The Role of Secular Evolution in Forming and Fuelling AGN

(i) Kinematic signatures of Seyfert fuelling from 1 kpc to 10 pc

(ii) The role of secular evolution in forming & fuelling Narrow Line Seyfert 1 Nuclei

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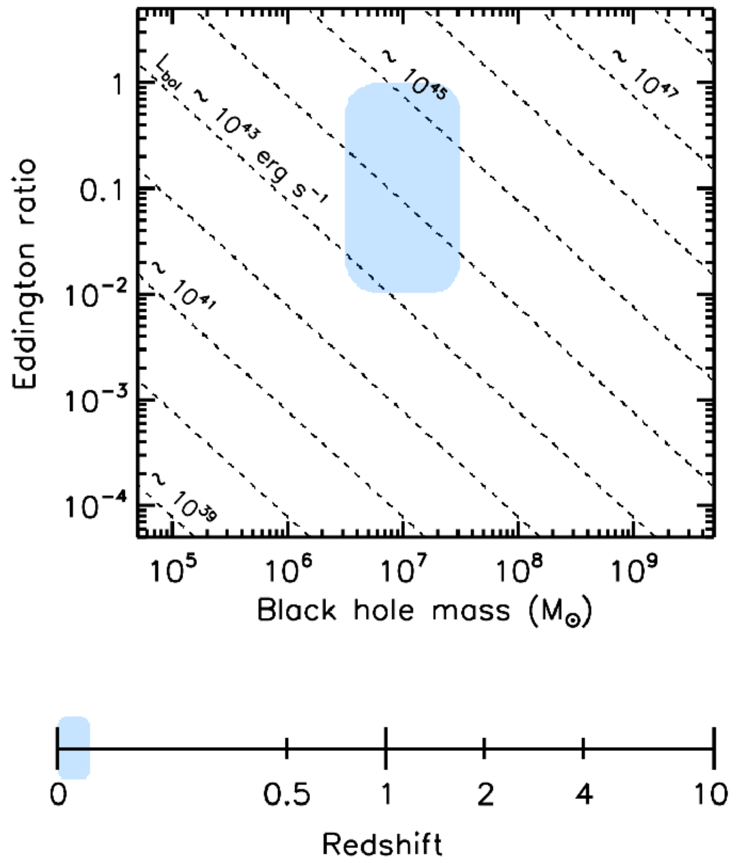

Kinematic signatures of Seyfert fuelling from 1 kpc to 10 pc

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Goal:
to understand the connection between BH growth in the local universe and the host galaxy

Seyfert Galaxies

- typify BH growth at low redshift

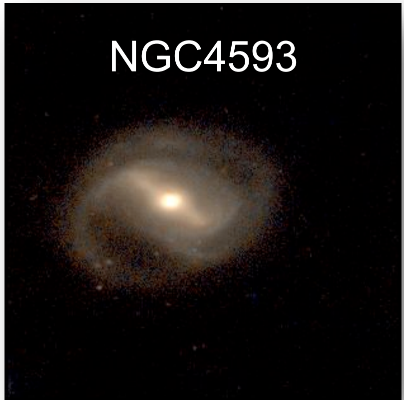
  M_{AGN}~$3\times10^7 M_{sun}$ & $L_{AGN}<10^{43}$erg/s (Heckman+ 04, Hasinger+ 05)

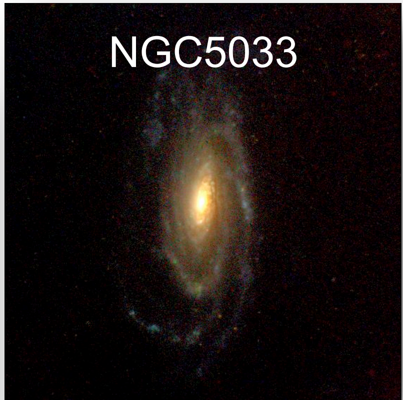
- are common

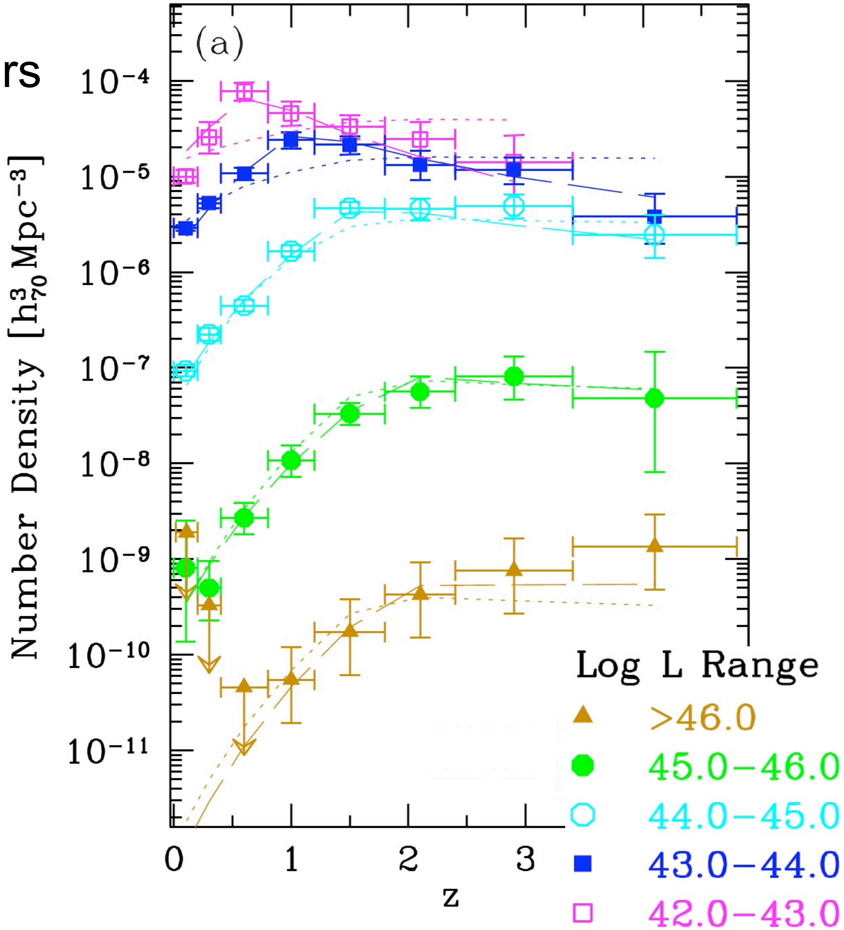
  10% of all local galaxies are Seyferts (Maiolino+ 95, Ho+ 97, Ho 08)

- usually have spiral hosts

  gas inflow is secular rather than via mergers

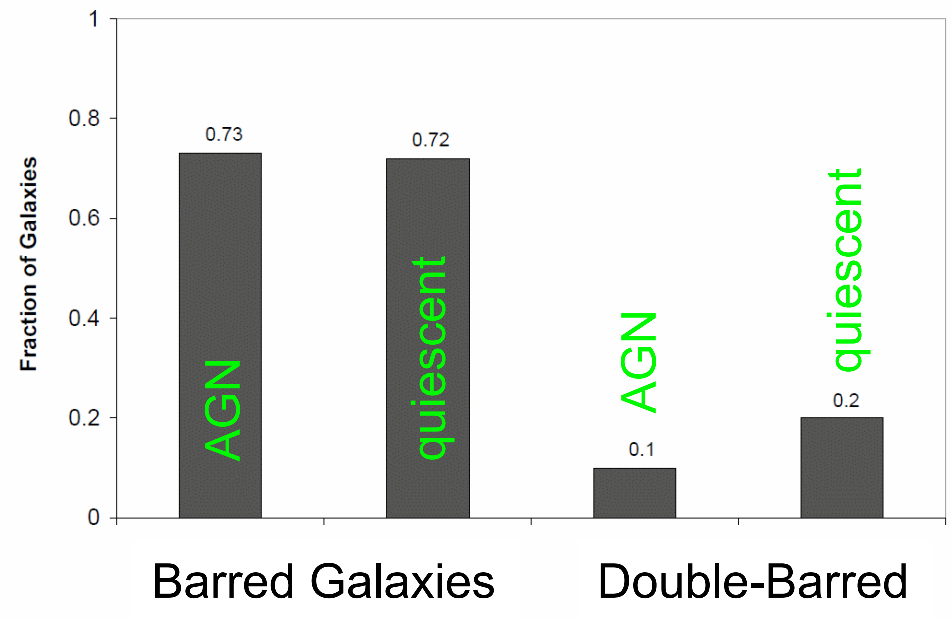






The role of bars in Seyfert activity

At best only a marginal relation between Seyferts and bars
(Mulchaey+ 97, Ho+ 97, Shlosman+ 00, Laine+ 02, Laurikainen+ 02,04, Hao+ 09, …)

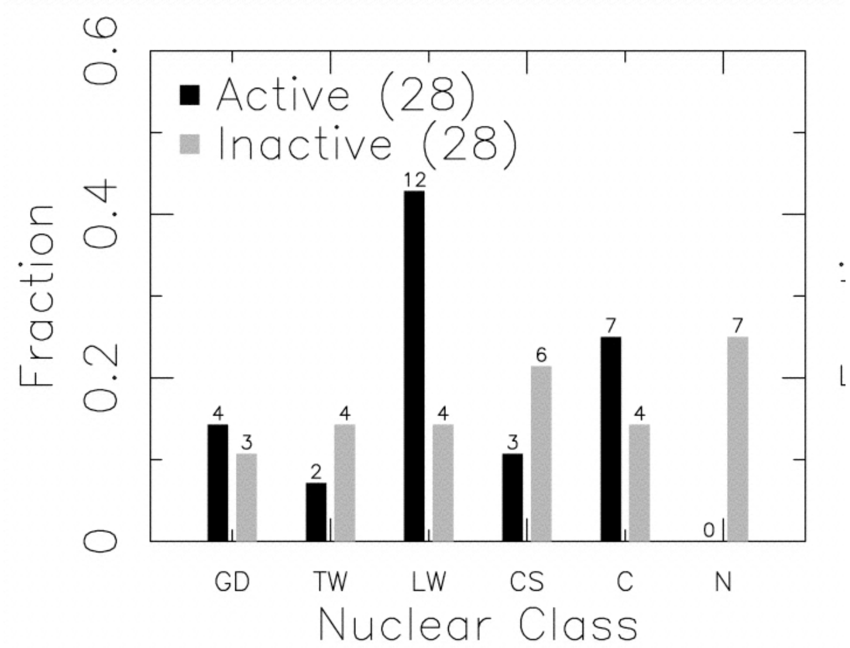


Mulchaey & Regan 97:
Seyferts & quiescent galaxies have similar bar fractions

Ho, Filippenko, & Wallace 97:
Seyferts occur equally often in barred & unbarred galaxies

The role of circumnuclear morphology in Seyfert activity

No obvious signature associated with AGN
(Martini+ 03, Hunt & Malkan 04)



Martini+ 03
nuclear dust spirals of any sort occur equally often in active & inactive galaxies

Hunt & Malkan 04
differences hint at an evolutionary scenario:
starburst – Seyfert 2 – Seyfert 1 – LINER
(see also Heckman+ 89, Storchi-Bergmann+ 01, Levenson+ 01, …)

Molecular gas on 10-1000 pc scales

Sample of Seyfert and quiescent galaxies

matched in large scale (>kpc) host galaxy properties:
Hubble type, *B*-band luminosity, angular size, inclination, heliocentric velocity

10 *pairs* observed at ~10 pc resolution

10 *pairs* observed at ~50 pc resolution

IFU Observations (on-going):

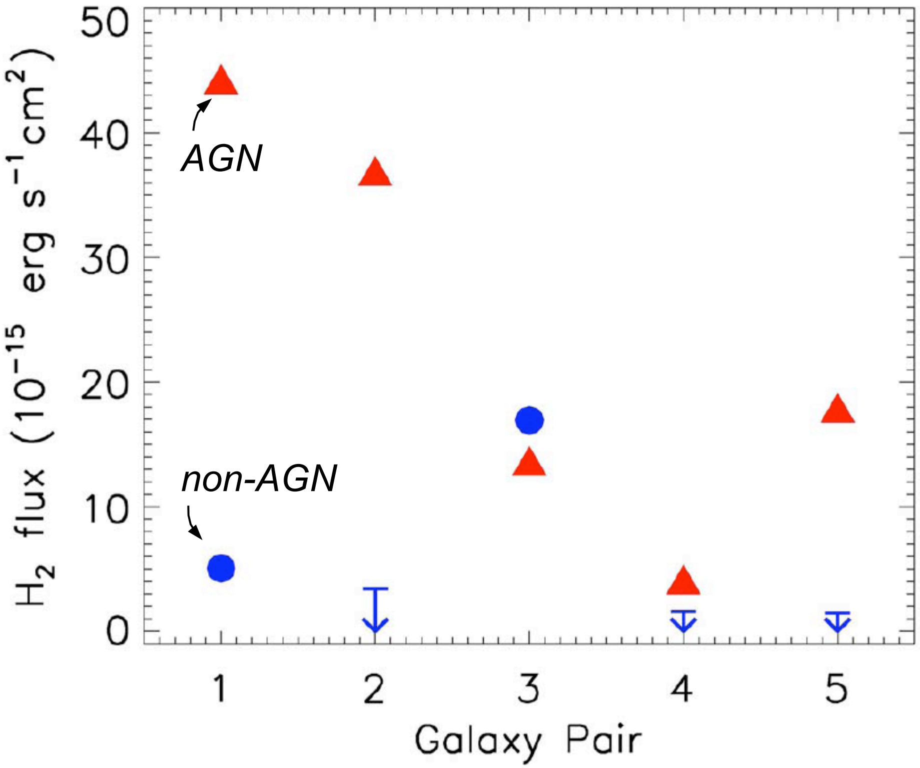
SINFONI@VLT, OSIRIS@Keck

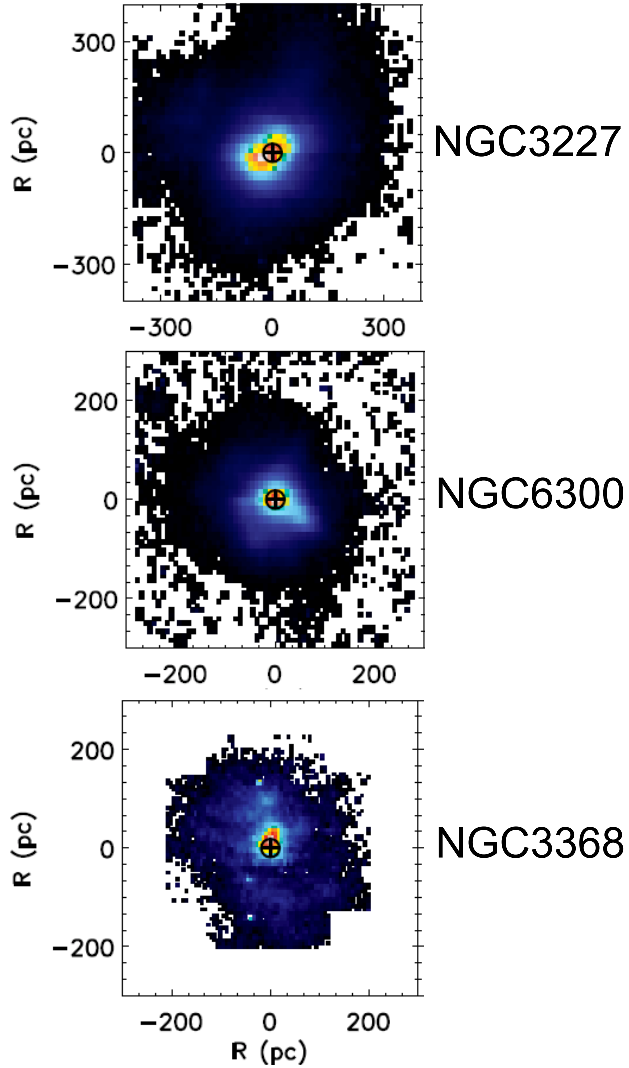
Quantify & Compare (between the AGN & quiescent galaxies):

- Stars: spatial distribution, age, star formation rate, kinematics
- Molecular gas: spatial distribution, mass, height, kinematics
- Gas inflow: driving mechanisms, rates

Seyferts have more molecular gas

2.12μm H_2 line emission





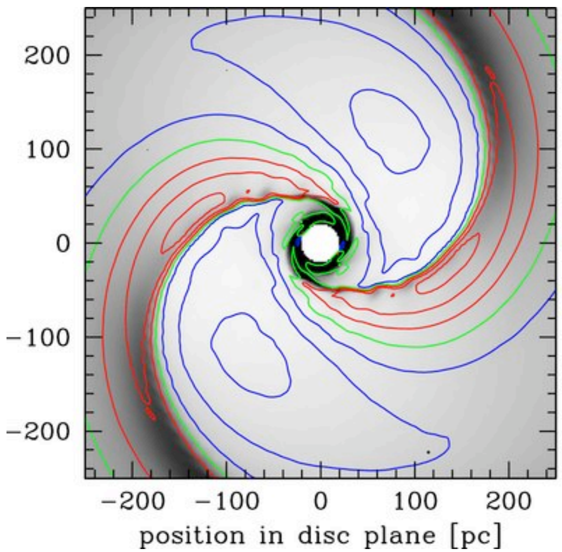
- central 200-300 pc
- AGN have higher H_2 1-0 S(1) luminosity than quiescent galaxies
- suggests AGN have more molecular gas
- what about kinematics? what is the gas doing?

Simulations of spiral driven inflow

- 2 morphological arms driven by large scale bar
- yields a 1-arm spiral in velocity residuals
- projected l.o.s. velocity for a logarithmic *m*-arm spiral is:

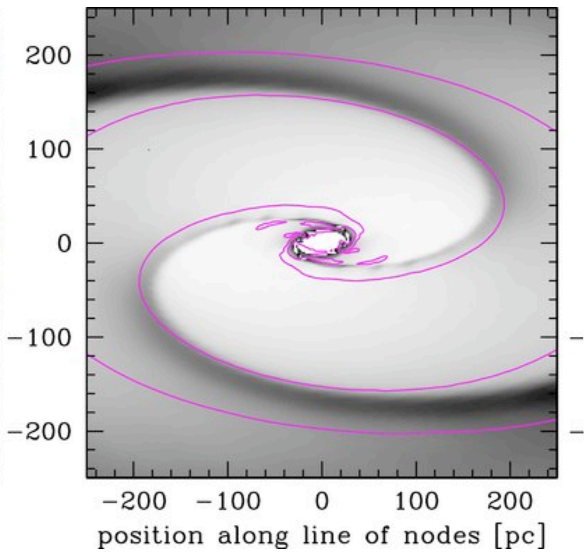
$$v_y = V_{rot}\cos\phi - \epsilon\frac{c}{2\sqrt{m^2-2}}[(m-1)\sin([m+1]\phi - f(R)) - (m+1)\sin([m-1]\phi - f(R))]$$

gas density,
face-on view



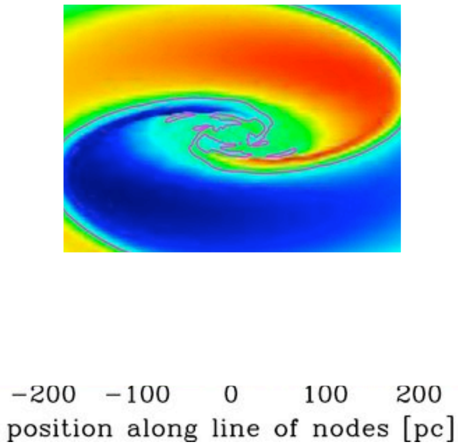
contours
blue: outflow
red: inflow

projected density



contour
magenta: zero velocity

line-of-sight
residual velocity



(Maciejewski 04,
Davies+ 09)

Spiral driven inflow in NGC1097

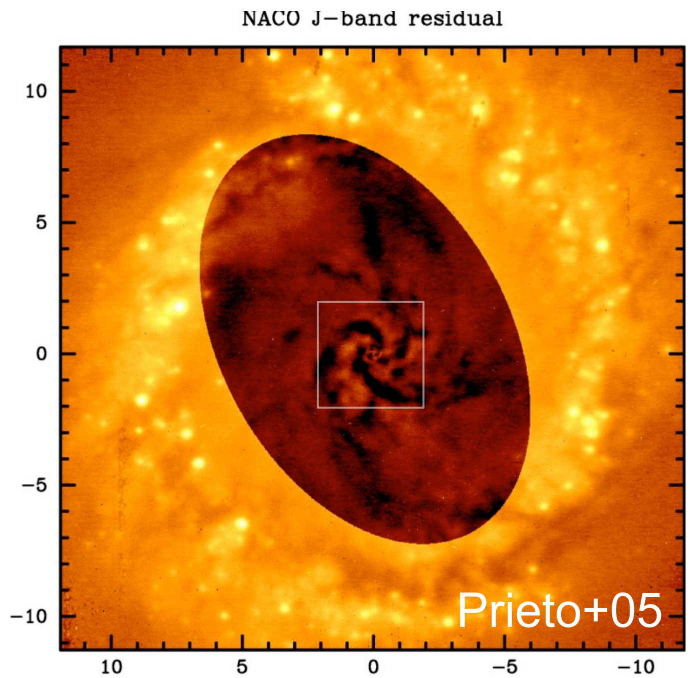
Prieto+ 05:

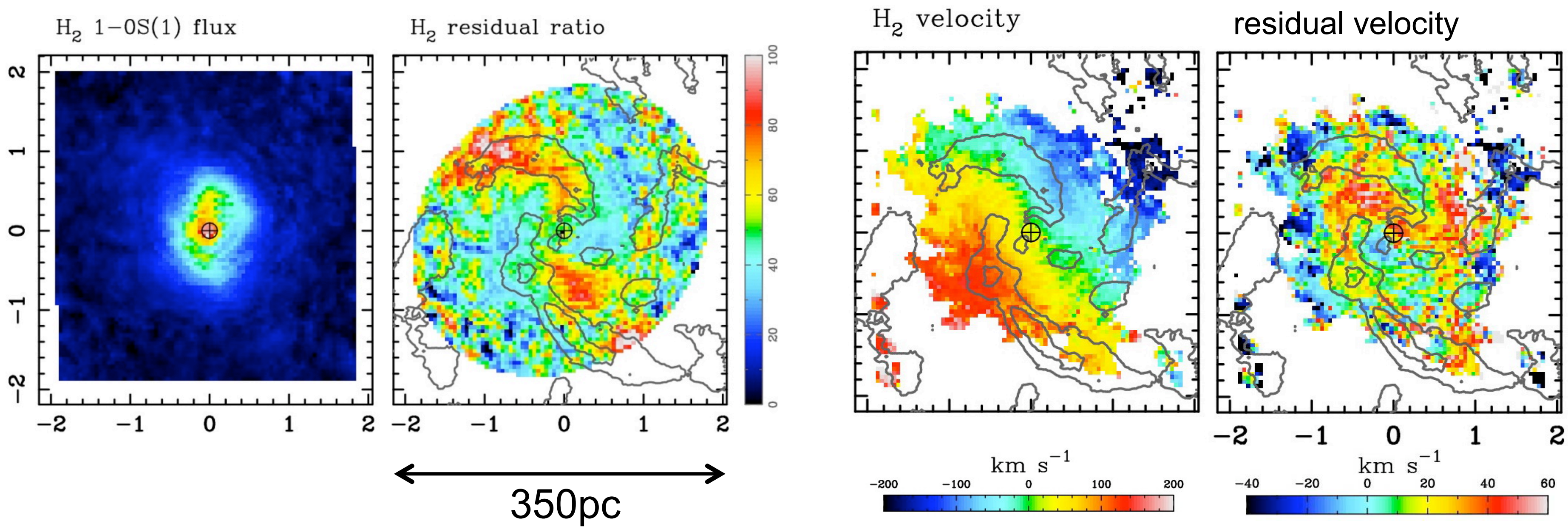
- 3 photometric spiral arms in stellar absorption

Davies+ 09:

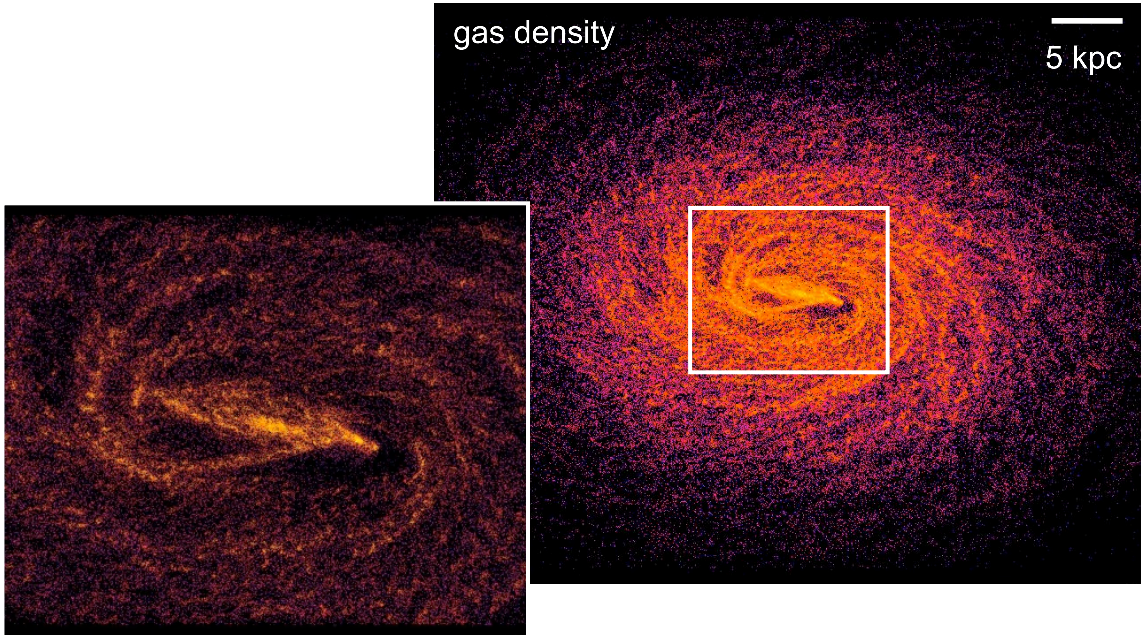
- 3 spiral arms seen in H_2 emission, but
- 2 kinematic arms
- residual velocity along arms ~60km/s

(see also Fathi+ 06, van de Ven & Fathi 10)





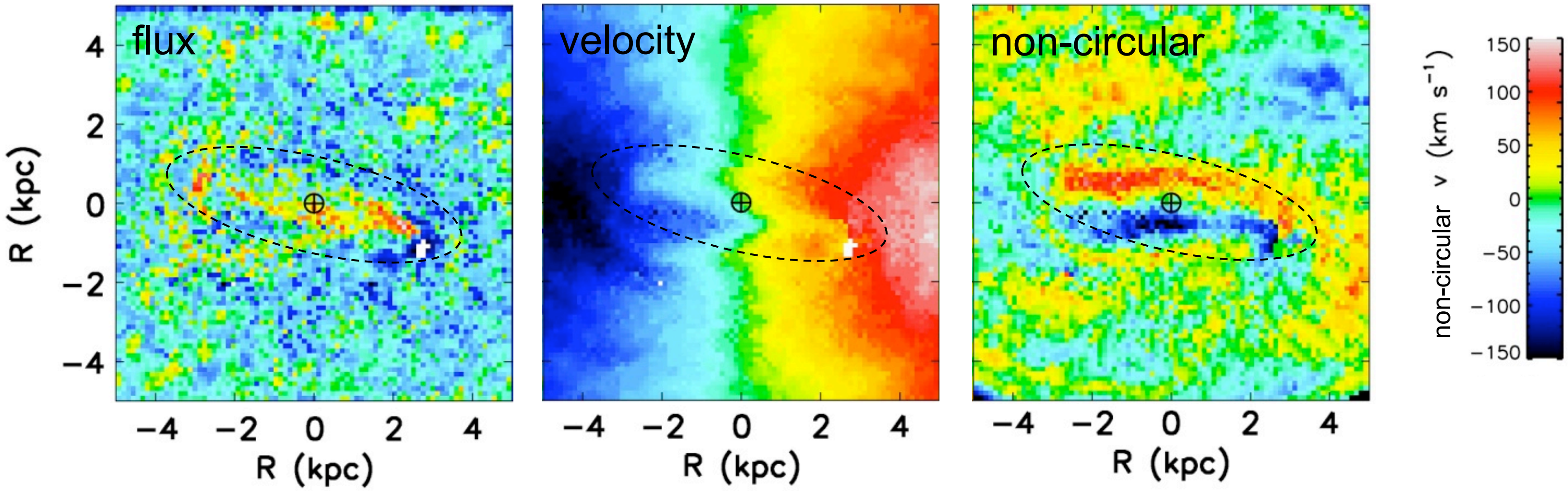
Simulations of bar induced inflow



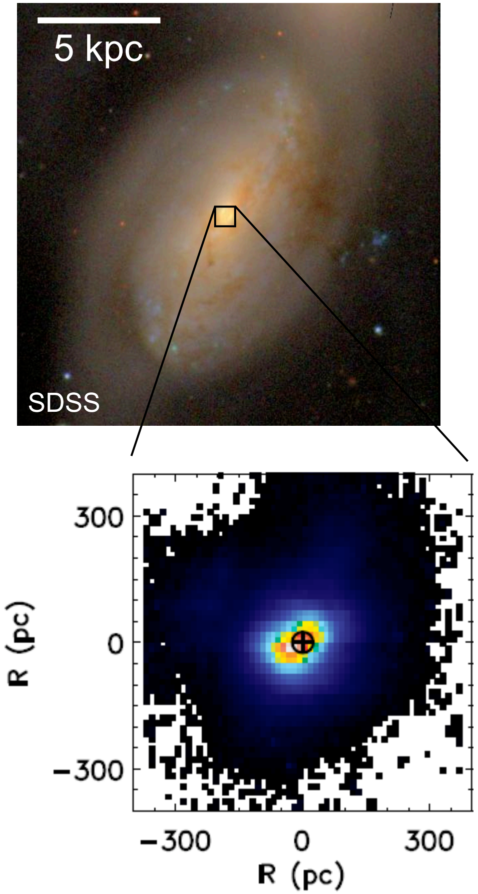
simulations by Quinn & Hicks

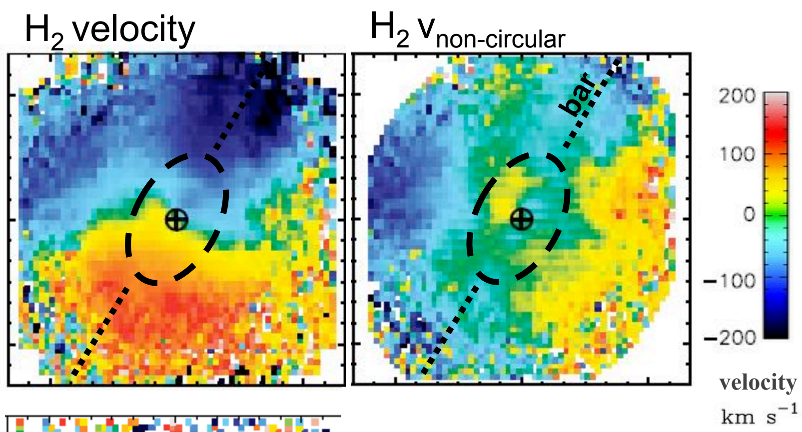
170 pc resolution
Evolved 0.7 Gyrs
Images generated with TIPSY

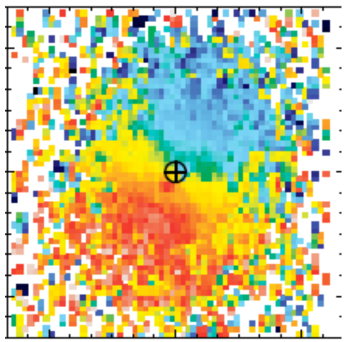
M_b/M_d=0.1, f_g=0.11, and R_b/R_d=0.5,
2.5×10^5 SPH particles



NGC3227: a Seyfert 1

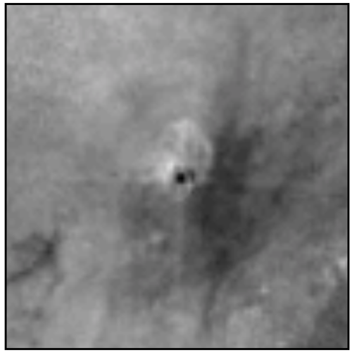




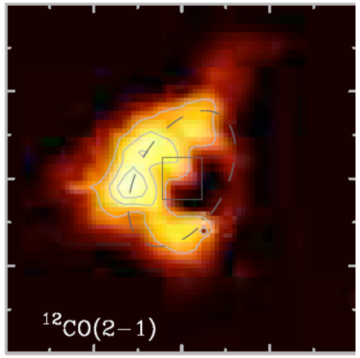


stellar velocity

V-H: ‘chaotic’ (Martini+ 03; darker = redder)

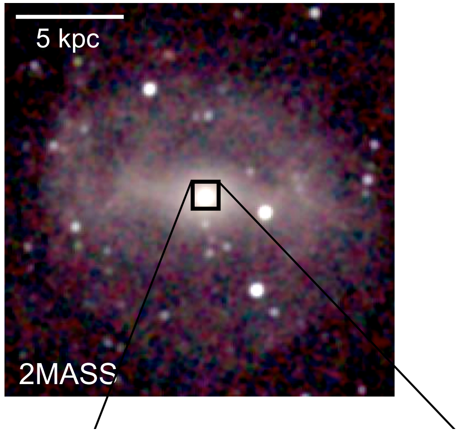


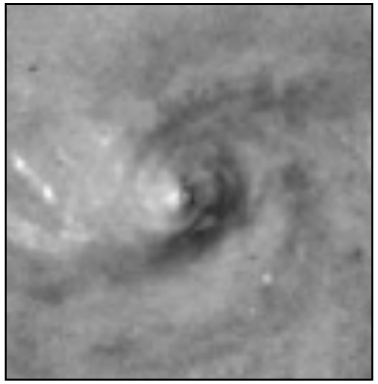
CO2-1 (Schinnerer+ 00, Davies+ 06)



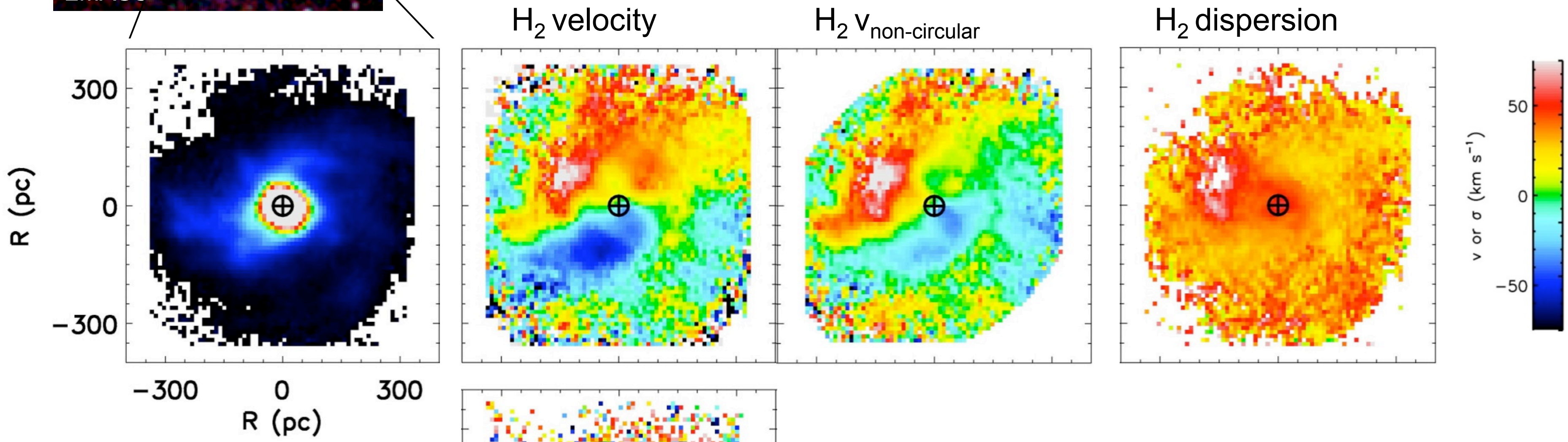
probably inflow along bar to circumnuclear ring; inside this is uncertain

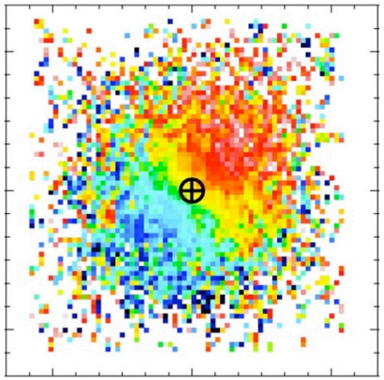
NGC 5643: a Seyfert 2





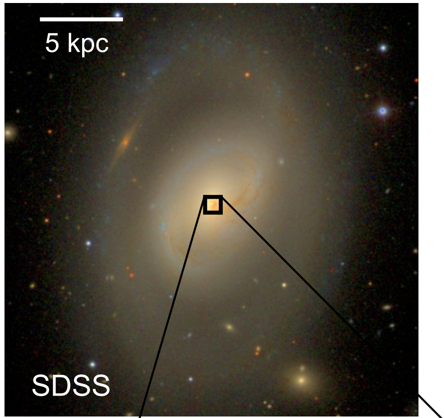
V-H: ‘grand design’
(Martini+ 03)

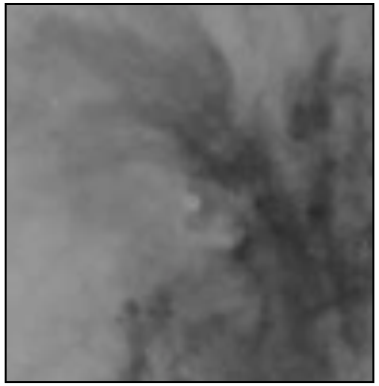




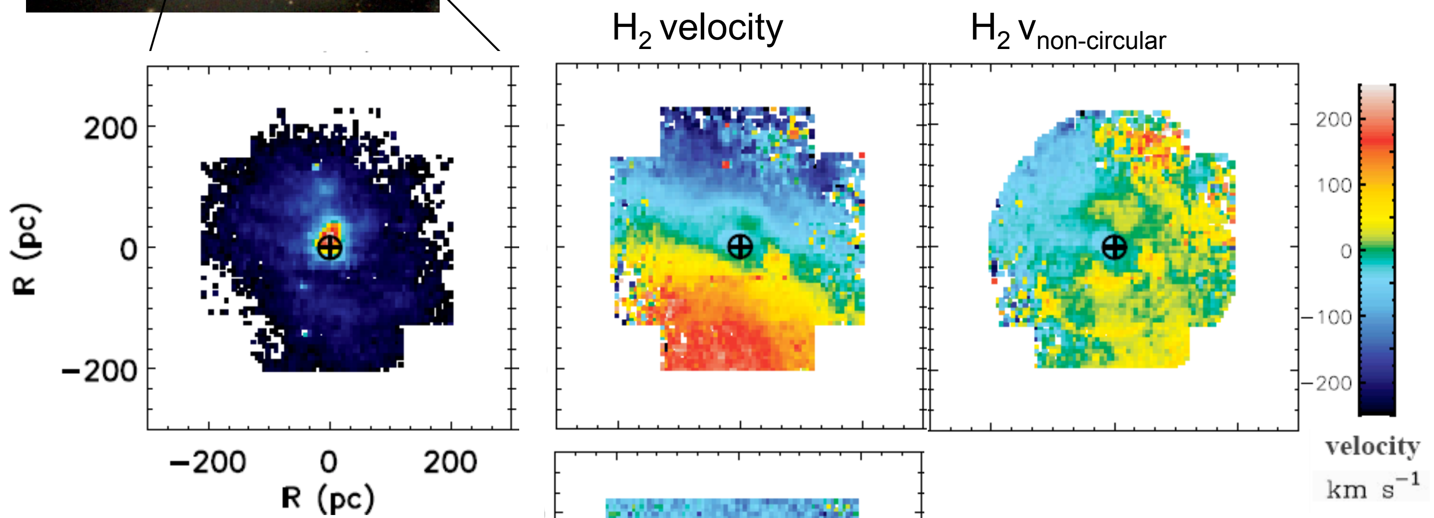
an example of molecular gas flowing along spiral arms; but complicated by outflow?

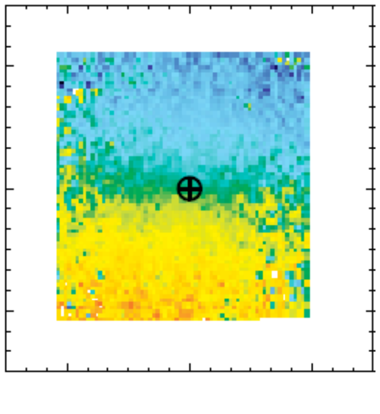
NGC 3368: a quiescent galaxy





V-H: ‘chaotic spiral’
(Martini+ 03)





stellar velocity

inflow occurs even in quiescent galaxies

Conclusions (first part)

❖ Kinematic Signatures of Gas Inflow on 10-1000pc Scales

- less H_2 in circumnuclear regions of quiescent galaxies
- significant non-circular motions in H_2
- whether characteristics of gas inflow in Seyferts & quiescent galaxies differ remains to be seen

The Role of Secular Evolution in Forming & Fuelling NLS1s

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NLS1s are a class of galaxies in which BH growth is, and always has been, dominated by secular processes:

(i) secular evolution is important for NLS1s at the current time

(ii) NLS1 hosts have pseudo-bulges, which are built by secular processes

(iii) angular momentum (a key characteristic of pseudo-bulges) will tend to hinder accretion of gas, leading to lower BH masses

(iv) there is a population of galaxies whose evolution has been purely secular

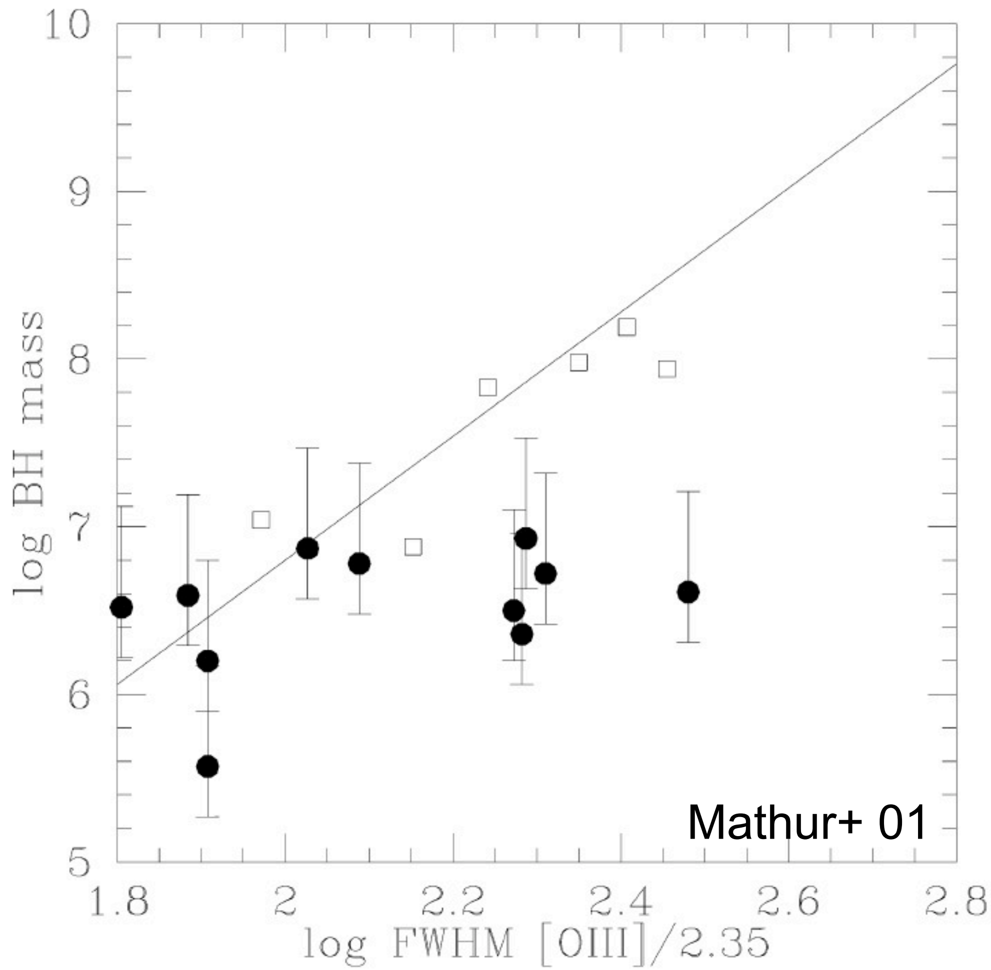
Narrow Line Seyfert 1s are a bit different

- have broad line FWHM < ~2000km/s
- NLS1s have high L/L_{Edd} and so are growing rapidly.
- But do they lie on the M_{BH}-σ relation ?

Has impact on whether or not BH and host grow in tandem:

correcting σ for [OIII] blue wing moves them left

correcting M_{BH} for radiation pressure moves them up

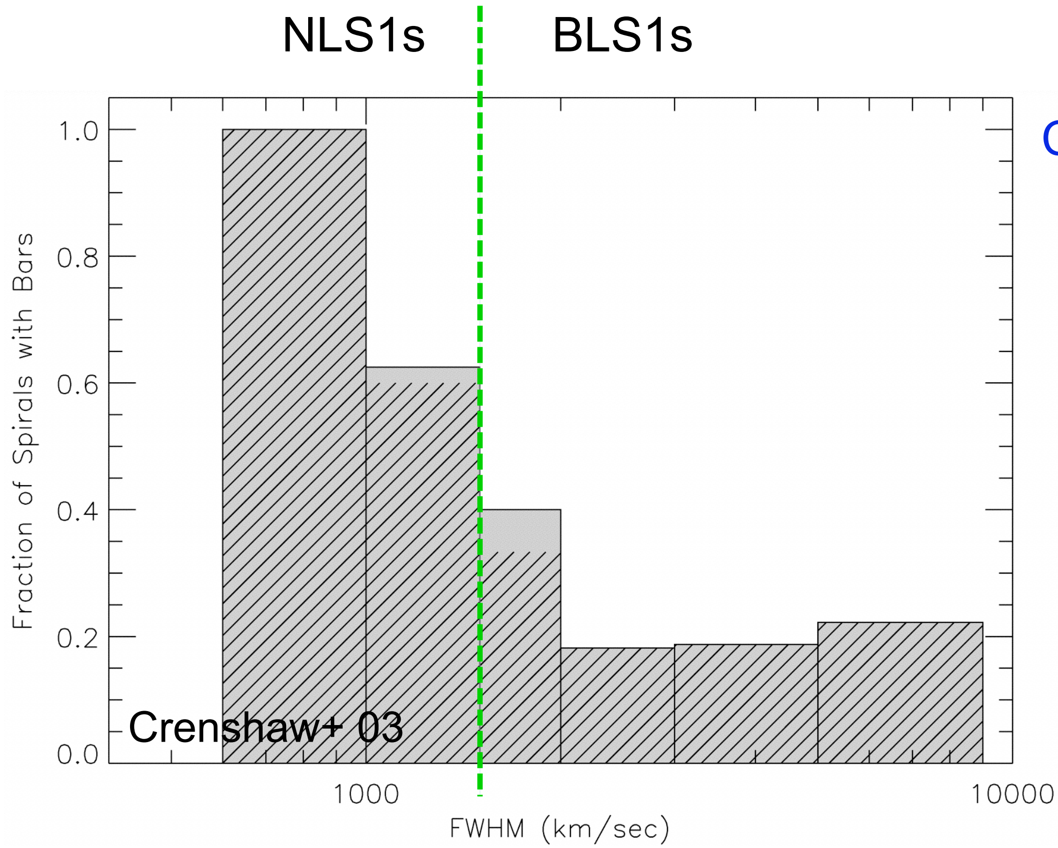


other unusual characteristics:

- strong soft X-ray excess
- strong Fe emission lines

& more

NLS1 hosts are likely to have bars



Crenshaw+ 03:

- most NLS1 & BLS1 are in disk galaxies
- ~65% of NLS1 disks are barred
- ~25% of BLS1 disks are barred

Ohta+ 07:

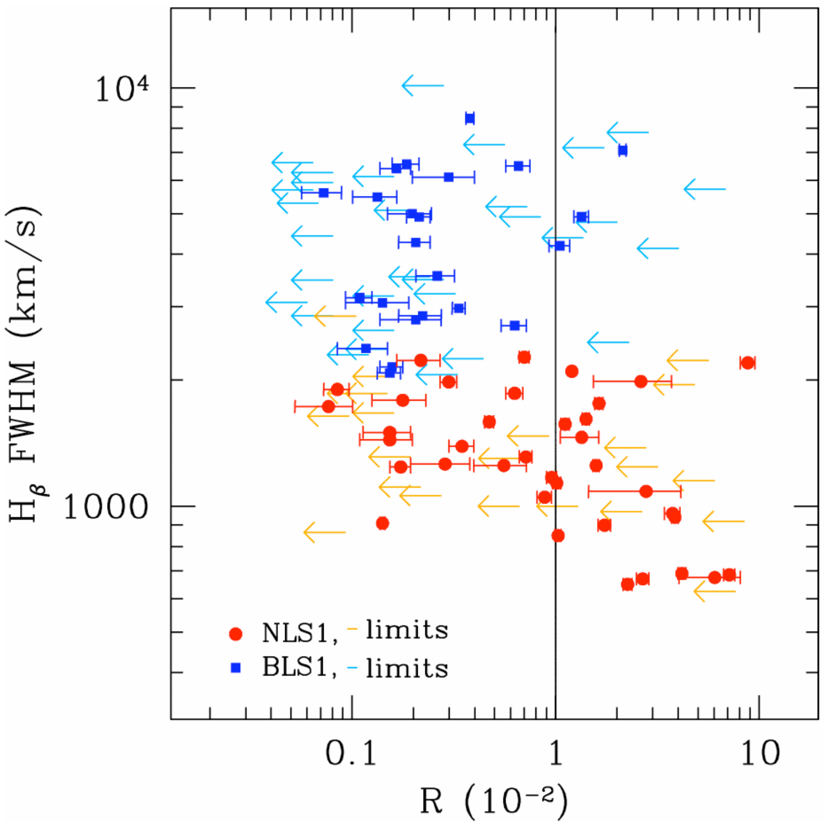
- most (38 /50) NLS1s are in disk galaxies
- 85%+/-7% of NLS1 disks are barred
- 40-70% of BLS1 disks are barred

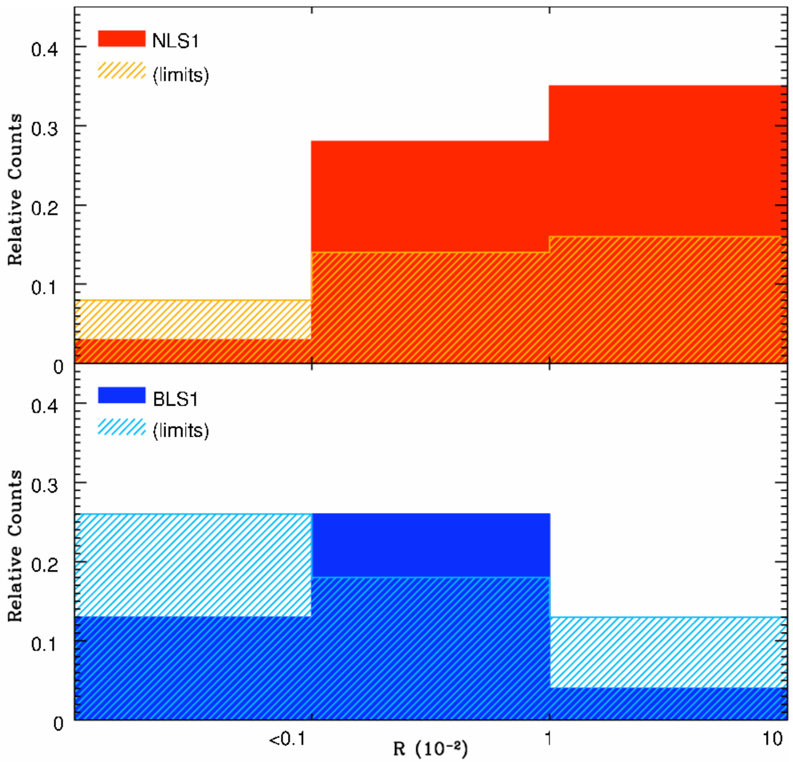
Bars drive gas in to central kpc. So is there evidence of enhanced star formation in NLS1s, which might be associated with the higher bar fraction?

NLS1 hosts have enhanced star formation in central kpc

Sani+ 10

- R is ratio of star formation (PAH) to AGN luminosities at 6μm
- significant difference in R between NLS1 & BLS1
  (checked for bias due to luminosity, distance, etc)

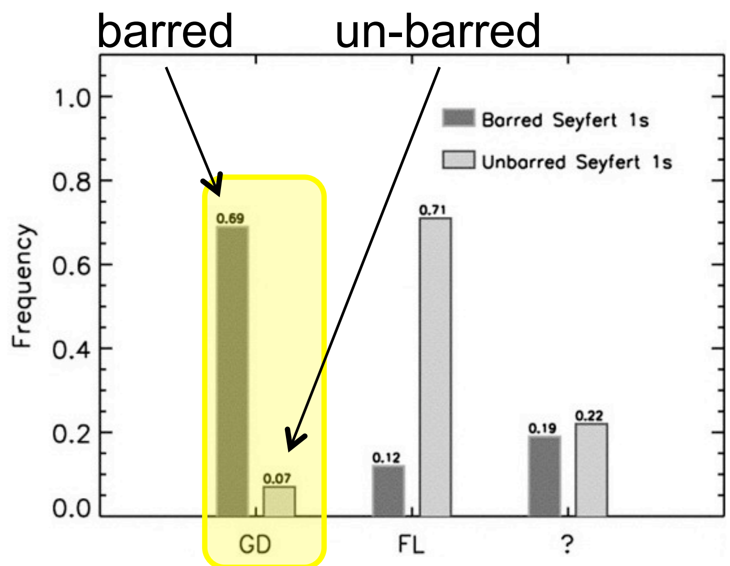


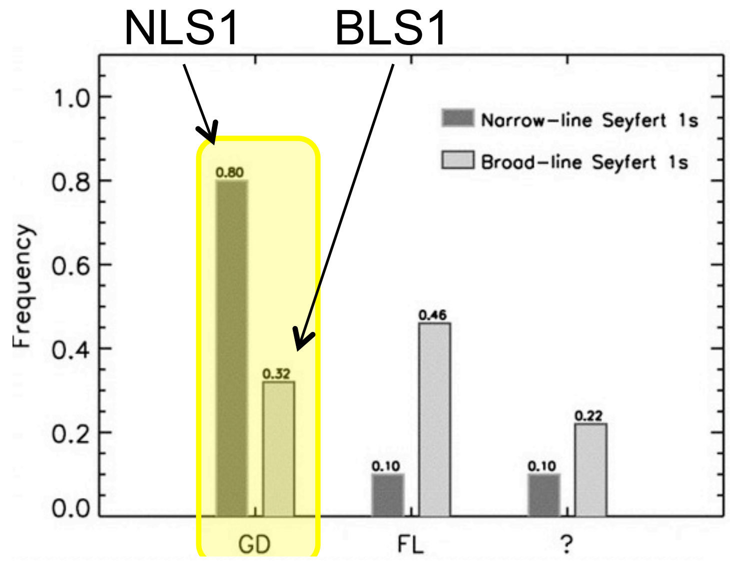


NLS1 hosts have circumnuclear spirals

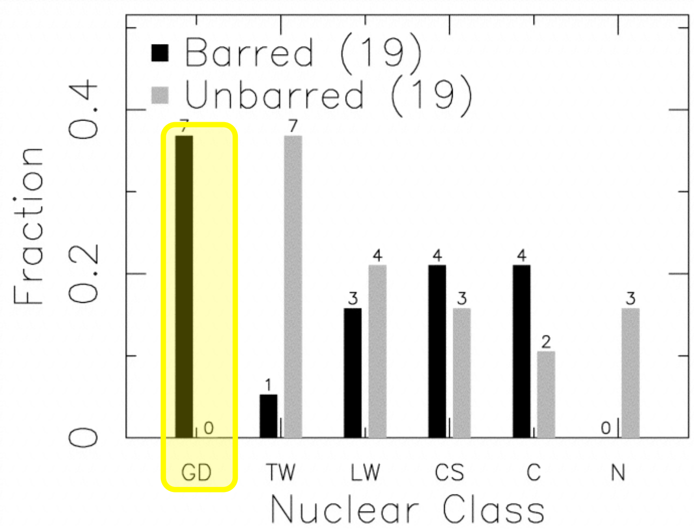
NLS1s have Grand Design cirumnuclear morphologies,
characteristic of barred galaxies

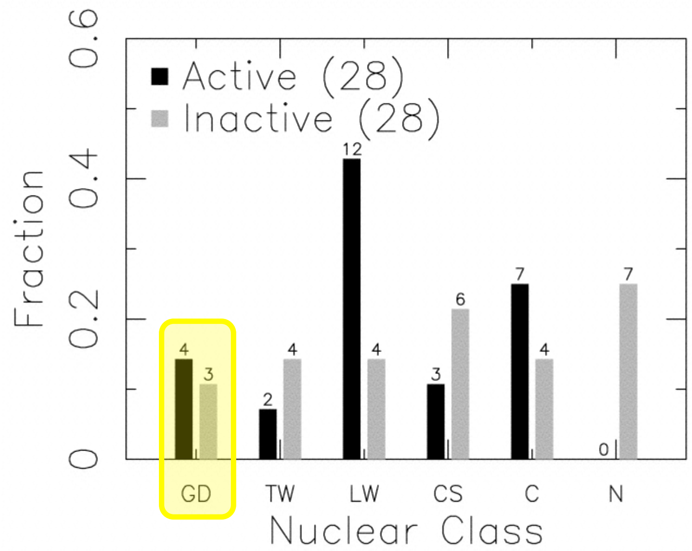
Deo 06





Martini 03





M_{BH}-σ: Black Hole Growth is about Bulge Growth

There are (at least?) 4 ways to make a bulge
(Kormendy & Kennicutt 04, Athanassoula+ 05, Genzel+ 08, Elmegreen+ 08):

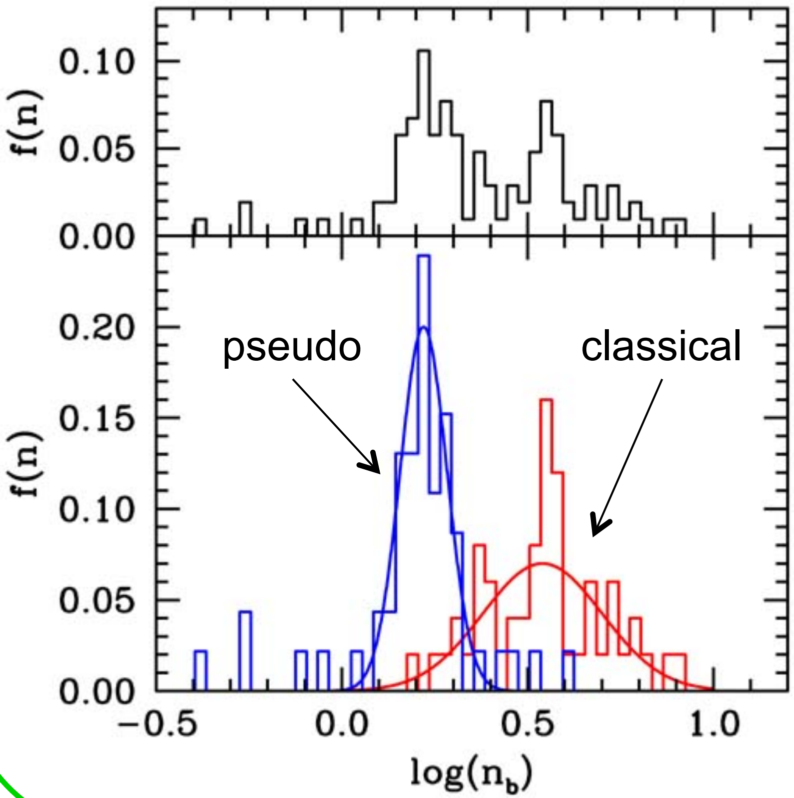
process	galaxy mergers	coalescence of clumps (violent secular)	bar heating & buckling (slow secular)	slow secular evolution
redshift	high	high	low	low
bulge type	classical (+ ellipticals)	classical	boxy pseudo	disky pseudo
sersic index	high	high	low	low
rotation speed	low	low	high	high
dispersion	high	high	increasing	low
stellar population	old	old	mixed	young
dark matter cusp	yes	no	no	no

Pseudo vs Classical Bulges

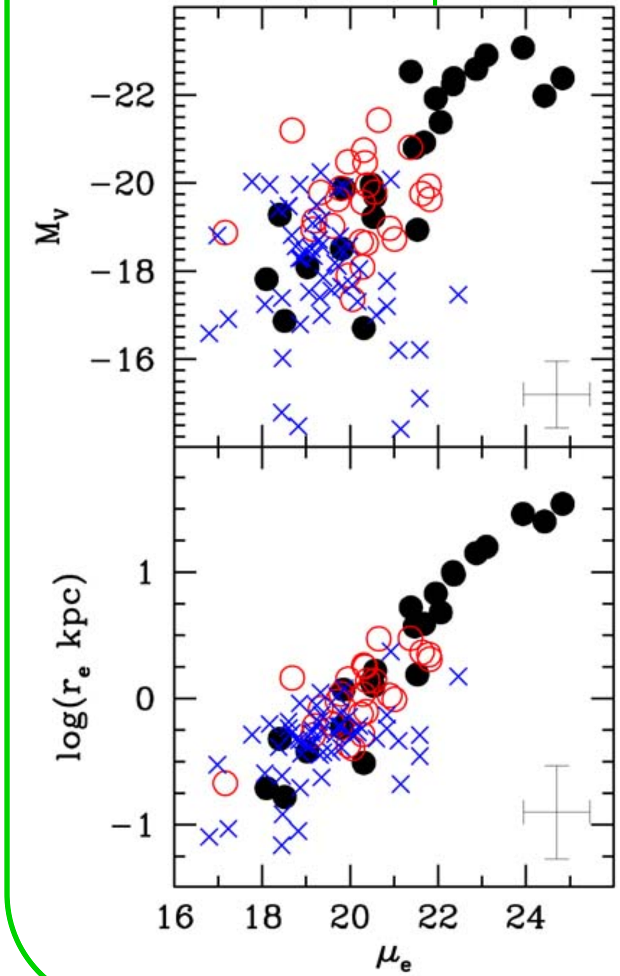
Fisher & Drory 2008:

pseudo-bulges: - have lower sersic index n
- may be slightly smaller

sersic index



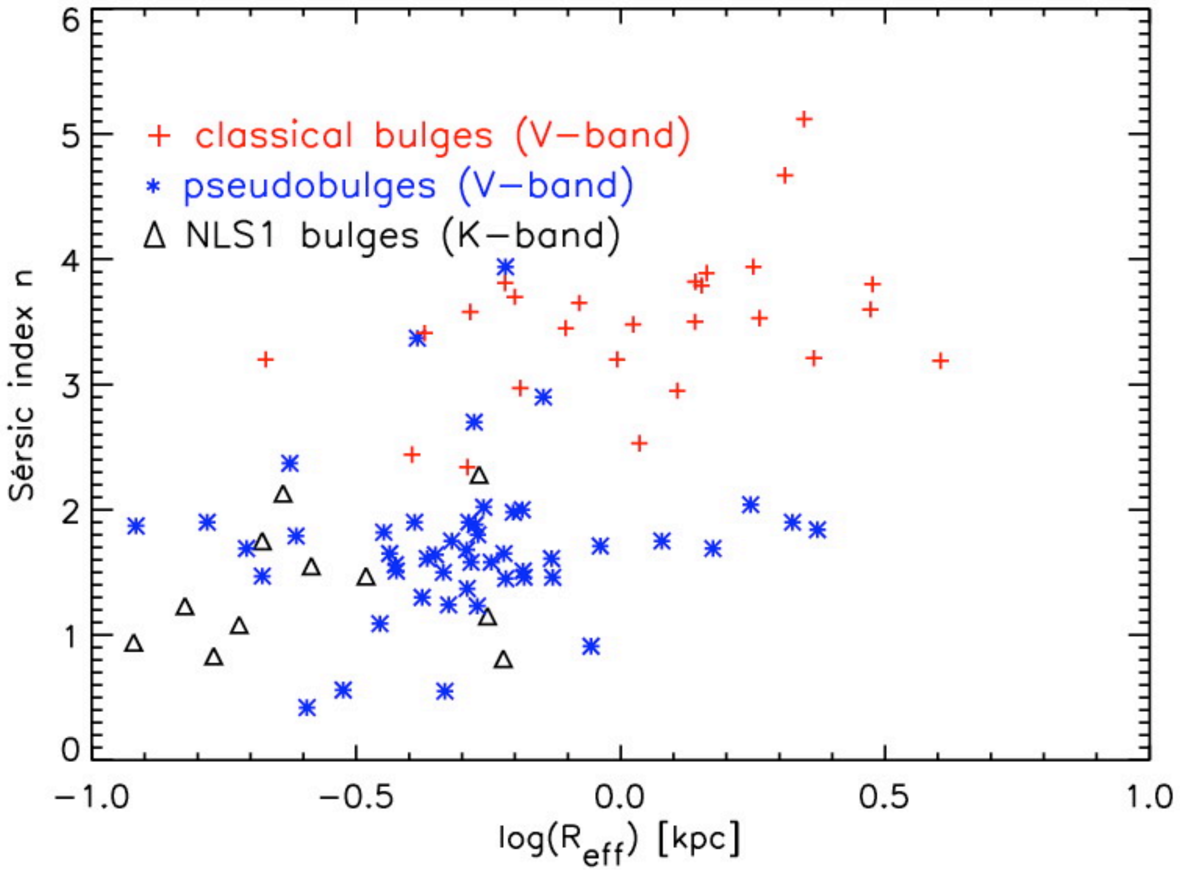
projections of fundamental plane



NLS1 hosts have pseudo-bulges

Orban de Xivry et al. (in prep)

- NLS1 have *n* and R_{eff} more similar to pseudo than classical bulges (based on data from Ryan+ 07, & is being verified using larger samples & new measurements of bulge kinematics)
- This implies that secular evolution was always dominant



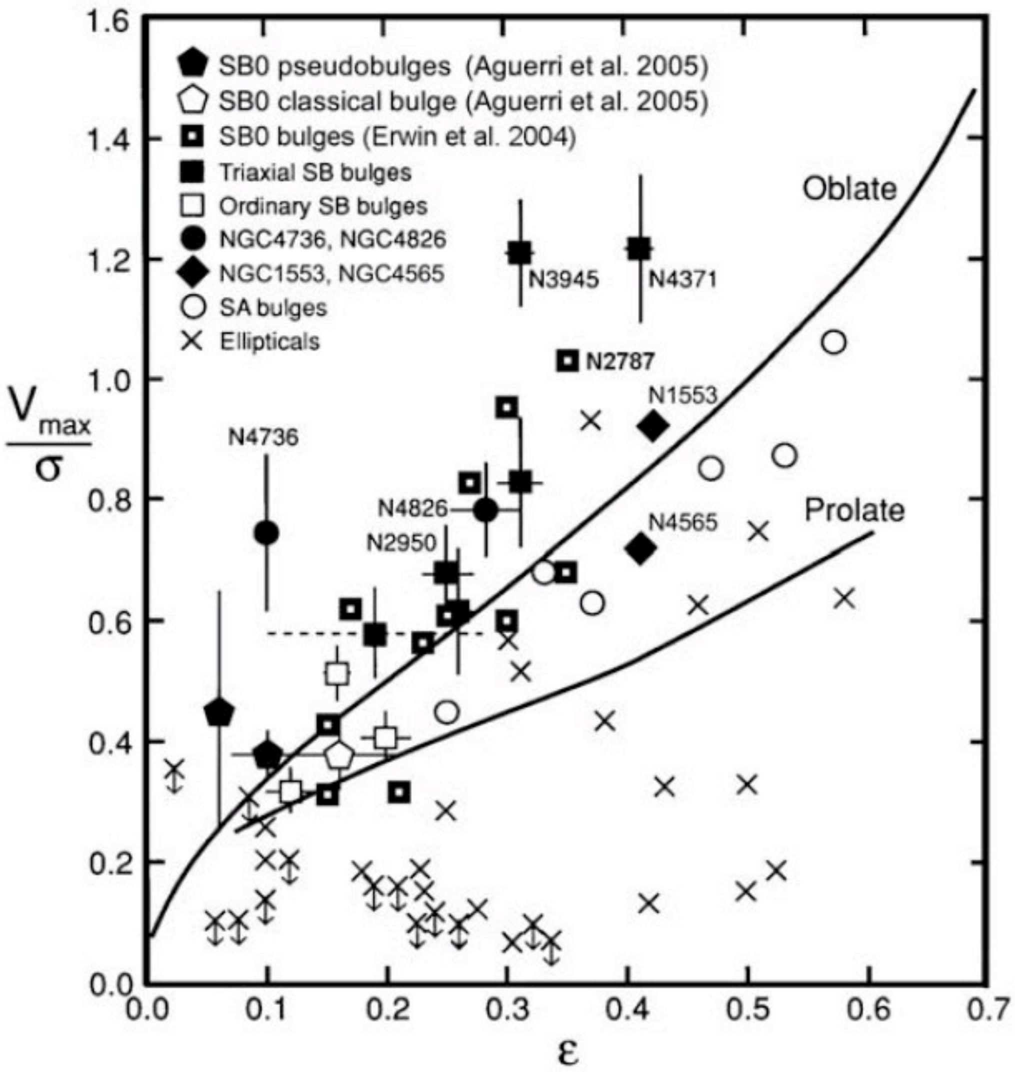
The importance of angular momentum

Kormendy & Kennicutt 04:
pseudo-bulges have more angular momentum then classical bulges

Cuadra+ 06, Schartmann+ 09, 10:
angular momentum hinders accretion of gas to small scales

put these together:
bulge rotation implies there is significant angular momentum, which will hinder inflow of gas and so slow BH growth, leading to lower BH mass.

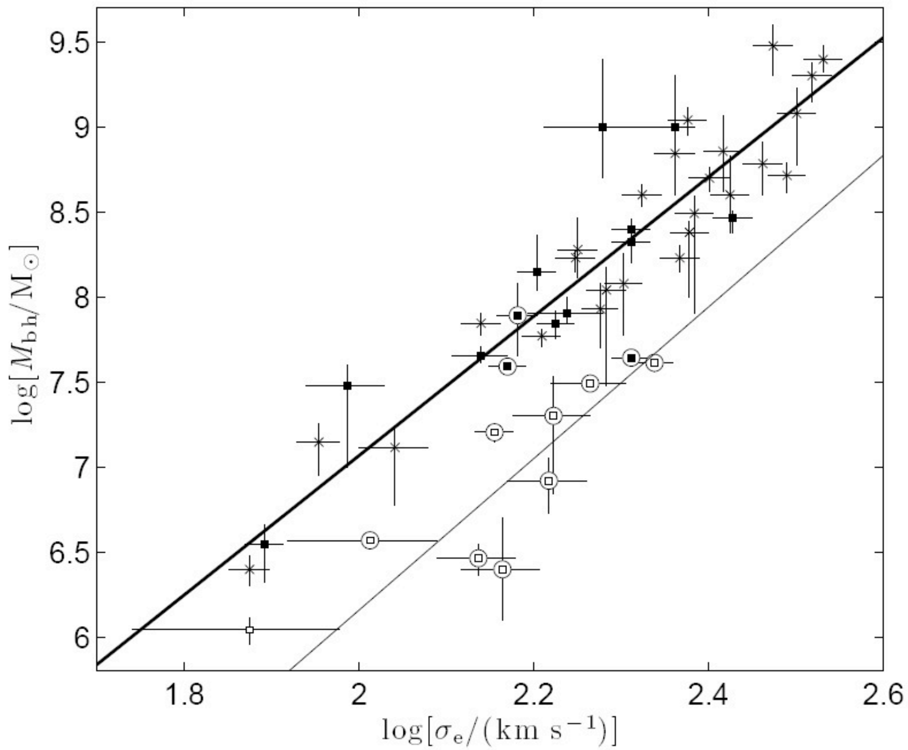
on-going work:
observationally (Orban de Xivry+) & using simulations (Schartmann+)



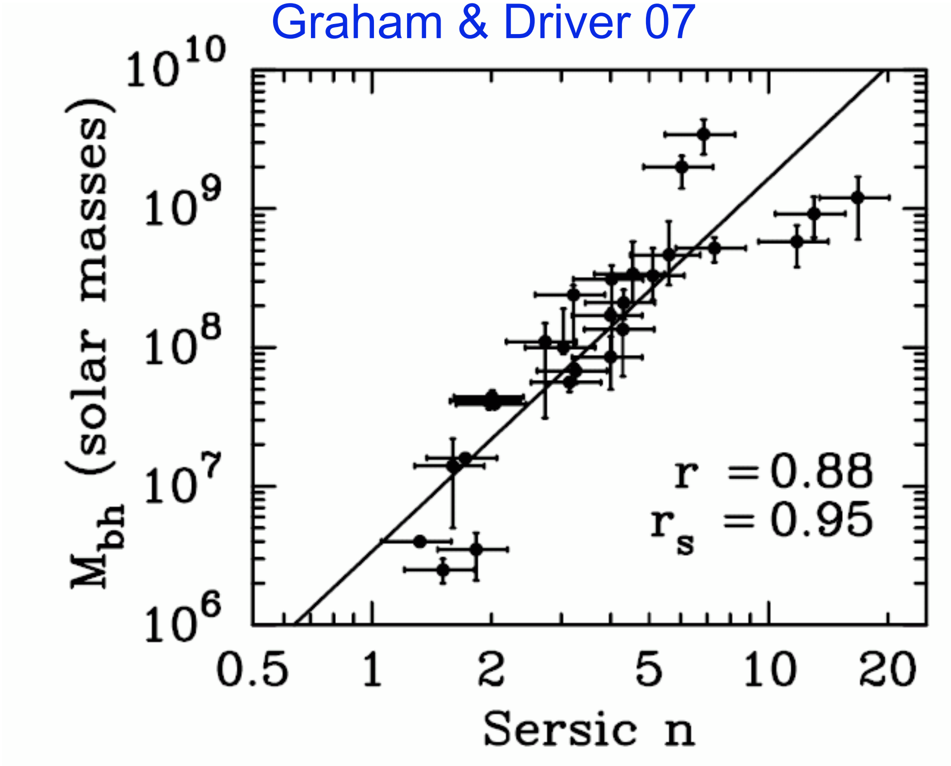
Kormendy & Kennicutt 04, Kormendy & Fisher 08

Do pseudo-bulges lie under the M_{BH}-σ relation ?

Hu 08



Graham & Driver 07

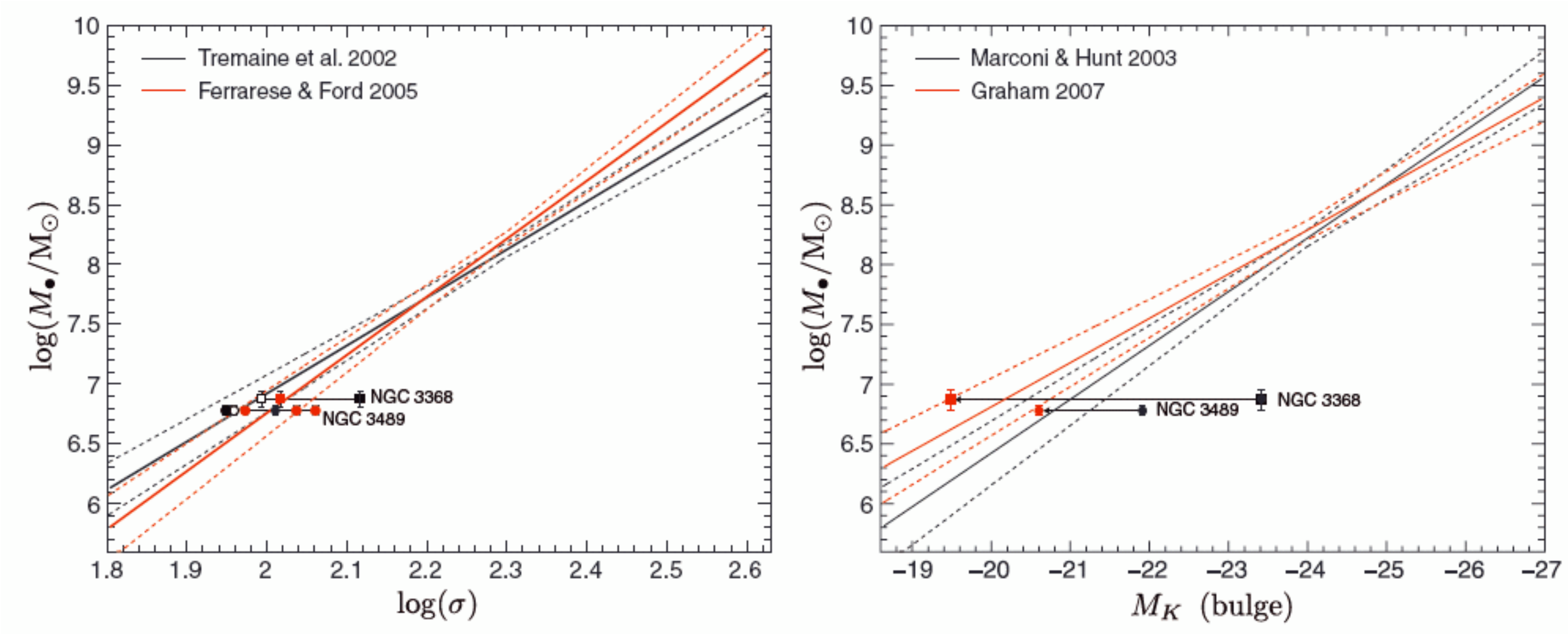


stars: ellipticals
filled squares: classical bulges
open squares: pseudo bulges
circles denote barred galaxies

Do pseudo-bulges lie under the M_{BH}-σ relation ?

Nowak+ 10

detailed M_{BH} for 2 composite bulges (i.e. classical & pseudo components)



- open symbols: small scale, dominated by classical bulge
- filled symbols: various larger scale σ, including pseudo-bulge

- red symbols: classical bulge only
- black symbols: including pseudo-bulge

How common are NLS1s ?

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

~15% of Seyfert 1s are NLS1

we assume 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

~43% can be considered AGN

up to 2-7% of local galaxies could be (similar to) NLS1s

A population of galaxies that have evolved without mergers

Genzel+ 08:
can see bulges starting to grow at z ~ 2-3

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

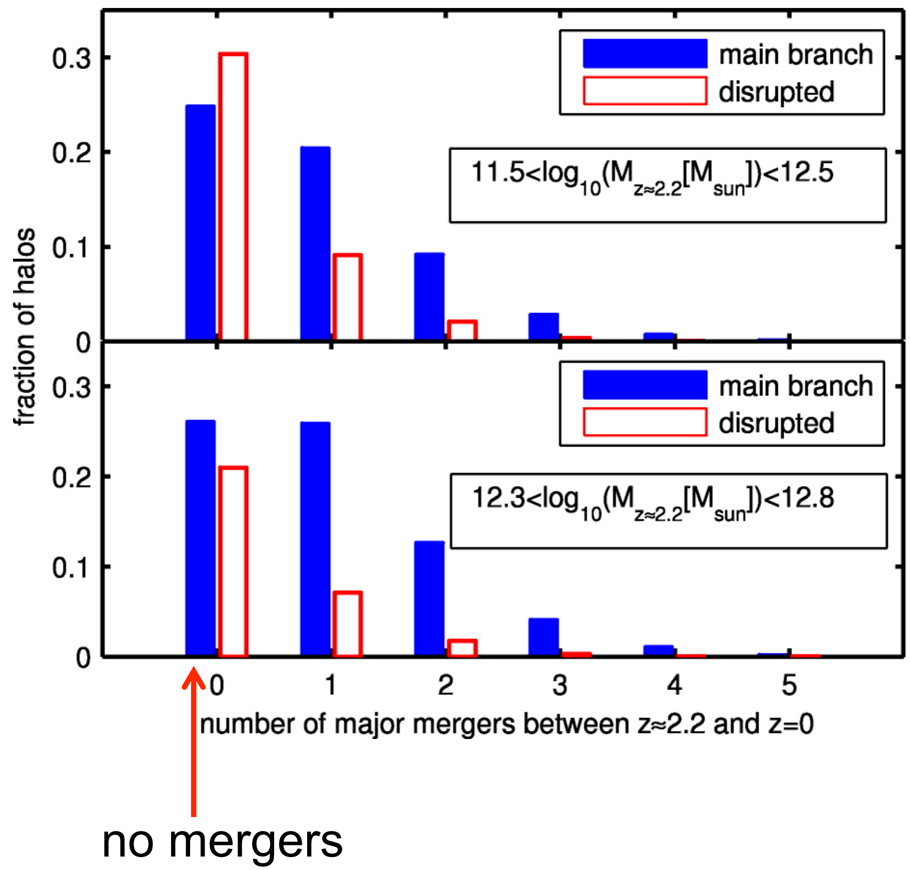
~40% are subsumed into a larger halo

~35% undergo a major merger

~25% experience no further major mergers

For ~40% of galaxies at z=0,
evolution from z~2 is secular .

This population could account for NLS1s.



Conclusions

❖ Kinematic Signatures of Gas Inflow on 10-1000pc Scales

- less H_2 in circumnuclear regions of quiescent galaxies
- significant non-circular motions in H_2
- whether characteristics of gas inflow in Seyferts & quiescent galaxies differ remains to be seen

❖ BH formation & growth in NLS1s is, and has always been, dominated by secular evolution

- AGN-host relation very different between NLS1 & BLS1
- secular process are strong & on-going
- they have pseudo-bulges, implying secular evolution was always important
- angular momentum hinders gas inflow from disk &/or pseudo-bulge, leading to slower BH growth & lower BH mass
- we expect there to be a population of galaxies whose evolution has been predominantly secular