

VO-DML and UTYPEs and VOTable

Author: Gerard Lemson

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Abstract

In this document we propose a possible mapping language for VOTable. It uses utype attributes and the structure of the VOTable meta-model elements to indicate how instances of data models are stored in VOTable documents. We show many examples and give a complete listing of allowed mapping patterns. We believe this approach to be a complete and in a certain sense most explicit mapping language.

It is however *not* meant to be *the* normative specification for using utypes in VOTable. But it can be used as a basis for such a specification when also other issues have to be taken into consideration.

In this draft attention should be paid mainly to sections 1-4. Here we give an introduction to the approach, an overview of VO-DML as a meta-model, and a bunch of examples that illustrate the mapping.

Section 5 aims to be a more rigorous listing of all valid annotations, but its attempt at a formal mapping syntax in the titles may be somewhat obscure. Section 6 discusses possible annotations that "we" propose should *not* be supported, though they may seem obvious. Section 7 has a discussion on the alternative utype syntax using path expressions rather than identifiers to reduce hierarchical grouping. Problems with that approach are listed. Section 8 raises some questions that we may still need to address. The appendices have some supplementary material, partially there as placeholder.

1 UTYPES as mapping language

When encountering a data container, i.e. a file or database containing data, one may wish to interpret its contents according to some external, predefined data model. That is, one may want to try to identify and extract instances of the data model from amongst the information. For example in the "global as view" approach to information integration, one identifies elements (e.g. tables) defined in a global schema with views defined on the distributed databases [TBD refs].

If one is told that the data container is structured according to some standard serialization format of the data model, one is done. I.e. if the local database is an exact *implementation* of the global schema, one needs no special annotation mechanism to identify these instances. An example of this is an XML document conforming to an XML schema that is an exact physical *representation* of the data model.

But in an information integration project like the IVOA, which aims to homogenize access to many distributed heterogeneous data sets, databases and documents are in general *not* structured according to a standard representation of some predefined, global data model. The best one may hope for is to obtain an *interpretation* of the data set, defining it as a *custom serialization* of the result of a *transformation* of the global data model¹. For example, even if databases themselves are exact replications of a global data model, results of general queries will be such custom serializations.

To interpret such a custom serialization one generally needs extra information that can provide a *mapping* of the serialization to the original model. If the serialization *format* is known, this mapping may be given in phrases containing elements both from the serialization format and the data model. For example if our serialization contains data stored in 'rows' in one or more 'tables' that each have a unique 'name' and contain 'columns' also with a 'name', you might be able to say things like:

- The rows in this table named SOURCE contain instances of object type 'Source' as defined in data model 'SourceDM'.
- The type's 'name' attribute (having datatype 'string', a primitive type) also acts as the identifier of the Source instances and is stored in the single column with name ID.
- The type's 'classification' attribute is stored in the table column CLASSIFICATION (from the data model we know its datatype is an enumeration with values ..., these are represented here by ...).
- The type's 'position' attribute (being of structured data type 'Coordinate' defined in model 'STC2.0') is stored over the two columns RA and DEC, where RA stores the Coordinate's attribute 'longitude', DEC stores the 'latitude' attribute. Both must be interpreted using an instance of the CoordinateSystem type, This instance is stored in 1) another document elsewhere and a reference to it is this url: <http://ivoa.net/documents/STC-Instances/ICRS>, or 2) in this document and its identifier is
- Instances from the collection of luminosities of the Source instances are stored in the same row as the source itself. Columns MAG_U and ERR_U give the 'magnitude' and 'error' attributes of type LuminosityMeasurement in the "u band", an instance of the Filter type. (stored elsewhere in this document (a reference to this Filter instance is ...). Columns MAG_G and ERR_G ... etc.

In this example the underlined words refer to concepts defined in VO-DML, an example of a meta-model that can be used as a formal language for expressing data models. The use of such a modeling language lies in the fact that it provides formal, simple and implementation neutral definitions of the possible structure, the 'type' and 'role' of the elements from the actual data models that one may encounter in the serializatio(SourceDM and STC2.0). This can be used to constrain or validate the serialization, but more importantly it allows us to formulate mapping rules between the serialization format (itself a kind of meta-model) and the meta-model, independent of the particular data models used; for example rules like:

- An object type MUST be stored in a 'table'.

¹ Or alternatively as a transformation of a (standard) serialization of the data model.

- A 'primitive type' MUST be stored in a 'column'.
- A reference MUST identify an object type instance represented elsewhere, either in another 'table', possibly in the same table, possible in another document.
- An attribute SHOULD be stored in the same table as its containing object type.
- etc

Clearly free-form English sentences as the ones in the example are not what we're after. If we want to be able to identify how a data model is represented in some custom serialization we need a formal, computer readable mapping language.

One part of the mapping language should be anchored in a formally defined serialization language. After all, for some tool to interpret a serialization, it MUST understand its format. A completely freeform serialization is not under consideration here. This document assumes VOTable. Alternatives that have been mentioned in our discussion are FITS and TAP_SCHEMA. VOTable is richer and has components the other two miss. Hence the language we propose here is not necessarily applicable to these two. We discuss possible ways how to deal with that impedance mismatch².

The mapping language must support the interpretation of elements from the serialization language in terms of elements from the data model. If we want to define a generic mapping mechanism, one by which we can describe how a general data model is serialized inside a VOTable, it is necessary to use a general data model *language* as the target for the mapping, such as the one described above. This language can give formal and more explicit meaning to data modeling concepts, possibly independent of specific languages representation languages such as XML schema, Java or the relational model. In this document we will use VO-DML as the target language; section 2 discusses this meta-model, but a full spec of the language should be made.

The final ingredient in the mapping language is a mechanism that ties the components from the two different meta-models together into "sentences". This generally requires some kind of explicit annotation, some meta-data elements that provide an identification of source to target structure. In general the ease with which a link can be made between two meta-models depends largely on how "similar" they are. The more similar, the easier an annotation can be.

In this document we will argue that in VOTable the 'utype' attribute can provide this link in a rather simple manner:

- The value of a utype attribute must correspond to the utype identifier of an element explicitly defined in a VO-DML document, or the concatenation of two such identifiers.
- The VOTable element owning the utype attribute is said to *represent* the identified VO-DML data model element. It identifies one or more instances of the data model element, the identification depends on the kind of element and on the context in which it appears.
- There is a set of rules that constrain *which* VOTable elements can be identified with *which* type of VO-DML element and how the context plays a role here.

We show that this solution is sufficient and that it is in some sense the simplest and most explicit approach for annotating a VOTable. It may *not* be the most natural or suitable approach for other meta-models such as FITS or TAP_SCHEMA. For example the current approach relies heavily using on

² http://en.wikipedia.org/wiki/Object-relational_impedance_mismatch

GROUPs to identify most of the structural mapping. FITS and TAP_SCHEMA do currently not possess such a construct. Massaging the approach so it works also for those cases, as well as producing some level of backwards compatibility *may* be possible though not necessarily the only solution. In any case it might be derived from the more explicit solution presented here. We will discuss this at the end of this document.

In the next section we review the main concepts in VO-DML, whilst we assume that all readers are familiar with VOTable. The following section shows examples of mappings as they may occur in realistic VOTables. We will discuss the different VO-DML elements and show how they might be serialized and how annotation with simple utype and other meta-data elements can help one interpret the VOTable. In the later normative sections we turn this around and explicitly list all legal annotations, their constraints and interpretation.

2 Summary of VO-DML concepts

VO-DML is ... TBC.

Containers:

- Model
- Package

Types:

- PrimitiveType
- Enumeration
- DataType
- ObjectType

Property:

- Attribute
- Reference
- Collection
- Extends

2.1 VO-DML/XML

VO-DML has an XML schema representation that defines the structure of XML documents containing valid data models. The schema is complemented by a Schematron file that defines rules on the documents that are hard if not impossible to define in XML schema; examples are constraints on valid data types for particular roles and are rules constraining links to external models. The schema files are located in [vo-dml.xsd](#) and [vo-dml.sch.xml](#) and example models can be found in <https://volute.googlecode.com/svn/trunk/projects/dm/vo-dml/models>.

2.2 Default utype syntax

The vo-dml.xsd schema defines for each referencable element an identifier named 'utype'. The value of each instance of this must be unique in the data model document and this is the *only* requirement on its value. To guarantee this uniqueness one may use some syntax rules to derive the utype value from the location of its parent in the document. The uniqueness assumes certain constraints on valid

data models such as uniqueness of names of types in a package, or of roles in a type. The syntax we use is the one first proposed in the Simulation Data Model (section 4.1), later taken over by a first draft of the UTYPE document, and reproduced here:

```
utype := [model-utype | package-utype | type-utype | attribute-utype | collection-utype
         | reference-utype | container-utype | identifier-utype | extends-utype]
model-utype := <model-name>
package-utype := model-utype ":" package-hierarchy
package-hierarchy := <package-name> ["/" <package-name>]*
type-utype := package-utype "/" <type-name>
attribute-utype := type-utype "." attribute
attribute := [primitive-attr | struct-attr]
primitive-attr := <attribute-name>
struct-attr := <attribute-name> "." attribute % not explicitly represented in VO-DML/XML doc %
collection-utype := type-utype "<collection-name>"
reference-utype := type-utype "." <reference-name>
container-utype := type-utype "." "CONTAINER"
identifier-utype := type-utype "." "ID"
extends-utype := type-utype "." "EXTENDS"
```

[TBD this started as a copy from the SimDM doc; changes in red; need to check whether it still conforms to our desired practice.]

2.3 'vo-dml:' utypes

It is sometimes useful to be able to use utypes to refer to elements in the *meta-model*. As there is no formal VO-DML representation of VO-DML, only a custom XML schema, we have to make up some utypes to represent concepts that one may want to represent explicitly in VOTable annotation. The following are actually used inside the specification and examples below.

- `vo-dml:Model`
 - Can be assigned to a GROUP element to indicate a certain model is used
 - `vo-dml:Model.url`
 - Can be assigned to an PARAM inside a Model GRUOP element to hold the URL of the VO-DML document defining the model.
 - `vo-dml:Model.prefix`
 - Can be assigned to an PARAM inside a Model GROUP element to hold the prefix used to identify utype-s form this model.
- `vo-dml:ObjectType`
 - Indicates the ObejctType definition.
 - `vo-dml:ObjectType.ID`
 - Indicates the ID attribute (implicitly) defined on ObjectType. Can be assigned to a FIELDref, PARAM or GROUP to indicate it represents an ObjectType's identifier. Can also be used in combination/concatenation with a Reference utype on a GROUP. This indicates that the GROUP represents the Reference, and the ID of the target object is represented by the contents of the GROUP, i.e. FIELDref(s) and/or PARAM(s).

One could imagine others such as `vo-dml:Collection` to indicate that a certain element is a collection rather than a collection element. One also could also consider using implicitly defined `vo-dml:ObjectType.CONTAINER` and `vo-dml:Type.EXTENDS` iso of the generated CONTAINER and EXTENDS utypes. It might facilitate the writing of a model a bit, requiring fewer explicit utype identifiers. And after all containers and extensions are 0..1, so there is no possibility of confusion.

3 Format of @utype: Mapping types and roles

In general a mapping from VOTable to VO-DML uses a @utype attribute of a VOTable element to identify the VO-DML element it represents. The approach here assumes that the @utype takes the value of the utype identifier of the VO-DML element it represents, or at least is built from such identifiers. This value may be built according to the default syntax described in section 2.2, but that is not required. These utypes generally identify type definitions or property definitions. A property is a role played by a type in the definition of another type and is an important piece of metadata to add to one's VOTable.

However, a @utype attribute identifying only a property may not provide sufficient information about the contents of the annotated element. This is due to the fact that our data modeling language supports inheritance and polymorphism. Polymorphism is the common object-oriented design concept that says that the declared type of a property may not be the same as the type of an instance of that property that is actually serialized. In particular, the value of a property may be an instance of a *subtype* of the declared type. So in general it is not enough to know the type of the attribute (for example) to uniquely know which type of instance to expect. And it may also not be possible to infer the instance type uniquely from the contents of the element representing the attribute.

Hence a single @utype attribute with value indicating only the role may not be sufficient to infer all DM information about a VOTable element. Typed languages such as Java support a casting operation, which provides more information to the interpreter about the type it may expect a certain instance to be. We might have to consider adding a similar kind of explicit *casting* to utype attributes, allowing clients to identify both role and type.

A separate motivation for such explicit casting support is simply to improve usability of the annotation. A typical usage scenario is [TBD may be?] a VOTable client tool that is sensitive to certain models only, say STC. Such a tool can be written to understand annotation with STC types. Finding an element mapped to a type definition from STC it might infer or example that it represents a coordinate on the sky and “do something with that information”. Such a tool would not necessarily understand other models where such an STC type is *used* as a role. If the annotation only refers to the attribute's utype, a tool will have to infer that it represents the role played by a known type after parsing the data model document. If instead the actual type can be inferred from the annotation directly usability might be increased.

Two possibilities have been proposed to support this kind of type casting, other might be considered:

1. Concatenate utypes. Identify both role and type using the corresponding utype-s, separated by a separator, for example a '+’.
2. Use the @utype to identify the type, and another attribute, for example the @name to identify the role. This may work for GROUP and PARAM on a GROUP, but not for FIELDref and PARAMref. In those latter cases one might use the @utype of the ...ref element to indicate the role, and the @utype of the referenced FIELD and PARAM respectively to indicate the type.

In the rest of this note we assume option 1, including the use of the '+’.

We could consider using a different separator, say a ';'.

Reason could be that ';' has been used in other interpretations already, basically to give an *alternative* annotation. We prefer the '+’ as it makes explicit that the two utypes

concatenated together are *complementary*; both are needed for a complete interpretation of an annotation aimed at a VO-DML document. It should be straightforward to change the description if another option is chosen.

TBD Note that the choice of how to do casting *does* have some consequences, namely that the utype identifiers used in VO-DML documents must not use this separator, or at least follow a syntax that allows the concatenation of utypes to be discovered.

4 Examples: Mapping VO-DML \Rightarrow VOTable

In this section we list some mappings from VO-DML to VOTable. We use examples extracted from a sample model with sample instances described in the next section. These should be seen as an introduction to the complete and formal specification in section 5 on how one SHOULD use utypes in VOTable to indicate mapping to VO-DML.

4.1 Sample model and instances

For examples we use a highly simplified version of a possible Source data model, illustrated by its UML representation in Figure 1. It has a VO-DML representation which is reproduced in Appendix A.

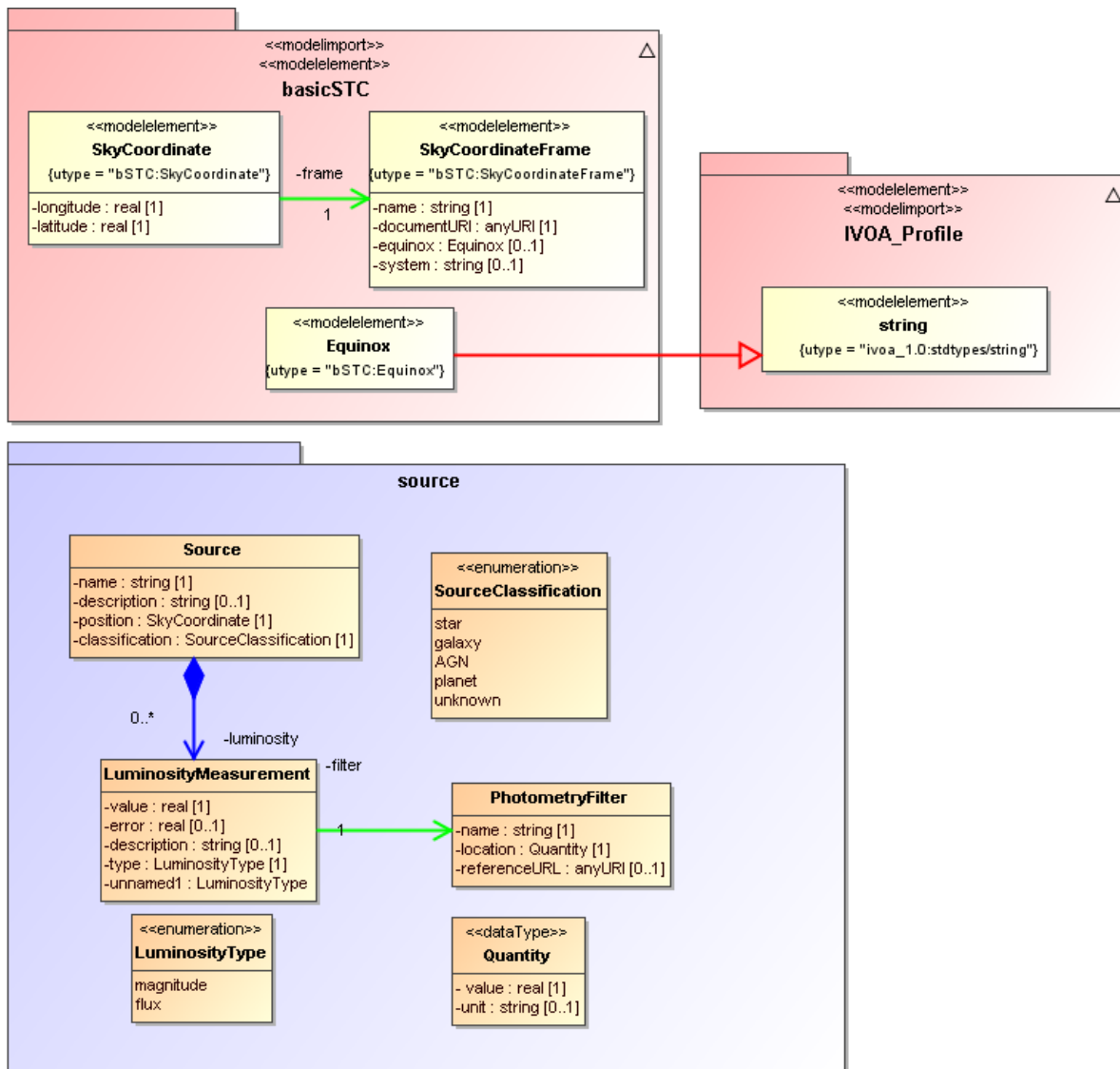


Figure 1 Example data model used in example. It represents a simplified Source data model, containing luminosities following a simplified PhotDM model. It imports a simplistic version of an STC model with some types for defining coordinates on the sky.

The model defines some types allowing one to define a Source with position on the sky and a collection of luminosities. The position is modeled as a DataType, ‘SkyCoordinate’ in a “basicSTC” model that is imported by the Sample model. SkyCoordinate has a reference to a coordinate frame that is required to interpret its longitude and latitude attributes. The luminosities are really *measurements* of luminosities in a given filter that is indicated by a reference to a PhotometryFilter; hence they have a value *and* an error. A Quantity DataType is introduced that provides a real value and a unit. The latter is actually the cause of a possible problem discussed in section 8.

The models are by no means meant to be comprehensive and include some admittedly artificial elements such as an Equinox PrimitiveType, which is supposed to be a simple string and might carry enough semantic value of its own to use it as an annotation on PARAM elements for example.

Note that this sample model defines a Package [TBD ref to VO-DML document needed] that contains all the types. This package shows up in the values of the utype-s we use to identify the different

elements. The values we use for these utype identifiers are generated from the VO-DML using the default utype described in section. I.e. they are path-like expressions that are guaranteed unique and give some impression of the location in the data model.

We also use some sample instances of the models. These are here illustrated by UML instance diagrams. The diagram in Figure 2 represents the first two lines returned from a query to the SDSS DR7 database.

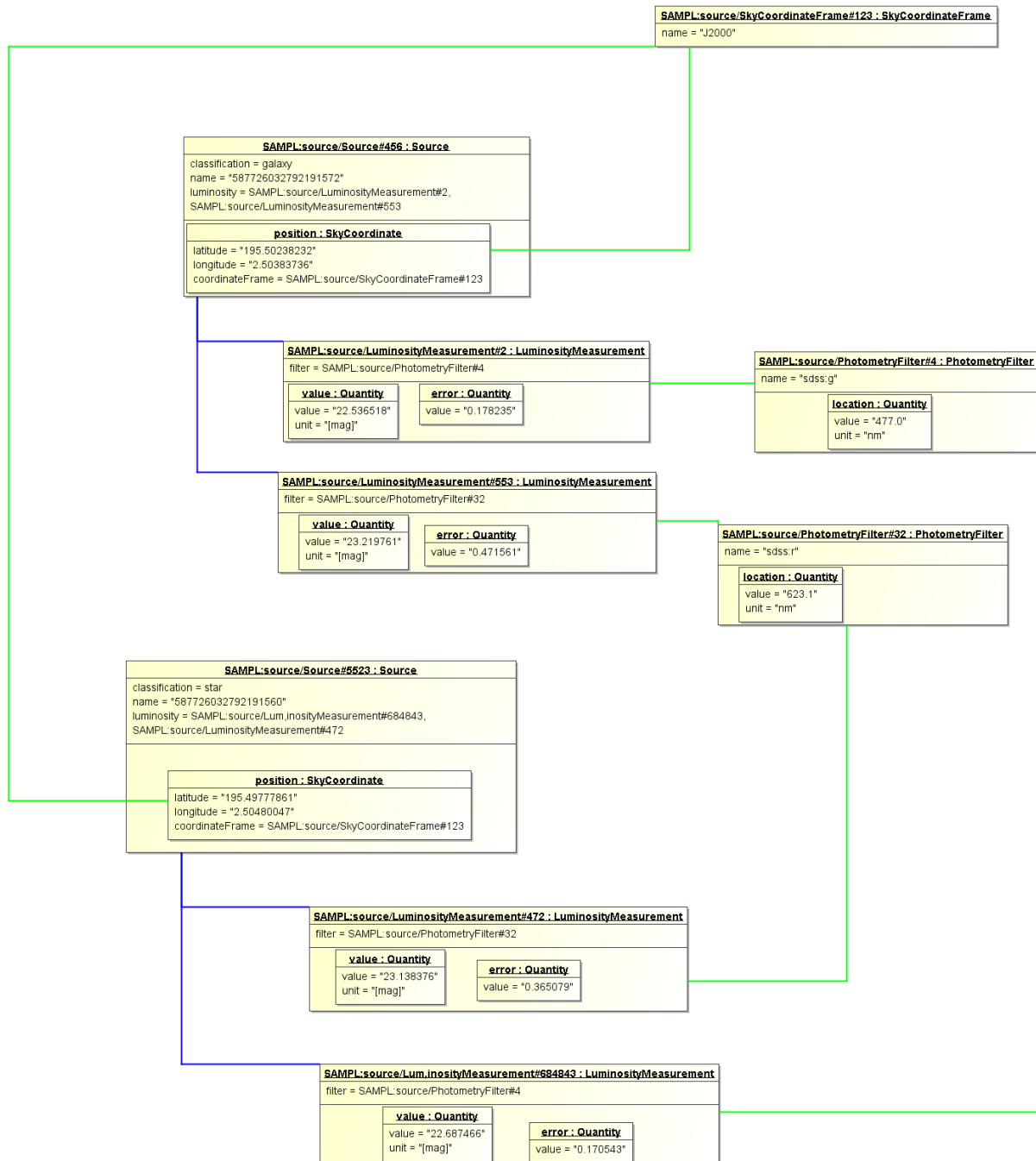


Figure 2 Instance diagram representing SDSS objects as sources in the sample data model. [TBD update to latest form of model]. The first few results are represented from the default radial SDSS query at <http://skyserver.sdss.org/dr7/en/tools/search/radial.asp> corresponding to the SQL query:

```

SELECT top 10 p.objID, p.run, p.rerun, p.camcol, p.field, p.obj,
p.type, p.ra, p.dec, p.u,p.g,p.r,p.i,p.z,
p.Err_u, p.Err_g, p.Err_r,p.Err_i,p.Err_z
  
```

```
FROM fGetNearbyObjEq(195,2.5,3) n, PhotoPrimary p
WHERE n.objID=p.objID
```

The instance diagram in Figure 3 represents one of the sources returned by a cone search query vs. the 2MASS catalogue, represented as instances of the Sample data model.

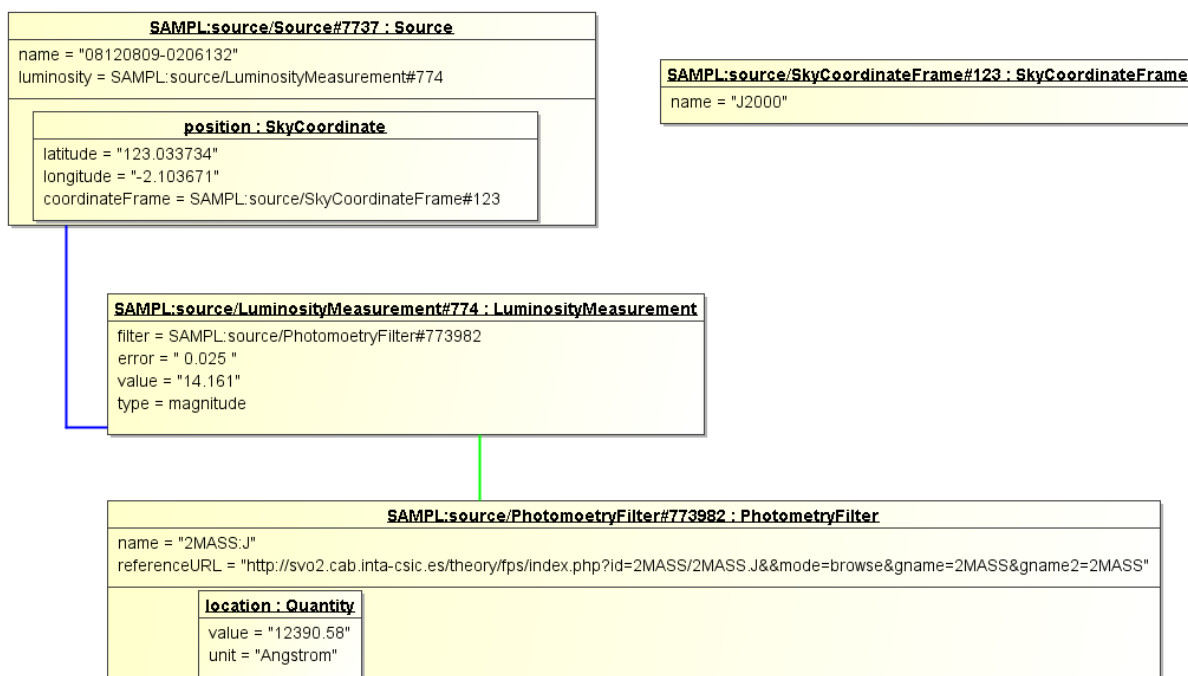


Figure 3 A 2MASS source is partially represented here according to the SAMPLE model in Figure 1. Result is obtained from <http://irsa.ipac.caltech.edu/> using coordinate "123 -2.1" with search radius 3'. **TBD** update to latest form of model

4.2 Data carriers in VOTable

VO-DML describes four different kinds of types: PrimitiveType (PT), Enumeration (E), DataType (DT) and ObjectType (OT). PT, E and DT are value types; OT is an object - or reference type [TBD add few sentences]. PT and E are atomic, their values consist of a single value; DT and OT are structured, they are built from multiple values, organized as attributes, and possibly of reference relations to OTs. An OT can also have collections of other OTs, and can have an identifier, an attribute of undetermined type that is implicitly defined for ObjectType-s.

To store instances (*values* and *objects*) of these types in a VOTable various options are available. Atomic values (i.e. instances of PT and E) are stored in cells in a row in a table (i.e. a TD) or in the value attribute of a PARAM (@value). To store an instance of a structured type one must store its components. To identify the structured instance in a serialization one must be able to identify the individual components and how they are to be combined. This last identification is done by the GROUP element. It is the main representation of structured types, both ObjectType and DataType. It is also used to represent relations to object types. These may be stored using foreign key like mechanisms or through some kind of hierarchy.

In fact in the approach described here virtually *all* mapping of VOTable to VO-DML is performed by GROUP elements and their components. They identify which elements are to be combined to create the object or DataType instance, what the roles are that these components play (attribute, reference) and they do so simply by using the utype of the corresponding type or role as defined in VO-DML for the value of their @utype attribute.

In the next few subsection we provide some examples how this mapping can be performed. It starts with the ObjectType and then discusses its components, Attribute, Reference and Collection. The mapping of the value types is discussed in the mapping of Attributes. The mapping of Reference and Collection relations is the most complex part of the whole mapping story and treated separately.

4.3 Mapping ObjectType

ObjectTypes consist of Attributes, References and Collections. How these are mapped is described in more detail below. But the important part for representing structured instance like an object is that these components must be combined together to construct a complete instance. In VOTable this is done using a GROUP element.

In the representation of ObjectType instances, GROUPs can be used in two different modes that are distinguished by the way the instance's data are ultimately stored. If all values are eventually stored exclusively in @value attributes of PARAM elements in the GROUP (or possibly outside the GROUP but accessed through PARAMrefs), the GROUP represents a complete instance *directly*. If even only one of the attributes is stored in a FIELD and accessed through a FIELDref, the GROUP is said to *indirectly* represents possibly multiple instances, one for each TR.

We will use these terms, “direct GROUP” and “indirect GROUP” as shorthand phrases for these representations all through the document. This freedom of choice *where* to store objects complicates the mapping of *relations* between objects, as many different referencing mechanisms must be taken into account. This is particularly important when discussing how to represent References in section 5.7 below.

We illustrate the two modes of mapping by showing an example how each mode may represent exactly the same object. For this we use the object type in Figure 4 and a corresponding instance in Figure 5.

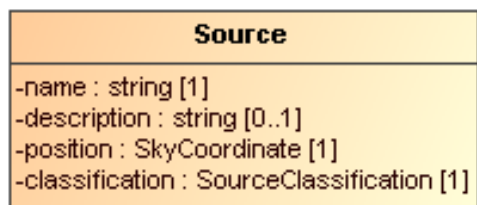


Figure 4 ObjectType representing a Source.

SAMPL:source/Source#7737 : Source	
name = "08120809-0206132"	
luminosity = SAMPL:source/LuminosityMeasurement#774	
classification = galaxy	
position : SkyCoordinate	
latitude = "123.033734"	
longitude = "-2.103671"	
coordinateFrame = SAMPL:source/SkyCoordinateFrame#123	

Figure 5 Instance of Source ObjectType.

Indirect serialization to a TABLE:

Source instance from Figure 5 is stored in the first TR below. The TABLE is annotated using a GROUP with utype attribute identifying the type. Some atomic attributes are stored in FIELDS annotated by FIELDref-s, some in PARAMS; a structured attribute is represented by the child GROUP with its attributes annotated by FIELDref. A reference is also represented by a GROUP (for discussion see section 4.5):

```
<TABLE>
<GROUP utype="SAMPL:source/Source" >
  <FIELDref ref="_designation" utype="vo-dml:ObjectType.ID"/>
  <FIELDref ref="_designation" utype="SAMPL:source/Source.name"/>
  <PARAM name="type" utype="SAMPL:source/Source.classification" value="galaxy"/>
  <GROUP utype="SAMPL:source/Source.position+bSTC:SkyCoordinate">
    <FIELDref ref="_ra" utype="bSTC:SkyCoordinate.longitude"/>
    <FIELDref ref="_dec" utype=" bSTC:SkyCoordinate.latitude"/>
    <GROUP ref="_icrs" utype=" bSTC:SkyCoordinate.frame"/>
  </GROUP>
</GROUP>
<FIELD name="designation" ID=" designation" .../>
<FIELD name="ra" ID="_ra" unit="deg" .../>
<FIELD name="dec" ID="_dec" unit="deg" .../>
<TR><TD>08120809-0206132</TD><TD>123.033734</TD><TD>-2.103671</TD></TR>
...
</TABLE>
```

Note the special representation of the identifier of the Source object. This attribute is not defined explicitly in the model; hence no utype exists for it there. We can interpret each ObjectType as ultimately being a subclass of some ObjectType class (just as in Java all classes ultimately extend java.lang.Object, generally implicitly). In VO-DML we can represent this by allowing an ObjectType to have a component of as yet unspecified type, that represents the ID attribute (implicitly) defined on this base class. We use a special utype for this attribute: vo-dml:ObjectType.ID.

Note furthermore that the same FIELD is referenced for holding both the 'name' attribute of the Source class, and for its identifier.

Direct serialization to a GROUP:

Here the instances is directly represented by a GROUP containing only PARAMS for the atomic attributes, and a GROUP with PARAMS for the structured attribute (and again a reference, see section 4.5).

```
<GROUP utype="SAMPL:source/Source" >
```

```

<PARAM utype="vo-dml:ObjectType.ID" value="08120809-0206132" .../>
<PARAM utype="SAMPL:source/Source.name" value="08120809-0206132" .../>
<PARAM utype="SAMPL:source/Source.classification" value="galaxy" .../>
<GROUP utype="SAMPL:source/Source.position+ bSTC:SkyCoordinate">
  <PARAM utype=" bSTC:SkyCoordinate.longitude" value="123.033734" .../>
  <PARAM utype=" bSTC:SkyCoordinate.latitude" value="-2.103671" .../>
  <GROUP ref="_icrs" utype=" bSTC:SkyCoordinate.frame"/>
</GROUP>
</GROUP>

```

Details on the mapping of the components are discussed next.

4.4 Mapping Attribute

An attribute is the role a value type plays in the definition of a structured type. They may represent atomic or may represent structured (Data)types themselves. These are represented differently.

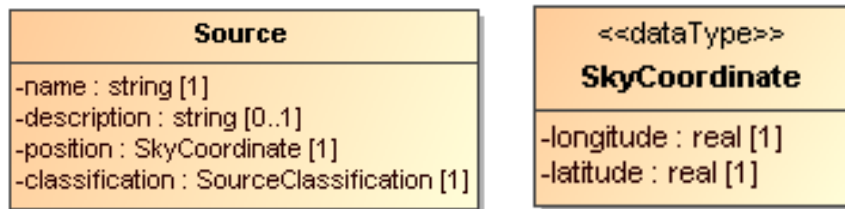


Figure 6 The ObjectType Source and the DataType SkyCoordinate both define attributes. Attributes can represent a PrimitiveType ('name' and 'description' in Source, 'longitude' and 'latitude' in SkyCoordinate), an Enumeration ('classification' in Source), or a structured DataType ('position' in Source).

PrimitiveType attribute as FIELDref, Enumeration as PARAM:

In the indirect representation of the ObjectType below a FIELDref indicates that an attribute is stored in field with ID=" _designation". It does so using the utype of the attribute:

SAMPL:source/Source.name, identifying the name attribute of the Source type. Note that in our example we use a utype syntax derived from the VO-DML model itself. From this string one can here infer directly that some role with name 'name' defined on a type named Source is represented. But that is all one might infer. In principle this could have been a string like SAMPL: _12_1_1dfa04c4_1354024272942_181358_515. In both cases one would need to inspect the formal data model to find out precisely *what* kind of model element this utype represents.

Another attribute, 'classification', is represented by a PARAM through its utype value SAMPL:source/Source.classification and assigns it the value 'galaxy'. The attribute has as datatype an Enumeration, SourceClassification and indeed the PARAM defines a VALUES element with various OPTIONS (note that that is almost useless for a PARAM that represents a single value directly anyway). Its set of Literals indeed contains a value 'galaxy'. In general however, especially for existing "legacy" databases, one cannot expect that enumerated values will exactly correspond to those in a model. Some type of mapping might be required, however OPTION does not support this in VOTable (i.e. has no @utype attribute). The fact that this attribute is stored in a PARAM in the GROUP indicates also that all Source instances stored in the TABLE are classified as galaxies.

```

<TABLE>
<GROUP utype="SAMPL:source/Source" >
  <FIELDref ref="_designation" utype=" vo-dml:ObjectType.ID"/>
  <FIELDref ref="_designation" utype="SAMPL:source/Source.name"/>
  <PARAM name="type" utype="SAMPL:source/Source.classification" value="galaxy">
    <VALUES><OPTION value="galaxy"/><OPTION value="star"/>...</VALUES></PARAM>

```

```

<GROUP utype="SAMPL:source/Source.position+ bSTC:SkyCoordinate">
  <FIELDref ref="_ra" utype=" bSTC:SkyCoordinate.longitude"/>
  <FIELDref ref="_dec" utype=" bSTC:SkyCoordinate.latitude"/>
  <GROUP ref="_icrs" utype=" bSTC:SkyCoordinate.frame"/>
</GROUP>
</GROUP>
<FIELD name="designation" ID="_designation" .../>
<FIELD name="ra" ID="_ra" unit="deg" .../>
<FIELD name="dec" ID="_dec" unit="deg" .../>
<TR><TD>08120809-0206132</TD><TD>123.033734</TD><TD>-2.103671</TD></TR>
...
</TABLE>

```

DataType attribute as GROUP:

As DataType-s are structured, their natural representation in a VOTable is as a GROUP, whether used directly or indirectly. Hence if an attribute is defined in a VO-DML data model as representing a DataType, it is most naturally represented by a GROUP embedded in the GROUP of the structured type owning the attribute. This is the mapping we [TBD that is, I, Gerard] favor and makes the utype annotation very simple.

The example below shows in red a GROUP representing the attribute 'position' (identified by utype SAMPL:source/Source.position) that has as data type an STC SkyCoordinate, which itself consists of a 'longitude' and 'latitude' attribute (we defer discussing the reference to the next section). Note that the attributes of the STC type have a different prefix (bSTC) to indicate they are imported from a different model. And note their structure indicates *only* their relation to their defining type, bSTC:SkyCoordinate (though this, as discussed above, is unimportant for the current approach which, apart from the prefix, assigns no importance to the syntax of the utype identifiers in VO-DML models).

```

<TABLE>
<GROUP utype="SAMPL:source/Source" >
  <FIELDref ref="_designation" utype="vo-dml:ObjectType.ID"/>
  <FIELDref ref="_designation" utype="SAMPL:source/Source.name"/>
  <PARAM name="type" utype="SAMPL:source/Source.classification" value="galaxy">
<VALUES><OPTION value="galaxy"/><OPTION value="star"/>...</VALUES></PARAM>
  <GROUP utype="SAMPL:source/Source.position">
    <FIELDref ref="_ra" utype="bSTC:SkyCoordinate.longitude"/>
    <FIELDref ref="_dec" utype="bSTC:SkyCoordinate.latitude"/>
    <GROUP ref="_icrs" utype="bSTC:SkyCoordinate.frame"/>
  </GROUP>
</GROUP>
<FIELD name="designation" ID="_designation" .../>
<FIELD name="ra" ID=" ra" unit="deg" .../>
<FIELD name="dec" ID=" dec" unit="deg" .../>
<TR><TD>08120809-0206132</TD><TD>123.033734</TD><TD>-2.103671</TD></TR>
...
</TABLE>

```

In this example the utype of the child GROUP *only* indicates its role in the definition of its parent GROUP, namely the attribute SAMPL:source/Source.position. It does not indicate the type, which would be bSTC:SkyCoordinate. In principle the role alone should be sufficient, as its definition in a VO-DML data model will provide its data type.

However there are arguments why one might wish to add information about the type as well. As we will argue in section 3, sometimes it is necessary to supply information about the type, as a kind of *casting* operation. There we propose a particular format for this, which consist of a concatenation of the utype identifiers of both role and type, separated by a '+'. According to that proposal the above example could have been written as follows:


```

<GROUP utype="SAMPL:source/Source" >
...
  <GROUP utype="SAMPL:source/Source.position+bSTC:SkyCoordinate">
...
  </GROUP>
</GROUP>

```

Data Type attribute as collection of fields with path-like utype:

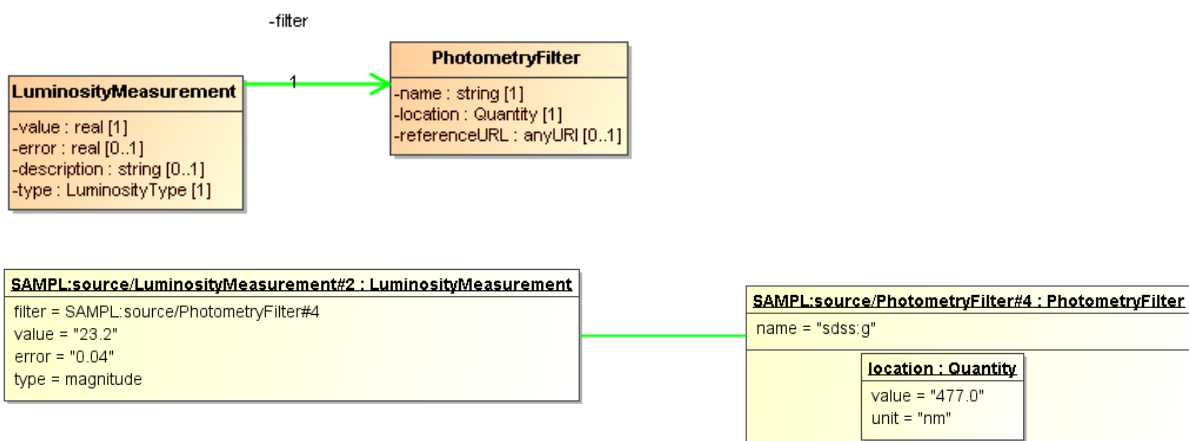
An alternative approach that will be discussed in section 7 tries to avoid the nesting of GROUP elements as much as possible. A structured attribute as 'position' in the example would not be represented with its own GROUP. To ensure one is able to collect the components of the SkyCoordinate type together one might put structure on the utype attribute. One approach is some kind of path expression. In that approach the example could be written as follows:

```

<TABLE>
<GROUP utype="SAMPL:source/Source" >
  <FIELDref ref="_designation" utype="vo-dml:ObjectType.ID"/>
  <FIELDref ref="_designation" utype="SAMPL:source/Source.name"/>
  <PARAM name="type" utype="SAMPL:source/Source.classification" value="galaxy">
  <VALUES><OPTION value="galaxy"/><OPTION value="star"/>...</VALUES></PARAM>
  <FIELDref ref="_ra" utype="SAMPL:source/Source.position.longitude"/>
  <FIELDref ref="_dec" utype="SAMPL:source/Source.position.latitude"/>
  <GROUP ref="_icrs" utype="SAMPL:source/Source.position.frame"/>
</GROUP>
<FIELD name="designation" ID=" designation" .../>
<FIELD name="ra" ID="_ra" unit="deg" .../>
<FIELD name="dec" ID="_dec" unit="deg" .../>
<TR><TD>08120809-0206132</TD><TD>123.033734</TD><TD>-2.103671</TD></TR>
...
</TABLE>

```

4.5 Mapping Reference



Referencing as "GROUPref" to direct GROUP:

The example below uses a GROUP+@ref to represent the reference from a position object stored in a TABLE to a SkyCoordinateFrame stored in a direct GROUP. Hence all rows in the table use the same frame and the reference needs no structure.

```

<GROUP utype="bSTC:SkyCoordinateFrame" ID="_icrs">
  <PARAM utype="bSTC:SkyCoordinateFrame.name" value="ICRS" .../>
  <PARAM utype="bSTC:SkyCoordinateFrame.equinox+bSTC:Equinox" value="J2000.0" .../>
</GROUP>
<TABLE>
<GROUP utype="SAMPL:source/Source" id=" source">
  <FIELDref ref="_designation" utype="vo-dml:ObjectType.ID"/>
  <FIELDref ref="_designation" utype="SAMPL:source/Source.name"/>
  <GROUP utype="SAMPL:source/Source.position+bSTC:SkyCoordinate">
    <FIELDref ref="_ra" utype="bSTC:SkyCoordinate.longitude"/>
    <FIELDref ref="_dec" utype="bSTC:SkyCoordinate.latitude"/>
    <GROUP ref="_icrs" utype="bSTC:SkyCoordinate.frame"/>
  </GROUP>
</GROUP>
<FIELD id="_designation" name="parentId" datatype="char"/>
<FIELD id="_ra" name="ra" datatype="float"/>
<FIELD id="dec" name="dec" datatype="float"/>
...
<DATA><TABLEDATA>
<TR><TD>08120809-0206132</TD><TD>123.034</TD><TD>-2.1037</TD>...</TR>
...
</TABLEDATA></DATA>
</TABLE>

```

ORM-like referencing from TABLE to TABLE:

A table with PhotometryFilter instances is referenced from a table with LuminosityMeasurement instances. The reference is represented by a GROUP that uses its @ref attribute to identify the GROUP representing the target filters. The reference GROUP contains a FIELDref.

Note, the ID of the PhotometryFilter is constructed from 2 columns, one identifying a catalogue, one a band. Hence the referencing object must use also two values. As there is no explicit linking possible in VOTable we introduce the rule that to reference an IDs one must replicate its structure. See 5.6 for more details.

```

<TABLE>
<GROUP utype="SAMPL:source/PhotometryFilter" id="_filters">
  <GROUP utype="vo-dml:ObjectType.ID"
    <FIELDref ref="_cat"/>
    <FIELDref ref="_bands"/>
  </GROUP>
  <FIELDref ref="_name" utype="SAMPL:source/PhotometryFilter.name"/>
</GROUP>
<FIELD name="catalogue" id=" cat" .../>
<FIELD name="band" id=" band" .../>
<FIELD name="name" id=" name" .../>
..
<DATA><TABLEDATA>
<TR><TD>SDSS</TD><TD>g</TD><TD>SDSS g-band</TD></TR>
<TR><TD>SDSS</TD><TD>u</TD><TD>SDSS u-band</TD></TR>
<TR><TD>2MASS</TD><TD>J</TD><TD>2MASS J-band</TD></TR>
</TABLEDATA></DATA>
</TABLE>
<TABLE>
<GROUP utype="SAMPL:source/LuminosityMeasurement" id="SDSS_mags">
  <GROUP utype="SAMPL:source/LuminosityMeasurement.CONTAINER+vo-dml:ObjectType.ID">
    <FIELDref ref="_container" />
  </GROUP>
  <FIELDref ref="_mag" utype="SAMPL:source/LuminosityMeasurement.value"/>
  <PARAM name="type" utype="SAMPL:source/LuminosityMeasurement.type" value="magnitude"/>
  <FIELDref ref="_mag" utype="SAMPL:source/LuminosityMeasurement.error"/>
  <GROUP ref="_filters"
    utype="SAMPL:source/LuminosityMeasurement.filter+vo-dml:ObjectType.ID">
    <FIELDref ref="_fcats"/>
    <FIELDref ref="_fbands"/>
  </GROUP>
</GROUP>
<FIELD id="_container" name="parentId" datatype="char"/>
<FIELD id="_mag" name="mag" datatype="float"/>

```

```

<FIELD id=" eMag" name="eMag" datatype="float"/>
<FIELD id="_ fcat" name="catalogue" datatype="char"/>
<FIELD id="_ fband" name="band" datatype="char"/>
<DATA><TABLEDATA>
<TR><TD>08120809-0206132</TD><TD>23.2</TD><TD>.04</TD><TD><TD>SDSS</TD><TD>g</TD></TR>
<TR><TD>08120809-0206132</TD><TD>25.2</TD><TD>.1</TD><TD><TD>2MASS</TD><TD>J</TD></TR>
...
</TABLEDATA></DATA>
</TABLE>

```

Referrer and target in same TR:

Following example shows a LuminosityMeasurement stored in a TR together with information about its PhotometryFilter. This might be the result of a query like:

```

SELECT M.value,M.error,F.id,F.name
FROM LUMINOISOTY_MEASUREMENT M
, PHOTOMETRY_FILTER F
WHERE F.ID=M.FILTER_ID

```

It joins the filter to the measurement and stores some of its fields.

```

<TABLE>
<GROUP utype="SAMPL:source/PhotometryFilter" id="_ filters">
  <GROUP utype="vo-dml:ObjectType.ID"
    <FIELDref ref="_ cat"/>
    <FIELDref ref="_ bans"/>
  </GROUP>
  <FIELDref ref=" name" utype="SAMPL:source/PhotometryFilter.name"/>
</GROUP>
<FIELD name="catalogue" id="_ cat" .../>
<FIELD name="band" id="_ band" .../>
<FIELD name="name" id=" name" .../>
..
<DATA><TABLEDATA>
<TR><TD><TD>SDSS</TD><TD>g</TD><TD>SDSS g-band</TD></TR>
<TR><TD><TD>SDSS</TD><TD>u</TD><TD>SDSS u-band</TD></TR>
<TR><TD><TD>2MASS</TD><TD>J</TD><TD>2MASS J-band</TD></TR>
</TABLEDATA></DATA>
</TABLE>
<TABLE>
<GROUP utype="SAMPL:source/LuminosityMeasurement" id="SDSS_mags">
  <GROUP utype="SAMPL:source/LuminosityMeasurement.CONTAINER+vo-dml:ObjectType.ID">
    <FIELDref ref="_ container" />
  </GROUP>
  <FIELDref ref="_ mag" utype="SAMPL:source/LuminosityMeasurement.value"/>
  <PARAM name="type" utype="SAMPL:source/LuminosityMeasurement.type" value="magnitude"/>
  <FIELDref ref="_ mag" utype="SAMPL:source/LuminosityMeasurement.error"/>
  <GROUP ref="_ filter" utype="SAMPL:source/LuminosityMeasurement.filter"/>
</GROUP>
<GROUP utype="SAMPL:source/PhotometryFilter" id=" filter">
  <FIELDref ref="_ filter.id" utype="vo-dml:ObjectType.ID"/>
  <FIELDref ref="_ filter.name" utype="SAMPL:source/PhotometryFilter.name"/>
</GROUP>
<FIELD id="_ container" name="parentId" datatype="char"/>
<FIELD id="_ mag" name="mag" datatype="float"/>
<FIELD id="_ eMag" name="eMag" datatype="float"/>
<FIELD id="_ filter.id" name="filter_id" datatype="char"/>
<FIELD id="_ filter.name" name="filter_name" datatype="char"/>
<DATA><TABLEDATA>
<TR><TD>08120809-0206132</TD><TD>23.2</TD><TD>.04</TD><TD>SDSS:g</TD><TD>SDSS g-band</TD></TR>
...
</TABLEDATA></DATA>

```

Note that both LuminosityMeasurement and PhotometryFilter are explicitly (and indirectly) represented by GROUPs that identify their type. The reference between the two is represented by a "GROUPref" construct without contents, i.e. *no* vo-dml:ObjectType.ID is used.

Referencing unspecified GROUP from within TABLE through ObjectType.ID:

It may be that objects of the same type are represented by different GROUPs in the same VOTable. It may then also be that from within a TABLE one may wish to reference one of these, but different rows may have references to different instances. The following example shows this.

```
<GROUP utype="SAMPL:source/PhotometryFilter">
  <PARAM utype="vo-dml:ObjectType.ID" value="sdss:g" .../>
  <PARAM type="SAMPL:source/PhotometryFilter.name" value="SDSS g band" .../>
</GROUP>
<GROUP utype="SAMPL:source/PhotometryFilter">
  <PARAM utype="vo-dml:ObjectType.ID" value="sdss:u" .../>
  <PARAM type="SAMPL:source/PhotometryFilter.name" value="SDSS u band" .../>
</GROUP>
..
<TABLE>
<GROUP utype="SAMPL:source/LuminosityMeasurement" id="SDSS_mags">
  <GROUP utype="SAMPL:source/LuminosityMeasurement.CONTAINER+vo-dml:ObjectType.ID">
    <FIELDref ref="_container" utype="vo-dml:ObjectType.ID"/>
  </GROUP>
  <FIELDref ref="_mag" utype="SAMPL:source/LuminosityMeasurement.value"/>
  <PARAM name="type" utype="SAMPL:source/LuminosityMeasurement.type" value="magnitude"/>
  <FIELDref ref="_mag" utype="SAMPL:source/LuminosityMeasurement.error"/>
  <FIELDref ref="_filter"
    utype="SAMPL:source/LuminosityMeasurement.filter+vo-dml:ObjectType.ID"/>
</GROUP>
<FIELD id="_container" name="parentId" datatype="char"/>
<FIELD id="_mag" name="mag" datatype="float"/>
<FIELD id="_eMag" name="eMag" datatype="float"/>
<FIELD id="_filter" name="filter" datatype="char"/>
<DATA><TABLEDATA>
<TR><TD>08120809-0206132</TD><TD>23.2</TD><TD>.04</TD><TD>sdss:g</TD></TR>
<TR><TD>08120809-0206132</TD><TD>22.5</TD><TD>.05</TD><TD>sdss:u</TD></TR>
...
</TABLEDATA></DATA>
</TABLE>
```

The mapping in this example is indirect in that the GROUP representing the target is not explicitly identified by the reference, which is here represented by a FIELDref representing the vo-dml:ObjectType.ID of the target instance. Different rows reference different GROUPs, hence a "GROUPref" construct is not applicable here. To find the target the client will have to search the document for a GROUP representing the right type and with an ID with a single field of the right value. If the value of a TD could be a @ref, we could use XMLs ID/IDREF mechanism which in some tools facilitates the lookup. But see section [TBD] for ideas how to best analyze a VOTable with data model structure, in particular how to deal with referencing. [TBD] do we want such a section? It might borrow from some more VO-URP implementation ideas.]

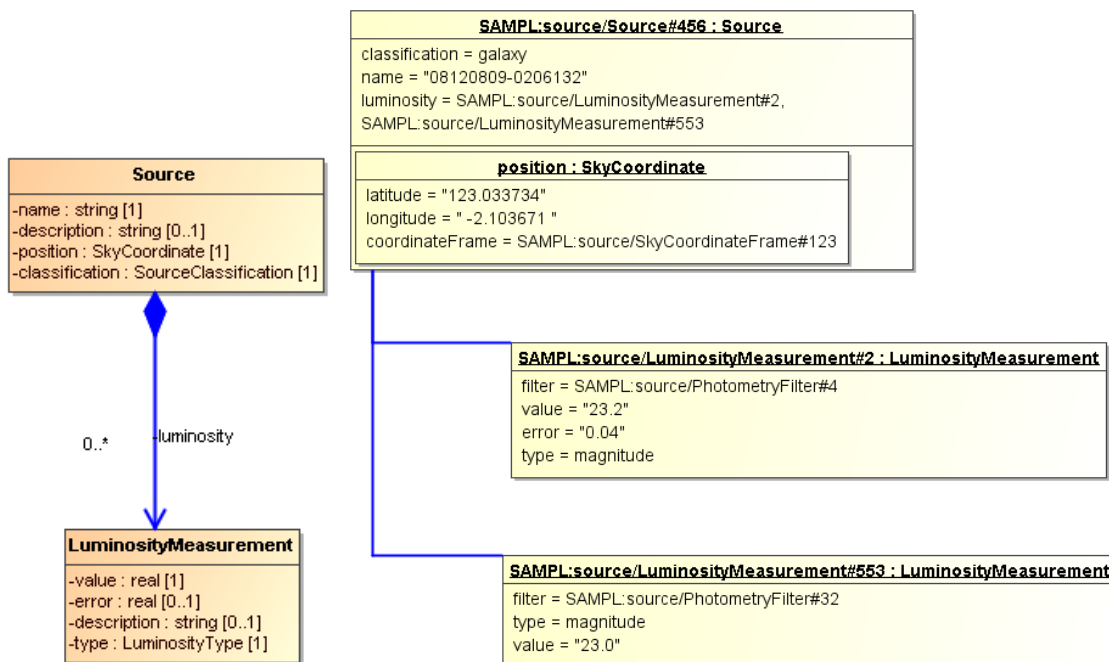
4.6 Mapping Collection

A collection is a composition relation between a parent ObjectType and a child, or *part*, ObjectType. The fact that objects can be stored in different ways implies many different ways in which the relation may need to be expressed. In XML serializations of a data model (such as used in VO-URP and the Simulation Data Model) one may choose to have the contained objects serialized *inside* the serialization of the parent. It is possible to do so in VOTable as well using child GROUP-s representing a complete child object embedded in the GROUP representing the parent object. This is natural for this relationship because a collection element is really to be considered as a *part* of the parent object.

This may be used to represent flattening of the parent-child relation. One or more child objects may be stored together with the parent object in the same row in a TABLE. Such a case is actually very

common, for example when interpreting tables in typical source catalogues. These generally contain information of a source together with one or more magnitudes. The latter can be seen as elements form a collection of photometry points contained by the sources.

Hence a GROUP inside another GROUP MAY represent a collection. It can do so in different modes that are illustrated by the following examples and described in more detail in section 5.8.



Container and contained objects in separate TABLE linked by "GROUPrefs":

The basic Object-Relational mapping has containers stored in one table, the objects in the collection in another. The child objects need a foreign key/pointer to the container object. In the example below we have the collection represented on the container using a "GROUPref" to the collection. The utype identifies *only* the collection, the @ref identifies the GROUP where the collection element(s) can be found. In this case that GROUP annotates a TABLE and has as @utype the type of the collection. It also contains a GROUP representing a pointer to the container object. Its utype is a concatenation of the CONTAINER utype and of the predefined vo-dml:ObjectType.ID to indicate it represents the ID of the container object.

```

...
<TABLE>
<GROUP utype="SAMPL:source/Source" id="_source">
  <FIELDref ref="_designation" utype="vo-dml:ObjectType.ID"/>
  <FIELDref ref="_designation" utype="SAMPL:source/Source.name"/>
  <PARAM name="type" utype="SAMPL:source/Source.classification" value="galaxy"/>
  <GROUP utype="SAMPL:source/Source.position+bSTC:SkyCoordinate">
    <FIELDref ref="_ra" utype="bSTC:SkyCoordinate.longitude"/>
    <FIELDref ref="_dec" utype="bSTC:SkyCoordinate.latitude"/>
    <GROUP ref="_icrs" utype="bSTC:SkyCoordinate.frame"/>
  </GROUP>
  <GROUP utype="SAMPL:source/Source.luminosity" ref="SDSS_mags"/>
</GROUP>
<FIELD name="designation" ID="_designation" .../>
<FIELD name="ra" ID="_ra" unit="deg" .../>

```

```

<FIELD name="dec" ID=" dec" unit="deg" .../>
<TR><TD>08120809-0206132</TD><TD>123.033734</TD><TD>-2.103671</TD></TR>
...
</TABLE>
...
<TABLE>
<GROUP utype="SAMPL:source/LuminosityMeasurement" id="SDSS_mags">
  <GROUP utype="SAMPL:source/LuminosityMeasurement.CONTAINER+vo-dml:ObjectType.ID">
    <FIELDref ref="_container"/>
  </GROUP>
  <FIELDref ref="_mag" utype="SAMPL:source/LuminosityMeasurement.value"/>
  <PARAM name="type" utype="SAMPL:source/LuminosityMeasurement.type" value="magnitude"/>
  <FIELDref ref="_eMag" utype="SAMPL:source/LuminosityMeasurement.error"/>
  <FIELDref ref="_filter" utype="SAMPL:source/LuminosityMeasurement.filter+vo-dml:ObjectType.ID"/>
</GROUP>
<FIELD id=" container" name="parentId" datatype="char"/>
<FIELD id="_mag" name="mag" datatype="float"/>
<FIELD id="_eMag" name="eMag" datatype="float"/>
<FIELD id="_filter" name="filter" datatype="char"/>
<DATA><TABLEDATA>
<TR><TD>08120809-0206132</TD><TD>23.2</TD><TD>.04</TD><TD>sdss:g</TD></TR>
<TR><TD>08120809-0206132</TD><TD>23.0</TD><TD>.03</TD><TD>sdss:r</TD></TR>
</TABLEDATA></DATA>
</TABLE>

```

Container and contained objects in same row in same TABLE:

A very typical case is the following example, which shows a Source object serialized in the same row as its luminosities. The Sample data model models luminosity measurements as a collection, which is flexible and allows measurements from different source to be combined in a natural manner. But for a given catalogue such as SDSS or 2MASS, it is known *a priori* how many magnitudes will be supplied and which bands they will correspond to. Hence for a given catalogue the natural representation is to simply add these as attributes to their model. Interestingly enough, the approach proposed here is able to support this mapping without any problem, even making a natural link to the actual photometry filter used for the measurements. And note that to indicate the fact the instances of the contained types are indirectly represented by these GROUPs, the utype attributes MUST be concatenations of the role (the collection) and the type.

```

<TABLE>
<GROUP utype="SAMPL:source/Source" id="_source">
  <FIELDref ref="designation" utype="vo-dml:ObjectType.ID"/>
  <FIELDref ref="_designation" utype="SAMPL:source/Source.name"/>
  <PARAM name="type" utype="SAMPL:source/Source.classification" value="galaxy"/>
  <GROUP utype="SAMPL:source/Source.position+bSTC:SkyCoordinate">
    <FIELDref ref="_ra" utype="bSTC:SkyCoordinate.longitude"/>
    <FIELDref ref="_dec" utype="bSTC:SkyCoordinate.latitude"/>
    <GROUP ref="icrs" utype="bSTC:SkyCoordinate.frame"/>
  </GROUP>
  <GROUP utype="SAMPL:source/Source.luminosity+SAMPL:source/LuminosityMeasurement">
    <FIELDref ref="_gmag" utype="SAMPL:source/LuminosityMeasurement.value"/>
    <PARAM utype="SAMPL:source/LuminosityMeasurement.type" value="magnitude" .../>
    <FIELDref ref="egMag" utype="SAMPL:source/LuminosityMeasurement.error"/>
    <GROUP ref="_gfilter" utype="SAMPL:source/LuminosityMeasurement.filter"/>
  </GROUP>
  <GROUP utype="SAMPL:source/Source.luminosity+SAMPL:source/LuminosityMeasurement">
    <FIELDref ref="_rmag" utype="SAMPL:source/LuminosityMeasurement.value"/>
    <PARAM utype="SAMPL:source/LuminosityMeasurement.type" value="magnitude" .../>
    <FIELDref ref="erMag" utype="SAMPL:source/LuminosityMeasurement.error"/>
    <GROUP ref="_rfilter" utype="SAMPL:source/LuminosityMeasurement.filter"/>
  </GROUP>
</GROUP>
</TABLE>
<FIELD name="designation" ID="_designation" .../>
<FIELD name="ra" ID=" ra" unit="deg" .../>
<FIELD name="dec" ID=" dec" unit="deg" .../>
<FIELD id="_gmag" name="gmag" datatype="float"/>

```

```

<FIELD id=" egMag" name="egMag" datatype="float"/>
<FIELD id="_ rmag" name="rmag" datatype="float"/>
<FIELD id="_ erMag" name="erMag" datatype="float"/>
<TR>
<TD>08120809-0206132</TD><TD>123.033734</TD><TD>-2.103671</TD><TD>23.2</TD><TD>.04</TD>
<TD>23.0</TD><TD>.03</TD>
</TR>
...
</TABLE>

```

Container and collection all as direct instances in GROUPs:

When not using tables at all in a mapping, the individual elements form a collection can be directly represented inside the parent GROUP. To indicate this explicitly the utype attributes MUST be concatenations of the role (the collection) and the type.

```

<GROUP utype="SAMPL:source/Source" id="_ source">
  <PARAM utype="SAMPL:source/Source.name" value="08120809-0206132" .../>
  <PARAM utype="SAMPL:source/Source.classifiication" value="galaxy" .../>
  <GROUP utype="SAMPL:source/Source.position+bSTC:SkyCoordinate">
    <PARAM utype="bSTC:SkyCoordinate.longitude" value="123.033734" .../>
    <PARAM utype="bSTC:SkyCoordinate.latitude" value="-2.103671" .../>
    <GROUP ref="_ icrs" utype="bSTC:SkyCoordinate.frame"/>
  </GROUP>
  <GROUP utype="SAMPL:source/Source.luminosity+SAMPL:source/LuminosityMeasurement">
    <PARAM utype="SAMPL:source/LuminosityMeasurement.value" value="23.2" .../>
    <PARAM utype="SAMPL:source/LuminosityMeasurement.type" value="magnitude" .../>
    <PARAM utype="SAMPL:source/LuminosityMeasurement.error" value="0.04" .../>
    <GROUP ref="_ gfilter" utype="SAMPL:source/LuminosityMeasurement.filter"/>
  </GROUP>
</GROUP>
<GROUP utype="SAMPL:source/Source.luminosity+SAMPL:source/LuminosityMeasurement">
  <PARAM utype="SAMPL:source/LuminosityMeasurement.value" value="23.0" .../>
  <PARAM utype="SAMPL:source/LuminosityMeasurement.type" value="magnitude" .../>
  <PARAM utype="SAMPL:source/LuminosityMeasurement.error" value="0.03" .../>
  <GROUP ref="_ rfilter" utype="SAMPL:source/LuminosityMeasurement.filter"/>
</GROUP>
</GROUP>
</GROUP>

```

4.7 Mapping value types

The examples above started from the assumption that the basis of a serialization was an ObjectType. Value types only show up as attributes. There may be some use cases however where one wishes to indicate *only* that a certain column or set of column represent some known value type. One reason may be that a standard, global data model does not exist that defines ObjectType-s matching the one in one's serialization, but that one can identify some sub-components that could be mapped to a DataType for example.

In fact the Sample used here is an example. It is a model for Source-s. The IVOA does currently not have an accepted model for this concept, though attempts in this direction have been made³. This implies many tables of interest in the VO can currently not formally declare they store instances of a Source. However they could declare they have columns that together correspond to a coordinate on the sky in the STC model. This could lead to a VOTable fragment as the following, which is a version of an example in 4.4, but with altered utypes, and removal of the GROUP representing the Source.

```

<TABLE>
<GROUP utype="bSTC:SkyCoordinate ">

```

³ See <http://wiki.ivoa.net/twiki/bin/view/IVOA/IVAODMCatalogsWP>.

```

<FIELDref ref=" ra" utype="bSTC:SkyCoordinate.longitude"/>
<FIELDref ref="_dec" utype="bSTC:SkyCoordinate.latitude"/>
<GROUP ref="_icrs" utype="bSTC:SkyCoordinate.frame"/>
</GROUP>
<FIELD name="designation" ID=" designation" .../>
<FIELD name="ra" ID=" ra" unit="deg" .../>
<FIELD name="dec" ID=" _dec" unit="deg" .../>
<TR><TD>08120809-0206132</TD><TD>123.033734</TD><TD>-2.103671</TD></TR>
...
</TABLE>

```

Tools that understand STC may be able to do something with this annotation, even though they cannot know what role the coordinate plays.

Another example arises from a possible access protocol specification. Say Simple Cone Search (SCS) would declare that the result of a request MUST be a VOTable with a GROUP representing the actual request consisting of a position and a search radius. It could insist the position must be serialized using a GROUP representing an STC coordinate following our data modeling serialization prescription. E.g. as in the following example:

```

<GROUP utype="bSTC:SkyCoordinateFrame" ID=" icrs">
  <PARAM utype="bSTC:SkyCoordinateFrame.name" value="ICRS" .../>
  <PARAM utype="bSTC:SkyCoordinateFrame.equinox+bSTC:Equinox" value="J2000.0" .../>
</GROUP>
...
<GROUP name="SCS">
  <INFO value="The SCS request "/>
  <PARAM name="SR" datatype="float" utype="ivoa_1.0:stdtypes/real"/>
  <GROUP name="center" utype="bSTC:SkyCoordinate">
    <INFO value="The center coordinate of the simple cone search"/>
    <PARAM name="ra" utype="bSTC:SkyCoordinate.longitude" value="123.00000" datatype="float"/>
    <PARAM name="dec" utype="bSTC:SkyCoordinate.latitude" value="-2.10000" datatype="float"/>
    <GROUP ref=" icrs" utype="bSTC:SkyCoordinate.frame"/>
  </GROUP>
</GROUP>
...

```

Note, this example even assigns a utype for the search radius SR, identifying it as the PrimitiveType “ivoa_1.0:stdtypes/real”. This shows that also PrimitiveType-s and Enumerations could be used directly, i.e. outside of a role they play. The use of this is probably limited, but we may allow it (see section 5.2 for details and constraints).

One could argue that alternatively a standard protocol like SCS might define a little standard data model to represent its full request and use it in the serialization of result. In that case also the parent group, currently named “SCS”, could have been declared to represent say an “scs:Request”, as follows:

```

<GROUP utype="bSTC:SkyCoordinateFrame" ID=" icrs">
  <PARAM utype="bSTC:SkyCoordinateFrame.name" value="ICRS" .../>
  <PARAM utype="bSTC:SkyCoordinateFrame.equinox+bSTC:Equinox" value="J2000.0" .../>
</GROUP>
...
<GROUP name="SCS" utype="scs:Request">
  <INFO value="The SCS request"/>
  <PARAM name="SR" datatype="float" utype="scs:Request.SR "/>
  <GROUP name="center" utype="scs:Request.center+bSTC:SkyCoordinate">
    <INFO value="The center coordinate of the simple cone search"/>
    <PARAM name="ra" utype="bSTC:SkyCoordinate.longitude" value="123.00000" datatype="float"/>
    <PARAM name="dec" utype="bSTC:SkyCoordinate.latitude" value="-2.10000" datatype="float"/>
    <GROUP ref="_icrs" utype="bSTC:SkyCoordinate.frame"/>
  </GROUP>
</GROUP>
...

```

[TBD I assume we do not have to spell out the SCS data model?]

5 Annotating VOTable: specification

In this section we list all legal mappings where a VOTable element uses its @utype to identify one or two VO-DML elements; we describe how such an annotation should be interpreted and what restrictions there are on the association. In its subsections it explicitly lists possible annotations of a VOTable with a utype value that one may encounter following this spec.

The organization of the following sections is based on the different VO-DML concepts that can be represented. Each of these subsections contains sub-subsections which represent the different possible ways the concept may be encountered in a VOTable and discuss rules and constraints on those annotations. We start with Model, and then we discuss value types (PrimitiveType, Enumeration and DataType) and Attributes. Then ObjectType and the relationships, Collection, Reference and Inheritance (extends). We leave out Package as we have not yet found a convincing use case why one might want to point at one from a VOTable (though we did not really look for a reason either).

The title of each subsection describing a legal mapping is structured according to a 'grammar'. It starts with a VOTable element on the left, the utype assignment and possible other constraints in square brackets []. A possible context is indicated by an \in with to its right a container formatted like the element of the left. Finally, an ' \rightarrow ' indicates a relation to another element; this will generally be defined in the same VOTable, but might be serialized elsewhere.

For example the section with title "GROUP[@utype \Rightarrow ObjectType]" discusses the rules on linking a GROUP to an ObjectType; similarly "GROUP[@utype \Rightarrow ObjectType] \in RESOURCE" discusses the same case restricted to GROUPs defined directly on a RESOURCE, i.e. *not* on a TABLE or another GROUP. Where relevant, subsections will be used for different cases or contexts within which to interpret the annotation. Appendix A contains an attempt at formalizing this grammar so one may argue about valid instances of it in a more explicit manner. This is TBD and likely too scary. Instead each section should spell state the meaning of the title explicitly.

Some comments on how we refer to VOTable and VO-DML elements

- When referring to VOTable elements we will use the notation by which these elements will occur in VOTable documents, i.e. in general "all caps", E.g. GROUP, FIELD, (though FIELDref).
- When referring to rows in a TABLE element in a VOTable, we will use TR, when referring to individual cells, TD. Even though such elements only appear in the TABLEDATA serialization of a TABLE. When referring to a column in the TABLE we will use FIELD, also if we do not intend the actual FIELD element annotating the column.
- When referring to an XML attribute on a VOTable element we will prefix it with an '@', e.g. @utype, @ref.
- References to VO-DML elements will be capitalized, using their VO-DML/XSD type definitions. E.g. ObjectType, Attribute.
- Some mapping solutions require a reference to a GROUP elsewhere in the VOTable. We refer to such a construct as a "GROUPref. In the examples we use a concrete implementation of this concept which (currently) does not exist in VOTable (and is likely not desired). The solution assumed in this document is to use a GROUP with a @ref attribute which we will assume *always* identifies another GROUP in the same document. This target GROUP must

have an @id attribute. In cases where this is important we will indicate that this combination is to be interpreted as a “GROUPref”, including the quotes.

The following list defines some shorthand phrases (underlined) which we use in the descriptions below:

- Generally when using the phrase type we mean a "kind of" type as defined in VO-DML. These are PrimitiveType, Enumeration, DataType and ObjectType.
- With atomic type we will mean a PrimitiveType or an Enumeration as defined in VO-DML.
- A structured type will refer to an ObjectType or DataType as defined in VO-DML.
- With a property available on or defined on a (structured) type we will mean an Attribute or Reference, or (in the case of ObjectTypes) a Collection defined on that type itself, or inherited from one of its base class ancestors.
- A VO-DML type plays a role in the definition of another (structured) type if the former is the declared data type of a property available on the latter.
- When writing that a VOTable element represents a certain VO-DML type, we mean that the VOTable element is mapped either directly to the type, or that it identifies a role played by the type in another type's definition.
- A descendant of a VOTable element is contained in that element, or in a descendant of that element. This is a standard recursive definition and can go up the hierarchy as well: an ancestor of an element is the direct container of that element, or an ancestor of that container.

5.1 Model

There has been quite some discussion how to indicate which models provide the utypes used in a certain VOTable. Options are to make an explicit statement through some INFO element for example, or to leave model usage implicitly defined through a predefined set of model prefixes. We here follow the former, explicit approach. We propose that for each model that is used an INFO element should exist which identifies the location of the VO-DML file representing the model. This element should also define the prefix used by utypes corresponding to that model.

5.1.1 GROUP[@utype ⇒ Model] ∈ VOTABLE

A GROUP element with @utype attribute identifying a Model and placed directly under the root VOTABLE element indicates that the corresponding VO-DML model is used in @utype associations.

Restrictions

- GROUP element must exist directly under VOTABLE and have @utype="vo-dml:Model"
- Must have child PARAM element with @utype="vo-dml:Model.url" and @value the url of the VO-DML document representing the model. @name is irrelevant, @datatype="char" and arraysize="*".
- SHOULD have child PARAM element with @utype="vo-dml:Model.prefix" and @value the prefix used in the current VOTable document for utypes coming from that model. @name is irrelevant, @datatype="char" and arraysize="*".

TBD How do we deal with prefix? Can it be different from utype prefix in VO-DML document? Do utypes in VO-DML document *have* a prefix?

Example

```

<VOTABLE>
<GROUP utype="vo-dml:Model" name="Sample">
  <PARAM utype="vo-dml:Model.url" name="url" datatype="char" arraysize="*"
value="http://volute.googlecode.com/svn/trunk/projects/dm/vo-dml/models/sample/Sample.vo-
dml.xml"/>
  <PARAM utype="vo-dml:Model.prefix" name="prefix" datatype="char" arraysize="*"
value="SAMPL"/>
</GROUP>
<GROUP utype="vo-dml:Model" name="IVOA_Profile">
<PARAM utype="vo-dml:Model.url" name="url" datatype="char" arraysize="*"
value="http://volute.googlecode.com/svn/trunk/projects/dm/vo-
dml/models/profile/IVOA_Profile.vo-dml.xml"/>
<PARAM utype="vo-dml:Model.prefix" value="ivoa_1.0" name="prefix" datatype="char"
arraysize="*" />
</GROUP>
...

```

5.2 Atomic types

Instances of atomic types (PrimitiveType and Enumeration in VO-DML) are *values*. In general these will be used as values for Attributes in instances of structured types (DataType and ObjectType) as will be described below. But there may be valid use cases for indicating simply that certain values occurring in a VOTable's data are instances of the VO-DML type. Such atomic values will be stored in a TD or in the @value attribute of a PARAM. They will be annotated by the @utype attribute of the corresponding FIELD or the PARAM itself respectively.

One might expect that Enumerations are represented by a FIELD or PARAM with a VALUES component. Its Literals might correspond to the OPTION values. *How* that association would be made is **TBD**. After all OPTION elements do not have a @utype attribute. Until that time the OPTION values may have to be identical to the Literals.

TBD We might wish to consider the more complex (if not perverse) possibility where an atomic value is cut up in two or more parts, each of these stored separately. An example could be a 'date', which might be distributed over three columns representing year, month and day. Do we want to support this?

Question: is it useful to declare that a value or set of values in a column represent some primitive type or enumeration? Could we not use UCDs for this?

Possible answer: This would seem to depend on the "expressivity" of the type. In general FIELD-s will be used as attributes of structured types, i.e. through the role the type plays in the definition of a parent ObjectType or DataType. But if no model exists that allows a parent to be defined, this link to a type might still be useful, probably more so for Enumerations.

5.2.1 FIELD[@utype ⇒ PrimitiveType]

A FIELD's @utype may identify a PrimitiveType directly (and without a role!). This indicates that the TDs corresponding to the FIELD hold values whose type may be interpreted as the identified PrimitiveType.

Restrictions

- This FIELD SHOULD NOT be used from within a GROUP with a FIELDref. (For reasons of trying to avoid redundancy.) If this is done anyway the @utype annotation of the FIELDref MUST refer to an Attribute whose data type is the same as the PrimitiveType identified by the FIELD. Otherwise the annotation is invalid.

- The FIELD's @datatype SHOULD (MUST?) define a valid serialization type for the PrimitiveType. (For reasons of translational semantics: It must be possible to create an instance of the PrimitiveType from the value stored in the VOTable).

Example

```

...
<TABLE>
...
<FIELD name="designation" ID="_designation" utype="ivoa_1.0:stdtypes/string">
<DESCRIPTION>source designation formed from sexigesimal coordinates</DESCRIPTION>
</FIELD>
...
</TABLE>
...

```

5.2.2 FIELD[@utype ⇒ Enumeration & VALUES]

A FIELD with a VALUES element may identify an Enumeration directly through its @utype. This indicates that the TDs in the FIELD hold values whose type may be interpreted as the identified Enumeration. The OPTION values should be interpreted in terms of the Literals of the Enumeration.

Restrictions

- A FIELD directly annotated with a type SHOULD NOT be used from within a GROUP with a FIELDref. (For reasons of trying to avoid redundancy).
If this is done anyway the @utype annotation of the FIELDref MUST refer to an Attribute whose data type is the same as the Enumeration identified by the FIELD. Otherwise the annotation is invalid.
- The FIELD's data type SHOULD (MUST?) be an exact serialization type for the Enumeration (For reasons of translational semantics: It must be possible to create an instance of the Enumeration from the value stored in the VOTable).
- The FIELD definition SHOULD (MUST?) have a VALUES element with OPTIONS corresponding to the Literals in the Enumeration's definition.
How that correspondence is made is TBD. A possible solution might be to have a link (through @utype) from the different OPTION values to the corresponding Literal. But OPTION does not have a @utype attribute. So currently the only way to make the identification is if the OPTION values are exact copies of the Literals.

Example

```

...
<TABLE>
...
<FIELD name="type" utype="SAMPL:source/SourceClassification">
<VALUES>
<OPTION value="star"/>
<OPTION value="galaxy"/>
<OPTION value="AGN"/>
<OPTION value="planet"/>
<OPTION value="unknown"/>
</FIELD>
...
</TABLE>
...

```

5.2.3 PARAM[@utype ⇒ PrimitiveType]

A PARAM's @utype may identify a PrimitiveType directly. This indicates that the @value of the PARAM may be interpreted as the identified PrimitiveType. The rules and interpretation are similar to those of a FIELD's mapping to a PrimitiveType (see section 5.2.1).

Restrictions

- A PARAM annotated with a @utype like this FIELD SHOULD NOT be used from within a GROUP with a PARAMref. (For reasons of trying to avoid redundancy.) If this is done anyway the @utype annotation of the PARAMref MUST refer to an Attribute whose data type is the same as the PrimitiveType identified by the PARAM. Otherwise the annotation is invalid.
- The PARAM's data type SHOULD (MUST?) be a valid serialization type for the PrimitiveType. (For reasons of translational semantics: It must be possible to create an instance of the PrimitiveType from the value stored in the VOTable).

Example

```
<GROUP name="SCS">
<PARAM name="SR" utype="ivoa_1.0:stdtypes/real"/>
...
</GROUP>
```

5.2.4 PARAM[@utype ⇒ Enumeration & VALUES]

A PARAM's @utype may identify an Enumeration directly. This indicates that the @value of the PARAM may be interpreted as the identified Enumeration. The rules and interpretation are similar to those of a FIELD's mapping to a Enumeration, see section 5.2.2.

Restrictions

- A PARAM mapped directly to an Enumeration MUST NOT be contained in a GROUP that is mapped to a structured type (see below).
- The PARAM's data type SHOULD (MUST?) be a valid serialization type for the Enumeration. (For reasons of translational semantics: It must be possible to create an instance of the Enumeration from the value stored in the VOTable).
- The PARAM definition SHOULD (MUST?) have a VALUES element with OPTIONS corresponding to the Literals in the Enumeration's definition.
How that correspondence is made should follow the same rules as for a FIELD mapped to an Enumeration in section 5.2.2.

5.3 DataType

A DataType instance (also a *value*) is structured; it consists of values assigned to each of its attributes and possibly references. To represent the complete instance of a DataType the various attributes

(and references) must be grouped together; in VOTable this is done using a GROUP element. GROUPs in fact can play two different roles, depending on where the instance's data is really stored. If all values are eventually stored exclusively in PARAMs in the GROUP, or possibly outside the GROUP but accessed through PARAMrefs, the GROUP *directly* represents a complete instance. If even only one of the attributes is stored in a FIELD and accessed through a FIELDref, the GROUP *indirectly* represents possibly multiple instances, one for each TR. This is also true in any child GROUP contains a FIELDref and so on. We will use these terms, direct and indirect representation all through the document. And note that this same classification holds for ObjectTypes discussed in 5.5, though with a twist related to possible child GROUPs representing Collections.

The attribute values of a DataType are stored according to the prescription for storing instances of their data type. For attributes with declared data type a PrimitiveType or Enumeration section 5.2 provides details. If the attribute's data type is itself a DataType the prescription in the current section should be used recursively. DataType-s can also have Reference-s to ObjectType-s, but a discussion of how to store References is deferred to section 5.7, after the discussion of storing ObjectType instances, which is provided in section 5.5.

Polymorphism

When assigning values to attributes and references an important issue arises due to polymorphism. Though an attribute is assigned a certain data type in the data model, instances of the attribute MAY have a different data type, namely one that is (ultimately) a subclass of the declared type. This is especially important for attributes with a structured DataType. Subclasses of PrimitiveTypes and Enumerations remain atomic, but subclasses of DataTypes may add attributes and references to the ones inherited from the base class. For this reason we advocate that the utype attribute of a component representing an Attribute SHOULD (MUST?) be a concatenation of the utypes of the Attribute *and* the type. See the discussion on the syntax of the utype attribute in section 3.

5.3.1 GROUP[@utype ⇒ DataType]

A GROUP's @utype may identify a DataType directly. Depending on the contents and context, i.e. the location of the GROUP within other VOTable elements, such a mapping indicates the existence of one or more instances of the DataType (i.e. *values* really, as a DataType is a value type). Different cases are discussed in subsets. In all cases the following restrictions hold:

Restrictions

- The components of a GROUP mapped to a DataType MUST be mapped to properties defined on that DataType. The following options are available:
 - FIELDref[@utype ⇒ Attribute [+ (PrimitiveType | Enumeration)]]
∈ GROUP[@utype ⇒ (DataType | ObjectType)] (see 5.4.1)
 - PARAM [@utype ⇒ Attribute + [(PrimitiveType | Enumeration)]]
∈ GROUP[@utype ⇒ (DataType | ObjectType)] (see 5.4.2)
 - PARAMref [@utype ⇒ Attribute + [(PrimitiveType | Enumeration)]]
∈ GROUP[@utype ⇒ (DataType | ObjectType)] (see 5.4.3)
 - GROUP [@utype ⇒ Attribute [+ DataType]]
∈ GROUP[@utype ⇒ (DataType | ObjectType)] (see 5.4.4)
 - GROUP [@utype ⇒ Reference [+ ObjectType]]
∈ GROUP[@utype ⇒ (DataType | ObjectType)] (see 5.7)

- If the GROUP is contained in a parent GROUP, the parent MUST NOT use its @utype attribute. This is consequence of previous rule really.
- ...

5.3.1.1 GROUP[@utype ⇒ DataType] ∈ RESOURCE

A GROUP in a RESOURCE cannot have FIELDrefs, only PARAMs, PARAMrefs and GROUPs. The GROUP represents therefore a single instance of the DataType directly as defined in 5.3, with the PARAM-s etc. providing the values of the components of the DataType.

The possible role this instance plays in the VOTable document must have been defined outside of any mapping to a data model. After all, in contrast to instances of ObjectTypes, the existence of instances of value types need not be explicitly stated (see the description of value types in section TBD). An example could be a VOTable containing the result of a simple cone search. A RESOURCE in that document might contain a GROUP representing the position of the cone, which may be mapped through its @utype to a DataType “stc:SkyCoordinate” (if such a type existed, our sample model contains a type like it).

Example

```
<RESOURCE>
...
<GROUP utype="bSTC:SkyCoordinate">
  <INFO value="The center coordinate of the simple cone search"/>
  <PARAM name="ra" utype="bSTC:SkyCoordinate.longitude" value="123.00000"/>
  <PARAM name="dec" utype="bSTC:SkyCoordinate.latitude" dec=-2.10000/>
  <PARAMref ref="_icrs" utype="bSTC:SkyCoordinate.frame"/>
</GROUP>
...
```

5.3.1.2 GROUP[@utype ⇒ DataType & ¬FIELDref] ∈ TABLE

A GROUP defined on a TABLE, annotated with a DataType, but without FIELDref-s in the GROUP or any of its descendant GROUPs, represents a DataType instance directly, just as was the case for the GROUP in a Resource in the previous subsection. In this case we can then interpret the GROUP “merely” as a structured PARAM following the VOTable spec [REF] “A PARAM may be viewed as a FIELD which keeps a constant value over all the rows of a table”. I.e. a GROUP without FIELDref is a structured set of columns all with the same value in each row. As the GROUP is mapped directly to a DataType rather than to a role, the use of such a GROUP in the context of the TABLE is not defined by a mapping, but possibly by a protocol as described in section 5.3.1.1.

5.3.1.3 GROUP[@utype ⇒ DataType & FIELDref] ∈ TABLE

If the GROUP is a descendant of a TABLE, is annotated with a DataType and contains at least one FIELDref element, either directly or in a descendant GROUP, the GROUP represents an instance of the DataType for each TR. The interpretation of the possible role it plays in terms of

Example

```
<TABLE>
...
```

```

<GROUP utype="bSTC:SkyCoordinate">
  <FIELDref ref="_ra" utype="bSTC:SkyCoordinate.longitude"/>
  <FIELDref ref="_dec" utype="bSTC:SkyCoordinate.latitude"/>
  <GROUP ref="_icrs" utype="bSTC:SkyCoordinate.frame"/>
</GROUP>
...
<FIELD name="ra" ID="_ra" unit="deg">
<DESCRIPTION>right ascension (J2000 decimal deg)</DESCRIPTION>
</FIELD>
<FIELD name="dec" ID="_dec" unit="deg">
<DESCRIPTION>declination (J2000 decimal deg)</DESCRIPTION>
</FIELD>
...

```

5.3.1.4 GROUP[@utype ⇒ DataType] ∈ GROUP[¬@utype]

A GROUP may be defined inside another GROUP and be mapped to a DataType. There are some restrictions. NONE of its ancestor GROUPs MAY be mapped to a data model element. This would conflict with rules of mapping such an ancestor GROUP that state that children of such GROUPs MUST be mapped to properties of the structured type represented by the containing GROUP (see the restrictions defined in 5.3.1).

Whether the GROUP represents the DataType instance directly or indirectly is independent of this embedding in a parent GROUP, only of the existence of a FIELDref in it or its descendants.

Example A GROUP representing parameters of a Simple Cone Search

```

<GROUP name="SCS">
  ...
  <GROUP name="center" utype="bSTC:SkyCoordinate">
    <INFO value="The center coordinate of the simple cone search"/>
    <PARAM name="ra" utype="bSTC:SkyCoordinate.longitude" value="123.00000"/>
    <PARAM name="dec" utype="bSTC:SkyCoordinate.latitude" dec="-2.10000"/>
    <GROUP ref="_icrs" utype="bSTC:SkyCoordinate.frame"/>
  </GROUP>
</GROUP>

```

5.4 Attribute

An attribute is the role a value type plays in the definition of a structured type. The mapping of the attribute is therefore almost identical to that of its type itself; similar elements can be used and the utype attribute may contain the utype of the actual type (must do so to support polymorphism). To annotate an element as attribute one MUST use also the utype of the attribute itself. Furthermore the element representing the attribute MUST be contained in a GROUP that represents the containing structured type.

How all of this is achieved in practice is described in the following subsections.

5.4.1 FIELDref[@utype ⇒ Attribute [+ (PrimitiveType | Enumeration)]]

A FIELDref MAY through its @utype declare that the FIELD it refers to stores an Attribute. It MAY (MUST?) add the utype identifying the actual type (a PrimitiveType or an Enumeration) that the FIELD represents separated by a '+' from the utype of the Attribute.

Restrictions

- The Attribute MUST be available to the structured type represented by the containing GROUP.
- The Attribute MUST have an atomic type.
- The datatype of the referenced FIELD must be compatible with the declared datatype of the Attribute, as well as the actual datatype indicated by the relevant part of the utype combination.
-

Example

See example in TBD.

5.4.2 PARAM[@utype ⇒ Attribute [+ (PrimitiveType | Enumeration)]] ∈ GROUP[@utype ⇒ (ObjectType | DataType)]

When defined inside of a GROUP that represents a structured type, a PARAM MAY represent an Attribute defined on the type. Which Attribute it represents it declares through its @utype. It MAY (MUST?) add the utype identifying the actual type (a PrimitiveType or an Enumeration) that the FIELD represents separated by a '+' from the utype of the Attribute.

Restrictions

- The Attribute must have an atomic data type.
- The PARAM's @datatype SHOULD be a compatible, valid serialization type for the type of the Attribute. (For reasons of translational semantics: It must be possible to create an instance of the atomic type from the value stored in the PARAM's @value).
- ...

Example

See example in TBD.

5.4.3 PARAMref[@utype ⇒ Attribute [(PrimitiveType | Enumeration)]]

Inside a GROUP a PARAMref identifies a PARAM defined inside the same RESOURCE or TABLE where the GROUP is defined. Using its @utype the PARAMref can annotate the PARAM as holding the value of an Attribute.

Restrictions

- The Attribute must be available to the structured type represented by the containing GROUP.
- Attribute's data type must be atomic.
- The PARAM must obey the restrictions defined for the annotation of a PARAM by the Attribute's type, if a PrimitiveType see 5.2.3, if an Enumeration see 5.2.4.

Example

TBD

5.4.4 GROUP[@utype ⇒ Attribute(DataType)] ∈ GROUP[@utype ⇒ ⟨ObjectType | DataType⟩]

A GROUP that is defined inside parent GROUP representing a structured type can be mapped to an Attribute with a (structured) DataType. The annotation will be a concatenation of the utype of the Attribute and of the actual DataType it represents.

Restrictions

- The Attribute represented by the child GROUP must be available on the structured type represented by the parent GROUP.
- ...

Example

```
<GROUP utype="SAMPL:source/Source">
  ...
  <GROUP utype="SAMPL:source/Source.position+bSTC:SkyCoordinate">
    <FIELDref ref="_ra" utype="bSTC:SkyCoordinate.longitude"/>
    <FIELDref ref="_dec" utype="bSTC:SkyCoordinate.latitude"/>
    <GROUP ref="_icrs" utype="bSTC:SkyCoordinate.frame"/>
  </GROUP>
  ...
</GROUP>
```

5.5 ObjectType

5.5.1 GROUP[@utype ⇒ ObjectType]

A GROUP's @utype may identify an ObjectType. Depending on the context, i.e. the location of the GROUP within other VOTable elements, such a mapping indicates the existence of one or more instances of the ObjectType. These may be directly represented by the GROUP, i.e. the GROUP *is* the instance, or the GROUP may indicate their existence when it is used to annotate a TABLE. These two cases are treated in the subsections below.

Much of the definition here mirrors that of the mapping of GROUP to DataType. The main difference is that having a GROUP annotated directly mapped an ObjectType, rather than to a role the ObjectType plays (say as reference or collection) is always meaningful. For the existence of instances of ObjectTypes cannot be inferred from the definition of the type.

Restrictions

- The components of a GROUP mapped to an ObjectType MUST be mapped to properties defined on that ObjectType. The following options are available:
 - FIELDref ∈ GROUP ⇒ Attribute ∈ ObjectType with atomic datatype (see)
 - FIELDref ∈ GROUP ⇒ ID ∈ ObjectType with atomic datatype (see)
 - PARAM ∈ GROUP ⇒ Attribute ∈ ObjectType with atomic datatype (see)
 - PARAM ∈ GROUP ⇒ ID ∈ ObjectType with atomic datatype (see)
 - PARAMref ∈ GROUP ⇒ Attribute ∈ ObjectType with atomic datatype (see)
 - PARAMref ∈ GROUP ⇒ ID ∈ ObjectType with atomic datatype (see)
 - GROUP ∈ GROUP ⇒ Attribute ∈ ObjectType with structured datatype (see)

- GROUP ∈ GROUP ⇒ ID ∈ ObjectType with atomic datatype (see)
- GROUP ∈ GROUP ⇒ Collection ∈ ObjectType (see)
- GROUP ∈ GROUP ⇒ Reference ∈ ObjectType (see)
- GROUP ∈ GROUP ⇒ Container ∈ ObjectType (see)
- GROUP ∈ GROUP ⇒ Extends ∈ ObjectType

5.5.1.1 GROUP[@utype ⇒ ObjectType] ∈ RESOURCE

GROUP as instance on RESOURCE

GROUP cannot have FIELDref-s, not can any of possible child GROUPS. Hence GROUP indicates an instance of the indicated ObjectType.

Example

```
<RESOURCE>
<GROUP utype="bSTC:SkyCoordinateFrame" ID="_icrs">
  <PARAM name="name" datatype="char" utype="bSTC:SkyCoordinateFrame.name" value="ICRS"/>
  <PARAM name="equinox" datatype="char" utype="bSTC:SkyCoordinateFrame.equinox+bSTC:Equinox"
value="J2000.0"/>
</GROUP>
...
</RESOURCE>
```

5.5.1.2 GROUP[@utype ⇒ ObjectType & ¬ FIELDref] ∈ TABLE

GROUP as instance on TABLE

¬ FIELDref means that the GROUP has not FIELDref-s directly under it, not in any GROUP *representing an Attribute or Reference*. Having no FIELDref, the GROUP represents an instance of the indicated ObjectType. Some of its child GROUPS may have a FIELDref, but only if they annotate an ObjectType.

It is allowed for a GROUP representing a Collection to have a FIELDref. In that case the GROUP represents an instance with ALL the TRs representing objects from the collection. There MUST NOT be more than 1 GROUP representing a Collection in this manner.

5.5.1.3 GROUP[@utype ⇒ ObjectType & FIELDref] ∈ TABLE

GROUP as annotation

A GROUP defined as child of a TABLE and having at least 1 FIELDref annotates the TRs in the TABLE, indicating that each row in the table represents at least part of an instance of the indicated ObjectType.

A child GROUP MAY contain a FIELDref, but *only* if that child GROUP is annotated to represent a collection defined on its GROUP. This represents one way of mapping a parent-child composition relation. The TABLE rows represent instances of the child ObjectType represented by the child GROUP. The parent GROUP represents the single instance of the container ObjectType.

Example

```
<TABLE>
```

```

<GROUP utype="SAMPL:source/Source">
  <FIELDref ref="_designation" utype="vo-dml:ObjectType.ID"/>
  <GROUP utype="SAMPL:source/Source.position+bSTC:SkyCoordinate">
    <FIELDref ref="_ra" utype="bSTC:SkyCoordinate.longitude"/>
    <FIELDref ref="_dec" utype="bSTC:SkyCoordinate.latitude"/>
    <GROUP ref="_icrs" utype="bSTC:SkyCoordinate.frame"/>
  </GROUP>
  . . .
</GROUP>
<FIELD name="designation" ID="_designation" utype="ivoa_1.0:stdtypes/string">
<DESCRIPTION>source designation formed from sexigesimal coordinates</DESCRIPTION>
</FIELD>
<FIELD name="ra" ID=" ra" unit="deg">
<DESCRIPTION>right ascension (J2000 decimal deg)</DESCRIPTION>
</FIELD>
<FIELD name="dec" ID="_dec" unit="deg">
<DESCRIPTION>declination (J2000 decimal deg)</DESCRIPTION>
</FIELD>
. . .

```

5.6 ID

It is assumed that *objects* (i.e. instances of an ObjectType) have an implicitly defined attribute that identifies instances uniquely; we will refer to this attribute as the ID. This attribute may be required for a serialization of an object, but is not modeled explicitly in VO-DML. The reason is that it often depends on the particular physical representation of model instances how the ID is represented. For example a relational database might use one or more INTEGER or BIGINT columns in the table storing the instance, whereas an XML document might have an ID attribute, or a URI. In fact different serializations of the same object may use different ways to represent the ID.

Hence an instance of an ID can generally be serialized to one or more columns in a TABLE, or to one or more PARAMs in a GROUP or even some combination of the two. The ID may therefore be represented by a single FIELDref or PARAM or PARAMref in the annotating GROUP, or possibly a child GROUP representing an ID with structure. Whatever the choice, an annotation must be provided that indicates the role of the element in the definition of the object serialization. We propose that the utype "vo-dml:ObjectType.ID" is used. See 2.2 for some more discussion on this choice.

5.6.1 FIELDref[@utype ⇒ ID] ∈ GROUP[@utype ⇒ ⟨ObjectType⟩]

The GROUP representing the ObjectType has an ID consisting of a single FIELD. Each row in the TABLE has an instance identified by that FIELD.

5.6.2 PARAM[@utype ⇒ ID] ∈ GROUP[@utype ⇒ ⟨ObjectType⟩ & ¬ FIELDref]

A GROUP representing an ObjectType has a single PARAM to identify it. Parent GROUP SHOULD NOT be contained in TABLE, or have no FIELDref. Otherwise it would indicate multiple rows all with same ID, which would be odd. **To be worked out**

5.6.3 GROUP [@utype ⇒ ID] ∈ GROUP [@utype ⇒ ⟨ObjectType⟩]

GROUP represents a struct as ID. Containing objects can only be FIELDref, PARAMref and or PARAM. Order and data type of these is important as references must replicate structure.

5.7 Reference

A Reference is a relation between a structured type (the “referrer”, an ObjectType or DataType) and an ObjectType, the “target object”, or “referenced object”. The reference is a property of the referrer and the target object can be referenced by many referrers. The GROUP representing the referrer

should hold on to an element representing the reference. The minimum requirement on this element MUST allow one to identify the target object.

In general one *cannot* assume that the target object can be found in the same element that contains the referrer. For example a standard Object Relational mapping will store both referrer and target objects in tables that will generally be different (unless referrer and target happen to have the same type). The referrer table will have a “foreign key” consisting of one or more columns that correspond to primary key columns in the target table. This kind of representation could be used in VOTable as well⁴; both referrer and target objects may be stored in TABLEs. This context requires that the mapping of the target objects includes an explicit mapping for their identifier. And the reference element must have a structure replicating the structure of that identifier.

This is the case where both referrer and target are indirectly represented by GROUP. Either or both may also be directly represented by a GROUP, which may offer different ways to represent the reference. An even more perverse possibility is that the target object is serialized in a different database or document altogether. For example one may wish to refer to a coordinate system formally defined in a document somewhere else, possibly officially registered in an IVOA registry. This object may be identifiable through some IVO identifier, and maybe our serialization can make use of this and not have to contain its own serialization of this reference data.

All in all we need to deal with the cases described in the following sections.

1. Both referrer and target directly represented by a GROUP.
2. Referrer directly in GROUP, refers to object indirectly represented by GROUP annotating TABLE. Referrer GROUP must be able to identify a row in the TABLE. The TABLE in which to look for the object MUST be annotated by a GROUP representing a type compatible with the type of the Reference. For it to be possible to identify the TR in the TABLE that stores the actual target object, the GROUP annotating the TABLE must define an ID. This may be through a single FIELDref, or possibly through a GROUP with multiple FIELDref-s in case the ID is structured. The referring GROUP MUST map the reference to a GROUP have a copy of this ID with values set. For each FIELDref there must be a PARAM referring (through its @ref) to the same FIELD as the ID's FIELDref and with @value set to the value in the TR. Since there is only a single referrer object here, it SHOULD be possible to indicate in which TABLE the target object resides, indeed which GROUP represents it. This again should be done using a “GROUPref”.
3. Object in TR refers to object in GROUP. The object in the TR can in general only use TDs to refer to an object elsewhere. Hence an object in a GROUP will have to define an ID with its PARAMs. If there is a single referenced object, the
4. Object in TR refers to object in TR
5. Object in GROUP to external object not in document.
6. Object in TR to external object not in document.

In the titles of the sections below the target representation is located on the right of an →

⁴ See old note by Louys and Bonnarel, <http://www.ivoa.net/Documents/Notes/DMVOTSer/ModelVOTSer-20040522.pdf>

**5.7.1 GROUP[@utype ⇒ Reference & @ref]
 ∈ GROUP[@utype ⇒ ⟨ObjectType | DataType⟩ & ¬ FIELDref]
 → GROUP[@utype ⇒ ⟨ObjectType⟩ & @id & ¬ FIELDref]**

The title indicates that a GROUP inside of a GROUP representing a structured type directly (¬FIELDref) represents a reference to another GROUP that also represents an object directly, either as a type or as a role (must be a collection element).

We have to assume that each referenced object has an identifier and each referrer must somehow have a copy of that identifier. As the definition of identifiers is not exactly prescribed, neither can we prescribe the form that the reference will take.

Restrictions

- GROUP identified by @ref MUST represent an ObjectType compatible with the data type of the Reference, i.e. either the same type of some of its subtypes.

Example

```
<GROUP utype="SAMPL:source/PhotometryFilter" ID="_2massJ">
  <PARAM name="name" datatype="char" utype="SAMPL:source/PhotometryFilter.name"
value="2mass:J"/>
</GROUP>
...
<GROUP utype="SAMPL:source/Source.luminosity;SAMPL:source/LuminosityMeasurement">
  <FIELDref ref="magJ" utype="SAMPL:source/LuminosityMeasurement.value"/>
  <FIELDref ref="_errJ" utype="SAMPL:source/LuminosityMeasurement.error"/>
  <GROUP ref="_2massJ" utype="SAMPL:source/LuminosityMeasurement.filter"/>
</GROUP>
...
```

**5.7.2 GROUP[@utype ⇒ Reference + 'vo-dml:ObjectType.ID']
 ∈ GROUP[@utype ⇒ ⟨ObjectType | DataType⟩ & ¬ FIELDref]
 → GROUP[@utype ⇒ ⟨ObjectType⟩ & FIELDref & ID] ∈ TABLE**

The title indicates an ObjectType or DataType instance directly represented by a GROUP (¬FIELDref) that contains a GROUP whose @utype is a concatenation of a utype identifying a Reference with the utype identifying the VO-DML ID concept, 'vo-dml:ObjectType.ID' (see 5.6). This indicates the GROUP represents a reference that identifies its target object using a copy of the identifier of that object. This is equivalent to the way foreign keys are used in the relational model to make links between rows in tables.

**5.7.3 GROUP[@utype ⇒ Reference + 'vo-dml:ObjectType.ID']
 ∈ GROUP[@utype ⇒ ⟨ObjectType | DataType⟩ & FIELDref]
 → GROUP[@utype ⇒ ⟨ObjectType⟩ & ¬FIELDref & ID]**

TBD

**5.7.4 GROUP[@utype ⇒ Reference + 'vo-dml:ObjectType.ID']
 ∈ GROUP[@utype ⇒ ⟨ObjectType | DataType⟩ & FIELDref]
 → GROUP[@utype ⇒ ⟨ObjectType⟩ & FIELDref & ID]**

TBD

5.8 Collection

A collection is a composition relation between a parent `ObjectType` and a child, or *part*, `ObjectType`. For the same reasons as discussed for reference mapping, the fact that objects can be stored in different ways implies many different ways in which the relation may need to be expressed.

In XML serializations of a data model (such as used in VO-URP and the Simulation Data Model) one may choose to have the contained objects serialized *inside* the serialization of the parent. It is possible to do so in VOTable as well using child `GROUP`-s representing a complete child object embedded in the `GROUP` representing the parent object. This is natural for this relationship because a collection element is really to be considered as a *part* of the parent object.

This may be used to represent flattening of the parent-child relation. One or more child objects may be stored together with the parent object in the same row in a `TABLE`. Such a case is actually very common, for example when interpreting tables in typical source catalogues. These generally contain information of a source together with one or more magnitudes. The latter can be seen as elements form a collection of photometry points contained by the sources.

Hence a `GROUP` inside another `GROUP` MAY represent a collection. It can do so in different modes that are described in the following subsections.

Restriction

- The parent `GROUP` must represent an `ObjectType` that can contain the Collection.

See also the treatment of the Container reference in section 5.8.3.

5.8.1 `GROUP` [`@utype` \Rightarrow `Collection+ObjectType`] \in `GROUP`[`@utype` \Rightarrow `<ObjectType>`]

Contained group represents an object of the indicated `ObjectType` that is an element of the indicated Collection. The `GROUP` MUST be contained inside of a `GROUP` that represents an `ObjectType` and is a valid Container of the Collection.

In this case the child `GROUP` represents a single object form the collection, not the collection as a whole. This can occur when annotating what is often called a flattened representation. One or more (must be a fixed number!) of elements of a collection are added to the container object and represented in the same TR in a `TABLE`.

Restriction

- The `@utype` MUST be a concatenation of the identifying utypes of both the Collection *and* the actual `ObjectType`.
- ...

Example

```

<TABLE>
<GROUP utype="SAMPL:source/Source">
  <FIELDref ref="_designation" utype="SAMPL:source/Source.name"/>
  <GROUP utype="SAMPL:source/Source.position;bSTC:SkyCoordinate">
    <FIELDref ref="ra" utype="bSTC:SkyCoordinate.longitude"/>
    <FIELDref ref="dec" utype="bSTC:SkyCoordinate.latitude"/>
    <GROUP ref="_icrs" utype="bSTC:SkyCoordinate.frame"/>
  </GROUP>
  <GROUP utype="SAMPL:source/Source.luminosity;SAMPL:source/LuminosityMeasurement">
    <FIELDref ref="_magJ" utype="SAMPL:source/LuminosityMeasurement.value"/>
    <FIELDref ref="_errJ" utype="SAMPL:source/LuminosityMeasurement.error"/>
    <GROUP ref="2massJ" utype="SAMPL:source/LuminosityMeasurement.filter"/>
  </GROUP>
  <GROUP utype="SAMPL:source/Source.luminosity;SAMPL:source/LuminosityMeasurement">
    <FIELDref ref="_magK" utype="SAMPL:source/LuminosityMeasurement.value"/>
    <FIELDref ref="_errK" utype="SAMPL:source/LuminosityMeasurement.error"/>
    <GROUP ref="2massK" utype="SAMPL:source/LuminosityMeasurement.filter"/>
  </GROUP>
  <GROUP utype="SAMPL:source/Source.luminosity;SAMPL:source/LuminosityMeasurement">
    <FIELDref ref="_magH" utype="SAMPL:source/LuminosityMeasurement.value"/>
    <FIELDref ref="_errH" utype="SAMPL:source/LuminosityMeasurement.error"/>
    <GROUP ref="2massH" utype="SAMPL:source/LuminosityMeasurement.filter"/>
  </GROUP>
</GROUP>
<FIELD name="designation" ID=" designation" utype="ivoa 1.0:stdtypes/string">
<DESCRIPTION>source designation formed from sexagesimal coordinates</DESCRIPTION>
</FIELD>
<FIELD name="ra" ID="_ra" unit="deg">
<DESCRIPTION>right ascension (J2000 decimal deg)</DESCRIPTION>
</FIELD>
<FIELD name="dec" ID=" dec" unit="deg">
<DESCRIPTION>declination (J2000 decimal deg)</DESCRIPTION>
</FIELD>

```

5.8.2 GROUP [@utype ⇒ Collection & @ref] ∈ GROUP[@utype ⇒ <ObjectType>]

If a child GROUP identifies a Collection, but *not* also an ObjectType, and it has a @ref identifying a GROUP elsewhere in the document, this should be interpreted as an indication that the referenced GROUP elsewhere in the document represents all or part of the identified Collection. This may be indirectly through a TABLE, in which case it might represent multiple objects [TBD need Container pointer?], or it may be a single element identified by this “GROUPref”.

During a “standard” object-relational mapping procedure, parent objects and the elements in a collection are generally mapped to different tables, with the child table having a pointer (foreign key in relational database) to the parent object. This can be handled by VOTable, which also provides the possibility for the parent object to be stored in a single GROUP (see).

In either case the child GROUP does *not* represent an element, but is a true pointer to a GROUP that annotates the TABLE that stores the collection objects. Actually, it may need to have multiple pointers, in case the collection is divided over multiple TABLES. Each individual pointer to a GROUP must act as a kind of GROUPref. Since such an element does not exist we propose the following solution.

- The child GROUP representing the collection MUST have as @utype the utype of the Collection, *not* concatenated with another utype.
- The child GROUP MUST contain one PARAM for each TABLE storing (part of) the collection. This PARAM MUST have a @ref identifying the @id of the GROUP wrapping the TABLE.

- That referenced GROUP MUST represent a type compatible with the declared type of the collection.
- IF the parent object is stored in a TR (i.e. the parent GROUP wraps a TABLE), the child table MUST have a Container reference (see 5.8.3) to identify the parent instance.
- **TBD** how about parent in GROUP?

5.8.3 GROUP[@utype ⇒ Container+ID] ∈ GROUP[@utype ⇒ ⟨ObjectType⟩]

Container is a special reference to remote object. But can only occur in ObjectType and container cannot be embedded. From the Container utype the possible type of the Container can be inferred.

5.9 Extends, inheritance

Object-relational mapping generally requires one to choose some approach to mapping inheritance hierarchies. One standard approach is to store a class distributed over multiple tables, linked using foreign keys. Each table stores the attributes etc. defined on one class in the hierarchy. To build a complete instance of the subclass requires one to join its contents to the contents of a table storing attributes etc. defined on its base class and so on. In VOTable one *may* encounter a similar mapping. The serialization (and annotation) of such a case requires a mapping of the “extends” relationship between subclass and base class.

An alternative mapping is to have one table per hierarchy, which then will store instances of different types. When using this in OR-mapping often a special column is used that identifies the type stored in a certain row. Note that such a column is also often added to the table representing the root base class of the inheritance mapping above.

Finally (?) one may have separate tables for each concrete class in the hierarchy, containing columns for all the attributes etc. from its base classes.

All of these different possibilities to store objects form a common inheritance tree furthermore complicates the treatment of polymorphism in references. If a reference is defined whose data type is a type that has subclasses, to find the target instances may require looking through more than one target table.

TBD i.e. it's quite a mess.

5.9.1 GROUP[@utype ⇒ Extends+ID] ∈ GROUP[@utype ⇒ ⟨ObjectType⟩]

...

TBC

6 Notable absences

The VOTable schema allows for redundancy in meta-data assignment. For example it allows assigning a ucd or utype to FIELDref-s, but also to the FIELD it references. How is one to interpret or use this? Our approach is at least for the use of utype attribute, to try to avoid this redundancy.

The design laid out in the previous subsections focuses utype assignments on the GROUP element and its components. The main reason is that in all but the most simplistic use cases we will not be able to void the use of GROUPs, and that at the same time they provide all functionality (and more) that TABLE and FIELD could provide. Choosing this approach implies client coders do not need to take the possibly conflicting assignments into account, they only need consider GROUPs.

Here we list a few possible assignments that we try to avoid, though they might seem valid.

TBD what more can we remove from section 5? FIELD annotation? All notation directly to PrimitiveType or Enumeration?

6.1 TABLE[@utype ⇒ ObjectType]

There might be some cases where a TABLE could be said to represent a structured type completely, and where the TABLE's @utype attribute could make that identification. However in probably most cases only part of the TABLE will correspond to the type, or multiple types will be stored inside a single row (see for example). In all of these cases one can (and MUST) use one or more GROUP elements contained by the TABLE to make the precise assignment. The extra cost of also doing so for TABLE-s where in principle the assignment could be made directly is minor. Client code only has to deal with GROUP-s, not also inspect the TABLE.

6.2 FIELD[@utype ⇒ Attribute] ∈ TABLE [@utype ⇒ ObjectType]

This assignment would only make sense inside of bigger context, which would have to be the TABLE here. But as we propose not to use TABLE to represent a DM element directly, consequently FIELD cannot be an attribute. We use FIELDref for that.

6.3 PARAM [@utype ⇒ Attribute] ∈ TABLE [@utype ⇒ ObjectType]

For the same reason that makes us avoid the assignment of Attribute to FIELD, we avoid assigning an attribute to a PARAM *that is contained in a TABLE*. The context (TABLE) is not used to indicate the type containing the Attribute. For this element a PARAMref inside a GROUP is to be used.

7 Utype: identifier or path expression?

Opposition has been raised against the explicit mapping of all structured types to GROUP elements with utype either the type, or the role(+type) the type plays in the definition of a parent GROUP.

1. It does not conform to existing usage.
2. It is complex and harder to parse using SED
3. It cannot be applied to TAP_SCHEMA or in FITS files
4. ...

The argument could be that in particular attributes with a structured data type might not need such a hierarchy, which, depending on data model, might be deep indeed (see some STC examples). Instead if utypes had a path like structure, then from the structure the grouping of attributes belonging together might be inferred.

Existing utypes lists such as STC and Characterization seem to have taken this approach as some examples from the usages document show:

- `stc:AstroCoords.Position2D.Value2.C1`
- `stc:AstroCoordSystem.SpaceFrame.CoordRefFrame.Equinox`
- `Char.SpatialAxis.Coverage.Location.Value`

Some examples used in Aladin even go further towards an XPath-like syntax

- `stc:AstroCoordArea/Region/reg:Sector/Center[1]`
- `ivoa:Characterization[ucd=pos]/Coverage/Bounds/min`

Counter arguments:

1. Structure of data model only implicitly expressed, by path expressions based on a non-existing serialization.
2. *Harder* to code against: a tool that wishes to use the data model structure to analyse/interpret a VOTable is most naturally coded in a language that easily expresses the data model, say Java or some other OO language. These naturally map attributes with structured types to fields with class representing the type. Such a class can easily be coded to expect a GROUP with structural components based on the definition of the type alone, NOT of some containing type. So a model importing STC, could also use an STC interpretation library as part of its own, does not need to write new code. Also, the interpreter only needs to see a GROUP, interpret its utype to decide whom to pass it on to. Does not first need to inspect all attribute, group some together to then pass it off to a component that does the same work anyway.
3. XPath expressions for inferring DM instances can be easily written against a hierarchy as well. Even easier as the natural XML structure is more easily queried. Simply search for appropriate GROUPs.
NOTE here it would have been better had UTYPE-s been element-s rather than attributes. These could have been given more structure that now must be encoded in @uype syntax.
4. Some Utype-s will only be defined implicitly. The data model itself will NOT contain an expression indicating explicitly the "attribute-of-attribute". Hence it cannot be looked up. It could be derived, but that is unnatural and breaks OO paradigm.
5. GROUPs MUST be supported anyway for collections, 0..* attributes, references. So coders must be able to deal with hierarchies anyway. Even in the most natural case: mapping a catalogue such as SDSS's PhotoObjAll, to the sample Source model.
6. Fact that FITS does not support GROUP-ing should not hold us back. FITS files SHOULD be wrapped by VOTable anyway in any VO context. [TBD DataLink?]. Its own metadata fields SHOUL NOT be used for this kind of annotation. We cannot be kept back in the expressiveness of our metadata by ancient formats as long as we already support wrapping FITS files anyway.
And see point 5. GROUPs should be supported for other parts of the mapping, so a solution must be found anyway. That same solution can be applied to structured attributes.
7. Fact that TAP_SCHEMA does not support GROUPs should not be a problem either. Most obvious solution is to extend the TAP_SCHEMA. Alternative is to provide TAP_SCHEMA with a

VOTable annotation similar to FITS. Each TAP service SHOULD be able to give a VOTable with TABLE definitions for each table in the database. There everything is available. Alternatively this could be added to VODataService or whatever other metadata format is desired. Note that querying a hierarchical data structure in tables is not supported naturally as it requires recursive queries. Since common table expressions are not part of ADQL this might be difficult. However see Appendix A for a possible schem extension that makes it still quite easy to find all groups in a table.

And see point 5. GROUPs should be supported for other parts of the mapping, so a solution must be found anyway. That same solution can be applied to structured attributes.

8. Formally there should not be existing usage, as there is no spec dealing with utypes. That spec is what we're trying to define and existing usage may indeed have to be re-implemented. Hopefully we can find a more friendly solution. In particular the fact that in the solution proposed here utype-s do not have a prescribed syntax (apart from prefix-> model and possible concatenation), may allow some existing utypes to be interpreted as identifiers into a model in the prescribed way. Particularly since the models do not have a VO-DML representation that might be possible. One way might be to provide the utype-s list in these models a translation in terms of a GROUP structure.

Note that this is only necessary for legacy implementations that should formally not have been there yet. SO another way to deal with existing utype-s lists is that utypes have to be interpreted in the context of the model that must be provided. IF the model (maybe extra meta-data field) does not have a VO-DML representation, in any case all spec is off. Special code only needs to be written against those models explicitly. We do not have to take them into account in the spec. A migration path exists to re-express all models in terms of VO-DML after which VOTables using these new versions of the model can also start using the formal version of the utype mapping spec.

9. ...

8 Notes, issues, questions, comments

Serializing data models after a transformation contains many possible complications. Some have been treated above, others still need discussions. Here are a few:

- Same VOTable component may be annotated in multiple ways. For example a "name" column (FIELD) can be given a utype of an Attribute, as well as of the ID of its ObjectType. (See example **TBD**). How shall we do that? Using multiple FIELDref-s, or using a concatenation of utype-s?
- Single attribute could be represented in multiple ways in the same serialization, say position in multiple coordinate systems, or in degrees *and* HMS.
- Some serialization (to VOTable) Map [x y z] to an array?
- @unit: Some data models support the storage of quantities and have an explicit 'unit' attribute. The sample data model in
- Can a FIELD have multiple annotations from a GROUP, for example being identified with a 'name' attribute and the ID attribute? Maybe only for ID can reuse a given FIELD? See example of Source. If OK, should there be multiple FIELDref-s or should we add utypes separated by ';' (not '+')?
- Non-standard models. CAN be easily

Appendix A. VO-DML/XML version of sample model

Here is the Sample model in the XML representation of VO-DML. Note that this model imports two other models, the IVOA Profile and a simple STC model. Those are not [TBD yet?] replicated here.

```
<?xml version="1.0" encoding="UTF-8"?>
<vo-dml:model xmlns:vo-dml="http://volute.googlecode.com/dm/vo-dml/v0.9">
  <identifier id="eee_1045467100313_135436_1">
    <utype>SAMPL</utype>
  </identifier>
  <name>Sample</name>
  <description>This is a sample data model. It contains the IVOA UML Profile and imports the
  IVOA_Profile data model with primitive types.
  It has some sample relationships etc to be used in documentation etc.</description>
  <title>Sample VO-DML data model.</title>
  <version>0.x</version>
  <lastModified>2013-02-08T17:03:40</lastModified>
  <import>
    <identifier id="_12_1_1dfa04c4_1360333713314_831168_335">
      <utype>bSTC</utype>
    </identifier>
    <name>basicSTC</name>
    <url>https://volute.googlecode.com/svn/trunk/projects/dm/vo-dml/models/simple-STC/bSTC.vo-
dml.xml</url>
    <documentationURL>https://volute.googlecode.com/svn/trunk/projects/dm/vo-
dml/models/simple-STC/bSTC.html</documentationURL>
  </import>
  <import>
    <identifier id="12_1_1dfa04c4_1352203901356_512837_228">
      <utype>ivoa_1.0</utype>
    </identifier>
    <name>IVOA_Profile</name>
    <url>http://volute.googlecode.com/svn/trunk/projects/dm/vo-
dml/models/profile/IVOA_Profile.vo-dml.xml</url>
    <documentationURL>http://volute.googlecode.com/svn/trunk/projects/dm/vo-
dml/models/profile/IVOA_Profile.html</documentationURL>
  </import>

  <package>
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        <utype>SAMPL:source/LuminosityMeasurement</utype>
      </identifier>
      <name>LuminosityMeasurement</name>
      <description>
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      </description>
      <container>
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          <utype>SAMPL:source/LuminosityMeasurement.CONTAINER</utype>
        </identifier>
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          <utyperef>SAMPL:source/Source.luminosity</utyperef>
        </collectionref>
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      <attribute>
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        <description>
          TODO : Missing description : please, update your UML model asap.
        </description>
        <datatype idref="_12_1_1dfa04c4_1352203901371_896288_236">
          <modelUtypeRef>ivoa 1.0</modelUtypeRef>
          <utyperef>ivoa 1.0:stdtypes/real</utyperef>
        </datatype>
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  </package>
</vo-dml:model>
```

```

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    <modelUtypeRef>ivoa_1.0</modelUtypeRef>
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  </description>
  <datatype idref="12_1_1dfa04c4_1352203901364_557823_229">
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  </datatype>
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  </description>
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```

```

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    <utyperef>bSTC:SkyCoordinate</utyperef>
  </datatype>
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  </datatype>
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```

```

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```



```

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  </literal>
  <literal>
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    </identifier>

```

```

        <value>flux</value>
        <description>
            TODO : Missing description : please, update your UML model asap.
        </description>
    </literal>
</enumeration>

</package>

</vo-dml:model>

```

Appendix B. Mapping "grammar"

[GL Please ignore this for now]

The following grammar defines the structure of mapping expressions used in some of the titles in section 5

```

vot-mapping := element-mapping | relation-mapping
element-mapping := vot-element [ '[' '@utype' '⇒' utype-value [constraints] ']' [context] ]
relation-mapping := element-mapping '→' element-mapping
vot-element := annotated-vot-element | basic-vot-element
basic-vot-element := 'GROUP' | 'FIELDref' | 'PARAM' | 'TABLE' | 'FIELD' | '@ref' | '@utype'
utype-value := vo-dml-concept | vo-dml-role '+' vo-dml-type
vo-dml-concept := vo-dml-type | vo-dml-role | vo-dml-types | vo-dml-type-rep | 'Model'
vo-dml-type := 'PrimitiveType' | 'Enumeration' | 'DataType' | 'ObjectType' | 'ID'
vo-dml-role := 'Attribute' | 'Reference' | 'Collection' | 'Container' | 'Extends'
vo-dml-type := '(' vo-dml-type ['|' vo-dml-type]* ')'
vo-dml-type-rep := '(' vo-dml-type ['|' vo-dml-type]* ')'
constraints := and-or constraint [constraints]
and-or := '&' | '|'
constraint := vot-element | '↪' vot-element
context := 'ε' element-mapping [context]*

```

Appendix C. GROUP in TAP_SCHEMA

Following is a possible extension to TAP_SCHEMA that would add GROUP-like annotation to a table. To query for a complete GROUP hierarchy for a table requires resolution of the GROUP-s nesting. In absence of common-table –expressions, the parent_table foreign key should allow one easily to collect all groups for a table and build the nesting in code.

```

CREATE TABLE tap_schema.group (
    id varchar(128) not null -- unique id of this group
    , parent_table varchar(128) not null -- foreign key to table ultimately owning this GROUP
    , parent_group varchar(128) -- if not null, id of GROUP owning this group
    , utype varchar(128) -- if parent_group is not null, the role the group plays in the parent,
    -- possibly concatenated with a utype for the actual type represented by the GROUP.
    -- HOWEVER that could be normalized by having a type utype and a role utype column instead
)

CREATE TABLE tap_schema.group_field (
    groupId varchar(128) not null -- ID of GROUP containing this field-ref
    , columnName varchar(128) not null -- column associated to the group, if null, this row is a
    PARAM
    , utype varchar(128) -- the utype of the role the field plays in group.
    -- Possibly concatenated with type? Or normalized (see above)
    , value varchar(8000) -- if this row represents a PARAM, this is its value
)

```

[NB, this schema implicitly supports stand-alone GROUP-s by not requiring a columnName, but all GROUP-s must be associated to some TABLE. I.e. standalone instances cannot be freely floating. This could happen if parent_table is allowed to be NULL.]