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Preview, explore and analyze numerical simulations inside the VO

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Abstract. Once the data output of a numerical simulation is stored and ingested into a database a web interface can be implemented to allow the end user to explore it. The VO idea is to handle the data directly on the server side leaving the user only with the results of the query, or other end products, on his own machine. This means providing services to let the user preview and analyze data and metadata (both generated on-the-fly or pre-computed) where the computing is performed on the server and only the results are visualized on the user desktop (or sent to him). Here we present an example as implemented on the IA2-ITVO archive web interface.

Key words. Virtual Observatory (VO)– VO: theoretical data – VO: data previewing – VO: data analyses

1. Introduction

The amount of data from astrophysical observations as well as from numerical astrophysical simulations is growing exponentially; at present days it is not unusual to think about TeraBytes of data stored from single observation or simulations (e.g. the raw data set from the cosmological simulation of Borgani et al. (2003), stored at IA2 - Italian center for Astronomical Archives - consists of about 1.2 TeraByte).

In this scenario it becomes day by day more clear that downloading or retrieving astronomical data sets for further analysis on local machines is not a simple nor a practical task.

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The Virtual Observatory (VO) approach to this problem is to let the astronomer seat in front of his own machine, querying relational databases and data archives located all over the world, then analyzing the chosen data remotely, and retrieving, at last, just the analysis' results.

2. VO, IVOA and theoretical data

The VO community, composed of national VO projects and organizations, converged on 2002 into the International Virtual Observatory Alliance (IVOA, see http://www.ivoa.net and Hanisch & Quinn (2002)). The IVOA work focuses on the development of the standards needed by the community to implement

Fig. 1. The Italian Center for Astronomical Archives - Italian Theoretical Virtual Observatory (IA2-ITVO) web portal. On the left the IA2 archives' menu with the ITVO one expanded into its main Levels.

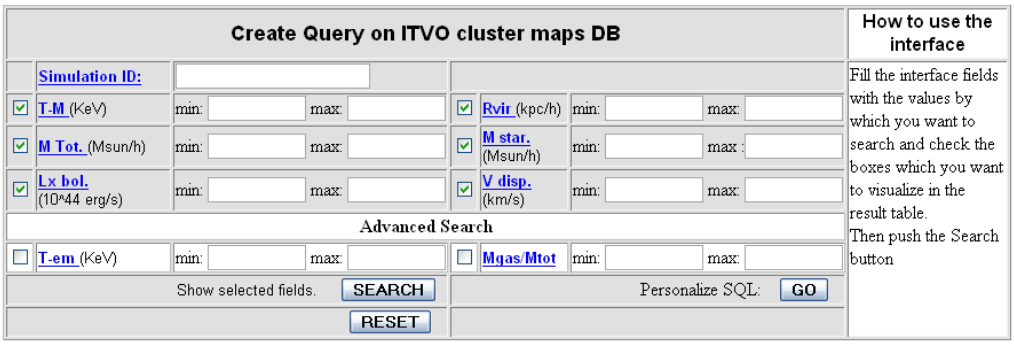
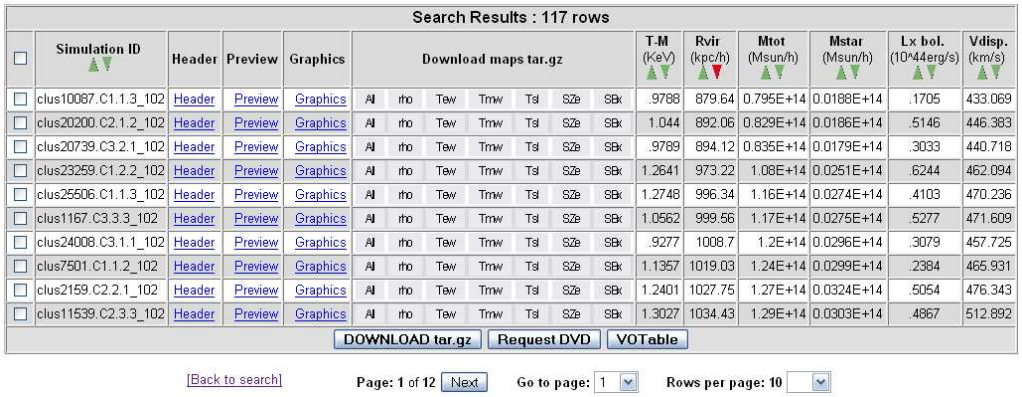


Fig. 2. The Level2 query form interface for ITVO database. SEARCH button submits the query. Once the fields of interest are filled in it is possible to personalize the SQL query clicking on the GO button on the bottom right of the form. The check boxes on the left of the available query fields enable return values in the query result, if unchecked the query fields are only used to search the database but are omitted in the output table.

services and tools to generate the VO physical structure. These standards are developed by the community not only for observational data but also for simulated data sets (IVOA Theory Interest Group, http://www.ivoa.net/cgi-bin/twiki/bin/view/IVOA/IvoaTheory) which require different parameters and formats. The IVOA Working Groups (WG) and Interest Groups (IG) members discuss and prepare Working Drafts, Documents and Standards to be used by the VO community to make uniform and interoperable the various data archives and databases scattered around the world.

While these documents (have a look at http://www.ivoa.net/Documents/ for an overview of available Documents and Drafts) are at a good level of evolution for observational data there is a lack of documents regarding theoretical and simulated data because interest for theory has entered the VO community more recently than other fields and is only now becoming mature. Given this situation, simulated or theoretical data archives and services have tried, until today, to use observational standards and definitions.

Within the Italian VO initiative (VObs.it) the ITVO (Italian Theoretical Virtual



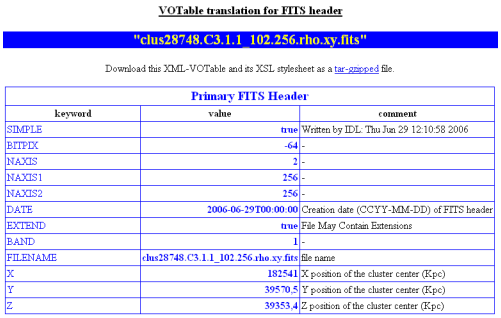
Search Results : 117 rows

	Simulation ID	Header	Preview	Graphics	Download maps tar.gz							T-M (KeV)	Rvir (kpc/h)	Mtot (Msun/h)	Mstar (Msun/h)	Lx bol. (10^44erg/s)	Vdisp. (km/s)
☐	clus10087.C1.1.3_102	Header	Preview	Graphics	Al	rho	Tew	Tmw	Tsl	SZe	SBx	.9788	879.64	0.795E+14	0.0188E+14	.1705	433.069
☐	clus20200.C2.1.2_102	Header	Preview	Graphics	Al	rho	Tew	Tmw	Tsl	SZe	SBx	1.044	892.06	0.829E+14	0.0186E+14	.5146	446.383
☐	clus20739.C3.2.1_102	Header	Preview	Graphics	Al	rho	Tew	Tmw	Tsl	SZe	SBx	.9789	894.12	0.835E+14	0.0179E+14	.3033	440.718
☐	clus23259.C1.2.2_102	Header	Preview	Graphics	Al	rho	Tew	Tmw	Tsl	SZe	SBx	1.2641	973.22	1.08E+14	0.0251E+14	.6244	462.094
☐	clus25506.C1.1.3_102	Header	Preview	Graphics	Al	rho	Tew	Tmw	Tsl	SZe	SBx	1.2748	996.34	1.16E+14	0.0274E+14	.4103	470.236
☐	clus1167.C3.3.3_102	Header	Preview	Graphics	Al	rho	Tew	Tmw	Tsl	SZe	SBx	1.0562	999.56	1.17E+14	0.0275E+14	.5277	471.609
☐	clus24008.C3.1.1_102	Header	Preview	Graphics	Al	rho	Tew	Tmw	Tsl	SZe	SBx	.9277	1008.7	1.2E+14	0.0296E+14	.3079	457.725
☐	clus7501.C1.1.2_102	Header	Preview	Graphics	Al	rho	Tew	Tmw	Tsl	SZe	SBx	1.1357	1019.03	1.24E+14	0.0299E+14	.2384	465.931
☐	clus2159.C2.2.1_102	Header	Preview	Graphics	Al	rho	Tew	Tmw	Tsl	SZe	SBx	1.2401	1027.75	1.27E+14	0.0324E+14	.5054	476.343
☐	clus11539.C2.3.3_102	Header	Preview	Graphics	Al	rho	Tew	Tmw	Tsl	SZe	SBx	1.3027	1034.43	1.29E+14	0.0303E+14	.4867	512.892

DOWNLOAD tar.gz | Request DVD | VOTable

[Back to search] Page: 1 of 12 Next Go to page: 1 Rows per page: 10

Fig. 3. A sample result after a Level2 database query. The leftmost columns contain the available services: download, metadata preview, map preview, profiles. The central buttons allow selective maps download. The rightmost summarize the properties over which the query is done, it contains only the fields checked at query submission.



VOTable translation for FITS header

"clus28748.C3.1.1_102.256.rho.xy.fits"

Download this XML-VOTable and its XSL stylesheet as a tar-gzipped file.

Primary FITS Header

keyword	value	comment
SIMPLE	true	Written by IDL: Thu Jun 29 12:10:58 2006
BITPIX	-64	-
NAXIS	2	-
NAXIS1	256	-
NAXIS2	256	-
DATE	2006-06-29T00:00:00	Creation date (CCYY-MM-DD) of FITS header
EXTEND	true	File May Contain Extensions
BAND	1	-
FILENAME	clus28748.C3.1.1_102.256.rho.xy.fits	file name
X	182541	X position of the cluster center (Kpc)
Y	39570.5	Y position of the cluster center (Kpc)
Z	39353.4	Z position of the cluster center (Kpc)

Fig. 4. Metadata visualization. The output VOTable (XML file) is displayed using an XSLT transformation. Above the table it is visible the download link.

Observatory) project was initiated, highly coordinated with the IVOA work in this field. The participants in this effort are INAF (OATs and OACt) and CINECA mainly.

The ITVO maintains a web portal that allows search for cosmological data simulations (at present a few) and also implements tools that let the user preview on-the-fly the data and the related metadata.

In this paper we describe a set of prototype previewing, analysis and exploration tools developed for the ITVO site located at IA2, Trieste. The tools are planned to be exported ot the ITVO sites and contributed to IVOA.

3. ITVO data archive and database

The ITVO archives consist of raw data output from cosmological simulations, mainly generated using the GADGET-2 simulation package (Volker 2005) but also contain data in FLY (Antonuccio-Delogu et al. 2003) and ENZO (O'Shea et al. 2004) format.

At present the most part of the ITVO archive at IA2 is devoted to a simulation from Borgani et al. (Borgani et al. 2003).

The related database is subdivided in a set of levels (at present 3): "Level 0", which consists of raw files, direct output of the simulations (e.g. the snapshots of the cosmological simulation), a "Level 1" which contains the objects (e.g. galaxy clusters) identified within Level 0 data, and a "Level 2" consisting of post-processed data from Level 1. The database reflects this subdivision of data and uses a web interface (§4) to produce queries at the various levels; this lets the user search for the most appropriate kind of data he is searching for. The level idea actually allows also the creation of other levels consisting of subsequent post-processing of data. Level connection has also been implemented allowing step by step refinement of data searches.

For a more exaustive and detailed description of the archive and database please refer to Manzato et al. (2007), Manzato et al. (2008a)

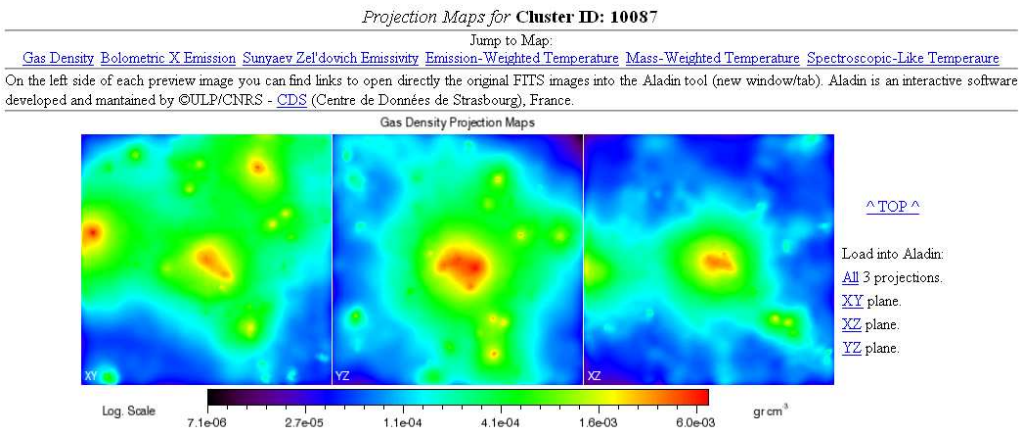


Fig. 5. 2-D orthogonal projection maps of selected physical quantities. On the right side of the images there are the links to load the original FITS files directly into the Aladin applet (see also Fig. 6)

and Manzato et al. (2008b). In this paper we will mainly deal with the Level 2 interface and connected tools.

4. ITVO portal

The ITVO portal reflects the database subdivision. Fig. 1 shows the IA2 web portal (http://wwwas.oats.inaf.it/IA2/) including the ITVO web interface links listed by Level. Clicking on Level 2 the interface for precessed data opens (see Fig. 2) and allows input to be given. Once the search is submitted (using the SUBMIT button) the result page appears (Fig. 3) and the user can manage the data output. Beside data download and the requested metadata description columns, there are a few other capabilities directly on the server which can be accessed by the user. In this paper we focus on the first 3 capabilities (the 3 main links on the left near the cluster ID):

- vizualization of the metadata (§5.1 and Fig. 4);
- 2-D projection maps of selected physical quantities derived from the data clusters (§5.2 and Fig. 5);
- generation of radial (1-D) profiles of the physical properties of the clusters (§5.3 and Fig. 8).

Visualization of multidimensional data can be performed with VisIVO (Becciani et al. 2006).

5. ITVO@Trieste portal web tools

The following description refers to the services at present state of development, future upgrade of this server-side application will mostly be made in the direction of a web service implementation and trying, if possible, to generate every output on-the-fly.

5.1. Metadata previewing

Metadata previewing consists of returning, as a VOTable (XML data file), the headers of the data files (Fig. 4). For user readability the XML is displayed within the browser window using an XSLT stylesheet but the metadata themselves are retrievable in a tarball gzip compressed file (together with the stylesheet) from a link on the same web page. The application is written in Java and acts as an HTTP-GET service call using a CGI script in Perl. The input consist of FITS HEADERS from the projection files (which we will talk about in next subsection).

5.2. 2-D data previewing

Another tool available for inspecting cluster data is the 2-D preview of physical quantities. This task is providing with 3 projections on orthogonal planes related to the sim-

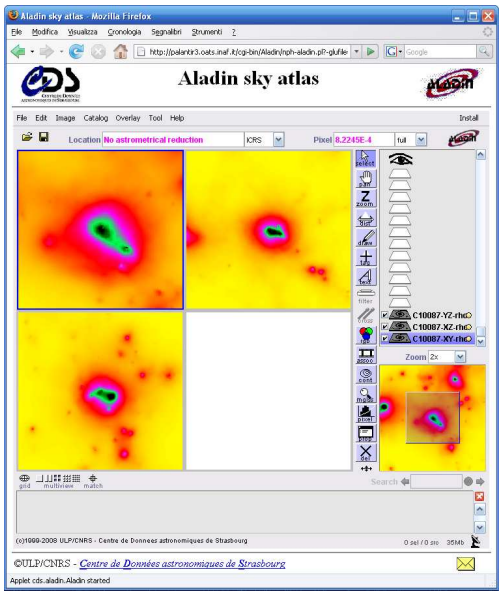


Fig. 6. The Aladin applet with the 3 projections FITS loaded.

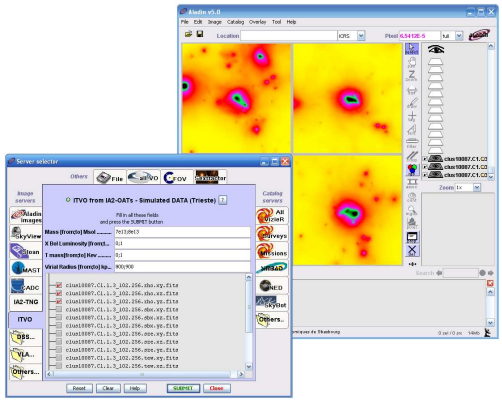


Fig. 7. The Aladin standalone version using the ITVO GLU dictionary extension (in the ServerSelector window you can see the "ITVO" label).

ulated box reference system. At present the FITS files containing the projections' images are pre-computed (and available only for snapshots at cosmological redshift z=0) and the tool only converts them into PNG static images with color coded intensities of the quantities. The result is loaded into a simple HTML page (Fig. 5) with all quantities and projection displayed. Besides the image display there are a set of links for each physical quantity that allows direct upload of the FITS images used for the preview into the Aladin applet developed by CDS (CDS 00). This can be done for a single chosen projection or for all of the 3 projection (Fig. 6). Aladin is useful both because it works in the direction of the VO interoperability and because it allows comparison between the simulated data and observational data searchable from the tool itself. The applet is loaded from a local machine, this is done not to overload CDS servers and also is likely to speed up work as data and applet are on the same group of machines. Next step for 2-D data previewing is to eliminate the double step, HTML preview plus Aladin applet call, directly loading FITS (or static images somehow generated on-the-fly) into Aladin.

The FITS files containing the 2-D maps can also be reached from the Aladin standalone version. This is done using a dedicated GLU (Fernique et al. 1997) dictionary for the ITVO data repository. The dictionary can be downloaded from the ITVO web portal and used launching Aladin from command line. Launching Aladin this way adds an "ITVO" tab in the Aladin Server Selector window from which you can search for simulated data (Fig. 7).

5.3. 1-D profile generation

The last tool of the web interface we will describe is the 1-D preview plots of physical quantities of clusters. The computation of the profile data is done on-the-fly when requested by the user by means of a software package written in C/C++ language and connected to the web interface by shell and Perl scripting. The main computation blocks were written by S.Ameglio and G.Murante for the Borgani et al. (2003) simulation. These programs were then embedded into the tool available from the ITVO web interface. Clicking on the "Graphics" link on the results page a new page will be displayed (Fig. 8) showing all available profiles computed from the cluster data. The profile data can be downloaded from the same page both as a FITS BINTABLE or

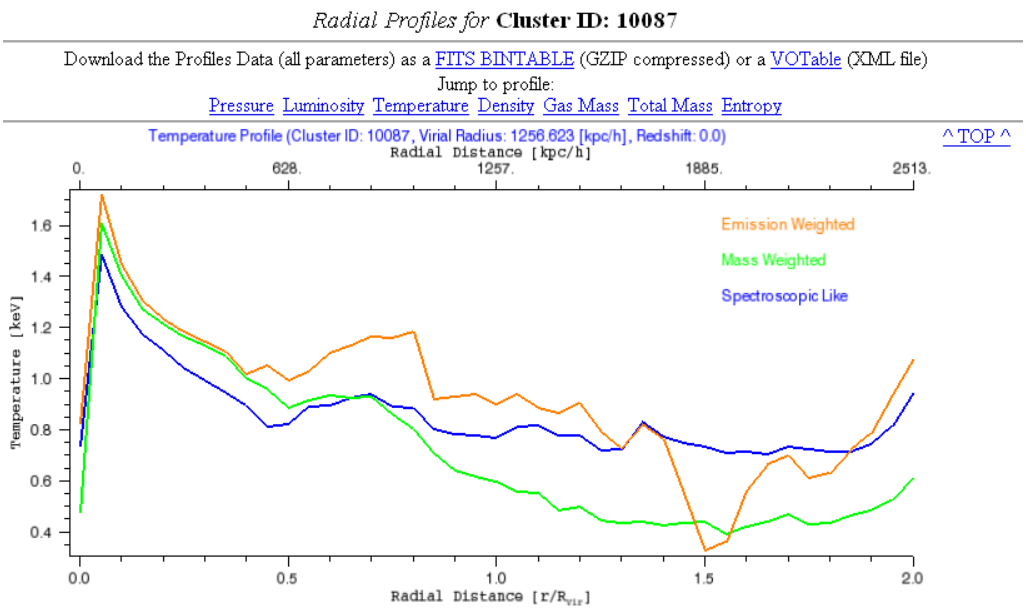


Fig. 8. Profiles' preview page example (Temperature profiles visualized). The XML VOTable data is downloadable using the fisrt two links after the title header.

in VOTable format allowing further analysis in tools like TOPCAT (Astrogrid, UK).

6. Conclusions

As an ongoing project ITVO capabilities need further refinement and upgrade, more direct connection to other VO related tools (maybe using the PLASTIC protocol), looser connection to simulation types (at present mainly Gadget-2). The tools will be made available tio the community through the IVOA.

Acknowledgements. The ITVO project is developed within the VObs.it as a collaboration between INAF (Trieste and Catania Observatories) and CINECA under the framework of the INAF-CINECA 2005-07 and 2008-10 agreements.

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