Issue 4 – Feb 26, 2020

ExoClock Newsletter

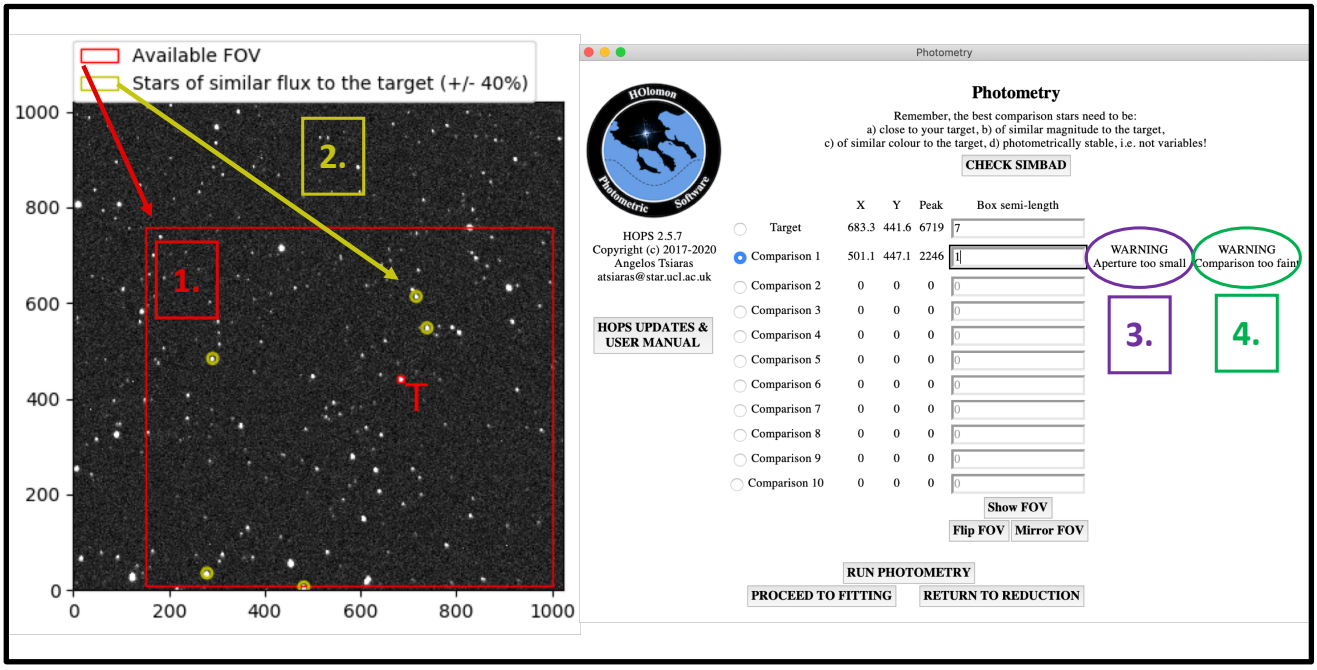
Dear ExoClock participants,

Hope you are all doing well! Thank you for submitting your observations, February has nearly finished; hopefully the weather will improve in the coming month. In this newsletter, alongside with the updates on HOPS and the website, we start sharing with you the first educational material according to your interests.

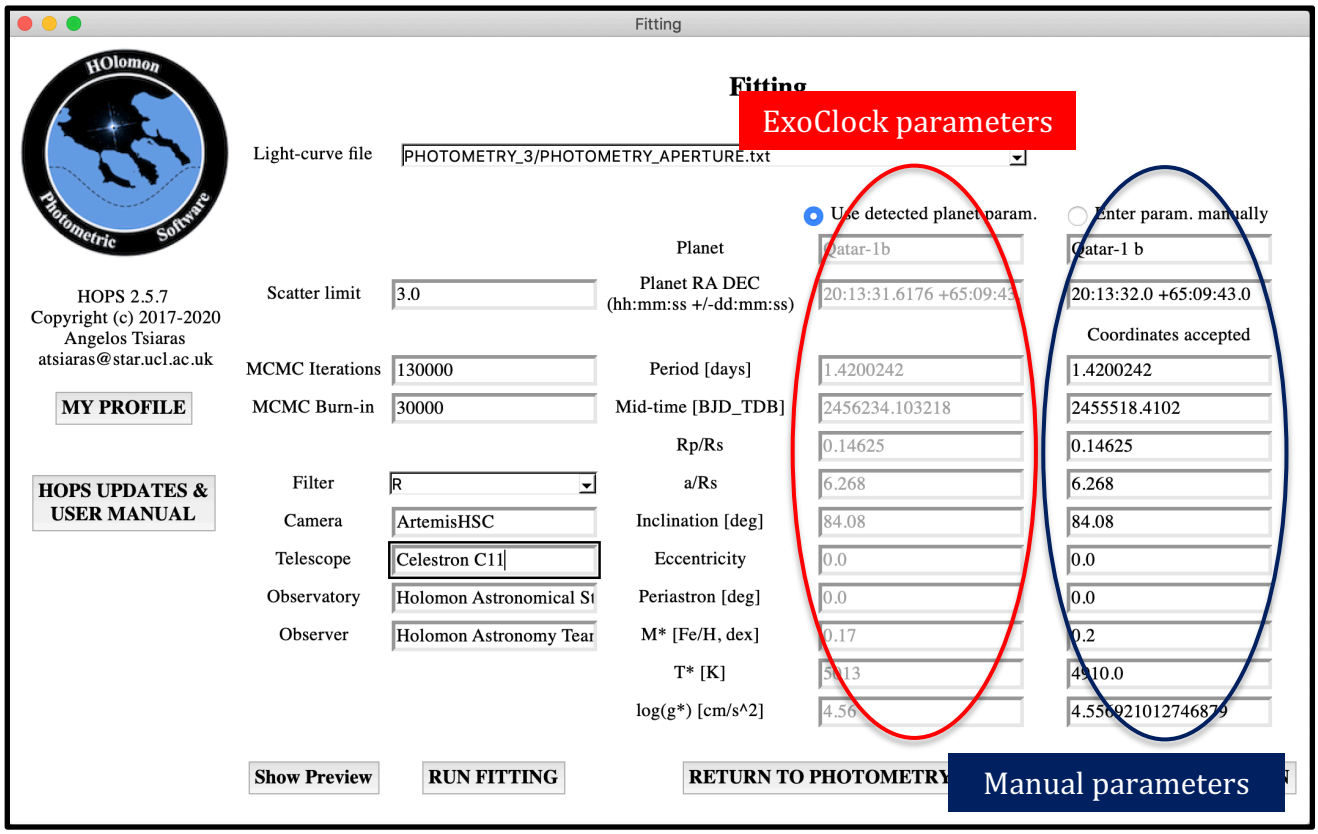
Updates on HOPS

You can download and install the latest version (2.5.7), as usual, form:
www.exoworldsspies.com/en/software
We continue to update the software to further assist you in the comparison stars selection process. In this version we added a few helpful features in photometry, as seen below:

1. A red box that indicates the available FOV, you will not be allowed to select stars outside this box as they drift outside the CCD during the observation.
2. Once you have selected your target, a few yellow circles will appear, indicating the stars that have a flux value +/- 40% of your target star. However, you will still need to check the produced light curve for variability of your comparison stars. Of course, you are not limited to the suggested stars, and you can still select other ones.
3. A warning if the aperture you are selecting is too small compared to the stars' PSF.
4. A warning if a comparison star is much fainter or brighter than your target. This is just an indication, there may be cases where, in absence of stars with similar flux, you may need to choose such fainter or brighter stars for comparisons.



In addition, we have now connected the ExoClock database with HOPS, so the fitting results on your computer will better match those on ExoClock (the previously used database contained many out-of-date parameters). During fitting, you will have the option to use either the ExoClock parameters or to manually input your preferred ones. Remember that any fitting you are performing on your computer will not affect your submission to ExoClock, because on ExoClock the fitting is performed again on the server.

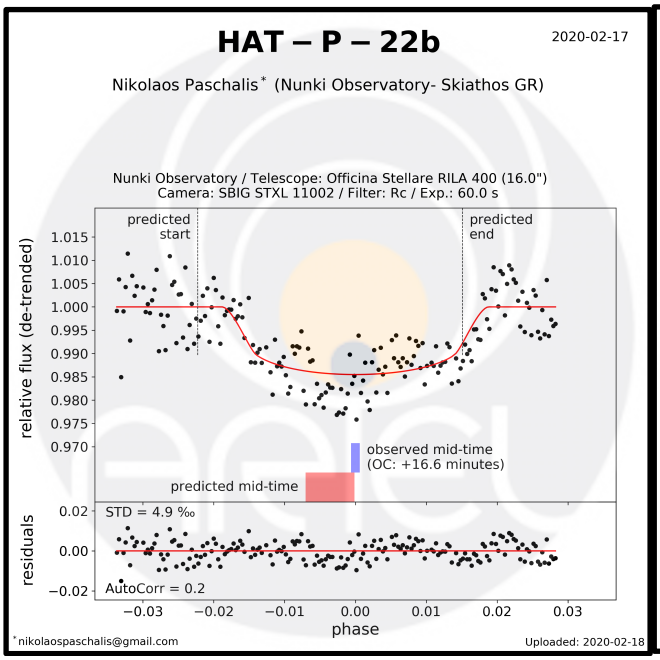


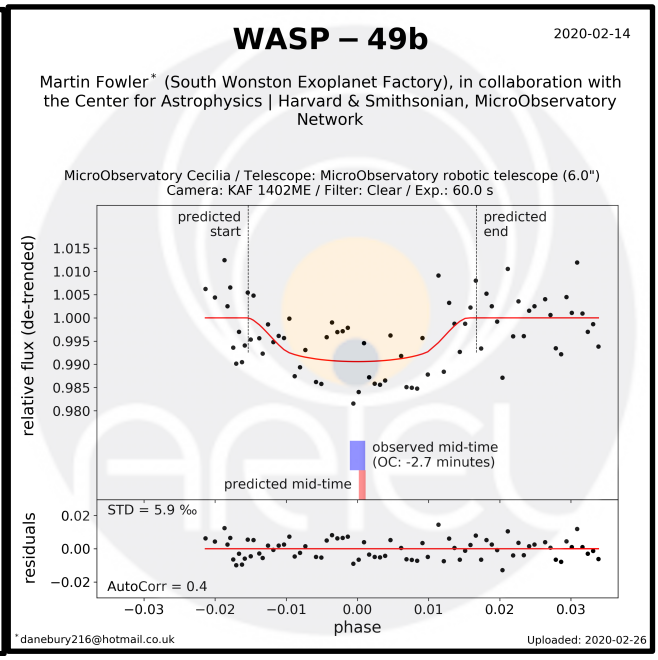
Highlighted observations

For this month's issue, two are the highlighted observations: HAT-P-22b and WASP-49b. These targets are showcased for different reasons. HAT-P-22b (captured by Nikos Paschalis) was marked with a high priority and there is a quite long time-shift observed. WASP-49b (by Martin Fowler), although it is a low priority target, it has very few observations and it is a challenging target – it is observable from specific locations. No matter what the target is, all observations are valuable. These are some showcases to give you examples of how different observations can be valuable (even if the target is not high priority!).

Congrats to our members Nikos Paschalis from Greece and Martin Fowler from the UK for their efforts!

We will reanalyse the data to achieve the highest possible precision, but below you can see a preliminary analysis of the two observations:





News on ARIEL

The Open Conference that took place in ESA/ESTEC last month was really successful, including many fruitful discussions and interesting presentations. If you are interested in learning more about ARIEL and specific aspects of the mission, the presentations are now online and accessible to everyone. The following presentations are highly recommended if you would like to get more information about ARIEL:

- *The Ariel Science Case Outline* by the Principal Investigator Giovanna Tinetti (UCL)
- *ARIEL: Mission overview and community participation* by Göran Pilbratt (ESA)
- *Welcome: ARIEL in Context of ESA Science Program* by Günther Hasinger (ESA)
- *The ExoClock Project: Pro-Am collaboration for ground-based observations in support of the ARIEL space mission* by Anastasia Kokori (UCL)
  This is the presentation regarding ARIEL and ExoClock, focusing on the contribution of ExoClock (including all of you!).

The above and many other presentations are accessible through the following link:
https://www.cosmos.esa.int/web/ariel/conference-2020

ALERTS

Thanks to everyone that reacted to the **Alert system** during the last month. It is quite important to confirm an observed time shift-especially for challenging targets or for targets that have rare transits. The current **alerts** are for the planets below. Please check your personalised alert schedule and if you get a clear sky, observe them!
https://www.exoclock.space/schedule/alerts

- **HAT-P-17b**
- **HAT-P-24b**
- **WASP-54b**
- **WASP-83b**

Educational material

As we have already announced in the previous newsletter, we will create a series of educational materials, which we will be sharing through the newsletters. Many thanks to everyone for updating their profiles! If you have not updated your profile yet, follow the link and click the categories of your interest here:
https://www.exoclock.space/users/my_profile

The scope of this material is to enrich participants' experience in the project and provide the opportunity to engage more in depth with the field of exoplanets and observational astronomy. We would like this to be as interactive as possible and thus, feel free to ask the ExoClock team any questions related to the educational material. Please note, that this is only optional and you don't need to read/study this material if you are not interested. The most important thing is to have fun alongside with learning something new. We will be providing some links and suggested readings, which again are optional.

We remind you to send us at exoclockproject@gmail.com:

- Your feedback on the website
- Suggestions for new features
- Questions on the observations or the analysis
- Ideas for topics you would like to see in the newsletters

Clear Skies,
the ExoClock team

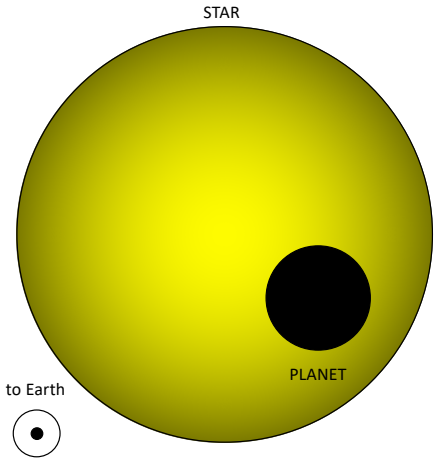
CHECK this out!

Please upload **ALL light curves** you have from the past. We will start organising the **first** publication so it is important to have all your data. The deadline for this will be the **30th of March 2020**. This is important, as our team will need time to re-analyse the data and finalise the results for publication. Of course, any other observations you might get in the meantime or later on **will** also be published, but in the second round. So please, make sure to upload any data you have from the past!

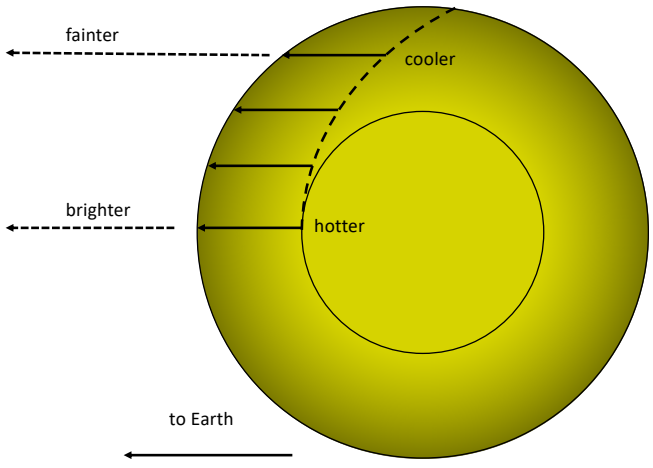
The effect of Stellar limb-darkening on transit light curves

why transits do not look like trapezoids?

There are two main bodies involved in modelling a transit phenomenon: the star and the planet. We are staring this educational journey by describing the stellar part of the transit model. Under certain circumstances related to the orbit of the planet, we will observe the planet passing in front of the star, as it is illustrated below:



Both the star and the planet have specific characteristics that play a role and influence the transit phenomenon and how this will be observed by us – the observers. In this issue, we will discuss how the star affects the transit: the **limb-darkening effect.** As you can notice in the figure above, the stellar disk does not look uniform, it gets darker as we move away from the centre of the disk. The light from the edge of the disk travels a longer distance within the star's atmosphere compared to the light coming from the centre of the disk. Because of this, the light from the edge will originate from a higher altitude in the stars' atmosphere. The temperature there is lower and so this light will be dimmer.



The strength of the limb-darkening depends on the physical parameters of the star (stellar temperature, stellar gravity, stellar metallicity) and the filter with which we are observing. This is the reason why we ask you to give us the observation filter for every transit that you upload. But how does the limb-darkening affect the transit? The weaker the limb-darkening is, the

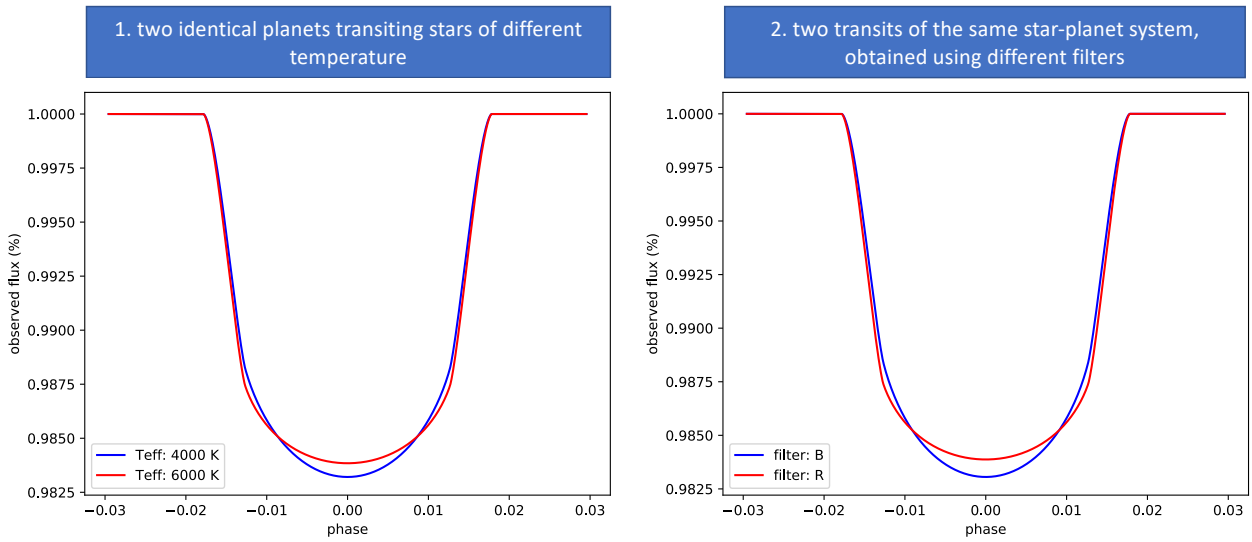
more uniform the stellar disk will be. This will produce a transit with sharper ingress and egress. Two factors affect the limb-darkening:

1. The nature of the star

Hotter stars have weaker limb-darkening. So, if we observe, with the same filter, two similar transiting planets around two different stars, the transit around the hotter star will look sharper.

2. The observing filter

Also, when the same star-planet system is observed at longer wavelengths, limb-darkening will be weaker, and the transit will look sharper. This is one reason why we prefer to observe transits with red filter, as the sharper transits give as better estimation of the transit timing.



Further reading:

One of the best ways we have to model this effect if the so-called 4-coefficients law:

$$I(\mu) = 1 - a_1(1 - \mu^{1/2}) - a_2(1 - \mu) - a_3(1 - \mu^{3/2}) - a_4(1 - \mu^2)$$

where **I** is the brightness of the stellar disk at a specific point, relatively to the brightness at the centre, **μ** is the cosine of the viewing angle (see figure below), and **a1,2,3,4** are the limb-darkening coefficients. More about this formula and other ones you can find in these papers:

- https://iopscience.iop.org/article/10.3847/1538-3881/aa8405/pdf
- http://articles.adsabs.harvard.edu/pdf/2000A%26A...363.1081C

Additional reading is available also within the references.