

The ALMA Frontier Fields Survey and the observation of strongly lensed galaxies

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The ALMA Quest for Our Cosmic Origins
A Symposium to Honor Pierre Cox

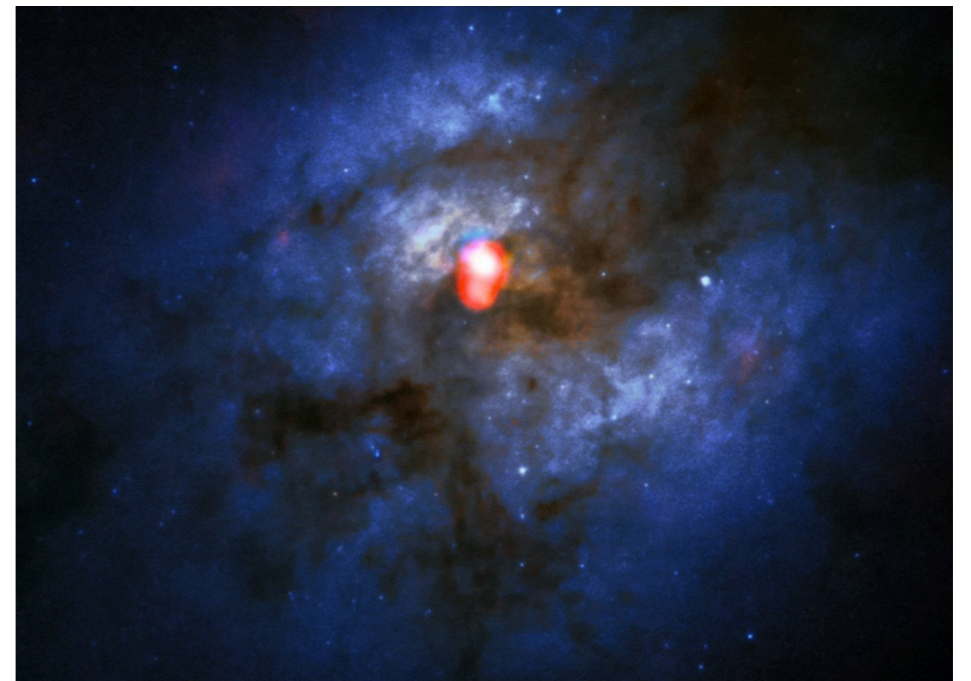
Dusty star-forming galaxies (bright end)

- The so-called submillimeter galaxies (SMGs)
- High redshift ULIRGs
- Starburst and MS galaxies

Mergers

Live in overdensities

Low number counts



Dusty star-forming galaxies (faint end)

- How are the number counts and distribution?
- What is the relation between stellar properties and dust content?
- How is the distribution of dust and gas across the galaxies?

How to study faint DSFGs?

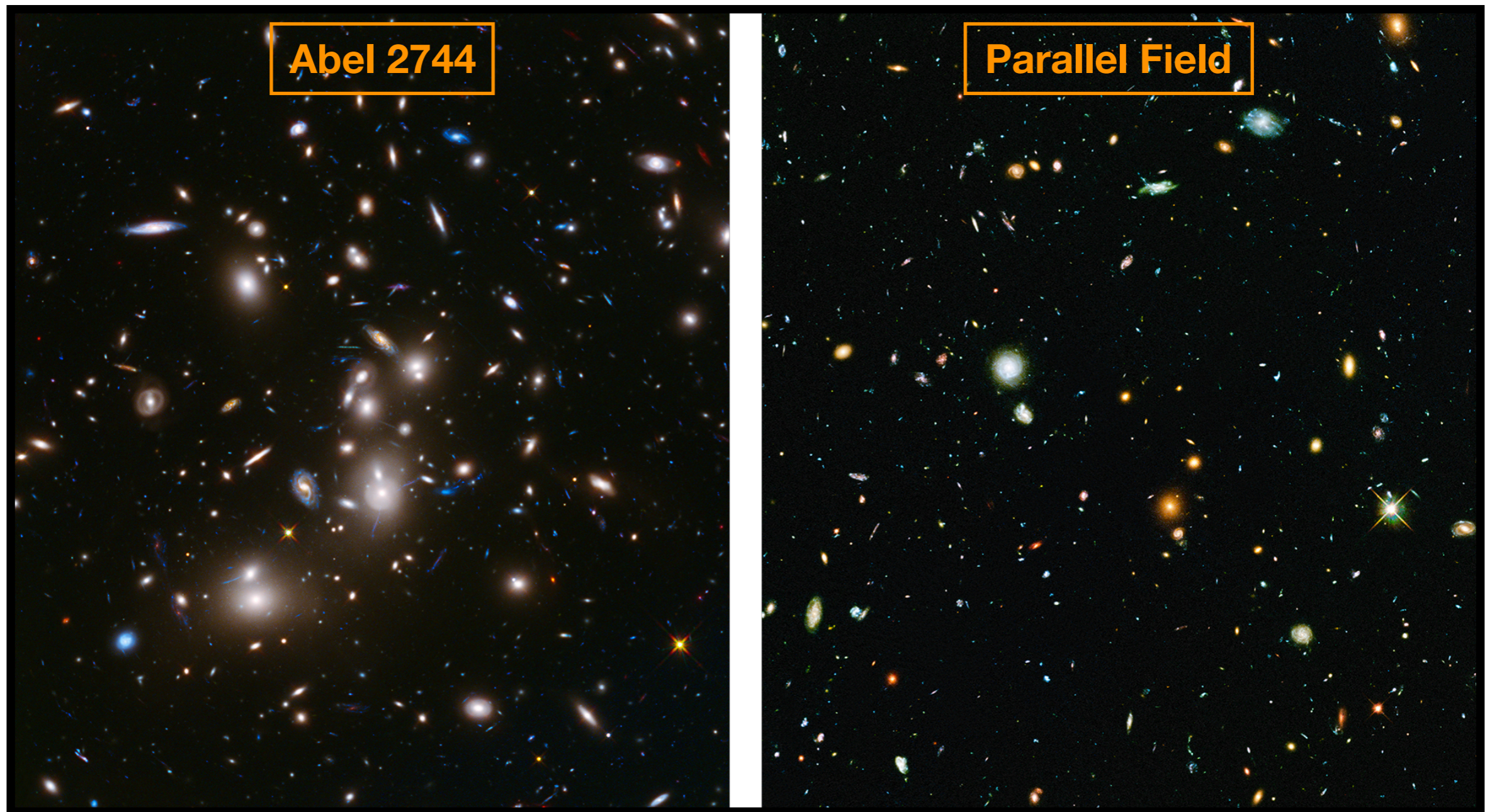
**Deep
observations of
blank fields**

Lensing fields

HST + Spitzer Frontier Fields

ACS (F435W=F606W=F814W \approx 28.4– 29.0 ABmag),
WFC3 (F105W=F125W=F140W=F160 \approx 29.1– 29.4 ABmag)
IRAC1/IRAC2 (\approx 25.0 ABmag)

Lotz et al. 2017



Galaxy Clusters with the best lensing models!!!

ALMA Frontier Fields Survey (AFF)

2.2'

Abel 2744

Parallel Field

Band 6 (1.1 mm)
rms of $70 \mu\text{Jy}$

2.2'

Objective: Obtain a ~ 4.5 square arcmin
mosaic in the central region of each cluster

A2744

MACSJ0416

MACSJ1149

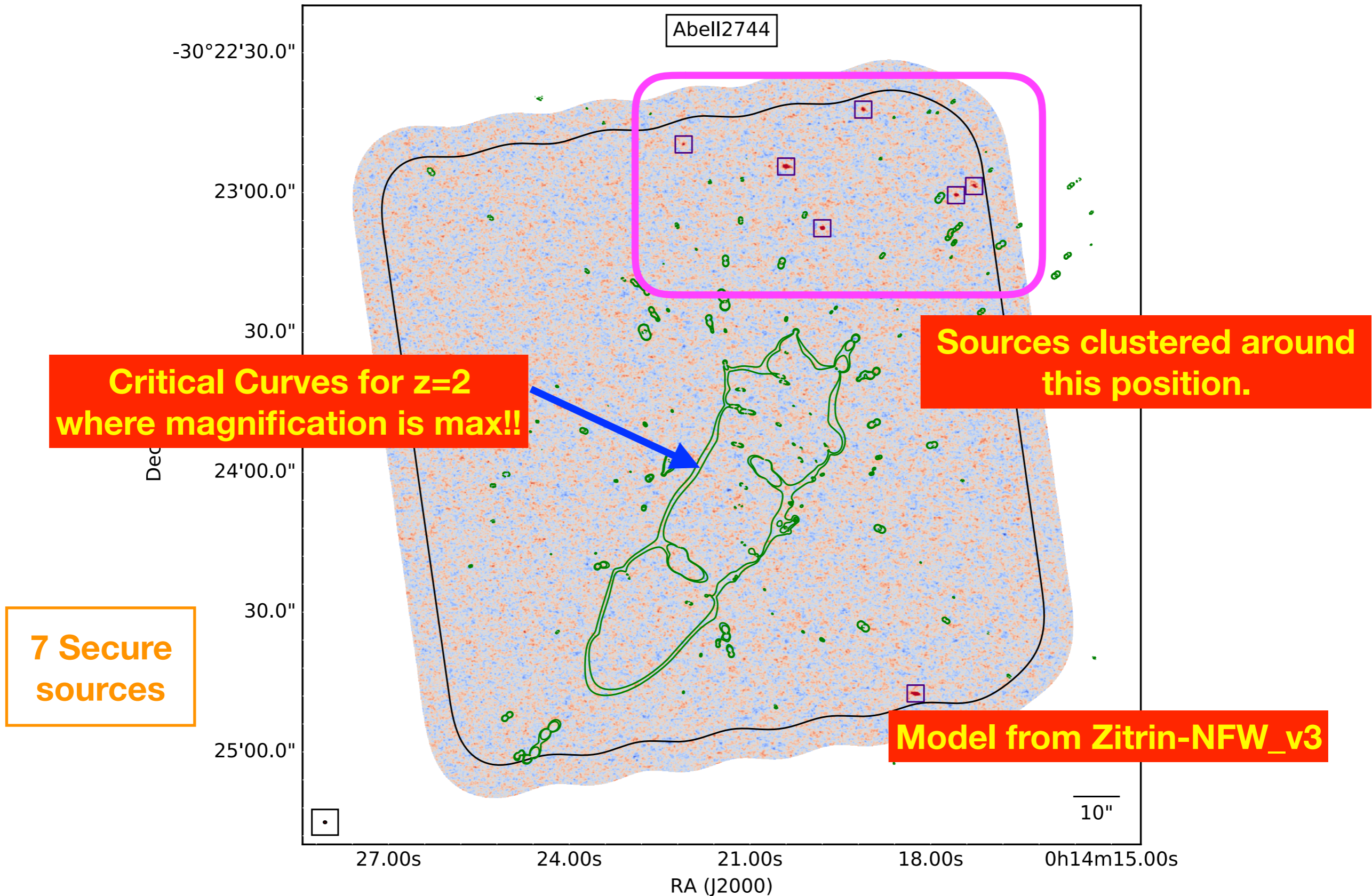
A370

AS1063

MACSJ0717

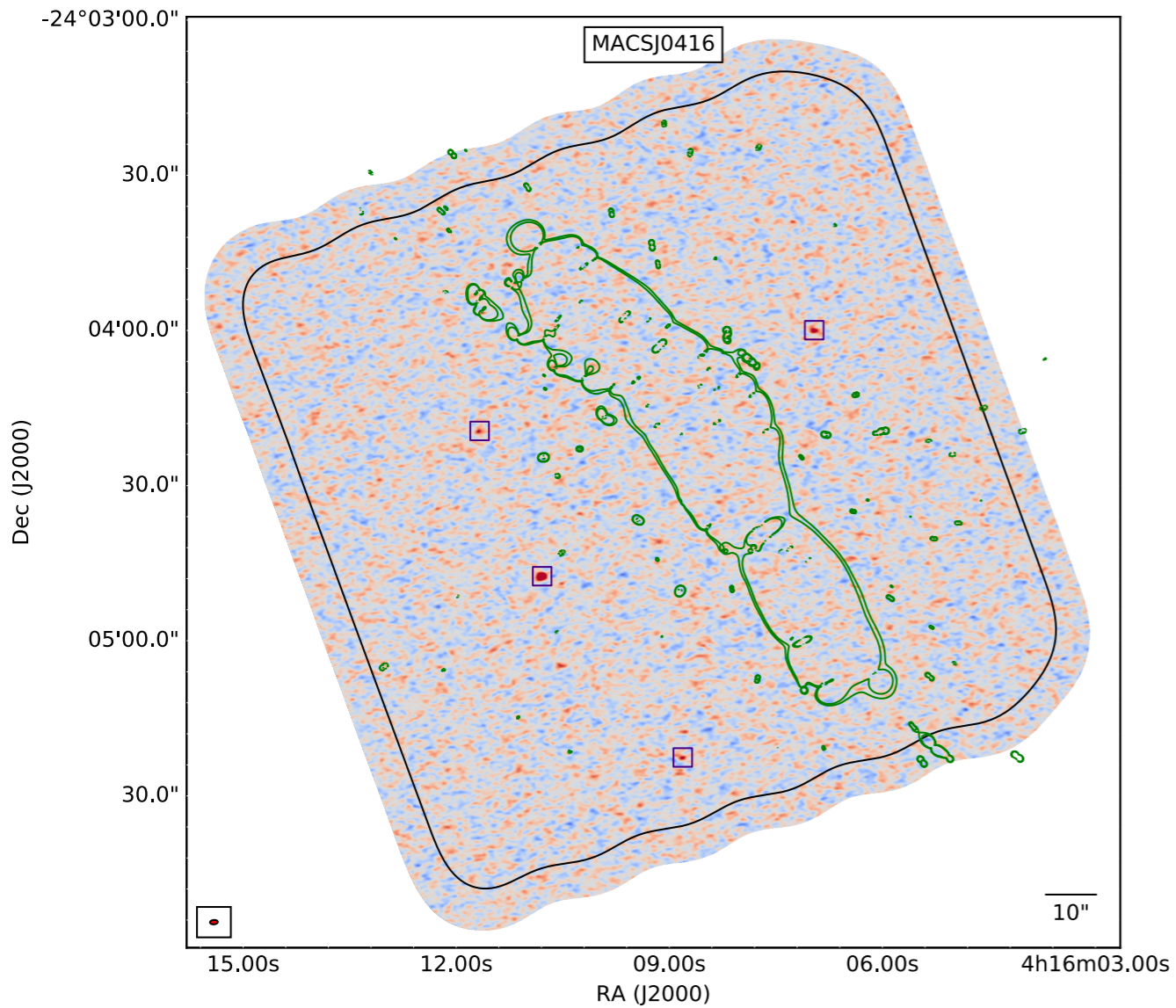
ALMA Frontier Fields first results

González-López et al. 2017a

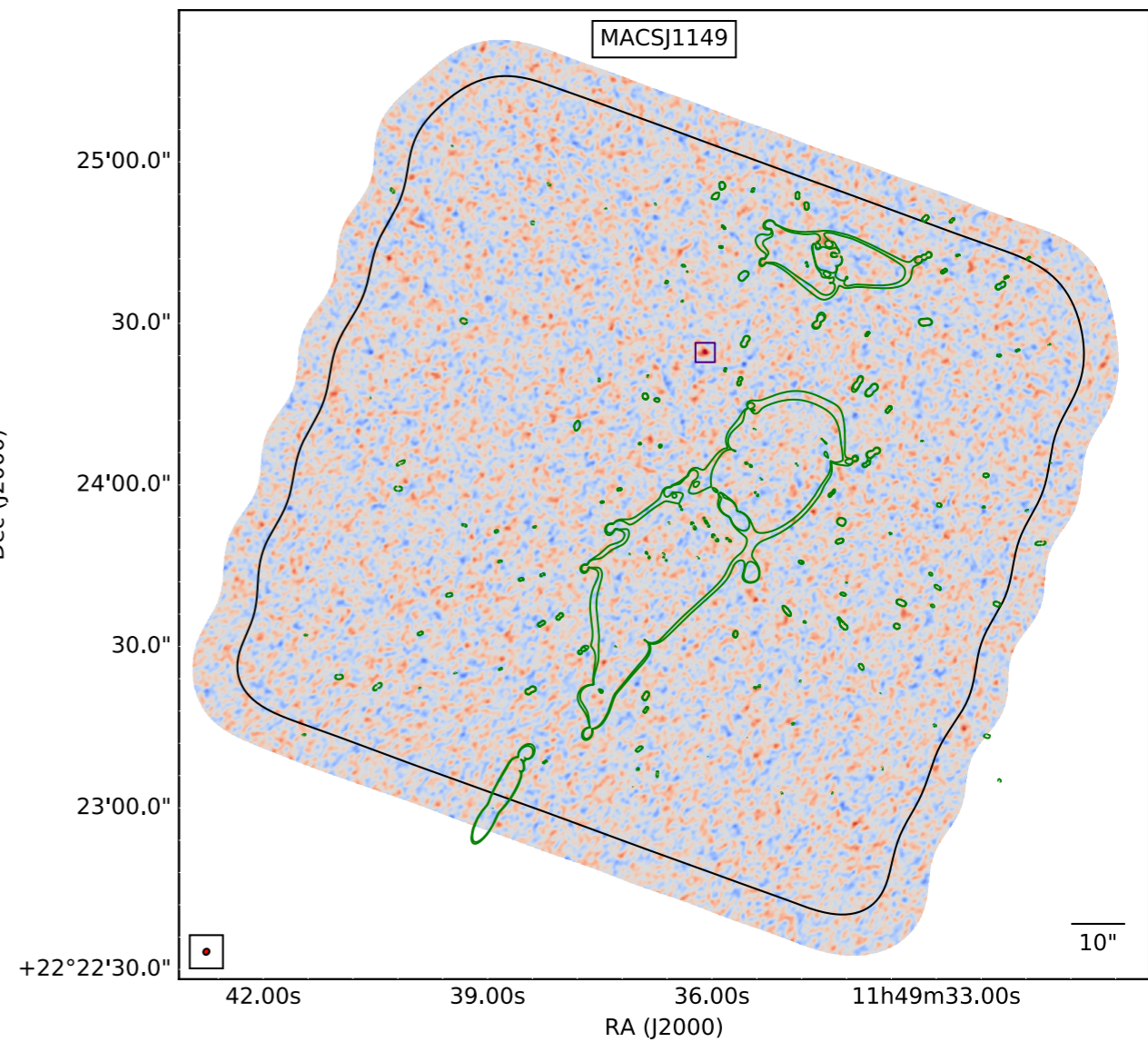


ALMA Frontier Fields first results

González-López et al. 2017a



12 Secure sources

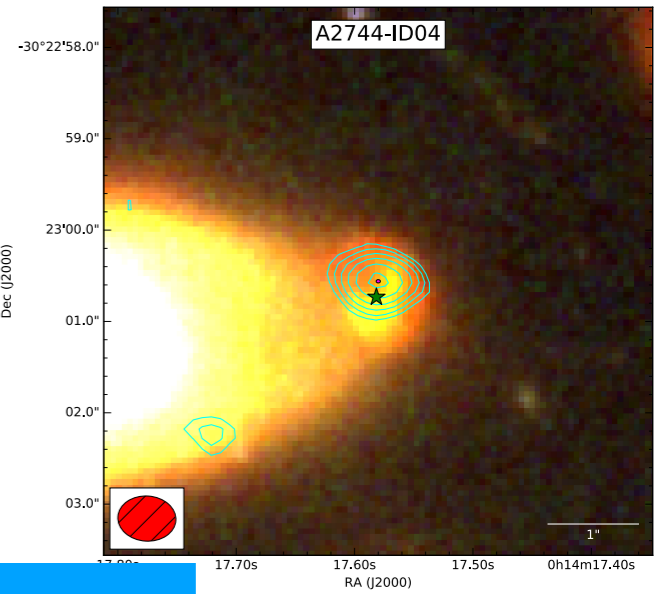
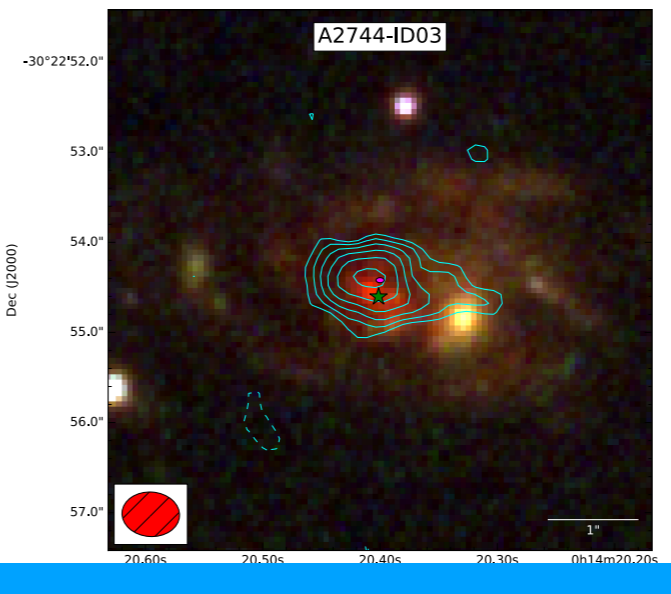
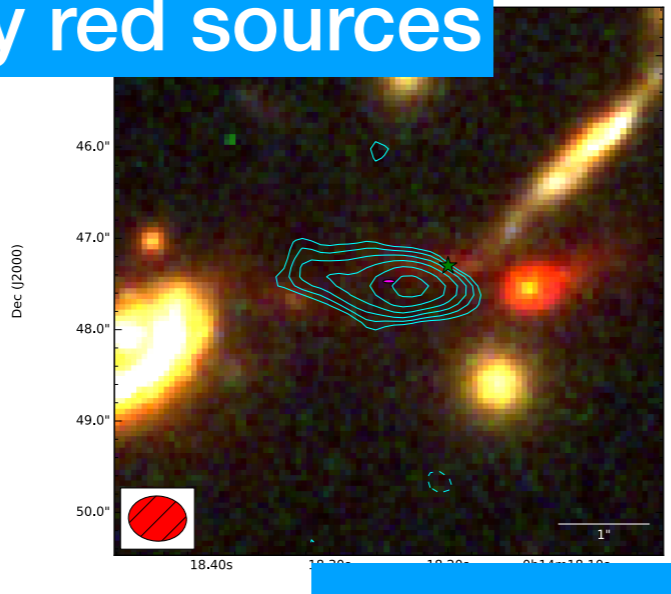
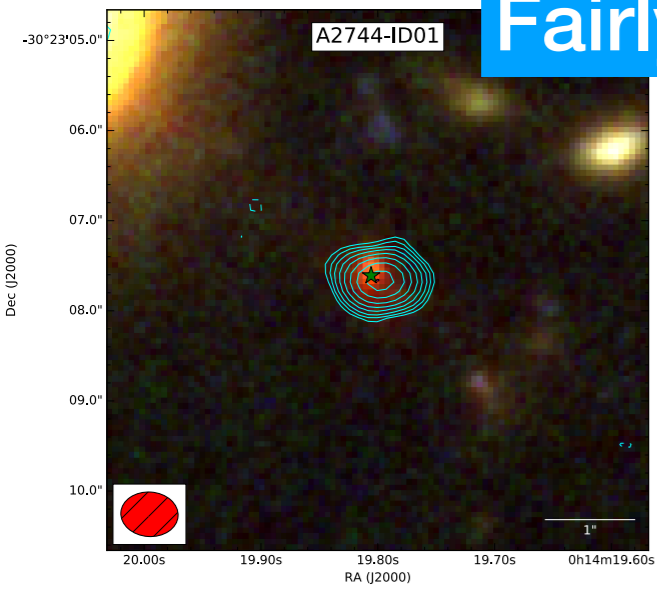


**Intrinsic Flux densities
between 0.1 and 1.7 mJy**

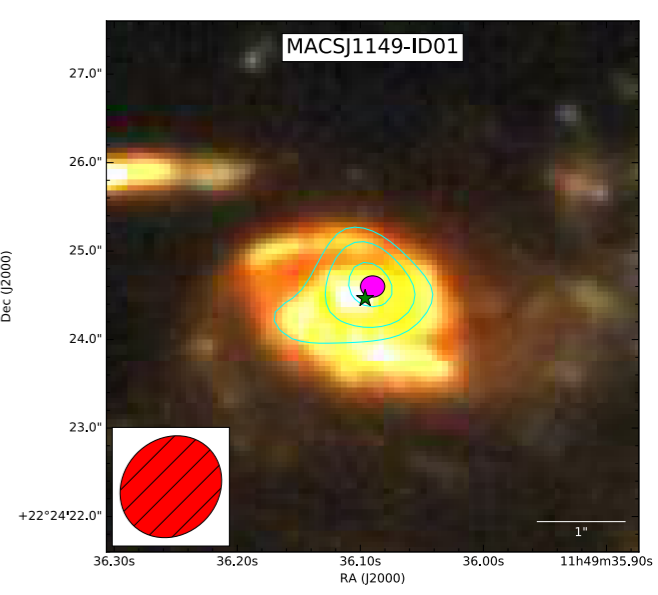
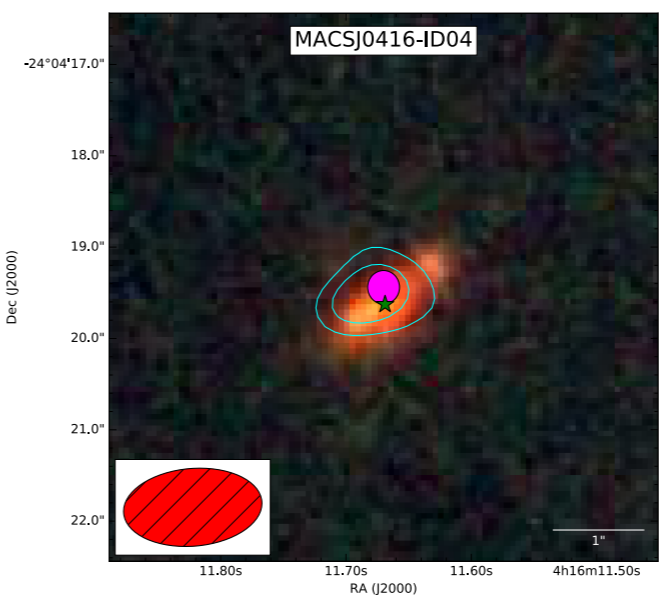
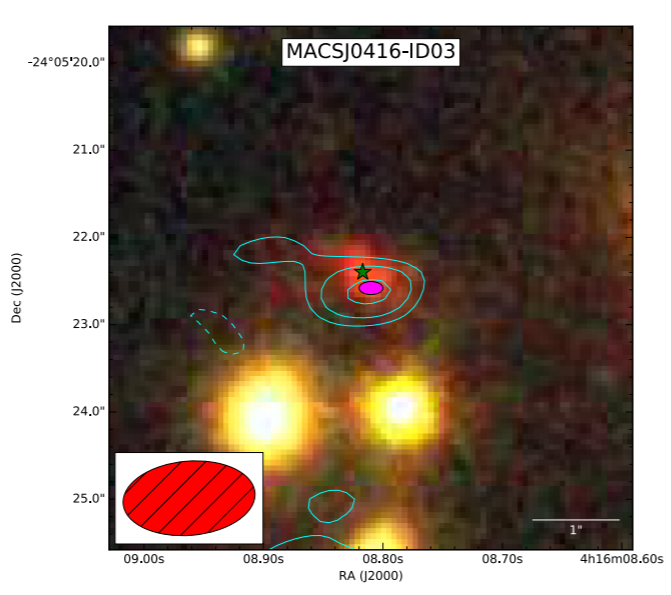
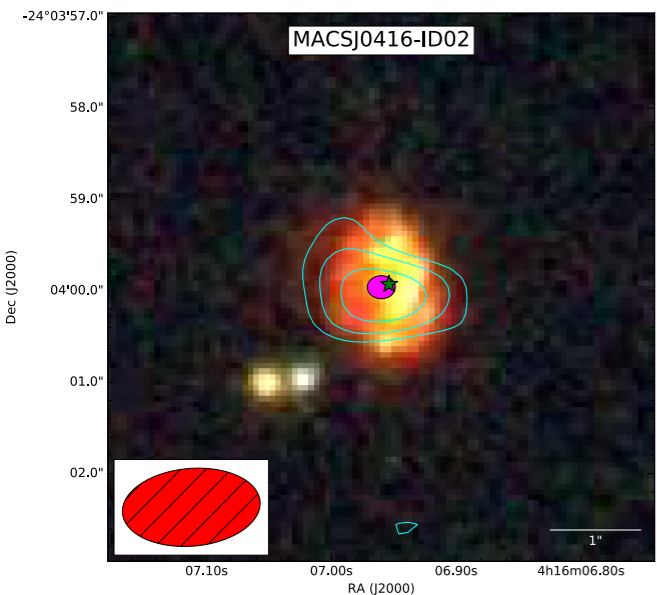
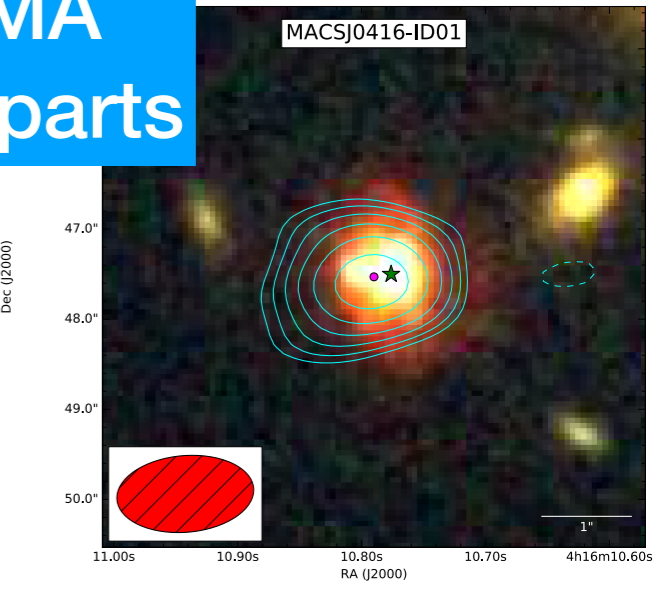
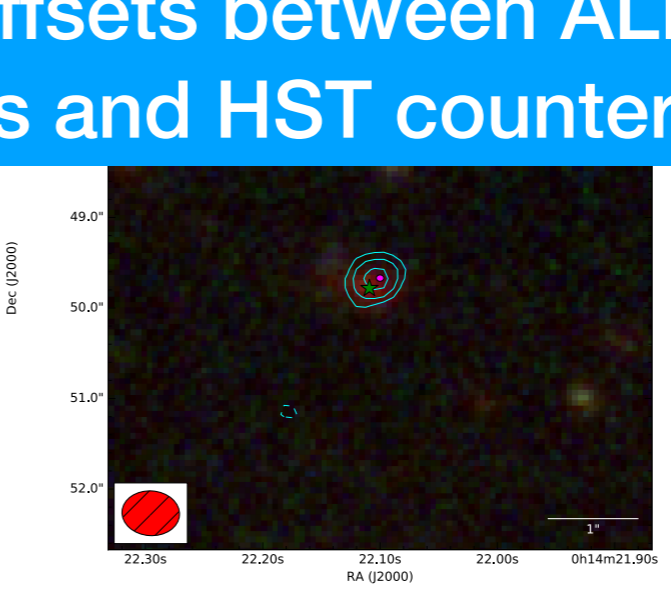
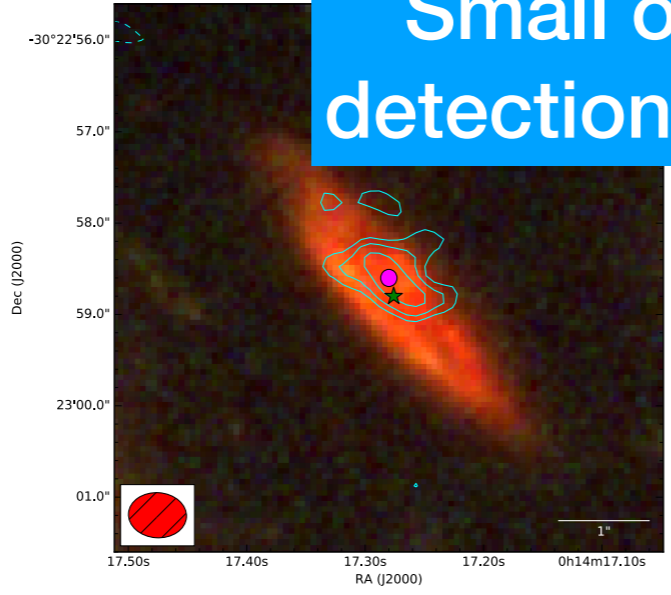
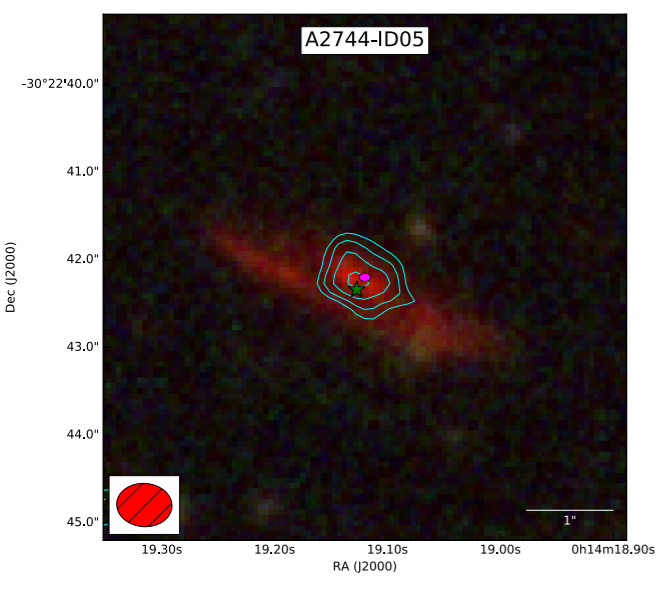
Magnification ~2-5

Counterpart Galaxies

Fairly red sources

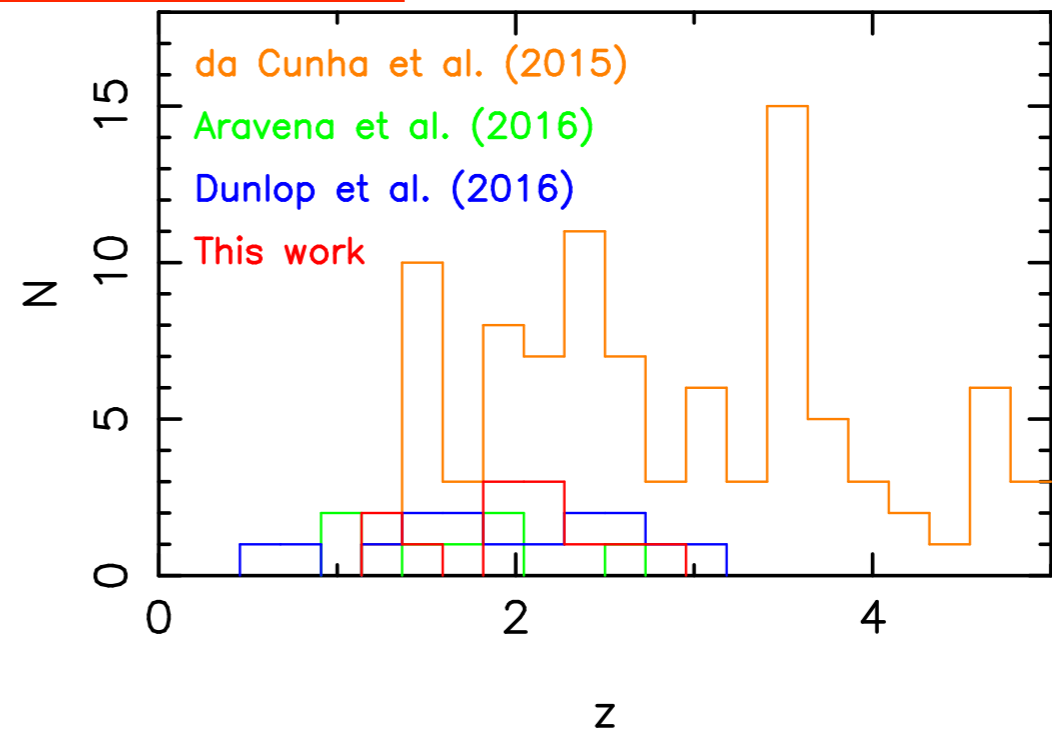
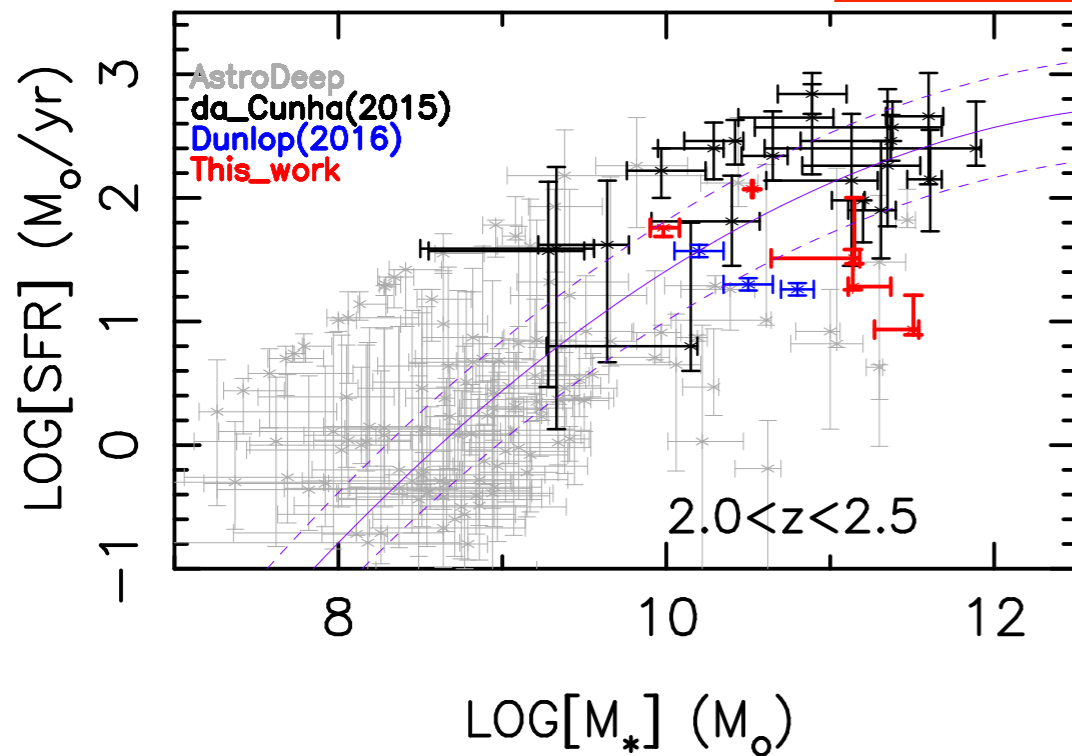
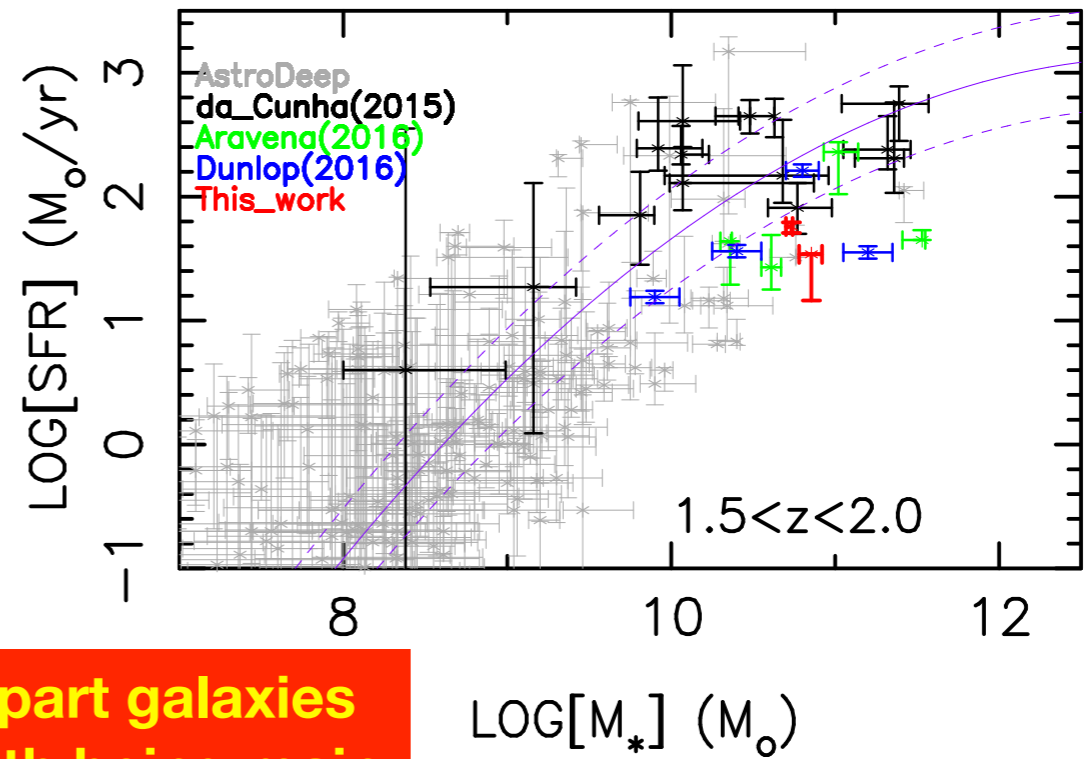
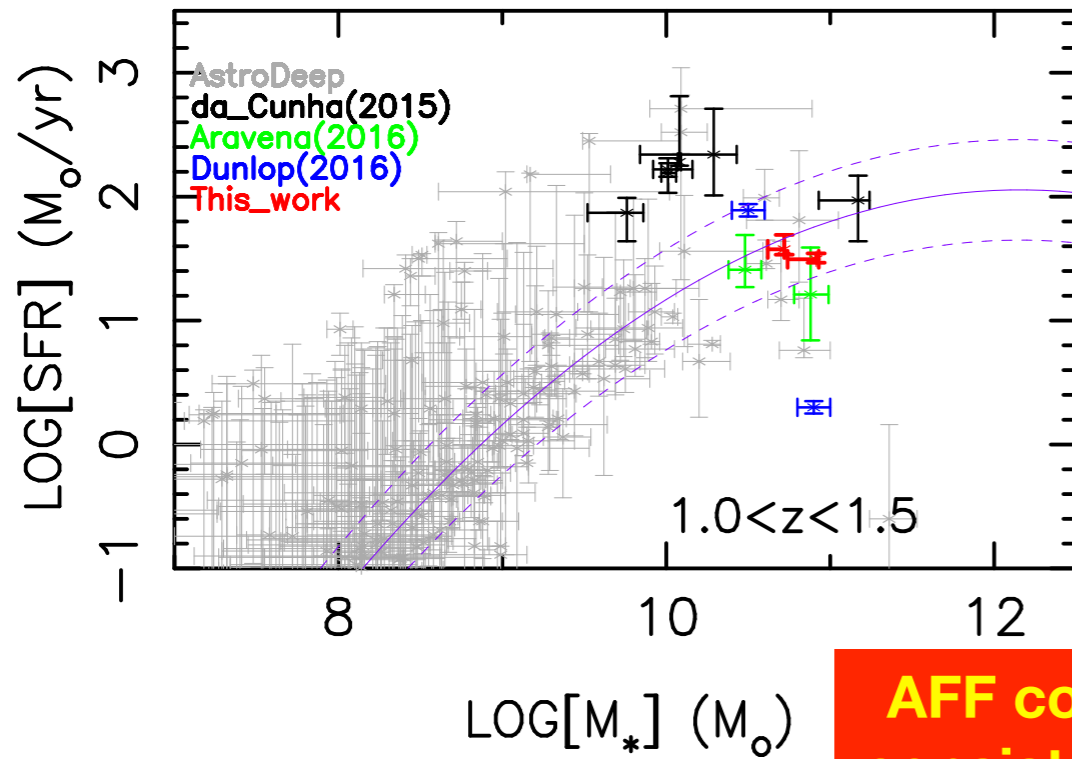


Small offsets between ALMA detections and HST counterparts



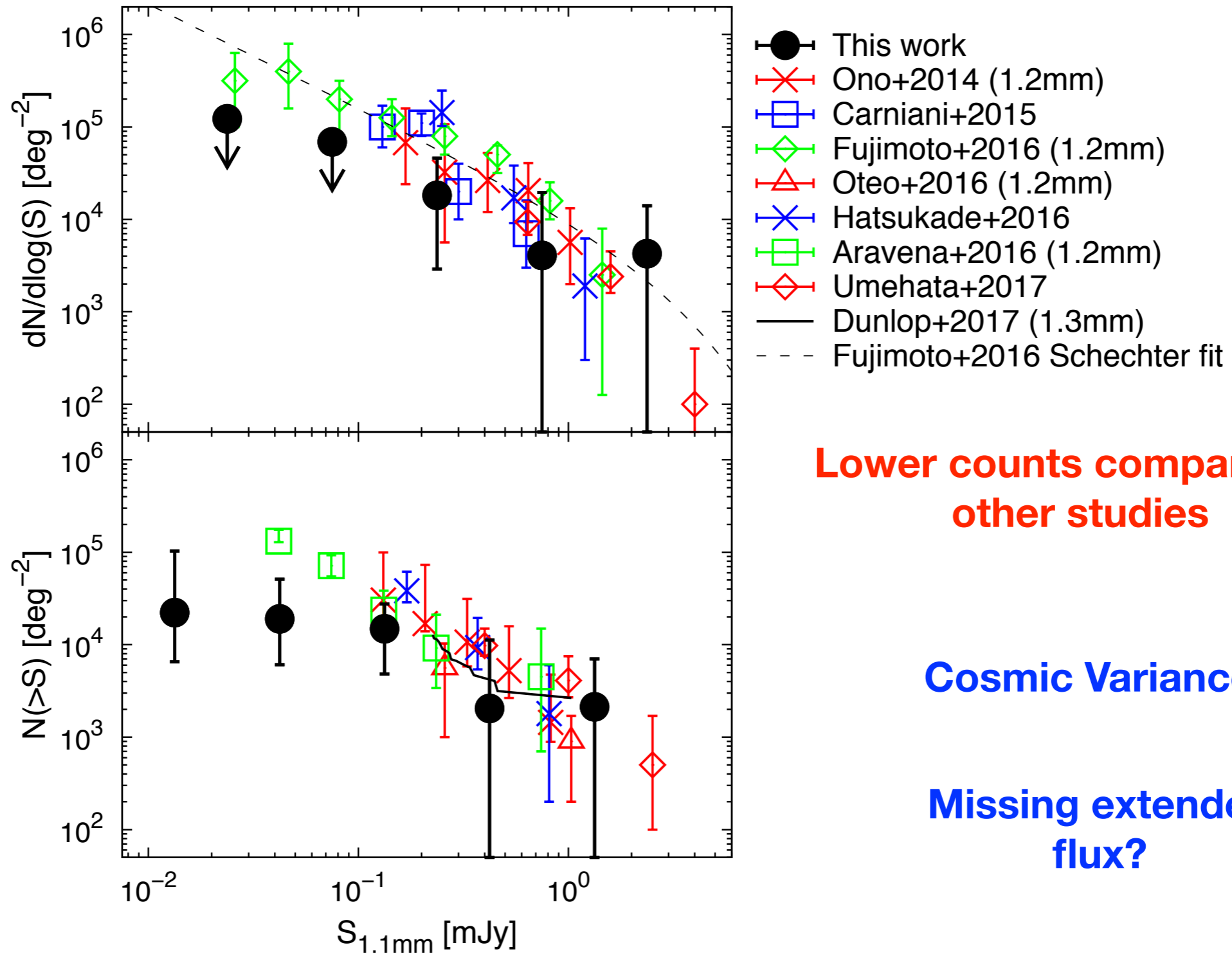
Counterpart properties

Laporte et al. 2017a



1.1 mm number counts

Muñoz-Arancibia et al (Submitted)



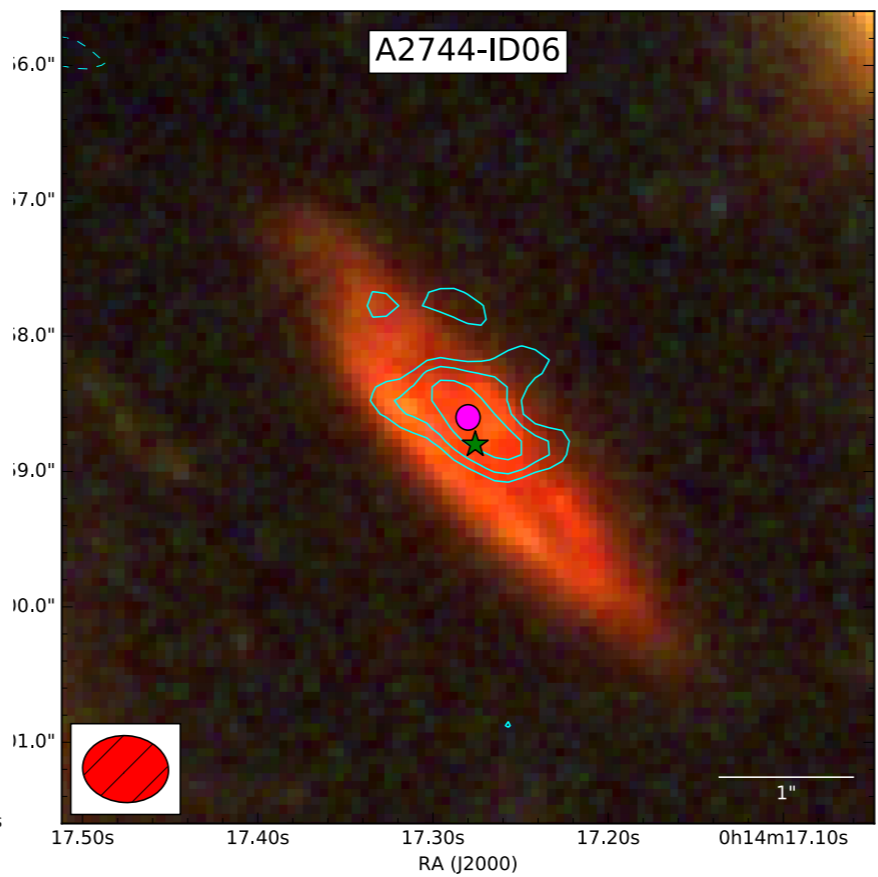
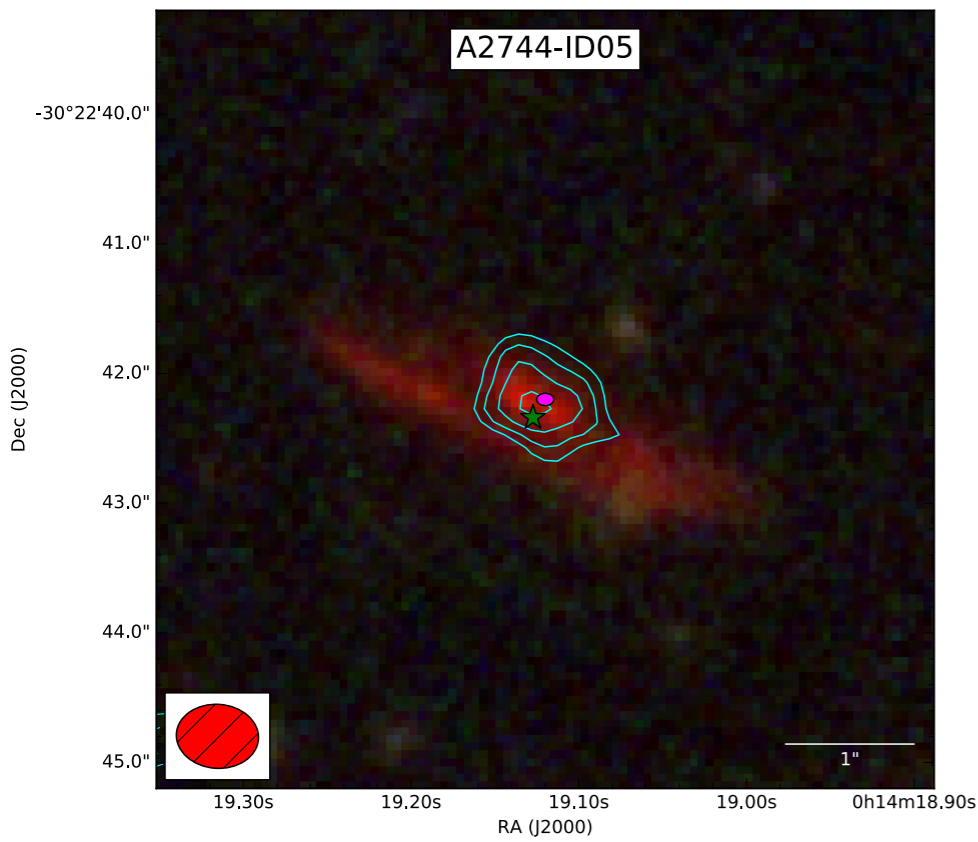
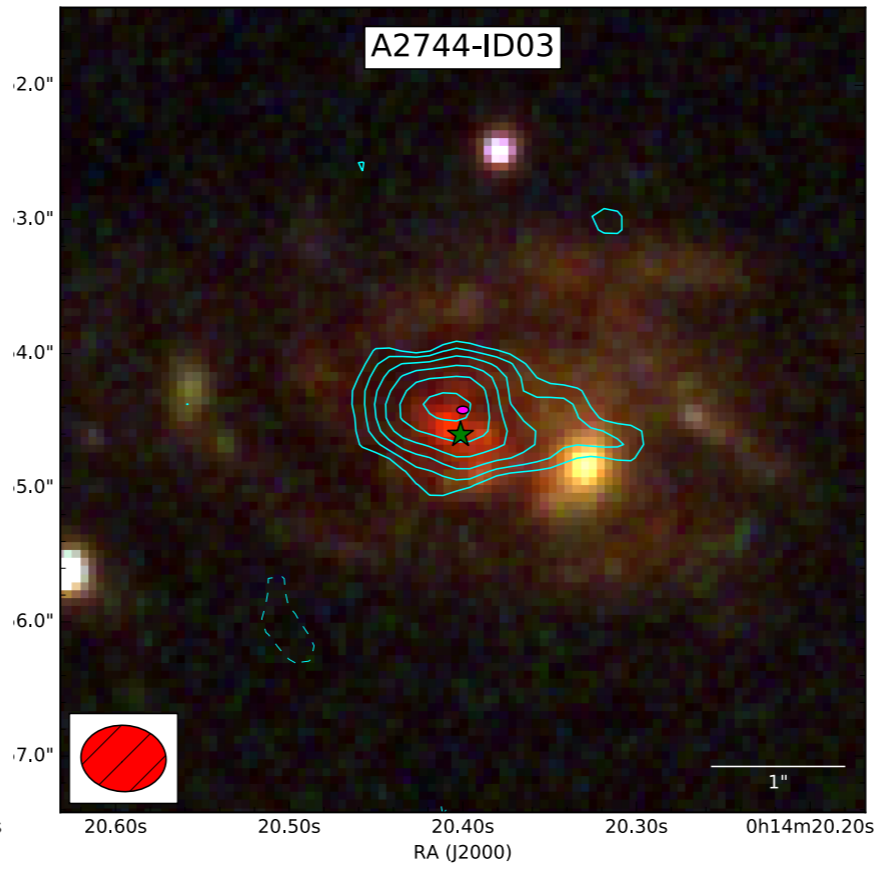
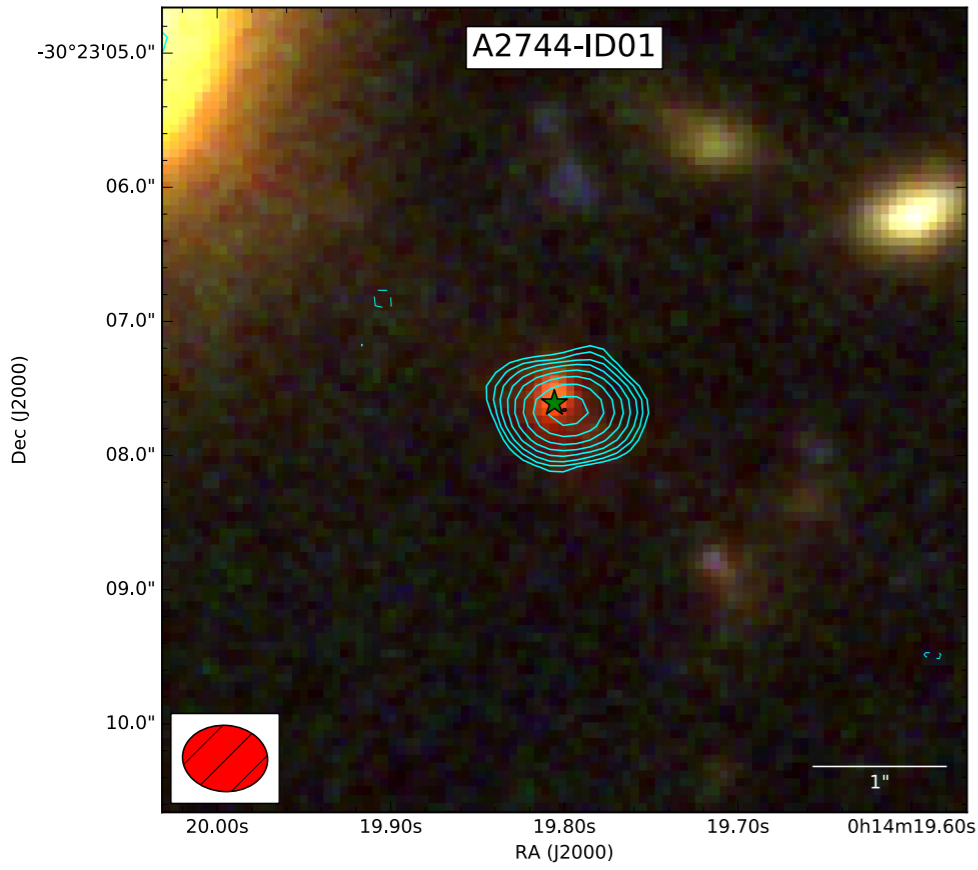
Lower counts compared to other studies

Cosmic Variance?

Missing extended flux?

**Missing sources towards
the faint end?**

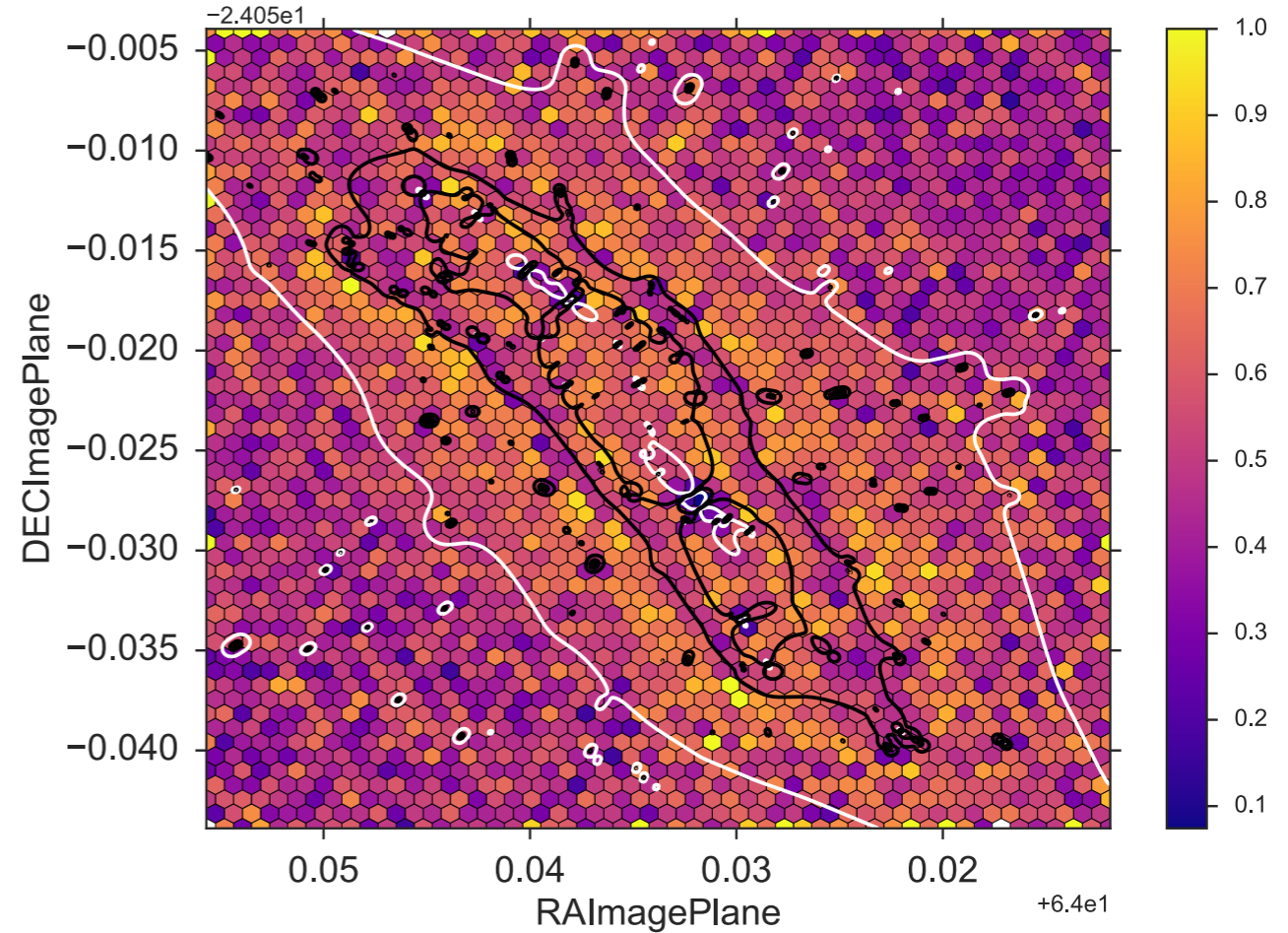
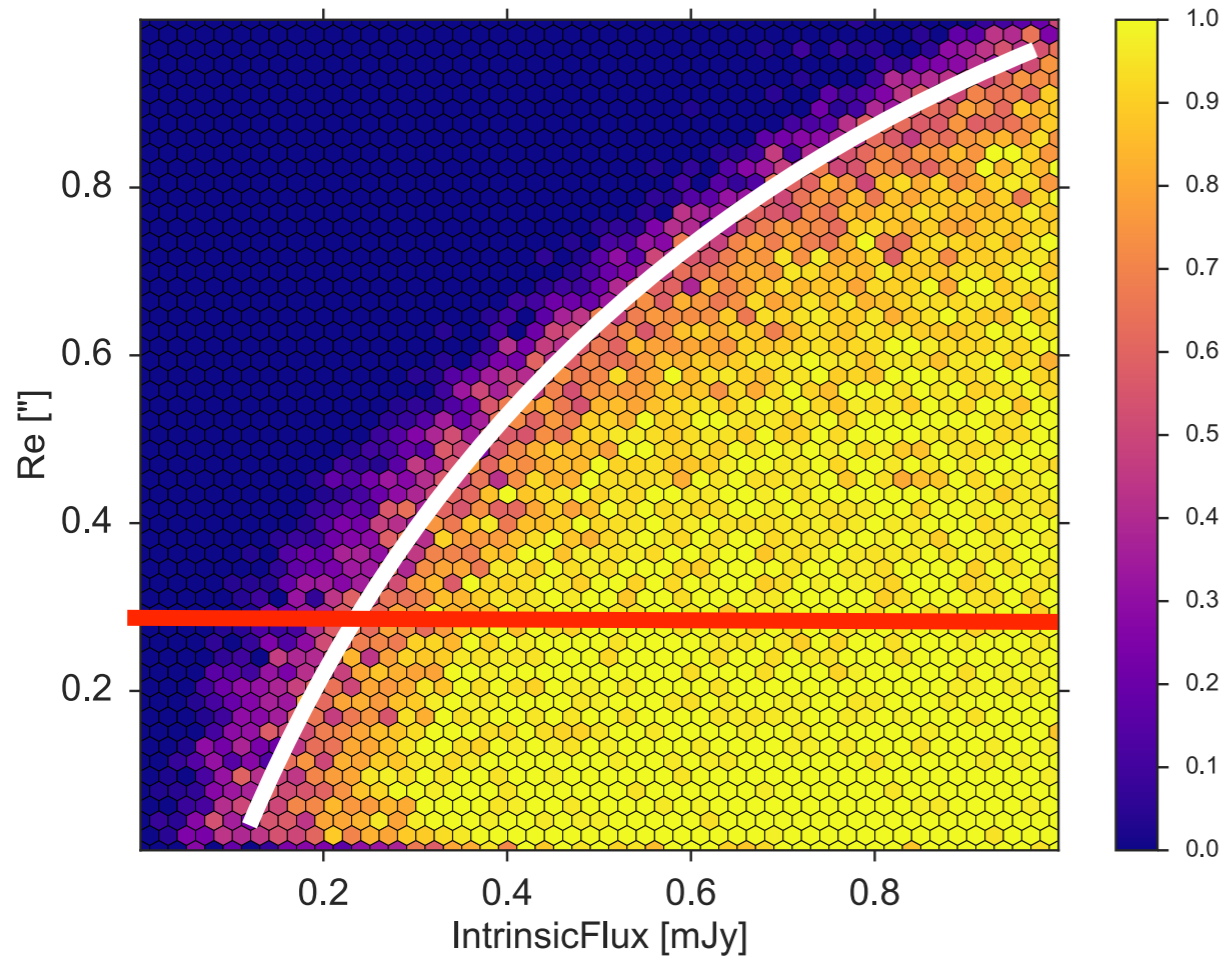
Sizes



**General trend:
dust emission
more compact
than optical/
NIR emission**

Completeness Simulations

MACSJ0416



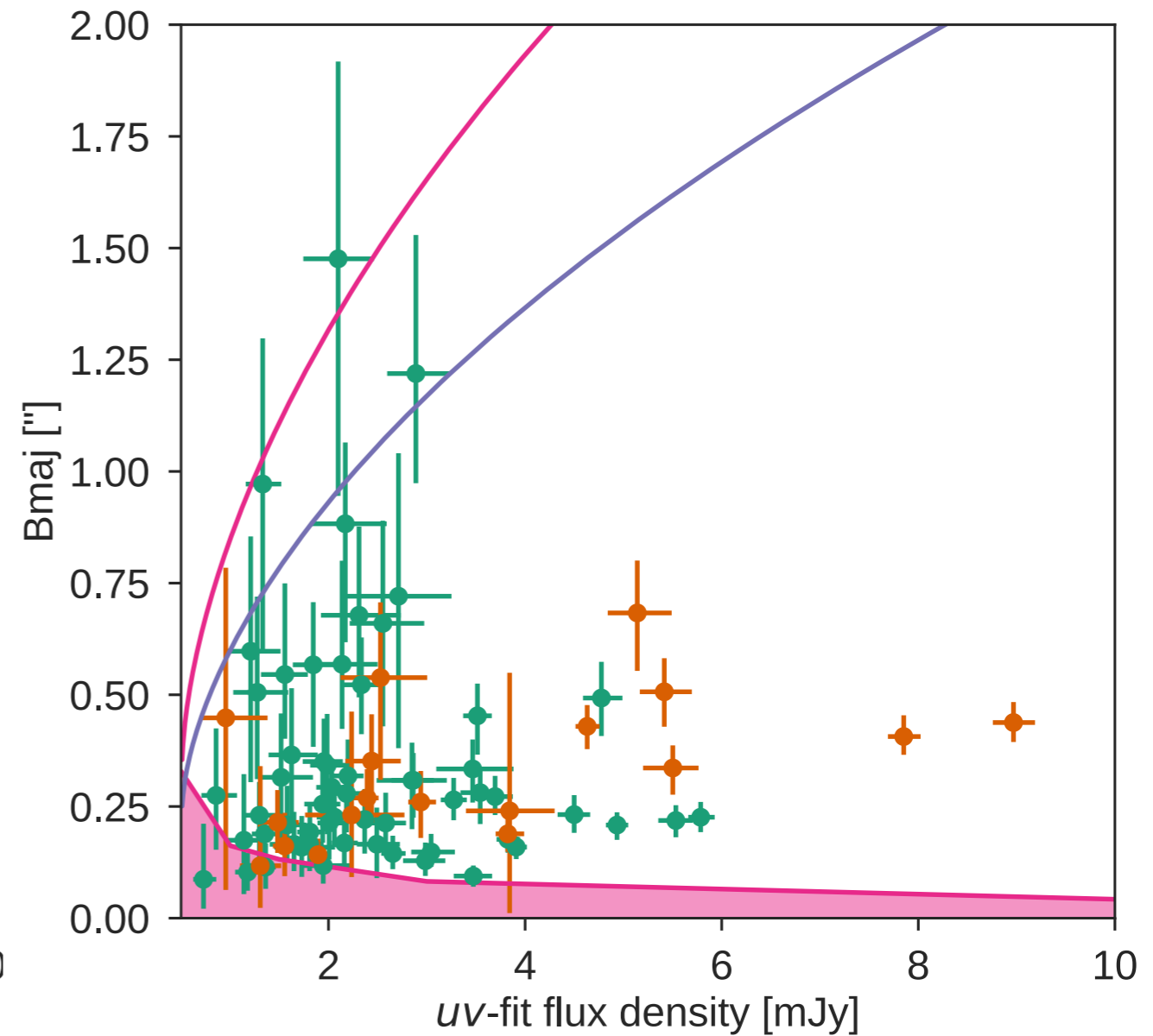
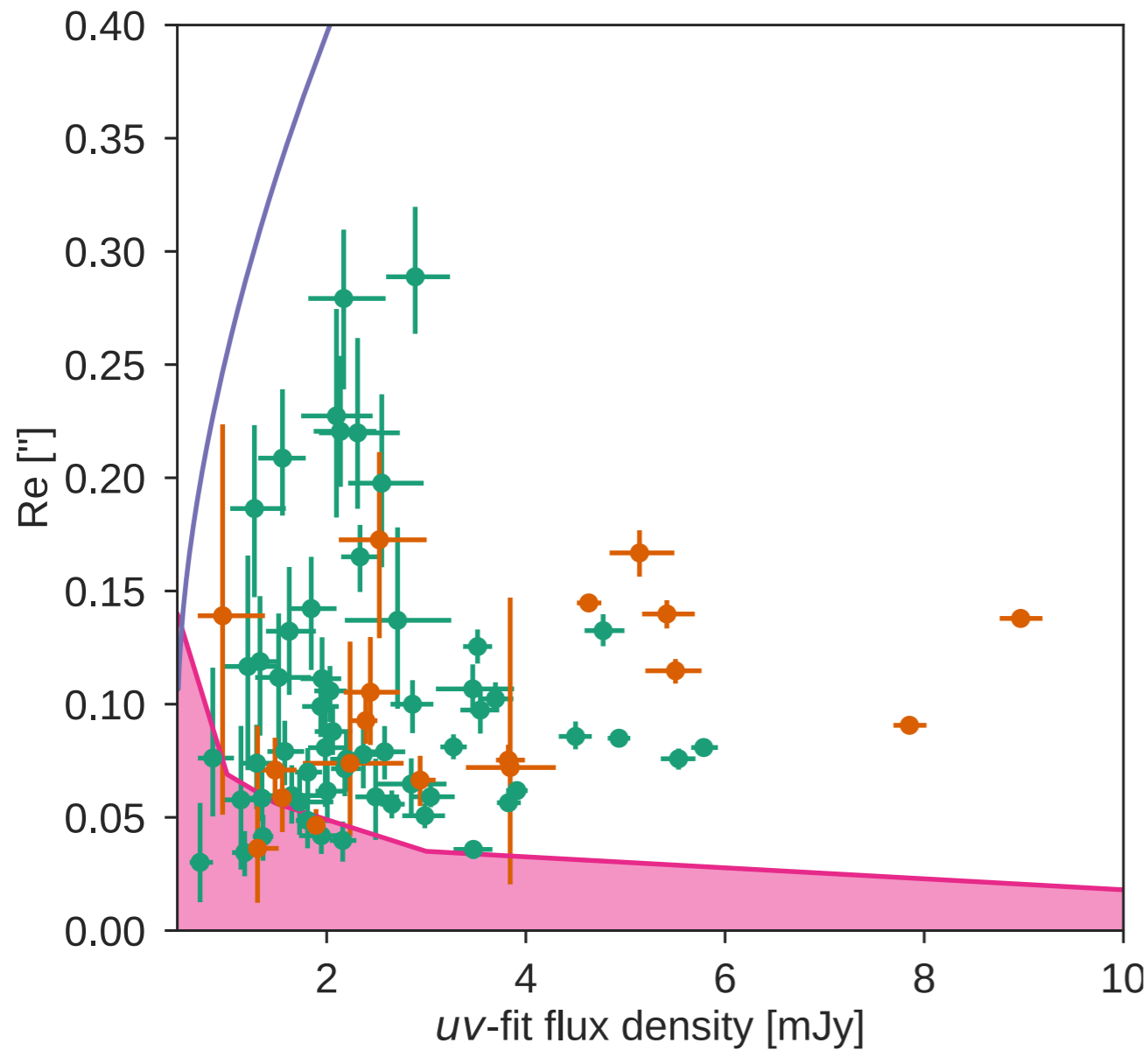
**Completeness curve
produced by interferometric beam size**

**Strong decrease in
completeness near critical curves**

BASIC: A Bright ALMA Survey In the CDF-S

Cowie et al. 2018 in preparation

González-López et al. 2018a in preparation



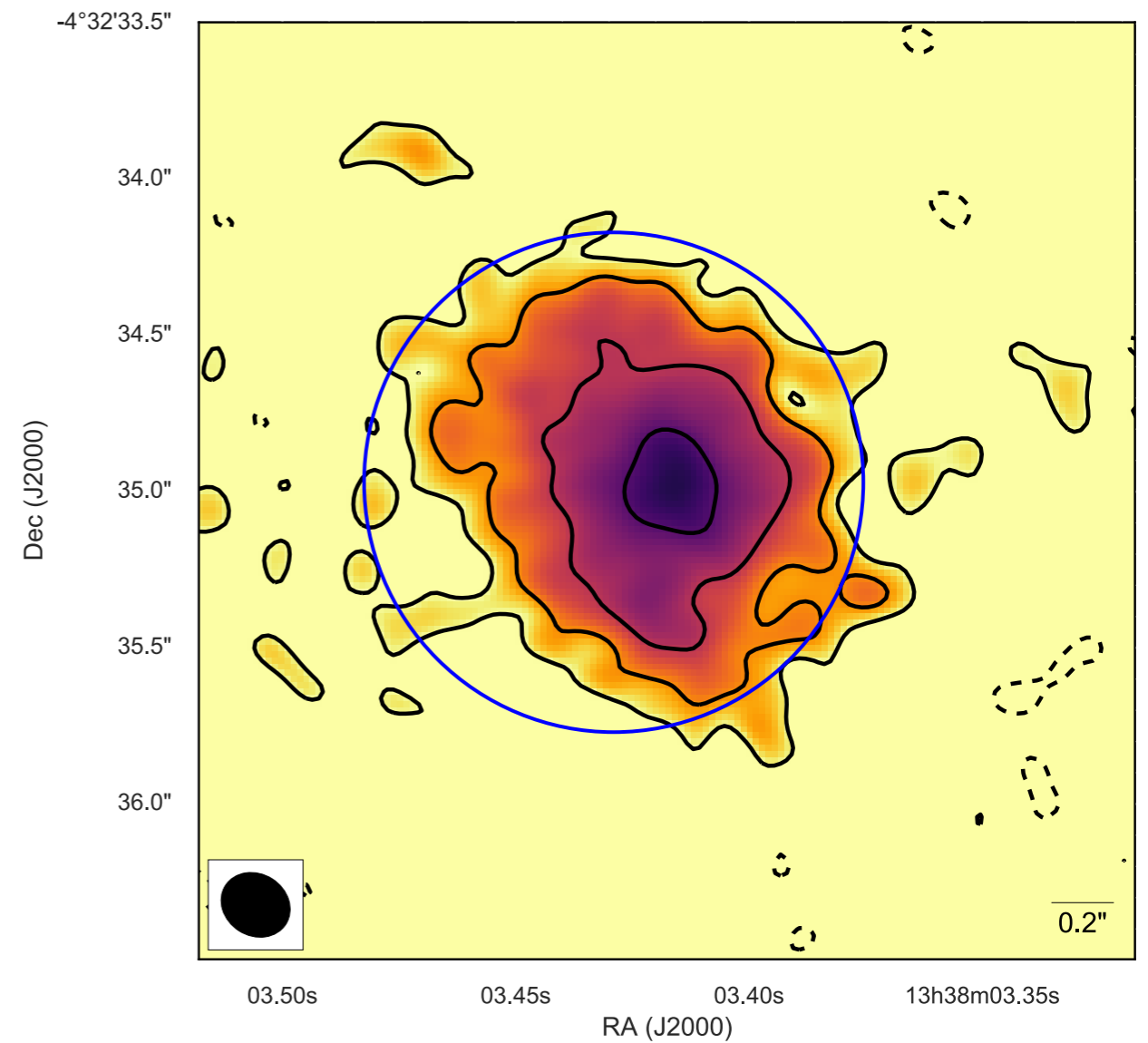
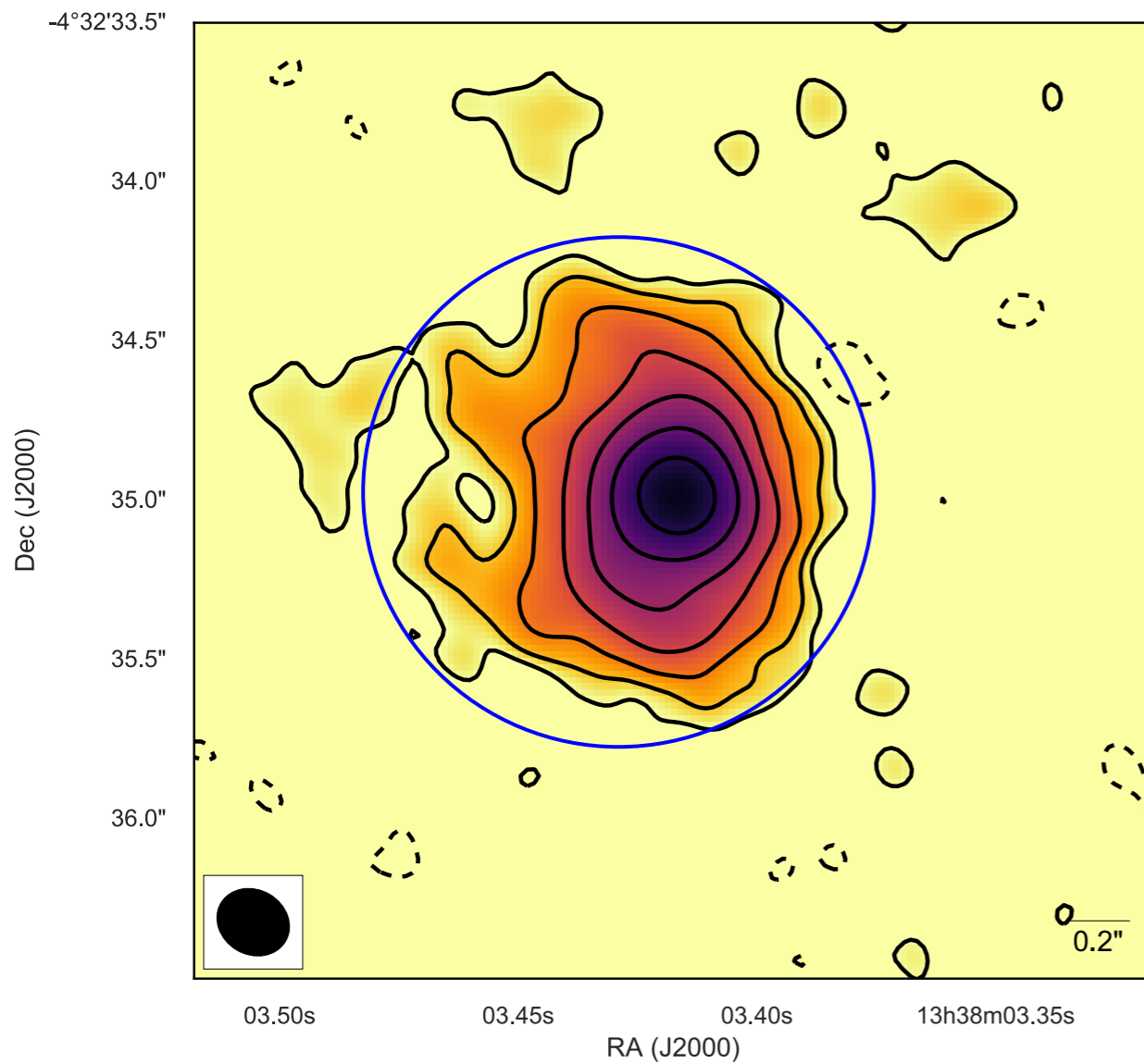
BRI1335-0417 (z=4.4)

González-López et al. 2018b in preparation

Infrared luminous QSO

Continuum band 7

[CII]

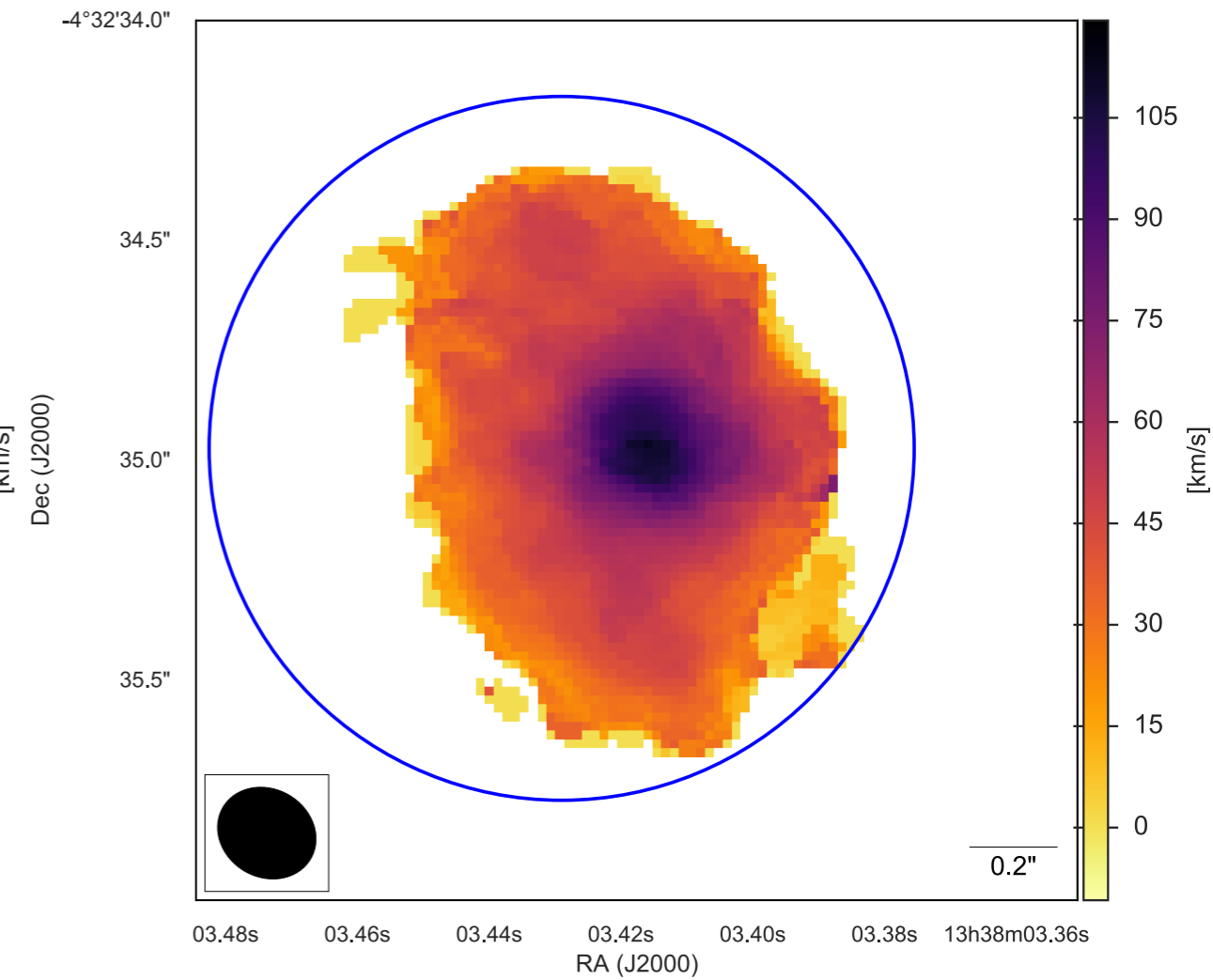
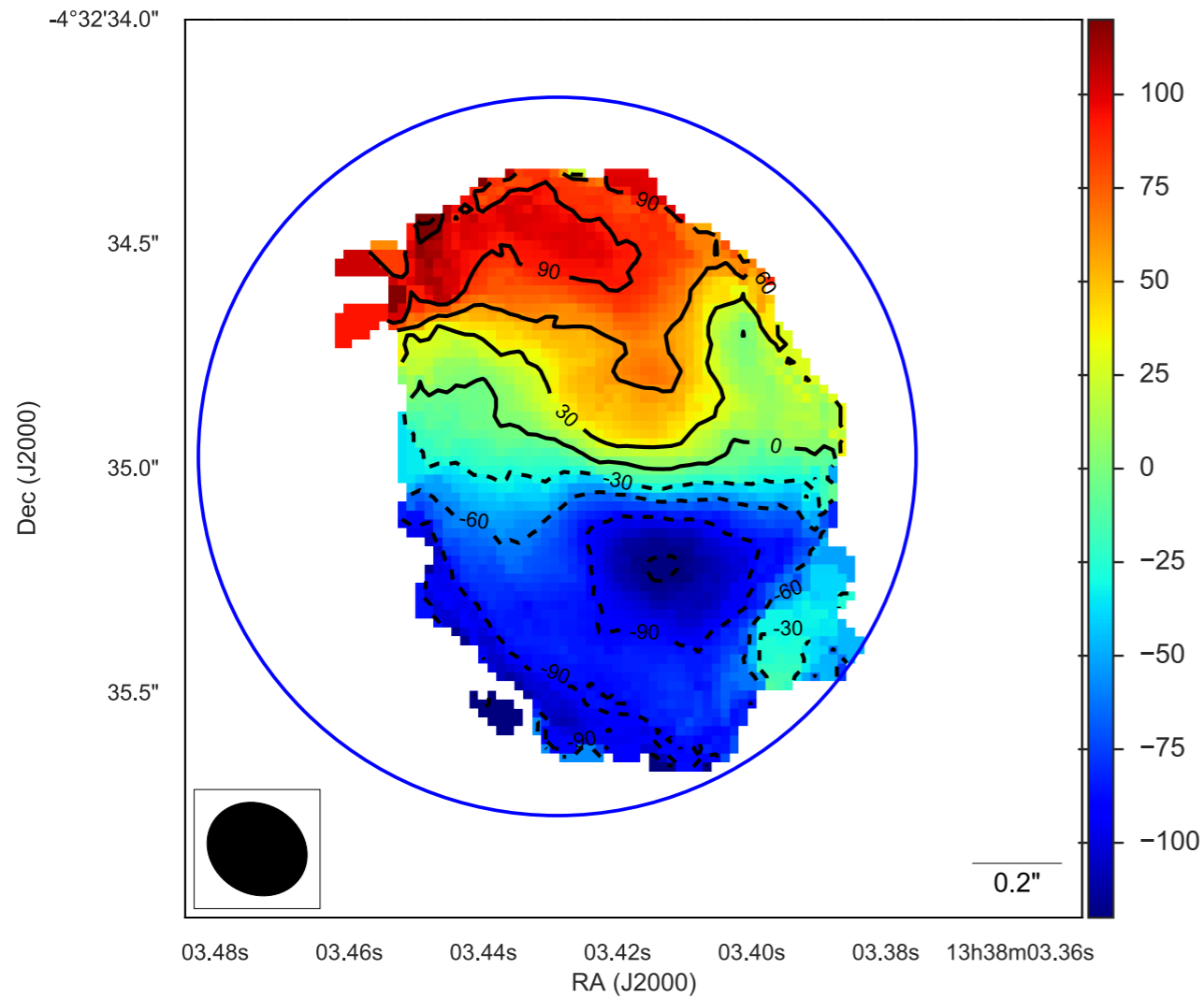


Beam~1.4 kpc

Contour levels = 2, 4, 8, 16, 32, 64 and 128 σ

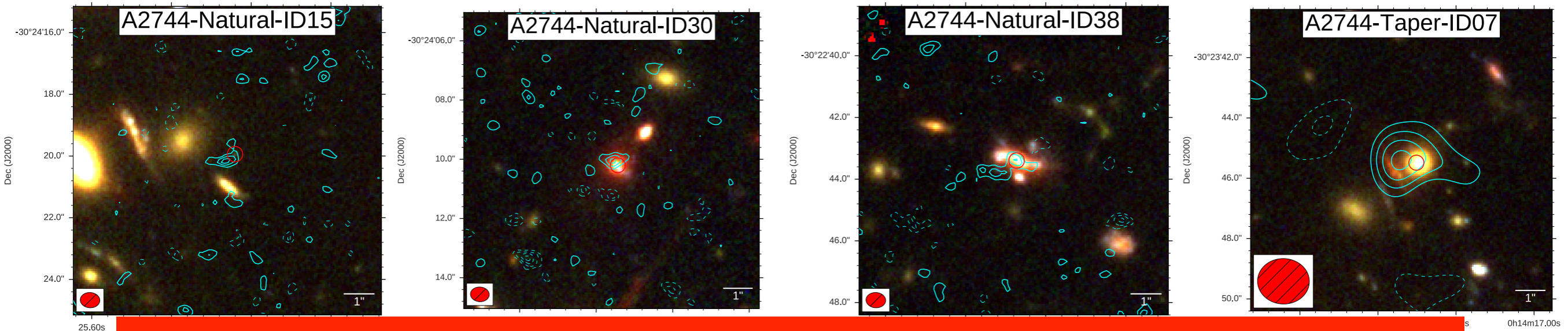
BRI1335-0417 ($z=4.4$)

González-López et al. 2018b in preparation

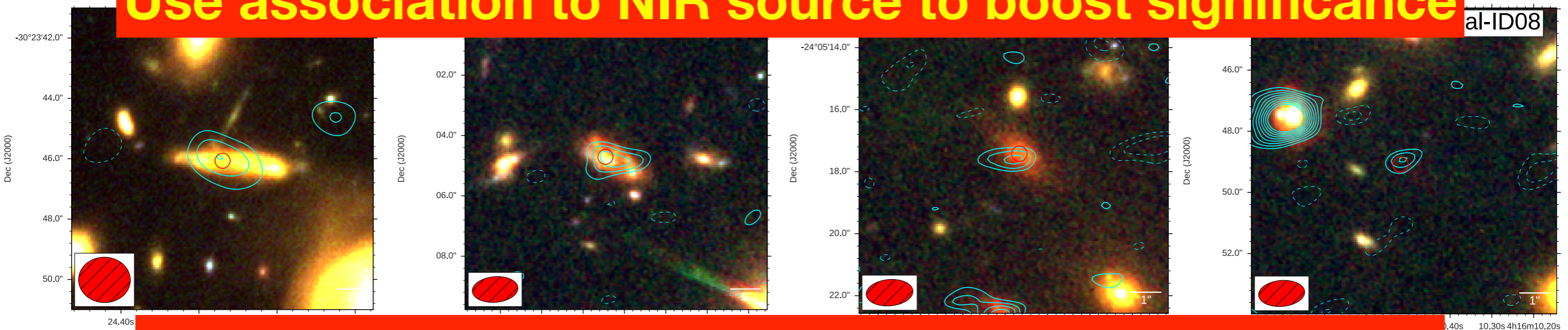


**What about lower
significance detections?**

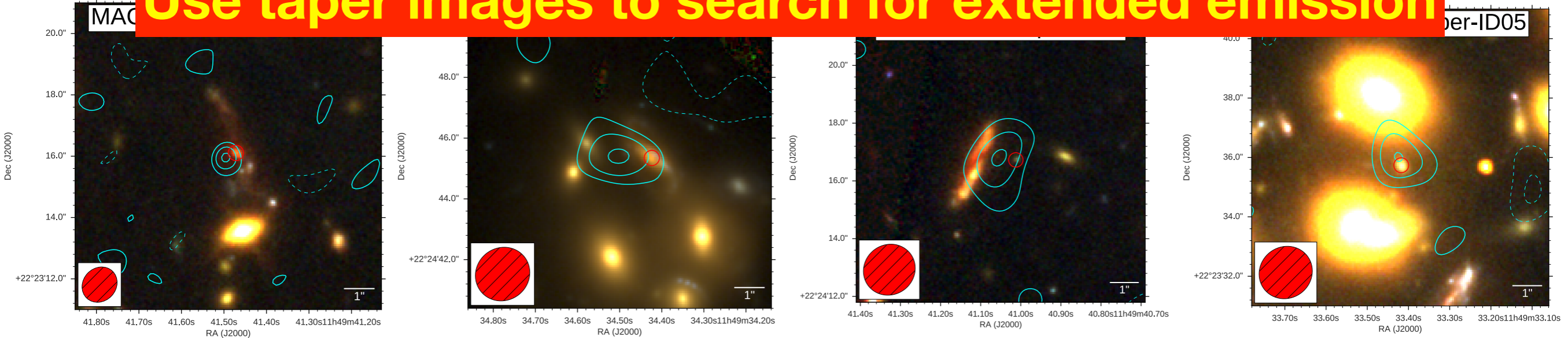
Work in progress ($3.5 < S/N < 5.0$)



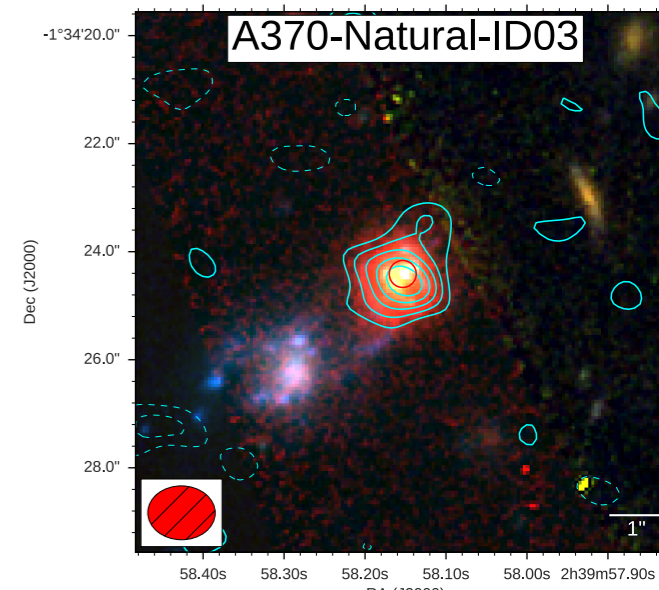
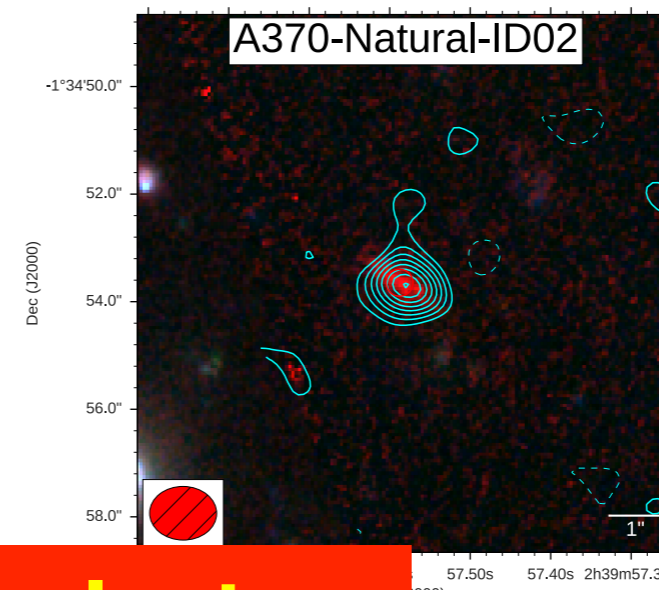
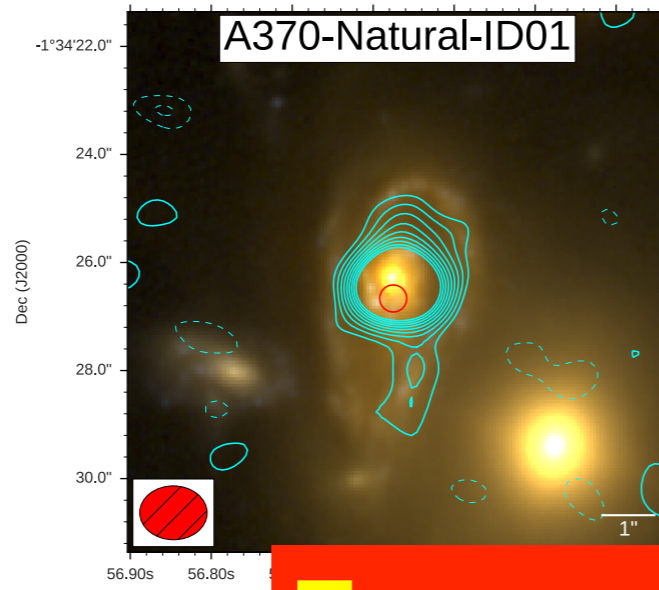
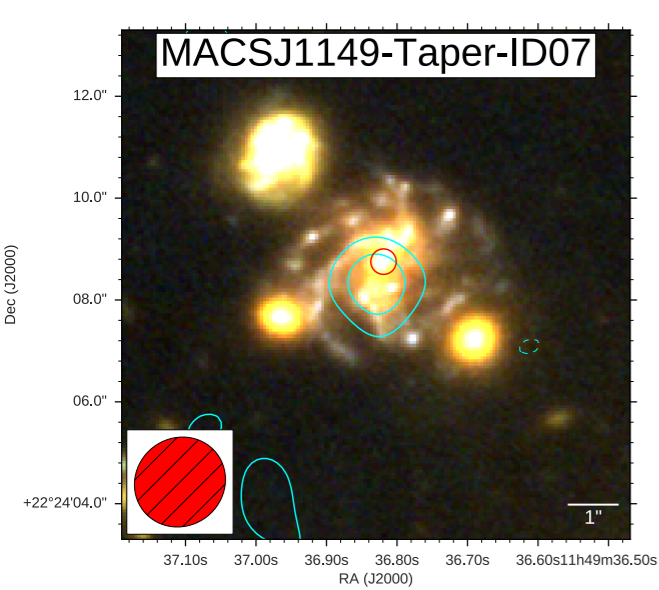
Use association to NIR source to boost significance



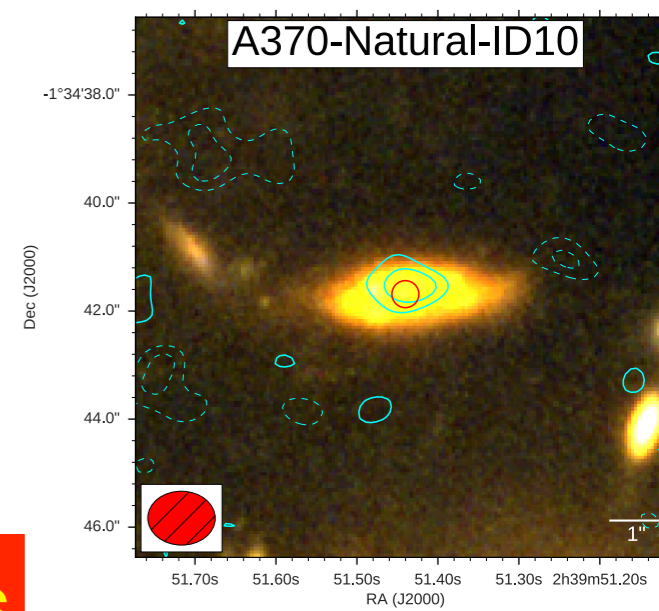
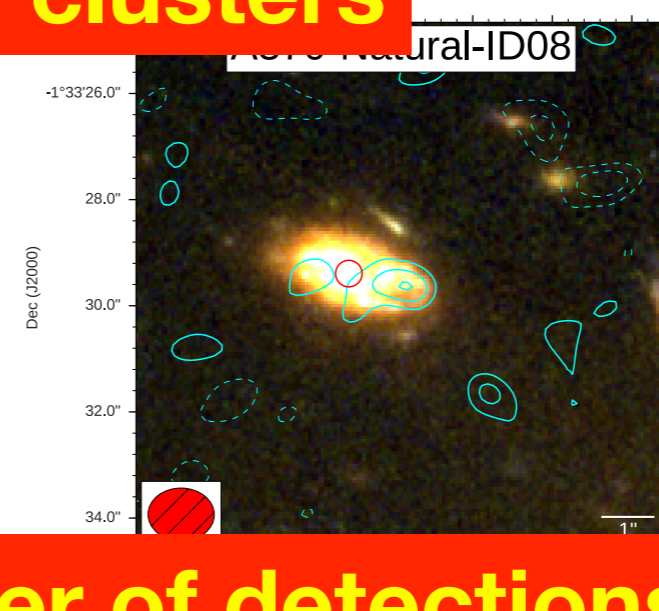
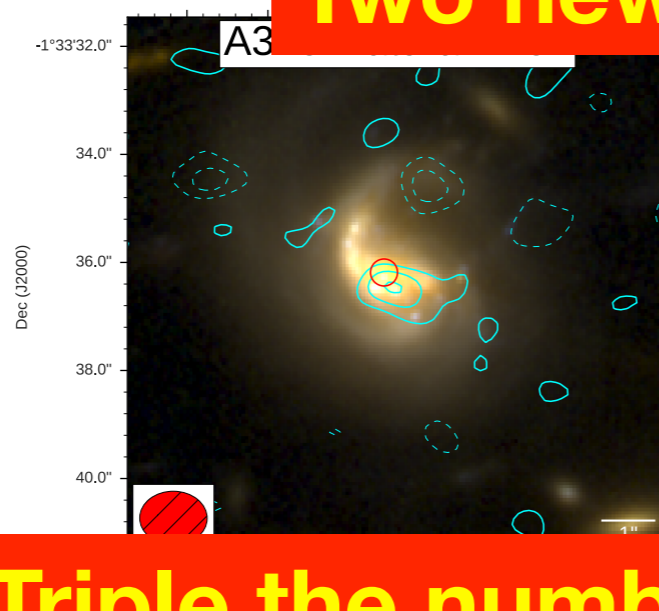
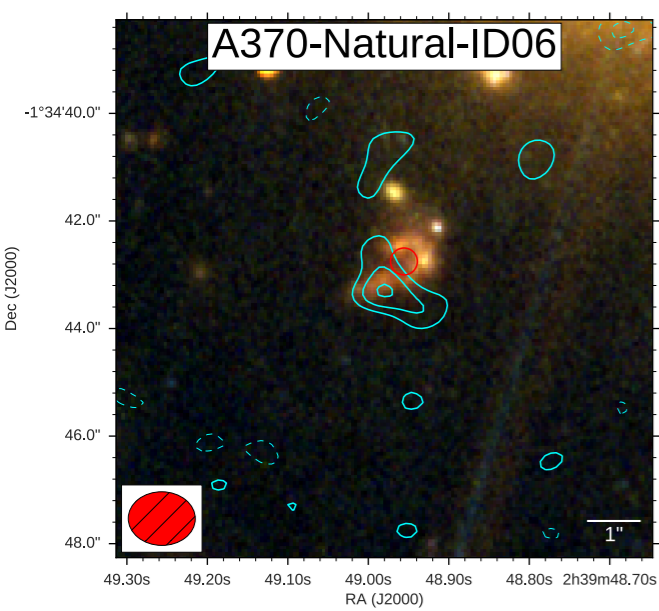
Use taper images to search for extended emission



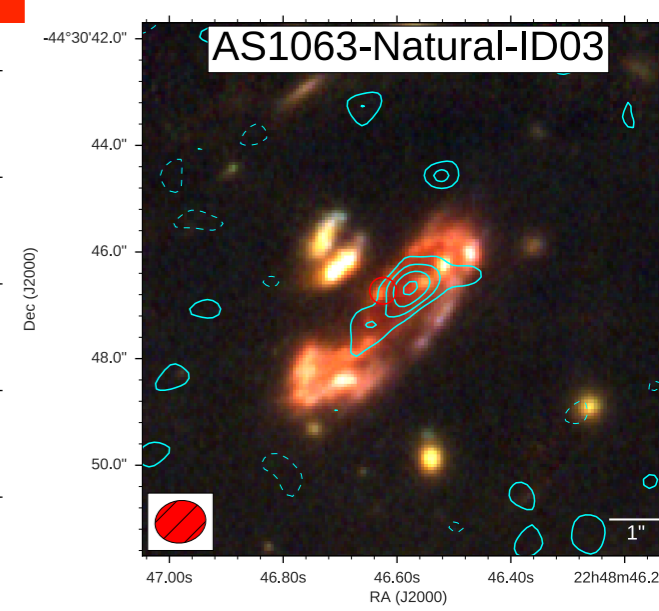
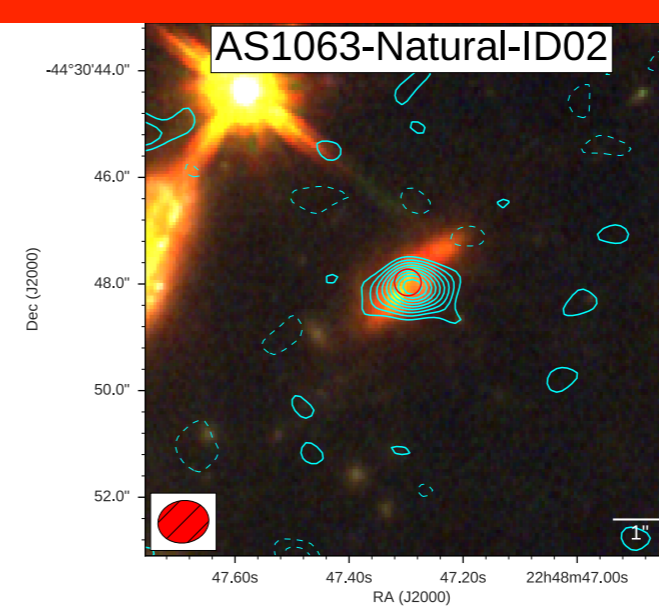
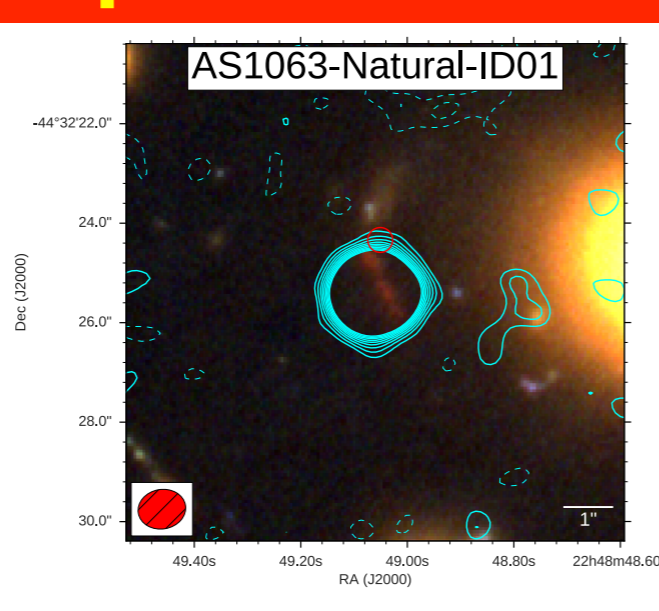
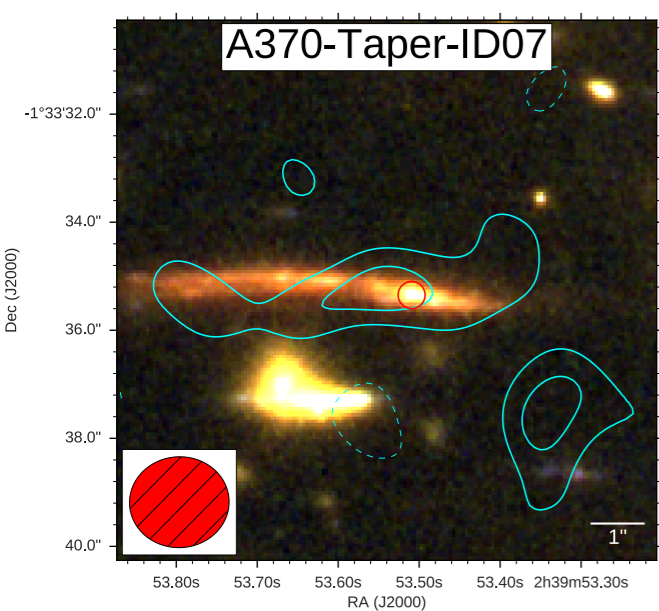
Work in progress



Two new clusters



Triple the number of detections

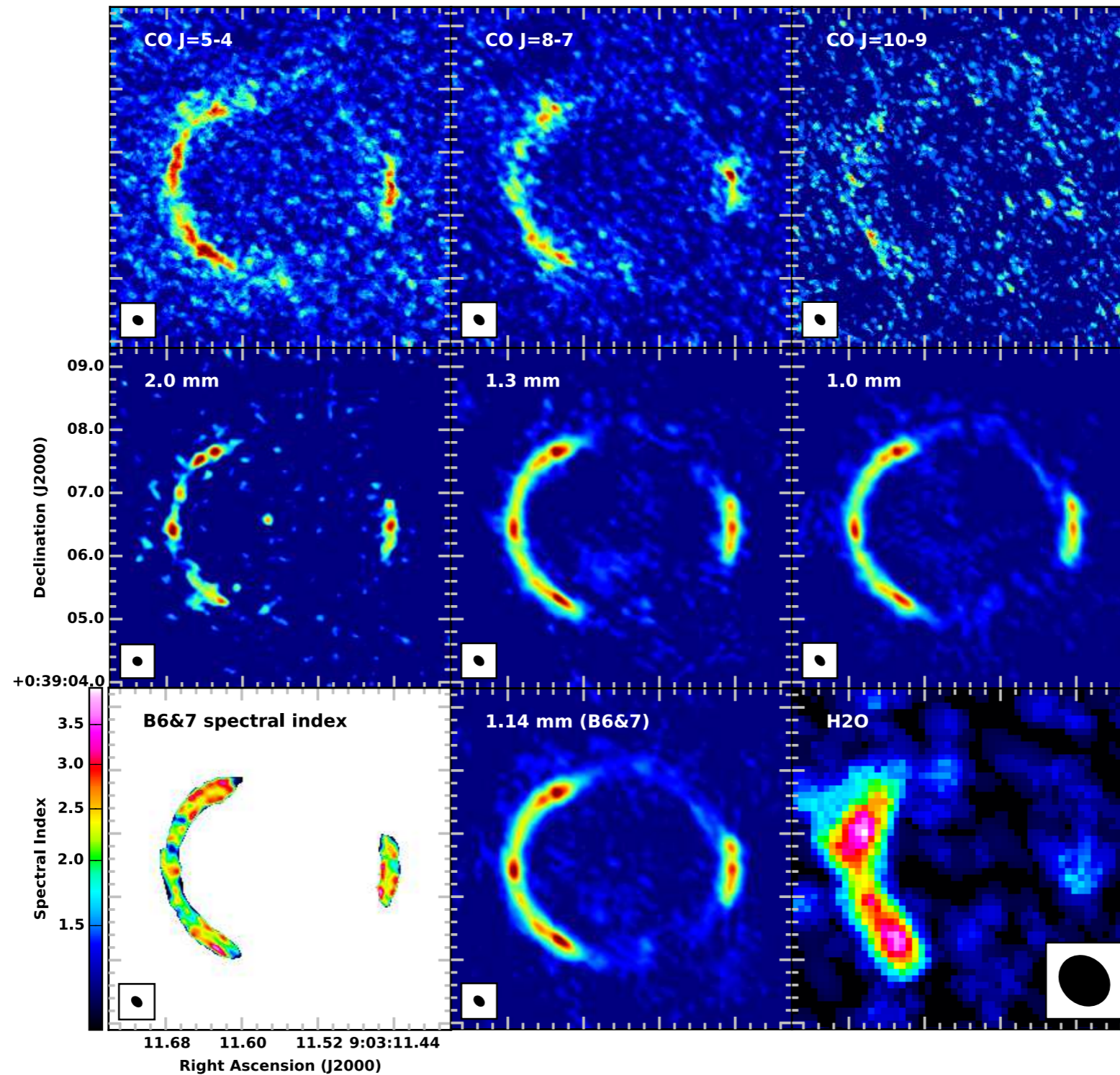


**Pushing the limits with
lensed gravitational arcs**

SDP.81 ($z=3.04$)

**Strongly lensed
SMG**

ALMA Partnership et al. 2015

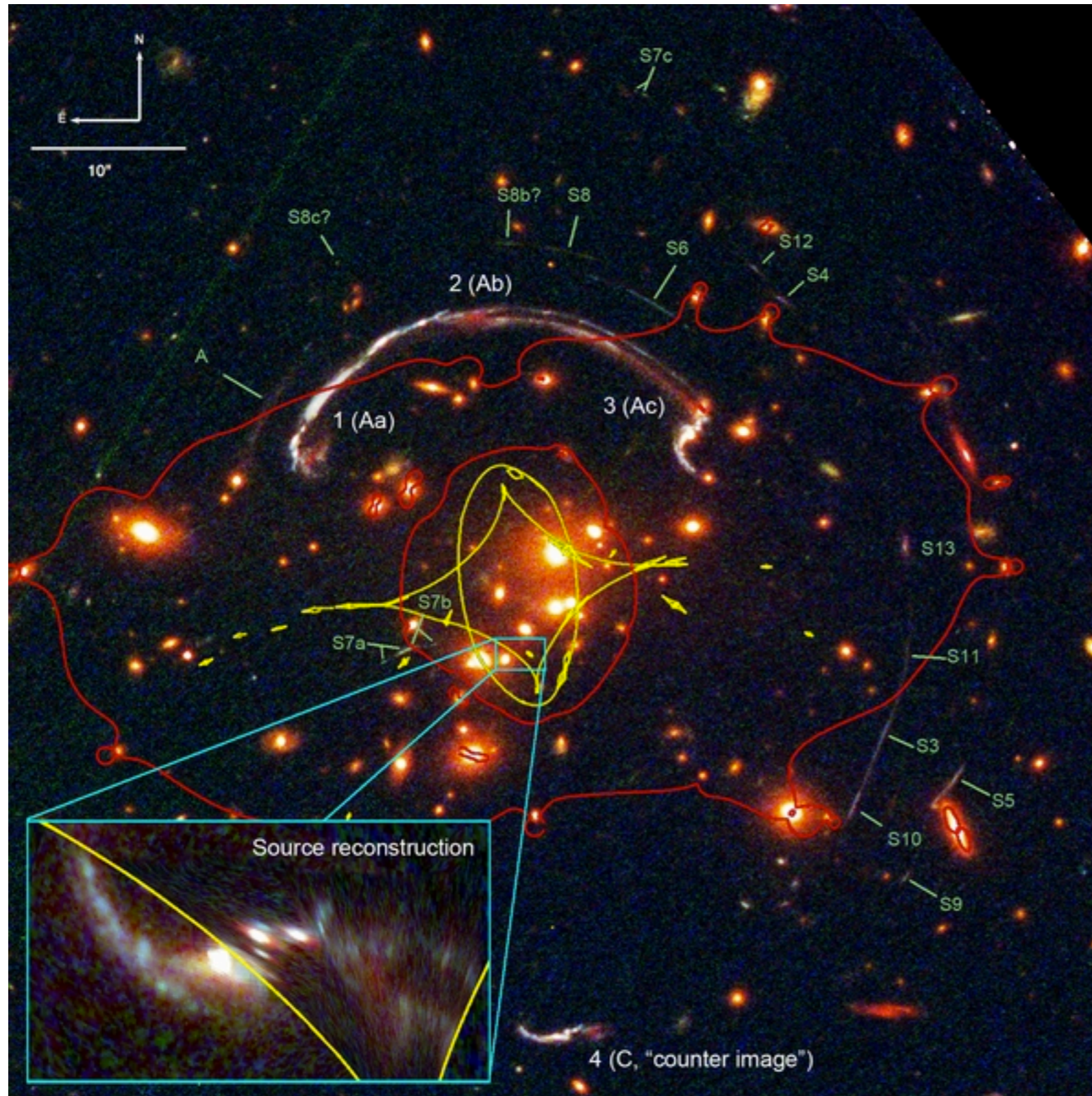


RCS0327 ($z=1.7$)

Sharon et al. 2012

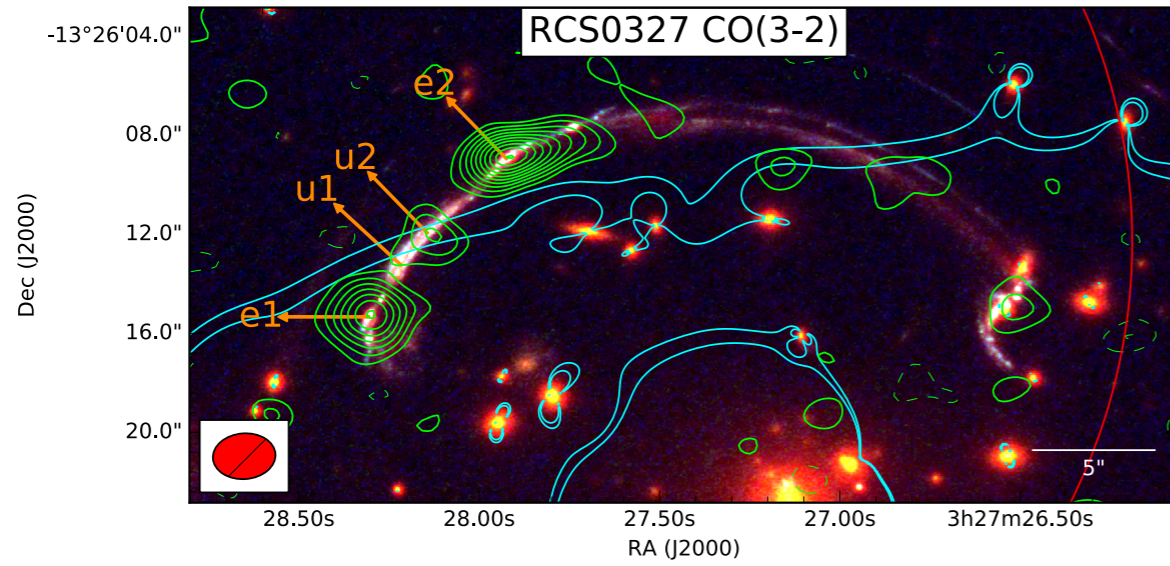
**Second brightest
optical giant arc**

**Low-metallicity
starburst**

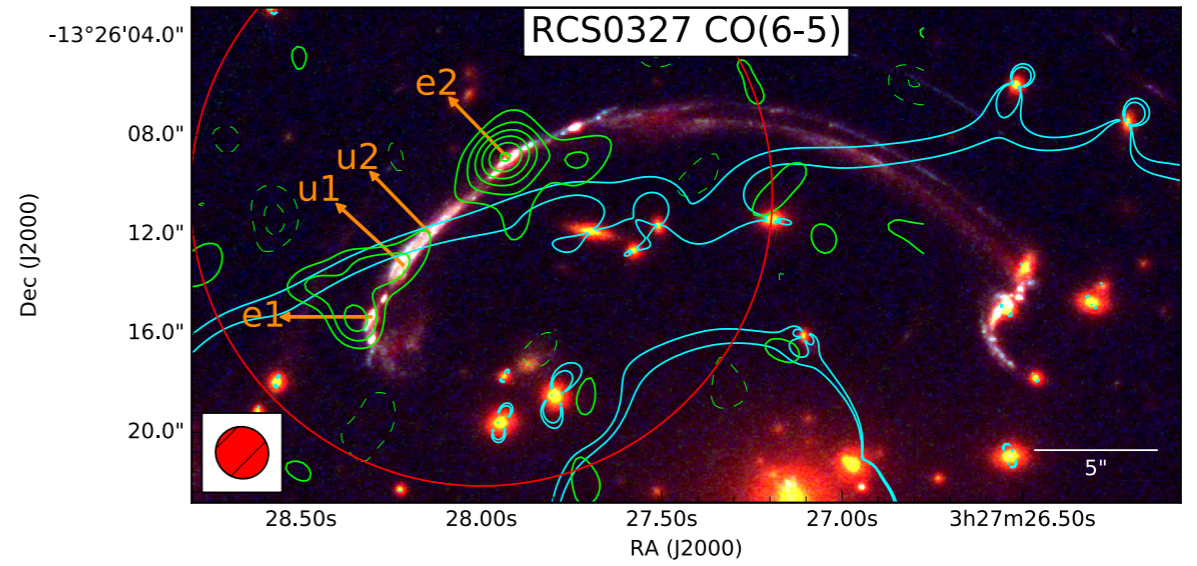


RCS0327 ($z=1.7$)

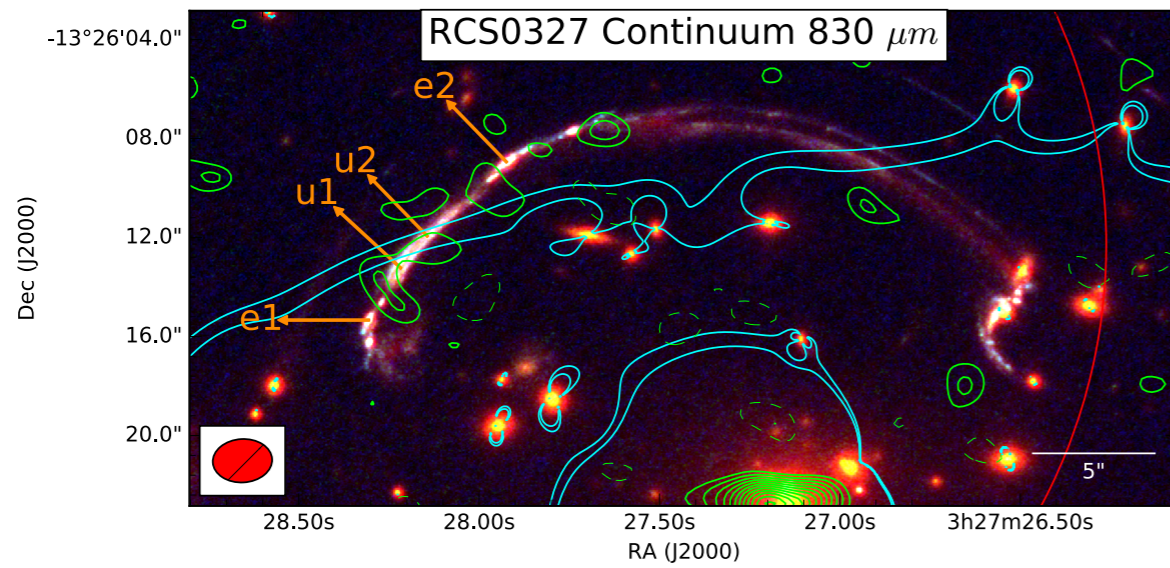
González-López et al. 2017b



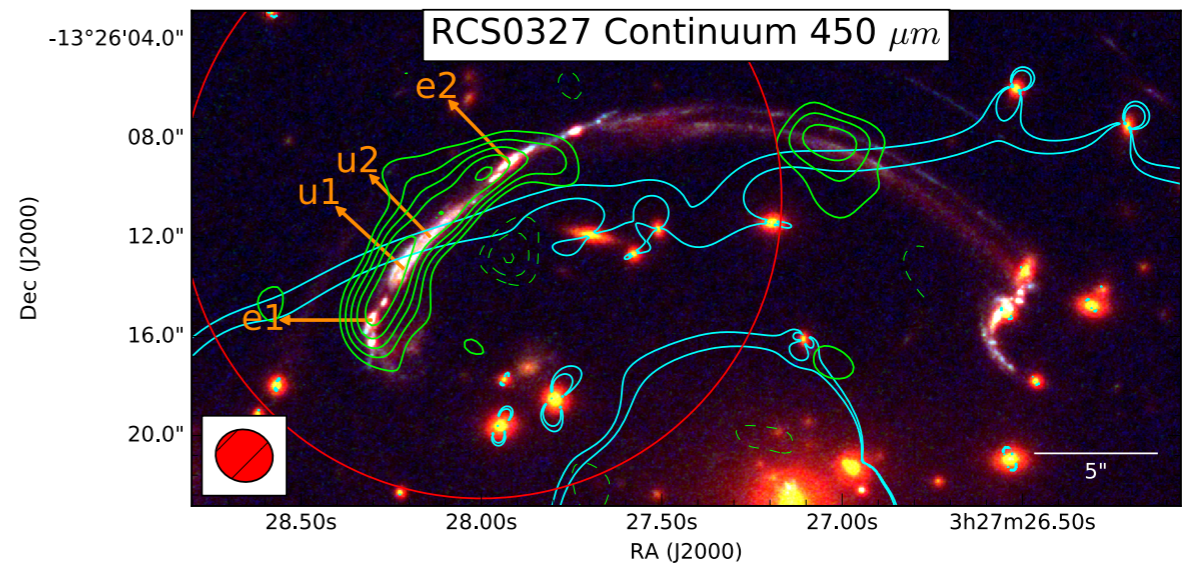
(a)



(b)



(c)

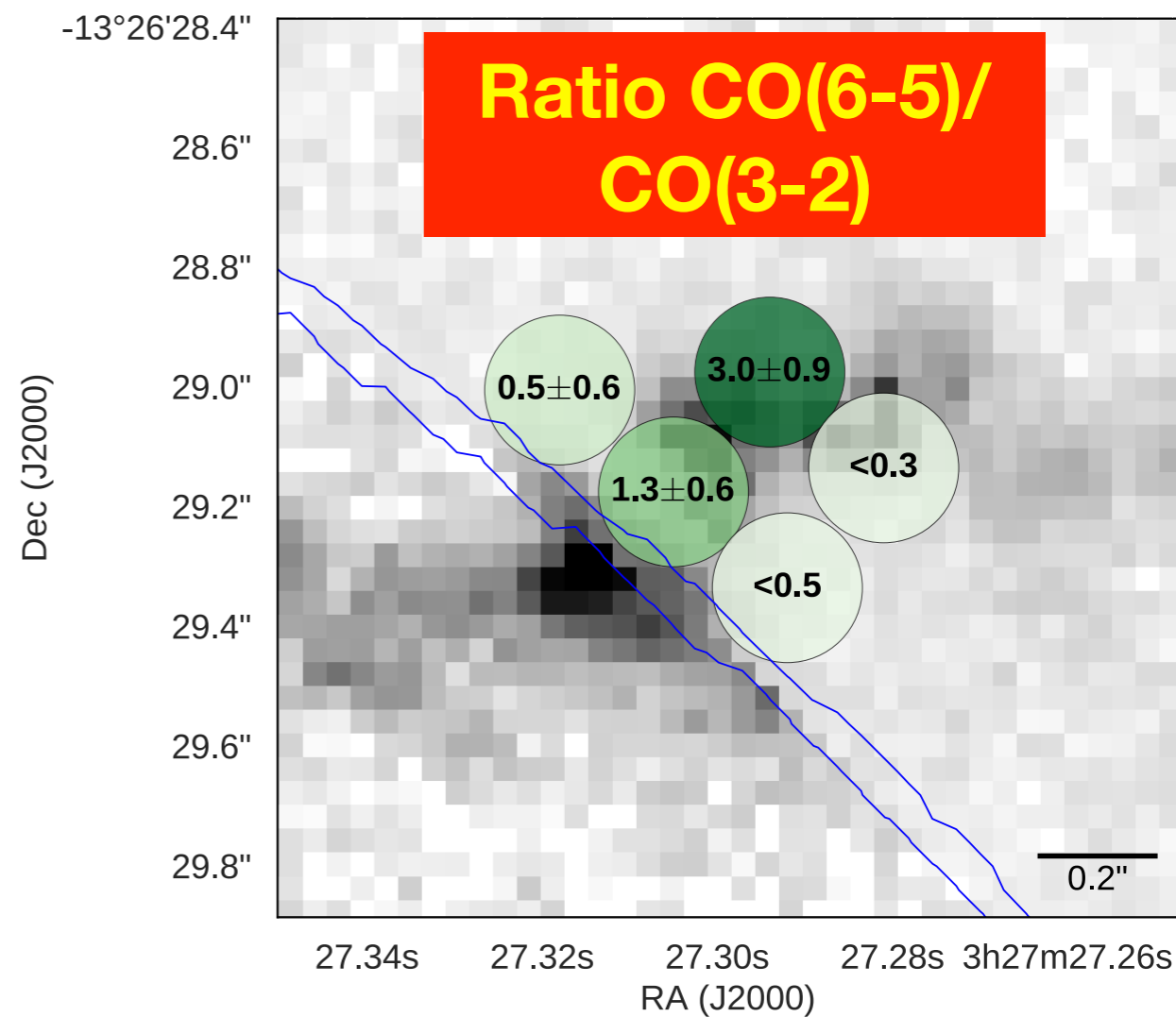
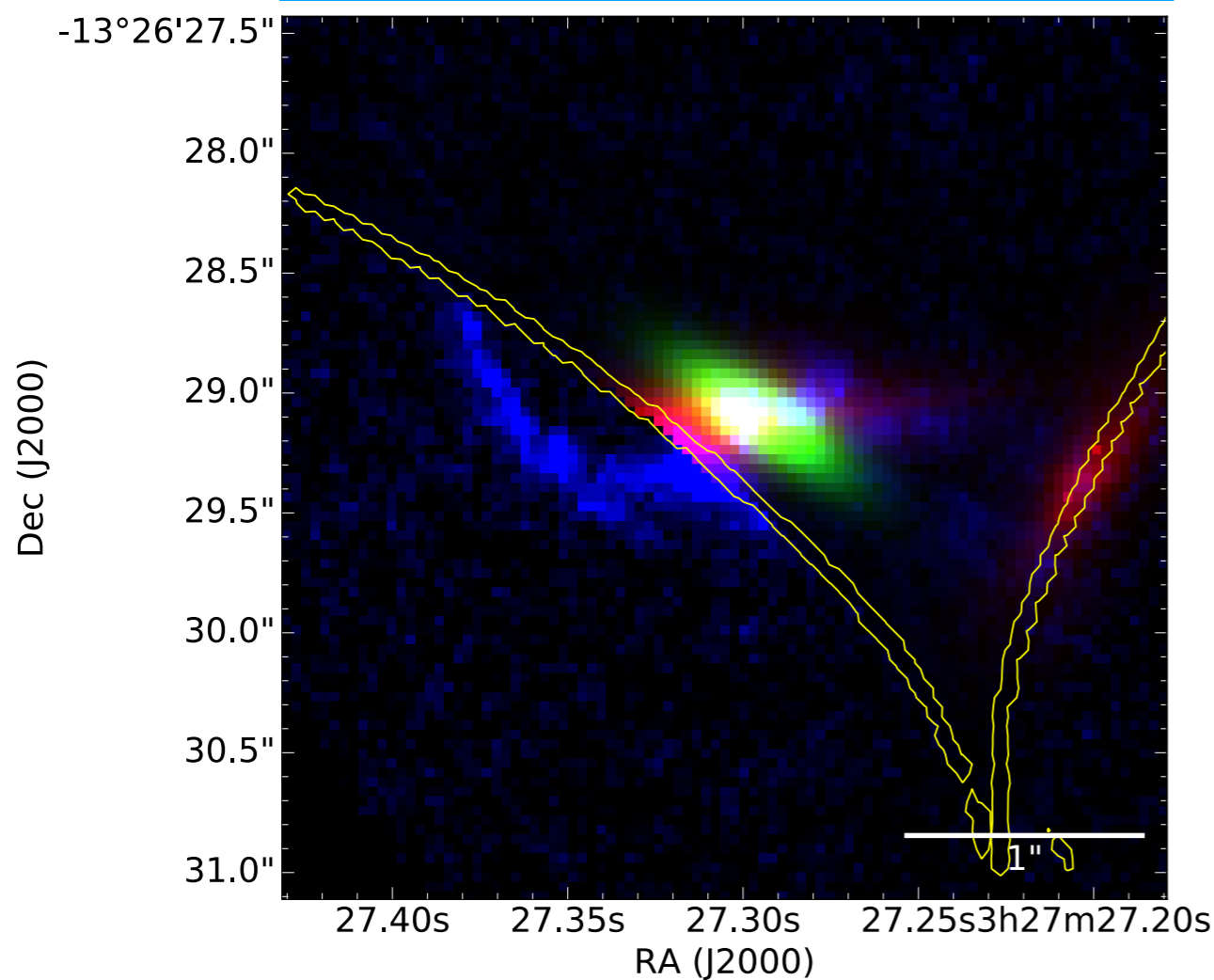


(d)

RCS0327 (z=1.7)

González-López et al. 2017b

Gas follows star-forming regions



Blue: UV

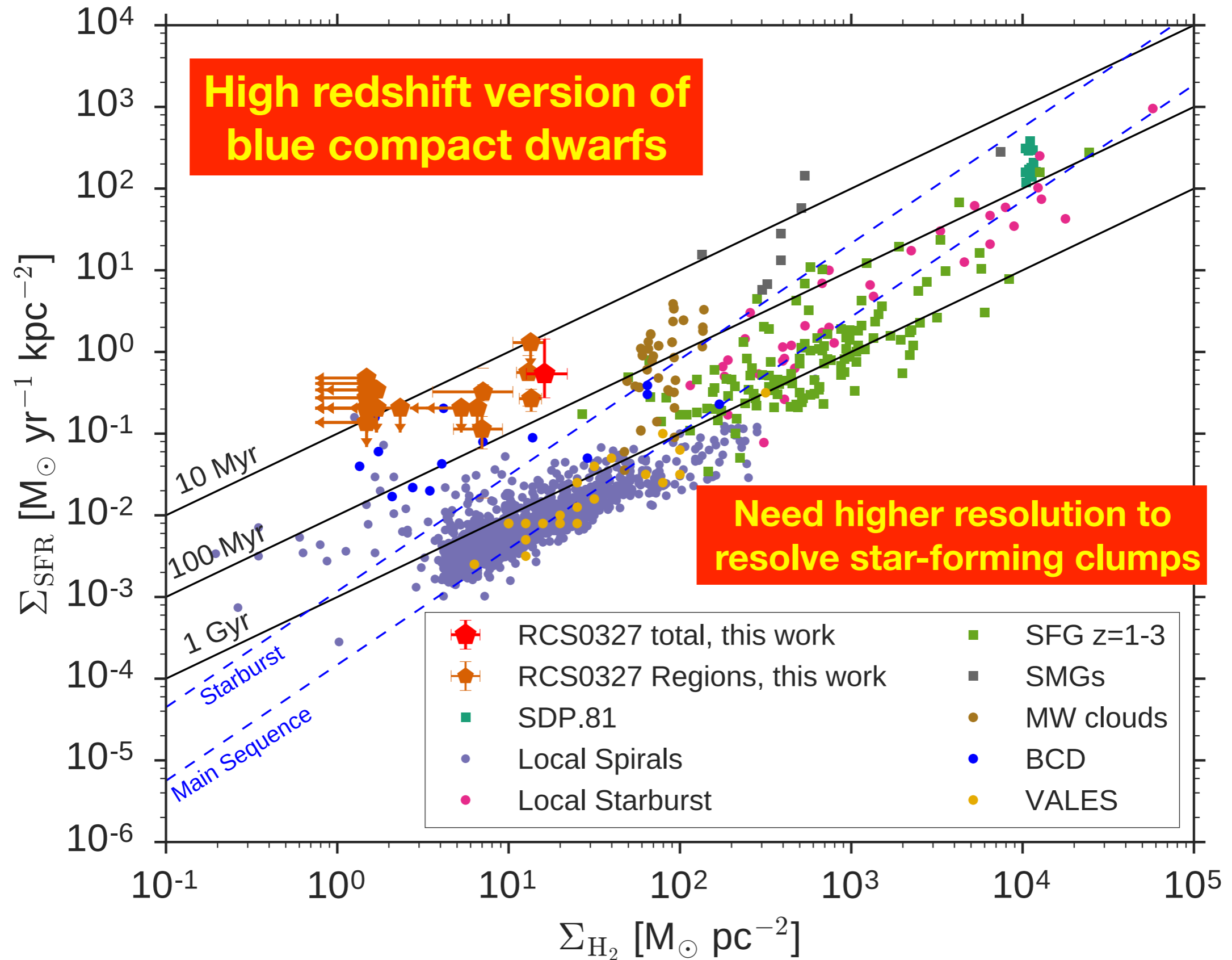
Red: Continuum

Green: CO(3-2)

Higher CO excitation towards star-forming clumps

RCS0327 (z=1.7)

González-López et al. 2017b



Results to date from ALMA observations of strongly lensed galaxies.

- The continuum images reveal 12 detections with intrinsic flux densities between 0.1 and 1.7 mJy (magnification between ~2-5).
- The counterpart galaxies are consistent with most being massive main sequence galaxies with a median redshift of $z \sim 2$.
- The lensing corrected number counts are lower than other studies. This could be explained by cosmic variance or some missing extended flux. Two phase continuum emission?
- The ALMA Frontier Fields have proven to be useful in the search for emission lines in deep continuum ALMA observations.
- Strongly lensed galaxies offer unique opportunity to resolved the interstellar medium of high redshift galaxies.