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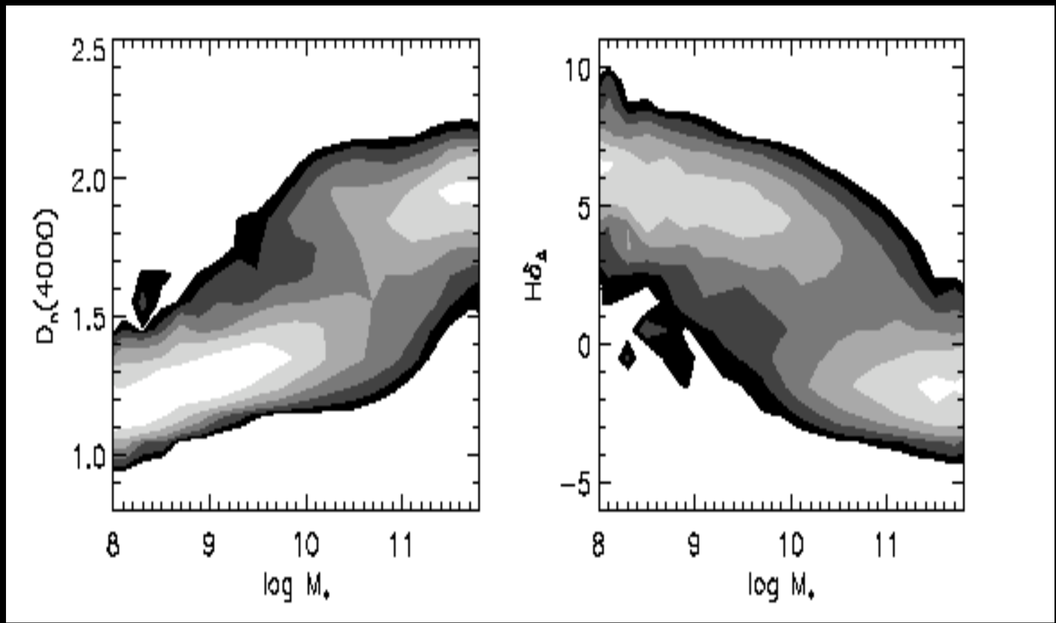
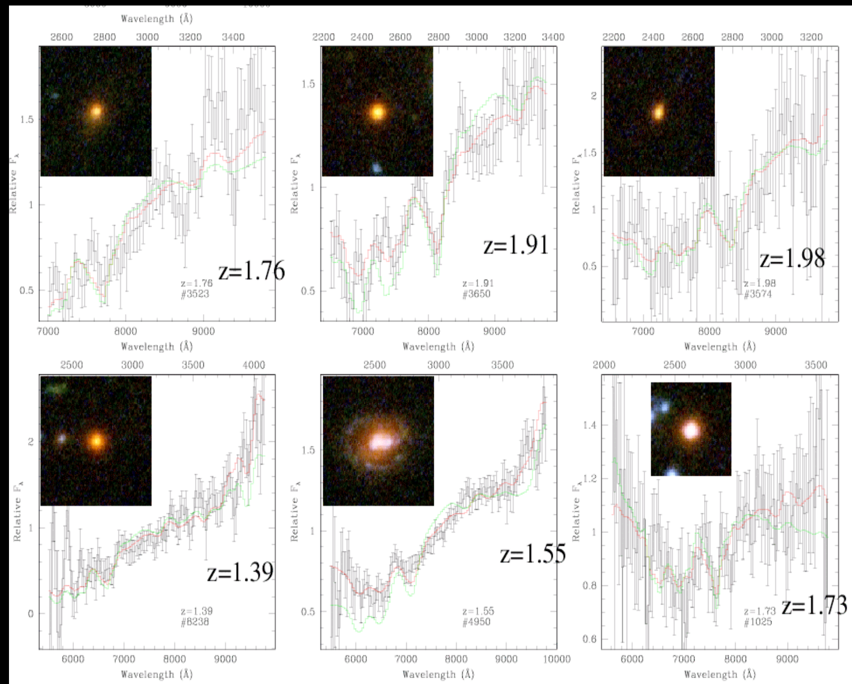
Galaxy Evolution with bolometric arrays @DomeC

Are we able to provide unique and major science contribution from 200um-450um imaging at DomeC ?

Can a facility there be used to address fundamental open questions in galaxy evolution ?

Big open question #1



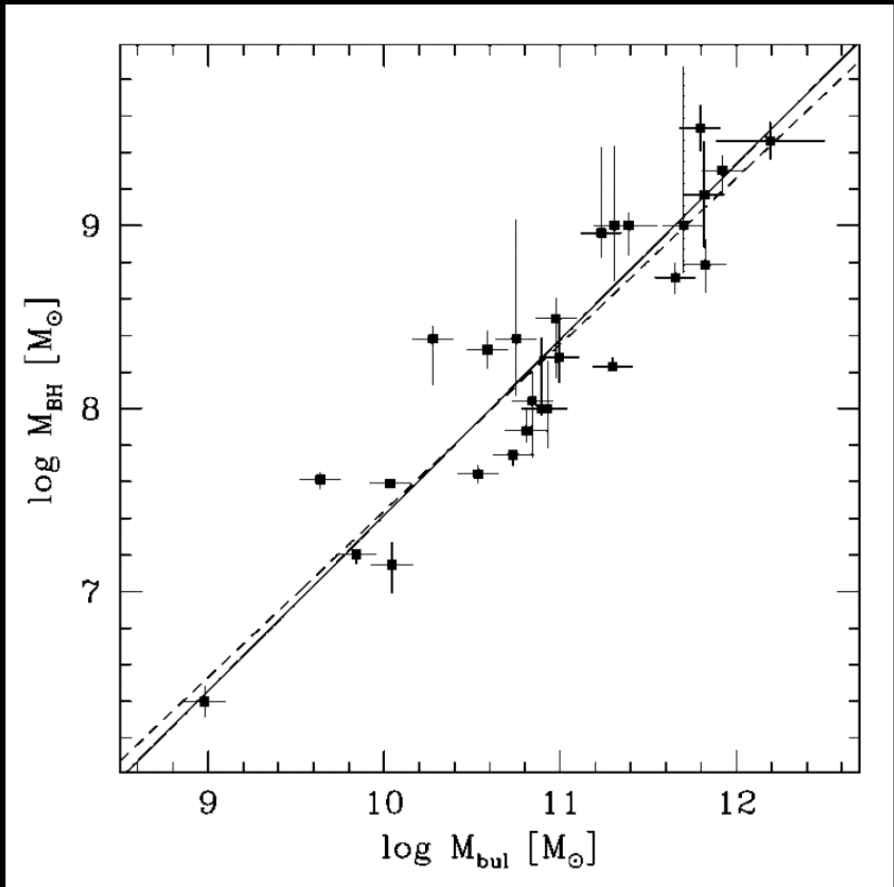


Most massive galaxies and ~60% of local mass in stars is in ellipticals

They exist up to redshift ~2 at least.

How massive ellipticals were formed ? When ? Role of merging ? In situ SF ? (hot issue since many decades…)

Big open question #2



Ellipticals and bulge dominated spirals (spheroids) contain Bhs

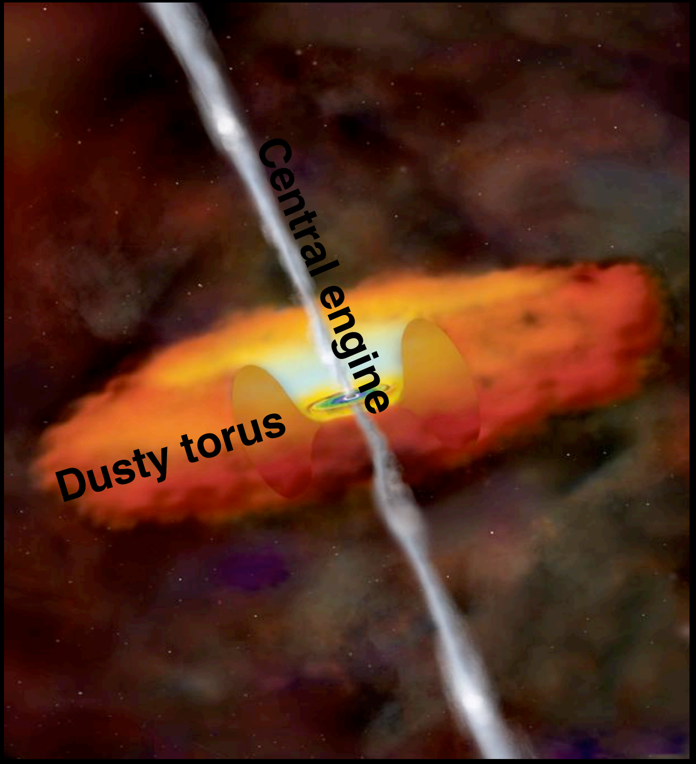
Tight correlations exist between BH masses and spheroid masses

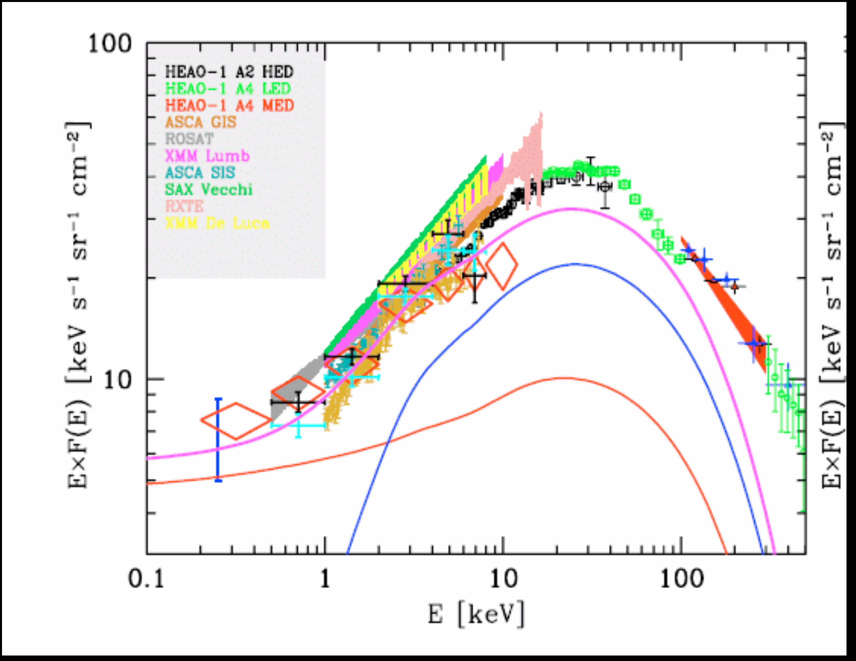
How does the BH know about its surrounding galaxy ?
What is the link between AGN and galaxy activity ?

Big Open Question #3: dust is hiding us things

Large fraction of high-z AGN activity is obscured, even in hard X-rays

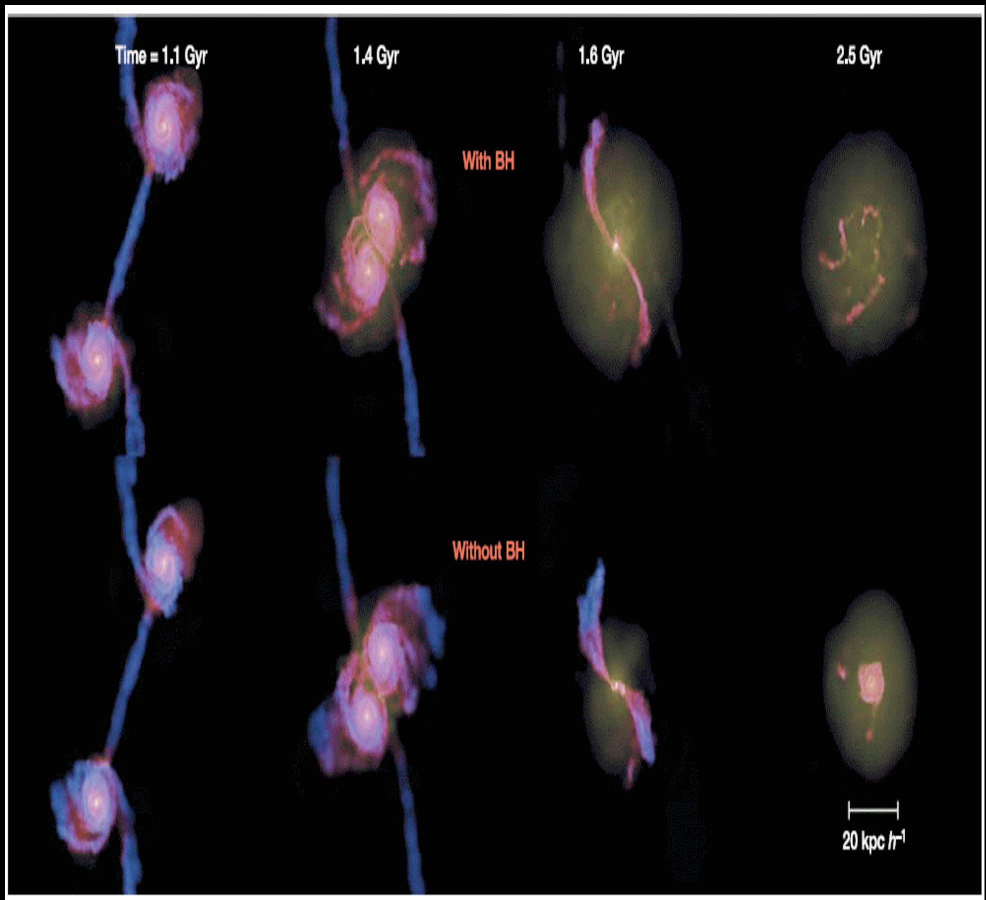
How to reveal the missing AGN population unidentified in X-ray ?

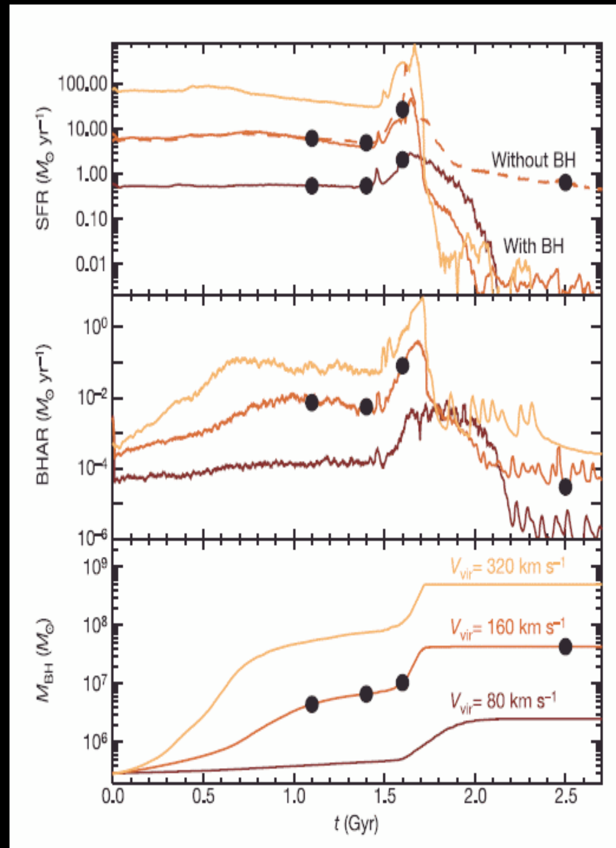




<u>Similarly, of course, large amount of SFR activity is obscured by dust at high-z</u>

Big question #4: role of merging (in a hierarchical ΛCDM Universe)





di Matteo et al. (2006), Nature

- AGN feedback is necessary to form red/dead spheroid
- most BH growth occurr during the merging phases

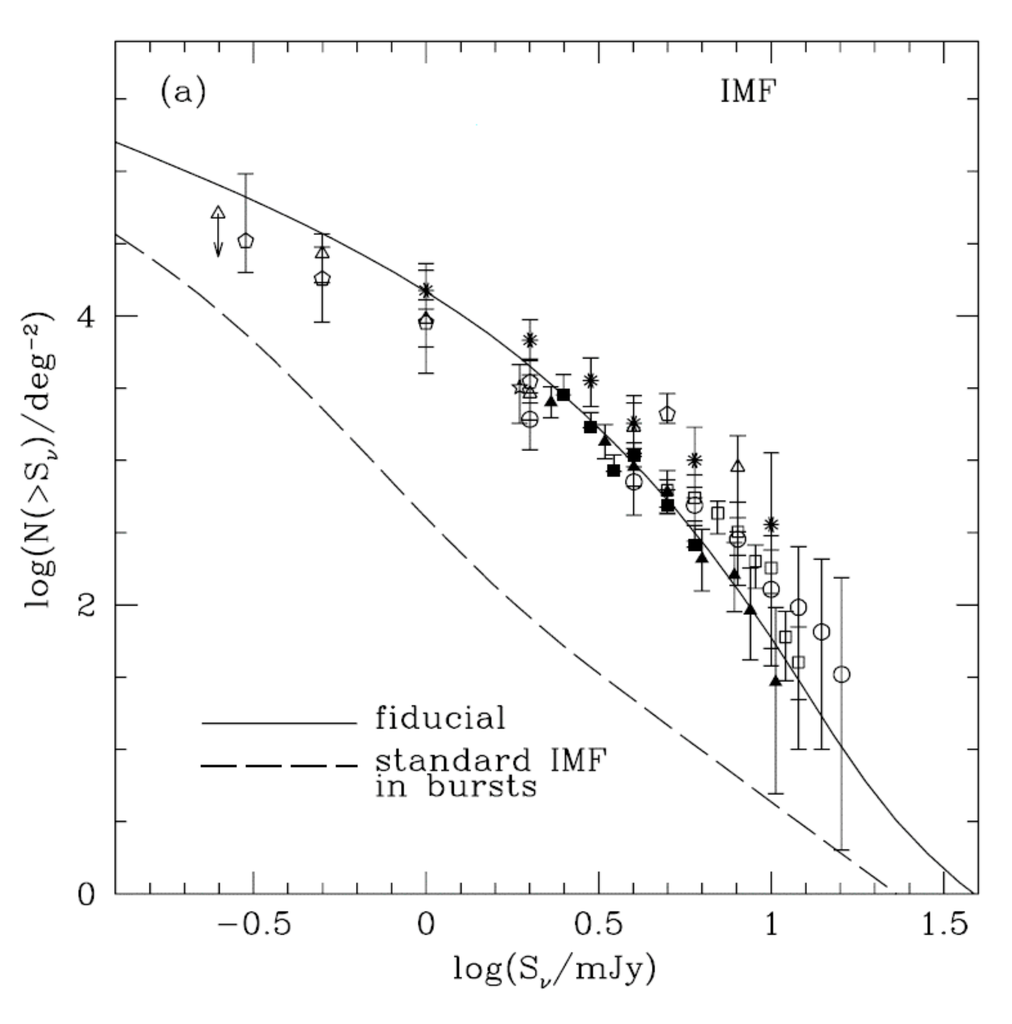
Major tasks to be accomplished:

1) Cense star formation in the distant Universe, to account for most of stellar mass in galaxies we see today
2) Cense obscured AGN activity
(show earlier that much of the evolution is obscured)

The 2 might be strongly connected, given the correlations between BH and galaxy properties

A detailed mapping of this SFR/AGN activity history will yield critical informations about the role of merging (growth in BH or stellar mass function)

... Although SF is a difficult thing to trace/understand, even more in the distant Universe



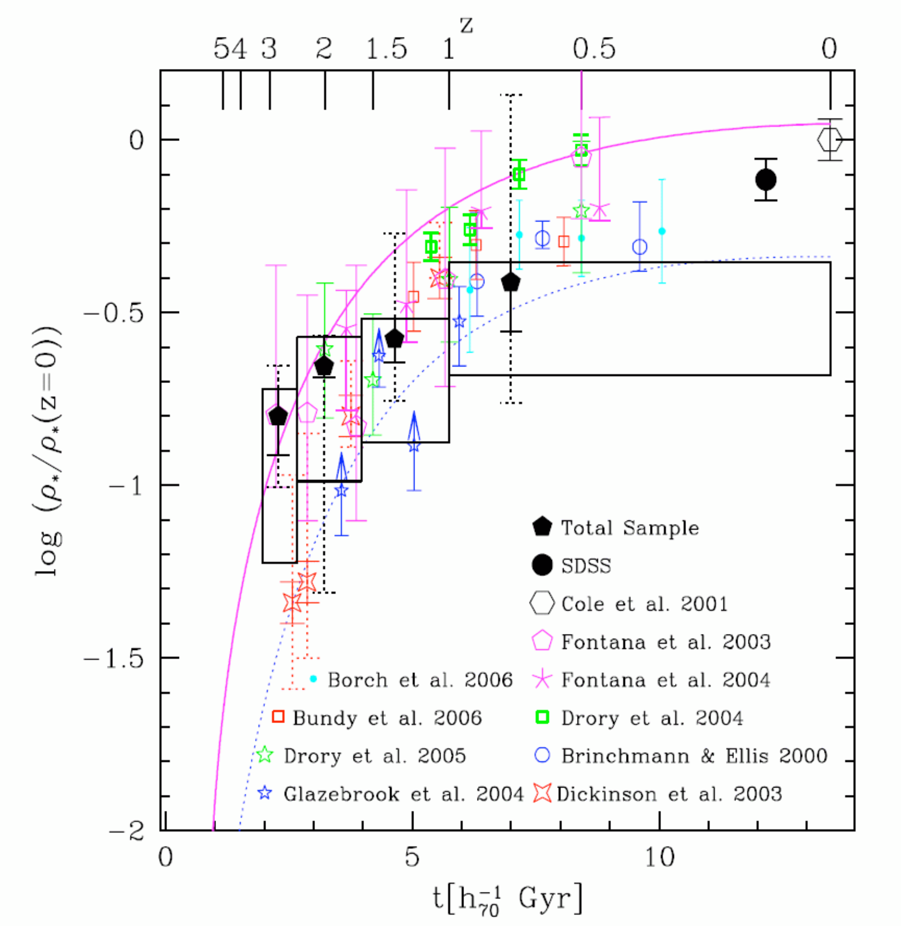
As of today, no ΛCDM based model can account for SMGs if not assuming top-heavy IMF

What is the “cosmological IMF” for galaxy formation at high-z, does it strongly depend on SFR ?

Can also be traced by mass growth to SFR detailed comparison

A detailed census of star formation is a major required advancement

Rudnick et al 2006

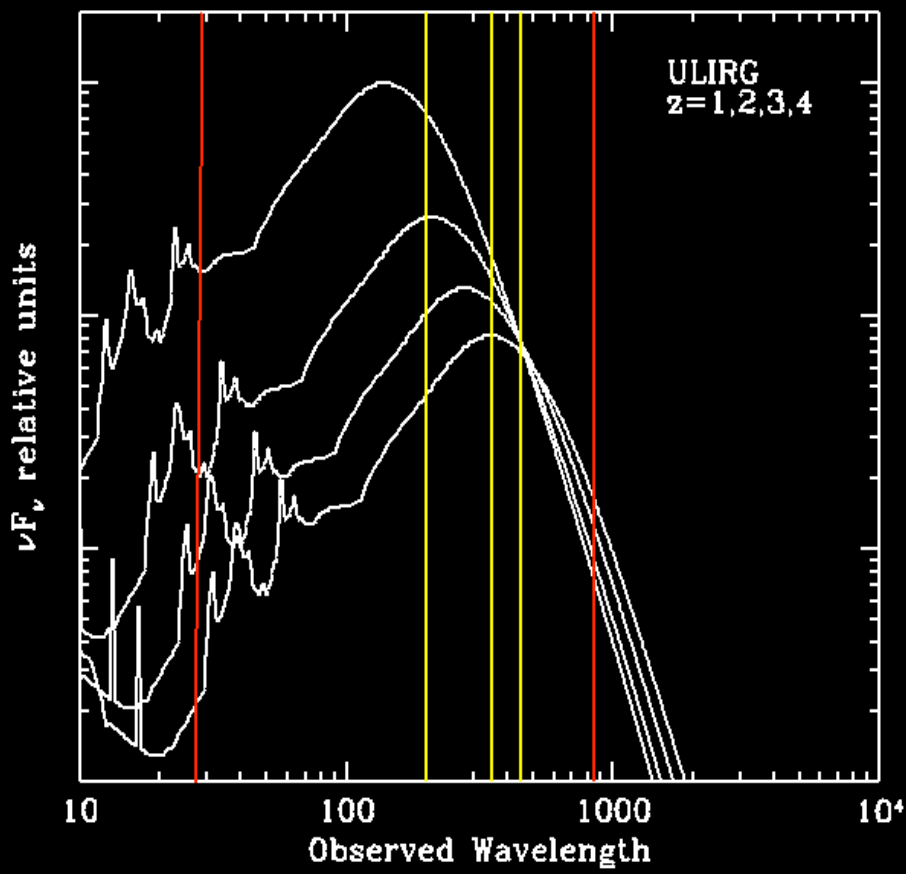


Major growth epoch of stellar mass (and massive galaxies) is 1<z<3

How do galaxy grow ?

It is crucial to measure SFRs in the distant Universe

DomeC is an exciting opportunity for galaxy formation at 1<z<3 z~1-3 is the redshift range where SFR is best studied at 200-450um wavelenghts (less plagued by cpt identification problems)

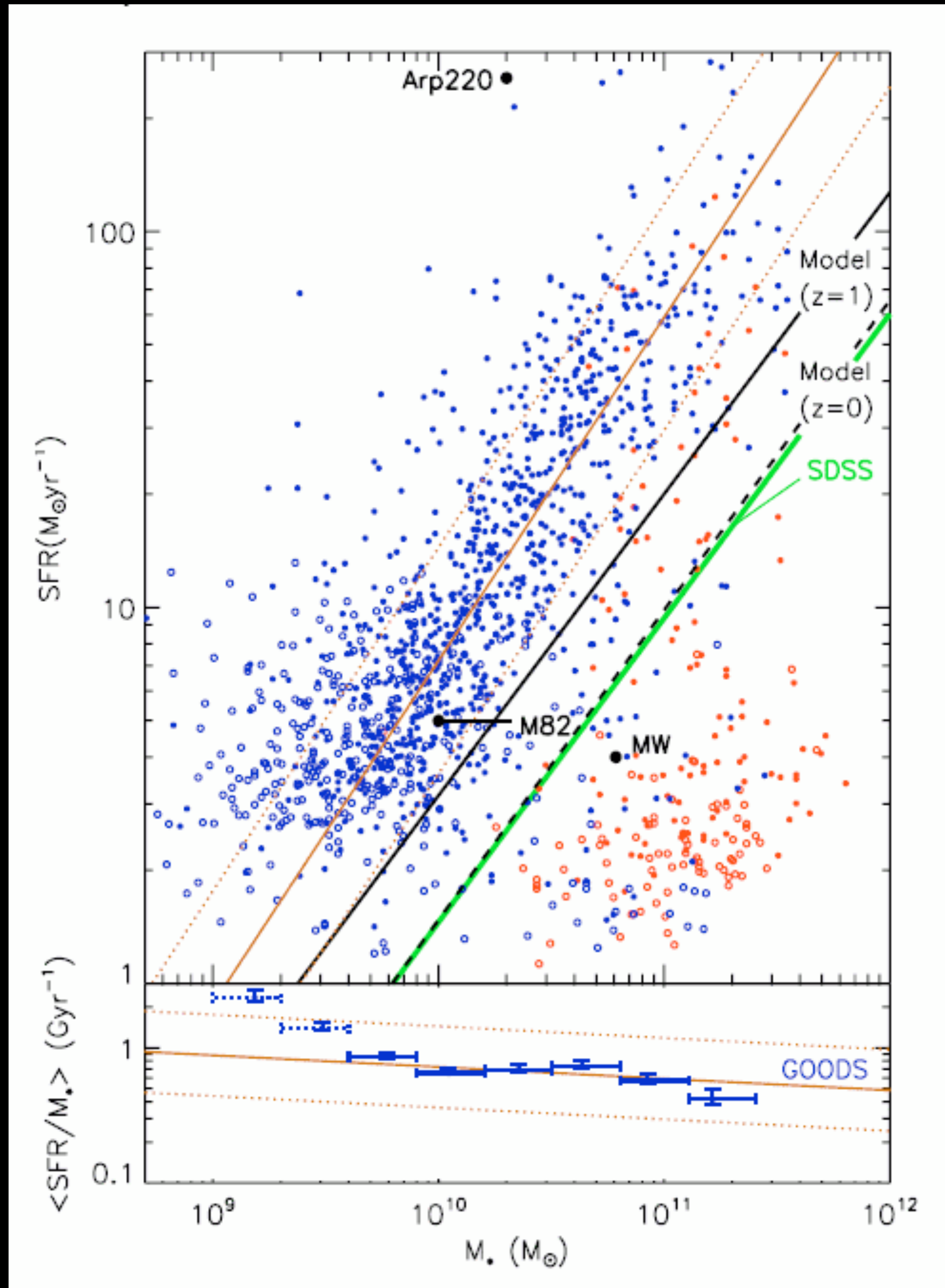


At these redshifts, 24um Spitzer surveys, 850um surveys only detect a small fraction of the energy emitted --> need large extrapolation

Mass and SFR correlate at z=0 – 2 (consistent with galaxy formation models)

Censing star formation requires properly censing massive galaxies

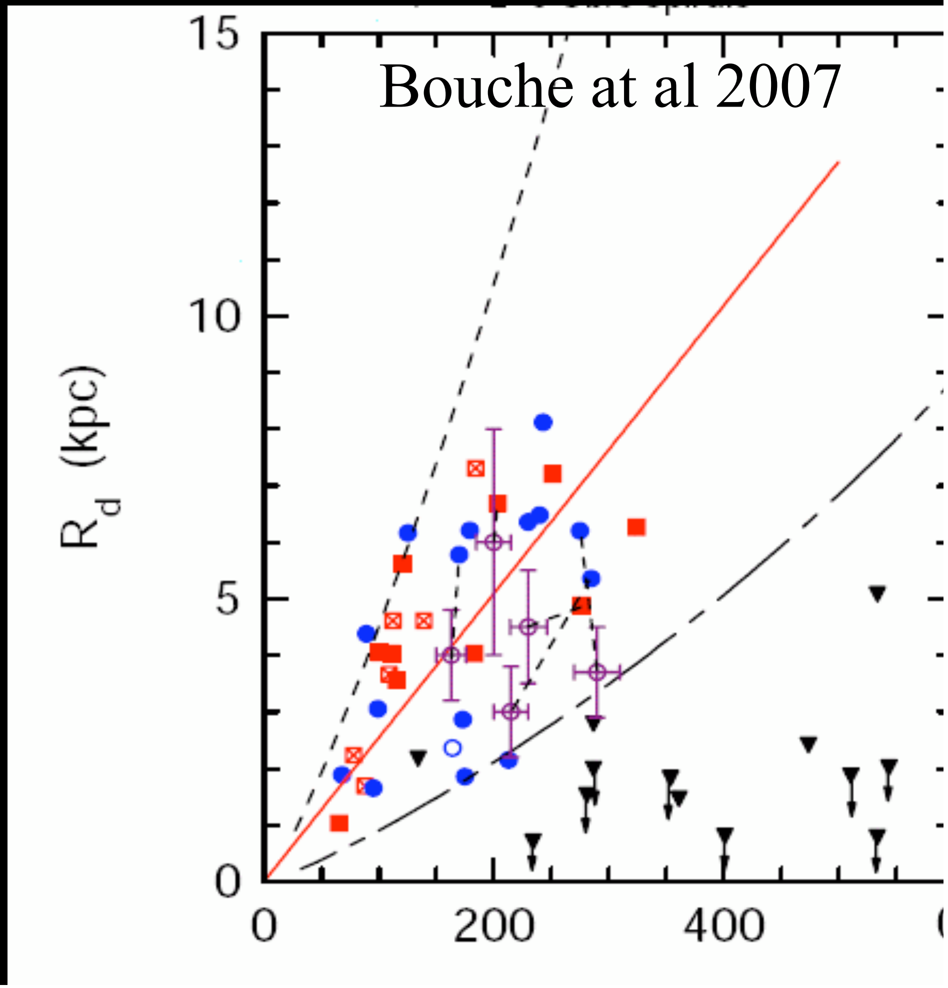
Where we need to reach for a major step forward ?



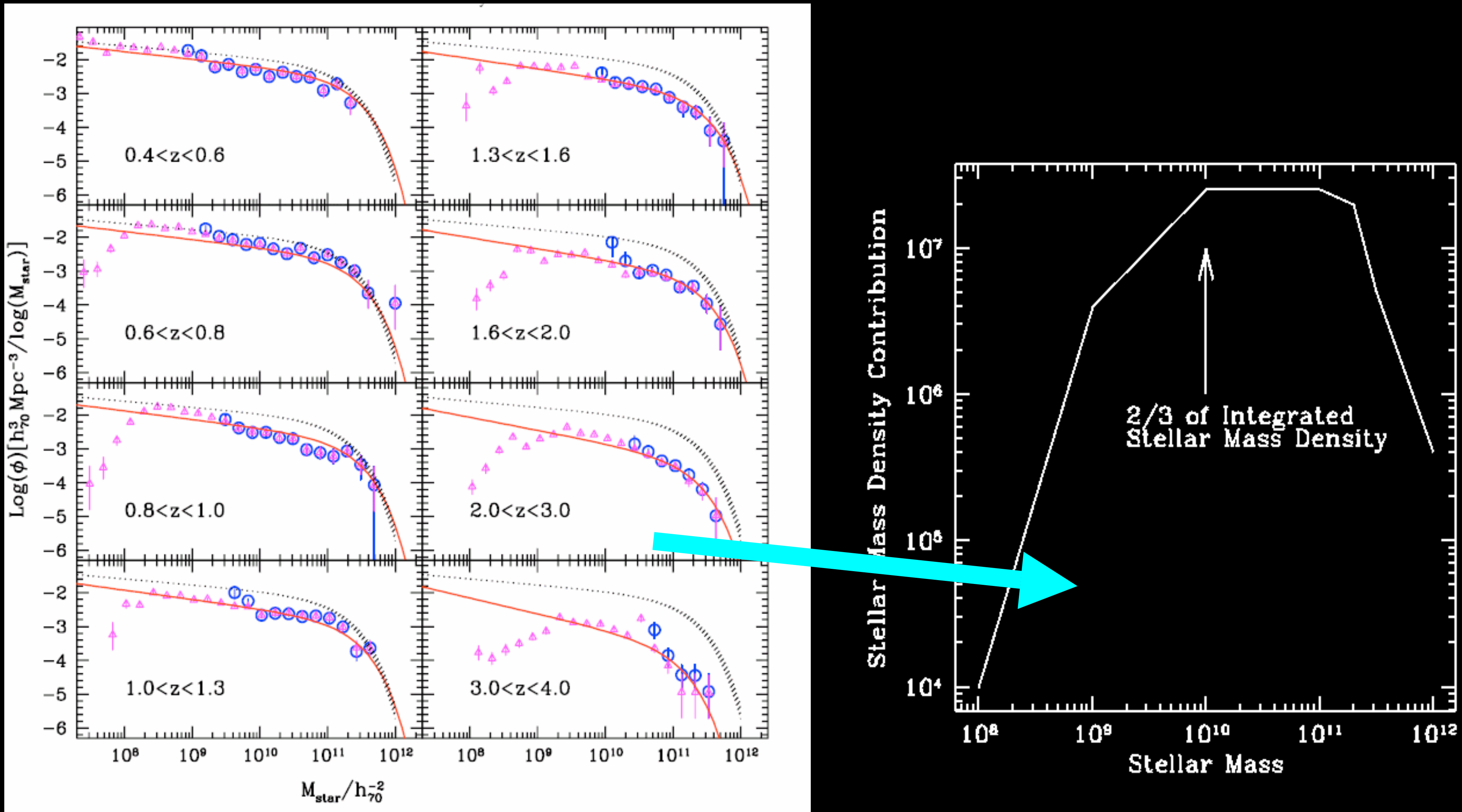
Qualitatively, we need to go quite faint to resolve the dichotomy SMGs, vs typical field massive galaxies

Transparent or not, duty cycle vs SFR, merging powered which ?

Make a bridge between bright SMGs (large fields) and more common faint galaxies (small fields)



How deep does one need to go: studying galaxy assembly



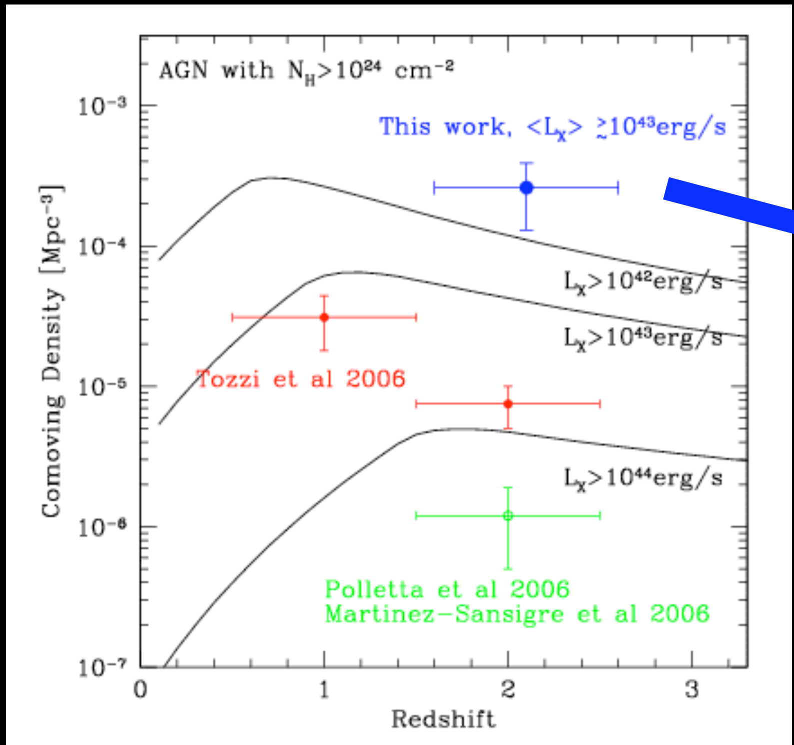
Need to reach at least typical M~10^10Mo galaxies

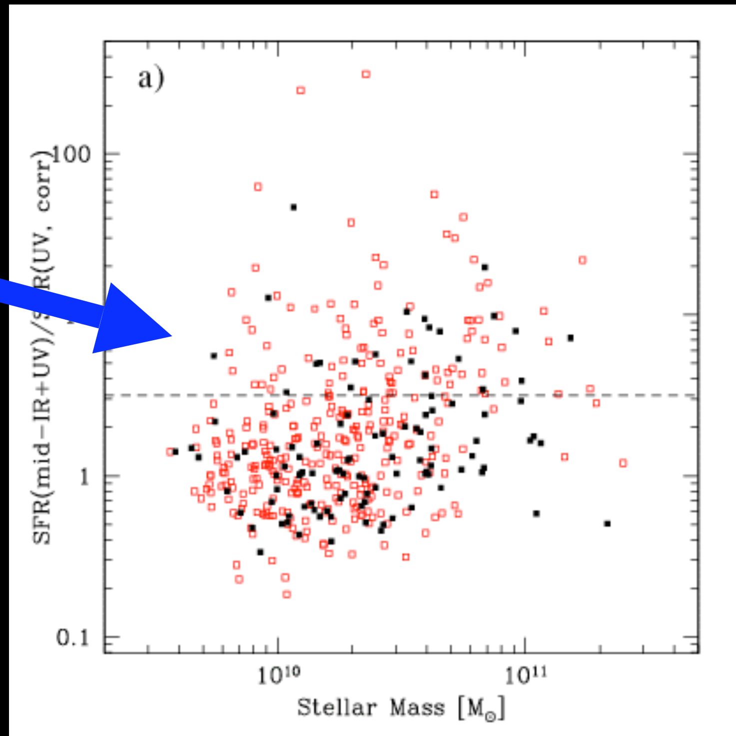
M~10^11 Msun galaxies have 850um flux ~1mJy (Daddi et al, Knudsen et al)

-> need sub-mJy levels

How deep does one need to go: detecting obscured AGNs to z=2-3

Daddi et al 2007

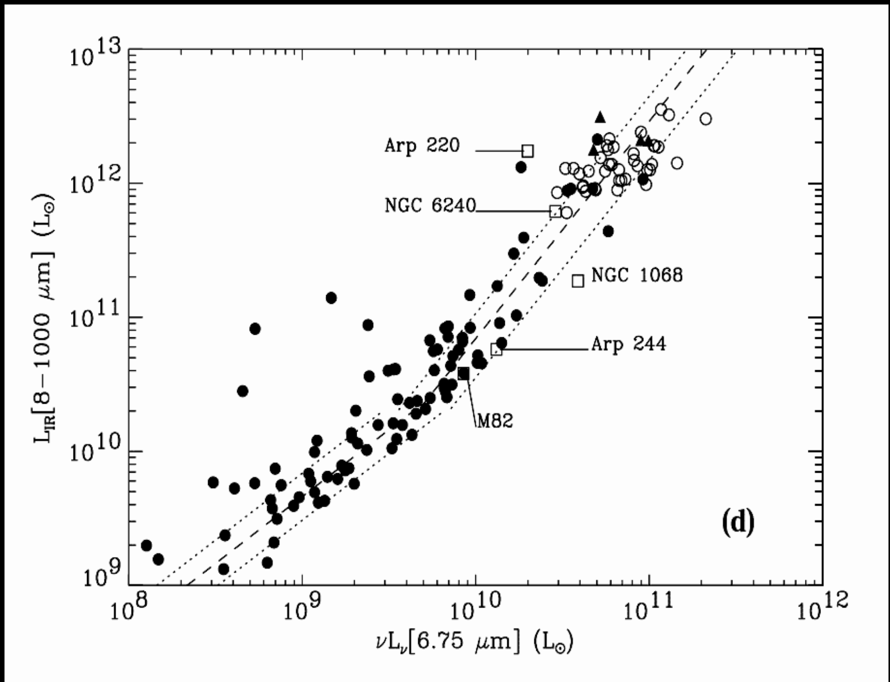


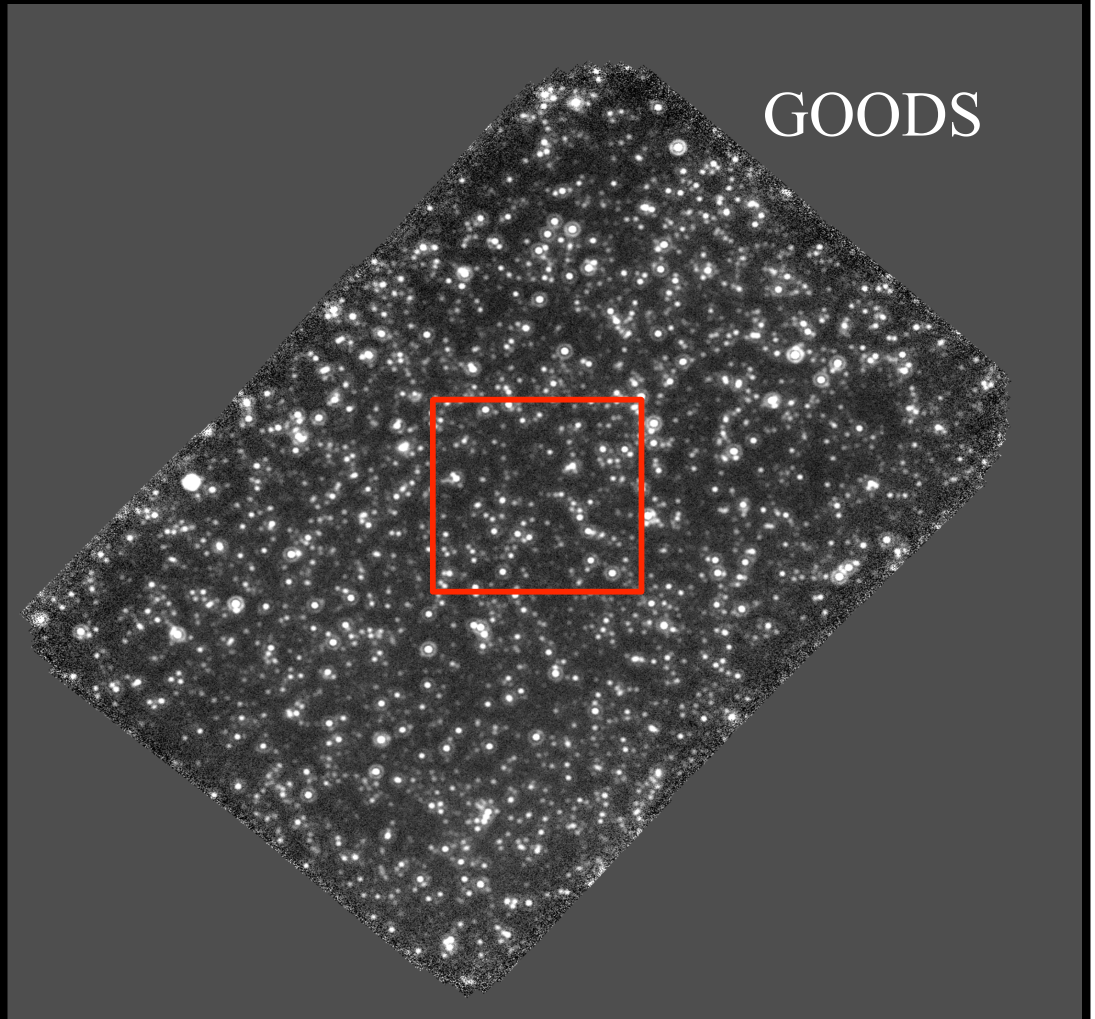


Again, need to reach 10^10 Msun galaxies

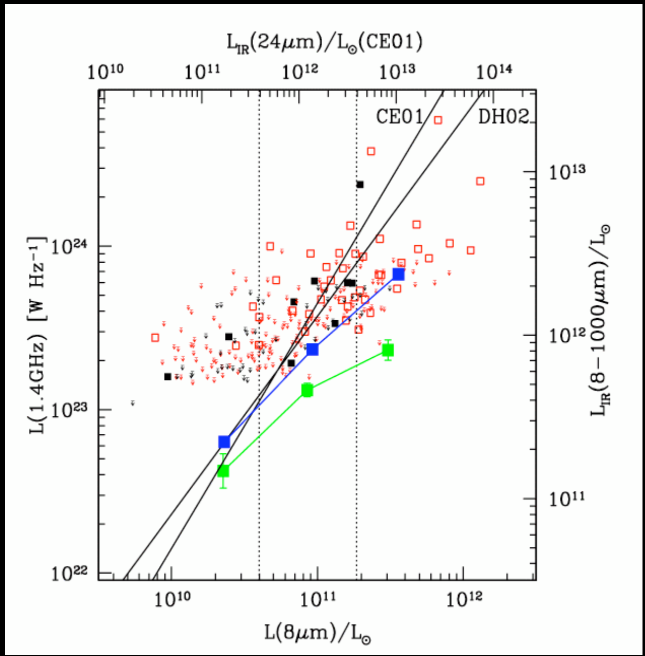
Do we really need to measure the peak ?

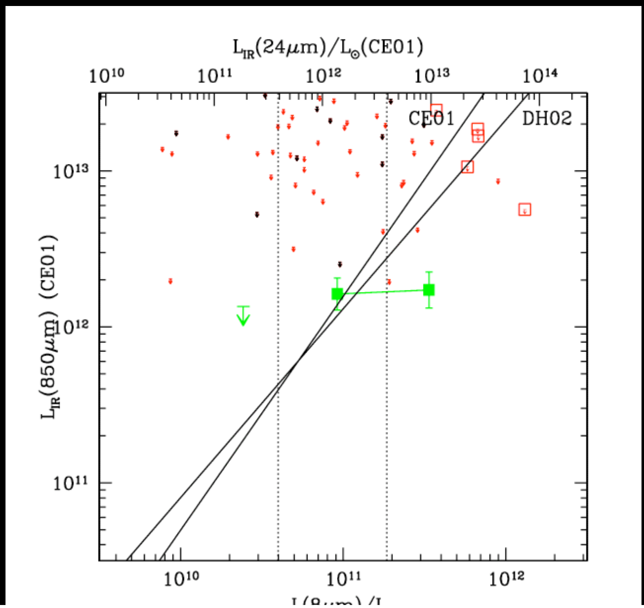
Elbaz et al 2002, Forster-Schreiber et al 2004, etc





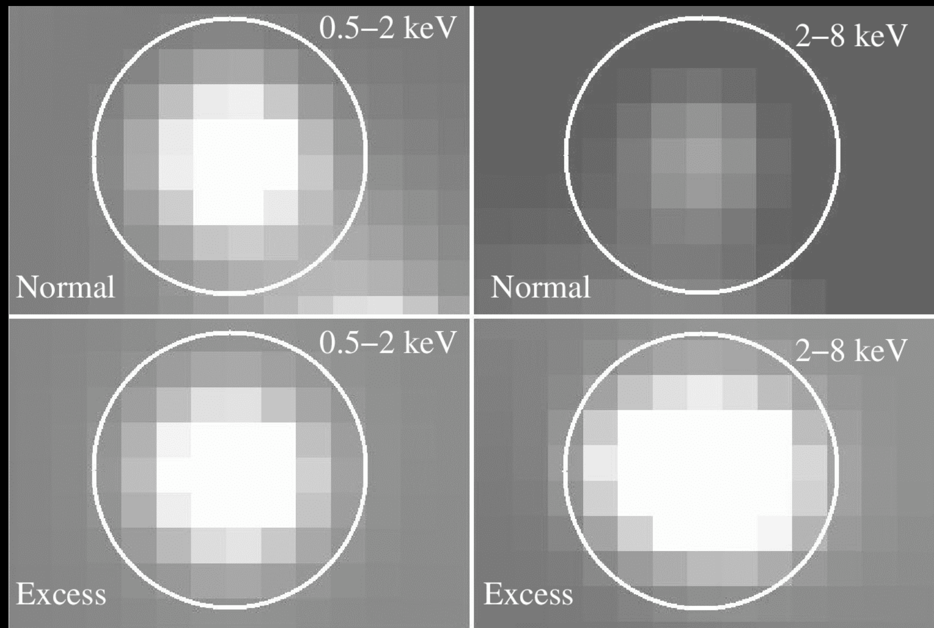
Cannot just exploit indirect correlations ?





It is now known that 24um alone is not sufficient to map SFR at high-z

E.g., due to the contamination from AGNs

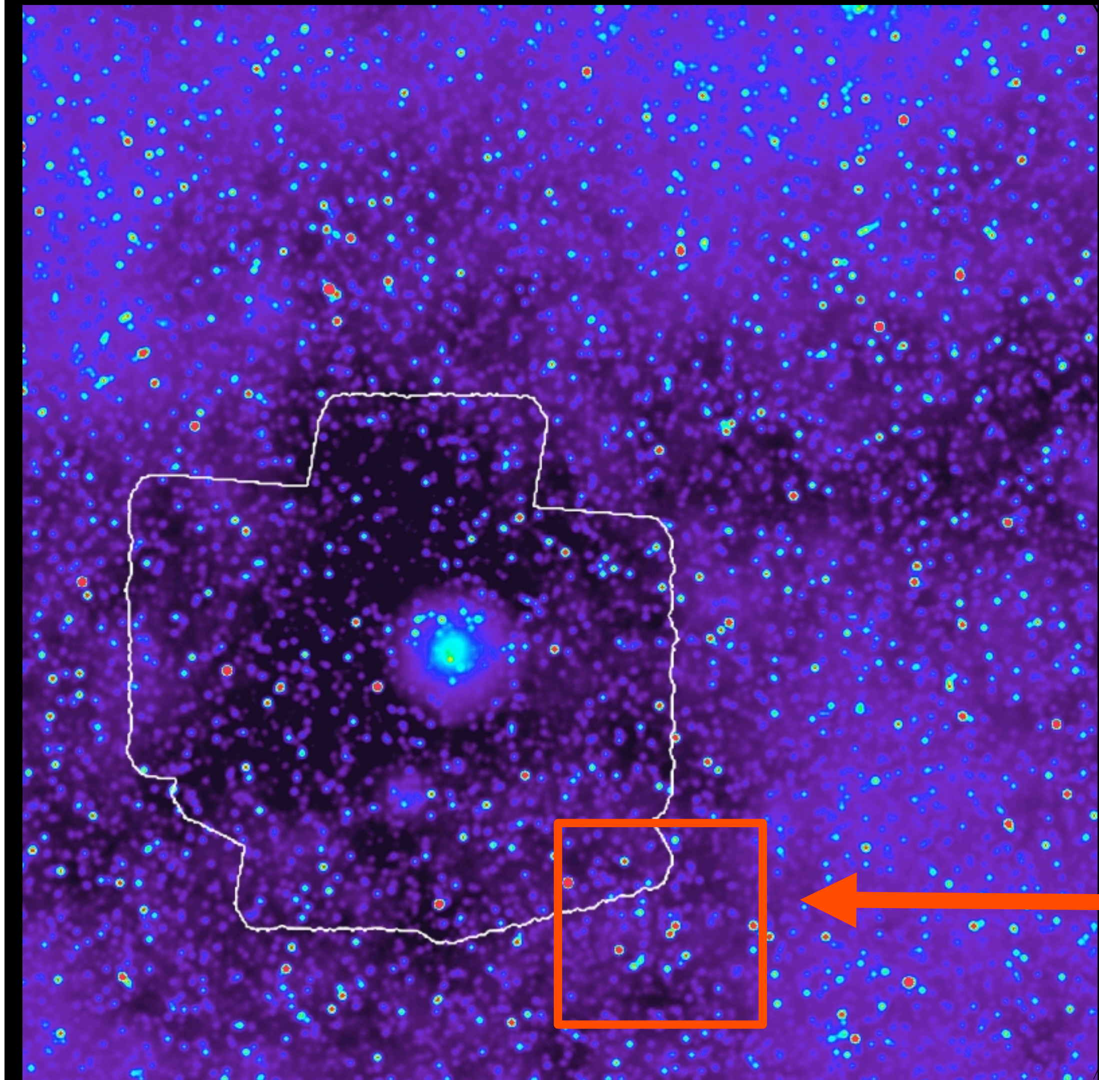


Daddi et al 2007
arXiv:0705.2831, arXiv:0705.2832
Fiore et al 2007 arXiv:0705.2864
Papovich et al 2007

Can we just use 850um surveys ? Substantial progress forthcoming
e.g., Large Millimiter Telescope +Aztec
50m diameter, ~5” resolution at ~1.2mm

AzTEC/LMT Surveys for SMGs and SZE Clusters

Courtesy: Mauro Giavalisco

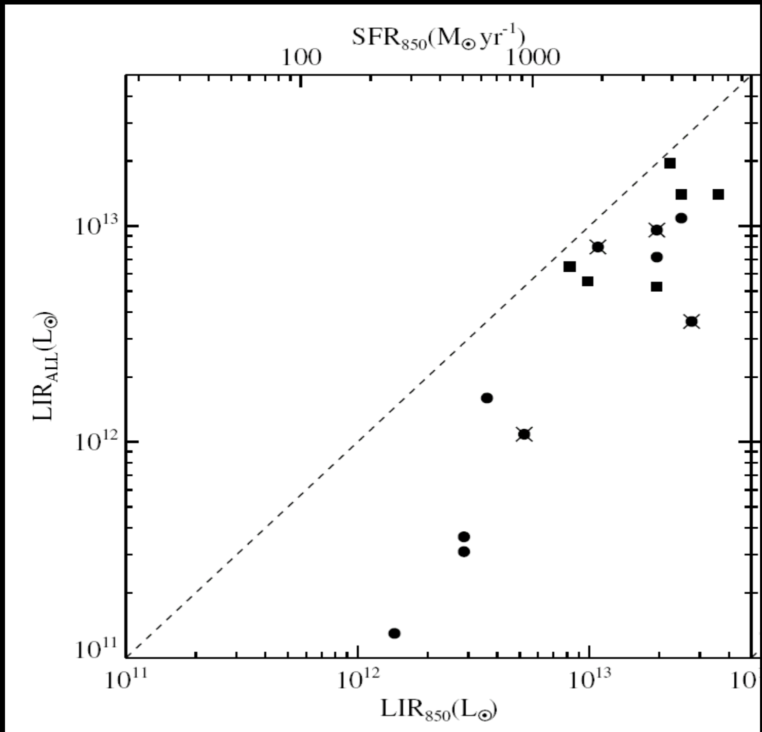


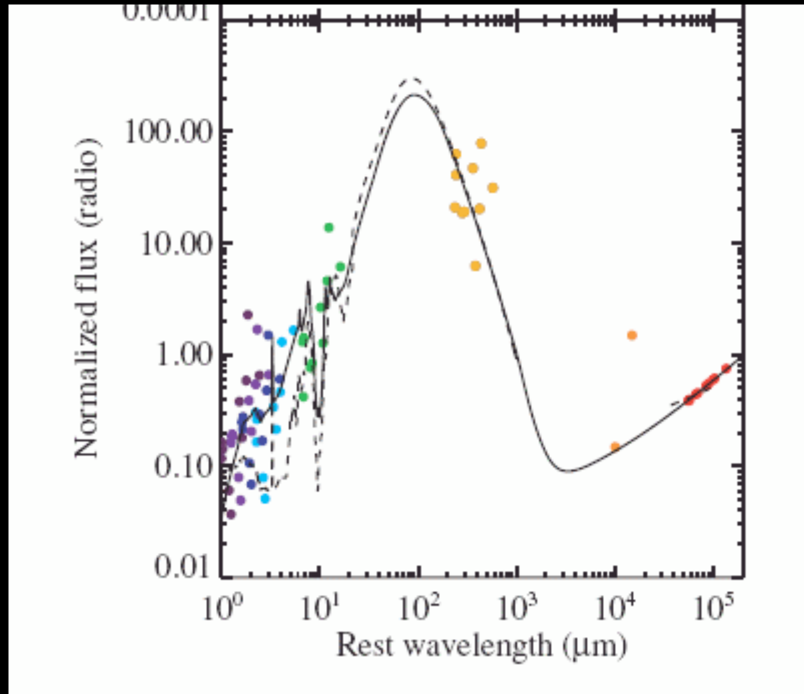
Large Area Survey:
30 sq. degrees
600 hrs, 100,000 sources

The Deep Survey:
25 sq. arcmin
to confusion limit (0.01mJy)
750 hrs, 1000 sources

LMT/AzTEC simulation including high-redshift starburst galaxies

What we have learnt on SCUBA galaxies from GOODS-N (Pope et al 2006)





There is still clearly a major need to go for the bolometric peak
--> 200um – 450um for 0.5<z<4

How do we do better:

Herschel 360-520um

Easy: 3x times higher angular resolution will push fainter the confusion limit (of order 15mJy currently over 300-500um, reached in <1h at DomeC)

Confusion limits estimates based on Le Borgne, Elbaz, et al (2007) model. Accounts for multiwavelength observed counts and predict confusion limits from current knowledge of deep surveys. <u>But all models at these wavelengths are extremely uncertain!</u>

200um band at DomeC: better than Herschel 170um ?

Herschel has 12.2” resolution @170um,
12m at DomeC has 3.4” resolution @200um

DomeC mapping speed: 18 times slower than Herschel
Herschel confusion limit @170um: ~5mJy
--> ~100 hours to reach with a 12m at 200um

<u>We cannot beat Herschel/PACS from the ground with a 12m telescope</u>

How do we do better: SCUBA2 (@JCMT 15m telescope)

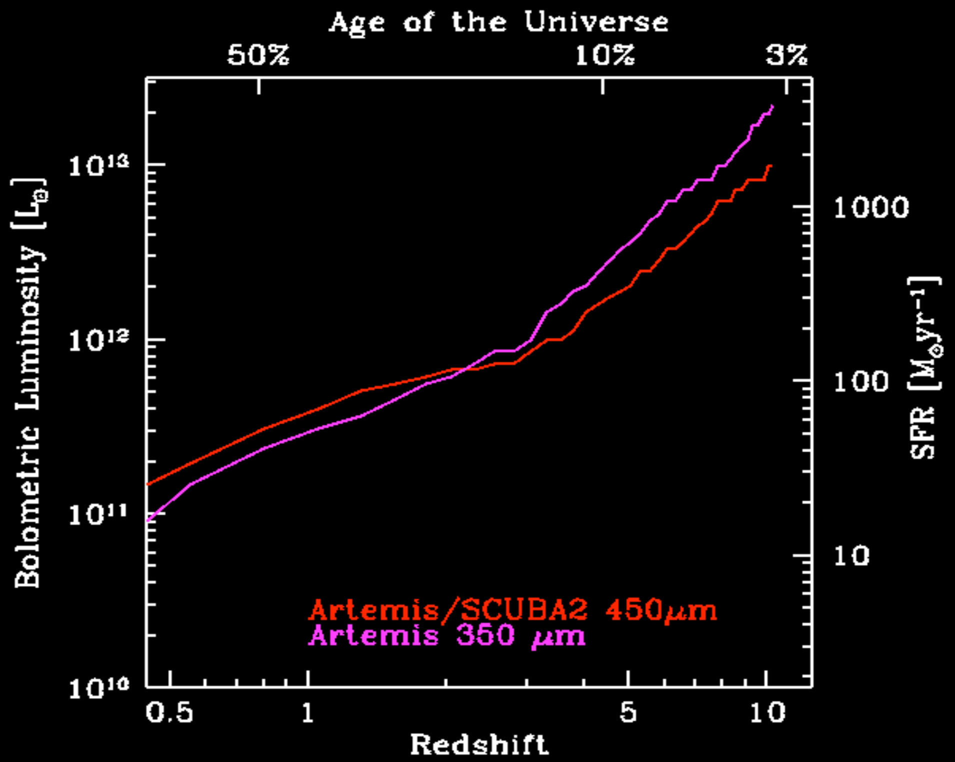
5-year plan to use all tau(CSO)<0.05 MaunaKea weather

450um survey (1390 hours)
--> 2.5mJy (5sigma) over 1.3 square degrees

OK...
data quality from DomeC will be much better
not clear if this 450um survey can be successful
etc

Time to duplicate SCUBA2 5-year plan with 4x4arcmin bolometer array@DomeC

@450um: 3600 hours, or ~1.4 Years (13h/field)
@350um: 1800 hours, or ~0.7 Years (6.6h/field



Need to think big to be competitive on galaxy evolution science

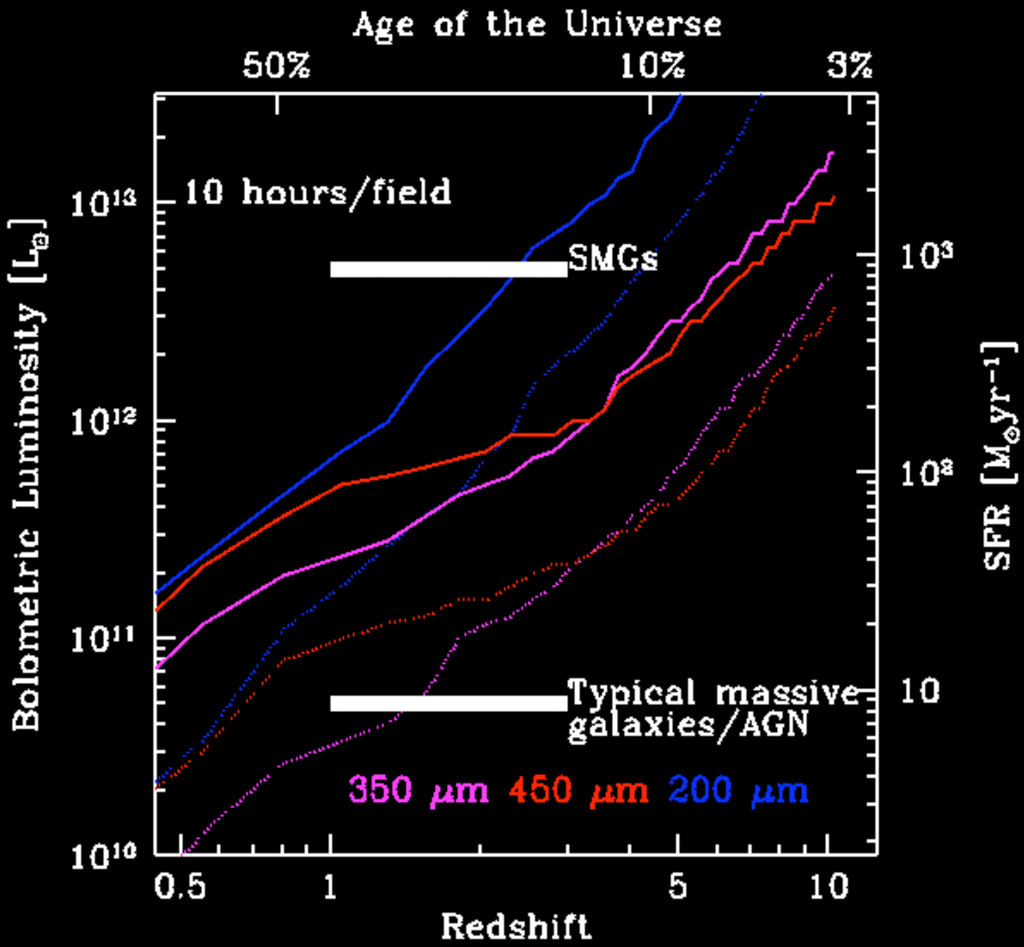
Full exploitation of 200um band at DomeC requires large telescope (larger than a 12m antenna)

Enormous gain in depth with telescope Diameter (D)

S/N (fixed time) α D^2
Time to reach a given flux density α D^4
Identification problems strongly decreasing with D
Confusion limit is pushed much deeper, depth reachable increases with D
Plus gain from non-linear flux-SFR relation (350um, 450um)

--> Strong case for a BIG telescope (e.g., 25m vs 12m)
19 times faster (reach Herschel 170um confusion limit in 5hours @200um)
1.6” beam-size @200um (solve all identification problems)
Definitively solve confusion issue at all wavelengths for all depths
Detect 10^10 Msun galaxies at z=2-3 in 10-20 hours at 350um
Duplicate SCUBA2—5 year plan in 100-200 hours observing

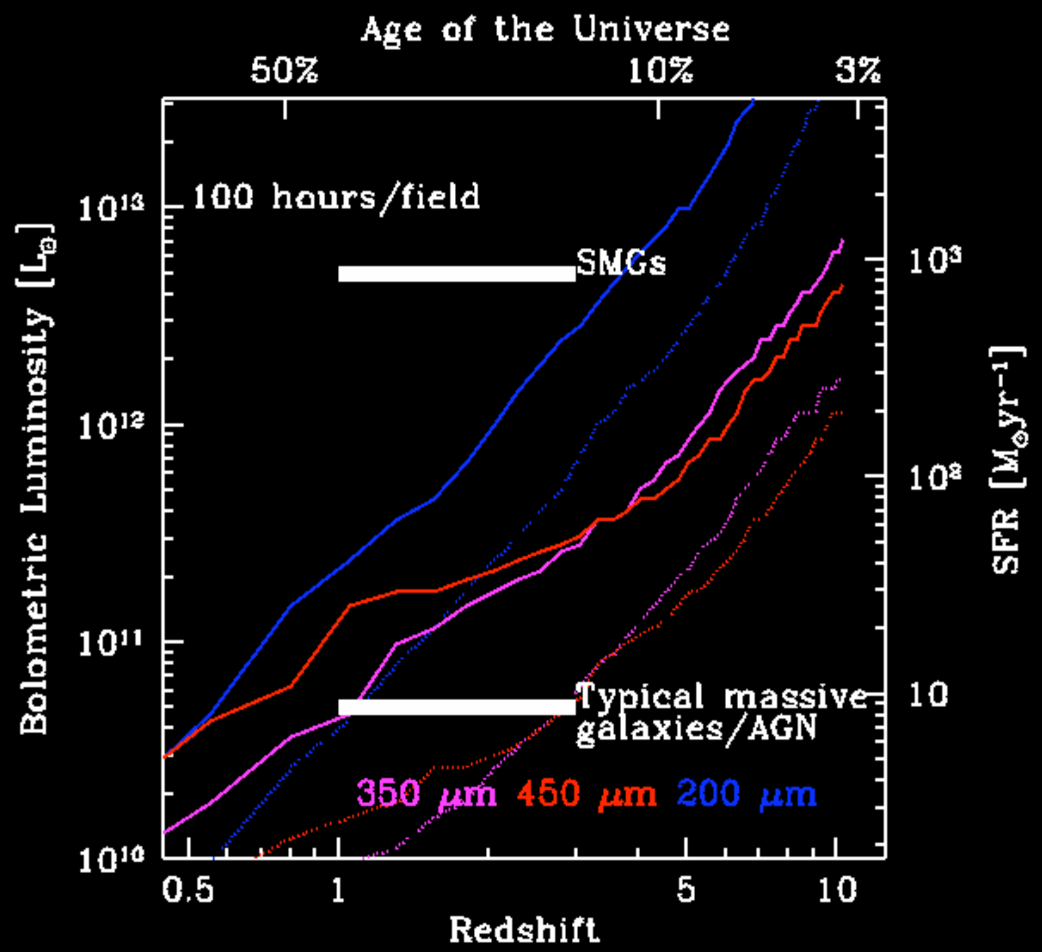
Reachable depths: 10 hours per field mapping



12m telescope:
detect all SMGs, even at 200um
detect all ULIRGs to z=3

25m telescope:
detect all ULIRGs at 200um to z=3
detect all LIRGs to z=3

Reachable depths: 100 hours per field mapping



25m telescope:
Complete SFR and IR-AGN census to z=3

Numbers of **<u>350um</u>** (>5sigma) sources expected in a 10 arcmin^2 field
(as envisaged with a 3.1x3.1 arcmin bolometer array)
mostly high-z (z>1) sources, based on LeBorgne et al 2007 counts

to 10mJy (plausible Herschel confusion limit): 8/field
(requires ~ 1 hour with a 12m telescope) Lbol ~ 2x10^12 @z=2

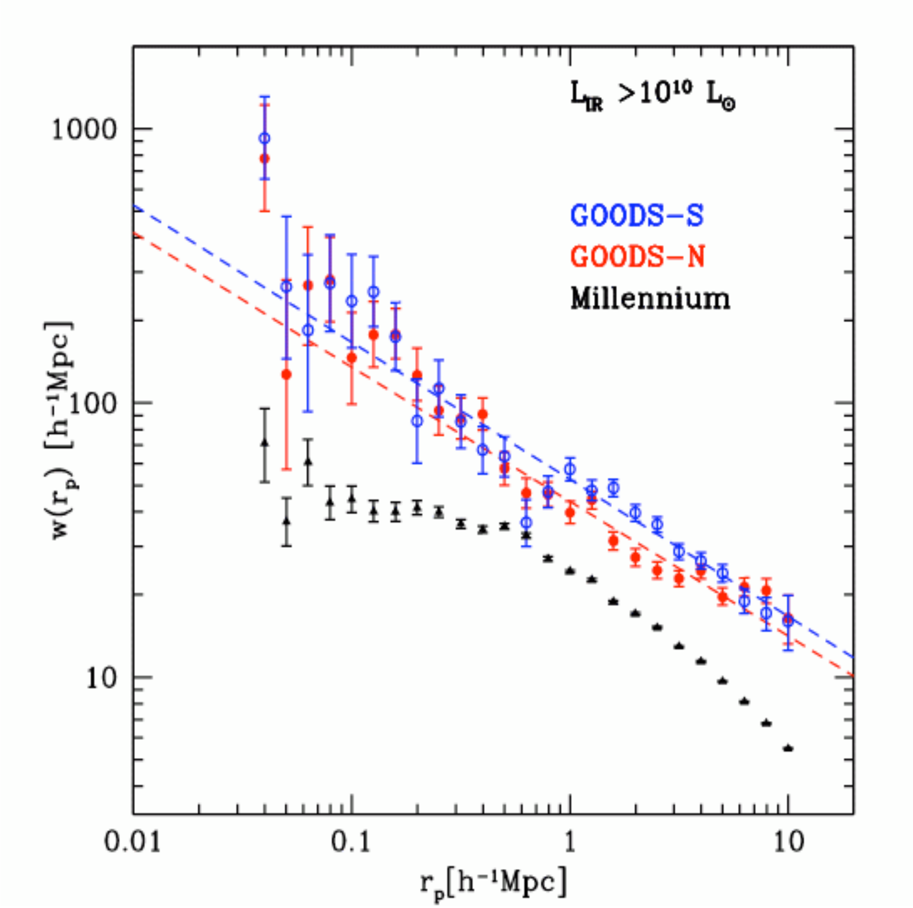
to 1mJy (~ confusion limit with 6.2" resolution): 110/field
(requires ~ 100 hours with a 12m telescope) Lbol~1.7x10^11 @z=2

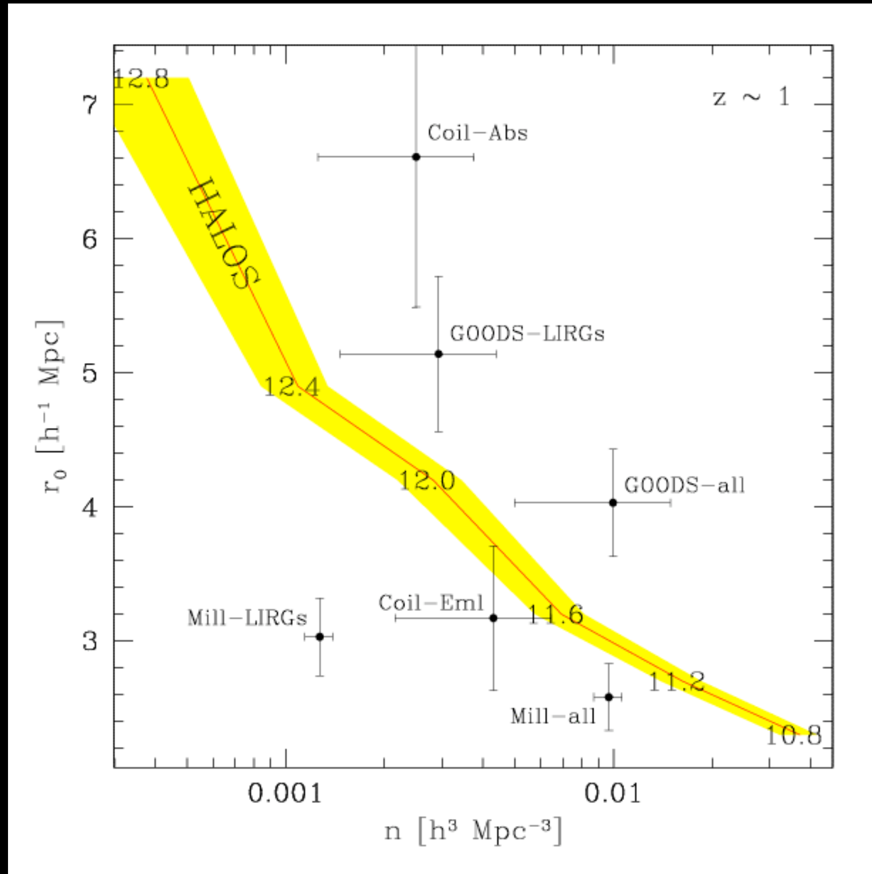
to 0.3 mJy: 200/field
(50 hours with a 25m telescope) Lbol~4x10^10 @z=2

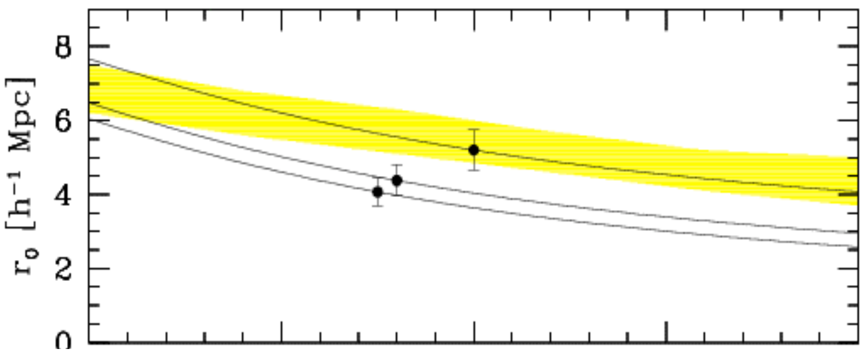
Large bolometer arrays to maximize mapping speed
many separated fields to overcome cosmic variance

Large scale structure work crucial for understanding star formation

And relating to dark matter halos

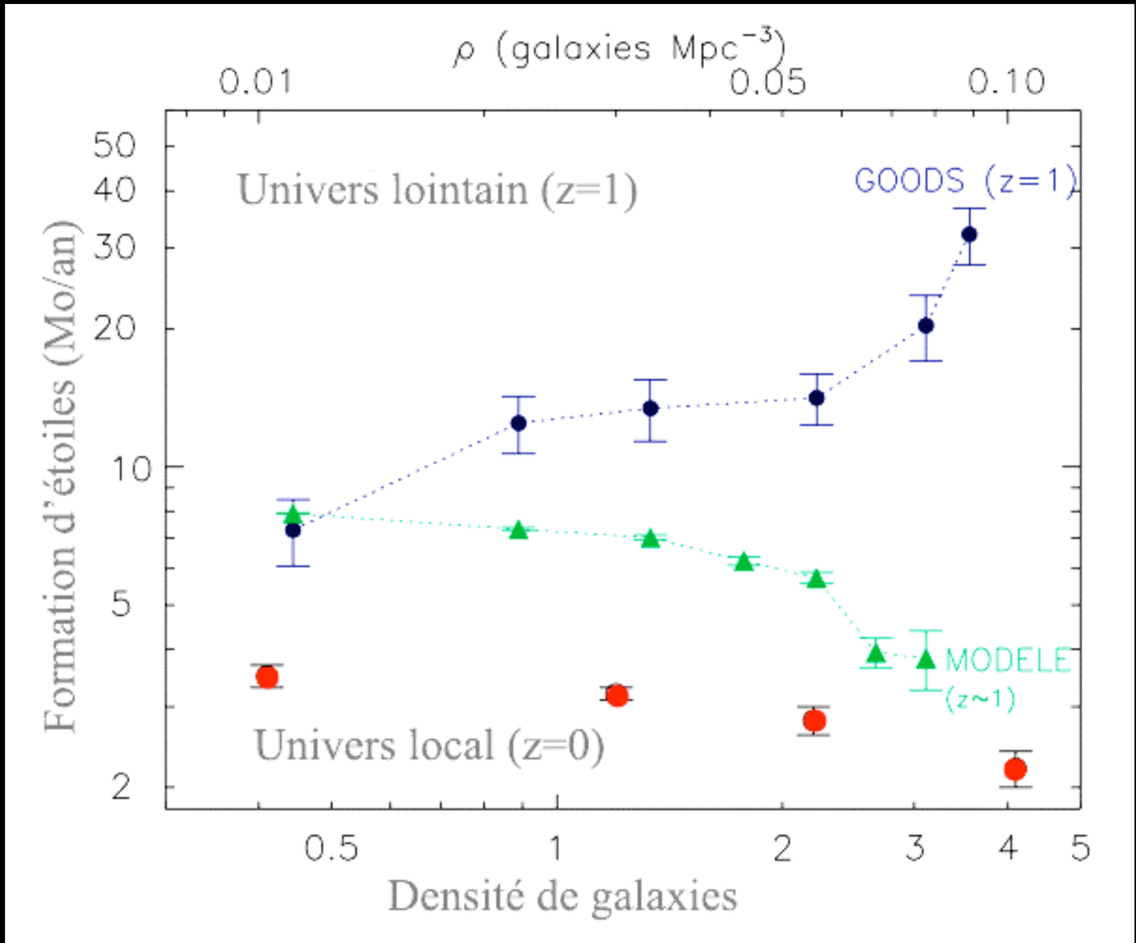






(results from Gilli et al 2007, submitted)
~1000 spec-z in GOODS
spec-z mapping to z=3 quite within reach

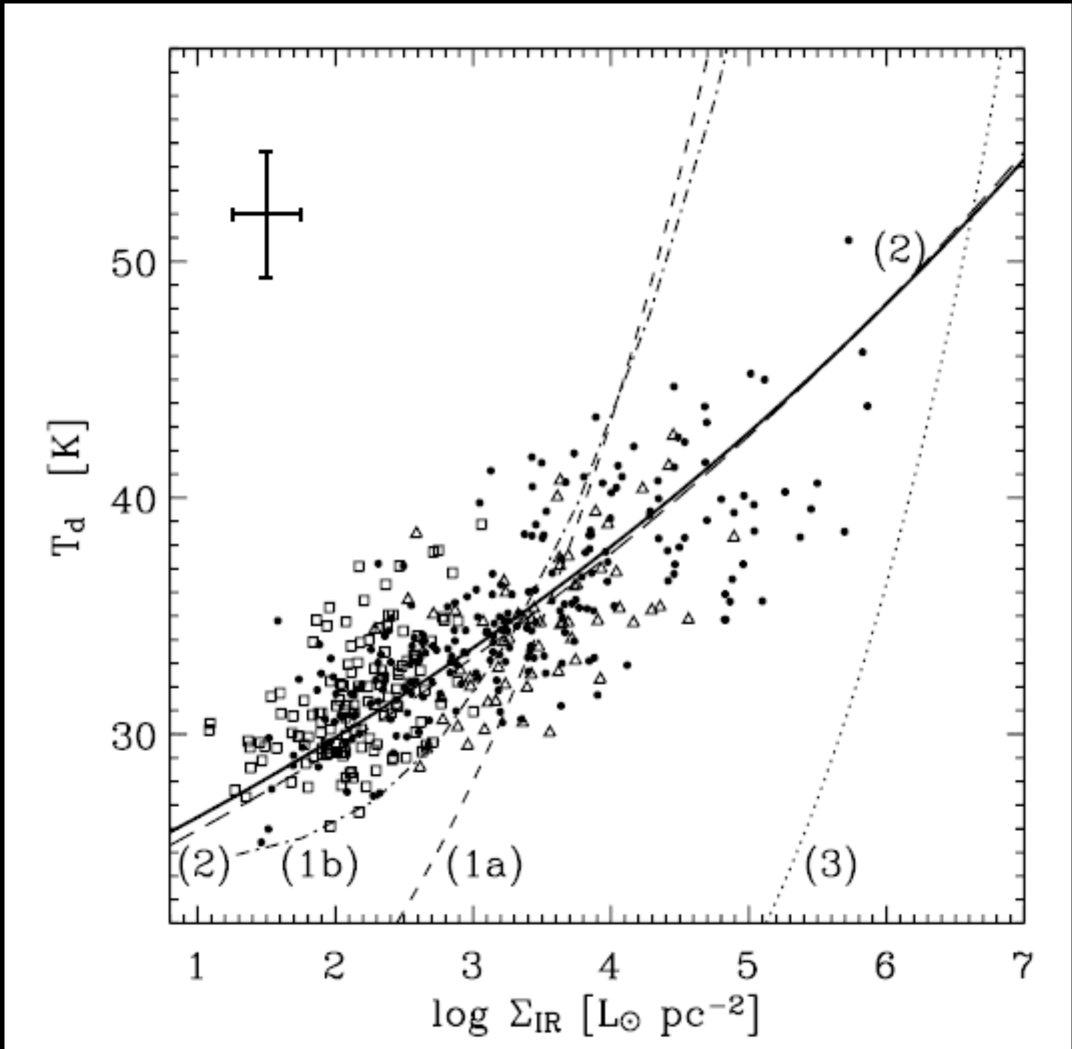
SFR and galaxy environment



Constrain SF to low level crucial to study effect of large scale structure on galaxy growth as a function of cosmic time

Elbaz et al 2007

SED and temperature characterization:
physical informations on high-z galaxy SF

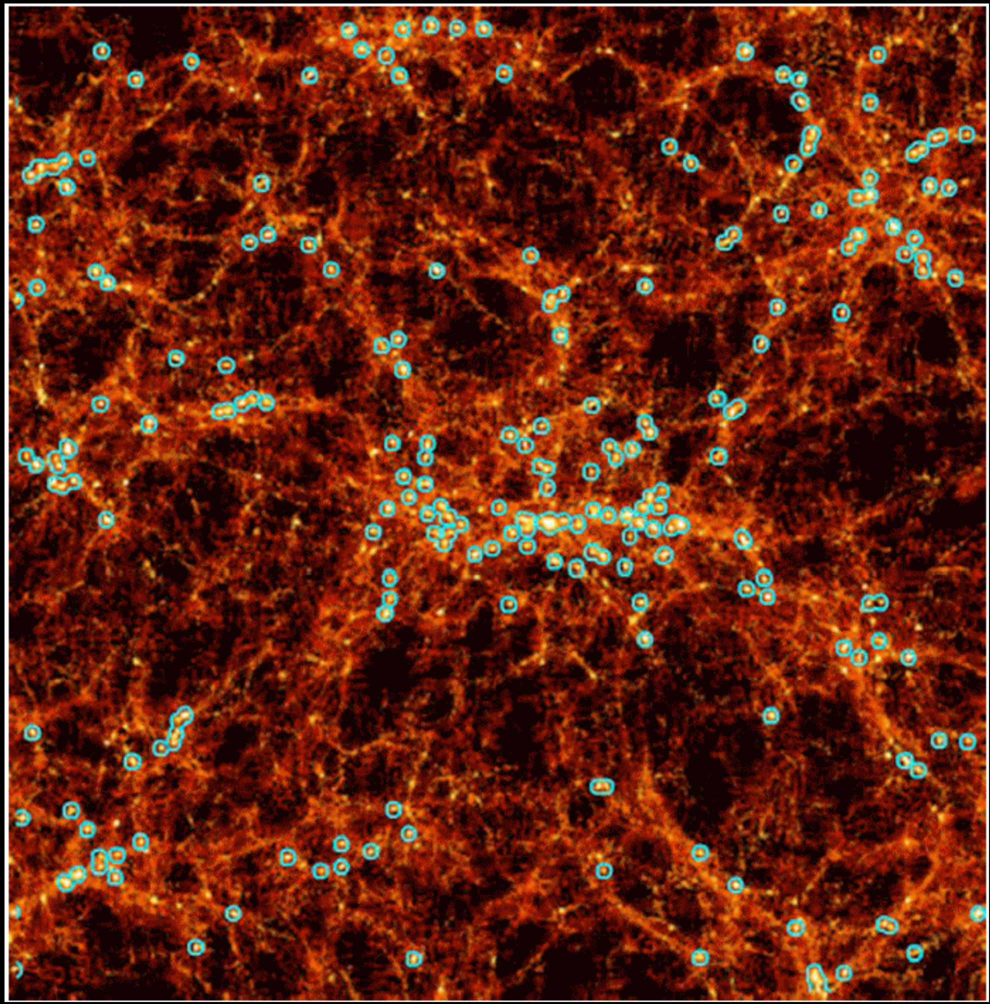


Connection to size bimodality ?

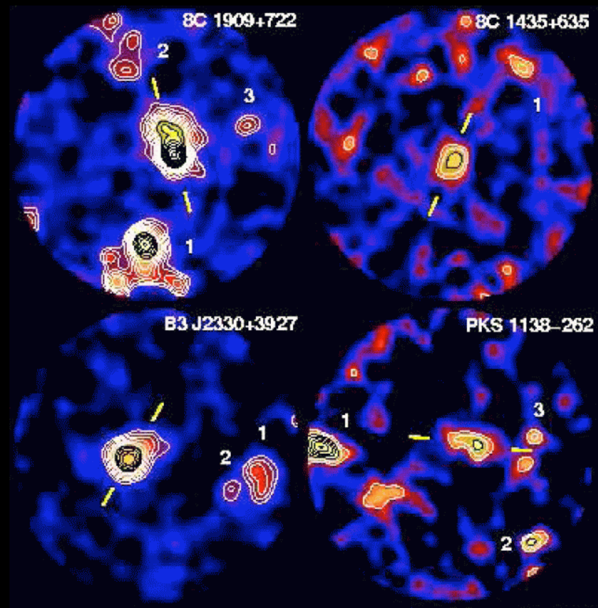
Uniquely possible at high-z exploiting the 200-450um window (Herschel will explore this first)

Correlations with specific SFR also expected, etc

Protoclusters: when/how massive cluster's galaxies were formed ?



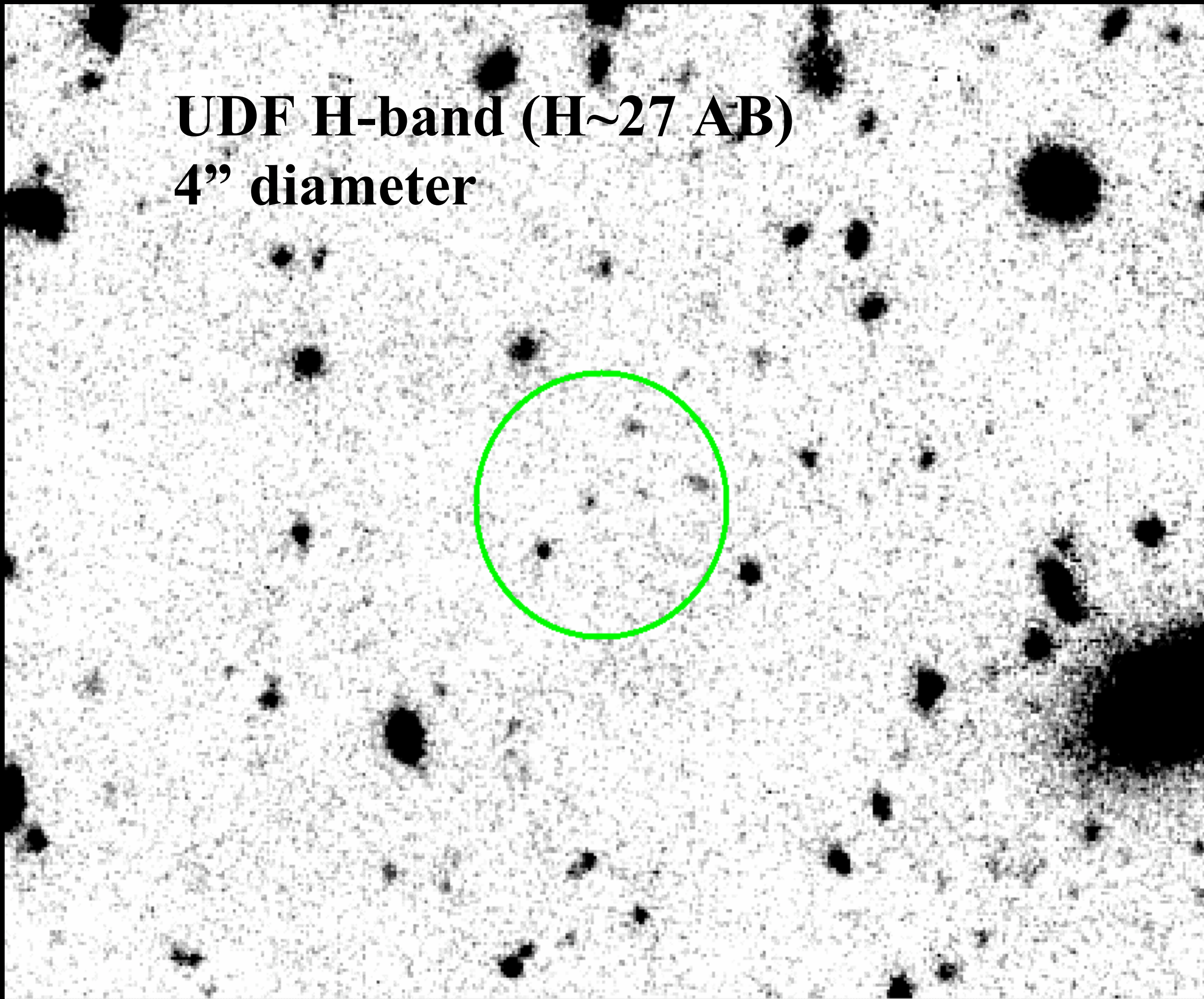
Governato et al 1998



Clemens et al 2003

It is not known yet to what Lbol levels progenitors can be found

Identification difficulties for very high-z starbursts ($z>4$—7):
negative K-correction does not apply to optical/UV rest



Deeper than Herschel 200-450um imaging might probe critical to correctly identify $z\sim4$—7 galaxies from, e.g., LMT surveys (e.g., for dedicated ALMA follow-up)

(better resolution and SED information)

DomeC possible difficulty for galaxy evolution studies: fields accessibility and multiwavelength complements

COSMOS field ~25 deg elevation max (NOT FEASIBLE)

GOODS-S/UDF (priority ALMA field): ~50 deg elevation max

Good visibility fields: (X-ray, Spitzer, radio, deep optical/NIR)
“Marano Field” -57 deg
Hubbe Deep Field South -62 deg

Will need ultra-deep follow-up of new fields with, e.g., VLT
and Southern facilities in general

Conclusions:

A) Clear opportunity window for new science in galaxy formation and evolution exist for 200-450um imaging at DomeC, crucial redshift range $1<z<3$ (or thereabout)

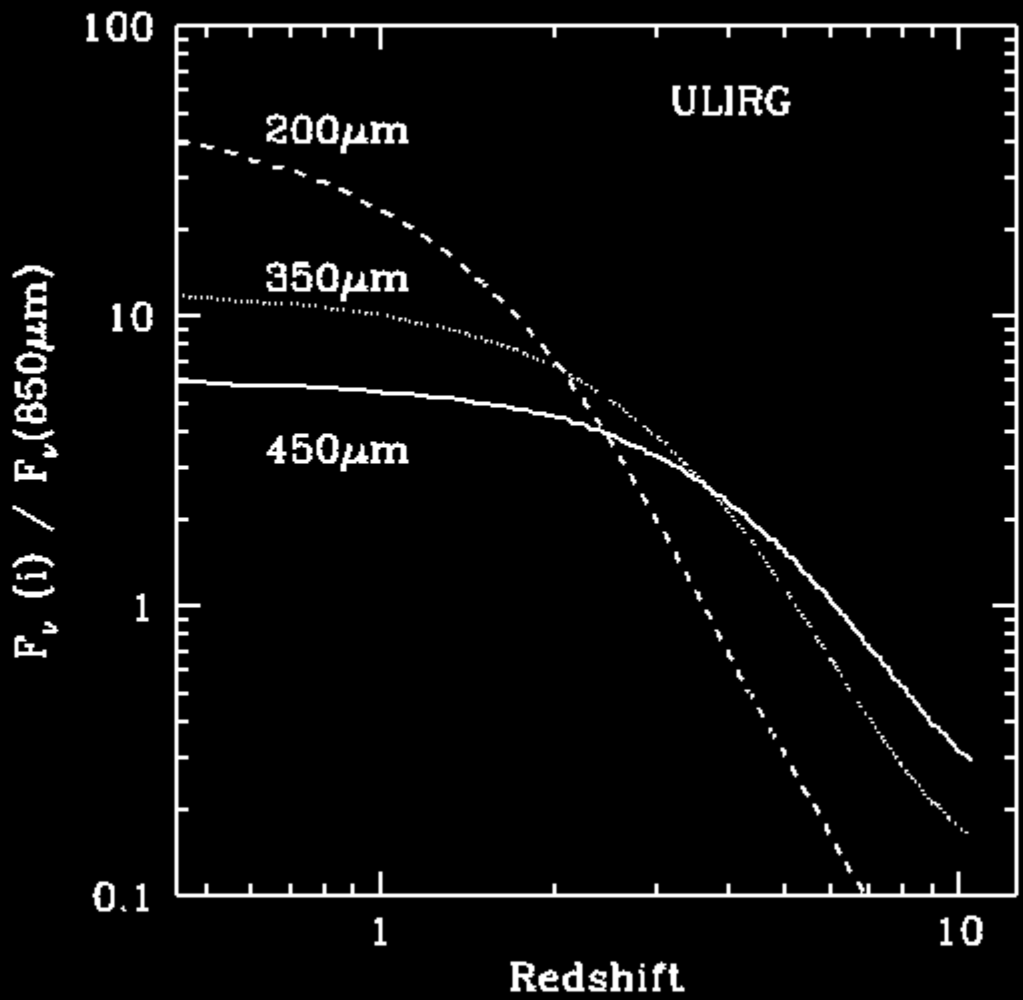
B) Possible to improve over Herschel+SPIRE in many respects, complementary to LMT and ALMA

C) SCUBA2 450um survey expensive to replicate with 12m telescope

D) Herschel PACS is better than 200um at DomeC for 12m telescope

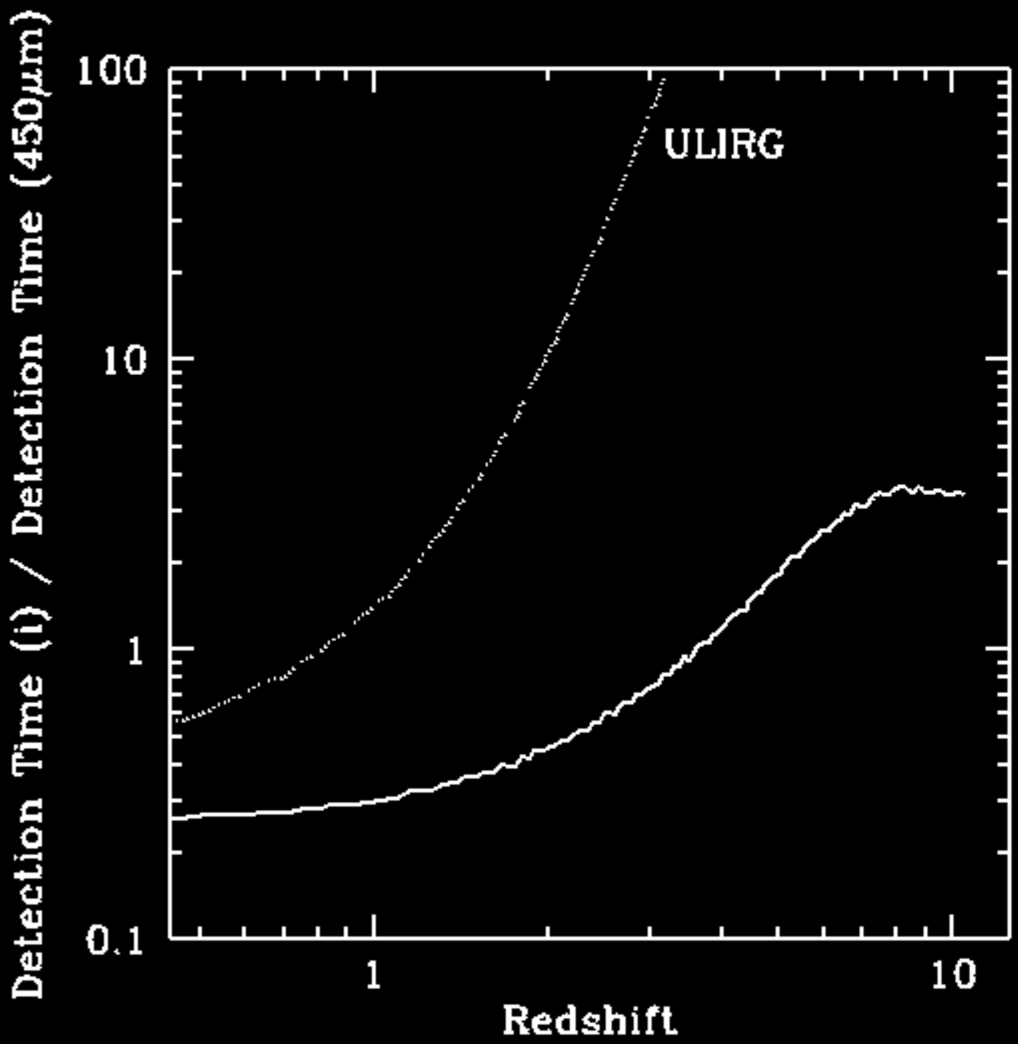
E) <u>Grand-goal of mapping SF and obscured AGN growth to typical levels within reach of a 25m telescope (would be a truly major accomplishment)</u>

F) Science cases strong, will be hot field still in 5-10 years from now (ALMA, JWST, etc) z<3-4 is favorite, after that flux sharply decrease beyond the peak

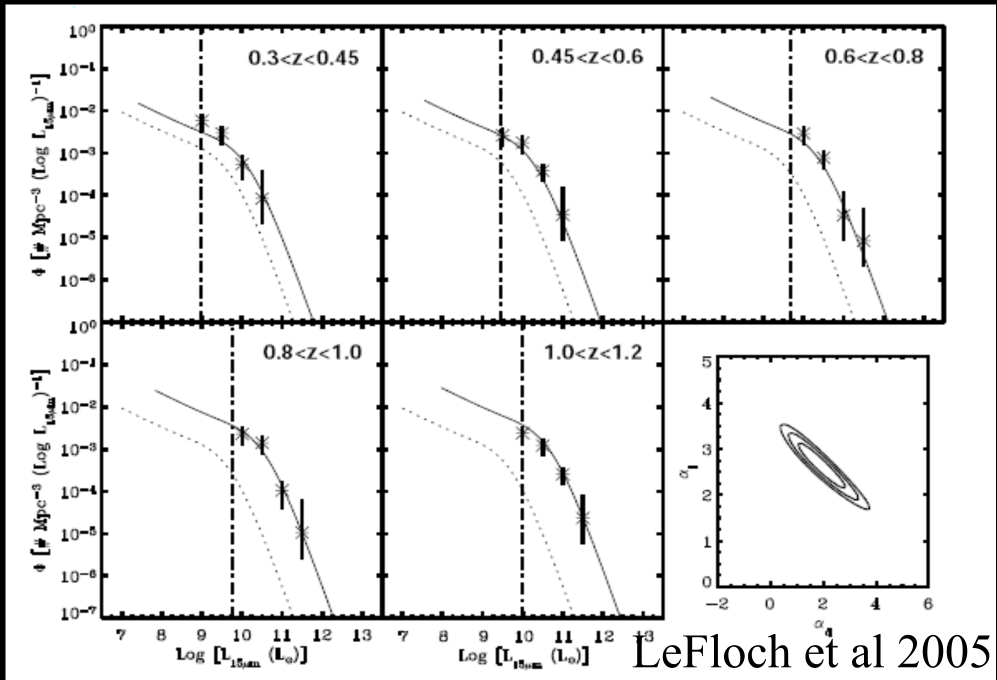


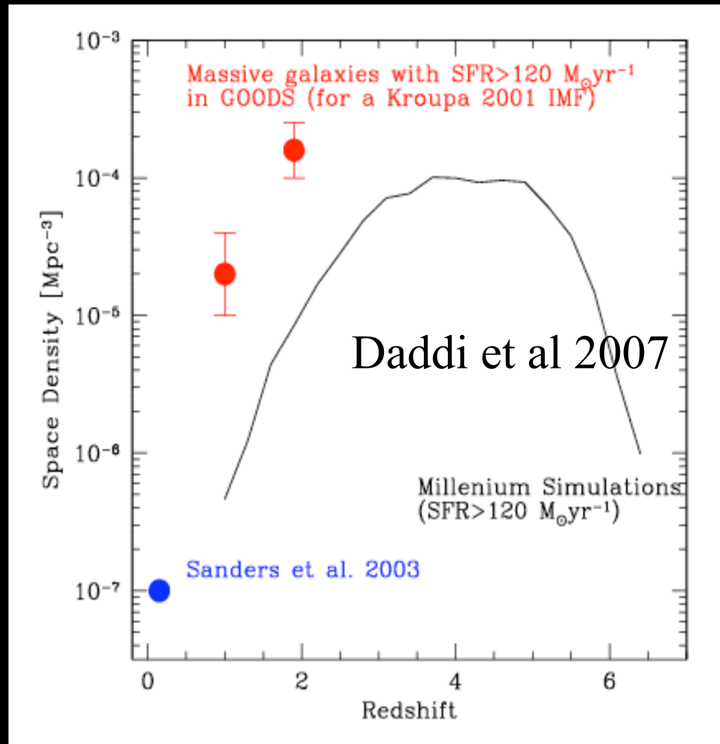
Ultra-high redshifts will be best done at longer wavelengths (SCUBA2, LMT, etc)

Which best band ? Using Vincent's figures for S/N and depths



Luminous starburst galaxies at high redshifts help the task of mapping distant star formation





Very rapid increase of space density with redshift
SED shapes, peak of the SED, LF evolution depths