Time Series Table Formats

Arnold Rots, SAO/CXC

STC Characteristics

STC was designed for use in tables, which makes it very easy to incorporate it in a simple table schema. Even the simplest table design still allows full STC metadata content. The following properties of the STC metadata standard are pertinent in this context:

- Any element in an STC document may contain its actual value or a reference to another element in the document. This allows the document's author to define an STC quantity (in particular, a "leaf") and refer to a table column for its actual values. This property is comparable to the "Greenbank convention" in FITS. It also allows one to refer to high-level constructs (such as AstroCoordSystem) specified elsewhere (for instance, in WhereWhen).
- In addition, elements (in particular AstoCoordSystem and ObservatoryLocation, but not limited to these) may refer to an instantiation outside the document – for instance, in a library.
- STC's core coordinate axes are Time, Space, Spectral, and Redshift. However, it also allows arbitrary axes to be defined, such as Flux Density.
- STC is extremely flexible and covers a very wide range of situations. However, all users (servers and clients) are free to choose to implement only a subset that makes sense for their particular applications. The important thing is that if and when one communicates with a partner that recognizes a wider subset, there will be adequate metadata information to allow that partner to be able to do any necessary conversions.

Simple Table

I implemented a simple schema that defines a table with STC metadata:

http://hea-www.harvard.edu/~arots/nvometa/STC/stcTab.xsd

```xml
<?xml version="1.0" encoding="UTF-8"?>
<!-- edited with XMLSpy v2009 (http://www.altova.com) by Arnold Rots (Smithsonian Astrophysical Obsv.) -->
<xs:schema xmlns="stcTab.xsd" xmlns:xs="http://www.w3.org/2001/XMLSchema"
    xmlns:stc="http://www.ivoa.net/xml/STC/stc-v1.30.xsd" xmlns:xlink="http://www.w3.org/1999/xlink"
    targetNamespace="stcTab.xsd" elementFormDefault="qualified">
        <xs:import namespace="ttp://www.ivoa.net/xml/STC/stc-v1.30.xsd"
            schemaLocation="http://www.ivoa.net/xml/STC/stc-v1.30.xsd"/>
        <xs:element name="STCTable" type="stcTableType"/>
        <xs:complexType name="stcTableType">
                <xs:sequence>
                        <xs:element ref="stc:STCmetadata"/>
                        <xs:element name="Table" type="tableType"/>
                </xs:sequence>
        </xs:complexType>
        <xs:complexType name="tableType">
                <xs:sequence>
                        <xs:element name="Documentation" type="docType" minOccurs="0"
                            maxOccurs="unbounded"/>
                        <xs:element name="Header" type="headerType"/>
                        <xs:element name="TR" type="rowType" maxOccurs="unbounded"/>
                </xs:sequence>
        </xs:complexType>
        <xs:complexType name="docType">
                <xs:sequence>
                        <xs:element name="Label" type="xs:string"/>
                        <xs:element name="Text" type="xs:string"/>
                </xs:sequence>
        </xs:complexType>
        <xs:complexType name="headerType">
                <xs:sequence>
                        <xs:element name="TH" type="columnType" maxOccurs="unbounded"/>
                </xs:sequence>
        </xs:complexType>
        <xs:complexType name="columnType">
                <xs:simpleContent>
                        <xs:extension base="xs:string">
                                <xs:attribute name="id" type="xs:ID"/>
                        </xs:extension>
                </xs:simpleContent>
        </xs:complexType>
        <xs:complexType name="rowType">
                <xs:choice maxOccurs="unbounded">
                        <xs:element name="TD" type="xs:double"/>
                        <xs:element name="TDI" type="xs:int"/>
                        <xs:element name="TDT" type="xs:dateTime"/>
                        <xs:element name="TDS" type="xs:string"/>
                        <xs:element name="TDU" type="xs:anyURI"/>
                        <xs:element name="TDA" type="stc:astroCoordAreaType"/>
                </xs:choice>
        </xs:complexType>
</xs:schema>
```

One may quibble about the details, for instance:

- Should the column headings be in FIELD elements, rather than TH elements?
- The schema defines different TD elements for different data types; this has the advantage that one can easily validate the correctness of the data type, but it does not enforce uniform typing along columns. There are other options in this regard.
- The schema defines a bare-bones table. One might want to add additional metadata elements, such as descriptions.
- One might consider allowing compound columns, consisting of values, errors, resolutions, and/or bounds.
- Units can be handled in the STC metadata, but it may be necessary to add them for columns that are not tied to an STC coordinate axis.

But these are details that should be fairly easy to work out. Note that the schema allows any type of table to be constructed, not just time series; for instance, it can be used to create lists of positions.

There are three sample time series, all providing flux densities as a function of relative time. The first is bare-bones:
http://hea-www.harvard.edu/~arots/nvometa/STC/STCTable3.xml
It is pretty self-explanatory, as it references the standard STC libraries for ObservatoryLocation and AstroCoordSystem. The base time to which the time column is offset is provided in the metadata item ISOTime, while that relative time column is pointed to in TimeOffset. But, of course, the time columns could also have contained absolute time stamps, in JD, MJD, or ISO-8601.

```xml
<?xml version="1.0" encoding="UTF-8"?>
<!--    A Lightcurve table using the STC table extension schema
                    that is based on STC        -->
<STCTable xmlns="stcTab.xsd"
        xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
        xsi:schemaLocation="stcTab.xsd
        http://hea-www.harvard.edu/~arots/nvometa/v1.30/stcTab.xsd">
        <ObsDataLocation xmlns="http://www.ivoa.net/xml/STC/stc-v1.30.xsd"
                xmlns:xlink="http://www.w3.org/1999/xlink"
                xsi:schemaLocation="http://www.ivoa.net/xml/STC/stc-v1.30.xsd
                    http://www.ivoa.net/xml/STC/stc-v1.30.xsd">
                <!-- Observatory location: all referred to geocenter -->
                <ObservatoryLocation xsi:nil="true" xlink:type="simple"
                        xlink:href="ivo://STClib/Observatories#GEO"/>
                <!-- STC metadata that go with the table -->
                <ObservationLocation>
                        <!--     Specify the coordinate system: TT, ICRS, Spectral, and
                                        Flux density as a generic coordinate         -->
                        <AstroCoordSystem id="UTC-ICRS-GEO" xsi:nil="true" xlink:type="simple"
                                xlink:href="ivo://STClib/CoordSys#UTC-ICRS-GEO"/>
                        <AstroCoords coord_system_id="UTC-ICRS-GEO">
                                <Time unit="s">
                                        <Name>Time</Name>
                                        <TimeInstant>
                                                <TimeOffset xsi:nil="true" idref="Time"/>
                                                <ISOTime>2007-09-27T12:34:56</ISOTime>
                                        </TimeInstant>
                                </Time>
                        </AstroCoords>
                </ObservationLocation>
        </ObsDataLocation>
        <!-- This is the table-proper -->
        <Table>
                <!-- Header definition -->
                <Header>
                        <TH id="Time">Time</TH>
                        <TH id="FDVal">FluxDensity</TH>
                        <TH id="FDErr">FD Error</TH>
                </Header>
                <!-- and table body -->
                <TR>
                        <TD>123.4</TD>
                        <TD>56.7</TD>
                        <TD>.98</TD>
                </TR>
                <TR>
                        <TD>133.4</TD>
                        <TD>46.7</TD>
                        <TD>.98</TD>
                </TR>
                <TR>
                        <TD>143.4</TD>
                        <TD>36.7</TD>
                        <TD>.98</TD>
                </TR>
                <TR>
                        <TD>153.4</TD>
                        <TD>26.7</TD>
                        <TD>.98</TD>
                </TR>
                <TR>
                        <TD>163.4</TD>
                        <TD>16.7</TD>
                        <TD>.98</TD>
                </TR>
        </Table>
</STCTable>
```

The second example:
http://hea-www.harvard.edu/~arots/nvometa/STC/STCTable2.xml
adds a celestial position to the time series in the STC metadata.

The third example:
http://hea-www.harvard.edu/~arots/nvometa/STC/STCTable.xml
has a full AstroCoordSystem that also defined the Flux Density coordinate axis.

SimpleTimeseries Schema

A different approach was taken in my version of John Brewer's SimpleTimeseries schema. The reasoning was that for this simple schema it would be sufficient to effect STC compliance by emulating the structure of the STC metadata object and making the connections explicit by assigning the same names as in the STC schema. My version of this schema may be found at:
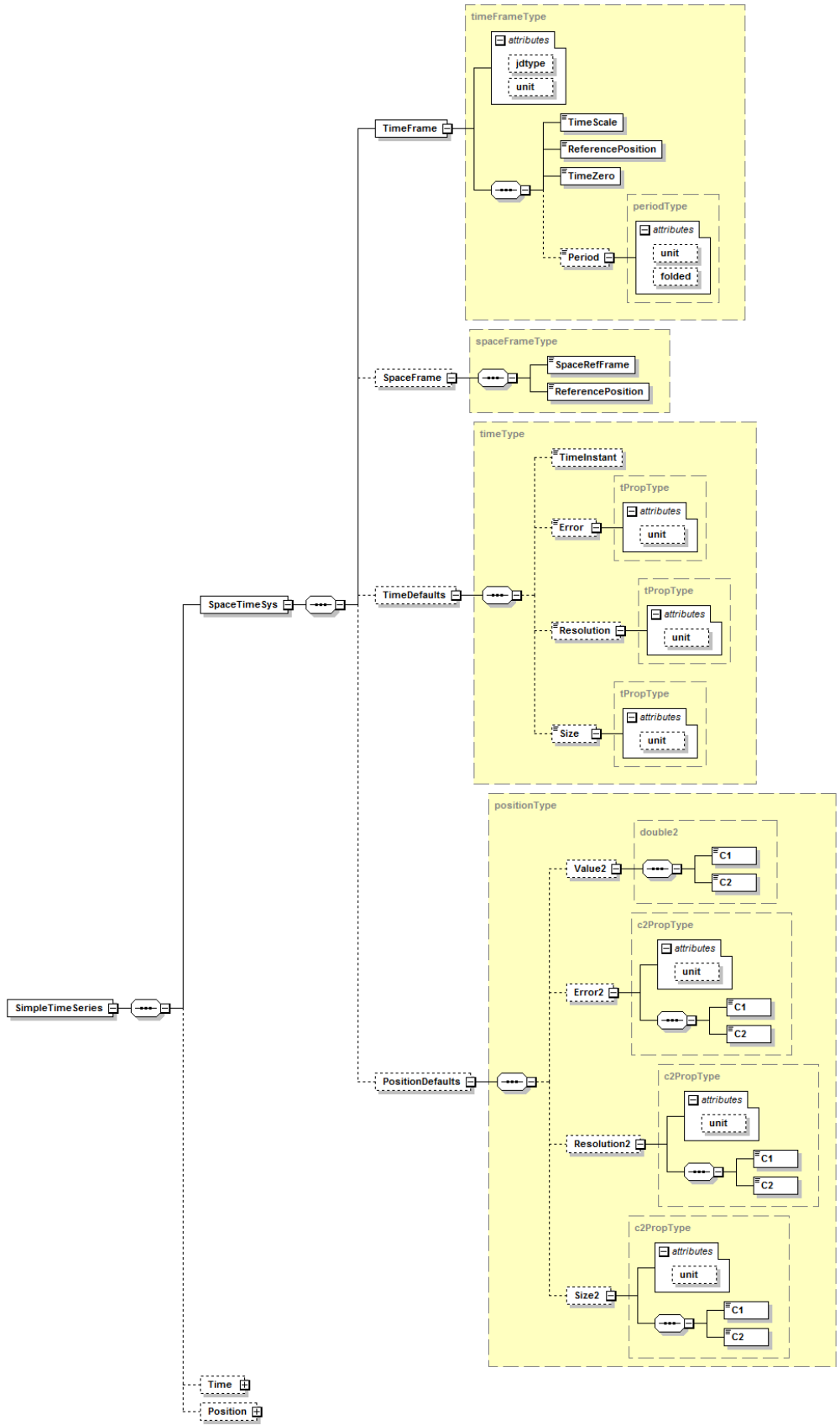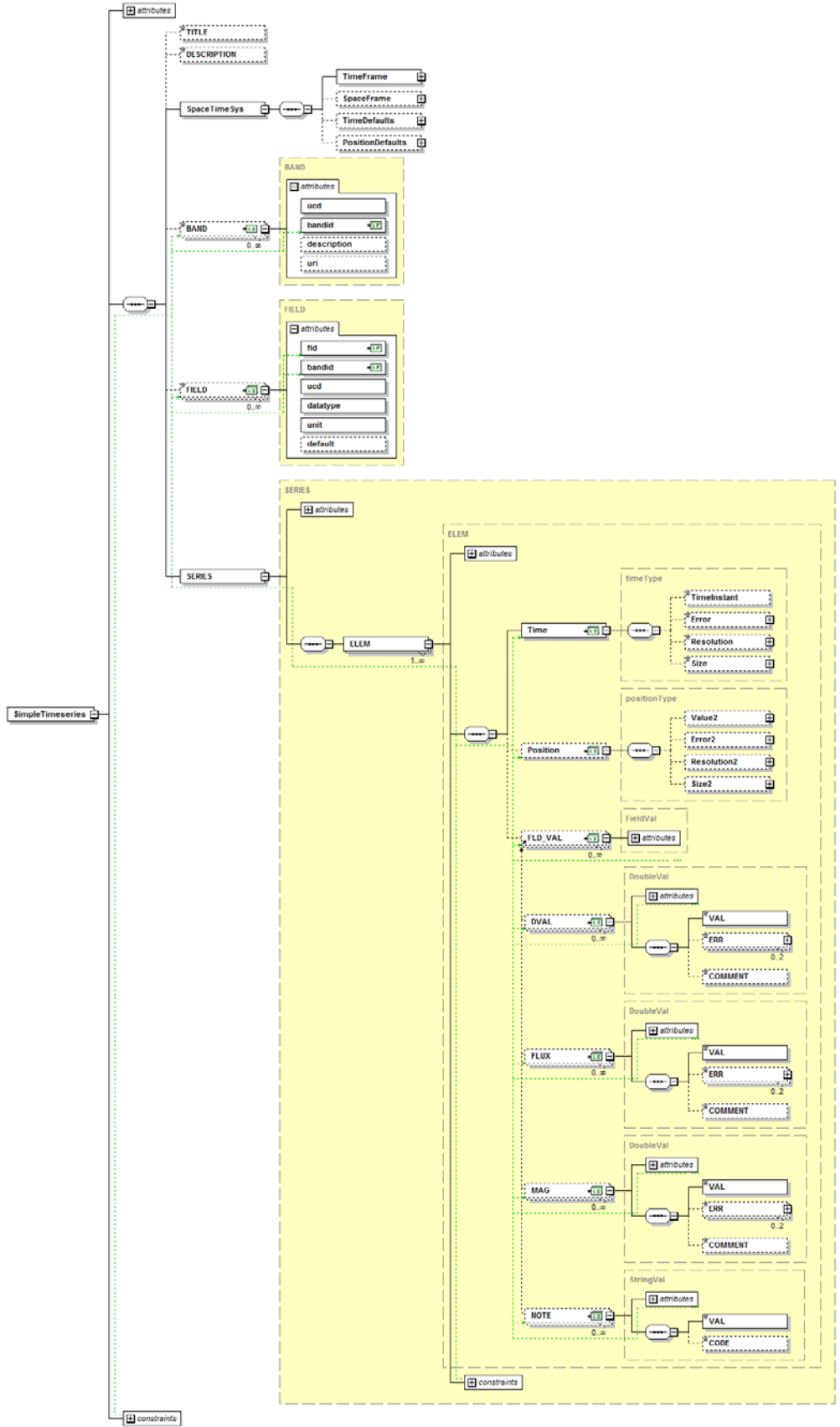http://hea-www.harvard.edu/~arots/nvometa/STC/sts.xsd
John has changed some of the tables structures, in the meantime, and the name of the main metadata element was changed to SpaceTimeSys, but that is not important for the purpose of showing what I see as a legitimate low-level compliance with the standard. The essential elements of low-level compliance are: preserve the structure of the STC components and preserve the nomenclature of the STC components.

The diagrams on the next two pages provide the essence of achieving STC-compliance for the simple Timeseries schema.

The first diagram focuses on the STC-like header, where SpaceTimeSys contains a TimeFrame, a SpaceFrame, TimeDefaults, and PositionDefaults; only the TimeFrame is required. The defaults (like the table columns later) only allow a value, error, resolution, and (bin)size. The TimeFrame, by necessity, contains two extra concepts that are not included in STC: jdtype and Period. The former allows specification of the TimeInstant format (JD or MJD), the latter accommodates periodic light curves. All elements only allow a limited set of values (e.g., only TT,TDB, and UTC for Time Scale).

The second diagram places the STC header in the context of the entire Time Series table. ELEM is the row element. It shows how Time and Position (which are, like their default counterparts, of type timeType and positionType, respectively) can appear as columns in the table, just like any of the FLD_VAL columns. Note that any of these columns may be compound, containing values, errors, etc. The diagrams are followed by a brief example.

timeFrameType

attributes
jdtype
unit

TimeFrame

TimeScale
ReferencePosition
TimeZero

periodType
attributes
unit
folded
Period

spaceFrameType
SpaceFrame
SpaceRefFrame
ReferencePosition

timeType
TimeInstant

tPropType
attributes
unit
Error

tPropType
attributes
unit
Resolution

tPropType
attributes
unit
Size

TimeDefaults

SpaceTimeSys

positionType

double2
C1
C2
Value2

c2PropType
attributes
unit
C1
C2
Error2

c2PropType
attributes
unit
C1
C2
Resolution2

c2PropType
attributes
unit
C1
C2
Size2

PositionDefaults

SimpleTimeSeries

Time
Position

```xml
<?xml version="1.0" encoding="UTF-8"?>
<!-- edited with XMLSpy v2010 (http://www.altova.com) by Arnold Rots (Smithsonian Astrophysical Obsv.) -->
<!-- <?xml-stylesheet type="text/xsl" href="timeseries_xhtml.xsl"?> -->
<SimpleTimeseries xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xsi:schemaLocation="http://dotastro.org/simpletimeseries http://hea-
    www.cfa.harvard.edu/~arots/nvometa/STC/sts.xsd" xmlns="http://dotastro.org/simpletimeseries">
        <DESCRIPTION>
                This is an example light curve in two filters (units of mags) of a real
                supernova (1992bg), as reported in Hamuy, Phillips, Suntzeff
                (bibcode = 1996AJ....112.2408H).
                The original data are at http://cdsarc.u-strasbg.fr/ftp/cats/J/AJ/112/2408/table4.dat

                When using a modern browser, a simple XSL stylesheet is applied to display
                the light-curve as a table.
        </DESCRIPTION>
        <SpaceTimeSys>
                <TimeFrame unit="d" jdtype="JD">
                        <TimeScale>TDB</TimeScale>
                        <ReferencePosition>BARYCENTER</ReferencePosition>
                        <TimeZero>0</TimeZero>
                </TimeFrame>
                <SpaceFrame>
                        <SpaceRefFrame>ICRS</SpaceRefFrame>
                        <ReferencePosition>BARYCENTER</ReferencePosition>
                </SpaceFrame>
                <TimeDefaults>
                        <Size unit="s">10</Size>
                </TimeDefaults>
        </SpaceTimeSys>
        <BAND ucd="instr.filter;em.opt" bandid="I" description="This is the Johnson-Cousins I-band">I</BAND>
        <BAND ucd="instr.filter;em.opt" bandid="V">g</BAND>
        <!-- this is a brief description of the bandpass -->
        <!-- future version could allow reference to RTML descriptions of the instrumental setup -->
        <FIELD fld="imag" bandid="I" ucd="opt;phot;i" datatype="float" unit="mag">I-band photometry</FIELD>
        <FIELD fld="vmag" bandid="V" ucd="opt;phot;v" datatype="float" unit="mag">V-band photometry</FIELD>
        <SERIES>
                <ELEM row="1">
                        <Time>
                                <TimeInstant>2448919.8</TimeInstant>
                        </Time>
                        <MAG fld="imag">
                                <VAL>17.535</VAL>
                                <ERR>0.03</ERR>
                        </MAG>
                        <MAG fld="vmag">
                                <VAL>17.327</VAL>
                                <ERR>0.03</ERR>
                        </MAG>
                </ELEM>
                <ELEM row="1.5">
                        <Time>
                                <TimeInstant>2448920.72</TimeInstant>
                        </Time>
                        <MAG fld="vmag">
                                <VAL>17.37</VAL>
                                <ERR>0.036</ERR>
                        </MAG>
                </ELEM>
        </SERIES>
</SimpleTimeseries>
```