SPECTROSCOPIC LINES IN THE VO CONTEXT: IVOA MODEL AND ACCESS

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ABSTRACT

In an action lead by the ESA-VO project and VO-France, the International Virtual Observatory Alliance (IVOA) is defining the access to spectral line databases, both theoretical and observational. Two standards are in development, the Simple Line Access Protocol (SLAP) and the Atomic and Molecular Spectral Line Data Model (AMSL).

The first one defines an uniform access to spectral line databases and, the second, a common universal language to interchange information. The SLAP and the already existing Simple Spectrum Access Protocol (SSAP), integrated in the same VO application, are a powerful combination for astronomical spectral studies.

Some very well known spectral line databases have already implemented SLAP services on their servers, e.g., the NIST Atomic Spectra Database (laboratory), LERMA (observational) or the IASD (Infrared Astronomical Spectral Database) (observational). Other projects, like ALMA (Atacama Large Millimeter Array), are preparing their databases to be as close as possible to the Spectral Line Data Model and are planning to expose their data in SLAP format.

We summarize the content of both the SLAP and AMSL and how these SLAP services have been integrated in VOSpec, VO reference application for spectral access developed by the ESA-VO team.

Key words: Virtual Observatory.

1. INTRODUCTION

During the last years, the IVOA (International Virtual Observatory Alliance) DAL (Data Access Layer) Working Group has been defining the access to different astronomy resources, such of the access to images through the Simple Image Access Protocol (SIAP) and to spectra through the Simple Spectra Access Protocol (SSAP).

Atomic and molecular line databases are a fundamental component in our process of understanding the physical nature of astrophysical plasmas. An action within the IVOA DAL WG was started to provide a uniform and consistent access to this kind of resources. To fulfill this task, three actions were started in parallel (see Salgado et al (2006)):

- Atomic and Molecular Spectral Line Data Model: A common reference data model to homogenize the semantics.
- Simple (Spectral) Line Access Protocol: This protocol will describe the syntax of the queries to a spectral lines database in a uniform way
- Reference client implementation: Integrate a SLAP client in one VO spectral tool; VOSpec.

In the present proceedings a summary of the aforementioned activities is presented.

2. ATOMIC AND MOLECULAR SPECTRAL LINE DATA MODEL (AMSL DATA MODEL)

The vocabulary involved in the atomic and molecular spectral lines description is quite complex, so a specific IVOA data model was required in order to allow homogeneous access to different spectral line databases. Fixing it, the syntax, the semantics of the query and result of any protocol access can be treated in a universal way. This is specially needed for the SLAP access but it will needed for any future complex access in the future. This will explained in the next section.

The AMSL (see Dubernet et al (2006)) data model is based in the object *Line*. A *Line* is defined as the results of a transition between two states. The bound-bound transitions are included as well as free-bound transitions.

Each transition is defined through a pair of *Level*s. Some attributes of the levels are *Specie*s and *QuantumState*. This latter characterized by a proper set of *QuantumNumber*s.

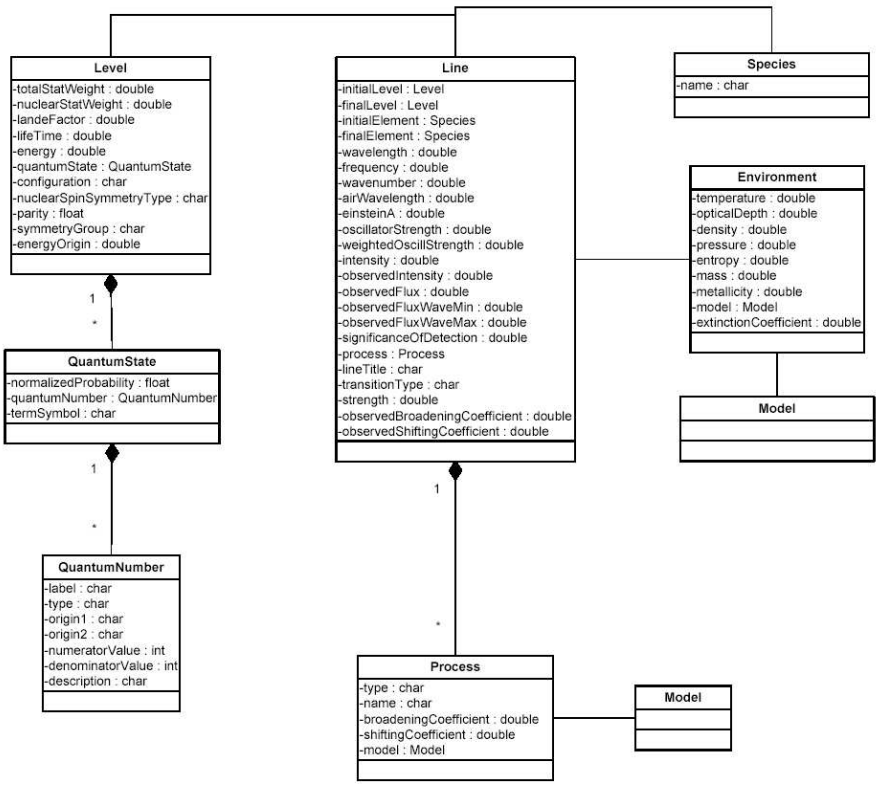

Figure 1. Line DataModel

The AMSL DM does not try to fully describe all the possible physics behind any spectral process, as that would imply a very complex and, probably, unmanageable data model. At contrary, it tries to simplify the access to spectral and molecular line databases so the description of a possible universal access could be a realistic task.

The present data model points to other IVOA data models and to external data models to be created, as, e.g., one to describe *Species* in a more detailed way. *Species* data model would be too complex to be incorporated as an add-on to the AMSL DM and it deserves a separated work.

The main classes that represent this data model are the following:

- *Line:* This class includes observables describing the line, as well as the main physical properties of the transition originating it. Recombination and dissociation are expressed through atomic coefficients rather than through global properties.
- *Level:* This class includes attributes to describe the an atomic/molecular system, to be used as initial and/or final quantum configuration that produces the line.
- *Quantum State:* This class includes attributes to describe the atomic/molecular quantum states for the initial and final levels.

3. SIMPLE (SPECTRAL) LINE ACCESS PROTOCOL (SLAP)

The Simple Line Access Protocol (SLAP) (see Salgado et al (2005)) makes use of the AMSL DM work as the source of the abstract representation of the spectral line. Before the definition of SLAP protocol, there were various spectral line databases already in place using their own protocol implementation. Most of them were HTML based, so, following the successful SIAP protocol (see Tody et al (2004)), it was decided to define the SLAP protocol as a HTTP/GET protocol.

This protocol could be used by two main types of protocols:

- Observational line databases: Lines observed and identified in real spectra collected by different instruments/projects.
- Theoretical/laboratory line databases: Servers containing theoretical or laboratory observed spectral lines.

In a medium term, a more detailed protocol could be created to allow a better granularity in the output and a better constraint input parameter definition. This kind of access

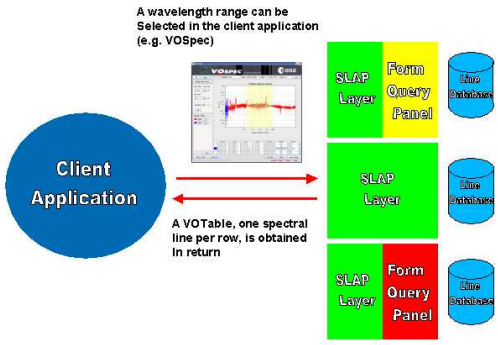

Figure 2. SLAP concept

should be based in the VOQL language (SQL for the Virtual Observatory) and it will be defined in coordination with the future evolution of the access protocols.

The translation from the current implementation of the various already in place HTML based query interfaces to SLAP should be trivial. A SLAP implementation requires:

- A SLAP service must support a query in wavelength range. Many other input parameters could be used to filter out spectral lines from the input. If possible, all these not-compulsory and free parameters should contain a link to the AMSL DM to clarify the semantic for the client-server interaction.

- The successful output returned by a SLAP service is a VOTable. This table lists all the spectral lines found in the server database that match the query constraints. The *utype* tag is important to characterize the different fields of the output table (see other utype uses at reference Osuna et al (2006)). It should contain the data model description of the field described in this column, e.g., *utype="ldm.Line.wavelength"*. This is specially useful for not-compulsory and free output fields.

A compliant SLAP service must support spectral line queries with a special parameter FORMAT=METADATA. By using this parameter, the service will expose optional and specific capabilities so any VO application can discover them.

This is strongly recommended for theoretical/laboratory line databases, that could make use of extra parameters not specifically described in the SLAP specification, but that could be used to filter out lines or score lines due to the application of physical models.

4. VOSPEC IMPLEMENTATION

The VOSpec (see Osuna et al (2005)) tool is an application developed by the ESA-VO and SAT team (see Barbarisi et al (2006)) to access spectra from the already accessible different SSAPs (Simple Spectra Access Protocol) servers . This tool was the first one to access this kind of services and, since them, it has been considered the reference application for other IVOA initiatives as the access to theoretical spectral data (TSAP) (see Osuna et al (2005)) and SLAP.

The tool contains also general astronomical functionality useful for any wavelength range, as this is the most usual case of use in the Virtual Observatory context. The most obvious initial one, coming from the definition itself of the algorithm for spectra superimposition, is the ability to change the display between different units, allowing for better qualitative analysis depending on the range of interest. The kind of spectral files accepted are, for the time being, FITS and XML Spectrum files.

The tool also supports fitting using some mathematical functions like N-Black Body, Gaussian and polynomial fitting and more will be available soon. Spectrum Line information will be available soon as well.

As VOSpec is mainly a spectral visualizer, the SLAP client implementation is fully integrated in the VOSpec spectral display, i.e.:

- Once the spectra accessed through SSAP services is displayed in VOSpec a wavelength region can be selected on the display.

- A new window that includes the already existing SLAP services will appear. The user will select SLAP servers to query and VOSpec will display the result in different tabbed tables.

- Moving the mouse on the spectral display, information on the closer line to the wavelength will be shown. The line will be selected on the tabbed table too.

5. SLAP SERVER IMPLEMENTATIONS

There are several SLAP server implementations already in place:

- 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. As all the lines from this database contains a link to a refereed publication, the curation of the lines is guaranteed. This service was adapted to SLAP format by the ESAVO

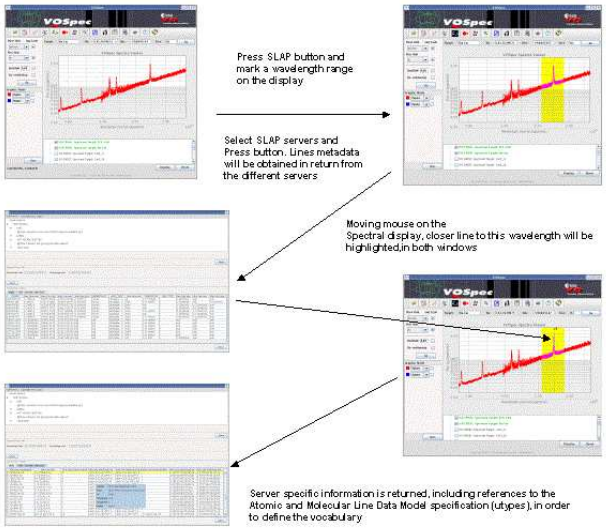

Figure 3. SLAP implementation in VOSpec

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, a free/public application that can be used by any investigator to publish their own data in SIAP, SSAP and SLAP, depending of the data involved.

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 Millimeter Array) Archive Group at The University of Manchester is making use of the AMSL DM as a basic data model for their databases.

This ALMA group has done, at the same time, a review of the SLAP specification to use this protocol for internal consumption for their project. As, in a first phase, the lines could be uncalibrated and, for most of the cases, unidentified, some requirements has been included in the protocol specification to support this.

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