Submillimeter-selected galaxies

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Abstract. The first generation of submillimeter(submm)-wave surveys are being carried out using the 450/850-µm SCUBA camera at the JCMT on Mauna Kea. These surveys are potentially sensitive to galaxies at very high redshift, and the galaxies that have been detected so far appear to contribute the greater fraction of the mm/submm-wave background radiation intensity measured by COBE. In order to understand this new population of galaxies, individual examples must be studied in detail across many wavebands; in particular their redshifts must be determined. We discuss the potential selection effects at work in submm-wave surveys and describe the spectral energy distributions (SEDs) of galaxies selected or luminous in the submm waveband. We also describe the general procedure for, and emphasize the difficulty of, identifying optical counterparts to submm-selected galaxies. Finally, we summarize what is known about the redshifts of these galaxies and the source of their luminosity.

1. Introduction

The first submm-wave surveys, designed to detect the redshifted restframe far-infrared(IR) radiation from warm dust in distant galaxies (Blain & Longair 1993), have recently been carried out (Smail, Ivison & Blain 1997; Barger et al. 1998, 1999b; Hughes et al. 1998; Blain et al. 1999b, 2000; Eales et al. 1999). These surveys are uniquely sensitive to high-redshift galaxies, and have been possible since the sensitive SCUBA camera (Holland et al. 1999) was commissioned at the JCMT in 1997. SCUBA is an imaging and photometric instrument, optimized to observe a 5-arcmin\(^2\) field simultaneously in the 450- and 850-µm
atmospheric transmission windows. The images produced have a resolution of about 15 arcsec at 850 µm and 7 arcsec at 450 µm.

The intensity of mm, submm and far-IR background radiation has been measured recently using data from the FIRAS and DIRBE instruments on the COBE satellite (Puget et al. 1996; Fixsen et al. 1998; Hauser et al. 1998; Schlegel, Finkbeiner & Davis 1998; Finkbeiner, Davis & Schlegel 1999). The results of the first galaxy surveys in the far-IR waveband, carried out using the ISO satellite, have also been reported recently (Kawara et al. 1998; Puget et al. 1999).

In this paper we review certain aspects of the existing submm-wave surveys, concentrating on the selection technique and the procedures for following up the submm-wave detections in other wavebands. We discuss whether any selection effects could act to prevent any types of high-redshift dusty galaxies being detected efficiently in submm-wave surveys, and compare all the well-determined SEDs of submm-selected galaxies with those of other dusty galaxies and active galactic nuclei (AGNs). We discuss the difficulties of identifying the galaxy responsible for the detected submm emission, and show an example, the SCUBA-selected galaxy SMM.J09429+4658 (Smail et al. 1999a), in which very deep multiwaveband images of the fields around the centroid of the SCUBA source were required in order to make progress in the identification. Finally, we discuss our current state of knowledge about the redshift distribution of the galaxies detected in SCUBA surveys, which is crucial for distinguishing between different models of galaxy evolution (Blain et al. 1999a,c), about the connections between the high-redshift SCUBA sources and the properties of dust in low-redshift galaxies, and about whether the SCUBA galaxies are powered by star-formation activity or by AGN accretion. Unless otherwise stated we assume an Einstein–de Sitter world model with Hubble’s constant $H_0 = 50\, \text{km s}^{-1}\, \text{Mpc}^{-1}$.

2. Submm selection effects: spectral energy distributions (SEDs)

The reason why a large fraction of the galaxies detected in submm-wave surveys are at high redshifts is the steep long-wavelength slope of the dust emission spectrum, which can be described well by a Rayleigh–Jeans thermal spectrum, modified by an emissivity function $\epsilon_\nu$. An emissivity with the form $\epsilon_\nu \propto \nu^\beta$, where $\beta \simeq 1.5$ provides a reasonable fit to the data, and so the submm-wave emission spectrum of a dusty galaxy $f_\nu \propto \nu^\alpha$, where $\alpha \simeq 3.5$. This steep spectrum leads to a strong negative $K$-correction, which at redshifts $z > 0.5$ can be sufficient to overcome the geometric dimming due to the inverse square law, and lead to a flat flux density–redshift relation in the submm waveband. The SED is also defined by a dust temperature $T_d$. Low-redshift spiral galaxies generally have dust temperatures of about 15–20 K, but there is evidence, from both individual high-redshift dusty galaxies and the background radiation spectrum, that hotter temperatures, $T_d \simeq 40$ K, are typical of the submm-selected galaxy population (see Section 4), at least as a luminosity-weighted mean temperature.

The strong submm-wave $K$-correction is illustrated in Fig. 1. We show the flux density–redshift relation predicted for a dusty galaxy with a fixed bolometric luminosity in the restframe far-IR waveband for a variety of dust temperatures $T_d$ and dust emissivity indices $\beta$. The SED template used is assumed to have a power-law slope $f_\nu \propto \nu^{-1.7}$ on the Wien side of the dust emission spectrum in the
mid-IR waveband. This power-law slope takes account of the contribution made to the SED at shorter wavelengths by the populations of hotter dust grains in the interstellar medium (ISM) of the galaxy, and provide a good representation of very deep 15-µm counts of galaxies determined using the ISO satellite (Altieri et al. 1999), see Blain et al. (1999a,c) for more information.

It is clear from the left-hand panel of Fig. 1 that the dust temperature has a significant effect on the detectability of a dusty galaxy with a fixed bolometric luminosity, both when observed close to the peak of the SED at 175 µm in the far-IR waveband and at 850 µm in the submm waveband. Hotter galaxies produce less submm-wave flux density per unit bolometric luminosity, and are thus less likely to be detected in the submm waveband. This effect is illustrated by a comparison of the 850-µm flux densities, dust temperatures and bolometric luminosities of APM 08279+5255 (Lewis et al. 1998) and IRAS F10214+4724 (Lacy et al. 1998). Although the 850-µm flux density of APM 08279+5255 is only a factor of 1.5 times greater than that of IRAS F10214+4724, because $T_d > 100$ K in APM 08279+5255 but only $\simeq 80$ K in IRAS F10214+4724, the inferred luminosity of APM 08279+5255 exceeds that of IRAS F10214+4724 by an order of magnitude.

It is interesting to note that the dust temperature that best accounts for the properties of the faint submm galaxy population (Blain et al. 1999a,c; Trentham et al. 1999) is close to 40 K, which also seems to be typical of the dust in high-redshift quasars and radio galaxies (Benford et al. 1999; Ivison et al. 1998a) and in IRAS galaxies (Lisenfeld, Isaak & Hills 1999). It is possible therefore that an additional population of high-redshift galaxies could exist with hotter dust temperatures, that are underrepresented in submm-selected samples. Note that such a population would probably be too distant to have been detected using the ISO satellite at 175 µm.

Figure 1. Flux density–redshift relations for dusty galaxies with fixed bolometric luminosities at wavelengths of 850 and 175 µm in the submm and far-IR wavebands. Left: the emissivity index $\beta = 1.5$ is fixed and the dust temperature $T_d$ varies. Right: $T_d = 38$ K is fixed and $\beta$ varies.
The flux density–redshift relation for a dusty galaxy with a dust temperature of 38 K and an emissivity index $\beta = 1.5$ in three different cosmological models. The relative size of the volume element as a function of redshift is also shown in each model, in arbitrary units.

The effect of varying the emissivity index of the dust spectrum is shown in the right-hand panel of Fig. 1. The value of the index has little effect on the detectability of galaxies at a far-IR wavelength of 175-$\mu$m, which is close to the restframe peak of the SED; however, the effects are more significant at a submm wavelength of 850-$\mu$m. Low-redshift galaxies would be more likely to be detected in a SCUBA survey if the emissivity index $\beta$ is low.

3. Submm selection effects: cosmology

Because submm-wave surveys probe the Universe at $z \geq 1$, the effects of different world models on the observability of dusty galaxies could be significant. The effects are illustrated in Fig. 2, in which the flux density–redshift relation for a dusty galaxy with a fixed template SED and a fixed bolometric luminosity is compared in three different world models. The $K$-correction is less dramatic in the two $\Omega_0 < 1$ models as compared with the Einstein–de Sitter model, and so in these two models, the intrinsic luminosity of a high-redshift dusty galaxy detected at a certain 850-$\mu$m flux density will be greater. However, the effect of the world model on the interpretation of submm-wave source counts is not very significant. This is because the volume element is also larger in the two $\Omega_0 < 1$ models, and so, in order to avoid overpredicting the measured source counts, the evolution of either the space density or luminosity of the population of submm-selected galaxies must be less dramatic in these models. The effects of an increased luminosity per unit flux density and a less dramatic form of evolution will largely counteract each other, and so the general conclusions about evolution are unchanged.
When accurate counts and redshift distributions are available for submm-selected galaxies, and their SEDs are known, it will be possible to investigate the effects of different cosmological models. However, at present the uncertainties due to the SED are greater than those due to the world model.

4. The SEDs of submm galaxies with known redshifts

In Fig. 3 we compare the observed restframe SEDs of luminous dusty galaxies with known redshifts and two template SEDs derived for use in galaxy evolution models. The Guiderdoni et al. (1998) model was compiled from a large sample of SEDs of IRAS galaxies, and the Blain et al. (1999c) model was derived from the counts of IRAS and ISO galaxies at 60 and 175 µm. Observed SEDs for several classes of submm-luminous source are shown: low-redshift IRAS galaxies, for which SEDs are available right across the submm, far- and mid-IR wavebands; submm-selected galaxies, of which four have known redshifts; lensed quasars; and both optical- and radio-selected high-redshift AGN. The optical-selected extremely red object (ERO) HR10 (Dey et al. 1999) is included as a submm-selected galaxy, as it would have been identified in the current surveys.

Both of the model spectra shown in Fig. 3 appear to provide reasonable descriptions of most of the galaxies, and all of the submm-selected ones. The exceptions are the sources that are known to be strongly lensed by foreground galaxies and some of the high-redshift active galaxies, in which the dust temperature is considerably higher than 40 K. However, it is reasonable to have a greater mid-IR luminosity from these objects, due both to intense heating by an AGN and to differential magnification across the nucleus of the source. Both of these processes would be expected to increase the dust temperature required to fit the observed SED (Eisenhardt et al. 1996; Blain 1999a). In general, an SED model with $T_d \approx 40$ K and $\beta \approx 1.5$ seems to describe the observed SEDs of submm-selected dusty galaxies reasonably well.

A lower value of $\beta = 1$ was assumed by Eales et al. (1999) to help explain the significant fraction of galaxies at $z < 1$ identified by Lilly et al. (1999) in their SCUBA survey of the CFRS fields. Very few galaxies are expected to be detected at these low redshifts based on models with $\beta = 1.5$ (Blain et al. 1999c), and in deep multiwavebands follow-up observations of fifteen background sources in the fields of seven lensing clusters (Smail et al. 1997, 1998, 1999a) none are found at $z < 1$. The most appropriate value of $\beta$ will be clarified by further observations, which will also reveal whether some of the low-redshift galaxies in the CFRS fields could be mis-identified.

4.1. The population of submm-luminous galaxies at low redshifts

Faint submm-wave surveys are currently only possible in small fields, and so probe very high-redshift pencil beams. It is also interesting to investigate the abundance, distribution and properties of dust in low-redshift galaxies, which reflects the evolutionary processes at work, both star formation and chemical evolution, in the ISM of galaxies throughout their history. Dunne et al. (1999) have recently reported the results of a survey of typical low-redshift IRAS galaxies, for which they obtained 450- and 850-µm submm-wave SCUBA photometry to investigate the dust temperature and spectral index. Note, however, that
Figure 3. The SEDs of a range of dusty galaxies with known redshifts (points), and two model spectra, that are chosen to accord with IRAS and ISO data (lines). There are four types of galaxies: low-redshift IRAS galaxies (I), sub-mm luminous galaxies (S), distant sources lensed by a foreground galaxy (L), and high-redshift radio-loud and radio-quiet AGN (H). The SED models include a dust emissivity index $\beta \simeq 1.5$ and a dust temperature $T_d \simeq 40$ K. Only the lensed galaxies and quasars, and some of the high-redshift AGN depart significantly from the template SEDs in the restframe mid-IR waveband.

at $z = 0$ the SEDs of even normal spiral galaxies, with dust temperatures as low as 20 K, are probed by SCUBA quite a long way down the Rayleigh–Jeans slope of the dust SED, and that their bolometric luminosity is constrained by the 60-µm IRAS data. The results will be interesting, but should have no dramatic consequences for the interpretation of the high-redshift SCUBA surveys, in which the detected galaxies are both observed at significantly shorter rest-frame wavelengths, closer to the peak of their restframe SED, and are much more luminous.

5. The identification of optical counterparts

Unusually, because of the flat flux density–redshift relation illustrated in Fig. 1, a measurement of the submm-wave flux density of a distant galaxy can be translated into a luminosity directly, independent of redshift, subject to an uncertain value of the dust temperature and emissivity index. However, a crucial step in
understanding the nature of submm-selected galaxies is still the determination of their redshifts, individually and as a population. A problem arises because the SCUBA beam is 15 arcsec in size at 850 \( \mu m \), and so there could easily be more than 5 plausible faint optical counterparts within 3 arcsec of the centroid of a SCUBA detection in images as deep as the Hubble Deep Field (HDF) see Hughes et al. (1998) and Downes et al. (1999). Identifying the correct optical counterpart will in general be very difficult, especially as a priori submm-selected galaxies would be expected to have large internal extinctions and thus to be optically faint: see for example the source SMM J14009+0252 (Ivison et al. 1999) and the brightest source in the SCUBA map of the HDF (Downes et al. 1999), which currently have no plausible optical counterparts.

Sensitive radio observations are very useful for improving the chances of making a correct association, as the maximum resolution of the VLA at 1.4 GHz is about 1 arcsec. Any submm-selected galaxy should be detectable in a sufficiently deep radio image, based on the the observed low-redshift radio–far-IR correlation (Condon 1992), which links the synchrotron radio emission from supernova remnants and the submm-wave dust emission powered by young high-mass stars. The consequences for locating submm sources and estimating their redshifts are discussed by Carilli & Yun (1999), Blain (1999b) and Carilli et al. (1999). This technique has been applied to a submm-selected sample by Smail et al. (1999b) and to a radio-selected, \( K \)-band faint sample by Barger, Cowie & Richards (1999a). Note, however, that extremely deep radio observations are required in order to detect the current population of submm-selected sources. Only seven of Smail et al.’s fifteen SCUBA galaxies have 1.4-GHz detections, the rest only upper limits (Smail et al. 1999b).

Plausible optical counterparts can be identified by overlaying the submm image with as many deep radio, near-IR and optical images as are available. Optical or near-IR spectroscopic redshifts are then required for the candidates. With such intrinsically faint sources, this is in general difficult, even using the largest telescopes (Ivison et al. 1998b; Barger et al. 1999c). The likelihood of an association being correct can be assessed based on photometric or positional arguments (Hughes et al. 1998; Smail et al. 1998); however, the final confirmation of the correct identification comes from the detection of molecular gas in interferometric mm-wave observations (Frayer et al. 1998, 1999). At 90-GHz the OVRO Millimeter Array has a resolution of several arcsec, a few times finer than SCUBA, and a bandwidth of 1 GHz. Hence, if the redshift of a plausible counterpart is known to better than 1%, ideally from near-IR spectroscopy of low-excitation lines, then the array can be tuned to the frequency of an appropriate CO rotation line at that redshift. If the line is detected at the position of the optical counterpart, then the presence of a large mass of molecular gas coincident in position and redshift ties together the optical and submm emission and confirms the identification.

In only two cases has this procedure been completed, for SMM J02399−0136 (Ivison et al. 1998b; Frayer et al. 1998) at \( z = 2.8 \) and SMM J14011+0252 (Ivison et al. 1999; Frayer et al. 1999) at \( z = 2.6 \). Another source, SMM J032399−0134, has a very good candidate at \( z = 1.06 \) (Barger et al. 1999c), with a blue ring galaxy morphology, distorted by the magnification of the cluster Abell 370, and a coincident 15-\( \mu m \) ISO detection (Soucail et al. 1999).
Figure 4. A multiwaveband view of the field of the submm galaxy SMM J09429+4658 (Smail et al. 1999a). The three larger images are 30 arcsec on a side and are centred on the position of the centroid of the 850-μm detection. From left to right: An HST difference image showing the dust lane in the spiral galaxy H1; SCUBA 850-μm submm emission (black contours; 3, 6 and 9σ) overlaid on a Hale 5-m Gunn-r image; VLA 1.4-GHz radio emission (black contours) overlaid on a deep Keck-II I-band image; and a UKIRT K-band image. The relative radio and optical astrometry is accurate to less than 0.4 arcsec.

With fluxes at or below the faintest detectable levels of radio and optical flux density, many of the counterparts of SCUBA sources necessarily remain enigmatic. The typical achromatic magnification by a factor of 2.5 experienced by background sources in the fields of rich clusters, and the associated expansion of the background sky by the same factor, has proved to be a great advantage for making follow-up observations.

5.1. SMM J09429+4658: a case study

The SCUBA source SMM J09429+4658, for which an array of high-quality data is available, has proved to be a very interesting case study in making identifications of submm sources. In Fig. 4 we show all the excellent multiwaveband data that has been compiled for this galaxy in the field of the z = 0.41 cluster Cl0939+4713/A851. A partial two-colour HST image, a Hale R-band image, a very deep 1.4-GHz VLA map, a deep Keck-II I-band image and a UKIRT K-band image are available (Smail et al. 1999a). These images are extremely deep: after correcting for lens magnification, the 1σ sensitivities are 3.6 μJy beam\(^{-1}\) at 1.4-GHz and \(I = 27\).

In the initial search for optical counterparts to the SCUBA galaxies (Smail et al. 1998), the dusty spiral galaxy H1 at z = 0.33 in the foreground of the cluster was identified as a possible counterpart, despite being 7 arcsec away from the SCUBA centroid and having no strong optical line emission (Barger et al. 1999c). When a deep 1.4-GHz VLA radio map was obtained, two radio sources were found within the SCUBA positional uncertainty: H1 (57 μJy) and a new source H5 (36 μJy), which has no optical counterpart but is aligned exactly with the SCUBA centroid. If H1 is the true counterpart, then unless its dust temperature is less than about 13 K, it lies well below the far-IR–radio correlation at z = 0.33; however, if H5 is the true counterpart, then its radio-submm flux ratio is typical of a 40-K dusty galaxy at z ≥ 3.5 (Blain 1999b; Smail et al. 1999a). Unfortunately H5, lies off the edge of the HST image, and it has no
optical counterpart in a very deep Keck-II $I$-band image. Only the acquisition of a deep UKIRT $K$-band image revealed a source at the H5 position. Keck NIRSPEC spectroscopy and, if a spectroscopic redshift is obtained, mm-wave observations of redshifted CO emission from H5 will hopefully confirm the identification over the 1999-2000 winter. The follow-up observations of this galaxy illustrate the importance of obtaining very deep multiwaveband data in order to identify SCUBA galaxies, especially radio and near-IR images.

6. The redshift distribution of submm-selected galaxies

The determination of the redshift distribution of submm-selected galaxies is crucial in order to constrain models of galaxy evolution (Blain et al. 1999c). There is considerable degeneracy between different models of the population of distant dusty galaxies that can all account for both the observed spectrum of mm, submm and far-IR background radiation and for the 450- and 850-$\mu$m counts of galaxies. The degeneracy can be broken most easily and definitively by determining the redshift distribution of the submm galaxies. Several different approaches have so far been taken to try and tackle this difficult problem.

Smail et al. (1998) made plausible identifications of optical sources in deep $HST$ and ground-based images of the fields of submm-selected galaxies behind seven rich clusters of galaxies. The lack of $V$-band dropout sources indicated that 80% of the proposed counterparts were probably at $z < 5$. Using Keck-II spectroscopy of this incomplete sample, Barger et al. (1999c) found a median redshift $\bar{z} \simeq 1.7$ for these counterparts. However, as illustrated by the detection of two EROs in the fields (Smail et al. 1999a), which were unknown at the time, this is likely to be a lower limit, as correct counterparts are more likely to be missing from the sample at higher redshifts. $\bar{z} \simeq 2.5–3.0$ is indicated by a Carilli & Yun analysis of the radio–submm flux density ratios of the SCUBA galaxies derived from very deep VLA images of the fields (Smail et al. 1999b).

Hughes et al. (1998) identified plausible faint optical counterparts to the brightest sources in the SCUBA $HDF$ image, and deduced from photometric arguments that the redshifts of the sources were in the range $2 < z < 4$. Working from a deep 1.4-GHz VLA image, Richards (1999) suggested a systematic offset of the SCUBA astrometry, and a lower typical redshift. A subsequent high-resolution mm-continuum map of this source made using the IRAM interferometer (Downes et al. 1999) has provided a more accurate position, ruling out both of the counterparts suggested by Hughes and Richards, but suggesting that the source is gravitationally lensed by an elliptical galaxy. A very high redshift is potentially indicated for this source by the lack of a detectable optical counterpart in the $HDF$ at this exact position.

Using a variety of optical, mid-IR and radio data, Lilly et al. (1999) investigated the SCUBA sources detected in the CFRS fields (Eales et al. 1999), and found a significant fraction ($\simeq 30\%$) of plausible counterparts at $z < 1$. This is a lower redshift distribution than reported in other surveys. Misidentification of some of these $z < 1$ galaxies remains a possibility; further follow-up observations should resolve this apparent discrepancy.

Recently, Barger et al. (1999a) made SCUBA maps of the areas around the 1.4-GHz radio sources as faint as $40\mu$Jy in the $HDF$ flanking fields with
no near-IR counterparts down to $K = 20.5$. By using Carilli & Yun’s radio-
submm redshift estimator they derived redshifts in the range $1 < z < 3$ for all
six of the galaxies they detected using SCUBA. When the area of the submm
maps and the number of detections are compared, it seems likely that there
is a significant overlap between this population of near-IR-blank faint radio
sources and the bright ($> 8\text{ mJy}$) SCUBA galaxies. However, this radio–near-IR
selection technique will tend to bias the sample as compared with a submm-
selected sample, by enhancing the fraction of radio-loud objects and AGN.

At present, there are only two submm-selected galaxies with certain red-
shifts, SMM J02399−0136 and SMM J14011+0252 at redshifts $z = 2.8$ and 2.6
respectively. This information alone suggests that the submm-selected popula-
tion as a whole is probably at a significant redshift. Other techniques based on
statistical arguments, tend to support the idea that $2 \leq \bar{z} \leq 4$ for the SCUBA
galaxies, and that there is probably a tail of sources at higher redshifts.

7. The power source of submm-selected galaxies

It is clear from the observed SEDs of submm-selected galaxies that thermal emission
from warm dust grains is being detected. However, it is an open question
whether the power source heating the grains is the radiation from young stars
or from the accretion disk of an AGN. The form of the broad-band submm and
far-IR SED provides no information about this question. However, at shorter
mid-IR wavelengths the slope of the continuum SED may tend to be harder in
sources which are heated by AGN, for example compare the different slopes of
Arp 220 and Mrk 231 in Fig. 3. Also, the properties of PAH spectral features
observed in nearby IRAS galaxies by the ISO satellite (Lutz et al. 1999), can pro-
vide an indication of the power source, because the large molecules that produce
them should not survive in the hard UV continuum radiation field expected in
the core of an AGN. Lutz et al. (1999) conclude that 70% of the far-IR radiation
from these galaxies appears to be powered by star formation.

At present, direct observations of high-redshift submm-selected galaxies and
of the X-ray background tend to support the continuation of this relative con-
tribution out to high redshifts. One of the two best-studied SCUBA-selected
galaxies (SMM J02399−0136; Ivison et al. 1998) shows clear signs of AGN ac-
tivity, but the other (SMM J14011+0252; Ivison et al. 1999) does not. Barger
et al. (1999c) see evidence for high-excitation optical line emission, typical of
AGN activity, in about 20% of their relatively shallow Keck spectra of plausible
optical counterparts to submm-selected galaxies (Smail et al. 1998). Note, how-
ever, that these are the easiest optical emission lines to detect, and so the AGN
fraction in a complete sample may differ. A fraction of the optical counterparts
targeted using the Keck will also certainly have been misidentified, leaving the
ture optical counterparts to the SCUBA galaxies unobserved. Almaini, Lawrence
& Boyle (1999) show that it is most plausible to explain the relative intensity
of hard and soft X-ray background radiation by a population of high-redshift
dust-enshrouded AGN, which can account for 10-20% of the SCUBA sources.

It is not yet definite, but it seems likely that the majority of the emission
making up the far-IR background and the counts of submm galaxies is powered
by young high-mass stars, with a less significant contribution from AGN.
8. Conclusions

1. A significant population of high-redshift galaxies with powerful dust emission has been discovered since the commissioning of SCUBA, the first submm-wave bolometer array camera.

2. The surface density of these galaxies is such that a significant fraction of the diffuse extragalactic background radiation detected by the COBE satellite has already been resolved into discrete sources.

3. The SEDs of the SCUBA galaxies and other submm-luminous distant galaxies are generally consistent with a dust temperature $T_d \approx 40$ K.

4. If there is a population of hotter submm-luminous sources, then these galaxies are less likely to be detected by SCUBA. At present there is little evidence that there is a significant population of such sources.

5. It is difficult and time consuming to identify and detect the current population of submm-selected galaxies in other wavebands. Only two such galaxies have so far been identified beyond reasonable doubt.

6. It seems likely at present that star-formation activity dominates AGN accretion as a power source for submm-selected galaxies in the approximate proportion 2 or 3:1. The AGN-powered subset will hopefully soon be detected in high-resolution Chandra and XMM X-ray observations.

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