Cosmic Evolution of NLS1s and the Growth of their Black Holes

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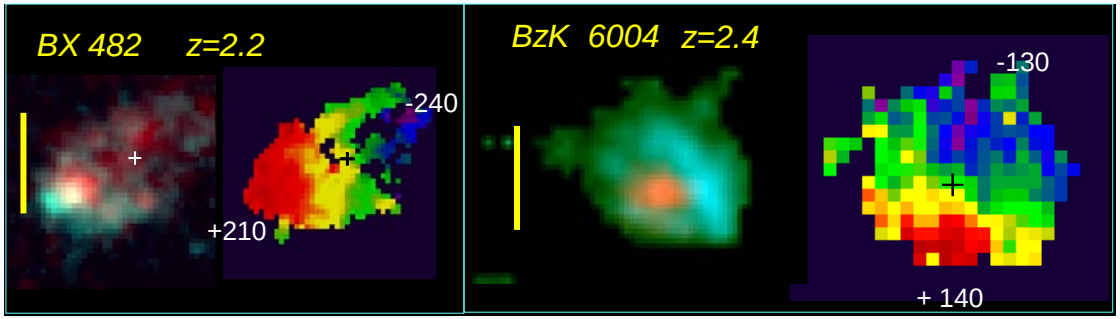
The bulges and BHs of NLS1s have grown purely through secular processes without mergers.

- Is such a population of galaxies expected?
- How long have their bulges & black holes been growing?
- Are their black holes in a special phase of growth?
- Do NLS1s lie on the M_{BH}-σ relation?

A population of galaxies that have evolved without mergers

Genzel+ 08:
can see bulges starting to grow at z ~ 2



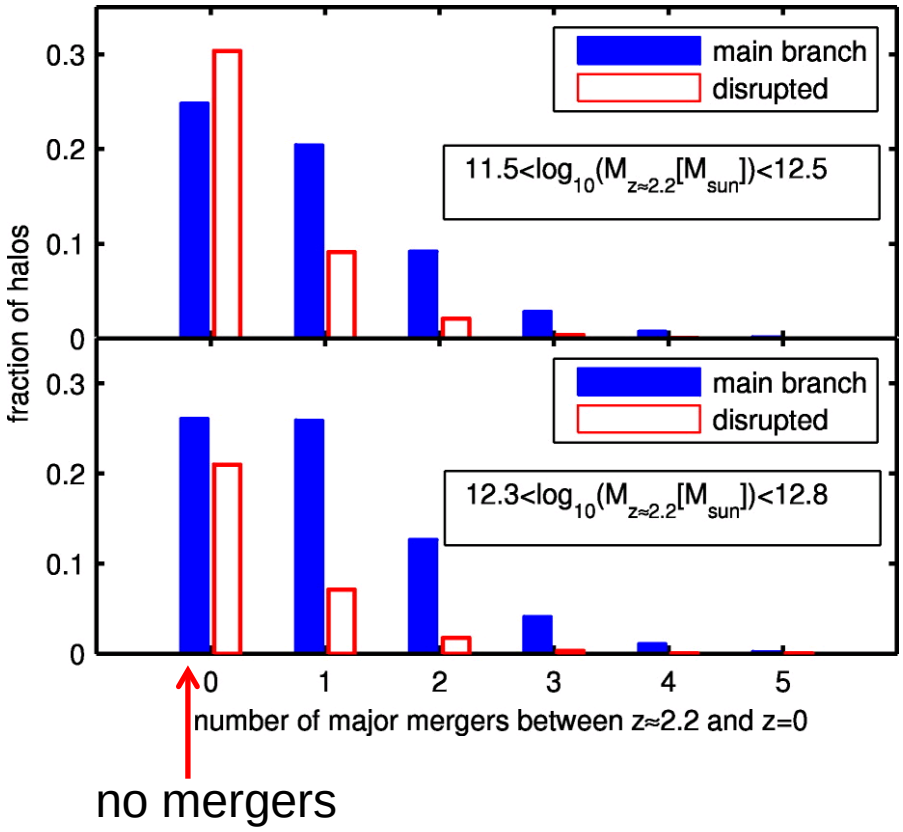
Genel+ 08:
fate of DM halos with masses
$11.5 < \log M_{z=2.2} < 12.8$ from z = 2.2 to z = 0
based on Millenium Simulation

~40% are subsumed into a larger halo

~35% undergo a major merger

~25% experience no major mergers

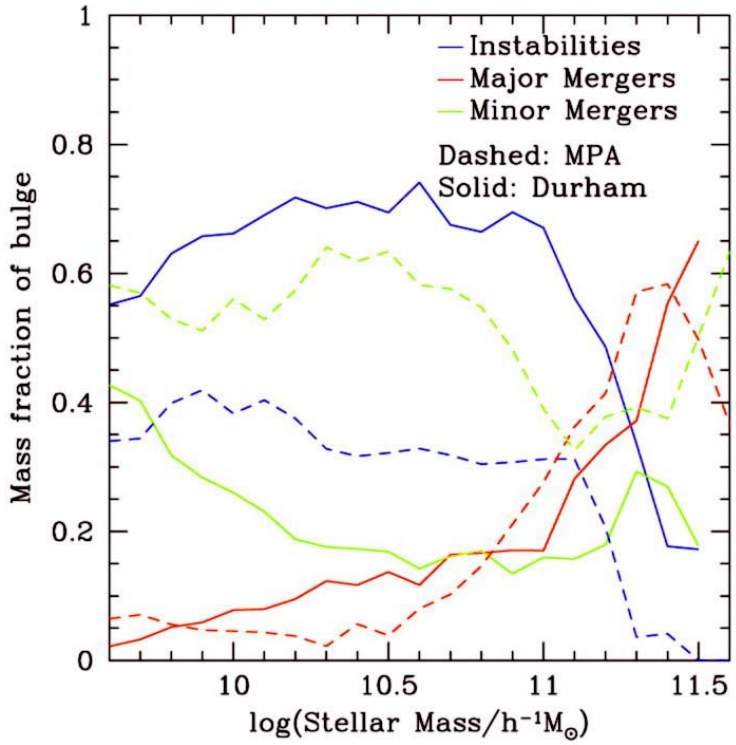
Genel+ 10:
minor mergers (mass fraction < 1/10) and smooth accretion account for ~70% of DM halo growth



A population of galaxies that have evolved without mergers

Parry+ 09

- Major mergers are *not* the primary mechanism by which most spiral bulges assemble their mass.
- The overwhelming majority of spirals never experience a major merger
- Most spiral bulges acquire their stellar mass through minor mergers or disc instabilities.



Questions and Answers

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  Yes – half or more of spiral bulges grow without major mergers

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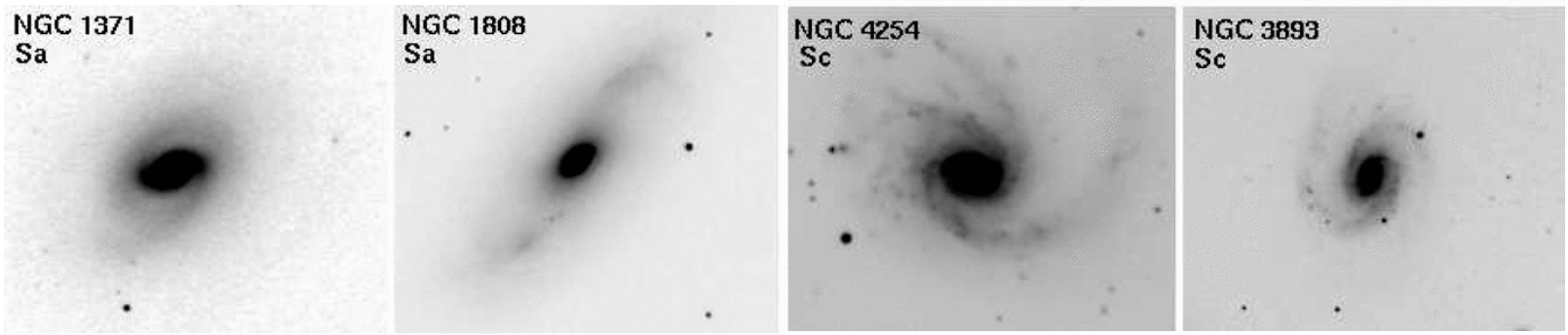
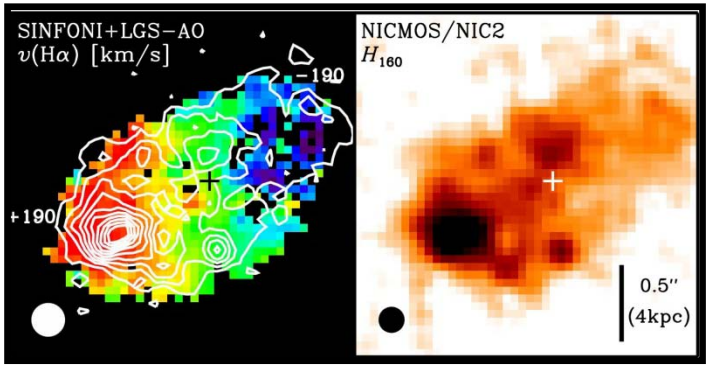
When did the Hubble Sequence form?

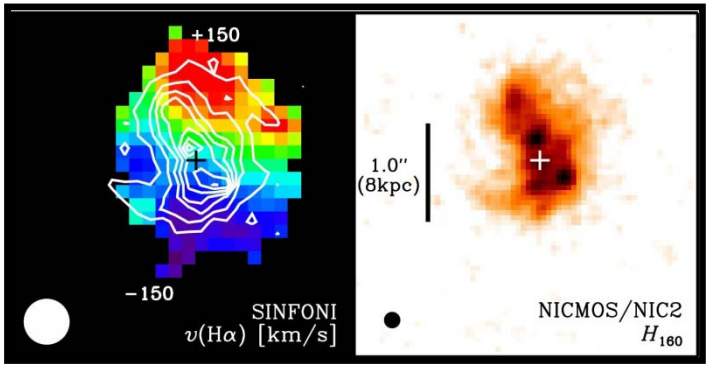
Local disks usually have prominent bulges and smooth spiral arms



Weinzirl+ 09

Disk galaxies at z~2 are turbulent and clumpy, and often lack a bulge





Förster Schreiber+ 06, 09, 10

When did the Hubble Sequence form?

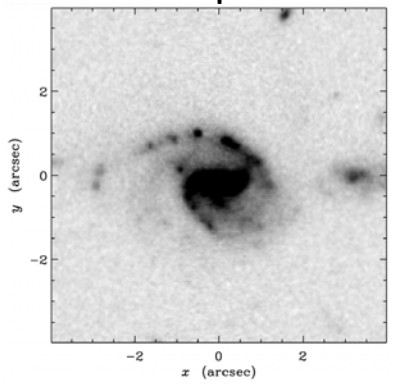
Disk galaxies at z~1 begin to show characteristics of the local Hubble Sequence

Van den Bergh+ 00, Kajisawa+ 01 — HDF North

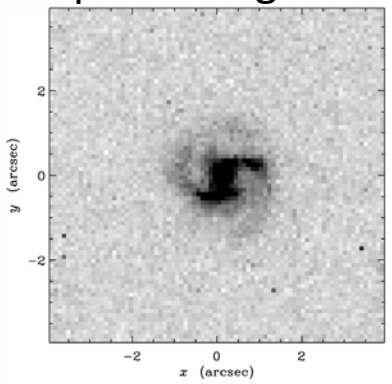
Conselice+ 04 — GOODS South

Oesch+ 10 — COSMOS

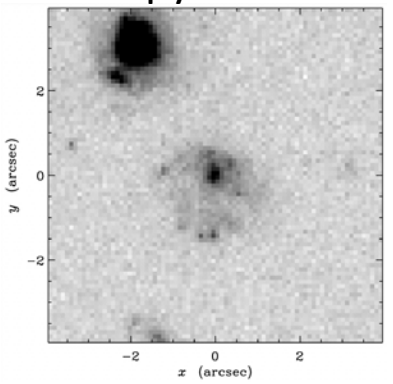
z=0.32: highest z barred spiral



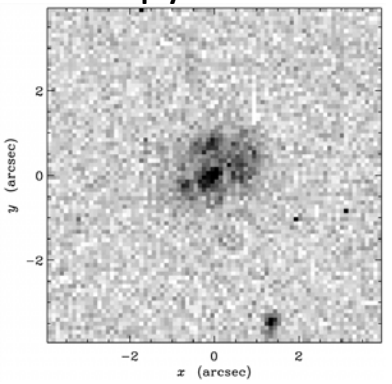
z=0.90: rare spiral at high z



z=0.95: clumpy disk

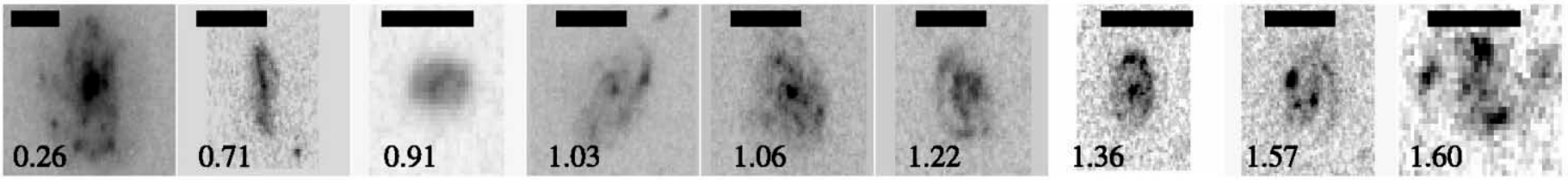


z=1.02: clumpy disk



Van den Bergh+ 00

'Luminous Diffuse Objects': proto-disks without prominent bulges

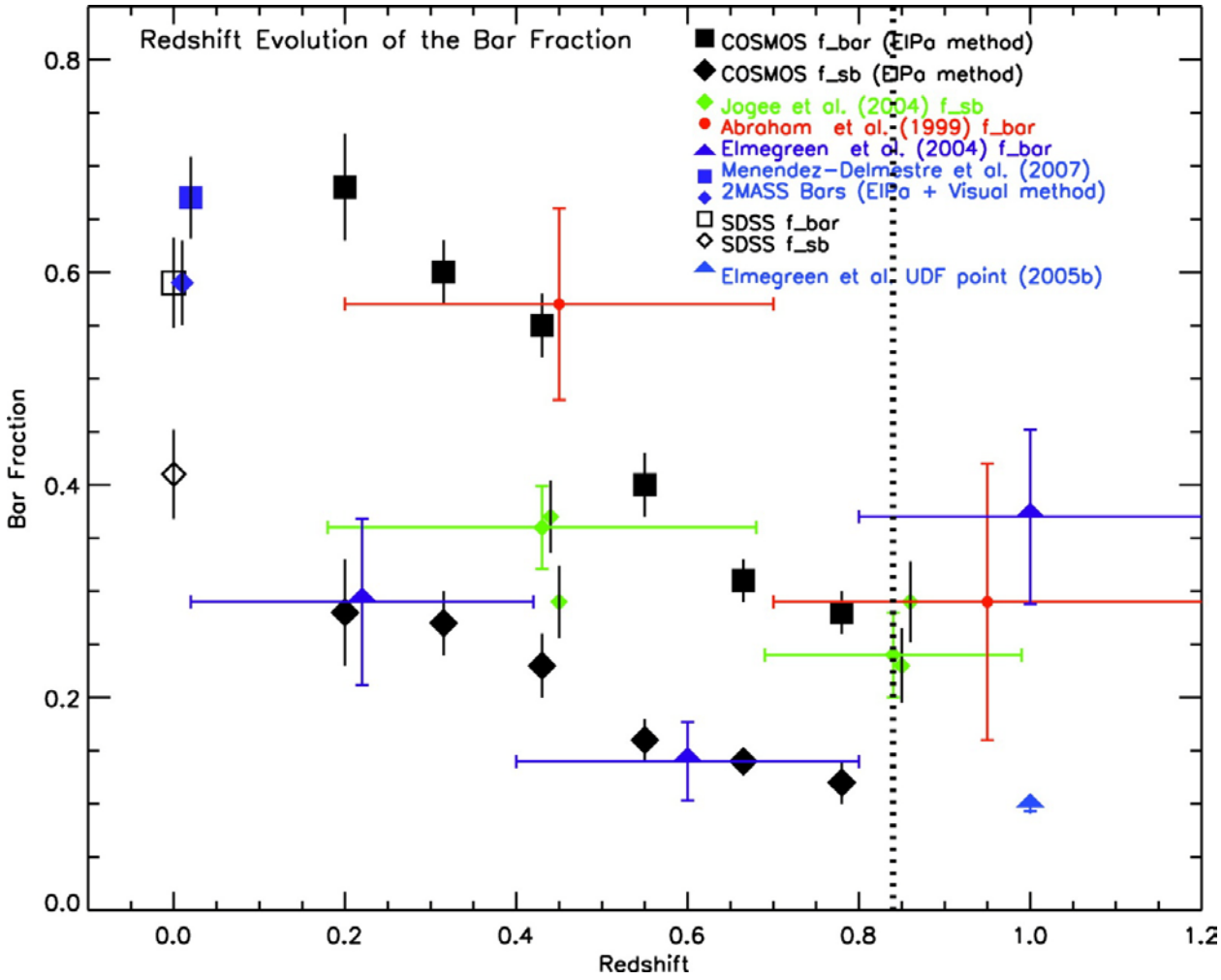


Conselice+ 04

When did bars become common?

- Fraction of bars and strong bars decreases with redshift
- Rate of decreases is slower for massive, luminous spirals
- Bars can be traced to z~1

Sheth+ 08
from COSMOS



Questions and Answers

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- Is such a population of galaxies expected?

  Yes – half or more of spiral bulges grow without major mergers

- How long have their bulges (& black holes) been growing?

  Since z~1, when Hubble sequence was in place and bars became common

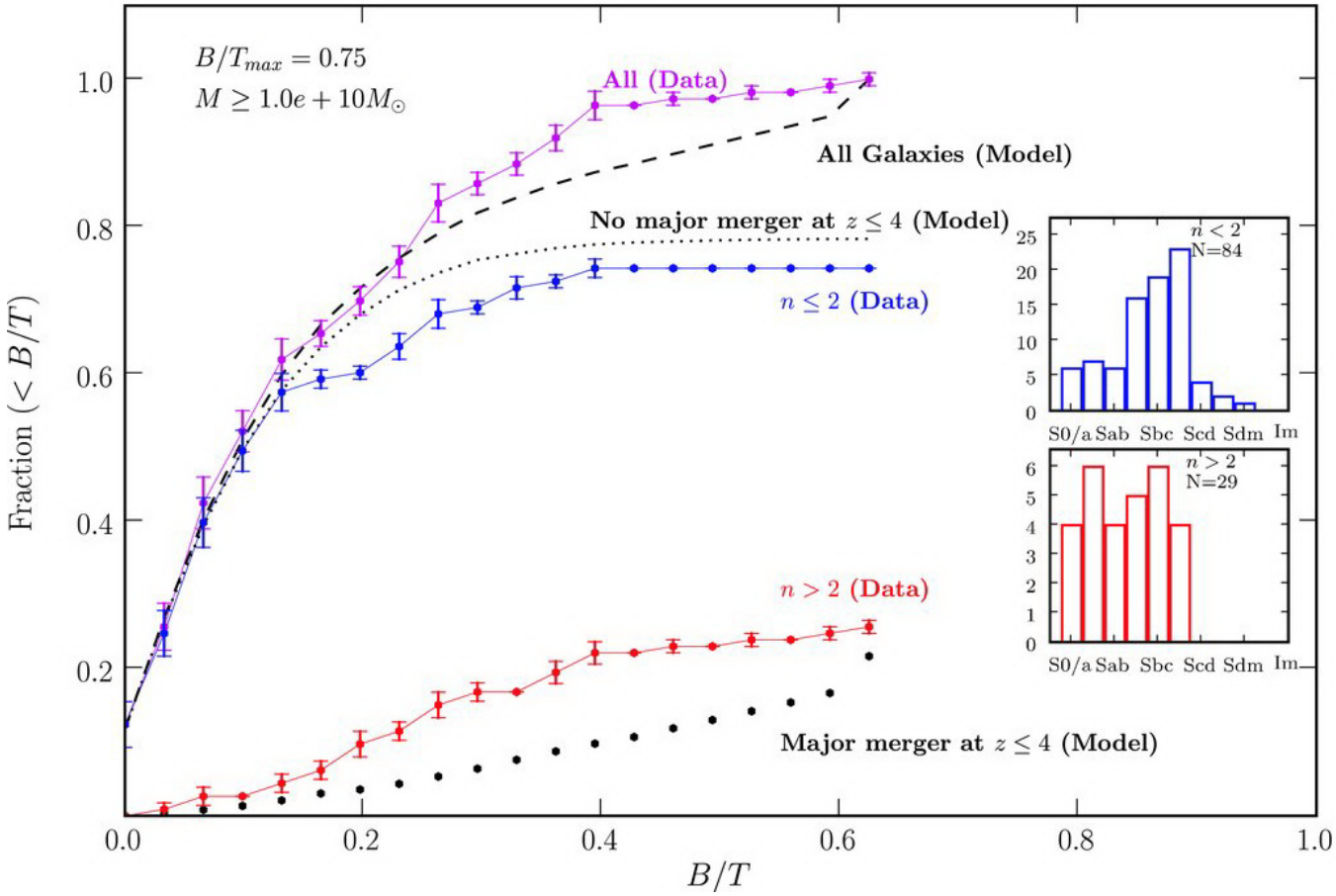
- Are their black holes in a special phase of growth?

- Do NLS1s lie on the M_{BH}-σ relation?

What fraction of local spirals are like NLS1 hosts?

Weinzirl+ 09

- Bulges built via major mergers fail to account for the bulges present in ~ 66% of high mass spirals.
- Most of these present-day B/T<0.2 bulges are likely to have been built by minor mergers and/or secular processes



How common are NLS1s? What is their duty cycle?

Osterbrock 88, Williams+ 02, Crenshaw+ 03, Zhou+ 06

- ~15% of Seyfert 1s are NLS1
- probably this fraction is also applicable to Seyfert 2s;
  & perhaps also intermediate types in which AGN is weak or obscured.

Ho 08

- essentially all local galaxies have detectable nuclear emission lines
- ~11% are Seyferts and ~43% can be considered AGN

➢ ***up to 2-6% of local galaxies could be (similar to) NLS1s***

Weinzirl+ 09

- about 2/3 of local disk galaxies are similar to NLS1 hosts

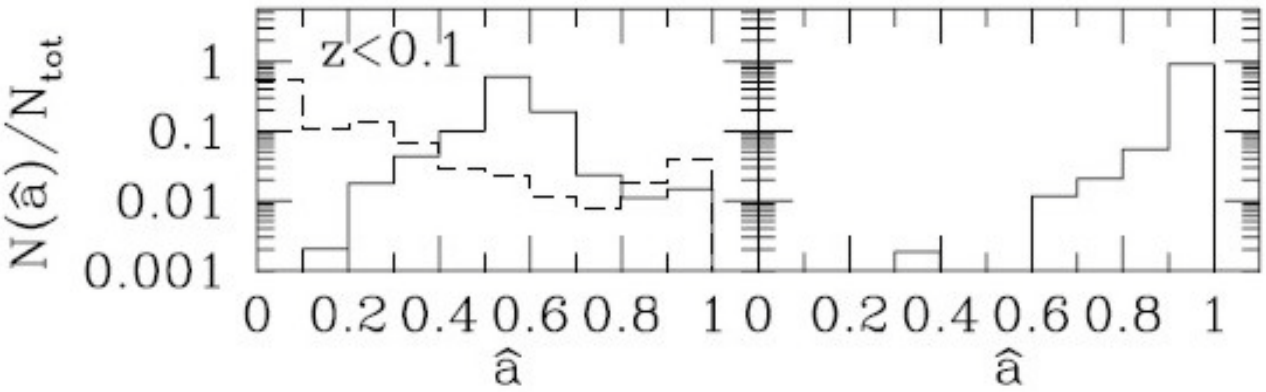
➢ ***the duty cycle is ~ 3-10%***

Radiative Efficiency & Black Hole Spin

Volonteri+ 05

- Major mergers increase BH spin; many minor mergers spins BHs down
- These effects cancel out in BH growth via mergers
- Gas accretion from a thin disk spins BHs up:

  70% of BHs are maximally rotating and have radiative efficiencies approaching 30%



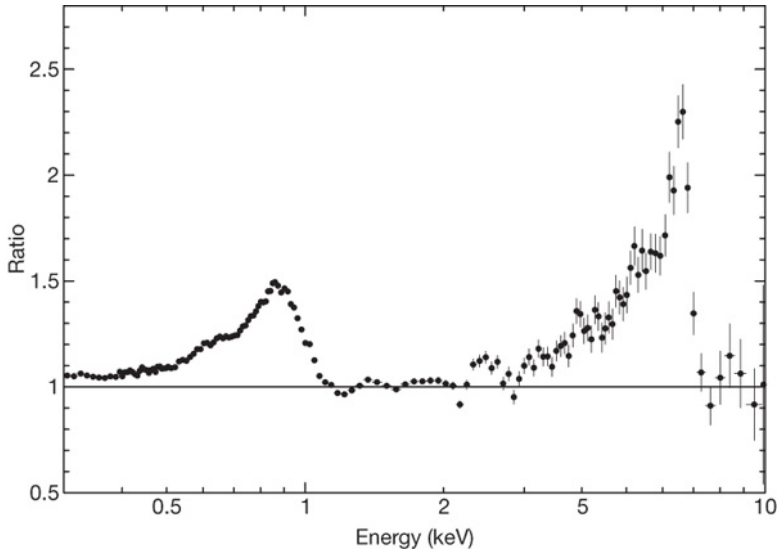
BH spin for coalescences (left) & with accretion (right)

This implies the BHs of NLS1s should have high spin

Black Hole Spin: Observational Evidence?

Fabian+ 09

- relativistic Fe lines in NLS1 1H 0707-495
- continuum/line reverberation lag



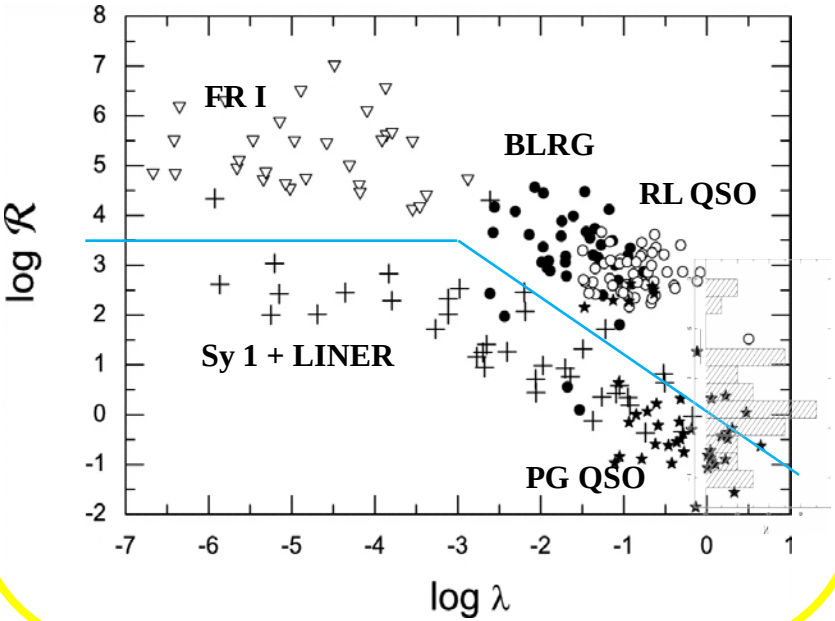
- need large number statistics, but first indications are positive
- 12 of 15 NLS1s in literature have a>0.6 (Gondoin+02, Brenneman+07, Miniutti+09, Fabian+09, Ai+10)

Vasudevan+ poster

highest T of accretion disk depends on inner radius, related to BH spin

Sikora+ 07

speculate RQ/RL depends on BH spin; *R* for NLS1s from Komossa+ 06



Past Black Hole Growth

look-back time to z=1: t=7.7 Gyr
duty cycle for NLS1s: δ=3-10%

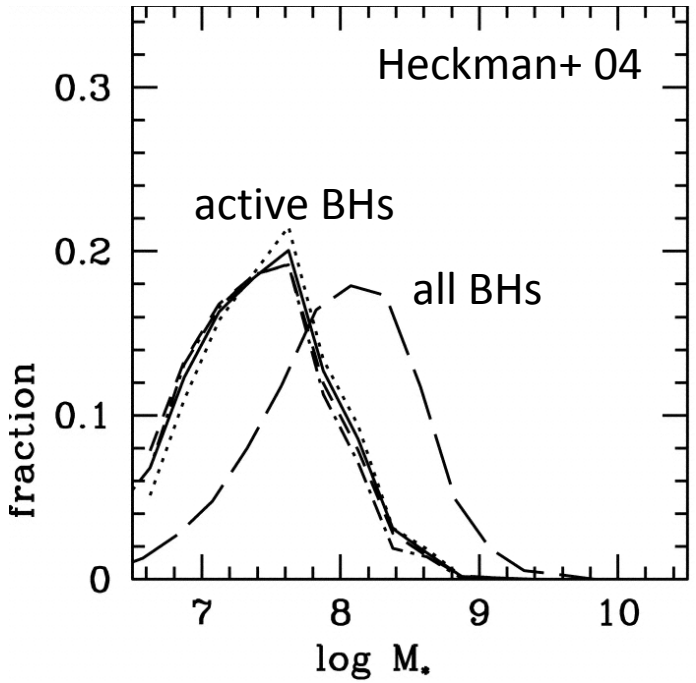
} BHs have actively accreted for tδ=230-770 Myr

$$M_{BH}(t) = M_{seed} \exp\left(\frac{1-\epsilon}{\epsilon}\frac{t\delta}{t_E}\right)$$

Assume BHs: - are accreting at Eddington rate, t_E ~ 440 Myr
- are spinning fast & so have high radiative efficiency, ϵ ~ 0.2
- have seed mass 10^4 M_{sun}

Current mass will be 10^5-10^7 M_{sun}

- Enough time for BHs to grow from seeds since z=1
- Expect low BH masses *because* they are radiatively efficient (or have low duty cycle)
- Can also grow some BHs of 'normal' mass
- Conflict between observational and astrophysical definitions:
  NLS1s are only a subset of the galaxies whose BHs have grown *purely* through secular processes



Future Black Hole Growth

NLS1s will grow more massive BHs and will look like BLS1s…
How long will it take to grow by a factor 10?

for $\epsilon \sim 0.2$, this requires 250 Myr of active accretion
for duty cycle 3-10%, this will take 2.5-8 Gyr

- NLS1s are only 1/2 to 2/3 of the way to becoming BLS1s
- NLS1s are not in a special phase of BH growth

Note: where NLS1s are on M-sigma plane and how they evolve across it depends on coupling of BH growth and bulge growth.

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  Not if one takes into account duty cycle & radiative efficiency

  (Masses are typically low because BHs are spinning rapidly, and they are spinning rapidly because they have grown through secular evolution)

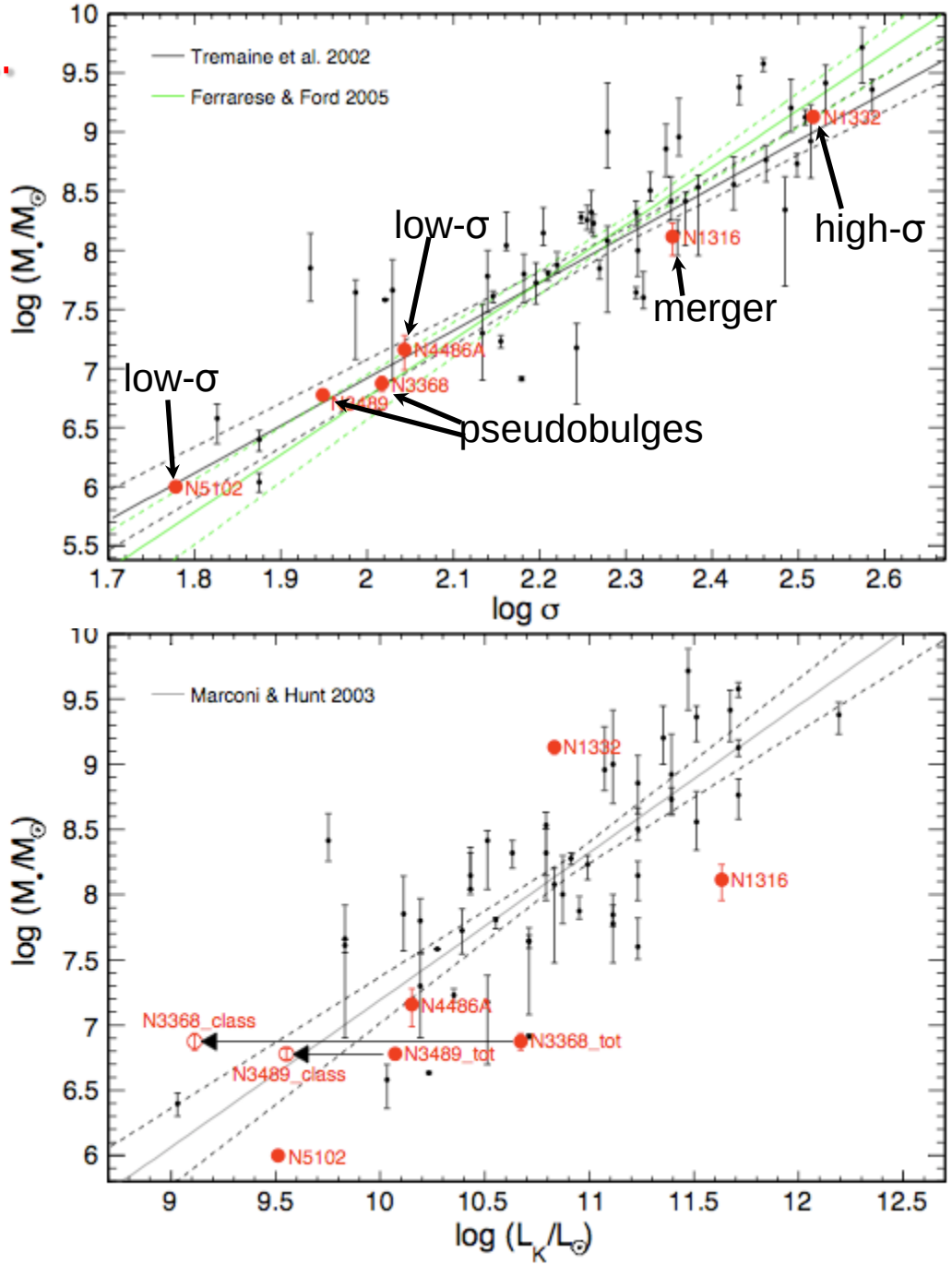
- Do NLS1s lie on the M_{BH}-σ relation?

It's not quite so simple...

Nowak+ 07, 08, 10

- integral field spectroscopy with adaptive optics
- spatially resolved stellar kinematics
- M_{BH} & σ
- Many bulges are composite:

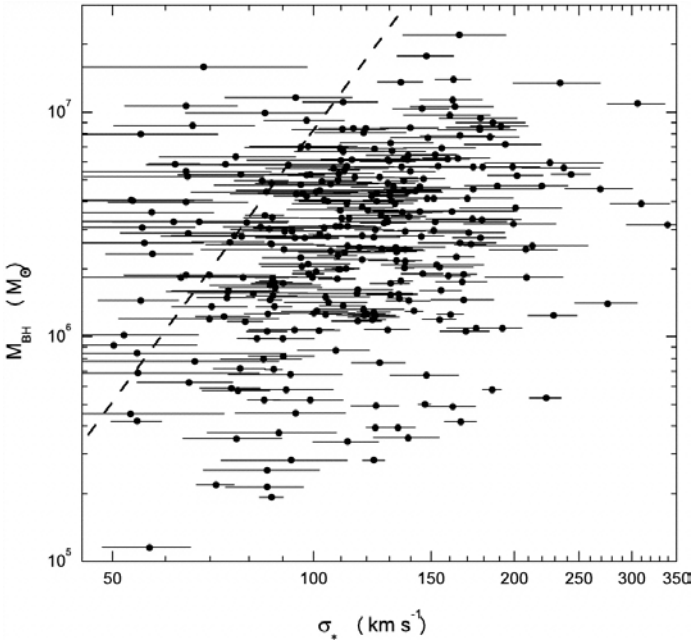
  M_{BH}-σ and M_{BH}-L relate only to the classical part



Where do pseudo-bulges & NLS1s lie in the M_{BH}-σ plane ?

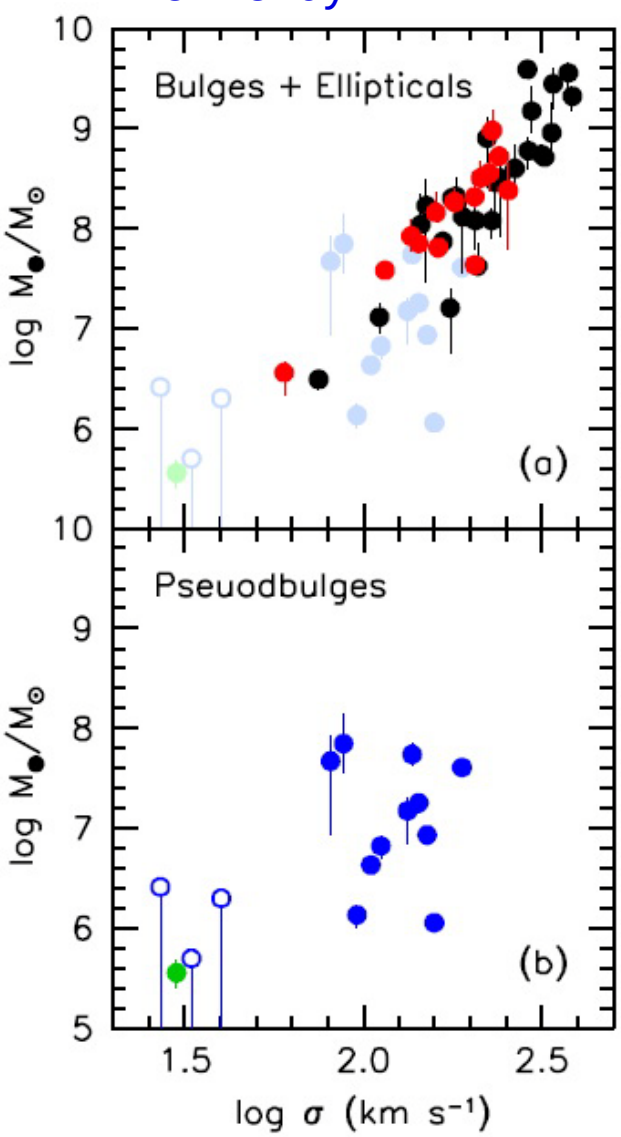
- Pseudo-bulges are scattered on and below the M_{BH}-σ plane; so many do lie under the relation
- NLS1s have pseudo-bulges and so scatter similarly

Zhou+ 06



NLS1s from SDSS with 'reliable' σ*

Kormendy+ 11



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  NLS1s are scattered similarly to pseudo-bulges on & under the M_{BH}-σ relation

see Orban de Xivry et al. 2011 – on the arXiv very soon