# 3D SPECTROSCOPY IN THE VIRTUAL OBSERVATORY: CURRENT STATUS

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## ABSTRACT

Three cornerstones for the 3D data support in the Virtual Observatory are: (1) data model to describe them, (2) data access services providing access to fully-reduced datasets, and (3) client applications which can deal with 3D data. Presently all these components became available in the VO. We demonstrate an application of the IVOA Characterisation data model to description of IFU and Fabry-Perot datasets. Two services providing SSA-like access to 3D-spectral data and Characterisation metadata have been implemented by us: ASPID-SR[1] at SAO RAS for accessing IFU and Fabry-Perot data from the Russian 6-m telescope, and the Giraffe Archive at the VO Paris portal for the VLT FLAMES-Giraffe datasets. We have implemented VO Paris Euro3D Client, handling Euro3D FITS format, that interacts with CDS Aladin and ESA VOSpec using PLASTIC[2] to display spatial and spectral cutouts of 3D datasets. Though the prototype we are presenting is yet rather simple, it demonstrates how 3D spectroscopic data can be fully integrated into the VO infrastructure.

Key words: Astronomical databases: miscellaneous; Technique: spectroscopic; Virtual Observatory.

## 1. INTRODUCTION

Integral field (or 3D) spectroscopy is a modern technique in astrophysical observing that was proposed by Georges Courtés in the late 60's. The idea is to get a spectrum for every point in the field of view of a spectrograph. Several instrumental approaches in the optical domain (as well as NIR and near-UV) exist: scanning Fabry-Perot interferometry, image slicing and transforming two-dimensional field of view into a slit using Integral-Field Unit (see review in Pécontal-Rousset et al., 2004 for a description of different image slicing techniques).

At present, nearly all large telescopes in the world are equipped with 3D spectroscopic devices, and rapidly growing volume of data produced by them pose a number of questions regarding the data discovery and retrieval. In this paper we demonstrate how 3D data are handled in a framework of the International Virtual Observatory.

All 3D spectroscopic observations result in datasets having both spatial and spectral information. They are usually referred as "datacubes", though sometimes (in case of IFU) they are not regularly gridded in spatial dimensions.

There are three cornerstones for the 3D data support in the Virtual Observatory:

1. data model – an abstract, self-sufficient and standardised description of the data
2. data access services – archives, providing access to fully reduced science-ready datasets
3. client applications – data-model aware software that is able to search, retrieve, and display 3D data, as well as to give a possibility for sophisticated scientific data analysis

All these blocks became available, and we will review them in the forthcoming sections.

[1]`http://alcor.sao.ru/php/aspid-sr`
[2]`http://plastic.sourceforge.net/`

## 2. DATA MODEL

An abstract, self-sufficient and standardised description of the astronomical data is known as a data model. Such a description is constructed in a way to become sufficient for any sort of data processing and analysis. The Data Modeling working group (DM WG) of the International Virtual Observatory Alliance (IVOA) is responsible for definition of data models for different types of astronomical data sets, catalogues, and more general concepts e.g. "quantity".

To describe 3D spectroscopic data we use Characterisation Data Model[3]. One of the most abstract data models developed by the DM WG, it gives a physical insight to the dataset, i.e. describes where, how extended and in which way the Observational or Simulated dataset can be described in a multidimensional parameter space, having the following axes: **spatial**, **time**, **spectral**, **observed** (e.g. flux, polarimetric), as well as other arbitrary axes. For every axis the three characterisation properties are defined: **coverage**, **resolution**, and **sampling**. There are four levels of details in the description of the dataset: (1) **location** or **reference value** – average position of the data on a given parameter axis; (2) **bounds**, providing a bounding box; (3) **support**, describing more precisely regions on a parameter axis as a set of segments; **map**, providing a detailed sensitivity map.

Details about applying Characterisation Data Model to the 3D spectroscopic datasets are given in Chilingarian et al. (2006). The algorithm for the characterisation metadata computation is described there as well.

## 3. 3D DATA ARCHIVES

We have developed two data archives providing access to fully-reduced "science-ready" IFU and IFP datasets: ASPID-SR and GIRAFFE Archive. For both archives the IVOA Simple Spectral Access (SSA, Tody et al. 2007) interfaces are provided.

### 3.1. ASPID-SR

ASPID stands for the "Archive of Spectral, Photometric, and Interferometric Data". The world largest collection of raw 3D spectroscopic observations of Galactic and extragalactic sources is provided. ASPID-SR (Chilingarian et al. 2007) is a prototype of an archive of heterogeneous science ready data, fed by ASPID, where we try to take full advantage of the IVOA Characterisation Data Model. Multi-level Characterisation metadata is provided for every dataset. The archive provides powerful metadata querying mechanism (Zolotukhin et al. 2007) with access to every data model element, vital for the efficient scientific usage of a complex informational system. ASPID-SR is one of the reference implementation of the IVOA Characterisation Data Model. The datasets are provided in several formats: stacked spectra, regularly-gridded data cubes, and Euro3D FITS.

A high level of integration between the archive WEB interface and existing VO tools is provided (see next section).

### 3.2. Giraffe Archive

GIRAFFE Archive (Royer et al., this conference) contains fully reduced data obtained with the FLAMES/Giraffe spectrograph at ESO VLT. Data obtained with all three observing modes of Giraffe: MEDUSA (multi-object spectroscopy), IFU (multi-IFU spectroscopy), and ARGUS (single IFU) are provided. Raw datasets are taken from the ESO archive after the end of their proprietary period and reduced in an automatic way using the Giraffe data processing pipeline. There is a possibility of accessing individual extracted 1D spectra from the multi-object spectroscopic observations, as well as full datasets in the Euro3D FITS format.

## 4. CLIENT SOFTWARE

Presently, there is a number of VO tools available that deal with images (such as CDS Aladin) and 1-D spectra (ESA VOSpec, SpecView, SPLAT). However, none of them is able to handle IFU datasets.

In a framework of the VO Paris project (Simon et al. 2006) we have developed VO Paris Euro3D Client specifically to deal with the datasets in the Euro3D FITS format in a VO context. This tool interacts with CDS Aladin to display position of the fibers (or slit) on the sky and display individual extracted spectra in ESA VOSpec. Catalogue of positions of fibers (or slit pixels) can be exported as VOTable.

VO Paris Euro3D Client is an open-source Java package, including basic functions for the Euro3D FITS I/O and a graphical user interface.

Individual or co-added spectra can be extracted from the Euro3D FITS file and exported as VOTable serialisation of the IVOA Spectrum Data Model 1.0 (McDowell et al. 2007). All the interaction between applications is done using PLASTIC (PLatform for AStronomical Tool InterConnection) – a prototype of the VO application messaging protocol.

Presently VO-Paris Euro3D Client is used as an integrated data visualising software at ASPID-SR - Science-Ready Data Archive at the Special Astrophysical Observatory of Russian Academy of Sciences.

[3] `http://www.ivoa.net/Documents/PR/DM/CharacterisationDM-20070530.pdf`

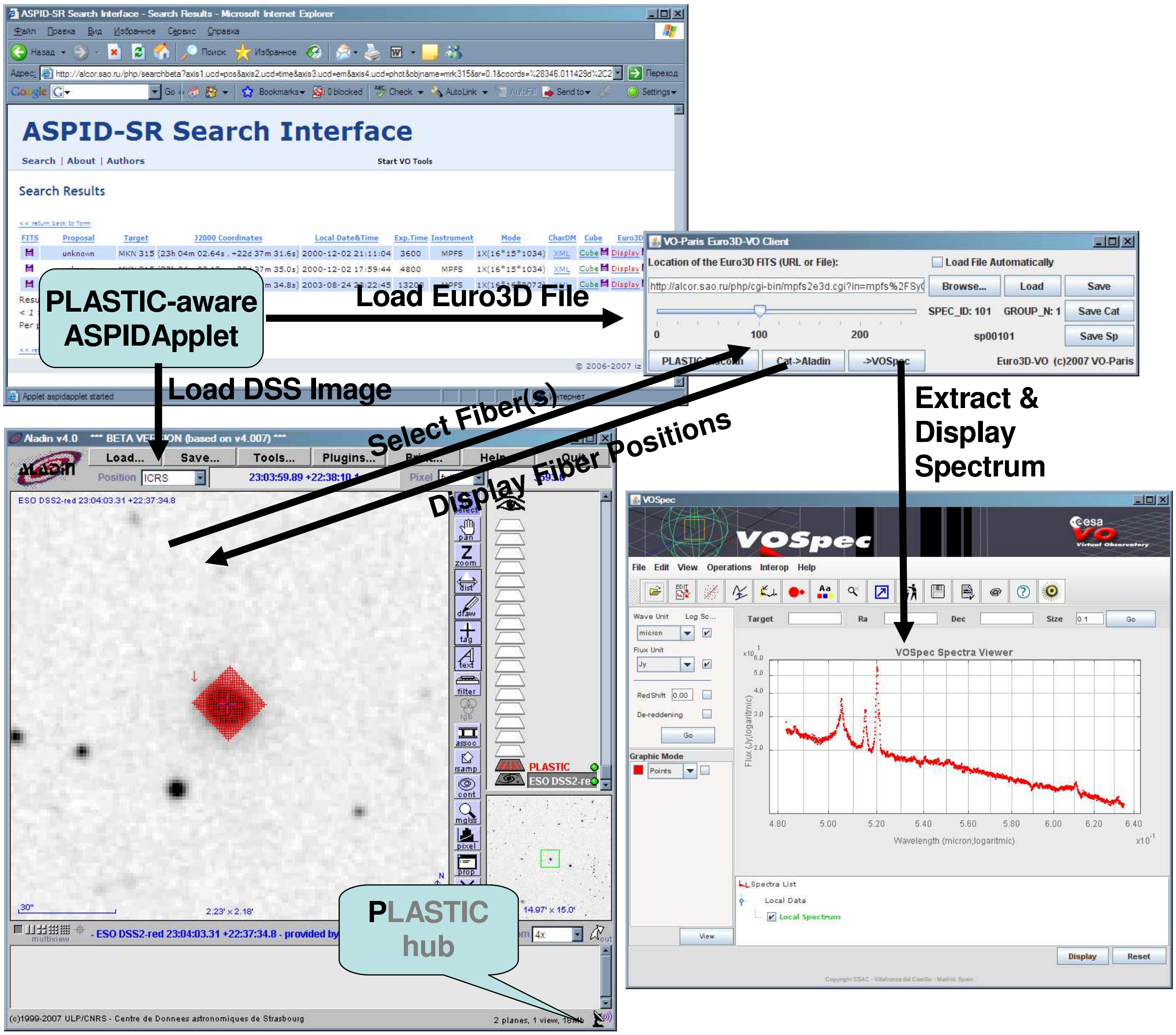


*Figure 1. Interaction between the ASPID-SR archive and PLASTIC-enabled VO tools.*

In Fig. 1 we demonstrate how the interaction between VO client applications and the ASPID-SR archive interface is implemented. There are several stages:

1. Querying the characterisation metadata using WEB-interface (see Louys et al., this conference)

2. Light-weight Java applet is integrated into the HTML pages, containing query response; it detects a PLASTIC hub, connects to it, and checks whether other tools (Aladin, VOSpec, VO Paris Euro3D Client) are registered within it. If the applications are not detected, they will be started using JavaScript and Java WebStart.

3. As soon as all the used applications have been started and registered within the PLASTIC hub, a small script is sent to CDS Aladin to display the DSS2 image of the area, corresponding to the position of the IFU spectrograph. At the same time, the IFU dataset in the Euro3D FITS format is loaded into VO Paris Euro3D Client.

4. Positions of IFU fibers are sent from VO Paris Euro3D Client to CDS Aladin and overplotted on the DSS2 image.

5. User can interactively select either groups of fibers or individual ones using CDS Aladin. An extracted spectrum (or co-added spectra of several fibers) is sent to ESA VOSpec using PLASTIC by clicking on the corresponding button in the user interface of VO Paris Euro3D Client.

## 5. SUMMARY

In Chilingarian et al. (2006) we concluded that ”all the necessary infrastructural components exist for building VO-compliant archives of science-ready 3D data and tools for dealing with them”. Since that time there was a substantial progress of VO standards and protocols. Now we are able to provide access to first two such VO-compliant archives. This not only a “proof-of-concept”, but the services that can be used for real scientific purposes. Another important conclusion that can be drawn is that the present state of VO standards (including PLASTIC – a prototype of the VO application messaging protocol) is totally sufficient for dealing with complex datasets in a VO framework without need to develop new client applications for every particular kind of data.

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