



Secular Evolution in the Host Galaxies of NLS1s



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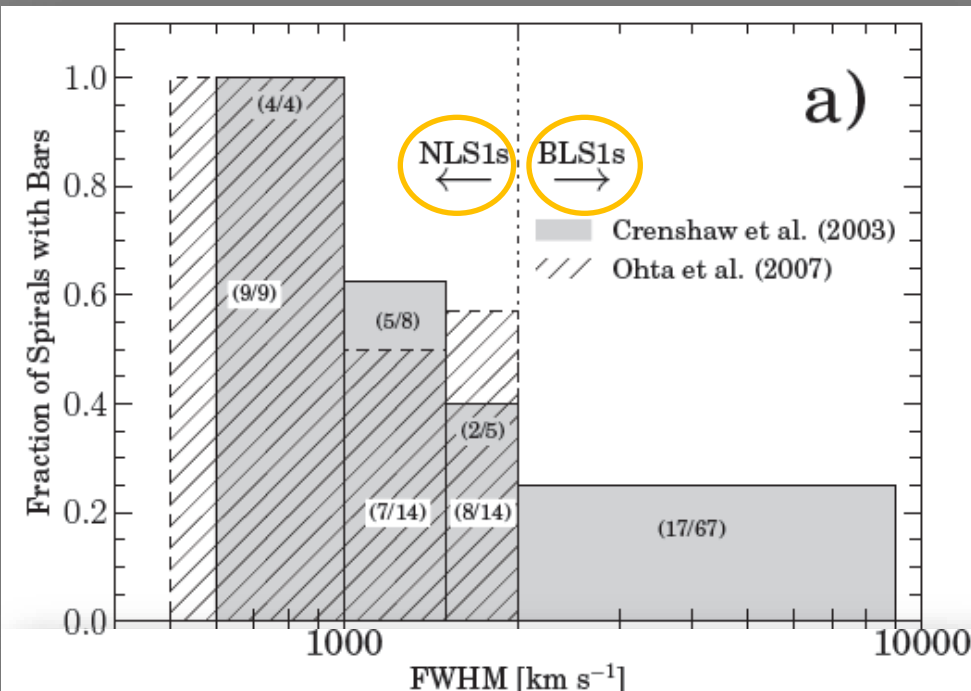
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- What is the importance of present secular processes in NLS1?
- Importance of past secular evolution in NLS1?
- Is it consistent with our understanding of galaxy population? What could have been the NLS1 BH growth? Are NLS1s in a particular evolutionary phase?
- BH spin of NLS1s - an observation evidence?

Present Secular Evolution & NLS1 Hosts

Secular Processes in NLS1 hosts

NLS1s galaxies are likely to be strongly barred spirals



Orban de Xivry+11

► Crenshaw+03:

- >90% of NLS1s and BLS1s are in spirals.
- ~65% of NLS1s spirals are barred
- ~25% of BLS1s spirals are barred

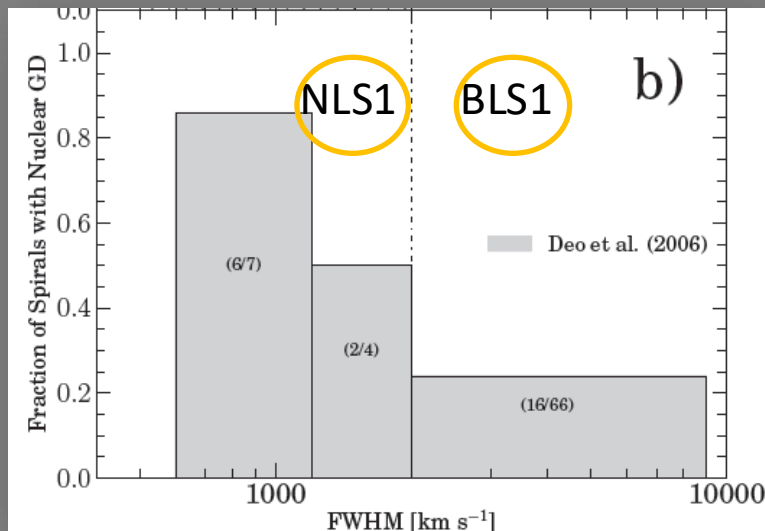
► Ohta+07, visual and ellipse fitting:

- Most NLS1s are in spirals galaxies.
- ~85% of NLS1 spirals are barred.
- SB (not SAB) show similar trend with FWHM(H β)

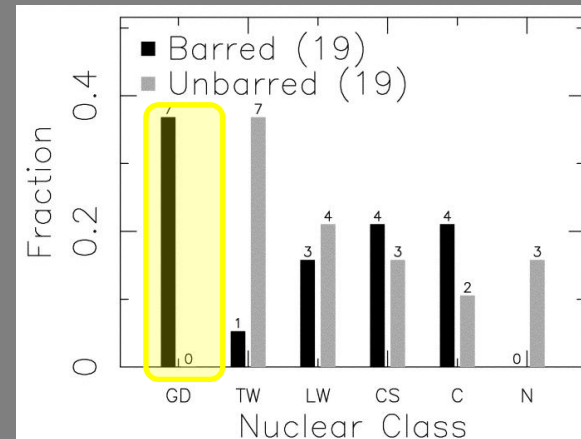
Present Secular Evolution & NLS1 Hosts

Morphological Properties - Circumnuclear

- ▶ *Deo+ 2006 (HST imaging survey from Malkan+ 98):*
 - ▶ NLS1s likely have 'grand-design' nuclear dust spirals
- ▶ Martini+03:
 - ▶ Nuclear grand design spirals are also characteristics of barred galaxies.
- ▶ Same trend with FWHM than bars fraction



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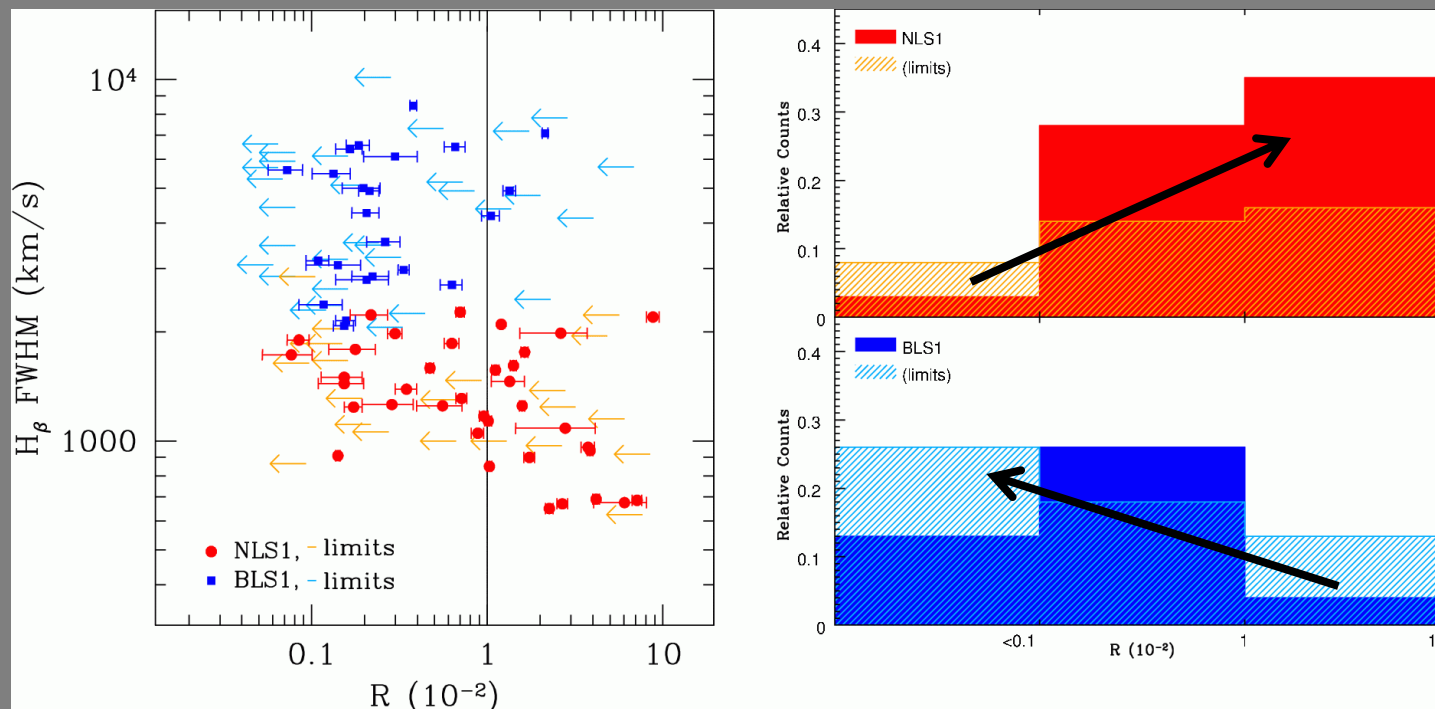
Martini+03

But bars also drives gas inwards ..

Present Secular Evolution & NLS1 Hosts

Star Formation

- ▶ *Sani+10* compare the star formation (PAH) to AGN luminosity ratio between NLS1s and BLS1s:
 - ▶ On average, star formation/AGN ratio is >2x larger in NLS1s than in BLS1s (checked for bias due to luminosity, distance, etc.)
- ▶ Consistent with higher bar fraction enhancing star formation (Ho+97)



Sani+10

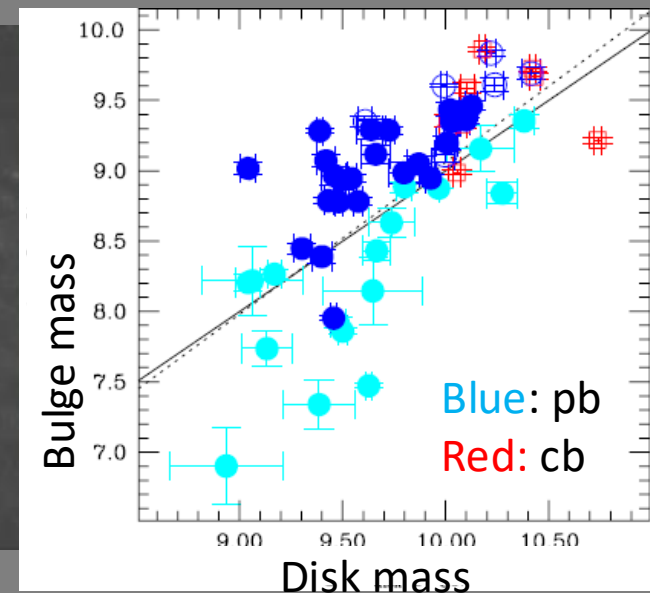
Past Secular Evolution & NLS1 Hosts

Pseudo-bulges, a secular phenomenon

- ▶ **bulges** : dense central components of galaxies
- ▶ **pseudo-bulges** : made slowly by disks out of disk material. They are formed by internal secular processes (bars, spirals, etc.) > < galaxy mergers or external secular evolution (e.g., Kormendy & Kennicutt 2004)



Fisher&Drory 2008

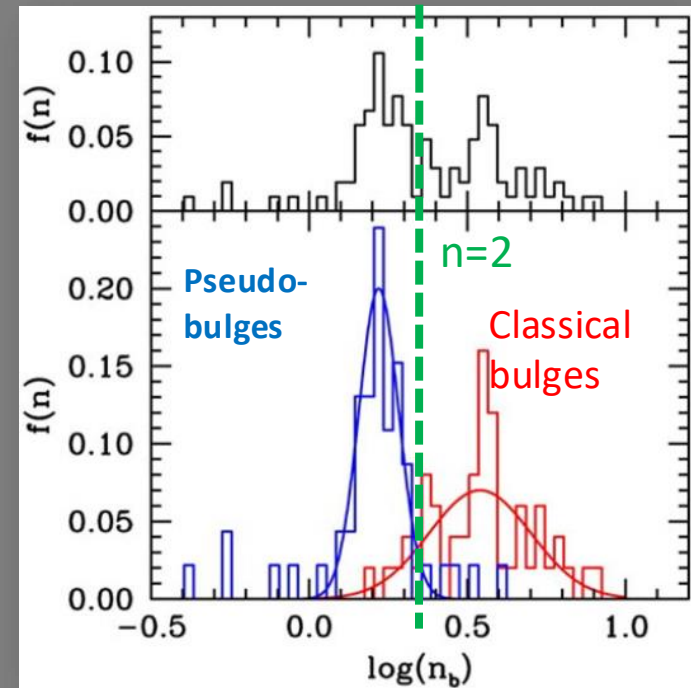


Fisher+09; larger disk makes larger bulges

Pseudo- vs. Classical bulges: Identification

Pseudo-bulge identification (e.g. KK04, Fisher&Drory08, Gadotti09, FD10)

- ▶ Dynamics are rotation dominated
- ▶ Structural properties :
 - low Sersic index (disk have $n \sim 1$),
 - Bulge prominence (low B/T,...)
- ▶ Stellar population

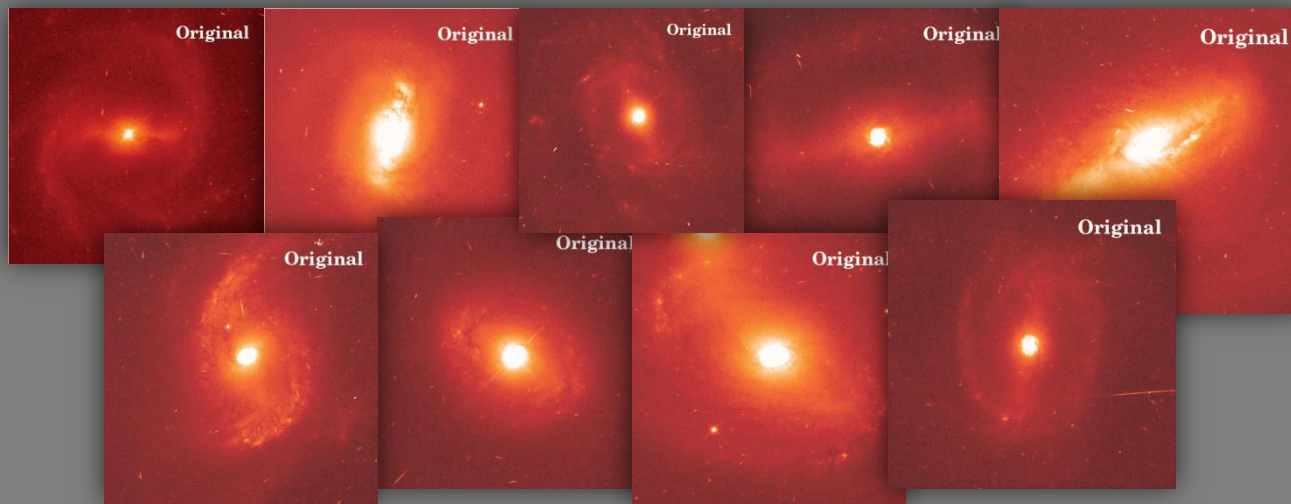


Fisher&Drory 08, high resolution data

Past Secular Evolution & NLS1 Hosts

Bulge-Disk decomposition - sample

- ▶ WFPC2 F606W images from HST survey of nearby AGNs by Malkan+98 ($z < 0.035$)
- ▶ Seyfert classification is first taken from previous papers using these data and then verified based on spectra.
- ▶ Final sample: 9 genuine NLS1s (Veron et al. 2001); 18 BLS1s for comparison
- ▶ *High resolution* images: mean pixel scale $\sim 20\text{pc/px}$



Past Secular Evolution & NLS1 Hosts

NLS1 vs BLS1 bulge properties: Sersic index

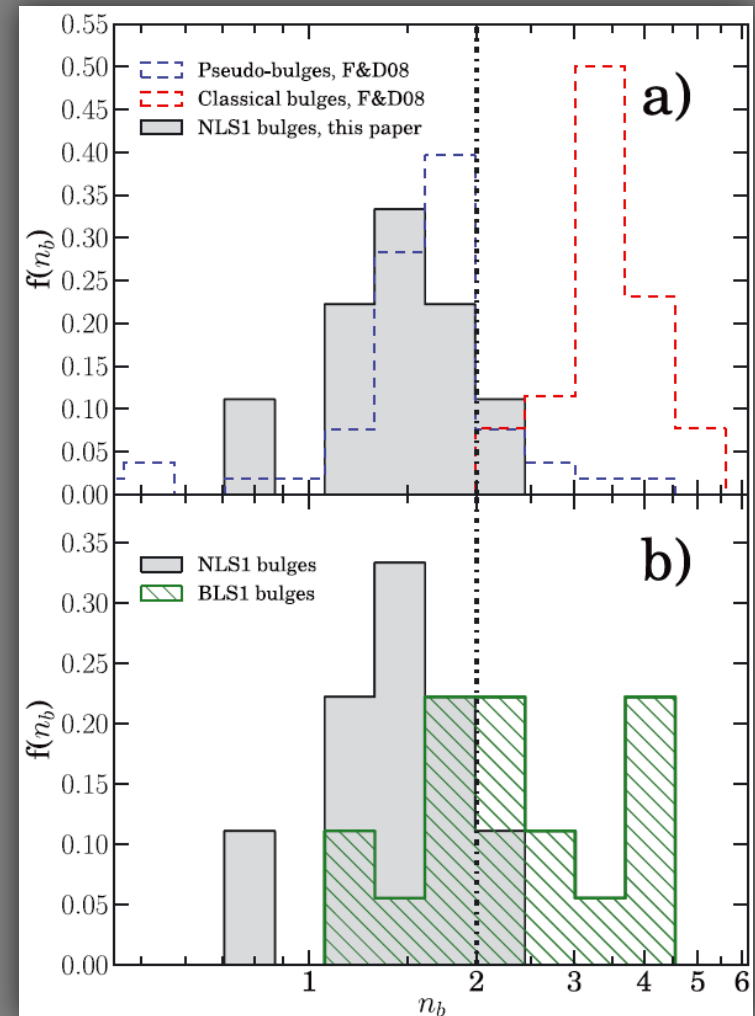
NLS1 bulges n is different than the one of BLS1s:

- ▶ $\langle n \rangle(\text{NLS1}) \sim 1.59$
- ▶ $\langle n \rangle(\text{BLS1}) \sim 2.54$
- ▶ FD08 : $\langle n \rangle(\text{pb}) \sim 1.69$, $\langle n \rangle(\text{cb}) \sim 3.49$

BLS1 hosts are distributed around $n \sim 2.5$ following the mean value across the Hubble sequence (Laurikainen+07)

NLS1 hosts, a distinct subclass of BLS1 host bulges, that have specifically pseudo-bulges

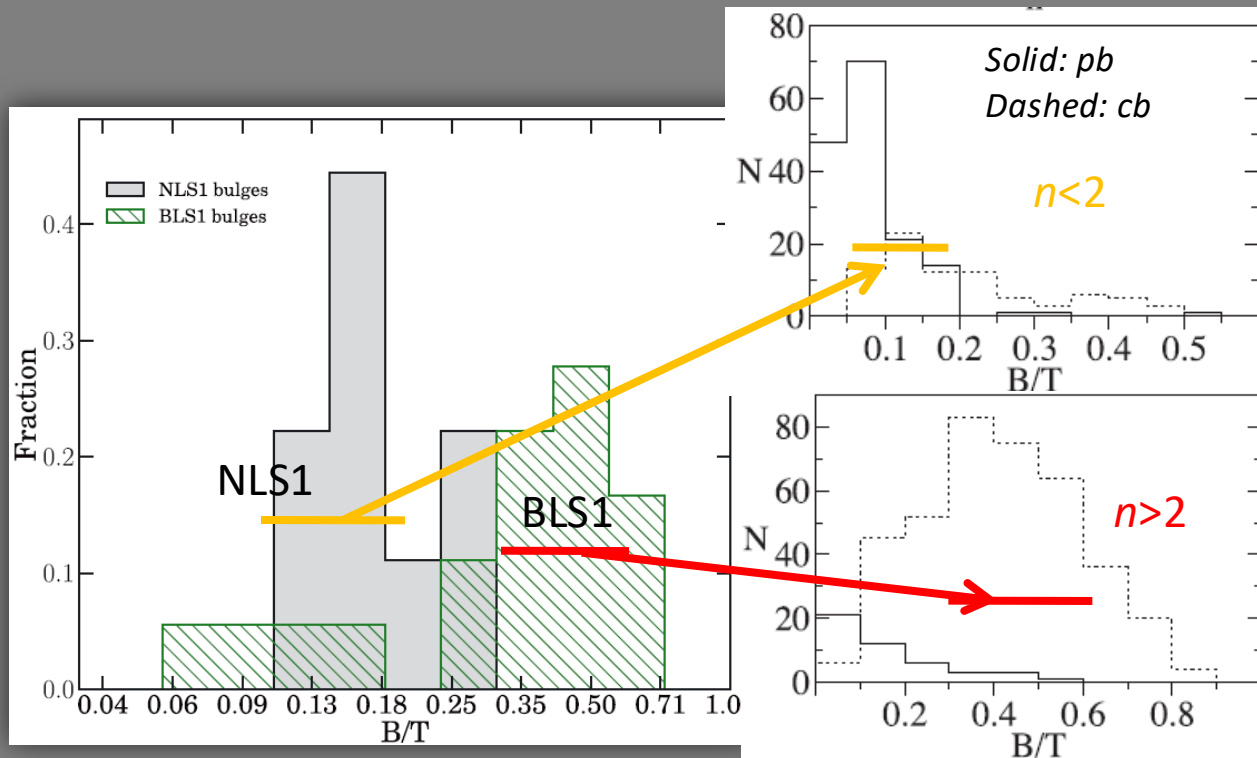
This result is not a consequence of different bar fractions in the two populations or of particular sub-Sy1 classes (S1, S1.5, ...)



Past Secular Evolution & NLS1 Hosts

NLS1 vs BLS1 bulge prominence

- ▶ NLS1 bulges are less prominent than BLS1 bulges, as pb and cb.
- ▶ NLS1 galaxies are later type than BLS1



Orban de Xivry+2011

Gadotti+09

Type	T	B/T	B/D
S0-	-3	0.6	1.5
S0	-2	0.57	1.3
S0+	-1	0.53	1.1
S0/a	0	0.48	0.92
Sa	1	0.41	0.69
Sab	2	0.32	0.47
Sb	3	0.24	0.32
Sbc	4	0.16	0.19
Sc	5	0.094	0.10
Scd	6	0.049	0.05
Sd	7	0.022	0.022

Masters+2010

What have we learned so far?

- What is the importance of present secular processes in NLS1?
- Importance of past secular evolution in NLS1?

Secular processes are present on all scales and have been dominant in the past:

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

- How can this fit to our understanding of galaxy population?
- What has been the growth of NLS1s and their BH holes?

Galaxy population and growth of NLS1

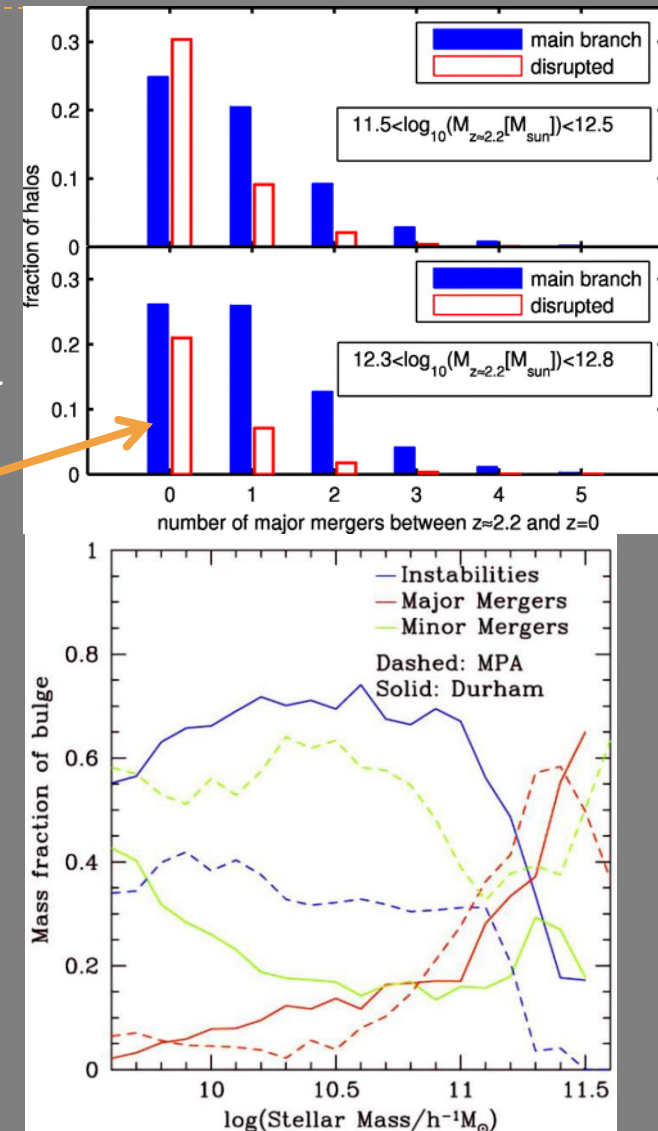
► Genel+08, Genel+10

- ~40% are subsumed into a larger halo
- ~35% undergo a major merger
- ~25% *experience no major mergers*
- *Minor mergers (<1:10) and smooth accretion account for ~70% of DM halo growth*

No major merger

► 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.



How common are NLS1? What is their duty cycle?

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

- ▶ ~15% of Sy1 are NLS1s
- ▶ Could also be applicable to Sy2

Ho 08

- ▶ ~11% of local galaxies are Sy1, ~43% are AGNs
- ▶ **Up to 2-6% of local galaxies could be (similar to) NLS1**

Weinzirl + 09

- ▶ 2/3 of local spiral galaxies similar to NLS1s ($B/T < 0.2$, $n < 2$, barred galaxies)

- ▶ **Duty cycle of NLS1s is 3-9%**

NLS1 BH growth

Look-back time $\sim 7.7\text{Gyr}$

(Hubble seq. since $z \sim 1$)

Duty cycle $\sim 9\%$

Active accretion during $\sim 700\text{Myr}$ (upper limit)

$$M_{\text{BH}}(t) = M_{\text{BH}}^{\text{seed}}(t_0) \exp \left(\frac{1 - \epsilon}{\epsilon} \frac{\tau}{t_{\text{E}}} \right)$$

Assuming: - Eddington accretion rate: $t_{\text{E}} \sim 440\text{Myr}$

- high radiative efficiency (high spin), $\epsilon \sim 0.2$

- seed mass $10^3 - 10^4 M_{\text{sun}}$

Current mass will be $5 \times 10^5 - 10^6 M_{\text{sun}}$

Enough time for BHs to grow from seeds since $z=1$

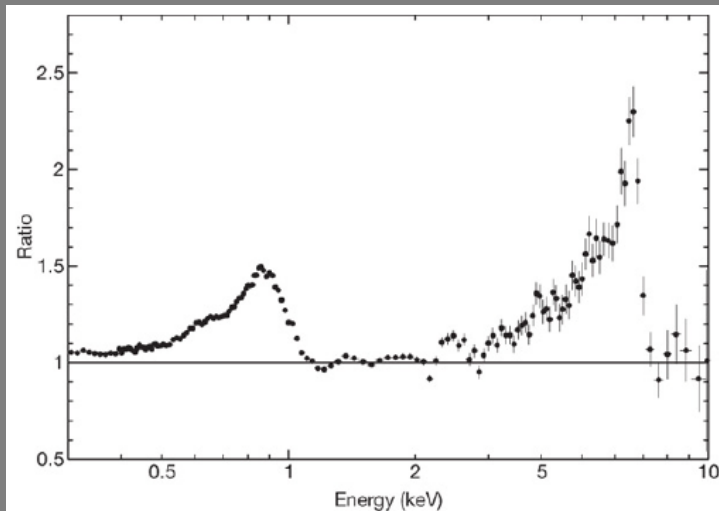
► *Are NLS1s in a particular phase of evolution?*

To grow by a factor 10, it would take $\sim > 2.5\text{Gyr}$ (assuming $\epsilon \sim 0.2$ and 9% duty cycle):

Suggest that **NLS1 are not in a special phase of BH growth**

BH growth and BH spin – Observational evidences?

- *Radiative efficiency has a direct impact on BH growth and final BH mass. And this depend on the BH spin*



Fabian+09

BH spin measurement: e.g. use of relativistic Fe lines

Most high spin detection are NLS1s (and 12/15 NLS1s in literature have $a > 0.6$)

A possible result of secular evolution

But issue is controversial :
chaotic accretion vs smooth accretion
Spin down vs. spin up processes

Another alternative :

not a standard thin disk but **slim disk** regime that could account for higher measured spins (Mineshige+00, Collin+04)

Questions and some answers...

- What is the importance of present secular processes in NLS1?

Dominant at all scales, strong large-scale bars, nuclear dust spirals, higher star formation,...

- Importance of past secular evolution in NLS1

Dominant as well and responsible to the formation of pseudo-bulges. In contrast to a wider variety among BLS1

- What could be the cosmic evolution of NLS1 and does it fit our expectations

A galaxy population that has grown purely through secular processes (without mergers) is indeed expected and allow us to suggest that NLS1s are not in a particular phase of their evolution

- BH spin of NLS1s - an observation evidence?

NLS1 BH observations show hints that they have predominantly high spin – that could support a steady secular evolution and/or a ‘slim’ accretion among NLS1.

End...



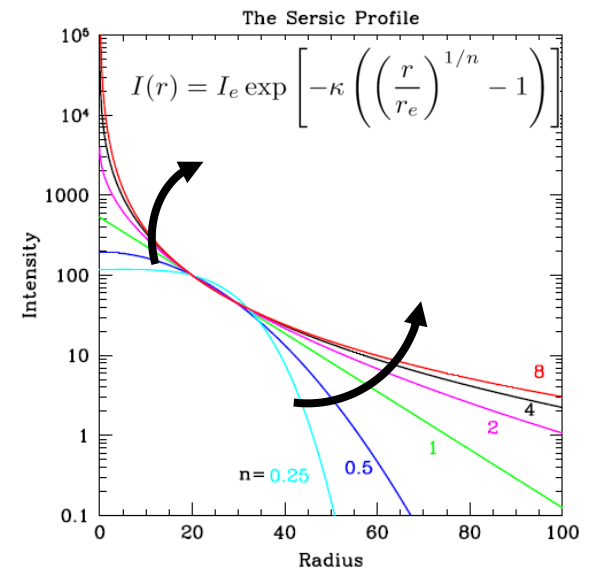
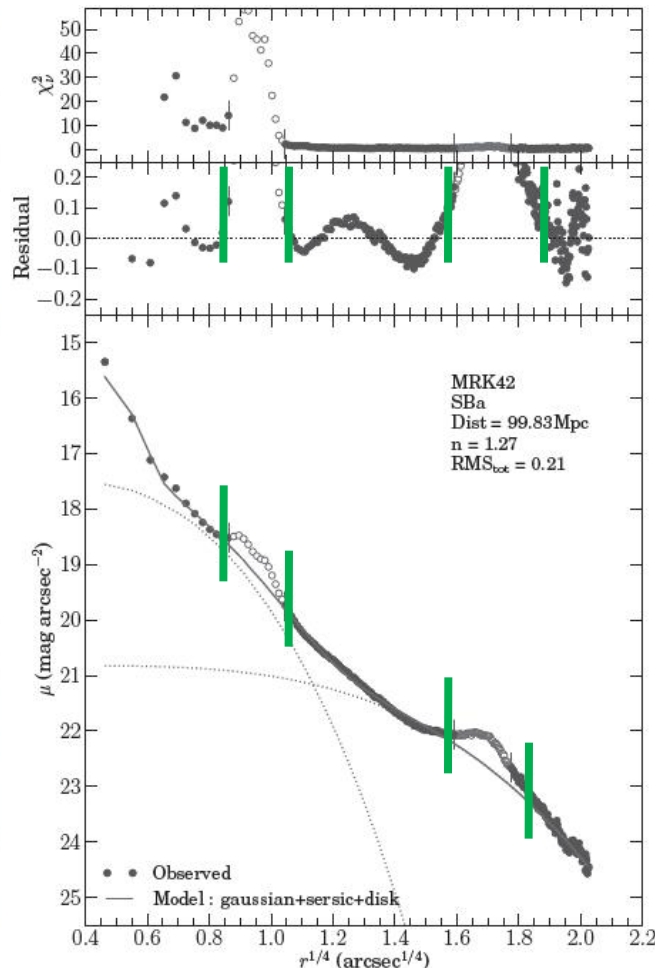
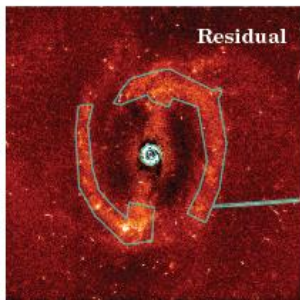
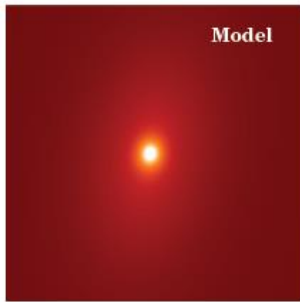
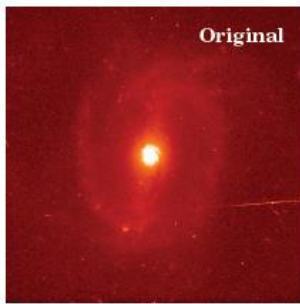
Past Secular Evolution & NLS1 Hosts

Bulge-Disk decomposition

Components:

1. Point source
2. Sersic profile (bulge), n index free ($n \sim 4$ elliptical, $n \sim 1$ disk)
3. Exponential profile (disk)

Additional features are masked



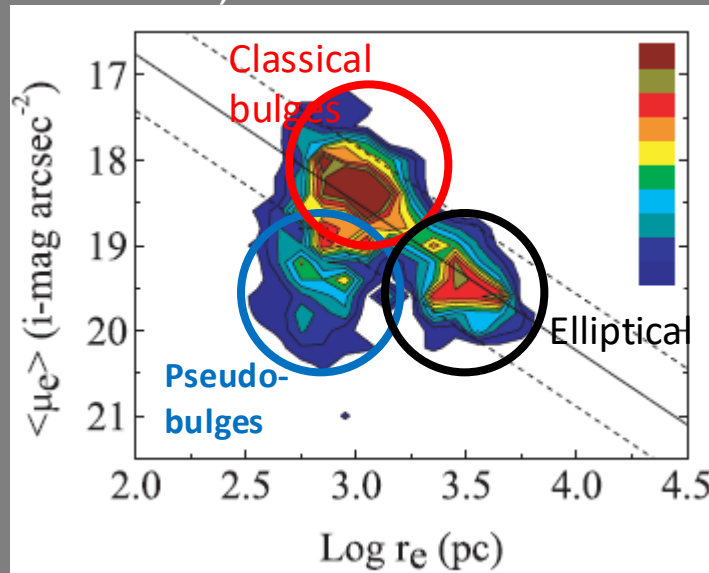
Doing this for 28 objects, we obtain...

Pseudo- vs. Classical bulges: Identification

Pseudo-bulge identification (e.g. KK04, Fisher&Drory08, Gadotti09, FD10)

- ▶ Dynamics are rotation dominated (see later)
- ▶ Structural properties :
 - low Sersic index (disk have $n \sim 1$), bulge scaling relation, bulge morphology
- ▶ Stellar population

Gadotti 09, SDSS data



Fisher&Drory 08, high resolution data

