VIRTUAL INSTRUMENTATION TO STUDY GALAXIES

Prugniel, Ph. 1,2, Chilingarian, I. 3, Flores, H. 1, Guibert, J. 1, Haigron, R. 1, Jégouzo, I. 1, Royer, F. 1,4, Tajahmady, F. 1, Theureau, G. 1 and Vétois, J. 1

Abstract. The MIGALE project provides databases and data analysis tools to study the evolution of galaxies from z=1 to z=0. It develops and maintain a general database, HyperLeda, to give a homogenized parameterization for 3 million objects, and several archives or specialized databases. It also develops tools to analyse on-the-fly data extracted from the database or obtained through the Virtual Observatory (Virtual Instruments). The package made for this project, Pleinpot, is distributed as open source.

1 How the Virtual Observatory approach can help for the data analysis?

The goal of the Virtual Observatory (VO, see http://www.ivoa.net/) is to enhance the scientific efficiency by providing a transparent access to the archive data stored throughout the world, so that the end user will have the filling that all these resources are located on its own computer. To make this enormous quantity of data useful (volumes are counted in Phbytes), high performance discovery tools are needed, and a condition is to provide an accurate description of any individual dataset.

A precise description also enables to change the strategy for the data analysis. For example, it will not be required anymore to tell to the analysis program what is the spectral resolution and how it changes with wavelength: This information will come with the data, as part of the so-called meta-data or more familiarly FITS keywords. It will be possible soon to push one step forward the automation of the data analysis.

Why is it desirable to automate analysis pipelines? Naturally, the main reason is that it is expected to be faster, and possibly more reliable since it eliminates some risks of errors during the preparation of the reduction procedure. The complexity

1 GEPI-Observatoire de Paris, UMR8111
2 Observatoire de Lyon, UMR142
3 Sternberg Institute, Moscow State University
4 Observatoire de Genève, Sauverny, Switzerland

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of data analysis also increases as it allows to put finer constraints to the details of
the physical mechanisms. So, astronomers interested in a specific phenomenon and
using multi-wavelength data can hardly be experts in all the aspects of the data
analysis; more automatic procedures are simpler to use and enable non-specialists
to interpret the data. There is obviously the risk to miss-use a procedure, as for
example give a wrong combination of parameters to a model, but astronomers are
highly aware of this danger which anyway already exists when we are using the
present software. The VO does certainly not worsen the situation.

Actually, not only it is desirable to automate processing, but it is necessary.
Some spectrographs produce millions of spectra over their lifetime, and it is abso-
lutely impossible to make a detailed interactive analysis of each of them (see for
example the analysis of SDSS data in Mathis et al. 2004).

Analysis pipelines, to compare models to observations, will be develop ed either
as client packages to be run on the user’s machine or as online services run on a
remote server fed by data provided by the user or extracted from the VO and
returning results in the formats defined by the VO so they can be used by other
VO tools. Such services already exist. For example, a VO implementation of
sextractor was used at the 2004 AVO science demo (Padovani et al. 2004).

2 The MIGALE project

The MIGALE project (http://www.sai.msu.su/migale/) has been started to share
common developments between different scientific projects aimed at studying the
evolution of galaxies from medium to low red-shifts.

MIGALE proposes some databases. In particular HyperLeda is a general
database for studying the physics of nearby galaxies. It contains about 3 mil-
liions objects for which data are collected from the literature and from the surveys
and are homogenized to a common scale. Data concerns the structure, kinematics,
stellar and gas content of galaxies. They are either integrated measurements or
spatially resolved information, as photometric or kinematical profiles. HyperLeda
stores also an archive of reference FITS data, images or spectra, and offers some
prototype of Virtual Instruments, such as the on-line version of PÉGASE (Le
Borgne et al. 2004).

Other new databases made in the frame of the MIGALE project are presented
at this conference. HiGi (Theureau et al. 2004) describes the HI content of galaxies
and gives access to HI raw and processed observations. The Giraffe Archive (Royer
et al. 2004) delivers processed data from the Flames/Giraffe instrument at ESO.
ASPID (Chilingarian et al. 2004) is archive containing the raw data from the
Russian 6 m telescope.

The different developments made in the frame of MIGALE share the same soft-
ware package, Pleinpot (http://leda.univ-lyon1.fr/pleinpot/pleinpot.html) provid-
ing in particular a library for database access, retrieval and formatting of the data
and for data processing and analysis. The software is freely available under the
terms of the GNU Public License. Pleinpot is used in other projects, as the
ELODIE-SOPHIE archive from Observatoire de Haute-Provence (Moultaka et al. 2004).

MIGALE results from a long term effort initiated by the Programme National Galaxies (CNRS) to coordinate the initiatives started in different laboratories, in particular in Observatoire de Lyon and in GEPI (Observatoire de Paris).

3 The Virtual Instruments planned by MIGALE

The main focus of MIGALE is on integral field spectroscopy. A large program is conducted using the Giraffe spectrograph at the ESO/VLT to study the gas content, kinematics and environment of distant galaxies. First results of velocity fields are presented in Flores et al. (2004) and the deconvolution method is presented in Puech et al. (2004). The corresponding package, Disgal3D, will evolve toward a Virtual Instrument using inputs from high spatial resolution images (HST) to deconvolve lower resolution data cubes from ground based integral field units.

In the Local Universe we are studying the counterparts of the star forming galaxies observed at larger distances. We are using the Russian 6 m telescope equipped with the MPFS integral field spectrograph to observe galaxies from the Virgo cluster. We are in particular interested in the smaller galaxies, such as diffuse ellipticals (dE), which have apparently formed their stars about 5 to 7 Gyr ago. A preliminary scientific result presented in Chilingarian and Prugniel (2004) shows a complex kinematical structure in a dE and demonstrates our ability to constrain the history of the stellar population.

![Architecture of the Virtual Instrument](image)

**Fig. 1.** Architecture of the Virtual Instrument to study the stellar population of galaxies.

The general principle to study a stellar population from a spectrum integrating all the light along a line-of-sight is to compare the observation with the spectrum of a modeled stellar population convolved by the appropriate distribution of internal velocities. Fig. 1 presents the main modules intervening in this process.
The synthetic spectrum may be either based on theoretical or empirical stellar spectra, e.g., Prugniel & Soubiran (2004). Empirical spectra need to be corrected for Galactic extinction and to be used to produce an interpolated grid, the atmospheric parameters must be available, for example from Soubiran et al (2002). The population synthesis package is fed by this grid and needs also models for the stellar evolution (evolutionary tracks), for the initial mass function and scenario of enrichment and star formation. A new package, PÉGASE.HR, has recently been published (Le Borgne et al. 2004). The analysis of 1 or 2-D spectra then requires to calibrate the spectral resolution and the photometry using an archive of stellar spectra and then to use elaborated inversion methods, as e.g., described in Ocvirk et al. (2004).

It is clear that the various modules enumerated here have a broader interest than this specific application. This calls for a separate implementation of these elementary bricks, the VO protocols and formats being used to interconnect them easily.

Though it is possible to execute all these modules on the fly, using the very last version of the stellar library, extinction model, ..., this would be heavily demanding in CPU resources and would introduce a large number of free parameters whose incidence on the result is difficult to assess. For these reasons, we are adopting compromises. In particular, the grids of stellar spectra used for synthesis are stored statically and updated only when either the archive, the reduction procedure or calibration is significantly improved.

Presently, this Virtual Instrument to study the stellar populations is still under development and gives its first scientific results. We expect to deliver a robust implementation of a tool to retrieve the internal kinematics and the stellar formation history within 3 years. It will be available both as an online service and as a client package that can be installed on the user’s machine.

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