IAC-star input/output guide

Version 2.0: 2003-October-28

1. IAC-star input parameters

The input parameters that the user should supply to IAC-star are the following:

- A seed for the random number generator. If 0 is entered, the computer will automatically generate it from its internal clock. The routine used for random number generation is "ran2", obtained from *Numerical Recipes in Fortran* (Press et al. 1997).
- Total number of stars computed or saved into the output file. The program will stop when the first of these numbers is reached. To prevent too long runs, the maximum allowed total computed star number is 10^7 stars and the maximum allowed number of saved stars is 10^5. These limits may change in future versions of the program.
- Logarithm of the minimum stellar luminosity or maximum magnitude in a given filter. Although fainter stars are computed, only those brighter than this value are saved into the output file. In the case of binary stars, this value is applied to total luminosities or magnitudes.
- The SFR, $\psi(t)$, sampled by a number of points (up to 20 in the current version). The number of points, including first and last, is given first. For a SFR defined by n points, the input is a list of $2n+1$ numbers of the form $n, t_1, t_2, ..., t_\mathrm{n}, \psi(t_1), \psi(t_2), ..., \psi(t_\mathrm{n})$, where $t_1, t_2, ..., t_\mathrm{n}$ are time instants and $\psi(t_1), \psi(t_2), ..., \psi(t_\mathrm{n})$, the corresponding SFR values. The age of the system, T, is asumed to be the last instant of time given, t_n. For an arbitrary instant of time t, the SFR, $\psi(t)$ is computed by simple linear interpolation between the two points embracing it; i.e. between t_i and $t_{\mathrm{i}+1}$, such that $t_\mathrm{i} \leq t \leq t_{\mathrm{i}+1}$. The time steps t_i must be given in Gyr. Units for the SFR, $\psi(t_\mathrm{i})$, are arbitrary. In fact, they are defined upon the end of the execution by the integral $\Psi(T) = \int_0^T \psi(t)\mathrm{d}t$, stored in the output file.
- The chemical enrichment law. Two alternative approaches are allowed to produce the chemical enrichment law: (i) just an interpolation in several age-metallicity nodes, defined by the user and permiting a completely arbitrary metallicity law; (ii) computation from usual parameters involved in physical scenarios of chemical evolution, even though a self-consistent physical formulation is not intended in this case. We describe separetely the input parameters of each approach in the following.
  - (i) In the interpolated CEL case, the values of t and $Z(t)$ for the nodes are given in a similar way as for the SFR above. This includes a simple, lineal CEL, varying from Z_0, Z_f and the obvious case of constant metallicity (for which $Z_0 = Z_\mathrm{f}$).

It is usefull for many purposes to allow metallicity dispersion at any time. For this, a second metallicity law can be introduced. If so, for any time, actual metallicities of synthetic stars are randomly distributed between the values of the two laws. If an unique, well defined metallicity for each age is required, the parameters of the second law must be all them 0 or leaved blank.

– (ii) The following ecuations are used to compute the chemical law for infall and outflow:

$$Z(t) = Z_0 + \frac{y}{\alpha}\{1 - [\alpha - (\alpha - 1)\mu(t)^{-1}]^{-\alpha/(1-\alpha)}\} \qquad \text{(Infall)} \qquad (1)$$

$$Z(t) = Z_0 + \frac{y}{\lambda + 1}\ln[(\lambda + 1)\mu(t)^{-1} - \lambda] \qquad \text{(Outflow)} \qquad (2)$$

Z_0 and $Z_{\rm f}$ are the initial and final metallicities; $\mu_{\rm f}$ is the final gas fraction, and α and λ are the infall and outflow parameters. These parameters are provided in the program input. Constant yield and $R = 0.2$ are assumed. The latter is obtained for a stellar system in which star formation has gone on at a constant rate from 13 Gyr ago to date. Small, probably not significant differences are found for other SFRs and depending on metallicity.

Since they are governed by different equations, infall and outflow can not be included simultaneously. However, an approximation is obtained if the infall case is used with $\alpha - \lambda$ as parameter. It must be noted, however, that the approximation refers only to the CEL morphology, but not to the physical scenario. In particular, the yield becomes rather unrealistic.

In general, the infall and outflow parameters should be $\alpha \geq 0$ and $\lambda \geq 0$ to have physical sense. Moreover they must verify the conditions $\mu > (\alpha - 1)/\alpha$, for the infall scenario, and $\mu > (\lambda + 1)/\lambda$, for the outflow one. The cases $\alpha = 1$, $\alpha = 0$ (infall scenario) and $\lambda = 1$ (outflow scenario), are overcome by the code by substituting these values by $\alpha = 1 - 1 \times 10^{-7}$; $\alpha = 10^{-7}$, and $\lambda = 1 - 1 \times 10^{-7}$ respectively. In this way, the code can produce the closed-box case and the infall limit case, in which infall is balanced by star formation.

As in the case (i), a second law can be defined if metallicity dispersion is required.

It must finally be mentioned that, in any case, the metallicity distribution is truncated to the range $0.0001 \leq Z_{\rm s} \leq 0.05$, which are the current limits of the used library.

- The IMF. It is assumed to be a power law of the mass, but several mass intervals can be defined. The user can set here the minimum and maximum stellar masses to be computed. It must be noted that, in most cases, the execution time can be considerably reduced by rising the minimum stellar mass.

- Binary star control. Both the fraction of binary stars and the secondary to primary minimum mass ratio can be supplied. If the first is 0, no binaries are computed. About the second, only the minimum value is requested, the maximum one being 1.

- Mass loss parameter. Although the default $\eta = 0.5$ seems a reasonable choice, the user can modify it here. It must be noted that η significantly affects the extension of the HB for low metallicity stars.

2. Output file content

The content of the IAC-star output file is as follows:

- Head: It contains information about the input parameters. In particular:
  - The total number of computed and stored stars.
  - The minimum luminosity or maximum magnitude stored.
  - The courrent age and the SFR law.
  - The CEL and IMF parameters.
  - The fraction of binaries and minimum secondary to primary mass ratio.
  - A heading line for the column content, including a list of the photometric bands for which magnitudes have been computed. Although in the current version this is limited to the Johnson-Cousins plus IR most common filters, the list may be expanded, reduced or changed in the future as an optional feature.
- Column 1: $\log L$ of the star. If it is a binary, this (and the following four columns) corresponds to the primary (most massive star) of the sistem. The value -9.999 is stored if this star is a dead member of binary with an alive secondary.
- Column 2: $\log T_{\rm eff}$ of the same star. The value -9.999 is stored if the star is dead, as in column 1.
- Column 3: $\log g$, where g is the surface gravity, for the same star. The value -9.999 is stored if the star is dead, as in column 1.
- Column 4: The initial mass of the star.
- Column 5: The current mass of the star. The mass of the remnant is stored if the star is dead.
- Column 6: $\log L$ of the secondary (less massive star) of the binary sistem. The value -9.999 is stored if the star is not a binary. Note that, since life time is larger for less massive stars and mass transfer is not considered, it is impossible that the secondary is dead and the primary alive in a binary system. On the other hand, if both components of the binary were dead, they would not be written in the output file (although they would have been considered for the total mass calculation).

- Column 7: $\log T_{\rm eff}$ of the same star. The value -9.999 is stored if the star is not a binary, as in column 6.
- Column 8: $\log g$ of the same star. The value -9.999 is stored if the star is not a binary, as in column 6.
- Column 9: The initial mass of the star. The value 0 is stored if the star is not a binary. See what has been said in column 6 for dead stars.
- Column 10: The current mass of the star. The value 0 is stored if the star is not a binary. See what has been said in column 6 for dead stars.
- Column 11: The age of the star. If it is a binary, both members are assumed to have the same age.
- Column 12: The metallicity of the star. If it is a binary, both members are assumed to have the same metallicity.
- Column 13: The secondary to primary initial mass ratio of the binary. If the star is not a binary the value 0 is stored.
- Column 14: Bolometric magnitude of the system (primary plus secondary if it is a binary).
- From column 15 ahead: magnitudes of the system (primary plus secondary if it is a binary) in the filters listed in the head.
- Closing: Integrated quantities are provided in the file closing lines. In particular:
  - The total number of i) ever formed, ii) currently alive and iii) stored stars (single and binary) and the same for binaries only.
  - The total mass ever incorporated into stars (in other words, this is just the time integral of the SFR, $\int_0^T \psi(t)dt$).
  - The mass currently locked into alive stars and into stellar remnants.
  - The logarithm of the total luminosity and the integrated magnitudes.
  - The logarithm of the sume of squared luminosities ($\log \sum_{\rm i} L_{\rm i}^2$, where $L_{\rm i}$ is the luminosity of the i-th star if it is single or the total luminosity of the system, if it is binary) and the magnitudes derived from this. These are the magnitudes associated to surface brightness fluctuations (SBF). In this sense, IAC-star can be used as a SBF population sysnthesis code (see Marín-Franch & Aparicio 2003).