**Discover and access GAPS Time Series prototyping for interoperability**

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**Abstract.** The GAPS (Global Architecture of Planetary Systems) project is a, mainly Italian, effort for the comprehensive characterization of the architectural properties of planetary systems as a function of the host stars’ characteristics by using radial velocities technique. Since the beginning (2012) the project exploited the HARPS-N high resolution optical spectrograph mounted at the 4-m class TNG telescope in La Palma (Canary Islands). More recently, with the upgrade of the TNG near-infrared spectrograph GIANO-B, obtained in the framework of the GIARPS project, it has become possible to perform simultaneous observations with these two instruments, providing thus, at the same time, data both in the optical and in the near-infrared range. The large amount of data obtained in about 5 years of observations provided various scientific outputs, and among them, time series of radial velocity (RV) profiles of the investigated stellar systems.

This contribution shows the first steps undertaken to deploy the GAPS Time Series as an interoperable resource within the VO framework designed by the IVOA. This effort has thus a double goal. On one side there’s the aim at making the time series data (from RV up to their originating spectra) available to the general astrophysical community in an interoperable way. On the other side, to provide use cases and a prototyping base to the ongoing time domain priority effort at the IVOA level. Time series dataset discovery, depicted through use cases and mapped against the ObsCore model will be shown, highlighting commonalities as well as missing metadata requirements. Future development steps and criticalities, related also to the joint discovery and access of datasets provided by both the spectrographs operated side by side, will be summarized.

1. **Introduction**

The extrasolar planets search through the radial velocity (RV) method takes advantage of a large amount of spectroscopic datasets, coming from dedicated observatories deployed in several countries.

A set of basic use cases has been developed to try to give first answers to dataset discovery and access to time series for spectroscopic RV in the exoplanets domain. This set of use cases (described in Sec. 2), even if not exhaustive, nonetheless show that probably a specific domain model is needed to be coupled with the ObsCore table metadata (IVOA ObsCore Recommendation Louys et al. 2017) and answer even some basic discovery cases.
The use cases come from the experience in exoplanets discovery and characterization gained by the GAPS project (Covino et al. 2013) and proceed from the results of the first years of the project (see, e.g. Benatti et al. 2017).

2. Use Cases

Here we describe the use cases (UC) adopted for this contribution, mapping case by case what fields of the ObsCore table are involved or what extra tables and columns we used. Essentially we added, alongside the mandatory and a few optional ObsCore fields, two dedicated tables:

- **exots** table to contain global metadata for the exoplanetary system;
- **exoplanets** to collect metadata for the exoplanets themselves.

This choice was made for two reasons: not to add new, domain specific, fields to the general purpose ObsCore main table, and, for the exoplanets table, to allow the 1-to-N relationship between the host system and its exoplanets. The *obs_publisher_did* ObsCore identifier field has been used to glue the three tables together.

**UC1** The first use case is to find all possible datasets that contain radial velocity time series given, e.g., a region on the celestial sphere. This one is easily accomplished using the *dataproduct_type* field set to *timeseries* in combination with the *o_ucd* (observable axis UCD) set to *spect.dopplerVeloc.opt* (since we are currently dealing only with optical data) and relying on the positional search capabilities of the ObsCore model. For future GIANO-B/GIARPS observations we’ll need to add a .IR leaf to the UCD branch or find an analogue solution to support infrared observation derived products.

**UC2** ObsCore’s use case 4.2 asks for constraints on the number of points in the series, its time span and resolution. Our second use case simply applies this to the exoplanets case. However, it seems not clear what information the time axis parameters (*t_* fields) should stand for, particularly the *t_resolution* field, given that the resolution of these time series is inherently uneven.

**UC3** The third use case deals with potentially detected exoplanets. This is the first added metadatum, that we put in an external table (*exots*) linked to the ObsCore one. There are two fields to deal with this: *candidates* and *confirmed* (see Table 1) to filter for candidate or confirmed planets in an host system.

**UC4** This use case is meant to identify what discovery method is used for the exoplanets whose time series are searched for. We set also this parameter *method* in the *exots* new table, setting it to *textbf{RV}spectroscopy*, but considering that this field should have values coming from a controlled vocabulary of discovery methods (transit, direct-imaging, astrometry, …). The use case may also be solved adapting, again, the *o_ucd* to express the discovery method, but it would be confusing in the usage, because it would mean mapping two distinct concepts in the same field.
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Table 1. **exots**: additional table to deal with exoplanets global parameters as explained in the presented use cases (see listing in Sec. 2).

| column name           | description                                                                 |
|-----------------------|-----------------------------------------------------------------------------|
| obs_publisher_did     | dataset identifier reference key to the obscore table                       |
| candidates            | number of candidate and confirmed planets in the stellar system             |
| confirmed             | number of confirmed planets in the stellar system                           |
| method                | discovery method used to detect the exoplanets (vocabulary based)           |
| host_activity         | host star activity index                                                    |
| host_mass             | host star mass                                                              |
| host_type             | host star spectral type                                                     |
| host_metallicity      | host star metallicity                                                       |
| host_age              | host star age                                                               |
| systemic_RV           | systemic radial velocity calculated for the system                          |
| updated               | last time the time series has been worked on                                 |

Table 2. **exoplanets**: additional table to deal with exoplanets parameter values (see UC6 listing in Sec. 2). Differently to the case of the **exots** table, here the obs_publisher_did defines a 1-to-N relation to the **exots** tables.

| column name         | description                                                                 |
|---------------------|-----------------------------------------------------------------------------|
| obs_publisher_did   | dataset identifier reference key to the exots table                         |
| planet_id           | exoplanets identifier in the system (b, c, d, ... )                         |
| msini               | exoplanet minimum mass parameter                                            |
| period              | period                                                                      |
| eccentricity        | orbital eccentricity                                                        |
| RVsemiampplitude     | radial velocity semi-amplitude                                              |
| t0                  | time at periastron (RV) or central transit time (transit)                   |
| omega               | periastron longitude                                                       |

**UC5** Also host star characterization is important, so we have a use case that tries to solve discovery for stars having, e.g., low stellar activity (currently GAPS hosts are all low activity stars, but this may change in the future with adoption of IR spectroscopy) or a specific spectral type or similar. See the **host_*** fields in Table 1 for an example set of star characteristics that are used.

**UC6** Planets parameter values and their ranges define another use case for filtering time series of exoplanets. Since this requires multiple values for each system, another custom table (**exoplanets**, Table 2) has been added to include planets’ data like mass and orbital coefficients.

**UC7** This use case is not discussed here, but it mainly focuses on linking the time series points to their originating spectra, thus providing provenance access the datasets used to build the time series. The idea is to use the Datalink (IVOA Recommendation, see Dowler et al. (2015)) for the access_url and access_format ObsCore fields.
Also the last use case is not discussed here. It asks to find time series of photometry of the host system, to use in combination with spectral data in the exoplanets identification. Standard ObsCore should be able to solve it.

3. Conclusions

Simple discovery and access use cases for exoplanets time series do not look a difficult task adopting an IVOA ObsCore solution (see use cases 1 and 2 in Sec. 2). However some changes may be needed if we want specific discovery scenarios to work, like use cases from 3 to 6. Moreover, some information, useful when dealing with spectroscopic RV time series, can be set using ObsCore fields (s_fov and the em_* fields) but may be misleading since they refer to the spectra from which the time series originate, rather than being a direct description of the series points.

Also, t_* fields (the time axis characterisation ones), that play a specific role in the scenario, are quite confusing or misleading for time series, where the concepts of resolution, exposure time and start/stop of an observation are quite different from those of a single observation.

The solution here presented, using a couple more tables referencing the ObsCore through the obs_publisher_did can be a solution (given we use a helper solution setting the dataproduct_subtype to RV:optical to allow for mixed ObsCore content). It would probably be better if a simple model for time series is developed, to which the depicted tables (modified, updated, generalized) follow as flat views to be connected to the ObsCore main table.

The two final uses cases, not solved within this contribution, should not present criticalities, because use case 7 fits the IVOA Datalink goals, while use case 8 should be already solved in ObsCore.

Acknowledgments. This contribution benefits funding from the ASTERICS project, supported by the European Commission Framework Programme Horizon 2020 Research and Innovation action under grant agreement n. 653477.

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