Spectroscopic follow-up of high-z dusty galaxies discovered by ALMA

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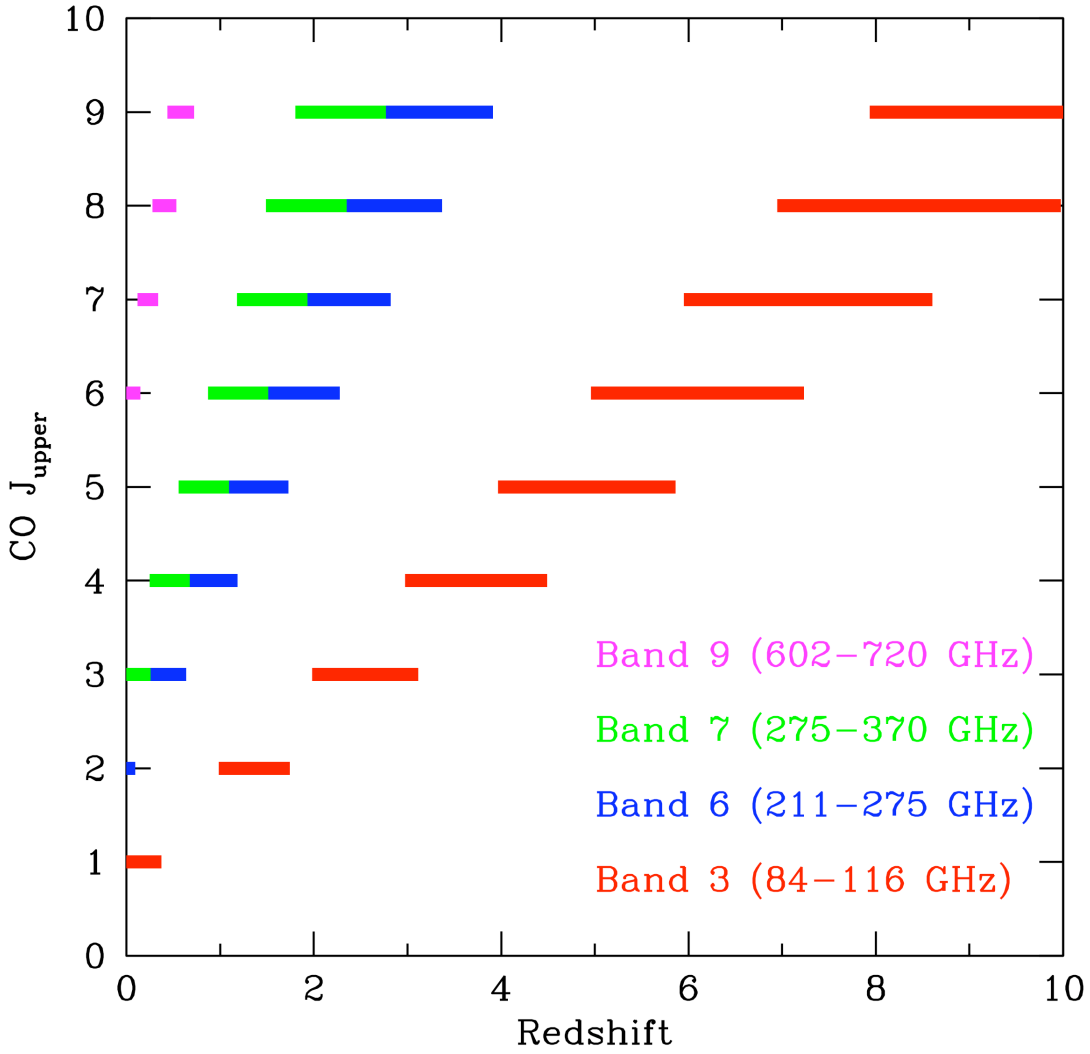
ALMA will observe a large number of high-z galaxies that contain significant amounts of dust.

Dust extinction strongly varies between galaxies, posing interesting questions on how to best design optical/IR spectroscopic surveys of such objects.

ALMA as a redshift machine



Redshift coverage for CO transitions as a function of rotational quantum number J

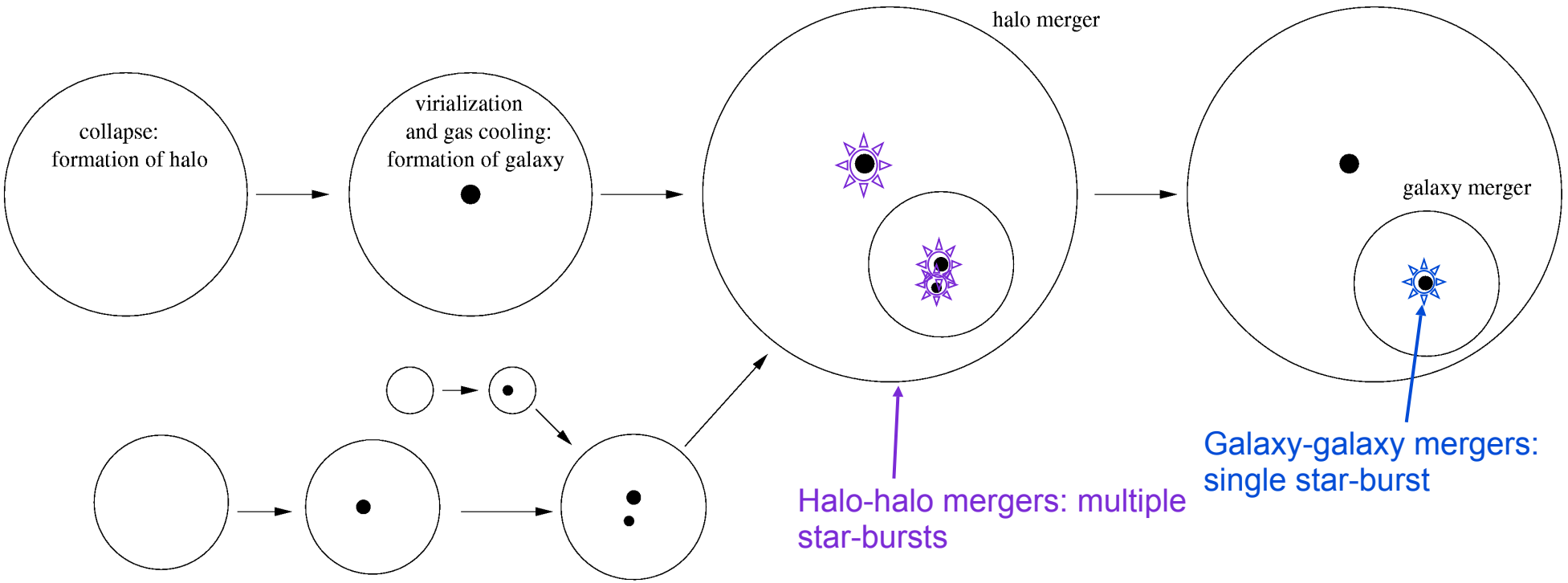
Feasible to measure z of galaxy detected in dust continuum alone

Atomic lines redshifted into ALMA bands at high z e.g.:
[OI] 63, 145μm
[OIII] 88μm
[NII] 122, 205μm

Studying the high-z Universe in the sub-mm

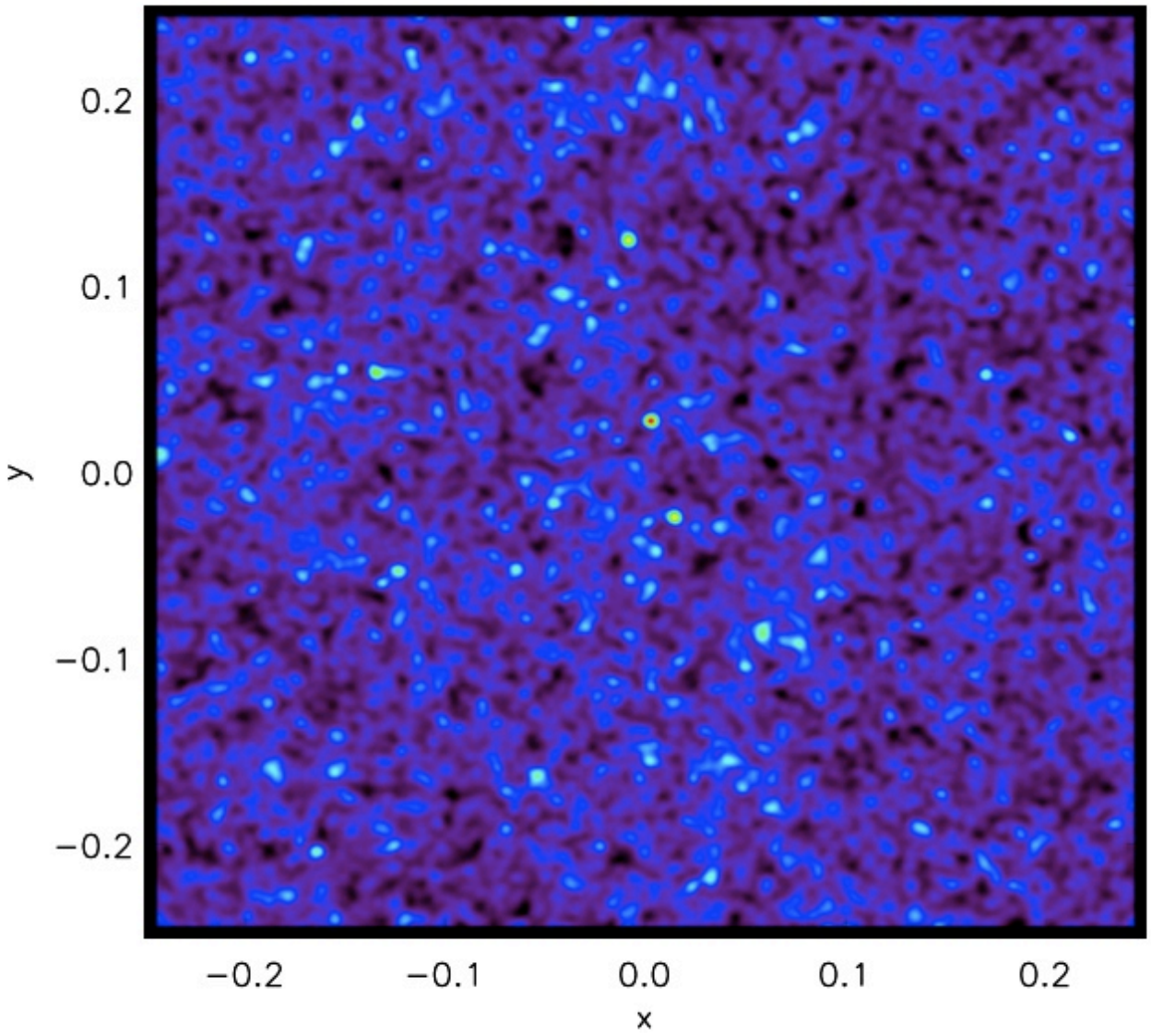
- the sub-mm waveband is (currently) a blurry but deep probe of the high-z universe
- existing and upcoming sub-mm surveys are excellent target finders for ALMA and the E-ELT
- but how to follow-up ALMA observations of high-z dusty galaxies ?

Sub-mm galaxies as merger-driven dusty starbursts

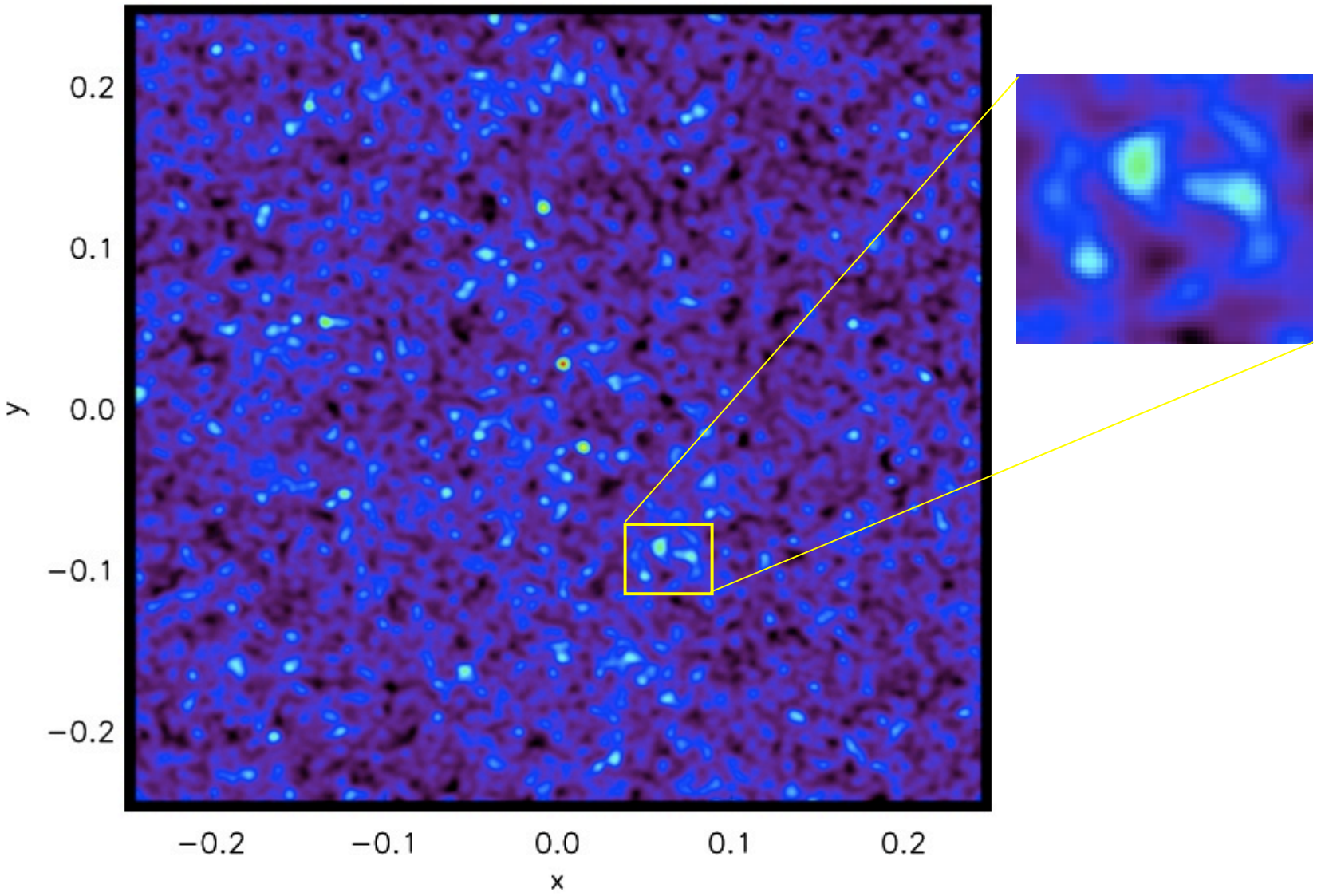


An example of a simple halo/galaxy merger sequence

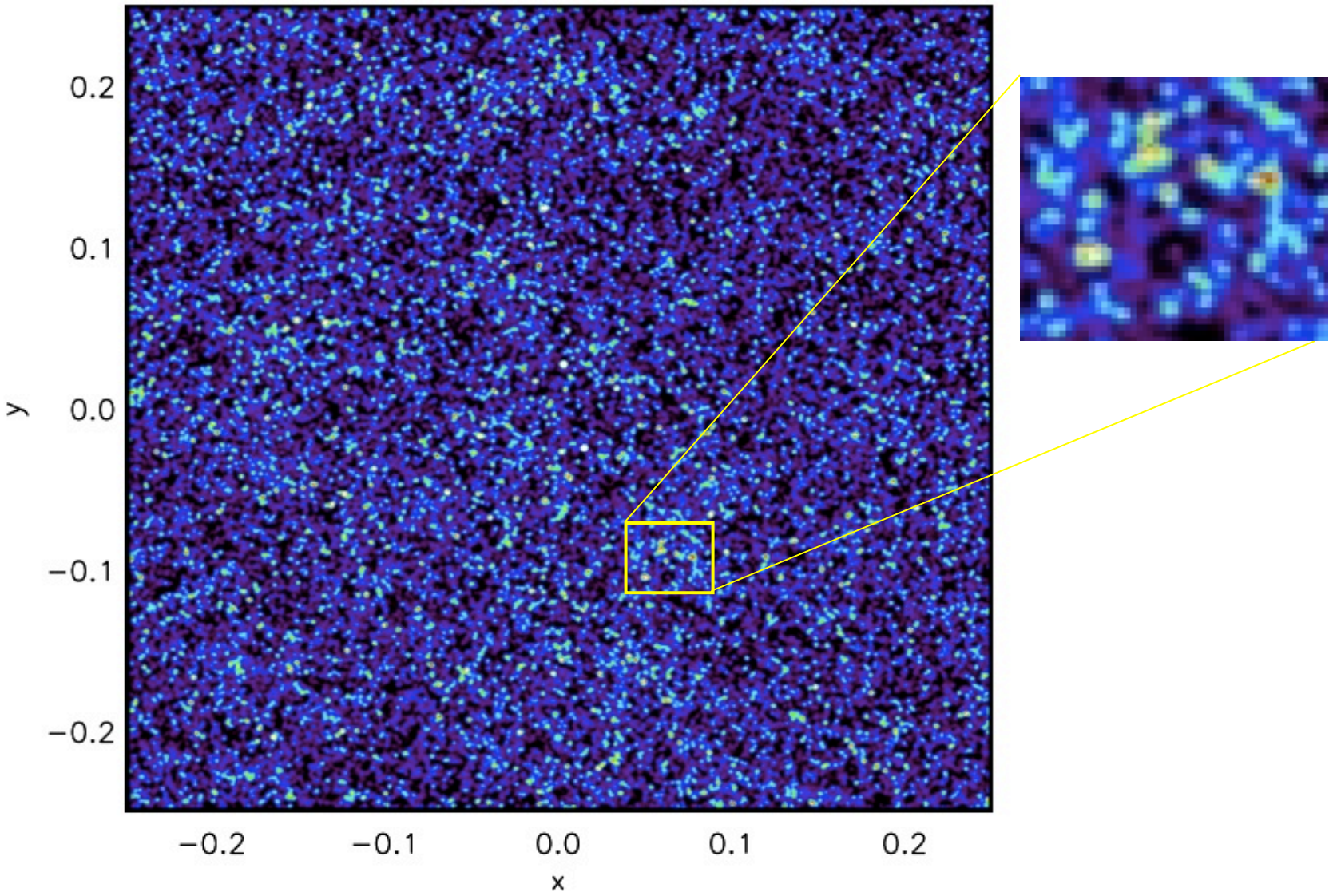
A mock sub-mm survey (AzTEC@JCMT)



A mock sub-mm survey (AzTEC@JCMT)



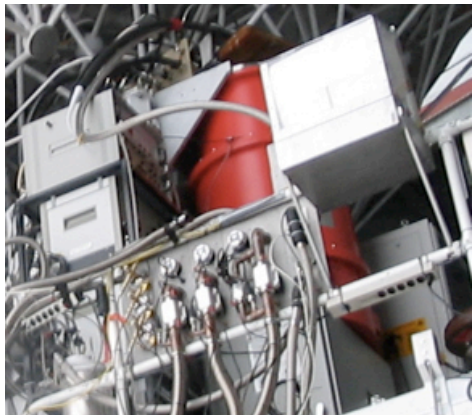
AzTEC @ LMT 50m

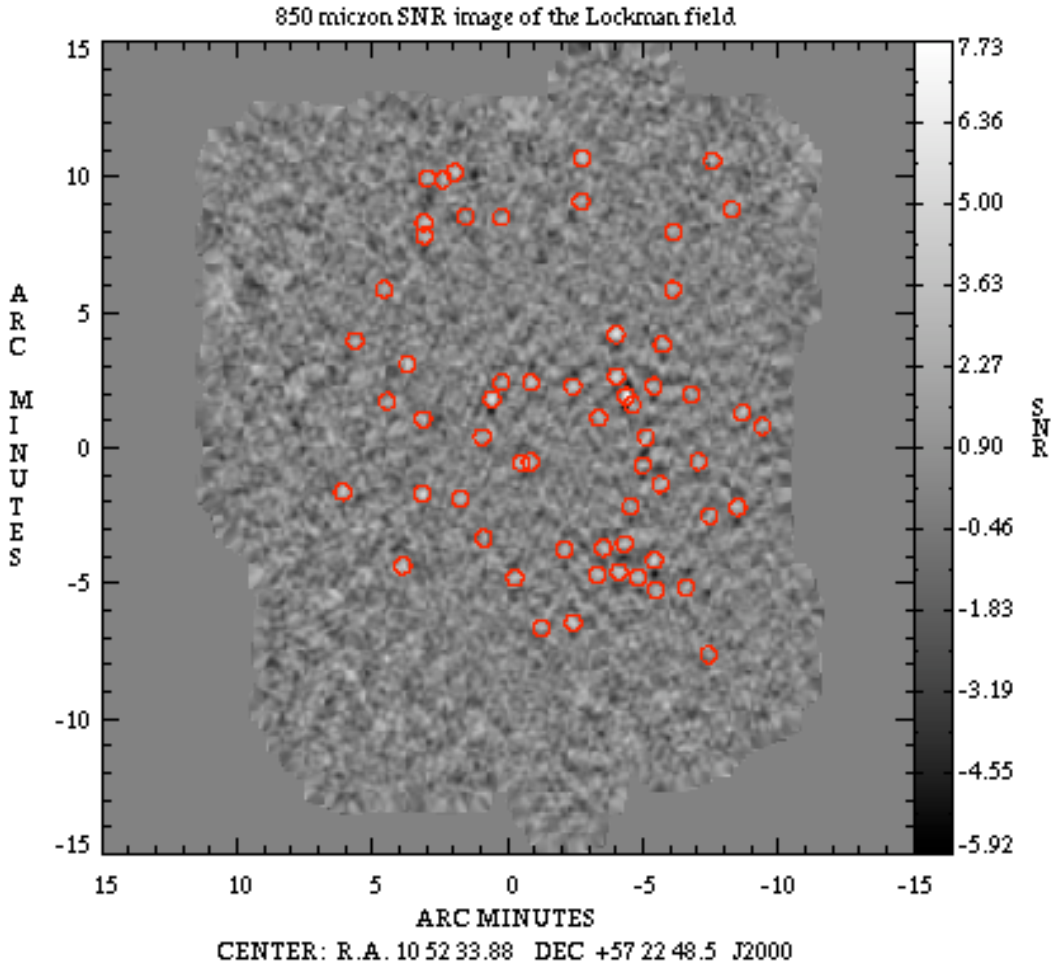


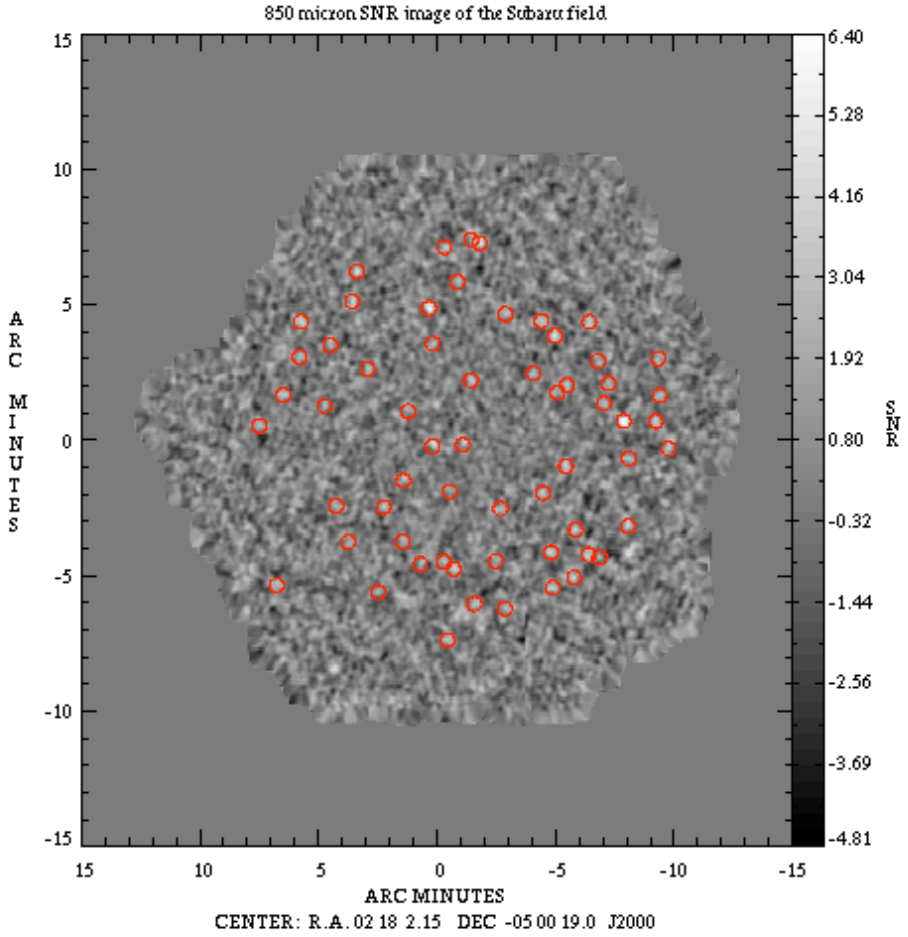
SHADES: SCUBA half-degree survey

2 fields – Lockman Hole & SXDF @ 850 micron

120 sources with unbiased (deboosted) flux densities



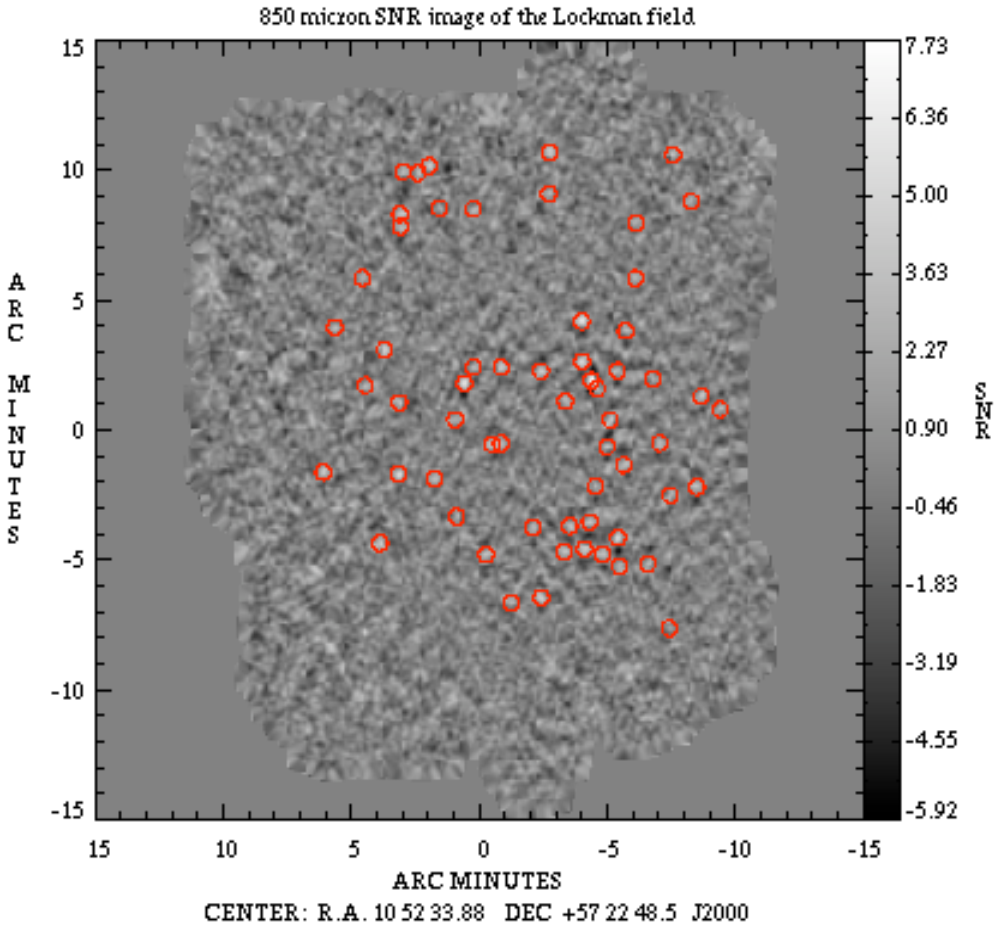




SHADES: Source identification

Ivison et al. (2007)

using *R*-band, VLA and Spitzer data ==>



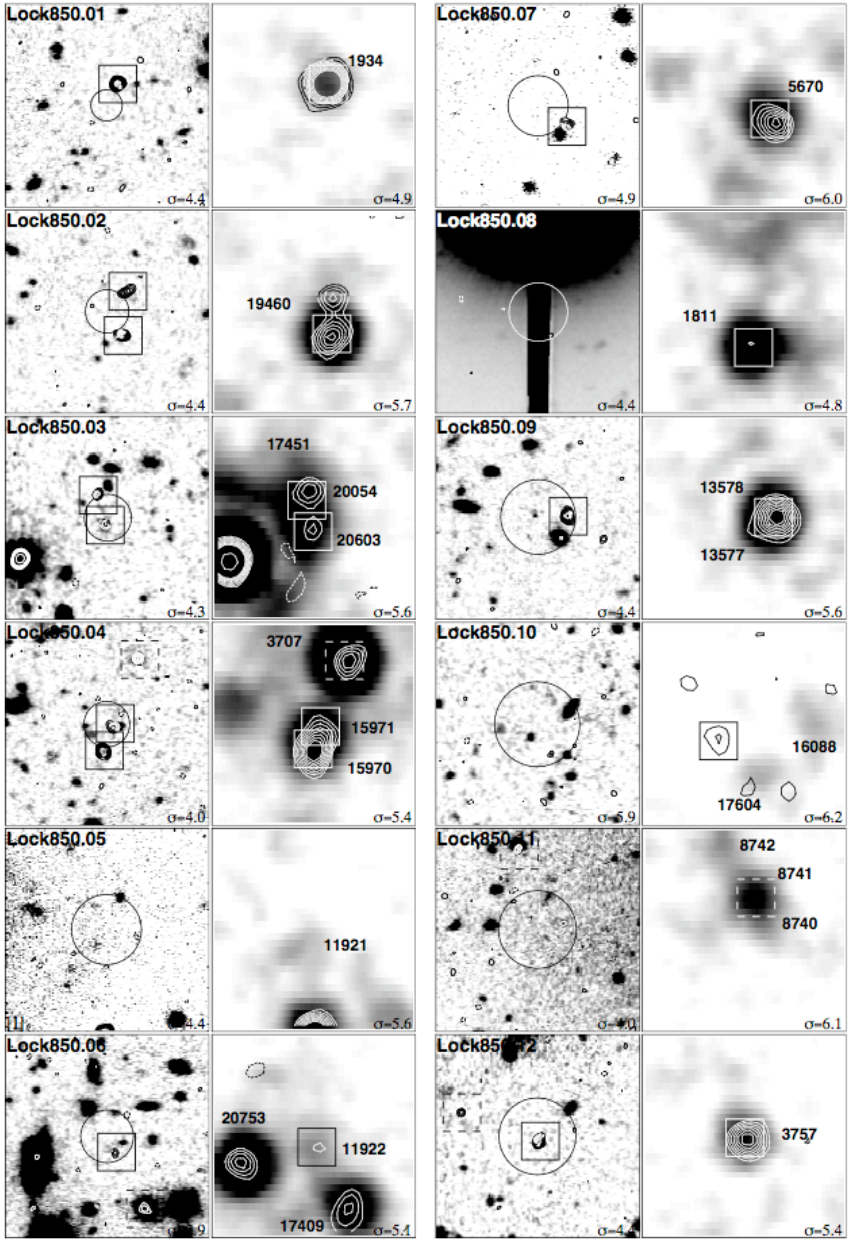


Figure A1. 25 × 25-arcsec postage stamp images of each SMG in the LH SHADES Source Catalogue. Greyscale *R*-band and 24-μm data are shown in the left- and right-hand panels, respectively, superimposed with radio contours. Circles indicate 2 σ positional uncertainties. Solid boxes indicate robust identifications, where $P \leqslant 0.05$ based on the radio or 24-μm counts, or a combination of the two. Dashed boxes indicate tentative associations.

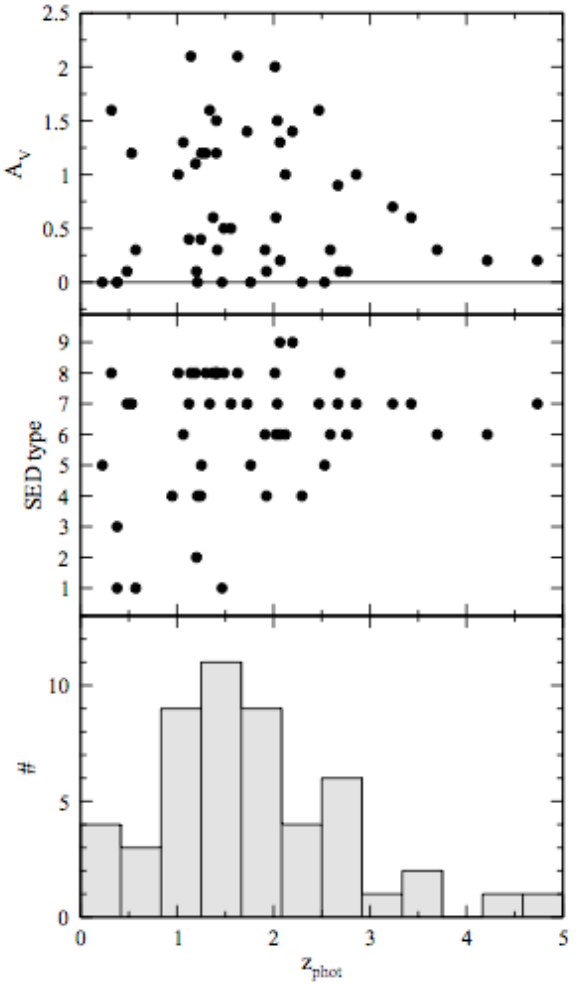
Extinction variation

Photo-z fitting from Dye et al. (2008) also provides an estimate for the extinction for each *SHADES* source.

This shows a clear variation in extinction over two magnitudes for bright sub-mm galaxies.

Worse for model galaxies: $\langle A_V \rangle \approx 2$

How to best design optical / IR multiple object spectroscopic surveys for dusty galaxies with highly variable extinction ?



Conclusions

ALMA will provide redshifts of cold gas at high redshifts, but not for the stellar populations that could or could not be part of the ALMA-discovered sub-mm galaxies. This will need to be done by multiple-object spectrographs because of the sheer number of sources.

To produce a statistically complete spectroscopic sample of high-z sub-mm galaxies one needs to account for the large variation in dust extinction of these galaxies when performing a MOS survey (where the integration time is the same for all galaxies).