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Virtual
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Alliance

A Proposal for a TIMESYS Element in VOTable

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Working group
Time Domain

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Abstract

Interoperability for data sets containing time-valued data requires the unambiguous declaration of certain pieces of metadata for that data, in particular the declaration of the time scale used and the reference position for which a time is given. This note proposes a simple means to furnish times in VOTables with the necessary metadata. It is not intended to replace efforts on full STC annotation using an IVOA-approved data model, but rather to supplant it with an easily implemented and agreed-upon mechanism until the advanced technologies are sufficiently defined and adopted.

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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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 (Bradner, 1997).

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

1.1 History

While simple metadata of spatial coordinates could be declared in VOTables since before the first version of the standard (Ochsenbein and Williams et al., 2004) using the COOSYS element, the declaration of metadata of temporal coordinates was deferred to a comprehensive data model for space-time coordinates (STC). However, neither the data model (Rots, 2007) nor the mechanism annotate VOTables with the roles defined by it (Demleitner and Ochsenbein et al., 2010) gained sufficient traction in the community. While the IVOA community works towards replacing both the data model ("STC2") and the annotation mechanism ("VODML mapping"), the timescale for the wide adoption of these technologies is unclear.

In effect, there currently (late 2018) is no widely accepted standard for the association of time-valued columns in VOTables with its system metadata. Several proposals have been brought up by various parties. This note formalises one of them and will be compatible with all of them in the sense that the annotation proposed here will not conflict with further annotation.

1.2 Use Case and Scope

The basic interoperability use case for time series and similar data products in the VO is the combination of two time series. This requires bringing the two time coordinates into a common frame as regards time scales (e.g., UTC, TT, TDB) and reference positions (e.g., the instrument, the center of the Earth, the barycenter of the solar system, or perhaps even the Galactic center). Neglecting such metadata typically leads to errors of the order of a few tens of seconds in the case of the time scales (e.g., leap seconds or relativistic effects) or of a few minutes in the case of reference positions, although conceptually it might as well be tens of kiloyears if the Galactic center were allowed as a reference position.

An additional important piece of metadata is the time origin of the time scale (also called the "epoch", but since that term has a quite different meaning in many fields of astronomy, its usage for a zero point of a time scale is discouraged in VO contexts). For instance, the time origin of the Modified Julian Date (MJD) that is in wide use in the VO is 2400000.5 in Julian Date, whereas the time origin of the common Unix times is 1970-01-01T00:00:00 UTC. Other time origins are in wide use, either for added precision or for convenience.

Hence, this proposal covers the declaration of

1. the time scale
2. the reference position, and
3. the time origin

for any temporal quantity in VOTables, whether stored in a table column (which means the annotation of FIELDs) or as a single value in a PARAM.

The proposal is *not* concerned with time representations; the distinction between times given as a floating point value (e.g., JD, julian or besselian years, unix times) and as civil dates is already effected by VOTable and the DALI *timestamp* xtype (Dowler and Demleitner et al., 2017). If further time representations ever appeared desirable (e.g., SOFA's high-precision times stored in two double precision floating-point values), they would probably be described with further xtypes in DALI.

This proposal also does *not* talk about units, which are sufficiently covered by the existing VOTable standard (Ochsenbein and Taylor et al., 2013) and the ancillary VOUnits standard (Derriere and Gray et al., 2014). As long as these standards are followed, no interoperability problems are forseen regardless of whether times are given in years, days, seconds or any derivation of them.

2 A TIMESYS Element

To cover the use cases outlined above, we propose to introduce a new VOTable element, TIMESYS. It is allowed whereever COOSYS is and would reside lexically behind COOSYS definitions if these are present. Multiple TIMESYS elements are allowed (and are, indeed, even necessary in several applications).

In keeping with the pattern set by COOSYS, FIELDs (and possibly PARAMs) SHOULD reference the TIMESYS giving their frame using the VOTable ***ref*** attribute; absent such a ***ref***, readers SHOULD assume the lexically first TIMESYS element in the VOTable to be pertinent for time-like quantities.

We note in passing that moving to an annotation pattern in which TIMESYS references FIELDs and PARAMs would be preferable and, indeed, is possible by adding an reference-valued attribute to TIMESYS. We do not propose this at this point because this would introduce an asymmetry between COOSYS and TIMESYS.

The metadata discussed above are given in attributes to the element, specifically:

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

TAI (International Atomic Time) atomic time standard, TT − TAI = 32.184s.

TT (Terrestrial Time; IAU standard) time measured by a continuous clock on the surface of an ideal Earth. Defined via TCG as having been idential on 1977-01-01 and since running slower than it by an empirically determined factor L_C. It is continuous with the ephemeris time ET widely used before 1984-01-01; in TIMESYS, the term TT should therefore be used for times in ET, too.

UT Earth rotation time. We do not distinguish between UT0, UT1, and UT2; applications requiring this level of precision need additional metadata. This should also be used to label GMT times in datasets covering dates before 1972-01-01.

UTC (Universal Time, Coordinated) this is TAI, with leap seconds inserted occasionally in order to keep UTC within 0.9 s of UT1.

GPS (Global Positioning System) runs (approximately) synchronously with TAI

TCG (Geocentric Coordinate Time) time measured by a clock moving with the Earth's center but not subject to the gavitational potential of the Earth.

TCB (Barycentric Coordinate Time) derived from TCG, but taking into account the relativistic effects of the gravitational potential at the barycenter as well as velocity time dilation variations due to the eccentricity of the Earth's orbit. See Irwin and Fukushima (1999) for details.

TDB (Barycentric Dynamical Time) runs slower than TCB at a constant rate so as to remain approximately in step with TT; runs therefore quasi-synchronously with TT, except for the relativistic effects introduced by variations in the Earth's velocity relative to the barycenter.

UNKNOWN This value indicates clients cannot transform the times reliably; this is to be used for simulated data, free-running clocks, or data for which information on the time scale has been lost.

Table 1: The initial list of defined time scales, evolved from the STC 1 data model (Rots, 2007). In a vocabulary, the descriptions should contain normative references.

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.[1] Future VOTable

[1] When using calendar epochs written in yr or Ba, note that conventionally Julian years

TOPOCENTER The location of the instrument that made the observation

GEOCENTER The center of the earth

BARYCENTER The barycenter of the solar system

HELIOCENTER The center of the sun

EMBARYCENTER The barycenter of the Earth-Moon system

UNKNOWN The times cannot be transformed to a different reference position reliably. This is to be used for simulated data or for data for which the reference position has been lost.

Table 2: The initial list of defined reference positions, evolved from the STC 1 data model (Rots, 2007). In a vocabulary, the descriptions should contain normative references.

or VOUnits versions may define other such representations.

timescale
: This is the time scale used. The IVOA defines a set of interoperable time scales. An initial list is given in Table 1. In the prototype, this list is hardcoded in the schema; we believe that the list should reside in an IVOA vocabulary in implementation both in order to attach precise meanings and in order to allow extensions to the list without having to change the schema.

refposition
: The reference position again is a simple string, with the initial set of defined values given in Table 2. Again, while the prototype schema contains an enumeration of the allowed values, we believe these should eventually reside in an IVOA vocabulary.

The attribute names correspond to attributes of the frame type in current drafts of the STC2 data model.

3 Examples

At this point, the time series available from the ivoa.obscore table on GAVO's Heidelberg TAP service[2] offer the TIMESYS annotation described here. As an example, here is a excerpt from a time series (slightly edited for compactness):

are tied to the TDB timescale and Besselian years to ET (written here as TT) (Rots and Bunclark et al., 2015).

[2]http://dc.g-vo.org/tap

```
<RESOURCE>
  <COOSYS ID="system" epoch="J2015.5" system="ICRS"/>
  <TIMESYS ID="gaia_frame" refposition="BARYCENTER" timeorigin="0"
    timescale="TCB"/>
  <TABLE name="ts_data">
    <FIELD ID="obs_time" datatype="double" name="obs_time"
      ucd="time.epoch" unit="d" ref="gaia_frame"/>
    <FIELD ID="flux" datatype="float" name="flux"
      ucd="phot.flux;em.opt.V" unit="s**-1"/>
    <FIELD ID="mag" datatype="float" name="mag" ucd="phot.mag;em.opt.V"
      unit="mag"/>
    <FIELD ID="flux_error" datatype="float" name="flux_error"
      ucd="stat.error;phot.flux;em.opt.V" unit="s**-1"/>
    <PARAM datatype="double" name="ra"
      ucd="pos.eq.ra" value="45.7164887146879" ref="system"/>
    <PARAM datatype="double" name="dec"
      ucd="pos.eq.dec" value="1.18583048057467" ref="system"/>
    <DATA>
      <TABLEDATA>
        <TR>
          <TD>2457018.7846388435</TD>
          <TD>168.358</TD>
          <TD>20.12281560517953</TD>
          <TD>8.71437</TD>
        </TR>
        ...
      </TABLEDATA>
    </DATA>
  </TABLE
</RESOURCE>
```

Note that TIMESYS can also be used to annotate PARAMs. For instance, a common epoch, given in MJD, in a VOTable could be written like this:

```
<TIMESYS refposition="TOPOCENTER" timescale="TT" timeorigin="2400000.5"
   ID="_MJD"/>
<PARAM ref="_MJD" name="epoch" datatype="double"
  value="58424.37"/>
```

4 Implementation Aspects

If this or a similar proposal were to be adopted by the IVOA, both the VOTable specification and its schema would need to be updated. A draft schema reflecting the proposal above comes with this note and is available from http://volute.g-vo.org/svn/trunk/projects/time-domain/timesysnote/VOTable-1.4-draft.xsd. As mentioned above, we believe the lists of accepted reference positions and time scales should probably reside in vocabularies rather than the schema in the finished specification.

At this point, there is support on the server side for the proposal in the DaCHS suite (Demleitner and Neves et al., 2014) as of the 1.2.1 beta. On the client side, the maintainers of the Aladin (Bonnarel and Fernique et al., 2000) and SPLAT Virtual Observatory clients have signaled they are considering an experimental adoption.

A Changes from Previous Versions

A.1 Changes from version 1.0

- Fixed `_MJD` example (which was plain broken in 1.0).
- Improved descriptions of a few time scales based on reviewer feedback.

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