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ITVO and BaSTI: databases and services for cosmological and stellar models

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Abstract. We have created a database structure to store the metadata of different types of cosmological simulations (Gadget, Enzo, FLY) and the first relational database for stellar evolution models BaSTI, it includes tracks and isochrones computed with the FRANEC code. We are also studying the feasibility of including different sets of theory data and services in the Virtual Observatory (VObs). Some examples of services are: the calculation on-the-fly of the profiles of some quantities for the simulated galaxy clusters, the preview of the object image opened with a VObs tool and retrieve a VOTable standard format. Furthermore, the BaSTI database development is the use case for studying the feasibility of storing in it the output of new simulations performed using the Grid infrastructure as demonstrating in the VO-DCA WP5, EU funded project. All that could be matter of discussion between the tool developers and the users, the scientists.

Key words. Virtual Observatory: archives - Cosmology: simulation - Stars: evolution model - Stars: tracks - Stars: isochrones

1. Introduction

This work has been conduced within the Italian Theoretical Virtual Observatory (ITVO) project (Pasian et al. 2006), which aims to register these theoretical data under the Virtual Observatory standard[1] and provide a set of standard tools able to visualize and analyze observational and also theoretical data. So the idea of the Theoretical Virtual Observatory (TVO) was born to develop standards and tools for simulated data in common with the observational ones. The challenge is to develop and supply to the community a set of services for data handling by providing a user-friendly access to a huge amount of heterogeneous data and also an optimized way to process and analyze these data in a distributed environment.

The main purpose of the TVO is to create a distributed database of simulated data accessible from anywhere in an easy and transparent

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[1] See Hanisch & Quinn 2003, http://www.ivoa.net/pub/info/

way, and to include some services to allow the user to visualize data, download them and extract information from them.

A simulation archive can include an extremely large amount of data; this implies strong difficulties in analyzing and moving these kind of data, especially cosmological simulation data. Therefore it is important to develop a system that analyses the data where they are stored. We have built a software layer that can easily allow us to handle data.

We have built a set of value-added services accessible online via Web portals. Providing these services makes our databases the first resource allowing direct comparison of simulated datasets with observations: we provide the creation on-the-fly of maps and graphics of various quantities, the maps are searchable via Aladin tools in common with observational data, for the stellar data we have a isochrone-tracks extractor; a luminosity function calculator; a synthetic color / magnitude diagram is a fundamental tool to interpret observations of resolved or unresolved stellar populations (stellar population synthesis program).

2. ITVO structure

The ITVO schema project structure contemplates a set of distributed archives and databases and also Web portals for the data access that can use many infrastructure and services.

In detail:

1. Archives contain the output files of the simulation;
2. Databases contain the metadata of the simulation that should include all the parameters to perform the run and not only the physical ones;
3. Data Access: it could be performed via Web portals or Web services or in future via Grid infrastructure, allowing to create on demand new simulated data.

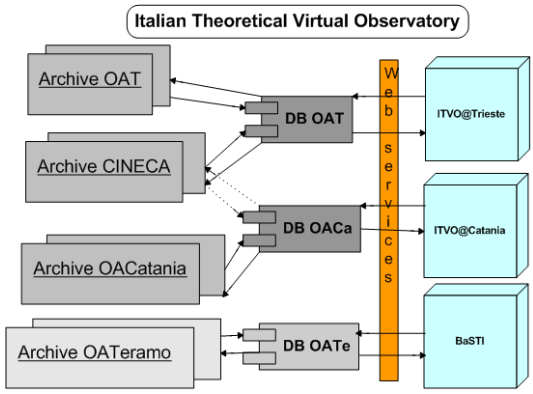

Fig. 1. The ITVO Structure: archives, databases and Web portals

3. Cosmological simulations - ITVO database and Web portal

We built a cosmological relational database that has been designed to store all kinds of cosmological simulations. We used an Oracle 10g[2] relational DB, whose query engines allow the user to make complex queries in a standard language, Simple Query Language (SQL), which is also the standard query language used by many tools developed under the IVOA standards.

As a test-bed we started to deal with three different simulations. The first one is a large cosmological hydrodynamic simulation (Borgani et al. 2004), which used the massively parallel tree N-body/SPH code GADGET-2.0 (Springel et al. 2001) to simulate a concordance Lambda CDM cosmological model within a box of $192h^{-1}Mpc$. The cosmological parameters assumed were $\Omega_m = 0.3$, $\Omega_b = 0.04$, $H_0 = 70kms^{-1}Mpc^{-1}$ and $\sigma_8 = 0.8$. This simulation regarded star formation, radiative cooling, metal production and galactic wind. It produced 102 snapshots for a total amount of approximately 1.2 TB of raw data.

The second simulation is an AMR (Norman & Bryan 1999), grid-based hybrid code (N-Body + hydrodynamic), designed to simulate the cosmological structure for-

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

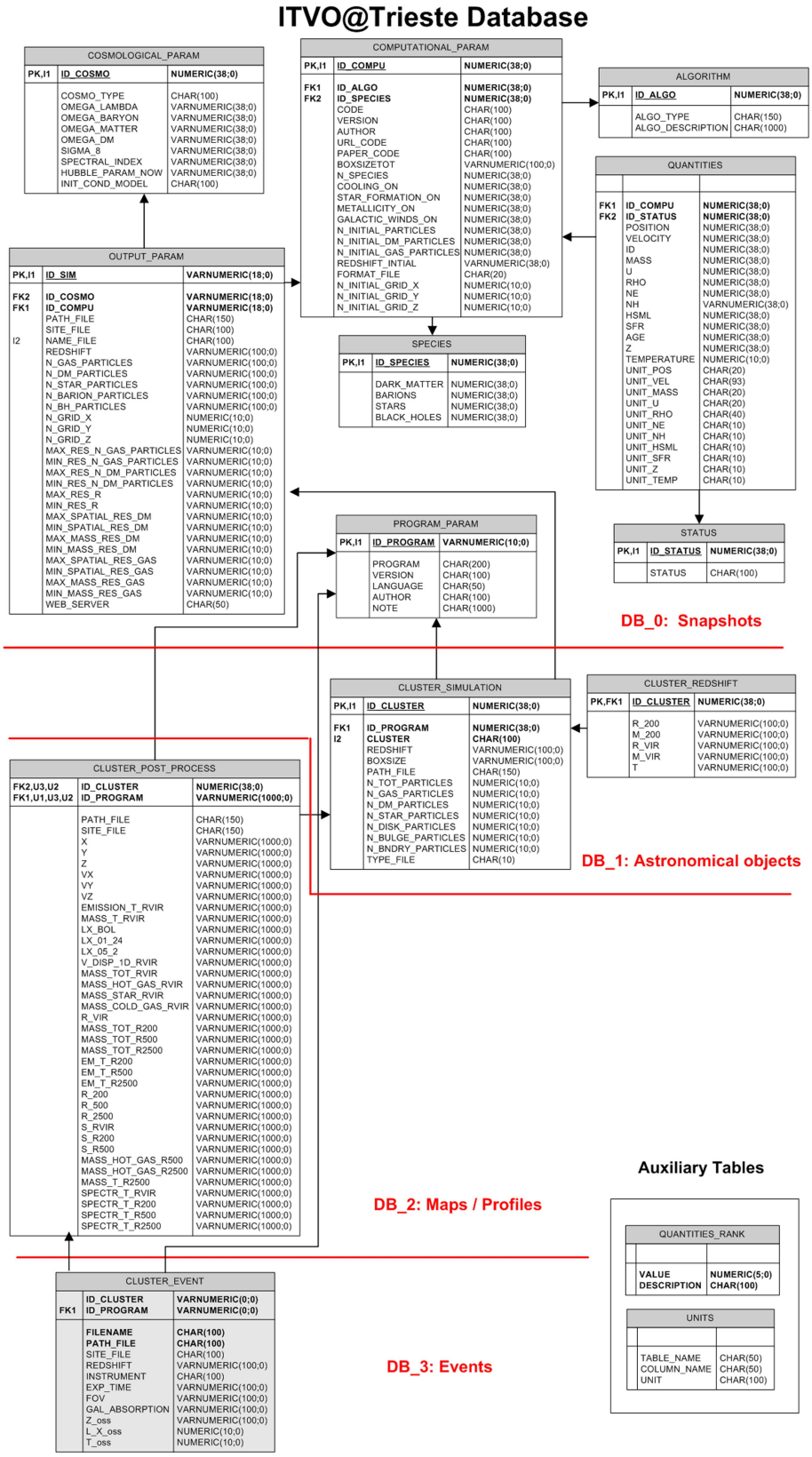

Fig. 2. The ITVO multilevel Database Structure: tables and their links. The Level 3, in grey, is under development.

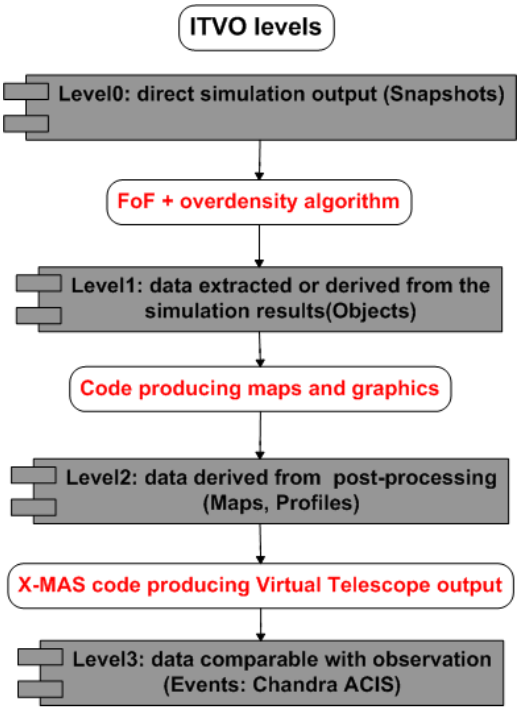

Fig. 3. The ITVO multilevel Database Structure: Level 0, Level 1, Level 2, and Level 3.

mation; it used the Enzo[3] code. We stored two simulations made with this code, both of them simulate a Lambda CDM universe with the following cosmological parameters: $\Omega_m = 0.27$, $\Omega_b = 0.044$, $H_0 = 71 kms^{-1} Mpc^{-1}$ and $\sigma_8 = 0.94$.

The third simulation consisted of a set of N-body results, it obtained using the FLY code (Becciani & Antonuccio-Delogu 2001); typically the N-body simulations were performed on boxes of sizes between 5 and $120h^{-1}Mpc$, with the number of particles varying between 128^3 and 400^3, and for different CDM cosmological models, ranging from $\Omega_{CDM} = 1$ and $\Omega_\Lambda = 0$ to the most popular "concordance" model ($\Omega_{CDM} = 0.3$ and $\Omega_\Lambda = 0.7$).

The ITVO DB (Manzato et al. 2008b) is a multilevel database, as can be seen in Fig. 2. Every level holds the data of one step of the whole data process. The Level 0 of the database includes the description of the algorithm, the computational and cosmological parameters used to make the computational run, the species of matter inserted in the simulation, the physical quantities linked to the particles or grid points and also the format (HDF5 and GADGET at the moment in our case), resolution and redshift of the output file. The next level includes the link to the code used for the extraction of the astronomical objects, for example the code used to extract the clusters and group of galaxies from the initial box and all also the metadata of these new output file, like virial radius, virial mass, temperature, etc. The others levels refers to a more refined post-processing: the Level 2 stores all the metadata of the FITS files concerning the two-dimensional maps (Ameglio et al. 2007) and, in future, the Level 3 contains all the FITS file obtained with X-MAS (X-ray MAp Simulator) a program for generating event files following the same standard used for real observations (cf. Gardini et al. 2004; Rasia et al. 2008). A schema of the levels can be found in the Figure 3.

At present the database access is allowed from three separate levels of Web interface accessible from the IA2 (Italian Astronomical Archives Center) Web site at the URL, `http://wwwas.oats.inaf.it/IA2/ITVO/`. Furthermore, there are many features described in Molinaro et al. and Borgani et al. inside these proceedings and Costa et al. (2008).

4. Stellar model - BaSTI database and Web portal

The database is structured to archive all the parameters regarding a stellar model simulation starting from the initial chemical composition, to the properties like: the type of model, the photometric system, the heavy element distribution, the mass loss, and even the type of scenario[4] and all the parameters regarding the numerical evolutionary code linked

[3] `http://www.cosmos.ucsd.edu/enzo/`

[4] In this context, with term 'scenario' we refer to the fact that the stellar models are computed under various assumptions about the efficiency of non-

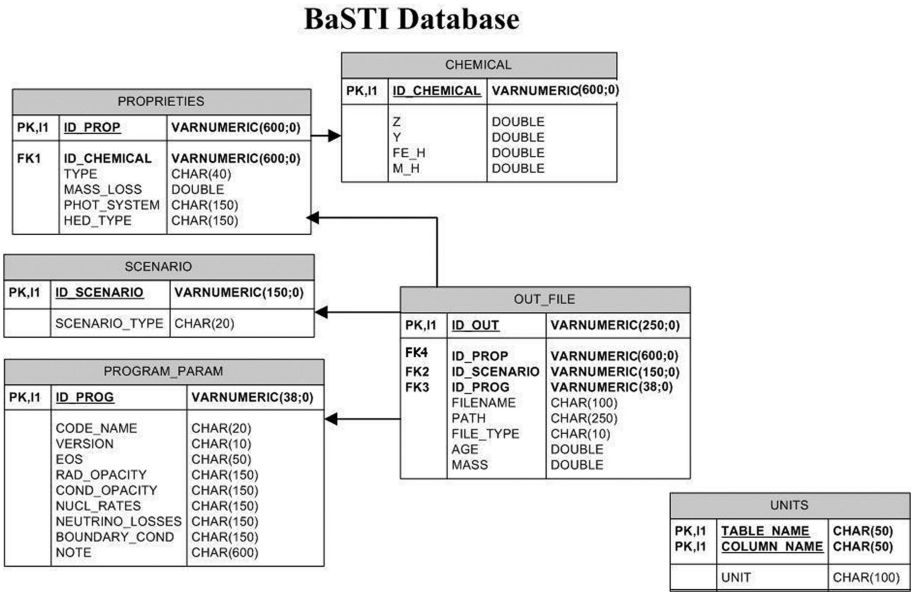

Fig. 4. The BaSTI relational database schema: PK indicates a primary key of a table and FK indicates a Foreign Key to link two tables.

Table 1. The main characteristics of the BaSTI evolutionary model 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							

to the metadata of the simulation output files (see the DB structure in the Figure4). This kind of relational database gives the possibility to store and search in an easy manner the data produced by many sets of stellar simulations. It also gives a user-friendly access to a huge amount of homogeneous data like the tracks and isochrones computed by using the FRANEC evolutionary code (Pietrinferni et al. 2004, and references therein), the main characteristics are listed in Table 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

canonical physical processes such as core convective overshooting, atomic diffusion, and rotation.

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

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 BaSTI Web site[8].

This functionality permits you to 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 (Manzato et al. 2008a).

5. Link with the VO

Inside the IVOA we are working to define new standard formats, access protocols and developing tools and Web services to make the life of astronomers easier. So we are continuing in the co-operation to develop a Data Model, SimDM [9], and the access protocol, SimDAP [10], for theoretical data, register the archives and all the services inside the VO registry and increase the number of theoretical data stored inside the TVO. We will also continue developing tools and services able to make an easy comparison between observational and theoretical data.

We are specifically working to transform the output data into VOTable, that is the VO standard file for tabular data; we are creating and/or modifying tools such as Aladin[11] and VisIVO[12] to enable them to visualize and analyze theoretical and observational data. We plan to use VisIVOServer to create on server side the preview of the snapshots and the maps of the astronomical objects. Furthermore, we are planning to transform the three useful BaSTI tools into web services so to give to the scientific community an easy manner to search and use them.

6. Conclusions

This paper describes the first prototypes to store, access and analyze the cosmological simulation and stellar data in order to reuse very expensive results of big numerical simulation runs. This work allows the scientists to access and compare theoretical and observational data in an easy and homogeneous way using IVOA standards. Furthermore these databases are continuously update by including additional data and new features to permit analysis and comparison.

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

[7] The IA2 is found at the URL: `http://wwwas.oats.inaf.it/IA2/BaSTI/`.

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

[9] The draft document *Simulation Database (SimDB)*, is visible at URL: http://volute.googlecode.com/svn/trunk/projects/theory/snapdm/doc/note/SimDB-note.html

[10] The draft document *Simulation Data Access Protocol (SimDAP)*, is visible at URL: http://volute.googlecode.com/svn/trunk/projects/theory/snap/SimDAP.html

[11] Aladin: `http://aladin.u-strasbg.fr/`

[12] VisIVO: `http://visivo.cineca.it/`

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