A new grid of evolutionary synthesis models in the Virtual Observatory

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Abstract

We present a new grid of evolutionary synthesis models available through the Virtual Observatory (VO). The grid includes a complete set of Single Stellar Population models covering a wide range in age and metallicity. In this poster we summarize the results for the youngest clusters (1 Myr – 10 Myr) and a first issue of the implementation for the Virtual Observatory. We are computing a grid with observed stellar libraries in the optical range, specifically thought for the preparation and further interpretation of the observations with the spectrograph Elmer, at the Gran Telescopio CANARIAS, by combining the theoretical models with the atmosphere, telescope and instrument parameters, which will be also available through the Virtual Observatory.

IMF

- The basic grid is composed by **Single Stellar Populations**.
- Five different IMF have been used
  - IMF-1: Salpeter (1955), $\Phi(m)=m^{-2.35}$; m_{low}= 0.15 $M_\odot$, m_{up} = 100 $M_\odot$
  - IMF-2: Salpeter (1955), $\Phi(m=m^{-2.35}$; m_{low}= 0.85 $M_\odot$, m_{up}= 120 $M_\odot$
  - IMF-3: Kroupa (2002) ; m_{low}= 0.15 $M_\odot$, m_{up} = 100 $M_\odot$
  - IMF-4: Chabrier (2003) ; m_{low}= 0.15 $M_\odot$, m_{up} = 100 $M_\odot$
  - IMF-5: Ferrini, Penco & Palla (1990) ; m_{low}= 0.15 $M_\odot$, m_{up} = 100 $M_\odot$
- The models do not include binaries, either mass segregation.
- We will include:
  - SSP models with different IMF parameters
  - Continuous Star Formation Models with different values of SFR and taking into account the chemical evolution (Mollá & Ferrini 1995)

Isochrones

- Isochrones: Bressan, Granato & Silva (1998) with some parameters specifically computed for this piece of work.
- Broad age and metallicity coverage and detailed treatment of mass-loss at both, young (O, B, WR) and old ages (post-AGB until planetary nebula)
- **Z = 0.0004, 0.001, 0.004, 0.008, 0.02 and 0.05** (1/50 to 2.5 solar)
- **Ages, logt = 5.00 to 10.30.** High time-resolution (up to logt=0.01)
- WN and WC are identified in the isochrones to ease the spectra assignation.
- **Code:** We have used the synthesis code by García-Vargas, Mollá & Bressan (1998), updated by Mollá & García-Vargas (2000) and revised García-Vargas etal. (2007) with new isochrones and atmosphere models.

Synthesis Code Description

Atmosphere Models

- For stars with **Teff < 25.000** we use the models by Lejeune Th. Cuisinier F. & Buser R. (1997). Excellent coverage in Teff, Z and logg.
- **For O, B and WR** we use non-LTE line blanketed models by Smith, Norris & Crowther (2002) at Z=0.001, 0.004, 0.008, 0.02 and 0.04
  - 110, O-B calculated with the code by Pauldrach, Hoffmann & Lennon (2001). Teff range 25.000 – 51500, logg (2.95 – 4.00)
  - 120 WR (60 WN + 60 WC) models calculated with the code CMFGEN, Hillier & Miller (1998).
  - T* and R* are Temperature and Radius at a Rosseland optical depth of 10)
  - 30.000K< T*<120000 K (WN) and 20.3 $R_\odot$ < R* < 1.3 $R_\odot$ (WN) and 40.000K< T* <140000K (WC) and 9.3 $R_\odot$ < R* < 0.8 $R_\odot$ (WC)
  - Above 54ev emergent flux is determined by the wind density as a function of metallicity and in this set of models the hardness of ionizing radiation decreases. The models produce a lower flux of HeI continuum, for Z>0.4Zo and Age < 7 Myr.
  - HeII 4686 is very low and HeI 5786 / Hβ decreases when metallicity increases due to line blanketing
  - The use of these Non-LTE blanketed models produce less hard ionizing photons more energetic than 54ev, which implies less excitation in regions ionized by young clusters. To explain the high metallicity HII regions emission line ratios, previous models with hotter atmospheres for massive stars – García-Vargas & Díaz 1991; García-Vargas, Bressan & Díaz 1995 - needed an artificial IMF flattening or mass segregation effects in small clusters. Today, we know that this is against evidences from HST, which has discovered very massive stars also in small clusters.
  - To assign an appropriate model to the WR, we do not use the effective temperature (since isochrones give the hydrodynamic one while atmospheres use the Teff at a Rosseland optical depth of 10). We use the relationships among opacity, mass loss and velocity wind. $d\tau = -\kappa(r)\,\rho(r)\,dr$ with $\kappa = 0.2(1+Xs)$; Xs = 0.2 (WN), Xs = 0 (WC, WO) ; $dM/dt = 4\pi r^2\rho(r)v(r)dr$; $V(r) = V_\infty (1-Rs/r)^\beta$; $\beta = 1$
  - We integrate the equations and find R* from the Rs (from the isochrones), and then we fit a model with that value of R*
- **For post-AGB and PN** we have included the NLTE models by Rauch (2003) up to 220.000 K and black bodies for higher temperatures.
  - These models include all elements from H to Ni. Teff ranges between 50.000K and 190.000K and logg between 5.00 and 8.00

Products already available at the Virtual Observatory

H-R Diagrams

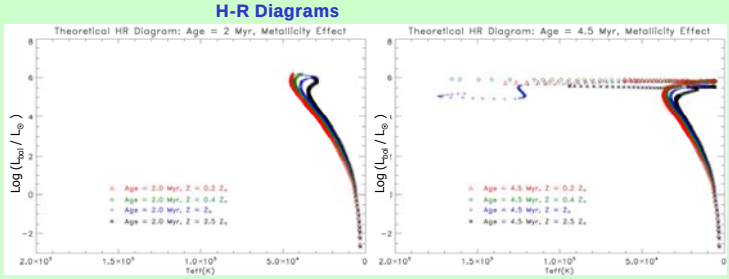


Figure 1: Theoretical HR Diagrams (isochrones) at 2Myr (top) and 4.5 Myr (bottom) and 4 different Z. The higher Z, the cooler the main sequence is and the turn-off is slightly cooler and less luminous. The WR phase as function of Z is shown at 4.5Myr.

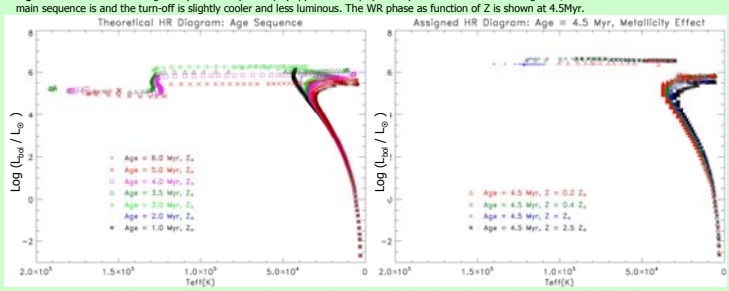


Figure 2: HR Diagrams for clusters at different ages and Z = 0.02. At the right panel, the real HR diagram is shown. Notice the high effective temperature of WR stars (corresponding to the hydrodynamic Teff). At the left, we show the computed HR diagram from which the SED is calculated. In this plot each point corresponds to the parameters of the assigned atmosphere model. In the case of the WR, the real atmospheric Teff (lower than the hydrodynamic Teff), is computed from the star radius and the velocity wind to allow a correct atmosphere model assignation.

Spectral Energy Distributions

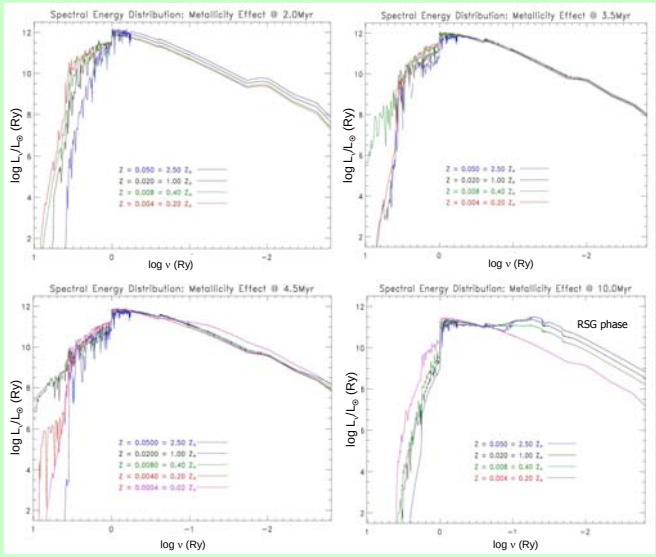


Figure 3: SEDs for young clusters at 2.0, 3.5, 4.5 and 10 Myr and 4 different metallicities. H ionizing spectrum corresponds to log ν (Ry) < 0. WR stars, whose presence depends on cluster's age and metallicity dominate the He ionizing spectrum. The current WR atmosphere models by Smith etal. (2002) produces the softening of the ionizing spectrum with respect previous grids. RSG phase is seen at 10 Myr.



Figure 4: SEDs for young clusters at Z = 0.02 and different ages as seen in the VOSpec. The models have been registered with the name of **PopStar** and can be used in combination with all the VO tools.

Spectra in the VO

We provide the spectra in the VO standard: λ (in Å) and L (in $ergs^{-1}$ $Å^{-1}$)
Spectra can be chosen by IMF type, age and Z and can be managed with VOSpec
Description of the models in http://www.fractal-es.com/SEDmod.htm/

HR Diagrams

We will include at the Virtual Observatory the HR diagram files covering the whole grid in age and metallicity. At the moment, there is not a specific VO access protocol for such files. However, we have produced VO tables that can be download from our webpage, www.fractal-es.com/SEDmod.htm/ to be used with some applications like Topcat. Each file's row correspond to the physical properties of a star with a given initial mass (when the cluster was formed).
The columns in the table give the following information:

(M/Mo)-HR	Initial mass ($M_\odot$)
nstar=	Number of stars in that mass interval (weights)
Teff-HR	Effective Temperature (K) as computed in the isochrone
logg-HR	Logarithm of the gravity (cms^{-2}) from the isochrone
log(L/Lo)-HR	Logarithm of the Luminosity (in $L_\odot$), from the isochrone
Teff-Md	Effective Temperature (K) of the assigned model
logg-Md	Logarithm of the gravity (cms^{-2}) of the assigned model
log(L/Lo)-Md	Logarithm of the Luminosity (in $L_\odot$) of the assigned model
log(Mdot)	Mass loss (in $M_\odot$/yr)
Err(Teff)	Error associated to the Teff (K) assignation
Err(logL/L$_\odot$)	Error associated to the Log($L/L_\odot$) assignation
WR	Parameter with the following meaning: 1 (WN star), 2 (WC star) 3 (evolved hot star, e.g. PN), 0 "normal" stars (the rest)

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Other Products already available

- SEDs with different IMF parameters
- Cluster's properties (numbers of O, B, WN, WC, WO,Q-numbers)
- Emission Line Spectra of the ionized gas

Next Products soon available

- Spectra for Continuous Star Formation (plus Chemical Evolution)
- Models with Dust
- Stellar Blue Spectral indices (Mgb, Mg_2, Fe52, Fe53, NaD and H_β)
- Stellar Near-IR Spectral indices (CaT, Na I and Mg I)
- SDSS Colours to be used with images taken with Elmer @GTC
- Optical spectra for each of the Elmer's spectroscopic configurations

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