International
Virtual
Observatory
Alliance

Referencing STC in VOTable
Version 1.03

IVOA Note 2009-06-12

This version:
http://www.ivoa.net/Documents/Notes/VOTableSTC/VOTableSTC-20090612.pdf

Latest version:
http://www.ivoa.net/Documents/latest/VOTableSTC.pdf

Previous versions:
http://www.ivoa.net/Documents/Notes/VOTableSTC/VOTableSTC-20081030.pdf V1.02
http://www.ivoa.net/Documents/Notes/VOTableSTC/VOTableSTC-20081018.pdf V1.01
http://www.ivoa.net/Documents/Notes/VOTableSTC/VOTableSTC-20080910.pdf V1.00

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Abstract

This note describes the recommended way to reference the coordinate systems in usage in Astronomy for an accurate specification of spatial and temporal reference frames. It was made in agreement between the *VOTable* and the *Data Models* Working Groups.

Status of this document

This is an IVOA Note. It attempts to clarify how to reference unambiguously, in a VOTable document containing space- and/or time-related data, the reference systems in which these data are expressed, systems which are described by the STC data model.

> *Comments to this note are welcome; it is expected that the expression of other data models into VOTable terms will be added in the future.*

Acknowledgments

This document is based on the W3C documentation standards, but has been adapted for the IVOA.

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1 Introduction

Astronomical catalogues are a very common source of tabular data, and among these the catalogs collecting astronomical sources observed at specific sky locations and epochs have routinely to be compared to other catalogues containing informations related to the same sources, but observed or modelled in different contexts: observations at different epochs, different wavelengths, simulated results, etc. An accurate knowledge of the meaning of the parameters included in these catalogues is therefore essential if one expects to derive scientifically significant conclusions from the comparisons of these data.

The VOTable format is an IVOA standard which ensures that large data collections, which can be structured as a set of tables, can efficiently be exchanged within the Virtual Observatory framework with a full understanding of the data meaning (the *metadata*). A lot of details may be required for a full description of the elements stored in these data collections, but the locations in space and time (the *coordinates*, spatial and temporal) are essential if any comparison of the sources observed is attempted.

The data in the context of the Virtual Observatory are described by *data models*, which formalize the context of the data for their accurate interpretation. Data described in this way can then be more efficiently compared with data of similar nature but coming out from other horizons, and valid conclusions or scientific results can be drawn with higher confidence.

2 The space-time coordinates

In the context of astronomical catalogues, *spatial* (location in the sky) and *temporal* (date/time) parameters are one characterisation of virtually *any* observation, and these parameters are therefore fundamental if one wishes to make any comparison of the behaviour of the astronomical sources described in different catalogs – typically catalogs of observations made in widely different wavelength regimes. Since several systems are currently in use to express the spatial coordinates, a dedicated `COOSYS` element was introduced in the original version (1.0) of VOTable: it did specify some minimal level of details about the coordinate system used in the table, and was merely an enumeration of the most commonly coordinate frames used in astronomy (ICRS, historical equatorial frames, galactic, ecliptic, etc) associated to a couple of parameters (equinox and epoch). This VOTable-specific way of specifying the frames used for spatial location is deprecated in VOTable version 1.2, in favor of a more generic way of specifying the space and time coordinates using the `utype` attributes and the `GROUP` constructs[1].

3 The `utype` attribute

VOTable is not a data model, it is more a container for data which can be structured as tables, with emphasis on a single description (the *schema* or *metadata*) for a potentially large number of elements (the *tuples* or *rows*). The description of the data cannot include all components of all the data models developed in the Virtual Observatory framework, but their accurate description requires to *reference* the data model, and to say how the various `FIELD`s composing the table are related to this data model. This relation — referencing a data model — is specified by the `utype` attribute, introduced in the version 1.1 of VOTable for this purpose; `utype` can also be an attribute of the `PARAM`, `GROUP`, `TABLE` and `RESOURCE` elements [1].

The syntax of the `utype` attribute has not yet been fixed in the Virtual Observatory context. This note assumes a syntax made from the model name (`stc`) followed by a colon (`:`), and the dot-separated hierarchy of elements, as e.g. `stc:AstroCoords.Position2D.Value2.C1` to refer to first component of a 2-D astronomical coordinate. The prefix (`stc`) should also be declared with the *name space* convention (as `xmlns:stc=http://...`) to specify the version of the STC data model used.

4 Specifying coordinate components in VOTable

The specification of an astronomical spatial and/or temporal coordinates requires essentially 2 definitions [2]:

1. the definition of the *coordinate system* (the frame in which the coordinates are expressed), which can

be an AstroCoordSystem (for astronomically defined frames) or a more generic CoordSys entity; these definitions may however be omitted in the case of coordinate systems referenced in the STC library (see the example in section 5.1)
2. what is the exact role of the numbers listed in a specific table, which is defined by the AstroCoords element in the astronomical context, or by the Coords element in a more generic context.

In a VOTable context, the utype attribute is used to specify the exact role of a specific field or parameter within the STC data model. The utype is an attribute of the FIELD element, and for instance the right ascension and declination components are defined by the attributes utype="stc:AstroCoords.Position2D.Value2.C1" and utype="stc:AstroCoords.Position2D.Value2.C2" respectively.

The full specification of the STC components in a VOTable is constructed with 2 GROUPs which follow the STC hierarchy, and is ordered in the same way: a group defining the *coordinate system*, and the second specifying the *coordinate components*.

4.1 The AstroCoordSystem group

In the case of a standard coordinate system known in the STC library (see section 5.1), the specification of the coordinate system may be achieved by a reference to this library.

In the general case, the coordinate system (AstroCoordSystem) is specified as a GROUP element containing the necessary information to describe completely a spatial–temporal–spectral–redshift coordinate system. This group will generally include sub-GROUPs for the specification of the temporal, spatial, spectral or redshift axes, which in turn include the necessary PARAMeters to completely specify the coordinate system, like the *equinox* for an equatorial frame, the number of axes for a non–2-D spatial frame, the *reference position* for the time axis, etc. This GROUP *must* have the attributes

- utype="stc:AstroCoordSystem"
- ID="*coordSys_name*", where *coordSys_name* is any name which satisfies the ID/ref requirements (begin with a letter, and contain alphanumeric characters or the underscore without any whitespace). such that it can be referenced from the group with utype="stc:AstroCoords" (group#2)

This group may be omitted in the case where the coordinate system is part of the STC library, as ub section 5.1. When present, the location of this group may be any of the acceptable locations of the GROUP element in the VOTable hierarchy [1]: as direct element of VOTABLE, as a sub-element of RESOURCE, or in a TABLE. The only requirement is that this group defining the coordinate system must always be placed *before* any reference to it; in other terms, the *definition* of the coordinate system must always precede its usage.

4.2 The coordinates group

The coordinates components are grouped in a GROUP element having the following attributes:

- utype="stc:AstroCoords"
- ID="*coordGroup_name*" attribute, such that the group can be referenced from FIELD elements; like *coordSys_name*, the *coordGroup_name* assigned name must satisfy the ID/ref requirements.
- a reference to the *AstroCoordSystem* used:
  - either with a ref="*coordSys_name*" attribute, where *coordSys_name* is the ID assigned in the *AstroCoordSystem* group defined above;
  - or, if no *AstroCoordSystem* group was defined, the group *must* include a PARAM element with the attributes utype="stc:AstroCoordSystem.coord_system_id" and value="*STClib_name*", where *STClib_name* stands for one of the coordinate systems defined in the STC library [2] (see some common names in Table 6).

This second GROUP may include additional PARAMeters to qualify the coordinates if needed (*e.g.* an epoch of the coordinates), and optionally FIELDref references which enumerate the actual coordinate components.

Since it describes the components of the coordinates in a given table, the *coordinates* group *must* be located *within* a TABLE element. It is also required that the *coordinates* group is placed *before* any reference to it — again the *definition* of the coordinates must precede any reference to this group.

The *epoch* of the coordinates, not described in the STC document, should be specified by a PARAM element having utype="stc:AstroCoords.Position.Epoch" attribute and a numeric datatype; the timescale used for the epoch expressed in years, which is generally Besselian years before 1984, and Julian years after the definition of the FK5 system, should be specified by a PARAM element having utype="stc:AstroCoords.Position.Epoch.Scale" and a value of J (for Julian years) or B (for Besselian years) – see example in section 5.2.

4.3 The coordinate components

The individual coordinates provided in the table are defined as FIELD elements and *must* have the attributes

- utype="stc:AstroCoords.*cootype*.*coorep*.*comp*" which specifies the role of the field in the STC data model. The *italicized* components are:
  - *cootype* can be "Position2D" for spherical coordinates, "Position3D" for 3-D coordinates, "Time" for the time axis;
  - *coorep* is the coordinate representation: "TimeInstant" for the time axis, "Value2" for spherical coordinates, "Value3" for 3-D coordinates (cartesian or spherical, depending on the parameter defining the *flavour*, which is characterized by utype="stc:AstroCoordSystem.SpaceFrame.CoordFlavor").
  - *comp* indicates the component: "C1", "C2", "C3" for the spatial axes, "ISOTime", "MJDTime" or one of the other times defined in the STC [2] for the time axis.
- ref="*coordGroup_name*" which refers to the GROUP having utype="stc:AstroCoords" (group#2)

It is quite possible to have several groups of coordinates in a single table, either in a common system (a common value of the ref attribute of the GROUPs having utype="stc:AstroCoordSystem"), or in several different systems (several GROUPs with different ID attributes).

5 Examples

Three examples are given here. The first one omits the *CoordSys* group and refers to the STClib described in the Appendix C of the STC model [2]; the other two illustrate the defiinition of non-standard coordinate system.

In all examples, we emphasize with different colors the STC-related utypes and the corresponding ID/ref attributes to visualize their role in the XML output below. We draw attention to the possibility of the *double referencing*, that is within a TABLE:

1. each FIELD which represents a component of the space-time coordinates is referencing the "AstroCoords" GROUP. This reference is *required* to ensure a correct interpretation (made by ref="Coo1" in the first example below)
2. within the "AstroCoords" GROUP, the components *may* be enumerated by means of FIELDref elements. This second referencing is *optional*.

5.1 List of observations

This simple example of a VOTable document lists 3 observations made with a telescope; each observation is characterized by the location (on the sky) of the CCD center, date/time of observation, and the exposure time. The XML serialisation looks like the following:

```
<?xml version="1.0"?>
<VOTABLE version="1.2" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
 xmlns:stc="http://www.ivoa.net/xml/STC/stc-v1.30.xsd"
 xmlns="http://www.ivoa.net/xml/VOTable/v1.2">

  <RESOURCE name="myObservations">
    <TABLE name="results">
      <DESCRIPTION>Observation log</DESCRIPTION>
      <PARAM name="Telescope" datatype="float" ucd="phys.size;instr.tel"
```

```
          unit="m" value="3.6"/>
      <GROUP ID="Coo1" utype="stc:AstroCoords" >
        <PARAM name="cooframe" datatype="char" arraysize="*" ucd="pos.frame"
               utype="stc:AstroCoords.coord_system_id"
               value="UTC-ICRS-TOPO" /> <!-- UTC-ICRS-TOPO defined in STC-Lib -->
        <FIELDref ref="ObsStart" /> <!-- second referencing, optional -->
        <FIELDref ref="RAJ2000"/>   <!-- second referencing, optional -->
        <FIELDref ref="DEJ2000"/>   <!-- second referencing, optional -->
      </GROUP>
      <FIELD name="RAJ2000" ucd="pos.eq.ra;meta.main" ref="Coo1"
             ID="RAJ2000" utype="stc:AstroCoords.Position2D.Value2.C1"
             datatype="float" precision="4" unit="deg" />
      <FIELD name="DEJ2000" ucd="pos.eq.dec;meta.main" ref="Coo1"
             ID="DEJ2000" utype="stc:AstroCoords.Position2D.Value2.C2"
             datatype="float" precision="4" unit="deg" />
      <FIELD name="ObsStart" ucd="time.start;obs" datatype="char" xtype="iso8601"
             arraysize="19" unit="s" ID="ObsStart" ref="Coo1"
             utype="stc:AstroCoords.Time.TimeInstant.ISOTime" />
      <FIELD name="ExpTime" ucd="time.duration;obs.exposure"
             datatype="float" width="6" precision="1" unit="s"/>
      <DATA>
        <TABLEDATA>
        <TR>
          <TD>035.0798</TD><TD>-05.2336</TD><TD>2005-11-01T12:00:55</TD><TD>1200</TD>
        </TR>
        <TR>
          <TD>035.0547</TD><TD>-05.2253</TD><TD>2005-11-01T12:25:20</TD><TD>600</TD>
        </TR>
        <TR>
          <TD>035.0463</TD><TD>-05.2503</TD><TD>2005-11-01T12:36:20</TD><TD>600</TD>
        </TR>
        </TABLEDATA>
      </DATA>
    </TABLE>
  </RESOURCE>
</VOTABLE>
```

The spherical coordinates (RAJ2000, DEJ2000) defined as `FIELD`s have their `utype` attribute which specify their role in the STC model; their `ref="Coo1"` attribute designates the `GROUP` having the attribute `ID="Coo1"`. In this example the coordinate system (UTC-ICRS-TOPO) is known in the **STC library** *(see Appendix* **C** *of [2])*, which is enough to fully define the time reference (UTC), the frame orientation (ICRS) and the reference point (TOPOcentric). The exact specification of this location could be specified by a `PARAM` or `GROUP` having the `utype="stc:AstroCoordSystem.SpaceFrame.ReferencePosition"` attribute.

5.2 Extract of the Hipparcos catalog

The Hipparcos catalog is the primary realization of the International Celestial Reference System (ICRS) for optical wavelengths. Its positions and proper motions are given for the epoch J1991.25 (roughly the mid-point of the mission). The astrometric frame is barycentric (the barycenter of the Solar system is assumed to be the origin of the frame); and the times used throughout the Hipparcos catalog (for the *epoch photometry*) is the geocentric terrestrial time [3].

Notice that the `GROUP` defining the coordinate system (first group below) is itself made of 2 groups, one for the definition of the time axis, and the second for the definition of the spatial axes.

```
<?xml version="1.0"?>
<VOTABLE version="1.2" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
 xmlns:stc="http://www.ivoa.net/xml/STC/stc-v1.30.xsd"
 xmlns="http://www.ivoa.net/xml/VOTable/v1.2">
```

```
<GROUP utype="stc:AstroCoordSystem" ID="HIP" >
  <DESCRIPTION>
         The original Hipparcos catalogue uses different origins for
         spatial (barycentric) and temporal (geocentric) components.
  </DESCRIPTION>

  <!-- The time axis has the position origin at the center of Earth -->
  <GROUP utype="stc:AstroCoordSystem.TimeFrame" >
    <PARAM name="TimeScale" datatype="char" arraysize="*"
           utype="stc:AstroCoordSystem.TimeFrame.TimeScale" value="TT"  />
    <PARAM name="refPosition" datatype="char" arraysize="*"
           utype="stc:AstroCoordSystem.TimeFrame.ReferencePosition"
           value="GEOCENTER" />   <!-- reference position for time -->
  </GROUP>

  <!-- The spatial frame is barycentric -->
  <GROUP utype="stc:AstroCoordSystem.SpaceFrame" >
    <PARAM name="CooFrame" datatype="char" arraysize="*"
           utype="stc:AstroCoordSystem.SpaceFrame.CoordRefFrame"
           value="ICRS"  />  <!-- Orientation of spatial axes -->
    <PARAM name="CooFrameOrigin" datatype="char" arraysize="*"
           utype="stc:AstroCoordSystem.SpaceFrame.ReferencePosition"
           value="BARYCENTER" />  <!-- Origin of spatial axes -->
    <PARAM name="CooType" datatype="char" arraysize="*"
           utype="stc:AstroCoordSystem.SpaceFrame.CoordFlavor"
           value="SPHERICAL"  /> <!-- 2-D is the default -->
  </GROUP>
</GROUP>

<RESOURCE name="hip_main">
  <TABLE name="hip_main_excerpt">
    <DESCRIPTION>A (tiny) excerpt from the Hipparcos catalog</DESCRIPTION>
    <GROUP ID="HIPcoo" utype="stc:AstroCoords" ref="HIP">
      <PARAM name="Jepoch" datatype="double" unit="yr"
        utype="stc:AstroCoords.Position.Epoch"
        value="1991.25" />   <!-- Epoch is a number, see Epoch.Scale -->
      <PARAM name="epochScale" datatype="char" value="J"
        utype="stc:AstroCoords.Position.Epoch.Scale"
        />                   <!-- specifies that Jepoch is Julian -->
      <FIELDref ref="RA1"/>  <!-- second referencing, optional -->
      <FIELDref ref="DE1"/>  <!-- second referencing, optional -->
      <FIELDref ref="pm1"/>  <!-- second referencing, optional -->
      <FIELDref ref="pm2"/>  <!-- second referencing, optional -->
    </GROUP>
    <FIELD name="HIP" ucd="meta.id;meta.main" datatype="int" width="6">
      <DESCRIPTION>Identifier (HIP number) (H1)</DESCRIPTION>
    </FIELD>
    <FIELD name="Vmag" ucd="phot.mag;em.opt.V" datatype="float"
           width="5" precision="2" unit="mag">
      <DESCRIPTION>Magnitude in Johnson V (H5)</DESCRIPTION>
      <VALUES null="" />
    </FIELD>
    <FIELD name="RA(ICRS)" ucd="pos.eq.ra;meta.main" ref="HIPcoo"
           ID="RA1" utype="stc:AstroCoords.Position2D.Value2.C1"
           datatype="double" width="12" precision="8" unit="deg">
      <DESCRIPTION>alpha, degrees (ICRS, Epoch=J1991.25) (H8)</DESCRIPTION>
    </FIELD>
    <FIELD name="DE(ICRS)" ucd="pos.eq.dec;meta.main" ref="HIPcoo"
           ID="DE1" utype="stc:AstroCoords.Position2D.Value2.C2"
           datatype="double" width="12" precision="8" unit="deg">
```

```
      <DESCRIPTION>delta, degrees (ICRS, Epoch=J1991.25) (H9)</DESCRIPTION>
    </FIELD>
    <FIELD name="Plx" ucd="pos.parallax.trig" datatype="float" width="7"
           precision="2" unit="mas">
      <DESCRIPTION>? Trigonometric parallax (H11)</DESCRIPTION>
    </FIELD>
    <FIELD name="pmRA" ucd="pos.pm;pos.eq.ra" ref="HIPcoo"
           ID="pm1" utype="stc:AstroCoords.Velocity2D.Value2.C1"
           datatype="double" width="8" precision="2" unit="mas/yr">
      <DESCRIPTION>Proper motion mu_alpha.cos(delta) ICRS(H12)
                   (for J1991.25 epoch)</DESCRIPTION>
    </FIELD>
    <FIELD name="pmDE" ucd="pos.pm;pos.eq.dec" ref="HIPcoo"
           ID="pm2" utype="stc:AstroCoords.Velocity2D.Value2.C2"
           datatype="double" width="8" precision="2" unit="mas/yr">
      <DESCRIPTION>? Proper motion mu_delta, ICRS (H13)
                    (for J1991.25 epoch)</DESCRIPTION>
    </FIELD>
    <FIELD name="e_Plx" ucd="stat.error" datatype="float" width="6"
           precision="2" unit="mas">
      <DESCRIPTION>Standard error in Plx (H16)</DESCRIPTION>
    </FIELD>
    <DATA>
      <TABLEDATA>
        <TR>
          <TD>1</TD><TD>9.10</TD><TD>0.00091185</TD><TD>1.08901332</TD>
          <TD>3.54</TD><TD>-5.20</TD><TD>-1.88</TD><TD>1.39</TD>
        </TR>
        <TR>
          <TD>2</TD><TD>9.27</TD><TD>0.00379737</TD><TD>-19.49883745</TD>
          <TD>21.90</TD><TD>181.21</TD><TD>-0.93</TD><TD>3.10</TD>
        </TR>
        <TR>
          <TD>3</TD><TD>6.61</TD><TD>0.00500795</TD><TD>38.85928608</TD>
          <TD>2.81</TD><TD>5.24</TD><TD>-2.91</TD><TD>0.63</TD>
        </TR>
        <TR>
          <TD>4</TD><TD>8.06</TD><TD>0.00838170</TD><TD>-51.89354612</TD>
          <TD>7.75</TD><TD>62.85</TD><TD>0.16</TD><TD>0.97</TD>
        </TR>
        <TR>
          <TD>5</TD><TD>8.55</TD><TD>0.00996534</TD><TD>-40.59122440</TD>
          <TD>2.87</TD><TD>2.53</TD><TD>9.07</TD><TD>1.11</TD>
        </TR>
      </TABLEDATA>
    </DATA>
  </TABLE>
 </RESOURCE>
</VOTABLE>
```

Note (1) the STC-schema specifies a numeric datatype for the Epoch; we neverthless added the **J** prefix which indicates values expressed in Julian years (365.25days) as opposed to **B**esselian years (about 365.2422 days).

5.3 Ephemeride of a Comet

This example gives the position of the comet 125P as a function of time. Notice that the planetary model used is specified by a PARAM having`utype="stc:AstroCoordSystem.SpaceFrame.ReferencePosition.PlanetaryEphem"`

```
<?xml version="1.0"?>
```

```
<VOTABLE version="1.2" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
 xmlns:stc="http://www.ivoa.net/xml/STC/stc-v1.30.xsd"
 xmlns="http://www.ivoa.net/xml/VOTable/v1.2">

  <GROUP utype="stc:AstroCoordSystem" ID="JPL-DE405">

    <!-- Times refer to the local observations -->
    <GROUP utype="stc:AstroCoordSystem.TimeFrame" >
      <PARAM name="TimeScale" datatype="char" arraysize="*"
             utype="stc:AstroCoordSystem.TimeFrame.TimeScale" value="UTC" />
      <PARAM name="refPosition" datatype="char" arraysize="*"
             utype="stc:AstroCoordSystem.TimeFrame.ReferencePosition"
             value="GEOCENTER" />
    </GROUP>

    <!-- Distance is geocentric -->
    <GROUP utype="stc:AstroCoordSystem.SpaceFrame" >
      <PARAM name="CooFrame" datatype="char" arraysize="*"
             utype="stc:AstroCoordSystem.SpaceFrame.CoordRefFrame"
             value="ICRS"  />      <!-- Orientation of spatial axes -->
      <PARAM name="CooFrameOrigin" datatype="char" arraysize="*"
             utype="stc:AstroCoordSystem.SpaceFrame.ReferencePosition"
             value="GEOCENTER" />  <!-- Origin of spatial axes -->
      <PARAM name="Ephemeris" datatype="char" arraysize="*"
         utype="stc:AstroCoordSystem.SpaceFrame.ReferencePosition.PlanetaryEphem"
         value="JPL-DE405">
         <DESCRIPTION>
           Planetary theory used to compute the ephemeris of the planets
         </DESCRIPTION>
      </PARAM>
      <PARAM name="CooType" datatype="char" arraysize="*"
             utype="stc:AstroCoordSystem.SpaceFrame.CoordFlavor"
             value="SPHERICAL" />
      <!-- default number of axes is 2, but here we are in 3-D -->
      <PARAM name="Naxes" datatype="int" value="3"
             utype="stc:AstroCoordSystem.SpaceFrame.coord_naxes" />
    </GROUP>
  </GROUP>

  <RESOURCE name="125P">
    <TABLE name="Ephemeris">
      <DESCRIPTION>Ephemeris of comet 125P in July 2007</DESCRIPTION>
      <GROUP ID="Ephem" utype="stc:AstroCoords" ref="JPL-DE405">
        <PARAM name="Ephemerides" datatype="char" arraysize="*"
               utype="stc:AstroCoords.coord_system_id"
               value="UTC-ICRS-GEO"/>
        <FIELDref ref="RA1"/>   <!-- second referencing, optional -->
        <FIELDref ref="DE1"/>   <!-- second referencing, optional -->
        <FIELDref ref="Dist1"/> <!-- second referencing, optional -->
      </GROUP>
      <FIELD name="UTC" ucd="time.epoch" datatype="double" ref="Ephem"
                  utype="stc:AstroCoords.Time.TimeInstant.JDTime"
                  width="9" precision="1">
        <DESCRIPTION>Date UTC </DESCRIPTION>
      </FIELD>
      <FIELD name="RA" ucd="pos.eq.ra" ref="Ephem"
             ID="RA1" utype="stc:AstroCoords.Position3D.Value3.C1"
             datatype="double" width="12" precision="8" unit="deg">
        <DESCRIPTION>alpha, degrees</DESCRIPTION>
      </FIELD>
```

```
      <FIELD name="DE" ucd="pos.eq.dec" ref="Ephem"
             ID="DE1" utype="stc:AstroCoords.Position3D.Value3.C2"
             datatype="double" width="12" precision="8" unit="deg">
        <DESCRIPTION>delta, degrees</DESCRIPTION>
      </FIELD>
      <FIELD name="Dist" ucd="pos.distance" ref="Ephem"
             ID="Dist1" utype="stc:AstroCoords.Position3D.Value3.C3"
             datatype="double" width="12" precision="9" unit="AU">
        <DESCRIPTION>Distance from geocenter </DESCRIPTION>
      </FIELD>
      <FIELD name="Vmag" ucd="phot.mag;em.opt.V" datatype="float"
             width="5" precision="2" unit="mag">
        <DESCRIPTION>Visual magnitude</DESCRIPTION>
      </FIELD>
      <DATA>
        <TABLEDATA>
          <TR>
            <TD>2454284.0</TD><TD>180.1745177</TD><TD>+10.2710289</TD>
            <TD>1.468825725</TD><TD>17.06</TD>
          </TR>
          <TR>
            <TD>2454286.0</TD><TD>181.2970157</TD><TD>+09.8077289</TD>
            <TD>1.476798829</TD><TD>17.07</TD>
          </TR>
          <TR>
            <TD>2454288.0</TD><TD>182.4335757</TD><TD>+09.3344139</TD>
            <TD>1.484770578 </TD><TD>17.09</TD>
          </TR>
          <TR>
            <TD>2454290.0</TD><TD>183.5839061</TD><TD>+08.8513908</TD>
            <TD>1.492750033</TD><TD>17.11</TD>
          </TR>
          <TR>
            <TD>2454292.0</TD><TD>184.7477408</TD><TD>+08.3589893</TD>
            <TD>1.500745242</TD><TD>17.13</TD>
          </TR>
        </TABLEDATA>
      </DATA>
    </TABLE>
  </RESOURCE>
</VOTABLE>
```

6 Summary of Interpretation and Defaults

A VOTABLE resource may contain multiple TABLEs and each of these tables may contain many header PARAMs and many FIELD columns, possibly giving several sets of positions and times in several different coordinate systems.

For any PARAM or FIELD that gives an STC utype, there must be a ref attribute pointing to the GROUP that contains the STC AstroCoords (or Coords) definition. This is how we tie a particular utype to a particular STC instance. For example:

```
<FIELD name="ObsStart" utype="stc:AstroCoords.Time.TimeInstant.ISOTime" ref="Coo1" .../>
```

says that the column in question contains the Time value for an AstroCoords instance whose frame is defined in the group which begins with `<GROUP ID="Coo1" utype="stc:AstroCoords" .../>`.

An AstroCoords instance may contain all of space, time, spectral and redshift coordinates. It is often meaningful to omit the spectral and redshift coordinates. Space and time coordinates are usually more tightly coupled. While in practice for some common coordinate systems and astronomical contexts it is reasonable to give a position with no time, or a time not explicitly tied to a position, this is not recommended.

This AstroCoords instance in turn contains a *reference* to the relevant AstroCoordSystem (or CoordSys) used: either with an explicit reference to a group having the attribute `utype="stc:AstroCoordSystem"` (or `utype="stc:CoordSys"`) included in the same document (ID/ref mechanism); or with a reference to the **STClib** component designated by the content of the `value` attribute of a `PARAM` element having the attribute `utype="stc:AstroCoordSystem.coord_system_id"`.

Table 1: Most important stc:AstroCoords components in `FIELD` elements

utype	**ucd**	Comments
stc:AstroCoords.Time... time components(1).		
TimeInstant.ISOTime	time.start;obs.exposure	Date with ISO-8601 convention (*e.g.* `2008-10-25T12:14:15`)
TimeInstant.JDTime	time.start	Julian date, applies to e.g. a variable phenomenon (*e.g.* `2454765.09323`)
TimeInstant.TimeOrigin.JDTime	time	Reference date
TimeInstant.TimeOffset	time	Time elapsed since the *TimeOrigin*
stc:AstroCoords.Position2D... position on the celestial sphere		
Value2.C1	pos.eq.ra	Right ascension or longitude
Value2.C2	pos.eq.dec	Declination or Latitude
Error2Radius	stat.error;pos.eq	Error radius of the spherical position
Error2.C1	stat.error;pos.eq.ra	Error on the Right Ascension or Longitude
Error2.C2	stat.error;pos.eq.dec	Error on the Declination or Latitude
stc:AstroCoords.Velocity2D... proper motion on the celestial sphere		
Velocity1D	pos.pm	Total proper motion
Velocity2D.C1	pos.pm;pos.eq.ra	Proper motion in RA or Longitude
Error2.C1	stat.error;pos.pm;pos.eq.ra	Error on a proper motion in RA or Longitude
stc:AstroCoords.Position3D... position in a 3-D spherical system(2), as in section 5.3		
Value3.C1	pos.ecliptic.lon	Ecliptic longitude
Value3.C2	pos.ecliptic.lat	Ecliptic latitude
Value3.C3	pos.distance;pos.barycentric	Distance to solar system barycenter

(1) *the reference position to which the time applies is defined in a parameter having a utype* stc:AstroCoordSystem.SpaceFrame.ReferencePosition

(2) *requires to specify a* SPHERICAL *frame (in* stc:AstroCoordSystem.SpaceFrame.CoordFlavor *component) and a value of* **3** *for the number of axes (in* stc:AstroCoordSystem.SpaceFrame.coord_naxes*)*

6.1 stc:AstroCoords components

The actual coordinate components which are present in a VOTable as `FIELD`s are characterized by

- a reference to a `GROUP` gathering the coordinate components, e.g. `ref="Coo1"`
- their *utype*, e.g. `utype="stc:AstroCoords.Position2D.Value2.C1"` for the right ascension.
- their *ucd* attribute, e.g. `ucd="pos.eq.ra"`
- ... and the other attributes necessary for a correct interpretation of the data: `datatype`, `unit`, `width`, `precision`, etc...

Illustrations with actual examples are given in section 5 above; the most important *utype* and *ucd* attributes of use in this context are listed in Table 1. Many more parameters are actually available in the STC model [2], which should be consulted for details.

6.2 stc:AstroCoordSystem components

The coordinate *systems* used in a VOTable, if these are not part of the STC Standard Library *(Appendix* **C** *of [2])*, must be defined in `GROUP` elements having the `utype="stc:AstroCoordSystem"` attribute, and an `ID` attribute to which the group of coordinate elements defined above can refer.

Table 2: Most important TimeScale values

`TT`	Terrestrial time	
`TAI`	Temps Atomique International	TT–32.184s
`UTC`	Coordinated Universal Time	TAI–leap seconds
`TDB`	Barycentric Dynamical Time	synchronous with TT
`LST`	Local Sideral Time	*(needs ObservationLocation)*
`LOCAL`	Local definition	

Table 3: Most important ReferencePosition values

`TOPOCENTER`	local position (generally on the Earth surface)	Location should be specified
`GEOCENTER`	center of Earth	
`HELIOCENTER`	center of Sun	
`BARYCENTER`	barycenter of the Solar System	
`LSR`	Local Standard of Rest	
`GALACTIC_CENTER`	center of our Galaxy	

Table 4: Most important coordinate flavors

`SPHERICAL`	Spherical coordinates, 2-D (2 angles) and 3-D(additional distance) *(coord_naxes required for 3-D)*
`CARTESIAN`	Cartesian frame
`POLAR`	Longitude + polar distance

The temporal, spatial (and eventually the spectral, velocity / redshift) components are defined as subgoups with the appropriate utypes, following the schema:

```
<GROUP utype="stc:AstroCoordSystem" ID="myFrame">

  <GROUP utype="stc:AstroCoordSystem.TimeFrame" ID="myTime">
    <PARAM name="TimeScale" datatype="char" arraysize="*"
           utype="stc:AstroCoordSystem.TimeFrame.TimeScale"
           value="(see Table 2)" />
    <PARAM name="refPosition" datatype="char" arraysize="*"
           utype="stc:AstroCoordSystem.TimeFrame.ReferencePosition"
           value="(see Table 3)" />
  </GROUP>
  <GROUP utype="stc:AstroCoordSystem.SpaceFrame" ID="mySpace">
    <PARAM name="CooFrame" datatype="char" arraysize="*"
           utype="stc:AstroCoordSystem.SpaceFrame.CoordRefFrame"
           value="(see Table 5)"  />
    <PARAM name="CooFrame" datatype="double"
           utype="stc:AstroCoordSystem.SpaceFrame.CoordRefFrame.Equinox"
           value="(equinox only for Equatorial or Ecliptic rame)"  />
    <PARAM name="CooFrameOrigin" datatype="char" arraysize="*"
           utype="stc:AstroCoordSystem.SpaceFrame.ReferencePosition"
           value="(see Table 3)" />
    <PARAM name="CooType" datatype="char" arraysize="*"
           utype="stc:AstroCoordSystem.SpaceFrame.CoordFlavor"
           value="(see Table 4)"  />
  </GROUP>
 </GROUP>
```

The most frequent values of the parameters defining the *time* are summarized in Table 2 *(time scales)* and Table 3 *(reference location of time measurement)*; among the parameters which define a spatial frame, Table 3 defines the origin of the frame (which may differ from the reference location of time measurements), Table 4 defines the frame type and dimensionality (standard frames used in astrometry are 2-D spherical), and Table 5 summarizes the most frequently frames used in astrometry.

Table 5: Most important astronomical frame values

ICRS	International Reference System	Compatible with FK5(J2000)
FK5	Equatorial frame based on FK5	Requires the Equinox (default J2000)
FK4	Equatorial frame based on FK4	Requires the Equinox (default B1950)
ECLIPTIC	Ecliptic frame	Requires the Equinox ((default J2000)
GALACTIC	Galactic frame	Also named GALACTIC_II
SUPER_GALACTIC	Local Group	
J2000	Equatorial on FK5, Equinox=J2000	Coincides with ICRS
B1950	Equatorial on FK4, Equinox=B1950	

7 History and Modifications

- Version 1.0 (2008-09-10) to 1.01 (2008-10-18):
  - the reference to STC-Lib definitions in the form `ref="ivo://STClib/CoordSys#UTC-ICRS-TOPO"` was removed (not conforming to the *ID/IDref* XML definitions). The `PARAM` with the `utype="stc:AstroCoordSystem.coord_system_id"` is used instead (section 5.1)
  - the `PARAM` element with `utype="stc:AstroCoordSystem.coord_system_id"` is reserved for STC-Lib standard values; these parameters were removed from examples in section 5.2 and section 5.3.
  - specification of coordinate components (section 4) was partly rewritten.
- Version 1.01 (2008-10-18) to 1.02 (2008-10-30): cosmetics

Table 6: A few *STC-library* values

TT-ICRS-TOPO	Terrestrial time reported at local place, ICRS orientation of axes with origin at local place
TT-FK5-TOPO	Coincides with TT-ICRS-TOPO at Equinox J2000.0
UTC-ICRS-TOPO	Universal Coordinated Time reported at local place, ICRS orientation of axes with origin at local place
UTC-FK5-TOPO	Coincides with UTC-ICRS-TOPO at Equinox J2000.0
TT-ICRS-GEO	Terrestrial time reported at center of Earth, ICRS orientation of axes with origin at center of Earth
TT-FK5-GEO	Coincides with UTC-ICRS-TOPO at Equinox J2000.0
UTC-ICRS-GEO	Universal Coordinated Time reported at center of Earth, ICRS orientation of axes with origin at center of Earth
UTC-FK5-GEO	Coincides with TT-FK5-GEO at Equinox J2000.0
TDB-ICRS-BARY	Barycentric Dynamical Time reported at Solar System Barycenter, ICRS orientation of axes with origin at Solar System Barycenter
TDB-FK5-BARY	Coincides with TDB-ICRS-BARY at Equinox J2000.0
TDB-ECLIPTIC-BARY	Barycentric Dynamical Time reported at Solar System Barycenter, along the Ecliptic axes *(the equinox has to be specified)*

- Version 1.02 (2008-10-30) to 1.03 (2009-06-12):
  - explicitation of how to specify the epoch of coordinates (section section 4.2
  - recommendation to write the coordinate definitions *before* referencing them (section section 4).
  - usage of `xtype="iso8601"` in section 5.1

8 References

[1] François Ochsenbein, et al. VOTable Recommendation
http://ivoa.net/Documents/latest/VOTable.html

[2] Arnold Rots Space-Time Coordinate Metadata for the Virtual Observatory (v1.30)
http://ivoa.net/Documents/latest/STC.html

[3] *The Hipparcos and Tycho Catalogues*, ESA SP1200 June 1997, Vol.1, section 1.2 (also available in PDF)