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Feeding an astrophysical database via distributed computing resources: the case of BaSTI

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Abstract

Stellar evolution model databases, spanning a wide ranges of masses and initial chemical compositions, are nowadays a major tool to study Galactic and extragalactic stellar populations. The Bag of Stellar Tracks and Isochrones (BaSTI) database is a VO-compliant theoretical astrophysical catalogue that collects fundamental data sets involving stars formation and evolution. The creation of this database implies a large number of stellar evolutionary computations that are extremely demanding in term of computing power. Here we discuss the efforts devoted to create and update the database using Distributed Computing Infrastructures and a Science Gateway and its future developments within the framework of the Italian Virtual Observatory project.

Keywords: Stellar evolution, semi-analytical code, science gateway, workflow

1. Introduction

The availability of large sets of stellar evolution models spanning a wide range of stellar masses and initial chemical compositions is a necessary prerequisite for any investigation aimed at interpreting observations of Galactic and extragalactic, resolved and unresolved stellar populations. In the last years, thanks to the new developments in various fields of Physics our understand-

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ing of the structure and evolution of stars improved and consequently also the stellar evolution models increased in complexity and completeness.

Pietrinferni et al. (2004) built a database of evolutionary predictions: The Bag of Stellar Tracks and Isochrones (BaSTI, see Pietrinferni et al. (2004, 2006, 2009, 2013), Cassisi et al. (2006), Cordier et al. (2007)). The database collects the results of a large number numerical simulations based on Frascati Raphson Newton Evolutionary Code (FRANEC) (Pietrinferni et al., 2004) and it is specifically devised for population synthesis studies of resolved and unresolved stellar populations.

BaSTI relational database archives a large number of parameters such as chemical composition coverage, improvements in the model input physics and bolometric corrections/colour transformations, coverage of physical parameters, reproduction of empirical constraints, ease of interpolation and inclusion in population synthesis codes. For this reason it is considered one of the most complete stellar libraries (Conroy, 2013; Gallart et al., 2005; Marín-Franch et al., 2010).

The Database has been designed to account the following main criteria for a reliable and homogeneous stellar evolution library:

1. the input physics employed in the model computations is the most up-to-date;
2. models for all initial chemical compositions are computed with the same evolutionary code and the same physical framework;
3. models and isochrones reproduce a large array of empirical constraints obtained from observations of single stars and local resolved stellar populations.
4. all results have to be easily available to the potential users.

Recently BaSTI has been expanded by adding new important quantities evaluated during the key points of stellar evolution to allow a fast visualisation of these phases. A particular effort has been devoted to port BaSTI to a VO-compliant environment (see Pietrinferni et al. (2014) for more details) and to develop a new simple and user-friendly web interface (Pietrinferni et al., 2014).

From a computational point of view, to populate the BaSTI database with a new isochrone it is necessary to execute a large number of FRANEC runs that are extremely demanding in terms of CPU time. New runs are necessary to update, maintain and extend the database and to keep the accuracy, homogeneity and completeness of the data. Extensions are often requested by Astronomers that need new data for their scientific activities.

To carry out this large set of simulations we need an extremely high computational power, Taffoni et al. (2010) showed that a Distributed Computing Infrastructure (DCI) can be successfully used to address this problem. However, even today's most powerful DCI such as Grid or Cloud computing infrastructures still have limitations, especially due to the design of the user interfaces. Many sophisticated tools are command line driven and are complex to use. As a consequence, new users have to become familiar, not only with Astrophysical methods and theories, but also with the use of new codes and with the handling of complex computing resources. In order to hide this complexity, it is common to adopt Science Gateways (SG) technologies (Raicu et al., 2006; Wilkins-Diehr et al., 2008) powered by a workflow management systems to distribute computation on various computing infrastructures (Belloum et al., 2011; Deelman et al., 2009; Barker and van Hemert, 2008; Curcin and Ghanem, 2008).

A SG or portal is defined here as a community-developed set of tools, applications, and data that are integrated via a portal customised to meet the needs of the Astronomical community. The computational processes supported by SGs are organized as scientific workflows that specify dependencies among underlying tasks for orchestrating DCI resources (such as clusters, grids or clouds). SG technologies allow a scientific research community to create a web-based working environment where researchers can concentrate on scientific problems without facing the complexities of the computing, data and workflow infrastructure.

In this paper we discuss the design and development of a SG that allows to execute different type of FRANEC runs giving the Astronomers the possibility of updating the BaSTI database or to make on demand simulations of synthetic stellar evolutionary tracks. In the next Section we discuss the physics inputs adopted in the updated version of FRANEC and we describe the global properties of the code. In Section 3 we present the SG technology adopted to develop a FRANEC SG that allows to execute FRANEC runs on local clusters, Grid or Cloud infrastructures. In Section 4 we present the FRANEC SG. Finally we compare this approach with the use of DCI previously adopted by Taffoni et al. 2009. We also discuss the "connection with the virtual observatory". Final remarks and a short discussion concerning the planned developments in the context of Euro-VO will conclude the paper.

2. FRANEC evolutionary code

BaSTI has been computed by using an new version of the FRANEC evolutionary code. FRANEC is a Fortran 77 code, that simulates the evolution of a star on the basic of a number of different physical inputs and parameters. Almost all the adopted physics inputs have been updated in the new version as well as numerical scheme for treating the nuclear burnings and the accuracy of the numerics. 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, that comes from Kunz et al. (2002). As for the Equation of State (EOS), we employ the new EOS by A. Irwin (Cassisi et al., 2003), that covers the full structure of the models along with all the relevant evolutionary stages.

All stellar models have been computed by fixing the extension of the convective core during core H-burning both classically (Schwarzschild criterion) and considering a non-negligible overshooting beyond the Schwarzschild boundary ($\lambda_{OV} = 0.2Hp$). This latter choice reproduces empirical constraints coming from intermediate-age cluster Color-Magnitude Diagrams (CMDs) and field eclipsing binaries.

We have also accounted for mass loss by using the Reimers formula (Reimers, 1975) with the free parameter η set to zero (no mass loss), 0.2 and 0.4, respectively.

A single run of FRANEC produces one synthetic model (SM). A model

mixture	scaled-solar					α-enhanced			
η	0.0	0.2		0.4		0.2		0.4	
λ_{OV}	0.2	0	0.2	0	0.2	0	0.2	0	0.2
N^O tracks	20	20	20	40	20	20	20	40	20
M_{min}(M$_\odot$)	0.5	0.5	1.1	0.5	1.1	0.5	1.1	0.5	1.1
M_{max}(M$_\odot$)	2.5	2.4	2.4	10	10	2.4	2.4	10	10
N^O isoc.	44	63	44	54	44	63	44	54	44
Age_{max}(Gyr)	9.5	19	9.5	14.5	9.5	19	9.5	14.5	9.5
Photometric system	UBVRIJKL - ACS HST - Strömgren - Walraven Sloan - WFC2 - WFC3 (UVIS, IR)								

Table 1: The main characteristics of the *BaSTI* archive

evolves from the Pre-Main Sequence phase up to the C-ignition, or until the first thermal pulses along the asymptotic giant branch. A SM run (SMR) is a very simple pipeline consisting of 2 different software (SW) modules: the FreeEoS code and FRANEC. It can last from 1 hour up to several hours according to the value of the initial mass and metallicity.

To compute an isochrone (Full Isochrone Run, FIR), it is necessary to execute a large number of SMR varying initial mass and metallicity. The calculations cover 13 different metallicities, namely $Z = 0.00001$, 0.0001, 0.0003, 0.0006, 0.001, 0.002, 0.004, 0.008, 0.01, 0.0198, 0.03 and 0.04, 0.05, with two different heavy element distributions each: a scaled-solar (N. and A., 1993) and an $\alpha-$enhanced (Salaris and Weiss, 1998) one. We adopted a cosmological He mass fraction $Y = 0.245$ (Cassisi et al., 2003), and a helium-to-metal entichment ratio $\Delta Y/\Delta Z \approx 1.4$, fixed by the initial solar metal mass fraction obtained from the calibration of the standard solar model.

For each chemical composition it is also necessary to compute additional He-burning 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 Branch

(HB) models ($\sim$ 30 for each chemical composition) constitute a valuable tool to perform synthetic HB modelling, and to investigate pulsational and evolutionary properties of different types of pulsating variable stars.

Data obtained by the simulations is then post-processed and correlated to compute the isochrones. Different isochrones are calculated making different FIR varying other physical parameters as the EOS or the heavy element distribution.

During a FIR a single EOS is shared by a number of independent FRANEC runs. Data produced is then processed to compute the isochrone. Figure 1 displays some tracks and isochrones for Z=0.002, Y=0.248 and scaled-solar mixture of BaSTI DB. Luminosities and effective temperatures of the models produced by the code should be transformed to magnitudes and colours for several photometric filters –see Table 1– by using colour-T_{eff} transformations and bolometric corrections obtained from an updated set of calculations of stellar model atmospheres and spectra.

The accuracy of theoretical predictions archived in BaSTI DB, have been extensively tested by employing comparisons with Color Magnitude Diagrams (CMDs) of field stars and a sample of stellar clusters with empirically established parameters like distance, [Fe/H] and reddening (Percival et al., 2009; Cordier et al., 2007; Pietrinferni et al., 2004, 2006)

On the other side, the BaSTI theoretical framework has been used by several authors to perform their scientific investigations (Skillman et al., 2014; Calamida et al., 2014; King et al., 2012; Monachesi et al., 2012; Milone et al., 2012; Cassisi et al., 2008; Piotto et al., 2005, 2007; Recio-Blanco et al., 2005)).

Different isochrones are calculated making different FIR varying other physical parameters as the EOS or the heavy element distribution.

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To populate the BaSTI DB with a new isochrone it is necessary to execute a large number of FRANEC runs (typically more than 100) exploring large number of different parameters. This type of runs are commonly called

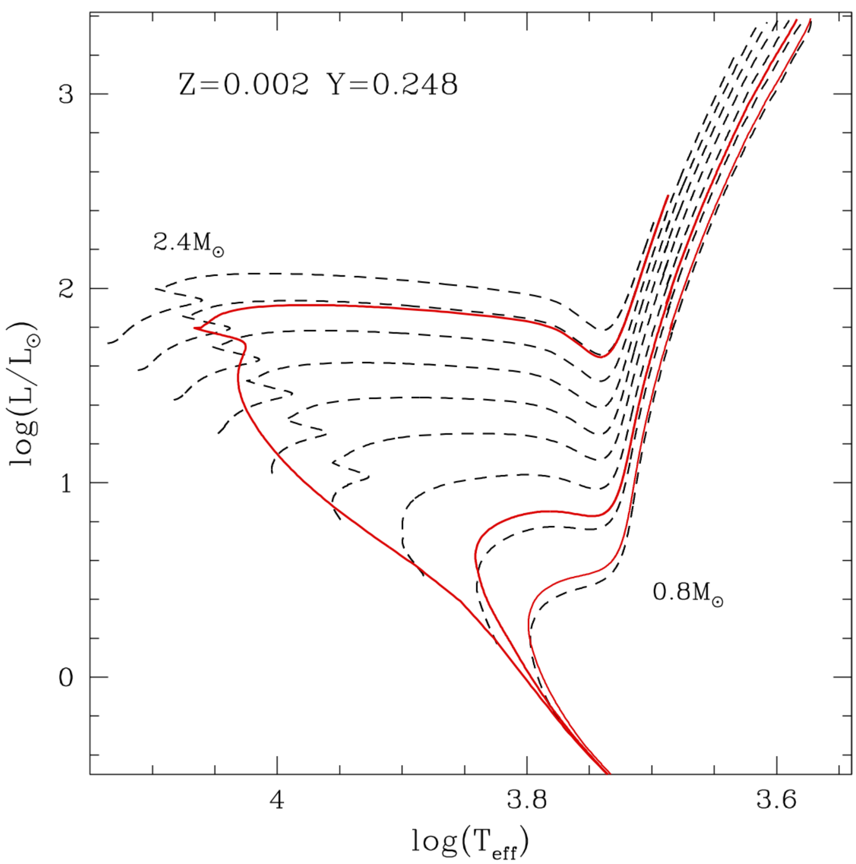

Figure 1: HR diagram for a sub-sample of tracks (black dashed lines) from $0.8M_\odot$ to $2.4M_\odot$ ($\Delta M = 0.2M_\odot$) and isochrones (red solid lines) with age equal to 0.5, 5.0 and 12.0 Gyr (from left to right) for Z=0.002, Y=0.248 and scaled-solar mixture.

parameter-sweep jobs.

To carry out this large set of simulations we need an extremely high computational power and disk space. A DCI can be successfully used to address this problem. Actually, the benefit of using a DCI does not come only from its computational resources but also from some other added values that are intrinsic in a distributed environment. For example it allows the distribution of datasets over different sites avoiding single points of failure and making them directly available to all the Astronomers involved in the computation.

This transparent access to resources and data allows Astronomers to test extensively the parameter space, either by simulating and storing data or by retrieving information already produced and eventually re-processing it.

3. Science Gateways and workflow technology

To develop FRANEC SG it is necessary to identify a framework that simplifies the web interface design, that allows to easily configure the access to DCIs or local clusters and enables to implement user defined SFR and FIR workflows.

Scientific workflows have become an effective programming paradigm to compose complex computational modules for scientific simulations such as FRANEC. A workflow is a formal specification of a scientific process, which represents, streamlines and automates the analytical and computational steps that Astronomers need to go through from computation and analysis to final data presentation and visualisation. A workflow system supports the specification, modification, execution, failure recovery and monitoring of a workflow using a workflow engine.

The SG technology used to develop the FRANEC gateway is based on gUSE/WS-PGRADE (Kacsuk et al., 2012). gUSE/WS-PGRADE[1] is a collaborative and community oriented web application development environment based on the Liferay[2] portal framework. gUSE/WS-PGRADE computational

[1] http://www.guse.hu
[2] http://www.liferay.com

processes are natively organised as workflows.

WS-PGRADE is the workflow engine (Kacsuk, 2011), it offers generic services to handle distribution, monitoring and fault-tolerant distributed computing in various types of platforms (e.g. web services, grids and clouds); automatic capture of provenance of the involved processes and data; workflow composition and progress monitoring; (see e.g. Kozlovszky et al. (2012))

gUSE is a resource virtualization environment providing a large number of high-level DCI services. These services include a workflow storage, an application repository, an information system, and a monitoring system. Several types of DCIs are supported for the submission of workflows like grid and cloud infrastructures, batch systems, and desktop grids (e.g., UNICORE, EMI, BOINC).

Moreover, gUSE/WS-PGRADE is integrated with SHIWA[3] workflow interoperability platform, that grants workflow developers the freedom to choose their preferred workflow system for development, whereas enabling the execution of all these workflows expressed in different languages within WS-PGRADE engine.

4. The Distributed Computing Infrastructure

The gUSE environment allows to implement different gateway back-ends where actual computations are executed. In the case of FRANEC we identify two different resource: the European Grid Initiative (EGI) grid and a local computing cluster.

4.1. EGI Grid environment

EGI developed a DCI based on the EMI Grid middleware (Aiftimiei et al., 2012). EMI middleware builds upon standard open source solutions like Condor (Frey et al., 2001), Globus (Foster et al., 2001), gLite (Laure et al., 2006), extended by the European Middleware Initiative[4]. This middleware provides

[3]http://www.shiwa-workflow.eu

[4]http://www.eu-emi.eu

the user with high level services for scheduling and running computational jobs, accessing and moving data, and obtaining information on the Grid infrastructure as well as Grid applications.

Workload Management System (WMS) is responsible for the distribution and management of tasks across Grid resources, in such a way that applications are efficiently executed. The computation tasks are described through a CONDOR ClassAds-based Job Description Language (JDL). Each JDL file specifies both the binary to execute (the processing to perform) and the input/output files (the data to process) either directly (explicit mention of the input and output data files) or indirectly (through the job input sandbox, command line parameters).

Data Management System (DMS) takes care of file I/O, mass storage and data access and replication. Each file stored in the Grid has a Unique IDentifier (GUID). To make the file accessible also to a human user it is possible to assign one or more Logical File Names (LFN) to the same GUID. A LFN is a human readable string. Starting from the GUID or LFN it is possible to find the physical location of the file (SURL) and the transport protocol to use in order to move the file or to download it. EMI DMS is based on LFC File Catalogue. LFC maps LFNs or GUIDs to SURLs. LFC exposes to the user a set of commands that allow to manage files in the Grid.

gUSE can be configure to interact with both high level services (WMS) and to low level resources (the computing elements of each grid site) thanks to a software components called DCI bridge. Once gUSE is properly configured the workflow developer can decide which resource is more appropriate to execute workflow tasks expressed in terms of JDL jobs. Additionally gUSE is able to manage input data and output data via LFC distributed file system.

5. FRANEC Science Gateway

FRANEC Science Gateway[5] is designed as a workflow enabled grid portal that is wrapped around WS-PGRADE providing the execution of a set of FRANEC runs from a simplified web interface (see Figure 2).

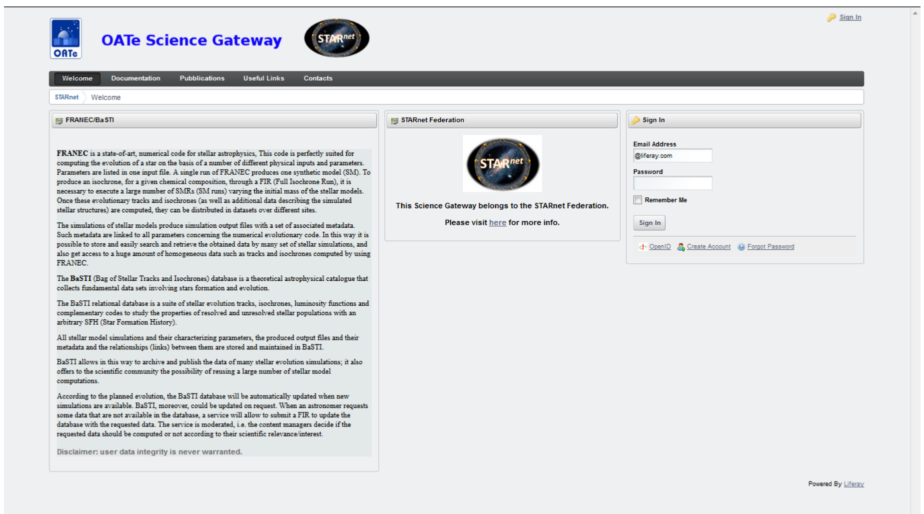

Figure 2: FRANEC Science Gateway home page.

A FRANEC workflow (as depicted in Figure 3) has been developed using WS-PGRADE native workflow language (Balasko et al., 2010). Moreover, we decided to adopt a modular architecture, each module is a workflow task that can be reused to build other workflows. We developed 7 modules as shown in Figure 3. In particular:

- **EOS** module provides the Equation of State in tabular form. The input values are the Metallicity Z and the type of mixture (combination of chemical elements heavier than helium).
- **OPACITY** module produces a table of Opacity from pre-calculated tables. Given the Metallicity value Z and the type of mixture it obtains a

[5] http://starnet.oa-teramo.inaf.it:8081

new table of opacity which is interpolated from the pre-calculated ones.

- **FRANEC** is the core module of the workflow. It produces the models of stellar evolution starting from the output of the two modules EOS and OPACITY and a set of input parameters given by the user to perform the evolution. It produces a set of parameter values varying in relation to time, quantities varying in relation to the radius of the model, the chemical composition of the core (vs. time), surface chemicals (vs. time), and energy resolution Flows(vs. time).

- **TAR** produces an archive of the main outputs.

- **GNUPLOT** produces the output plots.

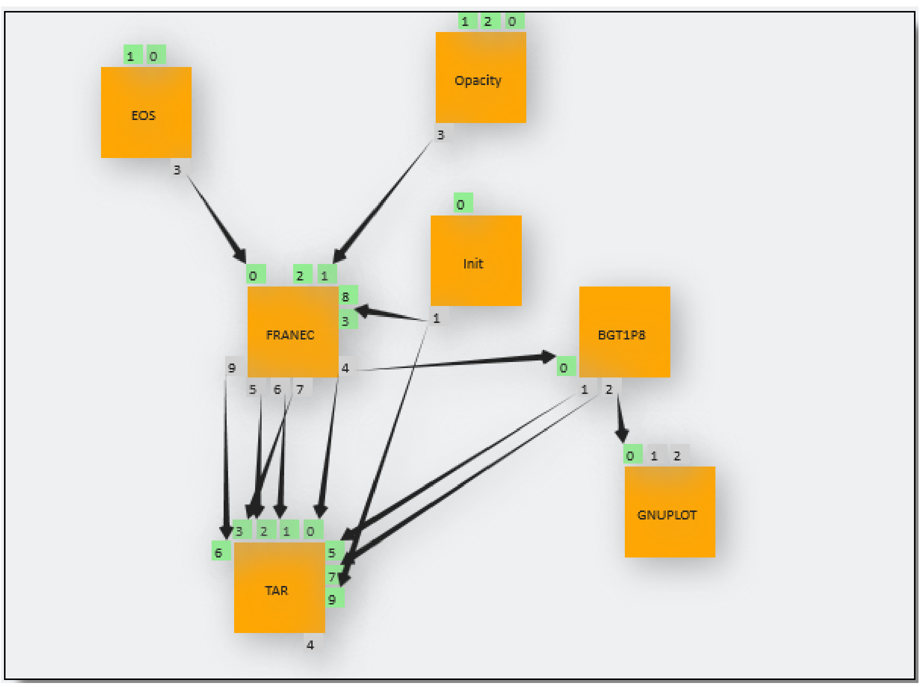

Figure 3: FRANEC workflow.

The dependencies between different modules are explicitly defined by the workflows visualisation and design interface. In Figure 3 we present the workflow used to execute SFR. The nodes of the graph, represented by boxes, are the modules and denote the activities related to individual computations. Each module is actually a job to execute on the DCI. Each job communicates with other jobs within the workflow through job-owned input and output ports. An output port (small grey boxes) of a job connected with an input port (small green boxes) of a different job is called channel; these are directed edges of the graph. A single port must be either an input, or an output port of a given job.

The FIR workflow is a parameter sweep workflow (Kacsuk et al., 2008) where SIR workflows are executed in parallel sharing the same EOS module.

The simulations of stellar models produce simulation output files with a set of associated metadata. Such metadata are linked to all parameters concerning the numerical evolutionary code. In this way it is possible to store and easily search and retrieve the obtained data by many set of stellar simulations, and also get access to a huge amount of homogeneous data such as tracks and isochrones computed by using FRANEC.

A portlet has been developed to allow the configuration of the workflow execution (see Figure 4).

This customised web interface (Figure 4) has been developed to allow users to execute a SFR or a FIR. It is a portlet that allows to run the workflow on a DCI and to configure the workflow execution specifying input parameters for the star such as: the initial mass (in solar unit), the metal content, the initial helium abundance, the mixing-length value, the efficiency of the mass loss and of the overshooting.

The access to this portlet (i.e. web page) is restricted only to authenticated users. In fact security is a critical issue in developing a SG in particular when SG's resources are not entirely dedicated to the SG and managed by it, but they are DCIs shared with other communities. In this case it is necessary to implement an efficient user authentication and authorisation service. FRANEC SG supports user authentication for personalization, managing user information across sessions, tracking usage, and providing authenticated access to external resource.

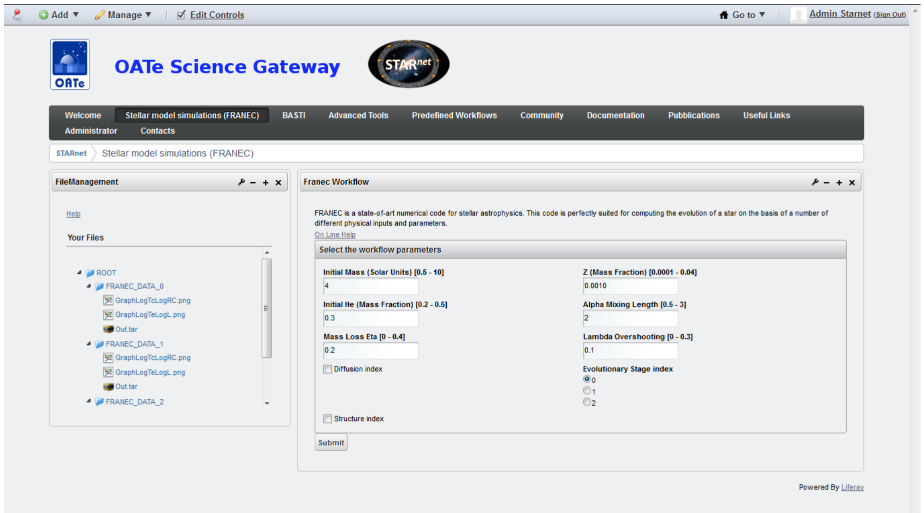

Figure 4: FRANEC portlet (on the right) and Data Management portlet (on the left).

The portal implements a login module based on user name and password and a role-based authorisation modules. Roles allow to identify differ users profiles that allow to give access to different applications and resources. Currently we define three roles: standard user, advanced user and administrator.

Guests are not provided with an account for the SG and they have access only to information about FRANEC and the features offered by the gateway. A new account can be created by a standard user or by exploiting credentials from already created Facebook or OpenId accounts.

Standard users are allowed to access the web interface to FRANEC runs. They are also allowed to change input and relevant parameters, to invoke and monitor workflows.

Advanced users can access additional features to create and change workflows and to set configurations of grid infrastructures.

The gateway implements some data management services by means of a graphical environment. A Data Management portlet (see the left portlet on Figure 4) allows users the recycling of their private staging area within the system for managing their datasets as well as images produced from such datasets.

All the evolutionary predictions generated by workflows are stored on a local file system or on an LFC distributed file system. The data management service is able to browse the two filesystems and gives the possibility to move upload and download user data from the web interface. Files can also be converted in VO-Tables, this allows to use VO tools like TOPCAT[6], to analyse the simulation data, and to easily compare the theoretical predictions with observational counterparts and to import easily in the BaSTI database.

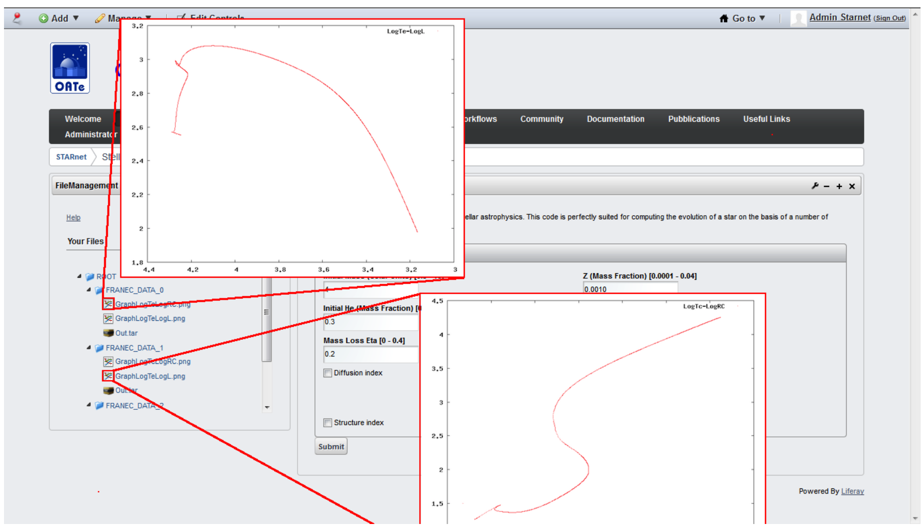

Figure 5: Data Management portlet (on the left) allows users to visualise graphs produced by FRANEC Workflow

All the implemented portlets are developed with the Java Vaadin web Framework [7]. This open source framework has been employed to implement server side Java Servlet based web applications using the full power and flexibility of Java without taking care of the client side since it compiles the Java source code to JavaScript which can then be run on browsers.

[6] http://www.star.bris.ac.uk/ mbt/topcat/

[7] `http://www.vaadin.com`

5.1. *Science gateway and VO standards*

In the framework of the Workflow4Ever project[8], the Astrophysics community has developed more than 50 workflows using Taverna (Oinn et al., 2006) and the AstroTaverna plugin (Schaaff et al., 2012). AstroTaverna integrates existing Virtual Observatory web services as first-class building blocks in Taverna workflows (e.g. to search a registry, add found services to the workflow, manipulate data in form of VOTables, and convert coordinates).

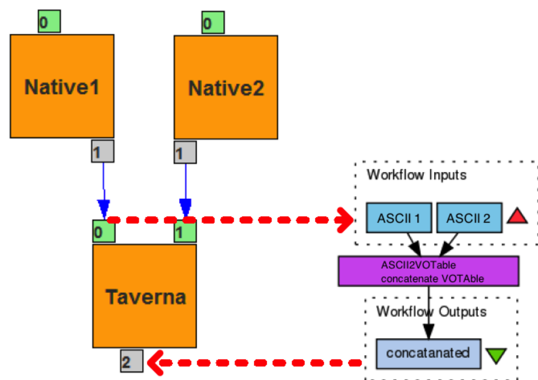

Figure 6: Example of a met-workflow that is designed using two native modules and one Taverna2 AstroTaverna module that manipulate the output.

Those *Data-oriented* workflows are used to interact with data, being mainly designed to search and get data in distributed database systems, manipulate data or perform simple data analysis tasks. Each of these “Atomic” operations are implemented by an individual simple workflow module. These workflow modules are simple to operate and do not demand large computing effort, so they are executed using the Taverna Desktop environment, by an astronomer. The data tasks run locally or on clusters using IVOA standards to access computing resources.

gUSE/WS-PGRADE technology allows to import and execute non-native workflows. A non-native workflow is a module in a WS-PGRADE workflow,

[8]http://www.wf4ever-project.org

which executes a workflow of some other workflow engine (e.g. a Taverna workflow). In this way it is possible to create a so called meta–workflow, which consists of a mixture of native and non-native workflows embedded within WS-PGRADE. Thanks to this capability we are able to embed AstroTaverna workflows as simple module to find and manipulate data and to access BaSTI database using IVOA standards directly from the gateway (see Figure 6). In particular we use modules to create VOTables from ASCII files, manipulate VOTables for visualisation and search data in BaSTI archive.

6. Discussion and Conclusions

In the last years, the BaSTI stellar evolution database has been largely used as a test-case for the integration and interoperability between VO and DCI facilities (see e.g. Taffoni et al. (2010)). Nowadays BaSTI provides, not only a database of stellar evolutionary tracks, but also a set of tools that facilitate the analysis of observations of stellar populations, providing "on demand" stellar evolution predictions thanks to a SG.

To provide an efficient "on demand service" for the Astronomical community and to feed the BaSTI database with new data, it is necessary to use an infrastructure able to execute a large number of numerical simulations. The vast number of simulations required can only be generated by computational resources that greatly exceed what the single institution can offer and for this reason DCI solutions are mandatory. Moreover, the adoption of a web interface can increase the number of Astronomers that benefit of this service and provides effective usage of the e-infrastructures.

A workflow-oriented gateway allows scientists to share their workflows and to identify best practices for investigating their datasets. More importantly, they can automate workflows for repeating computations varying input parameters (parameter-sweep jobs), which was a manual, slow and very error prone process in the past. In this way scientists can focus on their core scientific activities as opposed to spending time in data analysis on inadequate resources.

In this paper we discuss the use of a SG as an effective tool to profit of a DCI grid environment in running FRANEC jobs. The approach we propose here is an improvement respect to a previous work of Taffoni et. al. (2008) where a complex script–based environment was developed to allow Astronomers to execute FRANEC jobs on the Grid.

The use of a SG framework based on gUSE/WS-PGRADE has some main advantages:

- It speeds up the SG design and development. We focus our development activity on the design and implementation of the workflows and workflow modules, and on the web portlets used to configure and execute the SFR and FIR (Figure 4). All the implementation aspects, in particular the ones related to the interface towards the DCI, are built-in the gUSE/WS-PGRADE gateway framework and only need to be properly configured. The gateway framework offers the possibility to use different gateway's back-ends at the same time. Advanced users and developers can configure workflows or even workflow components to run on local linux clusters or on other DCIs.

- It offers an easy interface for Astronomers. A workflow-oriented gateway may offer a simple web user interface that allow to configure and execute simulation, visualise the simulation's results and to access to simulated data.

- It offers rapid prototyping of web user interfaces and strong support for parameter-sweep jobs.

- It offers a framework to integrate into the SG IVOA tools and services. The ability to execute meta–workflows can be used to re-use AstroTaverna workflows to access VO services directly from the portal.

We have received a positive feedback from the BaSTI users, reinforcing our belief that SG technology is a good approach for offering on–demand services to

Astronomers. The planned future developments of the Franec SG in the framework of the Italian Virtual Observatory initiative VObs.it, are the following:

1. We wish to include a TOPCAT visualization portlet on the SG and to implement SAMP (Taylor et al., 2012) technology to make the SG communicate directly with the TOPCAT installed in the user desktop when available;
2. We wish to improve the graphical treatment of the stored data by providing new and more efficient tools for improving the access to the data as well as the interoperability among various (theoretical and observational) resources;
3. We wish to implement IVOA Theory access protocols and standards. This effort is a fundamental requirement to facilitate and improve the inclusion of micro-simulations data inside the VO.

FRANEC gateway is also one of the partners of STARnet gateway federation. STARnet Gateway Federation, is a federation of Astronomy and Astrophysics oriented SG designed and implemented to support the Astronomy and Astrophysics community and its peculiar needs (Becciani et al., in press).

STARnet envisages sharing a set of services for authentication, a common and distributed computing infrastructure, data archives and workflows repositories. Each gateway provides access to specialized applications via customized workflows, the first implementation of STARnet provides workflows for cosmological simulations, data post-processing and scientific visualization. These applications run on local or shared computing infrastructures thus guaranteeing resources availability and they can be shared between the different communities of the federation, published worldwide for dissemination purposes or kept local for privacy issues.

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