The Herschel Lensing Survey (HLS)

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M. Rex (Arizona)	J. Bock (JPL/Caltech)	H. Ebeling (Hawaii)	J.-P. Kneib (Marseille)	D. Schaerer (Geneva)	M. Zemcov (JPL/Caltech)
B. Clement (Arizona)	F. Boone (Toulouse)	A. Edge (Durham)	D. Lutz (MPE)	I. Smail (Durham)	F. Combes (Paris)
M. Pereira (Arizona)	C. Bridge (Caltech)	R. Ellis (Caltech)	L. Metcalfe (ESAC)	M. Swinbank (Durham)	
G. Walth (Arizona)	S. Bussmann (CfA)	D. Fadda (IPAC/Caltech)	A. Omont (IAP, Paris)	G. Smith (Birmingham)	
Rujopakarn (Arizona)	A. Cava (Geneva)	O. Ilbert (Marseille)	R. Pello (Toulouse)	I. Valtchanov (ESAC)	
G. Rieke (Arizona)	S. Chapman (Dalhousie)	R. Ivison (Edinburgh)	P. Perez-Gonzalez (Madrid)	P. van der Werf (Leiden)	

Collaborators

- SMA (Giovanni Fazio, Mark Gurwell, Caitlin Casey...)
- LABOCA Lensing Survey (Axel Weiss)
- CARMA (Dominik Riechers)
- GBT/Zpectrometer (Andy Harris, Andrew Baker, Dave Frayer)
- SCUBA2 Lensing Survey (S2LS team)
- CLASH team (Marc Postman, Rychard Bouwens, Leonidas Moustakas, Piero Rosati...)
- SPT team (Dan Marrone, Joaquin Vieira, John Carlstrom...)
- CODEX team (Alexis Finoguenov, Eduardo Rozo...)

Outline

I. Motivation

II. What is Herschel Lensing Survey (HLS)?

- HLS-deep & HLS-snapshot

III. Scientific Highlights

(1) HLS-deep
z=5.24 SMG (Rawle+13, arXiv:1310.4090)

(2) HLS-snapshot

(3) IR-bright cluster members

IV. Public data release (HLS DR1)

1. Motivation

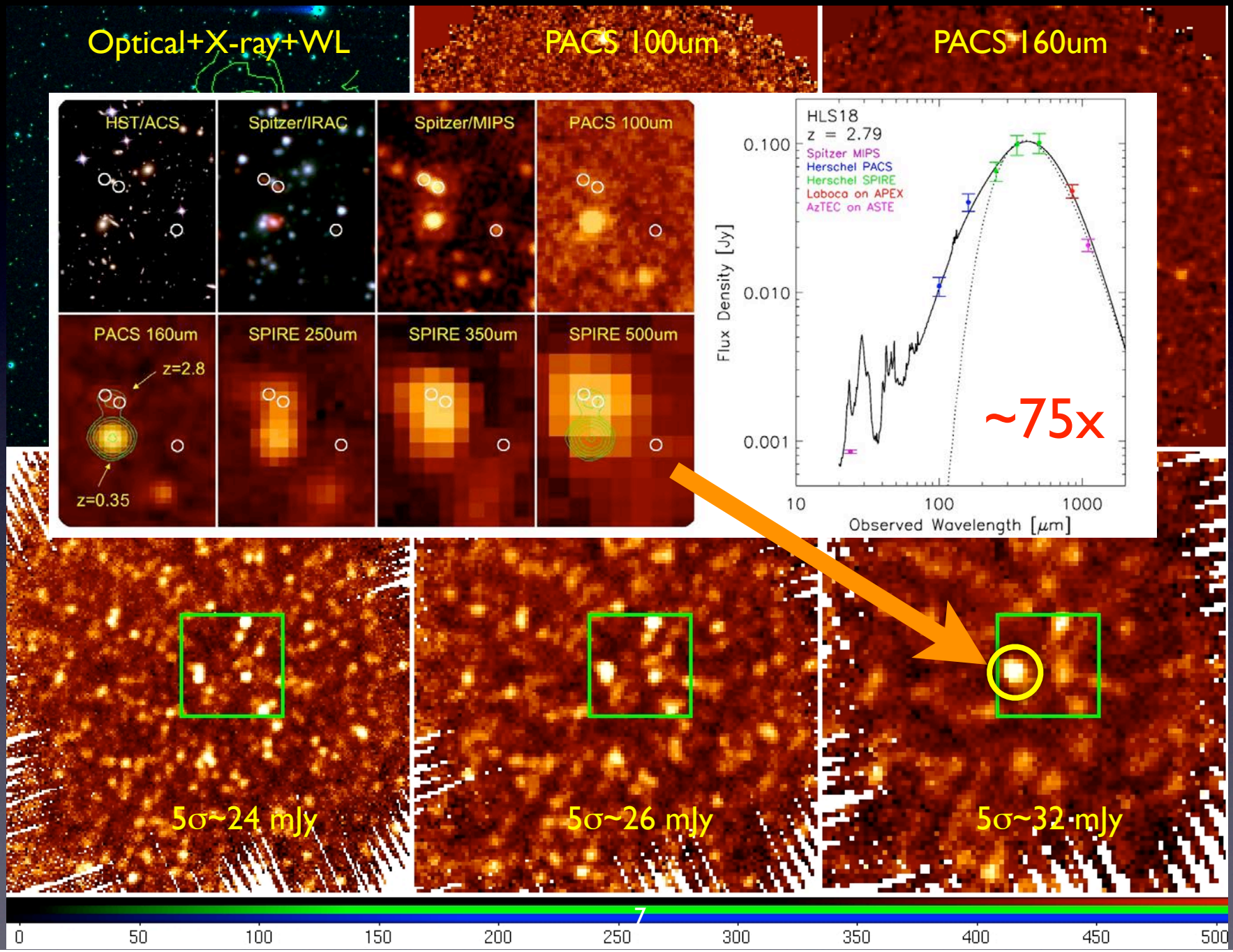
x10
lensi
ma

This is all for free!

Herschel D=3m

D=30m!

The Bullet Cluster (Egami+10, Rex+10, etc.)



II. What is HLS?

What *was* HLS?

	Cycle	Title	Tobs (hrs)	#clusters
HLS-deep I	0	"The Herschel Lensing Survey" Open-Time Key Program (OTKP)	318.2	44

What *is* HLS?

	Cycle	Title	Tobs (hrs)	#clusters
HLS-deep I	0	"The Herschel Lensing Survey" Open-Time Key Program (OTKP)	318.2	44
HLS-deep II	2	"Herschel Lensing Survey II": Completing the Herschel Legacy with the HST/MCT CLASH Sample"	48.2	10
HLS-snapshot I	1	"SPIRE Snapshot Survey of Massive Galaxy Clusters"	27.3	279
HLS-snapshot II	2	"SPIRE Snapshot Survey II: Using SPT/CODEX Massive Clusters as Powerful Gravitational Lenses"	25	248
		Total	418.7	581

HLS-snapshot inspired by the discovery
of the Eyelash galaxy at z=2.3 (Swinbank+10)

The Herschel Lensing Survey (HLS)

1. HLS-deep (366 hrs): Deep PACS (100/160 um) & SPIRE (250/350/500 um) imaging of 54 (➜ 65) massive (i.e., X-ray-luminous) cluster cores (z~0.1-0.5) to detect and study Herschel sources below the confusion limit.

2. HLS-snapshot (52 hrs): Shallow SPIRE-only imaging of 527 massive cluster cores (z~0.1-1) to discover exceptionally bright ($S_{peak} \gtrsim 100$ mJy) cluster-lensed galaxies that will allow a variety of multi-wavelength observations.

Note: Field surveys (H-ATLAS, HerMES, SPT, ACT, etc.)
➔ Galaxy-lensed systems

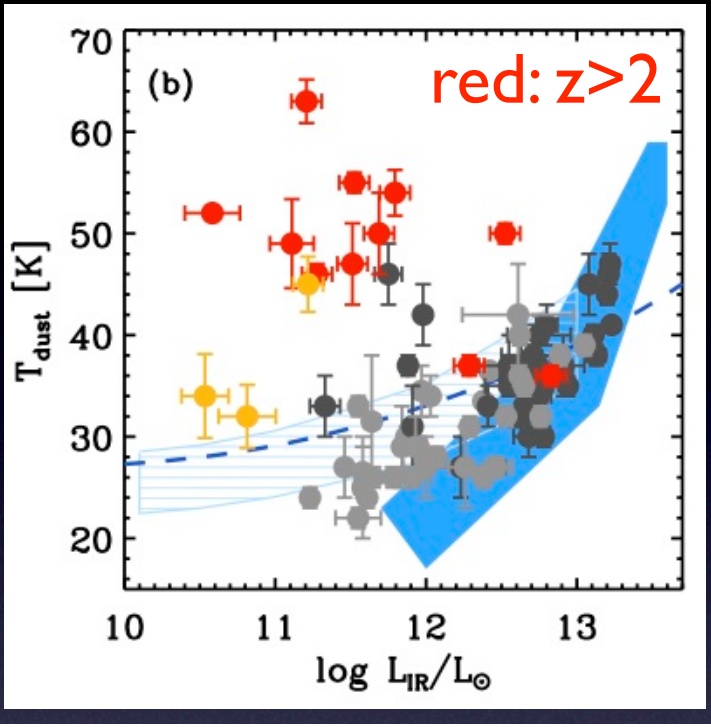
Cluster Samples

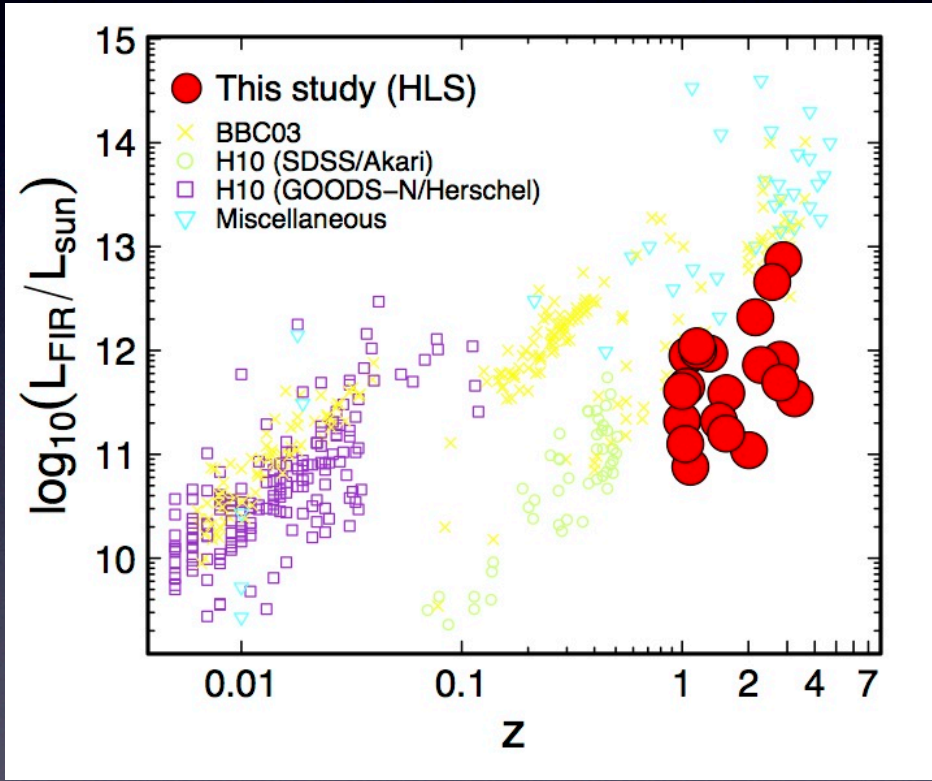
- HLS-deep: 54 clusters (HLS) ➜ +11 GT = 65
  - 54 well-studied massive clusters
  - Includes 23 CLASH clusters + 1 from GT (PI: Altieri) (1 missing: A1423)
  - Will eventually add 10 GT clusters
- HLS-snapshot: 527 clusters = 279 + 148 + 100
  - 279 ROSAT clusters (PI: Ebeling)
  - 148 SPT clusters (PI: Carlstrom)
  - 100 CODEX (ROSAT+SDSS) clusters (PI: Finoguenov)

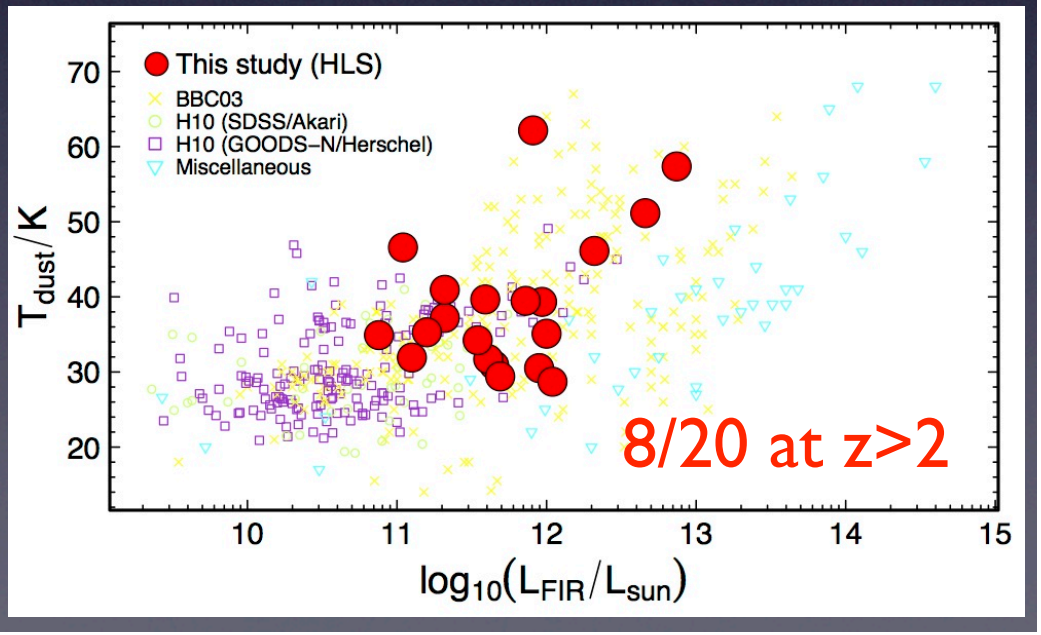
III. Scientific Highlights

(1) HLS deep

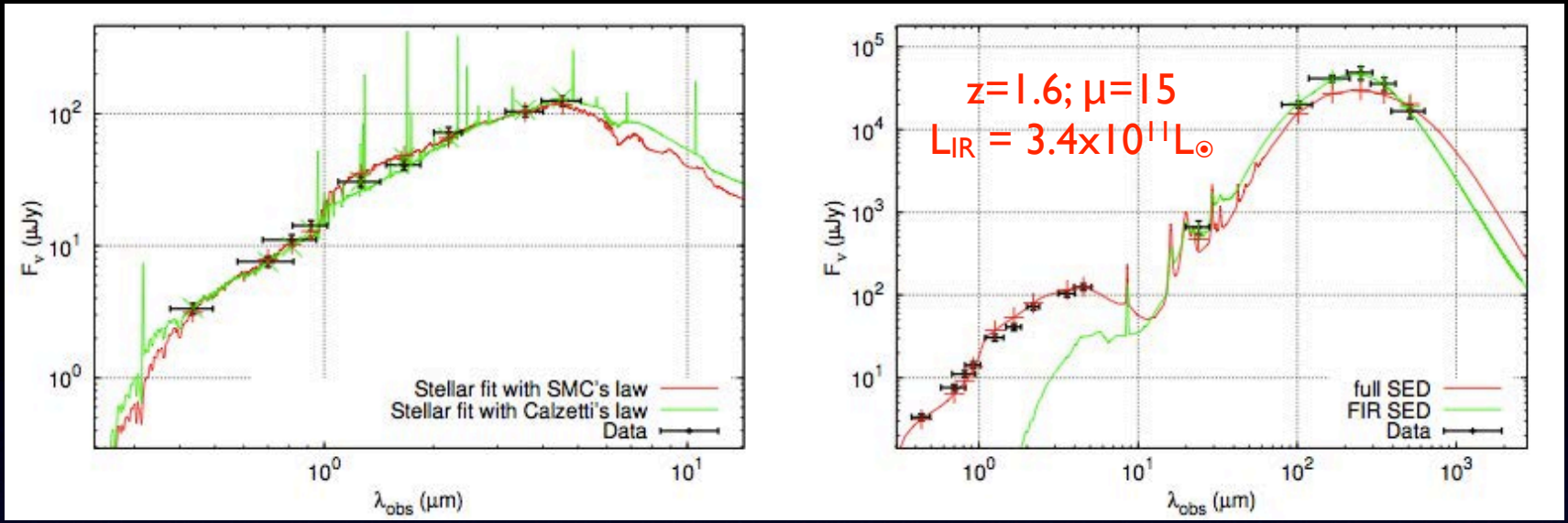
Saintonge+13



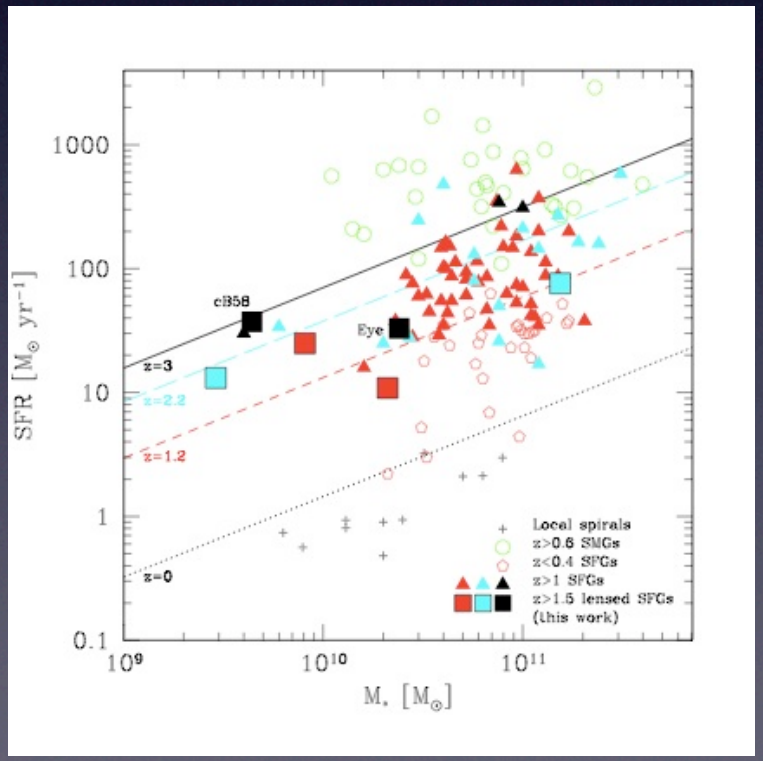




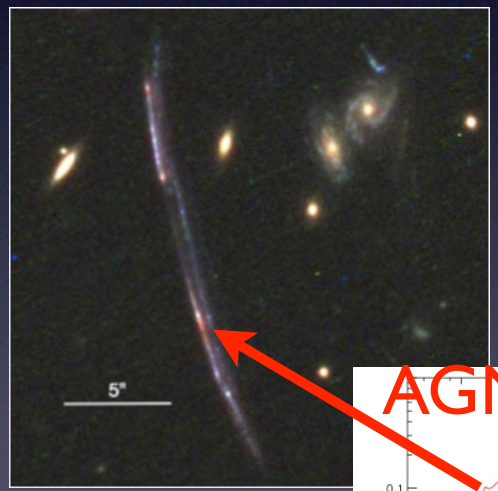
Rawle+13, in prep



Sklias+13 (arXiv:1310.2655) and poster

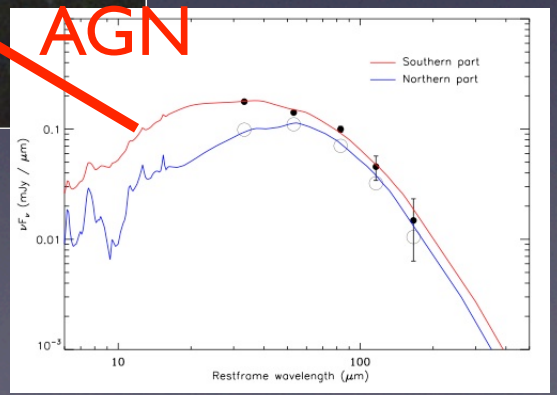


Schaerer poster



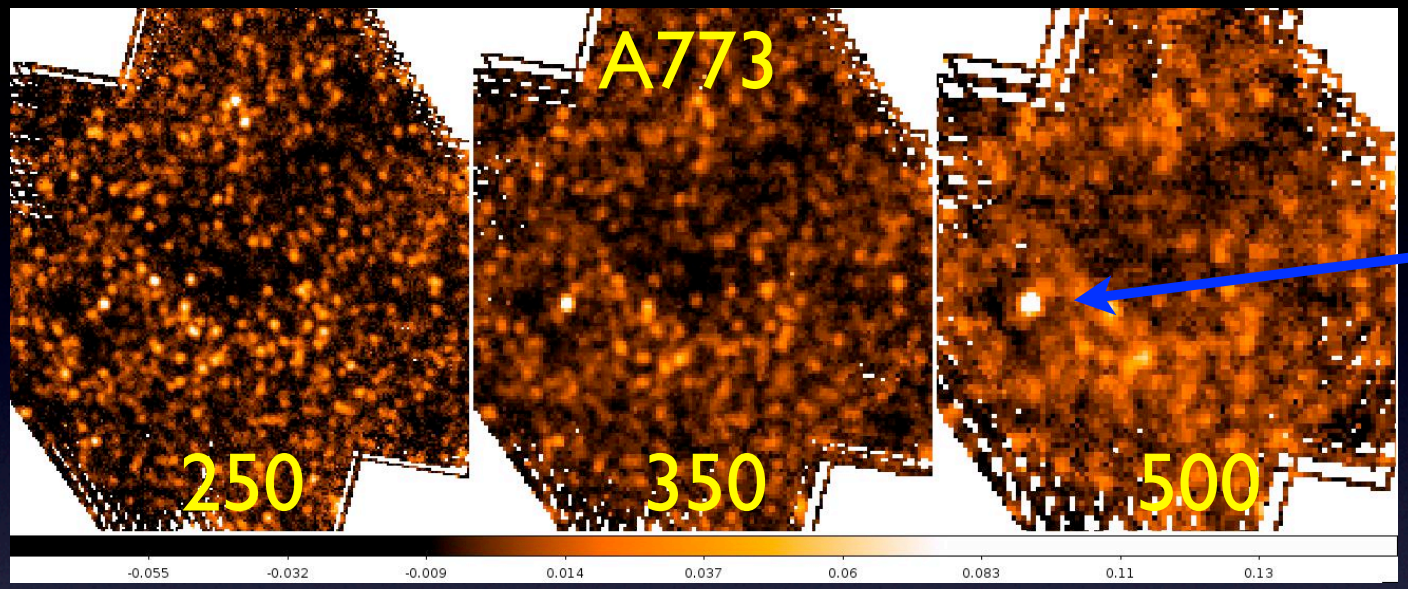
Zamojski poster

AGN

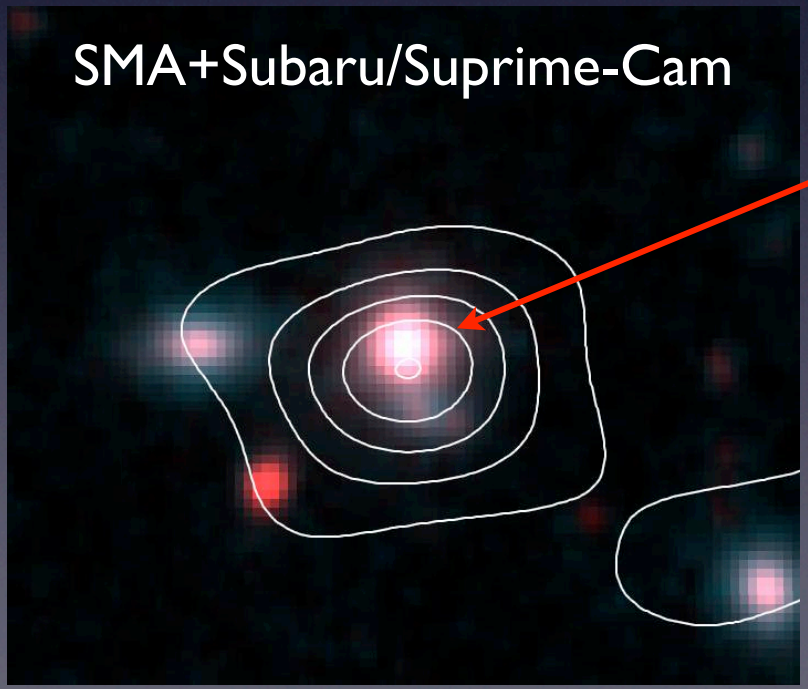


Super-bright z=5.2 galaxy-lensed SMG

Combes+12
Rawle+13
(arXiv:
1310.4090)



~200 mJy
at 500um



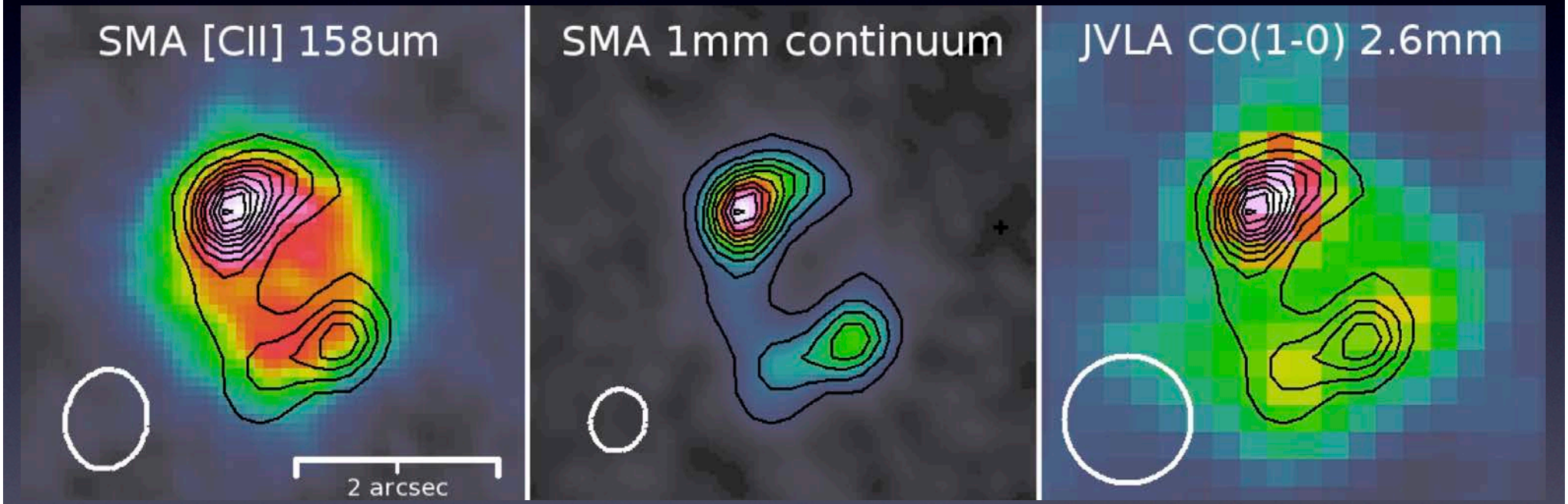
Lensing galaxy at z=0.6

50 mJy at 1.3 mm!
(SMA Compact)

CO redshift → z=5.24

New Data

(Rawle+13; arXiv:1310.4090)



Compact+Extended+ Very Extended

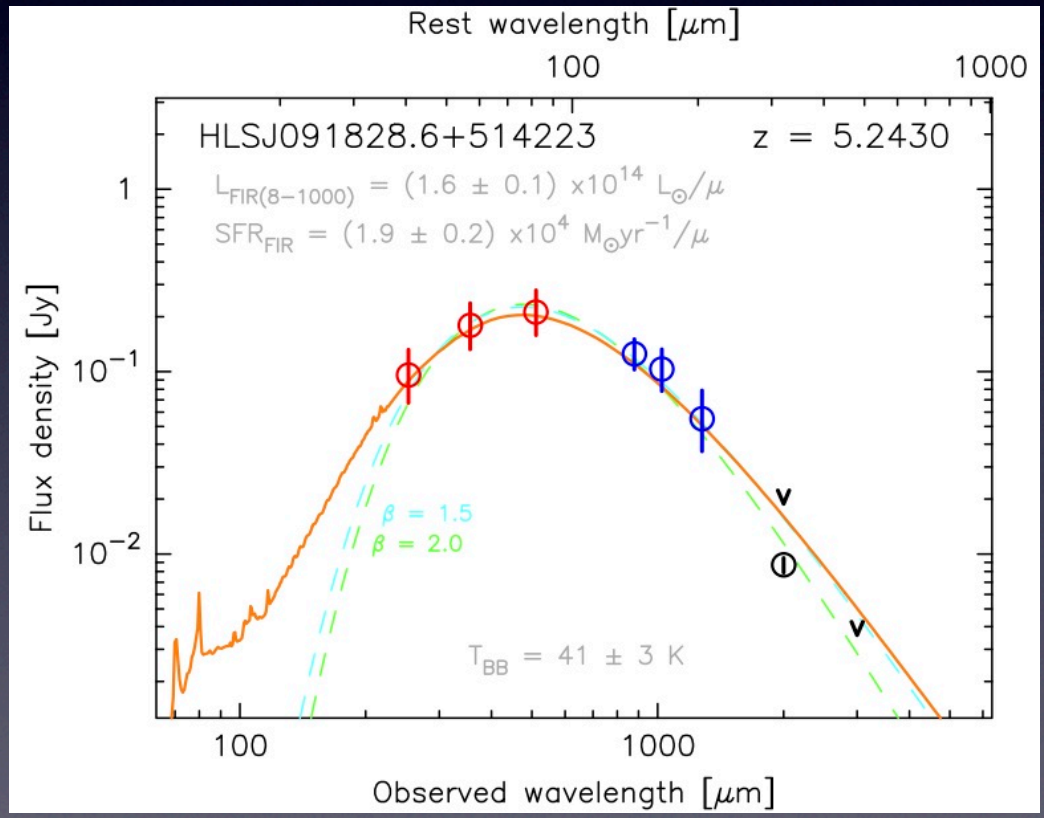
305 GHz=984 um

C and DnC config

HyLIRG with a LIRG-like SED

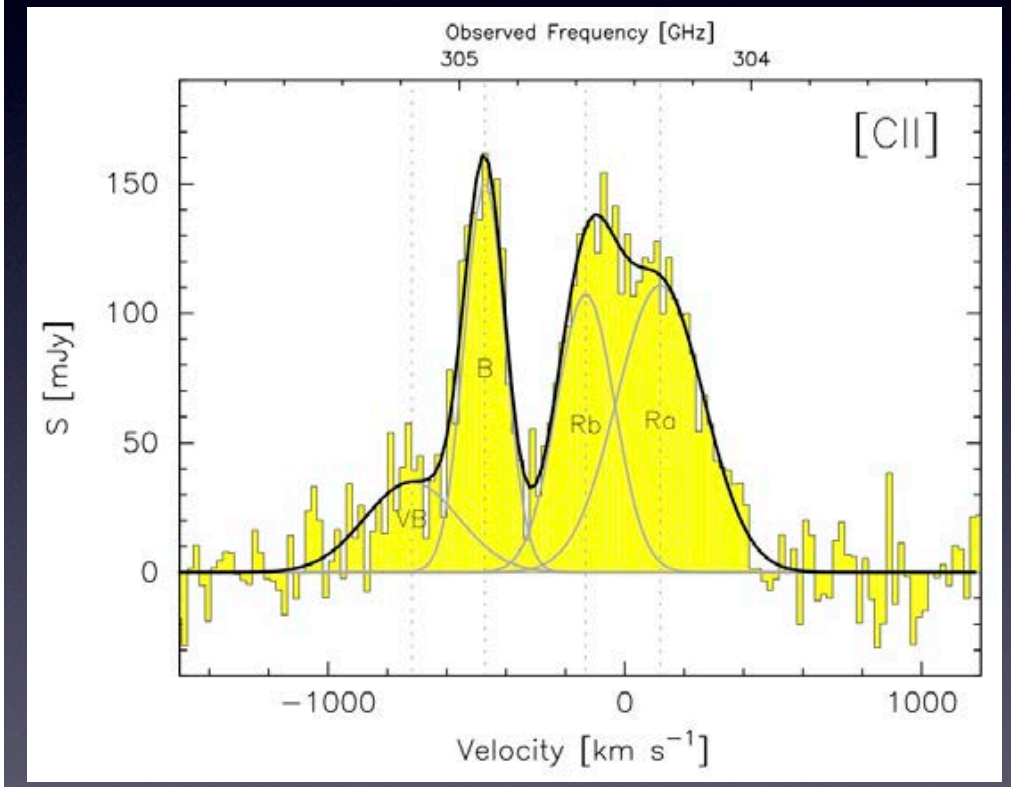
Magnification
μ= 8.9

L_{FIR} =1.8x10^{13} L $_\odot$
SFR_{FIR} = 2100 M $_\odot$/yr

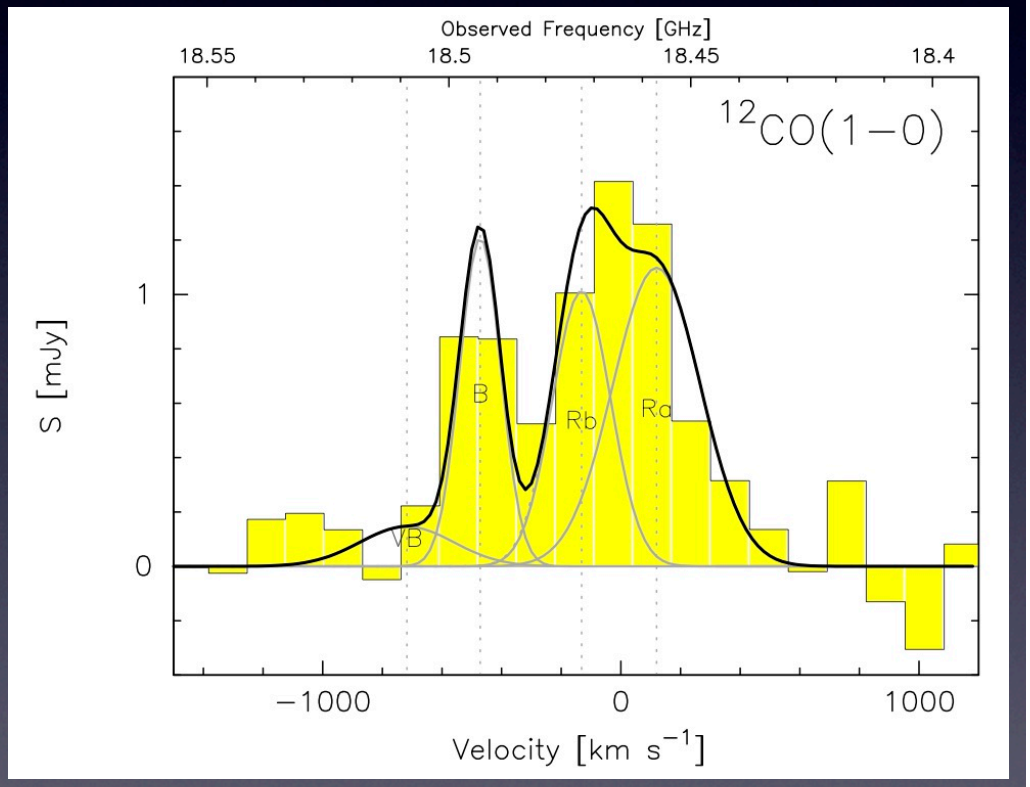


Complex Line Profile

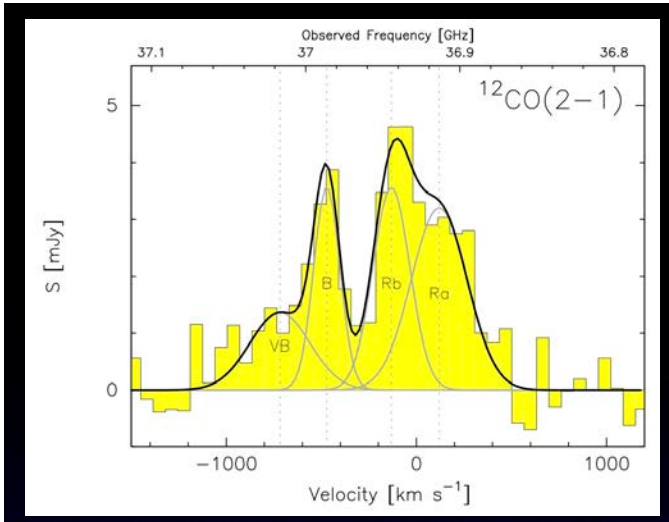
➜ Likely suggesting a merging system

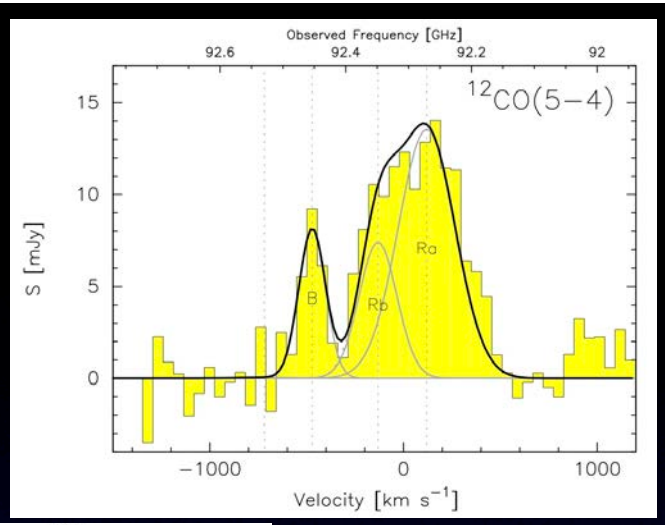


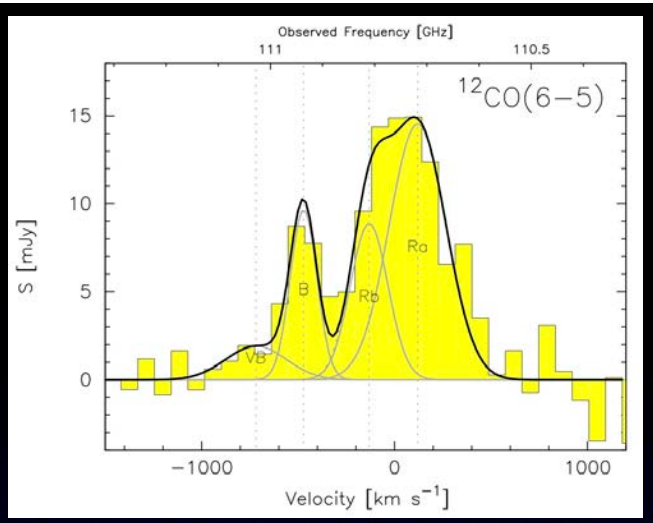
SMA

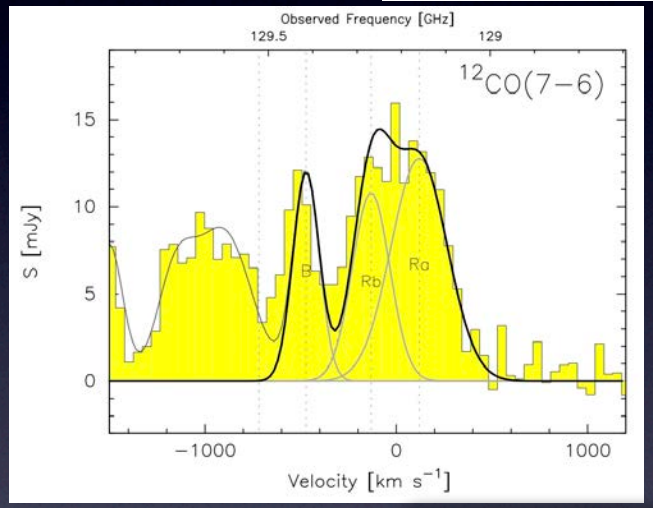


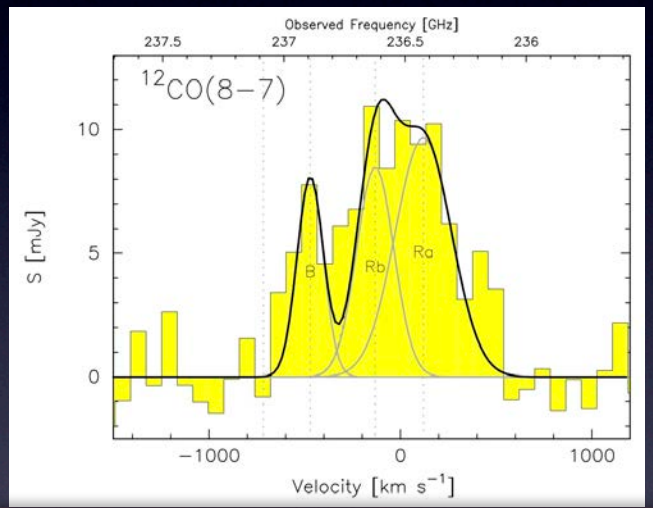
JVLA

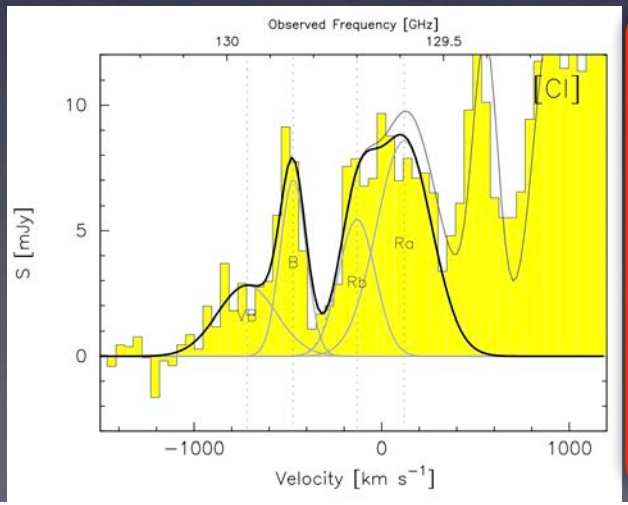

Observed Frequency [GHz]
37.1
37
36.9
36.8
^{12}CO(2−1)
S [mJy]
VB
B
Rb
Ra
Velocity [km s^{-1}]

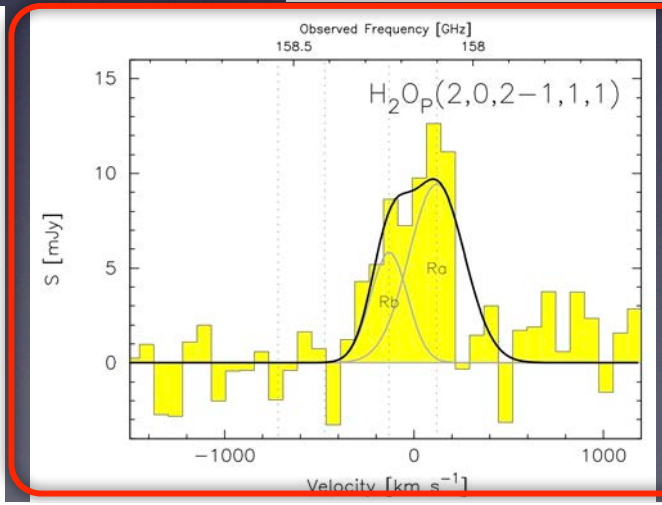

Observed Frequency [GHz]
92.6
92.4
92.2
92
^{12}CO(5−4)
S [mJy]
B
Rb
Ra
Velocity [km s^{-1}]

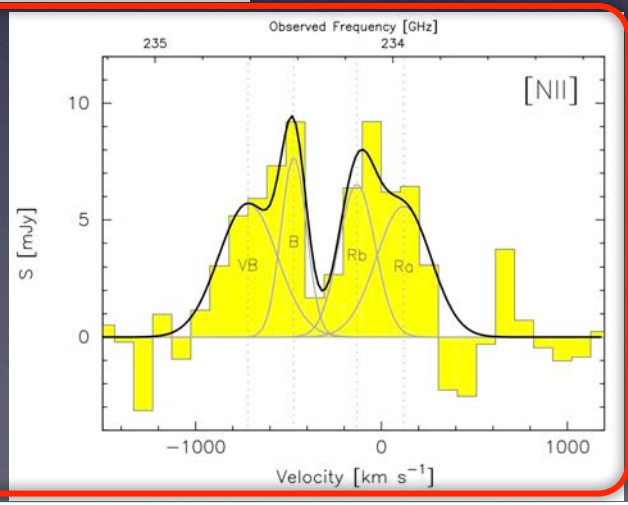

Observed Frequency [GHz]
111
110.5
^{12}CO(6−5)
S [mJy]
VB
B
Rb
Ra
Velocity [km s^{-1}]


Observed Frequency [GHz]
129.5
129
^{12}CO(7−6)
S [mJy]
B
Rb
Ra
Velocity [km s^{-1}]

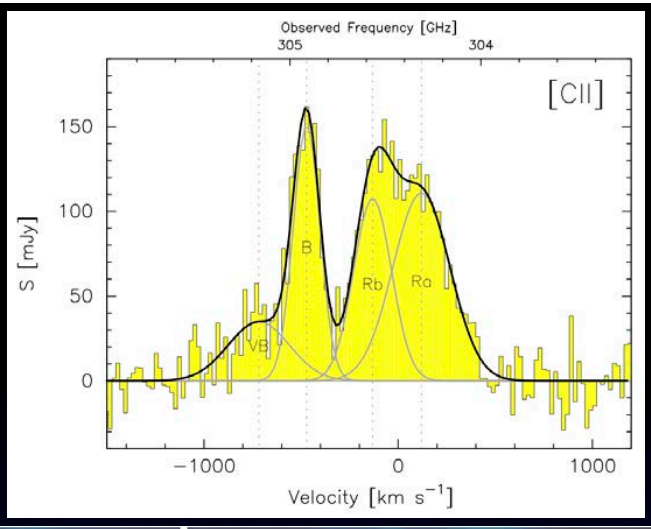

Observed Frequency [GHz]
237.5
237
236.5
236
^{12}CO(8−7)
S [mJy]
B
Rb
Ra
Velocity [km s^{-1}]

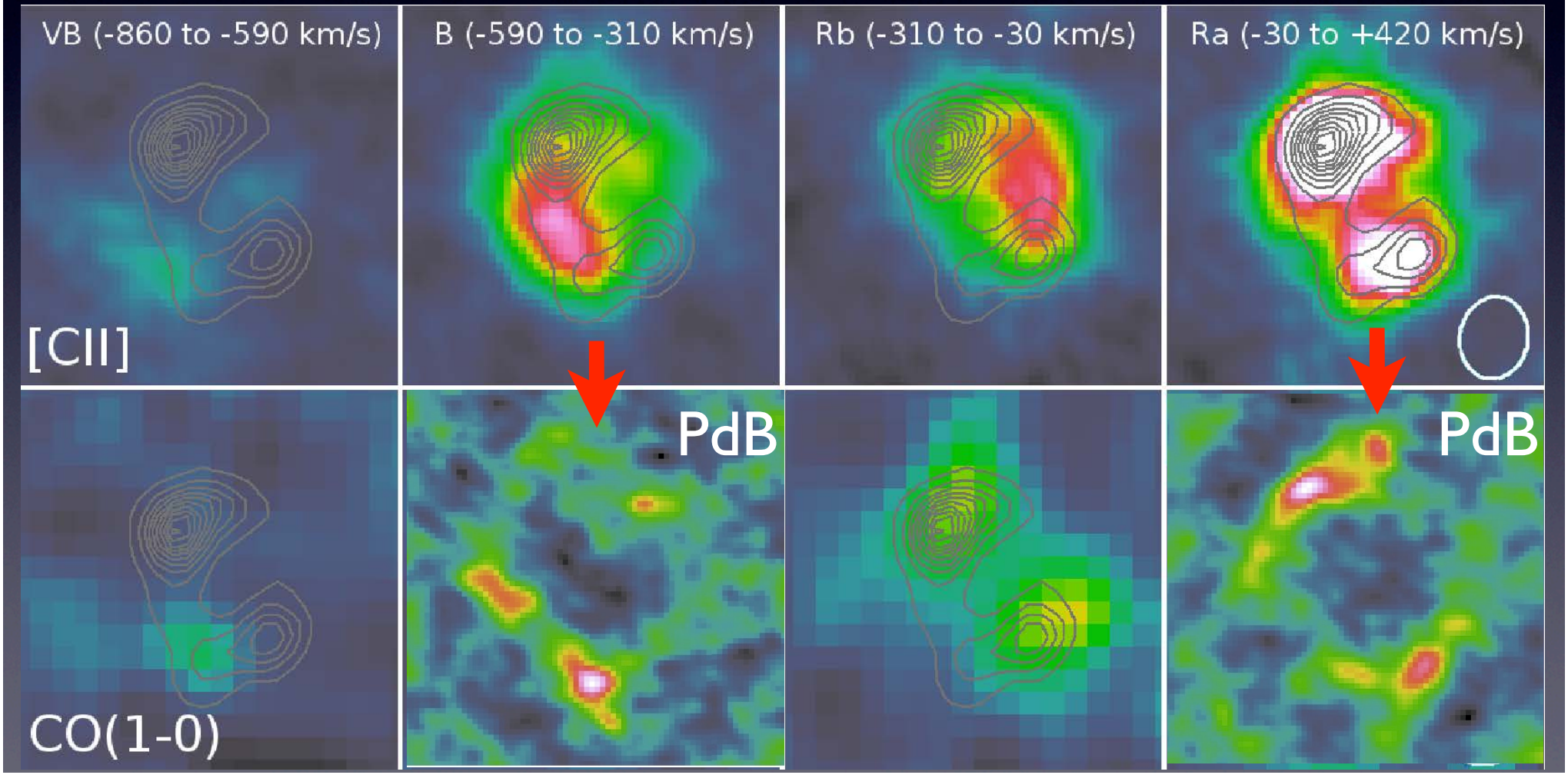

Observed Frequency [GHz]
130
129.5
[CI]
S [mJy]
VB
B
Rb
Ra
Velocity [km s^{-1}]

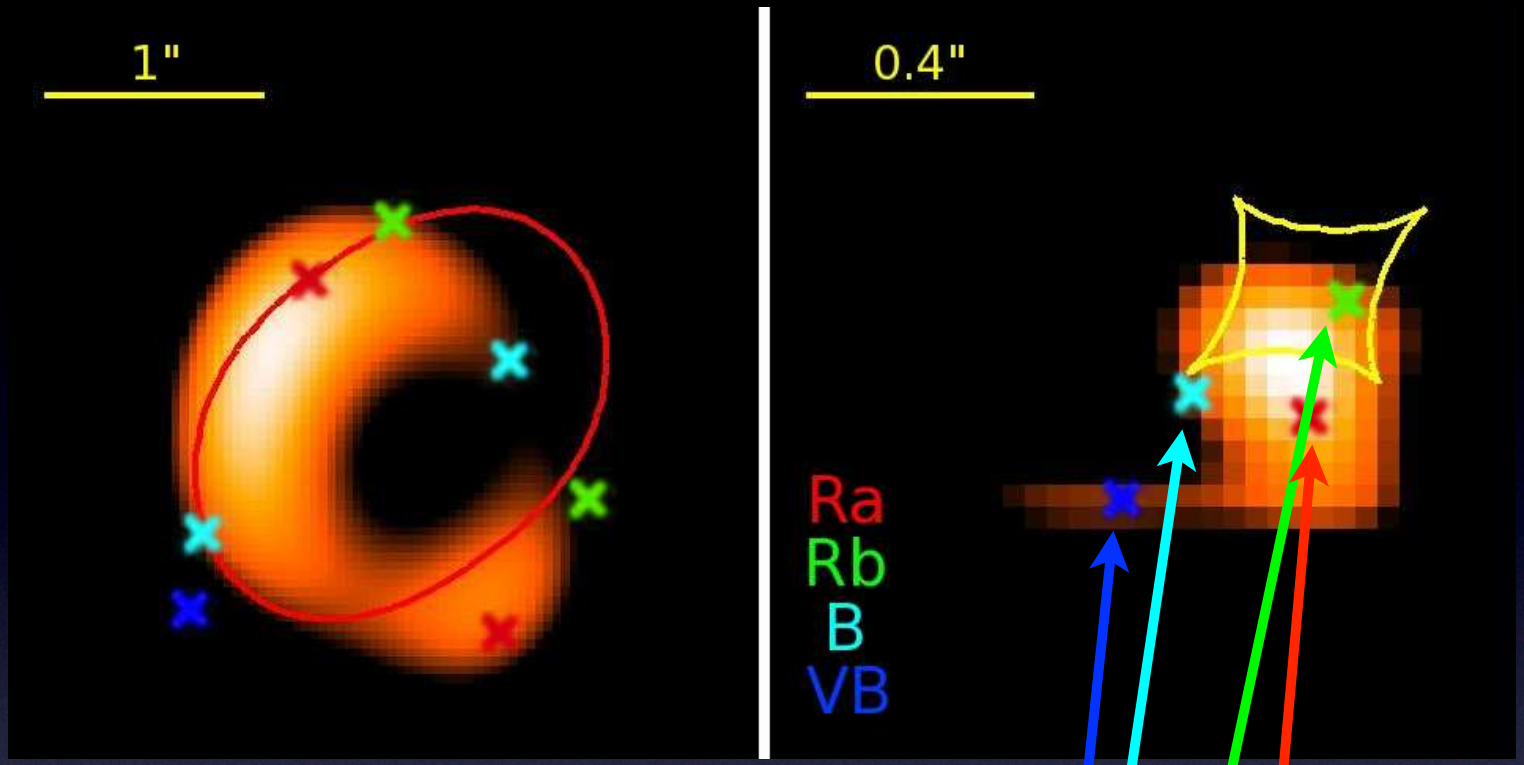

Observed Frequency [GHz]
158.5
158
$H_2O_P(2,0,2-1,1,1)$
S [mJy]
Rb
Ra
Velocity [km s^{-1}]

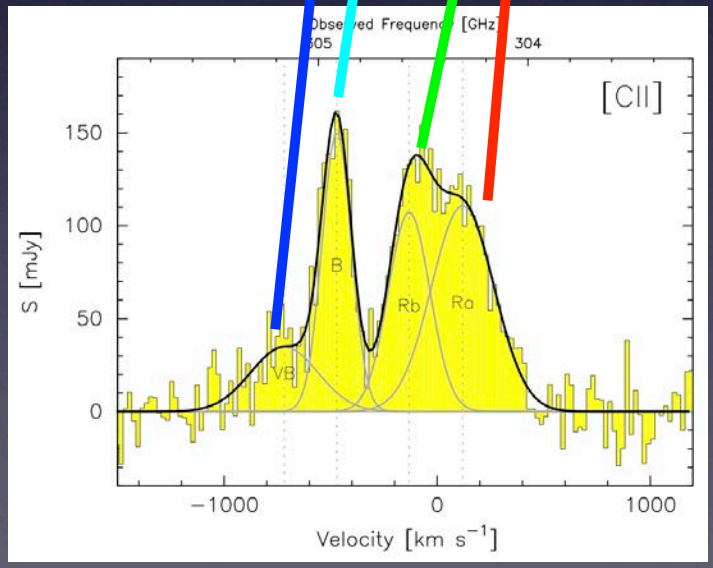

Observed Frequency [GHz]
235
234
[NII]
S [mJy]
VB
B
Rb
Ra
Velocity [km s^{-1}]

Spatially Distinct Velocity Components

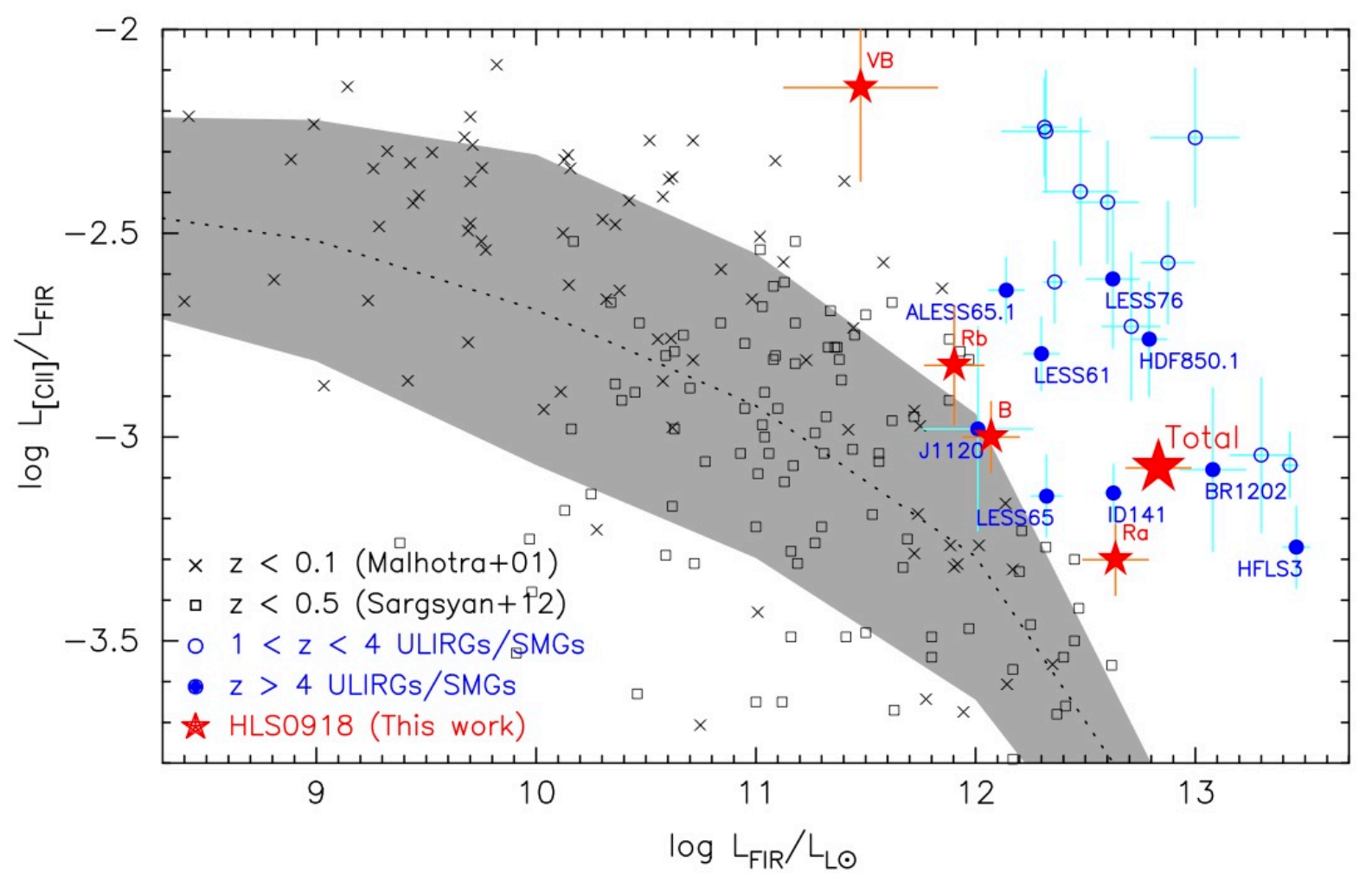








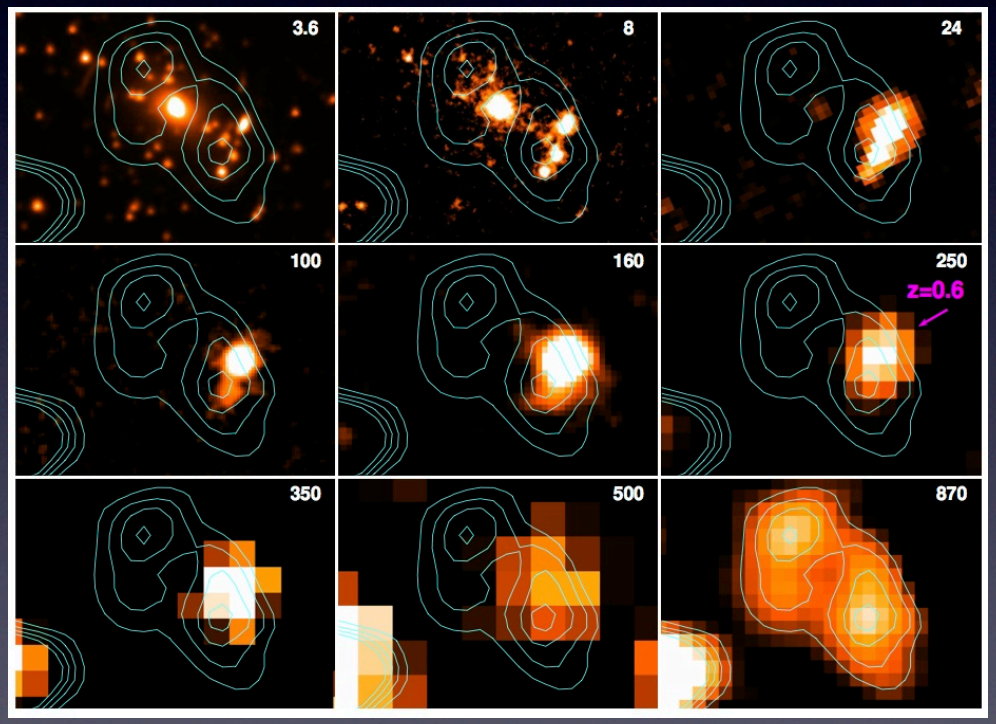
Spatial resolving z=5.2 galaxy!

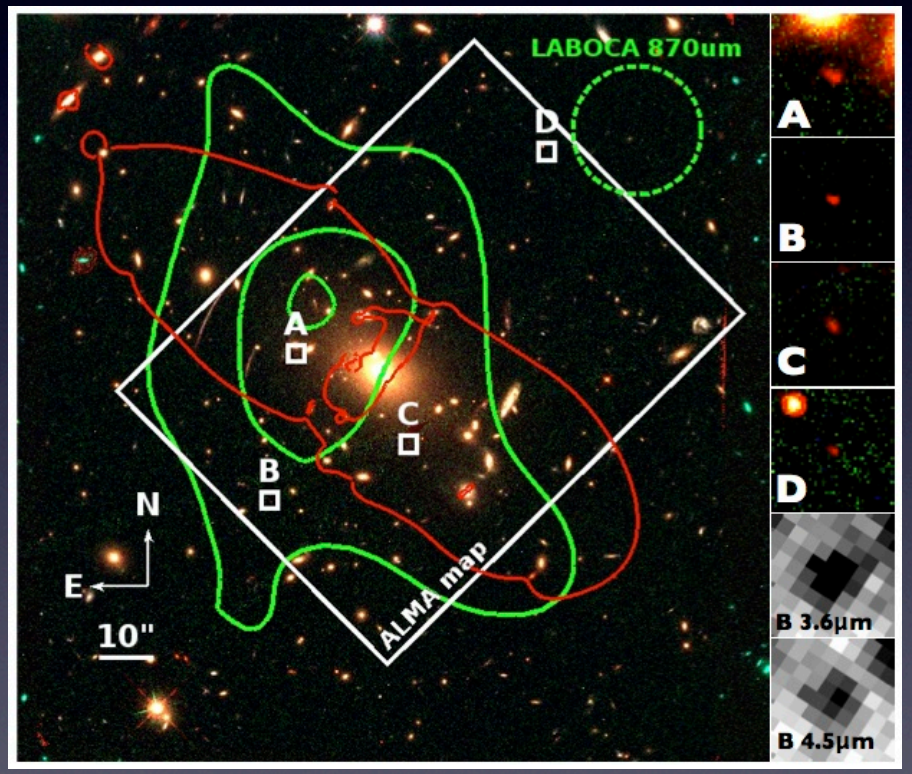


L[CII]/L(FIR) similar to other z>4 galaxies.
VB component shows an abnormally large ratio.

z=6.1 Quad system with submm emission?
or
SZ substructures?

AS1063



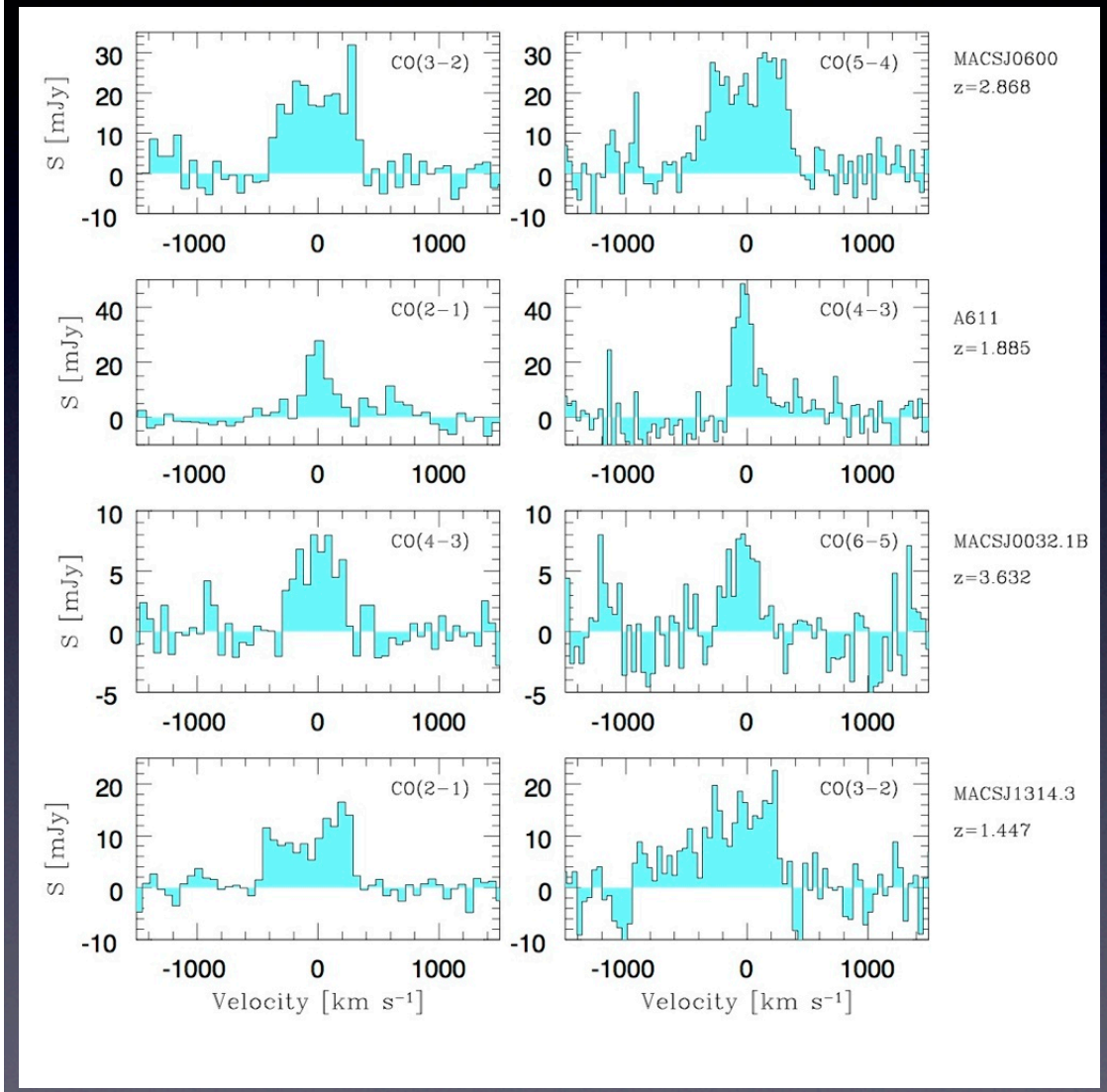


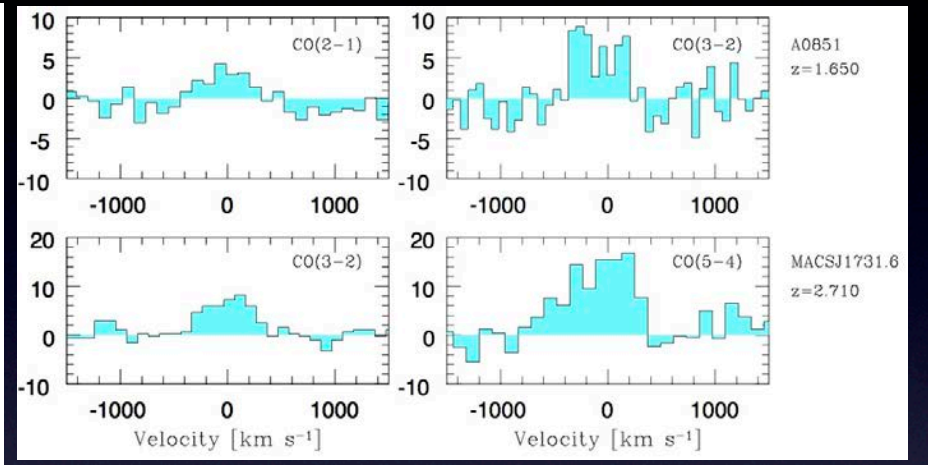
From the LABOCA Lensing Survey (Boone+13)

(2) HLS-snapshot

4 examples at
z=2.0, 1.9, 4.7, and 1

IRAM30m/EMIR z Search

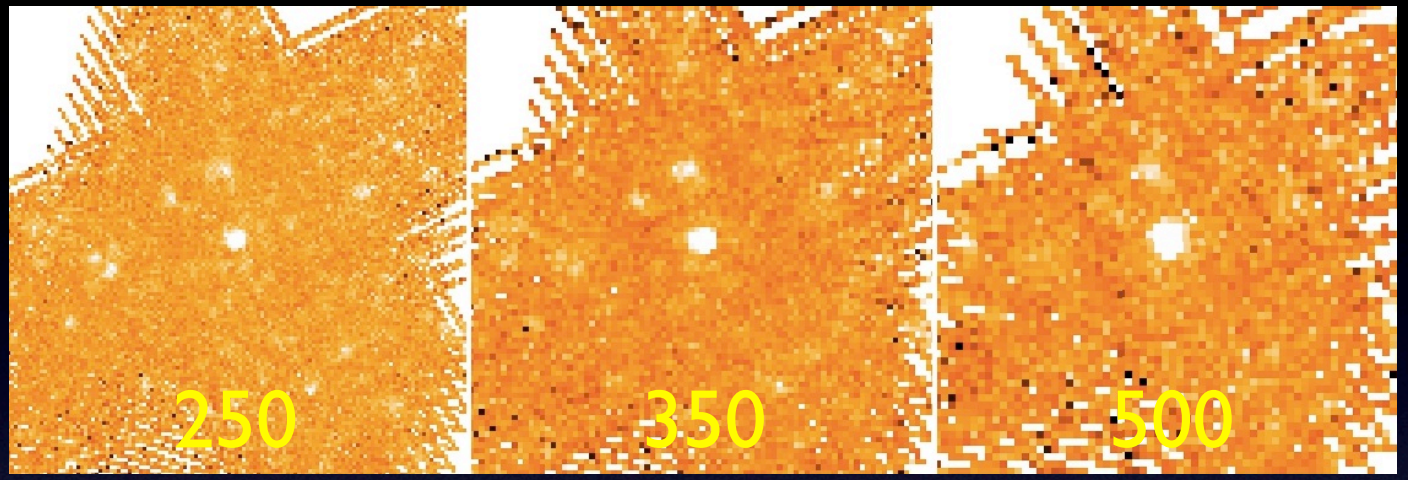


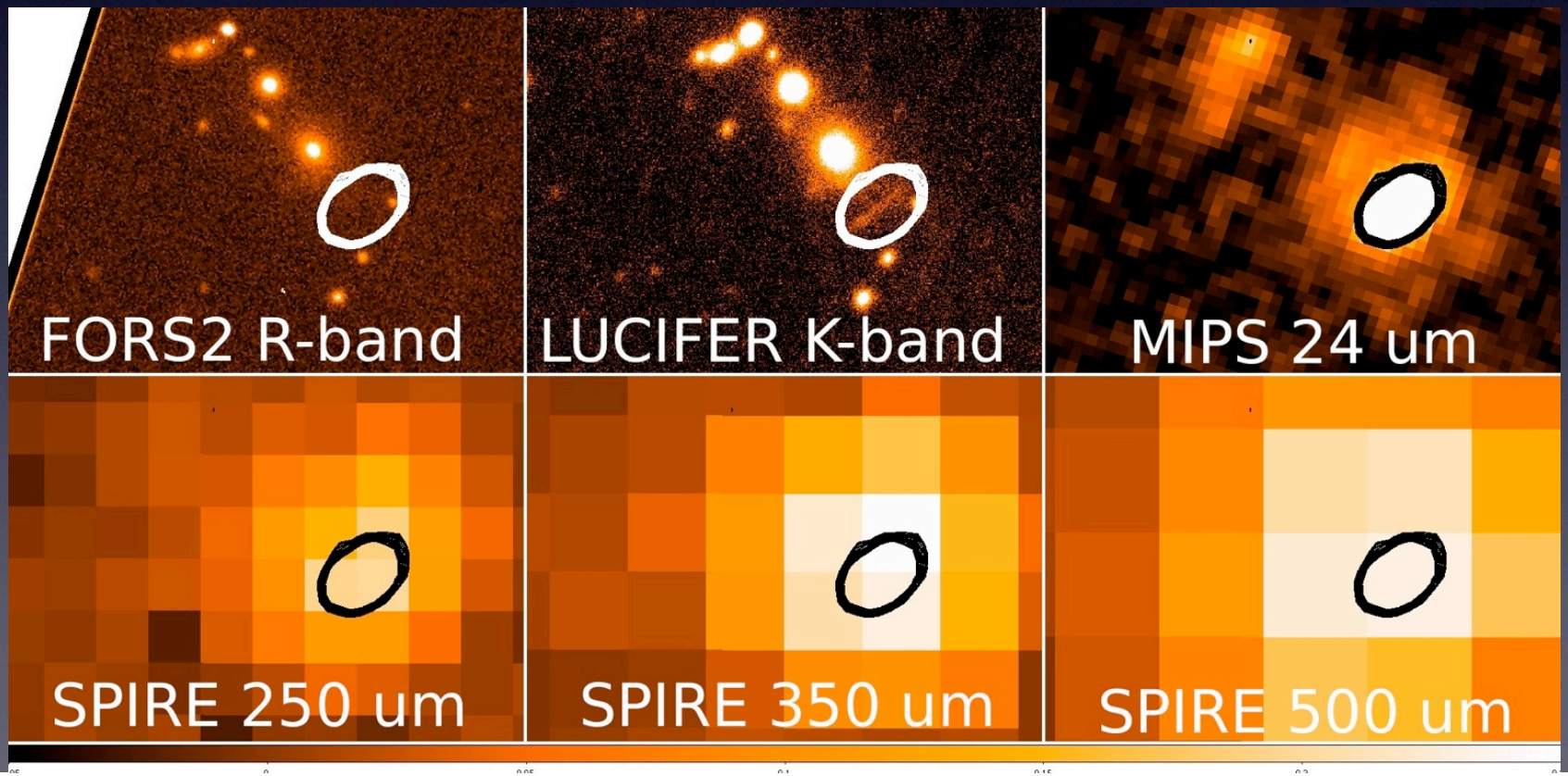


HLS-snapshot bright sources allow easy CO redshift measurements.

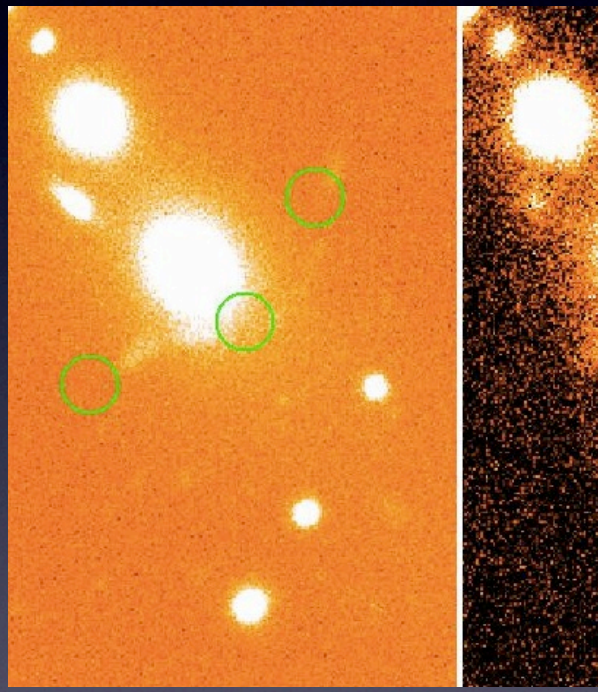
Optically-Faint IR Arc at z=2.0

Walth+13
in prep

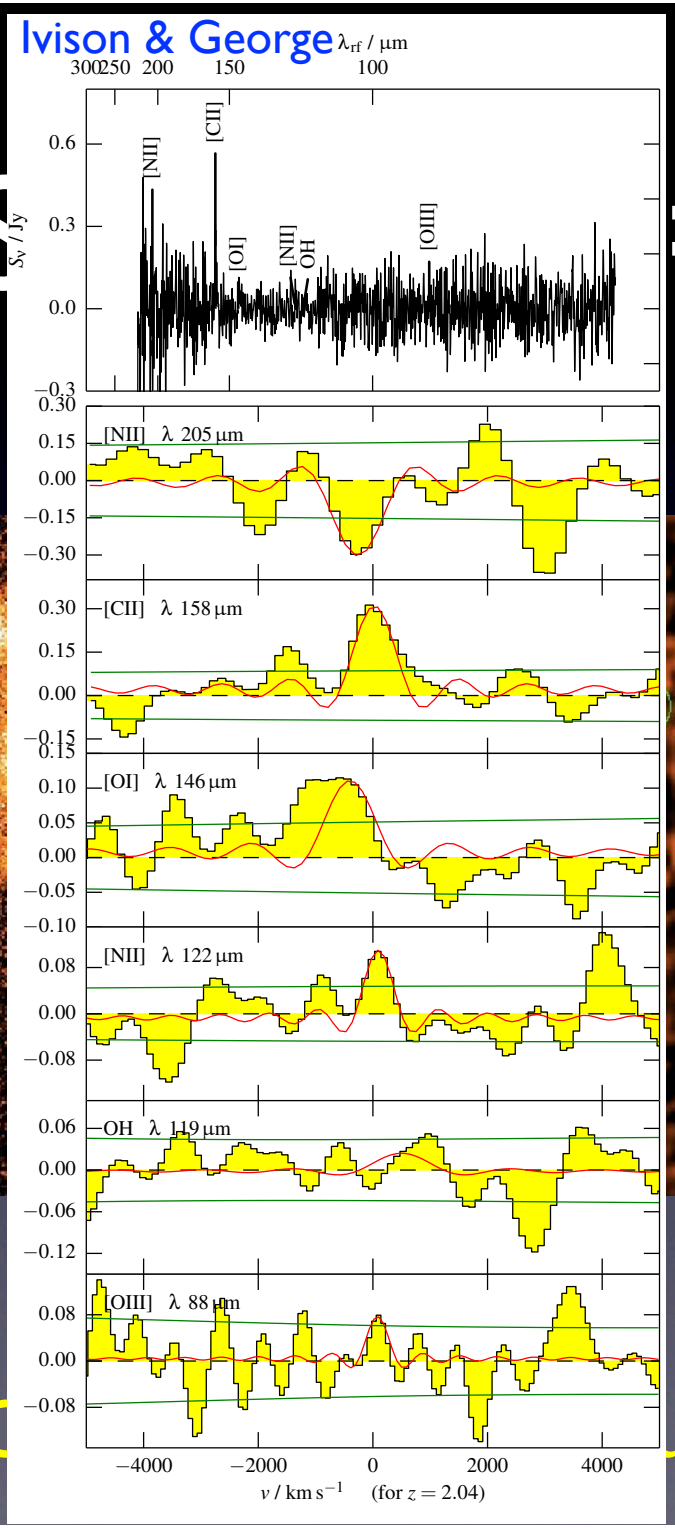


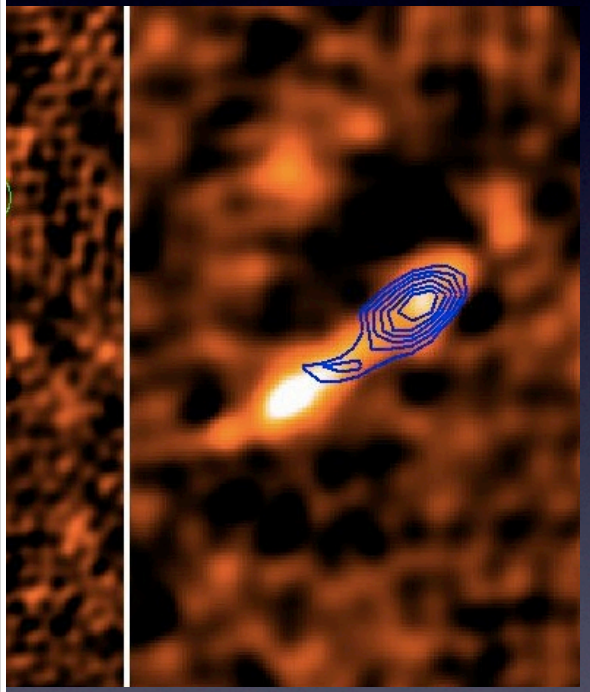


MACS =2.04



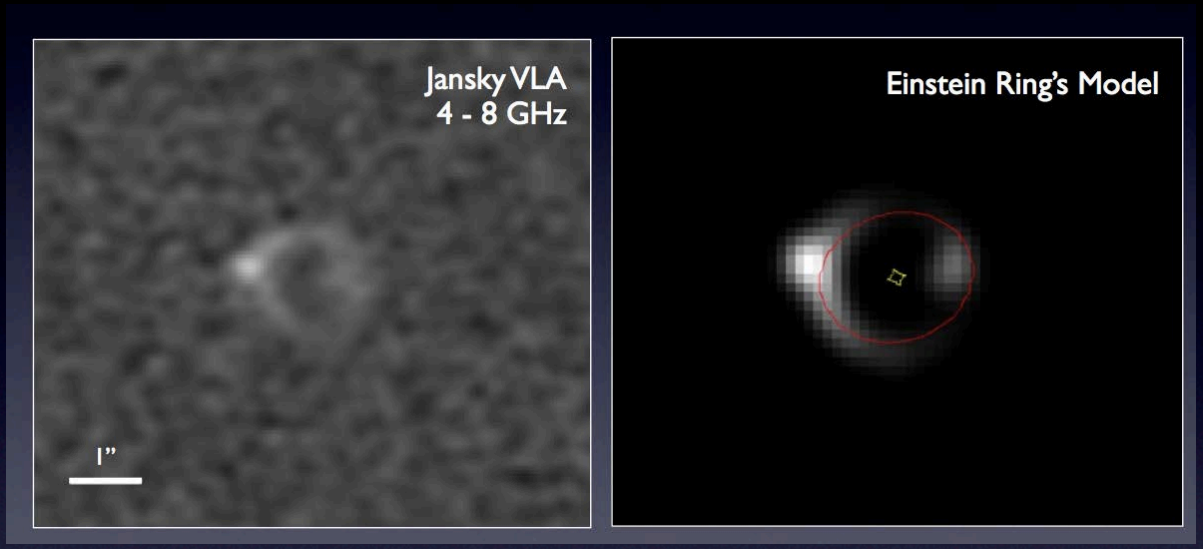
Magellan/IMACS
i band

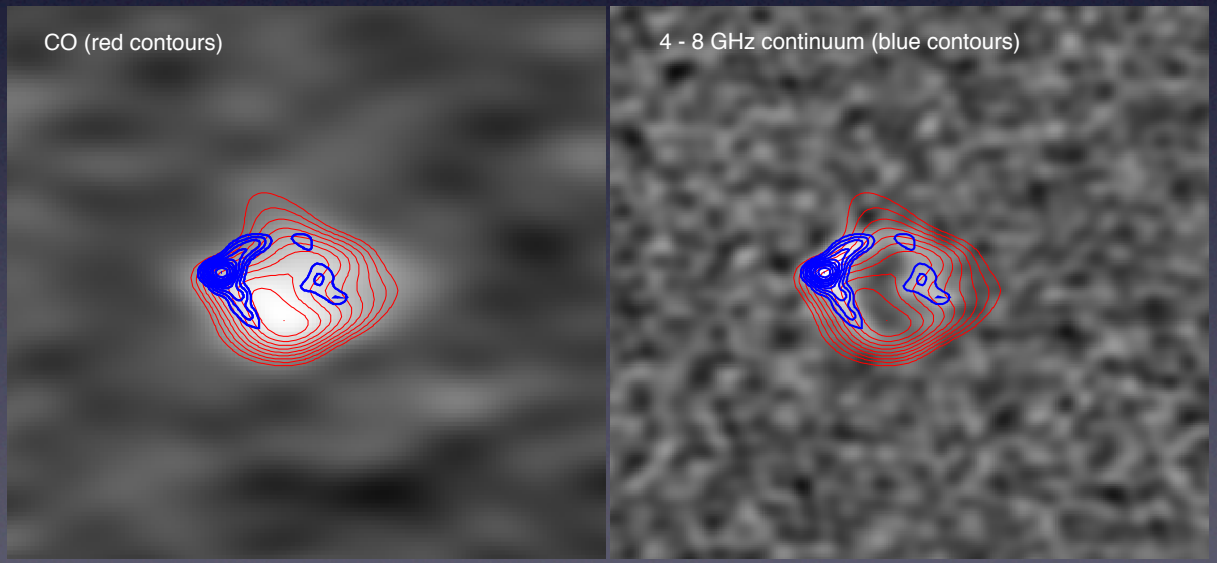




SMA
870um
JVLA
CO(1-0)

CO(1-0) ≠ Continuum



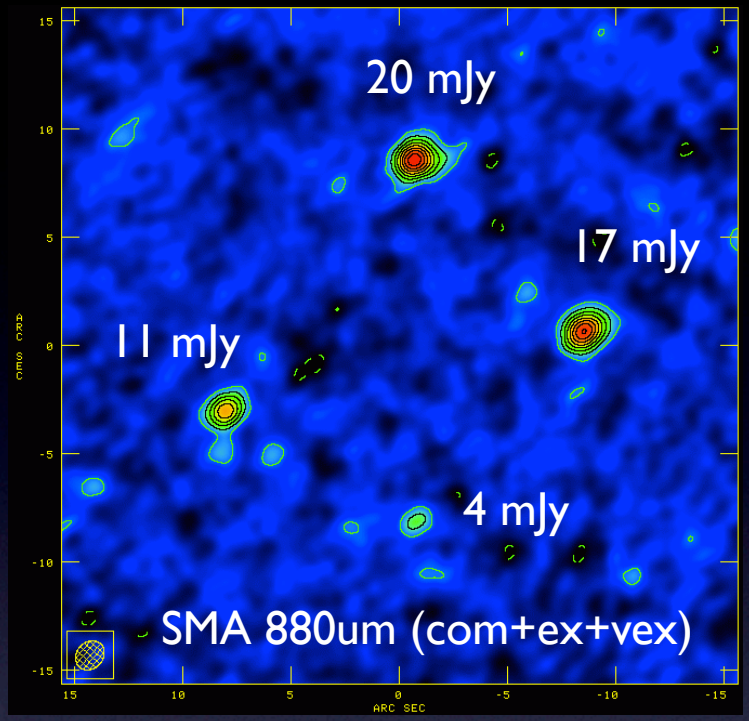


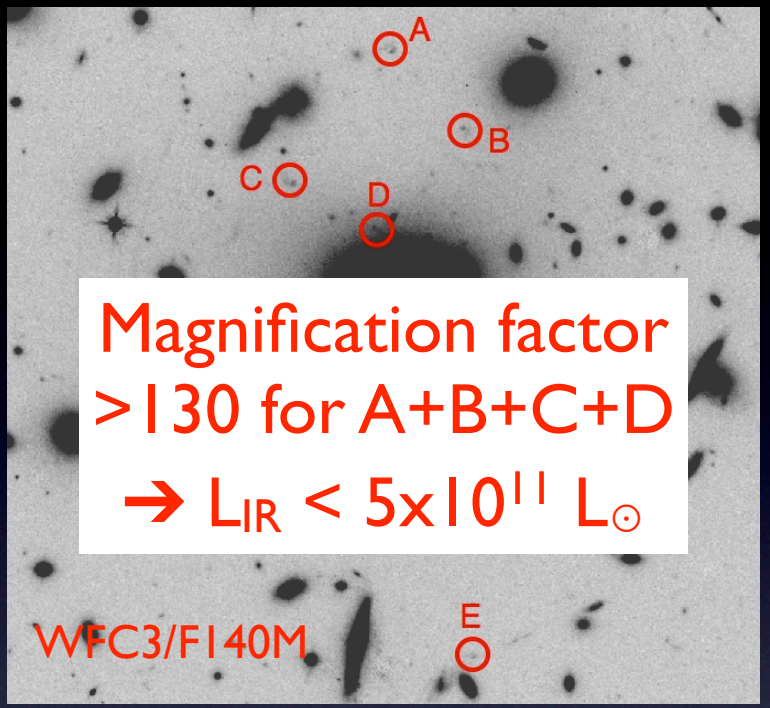
Rujopakarn+13
in prep

z=1.9 galaxy-lensed source from HLS-snapshot

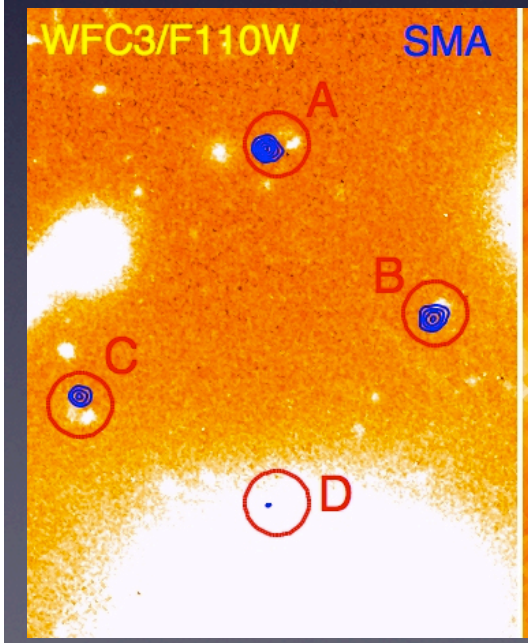
Quintuply lensed z=4.7 galaxy (Egami+13, in prep)

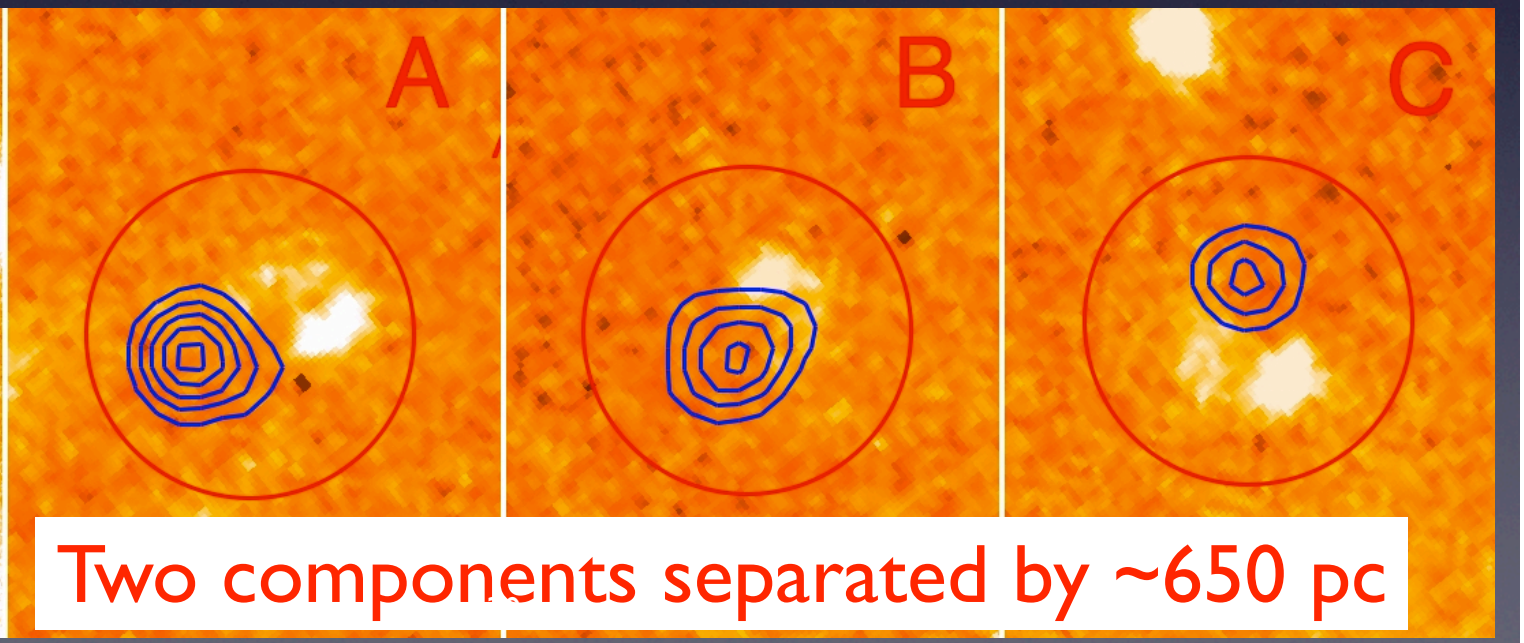
z(CO)=4.69





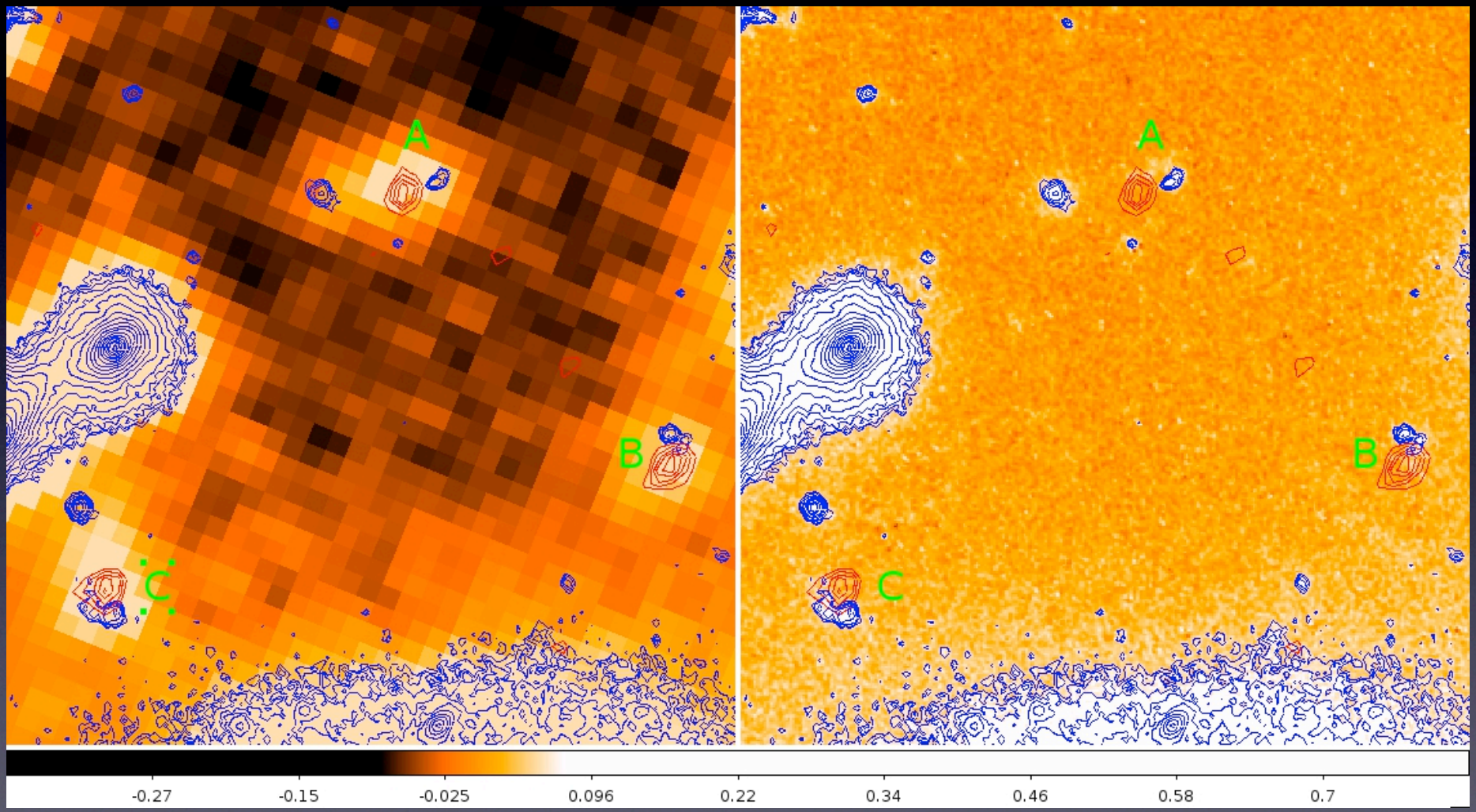
Magnification factor
>130 for A+B+C+D
→ $L_{IR} < 5 \times 10^{11}\ L_{\odot}$





Two components separated by ~650 pc

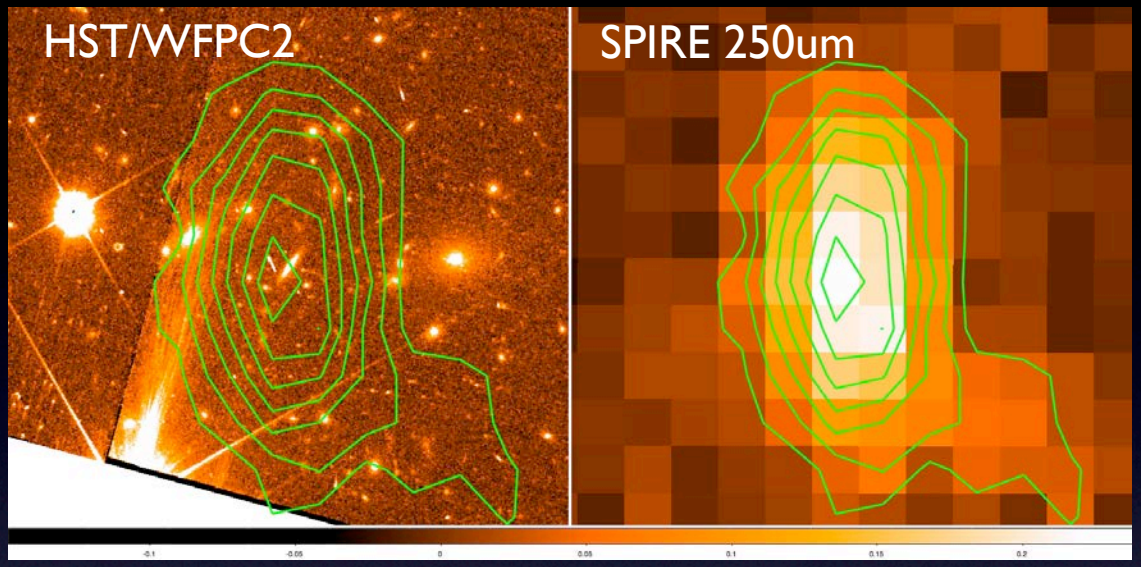
IRAC counterparts for the submm sources

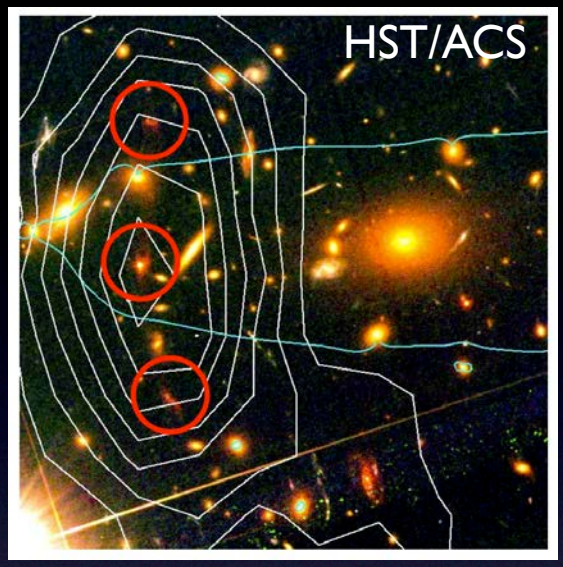


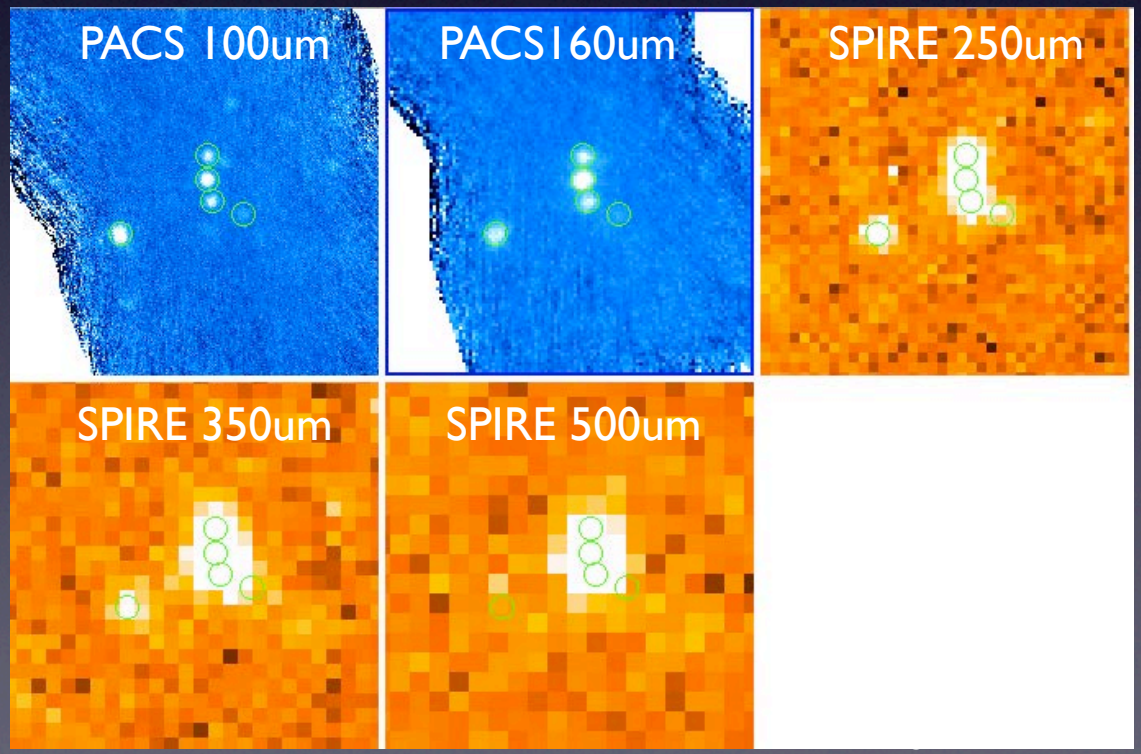
Spitzer/IRAC 3.6 um

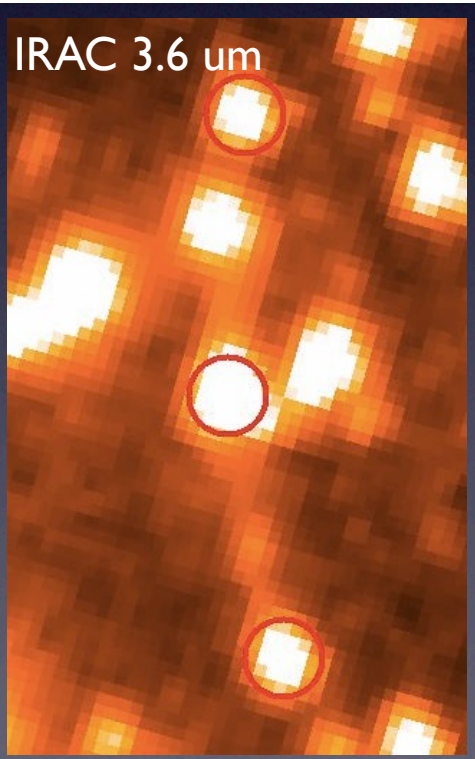
HST/WFC3 F140W

Triply lensed galaxy at z~1

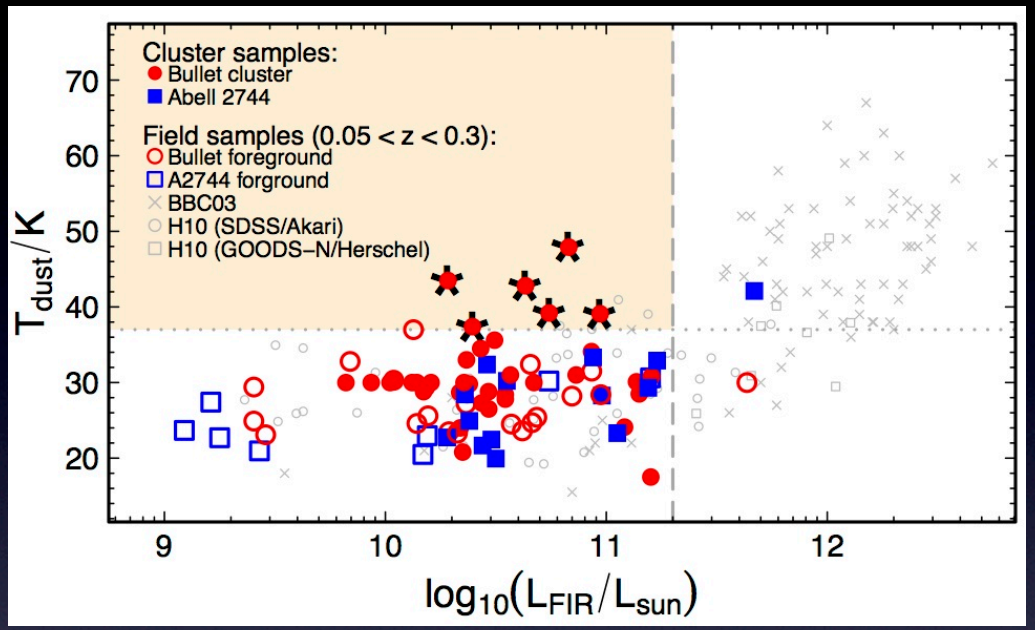


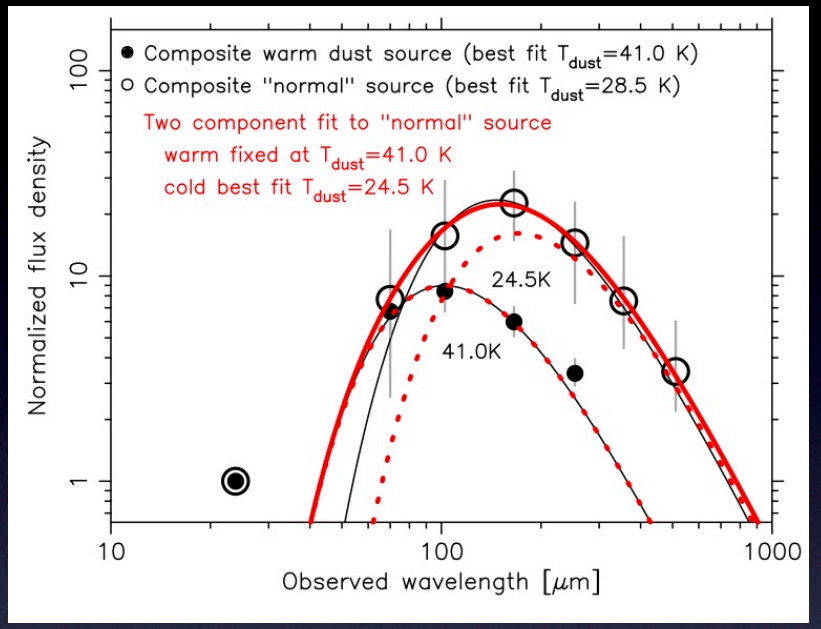


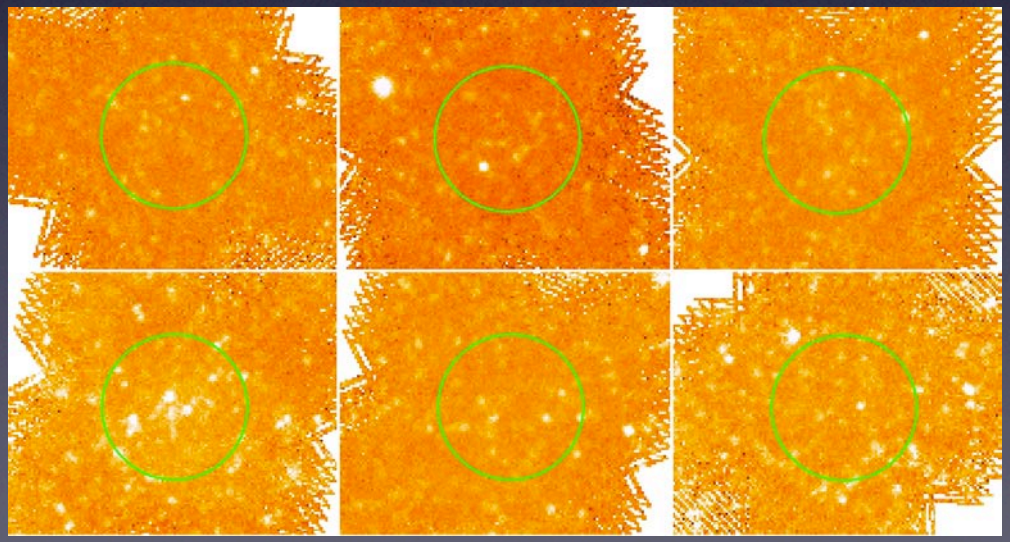




(3) IR-bright cluster galaxies







Rawle+12; Rawle Poster

z>0.9 SPT clusters

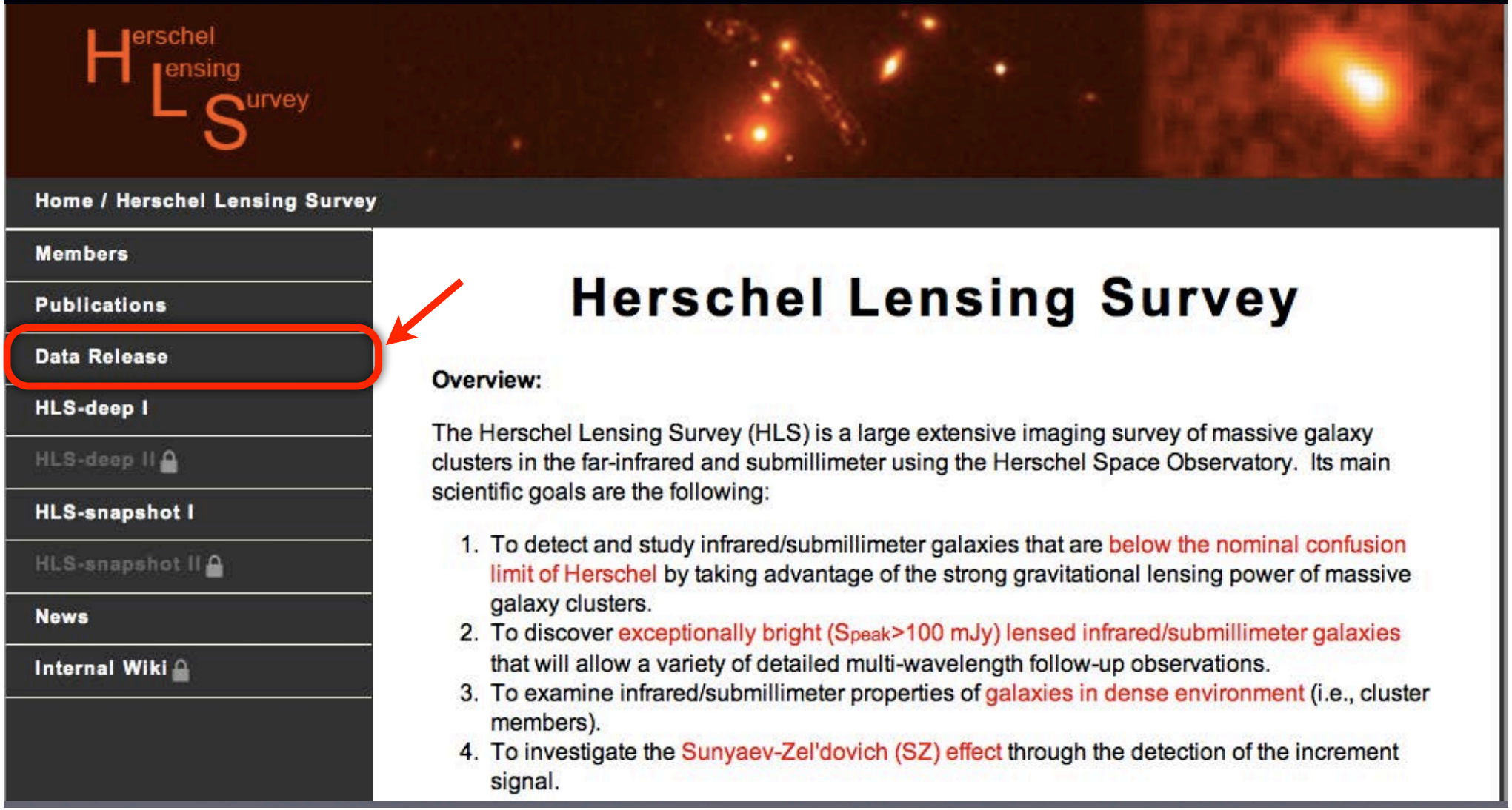
IV. HLS Data Release (DR1)

- HLS-deep 44 clusters (Original OTKP sample).
- Fully processed PACS and SPIRE images.
- Source catalogs with IRAC and/or MIPS priors will be released in ~1 month.
- We plan to release all HLS-deep images (with source catalogs) and HLS-snapshot images by the end of 2013 with the survey paper (Egami et al. 2013, in prep).

From the HLS website

http://herschel.as.arizona.edu/hls

(or google "herschel lensing survey")



Members
Cluster List
Rainbow Slicer (public)
Rainbow Slicer
Rainbow Navigator
Internal Wiki

There are three ways to download the images:

- **Simple tarballs (the "Download" column in the table)**

Each tarball contains the PACS (100/160 um) and SPIRE (250/350/500 um) images. PACS images come with coverage maps while SPIRE images come with coverage and uncertainty maps. All the HLS DR1 data are also available in one big tarball here : hls-deep1_dr1.tar.gz

- **Rainbow Data Extractor pages (the "Rainbow" column in the table)**

This interface allows downloads of individual images (use the link at the bottom of each page for a single tarball). In the future, these pages will provide additional files such as source catalogs and various ancillary data (e.g., Spitzer & WISE images).

- **Rainbow Slicer interface (Click the "Rainbow Slicer (public)" tab on the left)**

Rainbow Slicer allows the user to select images for downloads. It can also generate multi-wavelength postage-stamp images for a given sky position (N-BAND QUICKLOOK) or for a given set of source positions (N-SOURCE QUICKLOOK). The Rainbow Data Extractor pages described above are the outputs when "Select Filters = all".

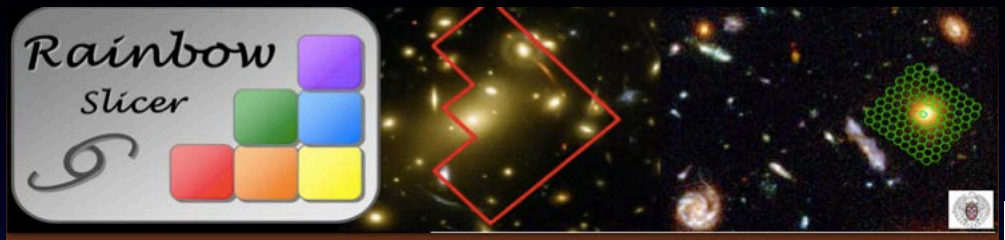
README file provides more detailed information on the images provided here.

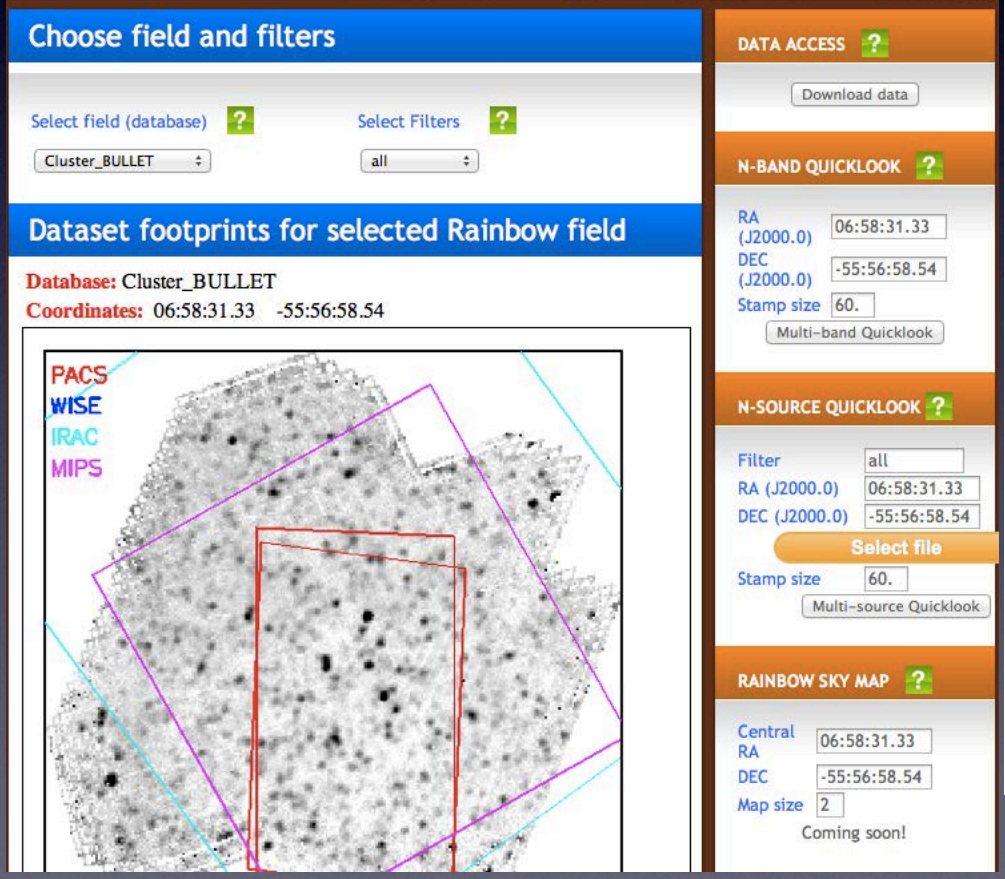
Note: We are still finalizing the processing of the Bullet cluster PACS data, which were obtained during the SDP period and require special treatment. These PACS images will be released shortly.

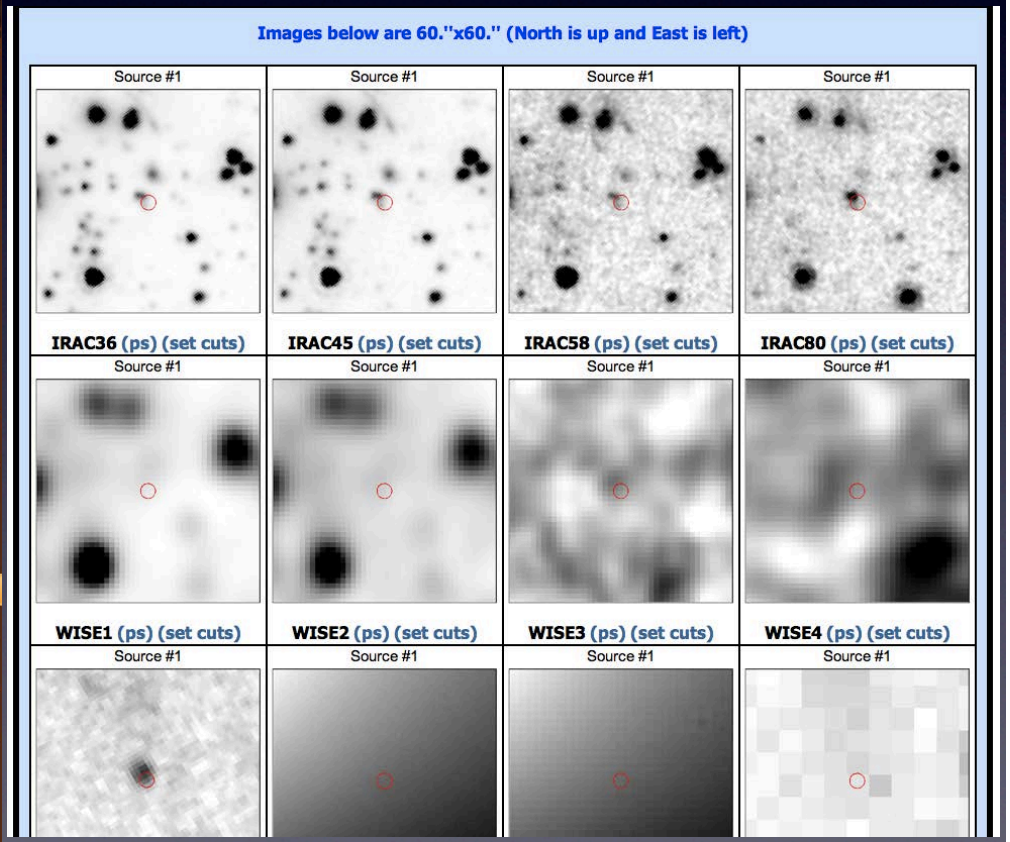
Cluster	Full / Alternate Name(s)	R.A.	Dec.	Redshift	Download	Rainbow
A2744	AC118	00h14m19.00s	-30d23m19.0s	0.308	maps	
MACS0018	CL0016+16	00h18m33.20s	+16d26m18.0s	0.541	maps	

Rainbow Slicer

by P. Perez-Gonzalez







Summary

- Gravitational lensing provides enormous gain in sensitivity for free.
- HLS-snapshot is picking up exceptionally bright lensed galaxies that can be studied in detail with pre-ALMA facilities.
- HLS-deep probes *faint* lensed galaxies that will require ALMA follow-ups (= strength of lensing cluster surveys).
- Submm/mm interferometers (especially ALMA) aided by lensing magnification resolve bright lensed galaxies into individual star-forming regions (HII regions, molecular clouds) → Next frontier