THE REDSHIFT DISTRIBUTION OF SUB-MM GALAXIES

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RESUMEN

Describimos un técnica de Monte Carlo para calcular corrimientos al rojo fotométricos de galaxias seleccionadas en bandas submilimétricas (SCUBA) y milimétricas (MAMBO), en base a sus colores en los dominios radio a IR lejano. La distribución acumulada de corrimientos al rojo de galaxias seleccionadas en campos amplios podría tener una larga cola. Se espera que del 40 al 90% de la población se encuentre entre $2 \leq z \leq 4$ pero, al mismo tiempo, el 50% de las galaxias tienen colores que son consistentes con $z > 4$.

ABSTRACT

Ground-based sub-mm (SCUBA) and mm-wavelength (MAMBO) blank-field surveys have identified more than 100 sources, the majority of which are believed to be dusty optically-obscured starburst galaxies. Colours derived from various combinations of FIR, submillimetre, millimetre, and radio fluxes provide the only currently available means to determine the redshift distribution of this new galaxy population.

In this paper we apply a Monte-Carlo photometric-redshift technique to the multi-wavelength data available for 50 galaxies selected at 850μm in wide-area SCUBA surveys. We calculate a probability distribution for the redshift of each galaxy, which includes a detailed treatment of the observational errors and uncertainties in the priors. The cumulative redshift distribution for this population is asymmetric, and broader than those published elsewhere, with a significant high-z tail. Approximately 40 to 90% of the sub-mm population is expected to have redshifts in the interval $2 \leq z \leq 4$. We also show, however, that the colours of many (50%) individual sub-mm sources are consistent with those of starburst galaxies that lie at extreme redshifts, $z > 4$.

Key Words: **SUB-MM GALAXIES, PHOTOMETRIC REDSHIFTS**

1. PHOTOMETRIC REDSHIFT TECHNIQUE

A Monte Carlo (MC) photometric redshift method has been developed to determine the redshift of a sub-mm source from its colours, taking into account constraining prior information on the population as a whole, such as the number counts of sub-mm galaxies, the favored evolutionary model of the sub-mm population, and the amplification and clustering properties of a certain field. This technique is explained in detail elsewhere, with an application to the sources detected in published sub-mm surveys (Aretxaga et al. 2002), and to the future BLAST/Herschel space missions that expect to constrain the redshifts of thousands of sub-mm sources to an accuracy of $\Delta z \approx \pm 0.5$ (Hughes et al. 2002).

We only offer a brief summary of the technique here. We generate a catalogue of 60μm luminosities and redshifts for mock galaxies from an evolutionary model for the 60μm luminosity function that fits the observed 850μm number-counts. Randomly selected template SEDs are drawn from a library of local starbursts, ULIRGs and AGN, to provide FIR–radio fluxes. The fluxes of the mock galaxies include both photometric and calibration errors, consistent with the quality of the observational data for the sub-mm galaxy detected in a particular survey. We reject from the catalogue those mock galaxies that do not respect the detection thresholds and upper-limits of the particular sub-mm galaxy under analysis. The redshift probability distribution of a sub-mm galaxy is then calculated as the normalized distribution of the redshifts of the mock galaxies in the reduced catalogue, weighted by the likelihood of identifying the colours and fluxes of each mock galaxy with those of the sub-mm galaxy in question. In order to quantify the sensitivity of the individual redshift distributions on the assumed evolutionary history of the sub-mm galaxy population, we consider a variety of models that are able to reproduce the observed 850μm number-counts within the uncertainties.

Fig. 1 shows, as an example, the resulting redshift distribution for the sub-mm brightest source in a survey area towards the Lockman Hole (Scott et al. 2002) which has extensive multi-wavelength coverage and, so far, no published spectroscopic redshift.

The comparison of the photometric and spectroscopic redshifts of the 6 non-AGN sub-mm galaxies

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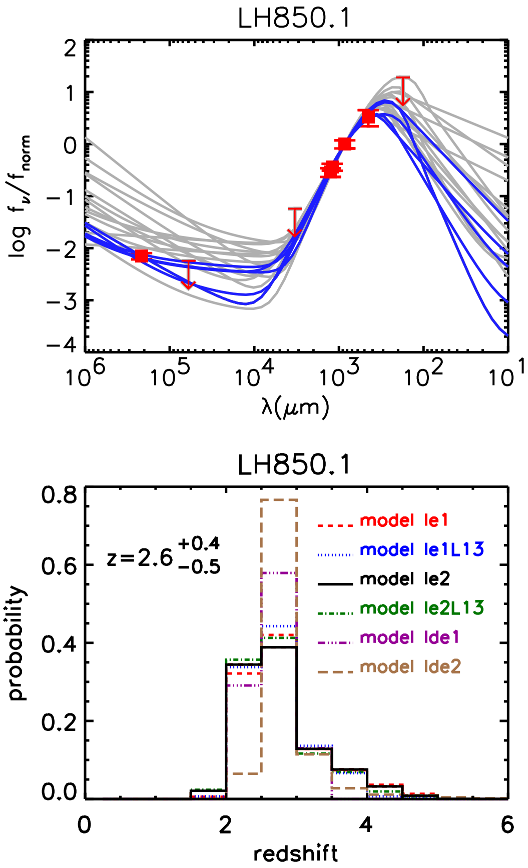

Fig. 1. *Top:* The observed SED of LH850.1 normalised to the flux density at 850μm is shown as squares (detections) and arrows (3σ upper limits). The template SEDs (lines) are redshifted to the mode of the resulting redshift probability distribution, $z = 2.6$, coming from the MC. The template SEDs *at this redshift*, compatible within 3σ error bars with the SED of LH850.1, are displayed in dark grey. *Bottom:* Output redshift probability distributions of LH850.1. The different line styles correspond to different evolutionary models used in the MC.

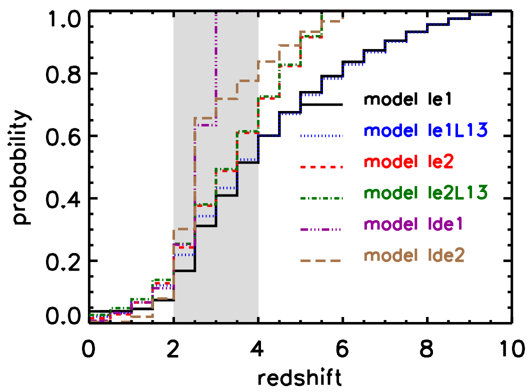

Fig. 2. Cumulative redshift distribution for the population of 50 sub-mm galaxies detected in wide-area blank-field surveys. The different lines represent different evolutionary models assumed for the sub-mm galaxy population in the MC.

with comparable multi-wavelength photometry and redshifts available in the literature, is fairly good ($\Delta z \sim 0.3$). For the other 2 galaxies with available redshifts, detected in only 2 bands, we find $\Delta z > 1$, still consistent with the derived error bars.

2. RESULTS FOR THE POPULATION

The cumulative redshift distribution for the sub-mm galaxy population is simply the coaddition of the individual probability distributions. We have included in this calculation of the cumulative distribution only those sub-mm sources identified in wide-area blank-field SCUBA surveys at a $\geq 3.5\sigma$ level: 50 sources (Fig. 2). Half of the sources in complete flux-limited sub-mm samples, such as these, have only a single 850μm detection with one, or more, additional upper-limits at other wavelengths. Since the redshift distributions of these sources are the most dependent on the priors used, the interpretation of the combined redshift distributions should be based on the range of results given by the different evolutionary models. This analysis implies that $50-90\%$ of the sub-mm galaxies lie between $z = 2-4$. The remainder of the galaxies, $\sim 10\%$, lie at $z < 2$. Fig. 2 also shows that $\sim 50\%$ of the galaxies have colours that are consistent with $z > 4$. Most of these are detected only at 850μm. The upper limits at other wavelengths do not usually help to constrain their redshifts between $2 \leq z \leq 10$, and hence their probability distributions are very flat in those regimes. Shorter-wavelength sub-mm data ($250-500\mu$m) from a future balloon-borne experiment, BLAST, will provide powerful additional constraints ($\Delta z \sim \pm 0.5$) on the redshift distribution of all the sub-mm galaxies at $z > 2$.

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