HELP-ing Radio Continuum Surveys

The Herschel Extragalactic Legacy Project

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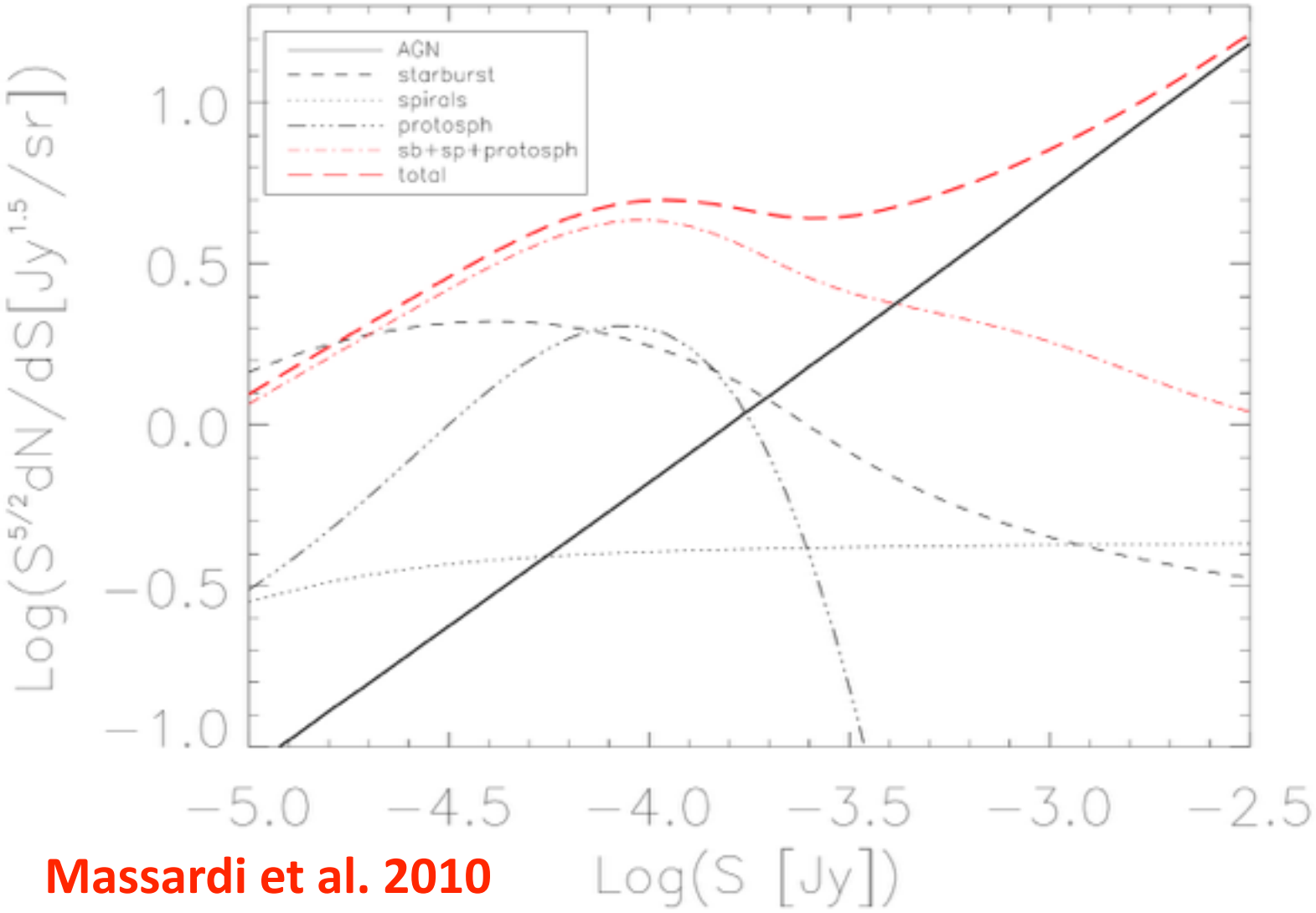
EC-REA - FP7-SPACE-2013

SA-DST - COINVEST-2014

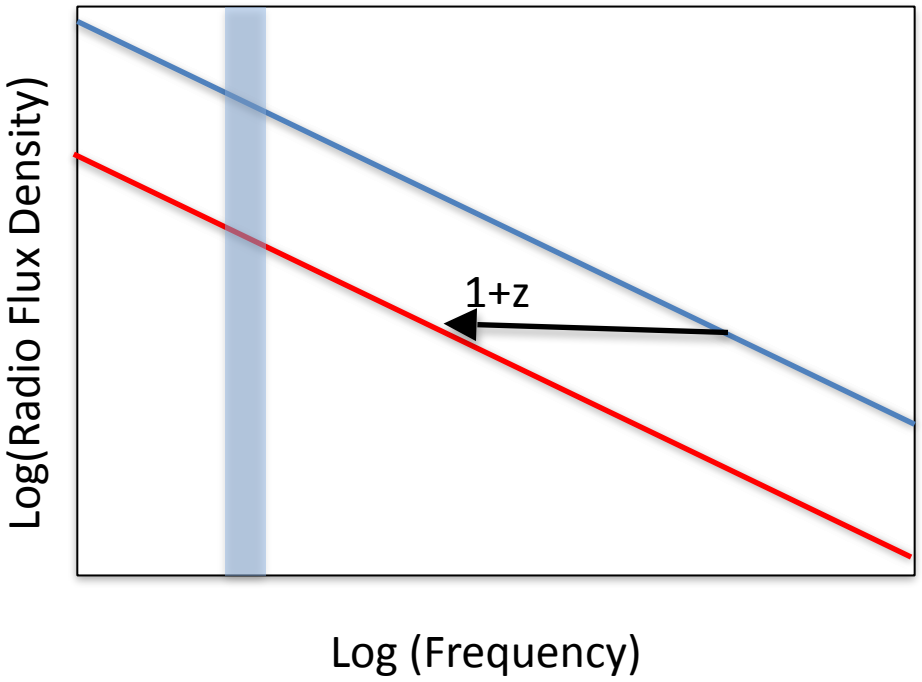
The Faint Radio Sky



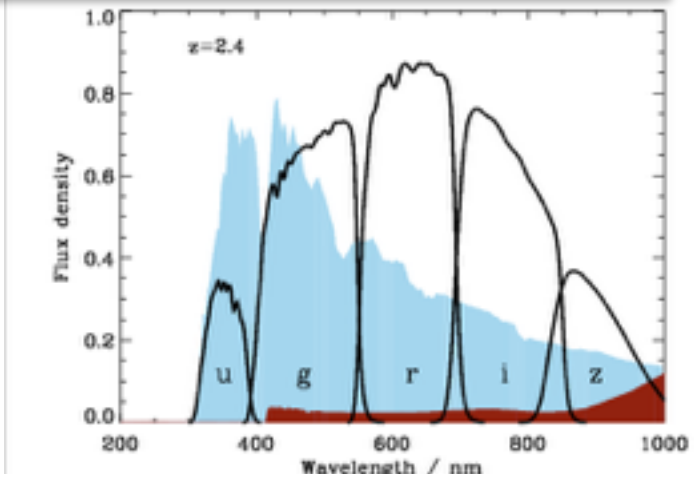
Massardi et al. 2010

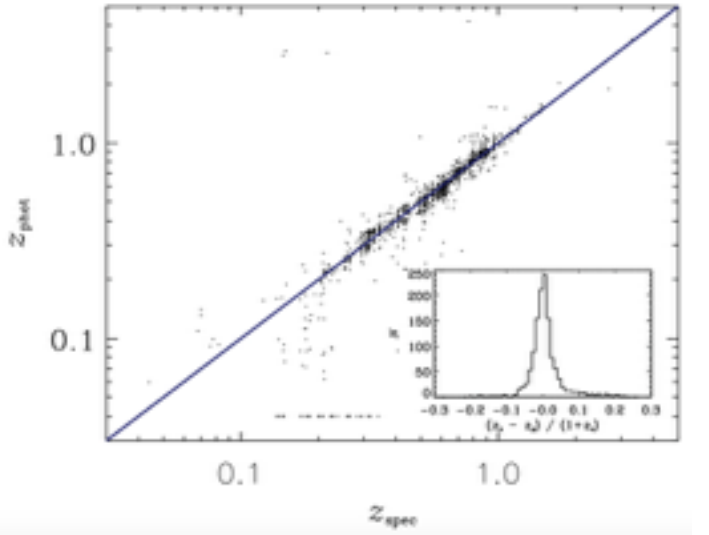
But of course…

There's nothing as useless as a radio source (Matt Jarvis)



Radio provides no (very little?) redshift information!

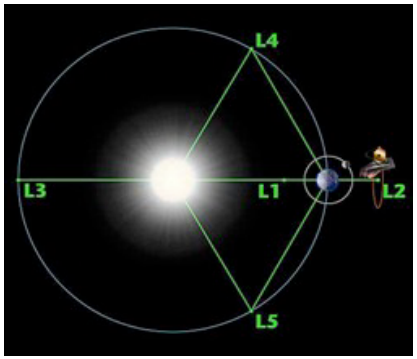


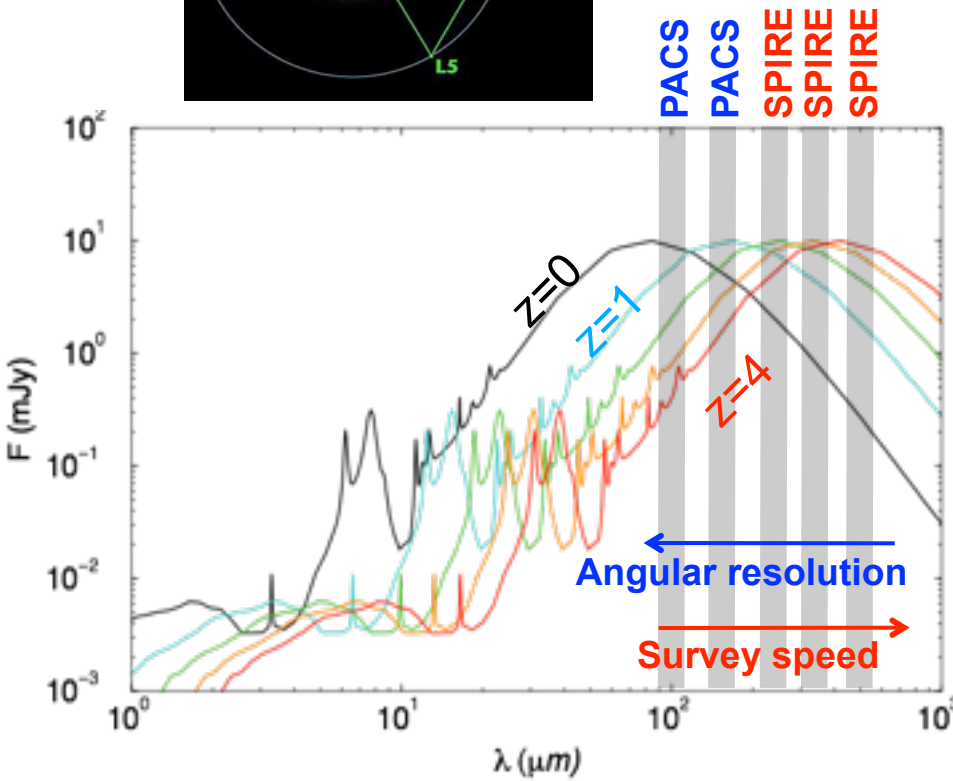


The Herschel Space Observatory

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?

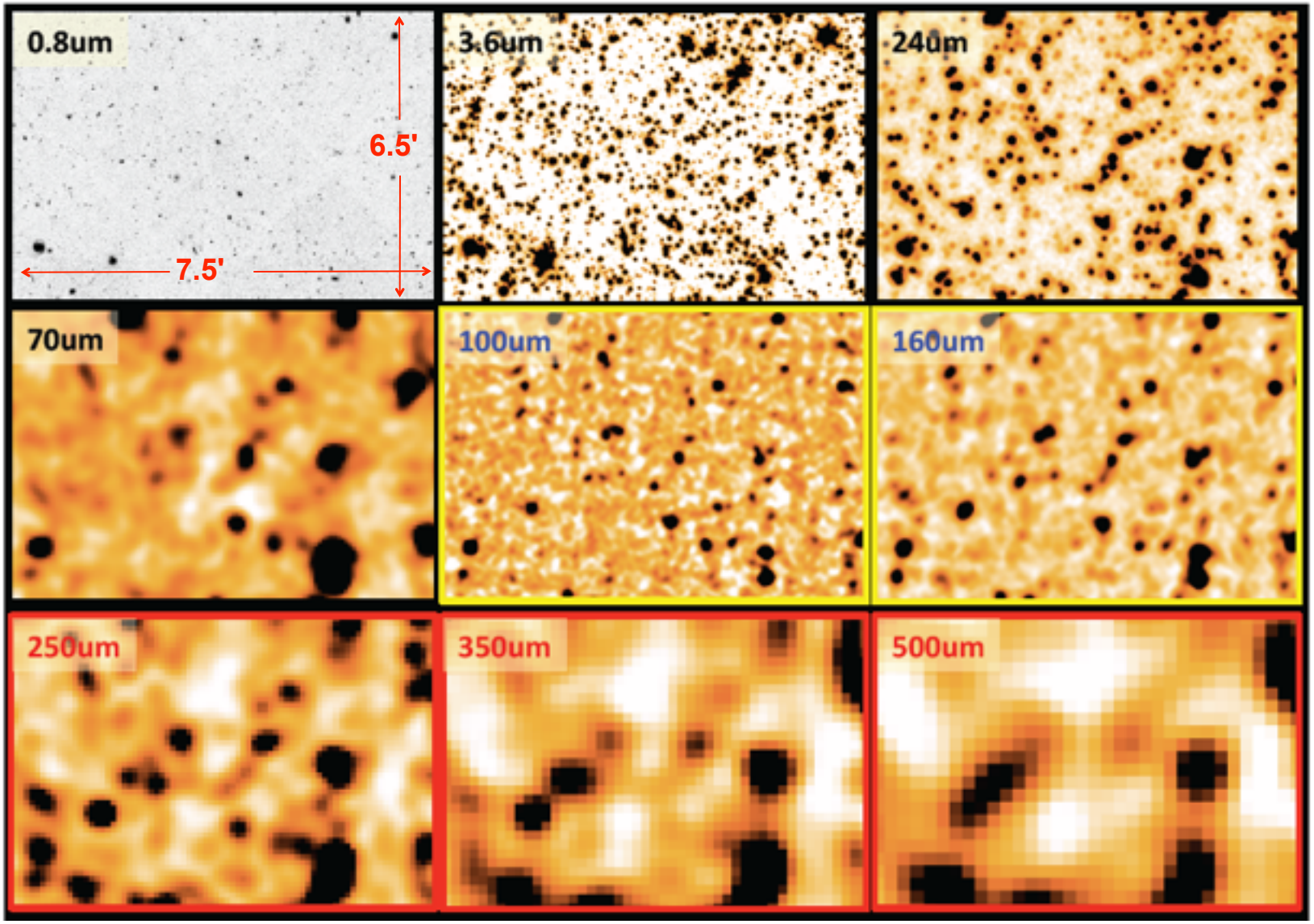
HERMES

ATLAS

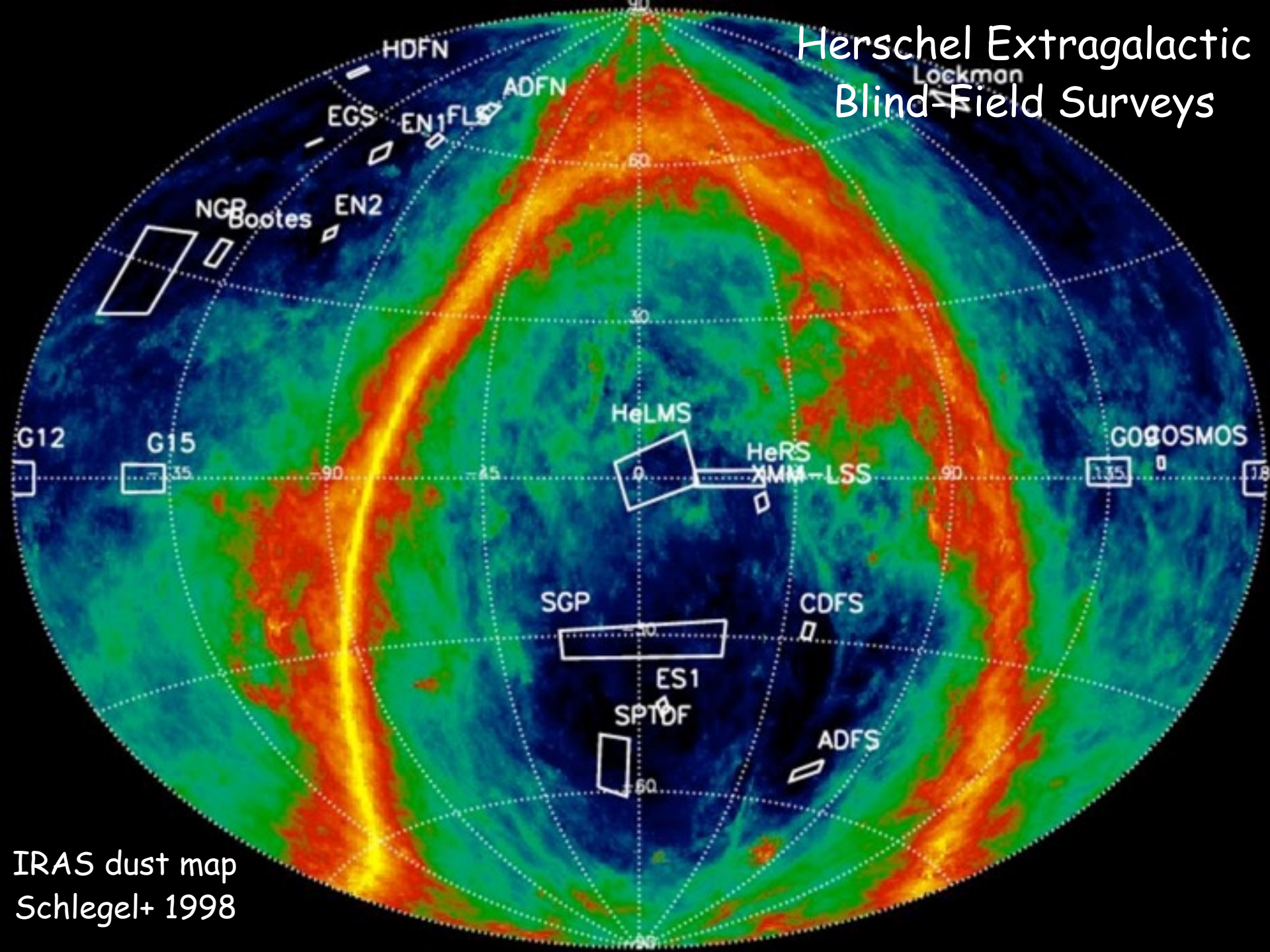
Herschel Extragalactic Imaging Surveys

- 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 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
SPIDF
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

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

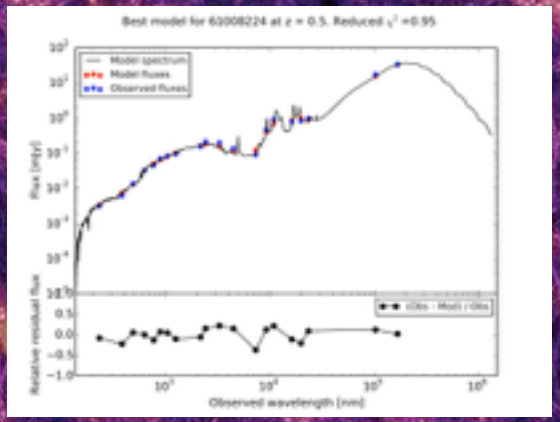
Need for Large Multi-λ Fields

3° at z=1

125 Mpc/h

ASTRODEEP fields

Typical HerMES field

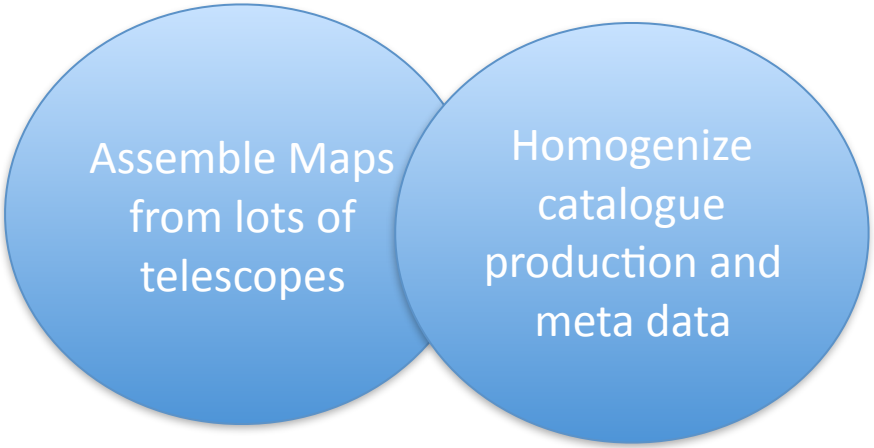


Δz=0.1 at z=1

Concept

Assemble Maps from lots of telescopes

Concept


Assemble Maps from lots of telescopes
Homogenize catalogue production and meta data

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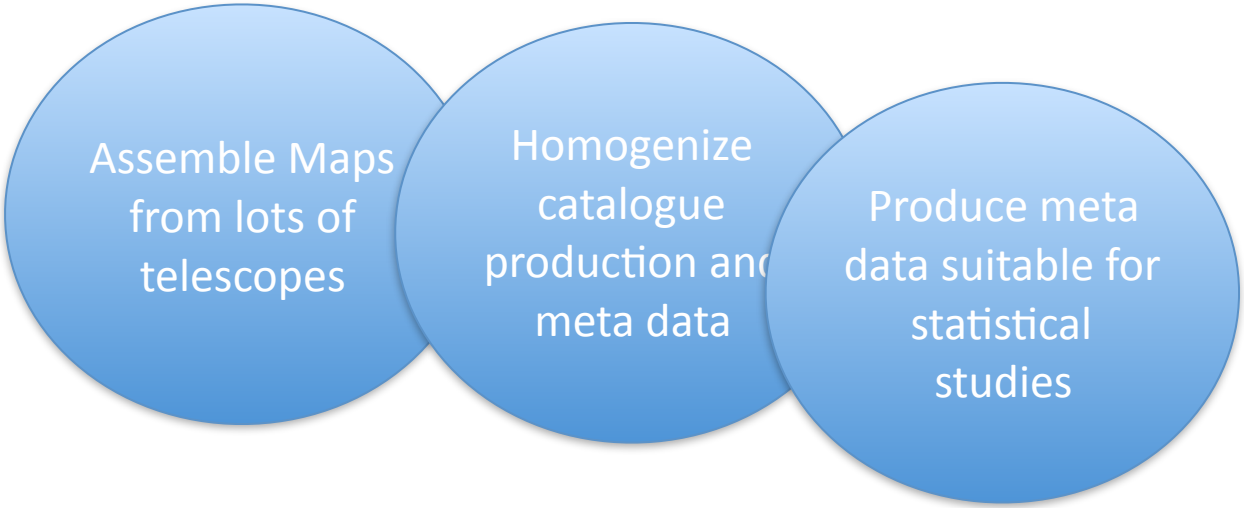
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Homogenize catalogue production and meta data
Produce meta data suitable for statistical studies

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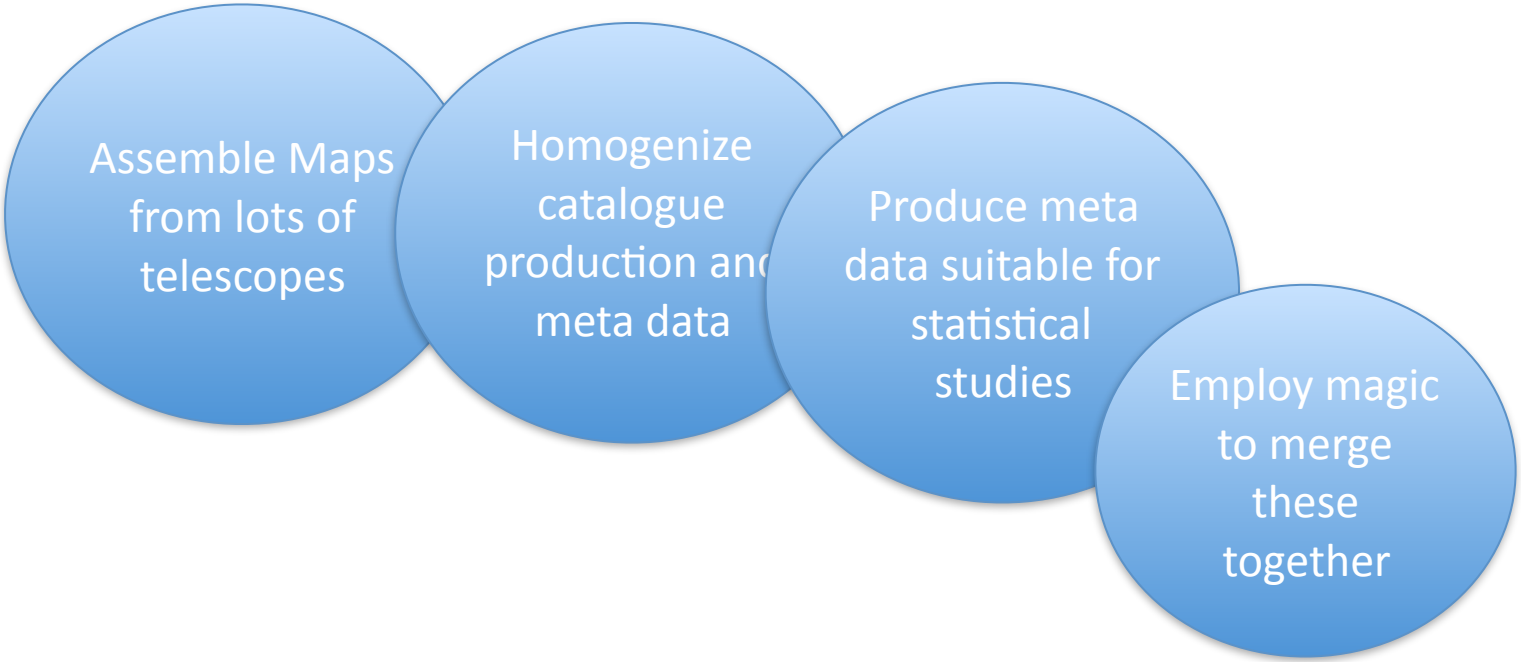
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Employ magic to merge these together

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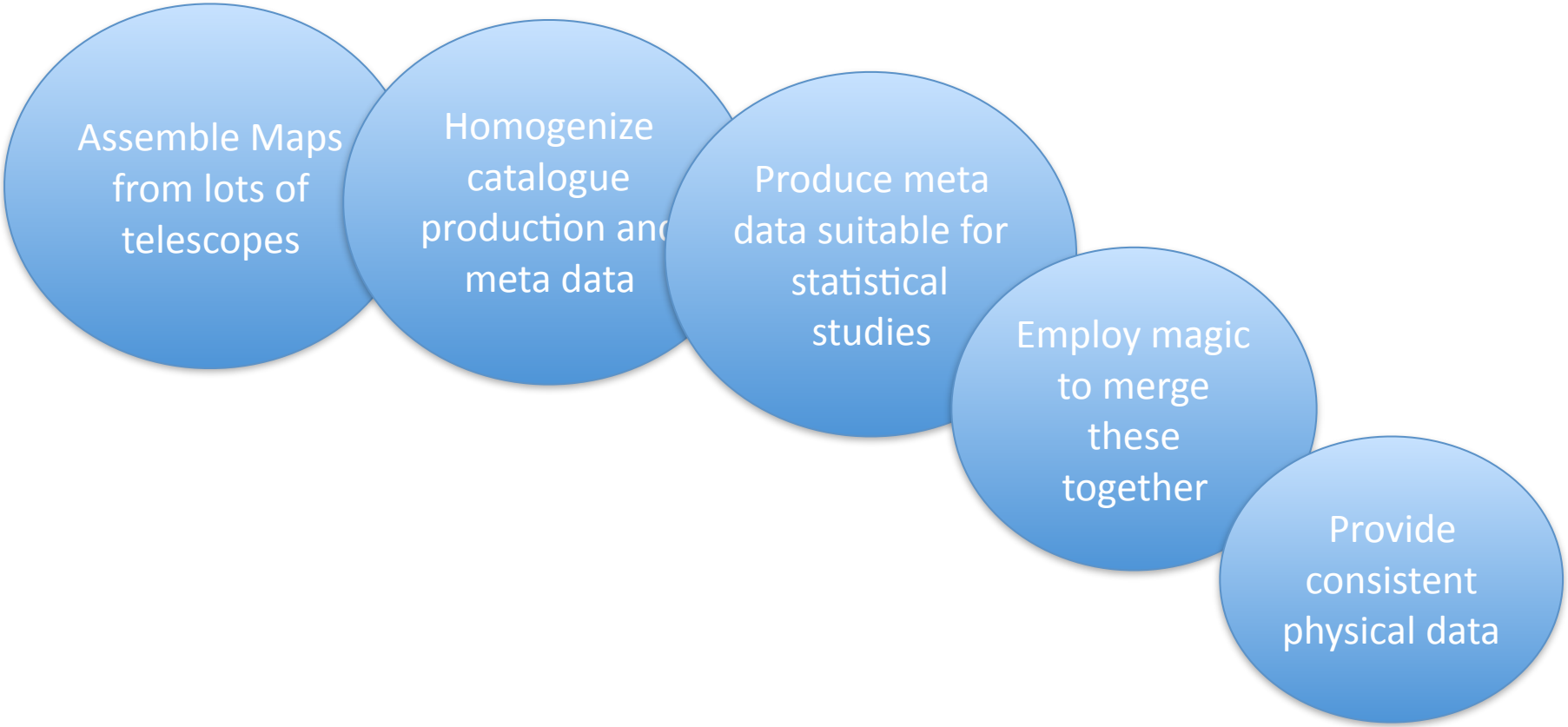
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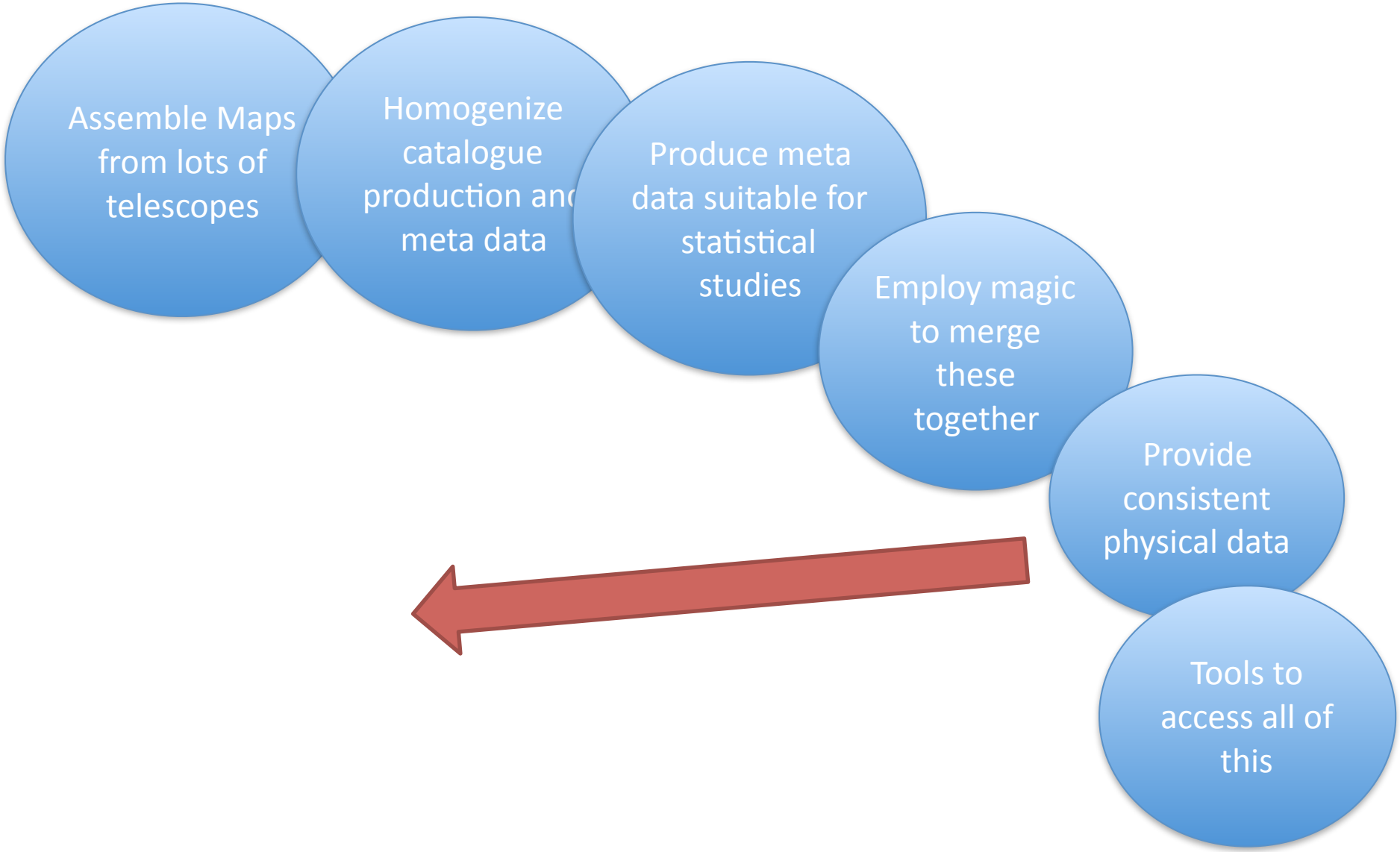
Produce meta data suitable for statistical studies
Employ magic to merge these together
Provide consistent physical data

Concept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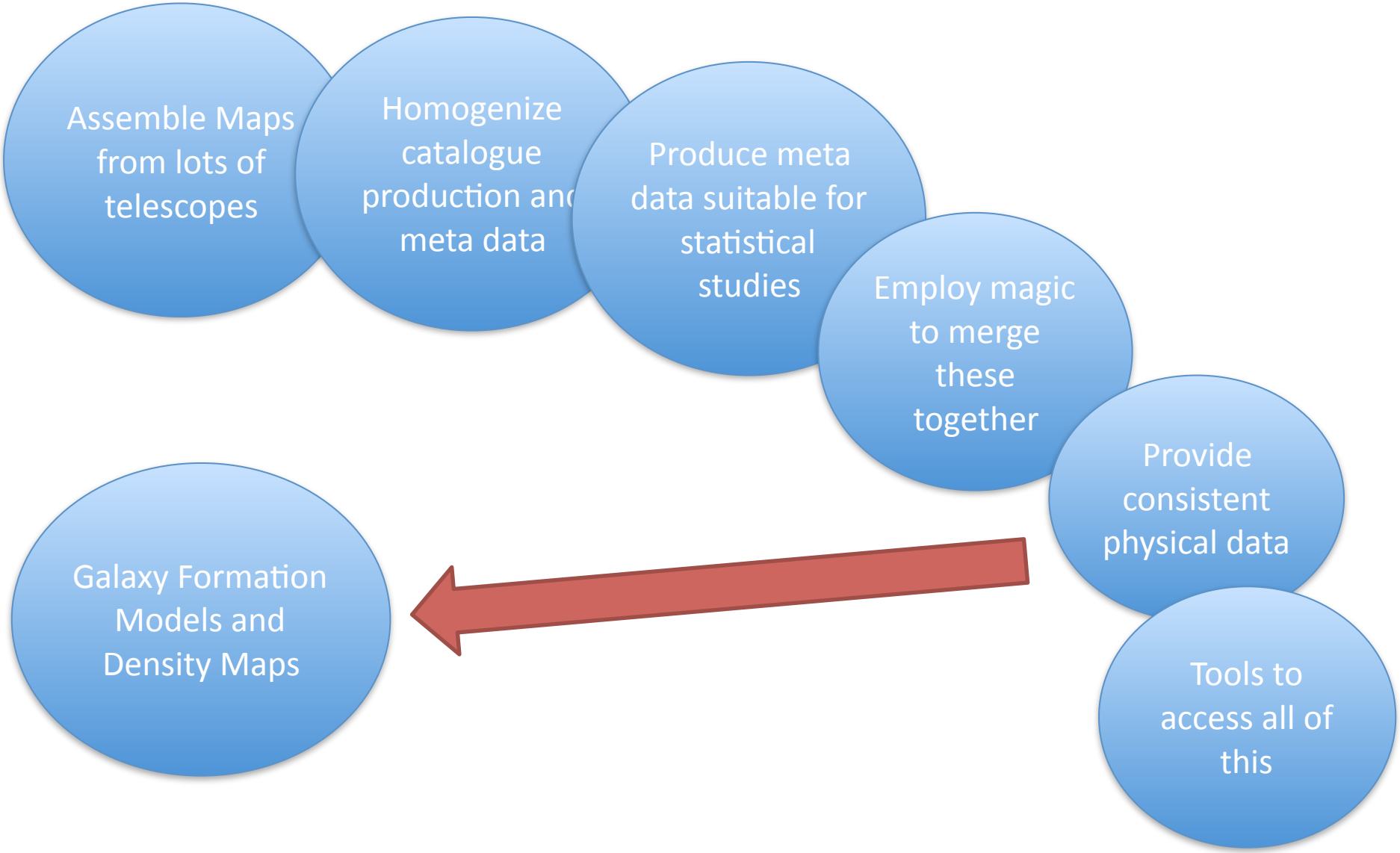
Provide consistent physical data
Tools to access all of this

Concept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Galaxy Formation Models and Density Maps

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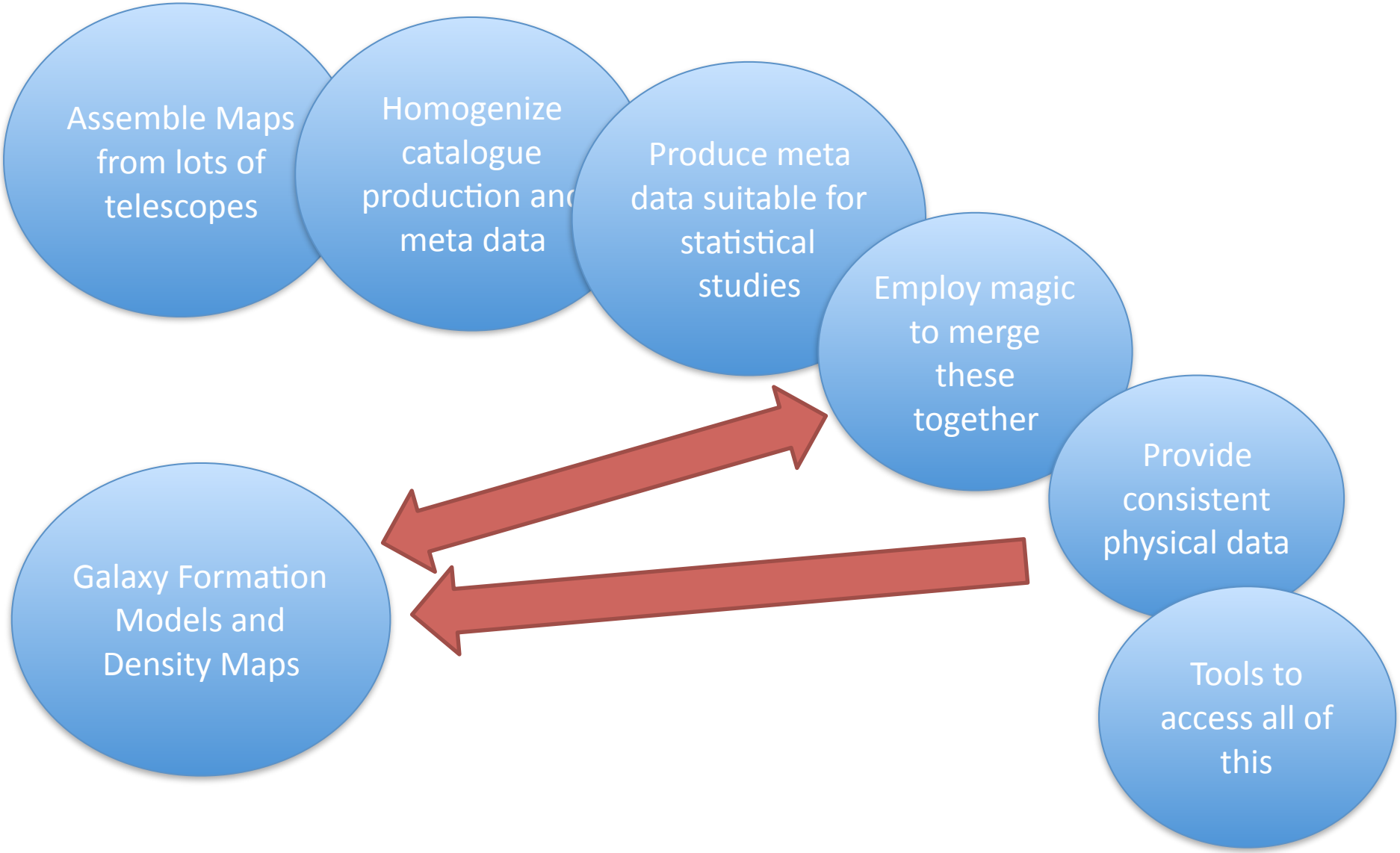
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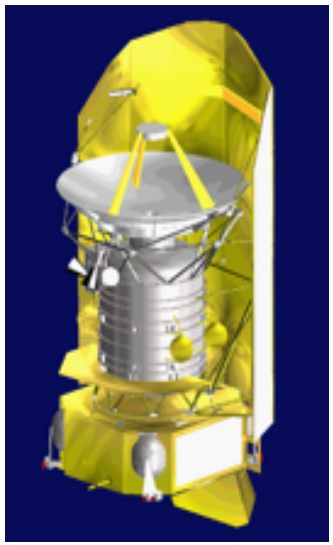
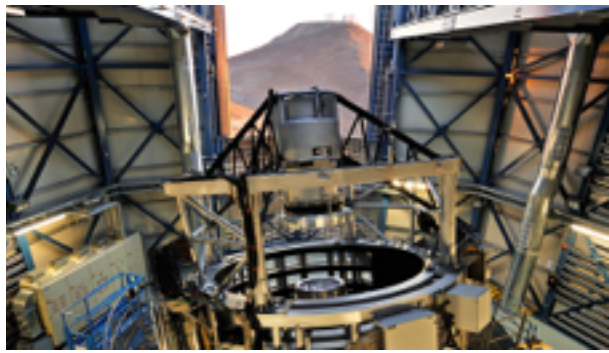
Galaxy Formation Models and Density Maps

Assemble maps from lots of telescopes

- SPIRE & PACS
  - HerMES & PEP
  - 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



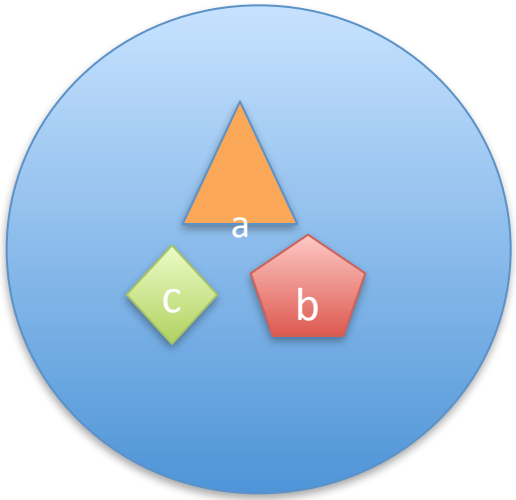
Homogenize Catalogs & Meta-Data

- 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"

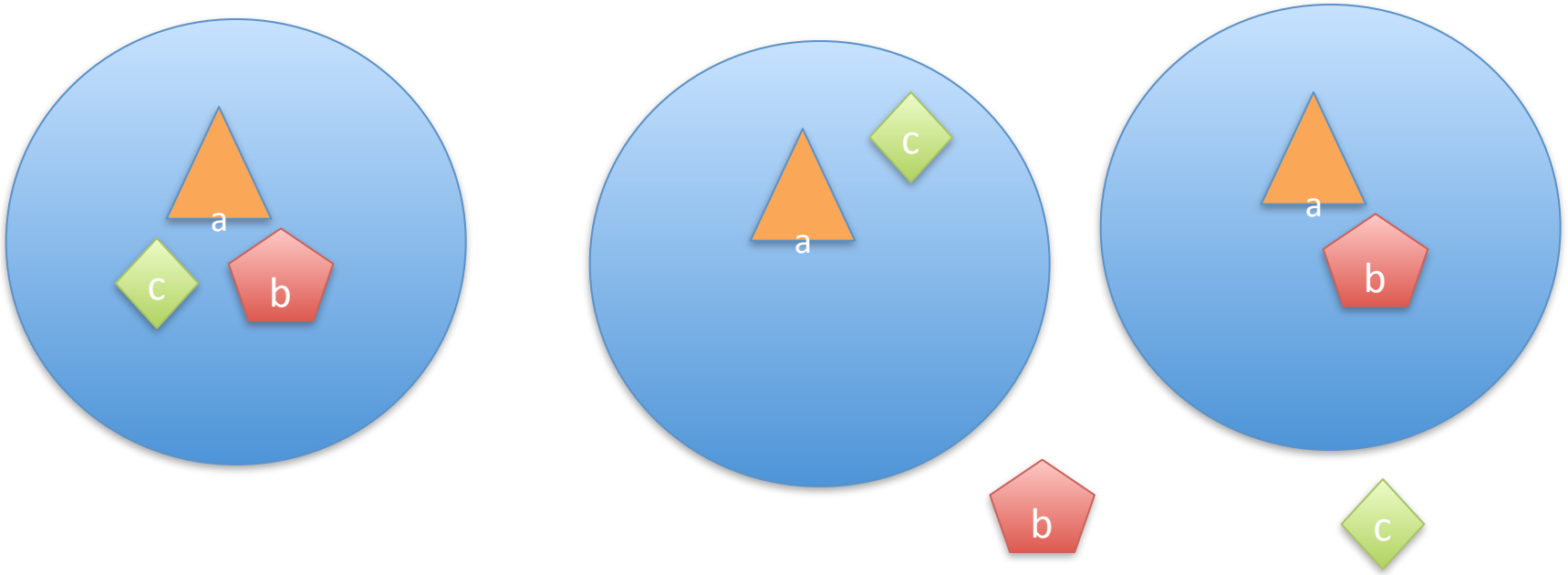
Herschel IDs with no prior

- 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



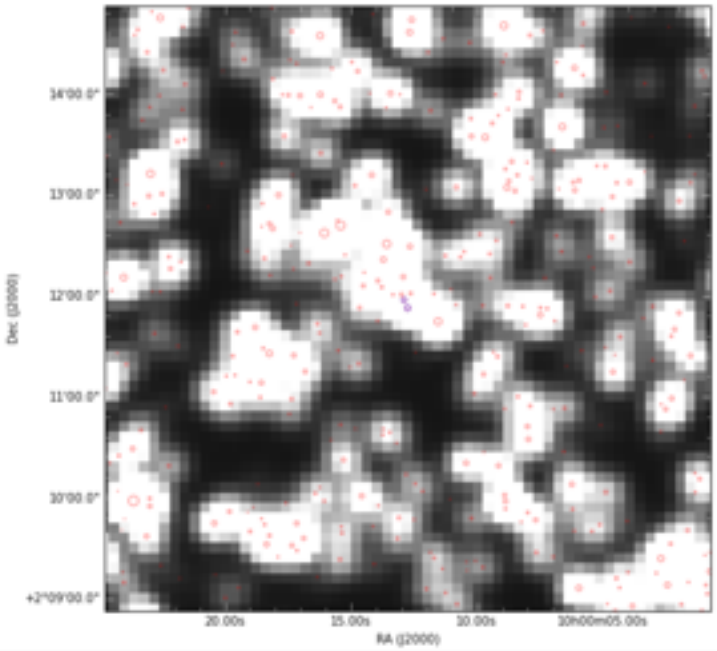
=> Employ magic to merge these together!

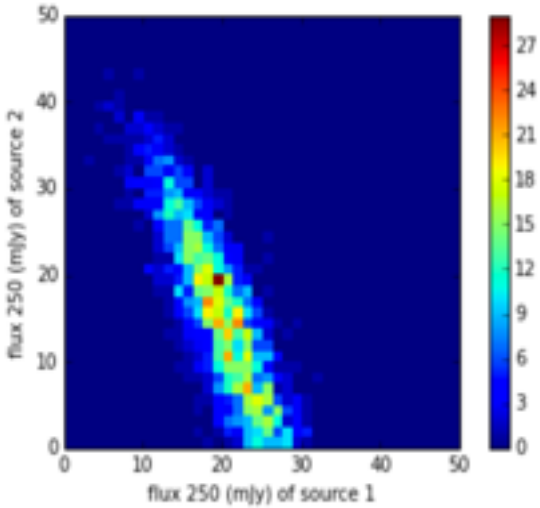
What do we really want?

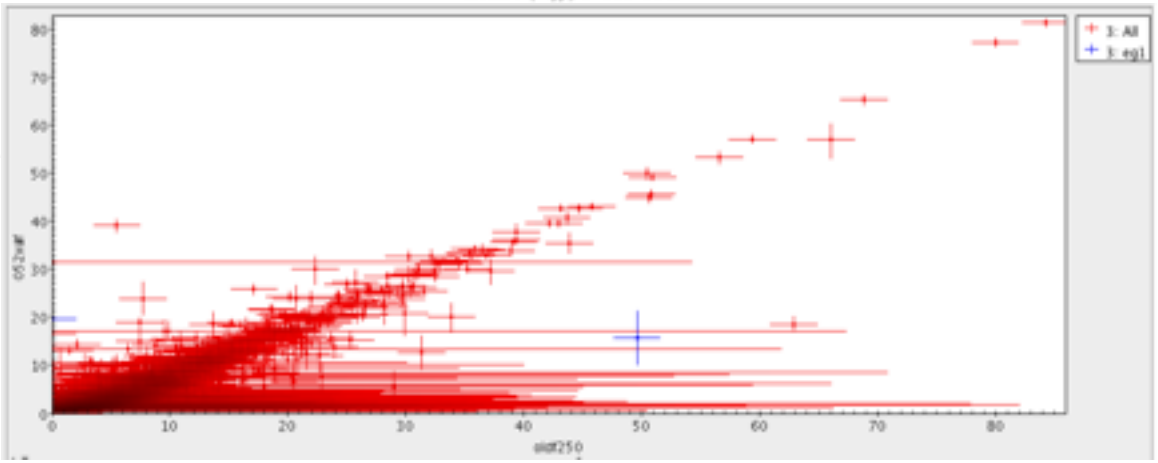
- True mapping of posterior rather than point estimate
- Proper measure of uncertainty on flux
- Consistently determine interplay of nearby sources
- Estimate background at same time
- Fit all three SPIRE bands at same time
- Transparent way of dealing with prior information

HELP : Enter XID+

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



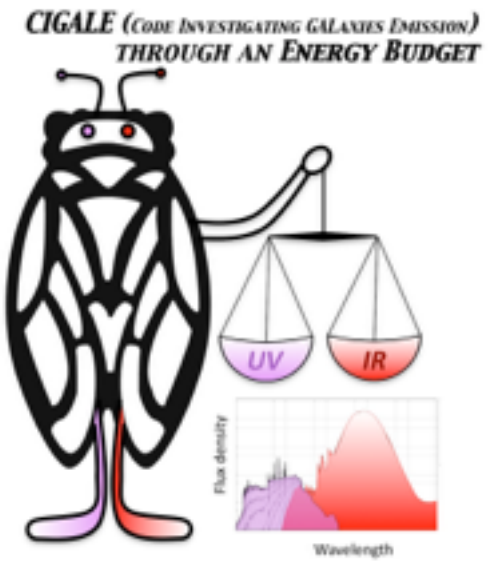


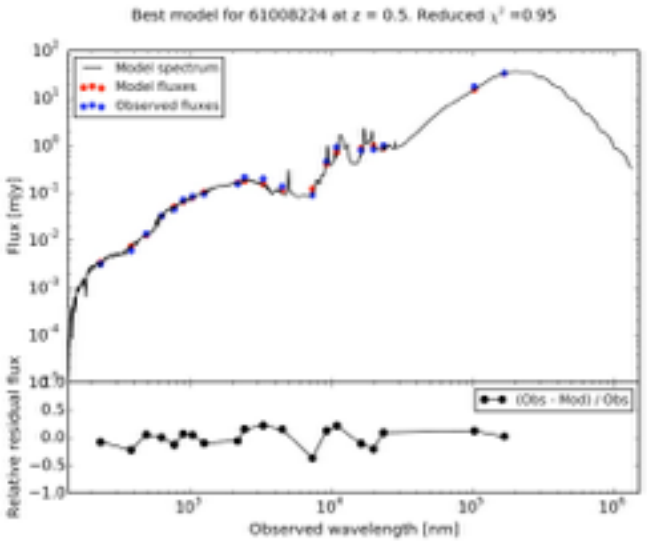


Peter Hurley

Consistent Physical Modeling Tools

- LePhare+
- Cigale+





Status

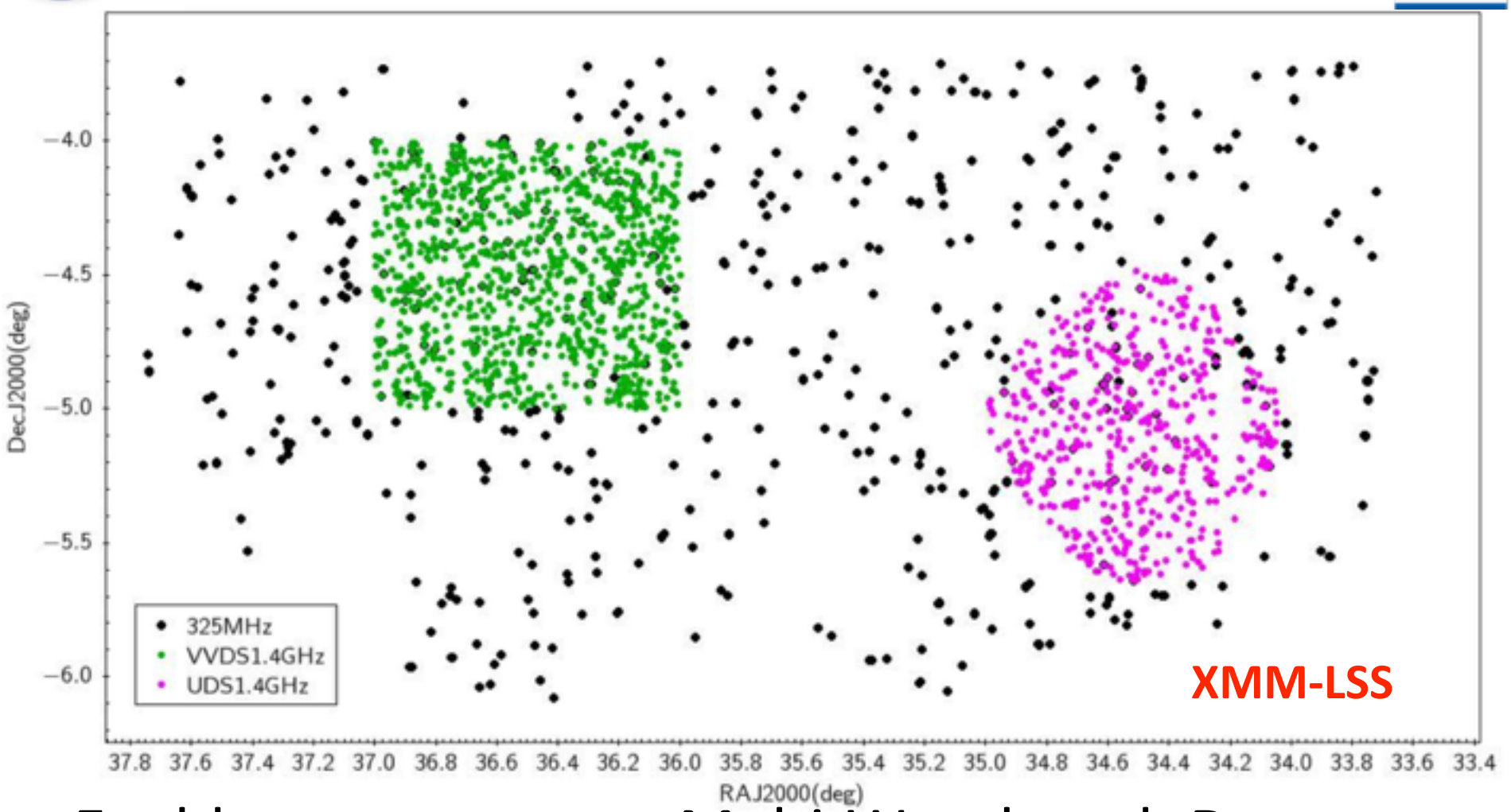
- Kick off meeting in April 2014 at University of Sussex

- 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 June 2016 (inviting external participation)

HELP & Radio Continuum Surveys

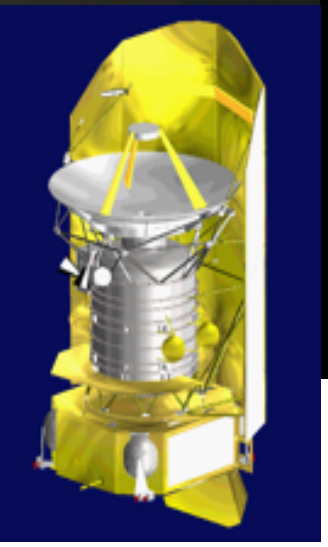


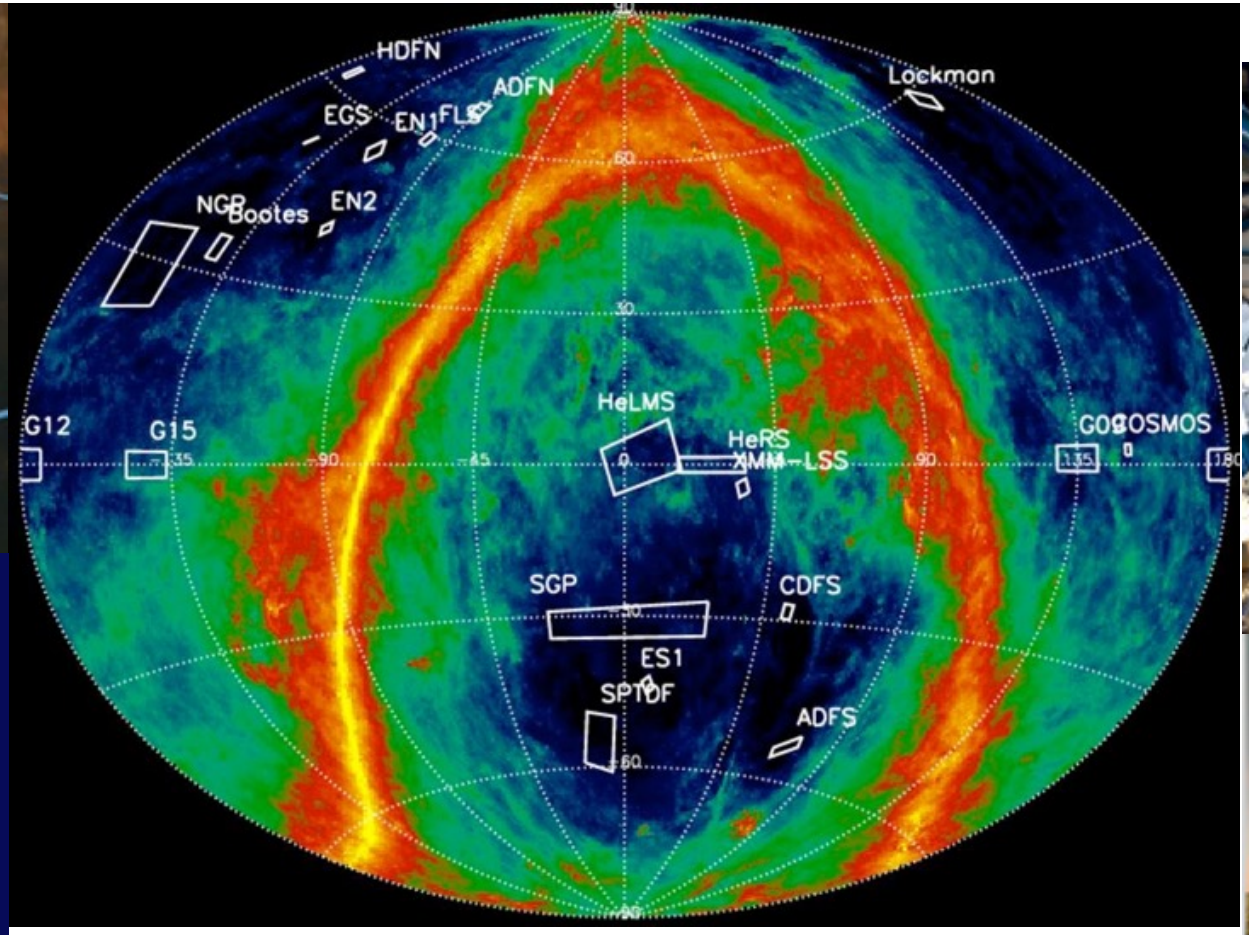
- Enable easy access to Multi-Wavelength Datasets
- Enable Timely Radio Survey Science Exploitation

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!





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