Time series vizualization tools though the so-called astronomical "Virtual Observatory"

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The Astronomical Virtual Observatory

- Virtual Observatory (VO) is an ambitious international proposal to :
  - provide **uniform**, **convenient** access
  - to **disparate, geographically dispersed archives of astronomical data**
  - from software which runs on the computer on the astronomer's desktop.
- The VO could be of interest for the geodetic community
- Astronomers using that Virtual Observatory are now organized within an international association called the **International Virtual Observatory Alliance (IVOA)**: http://www.ivoa.net/.
- formed in June 2002
- Mission: "Facilitate the international coordination and collaboration necessary for the development and deployment of the tools, systems and organizational structures necessary to enable the international utilization of astronomical archives as an integrated and interoperating virtual observatory."

The VO-Table format

- Several thousand users worldwide in the astronomical community.
- Existing standards.
- Existing self descriptive format based on these standards and XML : the VO-Table.
- Many tools already exist to manage, plot or analyze data supplied in VO-Table format (described non-ambiguously). Convert ones own data in VO-Table format means benefiting of all existing tools.
- Easy access to data by other scientific communities. Data that need to be distributed can be registered to a "registry". See for example http://esavo.esac.esa.int/registry/.
- Successful project in Astronomy. The historical collaboration and close foundation between Astronomy and geodesy encourages an adoption of VO standards by the geodetic community.

The VOTable Data Exchange Format

- VOTable is a **XML-based format** for representing astronomical catalogues (properties of celestial objects : celestial coordinates, brightness etc.)
- The VOTable has been defined in terms of XML in order to
  - take advantage of computer-industry standards
  - **utilize standard software and tools**
- Concerning time series:
  - geodetic tables are rich in metadata
  - annotation, interpretable by either computers or humans, both of the tables and the individual columns that they contain
  - these metadata should be preserved with the table and the VOTable has features to permit this
- VOTable is designed to describe a wide variety of physical parameters.
- Description through **Unified Content Descriptors (UCD)**
- for an accurate description of complex data: to be used conjointly with an **external data model**, such as the STC (**Space-Time Coordinate Metadata** for the Virtual Observatory) .

UCD relevant to geodesy time series approved by IVOA

Description	UCD	Commentaire	UCD existant (oui ou non)
UCD fréquemment utilisés en géodésie			
Généraux			
Epoque	time.epoch		oui
Système de Référence Céleste			
Ascension droite	pos.eq.ra		oui
Declinaison	pos.eq.de		oui
Ecart-type ascension droite	stat.stdev;pos.eq.ra		oui
Ecart-type declinaison	stat.stdev;pos.eq.de		oui
Correlation	stat.correlation		oui
Orientation de la Terre			
Coordonnée X du CIP dans le repère Terrestre	pos.eop.xp		oui (accepté sur recommandation OV(GAFF)
Coordonnée Y du CIP dans le repère Terrestre	pos.eop.yp		oui (accepté sur recommandation OV(GAFF)
Vitesse X du CIP dans le repère Terrestre	arith.rate;pos.eop.xp		oui
VitesseY du CIP dans le repère Terrestre	arith.rate;pos.eop.yp		oui
UT1-UTC	pos.eop.UT1mUTC		oui (accepté sur recommandation OV(GAFF)
Longueur du jour	arith.rate;pos.eop.UT1mUTC	Ajouter une description dans le VOTABLE: <DESCRIPTION>Length of day (k times UT1 rate, where k = ...)</DESCRIPTION>.	oui
Position X du CIP dans le repère céleste	pos.eop.dX		oui (accepté sur recommandation OV(GAFF)
Position Y du CIP dans le repère céleste	pos.eop.dY		oui (accepté sur recommandation OV(GAFF)
Ecart-type Coordonnée X du CIP dans le repère Terrestre	stat.stdev;pos.eop.xp		oui
Ecart-type Coordonnée Y du CIP dans le repère Terrestre	stat.stdev;pos.eop.yp		oui
Ecart-type Vitesse X du CIP dans le repère Terrestre	stat.stdev;arith.rate;pos.eop.xp		oui
Ecart-type VitesseY du CIP dans le repère Terrestre	stat.stdev;arith.rate;pos.eop.yp		oui
Ecart-type UT1-UTC	stat.stdev;pos.eop.UT1mUTC		oui
Ecart-type Longueur du jour	stat.stdev;arith.rate;pos.eop.UT1mUTC		oui
Système de Référence Terrestre			
Coordonnées X	pos.cartesian.x	coordonnées cartésiennes géocentriques	oui
Coordonnées Y	pos.cartesian.x	coordonnées cartésiennes géocentriques	oui
Coordonnées Z	pos.cartesian.x	coordonnées cartésiennes géocentriques	oui
Vitesses en X	arith.rate;pos.cartesian.x	coordonnées cartésiennes géocentriques	oui
Vitesses en Y	arith.rate;pos.cartesian.y	coordonnées cartésiennes géocentriques	oui
Vitesses en Z	arith.rate;pos.cartesian.z	coordonnées cartésiennes géocentriques	oui
Ecart-type position en X	stat.stdev;pos.cartesian.x		
Ecart-type position en Y	stat.stdev;pos.cartesian.y		
Ecart-type position en Z	stat.stdev;pos.cartesian.z		
Ecart-type vitesse en X	stat.stdev;arith.rate;pos.cartesian.x		
Ecart-type vitesse en Y	stat.stdev;arith.rate;pos.cartesian.y		
Ecart-type vitesse en Z	stat.stdev;arith.rate;pos.cartesian.z		
Vitesse en Est	arith.rate;pos.topocentric.east	repère centré sur le point (repère topocentrique)	oui (accepté sur recommandation OV(GAFF)
Vitesse en Nord	arith.rate;pos.topocentric.north	repère centré sur le point (repère topocentrique)	oui
Vitesse verticale	arith.rate;pos.topocentric.up	repère centré sur le point (repère topocentrique)	oui
Ecart-type Vitesse en Est	stat.stdev;arith.rate;pos.topocentric.east		oui
Ecart-type Vitesse en Nord	stat.stdev;arith.rate;pos.topocentric.north		oui
Ecart-type Vitesse verticale	stat.stdev;arith.rate;pos.topocentric.up		oui

Example of a VOtable file : ICRF-2

```
<?xml version="1.0" encoding="UTF-8" ?>
- <VOTABLE version="1.1" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xmlns="http://www.ivoa.net/xml/VOTable/v1.1" xsi:schemaLocation="
  http://www.ivoa.net/xml/VOTable/v1.1">
  <DESCRIPTION>VizieR Astronomical Server: vizier.cfa.harvard.edu 2008-02-20T13:12:48</DESCRIPTION>
- <DEFINITIONS>
    <COOSYS ID="J2000" system="eq_FK5" equinox="J2000" />
  </DEFINITIONS>
  <INFO ID="Ref" name="-ref" value="VOTx12474" />
  <INFO ID="MaxTuples" name="-out.max" value="50000" />
- <RESOURCE ID="yCat_51273587" name="J/AJ/127/3587">
    <DESCRIPTION>VLBI ICRF. II (Fey+, 2004)</DESCRIPTION>
  - <TABLE ID="J_AJ_127_3587_icrf" name="J/AJ/127/3587/icrf">
      <DESCRIPTION>All ICRF positions (tables 1, 2 and 3 of the paper)</DESCRIPTION>
      <!-- Now comes the definition of each field -->
    - <FIELD name="_RAJ2000" ucd="pos.eq.ra;meta.main" ref="J2000" datatype="double" width="13" precision="9" unit="deg">
        <DESCRIPTION>Right ascension (FK5) Equinox=J2000. (computed by VizieR, not part of the original data)</DESCRIPTION>
        <!-- ucd="POS_EQ_RA_MAIN" -->
      </FIELD>
    - <FIELD name="_DEJ2000" ucd="pos.eq.dec;meta.main" ref="J2000" datatype="double" width="13" precision="9" unit="deg">
        <DESCRIPTION>Declination (FK5) Equinox=J2000. (computed by VizieR, not part of the original data)</DESCRIPTION>
        <!-- ucd="POS_EQ_DEC_MAIN" -->
      </FIELD>
    - <FIELD name="ICRF" ucd="ID_MAIN" datatype="char" arraysize="16*">
        <DESCRIPTION>ICRF designation (1)</DESCRIPTION>
        <!-- ucd="(unassigned)" -->
      </FIELD>
    - <FIELD name="n_ICRF" ucd="NOTE" datatype="char">
        <DESCRIPTION>{\bf n} for new sources (table1), {\bf c} for candidate sources (table2), and {\bf r} for revised positions (table3)</DESCRIPTION>
        <!-- ucd="(unassigned)" -->
      </FIELD>
    - <FIELD name="RAJ2000" ucd="POS_EQ_RA_MAIN" ref="J2000" datatype="char" arraysize="15" unit=""h:m:s"">
        <DESCRIPTION>Hour of Right Ascension (J2000)</DESCRIPTION>
        <!-- ucd="(unassigned)" -->
      </FIELD>
    - <FIELD name="DEJ2000" ucd="POS_EQ_DEC_MAIN" ref="J2000" datatype="char" arraysize="15" unit=""d:m:s"">
        <DESCRIPTION>Degree of Declination (J2000)</DESCRIPTION>
        <!-- ucd="(unassigned)" -->
      </FIELD>
    - <FIELD name="e_RAs" ucd="ERROR" datatype="double" width="9" precision="6" unit="s">
        <DESCRIPTION>Error in RAs</DESCRIPTION>
        <!-- ucd="(unassigned)" -->
      </FIELD>
    - <FIELD name="e_DEs" ucd="ERROR" datatype="double" width="8" precision="5" unit="arcsec">
        <DESCRIPTION>Error in DEs</DESCRIPTION>
        <!-- ucd="(unassigned)" -->
      </FIELD>
    - <FIELD name="MEpoch" ucd="TIME_EPOCH" datatype="float" width="7" precision="1" unit="d">
```

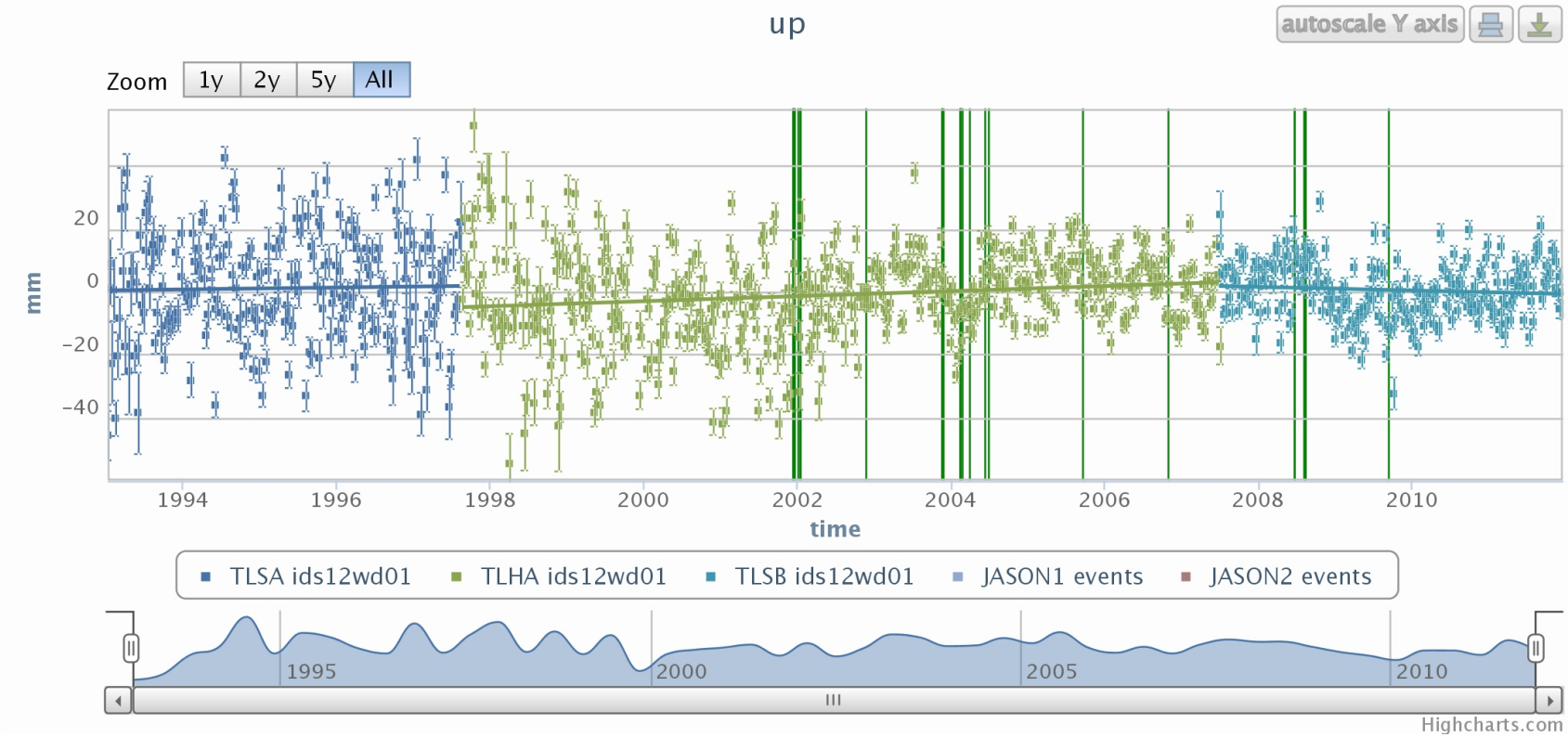
Example of a VOtable file: ILRS station coordinate time series

```
<!--
 !  VOTable written by STIL version 2.9-2x (uk.ac.starlink.votable.VOTableWriter)
 !  at 2013-05-22T07:00:11
 !-->
<RESOURCE>
<TABLE name="1884_ENU.dat" nrows="1">
<DESCRIPTION>
Serie temporelle de la station 1884
 Nom station : Riga
 No DOMES : 12302S002
 Unite position stations : m
</DESCRIPTION>
<FIELD datatype="double" name="DATE" ucd="time.epoch;obs">
<DESCRIPTION>Description</DESCRIPTION>
</FIELD>
<FIELD datatype="double" name="E" ucd="pos.?">
<DESCRIPTION>Description</DESCRIPTION>
</FIELD>
<FIELD datatype="double" name="DE" ucd="pos.?">
<DESCRIPTION>Description</DESCRIPTION>
</FIELD>
<FIELD datatype="double" name="N" ucd="pos.?">
<DESCRIPTION>Description</DESCRIPTION>
</FIELD>
<FIELD datatype="double" name="DN" ucd="pos.?">
...
```

Example of a VOtable file: ILRS station coordinate time series

```
...
<FIELD datatype="double" name="U" ucd="pos.?">
<DESCRIPTION>Description</DESCRIPTION>
</FIELD>
<FIELD datatype="double" name="DU" ucd="pos.?">
<DESCRIPTION>Description</DESCRIPTION>
</FIELD>
<DATA>
<TABLEDATA>
  <TR>
    <TD>2013.1957737506</TD>
    <TD>0.01095060877</TD>
    <TD>0.1269983646</TD>
    <TD>-0.05735097043</TD>
    <TD>0.2540255841</TD>
    <TD>-0.03239336204</TD>
    <TD>0.0816086837</TD>
  </TR>
</TABLEDATA>
</DATA>
</TABLE>
</RESOURCE>
</VOTABLE>
```

Visualization through dedicated libraires: highcharts.com



Example of a coordinate time series provided by IDS @ CLS, containing as well additional information (here: satellite events):

http://ids-doris.org/plottool/stcd/stcdtool.php

Conclusions and prospects

- all the framework already well defined
  - archiving and exploring geodetic products time series very efficient through VO tools
  - additional information can be managed with "VO-event"
- many tools available and well-documented on the web
  - visualization tools
  - UCD finder
  - VOTable: automatic transformation script from and to each common data formats
  - Current up-to-date version: 1.3
- Such files can easily and **automatically be built** thanks to dedicated tools from common **ASCII files**, such as "**stilts**" and "**TOPcat**".

thank you