



Extragalactic Surveys with Herschel-SPIRE

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IAC Tenerife**

**on behalf of the SPIRE high-redshift
extragalactic surveys (SAG-1) team**



The SPIRE Consortium

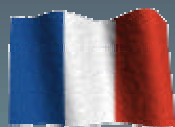
Canada



China



France



Italy



Spain



Sweden



UK



USA



- Cardiff University, UK
- CEA Service d'Astrophysique, Saclay, France
- Institut d'Astrophysique Spatiale, Orsay, France
- Imperial College, London, UK
- Instituto de Astrofisica de Canarias, Tenerife, Spain
- Istituto di Fisica dello Spazio Interplanetario, Rome, Italy
- Jet Propulsion Laboratory/Caltech, Pasadena, USA
- Laboratoire d'Astronomie Spatiale, Marseille, France
- Mullard Space Science Laboratory, Surrey, UK
- NAOC, Beijing, China
- Observatoire de Paris, Meudon, France
- Rutherford Appleton Laboratory, Oxfordshire, UK
- Stockholm Observatory, Sweden
- UK Astronomy Technology Centre, Edinburgh, UK
- Università di Padova, Italy
- University of Lethbridge, Canada



SPIRE SAG 1 (Hi-z) and SAG 2 (Lo-z) Teams

| | | | | | |
|---------------------|----------|---------------------|----------------|---------------------|----------------|
| Asier | Abreu | Erica | Ellingson | Seb | Oliver |
| Rick | Arendt | Alberto | Franceschini | (SAG-1 coordinator) | |
| Her vé | Aussel | Mark | Frost | Alain | Omont |
| Tom | Babbedge | Frederic | Galliano | Mat | Page |
| George | Bendo | Ken | Ganga | Pasquale | Panuzzo |
| Andrew | Blain | Walter | Gear | Ismael | Perez Fournon |
| Jamie | Bock | (SAG-2 coordinator) | | Michael | Rowan-Robinson |
| (SAG-1 coordinator) | | Jason | Glenn | Marc | Sauvage |
| Alessandro Boselli | | Matt | Griffin | Richard | Savage |
| Véronique Buat | | Bruno | Guiderdoni | Bernhard | Schulz |
| Jordi | Cepa | Mark | Halpern | Douglas | Scott |
| Pierre | Chanial | Martin | Harwit | Luigi | Spinoglio |
| Sarah | Church | Evanthia | Hatziminaoglou | Jason | Stevens |
| Dave | Clements | George | Helou | Mattia | Vaccari |
| Asantha | Cooray | Kate | Isaak | Laurent | Vigroux |
| Jon | Davies | Rob | Ivison | Ian | Waddington |
| Fred C. | Dobbs | Guilaine | Lagache | Tim | Waskett |
| Darren | Dowell | Glenn | Laurent | Christine | Wilson |
| Gianfranco De Zotti | | Suzanne | Madden | Kevin | Xu |
| Eli | Dwek | (SAG-2 coordinator) | | | |
| Simon | Dye | Bruno | Maffei | | |
| Steve | Eales | Phil | Maloney | | |
| David | Elbaz | Hien | Nguyen | | |

Herschel Key Science

formation and evolution of galaxies

- how and when did galaxies form?
- is there an unknown population of high- z IR galaxies?
- cosmologically evolving AGN/starburst symbiosis
- star formation rates; bolometric luminosities; AGN fraction
- connections between near-IR and sub-millimetre galaxies

star formation and the physics of the ISM

- how do stars form out of the ISM?
- circulation/enrichment of the ISM - astrochemistry
- detailed studies of nearby galaxies

study cometary, planetary, and satellite atmospheres

- history of the solar system
- pristine material in comets
- water important line



Extragalactic Science with SPIRE

- **High-Z GT Key Programme (SAG-1) to ...**

Carry out Multi-band Multi-tiered surveys covering the peak of the FIR background (PACS+SPIRE)

SAG-1 coordinators : Seb Oliver (Sussex) and Jamie Bock (JPL)

- **Local Galaxies GT Key Programmes (SAG-2) to ...**

Study the Physical Processes in the ISM of Very Nearby Galaxies (PACS + SPIRE)

Study The ISM in Low Metallicity Environments (PACS + SPIRE)

Do the Herschel Galaxy Reference Survey (SPIRE only)

SAG-2 coordinators: Sue Madden (Saclay) and Walter Gear (Cardiff)

- **Open Time programmes to ...**

Do many other thingsCheck EXTRA-Hot

<http://astronomy.sussex.ac.uk/~sjo/extrahot>





High-z GT Programme

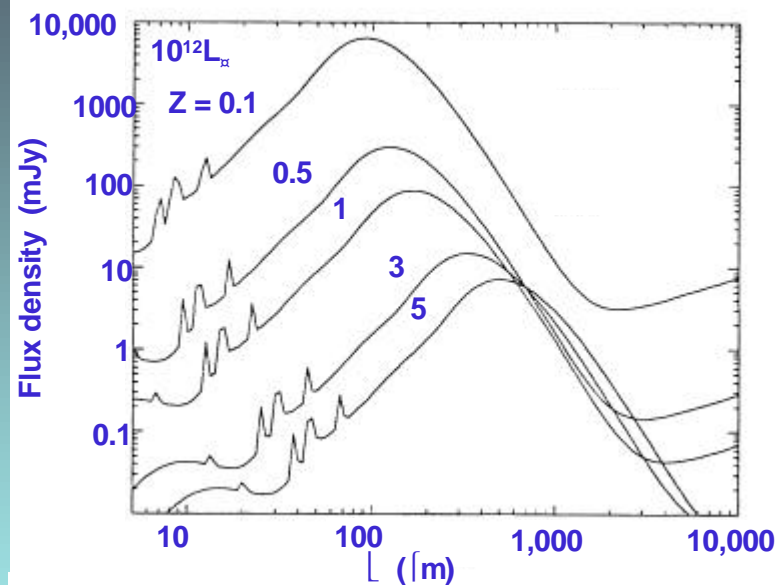
Herschel probes the rest-frame bolometric emission from galaxies as they formed most of their stars

Will address issues like:

- History of star formation and energy production
- Structure formation
- Cluster evolution
- CIRB fluctuations
- AGN-starburst connection

How?

- Investing 850hrs of SPIRE and 650hrs of PACS GT
- Observing a Set of Blank Fields in Different Depths
- Observing a Sample of Rich **Clusters** ($0.2 < z < 1.0$)



After Guiderdoni et al. MNRAS 295, 877, 1998

Wedding Cake Survey

7



Clusters

GOODS-S 0.04 sq.
deg.

GOODS-N 0.04

GOODS-S/ Groth
Strip/Lockman 3x0.25

Cosmos/XMM-LSS 2+2

CDFS/Lockman 7.75+4.3

SWIRE/NDWFS/FLS/
0444astrof 51 sq. deg.

will probe L_{bol} over a wide
redshift range

Wedding Cake Survey

8



Lensing, SZ

SEDs of Galaxies
Contributing to the CIB

Multi-band P(D) analysis

Structure Formation;
clustering on angular scales
< 10 arcmin

Wedding Cake Survey (Fields, Areas, Depths)

| Menu A | | Agreed Areas/Depths | | | | | | | | |
|----------|-------------------|---------------------|----------------------------|-------|-----------------------|------|------|------|-------|------|
| Name | Area /sq. deg. | Fields | Integration Time /hours | | Depth in Band /mJy | | | | | |
| | | | PACS | SPIRE | 75 | 110 | 170 | 250 | 350 | 500 |
| Clusters | | | 80 | 100.0 | | | | | | |
| Level-1 | 0.04 | GOODS-S | 230 | 40 | 1.0 | 1.0 | 1.0 | 3.3 | 4.0 | 4.6 |
| Level-2 | 0.04 | GOODS-N | 27 | 10.0 | 2 | 2.8 | 3.0 | 6.7 | 8.1 | 9.2 |
| Level-3 | 0.25 | GOODS-S | 34 | 25.0 | 2.2 | 6.2 | 6.7 | 10.5 | 12.7 | 14.5 |
| | 0.25 | Groth Strip | 34 | 25.0 | 2.2 | 6.2 | 6.7 | 10.5 | 12.7 | 14.5 |
| | 0.25 | Lockman (ROSAT) | 34 | 25.0 | 2.2 | 6.2 | 6.7 | 10.5 | 12.7 | 14.5 |
| Level-4 | 2.0 | COSMOS | 110 | 50.0 | 6.0 | 9.8 | 10.5 | 21.1 | 25.5 | 29.1 |
| | 1.0 | XMM-LSS (UDS) | 55 | 25.0 | 18 | 9.8 | 10.5 | 21.1 | 25.5 | 29.1 |
| | 1.0 | XMM-LSS (VVDS) | 55 | 25.0 | 18 | 9.8 | 10.5 | 21.1 | 25.5 | 29.1 |
| Level-5 | 10 | XMM/CDFS/Lockman | 185 | 200.0 | 18 | 16.9 | 18.0 | 23.6 | 28.5 | 32.5 |
| Level-6 | 50 | ELAIS S1 | | 150 | 18 | | 120 | 60.9 | 73.61 | 84 |
| | (~6*8) | XMM-LSS | | | | | | | | |
| | | CDFS | | | | | | | | |
| | | Lockman | | | | | | | | |
| | | ELAIS N1 | | | | | | | | |
| | | ELAIS N2 | | | | | | | | |
| | | NDWFS/Bootes | | | | | | | | |
| | | FLS | | | | | | | | |
| | | 0444astrof | | | | | | | | |

Total time: 5.5 Ms!!



Total time requested

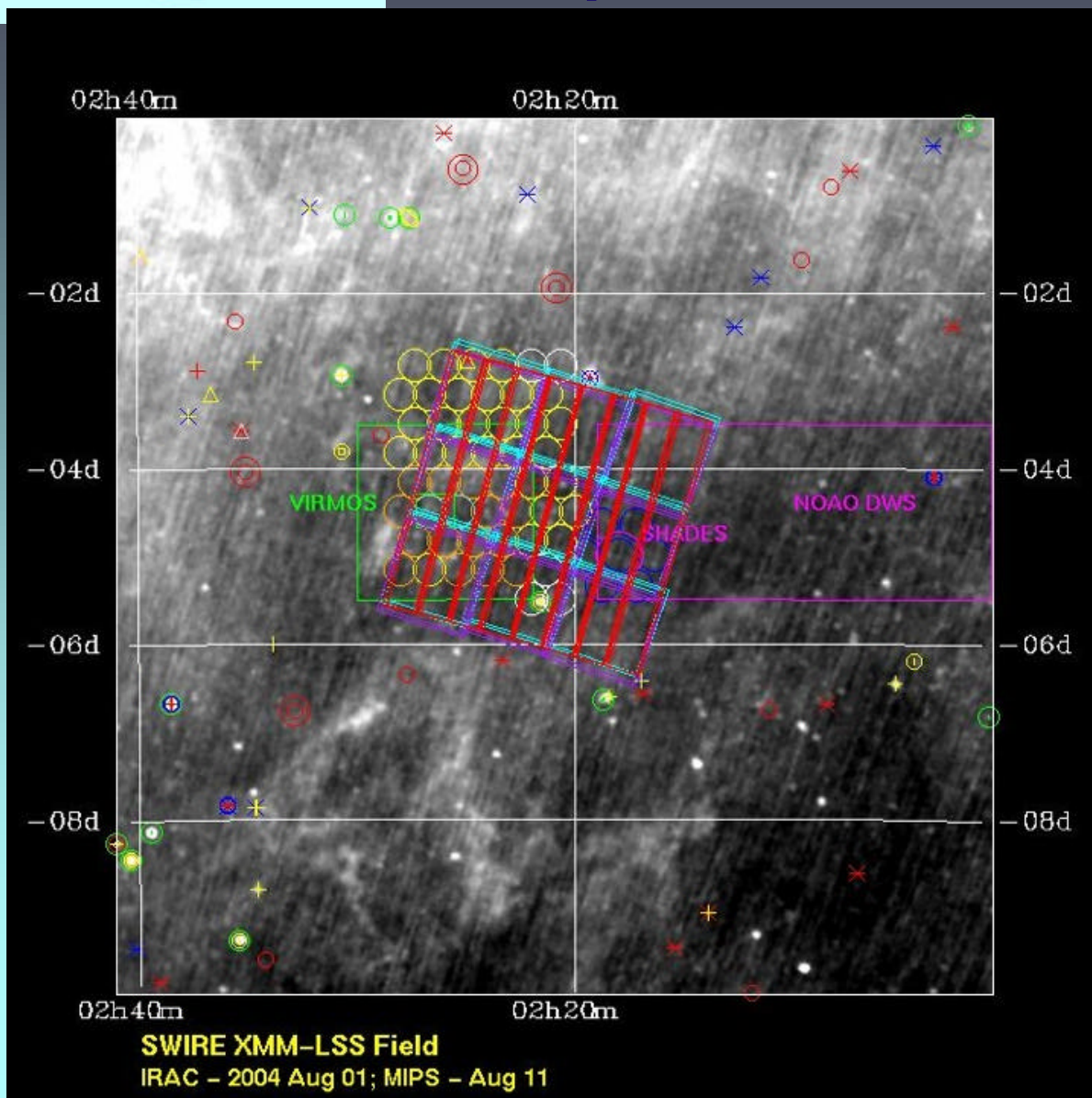
Hours

| | |
|------------|----------|
| M. Harwit | 10 |
| PACS-Team | 659 |
| SPIRE-Team | 853 |
| Total | 1522 |

5.5 Ms !!

the largest programme with a single space observatory?

Examples of Fields and Available Data



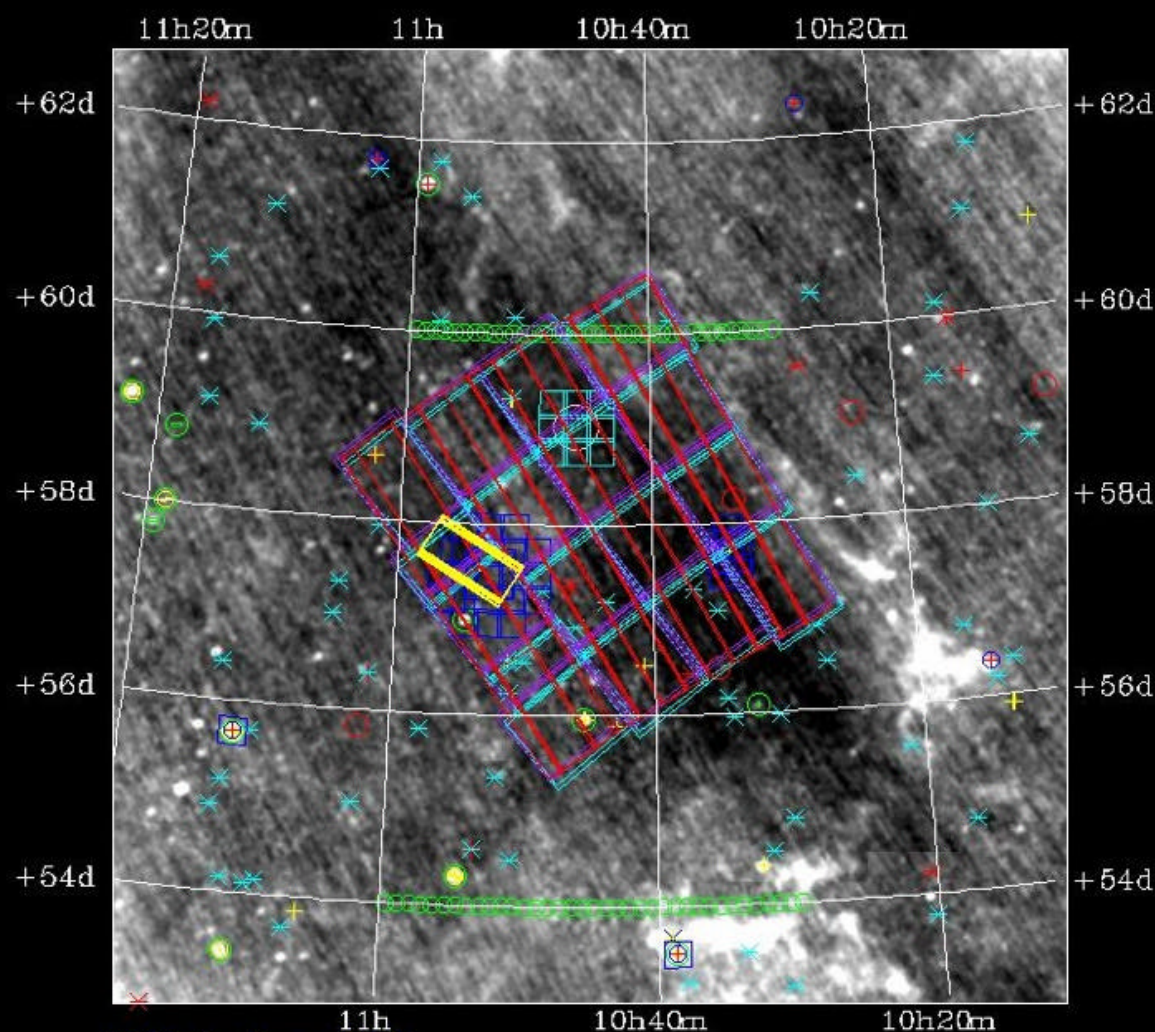
SWIRE IRAC/MIPS
Subaru XDF optical and X-ray
NOAO WDS
SHADES submm
GALEX
VIMOS deep spectroscopy survey
XMM-LSS X-ray survey

Examples of Fields and Available Data

SWIRE *irac*/MIPS

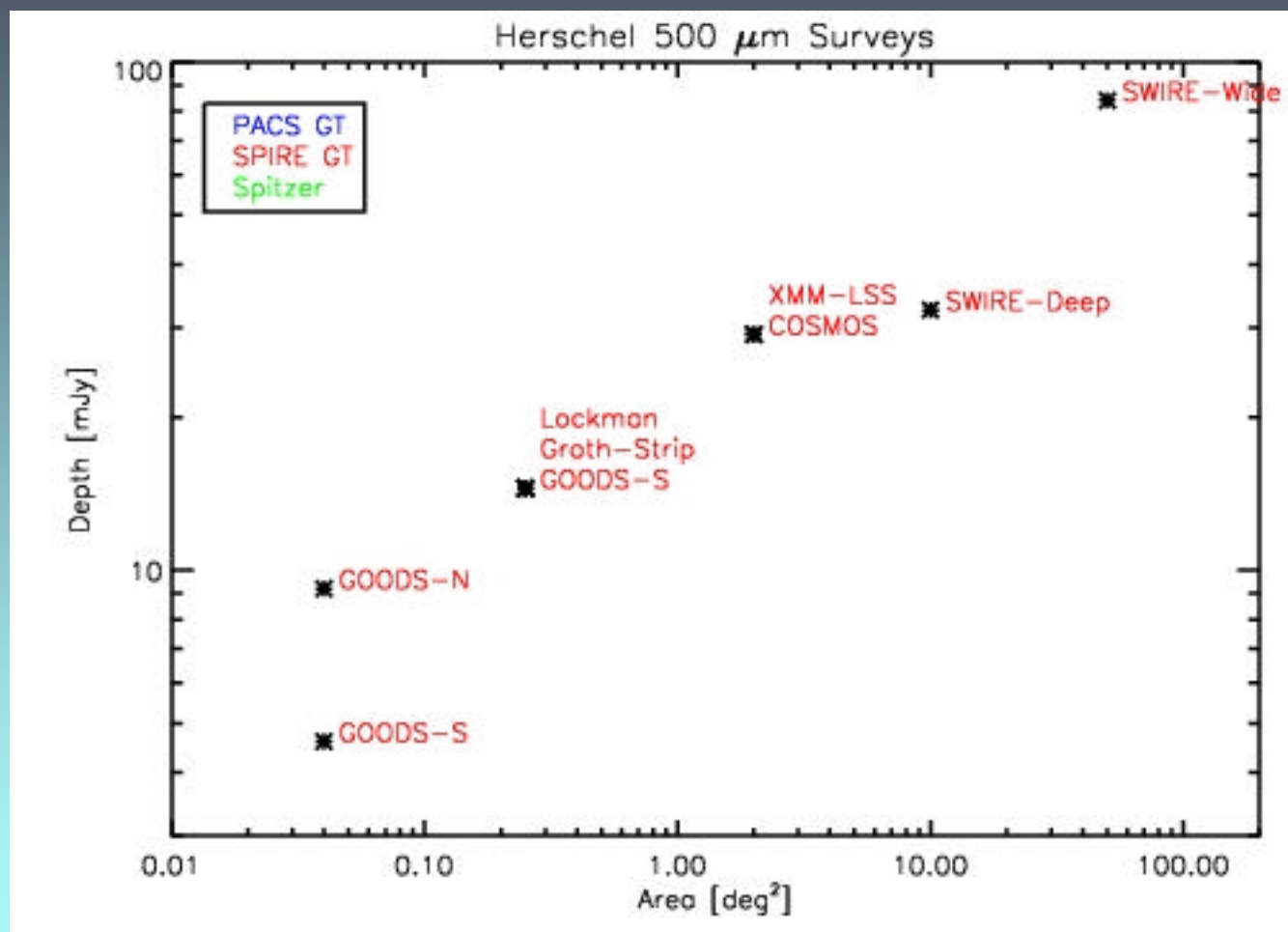
Chandra

MIPS GTO



SWIRE Lockman Field
2004 May

Wedding Cake Survey (Area vs Depth)



Clusters

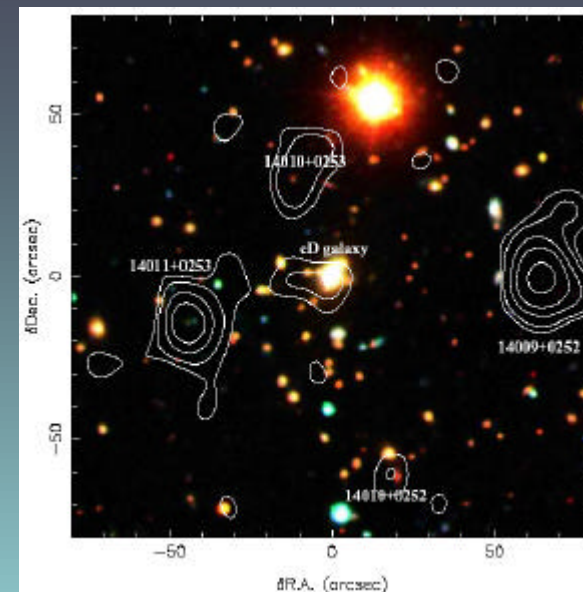
15 rich clusters from $z = 0.2$ to > 1

Deepest (possible) layer of a wedding cake survey for galaxies at $z \sim 1$ and above

Excellent existing (archival) data: HST-ACS/NICMOS, radio (μJy), Spitzer, Chandra & XMM

Wider surveys find only most luminous high- z galaxies

Unique imaging to beneath the confusion limit



Abell 1835

3-colour optical & 0.85mm
SCUBA image (2.5 sq arcmin,
40% SPIRE FoV)

Clusters

Lensing:

Extend below blank field confusion limit to about 5 mJy
About 180 detections expected

Shorter wavelength bands will allow contribution from cluster galaxies to be subtracted

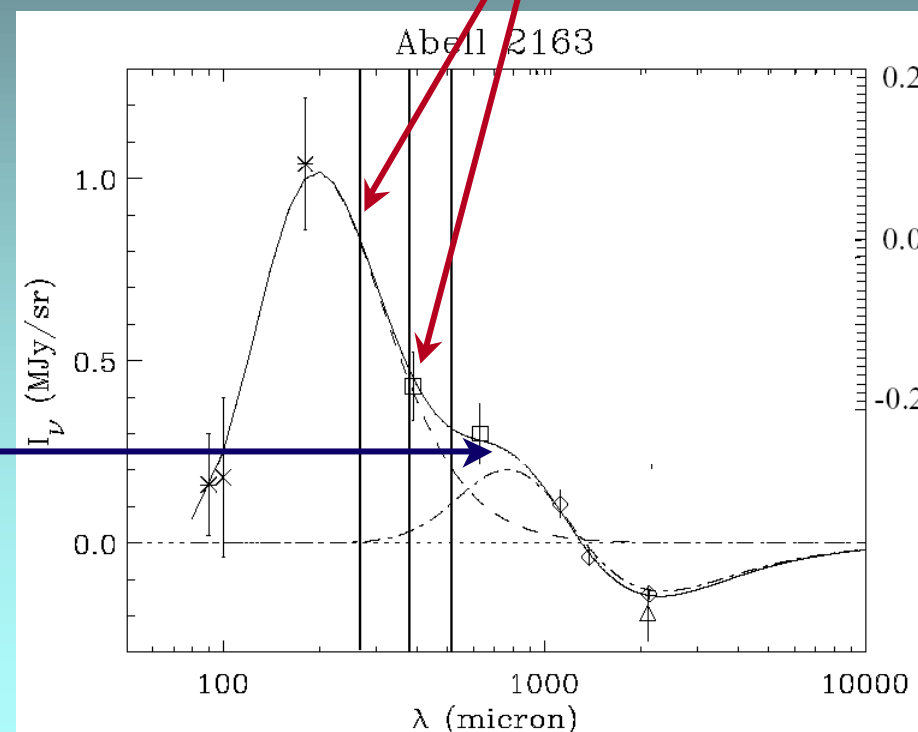
Sunyaev-Zel'dovich Effect:

Scattering of CMB photons by intra-cluster (or just hot) electrons

Primarily to $z \sim 1$

Significant at $500 \mu\text{m}$

SZ signal probes Cluster evolution and Cluster proper motion (kinematic SZ effect)



Lamarre et al. 1998

Star Formation Rate

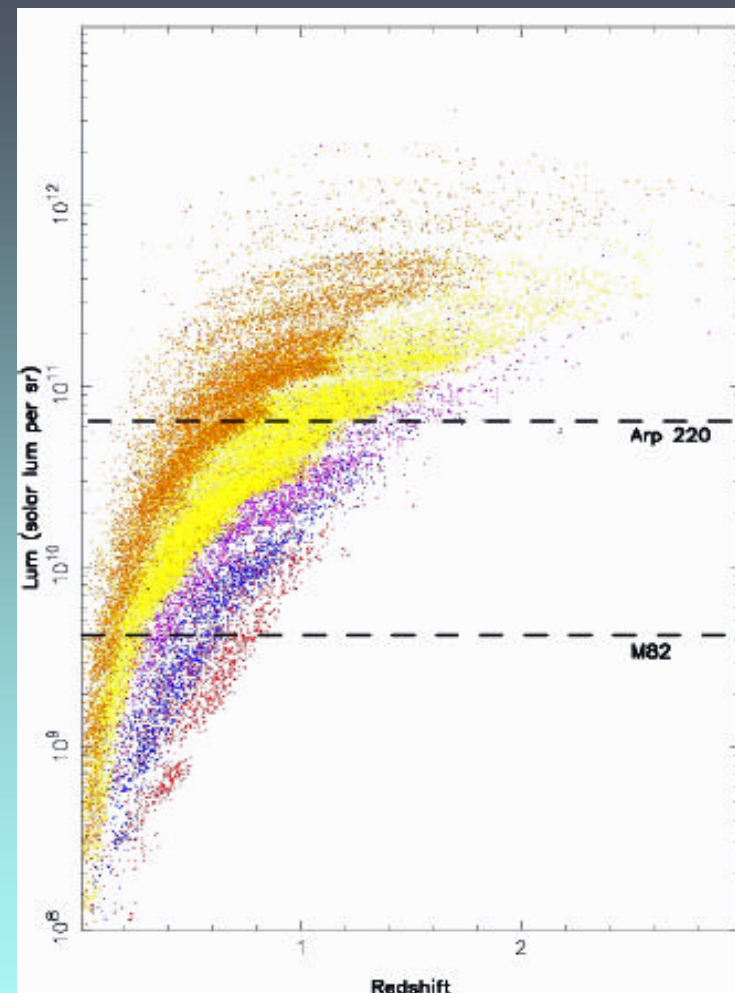
Main Science Driver: Measure the hidden (by dust) energy production of the Universe

Need to measure the **bolometric** dust emission and sample a **large area** in the $L_{\text{bol}} - z$ plane



the Wedding Cake Survey

Designed to sample the L-z plane and probe L_{bol} density at high redshift



OT Herschel proposals will push the study to even higher z



Possibilities to collaborate?

Provide additional data in other bands.

New surveys (optical & near-IR spectroscopy, SCUBA-2, LABOCA, Lyman alpha searches, etc.) should cover the SPIRE high-z survey areas

Theory and numerical simulations: provide clear predictions to be proved with Herschel (number counts, LF evolution, correlation functions, properties of extreme objects, large-scale structure, ..)

Follow-up:

Main survey to provide interesting extragalactic FIR/submm sources for ALMA, VLT, GTC, ELT, etc.