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BASTI: an interactive database of updated stellar evolution models

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Abstract. We present a new database of stellar evolution models for a large range of masses and chemical compositions, based on an up-to-date theoretical framework. We briefly discuss the physical inputs and the assumptions adopted in computing the stellar models. We explain how to access to the on-line archive and briefly discuss the interactive WEB tools that can be used to compute user-specified evolutionary tracks/isochrones/luminosity functions. The future developments of this database are also outlined.

Key words. CM diagram – H burning – He burning stars – Isochrone fitting

1. Introduction

A large database of stellar evolution models, spanning a wide range of stellar masses and initial chemical compositions, represents a fundamental tool to investigate the properties of stellar populations in both Galactic and extragalactic systems.

A good - reliable - library of stellar models has to fulfill some important requirements:

– accuracy - the physical inputs have to be updated;
– homogeneity - all the models have to be computed using the same evolutionary code and the same physical framework;
– completeness - for each fixed chemical composition, the range of star masses has to be sampled with a mass spacing appropriate to adequately cover all evolutionary stages;
– reliability - the models have to reproduce as many empirical constraints as possible;
– easy access - all results have to be easily available to the potential users.

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We have accounted for all of these criteria to set up the archive of stellar evolutionary models described in this paper. In the next section we shortly discuss the physical inputs adopted in the model computation; the grid of masses and chemical compositions is discussed in section 3. A presentation of the WEB database interface will close the paper. We refer the reader interested in assess the level of agreement between our library and observational constraints to the following papers: Pietrinferni et al. (2004), Salaris et al. (2004), Cassisi et al. (2003) and references therein.

2. The theoretical framework

Our model database has been computed by using a recent version of the FRANEC evolutionary code, updated in many aspects concerning both the numerical scheme for treating the nuclear burnings and the accuracy of the numerics. Almost all the adopted physical inputs have been updated as well. In particular, the radiative opacity tables (Iglesias & Rogers (1996) and Alexander & Ferguson (1994)), thermal conduction (Potekhin (1999)), plasma-neutrino processes (Haft et al. (1994)). The nuclear reaction rates have been updated by using the NACRE compilation (Angulo et al. 1999), with the exception of the $^{12}C(\alpha,\gamma)^{16}O$ reaction (Kunz et al. (2002)). As for the Equation of State (EOS), we employ the new EOS by A. Irwin[1] (see also Cassisi, Salaris & Irwin 2003), which covers all relevant evolutionary phases from the Main Sequence to the initial phases of White Dwarf cooling or advanced burning stages, for a large mass range. All models have been computed by fixing the extension of the convective core during the core H-burning phase both classically (Schwarzschild criterion) and considering a non-negligible efficiency of the overshoot process ($\lambda_{OV} = 0.2Hp$). We have also accounted for mass loss by using the Reimers (1975) formula with the free parameter η set to 0.2 and 0.4. A more detailed discussion about the physical inputs can be found in Pietrinferni et al. (2004).

3. The archive content

With the aim of covering a wide range of chemical compositions, we provide models for 11 different metallicities, namely Z = 0.0001, 0.0003, 0.0006, 0.001, 0.002, 0.004, 0.008, 0.01, 0.0198, 0.03 and 0.04, assuming two different heavy element distributions: scaled-solar (Grevesse & Noels 1993) and $\alpha-$enhanced (Salaris & Weiss 1998). As for the initial He-abundance, we adopt the value ($Y = 0.245$) provided by Cassisi et al. (2003); to reproduce the initial solar He-abundance obtained from the calibration of the solar model we assume an Helium enrichment law equal to $\Delta Y/\Delta Z \approx 1.4$.

For each fixed chemical composition we have computed models in the mass range $0.5 \leq M/M_\odot \leq 10$ with a very fine mass spacing (see details in Pietrinferni, et al. (2004)). All models, with the exception of the least massive ones whose central H-burning time scale is longer than the Hubble time, have been evolved from the Pre-Main Sequence phase up to the C-ignition, or until the first thermal pulses along the asymptotic giant branch. The main characteristics of our archive are listed in table 1. These models have been used to compute isochrones[2] for a wide range of ages, from 30 Myr to the upper limit listed in Table 1.

For each chemical composition we also have computed additional He-burning models with He core mass and envelope chemical profile fixed by a Red Giant Branch (RGB) progenitor having an age of $\sim$ 13 Gyr at the RGB tip, and a range of values of the total stellar mass. These Horizontal Branch (HB) models ($\sim$ 30 for each chemical composition) constitute a valuable tool to perform synthetic HB modeling, and to investigate pulsational and evolutionary properties of different kinds of pulsating variable stars.

[1] More informations about this new EOS can be found at the following URL site http://freeeos.sourceforge.net.

[2] The interested user can directly download from our WEB site both evolutionary tracks and isochrones as single files, or as a tar gzipped archive file

mixture	scaled-solar				α-enhanced			
η	0.2		0.4		0.2		0.4	
λ_{OV}	0	0.2	0	0.2	0	0.2	0	0.2
N^O tracks	20	20	40	20	20	20	40	20
M_{min}(M$_\odot$)	0.5	1.1	0.5	1.1	0.5	1.1	0.5	1.1
M_{max}(M$_\odot$)	2.4	2.4	10	10	2.4	2.4	10	10
N^O isoc.	63	44	54	44	63	44	54	44
Age_{min}(Myr)	30	30	30	30	30	30	30	30
Age_{max}(Gyr)	19	9.5	14.5	9.5	19	9.5	14.5	9.5
Color-T_{eff}	UBVRIJKL - ACS HST							

Table 1. The main characteristics of the BASTI evolutionary models database

All evolutionary results have been transferred from the theoretical plane to magnitudes and colours in various photometric filters, by using colour-T_{eff} transformations and bolometric corrections based on an updated set of model atmospheres (see Castelli & Kurucz 2003 for more details). At the moment, the evolutionary results are available in the photometric filters listed in table 1; in the near future we will also provide models in the Ströemgren, Walraven and HST WFI photometric filters. It is worth to point out that, for the first time, we have these transformations for both scaled-solar and $\alpha-$enhanced mixture[3].

We provide also tables (both in ascii and html format) for each chemical composition with relevant data about the theoretical models and the loci in the H-R diagram corresponding to the Zero Age Horizontal Branch and to the central He exhaustion.

4. Web library interface

The simplest way to obtain the data stored in the database is by using the World Wide Web. By following the link www.te.astro.it/BASTI/index.php the user can access our on-line library that includes two main sessions: the data archive and the web tools. Needless to say, both sessions are based on the same evolutionary tracks.

[3] At present, the transformations for the ACS HST filters are available only for a scaled-solar chemical composition.

The data archive contains all our computations listed by chemical composition. In this session, tracks, isochrones, HB models and various tables can be visualized and also downloaded.

The web tools session is a set of three web interfaces written in P.E.R.L.[4]. Behind these interfaces there are FORTRAN programs already used in previous published works by our group. This method is powerful and reliable because it is server side based and it uses well known FORTRAN programs. These web tools (see figure 1) are:

- isochrones-tracks maker. Using this tool it is possible to calculate an isochrone/track for a given age/mass for each chemical composition. The user can also choose: heavy element mixture, color-temperature transformation and the model type (with or without overshooting). This tool does not require registration and results are directly sent to the Internet browser.
- luminosity function maker. This tool provides the luminosity functions for a set of isochrones previously downloaded by the user. It is possible to select: heavy element mixture, the photometric filter, the number of isochrones, the number of the stars in the simulation, the and the Initial Mass Function exponent value. It is important to stress the fact that **this** program runs correctly only using isochrones of this database. As in the case of the isochrones-tracks maker, results are sent to the user's browser.

[4] Practical Extraction and Report Language

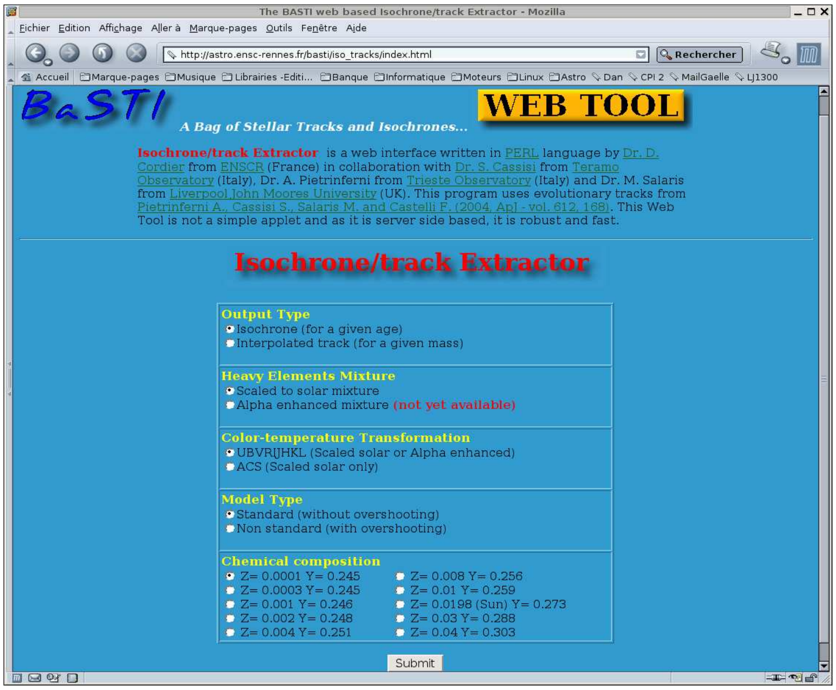

Fig. 1. The *isochrones-tracks maker* web interface.

– synthetic color-magnitude diagrams maker. This tool will be available soon[5]. It will allow stellar synthetic populations calculations, including accurate estimates of the pulsational properties of the expected population(s) of variable stars. The user will be free to fix various parameters like photometric and spectroscopic errors, colour excess, fraction of unresolved binaries, etc. This third tool will require registration [6], the results being sent to the user by e-mail.

5. Final remarks

This database is continuously updated by including additional stellar evolution data. More in detail, we will soon make available all the models (both tracks and isochrones) in additional photometric systems like the Ströemgren, Walraven and the HST WFI system. We plan also to extend as soon as possible the covered stellar mass range, adding models for both very low mass objects, and more massive stars than the current upper limits. In addition, we will extend the asymptotic giant branch evolution to cover the full thermal pulses' phase.

We wish to mention that we are available to compute (within one or two weeks) - on request - any specified evolutionary result which is not yet included in the archive.

In the future we will also allow users to run our evolutionary code through a simple World Wide Web browser, in order to compute ad-hoc stellar models for a specific project.

[5] A pre-release version can be seen at http://astro.ensc-rennes.fr/basti/synth_pop/ index.html

[6] Pre-registration can be done by sending an e-mail to S. Cassisi or D. Cordier

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