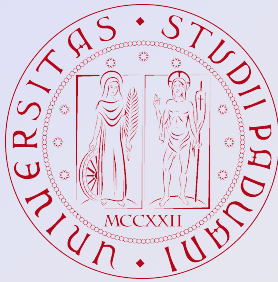


The Herschel Multi-tiered Extragalactic Survey (HerMES)

The Evolution of the FIR/SMM Luminosity Function and of the Cosmic SFRD



UNIVERSITÀ
DEGLI STUDI
DI PADOVA



Lucia Marchetti

University of Padova - Open University

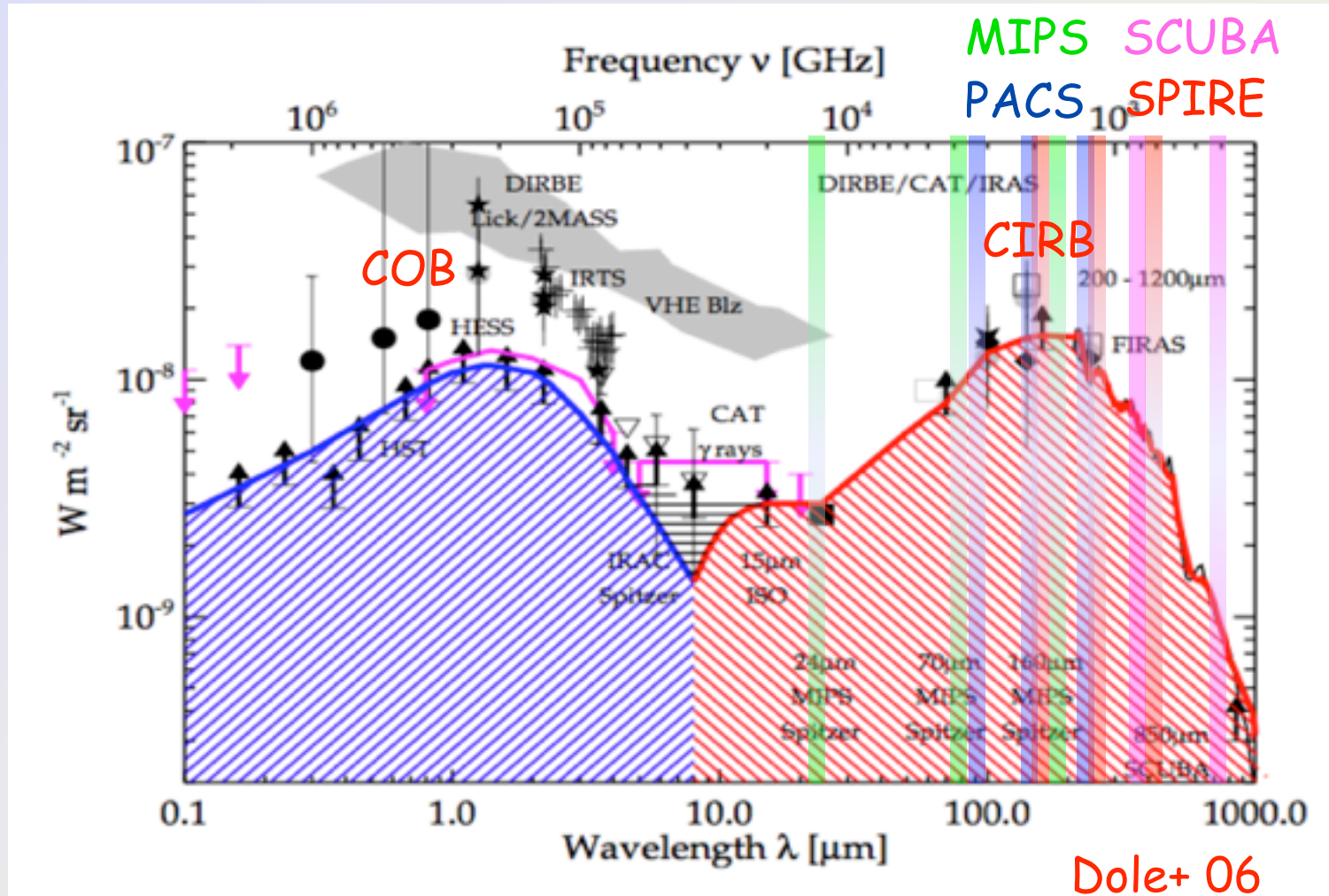
Mattia Vaccari - University of the Western Cape

Alberto Franceschini, Giulia Rodighiero - University of Padova

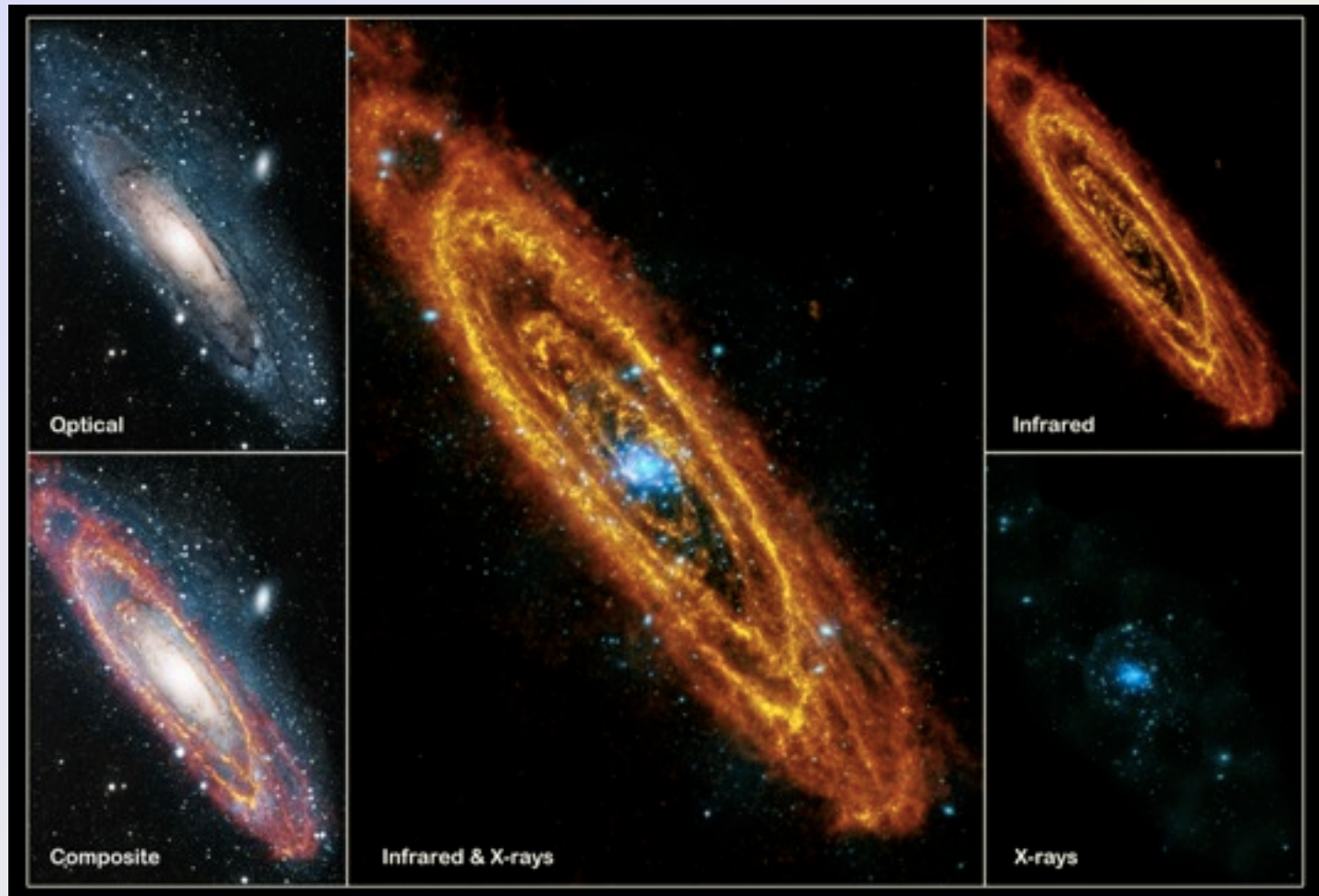
& the HerMES Consortium (Coordinated by Jamie Bock & Seb Oliver)

Resolving the background

A full understanding of galaxy formation and evolution requires resolving the CIRB into its constituent sources and studying their properties at 'all' wavelengths



Panchromatic view of galaxies

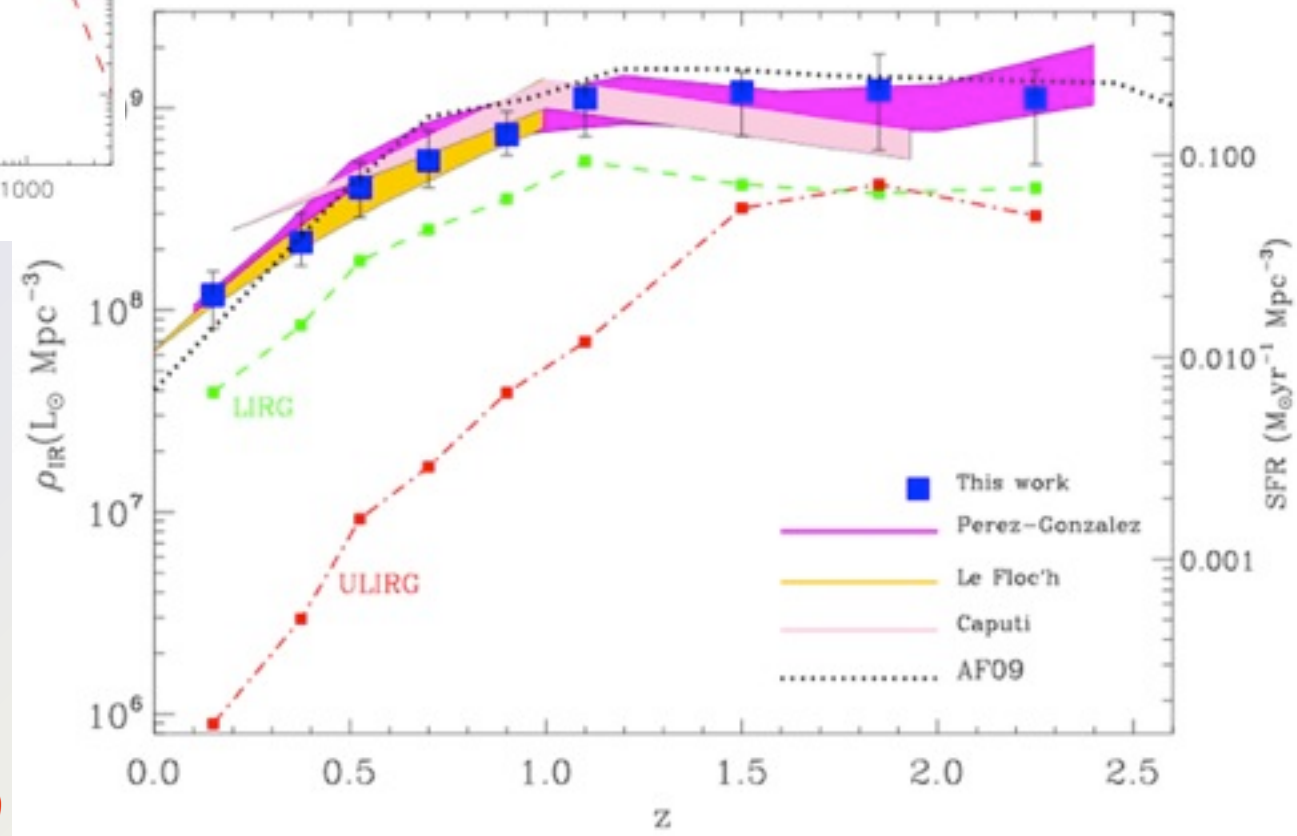
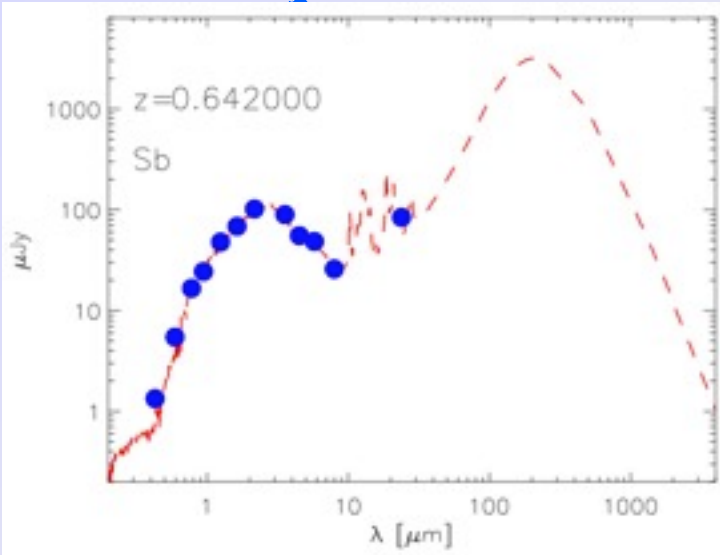


Andromeda
with Herschel
(PACS)

- Most multi-wavelength features in a galaxy SED have been used to trace its SFR
- All require some sort of correction for dust obscuration and/or metallicity

From the LF to the Cosmic SF Rate Density @ the end of Spitzer cold mission

MIPS 24 micron observations cannot accurately constrain the 8-1000 micron emission of high-z starbursts but we have got to rely on low-z SED models \Rightarrow ...**HERSCHEL !!**

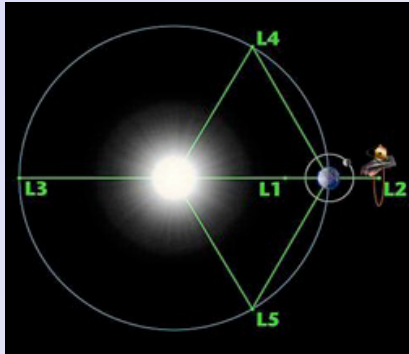


Rodighiero et al. 2010

Herschel/HerMES Science Motivation

Herschel is an **ESA cornerstone mission**

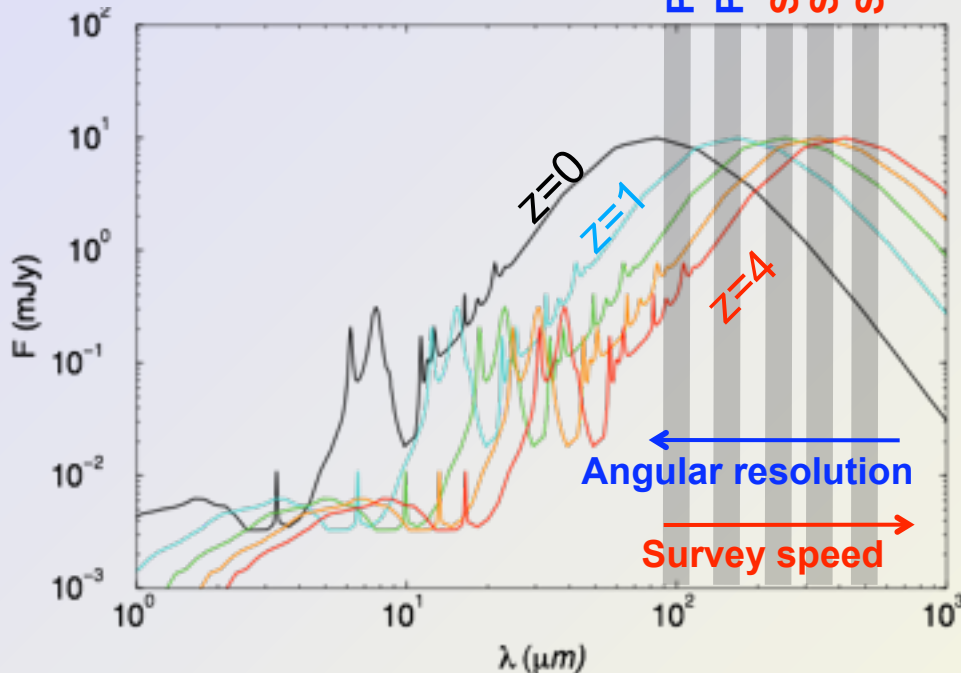
- large (3.5 m) aperture, low emissivity (~5%), passively cooled (70-90 K)
- **cryogenically cooled** focal plane science instruments with >3 yr lifetime (2009-2013)



SOME open questions we want to address with Herschel

- **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?

PACS
PACS
SPIRE
SPIRE
SPIRE



HERMES

Herschel Extragalactic Imaging Surveys

- High-sensitivity (albeit with moderate resolution)
- Use PACS & SPIRE at 100-500 μm
- Observe the SED peak of IR galaxies at $1 < z < 4$
- Derive IR 'Bolometric' (8-1000 μm) Luminosities
- Detect Large and Uniform Samples of (U)LIRGs

HerMES - Herschel Multi-tiered Extragalactic Survey

To study the evolution of galaxies in the distant Universe
The biggest project on the Herschel Space Observatory
A European Space Agency mission



Astronomy Technology Centre
California Institute of Technology
Cardiff University
CEA, Saclay
Cornell
ESAC
Godard Space Flight Centre



Imperial College, London
Infrared Processing Analysis Centre
Institut d'Astrophysique de Paris
Institut d'Astrophysique Spatiale
Institute Astrofisica Canarias
Jet Propulsion Lab.
Laboratory of Astrophysics of Marseilles



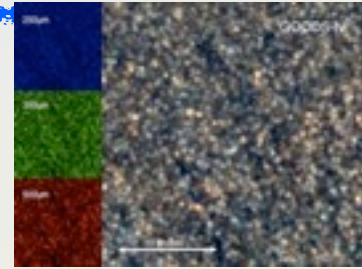
Mullard Space Science Laboratory
OAPd University of Padova
UC Irvine
University of British Columbia
University of Colorado
University of Hertfordshire
University of Sussex



Herschel Large High-z Surveys

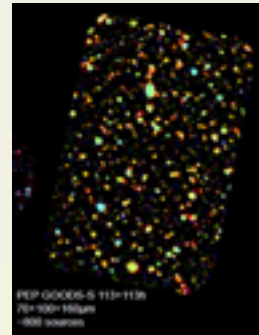
HerMES : Herschel Multi-tiered Extragalactic Survey

- 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



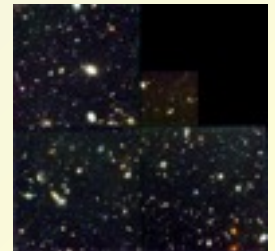
H-ATLAS : Herschel-Astrophysical Terahertz Large Area Survey

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

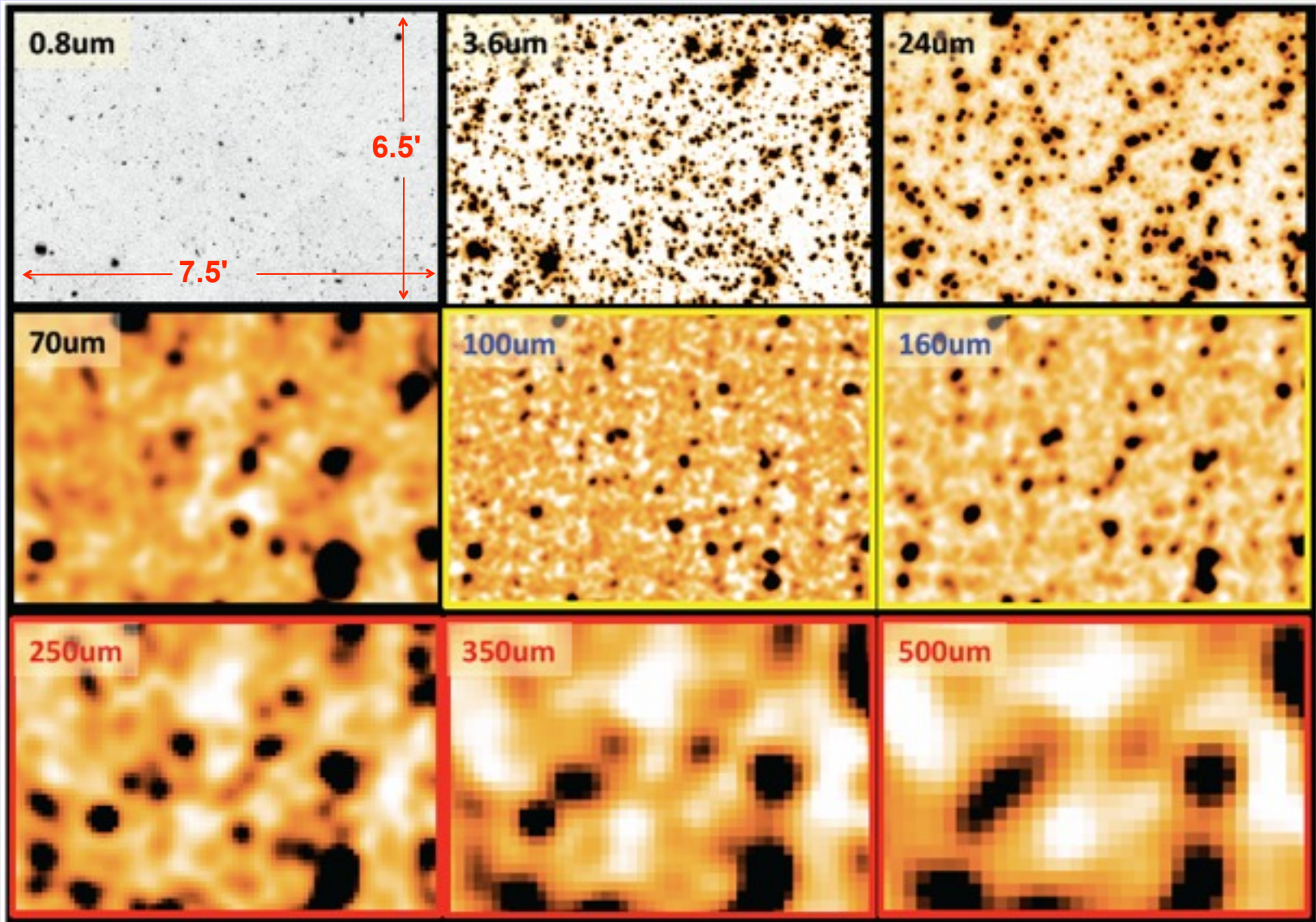


H-GOODS : Herschel-Great Observatories Origins Deep Survey

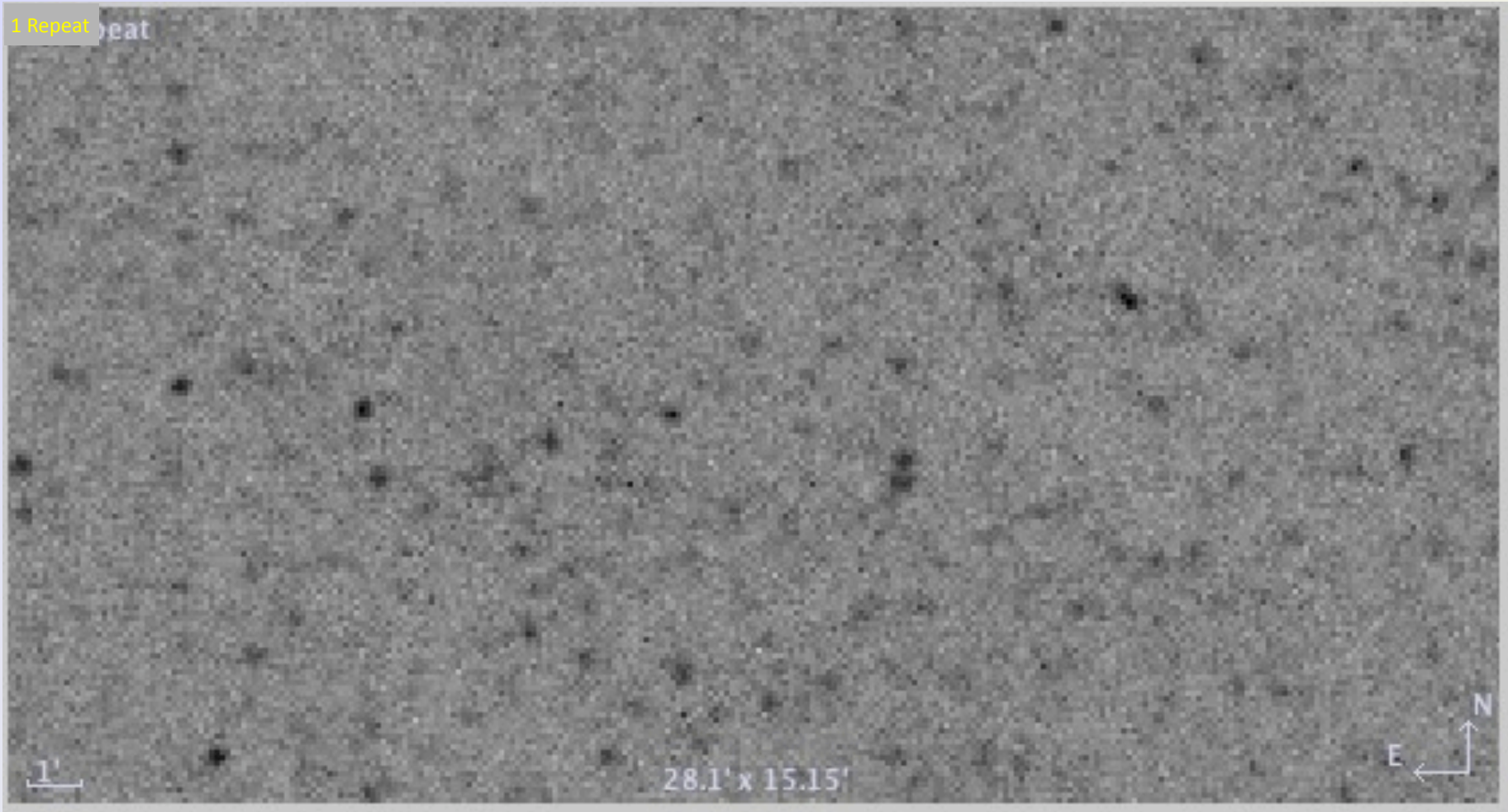
- PACS very deep imaging of the GOODS Field (330 hours)
- SPIRE deep imaging of the GOODS-N Field (30 hours)



The Confusion Challenge

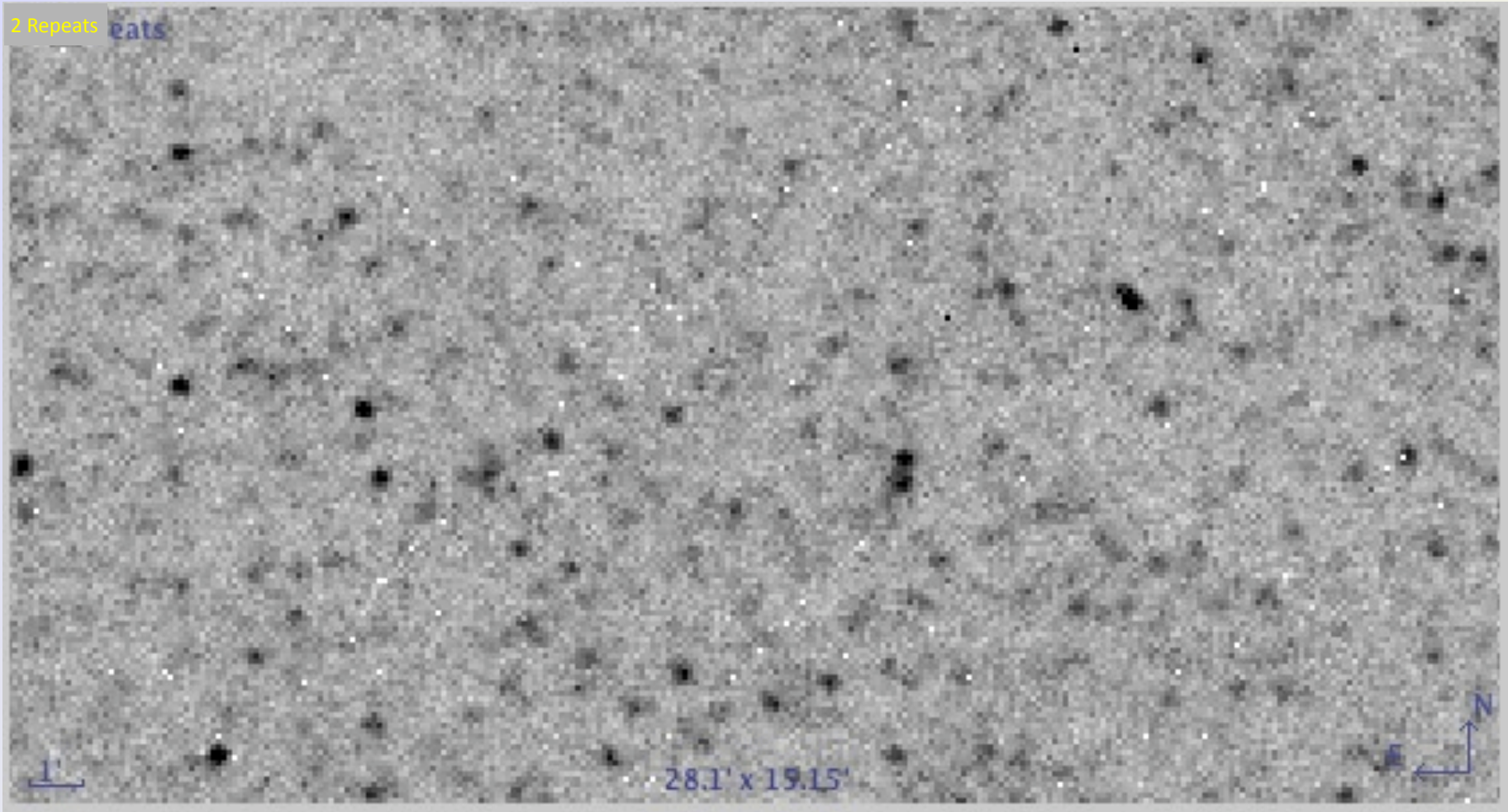


Mapping to the Confusion Limit



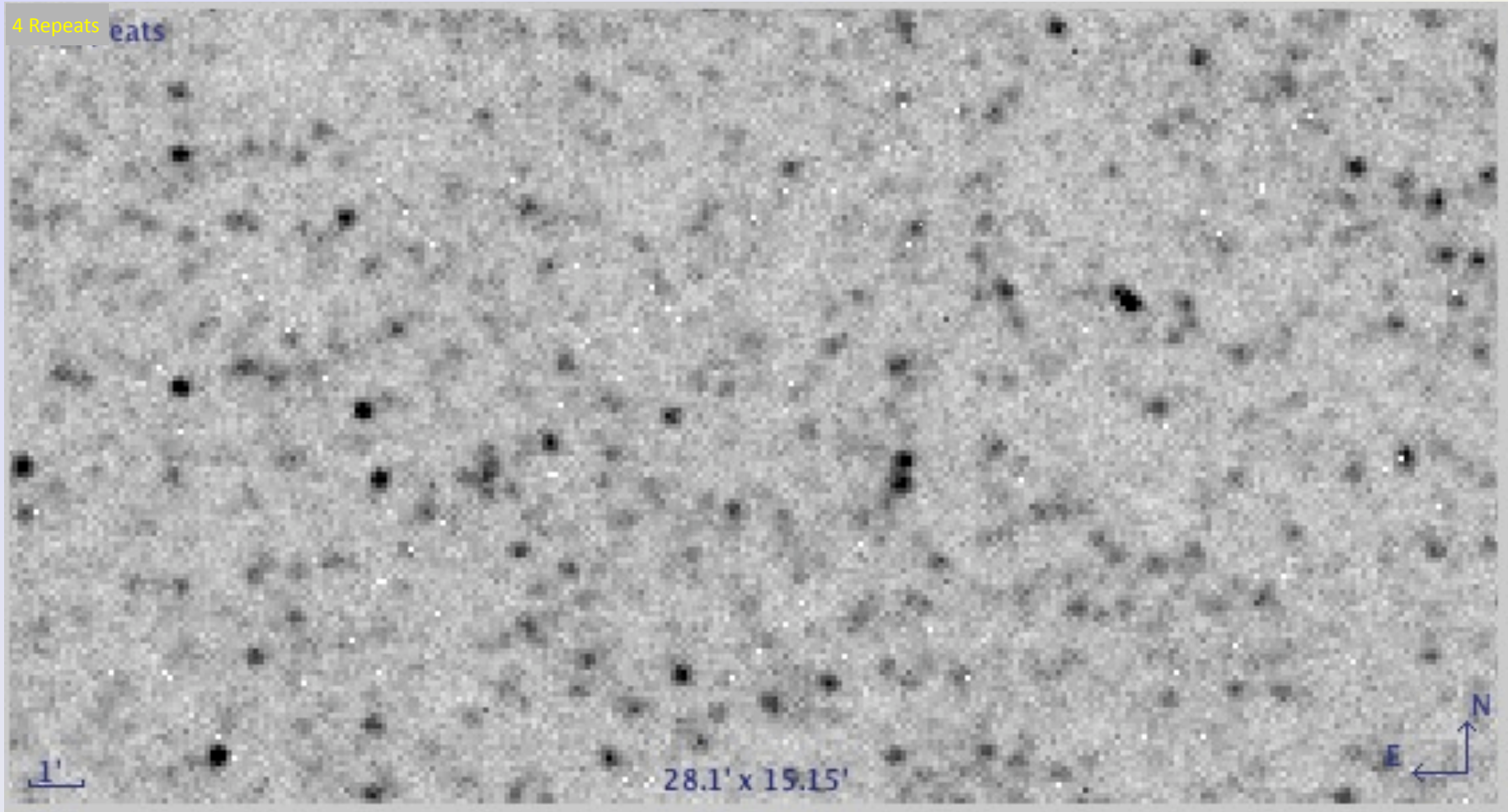
0.7 h for 1 sq. deg

Mapping to the Confusion Limit



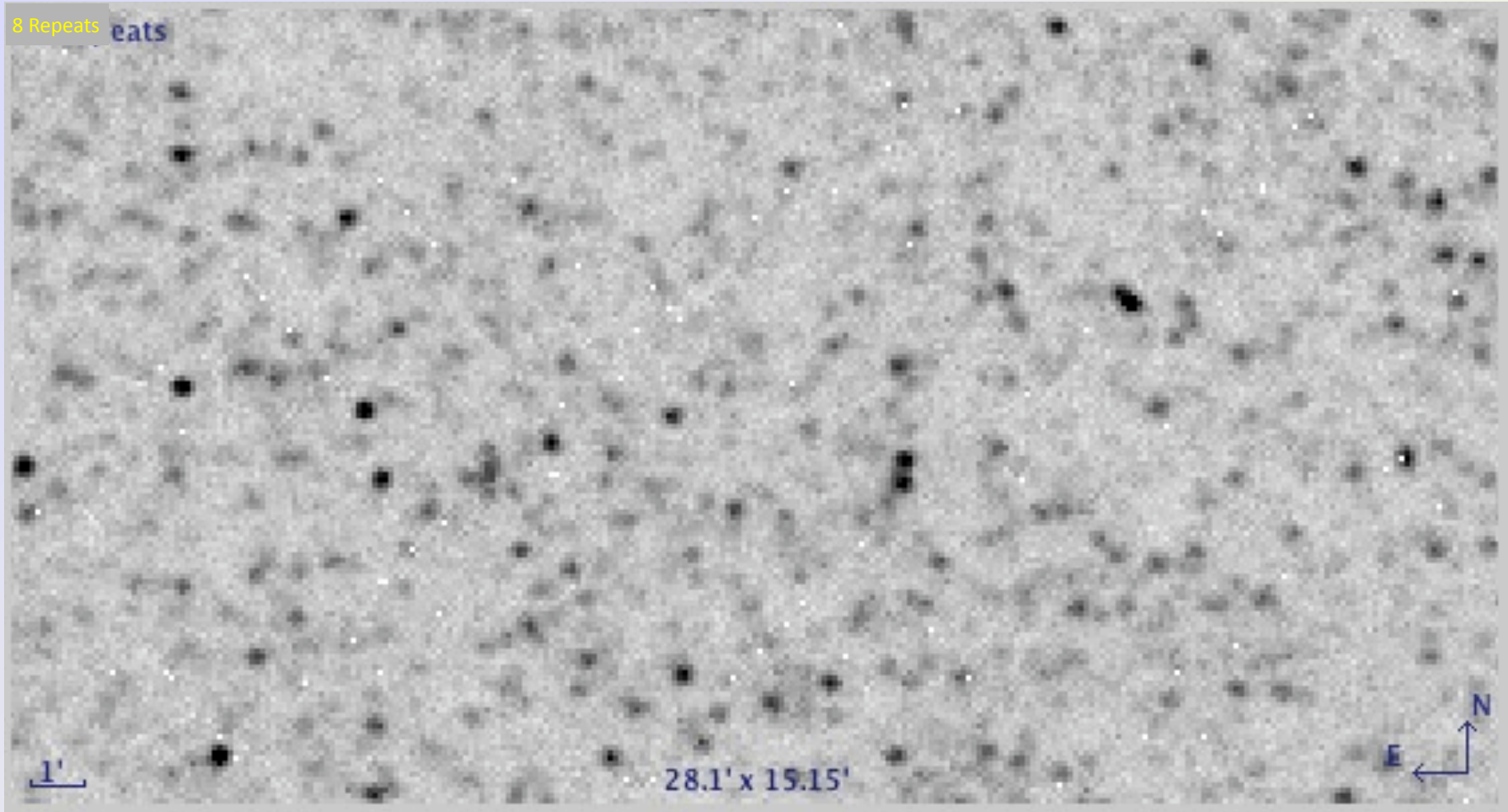
1.5 h for 1 sq. deg

Mapping to the Confusion Limit



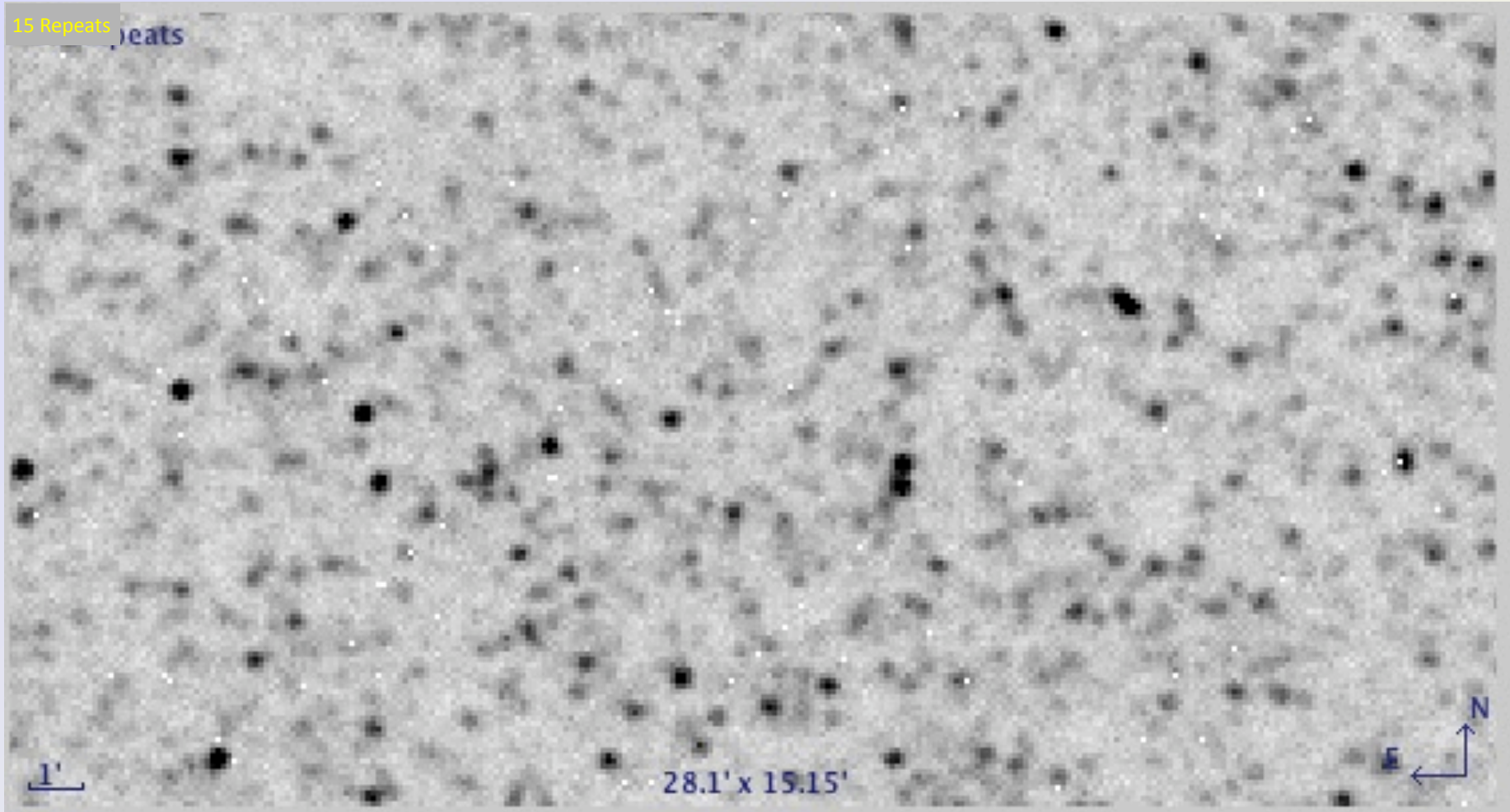
3 h for 1 sq. deg

Mapping to the Confusion Limit



6 h for 1 sq. deg

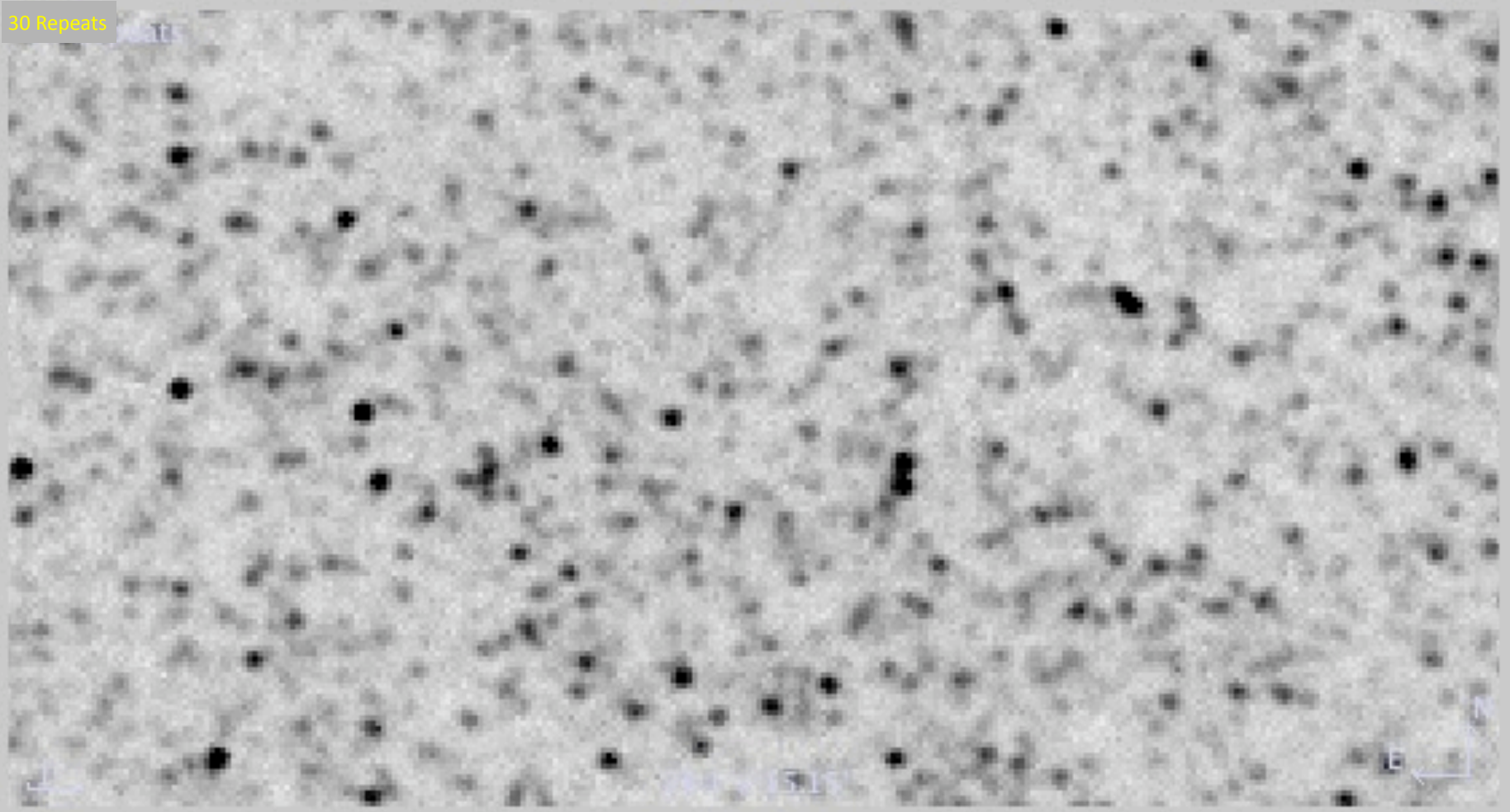
Mapping to the Confusion Limit



11 h for 1 sq. deg

Mapping to the Confusion Limit

30 Repeats



22 h for 1 sq. deg

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 : Wedding Cake Survey

Clusters

L1 0.11 \square°

L2 0.36 \square°

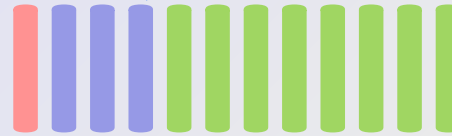
L3 1.25 \square°

L4 4 \square°

L5 30 \square°

L6 40 \square°

L7 270 \square°



GOODS
South

GOODS
North

ECDFS

Lockman
North

Lockman
East

EGS

UDS

COSMOS

EGS

UDS

VVDS

CDFS

ELAIS-S1

Lockman

Bootes

ELAIS-N1

FLS

ELAIS-S1

ELAIS-N2

Akari
SEP

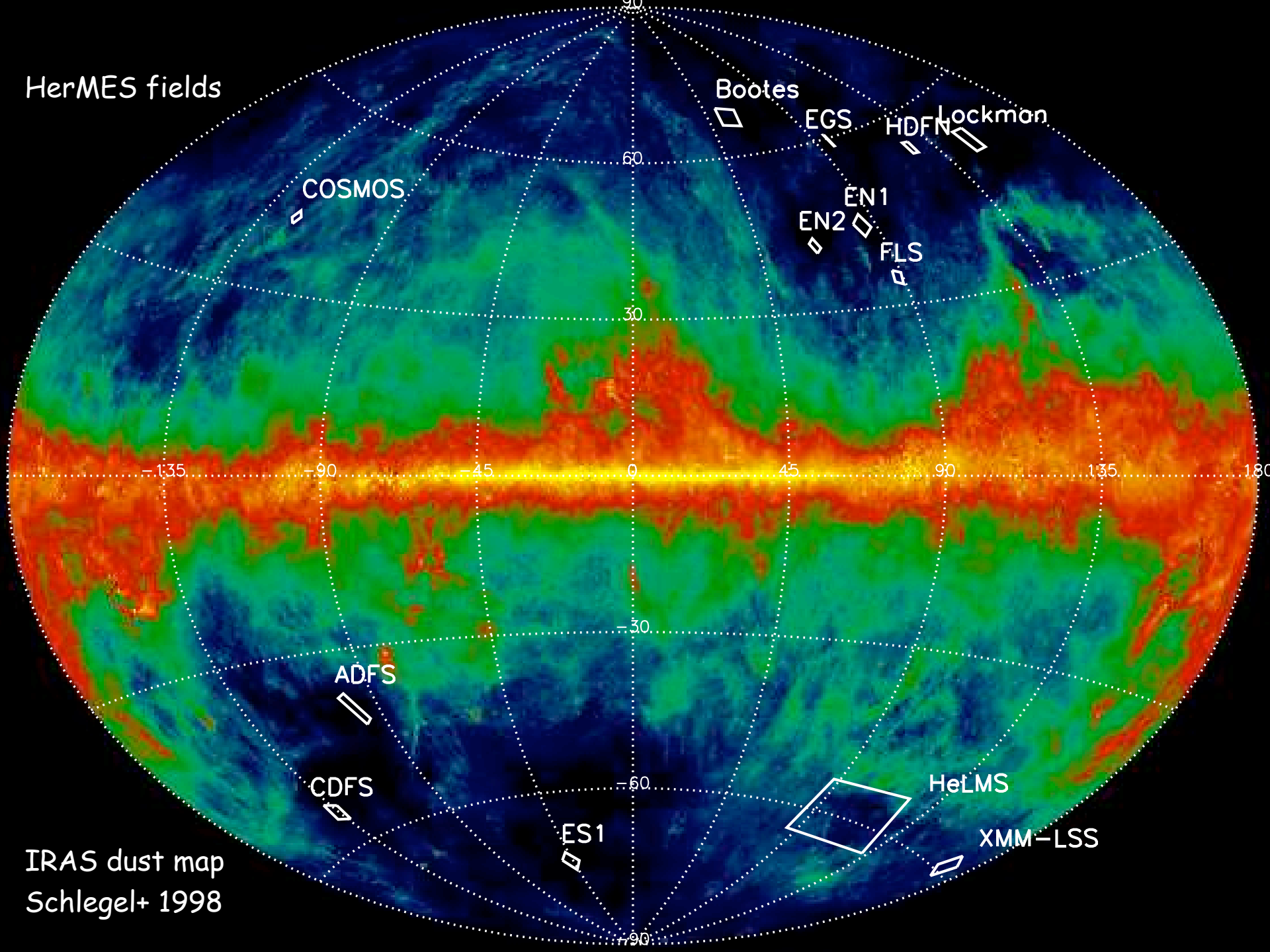
Bootes

ELAIS-N1

XMM-LSS

HeLMS / SDSS Stripe 82

HerMES fields



IRAS dust map
Schlegel+ 1998

A Data Fusion for HerMES science: The Spitzer Multi-Wavelength 'Data Fusion' (Vaccari+ in prep.)

# of Sources	IRAC 3.6/4.5	MIPS 24	MIPS 70	MIPS 160	GALEX NUV/FUV	SDSS ugriz	Optical ugriz	2MASS J/H/K	UKIDSS J/K	Area deg ²
ES1	390231	61236	2246	961	85039	NA	146537	10904	NA	~7.0
XMM	498027	69629	3823	1702	104344	NA	327024	14794	151565	~8.5
CDFS	462638	97002	4096	1813	101705	NA	177745	12952	NA	~7.5
LH	660682	110516	5548	2417	158981	217005	432490	17139	226838	~11.0
EN1	575524	102406	4652	2133	116180	210571	363949	21210	334955	~9.5
EN2	272412	59378	2331	970	63774	103460	173880	11443	NA	~4.5
Bootes	677522	41969	4325	2825	159218	228757	592136	7007	NA	~8.5
XFLS	107720	16712	2252	322	29208	62437	82576	11682	NA	~4.5

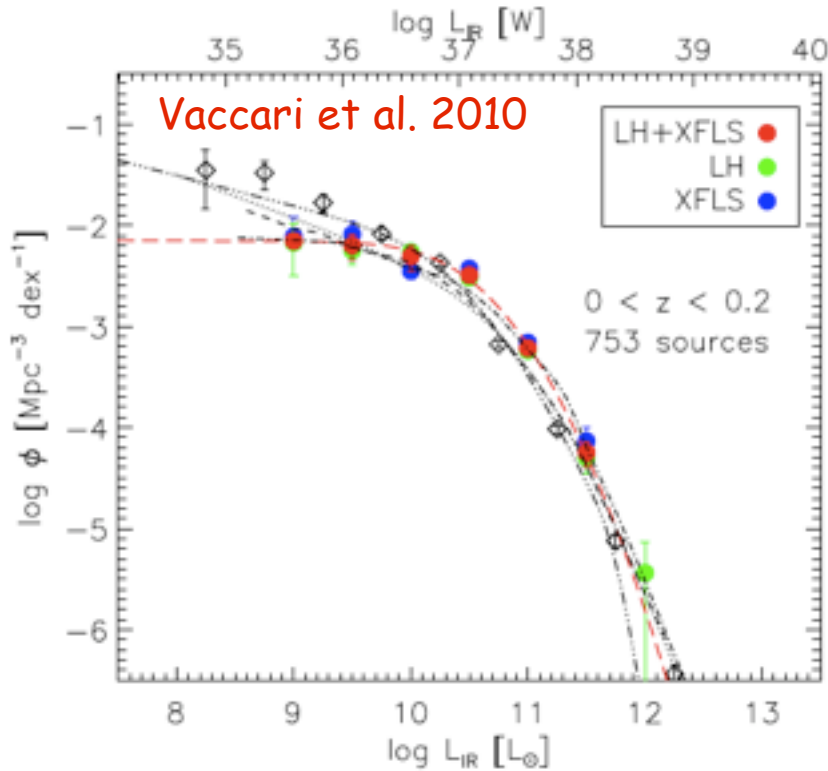
S
W
I
R
E

TOT : ~ 3 million of sources

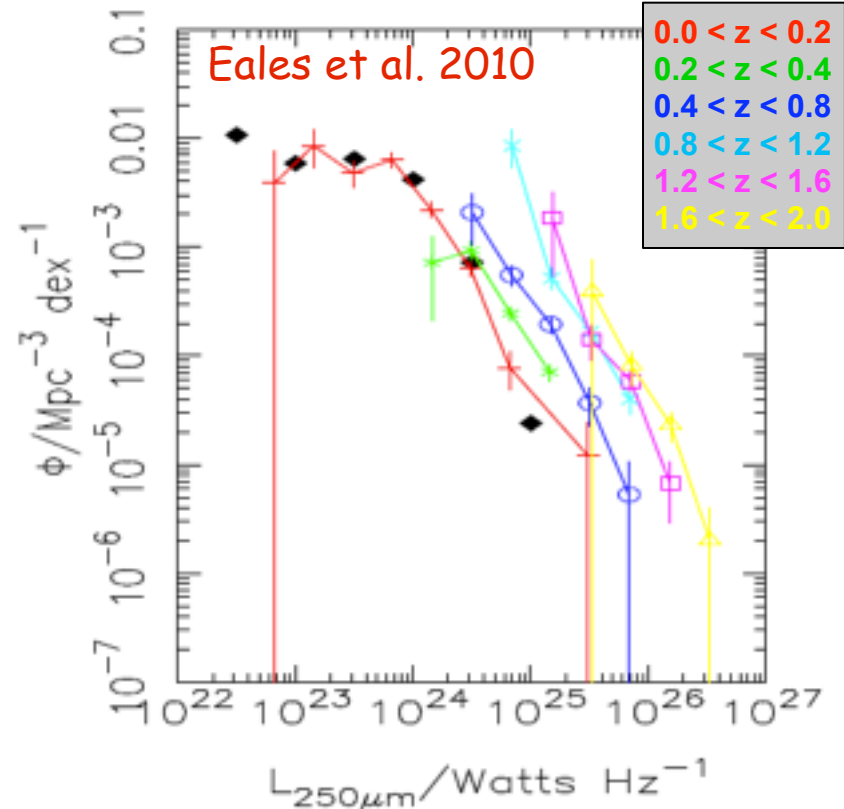
<http://www.astro.unipd.it/background/df/>

- COSMOS and other deep fields 'data fusion' carried out in collaboration with other consortia
- Aperture Matching currently based on heterogeneous flux measurements and SED fitting χ^2 min.
- Image-based aperture matching and multi-band source extraction to be tested to enable optimal combination of (in particular) IRAC, VISTA and VST data in equatorial/southern fields
- mrr's new redshift catalog (today's [arXiv:1210.3471v1](https://arxiv.org/abs/1210.3471v1))

HerMES IR Bolometric Local Luminosity Function



HerMES Rest-Frame 250 μm LF

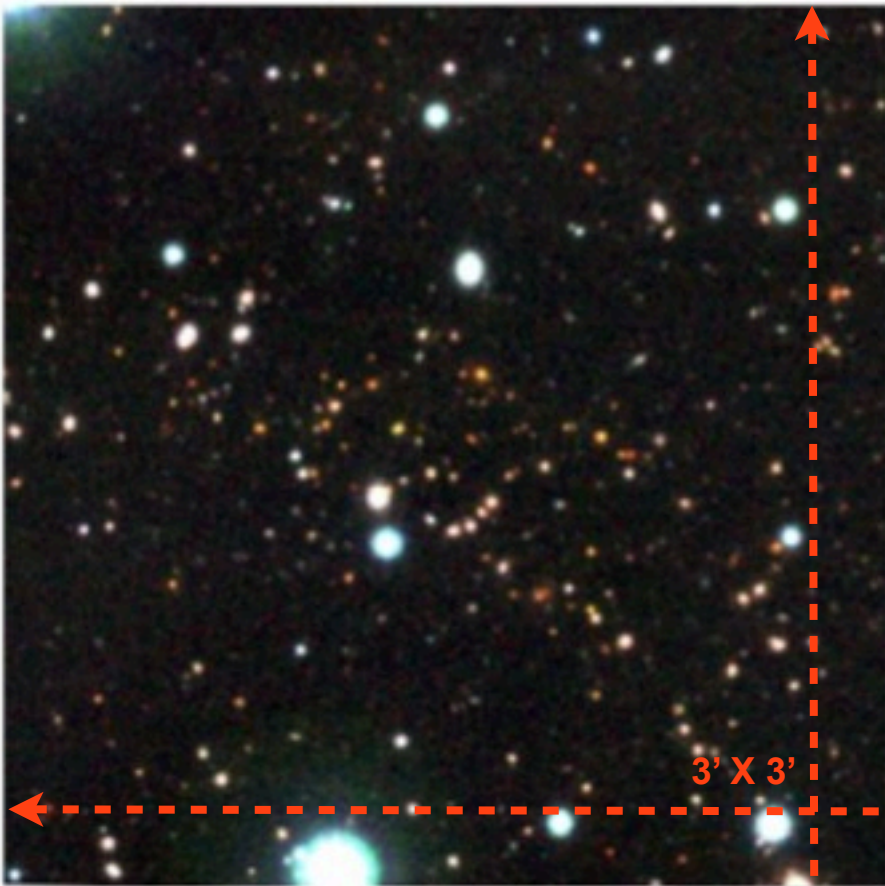


- Local sub-mm galaxy LF slightly above models
- Luminosity function evolves out to z ~ 2
- Is it flattening out at z > 1?
- Next : better statistics, SED models, LF estimators & selection functions

Conclusions

- ✓ Our **Herschel observations** have provided us with a first complete characterization of the spectral energy distributions for high- (and low-) redshift galaxies, including the previously unknown FIR and sub-mm portion of the spectrum, which is so critical for measuring the source bolometric emission.
- ✓ The **data-fusion** has been greatly exploited within HerMES & SERVS consortia and represents the best instrument to a panchromatic census of galaxy formation and evolution processes (e.g. for SED fitting, SFR estimates, color-color plots..). It will become publicly available and has been thought to be user friendly & VO compliant.

What's next ?



3' X 3'

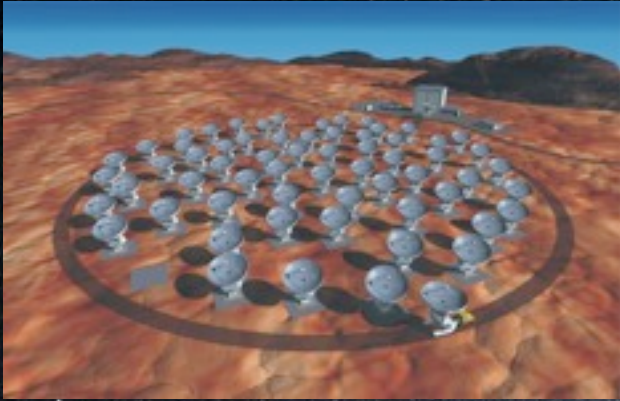
15' X 15'

VIDEO - Y/J/Ks in XMM3

Jarvis+ 2012

arXiv:1206.4263

ALMA :
Targeted Surveys Below Herschel Confusion Limits (Karim+ arxiv:1210.0249)



(completed in 2014)

