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PROPOSAL FOR 30M TELESCOPE
Deadline: 08 Sep 2005 Period: 15 Nov 2005 — 15 May 2006

For IRAM use
Registration N°:
Date:

TITLE

MAMBO observations of $z \sim 6$ SDSS QSOs

Type: *Solar system:* continuum ○ lines ○ other ○ *Extragalactic:* continuum ● CO lines ○ other ○
Galactic: continuum ○ lines ○ circumstel. env. ○ young stel. obj. ○ cloud struct. ○ chem. ○ other ○

ABSTRACT

We propose to observe four $z \sim 6$ SDSS QSOs with MAMBO to search for thermal emission from warm dust. Three of these sources were discovered very recently in the Sloan DS Survey (Fan et al. in prep.). This proposal is a continuation of our successful program to detect strong thermal emission in the most distant QSOs known, and to study the evolution of the radio-to-optical spectral energy distributions from $z = 2$ to 6. Our goals include: (i) studying the possible co-eval black hole and spheroidal galaxy formation, (ii) demonstrating the existence of large reservoirs of dust, and potentially molecular gas, in the first galaxies, and (iii) probing the host galaxy properties of the most distant QSOs, into the epoch of cosmic reionization.

Is this a resubmission of a previous proposal ? no ● yes ○ – proposal number(s): ....
Is this a continuation of (a) previous proposal(s) ? no ○ yes ● – proposal number(s): 163-04

Hours requested for this period: **13**

LST range(s): from: 7h to: 17h number of intervals: 1
from: to: number of intervals:

Number of hours foreseen for full completion of this proposal: [ ] of which [ ] were already allocated

Special requirements: pooled obs ● service obs ○ remote obs ○ polarimeter ○
Other requirements (dates, OTF, etc.) None

Receivers: AB ○ CD ○ AD ○ BC ○ HERA ○ Bolometer ●
Frequencies: (to 0.1 GHz and corrected for redshift) 250

List of Objects (give most common names) with equatorial coordinates
Epoch: J2000.0

Source	RA	DEC	V_{LSR}
0818+1722	08:18:27.40	17:22:51.8	6.00
0927+2001	09:27:21.82	20:01:23.7	5.79
1335+3533	13:35:50.81	35:33:15.8	5.93
1602+4228	16:02:54.18	42:28:22.9	6.07

(for additional sources which do not fit here use the `\extendedsourcelist` macro)

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Expected observer(s) Bertoldi, Walter, et al.

join to this form: scientific aims ≤ 2 typed pages and ≤ 2 of Figs., Tables and list of related publications

MAMBO observations of $z \sim 6$ SDSS QSOs

We propose MAMBO photometry of the highest redshift QSOs known ($z \sim 6$), selected from the Sloan Digital Sky Survey (SDSS). The detection of the Gunn-Peterson effect in these QSO's implies that we are seeing these sources at the near edge of cosmic reionization, when the first stars and massive black holes formed (Fan et al. 2003). The proposed observations are a continuation of our study of the evolution of the radio-to-optical spectral energy distributions of QSOs, one important goal of which is to address the interesting possibility of co-eval black hole and spheroidal galaxy formation. Such coeval evolution is suggested by the correlation between black hole mass and stellar bulge mass for low redshift galaxies. We have established a statistically significant and well defined sample of QSOs between $z = 2$ to 6 for which we have extensive observations at radio through optical wavelengths.

We have undertaken an extensive study of the radio through optical SEDs, and the molecular line emission properties, of optically selected QSOs from redshifts $z \sim 2$ to 6 (Omont et al. 2003; Carilli et al. 2002; Beelen et al. in prep). One key aspect of these studies is to determine the star formation, and the gas and dust properties of the host galaxies. This question has become paramount since the discovery of the bulge mass – black hole mass correlation in nearby galaxies, a result which suggests a fundamental relationship between black hole and spheroidal galaxy formation. We have found that roughly 1/3 of optically selected QSOs are also hyper-luminous infrared galaxies ($L_{FIR} \geq 10^{13}$ $L_\odot$), corresponding to thermal emission from warm dust. Searches for CO emission from these sources typically result in firm detections, with implied molecular gas masses $\geq 10^{10}$ $M_\odot$. Such molecular gas represents the requisit fuel for star formation, and can be used as a dynamical tracer in a forming galaxy (Walter et al. 2004).

We have recently extended our cm and mm studies of optically selected QSOs into the epoch of reionization ($z > 6$). We find that 3 of the 14 previously known $z > 6$ QSOs are also hyper-luminous IR galaxies, including the most distant QSO known, J1148+5251 at $z = 6.42$ with $S_{250} = 5.5$ mJy, plus J1048+4637 at $z = 6.2$ with $S_{250} = 3.0$ mJy, (Bertoldi et al. 2003a), and a new source J0840+5624 at $z = 5.85$ with $S_{250} = 3.2$ mJy that was detected in our MAMBO program last winter and that is target now of extensive follow-up molecular observations. CO line emission has been detected from J1148+5251 (Walter et al. 2003; Bertoldi al. 2003b), with an implied molecular gas mass of $\sim 2 \times 10^{10}$ $M_\odot$. Sensitive radio continuum imaging yields a reasonable detection of J1148+5251 with $S_{1.4} = 55 \pm 12\mu$Jy and J0840+4637 with $S_{1.4} = 47 \pm 11\mu$Jy, while J1048+4637 is marginally detected with $S_{1.4} = 26 \pm 12\mu$Jy (Carilli et al. 2004). Comparison of the radio and FIR luminosities shows that all three sources have radio-to-FIR luminosity ratios in the range defined by star forming galaxies via the radio-FIR correlation (Fig. 1). The implied (massive) star formation rates are $\sim 10^3$ $M_\odot$ year^{-1}. Imaging of the molecular line emission from 1148+5251 implies a dynamical mass within 3 kpc of the galaxy center $\sim 4 \times 10^{10}$ $M_\odot$, which is comparable to the molecular gas mass (Walter et al. 2004).

This proposal is a continuation of our efforts to detect mm-emission from the highest-z QSOs (e.g. 163-04), now including three new sources discovered last winter in the SDSS survey (Fan et al. in prep), plus one QSO from 163-04 that was not observed last season. You may ask: what will 4 new sources add to the existing sample of 14 already observed at $z \sim 6$? Again, we have detected 3 of the 14 with MAMBO. Of these three, the highest redshift QSD 1148+5251 at $z = 6.42$, remains the brightest of the mm detections, and the only CO detection at these extreme redshifts. But even this one molecular line detection has proven to be a critical pathfinder for future mm telescopes, such as ALMA, demonstrating that large dust and molecular gas masses can exist in the earliest galaxies, and showing the wealth of unique information that can be obtained on the host galaxies with mm line and continuum observations (Walter et al. 2003, Bertoldi et al. 2003b, Walter et al. 2004). Even one other example of the 1148-type would be instrumental in pushing mm studies of galaxy formation into the epoch of reionization. We are actively pursuing the other two MAMBO QSOs to search for CO emission using the IRAM, GBT, and Effelsberg facilities, and this current proposal is the natural extension of the MAMBO search for dust. Given the current statistics, we hope to detect one source in the new sample.

The study of the first generation of galaxies, during reionization ($z \geq 6$), is one of the prime motivations for all large area future telescopes, from meter to X-ray wavelengths. We should point out that submm galaxies have become important targets for mm line studies of galaxy formation, but these samples are still limited to $z < 4$. While admittedly extreme systems, the host galaxies of the $z \sim 6$ SDSS QSOs remain the only existing sample for extending mm studies of galaxy formation into cosmic reionization using current instrumentation.

Time Justification

In the past we have aimed at a 3-sigma detection limit of $\sim$ 1.5 mJy, which we like to reach for this sample as well. Following the recommendation of the IRAM observing time estimator, we apply for 13 hours of observing time for the 4 sources to reach an rms noise level of 0.5 mJy in typical winter conditions, including overheads.

Bertoldi etal. 2003b, A&A letters, 406, L55
Bertoldi etal. 2003a, A&A letters, 409, L47
Carilli et al. 2004, AJ, 128, 997
Carilli et al. 2002, AJ, 122, 1679
Fan et al. 2003, ApJ, 125, 1649
Omont et al. 2003, A&A, 398, 857
Walter et al. 2003, Nature, 424, 406
Walter et al. 2004, ApJ, 615, L17
Yun et al. 2001, ApJ, 554, 803

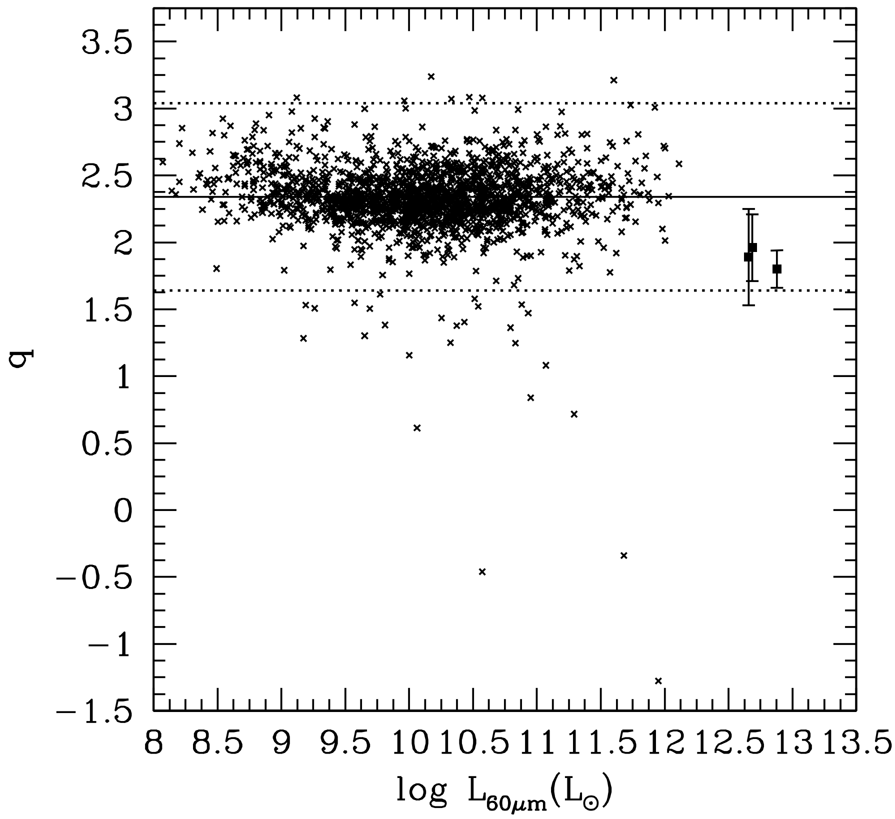

Fig. 1: The radio-FIR correlation for the IRAS 2Jy galaxy sample (x) from Yun et al. (2001), and for J1148+5251, J1048+4637, and J0840+4637 (points with error bars). The q parameter definition is given in Yun et al. (2001), corresponding to a log ratio of IR to radio luminosity. The solid line is the mean value for the IRAS galaxies, and the dotted lines indicate the range defined as star forming galaxies by Yun et al. (2001).