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Abstract

This document describes a simple proposal to add, in a VOTable, structured metadata, reusing elements from a Data Model, in order to provide the necessary information to characterize photometric data measurements.

Status of This Document

This is an IVOA Note. The first release of this document was 2010-12-02. The purpose of this note is to share ideas expressed in the first Euro-VO ICE technical meeting in Edinburgh in October 2010.

This is an IVOA Note expressing suggestions from and opinions of the authors. It is intended to share best practices, possible approaches, or other perspectives on interoperability with the Virtual Observatory. It should not be referenced or otherwise interpreted as a standard specification.

A list of [current IVOA Recommendations and other technical documents](http://www.ivoa.net/Documents/) can be found at <http://www.ivoa.net/Documents/>.

Acknowledgements

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1 Introduction

We started this work with the following reflections :

- A Spectral Energy Distribution (SED)¹ can be seen as a series of individual **Photometric Data Measurements** (PDM).
- The individual PDM can come in many different forms, but correspond to:

1 Note that the same reasoning can be applied to photometric time series.

- a specific radiative intensity (or spectral radiance), flux, counts or magnitude...
- measured for a given range of the electromagnetic spectrum (monochromatic or in a given waveband), described as wavelength/frequency/energy/wavenumber...
- with associated parameters : measurement errors, upper/lower limits...
- in a given context : filter transmission curve, instrument sensitivity, photometric aperture, ...
- Astronomers have a strong need to combine these heterogeneous PDM into a comprehensible form, often in the form of a two-dimensional plot, representing the flux versus spectral dimension.

Flux or magnitude measurements can be found in many places, like astronomical catalogues. However, the contextual metadata (information about the corresponding measuring frequency, filter characteristics, photometric aperture, etc) is often missing, or if present, is not stored in a standardized way, so that tools can not use it efficiently. And it is up to the astronomer to provide these missing metadata in order to use the PDM in the SED.

This Note presents a method to attach PDM description in VOTables, using elements from Data Models.

2 Architecture

We consider the general case of a service returning data in the form of a VOTable document [1]. In many cases, VOTables contain photometric data, but the proper metadata to characterize it is missing (observing frequency, photometric system identification, filter description, zero point for magnitudes, ...). We propose in section 3 a scheme to embed these metadata (hereafter referred to as “photometric metadata”) in the VOTable.

The **data provider**, or creator of the VOTable, is responsible for providing accurate photometric metadata for the VOTable.

A service returning VOTables containing photometric metadata following this scheme will claim a new **Capability** in the Registry. The precise naming should be defined with the IVOA Registry WG.

SED building tools will be able to add PDM to SED by parsing these photometric metadata, combining them with the actual table data.

3 Modifications to existing VOTables

This proposal aims at requiring minimum changes to existing VOTables. The goal is that photometric description can be added to existing services (e.g. ConeSearch) without breaking the existing service output. So tools able to interpret a VOTable coming from a ConeSearch service will still be able to parse the document.

We assume that the VOTable can contain a table with multiple (n) data rows, each containing several (m) PDM (e.g. magnitudes in different filters). Most often, the rows will correspond to different astronomical sources. With such a document, SED building tools will be able to interpret $n \times m$ PDM.

3.1 Requirement for table Fields

The only required change to an existing VOTable is that FIELD elements that will be used in the PDM have an **ID attribute**, so they can be referenced to.

The FIELD elements can have a native utype attribute. It does not need be erased, and the FIELDrefs referencing them can have a different utype attribute corresponding to the photometric data model used.

3.2 Adding Groups

The photometric metadata are stored in a GROUP element, following closely the examples given in section 4.9 of the VOTable Recommendation [1].

Each GROUP element will describe the n PDM corresponding to one kind of photometric measurement for n rows of the table.

We use in our examples utypes from the Photometry Data Model v0.2 [2], with a namespace **photdm:**, and utypes from the IVOA Spectral Data Model [3] with a namespace **spec:**, knowing that the photometry data model is still being discussed.

Should the utypes change in the photometry data model endorsed by the IVOA, the following proposal can be easily adapted.

Each GROUP of photometric metadata is identified with :

- `ucd="phot"`
- `utype="spec:PhotometryPoint"`

```
<GROUP name="Flux1" ucd="phot" utype="spec:PhotometryPoint"> </GROUP>
```

The GROUP will contain

- a DESCRIPTION element (optional)
- one or several FIELDref, corresponding to the IDs defined in section 3.1
- one or several PARAM or PARAMref

The only mandatory thing is that a SED building tool should be able to find the minimum information to characterize a PDM (i.e. a location along the Spectral

axis and a location along the “Flux” axis). The FIELDref and PARAM will be characterized by utypes from the Photometry Data Model or Spectral Data Model. The GROUP contents can be seen as a basic serialization of the data model, whose elements' values are either referenced in the table (via FIELDrefs) or explicitly declared (via PARAMs). The PARAMs serve as additional metadata with constant value for a column or group of columns.

In practice, if the table contains flux values, the only mandatory utypes in the GROUP will be `spec:Data.FluxAxis.Value` and `phfdm:PhotometryFilter.SpectralAxis.Coverage.Location.Value` . If the table contains magnitude values, the only mandatory utypes in the GROUP will be `spec:Data.FluxAxis.Value` and `phfdm:PhotometryFilter.SpectralAxis.Coverage.Location.Value` and `photdm:PhotCal.ZeroPoint.Flux.value`.

4 Examples

Here we present how this scheme can apply to existing catalogues with various contents.

Note that the following VOTable snippets come from ConeSearch queries, and therefore the FIELD descriptions use UCD1, not UCD1+. The FIELDref of the photometric metadata group can however contain UCD1+.

4.1 NVSS catalogue

The NVSS catalogue contains a column with fluxes measured at 1.4GHz, and another column with measurement errors. We add identifiers to these columns :

```
<FIELD ID="phot_f1" name="S1.4" ucd="PHOT_FLUX_RADIO_1.4G" datatype="double"
width="8" precision="1" unit="mJy"></FIELD>
<FIELD ID="phot_e1" name="e_S1.4" ucd="ERROR" datatype="float" width="7" precision="1"
unit="mJy"></FIELD>
```

And the GROUP will contain a PARAM indicating the observing frequency :

```
<GROUP name="Flux" ucd="phot" utype="spec:PhotometryPoint">
  <DESCRIPTION>For NVSS, the frequency is the same for all table rows and stored in a
param attached to the photometry group.</DESCRIPTION>
  <PARAM name="Freq" ucd="em.freq" unit="GHz" datatype="float" value="1.4"
utype="photdm:PhotometryFilter.SpectralAxis.Coverage.Location.Value" />
  <FIELDref ref="phot_f1" ucd="phot.flux.density;em.radio.750-1500MHz"
utype="spec:Data.FluxAxis.Value" />
  <FIELDref ref="phot_e1" ucd="stat.error;phot.flux.density;em.radio.750-1500MHz"
utype="spec:Data.FluxAxis.Accuracy.StatError" />
</GROUP>
```

4.2 Dixon catalogue

This radio catalogue contains a column with the observing frequency and another one with the corresponding measured radio flux.

We add identifiers to the FIELDS :

```
<FIELD ID="phot_n1" name="Freq" ucd="OBS_FREQUENCY" datatype="int" width="5"
unit="MHz"></FIELD>
<FIELD ID="phot_f1" name="S" ucd="PHOT_FLUX_RADIO_MISC" datatype="double"
width="10" precision="4" unit="Jy"></FIELD>
```

And the GROUP contains two FIELDrefs :

```
<GROUP name="Flux" ucd="phot" utype="spec:PhotometryPoint">
<DESCRIPTION>For Dixon, the frequency is given in one column, and the corresponding flux
in another column.</DESCRIPTION>
<FIELDref ref="phot_n1" ucd="em.freq"
utype="phfdm:PhotometryFilter.SpectralAxis.Coverage.Location.Value" />
<FIELDref ref="phot_f1" ucd="phot.flux.density;em.radio" utype="spec:Data.FluxAxis.Value"/>
</GROUP>
```

4.3 IRAS catalogue

Each row of the IRAS catalogue contains four infrared flux values, measured at different wavelengths, so there will be four GROUPs similar to :

```
<GROUP name="Flux1" ucd="phot" utype="spec:PhotometryPoint">
<DESCRIPTION>Description of the 12um flux</DESCRIPTION>
<PARAM name="ID" ucd="meta.id;instr.filter" utype="photdm:PhotometryFilter.identifier"
unit="" datatype="char" arraysize="*" value="IRAS/IRAS.12" />
<PARAM name="WavelengthMean" ucd="em.wl.effective"
utype="photdm:PhotometryFilter.SpectralAxis.Coverage.Location.Value" unit="Angstrom"
datatype="float" value="115979.853456" />
<PARAM name="WavelengthMin" ucd="em.wl;stat.min"
utype="photdm:PhotometryFilter.SpectralAxis.Coverage.Bounds.Start" unit="Angstrom"
datatype="float" value="75000" />
<PARAM name="WavelengthMax" ucd="em.wl;stat.max"
utype="photdm:PhotometryFilter.SpectralAxis.Coverage.Bounds.Stop" unit="Angstrom"
datatype="float" value="150000" />
<PARAM name="Facility" ucd="instr.obsty" utype="" unit="" datatype="char" arraysize="*"
value="IRAS" />
<PARAM name="WidthEff" ucd="instr.bandwidth"
utype="photdm:PhotometryFilter.SpectralAxis.Coverage.Bounds.Extent" unit="Angstrom"
datatype="float" value="60670.4190222" />
<PARAM name="ZeroPoint" ucd="phot.mag;arith.zp"
utype="photdm:PhotCal.ZeroPoint.Flux.value" unit="Jy" datatype="float" value="40.3423357083"
/>
<PARAM name="Description" ucd="meta.note" utype="photdm:PhotometryFilter.description"
unit="" datatype="char" arraysize="*" value="IRAS 12" />
<PARAM name="TransmissionCurve" ucd="DATA_LINK"
utype="photdm:PhotometryFilter.transmissionCurve" datatype="char" arraysize="*"
value="http://svo.laeff.inta.es/theory/fr/fps.php?ID=IRAS/IRAS.12" />
<FIELDref ref="phot_f1" ucd="phot.flux.density;em.IR.8-15um"
utype="spec:Data.FluxAxis.Value" />
<FIELDref ref="phot_q1" ucd="meta.code.qual;phot.flux.density;em.IR.8-15um"
utype="spec:Spectrum.Data.FluxAxis.Quality" />
</GROUP>
```

Note that for a rough description, only the second PARAM is required.

4.4 2MASS catalogue

The 2MASS catalogue contains three magnitudes, so we need three groups with at least a central wavelength value, a zero point and a FIELDref to the proper column.

```
<GROUP name="Flux1" ucd="phot" utype="spec:PhotometryPoint">
  <DESCRIPTION>2MASS J magnitude.</DESCRIPTION>
  <PARAM name="ID" ucd="meta.id;instr.filter" utype="photdm:PhotometryFilter.identifier"
unit="" datatype="char" arraysize="" value="2MASS/2MASS.J" />
  <PARAM name="WavelengthMean" ucd="em.wl.effective"
utype="photdm:PhotometryFilter.SpectralAxis.Coverage.Location.Value" unit="Angstrom"
datatype="float" value="12410.5176673" />
  <PARAM name="WavelengthMin" ucd="em.wl;stat.min"
utype="photdm:PhotometryFilter.SpectralAxis.Coverage.Bounds.Start" unit="Angstrom"
datatype="float" value="10660" />
  <PARAM name="WavelengthMax" ucd="em.wl;stat.max"
utype="photdm:PhotometryFilter.SpectralAxis.Coverage.Bounds.Stop" unit="Angstrom"
datatype="float" value="14420" />
  <PARAM name="PhotSystem" ucd="" utype="photdm:PhotometricSystem.description" unit=""
datatype="char" arraysize="" value="2MASS" />
  <PARAM name="WidthEff" ucd="instr.bandwidth"
utype="photdm:PhotometryFilter.SpectralAxis.Coverage.Bounds.Extent" unit="Angstrom"
datatype="float" value="1624.31986357" />
  <PARAM name="ZeroPoint" ucd="phot.mag;arith.zp"
utype="photdm:PhotCal.ZeroPoint.Flux.value" unit="Jy" datatype="float" value="1614.45260952"
/>
  <PARAM name="Description" ucd="meta.note" utype="photdm:PhotometryFilter.description"
unit="" datatype="char" arraysize="" value="2MASS J" />
  <PARAM name="TransmissionCurve" ucd="DATA_LINK"
utype="photdm:PhotometryFilter.transmissionCurve" datatype="char" arraysize=""
value="http://svo.laeff.inta.es/theory/fr/fps.php?ID=2MASS/2MASS.J" />
  <FIELDref ref="phot_m1" ucd="phot.mag;em.IR.J" utype="spec:Data.FluxAxis.Value" />
  <FIELDref ref="phot_e1" ucd="stat.error;phot.mag;em.IR.J"
utype="spec:Data.FluxAxis.Accuracy.StatError" />
</GROUP>
```

5 Conclusion

We suggest a method to attach photometric metadata to describe photometric data measurements from catalogues in VOTables. The metadata are described using a simple serialization of the photometry DM in GROUP elements in the header of the VOTable. The data provider is in charge of filling the metadata. SED building tools will be able to consume these metadata to interpret catalogue data to add points to SEDs. Services supporting this scheme will have a new capability in the Registry.

Changes from previous versions

- v0.1 to v0.2 : The utypes have been updated to reflect changes in WD-PhotDM-0.3-20110511 and SpectrumDMv1.2-20110319. References updated.

6 References

[1] Francois Ochsenbein, Roy Williams, *VOTable Format Definition*
<http://ivoa.net/Documents/VOTable/>

[2] J. Salgado et al., *Photometry Data Model* Version 0.3
<http://www.ivoa.net/internal/IVOA/PhotometryDataModel/WD-PhotDM-0.3-20110511.pdf>

[3] J. MacDowell, D. Tody, *IVOA Spectral Data Model* Version 1.2,
<http://www.ivoa.net/internal/IVOA/IVOADMSpectraWP/WD-SpectrumDMv1.2-20110319.pdf>