

ASTRONOMICAL SPECTROSCOPY IN THE VO ERA: VOSPEC

Pedro Osuna, Isa Barbarisi, Jesus Salgado, and Andrea Laruelo

ESA-VO

Research and Scientific Support Department

European Space Agency

ABSTRACT

VOSpec was born as a response to the need of the Scientific Community to have a Spectroscopic Tool able to work with VO available and enabled data. From a very simple interface to today, the VOSpec tool has gone through a series of changes and evolutions converting it in an Analysis tool of VO data. In this talk, an overview of the VOSpec tool is given, together with its latest available functionalities.

Key words: Technique: spectroscopic; Virtual Observatory.

1. INTRODUCTION

The Virtual Observatory is allowing seamless sharing of Astronomical Data. In a very similar way to the sharing of other types of data through the WWW, the VO is making it possible to publish and share Astronomical Data in a homogeneous and easy way. This is particularly true for the case of Astronomical Spectra. Making use of the Simple Spectrum Access Protocol (SSAP, ref Tody et al (2007)) Spectra coming from different projects, whether Space Based, Ground Based, Infrared, X-Ray, etc., can be accessed in a uniform way. Taking advantage of this fact allows developers to build clients that can access Spectral data which would otherwise be incredibly difficult to combine. The VOSpec was born as a response to the need of a tool that could make use of the available IVOA protocols for Spectral Access. Making use of the existing SSAP at the time, the VOSpec has shown how the Astronomical Spectra can be shared for the benefit of the final user: the Scientist.

2. MAKING SPECTRAL DATA AVAILABLE WITHIN THE VIRTUAL OBSERVATORY

The WWW allows people to publish their data, of whichever the type, so others can have access to them. The procedure for such publication is quite straightforward:

- A user (the "publisher") creates some type of "Document" that wants to be published
- The document is uploaded to a Web Server
- The user includes in the server published doc certain "keywords" for search robots to be able to know of its basic contents
- A user (the "consumer") wants to get certain type of data
- The consumer user makes a request to the Search engine to find which type of data are available, and where, according to its own interests
- The Search machine looks for available data taking into account the constrains from the user
- The Search machine gives the information on possible relevant data to the user
- The user browses the results and accesses the relevant places
- If satisfied, the user can eventually download the document that was published by the "publisher" user

In this way, a very simple procedure has allowed to share a single document with millions of potential users in a very reduced time. Both the publisher and the consumer are satisfied with a minimum amount of time spent. See figure 1 for a graphical summary of the procedure.

The same procedure used for WWW documents publishing can be somehow "mapped" to accessing spectral data within the VO paradigm. Here is how:

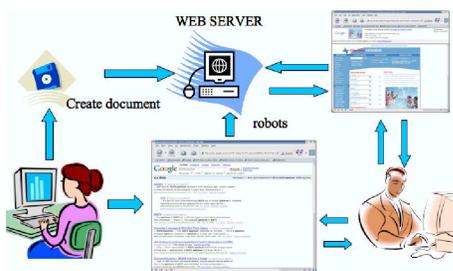


Figure 1. Publishing a document to the World Wide Web

- A user (the "publisher" or "Data Provider" in this case) creates some type of, e.g., Spectrum collection that wants to be published
- The Spectrum collection is put in a Web Service that understands the so called "Simple Spectrum Access Protocol" specification of the IVOA
- The user subscribes the Service just created in the IVOA Registry, which acts as the "yellow pages" of the IVOA VO.
- A user (the Scientist) wants to get spectra observed in a region of the sky
- The Scientist makes use of a client (VOSpec) that works in the VO environment and understands the VO protocols. The client makes a request to the Registry to find which type of services are giving access to their spectra through the SSAP protocol.
- The Registry gives the information on possible relevant providers of spectra through SSAP
- The client displays the providers and the scientist browses the results and eventually selects those services from which he/she would like to receive spectra
- The client makes a call to those services asking for metadata pertaining to data found in the selected region of interest
- The service responds with the metadata and pointers to the data
- The client finally downloads the data of interest to the user to allow for scientific analysis

The procedure is sketched in figure 2.

2.1. ESAVO DAL Toolkit: the tool to help you Publish your data

Not all users are aware of the technologies needed to implement, build and deploy a system able to handle the IVOA protocols for data access (e.g., the SSAP). Quite some technical knowledge is required, and it is felt that the IVOA should provide tools to help the data centres in

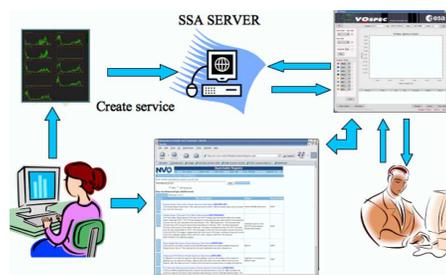


Figure 2. Publishing spectra on the VO

the creation of their services, compliant with the IVOA protocols.

With this idea in mind, the ESAVO project has developed the DAL Toolkit: a tool that allows the building of services which understand IVOA DAL protocols with minimum effort. The DAL Toolkit architecture is as follows:

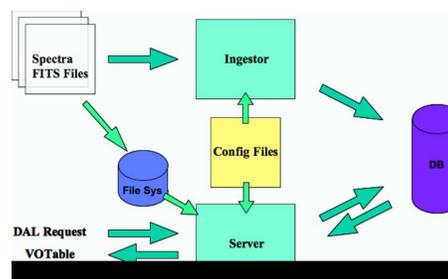


Figure 3. DAL Toolkit Architecture

Requests for more information and for getting the DAL-Toolkit should be sent directly to Pedro.Osuna@esa.int

3. VOSPEC: A TOOL FOR VO SPECTRAL ANALYSIS

Once the user has got access to the available data through the IVOA protocols, the user needs a client tool that can visualise the data and allow to do scientific analysis within the VO environment. The VOSpec is such a tool: it allows the handling of spectra available in SSAP format plus local data, so comparison among them is made really easy (see figure 4 and Osuna et al (2005))

3.1. VOSpec main features

The following are the current main features of VOSpec:

- Able to handle spectra accessible through the IVOA SSA Protocol
- Able to load local spectra (in FITS or VOTable formats)

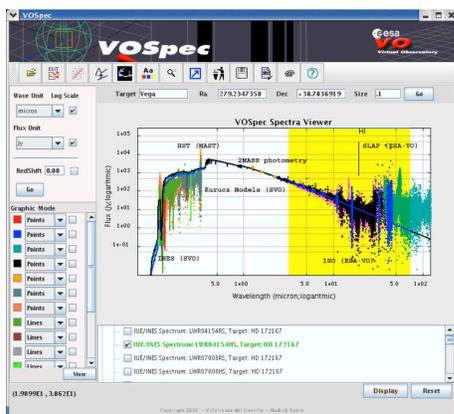


Figure 4. VOSpec tool

- Can create and SED of SSAP available and local spectra coming from any part of the wavelength spectrum
- Can create an SSAP wrapper with user's set of local spectra for immediate availability
- Common graphic manipulation options are available
- Easy superimposition of spectra in different units, and unit handling
- Possibility to save results as Image or VOTable
- Mathematical operations are available like Polynomial, Black Body and Gaussian fitting, Normalisation, Dereddening, Red-shift correction, Luminosity difference calculation, and many others on the way
- Access to theoretical spectra through the TSAP-like protocol (see below)
- Best fit to theoretical spectra (see below)
- Access to Spectral Lines through the IVOA Simple Line Access Protocol (SLAP, ref Salgado et al (2005))
- Interoperability with other VO-aware tools through Plastic technology

3.2. Theoretical Spectra access

VOSpec allows to access Theoretical Spectra through the so called TSAP (Theoretical Spectrum Access Protocol, see Osuna et al (2005)). The TSAP was initially described as a separate protocol from the SSAP, but has finally been integrated with this last one, as it basically can be implemented using the current capabilities of the SSAP. The way the VOSpec handles theoretical spectra is the following:

- VOSpec accesses the Registry to get information on servers available offering theoretical spectra

- VOSpec sends a query to the Services with theoretical spectra asking for the word "FORMAT=METADATA", which according to the SSAP specification gives the Input and Output parameters that the service understands and needs to provide the theoretically computed models. For instance, the service can respond saying that the parameters that describe the models available in that server correspond to "temperature, surface gravity, metallicity" (for the case of an available server on Stellar Theoretical Spectra).
- VOSpec builds a small User Interface on the fly from the metadata response from the service. This User Interface contains selection places for the available parameters, allowing the user to select those for which he/she is interested in getting the corresponding theoretically calculated spectra.
- Once the user has selected the parameters, a query is sent to the service asking for the available theoretical spectra gridded with that set of parameters
- The service sends the data, and VOSpec displays them

Once the theoretical spectra are available in VOSpec, the user can compare those with real spectra, and normalise them so they are overlaid and a visual inspection can be done to check which parameter set fits best to the observational results. Although this method is as good as it can get with gridded theoretical spectra, VOSpec implements a BestFit algorithm (see below) which does the computation for the user, and finds the best set of parameters that fit a certain observational spectrum.

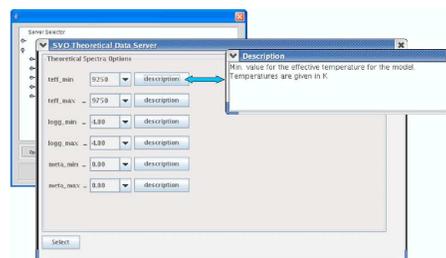


Figure 5. User Interface built on the fly with Theoretical parameters needed

3.3. Spectral Lines access

The IVOA deals with Atomic and Molecular Line Transitions through the use of:

- A Line Data Model for Spectral atomic and molecular transitions (see Dubernet et al (2006))
- A Simple Line Access Protocol (SLAP) for Line Access (see Salgado et al (2005))

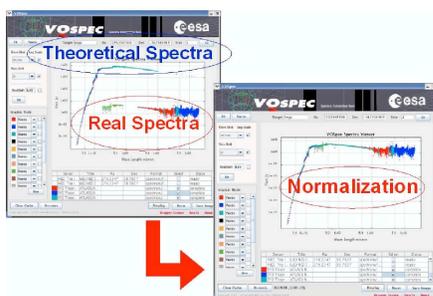


Figure 6. Overlay of Observational and Theoretical spectra with normalisation

With these two specifications, VOSpec is able to access Atomic and Molecular Line transitions in a seamless way. At the time of writing this paper, the following data are available in SLAP format for consumption within the VO (and therefore, from VOSpec) (see ref. Salgado et al (2007))

- IASD: ESA Observational database from ISO (Infrared Space Observatory) from the European Space Agency. This database covers the infrared spectrum range and it has been generated using identified lines from the different ISO observations. This service was adapted to SLAP format by the ESAVO team. It contains around 300 observed transitions in astrophysical observations.
- LERMA: VO-France theoretical server from CDMS and JPL molecules correlated to the Basecol DB. It covers the millimetric and sub-millimetric spectral range and it contains around 37500 transitions. This group is developing a different SLAP client and it is working actively in the protocol definition.
- NIST: Theoretical database. SLAP access to the NIST Atomic Spectra Database (more than 142000 transitions!). The Atomic Spectra Database (ASD) contains data for radiative transitions and energy levels in atoms and atomic ions. Data are included for observed transitions of 99 elements and energy levels of 56 elements. This service is an excellent source of information for observed in laboratory lines.
- CIELO: ESA Observational database from XMM satellite in the X-Ray wavelength range. The SLAP service was created by the ESAVO team using the DALToolkit utility (see above)

At the same time, other projects are making use of both the data model and the protocol access for internal purposes, e.g., the ALMA (Atacama Large Millimetre Array) Archive Group at The University of Manchester is making use of the AMSL DM as a basic data model for their databases.

3.4. Mathematical Algorithms

As already mentioned before, in order to find the parameters that best fit a set of observational spectra from a given theoretical grid of spectra, the user has to intervene in the process, and the inspection of the results is done in what Teukolsky (see Teukolsky et al (2006)) has come to call "Chi by eye". Although this inspection process can be beneficial as a first estimate, VOSpec implements a mathematical BestFit algorithm that allows the user to select the best possible combination of parameters for a given TSAP server without having to make guesses on which parameters will fit best the results. The algorithm for doing this is quite complex, and details of it will be given at the next ADASS XVII meeting (see ADASS (2007)).

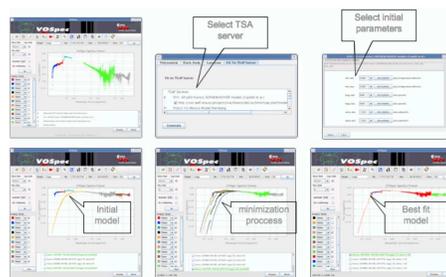


Figure 7. BestFit algorithm in brief

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