Resolving the Rise and Fall of Star Formation in Galaxies
Proceedings IAU Symposium No. 373, 2023
T. Wong & W.-T. Kim, eds.
doi:10.1017/S1743921322004793

New era of LSST data: Estimating the physical properties of main-sequence galaxies

G. Riccio

National Centre for Nuclear Research, Astrophysics division
ul. Pasteura 7, 02-093 Warszawa, Poland
email: gabriele.riccio@ncbj.gov.pl

Abstract. 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. In this work we employ simulated LSST 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, to constrain the physical properties of normal star-forming galaxies, such as their star formation rate (SFR), stellar mass (Mstar), and dust luminosity (Ldust). We fit their spectral energy distributions (SEDs) using the Code Investigating GALaxy Emission (CIGALE). The stellar masses estimated based on the LSST measurements agree with the full UV to far-IR SED, while we obtain a clear overestimate of the dust-related properties (SFR, Ldust) estimated with LSST. We investigate the cause of this result and find that it is necessary to employ auxiliary rest-frame mid-IR observations, simulated UV observations, or the far-UV attenuation (AFUV)-Mstar relation to correct for the overestimate.

Keywords. SED, LSST, Extragalactic Astrophysics, SFR

1. Introduction

The total spectral energy distribution (SED) of galaxies is the result of a complex interplay of several components, such as old and young stars, stellar remnants, the interstellar medium, dust, and super- massive black holes (Walcher 2011, Conroy 2013). For this reason, the study of the multi-wavelength emission of galaxies from X-rays to radio was found to be necessary to properly analyse the physical properties of galaxies, as only the panchromatic view can give the full information about their physical properties. For example, in the literature (i.e. Kennicutt 1998, Schreiber 2015) it has been shown that the ultraviolet (UV) to infrared (IR) SED contains important information about the star formation activity of galaxies. In fact, young stars emission is dominant in the UV band, while the dust, that surrounds the star forming regions, thermally absorb this light and re-emits it in the IR band. However, it is rare to have available the full SED 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, Ivezic 2019) from the Vera C. Rubin Observatory, will provide high-quality optical to near-IR images in the *ugrizy* bands of about 20 billion expected galaxies over ten years of observations. This large dataset will raise multi-fold questions, such as how we can use only LSST observations 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 LSST

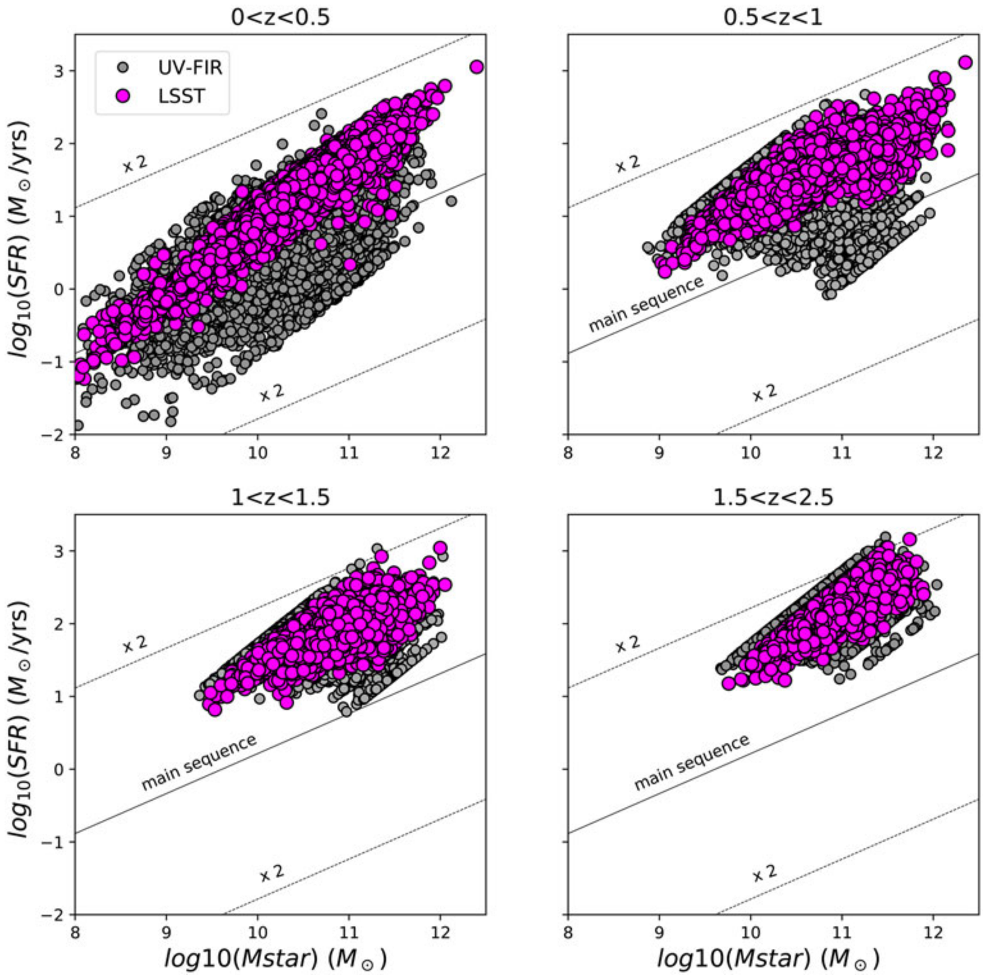

Figure 1. Main-sequence (SFR vs M_{star}) relation for the ELAIS-N1 and COSMOS fields in four redshift bins. In magenta we show the LSST-like sample, and in grey the real sample. The solid black line represents the MS by Speagle (2014), and the dashed lines mark the loci two times above and below the MS.

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 2021), that provides extremely valuable multi-wavelength data over the HerMES (Oliver 2012) and the H-ATLAS survey fields (Eales 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 2000), and the COSMOS field (Laigle 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 (Ivezic 2019) and perform the SED fitting. The detailed description of the methodology, used parameters, and test can be found in Riccio (2021).

https://doi.org/10.1017/S1743921322004793 Published online by Cambridge University Press

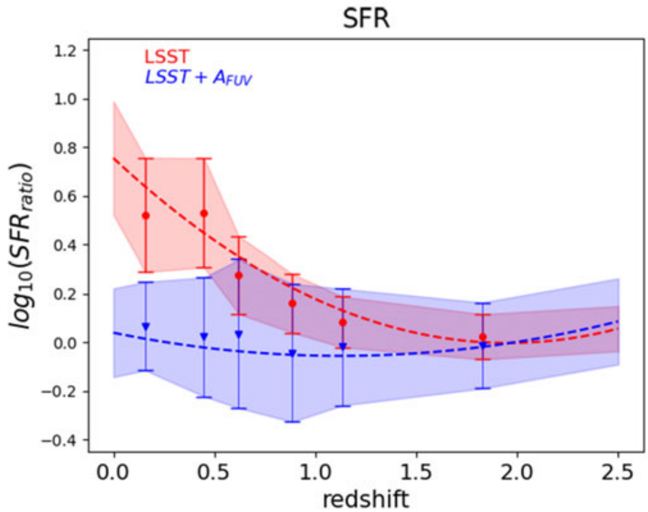

Figure 2. SFR ratio as a function of redshift for the ELAIS-N1 and COSMOS fields. Blue curve represents the result adding the A_{FUV} prior. The ratio is defined as $SFR_{ratio} = SFR_{LSST}/SFR_{UV-FIR}$, The points are the median values in each redshift bin, with the median absolute deviation as errors.

3. Results

We estimate the main galaxy physical properties (SFR, M_{star}, L_{dust}, M_{dust}) for the LSST sample and we compare the results with the full UV-FIR estimates. We obtain an overestimation of the dust related properties (SFR, L_{dust}, and M_{dust}). We found this overestimation strongly dependent on the redshift, due to the lack of information in the UV and MIR rest-frame wavelenghts. In Fig. 1 we show the MS relation obtained for the LSST-like sample with the relation obtained from the full UV-FIR SED fitting. At low redshift, the LSST estimation fails to probe low-SFR objects, and this leads to a clear division between the respective MS relations, which overlap at higher redshifts, however. The stellar masses are instead well estimated with LSST, leading to comparable results between the two runs, because their estimation mostly rely on optical data.

To provide a valid method of estimation of the physical properties using LSST observations with SED fitting we tried different methods to correct the observed overestimation. The first approach assumes usage of auxiliary data (e.g. 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 mid- and far- IR mainly constrain the dust emission from the star-forming regions and the SFR hidden by dust. Riccio (2021) showed that adding mid-IR or ultraviolet observations, along with LSST bands, the overestimation is completely corrected.

The second approach is to use a recently explored relation between attenuation in far-UV (A_{FUV}) and $log_{10}(M_{star})$ over a wide mass range ($9 \leq log_{10}(M_{star}) \leq 12$) (Buat 2009, Bogdanoska 2020). This method can be applied using LSST observations only, as the M_{star} employed to retrieve the A_{FUV} is well estimated by LSST. The procedure adopted is as follows: (1) from the LSST data we estimate the M_{star}, (2) from the real multi wavelength (UV-FIR) data we obtain the A_{FUV}-M_{star} relation, (3) we use the relation with the M_{star} estimated with LSST to retrieve the $A_{FUV\ LSST}$, (4) we use $A_{FUV\ LSST}$ as a prior of the new LSST CIGALE run to estimate the physical parameters. Fig. 2 shows the full correction of the estimated SFR employing this method. This result is particularly interesting because proves that knowing the A_{FUV}–M_{star} relation for a

https://doi.org/10.1017/S1743921322004793 Published online by Cambridge University Press

given sample of galaxies, it is possible to estimate SFR without the IR counterpart, making it a powerful tool to use with LSST.

Acknowledgements

GR acknowledges support from the Polish National Science Centre (UMO-2018/30/E/ST9/00082, and UMO-2018/30/M/ST9/00757). Authors are grateful for the support from Polish Ministry of Science and Higher Education through a grant DIR/WK/2018/12.

References

Walcher, J., Groves, B., Budavári, T., & Dale, D., *et al.* 2011, *Ap&SS*, 331, 1
Conroy, C., 2013, *ARA&A*, 51, 393
Kennicutt, J., Robert C., *et al.* 1998, *A&A*, 36, 189
Bogdanoska, J., Burgarella, D., *et al.* 2020, *MNRAS*, 496, 4, 5341
Buat, V., *et al.* 2009, *A&A*, 507, 2, 693
Eales, S., *et al.* 2010, *PASP*, 122, 891, 499
Ivezic, Z., *et al.* 2019, *ApJ*, 873, 2, 111
Laigle, C., *et al.* 2016, *ApJS*, 224, 2, 24
Oliver, S., *et al.* 2000, *MNRAS*, 316, 4, 749
Oliver, S. J., *et al.* 2012, *MNRAS*, 424, 3, 1614
Riccio, G., *et al.* 2021, *A&A* 653, A107
Schreiber, C., *et al.* 2021, *A&A* 575, A74
Shirley, R., *et al.* 2021, *MNRAS* 507, 1, 129
Speagle, J. S., Steinhardt, C. L., Capak, P. L., & Silverman, J. D., *ApJS*, 214, 15

https://doi.org/10.1017/S1743921322004793 Published online by Cambridge University Press