HELP-ing Radio Continuum Surveys

The Herschel Extragalactic Legacy Project

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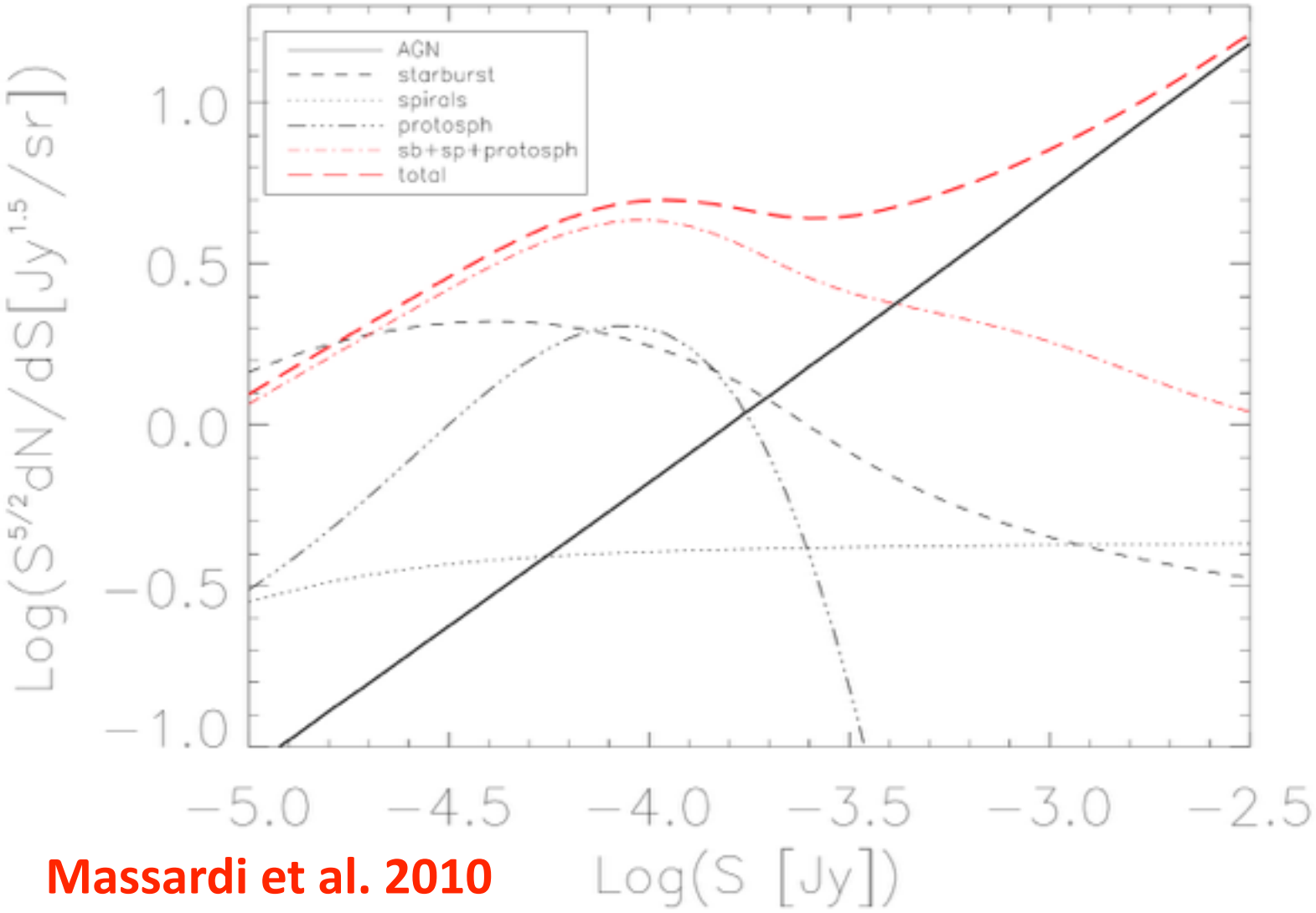
EC-REA - FP7-SPACE-2013-1

SA-DST - FP7-Co-Investment

The Faint Radio Sky

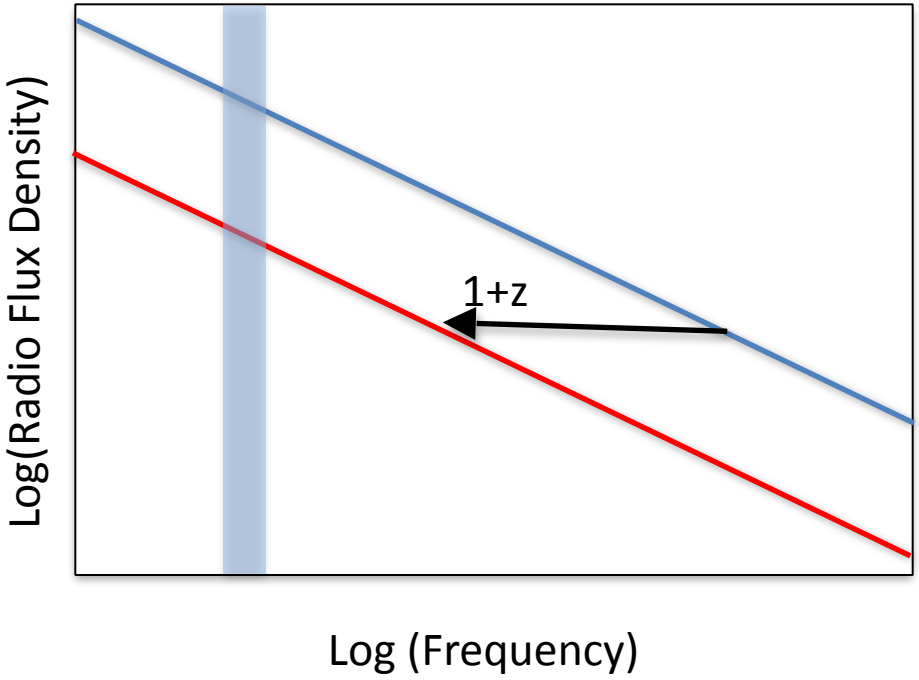


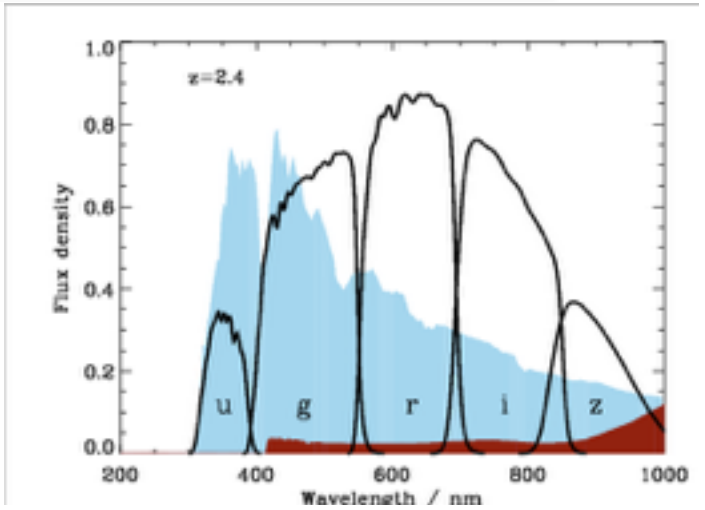
Massardi et al. 2010

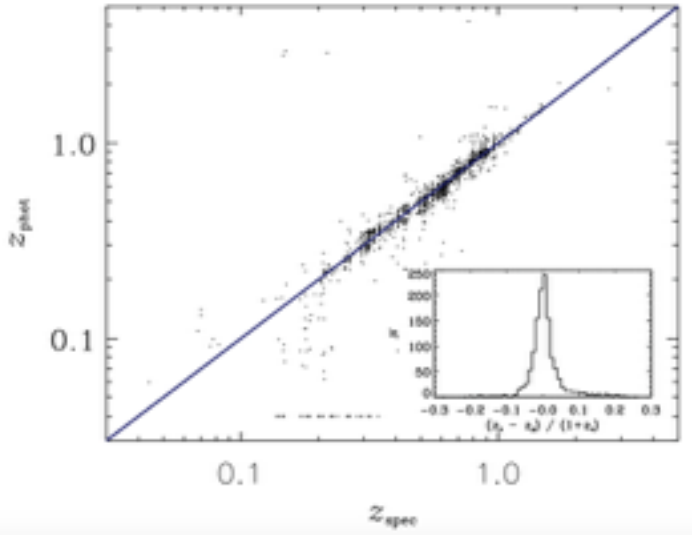
But of course…

There's nothing as useless as a radio source

(Matt Jarvis)





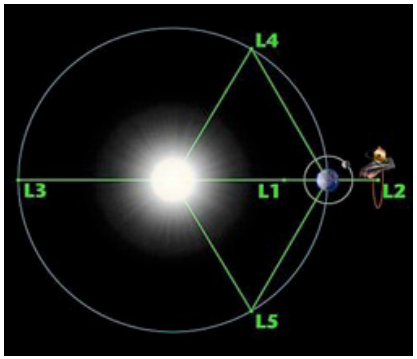


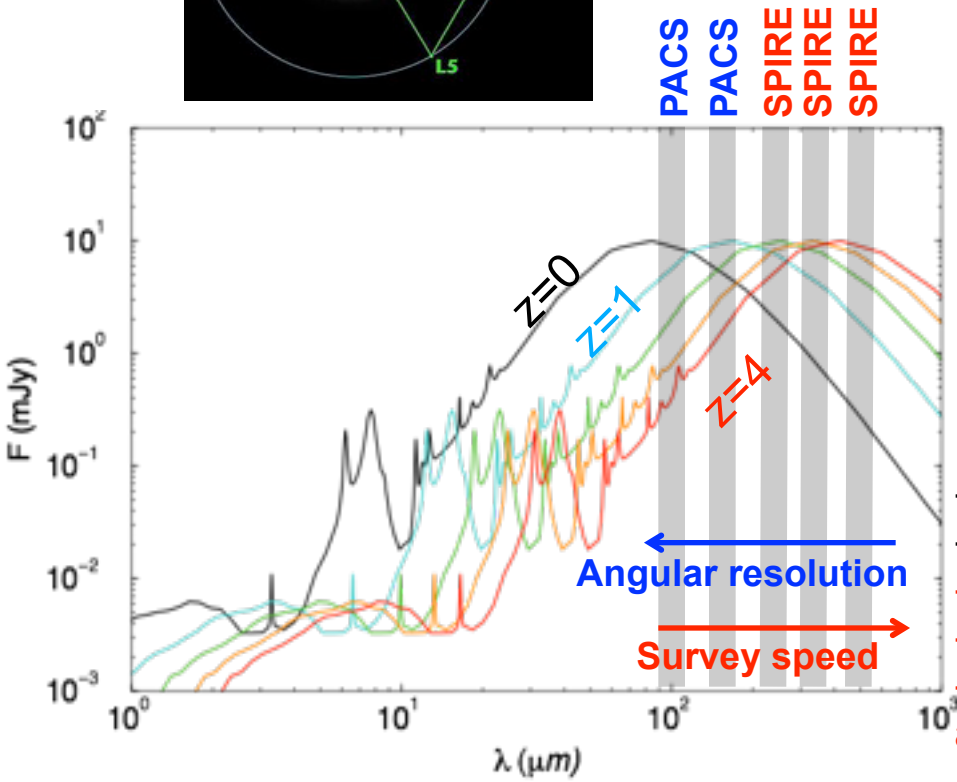
No redshift information!

The Herschel Space Observatory

Herschel is a recently completed ESA cornerstone mission (2009-2013)

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





Questions addressed by Herschel

- What is the history of Far-Infrared 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?

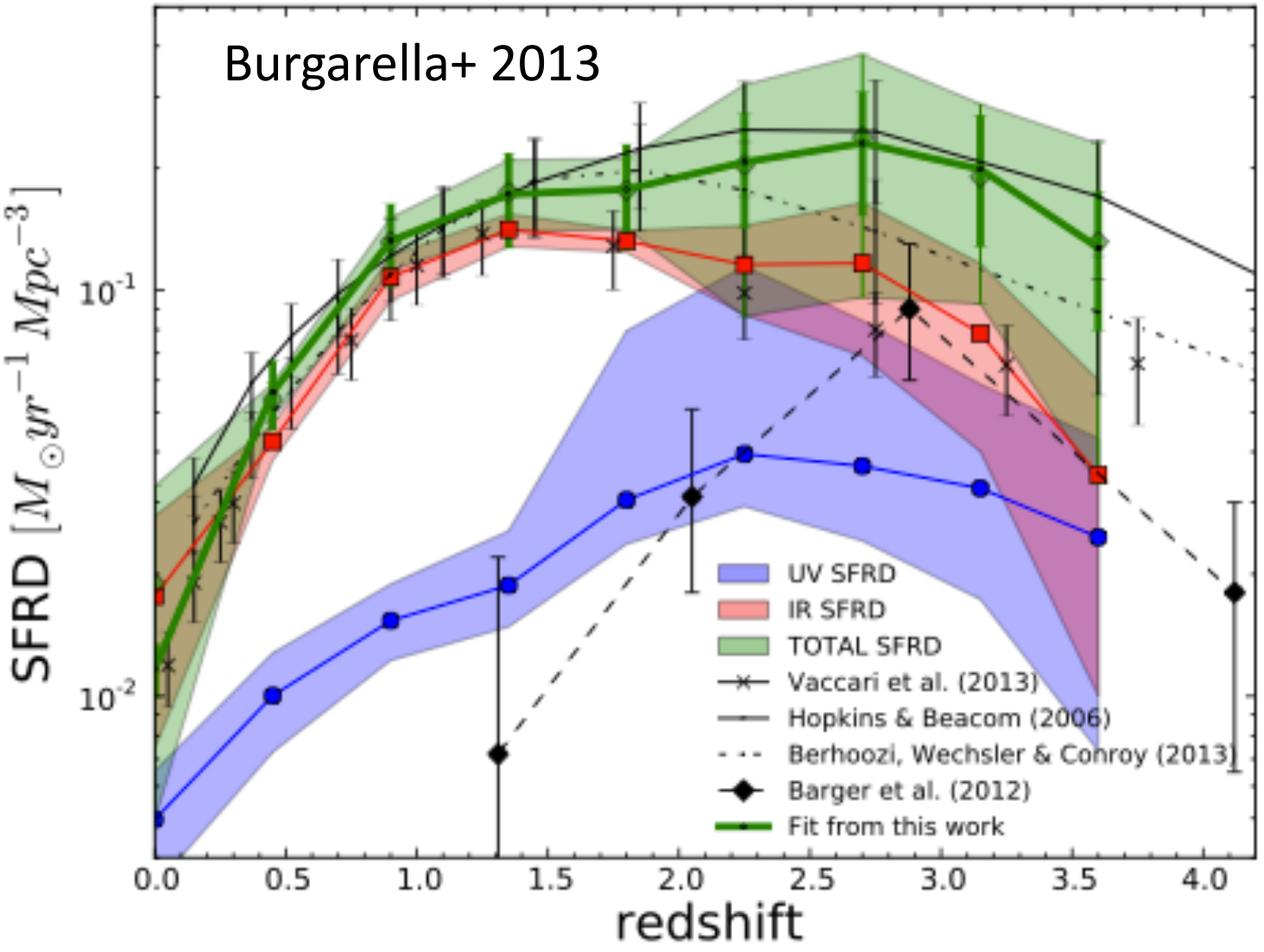
HERMES

ATLAS

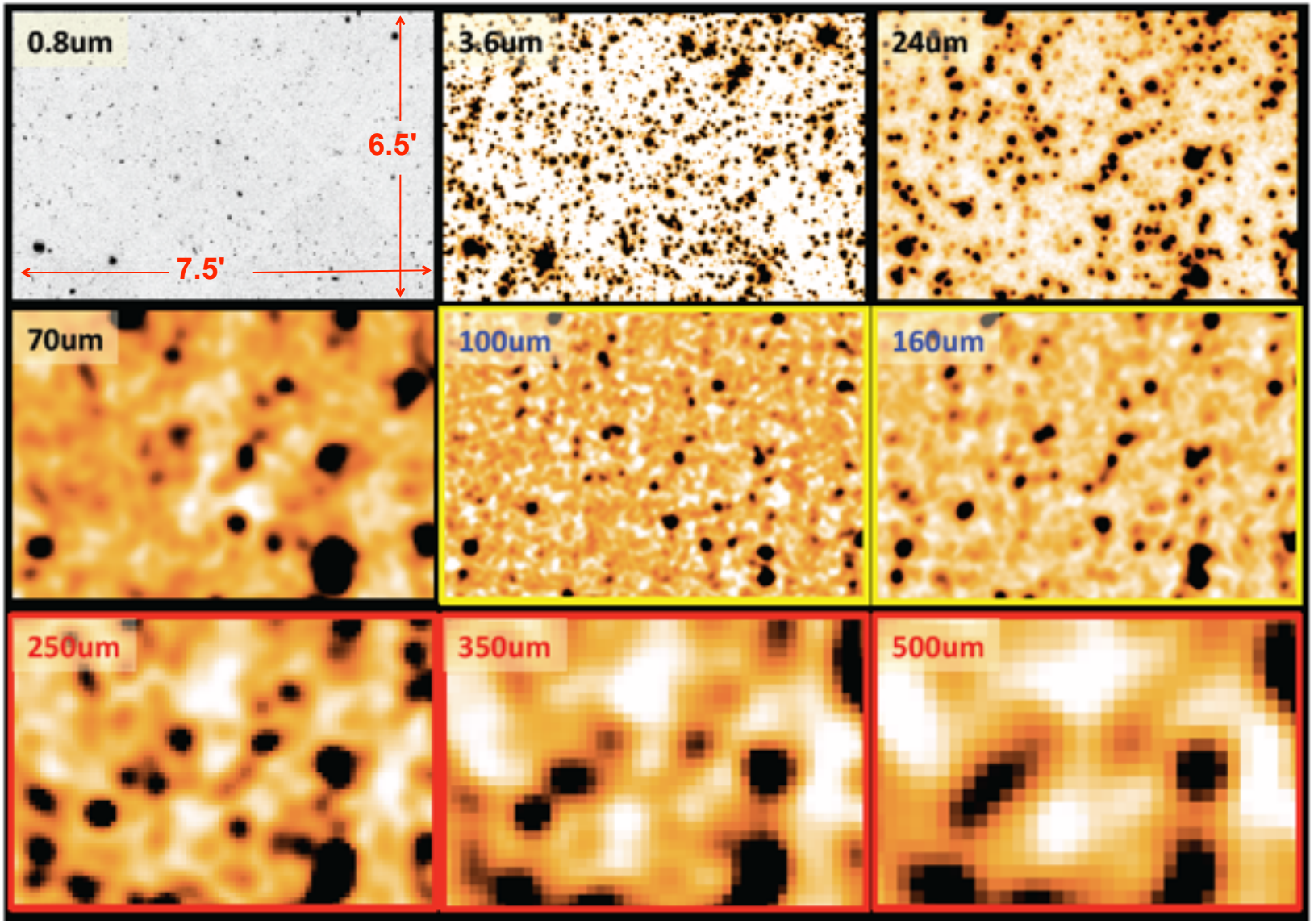
Herschel Extragalactic Imaging Surveys

- High-sensitivity (albeit with moderate resolution)
- Use PACS & SPIRE at 100-500 μm
- Observe the SED peak of IR galaxies at 1<z<4
- Detect Large and Uniform Samples of (U)LIRGs
- Derive IR "Bolometric" (8-1000 μm) Luminosity and use it as a Star Formation Rate Indicator

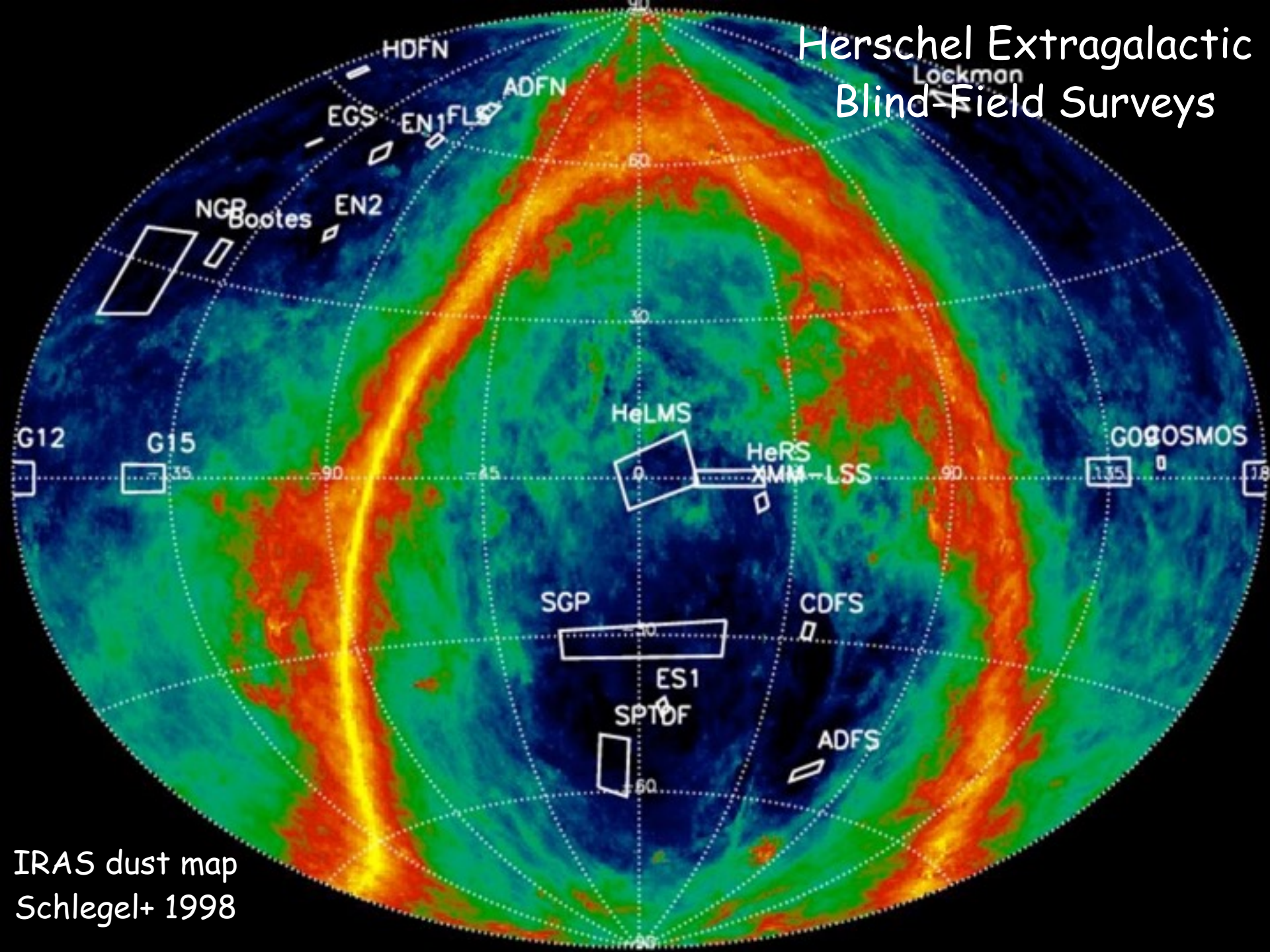
The Cosmic SFR Density



The Confusion Challenge



GOODS-N - David Elbaz


Herschel Extragalactic
Blind-Field Surveys
HDFN
ADFN
Lockman
EGS
EN1
FLS
NGP
Bootes
EN2
HeLMS
G12
G15
HeRS
XMM-LSS
COSMOS
SGP
CDFS
ES1
SPTDF
ADFS
IRAS dust map
Schlegel+ 1998

A Multi-Wavelength Catalog for Herschel Science
The Spitzer Multi-Wavelength 'Data Fusion'

# 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

SWIRE

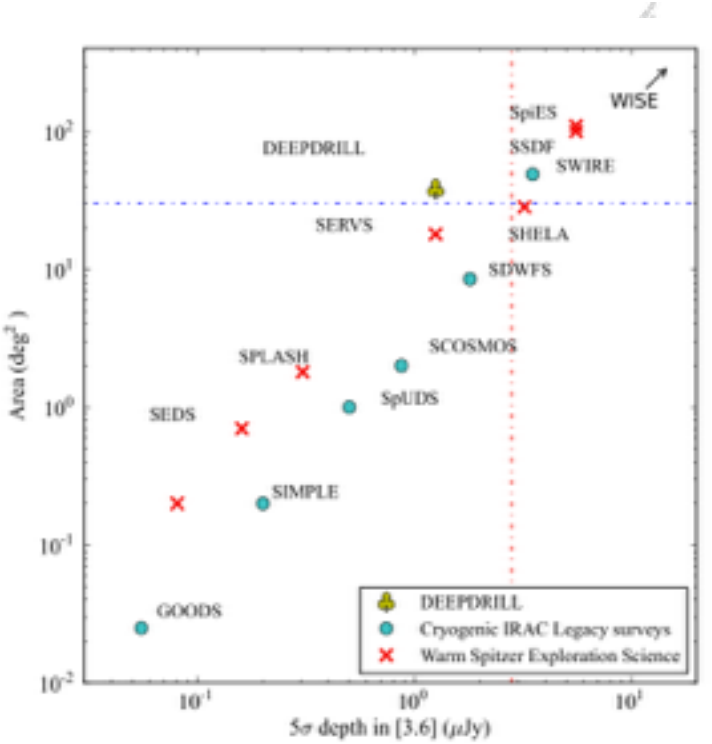
TOT : ~ 3 million of sources | 65 deg^2 | σ ~ 1 μJy in IRAC12 | http://www.mattiavaccari.net/df/

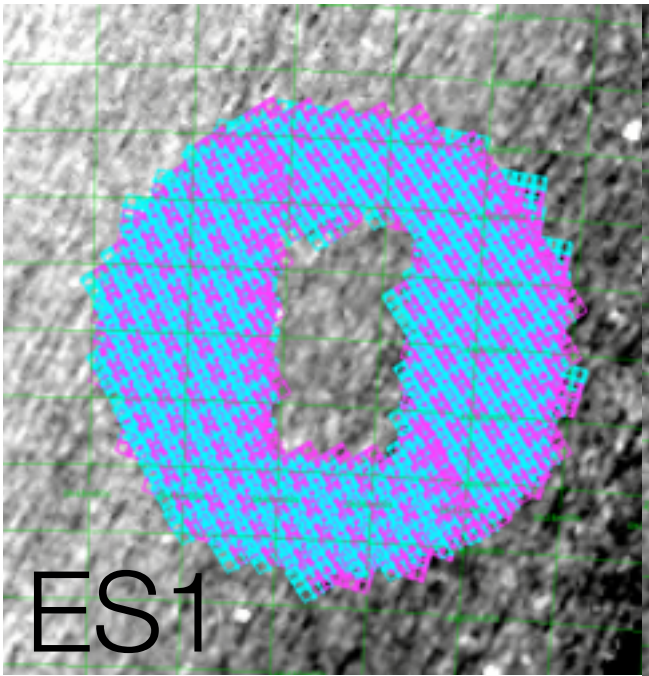
- Based on an homogeneous source re-extraction of IRAC and MIPS maps (IRAC1 or IRAC2 selection)
- UV/Optical/NIR catalog-level Aperture Matching and template fitting χ^2 minimization (Rowan-Robinson+ 2013) returning good photometric redshifts and physical constraints
- Image-level aperture matching and/or multi-band source extraction still required for the optimal exploitation of VOICE, DES, VIDEO & SERVS data in equatorial/southern fields

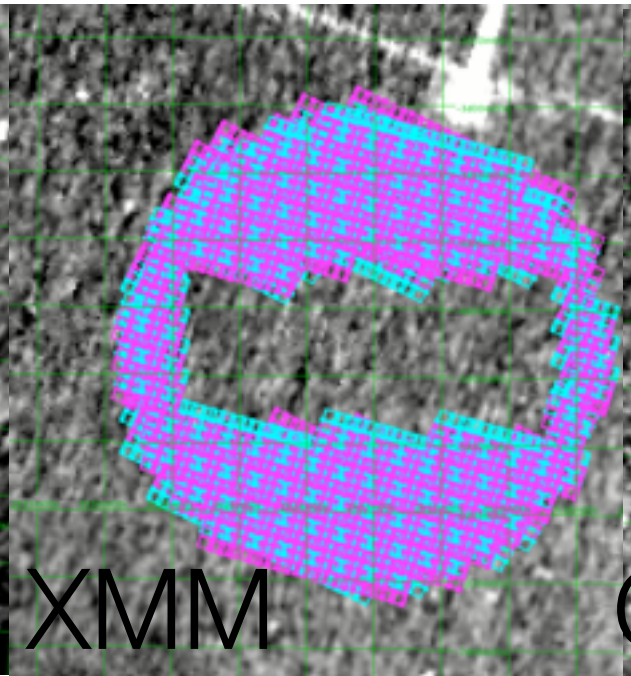
SERVS & DeepDrill

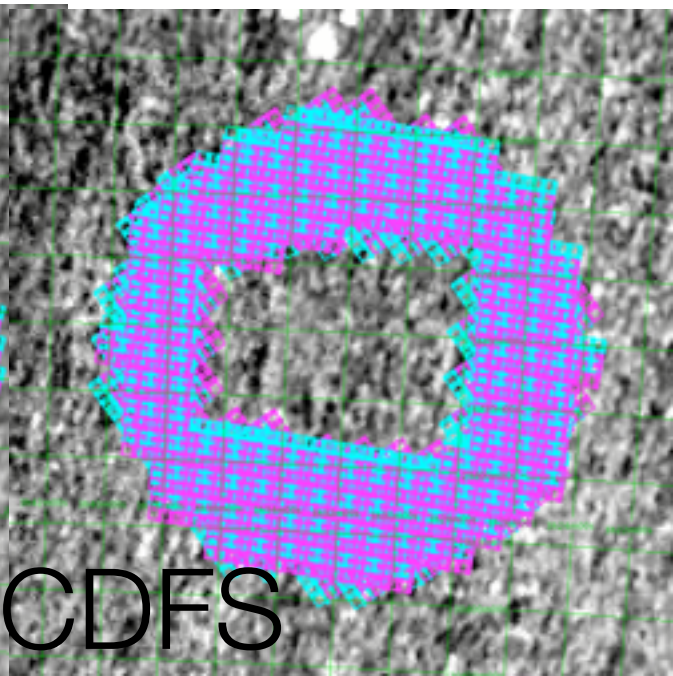
The recently approved Spitzer Warm DeepDrill survey will extend SERVS Southern Fields (ES1, XMM, CDFS) to the full LSST Deep Drilling footprint (35 deg^2)

=> Prime Targets for MeerKAT/MIGHTEE

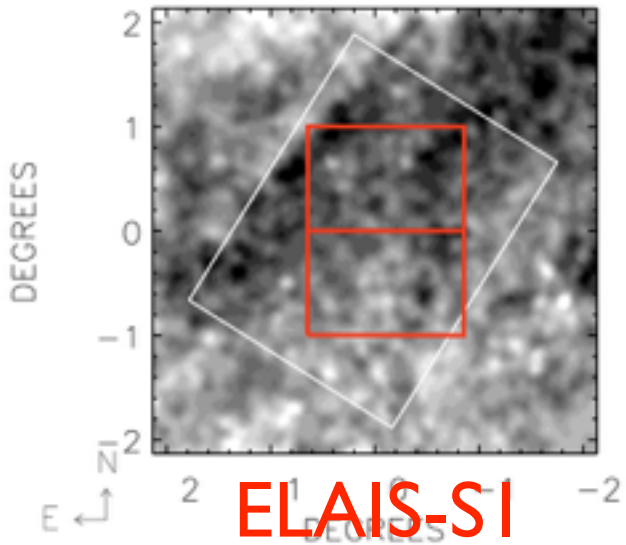


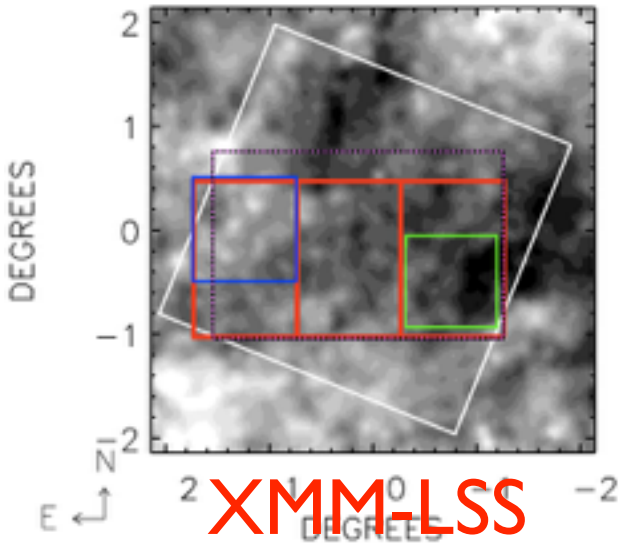


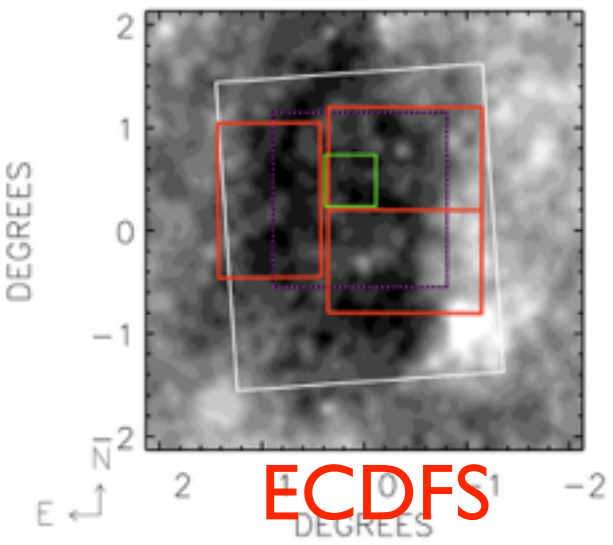




The VISTA-VIDEO Survey



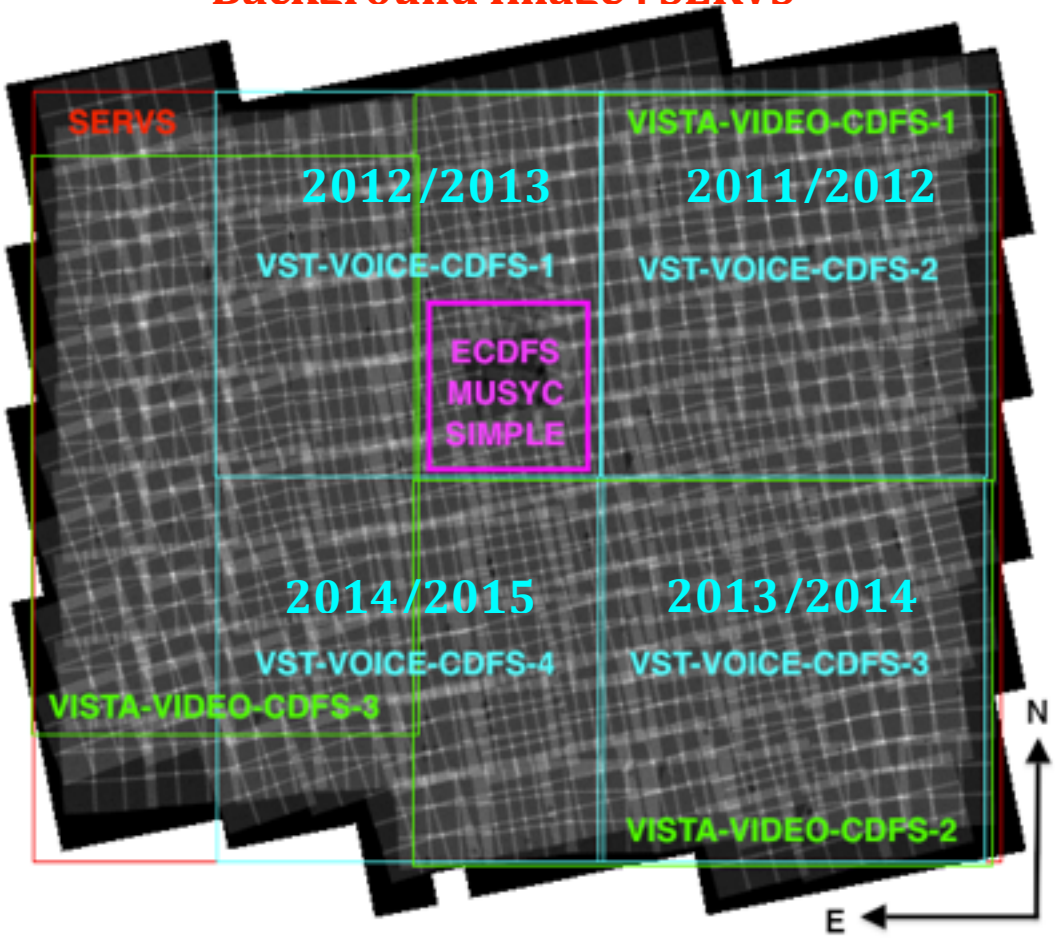




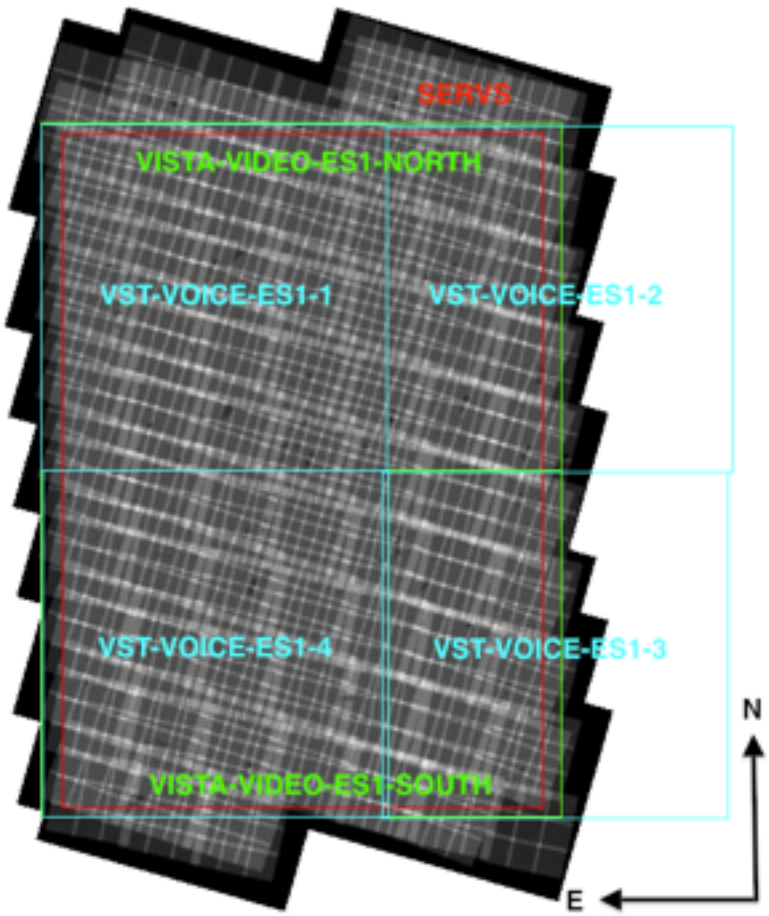
Filter	Time (per source)	Time (full survey)	5σ AB	5σ Vega	Seeing	Moon
Z	17.5 hours	456 hours	25.7	25.2	0.8	D
Y	6.7 hours	175 hours	24.6	24.0	0.8	G
J	8.0 hours	209 hours	24.5	23.7	0.8	G
H	8.0 hours	221 hours	24.0	22.7	0.8	B
K_s	6.7 hours	180 hours	23.5	21.7	0.8	B

The VST-VOICE Survey

Background Image : SERVS



Background Image : SERVS



VST Optical Imaging of the CDFS & ES1 (VOICE) - **PIs : Covone & Vaccari**

u+gri (BVR) VST (+WFI) survey over 4 deg^2 in CDFS (ES1) to AB=25-26

Multi-Epoch for SN Search and AGN Variability (De Cicco+ 2015, Falocco+ 2015)

http://mattiavaccari.net/voice/

The Dark Energy Survey

DES Supernova Survey Fields (cf. LSST Deep Drilling)

2 Deep + 8 Shallow (Mostly MIGHTEE/VIDEO) Fields

HELP Overview

- HELP = Herschel Extragalactic Legacy Project

- European Commission project funded (2014-17) to:
  - Bring together multi-λ surveys over more than 1000 deg^2
  - Lower the barriers to multi-λ statistical survey science
  - Provide a resource for astronomers to study the high redshift Universe akin to SDSS (also) using Herschel
  - Provide tools to make Herschel surveys easy to use

Meet The Team

http://herschel.sussex.ac.uk

- UK : Sussex (PI Seb Oliver), Cardiff & Cambridge
- France : LAM - Marseille & CEA - Saclay
- Netherlands (Leiden) & Cyprus (European University)
- South Africa : UWC - Cape Town

http://www.uwcastro.org/

Science Objectives

- Detecting rare objects (e.g. high-z galaxies)
- Multi-λ/multi-variate Luminosity Functions
- Statistical description of galaxy number density as a function of physical properties such as SFR, M_*, M_{dust} as well as redshift
- Galaxy properties as function of environment
- Connection between AGN and star formation

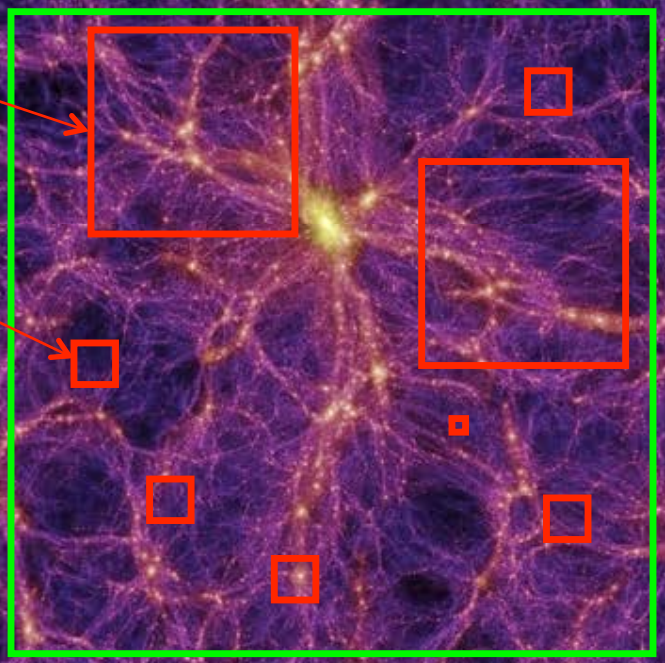
Need for Large Multi-λ Fields

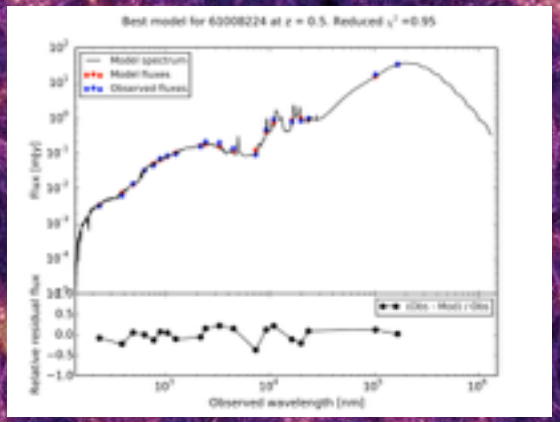
3° at z=1

125 Mpc/h

ASTRODEEP fields

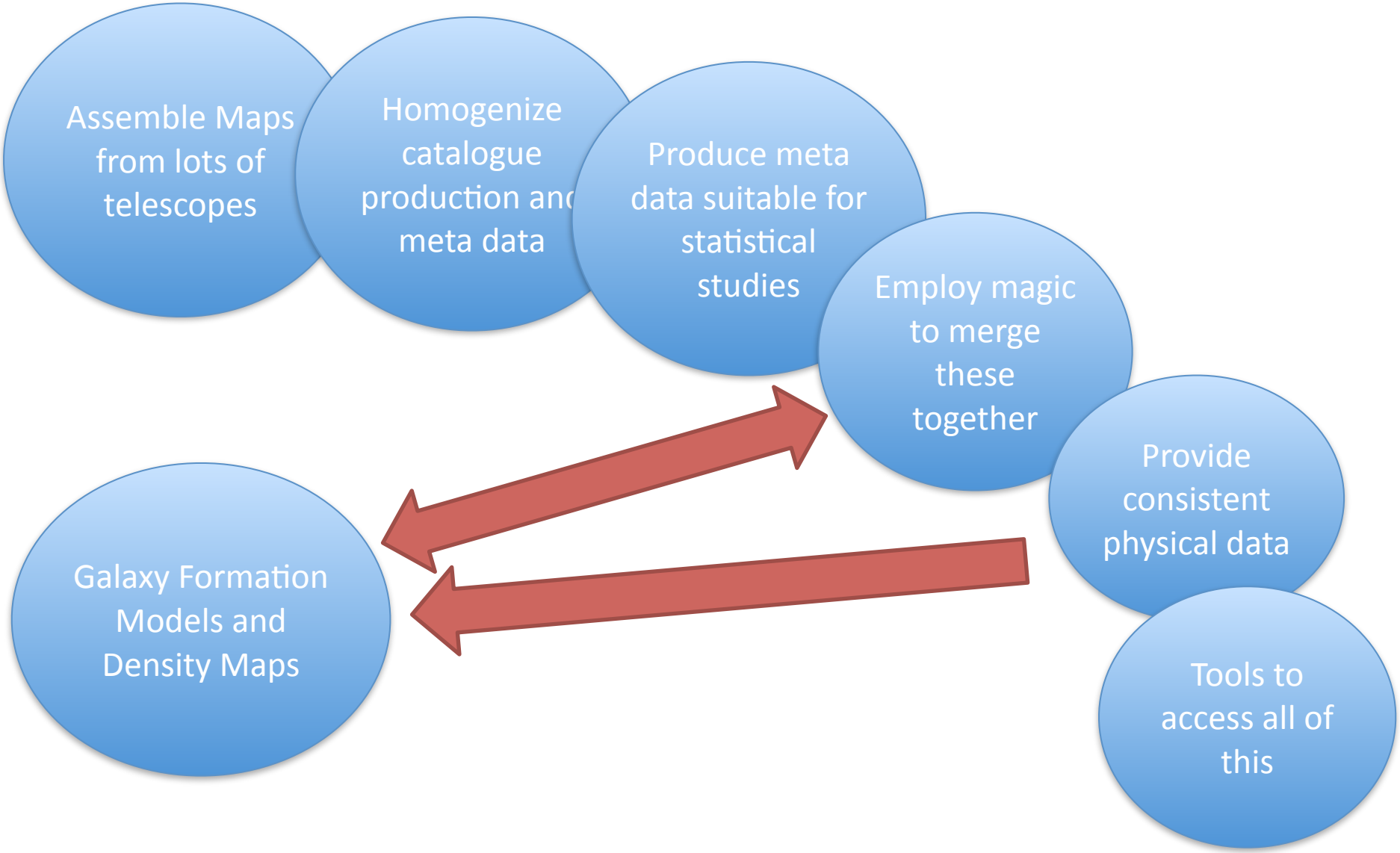
Typical HerMES field





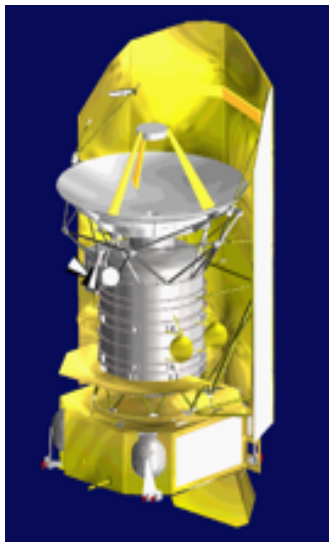
Δz=0.1 at z=1

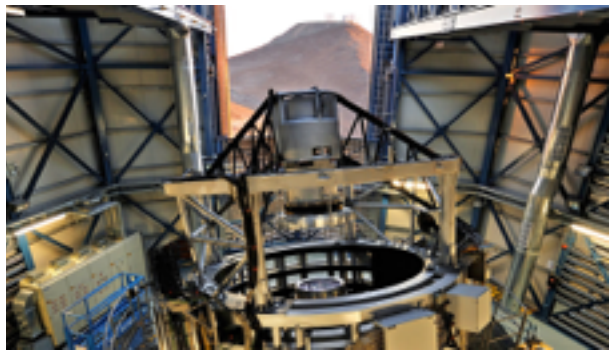
Concept


Assemble Maps from lots of telescopes
Homogenize catalogue production and meta data
Produce meta data suitable for statistical studies
Employ magic to merge these together
Provide consistent physical data
Tools to access all of this
Galaxy Formation Models and Density Maps

Assemble maps from lots of telescopes

- SPIRE Surveys
  - HerMES
  - H-ATLAS
  - HeRS, SPTDF...
- UV/Opt/NIR/IRAC/MIPS
  - GAMA, VST, DES, COSMOS
  - VISTA, SERVS, SWIRE...
- Radio (SKA Pathfinders)
  - LOFAR, ASKAP, MeerKAT
- Postage Stamp Viewer



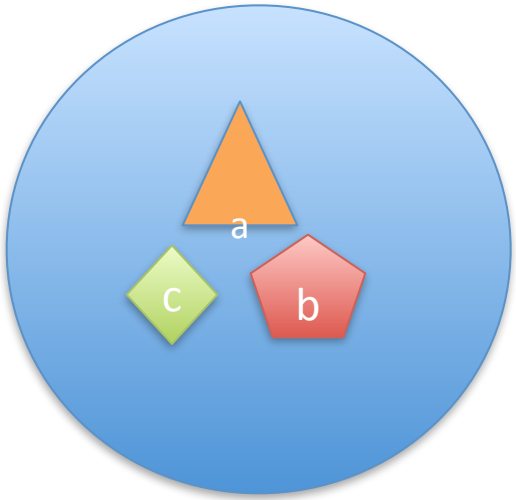
Homogenize Catalogs & Meta-Data

- Uniform calibration from telescope to telescope, field to field and band to band
- Image-level Aperture Matching where possible
- Multi-lambda consistent detection & photometry
- Meta data including calibration, bands, filters etc.
- Suitable for Statistical Studies
- Flexible Database Download/Upload/XID Features

"plug and play"

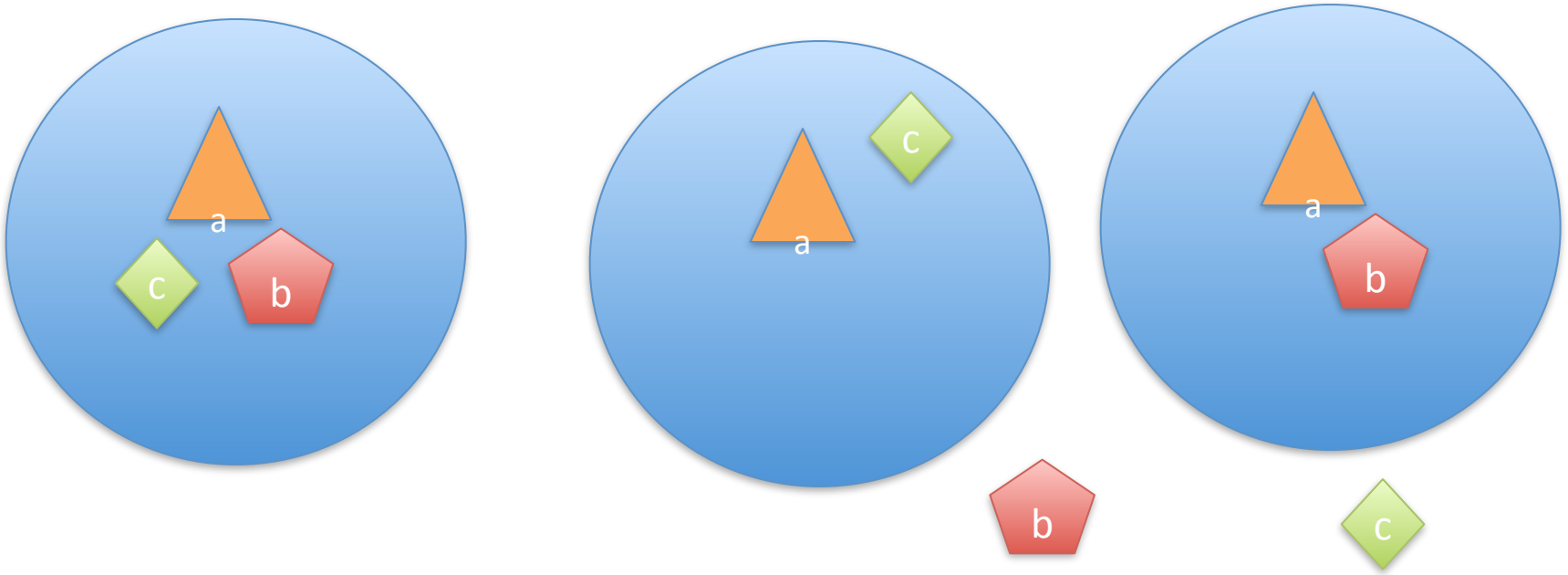
Herschel IDs with no prior

- Faced with a single Herschel source like this you don't know what to think. Is the Herschel blob (blue circle) associated with a, b or c?



Herschel IDs with prior

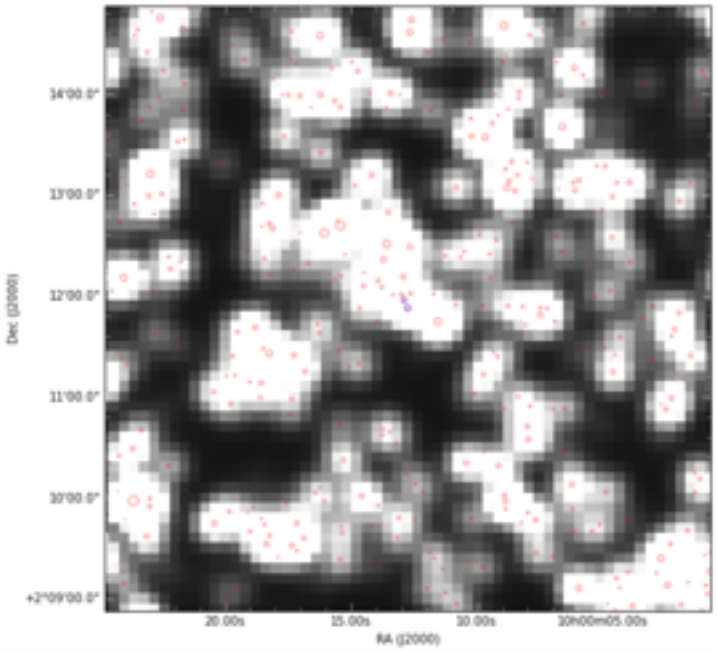
- With a large population of Herschel sources you have much more information you can use to determine the likelihood of any association

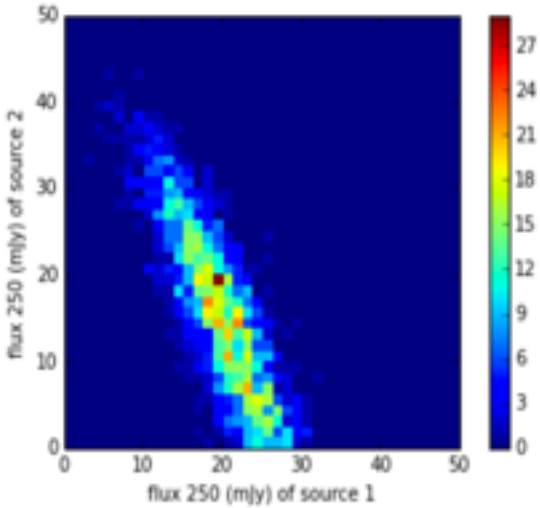


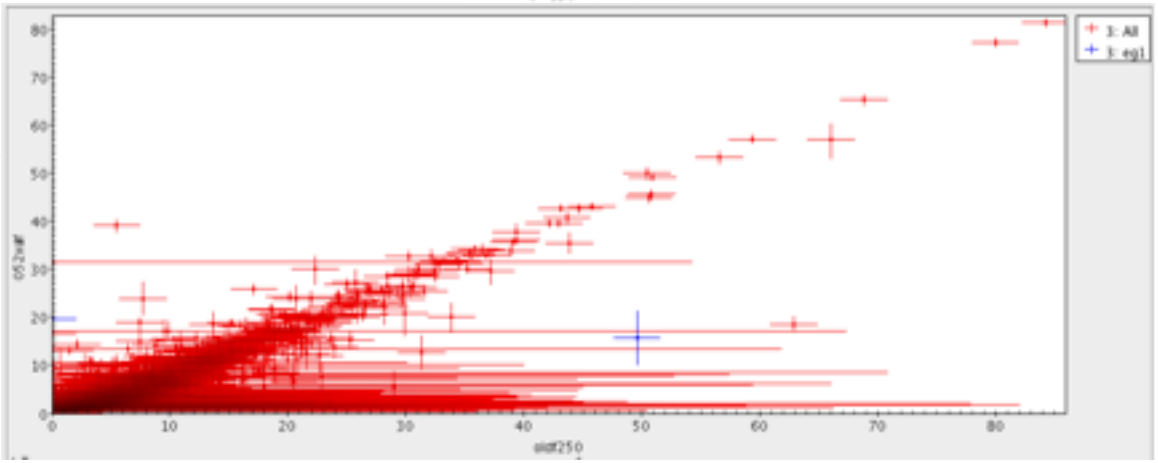
=> Employ magic to merge these together!

HELP : Enter XID+

- Use STAN as Bayesian inference engine (http://mc-stan.org/)
- Use a MCMC based approach to fully map posterior



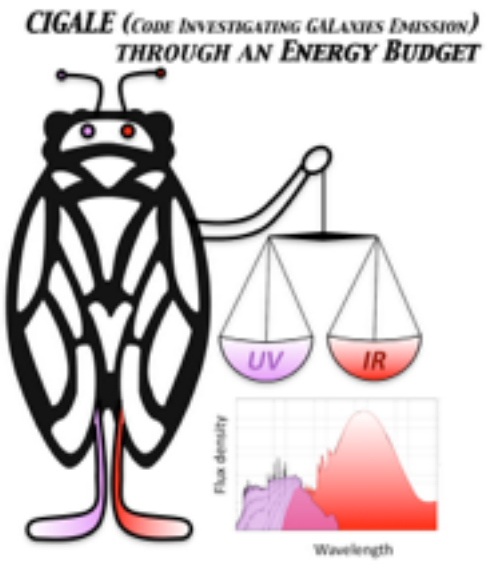


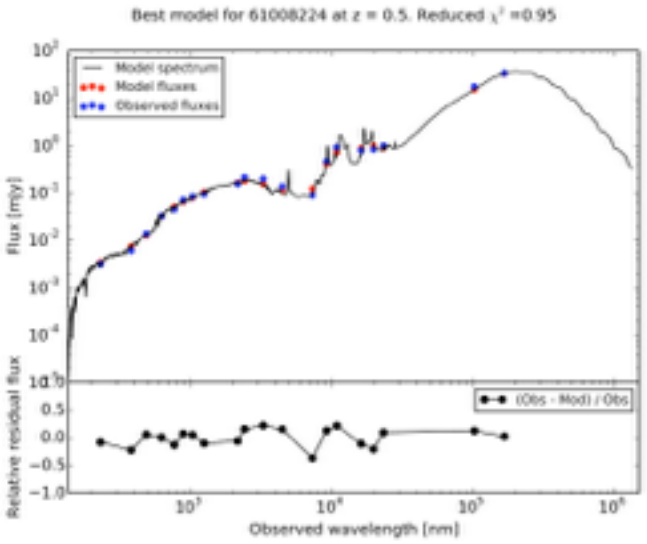


Peter Hurley

Consistent Physical Modeling Tools to investigate degeneracies etc.

- LePhare+
- Cigale+





Status

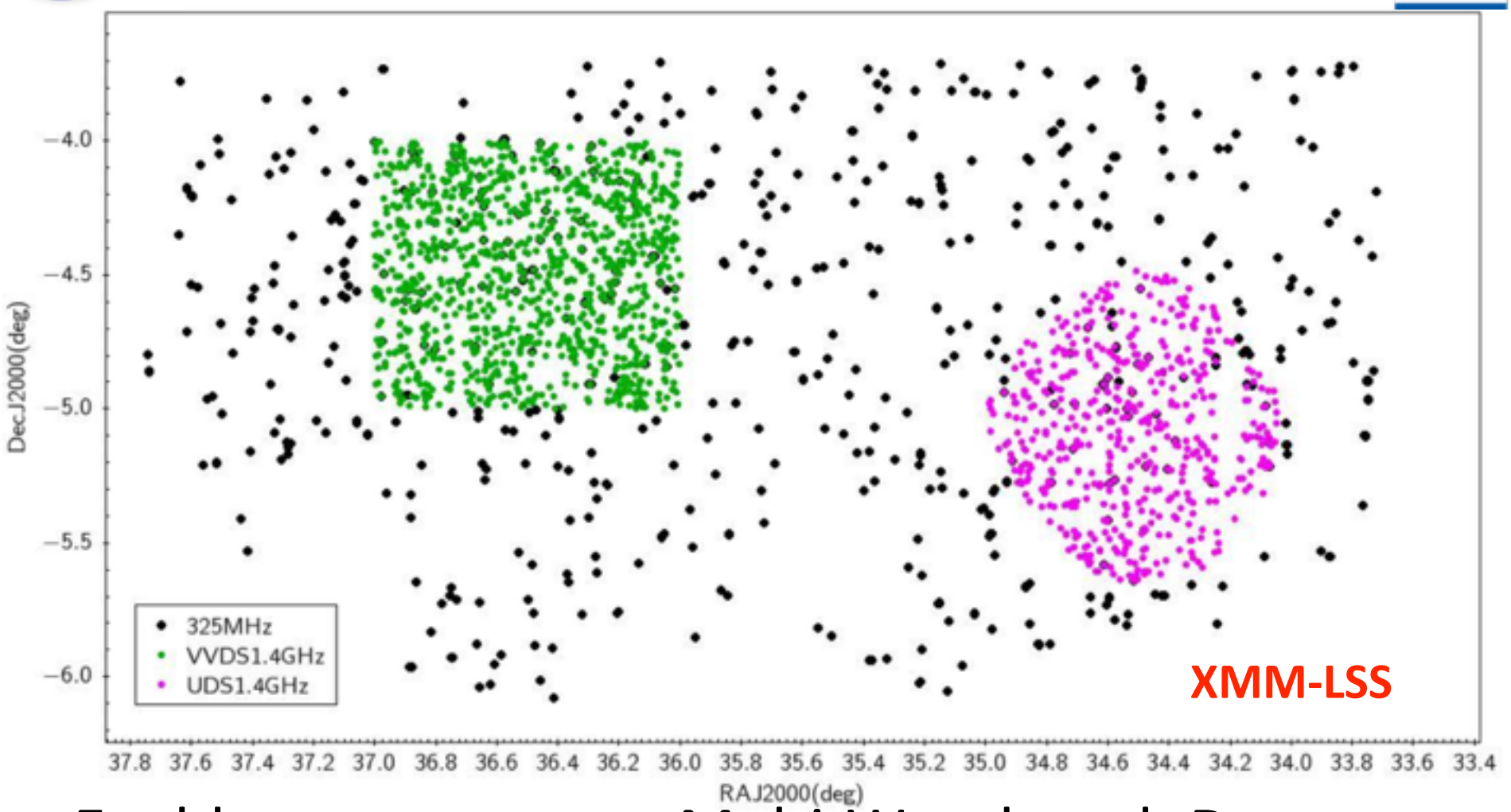
- Kick off meeting @ Sussex in April 2014

- Phase 1 completed in April 2015 with Data Workshop @ LAM/Marseille
  - SPIRE & Ancillary Data (Catalogs & Maps) assembled
  - Defined regions to prioritize (COSMOS, XMM-LSS, GAMA-15)
  - Defined "challenges", e.g. SPIRE prior & SED modeling challenges
  - Defined & Developed multi-wavelength photometry methods
  - Defined science goals and user requirements

- Phase 2 now running until end of 2015
  - End-to-End Data Reduction & SED Modeling on Data & Simulations
  - Complete challenges and define a first version of the HELP pipeline

- Phase 3 & Phase 4 (2016 & 2017) will refine and expand to other fields
  - Lorentz Centre Meeting in April 2016 (inviting external participation)

HELP & Radio Continuum Surveys

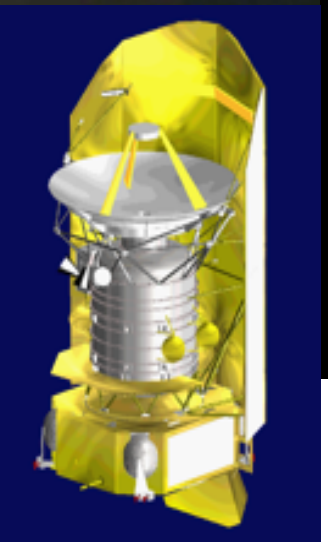


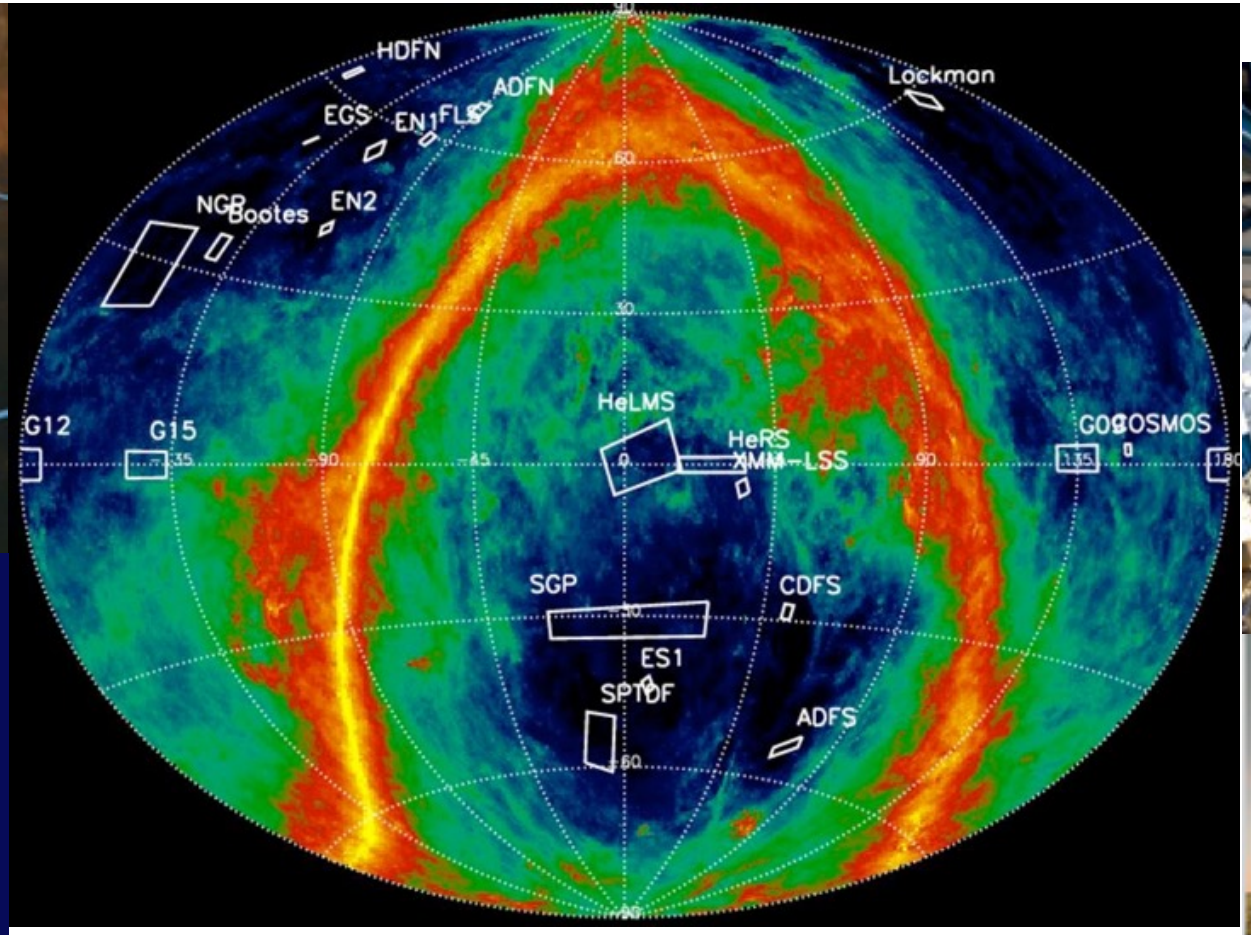
- Enable easy access to Multi-Wavelength Datasets
- Enable Timely Radio Survey Science Exploitation!

Conclusion

- "Plug-and-play" multi-λ surveys over 1000 deg^2
- Open to data / science collaboration (talk to me!)
- Aims to lower barriers to statistical studies
- Enable easy access to and use of (Herschel) data
- "Value-added" data products (z, SFR, M_*, M_{dust} ...)
- Easy comparison against galaxy formation models
- To provide a resource for astronomers to study the high-z Universe not unlike SDSS at low-z
- Delivering on the promise of Continuum Surveys

Thanks!





http://herschel.sussex.ac.uk/

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