



Fig. 1



Fig. 2



Fig. 3

1. Gaia DR2 Time Series at GAVO

(cf. Fig. 1)

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(cf. Fig. 2)

- What's the data?
- Time series as TAP-published arrays
- Cube-annotated time series through datalink
- Annotation details
- SSAP and Obscore

There's a less technical blog post on this:

<https://blog.g-vo.org/tag/gaia>

(cf. Fig. 3)

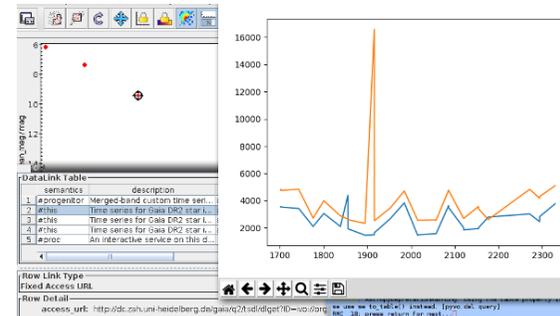


Fig. 4

source_id	g_transit_time	g_transit_flux	rp_obs_time
199266482883072	(1821.28463884353, 1821.358...	(168.358, 155.313, ...	(1821.28504145...
288243845193088	(1709.12149347339, 1709.195...	(839.831, 878.636, ...	(1709.12189430...
500243431117184	(1709.12073499955, 1709.194...	(1048.14, 967.225, ...	(1709.12113650...
507222753465440	(1709.12072062886, 1709.194...	(21800.5, 20744.4, ...	(1709.12112243...
594630948352256	(1709.62055392536, 1709.694...	(2031.78, 1784.16, ...	(1709.62095595...
721593161188608	(1709.69402180656, 1821.784...	(14287.5, 13187.3, ...	(1709.69445312...
782027645388032	(1709.69394153262, 1821.784...	(1534.34, 986.296, ...	(1709.69434521...

Fig. 5

2. What's the data?

(cf. Fig. 4)

With data release 2 of Gaia, there are light curves for 0.5 million objects classified as variable in three bands (G, BP, and RP).

ESAC publishes these as VOTables, pointed to from mostly-NULL columns (`dataLink.url` and `epoch_photometry.url`).

Grégory's Gaia-TAP service at ARI has a proper Datalink service block.

Although ESAC can produce per-band time series, their datalink links tables only point to mixed-band time series (where rows are, essentially band, time, flux). There is little machine-readable annotation on these time series.

Hence, I thought it might be a good idea to re-publish the time series data. Acknowledgement: Thanks to Grégory, who has handled the Gbin side of pulling the data.

3. TAP-Accessible Table

On <http://dc.g-vo.org/tap>, there's `gaia.dr2epoch`:

(cf. Fig. 5)

Arrays of NaN-filtered (epoch, flux, error) triples in G, RP, BP, plus `source_id` for joining with `gaia_source`.

Times are JD-2,455,197.5 here.

semantics	description	content_type	content
#progenitor	Merged-band custom time seri...	application/x-votable+xml	
#this	G time series for Gaia DR2 677...	application/x-votable+xml	
#this	BP time series for Gaia DR2 67...	application/x-votable+xml	
#this	RP time series for Gaia DR2 67...	application/x-votable+xml	
#proc	An interactive service on this d...		

Fig. 6

4. Desideratum

For server-side bulk analysis for the light curves, it would be cool to have analysis capabilities in ADQL.

Who's in on designing an Array UDF library for ADQL? (You can already say things like `SELECT rp_flux[1]-rp_flux[2]`... in DaCHS, but that doesn't take you far here)

5. Datalink

ADQL query:

```
FROM gaia.dr2epochflux
JOIN gaia.dr2light
USING (source_id)
```

gives you a datalink block:

(cf. Fig. 6)

6. Time Series Annotation I

Sanitised cube/VO-DML annotation – this is exactly as shown in Shanghai:

```
<INSTANCE dmtpe="ivoa:Measurement">
  <ATTRIBUTE dmrole="statError">
    <COLUMN ref="flux_error"/>
  </ATTRIBUTE>
  <ATTRIBUTE dmrole="value">
    <COLUMN ref="flux"/>
  </ATTRIBUTE>
</INSTANCE>

<INSTANCE dmtpe="ndcube:Cube">
  <ATTRIBUTE dmrole="dependent_axes">
    <COLUMN ref="flux"/>
    <COLUMN ref="mag"/>
  </ATTRIBUTE>
  <ATTRIBUTE dmrole="independent_axes">
    <COLUMN ref="obs_time"/>
  </ATTRIBUTE>
</INSTANCE>
```

Over what's in the database, I'm also spitting out magnitudes in the VOTabled time series. Hence, there are two dependent axis. Only flux has errors, though.

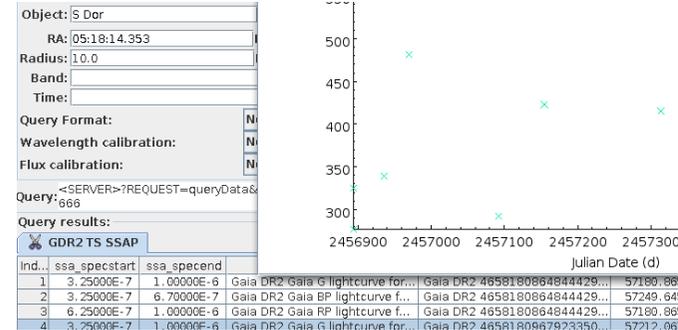


Fig. 7

7. Time Series Annotation II

```
<INSTANCE dmtpe="stc2:Coords">
  <ATTRIBUTE dmrole="time">
    <INSTANCE dmtpe="stc2:TimeCoordinate">
      <ATTRIBUTE dmrole="frame">
        <INSTANCE dmtpe="stc2:TimeFrame">
          <ATTRIBUTE dmrole="kind">
            <LITERAL dmtpe="ivoa:string">JD</LITERAL>
          </ATTRIBUTE>
          <ATTRIBUTE dmrole="refPosition">
            <LITERAL dmtpe="ivoa:string">BARYCENTER</LITERAL>
          </ATTRIBUTE>
          <ATTRIBUTE dmrole="timescale">
            <LITERAL dmtpe="ivoa:string">TCB</LITERAL>
          </ATTRIBUTE>
        </INSTANCE>
      </ATTRIBUTE>
    </INSTANCE>
  </ATTRIBUTE>
  <ATTRIBUTE dmrole="location">
    <COLUMN ref="obs_time"/>
  </ATTRIBUTE>
</INSTANCE>
</ATTRIBUTE>...
```

I'm not proposing LITERAL; I think we should have PARAMs for these and references to them. I am seriously proposing to only use attribute names in VO-DML serialisation.

The full time series deliver full, standard, JD.

For the full example, see, for instance:

<http://dc.g-vo.org/gaia/q2/tsdl/dlget?ID=6779821003058453120&BANDPASS=RP>

8. SSAP, Obscure

(cf. Fig. 7)

The time series can also be found, split-band, in an SSAP service and our obscure service. The figure shows that Splat can figure out that it's dealing with time series.

Note that SSAP already has a TIME parameter that works nicely for what we have here. I've added custom time_min and time_max columns, though.

9. Homework

In principle it all works nicely. Except we're going a bit beyond where standardisation currently stands. To make all this covered by standards, we'd need:

- VOTable annotation syntax
- STC DM, Values/Error, independent/dependent axes
- Officially make 1D access protocol from SSAP?
- Advanced Array manipulation in ADQL?