Far-Infrared Properties of UV Selected Galaxies from z=4 to z=1.5: Unveiling Obscured Star Formation

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ABSTRACT

We report on our recent results about the IR properties of FUV selected samples from the COSMOS field at z= 4, 3 and 1.5. The measurements are obtained by stacking at 250, 250 and 500 microns in the *Herschel*/SPIRE images. Almost no galaxy is detected individually and the stacking is performed as a function of FUV luminosity and stellar mass. We are able to reconstruct the average relation between dust attenuation and stellar mass and the so-called main sequence (star formation rate-stellar mass relation) of galaxies. Implications on star formation histories of galaxies are discussed. We investigate the future impact of SAFARI/*SPICA* in the study of distant FUV selected galaxies.

1. GENERAL CONTEXT

Star formation rates (SFR) and stellar masses ($M_\star$) are the main parameters measured on large samples of galaxies and at different redshifts to constrain their star formation history and the evolution of their baryonic content. Various calibrators are used to measure the SFR, in particular the far-ultraviolet (FUV- 1500) and the infrared (IR-5-1000 μm) emissions: the direct un-attenuated light from young stars is preferentially observed in the ultraviolet whereas the energy of photons is efficiently captured by dust. This energy is re-emitted in IR between 5-8 and 1000 μm with in general more energy is locked in IR and in FUV (Burgarella et al. (2013)). The IR emission is most of the time a reliable indicator of the SFR, the derivation from FUV data is more difficult since it relies on estimations of the amount of dust attenuation that are very uncertain when IR data are not available. The best situation is of course reached when both IR and FUV data are available. In this contribution we will focus on the measure of the SFR of FUV selected galaxies in the COSMOS field from z = 1.5 to z = 4 by using deep *Herschel* data combined to optical ones, corresponding to the FUV rest-frame (Heinis et al. (2013) and Heinis et al. (2013, MNRAS submitted)). The FUV-selection is useful for comparison with high redshift surveys performed in the visible or near-IR. The results of this study will help us to predict the huge improvement *SPICA* will provide for the study of these galaxies.

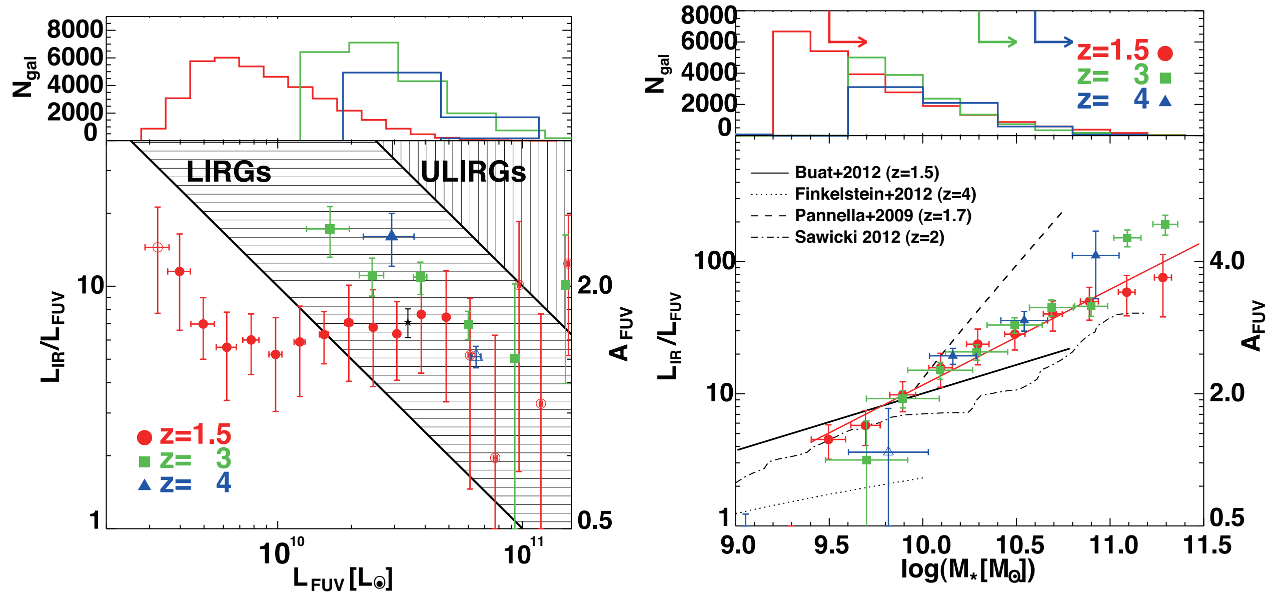

Figure 1. *Left:* $L_{\rm IR}/L_{\rm FUV}$ ratio versus $L_{\rm FUV}$, the IR fluxes are measured using stacking in bins of $\log(L_{\rm FUV})$. *Right:* $L_{\rm IR}/L_{\rm FUV}$ ratio versus the stellar mass $M_\star$, the IR fluxes are measured per bins of $\log(M_\star)$. The different lines represent other related studies in the literature. The top histograms in both figures represent the number of galaxies included in the stacking measurements, the arrows show the mass completeness limit.

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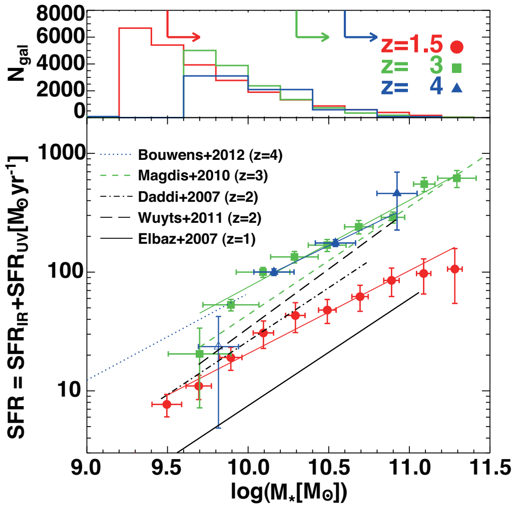

Figure 2. SFR measured as the sum of IR and FUV contributions versus $\log(M_\star)$, the various lines reproduce relations found in the literature and corresponding to redshifts close to those of our current study.

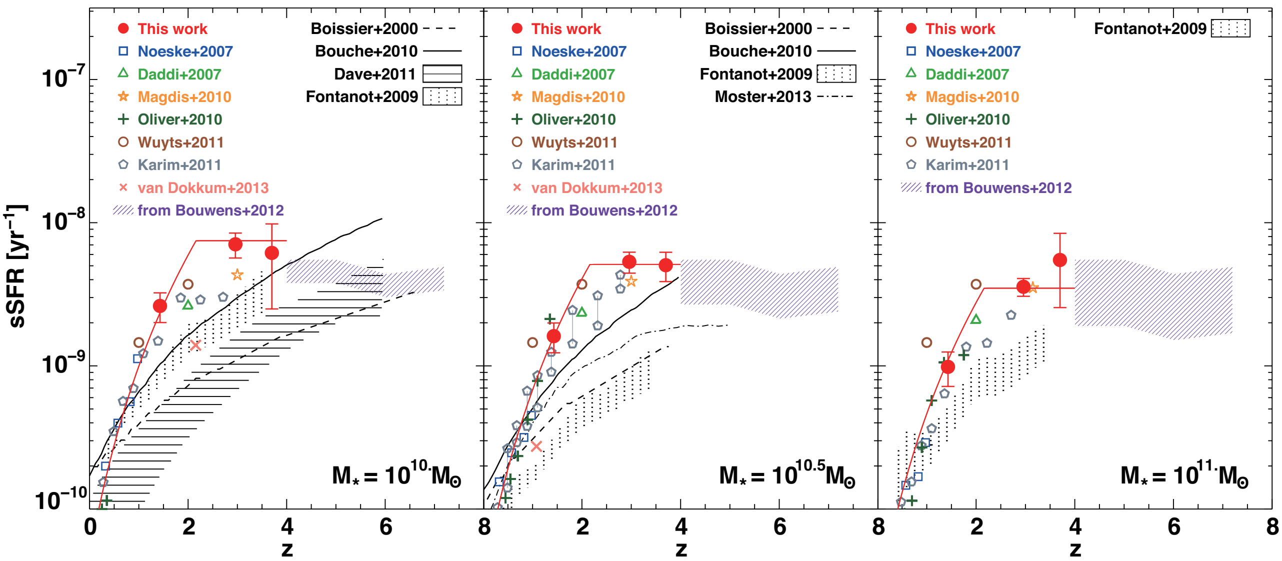

Figure 3. sSFR plotted as a function of z for 3 different bins of stellar mass. Other measures from the literature as well as model predictions are over-plotted.

2. DUST ATTENUATION AND STAR FORMATION FROM $Z = 1.5$ TO $Z = 4$ IN THE COSMOS FIELD

The COSMOS field was observed by *Herschel*/SPIRE in the framework of the HerMES key programme (Oliver et al. 2012). Three rest frame FUV-selected samples are built at $z \sim 1.5, 3$ and 4 using the optical images in u*, r+ and i+ and the photometric redshifts of Ilbert et al. (2013). ~ 42000, ~ 24000 and ~ 7700 galaxies are thus selected. Less than 1% of these sources are detected in the SPIRE images so we rely on a stacking analysis on the position of the selected sources. We first show the results of the stacking procedure as a function of the FUV luminosity $L_{\rm FUV}$ and then as a function of $M_\star$ in Figure 1. The $L_{\rm IR}/L_{\rm FUV}$ ratio can be translated in a measure of dust attenuation $A_{\rm FUV}$ (Buat et al. (2005). The average IR emission of the FUV selected galaxies put them in the LIRG and sub-LIRG range (corresponding to $L_{\rm IR} < 10^{11} L_\odot$). Dust attenuation is mostly independent of $L_{\rm FUV}$ at $z = 1.5$. Its decrease observed at $z = 3$ and 4 when $L_{\rm FUV}$ increases as well as the average increase of dust attenuation with redshift is found to be linked to the stellar mass of the galaxies. Indeed, dust attenuation as traced with the $L_{\rm IR}/L_{\rm FUV}$ ratio correlates with $M_\star$ and we do not find any clear evolution with redshift of the correlation. The SFR traced by the FUV and IR emissions (Figure 2) correlates with $M_\star$ defining a main sequence at each redshift considered well described by a power law (SFR $\propto M_\star^{-0.7}$) with a similar amplitude at $z = 3$ and 4, which is found lower by a factor of 4 at $z = 1.5$. In Figure 3 the specific SFR (sSFR = SFR/$M_\star$) is plotted as a function of z for different bins of $M_\star$ and compared to other measurements and various model predictions. The measured value is higher than the predicted ones, and roughly consistent with the plateau found by Bouwens et al. (2012) at higher redshift. The discrepancy with models is found stronger for the lower bin of mass.

3. WHAT CAN WE EXPECT FROM *SPICA* OBSERVATIONS?

The detection of FUV selected objects in the IR is a challenge. As we have seen in section 2, *Herschel* was almost unable to detect individual galaxies from our samples. The studies based on stacking analyses bring only general trends and the specific properties of the galaxies are not accessible. The situation with *SPICA* will evolve dramatically. With a deep cosmological survey at 70 μm a large number of individual UV selected galaxies will be directly detected. Let us assume a detection limit of 50 μJy at 70μm, such a value can be reached using a detection technics based on priors. Using the Dale & Helou (2002) templates with $\alpha = 2$ (representative of FUV selected galaxies up to z=2 (Buat et al. 2012)). Based on the average fluxes found with the stacking analysis, we expect to detect more than 9000 galaxies per sq.deg. at z=1.5, more than 3000 at z=3 and around 900 objects at z=4. With such a large sample of individual detections we will be able to measure the dispersion of the SFR-$M_\odot$ relation and to characterize normal versus starbursting galaxies by measuring their specific star formation rate and to compare their properties to those from models of high redshift galaxies.

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