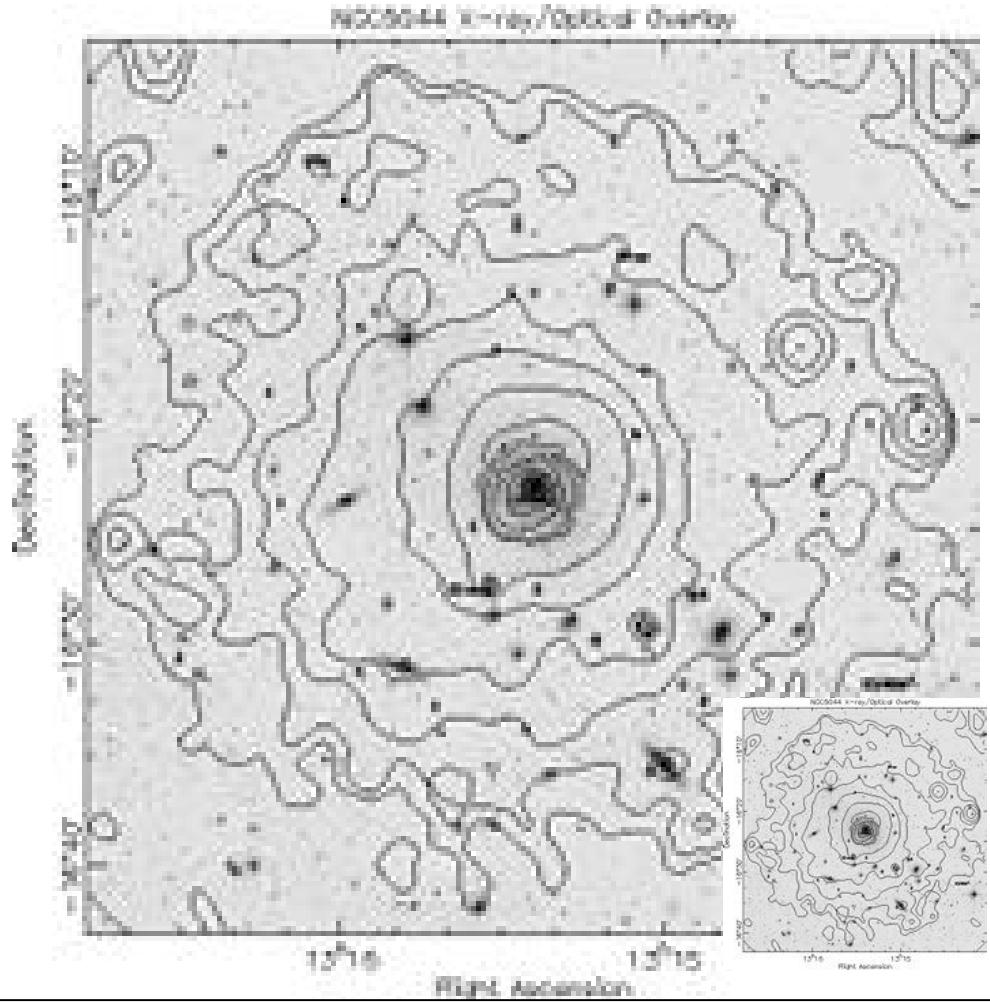
Galaxy group searches and surveys

V. Eke (Durham University)

1) What is a group?
2) Group-finding without redshifts
3) Group-finding with redshifts
4) The 2PIGG catalogue

What is a group?



NGC5044

log M~13.5 (Buote etal. 2004)

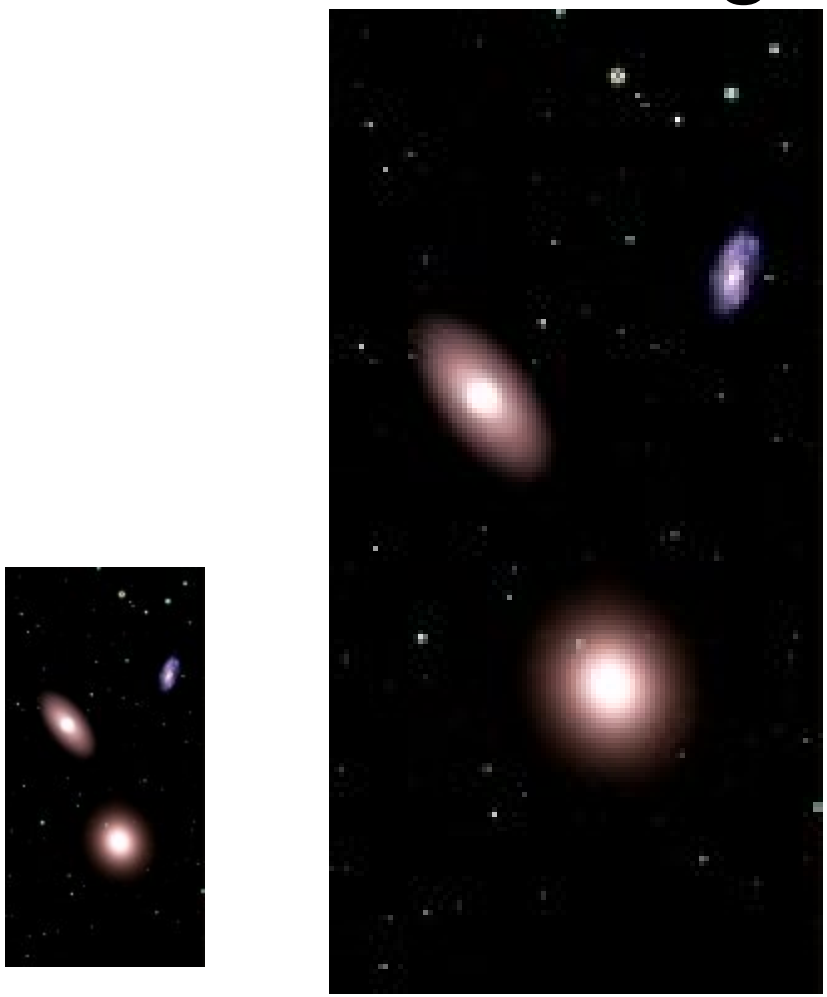
σ~430km/s

(Cellone & Buzzoni 2005)

12 13 14 15

log Mass

What is a group?



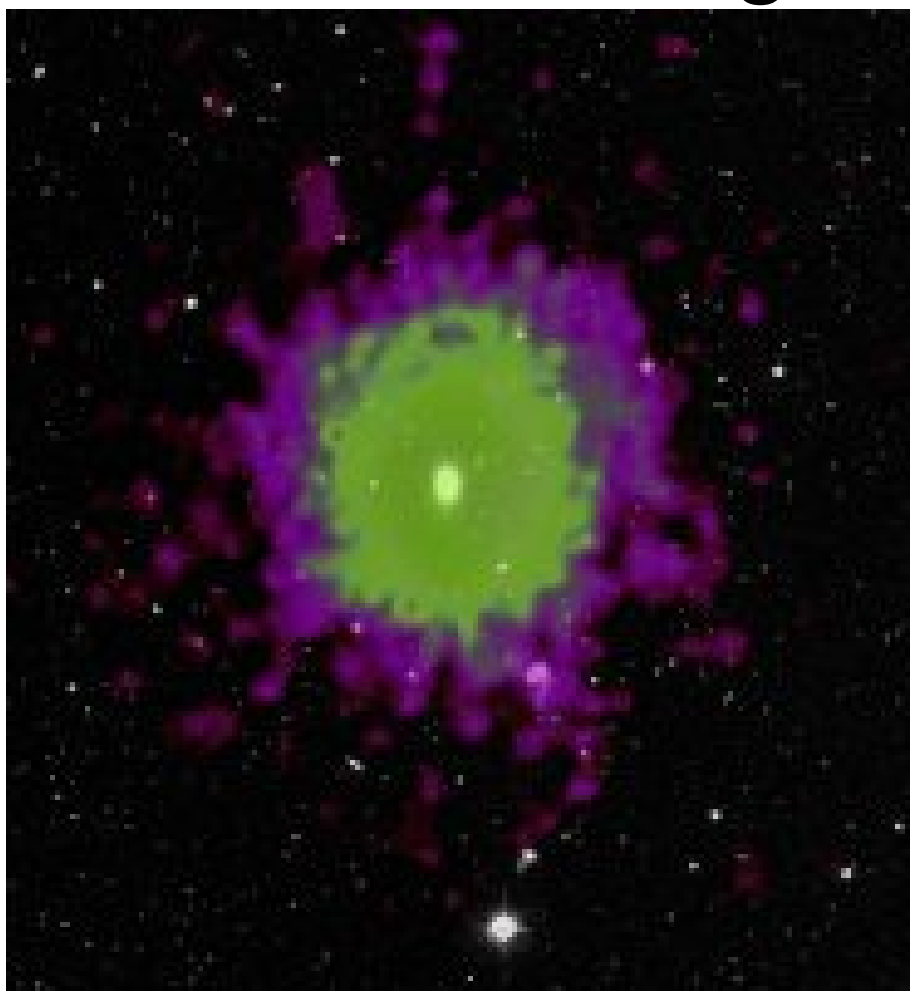
Leo group

log M~12.6 (Trentham & Tully 2002)

12 13 14 15

log Mass

What is a group?



NGC 4325

log M~13.3 (Figueroa-Feliciano et al. 2003)

12 13 14 15

log Mass

What is a group?

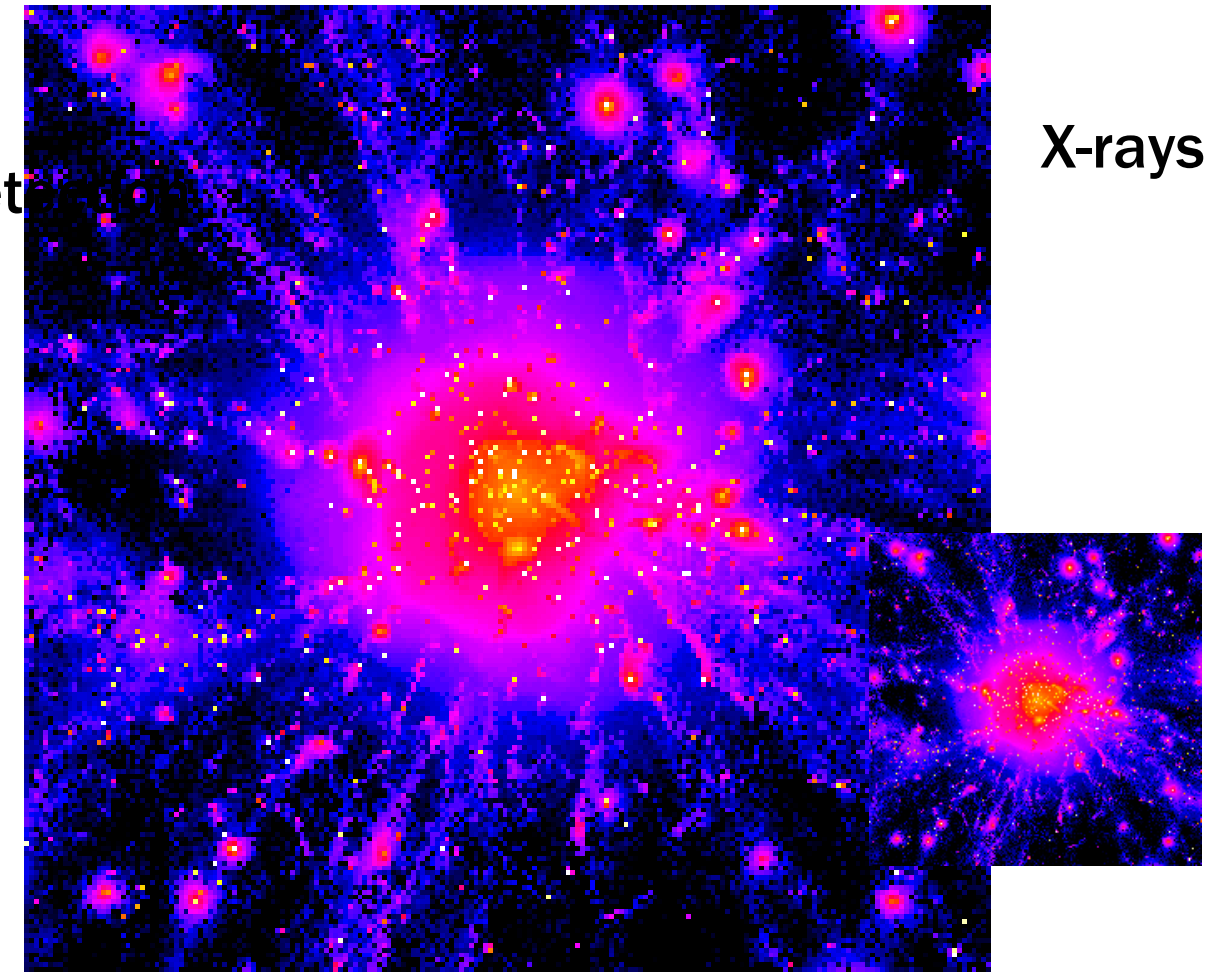
NGC 2300

log M~13.3 (Figueroa-Feliciano et al. 2003)

12 13 14 15

log Mass

What is a group?



Optical det

X-rays, S-Z, lensing

12 13 14 15

log Mass

What is a group?

A cluster is something with log M>14.

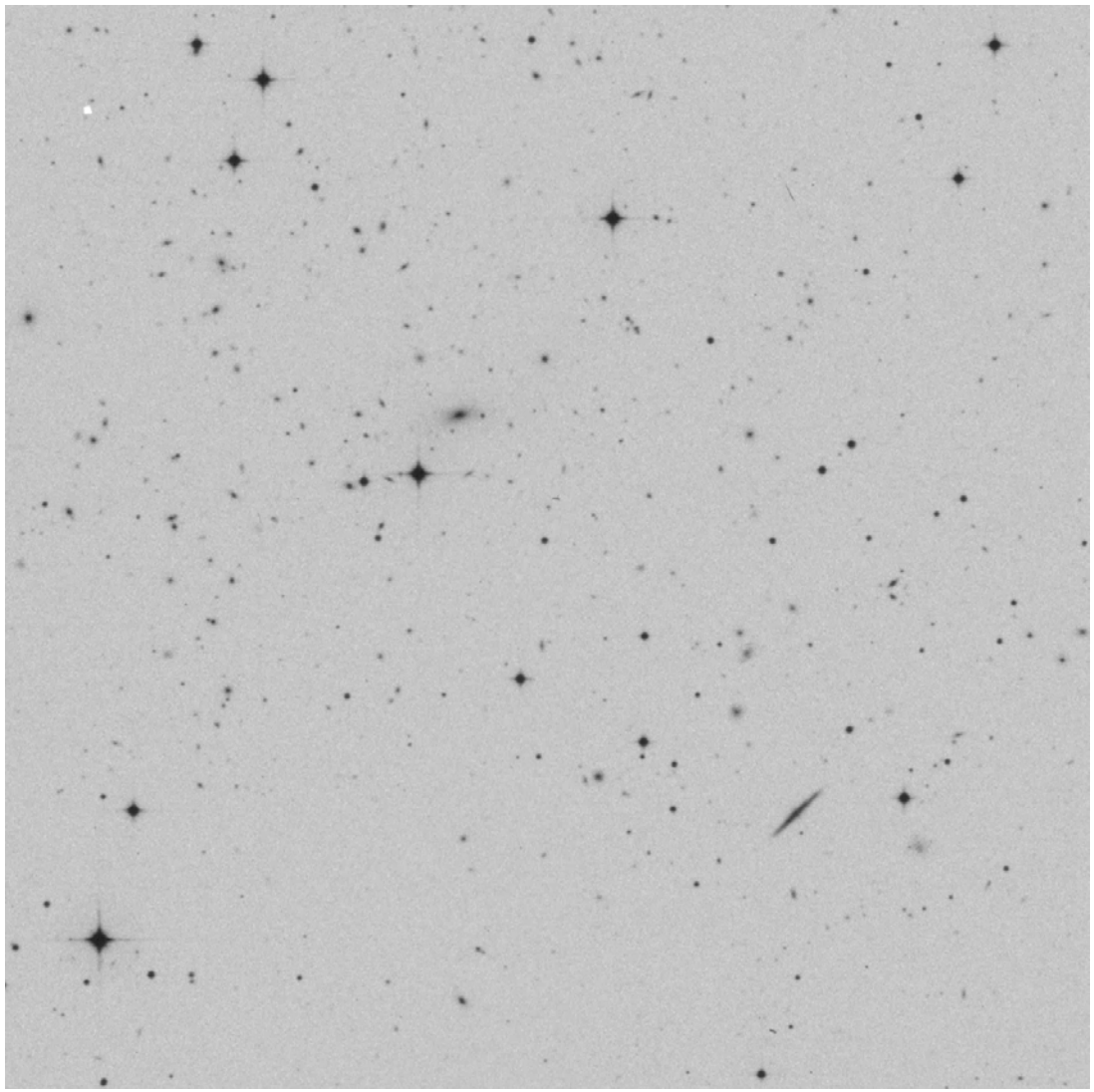
A group is something with log M>12.5.

Clusters of galaxies are big groups.

Galaxy group searches and surveys

1) What is a group?
2) Group-finding without redshifts
3) Group-finding with redshifts
4) The 2PIGG catalogue

z-less group-finding



← 15 arcmin →

SuperCOSMOS scan of a UKST sky survey plate.

www-wfau.roe.ac.uk/sss/

z-less group-finding

Sky surveys from which groups have frequently been found:

1) **Palomar Observatory Sky Survey (north)**

2) **UKST Sky Survey (south)**

z-less group-finding

Clusters:

Abell (1958) inspected PSS plates to find galaxies. ~1600 clusters had:

at least 50 galaxies (post-background correction)

1) within 2 magnitudes of the third brightest galaxy

2) within a 1.5Mpc/h projected radius at the distance of the cluster.

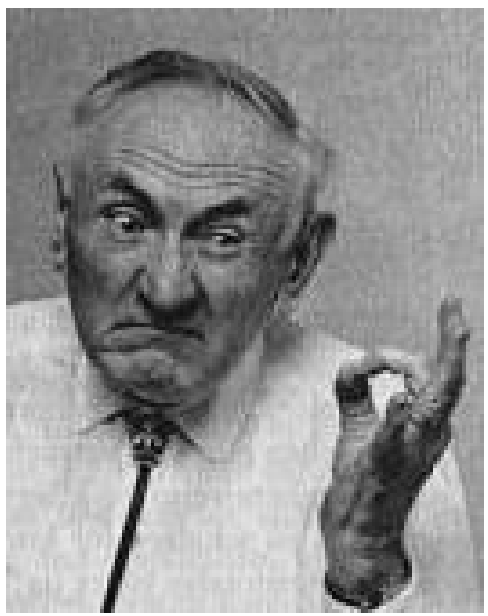
The cluster distance was estimated using m10.

[Abell, Corwin & Olowin (1989) use UKST plates to extend Abell's work to the south.]

z-less group-finding

Clusters:

1960s - Zwicky & collaborators also inspected PSS plates to find galaxies and define clusters as having at least 50 galaxies within the radius containing an average enclosed overdensity of 2.



z-less group-finding

Clusters:

1985 - Shectman used Seldner et al's (1977) 10x10 arcmin binned version of the Shane and Wirtanen (1967) galaxy counts from Lick Survey plates.

1) **Apply smoothing filter**
2) **Apply a threshold**

1/16	1/8	1/16
1/8	1/4	1/8
1/16	1/8	1/16

z-less group-finding

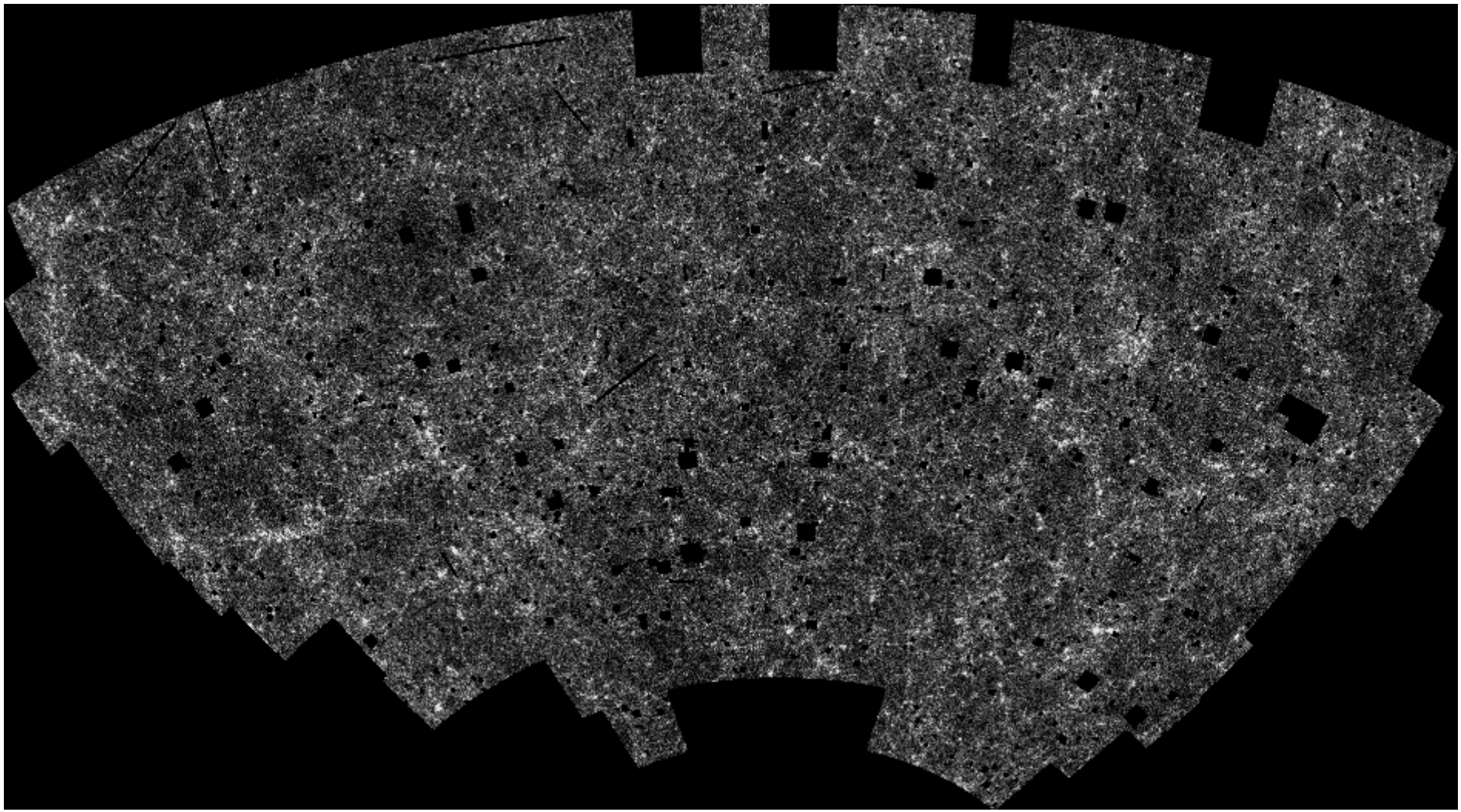
Clusters:

1990s - Plate scanning machines used to automate the galaxy-defining procedure.

1992 - Lumsden etal find clusters using COSMOS scans of UKST plates + Shectman filter + local background correction → 737 objects in EDCC.

1997 – Dalton etal, APM scans of UKST plates. Abell-like cluster definition, only 0.5Mpc/h → 957 clusters.

z-less group-finding

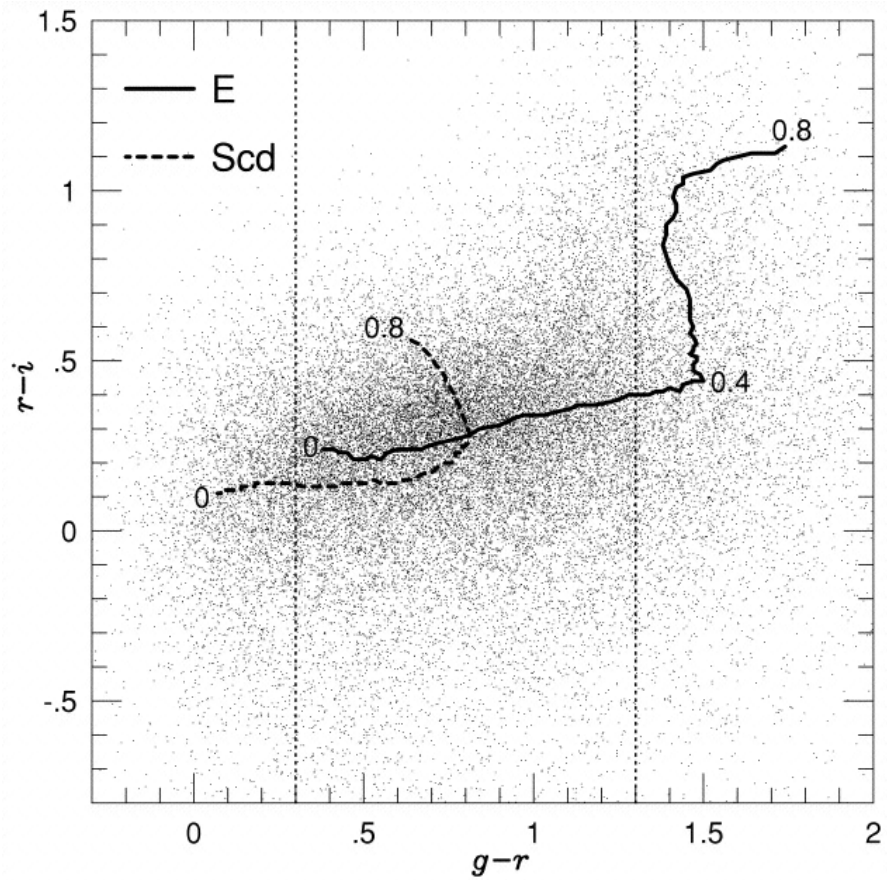


APM Galaxy Survey (Maddox, etal, Oxford University Astrophysics)

z-less group-finding

Clusters:

2000,2003 - Gal etal use DPOSS,DPOSS2



g-r<0.3 → field galaxy

g-r>1.3 → star or high-z

Adaptive kernel technique plus a peak-finder.

8155 candidate clusters in 5800deg^2.

z-less group-finding

$250+$16p&p

STScI press release, 1996

The Digitised Palomar Sky Survey (DPOSS)

z-less group-finding

Clusters:

Voronoi Tesselation – van de Weygaert & Icke '87

Matched Filter – Postman etal 1996, various subsequent adaptions

Red Sequence – Gladders & Yee 2000

SDSS clusters – Annis etal, Kim etal, Goto etal, Bahcall etal, 1999 and later.

z-less group-finding

Smaller groups:

1976 – Turner & Gott, found 103 groups in the Zwicky Catalogue (~70% of 1000 galaxies).

> **`In the present paper, a new catalog of groups is presented; this catalog, in contrast to earlier ones, has been generated by the "blind" application of a precisely defined group identification procedure. This procedure only considers the positions of galaxies in the sky. As a result, it sometimes makes "absurd" mistakes, but these are usually too obvious to be misleading. In addition, the shortcomings of the groups defined by our naïve method are offset, we feel, by their objectivity, homogeneity, and completeness.'**

z-less group-finding

Compact groups:

1977 – Rose created the first systematic search for compact groups. Motivated by

1) apparently high M/Ls using virial theorem

2) contamination and isolation of groups

PSS + Yale-Columbia southern proper motion plates. Rose found 2800 trios and ~500 quartets.

Conclusion: really anomalous zs consistent with projection, but groups tend to have atypically close neighbouring galaxies – virial theorem?

z-less group-finding

Compact groups:

1982 – Hickson found 100 compact groups, from the POSS, satisfying:

1) $N \geq 4$ **membership**

2) $\theta_N \geq 3\theta_G$ **isolation**

3) $\overline{\mu}_G < 26.0$ **compactness**

Spirals under-represented in CG relative to the field.

z-less group-finding

Compact groups:

Spectroscopic studies of HCG showed (Hickson etal 1992)

69 had at least 4 concordant velocities

23 systems were triplets

8 were less populous systems

Groups with short crossing times contained a smaller spiral fraction.

z-less group-finding

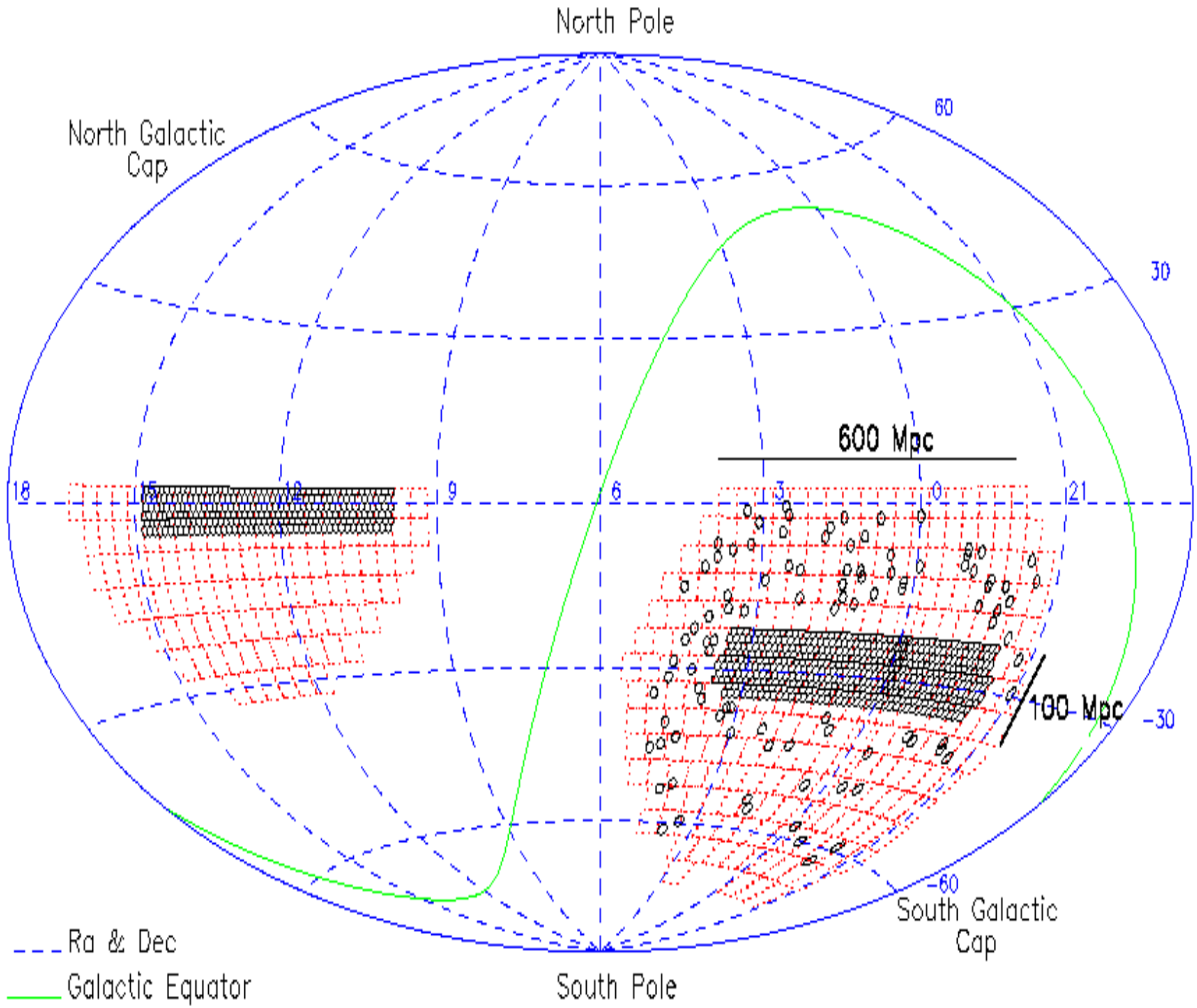
Compact groups:

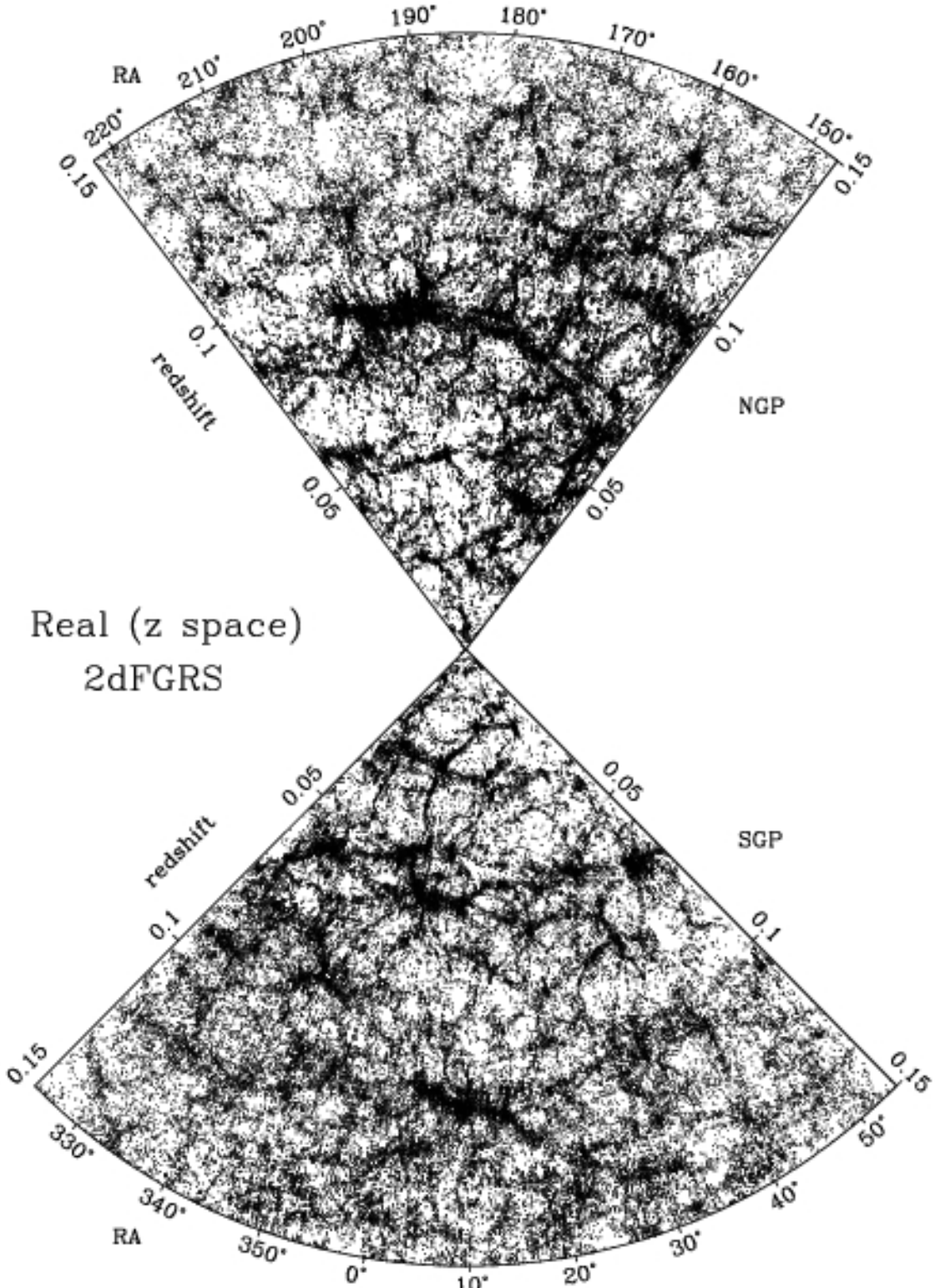
Similar criteria to those of Hickson have been applied by:

Who	Number	From where, no. of sq. deg.
Prandoni etal 1994	59	COSMOS, 1.3k
Iovino 2002	121	COSMOS, 5k
Iovino etal 2003	84	DPOSS2, 2k
Lee etal 2004	175	SDSS, 153
de Carvalho etal 2005	459	DPOSS2, 6k, $z<0.2$

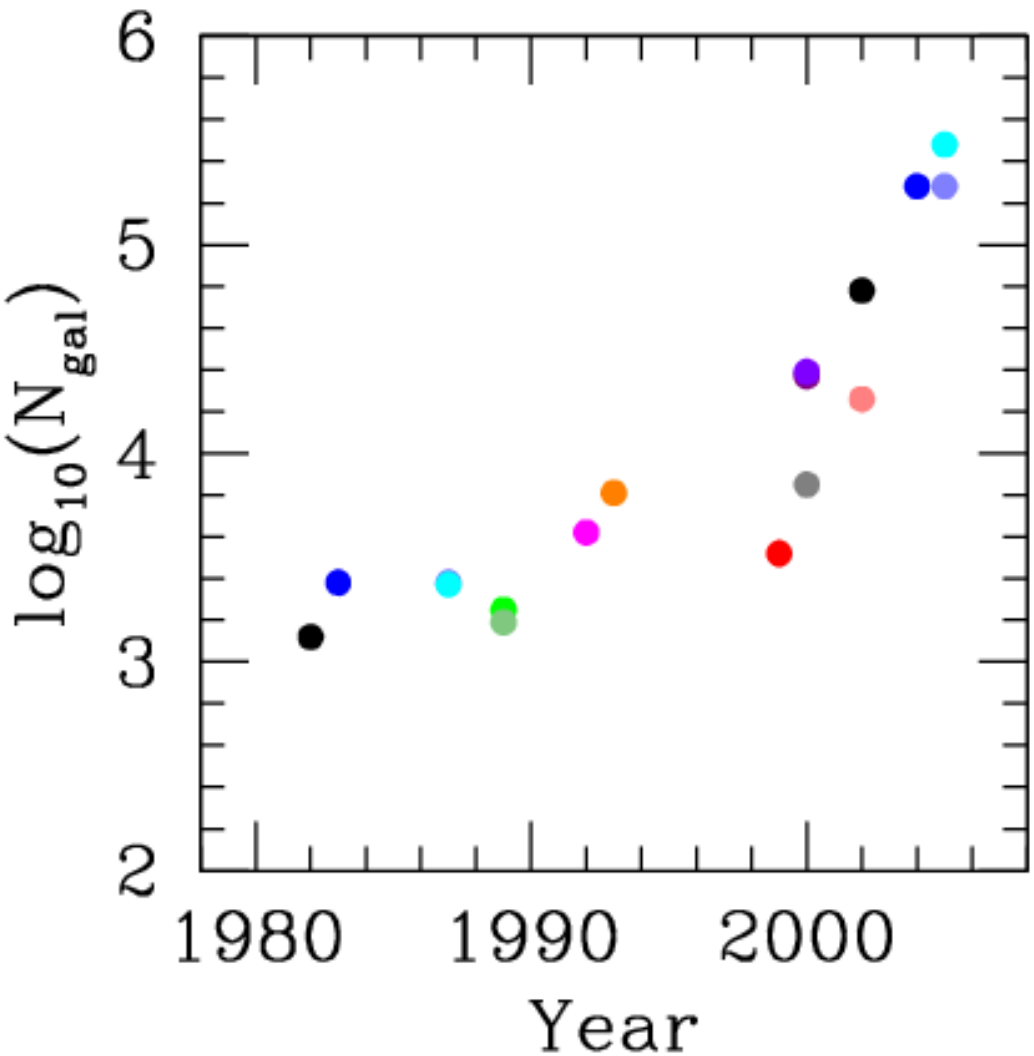
Galaxy group searches and surveys

1) What is a group?
2) Group-finding without redshifts
3) Group-finding with redshifts
4) The 2PIGG catalogue


North Pole
North Galactic Cap
60
30
18
15
12
9
6
3
0
21
600 Mpc
100 Mpc
-30
-60
South Galactic Cap
South Pole
Ra & Dec
Galactic Equator
2dF fields
APM scanned UKST fields


RA
redshift
NGP
SGP
Real (z space)
2dFGRS

Group-finding with zs



ZC+UGC: Huchra & Geller
CfA: Geller & Huchra
CfA: Nolthenius & White + mocks
Nearby GC: Tully
CfA: Ramella et al
SSRS: Maia et al
PGC: Gourgoulhon et al
Lyon−Meudon ED: Garcia
ESP: Ramella et al
LCRS: Tucker et al
NOG: Giuricin et al
UZC+SSRS: Merchan et al
UZC+SSRS: Ramella et al
2dFGRS: Merchan & Zandivarez
2dFGRS: Eke et al
2dFGRS: Yang et al
SDSS DR3: Merchan & Zandivarez

Techniques for group-finding

The Friends-Of-Friends (FOF) method (Huchra & Geller 1982).

- **Define a linking volume, such as a sphere or a cylinder**
- **Decide how to scale it with redshift (flux-limited surveys etc)**
- **Link together galaxies that fall within the linking volume of neighbouring galaxies**

Techniques for group-finding

The Hierarchical Method (Materne 1978, Tully 1980, 1987). Dendrogram-type method.

Define separations between 2 galaxies either

1) ignoring $V_{ij} \qquad V < V_l$

or

2) by including terms along the lines of

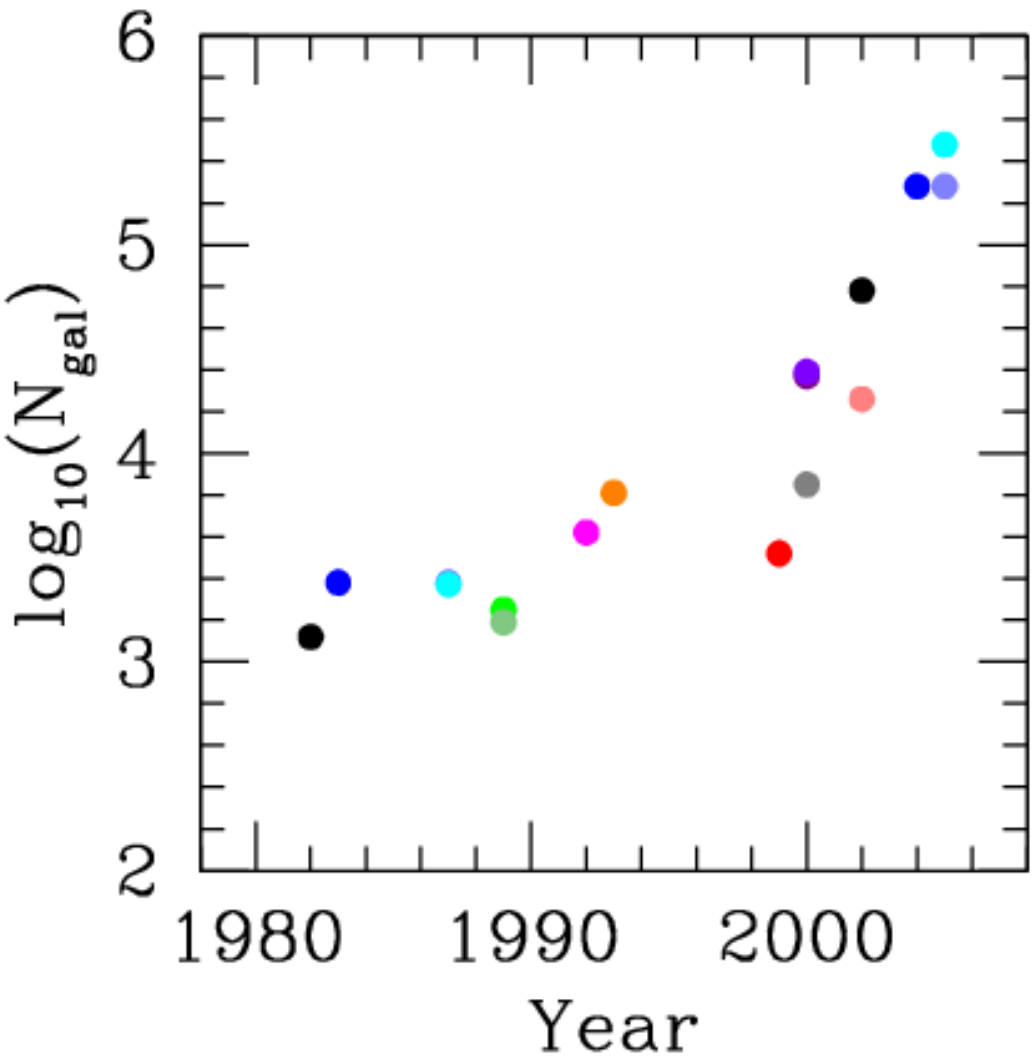
$$(V_{ij}^2 - V_l^2) / H_0^2 \qquad V > V_l$$

$$V_l = 300 km/s$$

Techniques for group-finding

1) For N galaxies, link together the two with the largest value of L / R_{ij}^2
2) Replace with a single node at the centre of L
3) Repeat steps (1) and (2) N-2 more times to leave a single node
4) Define group membership using a threshold in L / R_{ij}^3

Group-finding with zs



ZC+UGC: Huchra & Geller
CfA: Geller & Huchra
CfA: Nolthenius & White + mocks
Nearby GC: Tully
CfA: Ramella et al
SSRS: Maia et al
PGC: Gourgoulhon et al
Lyon−Meudon ED: Garcia
ESP: Ramella et al
LCRS: Tucker et al
NOG: Giuricin et al
UZC+SSRS: Merchan et al
UZC+SSRS: Ramella et al
2dFGRS: Merchan & Zandivarez
2dFGRS: Eke et al
2dFGRS: Yang et al
SDSS DR3: Merchan & Zandivarez

Compact group surveys using redshifts

1996: Barton etal used a FOF algorithm on the CfA2+SSRS2 data. Tuned to produce objects like HCG. 89 groups with N>=3.

2000: Allam & Tucker, FOF on LCRS. 76 CGs (N>=3) with median z=0.08.

2002: Focardi & Kelm, FOF/H hybrid applied to 3D UZC. 291 groups with N>=3.

Mock catalogues

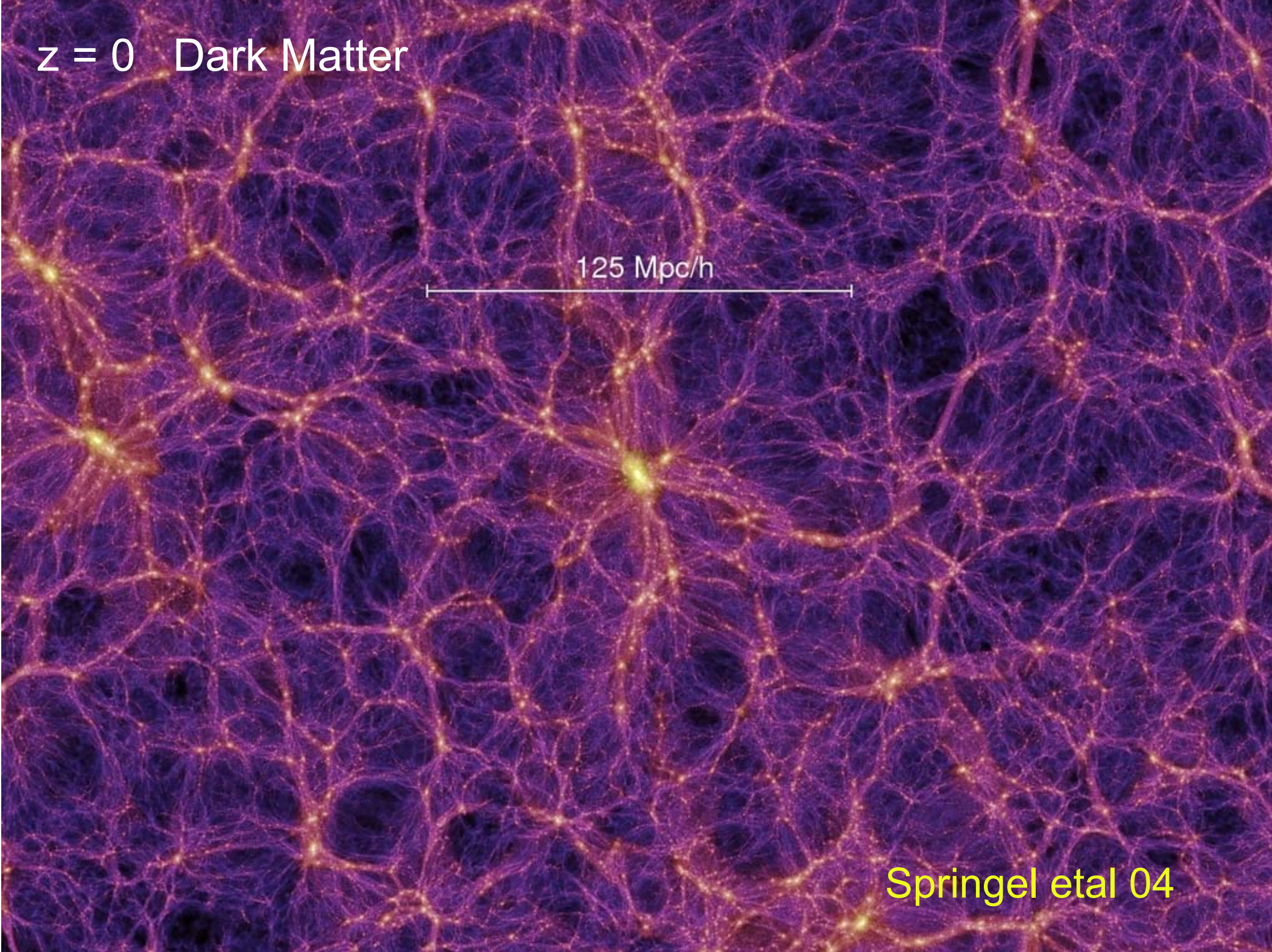
Mock catalogues serve 2 primary purposes:

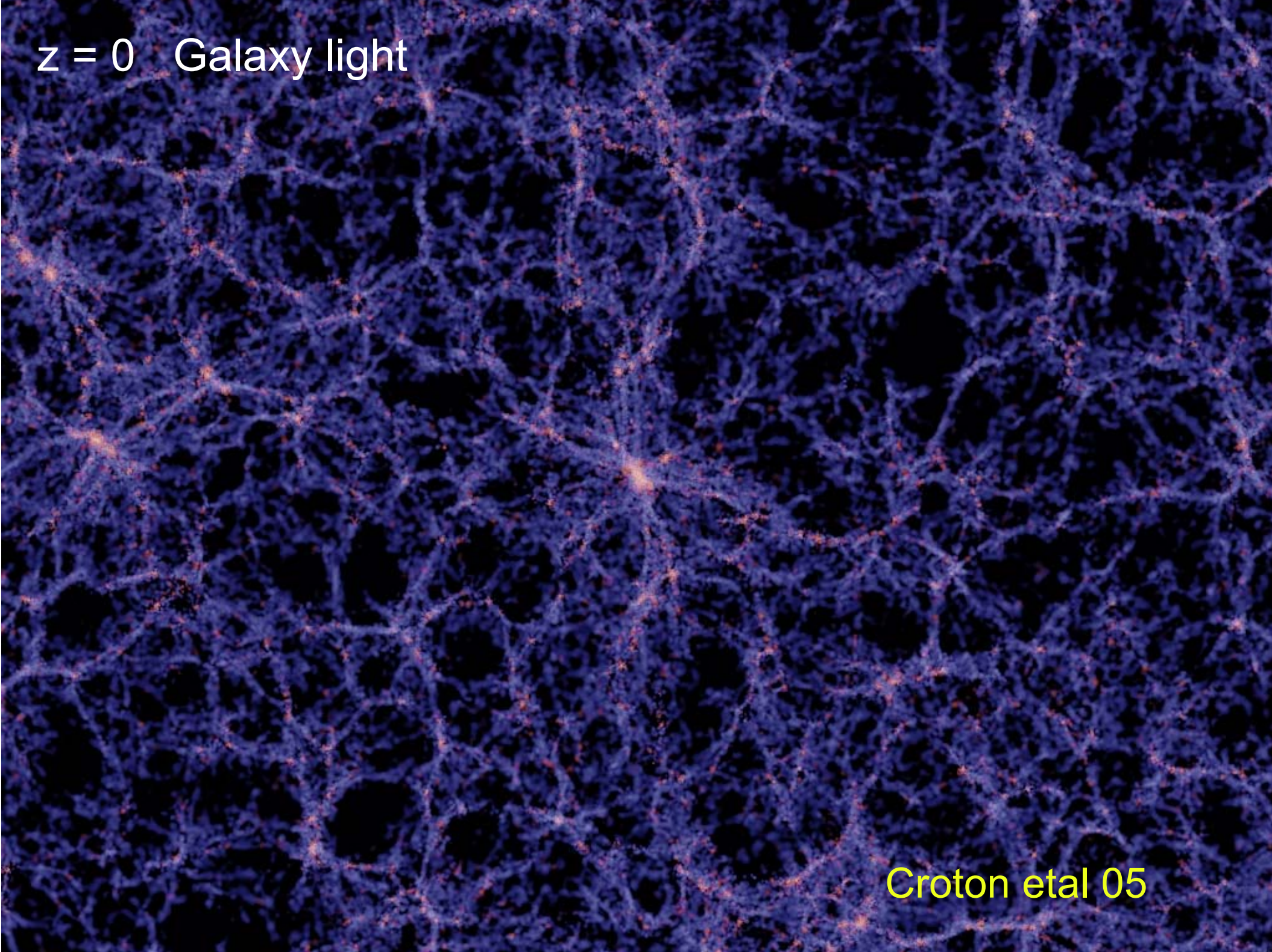
1) To optimize the groupfinding procedure

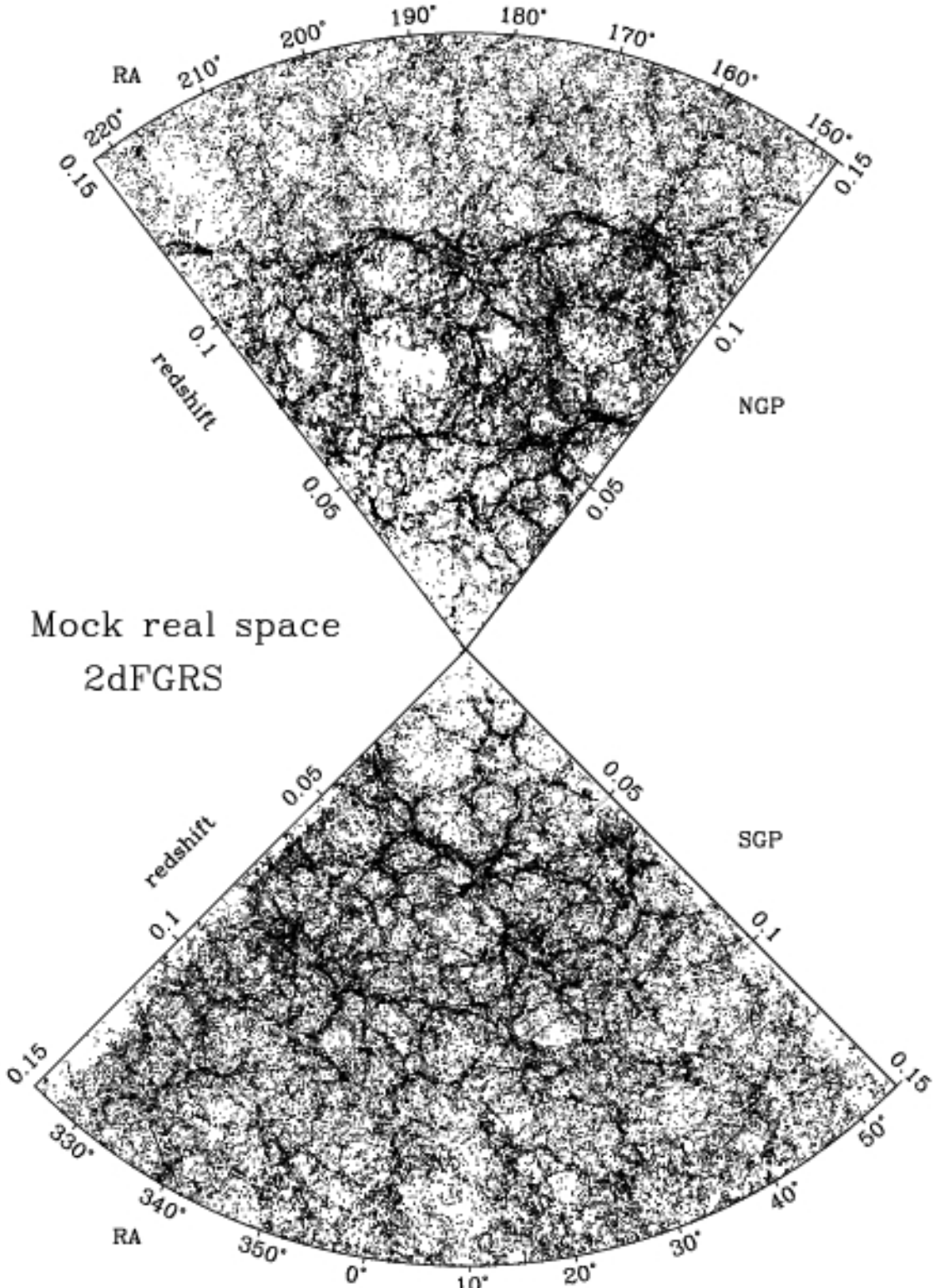
2) To compare models with data

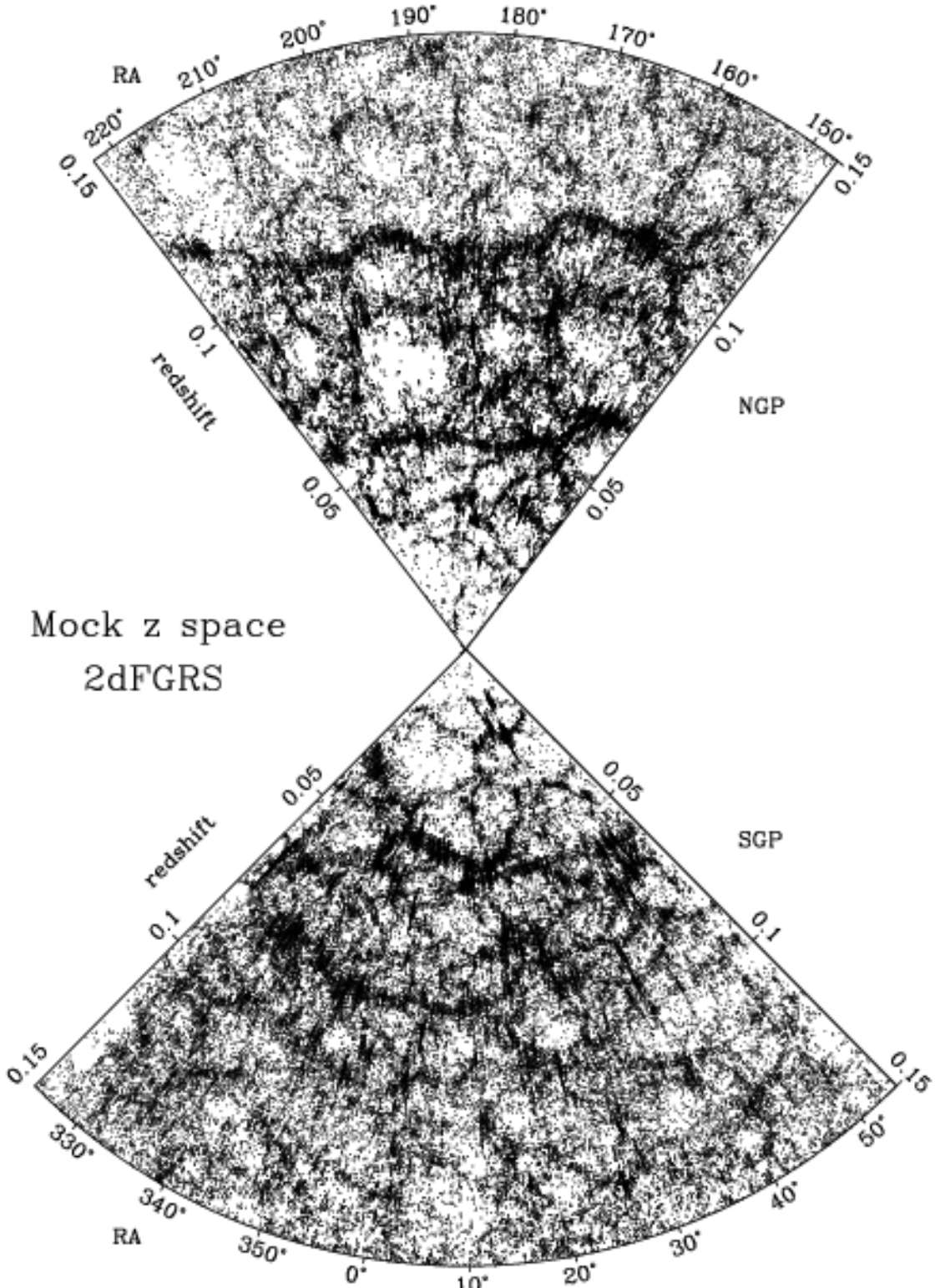
N-body simulations + semi-analytical method or H.O.D.

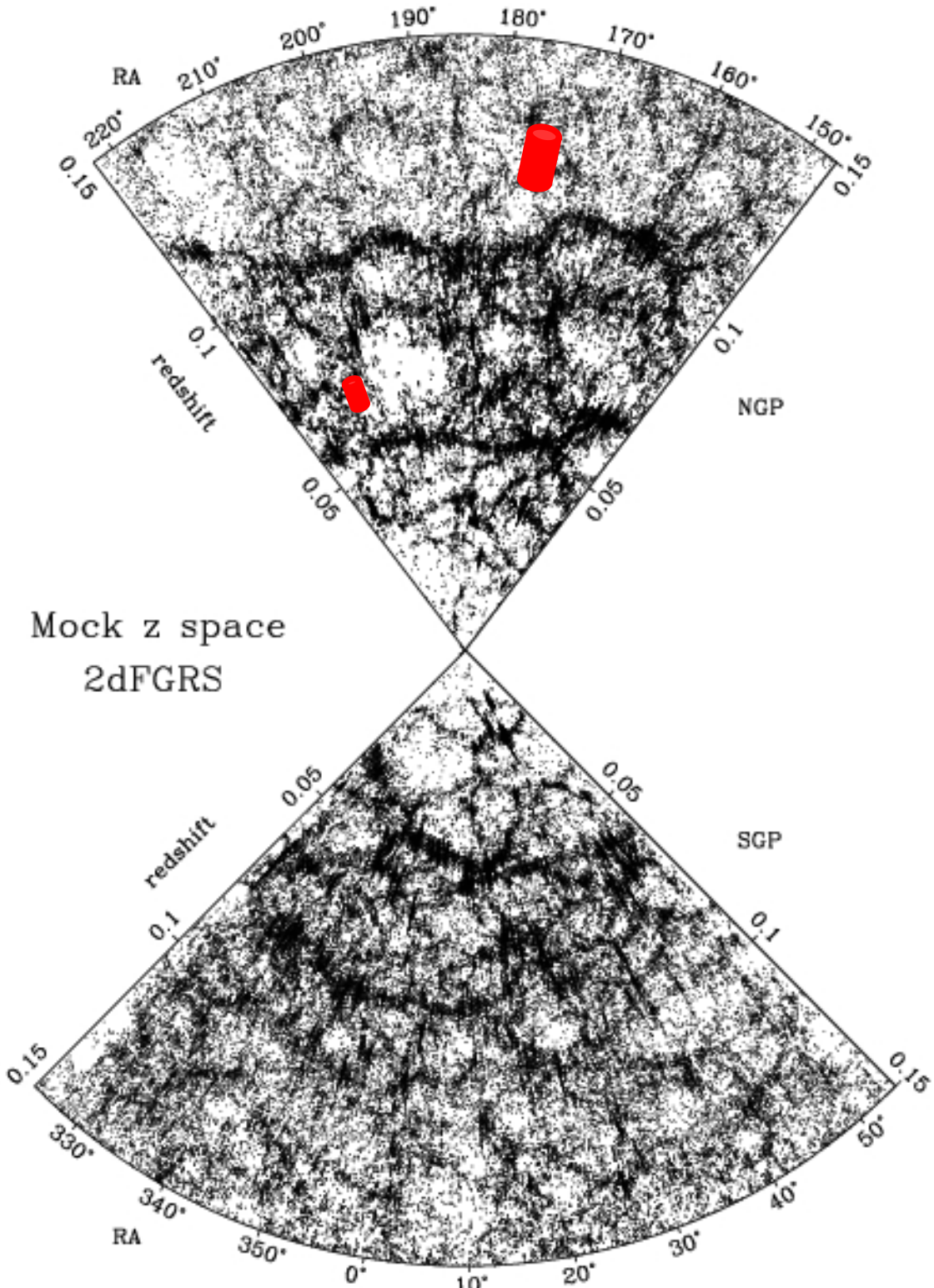
Cosmological model => galaxy distribution and group properties.

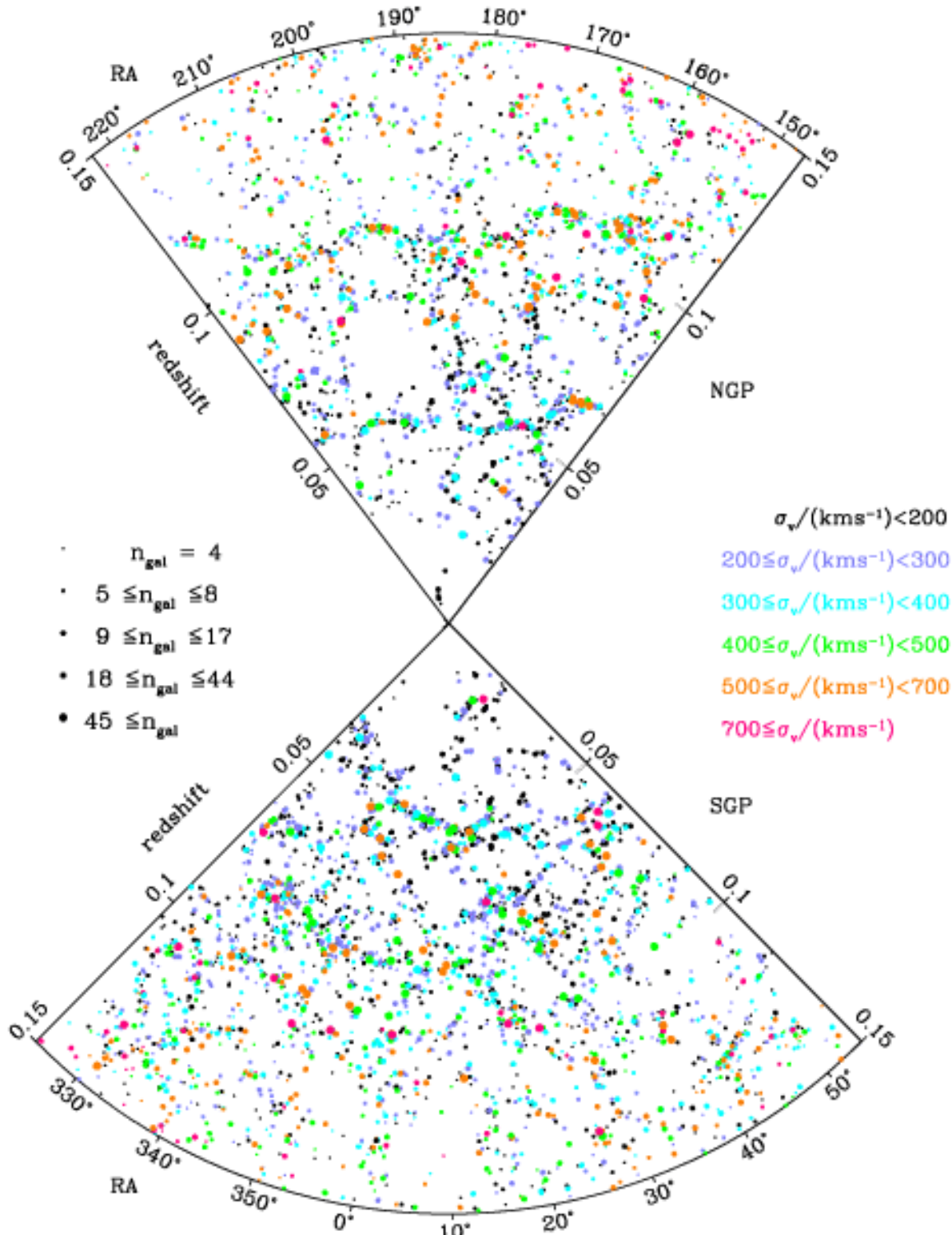

z = 0 Dark Matter
125 Mpc/h
Springel etal 04


z = 0 Galaxy light
Croton etal 05


RA
redshift
NGP
SGP
Mock real space
2dFGRS

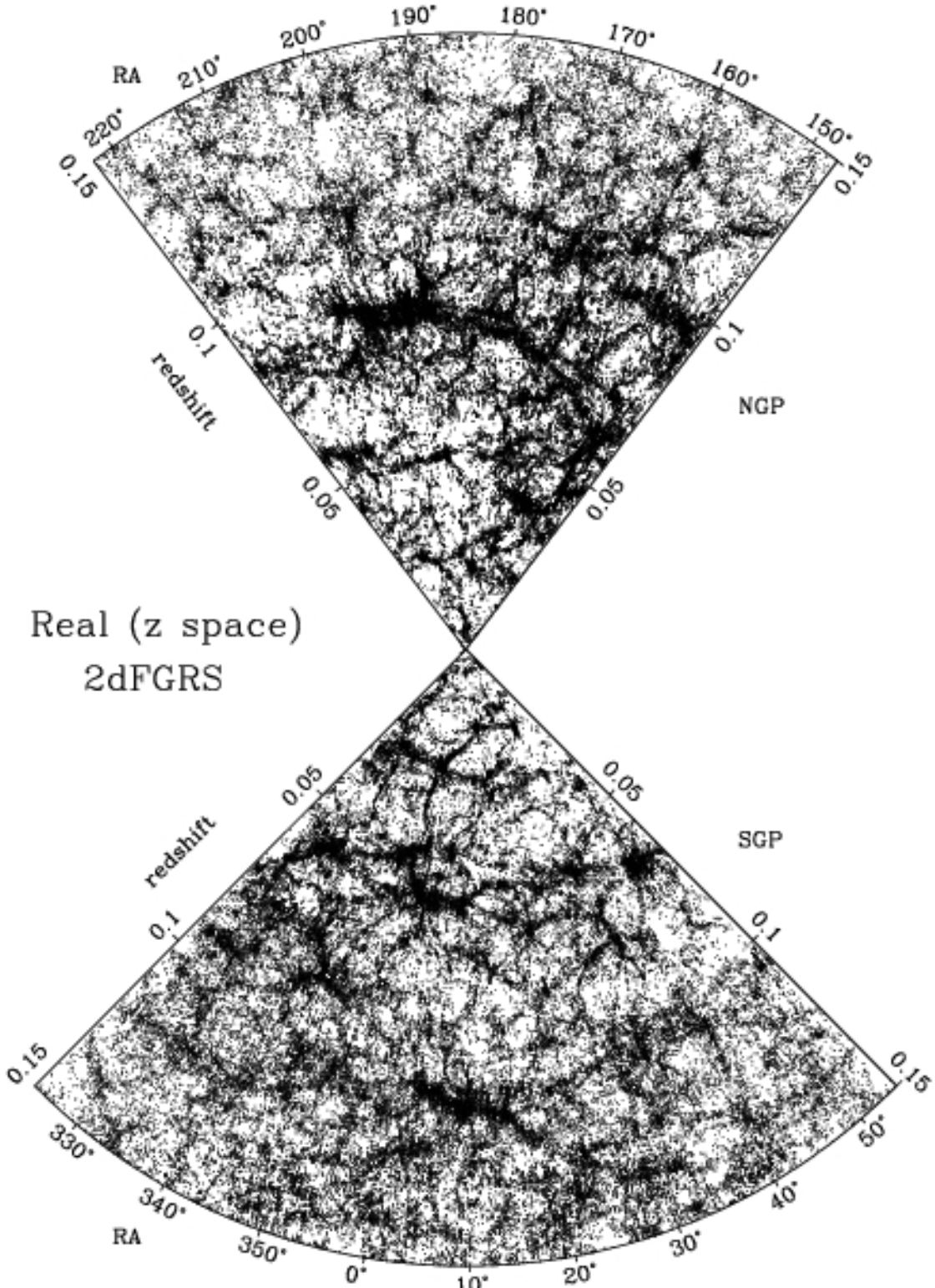

RA
redshift
NGP
SGP
Mock z space
2dFGRS

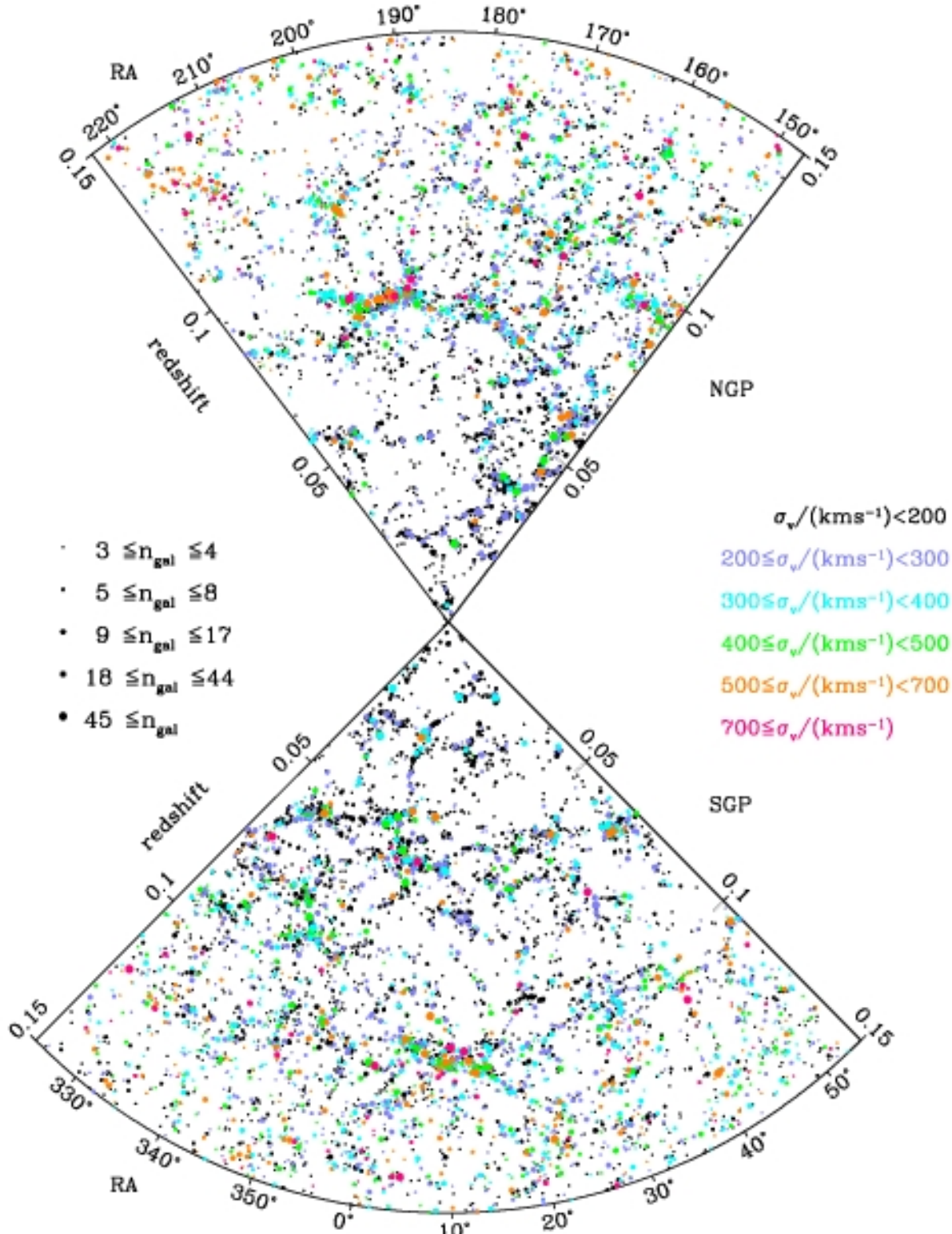

RA
redshift
NGP
SGP
Mock z space
2dFGRS


RA
redshift
NGP
SGP
n_{gal} = 4
5 ≤n_{gal} ≤8
9 ≤n_{gal} ≤17
18 ≤n_{gal} ≤44
45 ≤n_{gal}
σ_v/(kms^{-1})<200
200≤σ_v/(kms^{-1})<300
300≤σ_v/(kms^{-1})<400
400≤σ_v/(kms^{-1})<500
500≤σ_v/(kms^{-1})<700
700≤σ_v/(kms^{-1})

Galaxy group searches and surveys

1) What is a group?
2) Group-finding without redshifts
3) Group-finding with redshifts
4) The 2PIGG catalogue


RA
redshift
NGP
SGP
Real (z space)
2dFGRS

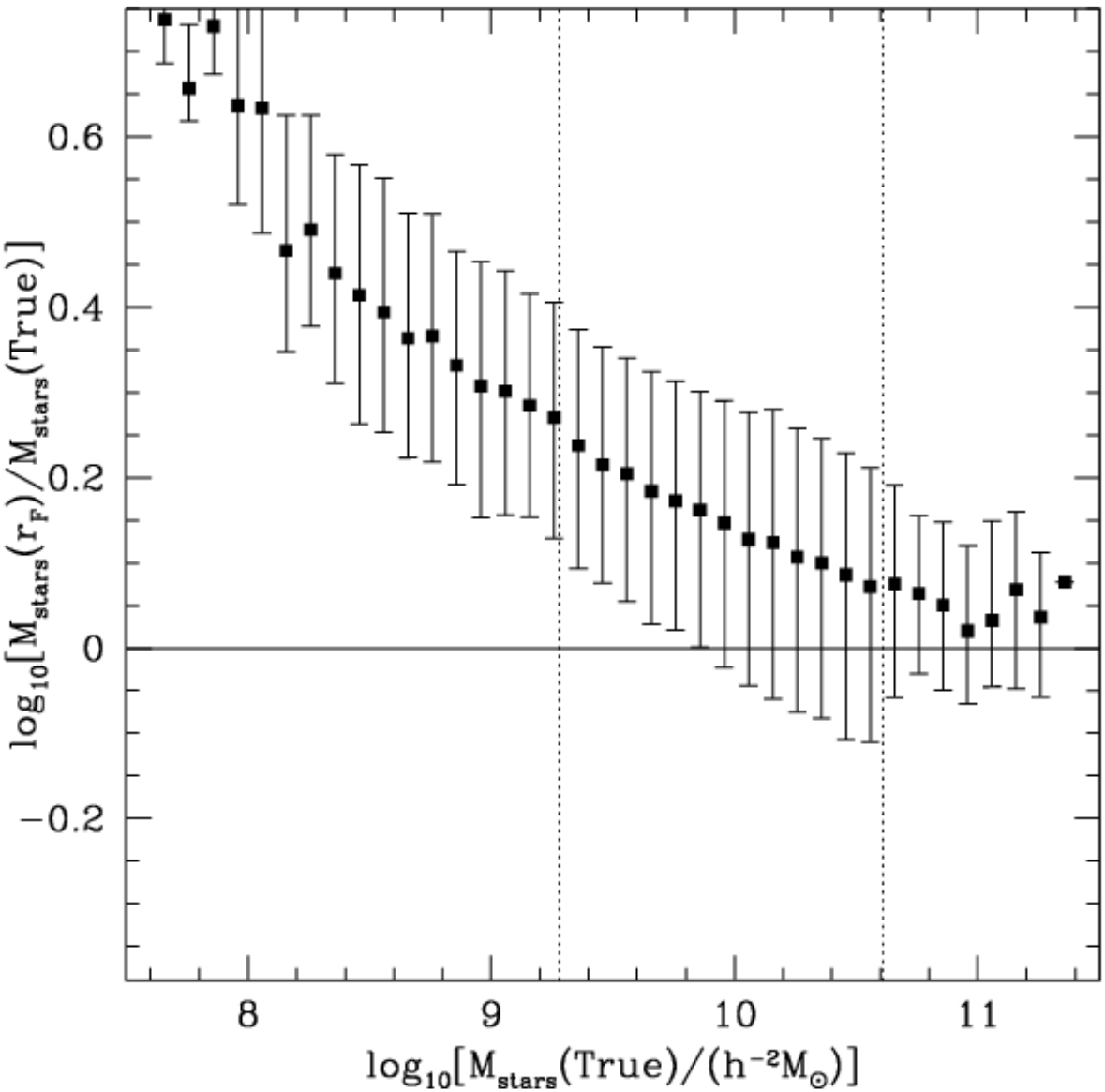

RA
redshift
NGP
SGP
3 ≤n_gal ≤4
5 ≤n_gal ≤8
9 ≤n_gal ≤17
18 ≤n_gal ≤44
45 ≤n_gal
σ_v/(kms⁻¹)<200
200≤σ_v/(kms⁻¹)<300
300≤σ_v/(kms⁻¹)<400
400≤σ_v/(kms⁻¹)<500
500≤σ_v/(kms⁻¹)<700
700≤σ_v/(kms⁻¹)

Measuring stellar masses

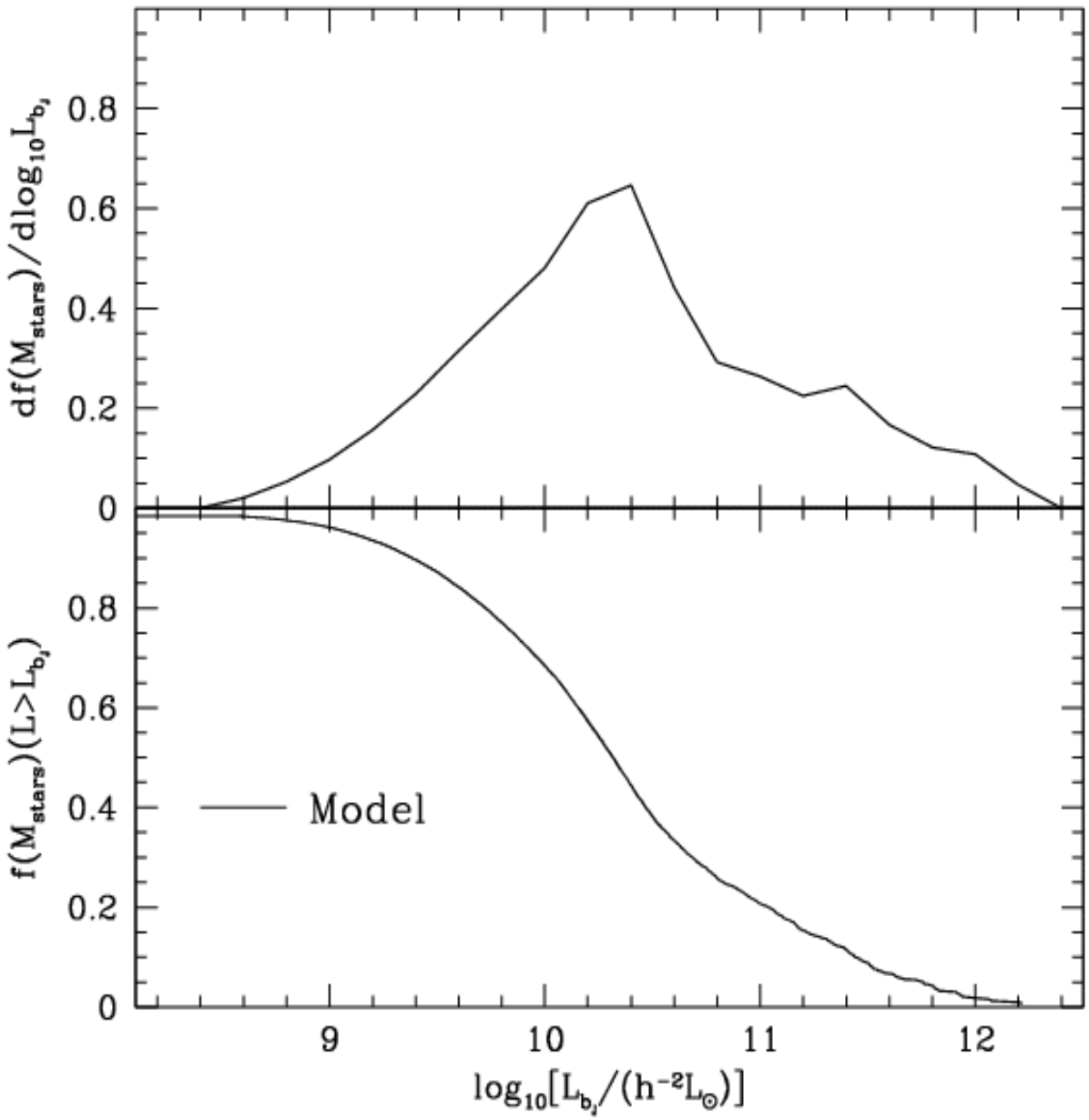
1) b- and r-band fluxes from SuperCOSMOS.
2) Some J- and K-band fluxes from 2MASS.
3) Fluxes+redshifts => luminosities.
4) Kennicutt stellar IMF + Bruzual & Charlot stellar evolution. Model galaxy tracks with exponential SF timescales and various metallicities to fit galaxy colours.

See Eke et al., 2005, MNRAS, 362, 1233 for details.

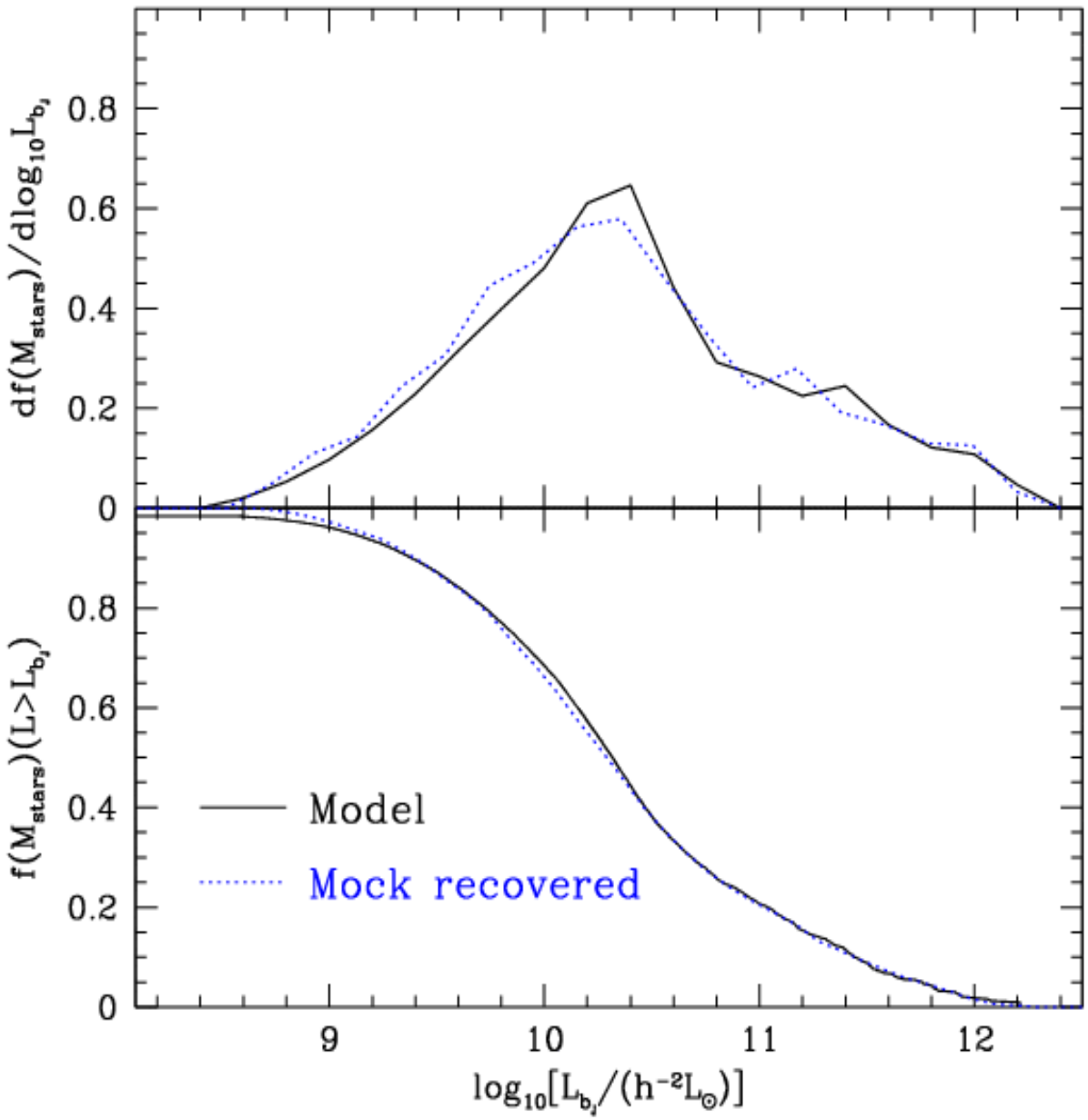
Accuracy of inferred stellar masses



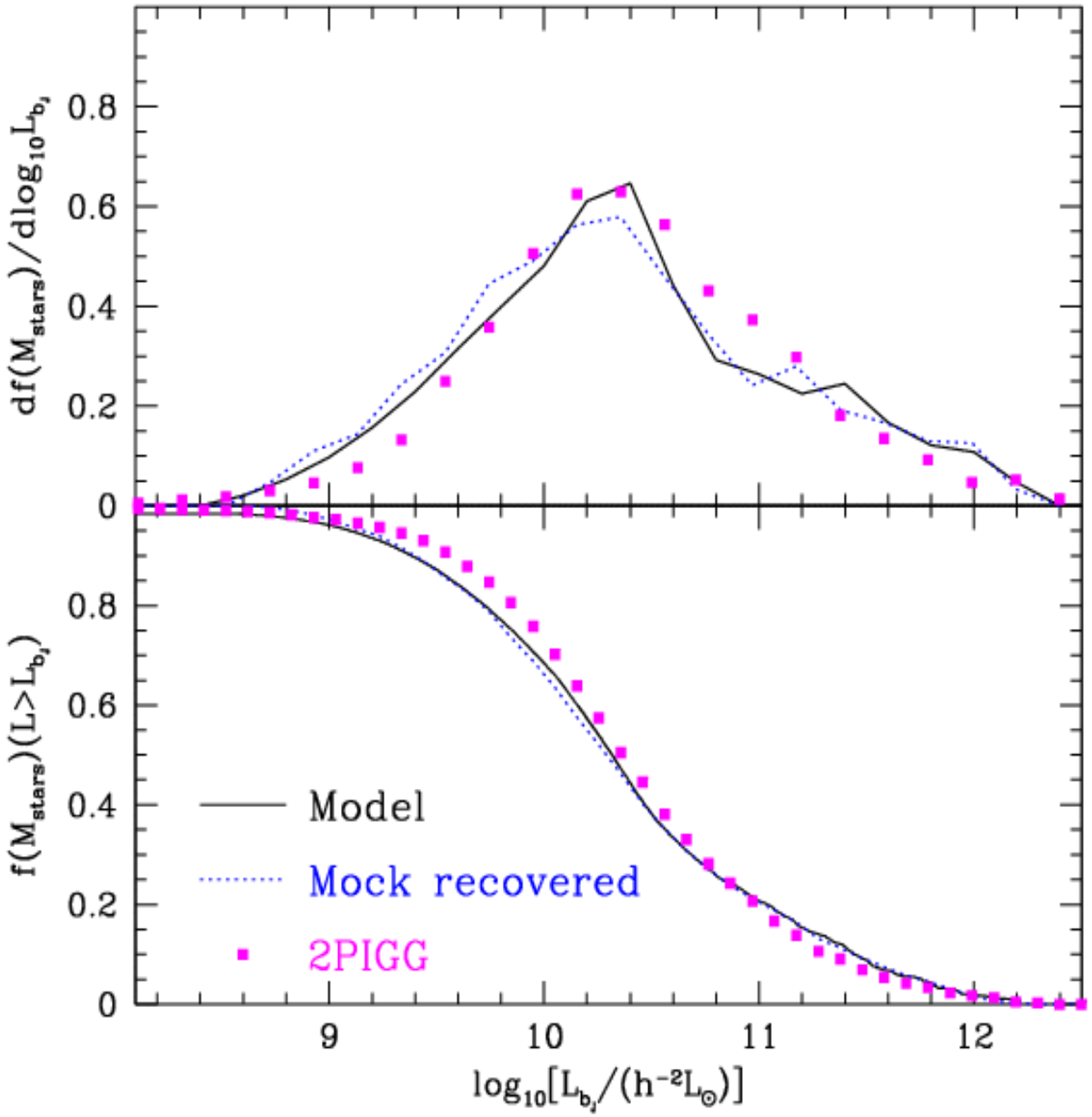
Where are the stars?



Where are the stars?



Where are the stars?



Eke et al., 2005, MNRAS, 362, 1233.

Other wavelengths

HI surveys locate another baryonic component.

Neutral gas is

1) typically more extended than stars, so provides a better tracer of interactions

2) necessary for star formation.

(This morning's talks.)

Other wavelengths

X-ray surveys locate yet another baryonic component.

ROSAT data used extensively:

e.g.

2 distinct components (see Mulchaey & Zabludoff 1998)

extended common haloes (Zabludoff & Mulchaey 1998)

deviations from cluster L-T (Ponman etal 1999)

but not in all samples (GEMS, Osmond & Ponman 2004).

Conclusions

1) A variety of wavelengths have and will be used for cluster surveys

2) Smaller groups tend to be found optically

3) Redshift surveys are now returning thousands of groups, and upcoming surveys will continue to do so (e.g. 6dFGRS locally, DEEP2, VIMOS-VLT deep survey at high-z)

4) Mock catalogues are essential for comparing a model with this sort of galaxy data and calibrating the group-finding procedures.