Astronomical Data Analysis Software and Systems XXVIII
ASP Conference Series, Vol. 523
P.J. Teuben, M.W. Pound, B.A. Thomas, and E.M. Warner, eds.

Open-source Web Tools for Spectroscopic and Imaging Data Visualization for the VOXAstro Initiative

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Abstract. Here we present a set of flexible open-source tools for visualization of spectral and imaging data developed for the VOXAstro projects. Using open-source web visualization libraries we developed interactive viewers to display low- and high-resolution spectra of stars and galaxies, allowing one to view spectra having resolution up to R=80000 without putting a significant load on server and client sides, which is achieved by choosing the adaptive spectral binning window and dynamically pre-loading the datasets. We implemented a number of additional features like multiple spectra display, output of header info (e.g., stellar atmospheric parameters or stellar population properties of galaxies), display of emission lines decomposition parameters (fluxes, widths, etc.). The spectral viewers can be easily embedded into any archive or database web-site. We also present a cutout service that extracts data on the fly from the UKIDSS near-infrared imaging survey and generates colour composite RGB stamps, which we use, e.g., in the RCSED web-site as an embedded service. The service uses IVOA SIAP to access images, which it then cuts out on the fly using Astropy functions. In the coming years we plan to expand the capabilities of our spectroscopic and imaging visualization services and use them in future projects within VOXAstro.

1. Introduction

With the rapid development of astrophysical web services the question how to efficiently display datasets of various types has become crucial. We developed and deployed several tools for visualization of imaging and spectral datasets for the VOXAstro initiative. VOXAstro stands for Virtual Observatory tools for eXtragalactic Astrophysics. This initiative includes several projects such as the Reference Catalog of Spectral Energy Distribution (RCSED; `http://rcsed.sai.msu.ru/` Chilingarian et al. 2017), K-corrections calculator (`http://kcor.sai.msu.ru/` Chilingarian et al. 2010) and several stellar spectral libraries. Here we present a set of flexible open-source tools for visualization of spectral and imaging data. For all applications, we tried to reach the maximal flexibility and convenience in embedding them into *html* pages which makes possible re-using them in other projects.

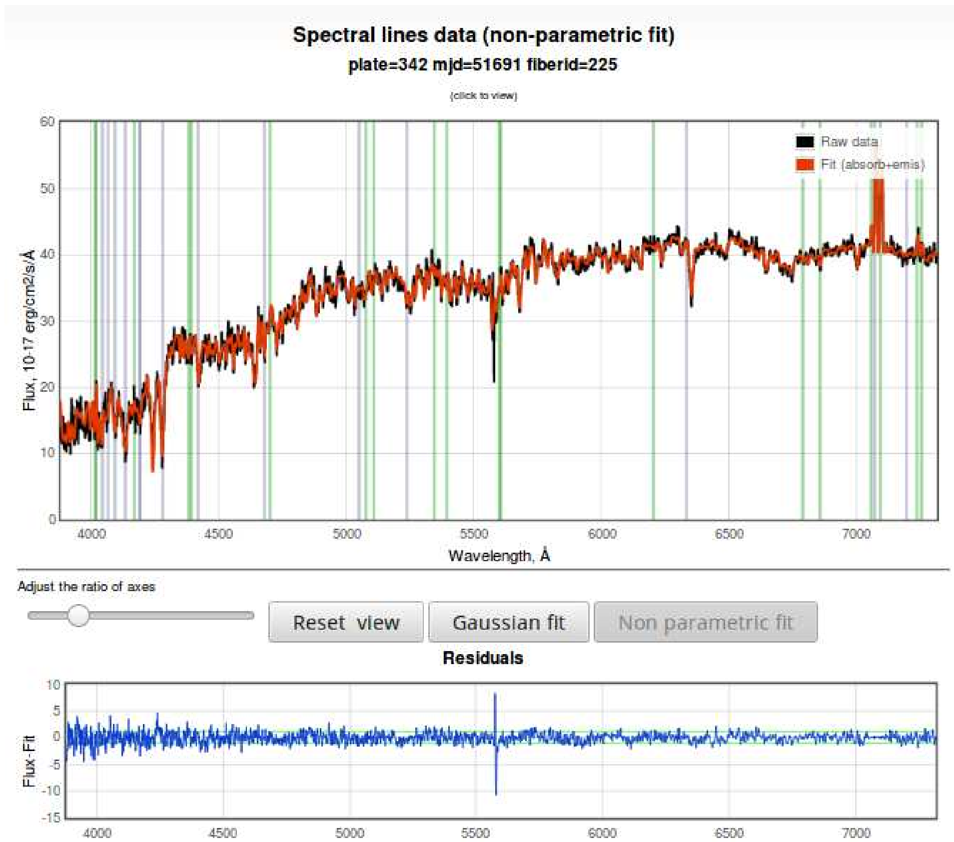

Figure 1. A galaxy spectrum from the RCSED project and its best-fitting template are displayed in the spectrum viewer. Fitting residuals are shown in the bottom panel.

An important aspect of data visualization in astrophysics arises from the fact that one needs to quickly generate plots, which potentially may contain tens of millions of data points. For example, it is often needed to plot a relatively small dataset of objects of interest over a 2D density plot for the entire reference sample of millions of sources, which always stay the same. This can be achieved using server side visualization to generate static plots, which are then displayed in a web-browser without the need of transmitting the entire dataset to the client. We successfully used this approach in the search of intermediate-mass black holes using RCSED (Chilingarian et al. 2018): for visual assessment of the complex multi-parametric selection we display several server-side generated plots reflecting various observed and derived properties of active galactic nuclei and their host galaxies – this resembles the well-known "connected views" paradigm of multi-dimensional data visualization.

2. A galaxy spectrum viewer in the RCSED project

For RCSED we developed a viewer of galaxy spectra. This application uses the FLOT JAVASCRIPT library (`https://www.flotcharts.org/`) which implements draggable

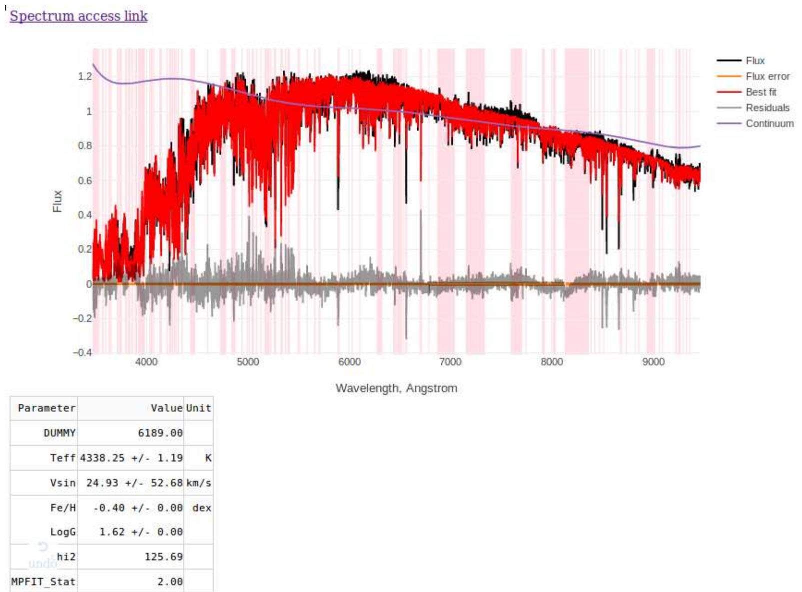

Figure 2. A spectrum of the star HD 163993 with its best-fitting model and residuals displayed in a simple spectrum viewer for the INDO-US stellar spectral library.

plots. The viewer (see Fig. 1) displays a calibrated spectrum and its best-fitting model (including models of emission lines and starlight). One can also get the information about fluxes in emission lines by clicking on them; the positions of lines are marked by vertical bars. Besides the spectrum plot, a clickable table is provided which contains emission line fluxes, flux errors, signal-to-noise ratios.

3. RGB stamp images for the UKIDSS near-infrared survey

Near-infrared RGB composite images are often useful for eyeball assessment of stellar populations and morphology in galaxies. The 2MASS survey (Skrutskie et al. 2006) gives access to all-sky JHK data, however it has relatively shallow depth because of short exposure times, therefore we use a much deeper UKIDSS (Lawrence et al. 2007) survey data in RCSED to study galaxies in detail. Unlike 2MASS, UKIDSS does not have an RGB MOC map in Aladin (Bonnarel et al. 2000), that is why it is non trivial to embed a UKIDSS RGB image to an arbitrary web page. We use the python library APLpy (`https://aplpy.github.io/`) to generate RGB images on the fly for the RCSED web-site. The Lupton et al. (2004) algorithm is used for the RGB composite generation from YHK data retrieved using IVOA Simple Image Access Protocol.

4. Interactive visualization for spectra of different types

In observational astrophysics one deals with spectral data of different flavors, from one-dimensional (like SDSS, Abazajian et al. 2009) to three-dimensional (e.g., MANGA, Bundy et al. 2015). The diversity of data one has to analyze makes it essential to develop a versatile spectral visualization tool. We developed a flexible interactive Web-based tool for spectral display. It is based on Dash and Plotly libraries (https://plot.ly/products/dash/). These libraries allow us to efficiently display even high-resolution spectra (R=80000, 500k data points) without heavy load on either server or client. For end users it could also be important to display some values from a FITS file in a tabular form, e.g., stellar parameters. There is also an option to plot some arbitrary data as a supplementary dataset (e.g., a correcting polynomial for the stellar continuum). Supplementary datasets and the output parameter table are controlled via a URL. One can also adjust the parameters of the displayed datasets (flux, error, etc), which default to the IVOA Spectrum Data Model. This makes it possible to use our web application to visualization nearly all existing types of spectra.

5. Interactive visualization for libraries of stellar spectra

It is often needed to simultaneously visualize several spectra in order to compare them against each other. An important example is libraries of stellar spectra, which provide uniformly processed data collections from the same instrument. For this purpose, we extended our simple spectrum viewer. This tool inherits all its features but it also allows interactive selection of spectra from a data collection. For stellar libraries, we use the stellar atmospheric parameter space ($T_{\rm eff}$, log g, [Fe/H]). The stars can be selected from a 3D plot or from an interactive table, which contains stellar parameters.

Acknowledgments. This project is supported by the Russian Science Foundation Grant 17-72-20119. KG is grateful to the ADASS XXVIII organizing committee for providing financial aid to support his attendance of the conference.

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