Fitting the spectral energy distributions of galaxies with CIGALE : Code Investigating GALaxy Emission *

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Fitting the spectral energy distributions of galaxies (SEDs) is a more and more used technique. SED-fitting codes have significantly evolved in the last decade towards specific purpose based on outputs people want to focus on. We describe the code CIGALE (Code Investigating Galaxies Emission : Burgarella et al. 2005; Noll et al. 2009b) which provides physical informations about galaxies by fitting their UV-to-IR SED.

CIGALE is based on the use of a UV-optical stellar SED plus a dust IR-emitting component. First, UV-to-IR models are built, and second, these models are fit to the observed SEDs. The code fits the observed data in the UV, optical, and NIR with models generated with a stellar populations synthesis code, assuming an star formation history and a dust attenuation scenario as input. The energetic balance between dust-enshrouded stellar emission and re-emission in the IR is carefully conserved by combining the UV/optical and IR templates.

With CIGALE we can estimate physical parameters related to the star formation : star formation rate (SFR), stellar mass, total IR luminosity (L_{IR})... and also attenuation parameters and the percentage of AGN contamination for the IR luminosity.

Description of CIGALE

Stellar populations

First step of CIGALE : the code builds complex stellar populations with several single stellar populations (SSP) according to the input parameters of the star formation history (SFH).
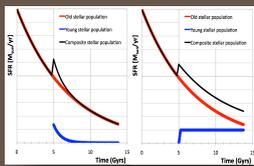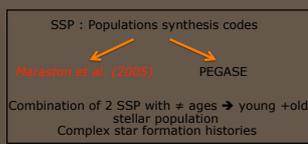

SSP : Populations synthesis codes

Maraston et al. (2005)   PEGASE

Combination of 2 SSP with ≠ ages ➔ young +old stellar population
Complex star formation histories

Figure 1

Dust attenuation

Second step of CIGALE : the construction of an attenuation law. It is based on the Calzetti et al. (2000) one. We can add a UV bump of varying width and amplitude on this law and we can also vary the slope.

Calzetti et al. (2000) ✚ UV bump ✖ power law

$$k(\lambda) = A(\lambda)/E(B-V)$$

$$\frac{E_{bump} \lambda^2 \gamma^2}{(\lambda^2 - \lambda_0^2)^2 + \lambda^2 \gamma^2}$$

$$(\lambda/\lambda_V)^\delta$$

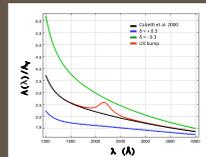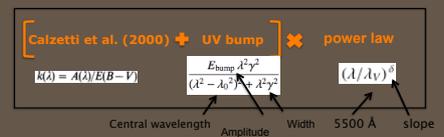Central wavelength   Amplitude   Width   5500 Å   slope

Figure 2

IR libraries

Third step of CIGALE : the code add an IR template to the attenuated stellar spectra previously built. The IR libraries available are Dale&Helou (2002), Chary&Elbaz (2001) and Siebenmorgen&Krugel (2007).
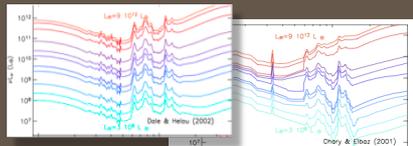

Figure 3

AGN templates

Fourth step of CIGALE : we can add the emission of an AGN to the UV-to-IR SEDs modelised by CIGALE. The emission of the AGN is weighted by the fraction of L_{IR} due to the AGN and not by the heating of stars.

CIGALE is optimized to fit starburst SEDs and not pure AGNs SEDs. We thus select 6 AGNs templates from Fritz et al. (2006) to be representative of the main AGN spectra of type 1 and 2. On Fig.4 we compare these templates to the entire librarie of Fritz et al. (2006).

Figure 4

Some results from CIGALE

Figure 5

GOODS-Herschel, Buat et al. 2011b, submitted, cf talk Véronique Buat

On Fig.5 is an exemple of SED-fitting with CIGALE, the blue dots correspond to the observed SED. In this paper we try to caracterise the presence of a UV bump at 2175 Å and the related implications on dust attenuation determinations. 31 galaxies observed by PACS instrument onboard Herschel have been selected in the CDFS, 0.97<z<2.13, as part of the GOODS-Herschel project. These galaxies are also detected from UV to mid-IR in broad bands and medium bands which allow to probe the wavelength range of the UV bump as seen on Fig.5 first pannel. For the whole sample we found a bump with a mean amplitude of 1.26(+/-0.30) (which corresponds to 32% of the amplitude of the bump in the average extinction curve of the Milky Way) and a mean FWHM of 353 +/- 20Å.
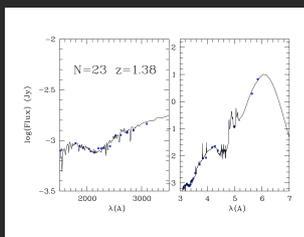
AKARI-SDSS-GALEX, Buat et al. 2011a

A sample of 363 galaxies is built from the AKARI/FIS all sky survey cross-correlated with GALEX and SDSS surveys. Broad band SEDs are fitted with CIGALE optimized to analyse variations in dust attenuation curves and SFR measurements and based on an energetic budget between the stellar and dust emission. Fig.6 shows the variations of η as a function of L_{IR} : $SFR_{tot}=(1-\eta)SFR_{IR}+SFR_{UV}$ (Iglesias-Páramo et al.,2006).

η represents the fraction of IR emission due to dust heating by old stars. Calibrations are from Buat et al. (2008) for a constant SFR over 10^8 years and a Kroupa IMF : $logSFR_{IR}=logL_{IR}+9.97$ and $logSFR_{FUV}=logL_{FUV}+9.69$

<η>=0.17 +/-0.10 for the whole sample. A small trend is found as a function of L_{IR} with <η>=0.14 +/-0.08 for L_{IR} > 10^{11} $L_\odot$. Thus we can say that η remains nearly constant over the entire range of L_{IR} which means that the increase of L_{IR} is due to dust heating by young stars, and higher the L_{IR}, higher the quantity of young stars.
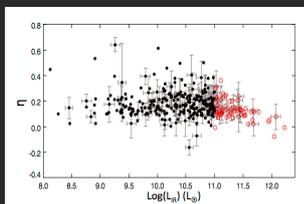

Figure 6

LIRGs in the ECDFS, Giovannoli et al. 2011

We study a sample of 180 Luminous InfraRed Galaxies (LIRGs) in the ECDFS with <z=>0.7. Objects are detected from NUV to 24µm. Fig.7 shows the SFR as a function of the stellar mass; both parameters have been provided by the fit to the observed SEDs with CIGALE. We overplot the analytical models of Buat et al. (2008) (dash-dotted yellow line) at z=0.7 and Noeske et al. (2007a) (connected blue crosses) at z~0.7, and obsevations of Elbaz et al. (2007) (solid black line,z=0 and 1), Daddi et al. (2007) (solid black line z=2) and Santini et al. (2009) at z~0.7 (dashed green line).

We do not observe a correlation between the SFR and the stellar mass but instead a flat distribution of the SFR. Filled circles (empty circles) illustrate galaxies for which the age of the young stellar population is found greater (lower or equal) than 0.3 Gyr. We can see that the SFH of our objects has an influence on the dispersion of the SFR-stellar mass relation.

We are actually working on this sample in the framework of the PEP/Hermes project and part of these objects are now detected by PACS and SPIRE. Adding Herschel data is a great improvement to fit these objects with a physically motivated code like CIGALE.
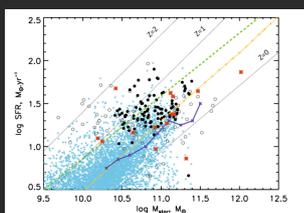

Figure 7

★ AGN contaminated objects
◆ semi-analytical Millenium simulations, z=0.7

*http://www.oamp.fr/cigale/