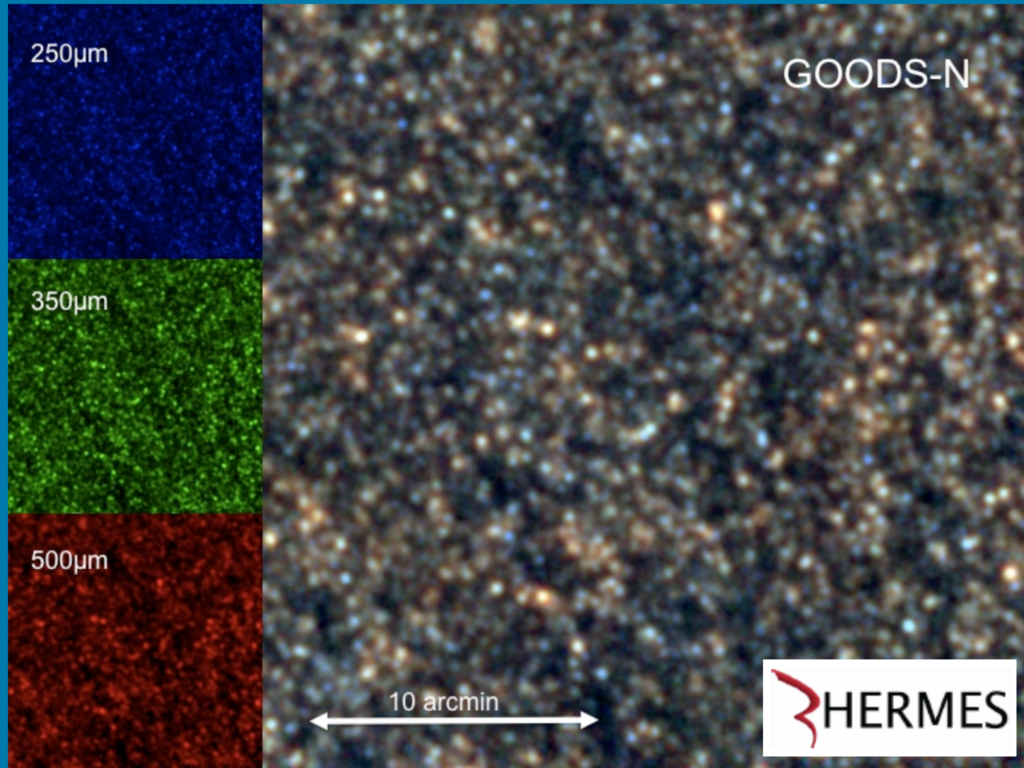
Early Distant Universe Results from the *Herschel Space Observatory*

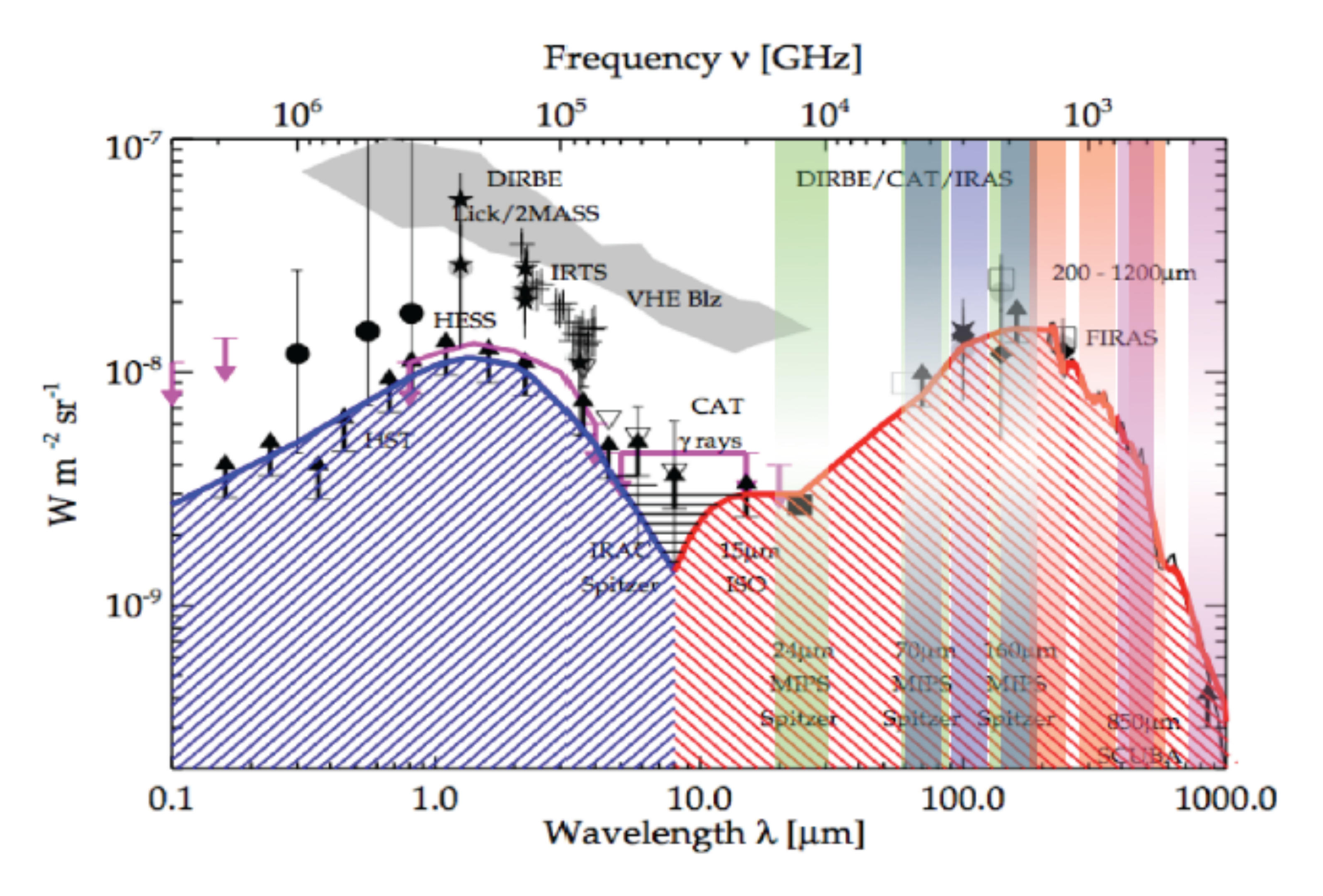
Results from Science Demonstration Phase Observations



Launched May 14, 2009

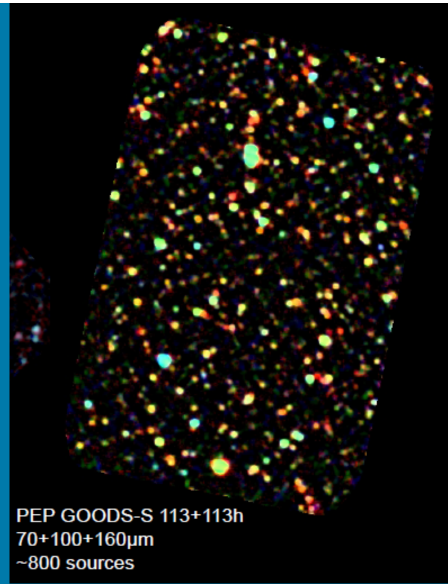
Jason Glenn – University of Colorado, Boulder

The Cosmic Far-Infrared Background (CFIRB)



Oliver http://herschel.esac.esa.int/FirstResultsSymposium/presentations/P74_OliverSJ_HerMES.pdf

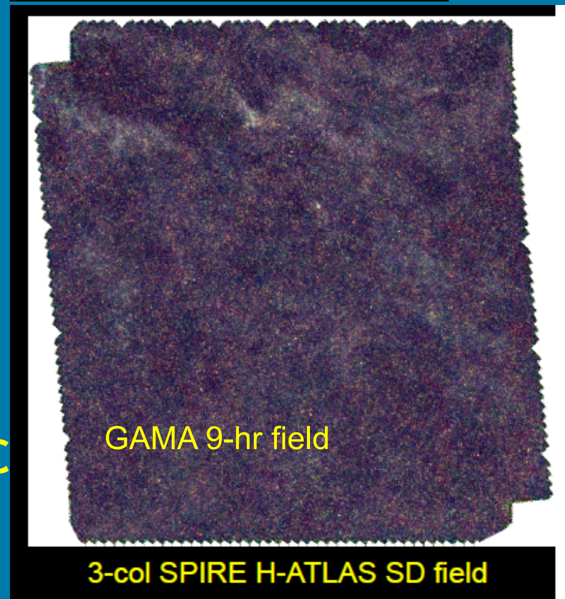
Herschel High-z Key Projects



PEP: PACS Evolutionary Probe

- 70, 100, & 160 μm
- Fields from 10′×15′ to 85′×85′ (574 hours) + 10 clusters
- Resolve CFIRB; L_{FIR} & SFRs

H-ATLAS: *Herschel*-Astrophysical Terahertz Large Area Survey



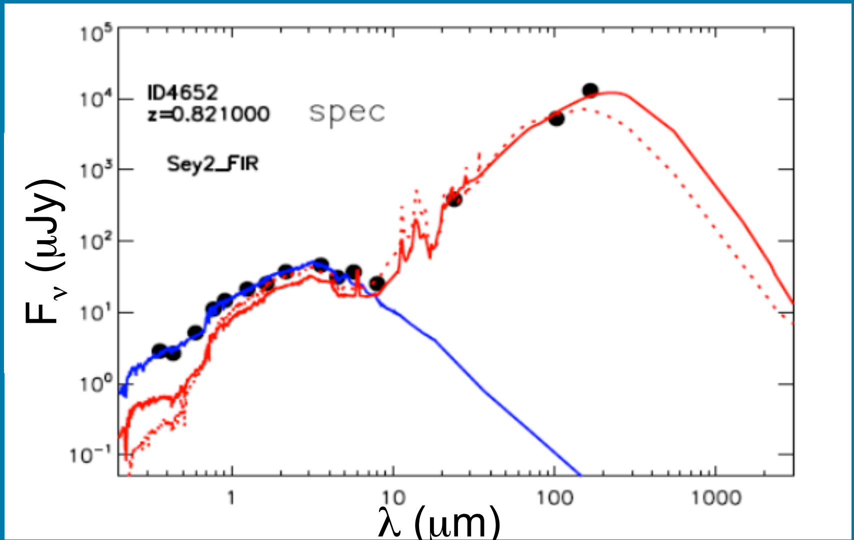
- PACS + SPIRE 250, 350, & 500 μm
- 550 sq deg
- Large-scale structure, AGN, rare objects
- Expect 10^5 galaxies to z~3

HerMES: *Herschel* Multi-tiered Extragalactic Survey

- Bolometric luminosities of galaxies, cosmic SFH
- Wedding cake to probe range of luminosities and environments
- 27,000 galaxies with SDP observations!

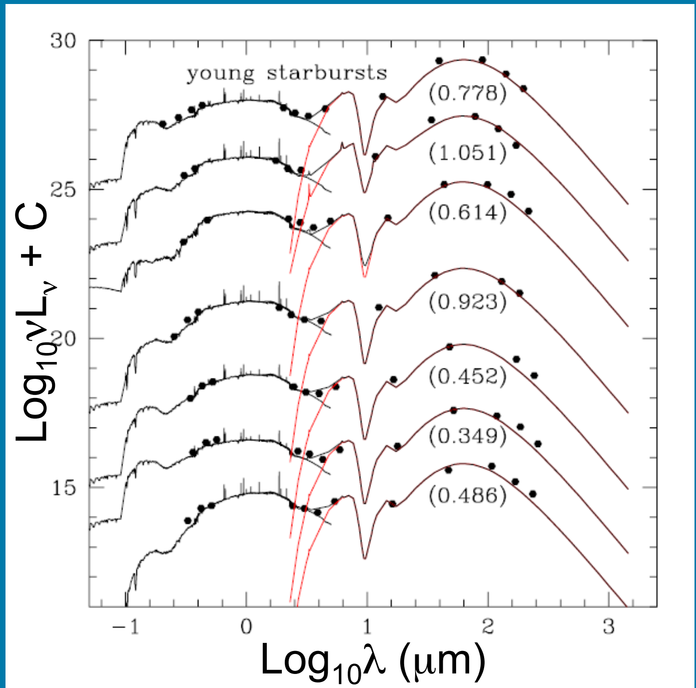
FIR and Submm Galaxy SEDs

PEP



Rodighiero, Gruppioni et al. (2010)
http://herschel.esac.esa.int/FirstResultsSymposium.shtml

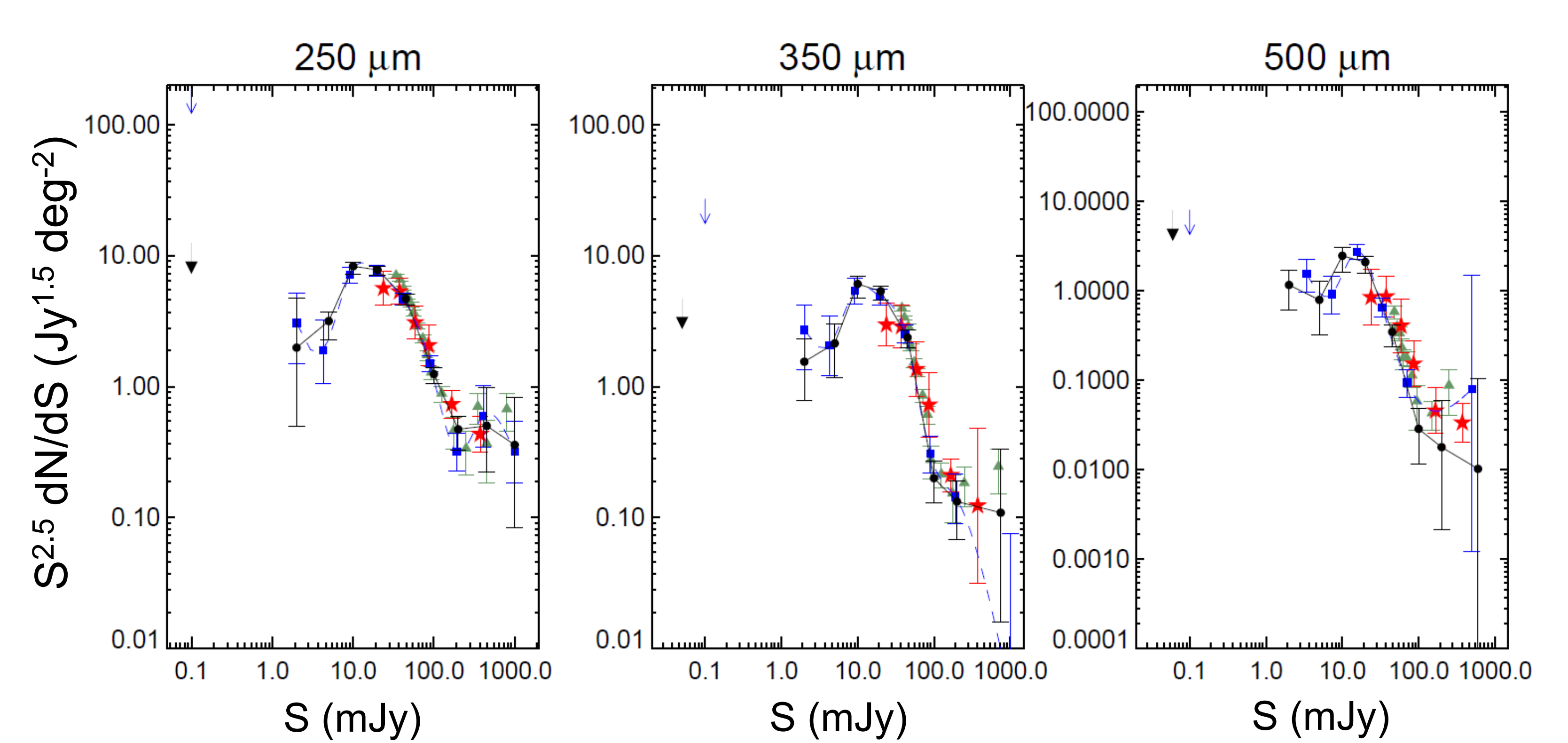
HerMES



Rowan-Robinson et al. (2010)

- *Herschel* provides a direct measure of bolometric luminosity and SFR
- Submm bands have a strong negative K-correction ⇒ sensitivity to high z
- L_{FIR} and SFR predicted from $\lambda \leq 24$ μm observations are inadequate
- SEDs require some lower temperatures than expected (10 – 20 K)
- SF density for z < 0.5 may have been dominated by spirals

Galaxy Number Counts



Black & Blue: HerMES P(D) (Glenn et al. 2010)

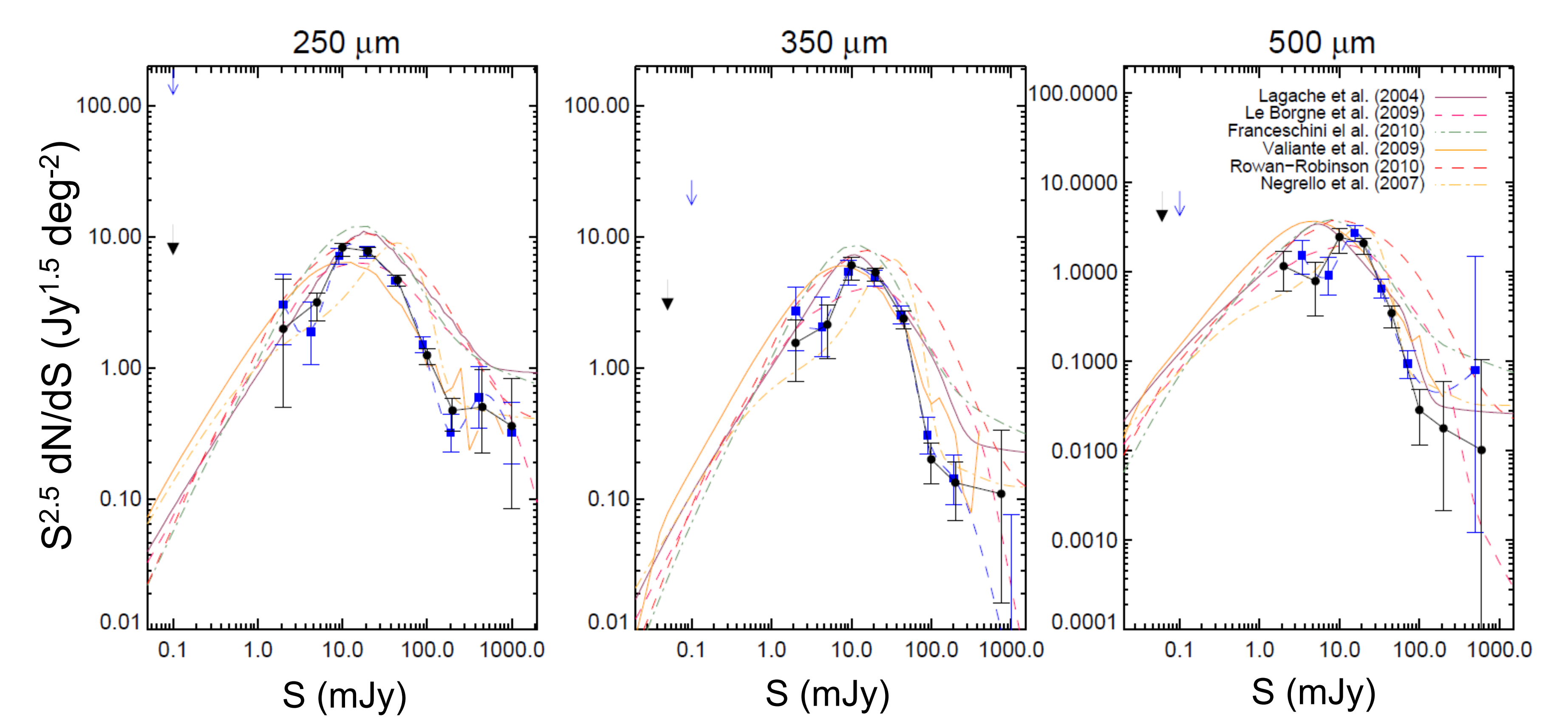
Red: HerMES counts (Oliver et al. 2010)

Green: H-ATLAS counts (Clements et al. 2010)

- Herschel SPIRE surveys are mutually consistent
- Consistent with previous work but 10x deeper
- Break is evident at 10 – 20 mJy in all bands

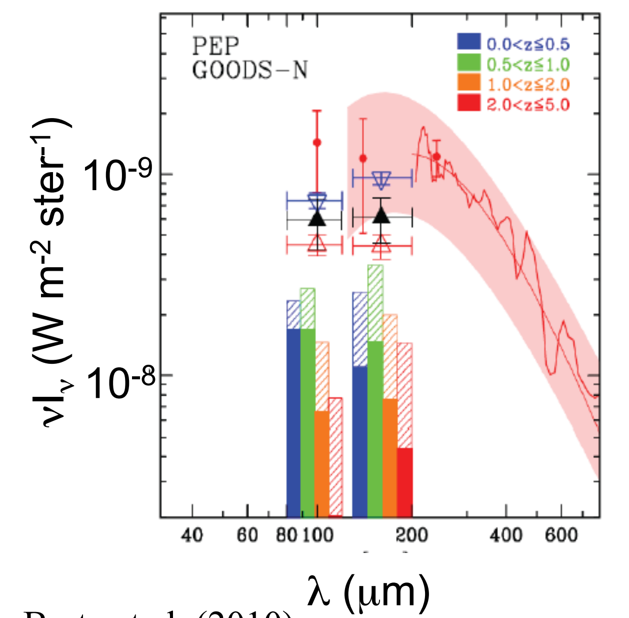
Galaxy Number Counts

Model revisions are already needed!



- Number counts of bright galaxies (ULIRGS+) over-predicted by models
- Bright-end counts are steeper than models generically

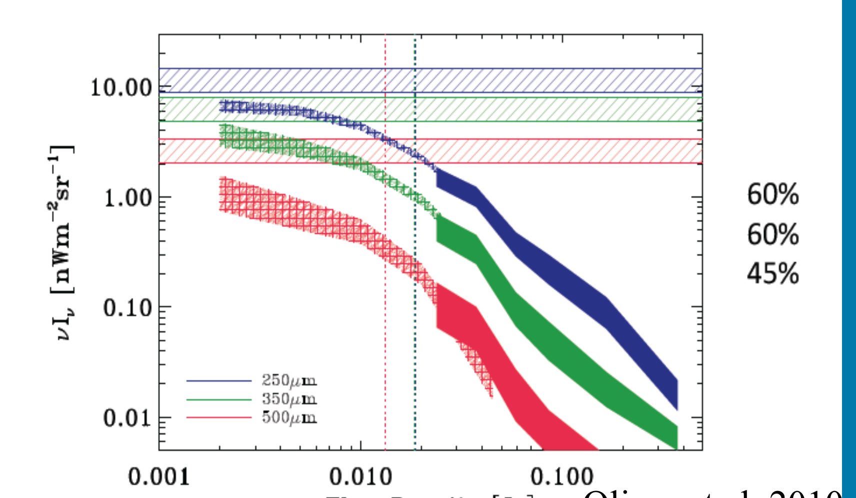
Resolving the Cosmic Far-Infrared Background



Berta et al. (2010)

PEP
- 100 & 160 μm:
  45% & 52%
- Stacking of 24 μm sources
  50% & 75%

H-ATLAS & PEP:
Much of the λ ≤ 250 μm CFIRB likely arose from z < 1 spiral galaxies

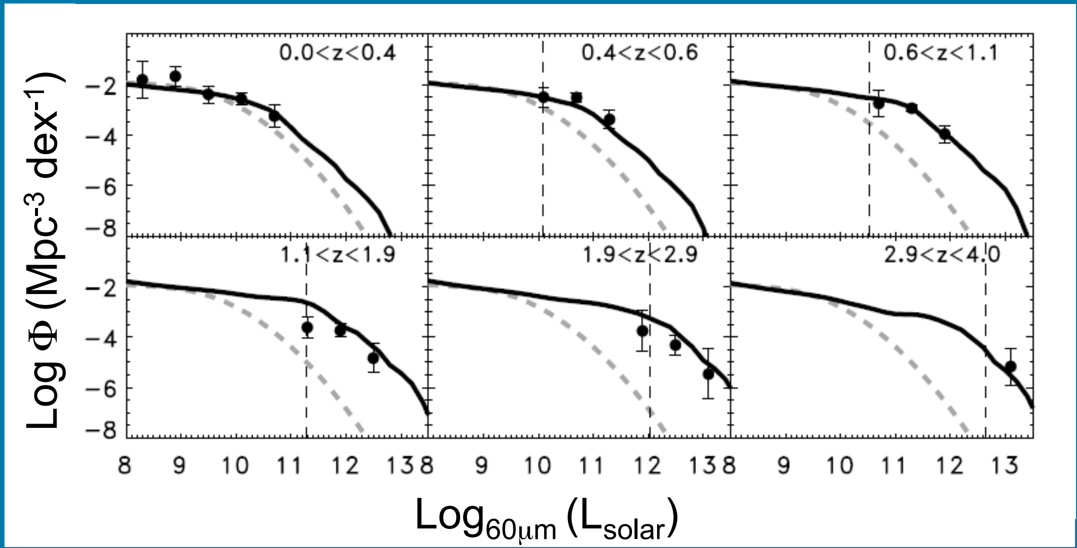


Oliver et al. 2010
Glenn et al. 2010

HerMES – confusion limited
- Counts
  250, 350, & 500 μm:
  15%, 10%, 6%
- P(D)
  250, 350, & 500 μm:
  65%, 60%, & 45%

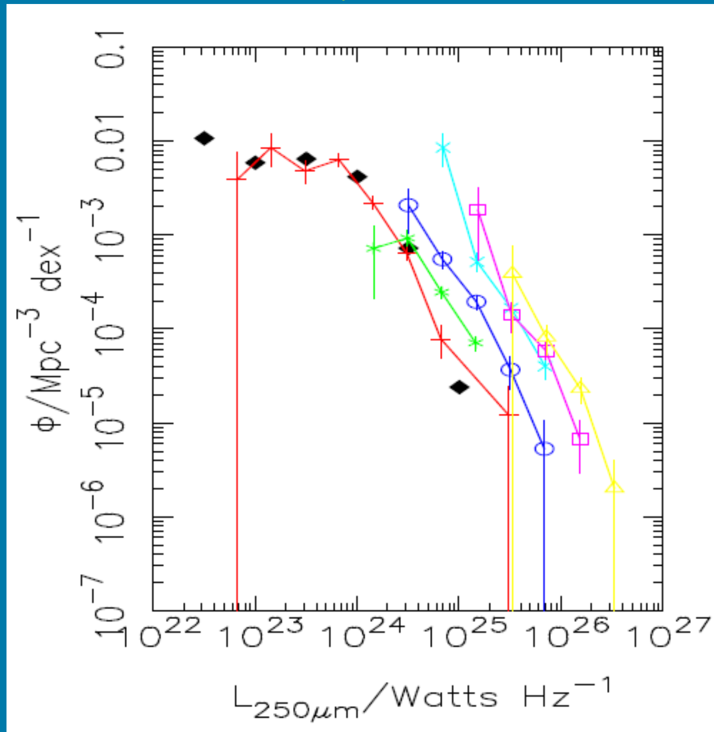
Strong Evolution of the FIR/Submm Luminosity Function Evident

PEP rest-frame 60 μm LF



Gruppioni et al. (2010)

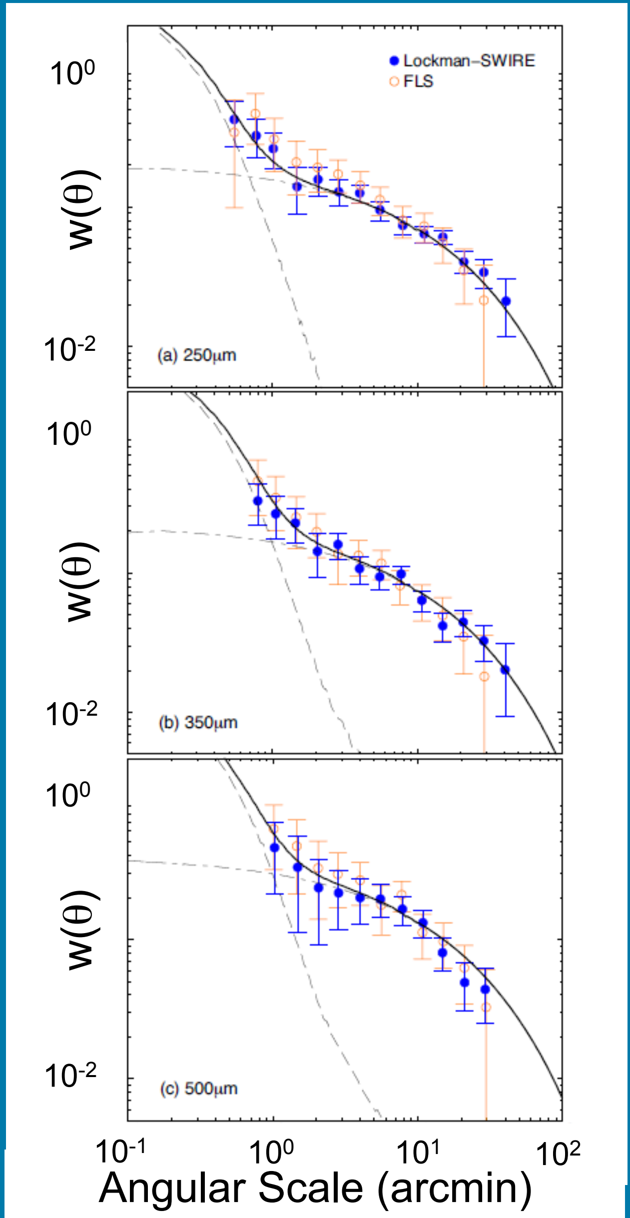
HerMES rest-frame 250 μm LF



Eales et al. (2010)

- Strong evolution evident to z ~ 1
- Continued but weaker to z ~ 2
- Next:
  - -Better statistics from bigger samples
  - -Reach to higher z with bigger samples
  - -Combined PACS & SPIRE for better-constrained bolometric SEDs

Clustering – Probing Dark Matter Halos



Angular correlation function

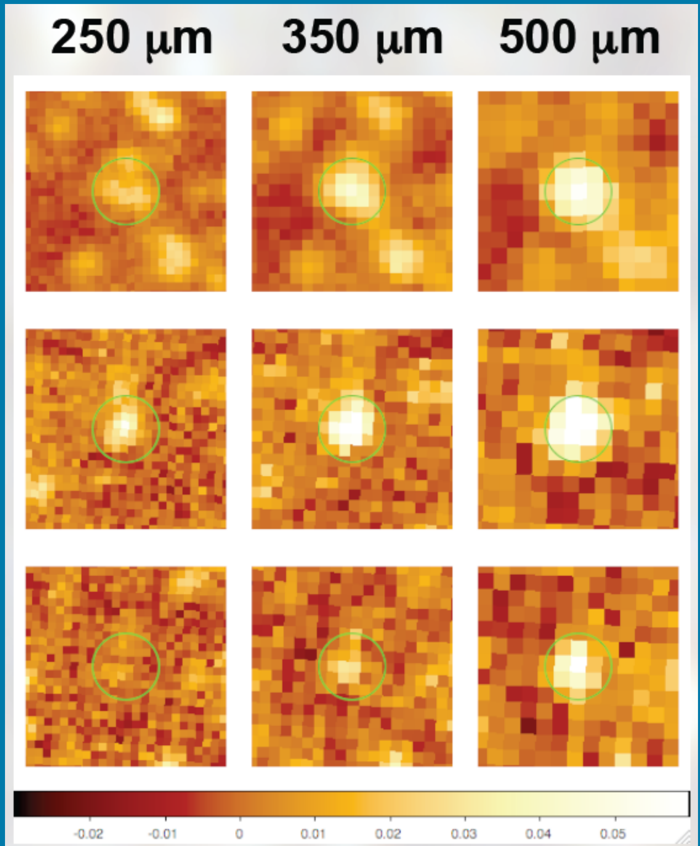
- Largest field – Lockman-SWIRE: 14 sq deg
- Spatial clustering of (mean z~2) galaxies compared to halo model to estimate occupation number
- Redshifts estimated via submm photometry
- Results suggest:
  - Galaxies with S(250μm) > 30 mJy reside in dark matter halos with M > (5±4)x10^{12} M_{solar}
  - ~15% appear as satellites in more massive halos

Cooray et al. (2010)
•Dot-dash: 2-halo model term traced by linear clustering
•Long-dashed: 1-halo term coming from multiple sources in the same halo

Very High Redshift Candidates

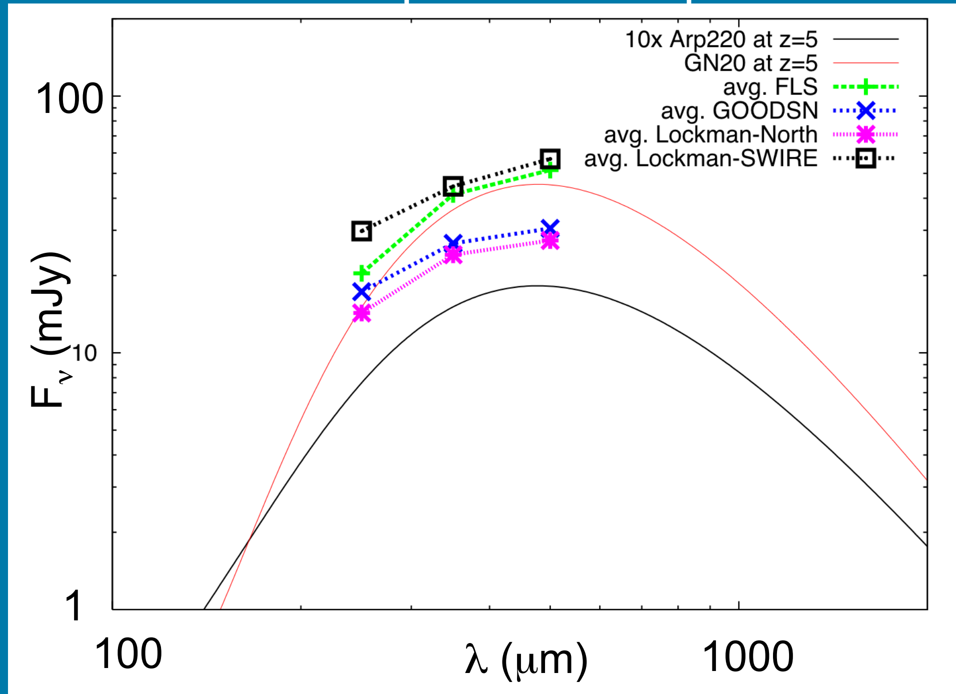
Rising-spectrum sources

Three examples:



Dowell et al. (2010)

Average spectra of sources detected in 4 HerMES fields compared to templates:



These could be:

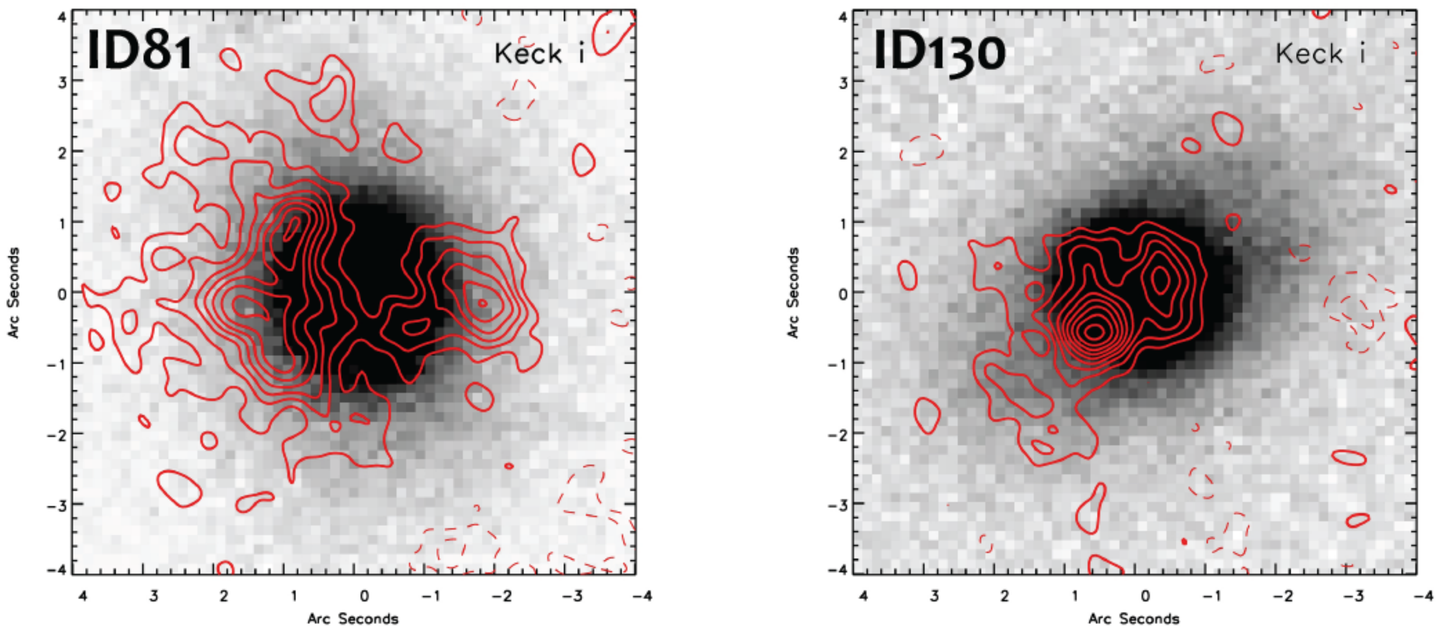
z = 1.5, T_{dust} = 20 K ULIRGs or

z = 5, T_{dust} = 35 K HLIRGs…

Lensing!

H-ATLAS:

- Bright 500 μm galaxies (> 100 mJy)
- Optical counterparts: $z_{phot/spec} < 1$
- CO z's: 3.04 & 2.63!



Red contours: SMA

CREDITS: Mark Gurwell (CfA)

Negrello et al. (2010)

Summary: What are some of the things we have learned so far?

1. Galaxy number counts have been measured much deeper than previous surveys; models need to be revised.
2. A substantial fraction (1/2 to 2/3) of the CFIRB has been resolved.
3. Bolometric luminosities and SFRs require FIR/submm data.
4. The FIR/Submm LF evolves steeply to z ~ 1 and flattens somewhat beyond that.
5. The angular correlation function implies most submm galaxies reside in $M > 10^{12}\ M_{solar}$ halos.

Stay tuned: These results are based on a few % of the 1st round key project data!