A panchromatic view fo the Herschel Virgo Cluster Survey background sources

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Abstract

Using deep Herschel data on behalf of the Herschel Virgo Cluster Survey, we investigate the physical properties of a sample of nearby galaxies (z<0.6) in the background of the Virgo cluster. Galaxies are selected at 250 micron and are complemented with a set of multiwavelengths data covering the Spectral Energy Distribution (SED) of each source from the Ultra Violet (0.15 micron) to the Far Infra Red (500 micron). The SEDs have been analyzed using the statistical method of MAGPHYS (Da Cunha et al. 08).

Our galaxies have in average a low star formation rate (0.02 < SFR < 70 M_{sol} yr^{-1}), and a low dust luminosity (average L_{IR} ~ 5+/- 2 X 10^{10} L_{sol}), and represent normal star forming galaxies experiencing the shut down of the star formation observed below z<1. This is clear observing their position in a SFR-M_* diagram, where they occupy a transition region between local spirals, low redshift Luminous Infra Red Galaxies (LIRGs) and z>1 Ultra Luminous Infra Red Galaxies.

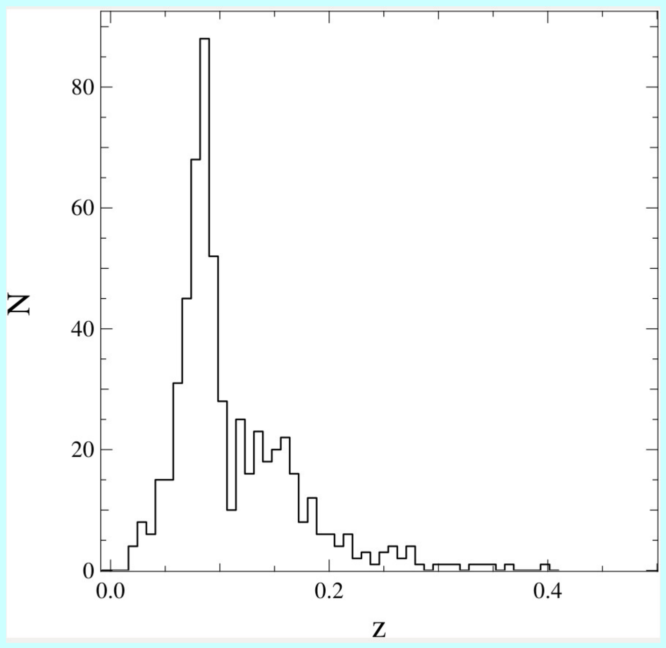
With respect to a similar Herschel survey (H-ATLAS, Eales et al. 10), we found comparable dust masses but lower SFR, implying that despite the presence of dust, our galaxies are in a quenching phase of their evolution. Also a similar analysis using IRAS instrument revealed a less prominent dust component, because of the selection more sensitive to the warm dust. We then used a stacking technique to build a Spectral Energy Distribution (SEDs) template representative of normal star forming galaxies at z<1. Comparisons with previous templates show the importance of Mid Infra Red data in determining the shape of the SED above 3 micron, above all in the regions where stellar and dust components mix together.

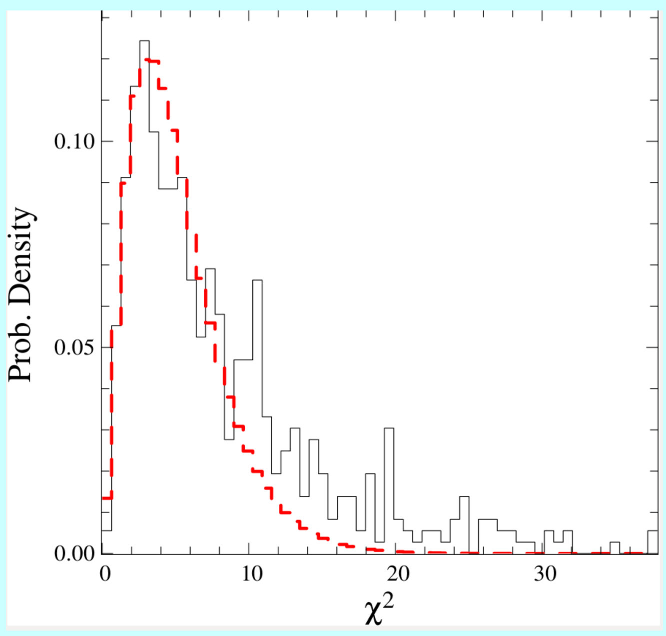
The sample

The starting point is the 250 micron selected point source catalogue of Pappalardo et al. 14. Data are complemented with ancillary data from GALEX (UV), SDSS (optical), UKIDSS (NIR), WISE (MIR), PACS (FIR). We ended up with about 800 sources with average redsfhit of 0.11+/-0.06

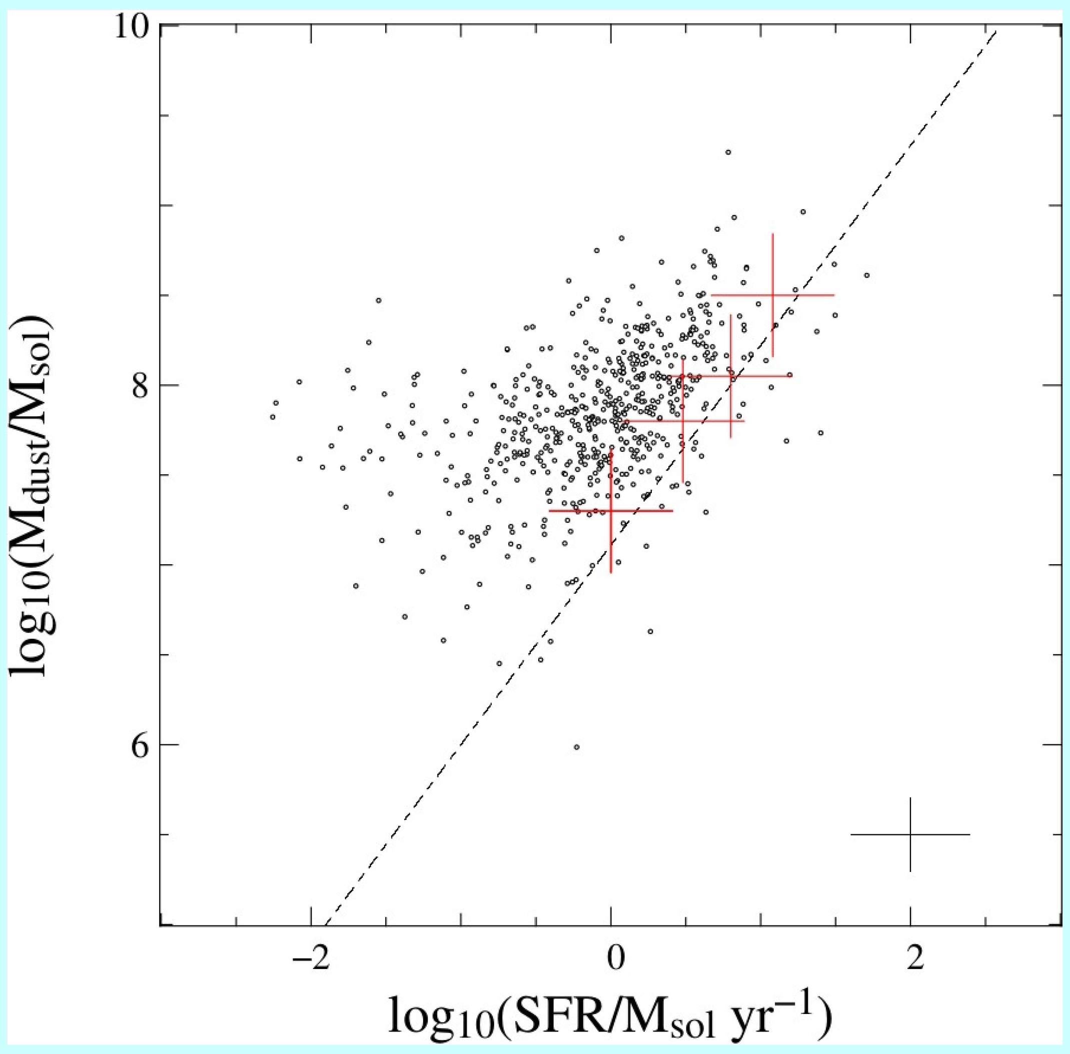
Analysis method

We use MAGPHYS to extract the relevant physical parameters, a statistical methods that reproduces the SED of a galaxy as a combination of different simple stellar population libraries and dust emission models. Left panel: Redshift histogram for the HeViCS sources with flux densities at 250 μm above 20 mJy, and SNR 250 > 3. Sources are selected to have counterpart in SDSS, 2MASS, and WISE with a reliability above 80%. Righ panel: Probability density function of our sample (black solid line). Red dashed line shows the best fit obtained from statistical analysis.





The table gives in the order: Dust Mass (M_{dust}), star formation rate (SFR), fraction of the total dust heated by the diffuse interstellar medium (f_{mu}), stellar mass (M_*), specific star formation rate (SFR/M_*), dust luminosity integrated between 3-1000 micron (L_{dust}), temperature of the cold and warm dust in thermal equilibrium in the diffuse ISM (T_c, T_w):



Parameter (1)	Mean (2)	σ(mean) (3)
$\log_{10} M_{dust}$ ($M_\odot$)	7.85	6.77
SFR ($M_\odot$ yr^{-1})	1.08	0.22
f_μ	0.65	0.03
$\log_{10} M_{star}$ ($M_\odot$)	10.38	9.75
$\log_{10}$ sSFR (yr^{-1})	-10.28	-10.86
$\log_{10} L_{dust}$ ($L_\odot$)	10.32	9.41
T_c (K)	16.91	0.58
T_w (K)	52.39	4.64

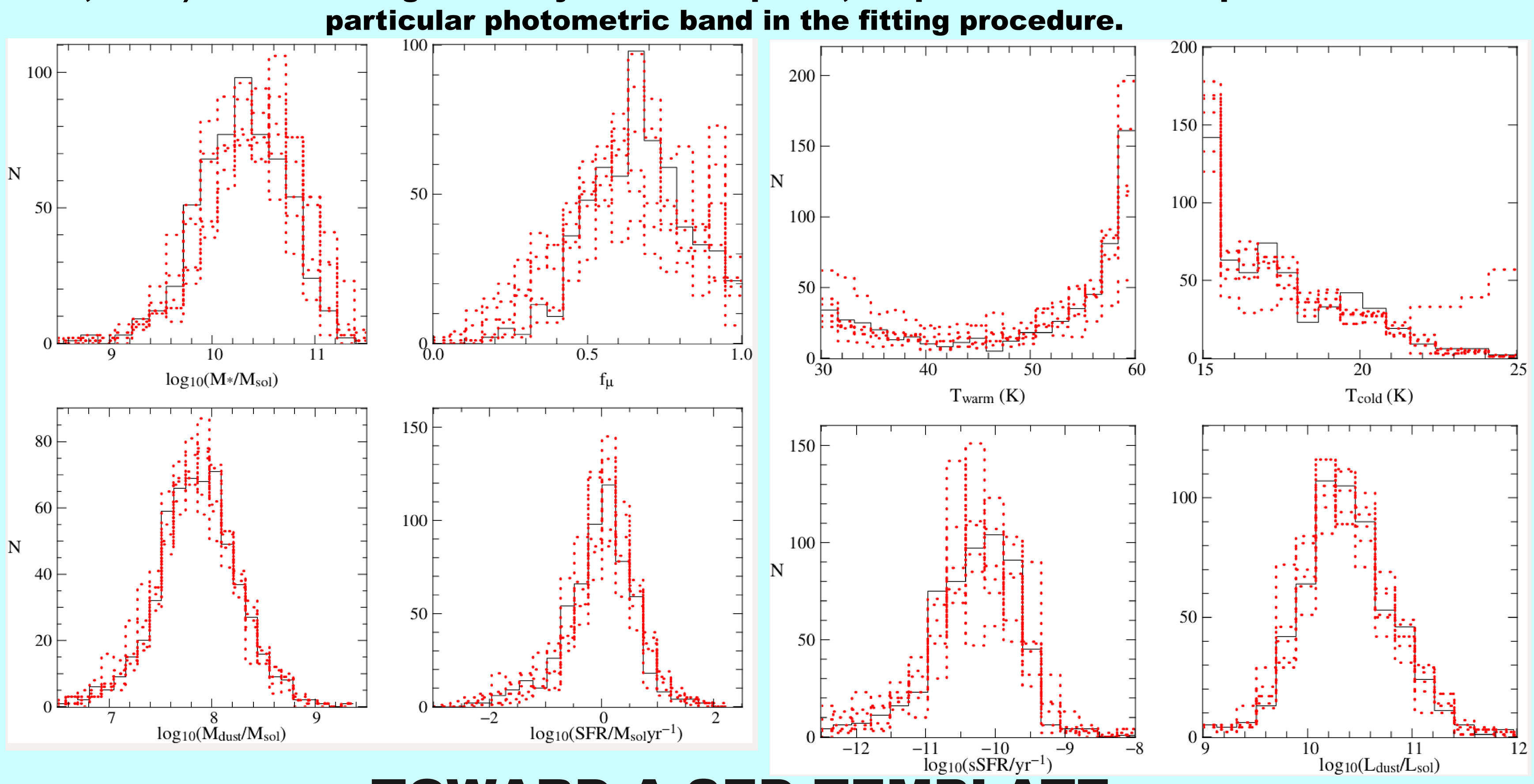
Figure on the left show the dust mass (Mdust) versus the star formation rate (SFR) for our sample of low IR luminous galaxies. Bottom right shows the median errors of the two quantities.
Red crosses reproduce the results for ~1400 objects selected at 250 micron with H-ATLAS at z<0.5 (Smith et al. 2012).
Dashed line shows best fit obtained in Da Cunha et al. 10 from a sample of ~1700 low redsfhit galaxies.

Analysis

Our sample has a median dust luminosity of L_{dus} ~ 2.1 × 10^{10} L_{sol} and an average SFR ~ 2 M_{sol} yr^{-1}, typical of low luminosity normal star forming galaxies.
These then are galaxy undergoing the SFR decline observed at z<1 (Madau et al. 1996, Hopkins 2004, Behroozi et al. 2013).
If we compare with the H-ATLAS (red crosses) we note that despite the similar range of dust masses investigated our sources have systematically lower SFR.
The average redshift of the H-ATLAS sample is z ~ 0.35, with a difference Δz ~ 0.2 with respect to our sources. This means that we are investigating a sample of galaxies at a different stage of its evolution with respect to Smith et al. (2012), a stage in which the star formation activity is reduced.
Dashed line is the best fit obtained in da Cunha et al. (2010) from a sample of about ~ 1700 galaxies with available GALEX, SDSS, 2MASS and IRAS data. Galaxies have been selected with IRAS, with a median dust mass of M_{dust}~5.5 × 10^7 M_{sol}, slightly smaller than our value, M_{dust}~7.2 × 10^7 M_{sol}.
The difference in dust masses is due to a combination of 2 factors:
- the average redshift of the da Cunha et al. (2010) sample is z ~ 0.05, a range slightly smaller than ours. Since Dunne et al. (2011) have shown that galaxies at higher redshift have larger dust masses, the larger amount of dust in our sample is consistent with the trend observed for galaxies at z < 0.5.
- Another reason for the different dust mass distribution observed is due to the selection criterion. Selecting galaxies at 250 μm with robust detection at 3.6 < λ < 500 μm we can constraint both the warm and the cold component of the dust, while IRAS selection is mostly sensitive to the warmest component. Some of our galaxies have dust not sufficiently warm to be detected at 60 μm, being still gas rich.

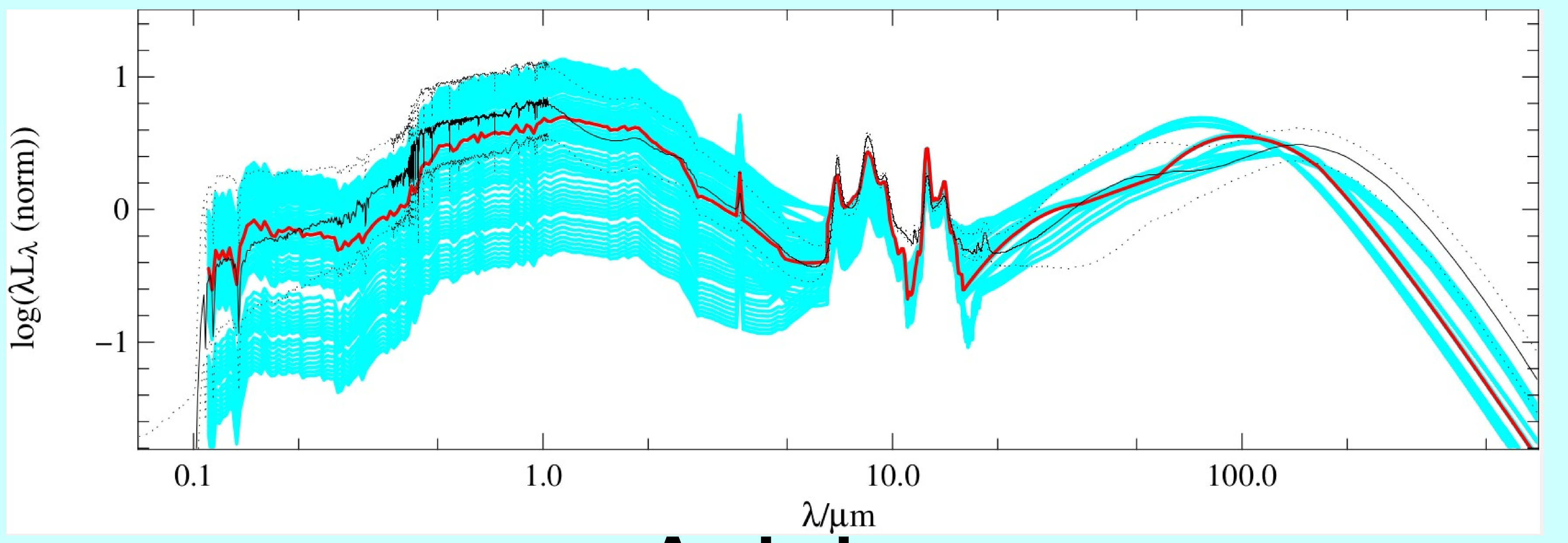
Dependence of the results on available data set

Figure in the bottom shows the distribution of stellar and dust masses (M_*, M_{dust}), the fraction of the total dust heated by the diffuse interstellar medium (fμ), star formation rates (SFR), specific star formation rates (sSFR = SFR/M∗), dust luminosities integrated between 3 and 1000 μm (L_{dust}), and the temperatures of the cold and warm dust in thermal equilibrium in the diffuse ISM (T_c, T_w), obtained with MAGPHYS considering all the bands available (black solid line) or different data selections (removing GALEX, UKIDSS, WISE). There is a high stability of the PDF peaks, despite the absence or presence of some particular photometric band in the fitting procedure.



TOWARD A SED TEMPLATE

The wavelength coverage of our sample is quite homogeneous and can be used to build a SED template representative of low luminosity star forming galaxies in the nearby Universe.
Using a stacking technique we built a median spectra of our galaxies, shown in the bottom of this panel as a solid line, and 16th and 84th percentile shown as black dotted lines. Cyan lines show the normalized spectra of Chary & Elbaz (2001) templates spanning the luminosity range of our sample, and the red line shows the spectrum with the dust luminosity equal to the median of our sample.

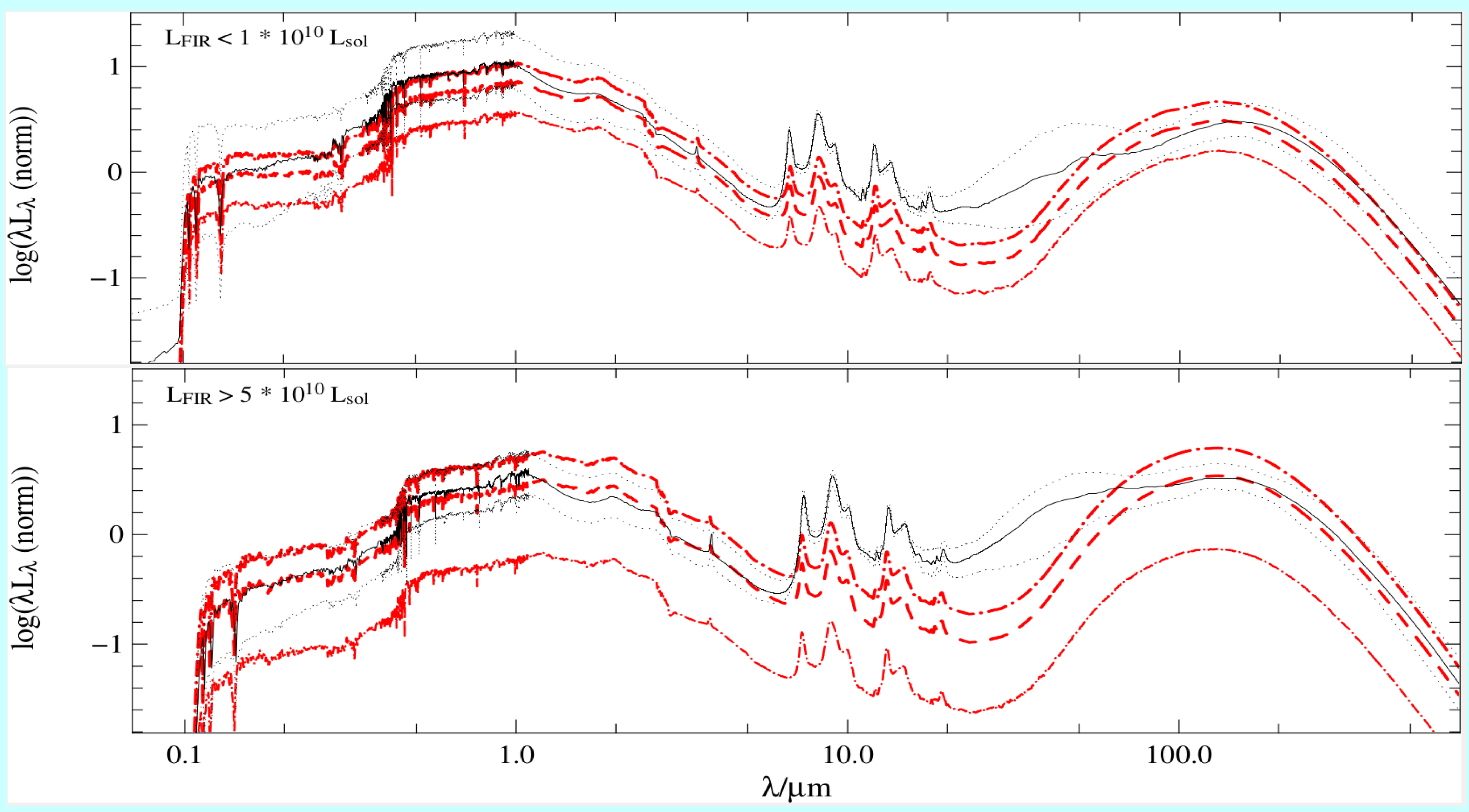


Analysis

Our median SED is compared to the empirical template of Chary & Elbaz (2001), based on ~ 100 galaxies selected from a variety of published survey. Objects were selected heterogeneously at different wavelengths, from 0.44 μm (Infrared Space Observatory) to 850 μm (Sub-millimeter Common-User Bolometer Array, SCUBA). Spectra are normalized between 3 and 500 μm, and selected to cover the range of L_{dust} of our sample, being the red line the model correspondent to our median L_{dust}L dust .
In the wavelengths range where the emission is dominated by stellar component, despite the different offset due to the normalization, the shape of the spectra are quite similar. Above 10 μm, where the IR emission due to the dust becomes relevant, the discrepancies increase, and in average the peak of the dust thermal component in Chary & Elbaz (2001) template is at lower wavelengths, implying hotter temperature.

Comparison with H-ATLAS template

Finally we compare the median of our sample with the spectra obtained from H-ATLAS in Smith et al. (2012), improved by an order of magnitude with respect to the initial 1400 sources (Smith, private communication). If we except the region between 9 < λ < 200 μm, our median spectra are almost identical to the templates of Smith et al. (2012) in both dust luminosity subsamples, despite the differences in star formations, stellar masses, and different redshift range. The shape of median SEDs change according to the selection criteria defined to built them, however in Smith et al. (2012) is shown that the parameter that mainly affects the shape of the median SEDs is dust luminosities selection.
With this figure we confirm this resultin low IR luminosity galaxies. Their redshift distribution is higher, but despite this at fixed luminosity the median spectra, in the available photometric bands, are consistent. The main differences are the spectral bands covered by WISE, where Smith et al. (2012) do not have constraints. This evidence confirms the importance of these bands in order to build a SED template for galaxies. The emission at MIR are in average lower than our sample when we have constraints in Herschel bands (Smith et al. 2012), and lower when there are no constraint in FIR (Chary & Elbaz 2001).



Conclusions

We selected from the HeViCS point sources catalogue of Pappalardo et al. (2014) ~800 sources with photometry spanning 0.15 < λ < 500 μm and average redshift z = 0.11 ±0.06. With the statistical approach of MAGPHYS (da Cunha et al. 2010), we investigate the effect of the available data in the determination of the physical properties of the sample.
– The median dust mass of our sample is 7.1±0.2 × 10 7 M_{sol}. Dust masses are quite stable with respect to the different bands removal. The median stellar mass for the full data set is 2± 0.1 × 10^{10} M_{sol}.
– Our sample has SFRs and low dust luminosities, selecting a galaxy sample experiencing a SFR decline. We have compared our results with a sample of H-ATLAS galaxies selected at 250 μm with average z ~0.35 Smith et al. (2012), and the IRAS selected sample of da Cunha et al. (2010) at z ~ 0.05. The range of dust masses covered by our sample is comparable to Smith et al. (2012), but at fixed M dust we found lower SFRs. Galaxies selected with IRAS (da Cunha et al. 2010) show lower dust masses, as a combination of lower redshift and selection effects.