

The Herschel Lensing Survey (HLS)

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Rujopakarn (Arizona)	A. Cava (Geneva)	O. Ilbert (Marseille)	R. Pello (Toulouse)	I. Valtchanov (ESAC)	
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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 DRI)

I. Motivation



Herschel D=3m

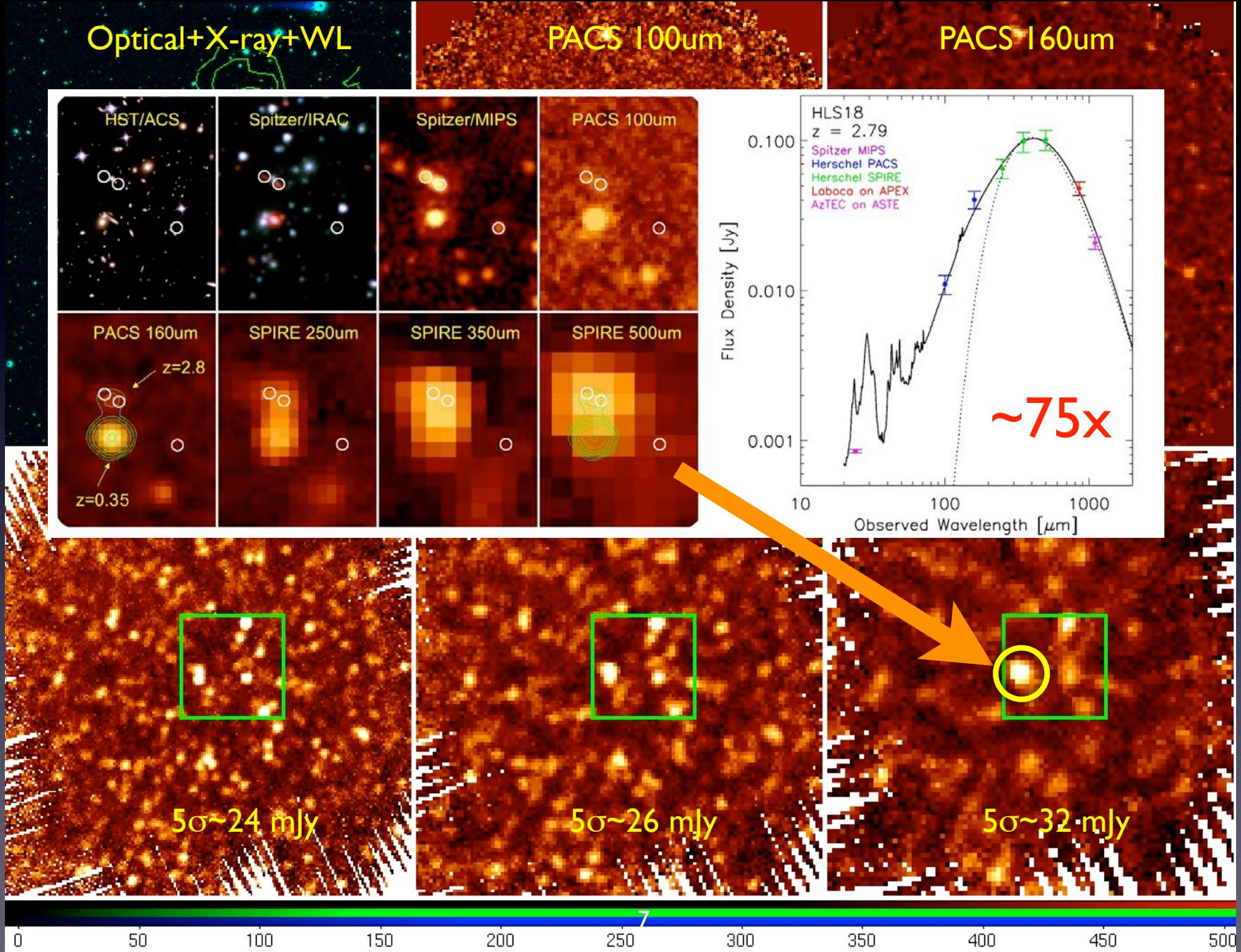
x10
lensin
m²

This is all for free!



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 (\rightarrow 65) massive (i.e., X-ray-luminous) cluster cores ($z \sim 0.1 - 0.5$) to detect and study Herschel sources below the confusion limit.
2. HLS-snapshot (52 hrs): Shallow SPIRE-only imaging of 527 massive cluster cores ($z \sim 0.1 - 1$) to discover exceptionally bright (S_{peak} $\gtrsim 100$ mJy) cluster-lensed galaxies that will allow a variety of multi-wavelength observations.

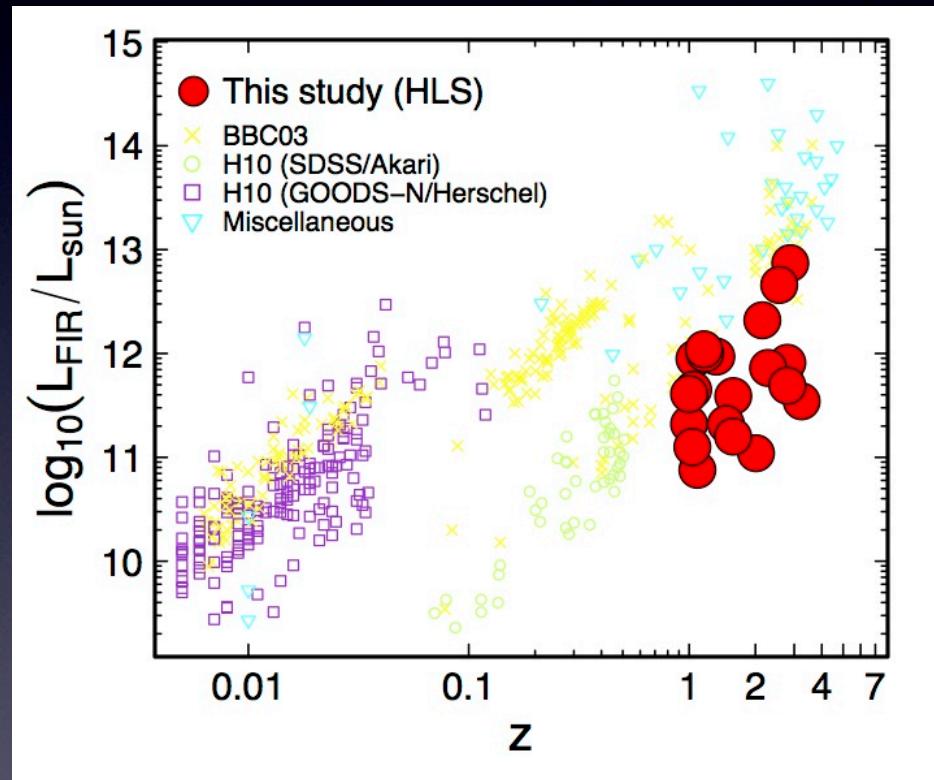
*Note: Field surveys (H-ATLAS, HerMES, SPT, ACT, etc.)
→ Galaxy-lensed systems*

Cluster Samples

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

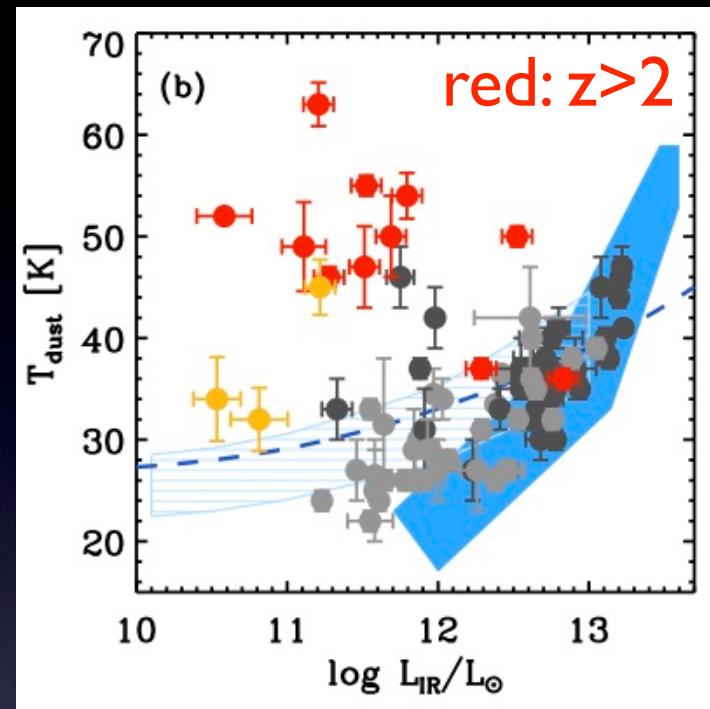
III. Scientific Highlights

(I) HLS deep

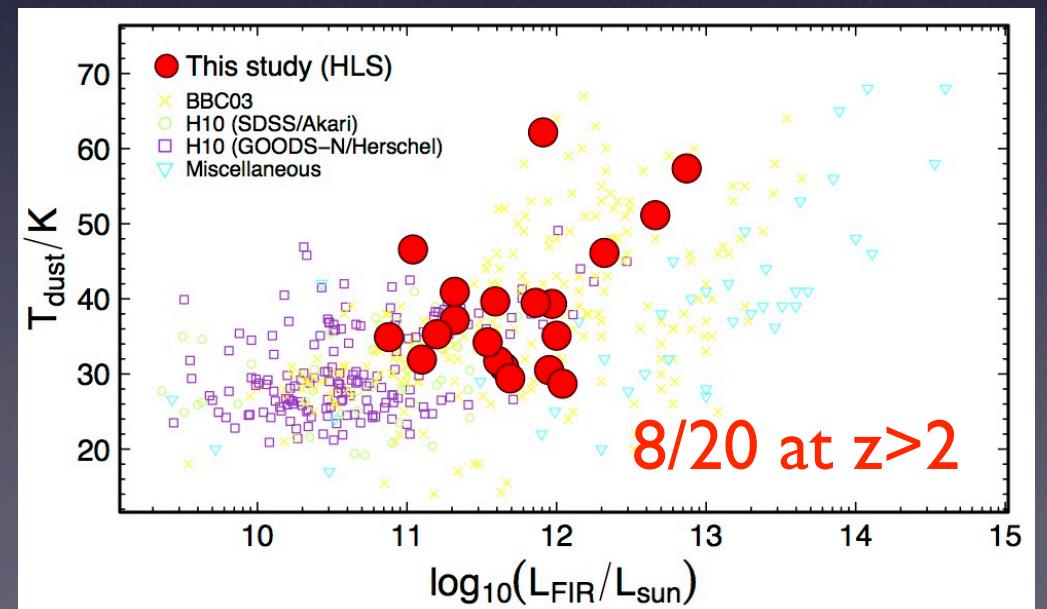


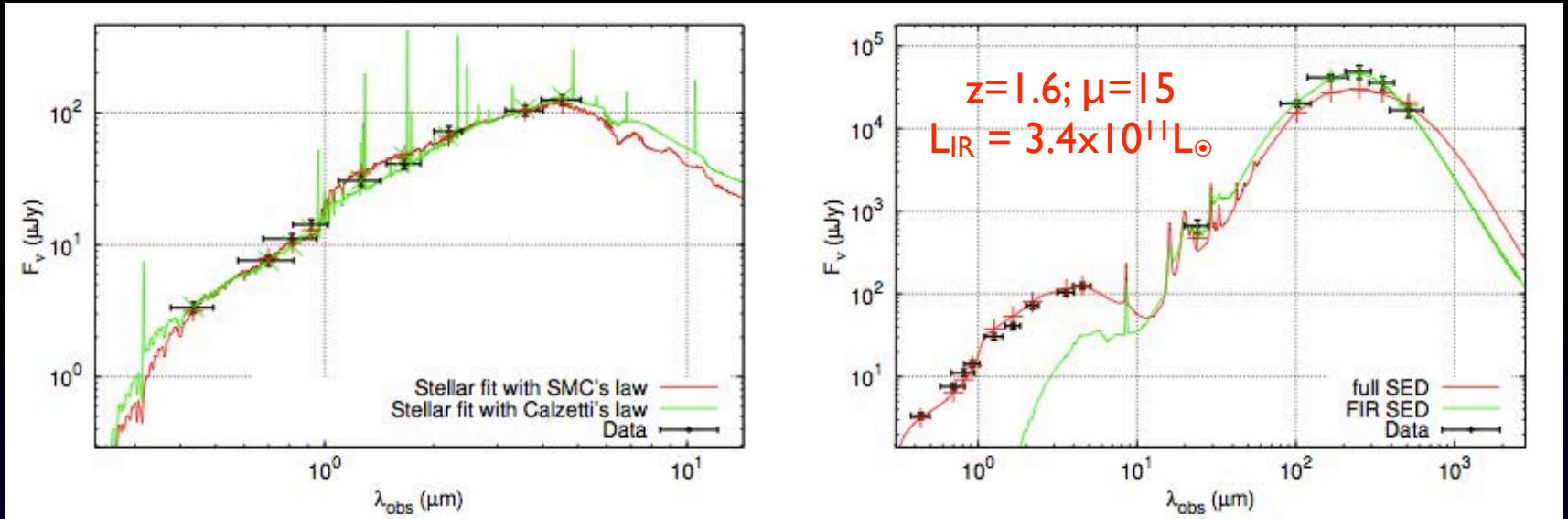
Rawle+13, in prep

Saintonge+13

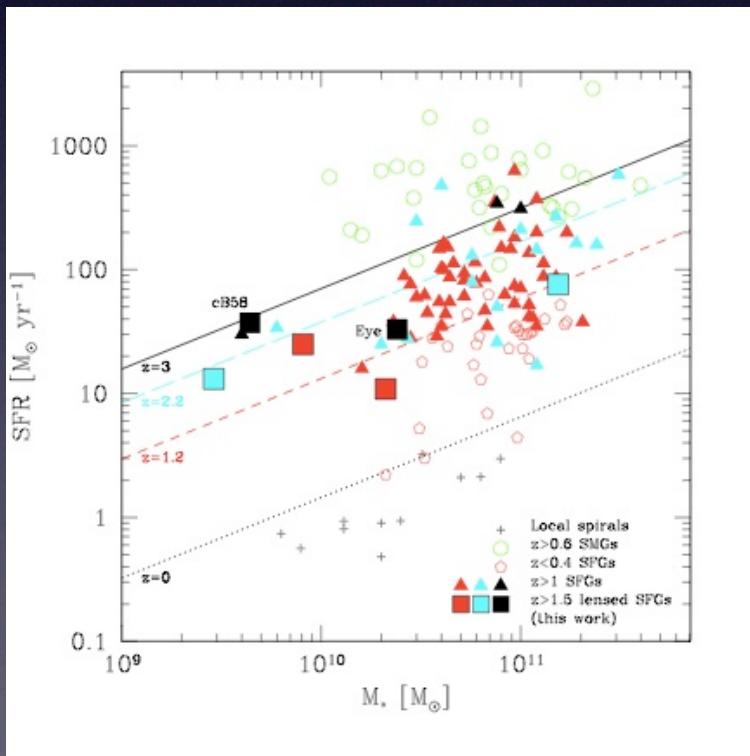


red: $z > 2$

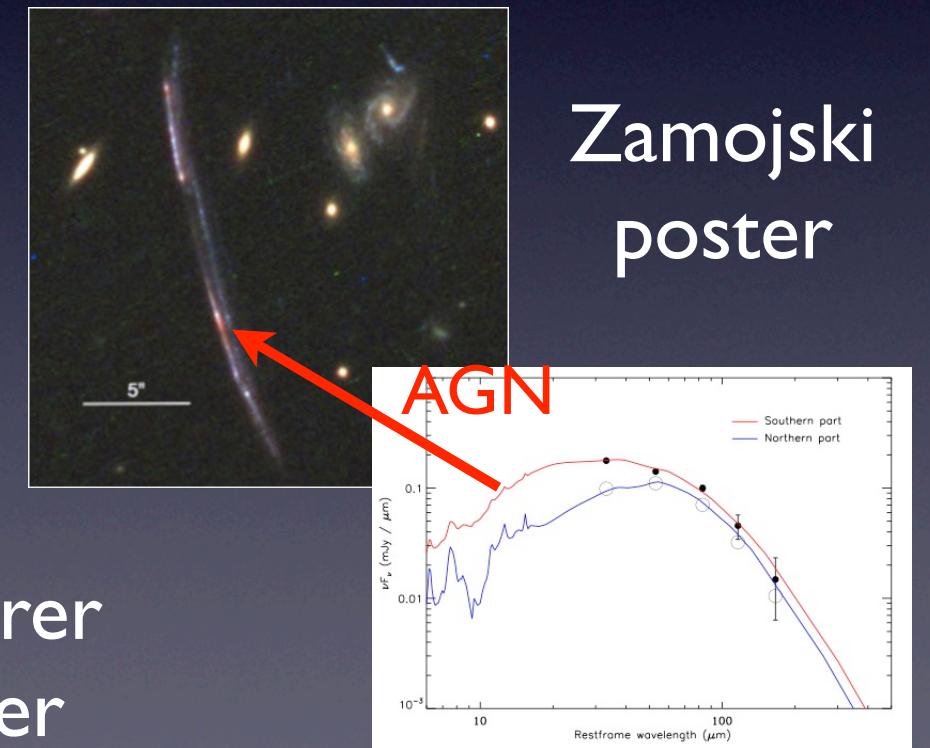




Sklias+13 (arXiv:1310.2655) and poster



Schaerer
poster

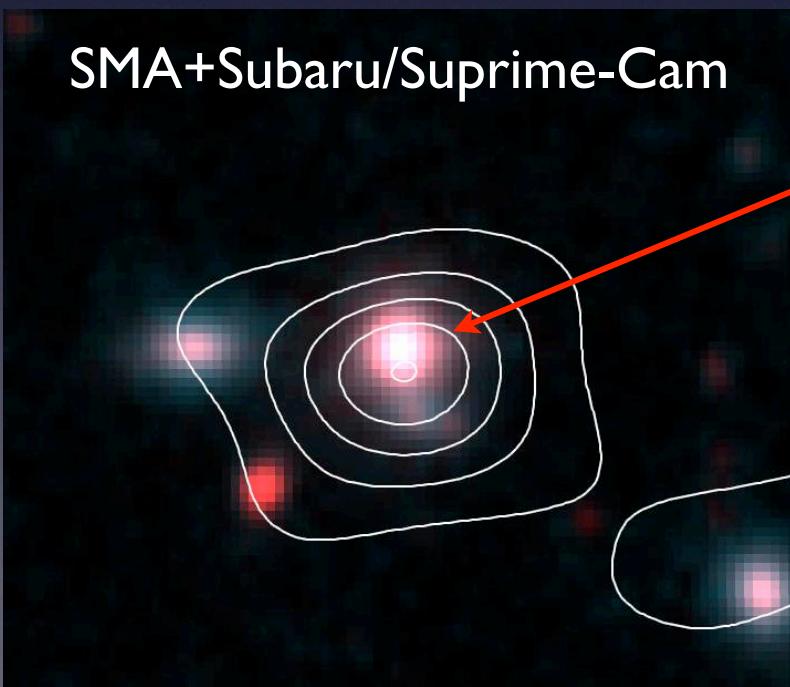
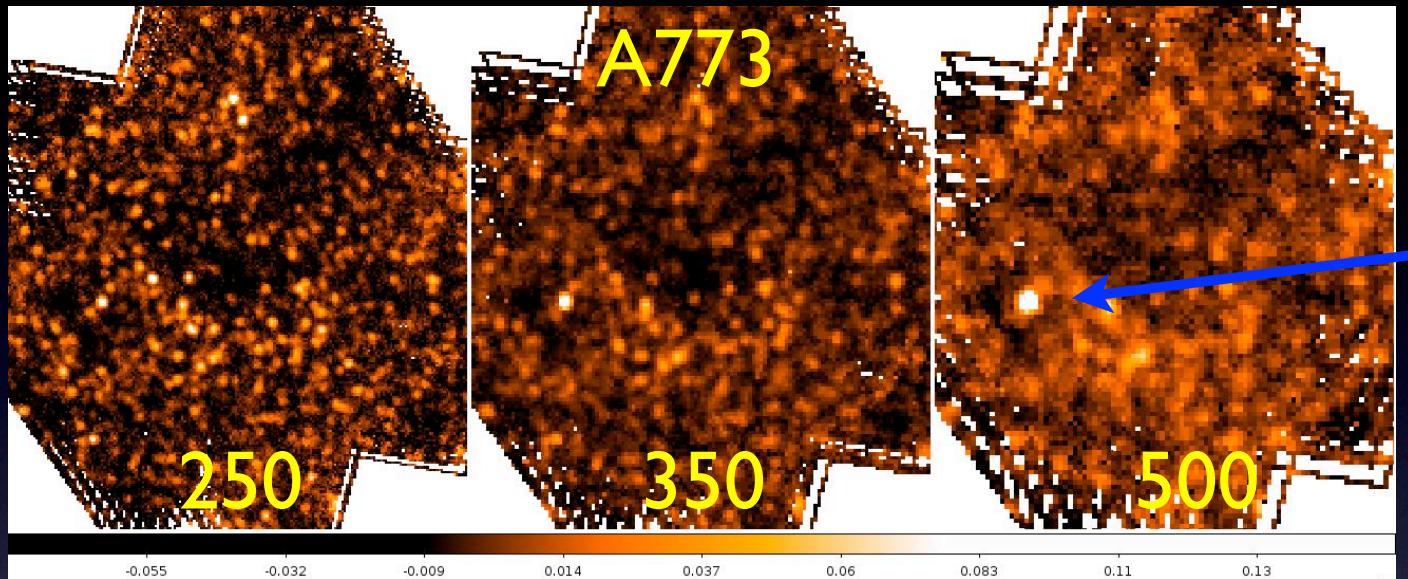


Zamojski
poster

Super-bright $z=5.2$ galaxy-lensed SMG

Combes+12
Rawle+13
(arXiv:
1310.4090)

~ 200 mJy
at 500um

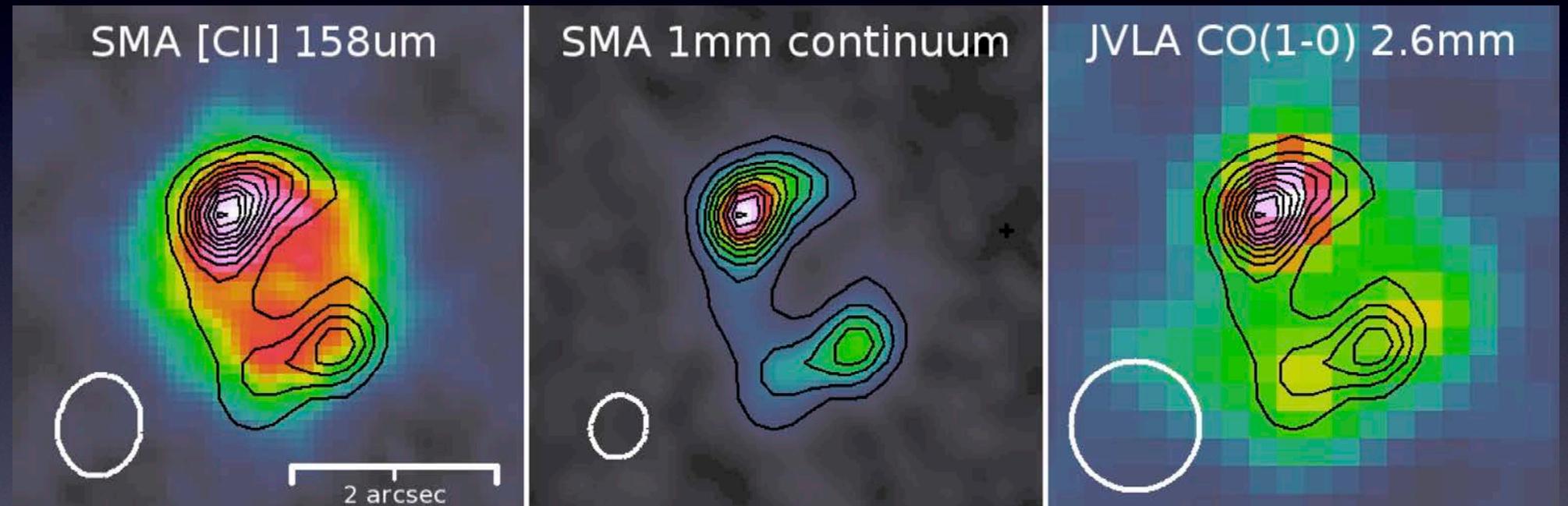


Lensing galaxy at $z=0.6$
 50 mJy at 1.3 mm!
(SMA Compact)

CO redshift $\rightarrow z=5.24$

New Data

(Rawle+13; arXiv:1310.4090)



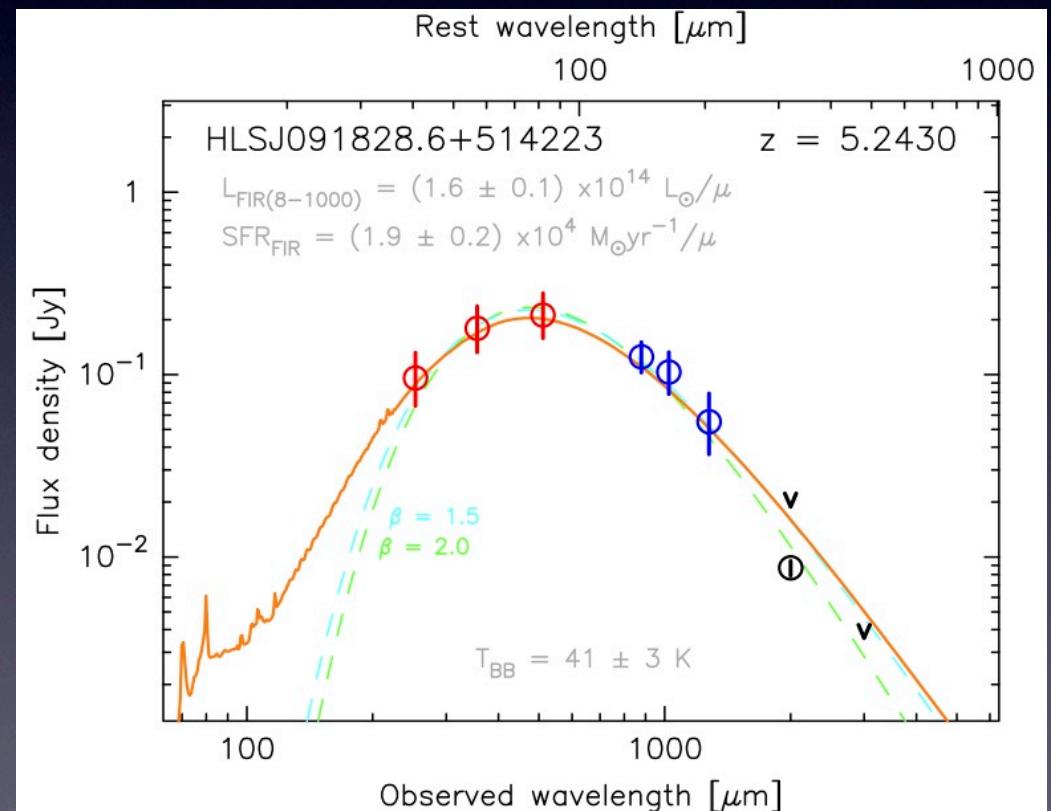
Compact+Extended+Very Extended
305 GHz=984 um

C and DnC config

HyLIRG with a LIRG-like SED

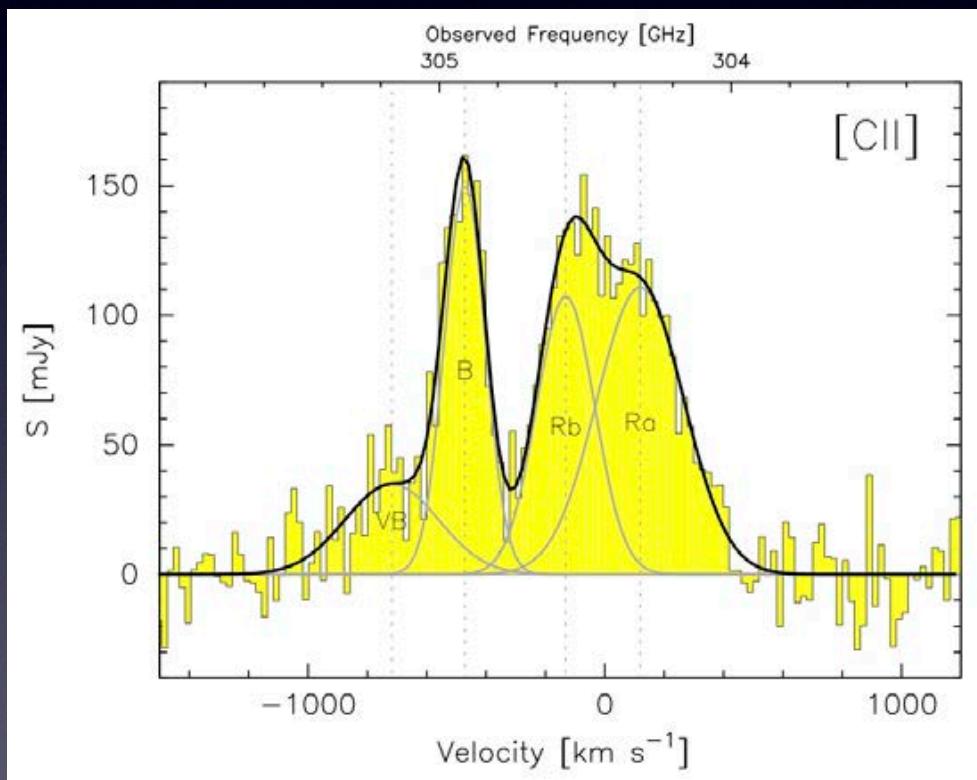
Magnification
 $\mu = 8.9$

$L_{\text{FIR}} = 1.8 \times 10^{13} L_{\odot}$
 $SFR_{\text{FIR}} = 2100 M_{\odot}/\text{yr}$

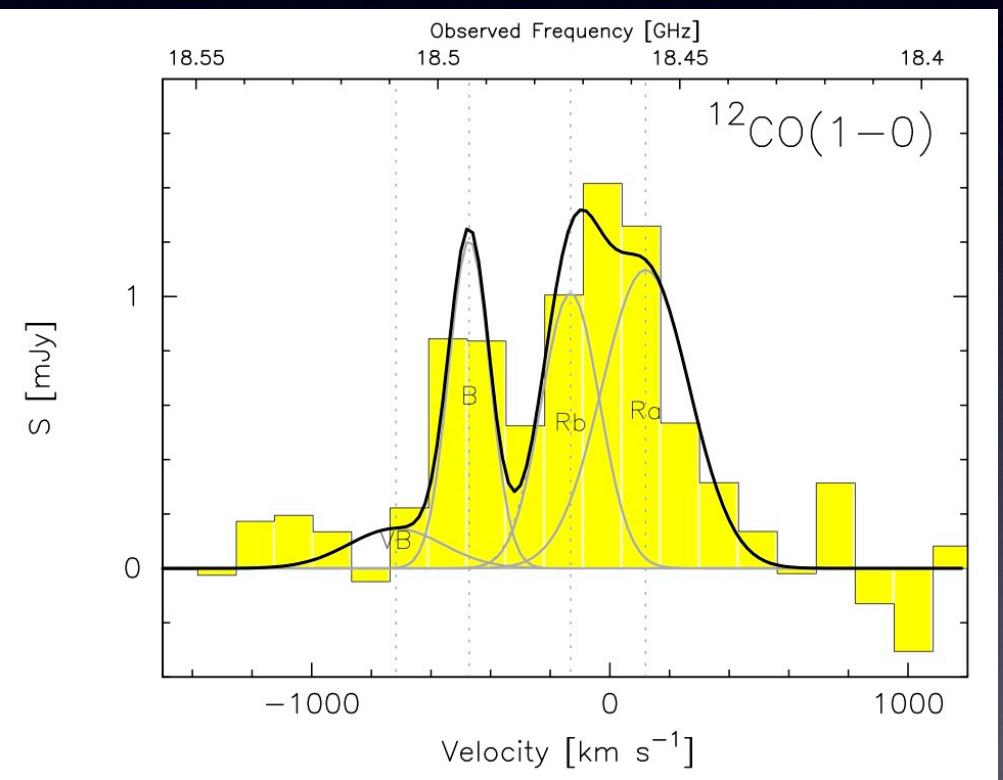


Complex Line Profile

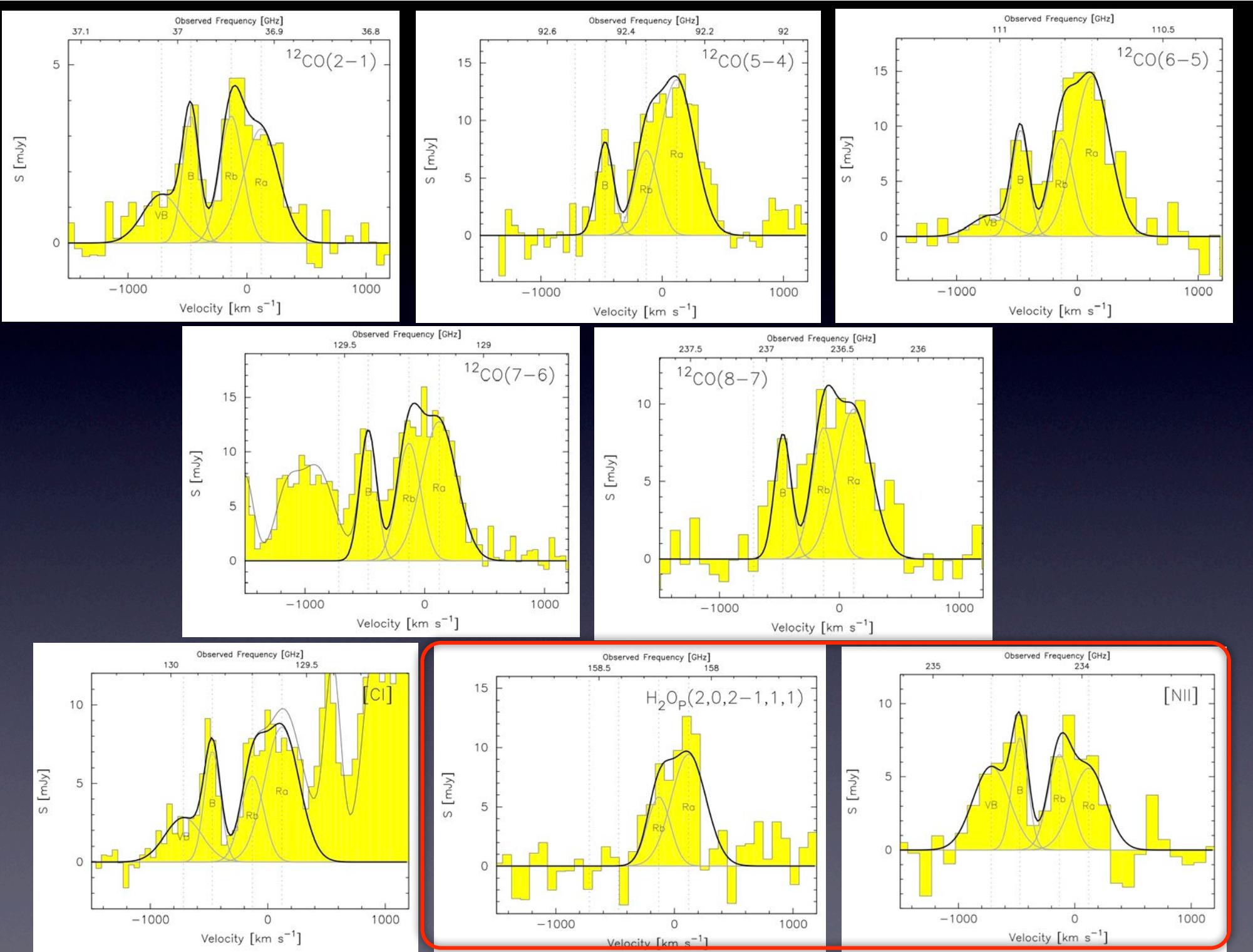
→ Likely suggesting a merging system



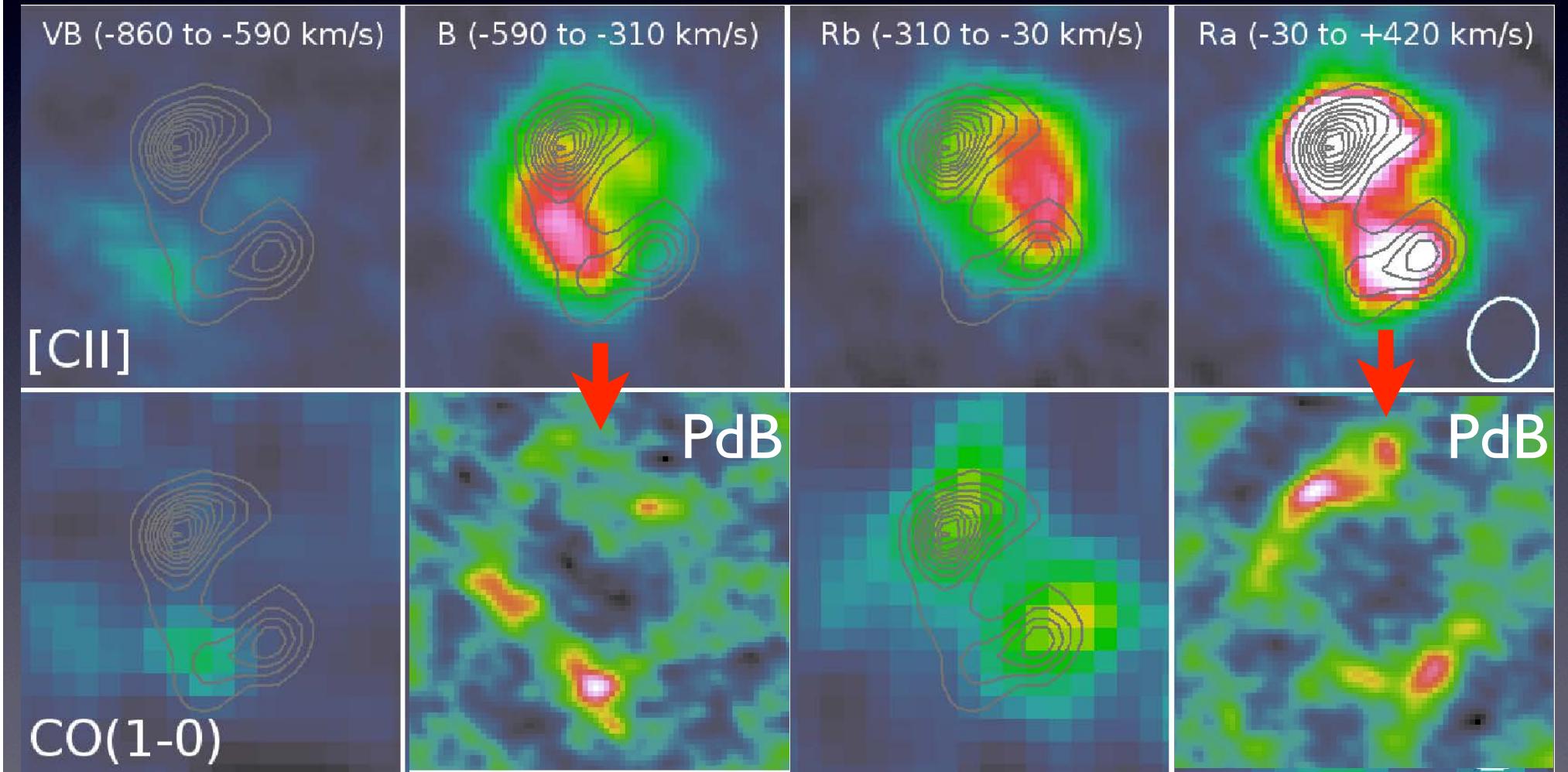
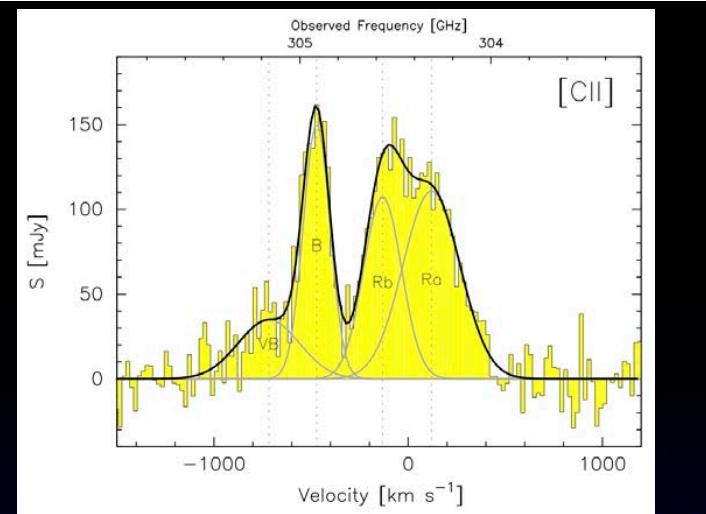
SMA

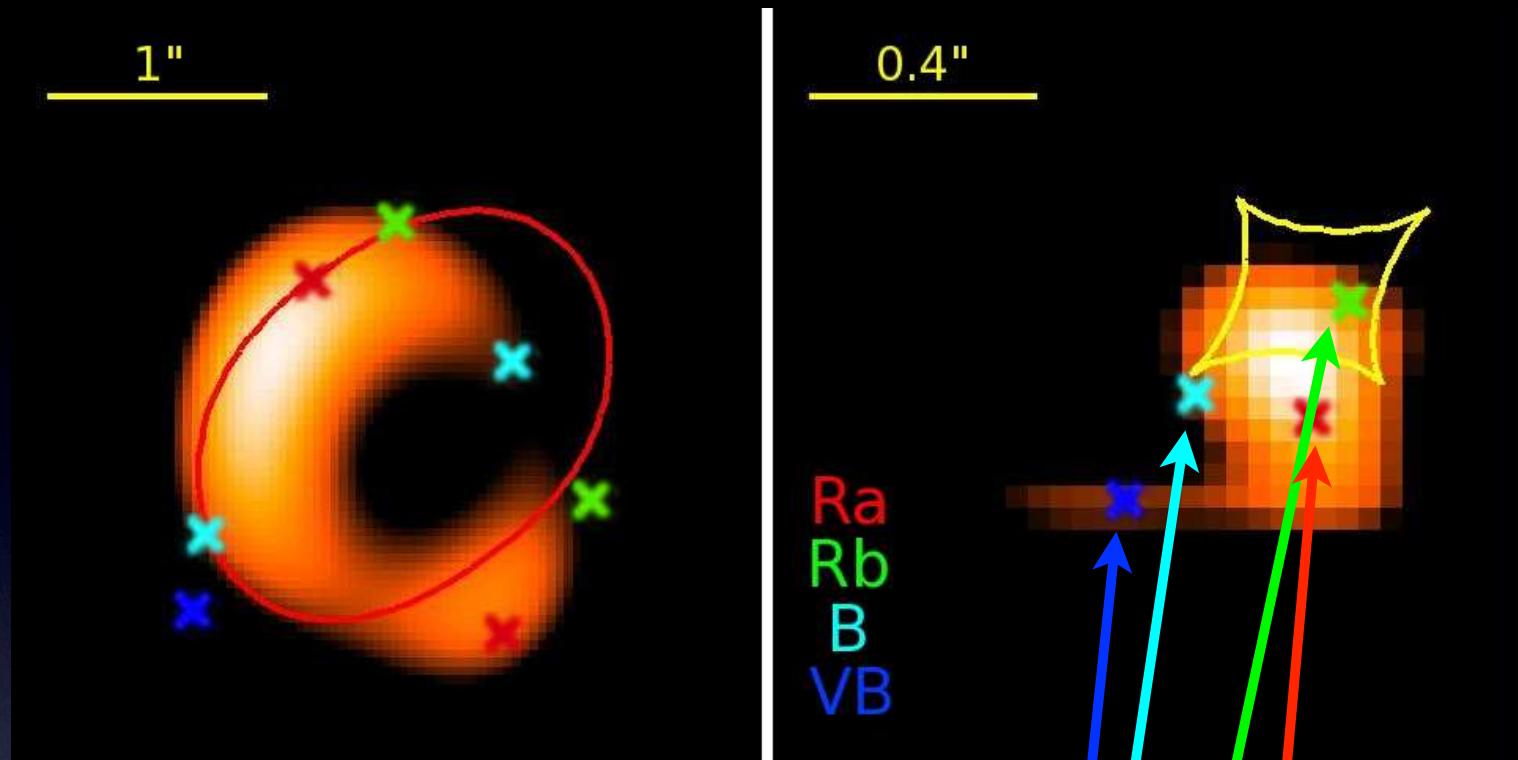


JVLA

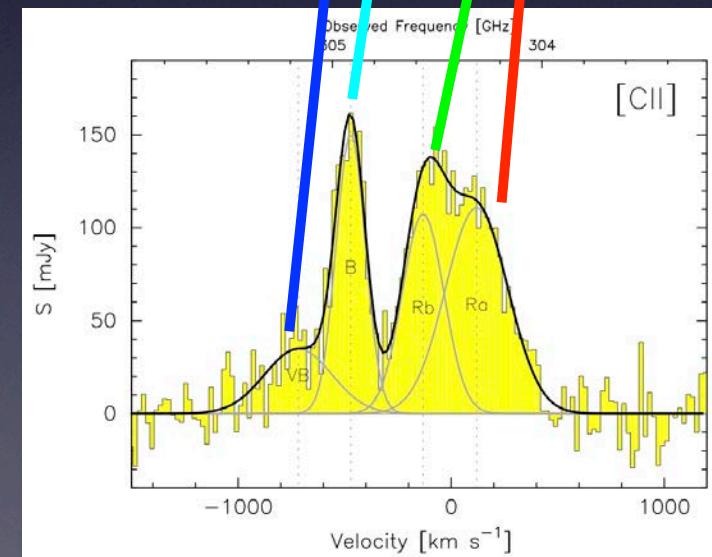


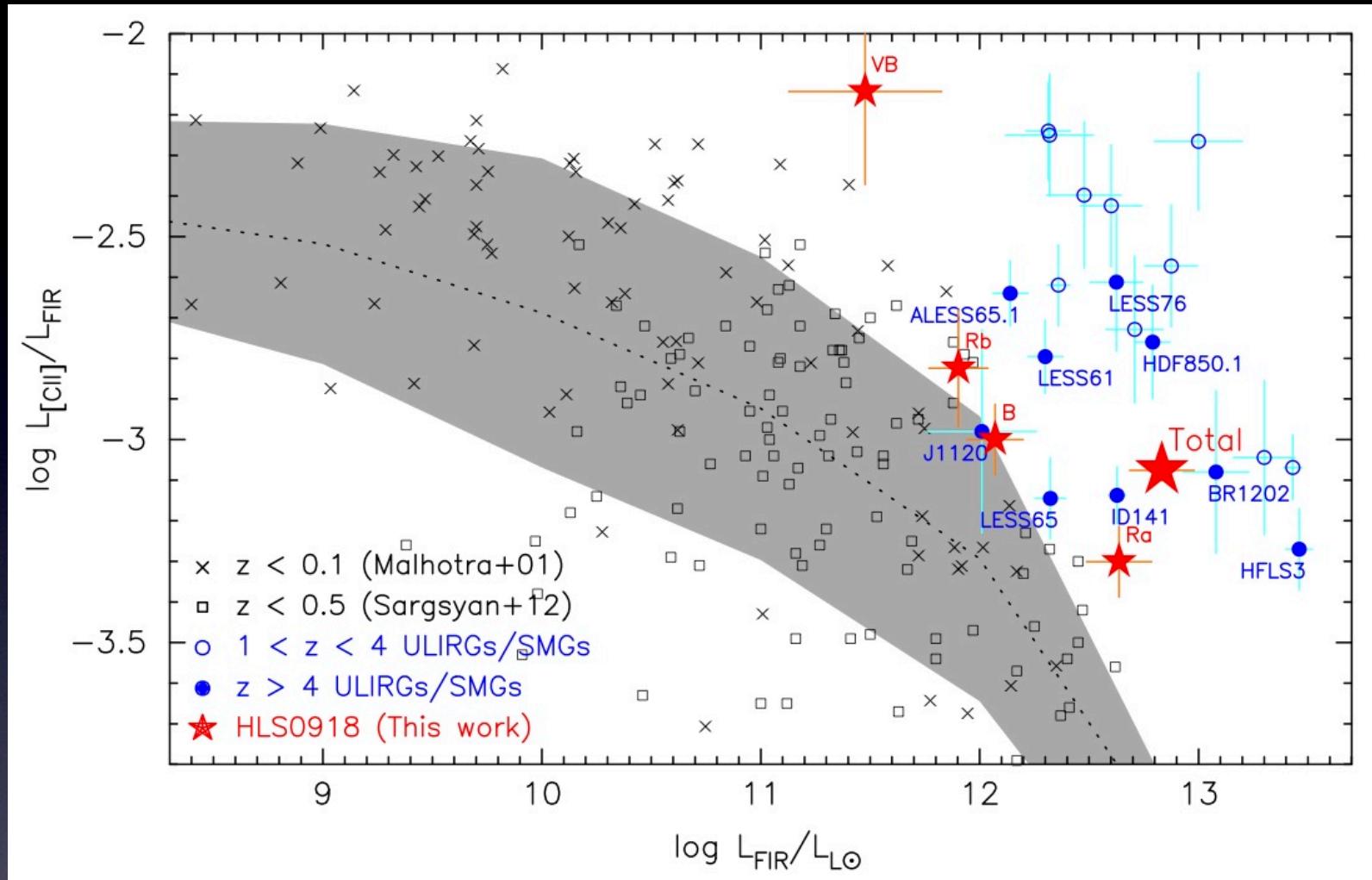
Spatially Distinct Velocity Components





Spatial resolving $z=5.2$ galaxy!

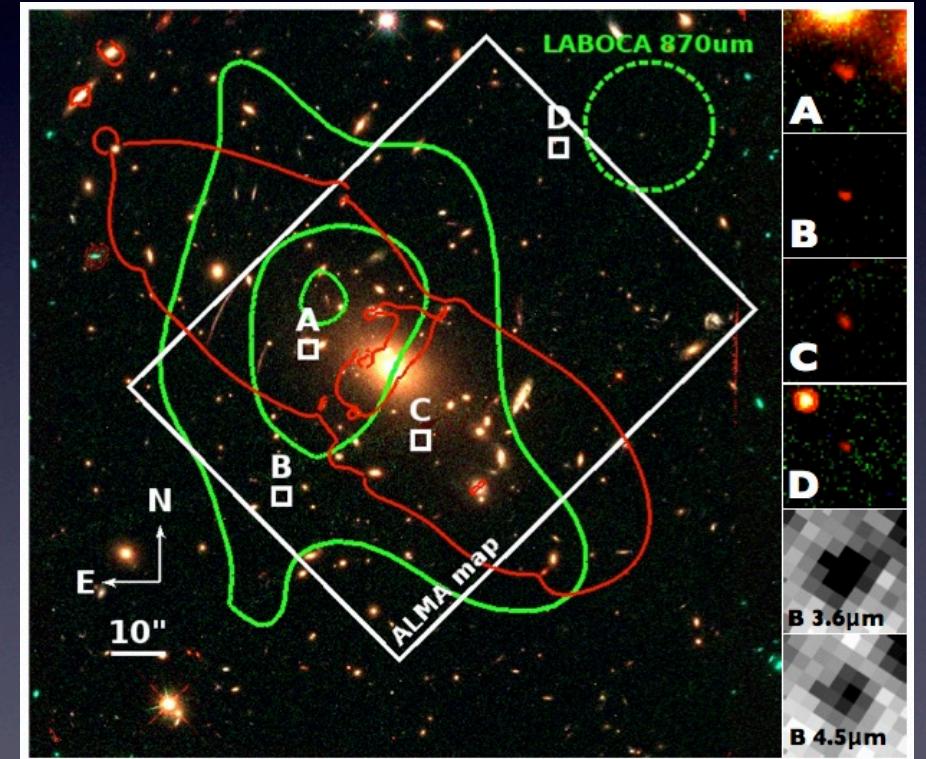
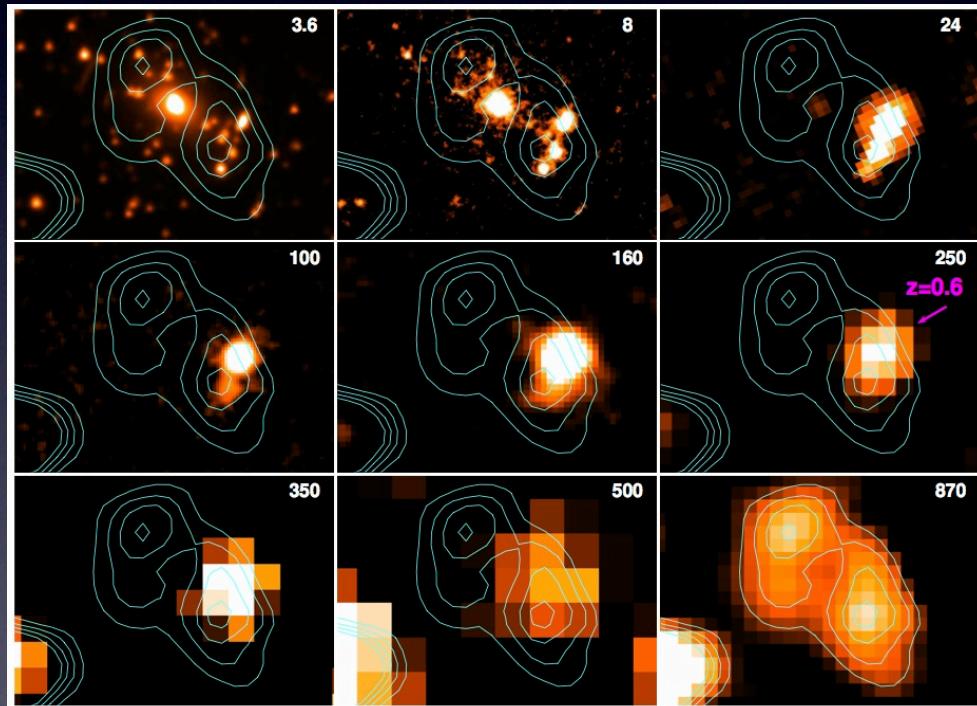




$L[\text{CII}]/L(\text{FIR})$ similar to other $z>4$ galaxies.
 VB component shows an abnormally large ratio.

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

ASI063

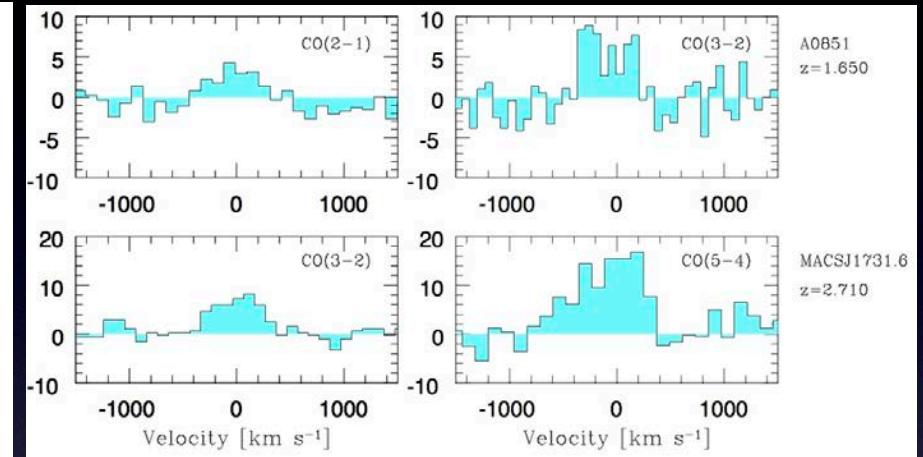
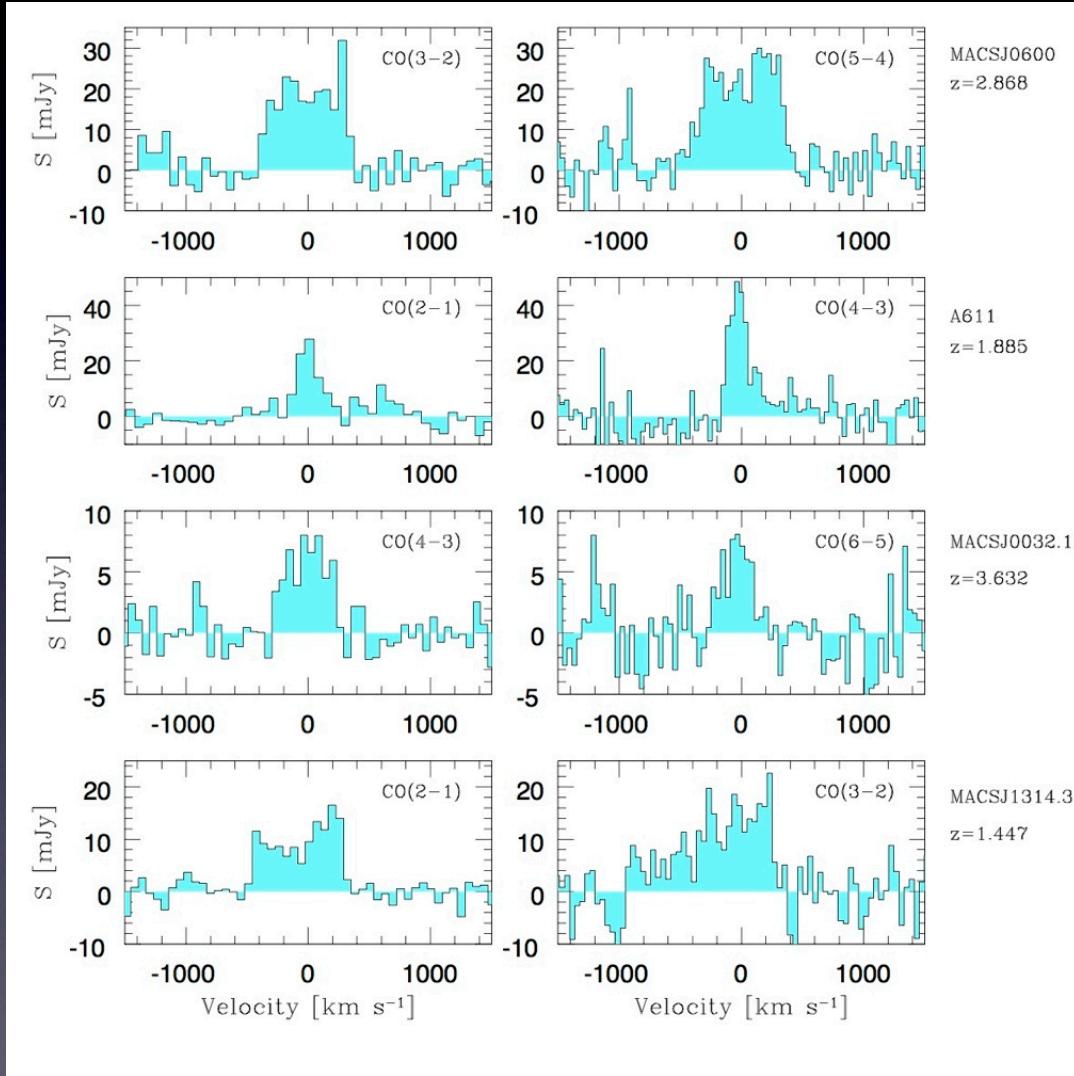


From the LABOCA Lensing Survey (Boone+13)

(2) HLS-snapshot

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

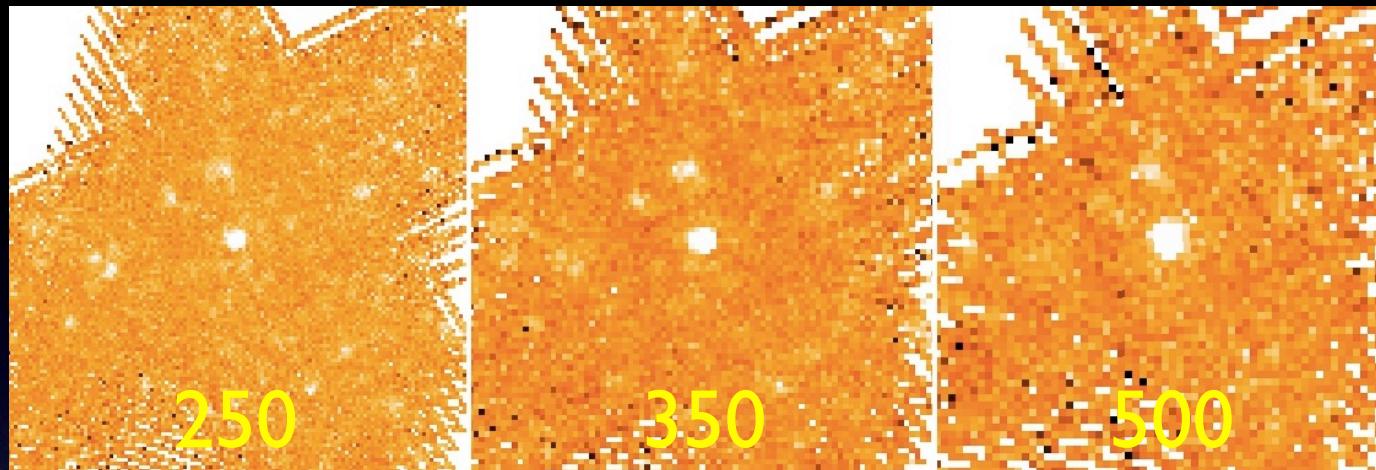
IRAM30m/EMIR z Search



HLS-snapshot bright
sources allow
easy CO redshift
measurements.

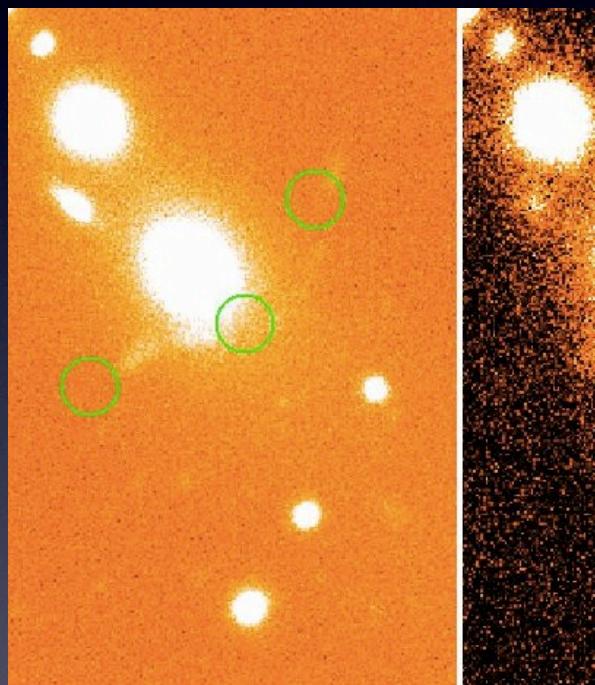
Optically-Faint IR Arc at z=2.0

Walth+13
in prep

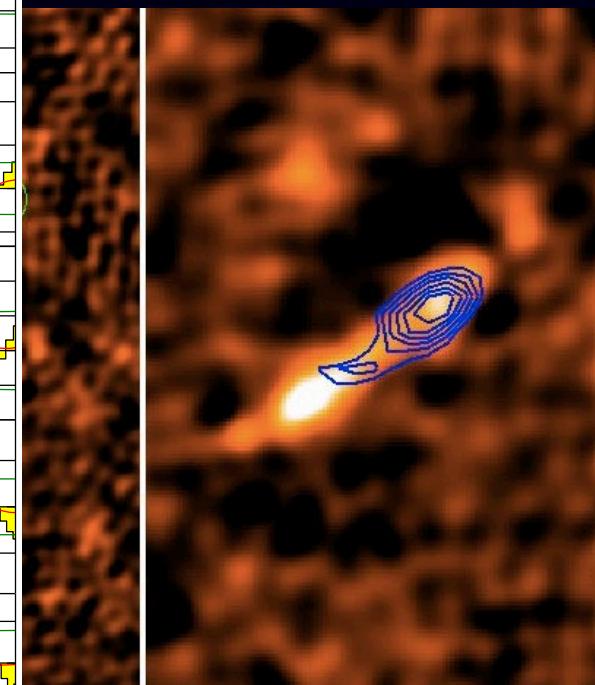
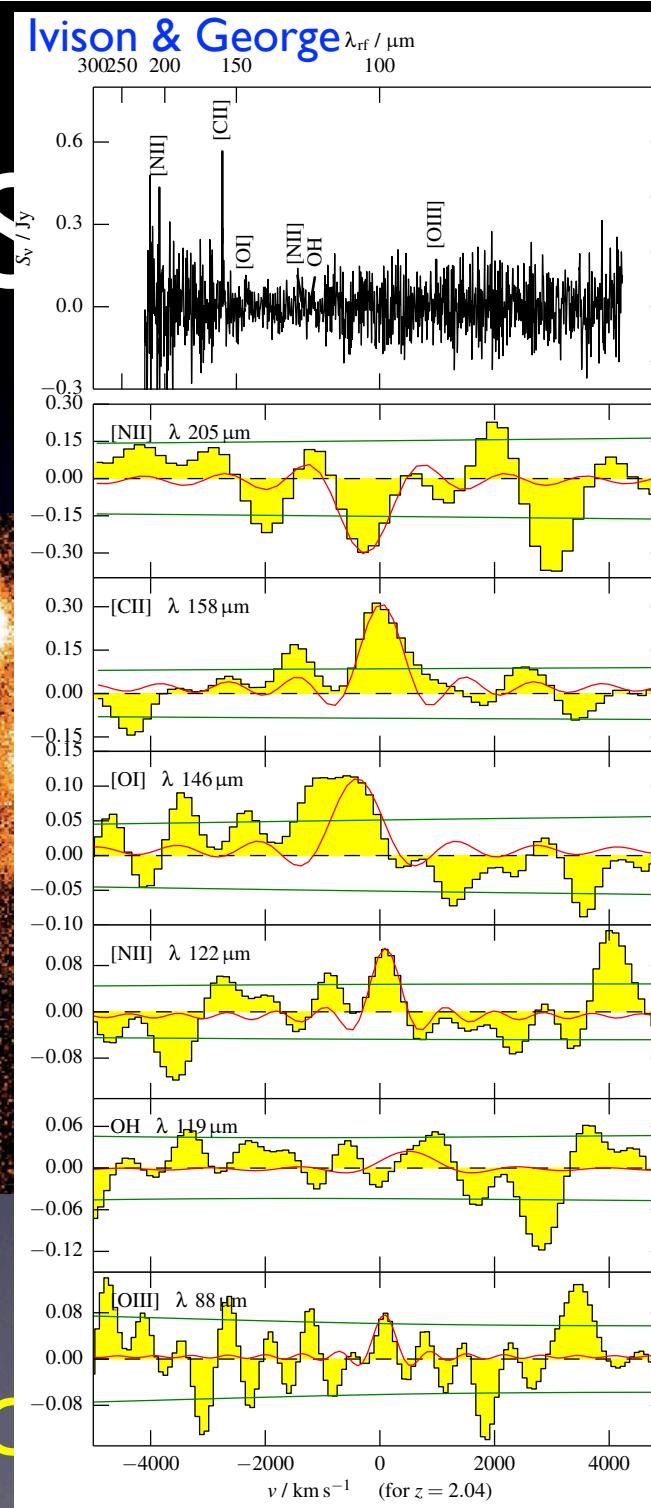


MACS

=2.04



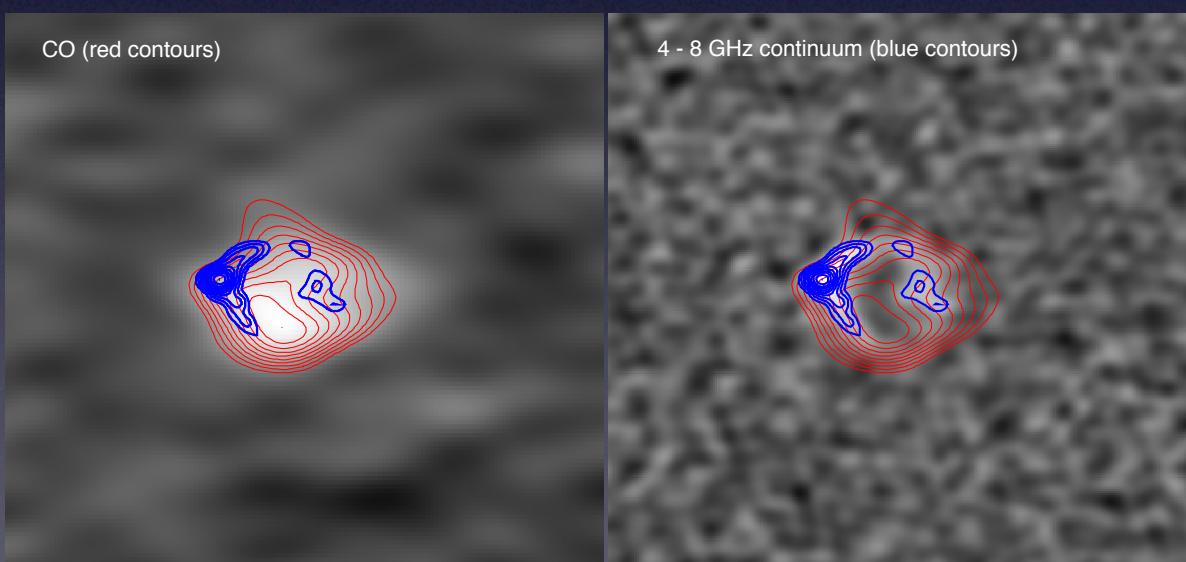
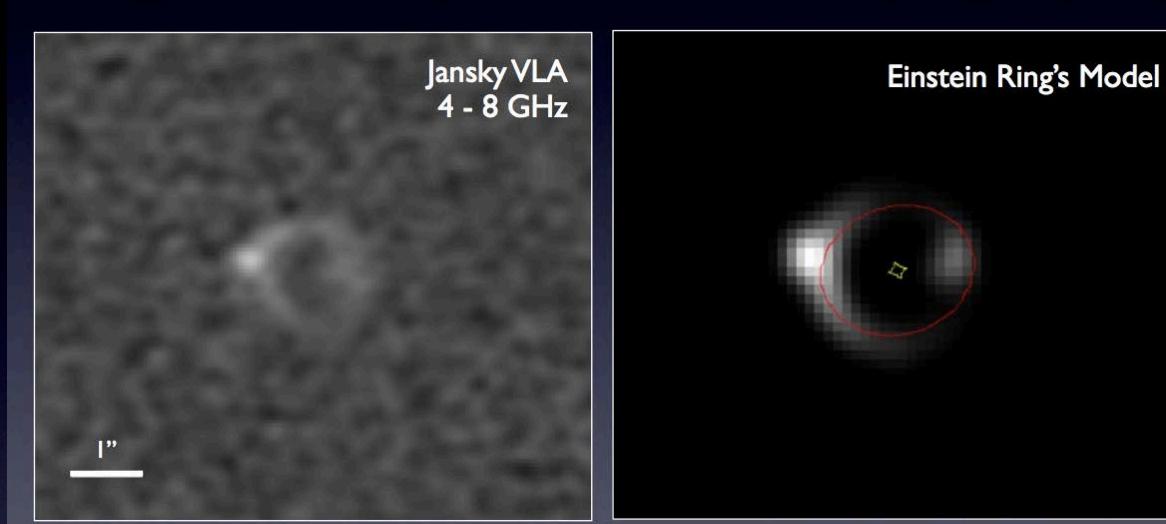
Magellan/IMACS
i band



SMA
870um
JVLA
CO(1-0)

μm

$\text{CO}(\text{I-0}) \neq \text{Continuum}$

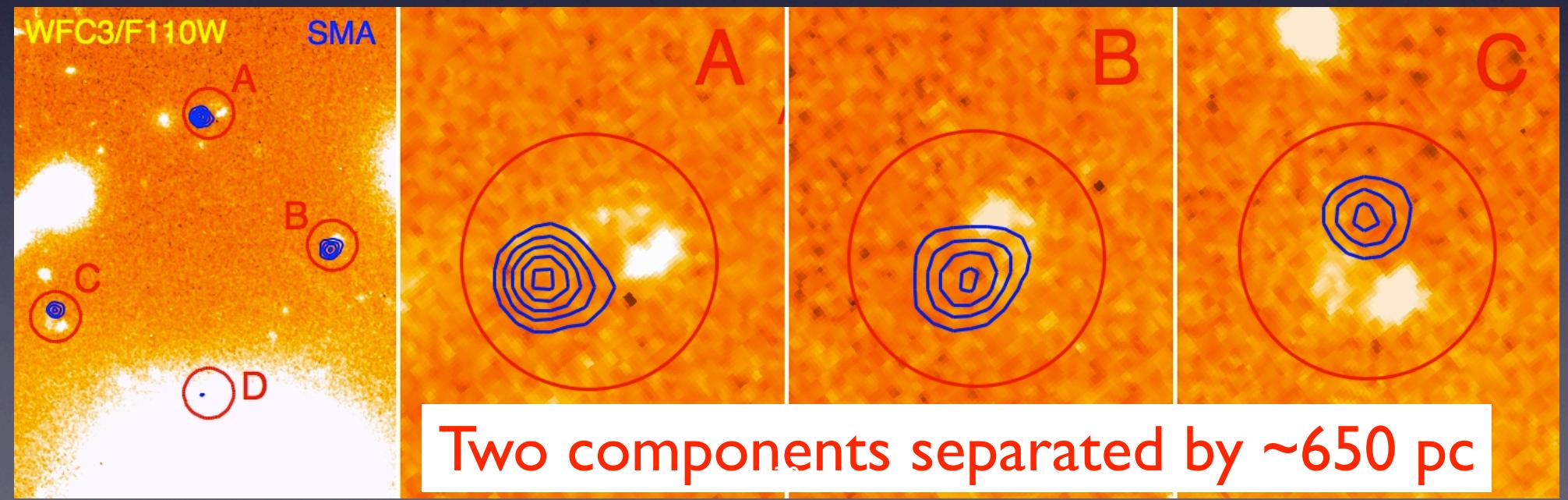
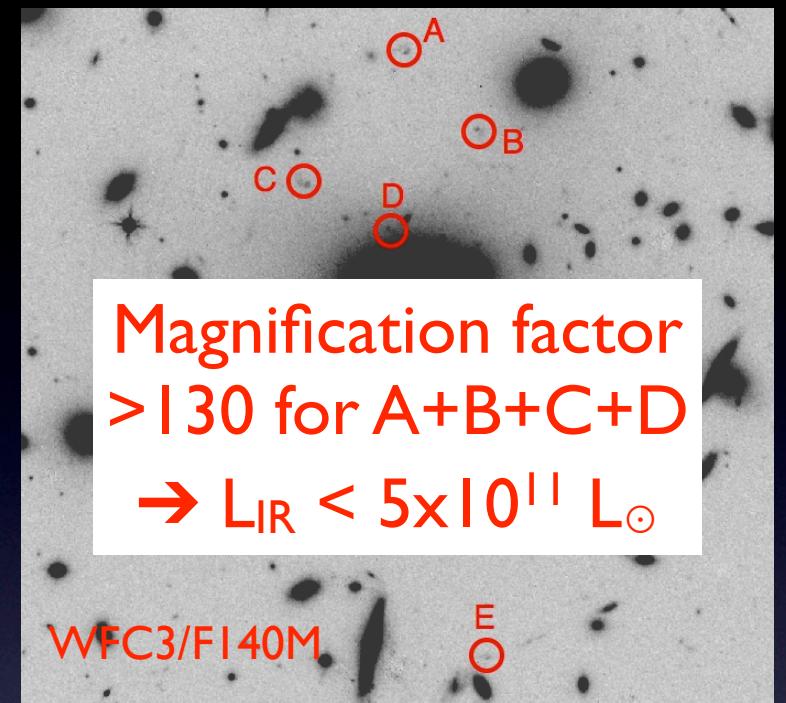
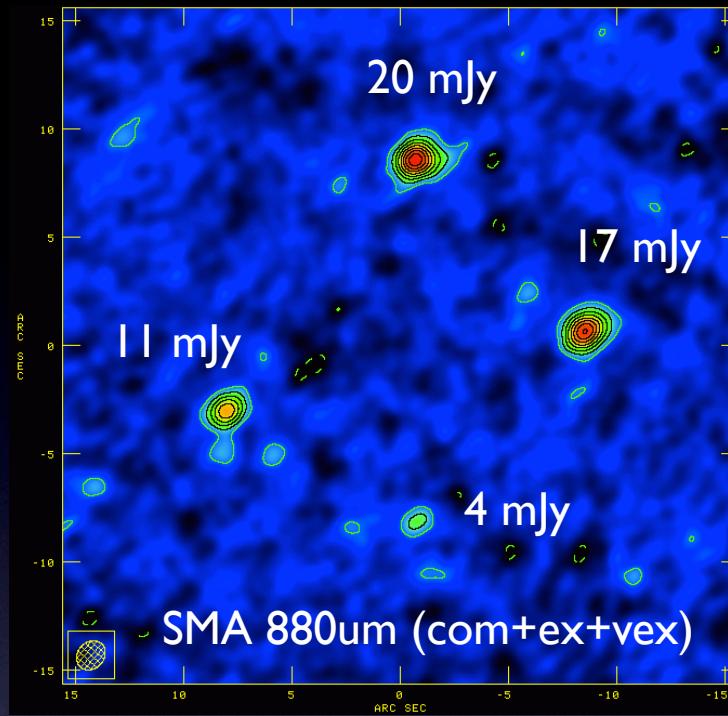


Rujopakarn+13
in prep

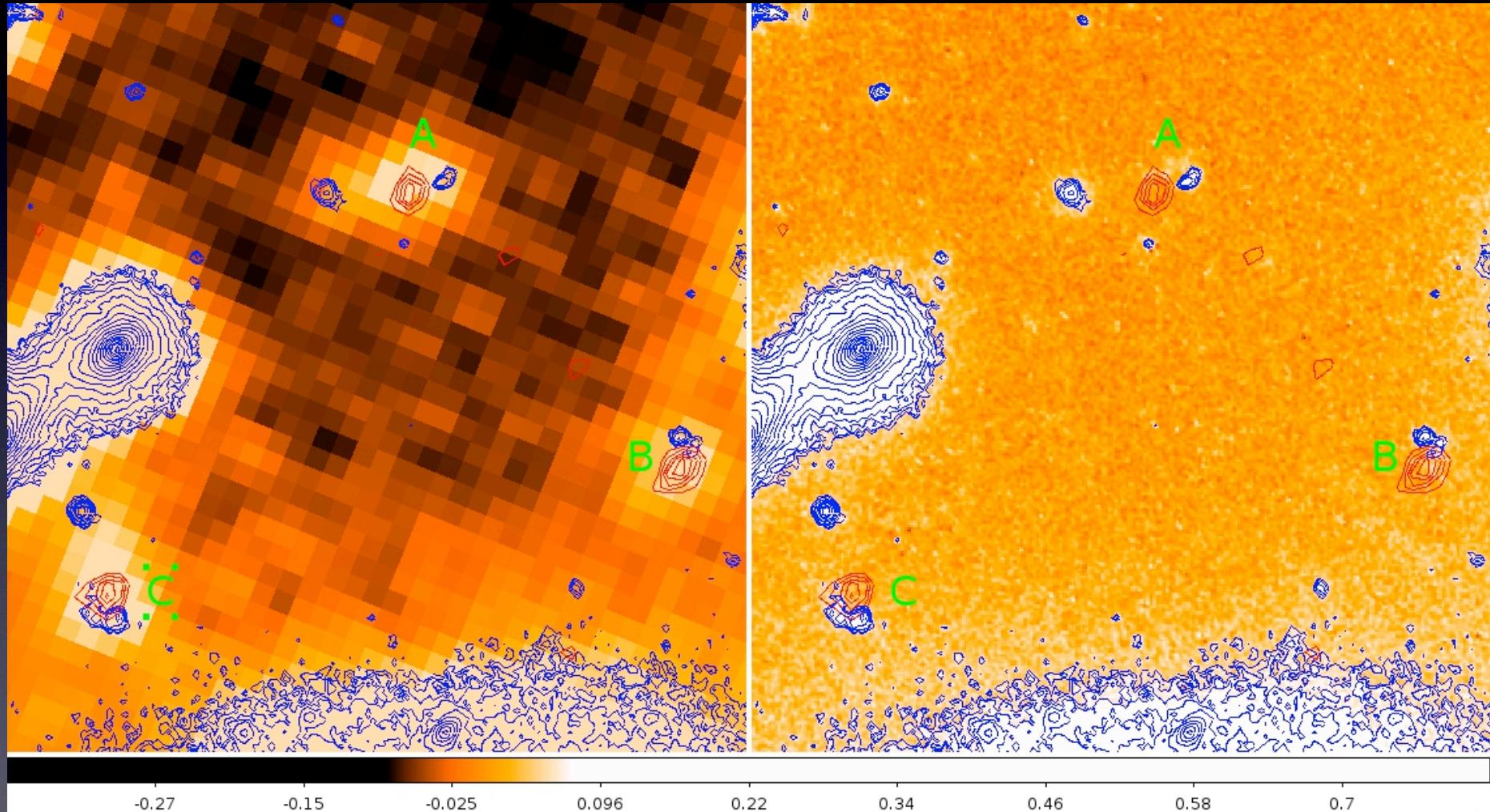
$z=1.9$ galaxy-lensed source from HLS-snapshot

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

$z(\text{CO})=4.69$



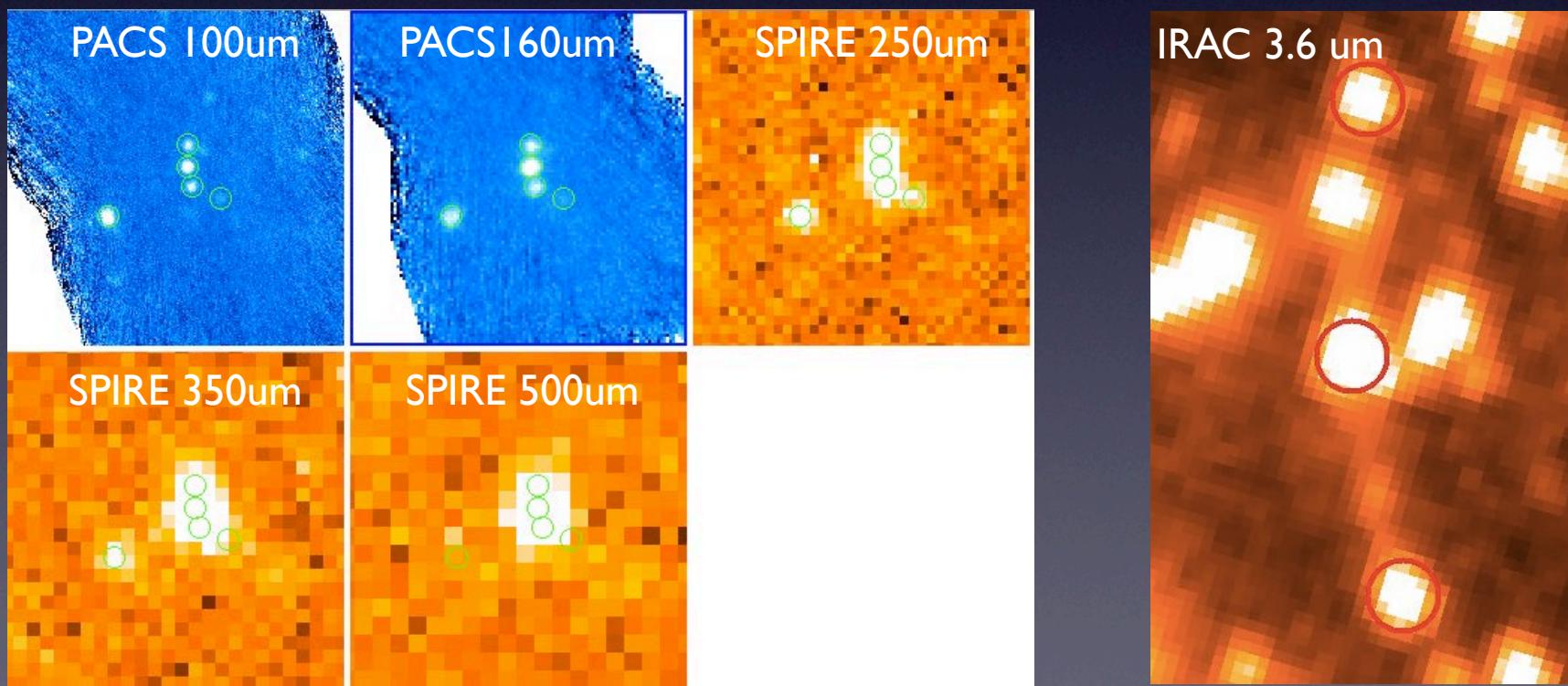
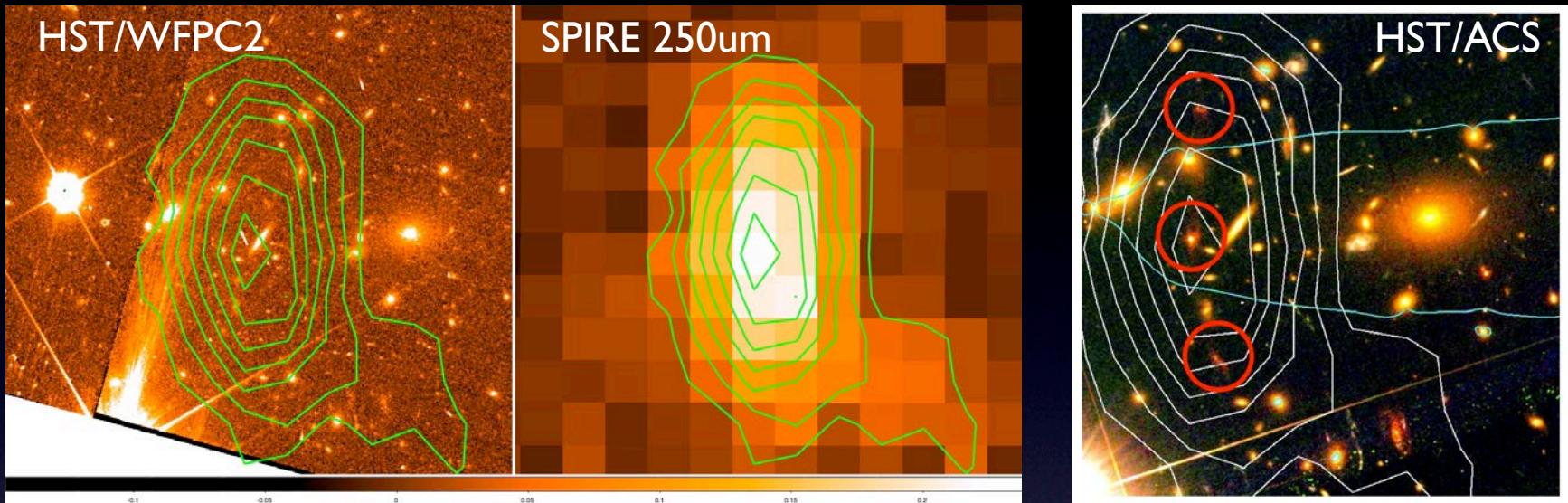
IRAC counterparts for the submm sources



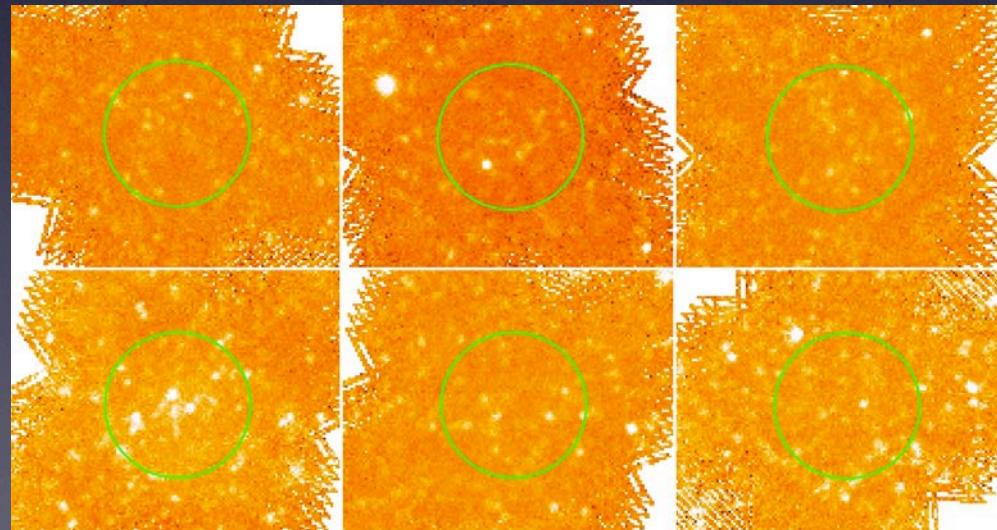
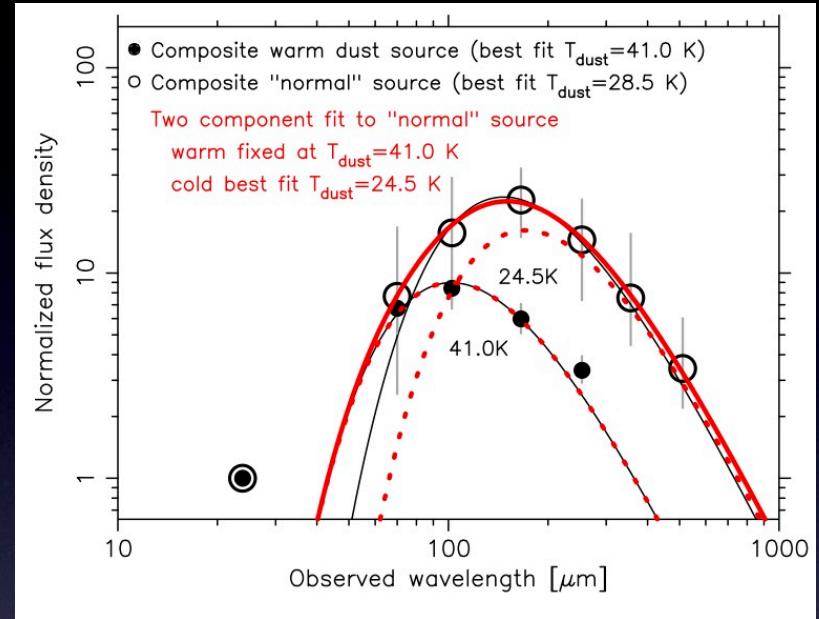
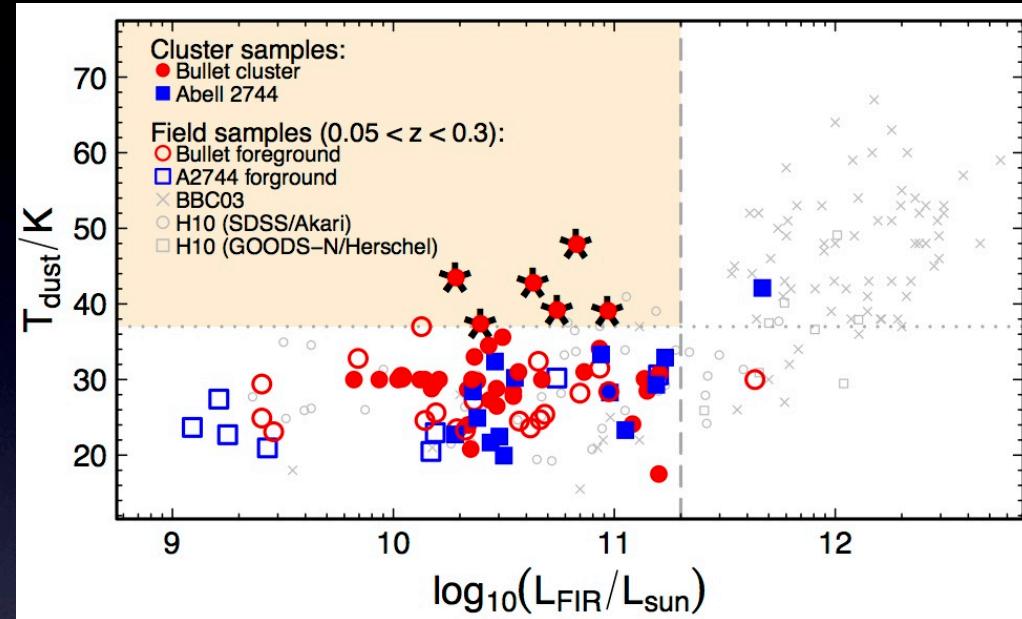
Spitzer/IRAC 3.6 μm

HST/WFC3 F140W

Triply lensed galaxy at $z \sim 1$



(3) IR-bright cluster galaxies



Rawle+12; Rawle Poster

$z > 0.9$ SPT clusters

IV. HLS Data Release (DRI)

- 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”)

The screenshot shows the homepage of the Herschel Lensing Survey (HLS) website. At the top left is the HLS logo. The main title "Herschel Lensing Survey" is displayed prominently in large black font. Below the title is a large, dark red background image showing a cluster of galaxies. On the left side, there is a vertical sidebar with a dark grey background containing several menu items: "Members", "Publications", "Data Release", "HLS-deep I", "HLS-deep II", "HLS-snapshot I", "HLS-snapshot II", "News", and "Internal Wiki". The "Data Release" item is highlighted with a red rectangular box and has a red arrow pointing from it towards the main content area. The main content area has a white background and features the title "Herschel Lensing Survey" in large bold black font. Below the title is a section titled "Overview:" followed by a paragraph of text. To the right of the text is a numbered list of four scientific goals.

Herschel Lensing Survey

Overview:

The Herschel Lensing Survey (HLS) is a large extensive imaging survey of massive galaxy clusters in the far-infrared and submillimeter using the Herschel Space Observatory. Its main scientific goals are the following:

1. To detect and study infrared/submillimeter galaxies that are **below the nominal confusion limit of Herschel** by taking advantage of the strong gravitational lensing power of massive galaxy clusters.
2. To discover **exceptionally bright (S>100 mJy)** lensed infrared/submillimeter galaxies that will allow a variety of detailed multi-wavelength follow-up observations.
3. To examine infrared/submillimeter properties of **galaxies in dense environment** (i.e., cluster members).
4. To investigate the **Sunyaev-Zel'dovich (SZ) effect** through the detection of the increment signal.

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

The screenshot displays the Rainbow Slicer software interface, divided into several sections:

- Top Left:** Logo and title "Rainbow Slicer".
- Top Right:** A background image of a galaxy cluster with a red polygonal region indicating the selected field.
- Left Panel:** "Choose field and filters" section.
 - Select field (database): Cluster_BULLET
 - Select Filters: all
- Middle Left:** "Dataset footprints for selected Rainbow field".
 - Database: Cluster_BULLET
 - Coordinates: 06:58:31.33 -55:56:58.54
- Middle Right:** "DATA ACCESS" section.
 - N-BAND QUICKLOOK
 - RA (J2000.0): 06:58:31.33
 - DEC (J2000.0): -55:56:58.54
 - Stamp size: 60.
 - Multi-band Quicklook
 - N-SOURCE QUICKLOOK
 - Filter: all
 - RA (J2000.0): 06:58:31.33
 - DEC (J2000.0): -55:56:58.54
 - Select file
 - Stamp size: 60.
 - Multi-source Quicklook
 - RAINBOW SKY MAP
 - Central RA: 06:58:31.33
 - DEC: -55:56:58.54
 - Map size: 2
 - Coming soon!
- Right Panel:** A grid of 16 small images showing multi-wavelength slices for Source #1. The images are arranged in a 4x4 grid and labeled as follows:
 - Row 1: IRAC36 (ps) (set cuts), IRAC45 (ps) (set cuts), IRAC58 (ps) (set cuts), IRAC80 (ps) (set cuts)
 - Row 2: WISE1 (ps) (set cuts), WISE2 (ps) (set cuts), WISE3 (ps) (set cuts), WISE4 (ps) (set cuts)
 - Row 3: Source #1, Source #1, Source #1, Source #1
 - Row 4: Source #1, Source #1, Source #1, Source #1

A caption above the grid states: "Images below are 60.''x60.'' (North is up and East is left)".

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**