SCUBA observations of the elliptical galaxy NGC 4374

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ABSTRACT

We present SCUBA imaging and photometry of the elliptical galaxy NGC 4374. The imaging observations are used to examine the spatial distribution of thermal emission from dust and the radio-to-infrared continuum spectrum. In the SCUBA 850-μm image, the galaxy is found to be a point source, constraining the emission to a region less than 15 arcsec across (1.5 kpc for a distance of 20.74 Mpc). The simplest interpretation is that the 2000–850-μm SCUBA emission is synchrotron from a compact core or inner jet, and most unlikely to be thermal emission from cold diffuse dust. We cannot exclude free–free emission, but this would be very unexpected. The thermal emission from dust is shown in IRAS data and these, along with the 450-μm SCUBA datum, give a dust temperature of 35 K, corresponding to a dust mass of 1.2 × 10⁵ M☉. These are pilot observations in a programme to look for cold, diffusely distributed dust in elliptical galaxies; however, much deeper 450-μm imaging is required to investigate this in NGC 4374.

Key words: radiation mechanisms: thermal – galaxies: elliptical and lenticular, cD – galaxies: individual: NGC 4374 – radio continuum: galaxies.

1 INTRODUCTION

The interstellar medium (ISM) in elliptical galaxies is not easily probed by optical observations, although observations at a range of other wavelengths have revealed unexpected amounts of gas in these galaxies (Roberts et al. 1991). With the gas we also expect some dust to be present, since red giant stars lose dust to the ISM. Small amounts of dust are seen in dust lanes and patches in ellipticals (Sparks et al. 1985; Goudfrooij et al. 1994). The submillimetre camera SCUBA (Holland et al. 1999) provides an opportunity to test if there is cold (less than about 30 K), diffusely distributed dust present in elliptical galaxies, as suggested from far-infrared observations. Dust temperatures (25 to 35 K) and masses (∼10⁴ to a few ×10⁶ M☉) were estimated from IRAS observations for a sample of ellipticals by Goudfrooij & de Jong (1995). They showed that dust masses derived from IRAS fluxes exceeded (by typically an order of magnitude) the dust masses estimated from optically identified dust lanes and patches in many ellipticals.

However, the IRAS data are limited for studying dust, since IRAS gave little information about the spatial distribution of the dust in galaxies, so they cannot be used to check directly if the dust is diffusely distributed or not. We also note that many ellipticals contain haloes of hot gas at around 10⁷ K with masses of a few ×10⁸ M☉ (Canizares, Fabbiano & Trinchieri 1987). This X-ray-emitting plasma is expected to destroy any dust grains through sputtering by hot gas particles in a short time (∼10⁷ yr; Draine & Salpeter 1979). So, for diffusely distributed dust to be present in a typical giant elliptical galaxy, the dust would have to be protected or shielded from the plasma in some way. SCUBA, being an imaging device, offers an opportunity to map out the distribution of any cool dust.

The giant elliptical NGC 4374 was chosen from the sample of Goudfrooij & de Jong (1995) as a candidate in which to look for diffusely distributed dust because it has optical dust lanes in the central region (<10 arcsec). The dust mass estimated from the dust lanes is 3.5 × 10⁵ M☉ and the dust mass estimated from the infrared (IRAS) fluxes (at 60 and 100 μm) is 1.35 × 10⁵ M☉ (for a dust temperature of 35 K), a factor of ∼4 greater than from the optically identified dust (Goudfrooij & de Jong 1995). Since most of this dust is not seen in the optical dust lanes, Goudfrooij & de Jong (1995) suggest that it must be diffusely distributed throughout the galaxy. Such dust would affect the colours in galaxies. However, this effect could be difficult to disentangle from age and metallicity variations in the stellar population, which also produce colour changes (Worthey 1994). Therefore the presence of a few million solar masses of dust, distributed throughout a galaxy, could well have escaped optical detection. On the other hand, spatially resolved submillimetre observations, through sputtering by hot gas particles in a short time (<10⁷ yr: Draine & Salpeter 1979). So, for diffusely distributed dust to be present in a typical giant elliptical galaxy, the dust would have to be protected or shielded from the plasma in some way. SCUBA, being an imaging device, offers an opportunity to map out the distribution of any cool dust.

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Note that there was a typographical error in Goudfrooij & de Jong (1995): the dust mass that they estimated from the IRAS data should have read log Md = 5.13 (not 5.3) (Goudfrooij, private communication). We quote the correct dust mass here.
sensitive to thermal emission from cool dust, may directly reveal the presence of any such distribution.

NGC 4374 (M84) is an E1 galaxy in the Virgo cluster lying at a distance of 20.74 Mpc. It is classified as a steep-spectrum Fanaroff–Riley I (FRI) radio galaxy with an infrared excess. Two-sided jets emerge from its compact core, which is less than 2 arcsec across (Jenkins, Pooley & Riley 1977). In the context of the Blandford & Rees (1974) jet model, the jets transport energy from the core to symmetrical, edge-darkened lobes which extend to about 2 arcmin and dominate the core emission (Laing & Bridle 1987; Wrobel 1991). The jets are perpendicular to the dust lanes.

There is a low-ionization region near the nucleus, extending for about 20 arcsec along the direction of the optical dust lanes (Baum, Heckman & van Breugel 1992). Bower et al. (1997) published HST images showing the central structure and estimate a dust mass of $10^7 M_\odot$ (for $D = 20.74$ Mpc) from their $(V - I)$ image. The HST images indicate central line emission from three components: a nuclear disc, an ‘ionization cone’ and outer filaments.

NGC 4374 also has a hot X-ray halo with $\sim 10^8 M_\odot$ of hot gas (Goudfrooij 1994). Its spectrum from the radio to the infrared was previously studied by Knapp & Patten (1991), who did not detect any submillimetre emission above that expected from the continuum of the radio-luminous source. They used a previous generation detector in the submillimetre (Duncan et al. 1990). Knapp & Patten (1991) inferred dust contents in a sample of radio galaxies (mostly ellipticals) from the order of that found in luminous spiral galaxies ($\sim 10^2$ to $10^5 M_\odot$). They assumed a dust temperature of 18 K ($\sim 15$–20 K estimated range) for the galaxies in their sample and estimated a dust mass of $2 \times 10^6 M_\odot$ in NGC 4374. Their low estimate of the dust temperature leads to a significantly larger dust mass estimate than that of Goudfrooij & de Jong (1995).

In this paper we explore whether SCUBA jiggle mapping at 850 and 450 $\mu$m and photometry at 2000, 1350, 850 and 450 $\mu$m can confirm the presence of diffusely distributed, cold dust in the giant elliptical galaxy NGC 4374. We use the SCUBA observations together with radio and infrared data from the literature to place tighter constraints on the spectral components, including the dust temperature and the size of the infrared-emitting region.

2 OBSERVATIONS AND REDUCTIONS

Imaging and photometric observations of NGC 4374 were obtained on 1997 September 3, as well as on 1998 January 22, February 1 and February 14 and 1999 March 19, with SCUBA, the Submillimetre Common-User Bolometer Array on the James Clerk Maxwell Telescope (JCMT) (see Table 1). In the imaging observations, we operated the 91 bolometers of the short-wave array (SW) at 450 $\mu$m and the 37 bolometers of the long-wave array (LW) at 850 $\mu$m, giving beamwidths of 8.5 and 14.5 arcsec (FWHM) respectively. The arrays have a 2.3-arcmin field of view, and a dichroic beam-splitter allows both arrays to be used simultaneously. The observations employed a 64-point jiggle pattern, fully sampling both arrays. Similarly, the submillimetre photometric observations were obtained by operating the central bolometers of the SW and LW arrays at 450 and 850 $\mu$m simultaneously, employing a nine-point jiggle pattern in a 3 by 3 grid 2 arcsec across. The 1350- and 2000-$\mu$m observations used the single photometry bolometers and also employed a nine-point jiggle pattern. Averaging the source signal in an area slightly larger than the beam is intended to achieve the best accuracy of photometry under good-to-moderate seeing, and, in the case of the simultaneous observations with the LW and SW arrays, also to compensate for the very small offset between the arrays. During the observations, the telescope was nodded and the secondary chopped in a specified scheme in order to eliminate sky emission, as is convention in submillimetre and infrared astronomy.

Residual sky emission was removed off-line by using quiet SCUBA array bolometers in which there was no source emission, usually the bolometers in the first ring (for LW) and second ring (for SW) from the centre (Jenness, Lightfoot & Holland 1998). The pointing stability was checked before and after each map and before each photometry observation. The focus was checked every 3 h or when there were noticeable dome temperature fluctuations. The atmospheric opacity was measured regularly by performing SCUBA skydips. The sky monitor at 225 GHz on the Caltech Submillimeter Observatory (commonly known as CSO tau or $\tau_{CSO}$; see Masson 1993) updates every 15 min and so was used to monitor sudden changes in atmospheric opacity, and, in cases where the SCUBA skydips were not measured or produced poor fits, the CSO data were used to extrapolate SCUBA atmospheric opacities as described in the SCUBA observing manual.

The dedicated SCUBA data reduction software surf (Jenness et al. 1998) and the Starlink packages KAPPA and FIGARO were used to reduce and analyse the observations. The data reduction consisted of first flat-fielding, correcting for atmospheric extinction, and then removing residual sky emission (see above). Noisy bolometers and integrations were blanked and spikes removed. For the 1350- and 2000-$\mu$m photometry observations no residual sky emission removal was done, as the observations used only a single bolometer. Spike removal was performed by clipping the data at a specified sigma. The resulting data were calibrated using instrumental gains that were determined from beam maps of Mars or Uranus nightly and in the same observation mode as the target observation (see Table 1). Planetary fluxes for each filter were obtained using the JCMT utility program FLUXES. During the 1998 January and February runs, the planets were not available and the JCMT secondary calibrators CRL 2688 and IRC+10216 were usually the bolometers in the first ring (for LW) and second ring (for SW) from the centre (Jenness, Lightfoot & Holland 1998). The pointing stability was checked before and after each map and before each photometry observation. The focus was checked every 3 h or when there were noticeable dome temperature fluctuations. The atmospheric opacity was measured regularly by performing SCUBA skydips. The sky monitor at 225 GHz on the Caltech Submillimeter Observatory (commonly known as CSO tau or $\tau_{CSO}$; see Masson 1993) updates every 15 min and so was used to monitor sudden changes in atmospheric opacity, and, in cases where the SCUBA skydips were not measured or produced poor fits, the CSO data were used to extrapolate SCUBA atmospheric opacities as described in the SCUBA observing manual.

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### Table 1. Submillimetre fluxes (Jy) for NGC 4374 from SCUBA.

<table>
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<tr>
<th>UT date</th>
<th>2000 $\mu$m</th>
<th>1350 $\mu$m</th>
<th>850 $\mu$m</th>
<th>450 $\mu$m</th>
<th>850/450 $\mu$m</th>
<th>850/450 $\mu$m</th>
<th>$\tau_{CSO}$</th>
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<td>221 GHz</td>
<td>350 GHz</td>
<td>677 GHz</td>
<td>Total int. time (s)</td>
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<td>0.18 ± 0.02</td>
<td>0.11 ± 0.02</td>
<td>2160</td>
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<td>0.06</td>
<td>Mars</td>
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<tr>
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<td>0.11 ± 0.02</td>
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<td>1260</td>
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<td>0.05</td>
<td>CRL 2688</td>
<td></td>
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<tr>
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<td>0.12 ± 0.12</td>
<td></td>
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<td>Mapping</td>
<td>0.05</td>
<td>IRC+10216</td>
<td></td>
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<td>0.12 ± 0.12</td>
<td></td>
<td>2340</td>
<td>Mapping</td>
<td>0.04</td>
<td>IRC+10216</td>
<td></td>
</tr>
<tr>
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<td>0.16 ± 0.03</td>
<td></td>
<td></td>
<td>2220</td>
<td>Mapping</td>
<td>0.1</td>
<td>Uranus</td>
<td></td>
</tr>
</tbody>
</table>
used (Sandell 1994; Sandell, in preparation). On nights when \( \tau_{\text{CSO}} > 0.07 \) (see above and Table 1) the atmosphere was opaque to 450-\( \mu \)m emission and observations could be made only at longer wavelengths.

3 RESULTS AND DISCUSSION

Fig. 1 shows the 850-\( \mu \)m image of NGC 4374 together with the beamwidth determined from observations of 3C 273, a standard point source for the JCMT, made in the same way and conditions as NGC 4374. The rms uncertainty on the map is less than 20 mJy beam\(^{-1}\). The image of NGC 4374 has small north-eastern and south-western spurs that are not real features of the galaxy but a manifestation of the beam smearing as a result of chopping. These spurs are in the chop direction and are detected at a much lower level than the central emission. An examination of the point spread function of the NGC 4374 image yielded FWHM\(_{\text{minor axis}} = 15.0\) arcsec and FWHM\(_{\text{major axis}} = 15.7\) arcsec. The result shows that the image of NGC 4374 is no more than 1 arcsec greater than the JCMT beam. This insignificant spatial extension is probably a result of a small pointing drift during the long observation (\( \approx 1 \) h). We conclude that NGC 4374 is not extended in the SCUBA 850-\( \mu \)m image, which constrains the spatial origin of the observed emission to less than 15 arcsec (1.5 kpc for a distance of 20.74 Mpc) in diameter. It is worth noting that, although the SCUBA beam is \( \approx 15\) arcsec at 850\( \mu \)m, the arrays have a 2.3-arcmin field of view, and therefore, at the distance of NGC 4374, we do not detect any diffuse emission to \( \approx 13 \) kpc in extent, as we observed with the array pointed at the centre of the galaxy and our observations were spatially sensitive to the entire field of view of SCUBA.

The results from the imaging and photometric observations are shown in Table 1. The uncertainties are a quadratic sum of the uncertainty arising from the measured signal-to-noise ratio and a systematic calibration uncertainty, which varies from 10 per cent at 850 \( \mu \)m and lower, to 27 per cent at 450 \( \mu \)m. The 450-\( \mu \)m fluxes listed for the 1998 February 1 and 14 and January 22 runs are 3\( \sigma \) upper limits. The submillimetre flux variation over the four observing runs was within the errors on the fluxes.

3.1 Decomposing the spectral energy distribution

Fig. 2 shows the spectral energy distribution (SED) for NGC 4374, including data from radio (Jenkins et al. 1977) to infrared (IRAS) wavelengths. The infrared fluxes were obtained from NED (the NASA/IPAC Extragalactic Database) and have been interpreted as thermal emission from dust (Knapp & Patten 1991; Goudfrooij 1994). At longer radio wavelengths, the lobes dominate the integrated flux from NGC 4374 (by a factor of 8 at 5 GHz: Wrobel 1991) and give an excellent power law of spectral index \( S_\nu \propto \nu^\alpha \) with \( \alpha = -0.6 \pm 0.03 \), as shown by the dotted line in Fig. 2. This spectral index is consistent with the classification of NGC 4374 as a steep-spectrum radio galaxy. The good fit suggests that variability larger than the errors on the fluxes is uncommon for the synchrotron power law of the radio emission.

The submillimetre data points for fluxes within the SCUBA beam and previous submillimetre measurements fall below an extrapolation of this steep radio power law from the integrated
flux. We see no sign of extended emission from the radio lobes on any of our maps, and the 3σ upper limit on the 850-μm integrated flux within a region approximately the size of the lobes is 0.6 Jy. This is much higher than the extrapolation of the radio power law from the integrated fluxes, showing that we are insensitive to the radio lobes (Fig. 1). As we show later, this indicates that, if the observed SCUBA 850-μm emission is non-thermal in nature, it is dominated by the compact core (or inner jet).

3.1.1 The core SED

In Fig. 2 we have plotted the single available core radio flux for NGC 4374, at 5 GHz (Jenkins et al. 1977; Wrobel 1991); the circles are the means of the SCUBA data listed in Table 1. The 5-GHz core flux, together with the SCUBA data, gives a power-law slope of $\alpha = -0.23 \pm 0.03$. In compact radio galaxies, such flat spectra have been found to comprise spectra from many unresolved components, each with its own synchrotron spectrum, the sum of which results in the observed flat power law. Although we do not wish to overinterpret our results, since we only have one radio core point and the SCUBA data, we note that the observed flatter power law of the NGC 4374 core could be a consequence of such unresolved synchrotron components. At 5 GHz, the northern jet in NGC 4374 is brighter than the southern jet for the first 10 arcsec (Bridle & Perley 1984). This one-sided inner jet may comprise such unresolved components.

It is worth noting that the SCUBA fluxes at 850, 1350 and 2000-μm alone give a spectral index of $\alpha_{350\text{GHz}} - \alpha_{146\text{GHz}} = -0.16 \pm 0.32$ in the submillimetre, forming a flat spectrum resembling that of a free–free emission component. While this 2000–850 μm spectral index is consistent with that of free–free emission ($\alpha = -0.1$), the large uncertainty on its value limits our ability to prove its origin conclusively. Our 450-μm point lies well below this $\alpha = -0.16$ spectrum, which does not help to prove or disprove its origin, but instead adds the complication that this free–free component might have a high-frequency cut-off between 850 and 450 μm. In steep-spectrum radio galaxies such as NGC 4374, it is uncharacteristic for a free–free component to dominate the power law in the millimetre–submillimetre wavelength range. Therefore if this component were real it would have to come from very high ionization and it would be an interesting discovery. We cross-correlated the ‘submillimetre flat-spectrum component’ in Fig. 2 with the well-known spectrum of 3C 273 using data taken with SCUBA on 1998 February 15, just one night after and under very similar conditions to the photometry observations of NGC 4374. The spectrum of 3C 273 gives a much steeper slope and a spectral index of $\alpha_{350\text{GHz}} - \alpha_{146\text{GHz}} = -0.7 \pm 0.1$, as expected of this variable object during its quiescent phase (Robson et al. 1993). Therefore with our current, limited data we cannot say that the 850-, 1350- and 2000-μm fluxes come from significant free–free emission, if any at all.

To model the radio-to-infrared SED we used a combination of a power law (non-thermal radio emission from the active nucleus) plus greybody (reprocessed emission from dust in the infrared: Hughes, Gear & Robson 1994). The greybody allows for the fact that we see to different physical depths at different wavelengths, for a given optical depth. The composite model flux is then

$$F_\nu = C \nu^{-\alpha} + \Omega B_\nu(T) \left[ 1 - \exp \left( -\frac{\nu}{\nu_c} \right)^\beta \right],$$

In equation (1), $C$ is the normalization for the power-law

![Figure 2](https://academic.oup.com/mnras/article-abstract/311/4/683/1746421)
component, $\alpha$ the power-law spectral slope, $\Omega$ the solid angle for the greybody component, $B_\nu(T)$ the Planck function at temperature $T$, $\lambda_0$ the wavelength at which the optical depth is unity, and $\beta$ the emissivity index of the grains. The normalization factors ($C$ and $\Omega$) are obtained by forcing the model to agree with the 5-GHz core radio and infrared (60 and 100 $\mu$m) fluxes respectively, since the two components dominate in these different wavebands. The power-law index and its uncertainty were estimated from linear regression fits to the core radio plus SCUBA data in a log–log plot. We assume that the IRAS emission comes from a region less than $\sim$10 arcsec across due to lack of extension seen at 450 $\mu$m. The best-fitting temperature and its uncertainty for the greybody component were estimated by eye from plots of the composite model versus the data. Other parameter values ($\lambda_0 = 7.9$ $\mu$m and $\beta = 1.3 \pm 0.5$) were fixed at the values given in Hughes et al. (1994) in their study of M82. The parameter values determined from the model are summarized in Table 2, and the model is plotted as a solid line in Fig. 2.

We note that the greybody fit demands that the warm dust emission comes from a very compact zone, much smaller than the SCUBA 450-$\mu$m resolution (see Table 2). Because the 450-$\mu$m data point lies below the sum of the thermal and non-thermal emission (see Fig. 2), the simplest explanation is that the synchrotron spectrum steepens between 850 and 450 $\mu$m (or somewhat longward of 850 $\mu$m, given the uncertainties). Also, some small part of the 450-$\mu$m emission could be due to low surface brightness dust of $\sim$15 to 20 K. Better spectral coverage and higher signal-to-noise ratio data in the submillimetre are clearly needed to test more complex spectral models.

### 3.2 Dust mass and its implications

The temperature that fits the IRAS data and is constrained by the SCUBA 450-$\mu$m measurement is $\sim 35 \pm 5$ K (see Fig. 2). Not surprisingly, this is the same temperature as Goudreauj (1994) found for this galaxy from his analysis of the IRAS data alone. Changing $\beta$ between 2.0 and 1.0 makes very little difference to the best-fitting temperature. The mass of emitting dust $M_d$ can be derived from a simple model adapted from Hildebrand (1983), where

$$M_d = \frac{S_\nu D^2}{k_\nu B_\nu(T)},$$

In equation (2), $S_\nu$ is the measured flux, $D$ the distance to the source (20.74 Mpc for NGC 4374 as assumed by Goudreauj 1994), $B_\nu(T)$ the Planck function and $k_\nu$ the grain mass absorption coefficient. We assumed $k_\nu(100\mu$m) = 2.5 $m^2$ kg$^{-1}$ (Hildebrand 1983) and estimated a dust mass of $1.2 \times 10^5 M_\odot$ for $S_{100\mu$m} = 0.98 $\pm$ 0.21 Jy and $T = 35$ K. The dust mass that we have calculated for NGC 4374 is about the same as that of Goudreauj & de Jong (1995), as expected since they used the same temperature. Furthermore, it is similar to that found in a recent $HST$ ($V - I$) study of dust lanes in NGC 4374 by Bower et al. (1997), who found the dust mass to be in agreement with that derived from IRAS data, in contrast with the dust deficit found in other optical studies of ellipticals (Goudreauj & de Jong 1995). However, for NGC 4374 it is at least one order of magnitude lower than the result of Knapp & Patten (1991), who assumed a lower temperature of 18 K (based on objects in their sample of nearby radio galaxies for which 1350-, 800- and 450-$\mu$m fluxes were detected). Also, they obtained the higher mass even though they assumed a smaller distance of 13 Mpc. While the low dust temperatures estimated by Knapp & Patten (15 to 20 K) are similar to the Galactic plane value of $T = 19$ K, they are inconsistent with the SCUBA plus IRAS observations of NGC 4374 if the dust is assumed to be all a single temperature.

As for the extended radio lobe emission, we have not detected the extended low-level emission from diffusely distributed dust with SCUBA. We have shown that the 2000–850 $\mu$m data are most unlikely to be due to diffuse cold dust, but some small part of the 450-$\mu$m emission could be due to dust of $\sim$15 to 20 K. Also, our $3\sigma$ upper limit to the surface brightness at 450 $\mu$m is too high and not useful for setting dust mass upper limits on this possibly colder dust. Deeper SCUBA imaging observations are clearly needed to address this question, and will be undertaken in the 2000 observing season.

### 4 CONCLUSIONS

Following the suggestion that elliptical galaxies may contain diffusely distributed dust (Goudreauj 1994), we searched for this dust with submillimetre imaging observations of the elliptical galaxy NGC 4374, using SCUBA on the JCMT. We have not detected low-level, diffusely distributed dust with SCUBA. The emission at 850 $\mu$m is spatially unresolved (diameter <15 arcsec, 1.5 kpc).

Adding the SCUBA submillimetre data to existing radio-to-infrared data for this galaxy we can constrain the dust component to a single temperature of $\sim$30 to 40 K, implying a dust mass of $1.2 \times 10^5 M_\odot$. The model fitting in Section 3.1 gives an angular extent of the dust of $\sim$15 arcsec. Mindful that this result is too simplistic for a radiative model of an active galactic nucleus (AGN) torus, we note in passing that, if we assume a co-mixing of the molecular gas and dust, this constrains the size of any molecular torus around the AGN core of NGC 4374 to $\sim$150 pc in diameter.

The millimetre–submillimetre observations show a flat spectral index that is consistent with the 5-GHz radio core flux. The spectral index of the 850–2000 $\mu$m fluxes alone is consistent with that expected from free–free emission. The possibility of a free–free component is very unusual and intriguing. Given the care we took over calibration, we see no systematic reasons for our peculiar millimetre–submillimetre SED. Future observations of NGC 4374 will aim to achieve very high signal-to-noise ratio observations in order to determine the spectral index to a much higher accuracy and therefore prove or disprove the presence of a third spectral component.

In future observations of dusty ellipticals, we will concentrate on those with luminous infrared emission, colder dust and less non-thermal radio emission in order to try to resolve the distribution of cold dust in ellipticals. We will obtain short millimetre images of the central regions of NGC 4374 to determine the spatial extent of the emitting region(s), and deeper SCUBA imaging observations to address the possibility of

<table>
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<th>Parameter</th>
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<th>Error</th>
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<td>$\alpha$</td>
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extended low-level emission from cold dust. These observations, together with ISO data, will be used in order to get a tighter constraint, and thus a better handle, on the radio-to-submillimetre SED. The observations have important consequences for the interpretation of colours and colour gradients in elliptical galaxies, which are attributed to age and metallicity changes in the absence of diffusely distributed dust.

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