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# INFRARED PROPERTIES OF RADIO-SELECTED SUBMILLIMETER GALAXIES IN THE *SPITZER* FIRST LOOK SURVEY VERIFICATION FIELD

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## ABSTRACT

We report on submillimeter and infrared observations of 28 radio-selected galaxies in the *Spitzer* First Look Survey verification field. All of the radio-selected galaxies that show evidence for emission at 850 $\mu$m with SCUBA have *Spitzer* counterparts at 24 $\mu$m, while only half of the radio-selected galaxies without 850 $\mu$m emission have detectable counterparts at 24 $\mu$m. The data show a wide range of infrared colors ($S_{70\ \mu\mathrm{m}}/S_{24\ \mu\mathrm{m}} < 5-30$, $S_{8\ \mu\mathrm{m}}/S_{3.6\ \mu\mathrm{m}} < 0.3-4$), indicative of a mixture of infrared-warm AGN-dominated and cooler starburst-dominated sources. The galaxies showing 850 $\mu$m emission have *Spitzer* flux densities and flux density ratios consistent with the range of values expected for high-redshift ($z = 1-4$) ultraluminous infrared galaxies.

*Subject headings:* galaxies: active — galaxies: evolution — galaxies: formation — galaxies: starburst — infrared: galaxies

## 1. INTRODUCTION

The *Spitzer Space Telescope* provides us with the exciting opportunity to study the high-redshift universe at mid- and far-infrared wavelengths. The *IRAS* mission first uncovered the presence of infrared luminous galaxies in the local universe (Neugebauer et al. 1984), and the submillimeter/millimeter surveys with SCUBA and MAMBO have highlighted the importance of ultraluminous infrared galaxies (ULIRGs; $>10^{12}\ L_\odot$) at high redshift (e.g., Smail et al. 1997; Hughes et al. 1998; Bertoldi et al. 2000). Studies of high-redshift ULIRGs are important for our general understanding of galaxy evolution, since they are responsible for a significant fraction of the total energy generated by all galaxies over the history of the universe (e.g., Blain et al. 2002).

The recent spectroscopic studies of the submillimeter galaxy (SMG) population show that the redshift distribution peaks at $z \sim 2-3$ (Chapman et al. 2003a, 2004) and that the population is composed of starbursts, active galactic nuclei (AGNs), and composite AGN+starburst systems (Ivison et al. 1998, 2000; Frayer et al. 2003; Knudsen et al. 2003). Even though many SMGs show the presence of AGNs, the molecular CO line emission (Frayer et al. 1998, 1999; Neri et al. 2003) and X-ray data (Alexander et al. 2003) are consistent with the majority of the infrared emission from a population arising from star formation. The Multiband Imaging Photometer for *Spitzer* (MIPS; Rieke et al. 2004) allows us to directly measure the infrared colors and constrain the fraction of infrared-warm AGN-dominated versus infrared-cool starburst-dominated SMGs.

## 2. OBSERVATIONS

Before the launch of *Spitzer*, we identified potential SMGs in the First Look Survey (FLS) verification field by selecting radio sources with faint optical counterparts, following previous successful selection techniques (e.g., Cowie et al. 2002; Chapman et al. 2003b). We used deep Westerbork 1.4 GHz radio data (rms = 9 $\mu$Jy; Morganti et al. 2004) and deep optical NOAO *R*-band data (3 $\sigma$ = 26.4 mag; Fadda et al. 2004) to derive a list of candidate sources for follow-up observations with SCUBA. In the spring of 2003, we observed 28 galaxies at the James Clerk Maxwell Telescope (JCMT) using the SCUBA two-bolometer photometry mode, achieving rms levels of 2–3 mJy at 850 $\mu$m.

The *Spitzer* observations were taken as part of the extragalactic component of the FLS.[6] The 28 galaxies in the sample are located within the 0.25 deg$^2$ of the FLS verification field and were observed with both the Infrared Array Camera (IRAC; Fazio et al. 2004) and MIPS. The data presented here have effective integration times of 480, 336, 168, and 34 s for the IRAC bands and the MIPS 24, 70, and 160 $\mu$m arrays, respectively. The data were reduced using the standard *Spitzer* Science Center (SSC) pipeline and were co-added and corrected offline as needed. The details of the data reduction will be described in future FLS data papers (IRAC: M. Lacy et al. 2004. in preparation; MIPS 24 $\mu$m: D. Fadda et al. 2004, in preparation; MIPS 70 and 160 $\mu$m: D.T. Frayer et al. 2004, in preparation).

## 3. RESULTS AND DISCUSSION

### 3.1. *Source Identification*

We observed 28 Westerbork radio sources with SCUBA and detected seven SMGs at signal-to-noise ratios (S/Ns) of greater than 3. Fourteen sources were not detected at 850 $\mu$m, and the remaining seven sources have marginal results, showing positive signals of 1.5–3 $\sigma$ (Table 1, col. [5]). The Westerbork

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