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Quasars as probes of the submillimetre cosmos at z > 5: I. Preliminary SCUBA photometry

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ABSTRACT
We present submillimetre (submm) continuum observations of a sample of some of the highest redshift quasars currently known, made with the SCUBA bolometer array on the JCMT. 12 of the sample have redshifts greater than five, and two have $z \geq 6$; the median redshift of the sample is 5.3. Two of the $z > 5$ objects are strong (6σ) detections, and are bright sources with $S_{850\,\mu\mathrm{m}} > 10\,\mathrm{mJy}$. Another firm ($5\sigma$) detection is obtained for the $z = 5.7$ quasar SDSS J1044−0125; and SDSS J1306+0356, at $z = 6.0$, is detected with a signal-to-noise ratio ≈4. We have obtained sensitive ($\sigma \approx$1.5mJy) upper limits for much of the remainder of the sample, including the $z = 6.3$ quasar SDSS J1030+0524.

Submm spectral indices measured for two of the sources ($\alpha \approx 3.3$) are consistent with thermal reradiation from dust, rather than from synchrotron emission. Sensitive upper limits at 450μm imply that the dust is cool, requiring large dust masses ($10^{8-9}\,\mathrm{M}_{\odot}$) to account for the observed fluxes— suggesting substantial prior star formation, even at $z = 6$ when the Universe was only 1.0Gyr old.

Key words: quasars:general – galaxies:high-redshift – cosmology:observations – submillimetre – dust, extinction

1 INTRODUCTION

Forty years ago, an accurate optical identification was obtained for the curious radio source 3C273 (Hazard, Mackey & Shimmins, 1963). Subsequent spectroscopy revealed an unexpectedly high redshift, $z = 0.16$, heralding a dramatic new type of astrophysical phenomenon— dubbed the “quasi-stellar object” (QSO). Ever since, the extremely luminous, compact emission from quasars has rendered them almost unrivalled as beacons to the distant Universe— whether as spotlights shining through absorption systems, pinpoints fixing their host galaxies or as tracers of large scale structure.

Recently, however, dedicated searches for *galaxies* at the highest redshifts have unveiled new populations of star-forming sources at $z > 5$ and $z > 6$ (e.g. Hu et al. 2002; Stanway, Bunker & McMahon 2003). Nevertheless, the latest AGN (Active Galactic Nuclei) surveys keep pace, and efficiently yield quasars at $z > 5$ (refs. under Fan et al.; Sharp et al. 2001), with the promise of many more to be discovered over the coming years. That AGN remain important cosmological tools was recently highlighted by the first evidence for Gunn–Peterson absorption, discovered in the spectrum of a $z = 6.3$ quasar (Becker et al. 2001). The high-redshift quasars of this new generation stand tantalizingly as signposts to the epoch of reionization.

The very existence of luminous quasars at $z > 5$, indeed, poses a challenge to structure formation theory. Their supermassive black hole engines ($M \sim 10^9\,\mathrm{M}_{\odot}$), and the fuel reservoir required to supply them ($\dot{M} \sim 100\,\mathrm{M}_{\odot}\,\mathrm{yr}^{-1}$), constitute a large mass concentration already in place only a gigayear after recombination. The Cold Dark Matter cosmogony, in contrast, predicts that the first objects to form were of predominantly low mass ($\sim 10^6\,\mathrm{M}_{\odot}$). High-redshift quasars therefore offer a a test of hierarchical cosmology operating at its extreme (Efstathiou & Rees, 1988; Turner, 1991). The signatures of high overdensity, for example the biased evolution of the surrounding region, can in principle be detected observationally by targetting quasars and their environs (e.g. in the submm, Ivison et al. 2000).

Here, we report continuum submillimetre observations, made with the SCUBA bolometer array on the James Clerk Maxwell Telescope, of a sample of some of the highest-redshift quasars currently known. These observations form part of a larger project to establish the fiducial properties of cool dust emission from radio-quiet, optically-selected quasars over a wide range in redshift ($z < 1$: Isaak et al., in prep.; $z = 2$: Priddey et al. 2003a; $z > 4$: McMahon et al. 1999, Isaak et al. 2002). Our earlier work suggested that a significant fraction of optically-bright quasars are ultra- or even hyper-luminous at far-infrared wavelengths. Additionally, no significant difference between the $z = 2$ and $z > 4$ samples was detected, contrasting with the SCUBA radio galaxy survey by Archibald et al. (2001). Several lines of evidence suggest that the submm light is powered by star formation, and multiband follow-up is in progress to test this hypothesis. Observation beyond $z > 5$, reaching yet further back in cosmic time, is a vital extension to the project. Are conditions at the highest redshifts favourable, or adverse, to the formation of luminous, dusty sources? Do we catch the quasars during an even more turbulent phase of youth (gas-rich, violently star-forming), or does there exist a redshift cut-off beyond which too little dust has formed for the object to be a SCUBA source?

This Letter is the first in a series of papers discussing submm sources at $z > 5$. Here we present initial submillimetre photometry of the sample, leaving a presentation of follow-up data, and a more thorough account of interpretation, to forthcoming works (Isaak et al. in prep.; Robson et al. in prep.). Throughout, we assume a flat, Λ-dominated cosmology Ω_M=0.3, Ω_Λ=0.7 with H_0=65 km s^{-1} Mpc^{-1}. Additional quantities (in parentheses) are for an Einstein–de Sitter (EdS) universe with H_0=50 km s^{-1} Mpc^{-1}.

2 OBSERVATIONS

The observed quasars are listed in Table 1.

2.1 The sample

The parent sample consisted of all quasars above a redshift of 4.90 that were known at the time of observation (i.e. late 2001). The targets were drawn from the Sloan Digital Sky Survey (SDSS: see Fan et al. refs.), the Isaac Newton Wide Field Survey (WFS: Sharp et al., 2001) and the single object (RD J0301+0020) reported by Stern et al. (2000). Targets were prioritized solely on the basis of redshift, with target visibility providing the only additional constraint.

Absolute B magnitudes are calculated from 1450Å continuum fluxes obtained from published spectra, assuming an optical spectral index $\alpha = -0.5$. In Table 1, the primary values are for the Λ cosmology, and those for $\Omega_M = 1$ are given in parentheses. In our previous submm quasar surveys (McMahon et al., 1999; Isaak et al., 2002; Priddey et al., 2003), we had targetted quasars brighter than $M_B = -27.5$ (based on the EdS cosmology). At $z > 5$, too few sources are known for this stringent criterion to be maintained: the median and mean magnitude are each now $M_B = -26.6$ (again EdS).

2.2 JCMT–SCUBA submillimetre data

Data for SDSS J1044−0125 were obtained through service observing time in July 2000 and January 2001. The bulk of the rest of the data were obtained during the period autumn 2001–summer 2002, through a combination of "flexible" scheduling, the scheduled time itself and Director's Discretionary Time.

SCUBA was employed in photometry mode, with the wide 850:450 filter set, and a standard 60 arcsec chop in azimuth at 7.8Hz. The source was placed on the central bolometer (H7, C14), and the median of the remaining (quiet) bolometers was used for additional sky removal. Flux calibration was performed against the planets Mars and Uranus, and against the standard continuum calibrators CRL618, OH231.8, IRC10216 and 16293−2422. Telescope pointing was checked frequently. Sky opacity was monitored via regular skydips at 850 and 450μm, and continuously at 225GHz via the JCMT Water Vapour Monitor and the CSO Tau Meter: over the whole set of observations, τ_{225} ranged between $0.04 < \tau_{225} < 0.14$. Data were reduced with both the ORAC-DR pipeline and the SURF software.

Both SDSS J1044−0125 and SDSS J1306+0356 were reobserved, after showing some inconsistencies in their initial datasets: the detections were confirmed in each case. For example, during initial observation of SDSS J1306+0356, in November 2001, the final two blocks of integrations were inconsistent with the data taken over the preceding few hours. Their mean signals were zero or negative, where the others had throughout been strongly positive. This marked change in consistency coincided not only with deteriorating weather (seeing poorer than 4 arcsec), but with sunrise, and consequent fleeting changes in atmosphere, dish figure and absolute pointing accuracy. We reobserved the quasar under good, stable conditions (seeing 0.5 arcsec, $\tau_{225\mathrm{GHz}} = 0.065$), conditions in March 2002. The signal thereby obtained was consistent with the first seven blocks from the previous November. The final flux quoted in Table 1 therefore consists of the November data minus the last two blocks, plus the March data. Adding back the suspect data would give $S_{850\mu\mathrm{m}}$=3.1±0.9mJy— a signal-to-noise which is still greater than three.

SCUBA consists of two detector arrays, dedicated respectively to long- and short-wavelength observations— in this case 850 and 450μm. The atmospheric transmission decreases with frequency, hence the long-wave array is the usual primary instrument. Nevertheless, 450μm data are obtained *gratis*, and they are here of particular interest, for they provide important constraints on the physical temperature of the dust. 450μm fluxes are thus included in Table 1 for reference, however none of the sources was detected in the band. Observations were made under a wide range of atmospheric conditions (450μm opacities $0.75 < \tau_{450\mu\mathrm{m}} < 3.0$), resulting in a very heterogeneous set of RMS values, between 10 and 100mJy. We emphasise that accurate calibration of these short-wavelength observations is possible only under the very best observing conditions. For comparison, the relative errors in flux calibration with the 850 and 450 arrays are typically 5–10 percent and ∼ 20 percent, respectively.

3 RESULTS

Two of the targets, **SDSS J0756+4104** and **SDSS J0338+0021** (both $z = 5.1$) are strikingly bright submm sources, with $S_{850\mu\mathrm{m}} > 10$mJy. The latter was also detected

Table 1. Quasars at $z > 5$ observed with SCUBA

Target name (1)	z (2)	M_B (3)	RA (J2000) (4)	Dec (J2000) (5)	Number of integrations (6)	$S_{850\,\mu\mathrm{m}}$ (mJy) (7)	$S_{450\,\mu\mathrm{m}}$ (mJy) (8)	Ref. (9)
SDSS J1030+0524	6.28	−27.8 (−27.4)	10 30 27.10	+05 24 55.0	475	1.3±1.0	−21±10	1
SDSS J1306+0356	5.99	−27.8 (−27.4)	13 06 08.26	+03 56 26.3	490	**3.7±1.0**	−7±14	1
SDSS J0836+0054	5.82	−28.5 (−28.1)	08 36 43.85	+00 54 53.3	250	1.7±1.5	−24±10	1
SDSS J1044−0125	5.74	−28.1 (−27.7)	10 44 33.04	−01 25 02.2	500	**6.1±1.2**	n/a[a]	2
RD J0301+0020	5.50	−23.1 (−22.7)	03 01 17.01	+00 20 26.0	200	1.9±1.5	−5±18	3
SDSS J0231−0728	5.41	−28.0 (−27.6)	02 31 37.65	−07 28 54.5	200	1.8±1.6	2±15	4
SDSS J1208+0010	5.27	−26.7 (−26.3)	12 08 23.82	+00 10 27.7	200	−2.0±2.5	−64±102	5
WF J2245+0024	5.17	−25.3 (−24.9)	22 45 24.28	+00 24 14.6	180	2.3±1.6	2±15	6
SDSS J0913+5919[b]	5.11	−26.3 (−26.0)	09 13 16.56	+59 19 21.5	200	2.8±1.8	4±28	4
SDSS J1204−0021	5.11	−28.0 (−27.6)	12 04 41.70	−00 21 49.6	200	4.2±2.0	−104±50	7
SDSS J0756+4104	5.09	−27.0 (−26.6)	07 56 18.14	+41 04 08.6	100	**13.4±2.1**	14±19	4
SDSS J0338+0021	5.07	−27.0 (−26.7)	03 38 29.31	+00 21 56.3	100	**11.9±2.0**	5±16	8
SDSS J2216+0013	4.99	−26.9 (−26.6)	22 16 44.02	+00 13 48.3	250	1.7±1.4	14±19	4
WF J1612+5255	4.95	−26.4 (−26.1)	16 12 53.10	+52 55 43.5	250	2.1±1.9	21±50	6

Refs: 1. Fan et al. 2001; 2. Fan et al. 2000b; 3. Stern et al. 2000; 4. Anderson et al. 2001; 5. Zheng et al. 2000; 6. Sharp et al. 2001; 7. Fan et al. 2000a; 8. Fan et al. 1999

[a] Observations made during high atmospheric opacity (Weather Grade 3): short-wave data consequently very poor

[b] Radio source: $S_{1.4\mathrm{GHz}}$=17.7mJy (NVSS catalogue)

at 1.2mm by Carilli et al. (2001), $S_{1.2\mathrm{mm}} = 3.7$mJy. The 850μm flux is consistent with a thermal spectrum (see Figure 1 and Section 4.1). **SDSS J1044−0125** ($z = 5.7$) is a moderately bright detection, $S_{850} = 7$mJy. Its 1.2mm flux of around 2mJy (Isaak et al., in prep.) is consistent with the steep Rayleigh–Jeans tail of a thermal greybody spectrum from dust. This source and its environs have formed the target of a range of follow-up observation, reported in a companion paper (Isaak et al., in prep.). It is notable that SDSS1044 is a broad absorption line (BAL) quasar, a fact drawn upon to account for its X-ray weakness, relative to the optical, as measured by Brandt et al. (2001). It is conceivable that the gaseous outflow responsible for the optical absorption also absorbs the X-rays; and that dust embedded within the gas gives rise to the submm emission. **SDSS J1306+0536** ($z = 6.0$) was detected at 850μm with a significance of 3.7σ (see also Section 2.2).

RD J0301+0020 (z=5.50) was detected at 1.2mm in a very deep IRAM–MAMBO observation by Bertoldi & Cox (2002): the 850μm limit presented here is consistent with a thermal spectrum given their $S_{1.2} = 0.87 \pm 0.20$mJy. RD J0301+0020 stands out from the other $z > 5$ quasars by virtue of its extremely low optical luminosity, $M_B = -23.1$. Using the Elvis et al. (1994) bolometric correction from νL_B ($C_B = 12$) implies $L_{bol} \approx 2 \times 10^{12}\,\mathrm{L}_\odot$. This is comparable to the far-infrared luminosity derived from the millimetric flux, if we assume a canonical cool dust spectrum ($T = 40 - 50$K). Assuming that the quasar (and not some foreground object) is the MAMBO source, then either the AGN is absorbed, and we are seeing reprocessed emission in the far-infrared, or the L_{FIR} derives from star formation (or, indeed, a combination of the two).

3.1 Caveat emptor: the effects of lensing

In neither Table 1 nor Table 2 do we attempt to correct the observed fluxes, and their derived quantities, for a gravitational lensing magnification. At $z > 5$, one would expect the optical depth to lensing to be significant; Wyithe & Loeb (2002) additionally point out that the $z > 5$ SDSS survey selects quasars on the steep, bright tail of the luminosity function, rendering it prone to magnification bias. Gravitational lensing is therefore a serious problem whose effects must be addressed on a source-by-source basis. For now we can only do so statistically: for our two $z > 5.5$ detections, SDSS J1306 and SDSS J1044, Wyithe & Loeb (2002) estimate a 7–30 percent probability of multiple imaging, with median (mean) magnifications between 1.1 (5) and 1.2 (30).

Schwartz (2002) examined the *Chandra*–ACIS images of the three highest-redshift objects in this sample. The six photons comprising the SDSS J1030 detection are widely distributed, statistically inconsistent with a point source. This is a possible signature of lensing, however the counts are too few to differentiate between a single extended source or multiple point sources. In contrast, Fan et al. (2003) report that *HST*–ACS images of SDSS J1030 and J0836 are consistent with unresolved point sources. Their ground-based imaging of SDSS J1306 promotes a similar conclusion.

4 DISCUSSION

4.1 Dust, metals and star formation at $z > 5$

The mm–submm spectral indices measured for SDSS J1044−0125 and J0338+0021— each $\alpha^{mm}_{submm} \approx 3.3$— are consistent with the Rayleigh–Jeans tail of thermal emission from cool dust. Such a spectral energy distribution (SED) would be expected to peak at a rest wavelength $\approx 50 - 100\mu$m; similar, for example, to star-forming galaxies such as M82. Indeed, existing 450 and 350μm detections of $z \approx 4$ quasars suggest that the SED tends to a plateau (see e.g. Priddey & McMahon, 2001 (PM01)) at around 100μm rest-frame: all but the brightest sources would lie below the short-wavelength limit that we could detect. At $z > 5$,

Table 2. Derived properties of the sample (detections and deep ($\sigma \leq 1.5$mJy) limits). Numbers in parentheses are for the EdS cosmology (except for $\dot{M}_{*}$(min), where the numbers for each cosmology are approximately equal). RD0301 is counted among the deep 850μm non-detections, but we have used its 1.2mm flux to calculate the parameters. N.B. $L_{\rm FIR}$ and $\dot{M}_{*}$ are *not* independent.

Source	z	$t(\infty) - t(z)$ Gyr	M_d $10^8\,{\rm M}_\odot$	$\dot{M}_{*}$(min) ${\rm M}_\odot\,{\rm yr}^{-1}$	$L_{\rm FIR}$ $10^{10}\,{\rm L}_\odot$	M_{bh} $10^9\,{\rm M}_\odot$	$\dot{M}_{acc}$ ${\rm M}_\odot\,{\rm yr}^{-1}$
SDSS J1306+0356	5.99	0.99 (0.70)	2.6 (1.8)	26	520 (370)	4.4 (3.0)	95 (65)
SDSS J1044−0125	5.74	1.04 (0.74)	4.2 (3.0)	41	870 (610)	5.6 (4.0)	125 (85)
SDSS J0756+4104	5.09	1.21 (0.86)	9.6 (6.9)	80	1970 (1410)	2.1 (1.4)	45 (30)
SDSS J0338+0021	5.07	1.22 (0.87)	8.5 (6.1)	70	1750 (1250)	2.1 (1.4)	45 (30)
SDSS J1030+0524	6.28	0.93 (0.66)	<1.4 (1.0)	—	<280 (200)	4.4 (3.0)	95 (65)
SDSS J0836+0054	5.82	1.02 (0.73)	<2.1 (1.5)	—	<430 (300)	7.6 (5.2)	165 (115)
RD J0301+0020	5.50	1.10 (0.78)	1.4 (1.0)	13	290 (200)	0.06 (0.04)	1.4 (0.9)
SDSS J2216+0013	4.99	1.25 (0.89)	<2.0 (1.4)	—	<410 (300)	1.9 (1.4)	40 (30)

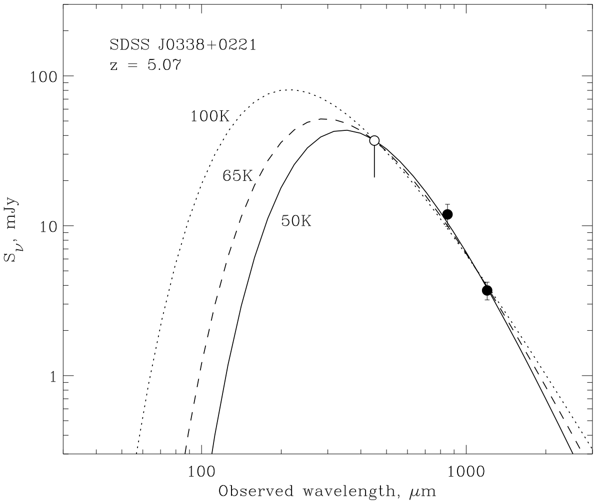

Figure 1. Constraining the dust temperature of SDSS0338. The 1.2mm point is from Carilli et al. (2001), the 850 and 450μm from this work. Curves are for the maximum dust temperatures (labelled) consistent with the 450μm upper limit (plotted as signal plus 2-σ with a σ-length bar), for three greybody indices: $\beta = 2.0$ (solid), $\beta = 1.5$ (dashed) and $\beta = 1.0$ (dotted). The steep submm–mm slope renders a better fit for a high β, thus favouring a low temperature.

then, a 450μm *detection* would imply that the dust is hot; conversely, the deep limits obtained for the bright 850μm detections are valuable constraints on their dust temperature. Again considering J0338+0021, 450 upper limit requires $T < 100$K for a greybody index $\beta = 1$, and $T < 50$K for $\beta = 2$, the higher β favoured by the steep mm–submm slope (Figure 1). (However we warn of the potentially considerable systematic uncertainties in the 450μm calibration.) In the following, we shall therefore assume the SED of PM01, namely β=2, T=40K.

Temperature uncertainty notwithstanding, determination of the dust opacity (κ) has, in the past, presented additional uncertainties to a derivation of a dust mass from a submm flux. We adopt a value $\kappa(125\mu{\rm m})=30\,{\rm cm}^2\,{\rm g}^{-1}$, at a normalisation wavelength (125μm) corresponding to observed 850μm at z=5.8. This is consistent with the κ(125) determined by Hildebrand (1983). Extrapolated to longer wavelengths assuming $\kappa \propto \lambda^{-2}$, it is also consistent with a Galactic mixture of Draine & Lee (1984) grains as well as with more recent measurements, e.g. the 850μm value of James et al. (2002). For our $z > 5$ sample, it yields masses in the range $10^{8-9}\,{\rm M}_\odot$ (Table 2).

The youth of the universe— 1Gyr at $z = 5$— imposes a constraint on the mechanisms of dust production, for it is comparable to the evolutionary timescale of the stars in whose atmospheres the dust is believed to condense. An alternate method of manufacture, on the winds of Type II supernovae, requires much shorter timescales, but its efficacy has yet to be proven. Crudely assuming an overall dust enrichment rate per mass forming stars of around 1 percent, and an absolute upper limit of 1Gyr available for star formation, then a dust mass of $10^{8-9}\,{\rm M}_\odot$ would require a minimum average star formation rate of $\sim 100\,{\rm M}_\odot\,{\rm yr}^{-1}$. It is thus plausible that star-forming activity is responsible for some or all of the observed submm luminosity. In Table 2, the quantity $\dot{M}_{*}$(min) is the minimum star formation rate necessary to produce the estimated dust masses, averaged the lifetime of the universe. Alternatively, $L_{\rm FIR}$ could be used to estimate the *instantaneous* star formation rate, $\frac{\dot{M}_{*}}{{\rm M}_\odot\,{\rm yr}^{-1}} = \Psi \frac{L_{\rm FIR}}{10^{10}\,{\rm L}_\odot}$, where Ψ is a constant of order unity, depending on the stellar initial mass function (IMF). This quantity represents an upper limit on the star formation rate, due to the potential of AGN contribution to dust heating. Nevertheless it is plausible that the dust we observe was formed during production of a substantial fraction of stars in the quasar's host galaxy.

Morgan & Edmunds (2003) present a detailed model of dust synthesis and discuss its implications for very high redshift submm sources such as the current sample. Their model implies that, in the absence of supernovae as a source of dust, the star formation efficiency must be very high to yield, by $z = 5$, the masses we observe.

4.2 The growth of supermassive black holes

The four highest-redshift quasars in the sample are all very luminous in the optical, $M_B \approx -28$. The assumption that this luminosity is supplied by Eddington-limited accretion then requires a black hole of at least $5{\times}10^9\,{\rm M}_\odot$ (Table 2). How does a black hole of such mass form? Imposing the maximum available time of ~1Gyr implies an average accretion rate of $5\,{\rm M}_\odot\,{\rm yr}^{-1}$. In comparison, assuming an (optimistic) radiative efficiency $\epsilon = 0.1$ (where $L_{\rm bol} = \epsilon \dot{M} c^2$), an (instantaneous) accretion rate of $\gtrsim 100\,{\rm M_\odot\,yr^{-1}}$ is required to fuel the bolometric power inferred from the optical. The e-folding time for Eddington accretion is $\approx 0.5\epsilon$Gyr; starting from a $10^{3-6}\,{\rm M_\odot}$ seed (e.g. Haehnelt, Natarajan & Rees, 1998), an observed redshift of z=6 would require a formation redshift z=10–18 in the Λ cosmology, but an upper limit longer than the age of the Universe in the matter-dominated cosmology.

In the local universe, quiescent supermassive black holes and their surrounding stellar bulges correlate in their mass and velocity dispersion (Magorrian et al. 1998; Ferrarese & Merrett 2000; Gebhardt et al. 2000). It is likely, therefore, that their formation processes— the one through accretion and an AGN phase, the other perhaps through a dusty starburst— are closely linked. What can we conclude concerning the coevolution of a quasar and its host galaxy, given these data? Both PM01 and Archibald et al. (2002) consider this matter. They propose a simple model in which a black hole exponentiating according to the Eddington rate, and an elliptical host galaxy forming stars and dust at roughly constant rate, conspire to produce a submm-luminous AGN just before the gaseous fuel supply is exhausted. In a future paper, we will consider a wider range of possibilities.

5 CONCLUSIONS AND FUTURE WORK

We have presented SCUBA 850μm observations a sample of quasars at $z > 5$— where the youth of the Universe itself ($\approx$1Gyr) starts to become a constraint on the histories of accretion and star formation— detecting four sources at 850μm. The few 1.2mm–850μm spectral indices that we can determine are consistent with thermal reradiation from dust; and deep 450μm limits imply that the dust is cool ($T < 100$K), consistent with their siblings at $z = 4$ (Priddey & McMahon, 2001). Although the sample is much smaller, and its median optical luminosity fainter, its submm properties seem tentatively similar to those of radio-quiet quasars we have studied at $z = 4$ and $z = 2$ (Isaak et al. 2002; Priddey et al. 2003a).

It is plausible that we are observing extreme, high-σ peaks in the overdensity distribution. The quasar host galaxies are likely massive, gas-rich and actively forming stars. We are pursuing a range of follow-up observations designed to investigate such a scenario. For example, submillimetre imaging of the fields of high-redshift AGN has been used (e.g. Ivison et al. 2000) to test for biased galaxy formation. In this spirit, we have obtained SCUBA jiggle maps of three of the sources from the current sample, and our findings will be reported in a forthcoming paper (Isaak et al. in prep.).

An important quantifier of the evolutionary state of the sources themselves will be obtained through detection of carbon monoxide emission lines, which would reveal the existence of reservoirs of molecular gas indicative of star formation. Simultaneously, it will be essential to improve the constraints on the infrared/submm SEDs of these quasars, to confirm the presence of dust, differentiate between AGN- and starburst-powered components and improve estimates of the dust mass and star formation rate. And of no less importance is the need to obtain high resolution optical/near-infrared images of the quasars, to assess the probable effects of gravitational lensing.

It is an oft-cited consequence of the negative submm K-correction that it hypothetically permits an unidentified SCUBA source to lie at a redshift as high as ten, without being intrinsically more luminous than a local object like Arp220. The difficulty of optically identifying such a source has prevented this claim becoming more than hypothetical. Now, however, the submillimetre study of samples of quasars at $z > 5$ provides a ready means of inferring the properties– indeed the very existence– of dust within one gigayear of the Big Bang.

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