Enhancements on the Virtual Observatory standards for Time Domain

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Index

- Time Domain Astronomy and (first order) users needs

  - Search & Find data

  - Visualise data

  - Analyse data

Search & Find

- Time needs interoperability:

  - Unambiguous declaration of metadata

  - **Minimum metadata about the time system**

    - **Time Scale** how the clock ticks (e.g. TAI, TT, UTC,…)

      - Very important for high precision studies (e.g. pulsars)

      - Different time scales can give differences in time of <~ 1minute

    - **Reference position** where the measurement is valid (e.g. instrument, center of the Earth, barycentre of the Solar System, satellite, …)

      - Very important for most of the time domain astronomy use cases

      - Differences up to ~ 16 minutes (2xEarth-Sun, but could be longer…)

    - **Time origin** offset subtracted to the data (e.g. JD-2455197.5)

      - Extremely important!

      - To be added to time values to compare times (in a pivot format)

Search & Find

➡ **TIMESYS element in VOTable (Demleitner et al. 2018, and next talk)**

http://ivoa.net/documents/Notes/TimeSys/20181212/index.html

http://www.ivoa.net/documents/VOTable/20190218/

A Proposal for a TIMESYS Element in VOTable

Version 1.1

IVOA Note 2018-12-12

Working group
    Time Domain
This version
    http://www.ivoa.net/documents/timesysnote/20181212
Latest version
    http://www.ivoa.net/documents/timesysnote
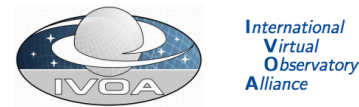Previous versions
    Version 1.0 (2018-10-29)
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VOTable Format Definition
Version 1.4

IVOA Working Draft 2019-01-31

This version:
    http://www.ivoa.net/Documents/VOTable/20190131/

Latest version:
    http://www.ivoa.net/Documents/latest/VOT.html

Previous versions:
    http://www.ivoa.net/documents/VOTable/20130920/   V1.3 (2013-09-20)
    http://www.ivoa.net/Documents/VOTable/20091130/   V1.2 (2009-11-30)
    http://www.ivoa.net/Documents/cover/VOT-20040811.html   V1.1 (2004-08-11)
    http://www.ivoa.net/Documents/PR/VOTable/VOTable-20031017.html   V1.0 (2002-04-15)

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Search & Find

➡ **TIMESYS element in VOTable (Demleitner et al. 2018, and next talk)**

- Next steps?
  - Encourage **Data providers** to provide VOTables which use this element
 - Encourage **Applications** to make use of it

Search & Find

How can applications make use of it?

An example: T-MOC

➡ **T-MOC defines the time coverage (see Fernique et al 2018):**

- Tables, catalogues, collection of images, ...

- Based on the existing technology used to support the Multi-Ordered Coverage (MOC)

- Replaced the HEALPix space discretisation with a time scale using the same properties as the MOC but covering only one axis (Fernique et al. 2015)

- Allows fast operations such as unions, intersections,...
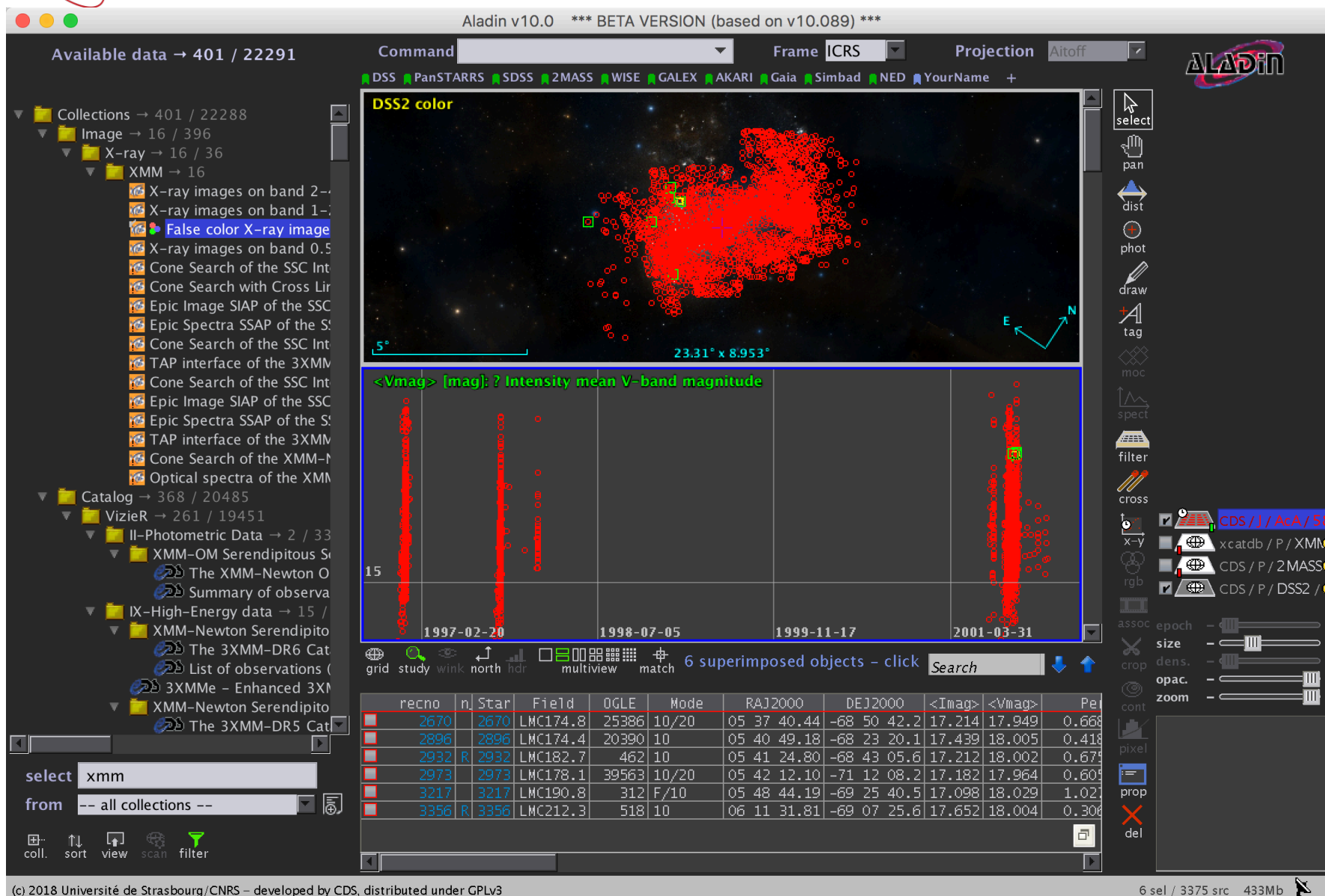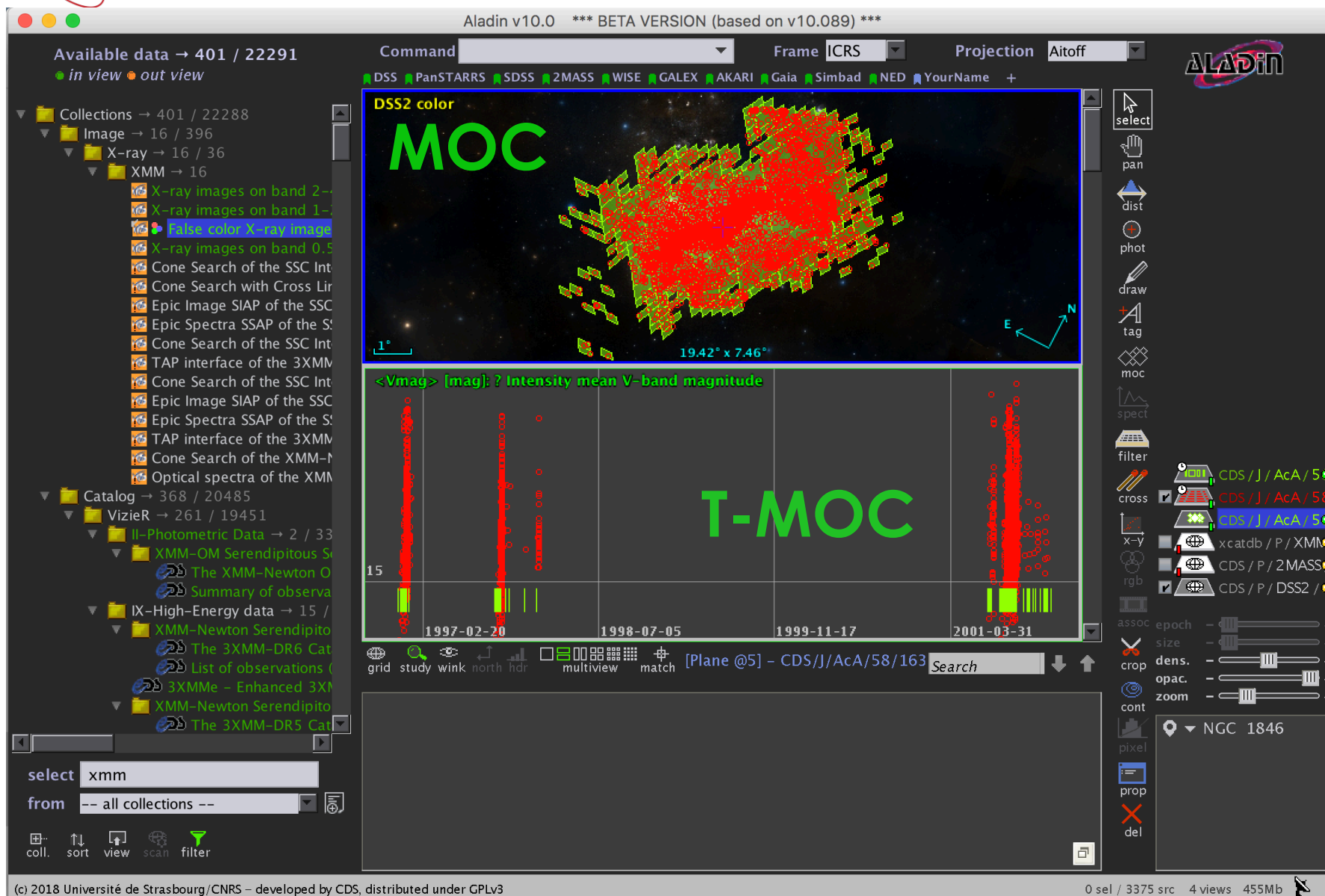
Search & Find

- T-MOC to define time coverage (see Fernique et al 2018):

  - Requirements to create a T-MOC:

    - Fix a system (pivot format): TCB, Barycentric of the Solar System, no offset

    - Set a resolution

order	Cell Resolution
0	9133y 171d 11h 22m 31.711744s
1	570y 307d 11h 35m 9.481984s
2	570y 307d 11h 35m 9.481984s
...	...
6	2y 83d 22h 52m 24.177664s
...	...
12	4h 46m 19.869184s
...	...
22	16.384ms
...	...
27	$16\,\mu s$
28	$4\,\mu s$
29	$1\,\mu s$

Search & Find

- T-MOC to define time coverage (see Fernique et al 2018):

    - Requirements to create a T-MOC:

        - Need to find the time value in a catalogue and it's system

        - With TIMESYS element defined it would be much easier

        - Need a library for system conversion

            - If the offset is unknown nothing can be done.

            - If the scale is not known set resolution to level 15 or 16 (100 seconds is ~ maximum difference between different scales)

            - If the reference position is unknown set the resolution to level 14 (16 minutes corresponds to ~ maximum difference in light travel between different reference positions)

                - T-MOC needs to keep track of unknown values in original metadata so warn users

Search & Find

- Search data based on other time constraints besides time of observation:

    - exposure time

    - cadence

    - duration

- **Extension of obscore for time**

    - Core components of queryable metadata required for global discovery of observational data. See ObsCoreDM (M. Louys et al 2017)

- See M. Molinaro's presentation and GAPS time series for a specific science case (exoplanets)
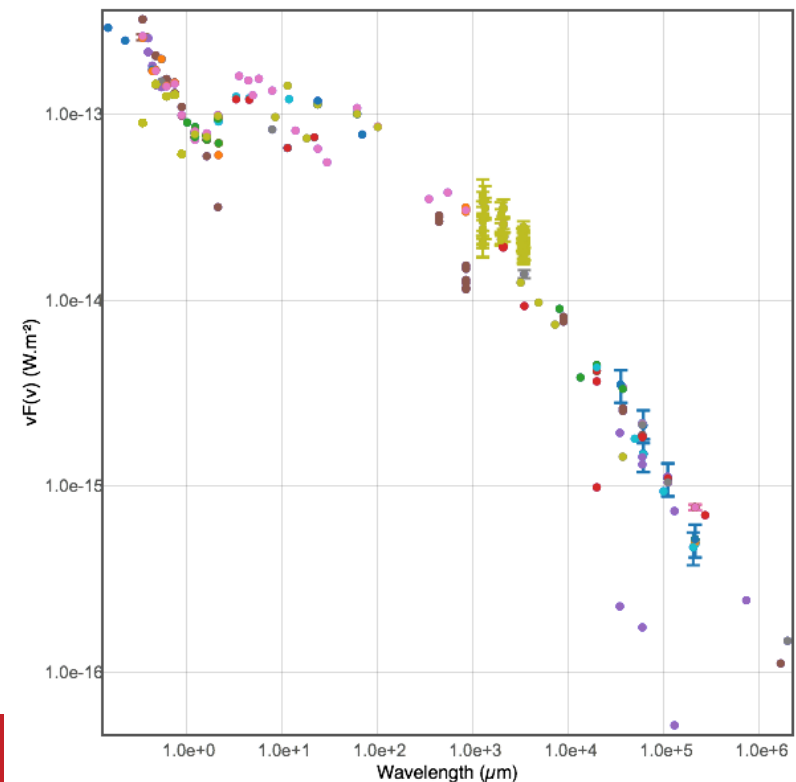
Data Visualisation

- A **quick photometric viewer**

- Find & plot all the photometry available in a certain region of the sky over **wavelength**

- Requirements on data and metadata for :

    - Position —> Cone search

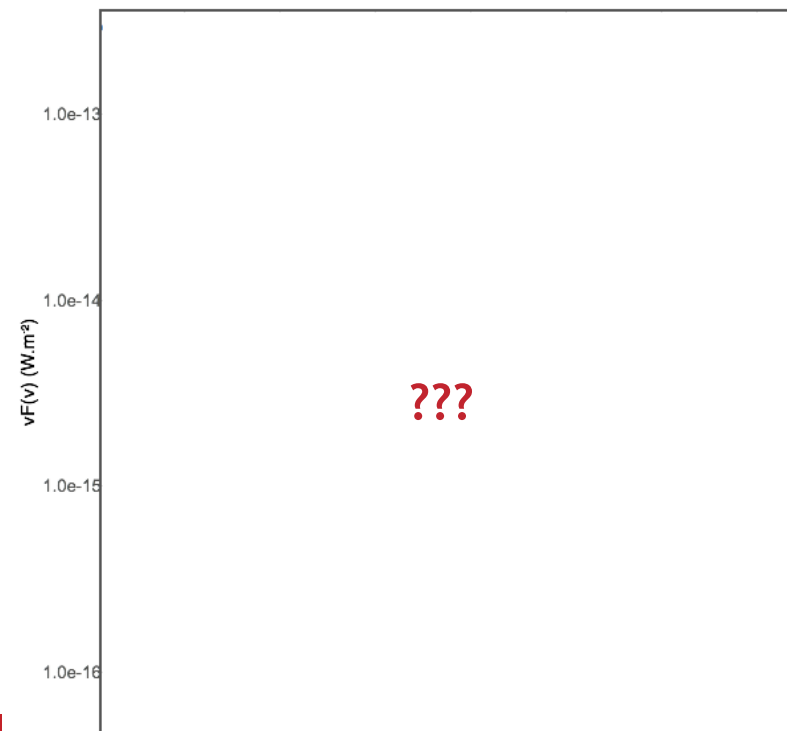   - Photometry —> **Photometric system**

Data Visualisation

- A **quick light-curve viewer** (see S. Derriere's presentation @ IVOA Shanghai)

- IDEA: Find & plot all the photometry available in a certain region of the sky over **time**

- Requirements on data and metadata for :

  - Position —> Cone search

  - Photometry —> Photometric system

  - Time —> **Time system**

    - elements defined in TIMESYS

    - covert to a pivot format

    - systematic error if unknown:

      - offset unknown —> nothing

      - scale unknown = 100 s

      - ref. position unknown 1000 s

Target: 3C 273
Radius (in arcsec): 5
submit

3C 273 (12 29 6.695+02 03 8.662),
radius : 5 arcsec

vF(v) (W.m²)

1.0e-13

1.0e-14

1.0e-15

1.0e-16

???

JD [days]

Data Visualisation

- A **quick time viewer** (see S. Derriere's presentation @ IVOA Shanghai)

- IDEA: Find & plot **all/a certain type of data** available in a certain region of the sky **over time**

- Requirements on data and metadata for :

  - Position —> Cone search

  - data —> **what type? RVs, magnitudes,.**

  - Time —> Time system

  - What is the quantity to represent?

    - "dependant variable"

Target: 3C 273
Radius (in arcsec): 5
submit

3C 273 (12 29 6.695+02 03 8.662),
radius : 5 arcsec

Radial Velocity? Photometry? magnetic field?

???

JD [days]

Data Visualisation

VizieR already compiling the metadata!

First results

- Catalogues with time metadata
    - 190 catalogues
    - ~300 tables
    - Scale is typically unknown
    - Ref. position is known for ~1/3 of the cases
    - offset set to > 2/3 of the cases ! extremely important !

    Next steps based on that

- Convert to a pivot format
- Create of T-Mocs for all those catalogues

Data Visualisation

- The **general case:** An **ideal time viewer** should be able to connect:

  - sources,

  - images,

  - spectra,

  - measurements,

  - …

  - and a model describing the data and the relations would help doing so

Data Visualisation

- The **IDEA in mind**: For any catalogue available through VO + users

    - Display measurements as a function of time

    - Simultaneously visualise the catalogue positions in the sky

    - Navigate through any image available through VO + users

    - Show the photometric information around any source of interest

        - As a function of time (light-curve viewer)

        - As a function of wavelength (photometric-viewer)

Data Visualisation

- Model dependancies: **Huge effort from the IVOA DMGW**
    - **CubeDM** (see D. Tody et al. 2015)
        - describes the sparse nature of a time cube
        - individual data points, light-curves, spectra, images, …
    - **Characterisation** (Louys et al. 2008, 2017)
        - describes the parameter space of observed data
        - to facilitate discovery, e.g. wavelength, sky location, …
    - **PhotoDM** (Salgado et al. 2013)
        - photometric system
    - **Coordinates**: (M. Cresitello-Dittmar work in progress)
        - describing coordinate system, among which time system
        - https://volute.g-vo.org/svn/trunk/projects/dm/STC/Coords/doc/WD-Coords-1.0.pdf
        - Huge work, and it's in good shape

Data Visualisation

- Serialisations on real data examples exist:

  - F. Bonnarel **for utypes** http://volute.g-vo.org/svn/trunk/projects/time-domain/time-series/note/DATA/

  - L. Michel for **VO-DML-lite** https://github.com/lmichel/vodml-lite-mapping

- What next?

  - First tests from VizieR based on Gaia light-curves (beta mode)

  - We need validators & applications to get more involved in the loop

Data Analysis

- Time Series **analysis of variance**

- Period04 (Lenz P., Breger M. 2005, CoAst, 146, 53)

  - Interoperable via SAMP

  - Latest release 2010 — Open for further development — First contacts with developer — new beta version soon to be released
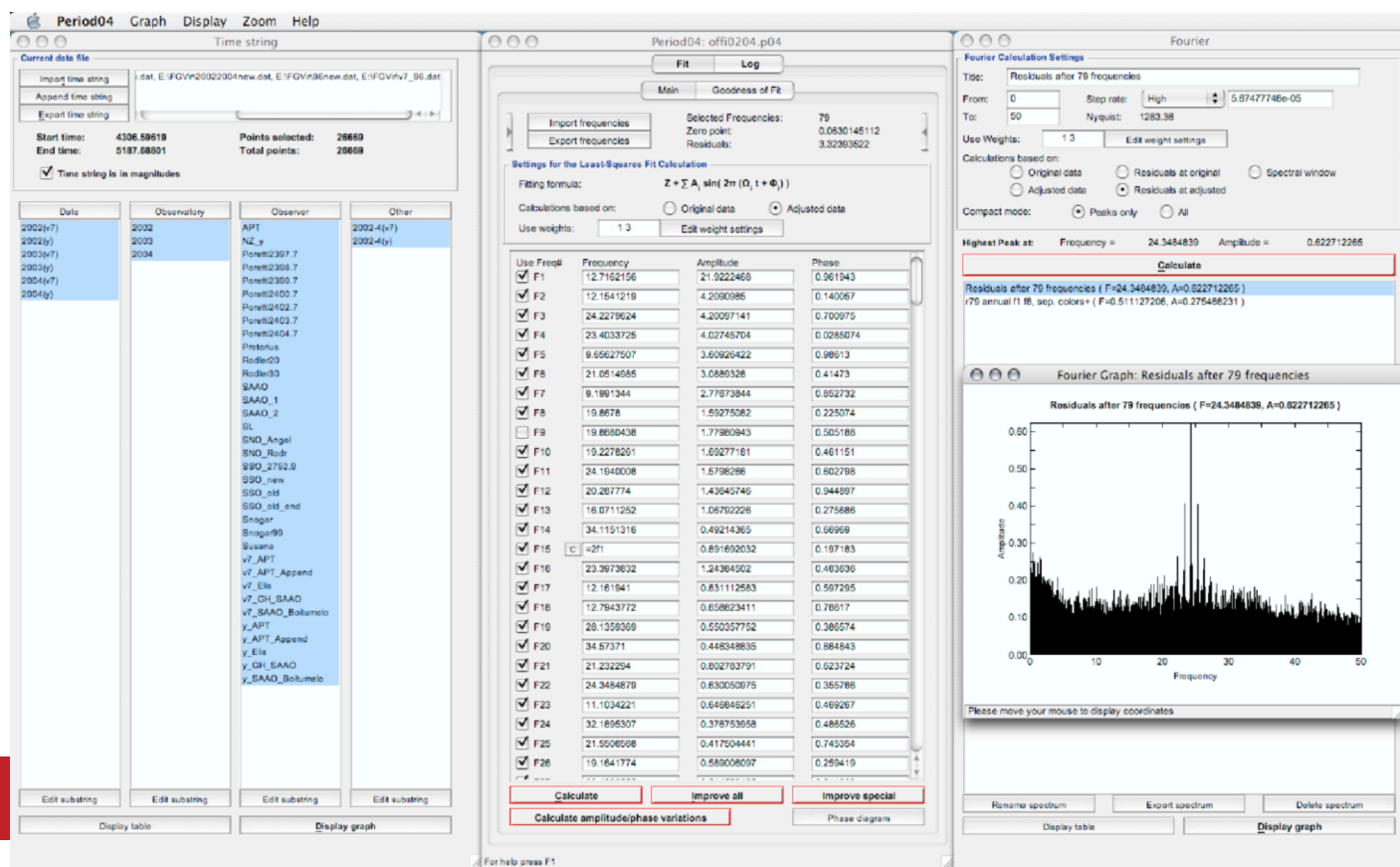
Conclusions

- Time Domain Astronomy and (first order?) users needs

  - Search & Find data:

    - Definition of metadata on TIMESYS element

    - T-MOC for time coverage

      - Need to connect to space for full exploitation

    - Extension of ObsCoreDM for time

  - Visualise data:

    - Towards a quick time-series photometric viewer

    - Towards an ideal time-series viewer — model dependance

  - Analyse data:

    - Period04 — a stable version exists and beta version exists and is open to suggestions before new release.

THANKS!