Atomic & Molecular lines with the SKA

The SKA contribution to galaxy formation and evolution

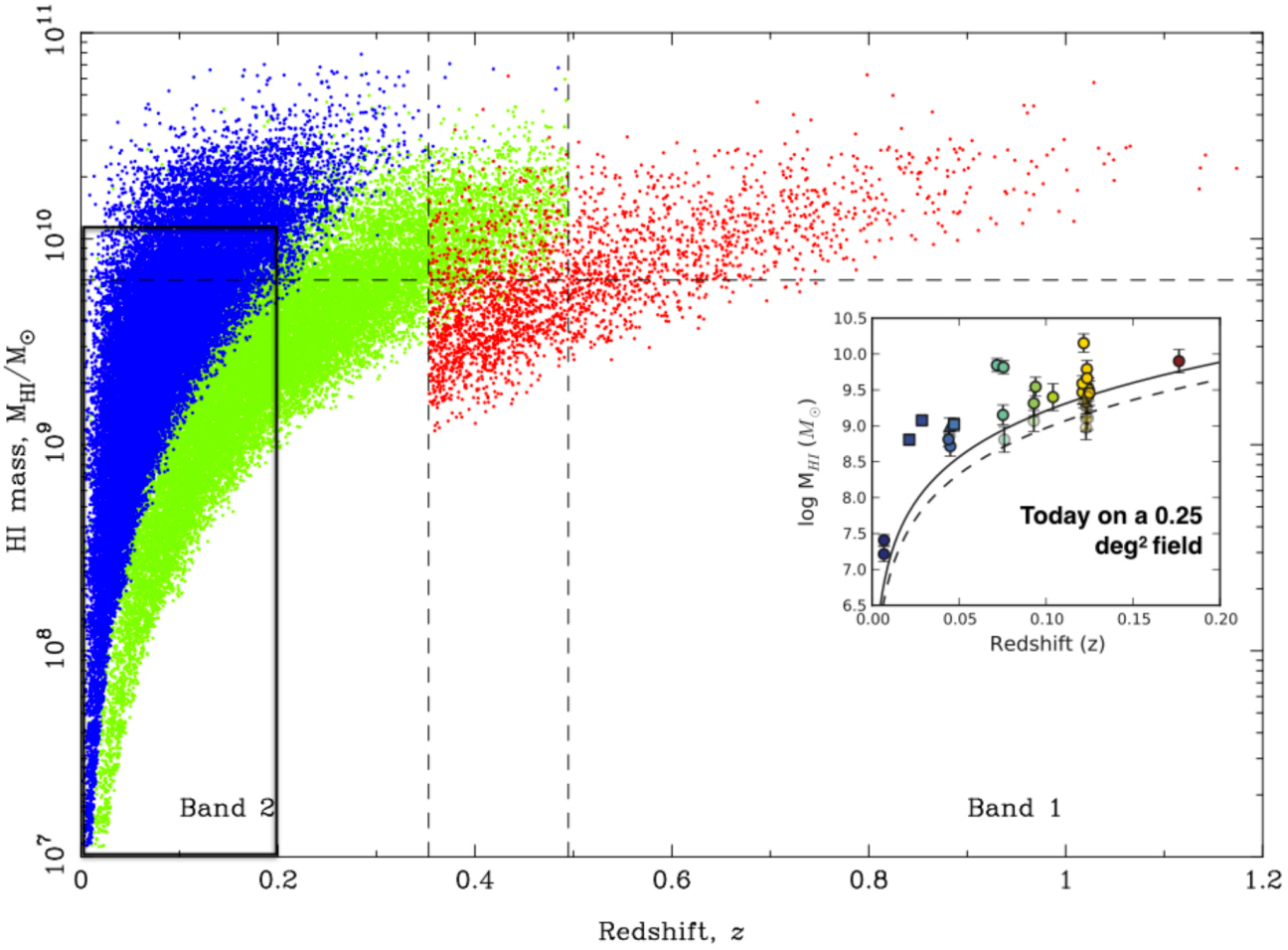
SKA1: HI to z=1 SKA2: to z=2—3 (potentially)

SKA1: up to 16 GHz, SKA2: up to 24 GHz
CO(1-0) [→H2] from z=3.8 and higher

SKA: continuum →SFRs to the highest redshifts

E. Daddi (AIM - CEA Saclay)
Thanks to F. Combes, P-A Duc

The revolution in HI sampling: orders of mag improvement
Respect to the current situation in numbers and depth/redshifts



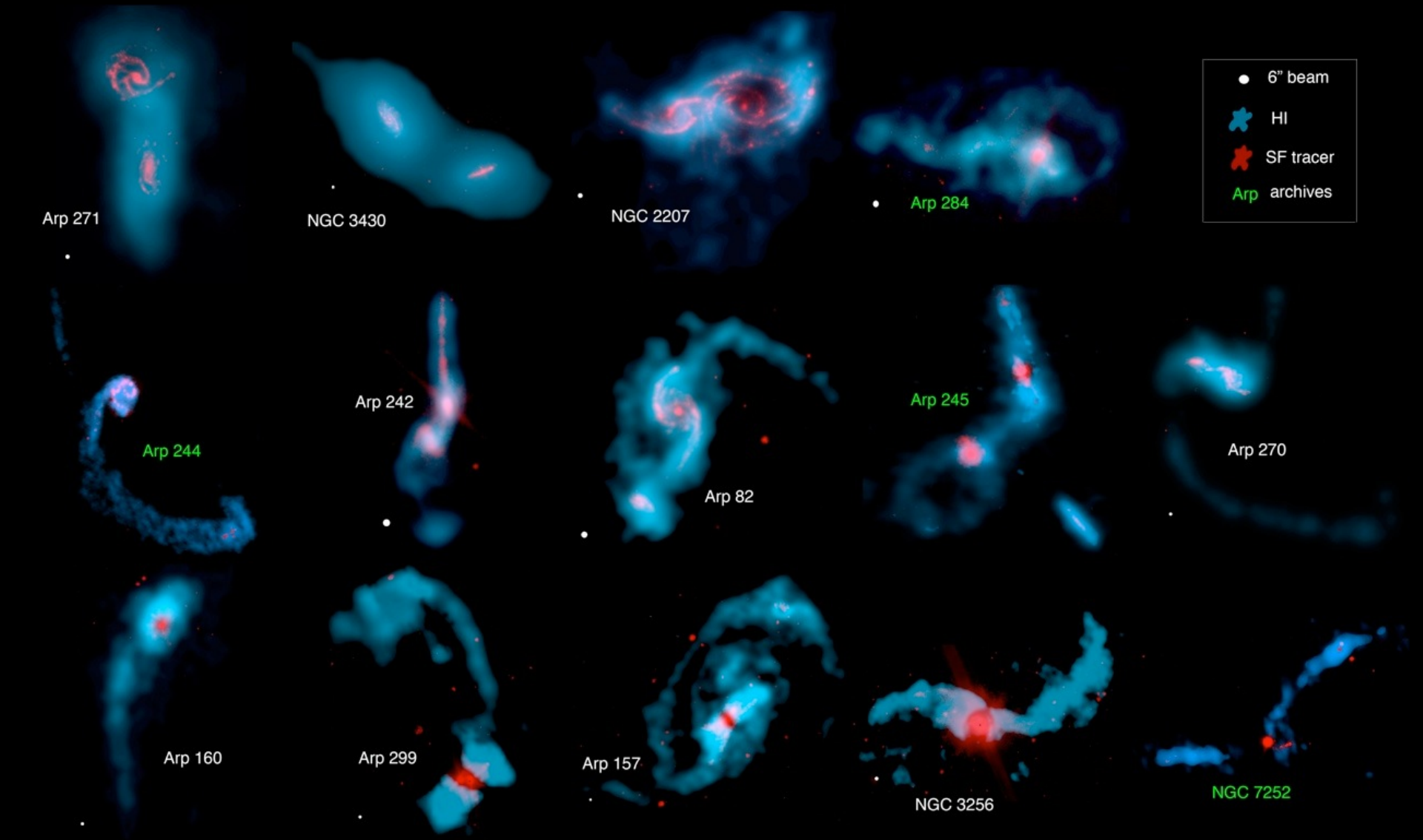
Staveley-Smith & Oosterloo 2015

Livre blanc

But why this is important and why should we care ? What is unique to HI ?

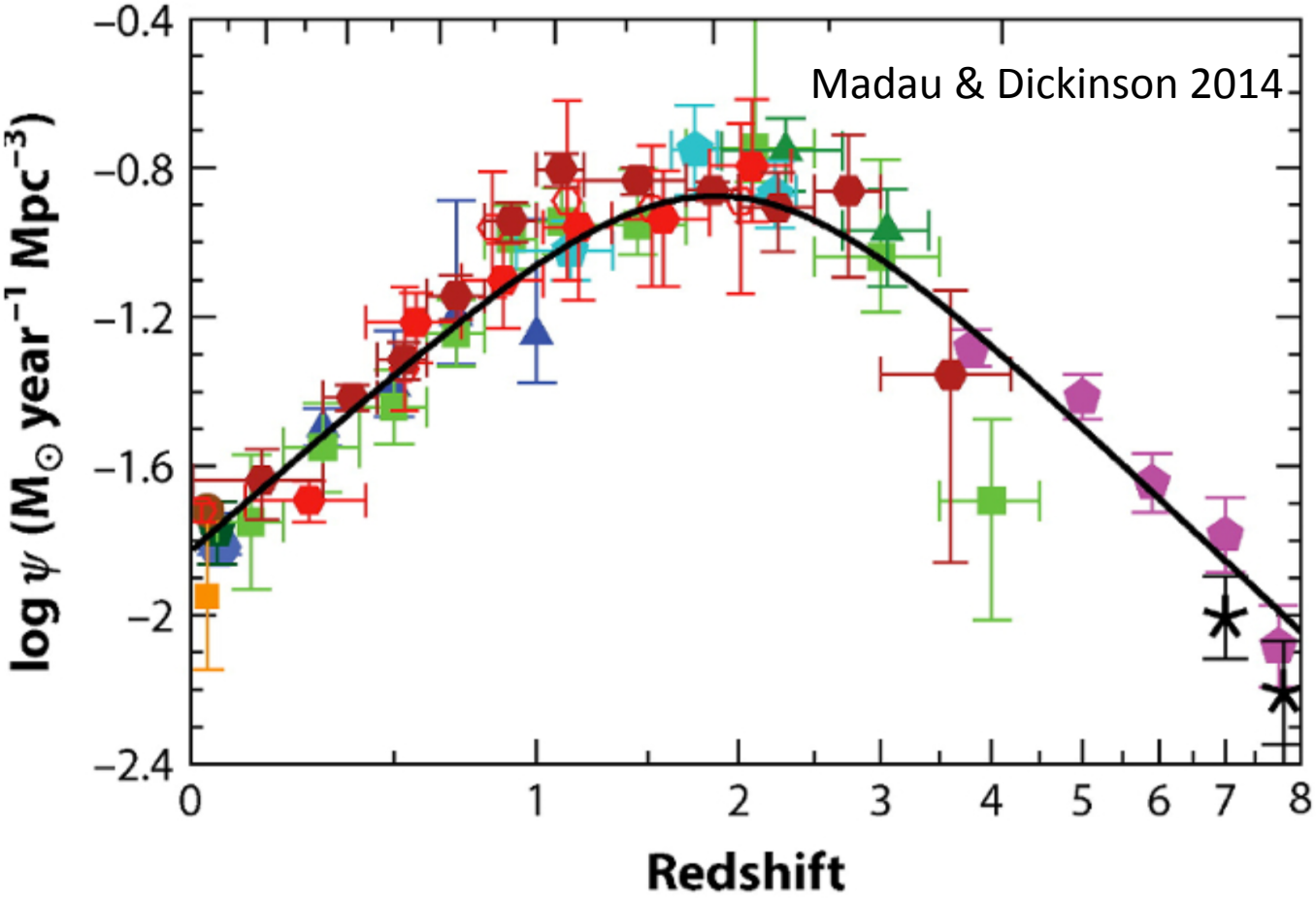
Atomic versus Molecular gas

ChaoticTHINGs (courtesy P-A Duc)



HI EVLA (B-array) observations, complementing database from THINGS, Little THINGS + SF tracers

Why HI is important to understand galaxy formation and evolution

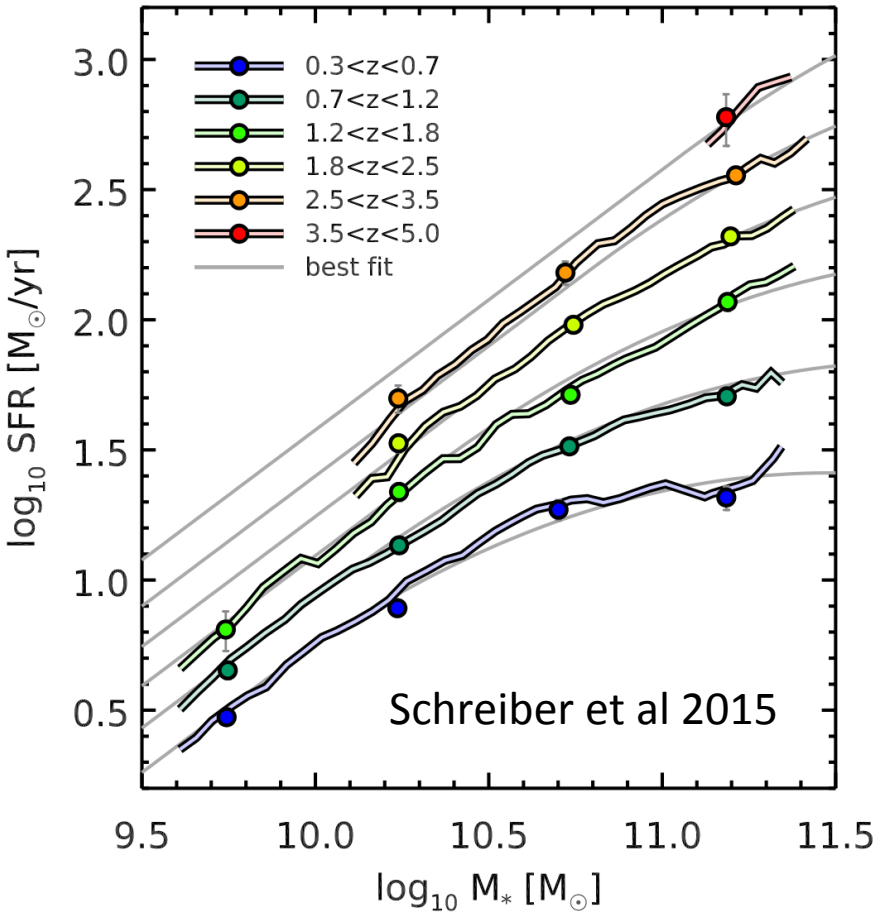


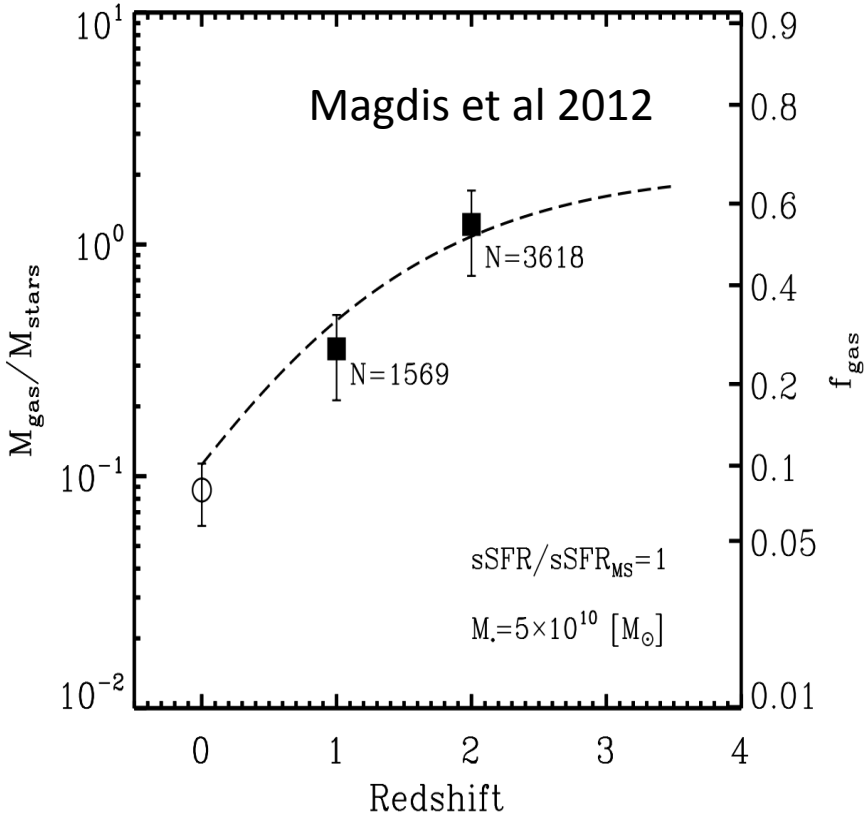
Long history of French contributions: ISO, Spitzer, Herschel, ALMA

The Main Sequence paradigm:

- SF was higher in the past at all masses
- Tight connection between SFR and M*

The evolution is driven largely by
A rise of gas content
Gas consumption efficiency changes little





Leading French contribution to the establishing of this picture: Herschel, ALMA

But this creates a couple of problems:

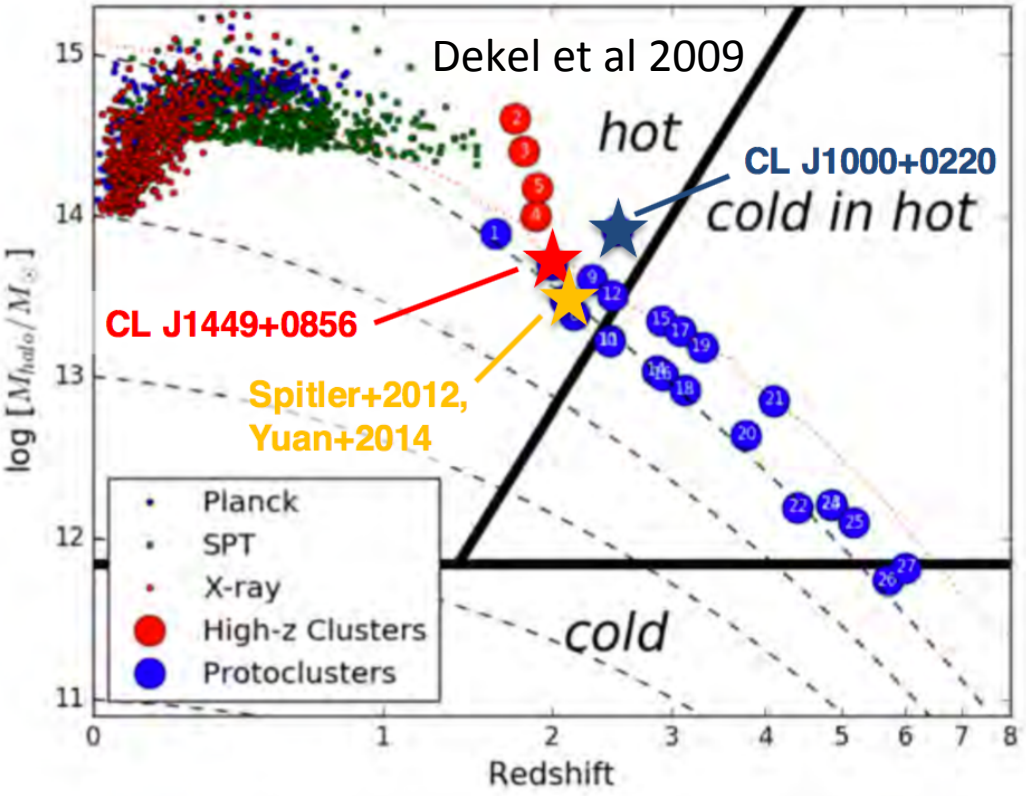
1) Galaxies have gas consumption times ~0.5-1 Gyr but keep going for x10 longer

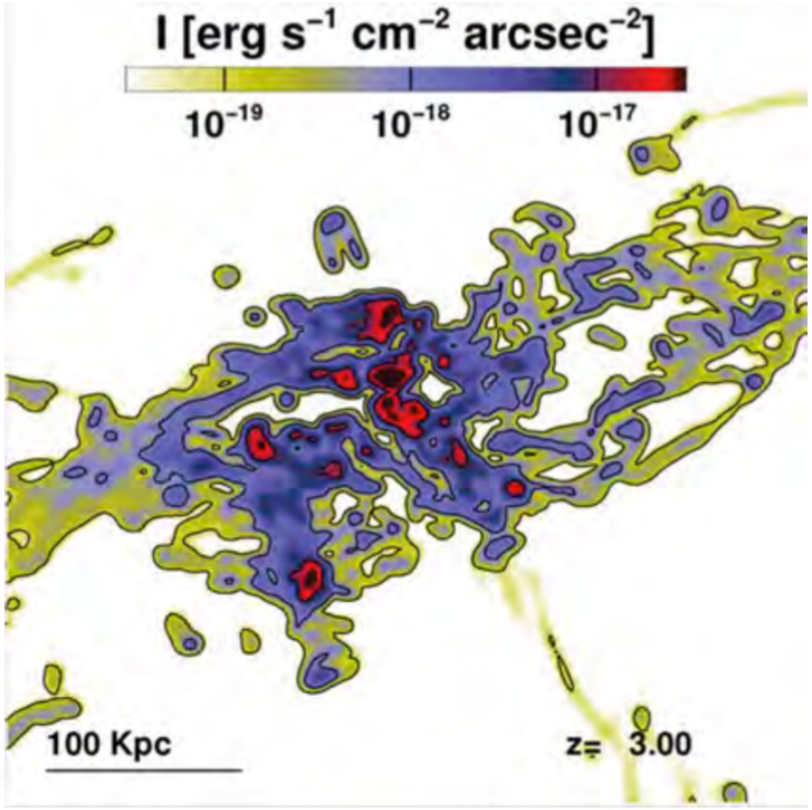
→ Need fueling and replenishment, otherwise cannot work

→ Postulate 'cold flows' accretion to maintain the 'steady state'

(predicted by theory, never convincingly/definitively observed so far)

Rosdahl & Blaizot 2012

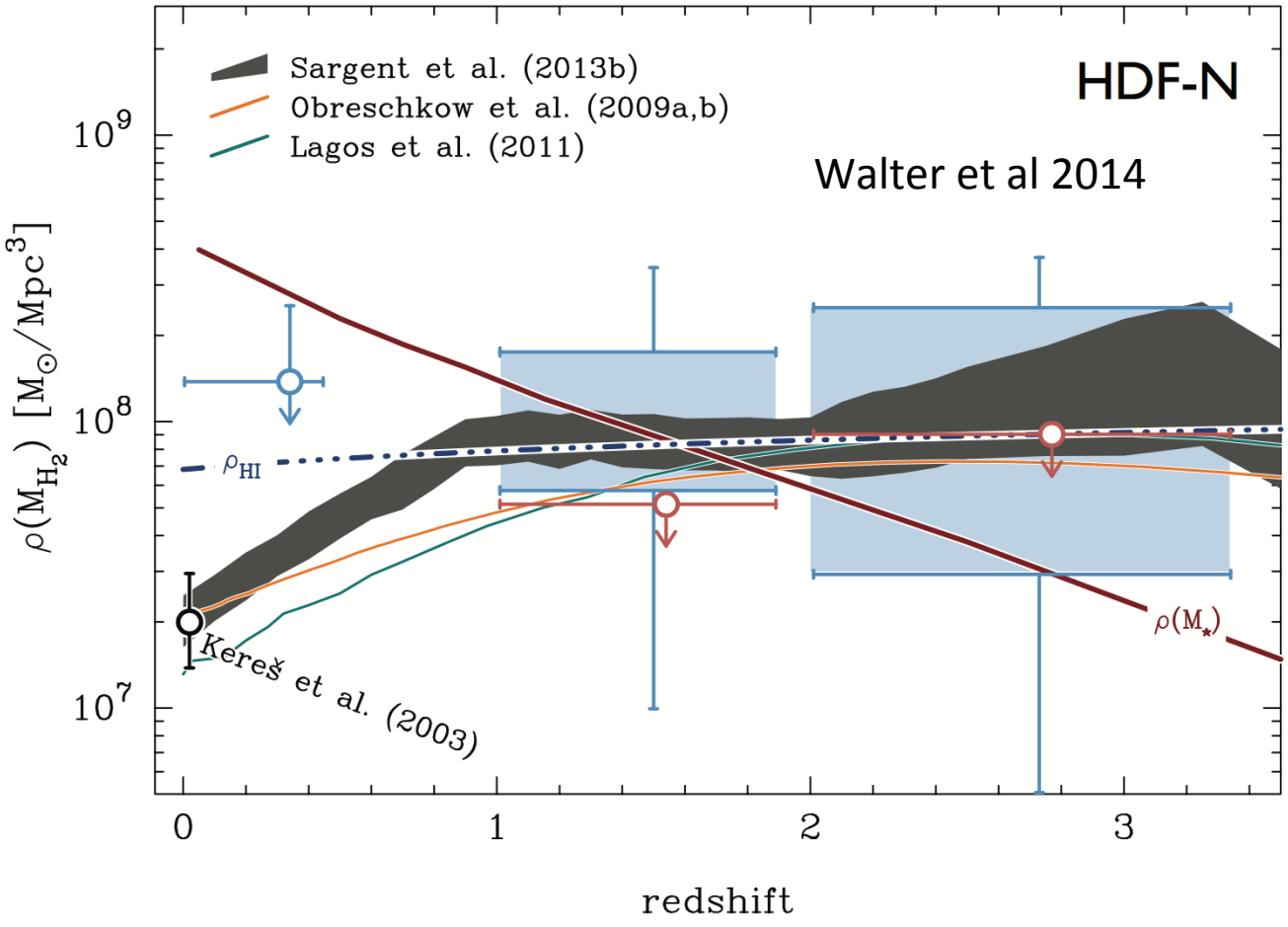




These flows are at low densities, galaxy outskirts, high redshift:

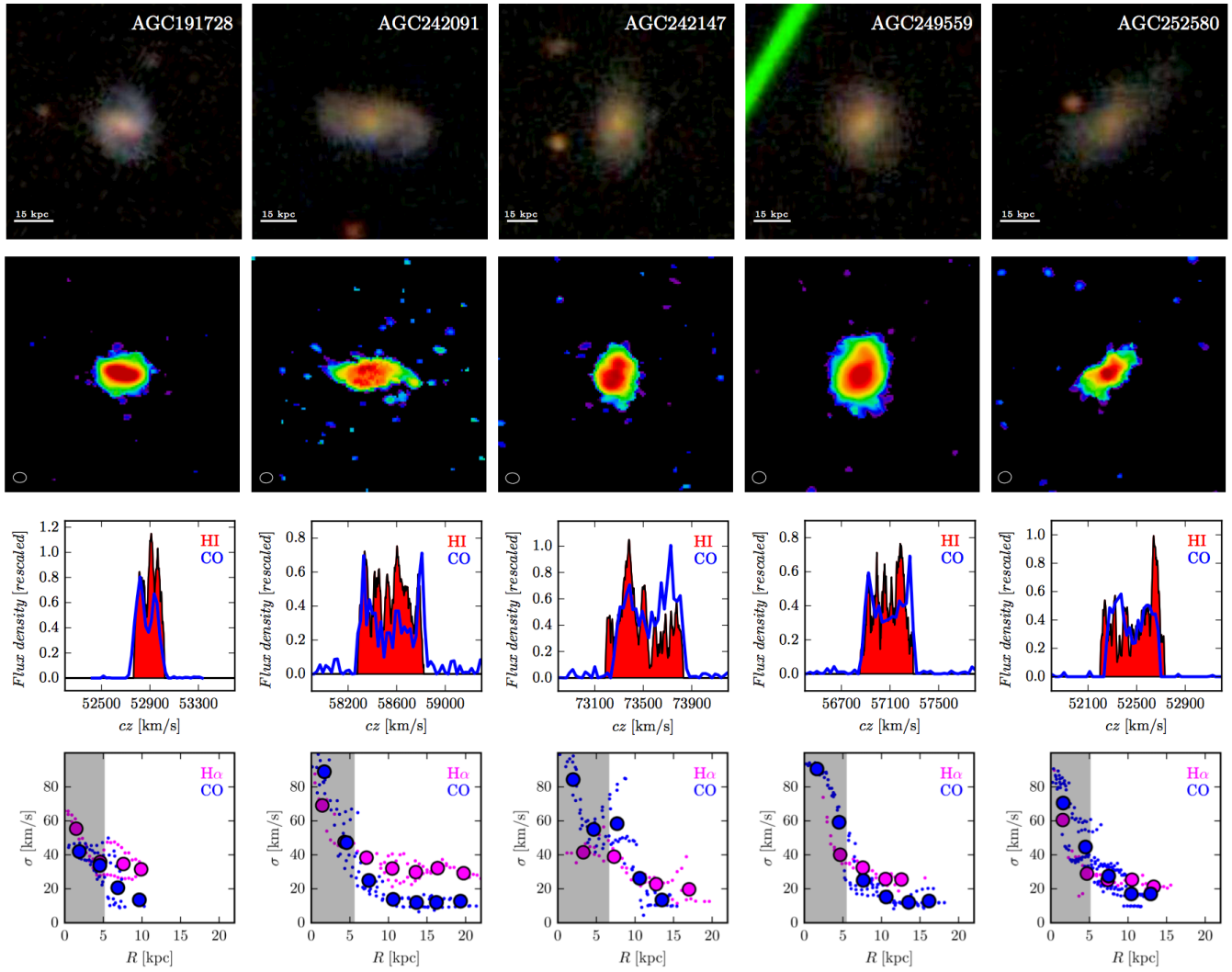
exactly what SKA will do in HI, great potential, detailed/quantitative predictions difficult

Cosmic evolution of HI, H2 and stars



Problem2: this assumes that HI is negligible in galaxies (H2 dominated), this has never been really tested

Minor role of HI disputed: Cortese et al 2017
Arecibo HI detections to z=0.2 with ALMA follow-up CO[1-0]



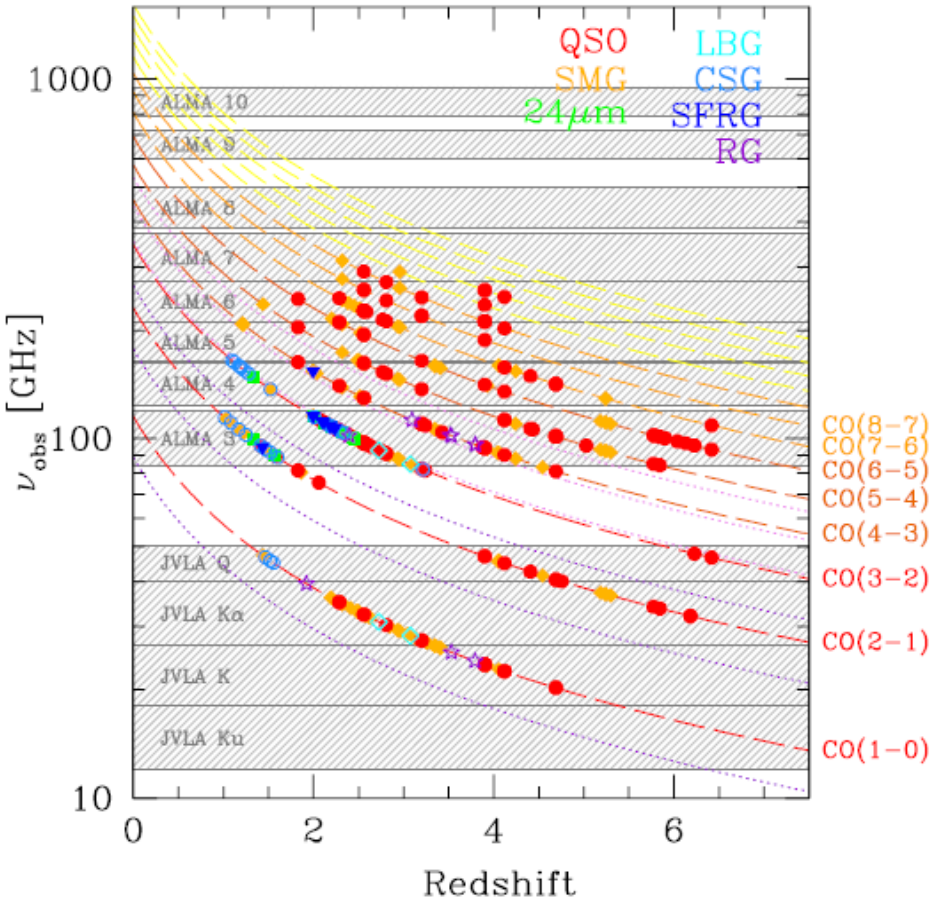
H2/HI ratio does not rise as expected

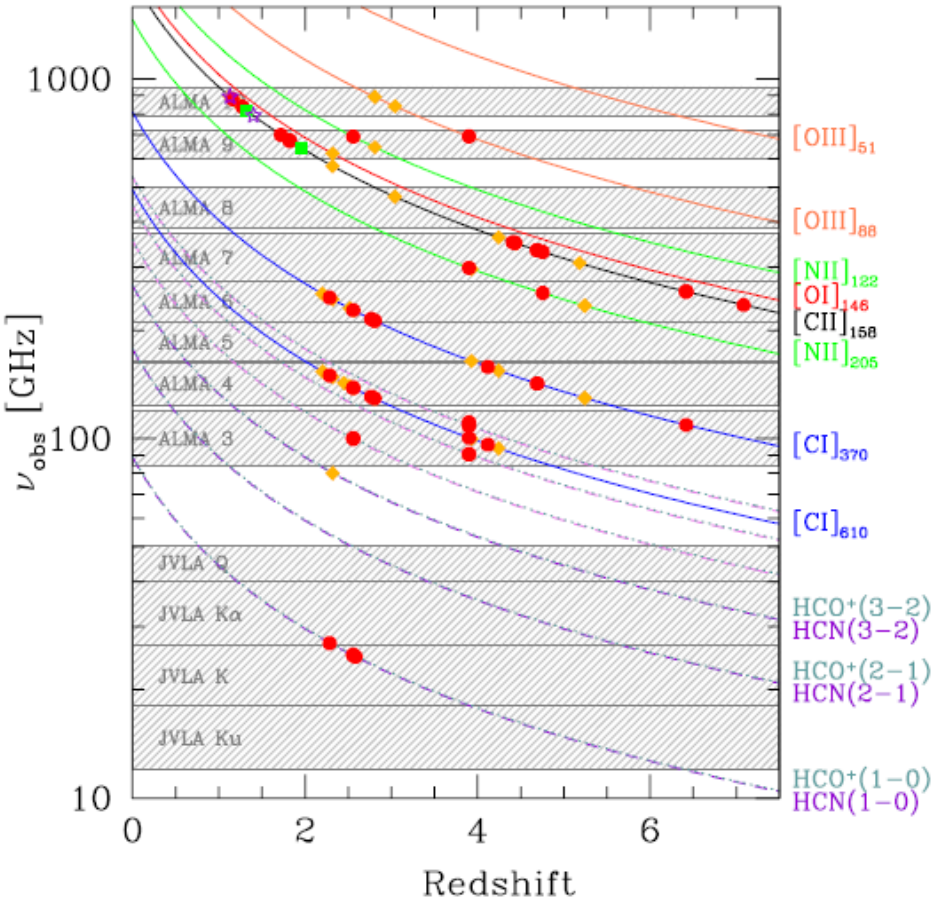
Problem: Arecibo beam is larger than the slide

SKA will definitely not Have this issue

Clarifying the role of HI for the gas budget in high-z galaxies crucial
- Understand the inner working of galaxies at high redshift
- Constrain masses: HI is secure, H2 is debatable alphaCO/etc

Molecular lines versus redshift

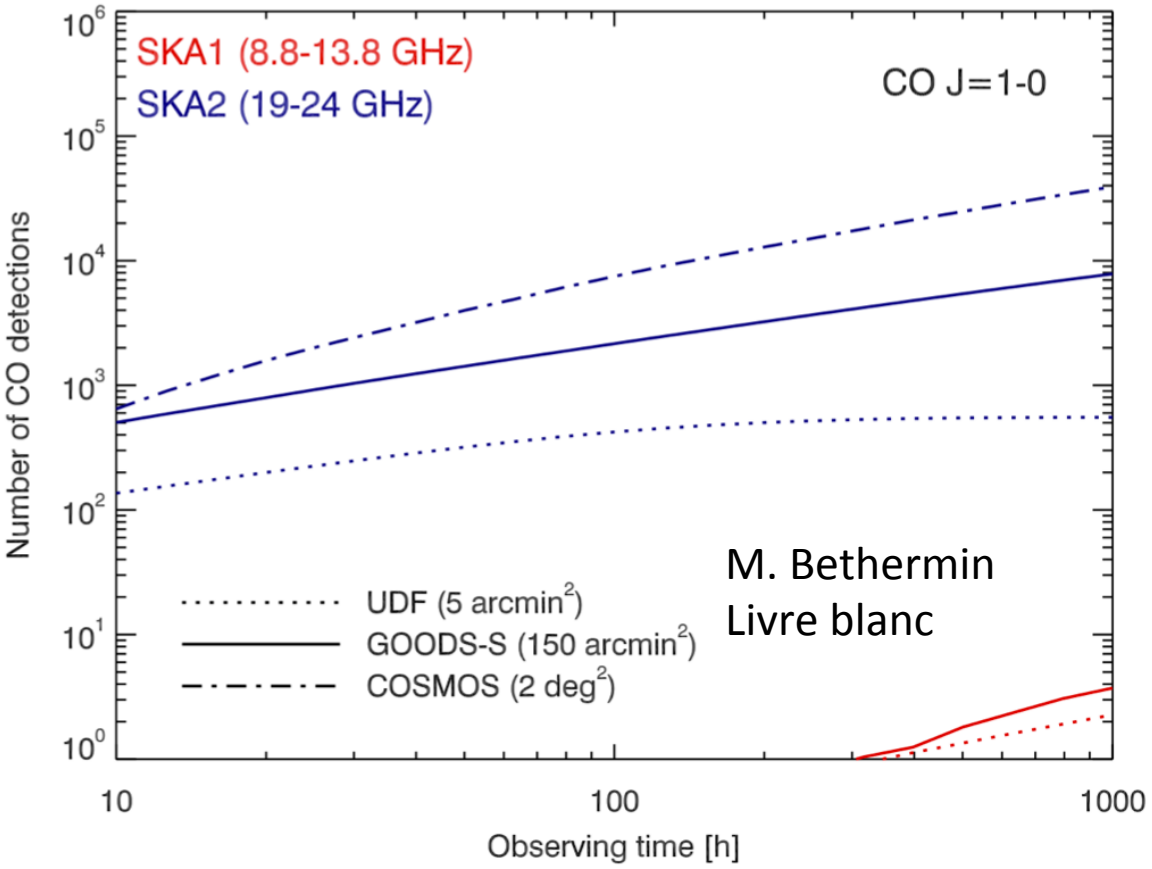


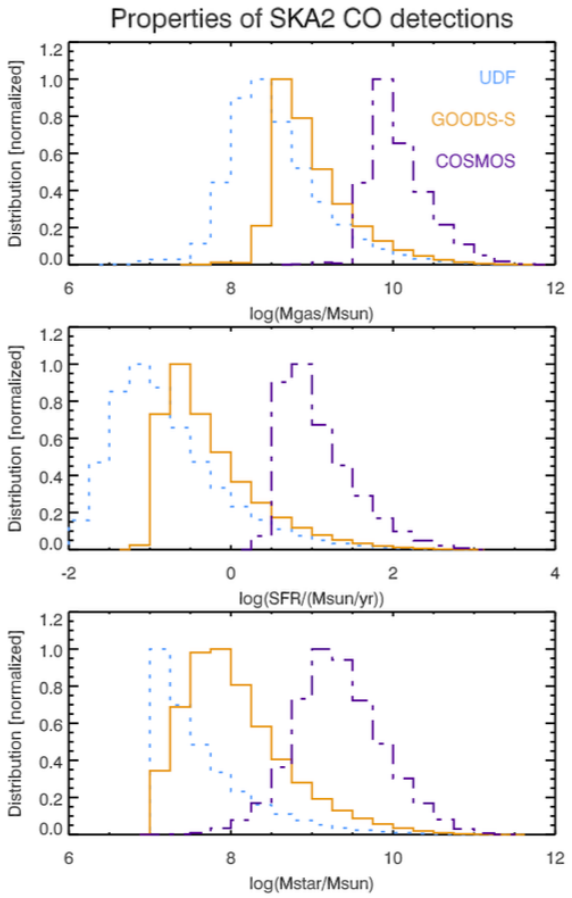


Points are detections, with colors indicating the object type

Carilli & Walter 2013, ARAA

Molecular gas: CO[1-0] from SKA only at very high-z

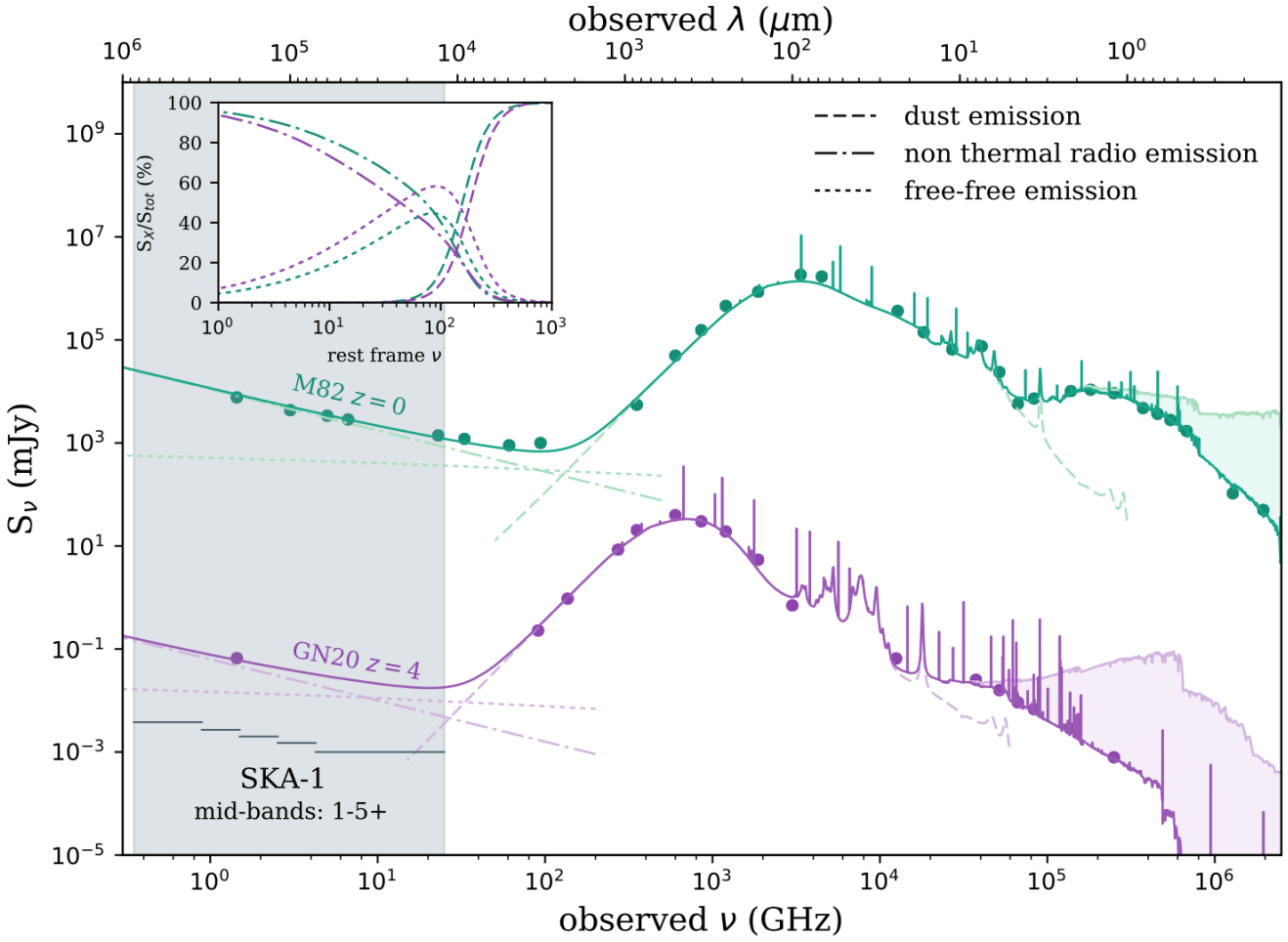




SKA1: molecular CO[1-0] only on pointed targets z>6

SKA2: surveys of molecular gas at z>3.8 (~10 detections per hour)

SKA trace denser star forming gas through continuum surveys (indirect)



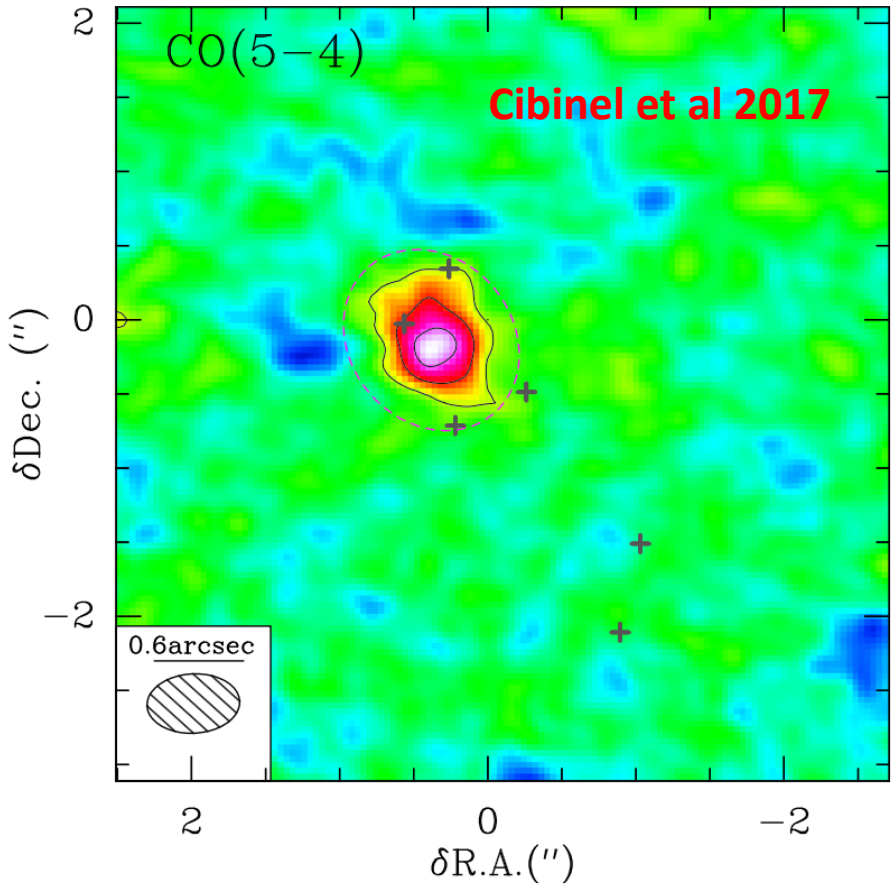
L. Ciesla

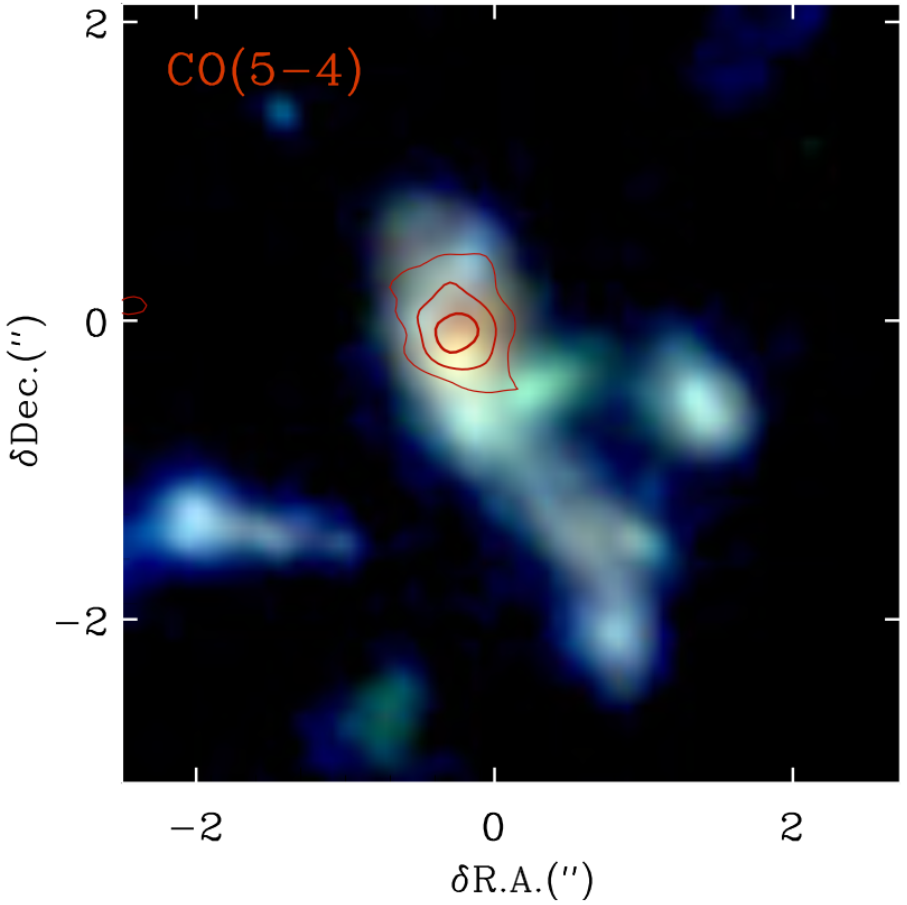
Livre blanc

Survey speed x10000 faster than ALMA at z=2 (~ same time to given SFR)
x100 faster at z=6 (ALMA is x100 faster in time for same SFR on single pointing)

SKA high resolution and high sensitivity imaging (continuum) will open new windows: dust-free tracer of star formation morphology

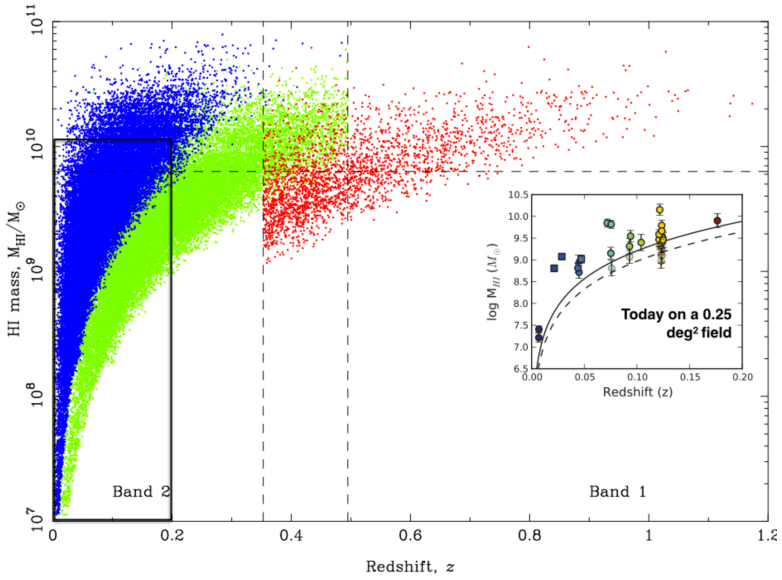
ALMA observations so far: somewhat disappointing
Galaxy at z=1.57 with SFR = 30 Msun/yr

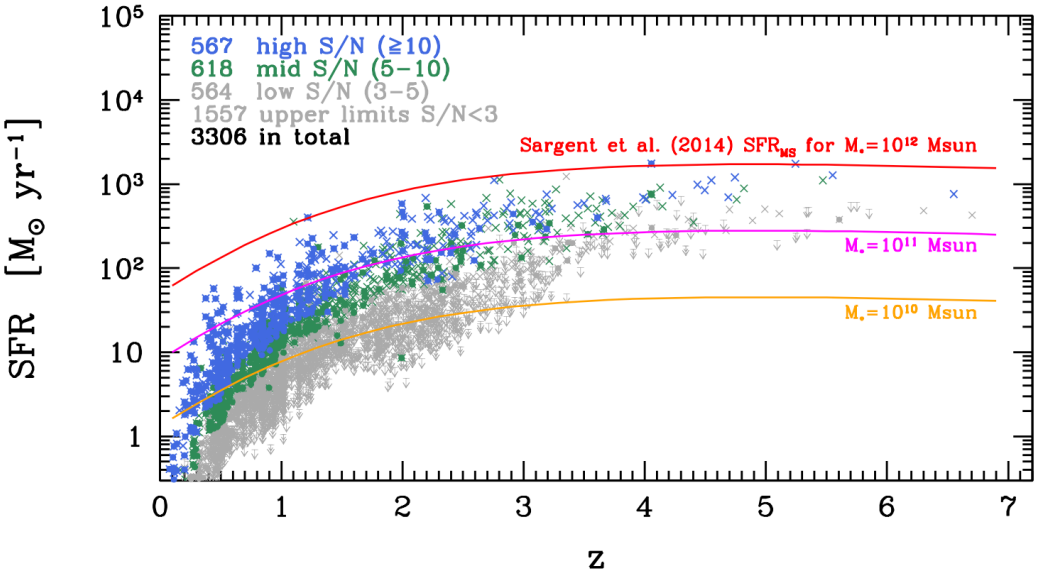




Detailed inner working of SF in galaxies (clumps, SF distributions, mergers) accessible with SKA in radio (continuum) on large samples with very long integrations

Large area continuum and HI surveys:



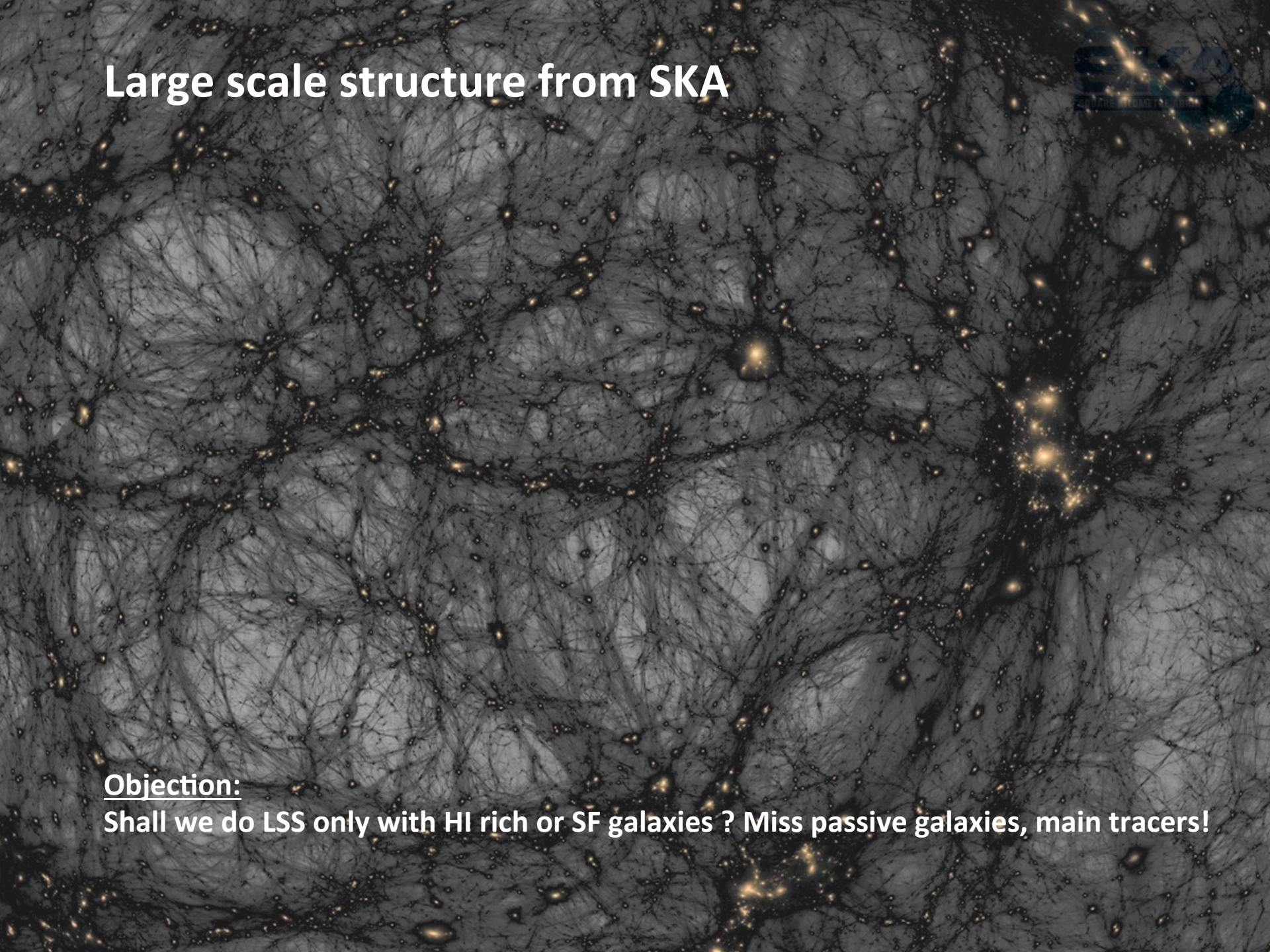


Deepest IR surveys in GOODS-N (Liu et al 2017)
(state of the art deep survey, with others)

SKA1 will match this in 1h over 10x the area
~10000 detections/hour

Gigantic samples of star forming galaxies

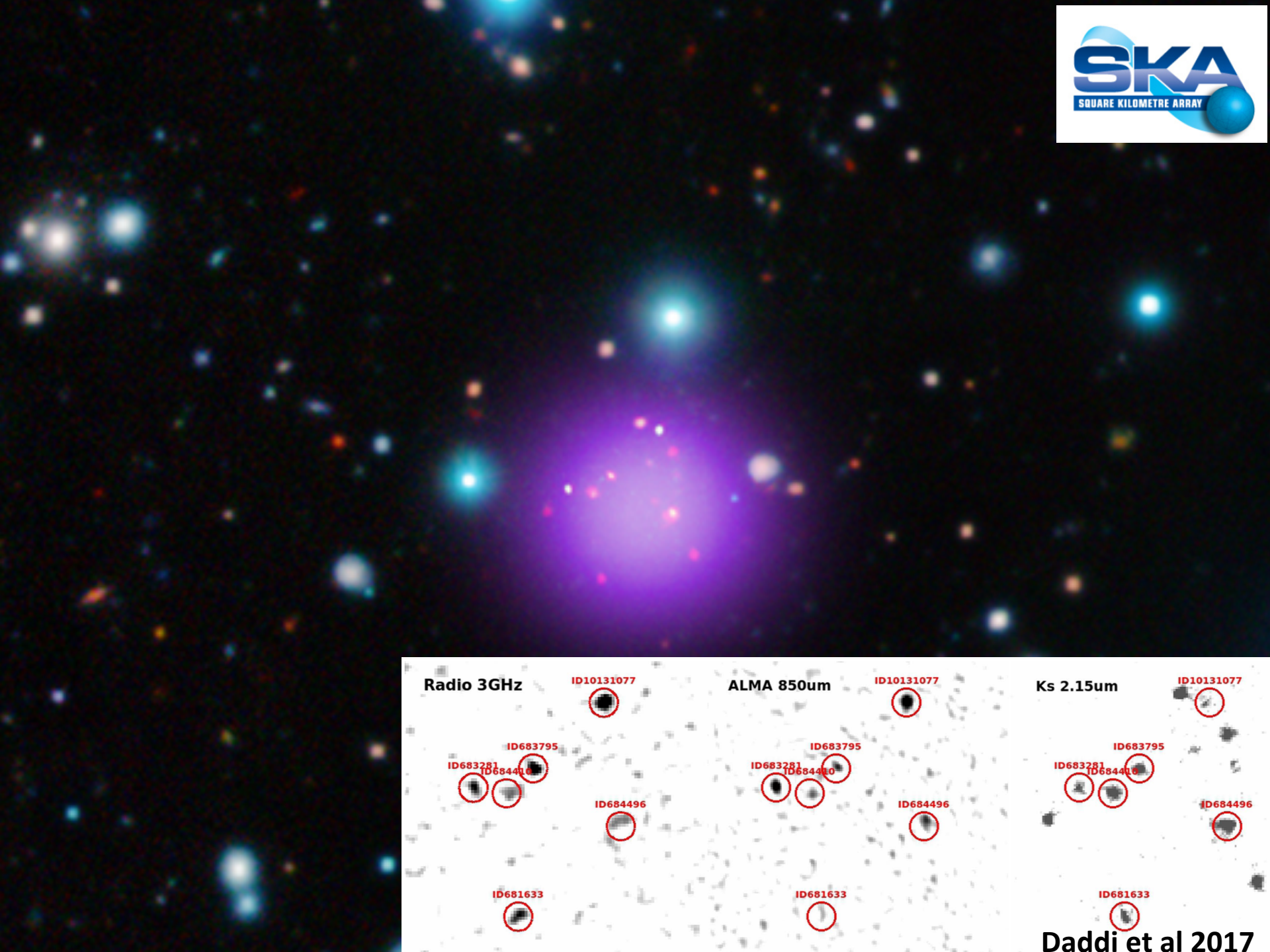
Large scale structure from SKA



Objection:

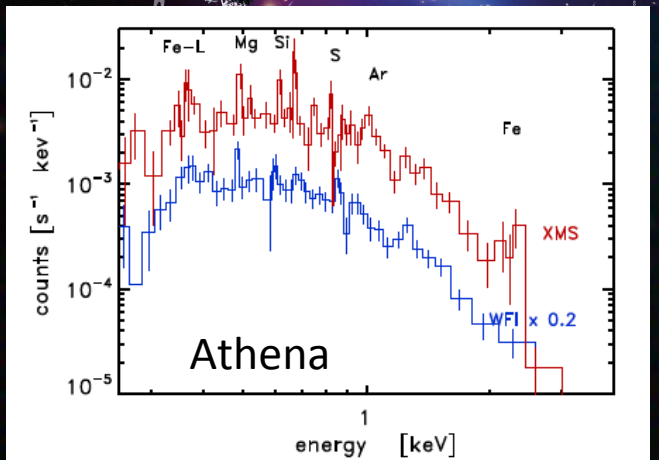
Shall we do LSS only with HI rich or SF galaxies ? Miss passive galaxies, main tracers!


z=2.5 most distant Xray cluster
SKA
SQUARE KILOMETRE ARRAY
Wang, Elbaz, Daddi et al 2016



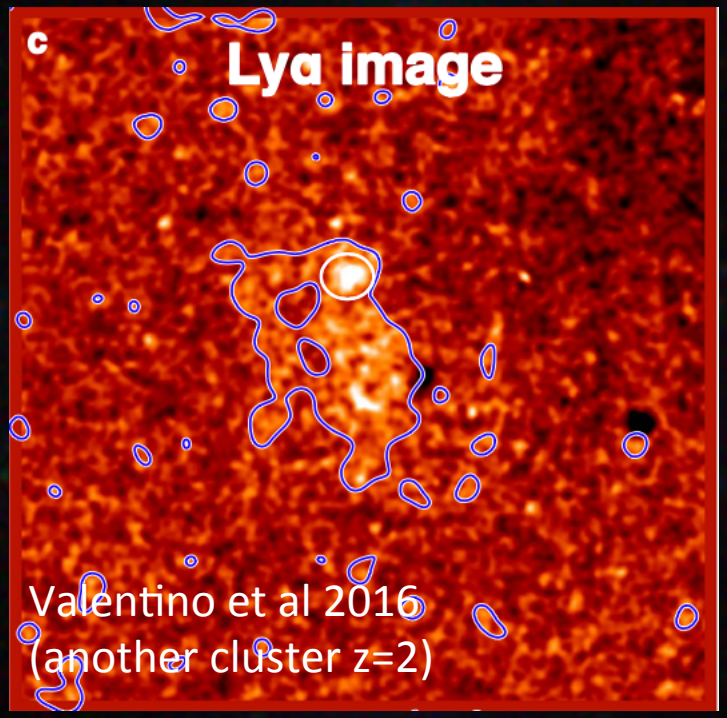
Daddi et al 2017

SKA1 already planned surveys will pinpoint thousands similar clusters at z>2—3, power to constrain cosmology, first cluster galaxy formation



Crucial synergy with Euclid/Athena
(key French strategic and scientific priorities)

And again, we will have access to the flow of cold gas to the large scale structure via HI



Valentino et al 2016
(another cluster z=2)

Athena

SKA will be a revolutionary instrument for galaxy formation and evolution touching upon new key science directions largely unexplored so far:

1. low-density outskirts of galaxies at cosmological distances, feeding, cold gas flows (possibly together with Lya tracing in emission − both so far undetected)

2. Inner working of galaxies, unveiling their neutral hydrogen content evolution, crucial to understand the physics of baryons → stars, buildup

3. Access early universe large scale structure as traced by forming galaxies (continuum) with unprecedented power, touch on cosmology and buildup of galaxies with environment

All of these are also very close to France historical, current and future key scientific interests, activities and recognized strengths

Although SKA is a large consortium, we will be able as a community in France to make a difference and capitalize on the investment