The SPARTAN project

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Abstract. As we gather more and more observations of billions of object we also re-observe astronomical objects with different facilities in order to inspect their emission in different wavelength domain and study their nature. SPARTAN (SPectroscopy And photometRy fiTting tool for Astronomical aNalysis) is a project of SED-fitting tool able to use combination of spectroscopic and photometric data to increase the constraints on physical parameters of galaxies. We describe in this proceeding the main function of this tool and give some usage examples.

1. Introduction

The study of galaxy formation and evolution implies the study of their properties at different epochs of the cosmic history. In the last decade the *template fitting* method have been widely used to try to constrain galaxy properties like Stellar Mass (M*), Star Formation rate (SFR), Dust extinction, age, etc. This was done mainly from photometric observations for which multi-wavelength domains are available (Bolzonella et al. (2000), Ilbert et al. (2006)). In parallel, the development of spectrographs allowed to take spectroscopic information of large sample of galaxies and tools have been developed to fit this spectroscopy e.g. GOSSIP+ (Thomas et al. 2017a) or Beagle (Chevallard & Charlot 2016). Following the same path as for the photometry, it becomes now common to have multi-spectral observations for a given object, in addition to the multi-wavelength photometry. In this framework we briefly present here the SPARTAN project that aims at constraining galaxy physical parameters from combination of spectroscopic and photometric galaxy observation. We first describe in sect 2 the fitting method and then present examples of single and multi-component fitting with simulated data in Sect. 3.

2. Methods: single and multi-component template fitting

The classical one-component fitting method follows the same recipe as standard SED-fitting approach (Thomas et al. 2017b). We first create libraries of template models to fit the single instrument observation. Then for each observed galaxy, we perform a minimization over the entire template library. For a given galaxy and a given template the χ^2 and its associated Probability are computed with

$$\chi^2 = \sum_{i=1}^{N} \frac{(F_{obs,i} - A_i F_{syn,i})^2}{\sigma_i^2}; \; P = \exp\left[-\frac{1}{2}\left(\chi^2 - \chi^2_{min}\right)\right] \tag{1}$$

where $F_{obs,i}$, $F_{syn,i}$, σ_i , A_i and χ^2_{min} are the observed flux (or magnitude), synthetic flux density (or magnitude) from the template, observed error, and normalization factor applied to the template, and the minimum χ^2 of the library of template, respectively. The set of χ^2 values are then used to create the PDF. From the PDF we create the cumulative distribution function (CDF) where the measured value of the parameter is taken where CDF(X)=0.5 and the errors on this measurements correspond to the value of the parameter for which the CDF=0.05 and 0.95.

For multi-component analysis we used the generalization of the method widely used in the literature with the classical photometric SED-fitting: a direct combined fitting of the components. Indeed, when fitting photometric data only for a given galaxy, people gather different kind of datasets coming from different instruments. For example in Ciesla et al. (2015) the authors used in their analysis multiple photometric systems : from MOSAIC (1 band every 1000Å) to Herschel (with 1 band every 150μm=1,500,000Å). In other words, the ratio between the lowest and highest *photometric resolution* is of ∼1500. The $\chi 2$ method deals with the different SNR (through the errors on the measurements), the different wavelength coverage and *photometric resolution*. The method implemented in SPARTAN to combine multi-instrumental datasets is a simple generalization of this method to spectroscopic/photometric combination. We fit the combination of data at once. For example, we fit the combination of two spectra (whatever the resolution and SNR) as if it was a single spectrum. This is equivalent to using the generalization of the χ^2 to multi-datasets with the following relation (Wall & Jenkins 2003) :

$$\chi^2_{tot} = \sum_{i=1}^{N} \chi^2_i \tag{2}$$

where χ^2_{tot} is the total χ^2 for the combination of multi-instrumental datasets and χ^2_i are the individuals χ^2 for each dataset taken separately.

3. Examples

To show the capabilities of SPARTAN with single and multiple component we simulate star forming galaxies between z=2.3 and z=3.5 with 2 spectroscopic components; a VIMOS-like spectrum and a HST-like spectrum and four photometric components; the *u*-band from Megacam, BVriz bands from the Subprime Camera in Subaru, JHK bands from Wircam and the two first channel of Spitzer-IRAC at 3.6 and 4.5 microns. Each template used for the creation of the simulation is selected randomely from a library with various age, dust extinction, metallicity, intergalactic medium transmission (IGM) and star formation history.

Figure 1 shows the different fits that can be performed by SPARTAN of one these simulated galaxies with different combination of observations (left column). The right hand side column shows the ΔSFR estimations for the sample of simulated galaxies space (with ΔSFR=SFR$_{measured}$-SFR$_{simulated}$). The first line shows the fit on all the photometric component (from *u* to Irac 4.5μm). It shows that with photometry only, it is hard to disentangle emission line galaxies with older, emission-line free galaxies.

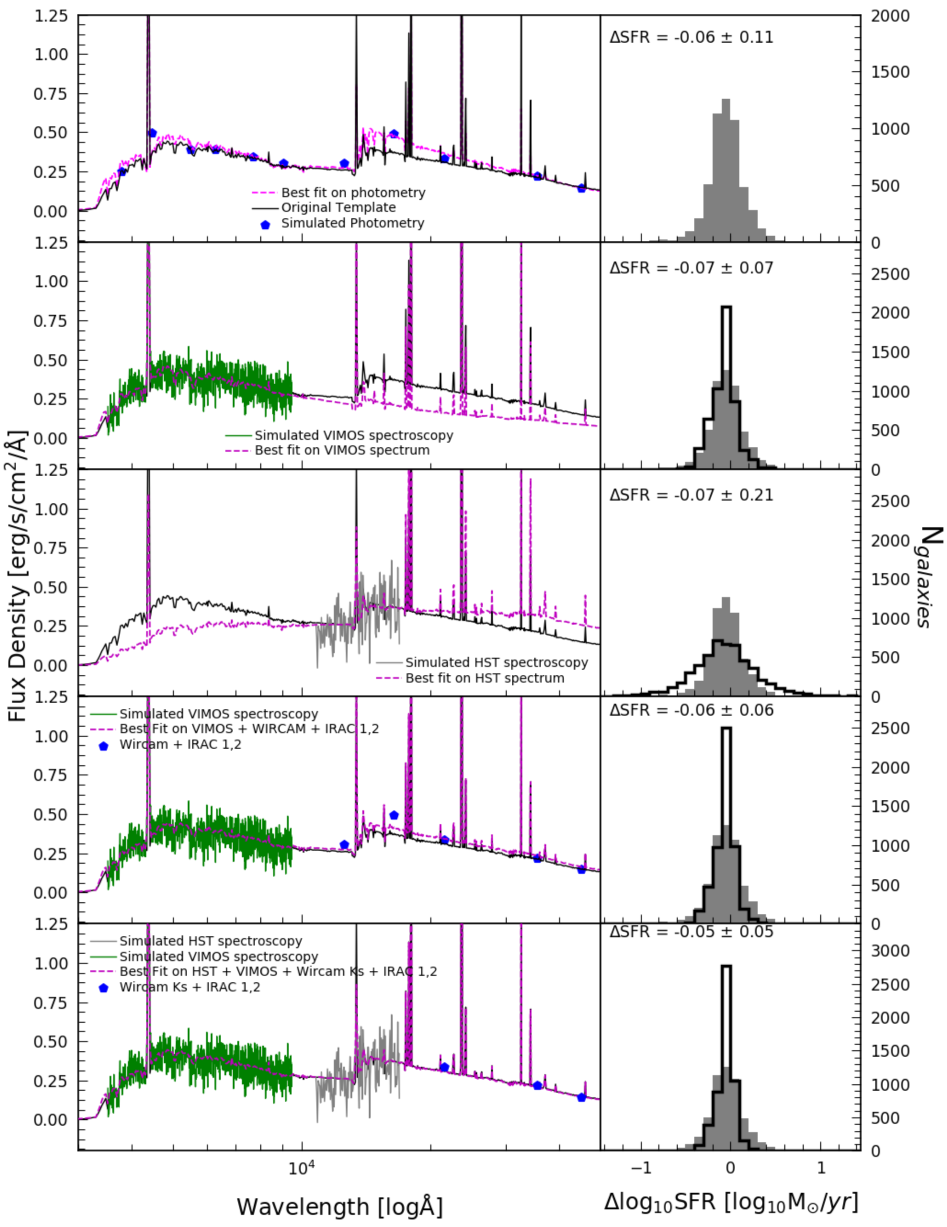

Figure 1. Fitting options allowed in SPARTAN (left column) and their relative merits with respect to star formation rate estimations (right column).The grey histogram shown in each distribution panel corresponds to the one of the fit of photometry only (top-right). Values in the histogram correspond to the median ± MAD.

The ΔSFR histogram shows that the systematic error (median value) is low, at -0.06 but the median absolute deviation (MAD) is of 0.11 (σ = 0.26). The fit of VUDS-like spectroscopy shows that the red part of the original template can not be reproduced. It is due to the fact that we do not constrain the red part of the wavelength domain (as shown by the fit example). Therefore the Mass will not be constrained. Moreover the precision on the SFR is higher than with photometry only (MAD=0.07) since the UV-restframe spectroscopy brings much more constraint in the UV where the young stars emit the most. Nevertheless the accuracy remain at the same level at -0.07. The third line shows the fitting of optical-rf spectroscopy only with HST-like simulation. Since we do not have constraints in the UV part of the domain, the estimation of the SFR is not reliable (low precision with MAD=0.21). Having single spectroscopy and multi-λ photometry in hands becomes common in the community. When combining them the results are better. We see that adding 5 NIR photometric points to ~ 1000 spectrscopic points helps a lot in the fit where now the red part of the best fit template is much closer than without photometry. The star formation rate estimation benefits from the strong constrains brought by the VIMOS-like spectrum and is twice as precise as with photometry only. The last option that SPARTAN allows is the combination of multi-λ spectroscopy and multi-λ photometry (fifth line). The fitting example shows that we have an excellent agreement between the original template and the best fit template. Replacing the photometry by the spectroscopy in two different wavelength window improves greatly the constraints. The SFR measurements are very good as they produce best median and MAD values at -0.05 and 0.05, respectively.

4. Conclusion

The SPARTAN project is a SED-fitting tool program. It aims at providing the community with a framework to perform multi-components (spectroscopy and photometry) fitting. Adding spectroscopy to the photometric information increases greatly the observational constraints on galaxy models and gives better parameter estimation than using photometric data only. In the era of spectroscopic observations this should become a standard way of galaxy template fitting analysis.

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