BaSTI, a Bridge between Grid and Virtual Observatory
Part 1: BaSTI inside the VO

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ABSTRACT. In the first part of this work we describe a new relational database (DB) created for storing metadata of stellar evolution models for a large range of masses and initial chemical compositions, which allows searching for data by scientific quantities and useful parameters. These data users can access the DB and might select a good catalog of evolutionary tracks and/or isochrones for making scientific studies and comparison with observational data. We also present a new Web portal where users can download scientific data of interest. This work has been conduced within the Italian Theoretical Virtual Observatory (ITVO) project , which aims to register these theoretical data under the Virtual Observatory standard and provide a set of standard tools able to visualize and analyze observational and also theoretical data. In the second part of the work we describe the link between the Grid infrastructure and the Virtual Observatory services as delineated by G. Taffoni and colleagues in 2006 and by F. Pasian and colleagues in 2008.

Online material: color figures

1. INTRODUCTION

This work is the second step inside the Italian Theoretical Virtual Observatory (ITVO) project (Pasian et al. 2006), whose first step consisted of archiving and publishing the data of many cosmological simulations (see Manzato et al. 2007), to offer the scientific community the possibility of reusing these data. As very long central processing unit (CPU) time was required to obtain these simulations, it was decided to insert other simulation data, like theoretical stellar data, in the virtual observatory (VO; see Hanisch & Quinn 2003) standards as part of VO–Data Centre Alliance (VO-DCA) WP4 and WP5 European asset and the ITVO Italian project.

In consideration of the covered wide range of stellar masses and chemical compositions, as well as of choices about important parameters such as mass loss and core convective over-shooting efficiency, the Bag of Stellar Tracks and Isochrones (BaSTI) database (DB) (see Pietrinferni et al. 2004, 2006; Cassisi et al. 2006; Cordier et al. 2007) represents a fundamental

tool to investigate the properties of stellar populations in both galactic and extragalactic systems.

The DB is structured to archive all the parameters regarding a stellar model simulation, starting from the initial chemical composition to their proprieties such as type of model, photometric system, heavy element distribution, mass loss, and even type of scenario,[1] and all parameters regarding the numerical evolutionary code linked to the metadata of the simulation output files. This relational DB offers the possibility of storing and easily searching the obtained data by many set of stellar simulations, and it also gives user-friendly access to a huge amount of homogeneous data such as these tracks and isochrones computed by using the Fraseati Raphson Newton Evolutionary Code (FRANEC) evolutionary code (see Pietrinferni et al. 2004

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[1] In this context, with 'scenario' we refer to the fact that the stellar models are computed under various assumptions about the efficiency of noncanonical physical processes such as core convective overshooting, atomic diffusion, and rotation.

TABLE 1
The Main Characteristics of the BaSTI Evolutionary Models Database

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
Photometric system	*UBVRIJKLH*—ACS *HST*—Ströemgren—Sloan—Walraven							

and references therein). So, the new Web portal provides users with the opportunity of downloading a single tar file within stellar tracks and/or isochrones of interest. We assigned a plus value to these data, thus developing a structure: archive +DB+ Web portal. In the past, one could only access the data archive through the links on a Web portal. Now we are creating a much more flexible structure that will allow many additional services in the future.

2. THE STORED STELLAR SIMULATIONS

Our model DB 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; Alexander & Ferguson 1994), thermal conduction (Potekhin 1999), plasma-neutrino processes (Haft et al. 1994) were updated. 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 have employed the new EOS by A. Irwin[2] (see also Cassisi et al. 2003), which covers all relevant evolutionary stages from the Main Sequence to the initial phases of White Dwarf cooling sequence 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 classically (i.e., according to the canonical Schwarzschild's criterion) and also considering a nonnegligible 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.

With the aim of covering a wide range of chemical compositions, we provide models for 11 different metallicities, namely $Z = 0.0001, 0.0003, 0.0006, 0.001, 0.002, 0.004, 0.008, 0.01, 0.0198$ (i.e. $Z_\odot$), 0.03 and 0.04, assuming two different heavy element distributions: scaled-solar (Grevesse & Noel 1993) and α-enhanced (Salaris & Weiss 1998). As for the primordial He abundance, we have adopted the value ($Y = 0.245$) provided by Cassisi et al. (2003). Through the calibration of the standard solar model we have set the following: the solar initial metal abundance $Z_\odot = 0.0198$, the mixing-length parameter[3] $m_l = 1.913$, and the initial Helium abundance for the Sun $Y_\odot = 0.2734$. As a consequence, we assume an Helium enrichment law equal to $\Delta Y/\Delta Z \approx 1.4$, in good agreement with the recent estimation $\Delta Y/\Delta Z = 2.1 \pm 0.9$ provided by Casagrande et al. (2007).

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 for a wide range of ages, from 30 Myr to the upper limit listed in Table 1. An extensive comparison between our isochrones and ones computed by other groups can be found in Pietrinferni et al. (2004, 2006) and Dotter et al. (2007).

For each chemical composition we have also computed additional He-burning low-mass stellar models with He core mass and envelope chemical profile fixed by a red giant branch (RGB) progenitor having an age of ~13 Gyr at the RGB tip, and a range of values of the total stellar mass. These horizontal

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[2] More informations about this new EOS can be found at the following uniform resource locator (URL) site http://freeeos.sourceforge.net.

[3] The mixing-length theory (Böhm-Vitense 1958) is a phenomenological, local, and time-independent approach to the stellar convective transport. This treatment introduces, for the computation of the temperature gradient, an adimensional parameter $m_l = l/H_P$ (where H_P is the local pressure height and l is the mean free path of the convective element), which has to be calibrated.

branch (HB) models (~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.

From the theoretical plane all evolutionary results have been transferred to magnitudes and colors in various photometric filters, by using color-T_{eff} transformations and bolometric corrections based on an updated set of model atmospheres (see Castelli & Kurucz 2003 for more details). The evolutionary results are available in the *UBVRIJKLH*, Advanced Camera for Surveys (ACS) on the *Hubble Space Telescope* (*HST*), Ströemgren, Sloan, and Walraven photometric filters; in the near future we will also provide models in the *HST* WFC3 photometric filters. It should be noted that, for the first time, these transformations are available for both scaled-solar and α-enhanced mixtures. The importance of adopting appropriate color-T_{eff} transformations and bolometric corrections has been pointed out by Cassisi et al. (2004); moreover, several comparisons have been made to verify that theoretical models coupled with consistent color-T_{eff} transformations and bolometric corrections properly reproduce observational data (see Bergbusch & Vandenberg 2001; Pietrinferni et al. 2004, 2006; Dotter et al. 2007 and references therein).

We have also provided tables 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 (ZAHB) and to the central He exhaustion.

3. BaSTI DATABASE, ARCHIVE, AND WEB PORTAL

The metadata of the simulated stellar files are stored in an Oracle 10g DB.[4] All data are stored in tables that are linked each other by foreign keys on primary keys to avoid any duplication of the information. There is also one auxiliary table to take into account the units used for the different quantities.

The metadata of the stored stellar simulation are as follows: all program parameters such as name code, version, initial conditions, boundary conditions, EOS, radiative and conductive opacities, nuclear reaction rates, neutrino losses. In addition, there are also stored the quantities of chemical compositions, for example, global metallicity Z, initial helium abundance Y, iron content [Fe/H], and the corresponding [M/H] value obtained from the adopted heavy elements mixture. More stored parameters include mass loss, type of model, photometrical system, heavy element distribution, and the scenario (canonical, overshooting, diffusion, rotation). All these tables have a link with the table where they are stored: the name of the output file, the directory where it is archived, the type of the files—i.e., if
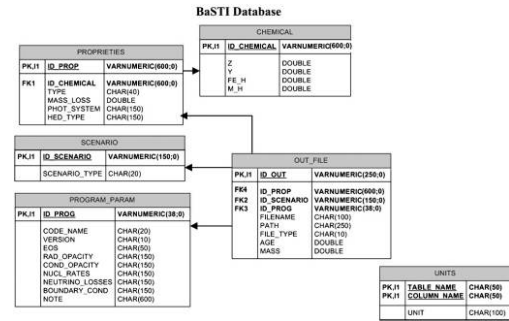

FIG. 1.—BaSTI relational DB schema: PK indicates a primary key of a table and FK indicates a foreign key to link two tables. See the electronic edition of the PASP for a color version of this figure.

the file refers to an isochrone, a track, an HB track, a ZAHB table or summary table, though at the moment all are American Standard Code for Information Interchange (ASCII) files. See the DB structure in the Figure 1.

The BaSTI Web portal is realized in hyper text mark-up language (HTML) for the static part, while the dynamic portion is written in Hypertext Preprocessor (PHP),[5] a server-side scripting language especially suited for Web development that can be embedded into HTML. The Web server used for our purposes is Apache 2.0 [6], the most famous open-source HTTP server for modern operating systems. At present the DB access is allowed from two different sites:

1. Italian Astronomical Archives Center (IA2) Web site[7]
2. OA-Teramo Web site[8]

This functionality permits a search over a large amount of scientific parameters allowing a simple and direct query to find the data that better satisfy the characteristics of a research typology. From the Web portal it is also possible to personalize the Simple Query Language (SQL) query, by making a more complex one and/or filtering on fields like a ratio of two quantities; see Figure 2. One example of a scientific query for the DB is discovering a set of simulated tracks for a given mass range and a ratio between mass and metallicity. The resulting catalog is shown in the Figure 3, where users can select and download a group of files and create a single tar file.

There is also a Help Web page[9] where the user can read a definition of the used quantities and get an idea of the value by which he/she can search into the archive.

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[4] The Oracle Web site is found at http://www.oracle.com.

[5] For more information on PHP, or to download the code, see http://www.php.net/.

[6] Apache Software Foundation is found online at http://www.apache.org/.

[7] The Italian Astronomical Archives Center is found at the URL http://wwwas.oats.inaf.it/IA2/BaSTI/.

[8] The OA-Teramo Web site is at URL http://albione.oa-teramo.inaf.it/.

[9] For BaSTI help, see http://albione.oa-teramo.inaf.it/index.html.

FIG. 2.—BaSTI Web portal: query form, personalized SQL form. See the electronic edition of the PASP for a color version of this figure.

The diagram flux of the data between the BaSTI Web portal and the Archive is shown in Figure 4.

3.1. BaSTI Web tools

In addition to tracks, isochrones, and tables, the BaSTI archive also includes three WEB TOOLS, which allow user-friendly manipulations on the stellar evolution library. Thanks to these tools one can compute user-specified isochrones, interpolate among evolutionary tracks to obtain the evolution for a

mass value not contained in the grid, determine the differential and cumulative luminosity functions from a set of isochrones previously downloaded and, finally, compute synthetic stellar populations with an arbitrary star formation history (SFH) and determine their integrated magnitudes and colors. One way for a Web server to interact with data generating program is by using the Common Getaway Interface (CGI). Input data provided by the user are transferred to our three Formula Translation (FORTRAN) programs through Practical Extraction and Report Language (Perl) programs.
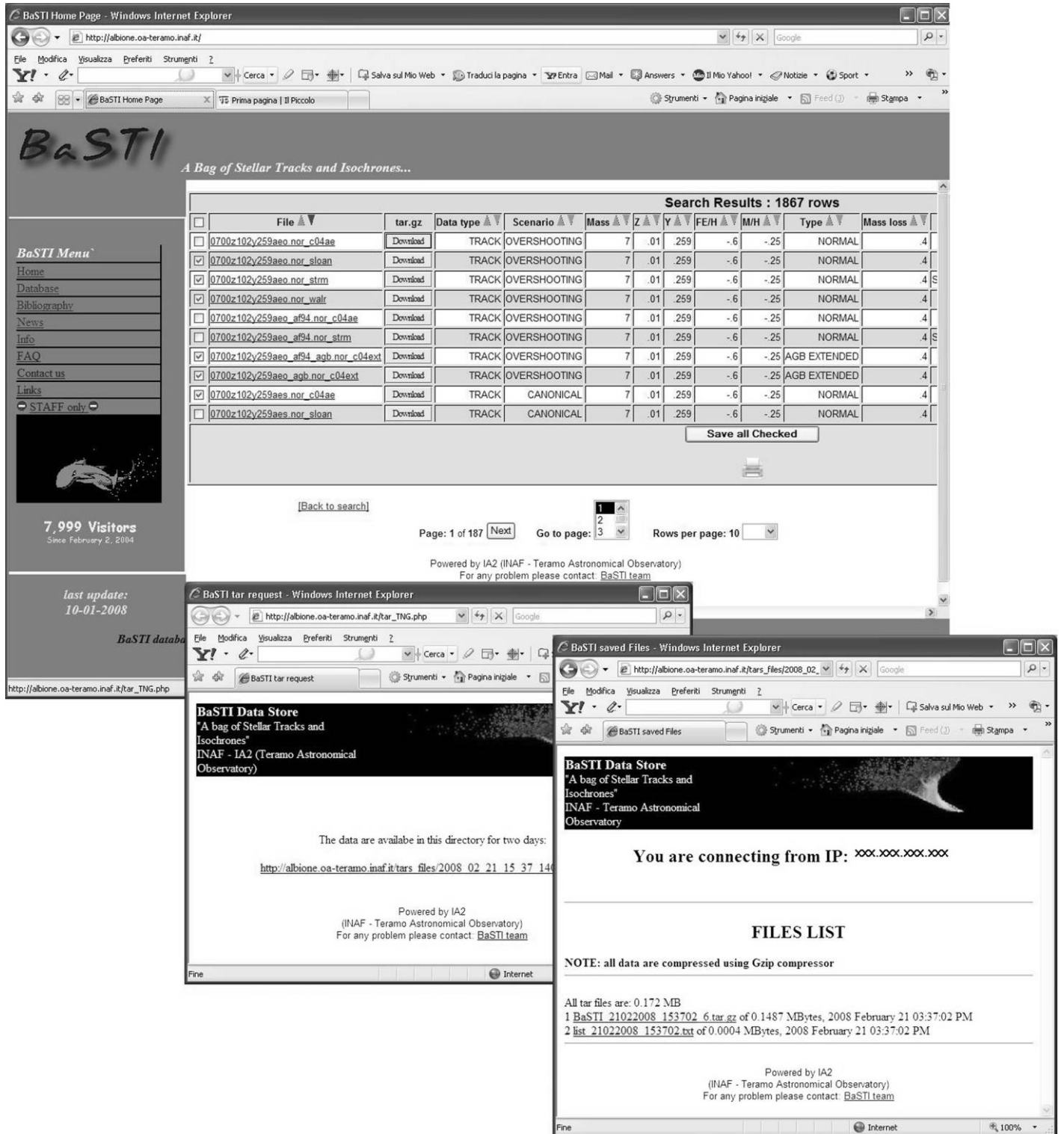
FIG. 3.—BaSTI Web portal result table: downloadable ASCII files. See the electronic edition of the PASP for a color version of this figure.
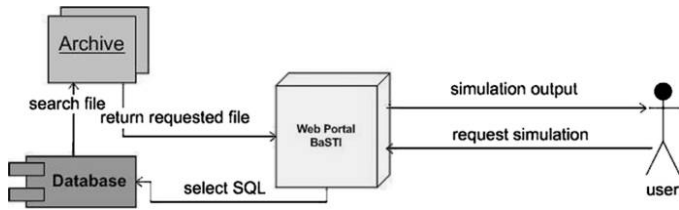
3.1.1. Isochrone Maker and Track Interpolation Program

A dedicated Web interface has been empowered to allow a direct computation of isochrone for any given age, for chemical compositions and within the age range listed in Table 1. Using the same interface, it is also possible to compute interpolated evolutionary tracks in the mass range 0.5–$10\ M_\odot$ for any chemical composition in the grid. To determine the track for the specified mass a linear interpolation on a point-by-point basis between two neighboring evolutionary tracks stored in the archive is performed. Due to the fine mass spacing of the tracks included in the BaSTI archive, a linear interpolation proves highly accurate. Once the track/isochrone has been computed, it is immediately transposed in the chosen photometric system.

This interface is particularly easy to use; the user has now to choose among a number of options:

1. The output type, i.e., isochrone or interpolated evolutionary track
2. The heavy elements mixture, i.e., scaled-solar or α-enhanced
3. The photometric system of interest; at the moment we allow a choice between the standard *UBVRIJKLH* filters and the ACS-*HST* ones
4. Core convection treatment, i.e., with or without convective core overshoot
5. The initial chemical composition (Y, Z).

Once these input parameters are fixed, the next screen allows the choice of the isochrone age (in Myr) or of the track initial total mass in solar units, as well as the job submission. The output tables (in the same format as the tracks and isochrones stored in the DB) are directly sent to the user's browser.

3.1.2. Luminosity Function Program

This tool provides differential and cumulative star counts as a function of the magnitude in a given wavelength band of single-age and single-metallicity stellar populations (e.g., the luminosity function). The isochrones stored in the BaSTI DB, or those obtained with the Web tool described in the previous section, represent the input files for the tool described

here. To run this Web tool the user has to provide five parameters: the number of isochrones whose luminosity functions are needed (maximum 20); the final stage of the isochrone, i.e., computing the luminosity functions only until the RGB tip, along the whole isochrone until the early asymptotic giant branch (early-AGB), or also including the thermal pulses–AGB (TP-AGB) phase; the photometric filter (in the *UBVRIJKLH* system); the initial mass function (IMF) exponent; the size of the magnitude bins within which the star counts are performed (e.g., 0.15 mag; these bins have to be larger than 0.05 mag). We adopt for the IMF a form of this type: $\frac{dN_\star}{dM} = CM^{-\alpha}$ where $dN_\star$ is the number of stars formed with mass between M and $M + dM$, and C is a normalization constant. A value of α of 2.35 corresponds to the Salpeter (1955) IMF.

As a final step one has to upload the isochrone files and submit the job. The output is directly sent to the user Internet browser as an ASCII file, which is divided into several sections, each of them corresponding to one individual isochrone. A summary of the selected input parameters is forwarded (age, metallicity, IMF exponent, etc.) into the output file, while the data themselves are displayed in three columns: the mean magnitude of the bin, the differential ($\log N$—where N denotes the star counts per magnitude bin as a function of the magnitude) and cumulative ($\log N+$—where $N+$ denotes the sum of the star counts from the faintest bin to the actual one, as a function of their magnitude) luminosity functions.

3.1.3. Synthetic CMD Code

The synthetic color-magnitude diagram (CMD) is often a fundamental tool to interpret observations of resolved or unresolved stellar populations. The simplest example of a synthetic CMD is an isochrone, because it represents the sequence occupied by stars formed at the same time and with the same initial chemical composition. Clearly, an isochrone cannot represent a multiple ages stellar population; moreover, it does not directly contain information about the distribution of stars along the various CMD branches. To include these effects one needs a synthetic CMD generator. In the BaSTI Web site the user can access the SYNTHETIC MAN(ager). This code computes magnitudes and colors of objects belonging to a synthetic stellar population with an arbitrary SFH. The program employs the grid of isochrones with TP-AGB included in the BaSTI archive.

The most important input is the SFH file through which one sets the grid of ages and for each age: the scale factor (which is proportional to the relative number of stars formed at that time), the metallicity [Fe/H] of the stars formed at that age, and the eventual 1 σ spread around this value.

The general structure of the code is as follows. At each age step t, the program sets the number of stars formed and their [Fe/H], as specified by the SFH. Then, according to the

TABLE 2
Variable Type Index and Sources Used in the Population Synthesis Program

Variables Type Index	Variable Type	Source for Instability Strip Boundaries
0	no variable	...
1	fundamental RR Lyrae	Marconi et al. (2003); Di Criscienzo et al. (2004)
2	first overtone RR Lyrae	Marconi et al. (2003); Di Criscienzo et al. (2004)
3	fundamental anomalous cepheid	Marconi et al. (2004)
4	first overtone anomalous cepheid	Marconi et al. (2004)
5	fundamental classical cepheid	Bono et al. (2000)

prescribed IMF, the values of the initial masses of the individual stars are randomly determined. For each value of the mass, the program interpolates among all the isochrones of age t in the grid (linear interpolation in mass, quadratic interpolation in metallicity), to determine its luminosity, effective temperature, actual value of the mass (in principle different from the initial value because of mass loss) and photometric properties. If the mass is too large to be still evolving at the age t, the next value of the mass is considered. For each mass an additional random number determines whether the generated star is a member of an unresolved binary system (the percentage of unresolved binaries has to be specified as input); if this is true, the mass of the second component is selected randomly, following Woo et al. (2003), and the fluxes of the unresolved components are properly added.

Once the photometric properties of an object (single or belonging to an unresolved binary system) are determined, additional effects are simulated, such as

1. Depth effects—according to a uniform stellar distribution with a user-specified total depth (in mag)

2. The effect of extinction—we have employed the extinction ratios by Bessel et al. (1998)

3. The photometric error—the individual magnitudes are perturbed according to a Gaussian distribution, with a user-specified 1 σ width (the same for all stars and for all photometric bands)

4. The effect of spectroscopic observational errors—the individual [Fe/H] values (that is, the [Fe/H] values at that age obtained from the SFH) are also perturbed according to a Gaussian error with user-specified 1 σ width.

The code can also search for variable stars, according to their location with respect to the boundary of RR Lyrae and Cepheid instability strips; pulsation periods are then determined. Table 2 shows literature references for the relevant type of variables.

Like all Monte-Carlo-method–based simulations, our program makes an extensive use of random numbers. Our random number generator (initially written by James 1990) needs seeds to be initialized; these seeds can be either provided by the user or got from Random.org,[10] which derived true random numbers from atmospheric electromagnetic noise.

The Web interface to SYNTHETIC MAN can been found in the BaSTI section called Synthetic Color—Magnitude Diagrams. This software is as simple to use as the others, but a registration is required before its first use. In order to get an user identification, one needs to contact S. Cassisi,[11] A. Pietrinferni,[12] or D. Cordier.[13]

In the following we summarize the input parameters for a run of SYNTHETIC MAN.

1. **Photometric error.** Photometric measurements are affected by observational errors that here are modeled following a Gaussian distribution. The user can fix a 1 σ constant error that is applied to all stars in the simulation for all 9 photometric bands. Another option is to employ an error that varies with the actual star magnitude and/or photometric band. The exact values have to be specified in an appropriate table. This table contains 18 columns. The first 9 columns display magnitudes in the 9 photometric bands, in order of increasing values. The remaining 9 columns are the corresponding photometric errors.[14]

2. **Mean spectroscopic error.** Spectroscopical abundances determinations are affected by observational errors that have been modeled following a Gaussian distribution. The allowed range of the 1 σ dispersion is between 0.0 and 1.0 dex.

3. **Color excess** $E(B - V)$. The color excess $E(B - V)$ toward the synthetic stellar population, are caused by the interstellar medium. The extinctions in the individual photometric bands are computed from the value of $E(B - V)$ employing the reddening low by Bessel et al. (1998).

4. **Total spatial depth of the population.** If stars belonging to the simulated stellar population cannot be assumed to be all at

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[10] x

Random.org is a random number service, accessed online at http://www.random.org.

[11] S. Cassisi can be reached at cassisi@oa-teramo.inaf.it.

[12] A. Pietrinferni can be reached at pietrinferni@oa-teramo.inaf.it.

[13] D. Cordier can be reached at daniel.cordier@ensc-rennes.fr.

[14] See the online help for more details http://albione.ao-teramo.inaf.it/BASTI/WEB_TOOLS/syn-th_pop/mean_phot_error_help.html.

the same distance, the population shows a spatial depth. At the moment the spatial depth is modeled with a uniform distribution in distance modulus.

5. **Fraction of unresolved binaries.** A fraction of the objects detected in a generic stellar population are unresolved multiple stellar systems. Only unresolved binaries are accounted for in our code. Their fraction is a free parameter.

6. **Minimum mass ratio for the unresolved binary systems.** The minimum mass ratio in the Woo et al. (2003) relationship (between 0.0 and 1.0, the suggested value is 0.7).

7. **Lower mass limit.** The lower limit of the mass of the stars in the simulation (the minimum allowed value at the moment is $0.50 \ M_\odot$).

8. **Scale factor for the SFR.** The star formation rate (SFR) contains the relative weight of the star formation episodes at the various ages. In order to fix the absolute number of objects in each stellar generation, a scale factor has to be chosen. The product of this scale factor times the relative weight in the input SFR gives the total number of stars created at a given time, with mass between 0.5 and 120 $M_\odot$. If more than 2×10^6 objects are expected to be formed at a given time step, the program will stop to highlight the excessive amount of computational time needed for the whole simulation.

9. **Exponent α of the IMF.** Assumed to be of the form $M^{-\alpha}$.

10. **Choice of the isochrone set to use.** That is, scaled-solar or α-enhanced, $\eta 0 0.2$ or $\eta = 0.4$ and standard (without over-shooting) or overshooting ($\lambda_{OV} = 0.2$).

11. **Possibility of searching for pulsating stars.** Search for pulsating stars harbored by the synthetic population and compute their periods.

12. **Desired SFH.** A number of prespecified SFHs for selected galaxies are also provided (see Table 3).

13. **Random number generation.** As with all simulations based on a Monte-Carlo method, our program needs seeds for random numbers generator initialization. The user can choose the values of the seeds, or let the program automatically get seeds from the server of entropy. We underline that all computations initialized with the same seeds will lead to identical outputs.

TABLE 3
AVAILABLE STAR FORMATION HISTORIES

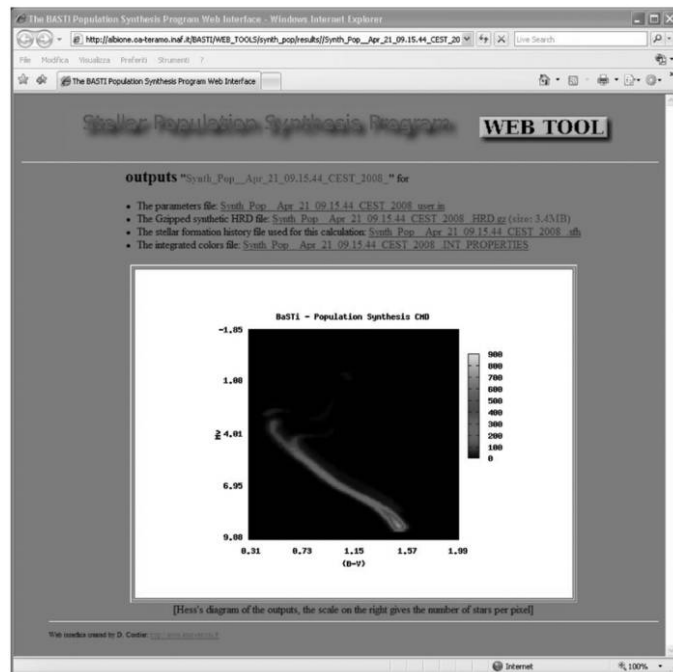| Stellar Population	Source
NGC 6822 (global SFH)	Gallart et al. (1996)
SMC (global SFH)	Harris & Zaritsky (2004)
LMC (bar field)	Holtzman et al. (1999)
Local disk	Rocha-Pinto et al. (2000a, 2000b)
Milky Way bulge	Molla et al. (2000)
Sextans A	Dolphin et al. (2003)
LGS3	Miller et al. (2001)

FIG. 5.—Example of the output Web page for the SYNTHETIC MAN Web tool. See the electronic edition of the PASP for a color version of this figure.

After specifying the input parameters, users can start their computations by clicking the "Submit" button. The calculation may take from a few minutes to hours, mainly depending on the requested number of stars. Because the size of the output files can amount to several MBytes, they cannot be sent directly to the user Internet browser, nor by email. So, once the computation is completed, an HTML page is created on the fly, and the user receives an email as notification, which includes the page URL. In the output Web page four data files are available:

1. `Synth_Pop_*_user.in`:[15] this ASCII file recalls the parameters used for the calculation.

2. `Synth_Pop_*_.HRD.gz`: this gzipped file contains data for the individual stars, in which one can find the following quantities: identification number, $\log(t)$ (yr), [Fe/H], the value of the actual mass, $\log(L/L_\odot)$, $\log(T_{eff})$, M_V, $(B - V)$, $(U - B)$, $(V - I)$, $(V - R)$, $(V - J)$, $(V - K)$, $(V - L)$, $(H - K)$, the value of the initial mass, the initial mass of the unresolved binary companion (if present—for stars without companion this quantity is set to 0.0), logarithm of the pulsation period (in days—if the search for variable is off or if the star is not pulsating this quantity is set to 99.99), an index denoting the

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[15] The symbol * indicates the date at which the calculation is obtained.

type of variable (see Table 2 for an explanation). This file can be uncompressed with the standard GNU software `gunzip`. As this file can be relatively large, the downloading is automatically forced when users click on the link.

3. `Synth_Pop_*_.sfh`: contains the Star Formation History data used for the calculations.

4. `Synth_Pop_*_.INT_COLORS`: file with the integrated *UBVRIJHKL* absolute magnitudes produced by the stars evolving in the synthetic population, several selected integrated colors, the total number of stars in the simulation, and their total mass.
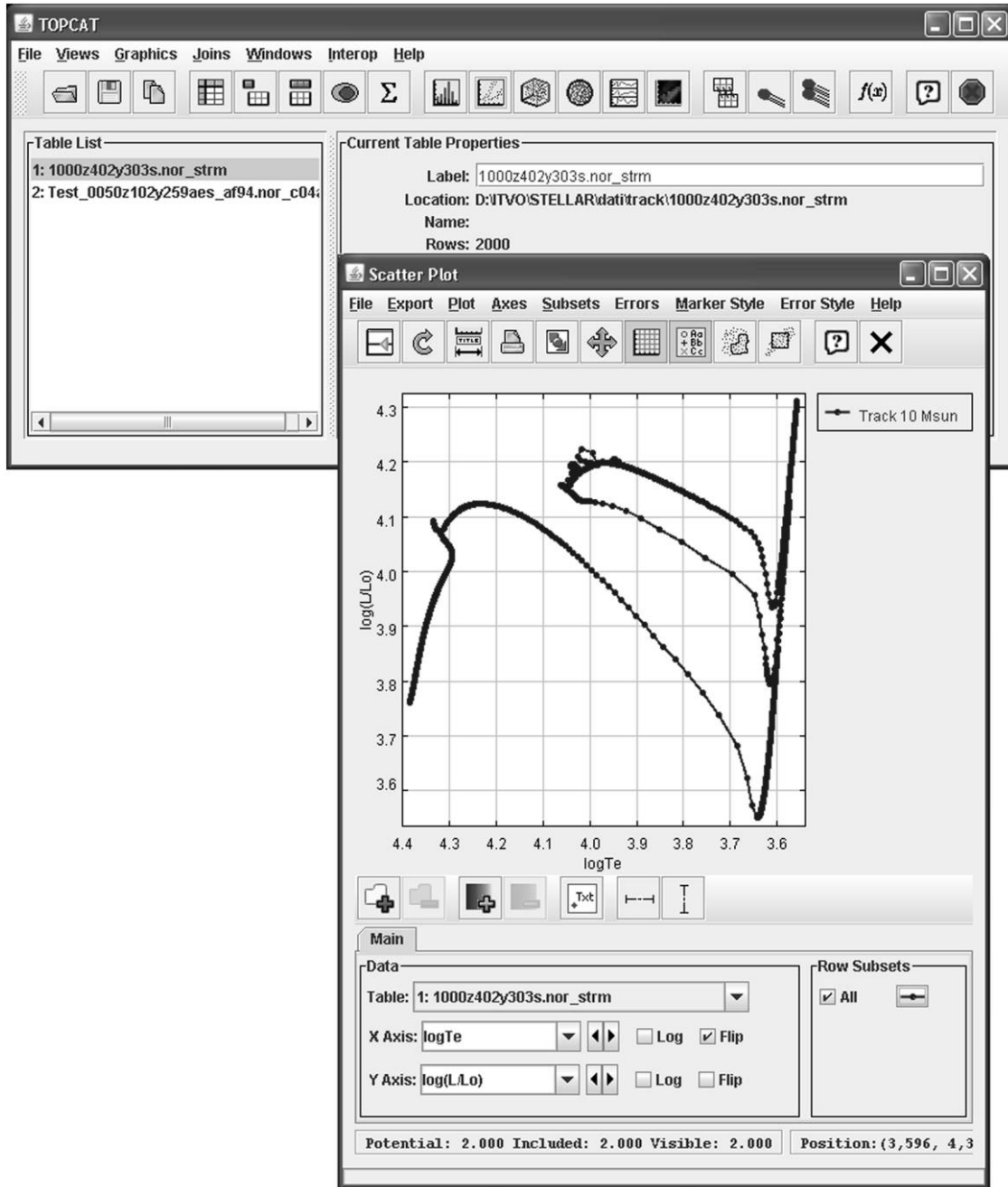

FIG. 6.—Plot of one track of a 10 $M_\odot$ star with [M/H] = 0.395, $Z = 0.04$ and $Y = 0.303$ created loading into TOPCAT tool a ASCII table downloaded from the BaSTI Web portal. See the electronic edition of the PASP for a color version of this figure.
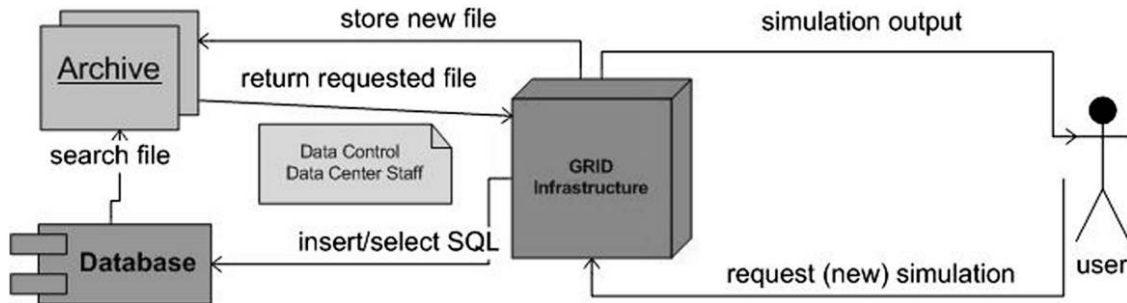
Fɪɢ. 7.—Future data flux diagram for the new request of simulated stellar data via grid infrastructure. See the electronic edition of the PASP for a color version of this figure.

An example of the output Web page is displayed in Figure 5. The $V - (B - V)$ Hess's diagram taking into account all the synthetic objects drawn for the simulation is also automatically displayed, stars number being encoded with colors. The user should be aware that—for obvious reasons—Web pages displaying program outputs are deleted by the software manager one month after the end of the computation.

4. VO TOOLS AND FUTURE DEVELOPMENT

The output format for all files at the moment are ASCII tables, so a user can open them with the TOPCAT VO tool to easily create a plots of the contained quantities, as shown for example in the Figure 6.

The problem is that the ASCII file is not a standard, so to see the column names in TOPCAT you have to remove the comment line between the column name and the column values, because for TOPCAT the last line starting with "#" must contain the column name. The idea for the future is obtain as output a FITS BINTABLE that is codified in a standard also well accepted by VO. The next step will be create a VOTable format for save or transform the data in this new extensible mark-up language (XML) VO standard.

In the future, we wish to create a data model inside the IVOA theoretical interest group as we are making for cosmological simulations (Lemson et al. 2007). That data model will be the future standard schema to use for accessing and creating services for these data. The theory data model consists in a unified modeling language (UML) diagram of classes including all the variables and quantities used and calculated in the simulations. The data model has to be validated from more than one real DB schema that contains the metadata of these simulations in order to enable future queries on distributed DBs and archives. We also have to write a standard access protocol for these data, to enable a simply and uniform query to retrieve the stellar simulations.

Another progress will be to install a Web service using the Symbolic Optimal Assembly Program (SOAP) engine

Axis,[16] SOAP[17] is an XML-based communication protocol, an encoding format for interapplication communication, that will allow development of tools and process via a Web service, in order to include these in the VO registry. For example, as a first step one can query the DB via the Web service or transform all the tools available from the BaSTI Web portal in Web services. Another future development could be seeing the header of these ASCII table or in future FITS Tables and also creating on-the-fly profiles of some quantities to get a better view of the data before downloading them. See the first work on this (Costa et al. 2008).

Another future development will be link to VO-Data Center Alliance project Work Package 5, which can produce new simulations using the Grid infrastructure (see Taffoni et al. 2006; Pasian et al. 2008), so that users may request new full-fledged simulations for personal use and their inclusion in the archive and database for wider use is filtered by the Data Centre staff (see the future data flux diagram in the Fig. 7).

5. CONCLUSION

This work includes the first relational database created to store and access the stellar simulation data in order to publish and to reuse very expensive—in term of computing time and man power—results like theoretical outputs, which took a long time to write and run the code. This work allows scientists to access and compare theoretical and observational data in an easy and homogeneous way using IVOA standards. Furthermore, this database is continuously updated by including additional stellar evolution data.

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[16] Axis Web Services can be found online at http://ws.apache.org/axis/.
[17] Simple Object Access Protocol information is available online at http://www.w3.org/TR/2000/NOTE-SOAP-20000508/.

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