Probing the merger sequence with ALMA

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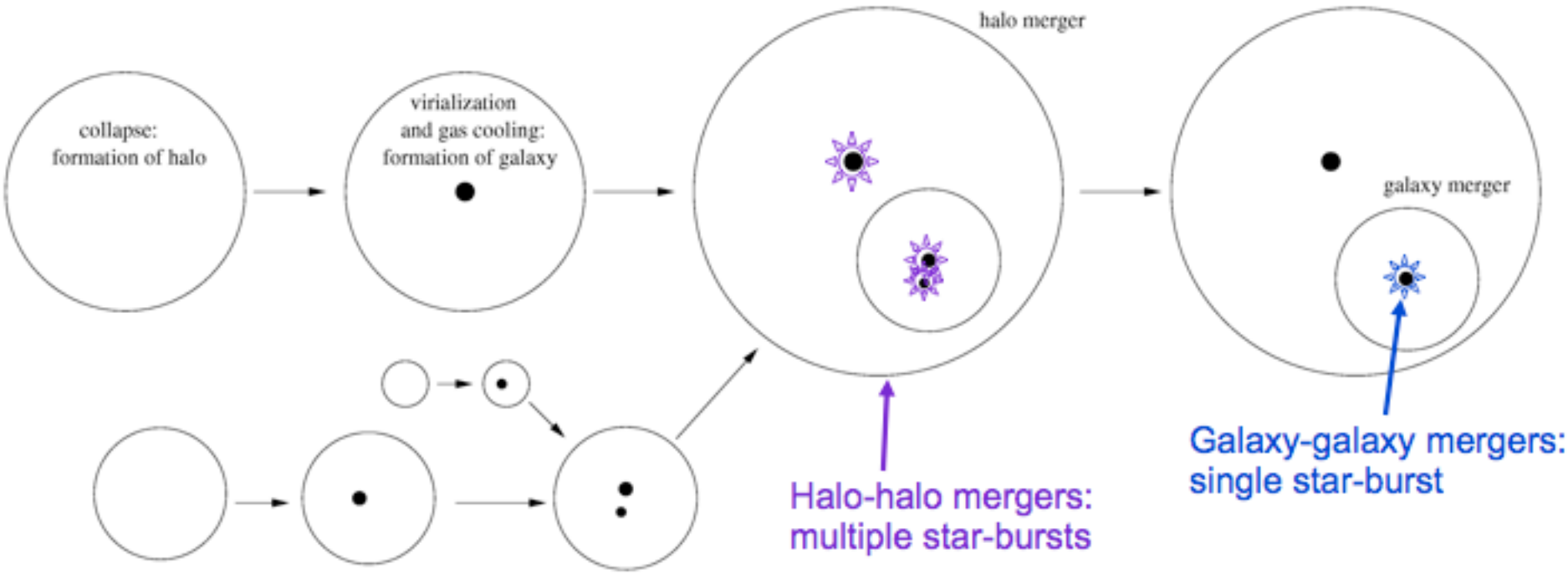
Where does this talk fit in ?

Meeting theme questions addressed (section 5b):

- Is the merger rate with redshift understood?
- What is the implication for galaxy growth and change with the merger rate?
- What role is ALMA playing in better understanding mergers over all cosmic time?

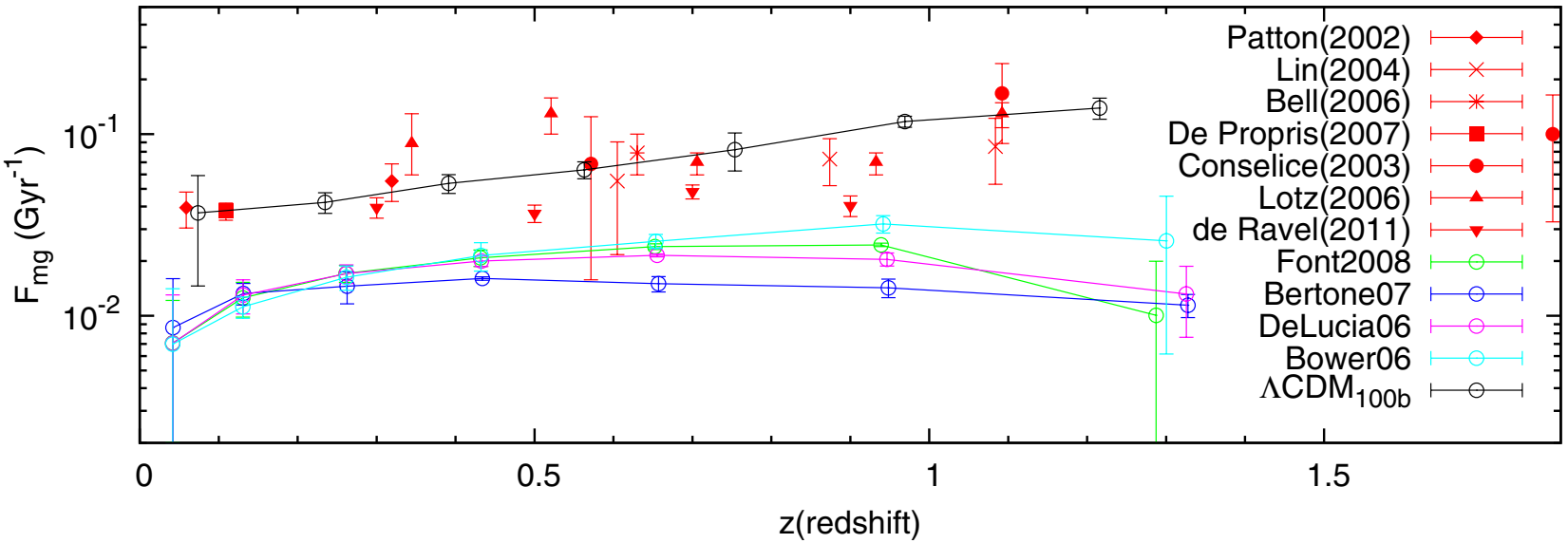
Is the merger rate with redshift understood ?

For dark matter: yes. But for galaxies ?



An example of a simple halo/galaxy merger sequence

Is the merger rate with redshift understood ?

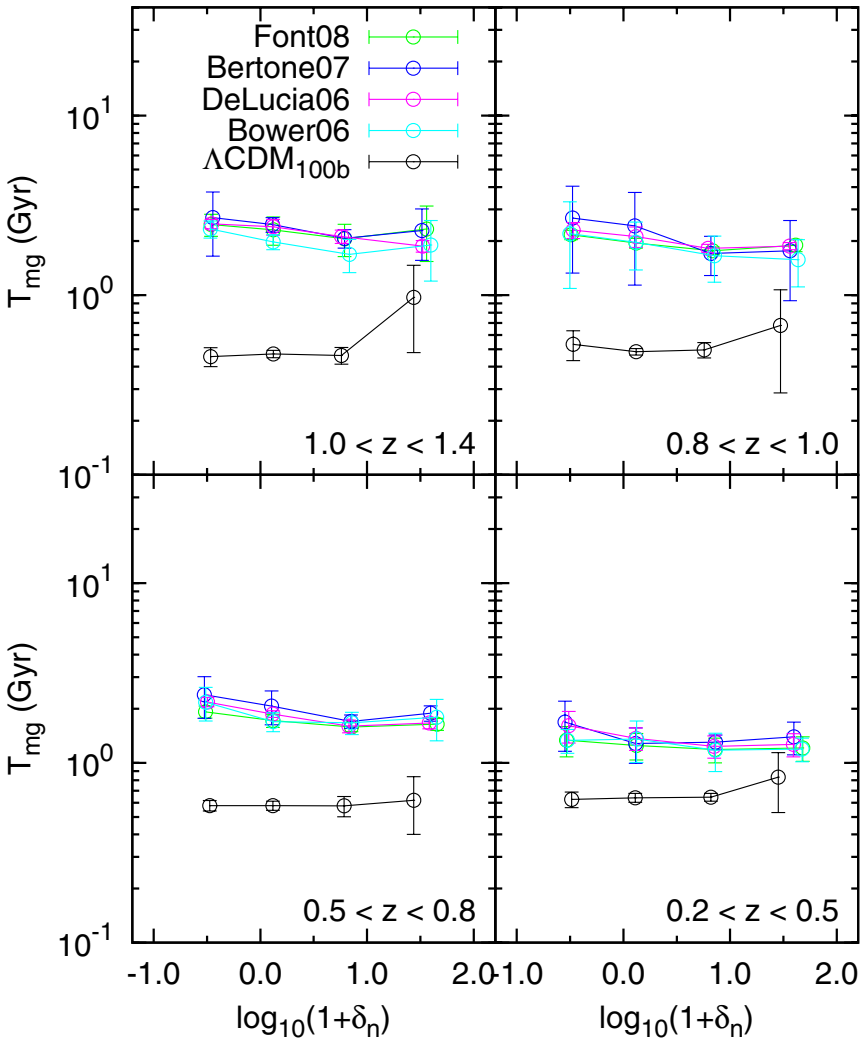


Normalized galaxy merger rates from observations and models as compiled by Jian et al. (2012). Observations are in red, various publicly available models in other colours, and DM in black.

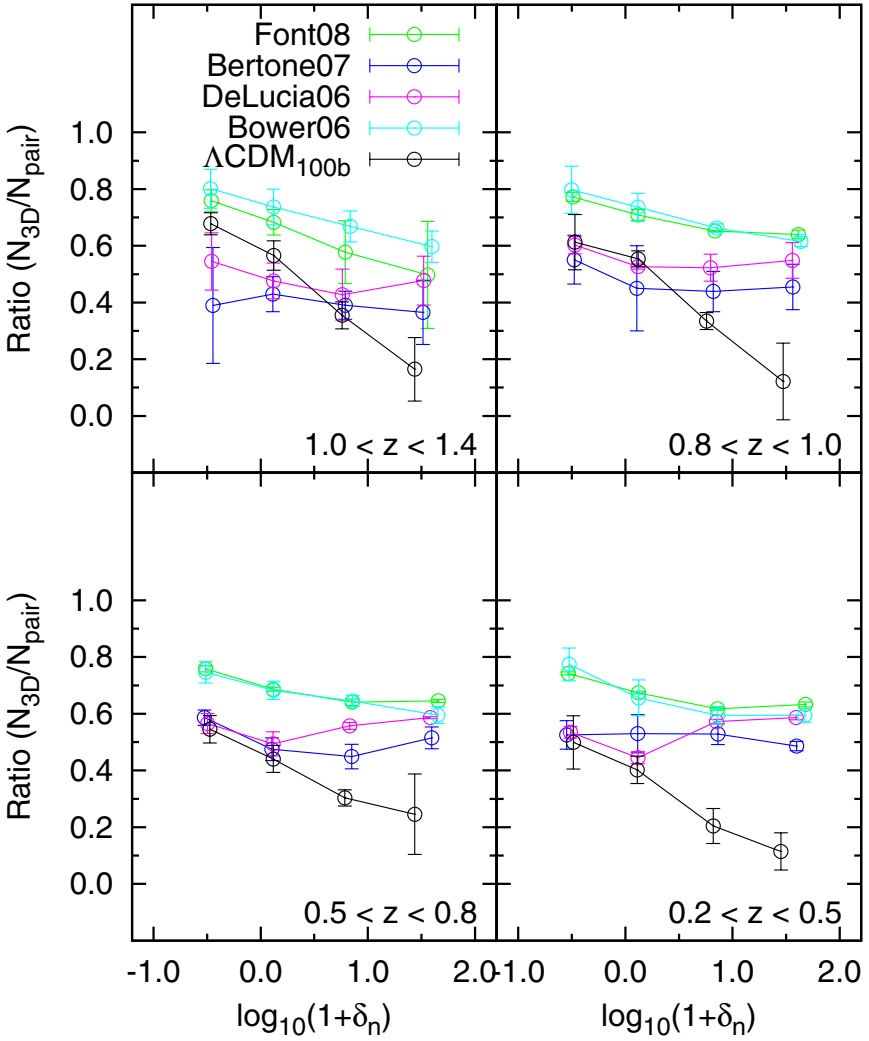
Observed merger rates are derived from close (projected) pair counts, with assumptions about projection effects (not all 2D pairs are merging systems) and merger timescales.

Jian et al. (2012) conclude that the large discrepancies between the models and observations are mainly due to the assumed merger timescales and probabilities for projected close pairs to actual merge.

Is the merger rate with redshift understood ?

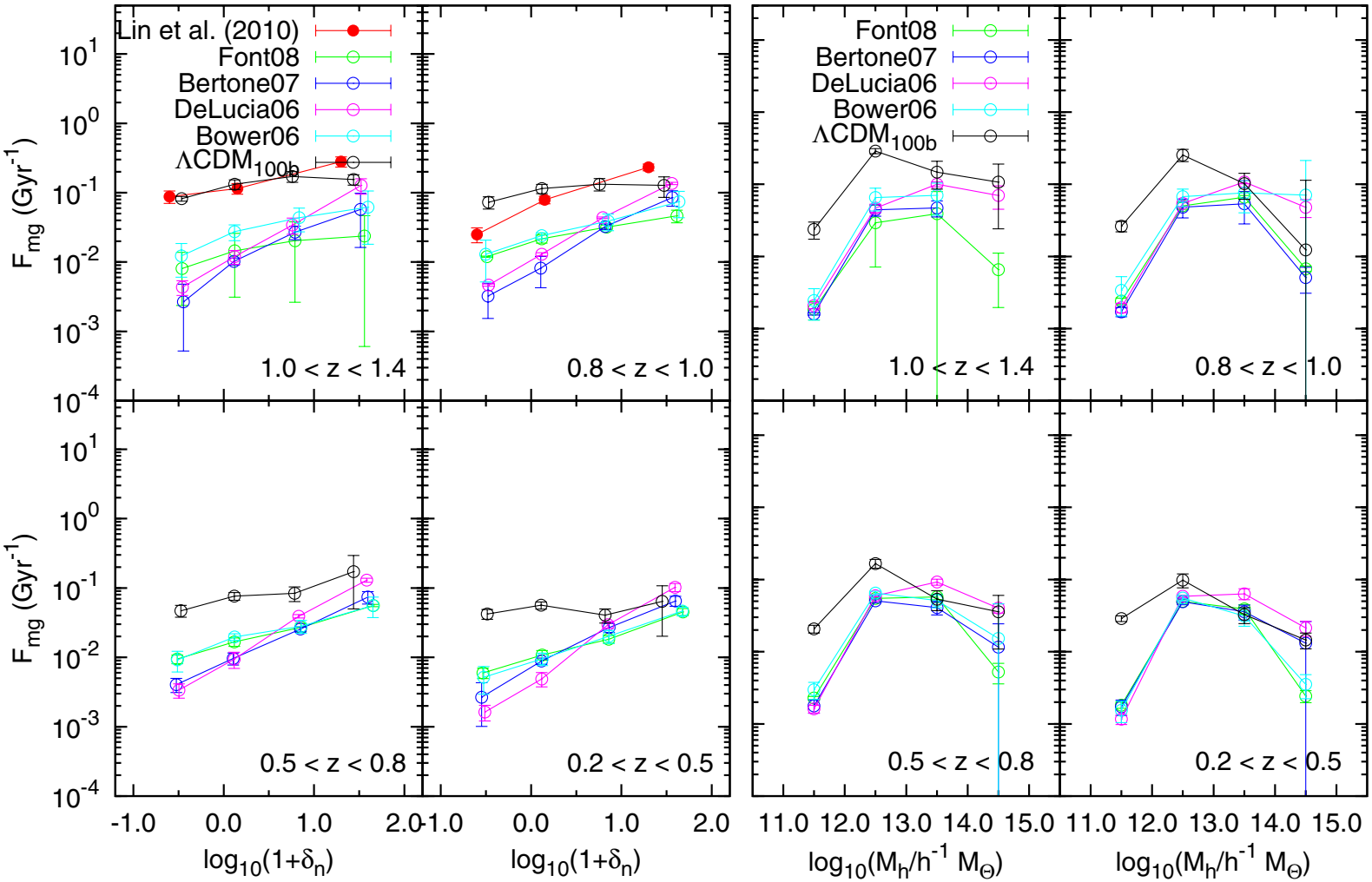


Merger time (in Gyr) as a function of local density (compiled by Jian et al. 2012).



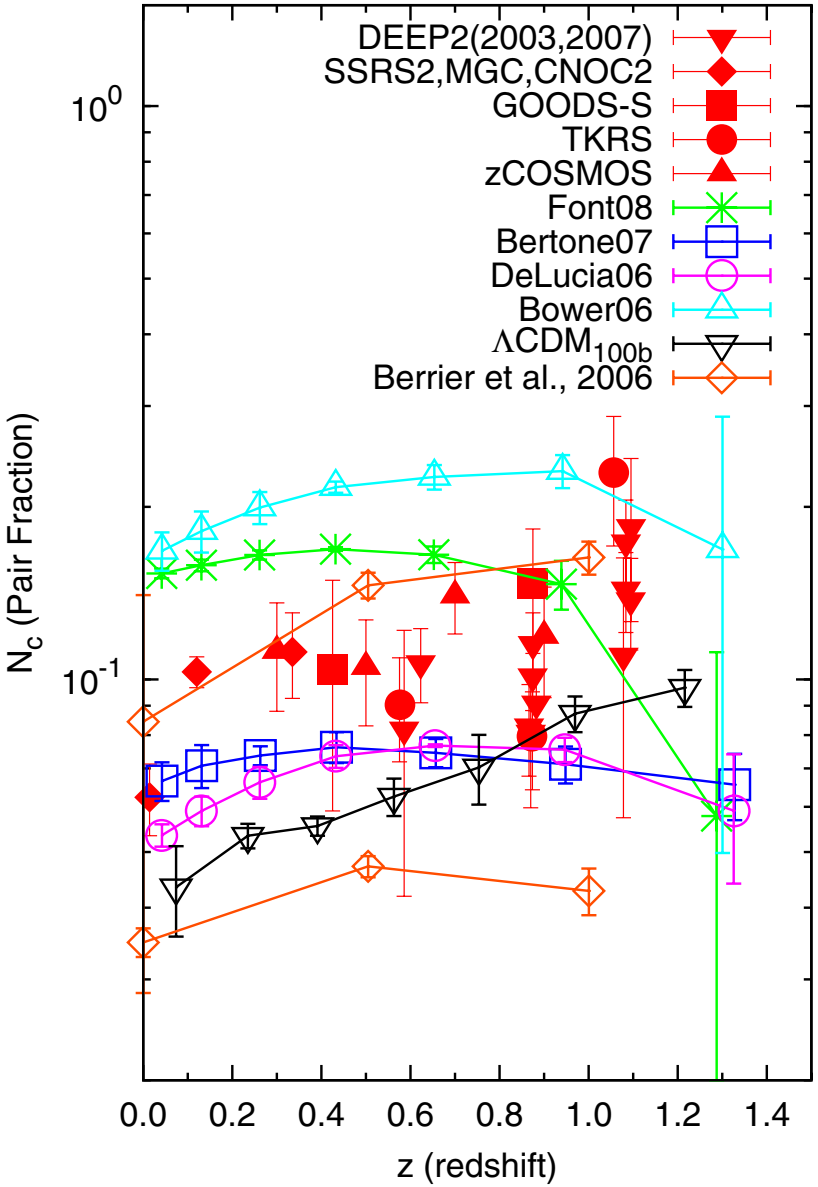
Same for the ratio of 3D to 2D pairs.

Is the merger rate with redshift understood ?



Normalized galaxy merger rates as a function of local density (left) and halo mass (right), as compiled by Jian et al. (2012).

Is the merger rate with redshift understood ?

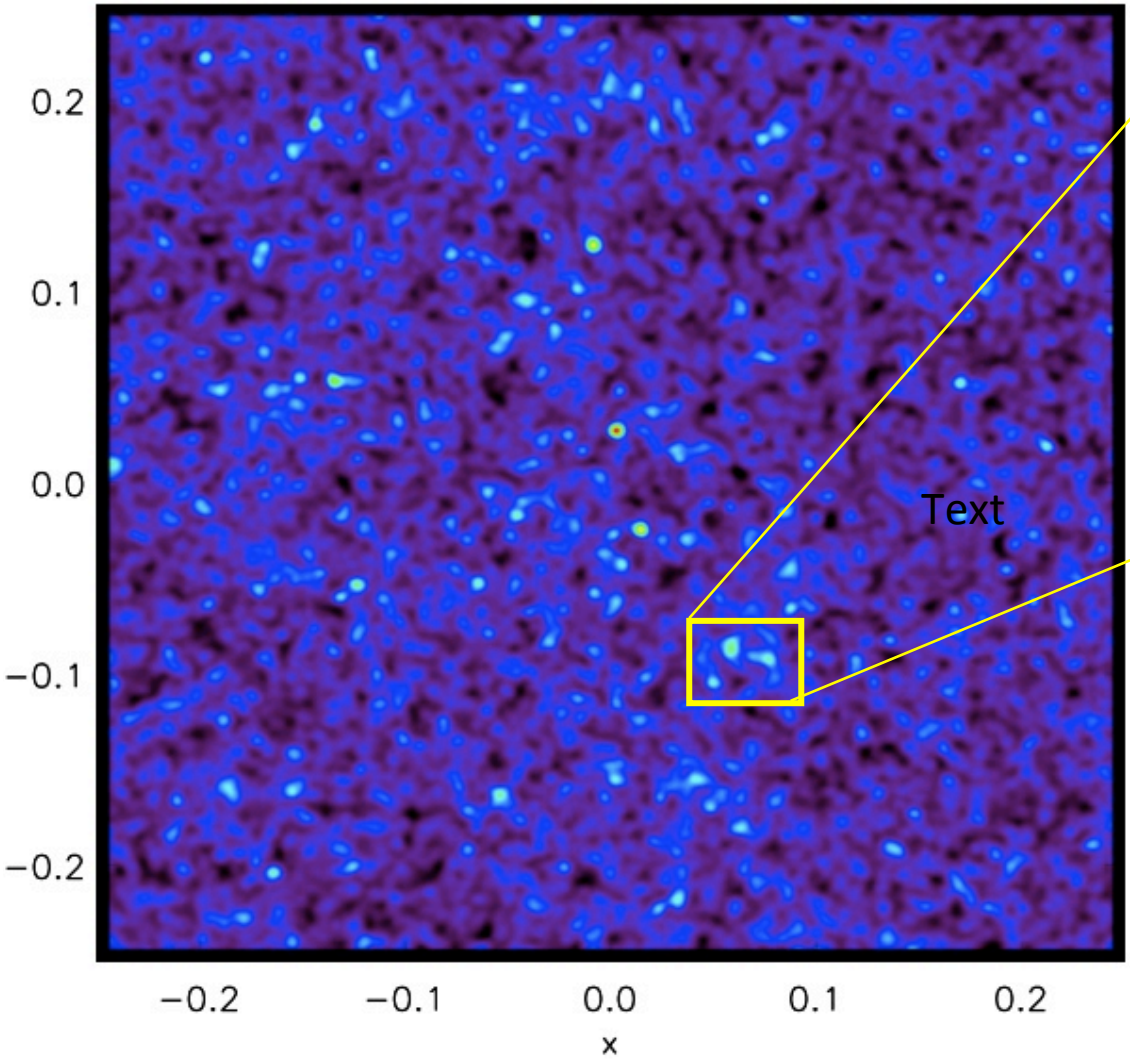


Pair fraction (the "average number of companions per galaxy") for:
- observations (red points)
- various publicly available models (other colours)
- dark matter only simulations (black)

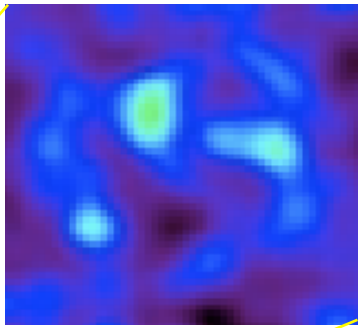
For z>1 it all gets a bit uncertain.
Can ALMA help here ?

Certainly, but as ALMA is not really a survey instrument. Surveys are not completely impossible though, and there is the growing ALMA archive to harvest ...

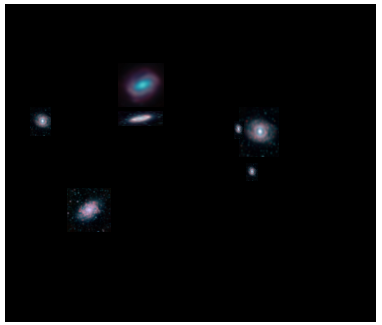
ALMA: from blobs to galaxies (and pairs !)



SCUBA-2 at JCMT (850 µm)



~18” resolution



sub arcsec resolution

Full ALMA (850 µm)

What role is ALMA playing in better understanding mergers over all cosmic time ?

- resolve high redshifts pairs in the sub-mm (from 'blobs' to single or multiple galaxies)
- measure the (molecular) gas and dust content for each (pre-merger) galaxy
- help secure redshifts (using CO lines, for example, if available at the redshift of the cluster)
- with significant line emission: measure the line profile
- eventually do statistics on all of the above

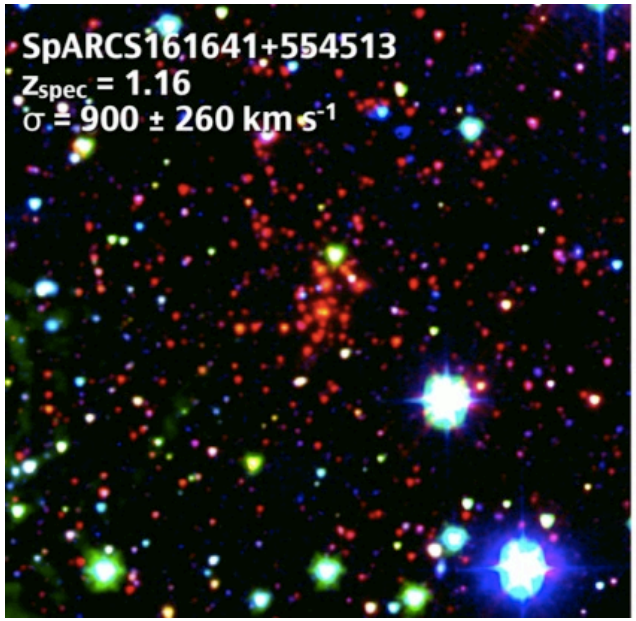
Plan:

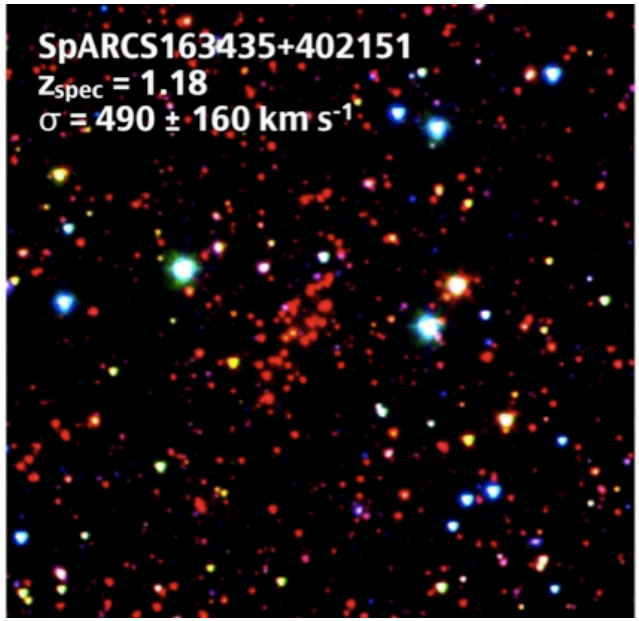
- find and get data on pairs beyond redshift 1, especially in and near clusters, including ALMA data
- produce a sample of simulated clusters to study selection and projection effects, amongst others, and generate realistic predictions for ALMA

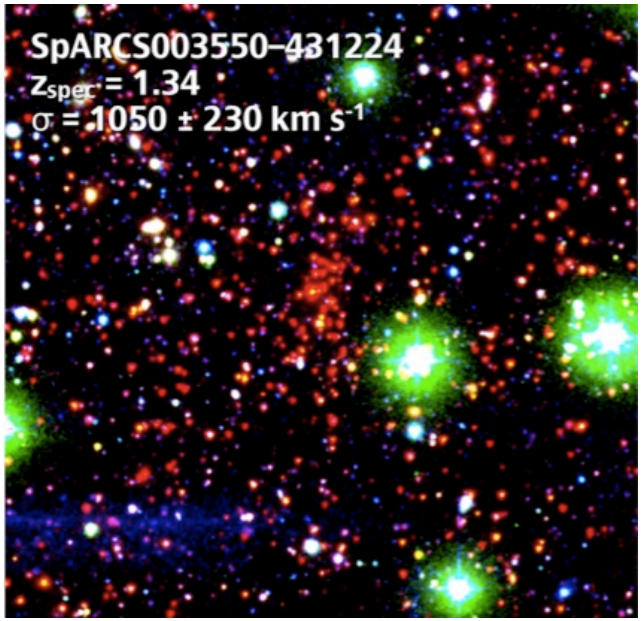
Observational part: pairs in and around z>1 clusters

For example, those detected by **SpARCS**:

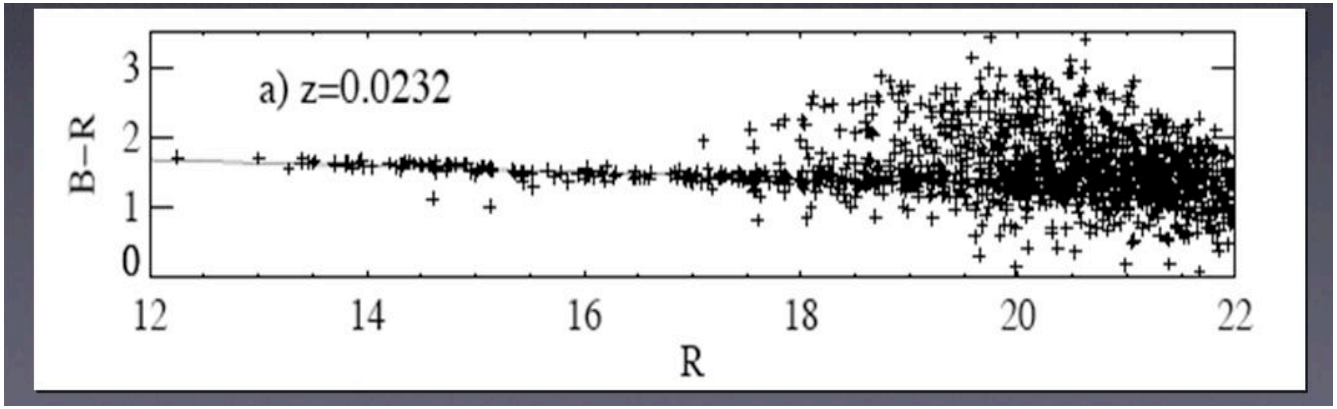
The *Spitzer* Adaptation of the Red-Sequence Cluster Survey (PI: Gillian Wilson)







Detected using the cluster red sequence, then confirmed by spectroscopic redshifts

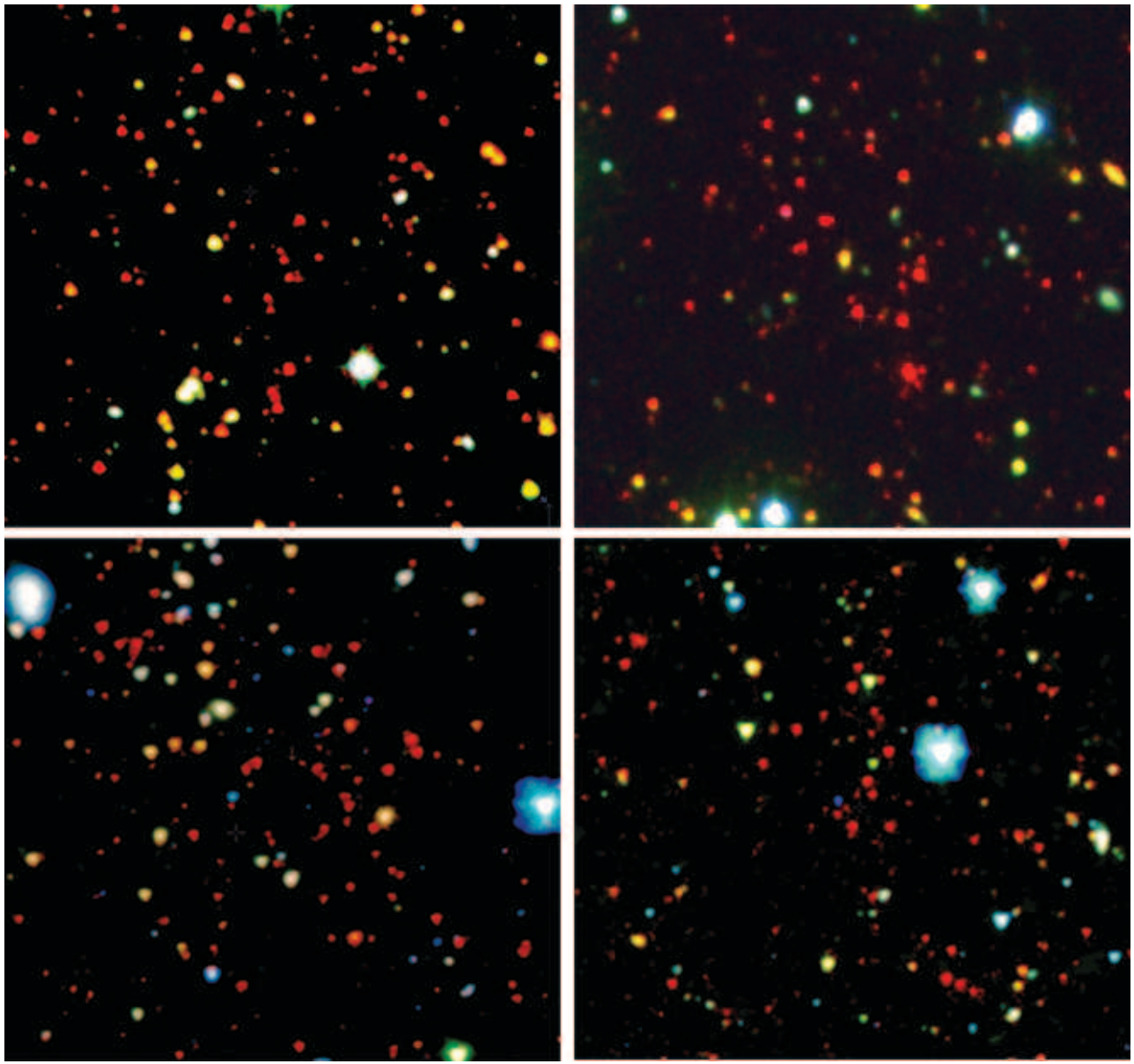


Coma cluster color-magnitude diagram

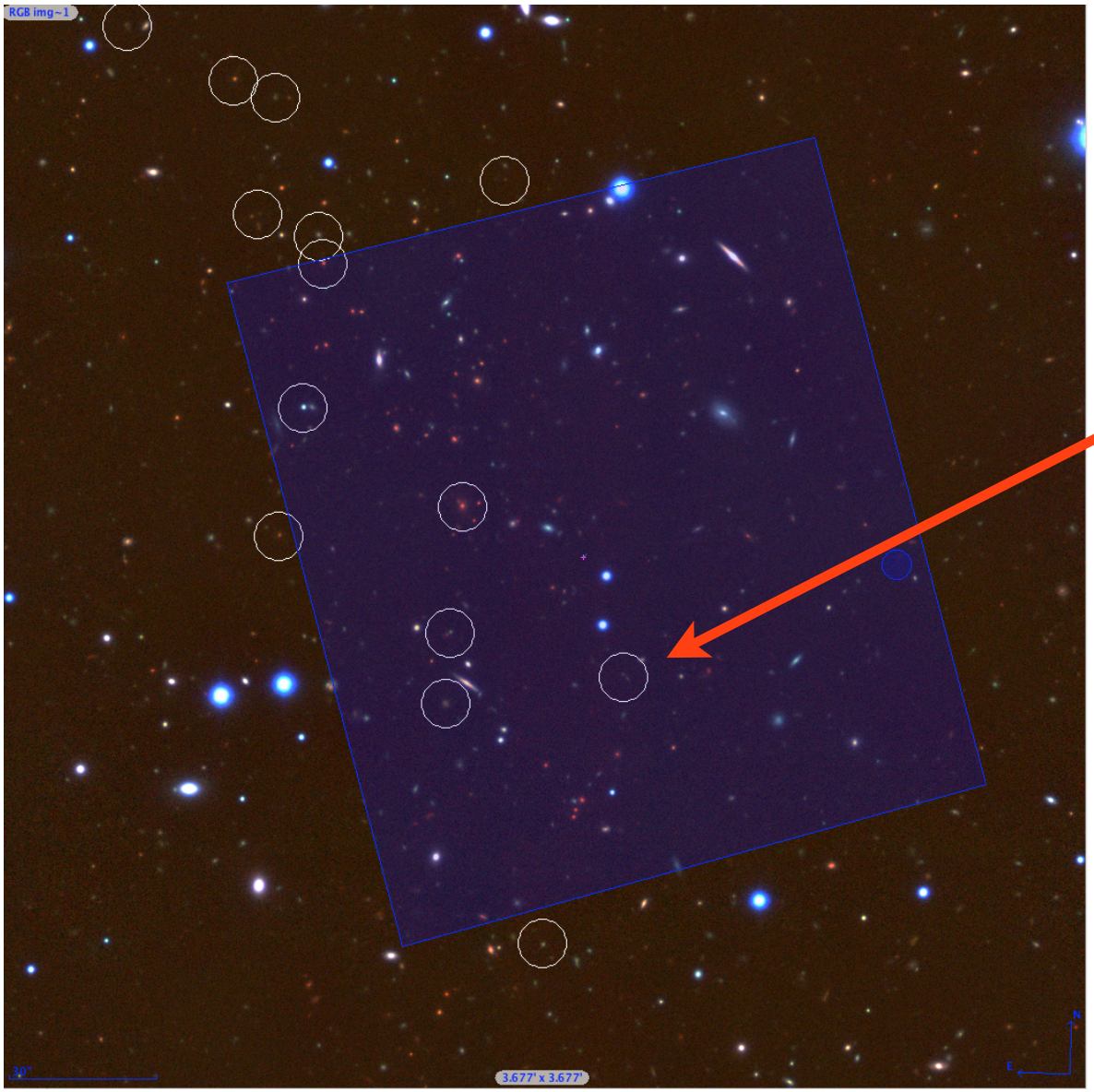
Moving out to z~1.6

g′z′[3.6] images of:
- J1053 (upper left)
- J0224 (lower left)
- J0330 (upper right)
- J0225 (lower right)

All spectroscopically confirmed at z = 1.646, 1.633, 1.626 and 1.594 (Muzzin et al. 2013, DeGroot et al. 2013, in prep, Wilson et al. 2013, in prep).

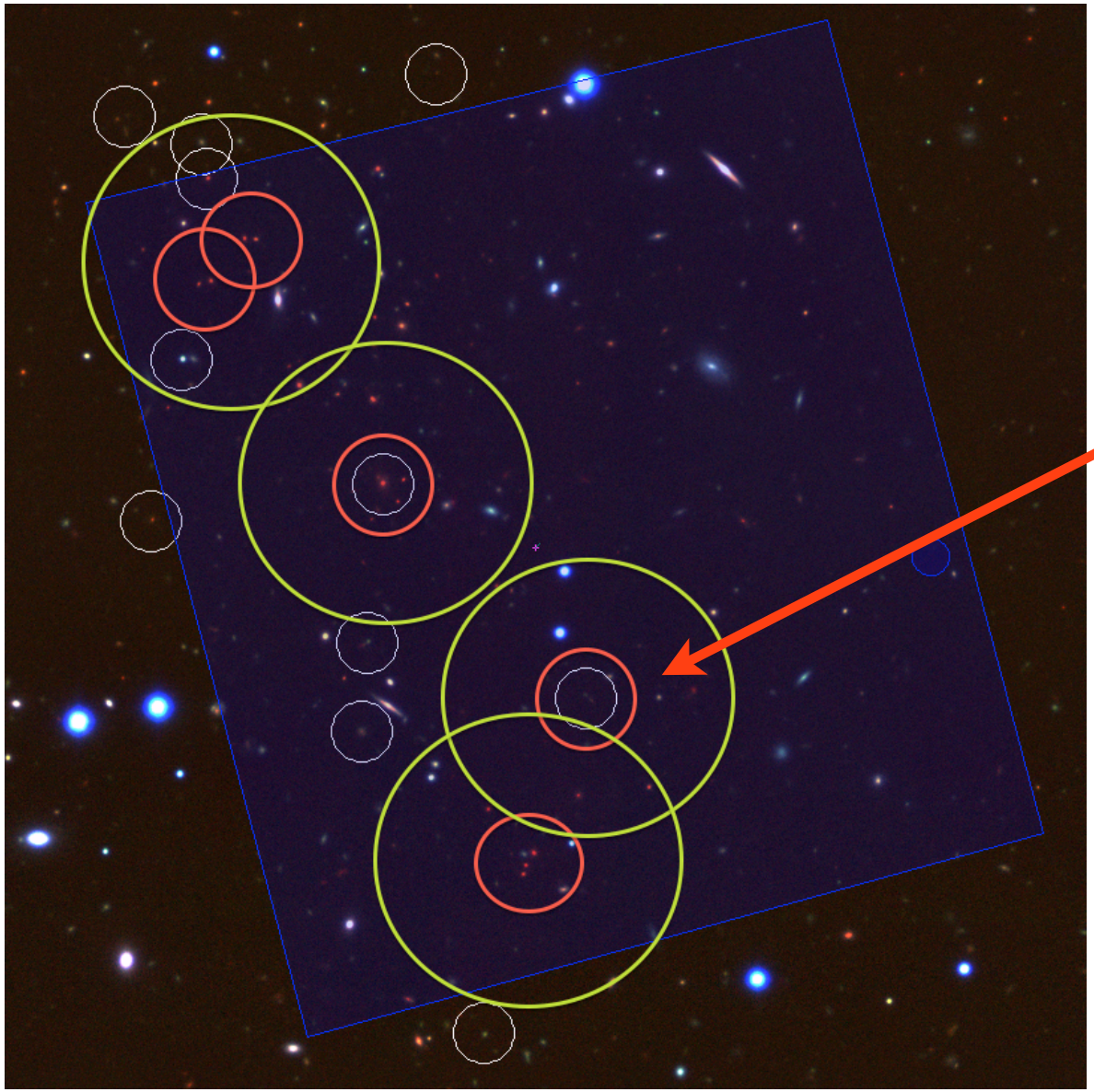


SpARCS J033056-284300



White circles: sources with spectroscopic redshifts.
Blue rectangle: HST coverage for 50 more (G102 spectroscopy) !

SpARCS J033056-284300

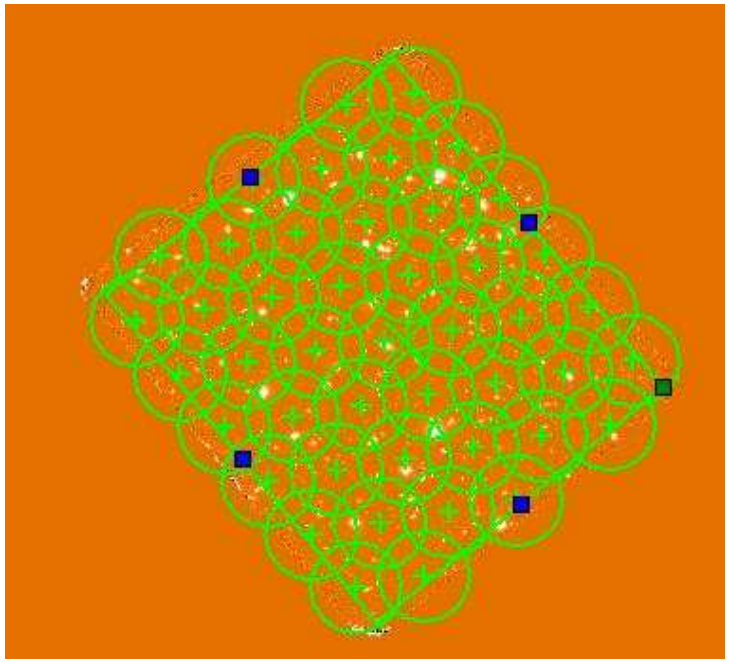


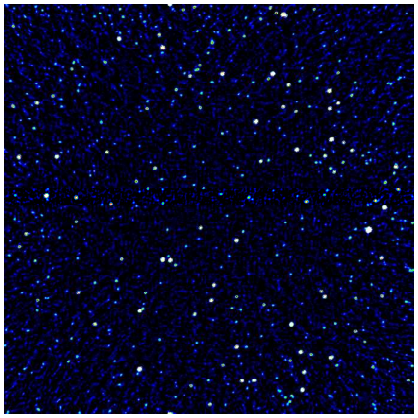
ALMA Cycle 2 proposal 2013.1.01000.S:
band 4 (yellow circles) for CO(3-2) line emission, and band 7 (red circles) for continuum

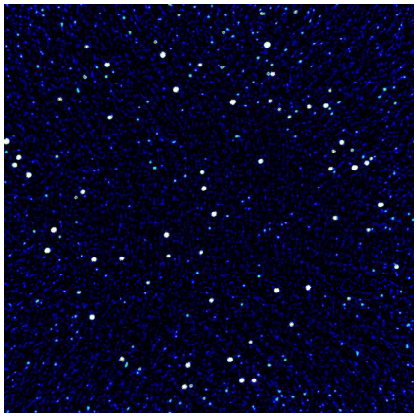
Pairs in the ALMA deep field ?

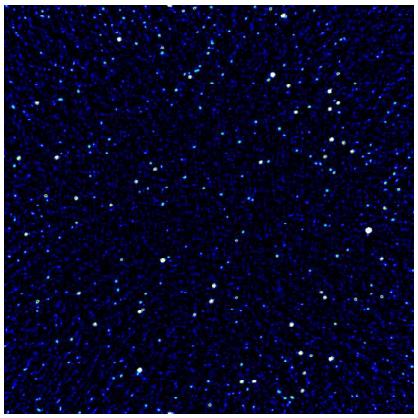
Soon (?): an ALMA 1.3-mm image of the Hubble Ultra Deep Field
(PI: Jim Dunlop, Edinburgh)

Mosaic of 45 deep pointings in ALMA's band 6
(40h total integration time), mapping 2' x 2'









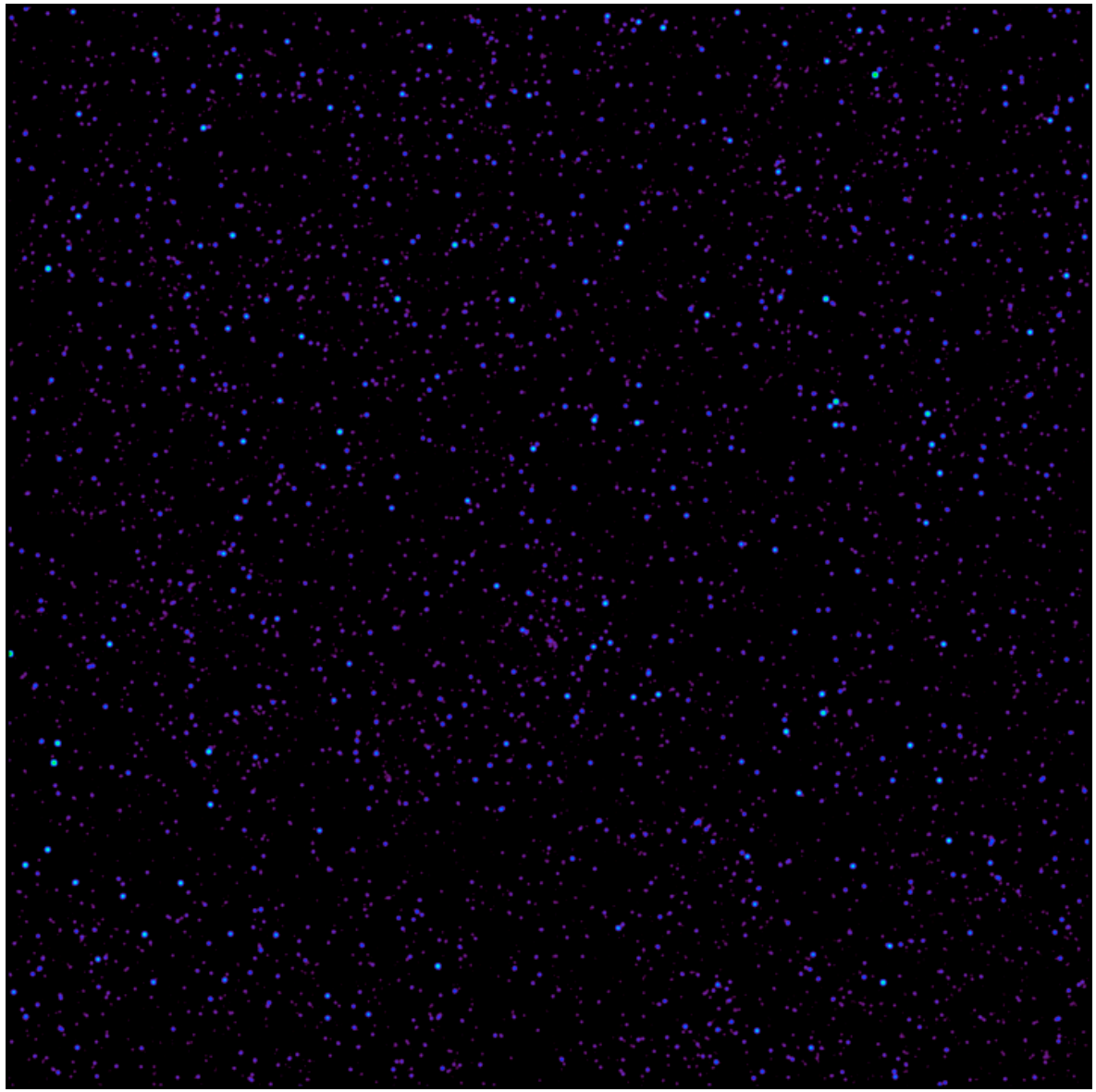
Simulations for three different
models predictions

Modelling part: predict pair counts etc. in and around mid- to high-z clusters

Method:

- produce a representative mock cluster sample (say 100 clusters), using N-body simulations with constrained initial conditions
- also produce a set of unconstrained ('field') N-body simulations
- run a phenomenological galaxy formation model plus a dust model to predict continuum fluxes in the ALMA bands
- build lightcones from the field simulations (lining up boxes along the line of sight), and insert a cluster simulation box at the intended cluster redshift(s)
- find pairs etc. !

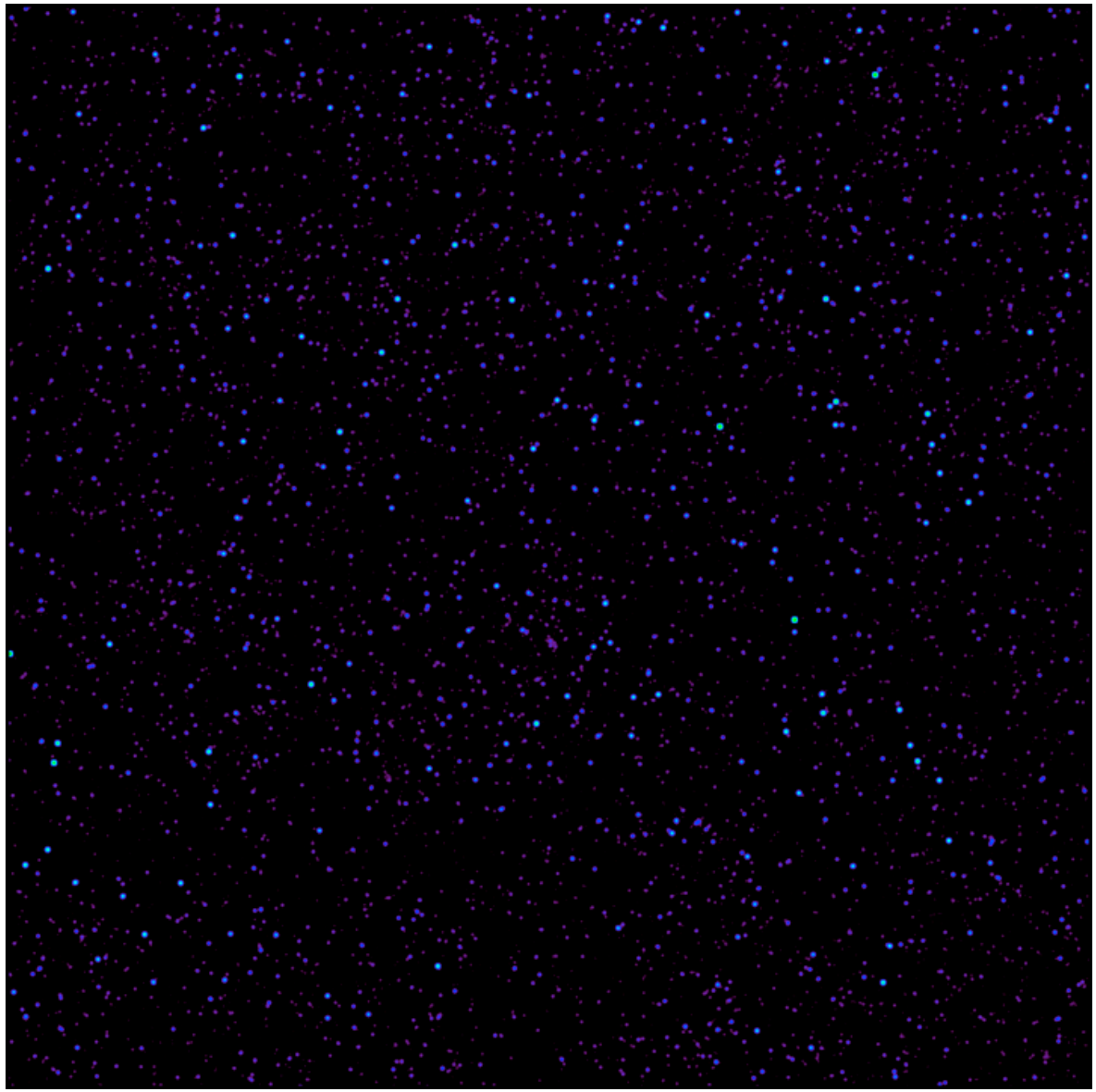
ALMA Band 4 field lightcone ('deep field')



ALMA band 4,
compact configuration:
~3" resolution
(~25 kpc at z=1.7)

Field size: 15' x 15'

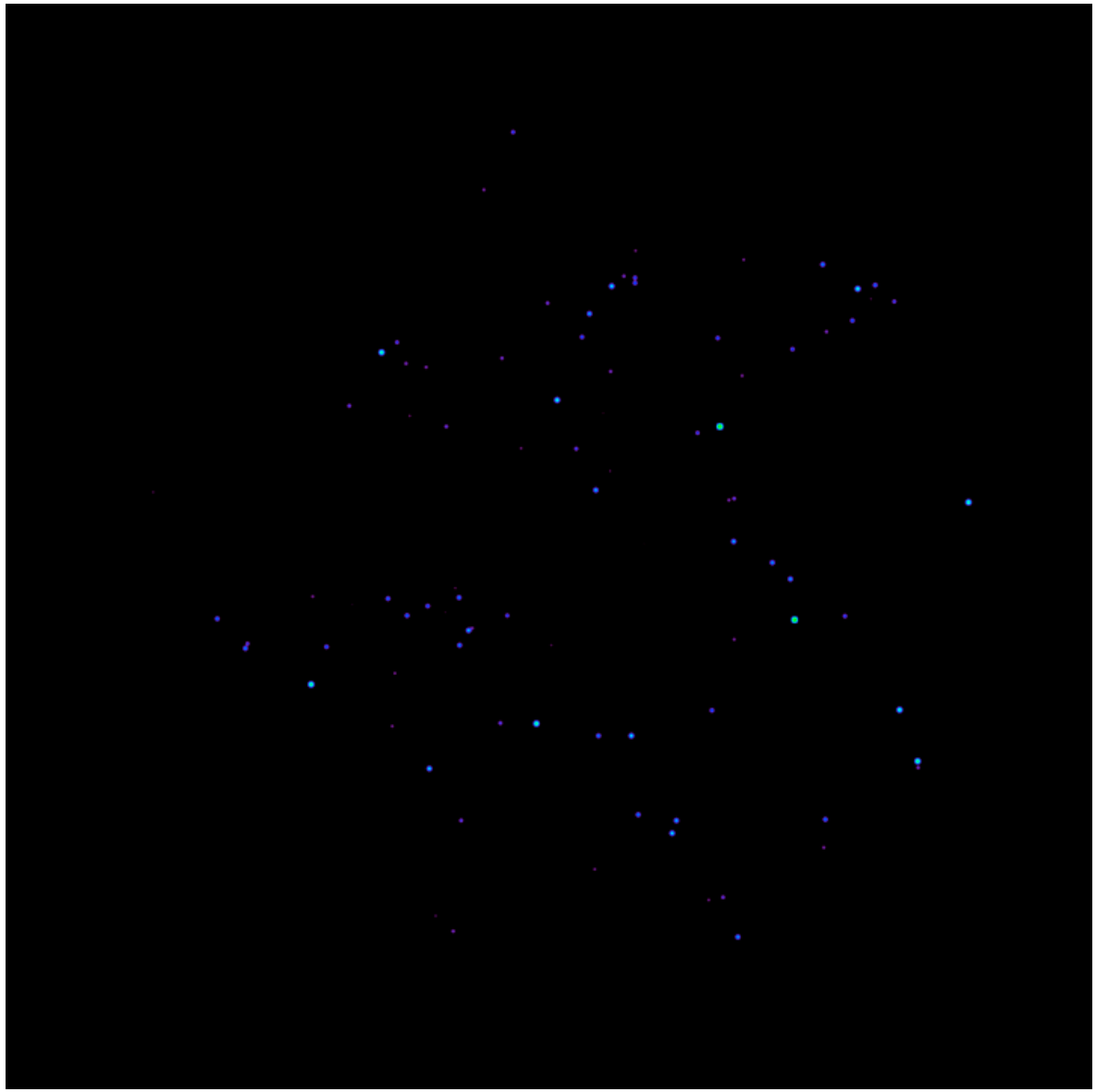
Add cluster at 1.7



ALMA band 4,
compact configuration:
~3” resolution
(~25 kpc at z=1.7)

Field size: 15’ x 15’

z=1.7 cluster sources only



ALMA band 4,
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Field size: 15’ x 15’

Questions, discussion, ...