CHILES

The COSMOS HI Large Extragalactic Survey

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(The pilot: ApJ Letters, 2013, Fernandez et al) …plus…

Lucas Hunt, John Hibbard, Min Yun, Rien van de Weygaert, Joe Lazio, Aeree Chung, Martin Meyer, Andreas Wicenec, Ryan Joung, Amidou Sorgho

USA, South Africa, Germany, Australia, The Netherlands, Korea

Present at this meeting

Unique aspects of JVLA among SKA path finders

- Strengths
- It is up and running
- Correlator is more powerful
- Sensitivity comparable to MeerKAT
- Baseline distribution, angular resolution of 5”

and most collecting area at spacings > 2 km

Weaknesses

It is a multi user instrument and it
will be harder to schedule large amounts of time
Relatively small FOV

Uniquely suited to do deep imaging at high redshifts

Main scientific motivation for CHILES

HI morphology as function of location in underlying large scale structure

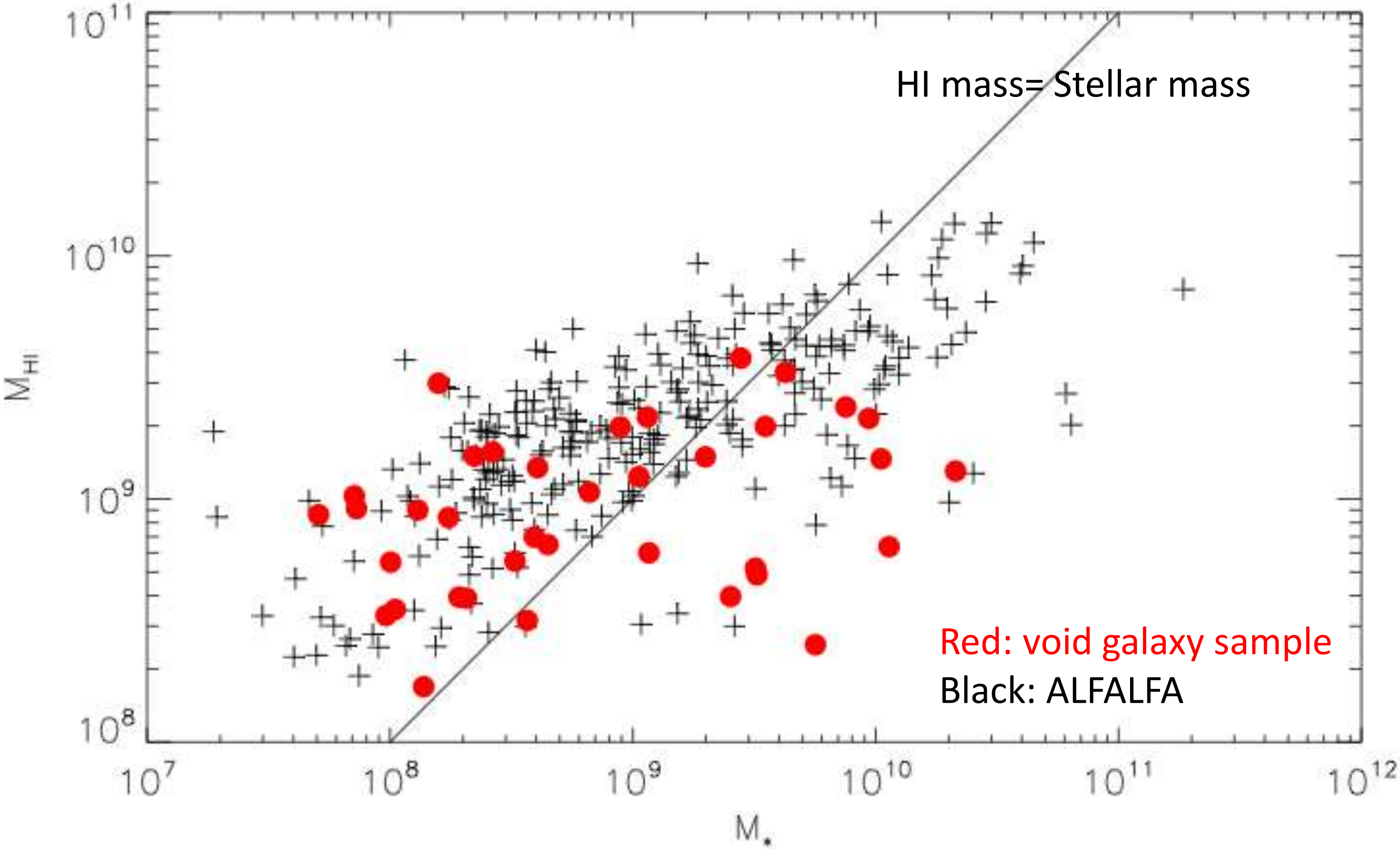
note that even at z=0.45 we will probably be able to say whether HI is inside or outside a galaxy

HI content, morphology and kinematics of individual galaxies
HI mass function as function of z and environment
Cosmic neutral gas density as function of z
Evolution of Tully Fisher relation

Very deep continuum studies (sub microJy)
source counts, star formation versus AGN

Transients.. Good overlap with transient surveys at other wavelengths, i.e. Pan-STARSS

HI must have something to do with galaxy evolution



Small galaxies are gas dominated– large galaxies have more mass in stars than in gas

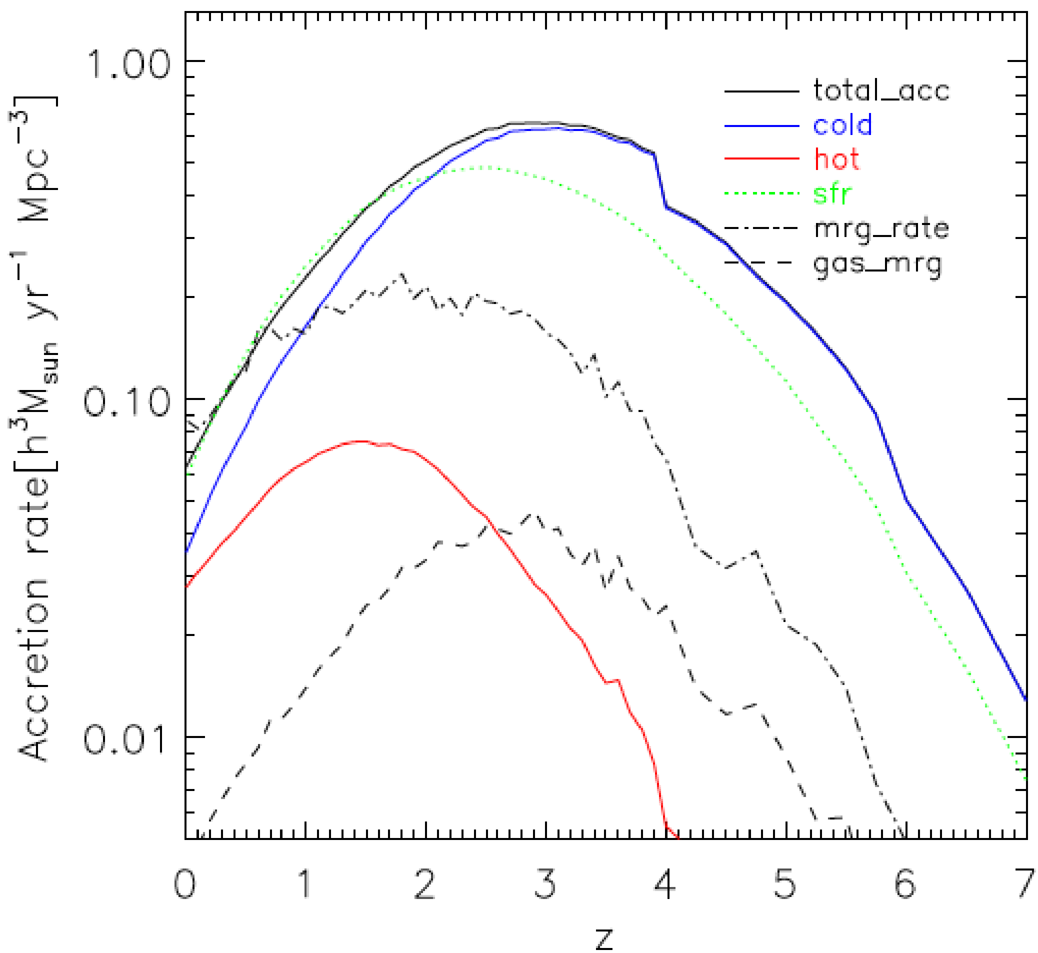
We (sort of) understand how large scale structure grows, but how galaxies form and evolve is less well understood.

Hierarchical galaxy formation in "standard" LCDM, used to make galaxies grow by merging, but the importance of gas accretion was underestimated and the physics misunderstood.

There are two ways for galaxies to grow

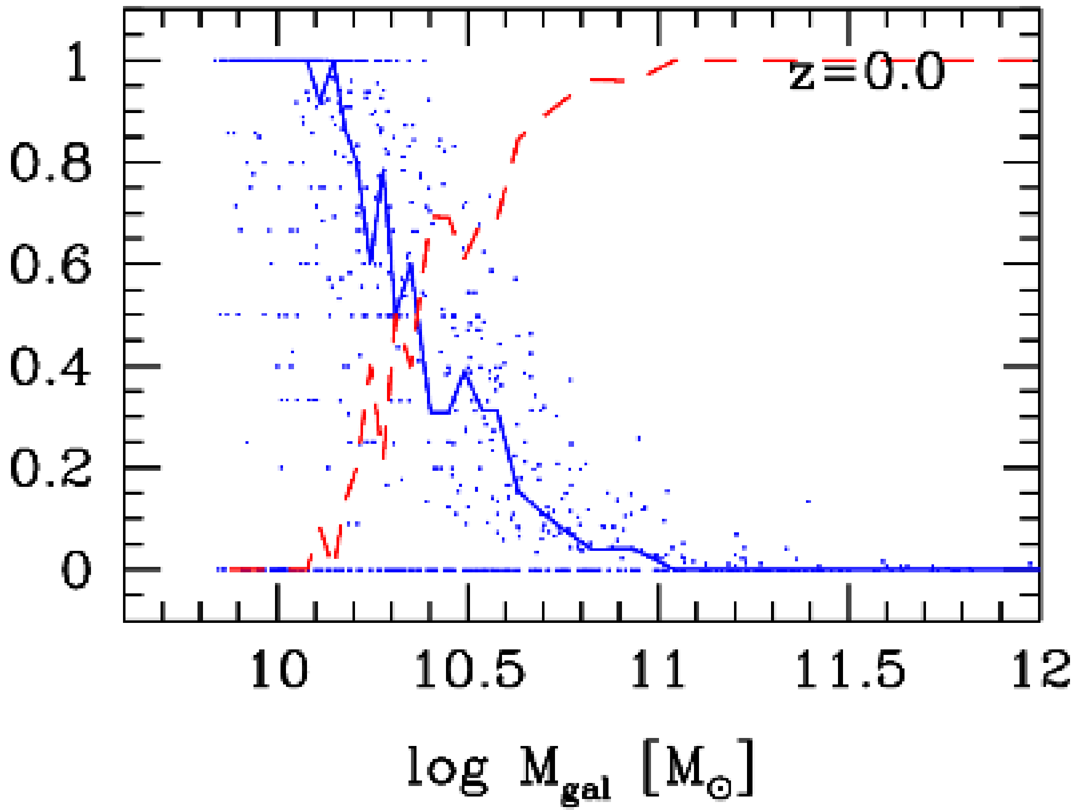
1) Merging with smaller galaxies can add gas and stars

2) Smooth accretion of cool gas
   dominates gas accretion at all z
   dominates total accretion at z>1



Keres et al 2005, Dekel and Birnboim 2006, Binney 1977

Modes of accretion depend on halo mass

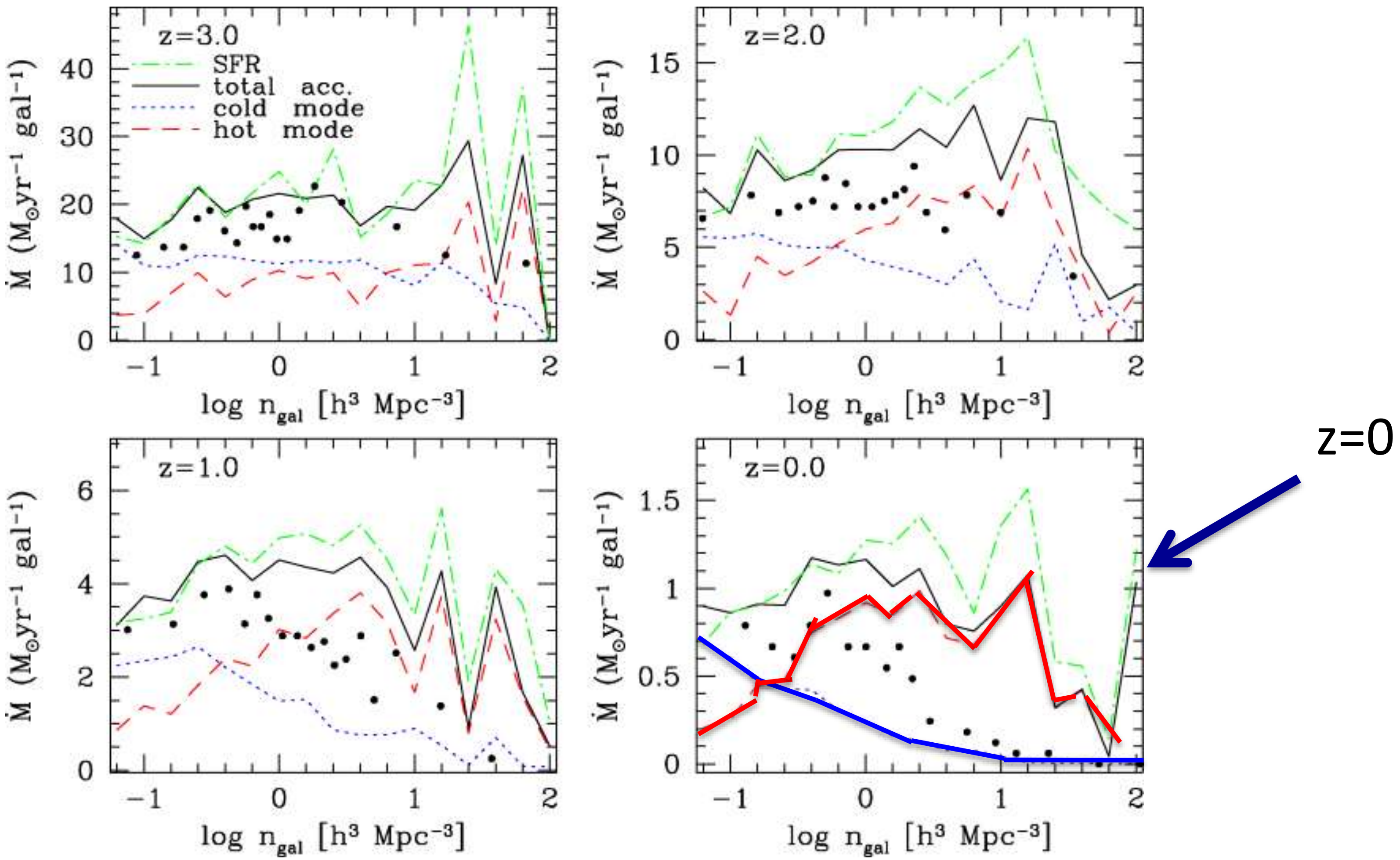


Blue: “cold mode” accretion

Red: “hot mode accretion

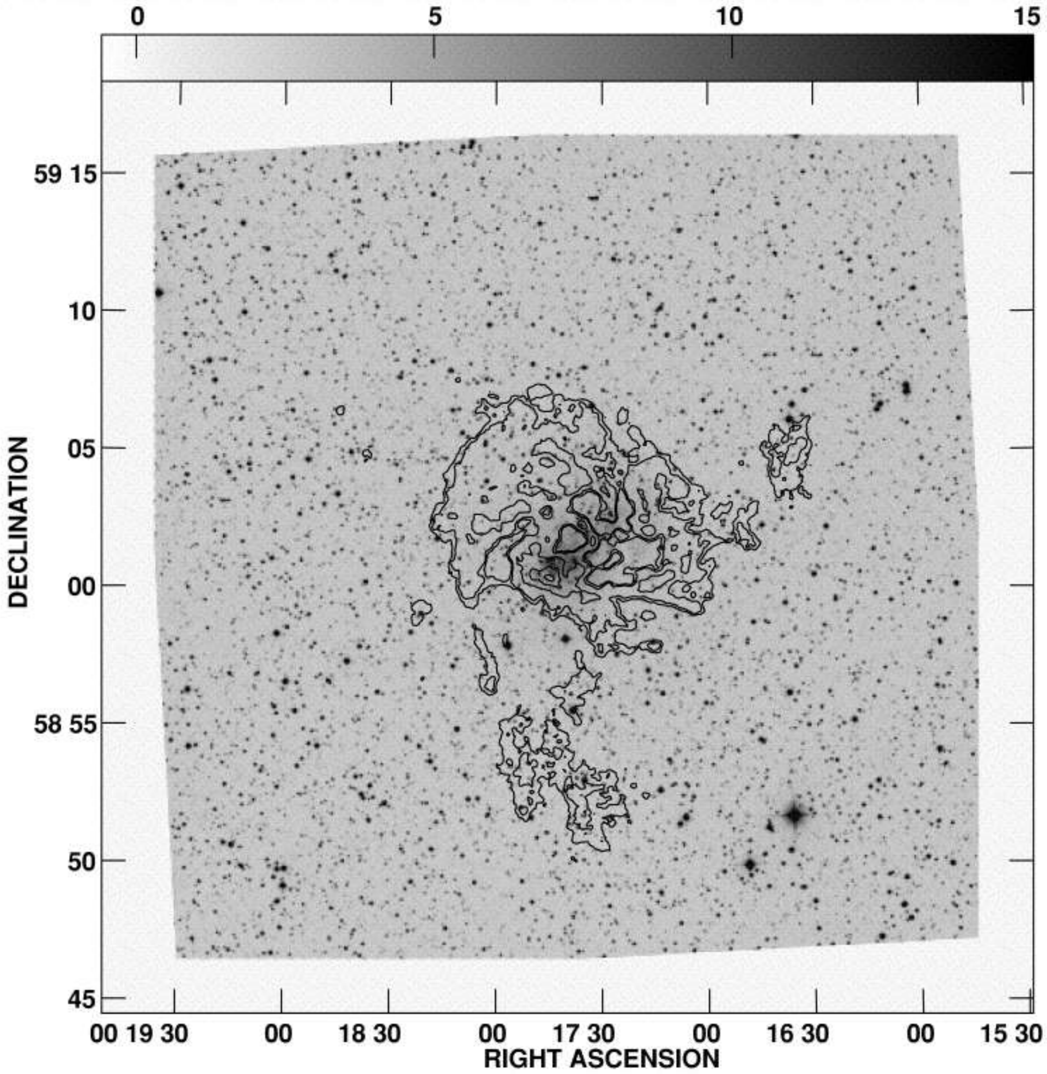
At low z cold mode accretion may still dominate in small galaxies

Best chance to see ongoing cold gas accretion at z=0 appears to be in low density regions and in low mass haloes



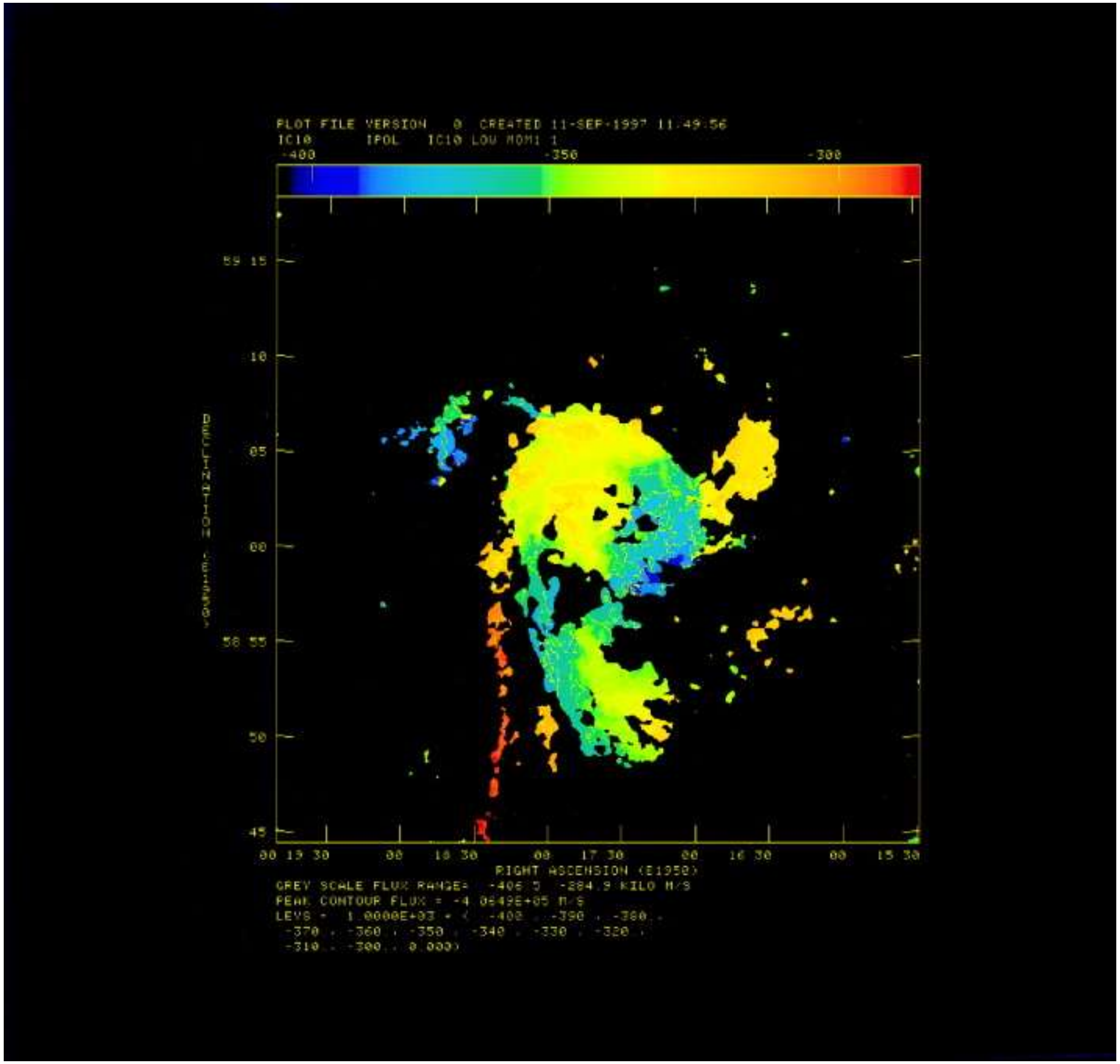
Keres et al, 2005, MNRAS 363, 2

IC10: A galaxy still forming via the accretion of gas (Wilcots & Miller 1998)



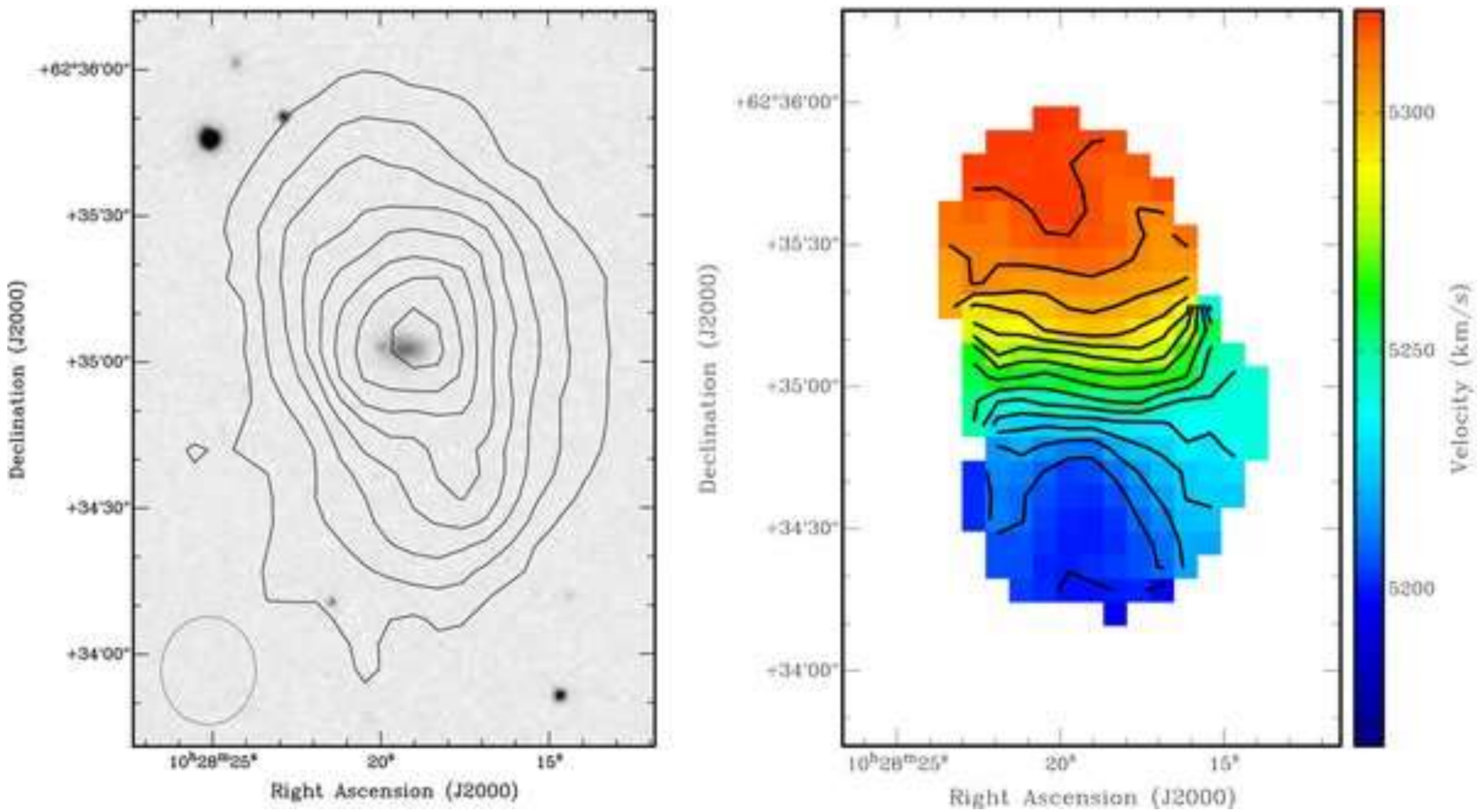
Even if simulations turn out to be wrong (recent Arepo results by Hernquist et al), we know from observations that some galaxies are accreting cold gas.

Intensity weighted velocity field.. Filaments seem disconnected



The discontinuities in velocity make it much more likely that this is accretion than tidal

The void galaxy survey: A polar disk

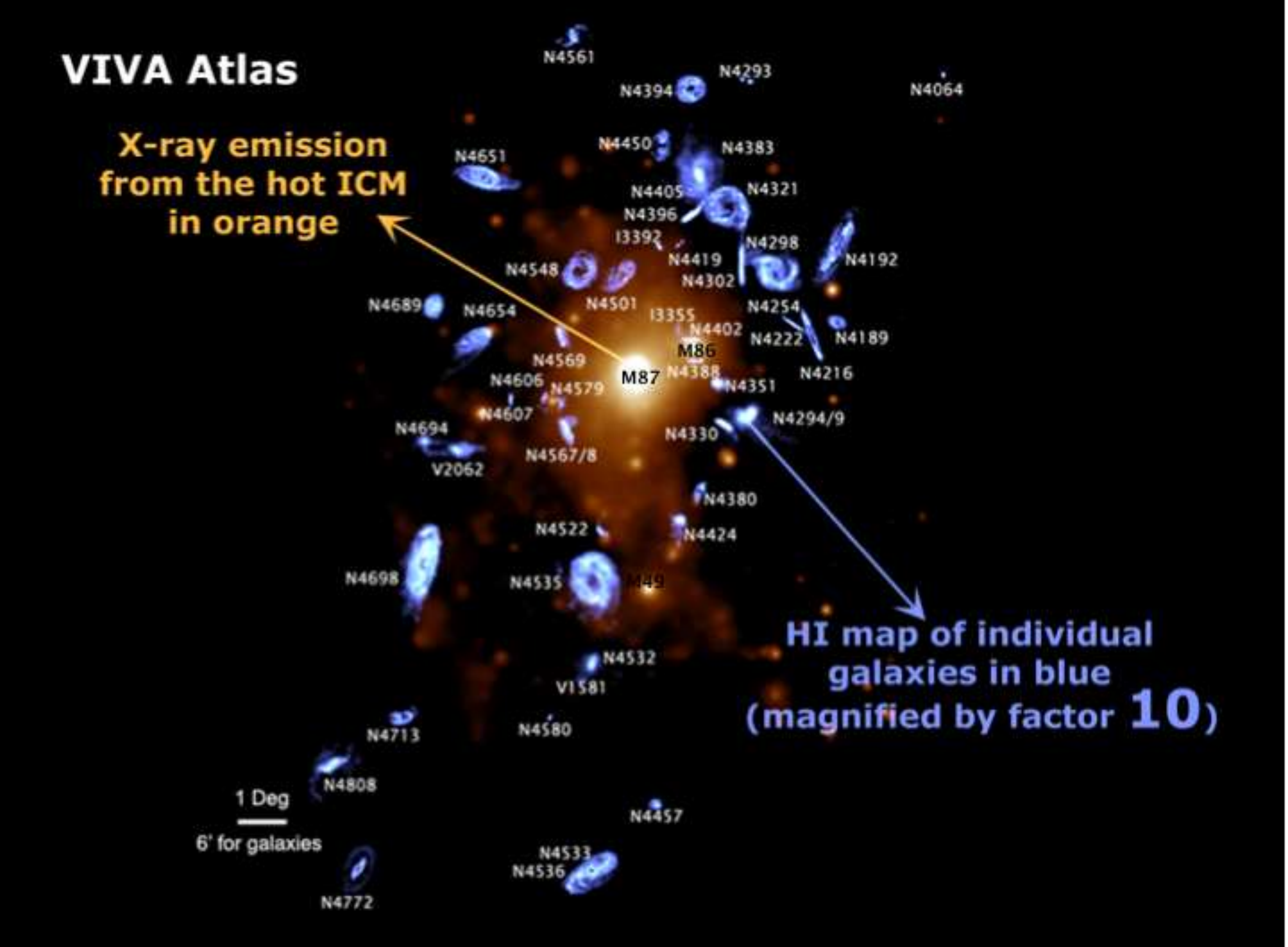


Void galaxies are small and show many hints that they are still accreting gas

Stanonik et al 2009, Kreckel et al 2012

In voids galaxies are small and still accrete gas,

In clusters.. and groups galaxies lose their gas…


VIVA Atlas
X-ray emission from the hot ICM in orange
HI map of individual galaxies in blue (magnified by factor 10)
1 Deg
6' for galaxies
N4561
N4293
N4394
N4064
N4450
N4383
N4651
N4405
N4321
N4396
I3392
N4298
N4192
N4419
N4548
N4302
N4501
N4689
N4654
I3355
N4254
N4402
N4222
N4189
M86
N4569
N4216
M87
N4388
N4606
N4579
N4351
N4607
N4294/9
N4694
N4330
N4567/8
V2062
N4380
N4522
N4424
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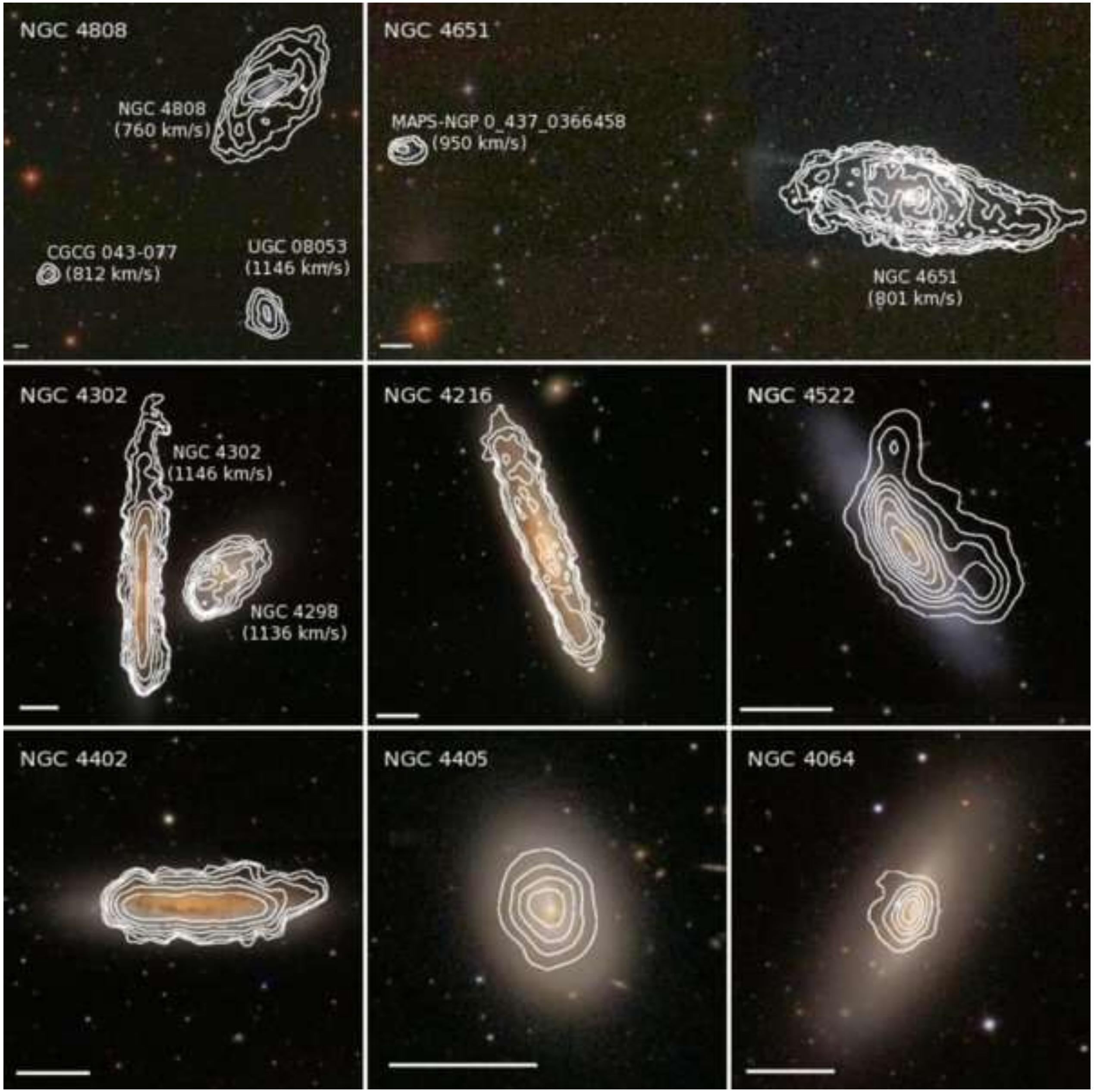
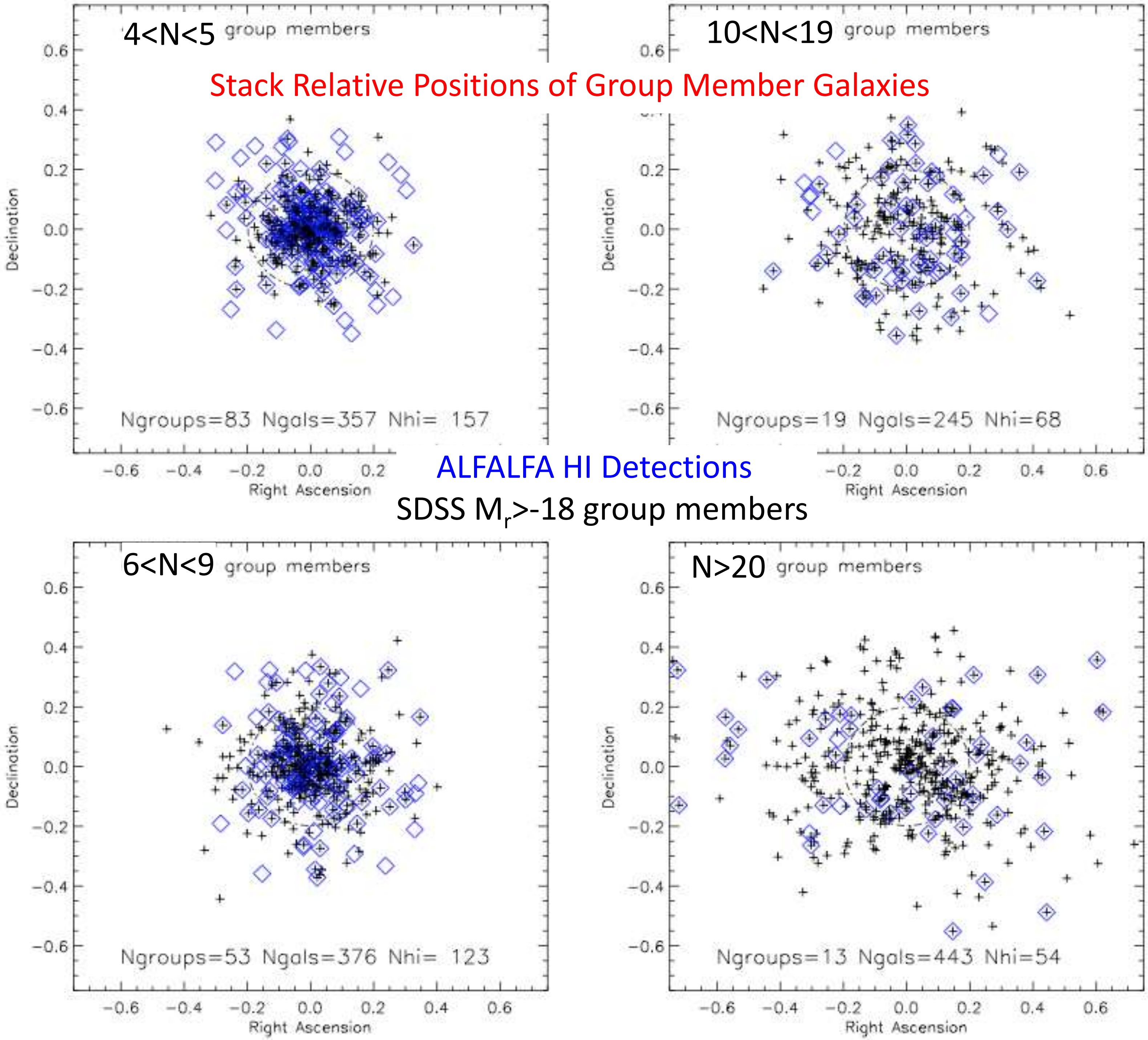
N4457
N4533
N4536
N4772



Chung et al, 2009


Stack Relative Positions of Group Member Galaxies
ALFALFA HI Detections
SDSS M_r>-18 group members
4<N<5 group members
Ngroups=83 Ngals=357 Nhi= 157
10<N<19 group members
Ngroups=19 Ngals=245 Nhi=68
6<N<9 group members
Ngroups=53 Ngals=376 Nhi= 123
N>20 group members
Ngroups=13 Ngals=443 Nhi=54
Declination
Right Ascension
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6

HI Imaging at Higher z

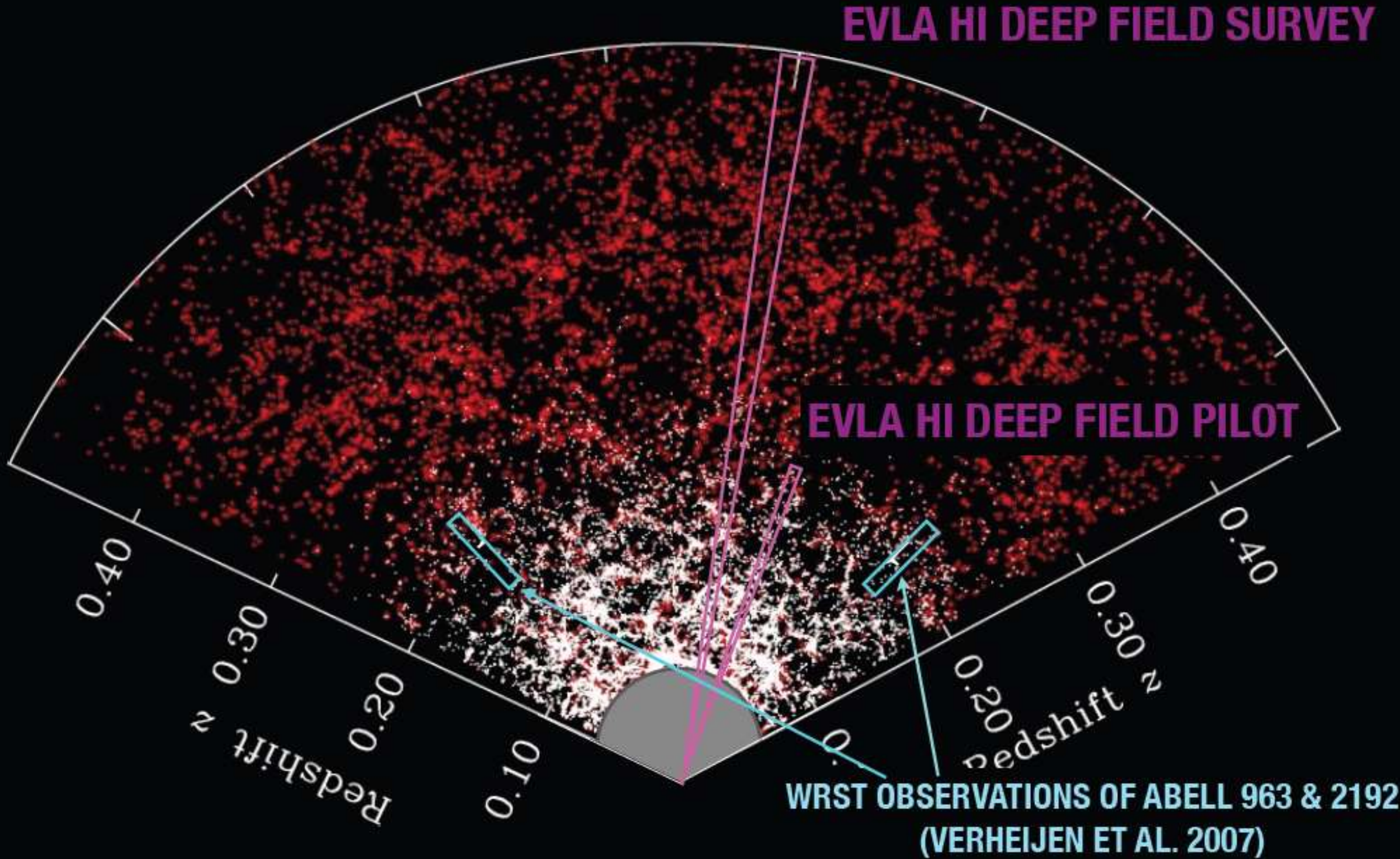
- Probing HI morphology in relation to large scale structure will become possible with future HI imaging instruments (out to z~1)

- JVLA (ready 2013), Apertif (2015)

- ASKAP (2016) MeerKat (2016)

Eventually SKA

HI surveys



EVLA HI DEEP FIELD SURVEY
EVLA HI DEEP FIELD PILOT
0.40
0.30
0.20
0.10
Redshift z
0.40
0.30
0.20
WRST OBSERVATIONS OF ABELL 963 & 2192
(VERHEIJEN ET AL. 2007)

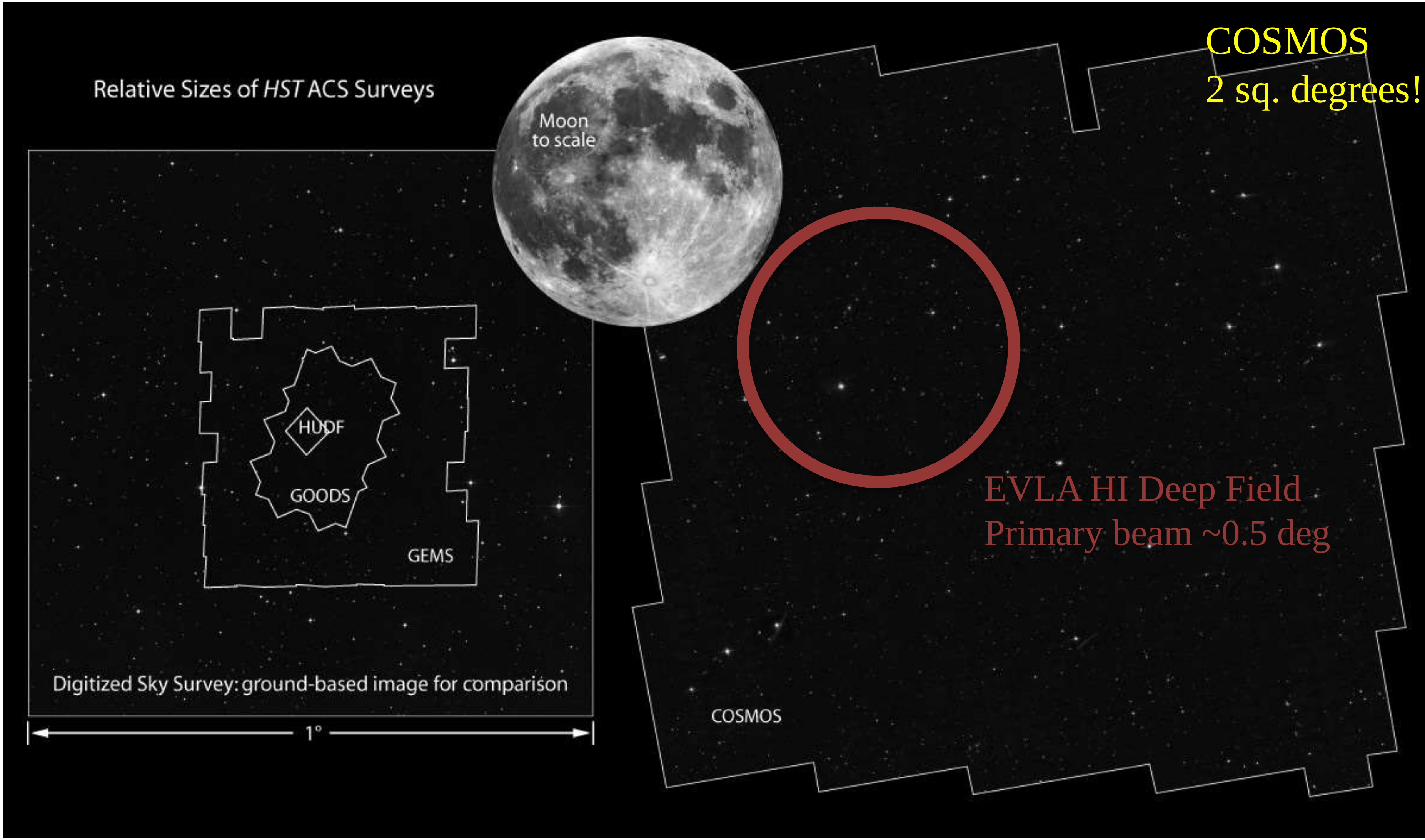
An Upgraded VLA

	OLD	PILOT	NEW
Bandwidth (MHz)	6.25	240	480
Channels	31	16384	32768
Velocity resolution (km/s)	40	3.5	3.5
Instantaneous z coverage	$0<z<0.004$	$0<z<0.193$	$0<z<0.45$

A Pilot for an EVLA HI Deep Field

CHILES

COSMOS HI Large Extragalactic Survey



Additional coverage by:

Spitzer, GALEX, XMM, Chandra

Subaru, VLA, ESO-VLT, UKIRT, NOAO, CFHT, CSO, CARMA, IRAM, Magellan

(Herschel, ALMA, APEX)

A pilot for an EVLA HI Deep Field

One pointing in COSMOS field

Fernandez, Hess, Momjian, Pisano, Oosterloo, JvG (the human calibration pipeline)
Popping, Chung, Henning, Verheijen, Schiminovich, Scoville

60 hours in B array (5 arcsec at z=0) , data taken in 2011.. 2.8 Tbyte
32 sub bands 16384 channels (1420-1190 MHz; z=0 to 0.2) vel resolution 3.3 km/s

Detection limits	z=0.07	$7x\ 10^8\ M_{sun}$
	z=0.13	$4x\ 10^9\ M_{sun}$
	z=0.2	$1.3 \times 10^{10}\ M_{sun}$

Column density sensitivity $3x10^{19}\ cm^{-2}$

Resolution	350 pc at 16 Mpc	17 kpc at z=0.2
FOV	150 kpc	7.5 Mpc

Goals of the PILOT

Can we handle the data volume? (2.8 Tbyte)

How bad is the RFI?

Can we reach theoretical noise?

Develop source detection algorithms.

Stacking.

SCIENCE: HI properties: content, morphology, kinematics as function of location in large scale structure

Deep continuum image… Star formation versus AGN

Transients

HI Mass Sensitivity

~Virgo, 16 Mpc

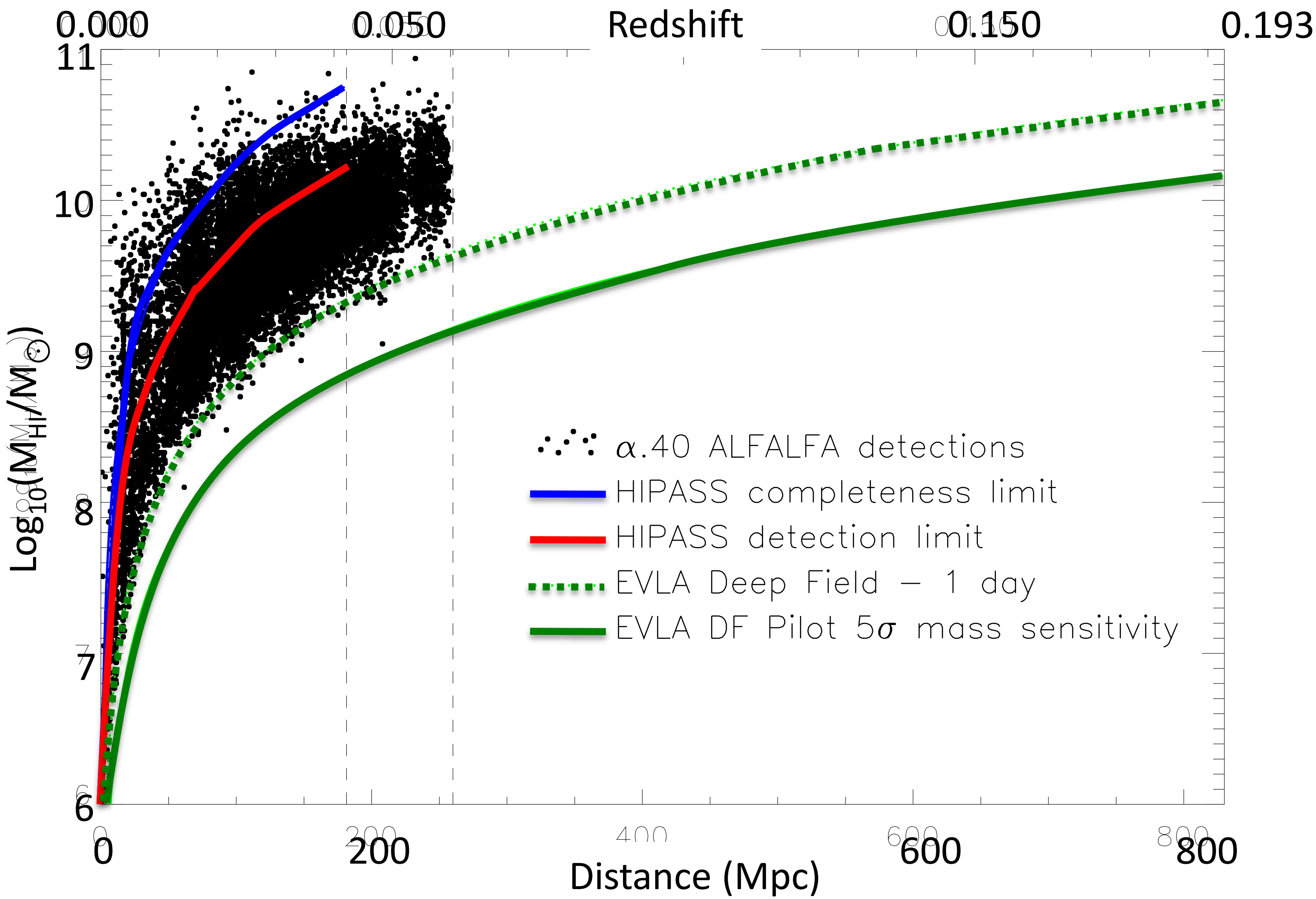
5σ M = 1.8×10^{6} M$_{\odot}$

z=0.07

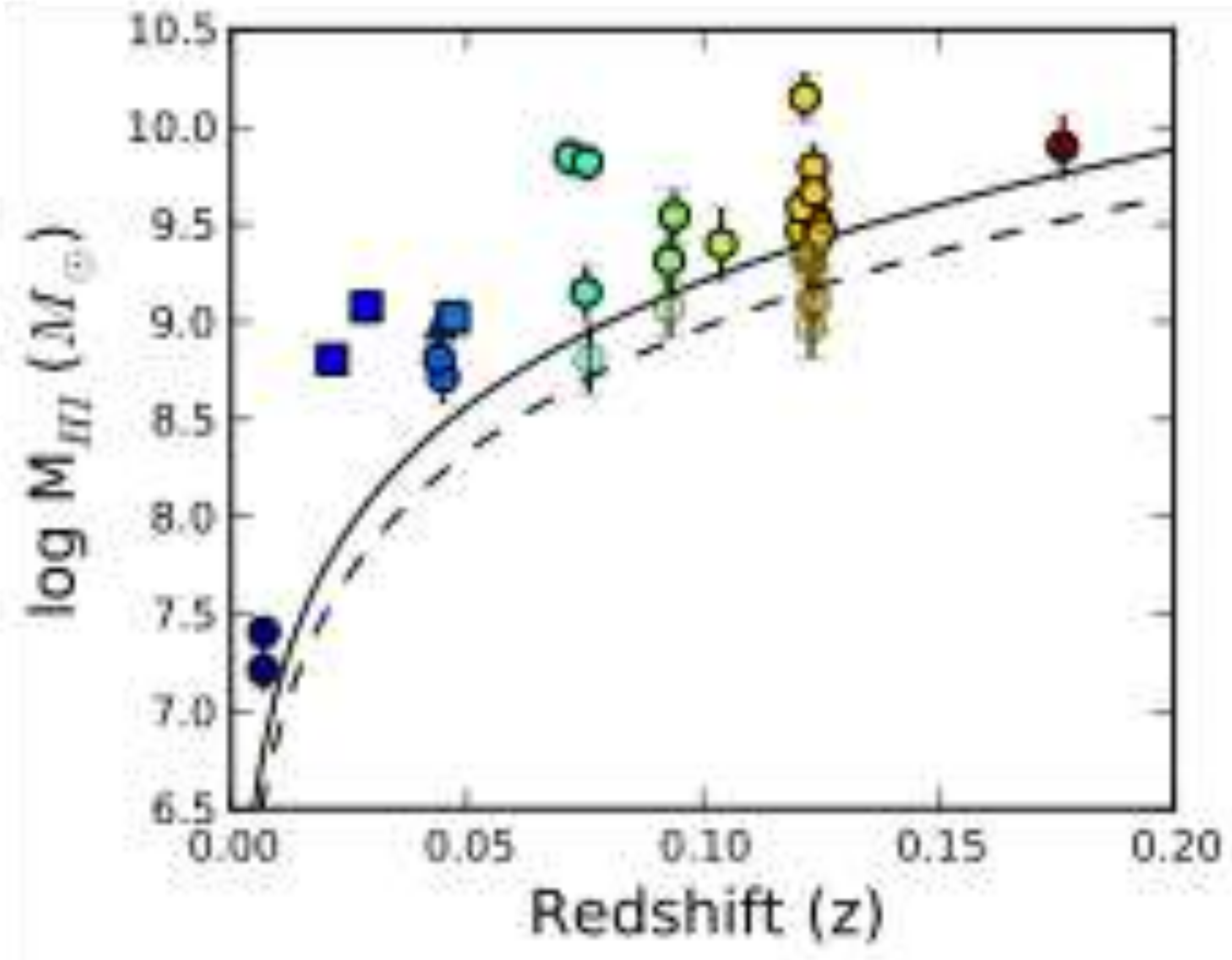
7×10^{8} M$_{\odot}$

4×10^{9} M$_{\odot}$

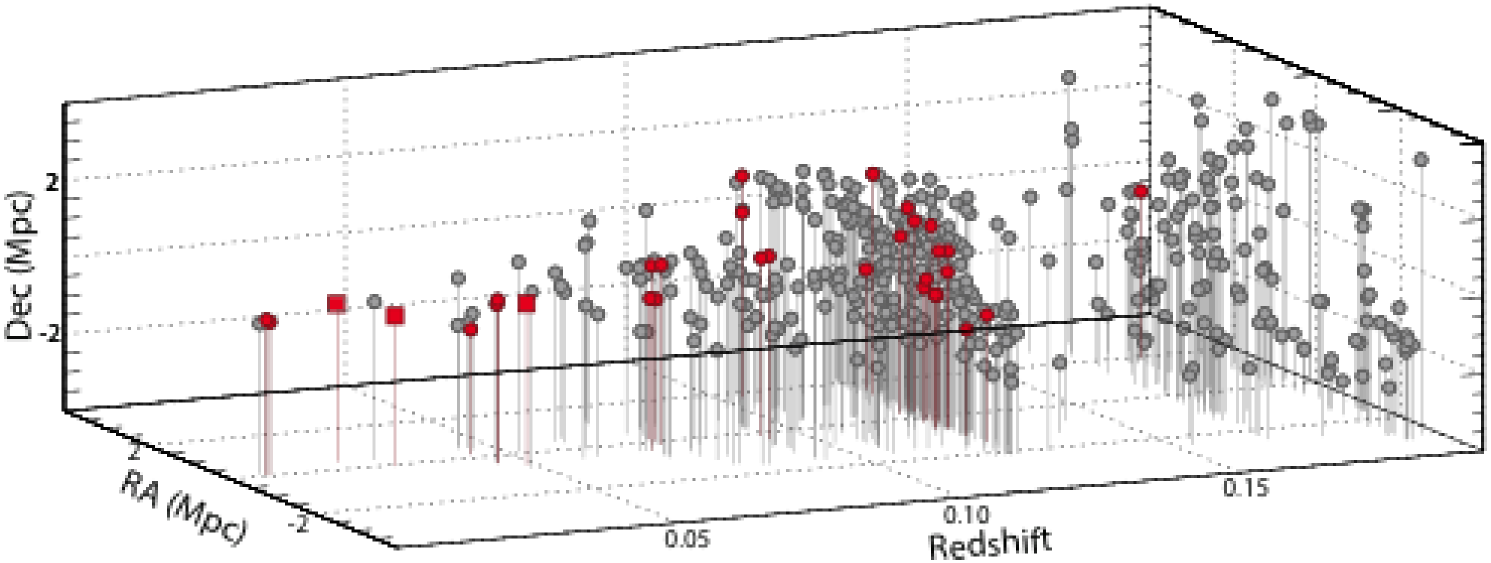
z=0.2



33 HI detections in pilot survey

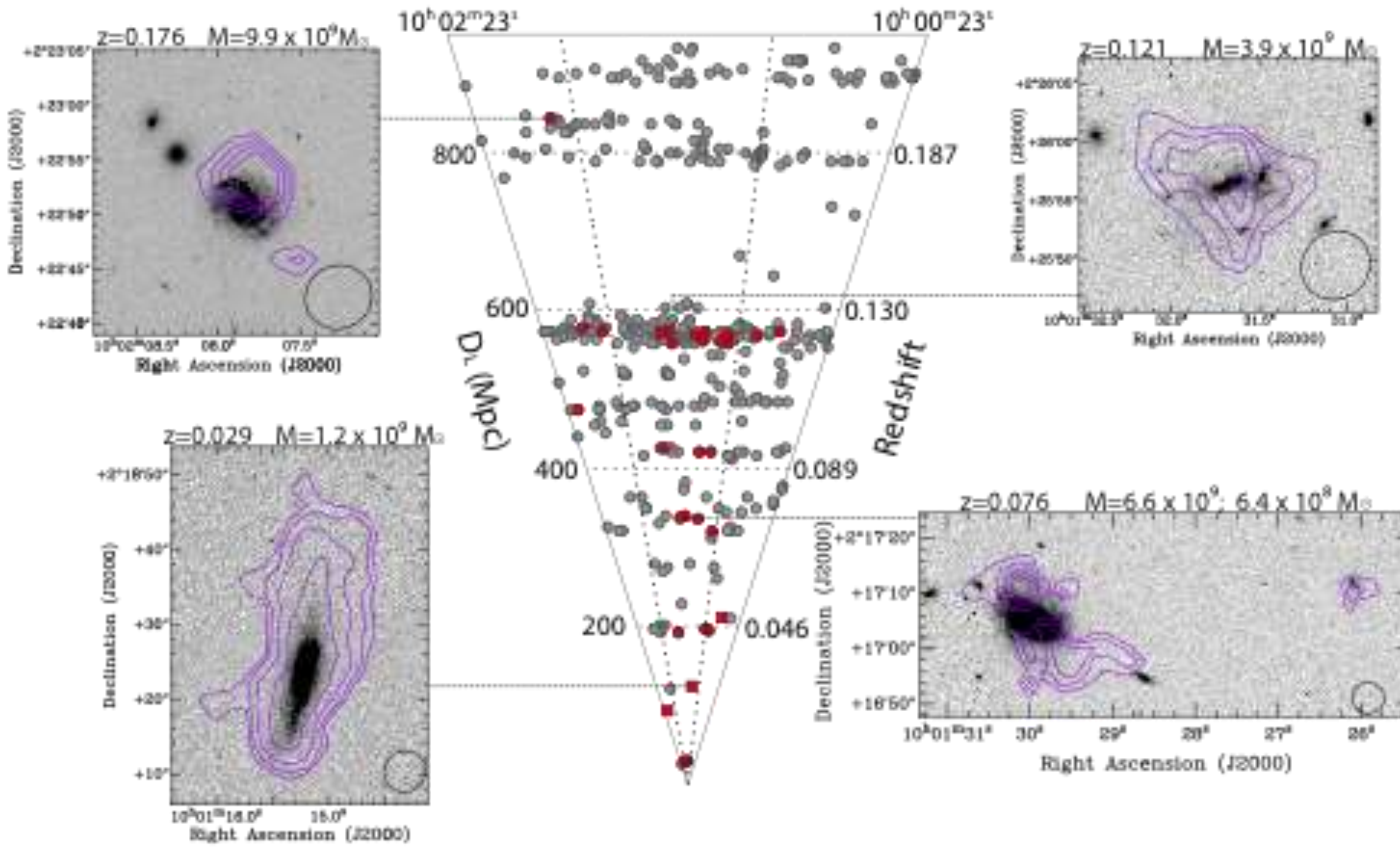


Solid line is 5 sigma limit, assuming 150 km/s width

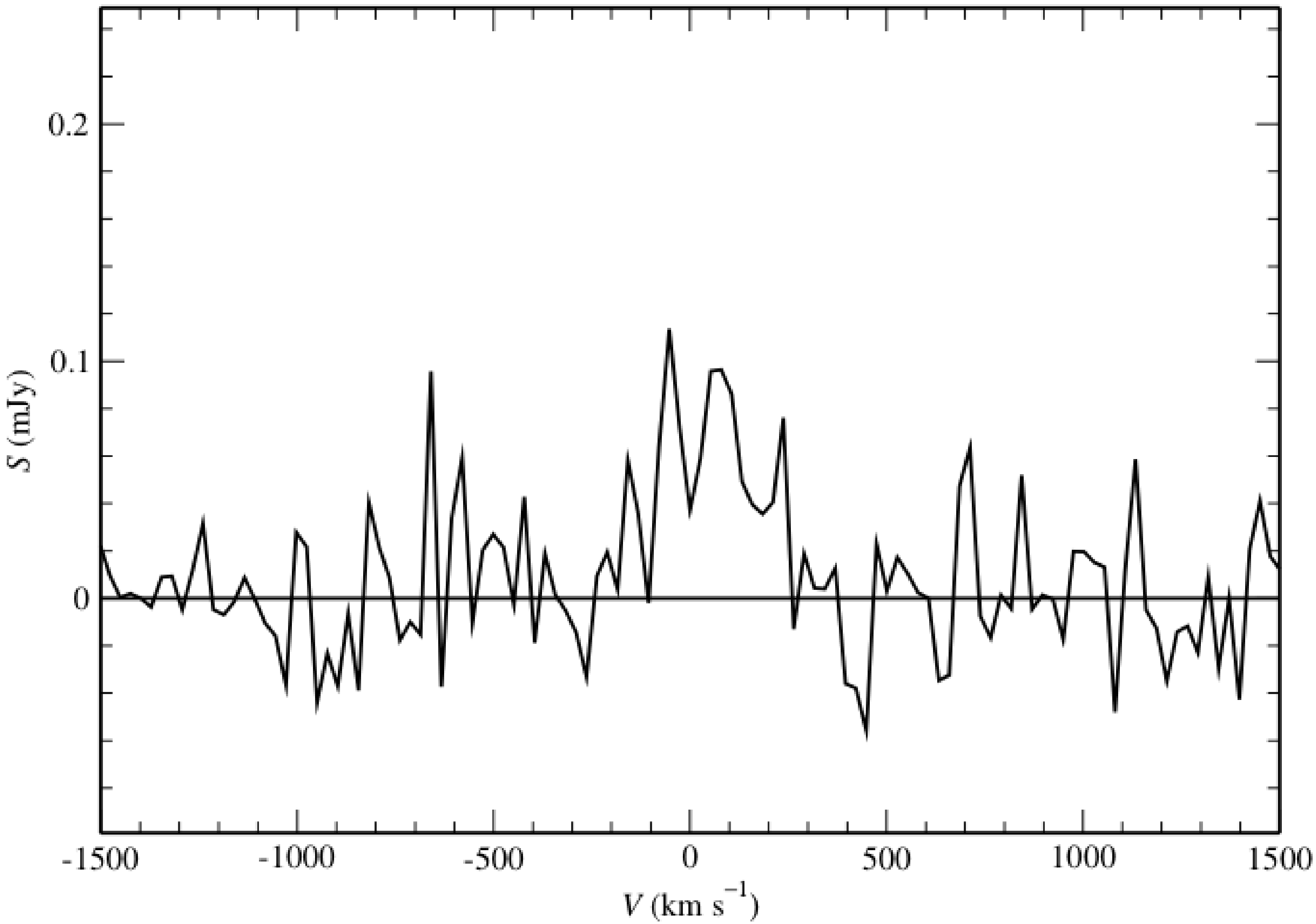


Sample detections in the CHILES field

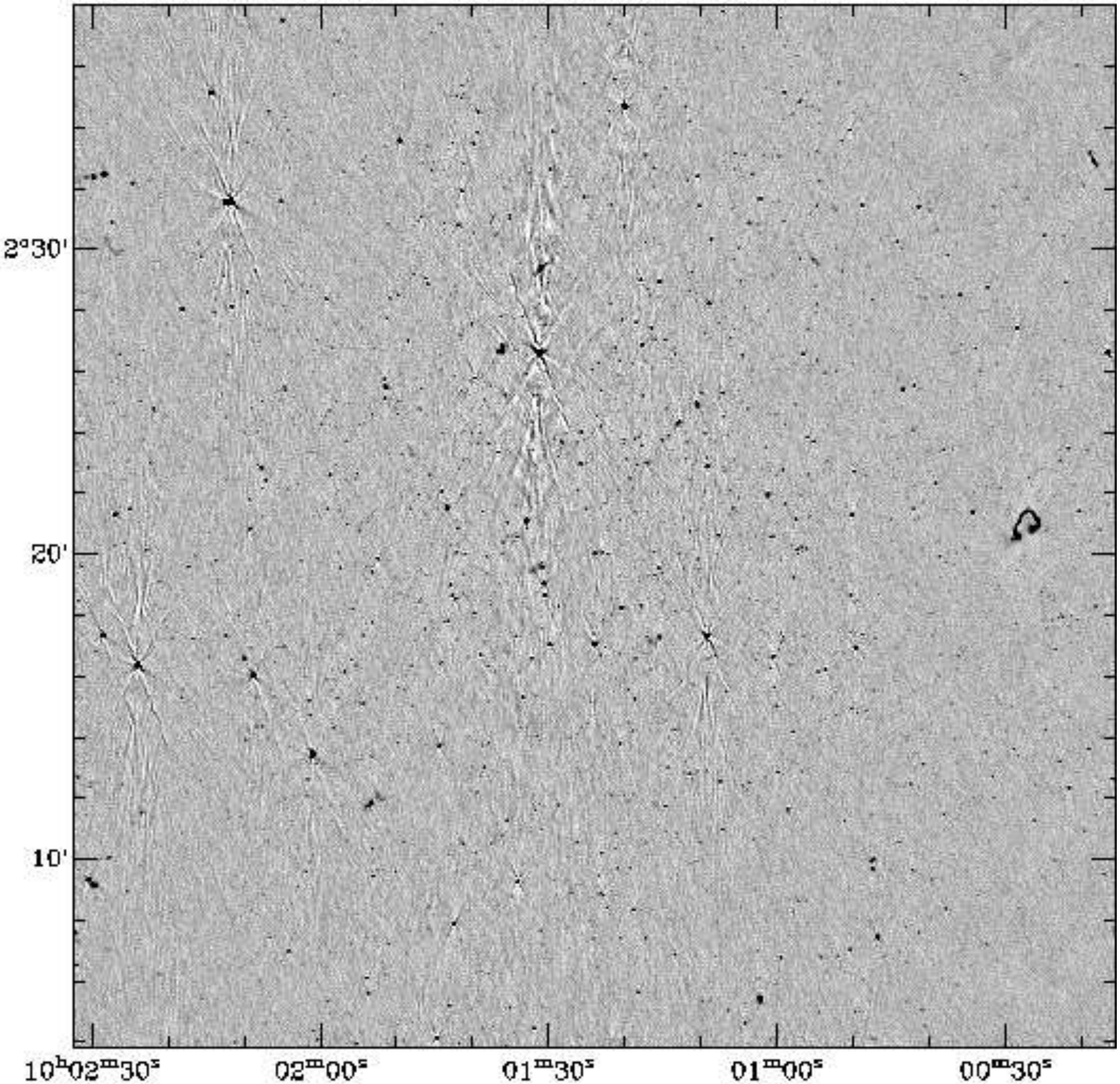
Detections in all LSS environments



Stacked signal of 80 galaxies in the wall



Average HI mass $1.8 \times 10^9\ M_{sun}$

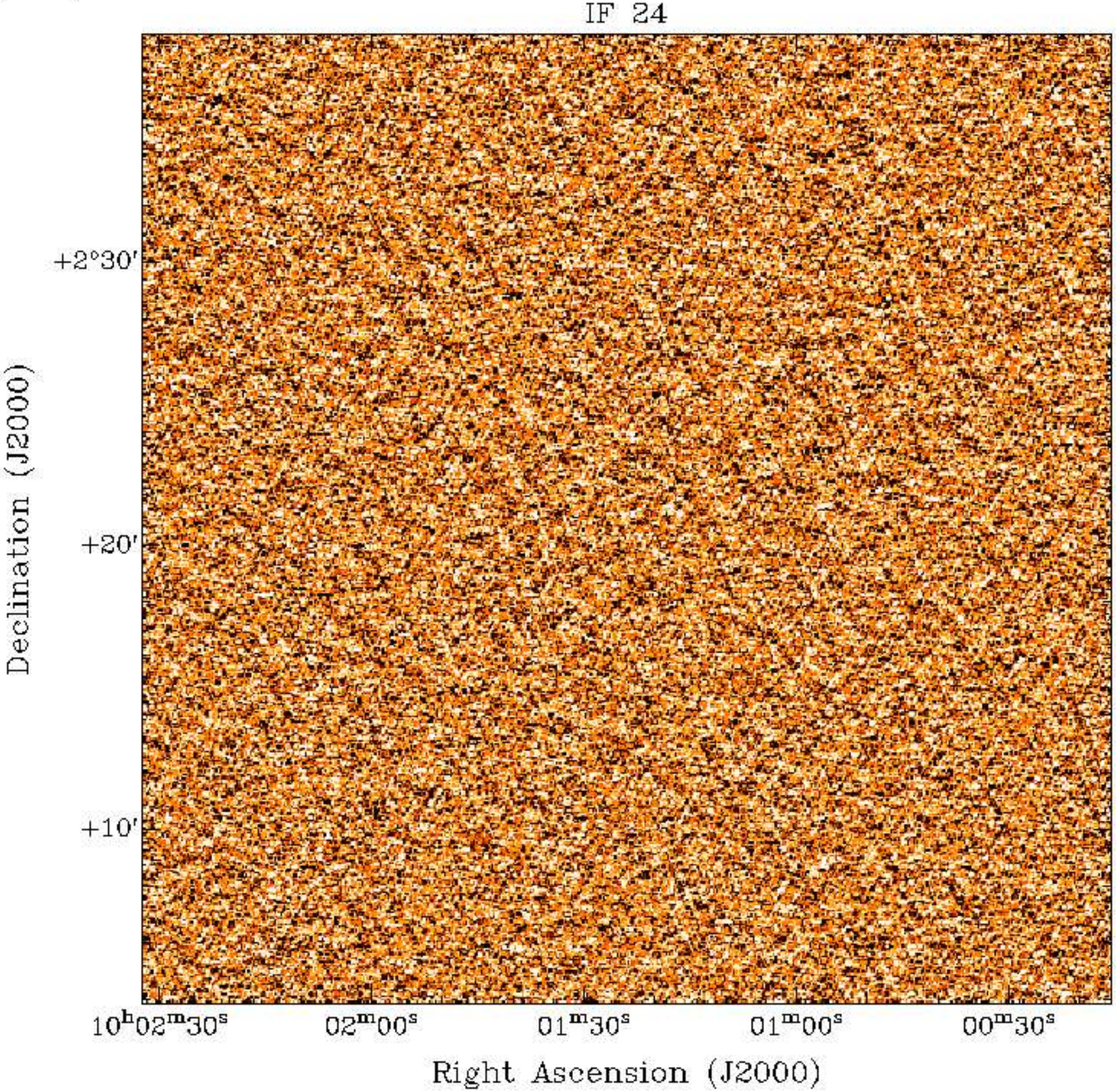


Deep Continuum Image

RMS:
4.8 µJY/BEAM

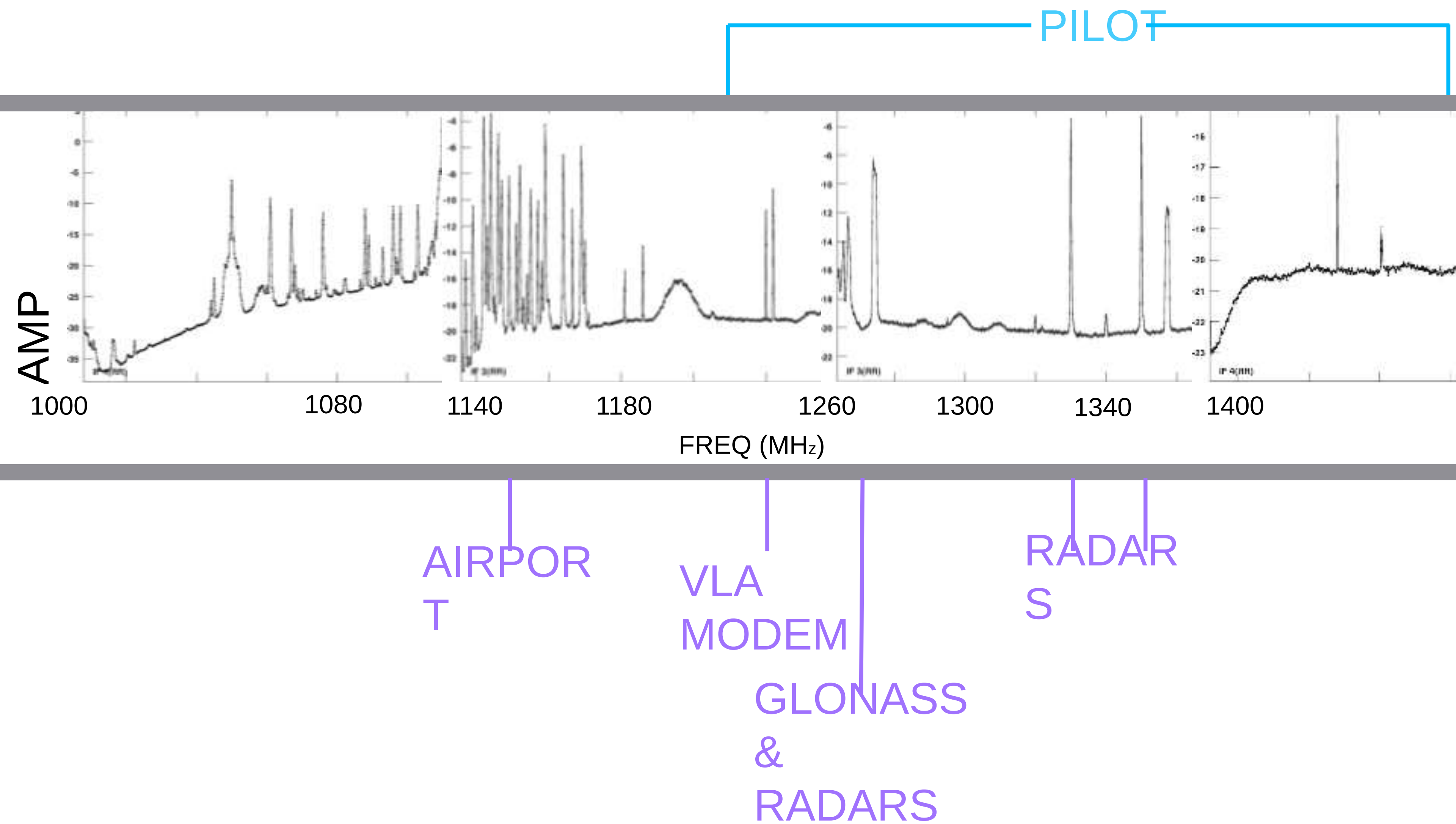
Chomiuk et al

Frequency: 1354.008 MHz

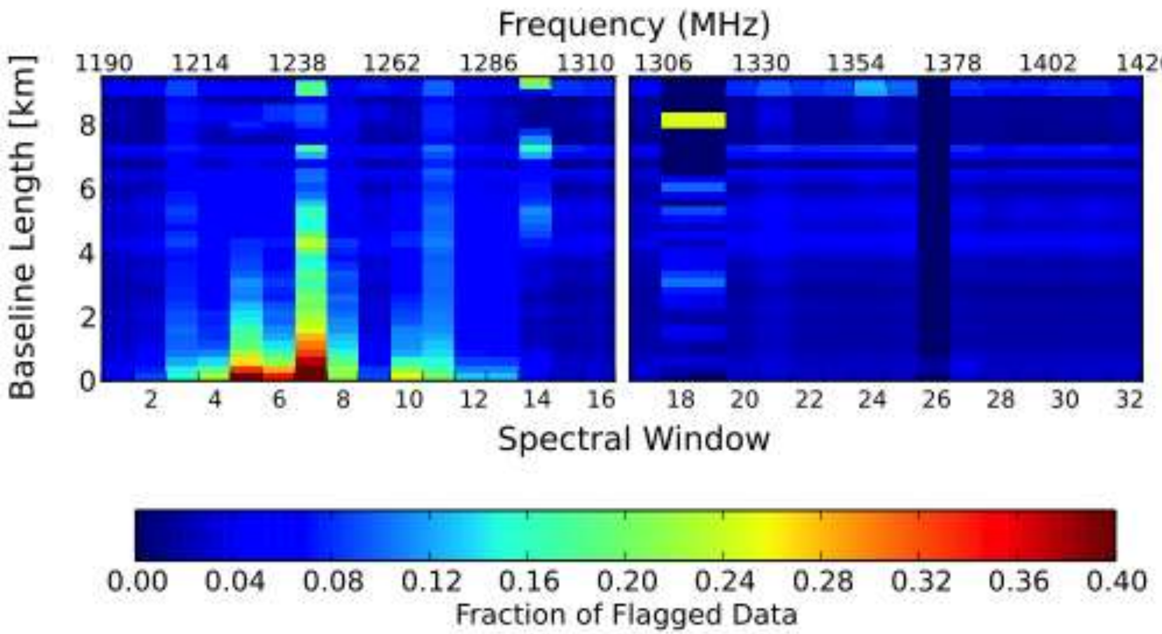


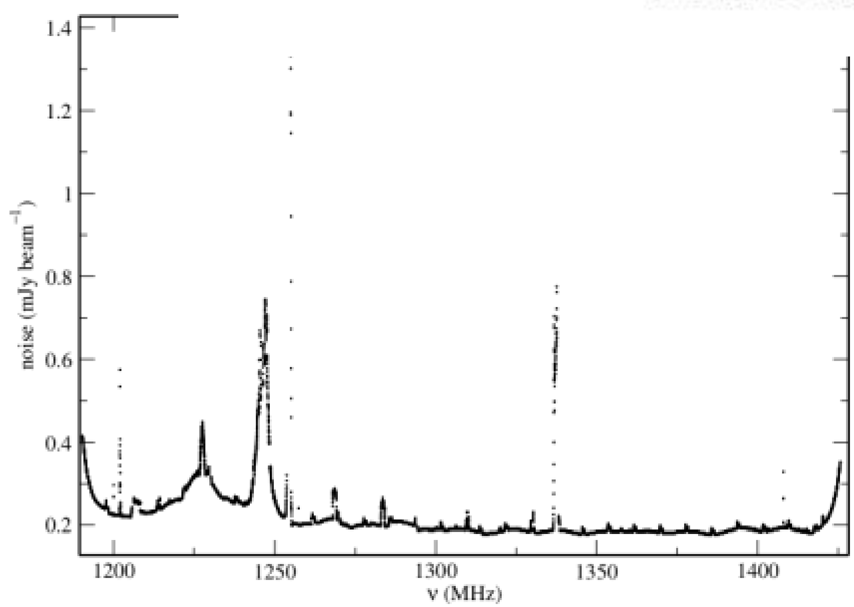
What did we learn?

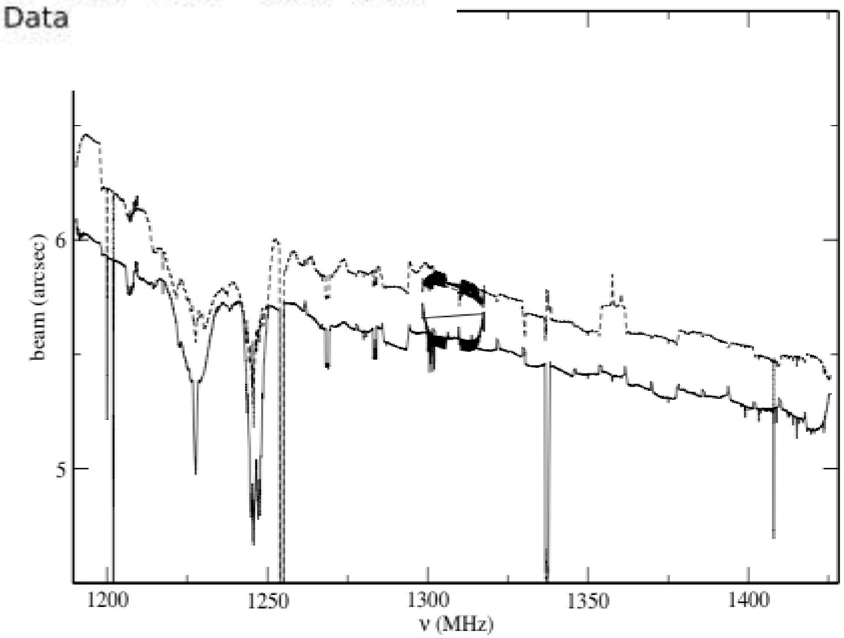
RFI in L-band



PILOT
AMP
1000
1080
1140
1180
1260
1300
1340
1400
FREQ (MHz)
AIRPORT
VLA MODEM
GLONASS & RADARS
RADARS



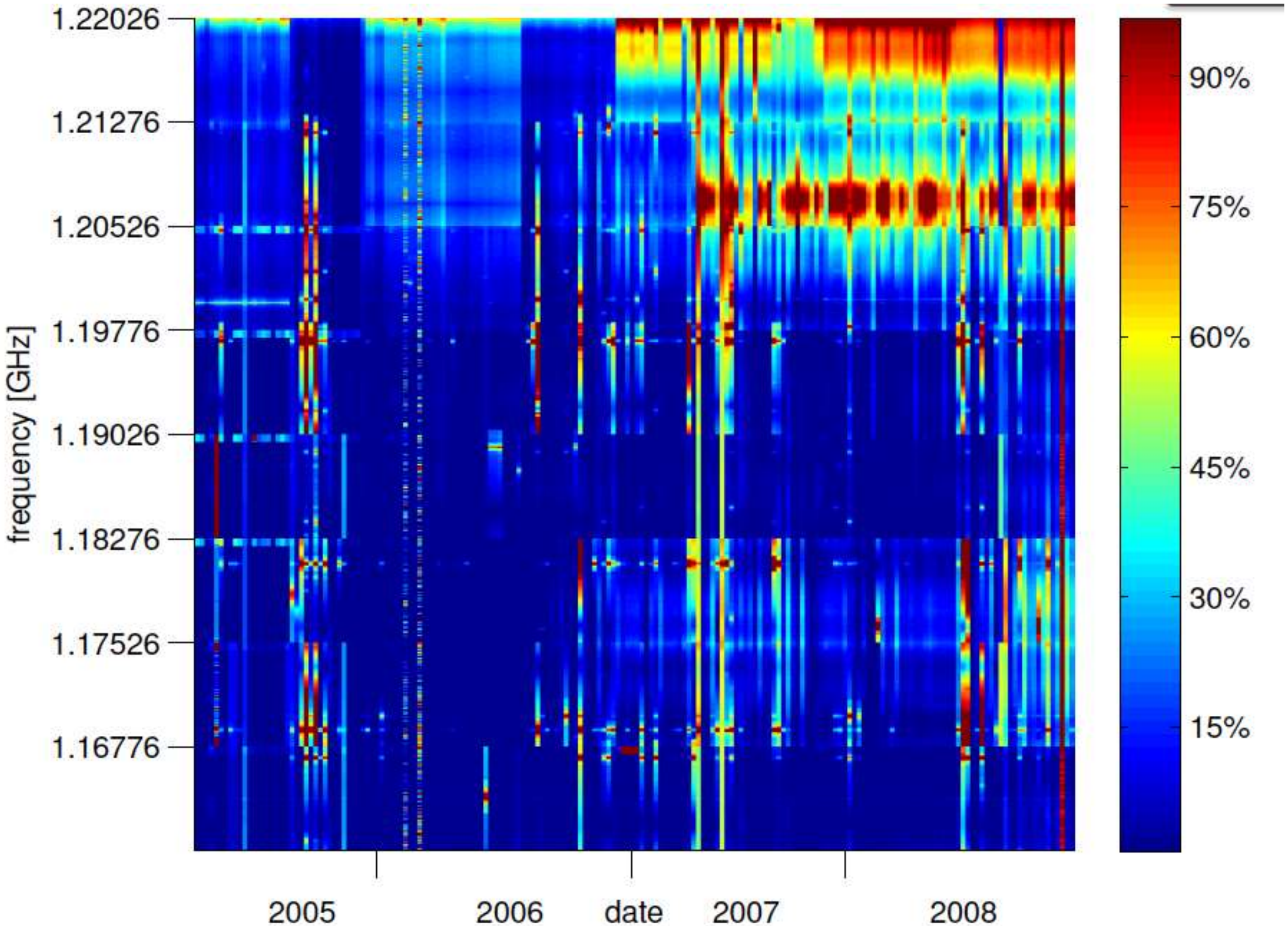




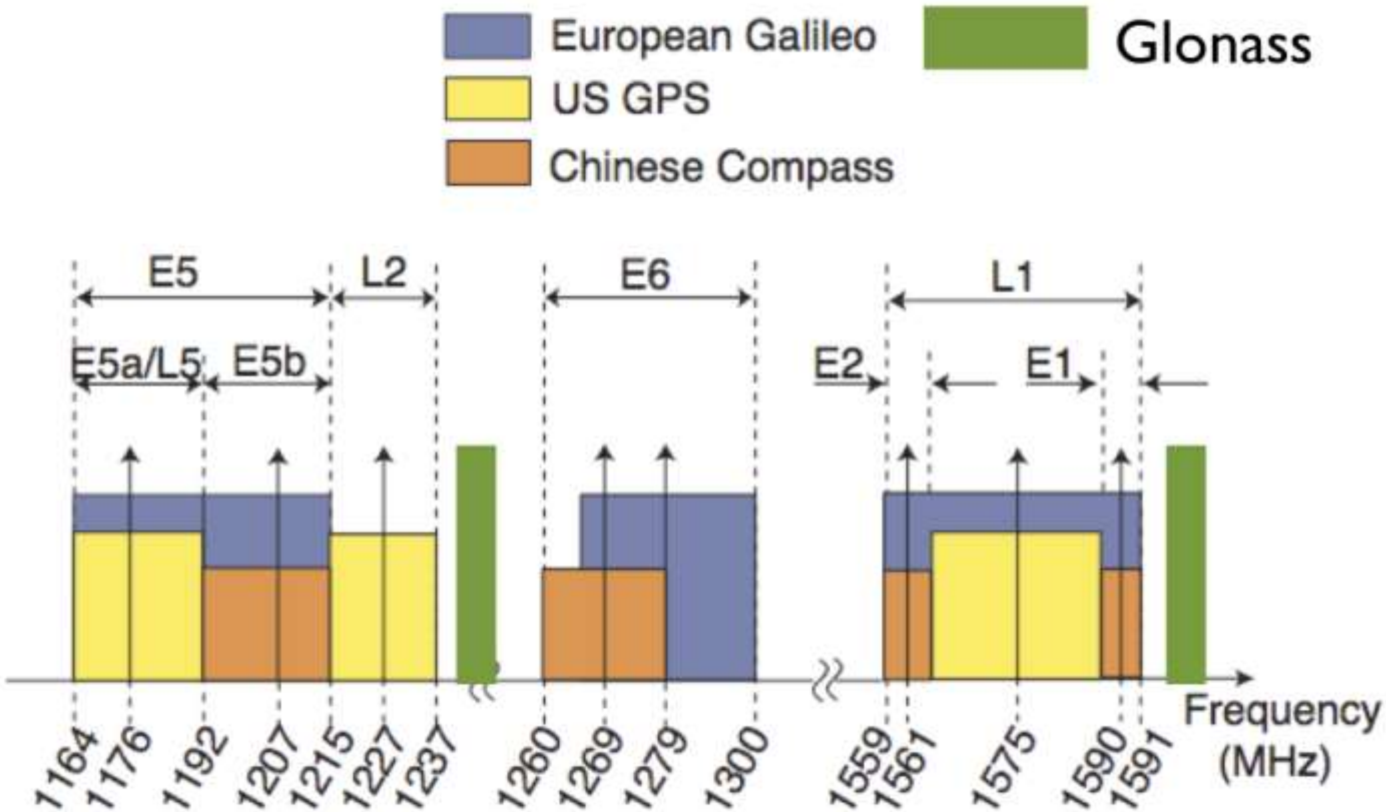
Rms noise as function of frequency

Synthesized beam

WSRT clusters   percentage of data lost over time due to RFI



Increasing number of GPS and GLONAS satellites



Galileo (European GPS) and COMPASS will be turned on in coming years

CONCLUSIONS from PILOT

A real JVLA HI Deep Field is now possible

We have 33 detections over entire redshift range
Detections follow the large scale structure as defined optically

RFI is the main challenge

Observing in B array mitigates the issue (avoid short spacings)
Automatic flagging algorithms work reasonably well
RFI will get worse.

Algorithms need be optimized to reduce data volume at every step

Example: baseline dependent time averaging

A real HI deep field

JVLA is perfect telescope for this

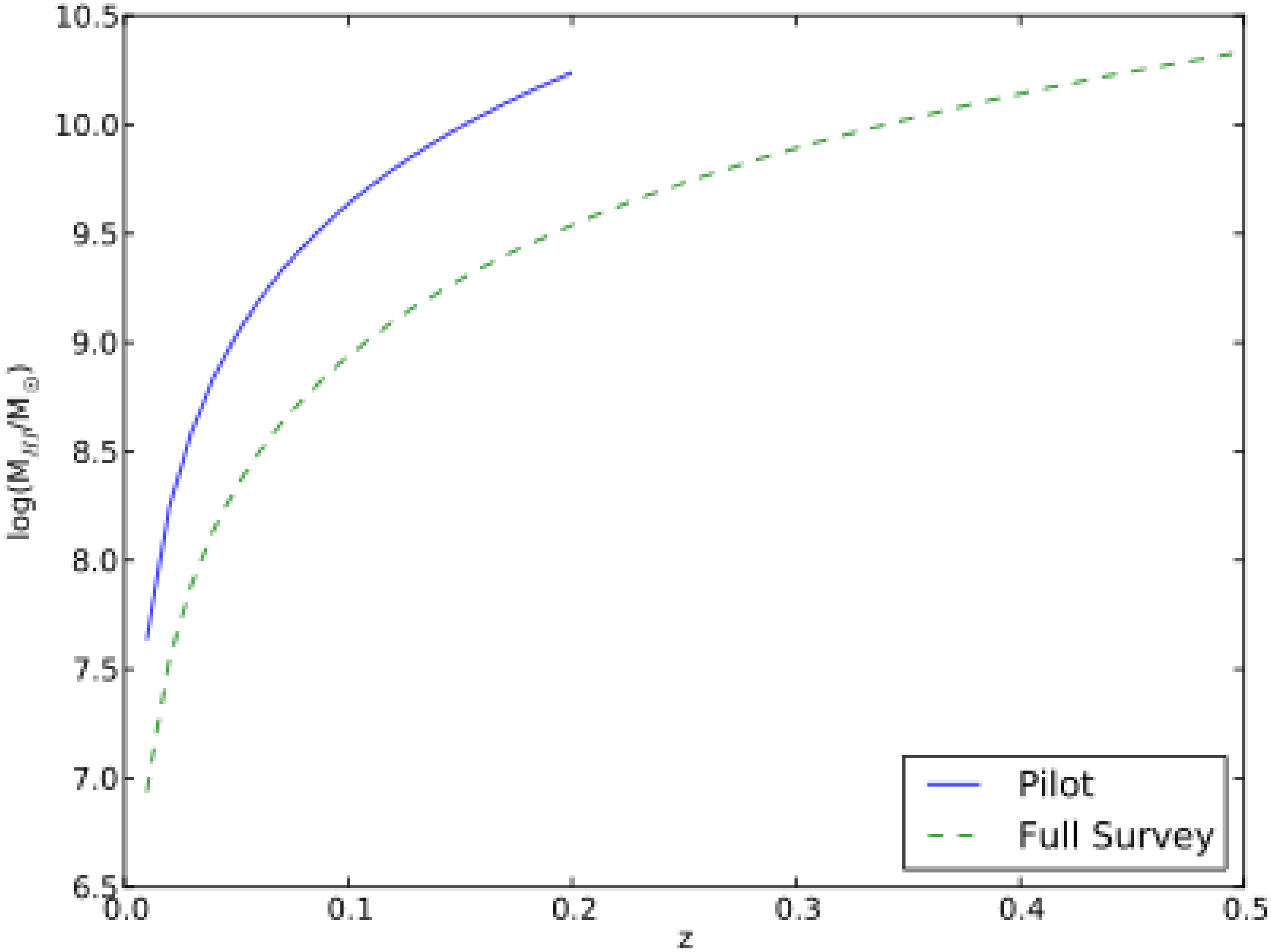
B array has optimal distribution of antenna spacings

Correlator allows to probe z=0 to z=0.45 with 3.3 km/s velocity resolution

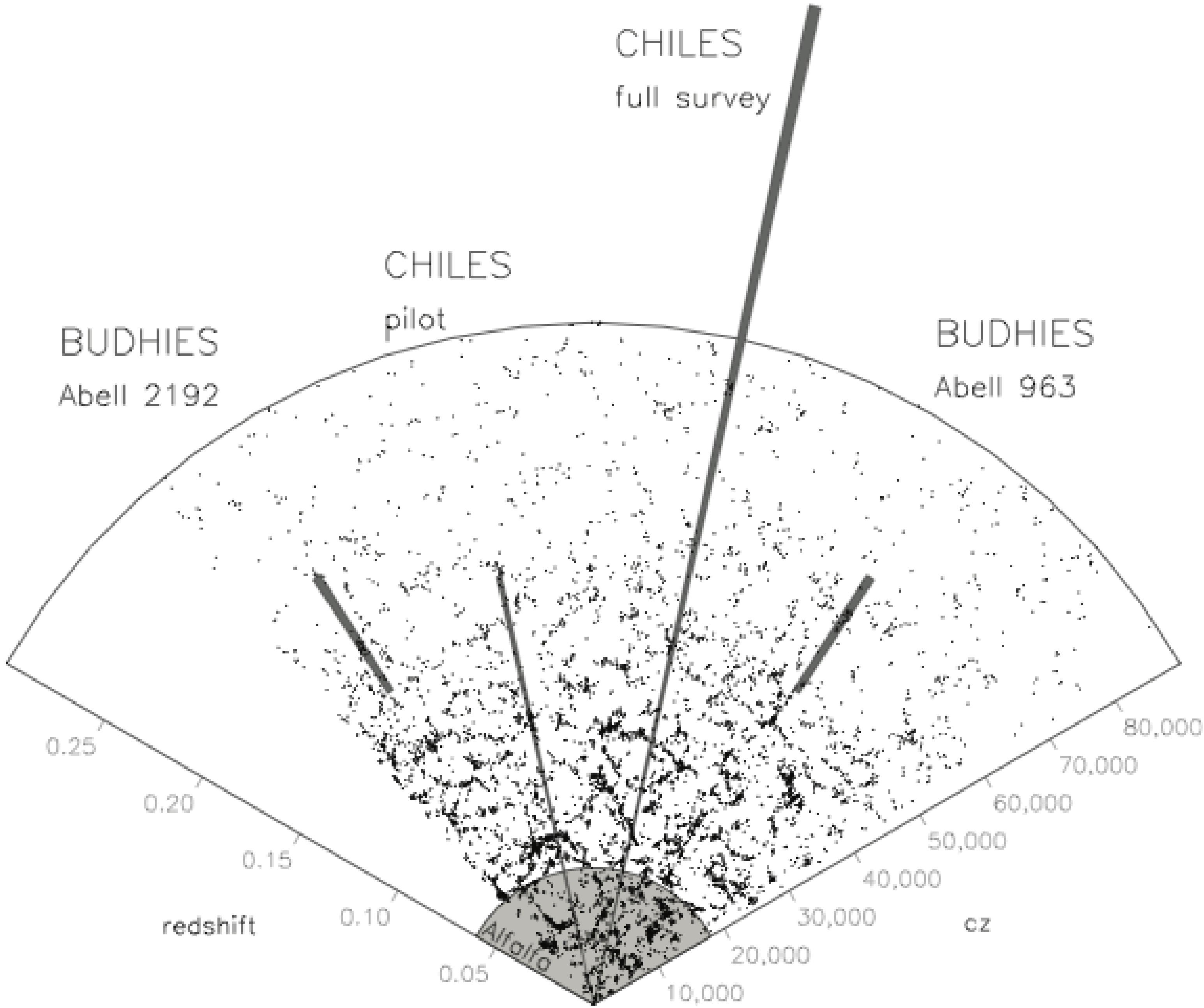
JVLA is up and running now (Thanks NRAO!!)

In 1000 hours on COSMOS field we will reach a mass limit 3×10^{10} M_{sun} at z=0.45

Full Survey



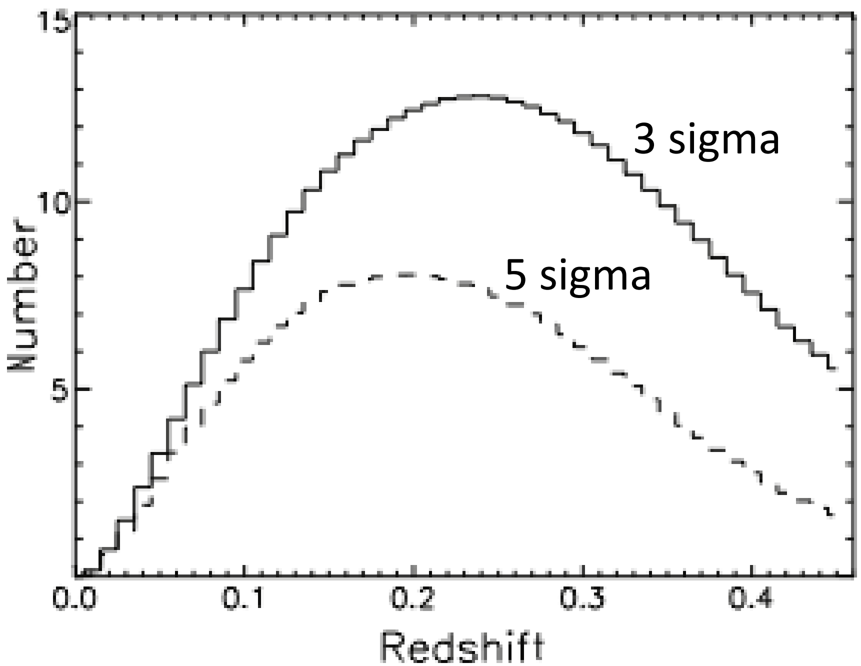
We aim to have same mass limit at z=0.45 as we had in pilot at z=0.2



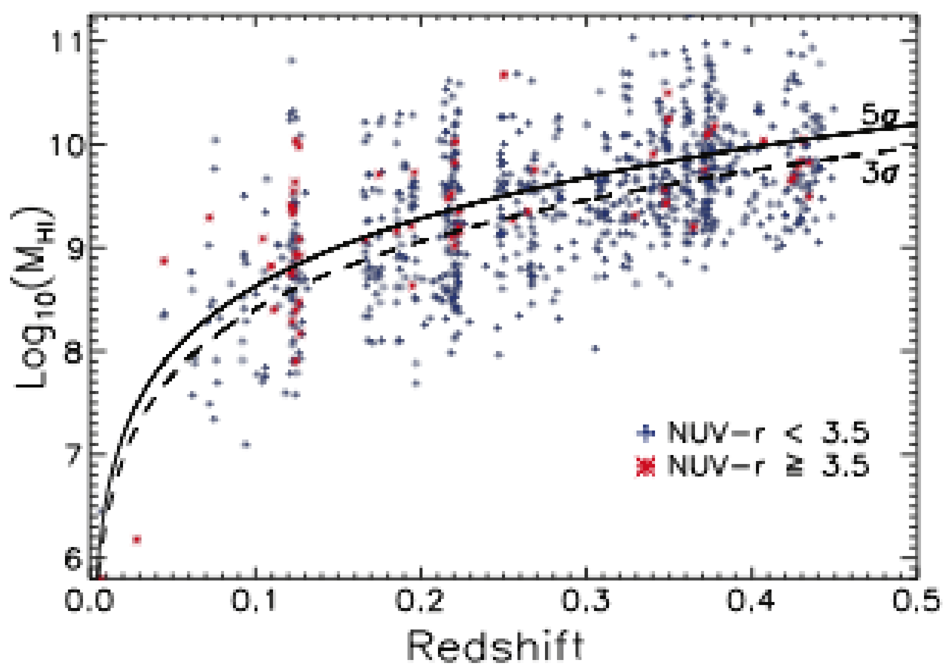
CHILES
full survey
CHILES
pilot
BUDHIES
Abell 2192
BUDHIES
Abell 963
0.25
0.20
0.15
0.10
0.05
redshift
Alfalfa
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
cz

Expected detection rates for a 1000 hour project

We expect about 300 direct detections... i.e. HI IMAGES

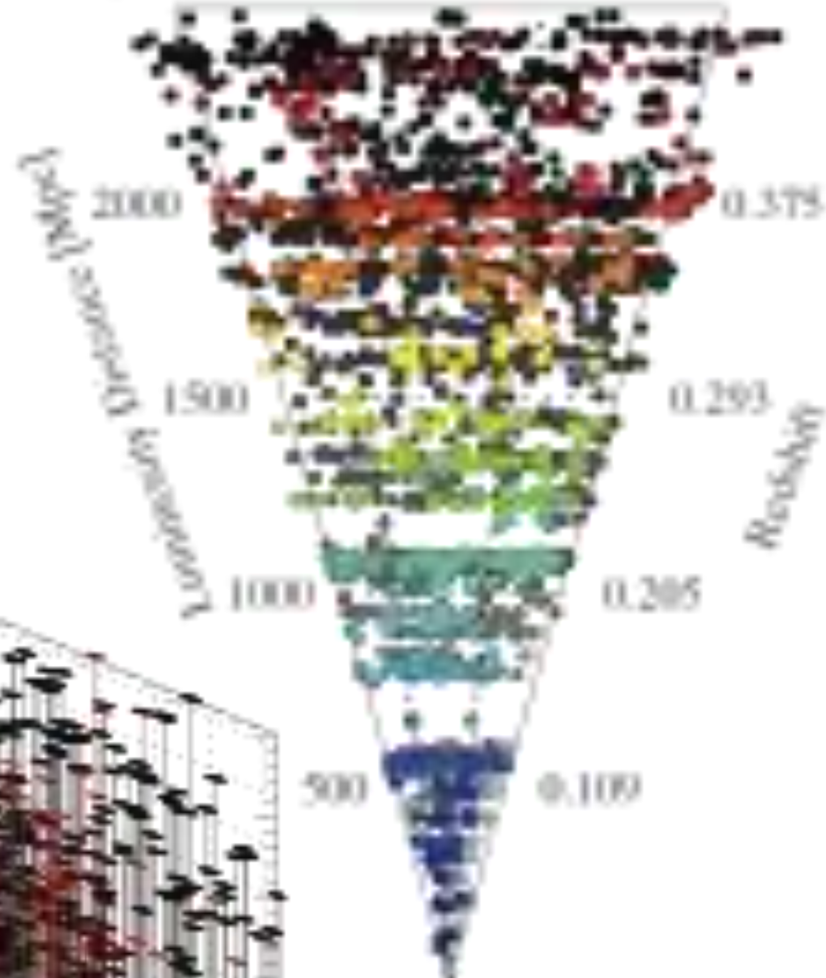


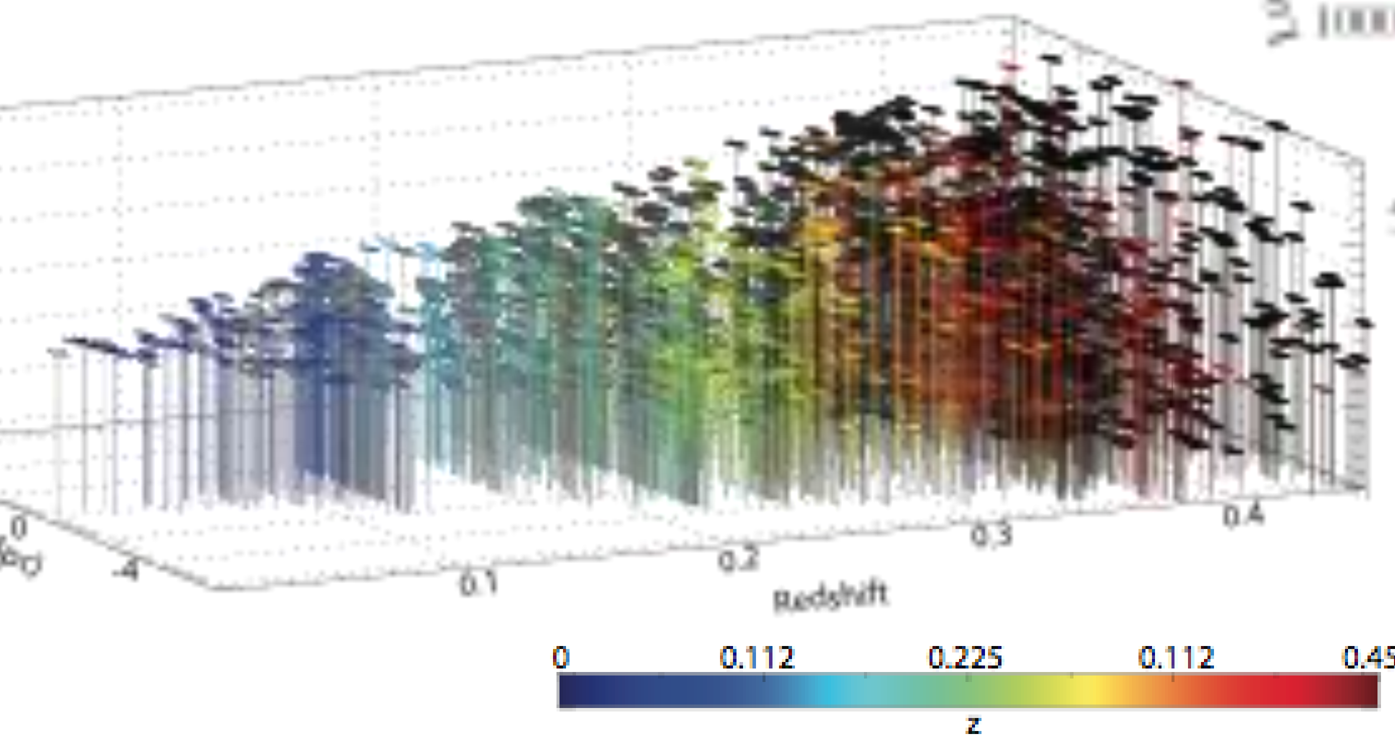
Estimate based on HI mass function of Martin et al 2010.



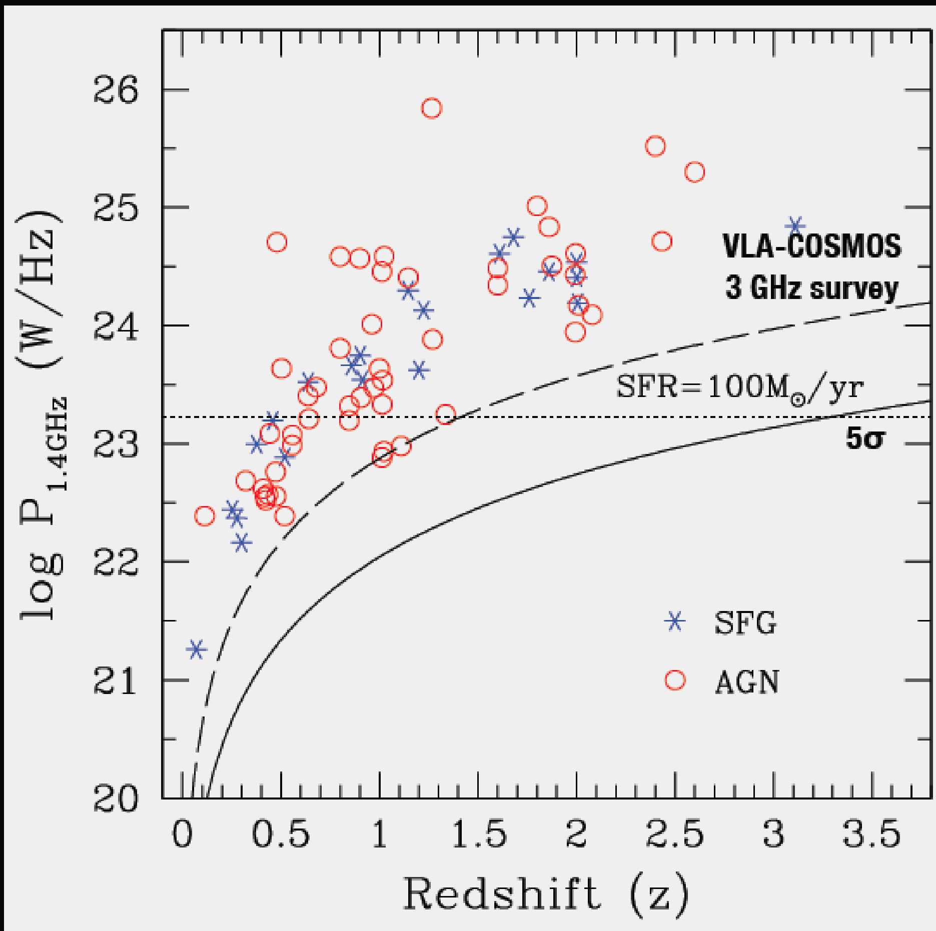
Estimate based on photometric gas fraction (e.g. Catinella et al 2010)

Spatial distribution of predicted 5 sigma detections





Deep Continuum Studies



Data from EVLA GOODS-North Survey (Gim et al., in prep)

sub-μJy noise: detect ULIRGs out to z~3.3

Large scale structure in JVLA HI Deep field