HerMES: Overview and Coming Results

The Herschel Multi-Tiered Extragalactic Survey

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for the Hermes Consortium

Hermes Survey Co-Coordinator with Seb Oliver

Through the Infrared Looking Glass
Pasadena
2-5 October 2011

Bruno Altieri, Alex Amblard, Vinod Arumugam, Robbie Auld, Herve Aussel, Tom Babbedge, Alexandre Beelen, Matthieu Bethermin, Andrew Blain, Jamie Bock, Alessandro Boselli, Carrie Bridge, Drew Brisbin, Veronique Buat, Denis Burgarella, Nieves Castro-Rodriguez, Antonio Cava, Pierre Chanial, Ed Chapin, Scott Chapman, Michele Cirasuolo, Dave Celments, Alex Conley, Luca Conversi, Asantha Cooray, Darren Dowell, Naomi Dubois, Eli Dwek, Simon Dye, Steve Eales, David Elbaz, Duncan Farrah, Patrizia Ferrero, Matt Fox, Alberto Franceschini, Walter Gear, Elodie Giovannoli, Jason Glenn, Eduardo Gonzalez-Solares, Matt Griffin, Mark Halpern, Martin Harwit, Evanthia Hatziminaoglou, Sebastian Heinis, Peter Hurley, HoSeong Hwang, Edo Ibar, Olivier Ilbert, Kate Isaak, Rob Ivison, Guilaine Lagache, Louis Levenson, Nanyao Lu, Suzanne Madden, Bruno Maffei, Georgios Magdis, Gabriele Mainetti, Lucia Marchetti, Gaelen Marsden, Jason Marshall, Angela Mortier, Hien Nguyen, Brian O'Halloran, Seb Oliver, Alain Omont, Francois Orieux, Mathew Page, Pasquale Panuzzo, Andreas Papageorgiou, Harsit Patel, Chris Pearson, Ismael Perez-Fournon, Michael Pohlen, Jason Rawlings, Gwen Raymond, Dimitra Rigopoulou, Laurie Riguccini, Davide Rizzo, Giulia Rodighiero, Isaac Roseboom, Michael Rowan-Robinson, Miguel Sanchez-Portal, Bernhard Schulz, Douglas Scott, Nick Seymour, David Shupe, Anthony Smith, Jason Stevens,, Myrto Symeonidis, Markos Trichas, Katherine Tugwell, Mattia Vaccari, Elisabetta Valiante, Ivan Valtchanov, Joaquin Vieira, Laurent Vigrouz, Lingyu Wang, Rupert Ward, Don Wiebe, Gillian Wright, Kevin Xu, and Mike Zemcov, + *Consultants and Working Members*

Faculty and Researchers, Postdocs, Students

The HerMES Bibliography

Science Demonstration Phase Papers (9)

HerMES: The SPIRE confusion limit Nguyen et al. 2010, A&A 518, L5
The HerMES SPIRE submillimeter local luminosity function Vaccari et al. A&A 2010, 518, L20
HerMES: SPIRE galaxy number counts at 250, 350, and 500 μm Oliver et al. 2010, A&A 518, L21
Halo occupation number and bias properties of dusty galaxies from clustering measurements , Cooray et al. 2010, A&A 518, L22
First results from HerMES on the evolution of the submillimetre luminosity function, Eales et al. A&A 2010, 518, L23
Herschel unveils a puzzling uniformity of distant dusty galaxies, Elbaz et al. A&A 2010, 518, L29
The far-infrared/radio correlation as probed by Herschel, Ivison et al. A&A 2010, 518, L31
HerMES: The submillimeter spectral energy distributions of Herschel/SPIRE-detected galaxies, Schulz et al. 2010, A&A 518, L32
HerMES: Far infrared properties of known AGN in the HerMES fields, Hatziminaoglou et al. 2010, A&A 518, L33

Papers since SDP (23)

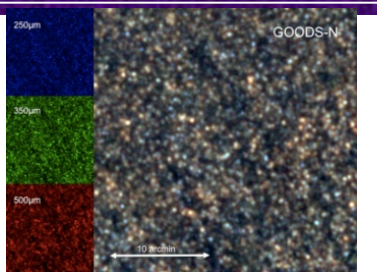
HerMES: Lyman-Break Galaxies Individually Dete
Modeling of the Hermes J105751.1+573027 Lense
Dynamical Structure of the Molecular interstellar M
Redshift Determination and CO Line Excitation Mo
Discovery of a Multiply-Lensed Submillimeter Gala
HerMES: Cosmic Magnification of Sub-mm Galaxi
HerMES: SPIRE Emission from Radio-Selected A
Galactic Nuclei, Seymour et al., 2011, MNRAS, 413, 1777.
Sub-millimetre Galaxies Reside in Dark Matter Halos with M > 3e11 Solar Masses, Amblard et al, 2011, Nature, 470, 510.
Measures of star formation rates from FIR and UV emissions of galaxies in HerMES fields, Buat et al. 2010, MNRAS 409, L1.
HerMES: Far-Infrared observations of Lyman Break Galaxies, Rigopoulou 2010, MNRAS 409, L7
The Deep SPIRE HerMES Survey: Secure SEDs and their Astrophysical Indications, Brisbin et al. 2010, MNRAS 409, 66.
Herschel-SPIRE, Far-Infrared Properties of Millimetre-Bright and -Faint Radio Galaxies, Chapman et al. 2010, MNRAS 409.
HerMES : SPIRE detection of high redshift massive compact galaxies in GOODS-N field, Cava et al. 2010, MNRAS 409, L19.
Cold dust and young starbursts: SEDs of SPIRE sources from HerMES, Rowan-Robinson et al. 2010, MNRAS 409, 2.
Herschel reveals a T_{dust} - unbiased selection of z≈2 ULIRGs, Magdis et al. 2010 MNRAS 409, 22.
HerMES: Source Extraction and Cross-IDs in Confusion-Limited SPIRE Images, Roseboom et al. 2010, MNRAS 409, 48.
Evolution of Dust Temperature of Galaxies through Cosmic Time as seen by Herschel, Hwang et al. 2010 MNRAS 409, 75.
HerMES: SPIRE Science Demonstration Phase Maps, Levenson et al. 2010 MNRAS 409, 83.
HerMES: Deep Galaxy Number Counts from P(D) of SPIRE SDP Observations, Glenn et al. 2010, MNRAS 409, 109.
HerMES: The X-Ray Infrared Correlation of Star-Forming Galaxies at z ~ 1, Symeonidis et al. 2011, MNRAS, in press.
HerMES: Point Source Catalogs from Deep Herschel-SPIRE Observations, Smith et al. 2011, arXiv 1109.5186
The Herschel Multi-Tiered Extragalactic Survey: SPIRE-mm Photometric Redshifts, Roseboom et al. 2011, arXiv 1109.2887
The Herschel Multi-Tiered Extragalactic Survey: HerMES, Oliver et al. 2011, MNRAS, in press.

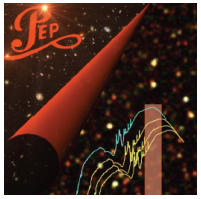
HerMES DR1 key papers
18 central and cohesive publications coming soon!

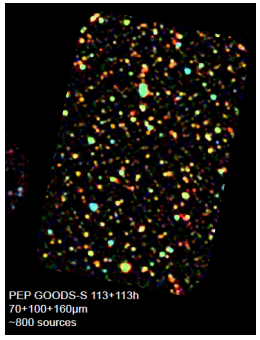
Herschel Large High-z Surveys

HerMES: *Herschel* Multi-tiered Extragalactic Survey

- PACS + SPIRE
- 70 sq deg from 20′×20′ to 3.6°×3.6° (900 hours) + 12 clusters
- Bolometric luminosities of galaxies, cosmic SFH
- Wedding cake to probe range of luminosities and environments





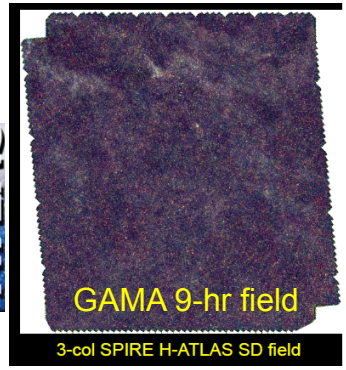


PEP: PACS Evolutionary Probe

- PACS only
- 2.7 sq deg from 10′×15′ to 85′×85′ (655 hours) + 10 clusters
- Resolve CFIRB; L_{FIR} & SFRs

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

- PACS + SPIRE
- 550 sq deg (600 hours)
- Large-scale structure, AGN, rare objects
- Expect ~500,000 detections to z~3, majority at 250 & 350 um



H-GOODS: Herschel-Great Observatories Origins Deep Survey

- PACS very deep imaging of the GOODS Field (330 hours)
- SPIRE deep imaging of the GOODS Field (30 hours)

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

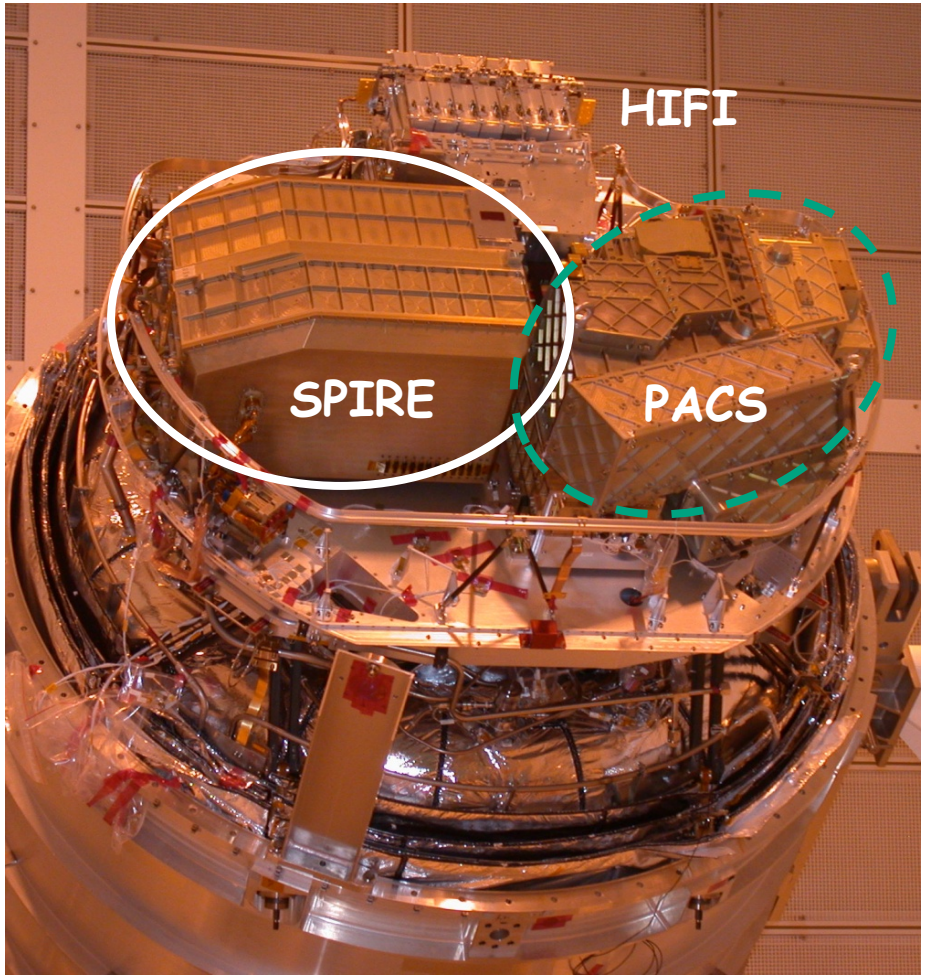
Imaging FTS

- 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

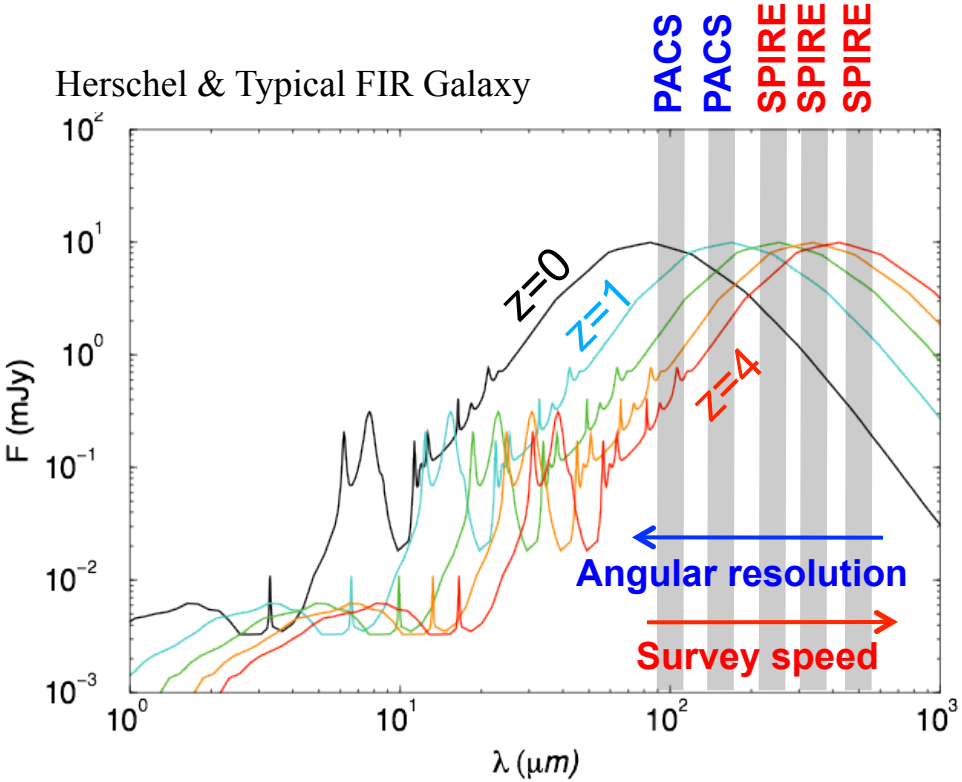
- Sensitivity limited by thermal emission from the telescope
- ^{3}He cooled detector arrays (0.3 K)
- Feedhorn-coupled spider-web bolometers
- Minimal use of mechanisms
  Beam steering mirror; FTS mirror drive
- Optimized for scan-mapped surveys

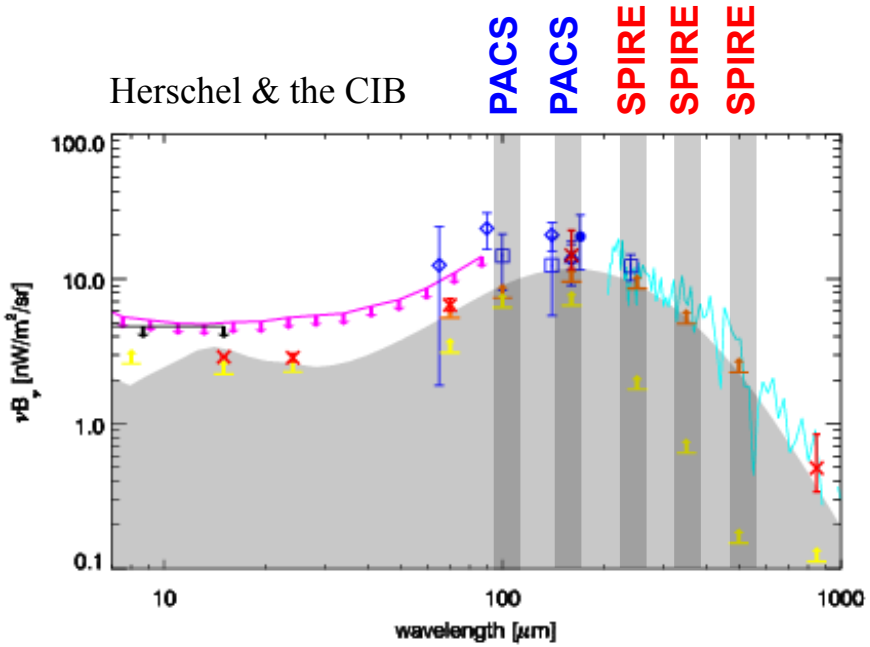


HerMES Science Motivation

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 Surveys

- Observe at SED peak
- Bolometric far-IR luminosities
- Large and uniform samples

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

Use Best Ancillary Fields Available

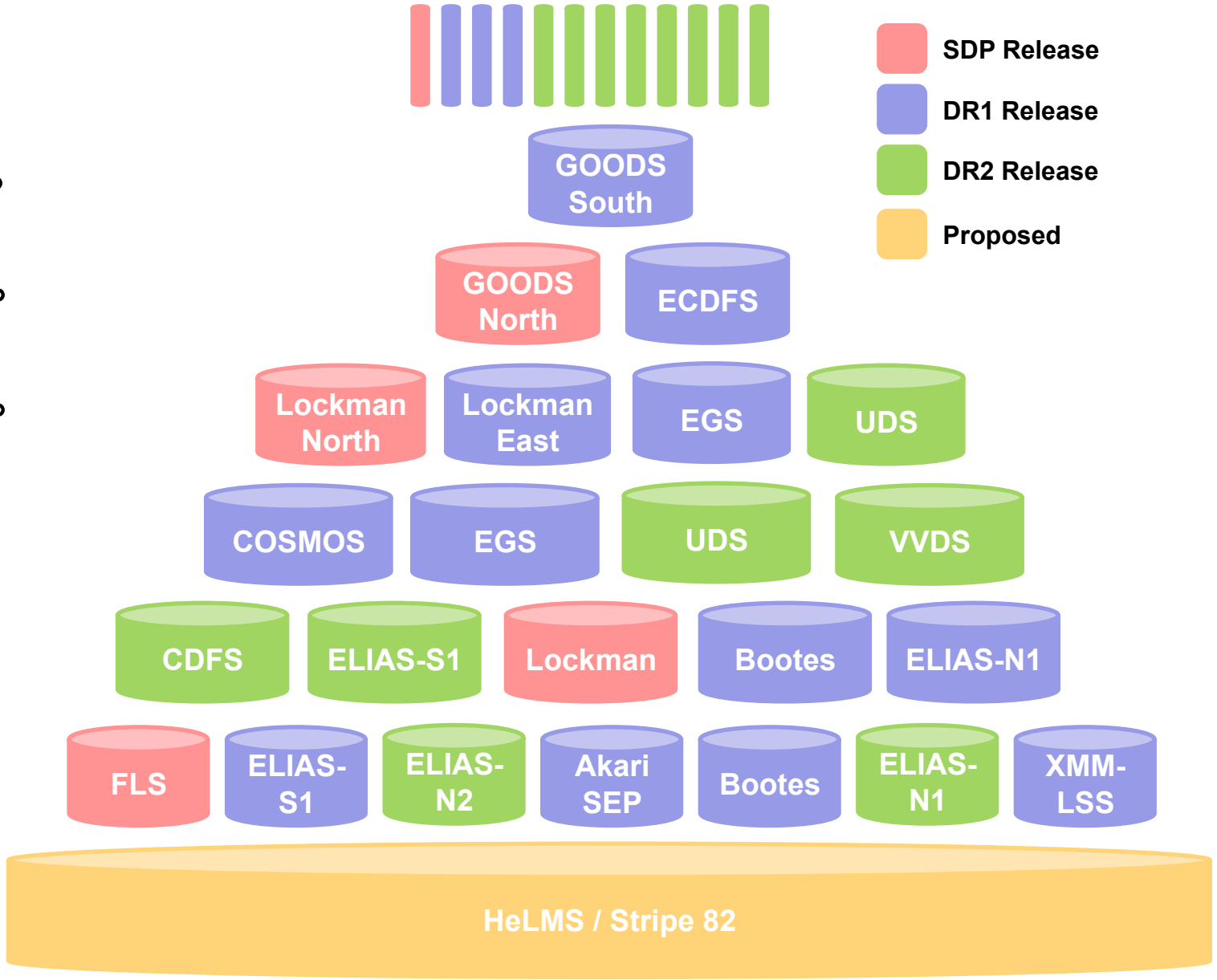
- Fields with Spitzer, Radio, Optical, NIR, X-ray, etc data

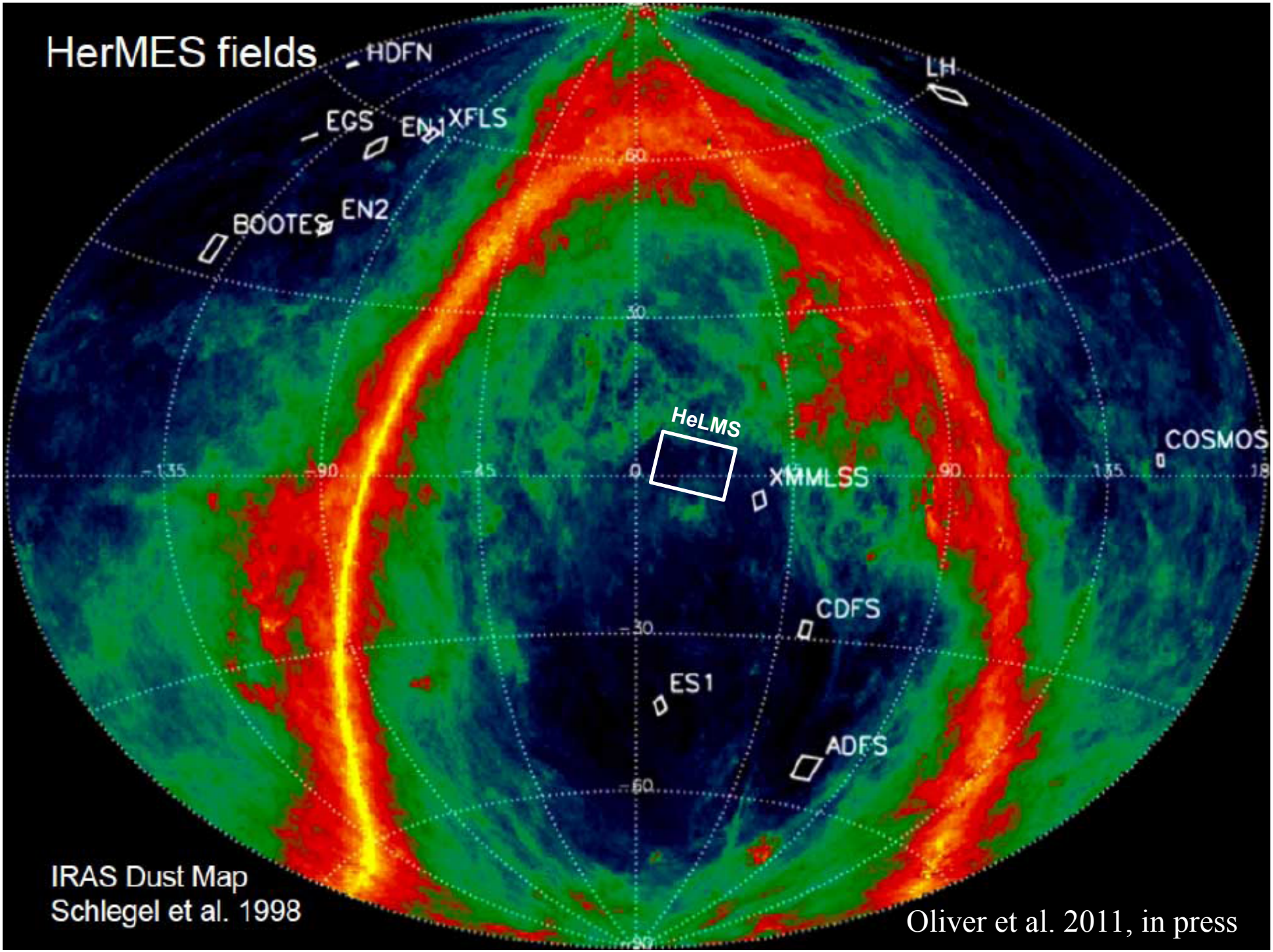
Do What Herschel Does Best

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

HerMES: Wedding Cake Survey

Clusters	
L1	0.11 □°
L2	0.36 □°
L3	1.25 □°
L4	4 □°
L5	30 □°
L6	40 □°
L7	270 □°

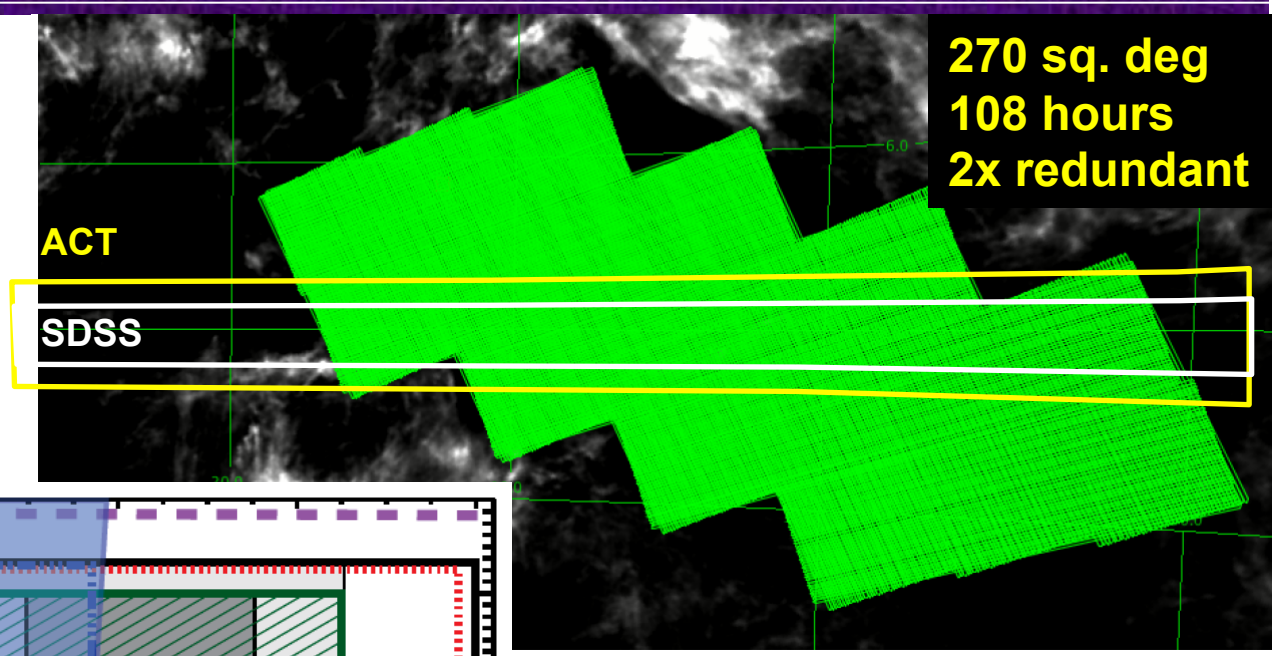


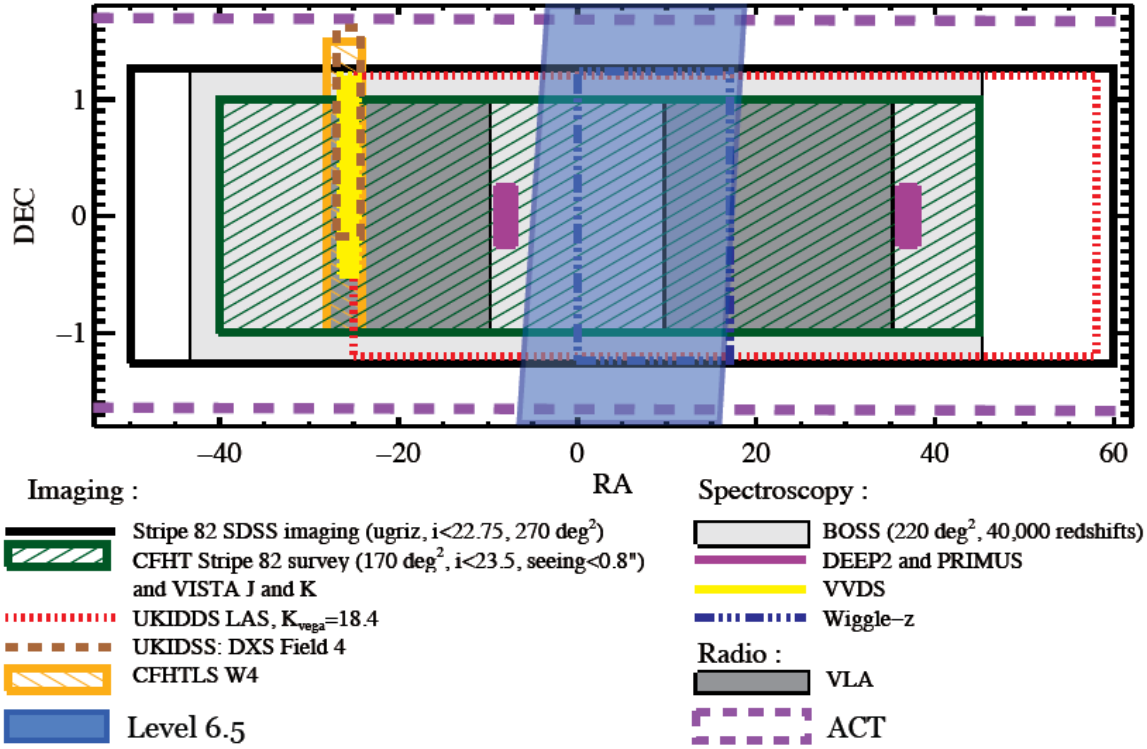

HerMES fields
HDFN
EGS
EN1
XFLS
BOOTES
EN2
LH
HeLMS
COSMOS
XMMLSS
CDFS
ES1
ADFS
IRAS Dust Map
Schlegel et al. 1998
Oliver et al. 2011, in press

HeLMS: A Cross-Linked Shallow Survey

Ancillary Data Science

- **BOSS** ~10^6 LRGs, z = 2 quasars
- **Hetdex** Ly-α galaxies out to z ~ 4
- **ACT** mm-wave CMB survey
- **SDSS, UKIDSS, VLA, Wiggle-z**
- Great legacy value



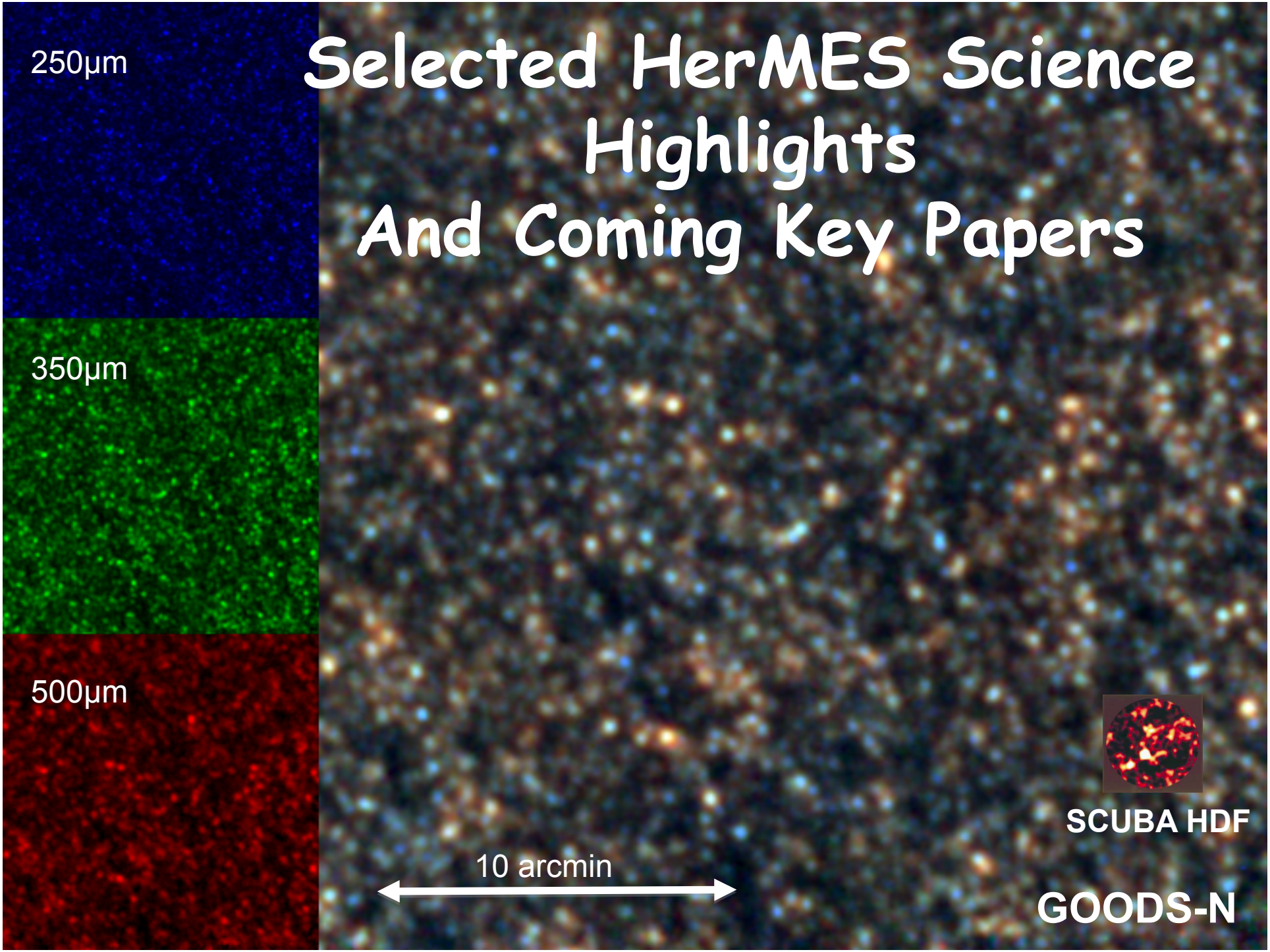


Luminous Sources

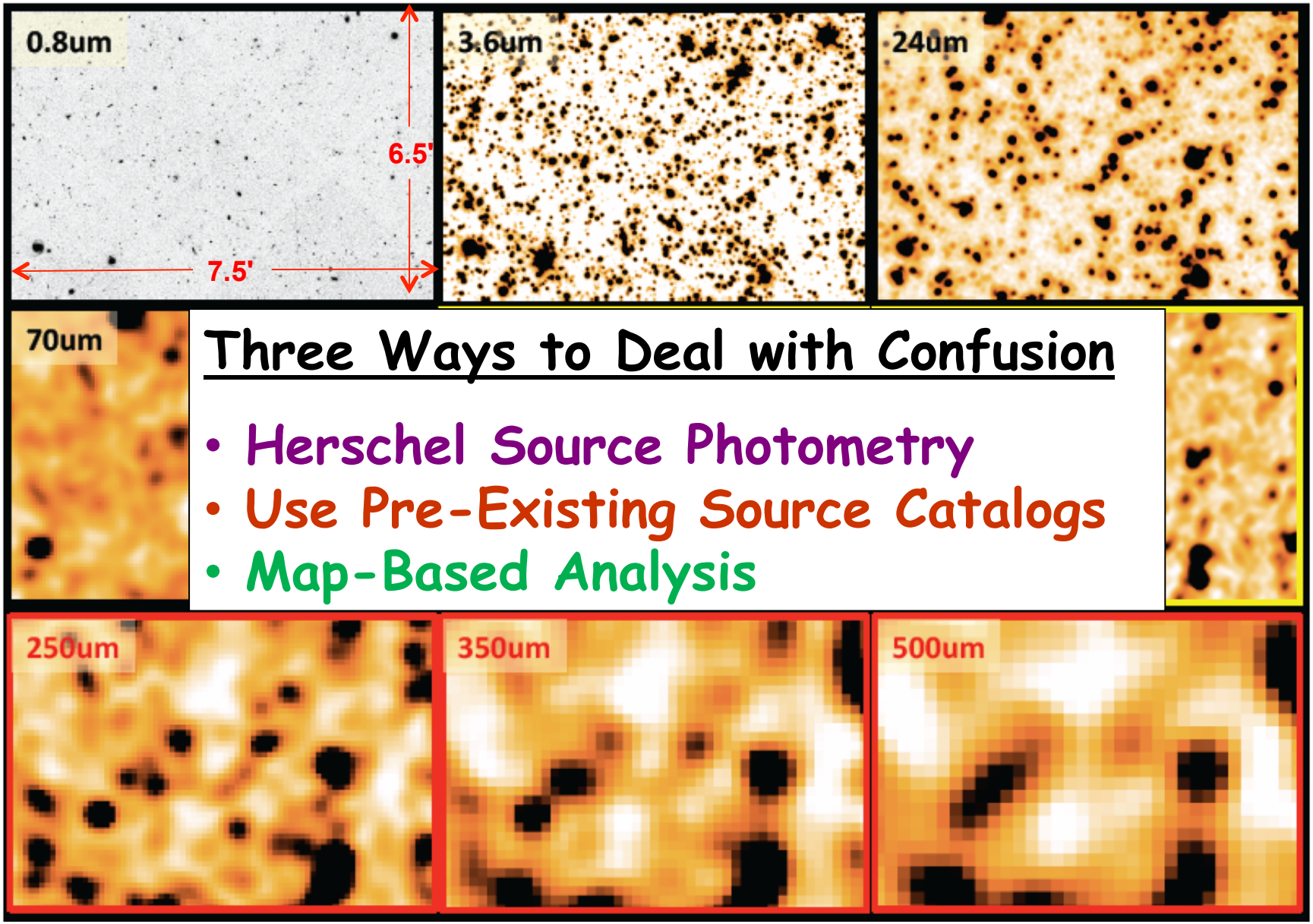
- ~25,000 galaxies at 5σ at 250 um
- ~250 lensed galaxies

Background Fluctuations:

- Extends galaxy x galaxy coverage to ℓ ~ 100
- CMB anisotropies x FIR galaxies
- CMB lensing x FIR galaxies


250μm
350μm
500μm
Selected HerMES Science Highlights And Coming Key Papers
SCUBA HDF
10 arcmin
GOODS-N

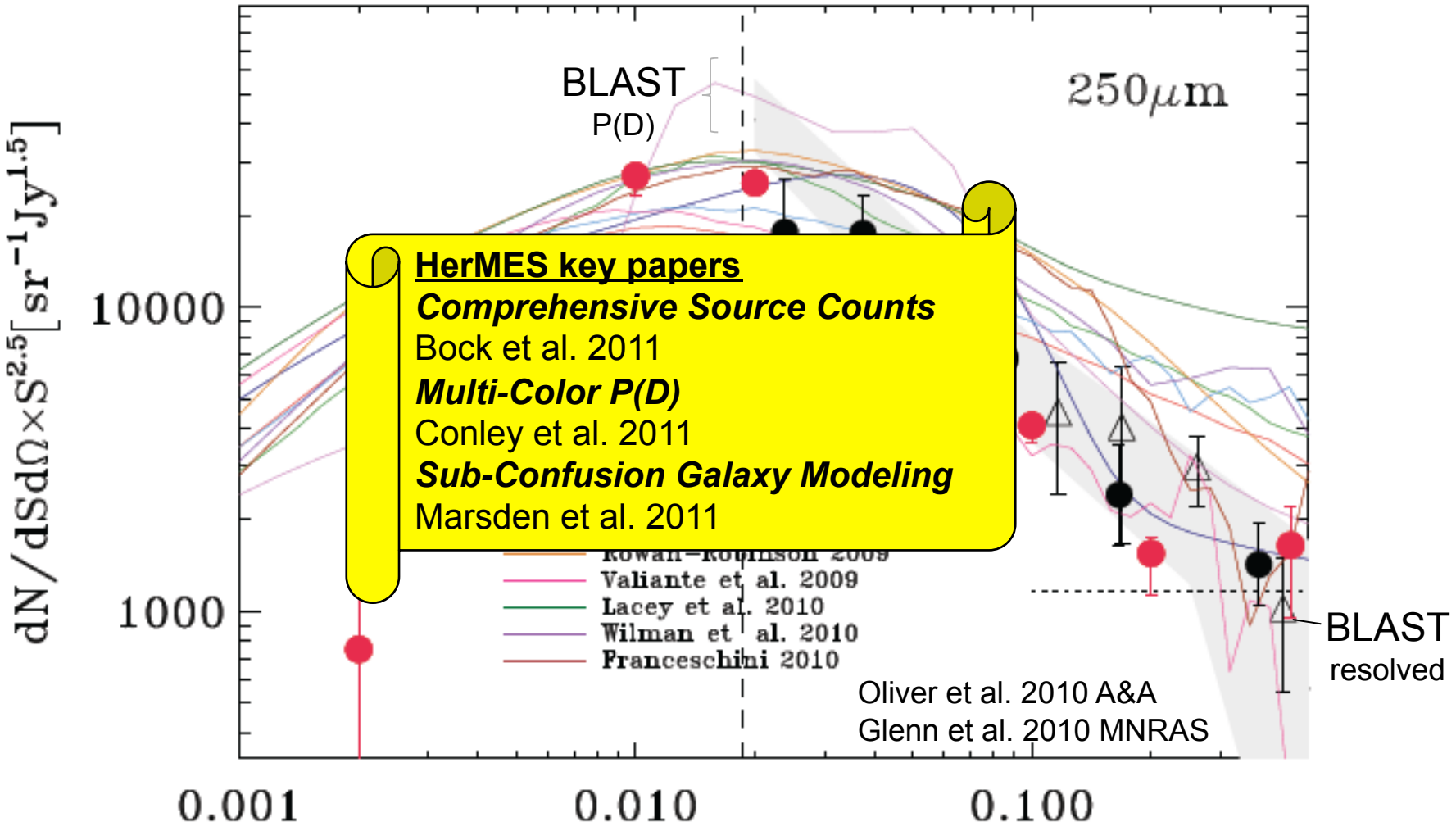
The Confusion Challenge



The SPIRE Confusion Limit, H. Nguyen et al. 2010, A&A

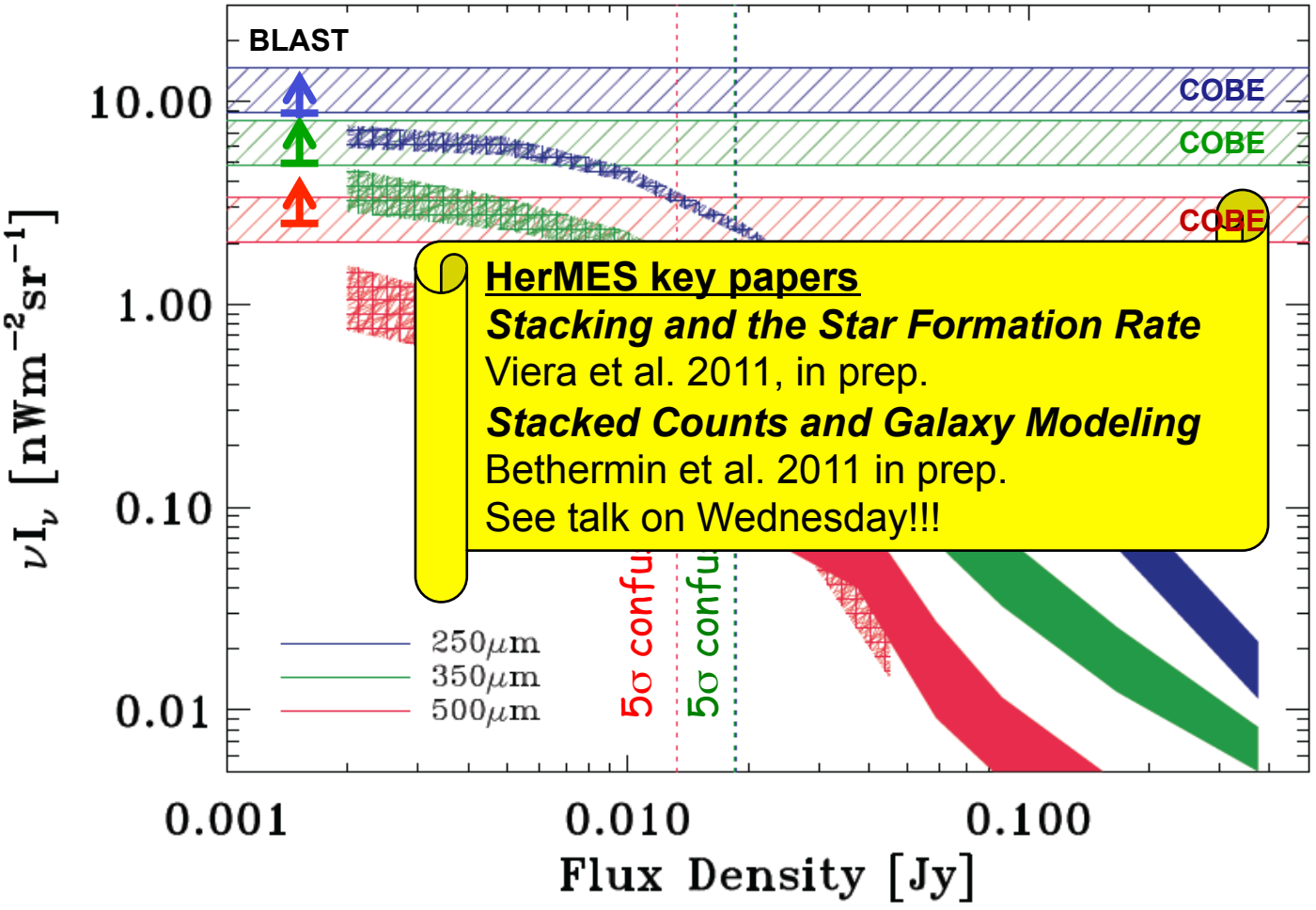
D. Elbaz

SPIRE Source Counts



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

CIB Resolved into Point Sources



HerMES key papers

Stacking and the Star Formation Rate
Viera et al. 2011, in prep.

Stacked Counts and Galaxy Modeling
Bethermin et al. 2011 in prep.
See talk on Wednesday!!!

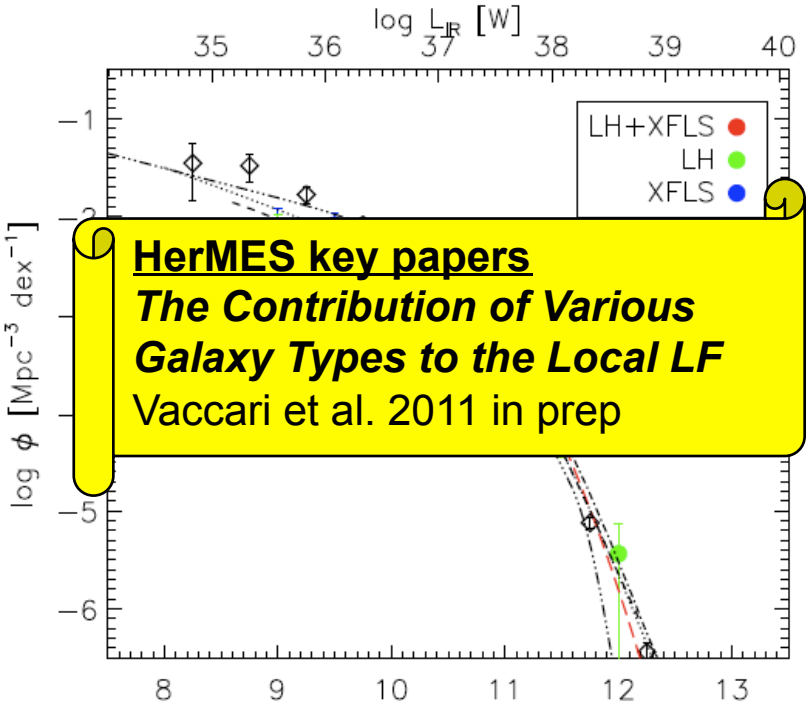
- **Source Counts**
  250, 350, 500 μm
  15%, 10%, 6%
- **P(D)**
  250, 350, 500 μm
  65%, 60%, 45%
- **Stacking** in prep
  With BLAST:
  250, 350, 500 μm
  80%, 80%, 85%

Marsden et al. 2010

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

Strong Luminosity Evolution

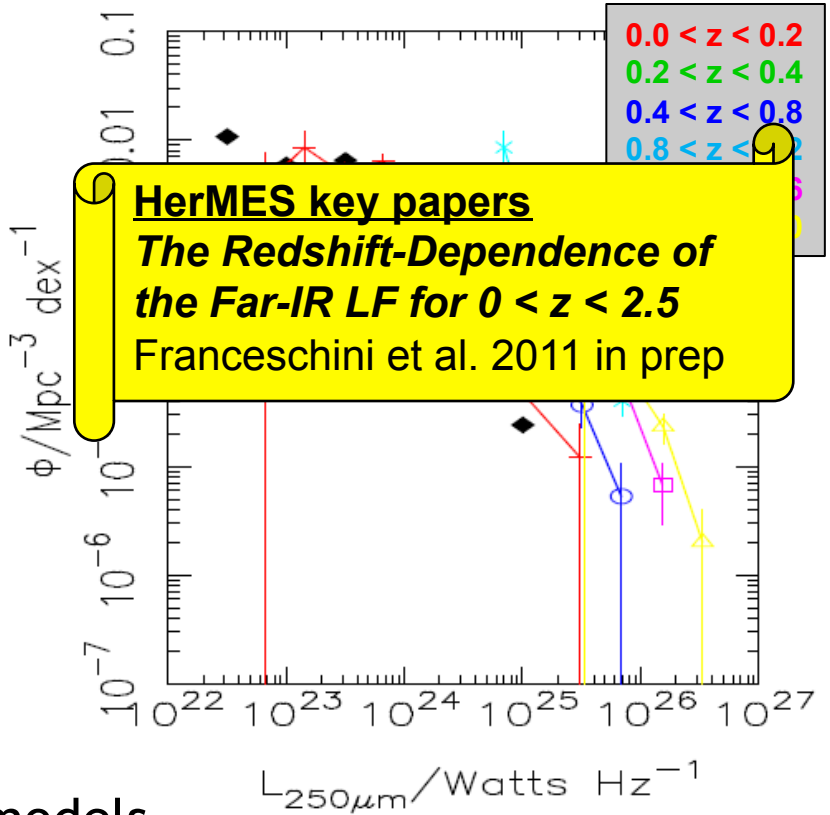
Local Luminosity Function



HerMES key papers
The Contribution of Various Galaxy Types to the Local LF
Vaccari et al. 2011 in prep

Vaccari et al. (2010)

HerMES Rest-Frame 250 μm LF



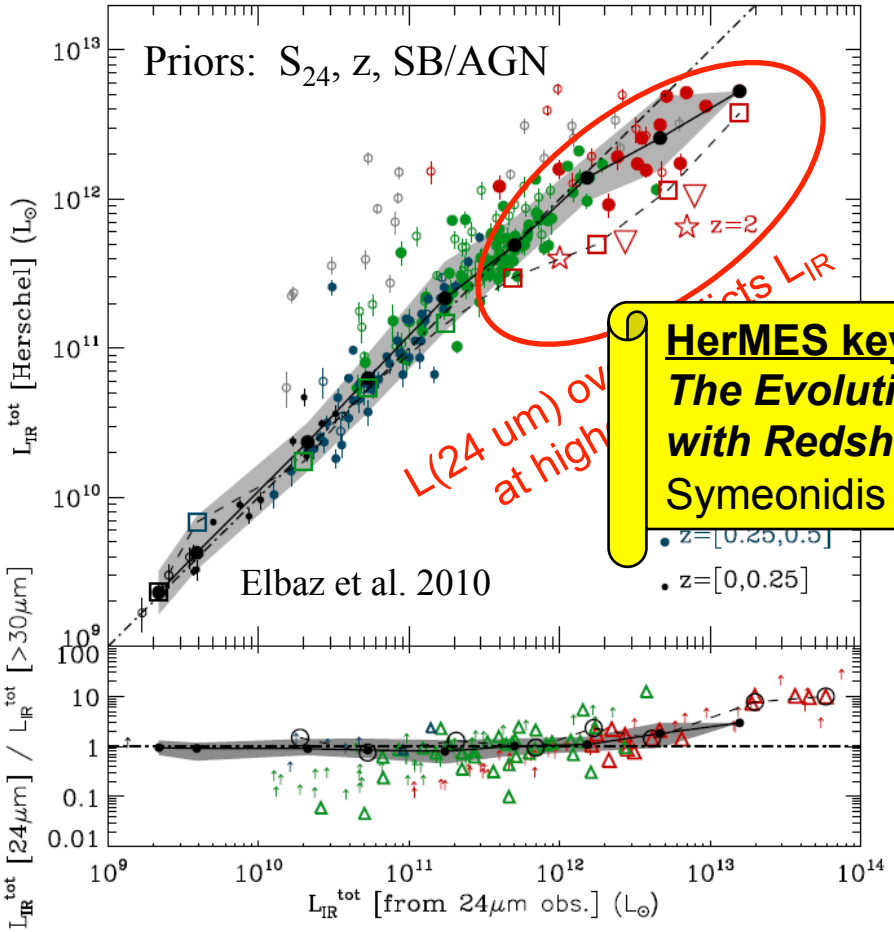
HerMES key papers
The Redshift-Dependence of the Far-IR LF for 0 < z < 2.5
Franceschini et al. 2011 in prep

Eales et al. (2010)

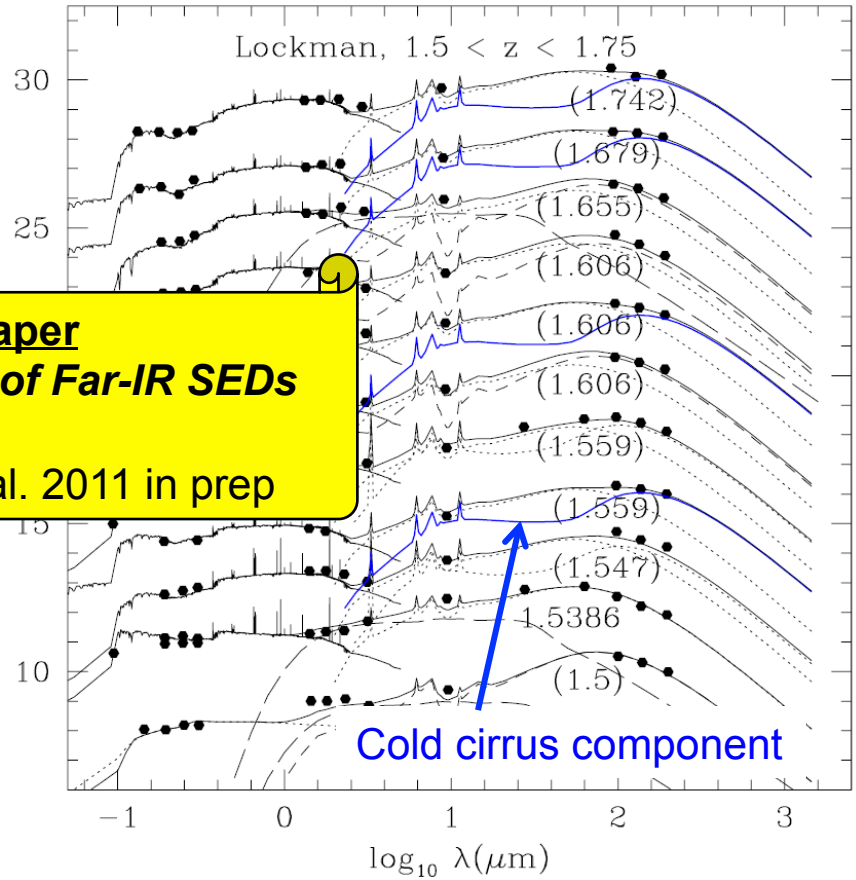
- Local sub-mm galaxy LF slightly above models
- Luminosity function increases out to z ~ 2
- Is it flattening out at z > 1?
- Next: better statistics from bigger samples

How Do Galaxy SEDs Evolve?

L_{IR} for Starbursts and AGNs



Multi-Wavelength SED Fits

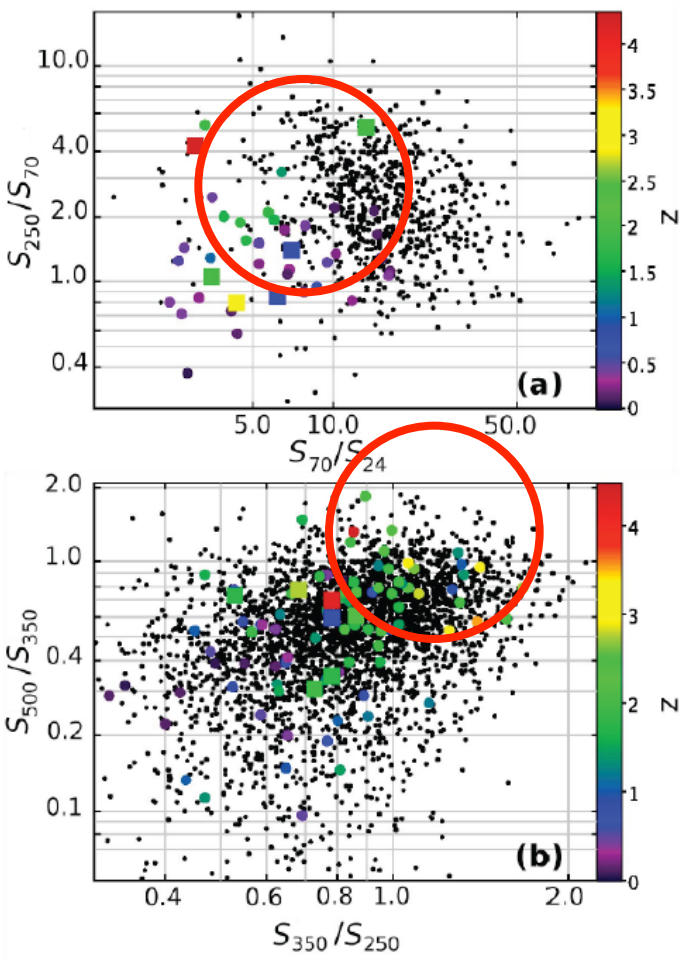


Rowan-Robinson et al. 2010

HerMES key paper
The Evolution of Far-IR SEDs with Redshift
Symeonidis et al. 2011 in prep

- *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)

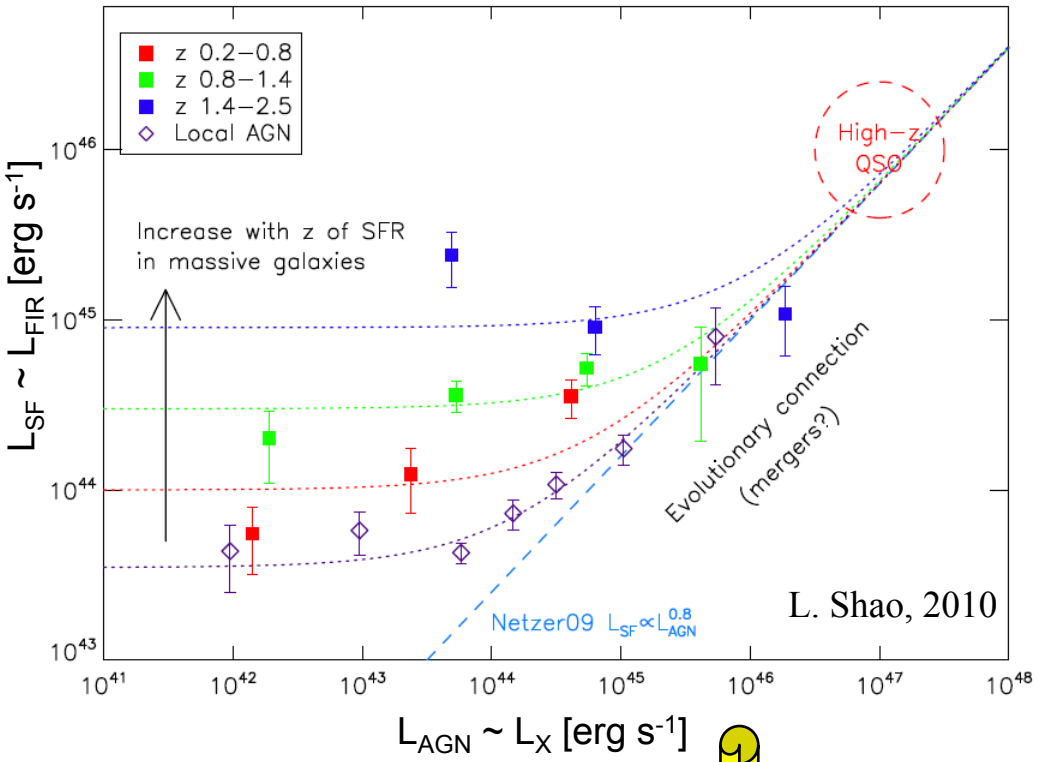
AGNs and Far-IR Galaxies



Distinct S_{70}/S_{24} colors, but not S_{250}/S_{350} S_{500}
- FIR emission due to star formation

E. Hatziminaoglou, 2010

Two Modes of Host & AGN Evolution?

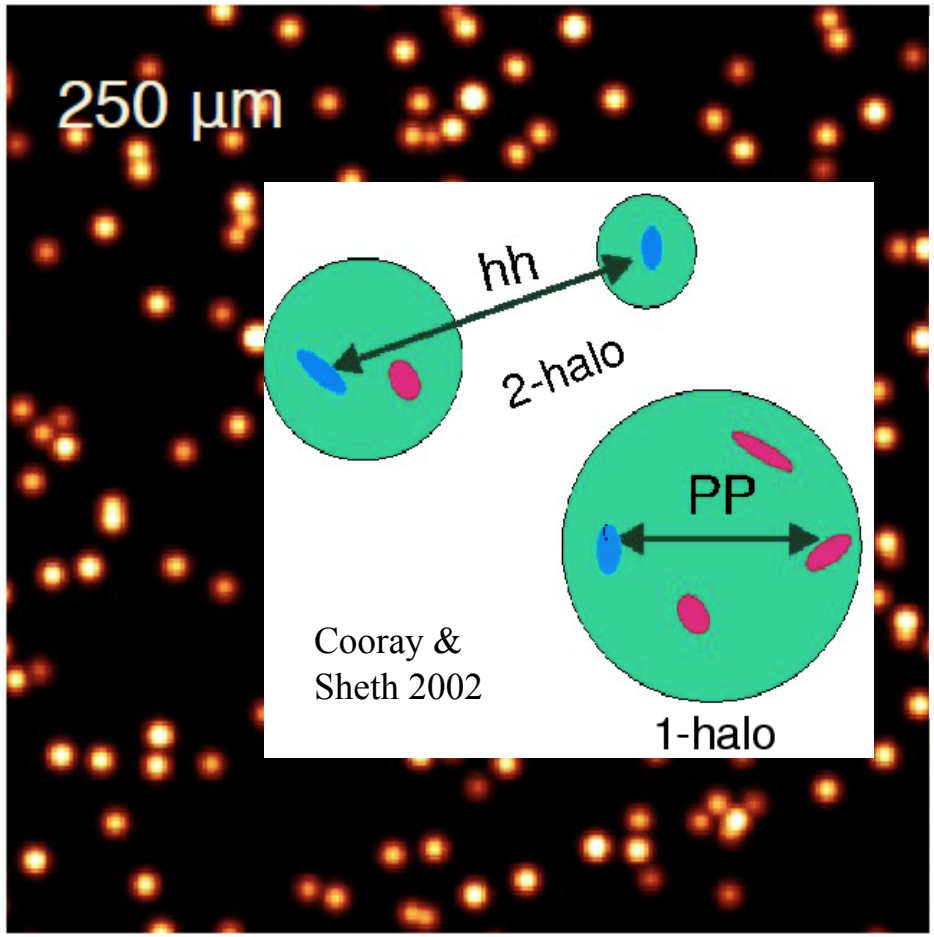


HerMES key paper
How do AGNs relate to SFR traced in SPIRE bands?
Page et al. 2011 in prep

L_{SF} w/ z
alaxies

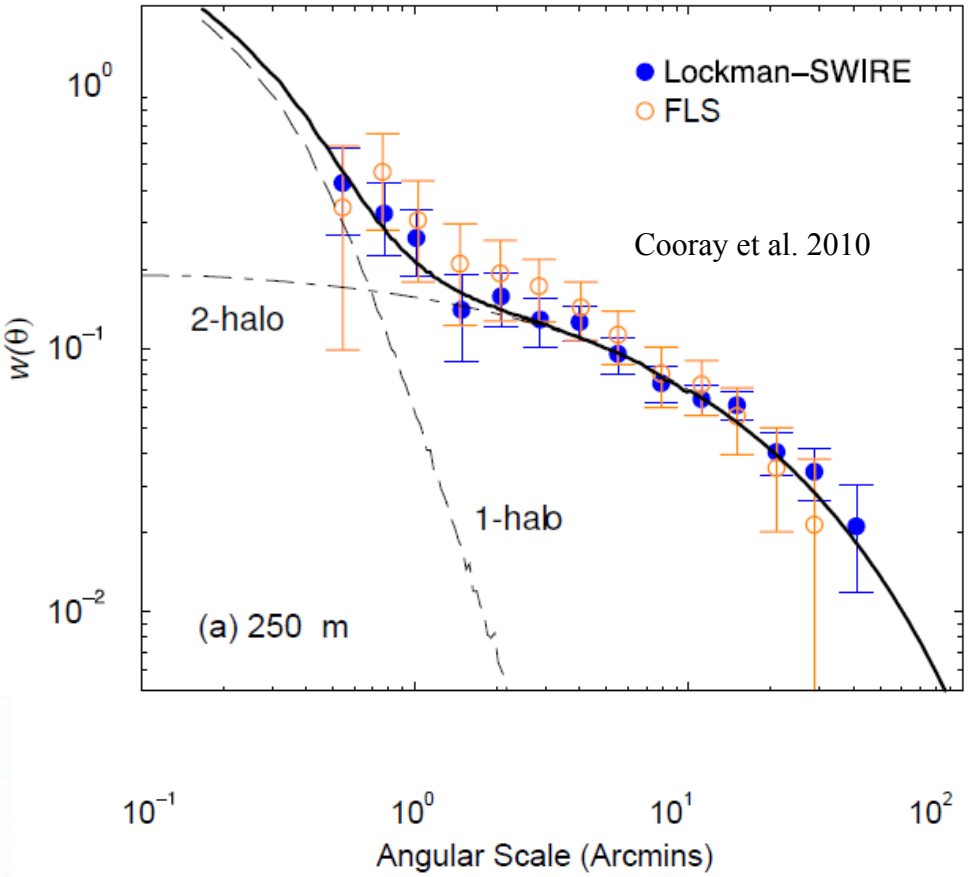
High L_{AGN}: Related to L_{SF}
- Trend is weaker
- Luminosities coupled by mergers?

Clustering From Point Sources



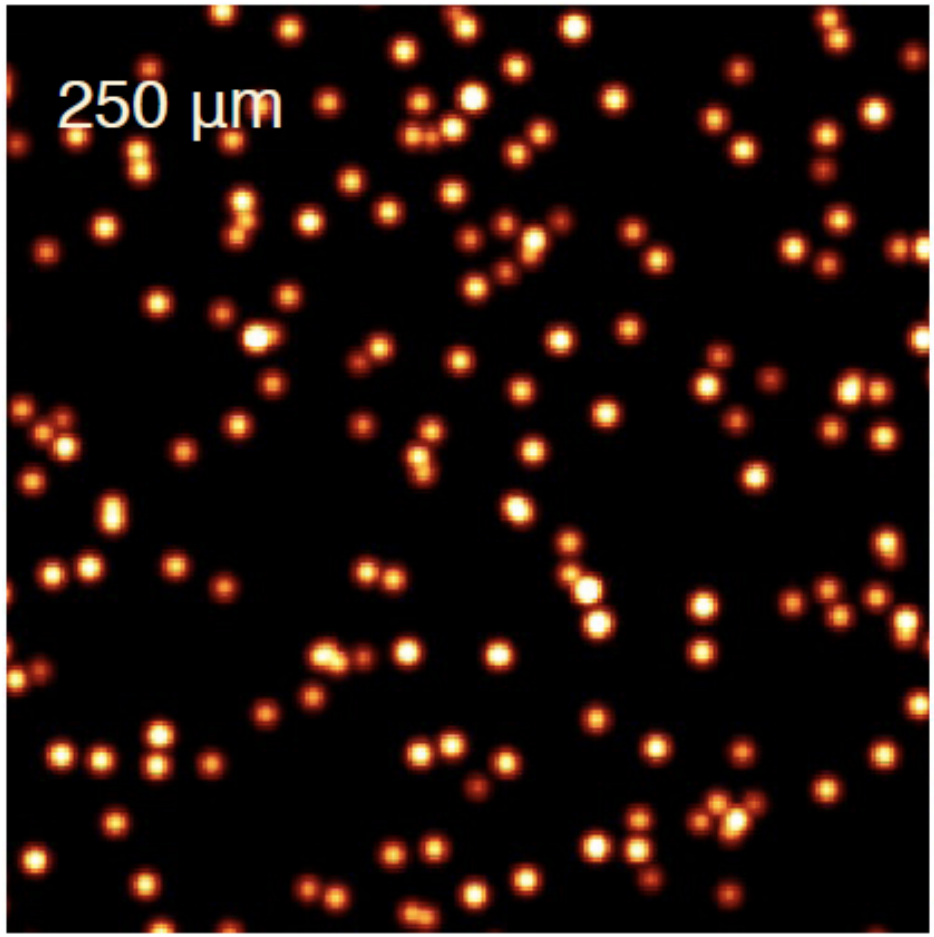
S > 20 mJy : 1,200/deg^2

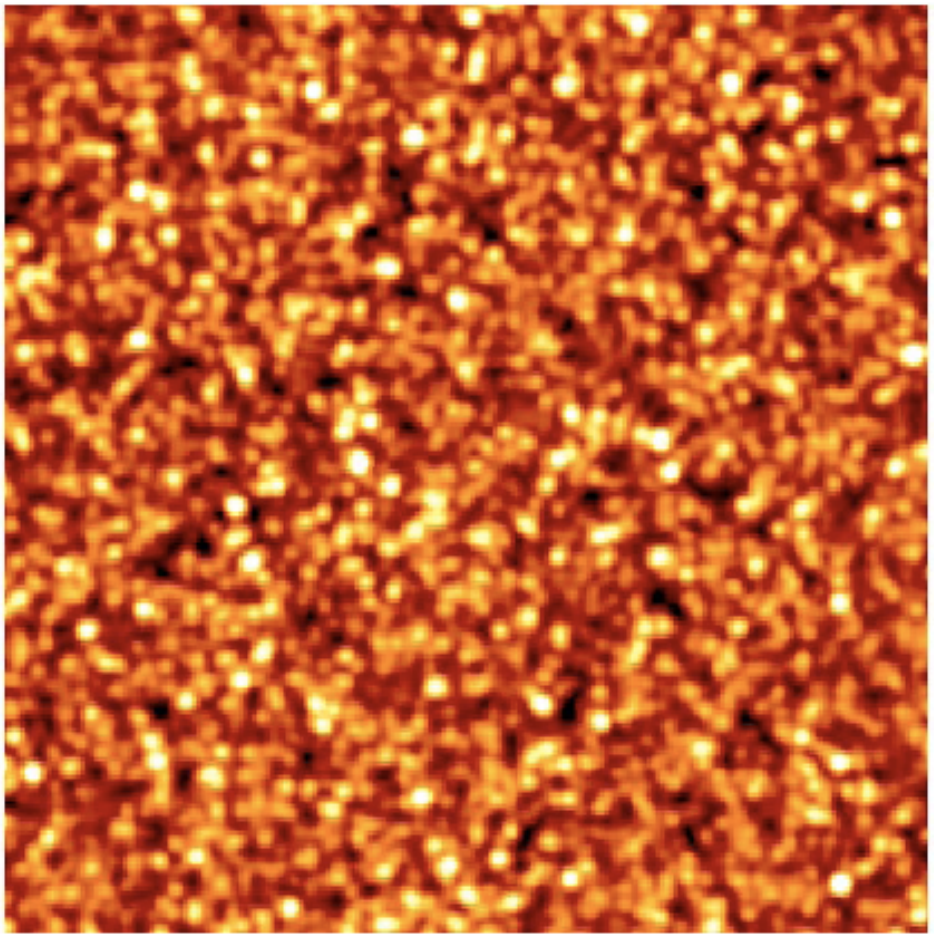
Angular Correlation of Detected Galaxies



- Halo hosting a > 30 mJy galaxy: M = $10^{12.6}$ M_{sun}
- Satellites in more massive halos M ~ $10^{13.1}$ M_{sun}

Use Maps to Measure Clustering





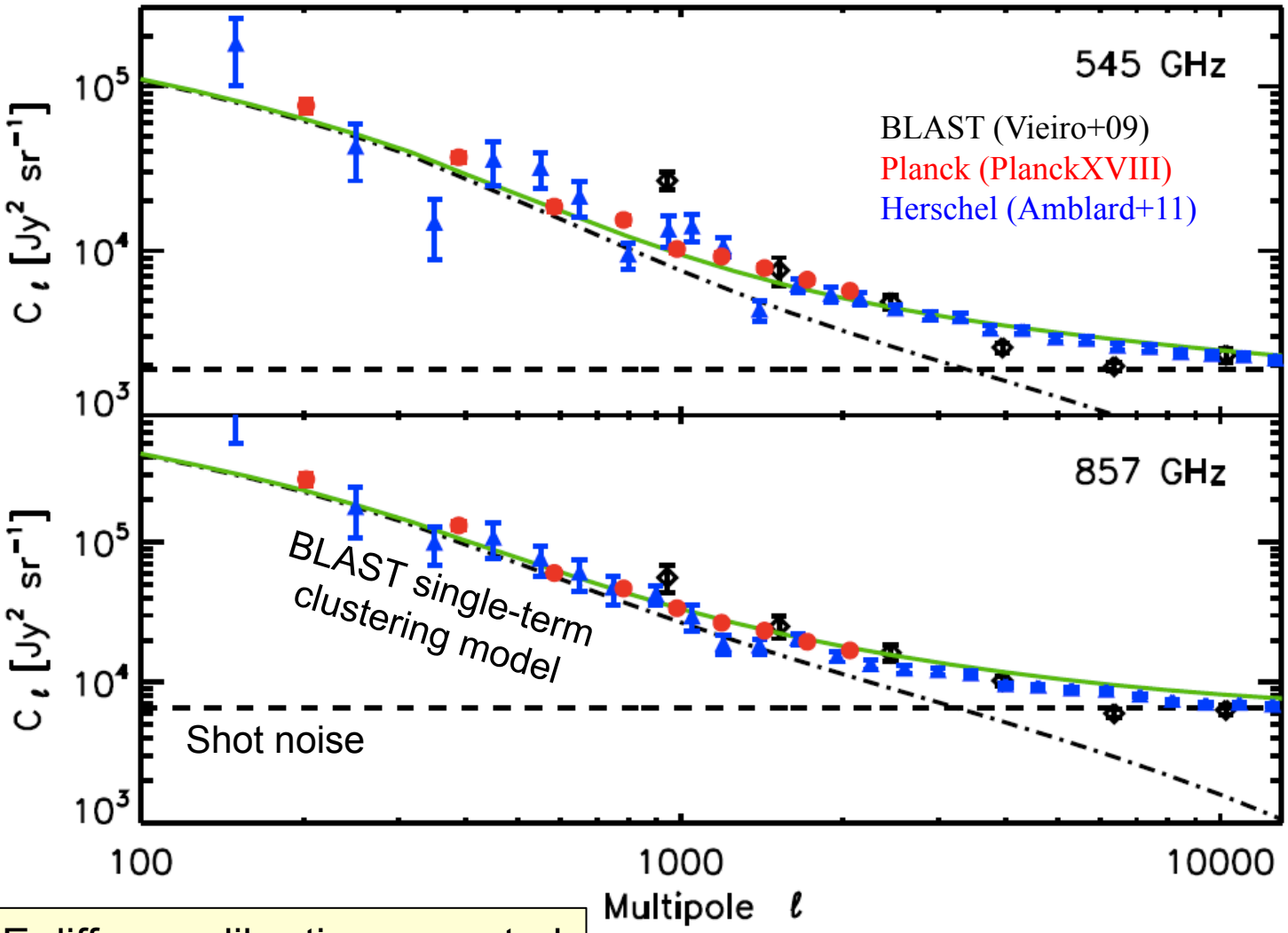
S > 20 mJy : 1,200/deg^2 S < 20 mJy : 480,000/deg^2

Large Scale Structure

Lockman Survey Field

3.6°

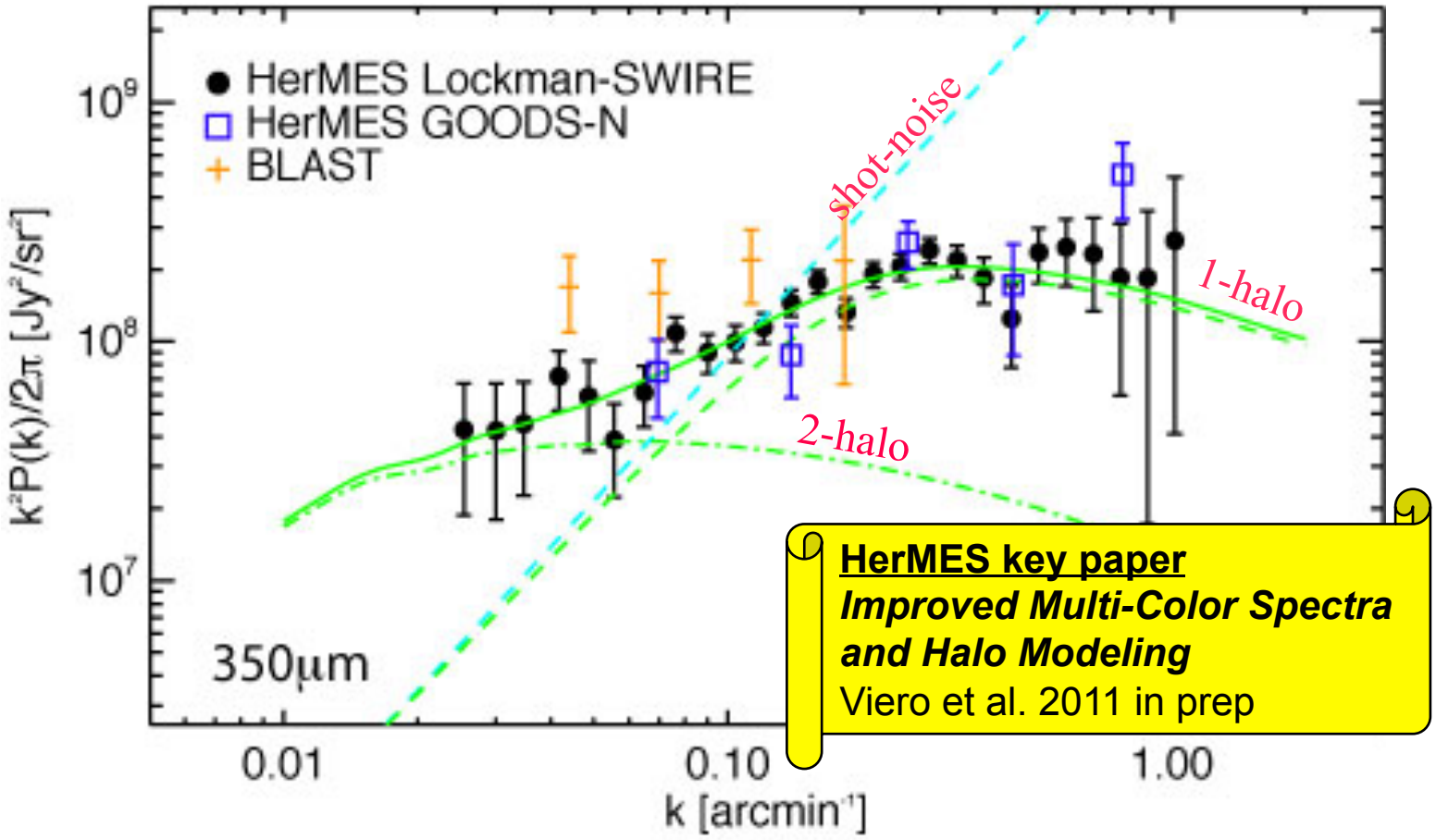
Combined EBL Spatial Power Spectra



- SPIRE diffuse calibration corrected
- BLAST flux cut
- No cirrus removal

From Planck XVIII (arXiv 1101.2028)

Non-Linear Galaxy Clustering

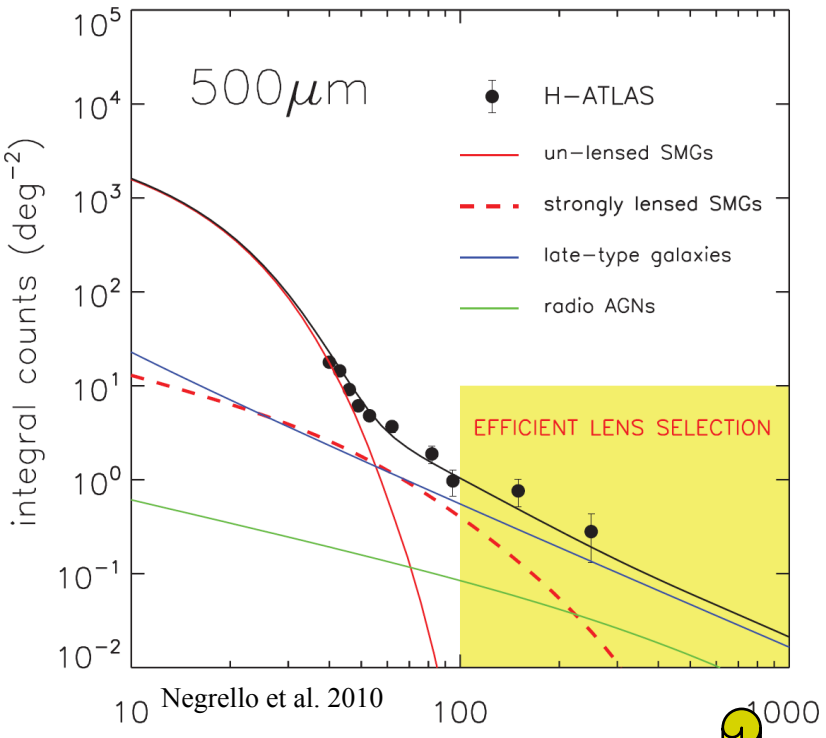


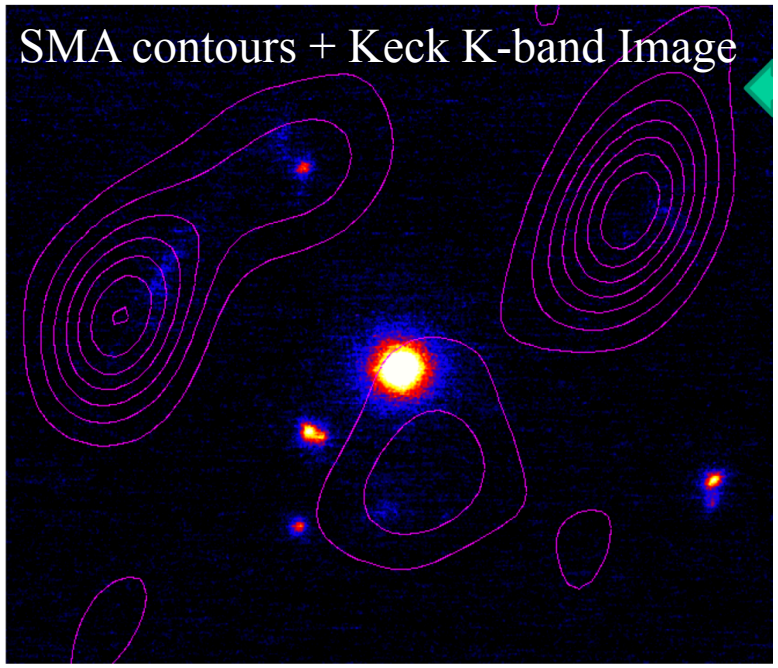
HerMES key paper
Improved Multi-Color Spectra and Halo Modeling
Viero et al. 2011 in prep

- Spectrum shown after removing shot noise and cirrus
- Clear 1-halo clustering seen
- Informs minimum halo mass ~3×10^{11} M_{sun}

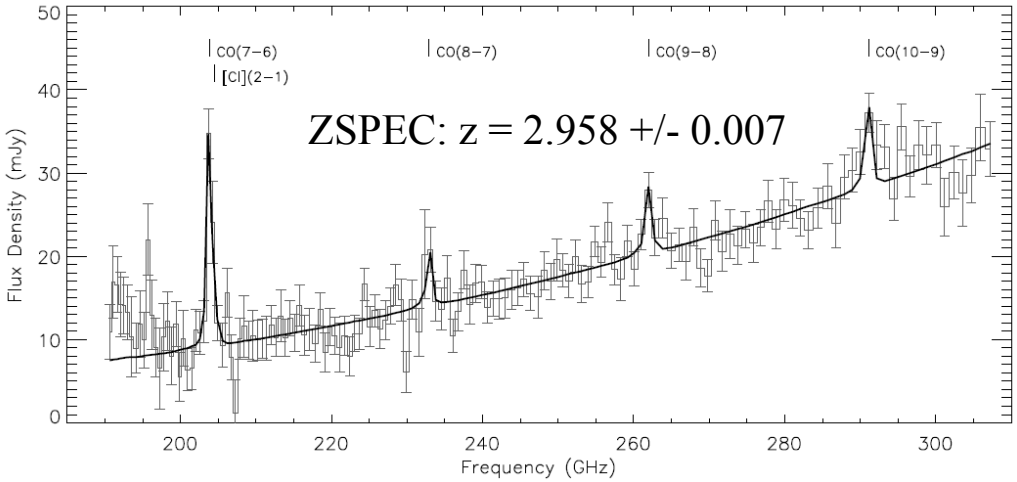
Lensing in Hermes by a Galaxy Group

Bright source found by HerMES: 420 mJy at 250 um





HerMES key paper
Lensing source statistics
Wardlow et al. 2011 in prep
Talk by A. Cooray on Monday

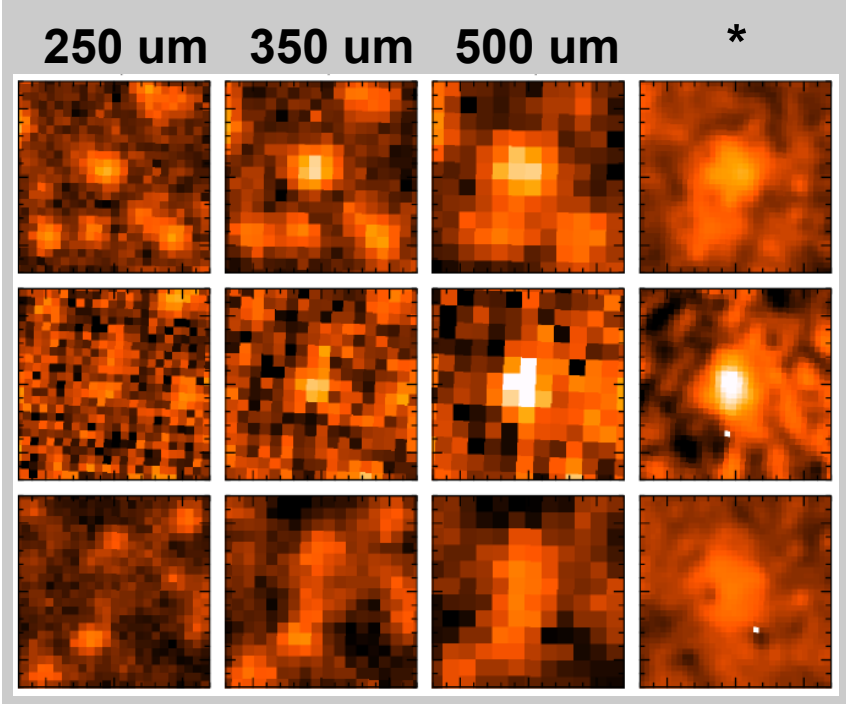


Gavazzi et al. 2011, Scott et al. 2011,
Conley et al. 2011, Riechers et al. 2011

High Redshift Galaxies in HerMES

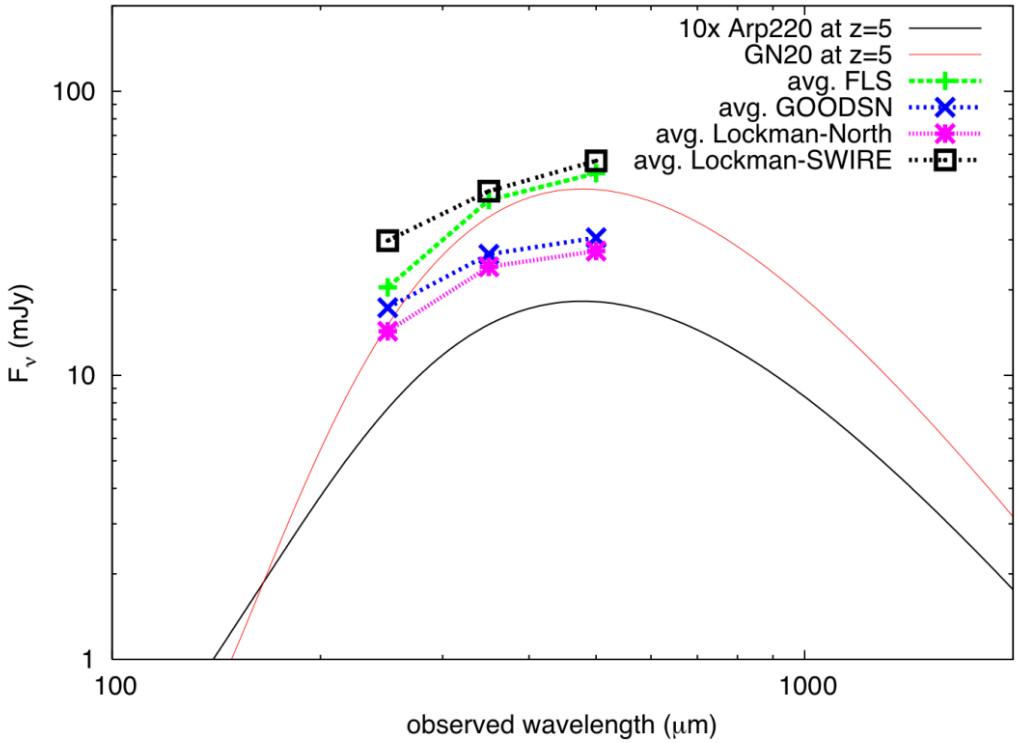
500 um peaked sources

Three examples:



***Confusion reduced S(500) – fS(250)**

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



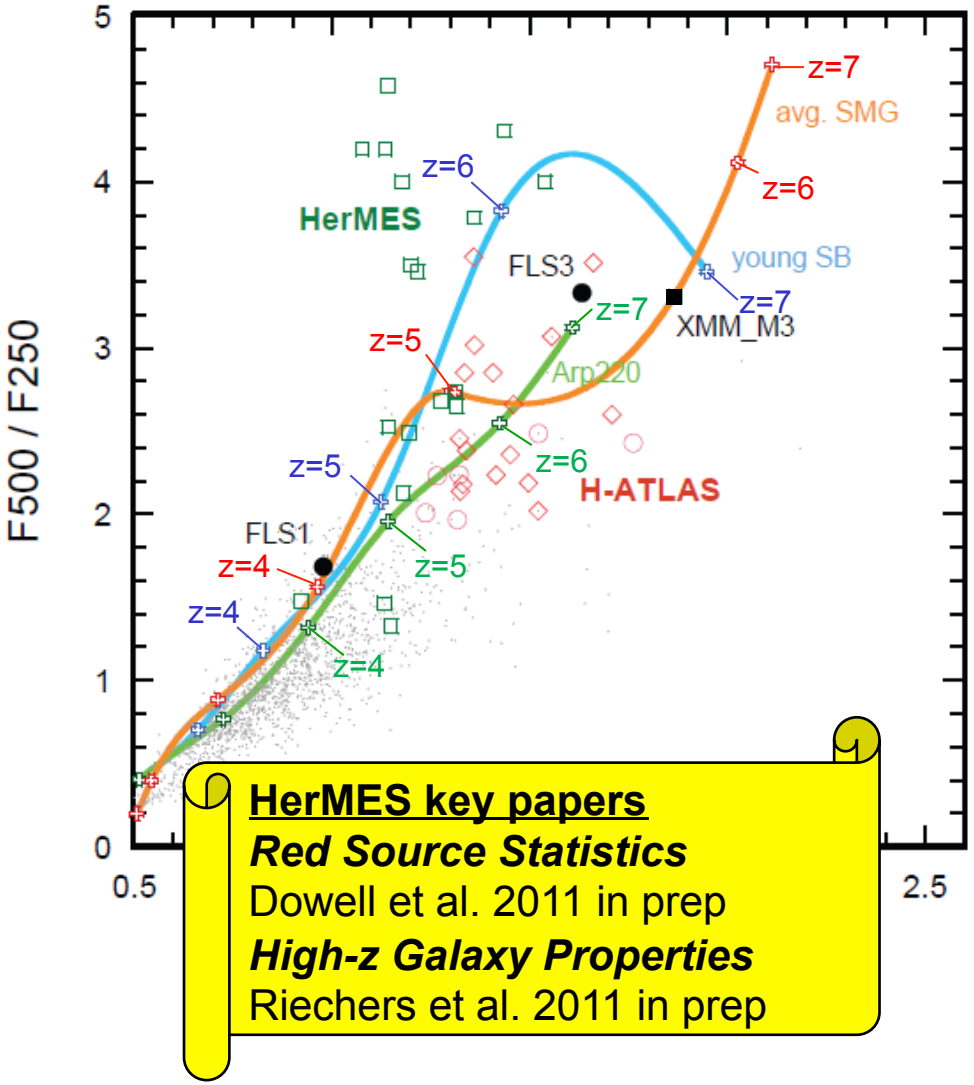
These could be:

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

$z = 5$, $T_{dust} = 45$ K HLIRGs…

High Redshift Candidates Follow-Up

FIR Photo-z Distributions



HerMES key papers

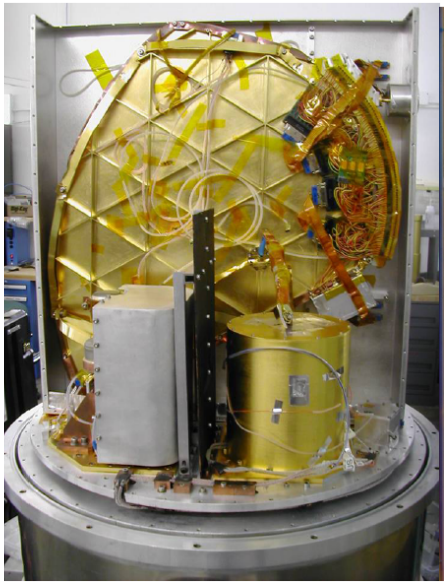
Red Source Statistics

Dowell et al. 2011 in prep

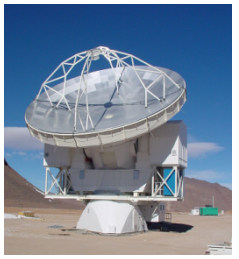
High-z Galaxy Properties

Riechers et al. 2011 in prep

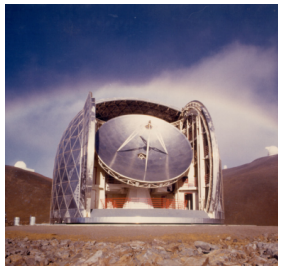
Obtain mm-wave redshifts (CO, C+)!!



ZSPEC: Bolometric spectrometer



APEX



CSO

PdBI

CARMA

HerMES: What's Coming Next?

ER2 Data Release!!!

Catalogs Now Available http://hedam.oamp.fr/HerMES/

- A2218
- L2 ECDFS
- L3/5 Lockman Hole
- L6 Bootes
- L6 FDS
- L6 XMM-LSS

DR1 Release: Key Papers C

+ Joint PEP/HerMES Projects
+ Collaboration Projects
+ Follow up Observations

HeLMS Shallow Survey App

DR2 Release at Mission Enc

See HerMES Talks at this conference

A. Cooray: Studies of Lensed Sources
D. Burgarella: HerMES Detections of Lyman-Break Galaxies
L. Wang: Halo Model of Galaxy Evolution
M. Bethermin: Constraints on the CIB
D. Farrah: Diagnostics of AGN Feedback