New photometric models of galactic evolution applied to the HDF

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Abstract.

We summarize our modelling of galaxy photometric evolution (GRASIL code). By including the effects of dust grains and PAHs molecules in a two phases clumpy medium, where clumps are associated to star forming regions, we reproduce the observed UV to radio SEDs of galaxies with star formation rates from zero to several hundreds $M_\odot yr^{-1}$.

GRASIL is a powerful tool to investigate the star formation, the initial mass function and the supernovae rate in nearby starbursts and normal galaxies, as well as to predict the evolution of luminosity functions of different types of galaxies at wavelengths covering six decades. It may be interfaced with any device providing the star formation and metallicity histories of a galaxy.

As an application, we have investigated the properties of early–type galaxies in the HDF, tracking the contribution of this population to the cosmic star–formation history, which has a broad peak between $z=1.5$ and 4. To explain the absence of objects at $z \gtrsim 1.3$, we suggest a sequence of dust–enshrouded merging–driven starbursts in the first few Gyrs of galaxies lifetime.

We are at present working on a complementary sample of late type objects selected in a similar way.

1. GRASIL

Standard spectrophotometric synthesis consists in summing the spectra of all generations of stars (Simple Stellar Populations, SSPs) of appropriate age and metallicity, as provided by the star formation history of the galaxy. This simple procedure neglects the complexities (e.g. dependence on geometry) introduced by a dust rich ISM, whose presence is probably the rule for star forming systems.

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To properly reproduce the spectral properties of galaxies from UV to sub-mm we have included in our modelling the effects of dust in three environments: (1) envelopes of AGB stars, (2) dense star forming molecular complexes (MCs=HII regions+Giant Molecular Clouds), and (3) diffuse ISM (cirrus).

AGB dusty shells are directly included in the spectra of SSPs according to the prescriptions given by Bressan, Granato & Silva 1998. As for (2) and (3), see the scheme sketched in Figure 1. The ISM of the axially symmetric galaxy is divided in a dense phase associated with younger stellar generations (MCs) and a diffuse phase. The association between dense dust and young stars stems from the fact that we decrease with the age of each SSP the fraction of its light radiated inside the cloud (Figure 2). The radiative transfer is solved whenever necessary.

The observed UV to radio SEDs of different types of galaxies, from quiescent ellipticals to massively star-forming ULIRGs, are remarkably well reproduced with our model (see Figure 3 for an example and Silva et al. 1998 for details).

Figure 1. Scheme of the galaxy model, including both a smooth medium and clumps (MCs) associated with star formation. The most general geometry consists in a superposition of a bulge and disk component.

The resulting code (GRASIL) may be used as the observational interface of any code providing the history of SF and eventually of metallicity of the galaxy (see for instance Silva et al. 1999).
The association between dust clumps and young stars stems from the fact that we decrease with the age of each SSP the fraction of its light radiated inside the cloud.

2. The contribution of field galaxies to the cosmic SF history.

In the past few years many efforts have been devoted in deriving the cosmic history of star formation and/or metal production, which may constrain models of structure formation. These derivations are mainly based on optically selected high–z galaxies, in particular by means of the Lyman drop–out technique. A well recognized problem is that optical surveys are strongly biased against very old or very dusty galaxies.

We have thus pursued a complementary approach: a study of the stellar populations of K band selected samples (one of early type and another of late type galaxies) in the HDF, as representatives of corresponding field populations. The K–band selection has two advantages: (1) it minimizes the effects of K- and evolutionary corrections and (2) the flux at these wavelengths is contributed mainly by stars dominating the barionic mass.

2.1. Early type galaxies

The early type sample consists in 35 objects with $K \leq 20.15$, $z \lesssim 1.3$, and with the bulk of the light distribution well described by $r^{-1/4}$ profiles. The objects appear to be essentially free from dust obscuration. As a consequence the 7 bands photometry (4 HST + 3 near–IR) from 0.3 to 2.2 micron allows to date the dominant stellar populations, which are found at $z \lesssim 1.3$ to have a quite wide range of ages (typically from 1.5 to 3 Gyr). Also the bright end of the E/S0 population appears to be
Figure 3. The observed radio to UV SED of the archetypal starburst galaxy M82 reproduced by GRASIL.

mostly in place by that cosmic epoch (see Franceschini et al. 1998 for details).

Having derived from the SED fitting procedure a good guess of the SF history for each sample galaxy, we have estimated the contribution of the population to the cosmic history of SF. This is compared with that derived from optical surveys in Figure 6. It is clear that a significant fraction of light emitted during the star–formation phases of early–type galaxies has been lost in the optical, probably because obscured by dust. This possibility could explain also the sharp cutoff at $z \sim 1.3$ in the $z$ distribution of our sample galaxies (Figure 4).

The IR/sub–mm extragalactic background may be a trace of this dust–extinguished SF, while a direct testing requires powerful dedicated instruments.

2.2. Late Type Galaxies

A complementary effort we are carrying on, is devoted to a sample of 52 late type (spiral and irregular) galaxies with $K \leq 20.5$. In this case the interpretation is more complex because the light emitted by these objects is clearly dust extincted to some degree. As an example we show in Figure 5 the best fit we obtain, for a typical object in the sample, together with its $\chi^2$ contours. The latter are intended to
Figure 4. Continuous line: observed $z$-distribution of our sample of early type galaxies; dotted and shaded lines: model predictions without dust obscuration during the star-forming phase; shaded region: model prediction including dust obscuration during star-formation.

give a feeling of the level of degeneracy between age and gas content: even assuming a specific model galaxy with a fixed star formation history typical for spirals, it is possible to obtain acceptable fits in a range of ages from 0.5 to 3 Gyr at least, simply adjusting the gas content and thus the amount of extinction. Only a good coverage of the IR region (in particular above $\sim 40\mu m$), where dust radiates the absorbed energy, would allow to discriminate between the many viable possibilities on the basis of optical and near-IR data alone. Therefore our preliminary determination of the contribution of these objects to the SF history of the universe, also shown in Figure 6, is prone to larger model uncertainties, presently under study.

References

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Figure 5. Best fit and $\chi^2$ contours for a typical object in the late type sample: acceptable fits have ages ranging from 0.5 to 3 Gyr, by adjusting the gas content and thus the amount of extinction.
Figure 6. Contribution of field galaxies to the cosmic SF history: the two lower solid line are upper and lower limit for field ellipticals, the lower shaded area is bounded by two different estimates for field late type, and the upper solid line is the sum of the previous two, which turns out to be in good agreement with average determinations based on metal abundance in clusters (horizontal shaded area).
