Time series and the VO

Enrique Solano

Spanish Virtual Observatory

CAB (INTA-CSIC)

Why is important to publish time series in the VO?

- **Motivation I:** The number of time series has enormously increased in the last years.

- **Motivation II:** Foster new science with this vast amount of data.

Motivation I

Ground-based projects (I)

ASAS All Star Catalogue

> 10 000 0000 light curves

SuperWASP Public archive

18 million light curves in the LMC and the Milky Way bulge.

18 million light curves
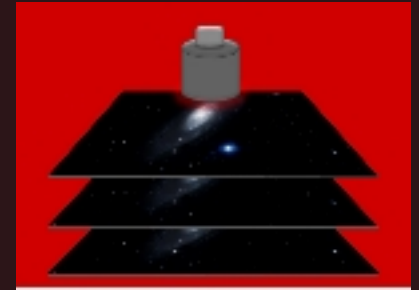
OGLE

> 40 million objects

EROS Experiment

Ground-based projects (II): robotics

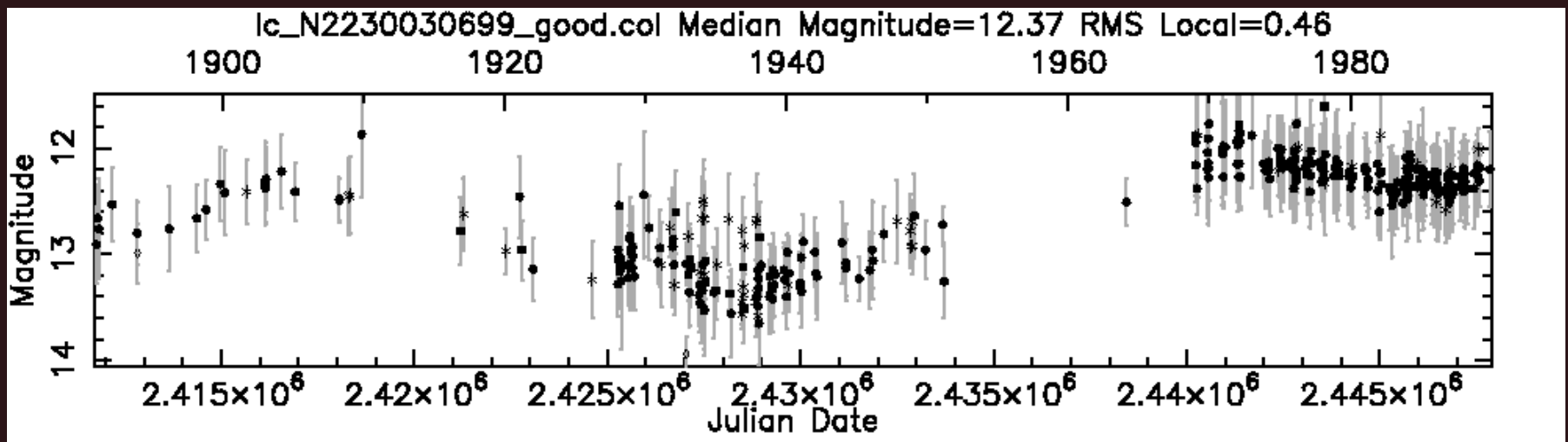| Description	Number of Ref.'s	Percentage
Gamma-Ray Bursts	32	20.3%
Service observations	28	17.7%
Photometric monitoring	16	10.1%
Education	20	12.7%
All-sky surveys	12	7.6%
Exoplanet searches	18	11.4%
Supernovae search	11	7.0%
Asteroids	9	5.7%
Spectroscopy	4	2.5%
Astrometry	4	2.5%
AGN, Quasars	4	2.5%
(Micro-)Lensing	1	0.6%
Other uses	8	5.1%

➢120 robotic telescopes already in operation (or in the near future)

➢ Small / medium size

➢ Professionals and / or amateurs. → AAVSO

➢ Follow-up of satellite alerts (e.g. Gaia)

Ground-based projects (III): digitization of photographic plates

DASCH Digital Access to a Sky Century @ Harvard

- Opens the window to phenomena that vary on a time-scales of decades (an order of magnitude longer than presently).

lc_N2230030699_good.col Median Magnitude=12.37 RMS Local=0.46

- No match with any of the common variability classes. May suggest extremely short-lived evolutionary stages.
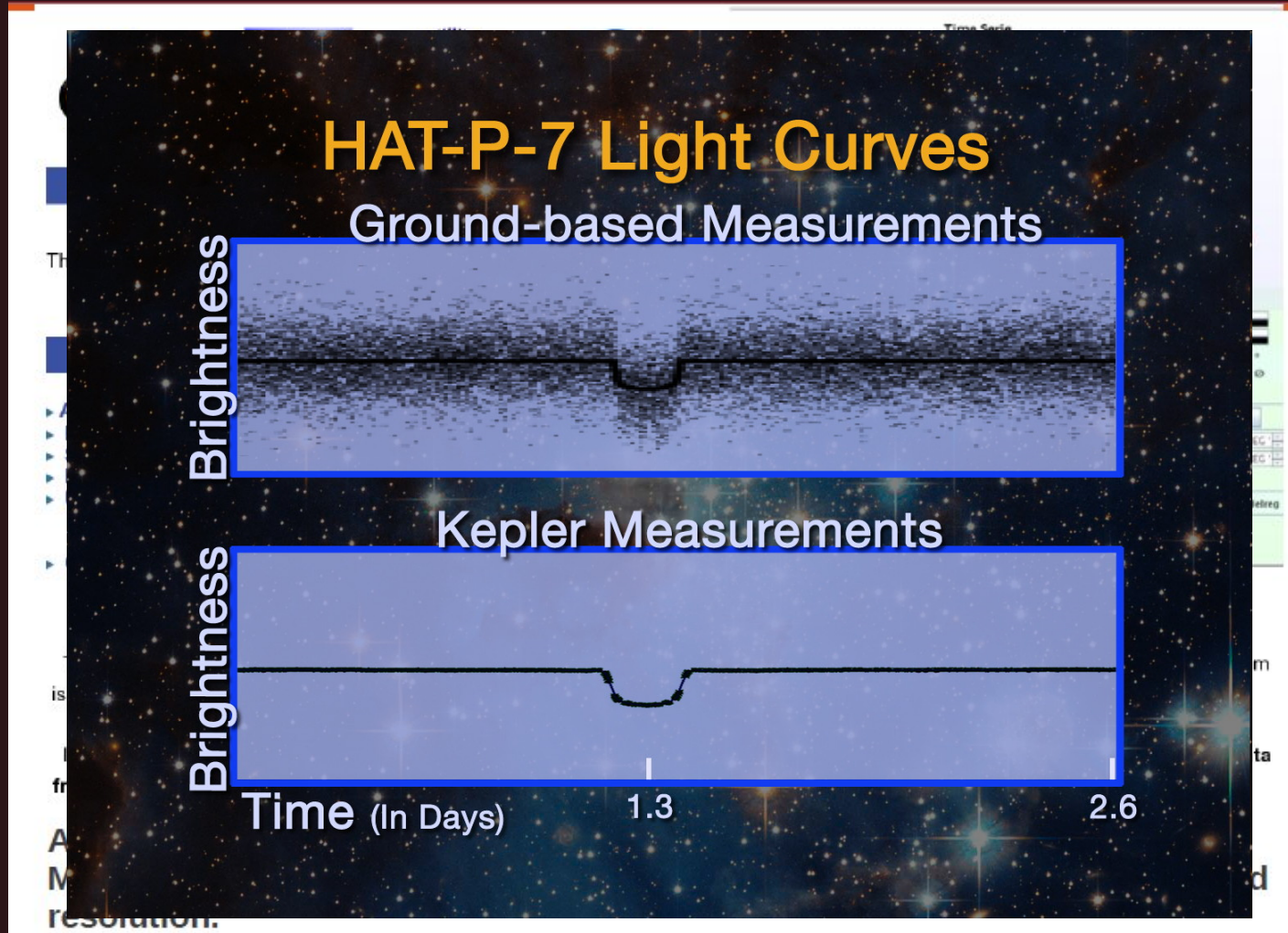
Ground-based projects (IV): the future

■ LSST: highest priority for ground-based astronomy (US decadal survey).

• A 3.2 gigapixel, 15-second exposure image every 20 seconds.
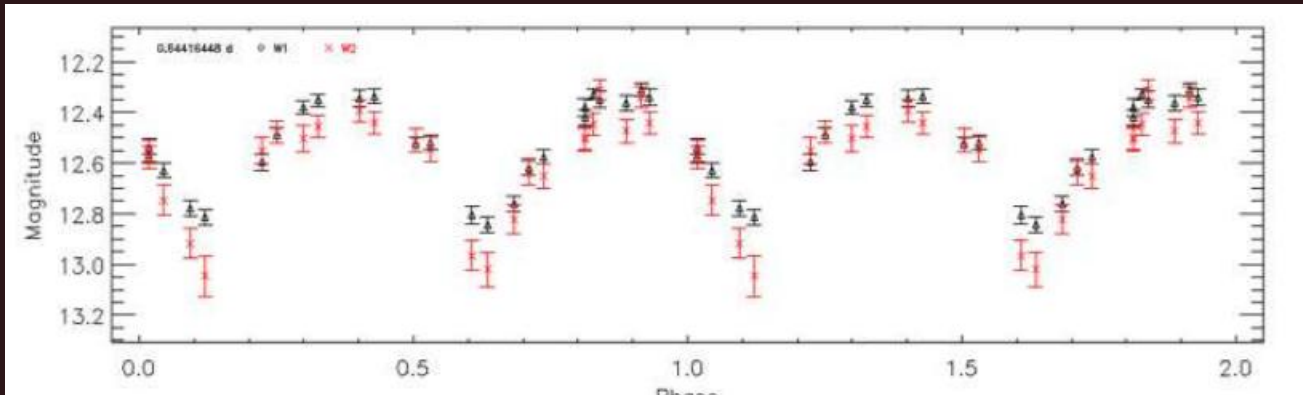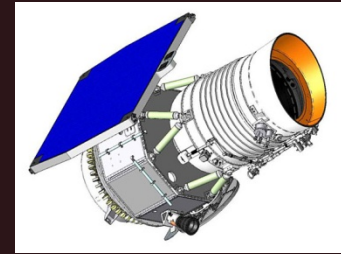
• 200000 images (1.28 PB/y).

Space-based projects

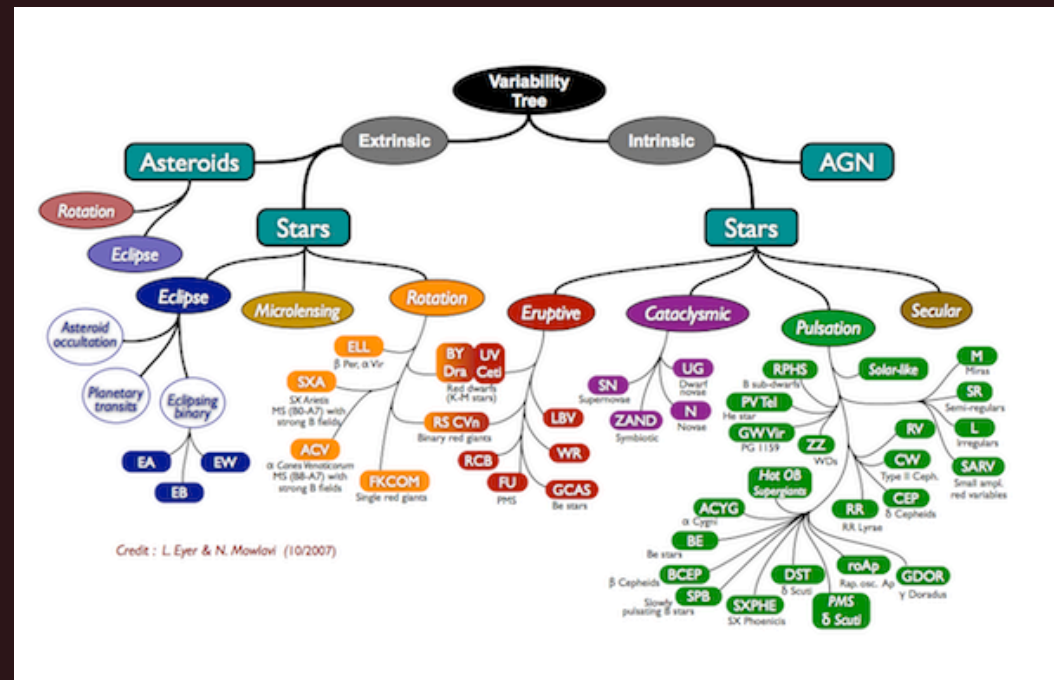- Unprecedented photometric accuracy and time sampling: CoRoT, Kepler

HAT-P-7 Light Curves
Ground-based Measurements
Kepler Measurements
Time (In Days)   1.3   2.6
Brightness

Space-based projects (II)

- New spectral regions: WISE

- The future: Gaia
  - ✓ Multi-epoch, multi-color photometry for 10^9 sources.
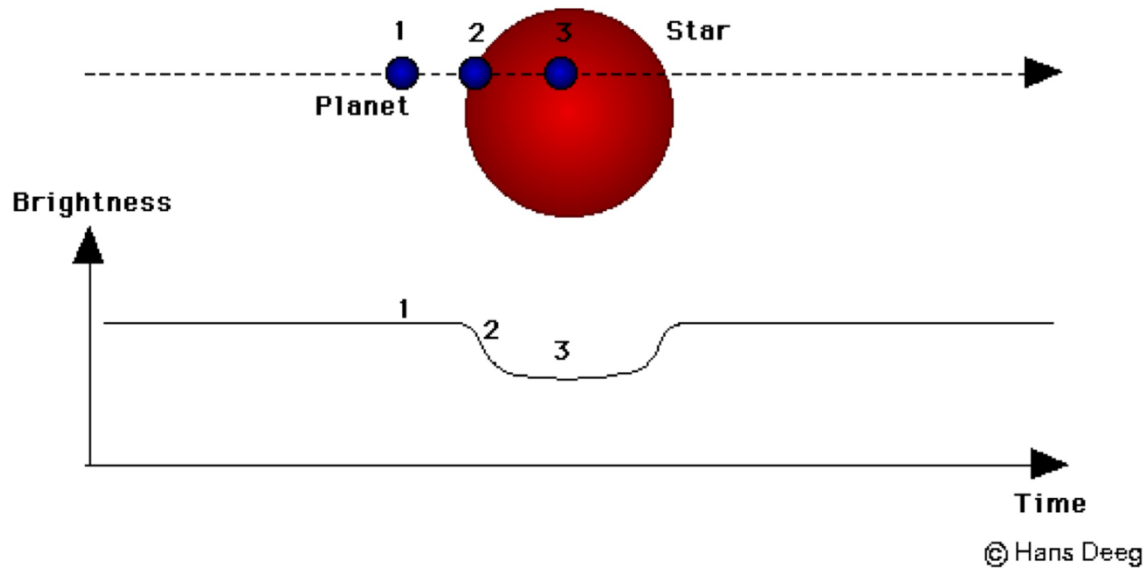

Credit : L. Eyer & N. Mowlavi (10/2007)

Motivation II

Long-term variability analysis

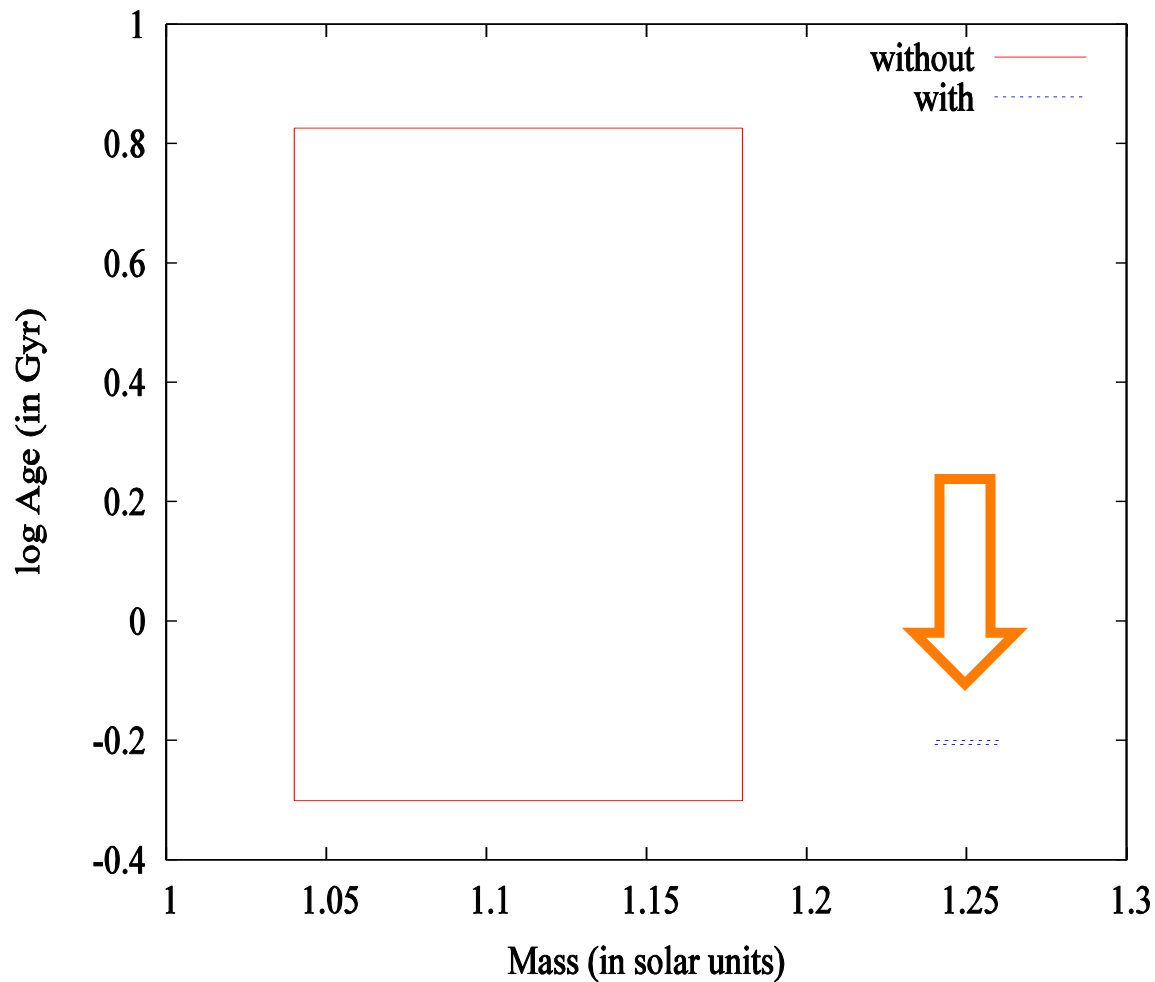- RR Lyr: study of the Blazhko effect with datasets of 100+ years.

Discovery and characterization of extrasolar planets

$$\frac{\Delta F}{F} = \left(\frac{R_P}{R_*} \right)^2$$

Asteroseismology

ɩ *Horologii*

	[Fe/H]	Age
	30%	86%
	18%	0.8%

Main conclusion:

Time series are important and should be published in the VO.

VO developments in the Time Series domain

- Standards:

  - VOEvent
    - Standardization of transient alert protocol and astronomical telegrams.
    - IVOA Recomm. since Nov. 2006

Time Series: Access protocols

- Time series: 1-D data
- SSAP: the natural "simple" protocol (TAP could also work).
- Only used for spectra so far.
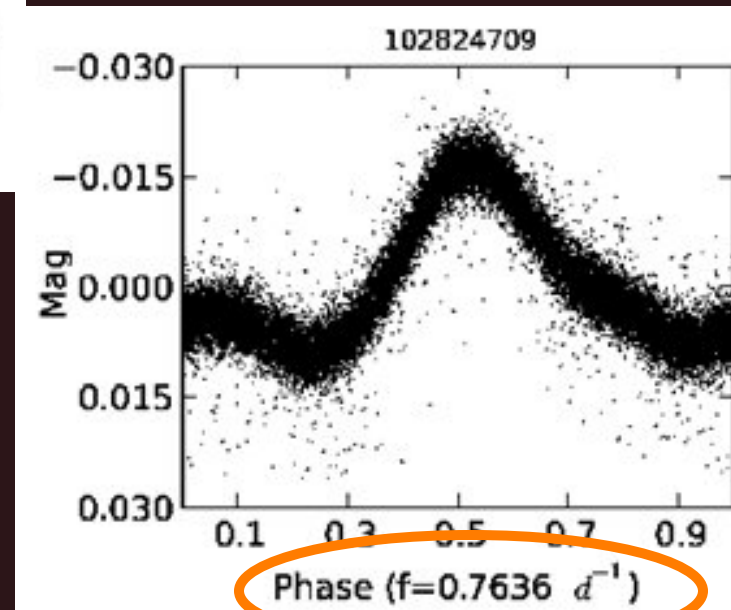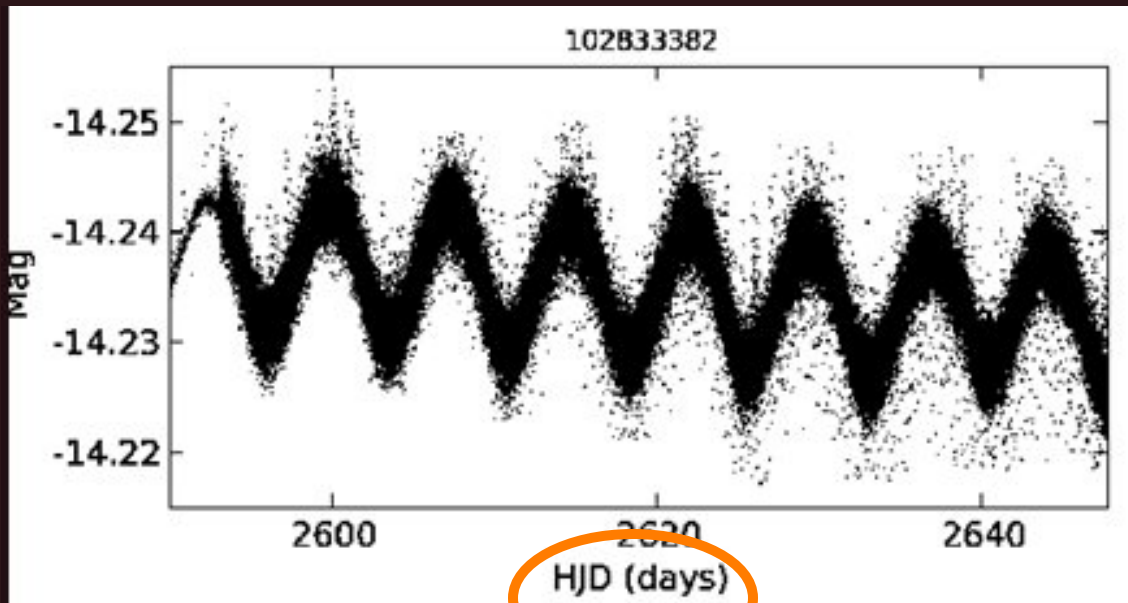- Just a few modifications

Proposal

SSA:

* New **Dataset.TimeAxis** needed for light curves in native format (FITS, ASCII, …)

* New **Dataset.Type** possible value: "**TimeSeries**"

* New **Access.forma**t values: "**timeseries/fits**"

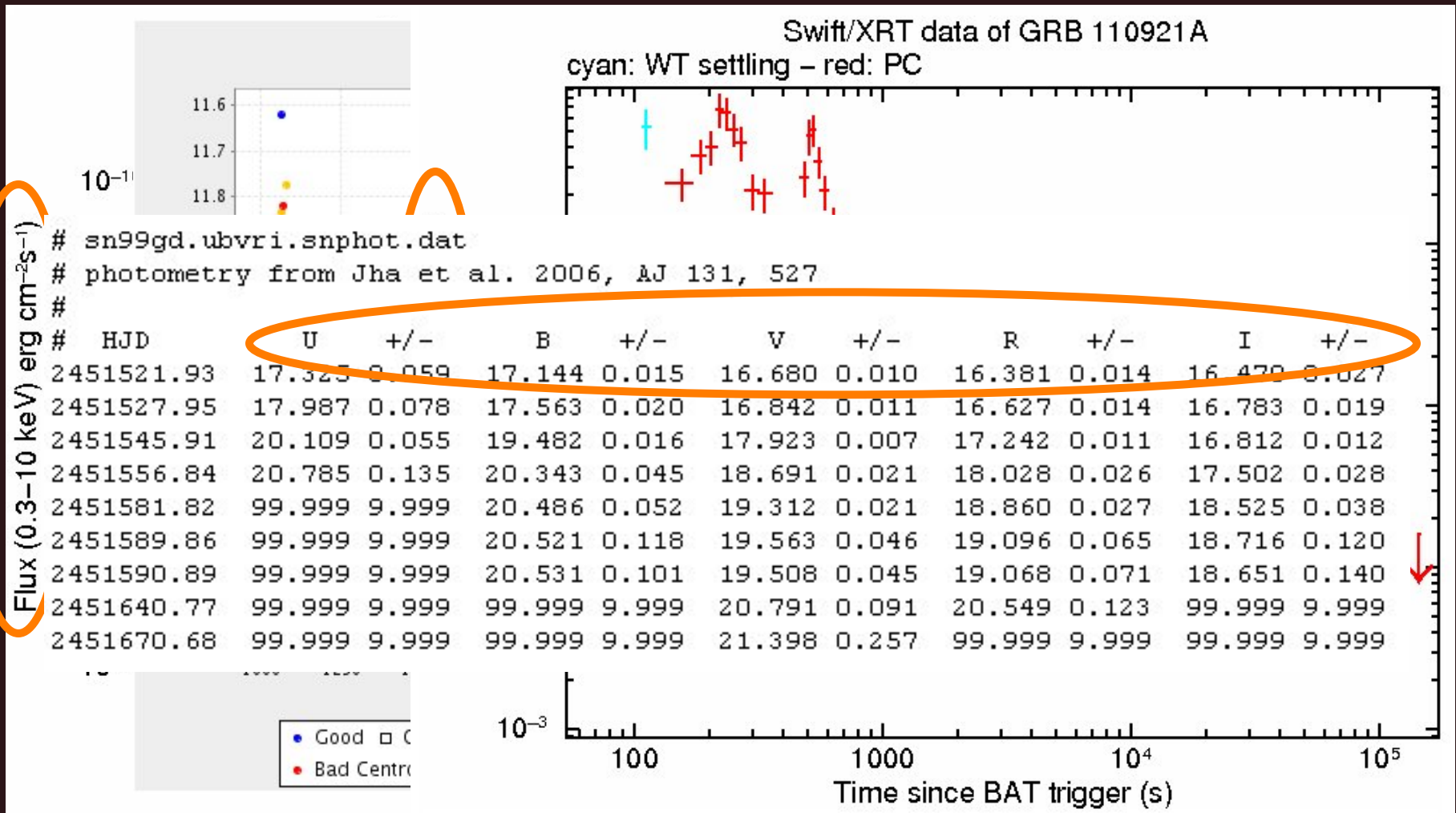* **Char.SpectralAxis.Coverage.Bound.Extent** set as recommended.

How to access time series services in the VO?

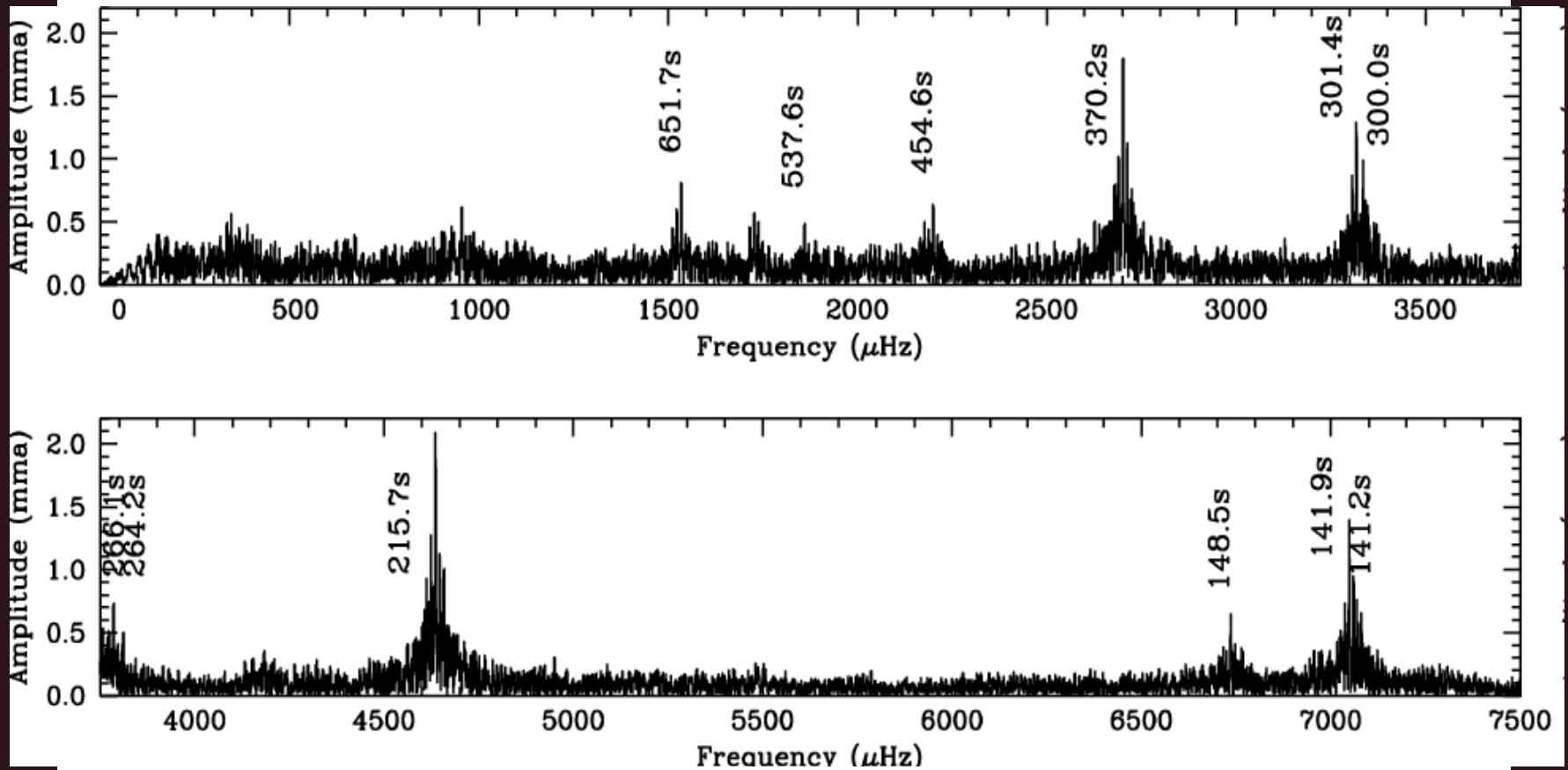- Important: More than just time vs flux…:

- More than just time vs flux…:

Swift/XRT data of GRB 110921A
cyan: WT settling – red: PC

```
# sn99gd.ubvri.snphot.dat
# photometry from Jha et al. 2006, AJ 131, 527
#
#   HJD        U      +/-      B      +/-      V      +/-      R      +/-      I      +/-
2451521.93  17.325 0.059  17.144 0.015  16.680 0.010  16.381 0.014  16.478 0.027
2451527.95  17.987 0.078  17.563 0.020  16.842 0.011  16.627 0.014  16.783 0.019
2451545.91  20.109 0.055  19.482 0.016  17.923 0.007  17.242 0.011  16.812 0.012
2451556.84  20.785 0.135  20.343 0.045  18.691 0.021  18.028 0.026  17.502 0.028
2451581.82  99.999 9.999  20.486 0.052  19.312 0.021  18.860 0.027  18.525 0.038
2451589.86  99.999 9.999  20.521 0.118  19.563 0.046  19.096 0.065  18.716 0.120
2451590.89  99.999 9.999  20.531 0.101  19.508 0.045  19.068 0.071  18.651 0.140
2451640.77  99.999 9.999  99.999 9.999  20.791 0.091  20.549 0.123  99.999 9.999
2451670.68  99.999 9.999  99.999 9.999  21.398 0.257  99.999 9.999  99.999 9.999
```

- More than just light curves…:

Other changes in VO standards

VO tools for Time Series

- ## VAO Time-Series tools
  - ### Pathfinder. Many other functionalities still to come.