Preparing for LSST Data: in Search of Main Physical Properties of the Main Sequence Galaxies

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The main goal of the Vera C. Rubin observatory is to perform the 10 year *Legacy Survey of Space and Time* (LSST). This future state-of-art observatory will open the new window to study billions of galaxies from Local Universe as well as the high redshift objects. To get ready to work with the petabytes of data collected by the LSST we performed a simulation of future observations and uncertainties based on the 50 385 real galaxies within the redshift range $0 < z < 2.5$, from the ELAIS N1 and COSMOS fields of the *Herschel Extragalactic Legacy Project* (HELP) survey. We obtain the main physical properties of the galaxies (such as SFR, $M_{\rm star}$, and $L_{\rm dust}$) using the Code Investigating GALaxy Emission (CIGALE) by modelling their spectral energy distributions. To test the performance of the fit on the LSST observations, we compared the main galaxy physical properties obtained from the SED fitting performed on the real galaxies (with UV to the far-IR coverage) with the one obtained with the simulated LSST optical measurements alone.

1 Introduction

In the past 20 years, the modeling of the spectral energy distribution (SED) of galaxies has become an important and powerful method to properly estimate their physical properties. Because the SED is the result of a complex interaction between several components (e.g., emission of stars, dust, and interstellar medium), only the entire spectral coverage (from X-ray to far infrared) would give an exhaustive understanding of the physical properties of galaxies. For example, in the literature (i.e., Kennicutt 1998, Le Floc'h et al. 2005, Schreiber et al. 2015, and Whitaker et al. 2017) it has been shown that the ultraviolet (UV) to infrared (IR) SED contains important information about the star formation activity of galaxies. In fact, newborn star tends to emit mainly in the UV band, while the dust, that surrounds the star forming regions, absorbs part of the UV emission and re-emits it in the IR band.

For this reasons, modeling the broad-band SED of galaxies has become one of the most commonly employed methods to evaluate and constrain the physical properties. However, the full SED is rarely available and considering only restricted wavelength ranges can cause problem in the estimation of the physical parameters, due to degeneration issues.

The upcoming *Legacy Survey of Space and Time* (LSST, Ivezić et al. 2019) from the Vera C. Rubin Observatory, will provide high-quality optical images in the *ugrizy* bands of about 20 billion galaxies over 10 years of observations. This large dataset will raise multi-fold questions, such as how we can use the LSST optical observations only to obtain estimates of the main physical properties of galaxies and how realistic and reliable they would be. We investigate these topics by performing a simulation of the LSST observations of main-sequence (hereafter MS) galaxies to estimate the main physical properties using an SED fitting method.

2 Data and methodology

The data adopted in this work comes from the *Herschel Extragalactic Legacy survey* (HELP, Shirley et al. 2021), that provides extremely valuable multi-wavelength data over the HerMES (Oliver et al., 2012) and the H-ATLAS survey fields (Eales et al., 2010) and other relevant *Herschel* fields. We use two of the HELP fields: the European Large Area ISO Survey North 1, hereafter ELAIS N1 (Oliver et al., 2000), and the COSMOS field (Laigle et al., 2016). In order to select MS galaxies, we remove all possible starburst and passive galaxies from the catalogue. We then simulate the LSST observations according to the technical description of the future survey (Ivezić et al., 2019) and perform the SED fitting. The detailed description of the methodology, used parameters, and test can be found in Riccio et al. (2021).

3 Results

We calculate the main galaxy physical properties: the star formation rate (SFR), the dust luminosity ($L_{\rm dust}$), and the dust mass ($M_{\rm dust}$) for the LSST sample and we compare the results with the full UV-FIR (far-IR) estimates. We obtain an overestimation of the dust related properties SFR, $L_{\rm dust}$, and $M_{\rm dust}$. We found this overestimation strongly dependent on the redshift, due to the lack of information in the UV and the mid-IR (MIR) rest-frame wavelenghts. This missing information causes an artificial rise of the attenuation of the young stellar population (Fig. 1) which results in overestimation of the physical properties. The ratio of the stellar masses is instead evenly distributed around zero, leading to comparable results between the two runs, because stellar masses mostly rely on the optical data.

To provide a valid method of estimation of the physical properties using the LSST observations with SED fitting we tried different methods to correct the observed overestimation. The first approach assumes usage of auxiliary data (e.g., the MIR *Spitzer* bands, FIR *Herschel* Spire bands). By adding the rest-frame near infrared (IR) measurements the attenuation of the old stellar population would be better constrained, while the MIR and FIR mainly constrain the dust emission from the star-forming regions and the SFR hidden by dust. Riccio et al. (2021) showed that adding mid-IR or ultraviolet observations, along with the LSST bands, the overestimation is completely corrected.

The second approach is to use a recently explored relation between attenuation in far-UV ($A_{\rm FUV}$) and $\log_{10}(M_{\rm star})$ over a wide mass range ($9 \leq \log_{10}(M_{\rm star}) \leq 12$; Xu et al. 2007, Martin et al. 2007, Buat et al. 2009, Bogdanoska & Burgarella 2020).

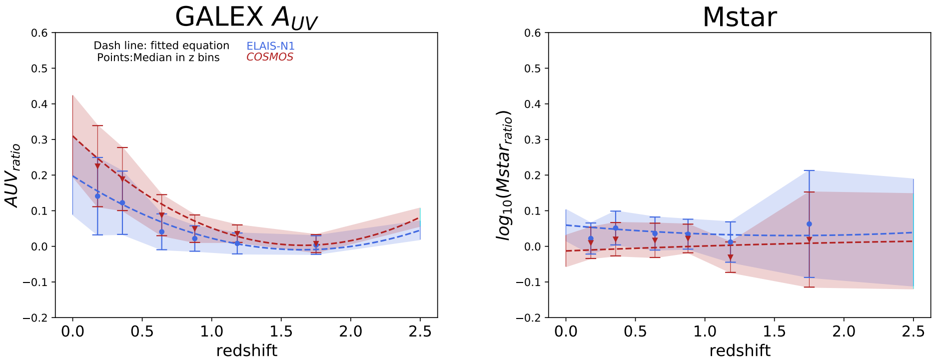

Fig. 1: UV attenuation ratio (*left*) and $M_{\rm star}$ ratio (*right*) as a function of redshift for the ELAIS N1 and COSMOS fields. The ratios are defined as $AUV_{\rm ratio} = AUV_{\rm LSST}/AUV_{\rm UV-FIR}$, The points are the median values in each redshift bin, with the median absolute deviation as errors.

This method can be applied using the LSST observations only, as the $M_{\rm star}$ employed to retrieve the $A_{\rm FUV}$ is well estimated by the LSST (see Fig. 1 right panel). The procedure adopted is as follows: (1) from the LSST data we estimate the $M_{\rm star}$, (2) from the real multi wavelength (UV-FIR) data we obtain the $A_{\rm FUV}$ -$M_{\rm star}$ relation, (3) we use the relation with the $M_{\rm star}$ estimated with the LSST data to retrieve the $A_{\rm FUV-LSST}$, (4) we use $A_{\rm FUV-LSST}$ as a prior of the new LSST CIGALE run to estimate the physical parameters. Riccio et al. (2021) shows the full correction of the estimated SFR employing this method. This result is particularly interesting because proves that knowing the $A_{\rm FUV}$ –$M_{\rm star}$ relation for a given sample of galaxies, it is possible to estimate the SFR without the IR counterpart, making it a powerful tool to use with the LSST.

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