HerMES : The Herschel Multi-Tiered Extragalactic Survey
Overview, First Results, Future Plans & Follow-Up with ELTs

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for the HerMES Consortium

(Coordinated by Jamie Bock & Seb Oliver)

Feeding the Giants : ELTs in the Era of Surveys

Ischia, 1 September 2011

The HerMES Consortium

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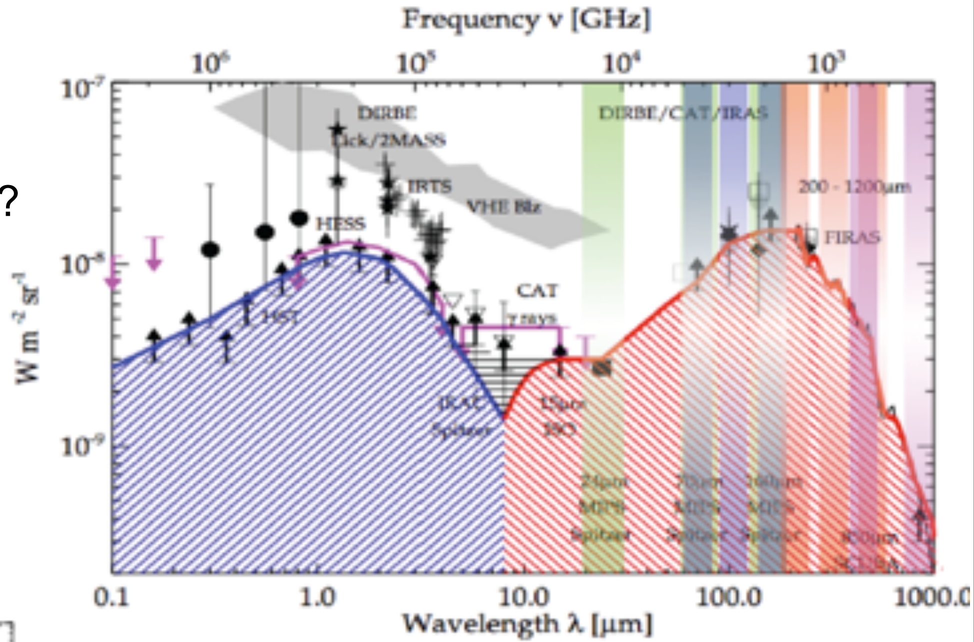
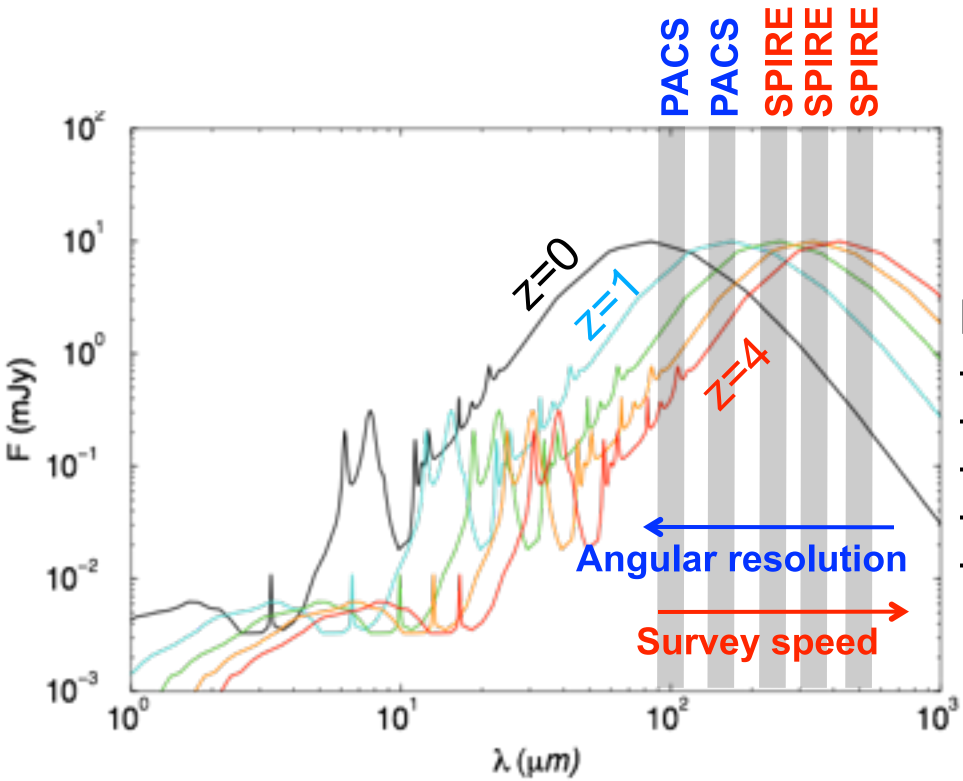
Faculty and Researchers, Postdocs, Students

HerMES Science Motivation

What is the history of Far-IR galaxies?

- How do they assemble and evolve over time?
- Where have luminous FIR systems gone today?
- How do FIR galaxies relate to dark matter?
- What is the role of dust in star formation?
- What is the connection between dusty star formation and AGNs?





Herschel Extragalactic Imaging Surveys

- High-sensitivity (albeit with moderate resolution)
- Use PACS & SPIRE at 100-500 um
- Observe the SED peak of IR galaxies at 1<z<5
- Derive Bolometric IR (8-1000 um) Luminosities
- Detect Large and Uniform Samples of (U)LIRGs

HerMES = SPIRE GT Program

Spectral and Photometric Imaging Receiver

Photometer

- 250, 350, 500 μm (simultaneous)
- 4 x 8 arcminute field of view
- Diffraction limited beams (18, 25, 36")

Fast scan mapping at long wavelengths

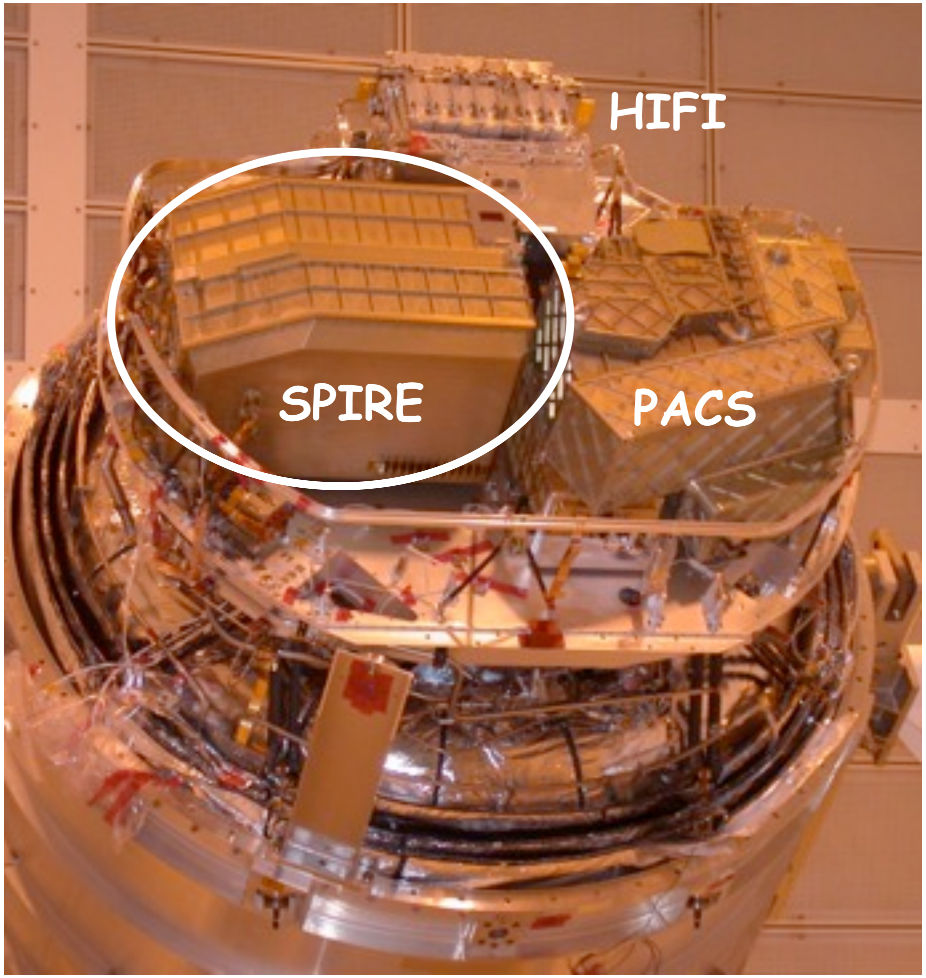
Imaging FTS

- 200 - 670 μm
- 2.6 arcminute field of view
- $\Delta\nu$ = 1.2 GHz high resolution mode
- $\Delta\nu$ = 25 GHz low resolution mode

Wide instantaneous bandwidth, map making

Design Principles

- Sensitivity limited by thermal emission from the telescope
- ^{3}He cooled detector arrays (0.3 K)
- Feedhorn-coupled spider-web bolometers
- Minimal use of mechanisms
  Beam steering mirror; FTS mirror drive
- Optimized for scan mapping surveys



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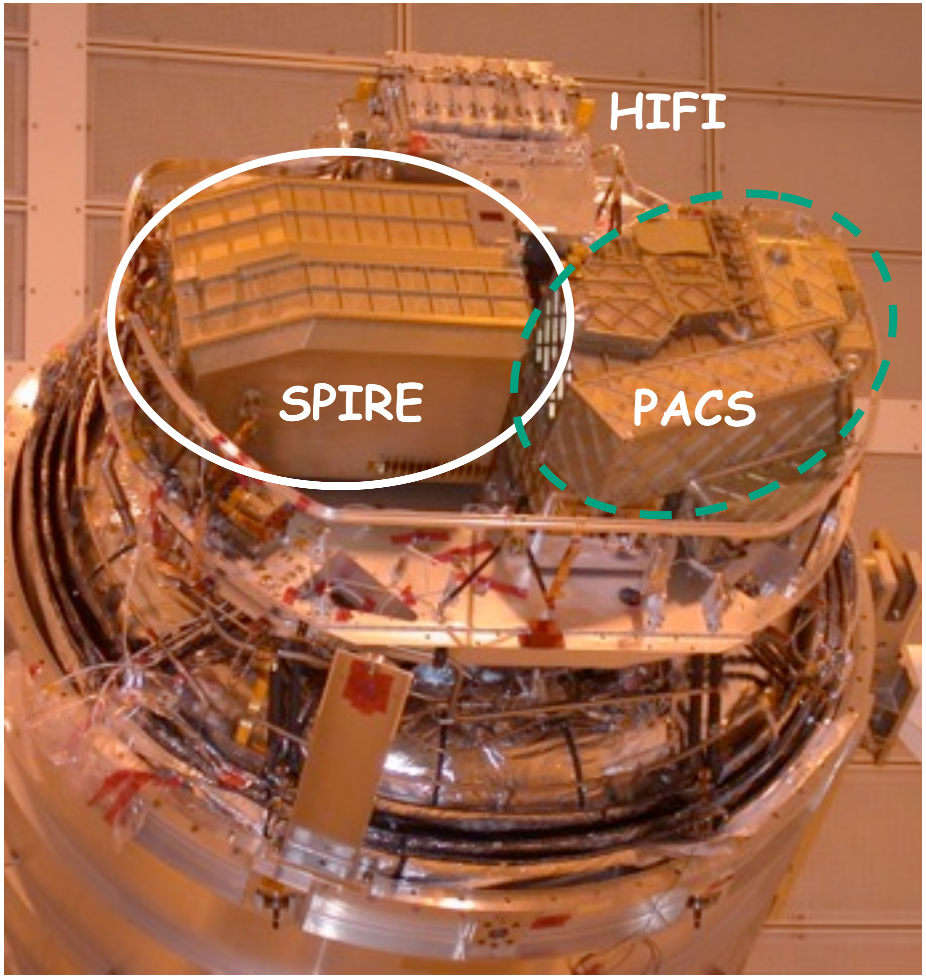
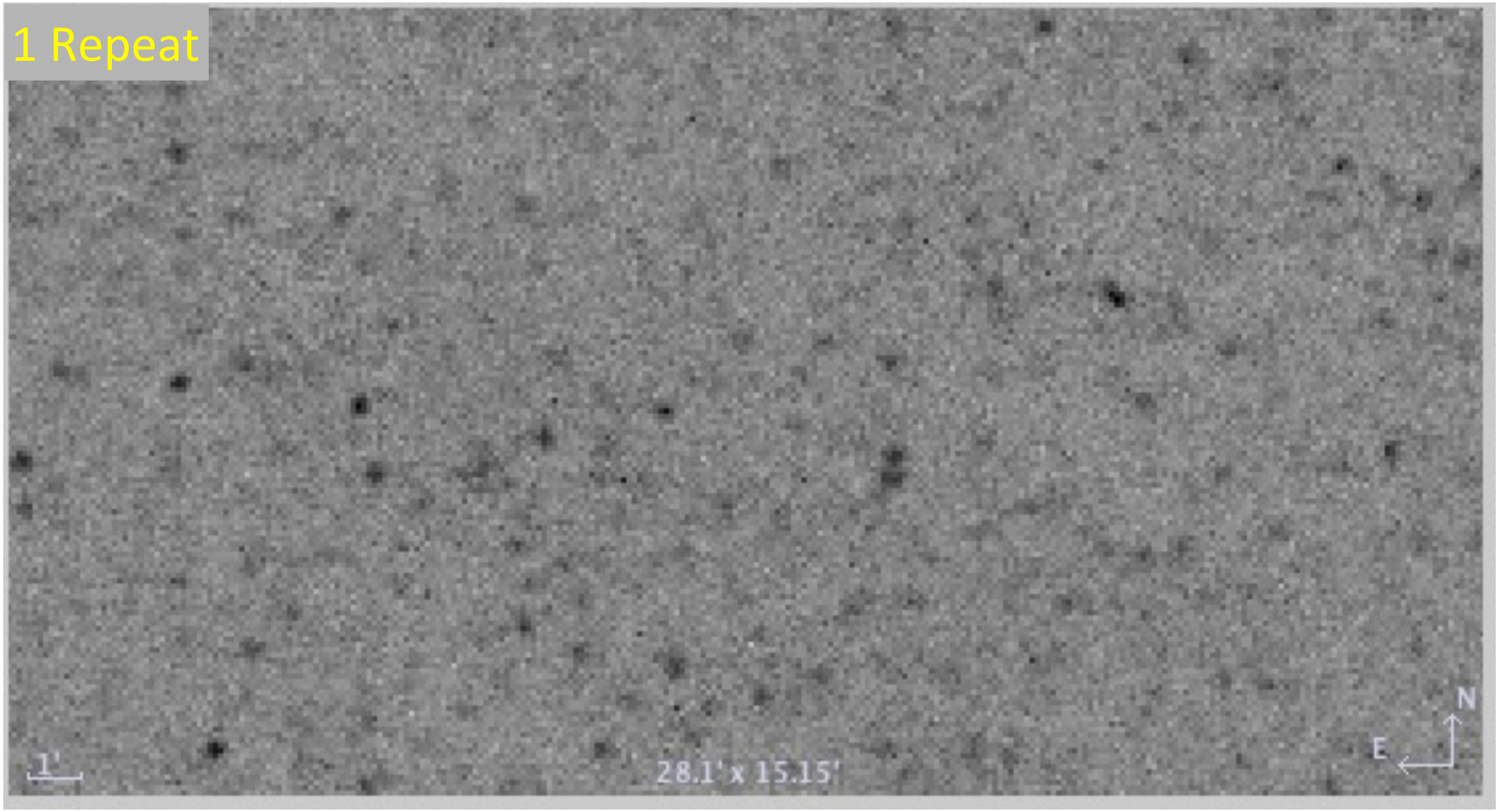
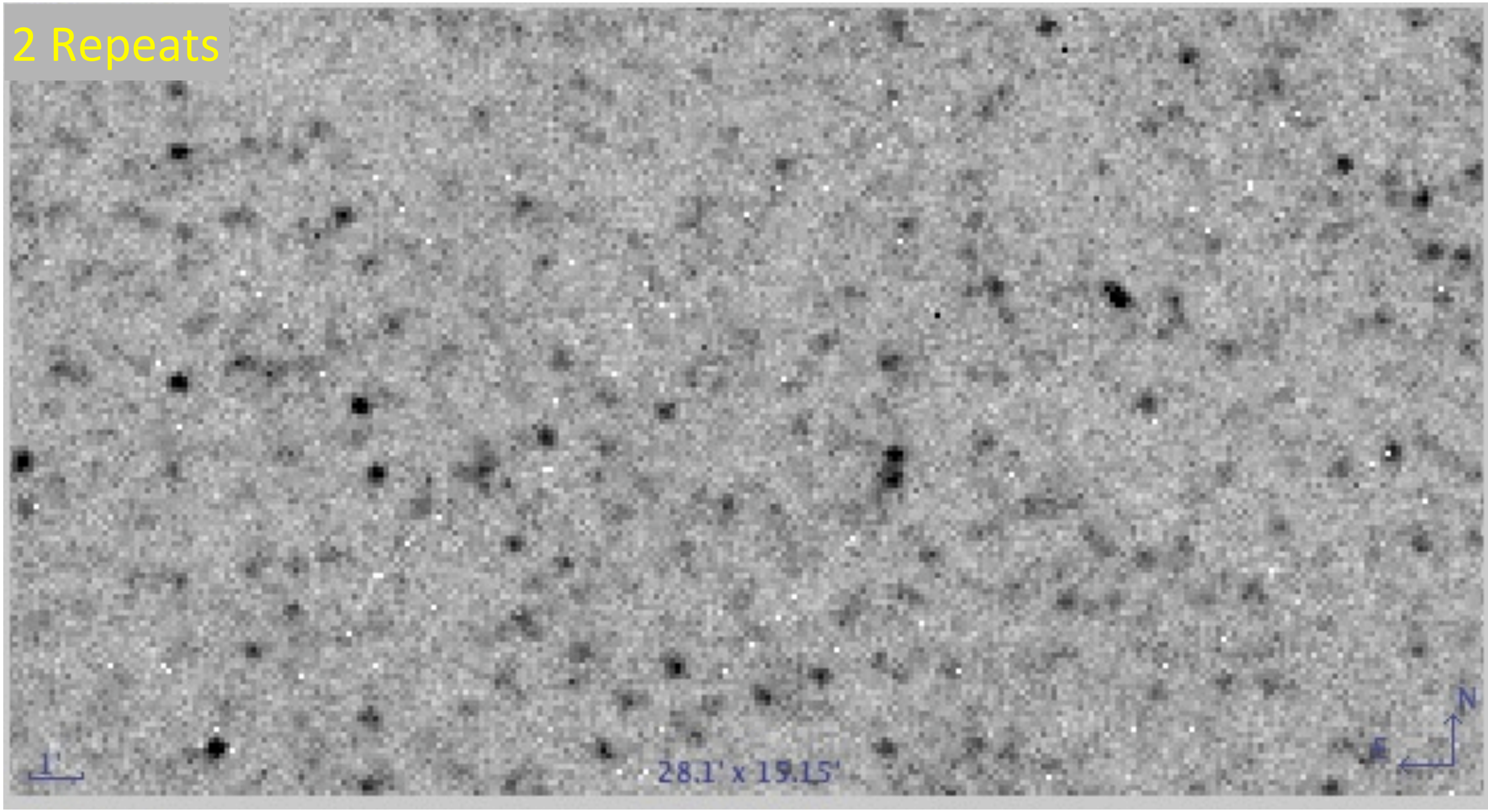


Mapping to the Confusion Limit



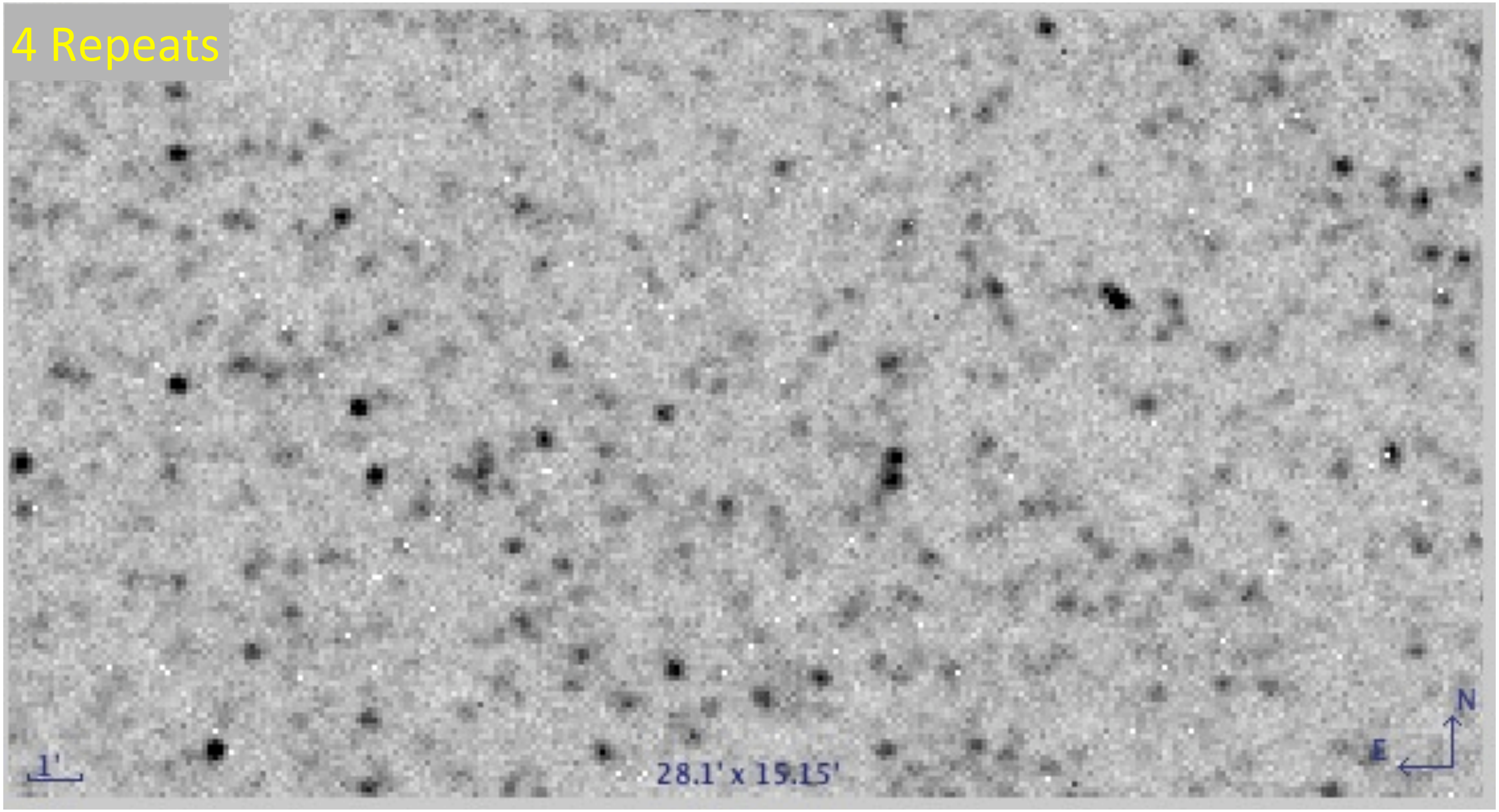
0.7 h for 1 sq. deg

Mapping to the Confusion Limit



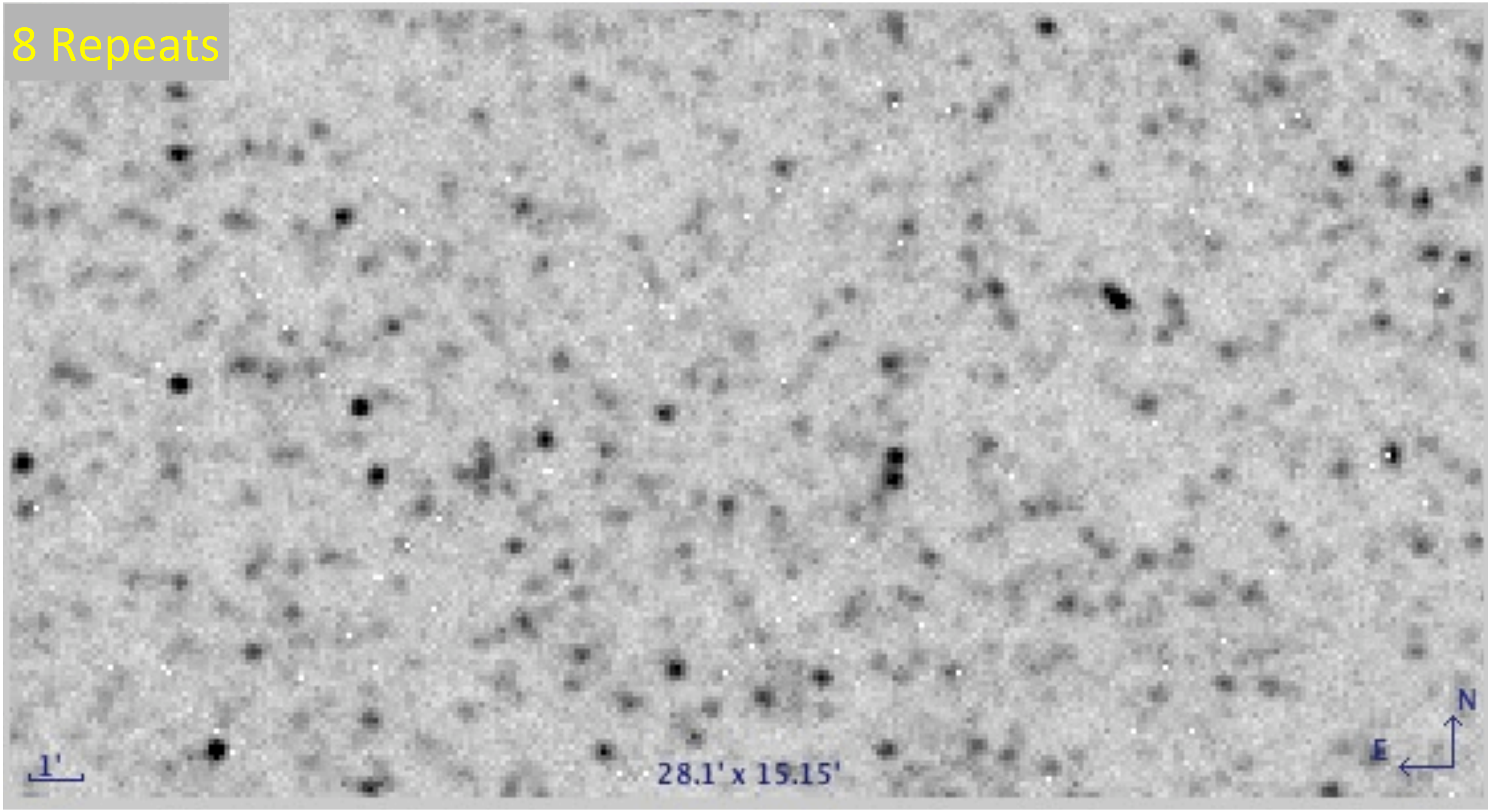
1.5 h for 1 sq. deg

Mapping to the Confusion Limit



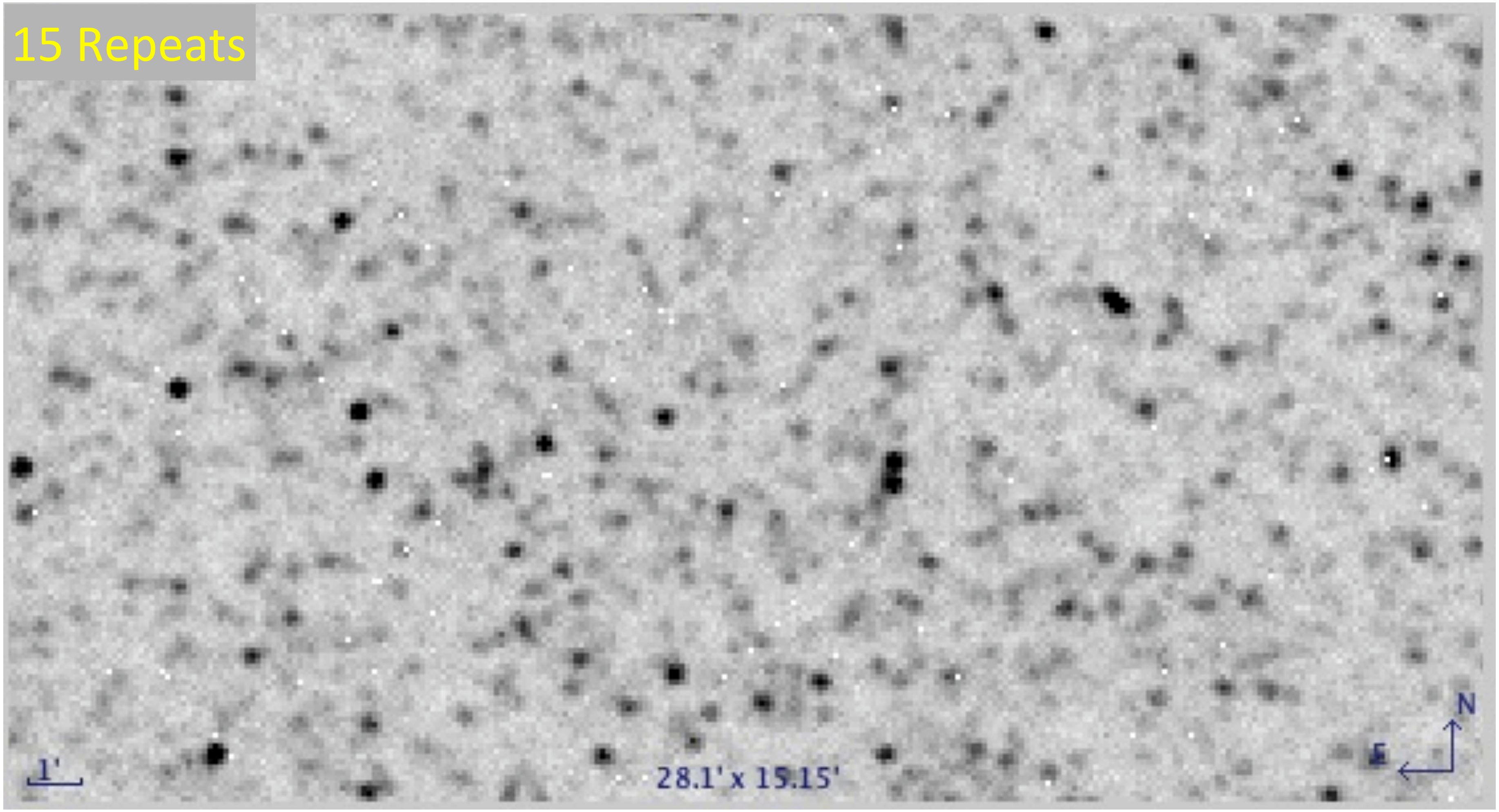
3 h for 1 sq. deg

Mapping to the Confusion Limit



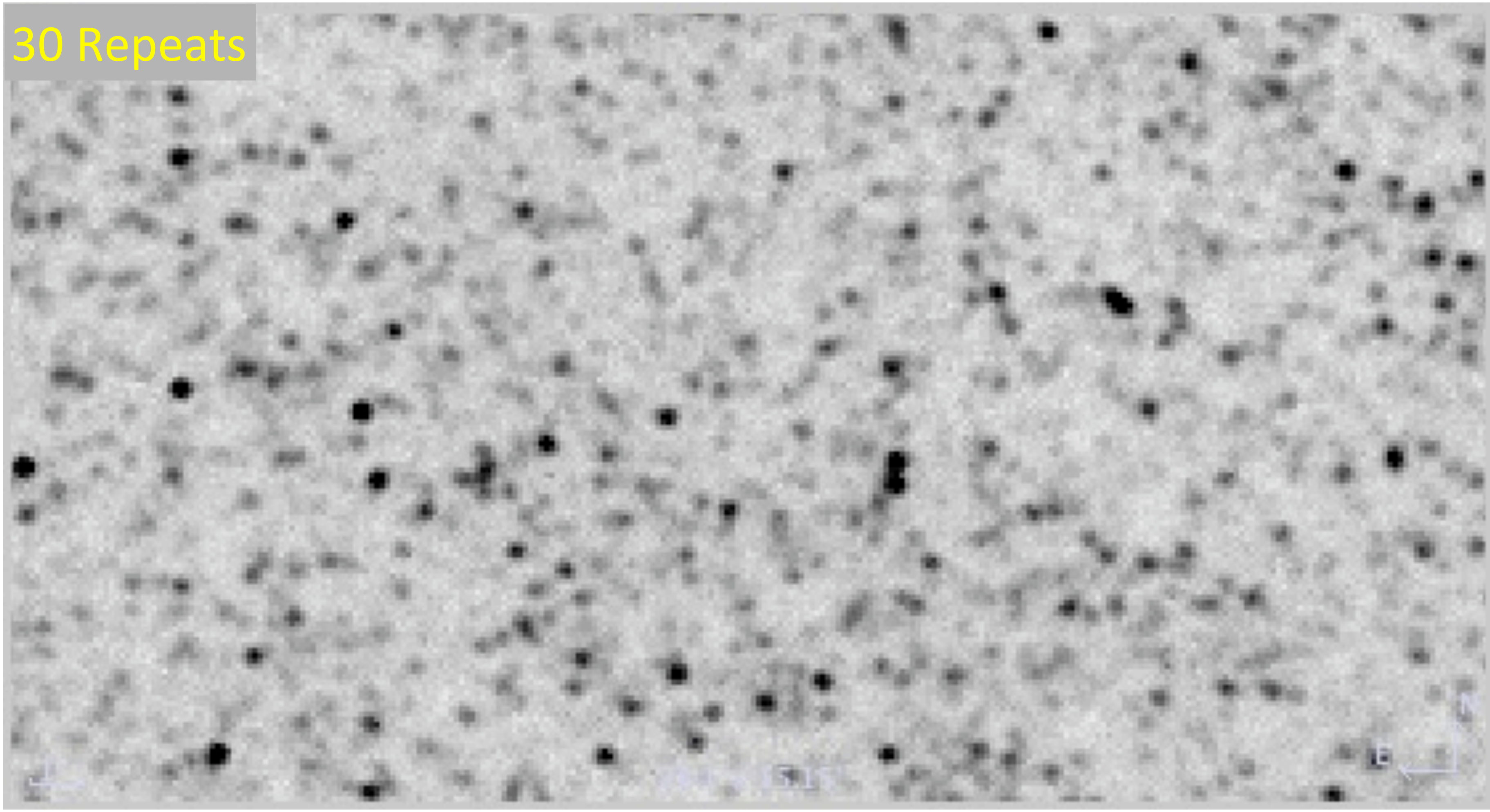
6 h for 1 sq. deg

Mapping to the Confusion Limit



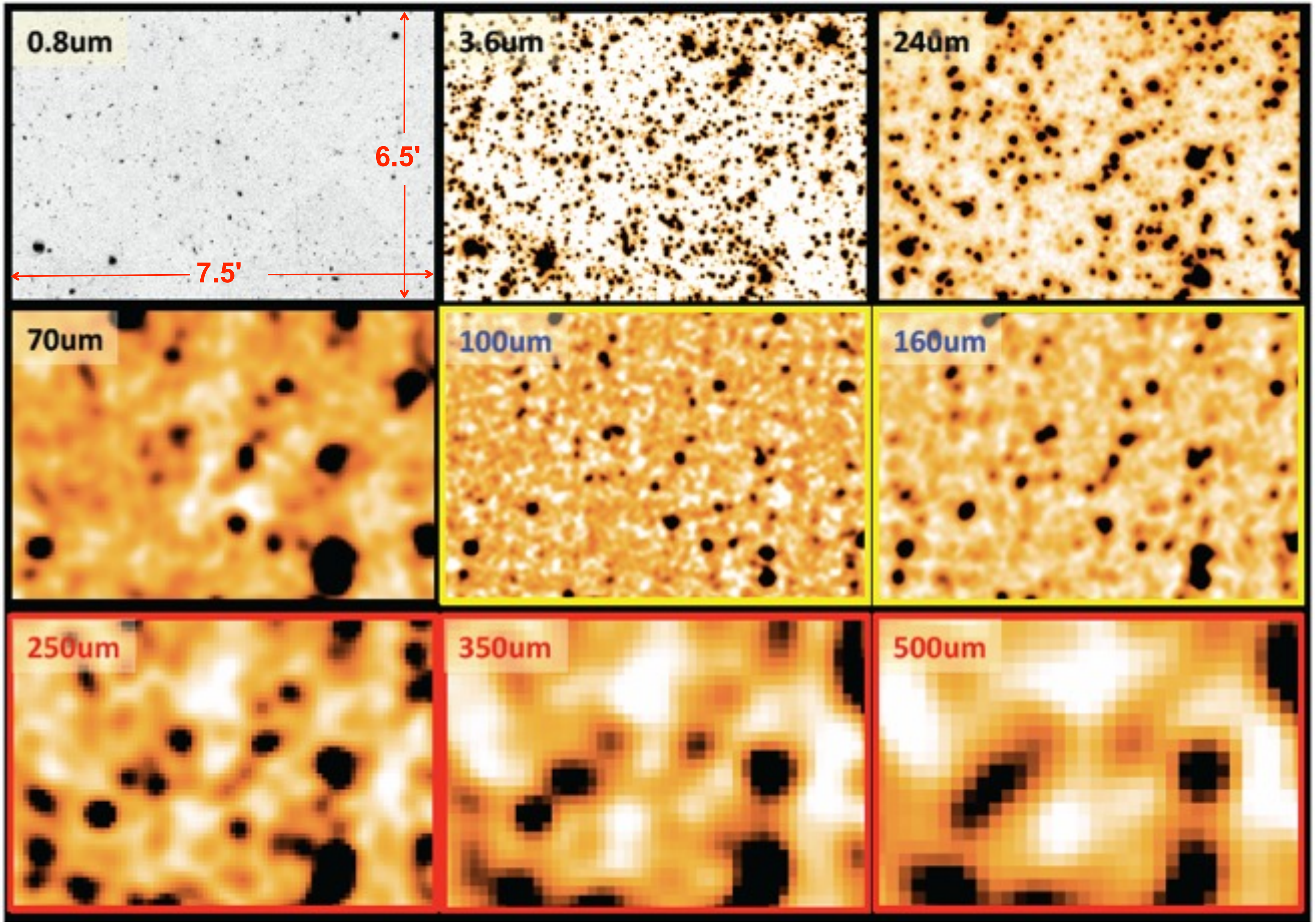
11 h for 1 sq. deg

Mapping to the Confusion Limit



22 h for 1 sq. deg

The Confusion Challenge



D. Elbaz

Three Ways to Deal with Confusion

Herschel Source Photometry

- Need to be careful about bias and source blending
- Blind follow-up in large beam is laborious (~SCUBA)
- However these are the most interesting source populations

Pre-Existing Source Catalogs

- Estimate Herschel flux of 'known' sources
- Reliable to within confusion noise
- Follows bias inherent in 'input' catalog

Map-Based Analysis

- Much more information in maps than in reliable sources
- Tends to be ensemble information : P(D), fluctuations, etc
- Maps have high statistical fidelity!

HerMES Survey Design Principles

Wedding Cake Design

- Probe a wide range of the luminosity function
- Deep fields for sub-confusion studies
- Wide fields for rare objects and fluctuations

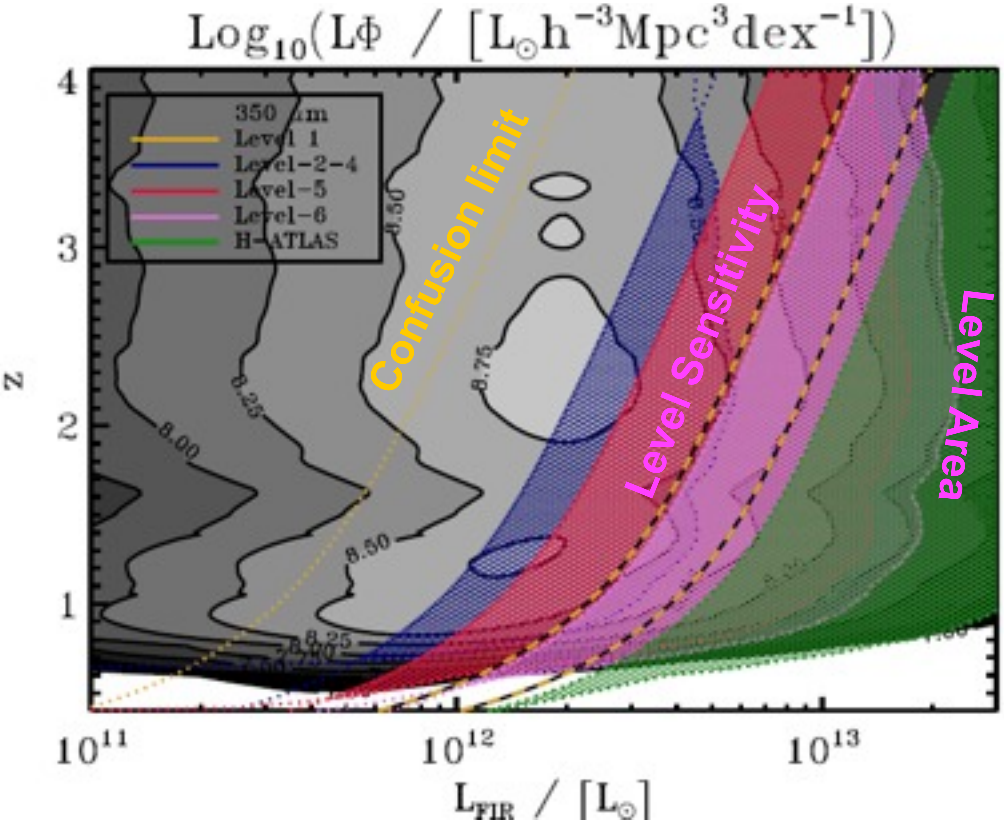
Target Survey Fields With Best Ancillary Data

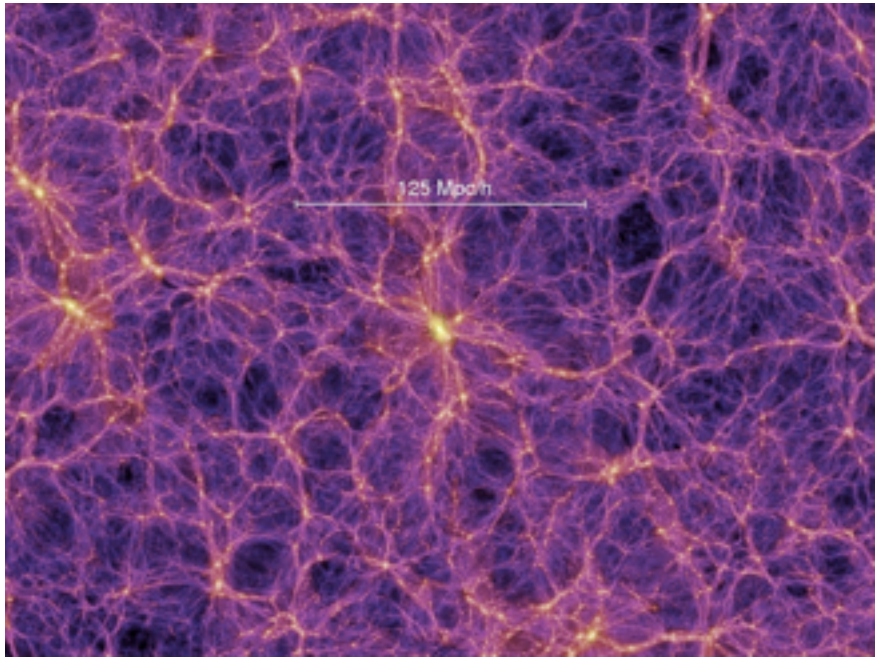
- Fields with Spitzer, Radio, UV, Optical, NIR, X-ray etc

Do What Herschel Does Best

- SPIRE excels at large maps
- PACS best at small deep maps
- Collaborate with PEP for PACS data
- Use parallel mode where possible

HerMES Survey Design Metrics





> 75 galaxies per $\Delta\log(L)*\Delta z = 0.1$ bin

Cover sufficient area to see large-scale structure and avoid sample variance

Lagache et al. 2003 galaxy models

Oliver et al. 2011, in prep.

HerMES : Wedding Cake Survey

Clusters

L1 0.11 □°

L2 0.36 □°

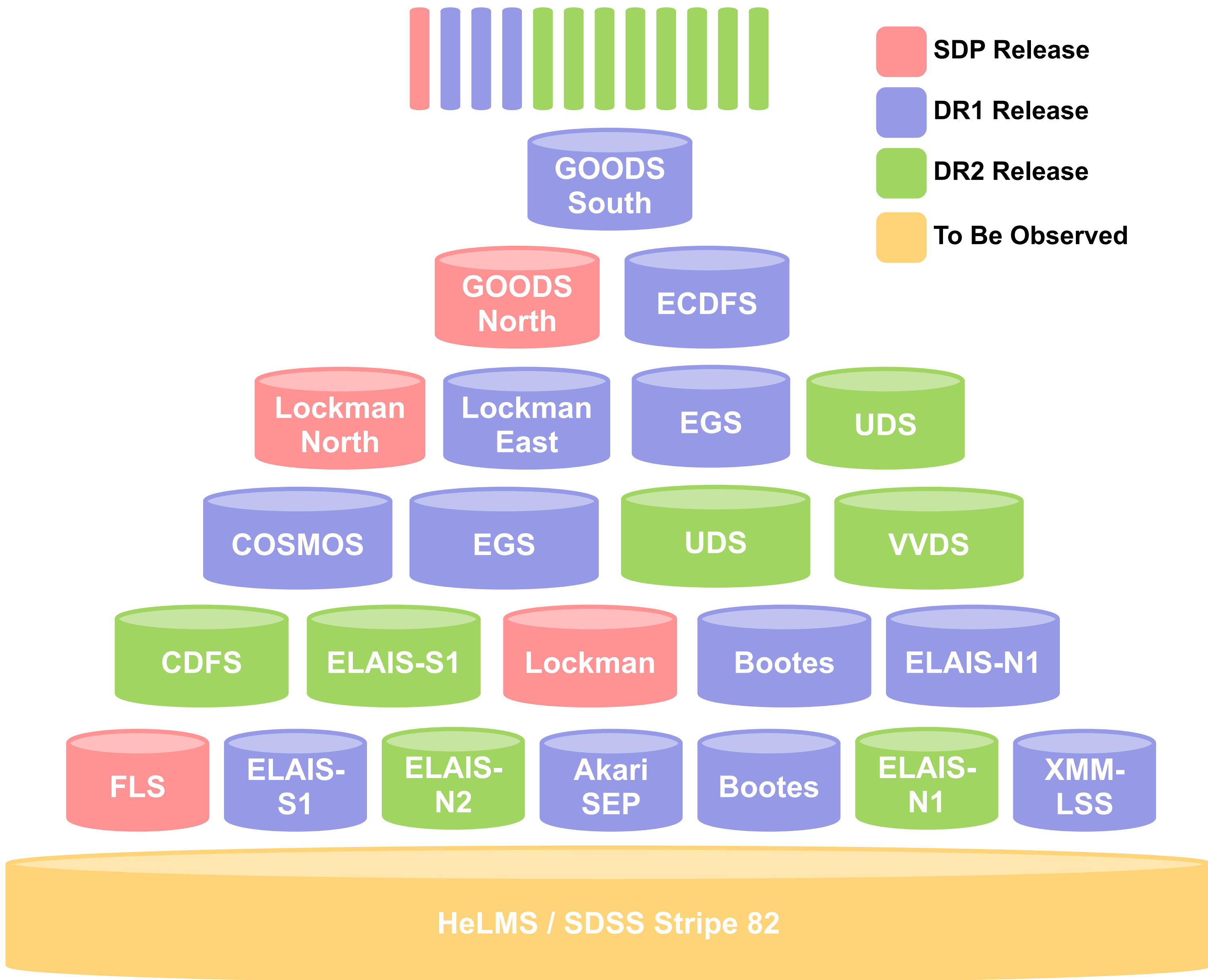
L3 1.25 □°

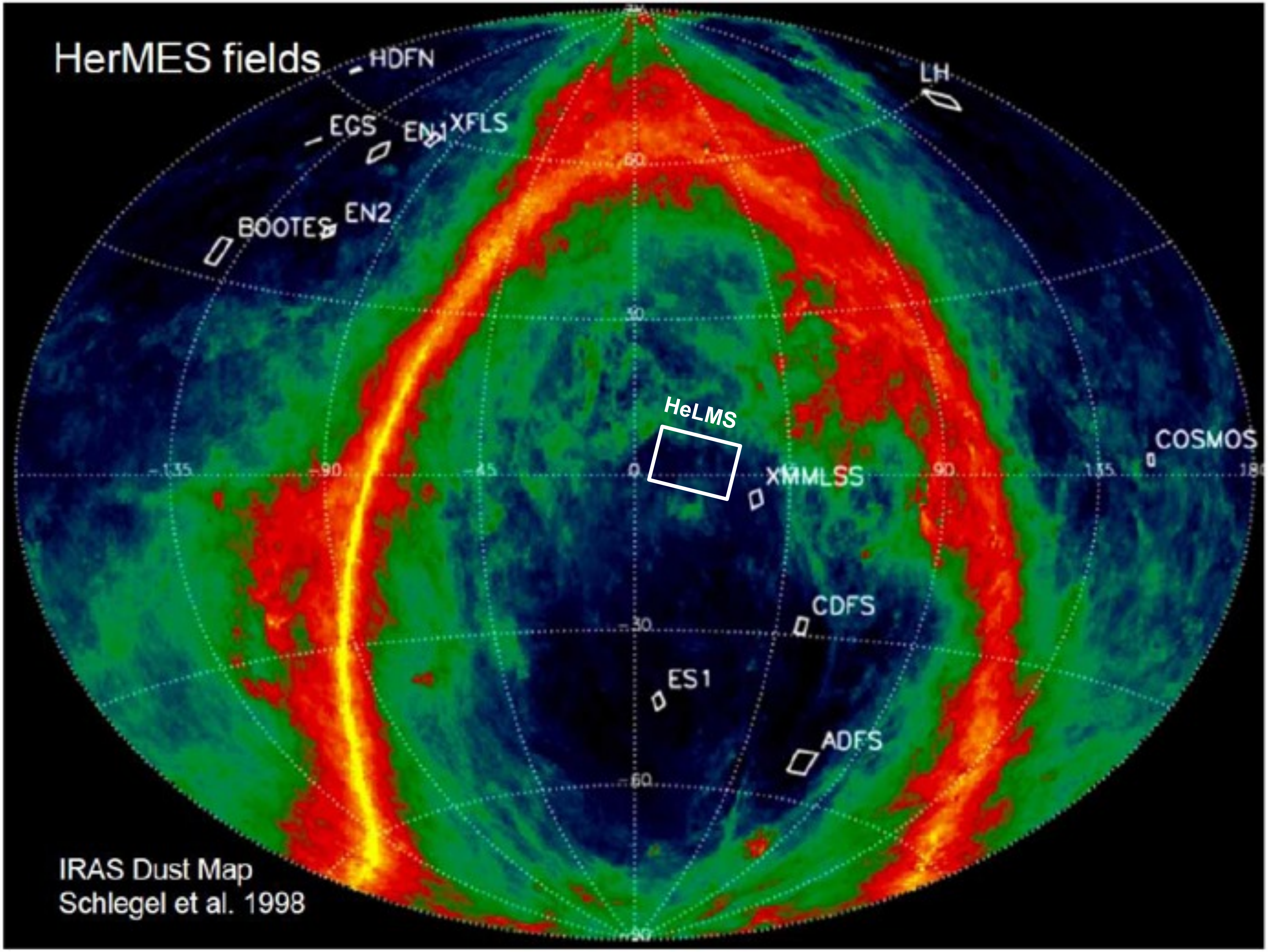
L4 4 □°

L5 30 □°

L6 40 □°

L7 270 □°




HerMES fields
HDFN
LH
EGS
EN1
XFLS
BOOTES
EN2
HeLMS
COSMOS
XMMLSS
CDFS
ES1
ADFS
IRAS Dust Map
Schlegel et al. 1998

A 'Data Fusion' for HerMES Science
(Vaccari et al. in prep)

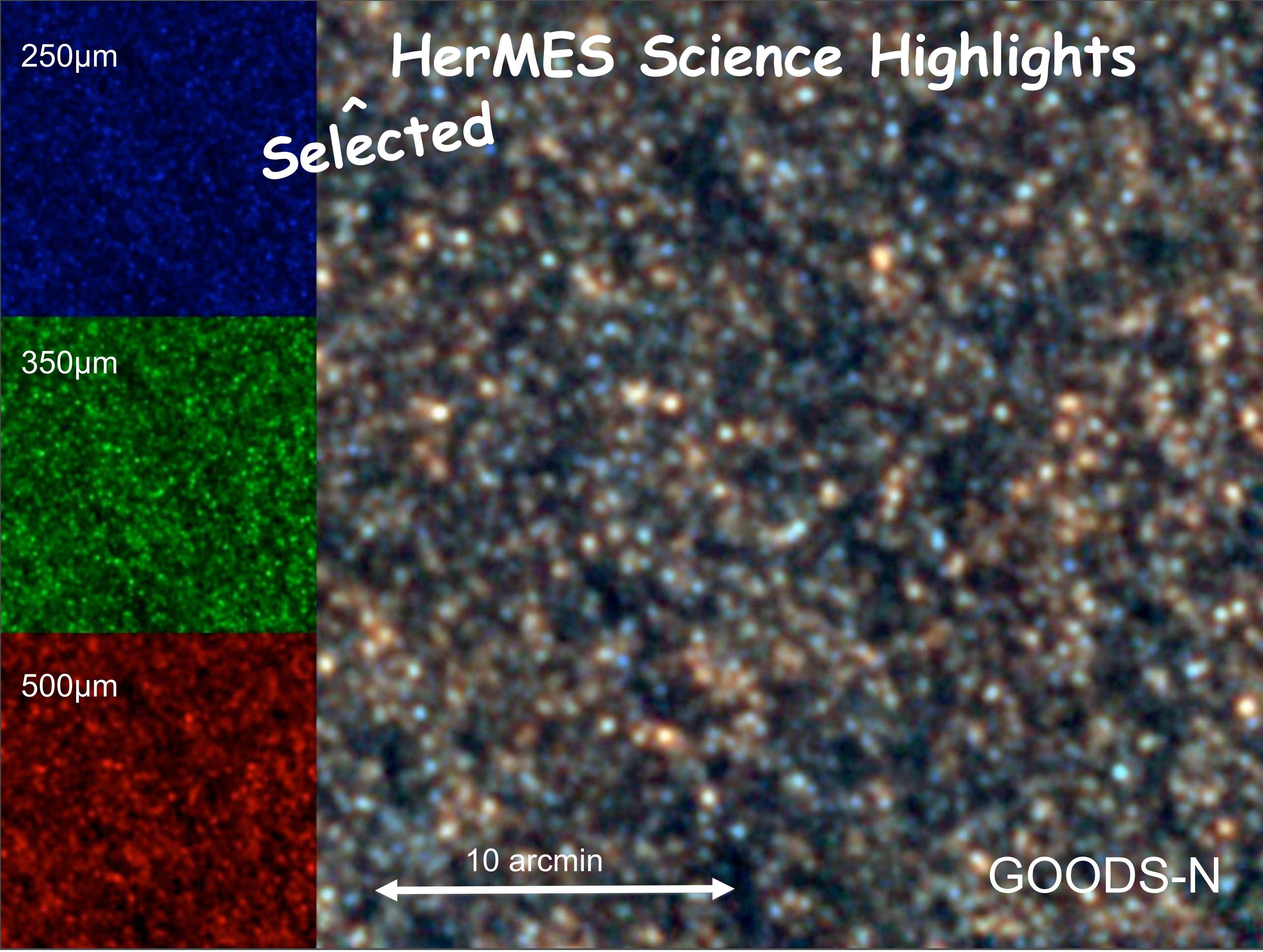
- A multi-wavelength catalog of IRAC-selected sources spanning FUV-to-FIR in HerMES Deep and Wide Fields

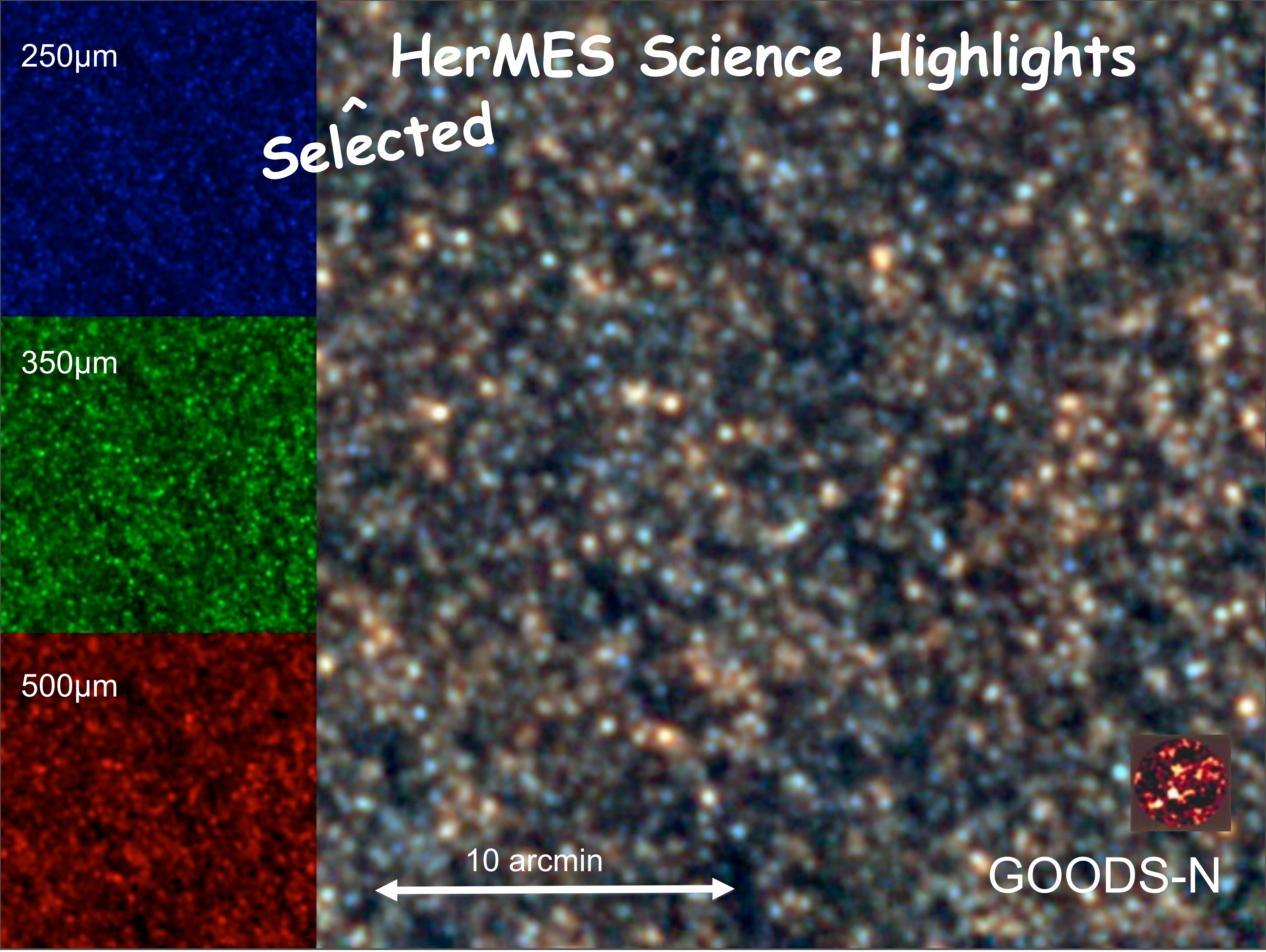
- GALEX GR6, SDSS DR8, 2MASS PSC/XSC, UKIDSS DR8
- Miscellaneous (Public & Proprietary) Deep Optical Imaging
- Spec-Z's / Phot-Z's from NED & our own Programs / Works

- Multi-Band Multiple Aperture and Total Flux Measurements
- Allowing SED fitting, Stellar Mass & SFR estimates (Phot-Z)

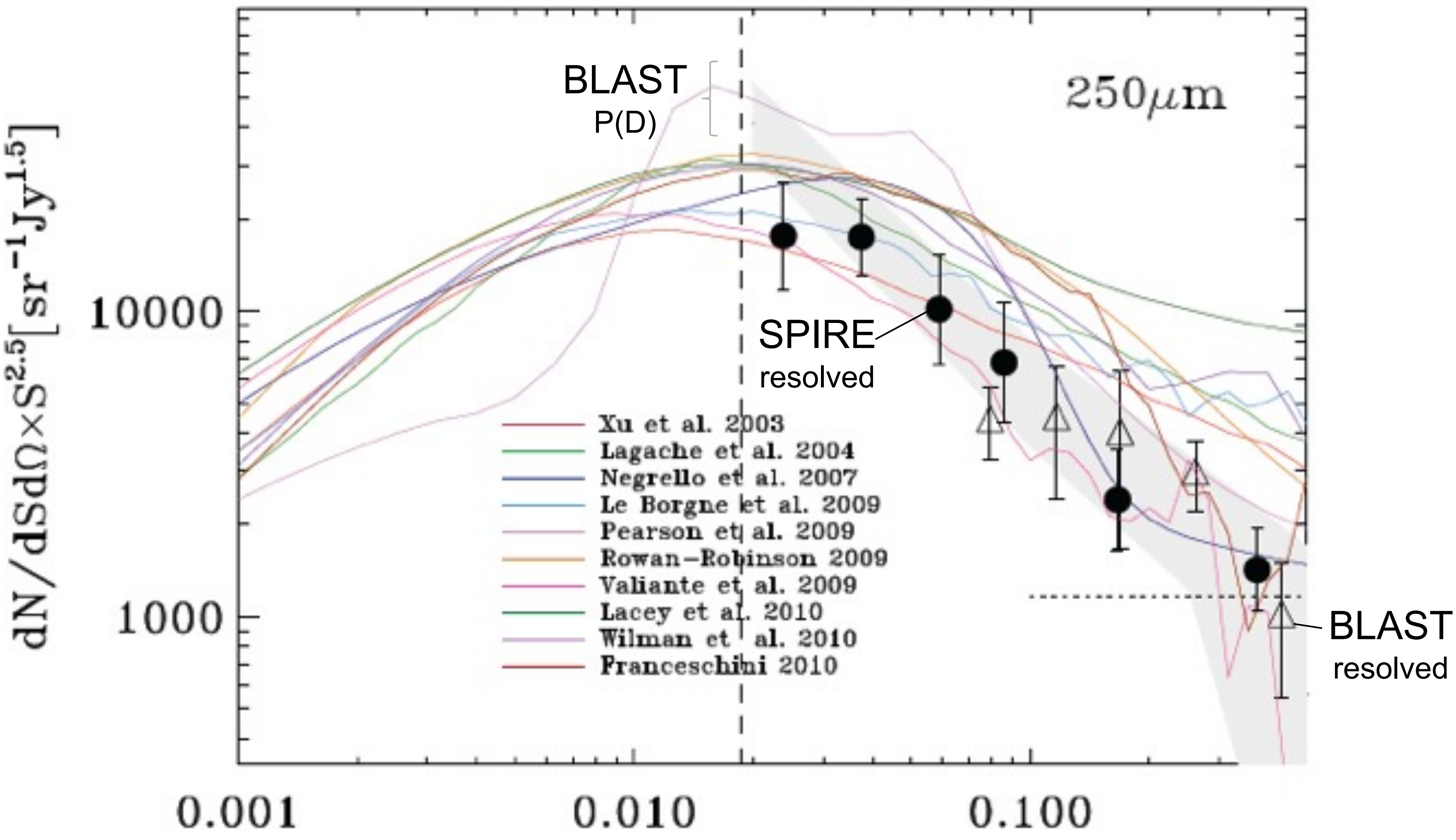
- Extended to SERVS (deeper & narrower than SWIRE) fields

HerMES Selected Science Highlights



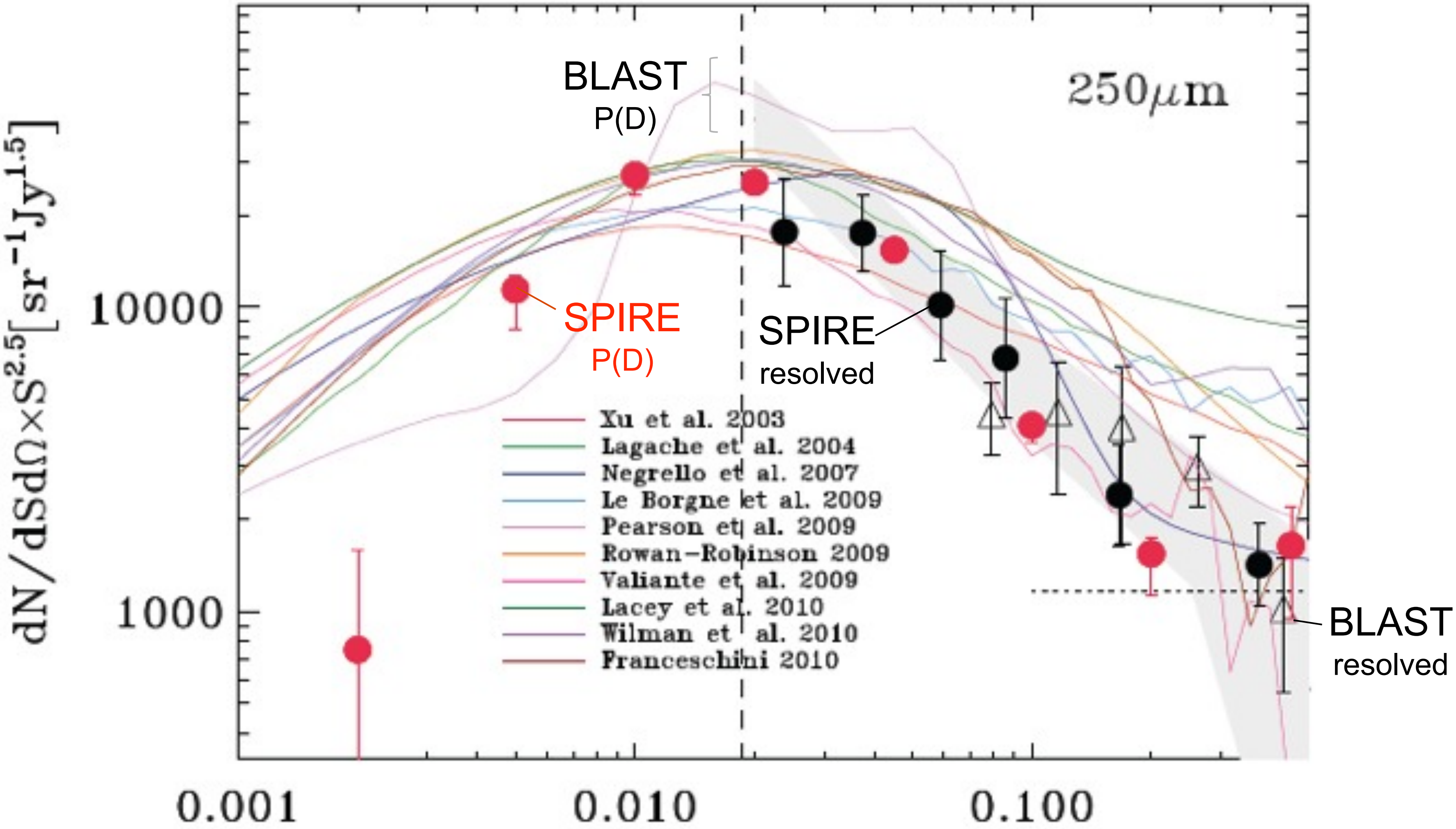

HerMES Science Highlights
Selected
250µm
350µm
500µm
10 arcmin
GOODS-N

SPIRE Source Counts



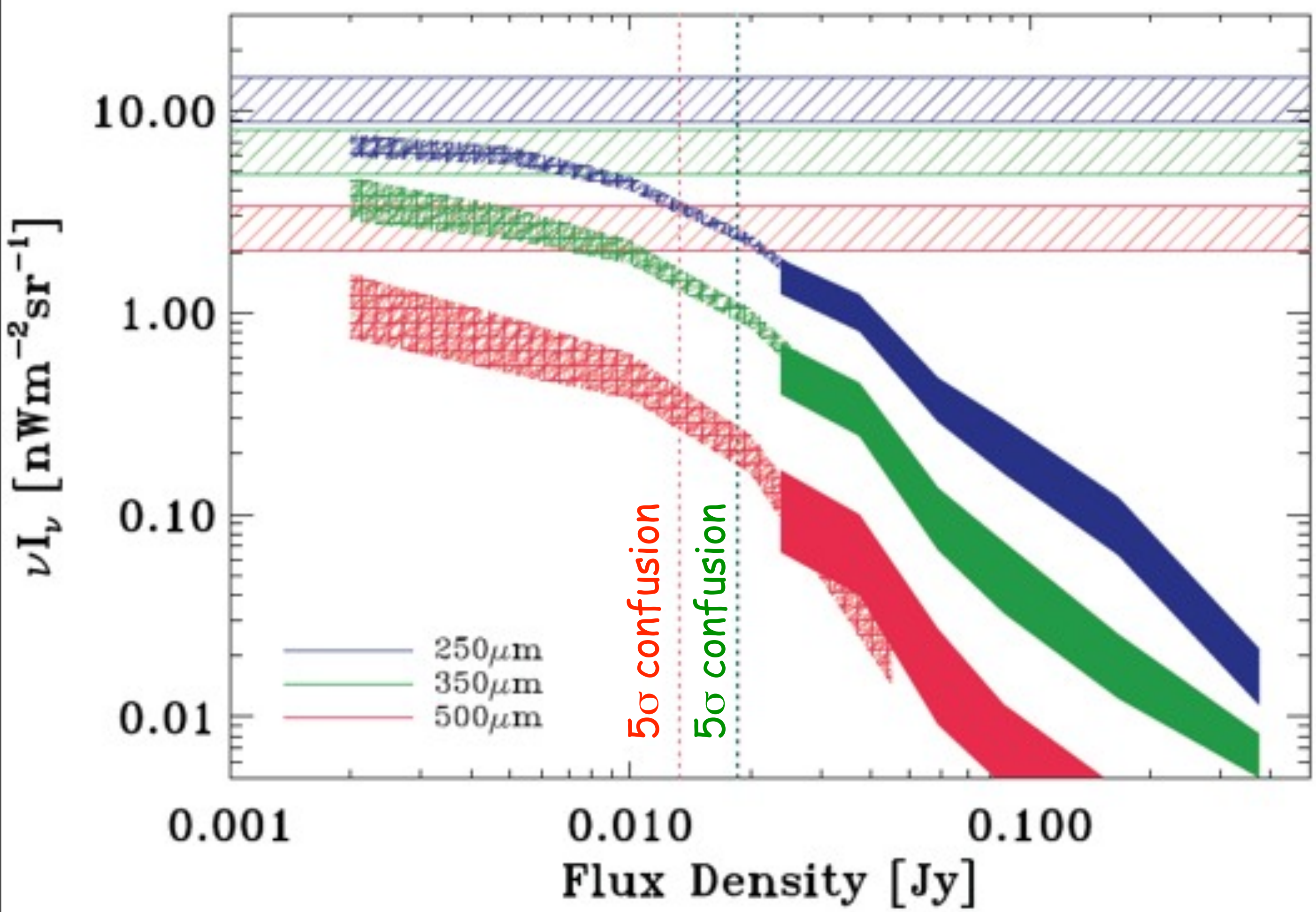
Oliver et al. 2010 A&A

SPIRE Source Counts



Glenn et al. 2010

Resolving the FIR Background

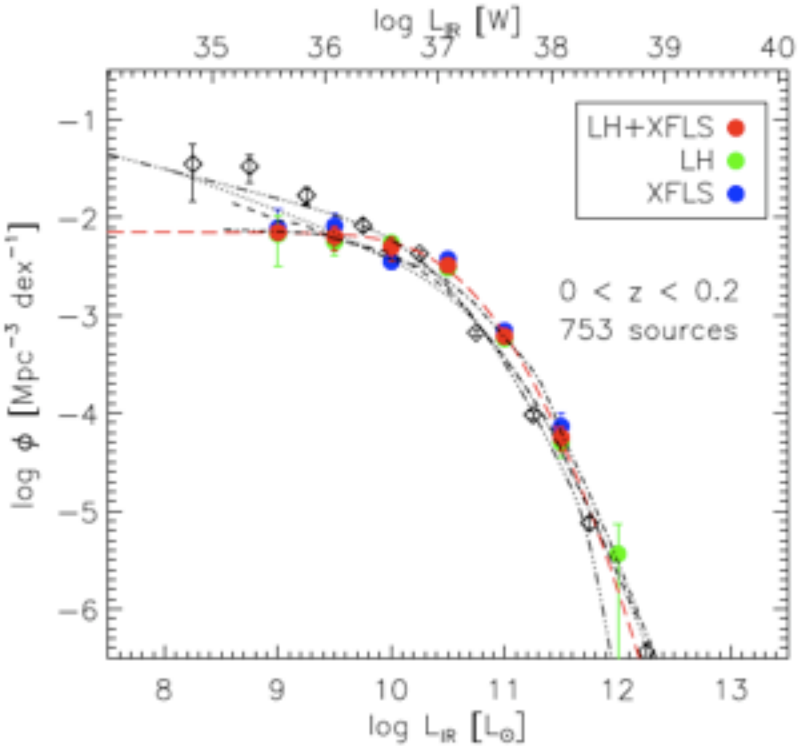


- **Source Counts**
  250, 350, 500 μm
  15%, 10%, 6%
- **P(D)**
  250, 350, 500 μm
  65%, 60%, 45%
- **Stacking TBD**
  With BLAST:
  250, 350, 500 μm
  80%, 80%, 85%

Of course: The remainder are the most interesting sources!
E.g. z > 3 galaxy populations

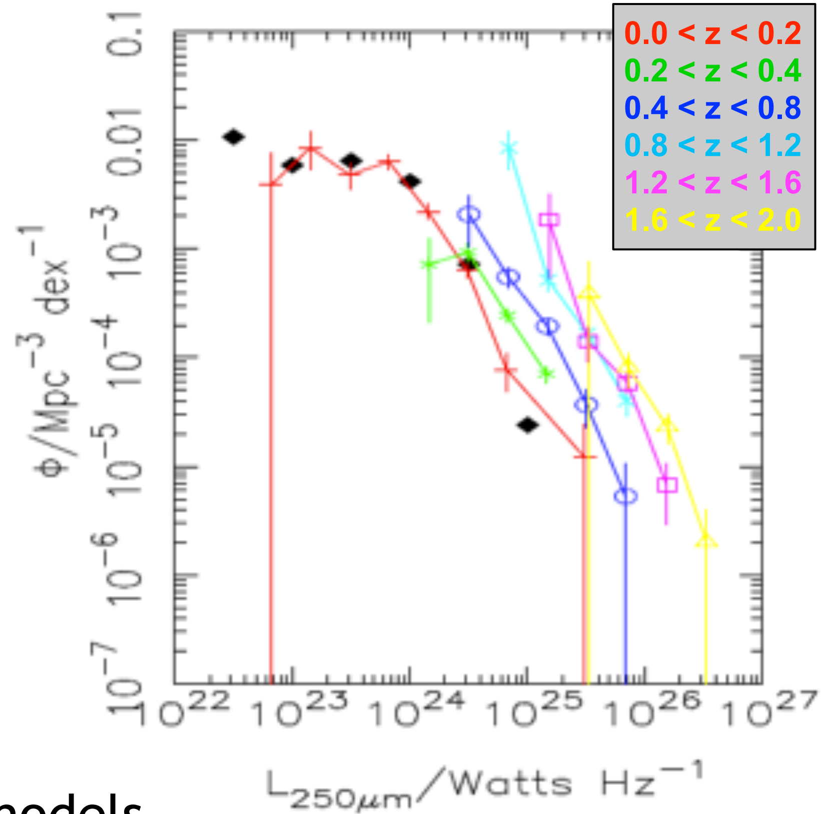
Strong Luminosity Evolution

HerMES IR Bolometric Local Luminosity Function



Vaccari et al. 2010

HerMES Rest-Frame 250 μm LF

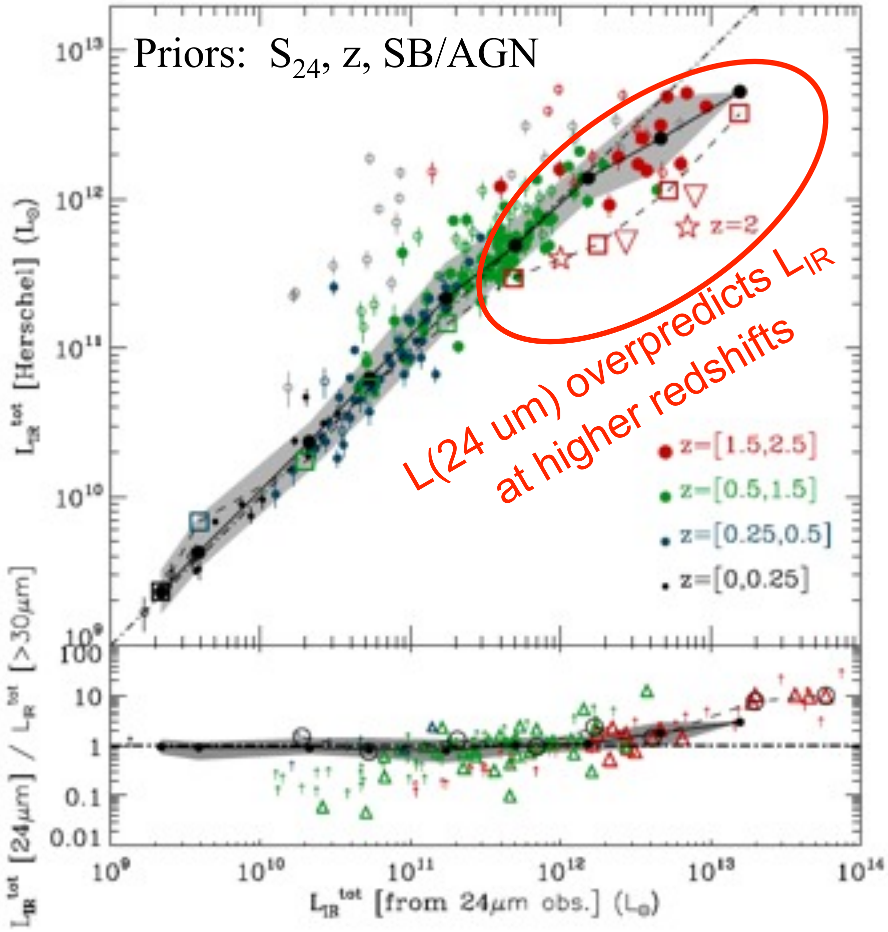


Eales et al. 2010

- Local sub-mm galaxy LF slightly above models
- Luminosity function increases out to z ~ 2
- Is it flattening out at z > 1?
- Next : better statistics from bigger samples

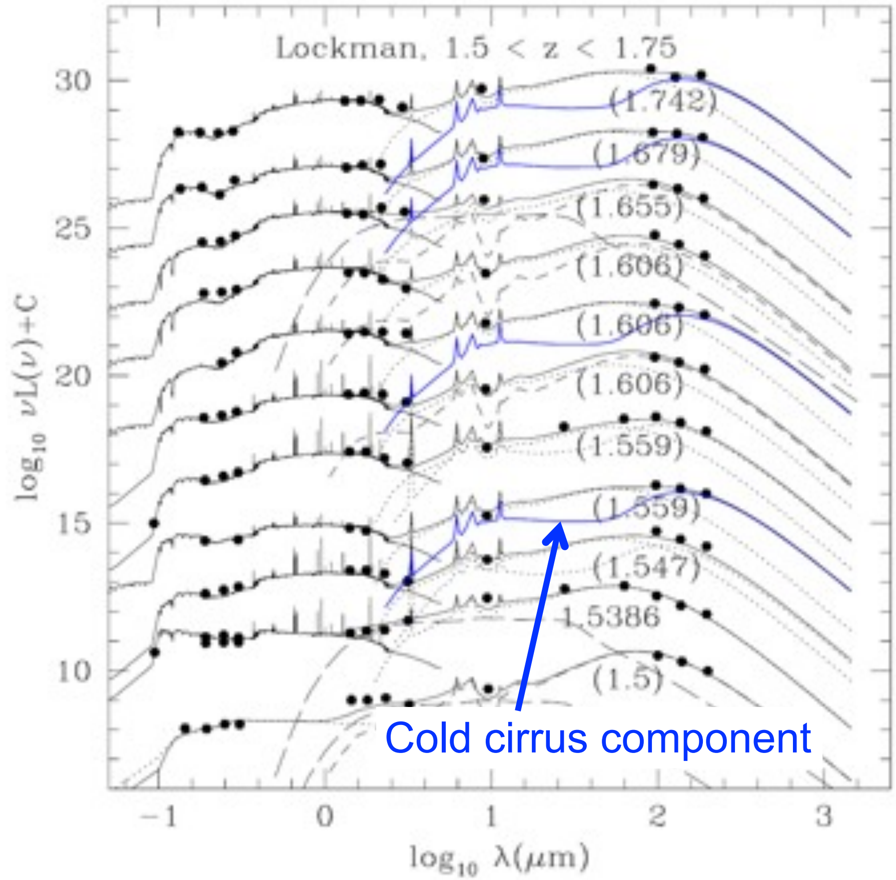
How Well Do Galaxy Templates Work?

L_{IR} for Starbursts and AGNs



Elbaz et al. 2010

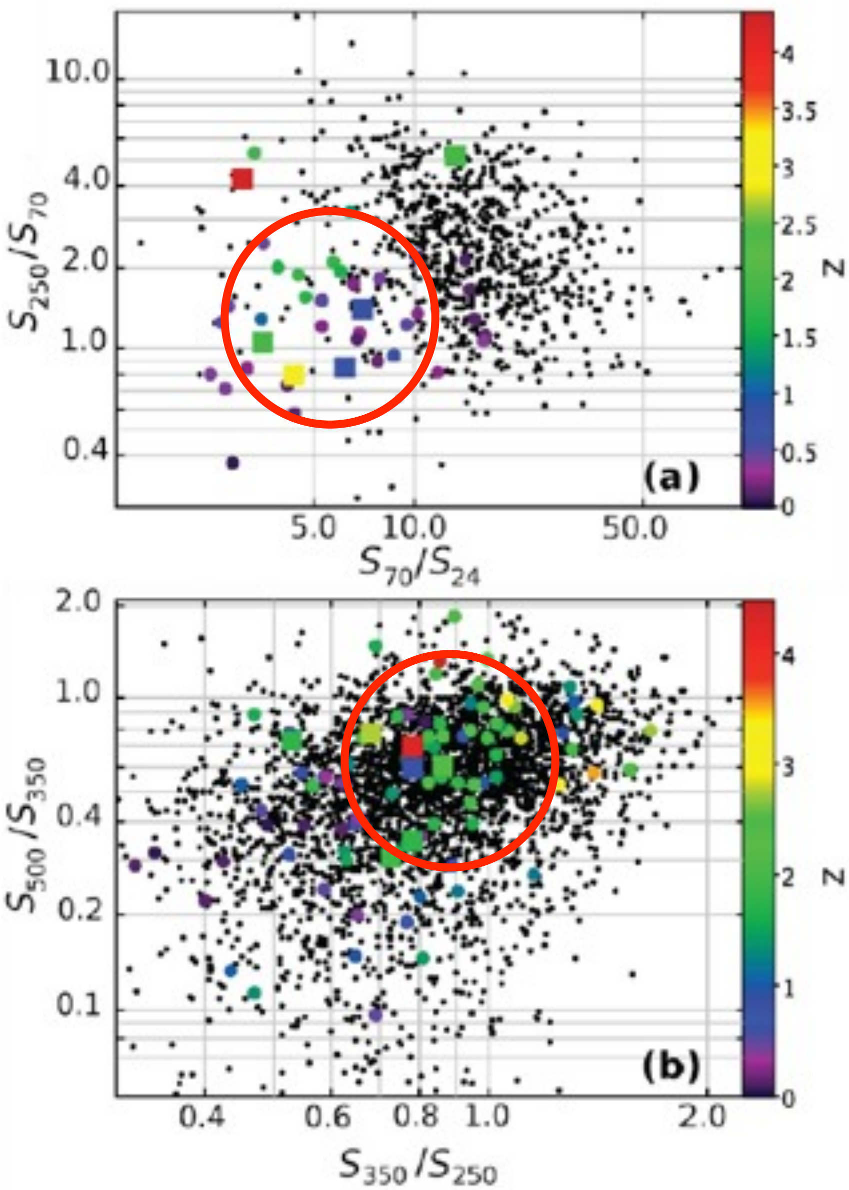
Multi-Wavelength SED Fits



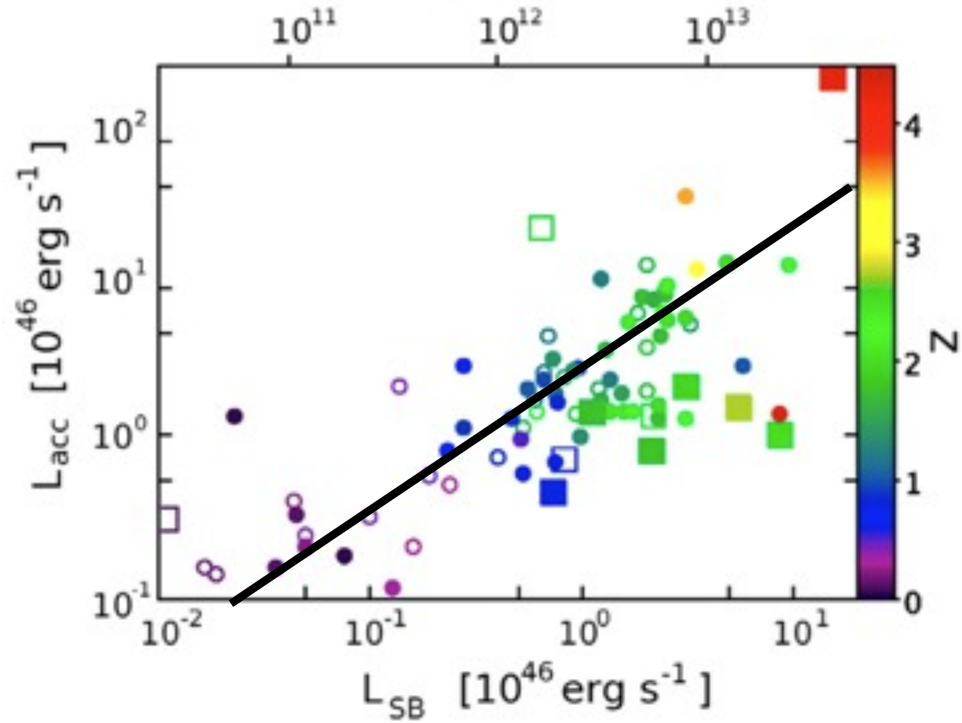
Rowan-Robinson et al. 2010

- *Herschel* provides a direct measure of bolometric luminosity and SFR
- L_{FIR} and SFR predicted from $\lambda \leq 24$ μm observations are inadequate
- ~Half the SEDs require lower temperature dust component (10 – 20 K)

AGNs and Far-IR Galaxies



Hatziminaoglou et al. 2010



L_{acc} prop. to L_{SB} (for high-L objects)

Distinct S_{70}/S_{24} but not $S_{250}/S_{350}/S_{500}$

FIR emission due do Star Formation

(Some) HerMES Ongoing Follow-Up

Optical/NIR Observations

La Palma International Time Program (Perez-Fournon+) : GTC/WHT/TNG/INT
optical imaging, bright MOS and faint longslit spectroscopy
Keck DEIMOS (Casey+) aimed at high-z sources (with spare fibers)
VLT VIMOS/FORS2 (Swinbank+) aimed at zLESS sources (with spare fibers)
Subaru FMOS (Roseboom+) aimed at MIPS/SPIRE 0.8<Z<2.0 Sources
Kec NIRC2 AO (Cooray+) of Lensed Sources

(S)MM Observations of Lensed Sources & 500 um Peakers

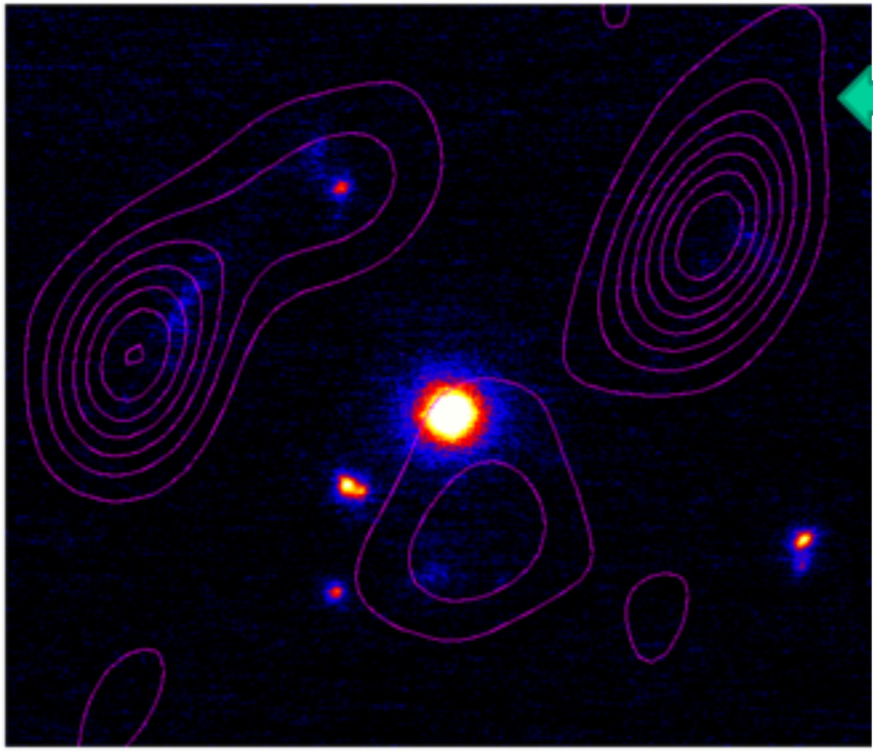
CARMA, EVLA, MAMBO, PdBI, SMA, ZSPEC : Imaging & Spectroscopy
ALMA Cycle 0 ?

Near Future Instrumentation

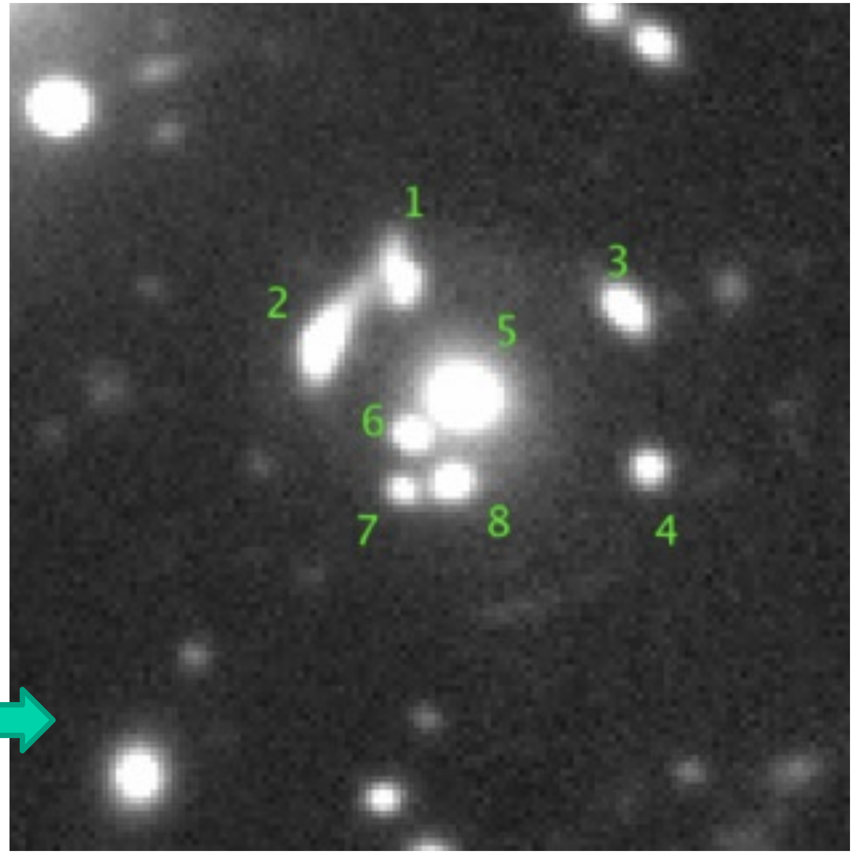
ALMA Completion
JWST Launch
Next-generation of instruments at 8-m-class telescopes

HERMES J105751.1+573027 (HLSW-01)

Multiply-Lensed Bright SMM Source : 420 mJy @ 250 um



SMA 850 um on Keck K AO



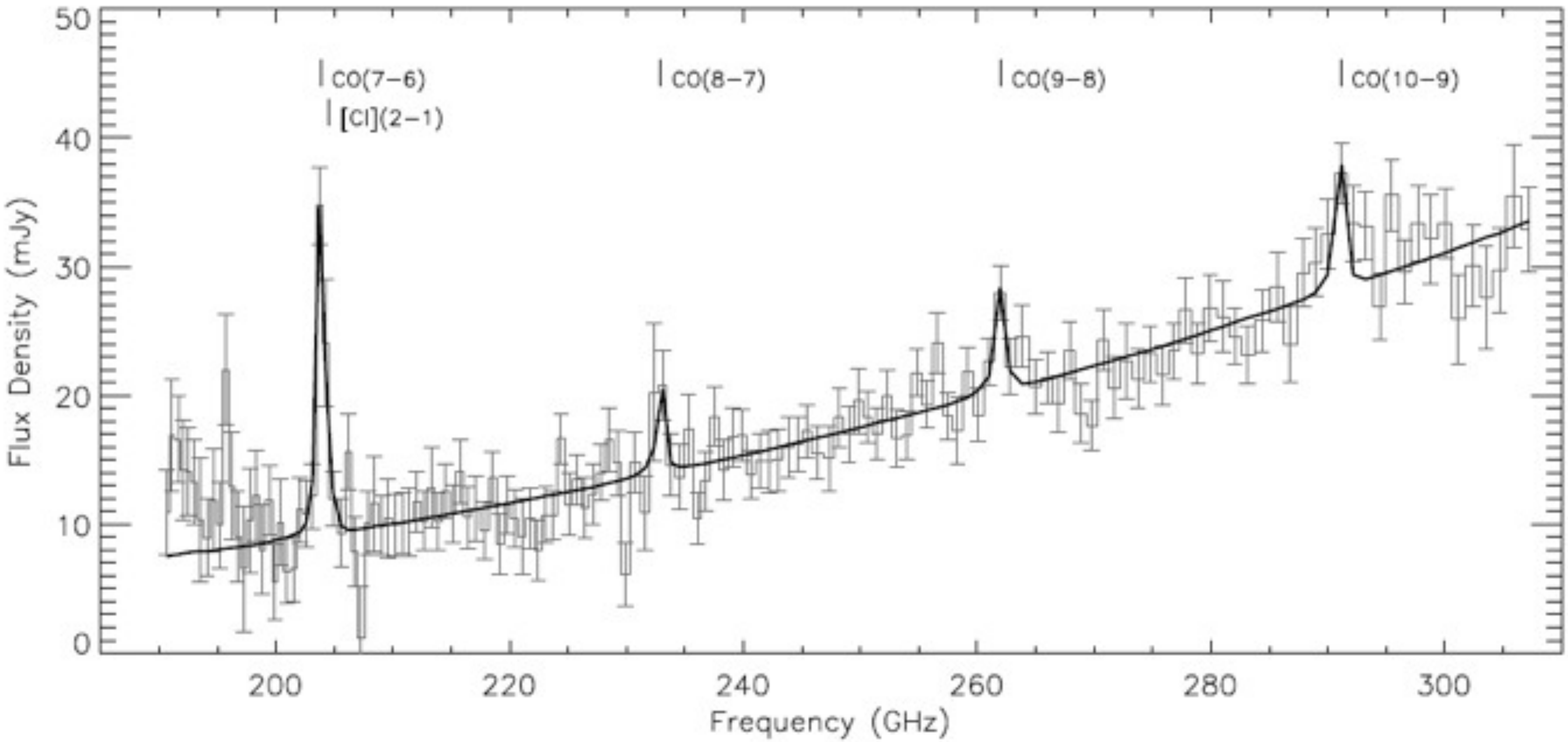
High-resolution allows for detailed lens modeling

Subaru i

Gavazzi et al. 2011

HERMES J105751.1+573027 (HLSW-01)

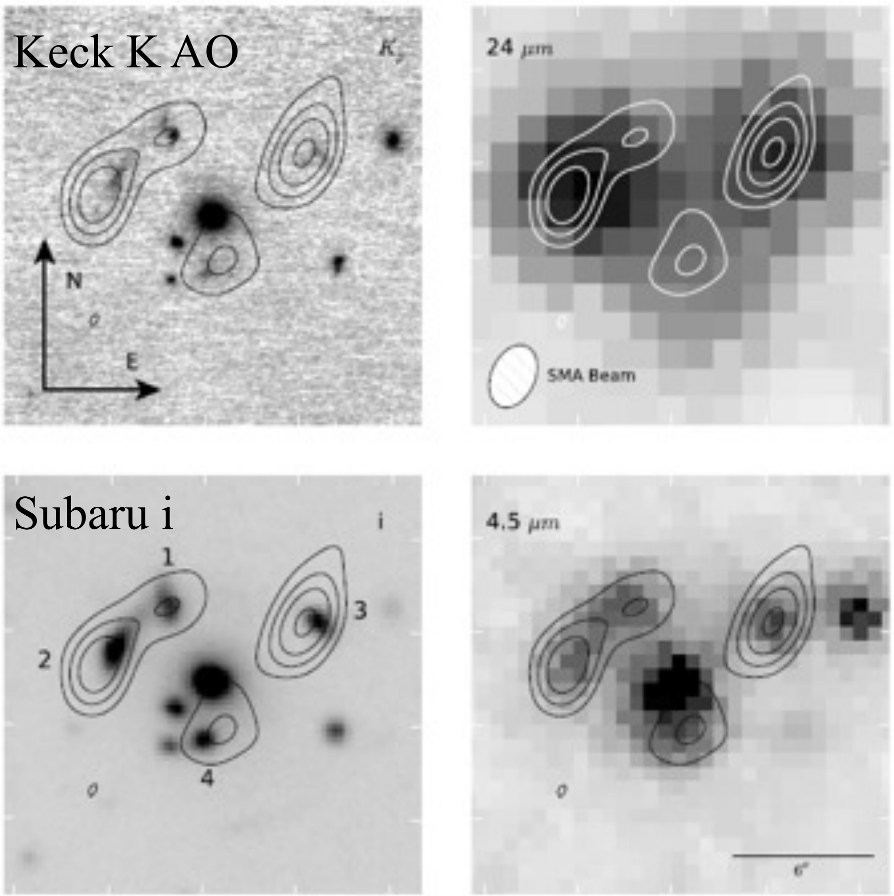
ZSPEC z = 2.958 +/- 0.007

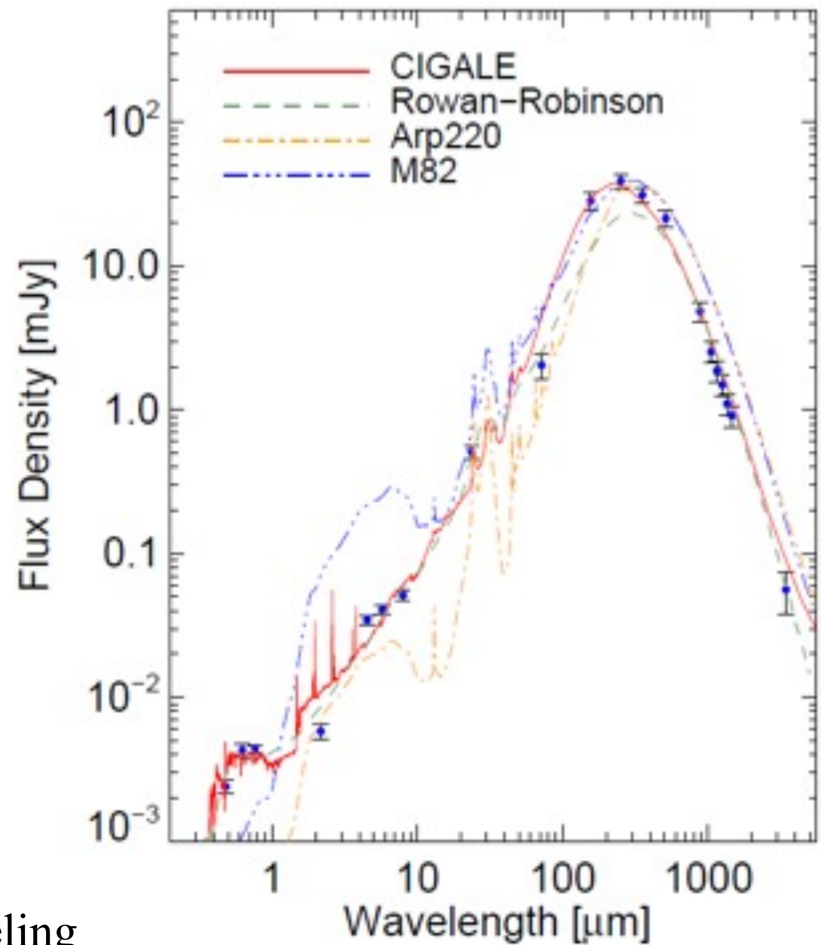


Scott et al. 2011

HERMES J105751.1+573027 (HLSW-01)

SMA 850 um Contours





Multi-wavelength coverage enables full SED modeling

Luminosity after deamplification : $L = 1.4 \times 10^{13} L_{sun}$

Surprisingly hot dust : $T = 88 \pm 3$ K

Templates do not fit well to full SED

Conley et al. 2011

HerMES Future Follow-Up & The ELTs

MIR High-Resolution Imaging & Spectroscopy

ALMA-like detail at JWST frequencies

ALMA and ELTs similarly ill-suited for 'surveys'

NIR IFU Spectroscopy

Kinematics of interesting individual and/or multiple sources

Spectroscopy of Optically-Faint Systems

although low source density of well-identified sources is likely to be a problem (which could be solved with concerted follow-up of UKIDSS/VIDEO & SERVS)

HerMES (with SCUBA2 & CCAT) will provide an efficient way to identify SMM sources suitable for high-resolution panchromatic follow-up observations by ALMA & the ELTs revealing their structure and physics in great detail

Conclusions

HerMES Early Work

- Herschel is a fantastic observatory!
- Based on Small Fraction of Data

Observations Now Almost Completed

- DR1 release and publications in preparation
- Collaborations to get the most out of Herschel
- Healthy Follow-Up Program Ongoing

Clear Connection to ELTs (with SCUBA2 & CCAT)