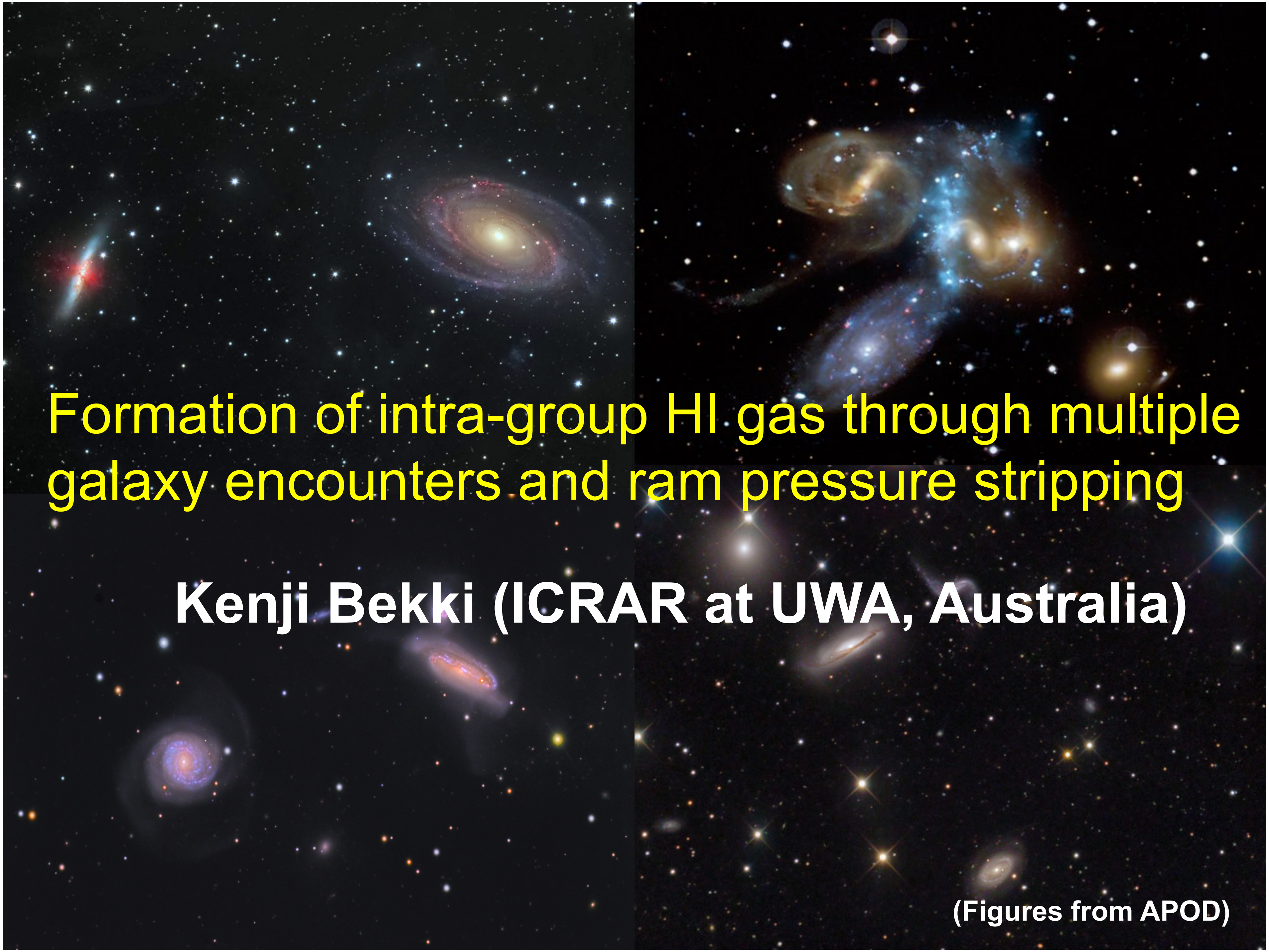


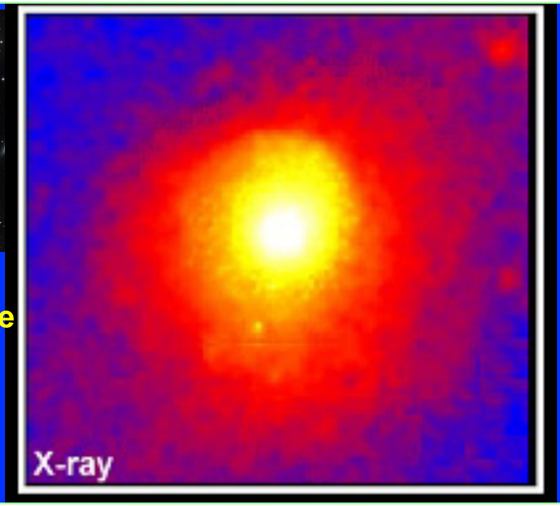
Formation of intra-group HI gas through multiple galaxy encounters and ram pressure stripping

Kenji Bekki (ICRAR at UWA, Australia)

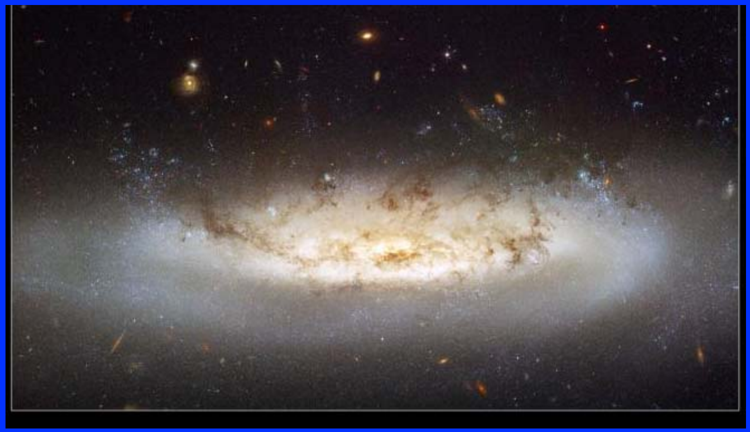
(Figures from APOD)

Physical processes that drive galaxy evolution in different environments.

(a) Ram pressure stripping due to hot intergalactic medium in clusters.



Virgo cluster
with Rosat image



NGC 4402 (Crowl
et al. 2005)

(b) Galaxy interaction/merging in groups.

NGC 3269 group

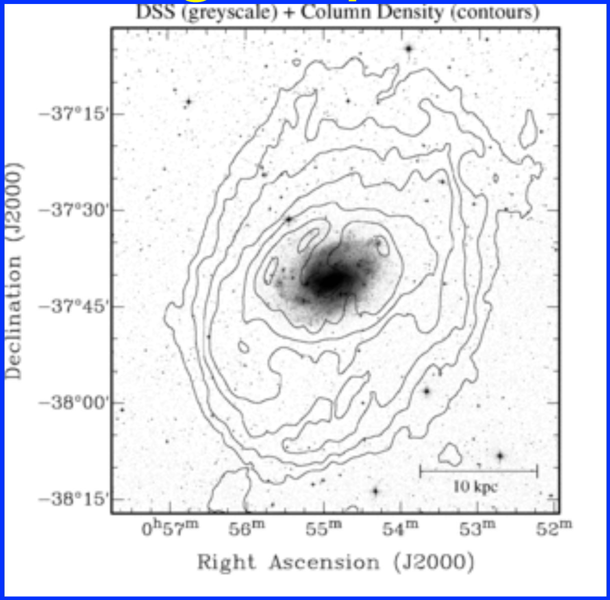
(NGC 2623)

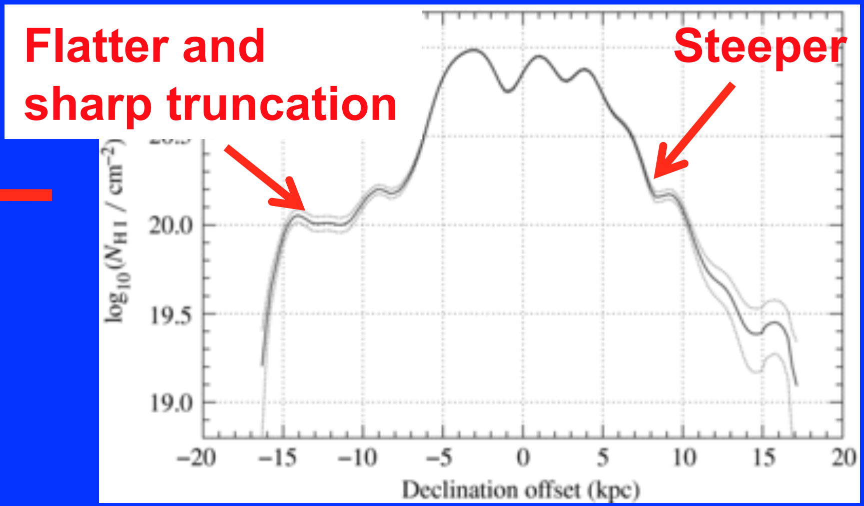
The WALLABY science: Galaxy evolution in groups.

- Ram pressure of warm/hot intra-group gas on extended gaseous (HI) disks of galaxies in small groups and filaments (with Westmeier T. et al. 2010).
- Transformation from spirals into S0s in groups of galaxies (with Couch W. et al. 2010).

Observational evidence for ram pressure effects on extended HI disks in groups ?

- Asymmetric 2D HI distribution of NGC 300 in the Sculptor group (Westmeier et al. 2010).
- The intriguing HI column density profile.



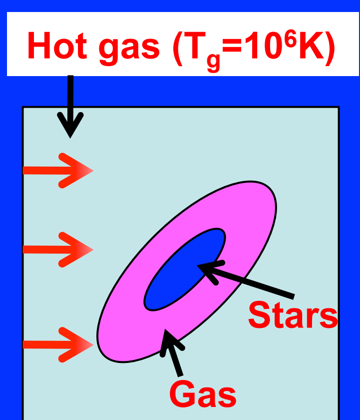


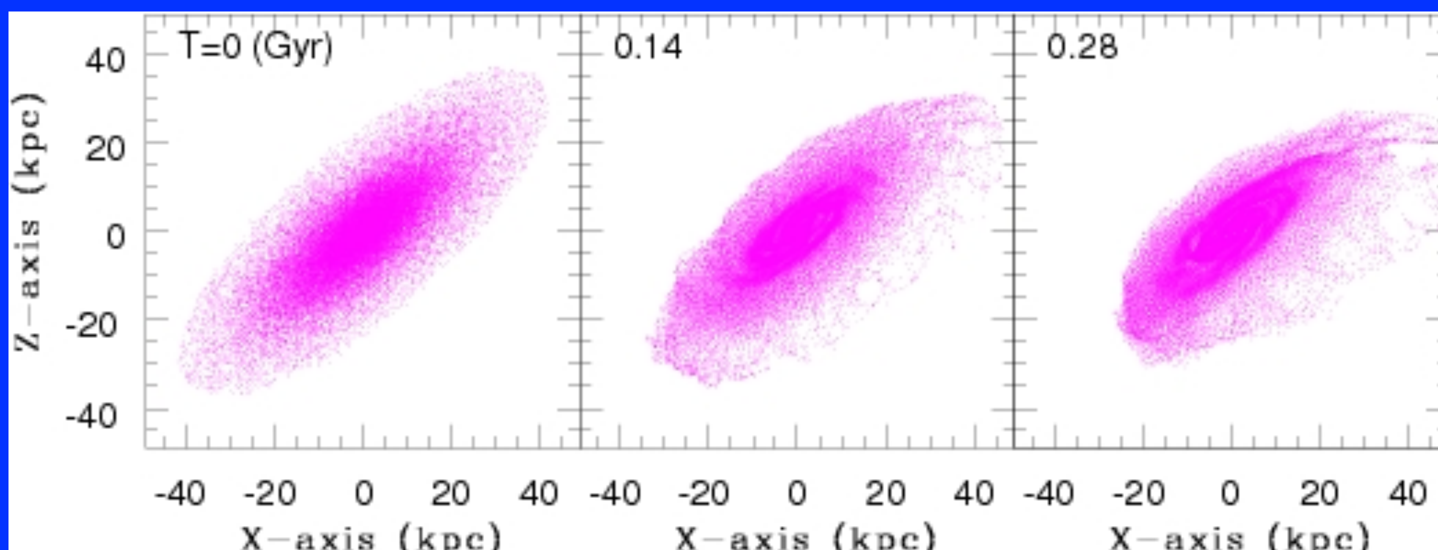
Numerical simulations of ram pressure effects (of intra-group warm/hot gas) on extended galactic gas disks.

$F_{ram} \sim \rho_g \, v_{rel}^2$

V_{rel} =250 km/s

$\rho_g = 10^{-4}$ atoms/cm^3





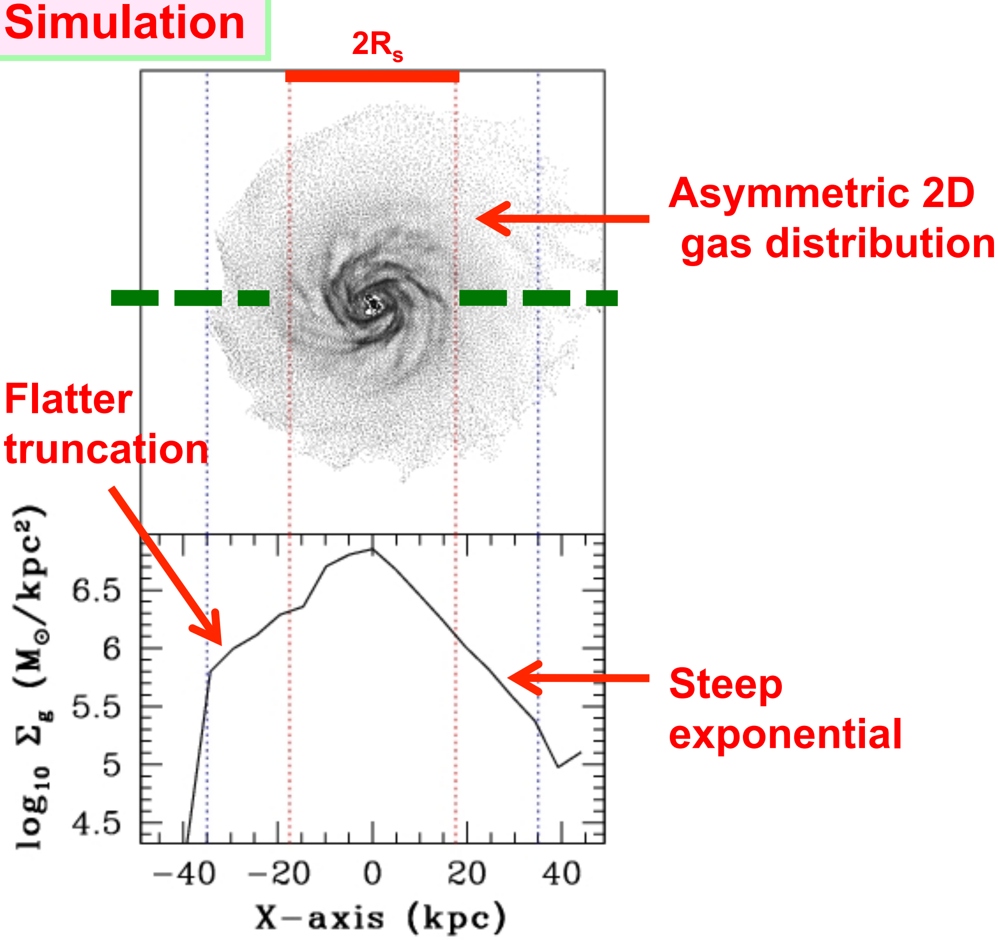
$R_g = 3R_s$, MW-type disk galaxy, $f_g = 0.1$

$\rho_g \sim 10^{-5} - 10^{-4}$ atoms/cm^3 for the MW (Sembach 2003)

(GRAPE7-SPH simulations: Bekki, Westmeier et al. 2011).

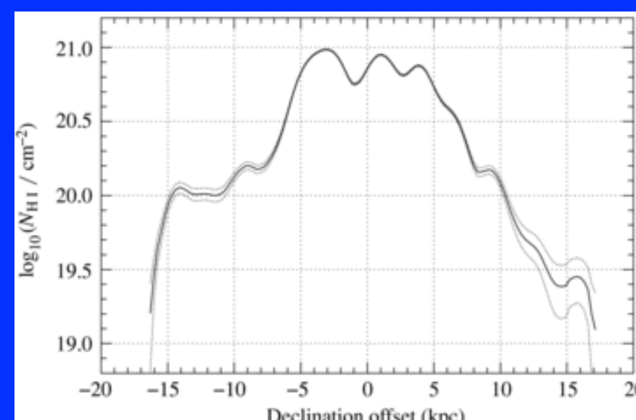
Characteristic 2D/radial gas distributions in disk galaxies under ram pressure of IGM.

Simulation



Flat column density distribution + sharp truncation (only on one side in a gas disk) are evidence of ram pressure ?

Observation (NGC 300)

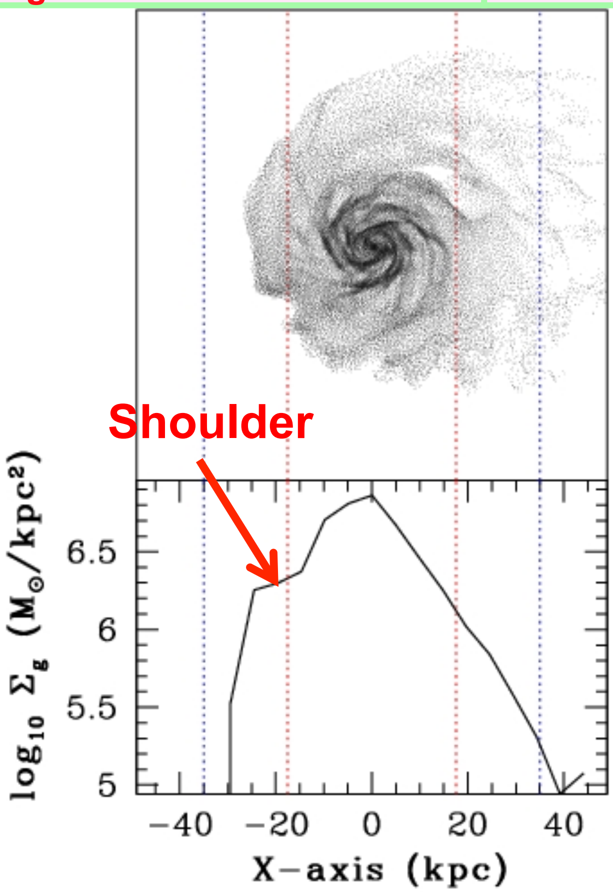


(Westmeier et al. 2010)

Dependences on model parameters.

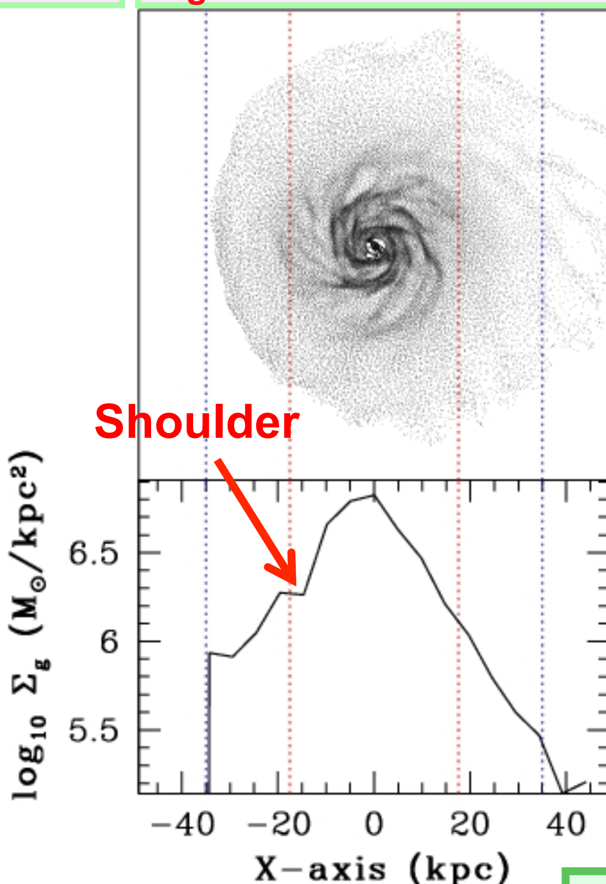
V_{rel} =500 km/s

ρ_g=10^{-4} atoms/cm^3 | θ=45,ψ=30



V_{rel} =250 km/s

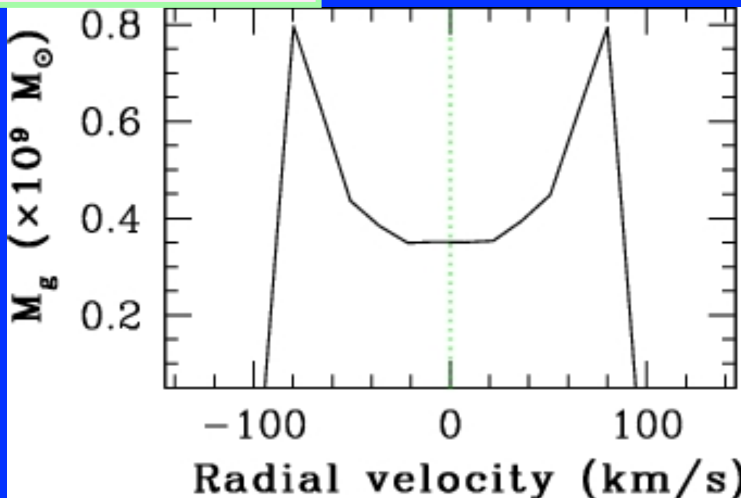
ρ_g=10^{-4} atoms/cm^3 | θ=30,ψ=0



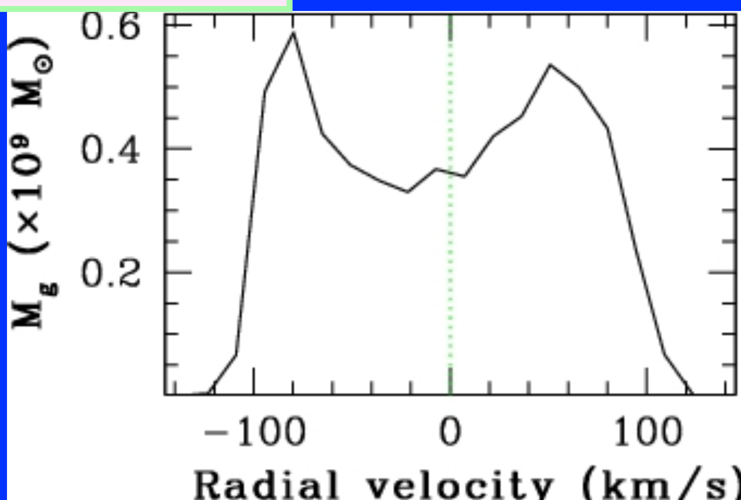
(Bekki et al. 2011)

Gas kinematics of disk galaxies under ram pressure.

Simulation (Initial)

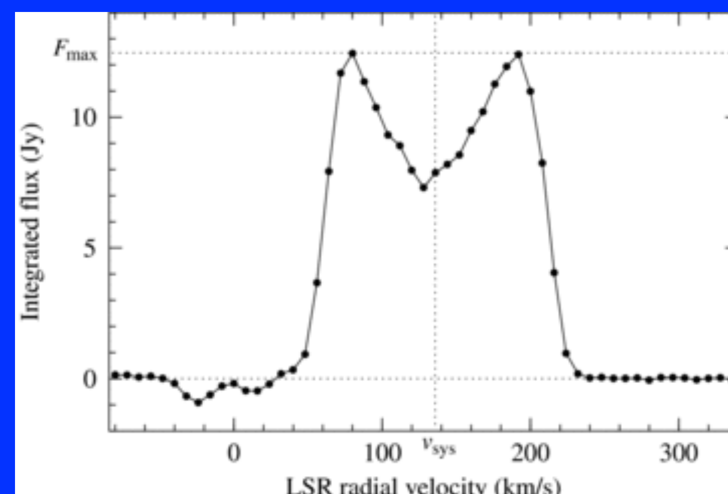


Simulation (Final)



These asymmetric kinematics can be evidence for ram pressure ?

Observation (NGC 300)



(Westmeier et al. 2010)

HI structure/kinematics derived by the WALLABY project will reveal the followings:

- Clear evidence of ram pressure effects on HI disks and thus indirect evidence of warm/hot IGM in groups.
- Differences in size-ratios of gas disks to stellar ones between fields and groups.
- New physical mechanisms for the formation of galactic warps and HVCs.

If comparison between the WALLABY observations and simulations enables us to estimate ***separately*** the density of IGM and the relative velocity then, we can discuss…..

$$\mathbf{F_{ram} \sim \rho_g\, v_{rel}^2}$$

- the total mass of warm/hot intra-group gas (IGM) in a small group/filament,
- 3D orbital motion of galaxies (i.e., 3D galaxy dynamics) and thus the total mass of a group (inclusive of DM halo).

Transformation from spirals into S0s.

NGC 1232

NGC 4565

Spiral → **S0**

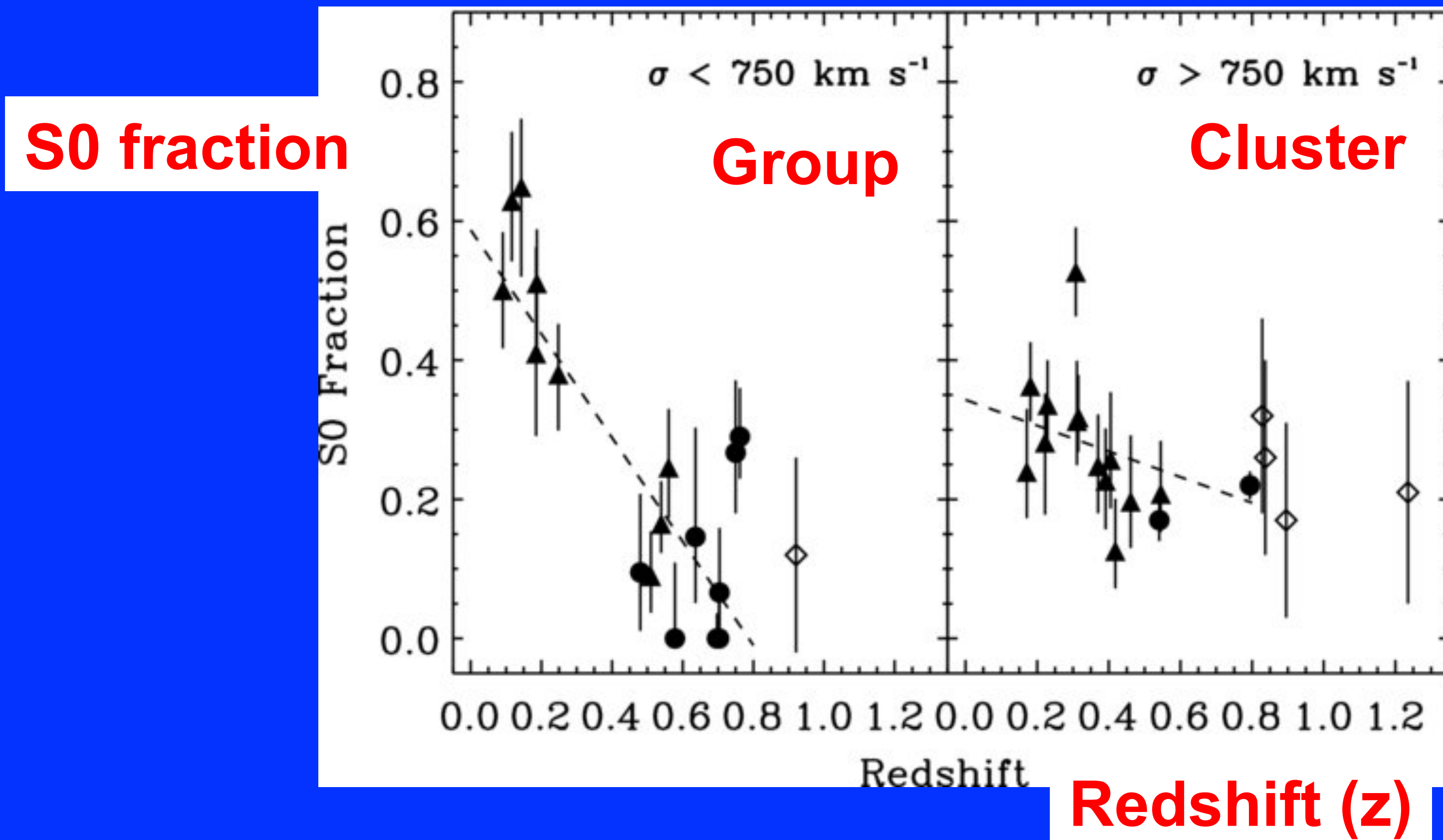
Owing to ram pressure stripping, strangulation, interaction/ merging etc ?

NGC 5866

NGC 3115

S0: disky system with no spiral arms, later than E7, central E-like distribution + outer exponential one

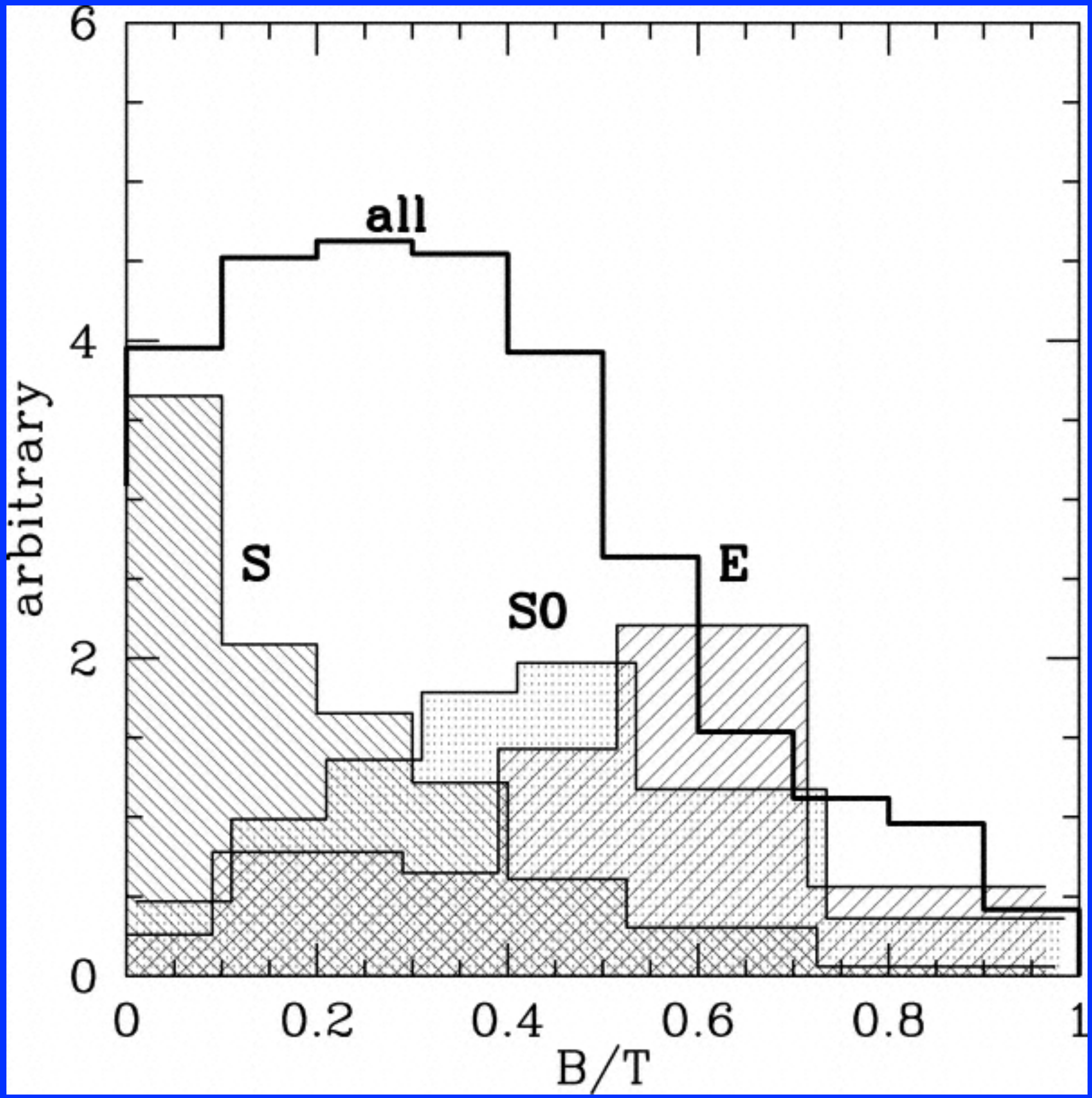
Two key observations on S0 formation.



- Number fractions of S0s evolve (i.e., smaller in higher redshifts), in particular, for group environment (e.g., Just et al. 2010; Dressler et al. 1997; Couch et al. 1998, but see Andreon 1998 for little/no S0 evolution).

Two key observations on S0 formation.

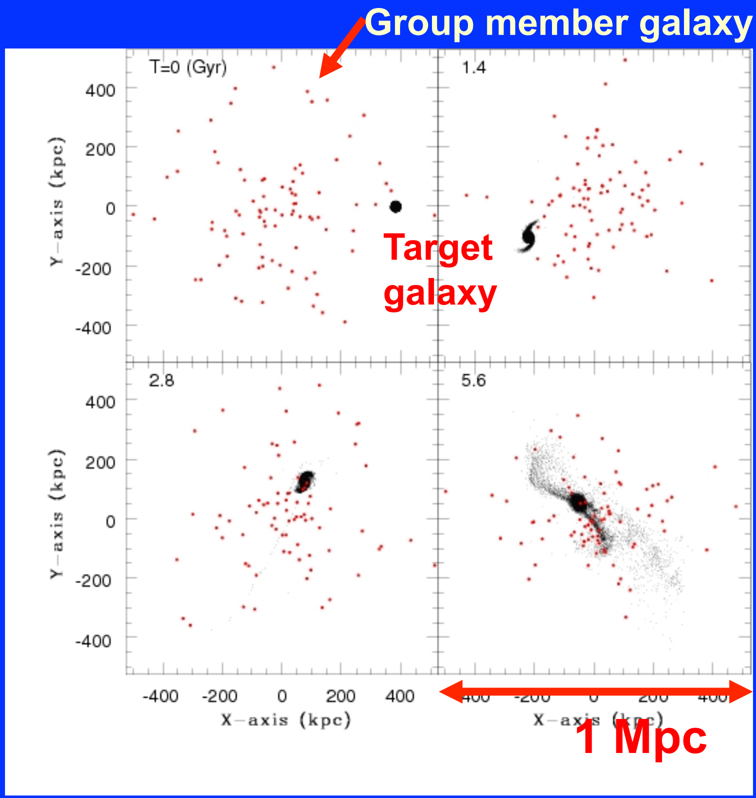
- Differences in the bulge-to-disk-ratios (B/T) between spirals and S0s (e.g., Christlein & Zabludoff 2004)



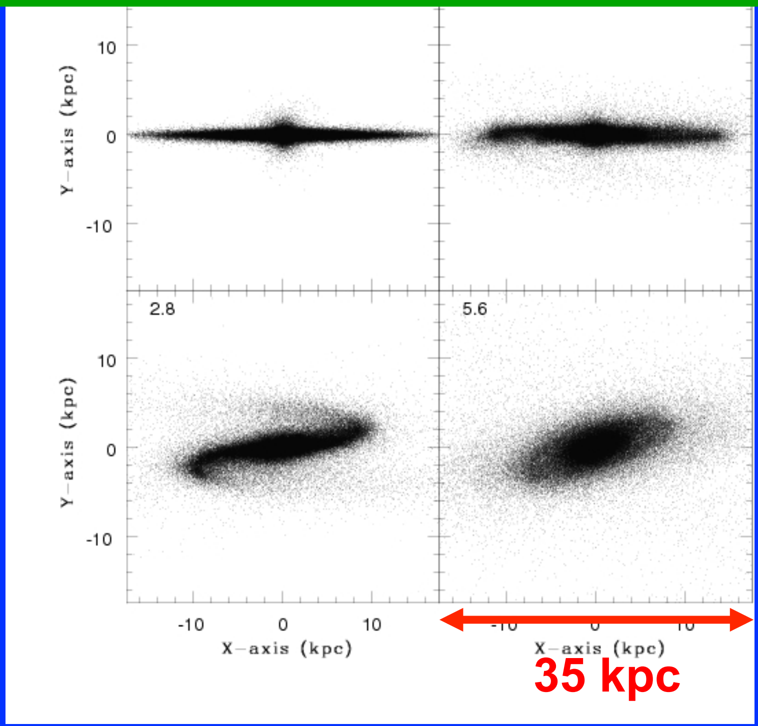
Ram pressure stripping and strangulation are not the major mechanism of S0 formation.

- These mechanism are more efficient in clusters and do not increase bulge masses of galaxies.
- S0 are at least as luminous as (if not more luminous) in the K-band than are spiral galaxies (Burstein et al. 2005).
- The observed large scatter in the local S0 Tully-Fisher relation can be due to kinematical disturbance during transformation from spirals into S0s (e.g., Hinz et al. 2003).

S0 formation with bulge rejuvenation and growth via repetitive ``slow'' encounters (and merging) in groups.



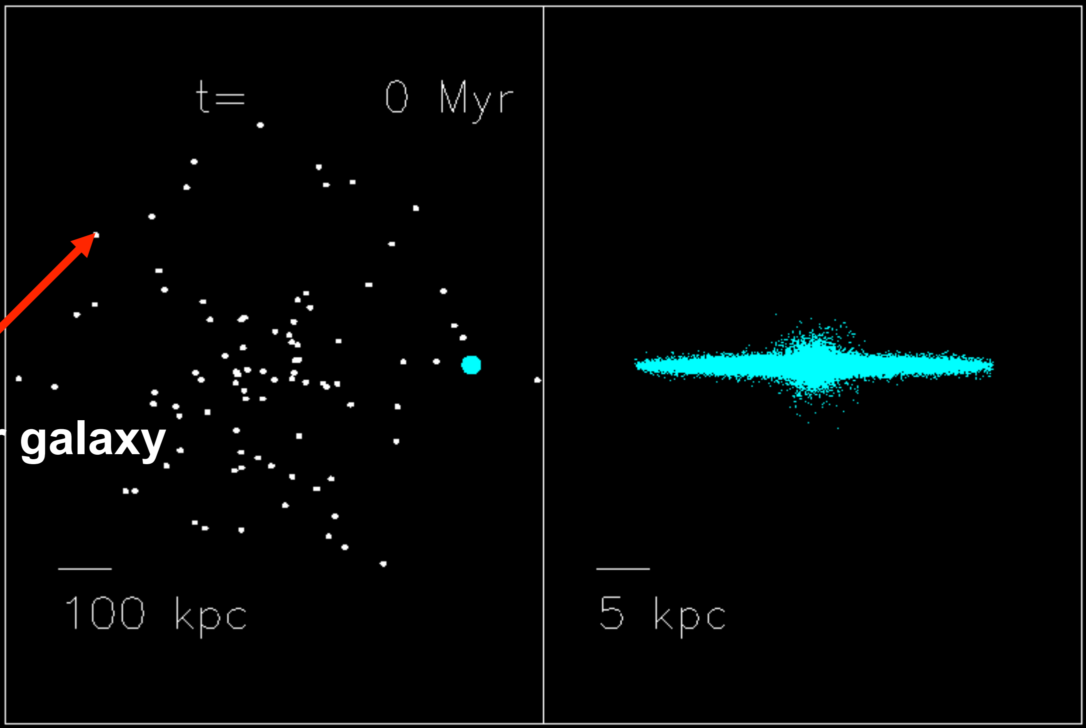
~5.6 Gyr evolution of a late-type spiral in a group of galaxies.



($M_{gr}=2*10^{13}\ M_{sun}$, $N_{gal}=87$)

(Bekki 2010)

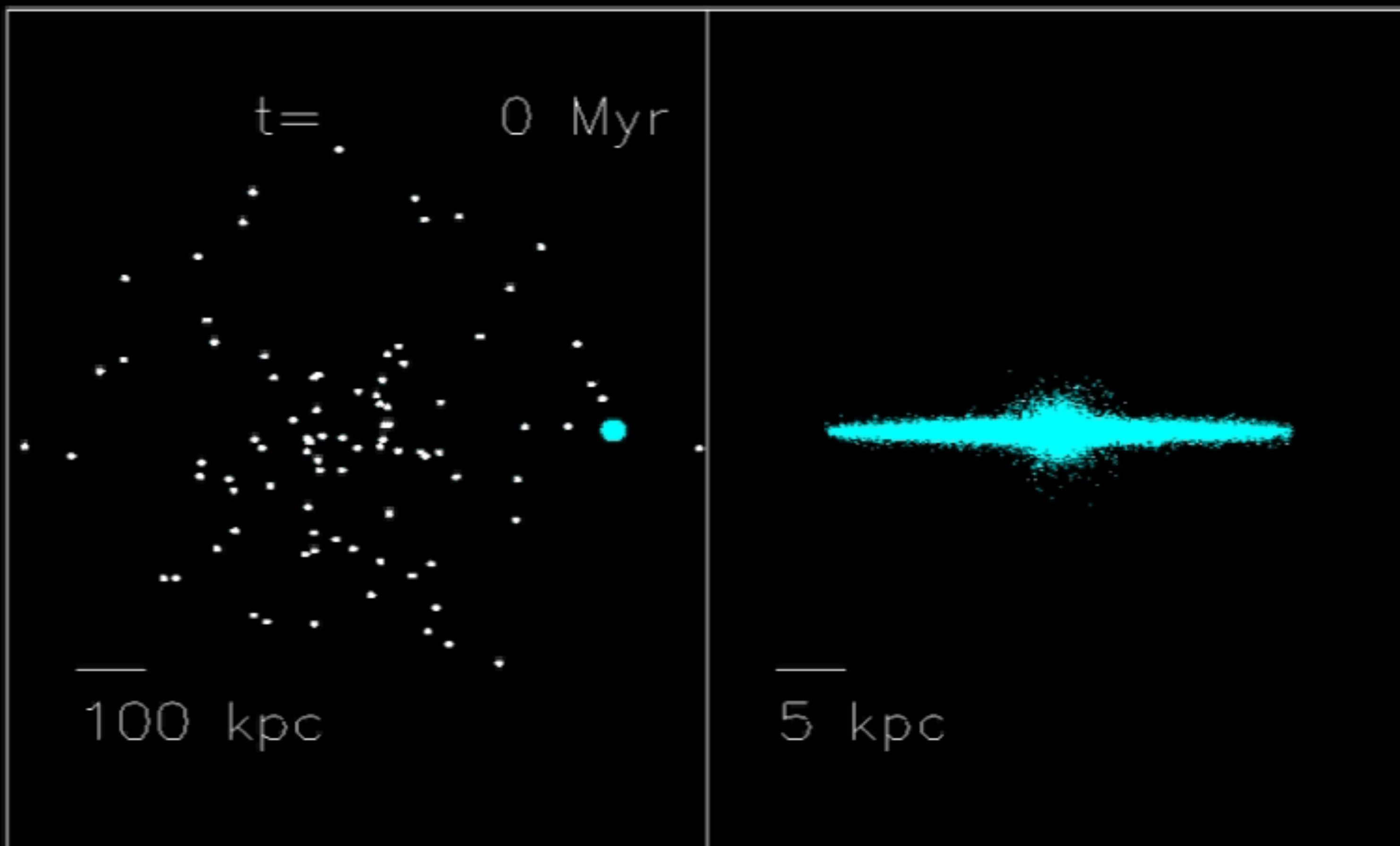
S0 formation via repetitive slow galaxy interaction.



Group member galaxy

(Bekki 2010)

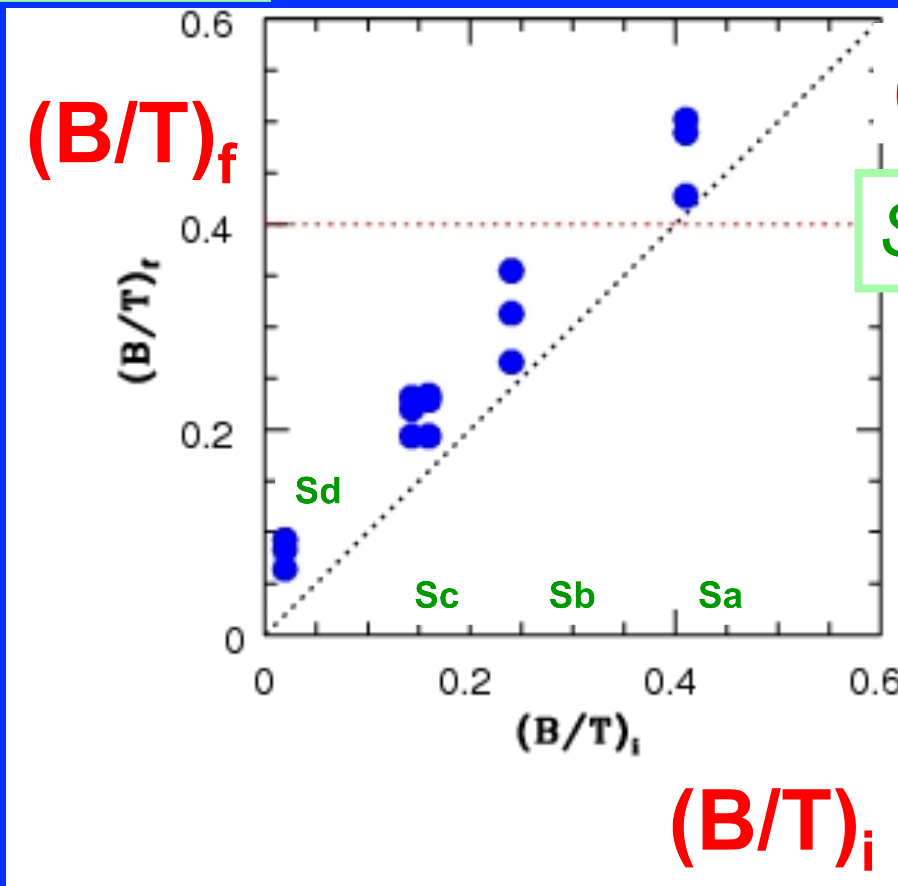
S0 formation via repetitive slow galaxy interaction.



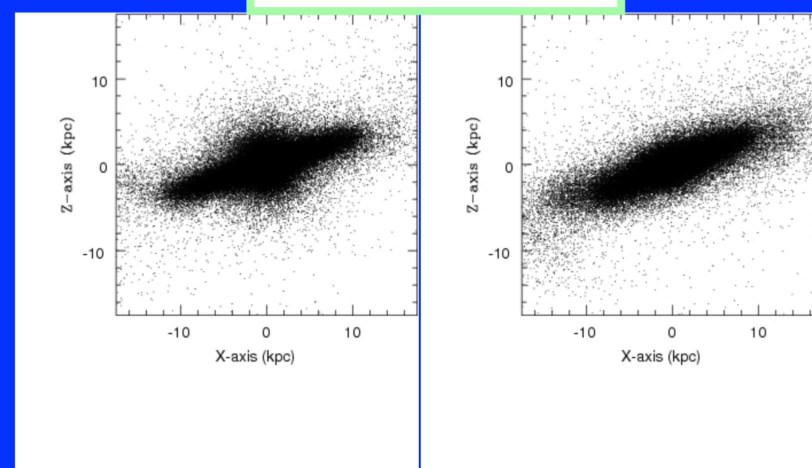
(Bekki 2010)

From spirals with smaller bulges to S0s with bigger ones.

Simulation

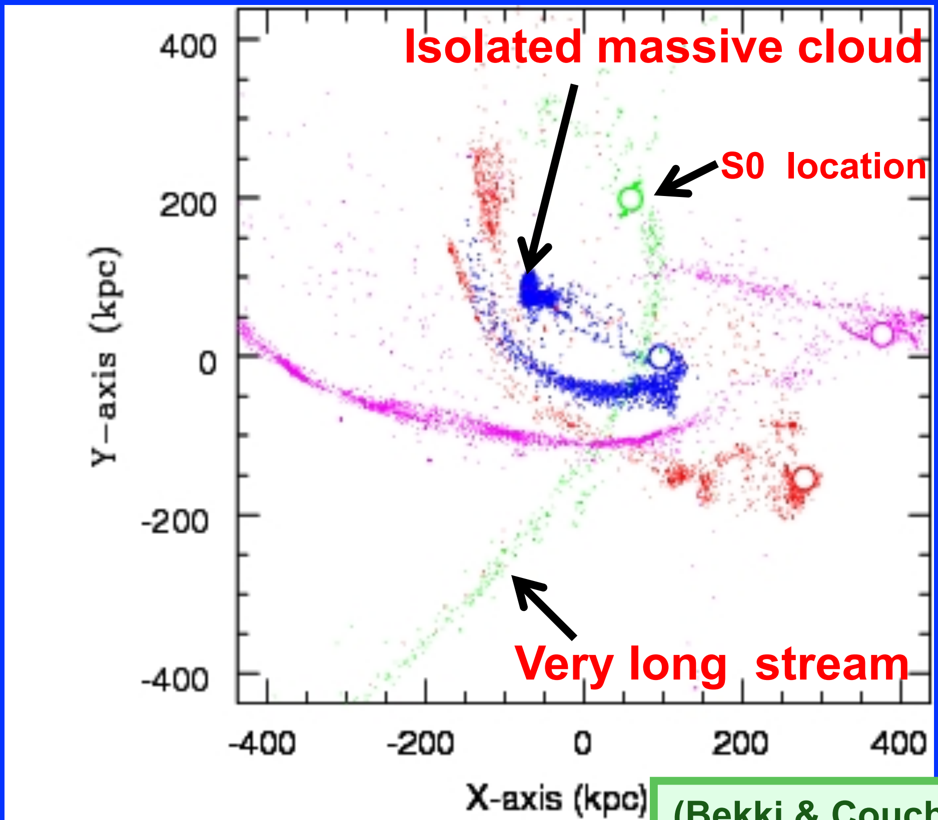


Simulated S0s



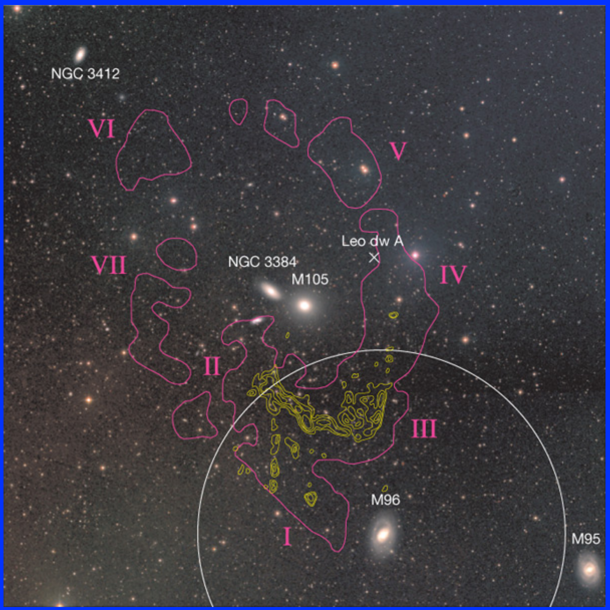
Intra-group HI gas (``Udon") as a clue to S0 formation.

The simulated distribution of stripped gas:



(Bekki & Couch 2010)

The observed Leo ring:



(Thilker et al. 2009)

(1) Will future ASKAP projects (e.g., WALLABY) detect this and thus provide a new clue to S0 formation in groups ?
(2) Is there any correlation between masses of intra-group HI gas and S0 fractions in groups ?

Conclusions.

- Comparison between the WALLABY observations and numerical simulations will reveal the physical properties of warm/hot intra-group gas.
- The WALLABY observations on intra-group HI streams enable us to better understand transformation from spirals into S0 in group environments.