The dust temperature of galaxies in the SFR-M_* plane

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Introduction

Over the last 10 Gyr of lookback time, we observe a clear correlation between the star formation rate (SFR) and the stellar mass (M_*) of star-forming galaxies (e.g., Rodighiero et al. 2010). The existence of this so-called "main sequence" (MS) of star formation is usually taken as evidence that the bulk of the star-forming galaxy (SFG) population is evolving through a steady mode of star formation, while occasional major mergers create extreme systems with intense short-lived starbursts, which are offset from the MS of star formation. One strong observational support of this interpretation is that the physical properties of SFGs (e.g., morphology, PAH-to-LIR, CII-to-LIR and CO-to-H_2 ratios) are fundamentally linked to their localisations with respect to the MS of star formation (i.e., $\Delta\log(\mathrm{SSFR})_{\mathrm{MS}}$; Wuyts et al. 2011, Elbaz et al., 2011, Gracia-Carpio et al., 2011, Magnelli et al., 2012).

In this context, we study the evolution of the dust temperature (T_{dust}) of galaxies in the SFR-M_* plane up to z~2 using far-infrared and submillimetre observations from the *Herschel* Space Observatory taken as part of the PACS Evolutionary Probe (PEP) and *Herschel* Multi-tiered Extragalactic Survey (HerMES) guaranteed time key programmes. Such analysis is crucial because T_{dust} estimates provide us with information on the physical conditions prevailing in the star-forming regions of galaxies.

Sample & Data Analysis

Using the large wealth of multi-wavelength observations available for the GOODS-N/S and COSMOS fields, we build a sample of ~265 000 galaxies with reliable SFR, M_* and z estimates (Wuyts et al. 2011). Starting from this sample, we grid the SFR-M_* parameter space in several redshift ranges and estimate the mean T_{dust} of each SFR-M_*-z bin. Dust temperatures are inferred by fitting the stacked PACS/SPIRE flux densities (100−500 μm) of each SFR-M_*-z bin. Based on this stacking analysis, we constrain the dust temperature of galaxies over a broad range of redshifts, L_{IR} and $\Delta\log(\mathrm{SSFR})_{\mathrm{MS}}$ (see Figure 1).

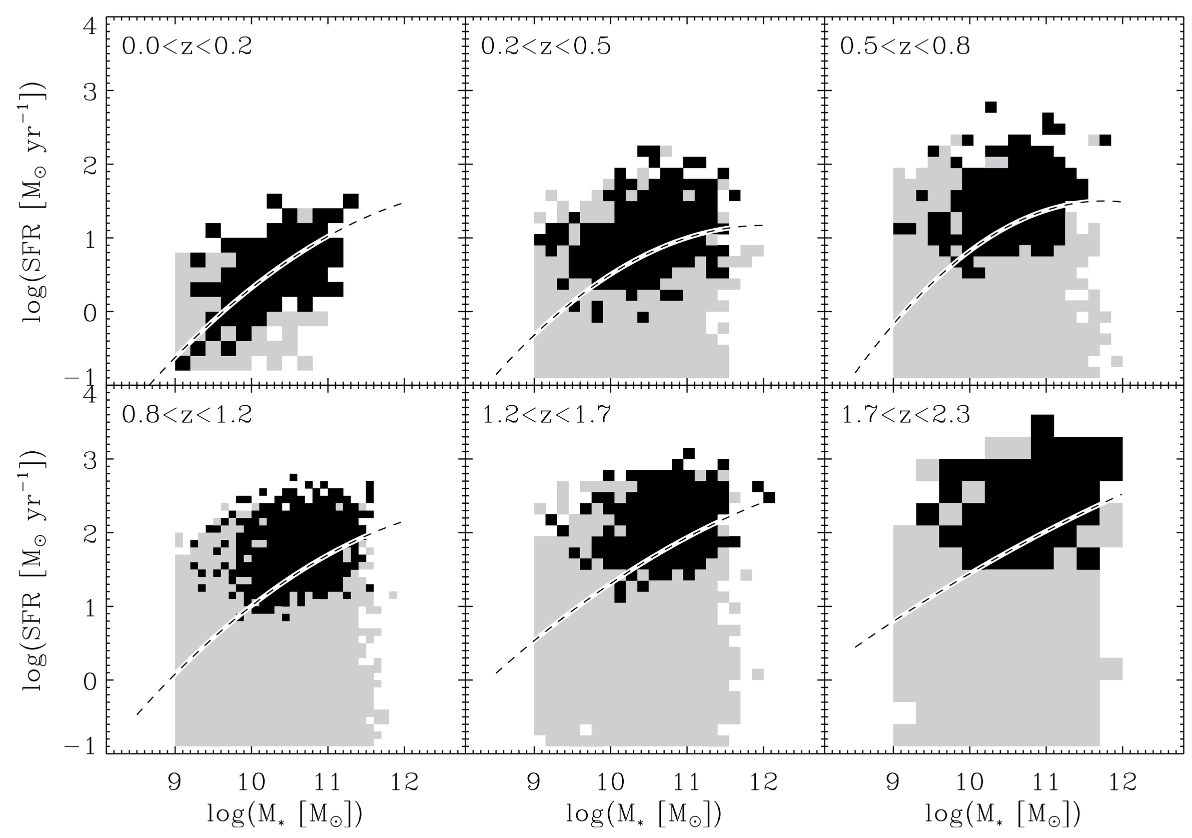
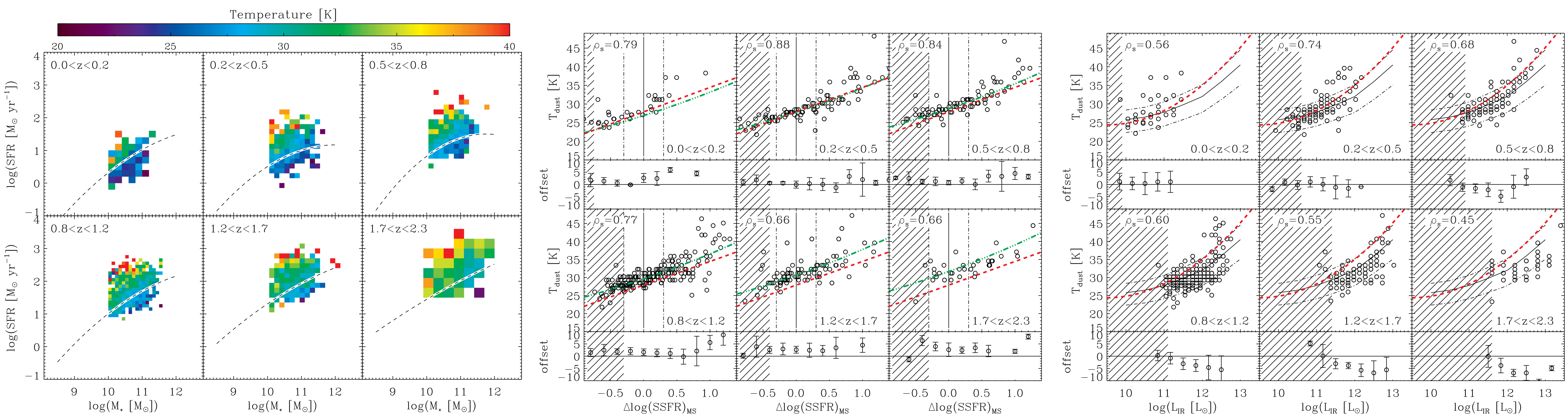


Fig. 1: Our gridded SFR-M_* parameter space. Black SFR-M_* bins have reliable T_{dust} estimates from our PACS/SPIRE stacking analysis. This stacking analysis allows us to obtain, up to z~2, complete constraints on the dust temperature of MS (dashed lines) and above-MS galaxies with $M_* > 10^{10}\,M_\odot$

Results : The importance of the T_{dust} - $\Delta\log(\mathrm{SSFR})_{\mathrm{MS}}$ correlation

Fig. 2: (left) Dust temperatures of galaxies in the SFR-M_* plane. Dashed lines show the MS of star-formation. Tracks of iso-dust-temperature are not characterised by vertical or horizontal lines but instead by diagonal lines. Dust temperatures of galaxies as a function of $\Delta\log(\mathrm{SSFR})_{\mathrm{MS}}$ (center) or L_{IR} (right). Red dashed lines correspond to a linear or a second order polynomial fit to the data points of the $0.2 < z < 0.5$ bin. Green triple-dot-dashed lines (center) show predictions inferred from the variations of the SFE with $\Delta\log(\mathrm{SSFR})_{\mathrm{MS}}$ and variations of the metallicity with redshift. Lower panel of each redshift bin shows the offset between the median dust temperature of our data points and the red dashed line. Hatched areas represent the regions of parameter space affected by incompleteness.



➡ The dust temperature of a galaxy smoothly increases with L_{IR} and $\Delta\log(\mathrm{SSFR})_{\mathrm{MS}}$. The T_{dust}-$\Delta\log(\mathrm{SSFR})_{\mathrm{MS}}$ correlation is statistically more significant than the T_{dust}-L_{IR} correlation.

➡ In a simple optically thin model, where T_{dust} traces the galaxy-integrated L_{IR} and M_{dust}, the slope of the T_{dust} -$\Delta\log(\mathrm{SSFR})_{\mathrm{MS}}$ correlation can be explained by the increase of the star-formation efficiency (SFE=SFR/M_{gas}) with $\Delta\log(\mathrm{SSFR})_{\mathrm{MS}}$ observed locally (Saintonge et al. 2012).

➡ The normalisation with redshift of the T_{dust} -$\Delta\log(\mathrm{SSFR})_{\mathrm{MS}}$ correlation can be explained by the decrease of the metallicity of galaxies with redshift (e.g., Erb et al. 2006)

➡ All these results support the hypothesis that the conditions prevailing in the star-forming regions of MS and far-above-MS galaxies are different

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