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MASS DUST EVOLUTION IN HIGH REDSHIFT QUASARS

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The observations in the submm/mm range are important to study the dust properties in the high redshift regime. FIR to mm observations show that most of the energy generated in star formation at $z > 1$ is absorbed by dust, which re-emits the energy at FIR wavelengths, a spectral range that is red-shifted into the transparent submm/mm atmospheric windows. We studied a sample of quasars with redshifts between $1.5 < z \leq 6.4$ and with observations in the submm/mm range. We found the FIR/UV ratio decreases at higher redshifts, indicating a dust mass evolution at $z > 5$.

In order to study the FIR emission we compiled from literature a list of 217 quasars observed at submm/mm wavelengths and between $1.5 < z \geq 6.4$. These objects were taken from Omont et al. (2001, 2003); Petric et al. (2003); Carilli et al. (2001); Isaak et al. (2002); Bertoldi et al. (2003), and Wang et al. (2007). In addition, we selected a sample of 13 quasars with data in the near-IR where the Hβ region is available ($2 < z < 3.5$) and we observed them in the submm/mm. As in the radio-loud quasars the mm emission is probably due to synchrotron radiation, the dominant process in radio-loud sources at submm/mm wavelengths, and not to dust thermal emission, we have excluded these objects from our sample. The final source selection (230 quasars) was based on its radio flux. We used the FIRST-VLA and NVSS radio catalogues. All sources with $S_{1.4GHz}$ >0.5 mJy were excluded from the final target list. We obtained 168 radio-quiet quasars.

The submm observations were made with the 15m James Clerk Maxwell Telescope (JCMT), located in Mauna Kea, Hawaii, using the Submillimeter Common-User Bolometer Array (SCUBA). The mm observations were made with the 30 m IRAM telescope at Pico Veleta (Spain), using the Max-Planck Millimeter Bolometer (MAMBO).

After compiling all the data, we calculated the FIR luminosity. For sources at $z > 1$ the peak of the emission is shifted to submm wavelengths. Tracing the peak of their spectral energy distribution (SED) is crucial for an accurate determination of the IR luminosity and star formation rate. We used the SED of a modified blackbody spectrum, with $\beta = 1.6$ and T=47 K (Beelen et al. 2006). We found the FIR luminosities of the $z \sim 2$ quasars are marginally higher than the luminosities of the $z \geq 4$ quasars (Figure 1), i.e., there is no strong evolution of the FIR luminosity between $1.5 < z \leq 6.4$.

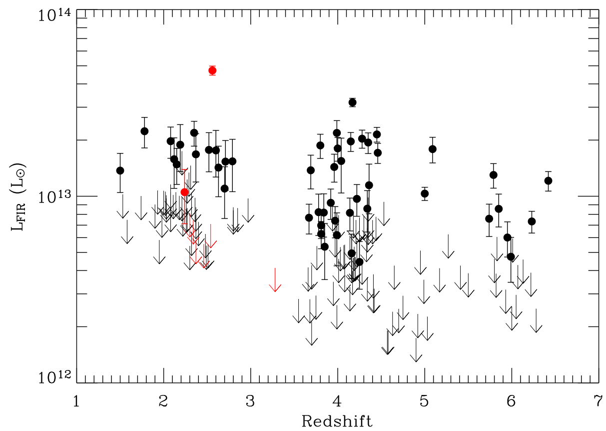

Fig. 1. FIR luminosity implied by the SCUBA 850-μm and MAMBO 1.2 mm flux densities, plotted against redshift. The filled symbols represent detections with 3σ errors. The down arrows denote upper limits; we adopt the value 2σ rms as upper limits for nondetected sources. Red: our observations.

On the other hand, the detection of strong thermal dust emission from many high redshift quasars shows that vigorous star formation is coeval with black hole (BH) masses. In order to obtain the BH masses for all the objects in our compiled list, we looked for the available spectra in the Sloan Digital Sky Survey (SDSS). We obtained the BH mass by using CIV, MgII, and Hβ emission linewidths and fluxes. In Figure 2, the FIR luminosities as a function of the BH masses are plotted, along with a sample of low redshift quasars observed at IR wavelengths (Haas et al. 2000, 2003). We found a trend between the FIR luminosity and the BH mass.

With respect to [OIII] luminosity, we found that it increases with the FIR luminosity. However, our

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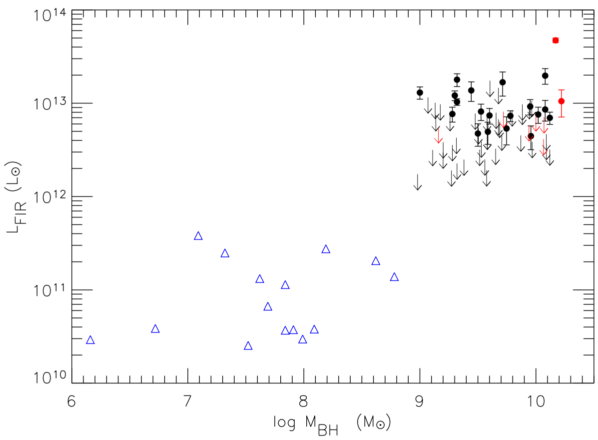

Fig. 2. FIR luminosity plotted against the BH mass. Symbols are the same as in Figure 1. Triangles: detections at IR wavelengths (z <0.12) (Haas et al. 2000, 2003).

sample is very small to provide a statistically reliable result. More observations on the Hβ region of quasars, with have mm and submm emission, are required.

FIR and UV emission are powerful star formation tracers. In order to check whether there is an evolution in the dust content, we have derived monochromatic luminosities for our quasar sample at the rest-frame 1500Å, using data from the SDSS. We found the FIR luminosity increases with UV luminosity (Figure 1, top panel), besides, the FIR/UV ratio in star forming galaxies is recognized as a powerful indicator of dust extinction. We found that FIR/UV ratio diminishes towards higher redshifts (Figure 3, bottom panel), indicating an evolution in the dust mass at $z \sim 5$. This result is expected from the theory of evolution and formation of dust (Calura et al. 2008; Dwek et al. 2007). This dependency we have found has crucial implications in the relation between star formation in quasars and dust evolution at high redshift. For this reason, it is very important to confirm this trend with deeper observations with the new telescopes that will be available soon, as the LMT, ALMA, and Herschel.

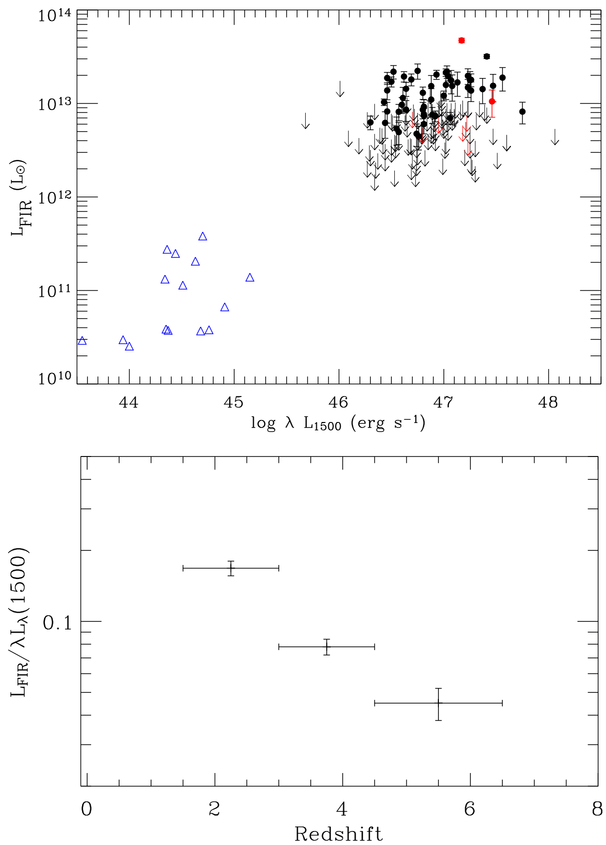

Fig. 3. (Top) FIR luminosity as a function of λL_λ(1500Å). Symbols are the same as in Figure 1. (Bottom) $L_{\rm FIR}/L_{\rm UV}$ as a function of redshift, for $L_{\rm UV}$ intervals.

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