Secular evolution in galaxies

Outline:

➔Evidence of secular evolution, pseudo-bulges and SF

➔Bar length and type, Ω and friction

➔Bar destruction, role of gas

➔ Evolutive scenarios, feedbacks & cycles

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Prague, 14 August 2006

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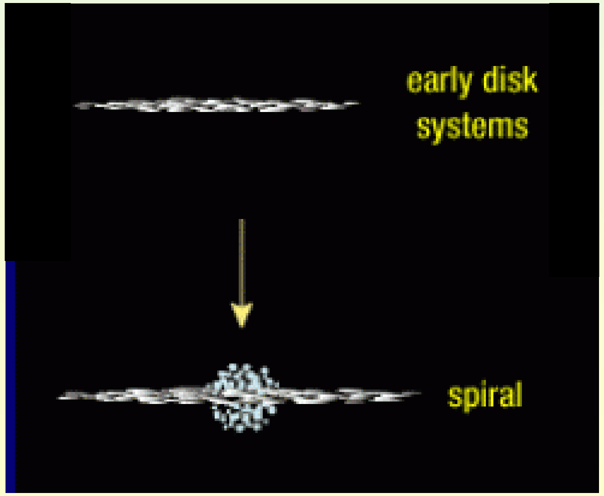
Monolithic

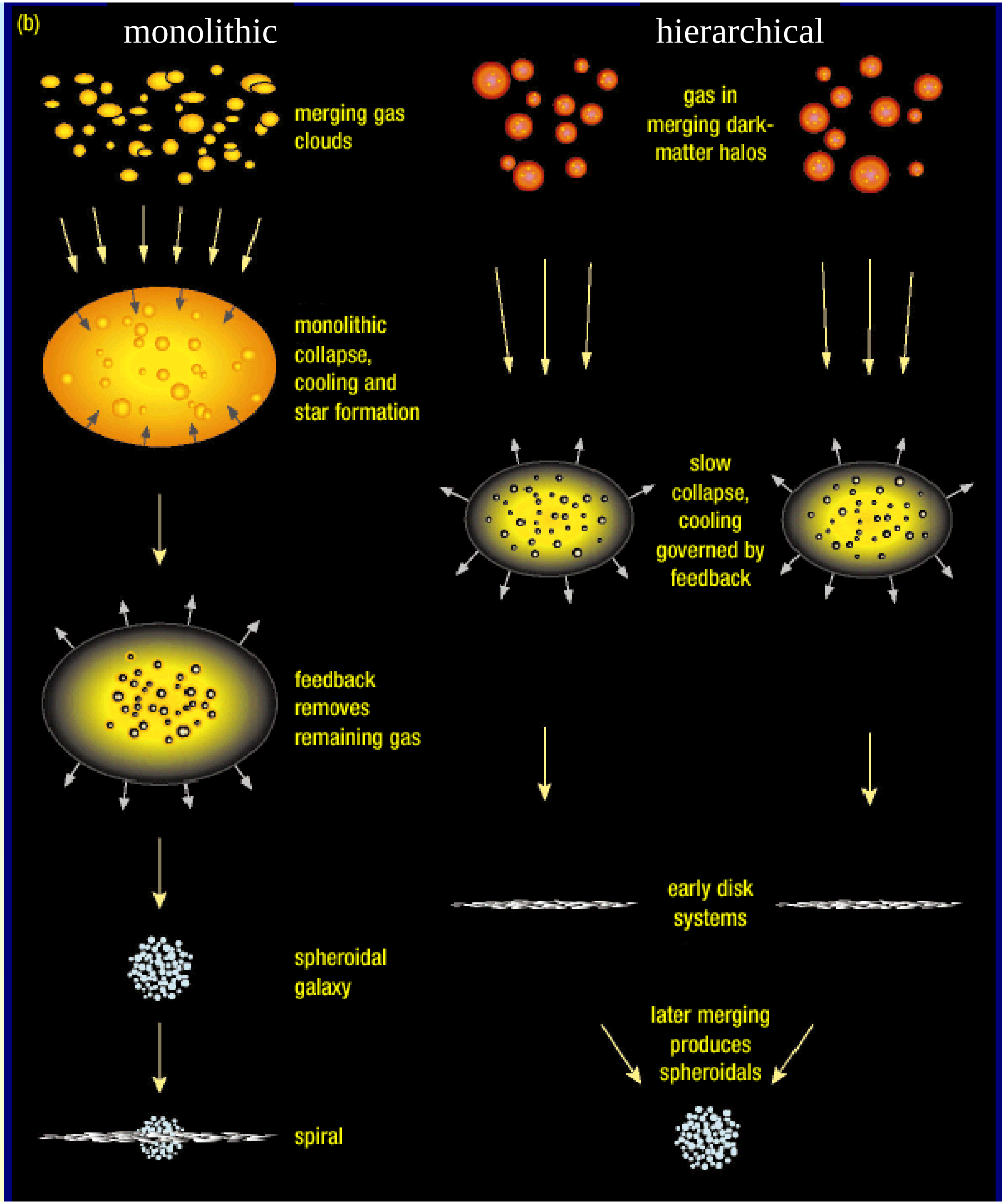
Disks form afterwards
by gas accretion

Hierarchical

Elliptical form later
by spiral mergers

Secular evolution





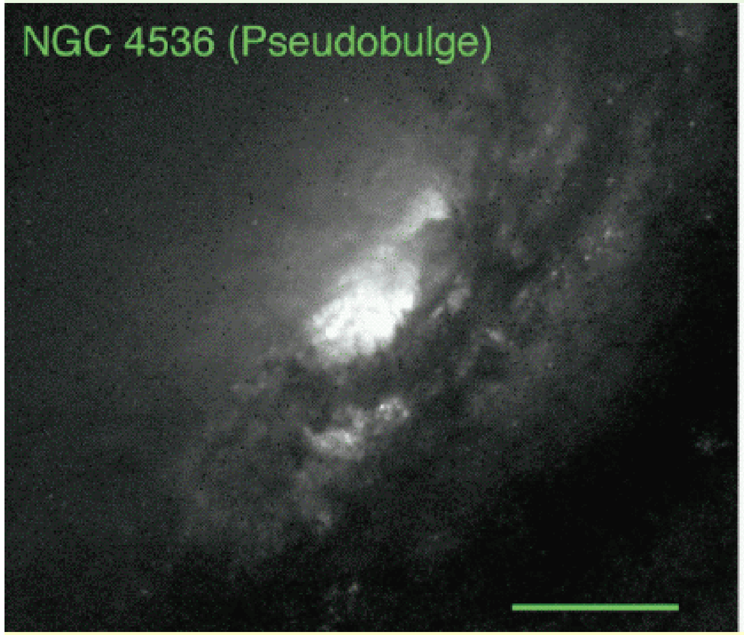
Pseudobulges characteristics

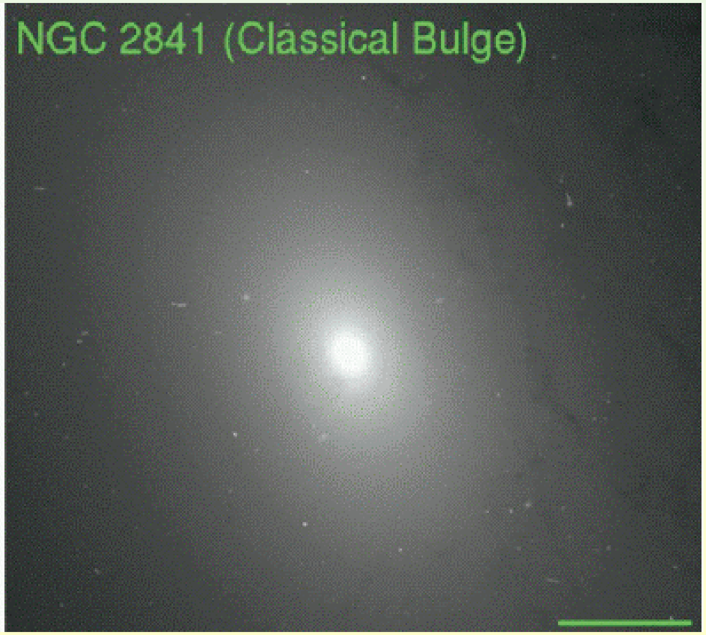
Pseudobulges have characteristics intermediate between a classical bulge (or Elliptical) and normal disks *(Kormendy & Kennicutt 2004)*

➔Sersic index $\mu \sim r^{1/n}$, with n =1-2 (disks: n=1, E: n=4 or larger)

➔Flattening similar to disks, box/peanut shapes ➔ Bluer colors

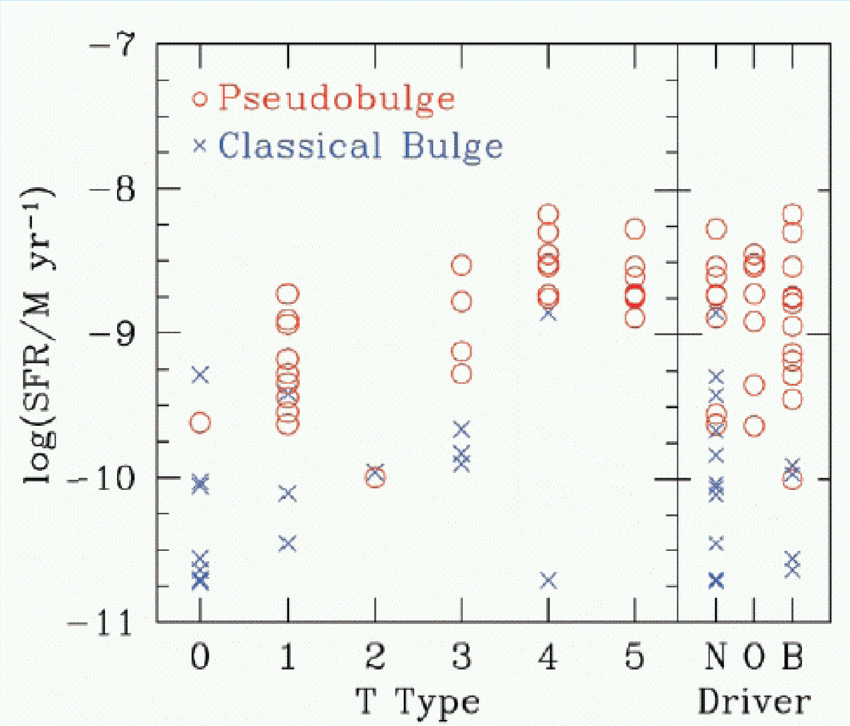
➔Kinematics: more rotation support than classical bulges





Fisher, 2006

Evidence of secular evolution



PAH as tracer of SFR (Spitzer)

Star formation is more spectacular in the center of pseudo-bulges (< 1.5kpc) (Fisher 2006)
Driver: B bar, O oval, N none


N3627


N3351

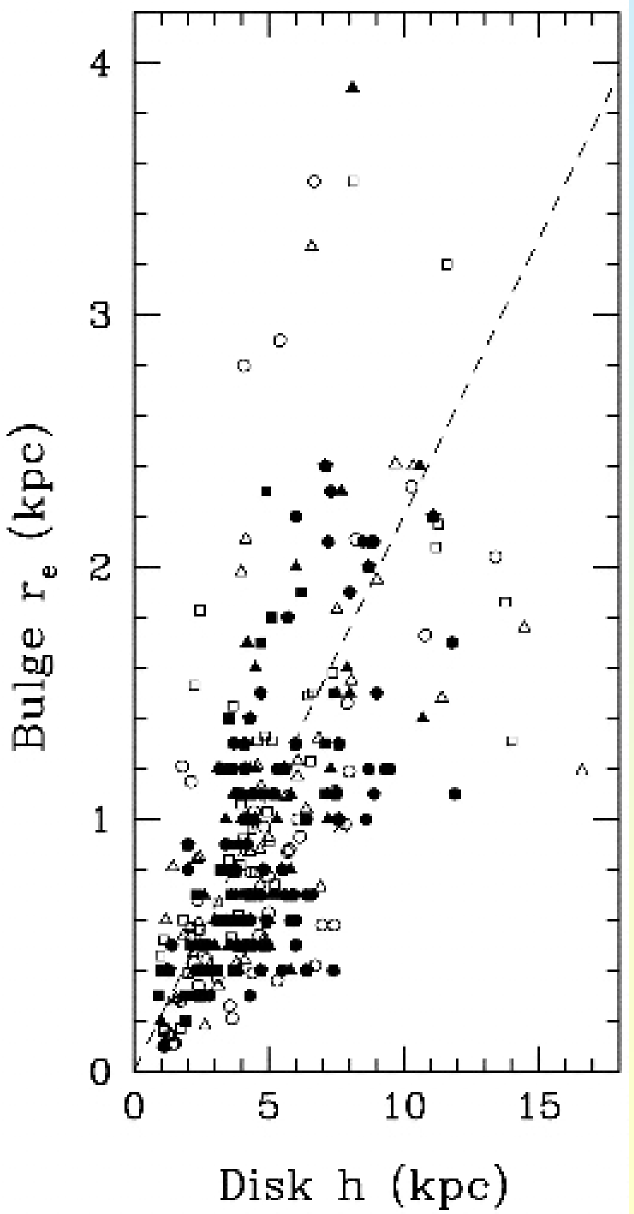
Regan et al 2006: Large central 8μ PAH emission ➔ pseudo-bulge
No 8μ concentration ➔ classical bulge
SINGS (Spitzer)

N7331

Bulge-disk size relation favors SE

<re/h> = 0.22 from 0.20 to 0.24 late → early

MacArthur, Courteau, Holtzman (2003)



Relation metallicity –velocity dispersion
But no relation age-metallicity (as in E-gal)
Less [α/Fe], but smaller mean age

Mg2 and Fe are not compatible with collapse
but with extended star formation with gas infall
Proctor & Sansom (2000, 2002)

Thomas & Davies (2006) young ages in bulges
→not old, but rejuvenated systems
Influence of disks only in late-types

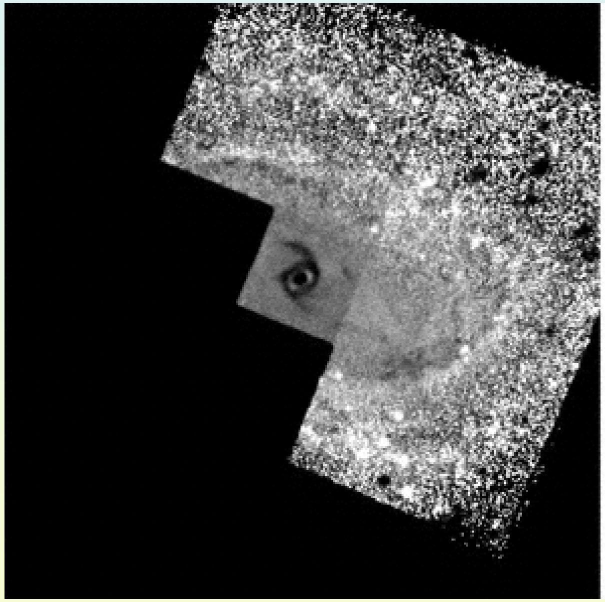
Pseudobulge in early-types as well

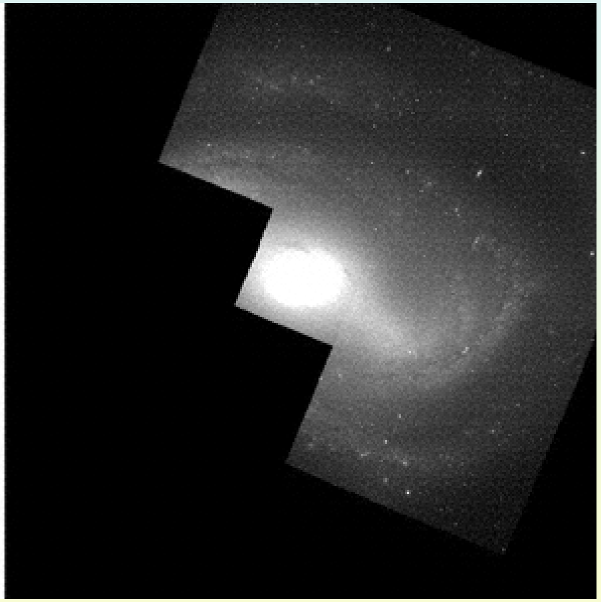
NGC 4593(SBb) and NGC 7690 (Sab), Kormendy et al 2006

Starbursts are visible in these galaxies (without any companion)

➔SF can be episodic

Not merger-built bulges but constructed slowly out of disk material.





N4593
V-K HST pictures

Gas and dust accumulate in the ring, which will form stars in the future

Relation between Bar Strength (Qb) and Circumnuclear dust (Peeples & Martini 2006) SB(r) weaker bars than SB(s)

Bar sizes and types

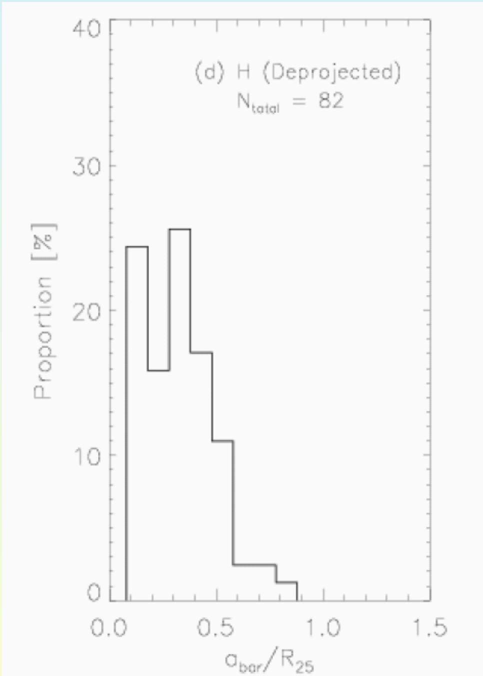
Bars are longer (%h, R_{25}) in early-types than late-types (Erwin 2005)

SF can add stars at the end of bars

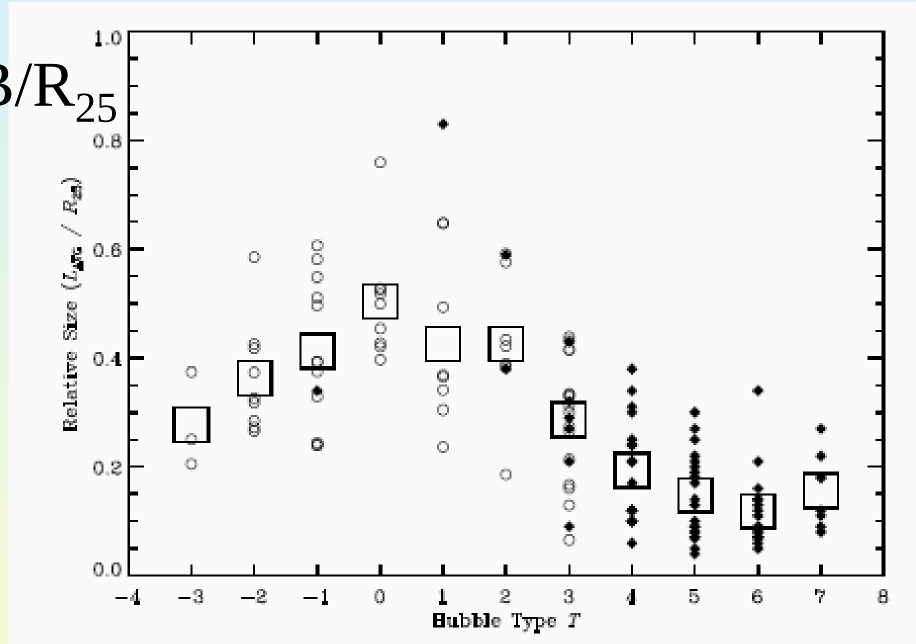
Amount of dark matter, to slow down bars?

Marinova & Jogee 06

a/R_{25} histogram



B/R_{25}



$0.2 < a/R_{25} < 0.4$

Diagnostics of the dynamical friction with the dark matter halo (Debbatista & Sellwood 1998, 2000)

But cases of possible metastability can occur (Valenzuela & Klypin 2003)

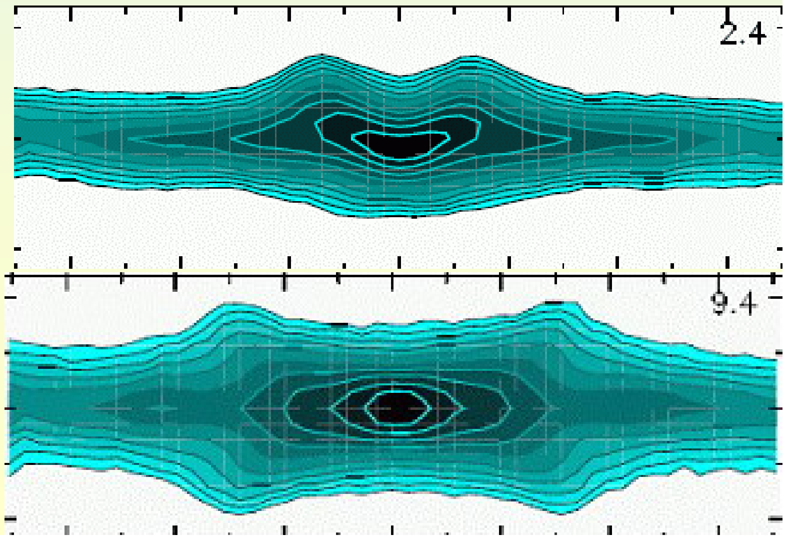
Evolution of bar size

Length of bars: depend on the definition (% CR or h, R_{25})
➔Is a tracer of the past history of the galaxy

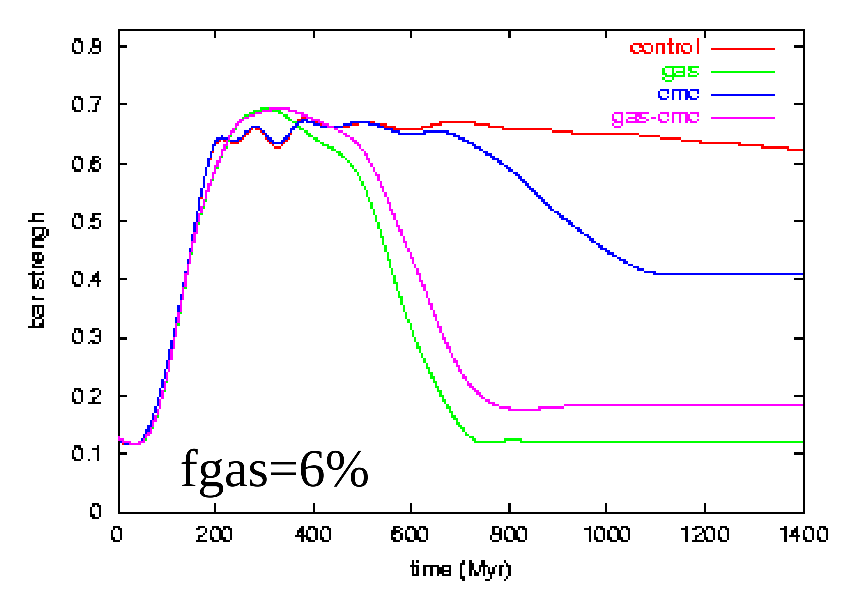
➔With gas accretion, bars are generally shorter (appear late-type just after accretion, Bournaud & Combes 2002)

➔Interactions can produce longer bars (Holley-Bockelman et al 2005)
Depending on mass and distance of satellite

➔Vertical resonance and peanut forming:
Ω_b increases first (mass concentration),
and decreases after
(Martinez-Valpuesta et al 2006)



Bar destruction by gas



Gas is driven in by the bar torques
The angular momentum is **taken up by the bar wave**

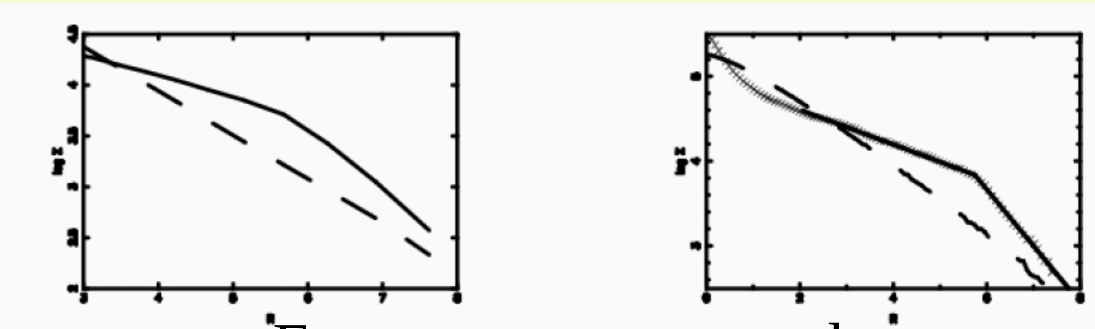
➔ **This destroys the bar**
negative momentum inside CR, ~ A_2 (Ω_b-Ω)
The gas AM from CR to center is of the same order

Not only the presence of the Central Mass Concentration
A CMC of only 1% is not sufficient to destroy the bar
(Shen & Sellwood 2004, Athanassoula et al 2005,
but Hozumi & Hernquist 2005)
But 1-2% of gas infall is enough to transform a bar in a lens
(Friedli 1994, Berentzen et al 1998, Bournaud & Combes 02, 04)

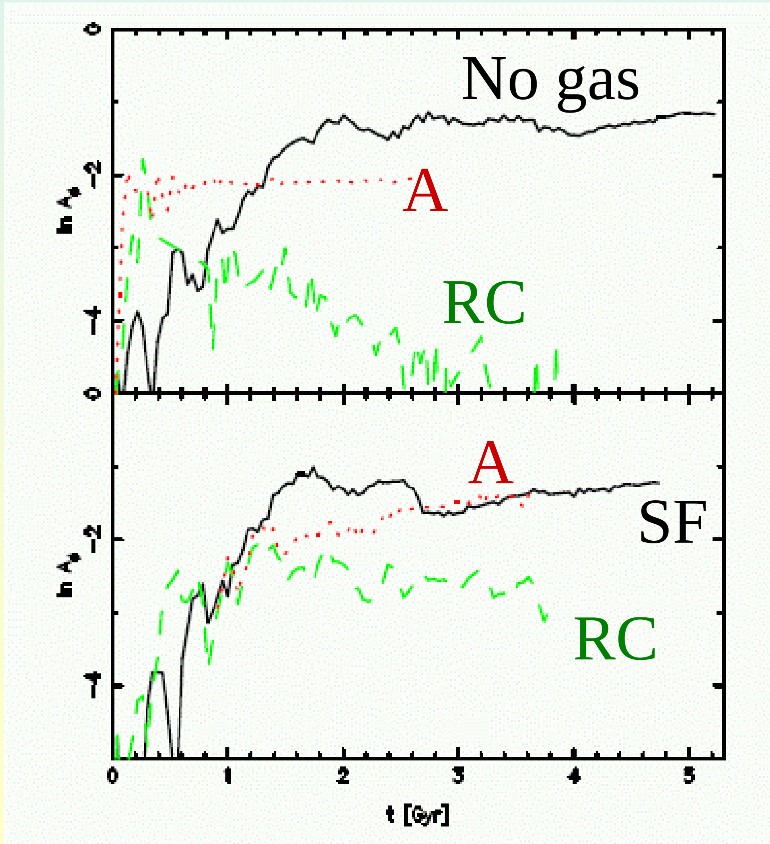
Secular evolution with gas

Effect of gas depends on the cooling:
Isothermal or adiabatic behaviours
Debattista et al (2006)

Breaks in the density profiles
Consequence of AM exchange
Outer and inner disks breaks
(Pohlen 2002, 79% of galaxies)



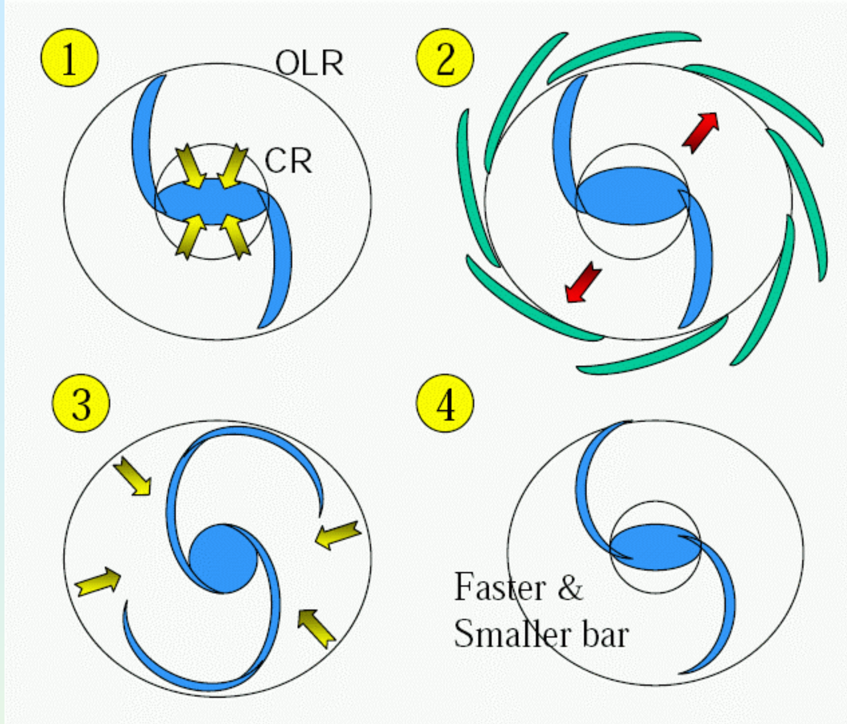
Face-on edge-on



Reformation of bars

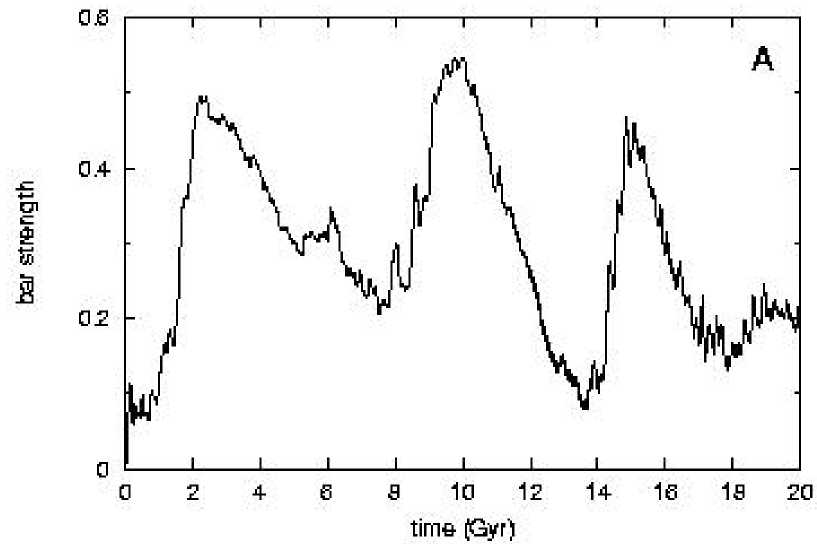
The observed frequency of bars requires
gas accretion to reform

Self-regulated cycle:
➔Bar forms in a cold unstable disk
➔Bar produces gas inflow, and
➔Gas inflow destroys the bar
+gas accretion



Gas accretes by intermittence
First it is confined
outside OLR until the bar weakens,

then it can replenish the disk, to make it unstable again to bar formation



Secular evolution + continuous gas accretion mimick interactions

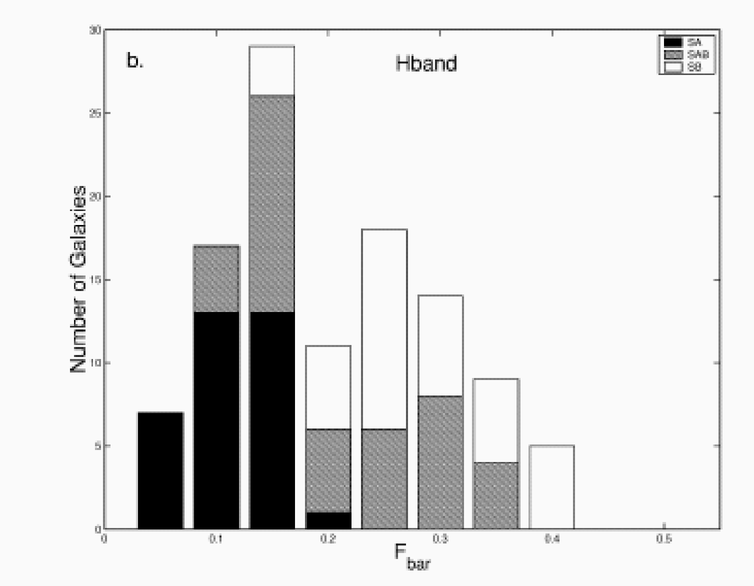
➔**Galaxies look peculiar**: can be due to a galaxy-galaxy interaction but also to mass accretion:
lopsided systems, warps, polar accretion..

➔**Starbursts:** by the action of bars and resonances, the gas is finally infalling towards the center in bursts
correlated starbursts and AGN

➔**Repeating starbursts**: several bar episodes in the galaxy life (cf Allard et al 2006)
Large CO concentration in the centers
Sheth et al 2005, Jogee et al 2005

Bar frequency

Whyte et al 2002

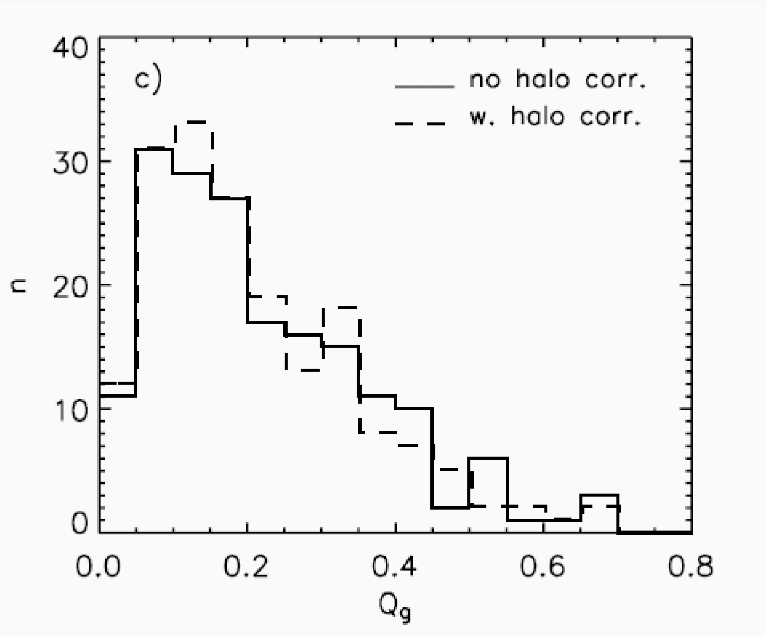


OSU NIR sample (Eskrige et al 02)

➔Paucity of weak bars

Marinova & Jogee 06

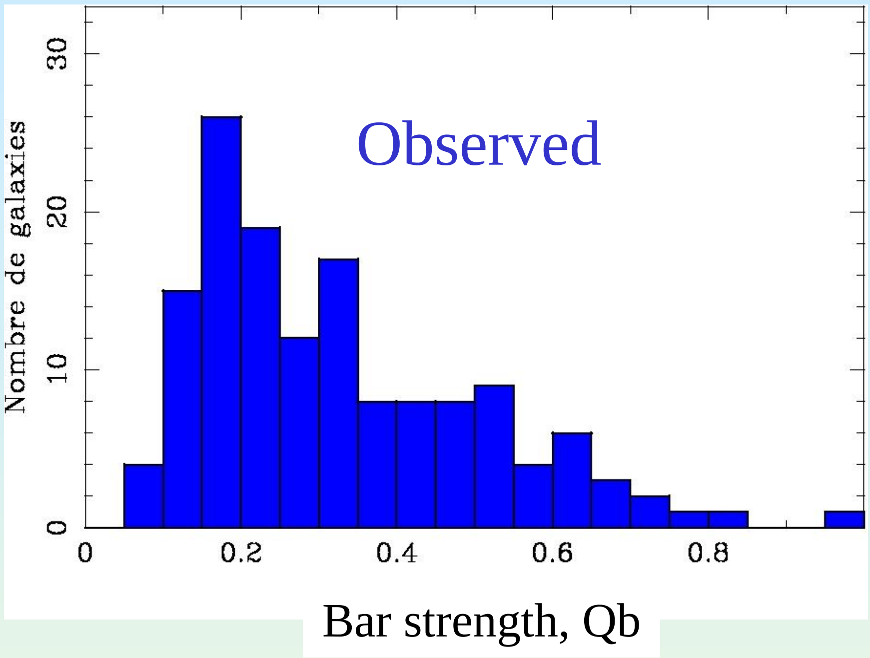
Buta et al 04

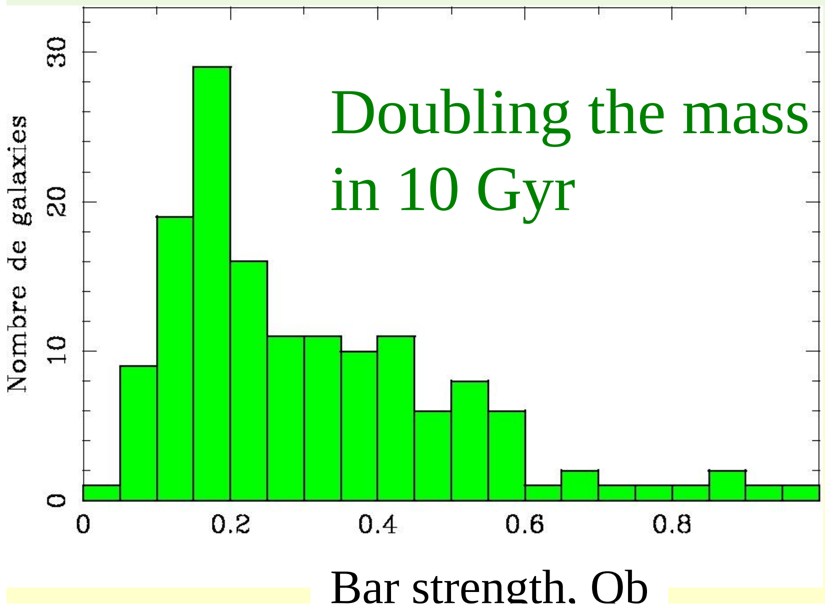


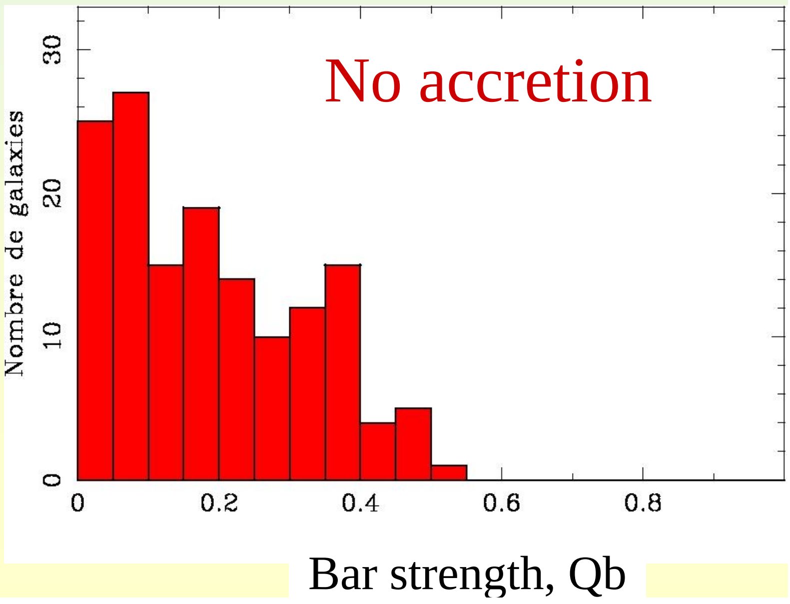
The majority of galaxies are barred (75%) and most of them (80%) are strongly barred

Bar frequency: quantification of the accretion rate

Block, Bournaud, Combes, Puerari, Buta 2002





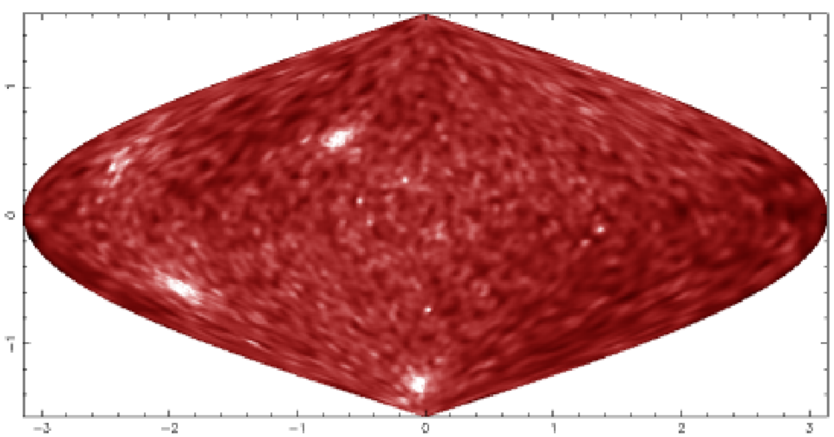


Constraints on gas accretion

To maintain a high frequency of bars, continuous accretion at a large rate is required

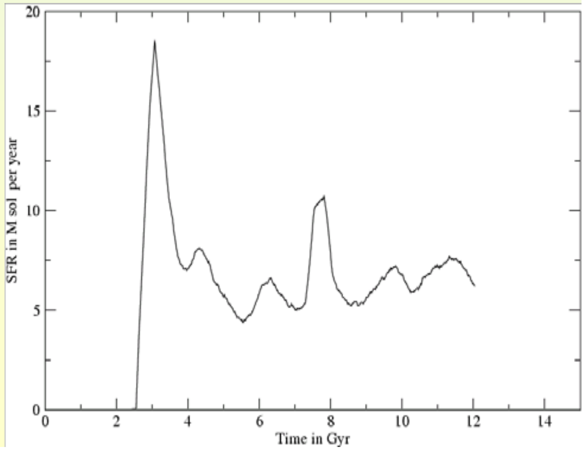
Dwarf companions: not more than 10% of accretion
(interactions between galaxies heat the disk, Toth & Ostriker 92)

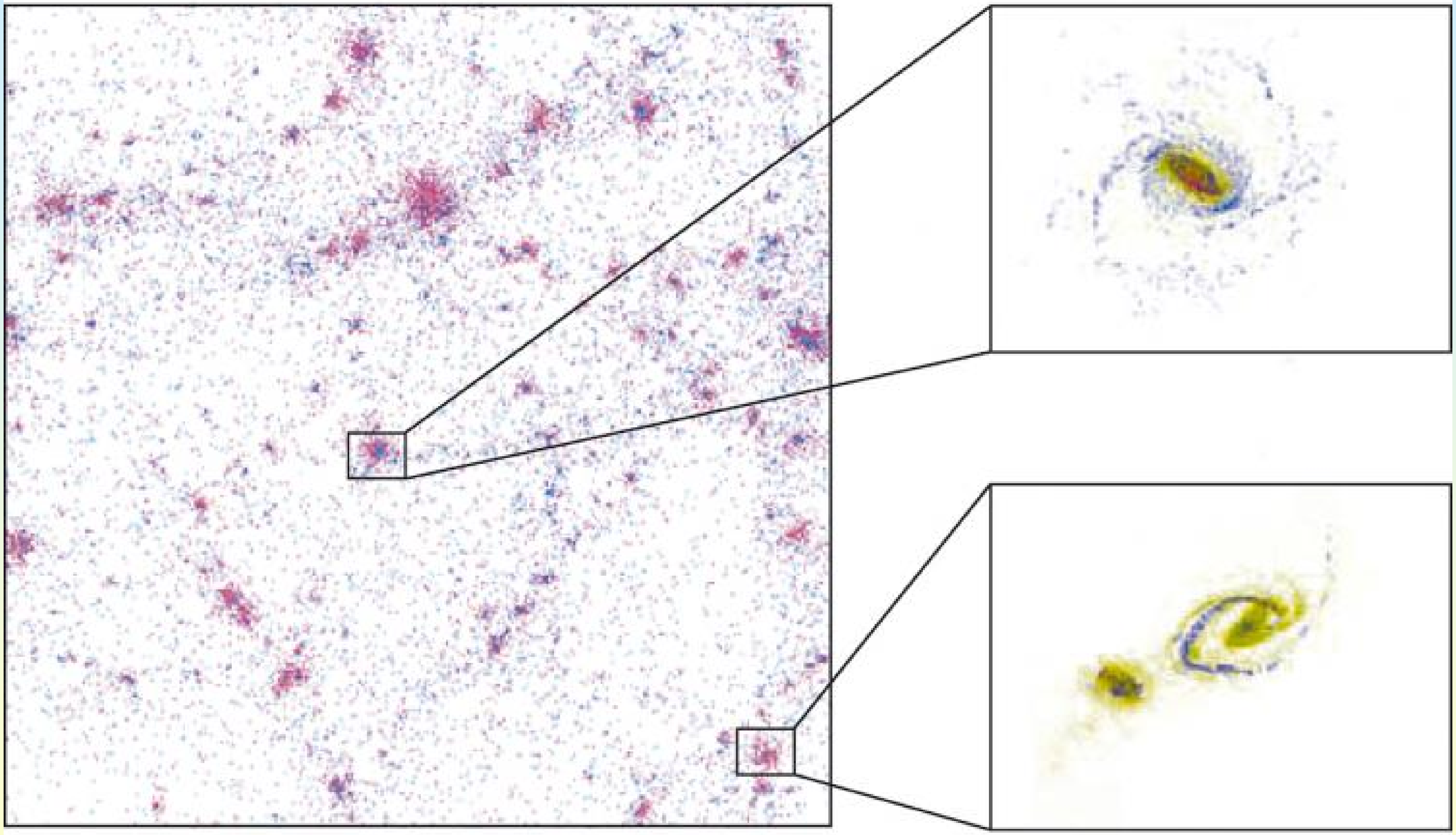
Required: a source of continuous cold gas accretion
from the filaments in the near environment of galaxies
➔Cosmological accretion is compatible with doubling the mass in 10Gyr



Semelin & Combes 05

SFR





Semelin & Combes 05

CONCLUSION

➔ Secular evolution plays a fundamental role in mass assembly, **fueling of SB, AGN, and bulge formation**

➔ Requires « diffuse » gas accretion, from cosmic filaments

➔ Bars (m=2) and m=1 perturbations constrain the accretion rate (mass doubling in 10 Gyr)

➔ Feedback mechanisms self-regulate the cycles:
bars are self-regulated
(SF, AGN and gravity instabilities)