Fast interactive web-based data visualizer of panoramic spectroscopic surveys

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Abstract.
Panoramic IFU spectroscopy is a core tool of modern observational astronomy and is especially important for galaxy physics. Many massive IFU surveys, such as SDSS MaNGA (10k targets), SAMI (3k targets), Califa (600 objects), Atlas3D (260 objects) have recently been released and made publicly available to the broad astronomical community. The complexity and massiveness of the derived data products from spectral cubes makes visualization of the entire dataset challenging, but nevertheless very important and crucial for scientific output.

Based on our past experience with visualization of spectral and imaging data built in the frame of the VOxAstro Initiative projects, we are now developing online web service for interactive visualizing spectroscopic IFU datasets (ifu.voxastro.org). Our service will provide a convenient access and visualization tool for spectral cubes from publicly available surveys (MaNGA, SAMI, Califa, Atlas3D) and results of their modeling, as well as maps of parameters derived from cubes, implementing the connected views concept. Here we describe the core components and functionality of the service, including REST API implementation on top of the Django+Postgres backend as well as a fast and responsive user interface built using the modern Vue.js-based framework Quasar.

1. Introduction

Massive spectroscopic surveys of galaxies provide extremely important information for studying galaxy evolution such as stellar and ionized gas kinematics, star formation history imprinted in the stellar population properties. Integral Field Spectroscopy (IFS) is a powerful observational technique that allows spatially resolved measurements of galaxy properties.

Here we present an online web service (hereafter IFU Visualiser) for interactive visualization of spectroscopic IFU datasets (https://ifu.voxastro.org), providing
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a convenient access and visualization tool for spectral cubes from publicly available surveys (MaNGA, SAMI, Califa, Atlas3D). The service is inspired by our first prototype http://manga.voxastro.org and the official Marvin web application released by the MaNGA Team (Cherninka et al. 2019).

2. Data sets and service functionality

To date (Nov 2021) IFU Visualiser involves data arrived from SDSS DR16 MaNGA Survey (Bundy et al. 2015), SAMI DR3 (Croom et al. 2012), Califa DR3 (Sánchez et al. 2012), Atlas3D (Cappellari et al. 2011). Table 1 shows the size of the datasets available in the IFU Visualiser service and the cross-matching between surveys.

Table 1. IFU Visualiser data sets

|             | MaNGA DR17 | MaNGA DR16 | SAMI | Califa | Atlas3D |
|-------------|------------|------------|------|--------|---------|
| MaNGA DR17  | **11236**  | 4824       | 106  | 40     | 0       |
| MaNGA DR16  | 4824       | **4824**   | 15   | 20     | 0       |
| SAMI        | 106        | 15         | **3426** | 1    | 1      |
| Califa      | 40         | 20         | 1    | **667** | 23      |
| Atlas3D     | 0          | 0          | 1    | 23     | **260** |

IFU Visualiser largely inherits the general architecture and functionality of another VOxAstro project RCSEDv2 (Chilingarian et al. 2017; Toptun 2021; Klochkov 2021). Briefly, IFU Visualiser provides two major ingredients: search tool for spectral cubes and interactive visualiser of individual cubes and two-dimensional maps of parameters extracted from spectra. Query language syntax described on the documentation page https://ifu.voxastro.org/docs where several search query examples can be found. Fig. 1 shows a screenshot of the individual Cube page.

![IFU Visualiser](image)

Figure 1. Example of an individual page of the MaNGA spectral cube (Cube ID: 4295) showing the low-mass post-starburst galaxy GMP 4188 in the Coma cluster, which will passively evolve into an ultra-diffuse galaxy (Grishin et al. 2021).
3. Implementation

All code, including the backend, frontend, and scripts to assemble the input tables for the database, is available on the GitHub repo [1].

3.1. Backend

PostgreSQL is used to manage access to the main and linked tables. The main spectral cube table contains basic information such as cube identifier, coordinates, field-of-view coverage, and the necessary survey identifiers needed to connect related tables to any given cube. The linked tables are taken from the corresponding survey and contain very diverse information about cubes as well as galaxies. We chose PostgreSQL as the backend database because of i) support for geometry queries thanks to q3c (Koposov & Bartunov [2006]) and pgSphere (Chilingarian et al. [2004]) extensions; and ii) natural compatibility with VO services (TAP, SSAP access) using GAVO DaCHS (Demleitner [2018]), which we plan to add soon to IFU Visualiser. The well-known Python-based Django REST Framework (DRF) [2] is used on top of the PostgreSQL database to provide API endpoints. In addition to Django high popularity, wide community, and excellent documentation, a decisive reason for using this framework is the large number of batteries. One of them is django-custom-query [3] which is designed to create simplified, but still very powerful SQL-like queries (e.g. survey=sami OR atlas_name~4551). We also modified the original library and incorporated coordinates Cone-search queries using the q3c function q3c_radial_query() (e.g. cone(195, 28, 0.5)). We also considered using the GraphQL [4] endpoint to provide data access, but after simple performance tests with Graphene-Django library [5] we found that DRF provides several times faster response time overall. Another problem with using GraphQL lies on the frontend side: the seeming simplicity of using, for example, with Apollo client [6] preserves potential problems in managing global application state. The Apollo client can be used as a state manager, but we use the standard Vuex state manager for Vue.js applications. Using both options leads to the "two sources of truth" problem. Switching completely to Apollo requires writing awkward chunks of code and abandoning browser testing tools not yet available for the Apollo client.

3.2. Frontend

We used the Vue.js-based frontend framework Quasar [7], which provides an awesome infrastructure and a large collection of Vue components built according to Material Design guidelines. Vue.js and the Quasar framework have a very low threshold of entry and allow one to create highly interactive user interfaces with very limited Javascript.

[1] https://github.com/voxastro/ifu-visualiser
[2] https://www.django-rest-framework.org/
[3] https://github.com/ivan-katkov/django-custom-query
[4] https://graphql.org/
[5] https://docs.graphene-python.org/projects/django/en/latest/
[6] https://apollo.vuejs.org/
[7] https://quasar.dev/
skills. In addition to the Quasar component library, we used Aladin Lite for imaging and Plotly.js library to create an interactive spectral plots and maps of parameters.

4. Next development steps

To date (November 2021), only a small part of the planned functionality of the IFU Visualiser has been developed. The next major steps for further development will be:

1. Regarding user interface development we will improve the spectral Cube page and implementing a more flexible interaction with spectra and parameter maps. Functionality will be similar to that we built in the frame of our first prototype of such a service [https://manga.voxastro.org/](https://manga.voxastro.org/) made with another technologies and uses only MaNGA data.

2. We also plan to add uniform basic galaxy parameters such as masses, luminosities, effective radii and colors for all galaxies available in the IFU Visualiser.

3. Another important milestone is to analyze the entire collection of spectral cubes to ensure a homogeneous set of data products extracted from the cubes using full spectral fitting technique NBursts, similar to what we do in the RCSED2 project but for IFU data.

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References

Bundy, K., et al. 2015, ApJ, 798, 7. [1412.1482](https://arxiv.org/abs/1412.1482)
Cappellari, M., et al. 2011, MNRAS, 413, 813. [1012.1551](https://arxiv.org/abs/1012.1551)
Cherinka, B., et al. 2019, AJ, 158, 74. [1812.03833](https://arxiv.org/abs/1812.03833)
Chilingarian, I., et al. 2004, in Astronomical Data Analysis Software and Systems (ADASS) XIII, edited by F. Ochsenbein, M. G. Allen, & D. Egret, vol. 314 of Astronomical Society of the Pacific Conference Series, 225
Chilingarian, I. V., et al. 2017, ApJS, 228, 14. [1612.02047](https://arxiv.org/abs/1612.02047)
Croom, S. M., et al. 2012, MNRAS, 421, 872. [1112.3367](https://arxiv.org/abs/1112.3367)
Demleitner, M. 2018, DaCHS: Data Center Helper Suite. [1804.005](https://arxiv.org/abs/1804.005)
Grishin, K. A., et al. 2021, Nature Astronomy. [2111.01140](https://arxiv.org/abs/2111.01140)
Klochkov, V. 2021, in ADASS XXX, edited by J.-E. Ruiz, & F. Pierfederici (San Francisco: ASP), vol. TBD of ASP Conf. Ser., 999 TBD
Koposov, S., & Bartunov, O. 2006, in Astronomical Data Analysis Software and Systems XV, edited by C. Gabriel, C. Arviset, D. Ponz, & S. Enrique, vol. 351 of Astronomical Society of the Pacific Conference Series, 735
Sánchez, S. F., et al. 2012, A&A, 538, A8. [1111.0962](https://arxiv.org/abs/1111.0962)
Toptun, V. 2021, in ADASS XXX, edited by J.-E. Ruiz, & F. Pierfederici (San Francisco: ASP), vol. TBD of ASP Conf. Ser., 999 TBD

[https://plotly.com/javascript/](https://plotly.com/javascript/)