National **A**eronautics and **S**pace Administration
Jet **P**ropulsion **L**aboratory
California **I**nstitute of **T**echnology

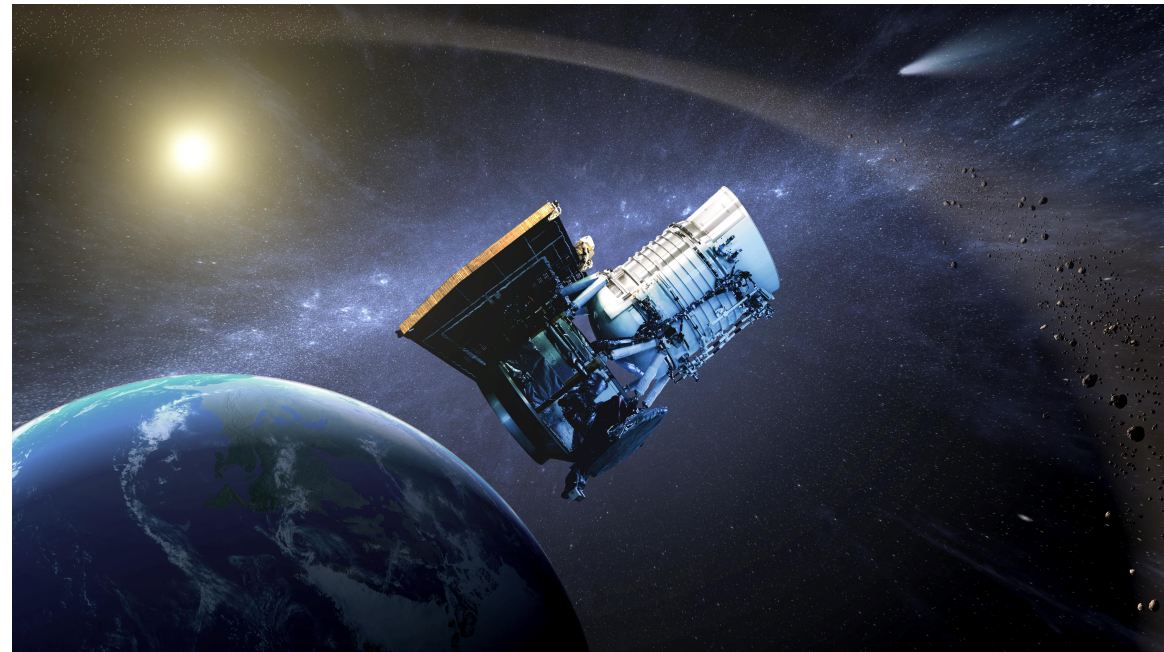**W**ide-field **I**nfrared **S**urvey **E**xplorer

Searching for Massive Distant Galaxy Clusters with WISE

Peter Eisenhardt (JPL), Dan Gettings, Anthony Gonzalez (U Florida),
Mark Brodwin (UMKC), Adam Stanford (UCDavis), Daniel Stern (JPL)
WFIRS Conference, 2014 November 18

- IR selection of Clusters
- A cluster we didn't expect
- MaDCoWs: AllWISE, Spitzer, CARMA
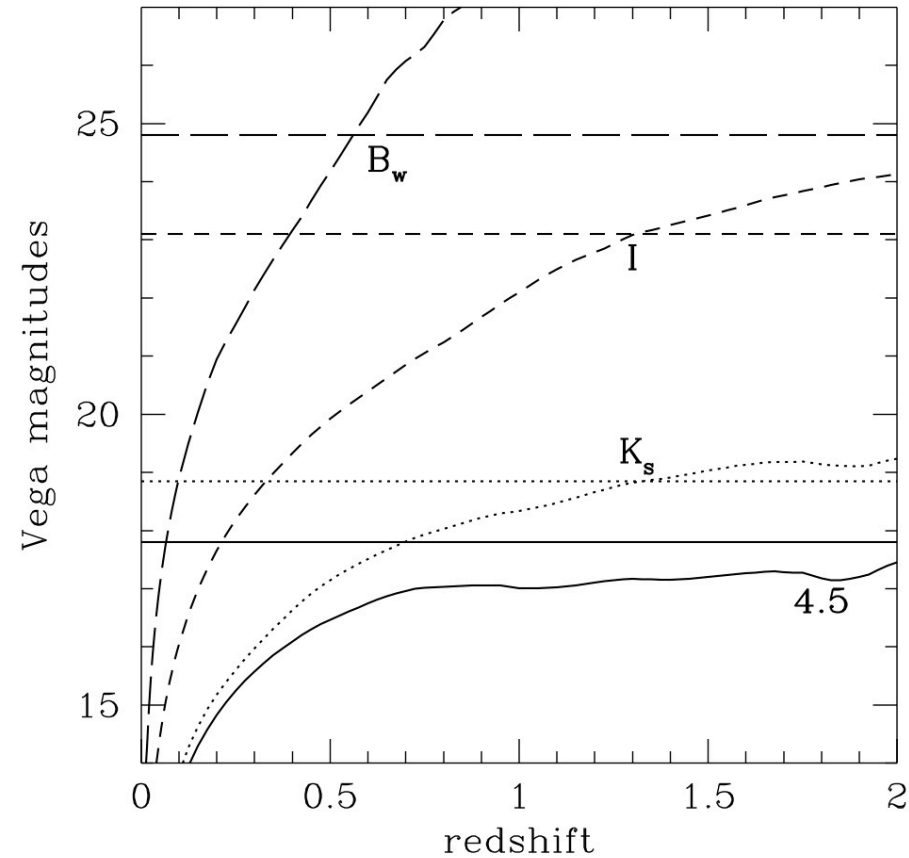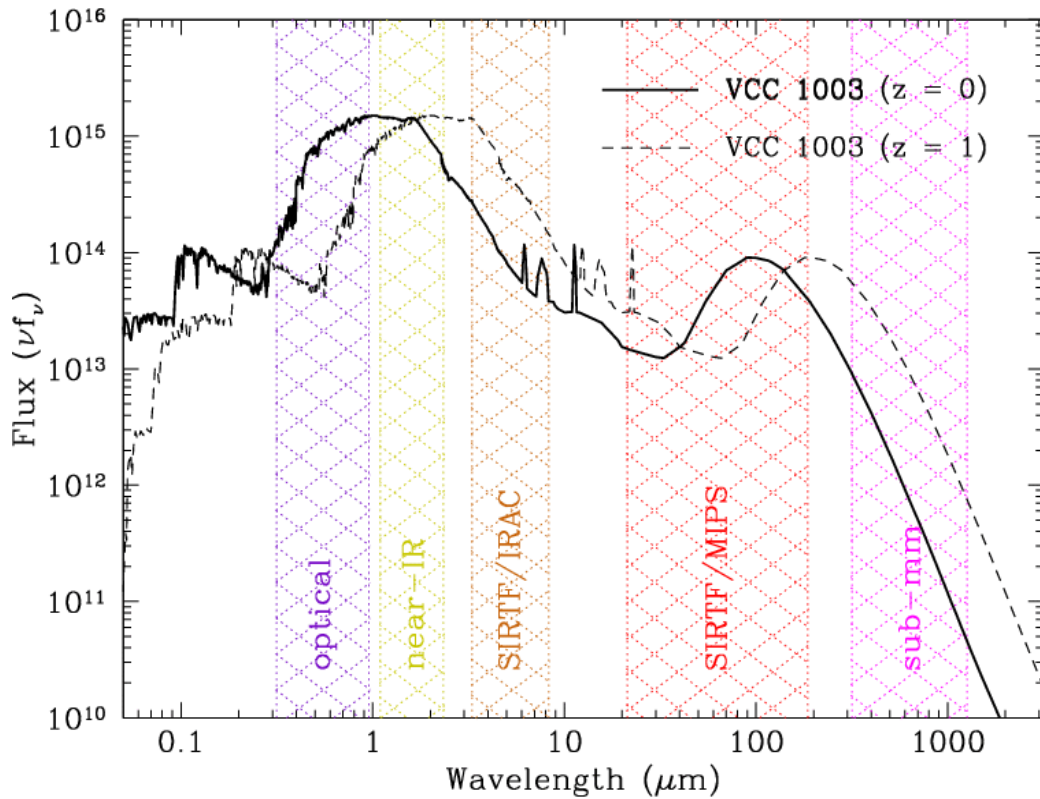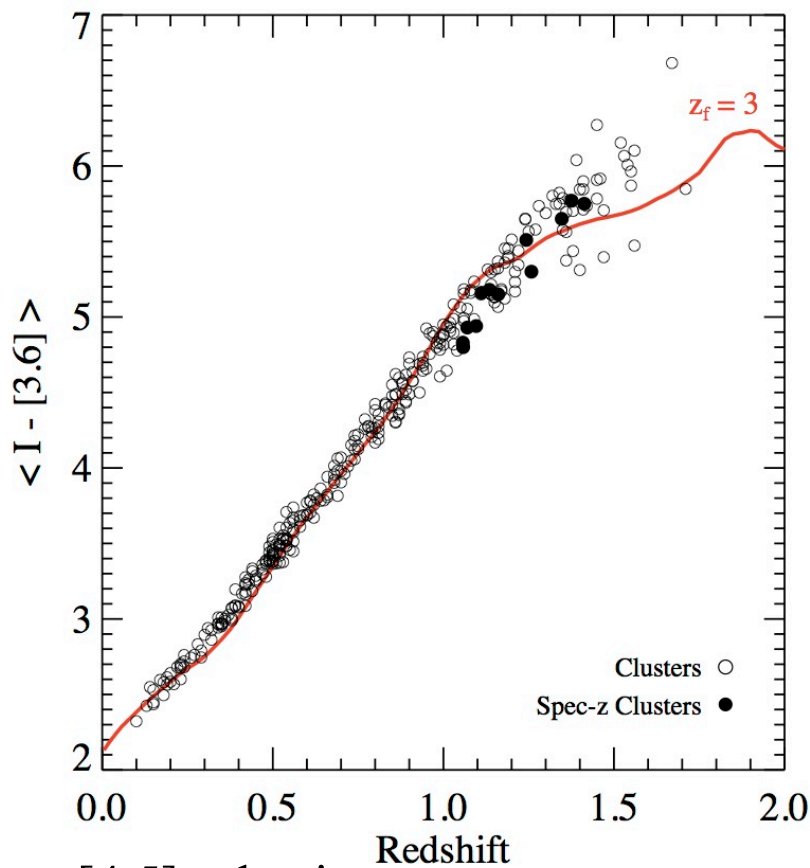- Richness and mass
- MaxWISE

Mid-IR is a Good Place to Select Distant Galaxies

Eisenhardt et al 2008

Wide-field Infrared Survey Explorer
IRAC Shallow Cluster Survey in NDWFS Boötes

- [4.5] selection

- Phot-z's from NOAO+IRAC

- Wavelet search

- Optical colors identify z < 1
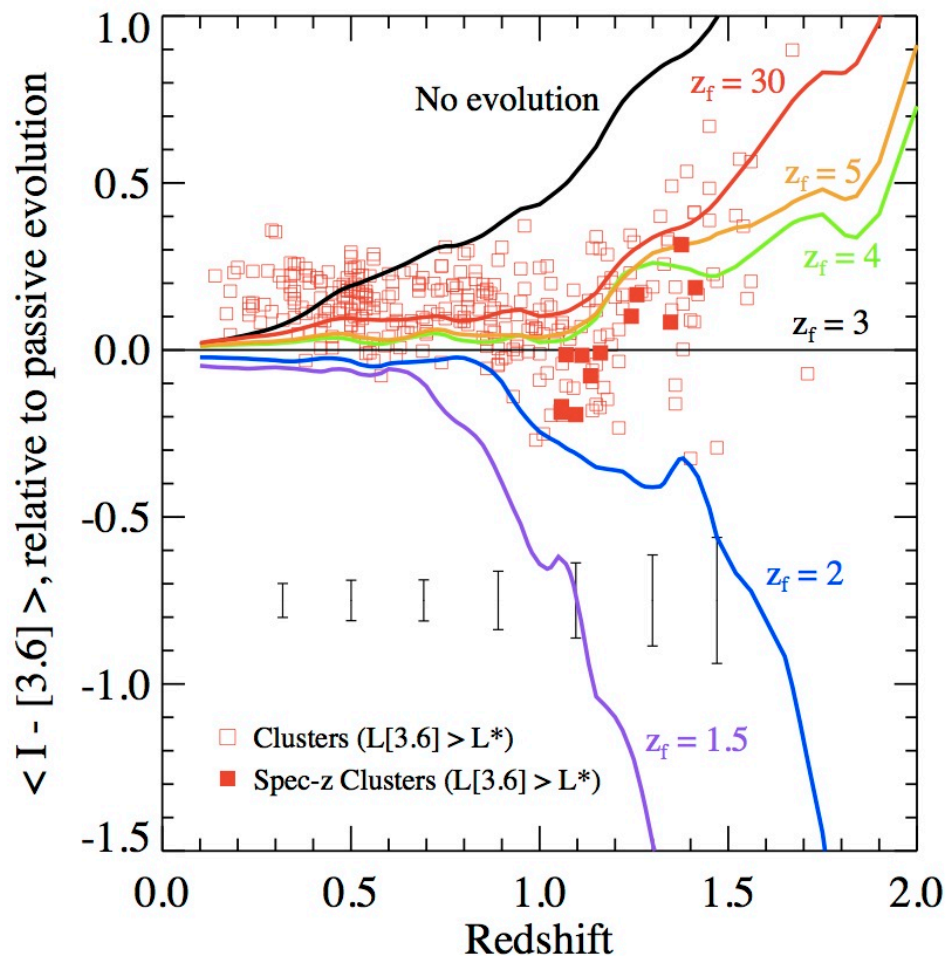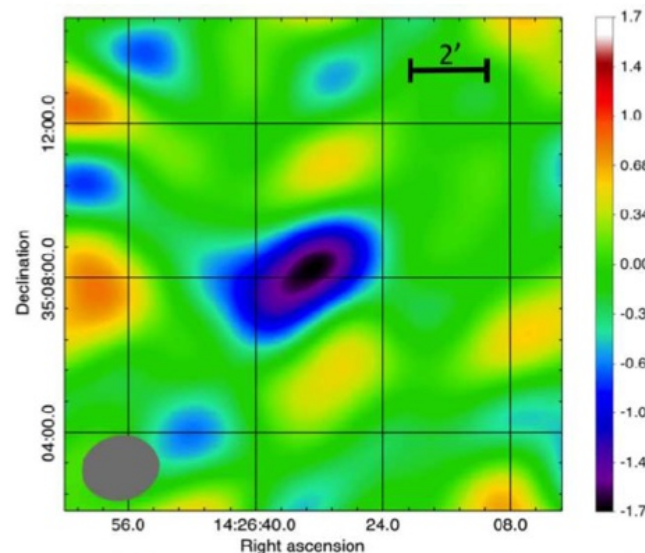
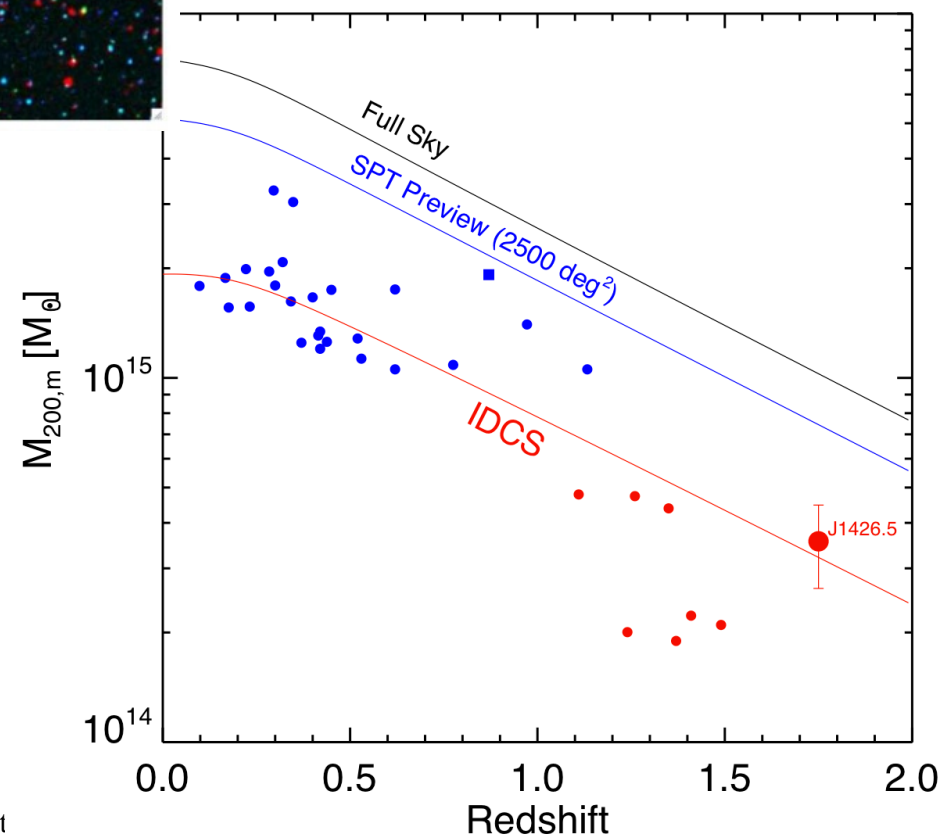- Passive evolution stops working by z=1.5

Eisenhardt et al 2008
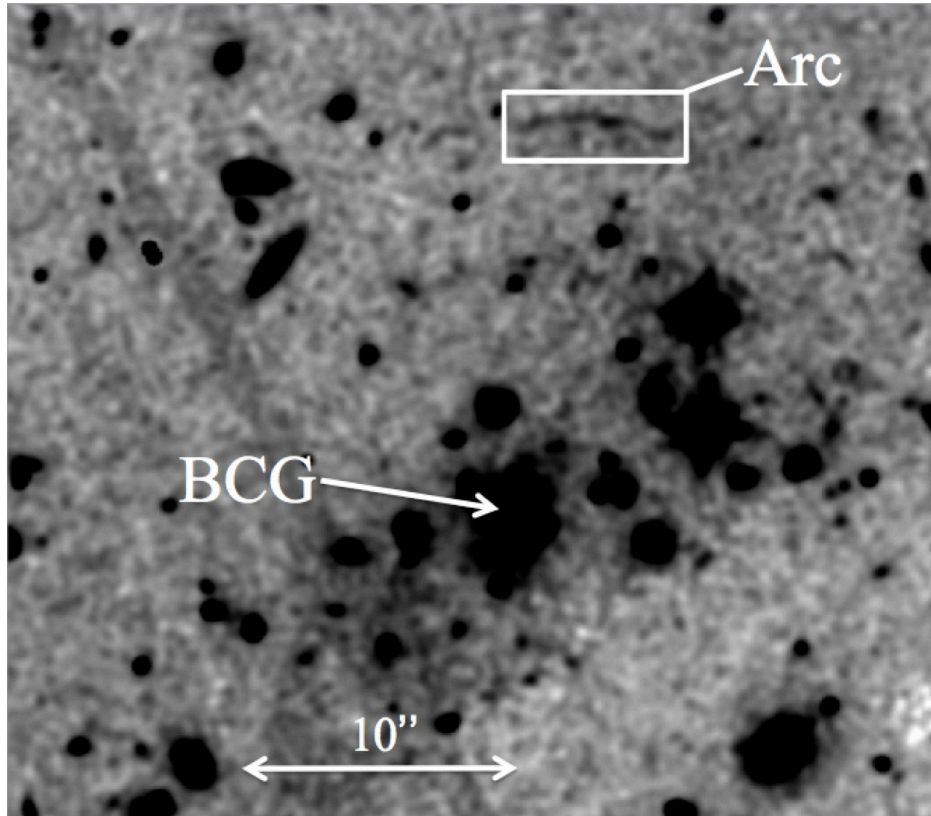
Some Clusters Are Surprisingly Massive
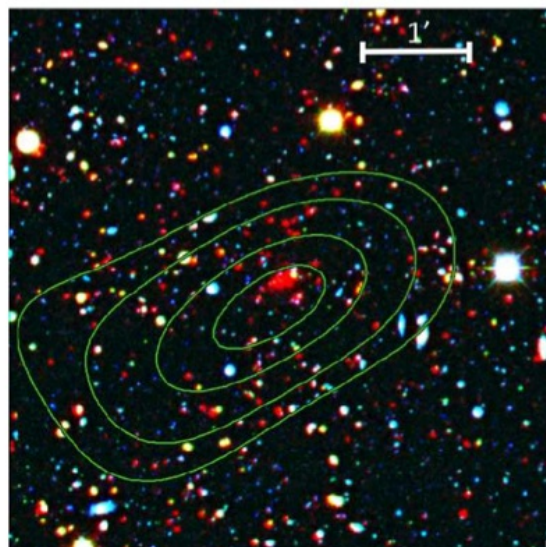
IDCS 1426.5+3508

z=1.75

Stanford et al 2012,

Brodwin et al 2012

CARMA S-Z detection gives M = 4×10^{14} M$_\odot$, similar to X-ray

Surprisingly massive for z=1.75 in 8 sq deg.

Lines are 95% exclusion limit for ΛCDM (Mortonson et al 2011)

WFIRS t

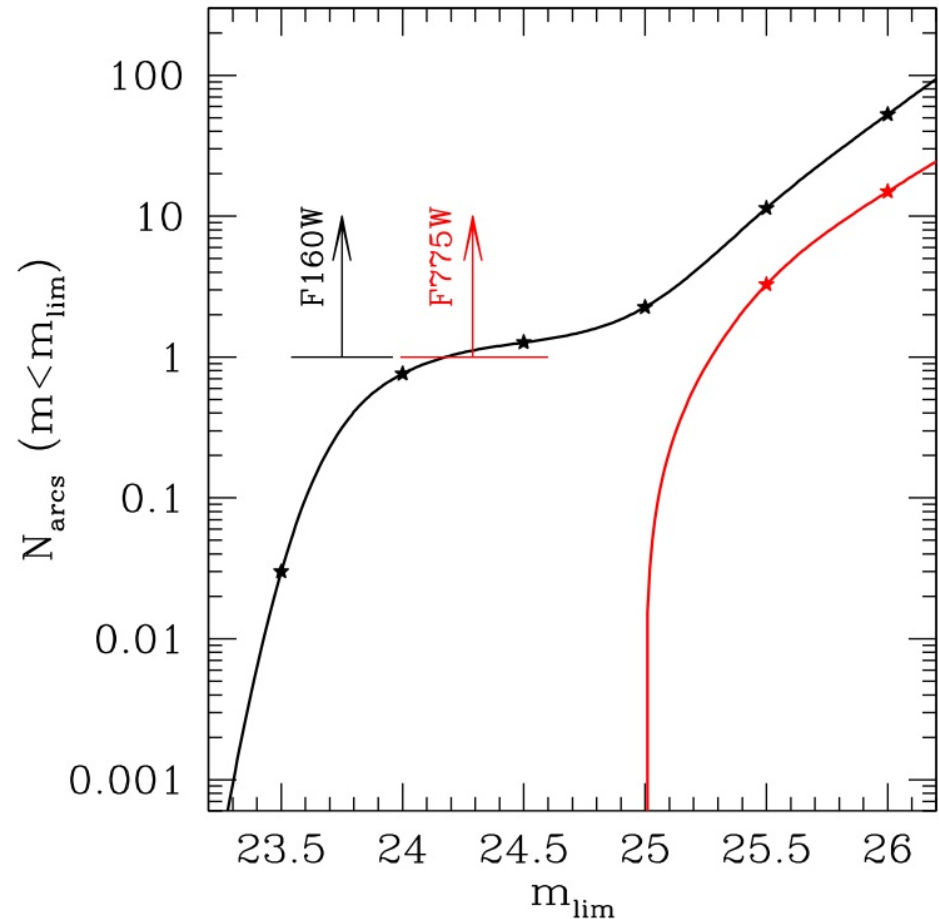# A Giant Arc That Should Not Exist

IDCS 1426.5+3508 Gonzalez et al 2012

Arc in both F814W and F160W should not be there

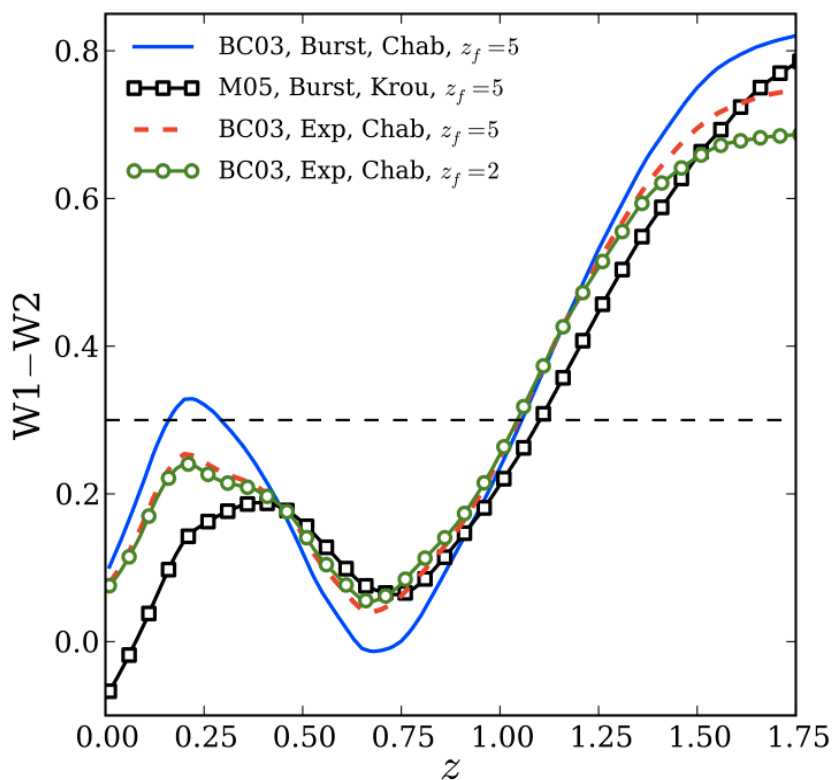Lines are predicted number of giant arcs *over entire sky* vs. F160W and F775W mag for clusters at z > 1.75

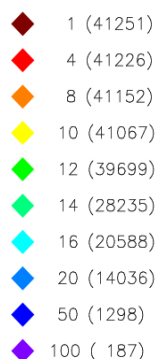Is this just lucky 8 sq deg? Nongaussian fluctuations? Check wider area – all sky.

MaDCoWs and AllWISE

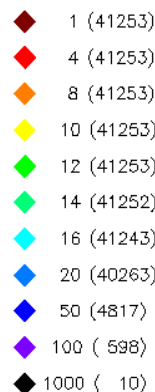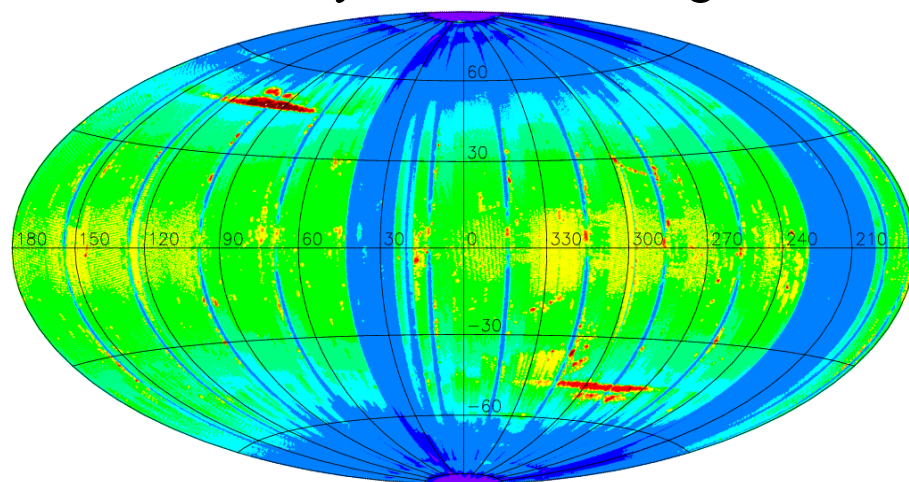Gettings et al. 2012 used WISE All-Sky and SDSS data to ID first z=1 MaDCoW

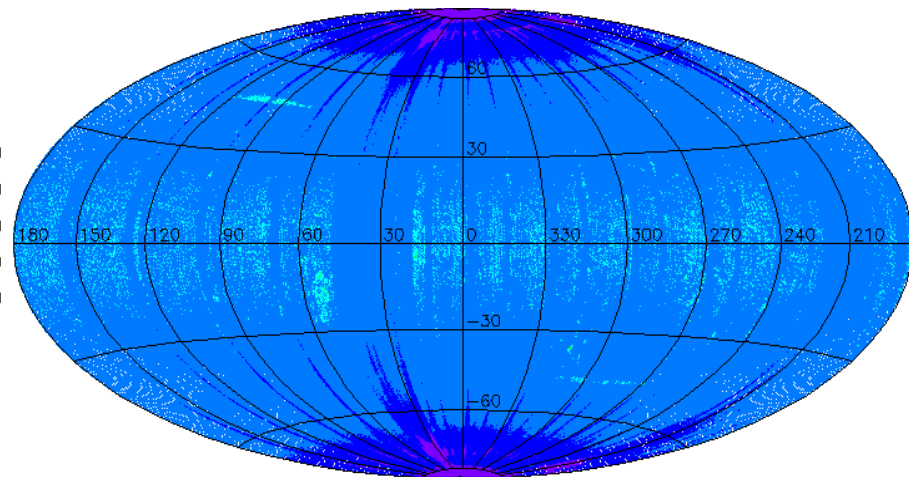AllWISE combined 2010 WISE and NEOWISE data and released to community in Nov. 2013.

All-Sky Release Coverage

AllWISE Coverage

Reject z < 1 with optical
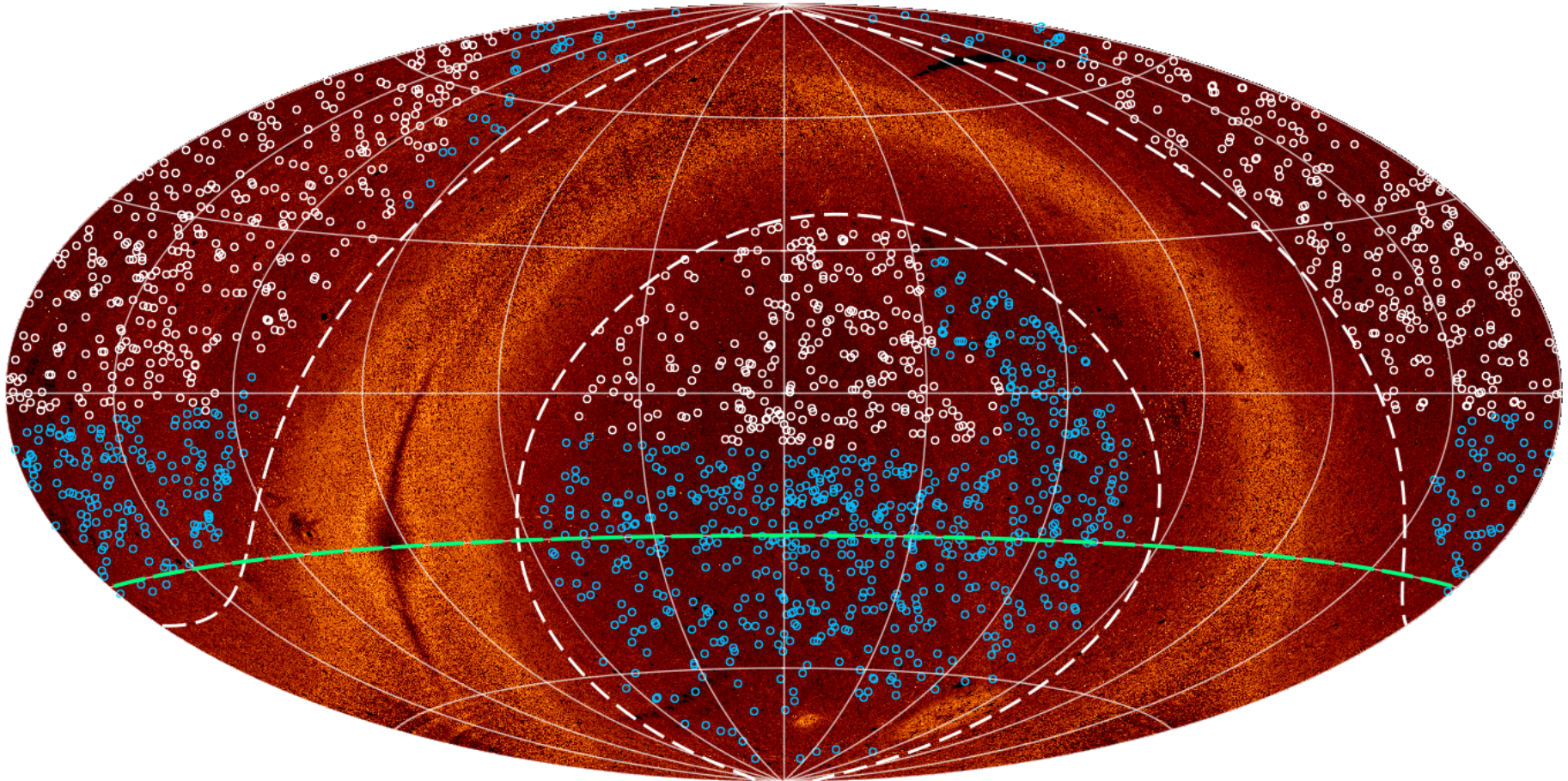Select z > 1 with IR color
We're now using AllWISE data

2000 MaDCoWS from AllWISE + Optical

Good places to point telescopes observing less of the sky: HST, JWST, WFIRST

Background: WISE source density
White: AllWISE + SDSS Clusters
Blue: AllWISE + SuperCOSMOS Clusters

White dashed line: |b|=25°
Green dashed line: δ=-30°

Wide-field Infrared Survey Explorer
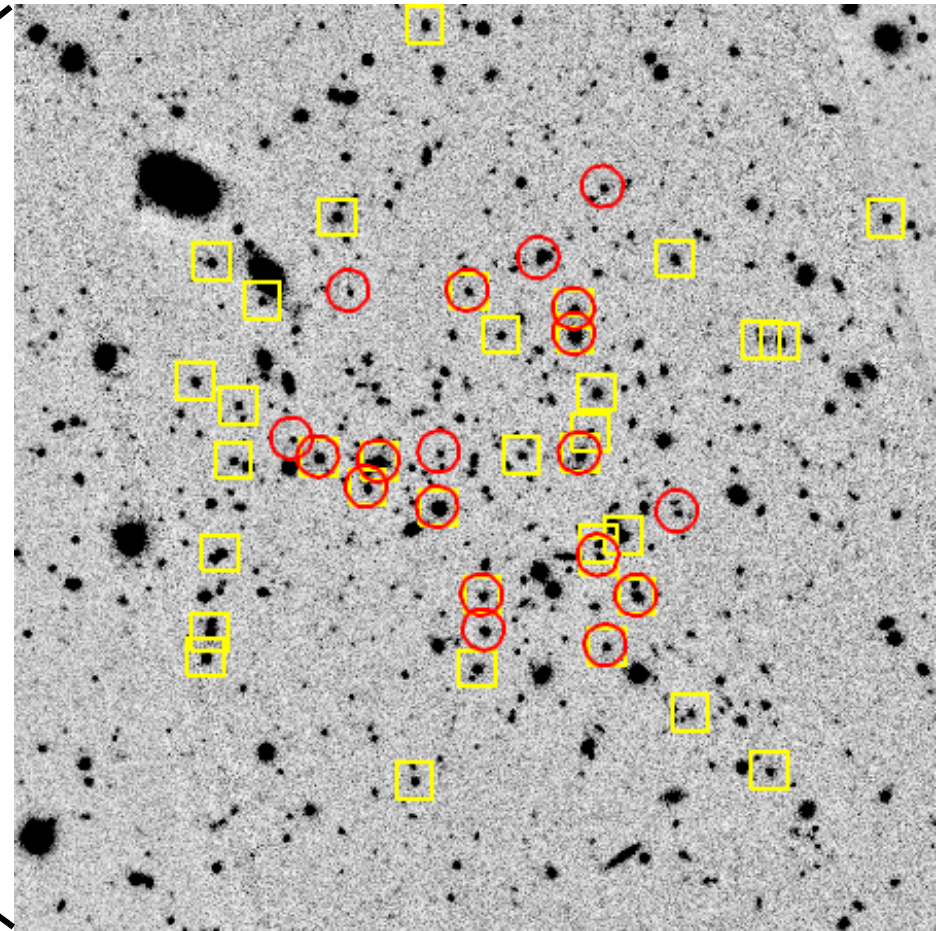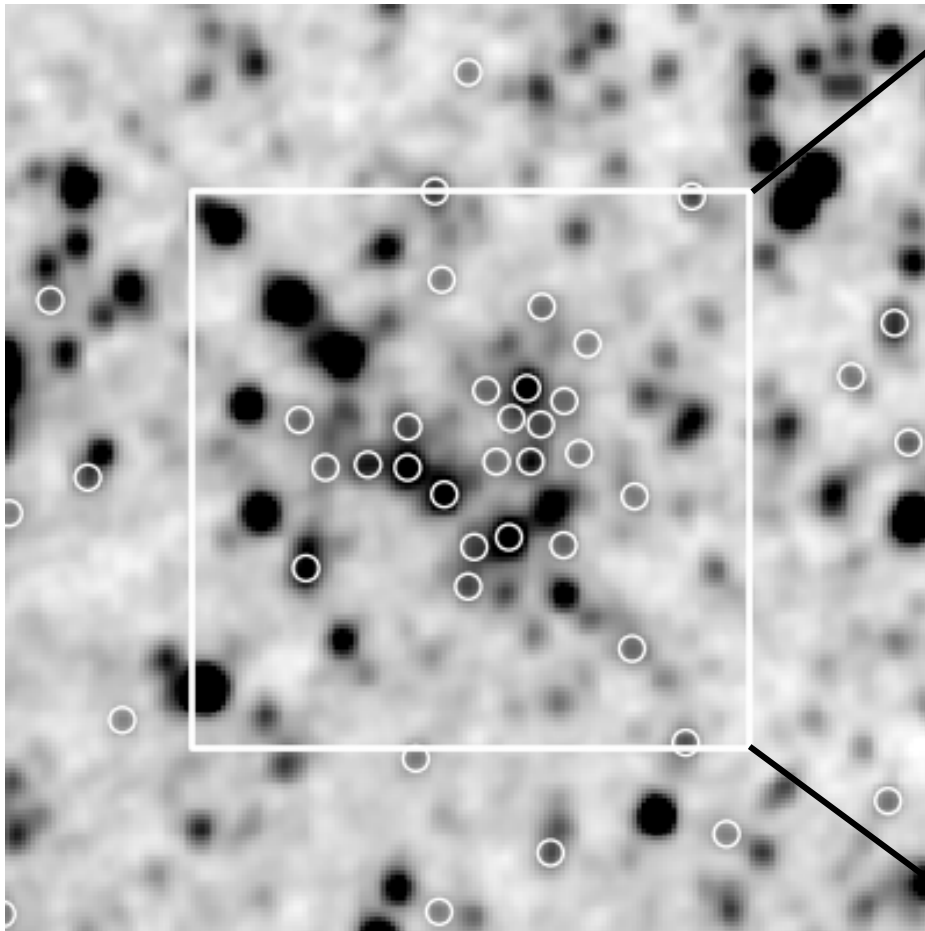# Massive Overdense Object
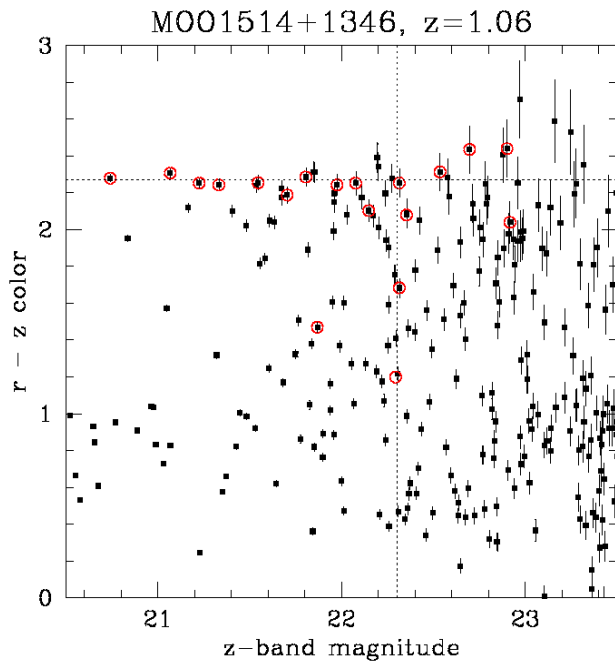# (MOO) 1514+1346
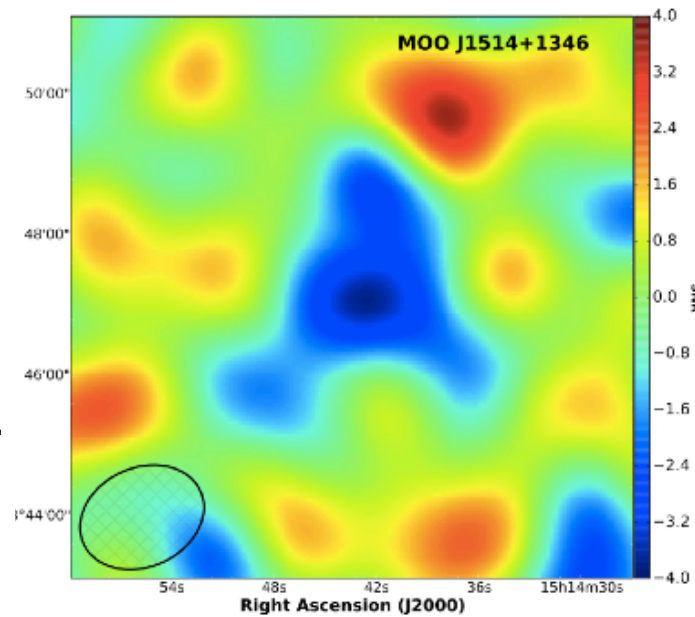
z=1.059
Stanford et al. 2014

WISE

Spitzer

⊚ WISE Selected   🔴 Spec z Member   🟨 Red Sequence

National Aeronautics and Space
Administration
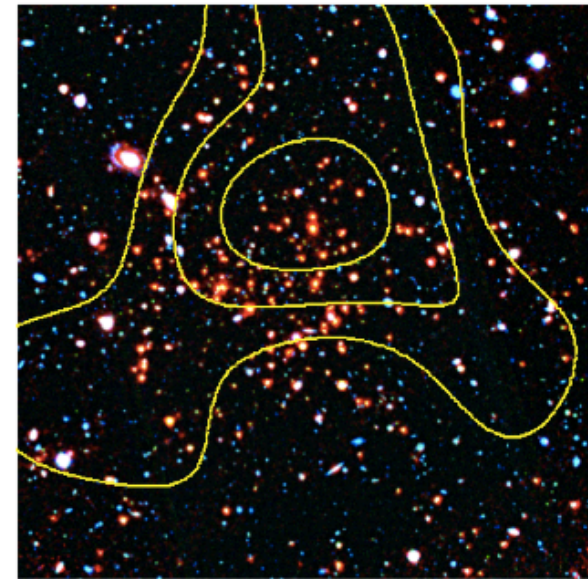**Jet Propulsion Laboratory**
California Institute of
Technology

Stanford et al. 2014

Brodwin et al. 2014
CARMA SZ
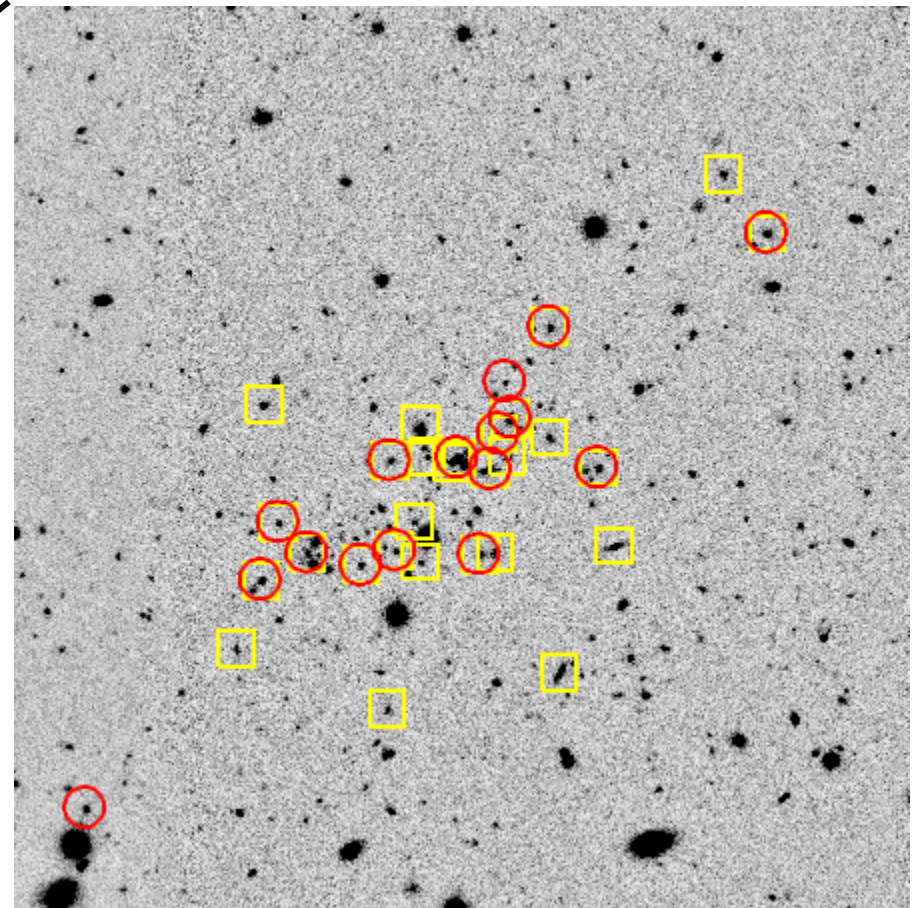$M_{200} = 3.5 \times 10^{14} \ M_{\odot}$
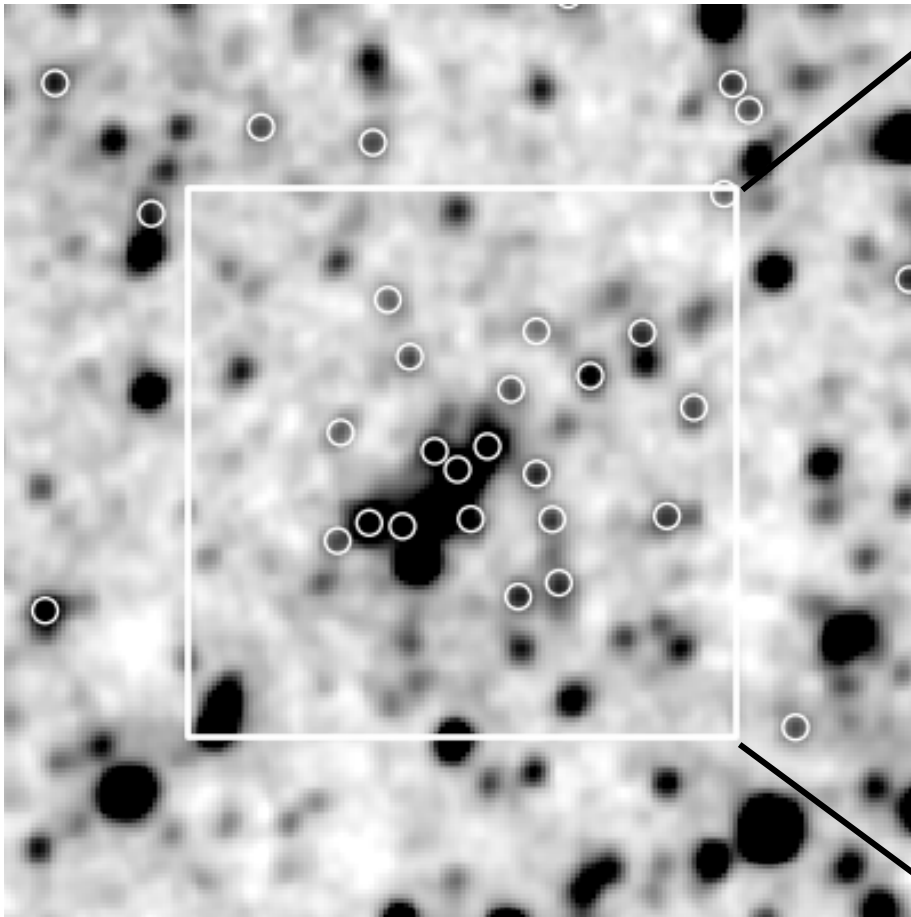
MOO 0319-0025

z=1.19
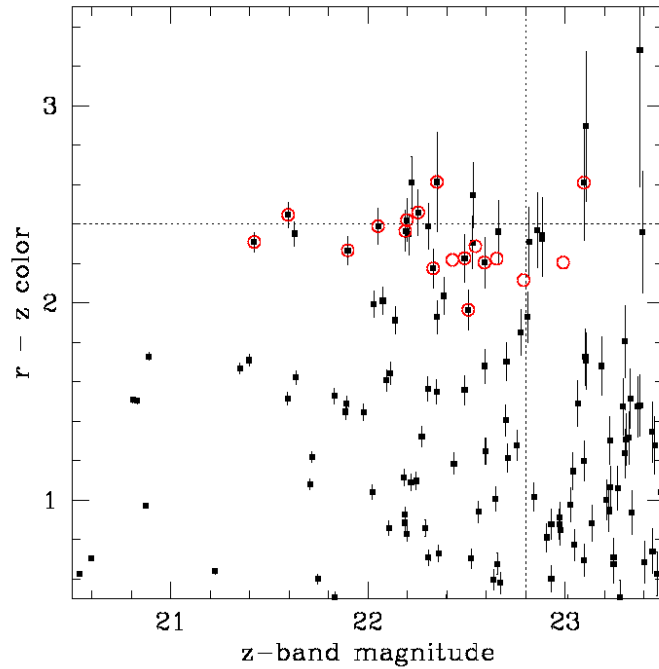Stanford et al. 2014

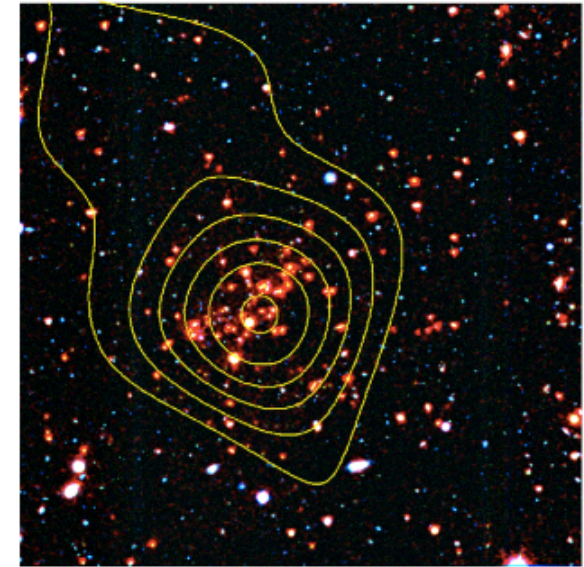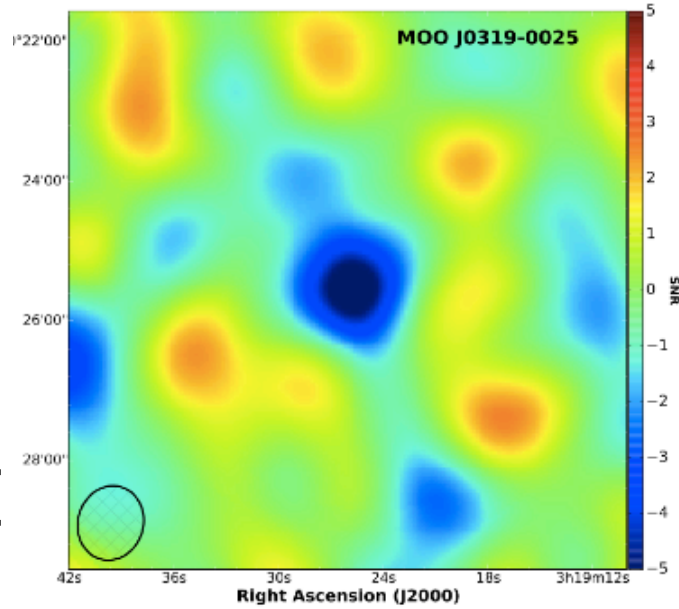WISE   Spitzer

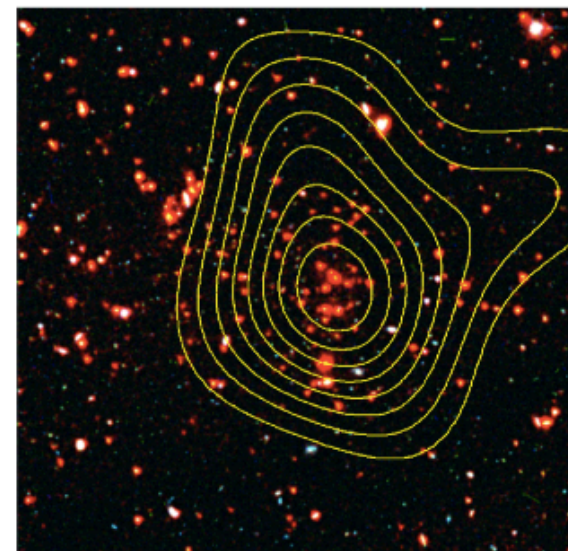◎ WISE Selected   ⬤ Spec z Member   ▢ Red Sequence
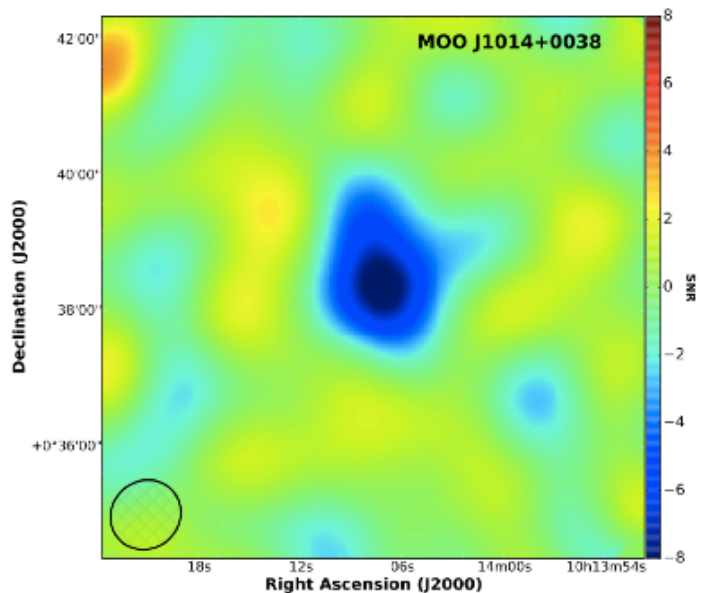
MOO 0319-0025

MOO0319-0025, z=1.19

Stanford et al. 2014

Brodwin et al. 2014
CARMA SZ
$M_{200} = 5.1 \times 10^{14} \, M_\odot$

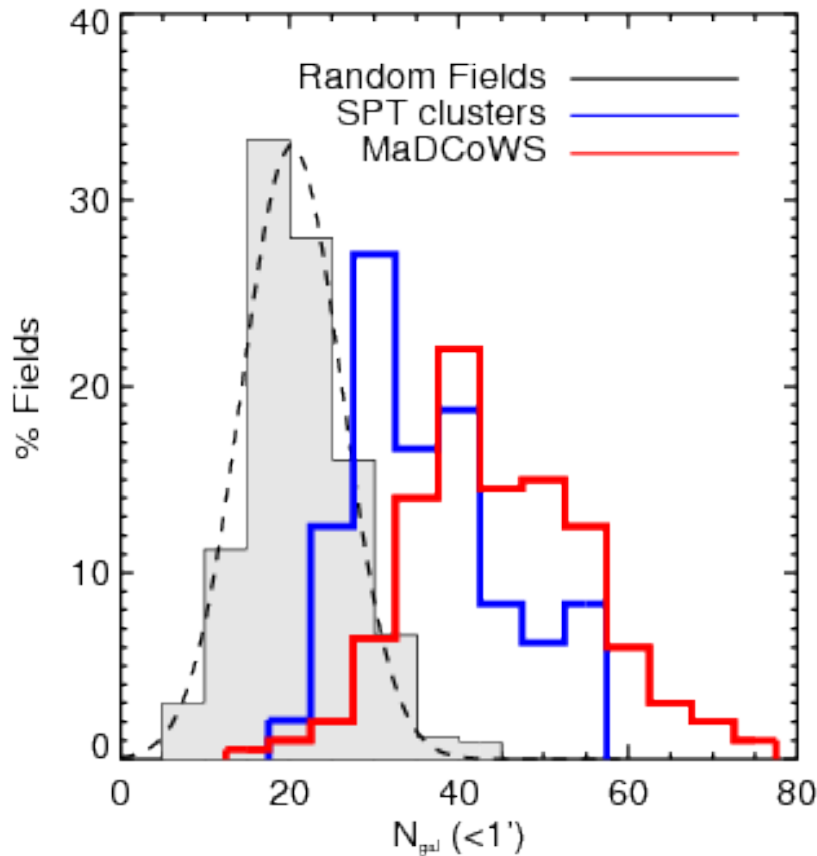**W**ide-field **I**nfrared **S**urvey **E**xplorer

MOO 1014+0038
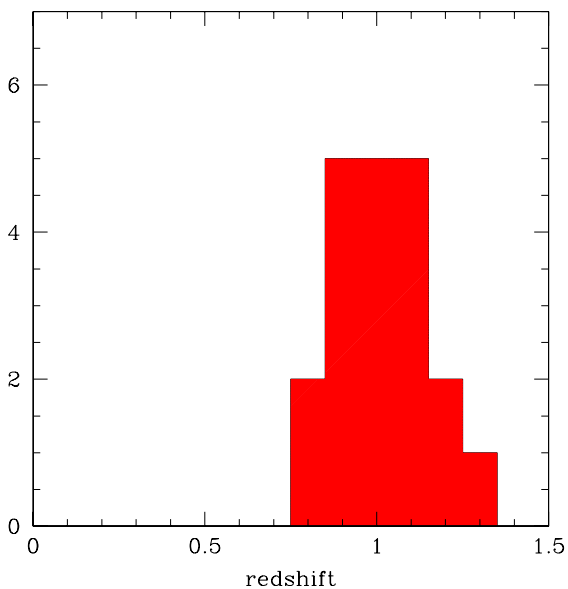
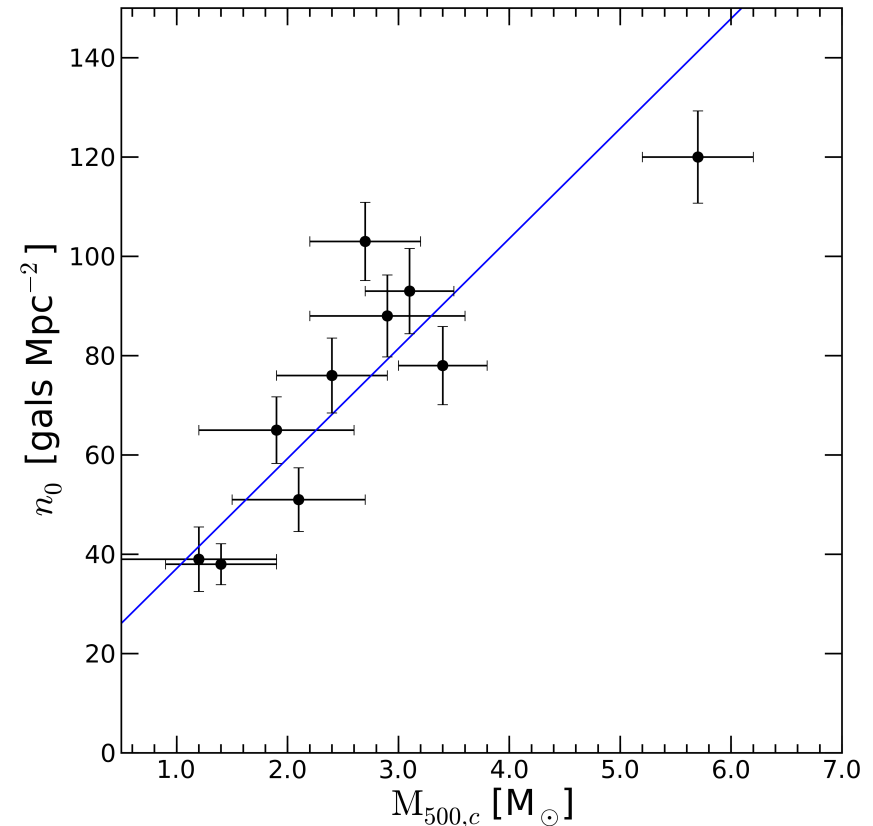

Stanford et al. 2014
20 spectroscopically
confirmed MaDCoWS
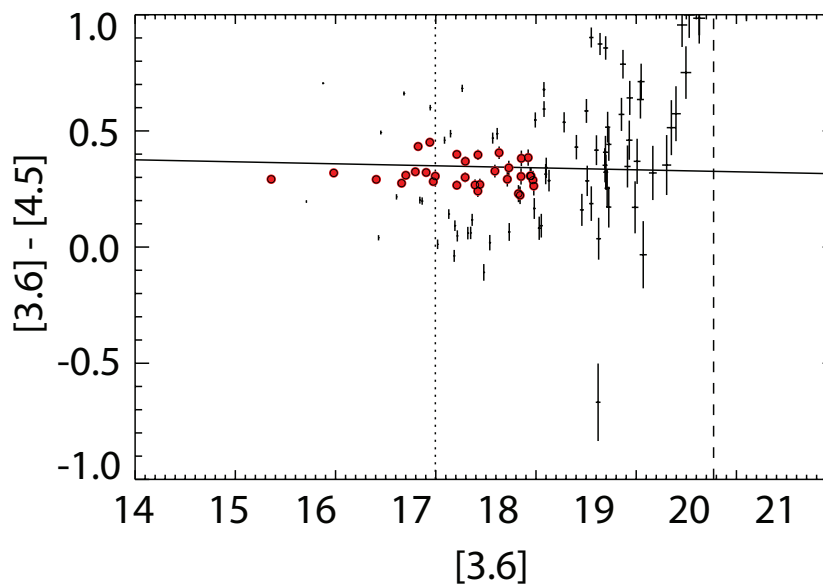
Brodwin et al. 2014
CARMA SZ
$M_{200} = 5.6 \times 10^{14}$ M$_\odot$
$z_{ph}=1.27$

Spitzer Richness

MaDCoWS are richer than SPT clusters in Spitzer data (Dominika Wylezalek)

Spitzer richness correlates well with CARMA SZ mass

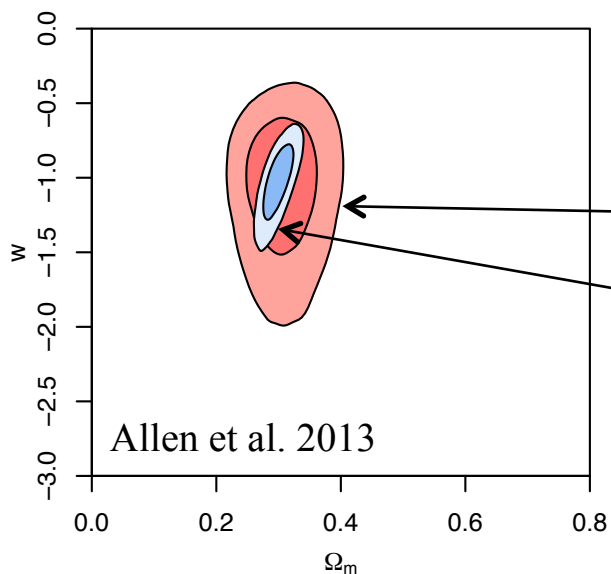JWST & WFIRST: Weak Lensing Masses, Magnified Views of Distant Universe

National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology

WISE

Most massive cluster expected over the entire sky at a given redshift (Holz & Perlmutter 2012)

⊙ MaDCoWs with no redshift available
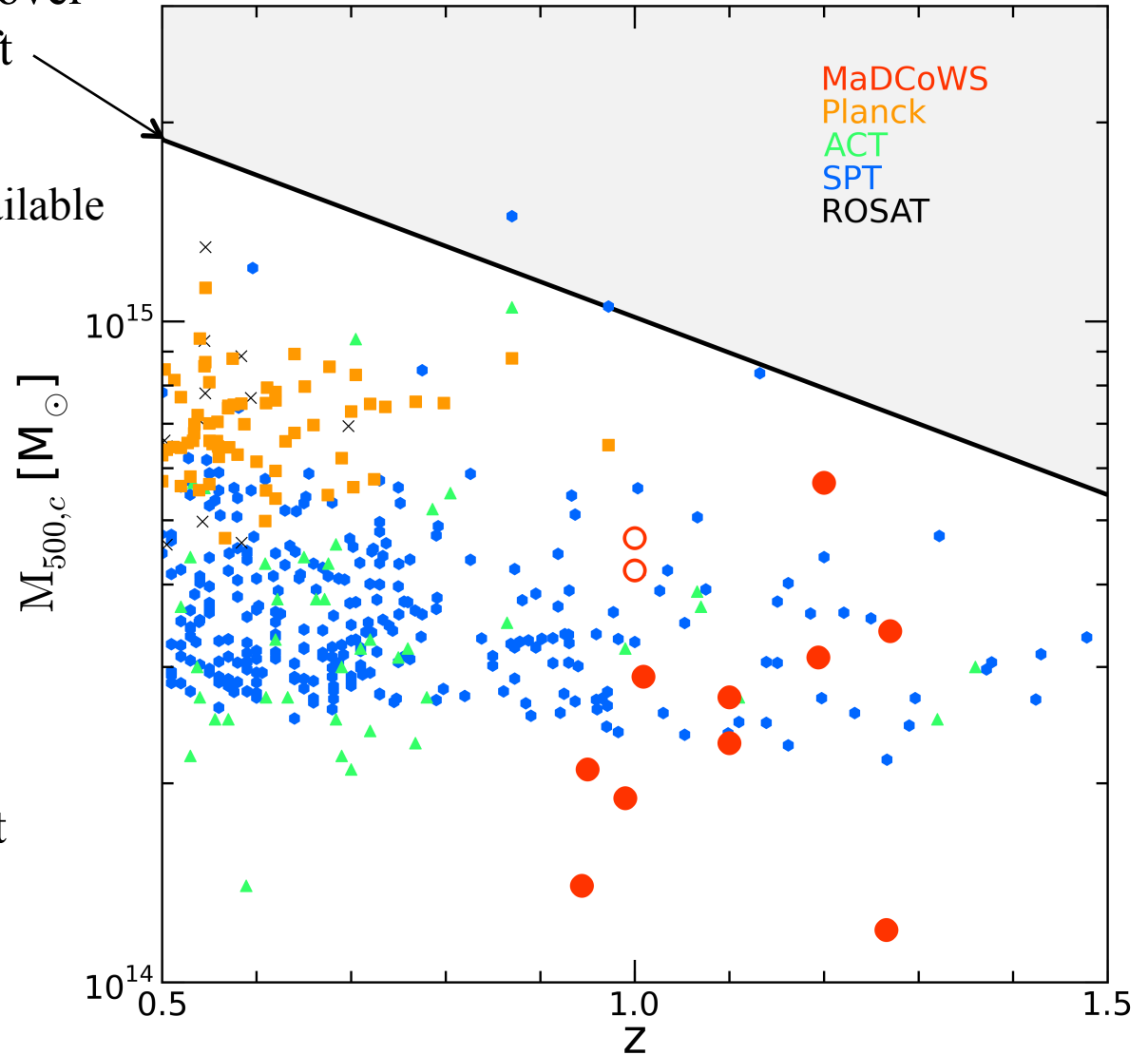
MaDCoWs are comparable in SZ mass to the highest redshift clusters selected from SPT

MaDCoWS
Planck
ACT
SPT
ROSAT

$M_{500,c}$ [$M_\odot$]

10^{15}

10^{14}

0.5   1.0   1.5

z

Relaxed Massive Distant Clusters
Needed for f$_{gas}$ Cosmology

Existing (unshaded) clusters used for red contours

Blue contours assume adding new (red shaded) clusters

Allen et al. 2013

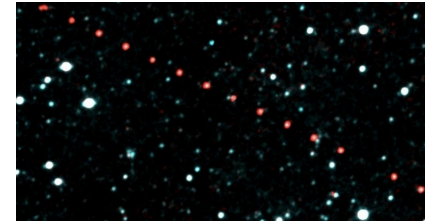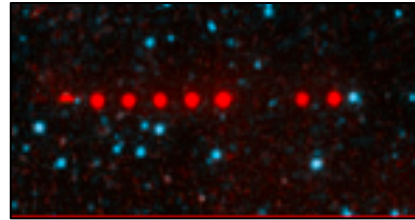Stanford et al. 2014 Spectroscopically confirmed WISE MaDCoWS clusters
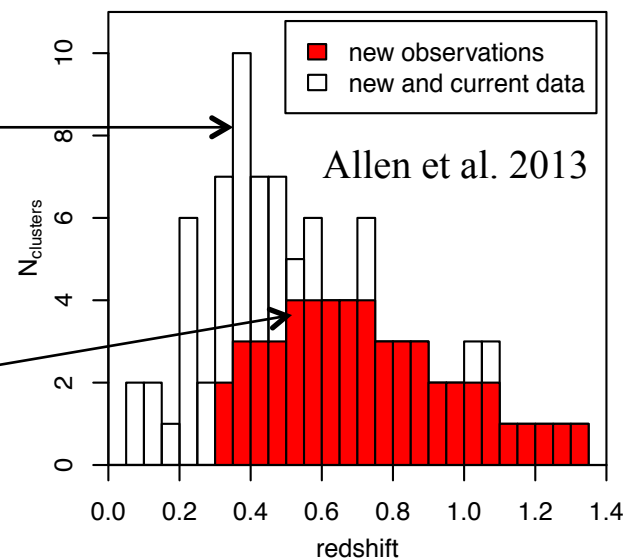
- Massive (> 5keV, about 6×10^{14} M$_{\odot}$), relaxed (about 1 in 10), distant clusters are needed to measure cosmological parameters with X-ray emitting gas mass fraction f$_{gas}$

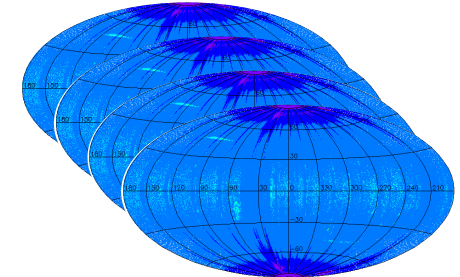- MaDCoWs is finding these rare clusters
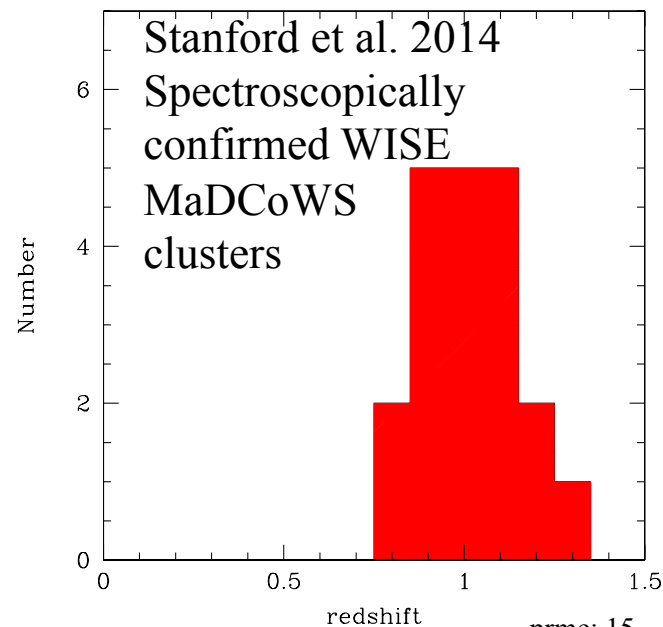
Madder Cows: MaxWISE

Distant Galaxies and MaxWISE
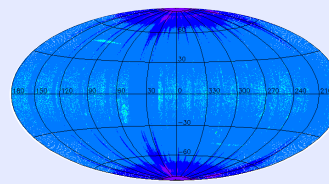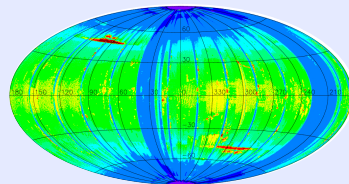
Increasing Exposures
on North Ecliptic Pole
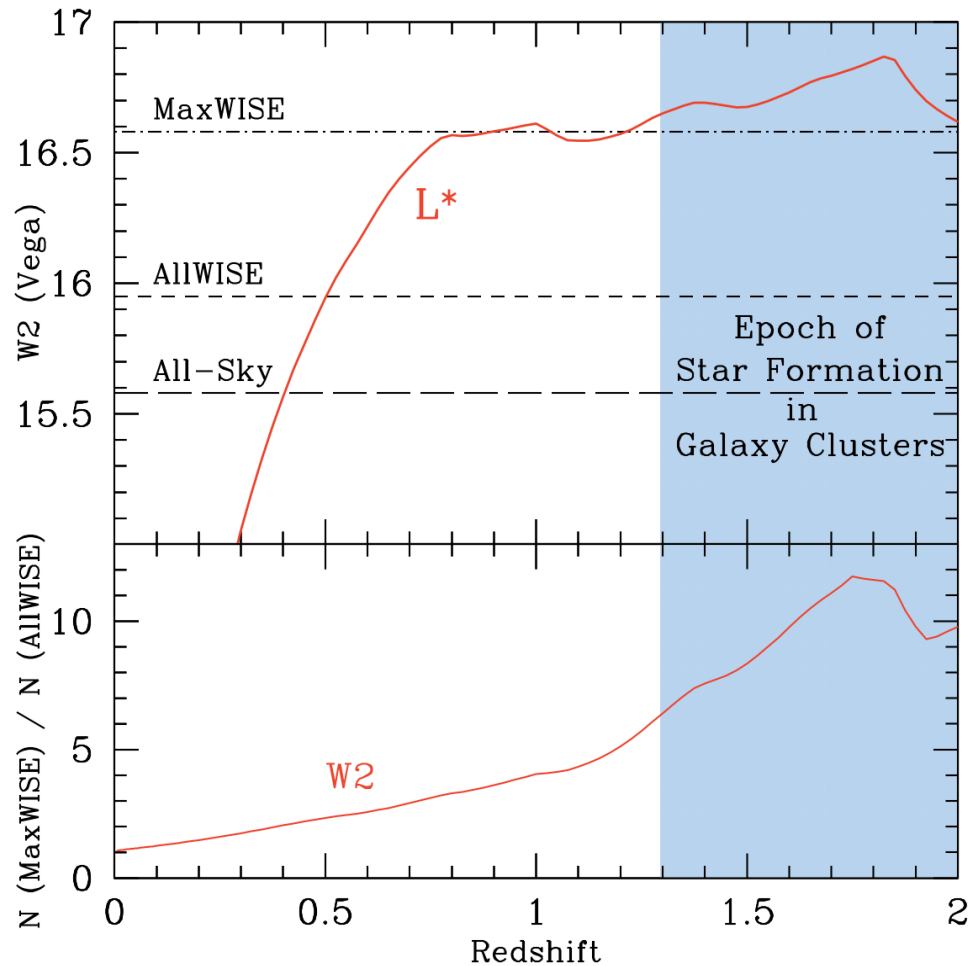
With four times as many exposures as AllWISE, MaxWISE sensitivity reaches a plateau for typical (L*) cluster galaxies that extends vastly further into the distant Universe
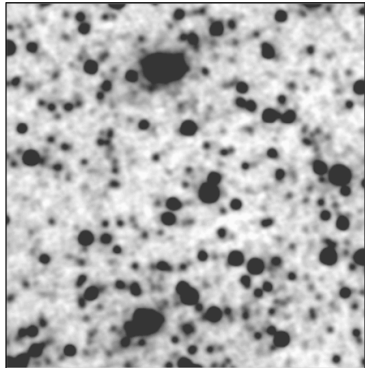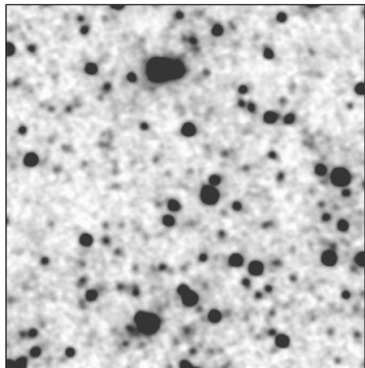
MaxWISE Depth

AllWISE Depth

WISE Depth

Summary

- 20 spectroscopically confirmed z ~ 1 MaDCoWS (Stanford et al. 2014)

- Initial set of CARMA SZ masses up to 6×10^{14} M$_\odot$ (Brodwin et al. 2014)

- IRAC richness correlates well with mass

- Richnesses for thousands of AllWISE MaDCoWs can be measured in a few hundred hours with Spitzer

- Adding together NEOWISE data now being collected would extend MaDCoWs to z > 1.5, sampling the epoch of star formation in clusters and probing massive structure growth, and provide outstanding targets for JWST and WFIRST