

THE HERSCHEL REFERENCE SURVEY

Boselli, A.¹ and the SPIRE extragalactic group

Abstract. In order to study the dust properties of different galaxies in the nearby Universe, the SPIRE extragalactic group selected a volume limited ($15 < D < 25$ Mpc), complete sample of 323 galaxies spanning the whole range in morphological type (from ellipticals to late-type spirals) and luminosity ($8.5 < \log L_H < 12 L_{H\odot}$, $-22 < M_B < -16$) extracted from 2MASS, to be observed in guaranteed time (114 h) with Herschel. The 250-360-520 μm SPIRE data, combined with those collected at other frequencies, will be used to trace the dust properties of normal galaxies and provide a reference sample for studies at high redshift.

1 Introduction

During their evolution, the different stellar populations of galaxies produce and inject into the interstellar medium metals that congregate to form dust particles of different size and composition. This dust, heated by the general stellar radiation field, re-emit the absorbed energy in the far-IR. In normal galaxies, those objects dominating in number the nearby universe, the emitting dust has a modified black body spectrum with a peak at $\sim 200 \mu\text{m}$ rapidly decreasing at longer wavelengths (Boselli et al. 2003). Because of the quiescent star formation activity of these objects, however, most of the dust has a relatively cold temperature (~ 20 K) and is emitting in the submillimetric domain. The total dust amount of normal galaxies can thus be measured only by means of observations in the 200-1000 μm spectral range.

All physical (star formation activity, gas content, metallicity; Boselli et al. 2001; 2002; Zaritsky et al. 1994; Gavazzi et al. 2004), structural (concentration index, light profile; Boselli et al. 1997; Gavazzi et al. 2000; Scodreggio et al. 2002), kinematical (shape of the rotation curve; Catinella et al. 2006) and stellar population (stellar spectral energy distribution; Gavazzi et al. 2002; Boselli et al. 2003) properties of galaxies are strongly related to their total stellar mass (downsizing effect) and marginally to their morphological type. Tracing the statistical dust properties of normal galaxies can thus be done by observing a large and complete sample of objects spanning the largest possible range in luminosity and Hubble type.

Although accessible to ground based facilities such as SCUBA, the observation of such large samples of normal, quiescent galaxies would be too time consuming (more than 20 hours per galaxy) (Dunne et al. 2000). Given its large field of view ($4' \times 4'$) and its sensitivity (~ 7 mJy for a 5σ detection for a point source in 1 hour integration), SPIRE on Herschel is the ideal instrument for such a survey. For such a purpose, the SPIRE extragalactic group selected a volume limited, complete sample of 323 galaxies to be observed in 114.5 hours of guaranteed time in the three SPIRE bands at 250, 360 and 520 μm .

2 The sample and the observations

To span the largest possible range in mass, the sample has been selected in the K band (from 2MASS) since near-IR luminosities are linearly related to the total dynamical mass of galaxies (Gavazzi et al. 1996). A distance constraint of $15 < D < 25$ Mpc has been introduced to construct a volume limited sample. This distance range limits distance uncertainties due to local peculiar motions and secure the presence of low-luminosity, dwarf galaxies, non accessible at higher redshift. To minimize galactic cirrus contamination, galaxies have been selected at high galactic latitude ($b > +55^\circ$) and in low galactic extinction regions ($A_B < 0.2$; Schlegel et al. 1998). Our sample contains all early-type galaxies (E-S0-S0a) with $K_{Stot} \leq 8.7$ (65 objects) and late-type with

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$K_{Stot} \leq 12$. A different limit for early-type galaxies has been adopted to avoid the dust poor ellipticals whose emission would be hardly detected within reasonable integration times.

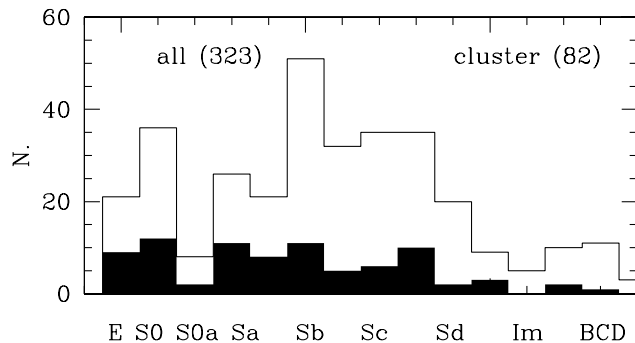


Fig. 1. The morphology distribution of the Herschel Reference Sample (HRS).

Figure 1 shows the histogram of the morphology distribution of the selected sample. As selected, the sample includes both relatively isolated and cluster object (Virgo) and is thus ideal for a statistical study on the effects of the environment on the dust properties of galaxies. Dwarf irregulars and blue compact galaxies, here undersampled in spite of the selected large range in luminosity, will be the targets of another SPIRE key program. As selected, the sample is representative of the K band luminosity function (Figure 2).

Pointed observations will be done with integration times of 30 minutes for ellipticals and lenticulars, and 12 minutes for late-types. Given a slewing overhead of 3 minutes per observation, this will ensure an efficient use of the telescope. For early-type galaxies the integration time has been determined by assuming a lower limit to their total dust mass of $\sim 10^4 M_{\odot}$ as determined from IRAS observations (Bregman et al. 1998). With 30 minutes of integration a detection limit of 11 mJy at $\sim 4 \sigma$ will be achieved. For spirals the integration time is dictated by the need of detecting the cold dust emission outside the optical radius. By combining ISOPHOT (Alton et al. 1998) and SCUBA (Valahakis et al. 2005) observations of extended sources with spectral energy distribution of normal galaxies of different type (Boselli et al. 2003), and assuming a standard dust to gas ratio we estimate that 12 minutes of integration are sufficient to detect the cold dust associated to the extended HI disc. With 12 minutes of integration time we will get to a detection limit of 22 mJy at $\sim 5 \sigma$.

3 Science projects

The selected sample will allow us to trace for the first time the variation of the cold dust properties (dust mass and temperature, dust to gas ratio,...) of normal galaxies along the Hubble sequence and as a function of luminosity. Combined with multifrequency datasets, the SPIRE data will be used to study the role of dust in the physics of the interstellar medium. Through the shielding of the interstellar radiation field, in particular of the UV light, dust participate in the cooling of the gas and thus plays a major role in the process of star formation. Dust is also an important catalyst in the formation of the molecular hydrogen, and thus is critical entity for the study of the feedback. Modeling the energetic balance between emitted and absorbed light, UV to sub-millimetric spectral energy distributions of these 323 galaxies will be used to quantify the dust obscuration in different objects. This analysis will allow us to define standard recipes for correcting UV and optical data, a useful tool for the interpretation of all modern surveys.

The presence of dust shells and discs in ellipticals will be used to study their hierarchical formation history. By studying the relationship between dust mass and other global properties of ellipticals we will determine how much dust is produced by the old stellar population and how much is the result of mergers.

The comparison of cluster and isolated galaxies will allow us to make a detailed study on the effects of the environment on the dust properties of galaxies, and thus understand whether the hot and dense cluster in-

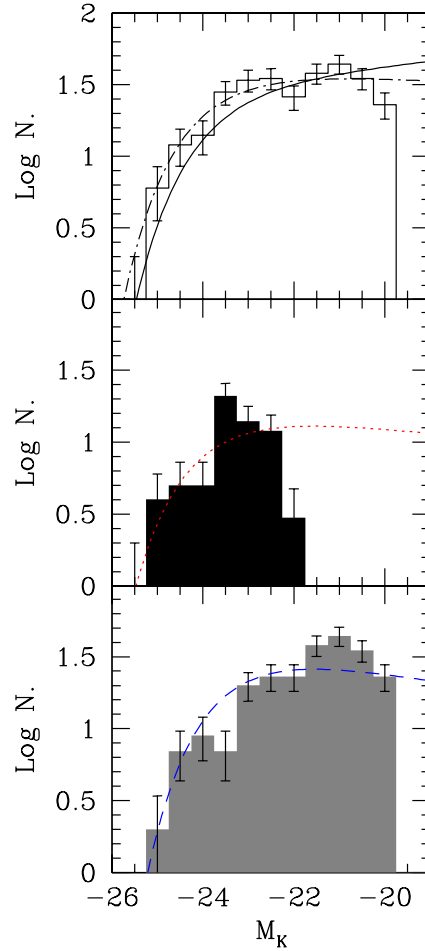


Fig. 2. The K band luminosity distribution of the HRS for all galaxies is compared to the 2MASS K band luminosity function of Kochanek et al. (2001) (black solid line) and Cole et al. (2001) (black dotted-dashed line) (upper panel). The K band luminosity distributions of the E-S0-S0a (central panel) and Sa-Sd-Im-BCD (lower panel) galaxies in the HRS are compared to the Kochanek et al. (2001) K band luminosity function of early-type (red dotted line) and late-type (blue dashed line) galaxies. Poisson errors are also indicated.

tergalactic medium can be polluted through the gas stripping process of late-type galaxies (Boselli & Gavazzi 2006). This dataset will be used to measure the local luminosity and dust-mass functions and distributions, important benchmarks for the deep Herschel surveys planned by the SPIRE team, providing at the same time a unique reference sample for any statistical study.

4 Corollary data

The proposed analysis can be done only once corollary data covering the whole electromagnetic spectrum will be available. Given its definition, the Herschel reference sample is easily accessible for ground based and space facilities: the selected galaxies are in fact relatively bright ($m_B < 15$ mag) and extended (~ 2 -3 arcmin). UV data at 1500 and 2300 Å will be taken from the GALEX all sky survey or the UV atlas of nearby galaxies (Gil de Paz et al. 2006), optical and near-IR images will be secured by the SDSS (Abazajian et al. 2005) and 2MASS (Jarrett et al. 2003) surveys. These data will be used to trace the underlying stellar population and

reconstruct the star formation history of the target galaxies.

Far-IR data in the 10-200 μm spectral range, needed for characterizing the whole dust emission and thus constraining dust masses and temperatures, will be taken from the AKARI/ASTRO-F survey at a similar spatial resolution ($\sim 20\text{-}30$ arcsec, depending on the wavelength). Radio continuum data are already available from the NVSS survey (Condon et al. 1998), while HI data will be obtained thanks to the ALFALFA survey (Giovanelli et al. 2005).

Dedicated spectroscopic observations in drift scan mode, needed to measure the metal content of the target galaxies as well as their underlying stellar population at higher spectral resolution than with imaging, has been almost completed with CARELEC at the OHP 1.93m telescope. We are also undergoing $\text{H}\alpha$ imaging observations (needed to measure the present day star formation activity) at the San Pedro Martir Observatory. $12\text{CO}(1\text{-}0)$ and $12\text{CO}(3\text{-}2)$ observations of the sample galaxies are under way at the Kitt Peak 12m and JCMT telescopes, while HI mapping at the Westerbork radiotelescope.

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