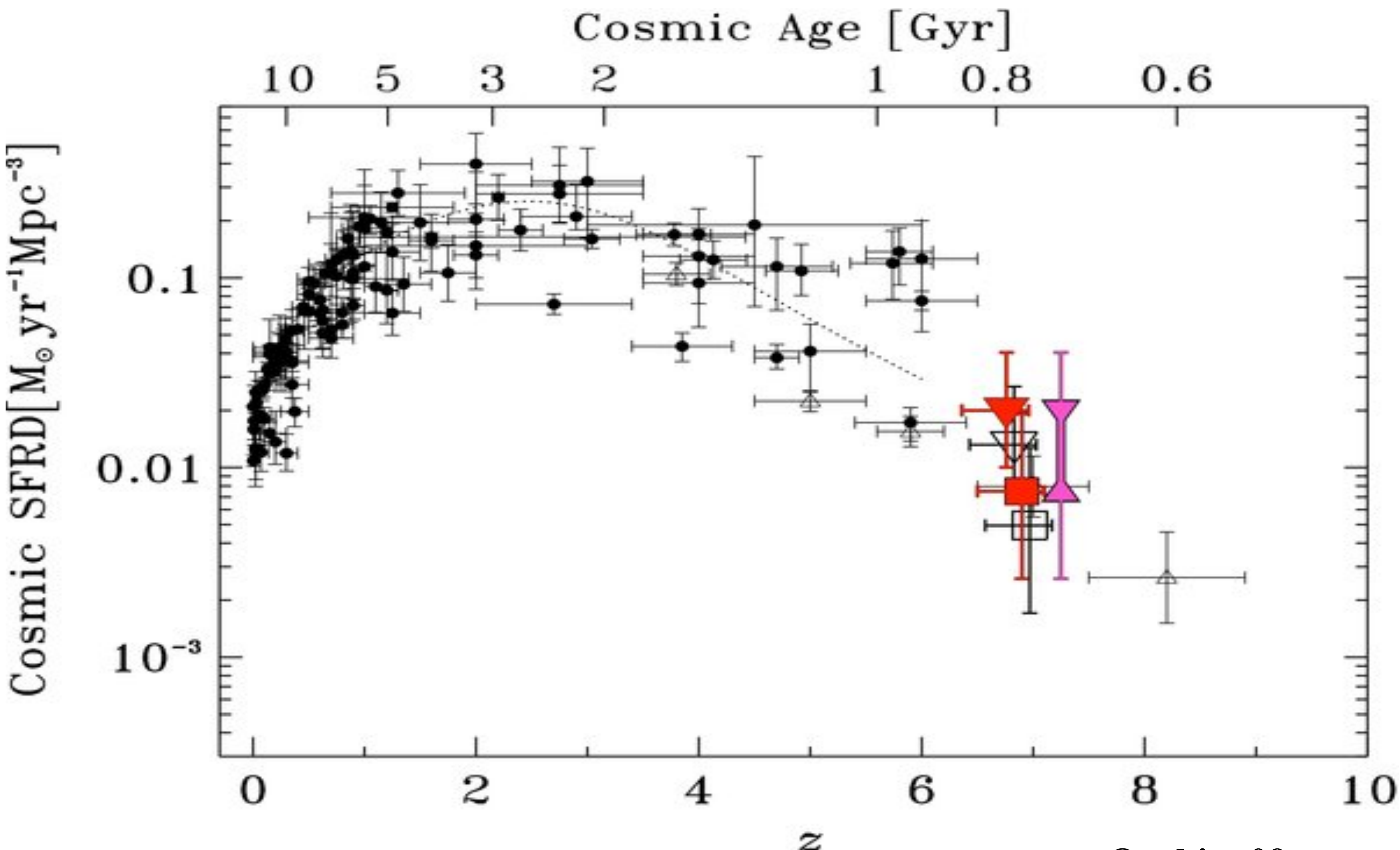
galaxy buildup and evolution
critically dependent on
star formation at high redshift



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Ouchi + 09

➔20x increase from z = 0 to 1

what is the cause of this buildup in activity out to z ~ 2

more gas (initial of accretion)
and/or
higher efficiency gas ➔ stars ??

- **more merging ?**
- **more disordered gas motions ?**

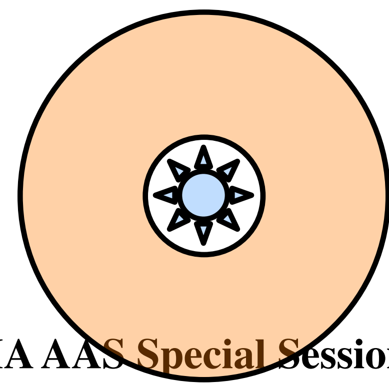
critical need : a robust, quick way to measure ISM contents

- **CO – slow and has the conversion factor uncertainties**
- **alternatively, measure dust IR continuum & dust / gas ratio**

a brief intro. to dust emission :

IR emission is opt/UV L from stars, reradiated in far IR

e.g. a central source of L, surrounded by dust --



IR emission from each radius determined by :

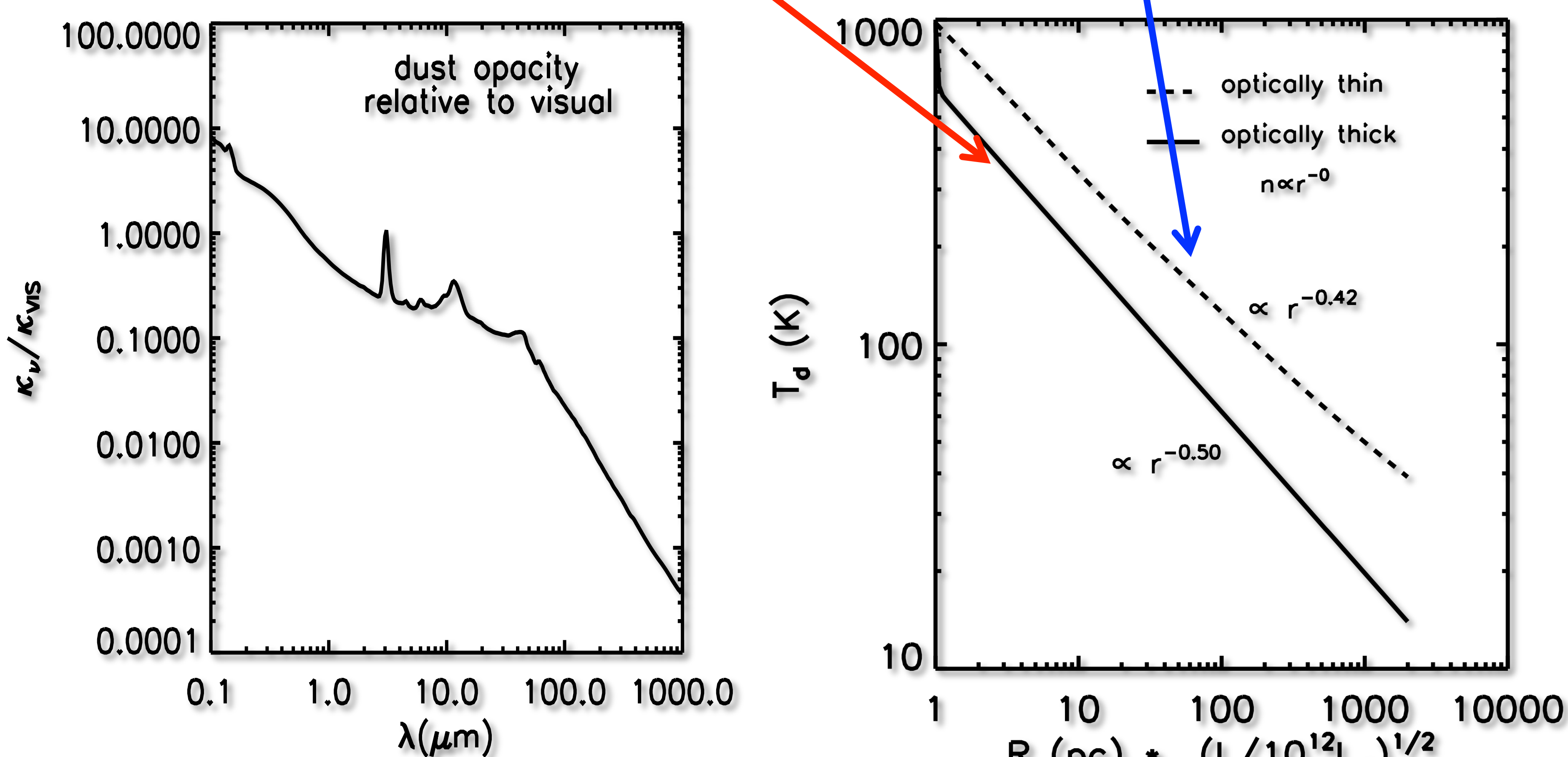
- **dust temp. and mass (R) +**
- **absorption by exterior dust**

radiative equilibrium of dust :

central L w/ power law radial dist. of dust

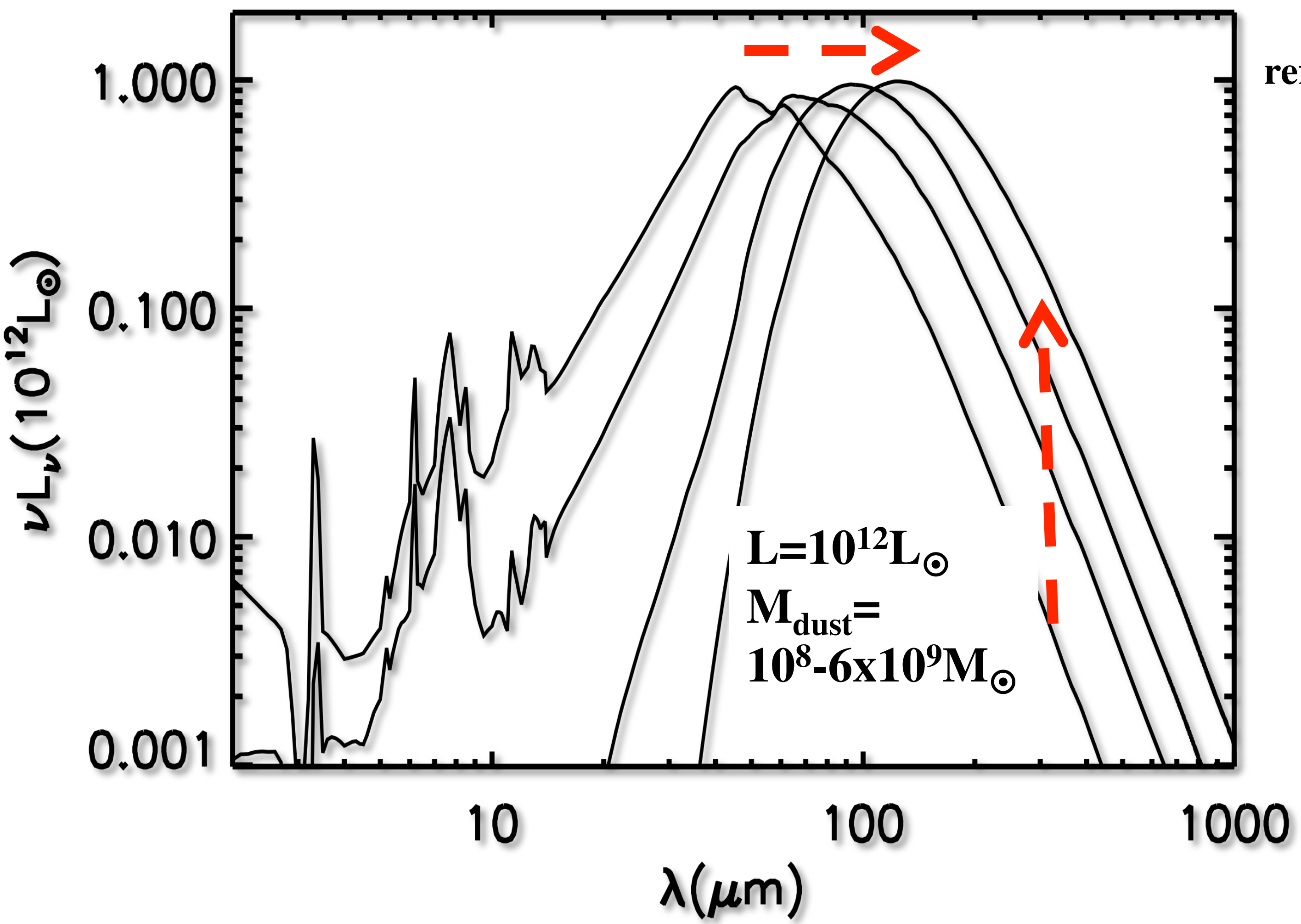
dust heated by : central source ($\tau < 1$)

& secondary reradiation ($\tau > 1$)



➔1 parameter problem : L / M_{dust}

emitted SED as function of dust mass



ref.: Scoville, 2011 Canary Is. winter school lectures

increasing opacity or M_{dust}

- peak shifts to longer λ for increased τ (or dust mass)
- <u>flux on long λ tail scales linearly with M_{dust}</u>

ALMA measurements of dust continuum to estimate ISM masses :

R-J tail is optically thin, therefore

$$F_\nu = \varkappa_\nu \, T_{dust} \, \nu^2 \, M_{dust} / (4\pi d_L{}^2)$$

T_{dust} = 20-25K in Gal. SF

= 30-50K in SB regions ➔ little dependence on T_{dust}

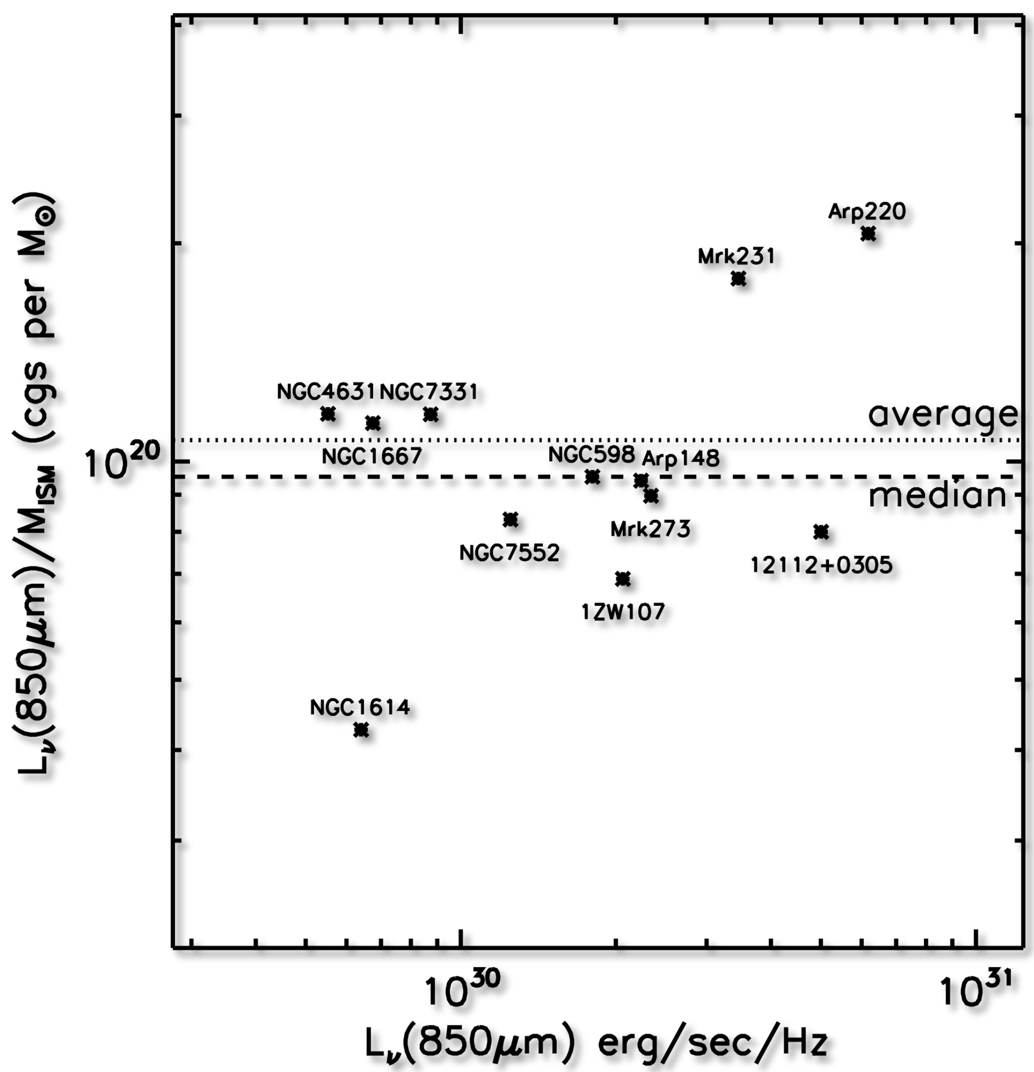
use obs. of nearby gal. with submm dust and ISM masses to calibrate : $\varkappa_\nu$ M_{ISM} / M_{dust}

use ALMA to measure F_ν

using local galaxies with total 850µm & ISM mass measures

(850µm from Dale '05, Clements '09, Dunne & Eales '09)

important that the local objects have total measurements



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from the previous plot , we can then predict fluxes at high z , if we know the spectral index on the RJ tail

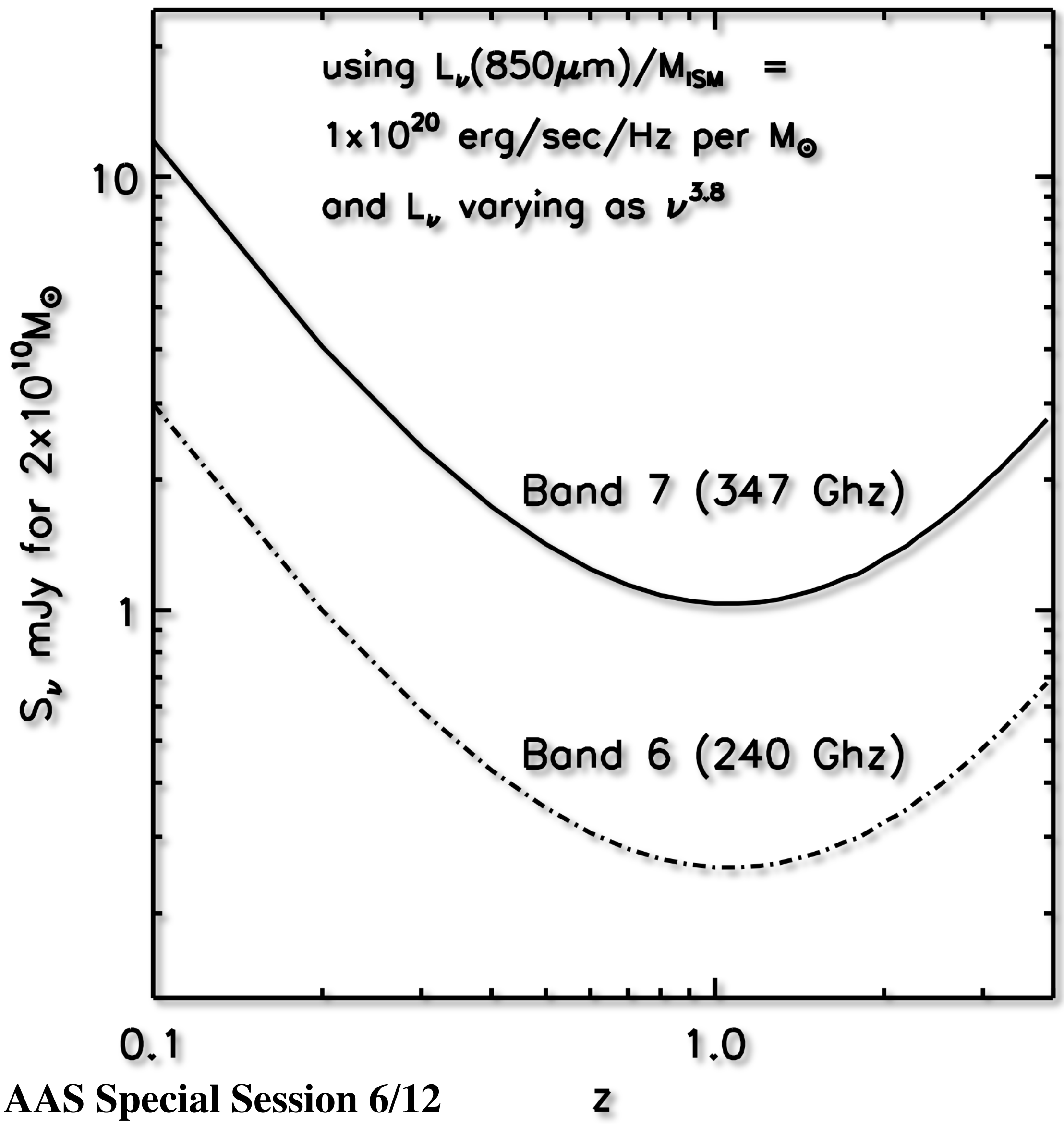
$$\alpha_{850} \equiv \frac{L_{\nu 850}}{M_{ISM}} \approx 1\text{x}10^{20}\, \text{erg / sec/ Hz / } M_{\Theta}$$

adopting $S_\nu \propto \nu^\beta$ for RJ tail w/ $\beta \approx 3.8$,

$$S_{\nu obs}(\text{mJy}) = 1.67 \frac{M_{ISM}}{2\text{x}10^{10} M_{\Theta}} (1+z)^{4.8} \left(\frac{\nu_{obs}}{350\text{GHz}}\right)^{3.8} \frac{1}{d_L{}^2(\text{Gpc})}$$

ref : Scoville 2011 Canary Islands Winter School lecture
Cambridge Univ. press (in press)

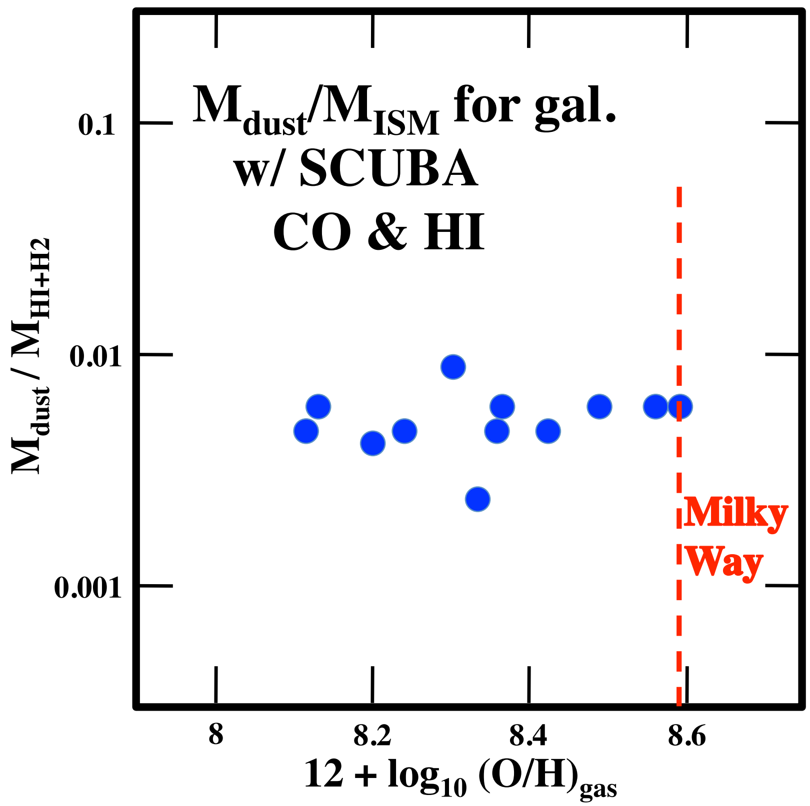
for ALMA BD 6 and 7 predict :



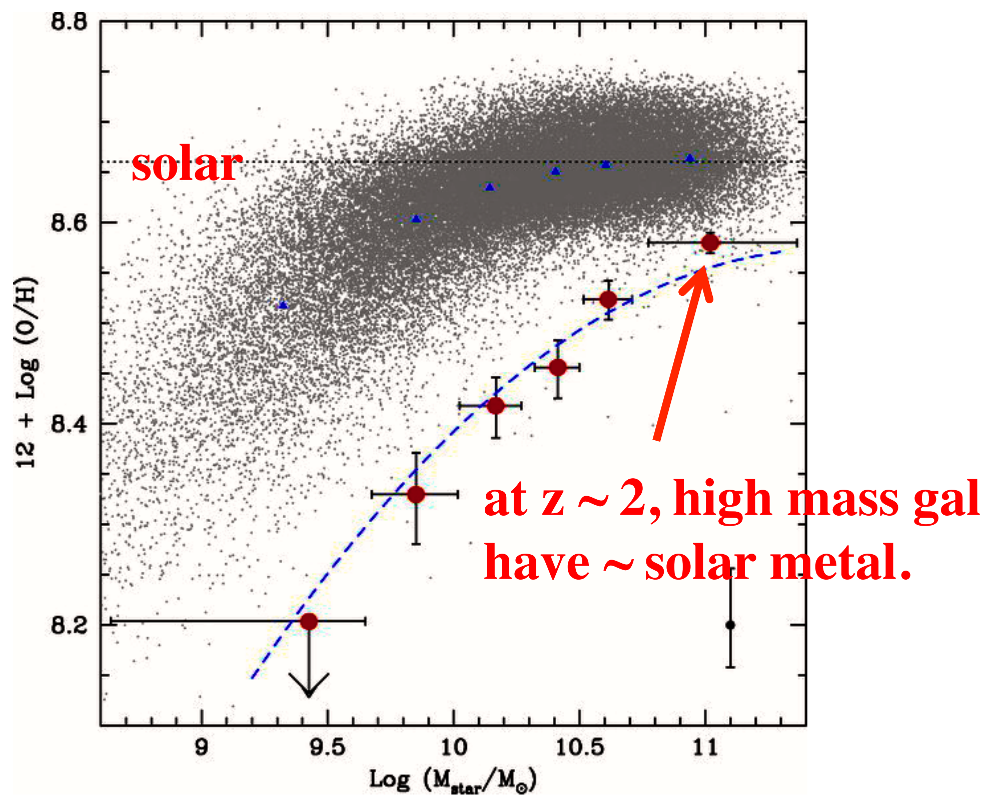
what about dust-to-gas ratio and lower metallicity at high z ?

doesn’t vary much for w/i factor
5 of MW metallicity

massive z ~2 galaxies
have nearly solar metallicity



Draine et al 2007



Erb etal 2006

ALMA Cycle 0 Project :

Evolution of the ISM Contents of Massive Galaxies z = 2.2 to 0.3

Nick Scoville, Kartik Sheth; Herve Aussel; Jeyhan Kartaltepe; Dave Sanders; Swarnima Manohar; Brant Robertson; Peter Capak; Simon Lilly

120 galaxies from COSMOS

stellar mass-selected : $M_{stellar} = 8x10^{10} - 2x10^{11}\ M_{\odot}$

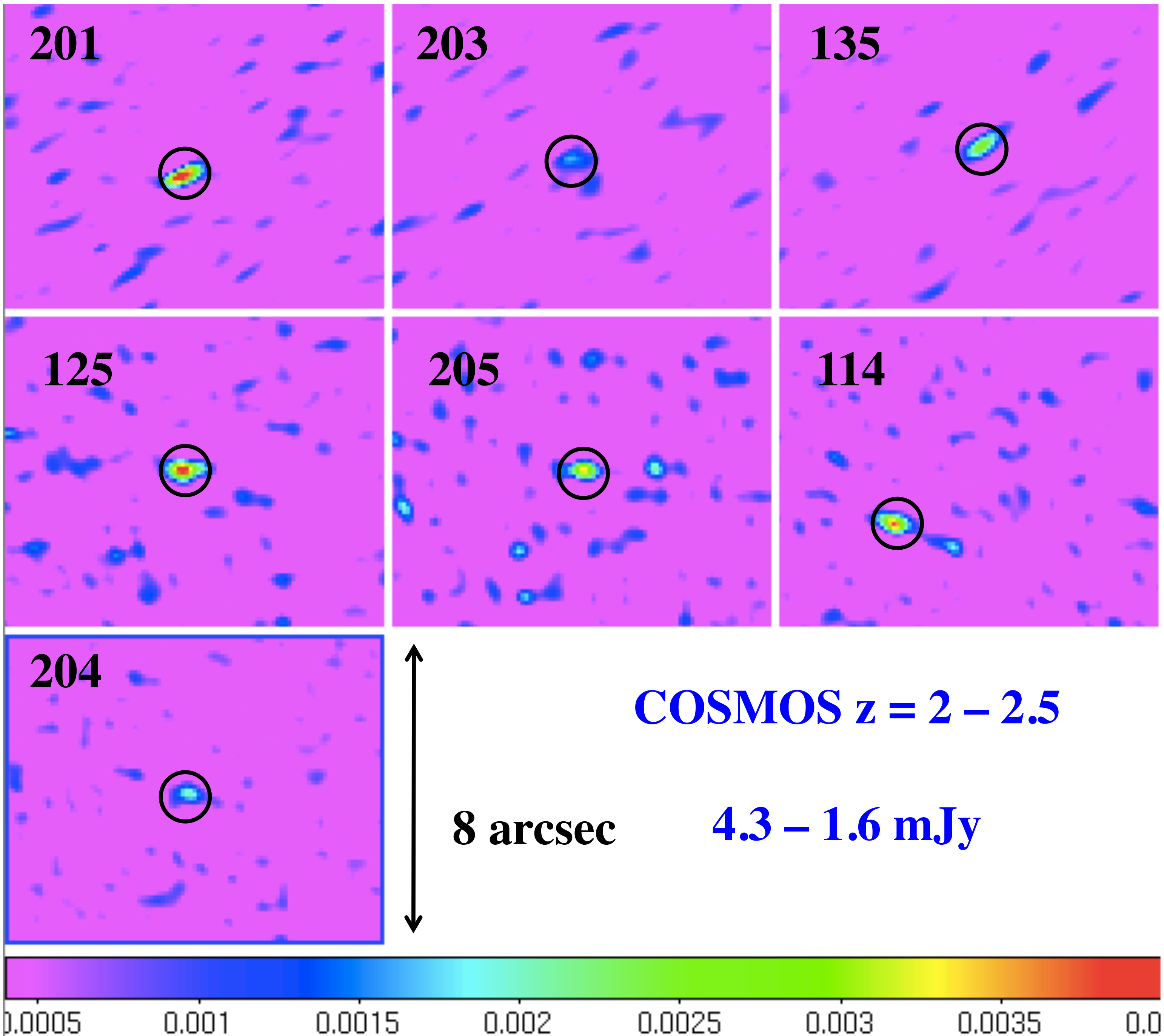
three galaxies samples from COSMOS survey

z ~ 0.3 (3.7 Gyr) 40 gal. 1 min (0.5 mJy rms)

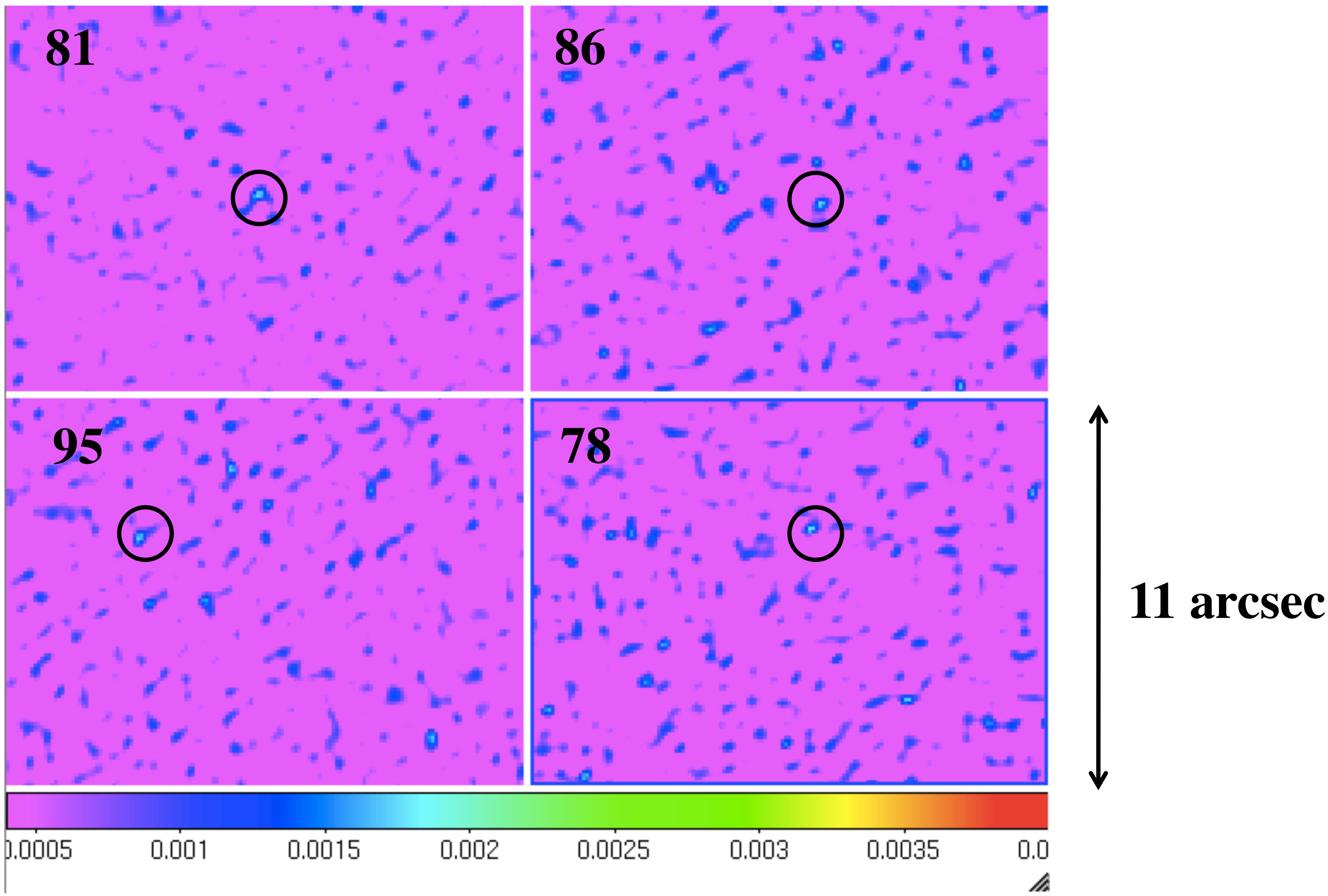
z ~ 0.8 – 1 (7.7 Gyr) 40 gal. 2 min

z ~ 2 – 2.5 (10.5 Gyr) 40 gal. 4 min (0.3 mJy rms)

preliminary data released just last week ...


201
203
135
125
205
114
204
8 arcsec
COSMOS z = 2 – 2.5
4.3 – 1.6 mJy
0.0005
0.001
0.0015
0.002
0.0025
0.003
0.0035
0.0

COSMOS z = 0.8 – 1



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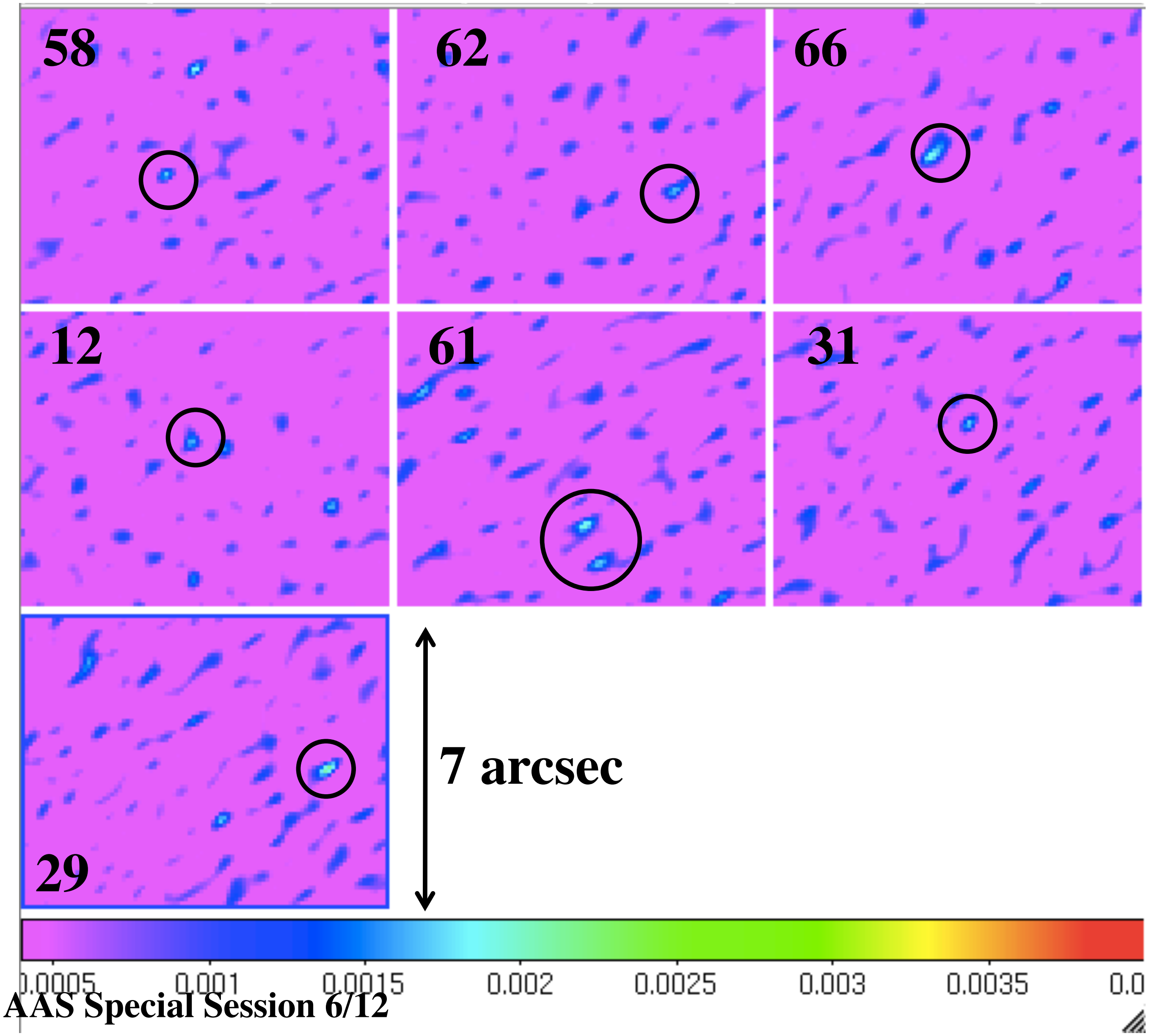
COSMOS z = 0.2 – 0.5



ALMA cycle 0 is able to measure dust continuum w/i few min.

➔ enables measurement of ISM masses in large samples of galaxies at high z

next step :

look for variation in M_{gas} / $M_{stellar}$ as function of :

- **$M_{stellar}$**
- **z (cosmic epoch)**
- **environment**
- **SF activity**