



*International  
Virtual  
Observatory  
Alliance*

## Time Series Annotation in VOTable Version 0.1

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Working group

Data Model

This version

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Latest version

<http://www.ivoa.net/documents/TimeSeries>

Previous versions

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### Abstract

This document describes a proposal to annotate in a VOTable time series data. It is limited to the most common type of time series, i.e. tabular data containing a parameter measured as a function of time. The annotation reuses elements of existing Data Models when possible and defines a set of new elements. This document can be taken as a test case of the more general purpose model CADM.

### Status of this document

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

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

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## Acknowledgments

Should we acknowledge previous work from M. Graham and others  
ESCAPE

## Conformance-related definitions

The words “MUST”, “SHALL”, “SHOULD”, “MAY”, “RECOMMENDED”, and “OPTIONAL” (in upper or lower case) used in this document are to be interpreted as described in IETF standard RFC2119 (?).

The *Virtual Observatory (VO)* is a 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)** is a global collaboration of separately funded projects to develop standards and infrastructure that enable VO applications.

## 1 Introduction

This document describes how data providers can publish time series of tabular data to the Virtual Observatory. This document does not describe how data providers store or manipulate the data, it only concerns how the data are exposed to the world using well-defined metadata. This document assumes that the data provider already distributes time series as a single table, this table can contain several columns. This document does not limit the number of columns the time series can contain to those explicitly mentioned here. It only suggest metadata to the most common columns in time series.

## 2 The Time Series Structure

This document proposes the minimum metadata in VOTables to describe time series. We assume that the tabular data can contain multiple rows for each astronomical source and for mixed types of time series (e. g. different filters, positions, radial velocities) and sometimes even include different types of data (e. g. spectra, or images).

We propose using some elements previously defined, such as **TIMESYS** and **COOSYS** (when applicable) in VOTable1.4 ? and define a set of new elements as well as how to structure these elements. The aim is to be able to combine multiple time series when they have common elements as described in this document. We include in this document the definition of **TIMESYS** and **COOSYS** as described in VOTable and based on those, we define the new elements **FILTERSYS** following the same type of structure. If these elements were to be added or modified in future versions of VOTable it should be straight forward to update this document.

### 2.1 **TIMESYS** Element

**TIMESYS** contains information on the time scale, reference position and offset regarding the time of the observation ???. A service providing time series **MUST** provide this element. To reference the time system defined by a **TIMESYS** element, **FIELDS** (and possibly **PARAMs**) **MUST** reference the **TIMESYS** using the VOTable **ref** attribute. A **TIMESYS** element referenced via a **ref** attribute **SHOULD** appear before the element that references it. The elements of **TIMESYS**, reported in the specification of VOTable1.4 ??, are the following:

**ID** This attribute is used to reference **TIMESYS** elements from the elements using the time system.

**timeorigin** This is the time origin of the time coordinate, given as a Julian Date for the the time scale and reference point defined. It is usually given as a floating point literal; for convenience, the magic strings **MJD-origin** (standing for 2400000.5) and **JD-origin** (standing for 0) are also allowed. The **timeorigin** attribute **MUST** be given unless the time's representation contains a year of a calendar era, in which case it **MUST NOT** be present. In VOTables, these representations currently are Gregorian calendar years with **xtype** **timestamp**, or years in the Julian or Besselian calendar when a column has **yr**, **a** or **Ba** as its unit and no time origin is given.

**timescale** This is the time scale used. Values **SHOULD** be taken from the IVOA *timescale* vocabulary (<http://www.ivoa.net/rdf/timescale>). This attribute is mandatory.

**reposition** The reference position again is a simple string, the values of which SHOULD be taken from the IVOA *reposition* vocabulary (<http://www.ivoa.net/rdf/reposition>). This attribute is mandatory.

```
<TIMESYS ID="time_frame" reposition="BARYCENTER" timeorigin="2455197.5"
timescale="TCB"/>
```

## 2.2 COOSYS Element

**COOSYS** element defines a celestial coordinate system, to which the components of a position on the celestial sphere refer. To reference the time system defined by a **COOSYS** element, **FIELDs** (and possibly **PARAMs**) **MUST** reference the **COOSYS** using the VOTable **ref** attribute. A **COOSYS** element referenced via a **ref** attribute **SHOULD** appear before the element that references it. The elements of **COOSYS**, reported in the specification of VOTable1.4 ??, are the following:

**ID** This attribute is used to reference the **COOSYS** elements from the elements using the coordinate system. This attribute is mandatory.

**system** This attribute specifies the coordinate system among "BCRS", "ICRS", "eq\_FK5", "eq\_FK4", "ecl\_FK4", "ecl\_FK5", "galactic", "supergalactic".

**equinox** This attribute fixes the equatorial or ecliptic systems (e.g., "J2000" as the default for "eq\_FK5" or "B1950" as the default for "eq\_FK4").

**epoch** This attribute specifies the epoch of the positions when necessary.

```
<COOSYS ID="system" epoch="J2015.5" system="ICRS"/>
```

## 2.3 FILTERSYS Element

**FILTERSYS** contains information on the photometric system of the observations. This element is partially associated to the intermediate class PhotCal of the Photometry Data Model ?. A service providing time series of the type light-curve (e. g. magnitudes, fluxes) **MUST** provide this element. To reference the photometric system defined by a **FILTERSYS** element, **FIELDs** (and possibly **PARAMs**) **MUST** reference the **FILTERSYS** using the VOTable **ref** attribute. A **FILTERSYS** element referenced via a **ref** attribute **SHOULD** appear before the element that references it.

Each **FILTERSYS** is defined as a **GROUP** with the following mandatory terms:

**name**="FILTERSYS" The name of the **GROUP** **MUST** be set to FILTERSYS. We realize that although this proposed usage of the **name** is not common, it is not forbidden by VOTable (, see Section 3.2) and in this context it will help clients interpret the contents of the **GROUP**.

**ID** This attribute is used to reference the **FILTERSYS GROUP** from the elements using the photometric system. This attribute needs to be unique within the document so that it can be referenced by **FIELDS** and is mandatory.

**DESCRIPTION** This attribute is used to describe the **FILTERSYS GROUP**. This attribute is optional, but recommended.

**utype**="timeseries:PhotometryPoint"

The attributes of this **GROUP** are defined as **PARAMs** containing the following information:

**uniqueIdentifier** This is the **PARAM** element to uniquely identify the zero point assigned to a filter and to a specific photometric system. This element **MUST** have the following attributes:

**name**="uniqueIdentifier"  
**ucd**="meta.id;instr.filter"  
**utype**="photDM:PhotometryFilter.identifier"  
**datatype**="char"  
**value**="value" Value **SHOULD** follow the syntax: Facility/Subcategory/Band (e. g. **value**="GAIA/GAIA.G/G", **value**="Palomar/ZTF.r").

**zeroPointFlux** Photometric zero point associated to this instance. This element **MUST** have the following attributes:

**name**="zeroPointFlux"  
**ucd**="phot.mag;arith.zp"  
**utype**="photDM:PhotCal.zeroPoint.flux.value"  
**datatype**="datatype"  
**unit**="unit"  
**value**="value"

**magnitudeSystem** Magnitude system associated to this instance (Vega, AB, ...). This element **MUST** have the following attributes:

**name**="magnitudeSystem"  
**ucd**="meta.code"  
**utype**="photDM:PhotCal.magnitudeSystem.type"

```

datatype="char"
unit="unit"
value="value"

```

**effectiveWavelength** Effective wavelength of the filter in this instance.  
This element MUST have the following attributes:

```

name="effectiveWavelength"
ucd="em.wl.effective"
utype="photDM:PhotometryFilter.spectralLocation.value"
datatype="float"
unit="unit"
value="value"

```

Proposed annotation example for a **FILTERSYS** element:

```

<GROUP name="filtersys" ID="phot_sys" ucd="phot"
  utype="timeseries:PhotometryPoint" />
<DESCRIPTION>Photometric system description </DESCRIPTION>
<PARAM name="uniqueIdentifier" ucd="meta.id;instr.filter"
  utype="photDM:PhotometryFilter.identifier"
  datatype="char" unit="" value="Palomar/ZTF.g"/>
<PARAM name="zeroPointFlux" ucd="phot.mag;arith.zp"
  utype="photDM:PhotCal.zeroPoint.flux.value"
  datatype="float" unit="Jy" value="3963.97"/>
<PARAM name="magnitudeSystem" ucd="meta.code"
  utype="photDM:PhotCal.magnitudeSystem.type"
  datatype="char" unit="" value="Vega"/>
<PARAM name="effectiveWavelength" ucd="em.wl.effective"
  utype="photDM:PhotometryFilter.spectralLocation.value"
  datatype="float" unit="Angstrom" value="4722.74"/>
</GROUP>

```

While following the same approach as for **COOSYS** and **TIMESYS** would result in a more compact annotation, we decide to define this element as a **GROUP** to allow for some flexibility on the data provider side. We are aware that this implies clients to work around more complex annotations. We hope to alleviate that by following the exact **name** and **utype** convention as proposed in this document.

The alternative to doing this, and which would simplify the annotation, is to bring this **GROUP** element closer to the **COOSYS** and **TIMESYS** elements by fixing the units of the **zeroPointFlux** and the **effectiveWavelength** to Jy and Angstrom respectively and add it to future versions of VOTable. This would look as follows:

```

<FILTERSYS ID="phot_sys" uniqueIdentifier="Palomar/ZTF.g/Vega"
  zeroPointFlux="3963.97" magnitudeSystem="Vega"
  effectiveWavelength="4722.74" />

```

For other type of time series data not explicitly defined in this document we recommend to use the appropriate UCD1+ in agreement with <http://www.ivoa.net/documents/UCD1+/index.html>. The data provider is responsible for providing accurate metadata for the elements here described.

## 2.4 TABLE

We could propose to define one **TABLE** element to describe the content of each timeseries with common meta-data (e. g. one per filter) with no **DATA**, and to add in a separate **TABLE** element the **DATA** part which will reference the appropriate **TABLE** element. But to be honest I am not sure about the pros and cons of that at the moment of writing.

We propose to use the **TABLE** element for describing the contents of the time series data itself. One **TABLE** element **MUST** be present for each **FILTERSYS GROUP** element defined. The **TABLE** must include:

**name="timeseries"** This attribute is mandatory and it should be set to **timeseries**.

**utype="timeseries"** This attribute is mandatory and it **MUST** be set to **timeseries**.

**DESCRIPTION** Human readable text describing the time series. This element is mandatory.

**ref** One or several **ref** to reference to the **TIMESYS** element. At least one such reference **MUST** be provided.

**ref** One or several **ref** to reference to the **COOSYS** (when applicable).

**ref** One or several **ref** to reference to each **FILTERSYS** defined (when applicable).

We explored other ways of annotating the data, for instance defining different tables and the relation between them as possible according to Section 4.10 of VOTable1.4, or even proposing a new XMLDATA serialization. After exploring those possibilities we conclude that the proposed solution is the most appropriate within the actual and most accepted usage of VOTable for both existing data providers and clients.

## 3 Example of VOTable serialization

### 3.1 Case 1: lightcurves in one filter

Let us consider the simplest time series case possible: a table containing only three columns:

*time, magnitude, magnitude error*

the minimum VOTable would look like this:

```

<VOTABLE version="1.4" xmlns="http://www.ivoa.net/xml/VOTable/v1.3">
<RESOURCE>
<RESOURCE>
<COOSYS ID="ICRS" system="ICRS" epoch="J2015"/>
<TIMESYS ID="timesys" refposition="HELIOCENTER"
timeorigin="0" timescale="UNKOWN"/>
<GROUP name="filtersys" ID="phot_sys" ucd="phot"
utype="timeseries:PhotometryPoint" />
<DESCRIPTION>Photometric system description </DESCRIPTION>
<PARAM name="uniqueIdentifier" ucd="meta.id;instr.filter"
utype="photDM:PhotometryFilter.identifier"
datatype="char" unit="" value="Palomar/ZTF.g"/>
<PARAM name="zeroPointFlux" ucd="phot.mag;arith.zp"
utype="photDM:PhotCal.zeroPoint.flux.value"
datatype="float" unit="Jy" value="3963.97"/>
<PARAM name="magnitudeSystem" ucd="meta.code"
utype="photDM:PhotCal.magnitudeSystem.type"
datatype="char" unit="" value="Vega"/>
<PARAM name="effectiveWavelength" ucd="em.wl.effective"
utype="photDM:PhotometryFilter.spectralLocation.value"
datatype="float" unit="Angstrom" value="4722.74"/>
</GROUP>
</RESOURCE>
<RESOURCE>
<TABLE name="TIMESERIES" utype="timeseries">
<DESCRIPTION>Light curve in filter zg </DESCRIPTION>
<FIELD datatype="double" name="hjd" ucd="time.epoch;meta.main"
unit="d" ref="timesys">
<DESCRIPTION>Heliocentric Julian date </DESCRIPTION>
</FIELD>
<FIELD datatype="float" name="mag" ucd="phot.mag;em.opt" unit="mag"
ref="phot_sys">
<DESCRIPTION>Magnitude</DESCRIPTION>
</FIELD>
<FIELD datatype="float" name="magerr" ucd="stat.error;phot.mag;em.opt"
unit="mag" ref="phot_sys">
<DESCRIPTION>Uncertainty in mag measurement </DESCRIPTION>
</FIELD>
<DATA>
<TABLEDATA>
<TR>
<TD>2458662.830467246</TD>
<TD>16.292145</TD>
<TD>0.02101822</TD>
</TR>
</TABLEDATA>
</DATA>
</TABLE>
</RESOURCE>
</VOTABLE>

```

This annotation would also work in the case of tables including multiple light filters in the form



*time\_1, magnitude\_1, magnitude\_error\_1, time\_2,*  
*magnitude\_2, magnitude\_error\_2*

### 3.2 Case 2: lightcurves in multiple filters

Let us consider now consider a more complicated case, in which the time series includes a column with name of the photometric filter of each row of the time series, i. e. a table containing four columns:

*time, magnitude, magnitude error, filter name.*

In those cases this complicates the annotation and the need of being able to reference rows (as well as columns) becomes an issue. It is to overcome such problem, that we propose to use different **TABLE** elements for different types of products. We propose therefore to annotate a VOTable as shown in the following example:

```

<?xml version="1.0"
<VOTABLE version="1.4" xmlns="http://www.ivoa.net/xml/VOTable/v1.3">
<RESOURCE>
<RESOURCE>
<COOSYS ID="system" epoch="J2015.5" system="ICRS"/>
<TIMESYS ID="time_frame" reposition="BARYCENTER"
timeorigin="2455197.5" timescale="TCB"/>
<GROUP name="filtersys" ID="phot_sys-G" ucd="phot"
utype="timeseries:PhotometryPoint" />
<DESCRIPTION>GAIA G filter, DR2</DESCRIPTION>
<PARAM name="uniqueIdentifier" ucd="meta.id;instr.filter"
utype="photDM:PhotometryFilter.identifier"
datatype="char" unit="" value="GAIA/GAIA2.G"/>
<PARAM name="zeroPointFlux" ucd="phot.mag;arith.zp"
utype="photDM:PhotCal.zeroPoint.flux.value"
datatype="float" unit="Jy" value="3296.2"/>
<PARAM name="magnitudeSystem" ucd="meta.code"
utype="photDM:PhotCal.magnitudeSystem.type"
datatype="char" unit="" value="Vega"/>
<PARAM name="effectiveWavelength" ucd="em.wl.effective"
utype="photDM:PhotometryFilter.spectralLocation.value"
datatype="float" unit="Angstrom" value="6230.0"/>
</GROUP>
<GROUP name="filtersys" ID="phot_sys-Gbp" ucd="phot"
utype="timeseries:PhotometryPoint" />
<DESCRIPTION>GAIA Gbp filter, DR2</DESCRIPTION>
<PARAM name="uniqueIdentifier" ucd="meta.id;instr.filter"
utype="photDM:PhotometryFilter.identifier"
datatype="char" unit="" value="GAIA/GAIA2.Gbp"/>
<PARAM name="zeroPointFlux" ucd="phot.mag;arith.zp"
utype="photDM:PhotCal.zeroPoint.flux.value"
datatype="float" unit="Jy" value="3534.7"/>
<PARAM name="magnitudeSystem" ucd="meta.code"
utype="photDM:PhotCal.magnitudeSystem.type"
datatype="char" unit="" value="Vega"/>
<PARAM name="effectiveWavelength" ucd="em.wl.effective"
utype="photDM:PhotometryFilter.spectralLocation.value"
datatype="float" unit="Angstrom" value="5050.0"/>
</GROUP>
<GROUP name="filtersys" ID="phot_sys-Grp" ucd="phot"
utype="timeseries:PhotometryPoint" />
<DESCRIPTION>GAIA Grp filter, DR2</DESCRIPTION>
<PARAM name="uniqueIdentifier" ucd="meta.id;instr.filter"
utype="photDM:PhotometryFilter.identifier"
datatype="char" unit="" value="GAIA/GAIA2.Grp"/>
<PARAM name="zeroPointFlux" ucd="phot.mag;arith.zp"
utype="photDM:PhotCal.zeroPoint.flux.value"
datatype="float" unit="Jy" value="2620.3"/>
<PARAM name="magnitudeSystem" ucd="meta.code"
utype="photDM:PhotCal.magnitudeSystem.type"
datatype="char" unit="" value="Vega"/>
<PARAM name="effectiveWavelength" ucd="em.wl.effective"
utype="photDM:PhotometryFilter.spectralLocation.value"
datatype="float" unit="Angstrom" value="7730.0"/>
</GROUP>
</RESOURCE>

```

```

<RESOURCE>
<TABLE name="TIMESERIES" utype="timeseries">
  <DESCRIPTION>Light curve in filter G </DESCRIPTION>
<FIELD datatype="double" name="obs_time" ucd="time.epoch" unit="d"
  ref="time_frame"/>
<FIELD datatype="float" name="flux" ucd="phot.flux;em.opt.V"
  unit="s**-1" ref="phot_sys-G"/>
<FIELD datatype="float" name="mag" ucd="phot.mag;em.opt.V" unit="mag"
  ref="phot_sys-G"/>
<FIELD datatype="float" name="flux_error"
  ucd="stat.error;phot.flux;em.opt.V" unit="s**-1"
  ref="phot_sys-G"/>
<DATA>
<TABLEDATA>
...
</TABLEDATA>
</DATA>
</TABLE>
<TABLE name="TIMESERIES" utype="timeseries">
  <DESCRIPTION>Light curve in filter Gbp </DESCRIPTION>
<FIELD datatype="double" name="obs_time" ucd="time.epoch" unit="d"
  ref="time_frame"/>
<FIELD datatype="float" name="flux" ucd="phot.flux;em.opt.V"
  unit="s**-1" ref="phot_sys-Gbp"/>
<FIELD datatype="float" name="mag" ucd="phot.mag;em.opt.V" unit="mag"
  ref="phot_sys-Gbp"/>
<FIELD datatype="float" name="flux_error"
  ucd="stat.error;phot.flux;em.opt.V" unit="s**-1"
  ref="phot_sys-Gbp"/>
<DATA>
<TABLEDATA>
...
</TABLEDATA>
</DATA>
</TABLE>
<TABLE name="TIMESERIES" utype="timeseries">
  <DESCRIPTION>Light curve in filter Gbp </DESCRIPTION>
<FIELD datatype="double" name="obs_time" ucd="time.epoch" unit="d"
  ref="time_frame"/>
<FIELD datatype="float" name="flux" ucd="phot.flux;em.opt.V"
  unit="s**-1" ref="phot_sys-Grp"/>
<FIELD datatype="float" name="mag" ucd="phot.mag;em.opt.V" unit="mag"
  ref="phot_sys-Grp"/>
<FIELD datatype="float" name="flux_error"
  ucd="stat.error;phot.flux;em.opt.V" unit="s**-1"
  ref="phot_sys-Grp"/>
<DATA>
<TABLEDATA>
...
</TABLEDATA>
</DATA>
</TABLE>
</RESOURCE>
</VOTABLE>

```

Do we have to say something about claiming a new capability in the registry?

Do we want to add a summary table with utype, UCD1+, Meaning, Default value, Data type, required?