A best fit evolution scenario for the SCUBA galaxies

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**Abstract.** We explore the evolution of the SCUBA sub-mm galaxy population using Monte Carlo simulations to generate synthetic sub-mm/radio color magnitude diagrams. To represent the local distribution of observed dust properties, we use a local far-infrared luminosity function derived from the IRAS 1.2 Jy catalog, bivariate in FIR luminosity and 60 $\mu$m/100 $\mu$m color. We assume a peak luminosity evolution scenario and a fixed cosmology, to fit a single parameter model to the existing sub-mm/radio data. Our best fitting model has a peak in the luminosity evolution at $z = 2.6$.

1. Introduction

Sub-mm luminous, extragalactic sources are now routinely detected with the SCUBA/JCMT and MAMBO/IRAM instruments, and over 100 blank field sources are now known (Smail et al. 2002, Hughes et al. 1998, Barger et al. 1999, Chapman et al. 2002a, Eales et al. 2000, Webb et al. 2002, Borys et al. 2002, Scott et al. 2002, Dannerbauer et al. 2002). However, the population continues to be poorly understood, largely as a result of two observational difficulties. Firstly, obtaining large samples of objects from sub-mm mapping is a time-consuming process, whereby one source is uncovered in a night worth of blank sky integration. Secondly, identifying secure detections at other wavelengths is difficult due to the positional uncertainty and large beam sizes ($\sim$15 arcsec), and the intrinsic faintness of most sources at all other wavelengths.

The tight correlation observed locally between thermal far-IR emission and synchrotron radio emission (Helou et al. 1985, Condon 1992) suggests a possibility for identifying the sub-mm sources. The positional accuracy and small beam sizes of large radio interferometers like the VLA can act as a surrogate to the sub-mm, allowing precise identifications at other wavelengths. Smail et al. (2000) demonstrated that a significant fraction of their sub-mm sources could be detected in the radio. Radio surveys, however, do not benefit from the neg-
ative K-correction inherent in sub-mm surveys, and galaxies with luminosities similar to the local ULIG, Arp220, will likely be missed by $z \sim 3$ in the radio. Barger, Cowie & Richards (2000) and Chapman et al. (2001) have demonstrated that selecting the optically fainter tail of the microjansky radio sources can be used to rapidly uncover a large portion of the blank field sub-mm population ($\sim 70\%$ of the bright counts). Chapman et al. (2002b – hereafter C02) have presented the results of a large campaign using the radio pre-selection technique to uncover sub-mm sources.

In this contribution, we continue to investigate the evolutionary behavior of the sub-mm population of galaxies, expanding on the models presented in C02. The key addition is an explicit model of the dust temperature distribution found locally. We use these models to better understand the range in properties sampled by the radio pre-selected sub-mm galaxy population. Our calculations are done in a $\Lambda = 0.7$, $\Omega = 0.3$, h=0.65 cosmology.

2. Fitting the evolution model

We anchor our model to the local FIR luminosity function (LF), constructed from the 1.2 Jy sample of IRAS galaxies (Fisher et al. 1995). Recent work has emphasized the variation in dust temperature found in luminous infrared galaxies (Chapman et al. 2002c). We therefore form an LF which represents the distribution in dust temperatures found in the 1.2 Jy sample, parametrized by the $60 \mu m/100 \mu m$ color (a full characterization of this LF will be presented in Chapman et al., in preparation).

We evolve this local bivariate LF using pure luminosity evolution of the form

$$\Phi(L, \nu) = \Phi_0(L/g(z), \nu(1 + z)).$$

Our evolution function has a power law peak,

$$g(z) = (1 + z)^4$$

out to a break redshift, and drops thereafter as $g(z) = (1 + z)^{-4}$. This power-law index is chosen based on evolutionary models fit to both optical and sub-mm wavelength data (Blain et al. 1999a,b). The $60 \mu m/100 \mu m$ color distribution does not evolve, but rather continues to scale with FIR luminosity as found locally. The model therefore has only one free parameter, the $g(z)$ break redshift. We then adopt a Monte Carlo approach, drawing luminous infrared galaxies randomly from the evolving distribution function. A galaxy thus selected is then assigned a template spectral energy distribution from the catalog of Dale et al. (2001, 2002), parameterized by the $60 \mu m/100 \mu m$ color. This model scenario does not incorporate the intrinsic scatter in the far-IR/radio correlation, as was done in C02. Rather we concentrate on the properties of the intrinsic dust temperature distribution.

In Fig. 1, we plot the distribution of measured sub-mm sources from C02 in the sub-mm/radio color-magnitude diagram (CMD), along with similar CMDs from our model for three peak redshifts, $z = 2.0, 2.5, 3.0$. Objects which are detectable in a $30 \mu Jy$ radio survey are shown as larger symbols.

We then fit the model galaxy distributions in the CMD to the C02 dataset, parameterizing only by the $z_{\text{break}}$ redshift of the peak evolution function. We minimize the residuals between the real and modeled galaxy distributions over the range $S_{850} = 5 - 20 \text{ mJy}$. A best fitting evolution is found for a peak redshift of $z = 2.6$. 
3. Discussion

The addition of the 60 $\mu$m/100 $\mu$m color distribution to our adopted FIR luminosity function results in a fraction of cold luminous galaxies which are preferentially selected with SCUBA at 850 $\mu$m (e.g., Blain 1999, Eales et al. 1999). As expected (see also the discussion in C02), the peak evolution redshift must be lower if a population of luminous colder sources exist at high redshifts. By comparison, in C02, a reasonable fit to the data was found for a peak evolution redshift of $z = 3$, when all objects were assumed to be as hot as Arp220 ($\sim 50$ K).

Note also that in this model, there are very few bright sub-mm sources missed by the 30 $\mu$Jy radio threshold. Any model with a peak in the luminosity evolution function will exhibit similar behavior. No bright blank field sub-mm sources have yet been identified with galaxies at $z > 3$. Our model fit to the existing radio/sub-mm data suggests a paradigm where this may remain largely true even with complete identifications. As redshifts are obtained for the radio/sub-mm sources, tighter constraints on the form of the evolution will be possible, breaking the degeneracy of dust temperature versus redshift.

Acknowledgements

We thank all our collaborators on the various aspects of this project for a stimulating romp through the enigmatic field of sub-mm galaxies. SCC gratefully acknowledges support from NASA through HST grant 9174.1. GFL thanks the Australian Nuclear Science and Technology Organization (ANSTO) for financial support.

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Figure 1. The $S_{850}\mu m$, radio color-magnitude diagram from C02, along with three example model outputs for luminosity evolution peaks at $z = 2, 2.5, 3$. In the data CMD, solid red circles show sub-mm detected sources, open circles show marginally detected sub-mm sources, and crosses show radio sources without significant sub-mm detection. The dashed line depicts the radio limit of the C02 survey. Model CMDs show larger symbols having 1.4 GHz flux greater than 40$\mu$Jy.