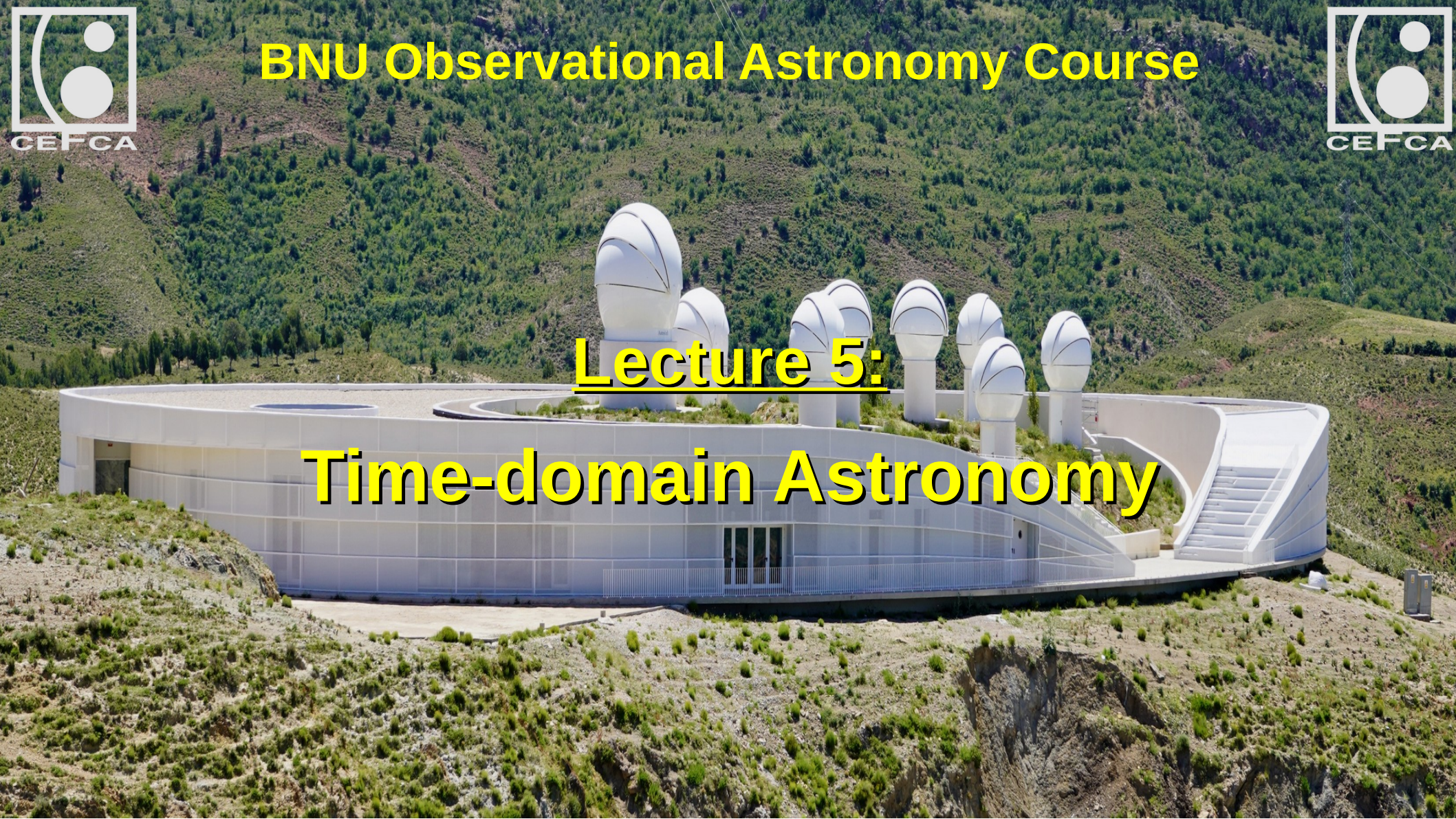
BNU Observational Astronomy Course



Lecture 5:

Time-domain Astronomy

Time-domain astronomy

We have seen how we can perform photometry and obtain the magnitude of an object in a single image.

This image has a ***timestamp*** associated to it, that is, the actual time (for example, in UTC) *when* the image was observed.

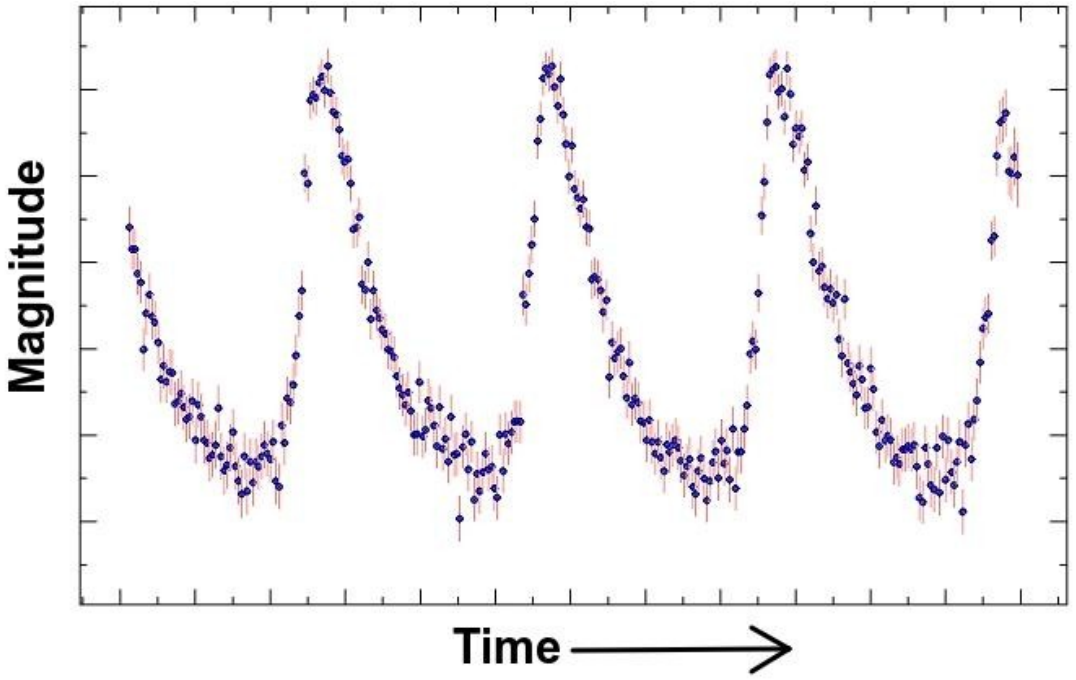
In time-domain astronomy, a series of images is taken, one image after the other, over a period of time, e.g. a few hours.

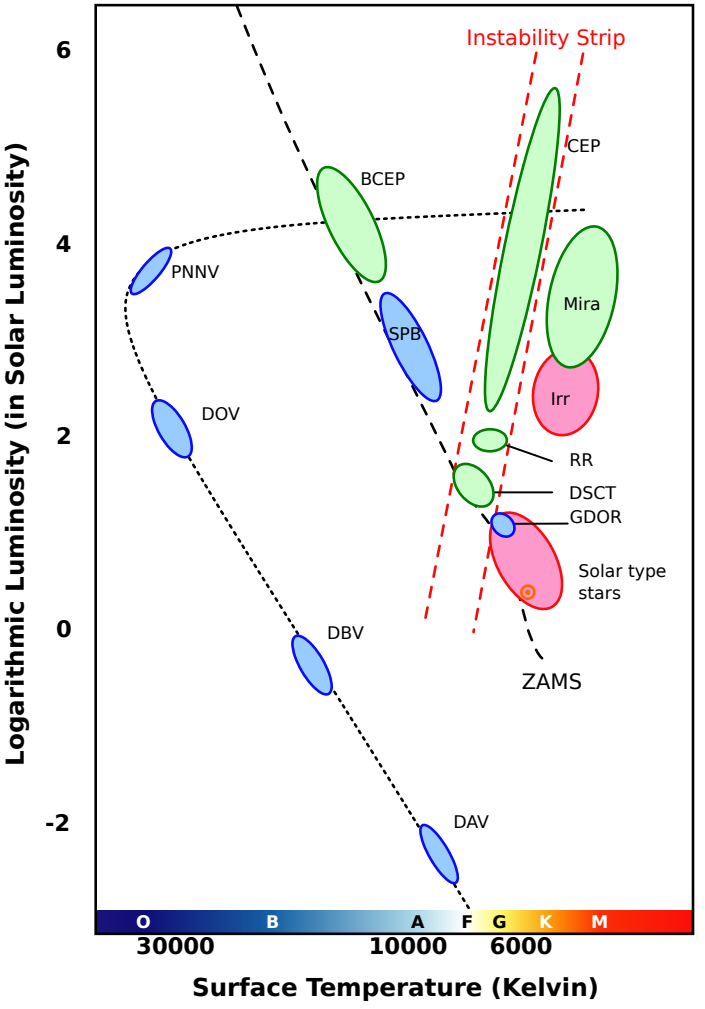
With this series of images in hand, we can construct on object's ***light curve***, which is basically a representation of the object's magnitude with respect to time.

Light curves are our basic tool to study ***variable*** objects, that is, objects whose magnitude varies in time.

Variable Star types #1

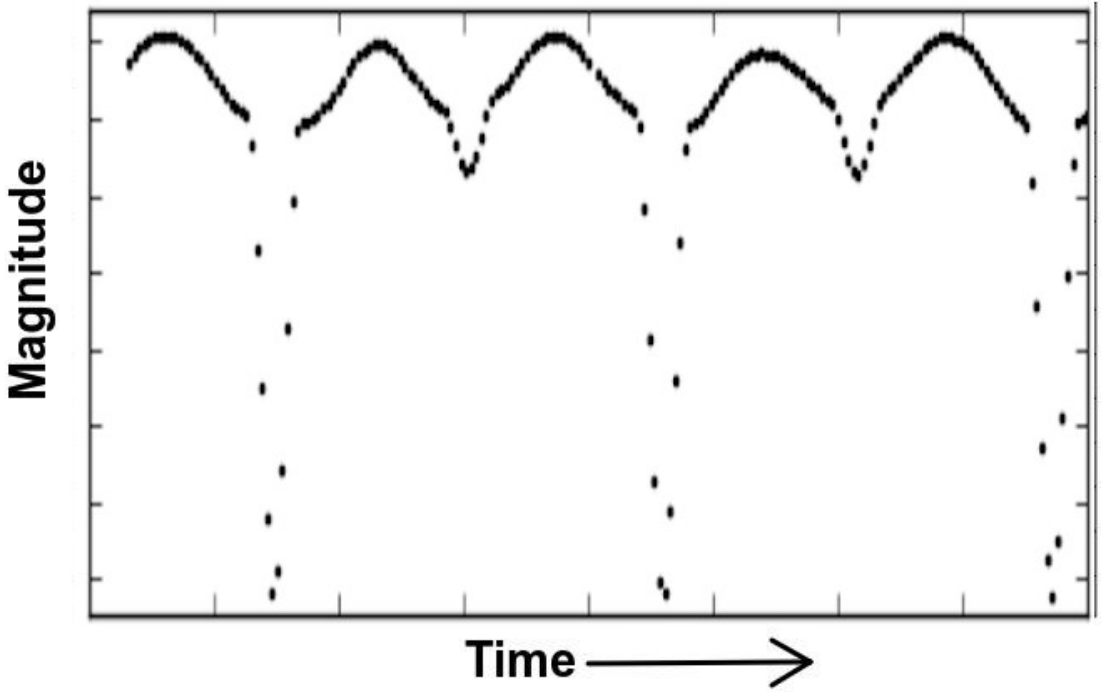
- **INTRINSIC** Variables: change in ***Luminosity*** due to a change in R and/or $T_{eff,}$ e.g. pulsating stars like delta-Scuti, RR-Lyrae and Cepheids

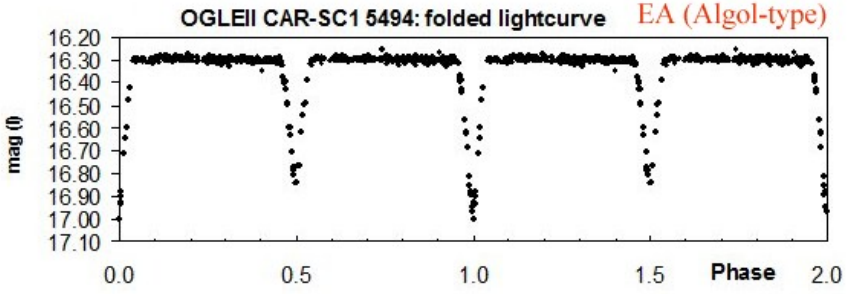


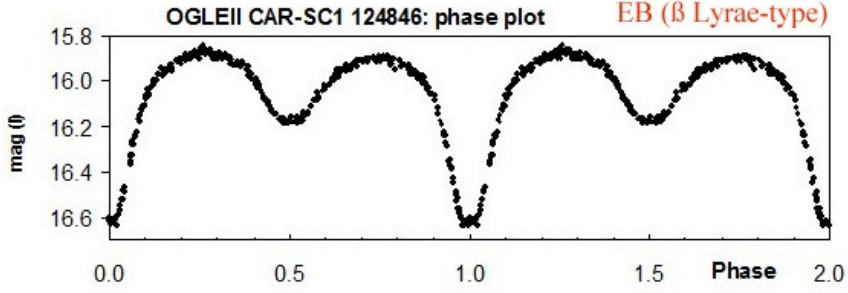


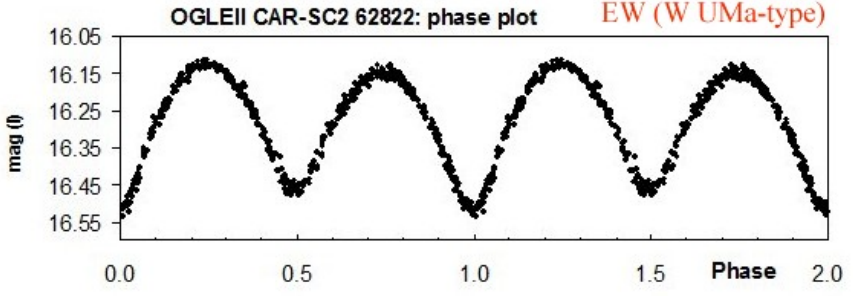
Variable Star type #2

- **EXTRINSIC** Variables: change in ***Brightness*** due to “outside” influence e.g. eclipsing binaries



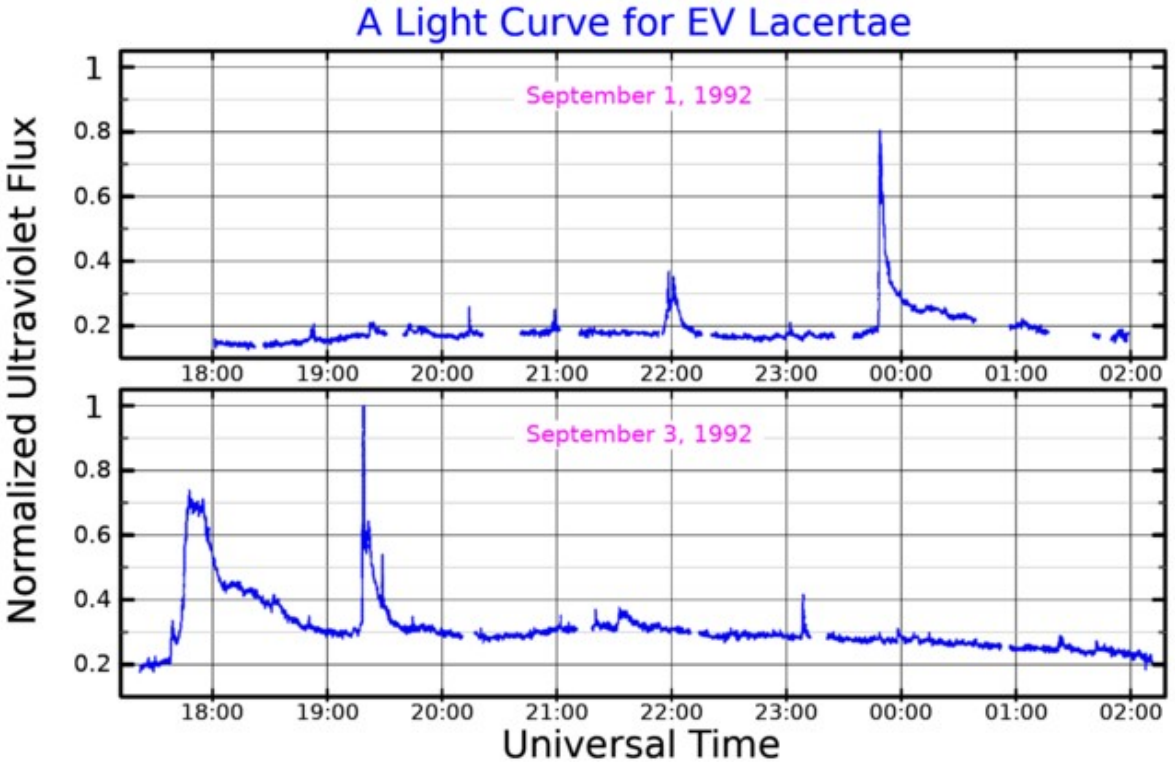


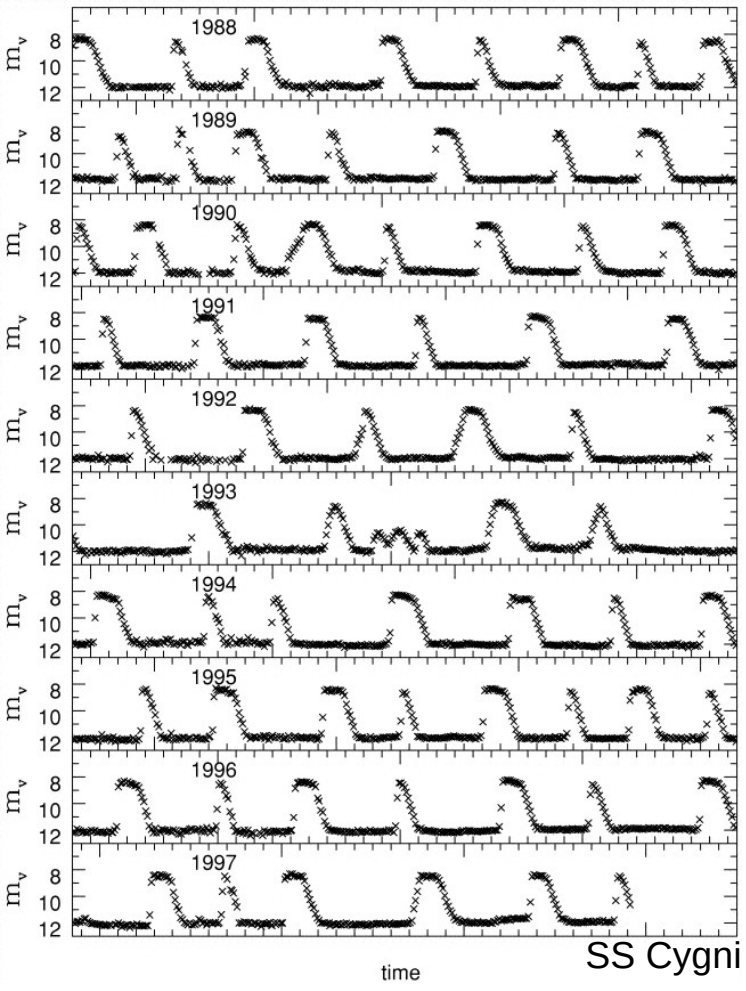




Variable Star types #3

- **TRANSIENTS**: basically things like Super Novae, Classical Novae, Cataclysmic Variables, flare stars etc...





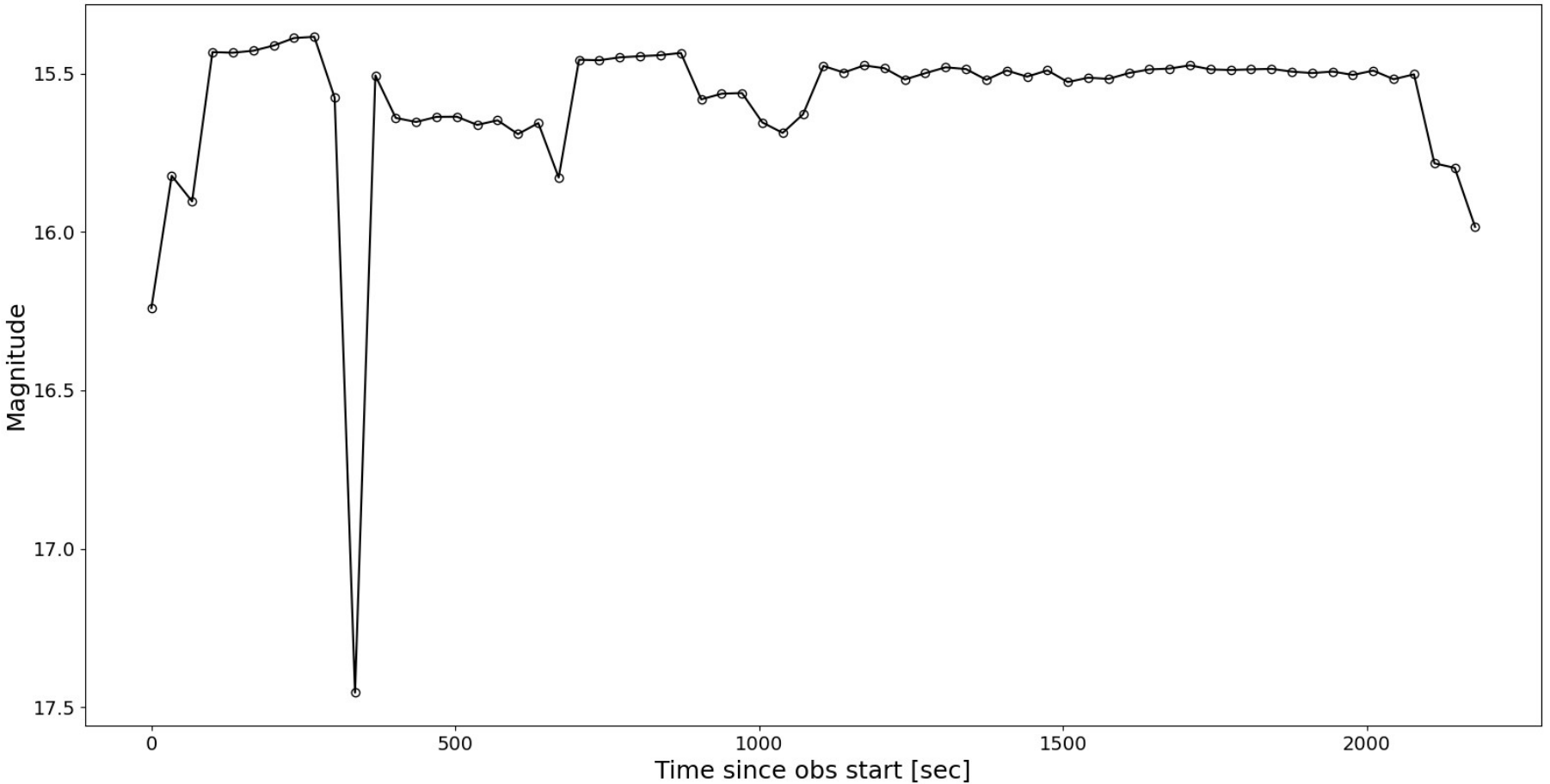
SS Cygni

Why study Variable Stars?

- Cepheid Variables: period-luminosity relation, standar candles for distance measurements
- Pulsating Stars: asteroseismology, study of stellar interior structure
- Eclipsing systems: model-independent measurements of stellar masses and radii
- Flare Stars: stellar spots, magnetic field activity
- Cataclysmic Variables: study of accretion processes

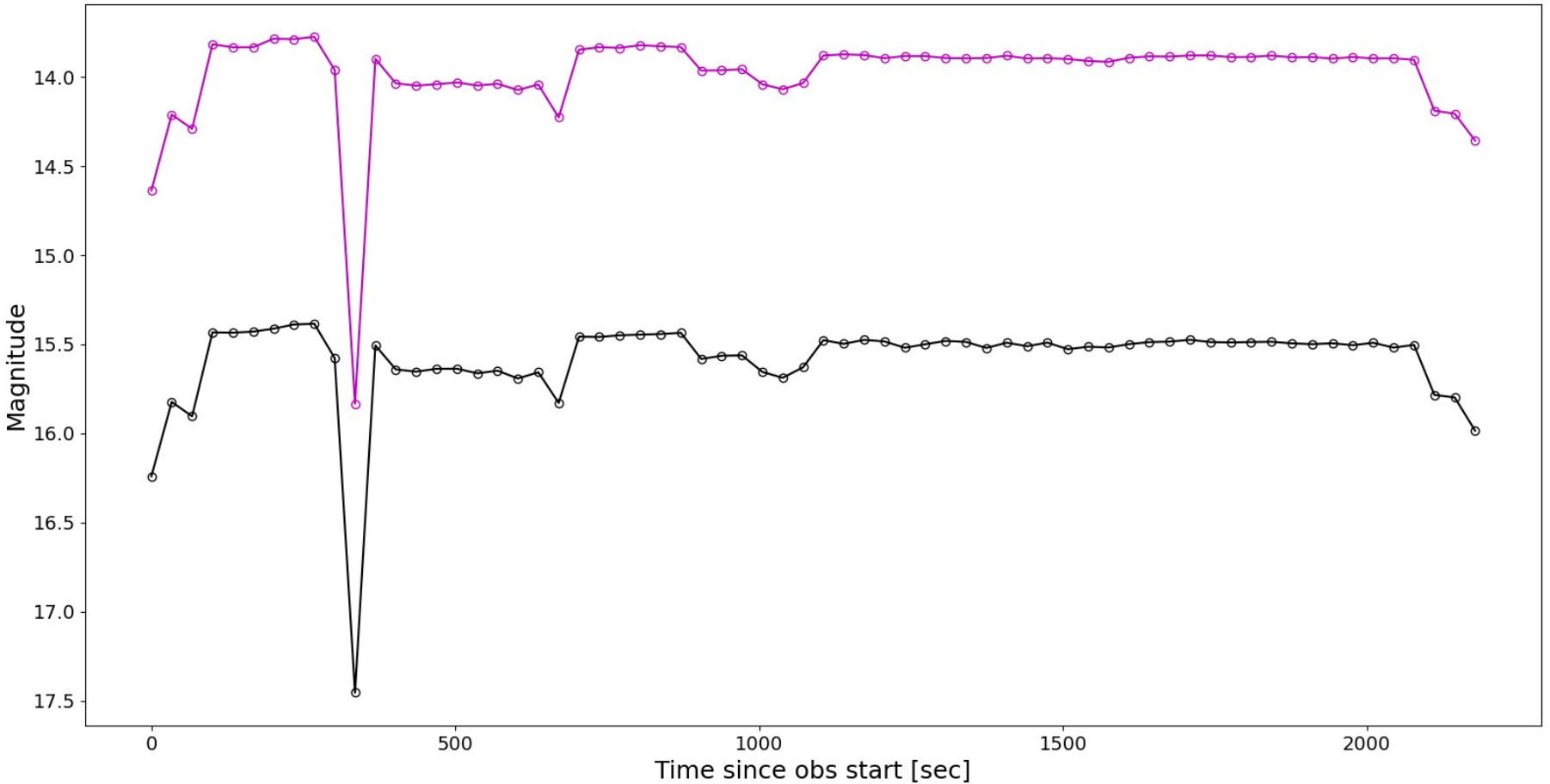
Differential photometry

An example light curve of a star – there are clearly some variations of magnitude



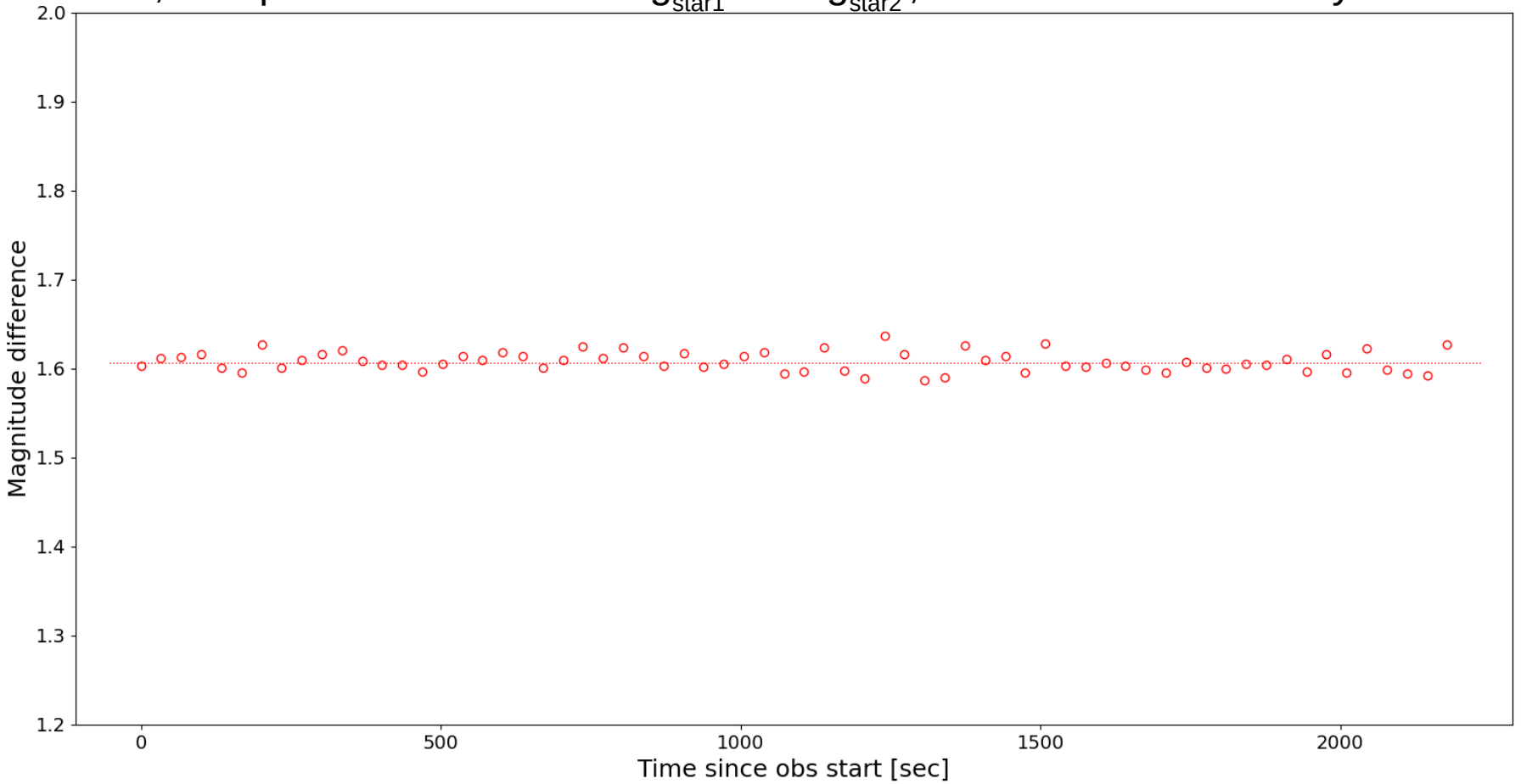
Differential photometry

Let’s plot the light curve of another star – what do you notice?



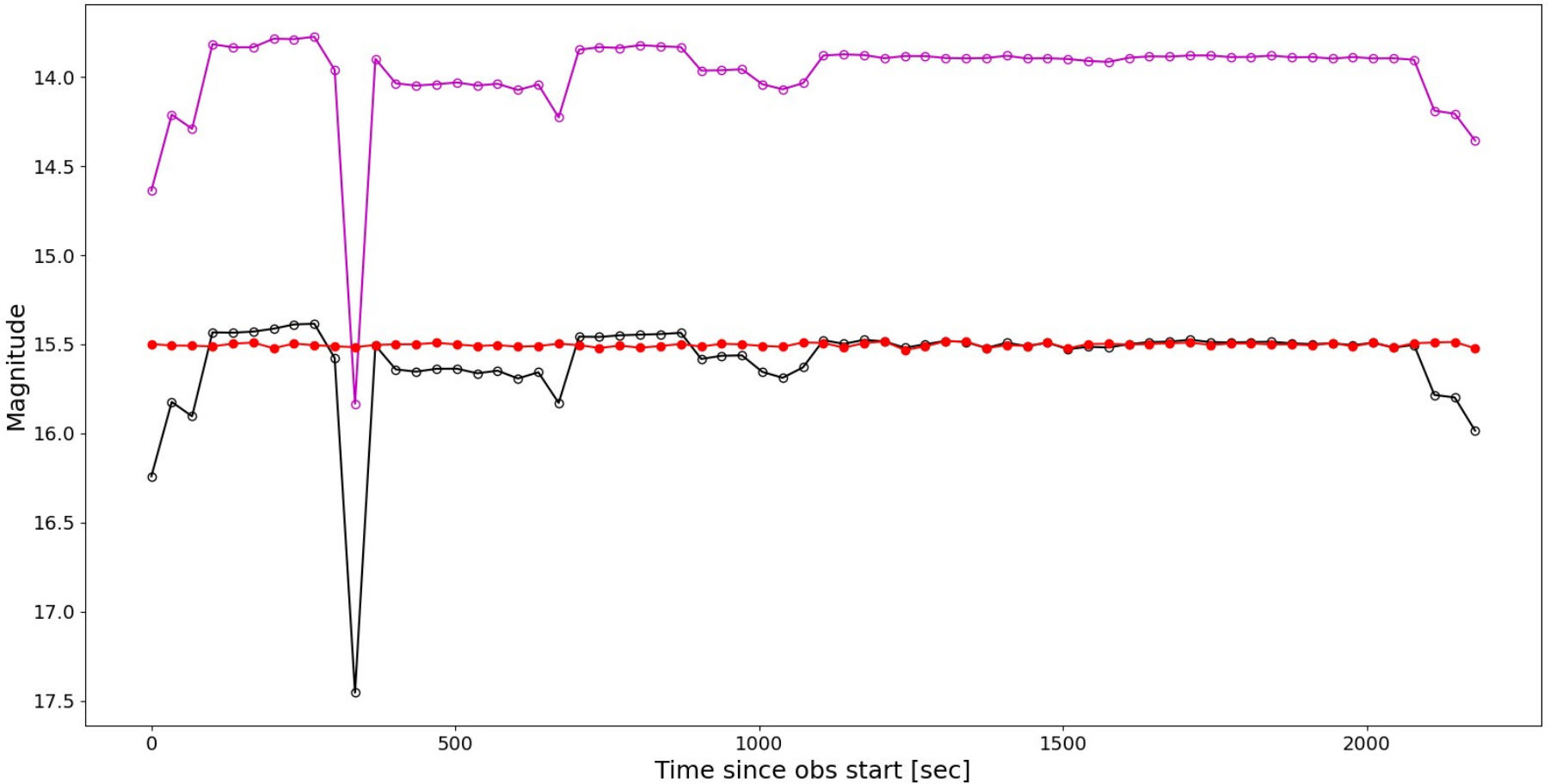
Differential photometry

Now, let's plot the difference $mag_{star1} - mag_{star2}$; notice how it's basically constant



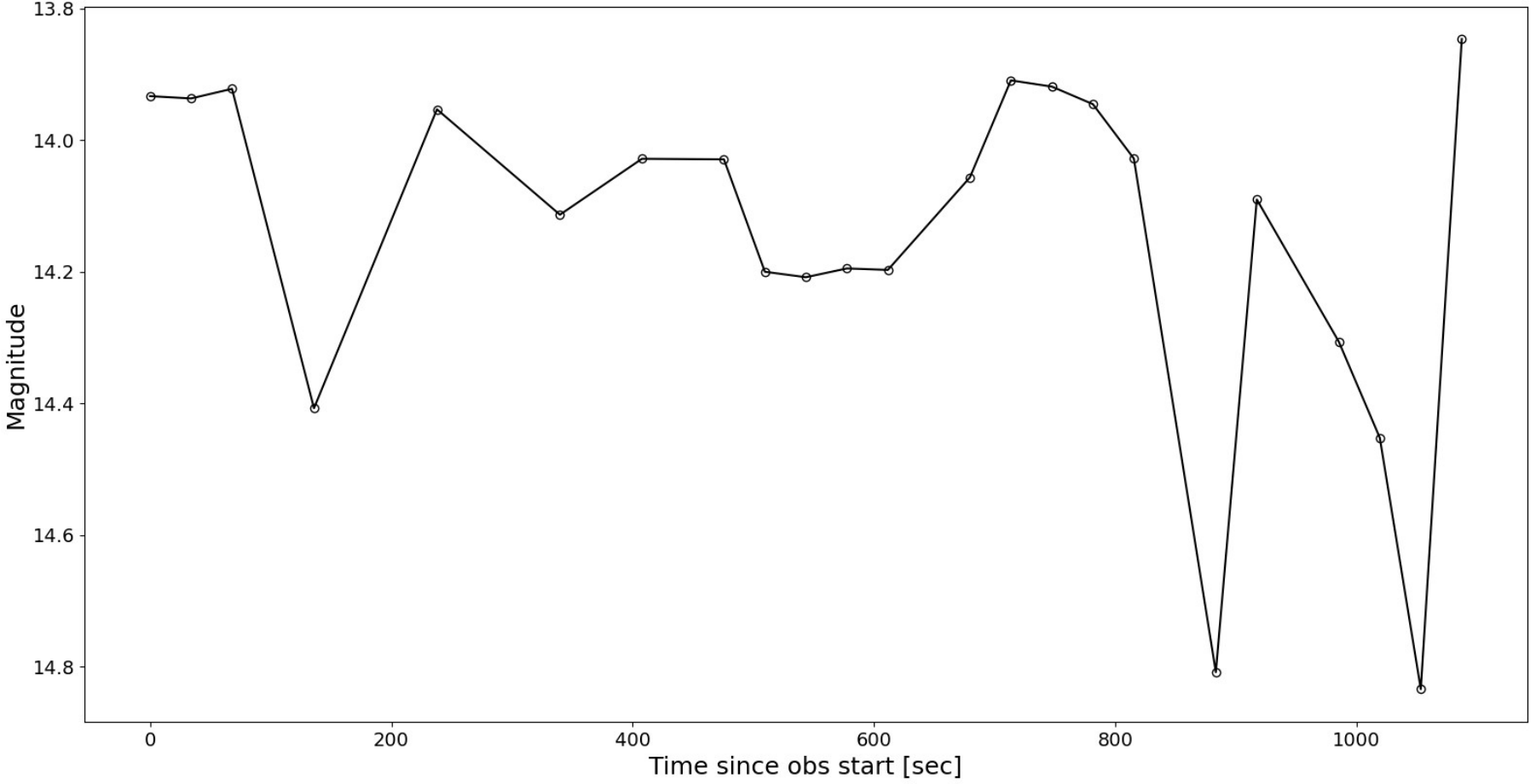
Differential photometry

In differential photometry, we use the light curve of one star to correct the light curve of another



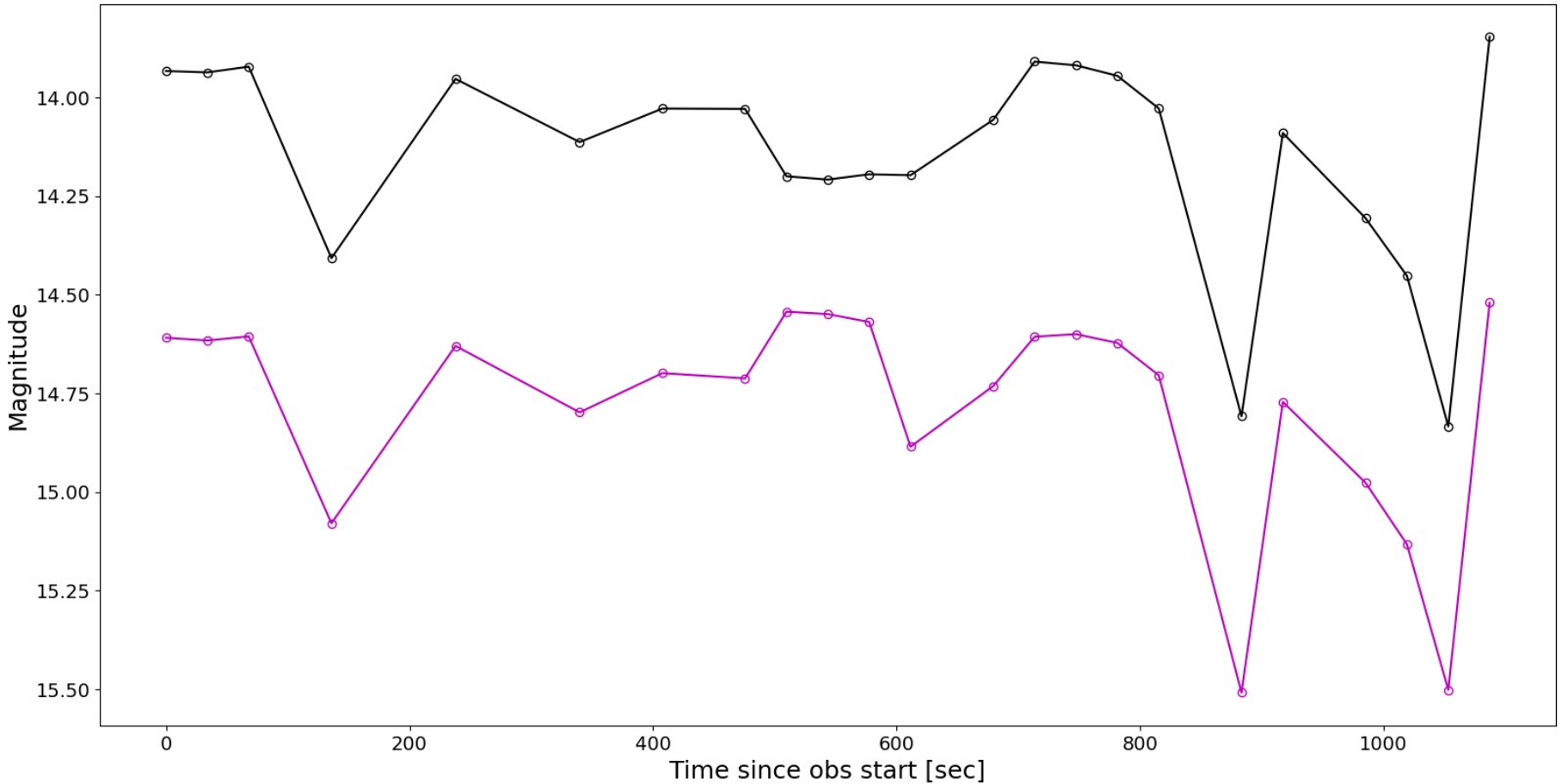
Differential photometry

Let’s look at another example



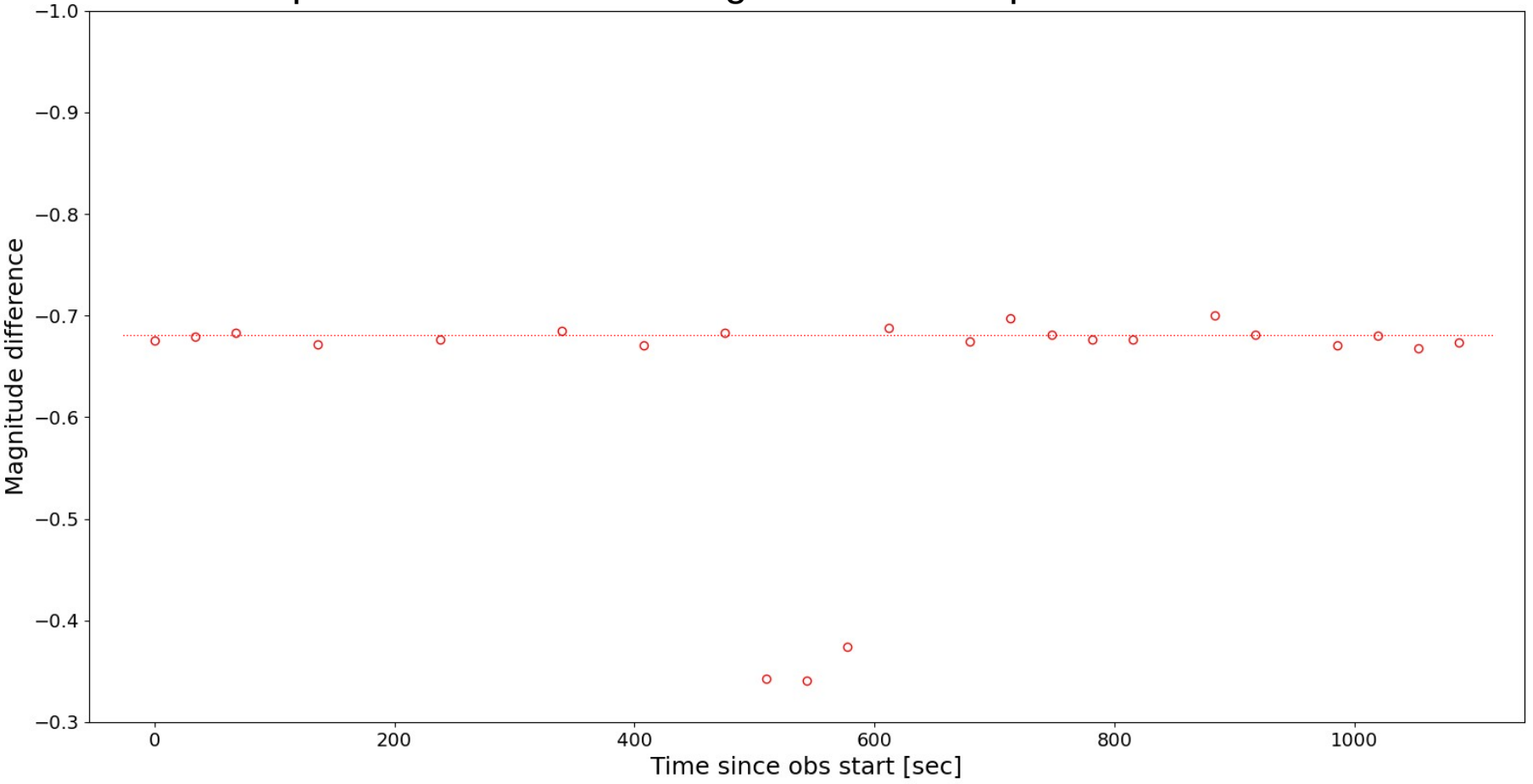
Differential photometry

Let’s plot another star. Do you notice anything different?



Differential photometry

Let’s plot the difference in magnitudes. Perhaps now it’s more clear.



Differential photometry

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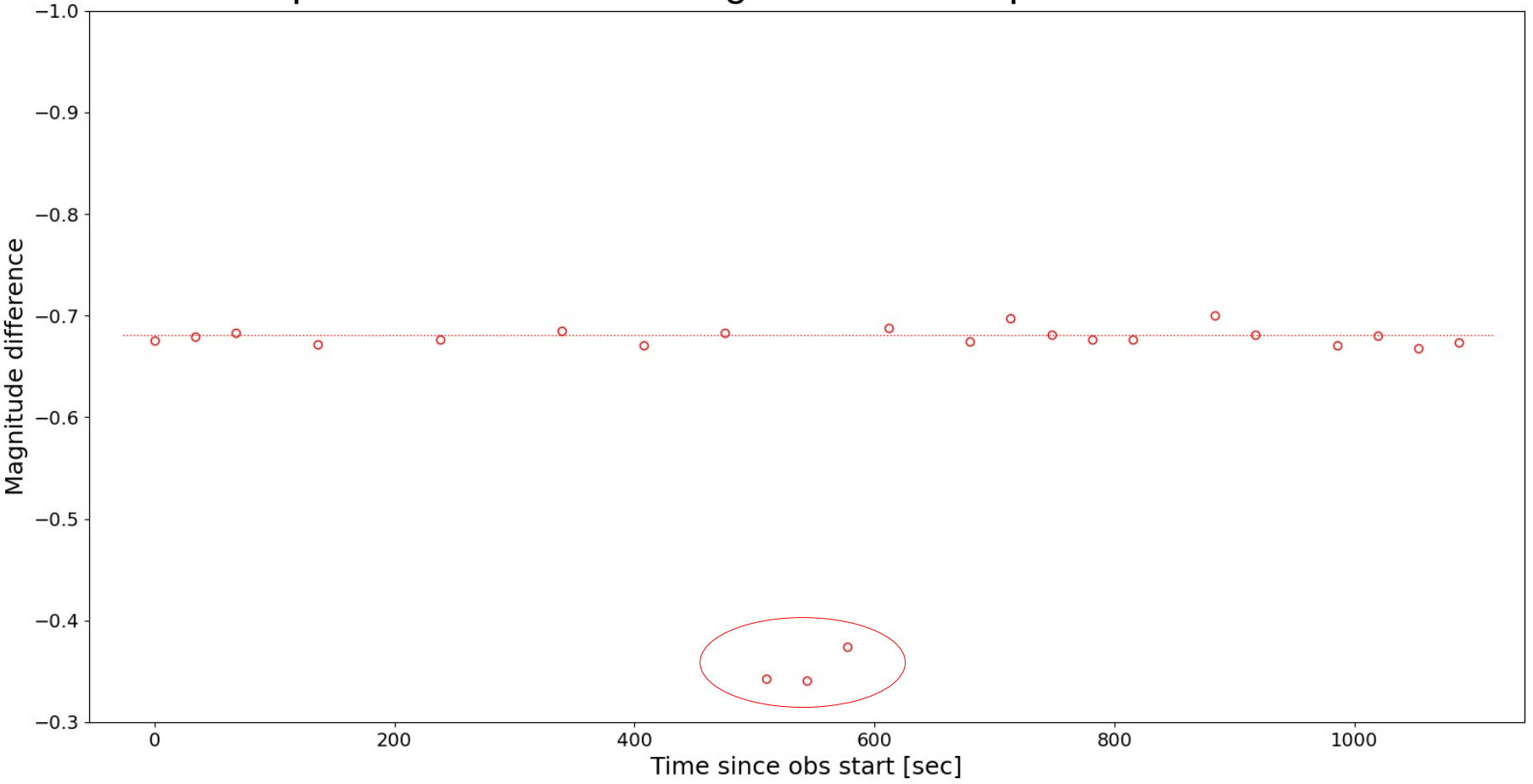
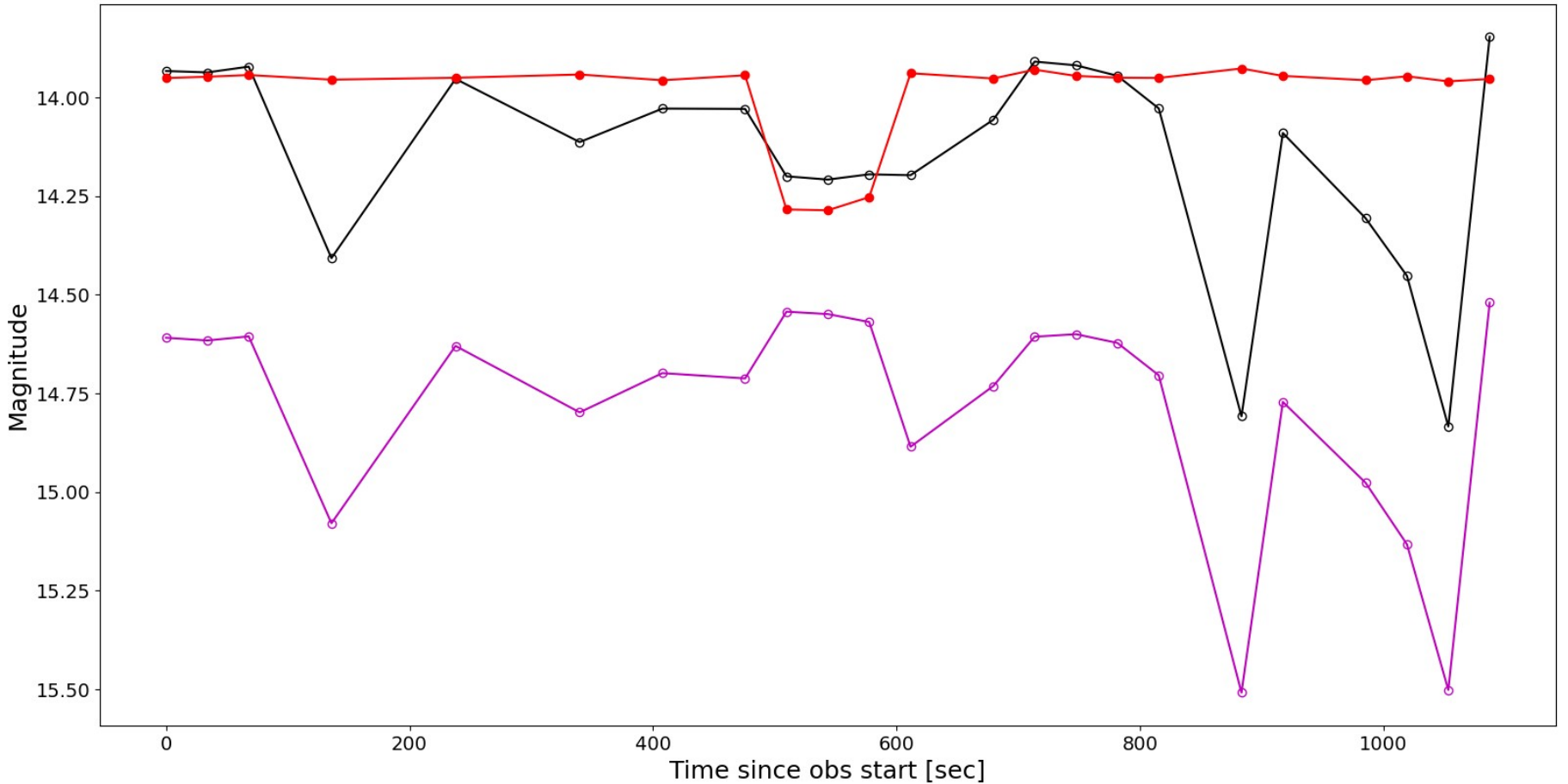


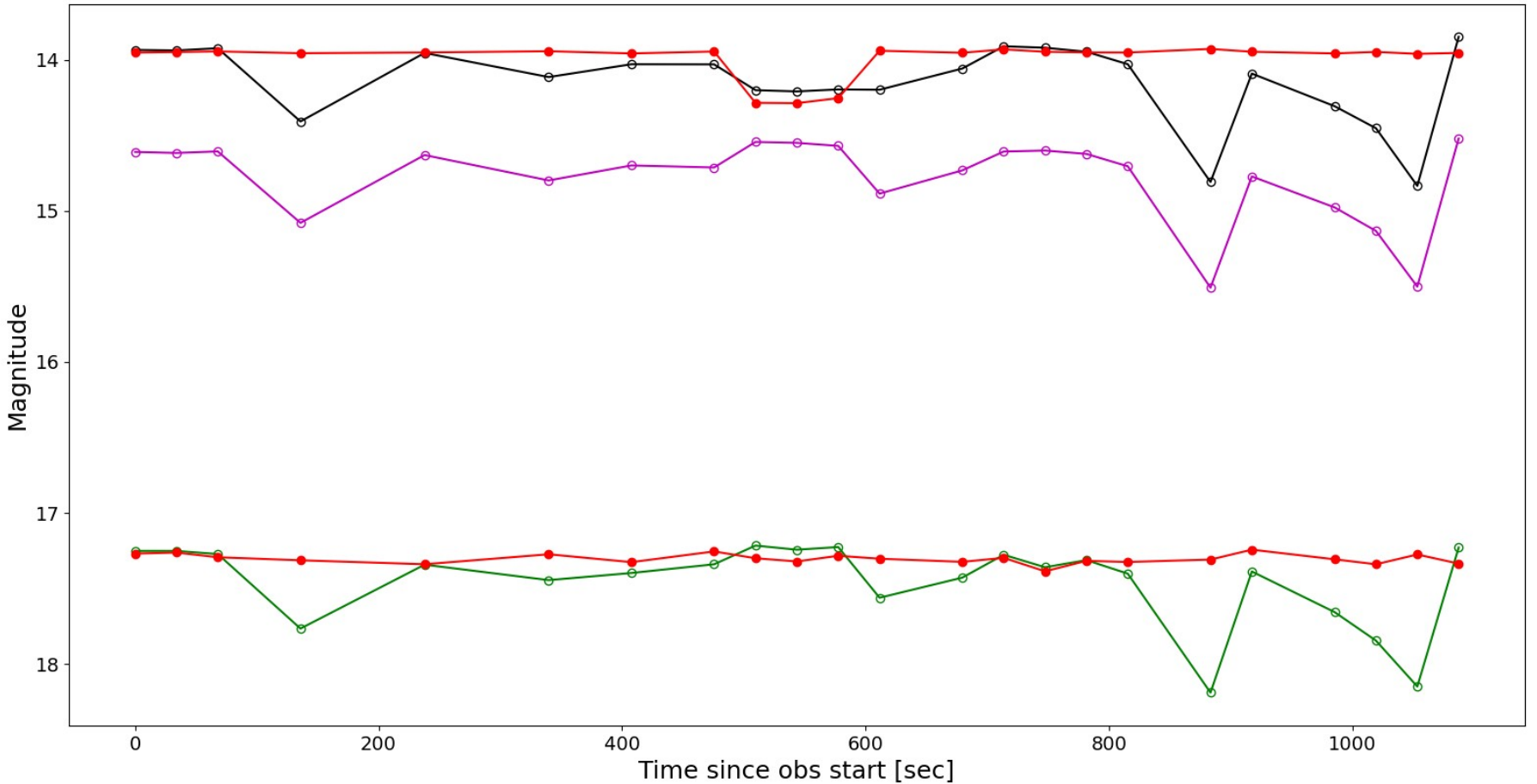
Differential photometry

It looks like in this case, the variation is real! It is actually an eclipse.



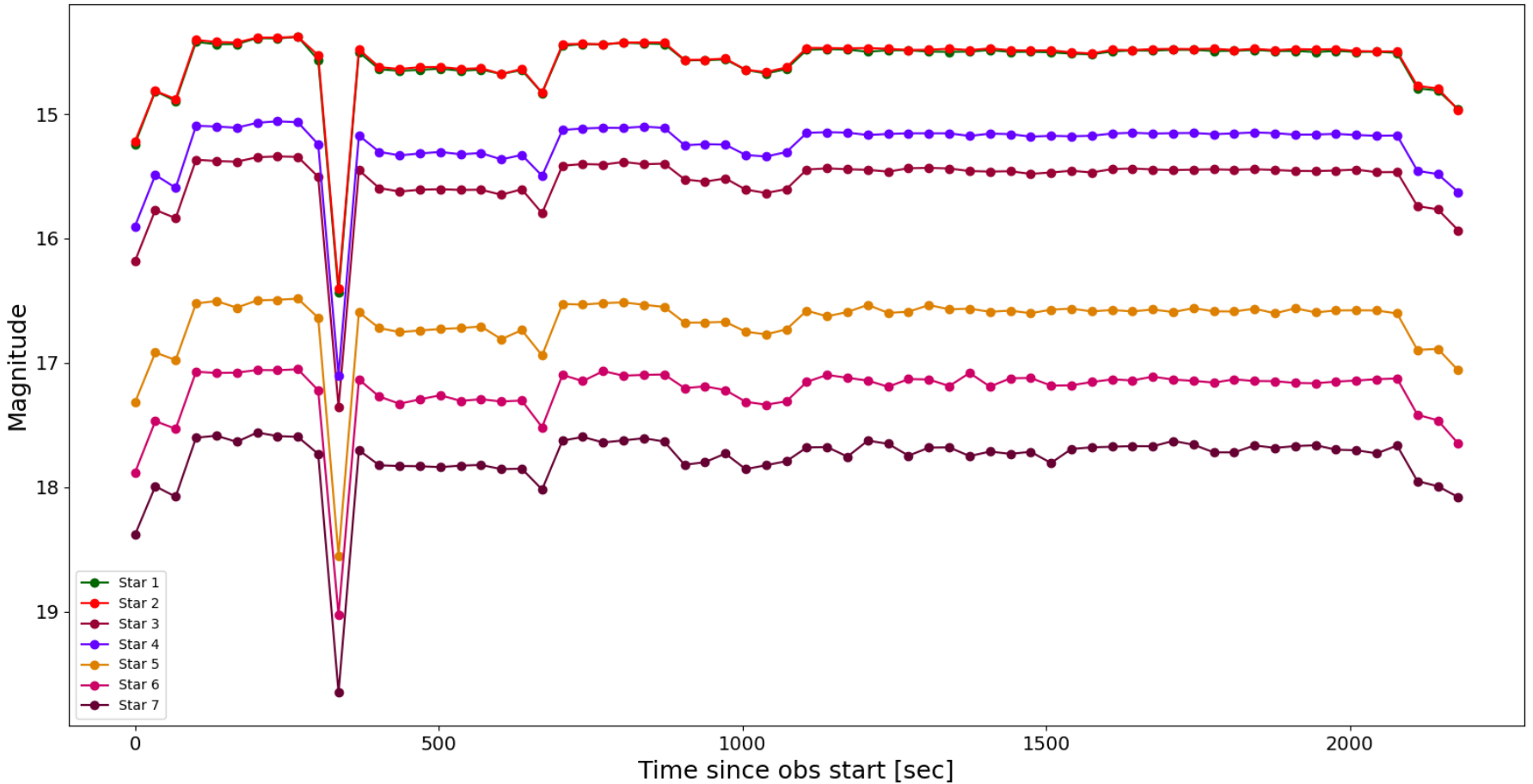
Differential photometry

Let’s make sure by checking another star.



Ensemble differential photometry

Much like calibration frames, we can actually use ***multiple*** comparison stars for statistics

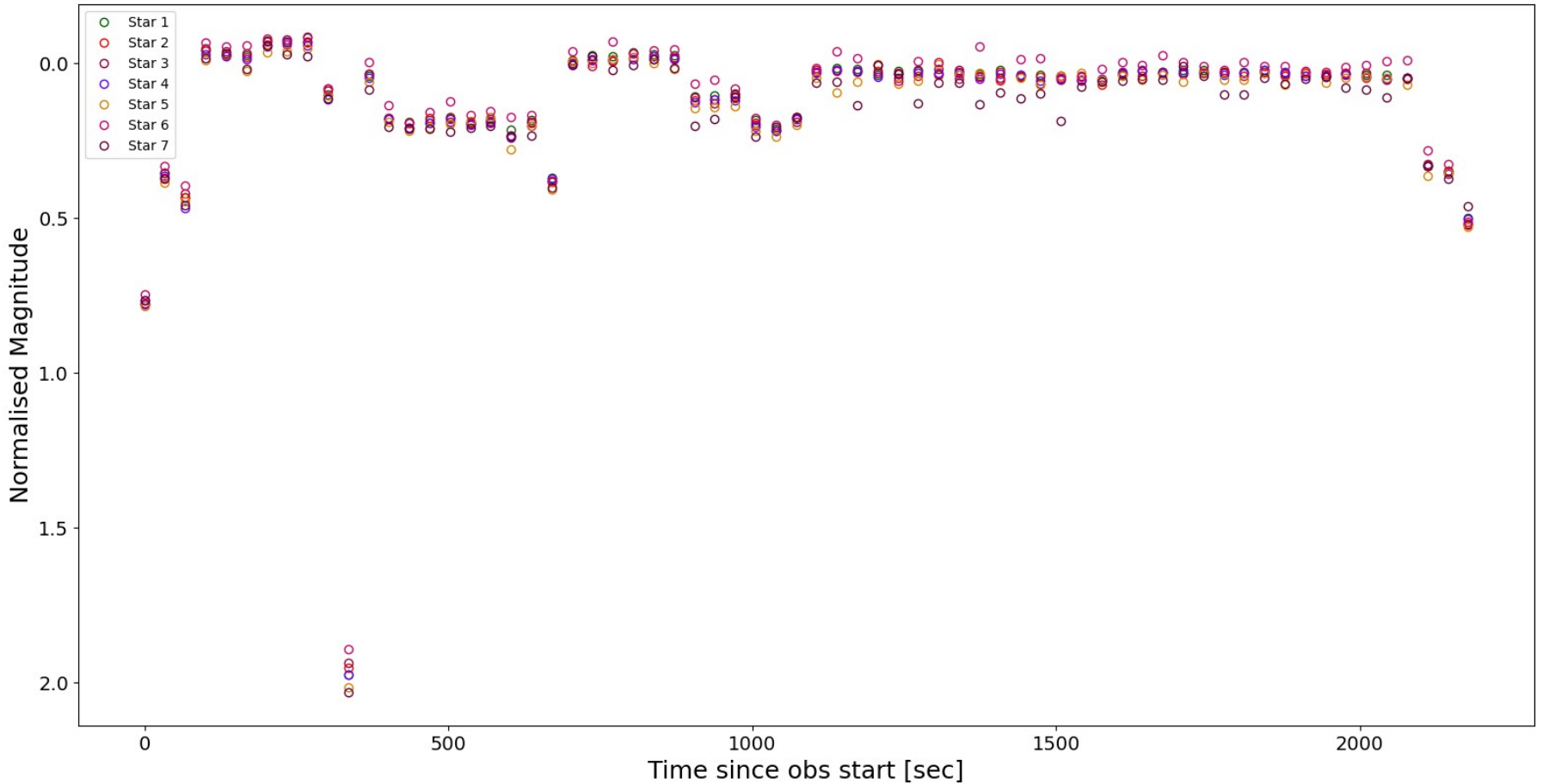


Ensemble differential photometry

Magnitudes are tricky beasts to work with

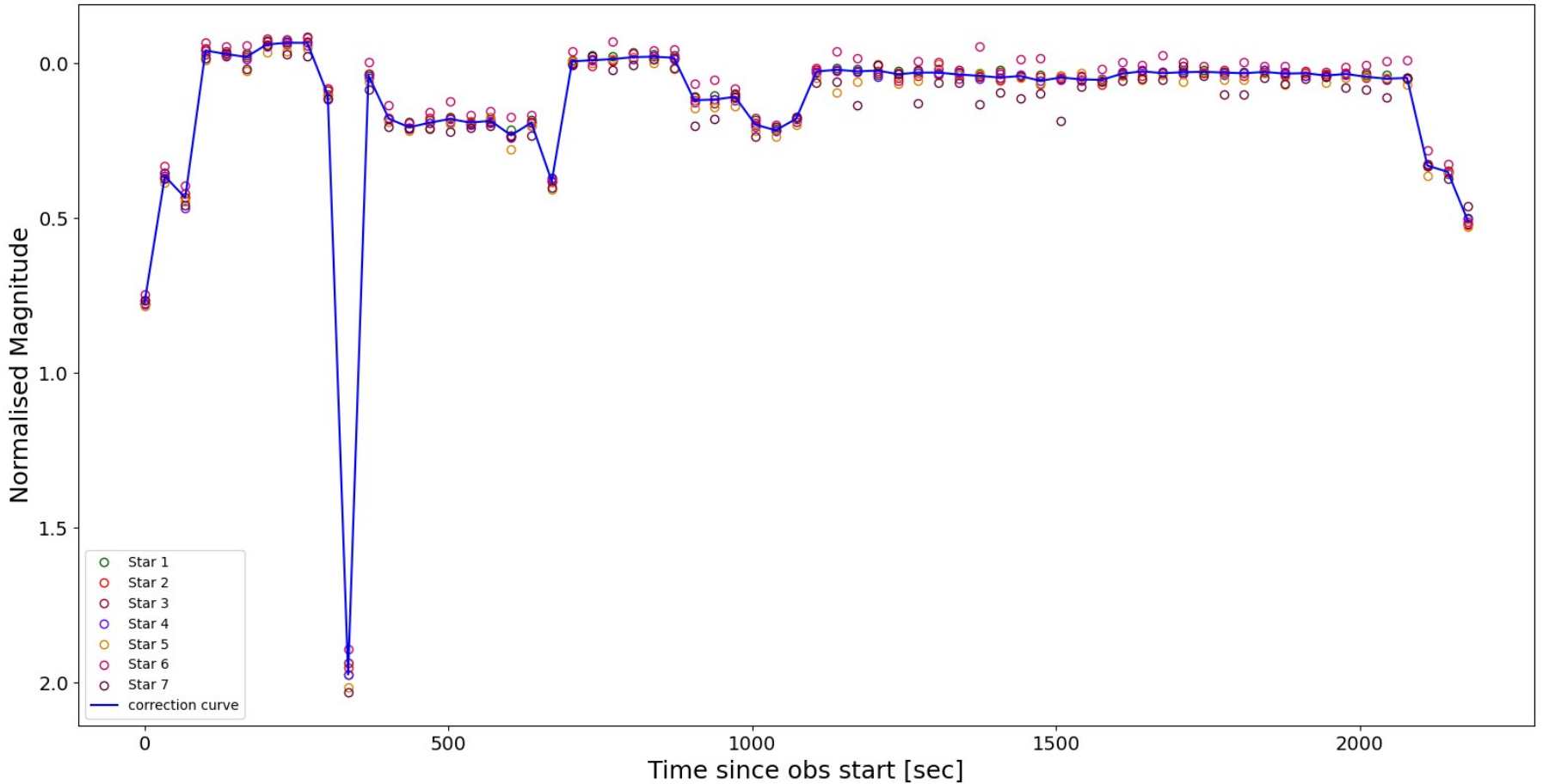
Ensemble differential photometry

Similar to flat frames, we are interested in relative changes, so we need to ***normalise*** first!



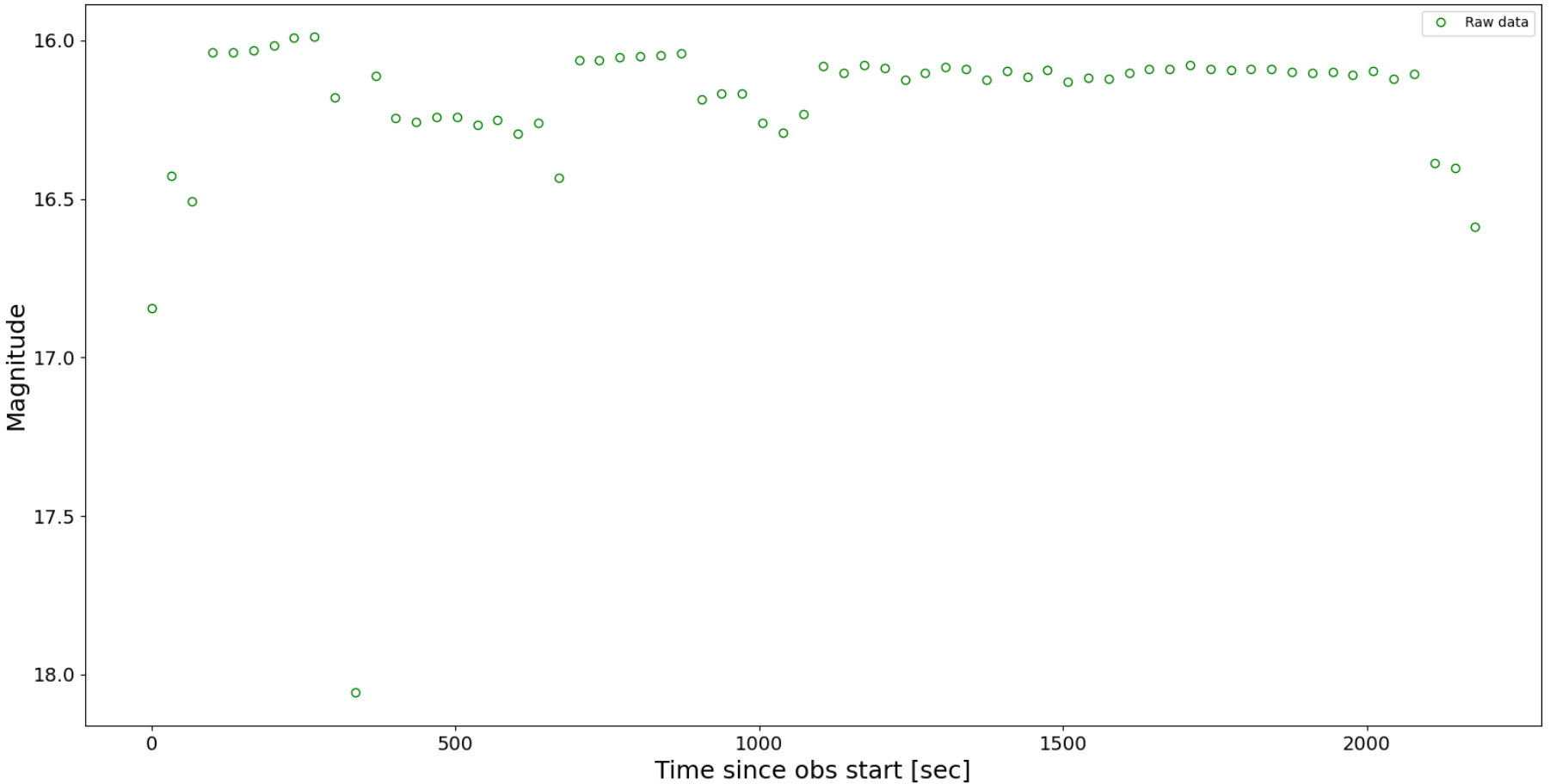
Ensemble differential photometry

Equivalently to calibration frames, we can then combine and create a ***master*** comparison star



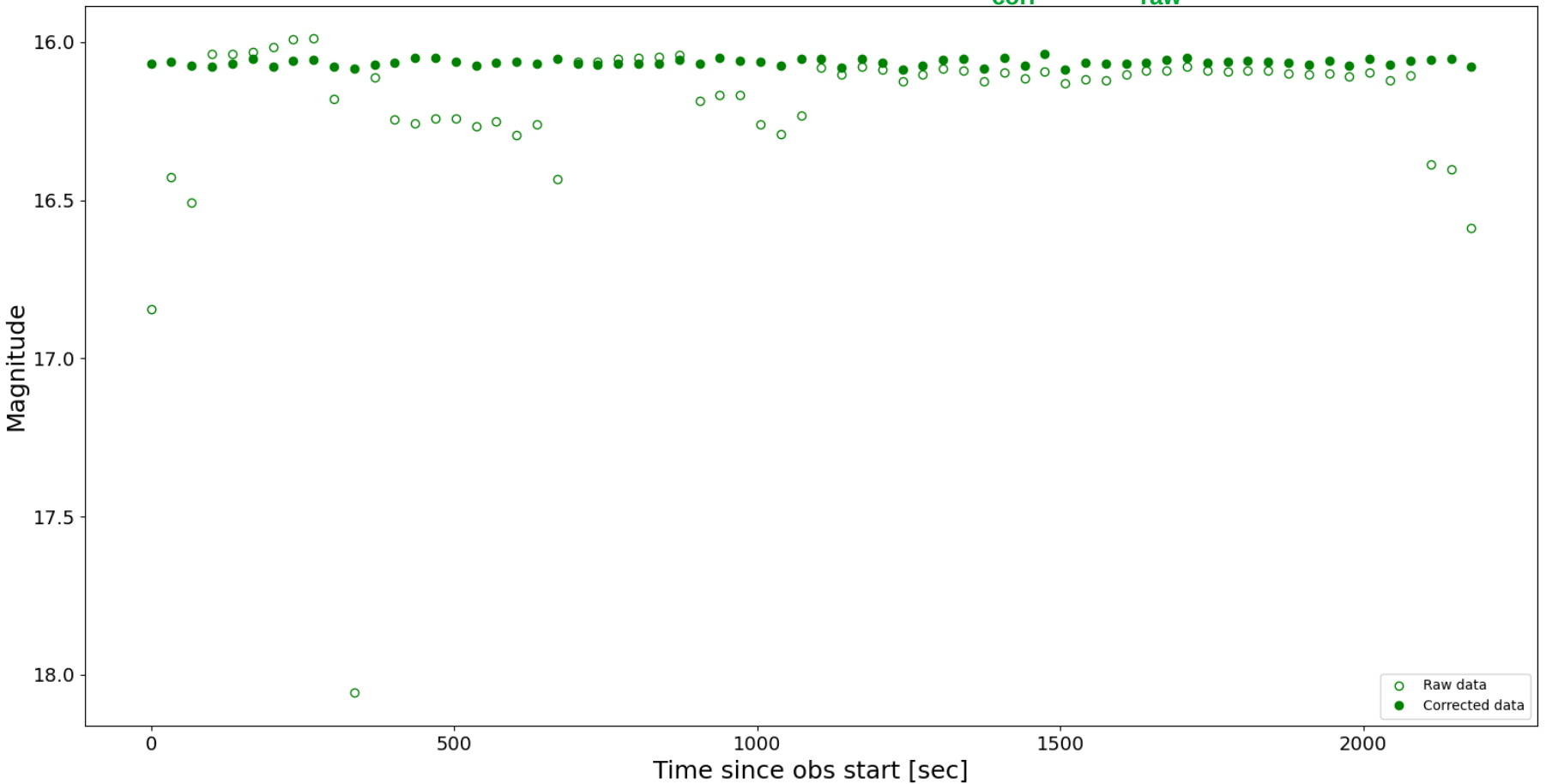
Ensemble differential photometry

Example: the raw (= uncorrected) light curve of a star

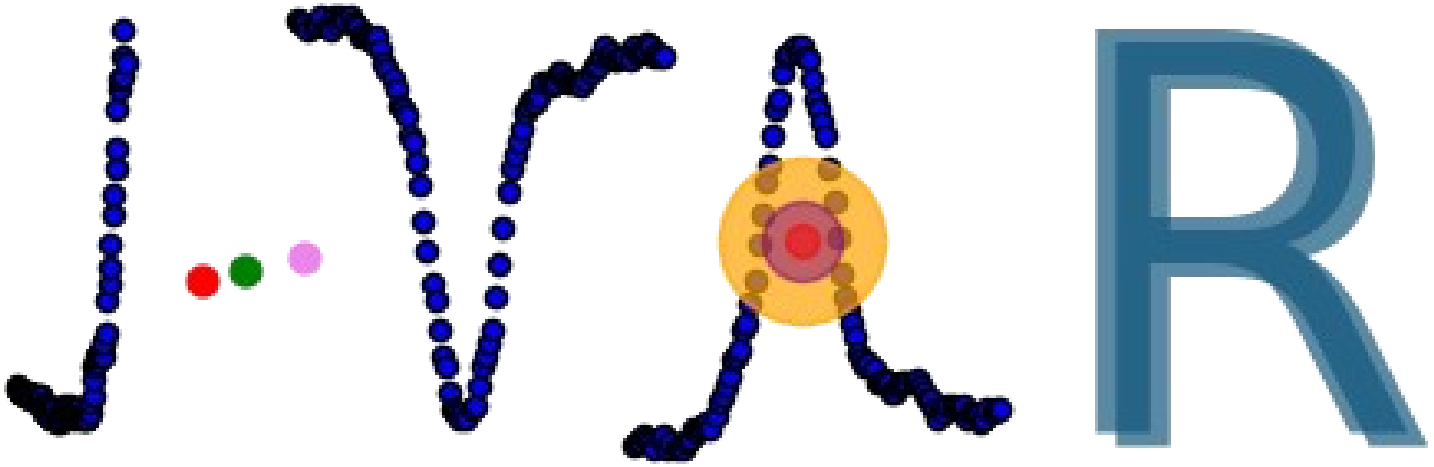


Ensemble differential photometry

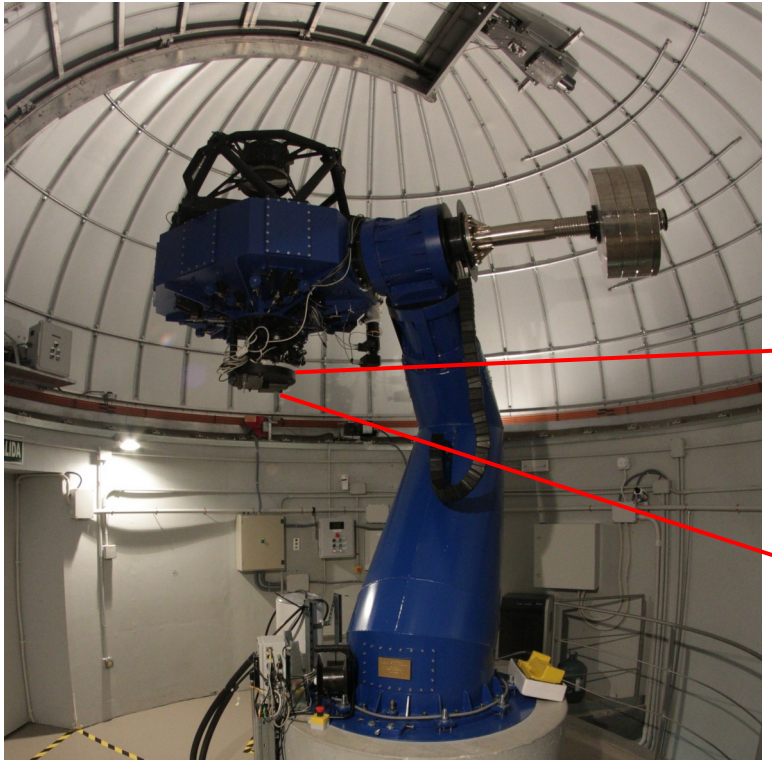
Example: correcting the raw light curve, **$LC_{corr} = LC_{raw}$ - CorrCurve**



The J-VAR survey

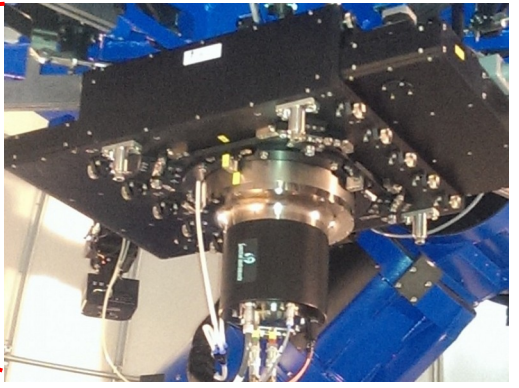


J-VAR observations

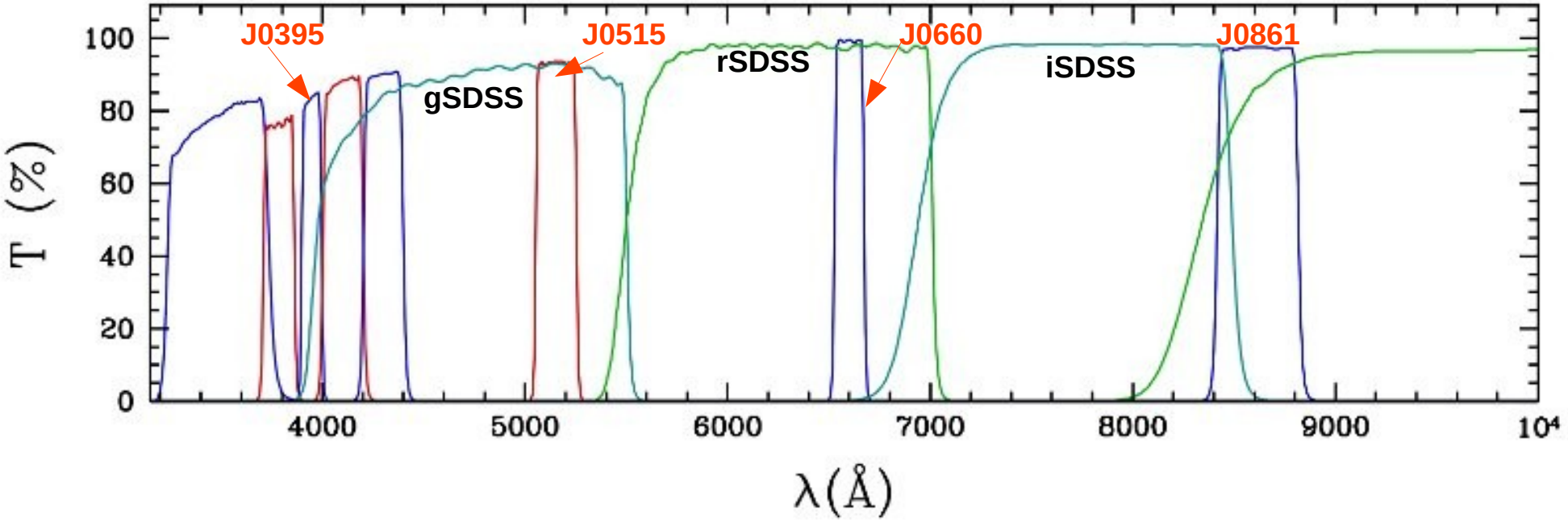


We observe with the JAST80 telescope at the OAJ using the T80Cam.

J-VAR follows the footprint of J-PLUS.
Its fields are *identical* to J-PLUS fields!



J-VAR filters



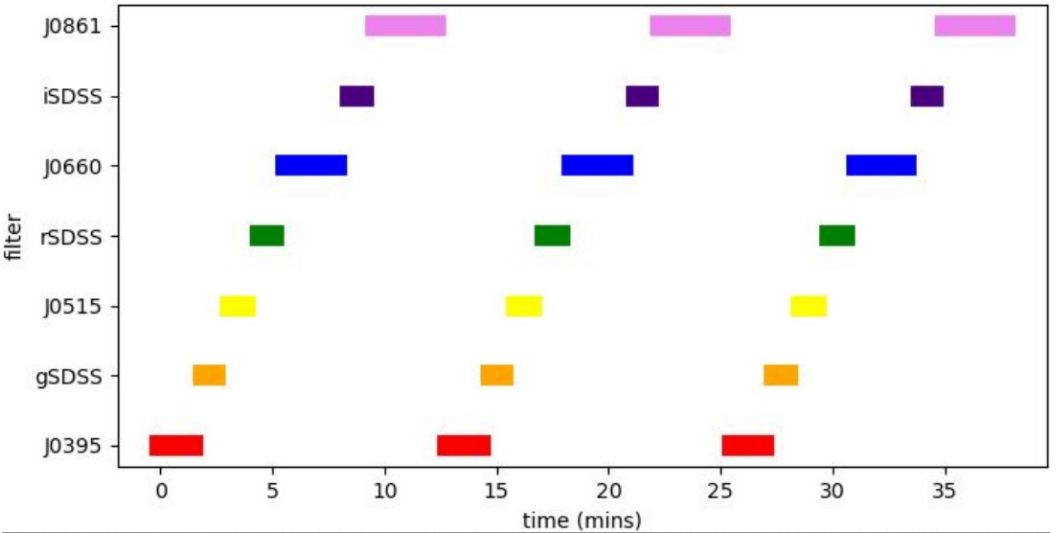
3 Broadbands: SDSS g, r, i,
4 Narrowbands: J0395, J0515, J0660, J0861

Filter	g	r	i	0395	0515	0660	0861
T_{exp} [sec]	33	40	34	87	40	135	160

J-VAR Strategy

J-VAR Mode: Multi-Epoch

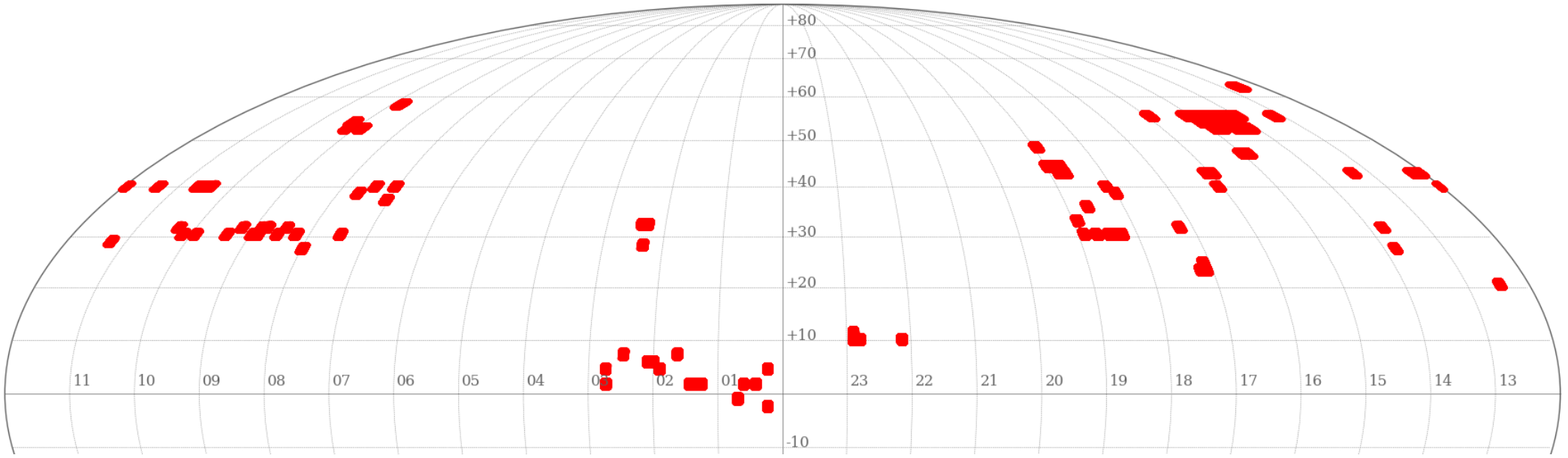
- We visit every J-VAR field 11 times; occassionally more (we're not too strict...)
- No fixed cadence between visits, but we try to spread them over the course of a year
- On each visit we take 3 sets of images in the 7 filters (cycling through the wheel 3 times)



J-VAR Mode: High Frequency

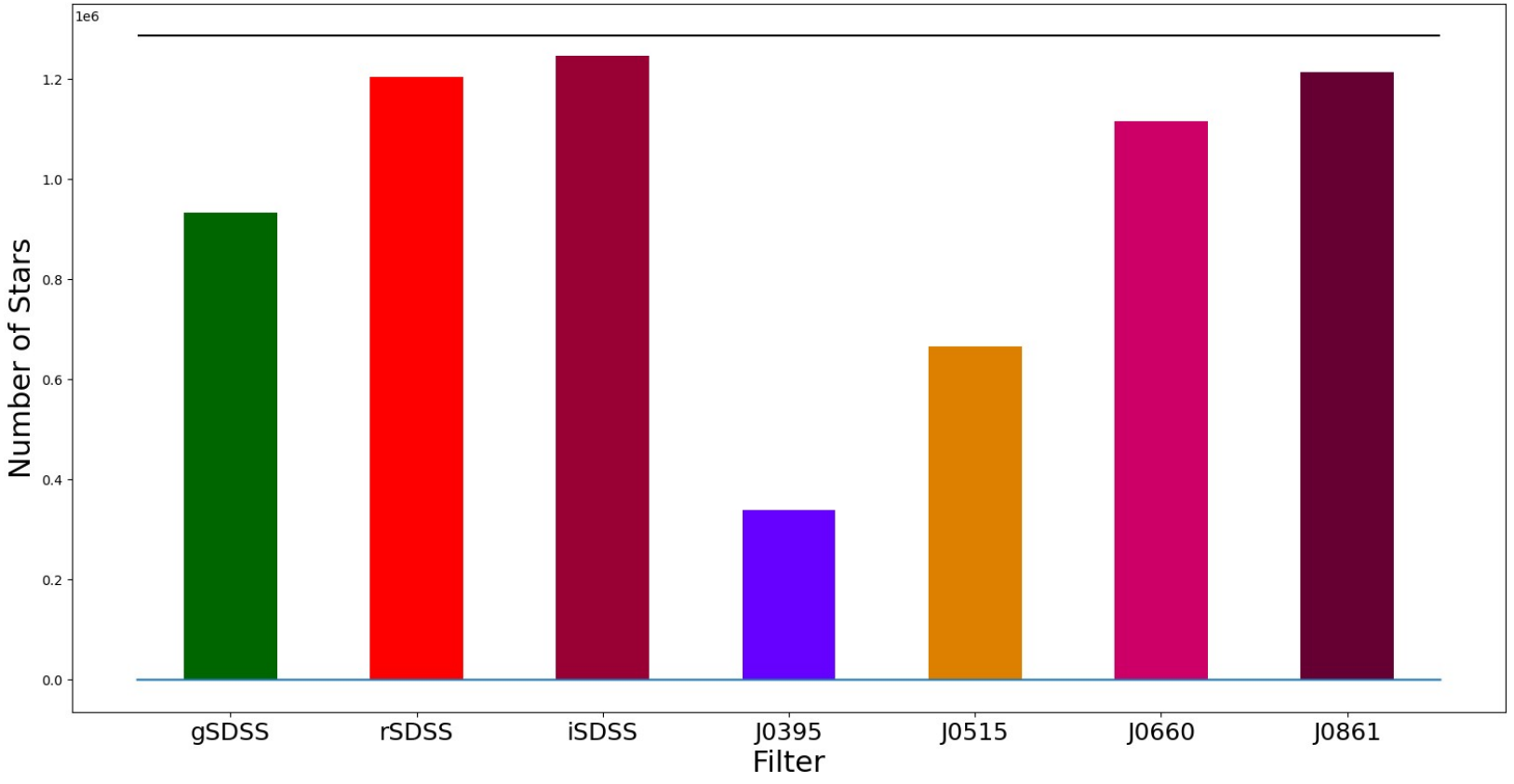
- Finally, we also add one (two) extra visit(s), when we stay on the field and observe for ~2-3 hrs continuously, cycling through the filters as many times as possible.

J-VAR Data Release 1 (DR1)



101 fields (~ 200 sq.deg) with light curves in 7 filters for ~ 1.3 million objects

J-VAR Data Release 1 (DR1)

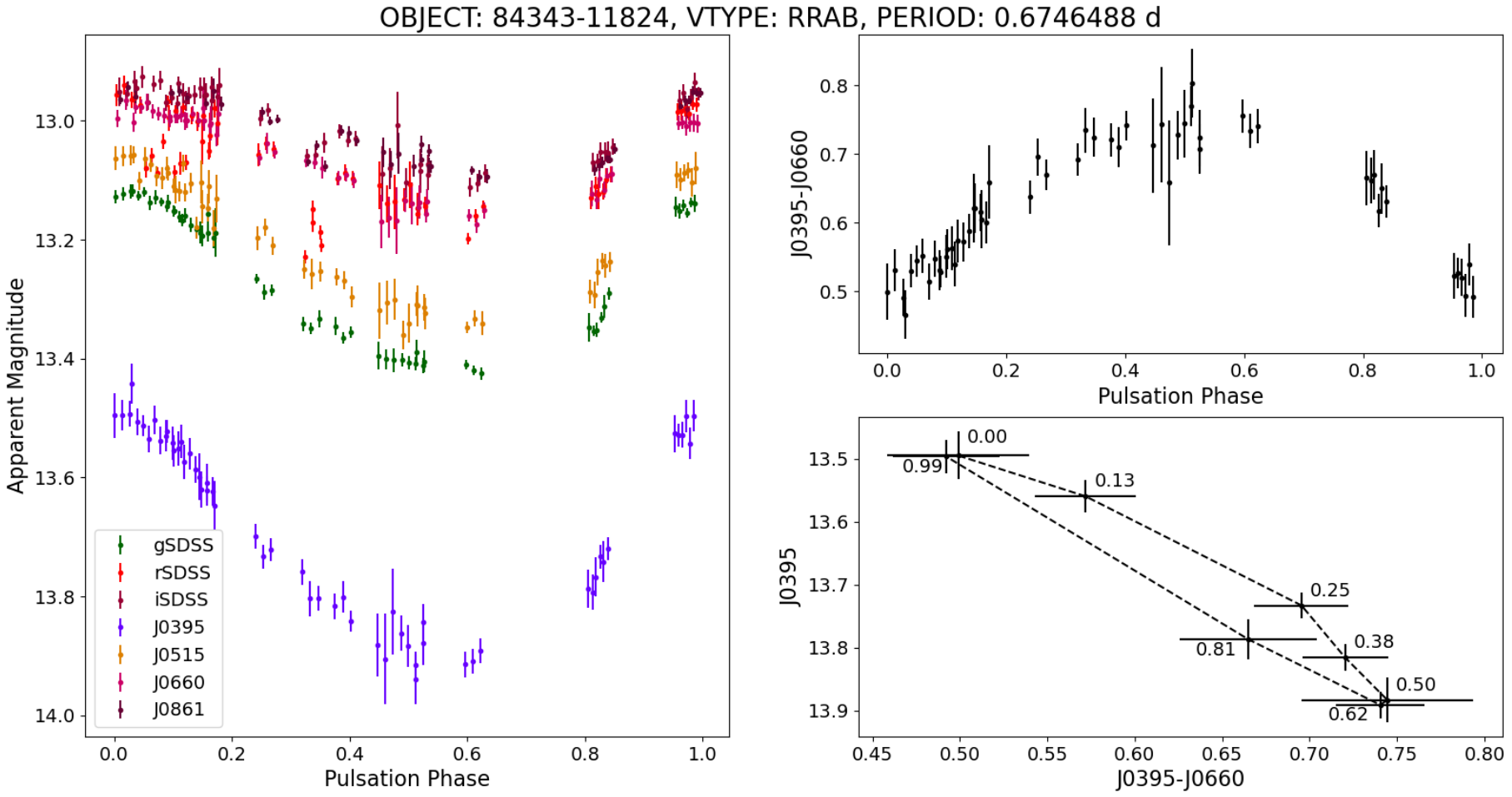


Total: 1,286,291

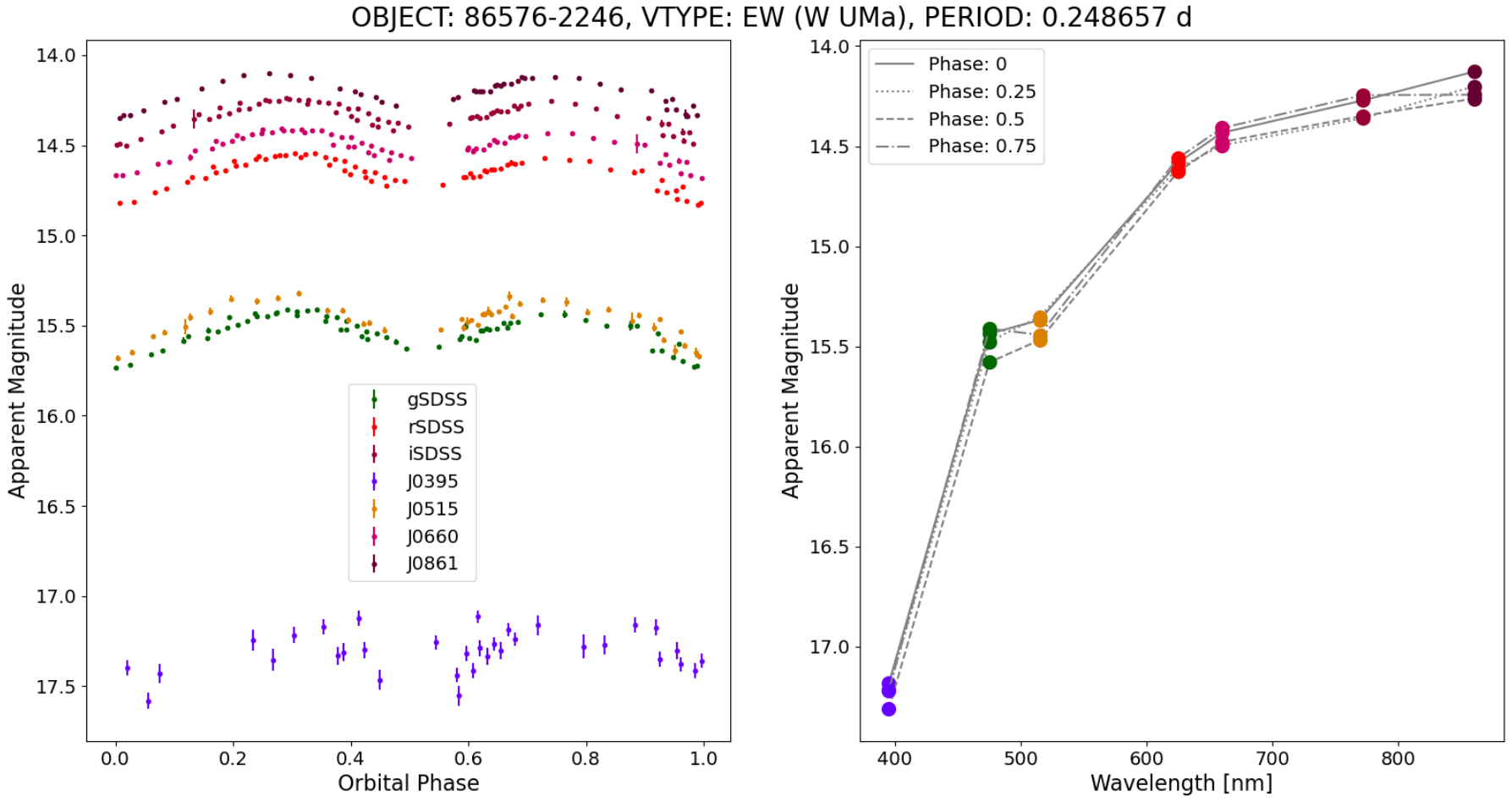
gSDSS: 932,348
rSDSS: 1,204,060
iSDSS: 1,246,646
J0395: 339,933
J0515: 665,415
J0660: 1,114,673
J0861: 1,213,148

Variables: 1,625

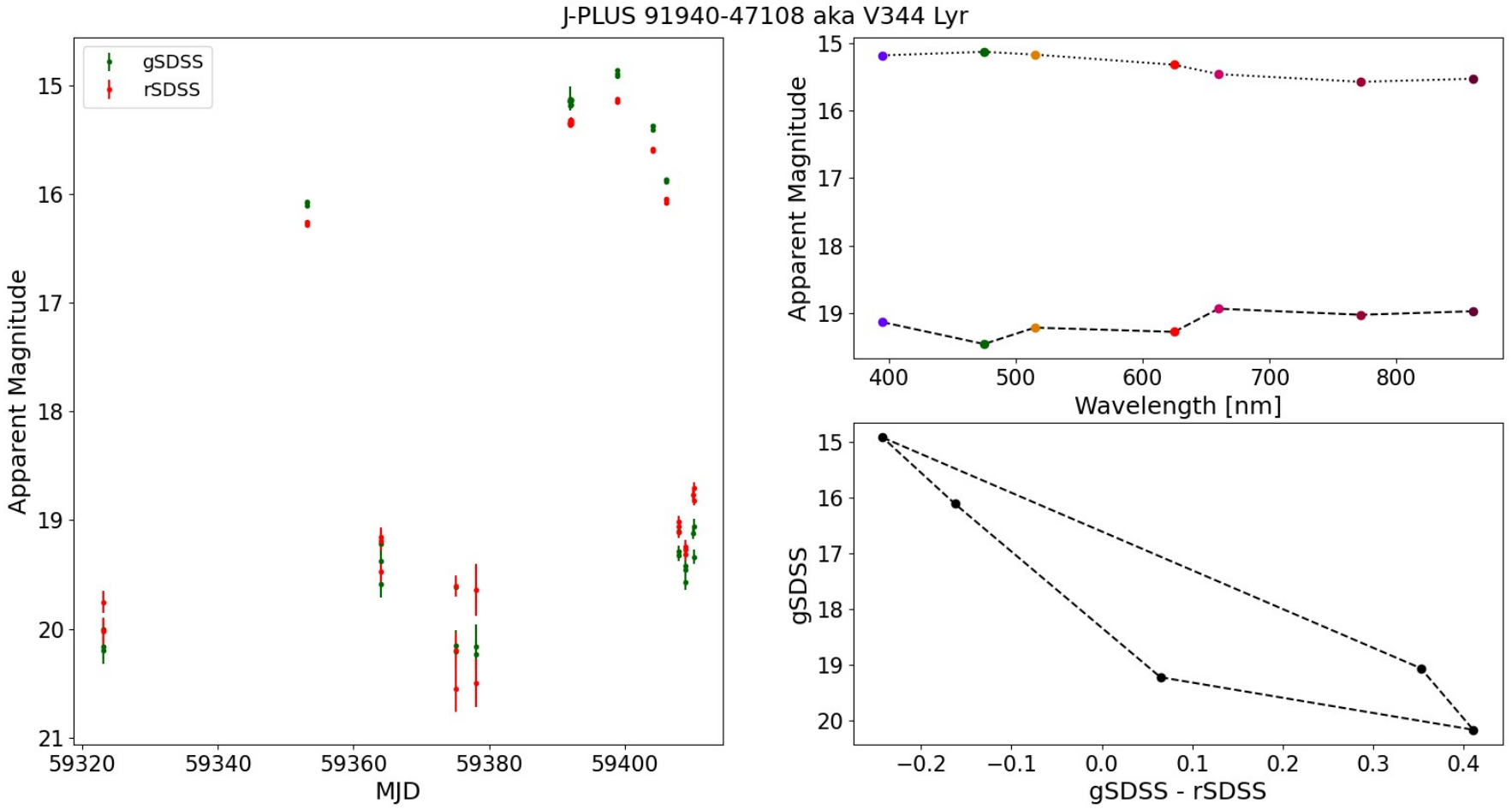
J-VAR Science



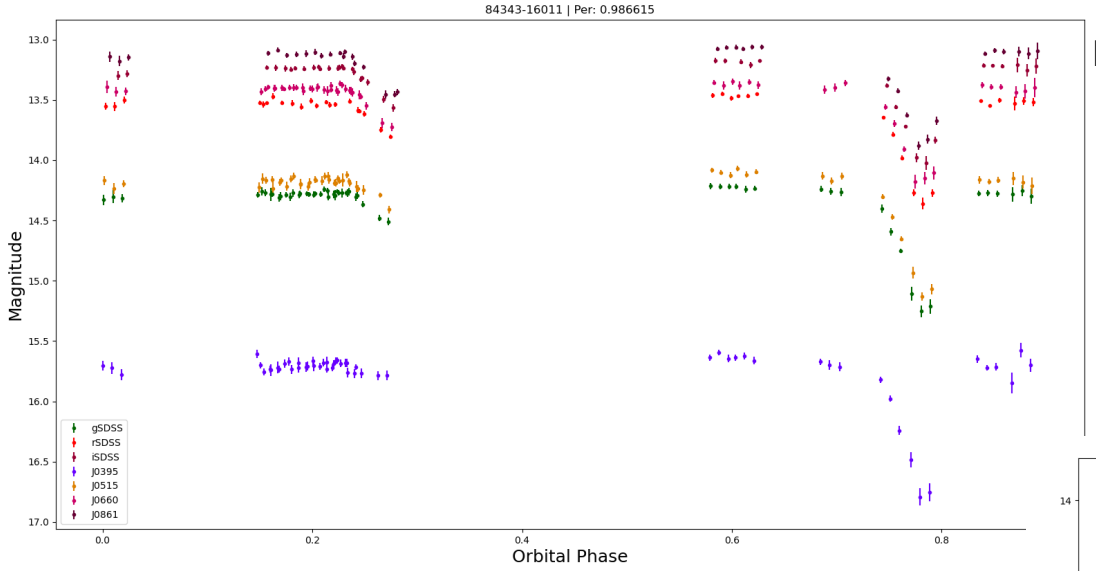
J-VAR Science



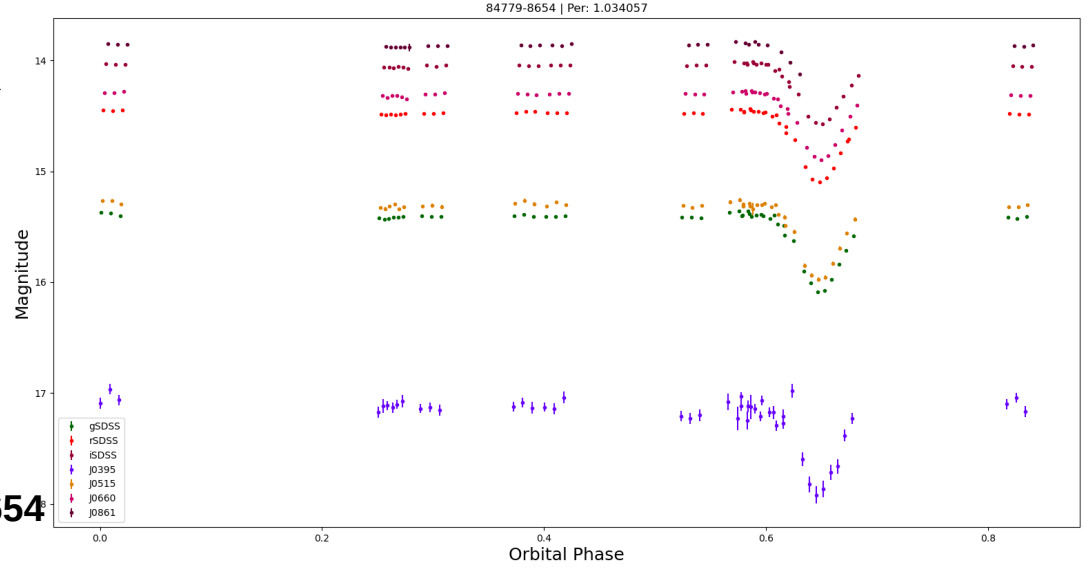
J-VAR Science



J-VAR Science



DG Com



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SUMMARY

- We spoke about time-domain astronomy and defined a stellar light curve.
- We saw different types of variable stars and why it is important to study them.
- We discussed the technique of differential photometry and saw how we can use one or many comparison stars to correct our light curves.
- We saw a brief introduction to the J-VAR survey