

# HI Absorption Possibilities with CHILES

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**HI Absorption Workshop, ASTRON**

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# The CHILES Collaboration

## People at this meeting:

Danielle Lucero, Natasha Maddox, Martin Meyer, Tom Oosterloo, Marc Verheijen, Attila Popping, Thijs van der Hulst, Eric Wilcots

## CHILES collaborators not present (an incomplete list):

Jacqueline van Gorkom, Ximena Fernandez, Kelley Hess, Emmanuel Momjian, D.J. Pisano, Lucas Hunt, Hansung Gim, Min Yun,, Aeree Chung, Trish Henning, Monica Barrantes, Julia Gross, Chris Hales, Laura Chomiuk, Charee Peters...

# Overview

- COSMOS HI Large Extragalactic Survey (CHILES) overview
- CHILES continuum properties
- Proposed HI absorption, stacking experiments

**The work presented here is very preliminary!  
CHILES is still very much in data collection/reduction mode**

# The COSMOS HI Large Extragalactic Survey

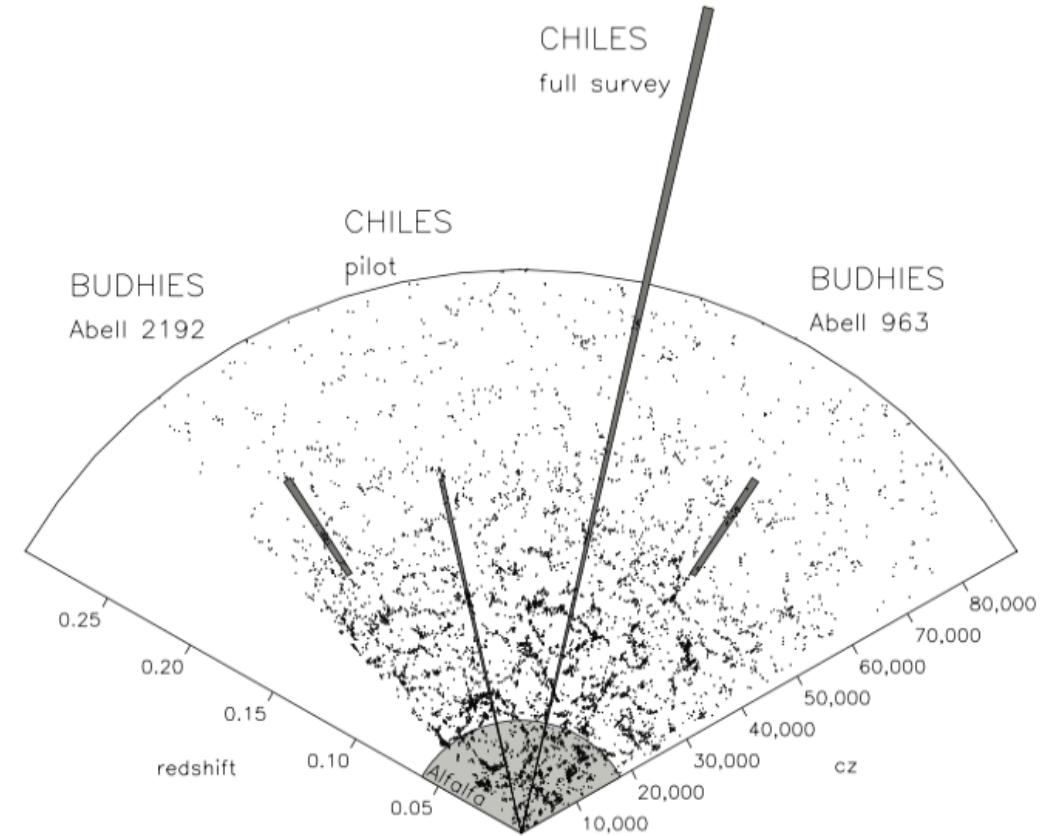
**1000 hour integration**, single pointing in COSMOS  
600 hours complete so far

VLA B-Array, L-band, 30' FOV

970-1450 MHz ->  **$0 < z < 0.45$**

15.5 kHz channels ->  **$6.6 \text{ km s}^{-1}$**  velocity resolution  
(after Hanning smoothing)

HI emission sensitivity:  **$50 \mu\text{Jy}$**



# CHILES

COSMOS HI LARGE EXTRAGALACTIC SURVEY

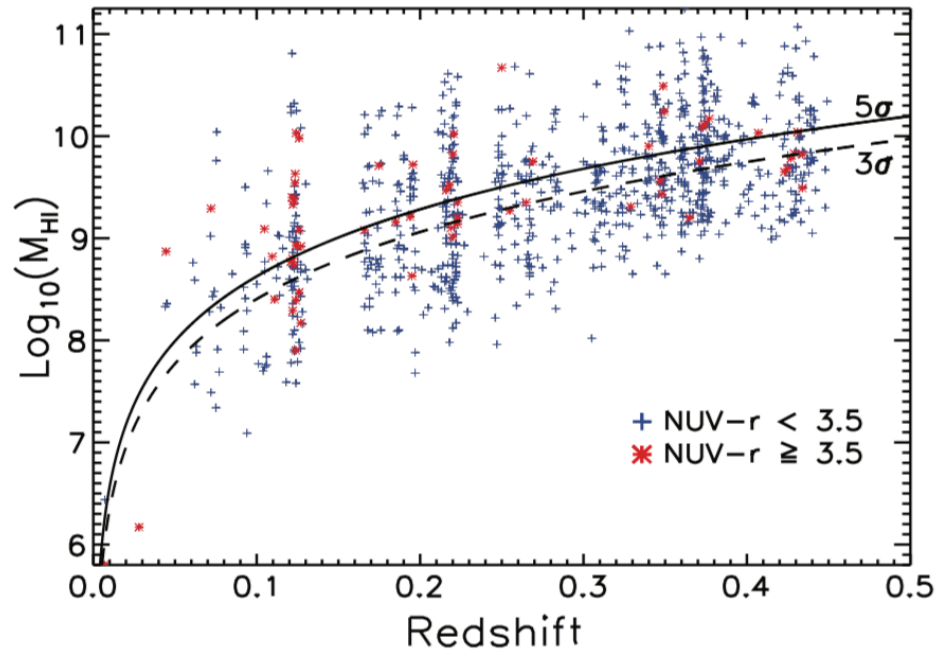
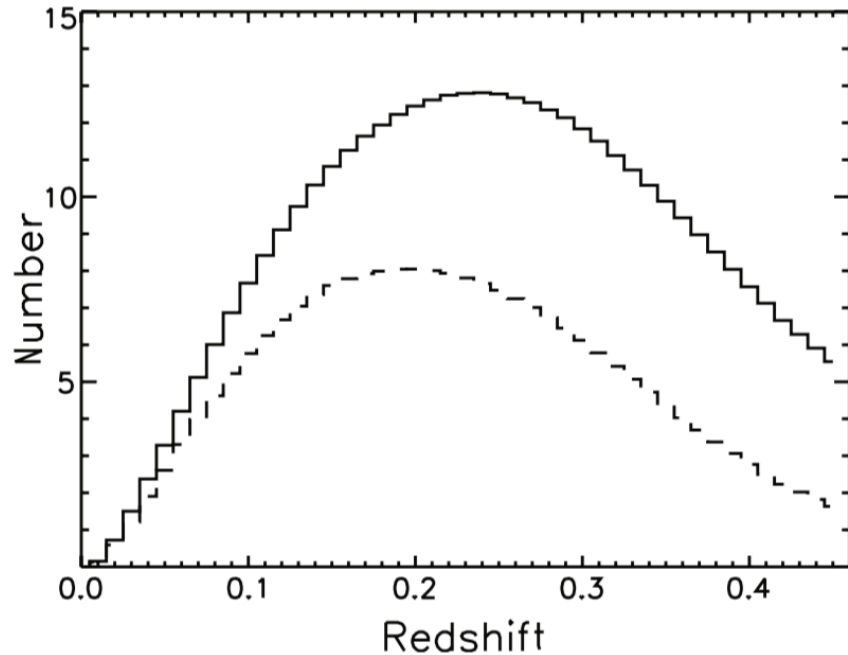
# The COSMOS HI Large Extragalactic Survey

300+ predicted detections in HI emission  
( $5\sigma$ ,  $150 \text{ km s}^{-1}$  profile width)

Column density of  $1.5 \times 10^{19} \text{ cm}^{-2}$   
per  $6.6 \text{ km s}^{-1}$

Mass sensitivities:  
 $\approx 10^6 M_{\odot}$  nearby,  $\approx 10^{10} M_{\odot}$  at  $z = 0.45$

Angular Resolution:  
350 pc nearby, 42 kpc at  $z = 0.45$



From CHILES VLA proposal,  
van Gorkom et al.

## Highest Redshift Detection: J100054

(180 hours integration)

Fernandez et al. 2016

LIRG with large SFR at  $z = 0.376$

Contours: column densities of (7.1, 14.2, 21.3)  $\times 10^{20} \text{ cm}^{-2}$

HI mass of  $(3.6 \pm 1.6) \times 10^{10} M_{\text{sun}}$

Extended and offset from optical center ->  
Interactions with small companions or  
possible accretion fueling large observed  
SFR?

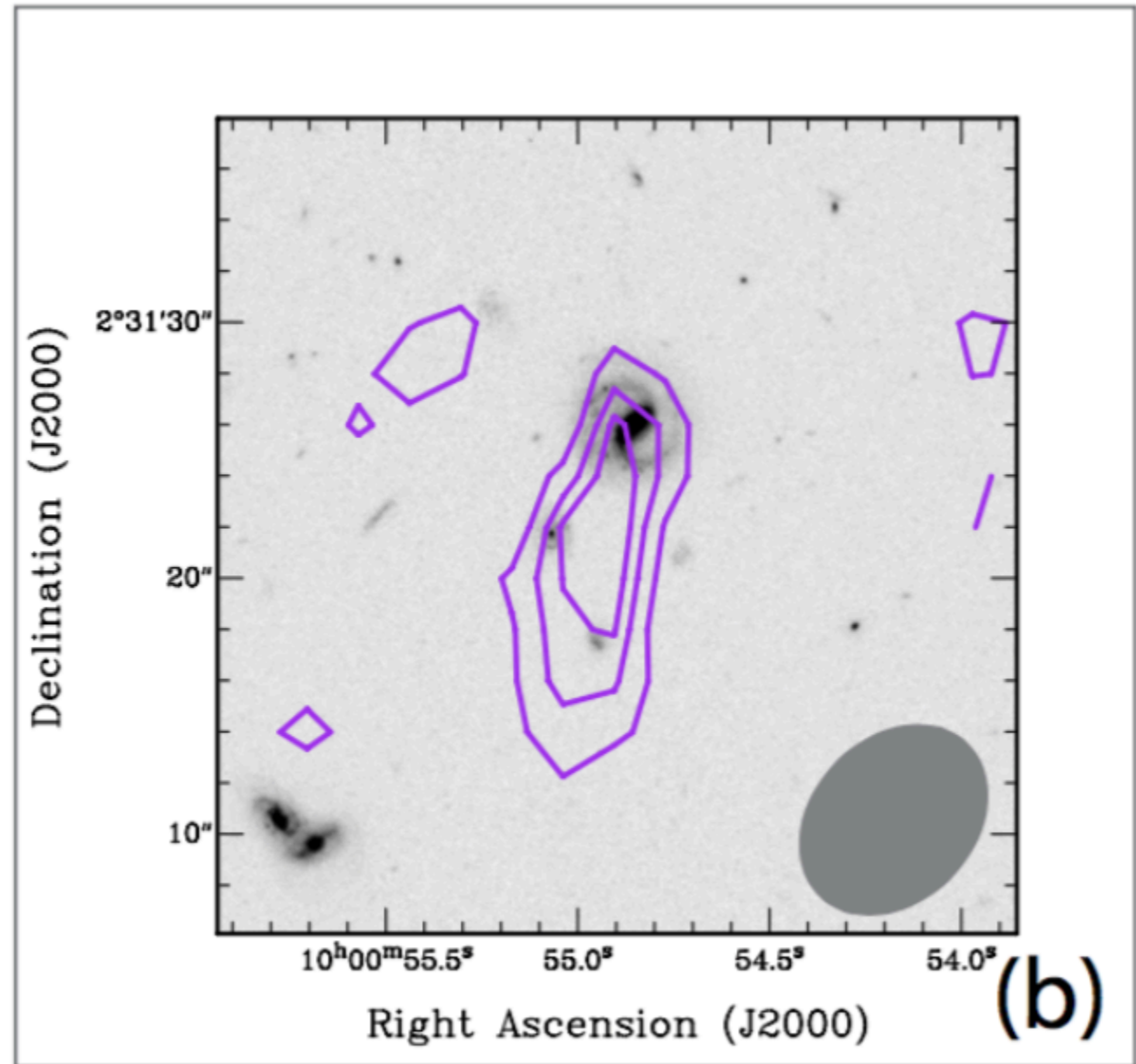
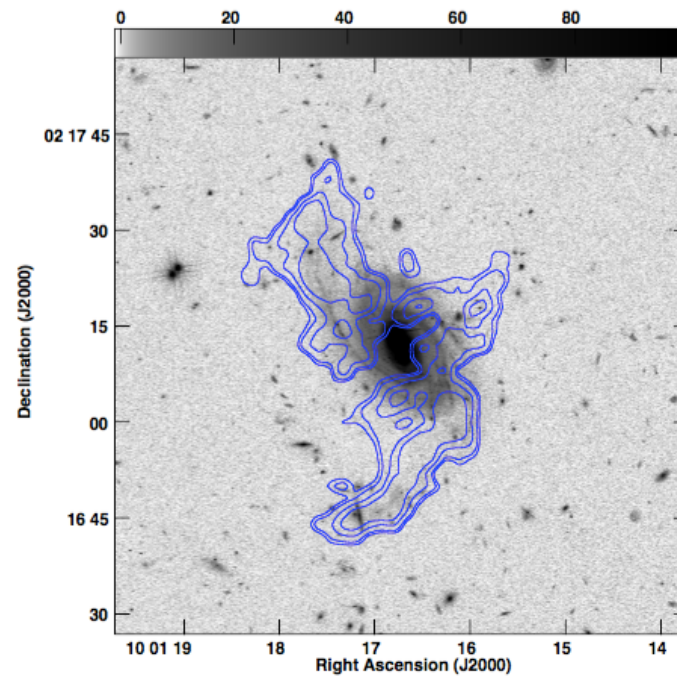
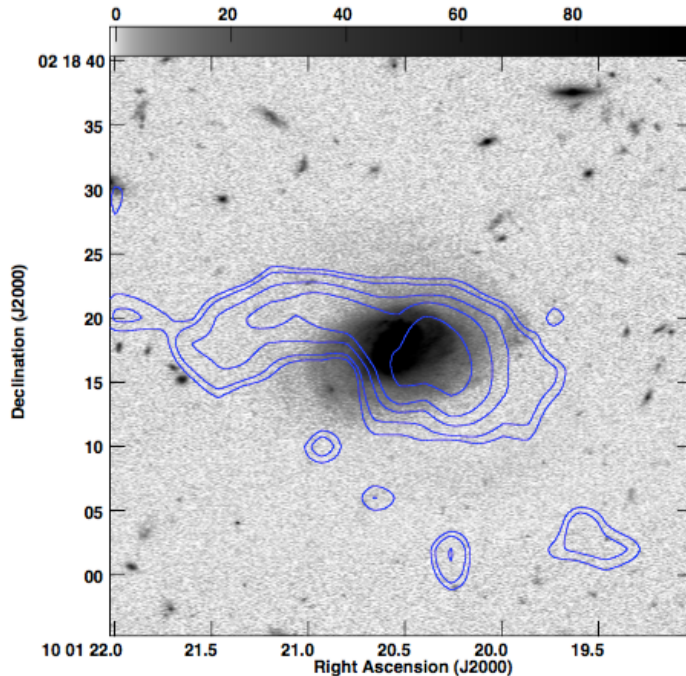
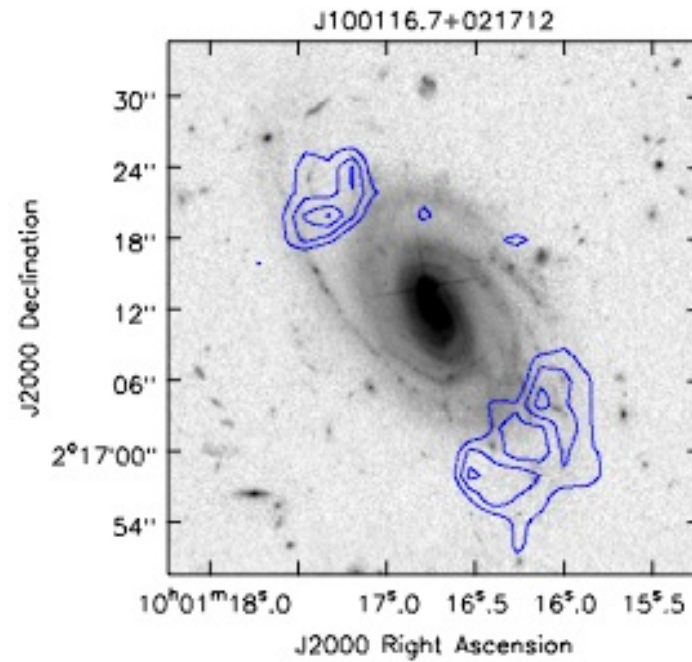
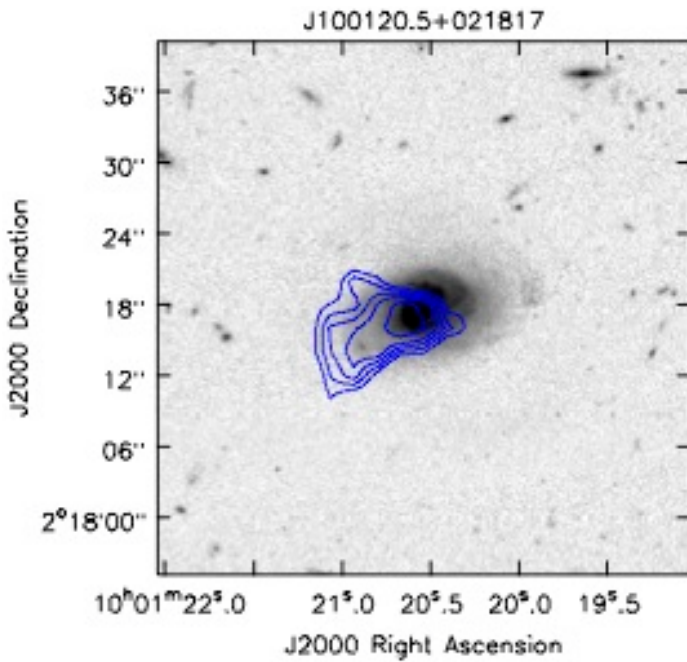


Image Credit: Fernandez et al. 2016, CHILES Collaboration



Extended HI already seen on  
“nearby” ( $z < 0.1$ ) galaxies

- Good sky coverage for potential absorption of background continuum sources?

Upper Panels: CHILES Pilot, 50 hours

Noise:  $0.085 \text{ mJy beam}^{-1}$

Lowest contours  $\approx 3 \times 10^{20} \text{ cm}^{-2}$

Lower Panels: CHILES first 180 hours

Noise:  $0.070 \text{ mJy beam}^{-1}$

Lowest contours:  $7 \times 10^{19} \text{ cm}^{-2}$

Contours courtesy X. Fernandez and K. Hess

# A Pathfinder for the Pathfinders

Lots of upcoming HI surveys planned for SKA pathfinders, with emphasis on wide area observing campaigns. Why 1000 hours on the VLA now?

- The upgraded VLA is complete and fully operational.
- CHILES will have higher angular resolution than upcoming deep fields
- VLA B-Array long baselines less affected by RFI (70% > 2km), data collection started prior to launch of several new GPS satellites

Techniques developed for CHILES may help guide survey strategies for SKA pathfinders



# Science Goals for HI Absorption in CHILES

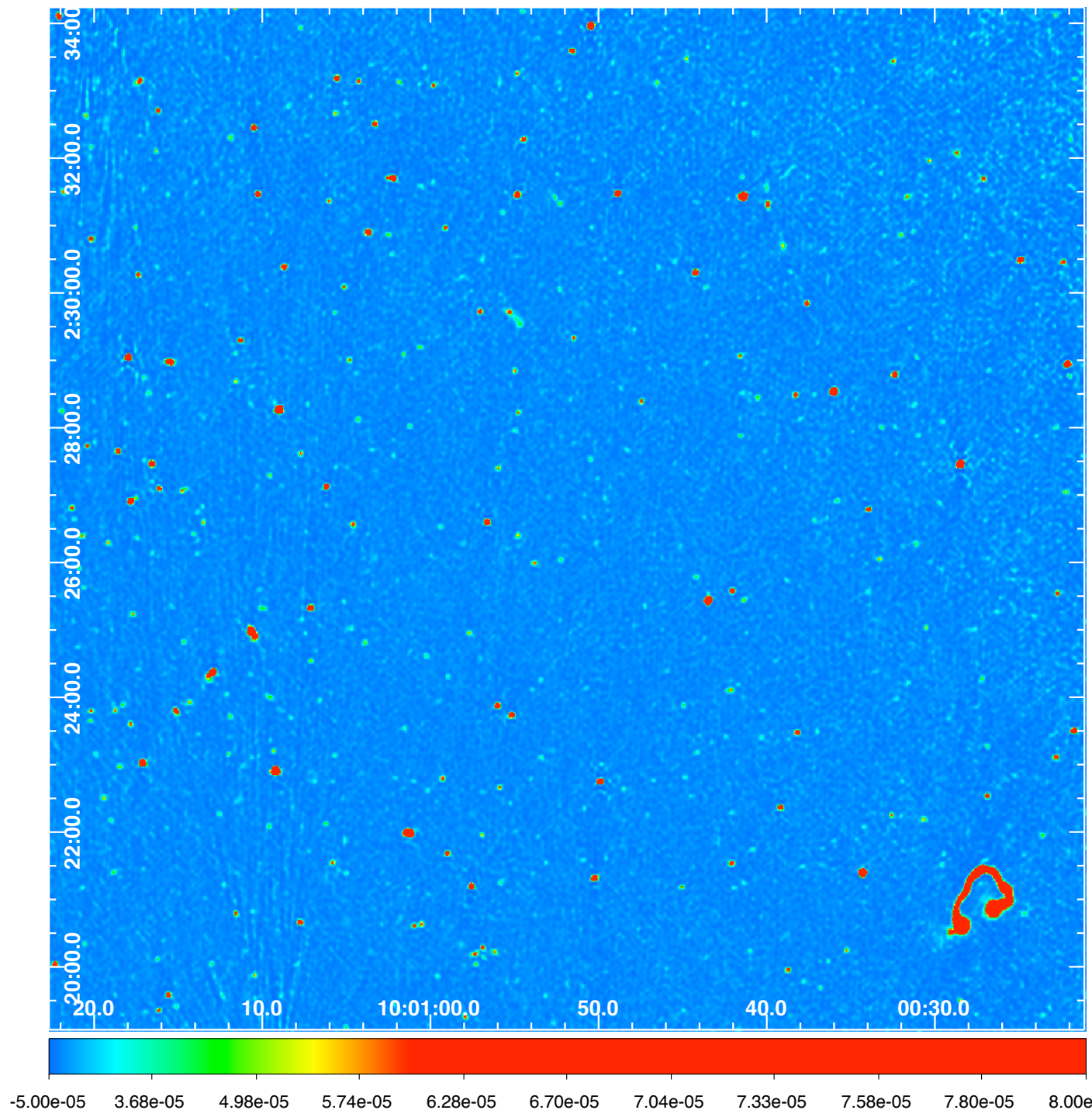
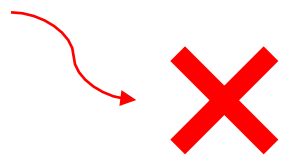
- An overarching goal of CHILES is investigating how gas gets into galaxies
  - Evolution of HI in different environments (voids to “walls”)
  - Evolution of HI out to redshift of  $z = 0.45$
- Probing the circumgalactic medium (CGM) grants important insight into galaxy gas cycles
  - Can we use CHILES high continuum sensitivity to probe an individual galaxy CGM? By stacking, can we probe the broader IGM in groups and filaments?
- Unlike much previous HI absorption work, we’re interested in looking at gas associated with the galaxy but not the stellar disk (as with most DLAs)
  - Need good alignment, lots of background continuum sources

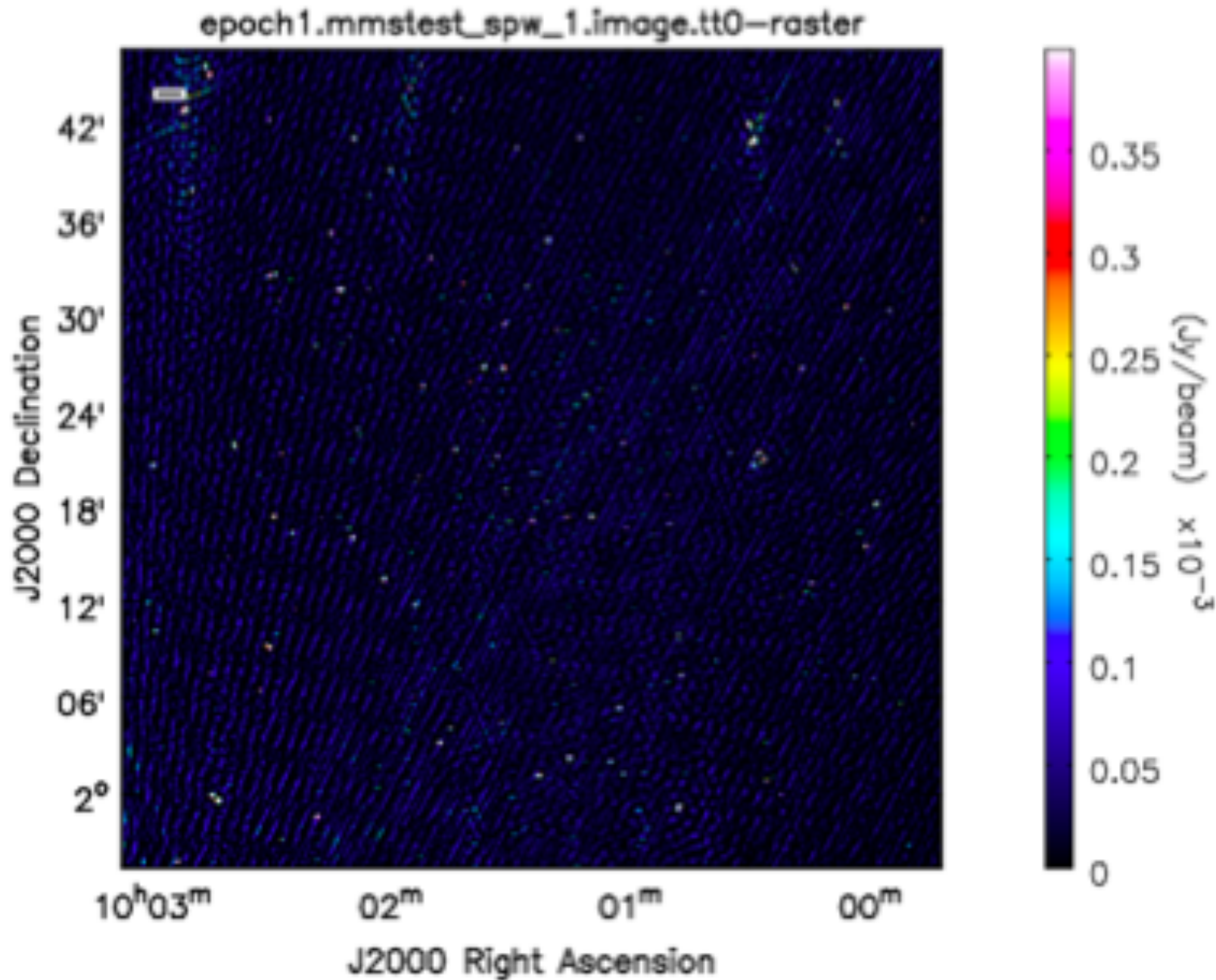
# Continuum Properties in CHILES

- 430 ( $\approx 15$  per square arcminute) continuum sources brighter than  $100 \mu\text{Jy}$ , 50 brighter than  $1 \text{ mJy}$ .
- Per channel sensitivity  $70 \mu\text{Jy}$  per beam (measured from the first 178 hours integration), full survey will have sub- $\mu\text{Jy}$  rms
- S/N of 100 & column density sensitivity toward the  $1 \text{ mJy}$  sources of  $< 10^{19} \text{ cm}^{-2}$  at  $5\sigma$  for full survey.
- Nature of background continuum sources mostly unknown, but COSMOS field has wealth of pan-chromatic data to supplement the HI investigations

A deep COSMOS continuum image  
representative of source density  
that will be seen in full CHILES field

CHILES Field Center



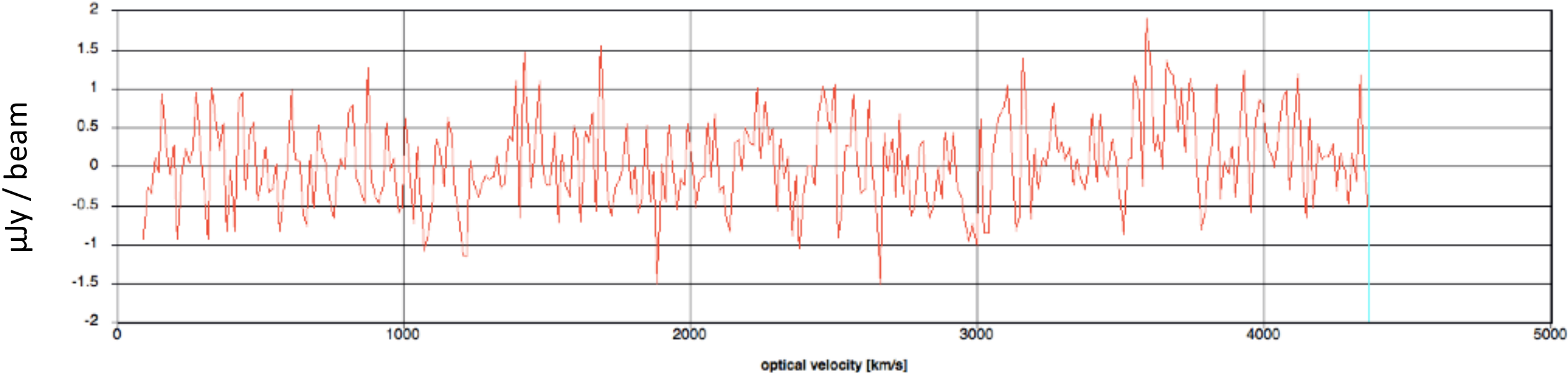


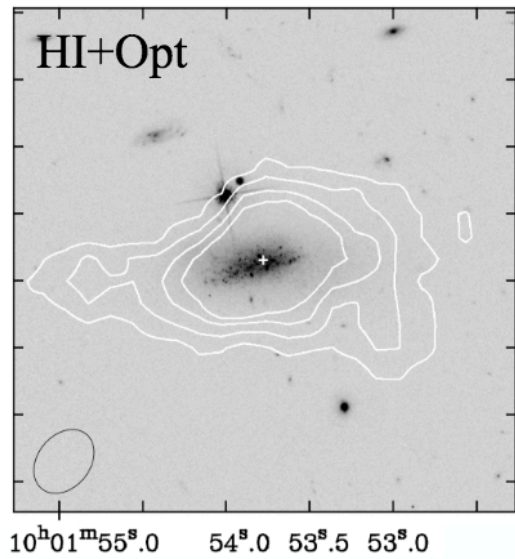
CHILES Field 180 Hour  
Continuum Image

Image courtesy of ICRAR

# Continuum-subtracted spectrum demonstrating current rms for rectangular region at center of CHILES pointing

1400 – 1420 MHz

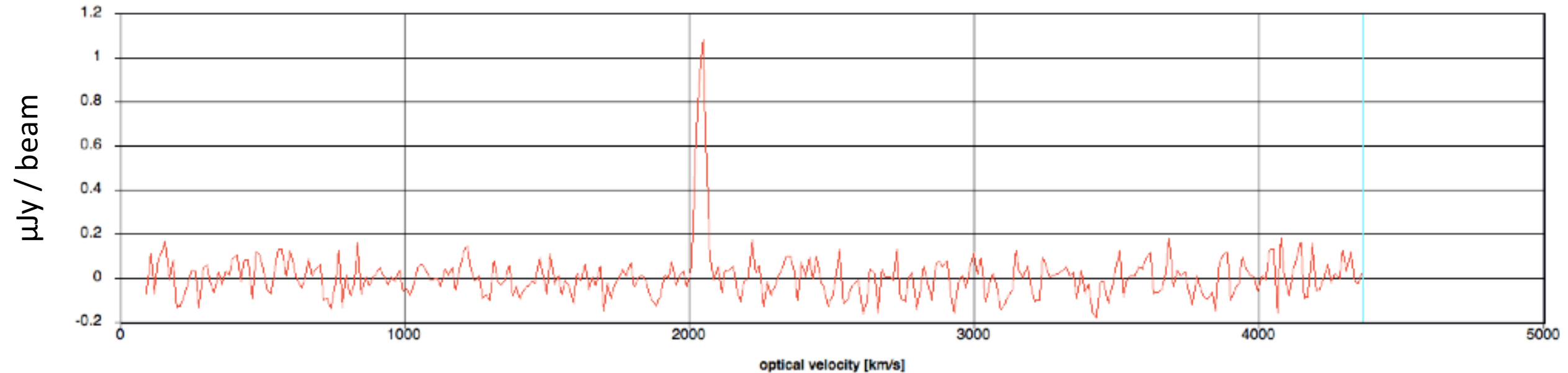




Continuum-subtracted spectrum demonstrating current rms for single point profile on a bright HI emission target

1400 – 1420 MHz

J100153+022449



Spectrum thanks to K. Hess

# Large Scale Structure Stacking

At higher redshifts, only highest HI masses and column densities will be detected

- Stacking experiments will help determine averaged properties of lower mass objects and probe possible large scale structure
- The COSMOS field has lots of redshift measurements to use for this
  - Spectroscopic and photometric, supplemented by on-going work with WIYN and SALT

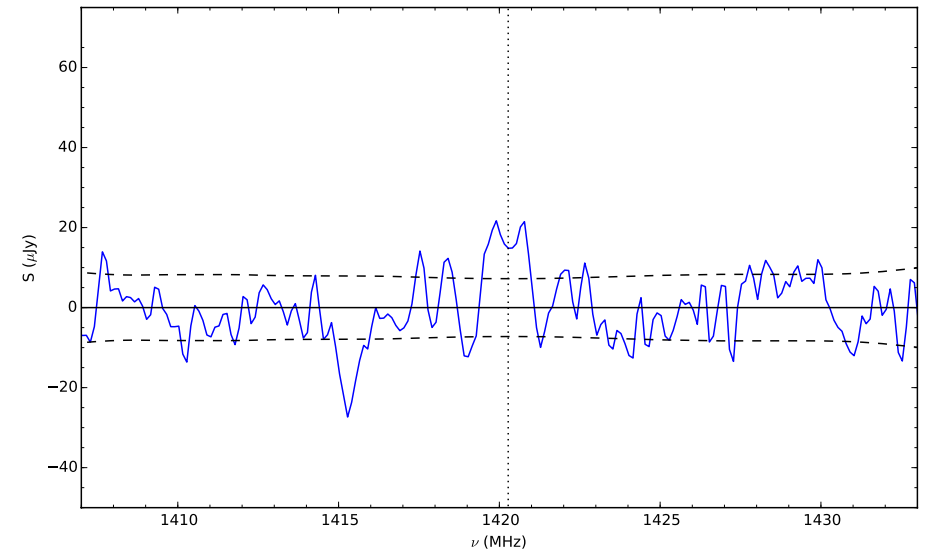
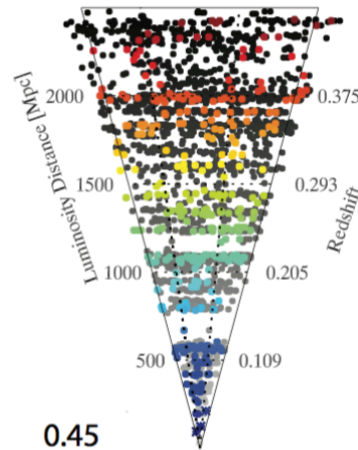
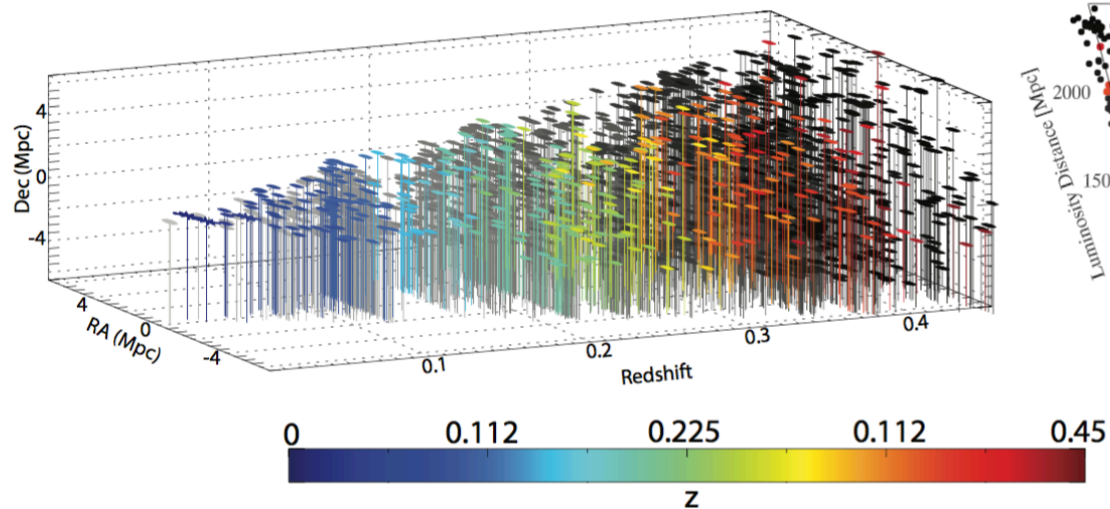
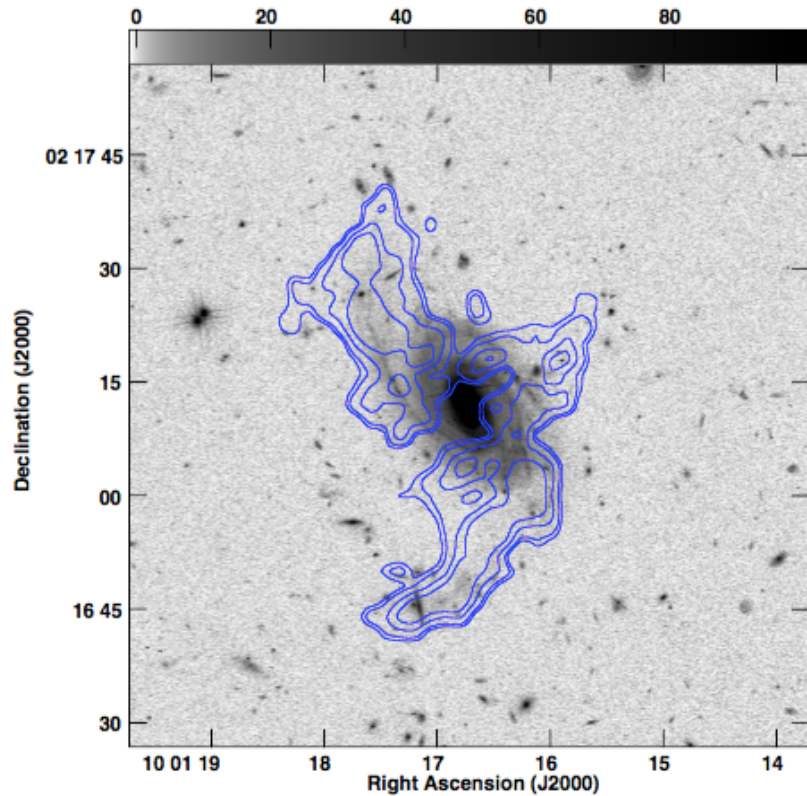


Figure from CHILES VLA proposal, van Gorkom et al.

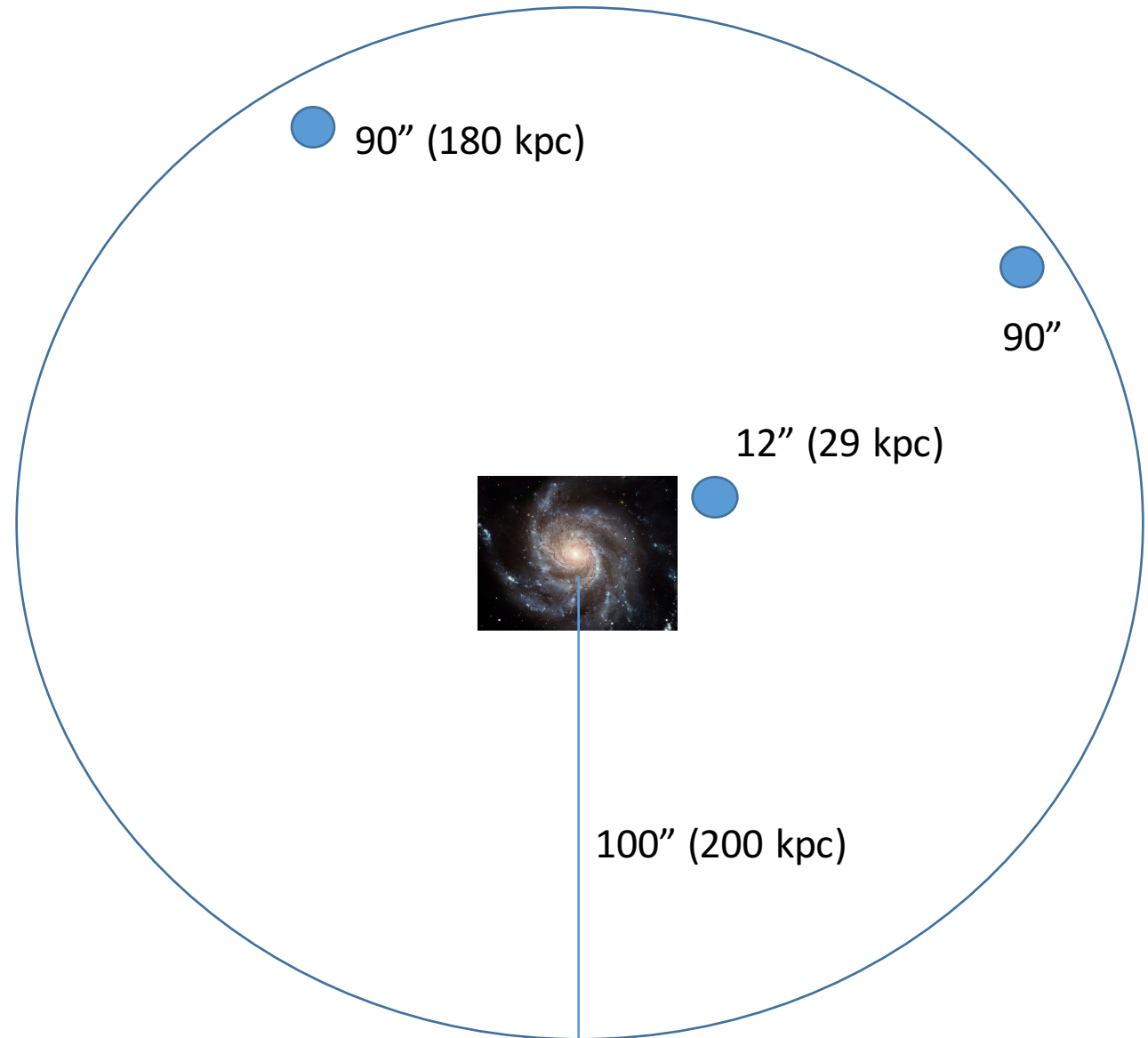
Figure courtesy of T. Oosterloo

Use multiple background continuum sources to probe a given foreground galaxy



Ex: This galaxy has 3 continuum sources  $> 100 \mu\text{Jy}$  within a  $100''$  radius (200 kpc)

## Halo Stacking



Cartoon schematic of continuum sources around J100116.7+021712

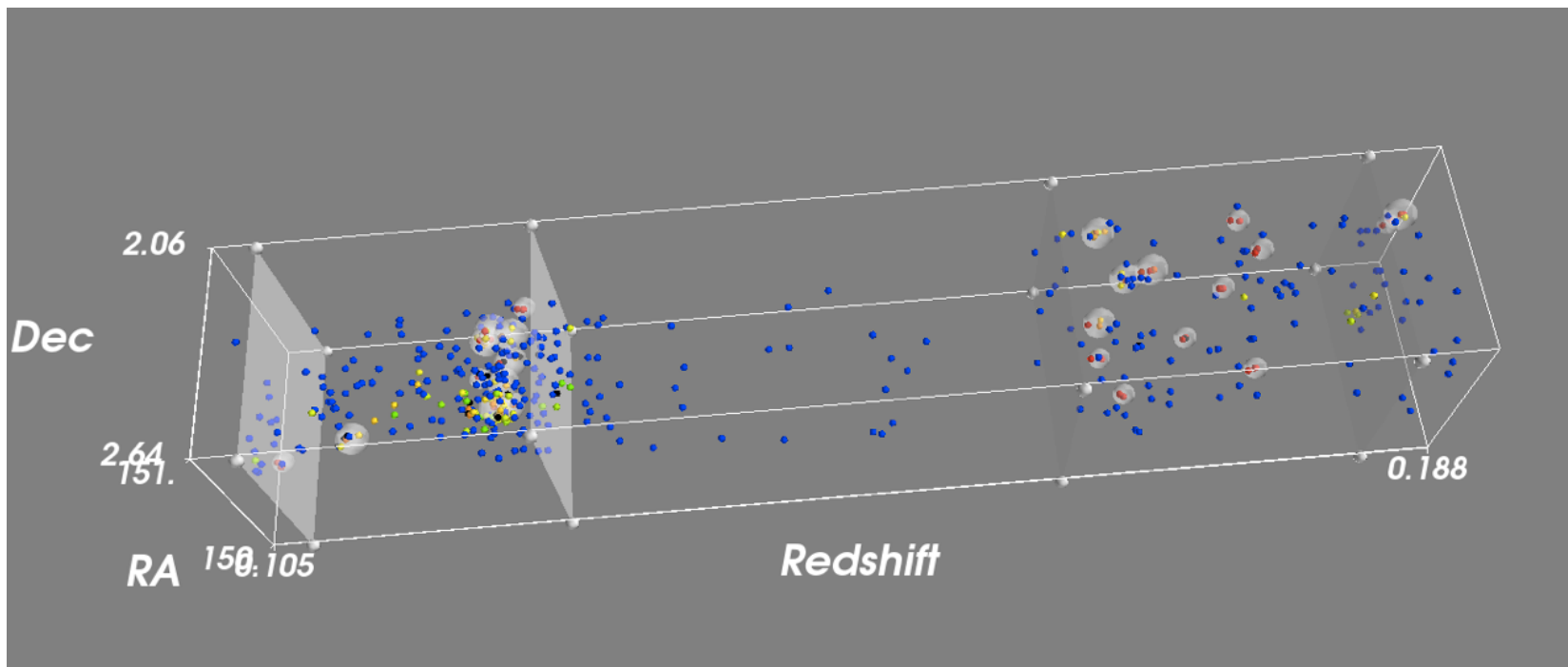
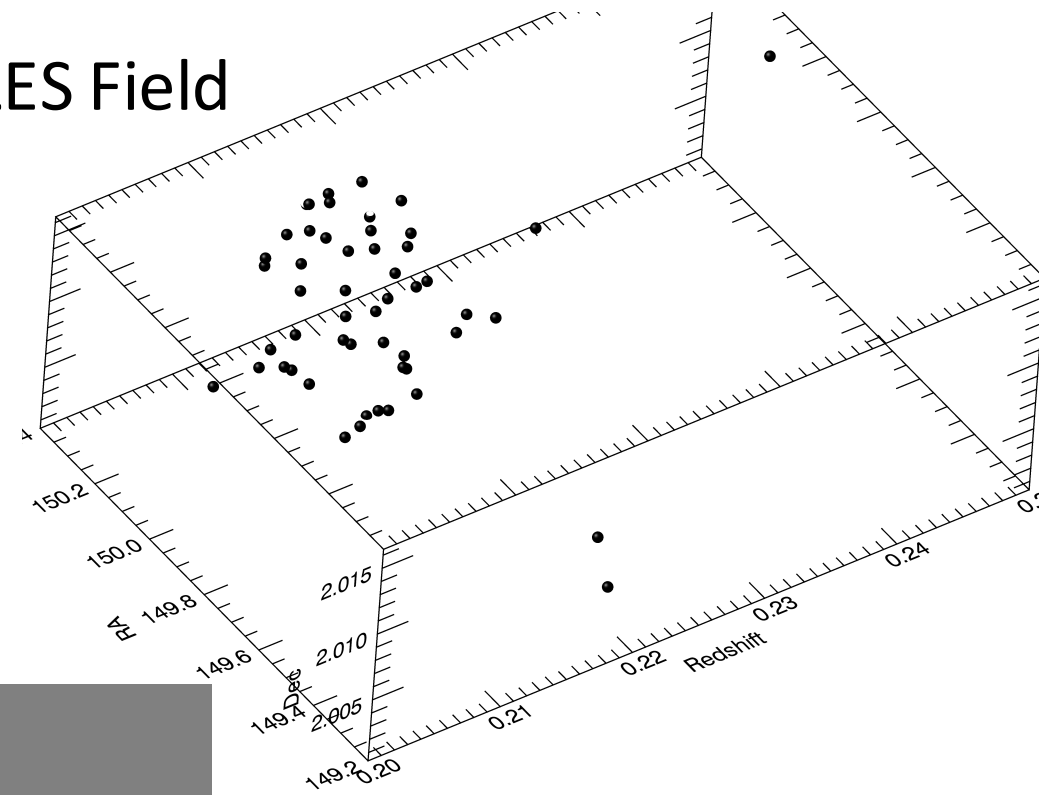


# Example Groups and Over-Densities in the CHILES Field

$z = 0.22$  over-density

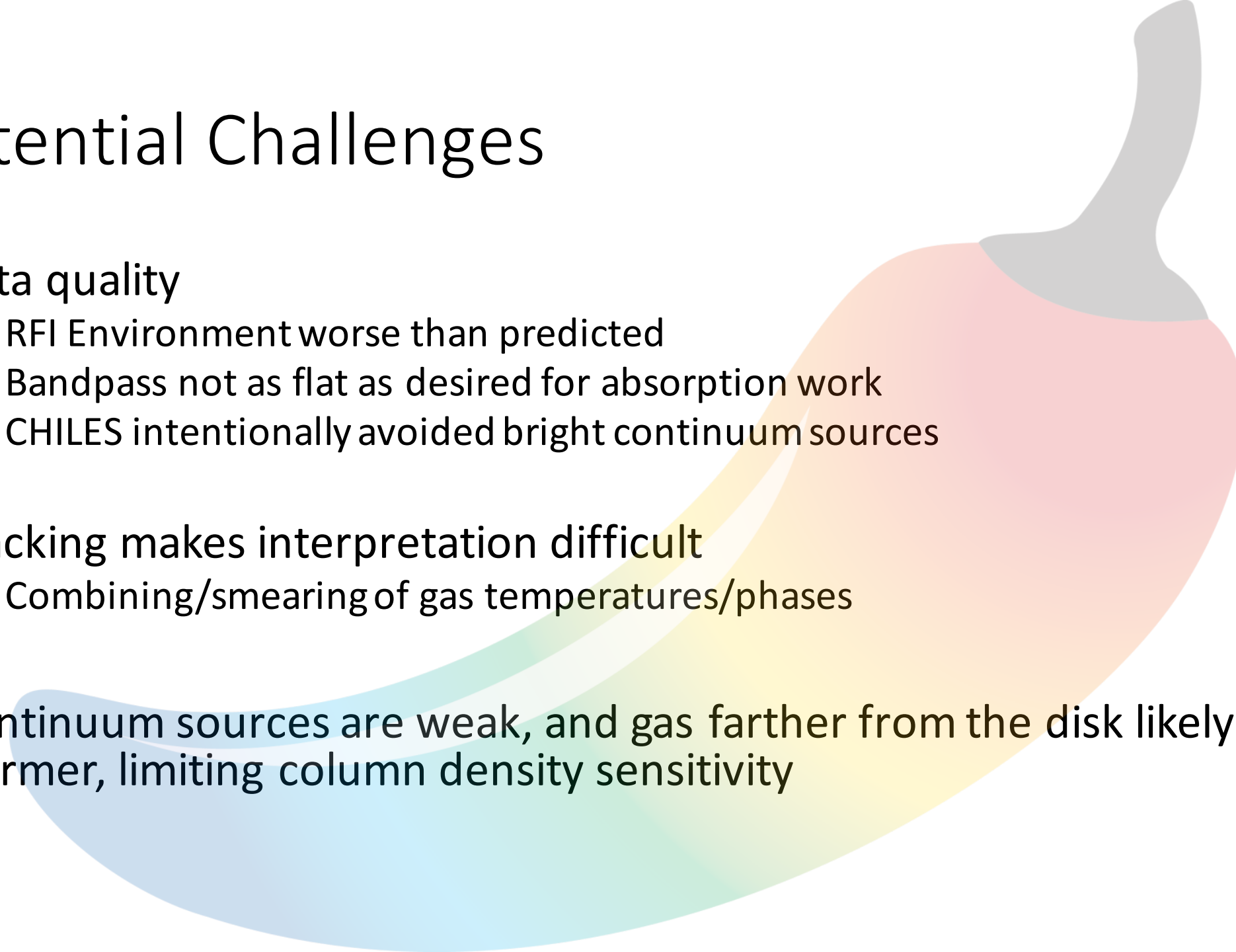
52 galaxies with redshifts (WIYN/Hydra)

HI detections with potential group membership indicated in color, based on Knobel et al. 2012



Galaxy Group work by K. Hess

# Potential Challenges

- Data quality
    - RFI Environment worse than predicted
    - Bandpass not as flat as desired for absorption work
    - CHILES intentionally avoided bright continuum sources
  - Stacking makes interpretation difficult
    - Combining/smearing of gas temperatures/phases
  - Continuum sources are weak, and gas farther from the disk likely warmer, limiting column density sensitivity
- 

# Summary

- CHILES is well underway, with 600+ hours observed and about half of that data reduced. RFI worse than expected, but noise properties are still very good.
- Exquisite continuum sensitivity provides opportunities for HI absorption stacking experiments
  - Probing individual galaxy halos
  - Probing large scale structure like groups

Questions?

