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THE THEORETICAL VIRTUAL OBSERVATORY

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Abstract. The initial concept of Virtual Observatory has been so far confined to observational data products and services. However, a great interest has been recently shown in including products of theoretical research, leading to the concept of Theoretical Virtual Observatory (TVO). I thus report on TVO development progress in France and in international community. The case of the HORIZON project is used for illustration.

1 Definition of the Theoretical Virtual Observatory (TVO)

Until now the various VO efforts have confined themselves to observational data products and services. However, considerable interest has been recently shown in including products of theoretical research. This push comes initially from groups involved in large-scale computer simulations who want to publish their results in a VO compatible form.

Theory needs a special attention in the VO. For instance, one of the main goals of the TVO is to enable federation of theoretical with observational archives. But position-based query protocols are irrelevant for TVO since such a federation is based on similarity, not identity. New observables can also be created from theoretical raw products and "exact" quantities can be compared to observable ones. On of the most advanced TVO service is the production of artificial observations (e.g. 'mock' catalogues made by the GalICS / Mock Map facility, cf. Guiderdoni this volume) from simulations. Such a service requires that developers remain in close contact with instrumental teams.

I will hereafter present a short status of TVO development. The case of the HORIZON project will be used for illustration. More details on the TVO can be found at the URL: http://www.ivoa.net/twiki/bin/view/IVOA/IvoaTheory.

2 Development status

During the International Virtual Observatory Alliance (IVOA) executive meeting of January 2004 in Garching, Germany, the IVOA Theory Interest Group, lead

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Resources	Country
Aus-VO-Wiki.Theory	Australia
GalICS	France
Model of stellar population synthesis of the galaxy	France
HORIZON	France
MPA Virgo data download	Germany
Cosmo.Lab	Italy
MODEST	USA
NEMO	USA
Virtual Cluster Exploratory	USA

Table 1. Census of theoretical VO initiatives at the date of september 2004

by Gerard Lemson from MPA Garching, was formed with the goal of ensuring that theoretical data and services are taken into account in the IVOA standards process. In a whitepaper published on the IVOA site issues specific to theory are discussed. This document also summarizes tasks that a possible theory working group should accomplish. In particular, the IVOA Theory Interest Group will:

- Provide a forum to discuss issues specific to theoretical products in a VO context.
- Contribute to other IVOA working groups to ensure that theory specific requirements are included.
- Incorporate standard approaches defined in these groups when designing and implementing services on theoretical archives.
- Define standard services relevant for theoretical archives.
- Promote development of services for comparing theoretical results to observations and vice versa.
- Define relevant milestones and assign specific tasks to interested parties.

A preliminary list of TVO initiatives is given in Table 1. It shows the strong interest of the French national community of theoreticians for the TVO. Such interest in some cases already exists for a long time (e.g. GalICS project) but further intentions still need to be converted into actions with the support of VO-France (Genova al. 2004).

3 The need to publish simulations/models in the VO

Amongst all the good reasons to publish theoretical products in the TVO, I would like to stress that observers, especially those preparing key programs and surveys for space missions (e.g. Herschel) or large telescope instruments (e.g. VLT/MUSE) need more and more simulation results in a format very close to real observations. In this respect, the TVO will make theoretical results more easily accessible and understandable for observers. Anyway, for the sake of efficiency, simulations of physical objects and TVO concept should be included in any instrumental project at the very beginning.

Moreover, a TVO will allow independent checks of conclusions based on theoretical results and further analysis by third parties based on the published data. Comparisons with similar results/methodologies or with the corresponding data by observers/theoreticians will be easier. Journals may allow or require links to actual data products and/or software used in published work.

4 Theory data products and services

TVO should certainly include non-observational products that are typical of numerical simulations, like lists of particles, halo catalogues and/or merger histories, etc. Many data products have been proposed for the theory/observation interface in the TVO whitepaper (e.g. synthetic observations of clusters, galaxy catalogues from semi-analytical work (e.g. GalICS, Planck CMB simulations, etc.).

However, most of them define a one-way link between theory and observation. On the contrary, the bridge between observation and theory should be more symmetric. Indeed one could imagine the need for some simulations or models (spectral synthesis, N-body, chemodynamical or orbit-based, etc.) made using initial conditions fitted on real observations of some single object (e.g. a nearby galaxy). Without going into details, here are a few examples:

- several authors have determined the pattern speed of a gaseous spiral structure by running hydrodynamic simulations in a fixed gravitational potential computed from the observed light distribution and constrained by the observed rotation curve.
- the mass of galactic black holes can be determined using the orbit-based Schwarzschild method which determines the weight of each orbits in a library in order to fit the observed light and velocity distribution. The orbit library depends on the gravitational potential and thus should be determined from the light distribution. Additional constraints on velocity and velocity dispersion can be added by spectroscopic data like those coming from Integral Field Spectrographs.
- quantitative analysis of stellar population can be achieved by the 'inversion' of a (or several) spectral synthesis model in order to recover the age and metalicities of the populations. This is more or less already implemented on the WEB but rarely as an inversion method.

Of course, this inventory is far from begin complete. All these examples, biased towards extragalactic concerns (those of the Programme National Galaxies), show that on the theoretical side we also need to handle the observational data to get constraints on our models or to determine some physical quantities needed by further computations.

5 HORIZON project

The HORIZON Project, lead by R. Teyssier (this volume) has the objective to federate numerical simulations activities around a program focused on galaxy formation in a cosmological frame. It gathers several research teams from different institutes. The HORIZON Project has not the vocation to cover exhaustively all research themes in the two domains of Galaxies and Cosmology. Its transverse and federative nature will however allow to develop in a few years high-level competences in parallel and distributed (GRID) computing, in data bases of virtual observations related to the TVO, as well as in applied mathematics, and build in the same time a strong theoretical knowledge in astrophysics.

The main objectives are:

- Numerical study of galaxy formation in a cosmological frame.
- Develop advanced techniques in parallel programing and in applied mathematics to simulate galaxy formation and predict their observational signatures, as a function of physical parameters.
- Gather several experts to exchange their competences, share their software, and rationalize the access to national computing centres.
- Provide the community, observers and theoreticians, with a friendly access to numerical results of international level.

The last item is the most challenging for the TVO because of the huge numbers involved. For instance, it is indeed planned to run dark matter simulations of 10^{10} particles in 1 Gpc^3. Many re-simulations of smaller boxes, including gas and star formation, will be perform for the study of interacting or isolated galaxies in a cosmological context. All these simulations will produce various multi-wavelength mock catalogues and images or 3D spectroscopic cubes to prepare future observatories (e.g. ALMA, SKA) and space missions (e.g. JWST). The valuable know-how acquired for the GalICS and MoMaF project will be obviously reused.

References

Genova F. et al., VO-France, http://www.france-ov.org/

Guiderdoni B. et al., GalICS Project, http://galics.iap.fr/

Lemson G., Colberg J., 2004,Theory in the VO, IVOA Theory Working Group whitepaper, http://www.ivoa.net/twiki/bin/view/IVOA/IvoaTheory

Teyssier et al. 2004, HORIZON project http://aramis.obspm.fr/HORIZON/main.php