Exoplanets for Everyone

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Abstract We report the detection of transiting exoplanet HD 189733b by photoelectric photometry using a modest setup and procedure easily accessible to many amateur astronomers and college or high school students. Detecting an exoplanet transit first-hand can be an inspiring experience. By describing our approach, we hope to make it easier for others to share this experience, using equipment they may already have available.

1. Introduction

Exoplanets capture the popular imagination like few other scientific topics, offering an opportunity to inspire wonder and motivate engagement in the process of science. For this purpose, photoelectric photometry (PEP) has some advantages over CCD/CMOS imaging. The procedure is relatively simple and maintains a direct connection between the observer and the star (Rochford 2013). Participants can look through the telescope and see the target and comparison stars, then watch numbers displayed on the photometer that match qualitatively with relative brightness perceived by eye. It's easy to understand the photometer as an extension of their own senses. Even the data reduction process is relatively straightforward and can be done by hand or with a simple spreadsheet. Only a brief background explanation is required for anyone to follow the steps of the observation/data analysis process. This allows participants to directly connect their starwatching experience to the resulting light curve indicating the presence of an orbiting planet. In this way the transit can come to life as something real and immediate rather than being understood only abstractly and obscured behind layers of computer image analysis.

For these reasons, it seems valuable to develop education and outreach activities based on the live observation of exoplanet transits using PEP. The first step in developing such activities is of course to determine if it's even possible to clearly detect a transit with a standard portable telescope and photometer. This paper describes our successful observation of a transiting exoplanet using an SSP-3 photometer and 8-inch Schmidt-Cassegrain telescope. We provide enough detail to encourage others to replicate and expand these observations with similar equipment they may be able to find (as we did) collecting dust in a storeroom or cabinet at their local college or astronomy club.

2. Methods

We chose HD 189733b for our test observations because of its bright host star and large transit depth (V = 7.7 mag, depth = 2.4%). Its short orbital period (2.2 days), summer-autumn visibility at mid-northern latitudes, and proximity to the Dumbbell Nebula (M27) also make it well-suited for public outreach events. A nearby star of similar magnitude and color index (HD 345459, less than 10 arc minutes away) provides an ideal comparison star (Chéreau 2020). We used a Meade 8-inch f/10 Schmidt-Cassegrain telescope and an Optec SSP-3 Generation 1 solid state photometer, set to 10 × gain and 10-second integration time (Optec 2012).

Our telescope has an equatorial mount and clock drive but no go-to capability, so we star-hopped our way to HD 189733. We began on Altair and then moved north about 10 degrees to find the constellation Sagitta. We then centered on γ Sagittae (a magnitude 3.5 star) and moved north about 3 degrees to reach HD 189733. (Chéreau 2020). M27 is a helpful marker to confirm that the correct field of view has been located. Figure 1 shows the field of view, with comparison and variable stars labeled along with the region of sky in which the background was recorded for both stars.

Eric Jensen's TAPIR web interface (Jensen 2013) makes it easy to predict observability of transits from any location. A suitable opportunity presented itself on July 3, 2020, with predicted transit midpoint at 8:15 UT (predicted ingress at 7:19 UT and predicted egress at 9:09 UT). We began observations at about 6:30 UT and ended prematurely due to clouds at about 8:30 UT.

We followed a standard differential photometry procedure (Calderwood 2020), modified slightly for the situation. To maximize signal to noise ratio, we used a clear filter rather than a standard photometric color filter. We also used the same background sky region for both stars, as indicated in Figure 1, and measurement sequence sky-comparison-variable-sky-comparison-variable…, etc. We linearly interpolated to estimate sky readings at the times of each star reading, and similarly to estimate comparison star readings at the time of each variable star reading.

3. Results

Our results are shown in Figures 2 and 3, indicating a clear detection of the transit at the predicted time, despite non-ideal conditions. M27 was barely visible in the eyepiece due to background light from the nearly full Moon and streetlights in a residential neighborhood. Clouds forced an early end to observations, so we were only able to see the first half of the

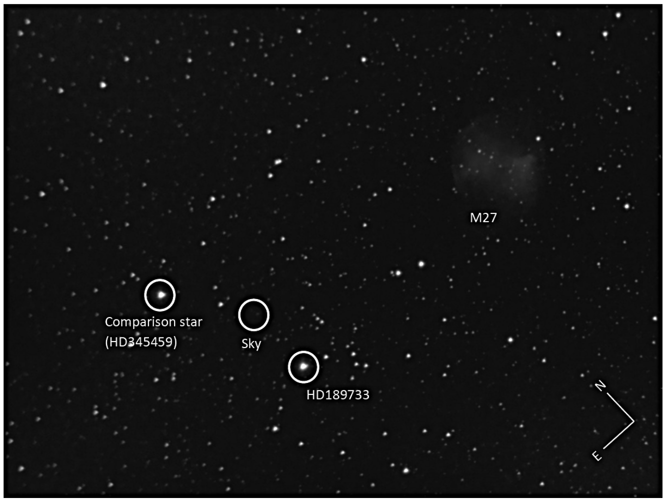

Figure 1. Field of view (about half a degree across) near HD 189733. The comparison star and region of sky for background readings are shown as well as the Dumbbell Nebula (M27) for reference. Photo by the authors.

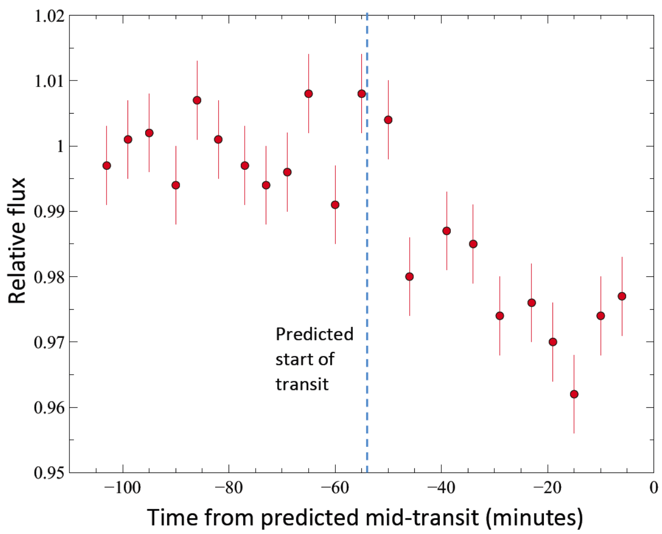

Figure 2. Individual HD 189733b data points obtained from 40-second integration on variable star, comparison star, and sky background. Relative flux is the ratio of net variable and comparison star readings, normalized to the mean ratio pre-transit.

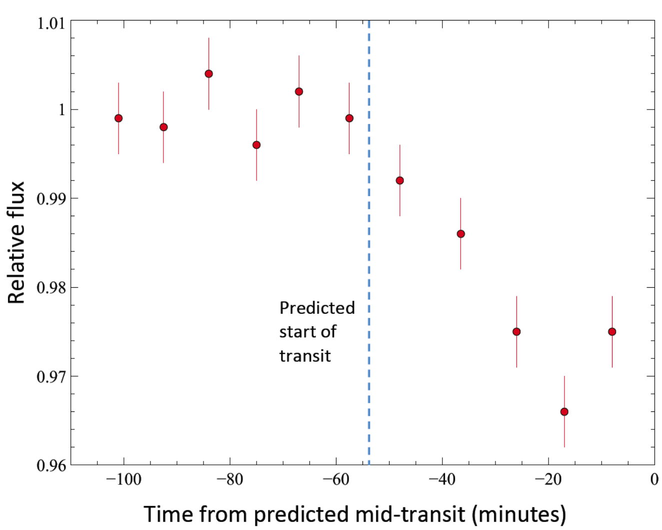

Figure 3. Data from Figure 2, binned in non-overlapping pairs.

transit. Our success under these conditions is encouraging for the possibility of incorporating "live" exoplanet transit viewing into astronomy education and outreach events in a wide variety of settings.

Importantly, the star was high in the sky from our location throughout the observation window (zenith distance ranged from about 30 to 40 degrees). Because of this and the close proximity and similar color indices of the two stars, no correction for atmospheric extinction was needed to reduce the data and generate the graphs shown in Figures 2 and 3.

4. Discussion and conclusions

One important objective in observing exoplanet transits is of course to gather data for the scientific community. In this regard, CCD/CMOS cameras have distinct advantages, and the bulk of scientific work on transits will be done with cameras. But there is also value in creating an experience of connection for participating observers. Here photoelectric photometry still has something to contribute with its simplicity and direct connection between the data and the observing experience. Our results suggest that live PEP exoplanet observations can be successfully incorporated into education and outreach events in easily accessible public spaces. This opens up many possibilities for going beyond just showing people the sky, but also engaging them in the process by which we discover the wonders they read or hear about in the news.

For example, the next step in our project is to incorporate exoplanet observations into some of the public "sidewalk star parties" we offer in our community. One telescope with attached photometer will be used to record data that will be entered directly into a spreadsheet and graphed in almost real-time, so that participants can see a display of the unfolding light curve as the transit happens. Another scope (with attached camera) will display the field of view on a screen for easy viewing of the transiting and comparison stars. Other volunteers will demonstrate models of how an exoplanet transit produces a decrease in brightness, and point out where in the sky the transiting star is located to help participants view it through binoculars. There are many variations on how such an event can be arranged to create an immersive experience for the participants that helps them really understand how we know there are planets around other stars.

Just as with PEP and DSLR imaging (Littlefield 2010), there are likely additional methods waiting to be discovered for detecting transits utilizing equipment that observers already have on hand or can easily access. Hopefully these examples will encourage others to explore possibilities for more people to directly experience transit observations. More generally, we hope the examples help inspire others to look for creative ways to do more than they thought was possible, more simply than they imagined it could be done.

5. Acknowledgements

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