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Structure and Dynamics of the supercluster of galaxies SC0028-0005

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Structure and dynamics of the supercluster of galaxies SC0028-0005

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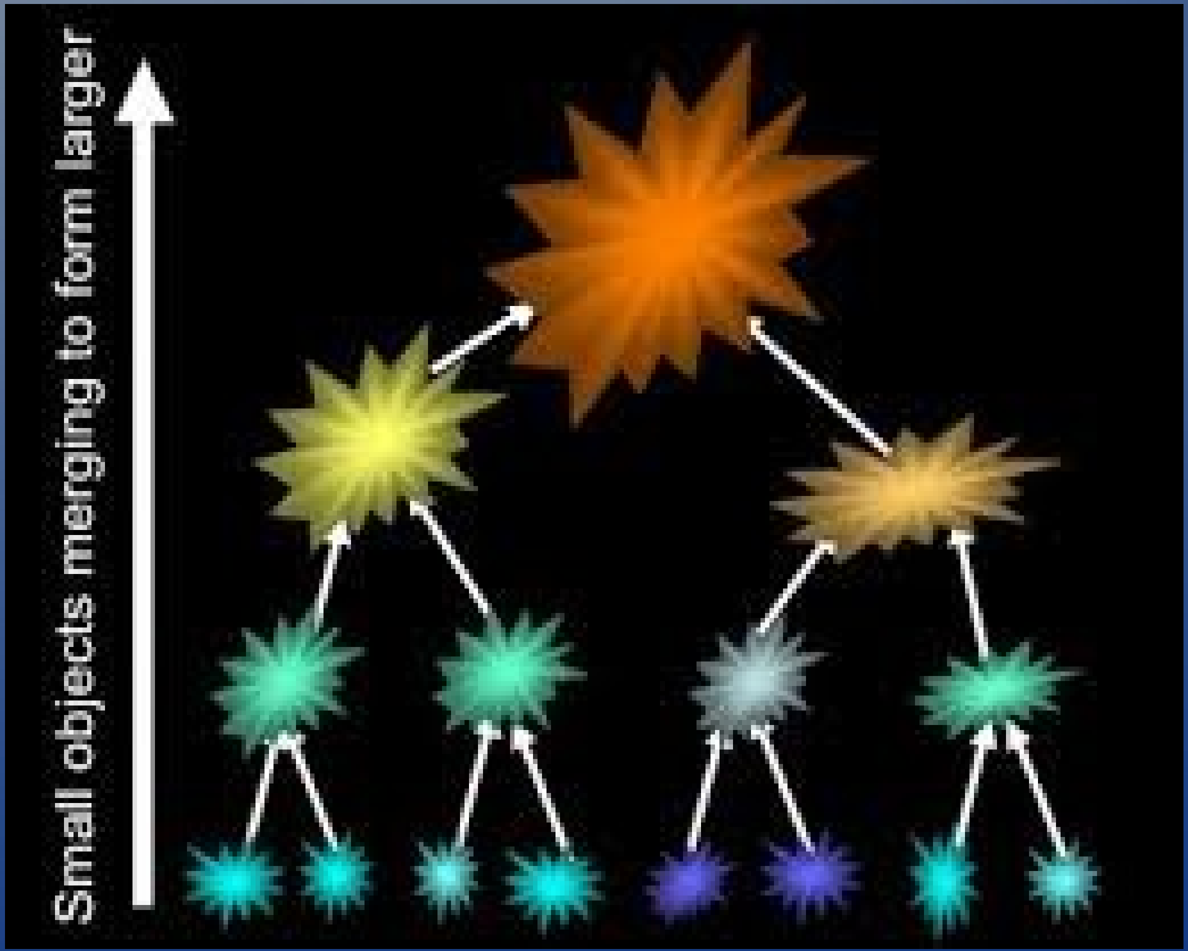
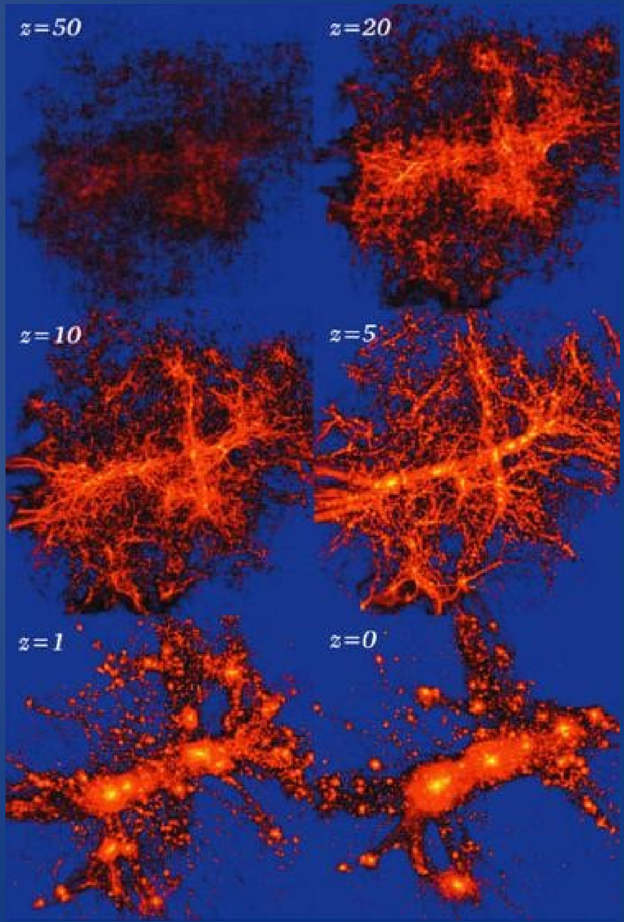
Structure formation in an hierarchical universe

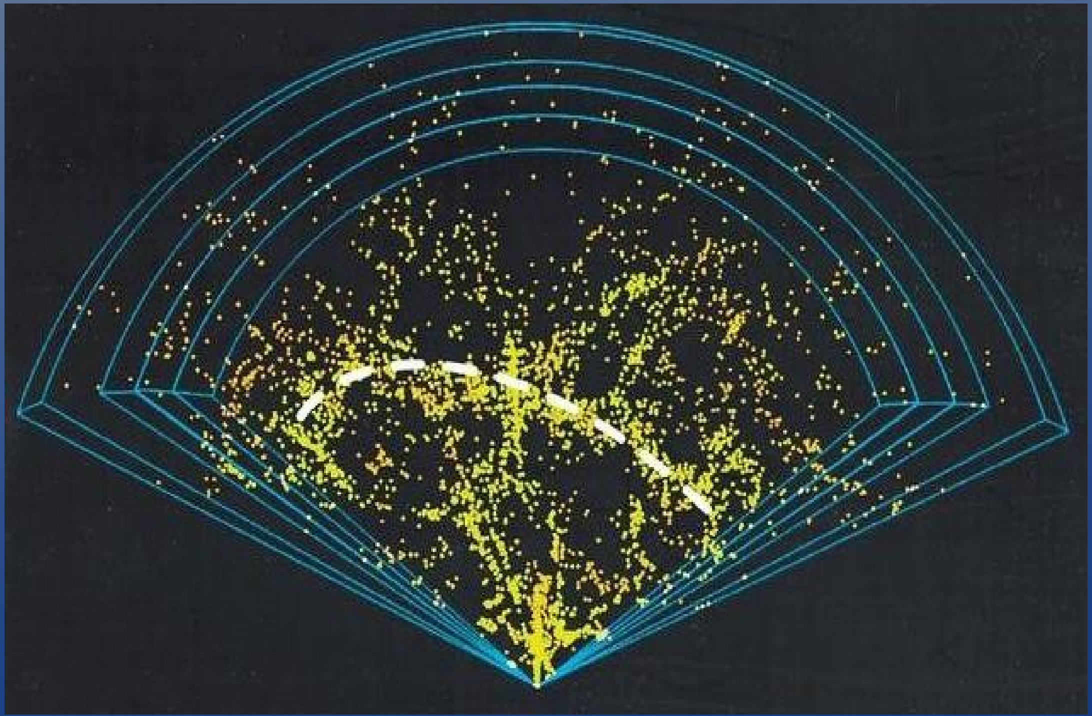
- Smallest structures are the first to form and virialize
- They later get collected into progressively larger structures, each of which going through the same stages of collapse and virialization

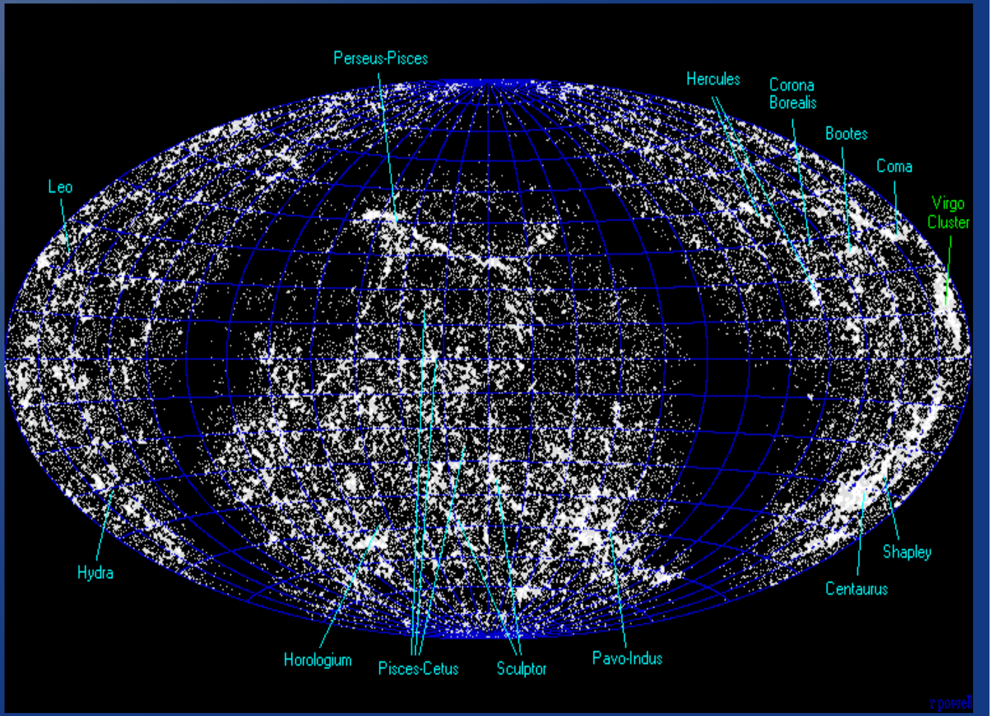




Superclusters (SCs)

- The largest structures in the universe that might/may/will collapse...: *transient structures*
- They may partially disperse or collapse in one or more structures (groups and clusters)
- In an accelerating universe, structures even larger cannot form; SCs will recede from each other at an accelerated rate





pilot study: SC0028-0005

- RA=00:28 DEC=-00:05   z=0.220
- Basilakos (2003): filamentary structure
- Goto+ (2003) cluster catalogue: 3 clusters with relative distances between 4 and 10h^{-1} Mpc

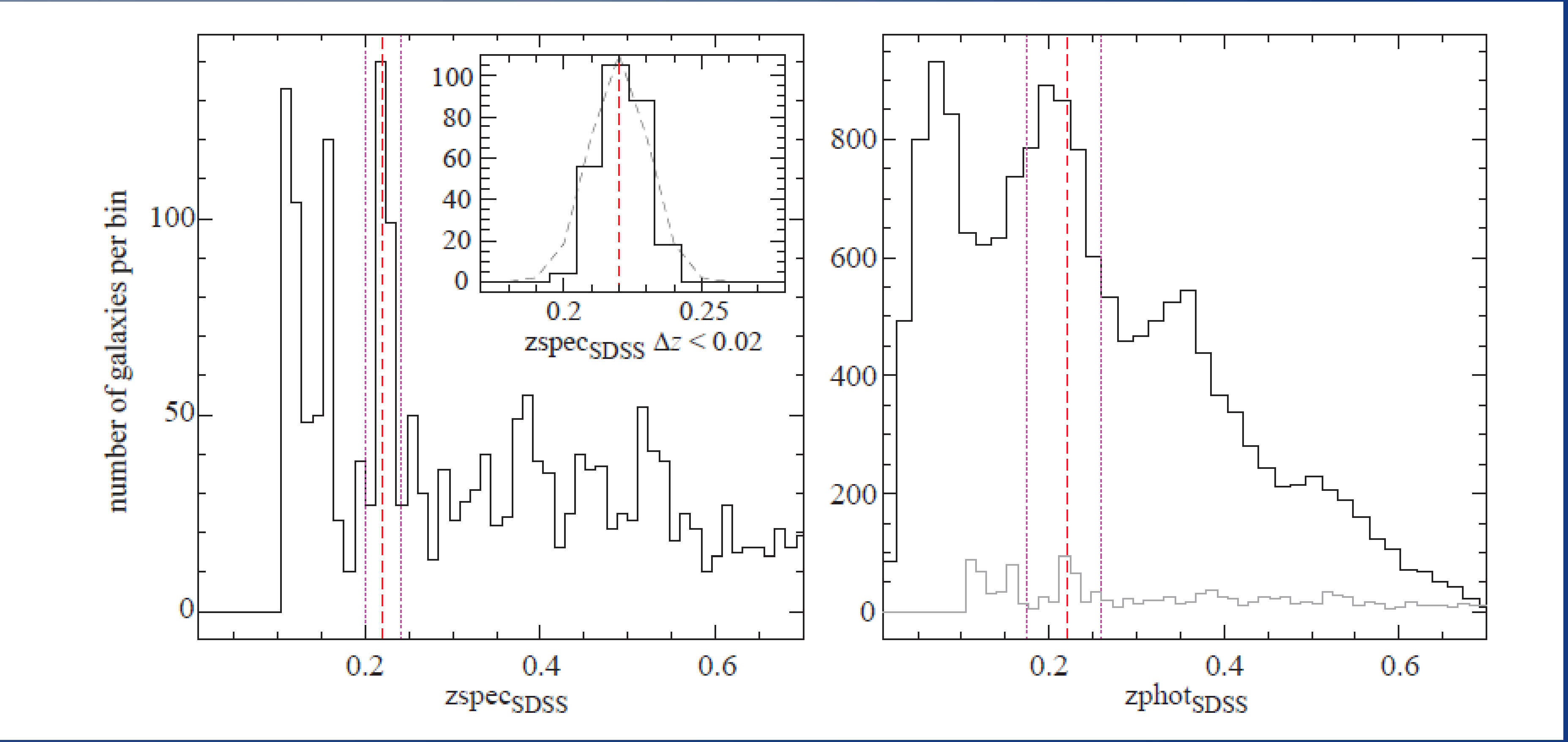
  suggestive of the presence of strong peculiar motions

Data:

- SDSS/DR10: photometric & spectroscopic data within an area of radius 1.2 deg around the SC center
- 4921 galaxies with spectroscopic redshifts
- 35757 galaxies with photometric redshifts
- CFHT gri imaging (completenes ~ 24.5) for the weak lensing analysis

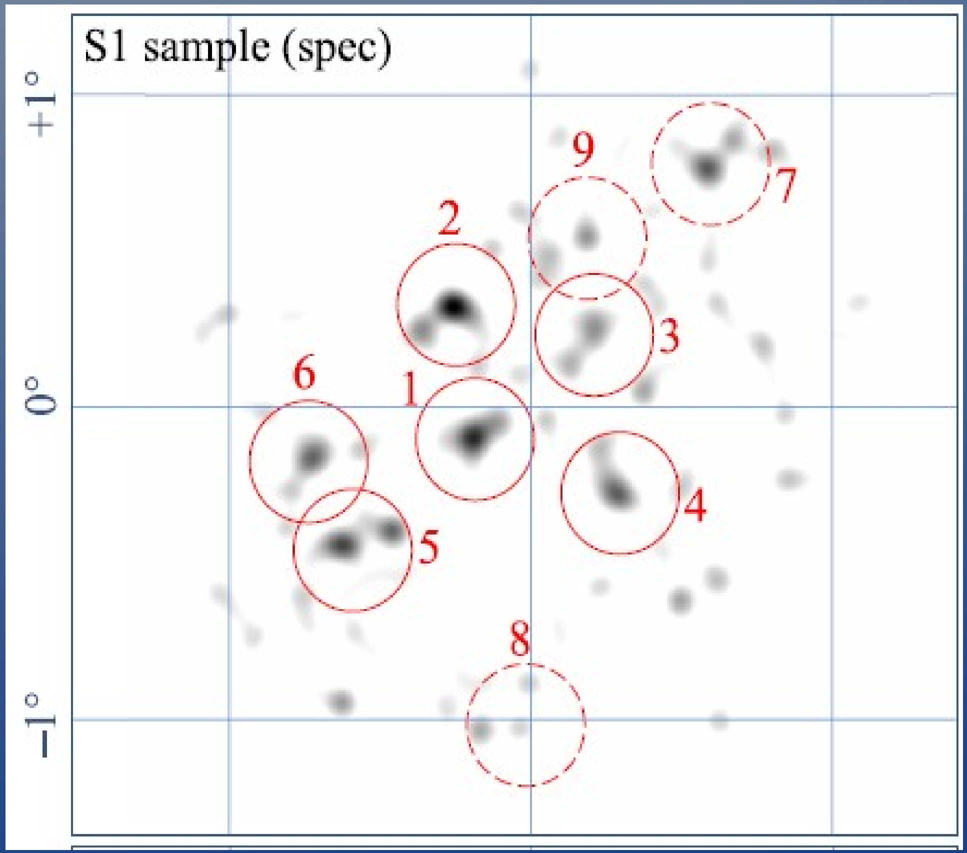
Identification of the SC members

- $\Delta z = |z - \langle z \rangle|$
- S1: spectroscopic sample – $\Delta z < 0.02$ – 271 galaxies - $\langle z \rangle = 0.220$
- S2: photometric redshifts – $\Delta z < 0.04$ ($\sim 2\sigma_{photoz}$) – 3549 galaxies



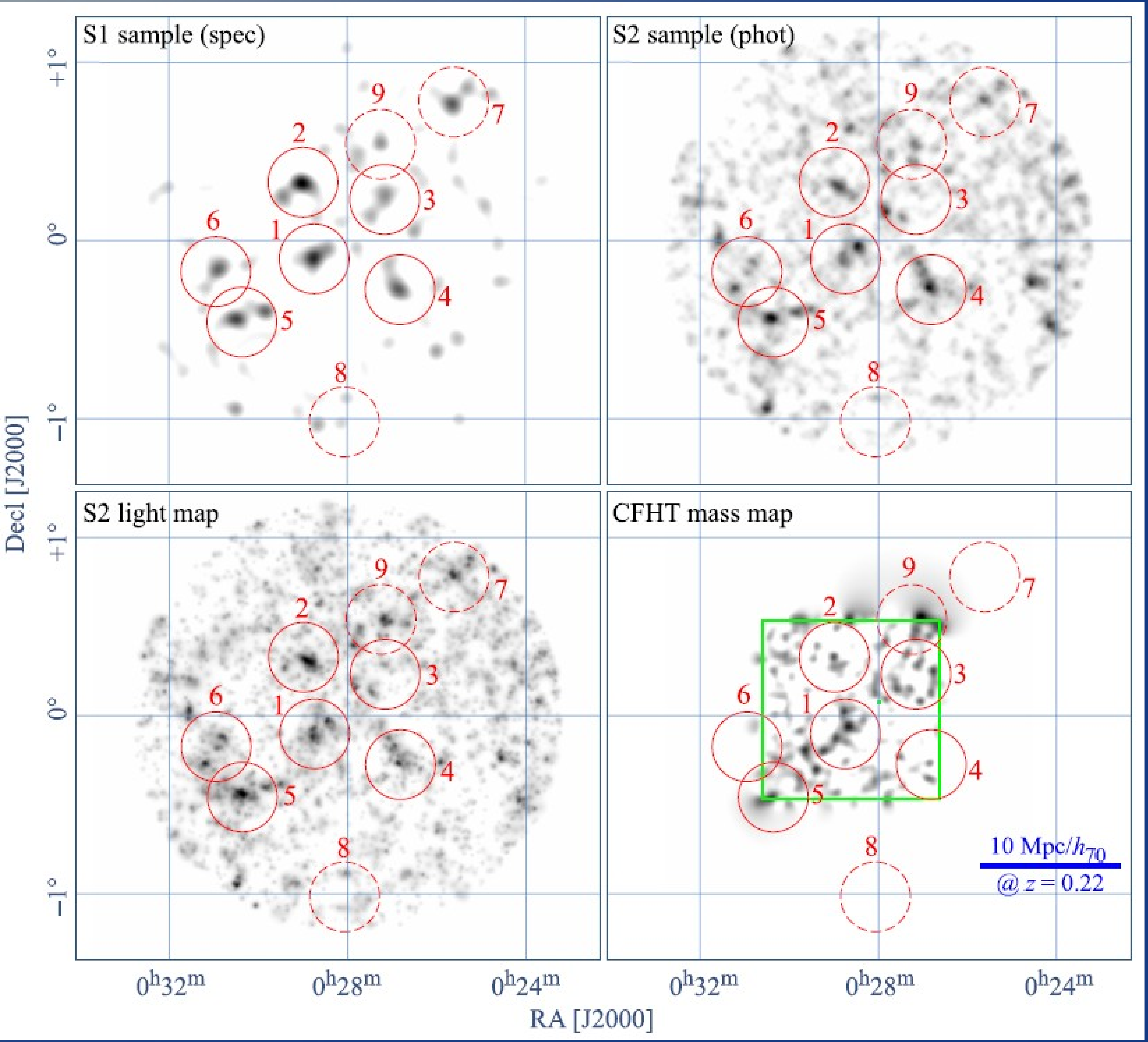
Identifying substructures

- Density map of S1: galaxy number in square cells of 15 arcsec width
- 9 peaks: candidates to groups or clusters
- Centre: BCG; members within 2.5 h_{70}^{-1} Mpc radius (11.7 arcmin)



Id	α (J2000.0) [h m s]	δ (J2000.0) [° ’ ”]	z	fraction of red galaxies [%]
1	00 28 44.28	−000547.16	0.218	78
2	00 28 59.35	+002000.64	0.222	66
3	00 27 09.43	+001413.95	0.217	55
4	00 26 48.78	−001609.73	0.226	69
5*	00 30 21.65	−002705.62	0.225	61
6*	00 30 56.81	−001007.15	0.225	57
7	00 25 36.75	+004701.09	0.220	38
8	00 28 03.93	−010042.28	0.217	30
9	00 27 14.99	+003246.67	0.217	46
SC	00 28 00.00	-00 05 00.00	0.220	81**

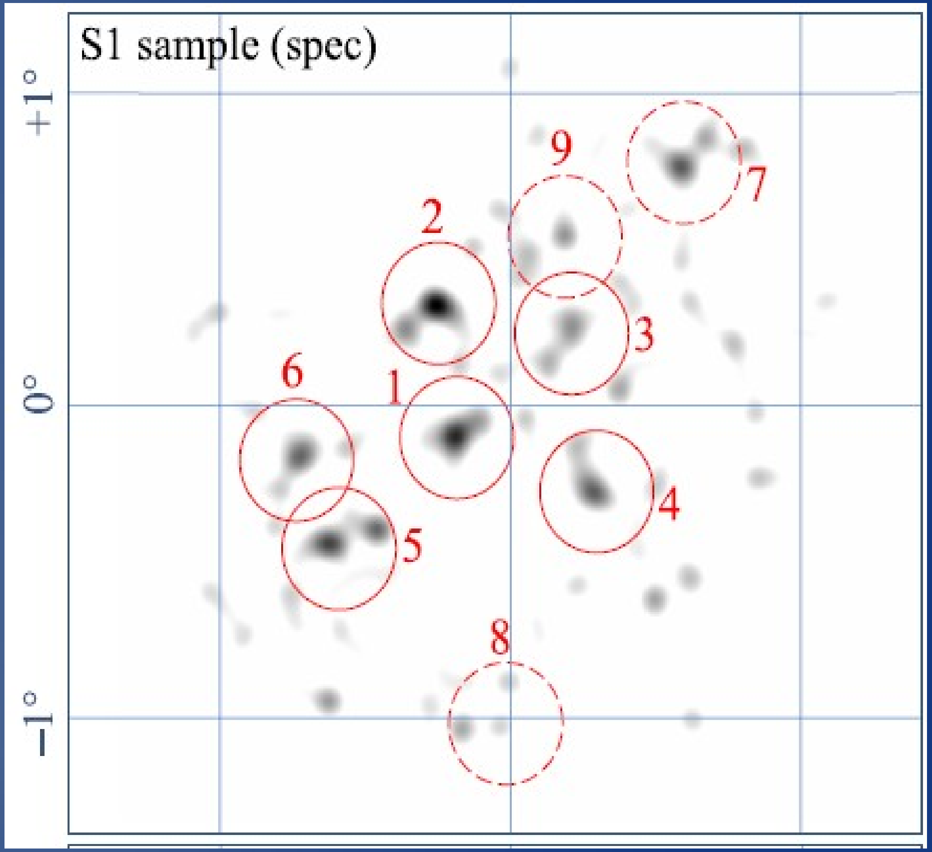
Note*: There is some overlap between regions 5 and 6 (Figure 2). After checking the (photometric) redshift of the 6 galaxies in the overlap region we decided that this area should belong to the structure in region 5.
Note:** The fraction of red galaxies was determined with the S2 sample.

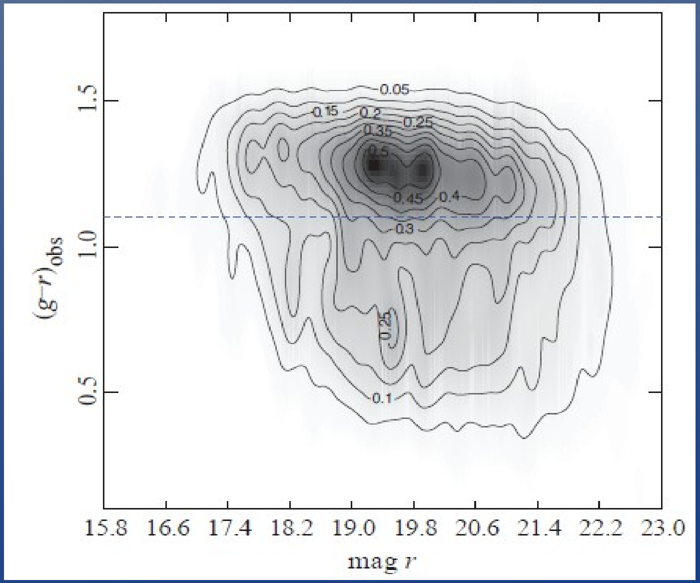


S1 sample (spec)
S2 sample (phot)
S2 light map
CFHT mass map
1
2
3
4
5
6
7
8
9
10 Mpc/h_{70}
@ $z = 0.22$
+1°
0°
−1°
Decl [J2000]
0^h32^m
0^h28^m
0^h24^m
RA [J2000]

Identifying substructures

- Massive groups and clusters tend to have a conspicous red sequence (g-r > 1.1)
- Substructures 7, 8 and 9 where removed from the sample because their fraction of red galaxies is smaller than 50%
- *Bona fide* sample: 6 dense and red enough substructures





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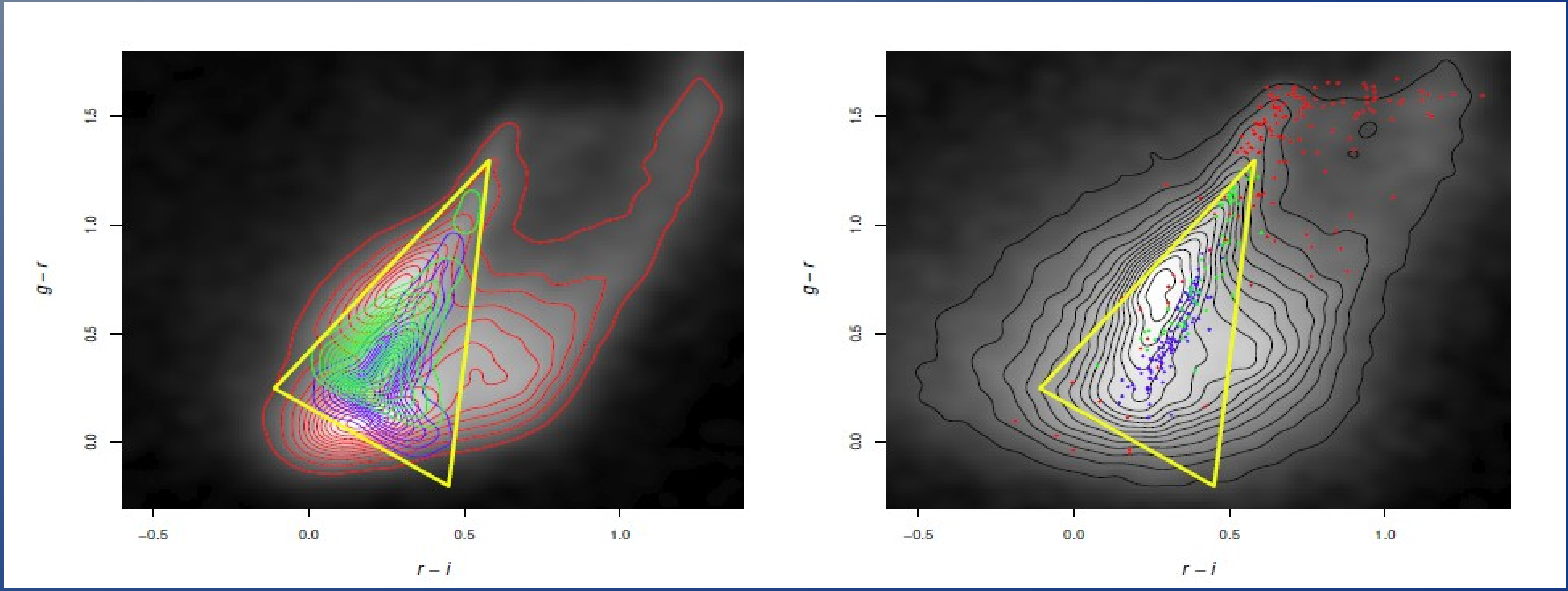
Weak lensing analysis

- Background sample selection: colour-colour diagrams

  ~20 arcmin^{-2}

- CFHTLS (Coupon+ 2009) SC0028-0005

Inside the triangle: SC and foreground galaxies

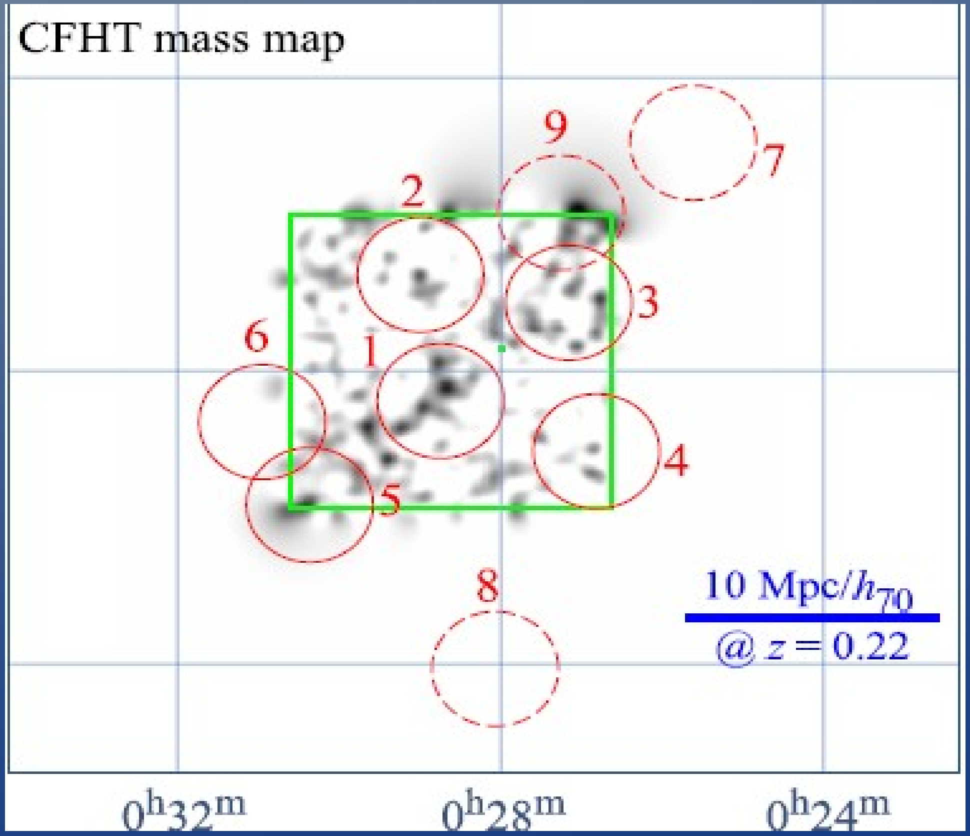


Weak lensing analysis

- Shape measurements: IM2SHAPE (Bridle+ 2002)

  fitting of multiple Gaussians with an elliptical base

  sample of ~15 gal. arcmin^{-2}
- Mass map: Lensent2 algorithm (Bridle+ 1998; Marshall+ 2002)
- Mass estimates: NFW model (fixed c=6.79; Prada+ 2012)

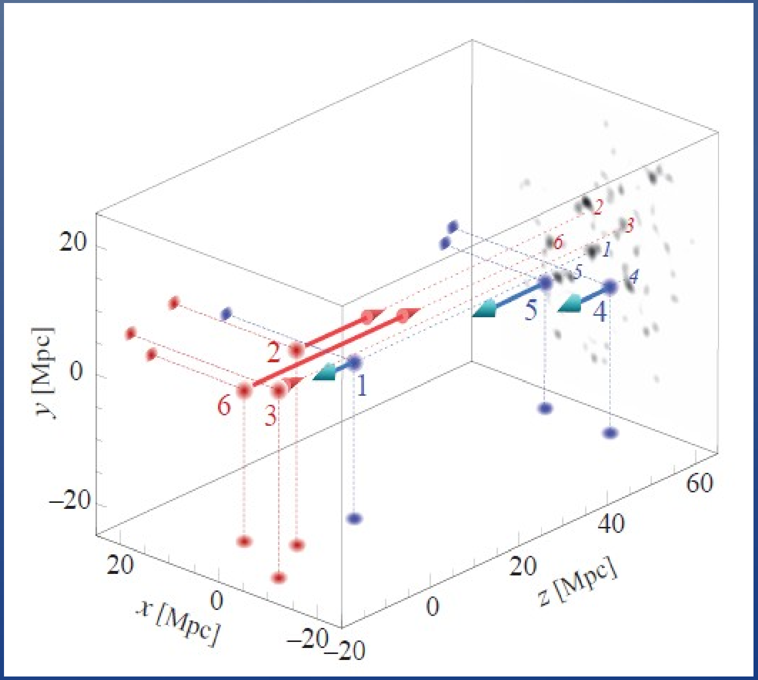


ID	M_{200} ($10^{14} M_\odot$)
1	0.65 ± 0.40
2	2.04 ± 0.58
4	1.21 ± 0.53
5	1.82 ± 0.88

Detection limit ~5x10^{13} M$_{sun}$

Dynamical analysis

- Where the substructures are?
- How they move?
- What will happen?
- Collapsing scenario: structures closer to the observer should have *positive* peculiar velocities, whereas those beyond the SC barycentre should have *negative* peculiar velocities

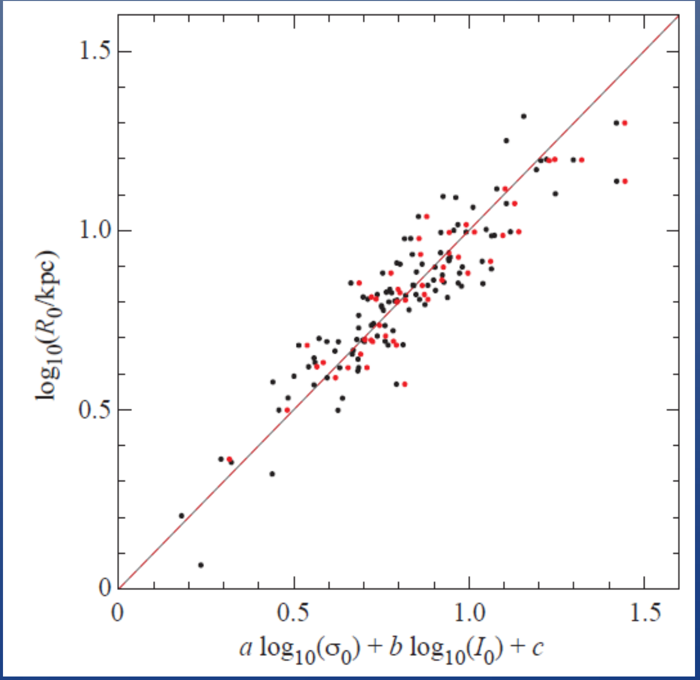


Distance estimates: the fundamental plane

- FP of red galaxies:

$$\log_{10}(R_0) = a\log_{10}(\sigma_0) + b\log_{10}(I_0) + c$$

- Scatter of ~0.09 in $\log(R_0)$
- The zero-point offset can be used to find relative distances



Sample id		rms	N
SC	a=1.035 ± 0.036 b=-0.775 ± 0.031 c=-9.105 ± 0.006	0.0787	57
1	c=-9.102 ± 0.015	0.055	11
2	c=-9.103 ± 0.012	0.061	10
3	c=-9.098 ± 0.014	0.062	8
4	c=-9.127 ± 0.014	0.064	9
5	c=-9.127 ± 0.012	0.056	10
6	c=-9.104 ± 0.017	0.065	9

Peculiar velocities

- Peculiar velocities are estimated from the redshift obtained from the FP and the mean SC redshift:

$$v_p = \frac{z_m - z_{FP}}{1 + z_{FP}}$$

- SC mean distance: 1090.50 h_{70}^{-1} Mpc

Id	z_{FP}	V_p[km/s]	err[%]
1	0.219	-489.810	4
2	0.217	1025.577	4
3	0.215	269.444	5
4	0.228	-611.016	5
5	0.228	-815.231	4
6	0.216	2036.244	4

Is SC0028-0005 a collapsing structure?

- Collapsing scenario: structures closer to the observer should have *positive* peculiar velocities, whereas those beyond the SC barycentre should have *negative* peculiar velocities

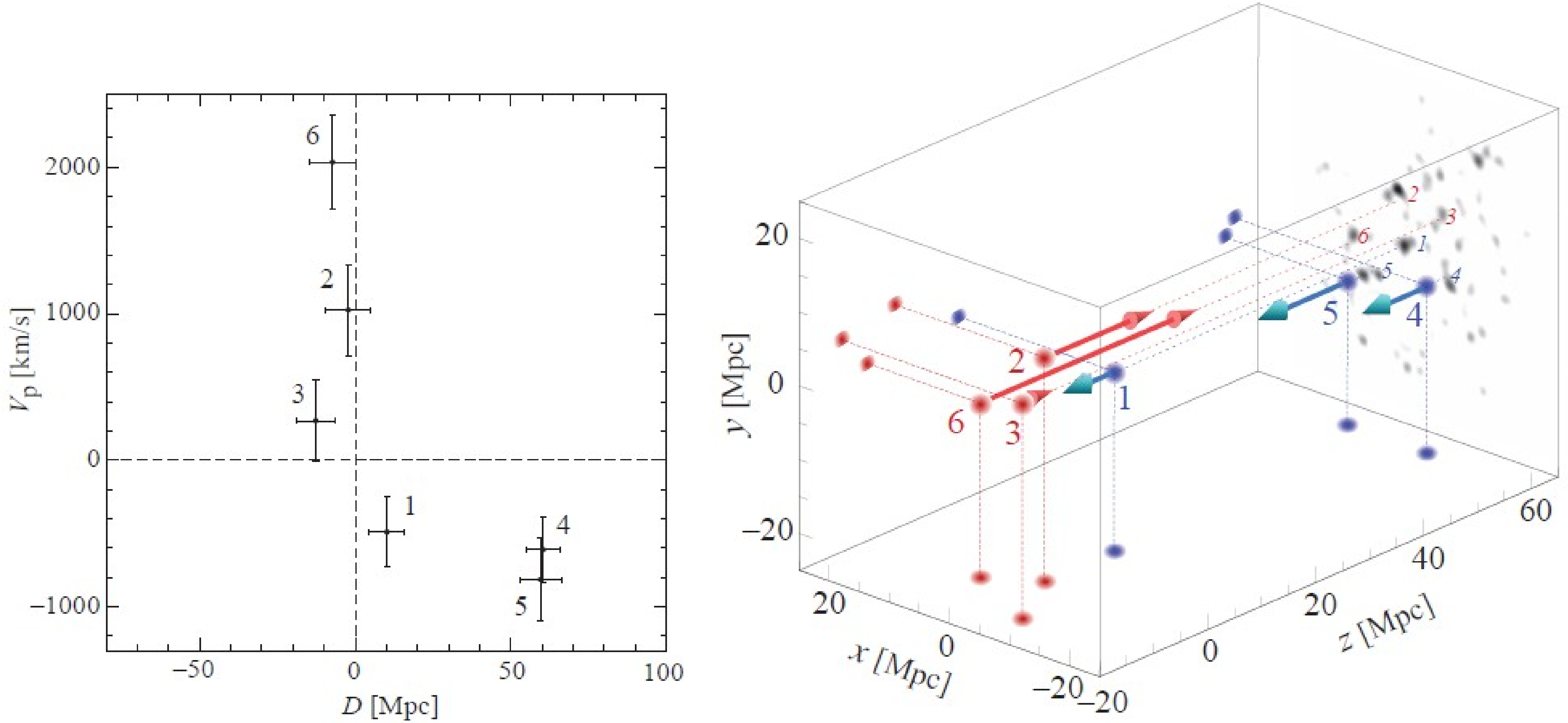


Figure 8. **Left panel:** Distances relative to the supercluster center *versus* peculiar velocities for the six substructures, using the Fundamental Plane method. **Right panel:** The 3-dimensional spacial distribution of SC0028 substructures also showing the LOS velocity vector. The length of the V_p vectors are in arbitrary units, proportional to the velocities derived using the Fundamental Plane.

SC mass: spherical collapse model

- Time evolution of a homogeneous spherical density fluctuation
- *Lower limit mass estimate*: what is the mass of the minimum density fluctuation having as initial conditions the observed positions and peculiar velocities?

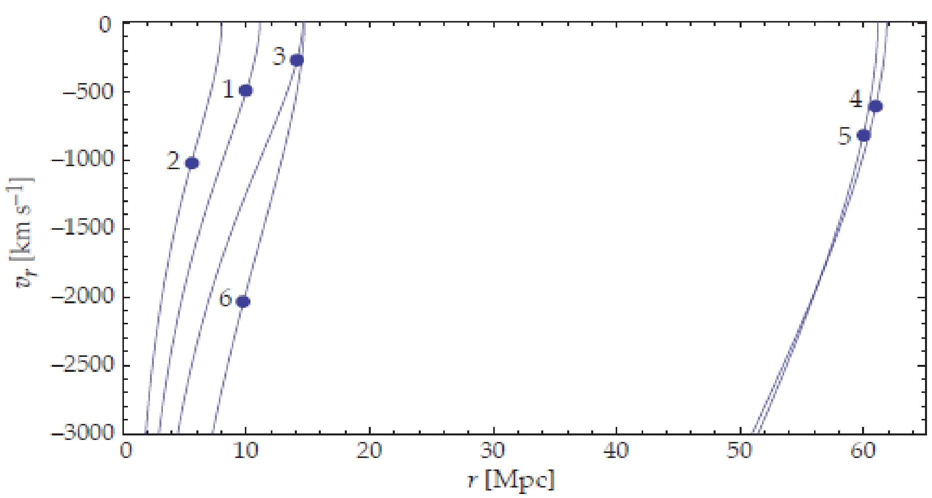


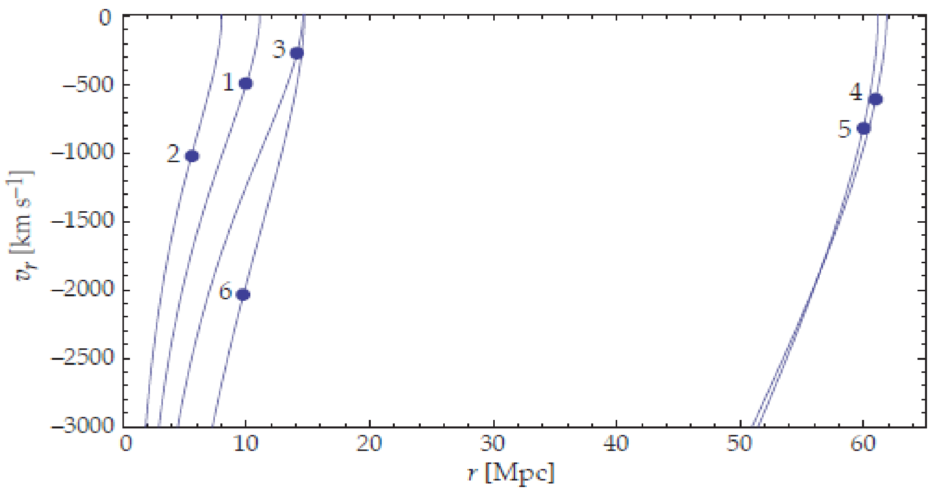
Figure 9. Free fall trajectories for the six substructures in SC0028 in phase-space. The inicial conditions are marked as large dots, with the corresponding numbers.

Table 6. Initial conditions, $r(0)$ and $v_r(0)$, and results of the integration of the spherical collapse equation. $\delta_{\rm sc}$ is the mean density contrast of the supercluster with respect to the critical density. $t_{\rm TA}$ and $r_{\rm TA}$ are the time of tune-around and the radial distance at that time.

Obj. Id	$r(0)$ [Mpc]	$v_r(0)$ [km/s]	$\delta_{\rm sc}$	$M[< r(0)]$ [$10^{15} M_\odot$]	$t_{\rm TA}$ [Gyr]	$r_{\rm TA}$ [Mpc]
1	10.0	-490	6.1	4.3	-5.7	11.1
2	5.5	-1026	21.6	2.6	-6.5	8.0
3	14.1	-269	3.6	7.2	-5.5	14.6
4	61.0	-611	2.8	445	-3.6	61.9
5	60.0	-815	3.2	489	-5.7	61.0
6	9.8	-2036	24.9	16.4	-7.4	14.7

SC mass: spherical collapse model

- 4,5: r- 60 Mpc, M~4.7×10^{17} M_{sun}, δ_{sc} ~ 3
- 1,2,3,6: r~10 Mpc, M~8×10^{15} M_{sun}, δ_{sc} ~ 14
- WL mass estimates of individual structures: ~1-2×10^{14} M_{sun}
- *There are many structures below our detection limit*, 5×10^{13} M_{sun}



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summary

- Photometry and spectroscopy allows testing the supercluster collapse scenario
- From the present analysis we propose that most of the mass in this SC at z~0.2 is in groups with mass smaller than 5×10^{13} M_{sun}
- This analysis can be extended to many SCs in the SDSS database

Many opportunities for post-docs (and visitors!) in São Paulo

- GMT
- LLAMA
- CTA mini-array

- J-PAS, A-PLUS, PFS

- Gemini, SOAR, CFHT
- ESO

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- Next Monday, 16h @ IAG-USP
- Ceremony in honor of Prof. Opher
- Emeritus Professor of IAG-USP