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Retrieving the stellar content in distant starbursts

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Abstract. In starburst galaxies, the light emitted by the young and massive stars dominates the photon budget along most of the SED and hides the old and intermediate stellar populations. The fraction of old stars and the stellar mass are systematically underestimated by current methods (Wuyts *et al.* (2009)). We have implemented a new method to retrieve stellar masses and stellar populations in distant galaxies from photometry and spectral features. The method uses a complex SFH description and a new constraint has been introduced: the star-formation rate (SFR).

Keywords. galaxies: high-redshift, galaxies: photometry , galaxies: starburst

1. Introduction

Many works have emphasised the fundamental role of stellar mass in galaxy evolution. Stellar mass is found to correlate with many galaxy properties, such as luminosity, gas metallicity, colour and age of stellar populations, star-formation rate, morphology, and gas fraction, to enumerate a few of them Brinchmann & Ellis (2000), Bell *et al.* (2003), Kauffmann *et al.* (2003), Tremonti *et al.* (2004), Bell *et al.* (2007). Ironically, the stellar mass is one of the most poorly constrained quantities in distant galaxies. This difficulty arises from the fact that one of the main contributors to stellar mass, the low-mass stars on the main sequence (type G to K stars) are extremely faint and almost do not contribute to the integrated light of the stellar population as a whole. The dominance of young massive stars in any stellar population is responsible for the strong sensitivity of the SED shape to the star-formation history.

2. Complex star formation history and the SFR constraint

In starburst galaxies the principal issue in the proper recovery of the stellar populations and the stellar mass is the fact that the young stars dominate the light budget throughout the SED. The methods available in the literature suffer from systematic effects due to the simplicity of the assumed star formation history for these objects. The implementation of a complex SFH without parametrisation - such as the combination of several single stellar population templates- is not possible because of the degree of degeneracy of the problem. To break the degeneracy, we propose to add a new constraint in the optimization problem: the total star-formation rate (SFR_{UV} and SFR_{IR}). Adding the total SFR constraint allows an alleviation of the problem by limiting the amount of young stars with ages younger than 100 Myr. In particular, it induces strong constraints in the blue part of the spectra - most especially the amount of light due to young stars - and permits a

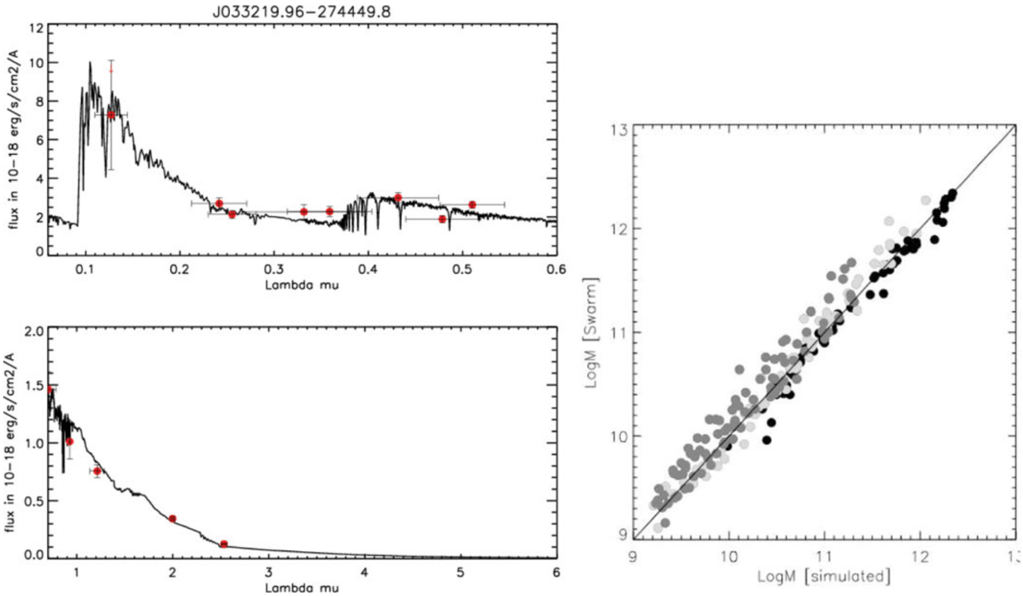

Figure 1. Left: Synthesis of a $z \sim 0.6$ starburst SED from photometry and observed SFR using a combination of 6 CSP with exponential decline timescale of 100Myrs and a two-component extinction law. The minimization of the χ^2 statistic has been realized with the swarm intelligence algorithm. **Right**: Comparison of the Mstar of a sample of simulated galaxies with the Mstar estimated by our code. The colour codes the mass fraction of old stellar population (older than 3 Gyr) in the galaxy: in black (light grey) galaxies with more than 80% (50-80%) of their Mstar locked into old stellar population. The dark grey symbols correspond to very young systems with 50% of stars younger than 3 Gyr.

better evaluation of dust obscuration from the blue slope of the SED. Moreover, adding the SFR constraint solves the problem encountered in spectrum synthesis Cid Fernandes *et al.* (2005), Mathis *et al.* (2006), i.e. the difficulty to recover the mass fraction of the intermediate age population.

3. Optimization problem

We have fitted the SED by a set of $N_\star$ single metallicity population synthesis templates $T^i(\lambda)$ (i=1,..., N). The best-fitting model SED $F(\lambda)$ is given by:

$$F(\lambda) = \sum_{i=0}^{N_\star} x_i \, T^i(\lambda) \otimes Dust(E(B-V), R_V) \qquad (3.1)$$

where x_i are non-negative coefficients representing the fraction of light of the template T^i, and Dust is the two parameter extinction law of Cardelli et al. (1989). We have assumed that only the young stellar population (age < 500 Myr) is affected by the dust and the same E(B-V) and R_V have been applied to these templates. The SFR constraint is imposed in the problem by a penalty function. The optimization function to minimize is thus:

$$\chi^2(x^i, E(B-V), R_V, SFR_{obs}) = \chi^2_{photo}(x^i, E(B-V), R_V) + P(SFR). \qquad (3.2)$$

$$\chi^2_{photo}(x_i, E(B-V), R_V) = \sum_{j=1}^{N_{filter}} \frac{(f_j^{obs} - f_j^{model})^2}{\sigma^2 f_j^{obs}} \qquad (3.3)$$

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where f_j^{obs} is the rest-frame flux of the object in filter j, its associated uncertainty is $\sigma fobs_j$, and f_j^{model} is the flux of the synthetic spectrum in the j-band. The penalty function on the SFR is given by:

$$P(SFR) = \left(\frac{SFR_{obs} - SFR_{model}}{\sigma SFR_{obs}} \right)^2 \quad (3.4)$$

Adding the SFR constraint introduces a plethora of local minima to the minimization problem, rendering the localization of the best solution difficult with conventional code based on the gradient or Hessian function. The global solution of the optimization problem was found with a metaheuristic approach, the Swarm intelligence algorithm.

4. Validation of the method

We have tested the accuracy of the algorithm to retrieve the stellar mass using a library of fake galaxies. The results are shown in figure 1. The algorithm recovers the stellar mass within a random uncertainty of $\pm 0.15\,dex$. There is a small systematic of +0.1 dex in the derived stellar mass for galaxies with extremely high fractions of young stars. The preliminary results show that the constraint on the SFR improves the accuracy on the derived stellar mass and stellar population in star-forming galaxies. Work is in progress to include the spectral information in the optimization process using lick indices or principal component analysis.

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