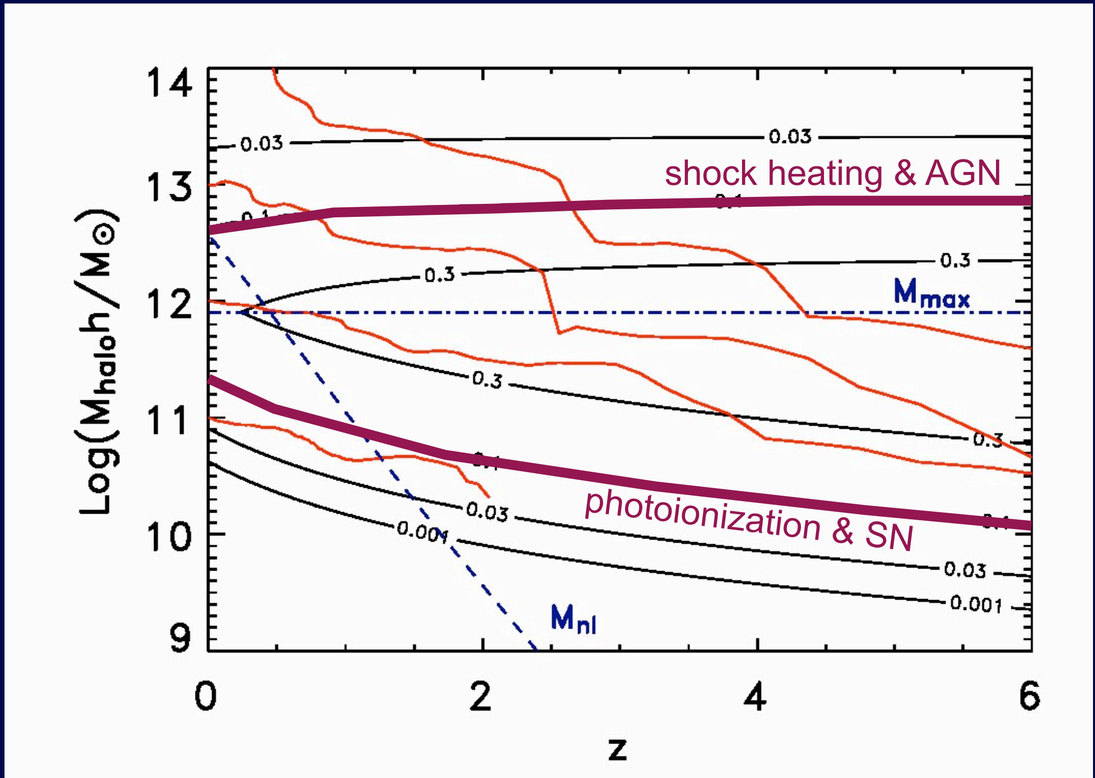
Toy model of galaxy formation

Cattaneo, Mamon, Riebe & Knebe 09 in prep



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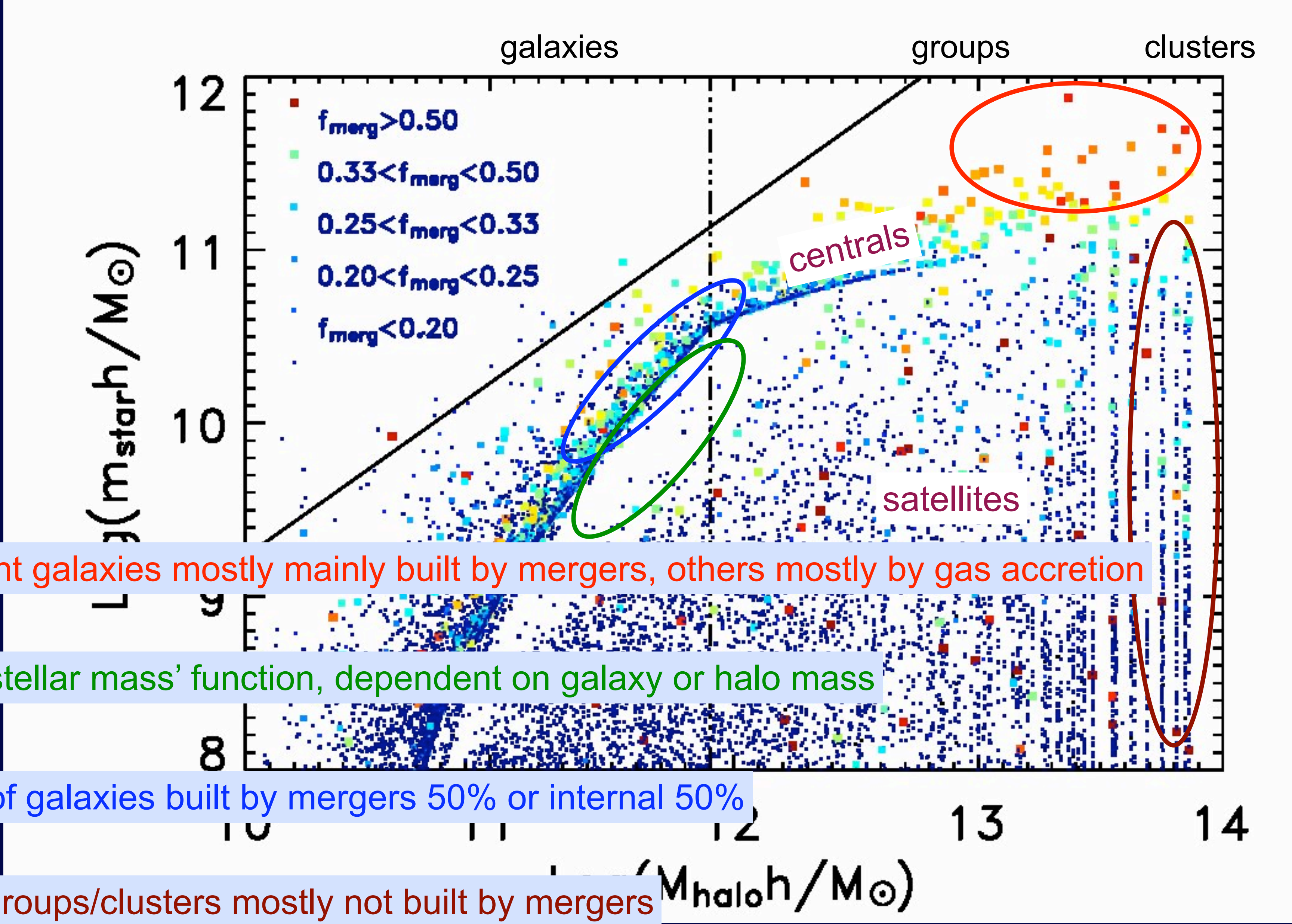


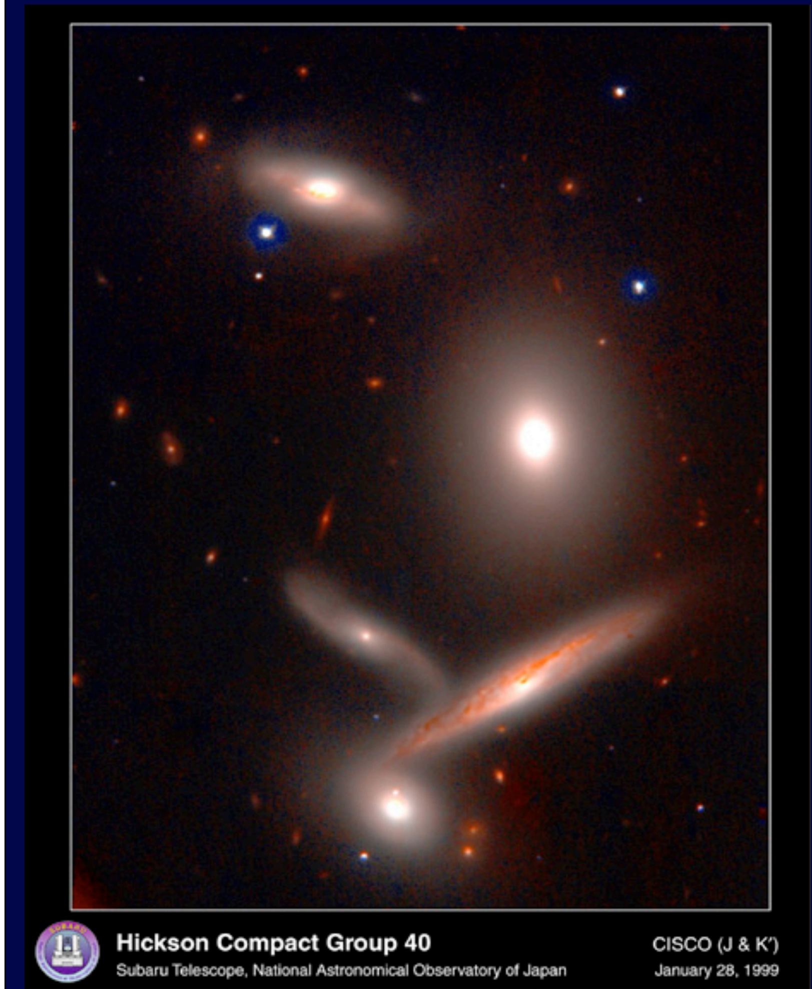
only giant galaxies mostly mainly built by mergers, others mostly by gas accretion

gap in `stellar mass’ function, dependent on galaxy or halo mass

bulges of galaxies built by mergers 50% or internal 50%

dEs in groups/clusters mostly not built by mergers

The Nature & properties of Compact Groups of Galaxies from cosmological simulations



with (*all in Cordoba, Argentina*)

- Eugenia DÍAZ-GIMÉNEZ
- Cinthia RAGONE-FIGUEROA
- Hernán MURIEL

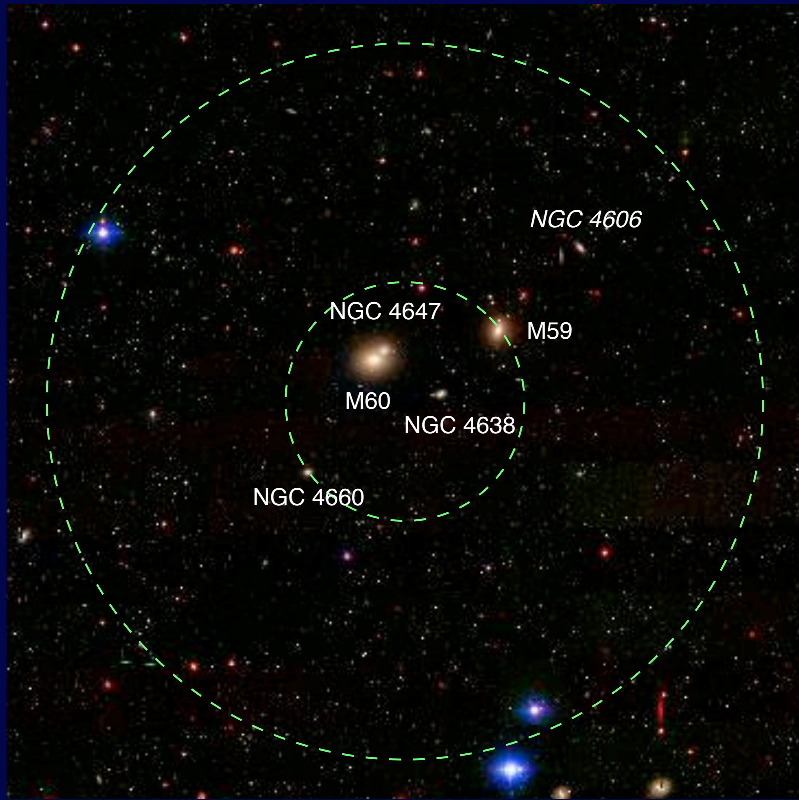
arXiv:0908.3483

Defining a Compact Group

Hickson 82

- Compact: $\mu_R < 26$
- Rich: $N \geq 4$ within R_1, R_1+3
- Isolated: empty ring within R_1, R_1+3

100 HCGs



Hickson et al. 92

Accordant velocities: $| v - \langle v \rangle | < 1000$ km/s

55 (not 92) accordant velocity HCGs

Motivation:

Are Compact Groups an extreme galaxy environment?

$$\frac{\delta\rho}{\rho} > 10^5$$

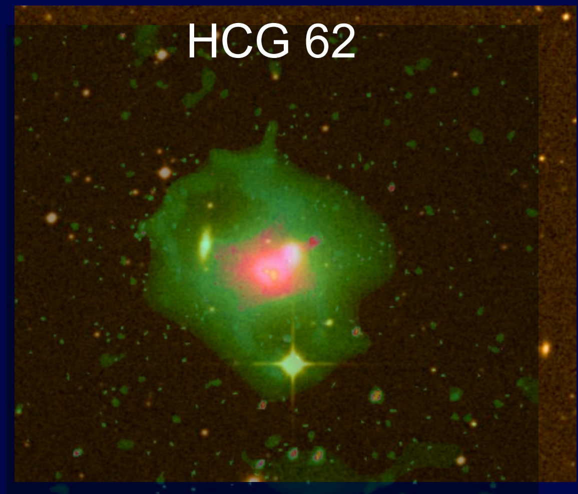
1000x greater than required for dynamical equilibrium

→ ideal laboratory for galaxy interactions & mergers

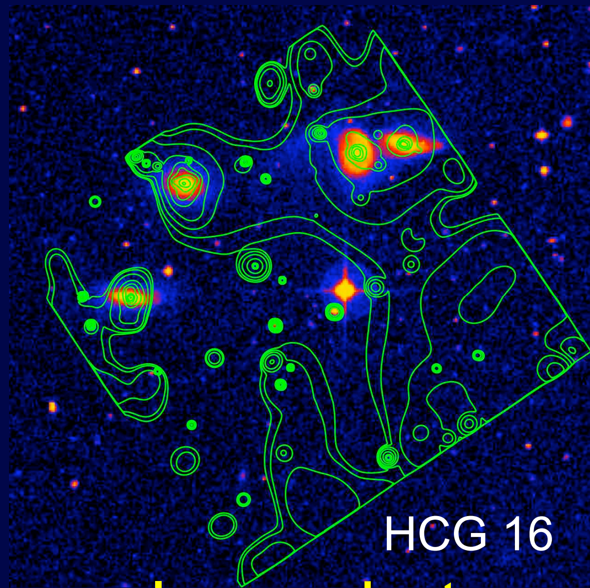
Compact Groups in X rays

Emissivity of X-ray gas $\propto \rho_{\rm gas}^2$

➡ fewer projection effects



extended diffuse hot gas



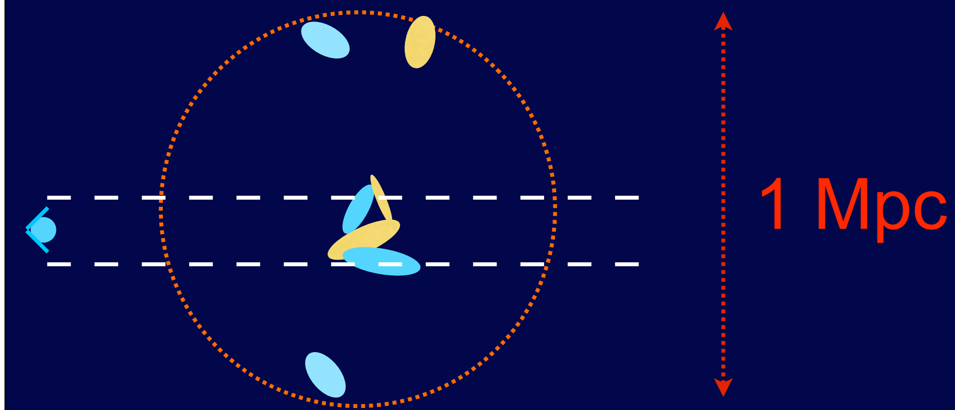
clumpy hot gas

Elliptical-rich, high velocity dispersion, diffuse X rays centered on dominant giant elliptical (often AGN)

Spiral-rich, low velocity dispersion, little diffuse X rays, no dominant gE

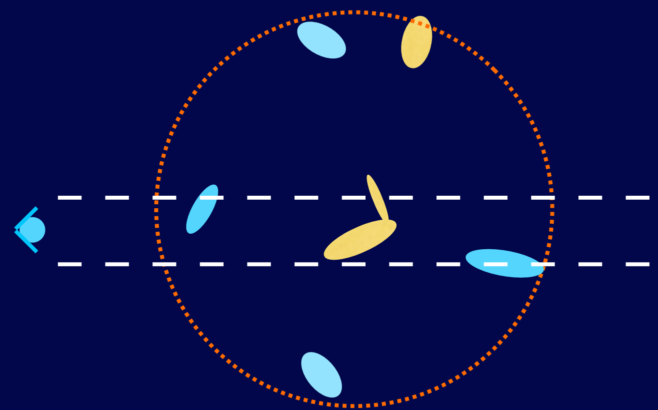
Osmond & Ponman 04

Nature of Compact Groups selected in redshift space



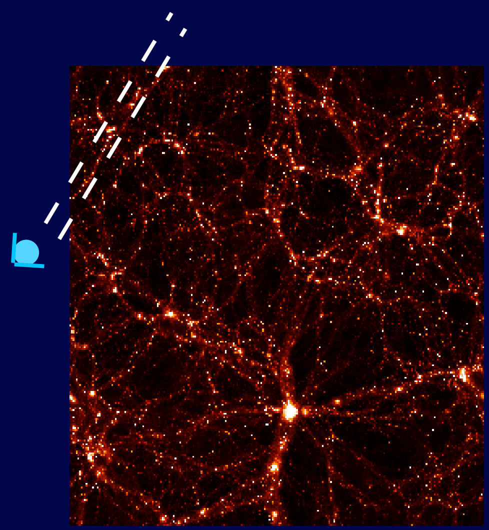
real dense

Hickson & Rood 88



chance alignment
within loose group (CALG)

Rose 77; Mamon 86, 87;
Walke & Mamon 89



chance alignment
within filament (CAF)

Hernquist, Katz & Weinberg 95

Δv = 1000 km/s ⇒ CGs up to 20/h Mpc long!

Arguments against real CGs

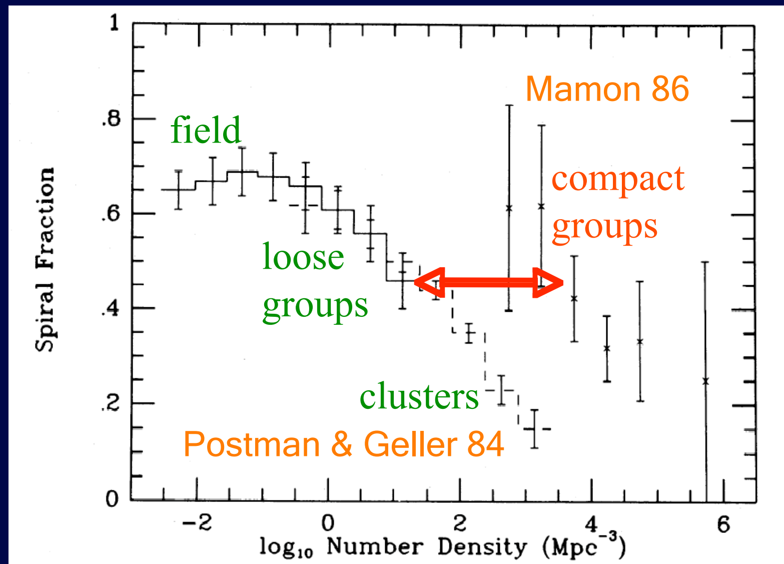
Mamon 86, 87, 92

mergers rapidly transform group → single elliptical
Barnes 85, Mamon 87, Barnes 89, Bode et al. 93;
but see Governato et al. 94, Athanassoula et al. 97

naïvely form at $z = 8$!

normal luminosity function mergers → high $\langle m_2 - m_1 \rangle$

morphology-density relation: too many spirals



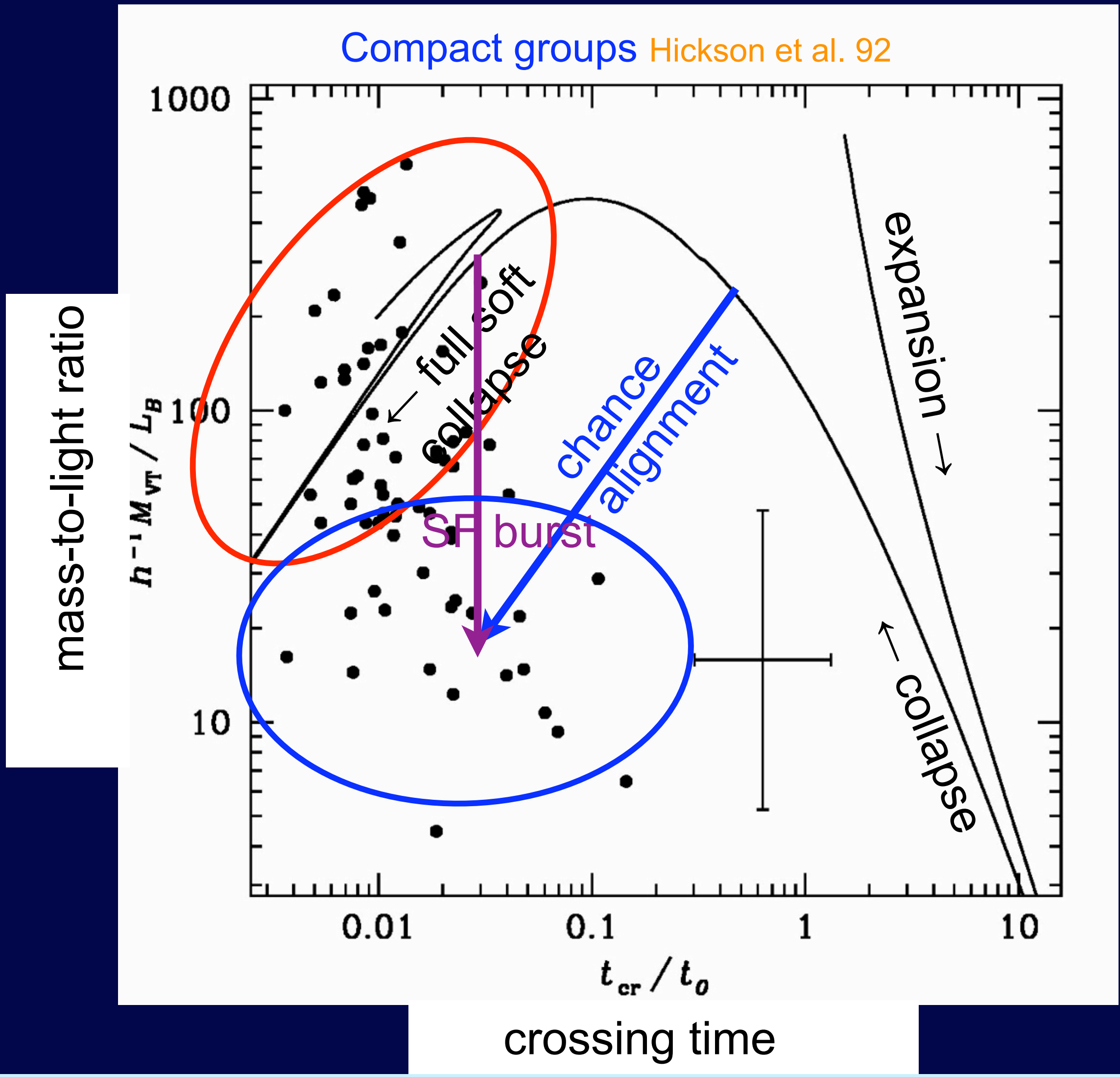
no luminosity segregation

chance alignments should be frequent Walke & Mamon 89

signs of interactions: ⟵ binaries in chance alignment

Low velocity dispersion HCGs off Fundamental Track

Mamon 93



high σ_v
spiral-poor
diffuse X-rays

low σ_v
spiral-rich
no X-rays

are low velocity dispersion HCGs caused by chance alignments?

Formation rate

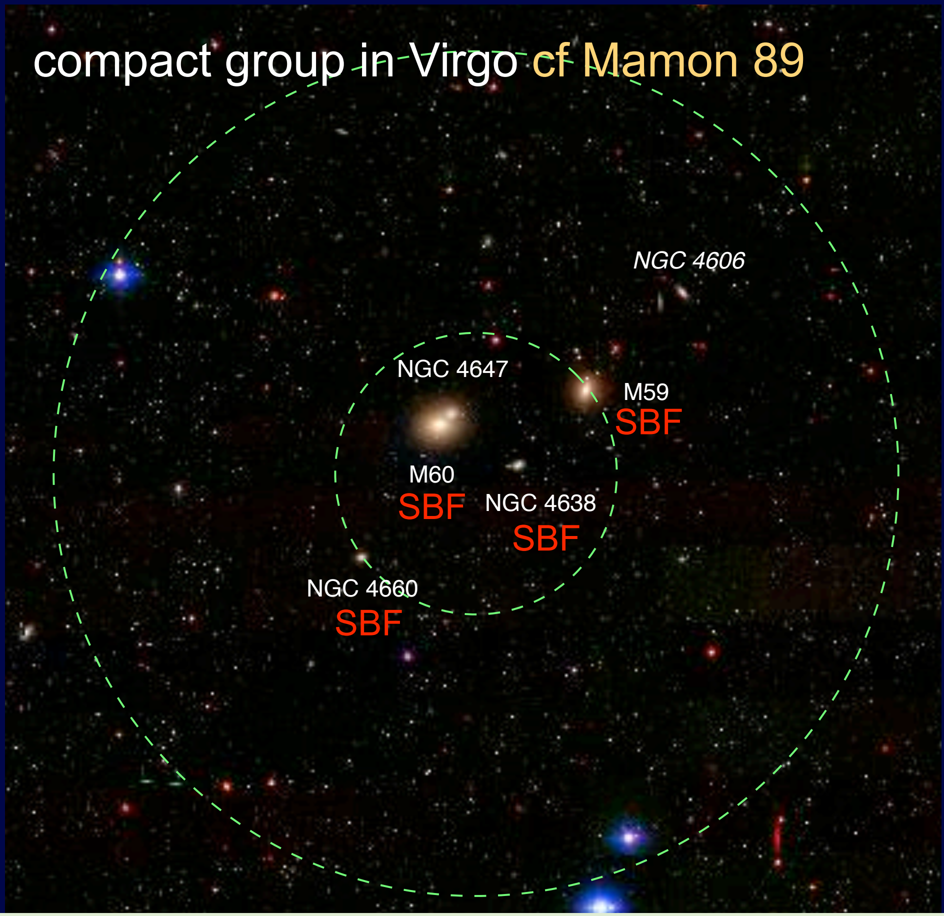
but ...

extended Press-Schechter

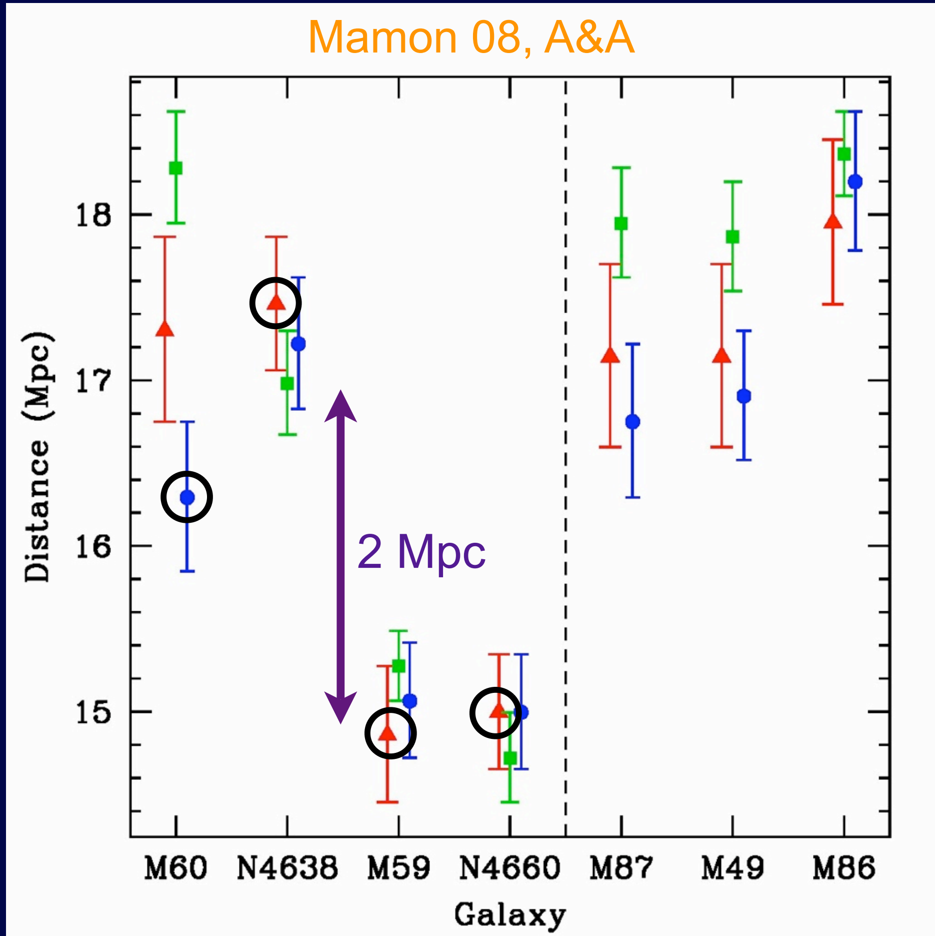
dense groups should form at sufficient rate to replenish those lost by coalesence

Mamon 00 (IAU coll.)

A direct test



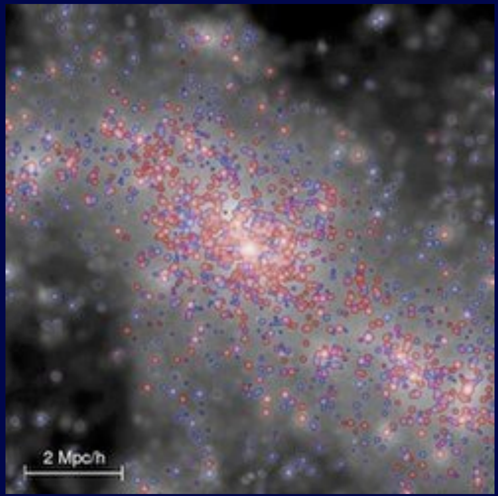
SBF = Surface Brightness Fluctuation (accurate distance estimator)



Virgo cluster CG = chance alignment!

The nature of CGs from simulations

Díaz, Ragone, Muriel & Mamon 08, MNRAS subm.



- Millennium dark matter simulation: 10G particles!
- 3 different galaxy formation codes: 7M galaxies
  - Croton et al. 06 — $M_R < -17.4$
  - Bower et al. 06
  - De Lucia & Blaizot 07
- mock samples in redshift space: 1M galaxies
  - $R < 17.44$
- *mock projected CGs*: 12k *mpCGs*
- *mock velocity-accordant CGs*: 7k *mvCGs*
- *mock velocity-accordant CGs with HCG biases*
  350 *mvHCGs*

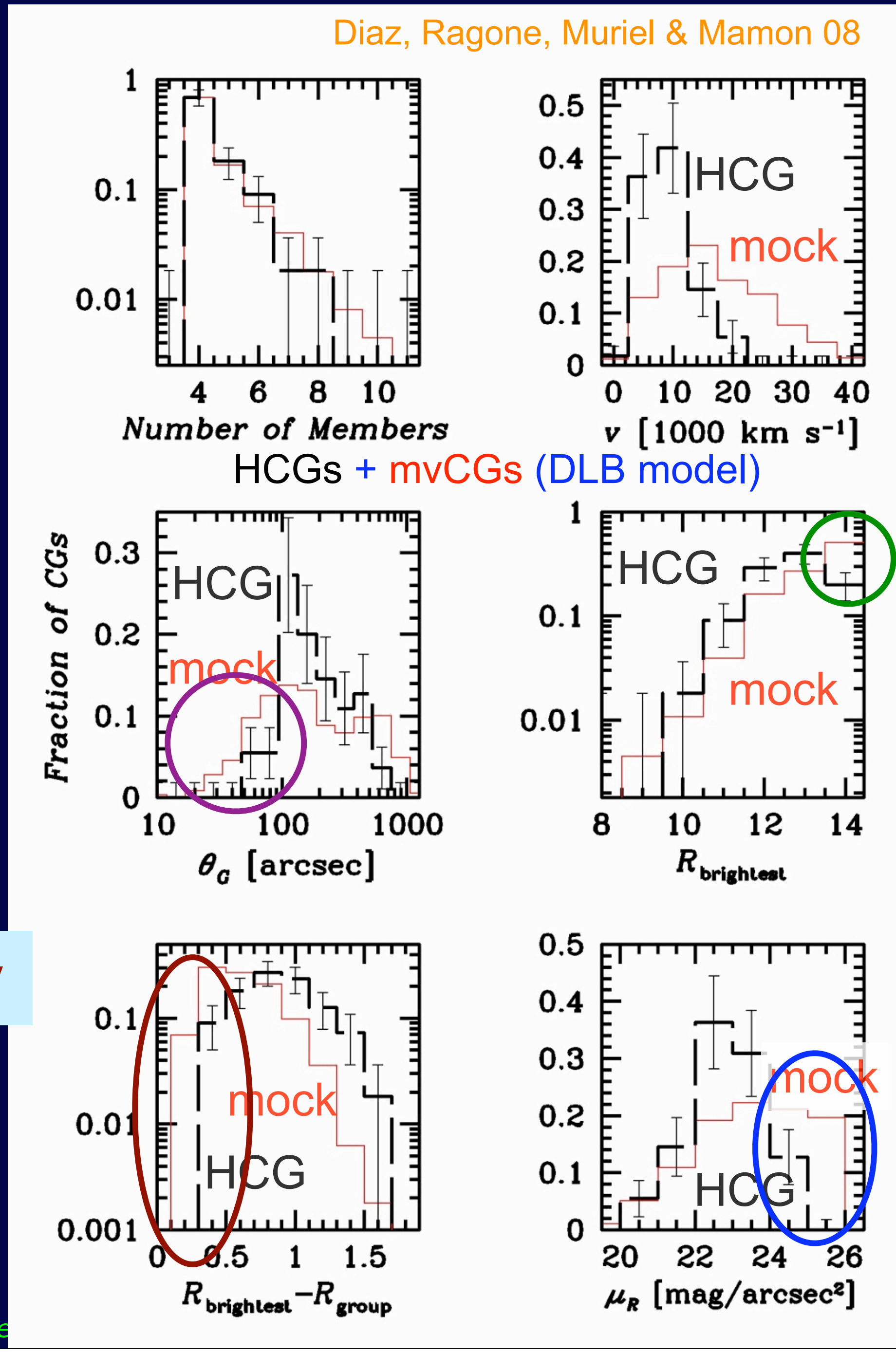
biases in HCG sample

number density of mock CGs
= 50x that of HCGs

Hickson missed CGs:

- fainter
- small angular size
- lower surface brightness
- with dominant brightest galaxy

also Walke & Mamon 89
Prandoni et al. 94



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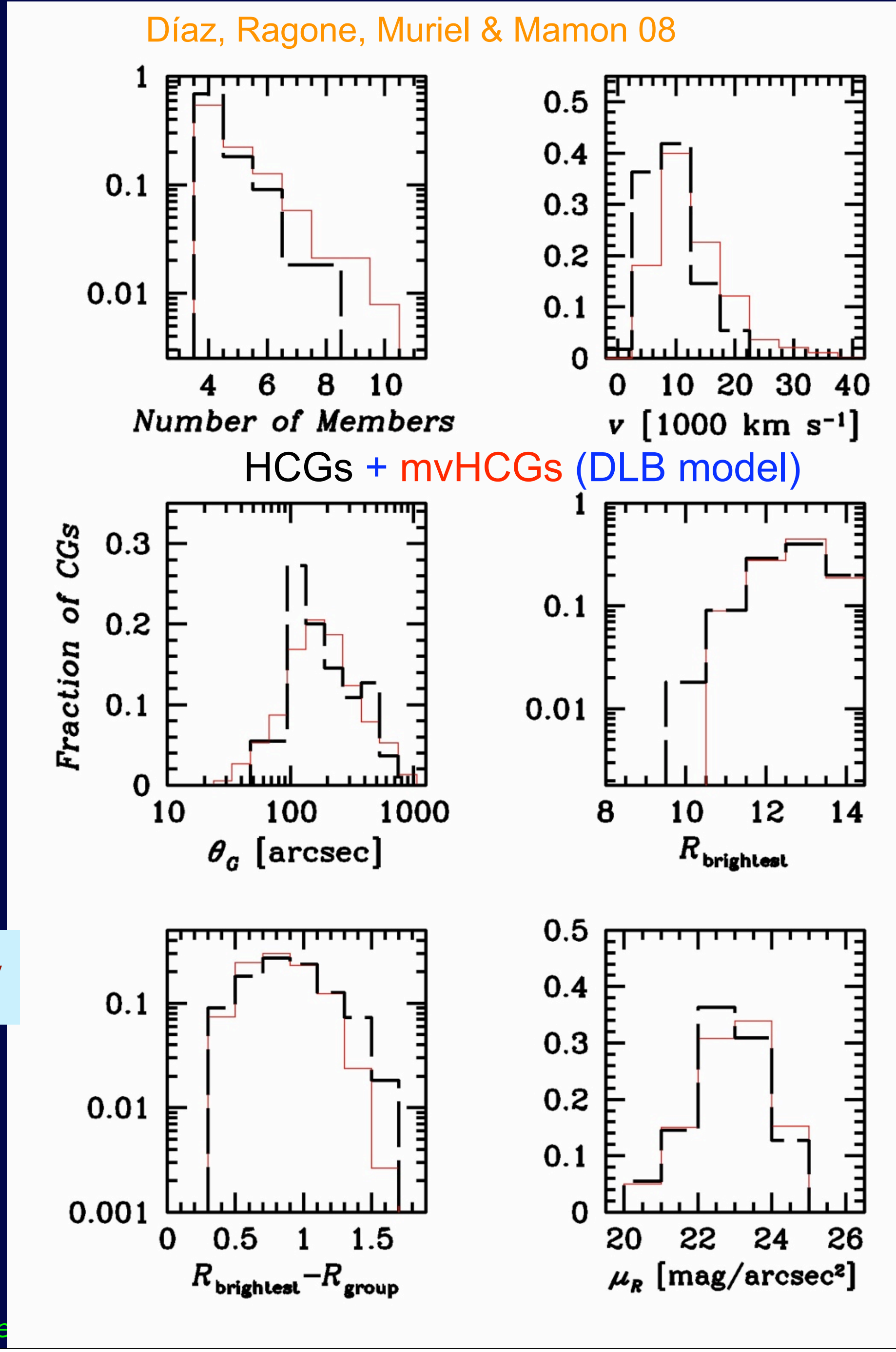

also Walke & Mamon 89
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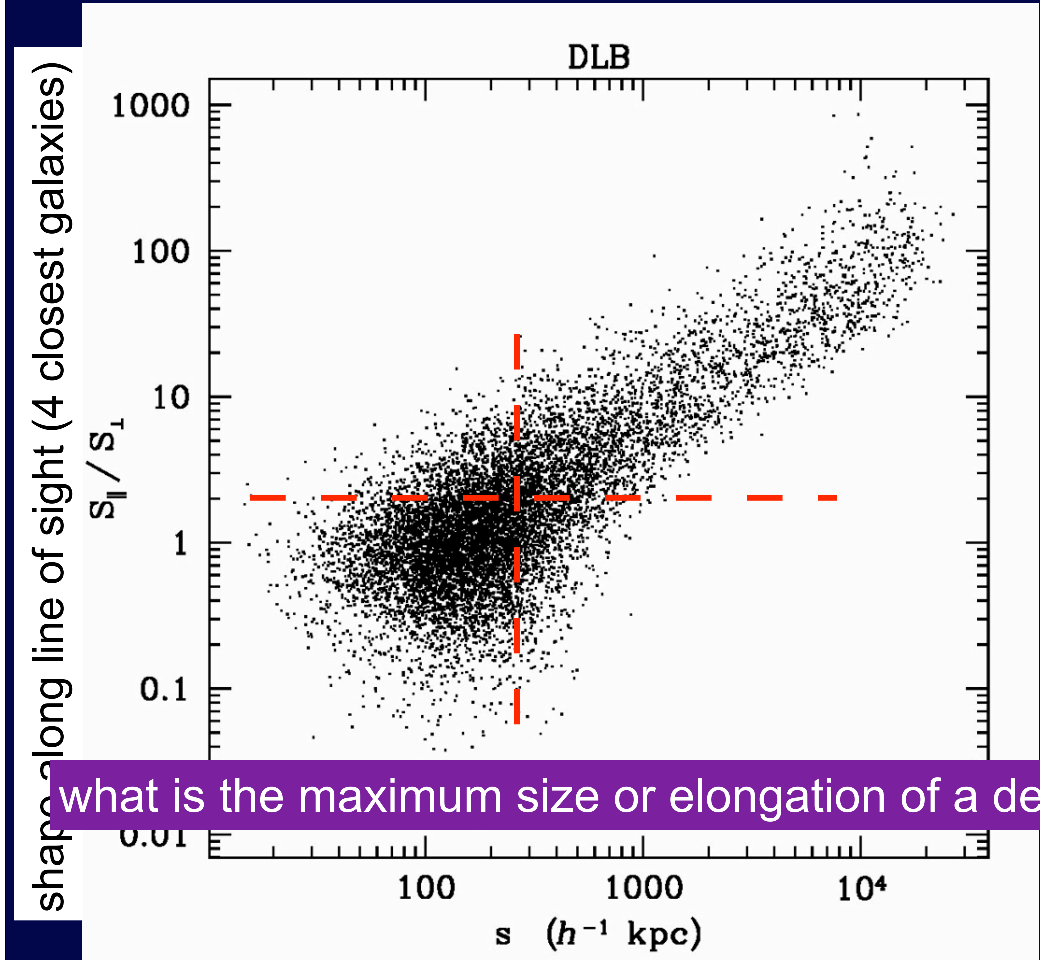
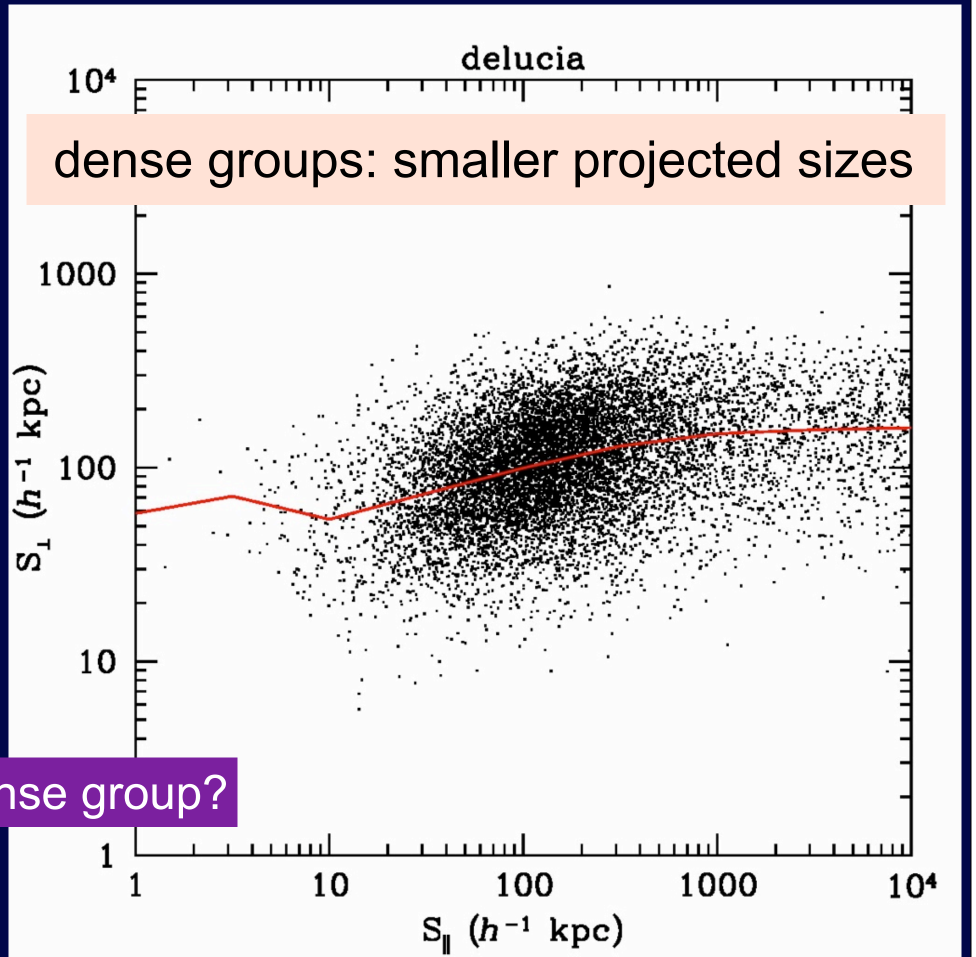
Differences in 3 SAMs

SAM	Bower et al. 06	Croton et al. 06	De Lucia & Blaizot 07
galaxy positions	*statistical*	subhalos	
galaxy merger rate	*complex*	*Springel+01*	1/2 Springel+01
IMF	*more hi mass*	*Salpeter*	fewer low mass
galaxy colors	*too blue*	?	*a little red*
Red Sequence	OK	*flattens at high luminosity*	
small-scale correlation of recent SF Mateus et al. 08	OK	?	*too strong*

Mock CGs: what is a dense group?





dense groups: smaller projected sizes

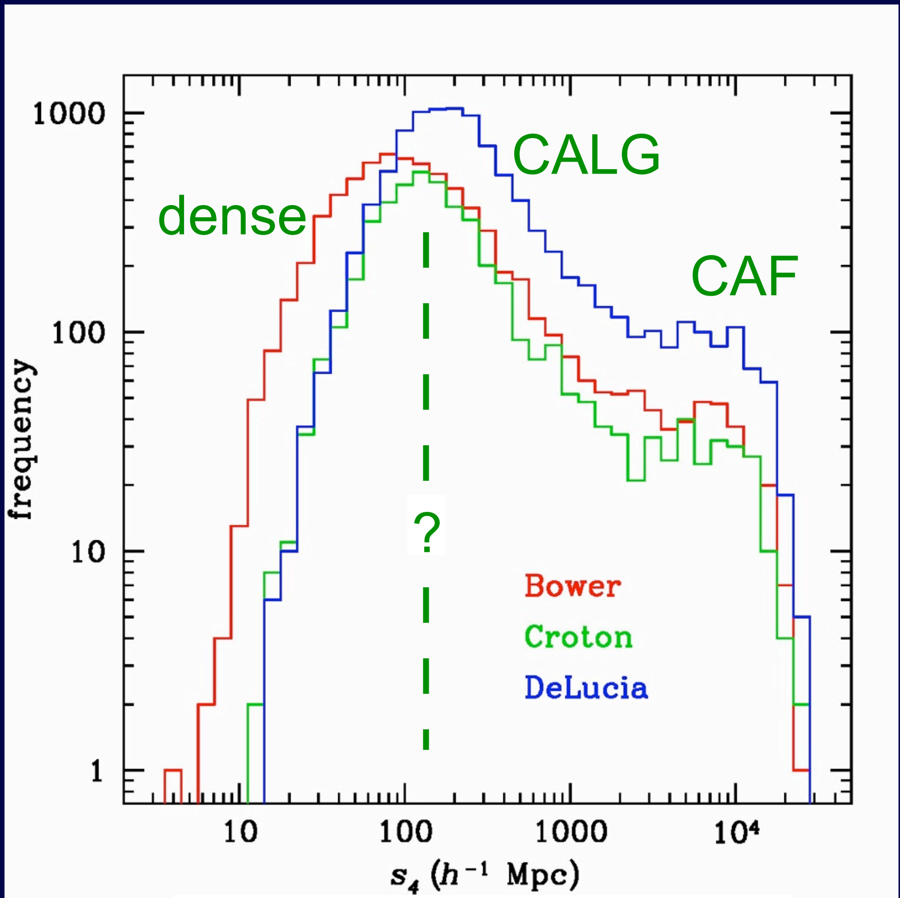
what is the maximum size or elongation of a dense group?

max 3D separation of closest 4 galaxies

dense groups: median l.o.s. shape
= that of real-space selected groups?

→ < 10% of CGs = dense!

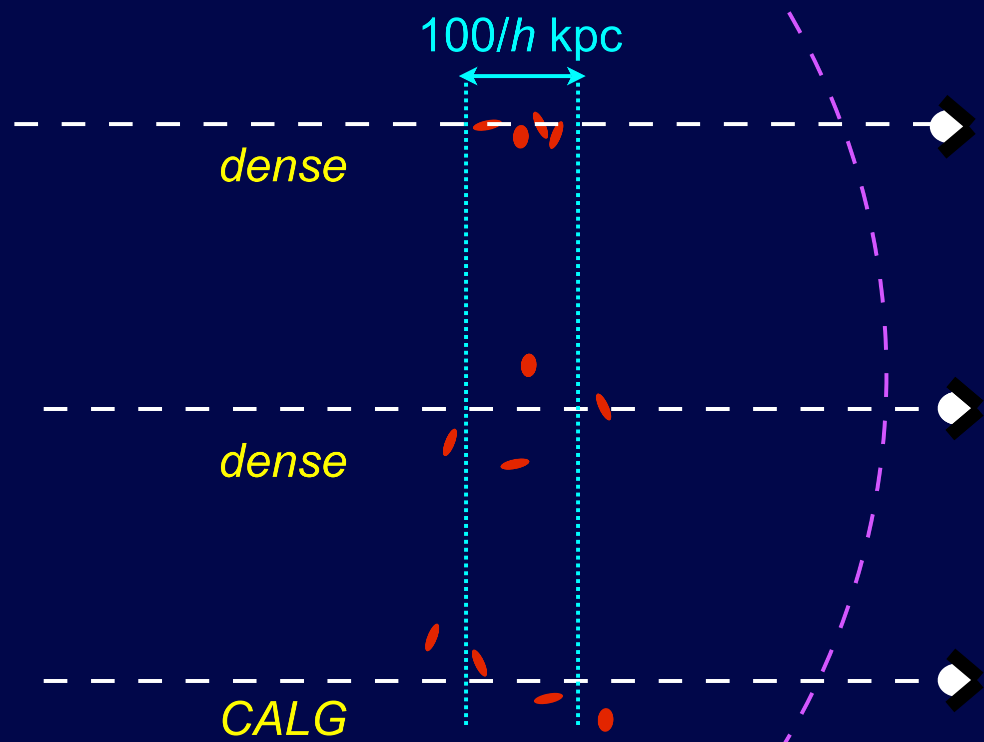
Mock CGs: what is a *dense group?*



max 3D separation of closest 4

Liberal conditions
for Chance Alignment:

* s > 100 (or 200) Mpc/h
AND
* $s/S_\perp > 2$



What fraction of mock CGs are physically dense?

Mamon 86: 40%

SAM	mock mpCGs
Bower et al. 06	36−44%
Croton et al. 06	37−41%
De Lucia & Blaizot 07	19−21%

20−40% of CGs selected in 2D with exact HCG criteria

McConnachie et al. 08: 35% of mpCGs = physically dense

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Bower et al. 06	36−44%	73−78%
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20−40% of CGs selected in 2D with exact HCG criteria

McConnachie et al. 08: 35% of mpCGs = physically dense

60−80% of CGs selected in 2D+*v* with exact HCG criteria

What fraction of mock CGs are physically dense?

Mamon 86: 40%

SAM	mock mpCGs	mock mvCGs	mock mvHCGs
Bower et al. 06	36−44%	73−78%	78−86%
Croton et al. 06	37−41%	67−75%	71−82%
De Lucia & Blaizot 07	19−21%	60−66%	64−72%

20−40% of CGs selected in 2D with exact HCG criteria

McConnachie et al. 08: 29% of mpCGs = physically dense

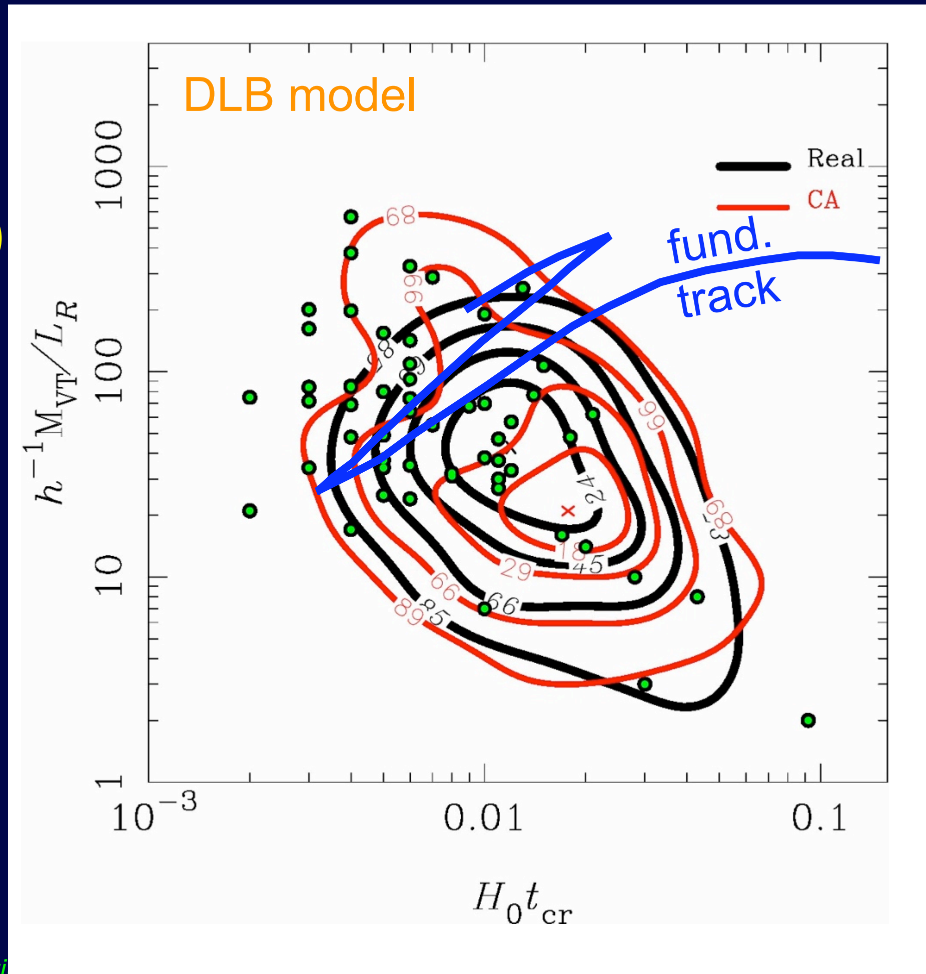
60−80% of CGs selected in 2D+*v* with exact HCG criteria

65−85% of CGs selected in 2D+*v* with HCG biases

Physically dense vs. chance alignments

Physically Dense CGs:

- smaller in projection
- higher surface brightness McConnachie et al. 08
- shorter "observed" crossing time:
- higher "observed" M/L: $R\,\sigma_v^2/(G\,L)$



Low velocity dispersion mock CGs

IF chance alignments have lower σ_v:

with De Lucia & Blaizot model

explain spiral richness, low X-rays, off FT

but IF low σ_v CGs slightly more likely to be Physically Dense:

with Bower and Croton models

most must then have recently formed

low σ_v from

- low mass given starbursting light
- energy dissipation (dynamical friction)

Which SAM reproduces best observed HCGs?

Global properties:

Croton et al. 06

Parameter correlations:

De Lucia & Blaizot 07

Differences in SAM predictions

fraction of mpCGs = dense: 2x lower with De Lucia

projected sizes of mvCGs: Bower 1.6x lower than De Lucia

Croton et al. unable to produce mag-concordant mvCGs

only Croton et al. find $f(\mu)$ keeps increasing near SB threshold