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How to run a model

First you need to specify your input parameters. This is done from the input page. There are quite a few parameters to play with, all of which are explained below. If you are not sure about an input parameter, start out with the default value.

- **MODEL DESIGNATION:** --- any identifier you want to assign to the model. You will find it in the header of each output file.
- **CONTINUOUS STAR FORMATION OR FIXED MASS :** -- select either continuous or instantaneous star formation. **fixed**
- **TOTAL STELLAR MASS [10^6 SOLAR MASSES] IF 'FIXED MASS' IS CHOSEN:**-- this is the total stellar mass (spread out between the upper and lower cut-off masses). It is only used if an instantaneous burst is specified. **0.05**
- **SFR [SOLAR MASSES PER YEAR] IF 'CONT. SF' IS CHOSEN:** -- the star formation rate (only used for a continuous rate). The total accumulated mass is spread out between the upper and lower cut-off masses. **---**
- **NUMBER OF IMF INTERVALS (KROUPA = 2):** -- users can specify a multi-power-law IMF. This is useful for approximating, e.g., a Kroupa IMF. If two intervals are specified, the program expects two IMF exponents and three IMF boundaries in the next two input fields. Up to ten such intervals may be specified. **?**
- **IMF EXPONENT(S) (KROUPA = 1.3,2.3):** -- one or more IMF exponent for a power-law can be specified. The exponents refer to the individual power-law intervals, ordered by increasing mass. For instance, 1.3,2.3 specifies an IMF with exponents of 1.3 and 2.3 at low and high masses, respectively, with the boundaries given in the next input field. A single Salpeter-type law would be entered as 2.35. If there is more than one input value, the entries must be comma separated. **?**
- **MASS BOUNDARIES FOR THE IMF (KROUPA = 0.1,0.5,100) [SOLAR MASSES]:** -- the boundaries of the IMF intervals corresponding to the specified exponents. In this specific example we define two intervals from 0.1 to 0.5 and from 0.5 to 100 solar masses, The former would have a slope of 1.3, and the latter 2.3. A single power law between 1 and 100 solar masses would be entered as 1,100. The input values must be comma separated. **1, 100**
- **SUPERNOVA CUT-OFF MASS [SOLAR MASSES]:** -- stars with ZAMS masses of 8 M and higher form supernovae. This is the suggested standard value but can be modified if desired. **8 (default)**
- **BLACK HOLE CUT-OFF MASS [SOLAR MASSES]:** -- stars with ZAMS masses of 120 M and lower form supernovae. An alternative scenario would be to let stars above a certain threshold form a black hole. For instance, BHCUT=40 results in SNe only from the mass range 40 to 8 M. **120 (default)**
- **METALLICITY + TRACKS:** -- this selects the evolutionary tracks and their metallicity. Details of the time steps are entered as well.
- **GENEVA TRACKS WITH STANDARD MASS LOSS:** -- selection of the 1994 Geneva tracks with "standard" mass-loss rates. The lowest mass included in the tracks is 0.8 solar masses. **Geneva high mass loss w/ Z = 0.008**
- **GENEVA TRACKS WITH HIGH MASS LOSS:** -- selection of the 1994 Geneva tracks with "high" mass-loss rates. Note that these are the tracks recommended by the Geneva group.
- **ORIGINAL PADOVA TRACKS:** -- selection of the 1992 - 1994 Padova tracks. The lowest mass included in the tracks is 0.15 solar masses.
- **PADOVA TRACKS WITH AGB STARS:** -- selection of the 1992 - 1994 Padova tracks with thermally pulsing AGB stars added.
- **WIND MODEL (EVOLUTION; EMP.; THEOR.; ELSON):** -- this selects the wind model to be used for the calculation of the wind power. The four models are discussed in ApJ, 401, 596 (1992). EVOLUTION uses the mass-loss rates from either the Geneva or Padova models. "EVOLUTION" is the suggested default parameter. **EVOLUTION (default)**
- **INITIAL TIME [1.E6 YEARS]:** -- the epoch of the onset of the star formation. In almost all cases you want this to be close to 0. It should not be exactly 0 for numerical reasons. 0.01 (i.e. 10e4 yr) is a good number. **0.01 (default)**
- **TIME SCALE:** -- a switch to select linear or logarithmic time intervals. This switch has no influence on the precision of the models; it is for purely practical purposes in order to have a nice distribution of points over time. Young models (< 1 Gyr) work better with a linear step, whereas the logarithmic step gives better results at older ages. The time scale is automatically reset to logarithmic for ages older than 1 Gyr on the STScI Starburst99 server. **linear**
- **TIME STEP [1.e6 YEARS]:** -- this is the timestep used for the calculations. It is a very important parameter. On the one hand, the computing time scales with the step size, so you want to avoid too high resolution, but on the other, short evolutionary phases can be missed. 0.1 (i.e. 10e5 yr) is a good value. A larger time step is suggested for tests --- but be aware that WR or RSG numbers are no longer properly calculated for too large steps. The time step is only used if linear time intervals are specified. **0.1**
- **NUMBER OF TIME STEPS:** -- if a logarithmic scaling is selected, the time step size varies with time and is no longer specified via the TIME STEP field. In this case, we enter the total number of time steps, which will then be distributed logarithmically between the first and the last time point. As before, users should beware of too small steps during short-lived evolutionary phases. **25**
- **LAST GRID POINT [1.e6 YEARS]:** -- the oldest age of the model. **3**
- **SMALL OR LARGE MASS GRID; ISOCHRONE ON LARGE GRID OR FULL ISOCHRONE :** -- these are four options for the interpolation in mass. They are explained in the code. Shortly: "SMALL" -- evolutionary synthesis with a mass resolution of 5 M (only recommended for tests); "LARGE" -- same as 0, but with a resolution of 1 M. This method was used in our previously published papers; "ISOCHRONE/LARGE" -- isochrone synthesis with a fixed mass resolution of 1 M; "FULL ISOCHRONE" -- isochrone synthesis with a variable mass grid. This is the recommended method. In particular, FULL ISOCHRONE must be used if masses below 1 solar masses from the Padova tracks are to be included in the modeling. **Full Isochrone (3) (default)**
- **LMIN, LMAX :** -- LMIN and LMAX are the indices of the evolutionary tracks, sorted by mass. Normally you do not want to mess with the variable and leave it at 0. However, if you want to track down some peculiarity of the output, you may want to compute the parameters for only one track. For instance, specifying 21,21 indicates that only a 100 M star should be used, and everything else is suppressed. The cross-ID's between index and mass are at the bottom of the input file which comes as part of the source code package. The example here refers to a large mass grid or isochrone on large grid. For a small mass grid, you would have chosen 5,5. This does not appy to the full isochrone model since the mass grid is variable. If "full isochrone" is selected, LMIN and LMAX are not used. **0 (default)**
- **ATMOSPHERES AND SPECTRA:** -- parameters for the different output spectra are selected here. Starburst99 calculates three groups of spectra. (i) Low-resolution spectra (~20 A) from X-rays to the radio. They are generated from atmospheres with a wide range of sophistication from a pure Planck curve to fully blanketed, extended, NLTE atmospheres. They are in output file 7 (Spectrum). The metallicity of the spectra is automatically selected via the evolutionary tracks. (ii) High-resolution optical spectra (0.3 A) from 3000 to 7000 A. This model set is discussed in Martins et al. The spectra are in output file 13 (Hires). The metallicity is independent of the evolution models and can be selected as desired. (iii) UV line spectra between 1000 and 1180 A at 0.13 A resolution and between 1200 and 1900 A at 0.75 A resolution. The libraries were collected with FUSE, HST, and IUE. Two metallicity groups can be specified, regardless of the choice of the evolution models. The spectra are in output files 12 (ovi) and 8 (line).
- **TIME STEP TO PRINT THE CONTINUOUS AND LINE SPECTRA [1.e6YR]:** -- the file containing the output spectrum can be pretty big. This parameter controls the time step to print out the spectrum. This is independent of the time resolution -- only the print out is affected! 1 Myr is usually a good value but if you compute the starburst up to 100 Myr, you may prefer TDEL=5 Myr to save disk space. **1 (default)**
- **ATMOSPHERE FOR THE LOW-RESOLUTION SPECTRUM: PLANCK, LEJEUNE, LEJEUNE/SCHMUTZ, LEJEUNE/HILLIER, PAULDRACH/HILLIER** -- this is the choice of the model atmosphere. "PLANCK" is a bare-bone version with black bodies, good only for tests. "LEJEUNE" uses the Kurucz models as compiled by Lejeune for all stars. "LEJEUNE/SCHMUTZ" uses Lejeune for stars with plane-parallel atmospheres and Schmutz with stars with strong winds. "LEJEUNE/HILLIER uses Lejeune, but replaces the Schmutz by the Hillier atmospheres. "PAULDRACH/HILLIER" is like "LEJEUNE/HILLIER", except for the O atmospheres, for which we use the Pauldrach models. "PAULDRACH/HILLIER" is the recommended value. **5 (default)**
- **METALLICITY OF THE HIGH-RESOLUTION SPECTRA** -- four choices are offered, and the user can decide how to match them to the evolution models. Details of the model atmospheres and spectrum synthesis are in Martins et al. (2005). **2 (0.008)**
- **METALLICITY OF THE UV LINE SPECTRUM: (1=SOLAR, 2=LMC/SMC)** -- a switch for the choice of the UV spectral library. This switch applies to both the FUSE and the HST/IUE libraries. It is independent of the metallicity of the tracks/atmospheres. **2**

- **RSG FEATURE: MICROTURB. VEL (1-6), SOL/NON-SOL ABUND** -- atmospheric parameters used for the spectral features in the near-IR. Detailed explanations are in the sp-feature subroutine. Defaults are microturbulent velocities of 3 km/sec and solar abundance ratios for alpha-element/Fe.
- **OUTPUT FILES** These are options to generate various outputs. We recommend to select the default, unless you are very familiar with the code. Some of the subroutines are interrelated. If you choose such a subroutine but not the other, required one, a warning will be issued. The 15 output flags are explained below.

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all for now

The output

Once the run is finished, you will be notified by e-mail. If everything went well, you should find the output files in the output directory. The e-mail gives you all the information you need to locate the files and the retrieve them. If you have set all output flags to "yes", you will find 17 files: 16 files with model results (note that (5) generates 2 files, therefore the 15 flags produce 16 files), and one output file which lists the model parameters which were used. The data files are:

1. Computation of the number of ionizing photons. (7) must be set to "yes" since the spectrum below 912 A is needed. Output is the number of ionizing photons in the HI, HeI, and HeII continuum, their fractions relative to the total luminosity, and the total luminosity. Default filename: **quanta**
2. Calculation of the supernova rate and the mechanical luminosities (winds and supernovae). It requires (4) to obtain the stellar wind luminosities. Otherwise it is independent of other subroutines. Default filename: **snr**
3. HRD with a few evolutionary tracks. This is mostly useful for test purposes. This part is independent of all other subroutines and can be turned on/off without doing any harm. It does not work with isochrone synthesis. Default filename: **hrd**
4. Mechanical luminosity and related quantities due to winds and supernovae. It does not depend on any other subroutine since no information on the energy distribution is needed. Default filename: **power**
5. Two output files containing the stellar spectral types during each time step and the relative numbers of WR stars. The spectral types follow the scheme by Schmidt-Kaler, oversampled by a factor of 2. For instance, there are 18 entries for spectral type B. They are the number of stars for types B0, B0.5, B1,...B9.5 (total of 18). Schmidt-Kaler's table has B0, B1,....B9 (total of 9). The spectral types are printed out only every TDEL. Otherwise it is too bulky. Default filenames: **sptyp1,sptyp2**
6. The mass in individual elements released via stellar winds and supernovae. No other subroutines are needed. Nucleosynthesis by supernovae is included. Default filename: **yield**
7. The spectrum of the stellar population for each time step. The columns are time, wavelength, stellar+nebular, stellar only, and nebular only fluxes. (1) is needed in order to calculate the nebular continuum. Default filename: **spectrum**
8. The ultraviolet line spectrum at 0.75 A resolution from 1200 to 1600 A (LMC/SMC library) or to 1800 A (Milky Way library). The subroutine needs (7) to compute the stellar continuum and (1) for the nebular continuum. If (1) is turned off, the nebular contribution can not be added (it is often small, though). The columns have time, wavelength, absolute luminosity, and rectified (continuum=1) luminosity. Default filename: **uvline**
9. Calculation of colors and magnitudes. The subroutine needs (7) to compute the stellar continuum and (1) for the nebular continuum. If (1) is turned off, the nebular contribution can not be added and the computed colors are for stars only (this may sometimes be desirable). The filter system is defined in the code. Default filename: **color**
10. Calculation of the strengths of H_alpha, H_beta, Pa_beta, and Br_gamma. For each line we give the continuum luminosity, the line luminosity, and the equivalent width (everything logarithmic). The subroutine needs (7) to compute the stellar continuum and (1) for the number of ionizing photons. Default filename: **ewidth**
11. Calculations of the strengths of various IR spectral features. First is the CO index as computed by Doyon et al. (1994, ApJ, 421, 101). (Please note that this calculation has no metallicity dependence. A later version of this routine will compute the CO index using the model atmospheres themselves and give metallicity-dependent results.) Next are two computations of the CaII IR triplet using the relations of Diaz et al. (1989, 239, 325). The relations from Diaz et al. have no temperature dependence; the first calculation has the feature present in stars of all temperatures; the second has the index set to zero strength for stars with T>7200K (spectral type A or earlier). Next come the 1.62 and 2.29 micron CO features, and the 1.59 micron Si feature, which were modeled for individual stars by Origlia et al. (1993, A&A, 280, 536.) The indices can be computed for solar [Si/Fe] and [C/Fe], or a model with enhanced [Si/Fe] and depleted [C/Fe] (as for young systems enriched primarily by Type II SNe), and for stellar atmospheric microturbulent velocities (MTVs) of 1-6 km/s. (Note that the changes to the abundance ratios and MTVs are are self-contained in this routine and have no effect upon the other outputs, e.g., colors, of the code.) The subroutine needs (7) to compute the stellar continuum and (1) for the number of ionizing photons. Default filename: **irfeature**
12. This subroutine is equivalent to (8), but it computes the spectral region between 1000 and 1180 A. Default filename: **ovi**
13. Calculates fully theoretical spectra between 3000 and 7000 A at 0.3 A resolution. These spectra are independent of the calculation of the low-resolution spectra in output 7. The file structure is the same as in (8). Default filename: **hires**
14. Calculation of the most important WR emission lines using the line luminosities of Schaerer & Vacca (1998, ApJ, 497, 658). These are only those lines originating in WR winds --- not the nebular lines in the HII region. Quantities given are the line fluxes and the equivalent widths. The subroutine needs (7) to compute the stellar continuum and (1) for the nebular continuum. If (1) is turned off, the nebular contribution can not be added. Default filename: **wrlines**
15. Calculation of a high-resolution UV line spectrum from model atmospheres, as opposed to using an empirical library. The output format and units are the same as those under (13). The library is discussed by Leitherer et al. (2010). Default filename: **ifaspec**

How to interpret the file *time-used*

The logfile *"time-used"* gives statistics on cpu and elapsed time, and it reports warnings and anomalies or errors that may have occurred during the run.

If you see *"CANNOT COMPUTE....."* you have specified to skip a particular output which was otherwise needed as input for another subroutine which you actually specified to compute. For instance, you may intentionally omit the nebular continuum (quanta) in order to compute a purely stellar continuum. But then you would not be able to compute equivalent widths (width) since the number of ionizing photons is needed for the emission line fluxes. When in doubt, compute all the output files. This will work.

"IEEE floating point exception flags" may also be ignored.