Data modeling in the Virtual Observatory Framework

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IVOA Working Groups / Interactions

Data Model

- Theory IG
- VOEvent IG
- Registry
- Grid/Webservices
- VOTable
- Applications
  - Visualise, compare, compute
- DataAccess Layer (Protocols)
  - Exchange, circulate
  - VOQL
  - Query Language for astronomical databases
- Semantics
  - Unified Content Descriptor, Vocabulary, Units

Localise resources and services

WS FrameWork
Grid Computing facilities

Transport: XML
Metadata modeling goals in the VO context

Describe metadata for all datasets exchanged in the astronomical community in an **homogeneous** way.

**Sustains the interoperability** objective of the Virtual Observatory

Based on the requirements:

- **For users**:
  
  To be able to ask the same question/query to various astronomical data bases, select the results and then retrieve data.
  
  Search seamlessly for observational data at all wavelengths and for all instruments.

- **For data providers**:
  
  Expose and distribute more data with a **standardized metadata description**.

  In core in the DB structure or as an interoperability layer on existing architecture (DB view).
What is metadata in our context?

- Organize
- Describe at the appropriate level of details
- Each use-case sets its own quality requirements and criteria
- Describe all properties on each physical axis of the data: spatial, temporal, spectral, polarization, etc.

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Modeling Strategy

Following the principle of Object Oriented Design:

• Describe the **responsibilities** and **properties** of the metadata involved for data produced by an observation or a simulation process.

• A dialog between data providers and users who came up with:
  – **Root concepts** qualifying astronomical data
  – A **vocabulary** (list of terms) based on existing practices (FITS, bibliographic services, archives contents, interviews from astronomers and data providers ..)
  – **logical structure** showing the dependencies and relations between all pieces of metadata

→ A general schema for metadata representation built from commonalities and specificities used at various data providers archives
## General building blocks models

<table>
<thead>
<tr>
<th>Metadata features</th>
<th>Data model name&amp;version</th>
<th>Year</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Astronomical Space Time Coordinates</td>
<td>STC v 1.33</td>
<td>2007</td>
<td>REC</td>
</tr>
<tr>
<td></td>
<td>STC v 2.0</td>
<td>2016</td>
<td>WD</td>
</tr>
<tr>
<td>Physical axis description and properties</td>
<td>Characterization v1.13</td>
<td>2008</td>
<td>REC</td>
</tr>
</tbody>
</table>

REC : IVOA Recommendation  
PR: Proposed Recommendation  
WD: Working Draft  
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## Observational Metadata

<table>
<thead>
<tr>
<th>Metadata features</th>
<th>Data model name &amp; version</th>
<th>Year</th>
<th>Status</th>
<th>Protocol</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spectral Line Transitions</td>
<td>Simple Spectral Line</td>
<td>2010</td>
<td>REC</td>
<td>SLAP</td>
<td>VOSpec, SPLAT-VO</td>
</tr>
<tr>
<td>1D Spectrum, Light Curves</td>
<td>Spectrum v1.0</td>
<td>2007</td>
<td>REC</td>
<td>SSA 1.0</td>
<td>SPLAT-VO, IRIS</td>
</tr>
<tr>
<td>1D Spectrum, Light Curves</td>
<td>Spectrum v1.1</td>
<td>2011</td>
<td>REC</td>
<td>SSA 1.1</td>
<td>SPLAT-VO</td>
</tr>
<tr>
<td>SED, Photometric Points, Time series, Multi-segment 1D spectrum</td>
<td>Spectral v2.0</td>
<td>2014</td>
<td>PR</td>
<td>SSA 1.1</td>
<td>SPLAT</td>
</tr>
<tr>
<td>Observational dataset Core Components</td>
<td>ObsCore v1.0</td>
<td>2011</td>
<td>REC</td>
<td>TAP 1.0, SIAv2</td>
<td>TAPHandle, TOPCAT</td>
</tr>
<tr>
<td>(All data products for global discovery)</td>
<td>ObsCore v1.1</td>
<td>2016</td>
<td>PR</td>
<td>TAP 1.0</td>
<td>TAPHandle, TOPCAT</td>
</tr>
<tr>
<td>Photometric calibration</td>
<td>Photometry v1.0</td>
<td>2013</td>
<td>REC</td>
<td>SPLAT-VO, CDS Sed browser, SVO Filter Profile Service</td>
<td></td>
</tr>
<tr>
<td>All observation datasets (Fine grain description)</td>
<td>DataSet Metadata v1.0</td>
<td>2015</td>
<td>WD</td>
<td></td>
<td>SPLAT-VO/time</td>
</tr>
<tr>
<td>N-D cubes; pixelated images, sparse data</td>
<td>NDCube v1.0</td>
<td>2015</td>
<td>WD</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Other Metadata

<table>
<thead>
<tr>
<th>Metadata features</th>
<th>Data model name &amp; version</th>
<th>Year</th>
<th>Status</th>
<th>Protocol</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>VOEvent: transients observations</td>
<td>VOEvent v2.0</td>
<td></td>
<td>REC</td>
<td>VTP 1.0</td>
<td>Service embedded desc.</td>
</tr>
<tr>
<td>Simple time series</td>
<td>Simple time series v1.0</td>
<td>2014</td>
<td>Note</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Simulation Data

<table>
<thead>
<tr>
<th>Simulations, data and code description</th>
<th>Simulation v1.0</th>
<th>2012</th>
<th>REC</th>
<th>SimDAL</th>
<th>DEUVO, Meudon PDR code, MilleniumDB, etc.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Micro simulations, Implementations of SimDM</td>
<td>Implementations of the Simulation DM v1.0</td>
<td>2012</td>
<td>Note</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Provenance metadata

| Datasets generation process, Progenitors               | Provenance DM v1.0        | 2016 | WD     | TBD      |                                            |
The DM fields arrangement contains the dependencies between different pieces of metadata.

Can be expressed as:
- UML class diagram
- Mind maps
- Tables
- Lists

Suitable the most for interpretation by humans (graphs) or by machine (tables, lists, XML documents)
<table>
<thead>
<tr>
<th>nameattr</th>
<th>unit</th>
<th>ucd</th>
<th>utype</th>
<th>dataType</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>obs_publisher_did</td>
<td></td>
<td>meta.ref.url;meta.curation</td>
<td>obscore:Curation.PublisherDID</td>
<td>VARCHAR</td>
<td>publisher dataset identifier</td>
</tr>
<tr>
<td>obs_collection</td>
<td></td>
<td>meta.id</td>
<td>obscore:DataID.Collection</td>
<td>VARCHAR</td>
<td>short name for the data collection</td>
</tr>
<tr>
<td>facility_name</td>
<td></td>
<td>meta.id;instr.tel</td>
<td>obscore:Provenance.ObsConfig.Facility.name</td>
<td>VARCHAR</td>
<td>telescope name</td>
</tr>
<tr>
<td>instrument_name</td>
<td></td>
<td>meta.id;instr</td>
<td>obscore:Provenance.ObsConfig.Instrument.name</td>
<td>VARCHAR</td>
<td>instrument name</td>
</tr>
<tr>
<td>obs_id</td>
<td></td>
<td>meta.id</td>
<td>obscore:DataID.observationID</td>
<td>VARCHAR</td>
<td>internal dataset identifier</td>
</tr>
<tr>
<td>dataproduct_type</td>
<td></td>
<td>meta.id</td>
<td>obscore:ObsDataset.dataProductType</td>
<td>VARCHAR</td>
<td>type of product</td>
</tr>
<tr>
<td>calib_level</td>
<td></td>
<td>meta.code;obs.calib</td>
<td>obscore:ObsDataset.calibLevel</td>
<td>INTEGER</td>
<td>calibration level (0,1,2,3)</td>
</tr>
<tr>
<td>obs_release_date</td>
<td></td>
<td>time.release</td>
<td>obscore:Curation.releaseDate</td>
<td>TIMESTAMP</td>
<td>timestamp of date the data becomes publicly available</td>
</tr>
<tr>
<td>target_name</td>
<td></td>
<td>meta.id;src</td>
<td>obscore:Target.Name</td>
<td>VARCHAR</td>
<td>name of intended target</td>
</tr>
<tr>
<td>s_region</td>
<td>deg</td>
<td>phys.outline;obs.field</td>
<td>obscore:Char.SpatialAxis.Coverage.Support.Area</td>
<td>REGION</td>
<td>region bounded by observation</td>
</tr>
<tr>
<td>s_resolution</td>
<td>arcsec</td>
<td>pos.angResolution</td>
<td>obscore:Char.SpatialAxis.Resolution.refval.value</td>
<td>DOUBLE</td>
<td>typical spatial resolution</td>
</tr>
<tr>
<td>s_xel1</td>
<td></td>
<td>meta.number</td>
<td>obscore:Char.SpatialAxis.numBins1</td>
<td>BIGINT</td>
<td>dimensions (number of pixels) along one spatial axis</td>
</tr>
<tr>
<td>s_xel2</td>
<td></td>
<td>meta.number</td>
<td>obscore:Char.SpatialAxis.numBins2</td>
<td>BIGINT</td>
<td>dimensions (number of pixels) along the other spatial axis</td>
</tr>
</tbody>
</table>
• Derived from UML modeling
• Expressed following the VO-DML meta-model
• Describes all data model classes, attributes and relations in a dedicated XML document
• On going specification in proposed recommendation phase
Interaction aspect /server side

Data Model
- IVOA standard document
- Schema
  - XML schema
  - VO-DML desc.
- Mapping rules

Validation
DM element <-> DB column

DB schema/views

DM items <-> table column

Client Application
- VO Query

Data provider Server
- VO Response
  - VOTable document
  - XML, JSON

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Interaction aspect /client side

Data Model
- IVOA standard document
- Schema
  - XML schema
  - VO-DML desc.
- Mapping rules

Object Design
- Meaning
  - types, units, rules, Etc.
- Documentation
- Annotation

Client Application
- VO Query

Data provider Server
- VO Response

VOTable document
- XML, JSON

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Data models in action

Models

- Dataset Metadata (abstract DM)
  - Dataset
  - Data ID
  - Target
  - Curation
  - Characterisation

- Spectral DM
- ObsCore DM
- ND-Cube DM

- uses concepts from Spectral DM
- extends ObsCore DM
- extends ND-Cube

Datamodels

- SED
- Spectrum
- TimeSeries
- ObsDataset
- ND-Cube

Dataproduct Class

- defines Dataproduct
- projection
- transported by Protocol

Datamodels

- SED
- Spectrum
- TimeSeries
- ObsDataset
- ND-Cube

Dataproducts

- SSA
- TAP
- ObsTAP
- SIA v2

Protocols
Lessons learnt (development strategy)

- Incremental development
- Gathering use-case has proven to be effective
- Discussions with data providers can be cumbersome but are essential
- Testing in real context with applications, protocols and data model update sets up a positive development feedback
- It was challenging to adjust the granularity level:
  - Details specific to particular data archives are not covered, but the common interoperable description layer works
Lessons learnt (technical aspects)

- Easy to prototype, but long and painful to get everything consistent and persistent in a large reference picture.
- Important to find the appropriate scope for data modeling:
  - Common features → mandatory data model fields
  - Specific features → optional features
  - We target interoperability and not exhaustivity
- Data model compliance checks improved when we can validate serialisations (owing to the Operations WG)
Conclusion

• VO data models offer a rich set of data models describing most of observation and simulation data products
• A good learning curve for VO developers thanks to the motivation of the actors
• Data models build up the underlying semantic and structural layer that binds together the VO framework
• Join us at IVOA meetings or contact us on dm@ivoa.net
Thanks for your attention
Thanks to all people involved
A collaborative effort thanks to

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