Time Domain Astronomy and the VO—user perspective

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Outline

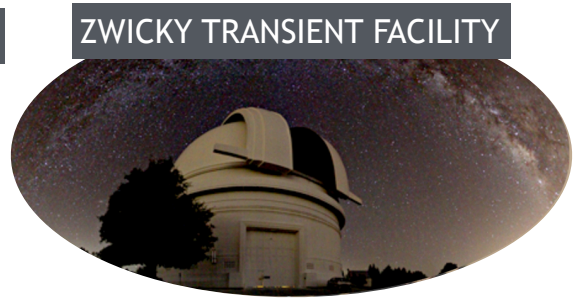
- Why bother about Time Domain?
- Why do astronomers need time series?
- How can the VO be useful for the Time Domain community?
- Success of VO with other kind of data.
- Do we have anything similar for Time Series?

Why bother about Time Domain?

- Time Domain astronomy encompasses every area of Astronomy:
  - **Periodic phenomena**: binary orbits of stars/extrasolar planets, stellar rotation, stellar pulsation…
  - **Stochastic phenomena**: accretion in CVs, X-ray binaries, Seyfert galaxies, quasars…
  - **Explosive phenomena**: supernovae, gamma-ray bursts, novae, X-ray bursts, transits, gravitational microlensing, flares, tidal disruption events…

Why bother about Time Domain?

- Lots of missions specifically designed for Time Domain Astronomy:



- **Transient phenomena** >> follow-up >> Connect events/facilities/people.
  ➡**VOEvent** developed to facilitate transmission
- **Time Series**

Why do astronomers need time series?

- Some astronomers look if an eruptive event on an specific object ever happened and perhaps we missed it (e.g. DASCH project).

- Some astronomers are expecting some stars to go through eruptions at a specific moment and are therefore looking at those stars in a regular basis.

Why do astronomers need time series?

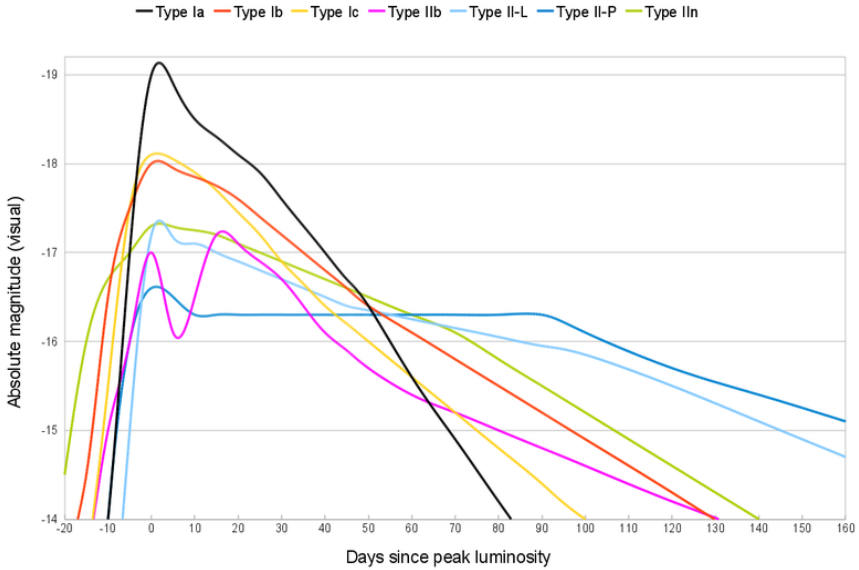
Science cases compiled and documented in the IVOA wiki:

http://wiki.ivoa.net/twiki/bin/view/IVOA/CSPTimeSeries

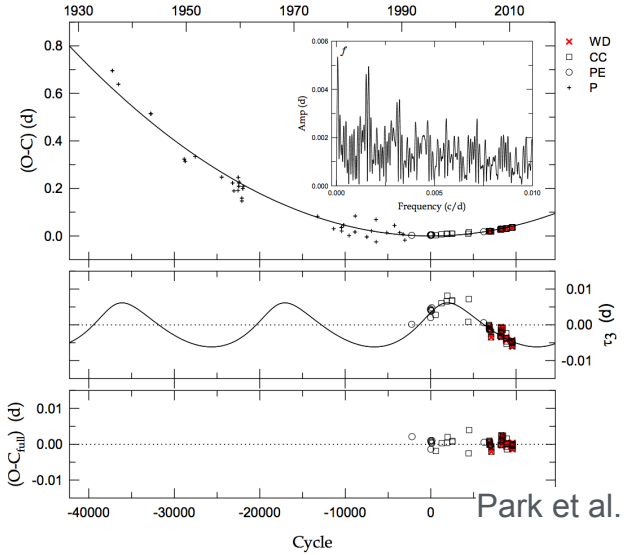
- **3 groups of science cases based on common requirements:**
  A. Combine photometry and light curves of a given object/list of objects in the same photometric band.

Why do astronomers need time series?

1. SN classification using the light curve.

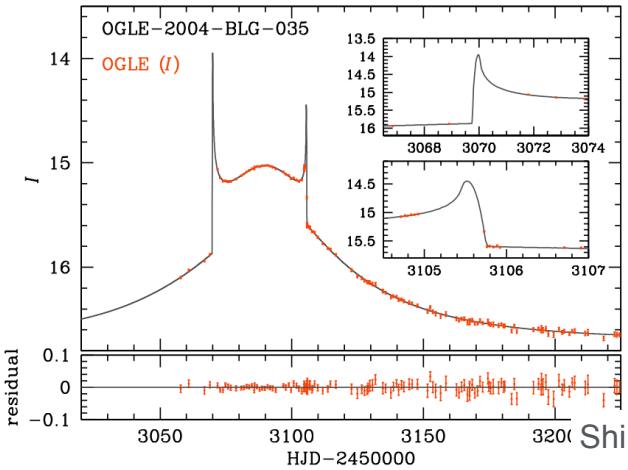


2. Long-term analysis of eclipsing binaries.



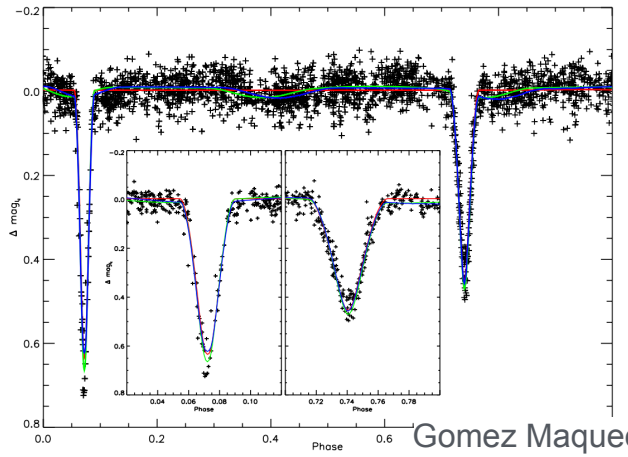
Park et al. 2012

3. Discovering BD by microlensing events.



Shin et al. 2012

4. Eclipsing binary systems.



Gomez Maqueo et al 2009

Why do astronomers need time series?

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- **3 groups of science cases based on common requirements:**

A. Combine photometry and light curves of a given object/list of objects in the same photometric band.

B. Combine photometry and light curves of a given object/list of objects in different photometric bands.

5. Follow-up characterisation of supernovae.

Why do astronomers need time series?

Science cases compiled and documented in the IVOA wiki:
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- **3 groups of science cases based on common requirements:**

A. Combine photometry and light curves of a given object/list of objects in the same photometric band.

B. Combine photometry and light curves of a given object/list of objects in different photometric bands.

5. Follow-up characterisation of supernovae.

C. Time series other than light curves.

6. Exoplanet studies using radial velocities.
7. Asteroseismic studies of pulsating variables.
8. Spectral and temporal variability study of X-ray sources.

How can VO be useful for the TD community?

- More science cases can be detailed if needed to, but…
  - Do we want to solve every single science case?
  - Should we start with the most complicated case?
  - Or should start from the most simple cases and go on from there?

    ➡What is simple? Astronomy isn't, that's for sure.
    - Astronomers like to see a lot of details in their data and will still develop their own tools for that, and that is good.

How can VO be useful for the TD community?

- Astronomers:
  - **produce data**: photometric/radial velocity curves, spectra, images, videos…
  - **connect data**: different kinds of observations (e.g. links between photometric & spectral evolution)
  - **share data**: mail, webpages, databases,…

    ➡Works at a small scale (people & data) and for some time.
  - **analyse data**

- VO tools and services can help to :
  - curate data (easier, stable and long lasting)
  - share data
  - make the connectivity (interoperability)

How can VO be useful for the TD community?

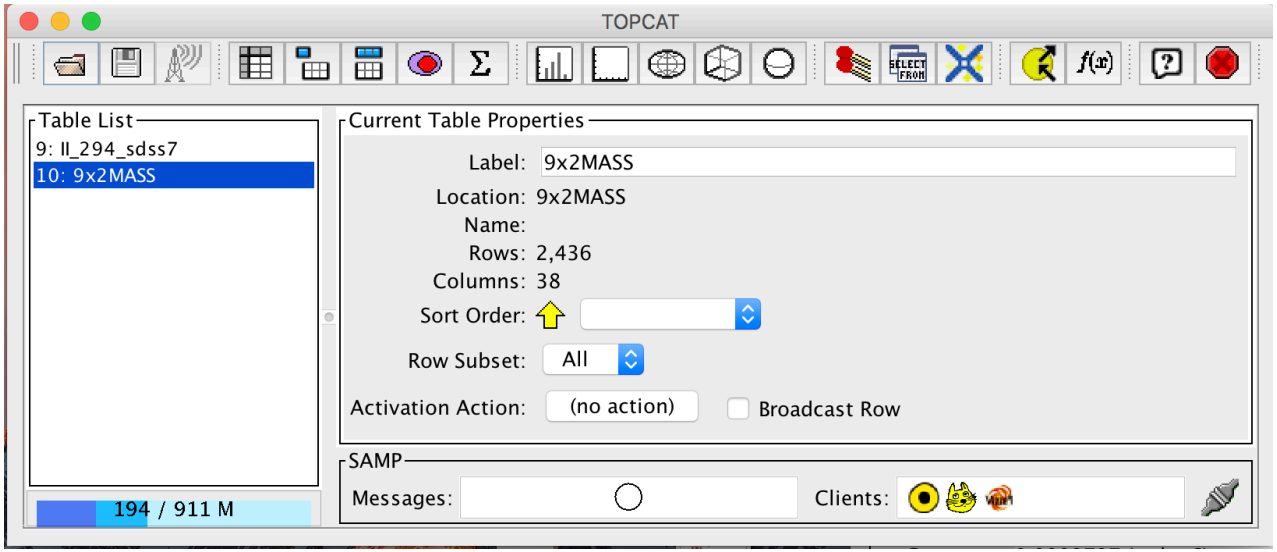
- For TD we want to do the same things we can do with other kind of data:
  - **Find data**: simple/sophisticated queries
  - Quickly **visualise data**: simple/sophisticated plots, videos
  - Make **operations**:
    - periodograms (analysis of variance) find possible periodicity
    - phase-folded curves
  - Interaction between the different services and tools — **interoperability**

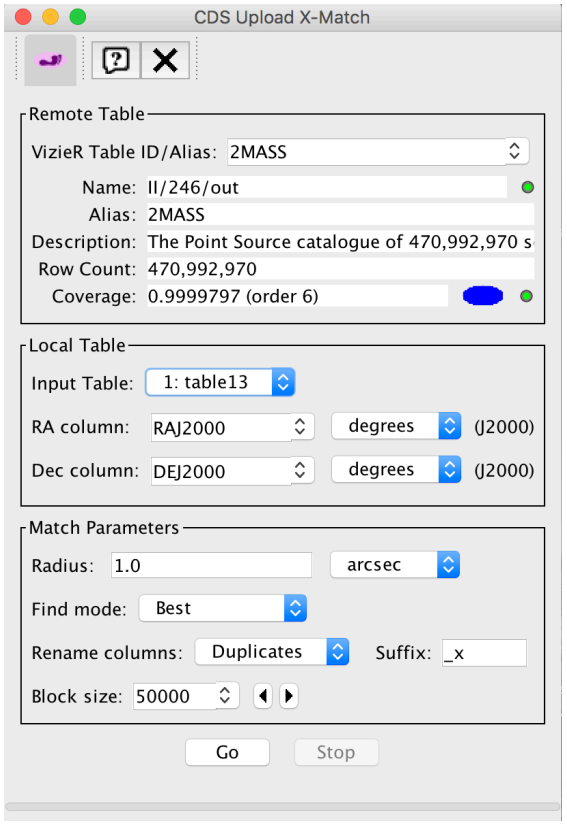
    ➡ gives the user the impression that everything is one unique system.

Discovery & access, visualisation & analysis in a seamless way for the user.

Success of VO with other kind of data

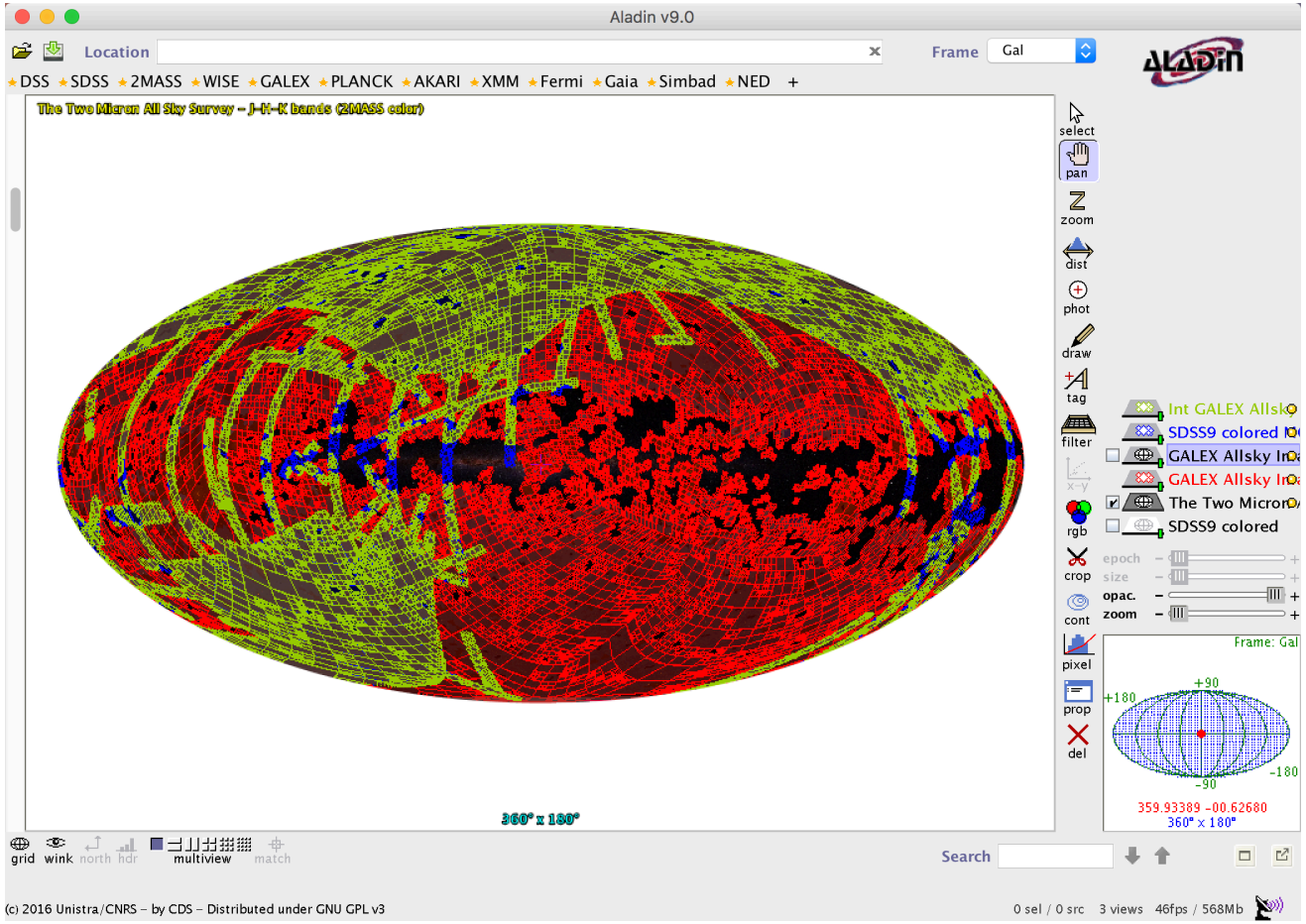
- **Tables**
  - CDS Xmatch using TOPCAT:
    - a sample of 50000 SDSS sources
    - ~470 million 2MASS sources
    - done in seconds





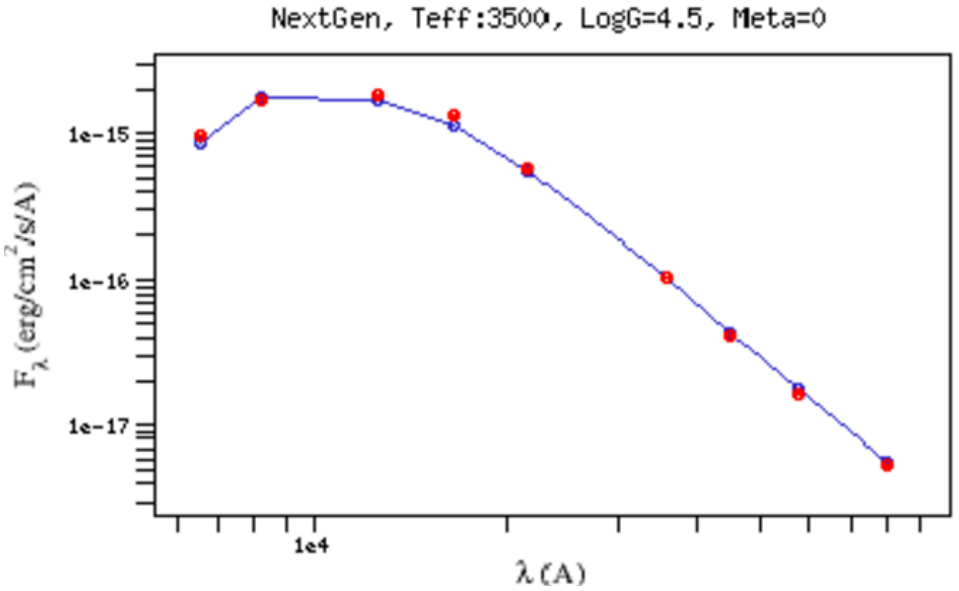
Success of VO with other kind of data

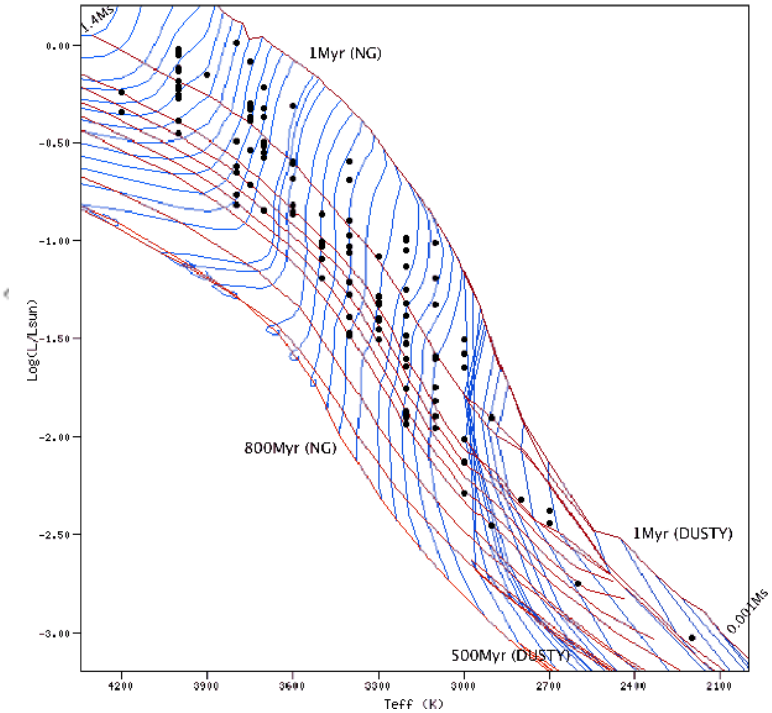
- **Images**
  - Aladin intersection of GALEX & SDSS coverage using MOCs.



Success of VO with other kind of data

- **SEDs**:
  - VOSA: retrieve photometry and fit stellar models to obtain physical parameters of thousand of objects.





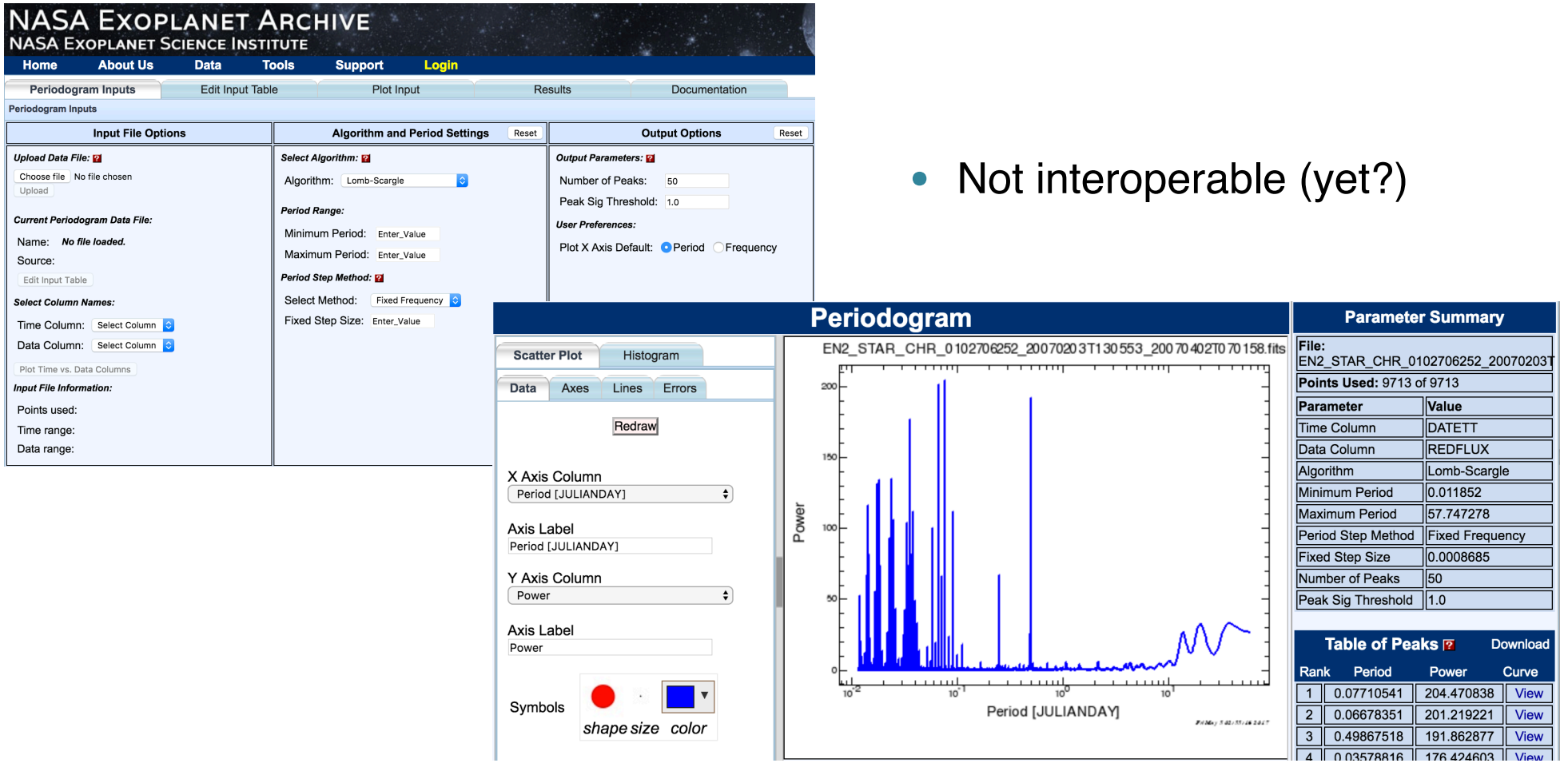
A&A 492, 277-287 (2008)

Do we have anything similar for Time Series?

- **Tables**:
  - time is documented in catalogues & literature in heterogeneous ways.
- **Visualisation**:
  - **Images** are static, videos or Cube-HiPS are more appropriate.
  - **2D Plots**
    - for photometry: SEDs viewer, *flux* VS *wavelength* based on *cone-search* on catalogues with:
      a) coordinates
      b) magnitudes / flux
    - for time domain: the equivalent? *flux* VS *time* based on cone-search on catalogues with:
      a) coordinates
      b) magnitudes / flux
      c) time
- **Operations / analysis**

Do we have anything similar for Time Series?

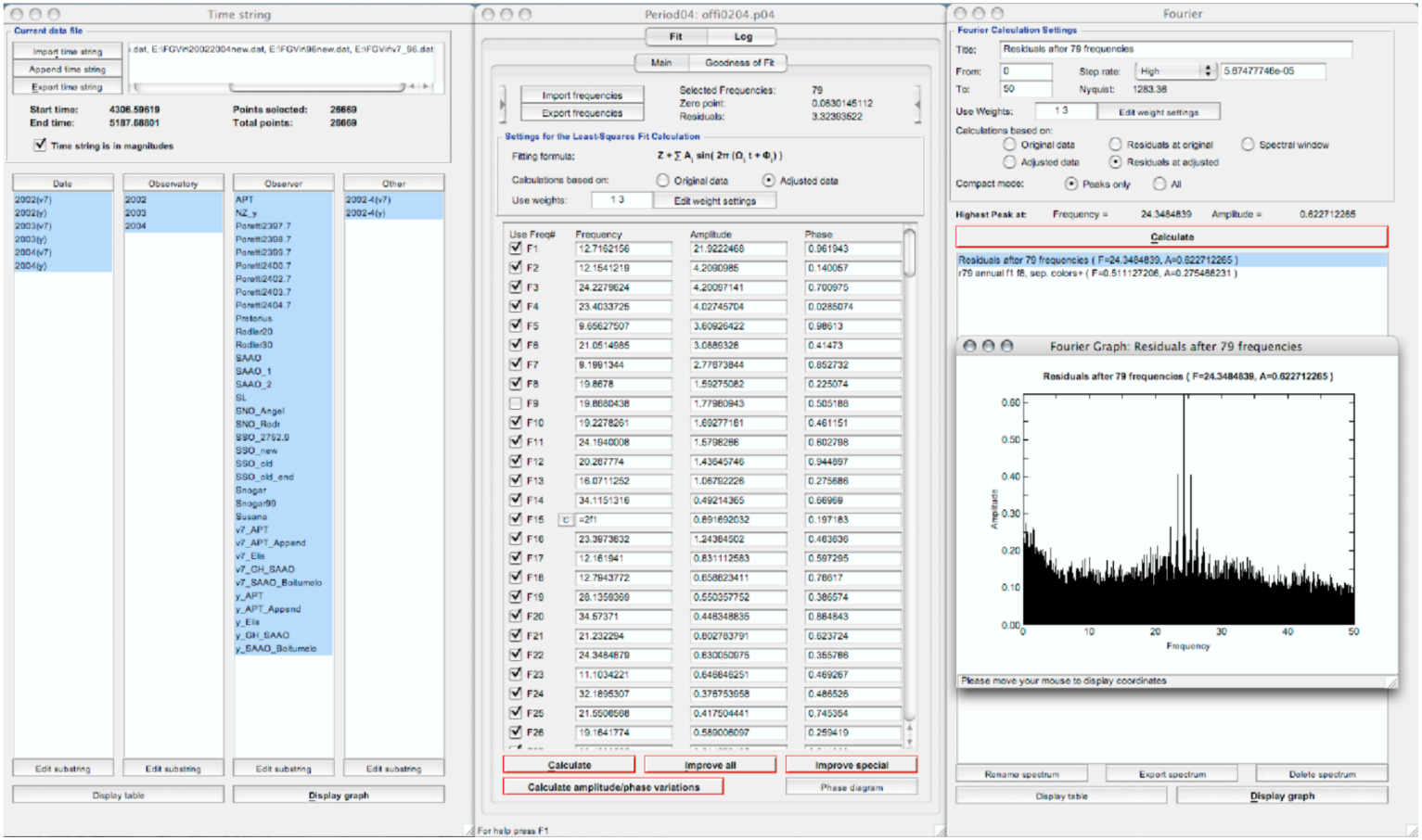
- NASA Exoplanet periodogram service



- Not interoperable (yet?)

Do we have anything similar for Time Series?

- Period04 (SAMP)
- Not maintained since 2010?



Why that? What is missing in the VO for Time Series?

We need standards to be defined as soon as possible to develop tools and services that will allow the community to work in Time Domain Astronomy in the VO context.