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MOLECULAR AND DUST EMISSION IN LIRGS AND ULIRGS

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Observations of molecular and dust emission in high redshift galaxies is one of the challenges for GTM. Current studies on the observability of the molecular lines and dust emission are based on observed templates of local ultraluminous infrared galaxies (ULIRGs, e.g. Bain et al.1996). However the environmental conditions in galaxies at higher redshifts could be different from those found among local galaxies and what is needed is a thorough investigation of the global relationships between gas, dust and star formation process. For this purpose we present a study of the properties of dust and molecular gas in 6 LIRGs and outline a new method that combines the dust emission models provided by GRASIL with one-zone molecular emission models.

GRASIL is a galaxy population synthesis model that accounts for effects of dust reprocessing (Silva et al. 1998), radio emission associated to star formation (SF) (Bressan et al. 2002) and non thermal emission from the central AGN (Prouton et al 2004). The total gas of the galaxy is divided, in two phases, the diffuse ISM, corresponding to the cirrus dust, and the much denser molecular clouds (*MCs*) of a given mass, m_c, and radius, r_c. The recent SF history, the total mass of the molecular gas and the optical depth of the clouds, proportional to the ratio m_c/r_c^2, is obtained by the fitting of the observed UV to radio SED. To better analyze the cloud environment, we study its molecular emission by means of a large velocity gradient (LVG) code, in the "one zone" approximation (de Jong et al. 1975). Free parameters of the LVG code are: the numerical density of colliders, n_{H_2}, the gas kinetic temperature, T_K, and the column density of the molecules per unit of velocity $\Lambda = X_{mol}/gradV$, where, $X_{mol} = N_{mol}/n_{H_2}$.

^{12}CO is the easier molecule to observe in external galaxies. So, our model of molecular emission will take into account only this molecule. By adopting the "one-zone" model for the molecular emission we assume that all the CO emission is coming from within the same region. Thus, line ratios of beam-matched data do not depend on the beam filling factor. In our model, the one-zone corresponds to the molecular clouds responsible of dust emission. Thus, the optical depth of the dust obtained from the SED fitting can be used to constrain r_c, the average molecular density, n_{H_2}, and the molecular mass needed in the molecular analysis. We applied this method to six galaxies, four LIRGs[5] and two ULIRGs[6] with available data from Mid-IR to radio, and in ^{12}CO(1-0), (2-1), (3-2) transitions for the analysis with the LVG. Beam-matched data were available only for

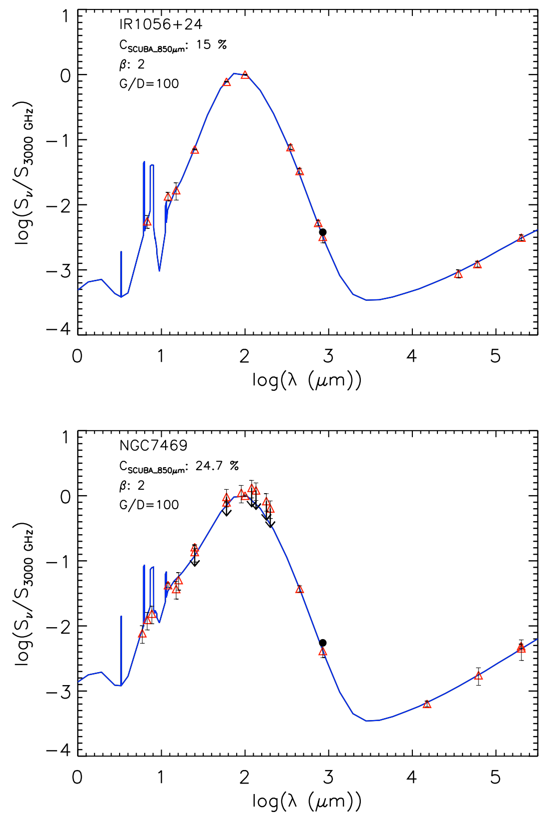

Fig. 1. Galaxies SED fitted with GRASIL. The triangles represent the observational data, and the circles are data at 850 μm without molecular line correction.

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[5]NGC5713,NGC6052, NGC 6181, NGC7469
[6]IR1056+24, ARP220

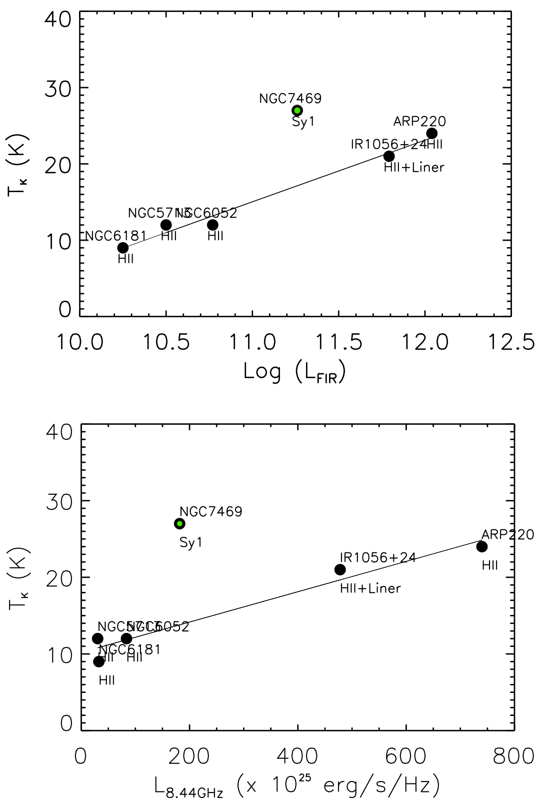

Fig. 2. Kinetic temperature versus FIR luminosity (up) and non-thermal radio luminosity (down). The lines represent the linear fits for the starburst galaxies.

ARP220 and NGC6052. For the others, we used the point source approximation, which is good for IR1056+24 and NGC7469, but probably not suited for NGC5713 and NGC6181. Our galaxy sample was selected so that the galaxies were far enough to ensure that most of their molecular emission is contained within the beam.

Preliminary results

In figure 1 we show two SEDs fitted with GRASIL. NGC7469 is the unique galaxy in our sample classified as AGN (Sy1.2). But Prouton et al. (2004) showed that the AGN contribution is $< 17\%$, so we model all galaxies using a starburst template (spherical King profile for the distribution between gas and stars + an exponential burst of star formation over the "normal" star formation). Observational data at 850 μm and 1300 μm were corrected from contamination by CO(3-2) and CO(2-1) lines. CO contamination at 850 μm is possible in galaxies with redshift < 0.05 and may affect the derived spectral index of the dust emission (β), the mass of the cold dust, and consequently the ratio of gas to dust masses (G/D). Best SED fits were obtained with G/D=100, fractions of molecular gas to total gas between 0.4 to 0.7, and ages of burst of $10^{7.4-7.8}$ Myr. We obtained average SFRs over the burst age from 30 to 383 $M\odot$/yr, and average dust temperatures from 30 K to 39 K. In galaxies where all the CO(3-2) emission is detected, i.e. IR1056+24 and NGC7469, we derived $\beta = 2$.

We found that the molecular emission in the LIRGs is optically thick and marginally sub-thermal. For the ULIRGS, it is sub-thermal and moderately optically thick ($\tau \sim 1-2$). There are hints that T_K is tightly correlated to the FIR and Radio emission over a wide range of luminosity (Fig. 2). NGC7469, a Sy1.2 galaxy, is clearly out of these correlations. A likely explanation is that, in starburst galaxies, the molecular excitation is driven by processes related to star formation. In the case of the AGN, the molecular gas seems to be *overheated*, probably by the central engine. The mean molecular densities for all the galaxies are $< 10^{3.5}$ cm^{-3}. This implies that the bulk of CO emission is coming from a low density medium. These results agree with those obtained by Radford et al. (1991) for ARP220. It is interesting to note that our model of ARP220 would require a very large exposure time, more than 30 hours, to be observed by GTM in CO at redshifts greater than 3.5.

Gao and Solomon (2003) have found large HCN emission in four galaxies of our sample. Preliminary computations show that the above models fail to reproduce the observed HCN emission. Thus, the molecular gas in LIRGs and ULIRGs seems to be characterized by sub-thermally excited CO and very bright emission from HCN. This suggests that a more suitable model is made at least of *two zones*: dense regions ($n_{H_2} \sim 10^{3.5} - 10^5$ cm^{-3}), responsible of the HCN emission and of most of the MC dust reprocessing seen by GRASIL, embedded in a low density ($n_{H_2} \sim 10^2 - 10^3$ cm^{-3}) medium, responsible for most of the lower excitation CO emission.

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