

## The Herschel–SPIRE instrument and its capabilities for extragalactic astronomy

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### Abstract

SPIRE, the Spectral and Photometric Imaging Receiver, is one of three instruments to fly on the European Space Agency's Herschel Space Observatory. It contains a three-band imaging photometer operating at 250, 350 and 500  $\mu\text{m}$ , and an imaging Fourier transform spectrometer covering 194–672  $\mu\text{m}$ . The SPIRE detectors are arrays of feedhorn-coupled bolometers cooled to 0.3 K. The photometer has a field of view of  $4 \times 8'$ , observed simultaneously in the three spectral bands. The spectrometer has an approximately circular field of view with a diameter of 2.6'. The spectral resolution can be adjusted between 0.04 and 2  $\text{cm}^{-1}$  (resolving power of 20–1000 at 250  $\mu\text{m}$ ). SPIRE will be used for many galactic and extragalactic science programmes, a number of which will be implemented as Herschel Key Projects. The SPIRE consortium's Guaranteed Time (GT) programme will devote more than 1000 h to Key Projects covering the high-redshift universe and local galaxies, which will be carried out in coordination with other GT programmes, especially that of the PACS consortium. It is also expected that substantial amounts of Herschel Open Time will be used for further extragalactic investigations. The high-redshift part of the SPIRE GT programme will focus on blank-field surveys with a range of depths and areas optimised to sample the luminosity-redshift plane and characterize the bolometric luminosity density of the universe at high-redshift. Fields will be selected

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that are well covered by Spitzer, SCUBA-2, PACS-GT and near-IR surveys, to facilitate source identifications and enable detailed studies of the redshifts, spectral energy distributions, and other properties of detected galaxies. The local galaxies programme will include a detailed spectral and photometric study of a sample of well resolved nearby galaxies, a survey of more than 300 local galaxies designed to provide a statistical survey of dust in the nearby universe, and a study of the ISM in low-metallicity environments, bridging the gap between the local universe and primordial galaxies.

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## 1. Introduction

The Herschel Space Observatory (Pilbratt, 2004), scheduled for launch in 2008, is the fourth cornerstone mission in the science programme of the European Space Agency (ESA). The main science goals of the mission are the detection and investigation of galaxies at high redshift and the study of star formation and the interstellar medium in our own and nearby galaxies. Herschel will carry a 3.5-m diameter telescope, passively cooled to 80 K, and three science instruments: HIFI, PACS and SPIRE. The operational lifetime of the mission will be at least 3 years, and approximately two thirds of the observing time will be available to the community as open time. SPIRE is designed to exploit the particular advantages of Herschel for observations in the FIR-submillimetre region: its large, cold, low-emissivity telescope, unrestricted access to the poorly explored 200–700  $\mu\text{m}$  range; and the large amount of high quality observing time. In this paper, we summarise the key design features of the SPIRE instrument, and outline its capabilities for extragalactic astronomy, using examples from the SPIRE Consortium's Guaranteed Time observational programme.

## 2. SPIRE instrument design and capabilities

SPIRE consists of a three-band imaging photometer and an imaging Fourier Transform Spectrometer (FTS), both of which use hexagonally close-packed arrays of feedhorn-coupled spider-web Neutron Transmutation Doped (NTD) bolometers operating at 0.3 K (Turner et al., 2001; Rownd et al., 2003; Griffin et al., 2002). Three bolometer arrays are used for broadband photometry ( $\lambda/\Delta\lambda \sim 3$ ) in spectral bands centred on approximately 250, 350 and 500  $\mu\text{m}$ , with diffraction-limited FWHM beam widths of approximately 18, 25 and 36", respectively. The same  $4 \times 8'$  field of view is observed simultaneously in the three bands through the use of two fixed dichroic beam-splitters. Signal modulation can be provided either by SPIRE's two-axis Beam Steering Mirror (Pain et al., 2003), or by scanning the telescope across the sky. The FTS (Swinyard et al., 2003) has spatially separated input and output ports. One input views a 2.6' diameter field of view on the sky and the other is fed by an on-board reference source. Two bolometer arrays at the output ports cover two overlapping bands of 194–324  $\mu\text{m}$  and 316–672  $\mu\text{m}$ . The photometer and spectrometer both have

cold pupil stops conjugate with the Herschel secondary mirror, which is the system pupil for the telescope and defines a 3.29-m diameter used portion of the primary. Conical feedhorns (Rownd et al., 2003; Chattopadhyay et al., 2003) provide a roughly Gaussian illumination of the pupil, with an edge taper of around 8 dB in the case of the photometer arrays.

The SPIRE cold focal plane unit (FPU) is approximately  $700 \times 400 \times 400$  mm in size and has three temperature stages: the Herschel cryostat provides temperatures of 4.5 K and 1.7 K and SPIRE's internal  $^3\text{He}$  refrigerator (Duband, 1997) cools all five detector arrays to approximately 0.3 K. The bolometers are AC-biased with frequency adjustable over the range 50–200 Hz, reducing  $1/f$  noise from the JFET readouts, and giving a  $1/f$  knee for the system of less than 100 mHz. There are three SPIRE warm electronics units: the Detector Control Unit (DCU) provides the bias and signal conditioning for the arrays and cold electronics, and demodulates and digitises the detector signals; the FPU Control Unit (FCU) controls the cooler and the two FPU mechanisms, and reads out all the FPU thermometers; and the Digital Processing Unit (DPU) runs the on-board software and interfaces with the spacecraft for commanding and telemetry. The 130 kbs available data rate allows all photometer or spectrometer detectors to be sampled and the data transmitted to the ground with no on-board processing.

### 2.1. Photometer design

Fig. 1 shows the opto-mechanical layout of the photometer. It is an all-reflective design (Dohlen et al., 2000) except for the dichroics used to direct the three bands onto the bolometer arrays, and the filters used to define the passbands (Ade et al., 2006). The image is diffraction-limited over the  $4 \times 8'$  field of view, which is offset by 11' from the centre of the Herschel telescope's highly curved focal surface. Input mirror M3 lying below the telescope focus, receives the  $f/8.7$  telescope beam and forms an image of the secondary at the flat beam steering mirror, M4. Mirror M5 converts the focal ratio to  $f/5$  and provides an intermediate focus at M6, which re-images the M4 pupil to a cold stop. Mirrors M7, M8 and a subsequent mirror inside the 1.7-K box form a one-to-one optical relay to bring the M6 focal plane to the detectors. The 4.5-K optics are mounted on the SPIRE internal optical bench. (The input optics are common to the photometer and spectrometer

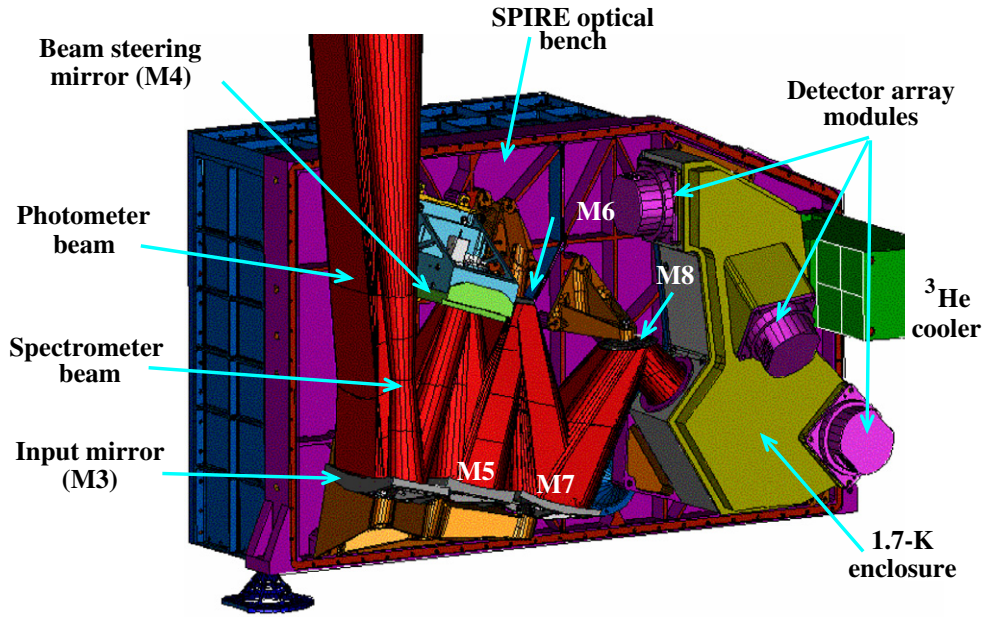


Fig. 1. Opto-mechanical layout of the photometer side of the FPU.

and the separate spectrometer field of view is directed to the other side of the optical bench panel by a pick-off mirror.) The 1.7-K enclosure contains the detector arrays, dichroics and fold mirrors. The bolometer array modules of the photometer are bolted to the outside wall of the 1.7-K box. Inside each one, the <sup>3</sup>He stage, accommodating the detectors, feedhorns and final filters, is thermally isolated from the 1.7-K mount by tensioned Kevlar threads, and cooled by a thermal strap to the <sup>3</sup>He cooler. The three photometer arrays contain 43 (500 μm), 88 (350 μm) and 139 (250 μm) detectors. Fig. 2 shows the array layouts and a photograph of an array module. The three arrays are overlaid on the sky and the shaded circles represent sets of detectors whose beams are coincident. The photometric passbands are defined by a combination of a set of edge filters (located at the instrument input, at the 1.7-K cold stop, and directly in front of the detector arrays), the reflection/

transmission edges of the dichroics, and the cutoff wavelengths of the feedhorn output waveguides.

The beam steering mirror (M4) can chop ±2' along the long axis of the 4 × 8' field of view, at frequencies up to 5 Hz (the nominal frequency is 2 Hz). It can simultaneously move at up to 1 Hz in the orthogonal direction by up to 30". This two-axis motion allows “jiggling” of the pointing to create a fully sampled image of the sky with the feedhorn-coupled detectors whose diffraction-limited beams on the sky are separated by approximately twice the beam FWHM. An internal calibration source (Hargrave et al., 2003) placed behind a hole in the centre of M4, is used to provide a repeatable signal for the bolometers. It occupies an area contained within the region of the pupil obscured by the hole in the primary. The source can produce a power at the detector of 1–2% of the telescope background.

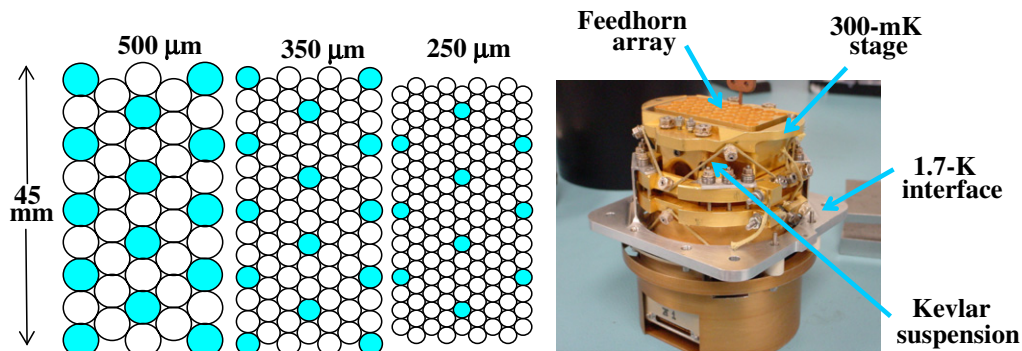


Fig. 2. Left: layout of the photometer arrays (the shaded detectors are those for which there is exact overlap on the sky for the three bands). Right: photograph of a SPIRE detector array module.

## 2.2. Spectrometer design

The FTS uses two broadband intensity beam-splitters in a Mach–Zehnder configuration. The optical design is described by Dohlen et al. (2000). The focal plane layout is shown in Fig. 3. A single back-to-back scanning roof-top mirror serves both interferometer arms. It has a frictionless mechanism using double parallelogram linkage and flex pivots, and a Moiré fringe sensing system. Detector arrays are placed in the two output ports. A filtering scheme similar to the one employed for the photometer channel is used to restrict the passbands of the two ports with overlapping bands covering 194–324  $\mu\text{m}$  (SSW) and 316–672  $\mu\text{m}$  (SLW). The FTS spectral resolution is given by  $1/(2d)$  where  $d$  is the total optical path difference. The maximum resolution available is  $0.04 \text{ cm}^{-1}$  (the corresponding FWHM of the instrument spectral response function is  $0.048 \text{ cm}^{-1}$ ). For this resolution,  $\lambda/\Delta\lambda$  varies between 1200 at the short-wavelength end and 300 at the long-wavelength end. The resolution appropriate for spectrophotometry is  $1 \text{ cm}^{-1}$  for which  $\lambda/\Delta\lambda$  varies from 50 to 15 between the short- and long-wavelength ends of the range.

The two hexagonally close-packed spectrometer arrays contain 37 detectors in the short-wavelength array and 19 in the long-wavelength array. The array modules are similar to those used for the photometer, with an identical interface to the 1.7-K enclosure. The feedhorn and detector cavity designs are carefully optimised to provide good sensitivity across the whole wavelength range of the FTS. The SSW feedhorns are sized to give  $2F\lambda$  pixels at 225  $\mu\text{m}$  and the SLW horns are  $2F\lambda$  at 389  $\mu\text{m}$ . This arrangement has the advantage that there are many co-aligned pixels in

the combined field of view. The SSW beams on the sky are 27" apart, and the SLW beams are separated by 48". Based on measurements and modelling of the optical performance of the FTS, the FWHM beamwidth is expected to vary with wavelength across the bands, with a minimum value in the centre of the band, rising at both longer and shorter wavelengths. For the SSW, the minimum is approx. 15" rising to 18" at the band edges, and for the SLW the minimum is approx. 30" rising to nearly 40" at the edges.

A thermal source at the second input port (Hargrave et al., 2003) allows the background power from the telescope to be matched: the amplitude of the interferogram central maximum is proportional to the difference in the radiant power from the two ports, so this allows the large telescope background to be nulled, reducing the dynamic range requirements for the detector sampling.

## 3. Instrument operating modes

The photometer will have three principal observing modes: point source photometry, field (jiggle) mapping, and scan mapping. In all modes, data are taken simultaneously for the three bands.

Point source photometry: For point or compact source photometry, several sets of three detectors have beams at the three wavelengths that are co-aligned on the sky (shaded circles in Fig. 2). By chopping through an angle of  $126''$ , three-band photometry can be carried out with maximum efficiency: the source is observed in one of the detectors in each band at all times. The absolute pointing uncertainty of Herschel is  $3.7''$  (requirement) and  $1.5''$  (goal). The standard observing mode for point sources will use the beam steering mirror to make a small seven-point

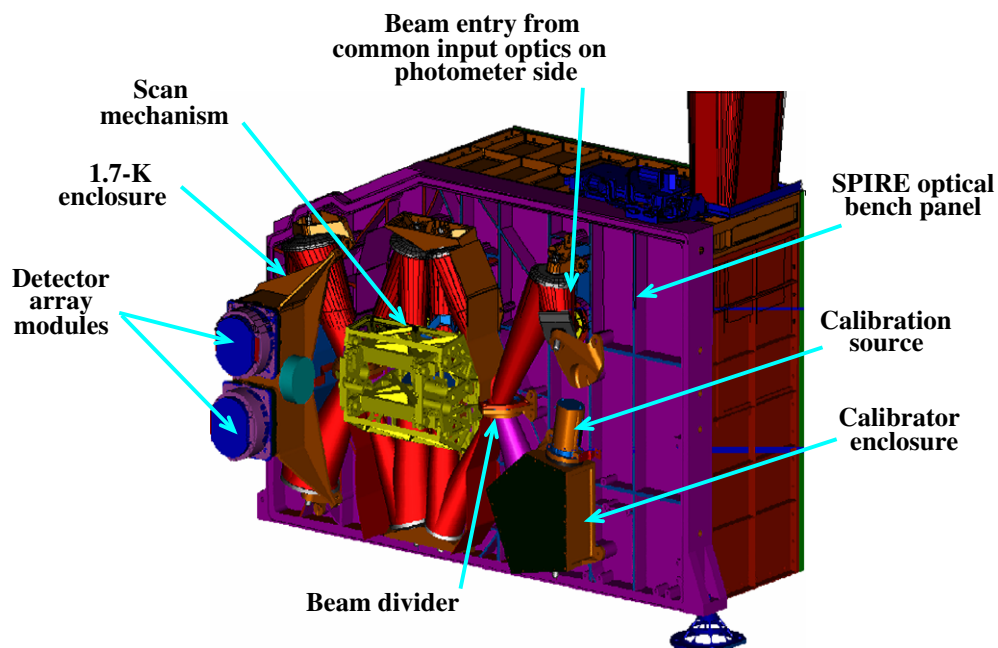


Fig. 3. Opto-mechanical layout of the spectrometer side of the FPU.



map in which the nominal position and six hexagonally arranged neighbouring positions are observed in turn. With an angular offset of  $6''$ , the S/N loss for a given integration time is about 20% in the worst case (250  $\mu\text{m}$  band). This is a small price to pay for assurance that any pointing or source position errors do not result in flux density errors. The data from all detectors in all of the arrays will also be transmitted to the ground, providing sparsely sampled  $4 \times 4'$  maps of the field around the object.

**Field mapping:** For mapping of regions a few arcminutes in size, the beam steering mirror will perform a jiggle map, similar to the mode of operation of the SCUBA bolometer camera on the JCMT (Holland et al., 1999). A 64-point jiggle pattern is needed to achieve full spatial sampling in all bands simultaneously, with a step size of  $9''$  (half-beam spacing at 250  $\mu\text{m}$ ). The 250- $\mu\text{m}$  band image will be critically sampled, and the other two will be over-sampled. A maximum field size of  $4 \times 4'$  is available in this mode as the  $2'$  regions at each end of the array will be chopped outside the field of view admitted by the photometer optics.

**Scan mapping:** This mode will be used for large maps (bigger than the SPIRE field of view), including deep surveys. The telescope will be scanned across the sky at up to  $1' \text{ s}^{-1}$  (the maximum rate that the spacecraft can provide). The nominal scan rate is currently taken to be  $30'' \text{ s}^{-1}$ . The good  $1/f$  stability of the detectors means that the beam steering mirror does not need to be operated – signal modulation is provided by the telescope motion. To give the beam overlap needed for full spatial sampling over a strip defined by one scan line, and to provide a uniform distribution of integration time over the area covered by the scan, the optimum scan angle is  $12.5^\circ$  with respect to one of the array axes (Sibthorpe et al., 2006).

The standard operating mode for the FTS is to scan the mirror at constant speed (nominally at  $0.5 \text{ mm s}^{-1}$ ) with the telescope pointing fixed, giving an optical path rate of  $2 \text{ mm s}^{-1}$  due to the factor of four folding in the optics. Radiation frequencies of interest are encoded by the scanning motion as detector output electrical frequencies in the range 3–10 Hz. The maximum scan length is 3.5 cm, corresponding to an optical path difference of 14 cm. For point sources, the object will be positioned at the centre of the array, but data will be acquired for all of the detectors, providing at the same time a sparsely sampled map of the emission from the region around the source. Likewise, a single pointing will give a sparsely sampled map of an extended object. For fully sampled spectral mapping, the beam steering mirror will provide the necessary pointing changes between scans.

#### 4. Instrument sensitivity estimates

The expected photometer and spectrometer sensitivities are summarised in Table 1. For point source photometry, the sensitivity is approximately 2 mJy ( $5\text{-}\sigma$ ; 1-h). For photometric mapping, the limiting flux density for a given inte-

Table 1  
Sensitivity estimates for the photometer and FTS

	250 ( $\mu\text{m}$ )	350 ( $\mu\text{m}$ )	500 ( $\mu\text{m}$ )
<i>Photometer</i>			
Point source (mJy, $5\text{-}\sigma$ ; 1-h)	1.8	2.2	1.7
$4' \times 4'$ jiggle map (mJy, $5\text{-}\sigma$ ; 1-h)	6.2	8.4	7.1
Scan map (mJy, $5\text{-}\sigma$ for one scan)	55	75	65
Scan map: time in hrs to map 1 sq. deg. to 3 mJy rms	7.8	16	13
<i>Spectrometer</i>			
Line flux limit for spectroscopy with $\Delta\sigma = 0.04 \text{ cm}^{-1}$			
Point source or sparse $2'$ map ( $\text{W m}^{-2} \times 10^{-17}$ , $5\text{-}\sigma$ ; 1-h)			2–4
Fully sampled $2'$ map ( $\text{W m}^{-2} \times 10^{-17}$ , $5\text{-}\sigma$ ; 1-h)			6–12
Flux density limit for spectrophotometry with $\Delta\sigma = 1 \text{ cm}^{-1}$			
Point source or sparse $2'$ map (mJy, $5\text{-}\sigma$ ; 1-h)			70–130
Fully sampled $2'$ map (mJy, $5\text{-}\sigma$ ; 1-h)			210–390

gration time is higher due to the need to produce a fully sampled image by scanning or jiggling the field of view. Scan map is the most efficient mode for large maps as it uses the full field of view and does not require chopping. The mapping sensitivity is best characterised in terms of the time needed to cover a certain area to a given sensitivity limit, expressed here in terms of a 1 sq. deg. map observed to 3 mJy rms. The spectrometer sensitivity varies across the band between the values given in Table 1, due to the detailed shape of the filter profiles, but is typically  $3 \times 10^{-17} \text{ W m}^{-2}$  ( $5\text{-}\sigma$ ; 1-h) for spectral lines and 100 mJy ( $5\text{-}\sigma$ ; 1-h) for low-resolution spectrophotometry. For FTS mapping, the unvignetted field of view is specified as  $2'$ . Data from the full field of view will be available, but the accurate calibration of the outer parts cannot be guaranteed at this time.

SPIRE sensitivity estimates are based on detailed instrument models and the results of tests on the flight instrument. However, it should be noted that, as with many cryogenic infrared space instruments, predicted sensitivity figures are subject to large uncertainties (at least a factor of two) due to uncertainties in the instrument performance in flight and, in the case of SPIRE, the effective telescope background. The numbers quoted here also exclude overheads associated with telescope movement and instrument set-up. Further details of the sensitivities and the estimation of observing times are given in the *SPIRE Observers' Manual* (2007), published by ESA as part of the Herschel Key Programmes Announcement of Opportunity.

#### 5. Extragalactic capabilities of SPIRE

SPIRE will be used in conjunction with the other Herschel instruments, particularly PACS, to carry out a number of coordinated observational programmes. For the investigation of high-redshift galaxies, the PACS and SPIRE photometers will together provide a multi-band imager covering the bulk of the FIR-submm peak in the spectral energy distribution of the universe; and they will

be able to carry out surveys over much larger areas than have been observed from the ground. ISO was the first satellite capable of doing FIR spectroscopy on nearby galaxies, and demonstrated the value of this in determining the nature, excitation, composition of the interstellar medium and the influence of AGN activity. Herschel, using all three instruments, will extend this to modest redshift and allow vastly more galaxies to be examined with much better angular resolution. It will be capable of multi-band imaging and spectroscopic studies of nearby galaxies to map out the global properties of the ISM and the properties of gas and dust in a variety of galaxy types and environments, and to make detailed investigation of the impact of metallicity on the ISM and the interaction of the ISM with central AGN. In this section we give some examples of such projects from the SPIRE consortium's Guaranteed Time programme. All of these observations will be implemented as Herschel Key Projects (Pilbratt, 2004) – observational programmes that will (i) exploit unique Herschel capabilities to address important scientific issues in a comprehensive manner, (ii) require a large amount of observing time to be used in a uniform and coherent fashion, and (iii) produce well characterised and uniform datasets of high archival value.

### 5.1. High-redshift galaxies

Approximately 850 h of SPIRE GT will be devoted to the high- $z$  galaxy programme, and the PACS consortium will use about 650 h of their GT on a related and very closely coordinated programme. This will be one of the flagship projects for Herschel and will address important scientific issues such as number count models, bolometric luminosity functions, formation and evolution of galaxy bulges and ellipticals, structure formation, cluster evolution, the history of energy production, the AGN-starburst connection, and cosmic infrared background fluctuations.

The main science driver for the SPIRE high- $z$  GT programme is to measure the bolometric luminosity density of the Universe as a function of redshift. In order to do this it is essential to measure the SEDs of the individual sources, and to carry out a number of surveys of different depths. The programme therefore consists mainly of a set of blank field imaging surveys (to be done in scan-map mode), forming a multi-tiered “wedding cake” covering a range of field sizes, from 0.04 to several tens of square degrees, and depths (a few mJy to several tens of mJy rms). The smaller fields will be observed to a depth comparable to the SPIRE extragalactic confusion limit (expected to be in the range 20–30 mJy at 40 beams/source) depending on the wavelength and the adopted source count model (e.g., Rowan-Robinson, 2001; Vaccari, in press).

The “wedding cake” will be designed to sample the luminosity-redshift plane and characterise the bolometric luminosity density of the universe at high redshift. Fields will be selected that are well covered by XMM-Newton, Spitzer, SCUBA-2, PACS-GT and near-IR surveys, to

facilitate source identifications and enable detailed studies of the redshifts, spectral energy distributions, and other properties of the detected galaxies. Fig. 4 shows a Monte-Carlo simulation of the coverage of the bolometric luminosity – redshift plane that will be produced by the surveys. For redshift  $<1$ , the surveys will cover almost a factor of 100 in luminosity. This will allow us to delineate the hidden history of luminosity (and hence energy production) over the last eight billion years. We will be able to obtain useful estimates of the bolometric luminosity density out to  $z \sim 2$ . Additional open-time proposals are expected to push this study out to higher redshifts.

Some of the deeper wedding cake fields will be used to carry out a multi-band P(D) analysis on an area of  $\sim 1$  sq. deg. to probe fluctuations down to 3 mJy (approx. 1 source/beam). As the P(D) distribution depends on the beam profile (which will be accurately known) and the slope of the number counts, the properties of the number counts below the confusion limit can be investigated. The availability of multi-band data will provide additional diagnostic capabilities in discrimination between different source count models. The survey will also allow a unique search for far-infrared background fluctuations originating from sources below the confusion limit, and associated with large-scale structure and galaxy clustering. The shallow tiers of the GT survey will be used to investigate clustering on angular scales less than  $10'$  (finer spatial scale than can be probed with Planck). The background fluctuations are sensitive to the nonlinear clustering within a dark matter halo, and the physics underlying the formation of

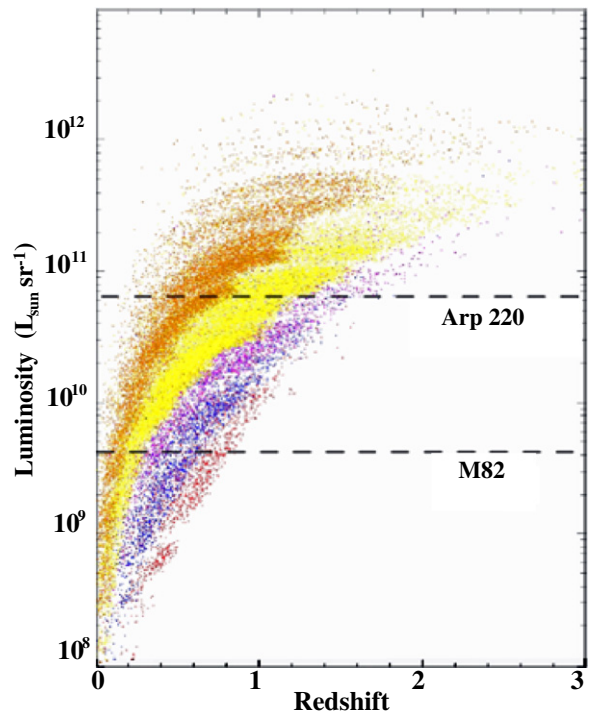


Fig. 4. Monte-Carlo simulation of the coverage of the bolometric luminosity-redshift plane which will be produced by the SPIRE blank-field surveys.

far-infrared galaxies within a halo (Cooray and Sheth, 2002).

The GT programme also includes observations of a sample of 15 rich clusters between  $z = 0.2$  and 1. Gravitational lensing of background galaxies will allow the detection limit to be extended below the blank field confusion limit to about 5 mJy. In addition, these observations will be sensitive to the Sunyaev Zel'dovich effect, which still produces a significant increment in the CMB in the longest-wavelength channel of SPIRE. The shorter wavelength bands will be used to subtract the contribution from cluster galaxies. Follow-up spectroscopy of selected sources detected in the GT surveys is expected to be carried out with Herschel and with ground-based facilities (ALMA and 10-m class optical/NIR telescopes). The spectrometers in all three Herschel instruments will give unique access to the most important cooling lines of interstellar gas, which give very important information on the physical processes and energy production mechanisms, and the roles of AGN and star formation.

### 5.2. Galaxies in the local universe

The SPIRE local galaxies GT programme comprises three Key Projects, requiring approximately 100 h each: Physical Processes in the ISM of Very Nearby Galaxies, The ISM in Low-Metallicity Environments, and The Herschel Galaxy Reference Survey. The first two are joint PACS-SPIRE projects, and the third is SPIRE only.

ISM in Nearby Galaxies: Spatially resolved photometry and spectroscopy with SPIRE and PACS will be carried out on a sample of 15 nearby well-studied galaxies, including examples of early and late type spirals, low mass spirals, edge-on spirals, starburst spirals, starburst galaxies, quiescent dwarfs, starburst dwarfs, Seyferts and ellipticals. Additional spectroscopic data will be obtained with the Herschel-HIFI instrument. These observations will allow the detailed SEDs and dust properties to be determined, and the variation and evolution of chemistry and metallicity to be studied (both within a galaxy and across the range of galaxy types).

Low Metallicity Dwarf Galaxies: Much progress has been made in characterising galaxies at high redshifts; but the objects discovered so far are already metal-rich, implying that they already have a history of star formation and metal enrichment processes. Although we are not yet able to observe the earlier stage in which primordial galaxies are undergoing their initial episodes of star formation, we do have access to low metallicity dwarf galaxies in the local universe that can serve as analogues to the high- $z$  building blocks from which galaxies are believed to have formed through mergers (Madden, 2005). A comprehensive programme of photometry with SPIRE and PACS will be implemented to study a sample of 55 dwarf galaxies, covering a broad metallicity range of 1/50 to 1/3 solar. Additionally, 60–600  $\mu\text{m}$  spectroscopy of a sub-sample using PACS and HIFI will be obtained on selected sources. The obser-

vations will shed light on the influence of metallicity on the UV radiation field, gas and dust properties, and star-forming activity, the effect of the dust properties on the heating and cooling processes in the low-metallicity ISM, and on the impact of the super star clusters prevalent in dwarf galaxies on the surrounding gas and dust.

The Herschel Galaxy Reference Survey: SPIRE will be used to carry out photometry of a sample of 320 local galaxies, constituting a benchmark survey of dust in the local Universe, and providing the first accurate measurements of the amount of dust both inside and outside galaxies. The primary sample of 155 galaxies comprises objects with  $K(2\text{MASS}) < 9$  (descendants of early universe luminous objects) and with distances between 15 and 25 Mpc (allowing the galaxies to be spatially resolved with a single pointing). A secondary sample of sources with  $K = 9\text{--}12$  will extend the mass range. This survey will also help relate present-day galaxies to their high- $z$  ancestors, and reveal how dust mass and distribution depend on galaxy type, environment, and luminosity. For example, because the sample encompasses all environments from the field to rich clusters, it will enable an investigation of the as-yet unknown process that appears to inhibit star formation in rich environments (Kauffmann et al., 2004).

### 5.3. Dust properties

A thorough understanding of dust properties and their dependence on environment is critical for the correct interpretation of far-infrared and submillimetre observations (e.g., Jones, 2005, in press). One of the SPIRE galactic Key Projects, The Evolution of Interstellar Dust, is very relevant in this respect, and will provide important results for the analysis and interpretation of the extragalactic observations. It involves systematic photometric and spectral surveys of the ISM covering the widest possible range of extinction, illumination, density, history, and star forming activity. It will trace the nature and evolution of dust in relation to the physical, dynamical and chemical properties of the ISM in different environments: diffuse shock-processed dust, cirrus, molecular clouds, low excitation PDRs, hot PDRs with HII regions, pre-stellar cores, and protostars. The results will allow study of the various processes acting on dust particles (fragmentation, coagulation, condensation, evaporation, photo processing) in all ISM environments from the most tenuous to the most dense.

## 6. Conclusions

SPIRE, in conjunction with the other Herschel instruments, will make major advances in extragalactic astronomy. The Guaranteed Time programmes summarised here (which take up more than half of the SPIRE GT), serve as examples to illustrate the scientific capabilities of the instrument and the mission. It is foreseen that there will be many more extragalactic programmes in Open Time.

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