HIGHz: a survey of the gas content of the most massive galaxies at z~0.2

Luca Cortese & Barbara Catinella

Swinburne University of Technology

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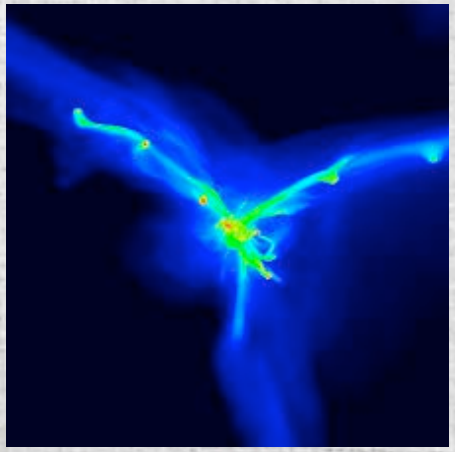
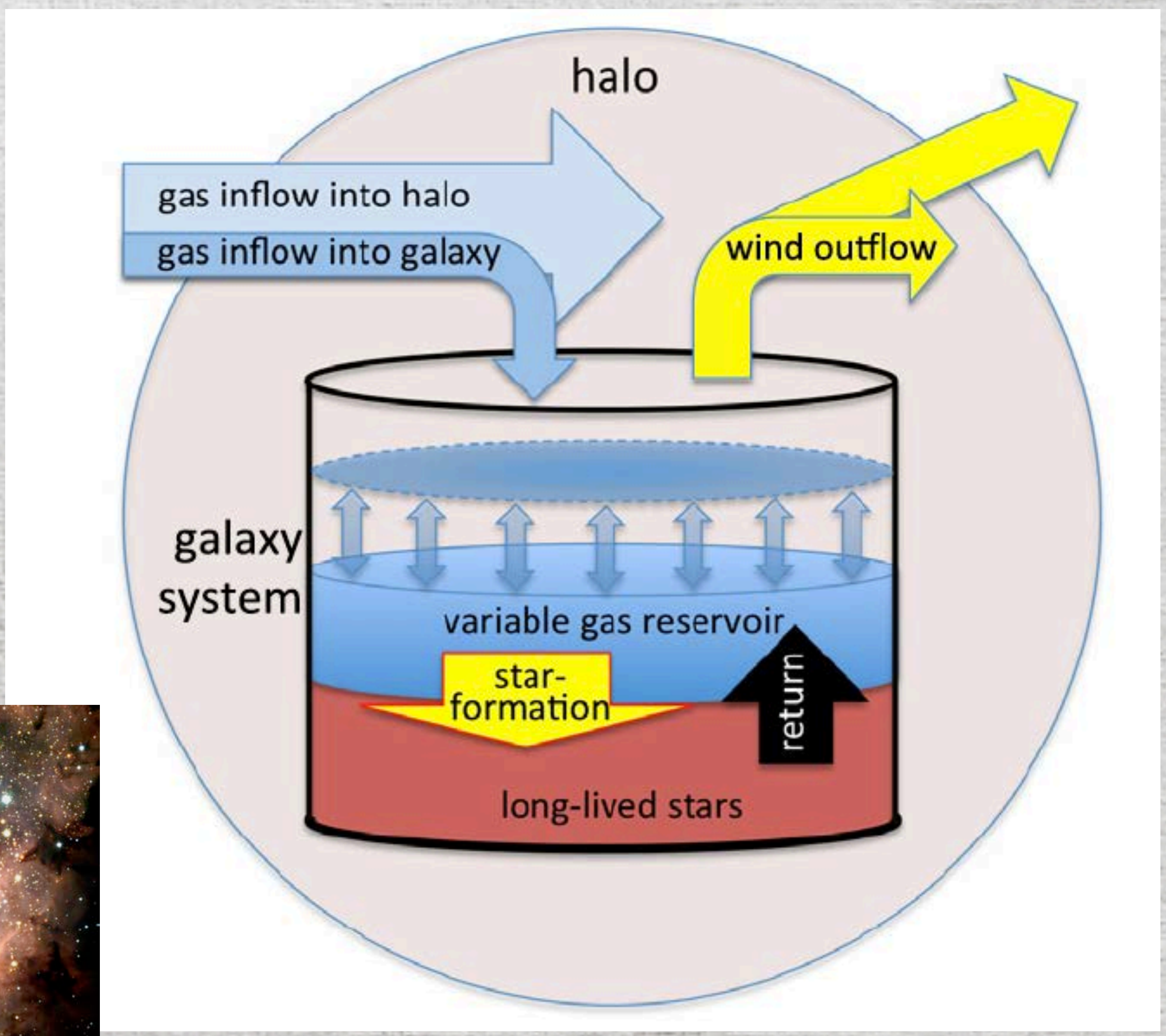
SWINBURNE UNIVERSITY OF TECHNOLOGY

Gas plays a central role in galaxy evolution



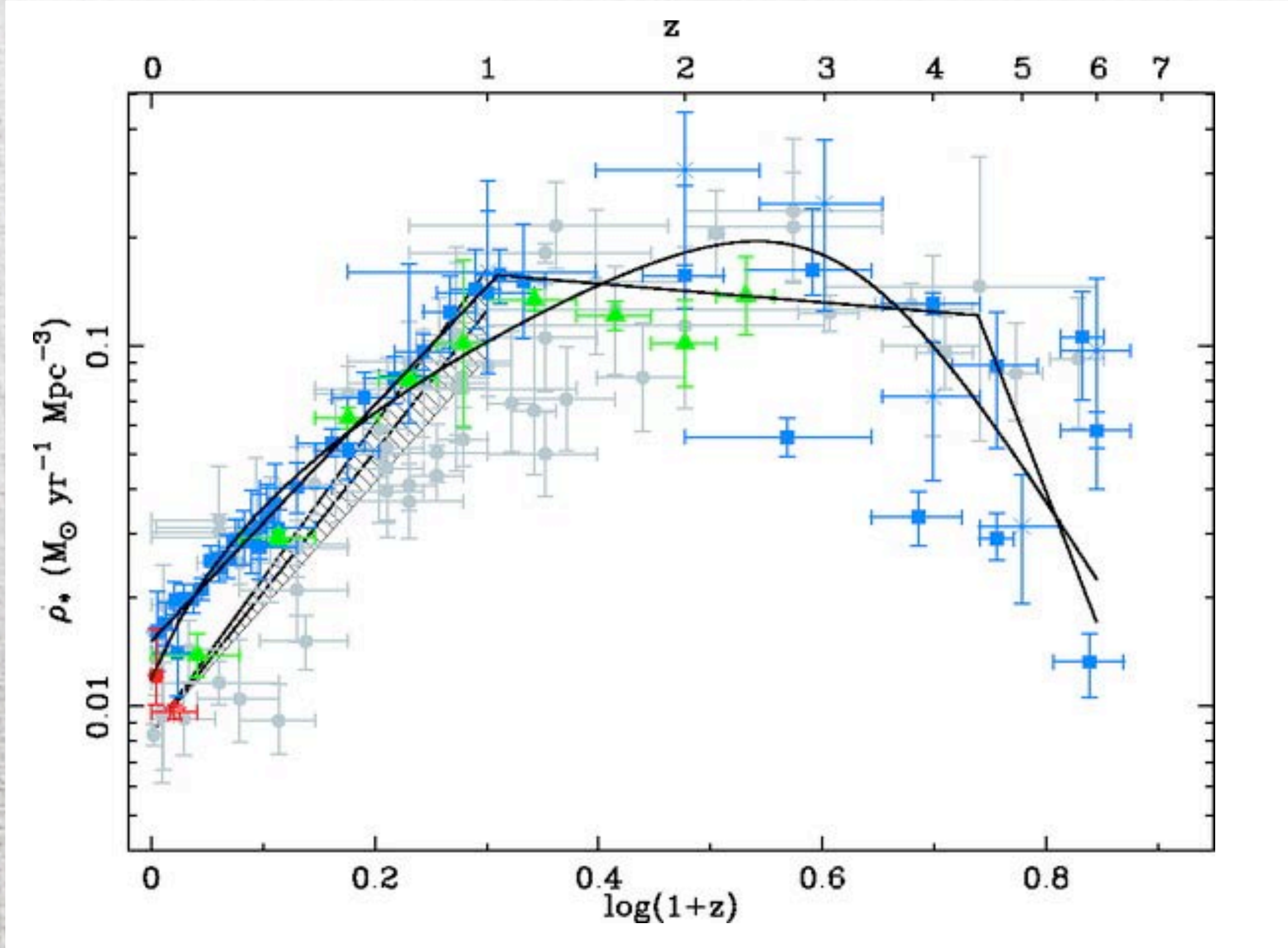


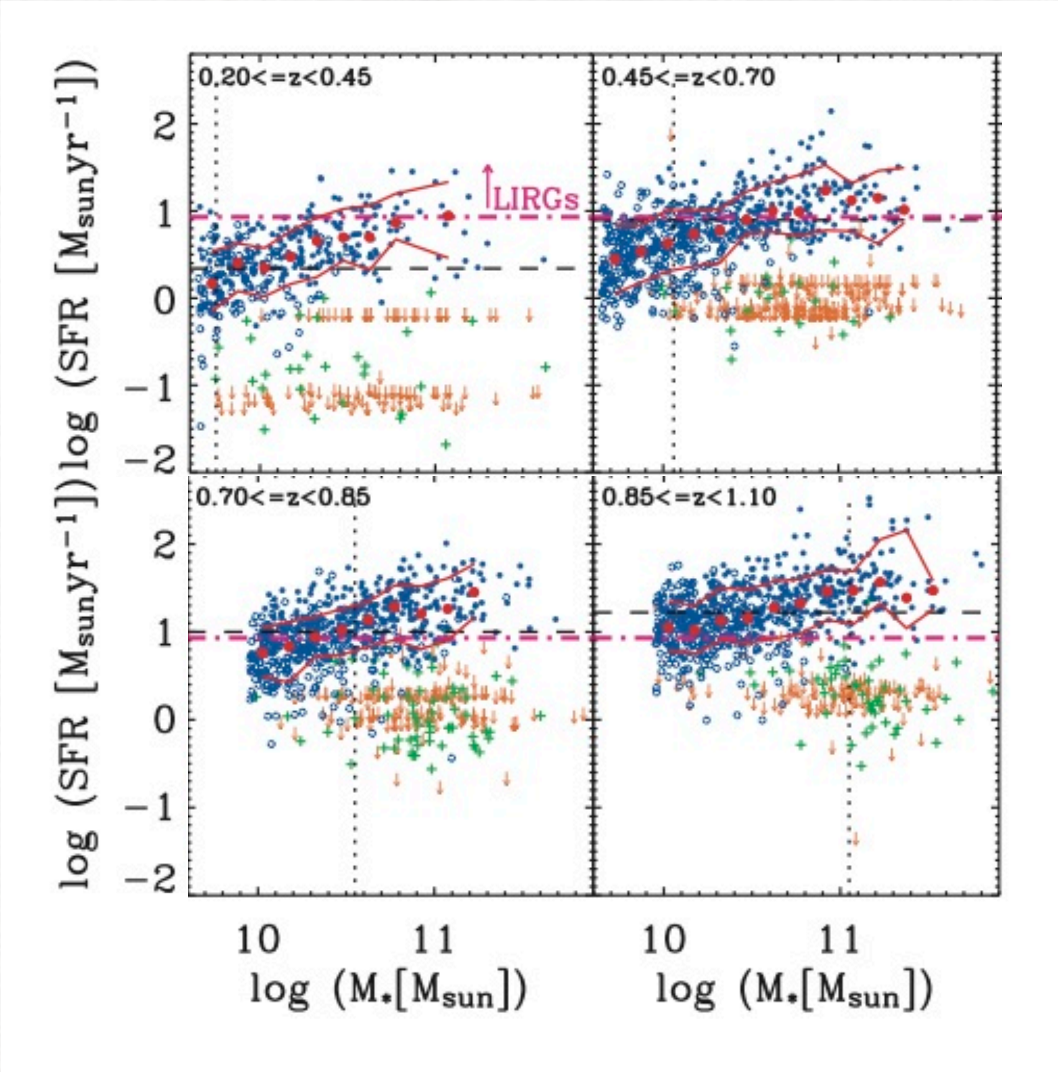
Lilly et al. (2013)

see also, e.g. Bouche' et al. (2010), Dave' et al (2011, 2012), Krumholz & Dekel (2012)

Still a lot of work to do to understand how gas cycles in and out of galaxies

SFR evolution



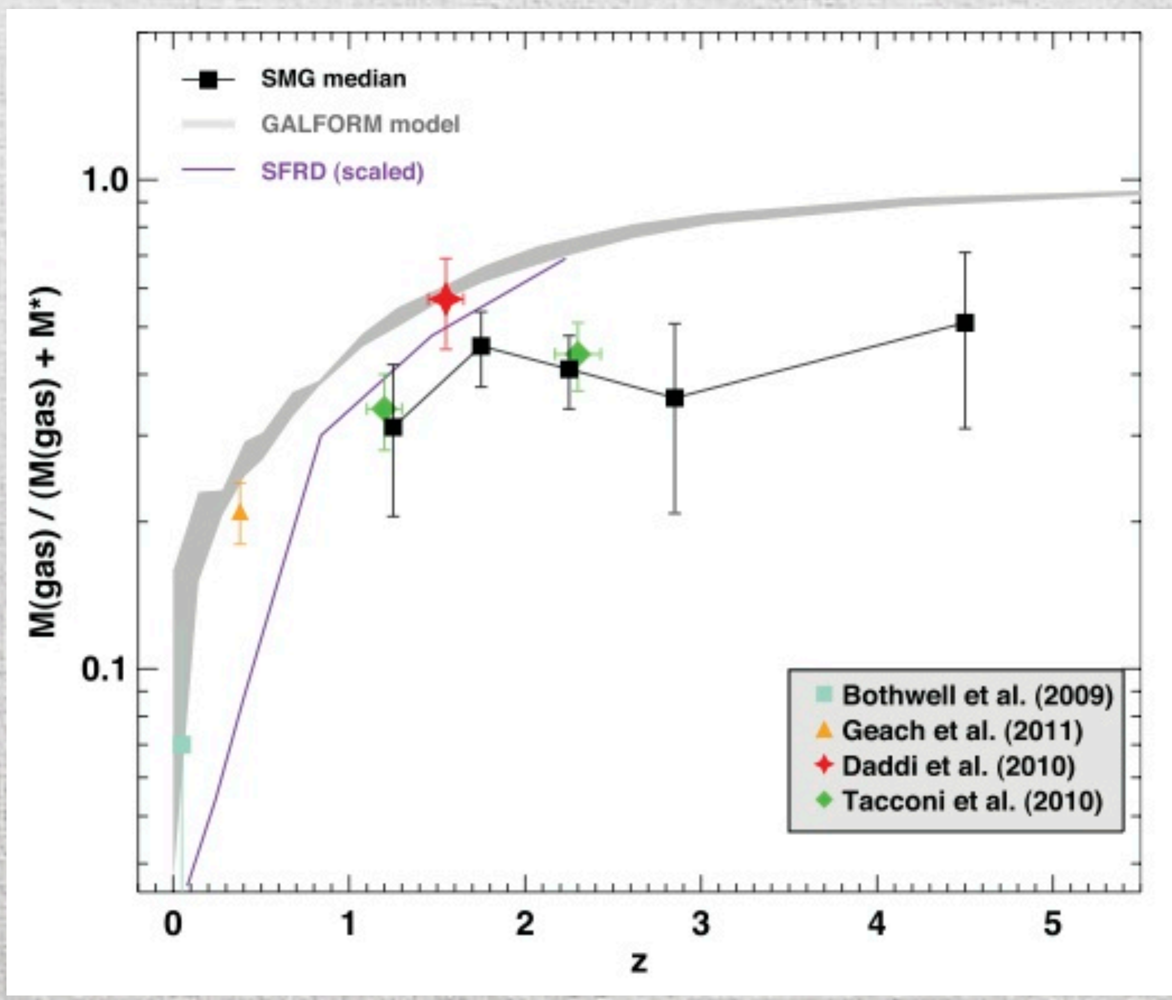


Hopkins & Beacom 2006

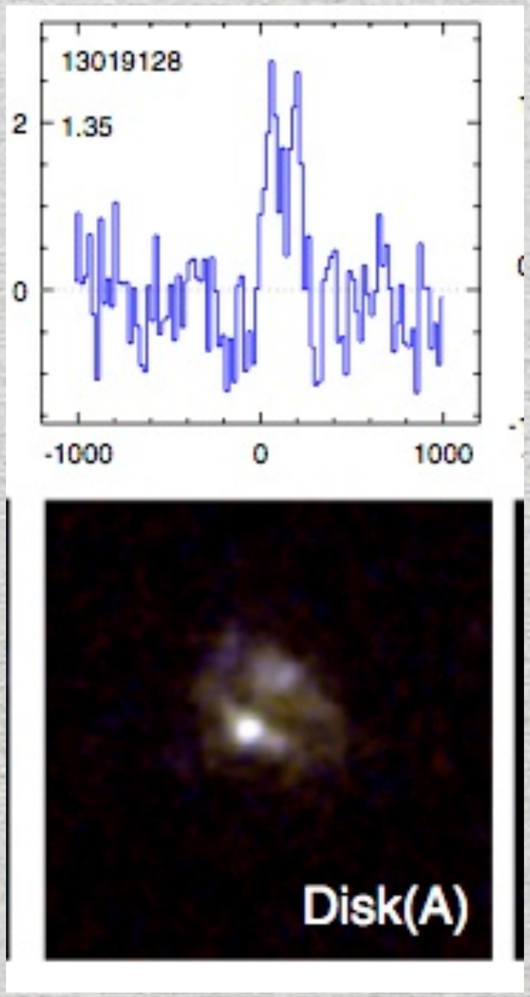
Noeske et al. 2007

What about gas?

Molecular Hydrogen: getting there...



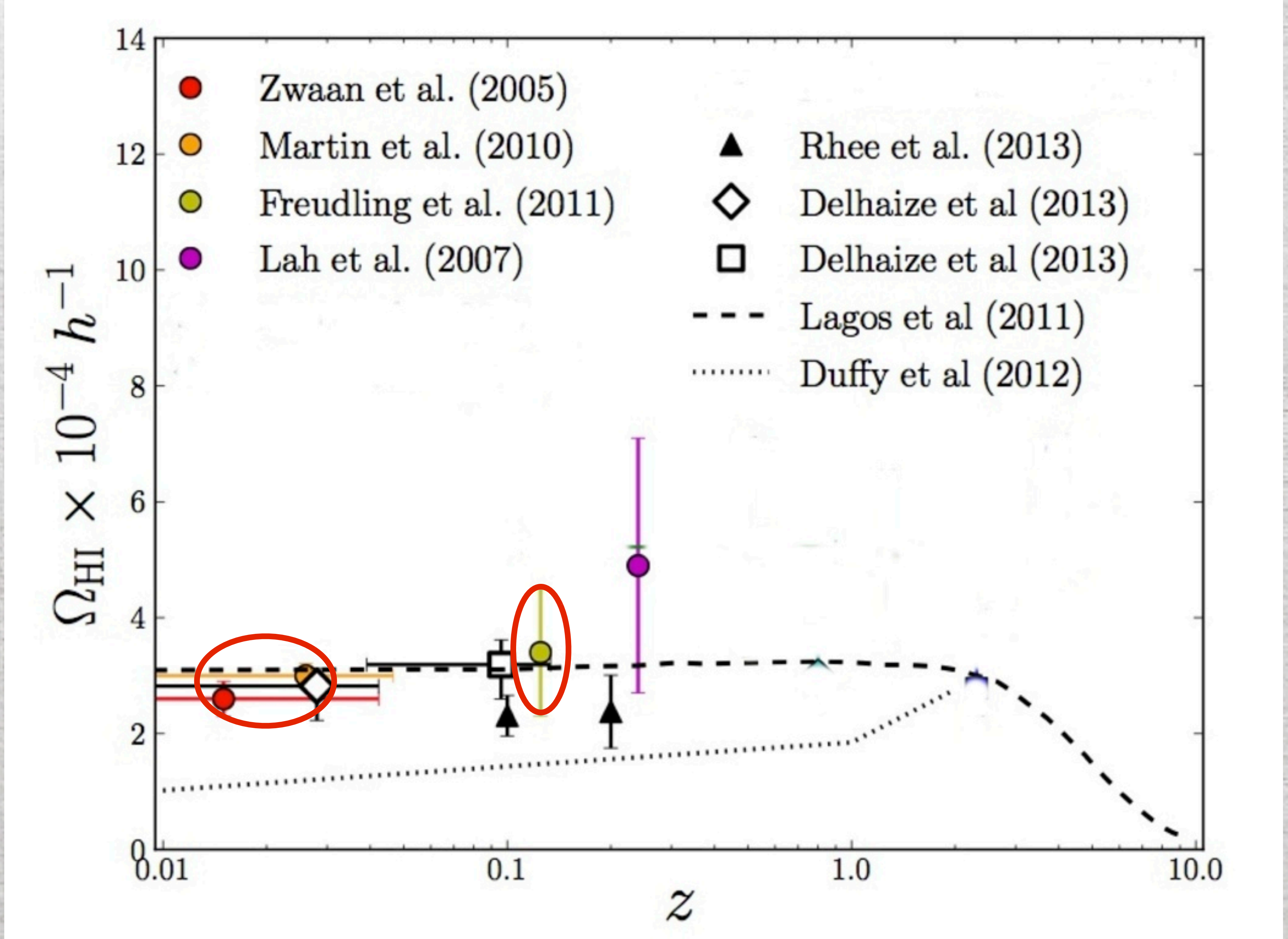
Bothwell et al. 2013



Tacconi et al. 2013

ALMA is the game changer

Atomic Hydrogen in emission: a long way to go...



Adapted from slide by A. Popping

HI emission up to z=0.5-1

The main SKA goal in HI science

Science Goal	SWG	Objective	SWG Rank
1	*CD/EoR*	Physics of the early universe IGM - I. Imaging	1/3
2	*CD/EoR*	Physics of the early universe IGM - II. Power spectrum	2/3
4	*Pulsars*	Reveal pulsar population and MSPs for gravity tests and Gravitational Wave detection	1/3
5	*Pulsars*	High precision timing for testing gravity and GW detection	1/3
13	*HI*	Resolved HI kinematics and morphology of ~10^10 M_sol mass galaxies out to z~0.8	1/5
14	*HI*	High spatial resolution studies of the ISM in the nearby Universe	2/5
15	*HI*	Multi-resolution mapping studies of the ISM in our Galaxy	3/5
18	*Transients*	Solve missing baryon problem at z~2 and determine the Dark Energy Equation of State	=1/4
22	*Cradle of Life*	Map dust grain growth in the terrestrial planet forming zones at a distance of 100 pc	1/5
27	*Magnetism*	The resolved all-Sky characterisation of the interstellar and intergalactic magnetic fields	1/5
32	*Cosmology*	Constraints on primordial non-Gaussianity and tests of gravity on super-horizon scales.	1/5
33	*Cosmology*	Angular correlation functions to probe non-Gaussianity and the matter dipole	2/5
37 + 38	*Continuum*	Star formation history of the Universe (SFHU) – I+II. Non-thermal & Thermal processes	1+2/8

Table 2. List of highest priority SKA1 science objectives, grouped by SWG, but otherwise in arbitrary order.

Arecibo observations at z>0.16

- Technical improvements at Arecibo (already 1/10 collecting area of SKA!!) new L-wide receiver in 2003: access to frequencies < 1.3 GHz
- SDSS → accurate z for ~10^6 galaxies!

- Galaxies selected from SDSS according to z, presence of Hα line emission, inclination, disk morphology, and relative isolation

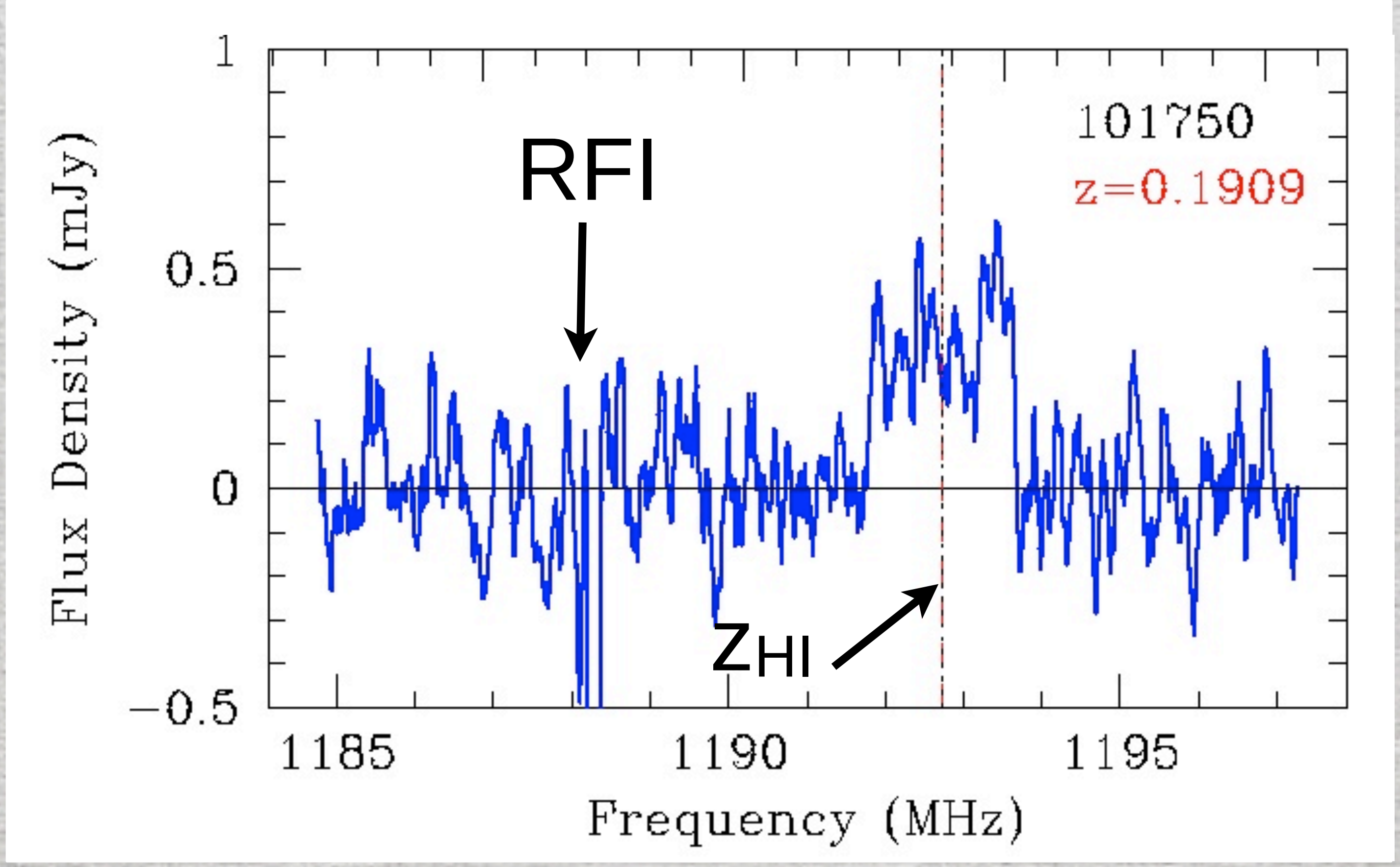
- Radio frequency interference (RFI)

  RFI sources: internal (electrical equipment) + external (broadcasting radio and TV stations, mobile phones, airport radars, telecommunication satellites...)

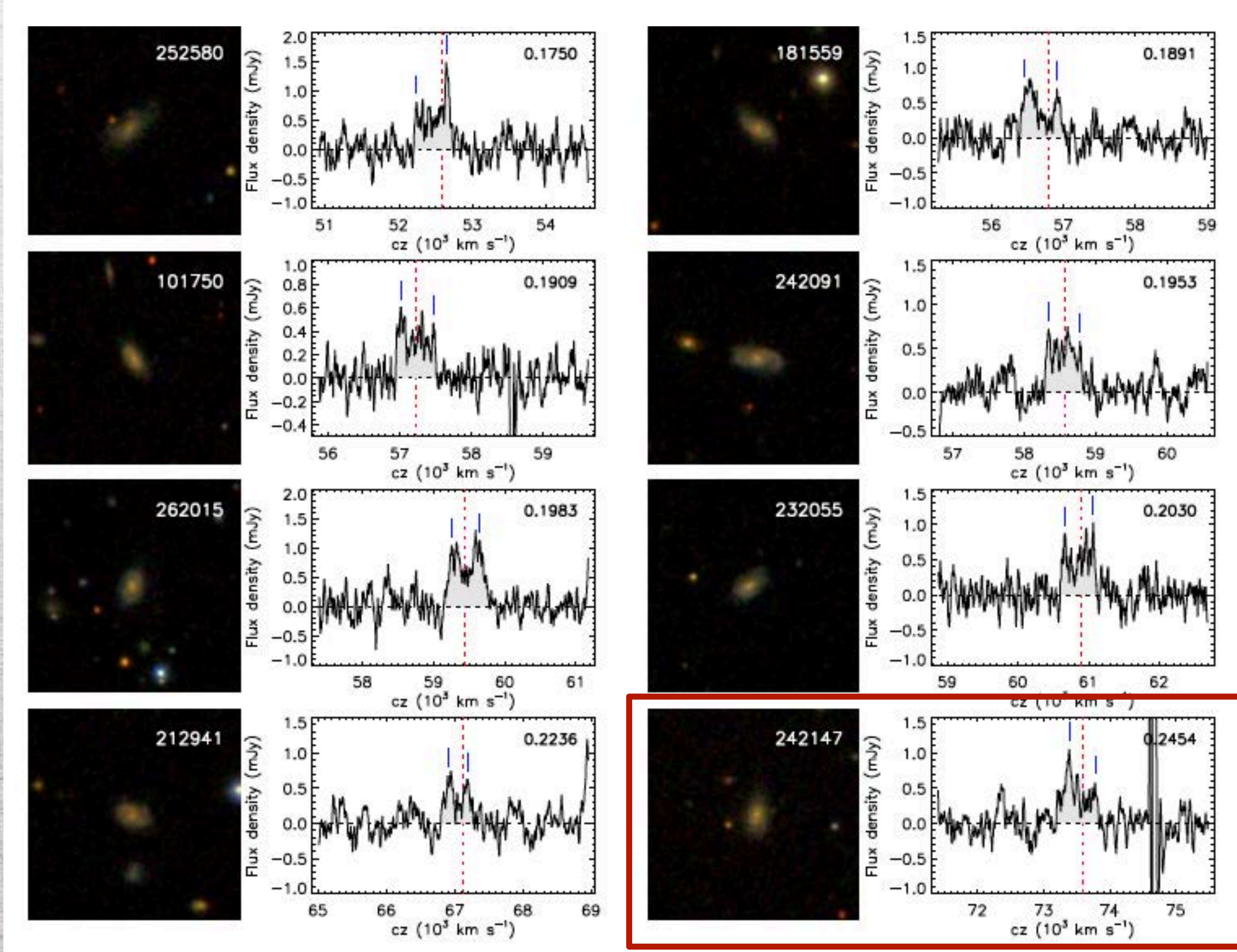
HIGHz Arecibo survey

- Observations completed in 2011
- 49 galaxies targeted, $0.16 < z < 0.27$
- Selection: SDSS, Hα emission, exponential disk profile, no beam confusion - ultimately cherry-picked (largest at those redshifts)
- on-source integration time of 1-5 hr per object; ~400 hr telescope time

1 arcmin
~ 200 kpc @ z=0.2

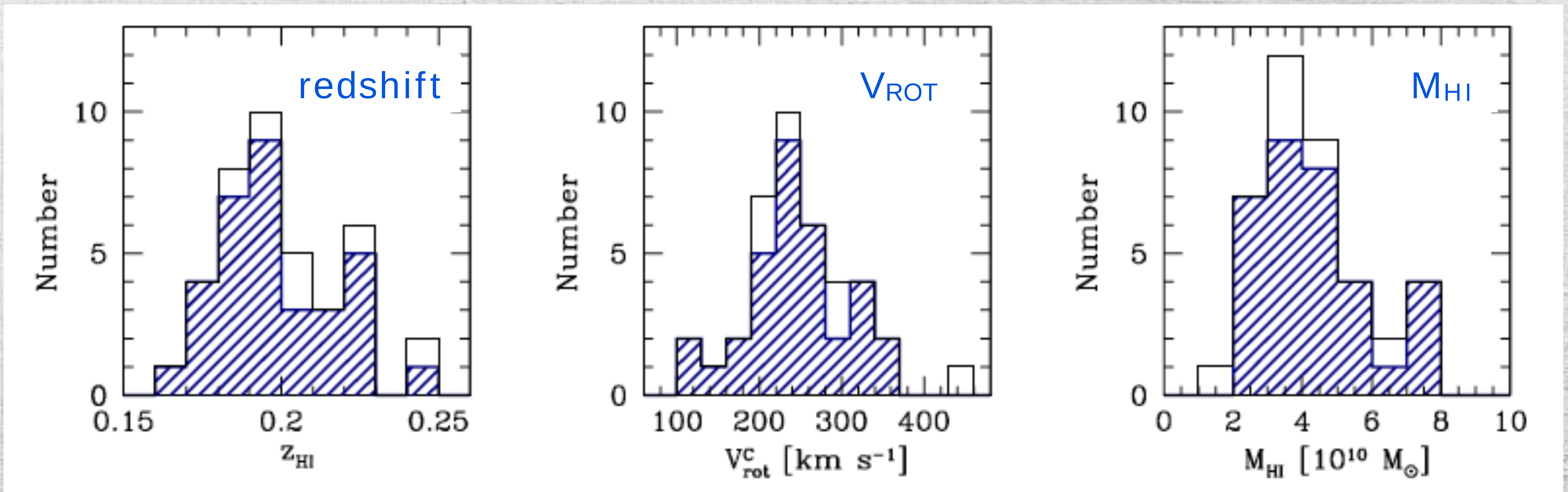


Catinella et al. 2008, ApJL



Highest z detection of HI emission to date (z=0.25)

The very HI-rich Universe



Catinella & Cortese (2015)

Among the most HI massive galaxies known

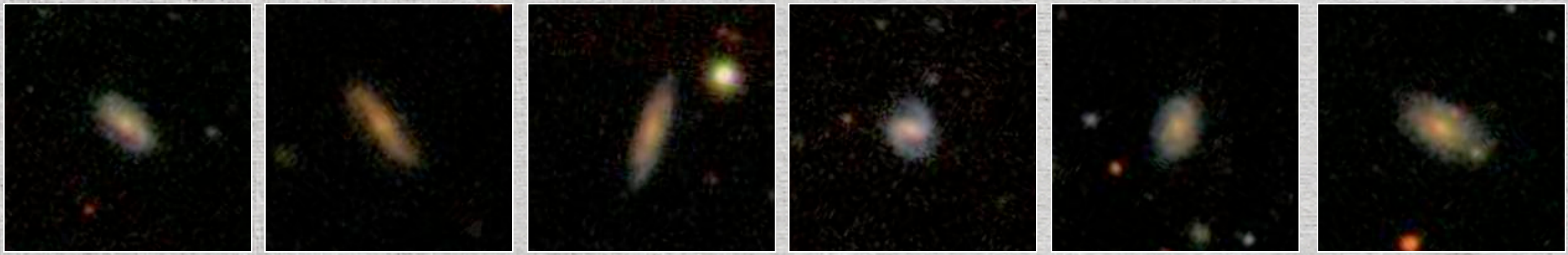
- 29 detections + 10 marginal
- $0.17 < z < 0.25$
- HI mass $2 - 8 \times 10^{10}$ $M_\odot$
- Stellar mass > 10^{10} $M_\odot$
- NUV-r < 3.5 mag (blue sequence)
- SFR = 3-35 $M_\odot$/yr

Why should you care?

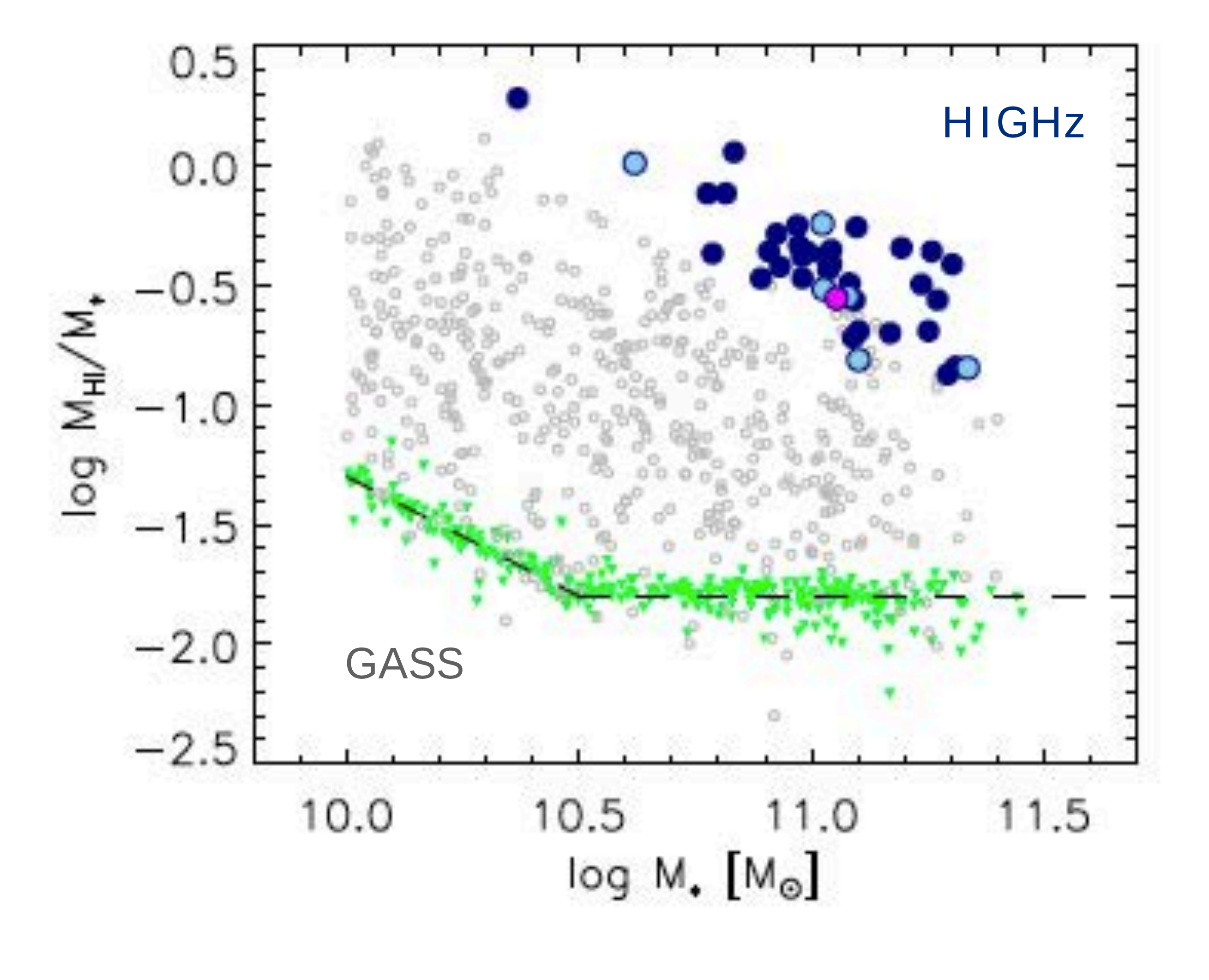
Our rms is just x2 higher than DINGO

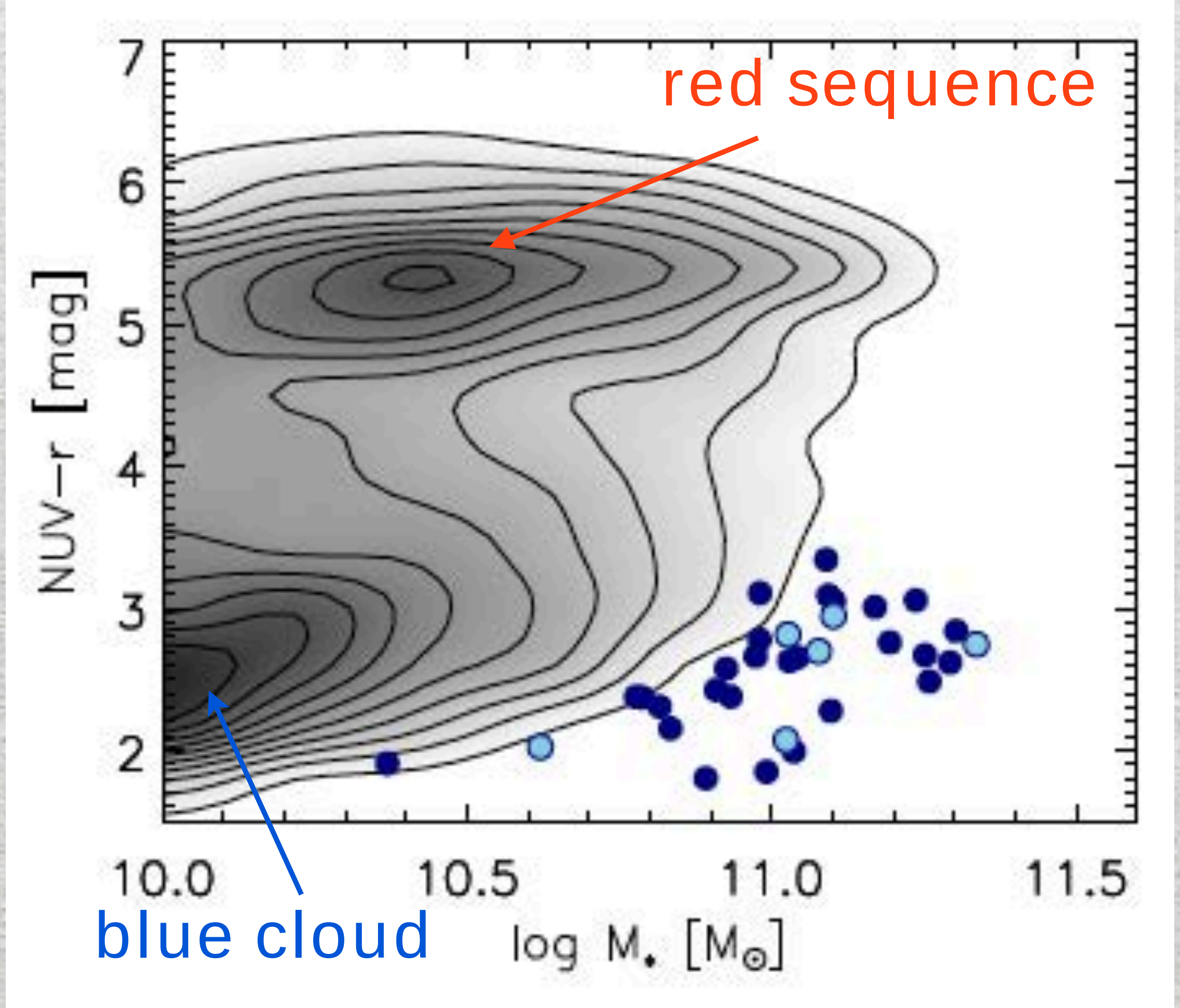
[assuming T_{sys}=50 K]

These are the galaxies that ASKAP/DINGO will see at z~0.2!



Comparison with local galaxies scaling relations

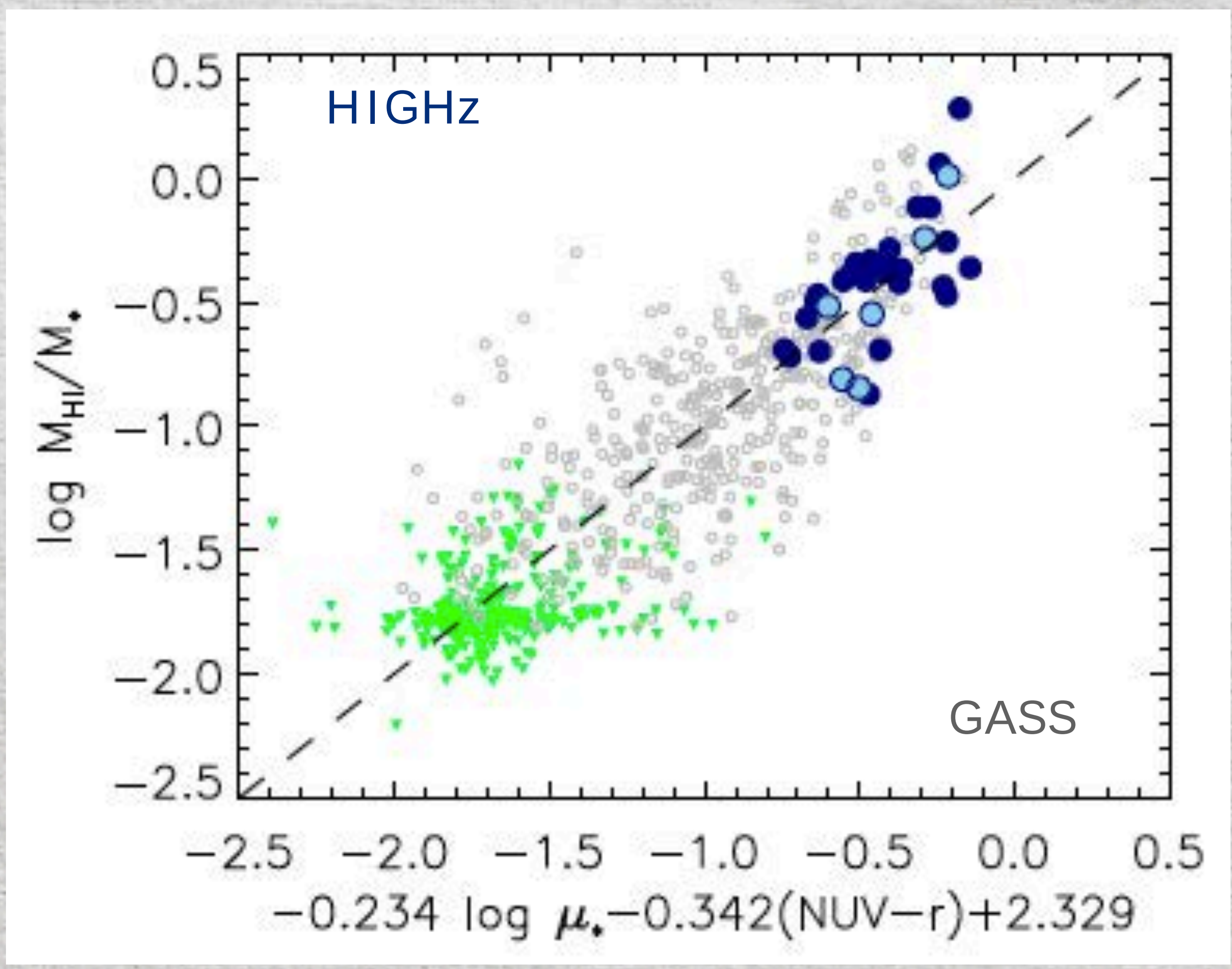




Unusually HI-rich and unusually blue for their stellar masses

HI as expected from SF and morphology

measured gas fraction



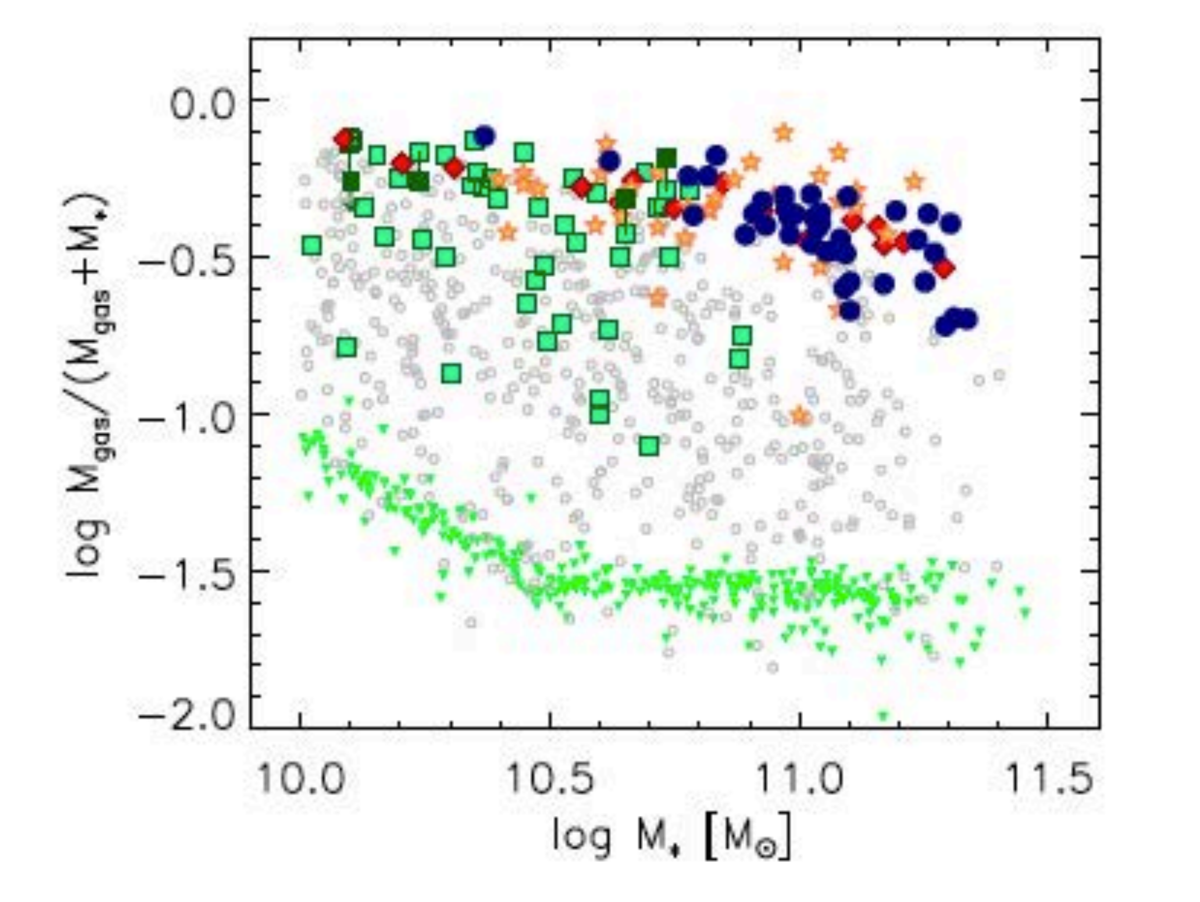
predicted gas fraction

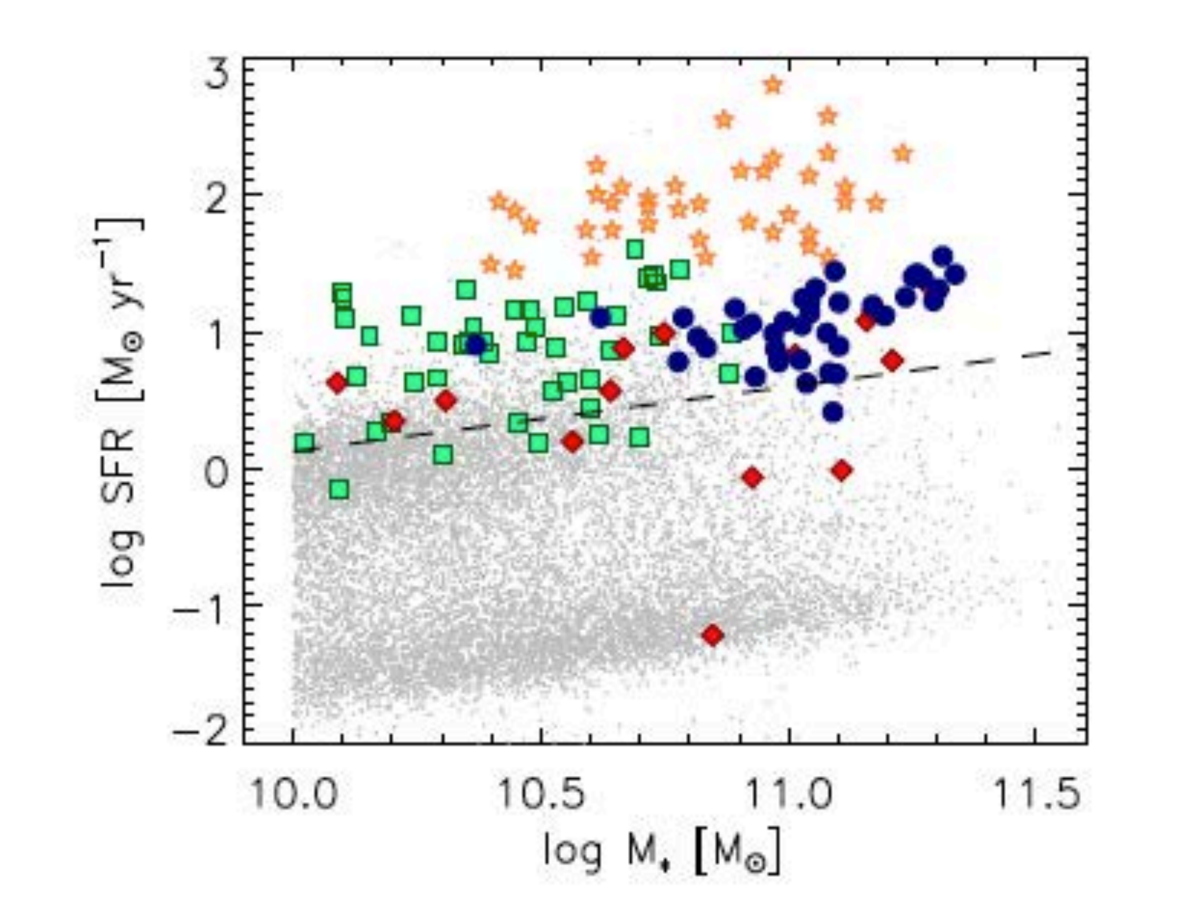
Not weirdos, just filling new parameter space!

How do they compare with high-z turbulent disks?

PHIBSS (Tacconi et al. 2013)
✦ IRAM PdB CO(3-2) survey of z~1-2 star-forming (SF) galaxies

DYNAMO (Green et al. 2014)
✦ local SF galaxies, selected to be analogs to PHIBSS (gas estimated from KS law)



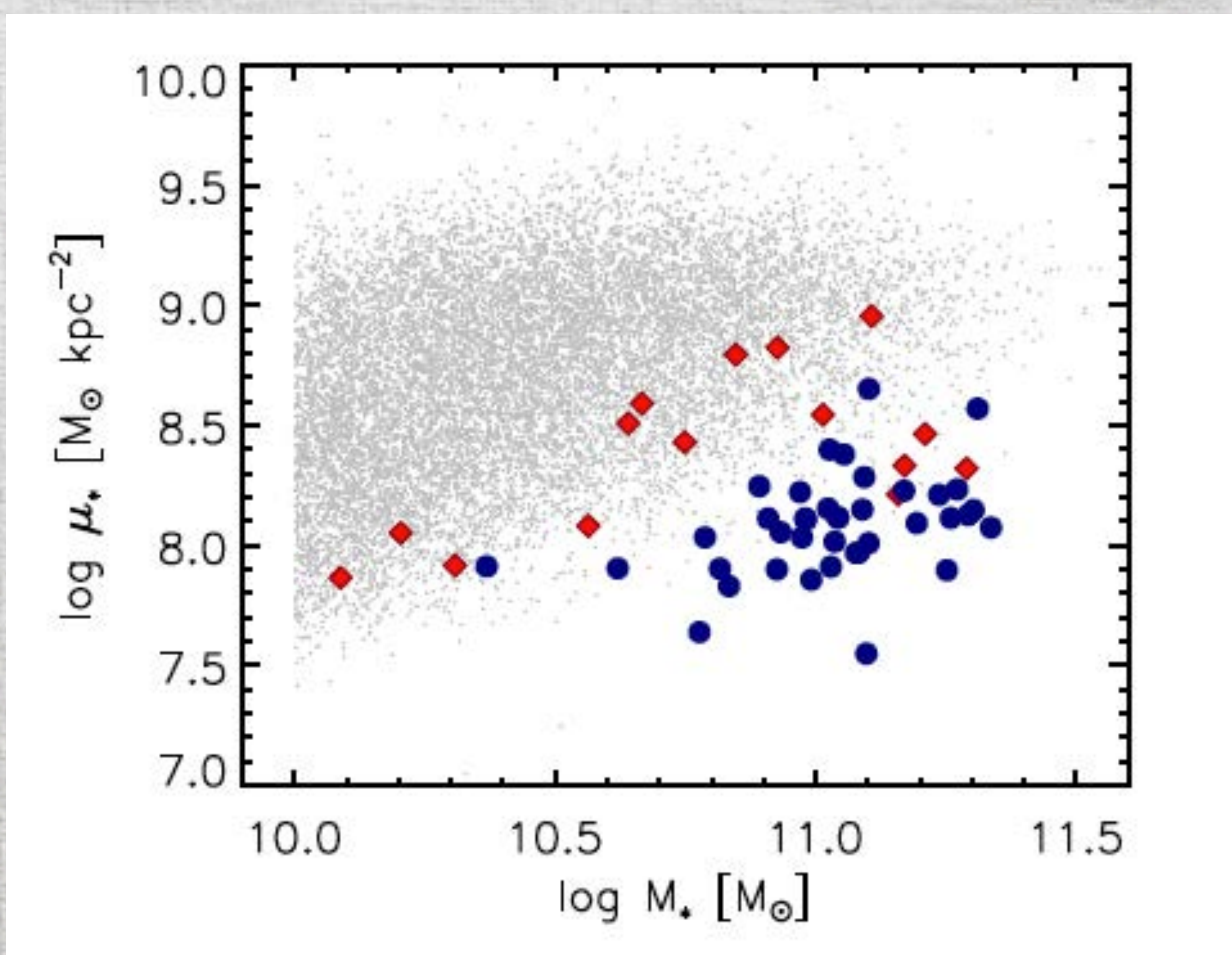


Catinella & Cortese (2015)

Why are these galaxies so gas-rich?

HIGHz: unusually gas-rich, star-forming...

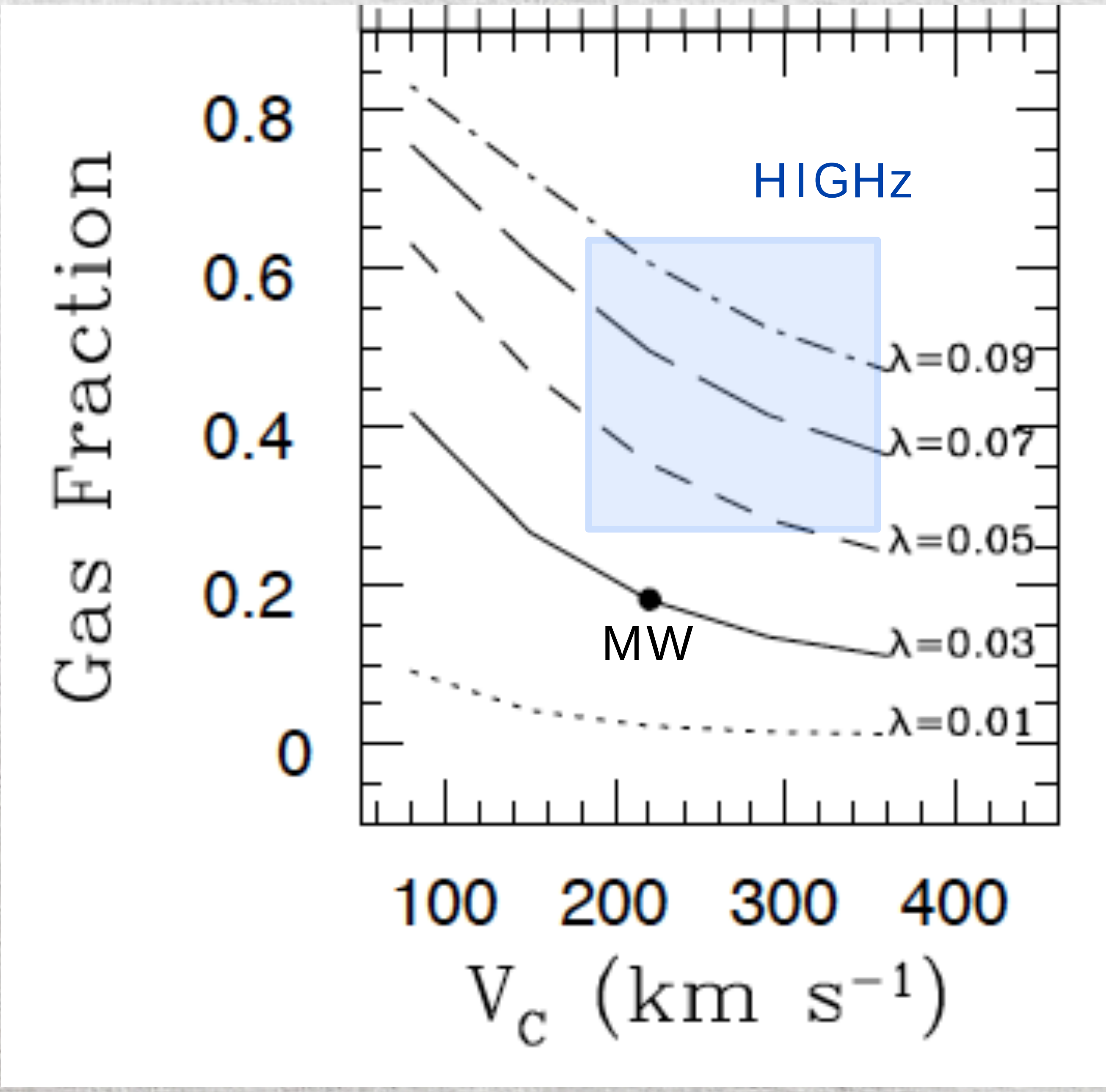
but also with more extended disks!



Low stellar surface densities ➔ larger optical radii ➔ extended disks

To form such large disks
angular momentum should be higher than typical disk galaxy

Large gas content and spin parameter

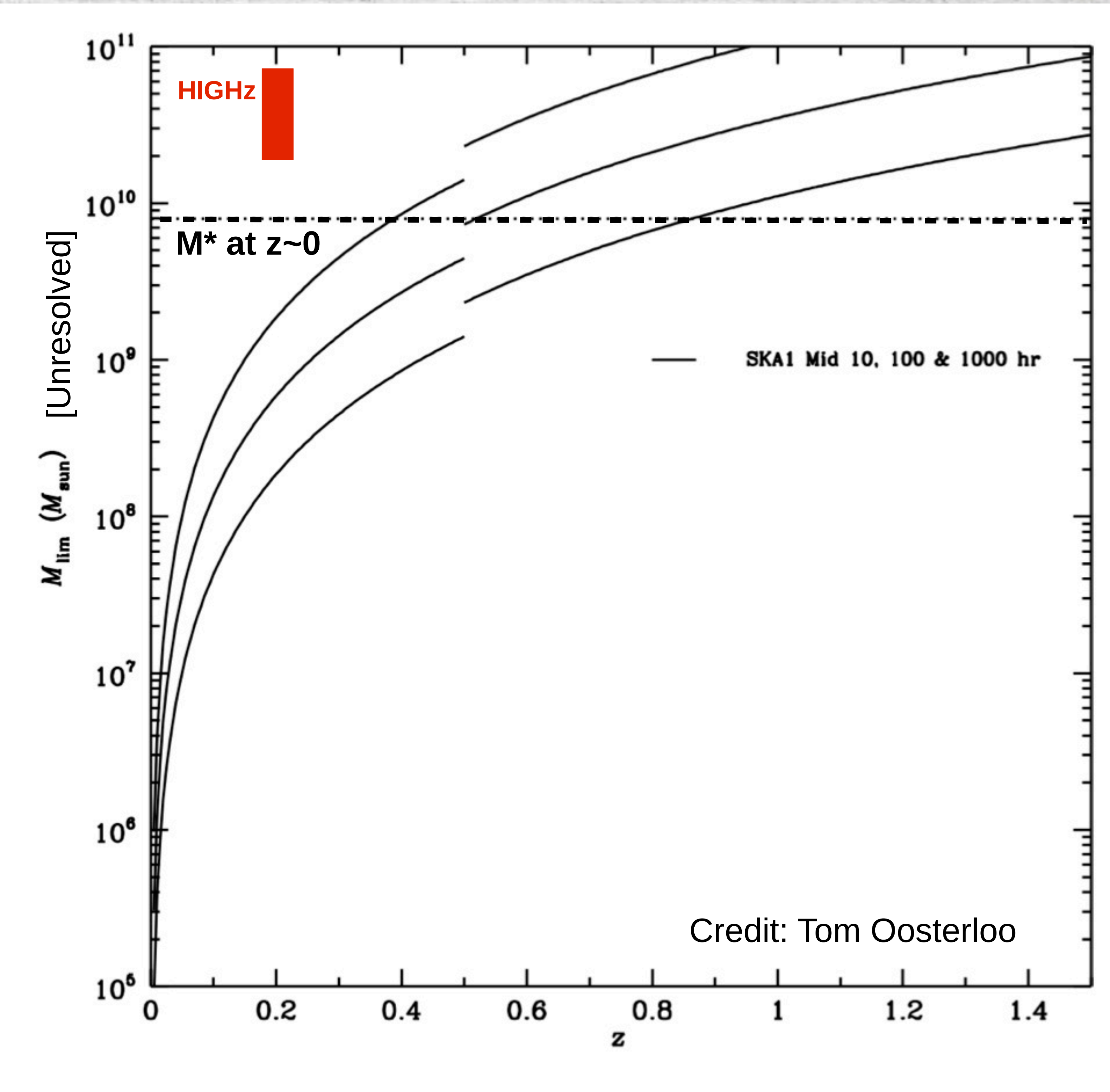


Boissier & Prantzos (2000)

Models assume exp disk with angular momentum proportional to that of the halo (Mo, Mao & White 1998). Hence $R_d \sim \lambda V_C$

High-end tail of the spin parameter distribution of local disks

What will we be able to do with SKA phase 1?



Large samples at z~0.5 should be doable... z>0.5 much harder

HIGHz: summary

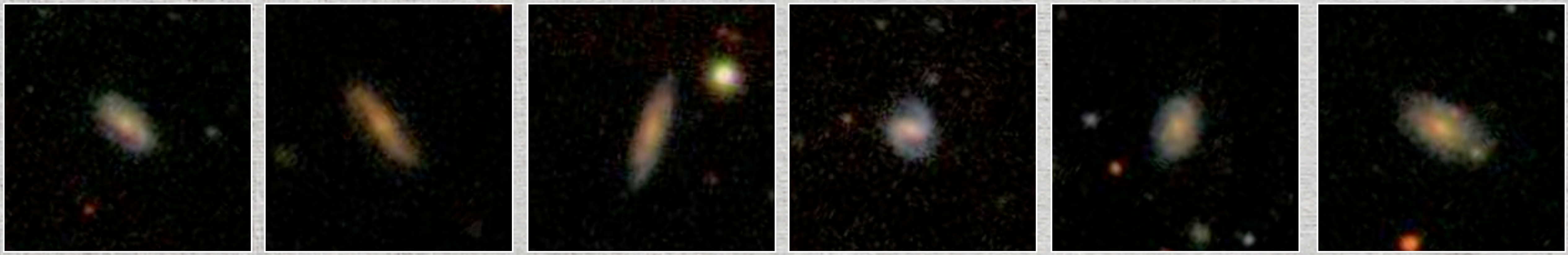
✦ HIGHz: 39 galaxies with HI measurements at 0.17 < z < 0.25

✦ Huge HI reservoirs, rare in local Universe – but their HI masses are as expected from their stellar surface densities and NUV-r colors

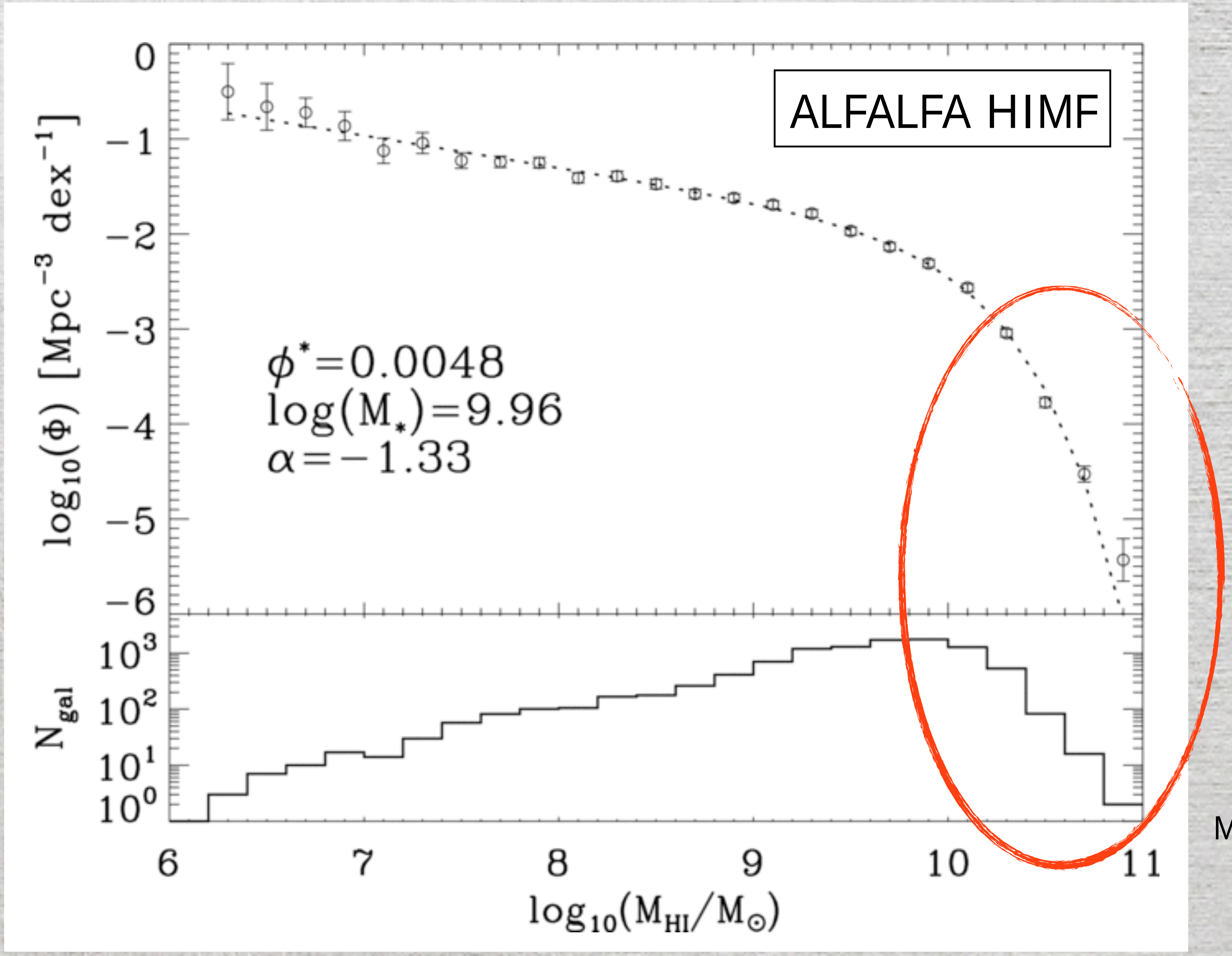
✦ High-end of spin parameter distribution of local disk galaxies

✦ Probe HI-star formation connection in unusually HI-rich regime

✦ These are the galaxies that SKA and its pathfinders will detect at higher z



HIGHz galaxies are rare, but found at z=0 as well



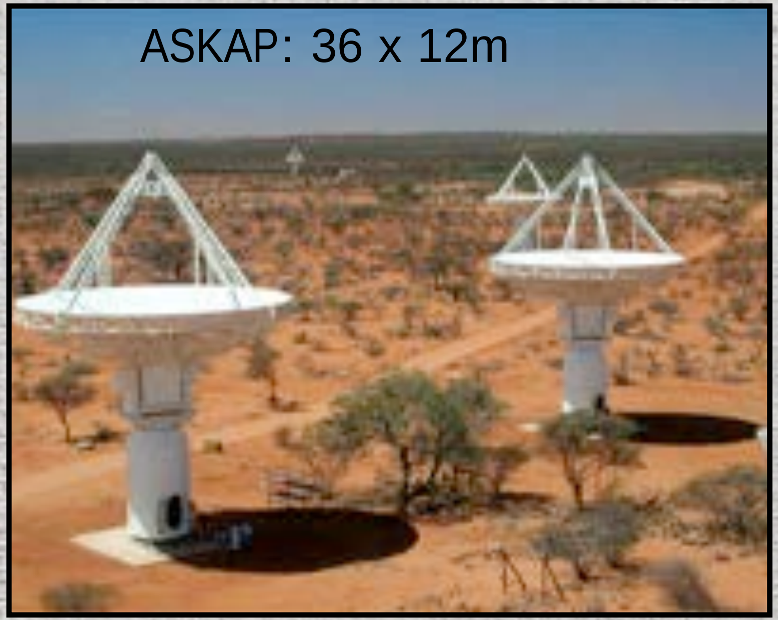
Martin et al. 2010

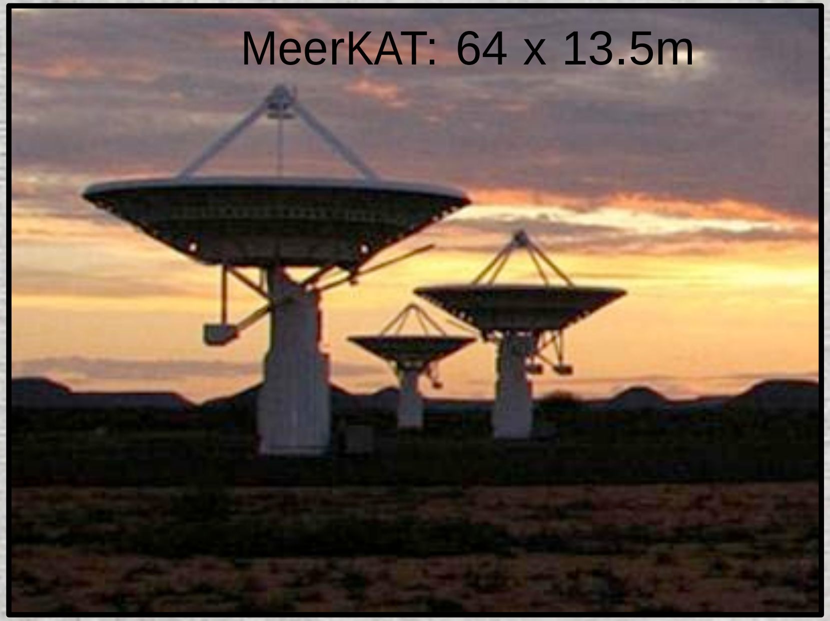
One of the most exciting outcomes of ALFALFA is the abundance of high HI mass galaxies (10x more than predicted by HIPASS)

Extragalactic HI astronomy: the future

SKA precursors will revolutionize HI astronomy:

- blind shallow surveys will provide unprecedented statistics of HI-bearing systems in the local Universe
- medium/deep surveys will image large number of galaxies, probe higher z

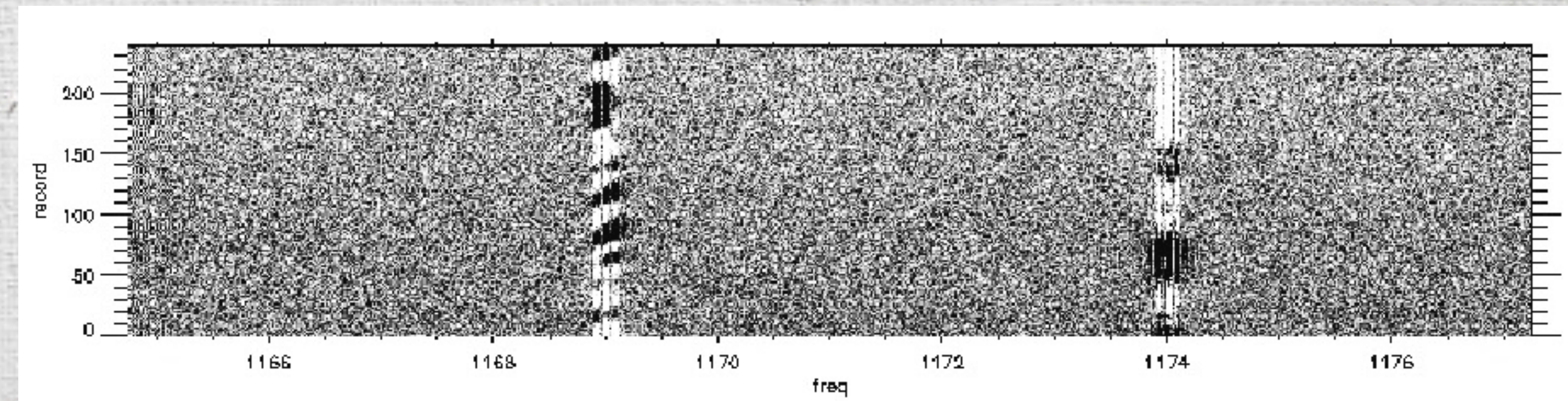




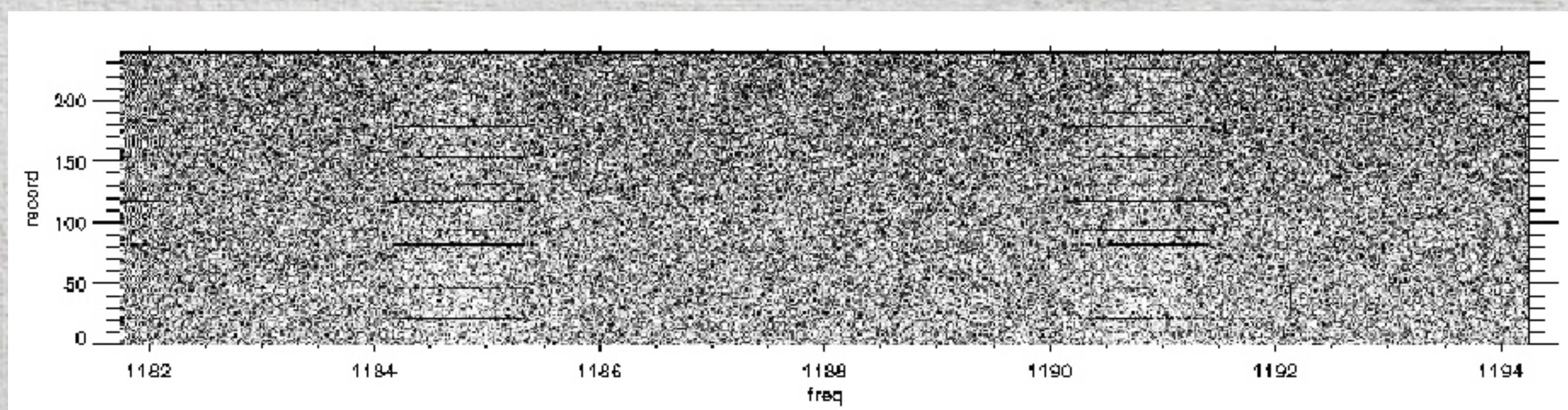
SKA
SQUARE KILOMETRE ARRAY
www.skatelescope.org

Radio Frequency Interference (RFI)

z=0.219 z=0.207

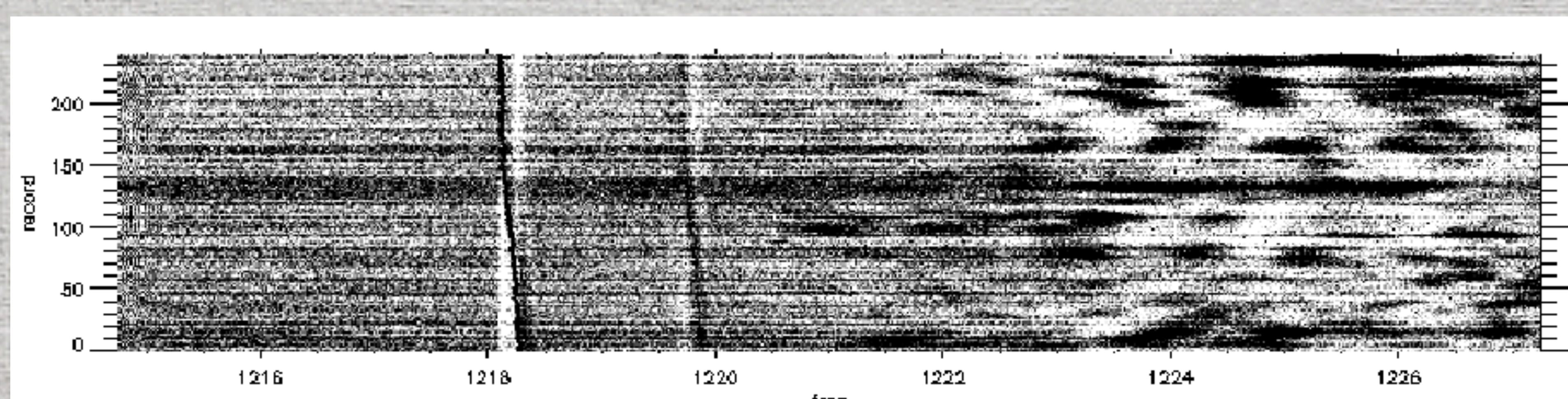


z=0.202 z=0.190



Time →

z=0.169 z=0.158



Frequency →

HI emission above z=0.1

Detection of 21 cm emission at z > 0.1 is DIFFICULT

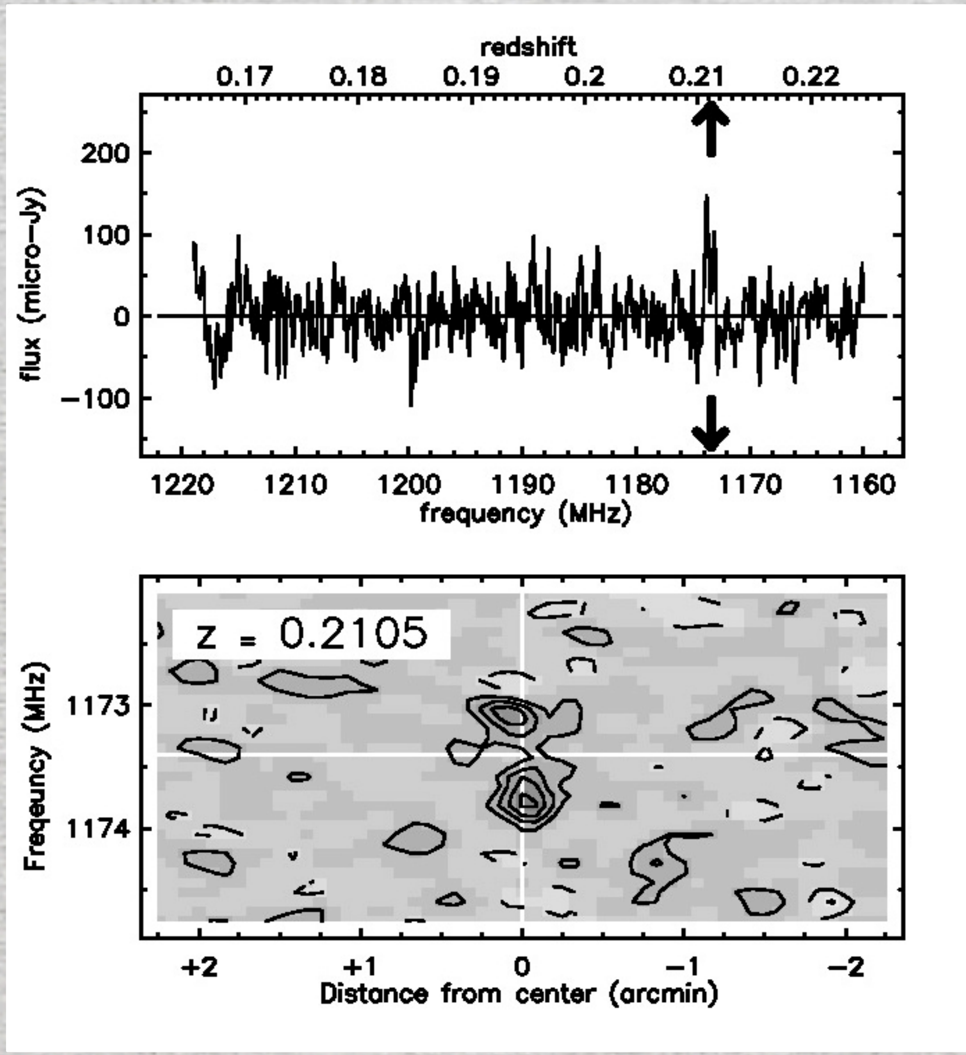
- weak signals → very long integration times
- radio frequency interference (RFI)

Almost NOTHING known about HI content of galaxies above z=0.1

- Zwaan et al. 2001 WSRT, 18×12 hrs
  Abell 2218 → 1 galaxy at z=0.1766

- Verheijen et al. 2007 WSRT
  Abell 963 (z=0.206), A2192 (z=0.188)
  pilot observations

Full survey: 1404 hr (A963) + 876 hr (A2192)
(unpublished)



Verheijen et al. 2007

Radio Frequency Interference (RFI)