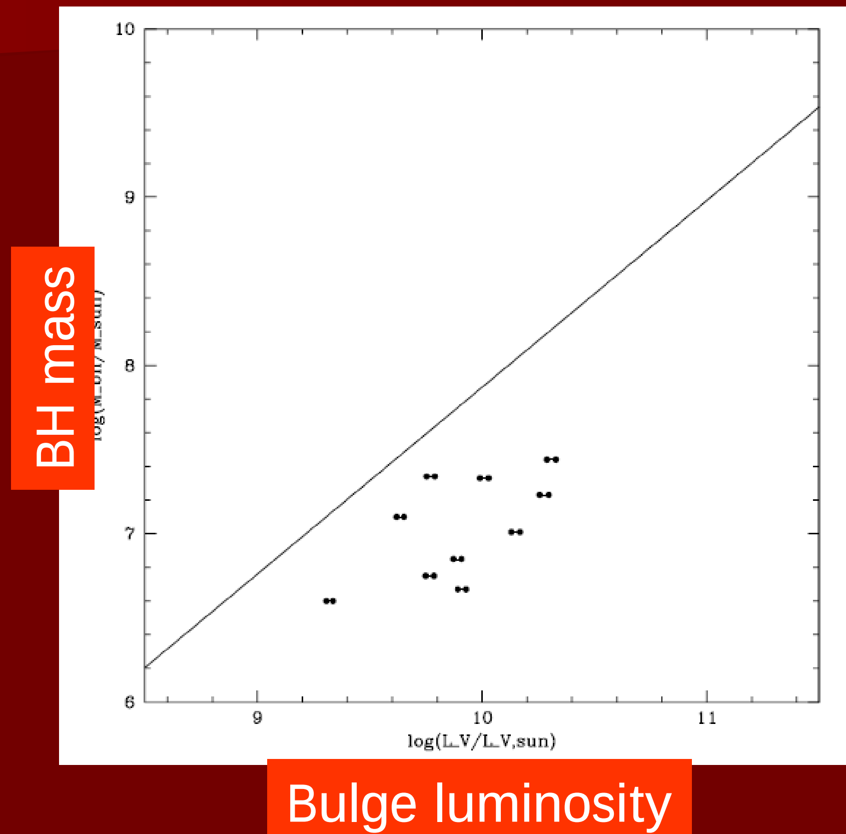


HST/ACS observations of NLS1s



Mathur et al. 2011

NLS1s lie below the “Magorrian” relation: a robust result



Mathur et al 2011

NLS1s also lie off the fundamental plane of AGNs (Barway & Kembhavi; Graham et al.)

Is bulge crucial for the existence of a BH?

Supermassive BHs in Bulge-less galaxies

1. NGC 4561, an Sdm galaxy

2. NGC 3184, an Scd galaxy

3. NGC 4713, an Sd galaxy

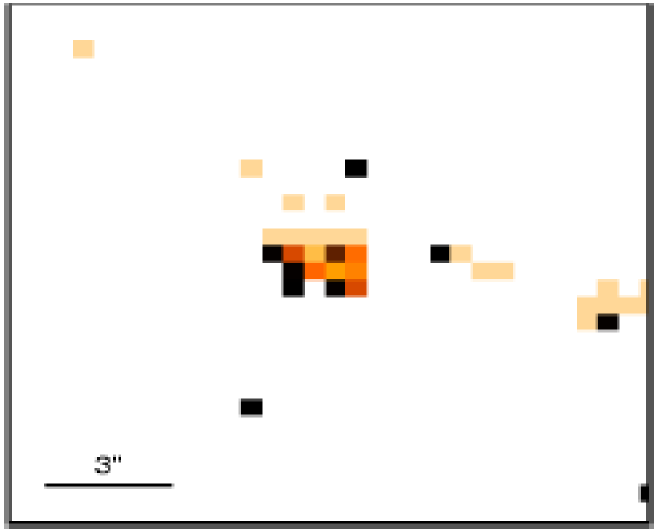
4. M 101, an Scd galaxy

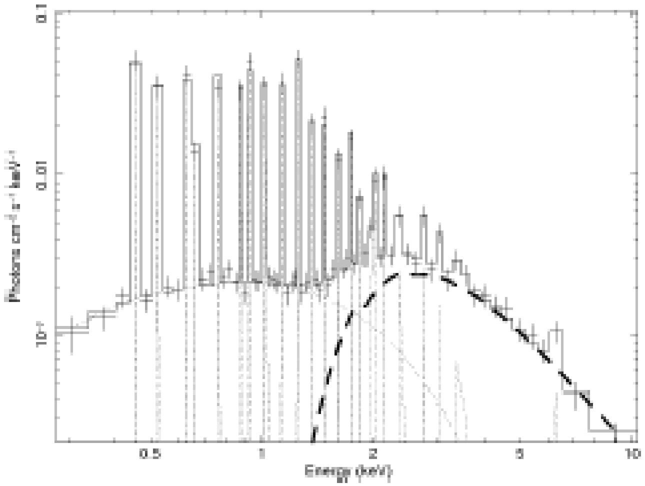
Ghosh, Mathur et al.

See also Satyapal et al; Shields et al; Peterson et al.

Chandra image

XMM spectrum



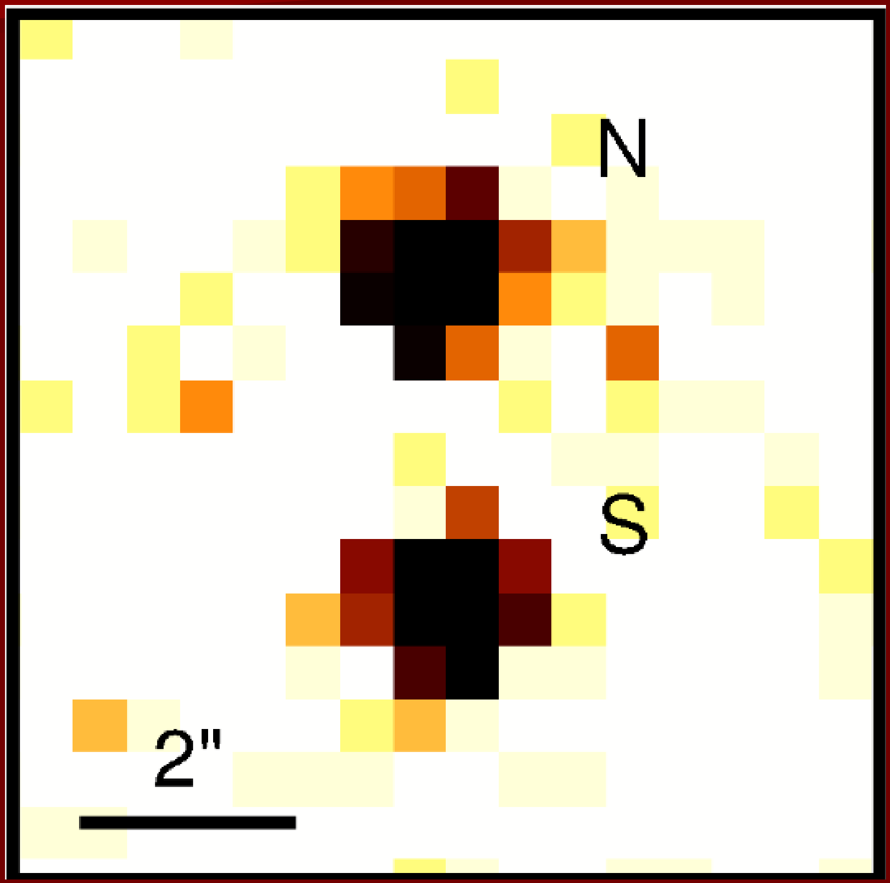


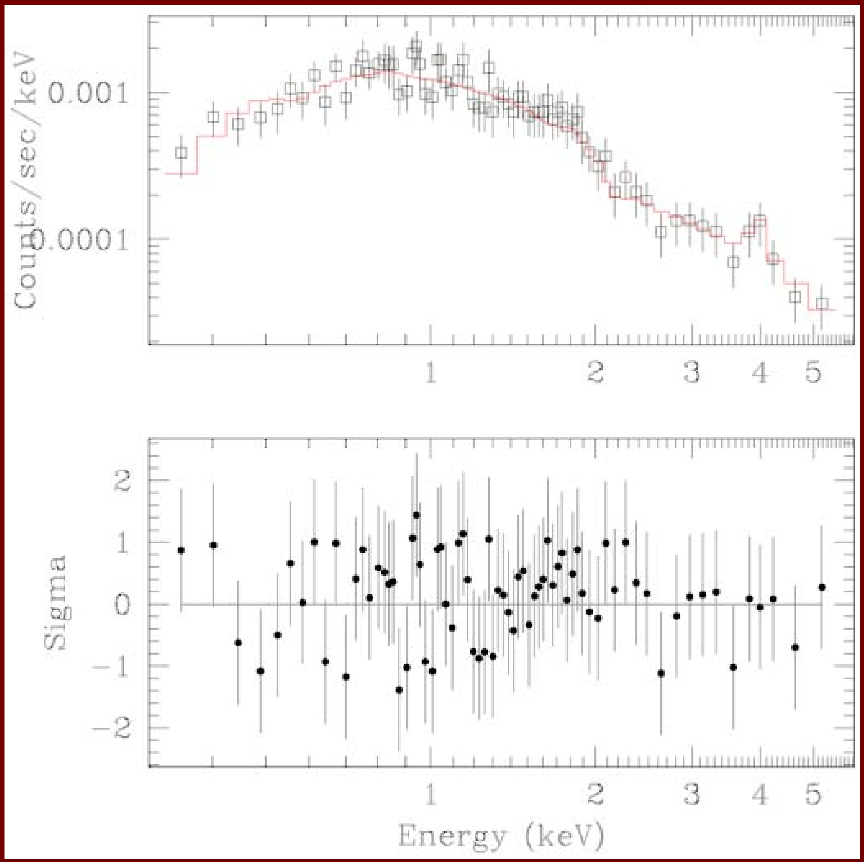
Unabsorbed luminosity
few x 10^42 erg/s

Araya et al 2011 Submitted

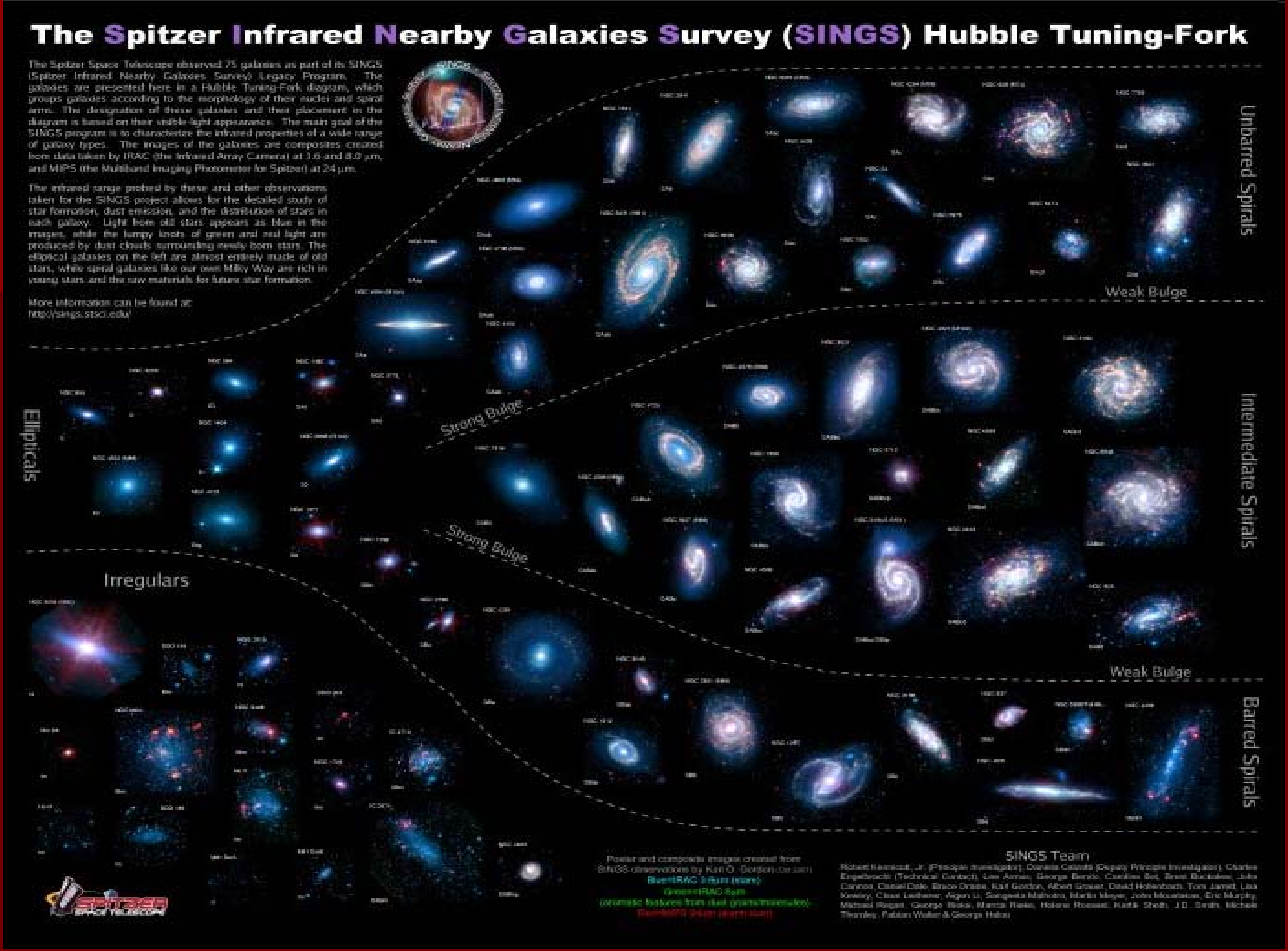
NGC 5457 (M101)

Scd, 7 Mpc, HII

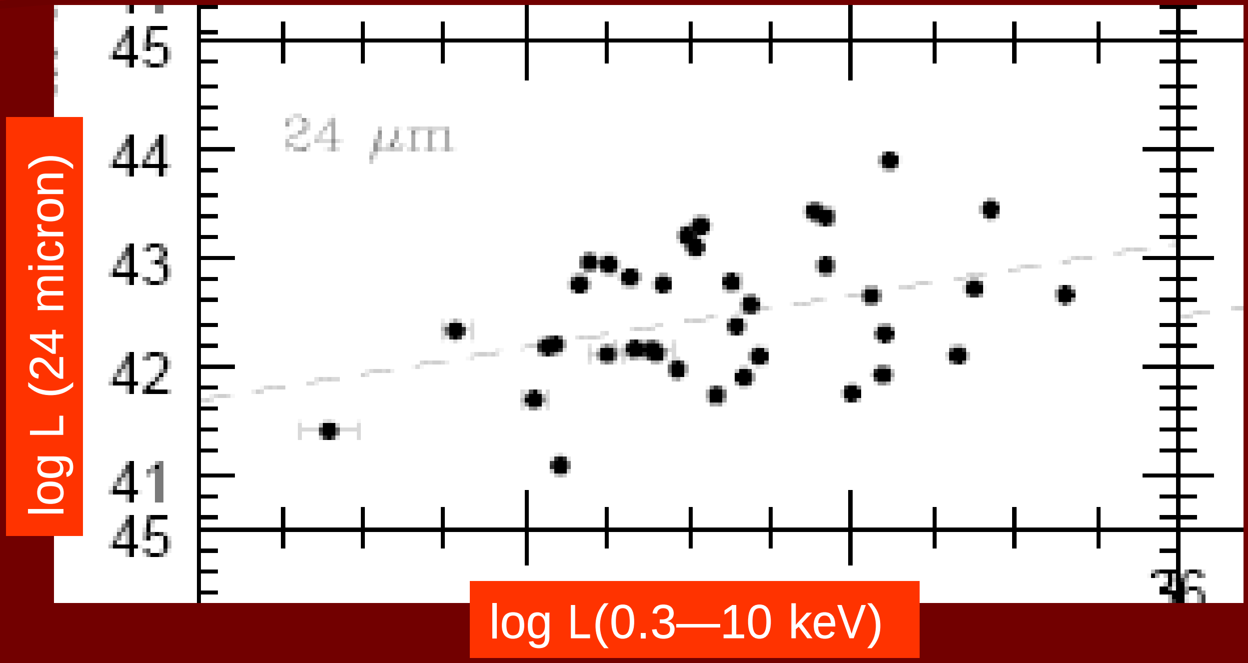




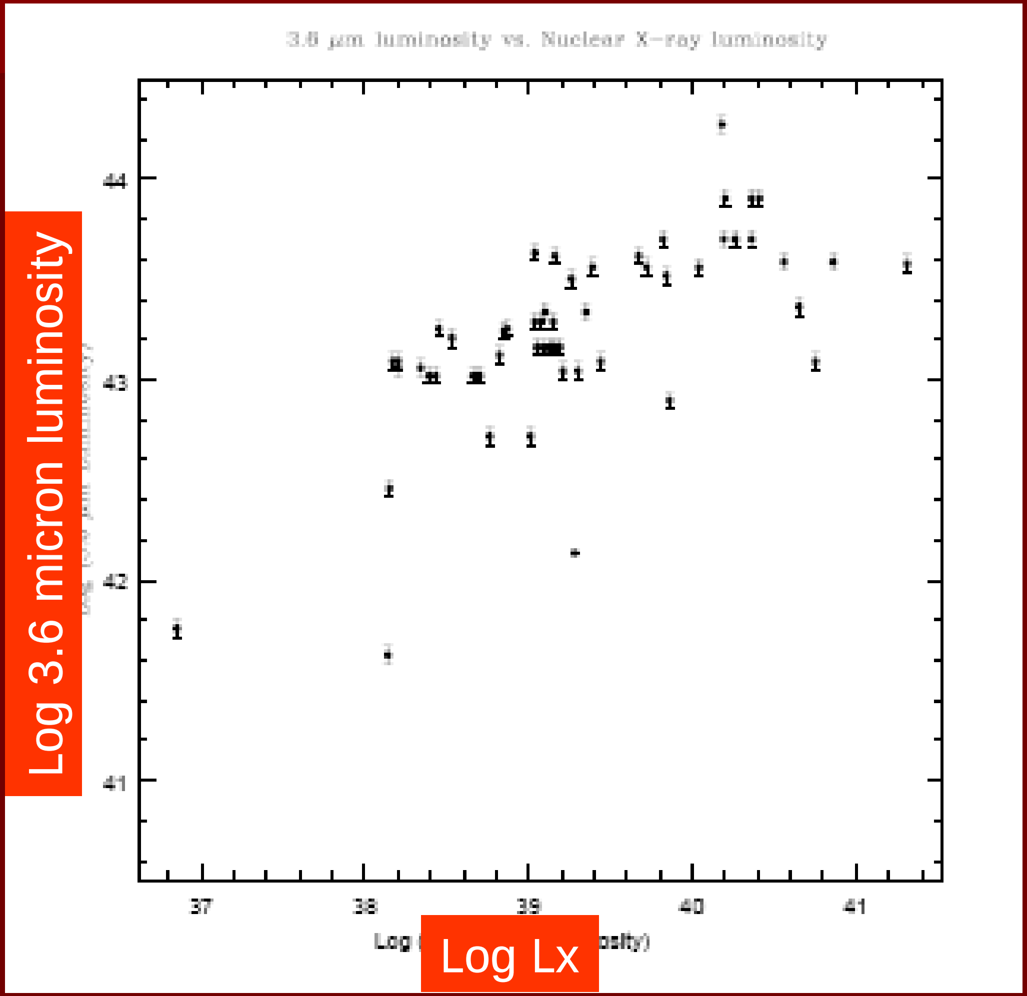
AGN activity – Star-formation


The Spitzer Infrared Nearby Galaxies Survey (SINGS) Hubble Tuning-Fork
The Spitzer Space Telescope observed 75 galaxies as part of its SINGS (Spitzer Infrared Nearby Galaxies Survey) Legacy Program. The galaxies are presented here in a Hubble Tuning-Fork diagram, which groups galaxies according to the morphology of their nuclei and spiral arms. The designation of these galaxies and their placement in the diagram is based on their visible-light appearance. The main goal of the SINGS program is to characterize the infrared properties of a wide range of galaxy types. The images of the galaxies are composites created from data taken by IRAC (the Infrared Array Camera) at 3.6 and 8.0 μm, and MIPS (the Multiband Imaging Photometer for Spitzer) at 24 μm.
The infrared range probed by these and other observations taken for the SINGS project allows for the detailed study of star formation, dust emission, and the distribution of stars in each galaxy. Light from old stars appears as blue in the images, while the lumpy knots of green and red light are produced by dust clouds surrounding newly born stars. The elliptical galaxies on the left are almost entirely made of old stars, while spiral galaxies like our own Milky Way are rich in young stars and the raw materials for future star formation.
More information can be found at:
http://sings.stsci.edu/
Unbarred Spirals
Weak Bulge
Strong Bulge
Ellipticals
Intermediate Spirals
Strong Bulge
Irregulars
Weak Bulge
Barred Spirals
SINGS Team

No clear correlation with star formation rate

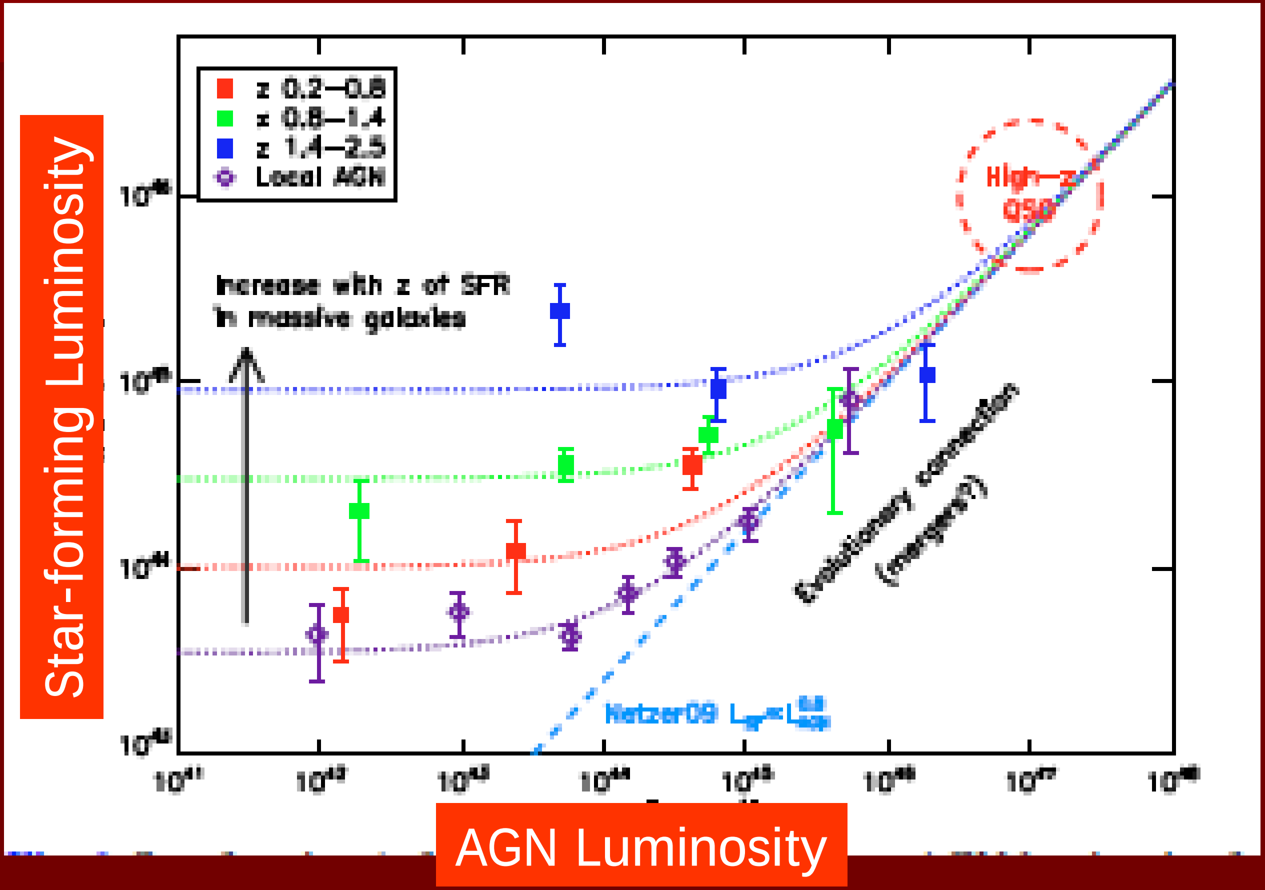


AGNs in SINGS galaxies



Grier, Mathur et al 2011

Hershel observations of GOODS

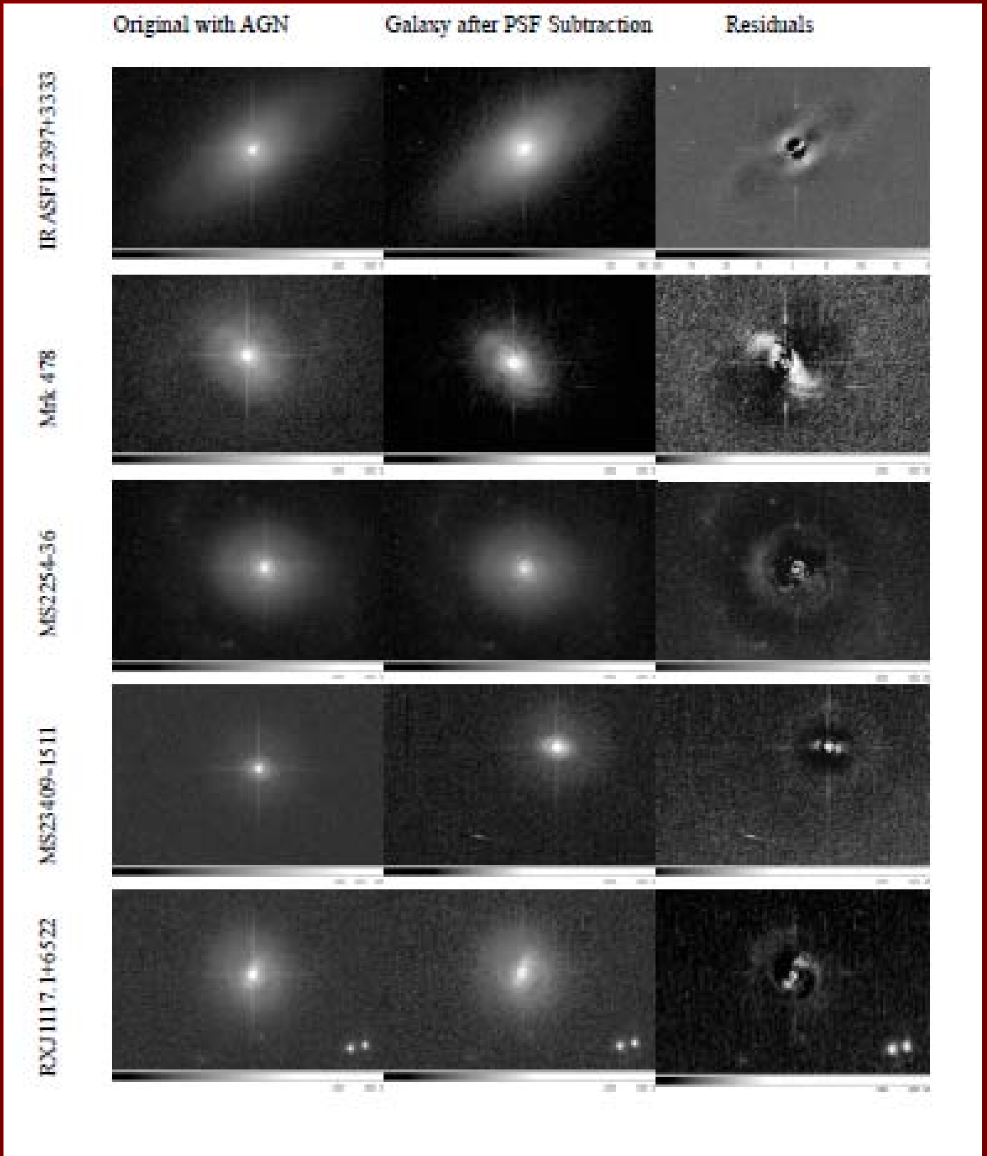


Shao, Lutz et al 2010

Classical bulges vs. Psuedobulges

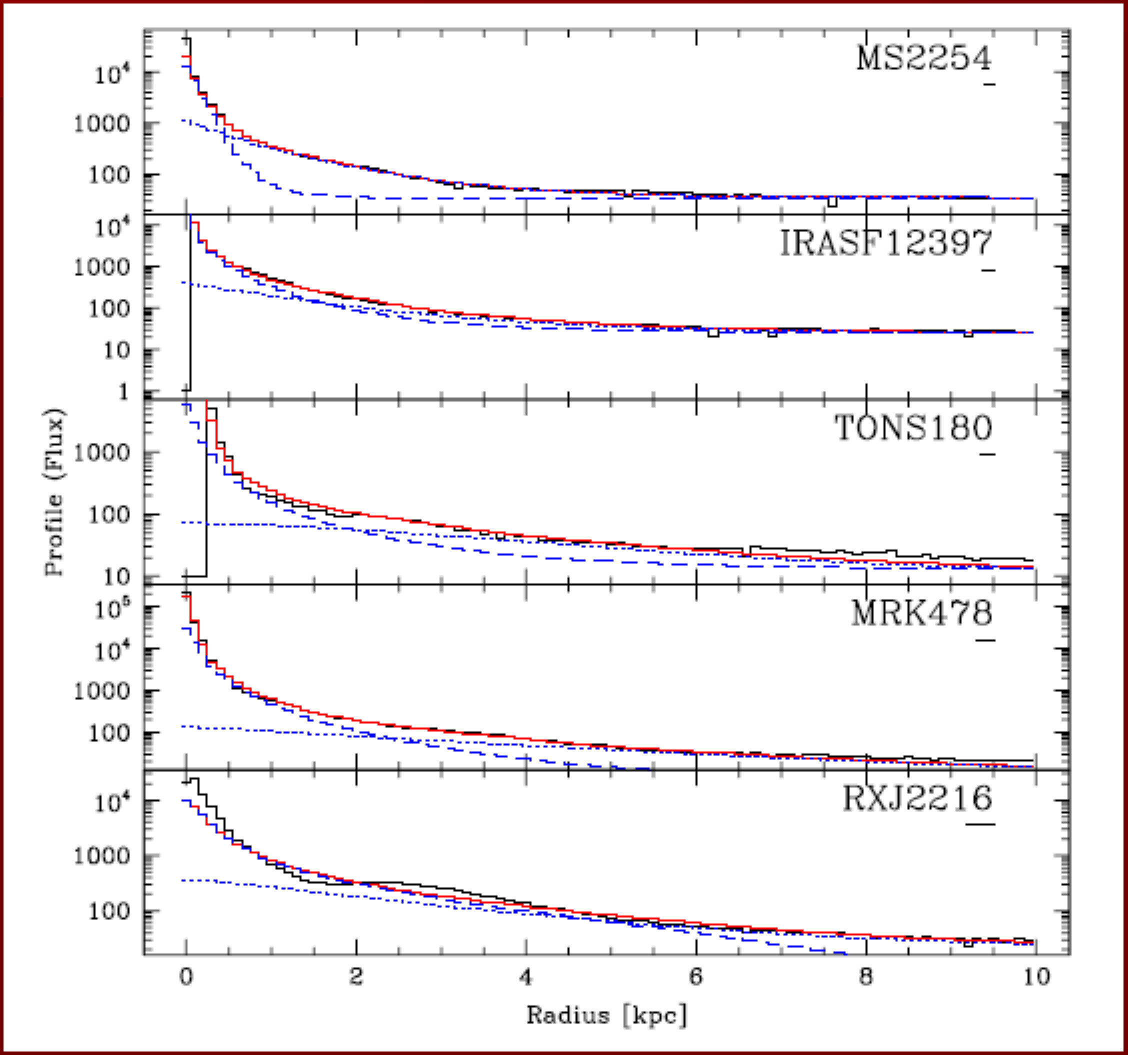
Classical bulges vs. Psuedobulges

HST/ACS observations of NLS1s

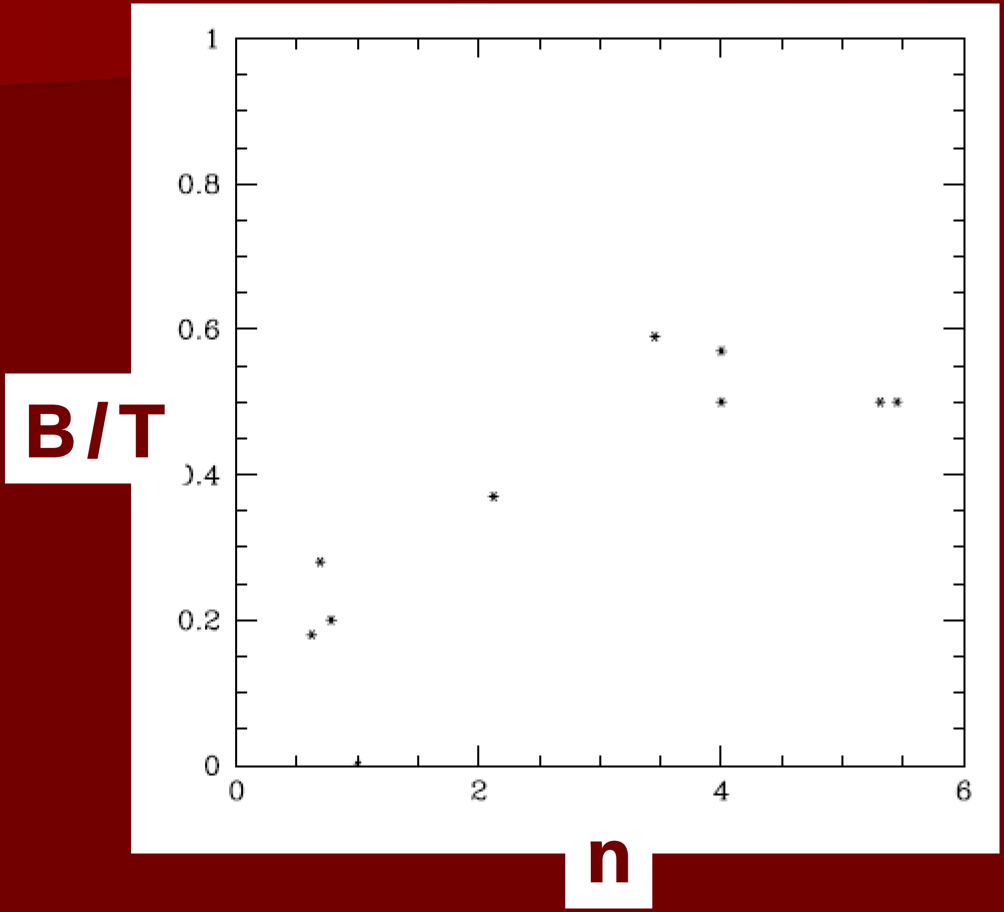


Mathur et al. 2011

Host galaxies have pseudobulges

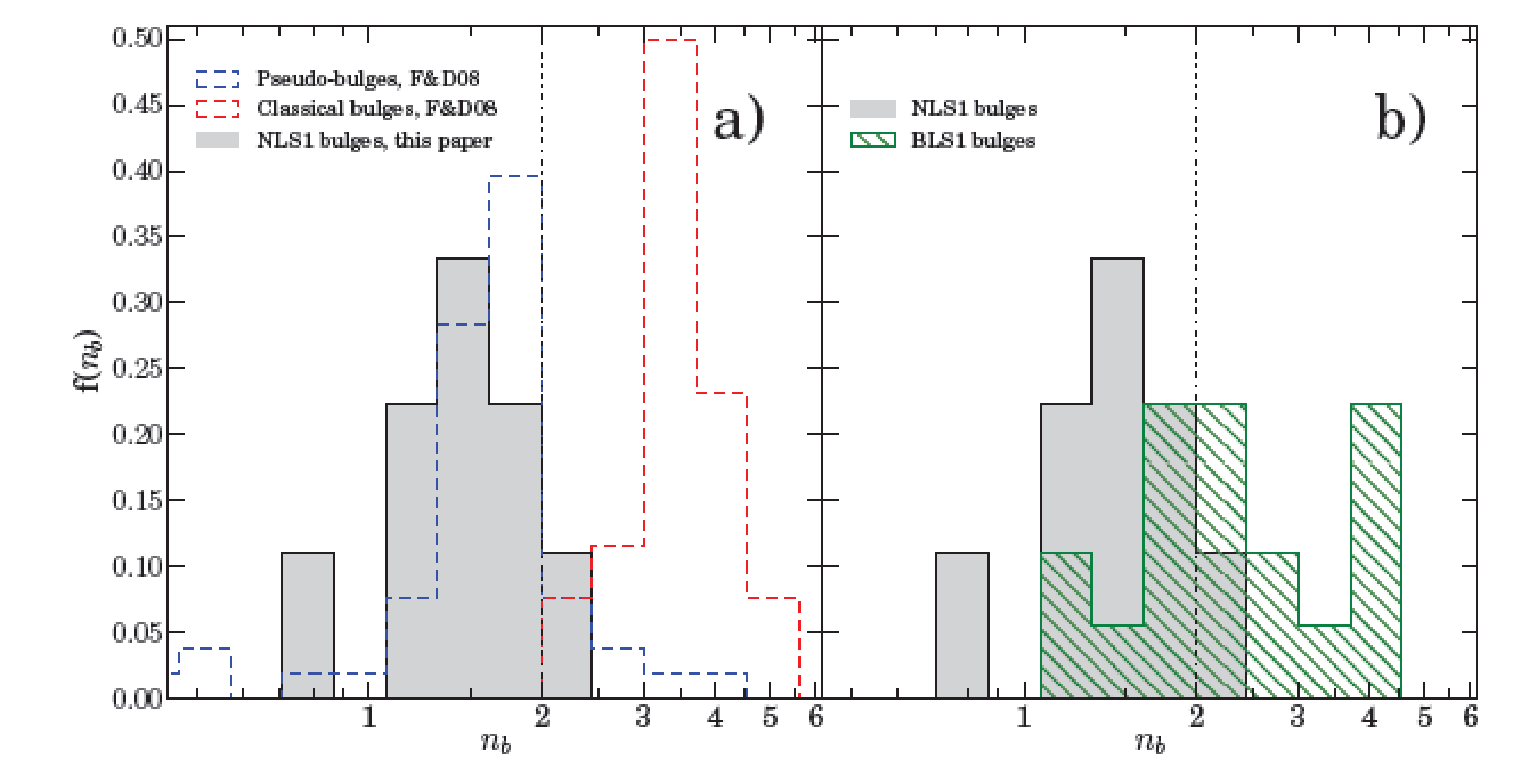


- Five out of ten galaxies have Sersic index n < about 2.2



B/T
n
1
0.8
0.6
0.4
0.2
0
0
2
4
6

NLS1s in Pseudobulges



Orban de Xivry et al 2011

Pseudobulges host BHs

- Pseudobulges do not follow the fundamental plane of galaxies

- **Pseudobulges form & grow by secular processes**

....and these are not pathological cases

- About 2/3 of all bright spirals host pseudobulges ($n \leq 2$) ($B/T \leq 0.2$)
- About 65% of these also host a bar

Weinzerl et al 2009

....and these are not pathological cases

- About 2/3 of all bright spirals host pseudobulges ($n \leq 2$) ($B/T \leq 0.2$)
- About 65% of these also host a bar

Weinzerl et al 2009

Several nails in the present paradigm

- Bulge crucial for BH formation & evolution: NO, we discovered BHs in bulge-less galaxies
- BH—bulge correlations tight: NO, we observe significant scatter/ offset
- Correlation of AGN activity with star formation rate: NO, not seen in local galaxies NOR at high redshift

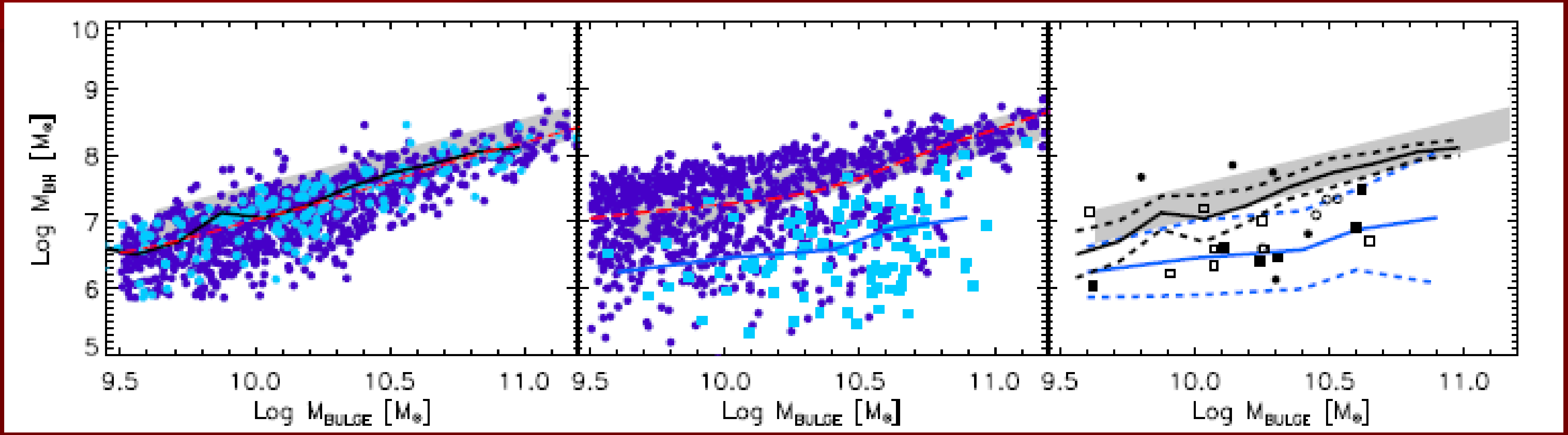
- Feedback regulates BH/Bulge growth: NO, measured feedback orders of magnitude smaller.
- Hierarchical growth is the driver: NO, pseudobulges host AGNs; secular processes important

Conclusions

- All galaxies host a supermassive BH
- Bigger galaxies, bigger BHs
- Total mass, not just the bulge mass
- Non-causal relation
- The current paradigm applicable only to luminous quasars
- Secular processes dominate

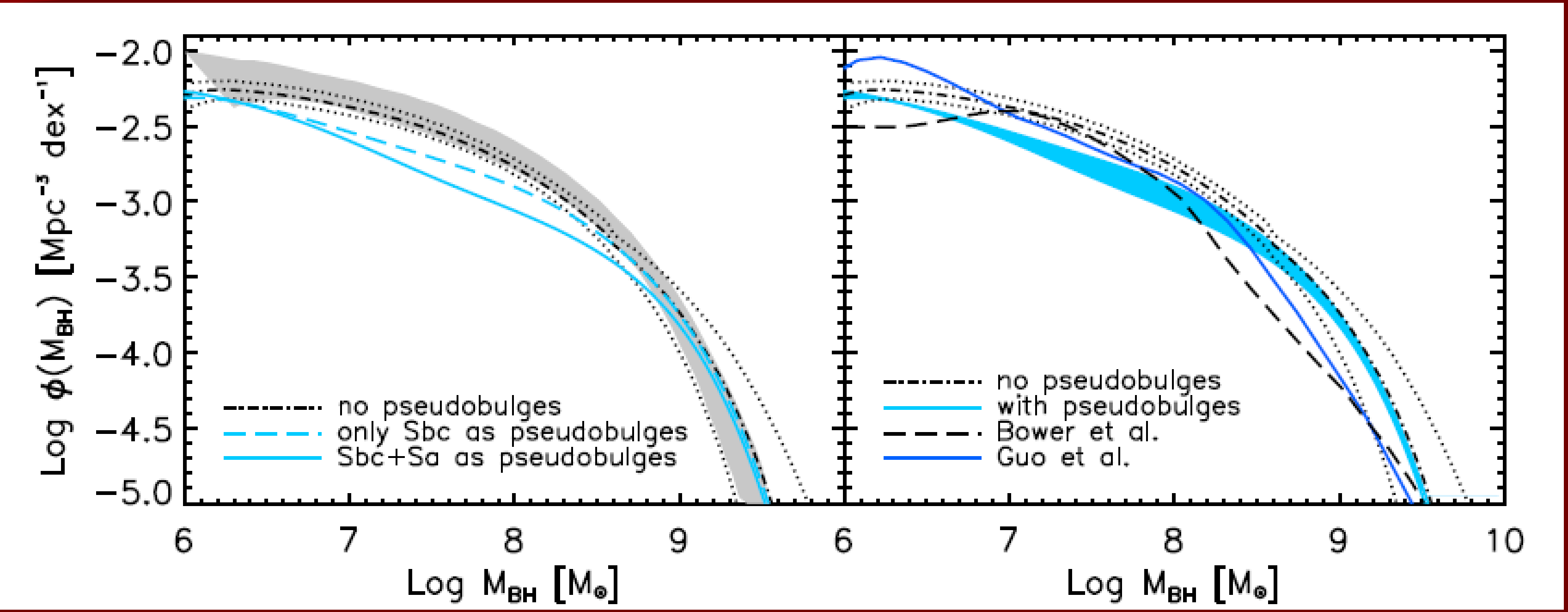
(fly-bys, gas rich mergers, DM halo mass........)

Semi-analytic models



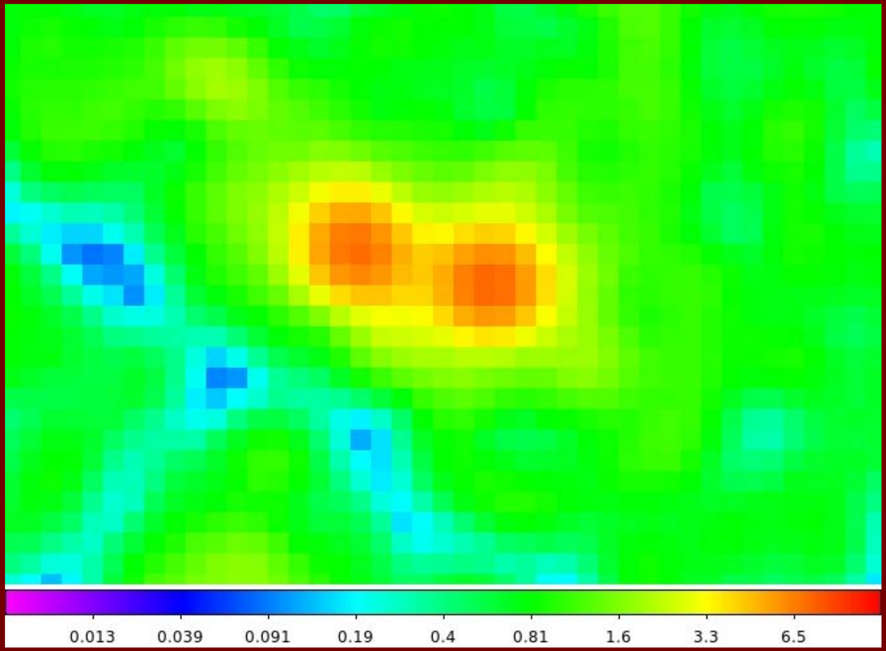
Shankar et al. Submitted.

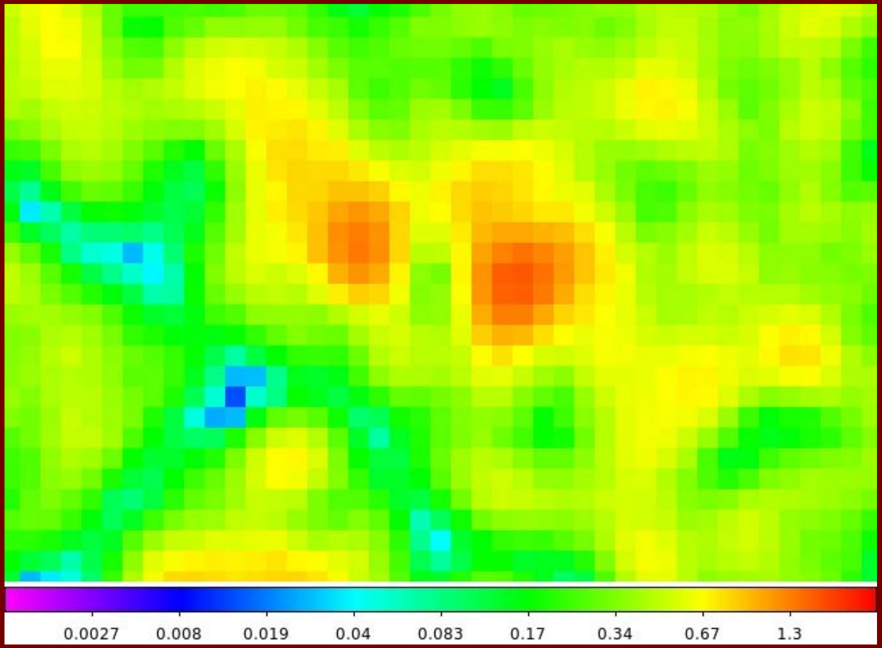
Pseudobulges and the local BH mass density



Shankar et al. 2011

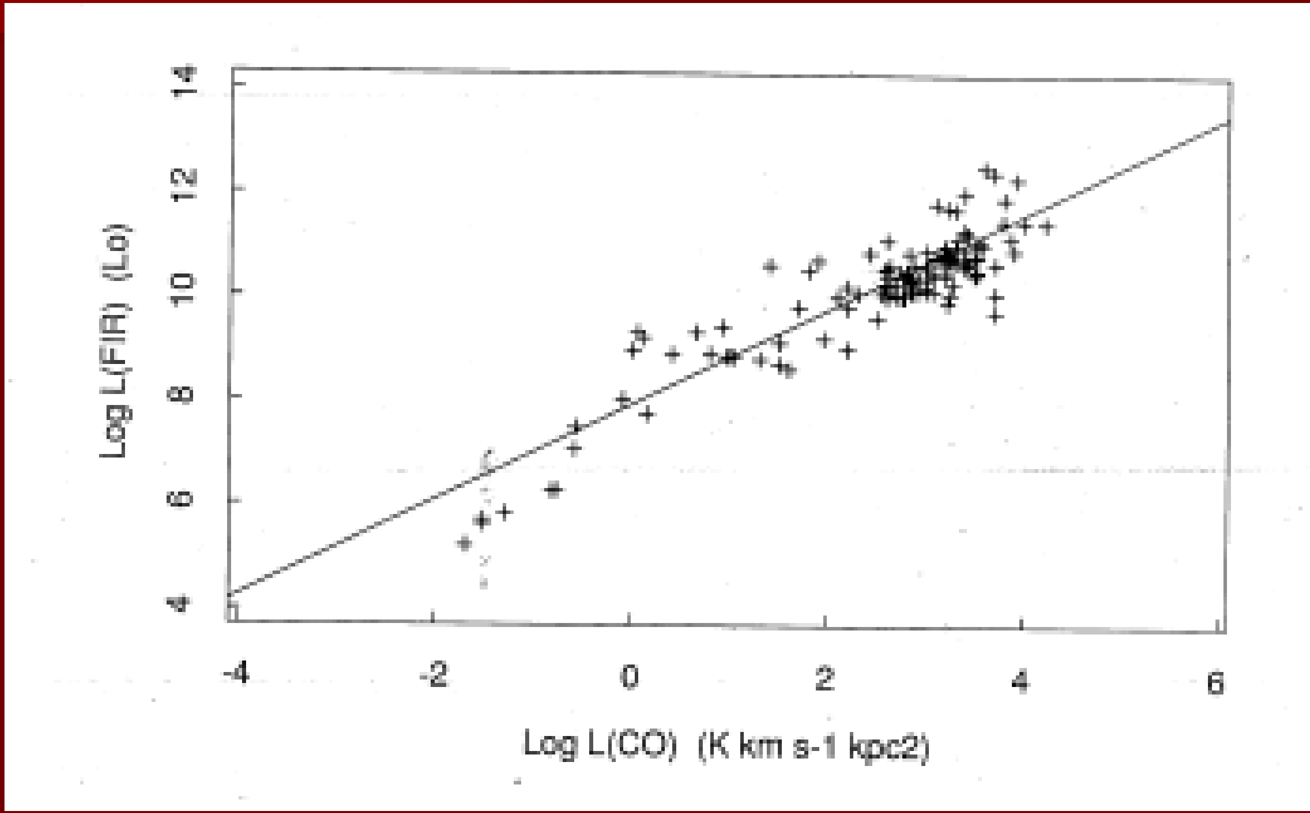
Double BHs



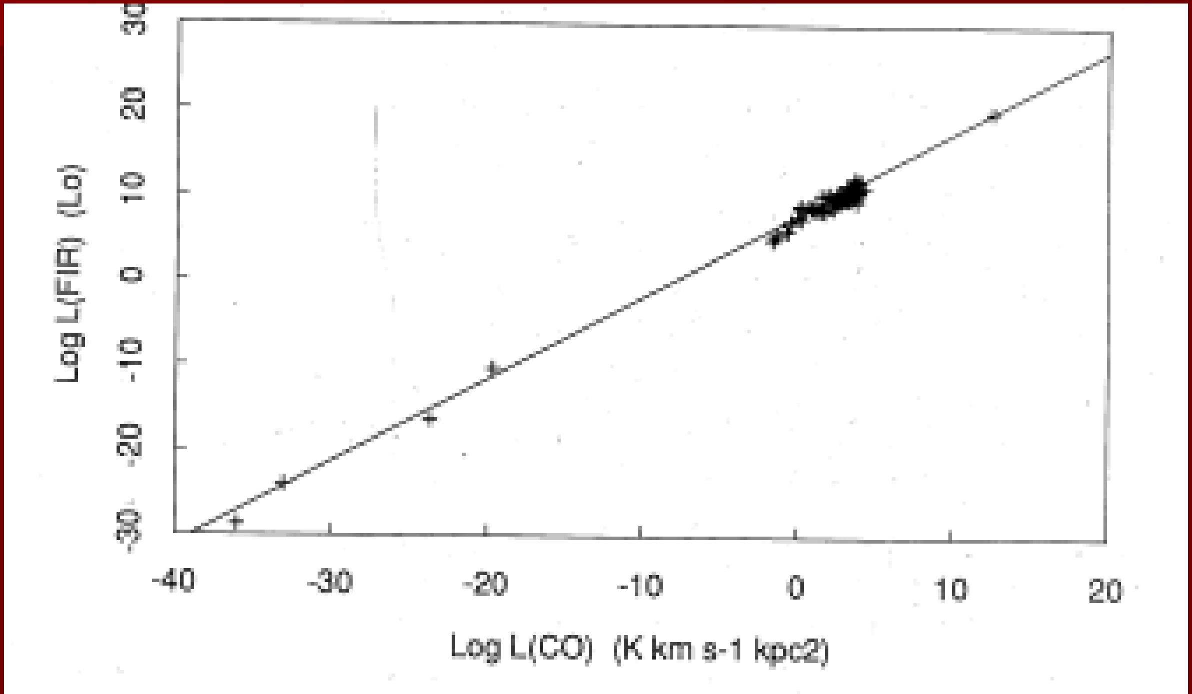


Stay tuned .....

A strong correlation......

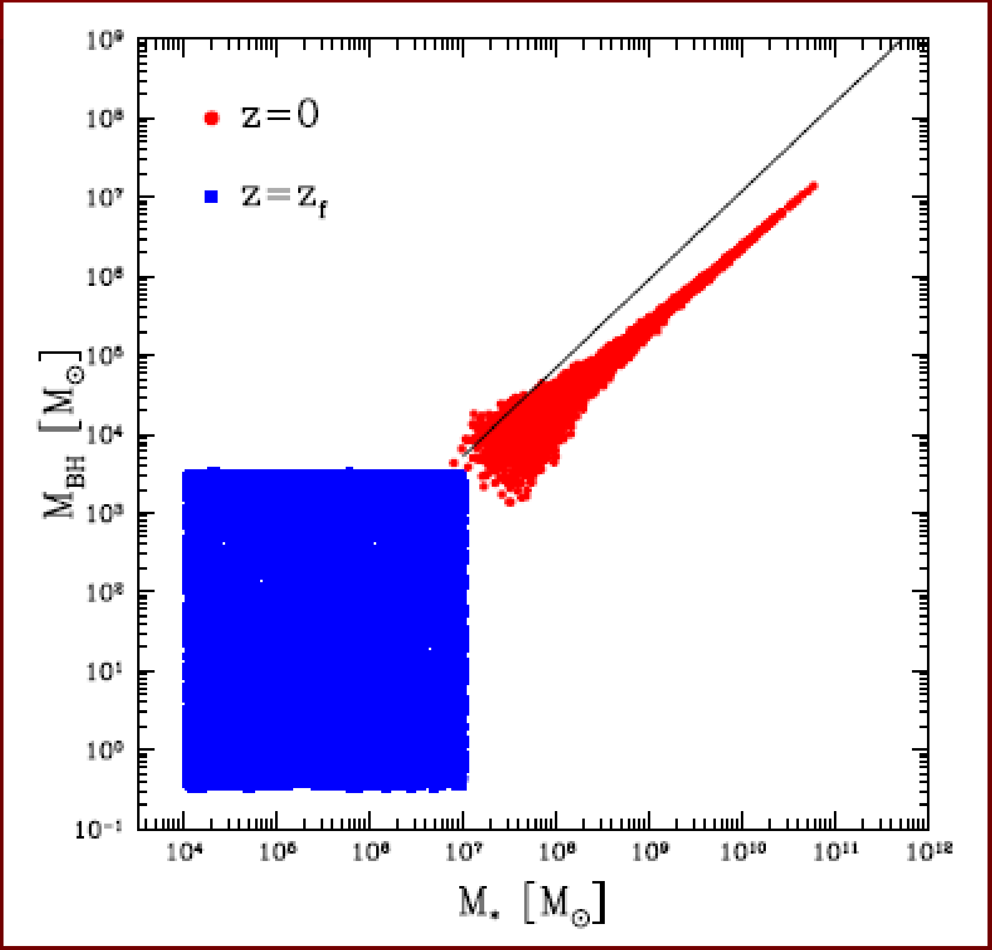


……does not mean causation



Kennicutt 1990

Non-causal origin of the black hole-- galaxy scaling relations



Janhke & Maccio 2010