A 1.2 mm MAMBO/IRAM-30m Survey of Dust Emission from the Highest Redshift PSS Quasars
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We report 250 GHz (1.2 mm) observations of redshift \( \geq 3.8 \) quasars from the Palomar Sky Survey (PSS) sample, using the Max-Planck Millimetre Bolometer (MAMBO) array at the IRAM 30-metre telescope. Eighteen sources were detected and upper limits were obtained for 44 with 3\( \sigma \) flux density limits in the range 1.5–4 mJy. Adopting typical dust temperatures of 40–50 K, we derive dust masses of a few 10\(^8\) M\(_{\odot}\) and far-infrared luminosities of order 10\(^{13}\) L\(_{\odot}\). We suggest that a substantial fraction of this luminosity arises from young stars, implying star formation rates approaching 10\(^3\) M\(_{\odot}\) yr\(^{-1}\) or more. The high millimetre detection rate supports current views on a connection between AGN and star forming activity, suggesting a parallel evolution of the central black hole and of the stellar core of a galaxy, although their growth-rate ratio seems higher than the mass ratio observed in nearby galaxies. The observed, exceptionally bright objects may trace the peaks of the primordial density field, the cores of future giant ellipticals.

Introduction
Understanding the history of the formation of stars and massive black holes during the early stages of galaxy evolution is one of the great challenges in our quest to understand the history of our Universe. Recent COBE, SCUBA, and MAMBO observations of the far-infrared to millimetre extragalactic background show that most of the energy generated in star formation at high redshift is absorbed by dust, which re-emits the energy at far-infrared (far-IR) wavelengths, a spectral range that is red-shifted into transparent submillimetre and millimetre atmospheric windows (e.g., Gispert et al. 2000; Ivison et al. 2000a; Blain 2001; Bertoldi et al. 2000a, b and Carilli et al. 2001a).

In the early stages of formation of galaxies, a large fraction of all stars apparently formed in strong bursts within highly obscured regions. At optical and near-IR wavelengths, much of the star formation activity in such objects remains not directly visible. Thus from the ground, only (sub)millimetre observations provide a comprehensive measure of the energy generated in such objects. Deep blank field surveys at 850 \( \mu \)m with SCUBA at the JCMT, and at 1.2 mm with MAMBO at the IRAM 30-m telescope have by now revealed over one hundred faint objects. This makes conventional, spectroscopic redshift determinations of this population mostly impossible.

Global estimates, based on photometric redshifts in the visible/IR (e.g., Ivison et al. 2000a; Smail et al. 1999) or (sub)millimetre/radio (Carilli & Yun 1999), on the far-IR/submillimetre background intensity and on theoretical modelling (Dole et al. 2000), show that the peak of star formation in the Early Universe probably occurred in the range \( z \sim 1 – 3 \), if we assume that much of the far-IR luminosity arises from star formation. It is unclear though, to what extent nucleus activity contributes to the luminosity of high-redshift starburst galaxies, and thereby to the far-IR background. The two brightest objects found in SCUBA and MAMBO blank field surveys (Knudsen et al. 2001; Bertoldi et al. 2000b) are in fact quasars, and two of the three SCUBA sources for which optical emission lines were detected show AGN signatures (Lilly et al. 1999; Smail et al. 1999; Ivison et al. 2000a).

To understand the relation between the formation of black holes, and the formation of galaxies and their bulges, it is necessary to study (aside from the (sub)millimetre background sources) the emission properties of distant objects identified at X-ray, optical, near- and mid-infrared, and radio wavelengths. At very high redshifts (\( z > 4 \)), where no blank field millimetre/submillimetre source has yet been spectroscopically identified, the relation between star formation and AGN is best studied through targeted (sub)millimetre observations of optically selected luminous QSOs and of radio galaxies. It is still unclear to what extent the thermal emission of radio-quiet QSOs is powered by starbursts, or by the black hole accretion. Just as for
local ULIRGs and Seyfert galaxies (Genzel et al. 1998), there is increasing evidence that in high-redshift AGN a substantial part of the thermal emission comes from starbursts.

Well before any SCUBA or MAMBO deep imaging surveys, we were able to detect seven powerful high-redshift millimetre sources through targeted observations of ultra-luminous $z > 4$ quasars using the 7- and 19-element bolometer arrays at the IRAM 30-metre telescope (McMahon et al. 1994; Omont et al. 1996a) and the JCMT (Isaak et al. 1994). Evidence for the starburst origin of their millimetre emission arose from the determination of their spectral energy distribution, including 850–450 $\mu$m observations at the JCMT (Isaak et al. 1994, McMahon et al. 1999) and 350 $\mu$m measurements at the CSO (Benford et al. 1999), and from the detection of CO emission in three objects (Ohta at al. 1996; Omont et al. 1996b; Guilloteau et al. 1997, 1999).

We here report on a substantial extension of the surveys for 1.2 mm continuum emission from $z > 4$ ultra-luminous quasars with 18 detections, which multiplies by three the number of detections. Results of 850 $\mu$m observations of a part of the present sample are presented in Isaak et al. (2001).

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Redshift distribution for the PSS quasars which were detected...