IVOA Photometry Data Model
Version 0.2
IVOA Note

V0.2 Mod 4

http://www.ivoa.net/Documents/TBD

Latest version:

http://www.ivoa.net/Documents/latest/SED.html

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Abstract

We present a data model for photometry, intended for use in conjunction with the IVOA Spectral Energy Distributions (SED) and Spectrum data models.

Status of this document

This is a draft for discussion among the relevant VAO and IVOA working groups.

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The **Virtual Observatory (VO)** is general term for a collection of federated resources that can be used to conduct astronomical research, education, and outreach.

The **International Virtual Observatory Alliance (IVOA)** (http://www.ivoa.net

) is a global collaboration of separately funded projects to develop standards and infrastructure that enable VO applications.

Contents

Part 1: Photometry Data Model

1 Introduction and Motivation

The IVOA has identified creation and analysis of spectral energy distributions as a key science capability desired in the VO. In this document we present a proposed abstraction for photometry data to be used in two different use cases: first, to describe photometry data points in spectral energy distributions; and second, to describe photometric bands in isolation, e.g. in a database of such bands for a telescope exposure-time calculator.

The model is simply an instance of the Spectrum model but with a few additional fields in the FluxAxis part of the Characterization.

1.1 Change Log

```
2010 Nov 4   Initial draft.
2010 Nov 25 (Mod 1) Base draft using Char.FluxAxis.
2010 Nov 26 (Mod 2) Changed to use CoordSys.FluxFrame.
2010 Nov 26 (Mod 3) Added aperture corrections. Change FluxFrame to Band. Support multiple ban
2010 Nov 26 (Mod 4) Minor improvements
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2 Mathematical model

2.1 Astronomical magnitudes

We consider an astronomical source whose flux density at the observer is $F(x)$, where x is a spectral coordinate (wavelength, frequency or energy). A magnitude-based photometric band represents this flux density by a single real-valued number m. To evaluate m, we need the effective band transmission curve $T(x)$, the reference coordinate x_0, the reference spectrum $F_R(x)$ including its zero point $F_R(x_0)$, and the reference magnitude m_0.

Then,

$$m - m_0 = -2.5 \log_{10}(<F>/<F_R>)$$

or equivalently

$$<F> = <F_R> 10^{-0.4(m-m_0)}$$

where we define

$$<F> = \int_0^\infty F(x)T(x)dx$$

and

$$<F_R> = \int_0^\infty F_R(x)T(x)dx$$

We often, without loss of generality, choose $m_0 = 0$ so F_{R0} is the flux at the reference coordinate for an object of magnitude zero and spectral shape the same as the reference spectrum.

The function $T(x)$ represents the 'relative spectral response' (e.g. Tokunaga and Vacca 2005, PASP117,421) of the instrument to a delta-function incoming signal.

2.2 Color correction and zero-point flux

Let us further define normalization values $F_0 = F(x_0)$ and $F_{R0} = F_R(x_0)$, and normalized spectra $f(x) = F(x)/F(x_0)$, $f_R(x) = F_R(x)/F_R(x_0)$ so

$$\frac{<F>}{<F_R>} = (F_0/F_{R0}) \frac{\int f(x)T(x)dx}{\int f_R(x)T(x)dx}$$

We can call the right hand term the 'color correction',

$$c(f, f_R, T) = \frac{\int f(x)T(x)dx}{\int f_R(x)T(x)dx}$$

If the source and the reference have the same spectral shape, then $c = 1$ and the monochromatic flux of the source at the reference coordinate is simply related to the magnitude by

$$F_0 = F_{R0} 10^{-0.4m}$$

if we have chosen $m_0 = 0$.

More generally,

$$F_0 = F_{R0} 10^{-0.4(m-m_0-C)}$$

where the color correction in magnitudes is

$$C(f, f_R, T) = -2.5 \log_{10} c(f, f_R, T)$$

2.3 Choice of reference coordinate

- It is sometimes useful to choose x_0 to be the 'effective wavelength' of the transmission curve for a given reference spectrum,

$$\lambda_{\text{eff}} = \frac{\int \lambda F_R(\lambda)T(\lambda)d\lambda}{\int F_R(\lambda)T(\lambda)d\lambda}$$

- or, a photon-weighted reference-spectrum effective wavelength

$$\lambda_{\text{eff,p}} = \frac{\int \lambda^2 F_R(\lambda)T(\lambda)d\lambda}{\int \lambda F_R(\lambda)T(\lambda)d\lambda}$$

- or, the 'mean wavelength',

$$\lambda_0 = \frac{\int \lambda T(\lambda)d\lambda}{\int T(\lambda)d\lambda}$$

- or, the 'isophotal wavelength', λ_{iso}, defined implicitly by (Tokunaga and Vacca 2005)

$$F_R(\lambda_{\text{iso}}) = \frac{\int \lambda F_R(\lambda)T(\lambda)d\lambda}{\int T(\lambda)d\lambda}$$

- one can also use the frequency-weighted equivalents of each of the above, which in wavelength terms are

$$\lambda(\nu_{\text{eff}}) = \left(\frac{\int \lambda^{-1} F_R(\lambda)T(\lambda)d\lambda}{\int F_R(\lambda)T(\lambda)d\lambda} \right)^{-1},$$

and

$$\lambda(\nu_{\text{eff,p}}) = \left(\frac{\int F_R(\lambda)T(\lambda)d\lambda}{\int \lambda F_R(\lambda)T(\lambda)d\lambda} \right)^{-1},$$

and

$$\lambda(\nu_0) = \left(\frac{\int \lambda T(\lambda)d\lambda}{\int \lambda^2 T(\lambda)d\lambda} \right)^{-1},$$

and

$$\lambda(\nu_{\text{iso}})^2 F_R(\lambda(\nu_{\text{iso}})) = \frac{\int \lambda F_R(\lambda)T(\lambda)d\lambda}{\int \lambda^{-1} T(\lambda)d\lambda}$$

- Finally, there is also the 'pivot wavelength' (Bushouse and Simon 1998, HST Synphot Users Guide)

$$\lambda_{\text{pivot}} = \lambda(\nu_{\text{pivot}}) = \sqrt{\frac{\int \lambda^2 T(\lambda)d(\ln\lambda)}{\int T(\lambda)d(\ln\lambda)}}$$

However, it is often preferable to use a standard reference coordinate for simple comparison between

different observatories; thus V magnitudes are traditionally converted to fluxes by using a reference flux at 5400 Å even if the particular V filter in use has a slightly different effective wavelength; it would be annoying and unhelpful to have to compare a flux $f(5382.1\text{Å})$ with another flux $f(5413.8\text{Å})$, and for a broad $T(\lambda)$ any reference coordinate within the range where T is not close to zero will represent the flux as well as any other.

Further, in archival data the detailed T function and the exact effective spectral coordinate may not be available; therefore, the effective wavelength or effective spectral coordinate, while a useful quantity to include in the model, should not be a required quantity. We support defining one or more of them as optional quantities using the following tags to define which type we are talking about (in the absence of sufficiently finely defined UCDs:)

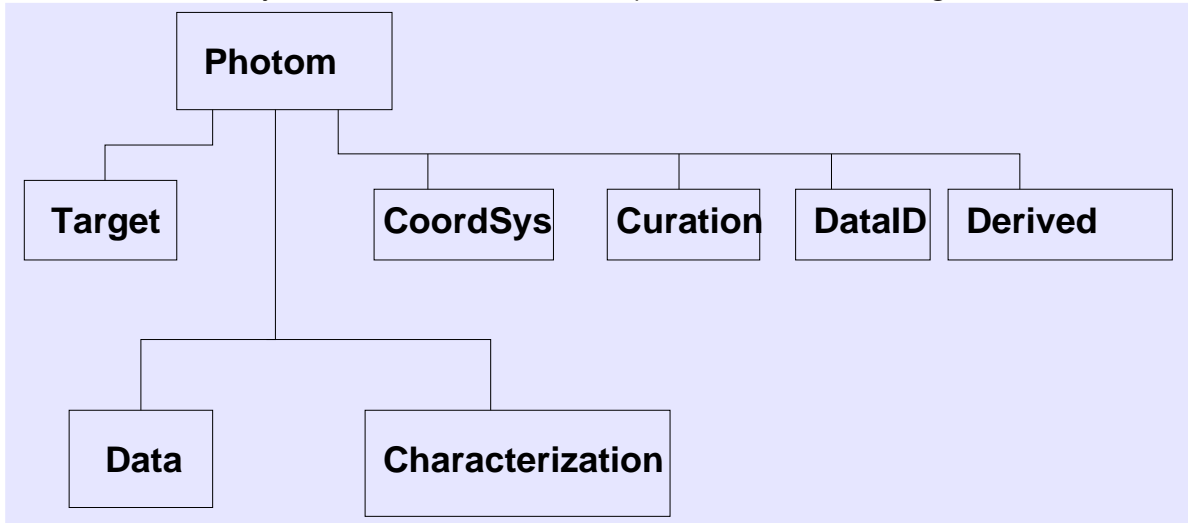| Tag	Type	Weighting type	Weighting
EFLAM	Effective	Wavelength	Flux Ref * T
EPLAM	Effective, photon	Wavelength	Photon Ref * T
MLAM	Mean	Wavelength	T
ISO	Isophotal	Wavelength	Implicit
EFNU	Effective	Frequency	Flux Ref * T
EPNU	Effective, photon	Frequency	Photon Ref * T
MNU	Mean	Frequency	T
ISONU	Isophotal	Frequency	Implicit
PIVOT	Pivot	Either	Require $F\_\nu = F\_\lambda$

2.4   Further notes

- It is often convenient to normalize T so that either its peak or its integral are unity, but, since T's normalization always cancels out, this is not required.

- We often refer to T as the 'filter transmission curve'. It is important to remember that in an observation the effective value of T as defined above is the product of multiple spectral filters imposed by factors like the atmosphere and the data processing, not just the physical hardware filter in the instrument. In practice we often neglect this distinction and assume that the hardware filter is the only significant contributing factor to T.

- We refer to the combination of T, f_R, x_0, F_{R0}, m_0 (a tuple of two functions and three numbers) as defining a 'photometric band'. The word 'filter' is also used synonymously.

- The photometric band also may have both a generic and a specific name. For example, a filter may be specifically called 'FLWO 2S-V', and be generically a 'V' band filter, meaning that it attempts to generally replicate the transmission of the standard Johnson V, but its magnitudes may require correction because of some differences in detail for the T function. Be careful, because the published data may be corrected, and therefore the appropriate T becomes the standard one, not the instrument-specific one (and of course some information has in principle been lost).

- In theory one might argue that the names are redundant, since the tuple defined above is all you need to know. But a common query case might be to look for all broad band Johnson V band data on an object. To determine from the numerical tuple values that a particular filter is a V filter is not trivial - the user may not want to include narrow-band filters at similar wavelengths. Having a simple indicator that indeed this data point represents a particular named filter is helpful.

3   Summary of the model for SED photometry

Here we present the proposed model; it is based on Spectrum. At first sight it may seem quite complex, but many features are optional and there are only small additions to the Specturm model. A simplified version is given later in the document.

The basic Photometry model is identical with the Spectrum model at the highest level:

The Data model is also the same as in spectrum. Here we note that the quantities Resolution and BinSize will apply to the time axis (for a light curve), but will be omitted for the spectral axis since we are definining a single spectral point.

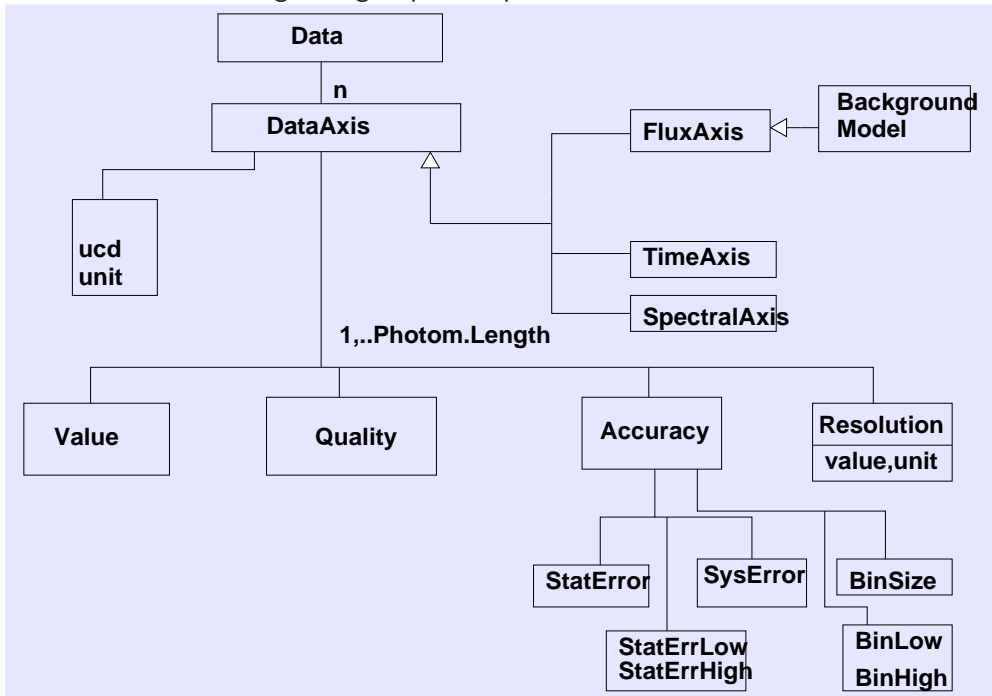
Figure 2: Diagram for Data object

The main difference in the model is in the Flux CoordFrame part of the CoordSys model, to which we give the special name Band. We need to define the photometric band and its zero point; this information is most naturally attached to the CoordSystem. We also need to provide a pointer to the filter transmission curve, and this is added to the Coverage object of

the spectral axis characterization.

We also provide the ability to store one or more 'effective spectral coordinates' as described in the mathematical model above.

The band metadata can either be present in the document/dataset, or it can be pointed to in an external database using the Band ID field; the (name,ID) pair defines a mapping between a band name and a band definition.
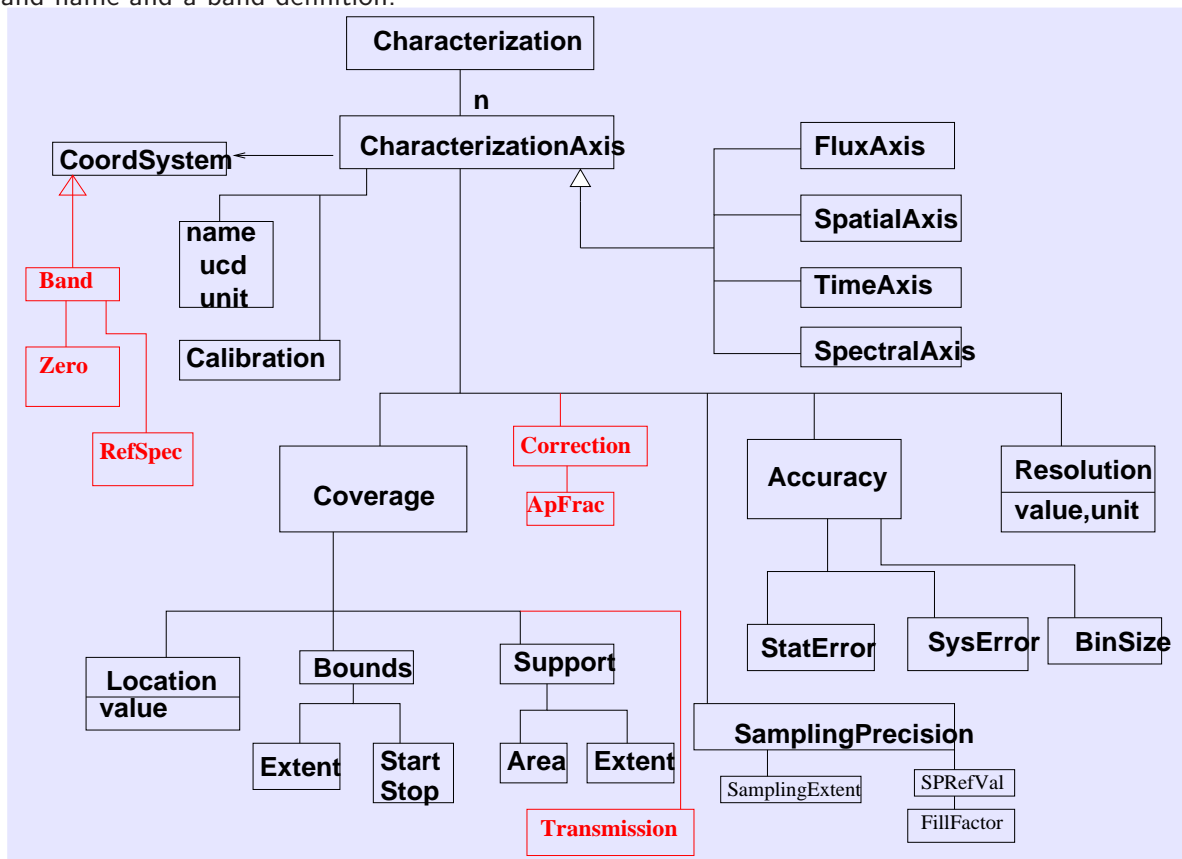

Figure 3: Diagram for Char object

3.1   Coverage and Transmission

Recall (from the Spectrum and Characterization standards) that the Coverage describes 'where the data is' at different levels: the Location give a point in parameter space which roughly defines where the data can be found; the Bounds is a parameter space region which bounds (contains) the data; the Support provides a detailed map (subspace, set of intervals) of parameter space saying where we looked to measure data and where we didn't look - time intervals, apertures on the sky etc. The next level, discussed in the Characterization model but not previously implemented, is the Sensitivity which pushes the idea one step further to say 'we looked here with 10 percent efficiency, here with 80 percent efficiency, and there with 90 percent efficiency'. In the present concept, for the spectral coordinate axis, this maps exactly to the concept of a filter transmission curve. Further, the transmission curve $T(x)$ can be represented in detail as just another Spectrum instance - it is a dimensionless 1-D function of the spectral coordinate; in the serialization of the model we can represent it as a URI resolving to such a Spectrum instance, since it's likely that many different photometry datasets will share the same transmission curve.

This approach is consistent with the Characterization idea that the different levels of Coverage give successively more accurate and detailed descriptions of the data coverage (the exposure). One can think of the lower levels of Coverage as cruder approximations to the filter curve - Location is a delta function approximation, Bounds is a top-hat (rectangular) approximation, Support is a series of top-hats (to allow for sidelobes), and Sensitivity (Transmission) is the detailed curve. Many older datasets may only be able to support the cruder cases.

The implementation in this document uses the simplified Characterization model used in the Spectrum standard, which is easily mapped to the general IVOA Characterization model recommendation.

3.2   A note on aperture corrections

To include individual photometric observations in an SED, it may be important to make aperture corrections: typically a photometric measurement captures only part of the flux from the object. For a point source, the measurement aperture (physical or software) may include only a finite fraction of the instrument point spread function. For an extended source such as a galaxy, we may wish to guess the total object brightness based on the fraction actually observed. In each case this correction depends on comparing the observation aperture to a spatial model of the light distribution of the source. It is therefore a function not of the photometric band, but of the individual data points - if such a correction has been applied, we will wish to record the amount of the correction. If no correction has been applied, one could record the appropriate point-source correction, bearing in mind that it may not be relevant. We consider two new optional pieces of information, the point source aperture fraction and the actually applied aperture fraction correction (default 1.0), defined by

$$\text{Measured flux} = \text{Ap Fraction} \times \text{ Total flux}$$

so that the correction is between 0.0 and 1.0.

Would we ever want to know both? If the applied correction is not equal to the point source correction, it's usually because the source is not a point source in which case we probably don't care what the point source correction was. A more useful pair of metadata items is probably the 'adopted aperture fraction' (i.e. what you think the right correction is) and an 'aperture fraction flag', true or false if the flux value does or does not have the correction applied to it (since we may want to record the proposed correction whether or not it has actually been applied).

These new metadata could logically appear either in the Data object (considered as extra data for each flux point) or in the Characterization object (considered as metadata applying to all flux points in the band.) Conceptually we can generalize them as examples of 'corrections to apply' and 'corrections applied'. This particular correction is conceptually quite close to the spatial filling factor (Char.SpatialAxis.SamplingPrecision.FillFactor), defined in the IVOA Characterization model to account for e.g. gaps between pixels. However, the filling factor is thought of as a statistical correction, while the aperture fraction is a single modelled correction. Guided by this, we add a new category to the CharacterizationAxis class, Correction, so that we have Char.FluxAxis.Correction.ApFrac.Value and Char.FluxAxis.Correction.ApFrac.Applied

Since what is being corrected is the flux value, we put the correction on the flux axis, even though it is a spatially dependent correction; one might imagine a SpatialAxis correction that involved astrometric corrections to the position, so it's probably better to reserve SpatialAxis corrections for things that actually change the value of the SpatialAxis coordinate. The Characterization.FluxAxis is otherwise mostly used for Accuracy, defining systematic and statistical errors on the flux values.

The aperture area or diameter itself is recorded in Char.SpatialAxis.Support.Area and Char.SpatialAxis.Bounds.Exten

3.3 New and old data model fields (utypes) for Photometry

The photometric band fits naturally into the CoordSys model as it defines a coordinate frame for the flux axis.
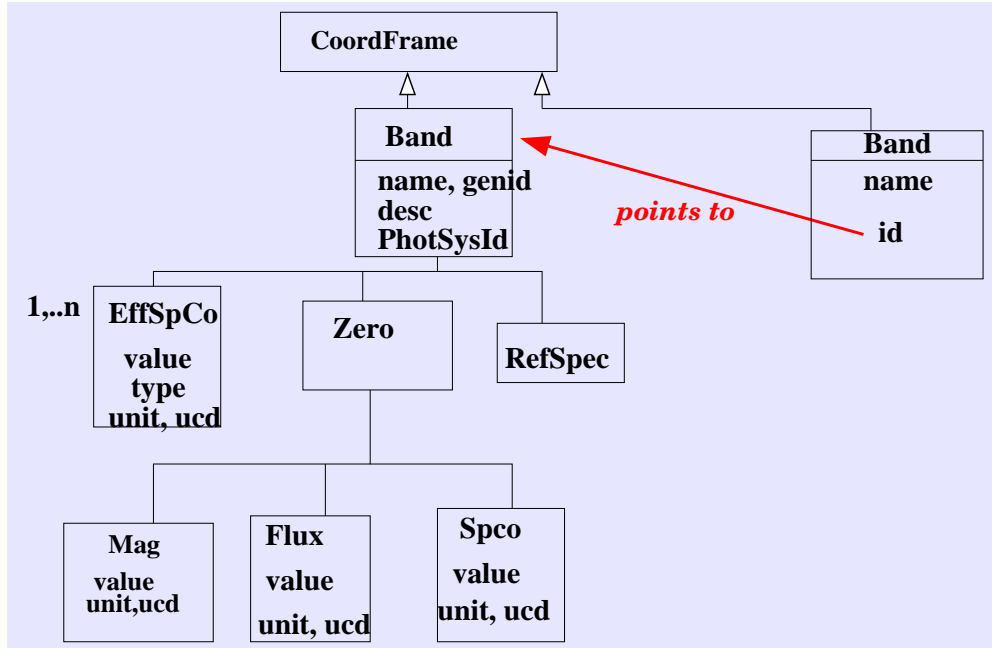

Figure 4: Diagram for CoordFrame object with Photometry specifics. Band can either be a full definition or a name, URI pair pointing to a full definition.

The reference coordinate x_0 and its metadata are already well described by the Spectrum model's Char.SpectralAxis.Coverage.Location object, but we repeat it in the band definition to couple it tightly to the definition of the coordinate system.

The T(x) is handled by adding Transmission to Char.SpectralAxis.Coverage as described above.

The remaining quantities describe how the flux is evaluated; they represent a mapping from instrumental values (mag) to physical values (flux density). We don't have a general mapping/transformation model in the IVOA, so we implement a simple representation. The essence of a mapping of this kind is that we define a reference position in the 'raw' space, in this case the reference zero point magnitude m_0, its corresponding value in the 'mapped', flux, space, in this case F_{R0}, the flux at the reference coordinate for an object with the reference spectrum, and a transformation function to let you calculate points in the mapping which are not at the reference position. In this case that transform is the color correction, for which the metadata are T(x) and the reference spectral shape $f_R(x)$.

In addition to the existing Spectrum utypes, we add the following.

- CoordSys.Band.name: The Band ID, a specific name for the band (although it doesn't have to be unique).

- CoordSys.Band.id: The Band unique URI, optionally pointing to an external band definition.

- CoordSys.Band.gid, The Band generic ID, a generic name for the band - this is a new field

- CoordSys.Band.desc The band description, a string for human-readable text.

- CoordSys.Band.refspec, The Band reference spectrum, a URI to the reference spectrum (we should have a set of standard URIs like Vega and Flat that will cover most cases).

- CoordSys.Band.zero.mag, The zero-point reference magnitude, 0.0 by default

- CoordSys.Band.zero.flux, the zero-point flux, which has a value, unit and UCD. Zero point fluxes may be in $f(\lambda)$, $f(\nu)$ or any other flux type defined by the Spectrum model.

- char.spectralaxis.coverage.trans, the transmission curve. If this is absent, we fall back to the other coverage elements (Support, Bounds, Location). If those are absent, we fall back to the Char.SpectralAxis.Coverage.Location

  We also reuse

- char.spectralaxis.coverage.location, the zero-point spectral coordinate. This has a value, unit and UCD. For optical photometry, we anticipate that most bands will use a unit of Angstrom and a UCD of 'em.wl', but we provide the flexibility to accomodate radio astronomy with bands defined in (GHz, em.freq), etc.

  We further support defining effective spectral coordinates (e.g. effective wavelengths) with

- CoordSys.Band.effspco.value the value of the effective wavelength, frequency, etc.

- CoordSys.Band.effspco.unit, char.fluxaxis.effspco.ucd the unit and UCD of the effective coordinate

- CoordSys.Band.effspco.type The type of effective coordinate, per the table.

  These are optional, but if one is present, the default is for the coordinate to be a mean (transmission-weighted) wavelength in Angstroms.

  For the aperture correction, we have as noted above

- Char.FluxAxis.Correction.ApFrac.Value and

- Char.FluxAxis.Correction.ApFrac.Applied

These are formally summarized in the attached table. MAN indicates mandatory fields and OPT optional fields for a full band definition. However, for use cases where you are referring to an external band definition, only the Name and ID fields are mandatory to be present in the dataset, as the rest are resolved by loading the external definition.
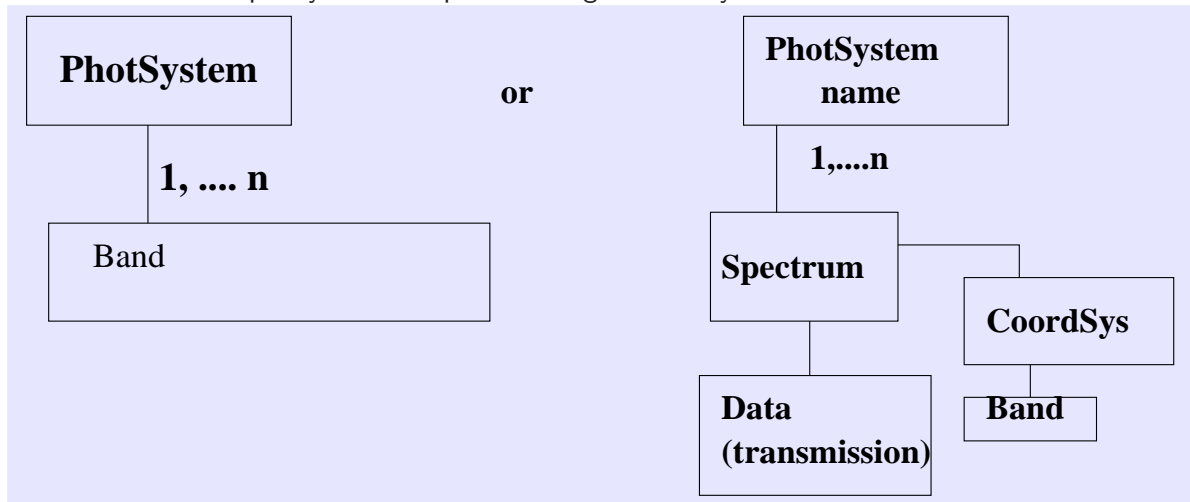
Table 1: Photometry supplementary metadata fields

Field	FITS	UCD1+	Meaning	Req	Default
DataModel	VOCLASS		Data model name and version	MAN	Photometry-1.0
CoordSys.Band.Name	PHBAND		Specific name for band	OPT	(None)
CoordSys.Band.ID	PHID		URI for band definition	OPT	(None)
CoordSys.Band.GenID	PHGID		Generic name for band	OPT	(None)
CoordSys.Band.Desc	PHDESC		Description of band	OPT	
CoordSys.Band.PhotSysID	PHSYS		System that band is a member of, if any	OPT	
CoordSys.Band.Zero.Mag.Value	PHMAGZ		Zero point reference mag	OPT	0.0
CoordSys.Band.Zero.Mag.Unit	-		Unit for ref mag	OPT	mag
CoordSys.Band.Zero.Mag.UCD	-		UCD for ref mag	OPT	phot.mag
CoordSys.Band.Zero.Flux.Value	PHZERO		Flux density at ref coord	MAN	
CoordSys.Band.Zero.Flux.Unit	PHFUNI		Unit for flux density	MAN	
CoordSys.Band.Zero.Flux.UCD	PHFUCD		UCD for flux density	OPT	phot.flux.density
CoordSys.Band.Zero.SpCo.Value	PHSPZ		Zero point reference spectral coordinate	MAN	
CoordSys.Band.Zero.SpCo.Unit	PHSPUNI		Unit for spectral coordinate	OPT	Angstrom
CoordSys.Band.Zero.SpCo.UCD	PHSPUCD		UCD for spectral coordinate	OPT	em.wl
CoordSys.Band.RefSpec	PHREFS		URI for Reference spectrum	OPT	(None)
CoordSys.Band.EffSpCo.Value	ESPCO		Effective spectral coord	OPT	
CoordSys.Band.EffSpCo.Type	ESPCOTY		Type of ESPCO	OPT	MLAM
CoordSys.Band.EffSpCo.Unit	ESPCUN		Unit of ESPCO	OPT	Angstrom
CoordSys.Band.EffSpCo.UCD	ESPCUCD		UCDof ESPCO	OPT	em.wl
Char.SpectralAxis.Coverage.Location.Value			Zero point reference spectral coordinate	MAN	
Char.SpectralAxis.Unit	PHSUNIT		Unit for spectral coord	REC	Angstrom
Char.SpectralAxis.UCD	PHSUCD		UCD for spectral coord	OPT	em.wl
Char.SpectralAxis.Coverage.Trans	PHTRANS		URI for Transmission curve	OPT	(None)
Char.FluxAxis.Correction.ApFrac.Value	APFRAC		Aperture fraction 0 to 1	OPT	1.0
Char.FluxAxis.Correction.ApFrac.Applied	APFAPP		Aperture fraction applied	OPT	FALSE

4 Summary of the model for isolated photometry bands

For a document/dataset describing a photometry band representing a physical filter associated with a telescope, the same model can be used. In this case, however, the characterization does not apply to a specific observation - there is no spatial axis coverage defining a region on the sky, for example, and the relevant time-axis coverage is the time period that the filter was available for use on the telescope, rather than the duration of a specific observation. In this case the Char.Coverage.Bounds element naturally describes the start and stop times of this validity range.

The band is stored as a CoordSys element. It can also be stored as a Spectrum instance whose CoordSys is the band and whose data is the transmission curve.

For a model of an archive describing a database of photometric bands, we may also want to define the band's membership in a larger collection. Here a PhotSystem will collect information aggregating a set of related filters. It is possible that a band may be a member of more than one PhotSystem. One way to represent this is a PhotSystem model in which the information on which bands make up a system is kept at the higher PhotSystem level:

There may be use cases in which the information that a band is a member of particular system needs to be kept with the band itself; we add an optional PhotSysId field to the band description for this purpose.

4.1 Mapping to ESA model

The ESAC model fields are now completely supported by the model, as mapped below.

ESAC	Meaning	This doc
uniqueidentifier	Specific name for this filter, e.g. 'B-LCO-CCD4'	CoordSys.Band.name
filterName	Generic name for filter, e.g. 'B'	CoordSys.Band.GenID
filterDescription	Explanation of filter	CoordSys.Band.Desc
photometricSystem	Membership of related group of filters, e.g. 'LCO'?	CoordSys.Band.PhotSysID
spectralBoundsmean	Formal trans.curve-averaged wavelength	CoordSys.Band.EffSpCo.Value
spectralBoundsmin	) Thresholded cutoff range	Char.SpectralAxis.Coverage.Bounds.Start
spectralBoundsmax	)	Char.SpectralAxis.Coverage.Bounds.Stop
effectiveWidth	?	Char.SpectralAxis.Coverage.Bounds.Extent
zeroPoint	Flux corresponding to zero	CoordSys.Band.Ref.Flux.Value
objectReferenceSpectrum	Assumed spectral shape	CoordSys.Band.RefSpec
validityRange	Time range this was in use	Char.TimeAxis.Coverage.Bounds.Start,Stop
filterTransmissionCurve	Normalized filter curve	Char.SpectralAxis.Coverage.Trans (URI ref) or (filter library) Spectrum.Data

5 Multiple photometry bands and colors

In the preceding sections we have assumed that only one band will be used in a single data segment. However, in catalogs it is frequently the case that we wish to include many related bands at once, e.g. UBVRI measurements of a set of objects or of a single object versus time. It would be too cumbersome to include the full band definitions in the metadata in this case, but we can support the indirect band-reference method by allowing multiple instances of the Band CoordFrame in the CoordSys, and then add a column whose value is the Band name and whose utype is Data.SpectralAxis.Value. This is an extension to the Spectrum model to allow string-valued instances of the latter field. See Example 5 in the examples section.

6 Examples

Example 1: Here is a VOTABLE example of a V flux measurement, recording all the information on the target, observing configuration, etc.

```xml
<?xml version="1.0" encoding="UTF-8"?>
<VOTABLE version="1.1"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  xsi:noNamespaceSchemaLocation="xmlns:http://www.ivoa.net/xml/VOTable/VOTable-1.1.xsd"
  xmlns:spec="http://www.ivoa.net/xml/SpectrumModel/v1.01"
  xmlns="http://www.ivoa.net/xml/VOTable/v1.1">
<RESOURCE utype="spec:Spectrum">

<TABLE utype="spec:Spectrum">
<GROUP utype="spec:Target">
 <PARAM name="Target" utype="spec:Target.Name" datatype="char" arraysize="*" value="Arp 220"/>
 <PARAM name="TargetPos" utype="spec:Target.pos" unit="deg" datatype="double"
                                arraysize="2" value="233.737917 23.503330"/>
 <PARAM name="z" utype="spec:Target.redshift" datatype="float" value="0.0018"/>
</GROUP>

<!-- SegmentType can be Photometry, TimeSeries or Spectrum -->
<PARAM name="Segtype" utype="spec:SegmentType" datatype="char" arraysize="*"
                                        value="Photometry" ucd="meta.code"/>
<GROUP name="CoordSys" utype="spec:CoordSys">
 <GROUP utype="CoordSys.SpaceFrame">
   <PARAM name="System" utype="spec:CoordSys.SpaceFrame.Name" ucd="frame.pos.system"
                                 datatype="char" arraysize="*" value="ICRS"/>
   <PARAM name="Equinox" utype="spec:CoordSys.SpaceFrame.Equinox" ucd="time.equinox;pos.eq"
                                 datatype="float" value="2000.0" />
 </GROUP>
 <GROUP utype="spec:CoordSys.TimeFrame">
  <PARAM name="TimeFrame" utype="spec:CoordSys.TimeFrame.Name" ucd="frame.time.scale" datatype="char"
                              arraysize="*" value="UTC"/>
 </GROUP>
 <GROUP utype="spec:CoordSys.SpectralFrame">
  <PARAM name="SpectralFrame" utype="spec:CoordSys.SpectralFrame.RefPos" ucd="frame.em.system"
                              datatype="char" arraysize="*" value="TOPOCENTER"/>
 </GROUP>

 <GROUP utype="spec:CoordSys.Band">
  <PARAM name="FluxAxisID" utype="CoordSys.Band.Name"  value="FLWO CCD V"/>
  <PARAM name="FluxAxisGID" utype="CoordSys.Band.GenID"  value="V"/>
  <PARAM name="FluxAxisDesc" utype="CoordSys.Band.Desc"  value="Johnson V magnitude photometry"/>
  <GROUP utype="spec:CoordSys.Band.Zero">
   <GROUP utype="spec:CoordSys.Band.Zero.SpCo">
    <PARAM name="FluxAxisRefMag" utype="CoordSys.Band.Zero.SpCo.Value" value="5400"/>
    <PARAM name="FluxAxisRefUnit" utype="CoordSys.Band.Zero.SpCo.Unit" value="Angstrom"/>
    <PARAM name="FluxAxisRefUCD" utype="CoordSys.Band.Zero.SpCo.UCD" value="em.wl"/>
   </GROUP>
   <GROUP utype="spec:CoordSys.Band.Zero.Flux">
    <PARAM name="FluxAxisRefMag" utype="CoordSys.Band.Zero.Flux.Value" value="3548.0"/>
    <PARAM name="FluxAxisRefUnit" utype="CoordSys.Band.Zero.Flux.Unit" value="Jy"/>
    <PARAM name="FluxAxisRefUCD" utype="CoordSys.Band.Zero.Flux.UCD" value="phot.flux.density;em.freq"/>
   </GROUP>
  </GROUP>
  <PARAM name="FluxAxisRefSpec" utype="CoordSys.Band.RefSpec" value="ivo://cfa.harvard.edu/vo/templates/Vega"/>
 </GROUP>


</GROUP>
```

```
<GROUP utype="spec:Char">
 <GROUP utype="spec:Char.SpatialAxis">
   <PARAM name="SpatialAxisName" utype="name" ucd="pos.eq" unit="deg" value="Sky"/>
   <GROUP utype="spec:Char.SpatialAxis.Coverage">
    <GROUP utype="spec:Char.SpatialAxis.Coverage.Location">
     <PARAM name="SkyPos" utype="Char.SpatialAxis.Coverage.Location.Value"
                                  ucd="pos.eq" unit="deg"
                                  datatype="double" arraysize="2" value="132.4210 12.1232"/>
   </GROUP>
   <GROUP utype="Bounds">
     <PARAM name="SkyExtent" utype="Char.SpatialAxis.Coverage.Extent" ucd="pos.region.diameter"
                   datatype="double" unit="arcsec" value="20"/>
   </GROUP>
  </GROUP>
 </GROUP>



 <GROUP utype="spec:Char.TimeAxis">
  <PARAM name="TimeAxisName" utype="Char.TimeAxis.Name" ucd="time" unit="d" value="Time"/>
  <GROUP utype="Char.TimeAxis.Coverage">
   <GROUP utype="Char.TimeAxis.Coverage.Location">
    <PARAM name="TimeObs" utype="Char.TimeAxis.Coverage.Location.Value" ucd="time.obs"
                                  datatype="double" value="52148.3252"/>
   </GROUP>
   <GROUP utype="Char.TimeAxis.Coverage.Bounds">
    <PARAM name="TimeExtent" utype="Char.TimeAxis.Coverage.Bounds.Extent" ucd="time.duration"
                  unit="s" datatype="double" value="1500.0" />
    <PARAM name="TimeStart" utype="Char.TimeAxis.Coverage.Bounds.Start" ucd="time" unit="s"
                                   datatype="double" value="52100.000" />
    <PARAM name="TimeStop" utype="Char.TimeAxis.Coverage.Bounds.Stop" ucd="time" unit="s"
                                   datatype="double" value="52300.000" />
   </GROUP>

  </GROUP>
 </GROUP>

 <GROUP utype="spec:Char.SpectralAxis">
  <PARAM name="SpectralAxisName" utype="Char.SpectralAxis.Name" ucd="em.wl" unit="Angstrom" value="Wavelength"/>
  <GROUP utype="Char.SpectralAxis.Coverage">
   <GROUP utype="Char.SpectralAxis.Coverage.Location">
    <PARAM name="SpectralExtent" utype="Char.SpectralAxis.Coverage.Location.Value"
                  unit="Angstrom" datatype="double" value="5400.0"/>
   </GROUP>
   <GROUP utype="Char.SpectralAxis.Coverage.Bounds">
    <PARAM name="SpectralExtent" utype="Char.SpectralAxis.Coverage.Bounds.Start"
                  unit="Angstrom" datatype="double" value="5200.0"/>
    <PARAM name="SpectralExtent" utype="Char.SpectralAxis.Coverage.Bounds.Stop"
                  unit="Angstrom" datatype="double" value="5600.0"/>
   </GROUP>
   <PARAM utype="Char.SpectralAxis.Coverage.Transmission" value="ivo://cfa.harvard.edu/vo/bands/FLWOCCD/V"/>
  </GROUP>
 </GROUP>

 <GROUP utype="spec:Char.FluxAxis">
  <GROUP utype="spec:Char.FluxAxis.Accuracy">
   <PARAM name="SysErr" utype="SysErr" unit="" datatype="float" value="0.05"/>
  </GROUP>
  <GROUP utype="spec:Char.FluxAxis.Correction">
   <GROUP utype="spec:Char.FluxAxis.Correction.ApFrac">
    <PARAM name="ApFrac" utype="value" unit="" datatype="float" value="0.92"/>
    <PARAM name="ApFracApp" utype="applied" unit="" datatype="boolean" value="T"/>
```

```
<GROUP utype="spec:Curation">
 <PARAM name="Publisher" utype="spec:Curation.Publisher" ucd="meta.organization;meta.curation"
                    datatype="char" arraysize="*" value="SAO"/>
 <PARAM name="PubID" utype="spec:Curation.PublisherID" ucd="meta.curation.pubid" datatype="char"
                                    arraysize="*" value="ivo://cfa.harvard.edu"/>
 <PARAM name="Contact" utype="spec:Curation.Contact.Name" ucd="meta.human;meta.curation"
                    datatype="char" arraysize="*" value="Jonathan McDowell"/>
 <PARAM name="email" utype="spec:Curation.Contact.Email" ucd="meta.email" datatype="char"
                                    arraysize="*" value="jcm@cfa.harvard.edu"/>
</GROUP>


<GROUP utype="spec:DataID">
 <PARAM name="Title" utype="spec:DataID.Title" datatype="char" arraysize="*" value="Arp 220 SED"/>
 <PARAM name="Creator" utype="spec:Segment.DataID.Creator" ucd="meta.curation.creator" datatype="char"
                                    arraysize="*" value="ivo://sao/FLWO"/>
 <PARAM name="DataDate" utype="spec:DataID.Date" ucd="time;soft.dataset;meta.curation"
                    datatype="char" arraysize="*" value="2003-12-31T14:00:02Z"/>
 <PARAM name="Version" utype="spec:DataID.Version" ucd="soft.dataset.version;meta.curation"
                    datatype="char" arraysize="*" value="1"/>
 <PARAM name="Instrument" utype="spec:DataID.Instrument" ucd="inst.id" datatype="char"
                                    arraysize="*" value="48-inch CCD"/>
 <PARAM name="Filter" utype="spec:DataID.Collection" ucd="inst.filter.id" datatype="char"
                                    arraysize="*" value="V"/>
 <PARAM name="CreationType" utype="spec:DataID.CreationType" datatype="char" arraysize="*" value="Archival"/>
 <PARAM name="Logo" utype="spec:DataID.Logo" ucd="meta.curation.logo" datatype="char"
                                        arraysize="*" value="http://cfa-www.harvard.edu/nvo/cfalogo.jpg"/>
</GROUP>
```

```
<GROUP utype="spec:Data">

<GROUP utype="spec:Data.FluxAxis">
 <FIELDref ref="Flux1"/>
 <GROUP utype="spec:Data.FluxAxis.Accuracy">
  <FIELDref ref="ErrorLow"/>
  <FIELDref ref="ErrorHigh"/>
 </GROUP>
</GROUP>
</GROUP>

</GROUP>

<FIELD name="Flux" ID="Flux1" utype="spec:Data.FluxAxis.value" ucd="phot.flux.density;em.wavelength"
              datatype="double" unit="mag"/>
<FIELD name="ErrorLow" ID="ErrorLow" utype="spec:Data.FluxAxis.Accuracy.StatErrLow"
              datatype="double" unit="mag"/>
<FIELD name="ErrorHigh" ID="ErrorHigh" utype="spec:Data.FluxAxis.Accuracy.StatErrHigh"
              datatype="double" unit="mag"/>

<DATA>
<TABLEDATA>
<TR><TD>15.52</TD><TD>0.02</TD><TD>0.015</TD></TR>
</TABLEDATA>
</DATA>
</TABLE>
</RESOURCE>
</VOTABLE>
```

Example 2: Here is an example of a light curve: recall that the Spectrum model defines how to record time-resolved data in MJD, so we inherit that description.

```xml
<?xml version="1.0" encoding="UTF-8"?>
<VOTABLE version="1.1"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  xsi:noNamespaceSchemaLocation="xmlns:http://www.ivoa.net/xml/VOTable/VOTable-1.1.xsd"
  xmlns:spec="http://www.ivoa.net/xml/SpectrumModel/v1.01"
  xmlns="http://www.ivoa.net/xml/VOTable/v1.1">
<RESOURCE utype="spec:Spectrum">

<TABLE utype="spec:Spectrum">
<GROUP utype="spec:Target">
 <PARAM name="Target" utype="spec:Target.Name" datatype="char" arraysize="*" value="Arp 220"/>
 <PARAM name="TargetPos" utype="spec:Target.pos" unit="deg" datatype="double"
                                  arraysize="2" value="233.737917 23.503330"/>
 <PARAM name="z" utype="spec:Target.redshift" datatype="float" value="0.0018"/>
</GROUP>

<!-- SegmentType can be Photometry, TimeSeries or Spectrum -->
<PARAM name="Segtype" utype="spec:SegmentType" datatype="char" arraysize="*"
                                                value="Photometry" ucd="meta.code"/>
<GROUP name="CoordSys" utype="spec:CoordSys">
 <GROUP utype="CoordSys.SpaceFrame">
   <PARAM name="System" utype="spec:CoordSys.SpaceFrame.Name" ucd="frame.pos.system"
                                      datatype="char" arraysize="*" value="ICRS"/>
   <PARAM name="Equinox" utype="spec:CoordSys.SpaceFrame.Equinox" ucd="time.equinox;pos.eq"
                                      datatype="float" value="2000.0" />
 </GROUP>
 <GROUP utype="spec:CoordSys.TimeFrame">
  <PARAM name="TimeFrame" utype="spec:CoordSys.TimeFrame.Name" ucd="frame.time.scale" datatype="char"
                                     arraysize="*" value="UTC"/>
 </GROUP>
 <GROUP utype="spec:CoordSys.SpectralFrame">
  <PARAM name="SpectralFrame" utype="spec:CoordSys.SpectralFrame.RefPos" ucd="frame.em.system"
                                      datatype="char" arraysize="*" value="TOPOCENTER"/>
 </GROUP>

 <GROUP utype="spec:CoordSys.Band">
  <PARAM name="FluxAxisID" utype="CoordSys.Band.Name"  value="FLWO CCD V"/>
  <PARAM name="FluxAxisGID" utype="CoordSys.Band.GenID"  value="V"/>
  <PARAM name="FluxAxisDesc" utype="CoordSys.Band.Desc"  value="Johnson V magnitude photometry"/>
  <GROUP utype="spec:CoordSys.Band.Zero">
   <GROUP utype="spec:CoordSys.Band.Zero.SpCo">
    <PARAM name="FluxAxisRefMag" utype="CoordSys.Band.Zero.SpCo.Value" value="5400"/>
    <PARAM name="FluxAxisRefUnit" utype="CoordSys.Band.Zero.SpCo.Unit" value="Angstrom"/>
    <PARAM name="FluxAxisRefUCD" utype="CoordSys.Band.Zero.SpCo.UCD" value="em.wl"/>
   </GROUP>
   <GROUP utype="spec:CoordSys.Band.Zero.Flux">
    <PARAM name="FluxAxisRefMag" utype="CoordSys.Band.Zero.Flux.Value" value="3548.0"/>
    <PARAM name="FluxAxisRefUnit" utype="CoordSys.Band.Zero.Flux.Unit" value="Jy"/>
    <PARAM name="FluxAxisRefUCD" utype="CoordSys.Band.Zero.Flux.UCD" value="phot.flux.density;em.freq"/>
   </GROUP>
  </GROUP>
  <PARAM name="FluxAxisRefSpec" utype="CoordSys.Band.RefSpec" value="ivo://cfa.harvard.edu/vo/templates/Vega"/>
 </GROUP>



</GROUP>
```

```xml
<GROUP utype="spec:Char">
 <GROUP utype="spec:Char.SpatialAxis">
   <PARAM name="SpatialAxisName" utype="name" ucd="pos.eq" unit="deg" value="Sky"/>
   <GROUP utype="spec:Char.SpatialAxis.Coverage">
    <GROUP utype="spec:Char.SpatialAxis.Coverage.Location">
     <PARAM name="SkyPos" utype="Char.SpatialAxis.Coverage.Location.Value"
                                ucd="pos.eq" unit="deg"
                                datatype="double" arraysize="2" value="132.4210 12.1232"/>
   </GROUP>
   <GROUP utype="Bounds">
     <PARAM name="SkyExtent" utype="Char.SpatialAxis.Coverage.Extent" ucd="pos.region.diameter"
                   datatype="double" unit="arcsec" value="20"/>
   </GROUP>
  </GROUP>
 </GROUP>



 <GROUP utype="spec:Char.TimeAxis">
  <PARAM name="TimeAxisName" utype="Char.TimeAxis.Name" ucd="time" unit="d" value="Time"/>
  <GROUP utype="Char.TimeAxis.Coverage">
   <GROUP utype="Char.TimeAxis.Coverage.Location">
    <PARAM name="TimeObs" utype="Char.TimeAxis.Coverage.Location.Value" ucd="time.obs"
                                 datatype="double" value="55510.0000"/>
   </GROUP>
   <GROUP utype="Char.TimeAxis.Coverage.Bounds">
    <PARAM name="TimeExtent" utype="Char.TimeAxis.Coverage.Bounds.Extent" ucd="time.duration"
                   unit="d" datatype="double" value="0.5" />
    <PARAM name="TimeStart" utype="Char.TimeAxis.Coverage.Bounds.Start" ucd="time" unit="d"
                                     datatype="double" value="55510.000" />
    <PARAM name="TimeStop" utype="Char.TimeAxis.Coverage.Bounds.Stop" ucd="time" unit="d"
                                     datatype="double" value="55510.500" />
   </GROUP>
  </GROUP>
 </GROUP>

 <GROUP utype="spec:Char.SpectralAxis">
  <PARAM name="SpectralAxisName" utype="Char.SpectralAxis.Name" ucd="em.wl" unit="Angstrom" value="Wavelength"/>
  <GROUP utype="Char.SpectralAxis.Coverage">
   <GROUP utype="Char.SpectralAxis.Coverage.Location">
    <PARAM name="SpectralExtent" utype="Char.SpectralAxis.Coverage.Location.Value"
                   unit="Angstrom" datatype="double" value="5400.0"/>
   </GROUP>
   <GROUP utype="Char.SpectralAxis.Coverage.Bounds">
    <PARAM name="SpectralExtent" utype="Char.SpectralAxis.Coverage.Bounds.Start"
                   unit="Angstrom" datatype="double" value="5200.0"/>
    <PARAM name="SpectralExtent" utype="Char.SpectralAxis.Coverage.Bounds.Stop"
                   unit="Angstrom" datatype="double" value="5600.0"/>
   </GROUP>
   <PARAM utype="Char.SpectralAxis.Coverage.Transmission" value="ivo://cfa.harvard.edu/vo/bands/FLWOCCD/V"/>
  </GROUP>
 </GROUP>

</GROUP>
```

```
<GROUP utype="spec:Curation">
 <PARAM name="Publisher" utype="spec:Curation.Publisher" ucd="meta.organization;meta.curation"
                       datatype="char" arraysize="*" value="SAO"/>
 <PARAM name="PubID" utype="spec:Curation.PublisherID" ucd="meta.curation.pubid" datatype="char"
                                     arraysize="*" value="ivo://cfa.harvard.edu"/>
 <PARAM name="Contact" utype="spec:Curation.Contact.Name" ucd="meta.human;meta.curation"
                       datatype="char" arraysize="*" value="Jonathan McDowell"/>
 <PARAM name="email" utype="spec:Curation.Contact.Email" ucd="meta.email" datatype="char"
                                     arraysize="*" value="jcm@cfa.harvard.edu"/>
</GROUP>


<GROUP utype="spec:DataID">
 <PARAM name="Title" utype="spec:DataID.Title" datatype="char" arraysize="*" value="Arp 220 SED"/>
 <PARAM name="Creator" utype="spec:Segment.DataID.Creator" ucd="meta.curation.creator" datatype="char"
                                     arraysize="*" value="ivo://sao/FLWO"/>
 <PARAM name="DataDate" utype="spec:DataID.Date" ucd="time;soft.dataset;meta.curation"
                       datatype="char" arraysize="*" value="2003-12-31T14:00:02Z"/>
 <PARAM name="Version" utype="spec:DataID.Version" ucd="soft.dataset.version;meta.curation"
                       datatype="char" arraysize="*" value="1"/>
 <PARAM name="Instrument" utype="spec:DataID.Instrument" ucd="inst.id" datatype="char"
                                     arraysize="*" value="48-inch CCD"/>
 <PARAM name="Filter" utype="spec:DataID.Collection" ucd="inst.filter.id" datatype="char"
                                     arraysize="*" value="V"/>
 <PARAM name="CreationType" utype="spec:DataID.CreationType" datatype="char" arraysize="*" value="Archival"/>
 <PARAM name="Logo" utype="spec:DataID.Logo" ucd="meta.curation.logo" datatype="char"
                                     arraysize="*" value="http://cfa-www.harvard.edu/nvo/cfalogo.jpg"/>
</GROUP>
```

```
<GROUP utype="spec:Data">

 <GROUP utype="spec:Data.TimeAxis">
 <FIELDref ref="Time"/>
 </GROUP>
 <GROUP utype="spec:Data.FluxAxis">
 <FIELDref ref="Flux1"/>
  <GROUP utype="spec:Data.FluxAxis.Accuracy">
   <FIELDref ref="ErrorLow"/>
   <FIELDref ref="ErrorHigh"/>
  <PARAM name="SysErr" utype="SysErr" unit="" datatype="float" value="0.05"/>
  </GROUP>
 </GROUP>
</GROUP>
<FIELD name="Time" ID="Time" utype="spec:Data.TimeAxis.value" ucd="time"
              datatype="double" unit="d"/>
<FIELD name="Flux" ID="Flux1" utype="spec:Data.FluxAxis.value" ucd="phot.flux.density;em.wavelength"
              datatype="double" unit="mag"/>
<FIELD name="ErrorLow" ID="ErrorLow" utype="spec:Data.FluxAxis.Accuracy.StatErrLow"
              datatype="double" unit="mag"/>
<FIELD name="ErrorHigh" ID="ErrorHigh" utype="spec:Data.FluxAxis.Accuracy.StatErrHigh"
              datatype="double" unit="mag"/>

<DATA>
<TABLEDATA>
<TR>55510.0000<TD>15.52</TD><TD>0.02</TD><TD>0.015</TD></TR>
<TR>55510.0400<TD>15.51</TD><TD>0.02</TD><TD>0.015</TD></TR>
<TR>55510.2812<TD>14.02</TD><TD>0.02</TD><TD>0.015</TD></TR>
<TR>55510.4487<TD>14.83</TD><TD>0.02</TD><TD>0.015</TD></TR>
</TABLEDATA>
</DATA>
</TABLE>
</RESOURCE>
</VOTABLE>
```

Example 3: Here is an example of a filter band definition with CoordSys; the data is the transmission curve. This is what the Band and Transmission elements in a photometry dataset would point to.

```xml
<?xml version="1.0" encoding="UTF-8"?>
<VOTABLE version="1.1"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  xsi:noNamespaceSchemaLocation="xmlns:http://www.ivoa.net/xml/VOTable/VOTable-1.1.xsd"
  xmlns:spec="http://www.ivoa.net/xml/SpectrumModel/v1.01"
  xmlns="http://www.ivoa.net/xml/VOTable/v1.1">
<RESOURCE utype="spec:Spectrum">

<TABLE utype="spec:Spectrum">
<!-- SegmentType can be Photometry, TimeSeries or Spectrum -->
<PARAM name="Segtype" utype="spec:SegmentType" datatype="char" arraysize="*"
                                            value="Spectrum" ucd="meta.code"/>
<GROUP name="CoordSys" utype="spec:CoordSys">
 <GROUP utype="spec:CoordSys.SpectralFrame">
  <PARAM name="SpectralFrame" utype="spec:CoordSys.SpectralFrame.RefPos" ucd="frame.em.system"
                                    datatype="char" arraysize="*" value="TOPOCENTER"/>
 </GROUP>
 <GROUP utype="spec:CoordSys.Band">
  <PARAM name="FluxAxisID" utype="CoordSys.Band.Name"  value="FLWO CCD V"/>
  <PARAM name="FluxAxisGID" utype="CoordSys.Band.GenID"  value="V"/>
  <PARAM name="FluxAxisDesc" utype="CoordSys.Band.Desc"  value="Johnson V magnitude photometry"/>
  <GROUP utype="spec:CoordSys.Band.Zero">
   <GROUP utype="spec:CoordSys.Band.Zero.SpCo">
    <PARAM name="FluxAxisRefMag" utype="CoordSys.Band.Zero.SpCo.Value" value="5400"/>
    <PARAM name="FluxAxisRefUnit" utype="CoordSys.Band.Zero.SpCo.Unit" value="Angstrom"/>
    <PARAM name="FluxAxisRefUCD" utype="CoordSys.Band.Zero.SpCo.UCD" value="em.wl"/>
   </GROUP>
   <GROUP utype="spec:CoordSys.Band.Zero.Flux">
    <PARAM name="FluxAxisRefMag" utype="CoordSys.Band.Zero.Flux.Value" value="3548.0"/>
    <PARAM name="FluxAxisRefUnit" utype="CoordSys.Band.Zero.Flux.Unit" value="Jy"/>
    <PARAM name="FluxAxisRefUCD" utype="CoordSys.Band.Zero.Flux.UCD" value="phot.flux.density;em.freq"/>
   </GROUP>
  </GROUP>
  <PARAM name="FluxAxisRefSpec" utype="CoordSys.Band.RefSpec" value="ivo://cfa.harvard.edu/vo/templates/Vega"/>
 </GROUP>
</GROUP>
```

```
<GROUP utype="spec:Char">
 <GROUP utype="spec:Char.TimeAxis">
  <PARAM name="TimeAxisName" utype="Char.TimeAxis.Name" ucd="time" unit="d" value="Time"/>
  <GROUP utype="Char.TimeAxis.Coverage">
   <GROUP utype="Char.TimeAxis.Coverage.Location">
    <PARAM name="TimeObs" utype="Char.TimeAxis.Coverage.Location.Value" ucd="time.obs"
                                datatype="double" value="52100.000"/>
   </GROUP>
   <GROUP utype="Char.TimeAxis.Coverage.Bounds">
    <PARAM name="TimeStart" utype="Char.TimeAxis.Coverage.Bounds.Start" ucd="time" unit="s"
                                datatype="double" value="52100.000" />
    <PARAM name="TimeStop" utype="Char.TimeAxis.Coverage.Bounds.Stop" ucd="time" unit="s"
                                datatype="double" value="62000.000" />
   </GROUP>

  </GROUP>
 </GROUP>

 <GROUP utype="spec:Char.SpectralAxis">
  <PARAM name="SpectralAxisName" utype="Char.SpectralAxis.Name" ucd="em.wl" unit="Angstrom" value="Wavelength"/>
  <GROUP utype="Char.SpectralAxis.Coverage">
   <GROUP utype="Char.SpectralAxis.Coverage.Location">
    <PARAM name="SpectralExtent" utype="Char.SpectralAxis.Coverage.Location.Value"
                     unit="Angstrom" datatype="double" value="5400.0"/>
   </GROUP>
   <GROUP utype="Char.SpectralAxis.Coverage.Bounds">
    <PARAM name="SpectralExtent" utype="Char.SpectralAxis.Coverage.Bounds.Start"
                     unit="Angstrom" datatype="double" value="5200.0"/>
    <PARAM name="SpectralExtent" utype="Char.SpectralAxis.Coverage.Bounds.Stop"
                     unit="Angstrom" datatype="double" value="5600.0"/>
   </GROUP>
  </GROUP>
 </GROUP>

</GROUP>
```

```
<GROUP utype="spec:Curation">
 <PARAM name="Publisher" utype="spec:Curation.Publisher" ucd="meta.organization;meta.curation"
                        datatype="char" arraysize="*" value="SAO"/>
 <PARAM name="PubID" utype="spec:Curation.PublisherID" ucd="meta.curation.pubid" datatype="char"
                                    arraysize="*" value="ivo://cfa.harvard.edu"/>
 <PARAM name="Contact" utype="spec:Curation.Contact.Name" ucd="meta.human;meta.curation"
                        datatype="char" arraysize="*" value="Jonathan McDowell"/>
 <PARAM name="email" utype="spec:Curation.Contact.Email" ucd="meta.email" datatype="char"
                                    arraysize="*" value="jcm@cfa.harvard.edu"/>
</GROUP>


<GROUP utype="spec:DataID">
 <PARAM name="Title" utype="spec:DataID.Title" datatype="char" arraysize="*" value="FLWO CCD V filter"/>
 <PARAM name="Creator" utype="spec:Segment.DataID.Creator" ucd="meta.curation.creator" datatype="char"
                                    arraysize="*" value="ivo://sao/FLWO"/>
 <PARAM name="DataDate" utype="spec:DataID.Date" ucd="time;soft.dataset;meta.curation"
                        datatype="char" arraysize="*" value="2003-12-31T14:00:02Z"/>
 <PARAM name="Version" utype="spec:DataID.Version" ucd="soft.dataset.version;meta.curation"
                        datatype="char" arraysize="*" value="1"/>
 <PARAM name="Instrument" utype="spec:DataID.Instrument" ucd="inst.id" datatype="char"
                                    arraysize="*" value="48-inch CCD"/>
 <PARAM name="Filter" utype="spec:DataID.Collection" ucd="inst.filter.id" datatype="char"
                                    arraysize="*" value="V"/>
 <PARAM name="CreationType" utype="spec:DataID.CreationType" datatype="char" arraysize="*" value="Archival"/>
 <PARAM name="Logo" utype="spec:DataID.Logo" ucd="meta.curation.logo" datatype="char"
                                        arraysize="*" value="http://cfa-www.harvard.edu/nvo/cfalogo.jpg"/>
</GROUP>
```

```
<GROUP utype="spec:Data">

<GROUP utype="spec:Data.FluxAxis">
 <FIELDref ref="Wavelength"/>
 <FIELDref ref="Transmission"/>
</GROUP>

</GROUP>

<FIELD name="Wavelength" ID="Wavelength" utype="spec:Data.Spectral.value" ucd="em.wl"
            datatype="double" unit="Angstrom"/>
<FIELD name="Transmission" ID="Transmission" utype="spec:Data.FluxAxis.value" ucd="phys.transmission"
            datatype="double" unit=""/>
<DATA>
<TABLEDATA>
<TR><TD>4600 </TD><TD>0.00</TD></TR>
<TR><TD>4800 </TD><TD>0.02</TD></TR>
<TR><TD>5000 </TD><TD>0.38</TD></TR>
<TR><TD>5200 </TD><TD>0.91</TD></TR>
<TR><TD>5400 </TD><TD>0.98</TD></TR>
<TR><TD>5600 </TD><TD>0.72</TD></TR>
<TR><TD>5800 </TD><TD>0.62</TD></TR>
<TR><TD>6000 </TD><TD>0.40</TD></TR>
<TR><TD>6200</TD><TD> 0.20</TD></TR>
<TR><TD>6400</TD><TD> 0.08</TD></TR>
<TR><TD>6600</TD><TD>0.02</TD></TR>
<TR><TD>6800</TD><TD> 0.01</TD></TR>
<TR><TD>7000</TD><TD> 0.01</TD></TR>
<TR><TD>7200</TD><TD>0.01</TD></TR>
<TR><TD>7400</TD><TD> 0.00</TD></TR>
</TABLEDATA>
</DATA>
</TABLE>
</RESOURCE>
</VOTABLE>
```

Example 4: Here is an example of a table with multiple bands, referring to external band definitions.

```xml
<?xml version="1.0" encoding="UTF-8"?>
<VOTABLE version="1.1"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  xsi:noNamespaceSchemaLocation="xmlns:http://www.ivoa.net/xml/VOTable/VOTable-1.1.xsd"
  xmlns:spec="http://www.ivoa.net/xml/SpectrumModel/v1.01"
  xmlns="http://www.ivoa.net/xml/VOTable/v1.1">
<RESOURCE utype="spec:Spectrum">

<TABLE utype="spec:Spectrum">
<GROUP utype="spec:Target">
 <PARAM name="Target" utype="spec:Target.Name" datatype="char" arraysize="*" value="Arp 220"/>
 <PARAM name="TargetPos" utype="spec:Target.pos" unit="deg" datatype="double"
                              arraysize="2" value="233.737917 23.503330"/>
 <PARAM name="z" utype="spec:Target.redshift" datatype="float" value="0.0018"/>
</GROUP>

<!-- SegmentType can be Photometry, TimeSeries or Spectrum -->
<PARAM name="Segtype" utype="spec:SegmentType" datatype="char" arraysize="*"
                              value="Photometry" ucd="meta.code"/>
<GROUP name="CoordSys" utype="spec:CoordSys">
 <GROUP utype="CoordSys.SpaceFrame">
   <PARAM name="System" utype="spec:CoordSys.SpaceFrame.Name" ucd="frame.pos.system"
                              datatype="char" arraysize="*" value="ICRS"/>
   <PARAM name="Equinox" utype="spec:CoordSys.SpaceFrame.Equinox" ucd="time.equinox;pos.eq"
                              datatype="float" value="2000.0" />
 </GROUP>
 <GROUP utype="spec:CoordSys.TimeFrame">
  <PARAM name="TimeFrame" utype="spec:CoordSys.TimeFrame.Name" ucd="frame.time.scale" datatype="char"
                              arraysize="*" value="UTC"/>
 </GROUP>
 <GROUP utype="spec:CoordSys.SpectralFrame">
  <PARAM name="SpectralFrame" utype="spec:CoordSys.SpectralFrame.RefPos" ucd="frame.em.system"
                              datatype="char" arraysize="*" value="TOPOCENTER"/>
 </GROUP>

 <GROUP utype="spec:CoordSys.Band">
  <PARAM name="FluxAxisName" utype="CoordSys.Band.Name"  value="U"/>
  <PARAM name="FluxAxisID" utype="CoordSys.Band.ID"  value="ivo://cfa.harvard.edu/vo/bands/FLWO/U"/>
 </GROUP>

 <GROUP utype="spec:CoordSys.Band">
  <PARAM name="FluxAxisName" utype="CoordSys.Band.Name"  value="B"/>
  <PARAM name="FluxAxisID" utype="CoordSys.Band.ID"  value="ivo://cfa.harvard.edu/vo/bands/FLWO/B"/>
 </GROUP>

 <GROUP utype="spec:CoordSys.Band">
  <PARAM name="FluxAxisName" utype="CoordSys.Band.Name"  value="V"/>
  <PARAM name="FluxAxisID" utype="CoordSys.Band.ID"  value="ivo://cfa.harvard.edu/vo/bands/FLWO/V"/>
 </GROUP>


</GROUP>
```

```xml
<GROUP utype="spec:Char">
 <GROUP utype="spec:Char.SpatialAxis">
   <PARAM name="SpatialAxisName" utype="name" ucd="pos.eq" unit="deg" value="Sky"/>
   <GROUP utype="spec:Char.SpatialAxis.Coverage">
    <GROUP utype="spec:Char.SpatialAxis.Coverage.Location">
     <PARAM name="SkyPos" utype="Char.SpatialAxis.Coverage.Location.Value"
                          ucd="pos.eq" unit="deg"
                          datatype="double" arraysize="2" value="132.4210 12.1232"/>
    </GROUP>
    <GROUP utype="Bounds">
     <PARAM name="SkyExtent" utype="Char.SpatialAxis.Coverage.Extent" ucd="pos.region.diameter"
                  datatype="double" unit="arcsec" value="20"/>
    </GROUP>
   </GROUP>
 </GROUP>



 <GROUP utype="spec:Char.TimeAxis">
  <PARAM name="TimeAxisName" utype="Char.TimeAxis.Name" ucd="time" unit="d" value="Time"/>
  <GROUP utype="Char.TimeAxis.Coverage">
   <GROUP utype="Char.TimeAxis.Coverage.Location">
    <PARAM name="TimeObs" utype="Char.TimeAxis.Coverage.Location.Value" ucd="time.obs"
                          datatype="double" value="55510.0000"/>
   </GROUP>
   <GROUP utype="Char.TimeAxis.Coverage.Bounds">
    <PARAM name="TimeExtent" utype="Char.TimeAxis.Coverage.Bounds.Extent" ucd="time.duration"
                  unit="d" datatype="double" value="0.5" />
    <PARAM name="TimeStart" utype="Char.TimeAxis.Coverage.Bounds.Start" ucd="time" unit="d"
                              datatype="double" value="55510.000" />
    <PARAM name="TimeStop" utype="Char.TimeAxis.Coverage.Bounds.Stop" ucd="time" unit="d"
                              datatype="double" value="55510.500" />
   </GROUP>
  </GROUP>
 </GROUP>

 <GROUP utype="spec:Char.SpectralAxis">
  <PARAM name="SpectralAxisName" utype="Char.SpectralAxis.Name" ucd="em.wl" unit="Angstrom" value="Wavelength"/>
  <GROUP utype="Char.SpectralAxis.Coverage">
   <GROUP utype="Char.SpectralAxis.Coverage.Location">
    <PARAM name="SpectralExtent" utype="Char.SpectralAxis.Coverage.Location.Value"
                  unit="Angstrom" datatype="double" value="5400.0"/>
   </GROUP>
   <GROUP utype="Char.SpectralAxis.Coverage.Bounds">
    <PARAM name="SpectralExtent" utype="Char.SpectralAxis.Coverage.Bounds.Start"
                  unit="Angstrom" datatype="double" value="5200.0"/>
    <PARAM name="SpectralExtent" utype="Char.SpectralAxis.Coverage.Bounds.Stop"
                  unit="Angstrom" datatype="double" value="5600.0"/>
   </GROUP>
   <PARAM utype="Char.SpectralAxis.Coverage.Transmission" value="ivo://cfa.harvard.edu/vo/bands/FLWOCCD/V"/>
  </GROUP>
 </GROUP>

</GROUP>
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```
<GROUP utype="spec:Curation">
 <PARAM name="Publisher" utype="spec:Curation.Publisher" ucd="meta.organization;meta.curation"
                        datatype="char" arraysize="*" value="SAO"/>
 <PARAM name="PubID" utype="spec:Curation.PublisherID" ucd="meta.curation.pubid" datatype="char"
                                       arraysize="*" value="ivo://cfa.harvard.edu"/>
 <PARAM name="Contact" utype="spec:Curation.Contact.Name" ucd="meta.human;meta.curation"
                        datatype="char" arraysize="*" value="Jonathan McDowell"/>
 <PARAM name="email" utype="spec:Curation.Contact.Email" ucd="meta.email" datatype="char"
                                       arraysize="*" value="jcm@cfa.harvard.edu"/>
</GROUP>


<GROUP utype="spec:DataID">
 <PARAM name="Title" utype="spec:DataID.Title" datatype="char" arraysize="*" value="Arp 220 SED"/>
 <PARAM name="Creator" utype="spec:Segment.DataID.Creator" ucd="meta.curation.creator" datatype="char"
                                       arraysize="*" value="ivo://sao/FLWO"/>
 <PARAM name="DataDate" utype="spec:DataID.Date" ucd="time;soft.dataset;meta.curation"
                        datatype="char" arraysize="*" value="2003-12-31T14:00:02Z"/>
 <PARAM name="Version" utype="spec:DataID.Version" ucd="soft.dataset.version;meta.curation"
                        datatype="char" arraysize="*" value="1"/>
 <PARAM name="Instrument" utype="spec:DataID.Instrument" ucd="inst.id" datatype="char"
                                       arraysize="*" value="48-inch CCD"/>
 <PARAM name="Filter" utype="spec:DataID.Collection" ucd="inst.filter.id" datatype="char"
                                       arraysize="*" value="V"/>
 <PARAM name="CreationType" utype="spec:DataID.CreationType" datatype="char" arraysize="*" value="Archival"/>
 <PARAM name="Logo" utype="spec:DataID.Logo" ucd="meta.curation.logo" datatype="char"
                                          arraysize="*" value="http://cfa-www.harvard.edu/nvo/cfalogo.jpg"/>
</GROUP>
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```
<GROUP utype="spec:Data">

 <GROUP utype="spec:Data.TimeAxis">
 <FIELDref ref="Time"/>
 </GROUP>
 <GROUP utype="spec:Data.SpectralAxis">
  <FIELDref ref="BandID"/>
 </GROUP>
 <GROUP utype="spec:Data.FluxAxis">
 <FIELDref ref="Flux1"/>
  <GROUP utype="spec:Data.FluxAxis.Accuracy">
   <FIELDref ref="ErrorLow"/>
   <FIELDref ref="ErrorHigh"/>
  <PARAM name="SysErr" utype="SysErr" unit="" datatype="float" value="0.05"/>
  </GROUP>
 </GROUP>
</GROUP>
<FIELD name="Time" ID="Time" utype="spec:Data.TimeAxis.value" ucd="time"
               datatype="double" unit="d"/>

<FIELD name="BandID" ID="BandID" utype="spec:Data.SpectralAxis.value" ucd=""
               datatype="string" unit=""/>

<FIELD name="Flux" ID="Flux1" utype="spec:Data.FluxAxis.value" ucd="phot.flux.density;em.wavelength"
               datatype="double" unit="mag"/>
<FIELD name="ErrorLow" ID="ErrorLow" utype="spec:Data.FluxAxis.Accuracy.StatErrLow"
               datatype="double" unit="mag"/>
<FIELD name="ErrorHigh" ID="ErrorHigh" utype="spec:Data.FluxAxis.Accuracy.StatErrHigh"
               datatype="double" unit="mag"/>

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</RESOURCE>
</VOTABLE>
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