ALMA in practice – Helmut‘s View

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MINISTERIO
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Astronomy & Astrophysics

ASW²DF: Census of the obscured star formation in a galaxy cluster in formation at $z = 2.2$

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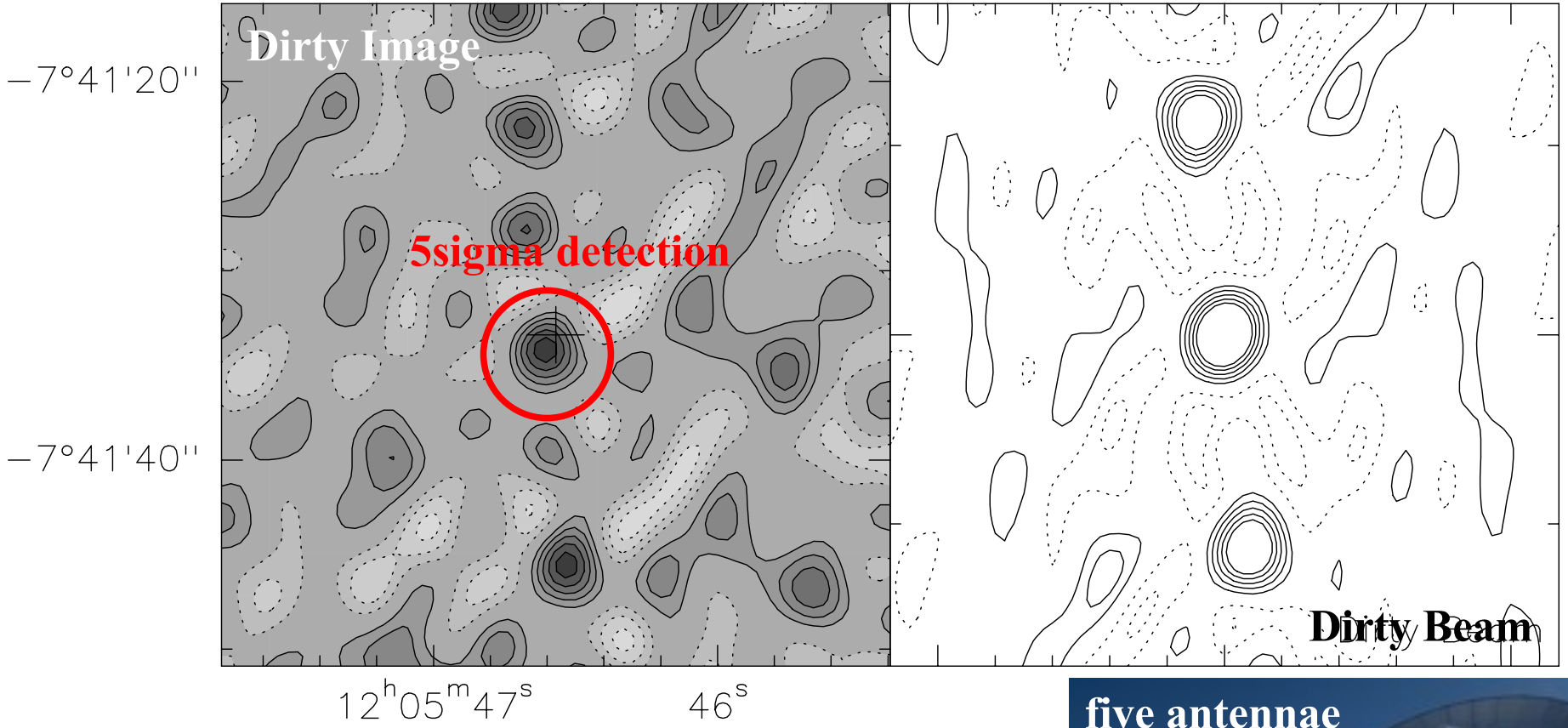
Thesis partly done with IRAM Plateau de Bure Interferometer

dusty starburst @ z~4



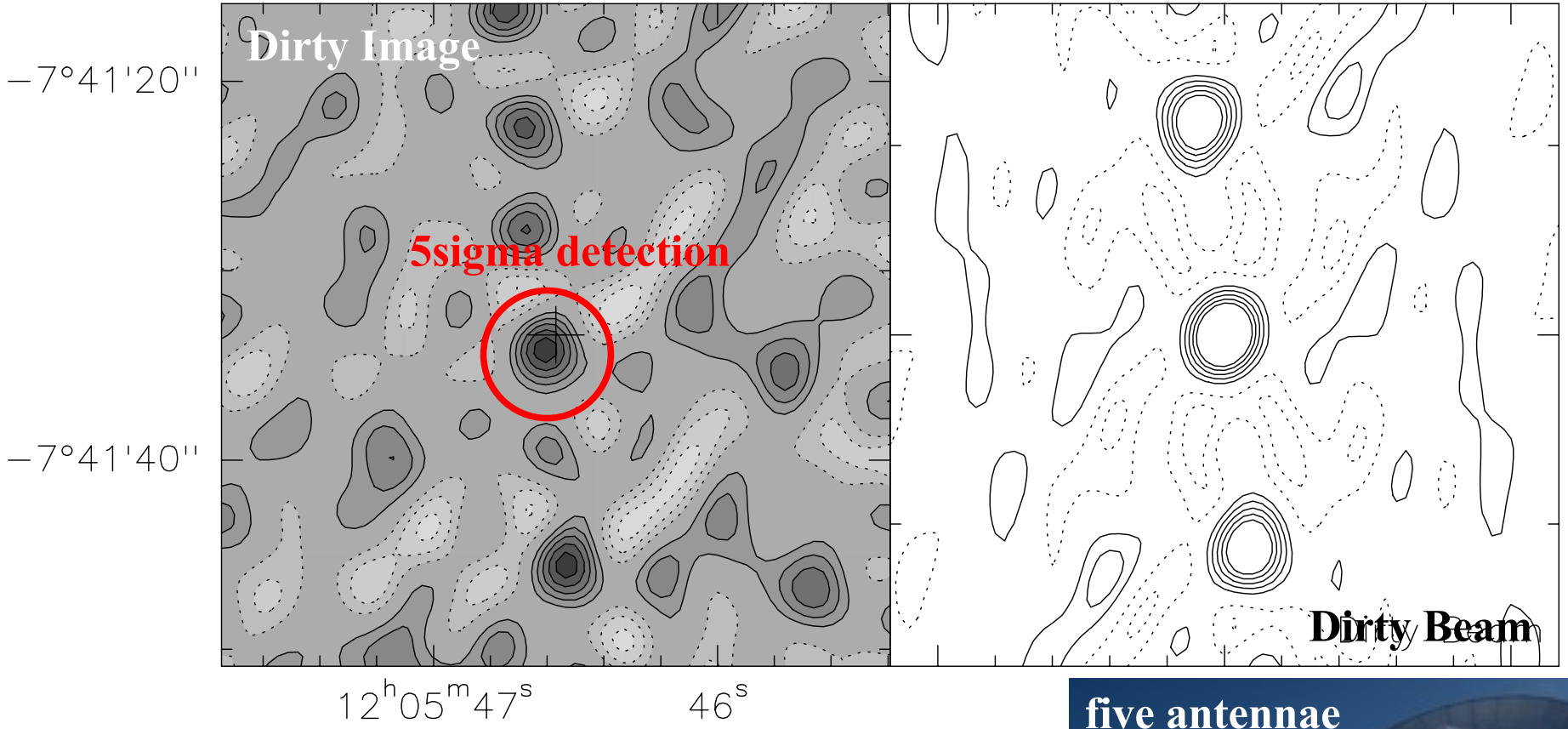
12hrs @ 1.26mm down to 1.2mJy

with ALMA: 0.7

Dannerbauer+02

Thesis partly done with IRAM Plateau de Bure Interferometer

dusty starburst @ z~4

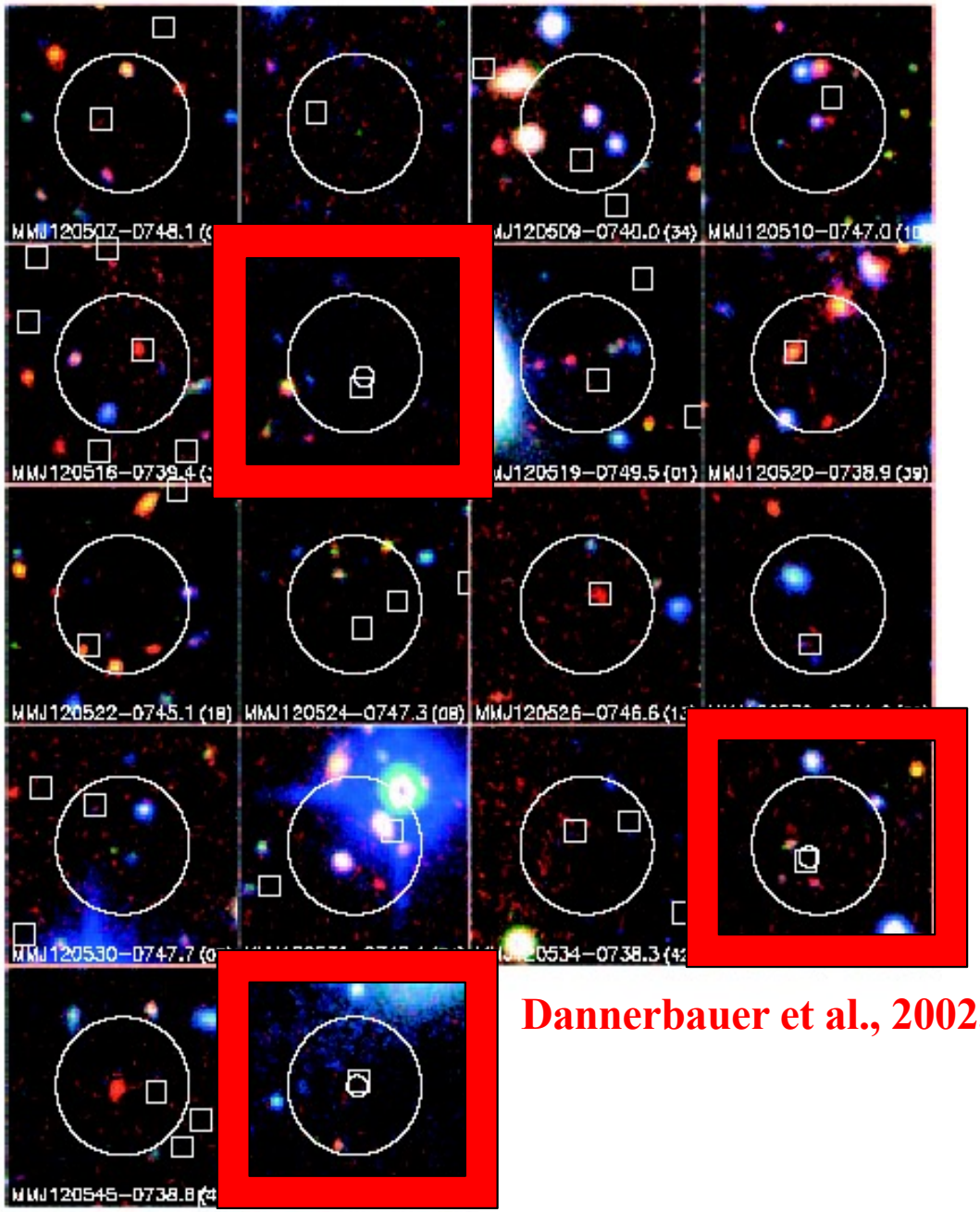


12hrs @ 1.26mm down to 1.2mJy

with ALMA: 0.7 seconds!!!

Dannerbauer+02

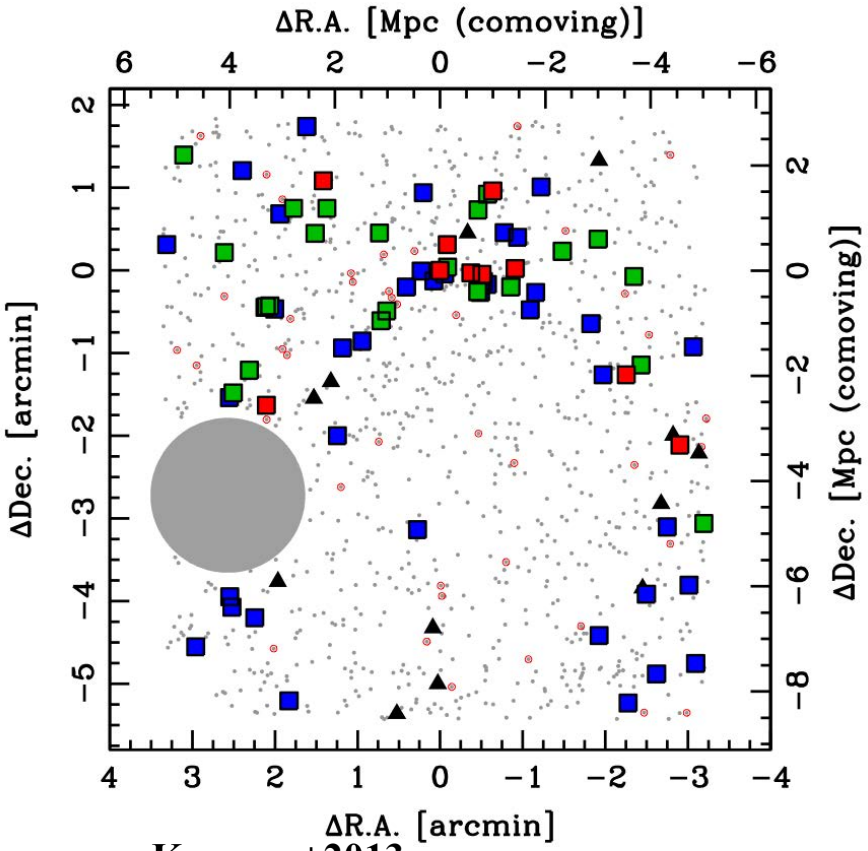
Quantensprung by ALMA



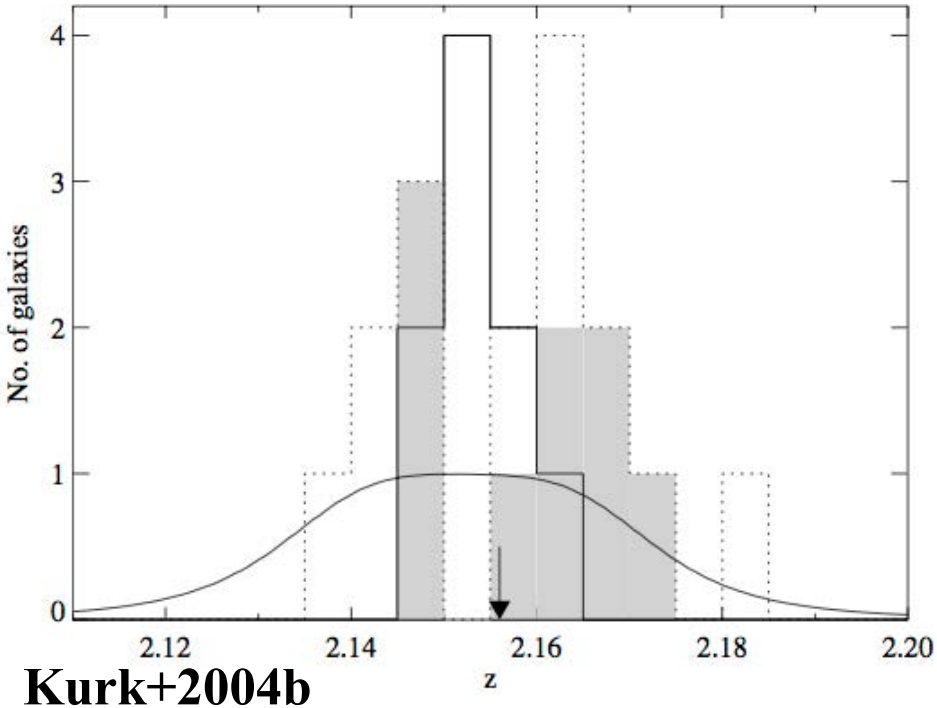
2001 PdBI: 61hrs
2010 PdBI: 1hr
2011 ALMA SV: 10m
2011 ALMA ES: 2.5m
2012 ALMA C1: <1m
2015 ALMA C3: <20s

Dannerbauer et al., 2002, 2004

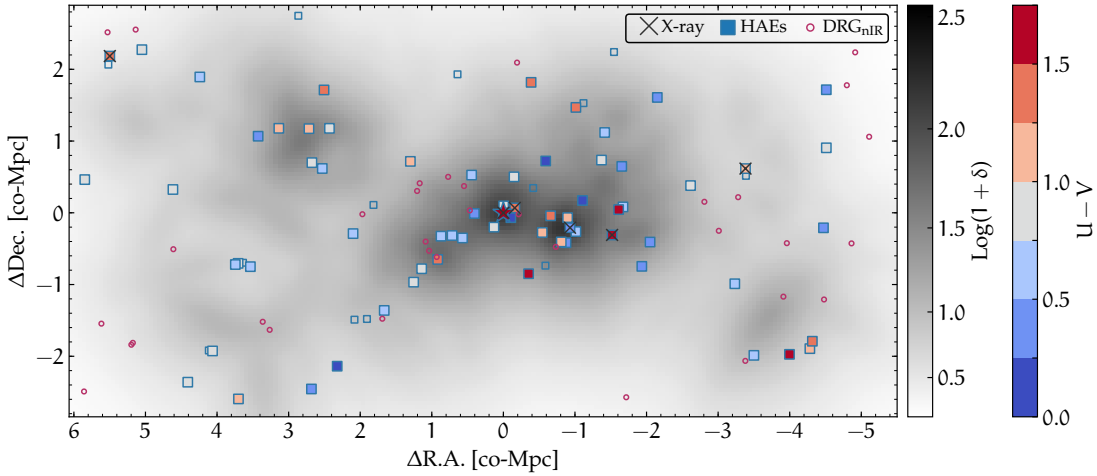
Protocluster MRC1138 @ z=2.16



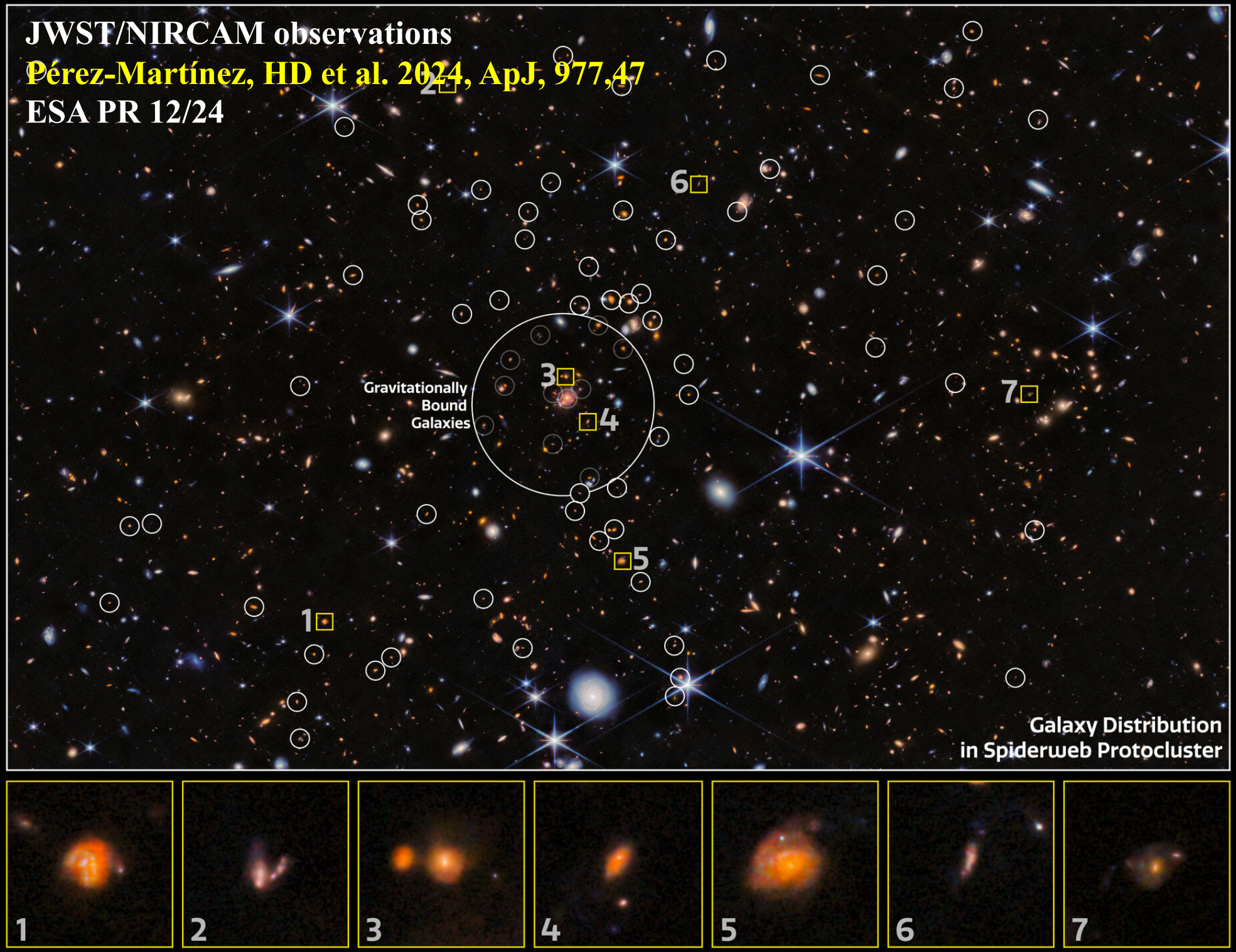
Koyama+2013



Kurk+2004b

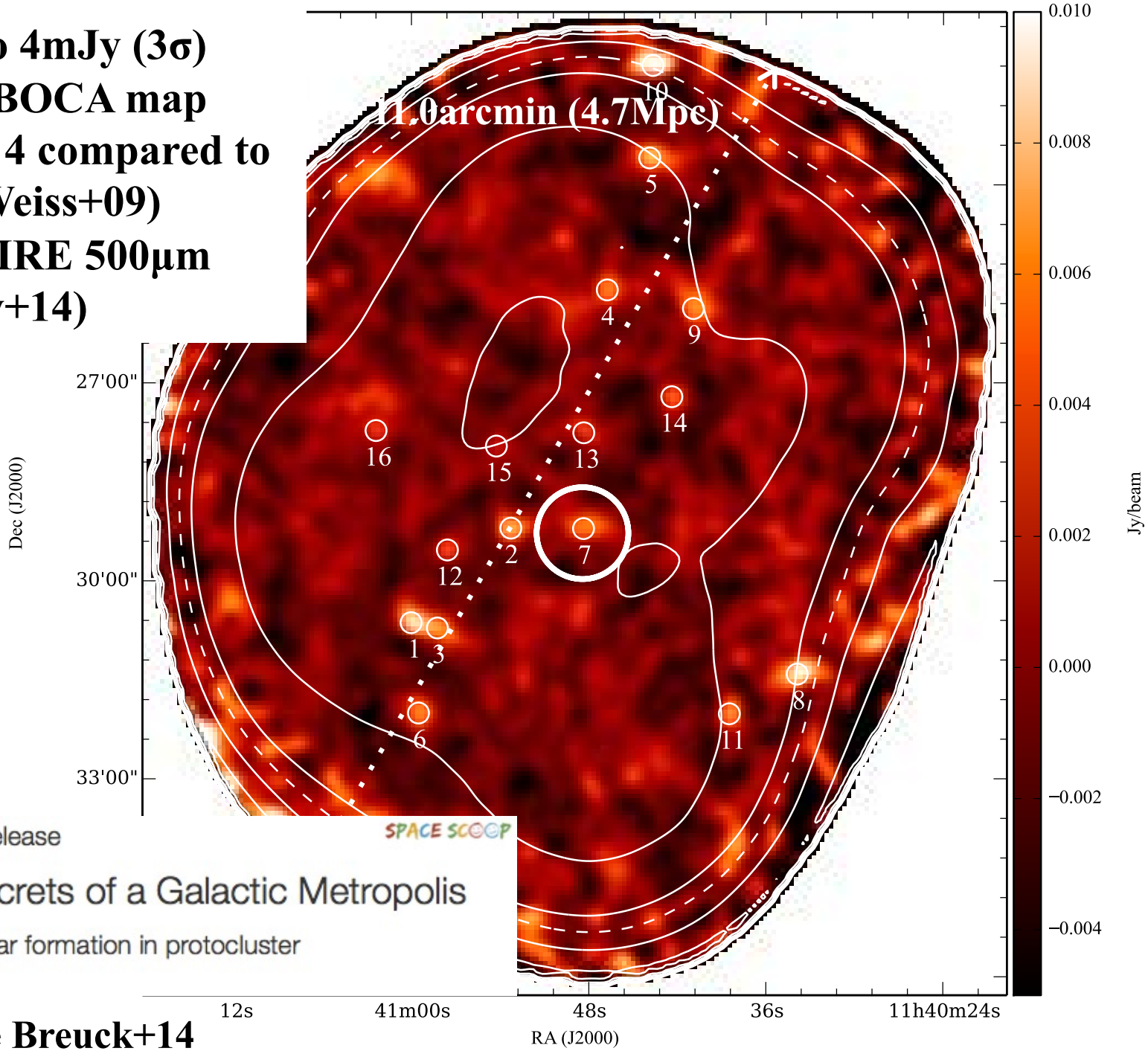


Shimakawa … HD et al. 2018, MNRAS


JWST/NIRCAM observations
Pérez-Martínez, HD et al. 2024, ApJ, 977,47
ESA PR 12/24
2
6
Gravitationally
Bound
Galaxies
3
4
7
5
1
Galaxy Distribution
in Spiderweb Protocluster
1
2
3
4
5
6
7

APEX LABOCA Observations

- 16 sources down to 4mJy (3σ)
- one of deepest LABOCA map
- overdensity factor 4 compared to blank fields (e.g. Weiss+09)
- consistent with SPIRE 500µm overdensity (Rigby+14)



eso1431 — Science Release

SPACE SCOOP

Construction Secrets of a Galactic Metropolis

APEX reveals hidden star formation in protocluster

15 October 2014

Dannerbauer, Kurk, De Breuck+14

Project History

- **first idea in 2017 or even before…**
- **in 2017 (C-rated; no data obtained) and 2018 (rejected)**
- **then next try in 2021, A-rated (this time via East Asia time)…awarded JWST Cycle 1 proposal just a month before☺**
- **data taken in January and April 2022, in different configurations**
- **PhD student, Y. Zhang, started to work from September 2022 on**
- **submission of manuscript to A&A in July 2024**
- **acceptance in October 2024**
- **publication in November 2024**

➢ **from first proposal to publication…7 years☺**

Proposal

ASW2DF: Census of the Star-Formation Properties in a Protocluster at z=2.2

2021.1.00435.S

ABSTRACT

One of the best studied high-z large scale structures so far is the protocluster associated with the HzRG MRC1138-262 at z=2.16, the so-called "Spiderweb" protocluster. We propose an ambitious, wide and deep ALMA 1.2mm mapping of a unique 3'x6' field (equivalently ~1.5 x 3.0 pMpc) within this overdense field. Our ALMA dust continuum imaging down to SFR=80Msun/yr will add the missing piece to our exquiste multi-wavelength coverage with a huge investment of telescope time (e.g. ESO VLT, Subaru). We expect to find ~80 ALMA sources based on the reported overdensity of LABOCA sources in this field. The major goal of this program is to study the impact of environment on galaxy formation and evolution. To achieve this goal, we aim to: 1) derive the reliable number counts for dusty galaxies in the protocluster environment without suffering from source confusion, 2) measure the star formation efficiency of protocluster member galaxies and test their environmental dependence. The requested contiguous ALMA 1.2mm mapping will complement the existing ATCA CO(1-0) data and the scheduled JWST GO cycle-1 Pa-beta imaging, both covering the same 3'x6' field.

SCIENCE CATEGORY:	Cosmology and the High Redshift Universe				
ESTIMATED 12-M TIME:	**24.4 h**	**ESTIMATED 7-M TIME:**	**0.0 h**	**ESTIMATED TP TIME:**	**0.0 h**
DUPLICATE OBSERVATION JUSTIFICATION:					

REPRESENTATIVE SCIENCE GOALS (UP TO FIRST 30)

SCIENCE GOAL	POSITION	BAND	ANG.RES.(")	LAS.(")	ACA?
Mosaic of MRC1138 - Field 1	ICRS 11:40:48.3540, -26:29:20.784	6	1.000 - 0.300	1.000	N
Mosaic of MRC1138 - Field 2	ICRS 11:40:53.8820, -26:29:20.784	6	1.000 - 0.300	1.000	N
Mosaic of MRC1138 - Field 3	ICRS 11:40:49.4110, -26:29:20.784	6	1.000 - 0.300	1.000	N
Mosaic of MRC1138 - Field 4	ICRS 11:40:44.9390, -26:29:20.784	6	1.000 - 0.300	1.000	N
Mosaic of MRC1138 - Field 5	ICRS 11:40:40.4730, -26:29:20.784	6	1.000 - 0.300	1.000	N
Mosaic of MRC1138 - Field 6	ICRS 11:40:36.0060, -26:29:20.784	6	1.000 - 0.300	1.000	N
Total # Science Goals : 6					

SCHEDULING TIME CONSTRAINTS	NONE	**TIME ESTIMATES OVERRIDDEN ?**	No

Proposal

2021.1.00435.S

SG : 1 of 6 Mosaic of MRC1138 - Field 1 Band 6

1.2mm mosaic of 3xarcmin x 1arcmin field. All six mosaics will form a 3x6arcmin field.

Science Goal Parameters

Ang.Res.	LAS	Requested RMS	RMS Bandwidth	Rep.Freq.	Cont. RMS	Cont. Bandwidth	Poln.Prod.
1.0000" - 0.3000"	1.0"	60 µJy, 1.5 mK-16.2 mK	10037.694 km/s, 7.5 GHz	224.000000 GHz	59.61 µJy, 1.5 mK-16.1 mK	7.500 GHz	XX,YY

Use of 12m Array (43 antennas)

t_total(all configs)	t_science(C43-3,C...	t_total()	Imaged area	#12m pointing	12m Mosaic spacing	HPBW	t_per_point	Data Vol	Avg. Data Rate
3.0 h	1.9 h	0.0 h	180" x 60"	81	13.3 arcsec	26.0 "	84.7 s	19.6 GB	2.1 MB/s

Use of ACA 7m Array (10 antennas) and TP Array

t_total(ACA)	t_total(7m)	t_total(TP)	Imaged area	#7m pointing	7m Mosaic spacing	HPBW	t_per_point	Data Vol	Avg. Data Rate

Spectral Setup : Single Continuum

Center Freq (Sky)	Center Freqs. SPWs	Eff #Ch p.p.	Bandwidth	Resolution	Vel. Bandwidth	Vel. Resolution	RMS
233.000000	224.000000	128	1875.00 MHz	31.250 MHz	2509.4 km/s	41.824 km/s	120 µJy, 32.5 mK
	226.000000	128	1875.00 MHz	31.250 MHz	2487.2 km/s	41.454 km/s	124.07 µJy, 33.0 mK
	240.000000	128	1875.00 MHz	31.250 MHz	2342.1 km/s	39.035 km/s	127.61 µJy, 30.1 mK
	242.000000	128	1875.00 MHz	31.250 MHz	2322.8 km/s	38.713 km/s	129.8 µJy, 30.1 mK

1 Target

No.	Target	Ra,Dec (ICRS)	V,def,frame --OR--z
1	1-Field_1_MRC11...	11:40:48, -26:29:20	0.00 km/s,hel,RADIO

Expected Source Properties

	Peak Flux	SNR	Linewidth	RMS (over 1/3 linewidth)	linewidth / bandwidth used for sensitivity	Pol.	Pol. SNR
Line	0.00 uJy	0.0	0 km/s			0.0%	0.0
Continuum	3.00 mJy	50.3				0.0%	0.0

Dynamic range (cont flux/line rms): N/A

Justification for requested RMS and resulting S/N (and for spectral lines the bandwidth selected) for the sensitivity calc...

In order to achieve our scientific goals we aim to reach an RMS of 0.06mJy, resulting in a53sigma LIR=5x10^11 Lsun. Our depth is similar to the pionieering works by e.g Hatsukade et al. (2016, 2018).

Justification of the chosen angular resolution and largest angular scale for the source(s) in this Science Goal.

This is a detection experiment, using any configuration offered configuration would be sufficient for reaching our goals.

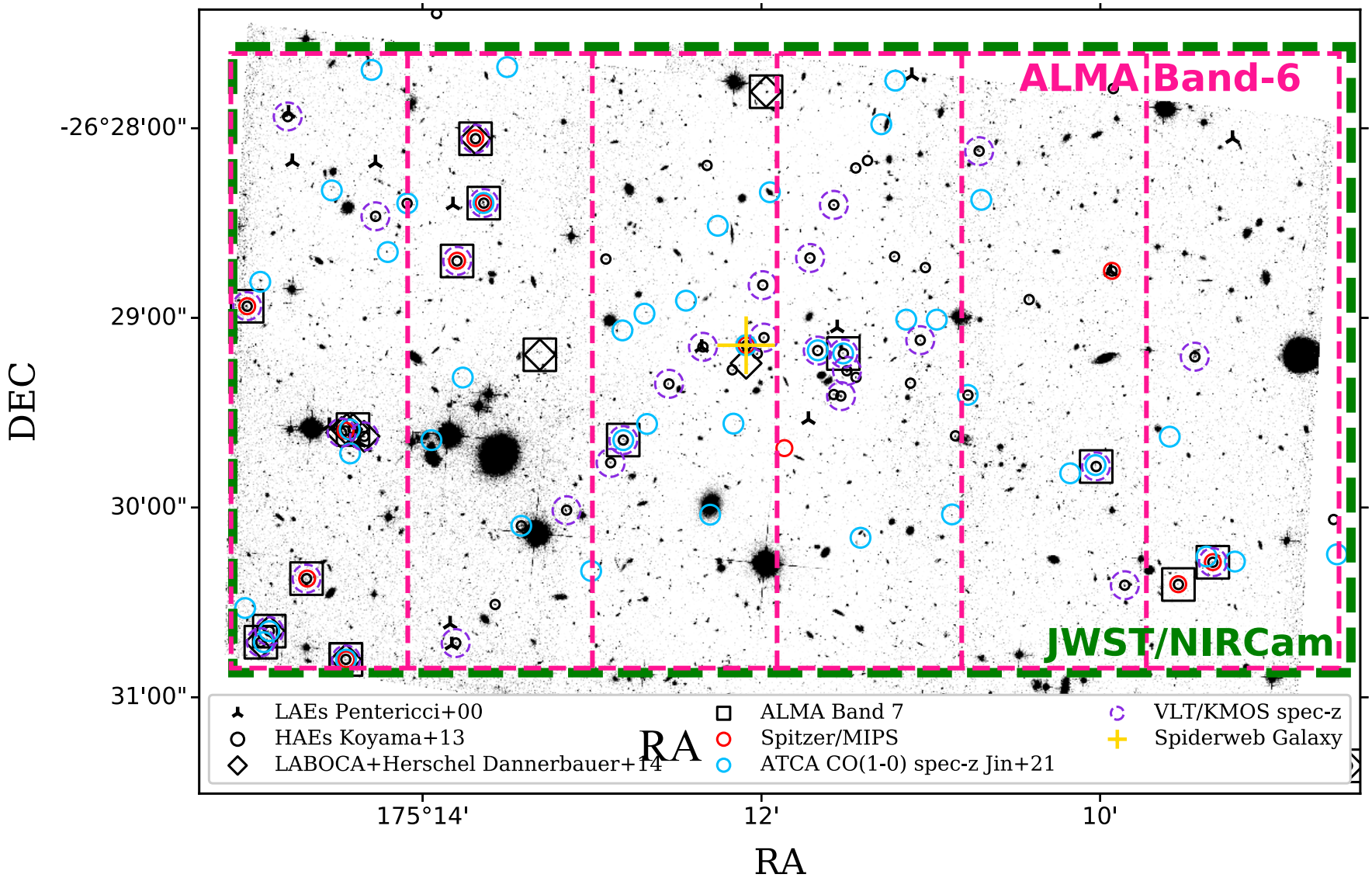
Justification of the correlator set-up with particular reference to the number of spectral resolution elements per line wi...

We expect line width between 250-500km/s for the "bonus" observations of the [CI(2-1)] and CO(7-6) line at z=2.16. Our choosen resolution gives us enough element to determine the shape and the width of the line.

Requested Observing Parameters – why?!

- **12m array only : sensitivity, spatial resolution and no flux loss**
- **continuum: reveal the obscured star formation**
- **frequency 1.2mm (Band 6): more efficient than e.g Band 7**
- **field size of 6arcmin x 3arcmin: triggered by approved JWST observations; covers the core and outer regions**
- **spatial resolution of 0.3-1 arcsec: unresolved point sources ok; increase chances to get observed**
- **chosen configuration defined by spatial resolution: detection experiment, unresolved is enough**
- **chosen spectral windows: trying to detect additional lines such as [CI(2-1)] and CO(-7-6), therefore chosen channel width of about 40km/s**
- **RMS of 0.06mJy: probing SFR down to 80M_{sun}/yr (5sigma)**
- **total observing time of 25 hrs: combination of field size, expected number of sources (80) and efficiency**

Requested Observing Parameters – why?!

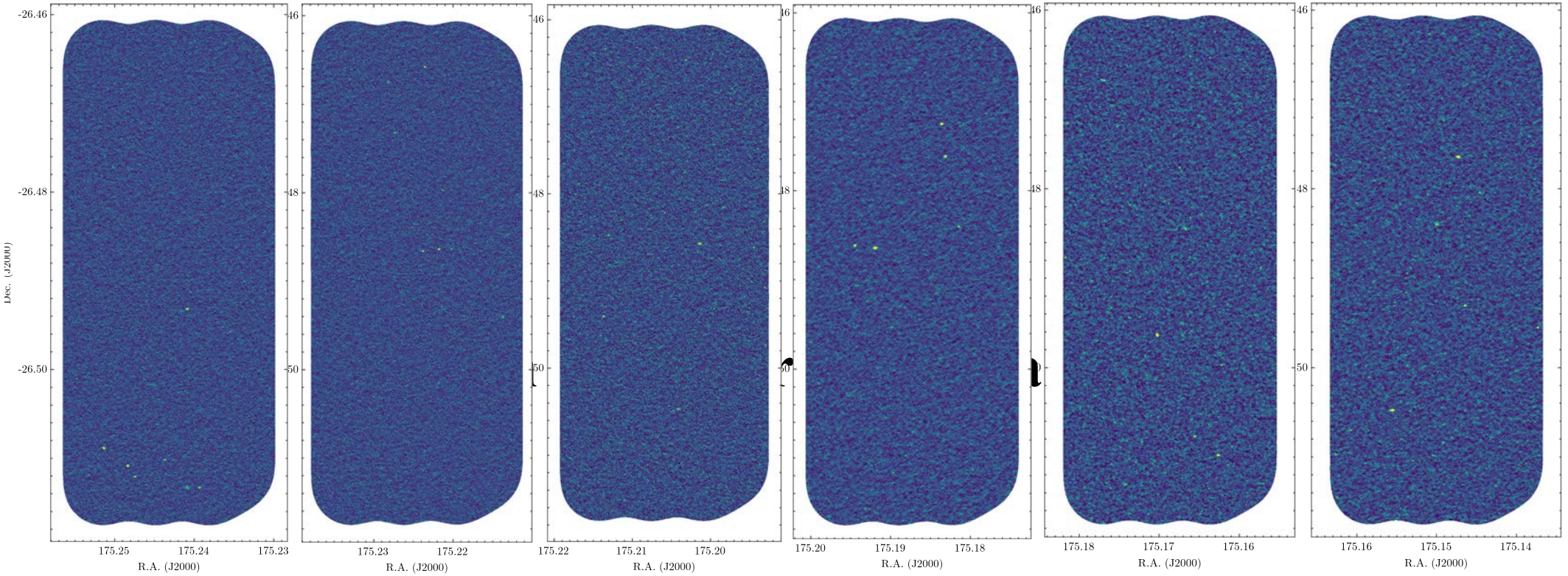


from the proposal

ALMA 1.2mm observations

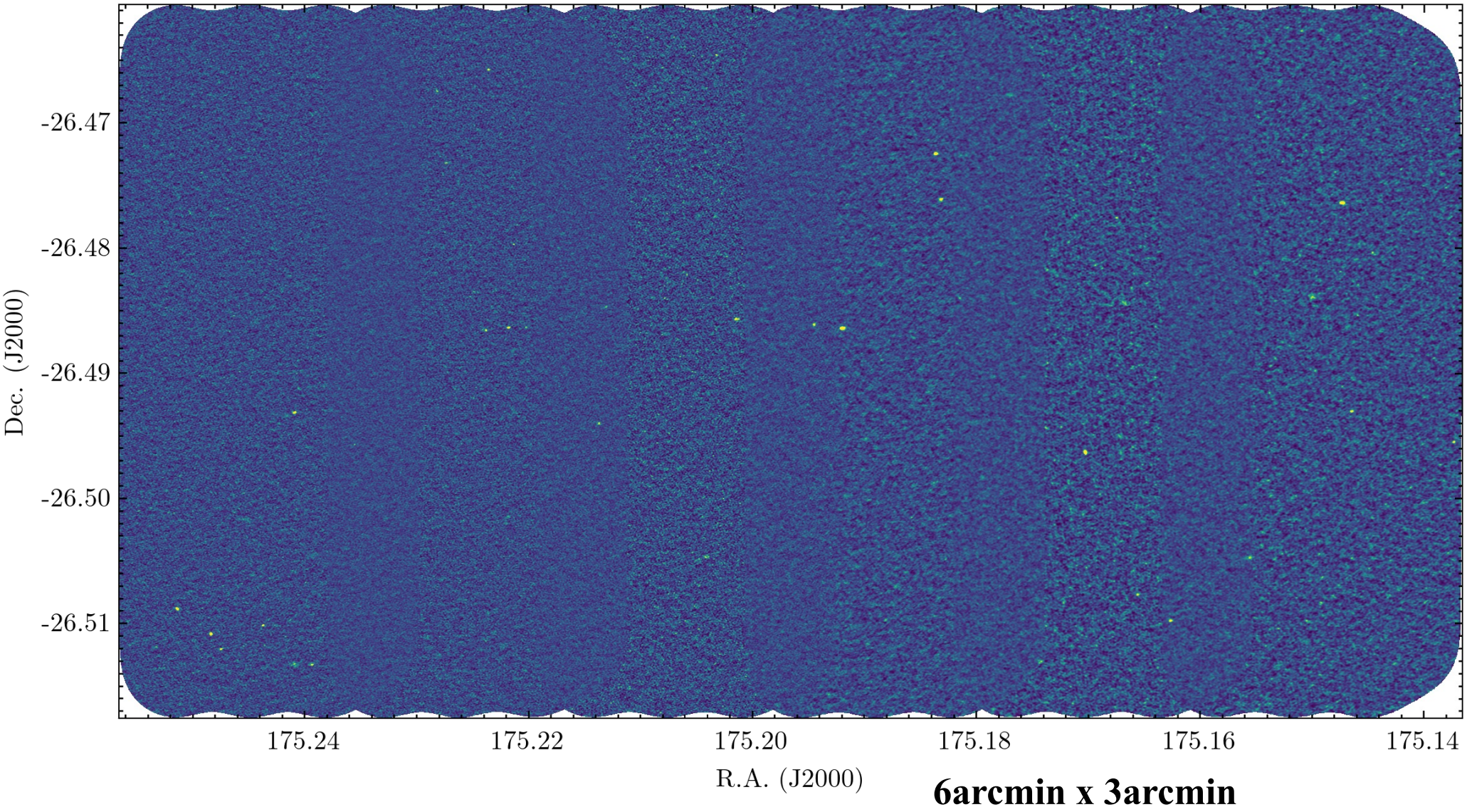
- **about 25hrs of ALMA observations (PI: Y. Koyama); 6 fields (rms~0.05mJy)**

In total: 6arcmin x 3arcmin



about 90 pointings per field

ALMA 1.2mm mosaic



6arcmin x 3arcmin

Data Analysis & ALMA tools

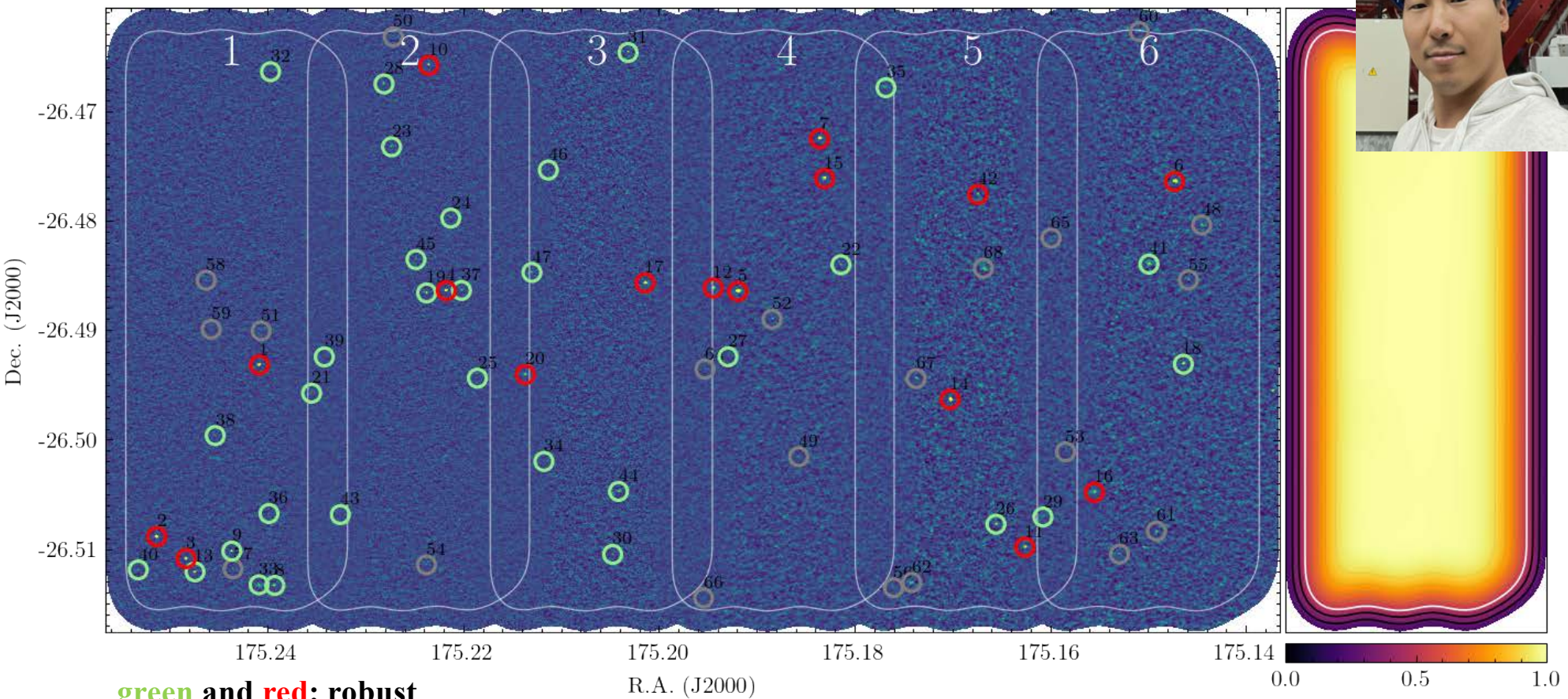
- **data products from the archive, in case of continuum it seems to be OK, no need to re-run *tclean***
- **major task was to conduct a reliable source extraction**
- **several source extraction tools are at the market**
- **give different results, not the same!**
- **Flux measurements: peak flux and “aperture” flux**

- **SnooPI**
- **ALMA archive**
- **carta**

thesis work by Yuheng Zhang
(PMO/U Hefei + IAC)

ALMA 1.2mm mosaic

6arcmin x 4arcmin

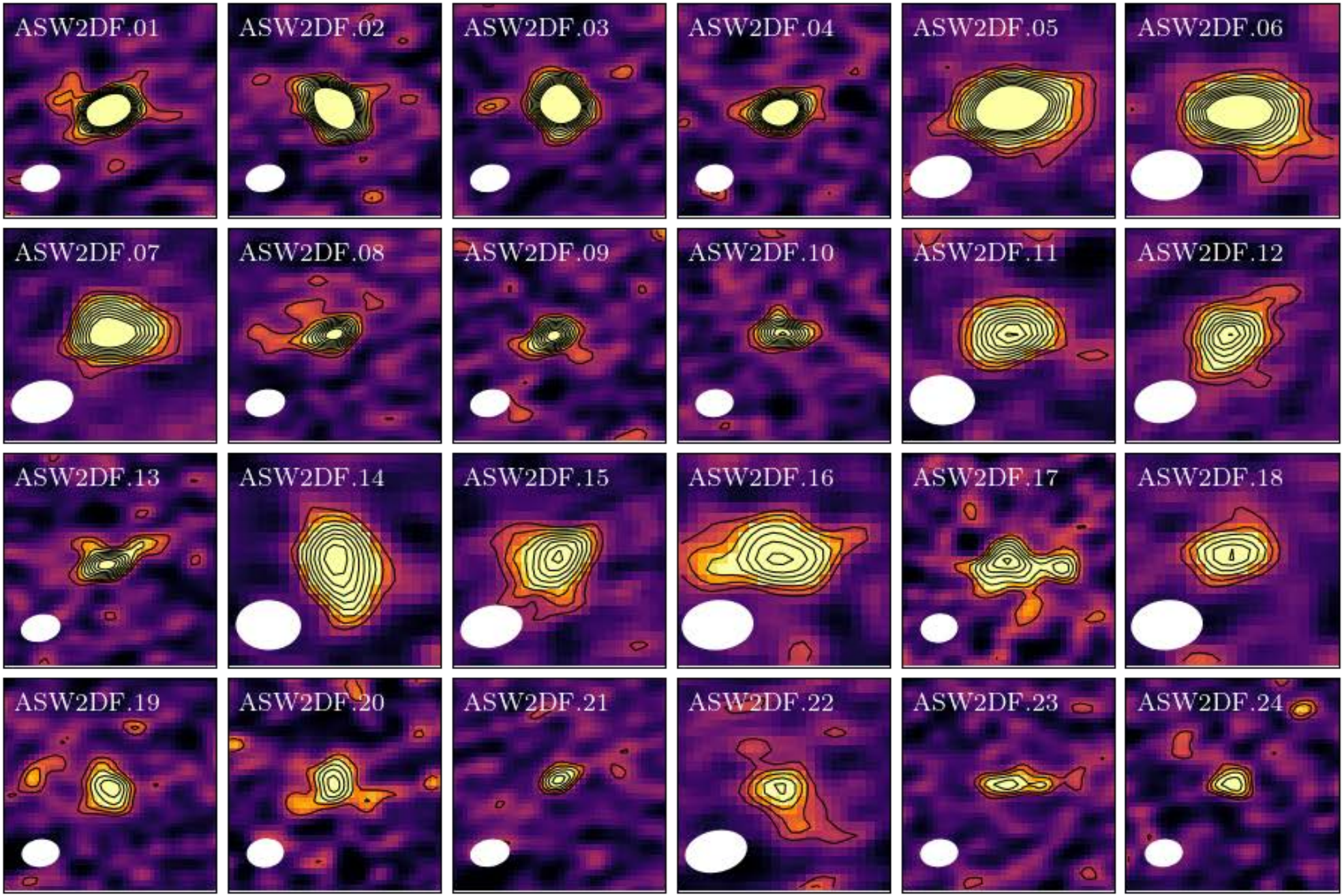


green and red: robust
grey: tentative

- almost 50 detections, we used three codes (SExtractor, AEGAN, SoFiA+„eye“)

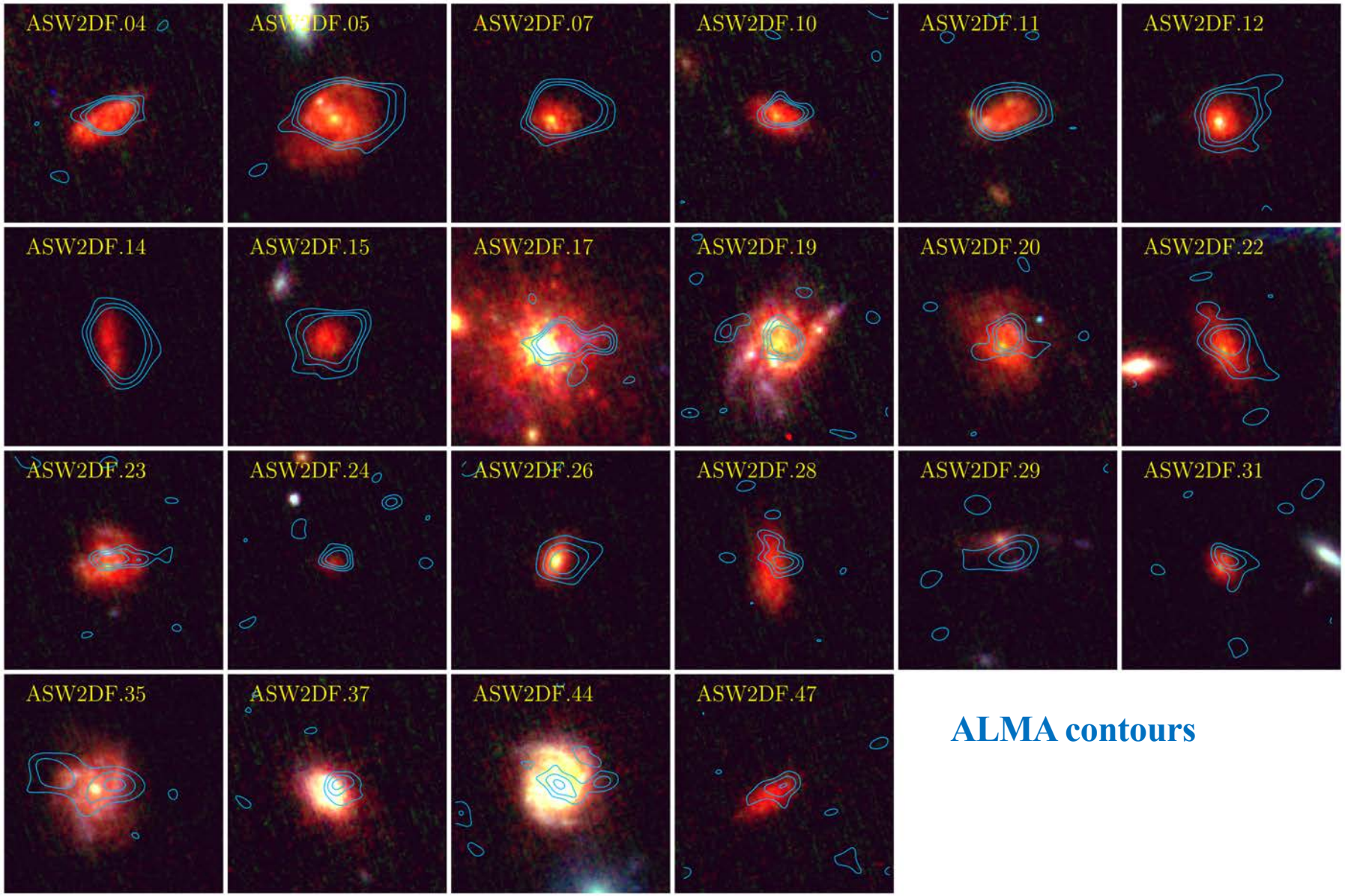
Y. Zhang, HD et al., 2024, A&A, 692, 22

ALMA 1.2mm mosaic



Y. Zhang, HD et al., 2024, A&A, 692, 22

JWST counterparts of ALMA sources

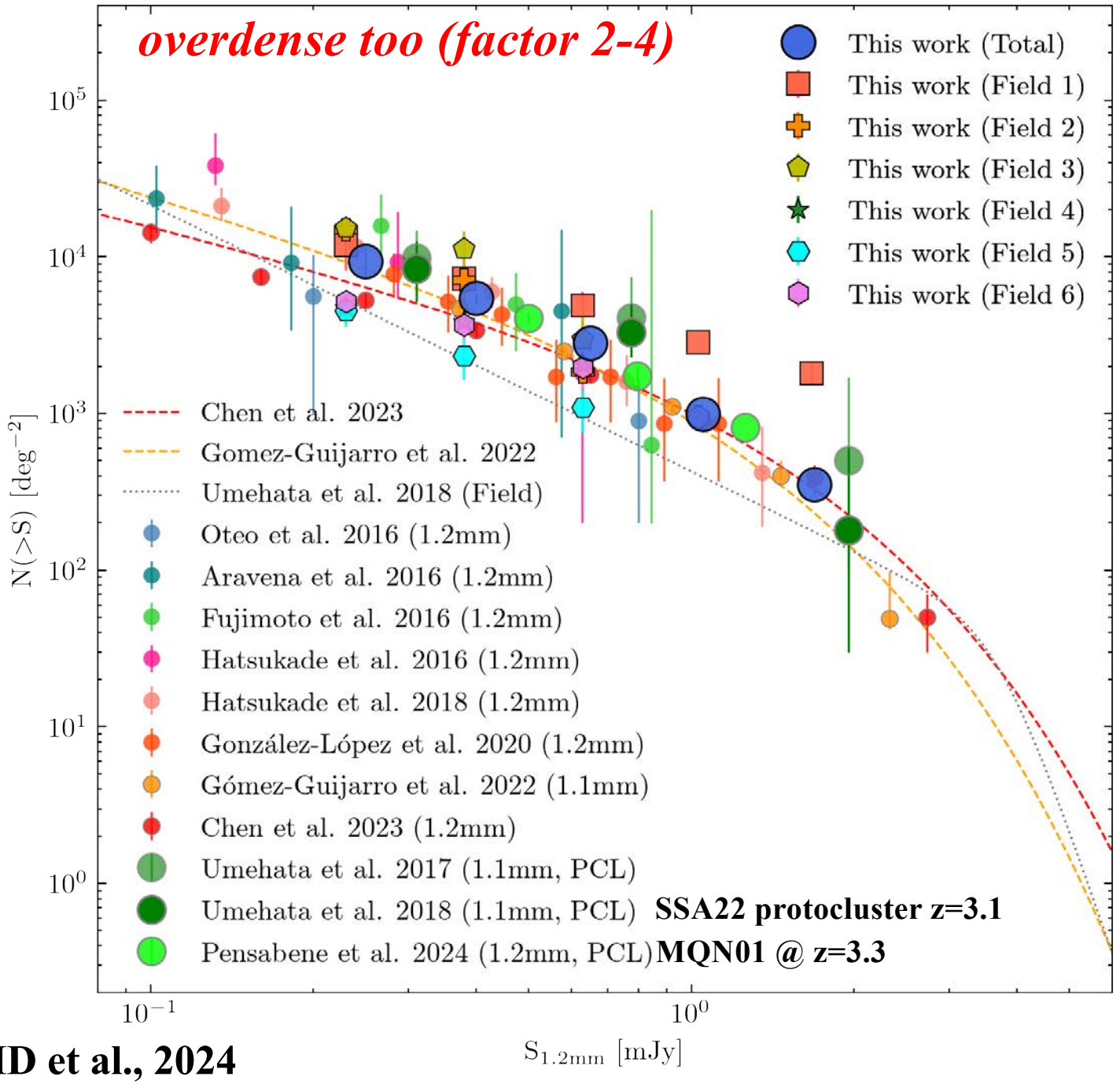


ALMA contours

cutouts: 4arcsec x 4arcsec

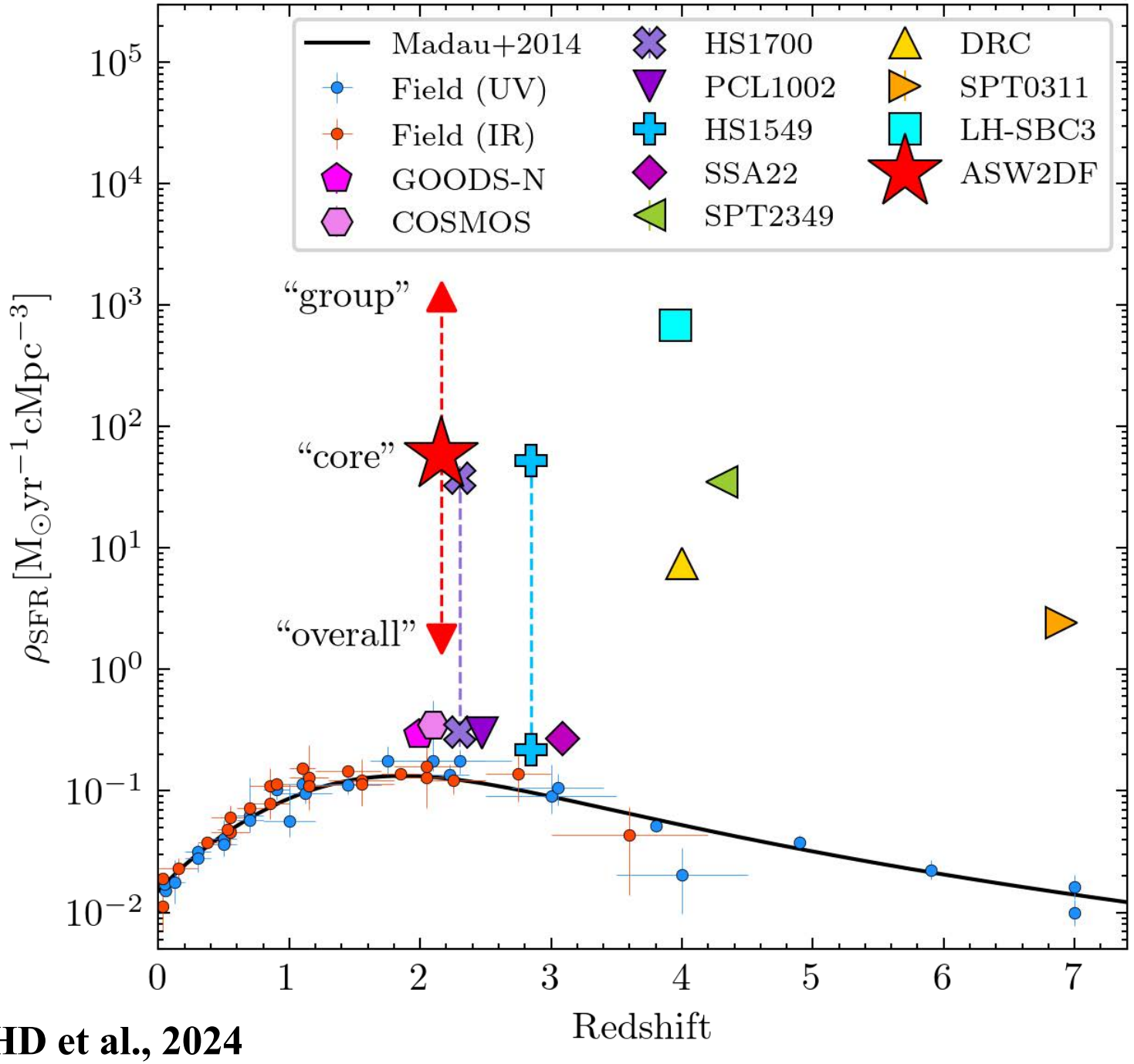
Y. Zhang, HD et al., in prep.

Dusty Starbursts Number Counts



Y. Zhang, HD et al., 2024

Cosmic Star-Formation Rate Density



Y. Zhang, HD et al., 2024

Lessons Learnt

- **great data☺**
- **be patient**
- **be creative**
- **request what you need, be ambitious!**
- **contact help desk & ALMA Regional Centers when you have doubts, very helpful☺**
- **Proposal documentation is helpful too☺**
- **try to take comments into account**
- **depending on the science archival data products can be trusted resp. are science ready**