The SMA, Herschel, and the High Redshift Universe

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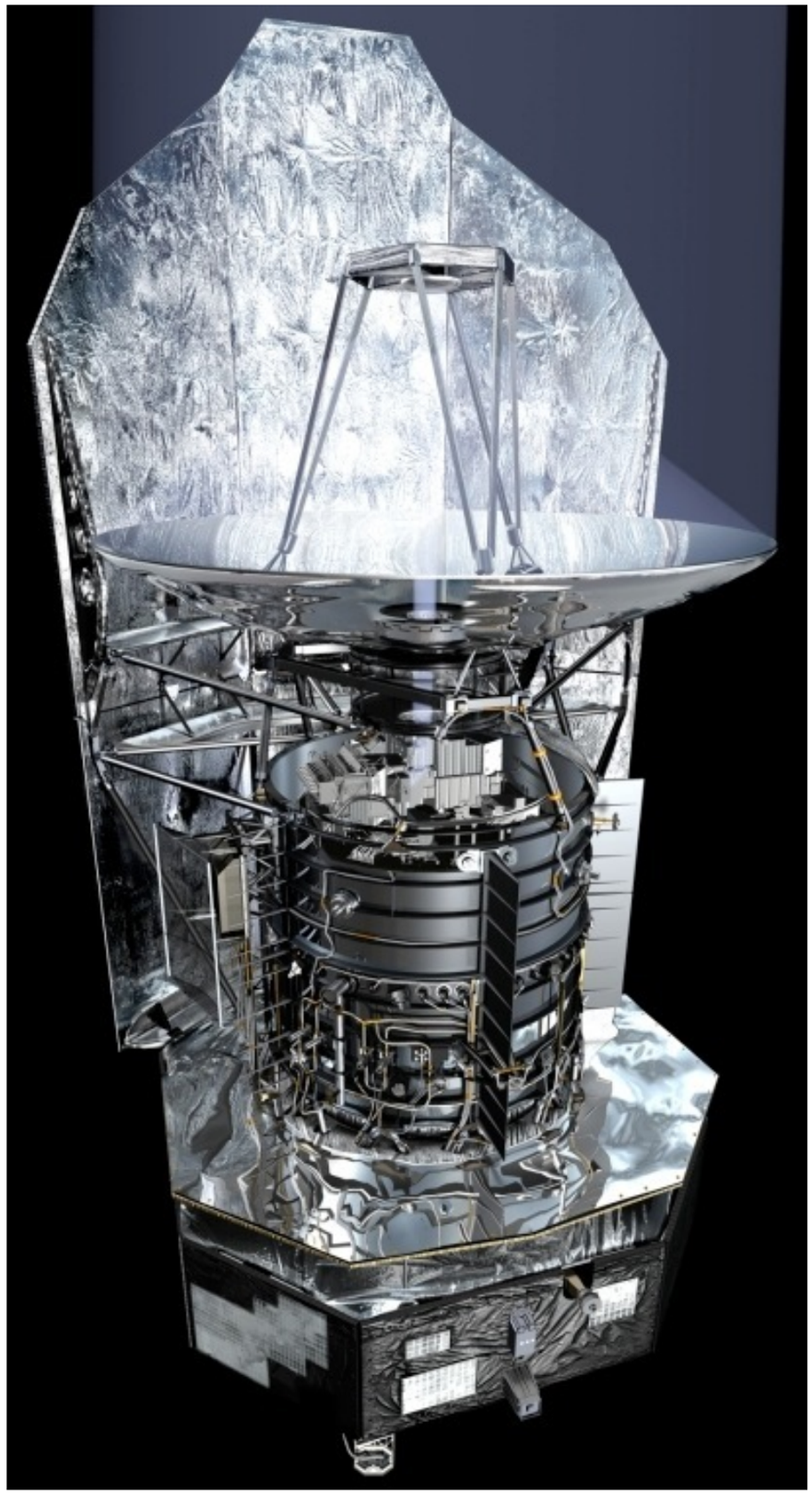
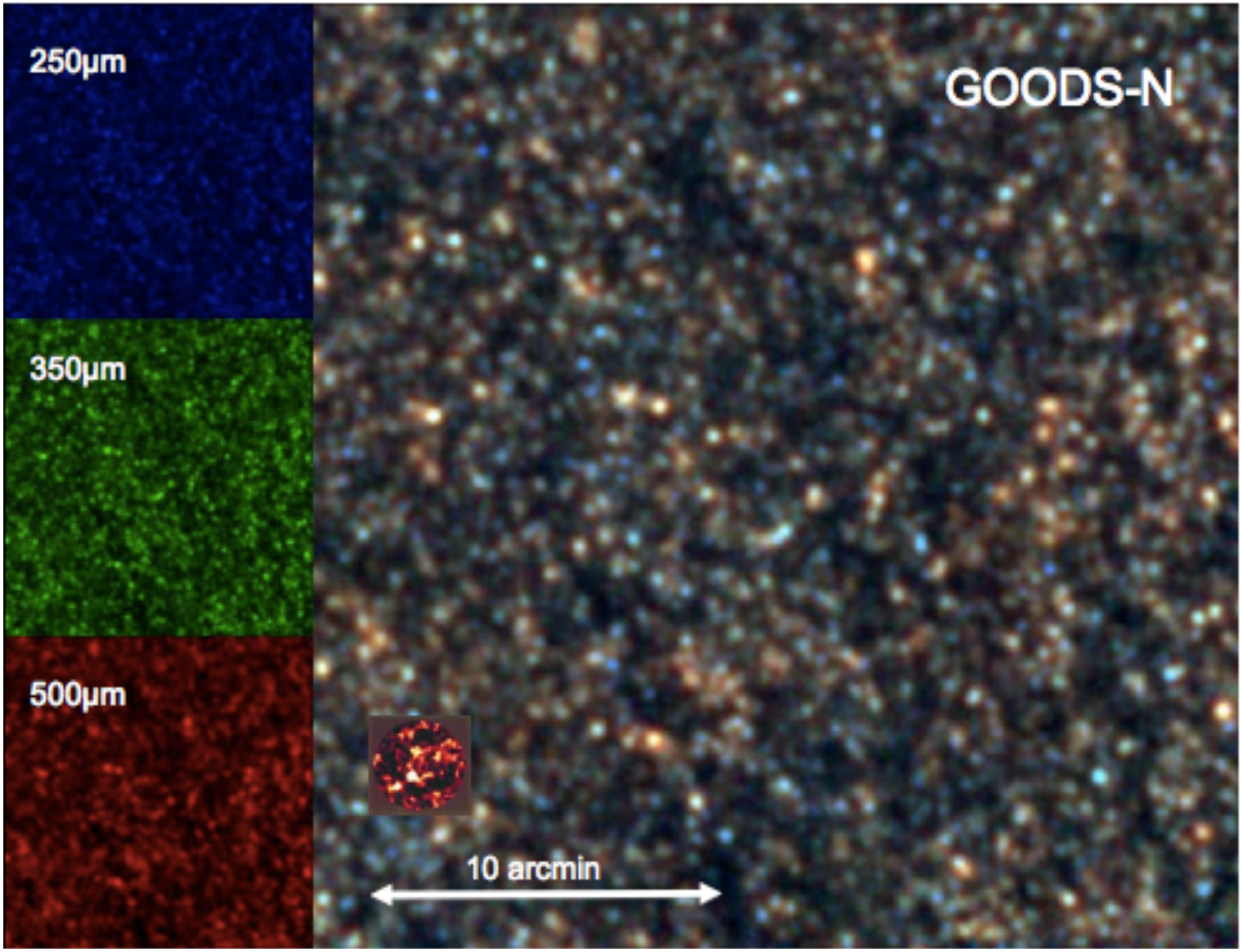
Herschel

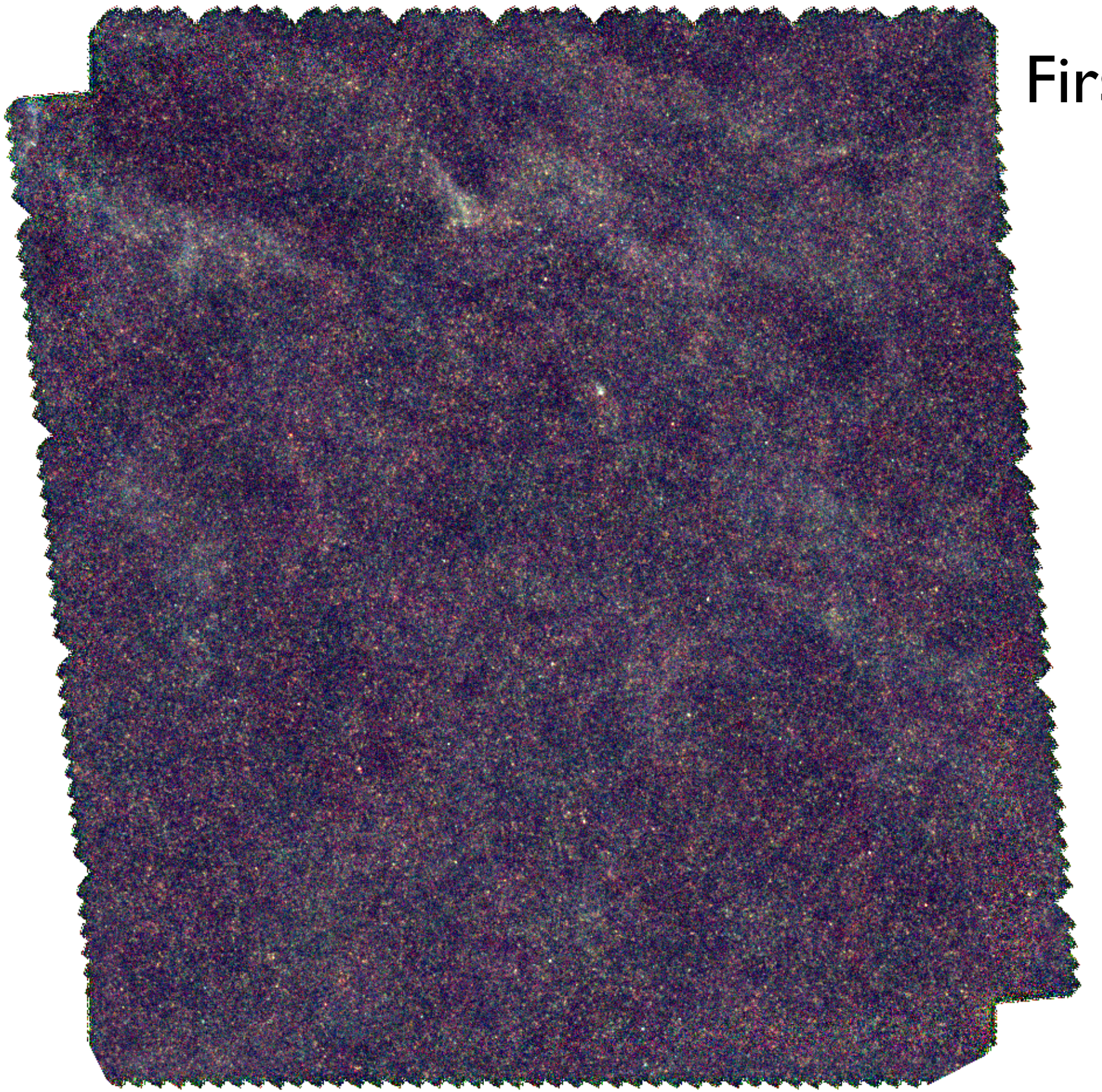
- Far-IR space telescope
- 3.5m passively cooled primary
- 3 instruments, HIFI, PACS, SPIRE
- SPIRE operates at 250, 350 & 500 microns
- Can survey large areas very rapidly



Herschel Surveys: HerMES



Herschel Surveys: H-ATLAS



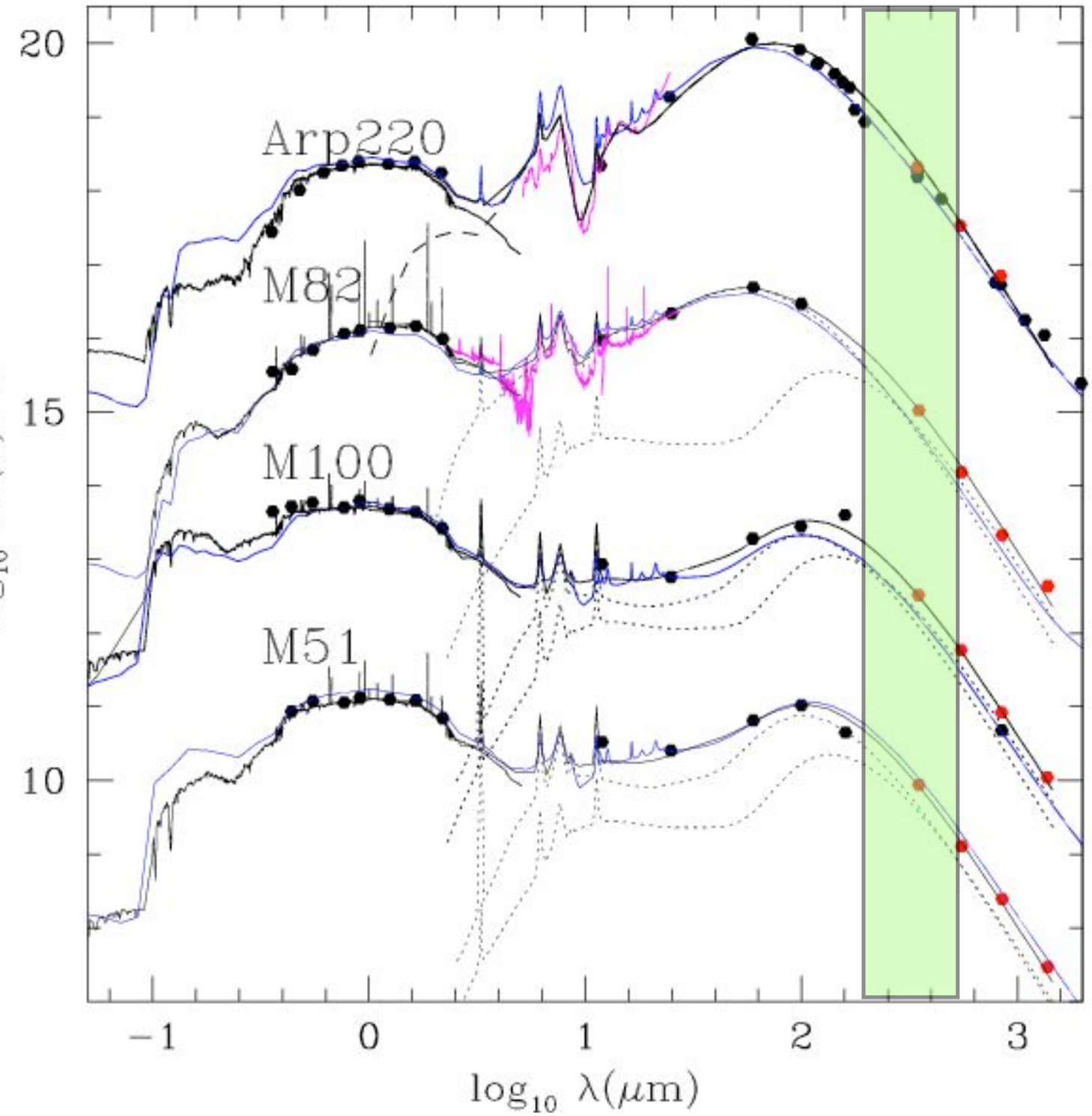
First ~14.4 sq deg of
H-ATLAS
7000 sources

HerMES & H-ATLAS Summary

- HerMES: 90 sq. deg. to confusion limit in SPIRE or below + 250 sq. deg. to brighter limits
- H-ATLAS: 570 sq. deg. to confusion limit in SPIRE
- Hundreds of thousands of galaxies found

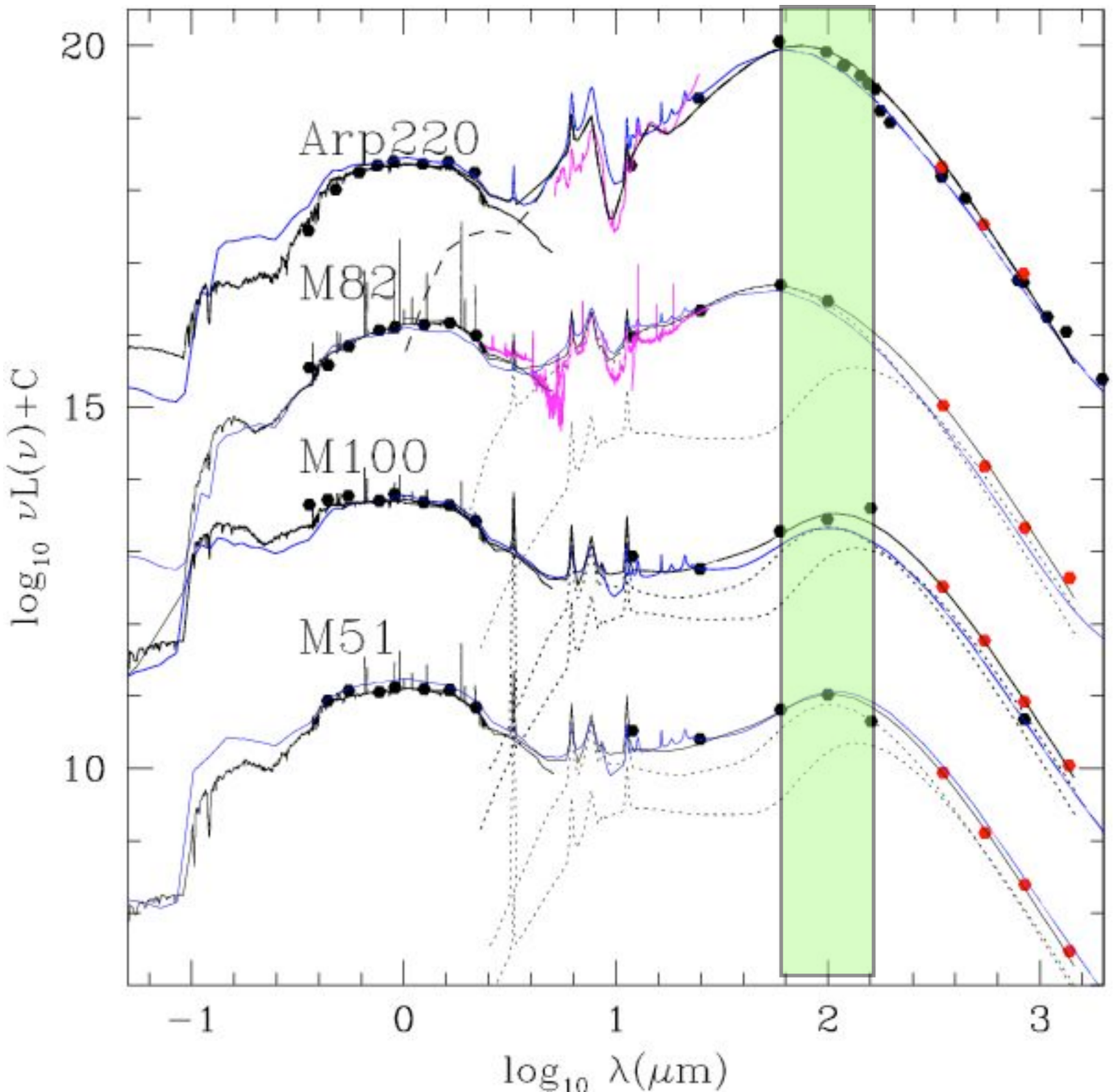
Galaxy SEDs at z=0

All sources at low z are blue in SPIRE bands: F250>F350 >F500



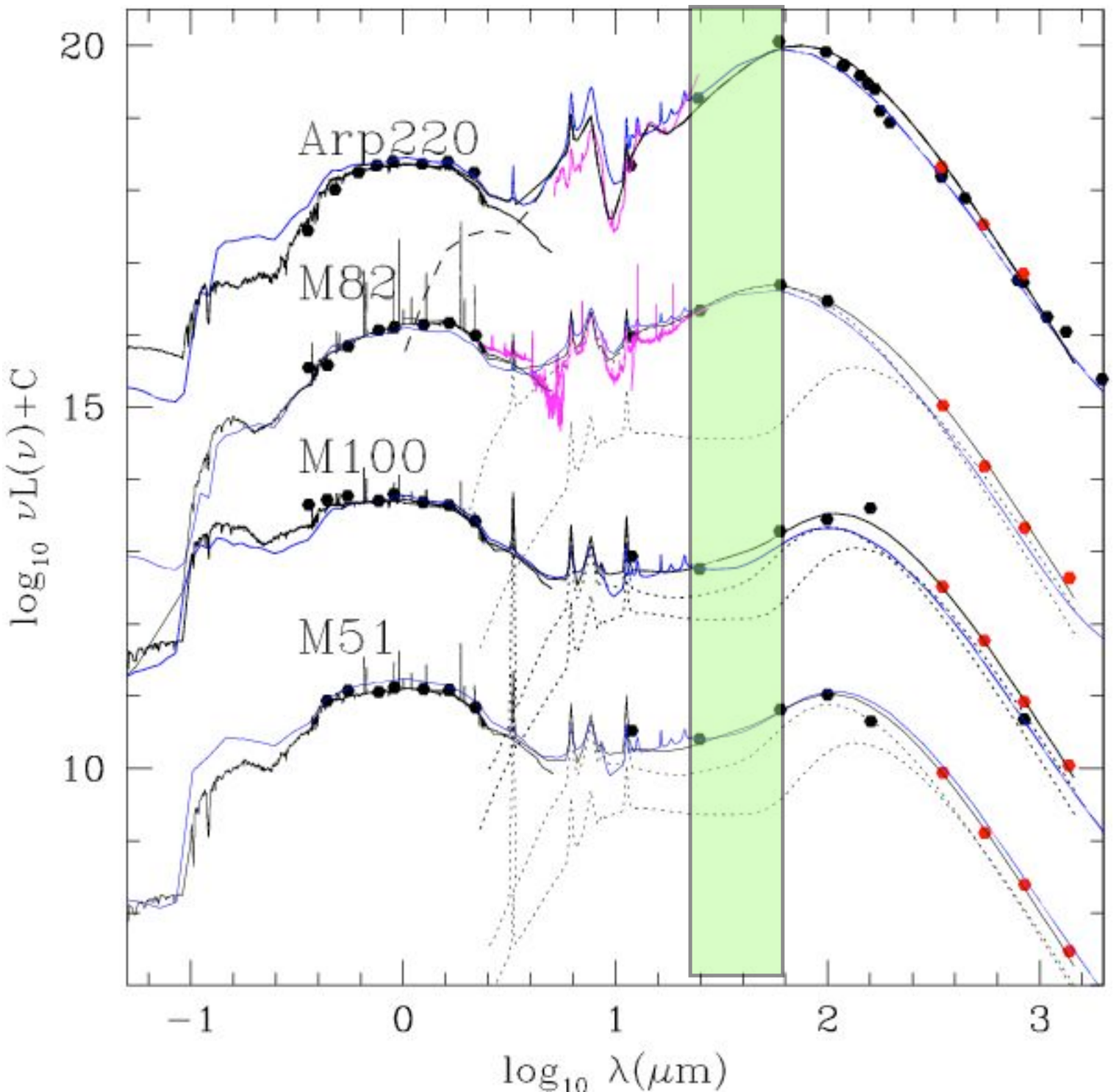
But at z=3...

At z~3 redshift means flat SED between 250 & 350 microns

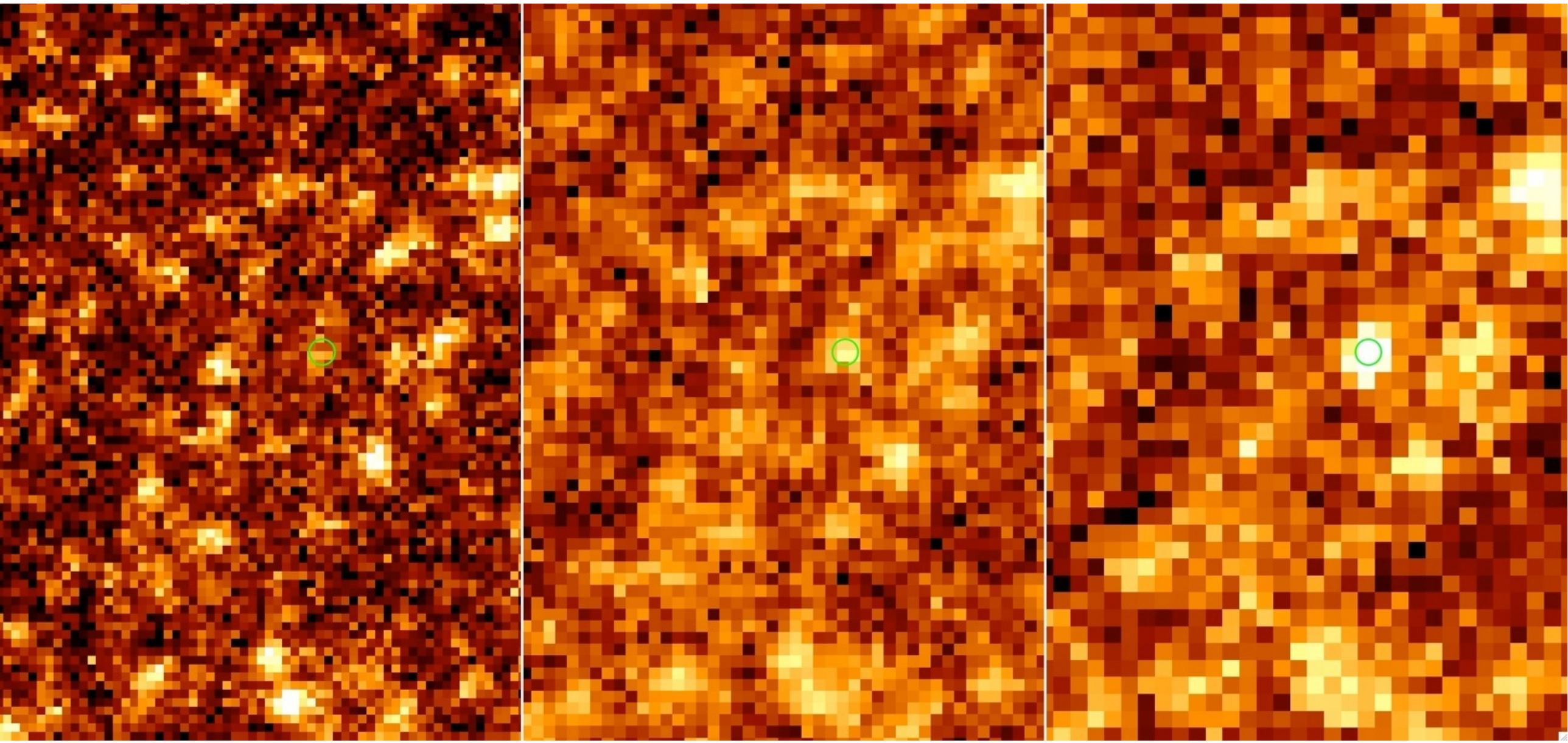


And at still higher redshift...

At z>5 SED peak is at wavelengths longer than 500 microns: F500>F350> F250

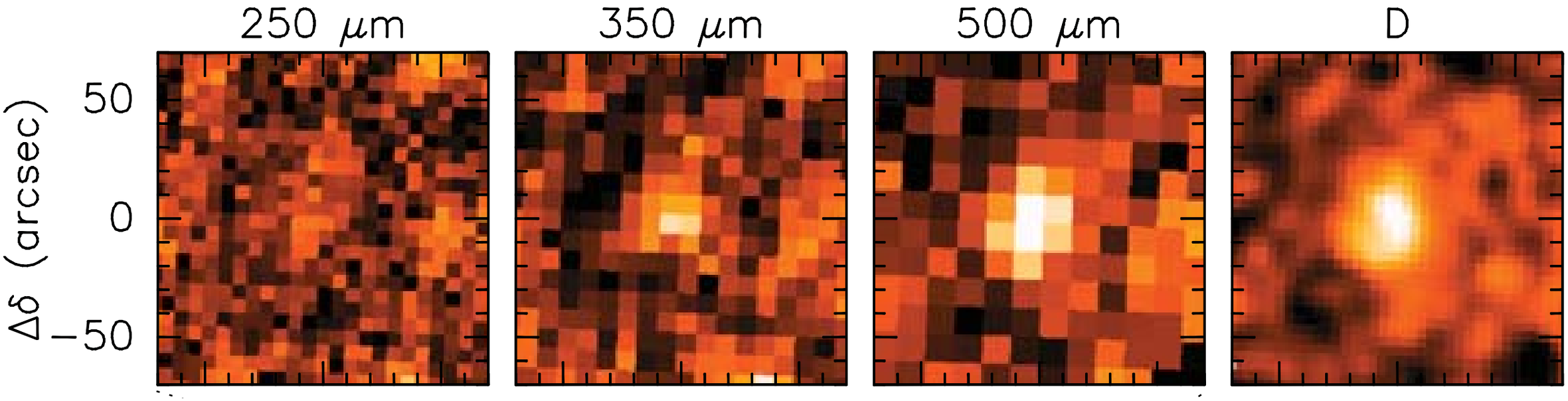


Do Such red Sources Exist?



250 microns 350 microns 500 microns

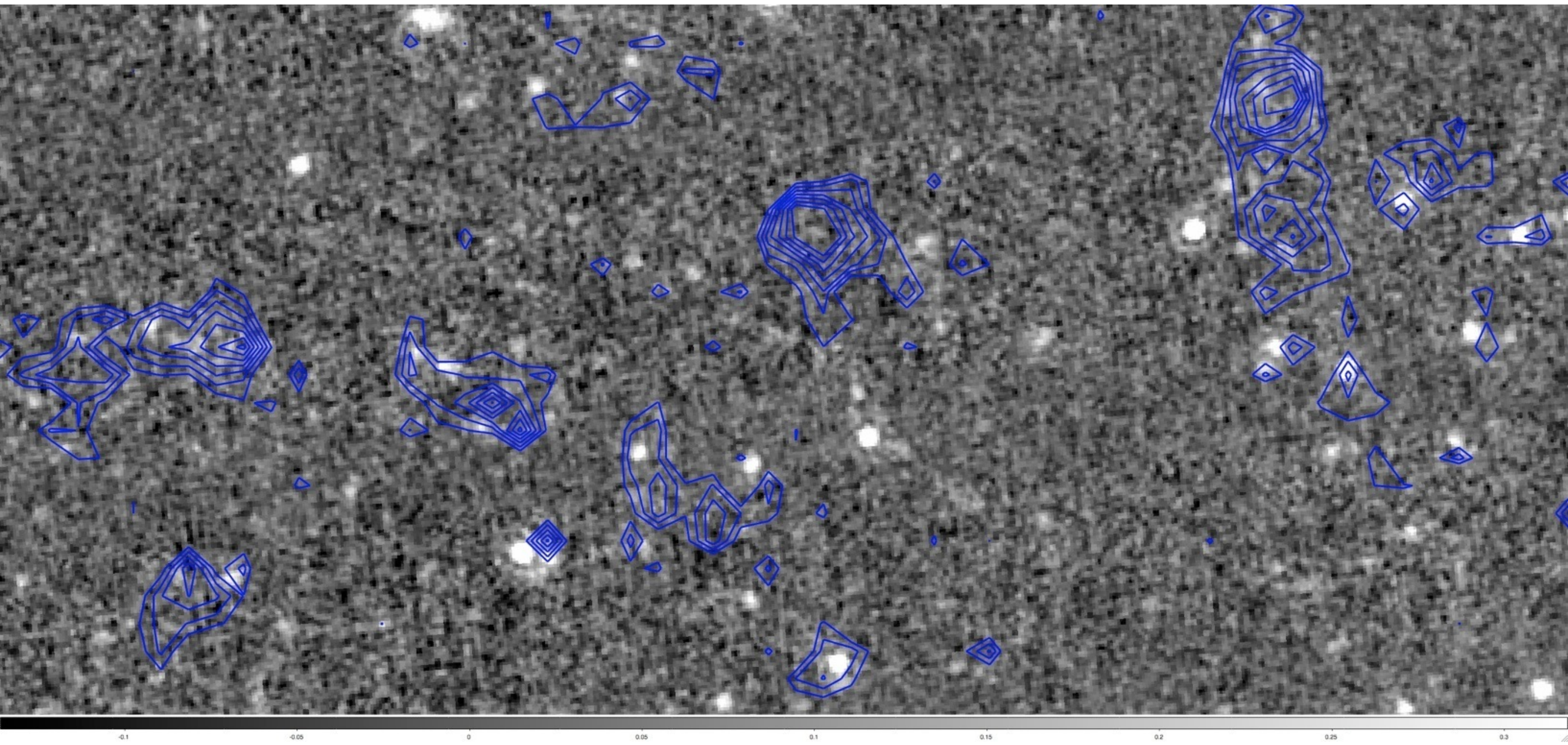
Can produce Redness Map



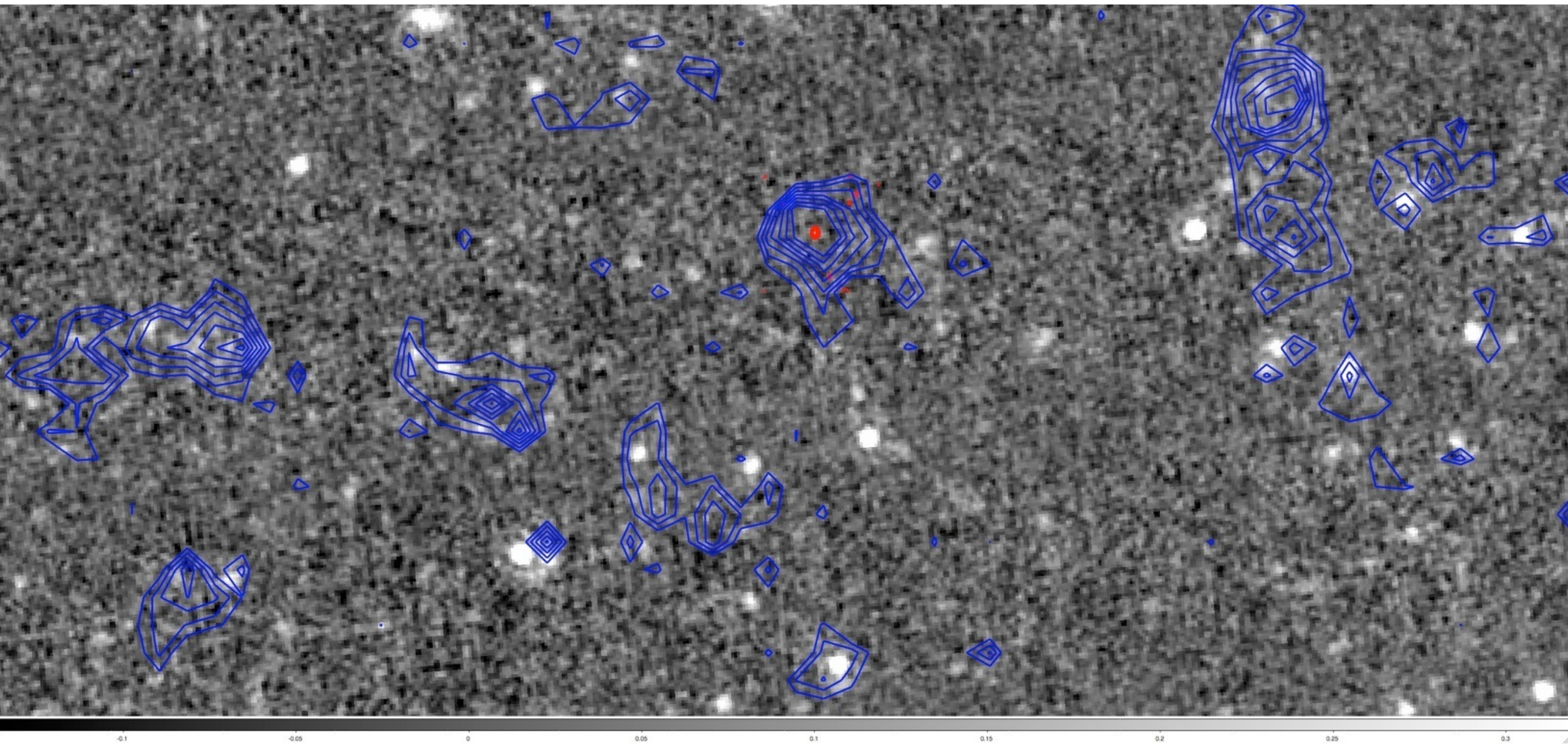
Riechers et al. 2013

The Identification Problem

- Herschel beams are 18” at 250 microns and 36” at 500 microns
- Matching a 500 micron source to a source at other wavelengths can be challenging!



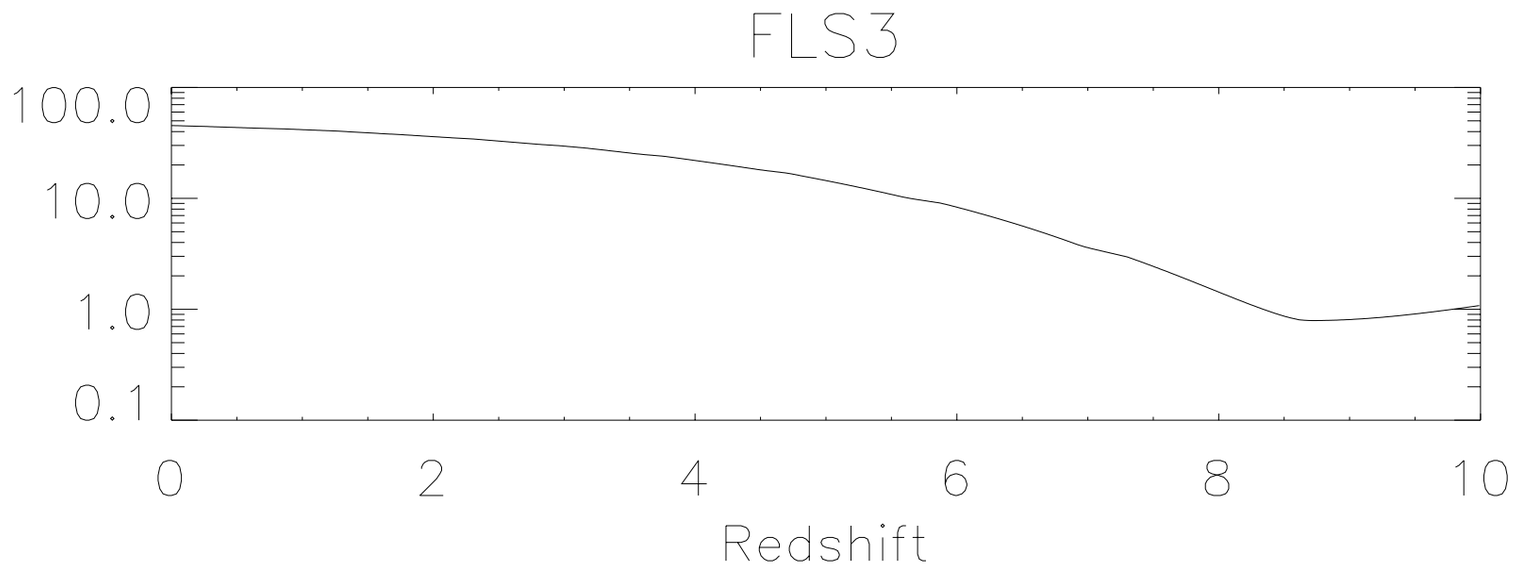
24 micron image of FLS with 500 micron Herschel contours



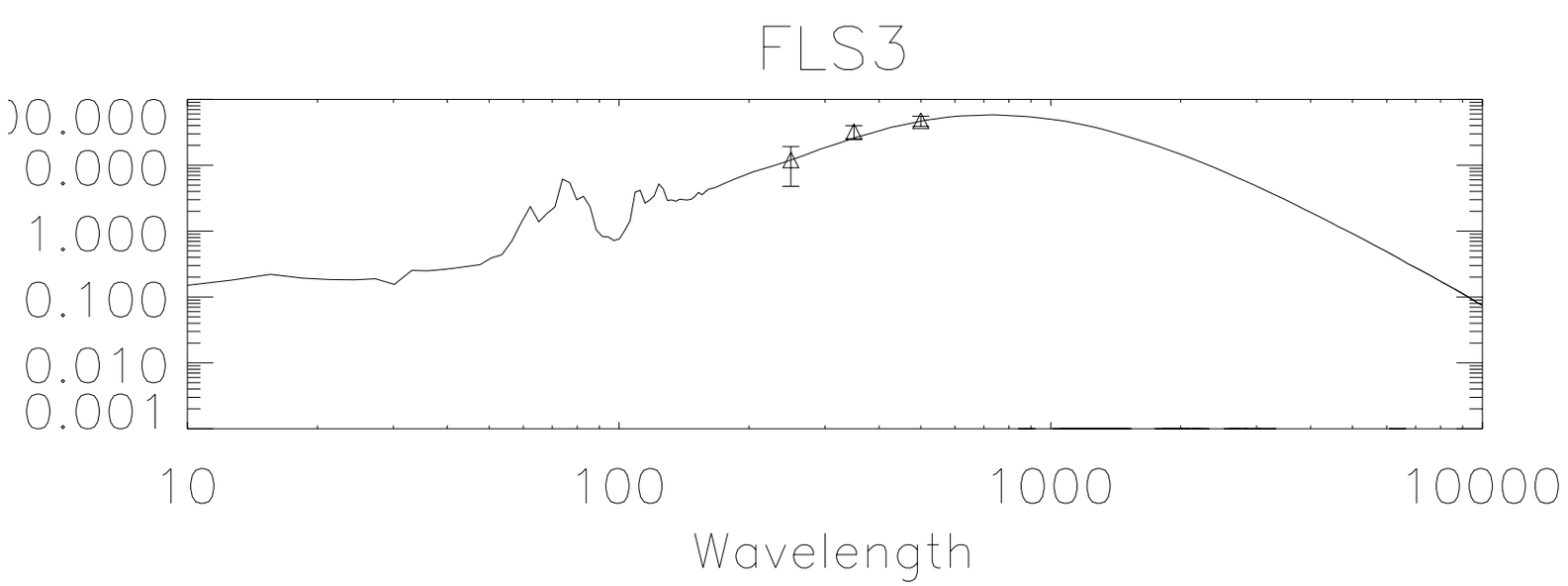
24 micron image of FLS with 500 micron Herschel and 270GHz SMA contours (source at z=4.44)

Additional Flux: Submm Photo-z

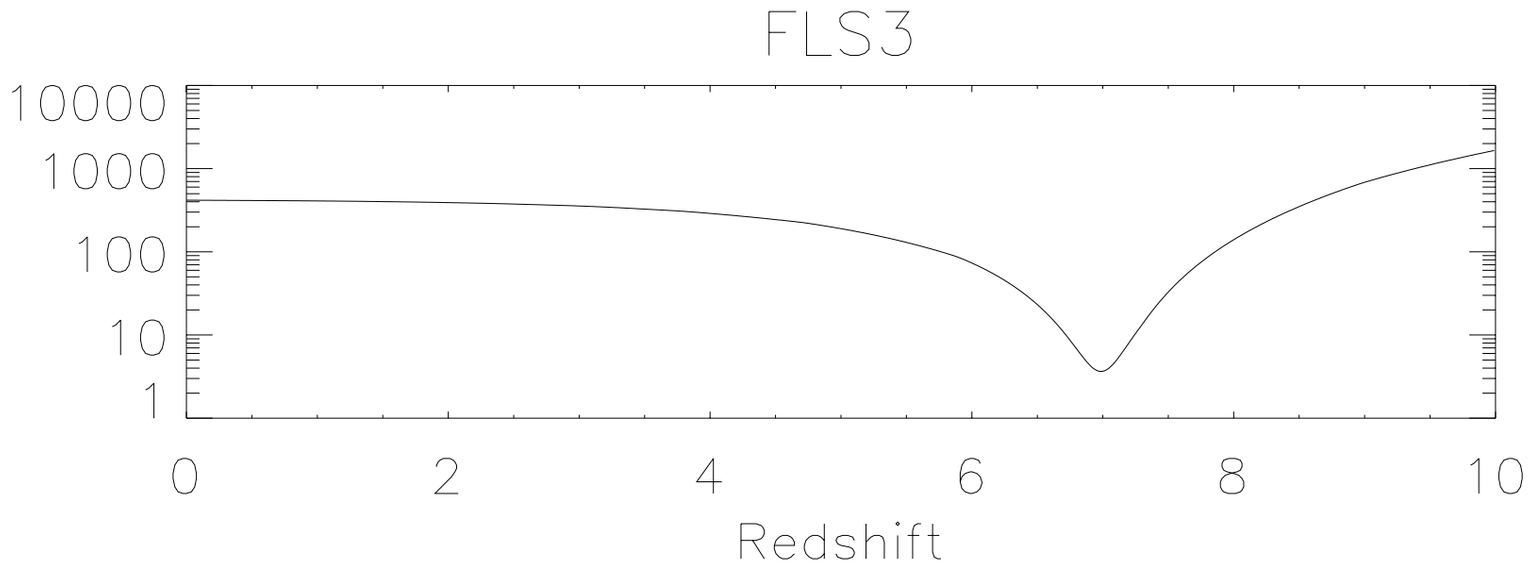
- Can use model far-SEDs as templates in a crude photo-z estimator
- With Herschel data alone similar to red selection
- Additional submm data greatly improves photo-z accuracy



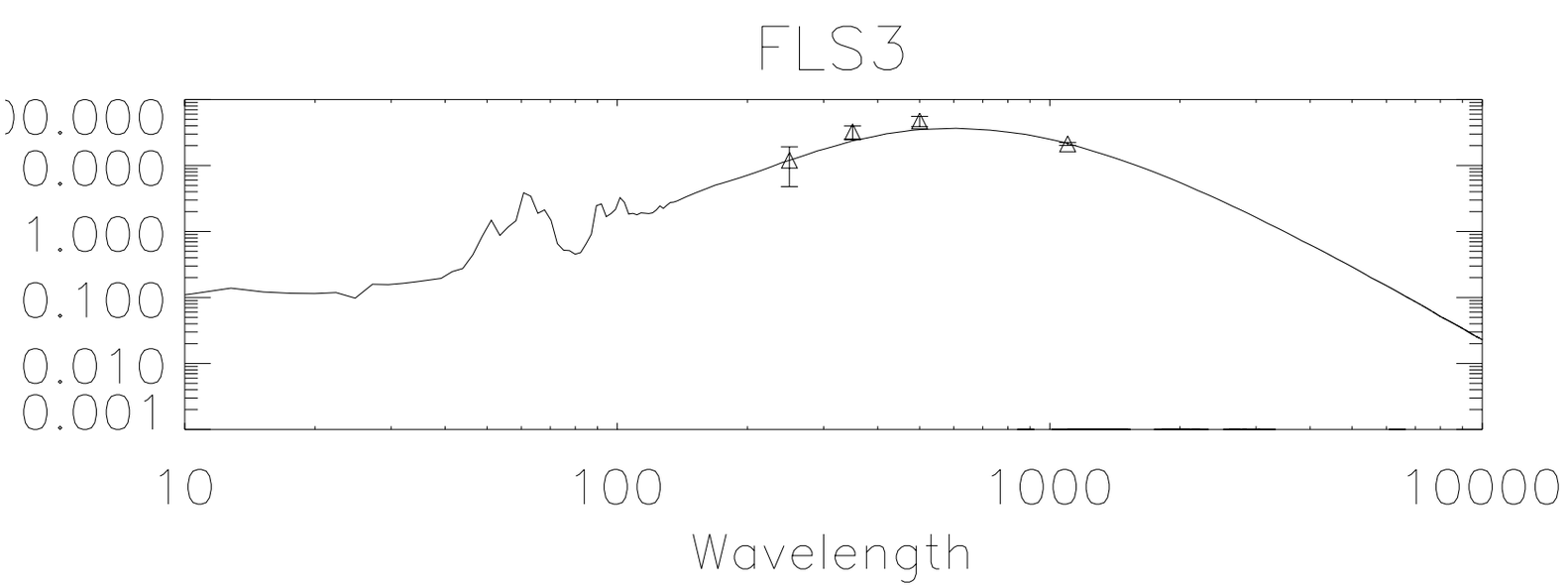
Redshift Likelihood



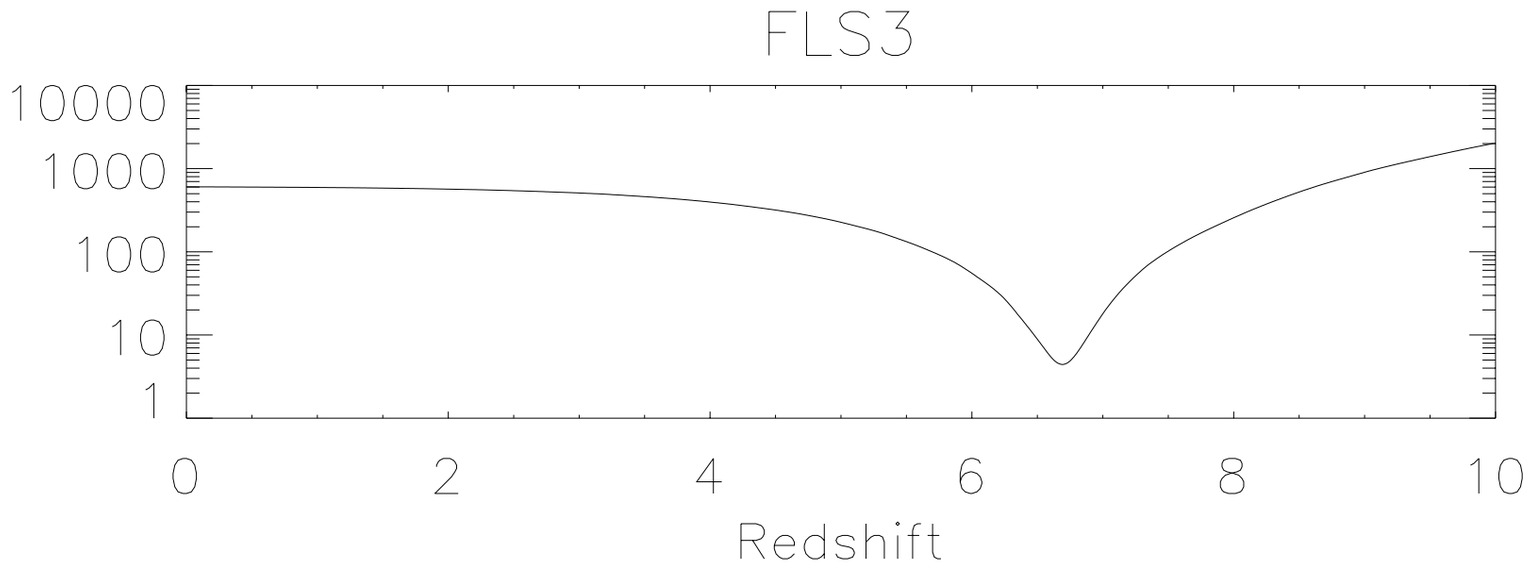
Fitted SED



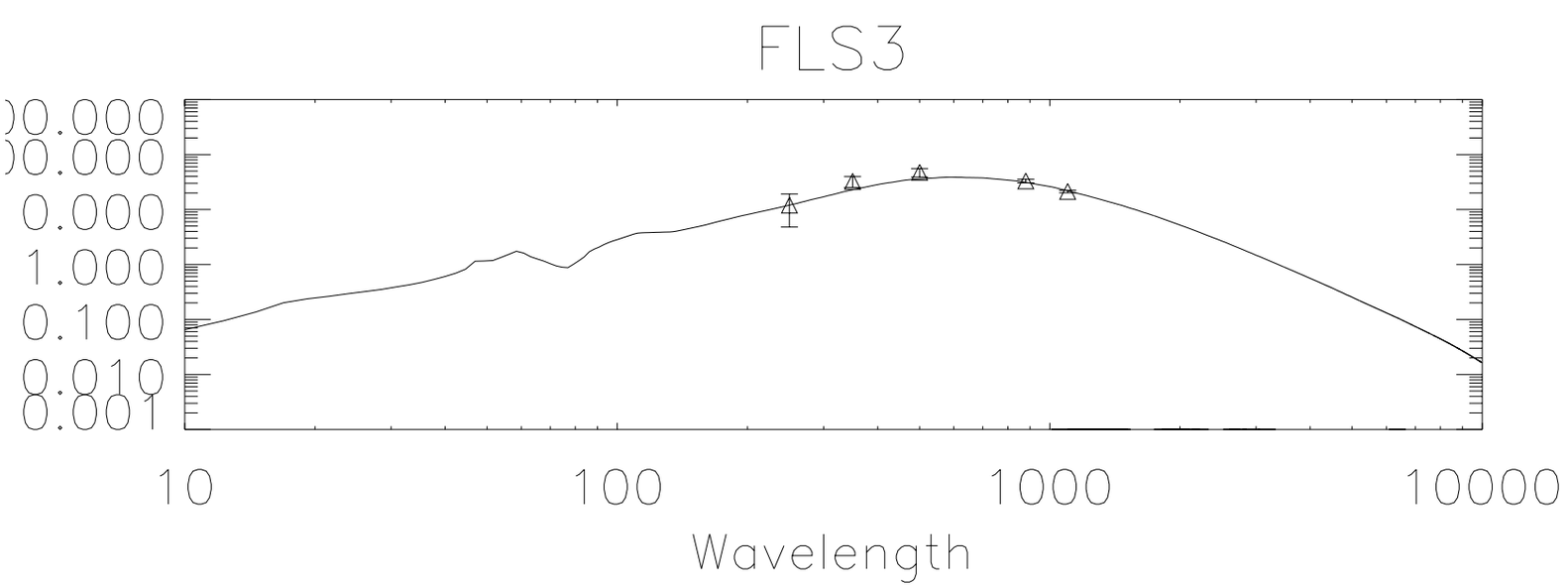
Redshift Likelihood



Fitted SED



Redshift Likelihood



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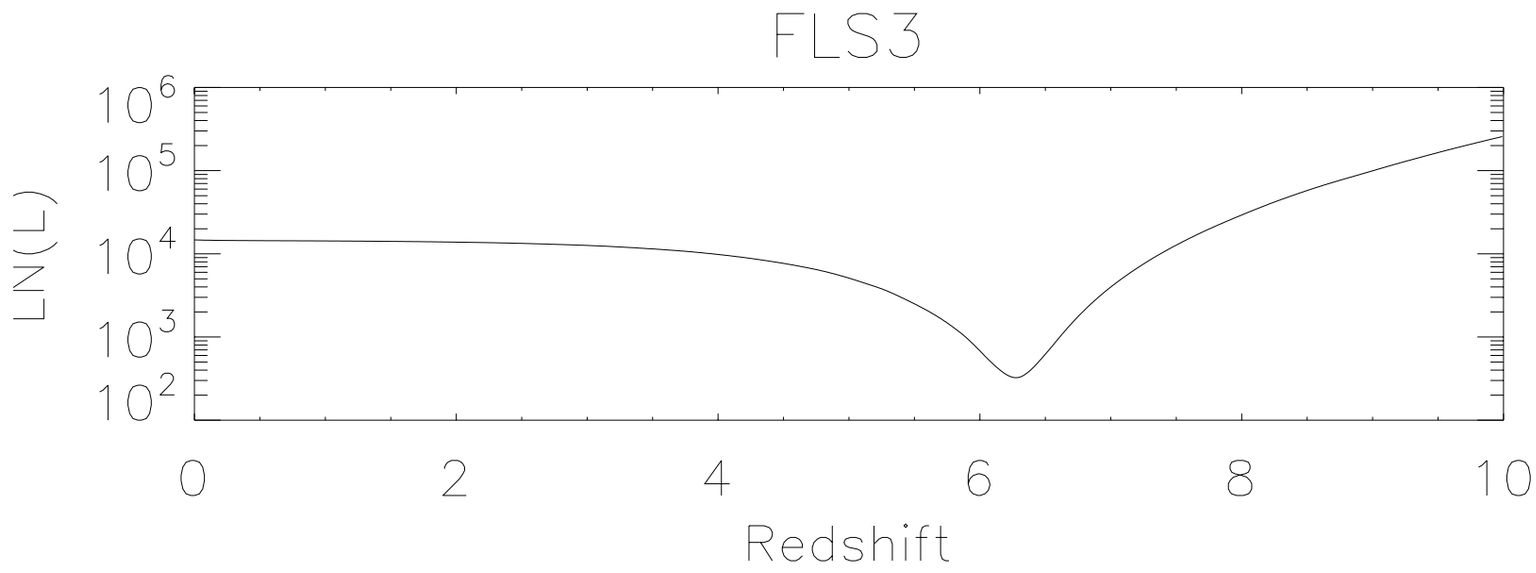

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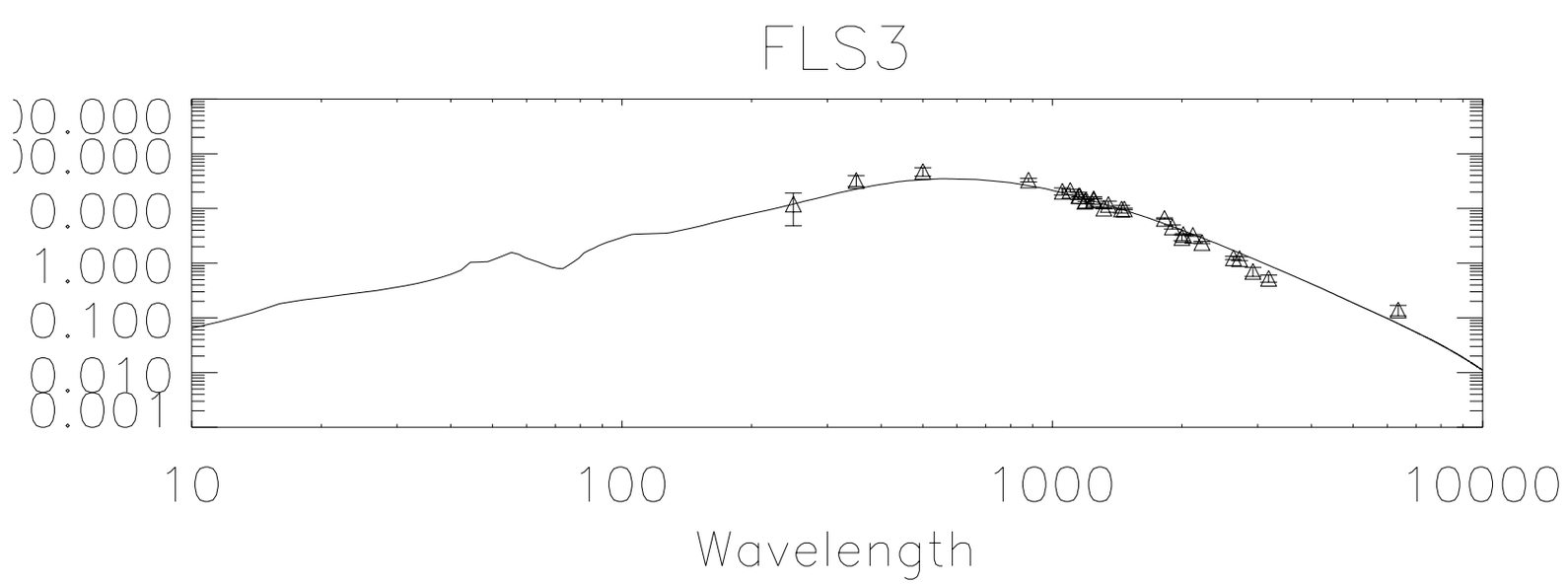
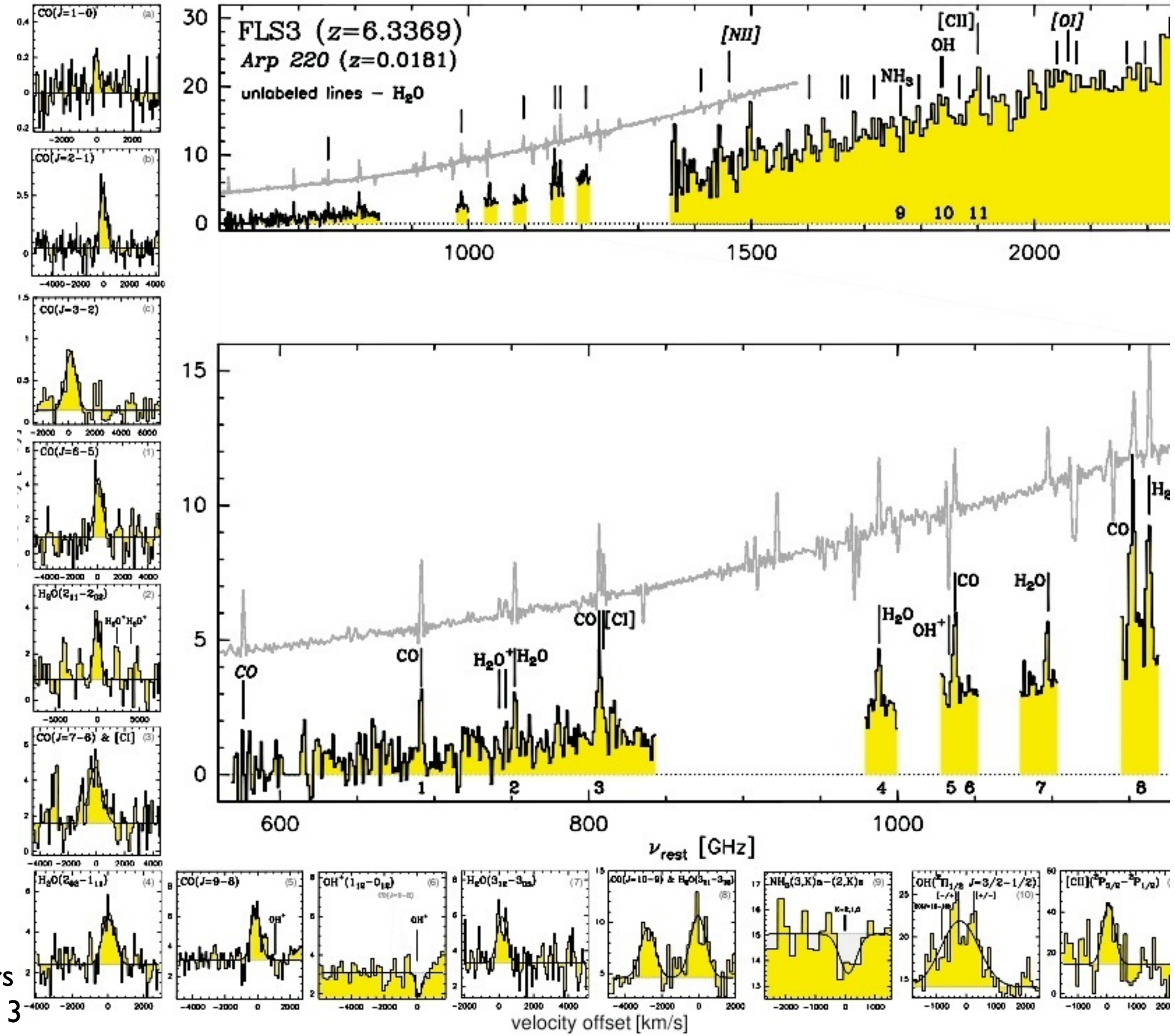


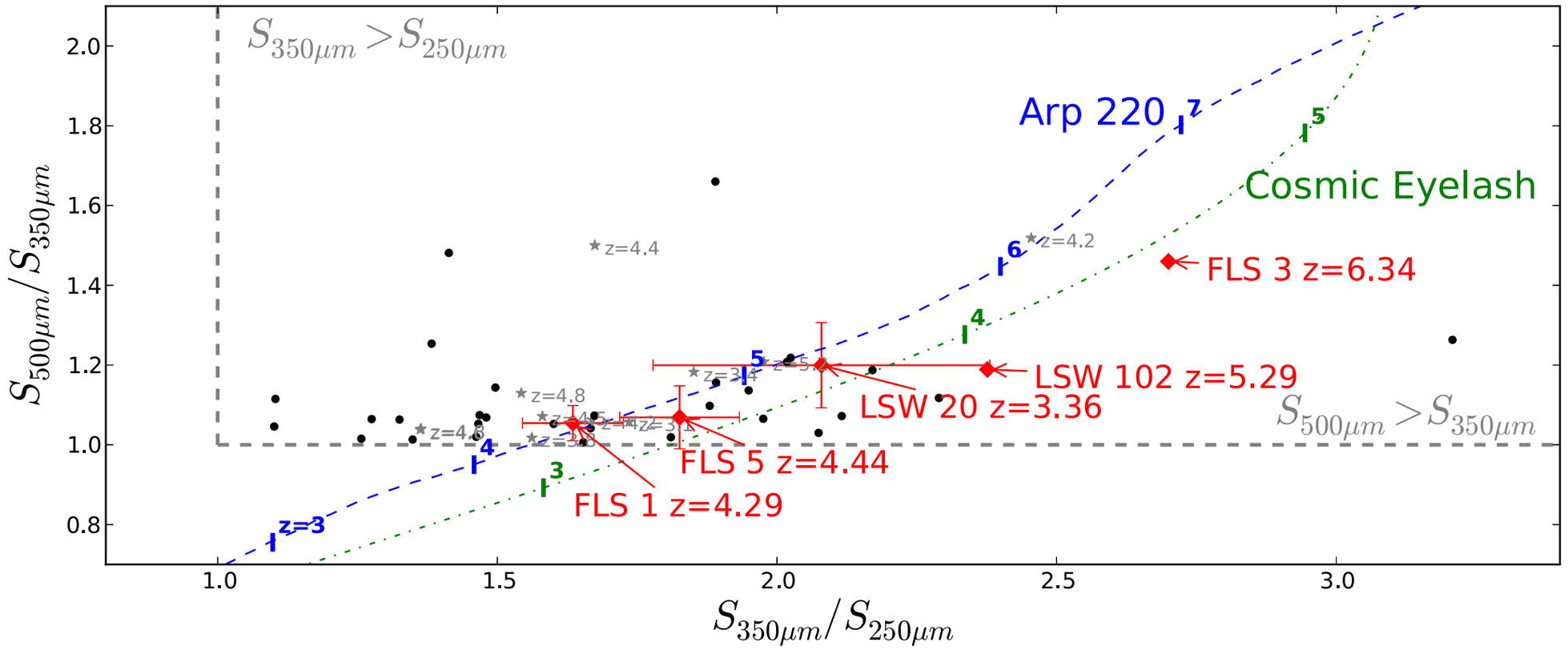
Fitted SED



Riechers et al 2013

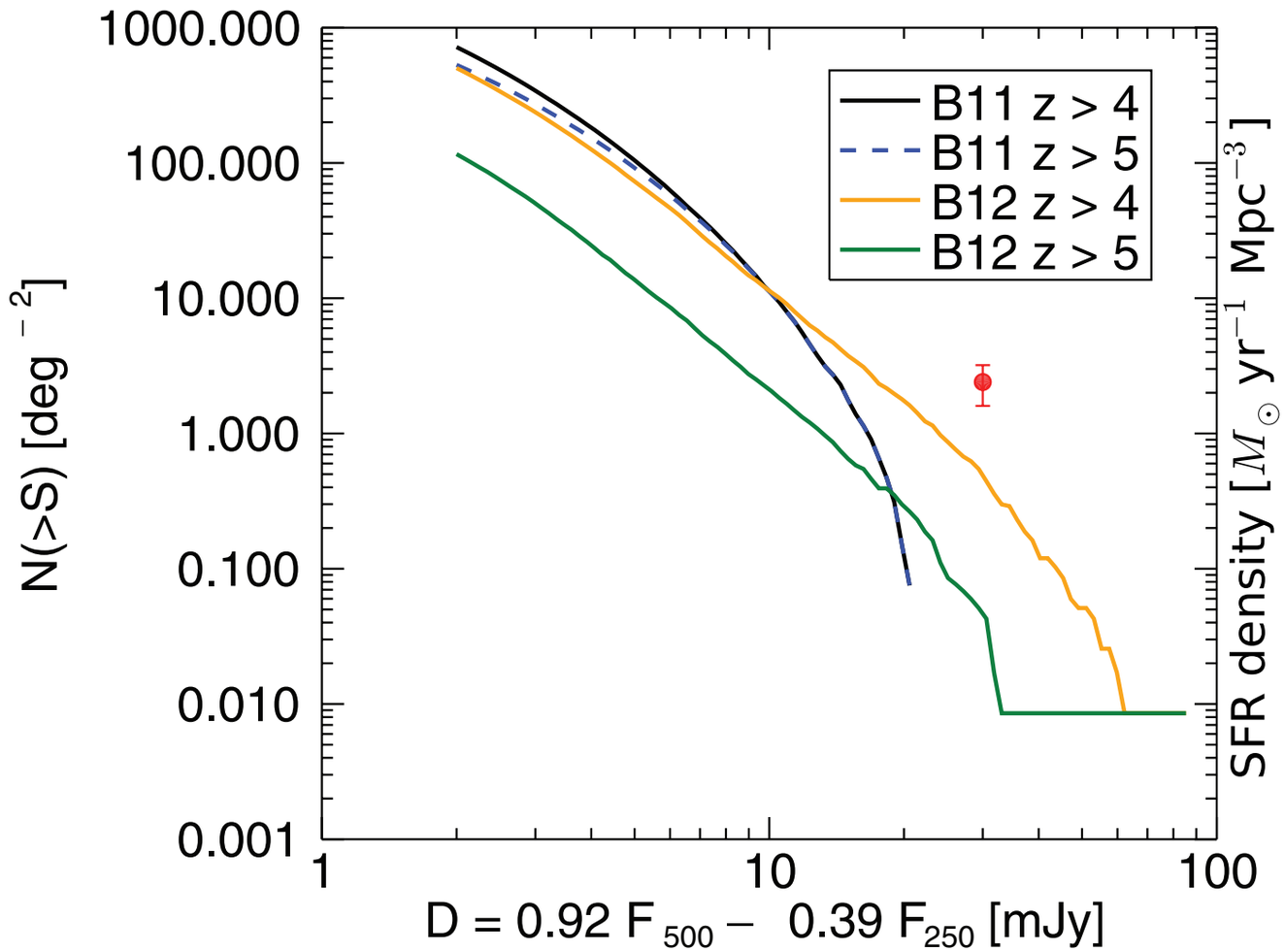
z>4 Sources: Status

- Dowell et al, 2014 reports first followup
- 38 candidates over 21 sq. deg.
- SMA, PdB, ZSpec & Bolocam followup for some
- 5 spectroscopic redshifts: 3.39 to 6.3

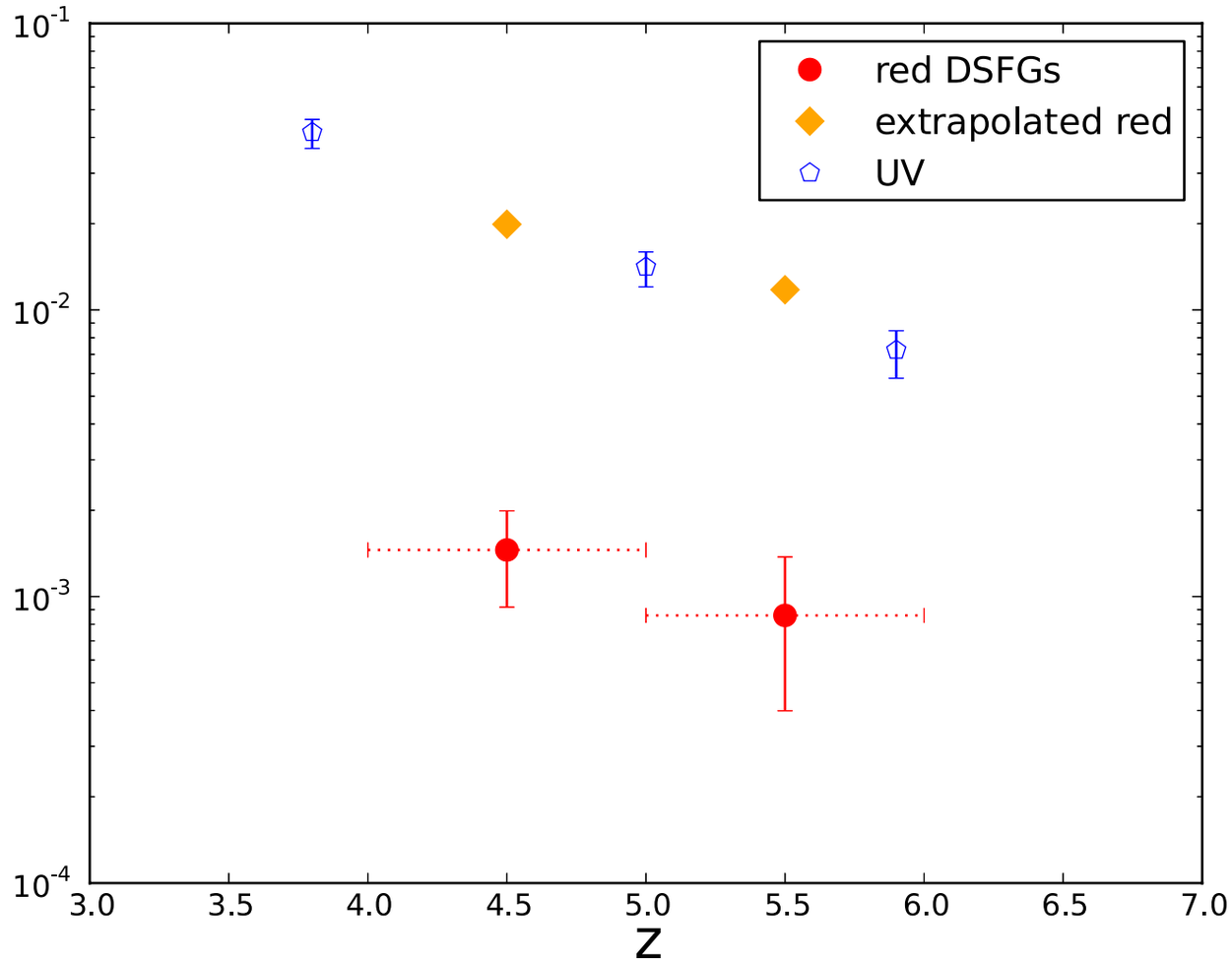


Dowell et al. 2014

DSFGs at z>4: Unexpectedly Common



We find more than current models predict



Comparison of SFRD of z>4 DSFGs & UVGs

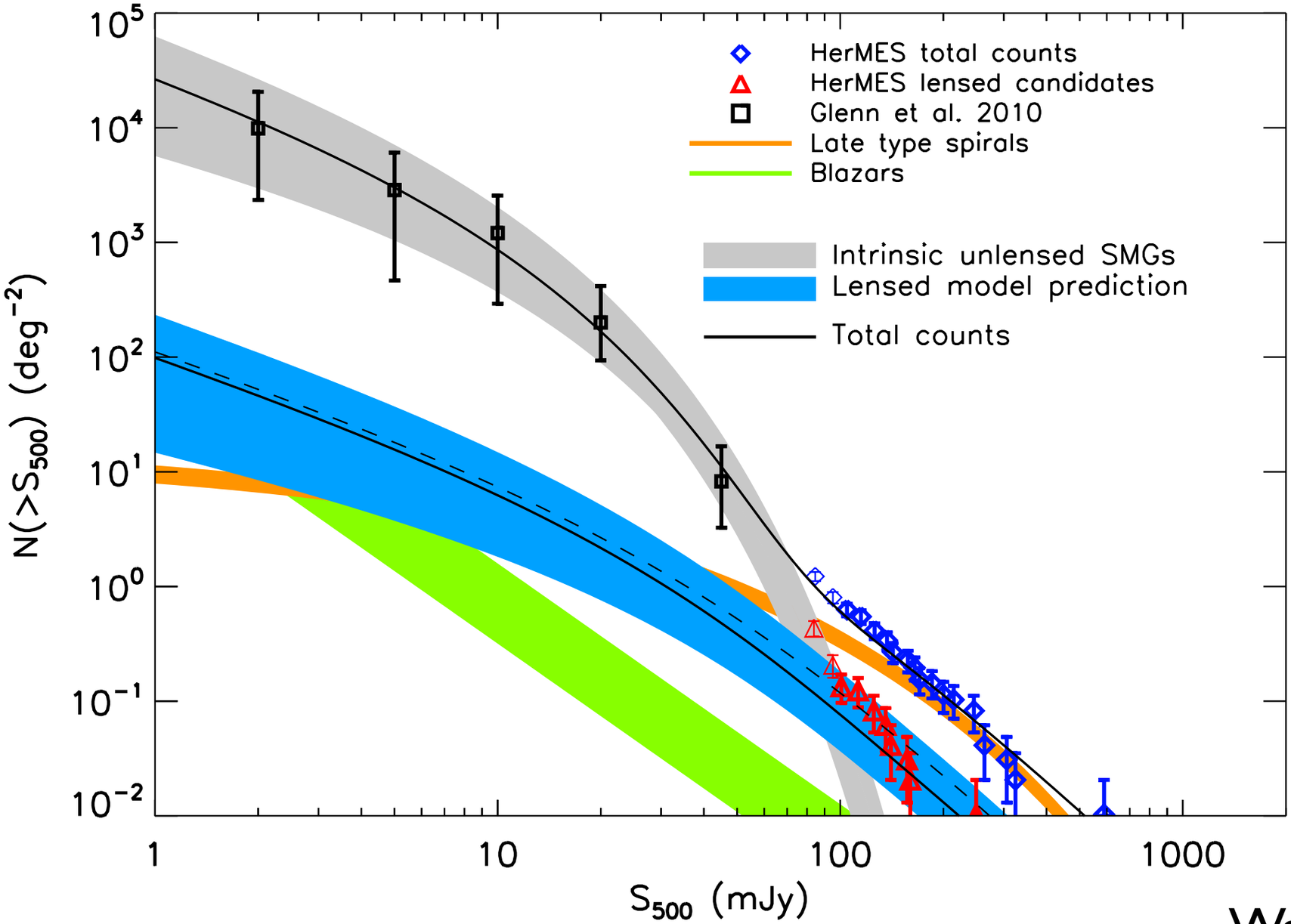
Dowell et al. 2014

More Followup Underway

- 31 z>4 candidates now observed by SMA - most confirmed
- More coming, and others observed by PdB etc.

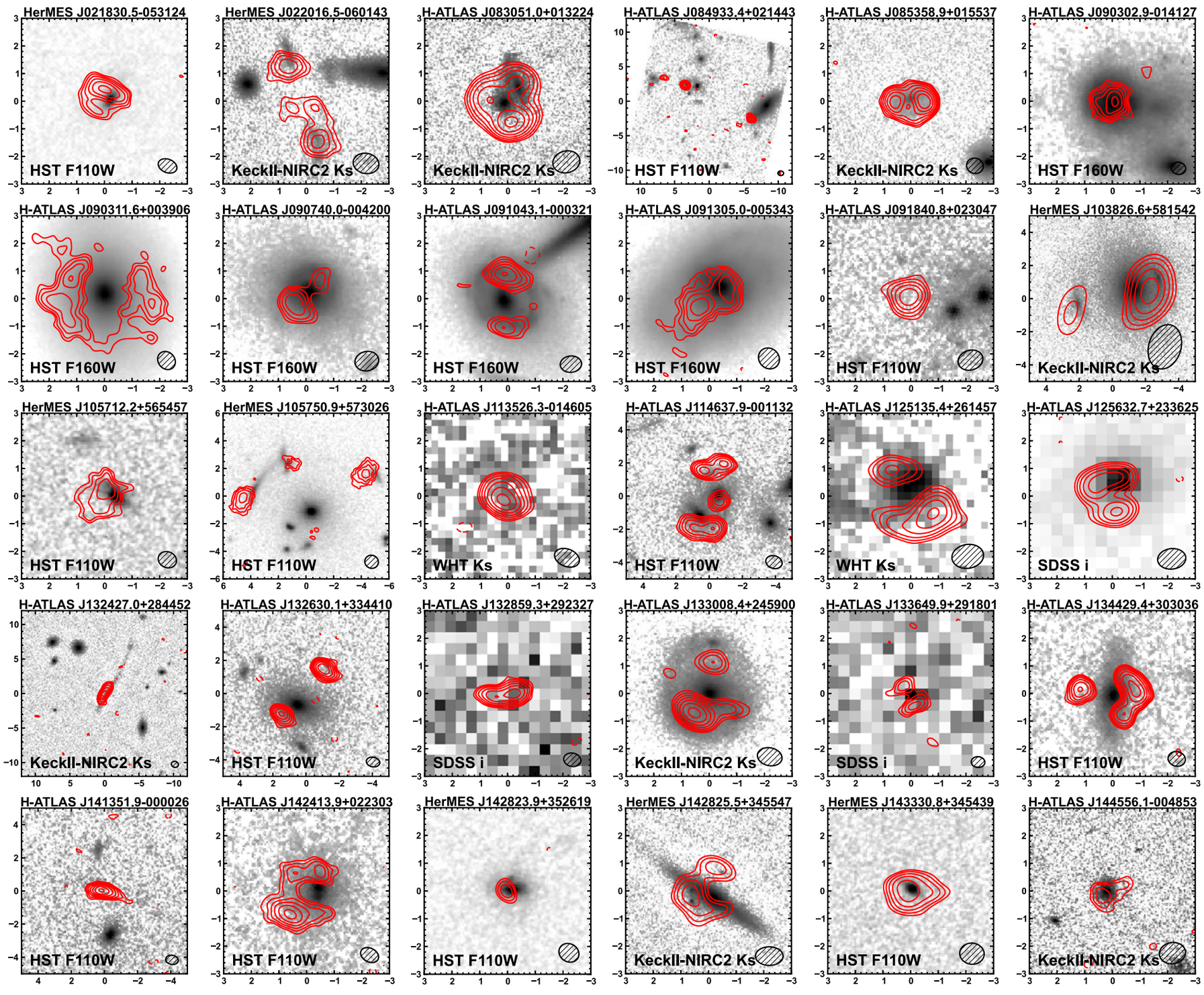
Role of Lensing

- Bright Herschel sources often lensed (eg. Negrello et al., 2010; Wardlow et al., 2013; Bussmann et al. 2013)



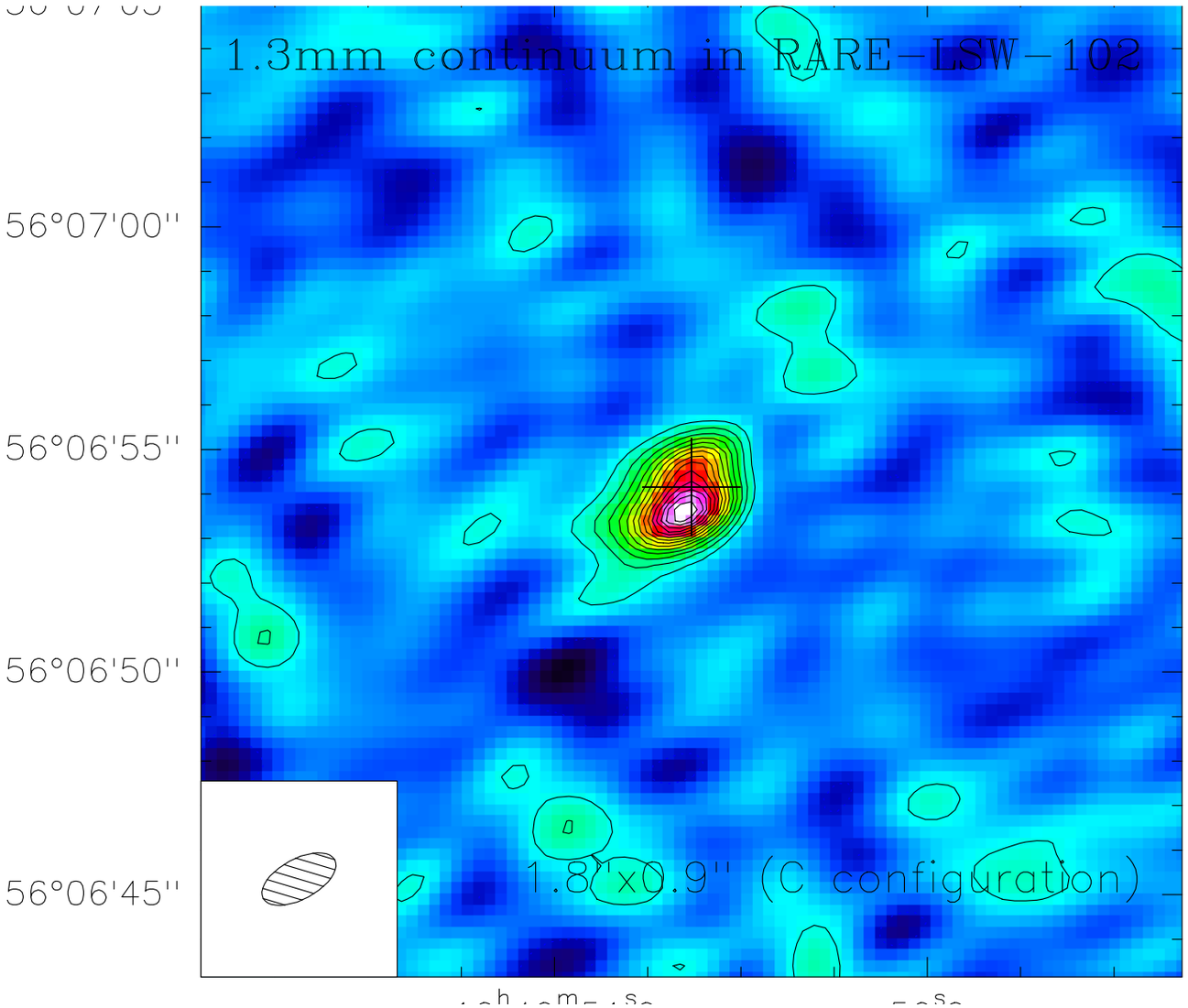
Wardlow et al. 2013

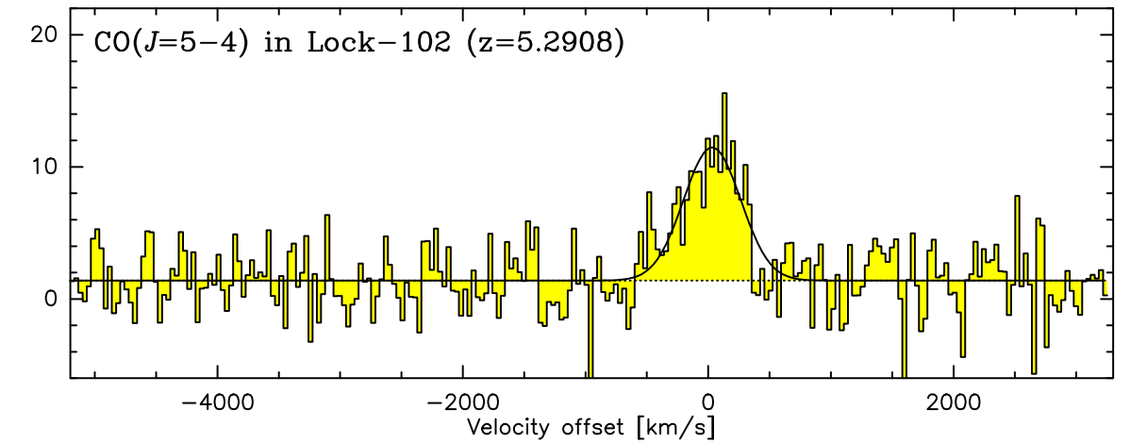
SMA and Lensing Models

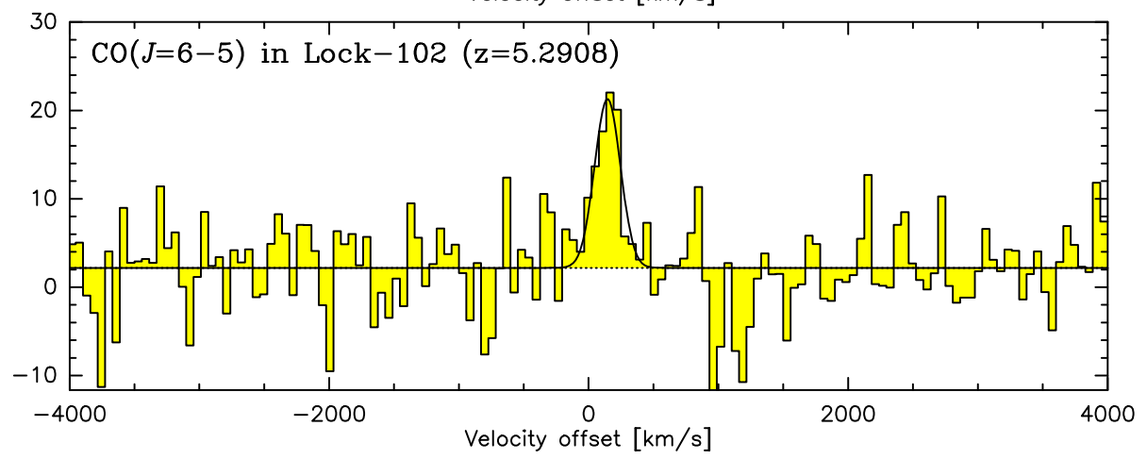


Bussmann et al. 2013

Some Surprises

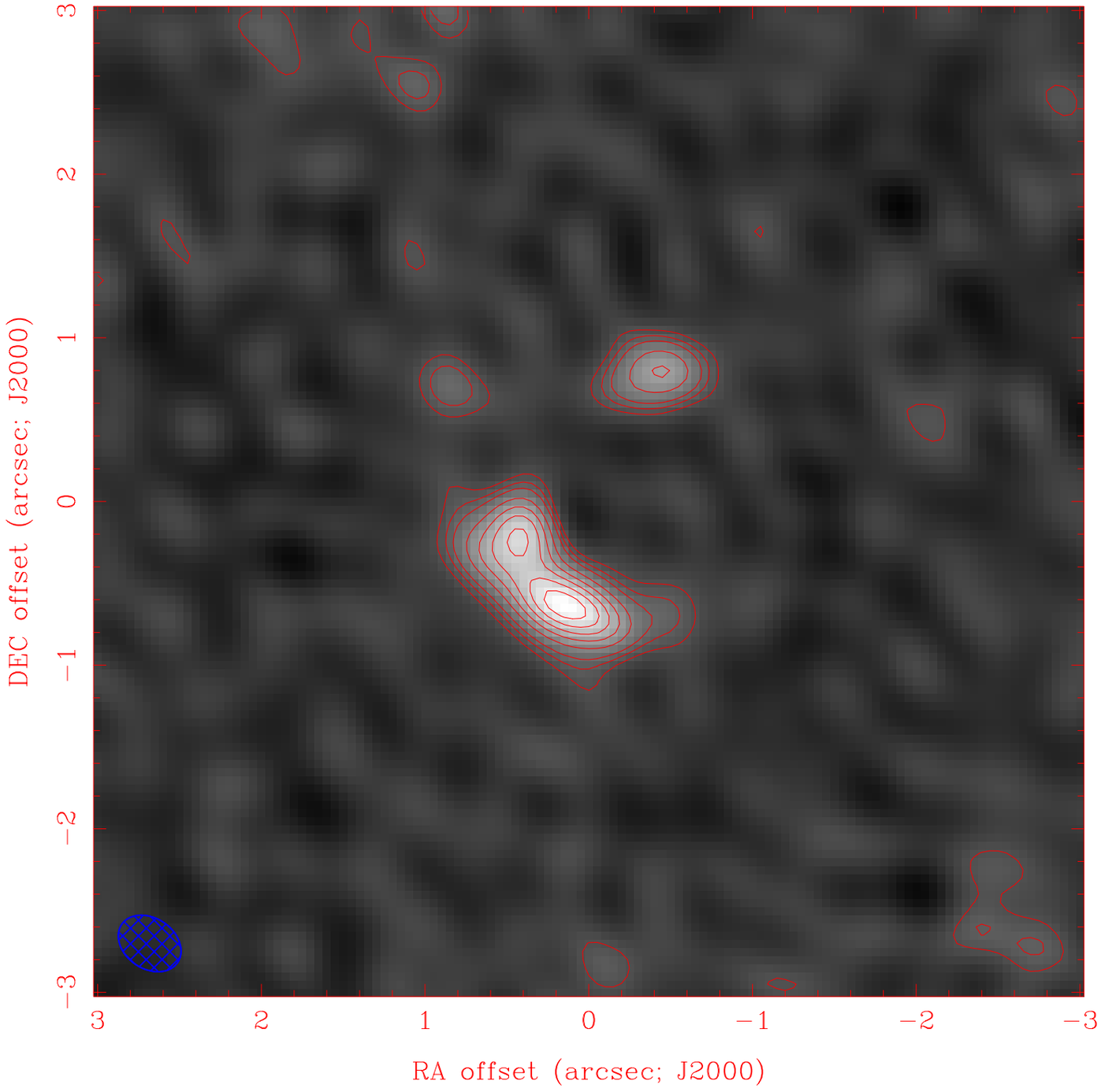






Lockman-102: very bright - 140mJy at 500 microns - but very high redshift: z=5.29

Lock-102: Lensed



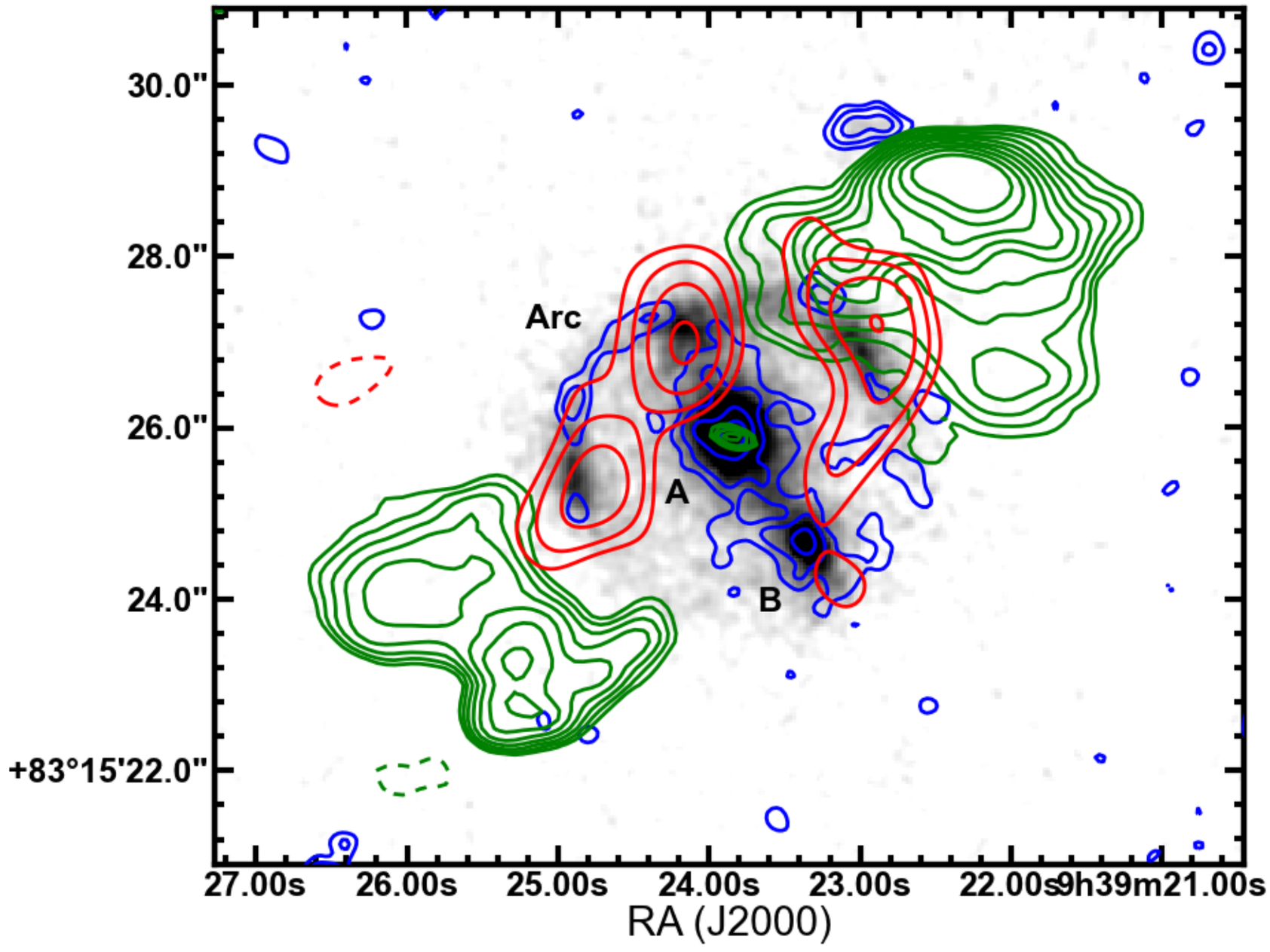
Perez-Fournon, Bussmann, et al. in prep

Lens not yet fully identified - highest z lens to date?

SMA data looking at kinematics of CII line at z=5.29

3C220.3

- z=0.685 3C radio source
- Unexpectedly red & bright in Herschel
- An AGN lensing a background DSFG at z=2.21



Green=radio; blue= HST; red = SMA; grey= Keck K' band AO

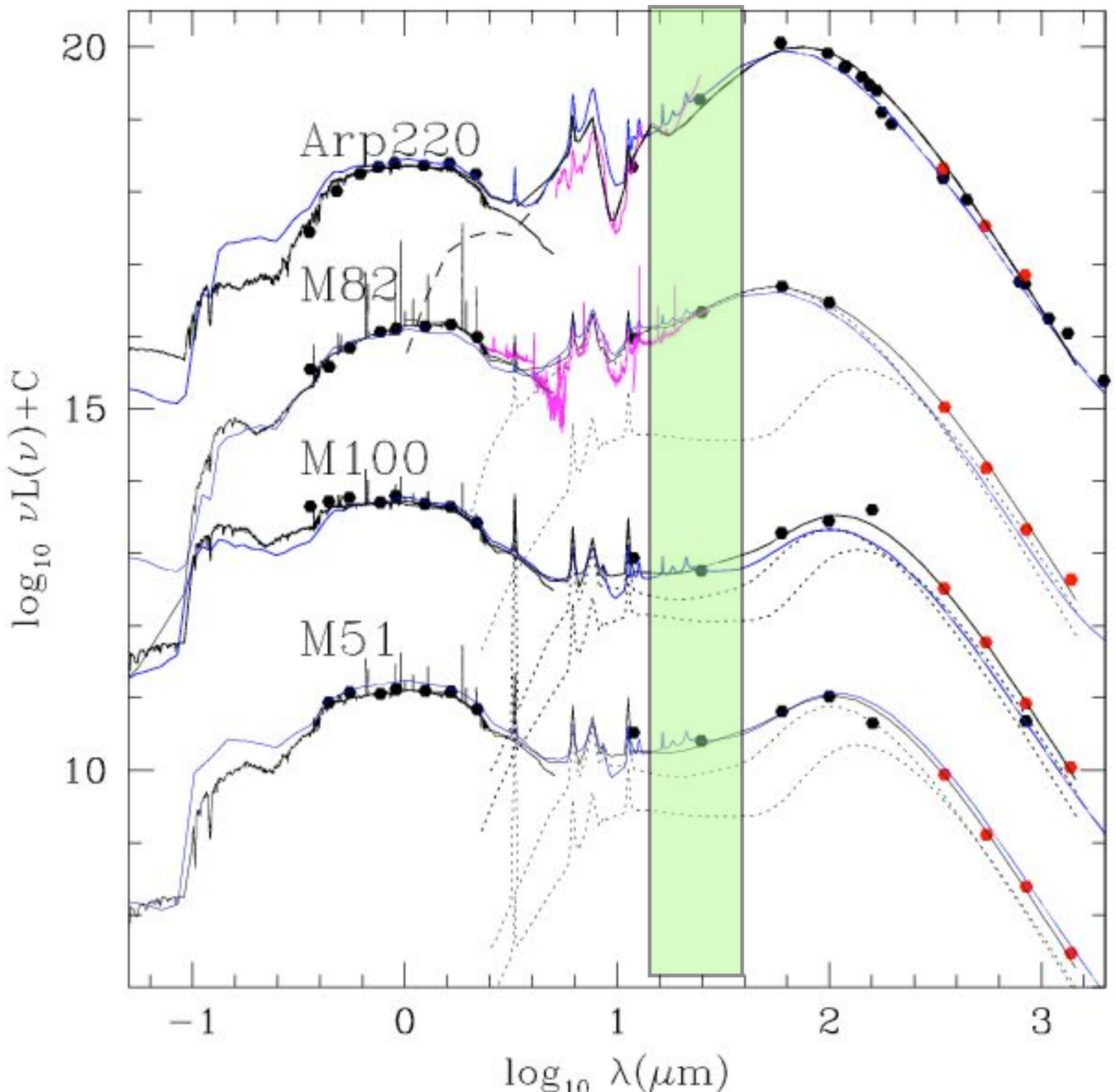
Haas et al., ApJ, in press

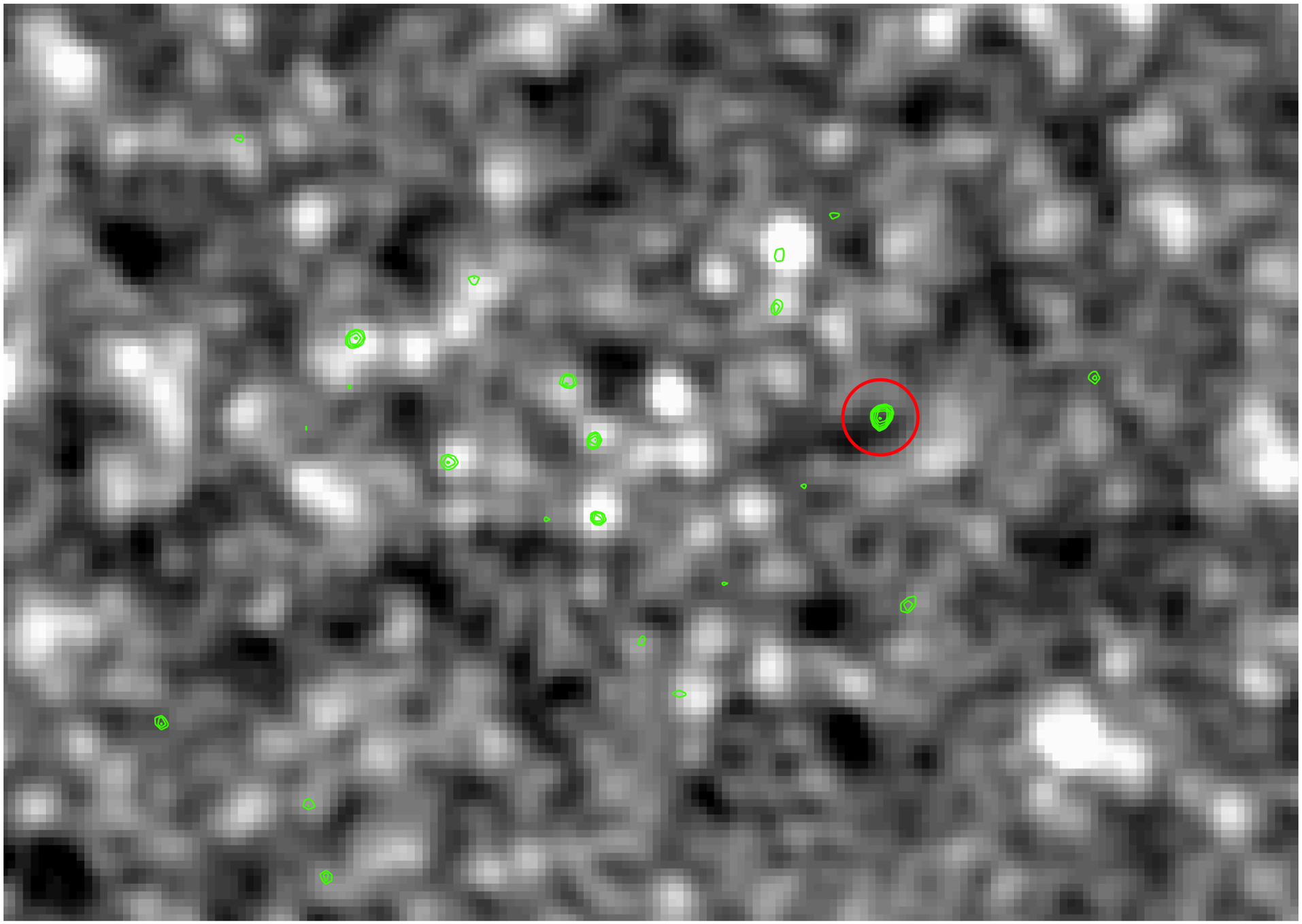
What next?

- Systematic followup of high z sources to determine LF & evolution of z>4 DSFGs
- Detailed study of lensed sources - large lensing sample powerful cosmological tool
- Pushing to higher z and lower L
- More spectroscopic redshifts

SPIRE Dropouts

- At z>6 sources may be too faint to be seen in SPIRE
- Still bright in submm: SPIRE dropouts
- Same effect for lower L z~5 sources





SPIRE 250 micron image with SCUBA2 850 micron contours in green. Indicated source has is 6.6σ12.2 mJy source at 850, but not detected in any SPIRE band

Roll on SWARM!

- More bandwidth=> more continuum sensitivity, so can reach fainter sources
- More bandwidth=> possibility to do blind redshift searches without frequency scanning
- Herschel + SMA + SWARM: keys to the high redshift dusty universe!