Follow-up observations of transiting exoplanets: data collection and analysis

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ABSTRACT

The presented work is a long-term project to monitor transiting exoplanets with small and medium scale telescopes, with the aim of improving their ephemerides and help their characterisation. In the case of a project on characterising exoplanets, long-term continuous monitoring of targets is necessary. This is a process that amateur astronomers can work together with professionals and contribute by obtaining or analysing data from small ground-based telescopes. In this context, our team consists of both amateur and professional astronomers and together we have conducted a number of observations using the equipment at two observatories in Greece: the Holomon Astronomical Station and Nunki Observatory. For data analysis and light curve extraction, our team has developed the Holomon Photometric Software (HOPS). We designed the software in a user friendly way to facilitate participants' use, and in parallel, to ensure high data quality and reliability in the scientific results. Below, we present the methodology, the tools and the first scientific results that have been produced out of this collaboration. We are open for contributions in our project either on the observations part or the data analysis. Our ultimate goal is to create a collective list of observations from transiting exoplanets to better identify their ephemerides and characteristics. At the same time, such an effort would contribute to future space missions dedicated to exoplanet research.

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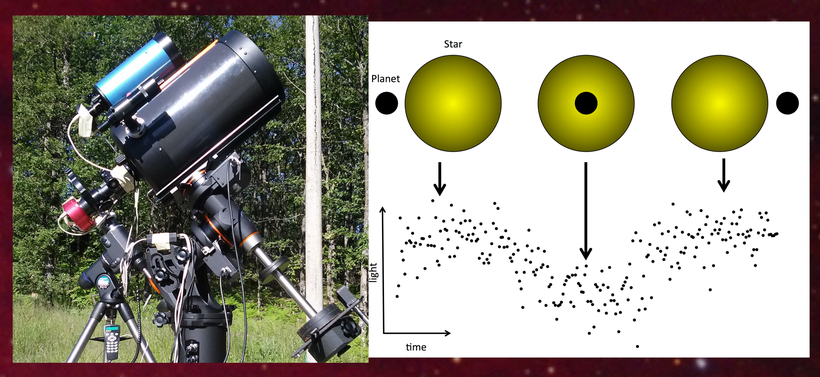
SMALL TELESCOPES CONTRIBUTING IN EXOPLANET RESEARCH

Currently the number of exoplanets is rapidly growing, with over 3500 planets discovered. This number is expected to grow even more in the future with dedicated missions that are expected to find additional planets. While discovering new exoplanets is still important, we have now entered a new era, where the better characterisation of these planets and their host stars is of extreme importance. A technique that is being used to probe the atmosphere of an exoplanet is transit spectroscopy. During a transit, the stellar and the planetary discs overlap, and while a part of the stellar light is blocked by the core of the planet, another, smaller, part is filtered through its atmosphere. Future space observatories will observe known exoplanets to obtain their spectra and characterise their chemical consistency. For this technique to be as efficient as possible and to organise large-scale surveys we need to have a good knowledge of the orbital parameters of the planets observed, especially of the expected transit time. This is where small and medium-scale telescopes can contribute significantly and make a difference.

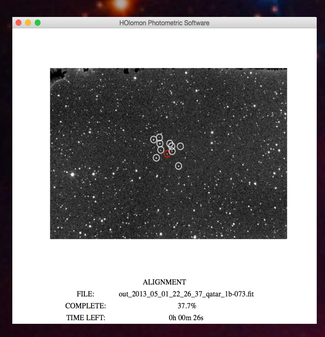
HOW?

The methodology we follow is:

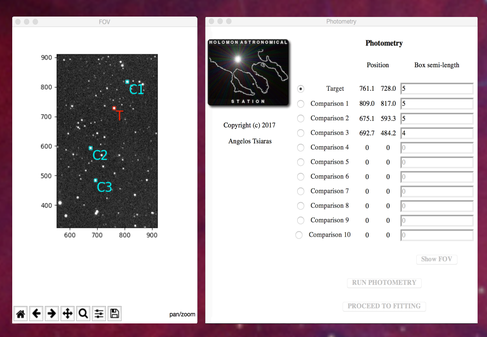
1. Obtain data with small ground telescopes.
   Specifically, we take photos of a star while an exoplanet is passing in front of it. So far, we have collected a number of observations from the Holomon Astronomical Station and the Nunki observatory in Greece.
2. Analyse the data.
   At this stage, we are measuring the light coming from the star. The star seems a bit fainter when its planet transits.
3. Interpret the data.
   The drop of the light will give us more information about the planet: its size, its orbit and its transit timing. This process needs to be done on a regular basis with the aim of tracking any changes in the long term.



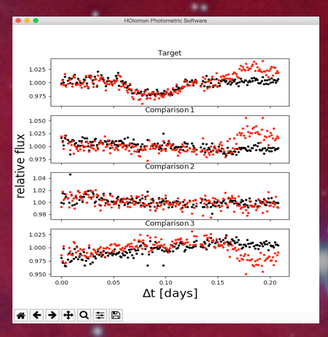
When an exoplanet is passing in front of its star we can observe a decrease in the stellar light, as a part of the star is hidden.



The frames are automatically aligned using a star pattern in polar coordinates. Able to handle large shifts and rotation / meridian flip.

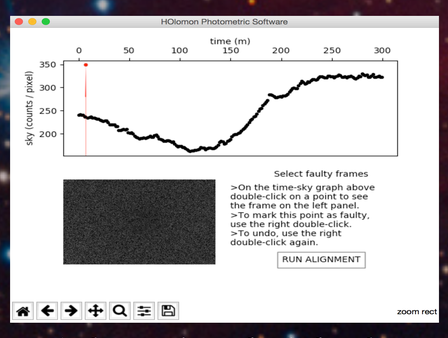


A window showing the field of view allows the user to select the target and the comparison stars and set the size of the extraction apertures.



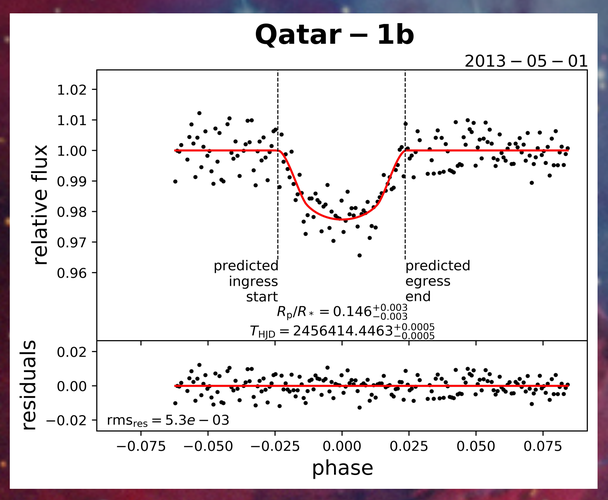
Two light-curves are extracted, one using an aperture and one using a 2D ellipsoidal function. These plots help the user identify and exclude bad comparison stars.

PHOTOMETRY

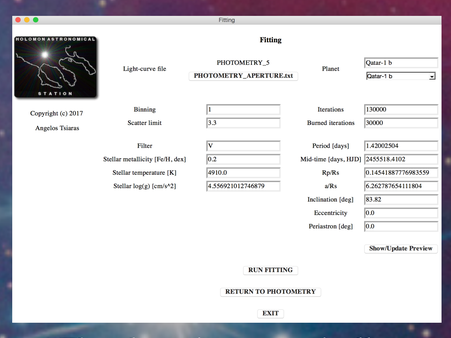


A sky vs. time plot helps the user identify any damaged frames.

BAD FRAMES

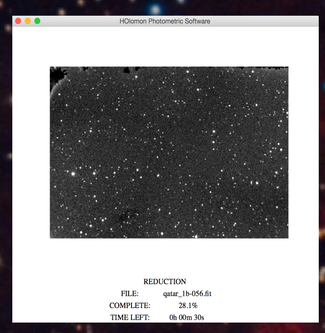


FITTING

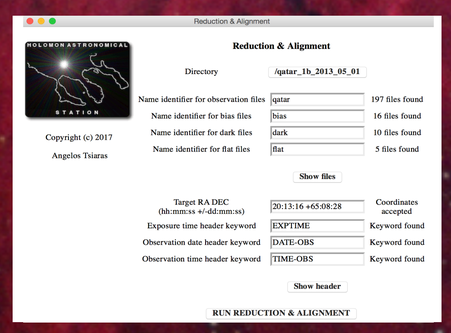


The planet is automatically detected and the parameters are chosen based on the Open Exoplanet Catalogue.

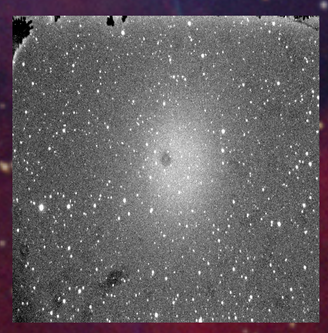
REDUCTION



Master bias, dark and flat frames (median) are automatically created and applied to the raw images.



The user provides a small number of input parameters.



Raw image of the Qatar-1 field obtained from the Holomon Astronomical Station.

TOOLS

The analysis is performed with the HOlomon Photometric Software (HOPS), a python-based package which includes a user interface and is compatible with Linux, OSX and Windows. It is open-source (https://github.com/HolomonAstronomicalStation/hops) and has been designed to analyse data from small and medium class telescopes. The basic features included, are: a) reduction, which includes the calculation of master bias/dark/flat frames and the correction of the scientific frames, b) frame selection, which provides interactive graphs for selecting the damaged images, c) alignment, an automatic detection of star patterns in the field of view, despite large shifts or meridian flips, d) photometry, which includes an interactive window for selecting the target and comparison stars and extracts the light-curves using both aperture and PSF photometry, e) transit fitting, which provides the fitting of the transit model on the relative light-curve using mcmc sampling.

GET INVOLVED!

To analyse exoplanet transits yourself visit our website, where you can find all the instructions on how to install and how to use the software. In addition, we have uploaded a test dataset containing six transits of Qatar-1b, for you to get stared. These data have been analysed up to the alignment stage, but you can optionally analyse them from the beginning to familiarise yourself with the software.

So far, we have collected over 50 transit observations both from the Holomon Astronomical Station (http://www.astro.auth.gr/n/) and the Nunki (nunki.gr) observatories in Greece. We will also carry out more observations using the equipment of the observatories we collaborate. These observations will become available as the project evolves. Our ultimate goal is to create a collective list of observations from transiting exoplanets to better identify their ephemerides and characteristics.