CHILES

CHILES, the COSMOS HI Large Extragalactic Survey

1002 hours JVLA B array

SKA Science and a path finder for the path finders

Jacqueline van Gorkom, Ximena Fernandez, Kelley Hess, D.J. Pisano, Kathryn Kreckel, Emmanuel Momjian, Attila Popping, Tom Oosterloo, Laura Chomiuk, Marc Verheijen, Patricia Henning, David Schiminovich, Matthew Bershady, Eric Wilcots, Nick Scoville

(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, Amidou Sorgho, Claude Carignan, Danielle Lucero, Natasha Maddox, Genevieve Vaive, Charee Peters, Hansung Gim, Julia Gross, David Hendel

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

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graduate students and postdocs

Unique aspects of VLA among SKA path finders

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

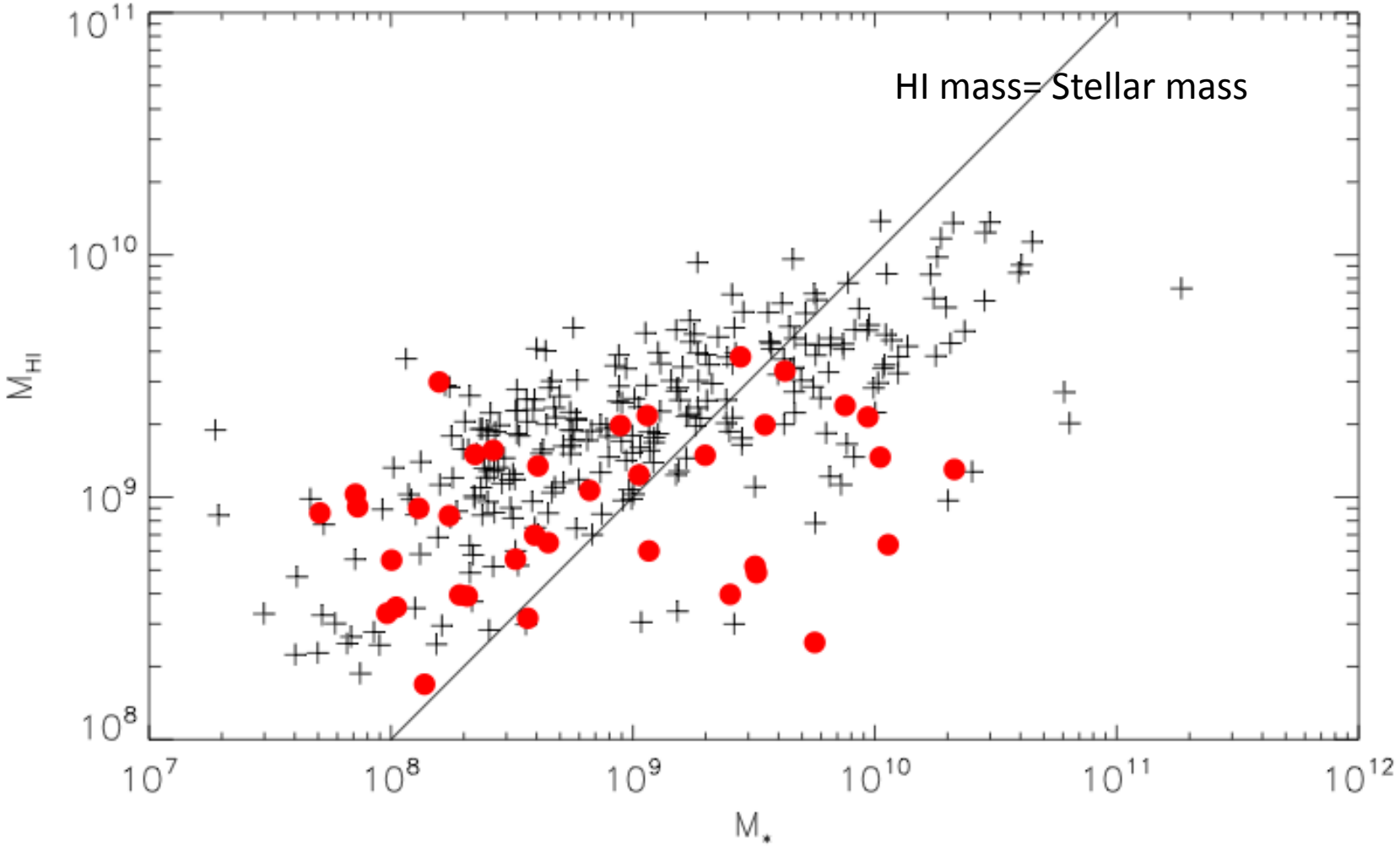
and most collecting area at spacings > 2 km

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

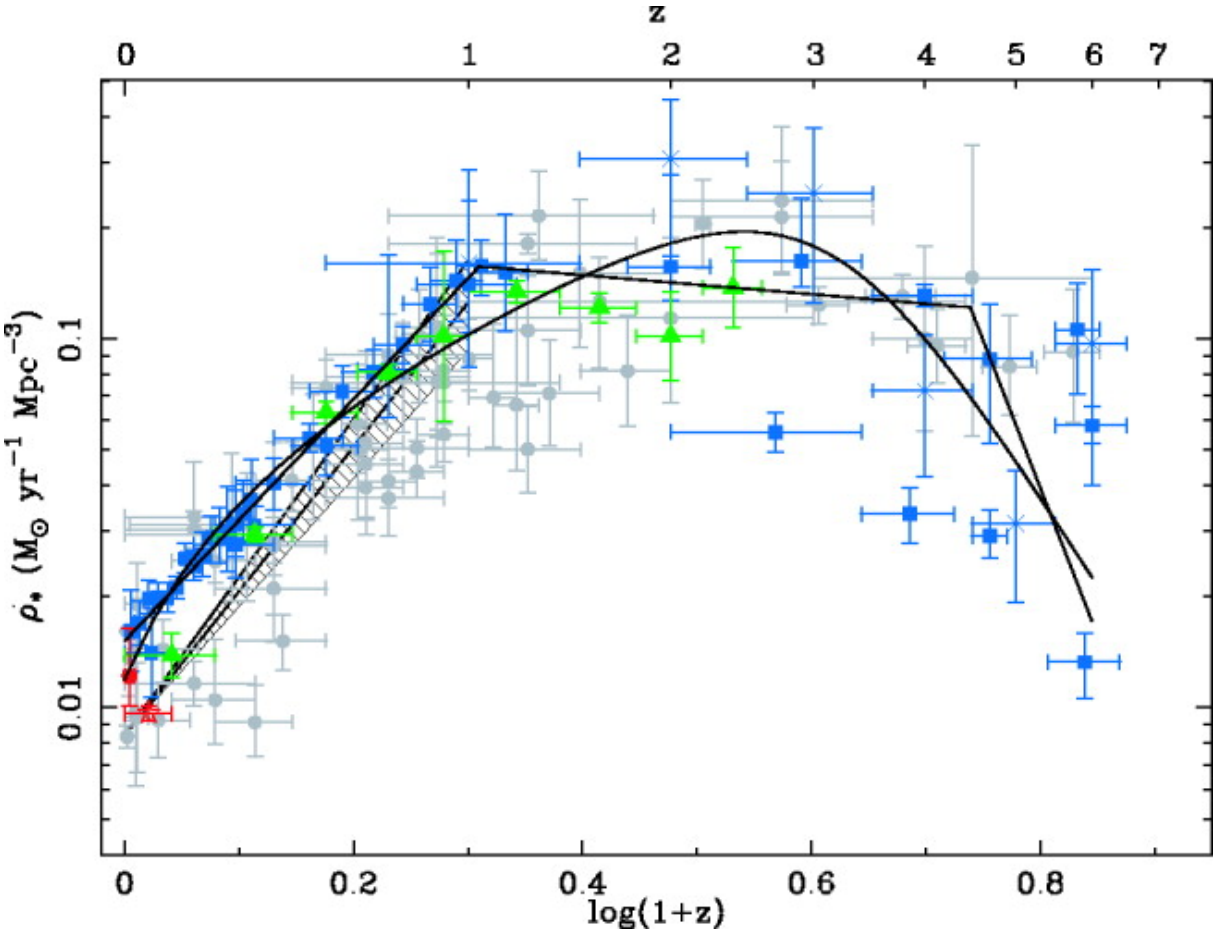
HI must have something to do with galaxy evolution but to first order all galaxies have same HI mass



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

Red void galaxy sample BLACK alfalfa

HI imaging of galaxies z=0 to z=0.45



Evolution of Star Formation Rate Density (Hopkins and Beacom 2006)

Gas is the fuel for star formation Images tell how galaxies get and lose their gas

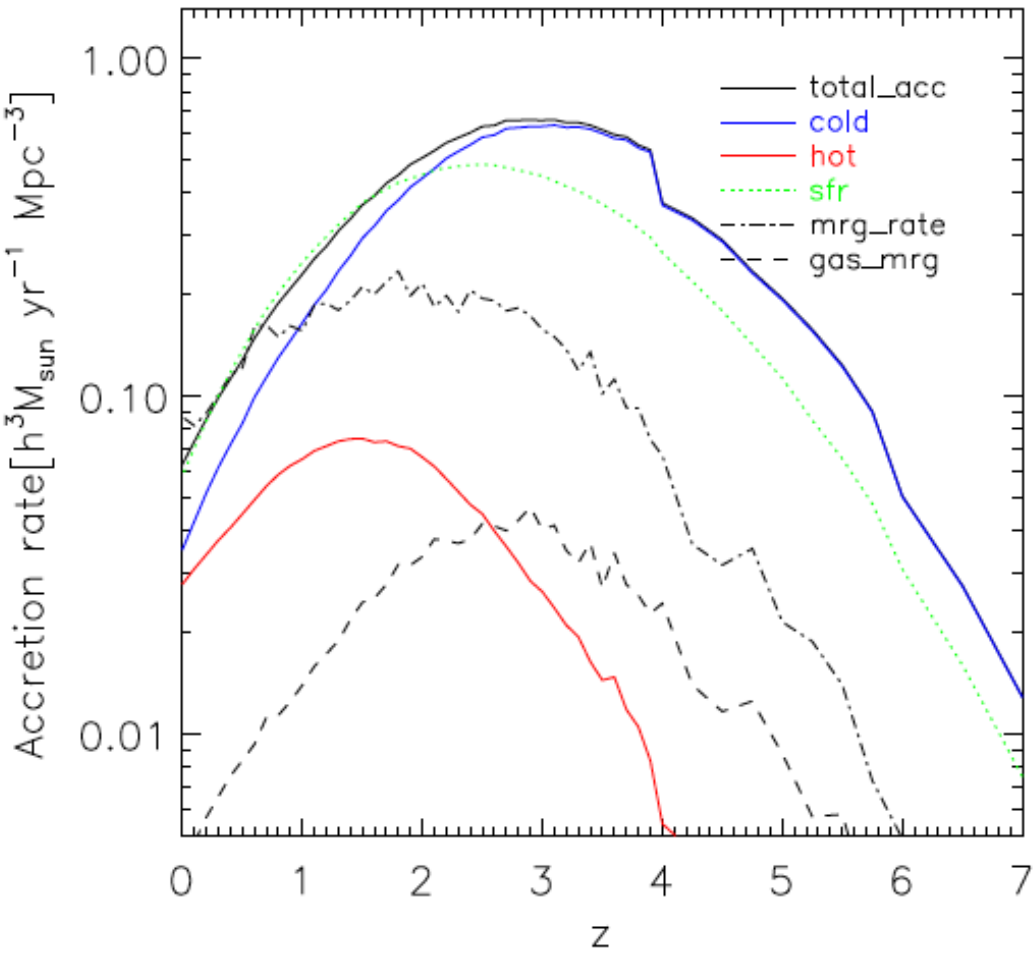
We (sort of) understand how large scale structure grows, but how galaxies form and evolve is less well understood.

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

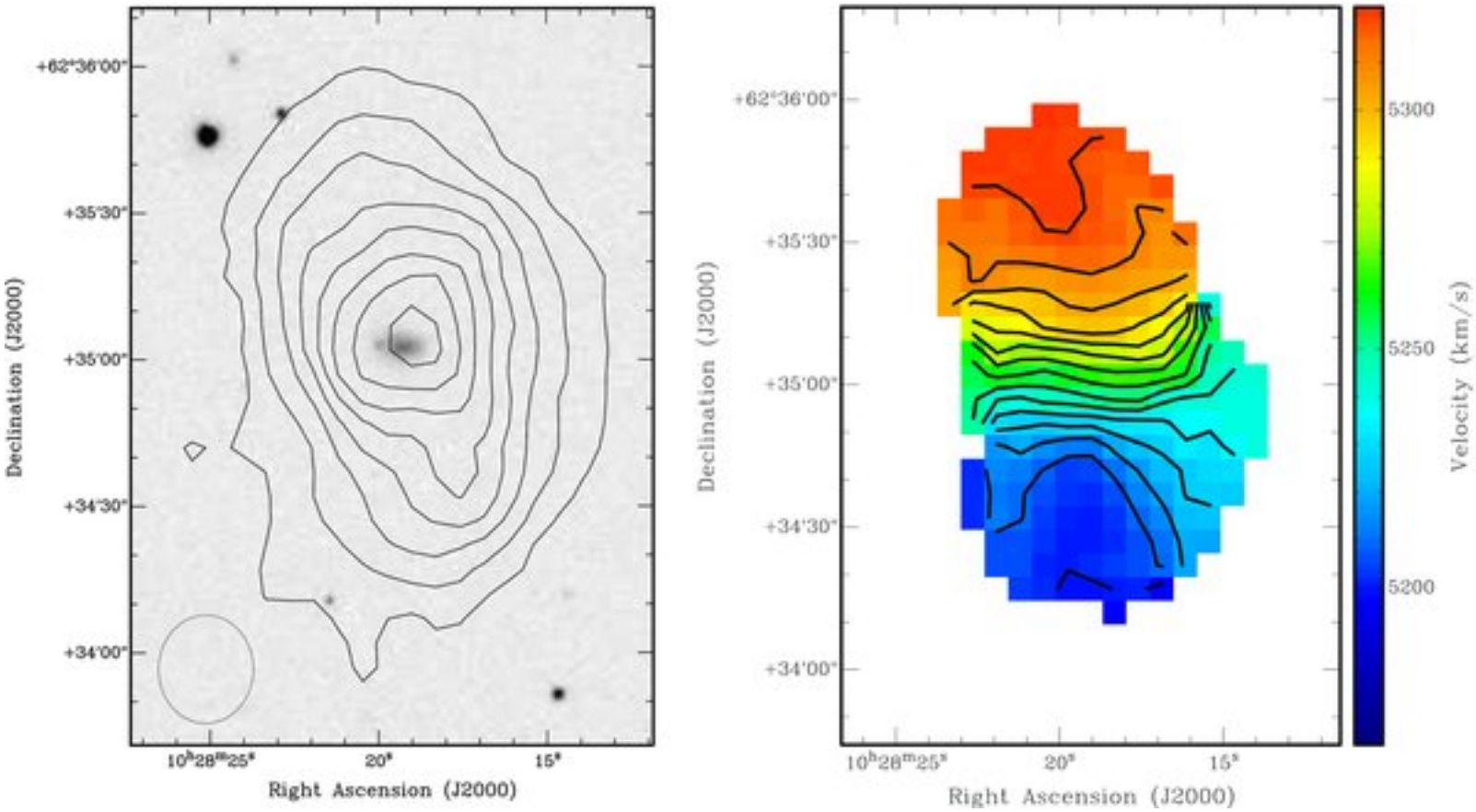
2) Smooth accretion of cool gas dominates gas accretion at all z dominates total accretion at z>1



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

This is controversial

The void galaxy survey



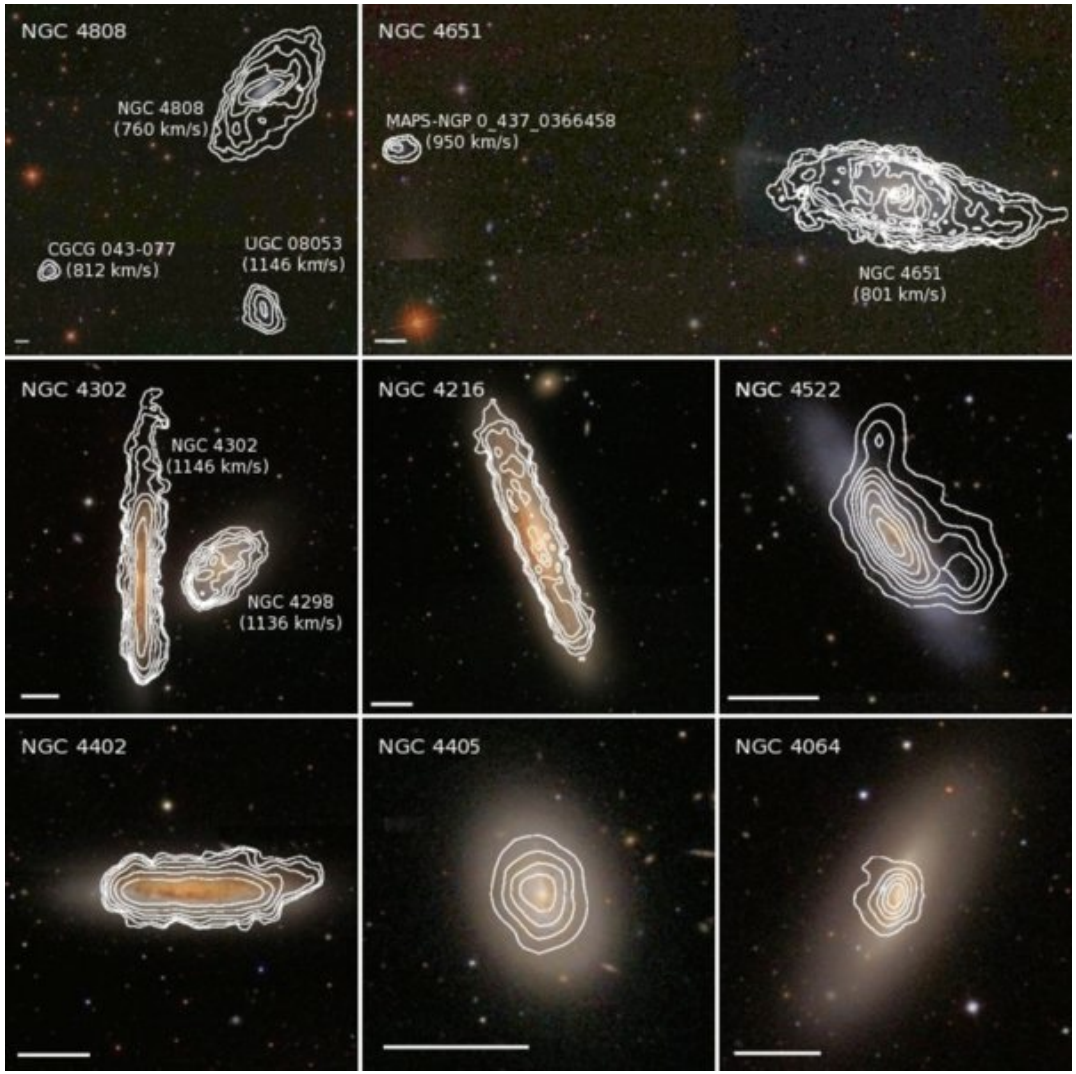
A polar disk

Stanonik et al 2009

Kreckel et al 2012 void galaxies are small and show many hints that they are still accreting gas

HI Images tell how galaxies get their gas

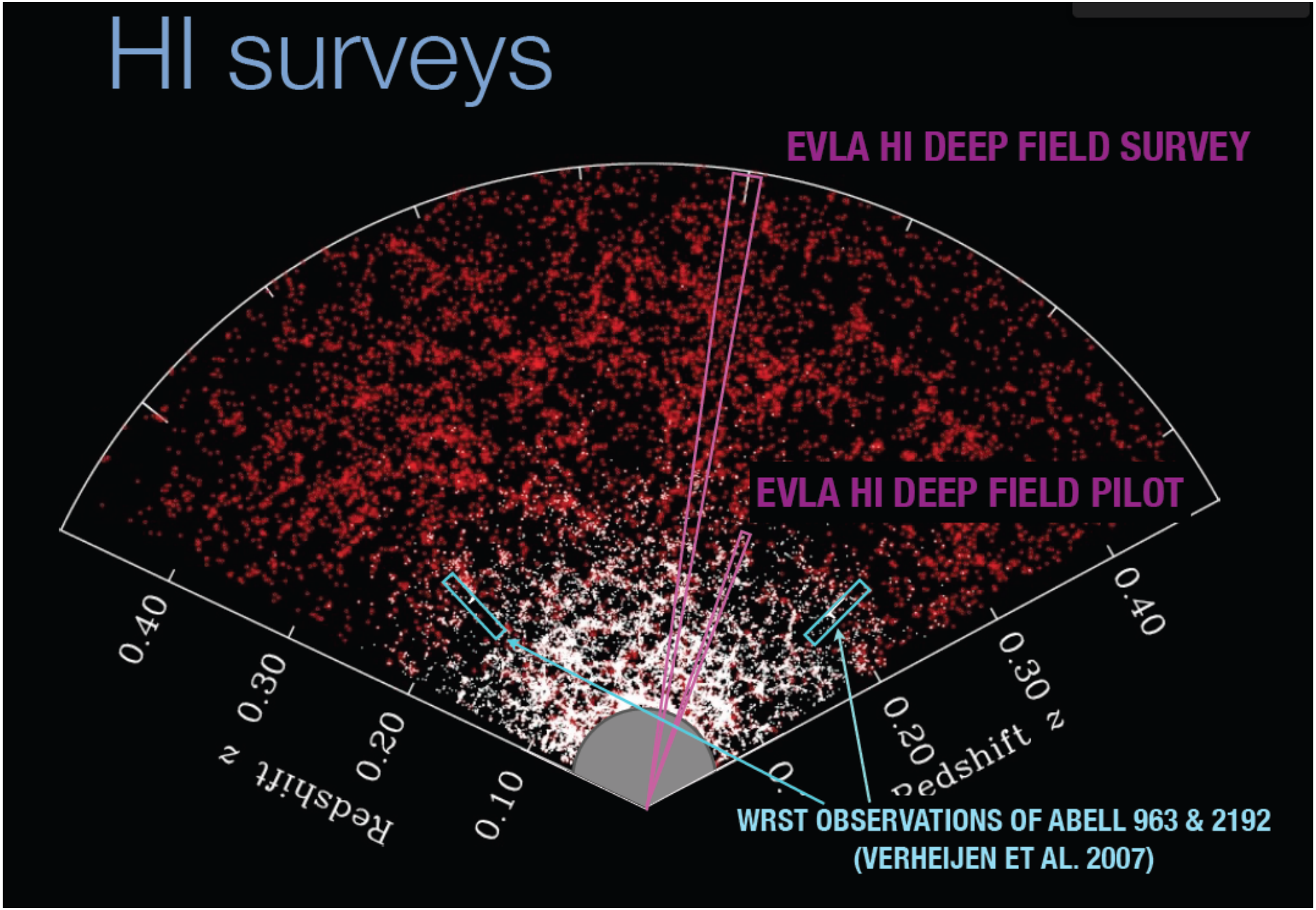
Galaxies in around the Virgo cluster VIVA



Chung et al, 2009

HI Images tell how galaxies lose their gas

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
Redshift z
WRST OBSERVATIONS OF ABELL 963 & 2192
(VERHEIJEN ET AL. 2007)

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

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.. 2.5 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 7×10^8 M_{sun}

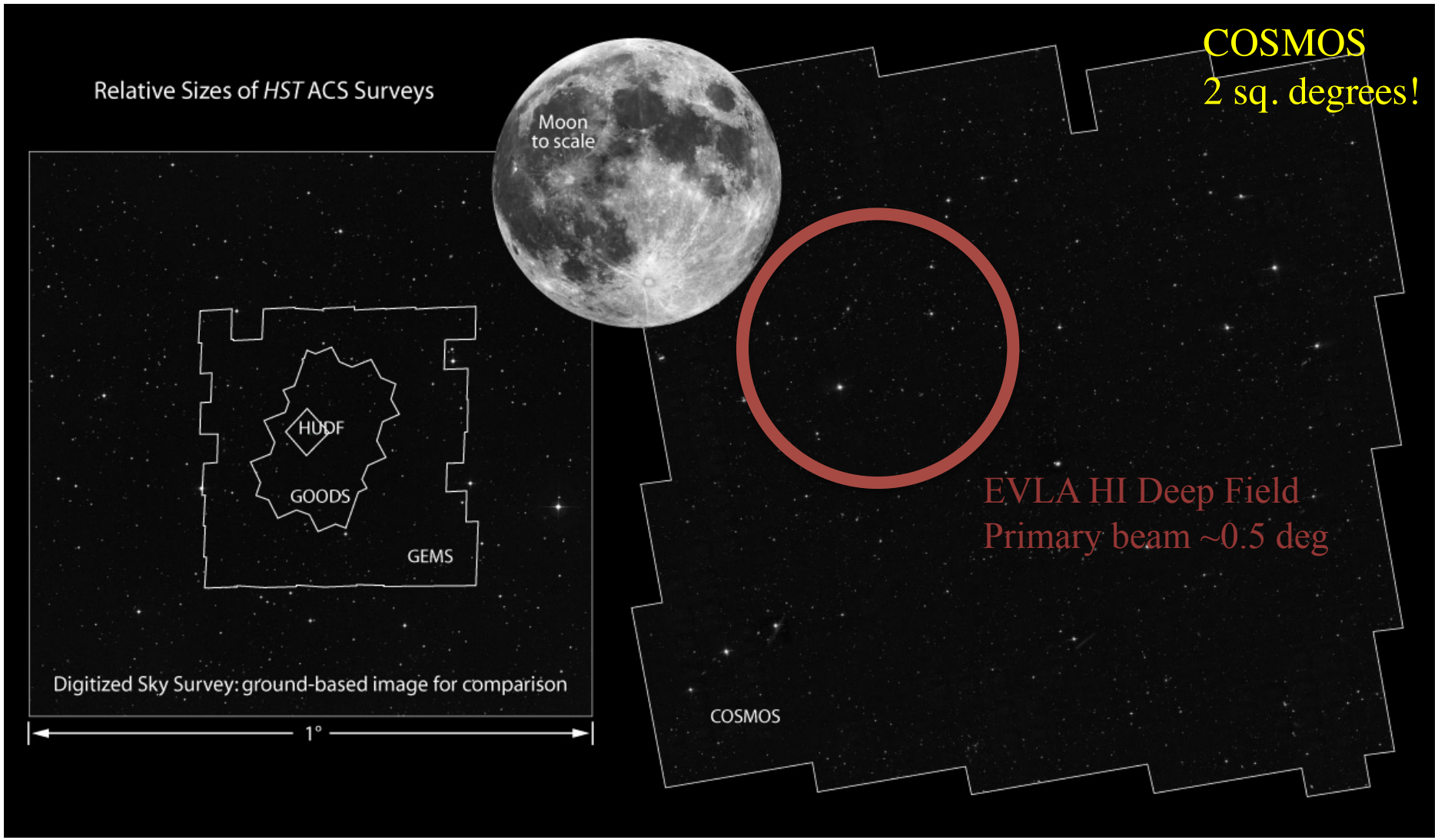
z=0.13 4×10^9 M_{sun}

z=0.2 1.3×10^{10} M_{sun}

Column density sensitivity 3×10^{19} cm^{-2}

Resolution 350 pc at 16 Mpc 17 kpc at z=0.2

FOV 150 kpc 7.5 Mpc



Additional coverage by:

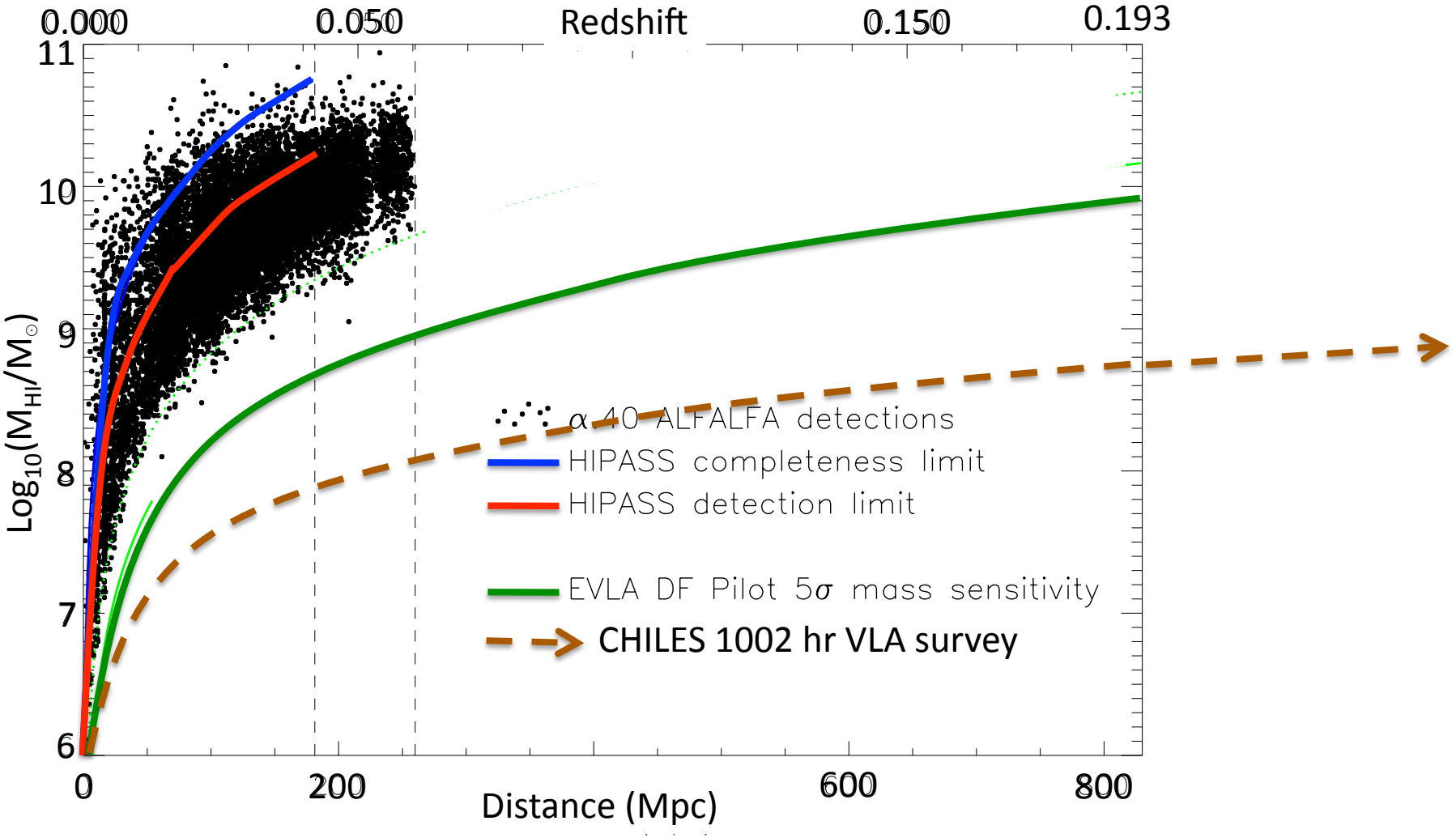
Spitzer, GALEX, XMM, Chandra

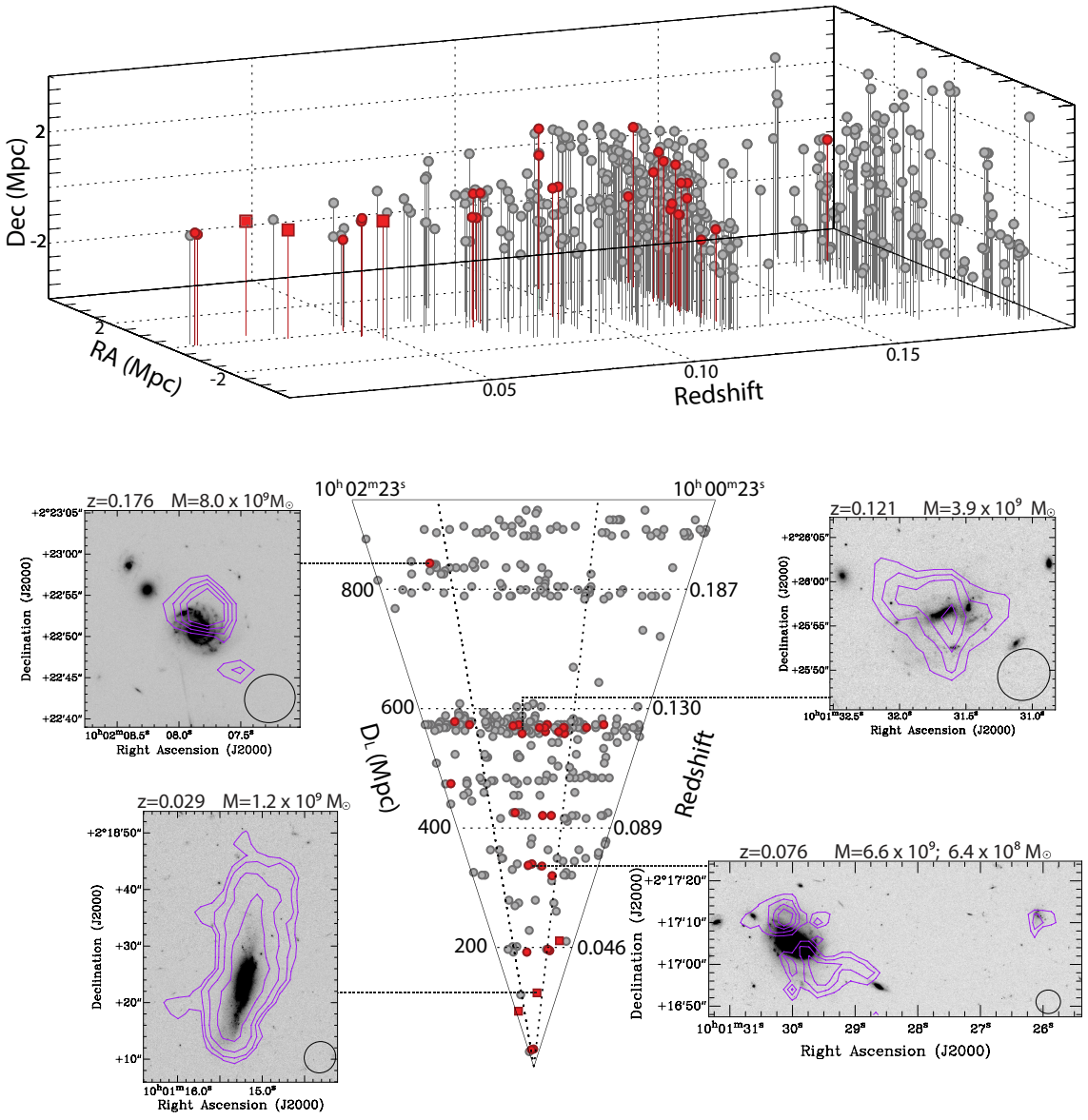
Subaru, VLA, ESO-VLT, UKIRT, NOAO, CFHT, CSO, CARMA, IRAM, Magellan

(Herschel, ALMA, APEX)

Pilot HI Mass Sensitivity

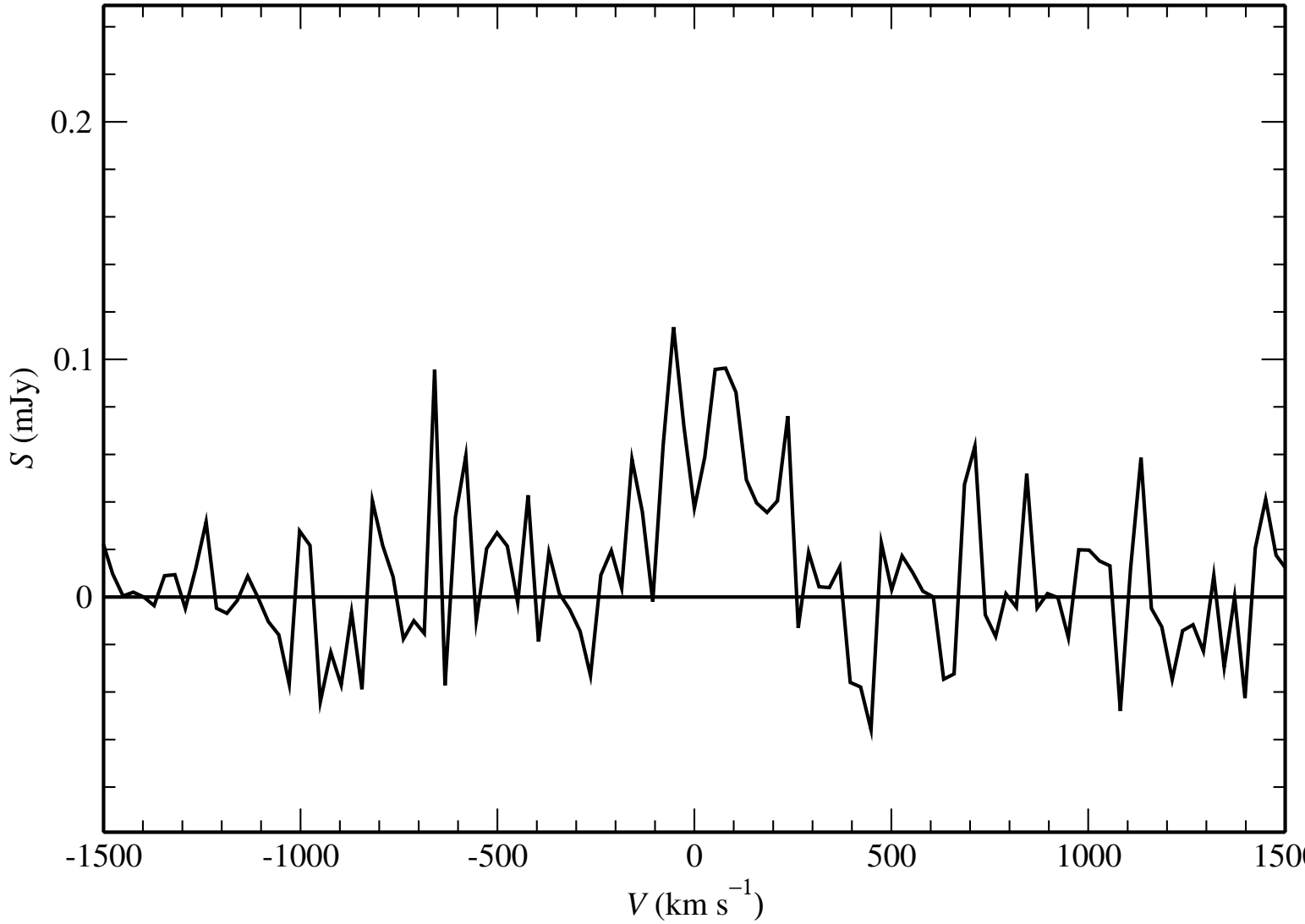
~Virgo, 16 Mpc	z=0.07	z=0.13	z=0.2
5σ M = 1.8×10^{6} $M_{\odot}$	7×10^{8} $M_{\odot}$	4×10^{9} $M_{\odot}$	1.3×10^{10} $M_{\odot}$





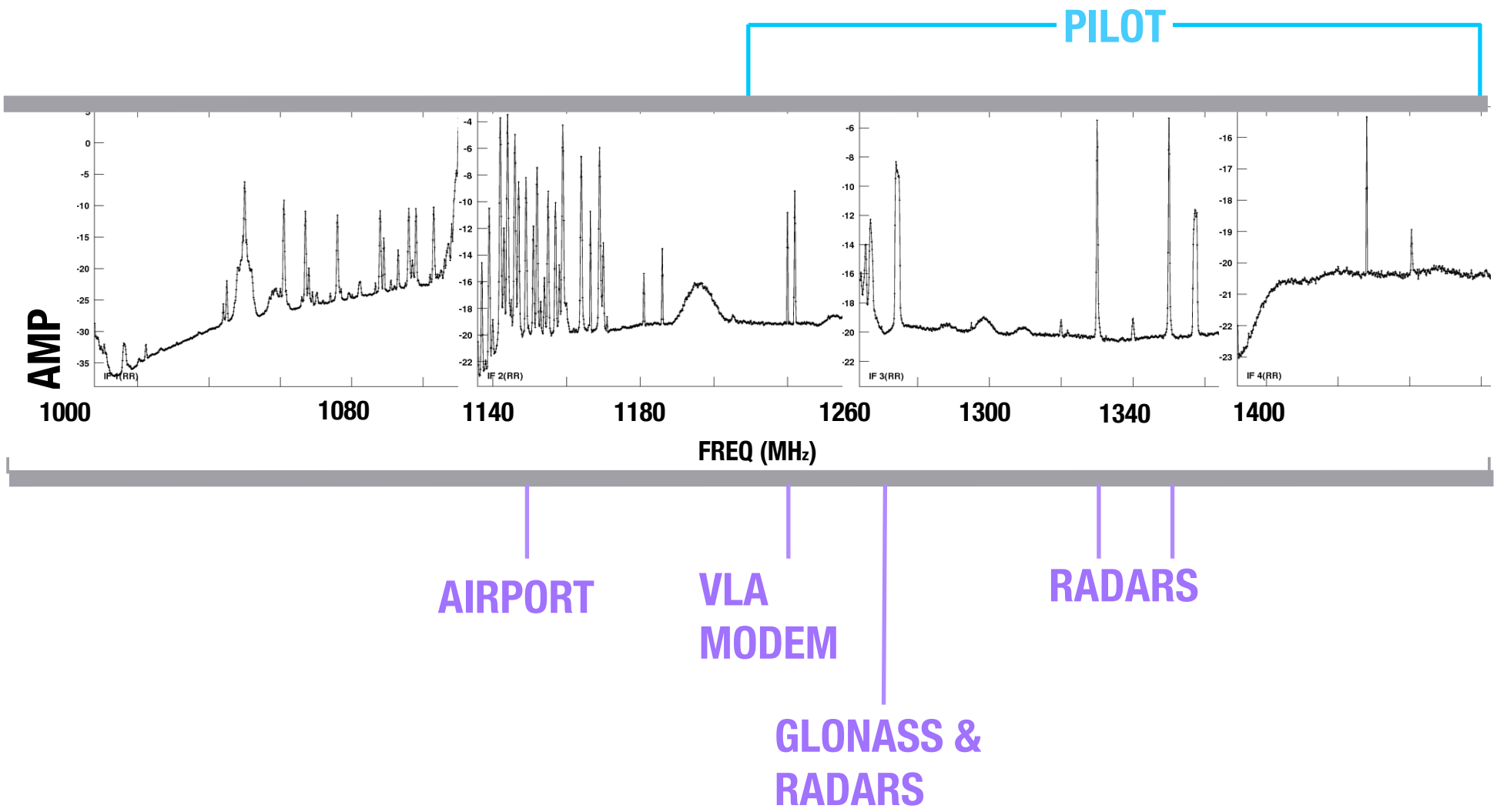
Results of pilot survey Fernandez et al 2013

Stacked signal of 80 galaxies in the wall

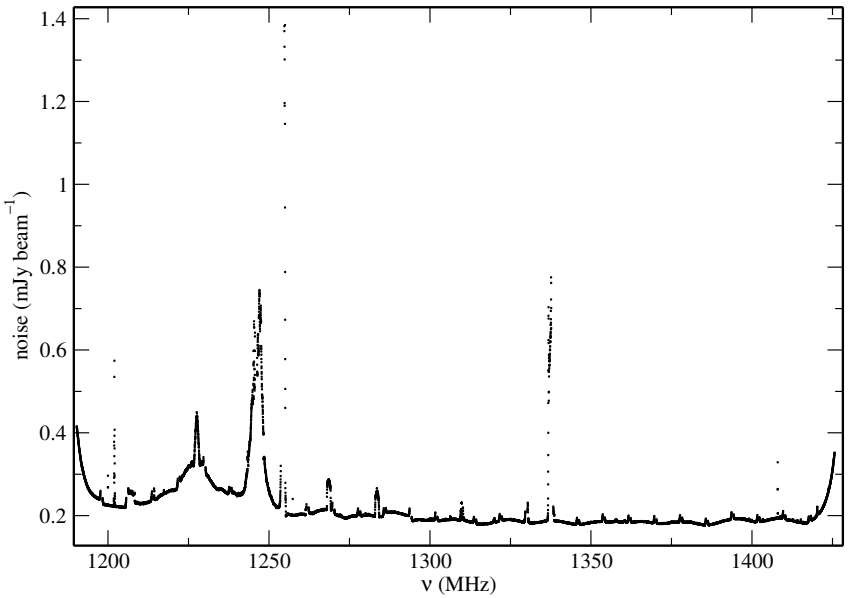


Average HI mass $1.8 \times 10^9 M_{sun}$

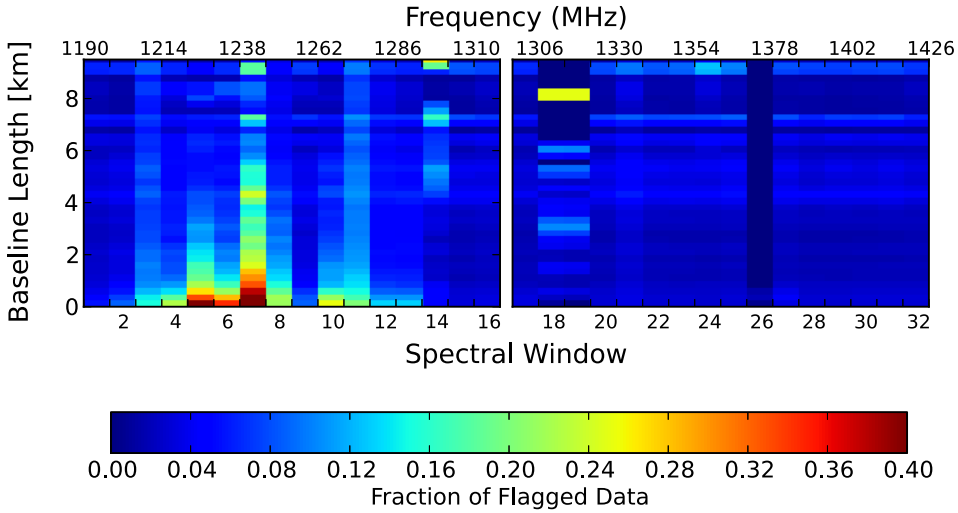
RFI in L-band

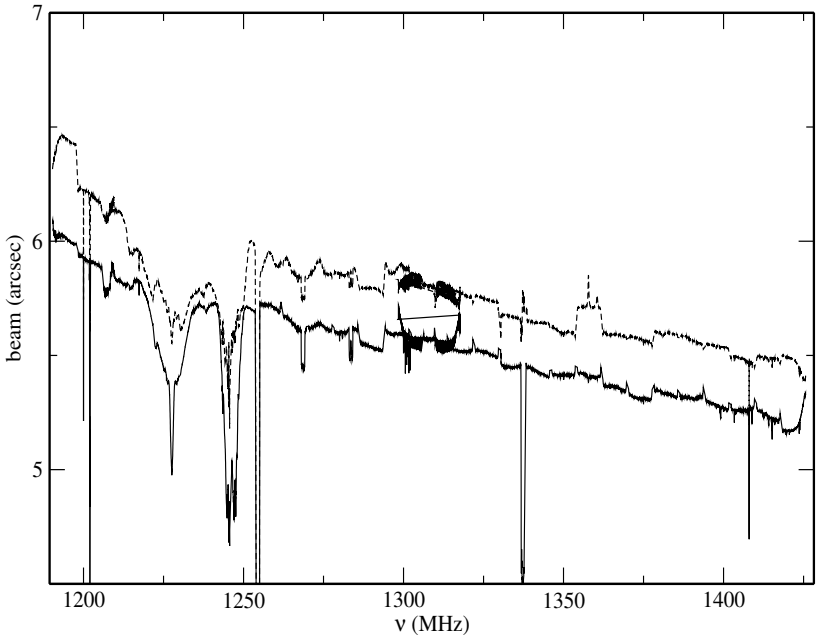

PILOT
AMP
IF 1(RR)
IF 2(RR)
IF 3(RR)
IF 4(RR)
1000
1080
1140
1180
1260
1300
1340
1400
FREQ (MHz)
AIRPORT
VLA
MODEM
GLONASS &
RADARS
RADARS

Rms noise as function of frequency



Baseline distribution is really important





Synthesized beam

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
Images provide useful information out to highest z in pilot

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

CHILES 1002 hours in B array spread over 3 or 4 B arrays

Same detection limit at z=0.45 about 3×10^{10} M_{sun} as for pilot at z=0.2

Cover z=0 to 0.45… (31 000 velocity channels)

15 subbands of 32 MHZ 2048 channels each 3.3 km/s
use frequency dithering

Calibrate data in Socorro
6 hours of data 1.5 Tbyte.. pipeline (switched to CASA) 60 hours
inspection takes roughly 1 astronomer week (few hours a day)

ship data to Perth.. (both calibrated data and raw data with tables)
imaging in Perth

CHILES con POL
Chris Hales et al

Commensal observing

4 subbands 128 MHz each full polarization mode (64 channels each)

Placed at 1000-1128 MHz, 1384-1512 MHz, 1640-1768 MHz, 1768-1896 MHz

Separate pipeline calibration done in a day by Chris

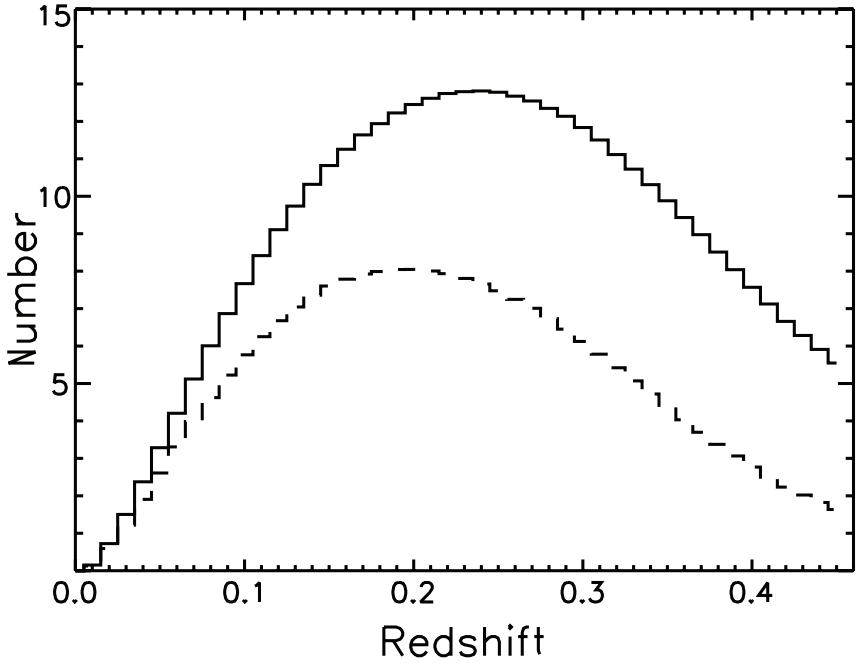
Transient search uses continuum pipeline.. Keeps up with the data
Laura Chomiuk et al

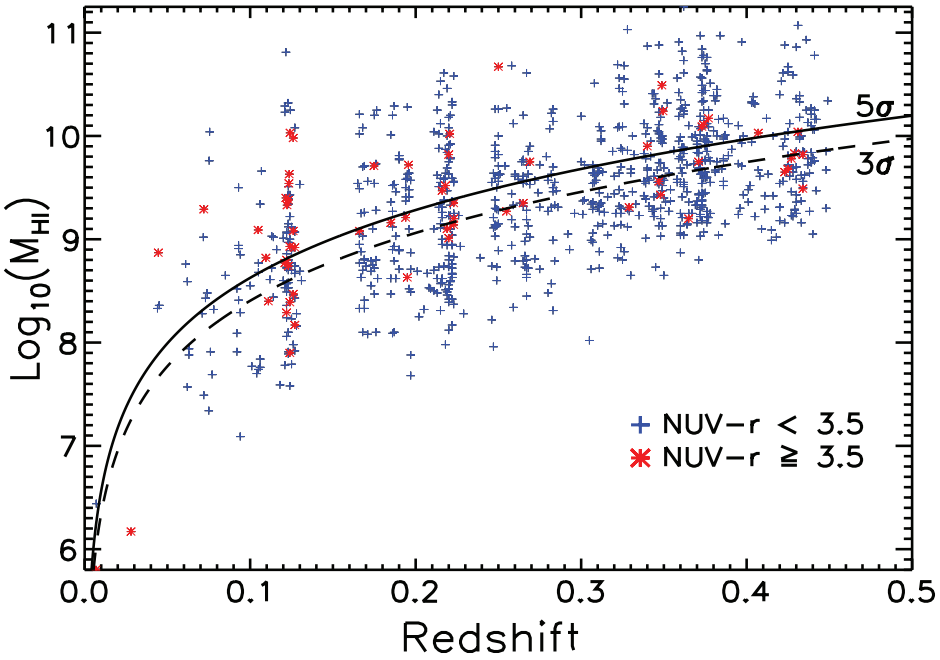
Science:

Source counts, luminosity functions, slow transients, magnetism in targeted sources, magnetism in the cosmic web, weak lensing, high z sources, spectral index AGN/SFG, radio FIR correlation and stacking

Expected detection rates for 1000 hour project

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

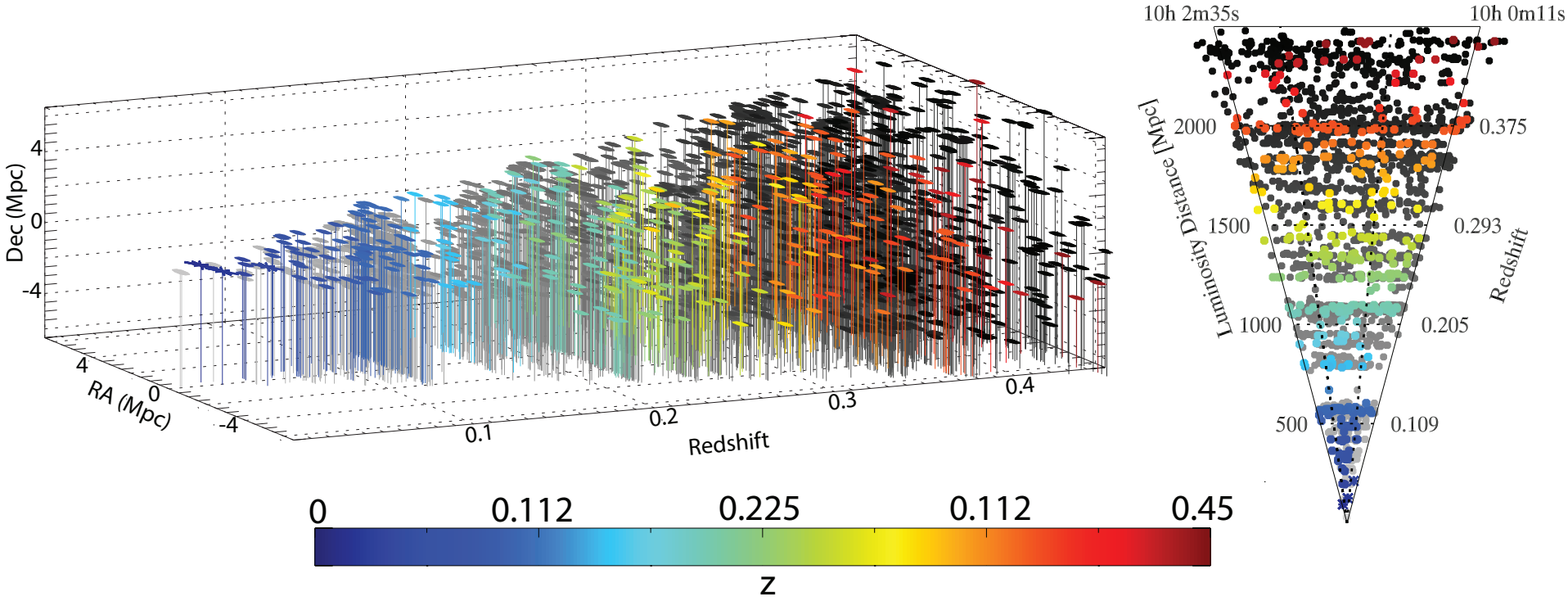




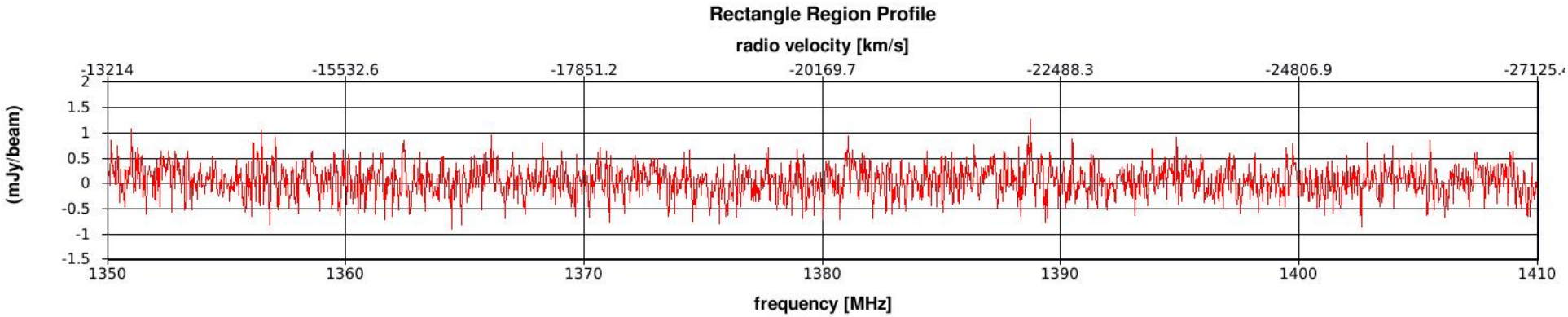
Estimate based on HI mass function

Estimate based on photometric gas fraction

Spatial distribution of predicted 5 sigma detections

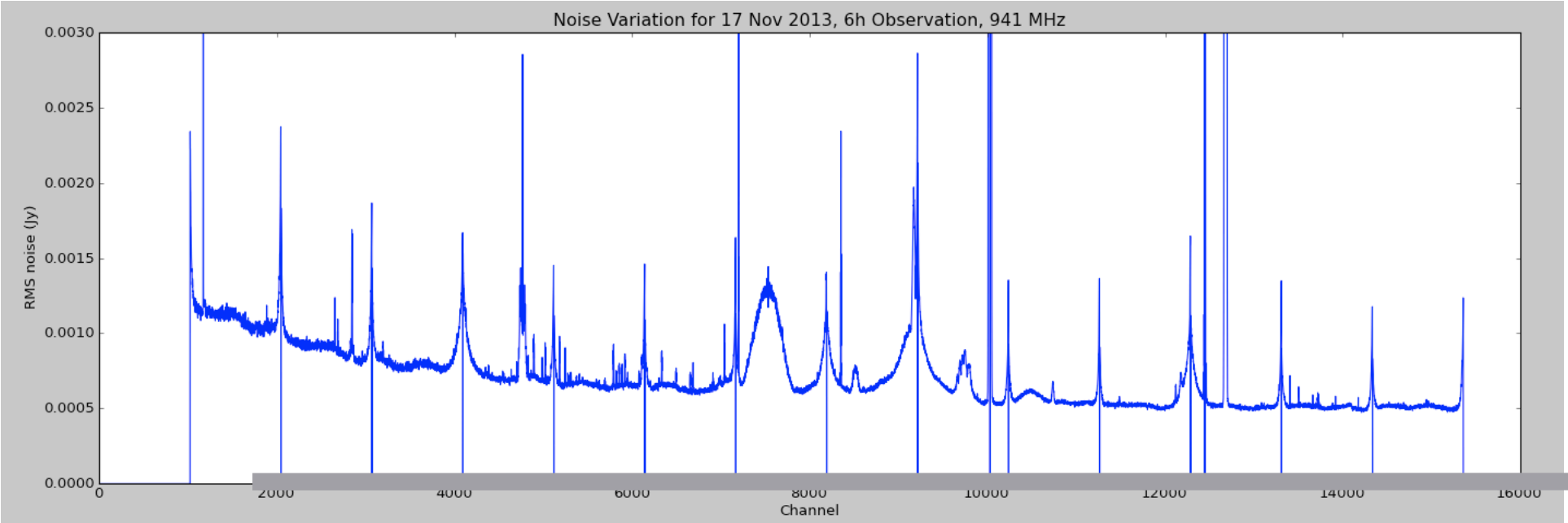


We are up and running! We already got 178 hours with 31000 channels to z=0.45



Half the data are calibrated.. Cubes are being made
Small ones in Socorro, big ones in Perth

Noise Variation for 6 hour Observation

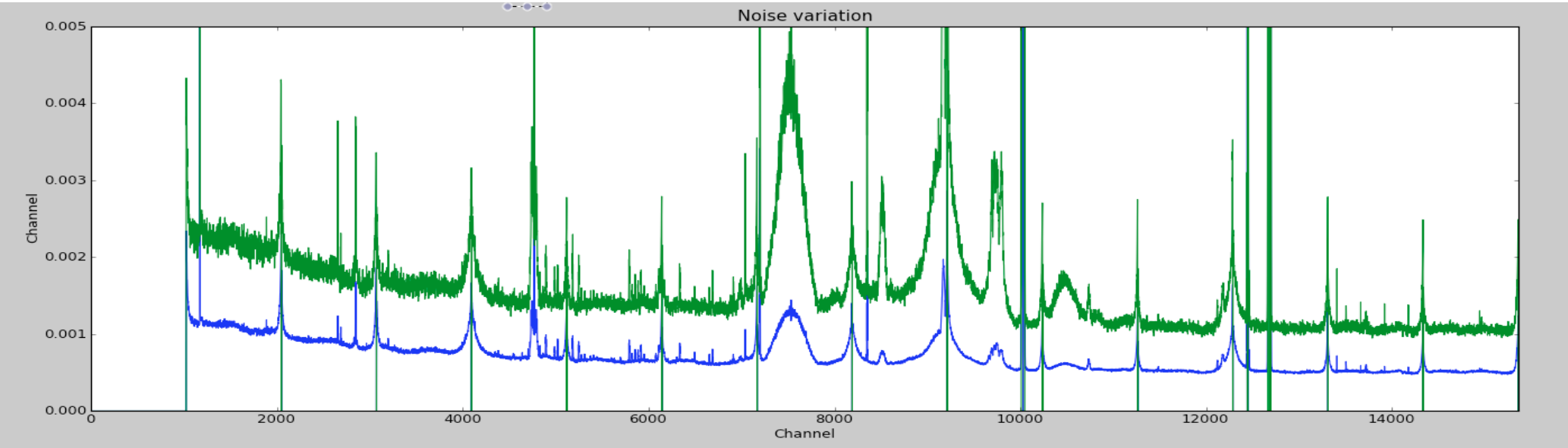


- First 15360 channel cube ever made!
- 15 x 32 MHz dual polarization spectral windows covering 941 – 1421 MHz (z = 0-0.509)
- 2048 channels per spectral window
  (~ 3.3 km/s at z=0)

six hours of data November 17

Cube with only baselines shorter than 2km

Cube with all baselines



973 1037 1101 1165 1229 1293 1357 MHz

Lessons learned so far .. We are very excited because we got DATA

Software should be robust and easy to use…… CASA is neither

Most important problem in data reduction
you can not quickly inspect data,
you can not quickly inspect what you have done

New algorithms important.. We will make gridded UV cube reducing
ENTIRE UV data base to a few Tbytes

RFI removal remains challenging
we may have to give up on range from 1160 to 1260 MHz

Source finding in cubes with non gaussian noise remains challenging

We hope to have a cube of 178 hours in August

stay tuned