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Gas distribution in a strongly lensed "normal" galaxy at z~2

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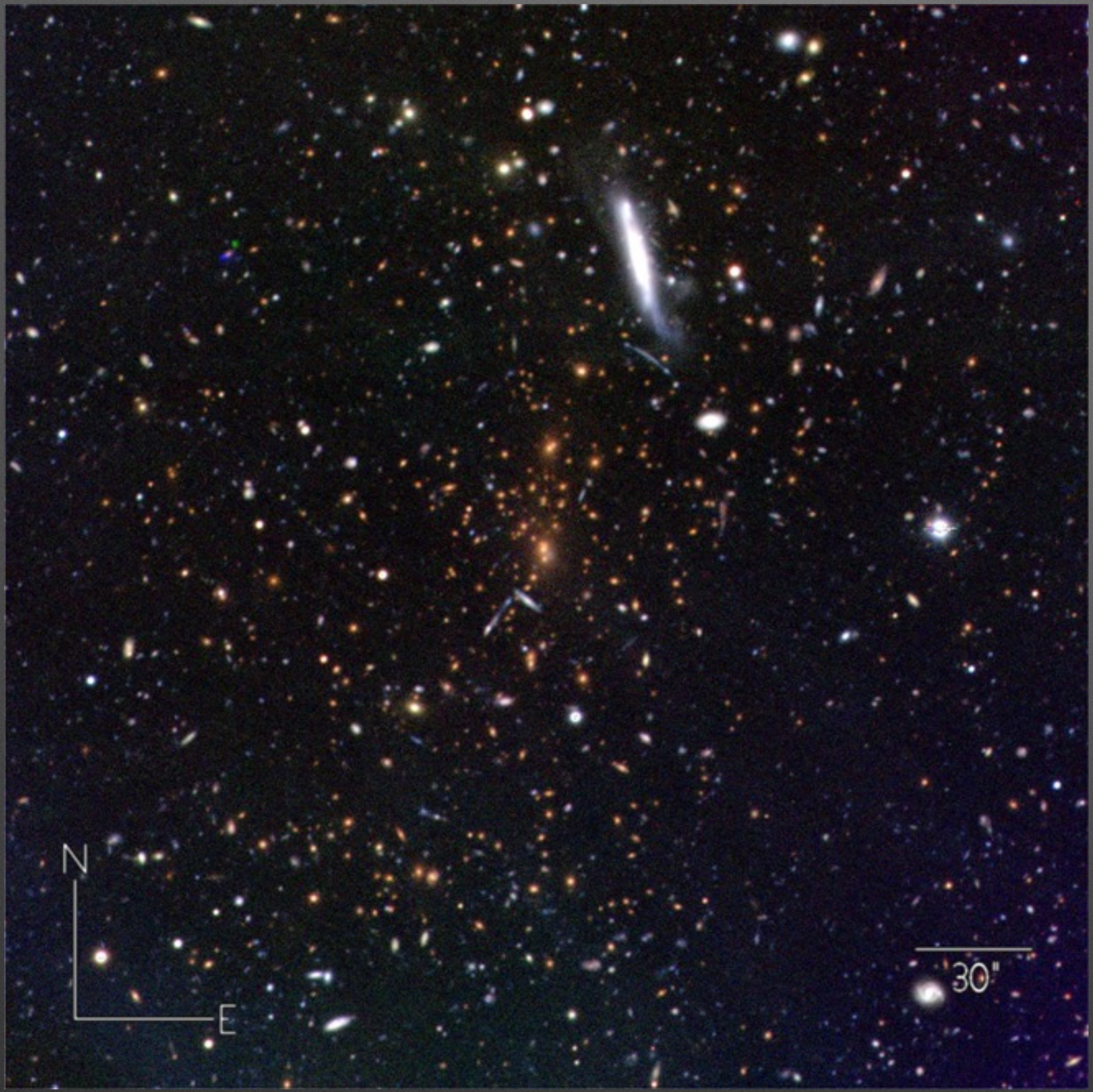
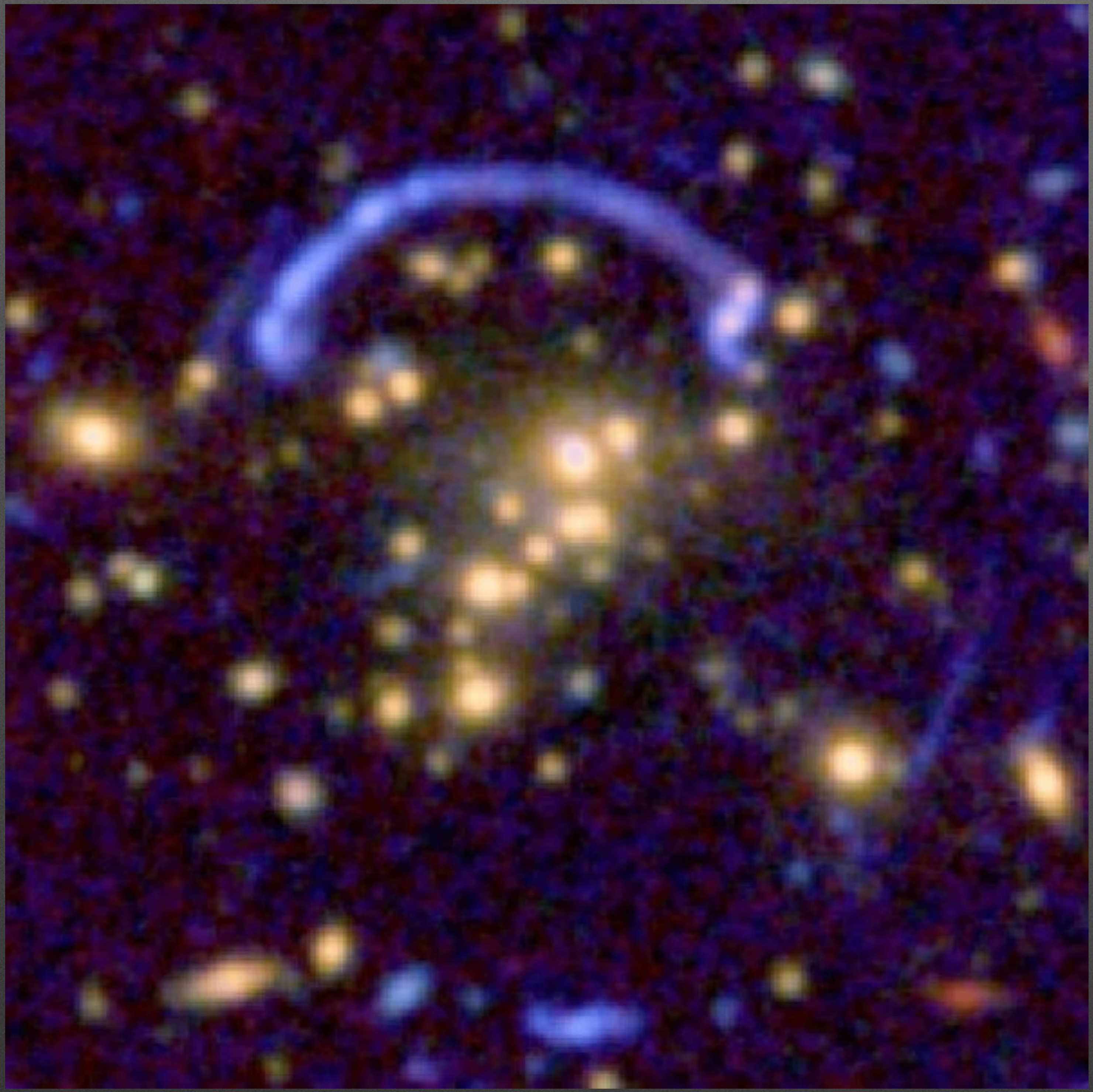


RCS2 J232727.6-020437
M ~3×10^{15} $M_{\odot}$, z = 0.7

Sharon et al. 2015



One of the brightest arcs known

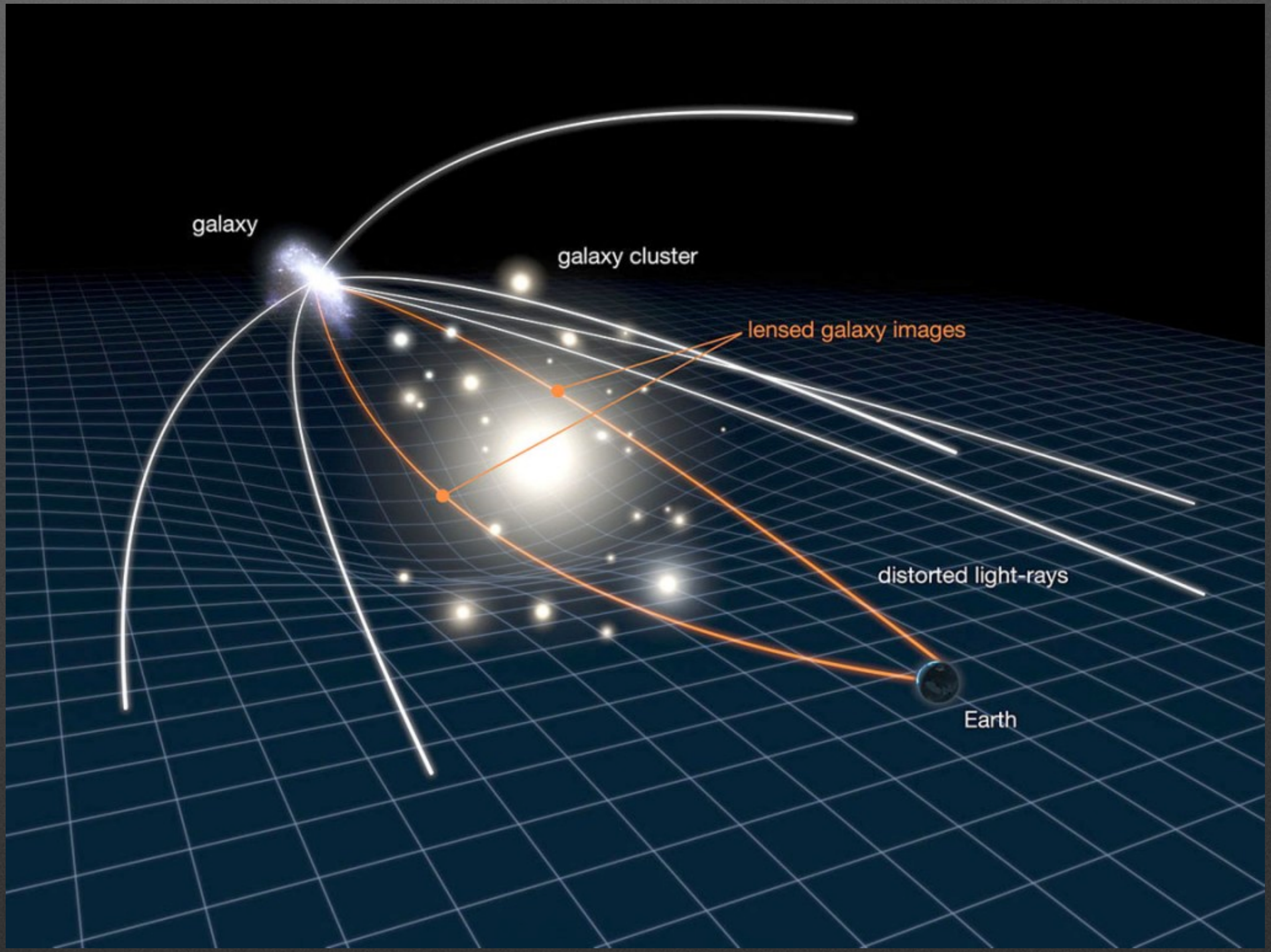
RCS2 J032727-132627
M ~10^{15} $M_{\odot}$, z_{CL} = 0.56

Wuyts et al. 2010

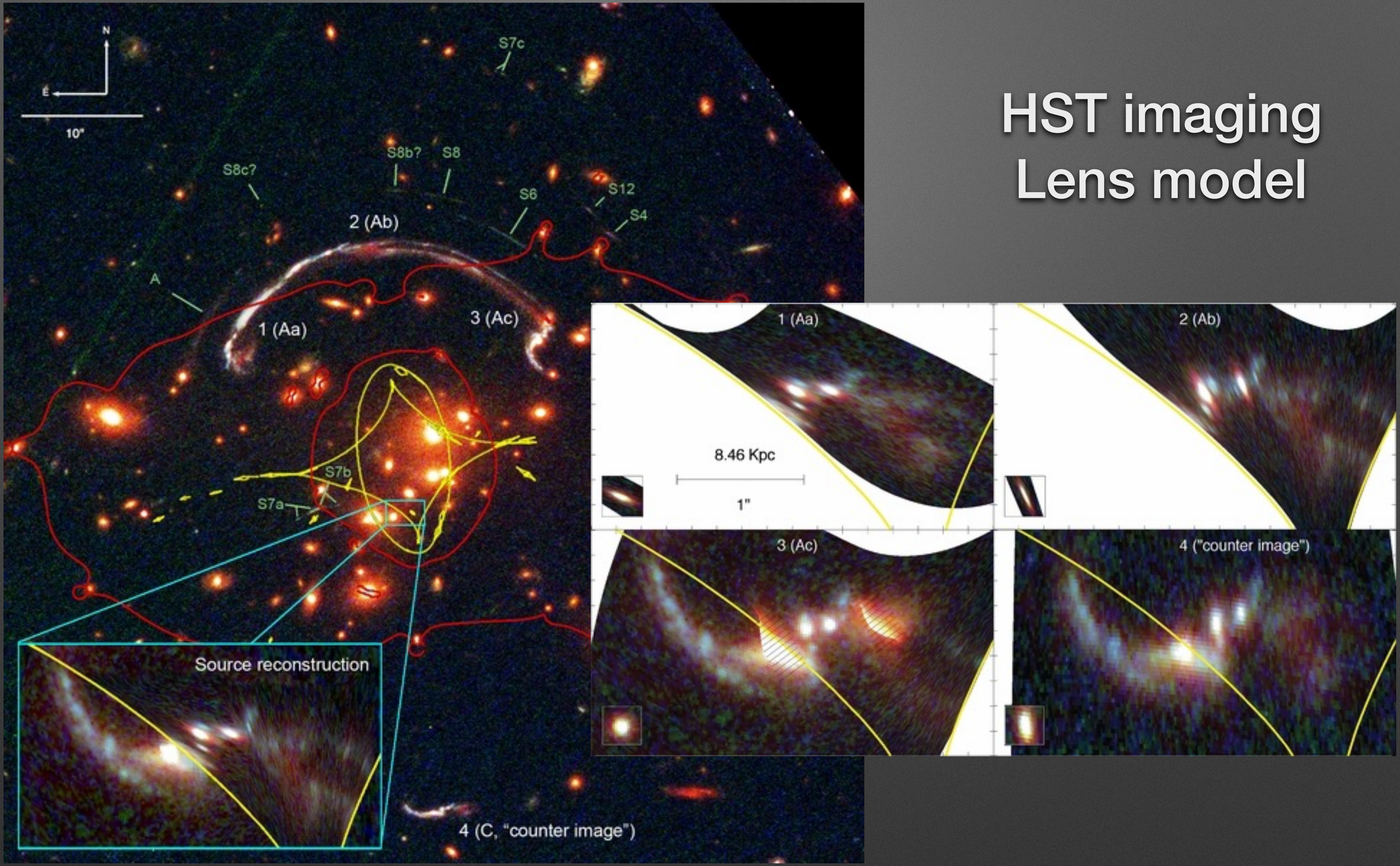
z_{arc} = 1.7, r_{AB} = 19.1
38” length in 4 images
u ~ < 30x > from 4x to 100x

Strong lensing depends on three elements

1. The lens - here the cluster of galaxies
2. The source - the distant galaxy
3. The distances - cosmology

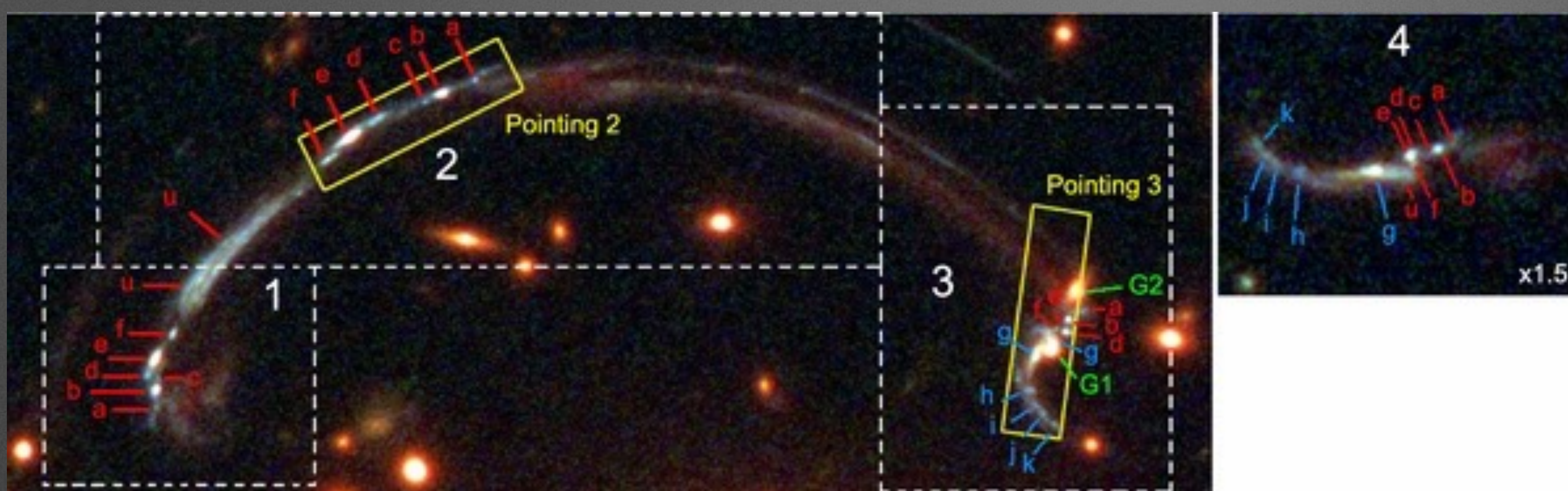


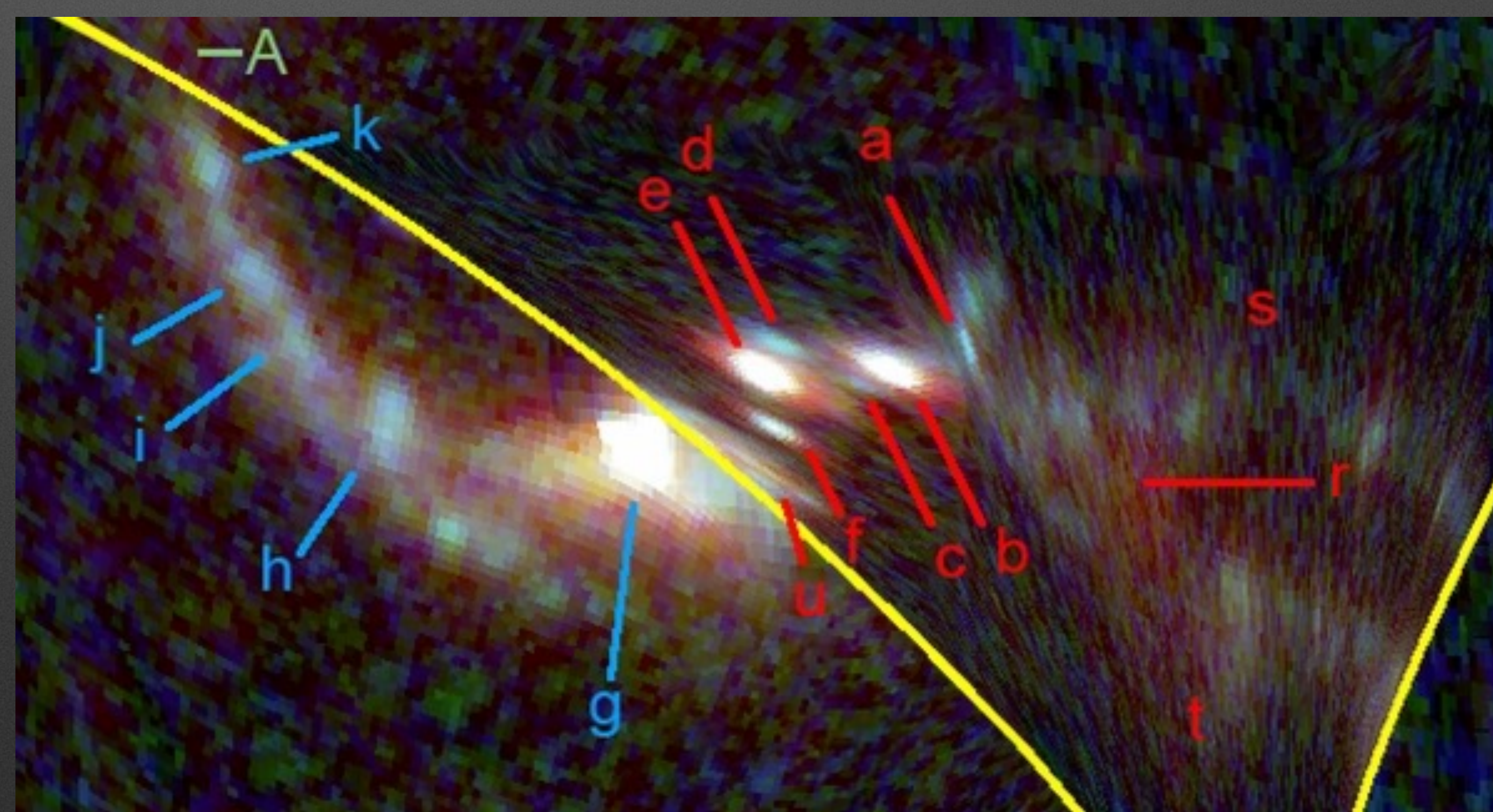
HST imaging
Lens model



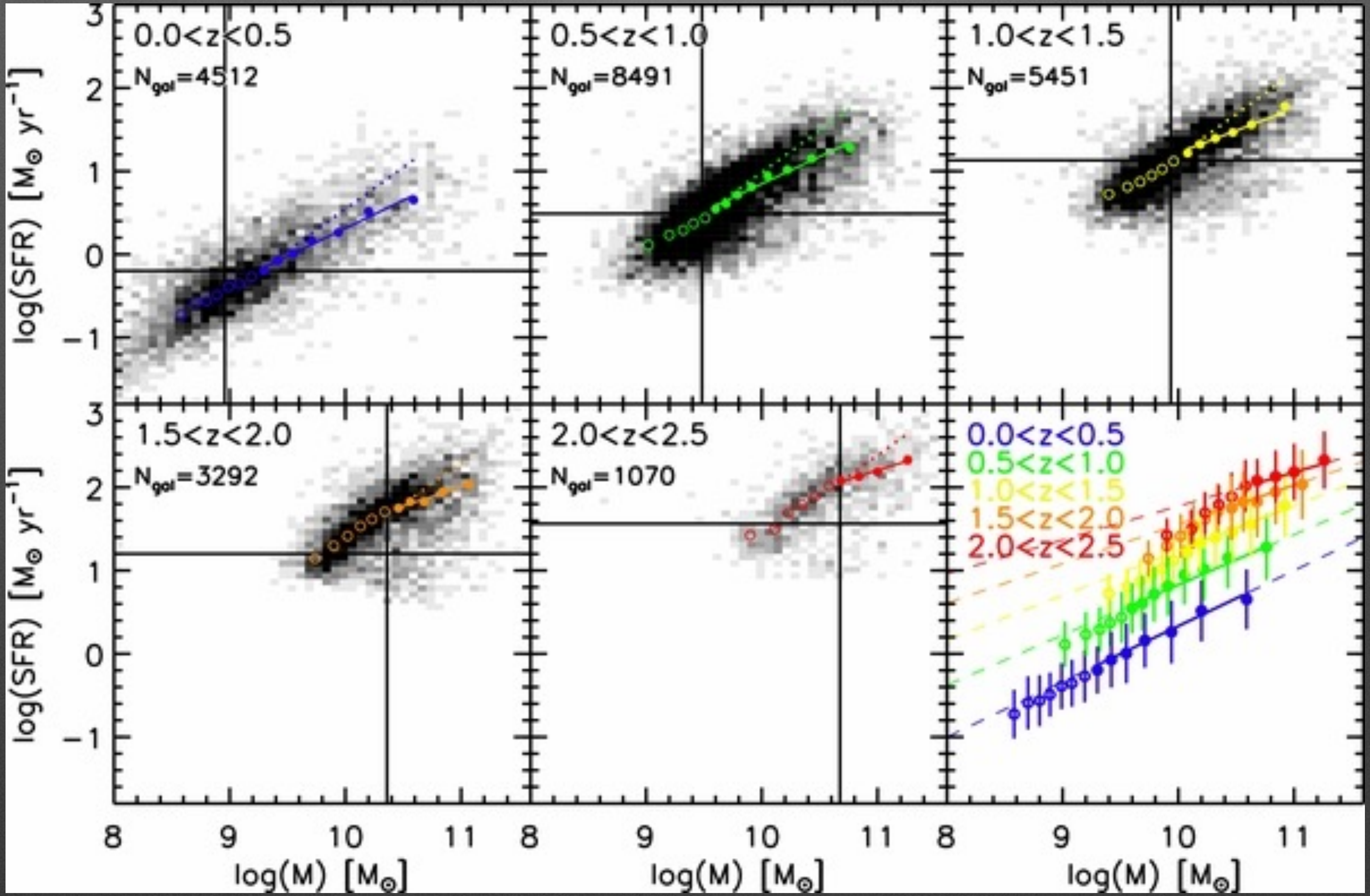
Sharon et al 2012

An accurate model allows us to study this galaxy in a x100 pc scale





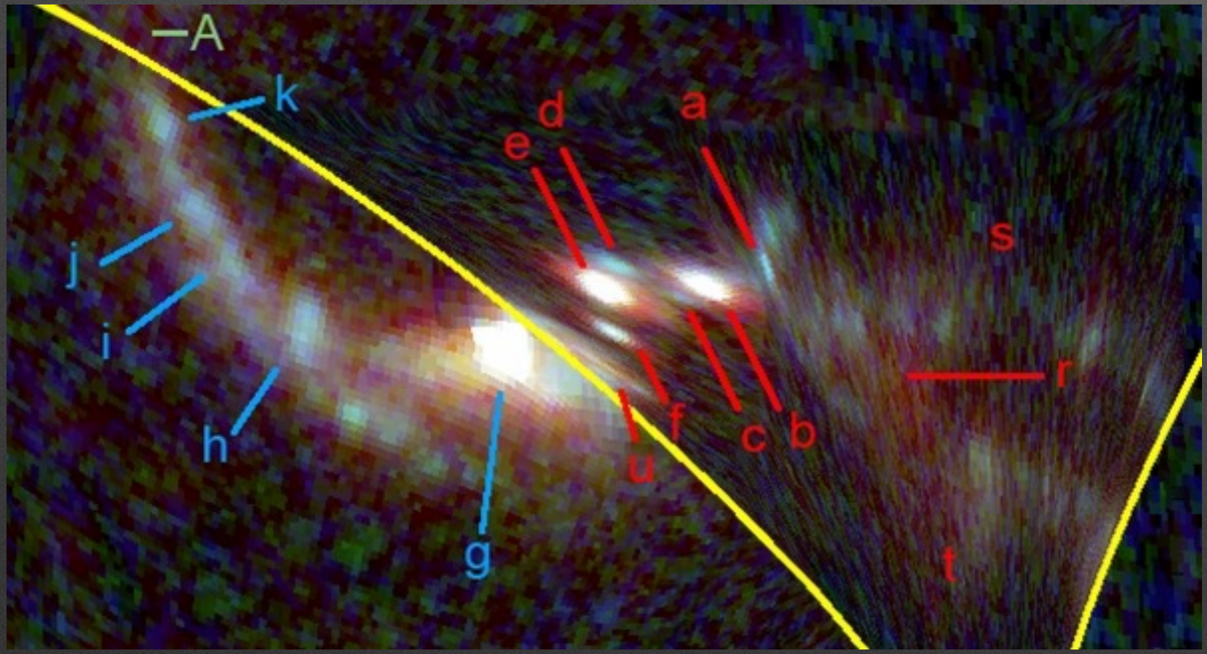
SFR mass sequence for star forming galaxies (integrated quantities)

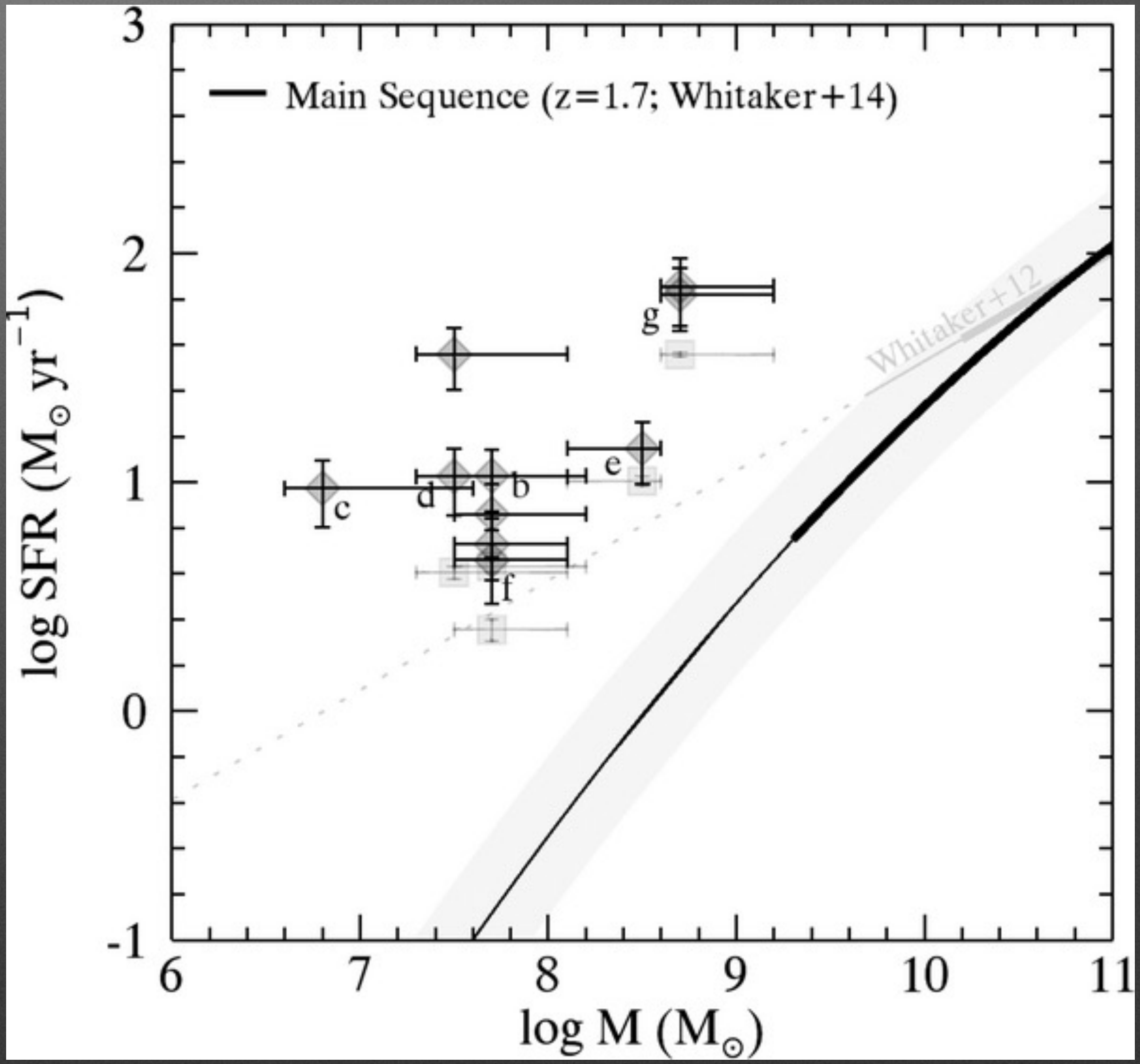


Whitaker et al 2012

RCS0327 provides an opportunity for probing low mass galaxies at high redshifts

*individual clumps





Whitaker et al 2014

- We conducted an ALMA program to map the dust and molecular gas in the RCS0327 arc, similarly to what has been done in the OIR

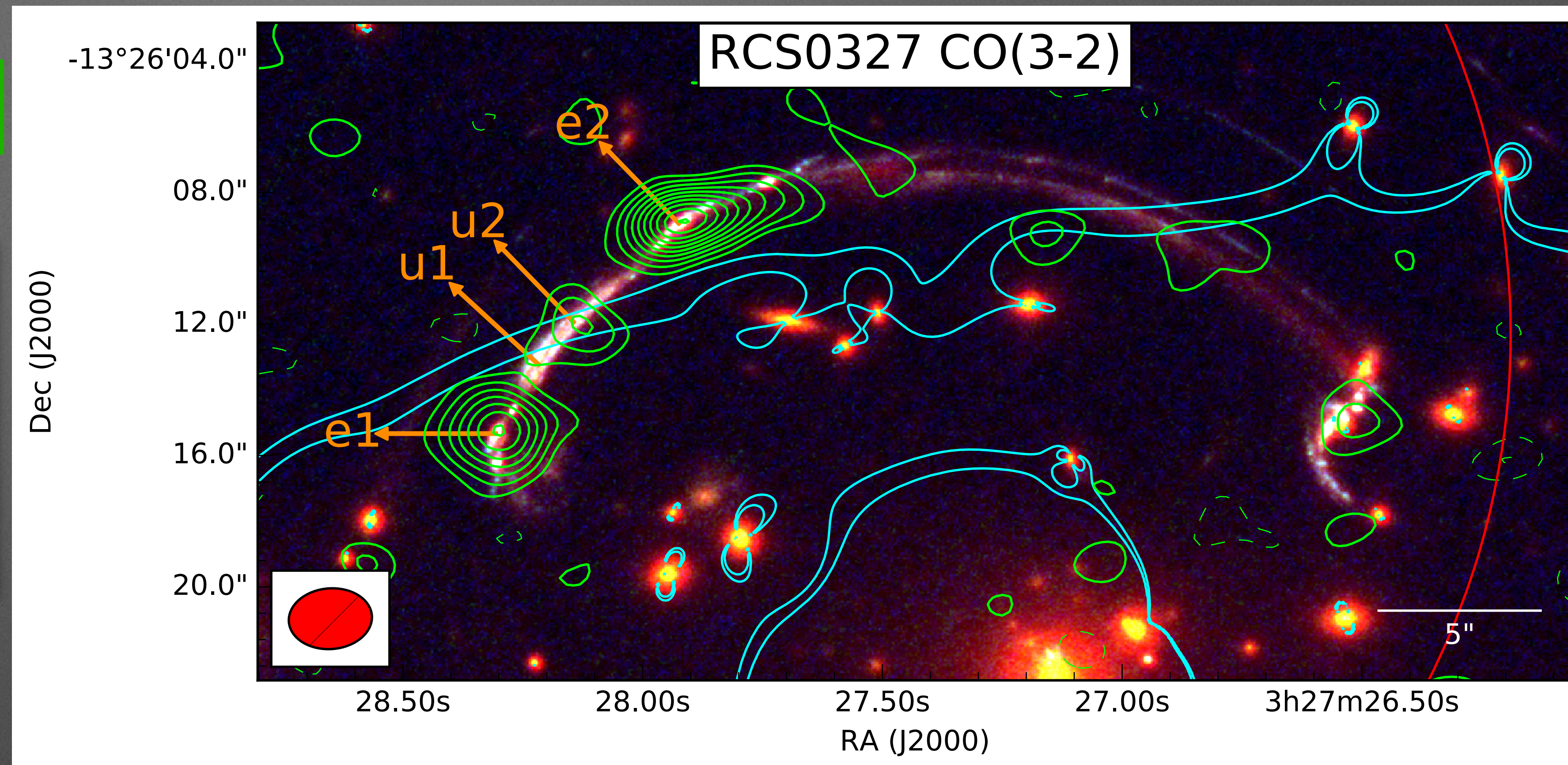
    - CO(3-2), CO(6-5), ~~CO(8-7) and [CII]~~

127.895 GHz Band 4

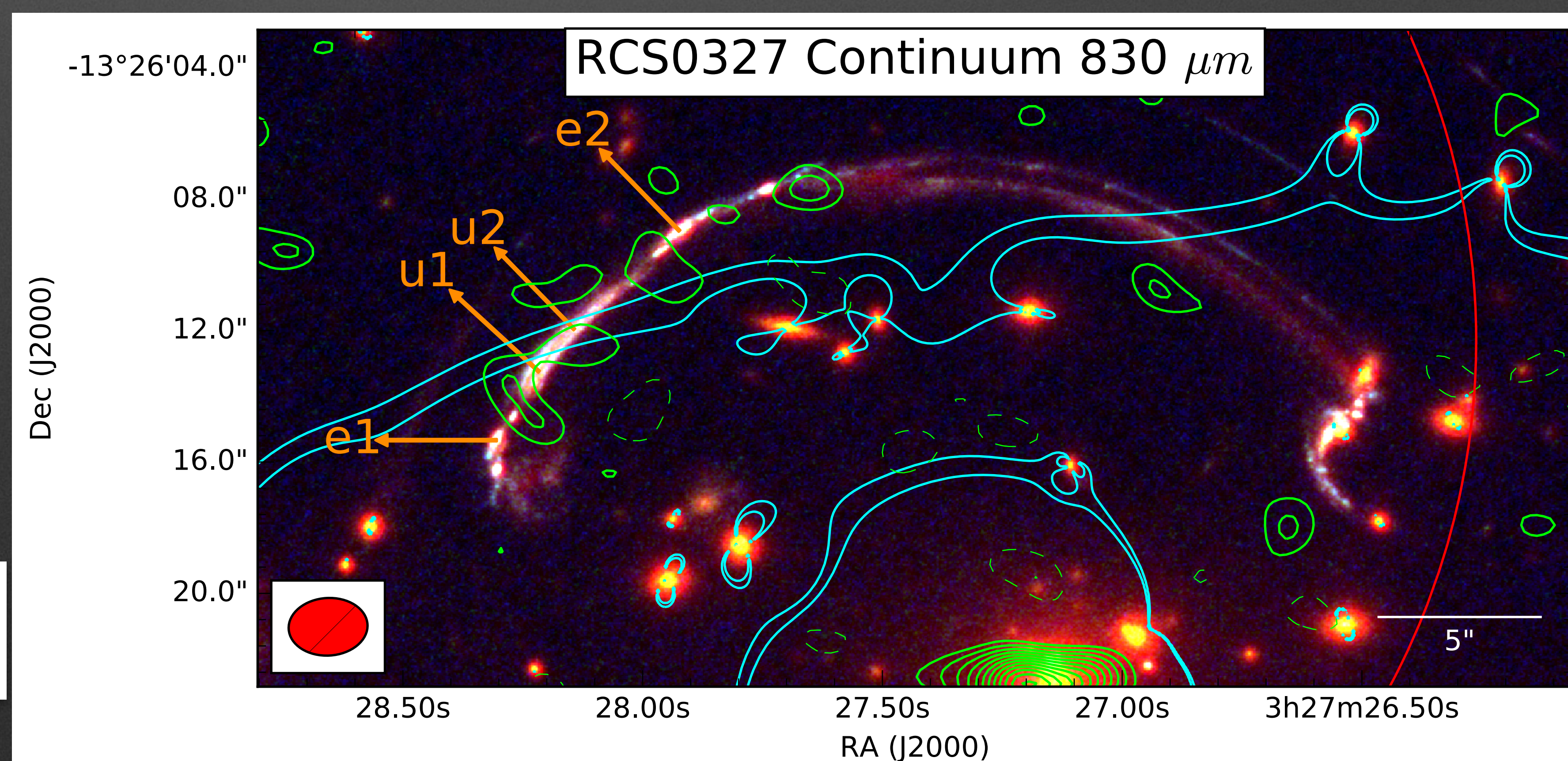
$$S_{\mathrm{CO(3-2)}} = 2.3 \pm 0.3\,\mathrm{mJy}$$

$$I_{\mathrm{CO(3-2)}} = 0.557 \pm 0.071\,\mathrm{Jy\,km\,s^{-1}}$$

$$dv \approx 239.3\,\mathrm{km\,s^{-1}}$$



$$\mathrm{S}_{875\,\mu m} = 141 \pm 31\,\mu\mathrm{Jy}.$$



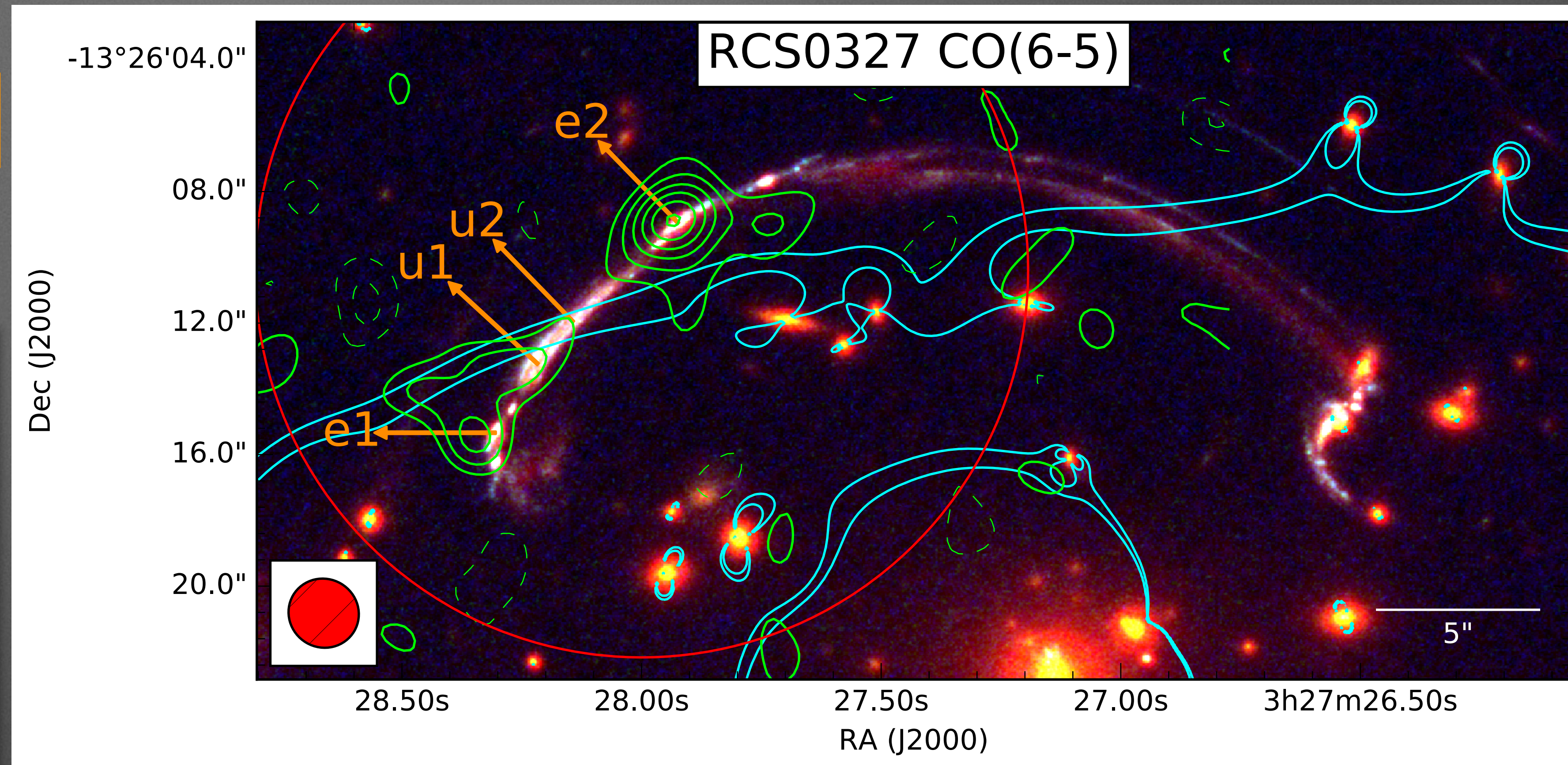
$$2.54'' \times 1.85''$$

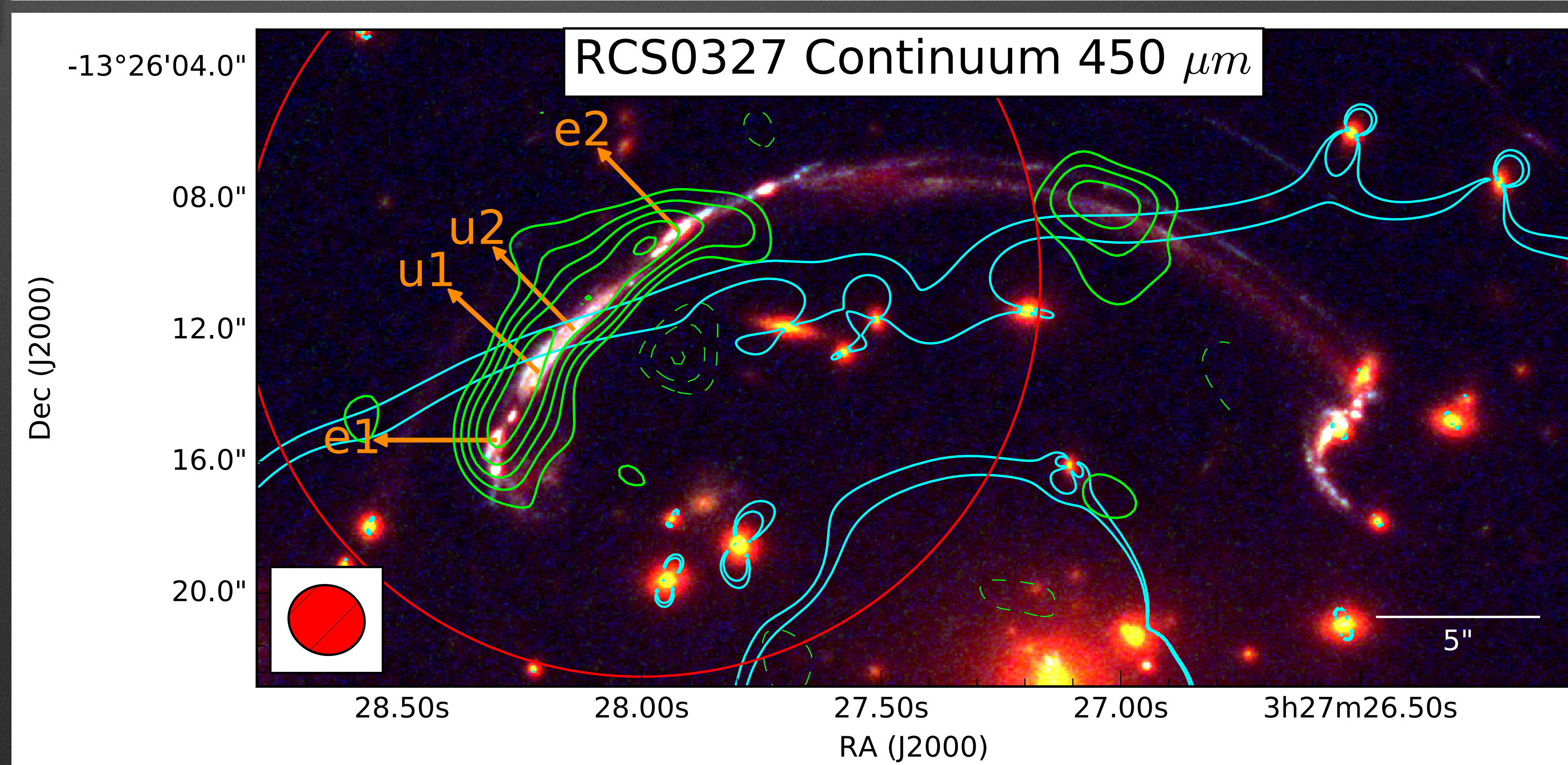
255.746 GHz Band 6

$$S_{\mathrm{CO}(6-5)} = 3.7 \pm 0.3\,\mathrm{mJy}$$

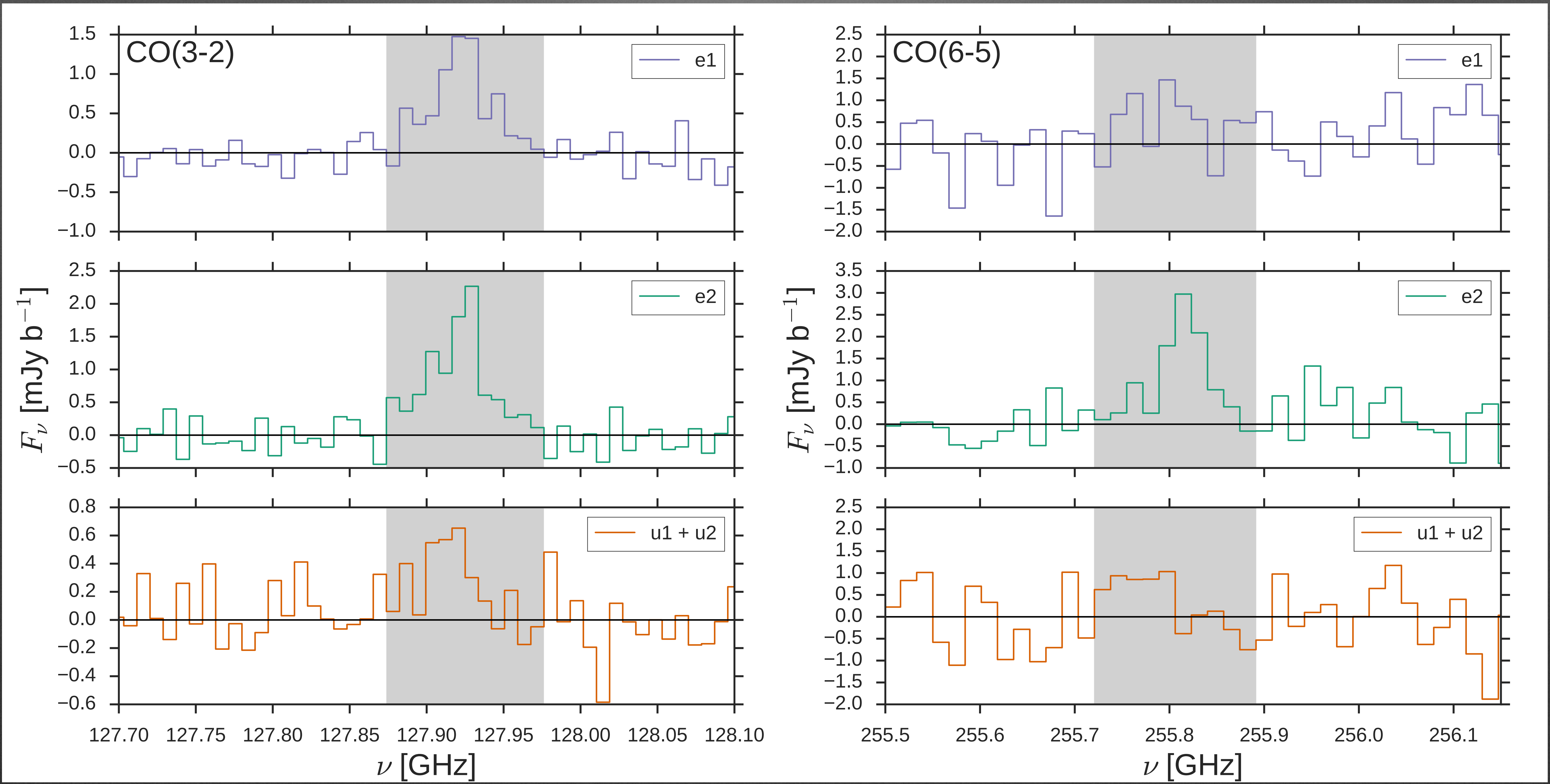
$$I_{\mathrm{CO}(6-5)} = 0.885 \pm 0.117\,\mathrm{Jy\,km\,s^{-1}}$$

$$\mathrm{S}_{450\,\mu m} = 960 \pm 98\,\mu\mathrm{Jy}$$

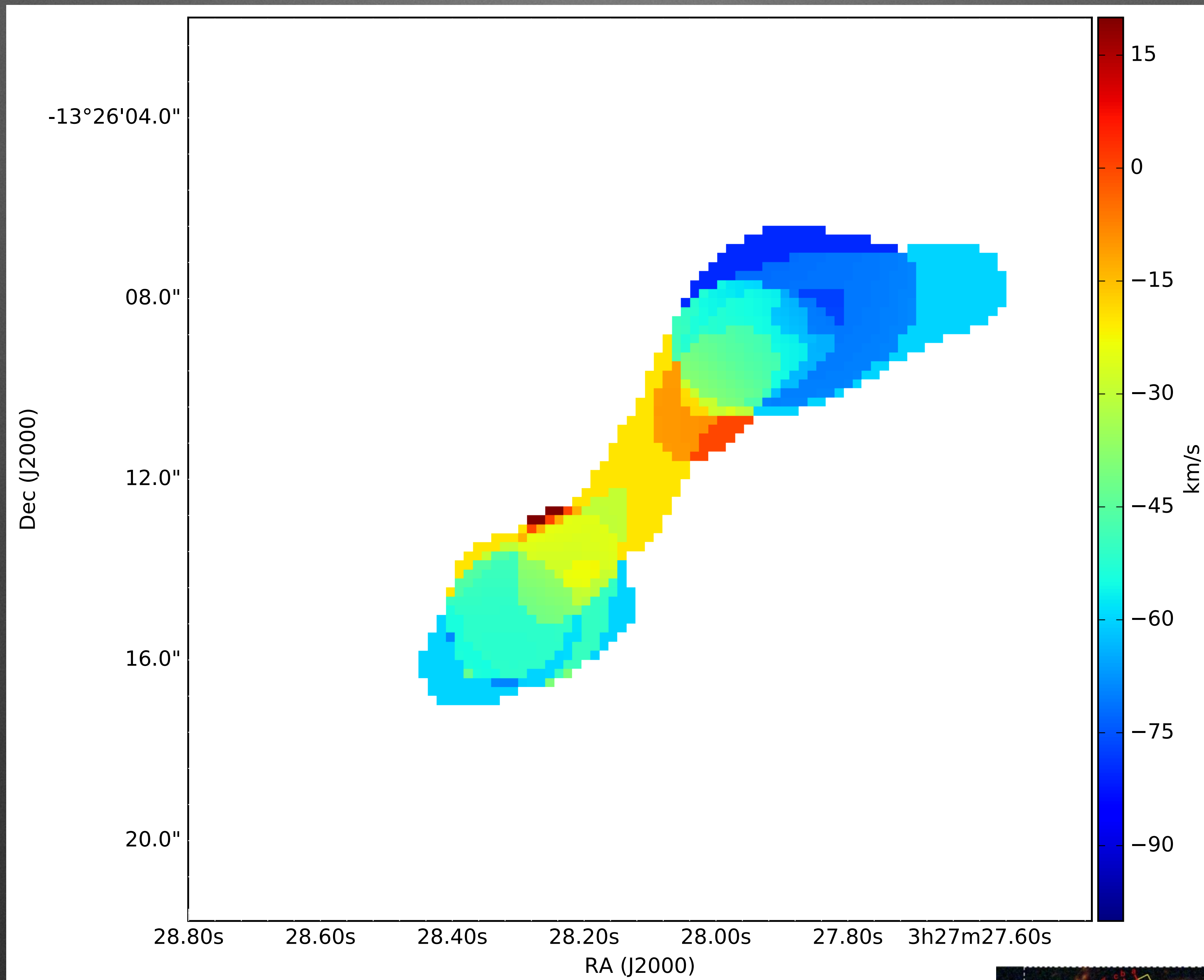
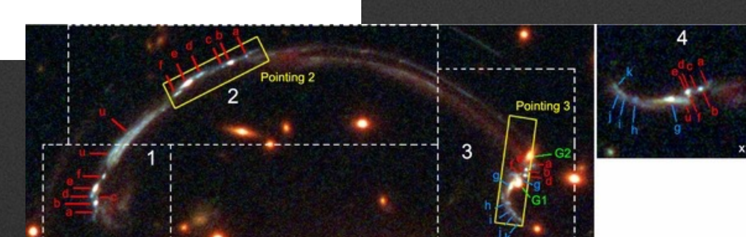




$2.16'' \times 2.08''$

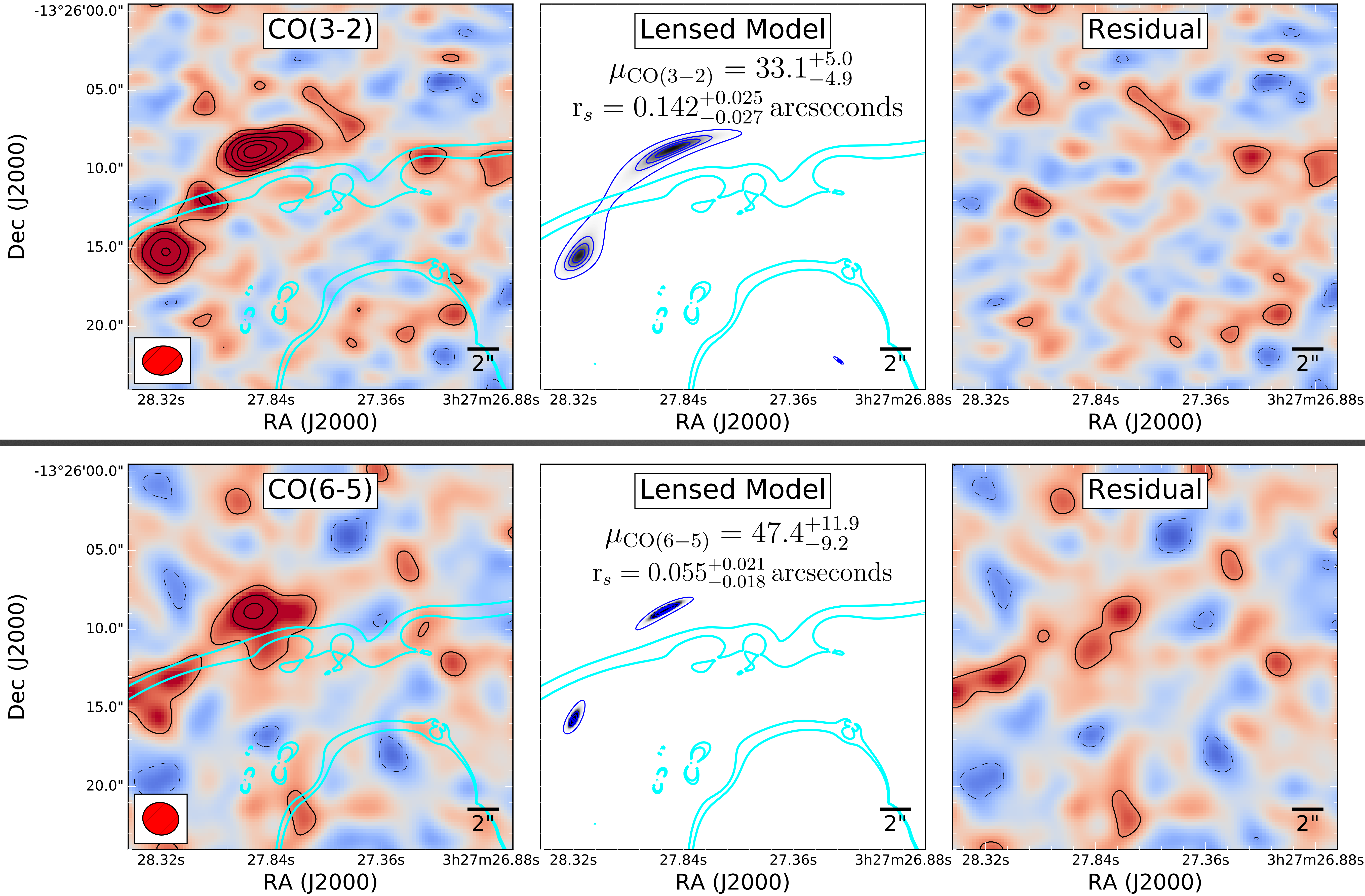


CO(3-2)
CO(6-5)
e1
e2
u1 + u2
F_ν [mJy b^{-1}]
ν [GHz]
127.70
127.75
127.80
127.85
127.90
127.95
128.00
128.05
128.10
255.5
255.6
255.7
255.8
255.9
256.0
256.1

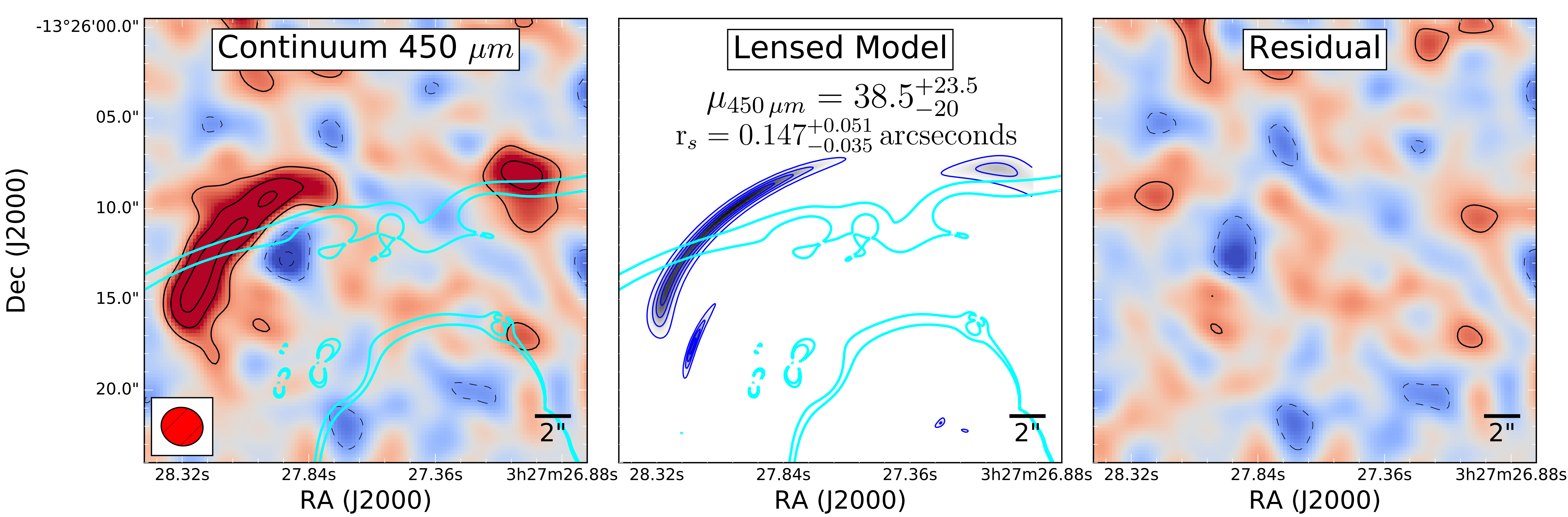

-13°26'04.0"
08.0"
12.0"
16.0"
20.0"
Dec (J2000)
28.80s
28.60s
28.40s
28.20s
28.00s
27.80s
3h27m27.60s
RA (J2000)
15
0
−15
−30
−45
−60
−75
−90
km/s

Pointing 2
Pointing 3
1
2
3
4
G1
G2
x1.5

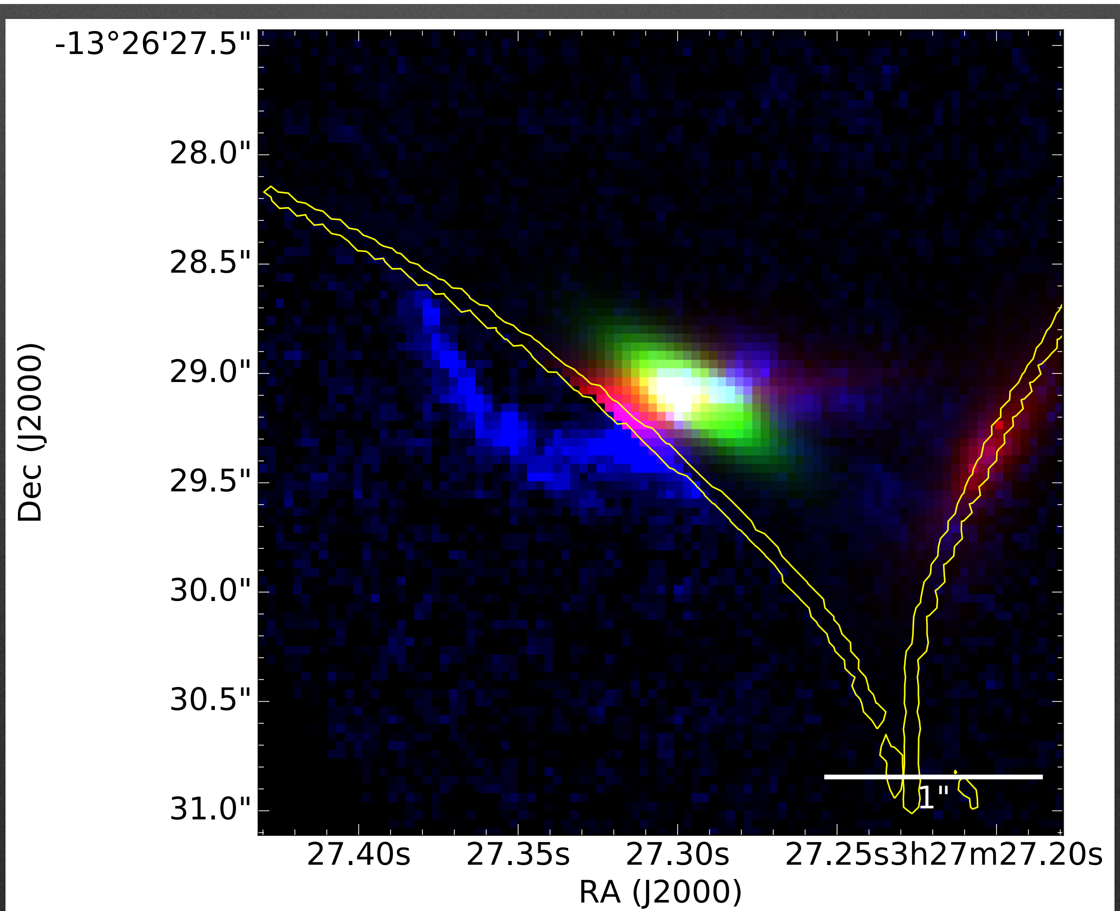
Source plane reconstruction

uvmcmcfit (Bussmann et al. 2013)

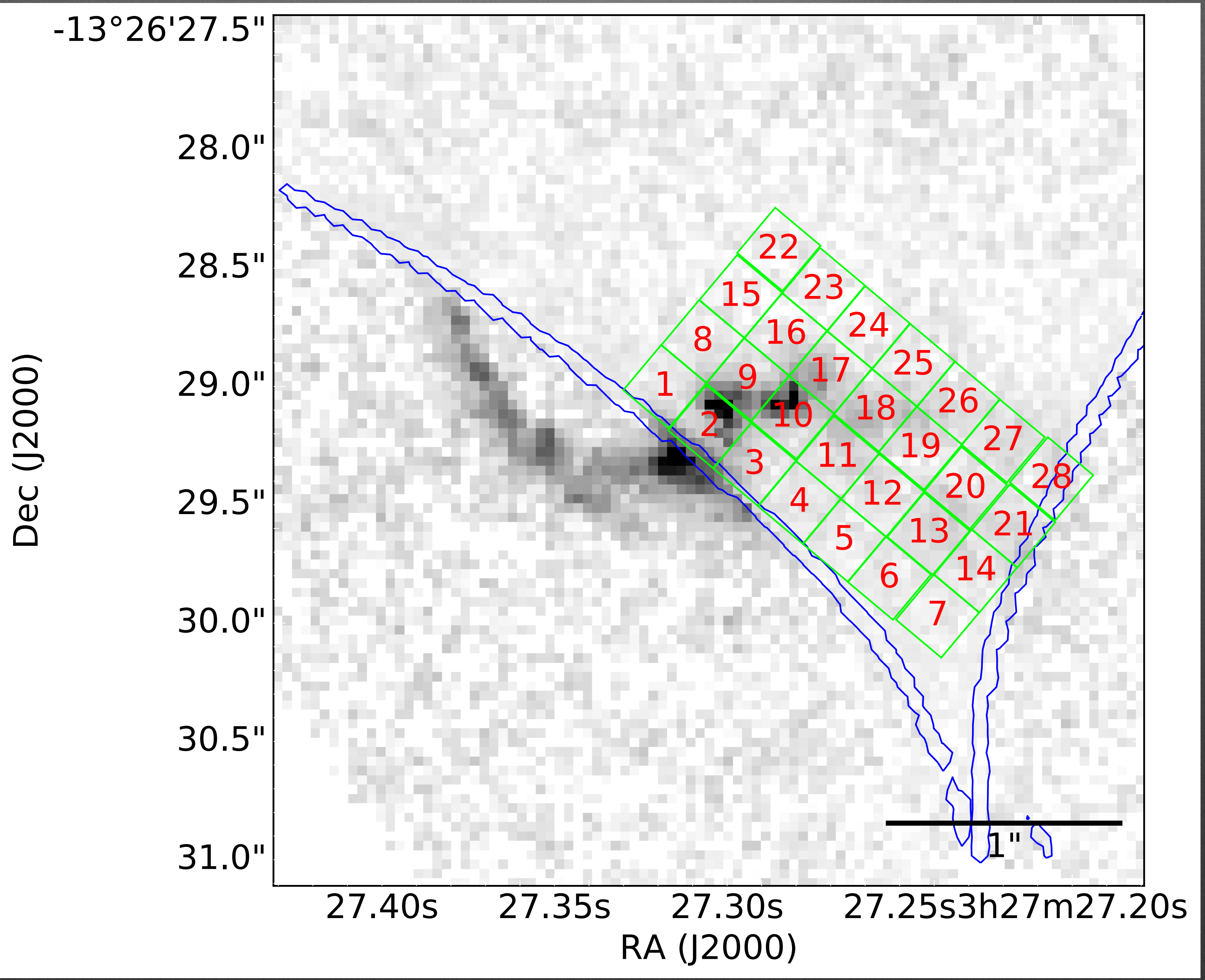


Source plane reconstruction

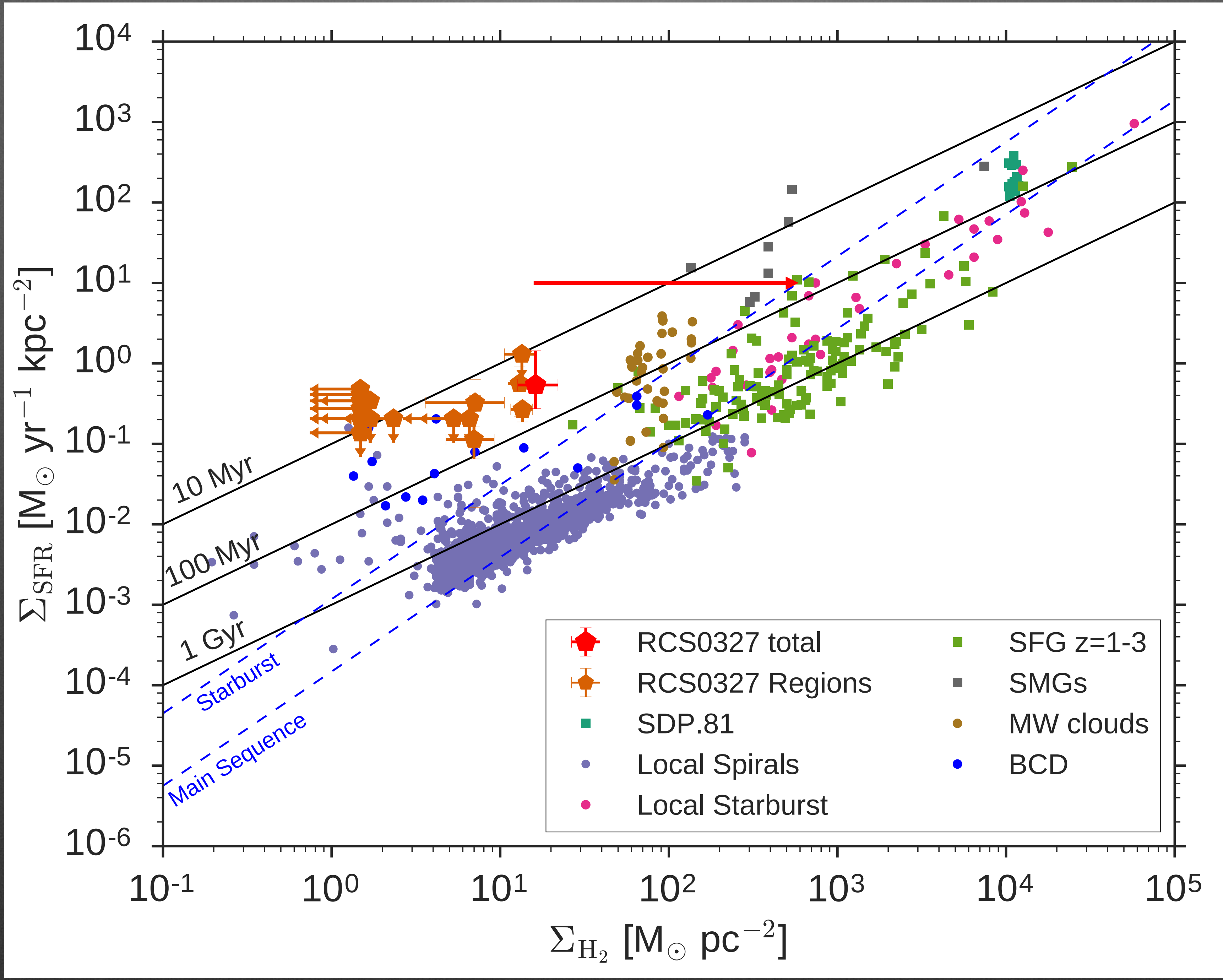




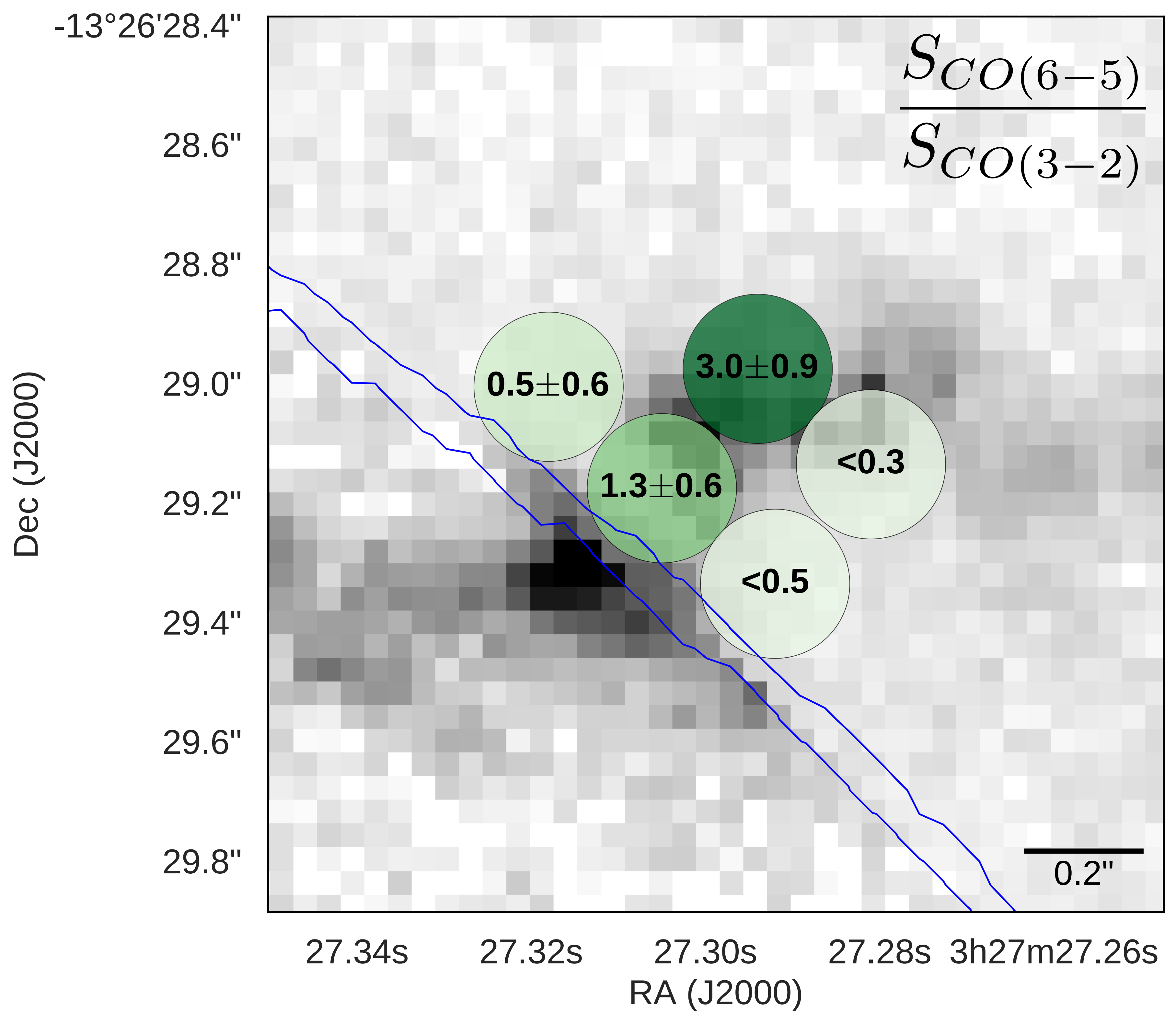
Resolved properties



Resolved properties



Resolved properties



Summary

We managed to detect CO lines and dust emissions in a relatively faint galaxy at z=1.7.

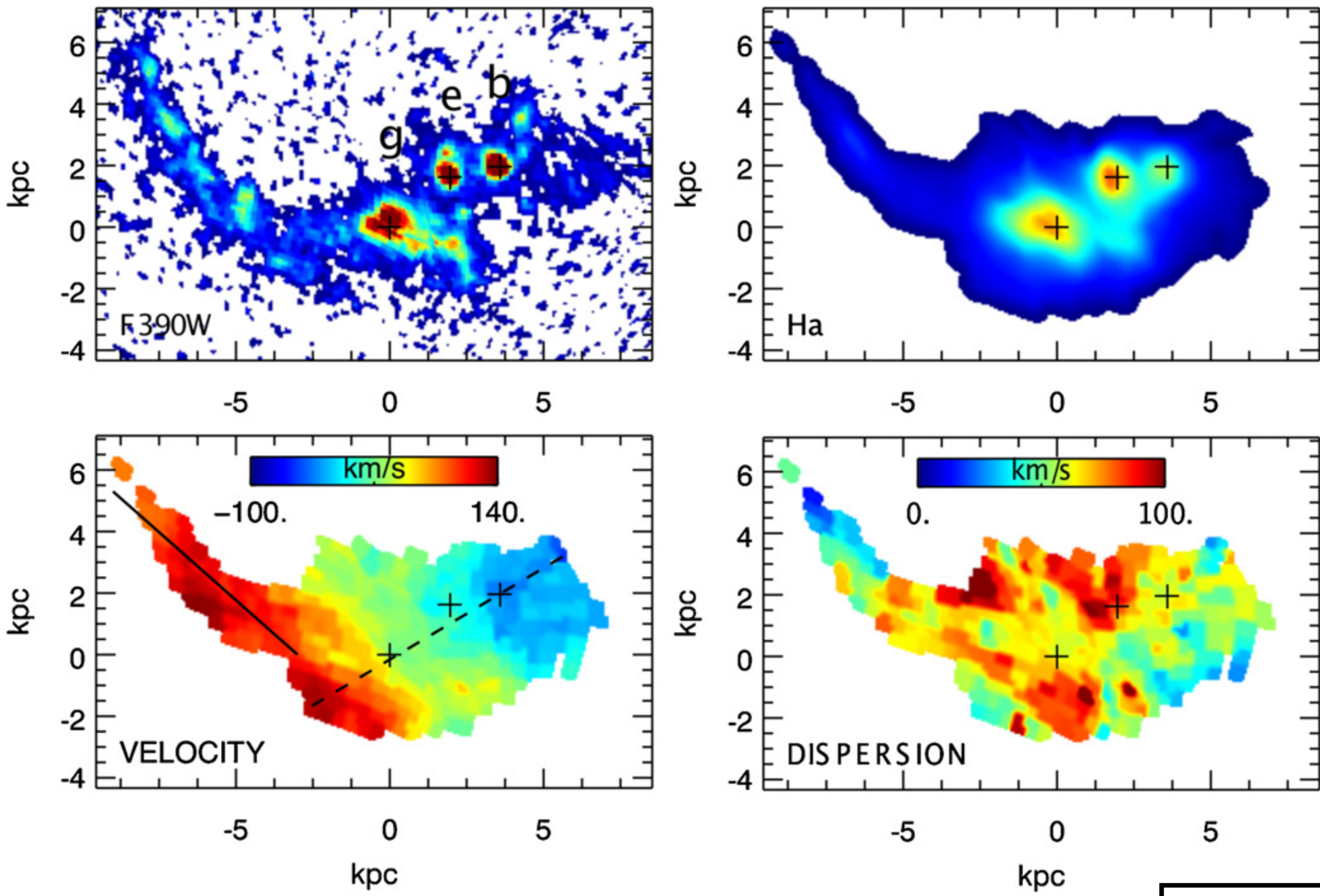
Using the best lens model available we were able to resolved the molecular gas and dust emission down to sub-kpc scale on the galaxy.

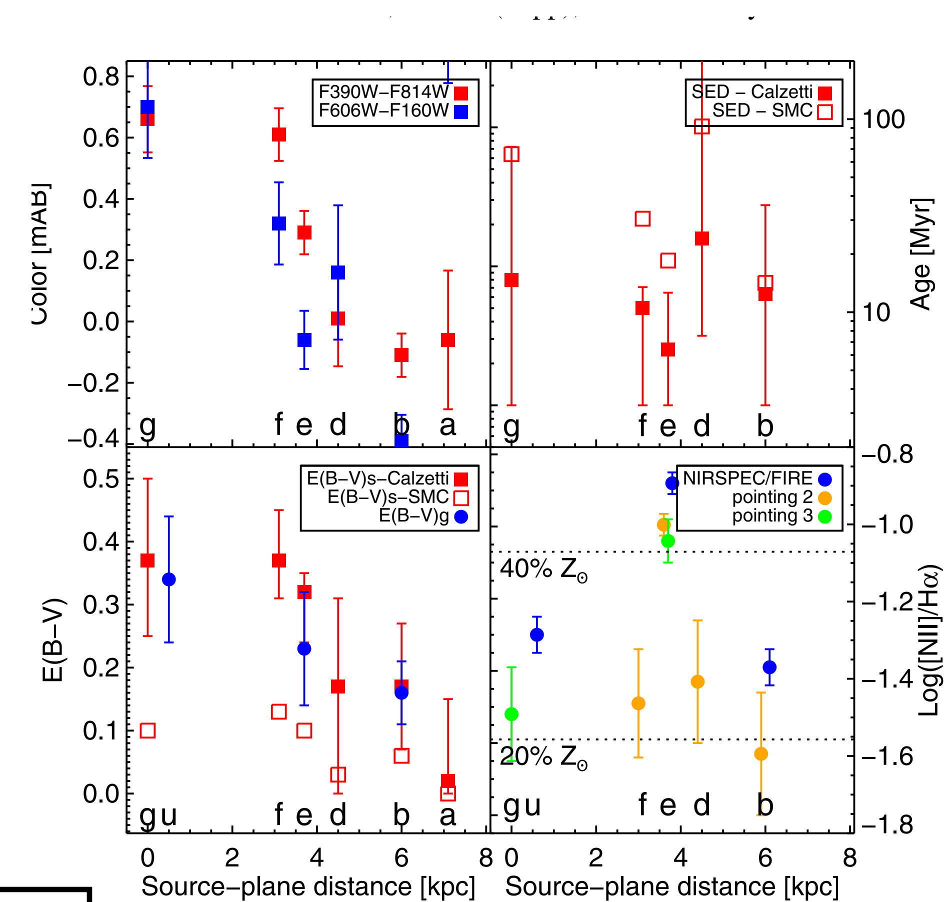
We find that RCS0327 is consistent with being a starburst and has properties similar to local low-metallicity starburst BCDs.

The detected CO(3-2) and CO(6-5) return a CO excitation level consistent with having the peak at J~5 at large scales. Which is a combination of compact and extended gas different with excitations.

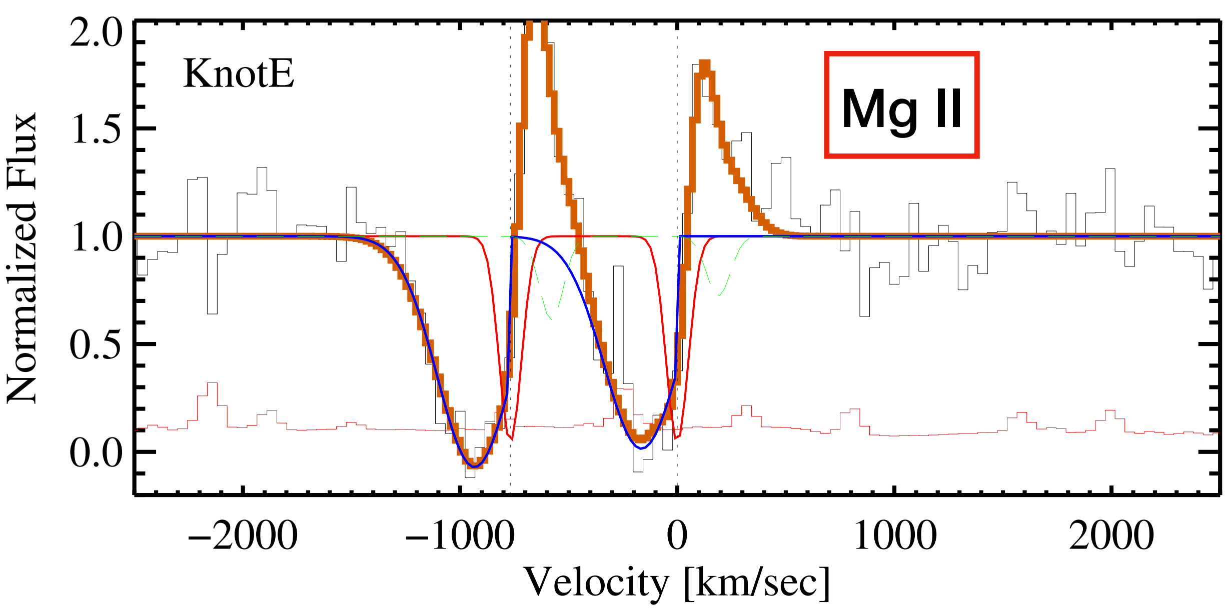
What is next?

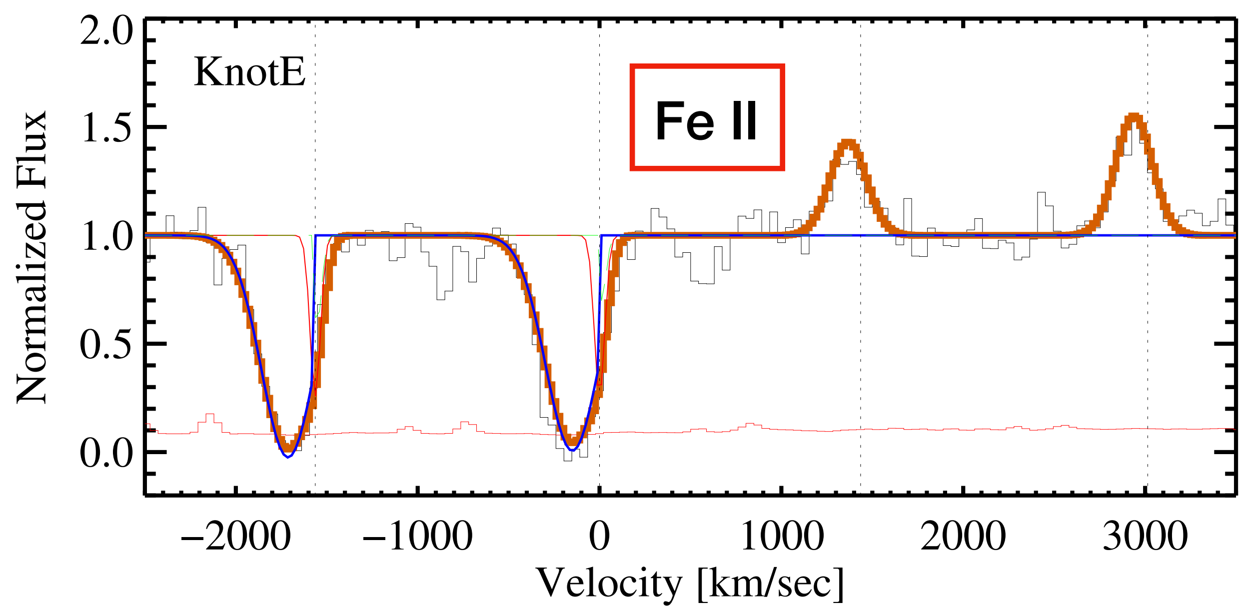
- Exploit the higher resolution of ALMA
- Include [CII]
- Expand this study to other lensed galaxies
  - We got ACA time for a small sample





Wuyts et al. 2014





Bordoloi et al. 2016

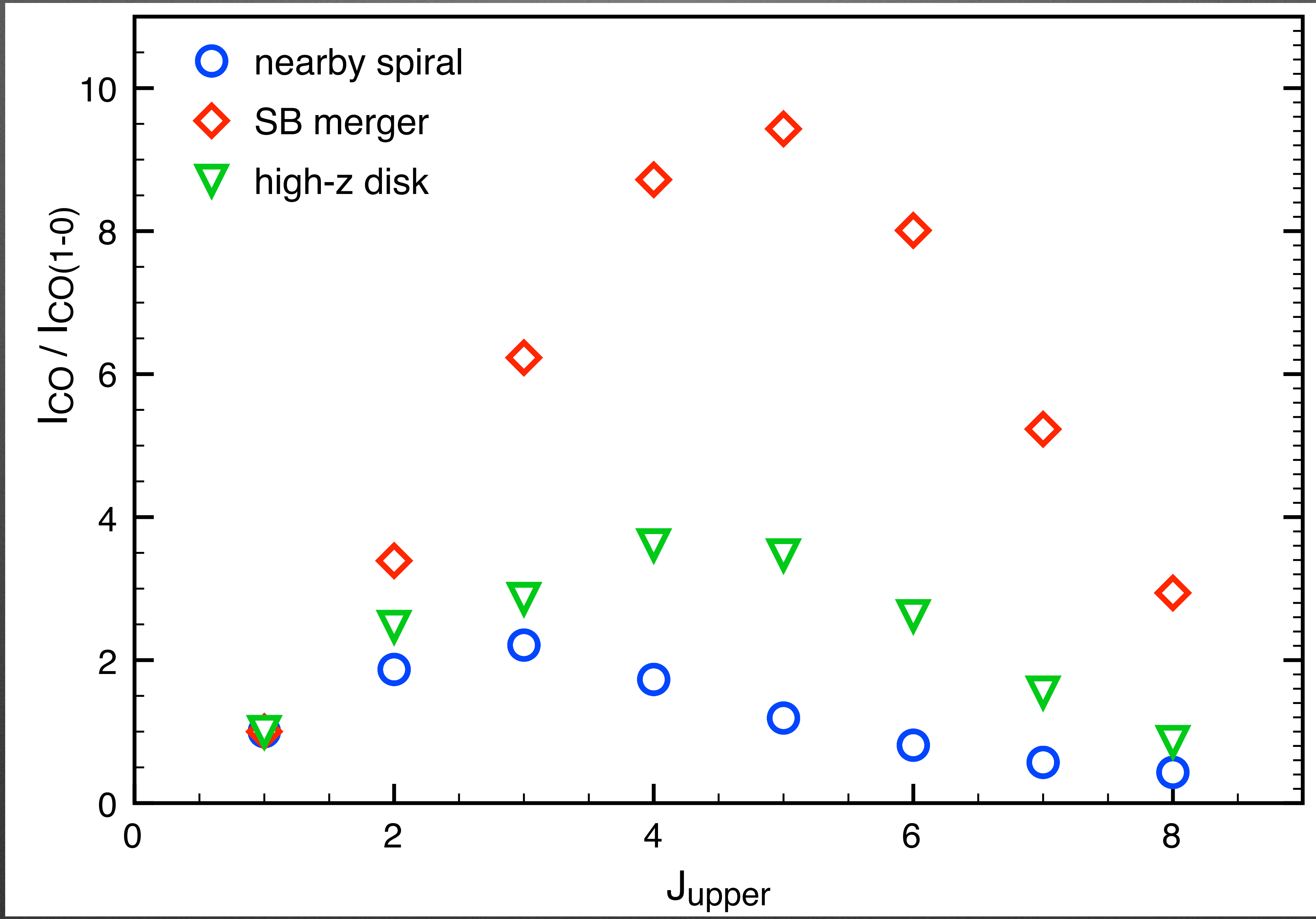
Resolved properties

$$H_2 = 3.51^{+0.26}_{-0.28} \times 10^8 M_\odot$$

Table 1. Flux density values measured in the source plane.

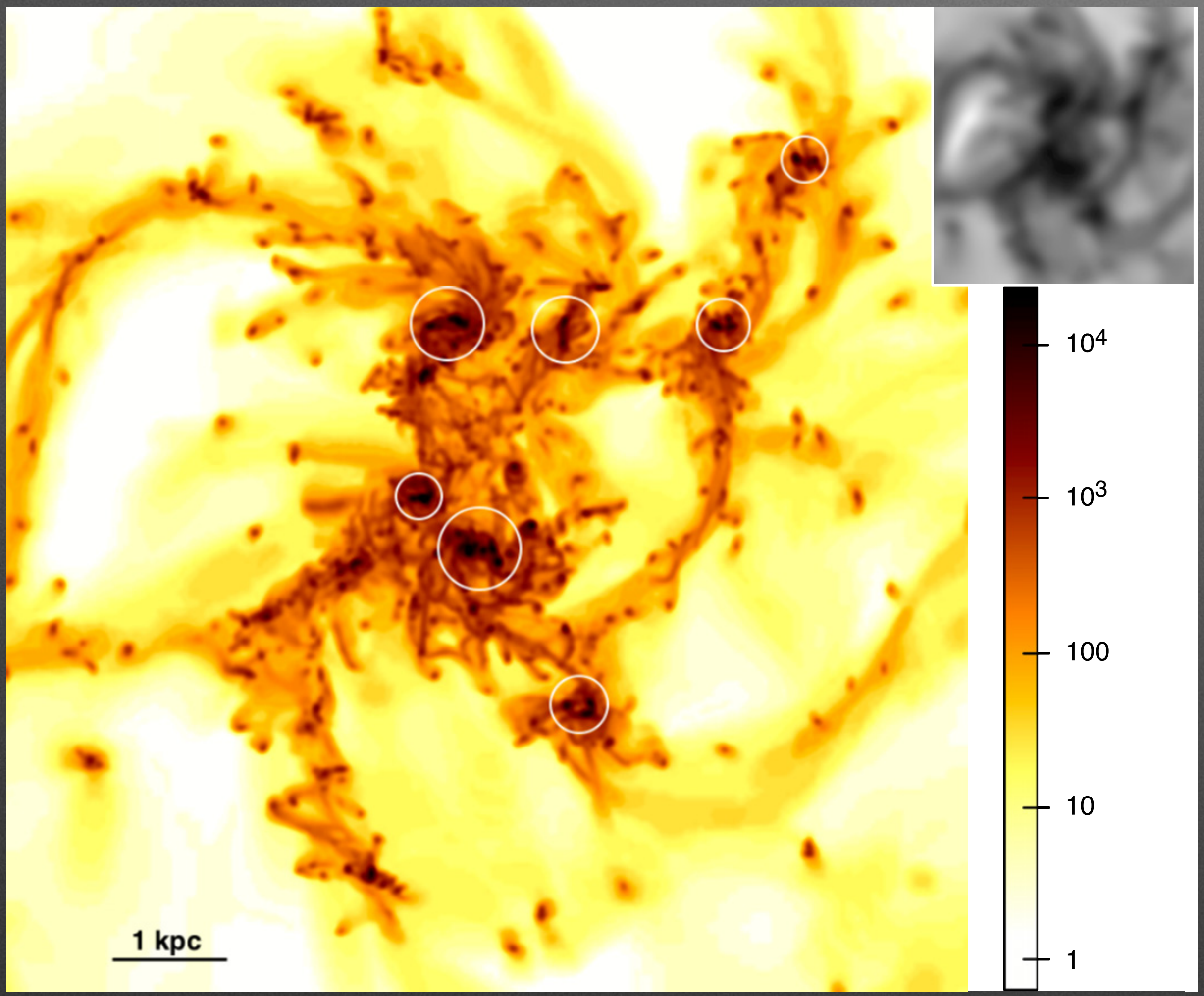
Region	$S_{450\,\mu m}$	$S_{CO(3-2)}$ [a]	$S_{CO(6-5)}$ [a]	$S_{CO(6-5)}/S_{CO(3-2)}$	Σ_{H2} [b]	Σ_{SFR}
	μJy	μJy	μJy		$M_\odot$ pc^{-2}	$M_\odot$ yr^{-1} kpc^{-2}
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Main Component	$48.1^{+54.9}_{-16.6}$	$70.5^{+5.1}_{-5.6}$	$77.1^{+13.8}_{-12.9}$	1.1 ± 0.2	$16.2^{+5.8}_{-3.5}$	$0.27^{+0.43}_{-0.13}$
01	4.0 ± 0.9	6.7 ± 3.3	3.6 ± 3.4	0.5 ± 0.6	7.1 ± 3.5	$0.16^{+0.15}_{-0.04}$
02	6.9 ± 1.0	12.3 ± 1.8	16.3 ± 6.4	1.3 ± 0.6	13.0 ± 1.9	$0.27^{+0.17}_{-0.04}$
03	1.4 ± 0.6	6.6 ± 2.1	0.0 ± 1.6	< 0.5	7.0 ± 2.2	$0.06^{+0.10}_{-0.02}$
04	0.0 ± 0.3	1.2 ± 1.1	0.0 ± 1.6	$\cdots$	< 2.3	< 0.10
05	0.0 ± 0.2	0.1 ± 0.7	0.0 ± 1.5	$\cdots$	< 1.5	< 0.07
06	0.0 ± 0.2	0.0 ± 0.7	0.0 ± 1.6	$\cdots$	< 1.5	< 0.07
07	0.0 ± 0.3	0.0 ± 0.7	0.0 ± 1.8	$\cdots$	< 1.5	< 0.10
08	0.5 ± 0.3	5.0 ± 3.1	10.2 ± 9.7	$\cdots$	< 6.6	< 0.10
09	3.3 ± 1.0	12.8 ± 1.9	38.7 ± 9.9	3.0 ± 0.9	13.5 ± 2.0	$0.13^{+0.17}_{-0.04}$
10	3.0 ± 1.9	12.7 ± 2.7	0.0 ± 1.6	< 0.3	13.4 ± 2.9	< 0.64

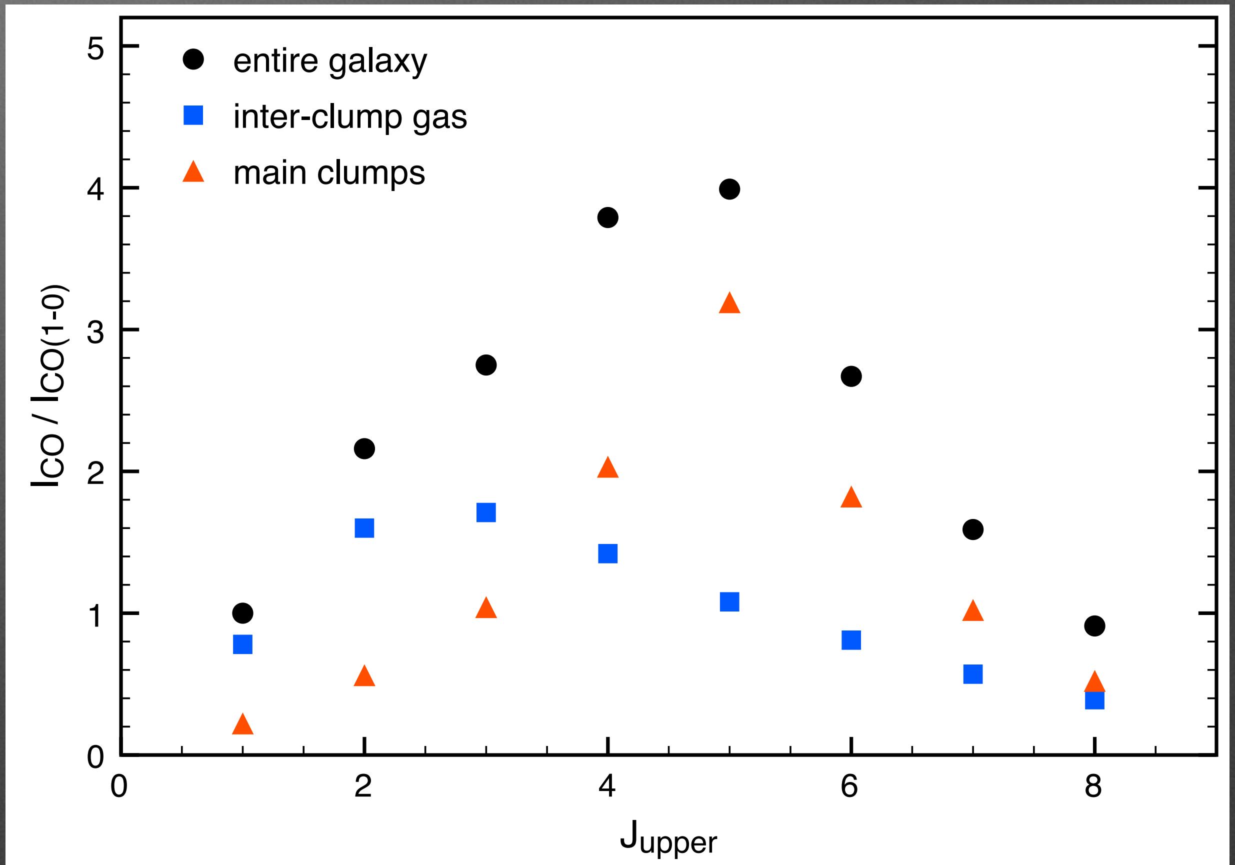
Comparison with simulations



Bournaud et al. 2015

Comparison with simulations





Bournaud et al. 2015