1. INTRODUCTION

The cosmic infrared background (CIB), relic emission of the formation and evolution of the galaxies, peaks in the far-infrared (FIR) in the 60–200 μm wavelength range (Puget et al. 1996; Hauser et al. 1998; Lagache et al. 1999; Gispert et al. 2000; Hauser & Dwek 2001). In the local universe only about a third of the extragalactic emission is released in the FIR (Soifer & Neugebauer 1991). However, the CIB FIR peak accounts for more than half of the total optical/infrared background, indicating strong evolution of galaxy properties toward high FIR output in the past. Characterizing the galaxies responsible for most of the CIB is therefore an important goal of cosmological surveys. Galaxy counts (or number counts) provide a powerful tool to investigate the evolution of the galaxies and their contribution to the CIB.

The cryogenic infrared space missions of the Infrared Astronomical Satellite (IRAS) and Infrared Space Observatory (ISO) (see Genzel & Cesarsky 2000 and Dole 2003 for reviews) provided important data on source counts at 60 μm (Hacking & Soifer 1991) and at 100 μm (Rowan-Robinson et al. 1986), and more recently at 90 μm (Kawara et al. 1998, 2004; Efstathiou et al. 2000; Juvela et al. 2000; Linden-Vornle et al. 2000; Matsuura et al. 2000; Rodighiero et al. 2003) and 170 μm (Kawara et al. 1998, 2004; Puget et al. 1999; Matsuura et al. 2000; Dole et al. 2001). Mid-infrared (MIR) observation with ISO CAM at 15 μm (Elbaz et al. 1999) are also of great interest, since they are believed to resolve a significant fraction of the CIB into sources (Elbaz 2002). The Spitzer Space Telescope (Werner et al. 2004) provides the ability for much deeper and wider area surveys from 3.6 to 160 μm. This paper investigates source counts at 70 and 160 μm from Spitzer. A companion paper addresses the MIR source counts at 24 μm (Papovich et al. 2004). The three-band source counts are the basis of new phenomenological models by Lagache et al. (2004).

2. OBSERVATIONS AND DATA REDUCTION

Observations were carried out with the Multiband Imaging Photometer for Spitzer (Rieke et al. 2004) in the Chandra Deep Field–South (CDF-S) and the Boötes field corresponding to the NOAO Deep Wide Field Survey (NDWFS; Jannuzi & Dey 1999); we also used an engineering MIPS observation of the Marano field. The observational mode (scan map) provides multiple sightings of each source, typically 10 and 60 at 70 μm in the Boötes and CDF-S, respectively. However, at 160 μm, the number of sightings is only typically 2 in Boötes and 12 in CDF-S. See Table 1 and Papovich et al. (2004) for details.

The data were reduced with the Data Analysis Tool (Gordon et al. 2004), from the raw data (ramps) to the final coadded mosaics. The illumination corrections were derived from the data themselves. At 70 μm, the data have been median-filtered in the time domain before mosaicking. Note that data from Ge:Ga detectors are always challenging to process; but with MIPS, most of the difficulties are overcome with frequent calibrations (stimulator flashes), which track the responsivity variations. Nevertheless, the noise properties at faint fluxes are still being investigated at both 70 and 160 μm. In this work, we adopt conservative detection limits. A future paper will address extracting the ultimate sensitivity from these data. Sample images in the CDF-S are shown in Figure 1 (Plate 1).

3. PHOTOMETRY AND CATALOGS

To control the sample and the selection function, we accepted source detections only where the redundancy was high (typically 80% or more of the mean weight), avoiding the
edges and the noisiest areas of the images. The resulting positions were fed to DAOPHOT (Stetson 1987) in IRAF\(^8\) for PSF fitting. We checked that the residual maps were free of sources.

At 70 \(\mu m\) the photometric calibration is derived from many observation campaigns, and its uncertainty is conservatively estimated at the order of 20%. We use only detections at 15 mJy and brighter in the CDF-S, 25 mJy and brighter in Marano, and 80 mJy and brighter in the Boo"tes field. These flux levels are determined using the sharp decrease in the counts due to the incompleteness effect. At 160 \(\mu m\), the calibration is based on a combination of observations of standard stars, asteroids, and comparisons with measurements with other FIR missions (ISO, COBE, and modeling including IRAS measurements). It is also estimated to be accurate to about 20%. We have included in our counts only objects of 50 mJy flux only. In order to visualize the contribution from each field, source counts have not been merged and have been overplotted. One should keep in mind that MIPS source counts will eventually go deeper and will be corrected for incompleteness.

The observed fields nicely complement each other in terms of area and depth. This allows us to probe a flux range of almost 2 orders of magnitude at 70 \(\mu m\). One order of magnitude is covered at 160 \(\mu m\). It is possible to check consistency and the cosmic variance in the common flux density range. At 70 \(\mu m\), in the range 25 to 100 mJy where three fields overlap in flux density, the differential counts are almost consistent within the error bars. At 160 \(\mu m\), in the range 100 to 300 mJy, the differential counts are consistent within the error bars. At both wavelengths, number counts in CDF-S appear consistently lower than in Marano.

### 5. DISCUSSION

#### 5.1. 70 \(\mu m\)

The MIPS 70 \(\mu m\) counts show a great consistency with the IRAS 60 \(\mu m\) counts of Lonsdale et al. (1990) converted at 70 \(\mu m\) using \(\nu_{60}\delta_{60} = \nu_{70}\delta_{70}\).

A selection of recent models is shown in Figure 2, including a nonevolution scenario. The most striking result is the strong excess of MIPS 70 \(\mu m\) sources compared to the nonevolution model, a factor of 3 at around 20–30 mJy. Strong evolution had been reported previously at 60 and 90 \(\mu m\), and these data provide unambiguous confirmation.

The two models lie close to the data: King & Rowan-Robinson (2003) and Lagache et al. (2003, 2004). These models, developed to fit observables mostly from IRAS, ISO, and SCUBA surveys as well as the CIB spectral energy distribution (SED), are based on a strong evolution of luminous (and ultraluminous) infrared galaxies (LIRGs and ULIRGs, respectively). The latter model predicts a peak in the redshift distributions of resolved sources at 70 \(\mu m\) near \(z \sim 0.7\) (Dole et al. 2003). Figure 4a shows the galaxy contribution to the differential counts, as a function of redshift, from the Lagache et al. (2004) model. Between \(\sim 5\) and \(\sim 100\) mJy, sources at \(0.7 \leq z \leq 0.9\) contribute the most to the counts. At brighter fluxes (reached by IRAS and ISO), contributions from local galaxies are more important.

The source counts integrated at 70 \(\mu m\) correspond to a brightness of 0.022 MJy sr\(^{-1}\) or 0.95 nW m\(^{-2}\) sr\(^{-1}\). The value of the CIB at this wavelength is not known accurately owing to

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**TABLE 1**

| Field Name \(^a\) | MIPS AOT \(^b\) | 70 \(\mu m\) | 160 \(\mu m\) |
|-----------------|---------------|-------------|-------------|
|                 |               | Area (deg\(^2\)) | 50\(^a\) | 120\(^d\) | Area (deg\(^2\)) | 70\(^b\) | 50\(^d\) |
| Bo"otes ......  | Med.          | 8.75        | 40          | 80          | 7.70          | 8          | 50          |
| Marano ......   | Slow          | 0.42        | 100         | 25          | 0.31          | 20         | 50          |
| CDF-S ......    | Slow          | 0.67        | 600         | 15          | 0.54          | 120        | 50          |

\(^{a}\) See Papovich et al. (2004) for details on fields.

\(^{b}\) Scan map mode.

\(^{c}\) Per sky pixel.

\(^{d}\) Flux density at which catalog was cut.

\(^{e}\) Field data not used at 160 \(\mu m\).
contamination by zodiacal light. If we use the CIB value from the model of Lagache et al. (2004), the MIPS counts show that at 70 μm about 23% of the 70 μm CIB is already resolved.

5.2. 160 μm

At 160 μm, the comparison with the ISO FIRBACK 170 μm survey (Dole et al. 2001) shows that the counts are consistent and within the error bars in the whole common range, 180–300 mJy. Other ISO observations (Matsuhara et al. 2000; Kawara et al. 2004) agree as well.

Figure 3 overplots the same models as at 70 μm. The evolution detected at 170 μm is confirmed at 160 μm, down to fainter levels. At about 100 mJy, an excess of sources by more than a factor of 2 is observed compared to a nonevolution scenario. Interestingly, as for 70 μm, the observed evolution is better fitted by the models of Lagache et al. (2004) and King...
& Rowan-Robinson (2003). The observed slope also agrees with Mould (2003).

We have constrained the bright end of galaxy number counts at 170 \( \mu \)m by using data from the ISOPHOT Serendipity Survey (ISOSS). ISOSS provides a total sky coverage of 15% and is virtually complete at a flux density level of \( S_{170 \mu m} = 50 \text{ Jy} \). Based on all optically identified galaxies detected by ISOSS (Krause 2003; Stickel et al. 2004) we have derived an integral number density of \( n(S_{170 \mu m} > 50 \text{ Jy}) = 14 \pm 3 \text{ gal sr}^{-1} \) galaxies at high Galactic latitudes. This point is perfectly matched by the model of Lagache et al. (2003, 2004).

The most striking result of the models that fit the number counts is the existence of two regimes in flux density. In the ISO range (fluxes above 200 mJy) most of the sources contributing to the counts are local; this is confirmed by observation (Patris et al. 2003). At fainter fluxes, between \( \sim 10 \) and 200 mJy, the counts should be dominated by a population located at redshifts between 0.7 and 0.9.

**Fig. 3.—** Source counts at 160 \( \mu \)m with no correction for incompleteness. Red star, CDF-S; blue diamond, Marano field; black diamond, ISO FIRBACK 170 \( \mu \)m counts from Dole et al. (2001). (a) Integral source counts. For clarity, photometric uncertainty is only shown for \( S_{160 \mu m} > 200 \text{ mJy} \). (b) Differential source counts. Models are also plotted with the same symbols as Fig. 2.
The source counts integrated at 160 $\mu$m correspond to a brightness of 0.07 MJy sr$^{-1}$ or 1.4 nW m$^{-2}$ sr$^{-1}$. The CIB value at this wavelength is 1 MJy sr$^{-1}$ (Lagache et al. 2000); the MIPS counts show that at 160 $\mu$m about 7% of the CIB is resolved. Since these counts are preliminary, are not corrected for incompleteness, and are subject to cosmic variance, we anticipate that the actual value might be higher.

5.3. Concluding Remarks

The first MIPS far-infrared source counts, spanning about 2 orders of magnitude in flux density at 70 $\mu$m (and one at 160 $\mu$m), are consistent with previous observations on the bright end and show unambiguous evolution on the faint end. Models predict that most of the sources lie at $z \sim 0.7$ with a tail up to $z \sim 2$ (Dole et al. 2003; Lagache et al. 2003, 2004). This work and companion papers on source counts at 24 $\mu$m (Papovich et al. 2004), confusion at 70, and 160 $\mu$m (Dole et al. 2004), and on the interpretation of these new data from the Spitzer cosmological surveys (Lagache et al. 2004) shed new light on the statistical properties of galaxies in an unexplored regime in flux density, and likely in a critical region of redshift space (up to redshifts $z \sim 2$) in the FIR (Egami et al. 2004; Le Floc’h et al. 2004).

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Fig. 1.—MIPS observations of the *Chandra* Deep Field-South at 70 and 160 μm. The field covers an area of 25′ × 1′.