Multiwavelength Views of the ISM in High-Redshift Galaxies,
Santiago, 27/06/2011

"High-redshift dust emission and CO emission predictions for ALMA"

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TAMASIS project

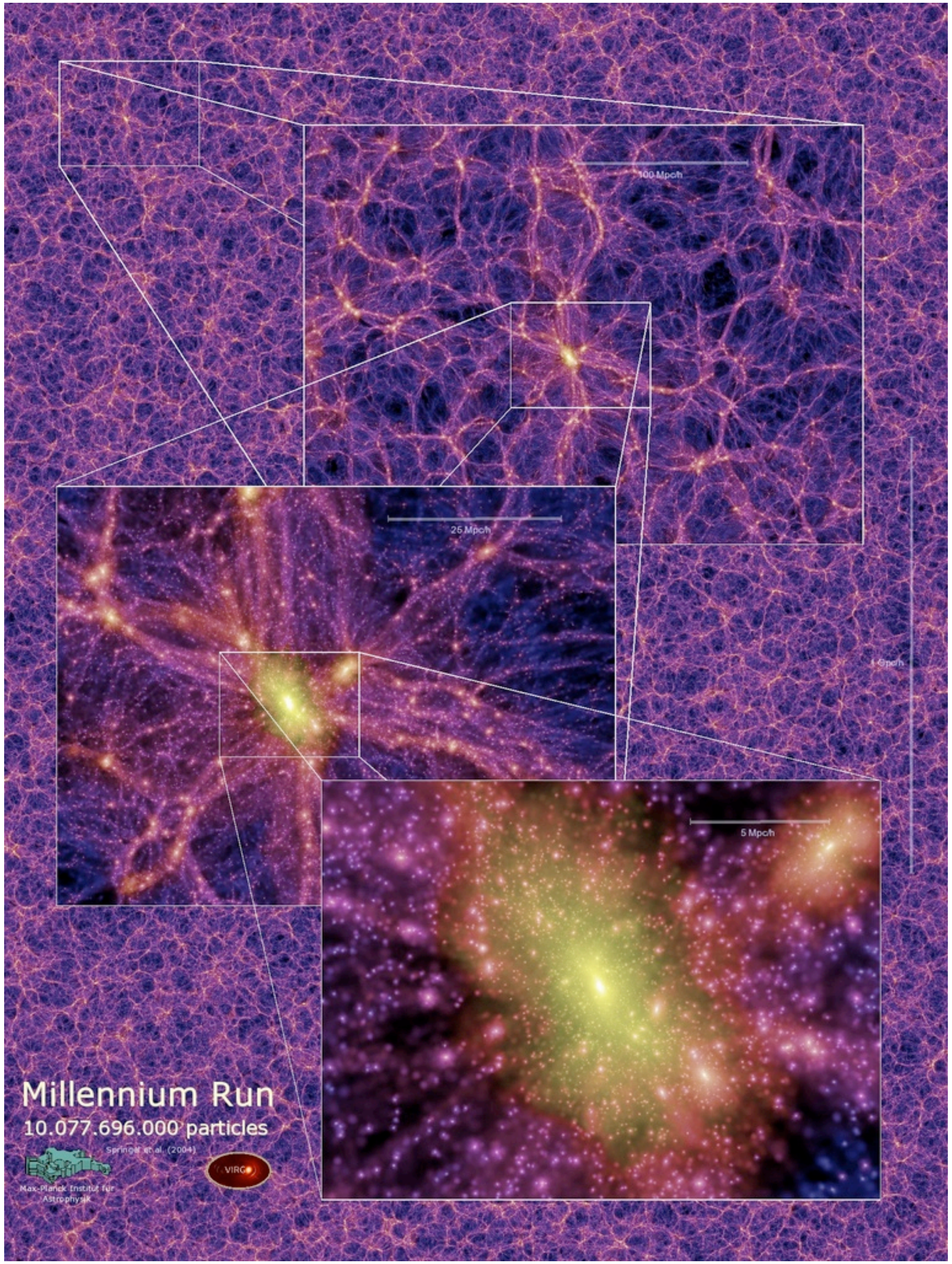
- People:
    - ESO (Eelco van Kampen)
    - CE Saclay (Marc Sauvage, Pierre Chanial, Barbey Nicolas)
    - IAS Orsay (Abergel Alain)
    - Leiden (Paul van der Werf, Meijerink Rowin)

- Generate tools to produce mock sub-mm maps predictions for Herschel, SCUBA-2 & ALMA.

Models

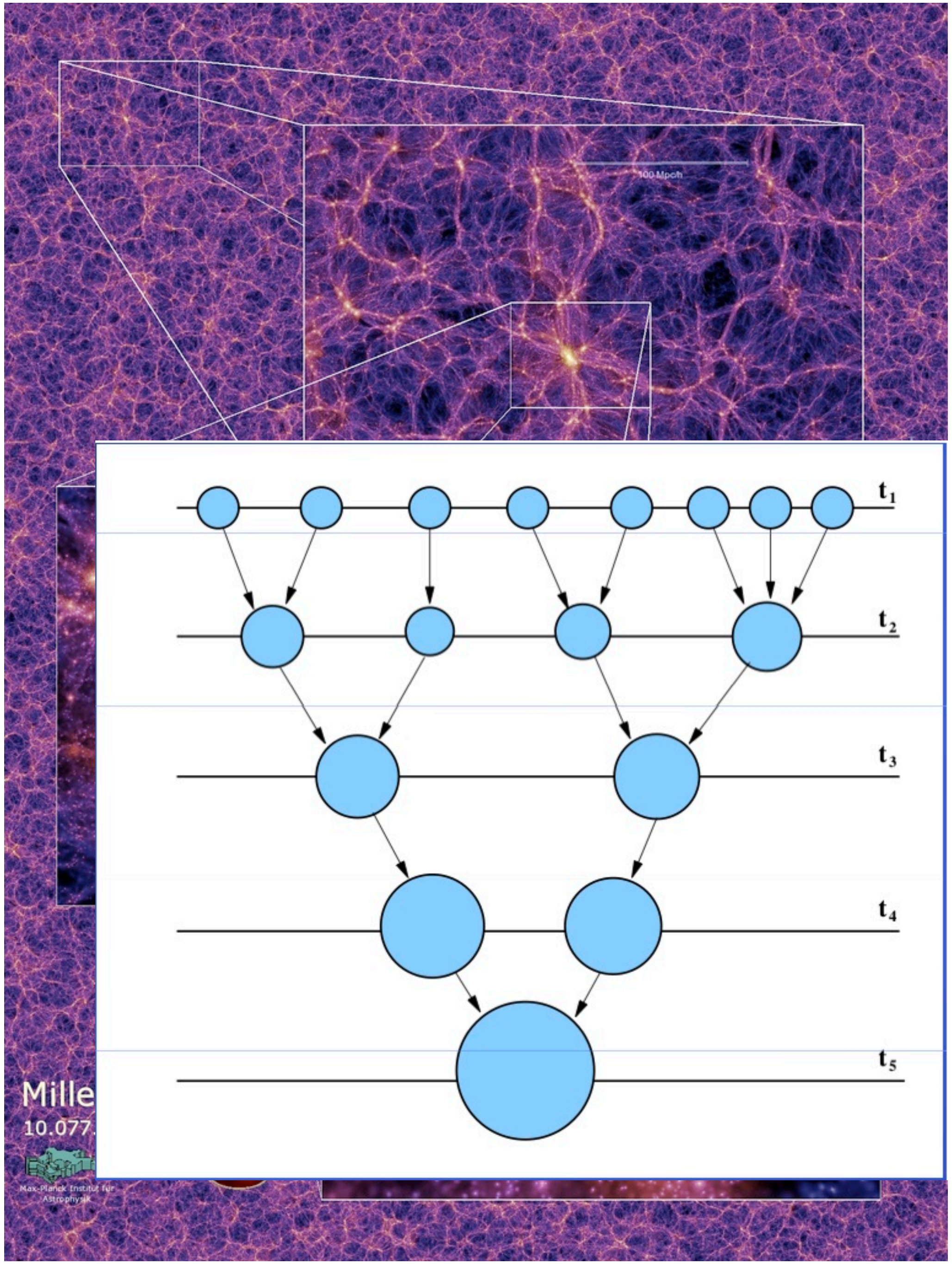
- Semi-analytical models:
  - DM evolution (numerical simulations)
  - BM evolution (analytic simulation)

- Semi-analytical models: Dark Matter:
  - Millennium simulation:
  - 10^{10} particles to follow the dark matter distribution
  - cubic region $500h^{-1}$Mpc on a side
  - 63 outputs in redshift



Models

- Semi-analytical models: Baryonic Matter:
  - Set of “equations” for each physical process considered (e.g. Star formation, SN feedback, galaxy mergers, stellar population evolution, dust extinction & emission).
  - Catalogue with galaxy properties and positions inside the volume.



Splitting the Interstellar Medium

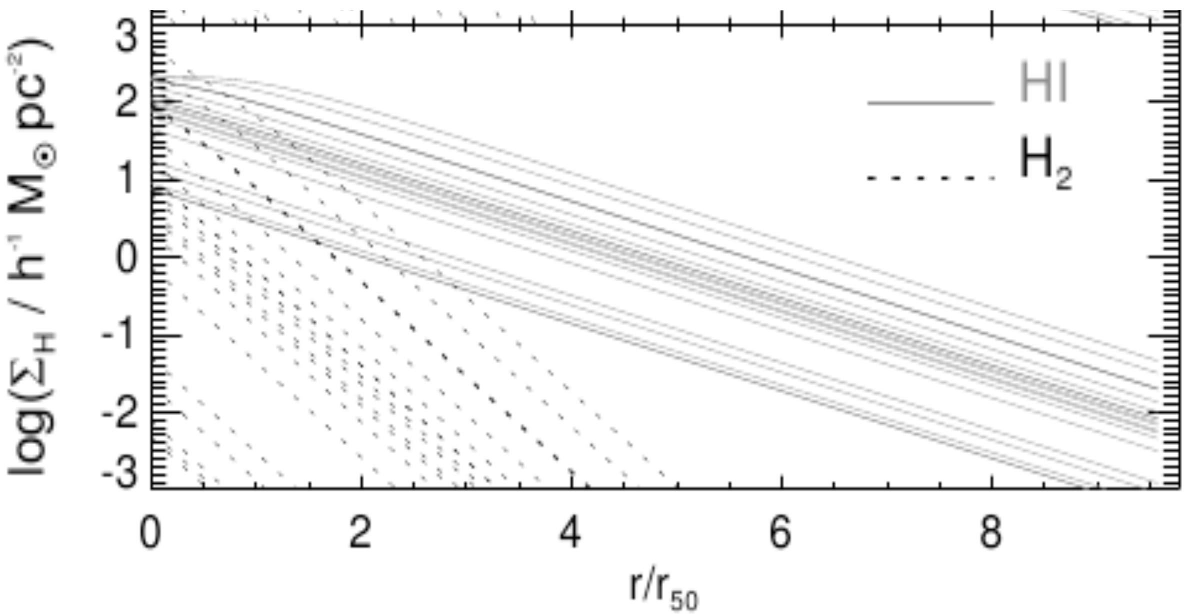
Durham GALFORM semi-analytic model

- Compute atomic and molecular hydrogen components

$$\Sigma_{\rm SFR} = \nu_{\rm SF}\, \Sigma_{\rm mol}$$

$$\frac{\Sigma(\mathrm{H}_2)}{\Sigma(\mathrm{HI})} = \left(\frac{P_{\rm ext}}{P_0}\right)^{\alpha}$$

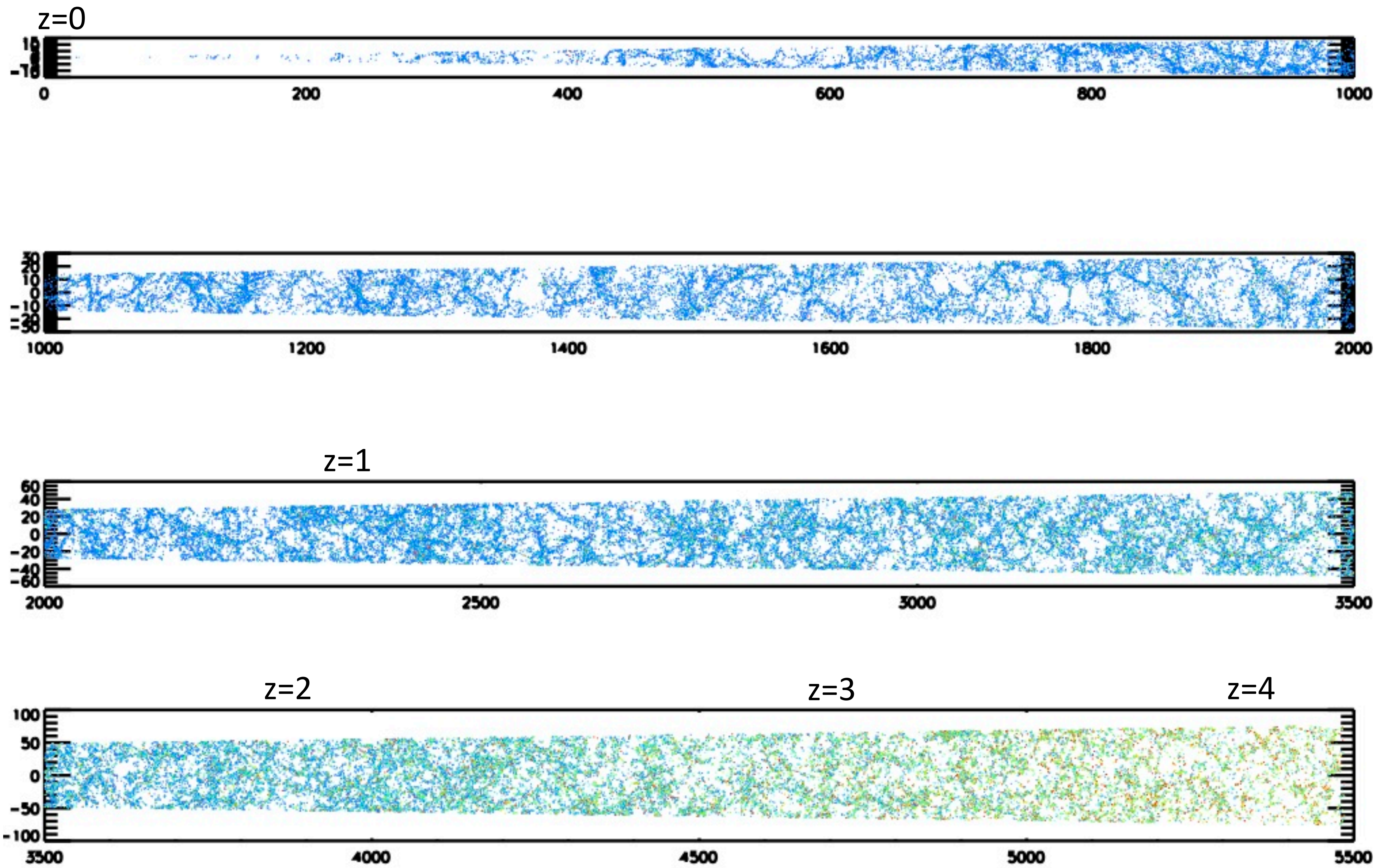
The Blitz & Rosolowski law



Lagos+ 2011, preprint.

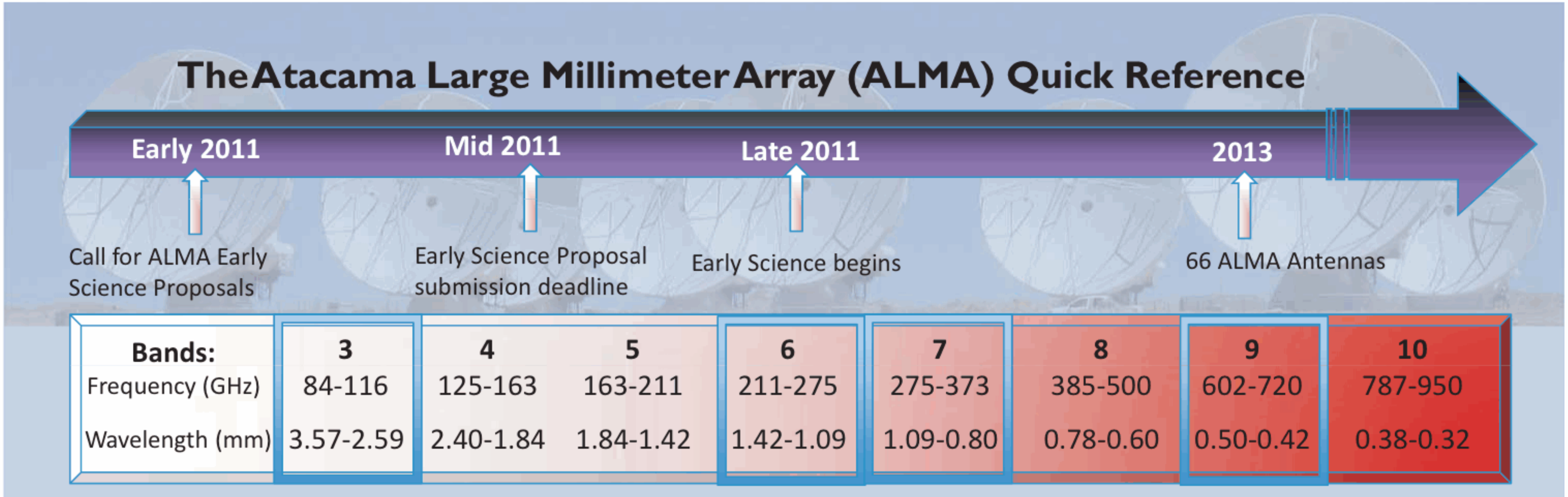
Lightcone properties

- The orientation of the lightcone is given by the vector: (3, 4, 1).
- With no repetition of galaxies in the Simulation:
  - Gives a area of about 2 square deg.
  - Out to z~4.2



Each point represents a galaxy: $\frac{\sum_{H_2}}{\sum_{H_I}} = 0$ (blue) $\frac{\sum_{H_2}}{\sum_{H_I}} = 2$ (red)

In ALMA:



For band 3 we can identify transitions:

- CO (2->1) [230.5Ghz] [1301µm] in redshift range: z= 1 -> 1.7
- CO (3->2) [345.8Ghz] [867.5µm] in redshift range: z= 2 -> 3.1
- CO (4->3) [461.0Ghz] [650.8µm] in redshift range: z= 3 -> 4.5

The Atacama Large Millimeter Array (ALMA) Quick Reference

Early 2011 – Call for ALMA Early Science Proposals

Mid 2011 – Early Science Proposal submission deadline

Late 2011 – Early Science begins

2013 – 66 ALMA Antennas

Bands:	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Frequency (GHz)	84-116	125-163	163-211	211-275	275-373	385-500	602-720	787-950
Wavelength (mm)	3.57-2.59	2.40-1.84	1.84-1.42	1.42-1.09	1.09-0.80	0.78-0.60	0.50-0.42	0.38-0.32

	Early Science	Array Completion
Antennas	≥16 x 12m	At least 54 x 12m & 12 x 7m
Bands	Bands 3, 6, 7, 9	Bands 3, 4, 6, 7, 8, 9 & 10
Maximum Bandwidth	16 GHz (2 polarizations x 8 GHz)	
Correlator Configurations	21 (0.02 – 40 km/s)	71 (0.01 – 40 km/s)
Maximum Angular Resolution	$0.02'' \left(\frac{\lambda}{1\text{ mm}}\right)\left(\frac{10\text{ km}}{\text{Max Baseline}}\right)$	
Max Baseline	250m (may achieve 500m)	15 km
Continuum Sensitivity (60 sec, Bands 3–9)	~0.2 – 4.2 mJy	~0.05 – 1 mJy
Spectral Line Sensitivity (60 sec, 1 km/sec, Bands 3–9)	~30 – 250 mJy	~ 7 – 62 mJy

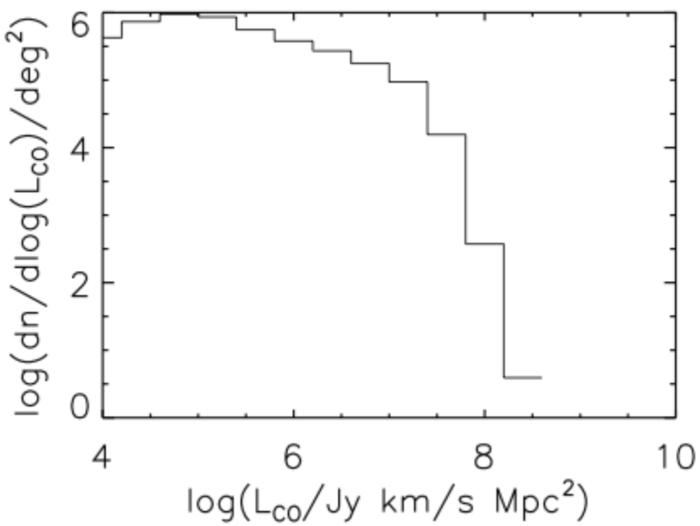
Sensitivity Calculator: http://science .nrao.edu/alma/tools.html

CO Lines estimations

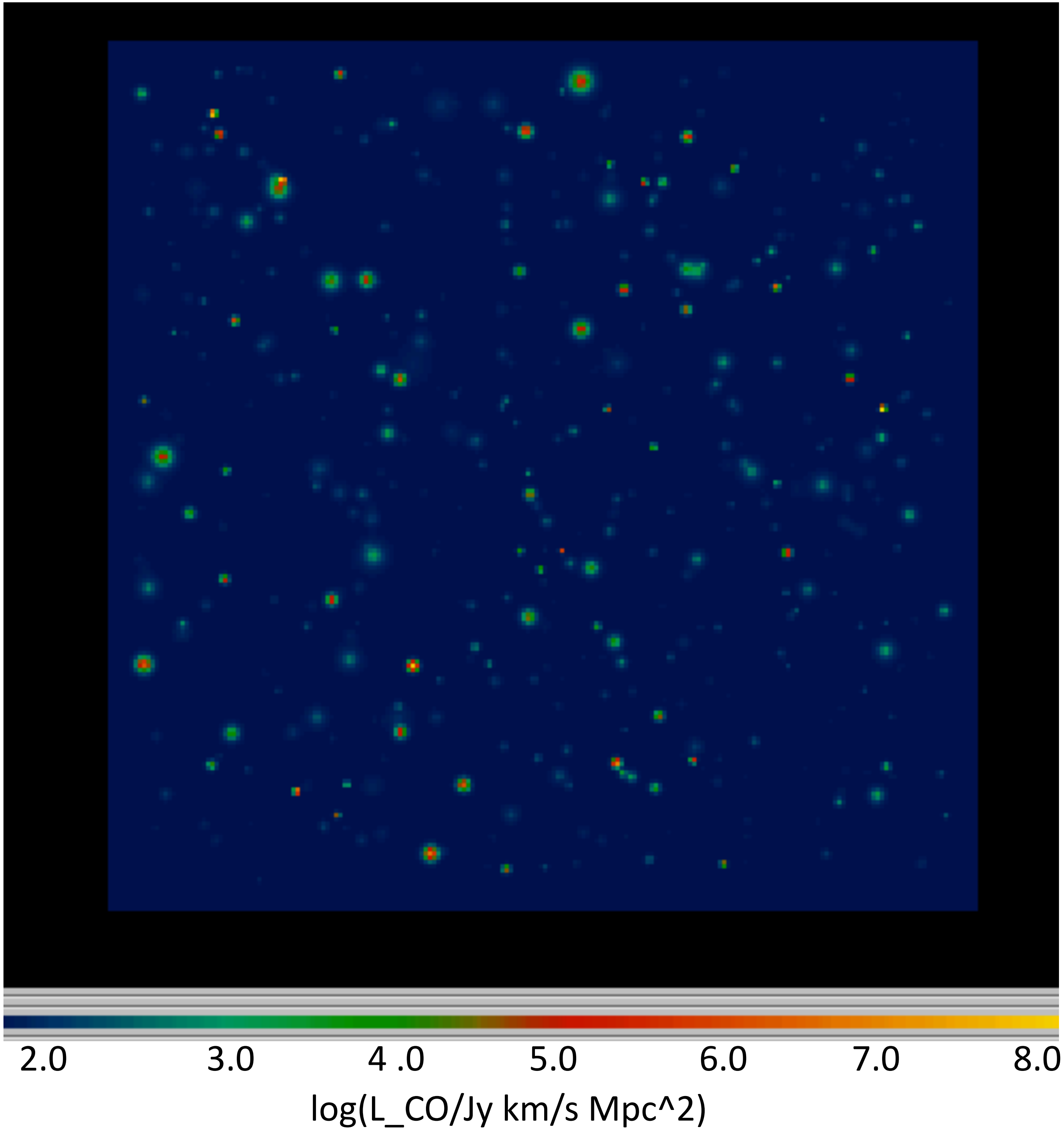
To convert the amount of molecular Hydrogen to CO luminosities we apply standard conversion factors:

$$I_{\rm CO}/{\rm K\,km\,s^{-1}} = \frac{N_{\rm H_2}/{\rm cm^{-2}}}{{\rm X}\times 10^{-20}}.$$

First, we use the assumption made in Lagos+ 2011 for transition 1->0
CO (1->0) X=3.5 for quiescent-galaxies (e.g. Boselli+ 2002, Blitz+ 2007)
and X=0.5 for burst-galaxies (e.g. Meier & Turner 2004)

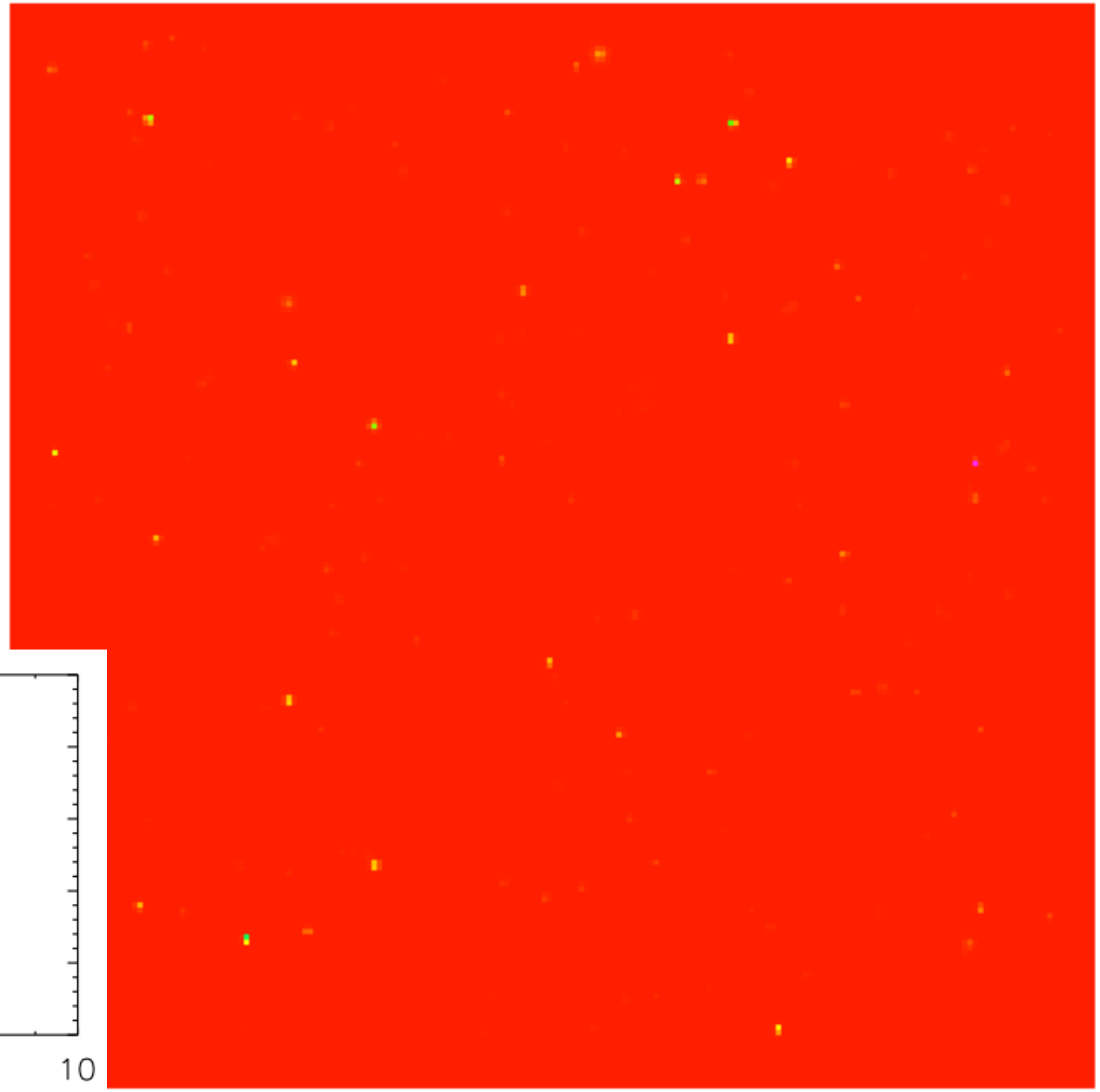


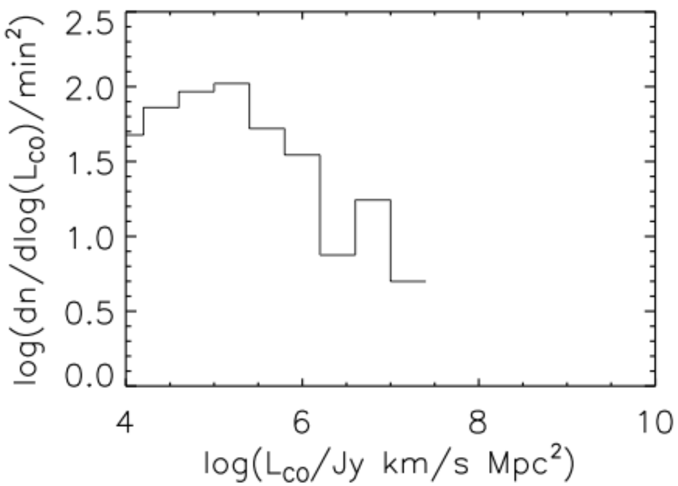
Then, we take L_CO(3 –> 2) ≈ 0.6 × L_CO(1–>0) (Harris+ 2010) : burst galaxies
L_CO (3-> 2) ≈ 1 x L_CO(1->0) (Zhu+ 2009): quiesc. galaxies

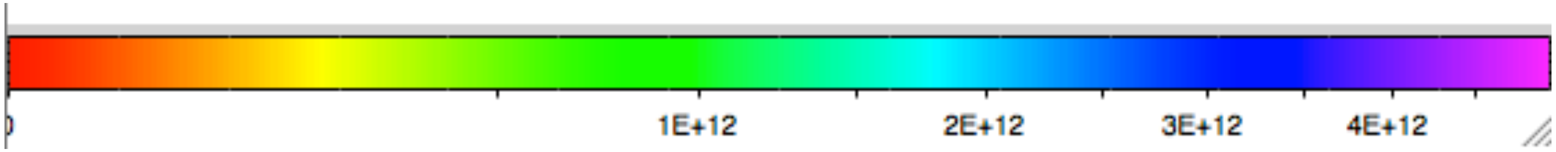

2.0
3.0
4 .0
5.0
6.0
7.0
8.0
log(L_CO/Jy km/s Mpc^2)

60'' by 60''

CO(3->2)
Band 3 ALMA≈

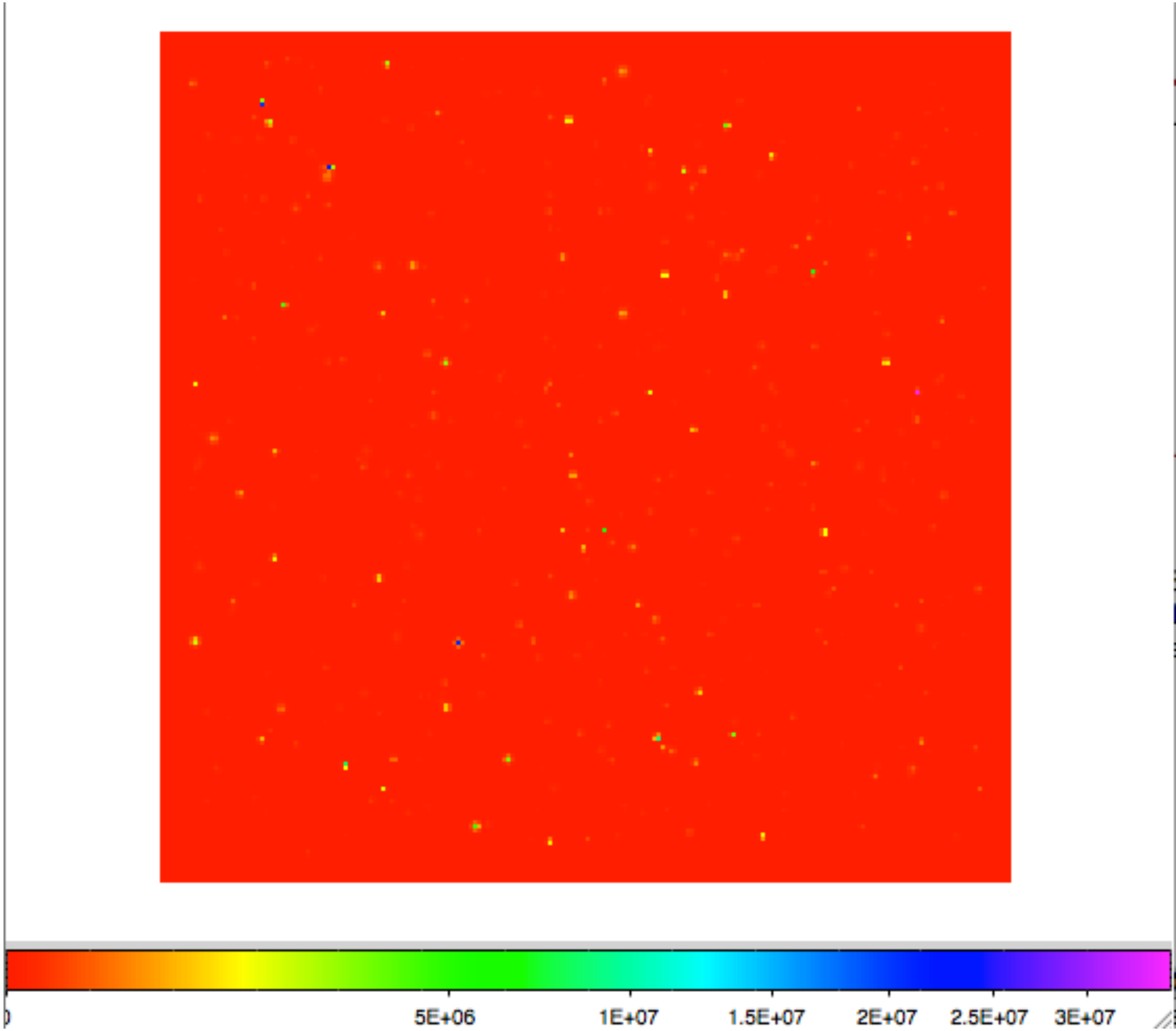






60’’ by 60’’

CO(3->2)
Band 3 ALMA≈



(L_CO/Jy km/s Mpc^2)

Summary

- Splitting the ISM into the atomic and molecular hydrogen, we can study the evolution of the ratio $\frac{\sum_{H_2}}{\sum_{H_I}}$
- By assuming a simple conversion we can make predictions for the observation of the CO lines at high-z with ALMA,
- New observations will allow to refine these conversions.