Brightest Cluster Galaxies in Cool Core Clusters

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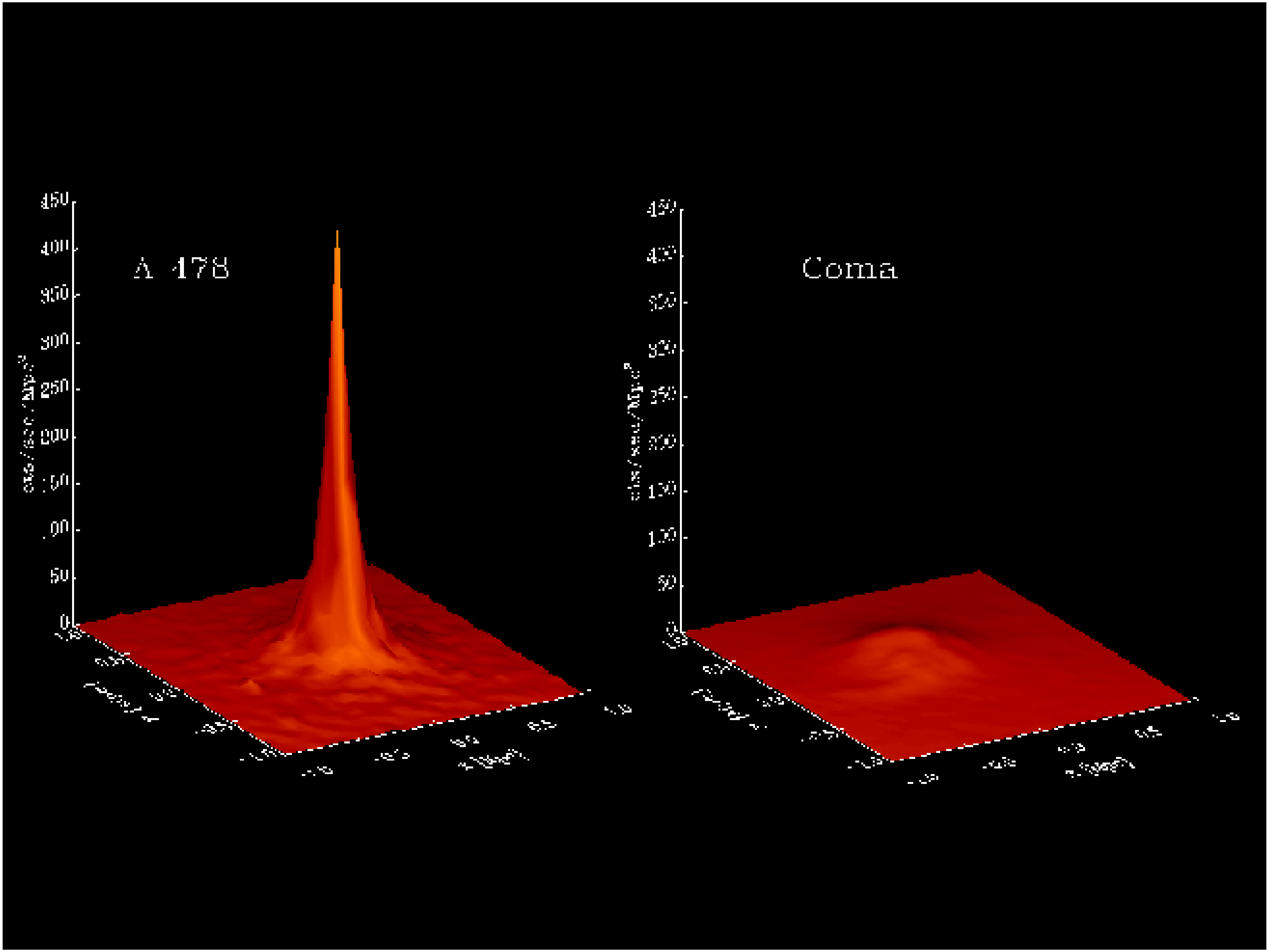
and 25 co-investigators

Motivation

The cores of a significant fraction of all X-ray luminous clusters have X-ray emission in their cores that implies cooling times of less than 10^9years.

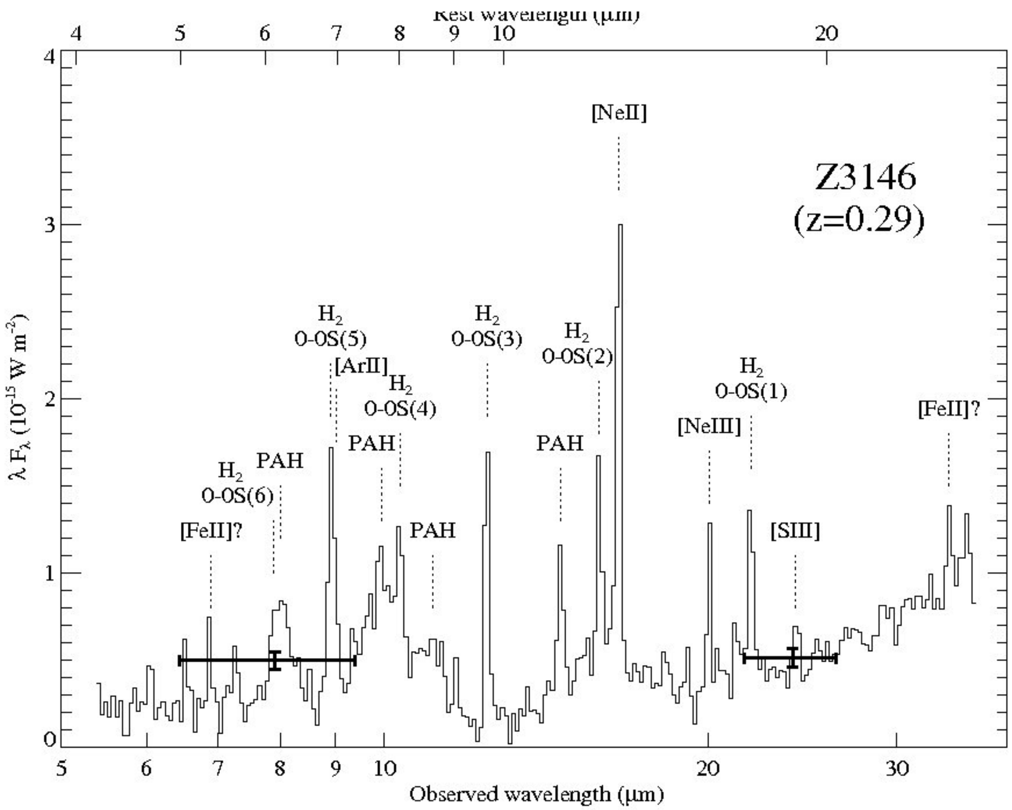
The implied rates of cooled gas deposition are 1-300 $M_o yr^{-1}$ in that central region.


A 478
Coma

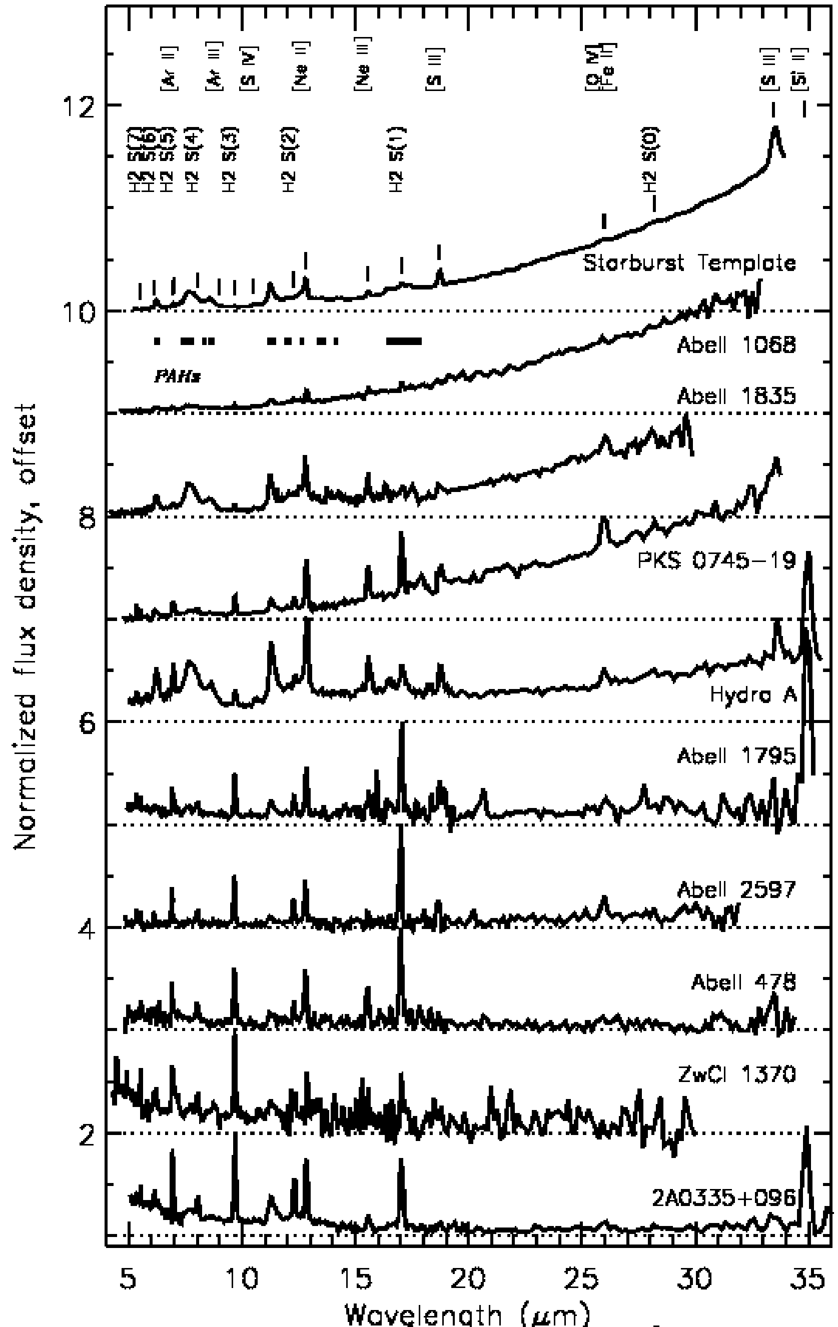
Where's the beef?

The crucial issue with the prediction of significant gas cooling is to find where it goes.

The discovery of CO in a significant number of cluster cores (now more than 40) points to 10^9-$10^{11.5} M_o$ in molecular gas.



Egami etal 2006



DeMessieres etal 2009

Our OTKP strategy

The key objectives of our OTKP is to obtain the line fluxes and velocity widths of as many as 6 atomic cooling lines (CII, OI, NII, OIII, NIII and SiI) with PACS and to obtain 70 to 500μm photometry with PACS and SPIRE for 11 brightest cluster galaxies.

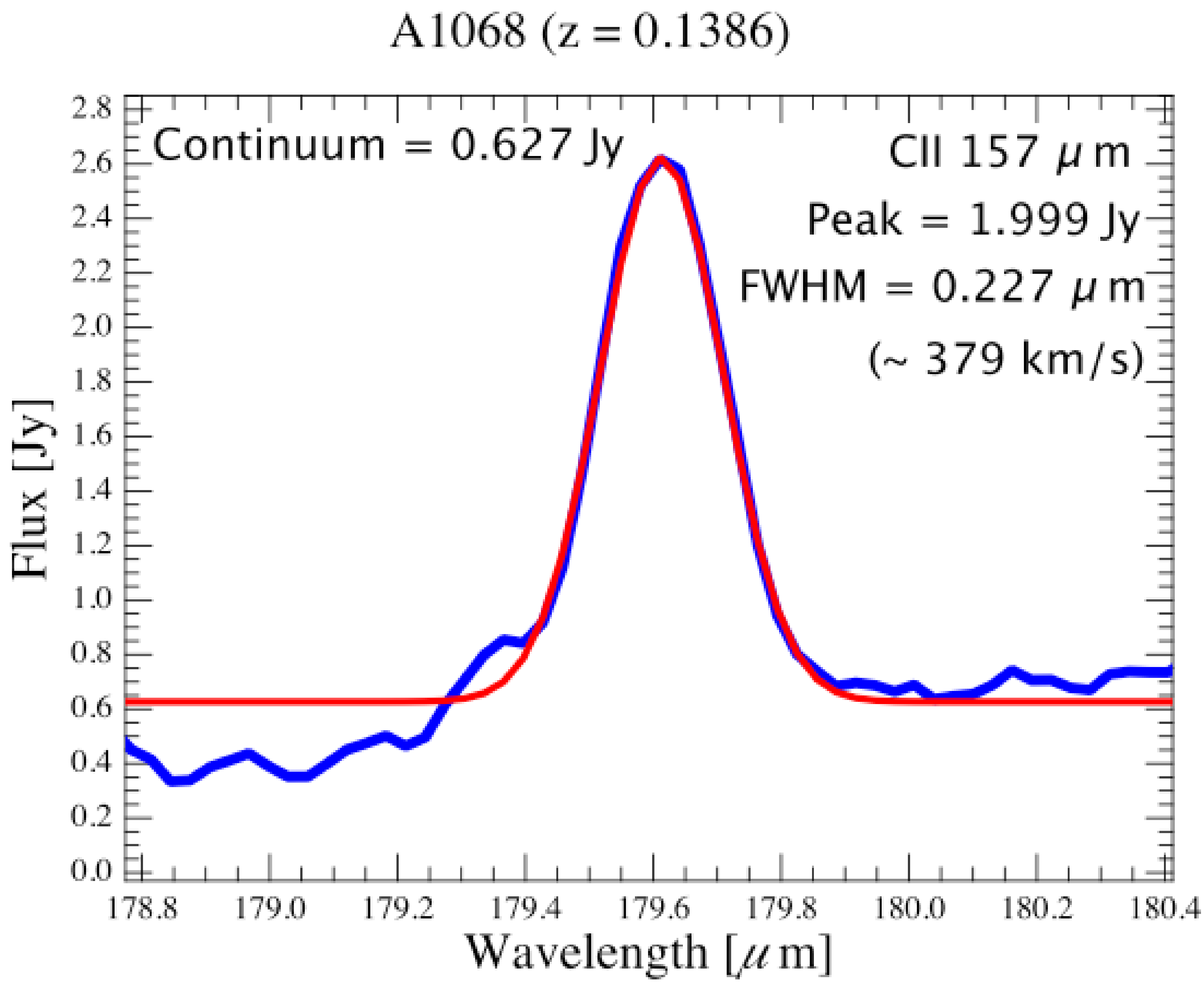
Herschel SDP observations

For the SDP observations we selected three objects with a range of optical line flux, L_{IR} and radio power - Zw3146 (z=0.29), A1068 (z=0.13) and A2597 (z=0.08).

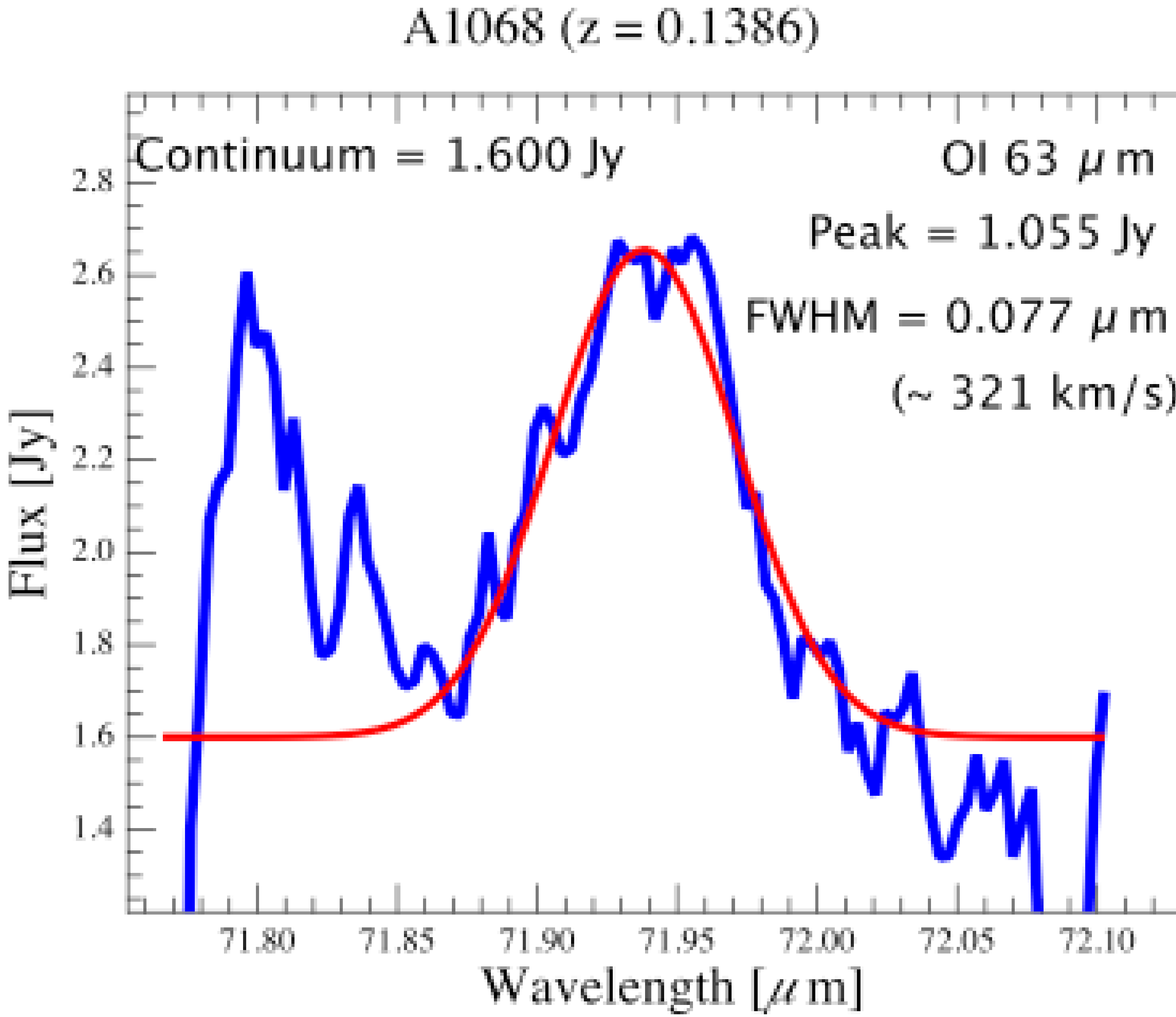
We obtained spectra for CII (157μm) and OI (63μm) to test how bright these lines are.

The results

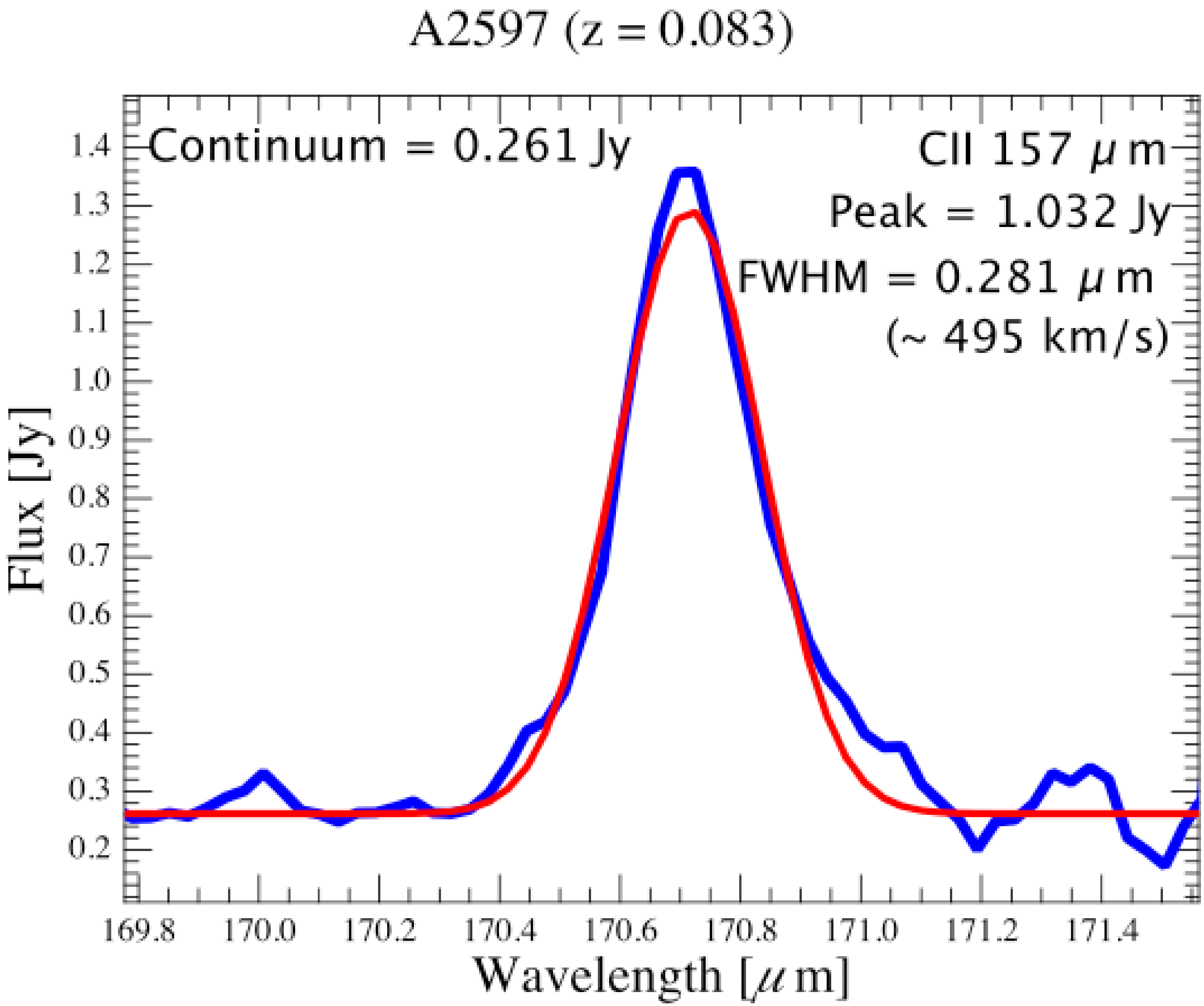
The spectra are of excellent quality and the lines are detected in two of the observations.

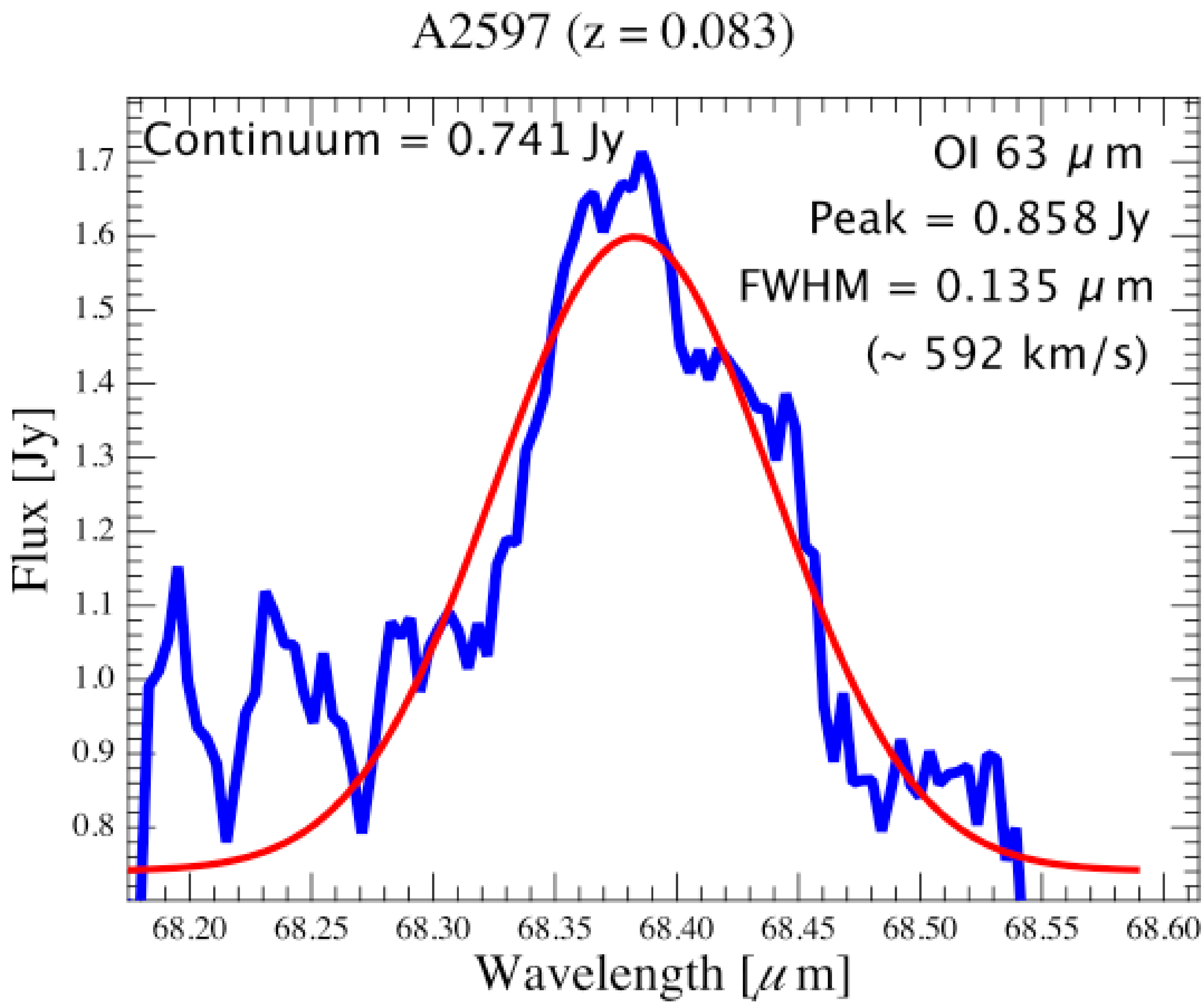


A1068 (z = 0.1386)
Continuum = 0.627 Jy
CII 157 μm
Peak = 1.999 Jy
FWHM = 0.227 μm
(~ 379 km/s)
Flux [Jy]
Wavelength [μm]
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
178.8
179.0
179.2
179.4
179.6
179.8
180.0
180.2
180.4



A1068 (z = 0.1386)
Continuum = 1.600 Jy
OI 63 μm
Peak = 1.055 Jy
FWHM = 0.077 μm
(~ 321 km/s)
Flux [Jy]
Wavelength [μm]
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
71.80
71.85
71.90
71.95
72.00
72.05
72.10


A2597 (z = 0.083)
Continuum = 0.261 Jy
CII 157 μm
Peak = 1.032 Jy
FWHM = 0.281 μm
(~ 495 km/s)
Flux [Jy]
Wavelength [μm]
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
169.8
170.0
170.2
170.4
170.6
170.8
171.0
171.2
171.4

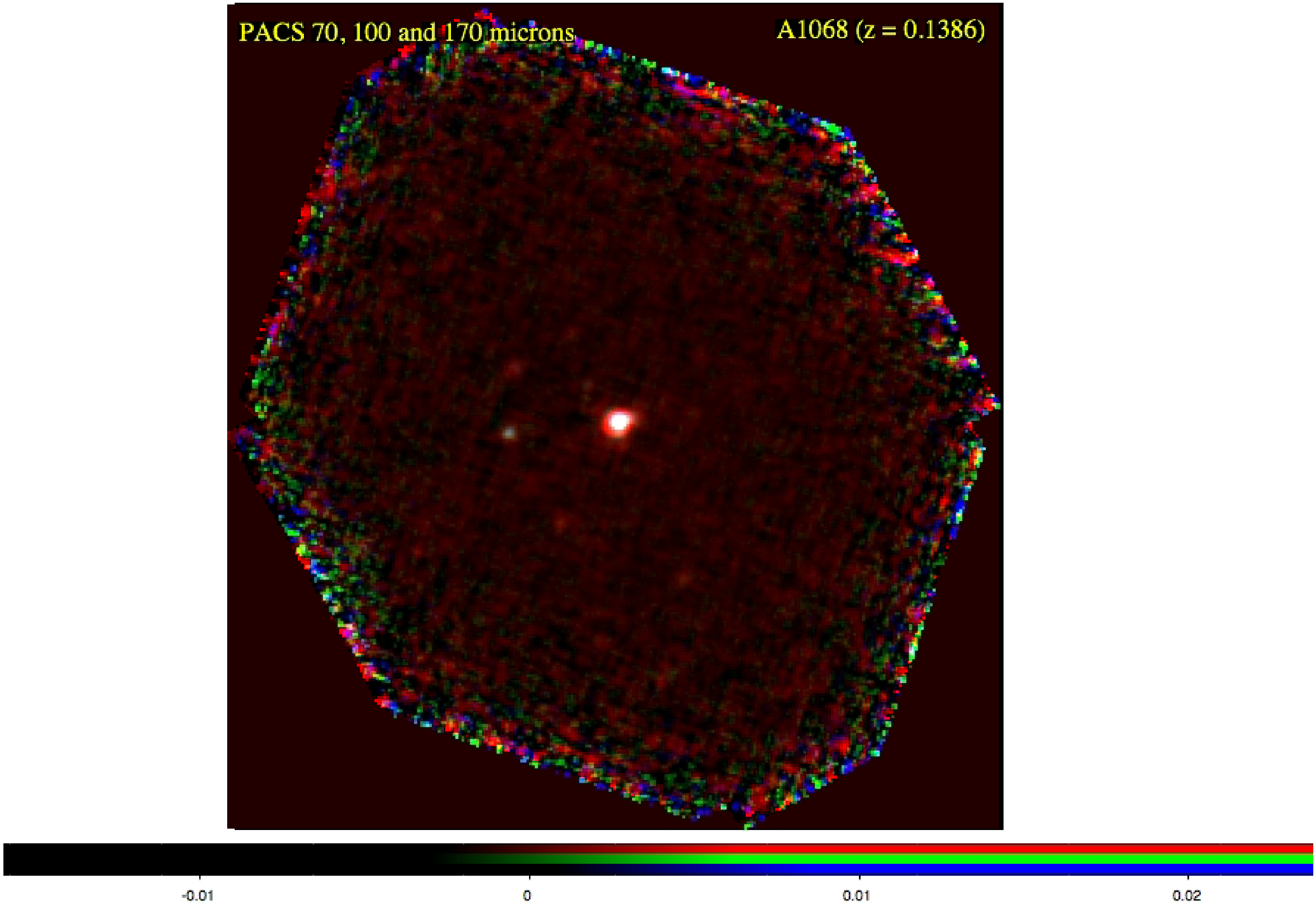


A2597 (z = 0.083)
Continuum = 0.741 Jy
OI 63 μm
Peak = 0.858 Jy
FWHM = 0.135 μm
(~ 592 km/s)
Flux [Jy]
Wavelength [μm]
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
68.20
68.25
68.30
68.35
68.40
68.45
68.50
68.55
68.60

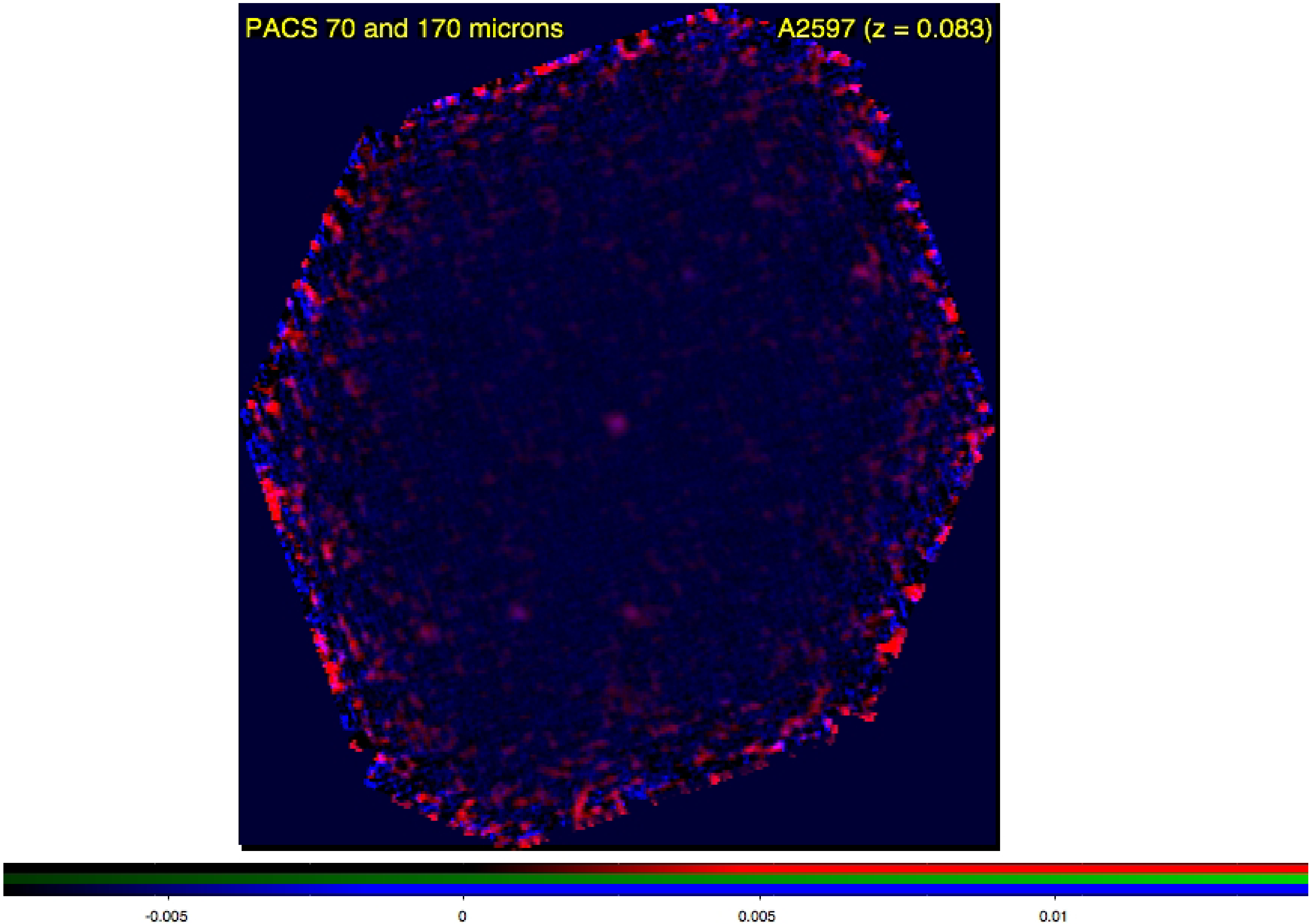
The results

The spectra are of excellent quality and the lines are detected in two of the observations.

The photometry was equally successful and each BCG is detected at all 6 wavelengths covered.

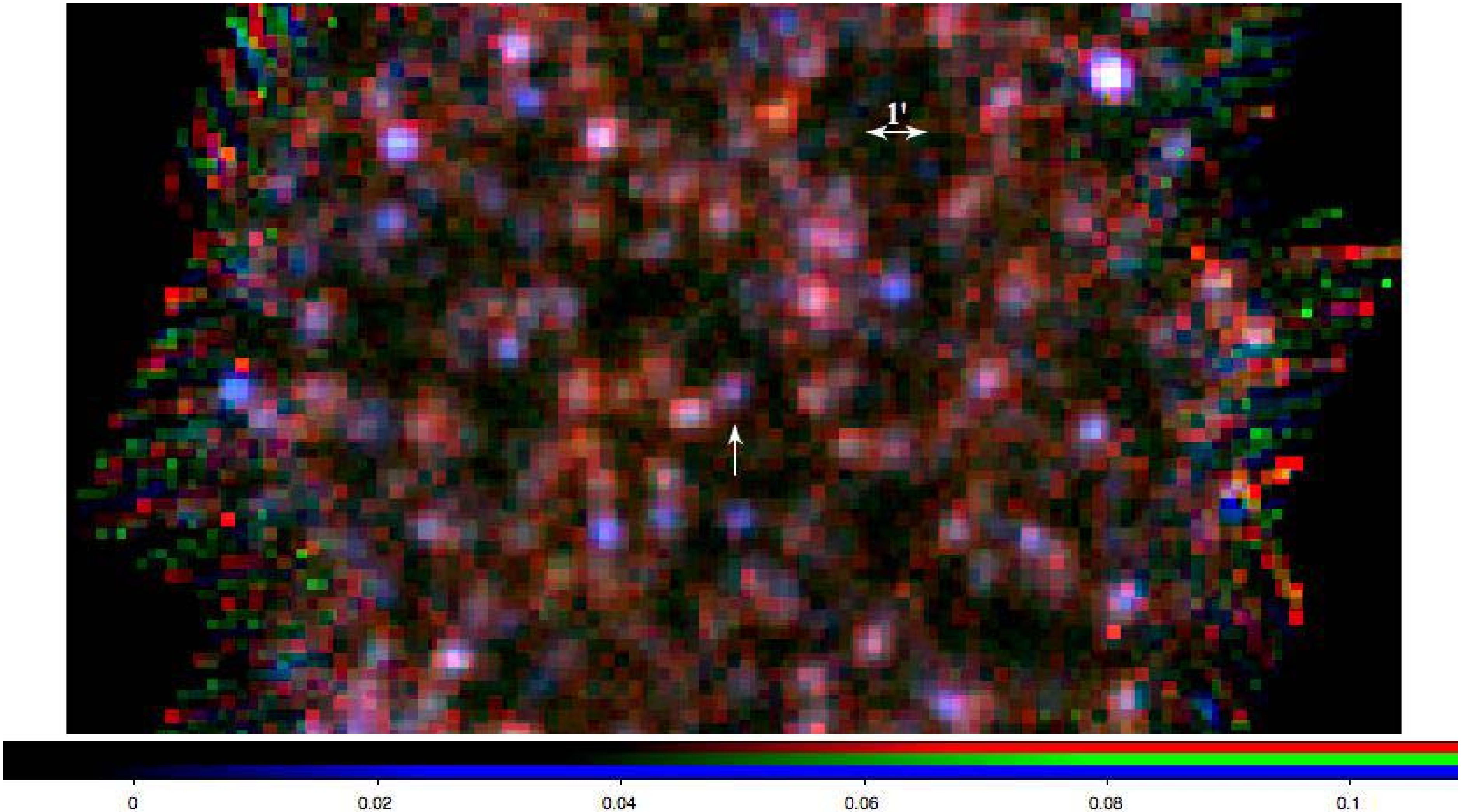


PACS 70, 100 and 170 microns
A1068 (z = 0.1386)
-0.01
0
0.01
0.02

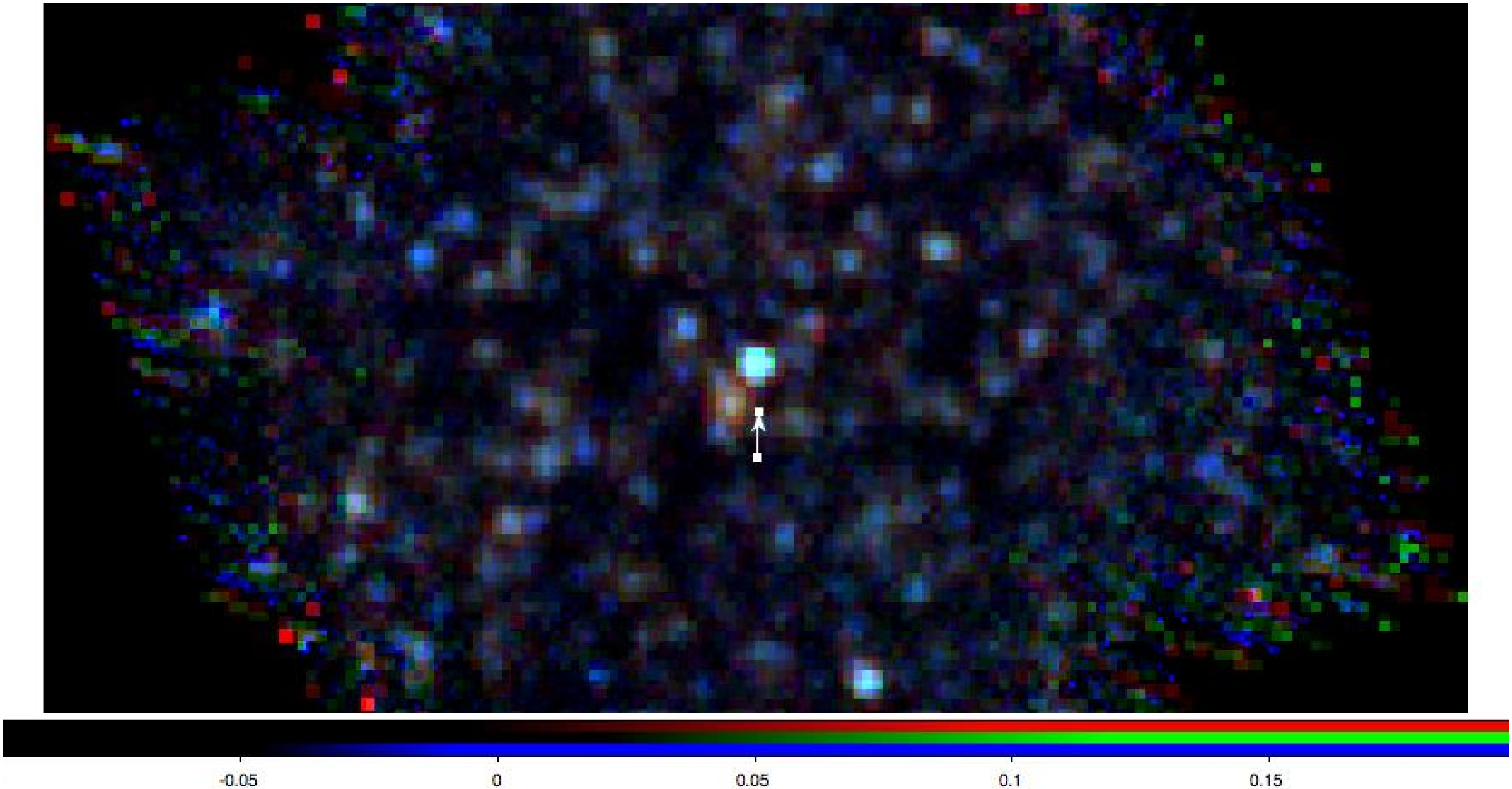


PACS 70 and 170 microns
A2597 (z = 0.083)
-0.005
0
0.005
0.01

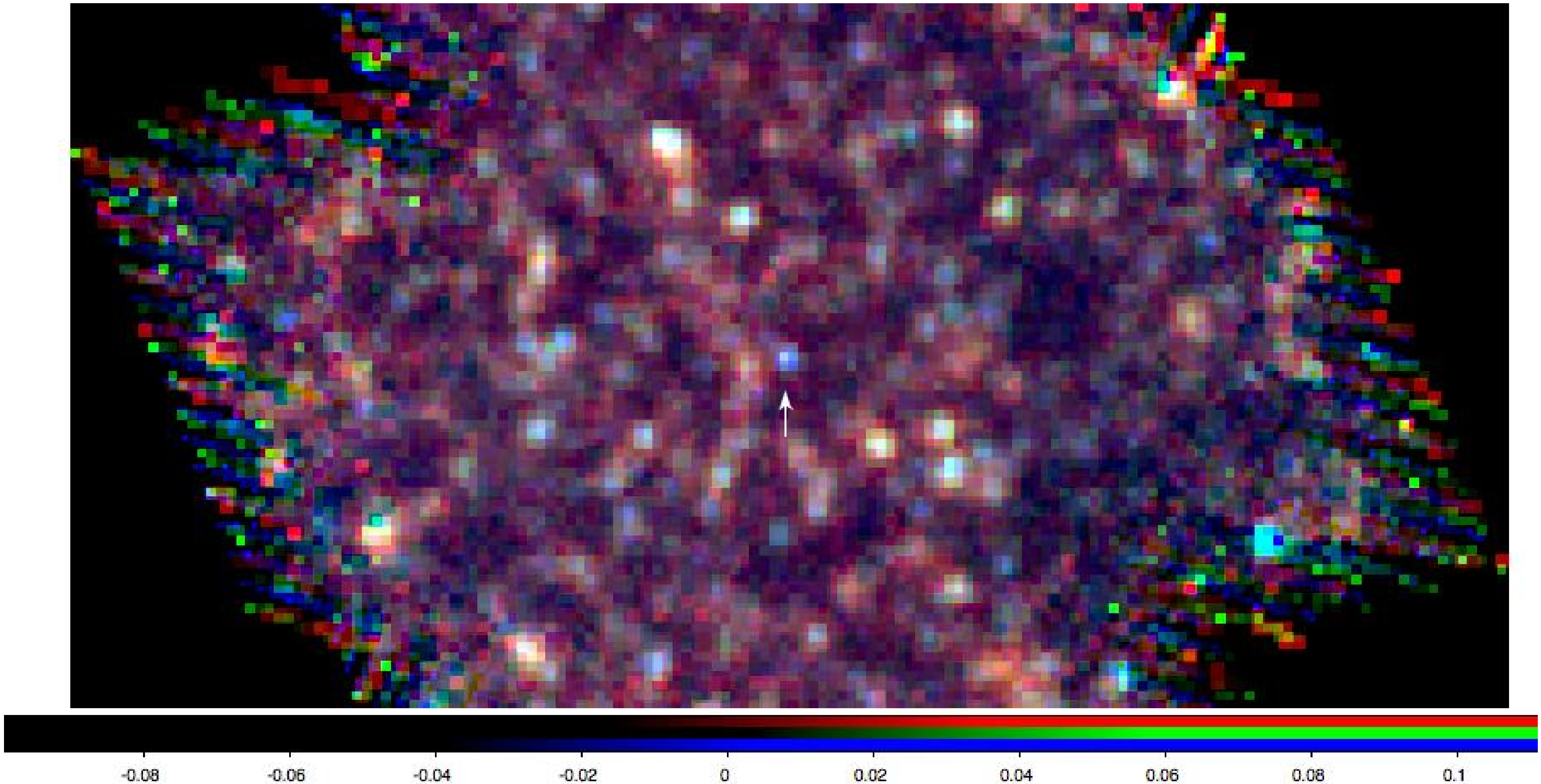
A2597 SPIRE image 500/350/350μm



A1068 SPIRE image 500/350/350μm



Zw3146 SPIRE image 500/350/350μm

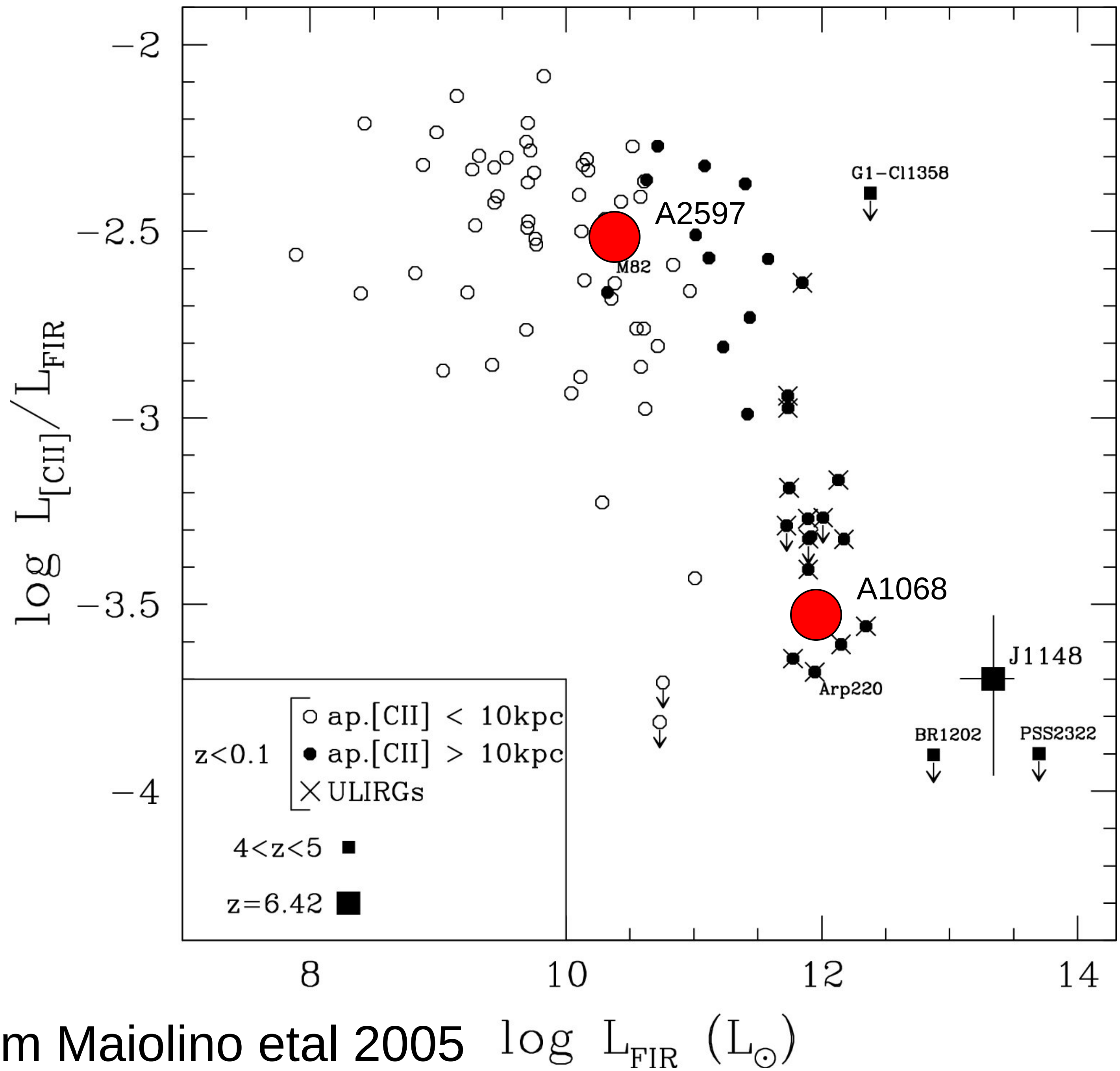


What does it all mean?

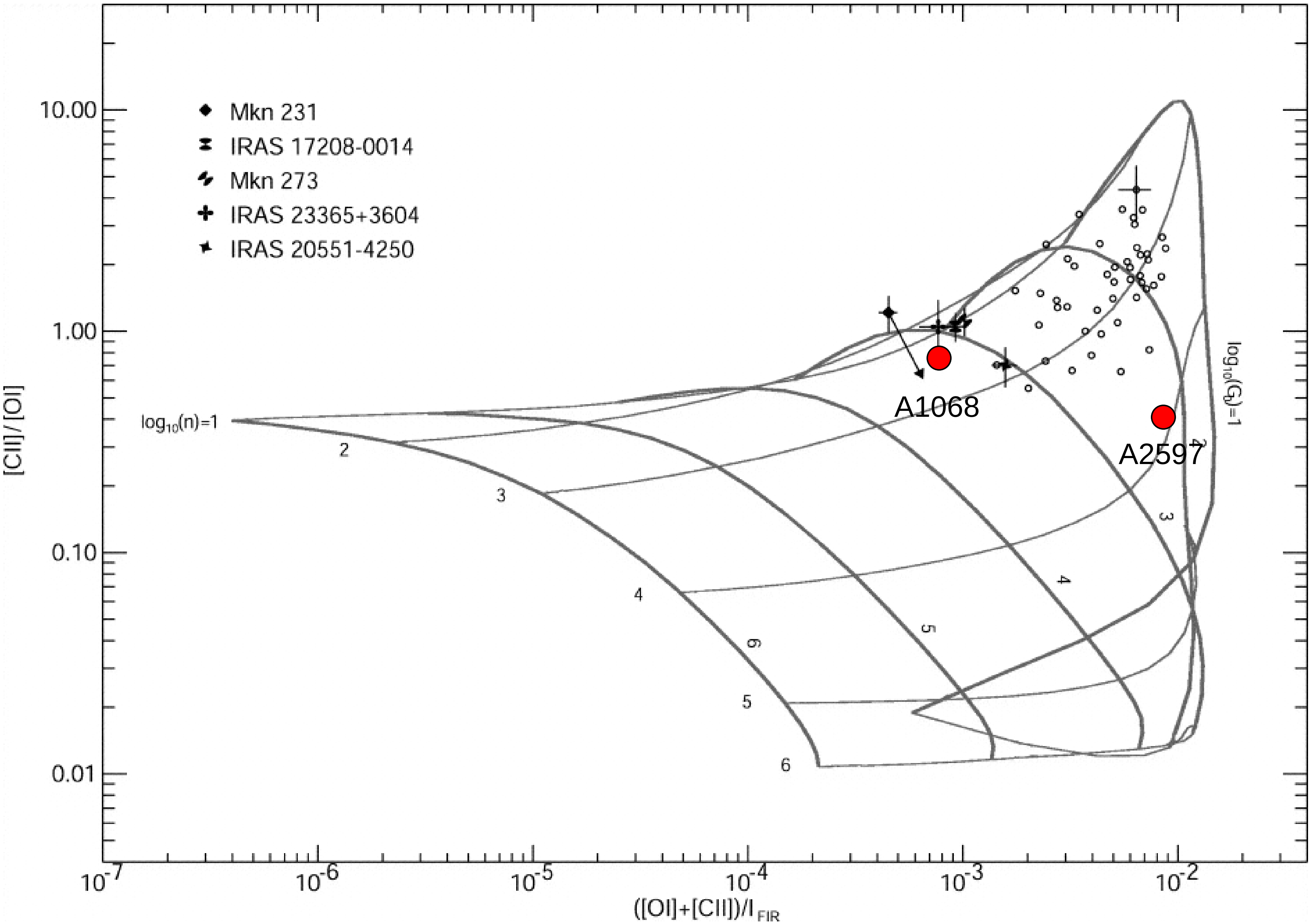
The spectra imply that the BCGs have the same CII line emission with respect to L_{IR} as other galaxies and ULIRGs.

The ratio of CII and OI are also consistent with other star-forming galaxies.

But the line widths are broader than expected from CO.



From Maiolino etal 2005

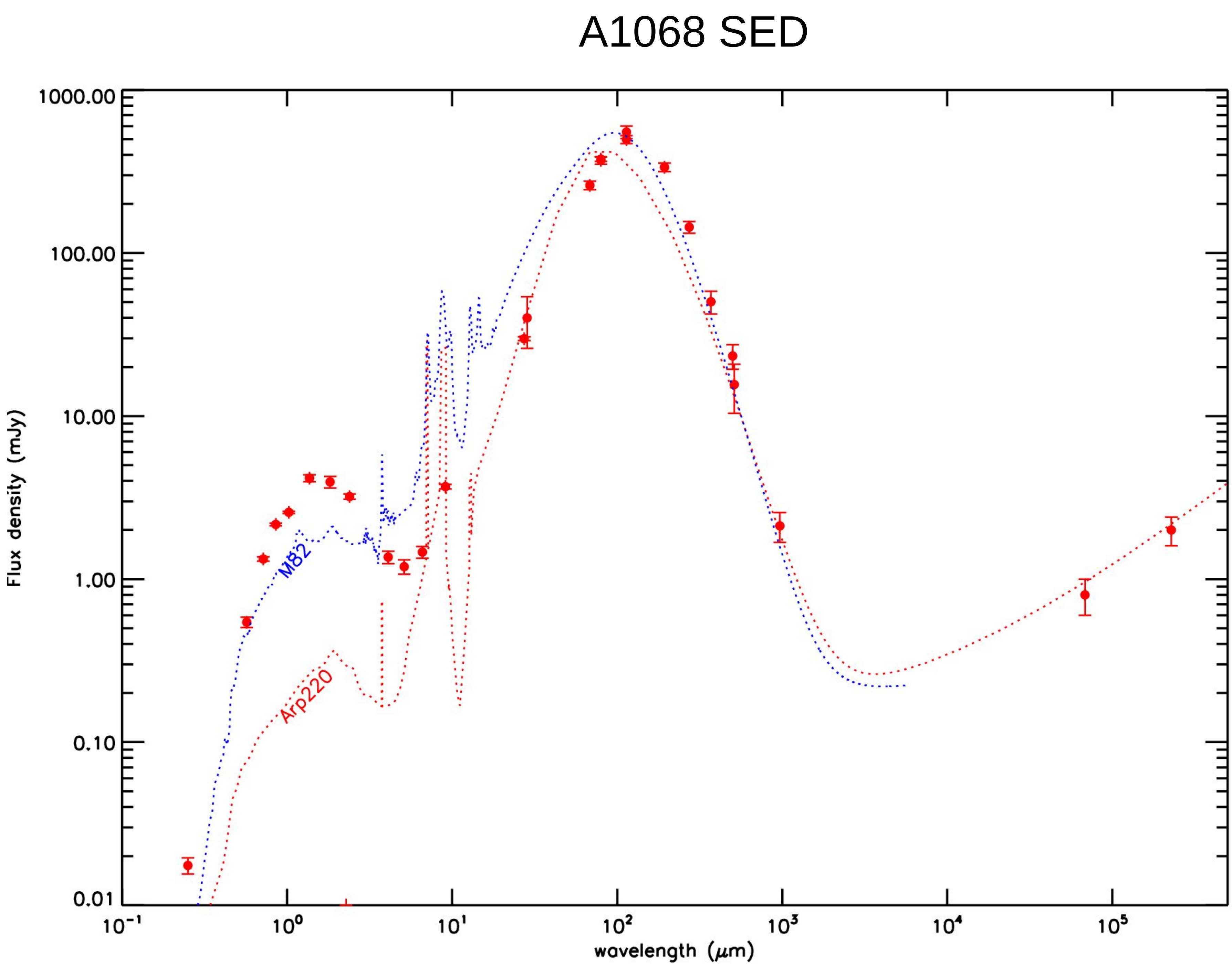


From Luhman et al 2003

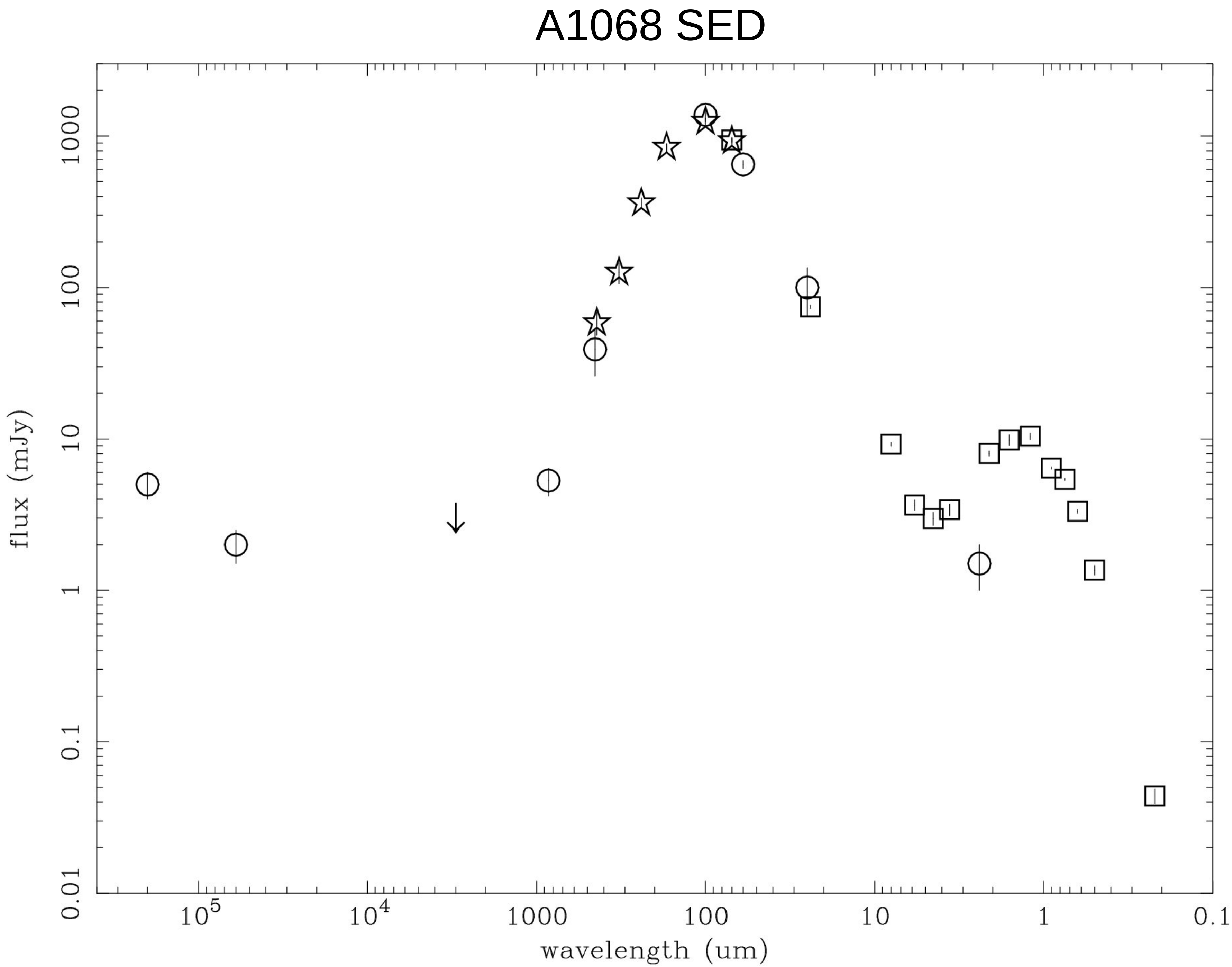
What does it all mean? II

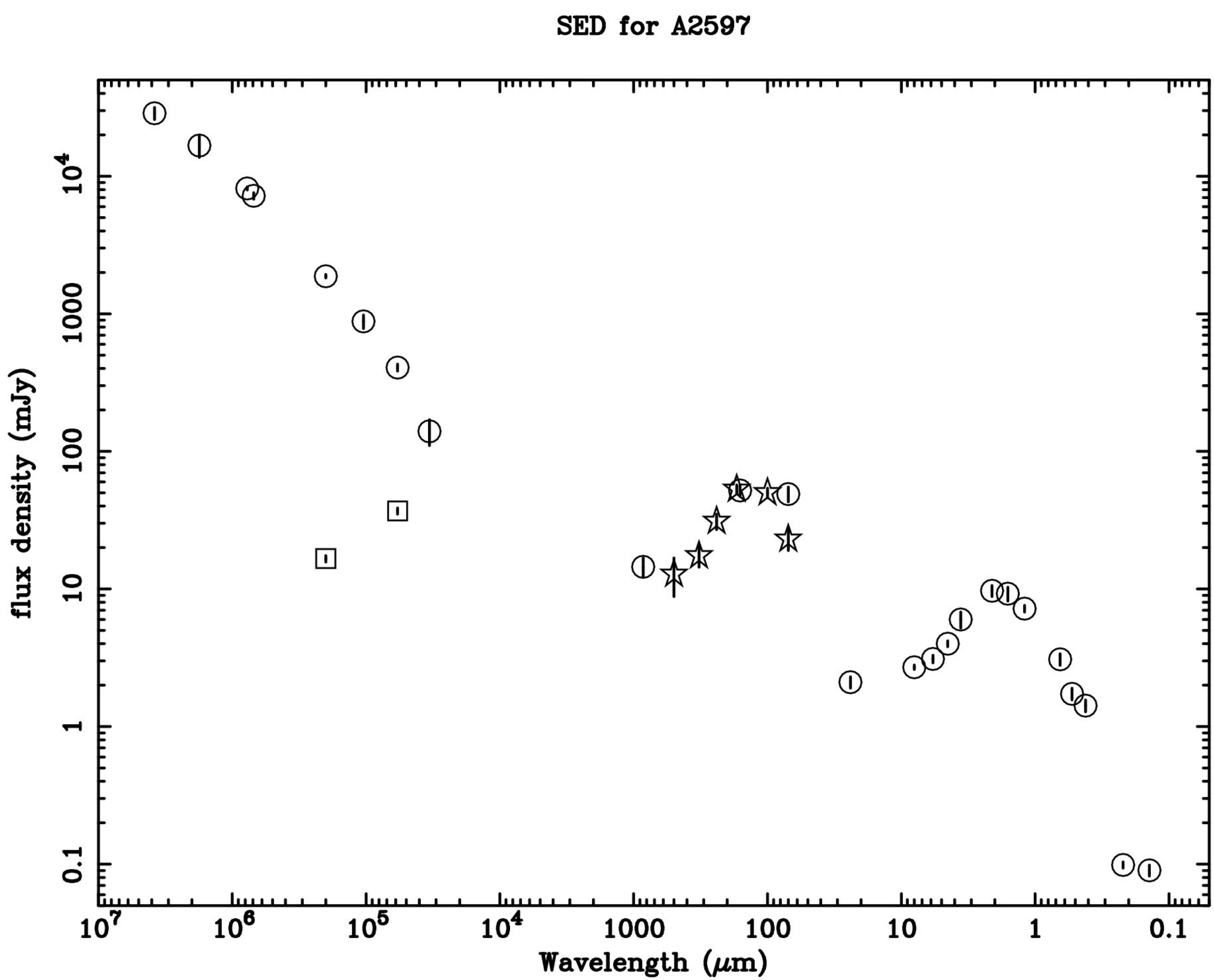
The photometry are consistent with the expected dust temperature of ~40K and L_{IR} of $10^{10-12}L_o$.

The other cluster OTKPs will detect many more BCGs (see previous talks by Egami and Smith).



A1068 SED
Flux density (mJy)
wavelength (μm)
1000.00
100.00
10.00
1.00
0.10
0.01
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
10^{4}
10^{5}
M82
Arp220


A1068 SED
flux (mJy)
wavelength (um)
0.01
0.1
1
10
100
1000
10^5
10^4
1000
100
10
1
0.1



SED for A2597
flux density (mJy)
Wavelength (μm)
10^4
1000
100
10
1
0.1
10^7
10^6
10^5
10^4
1000
100
10
1
0.1

What next?

The start of Routine Phase observations means that we will roll out observations of all our target lines and the other 8 objects.

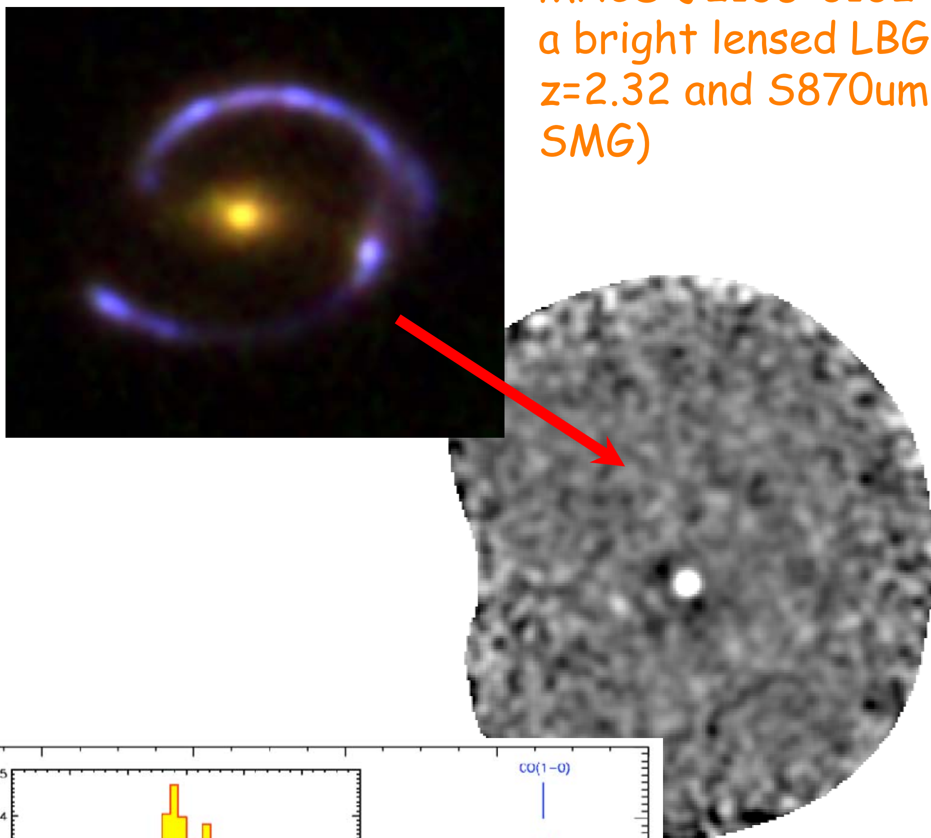
This will start with Centaurus, RXCJ1504-02, A1795 and A1835 in the next 2 weeks.

STOP PRESS!

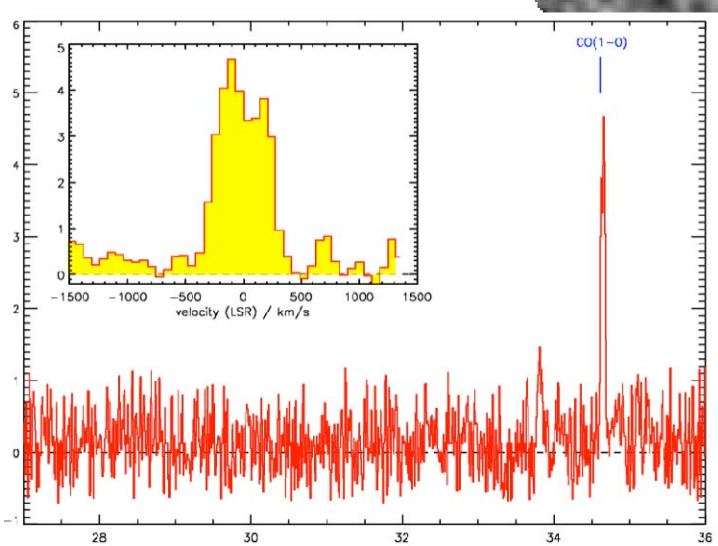
- I have been requested to mention some PV observations of a source that was found in May this year by Mark Swinbank (Durham) that offers a unique opportunity to make use of Herschel.
- These data come with great thanks from we observers to the instrument and observatory teams.

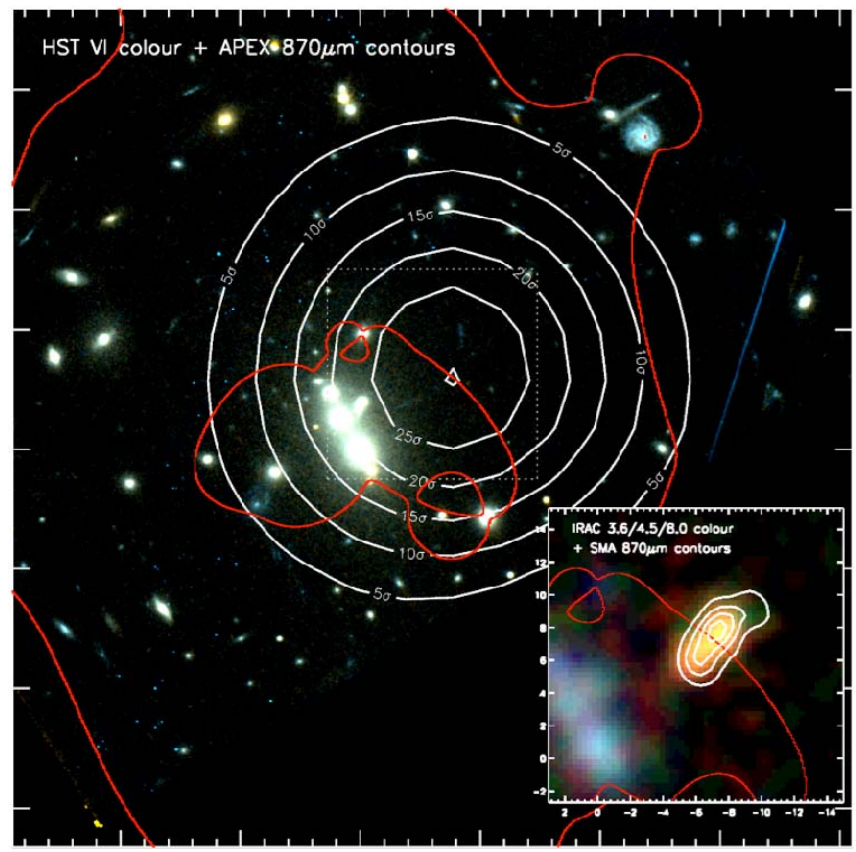
Multi-wavelength serendipity

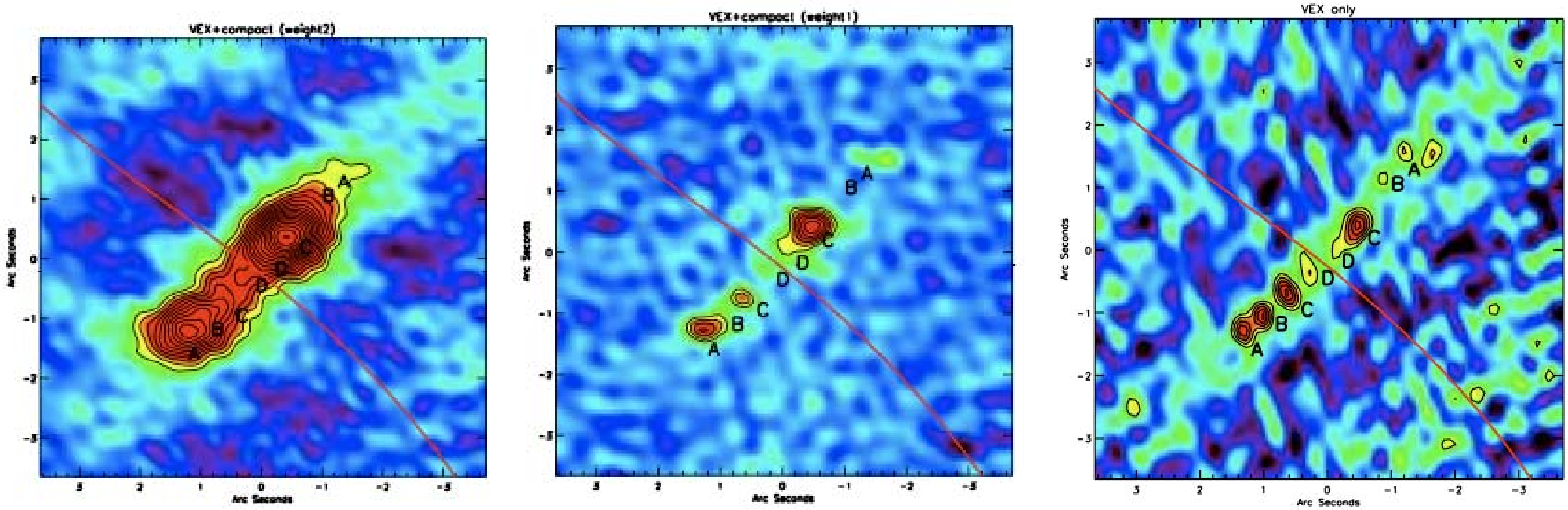
MACS J2135-0102: an X-ray luminous cluster at z=0.32 ... with a bright lensed LBG at z=3.07 and the brightest SMG, with z=2.32 and S870um=106+/-3mJy (3x brighter than any other SMG)



❍=32.5+/-4.5
(so intrinsic flux=3mJy; ie a typical high-z ULIRG).
For ❍■32, 0.2"=100pc (source-plane)



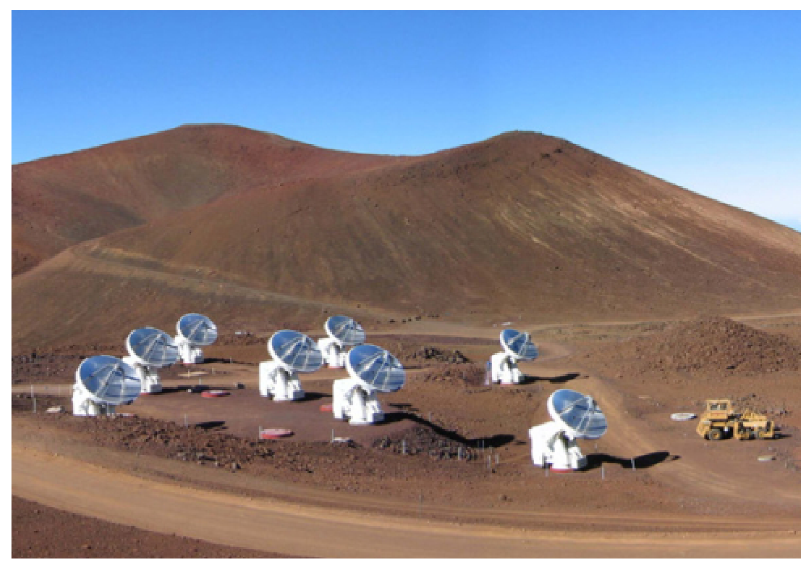


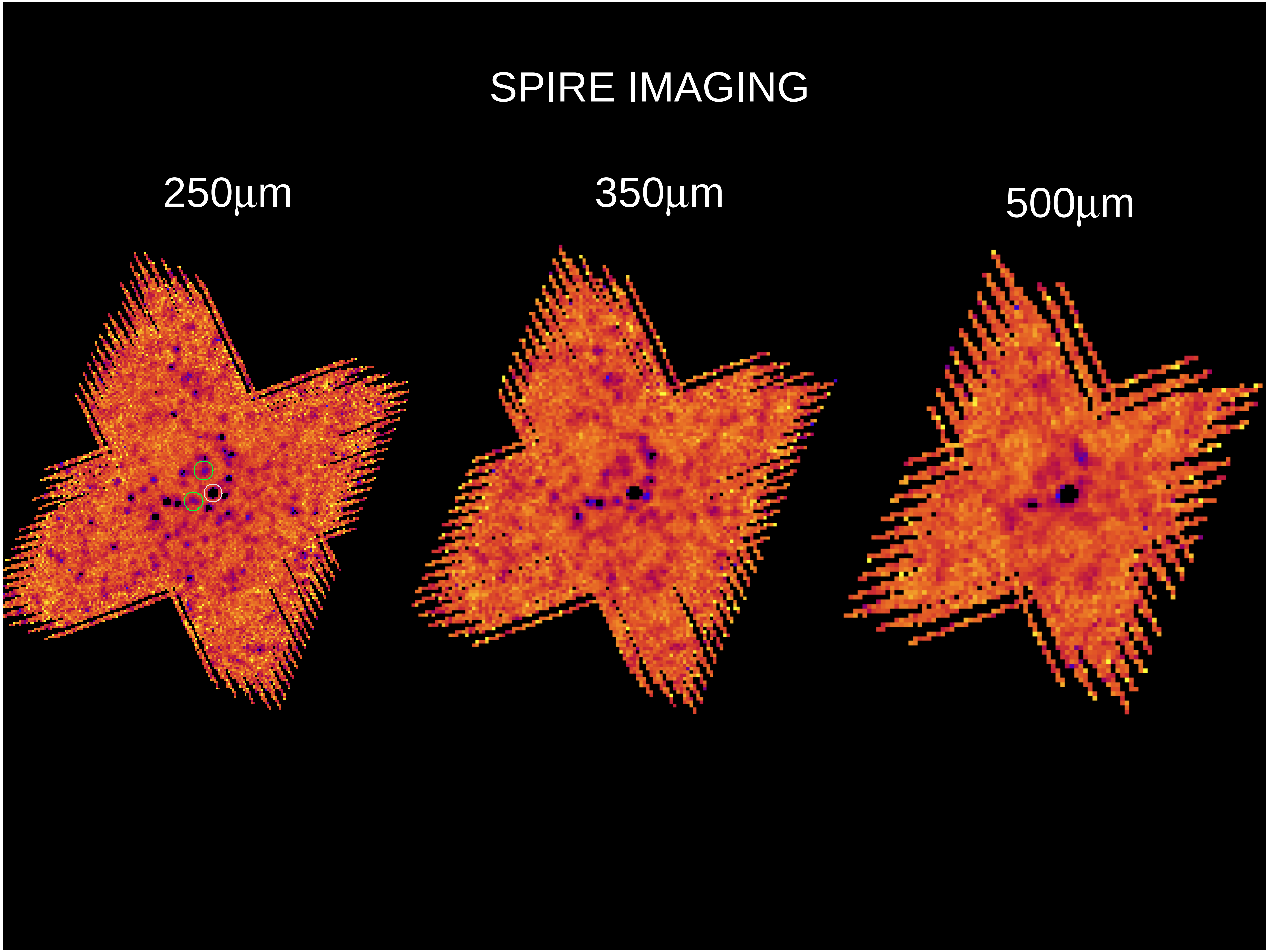


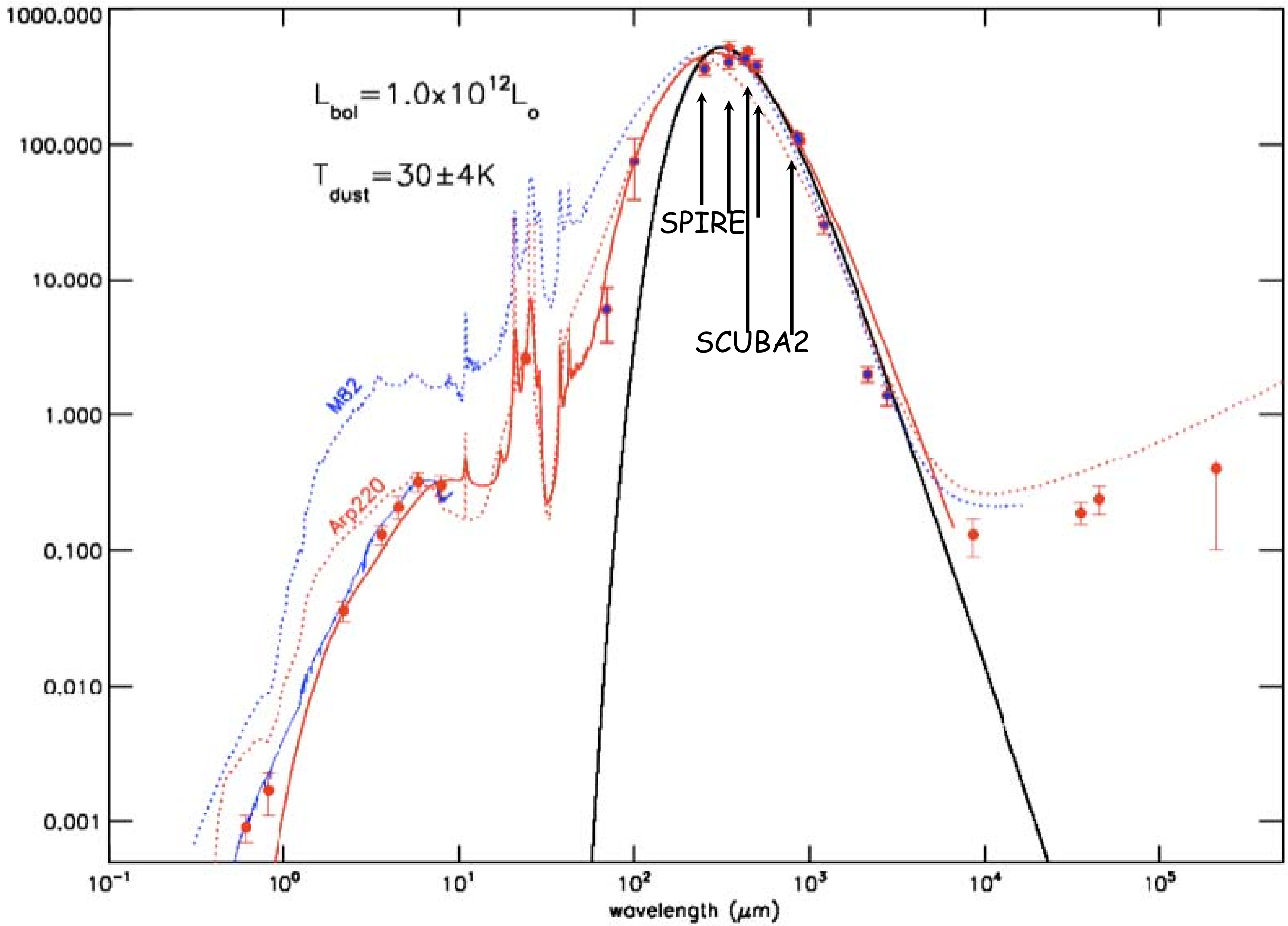
To resolve the sub-mm emission, we used the Smithsonian Sub-mm Array (SMA) at 3 configurations: compact (1.5"), Extended (0.7"), Very Extended (VEX; 0.2")

In all configurations, we detect the source and it continues to break up into smaller clumps

In highest configuration, beam is 0.2" (90-150pc after accounting for lensing).

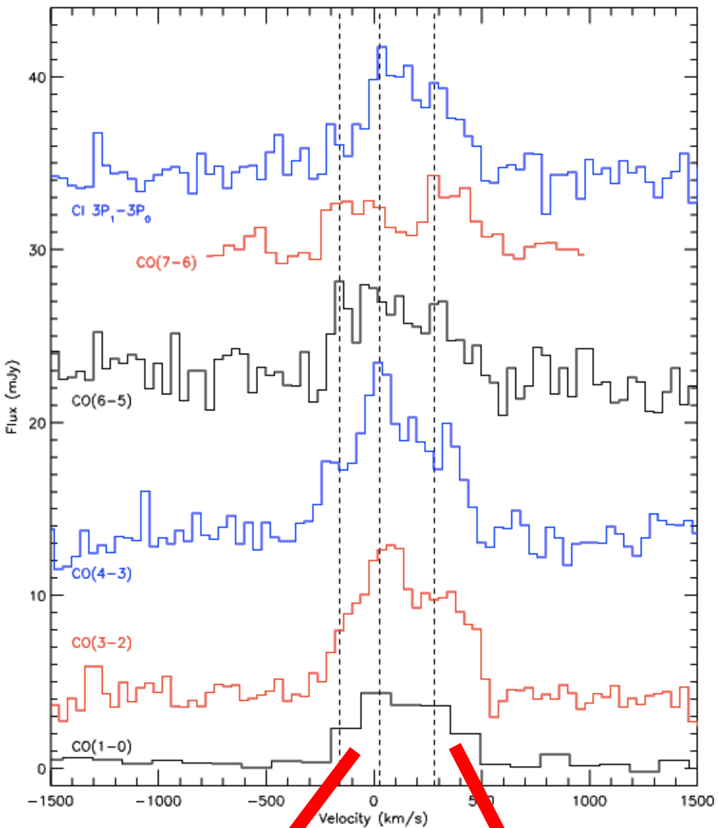


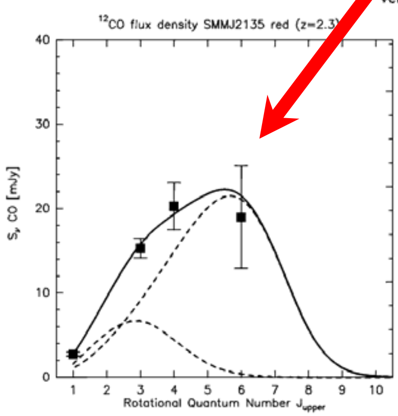

SPIRE IMAGING
250µm
350µm
500µm

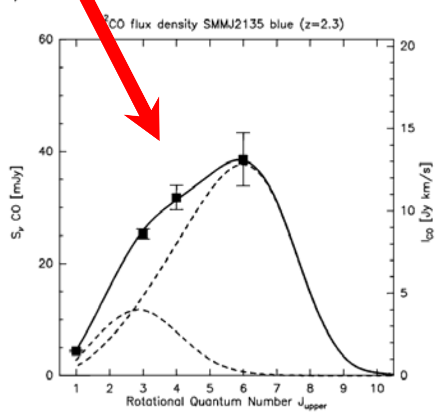


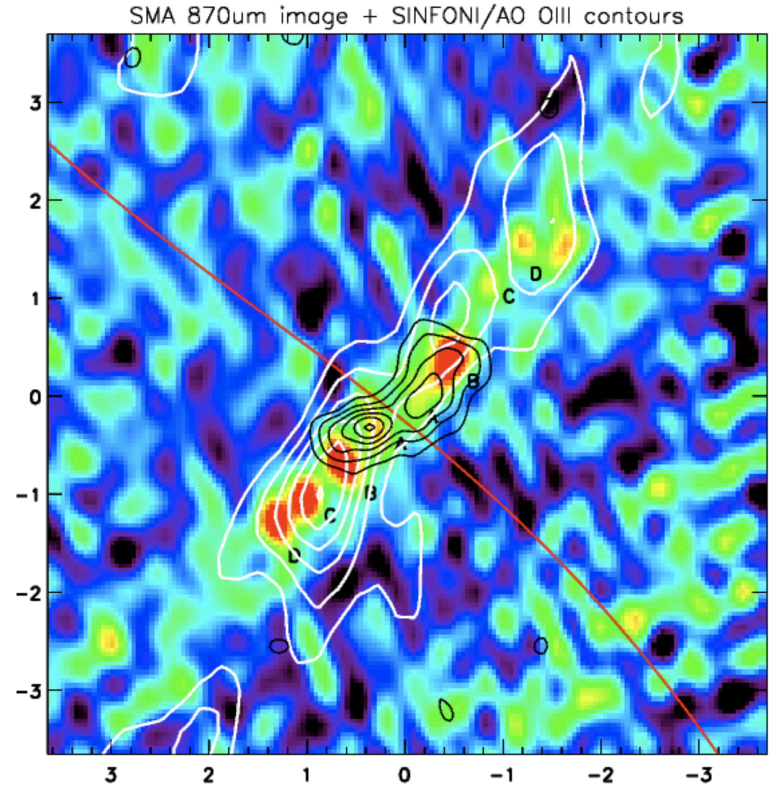
1000.000
100.000
10.000
1.000
0.100
0.010
0.001
$L_{bol}=1.0\times10^{12}L_o$
$T_{dust}=30\pm4K$
M82
Arp220
SPIRE
SCUBA2
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
10^{4}
10^{5}
wavelength (μm)

Interpretation



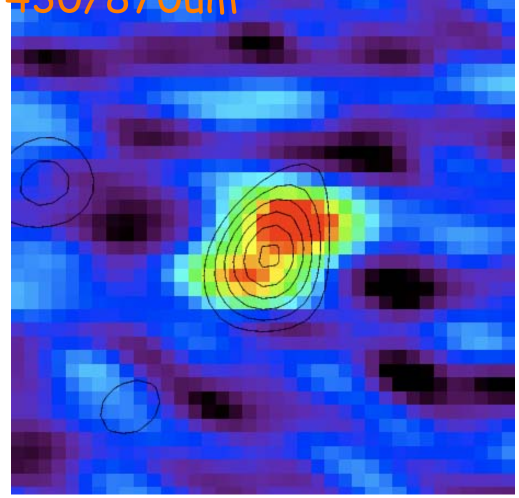






SMA map overlayed with EVLA CO(1-0) map + SINFONI LGS AO

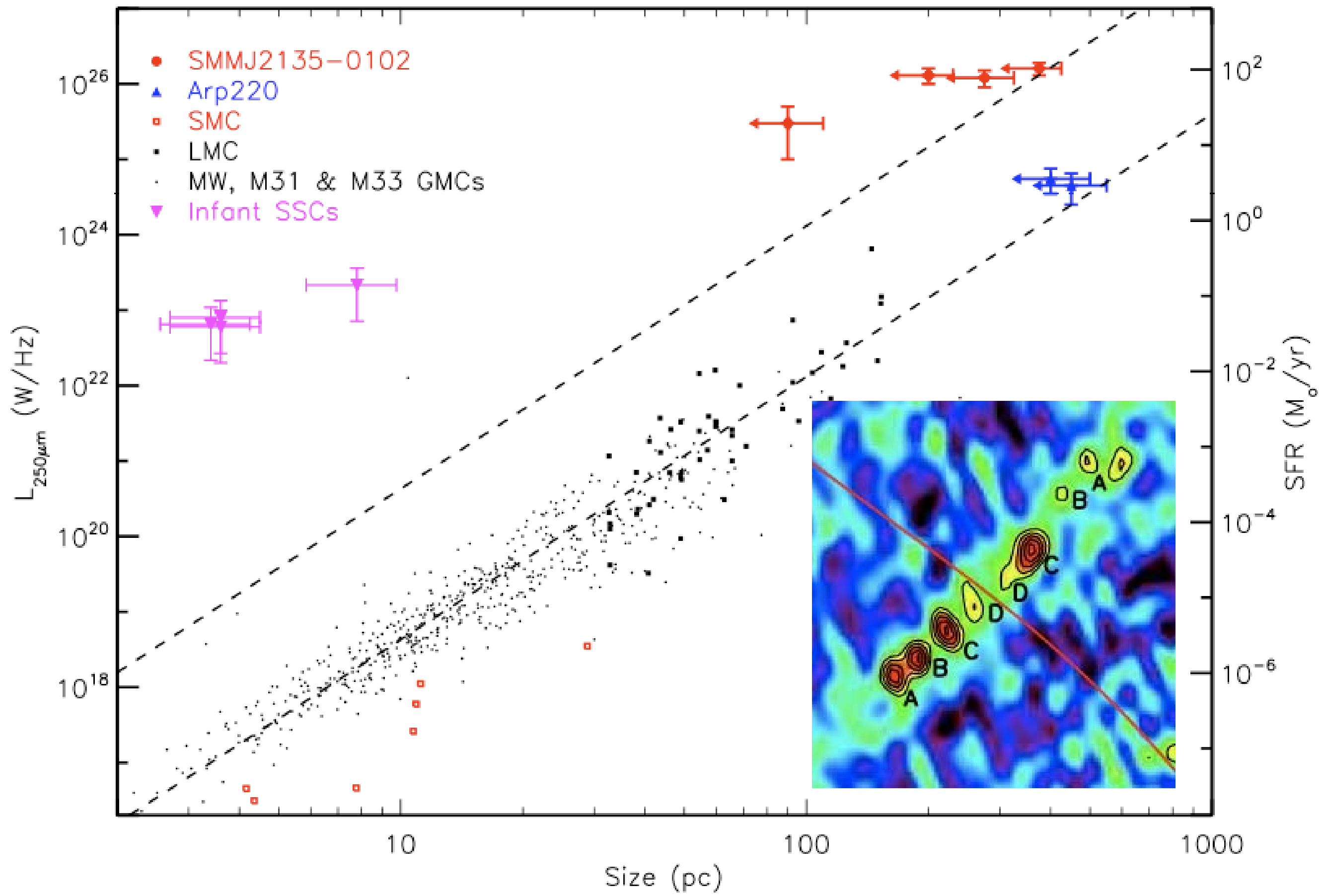
430/870um



SMA 870❍m+434❍m contours (so - hot component is A+B)

Internal Properties

We can compare the sizes and luminosities of 'clumps' with those locally (MW, M31, M33 and LMC from IRAS).



- GMCs within SMMJ2135-0102 show a factor ~100x more (rest-frame) 250um luminosity at fixed size cf local GMCs.
- Increased star-formation efficiency? dust-to-gas ratios or dust properties? Top-Heavy IMF?

Swinbank et al. 2010 (Nature)