Time Domain Metadata modeling, sharing, exploring

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Time Domain Astronomy

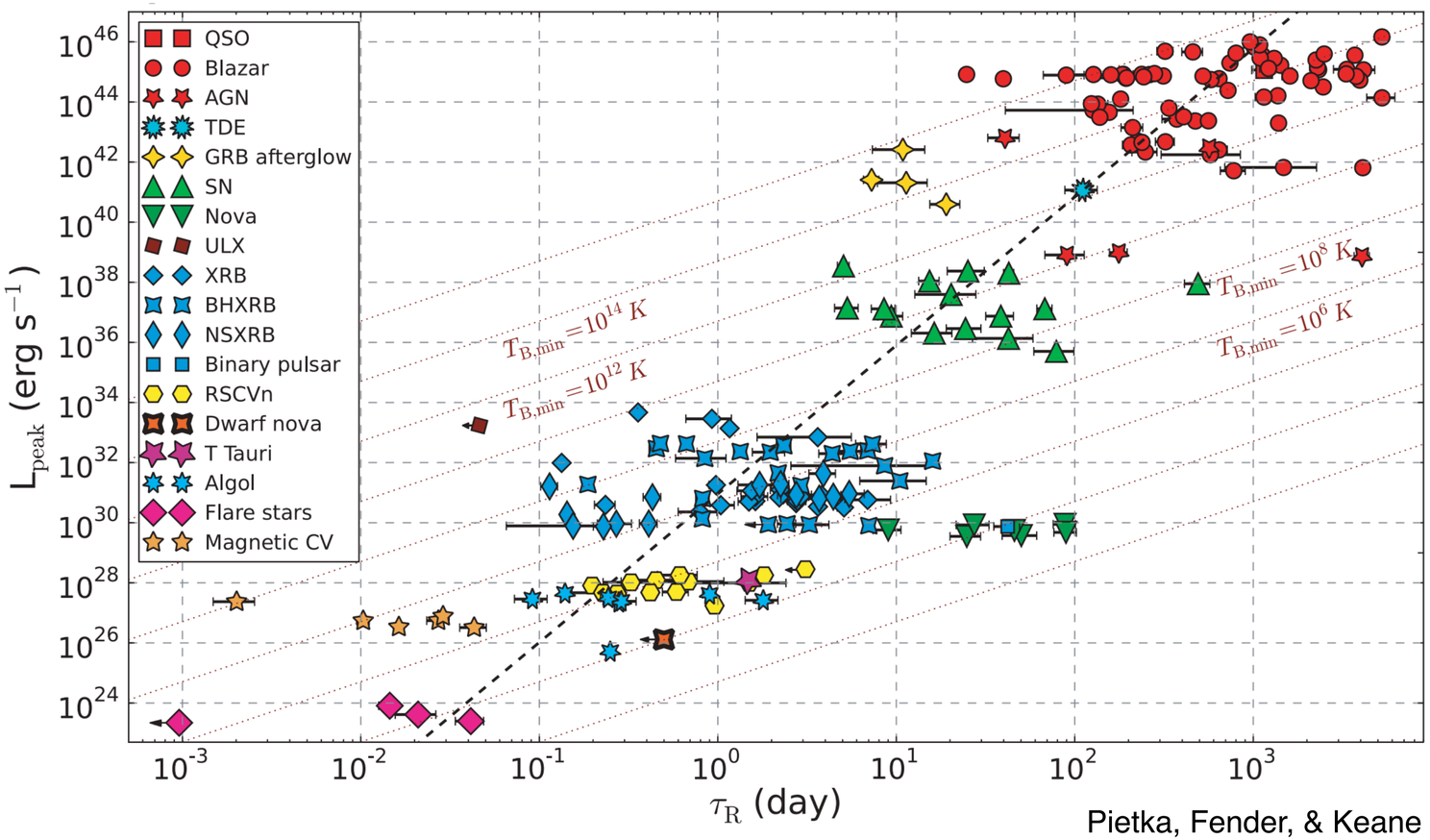
*The study of **variability** of astronomical objects over different time-scales*

- What type of variable phenomena?
  - **Periodic:** binary orbits of stars/extrasolar planets, stellar rotation, stellar pulsation…
  - **Transient:** supernovae, gamma-ray bursts, novae, X-ray bursts, transits, gravitational microlensing, flares, tidal disruption events…
  - **Stochastic:** accretion in CVs, X-ray binaries,…

Time Domain Astronomy

*The study of variability of astronomical objects over different **time-scales***

- What time-scales are we talking about?



Pietka, Fender, & Keane 2015

Time Domain Astronomy

*The study of variability of astronomical objects over different **time-scales***

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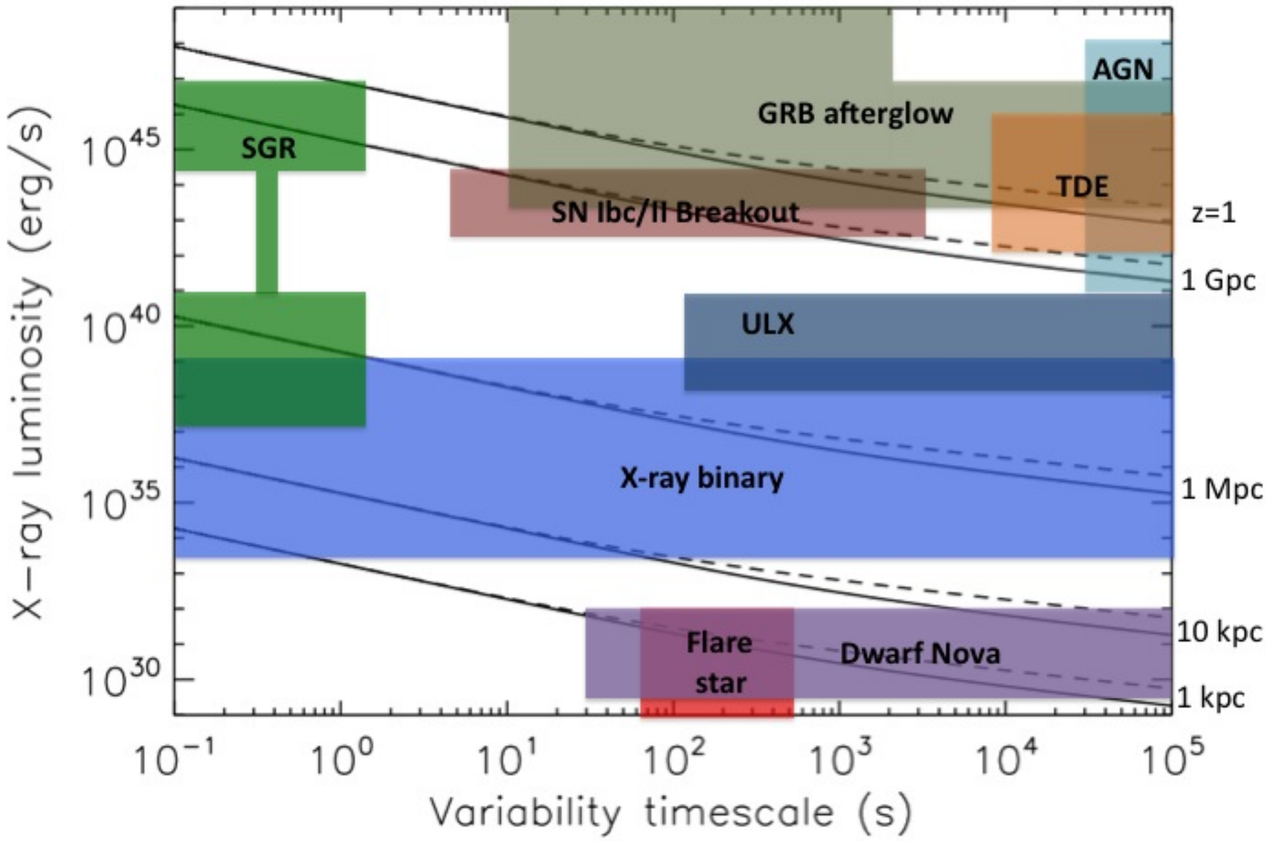


EXTraS Collaboration, De Luca, A. et al. 2016

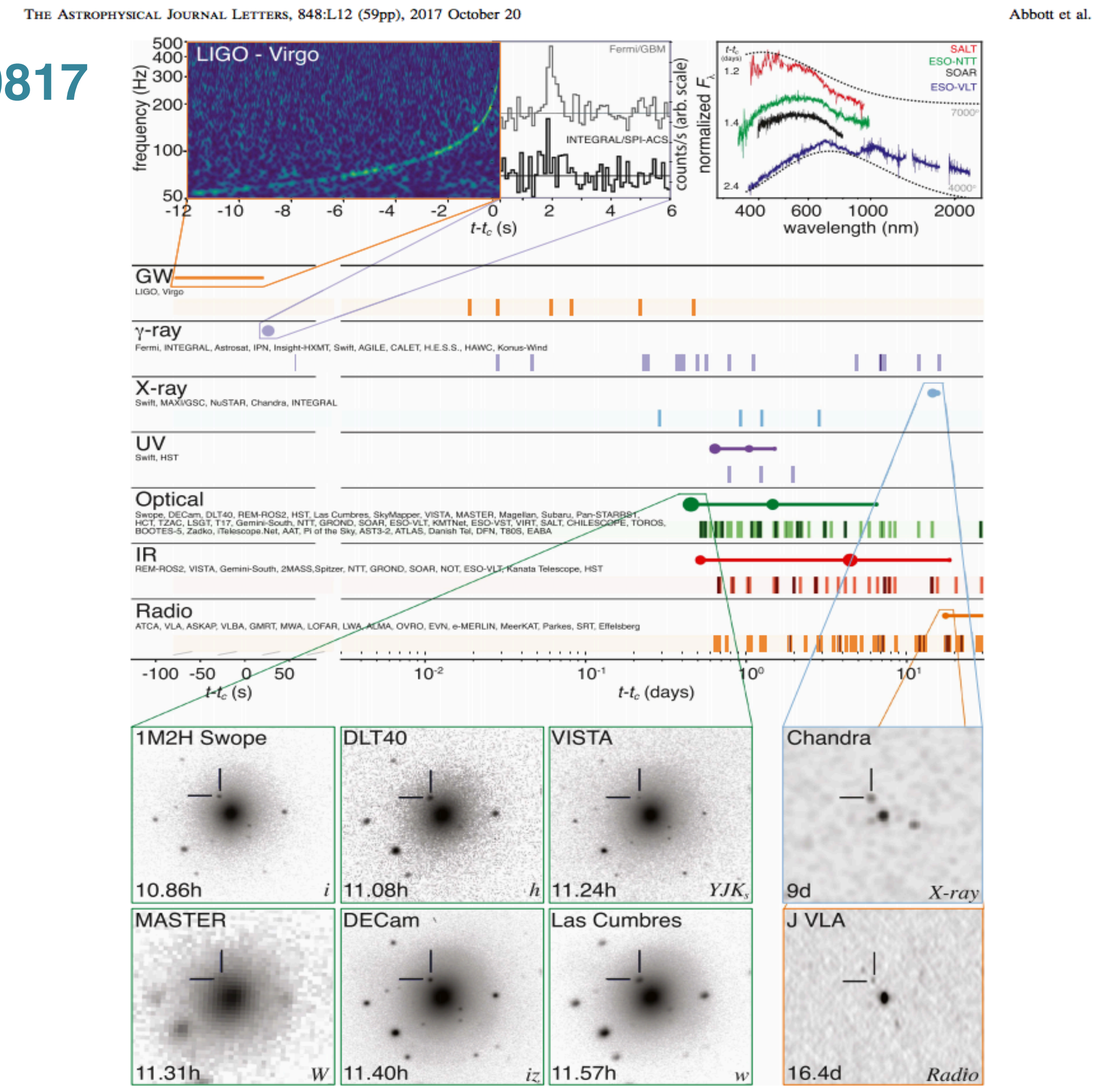
Time Domain Astronomy

- Characterisation and classification of sources on the basis of their variability

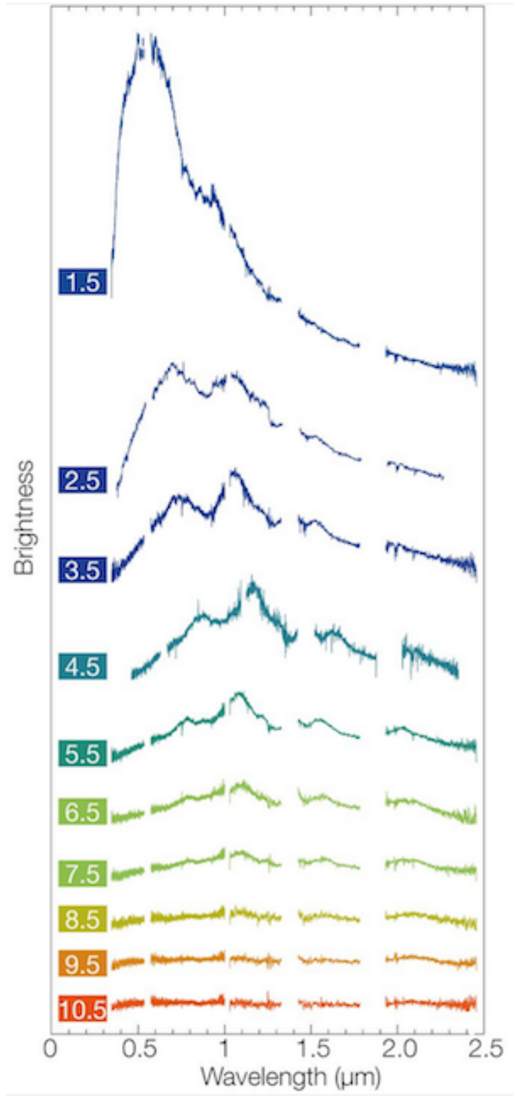
- Need to make explicit
  - Spatial characterisation: position, precision
  - Spectral coverage for a multi-wavelength approach
  - Type of Observable : flux, radial velovity, …

Time Domain Multi-messenger Astronomy

GW170817



Abbott et al. 2017



X-shooter spectra in the kilonova in NGC 4993 over 12 days.
Image credit: ESO/Pian et al./Smartt & ePESSTO.

Visualisation of the sky

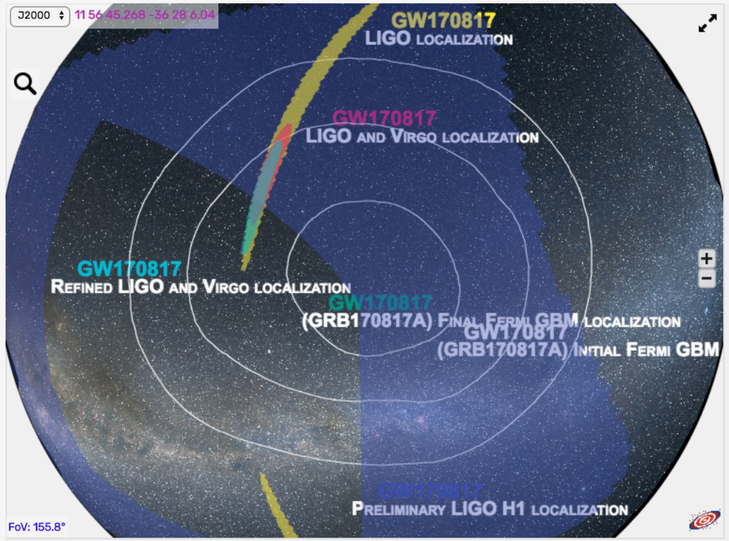
- AladinLite implementation for GW localisation in the sky
- Background image can be DSS, 2MASS, WISE, XMM, Fermi,…
- We can overlay catalogues of interest

Interactive Detection Skymap

Return to the Virgo homepage Go to the LIGO Open Science Center

The interactive skymap shows the localizations of the various gravitational-wave detections in the sky and helps to understand the importance of multimessenger astronomy.

Tweet Share



Using the skymap

Click on the various options below to display information relating to each detection.

Detection	Sky localisation	Label	Pop-up info
GW170817 - H1 only	☑	☑	☐
GW170817 - L1/H1 only	☑	☑	☐
GW170817 - L1/H1/V1	☑	☑	☐
GW170817 - Refined skymap	☑	☑	☐
GW170817 - (GRB170817A) Initial Fermi GBM localization	☑	☑	☐
GW170817 - (GRB170817A) Final Fermi GBM localization	☐	☑	☐
GW170817 - SSS17a/AT2017gfo Transient sky position	☐	☐	☐
GW170814 - H1/L1	☐	☐	☐
GW170814 - H1/L1/V1	☐	☐	☐
GW170814 - Refined skymap	☐	☐	☐
GW170608 - Refined LIGO localization	☐	☐	☐
GW170104 - Refined LIGO localization	☐	☐	☐
GW151226 - Refined LIGO localization	☐	☐	☐
GW150914 - Refined LIGO localization	☐	☐	☐

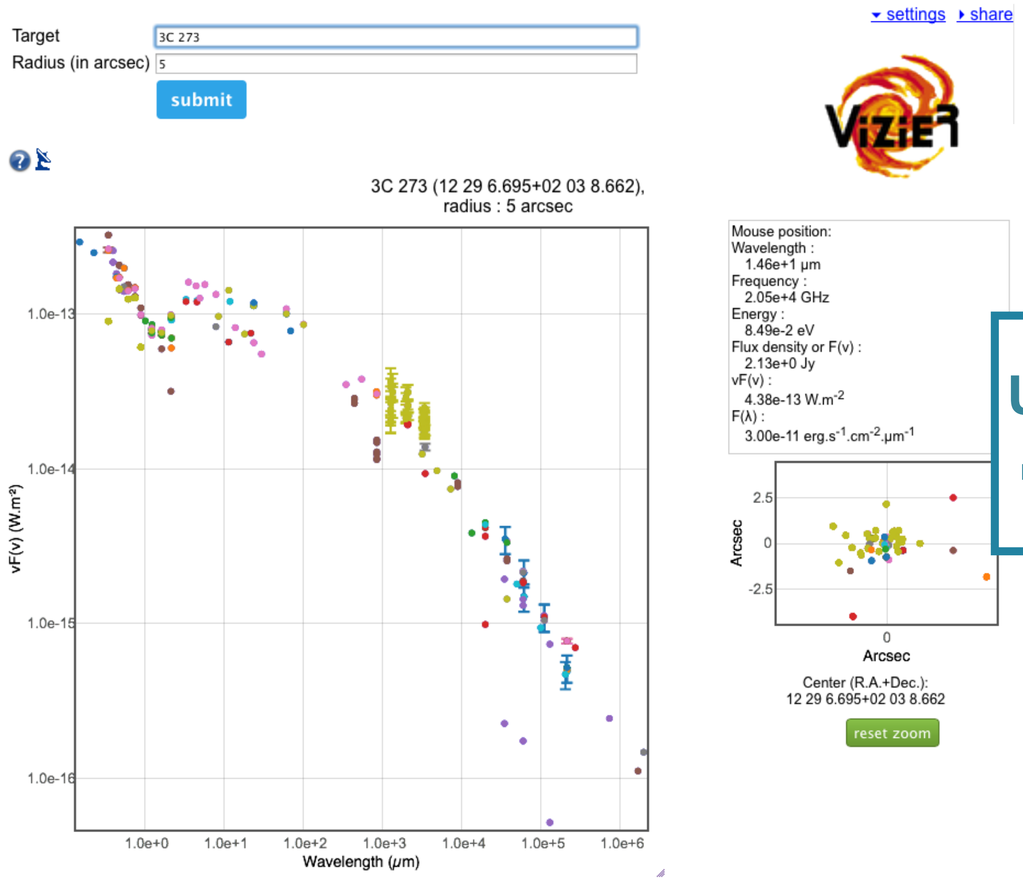
Backgrounds

If you want to see the extension of these sky regions through the constellations you can select an artistic background image ○ Constellations.

You can also select various background images at different wavelengths, combining the electromagnetic data with the gravitational-wave information: ◉ Mellinger (default) ○ WISE ○ 2MASS ○ DSS color ○ XMM ○ Fermi

Visualisation of photometry

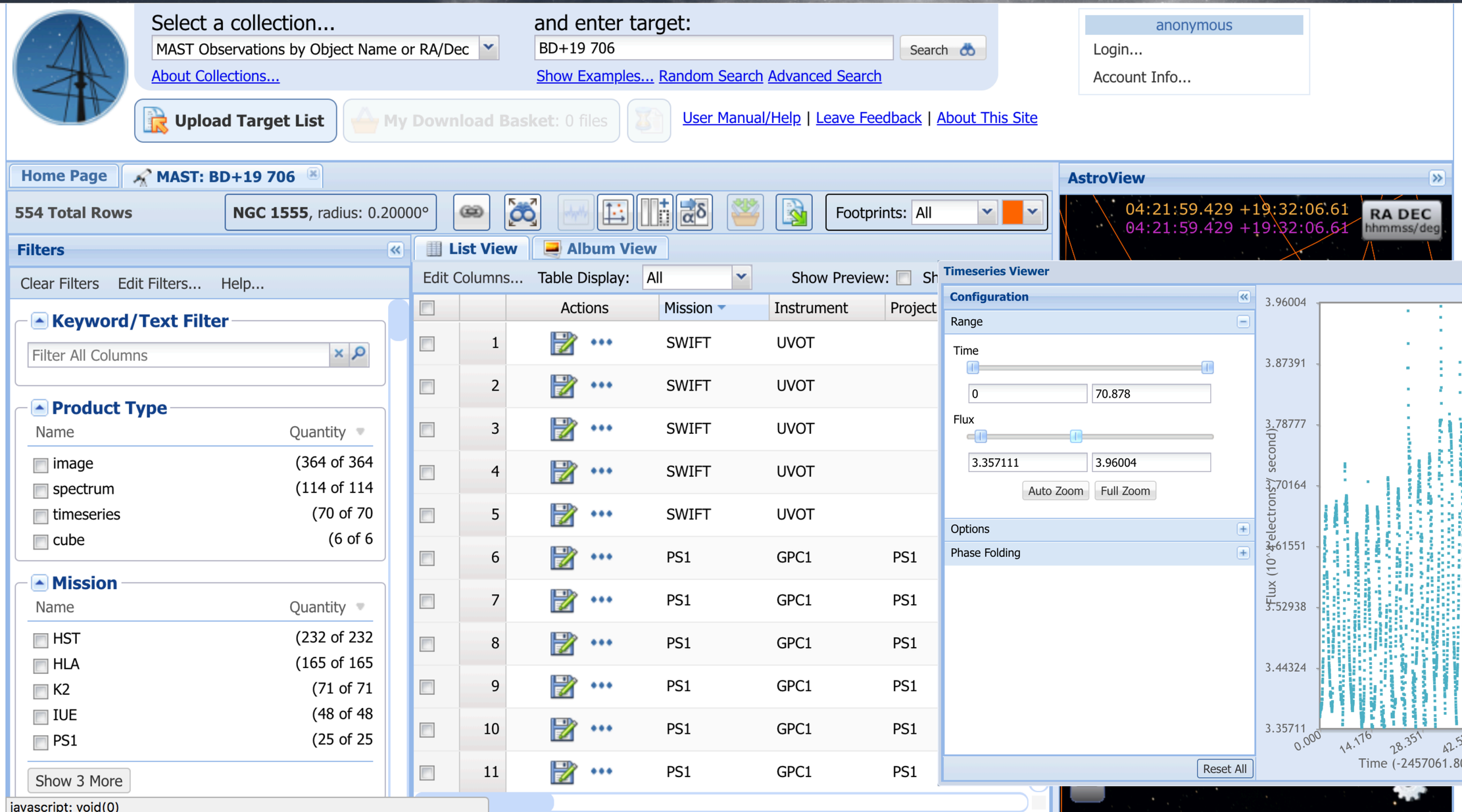
- Search all the photometry available around a position in the sky
- Plot photometry against wavelength



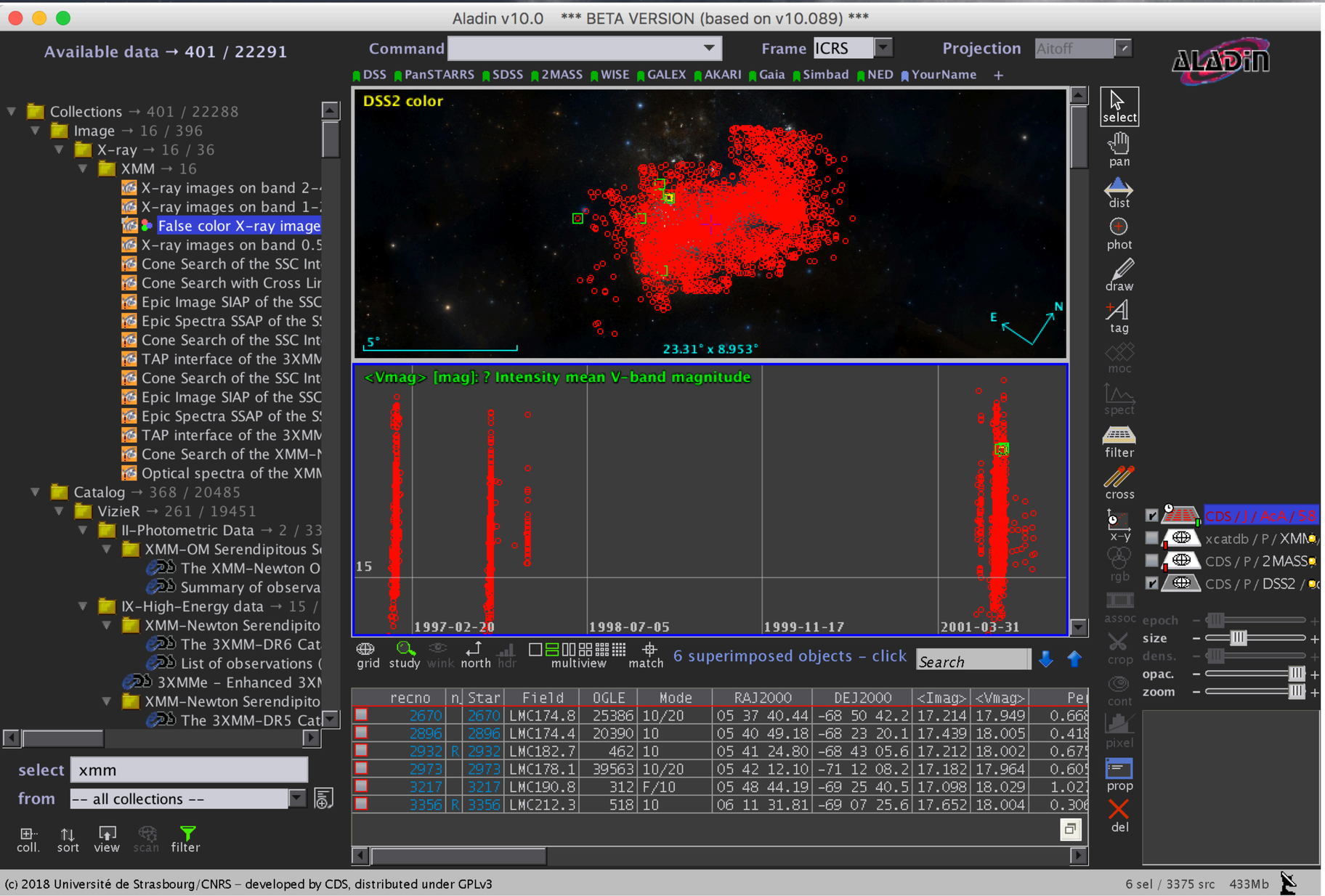
Under dev.: A time (series) viewer

- **Plot photometry against time**

Time Series visualisation tools



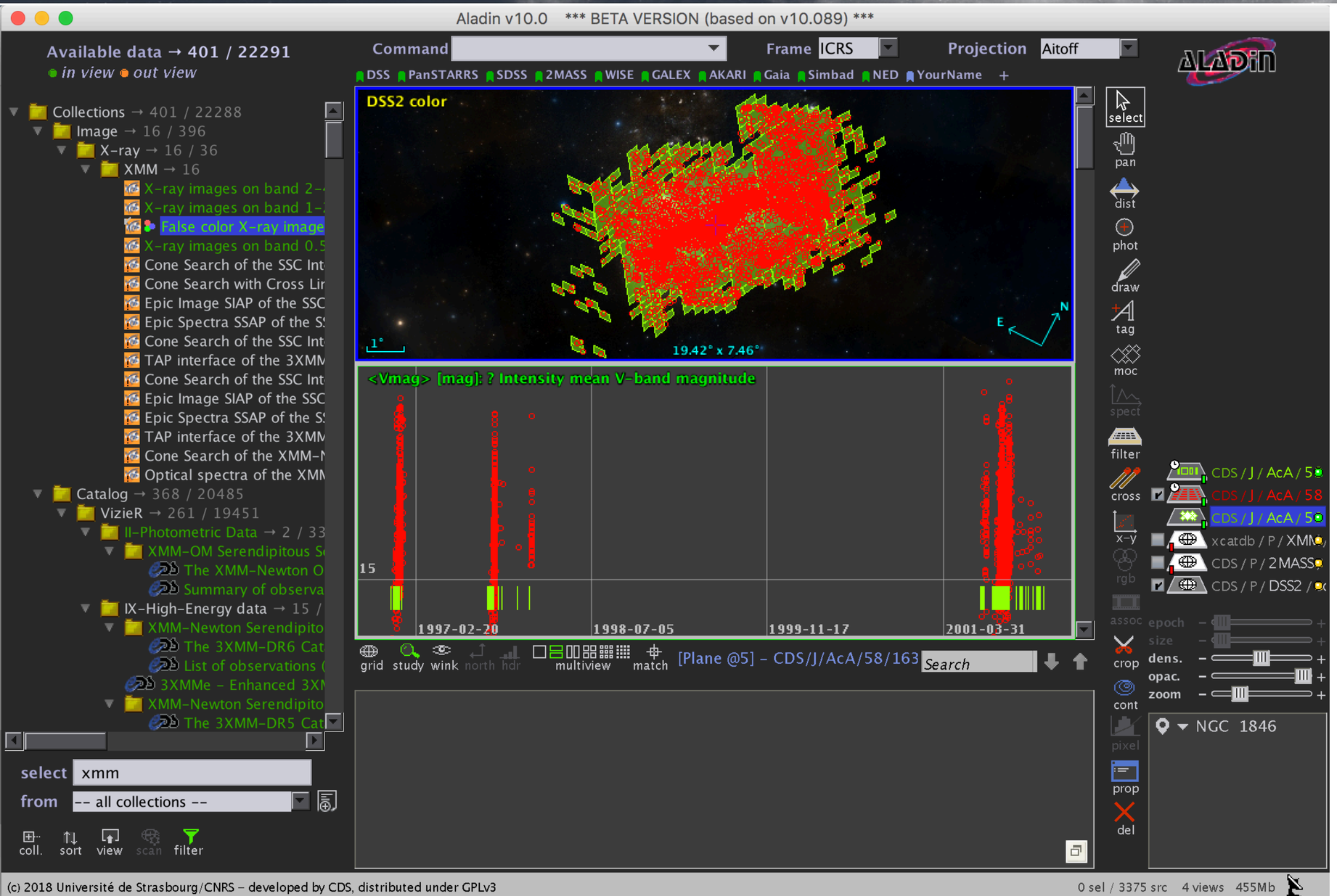
Time Series view (Aladin beta)



- For all catalogues available through Aladin (VizieR, Simbad,…)+ users
- Plot position in the sky
- Background image can be any available through Aladin + users

- **Under dev.:**
- **Measurements as a function of time**
- **Simultaneously visualise the catalogue positions in the sky**

Time Series view (Aladin beta)



- Coverage of a survey in space: MOC

Under dev.:

- **Temporal coverage of a survey: TMOC**
- **Simple operations such as union, intersections, filter a catalogue by temporal coverage, …**

Under dev.: combine both spatial and temporal coverages

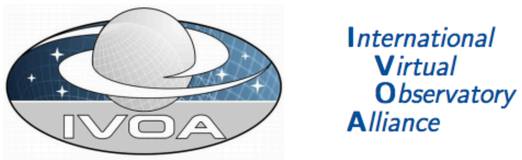
Data Access, Discovery and Interoperability for time

- Need of unambiguous declaration of metadata associated to time values
- **Minimum metadata**
  - time scale (TT, TAI, TDB, TCB,…)
  - reference position (topocenter, barycenter,…)
  - offset (random values subtracted to the time values)

Under dev.: A standard way to annotate data to allow for interoperability

A Proposal for a TIMESYS Element in VOTable

Version 1.1

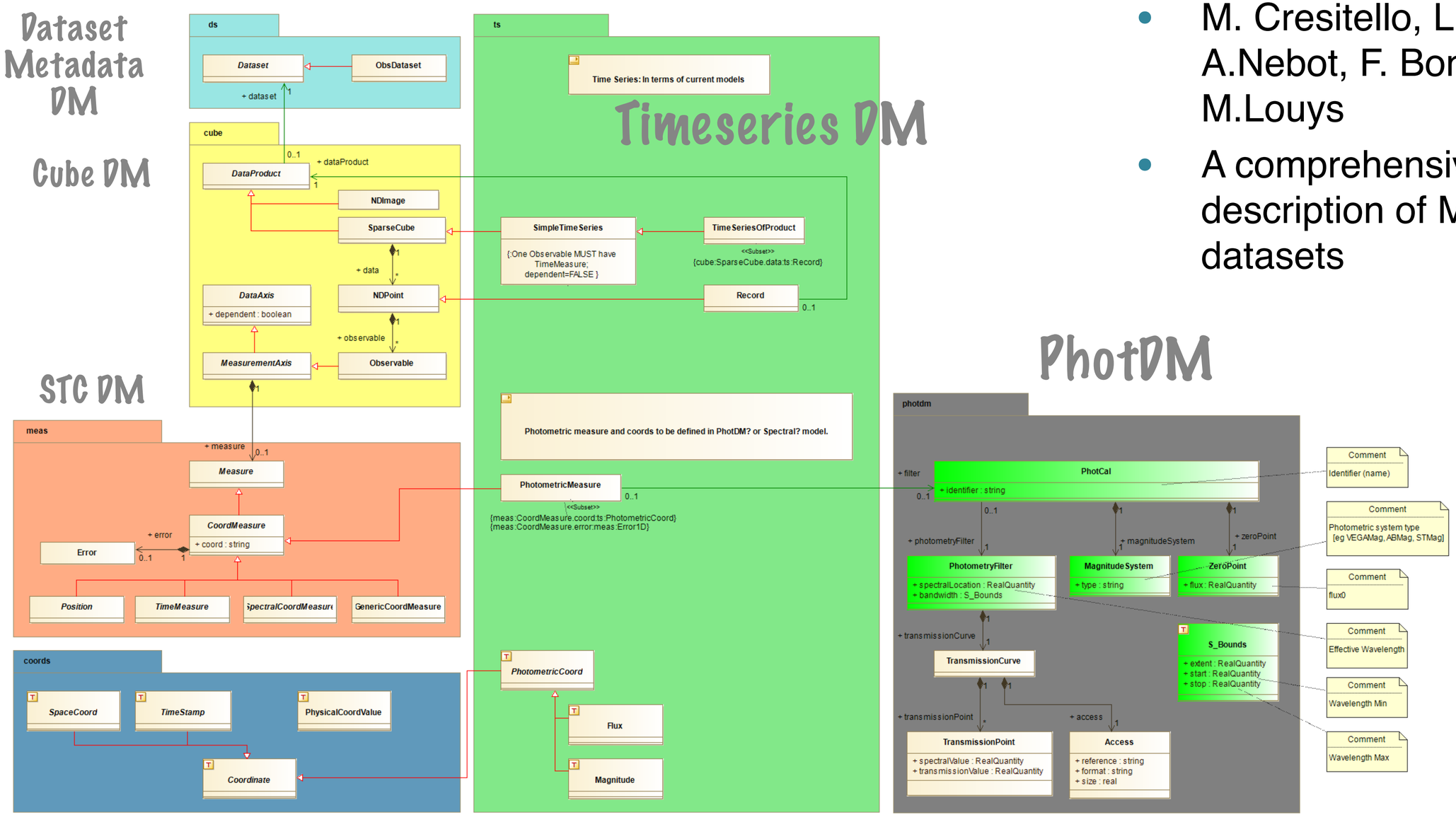


VOTable Format Definition Version 1.4

IVOA Working Draft 2019-01-31

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

Time domain model



- M. Cresitello, L.Michel, A.Nebot, F. Bonnarel, M.Louys
- A comprehensive description of Multi-D datasets

TAP metadata profile for Time series

- A suggestion to access time series of any kind (spectra, images, cubes, etc.)
- Based on the principles of ObsCore and EPN Core
  - data product type and curation
  - List metadata characterising all axes : Time, Space, Spectral, Polarimetry, Observable

- Current proposal discussed https://wiki.ivoa.net/internal/IVOA/TimeSeries/
  - compare with EPN -TAP description
  - validate on other projects (eg. GASP, exoplanets data sets , etc)

Thanks 🙏 Merci