

CASSIS and Aladin interfaced for a VO-compliant spectral data cube analysis tool

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Abstract.

Spectral cubes are now usual data products in astronomy, independently of the spectral domain, in part due to the high data production rate of large projects such as MUSE in optical, LOFAR, ALMA, VLA, NOEMA or ASKAP in radio astronomy, or Chandra and XMM in Xray. And this is only a hint of what will happen with the emergence of SKA or other Petascale projects in a near future. These cubes are, at least in part, accessible online and easy to find due to the large number of VO services which distribute them. However, efficient display and analysis of such spectral cubes is a big challenge.

In this context the CASSIS team at IRAP and the Aladin team at CDS decided to work together on the combination of their VO applications in order to create a tool able to explore simultaneously both the spatial and spectral dimensions of data cubes. CASSIS is a Java tool able to discover spectra in remote services via the SSAP protocol and analyse them. It provides functionalities such as spectrum display, spectral line identification, prediction of spectra from any telescope, comparison of spectra with various models and determination of the physical parameters of the sources. Aladin Desktop is also a Java tool enabling anyone to discover and display on-sky data (images, cubes and catalogs). Images and cubes can be either in standard FITS format or in the IVOA HiPS format. Different overlays, including catalogs, survey coverages (e.g. MOC) or fields of view are available as graphic layers in this Virtual Observatory landscape that favors the comparison of data.

The focus demo shows how the two desktop applications are interfaced to cooperate on data access in order to provide spectral cube analysis functionalities. For example CASSIS can analyse a spectrum built on the fly by Aladin, out of a spectral data cube, after hand selection of a specific area. Reversely CASSIS allows to select spectral ranges on such spectra and ask Aladin to display 2D images combining the corresponding spectral planes in the cube. The tool can work both on local data available on the user's disk or on cubes discovered in VO services via the VO registry. The goal

is that this new tool will favor the joined spectral and spatial exploration of data cubes in a generic way.¹.

1. Introduction

Recently the CDS Aladin team (Centre de Données Astronomiques de Strasbourg 2011) held a brainstorming session on data access and visualisation for spectral cubes in the Virtual Observatory. CDS decided to contact the CASSIS (CASSIS team 2014) team at IRAP to join the efforts for building an interface so that data and commands could be exchanged seamlessly in order to bind the spatial and spectral capabilities of both applications. After a couple of months of development on both sides, the CASSIS plugin is now available from Aladin Desktop and provides functionalities, which have been demonstrated during the focus demo. CASSIS plugin and Aladin share the same virtual machine and memory buffers and can exchange commands easily. The next sections summarize the demonstration of a typical interaction scenario.

2. Discovering and loading a cube in Aladin

Assuming we are interested in an Orion type emission star (V* V2423 Ori), we look for spectral cubes at this position. For example we know that ESO is distributing MUSE cubes. We query an area of 30' around V* V2423 Ori with the ESO ObsTAP service. A cube is available for this young stellar object and is part of the public release. We open the DataLink menu for this dataset and ask for the SODA interface, which helps us to request a cutout. We restrict the size to an area of 2'' \times 2'' and a wavelength range from 500 nm to 750 nm. The ESO SODA service sends back the requested subcube (Fig. 1).

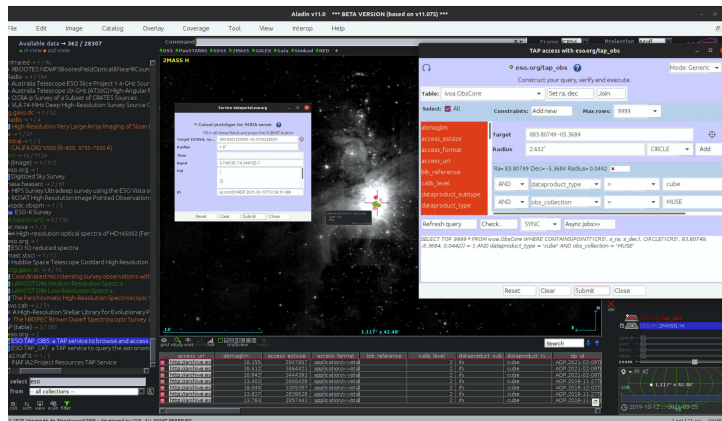


Figure 1. Discovery of MUSE cubes in Orion area with ESO ObsTAP service and SODA interface to obtain a cutout on one of the cubes.

¹All IVOA standards quoted here: MOC, ObsTAP(ObsCore), SODA, SLAP, HiPS can be found at <https://www.ivoa.net/documents>
VAMDC is at https://portal.vamdc.eu/vamdc_portal/home.seam

3. Extracting spectra from a spatial position in the cube and displaying them in CASSIS

When the cube is uploaded in Aladin, we open the CASSIS interface. The cube is shown as a multi-image movie. We select a position in the Aladin 2D-plane with the "spec" icon in the right Aladin tool list to extract a spectrum. This creates a spectral profile in CASSIS for this position. The spectrum has the same color as the cursor. Integrated spectra can also be computed by defining either a circular area (via the "phot" icon) or a closed polygon (via the "draw" icon).

4. Playing back and forth between Aladin and CASSIS

Cursors and spectral profiles are synchronised between the two applications. The color of the spectrum can be modified in CASSIS, which automatically changes the color of the cursor in Aladin. Spectra in CASSIS can be deleted by suppressing the corresponding position mark in Aladin. The spectrum in CASSIS evolves synchronously when the "spec" or "phot" selections are moved in Aladin.

We compute 2D images of integrated spectral planes by selecting the spectral range on the CASSIS display. Alternatively we can change the spectral plane displayed in Aladin by moving the selector along the wavelength axis in CASSIS. An example is presented in Fig. 2 for a local radio (GBT) cube.

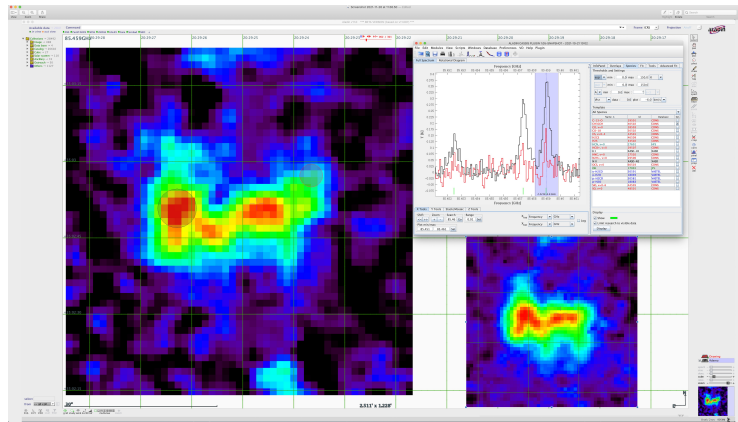


Figure 2. Selected areas on the cube field in Aladin (left) with the corresponding spectra in CASSIS (top right) and integrated spectral plane in Aladin driven by the blue limits set on the spectrum into the CASSIS window (bottom right).

5. CASSIS functionalities: Line identification, line profile fitting and rotational diagrams

Spectral lines can be identified with CASSIS. The spectroscopic metadata are available through VAMDC, SLAP services or local SQLite databases. They can be customized by the user through the line parameter profile interface. Source velocities/Doppler shift

can be measured by using the rest frequency of the considered line given in the spectroscopic databases.

The user can fit the spectral line profiles in CASSIS and estimate various parameters from this fit (radial velocity, line width, intensity). The values can be saved and reused in the case of radio and (sub)millimeter emission to plot rotational diagrams. This method assumes Local Thermodynamic Equilibrium and allows the user to estimate physico-chemical parameters such as excitation temperatures and column densities. All these features are illustrated in Fig. 3 for the GBT cube.

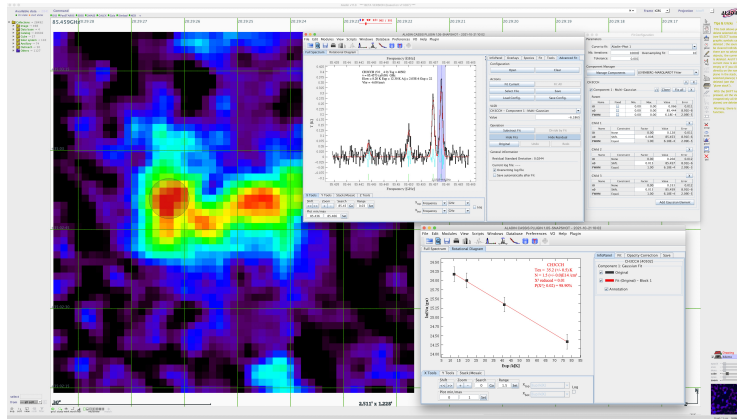


Figure 3. Spectral line identification in CASSIS, spectral multi-line fitting and determination of the physico-chemical parameters with the rotational diagram analysis.

6. Conclusion

The CASSIS Aladin plugin provides display and advanced functionalities in order to analyse spectra extracted from spectral cubes loaded in Aladin from the user's disk or retrieved from VO services. In the future, we plan to add the possibility to manage spectra extracted from several cubes in parallel and also to provide HiPS-server-side crop functionalities in order to generate FITS cutouts extracted from HiPS cubes.

Acknowledgements. The CASSIS team is supported by the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme through ERC Starting Grant "Chemtrip" (Grant Agreement n. 949278). Aladin developments have been supported in-part by the ESCAPE project (the European Science Cluster of Astronomy & Particle Physics ESFRI Research Infrastructures) that has received funding from the European Union's Horizon 2020 research and innovation programme under the Grant Agreement n. 824064.

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