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Catalog of New *K2* Exoplanet Candidates from Citizen Scientists

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1. Exoplanet Explorers

The *K2* mission has successfully found ≈1000 new exoplanet candidates.[12] Now with an enormous data set (≈400,000 stellar targets) that nearly doubles the source count of *Kepler* (Huber et al. 2016), data parsing provides a unique time intensive obstacle. The Exoplanet Explorers[13] project, part of the Zooniverse platform, allows citizen scientists to help overcome the abundance of transit data (Christiansen et al. 2018). We make available 204,855 statistically significant dips in *K2* light curves from campaigns 0–8, 10, and 12–14. We used the `k2phot` pipeline (Petigura et al. 2018) to remove the *K2* systematics and searched for periodic transits using

the TERRA search algorithm (Petigura et al. 2013). For training, each participant is shown an example of a real folded exoplanet transit light curve, with the expected model plotted over the data. The volunteer is then instructed to look for dips that provide a similar match to this basic transit model. Each folded light curve presented are assigned a "Yes" or "No" value by the citizen scientist, indicating their belief that the source of the dip is caused by a transiting exoplanet. This simple visual inspection helps create a targeted search of the *K2* light curves.

2. Criteria for Selection

For selection within this catalog we require additional cuts to provide a more focused list of potential candidates. We only consider dips that have received a "Yes" vote by ≥90% of the reviewers. All sources have been reviewed by at least 20 citizen scientists. Furthermore, we remove planet candidates that have been previously noted on the ExoFOP[14] website (as of 2019 February 20). To eliminate eclipsing binaries, we exclude candidates with an inferred planet radius $R_{pl} > 0.2\ R$. An expert visual inspection of the fitted light curve is performed to further eliminate noisy and problematic fits. Strong V-shape transits have been removed. These grazing transits only provide a lower limit for the planetary radius, making it difficult to eliminate eclipsing binaries.
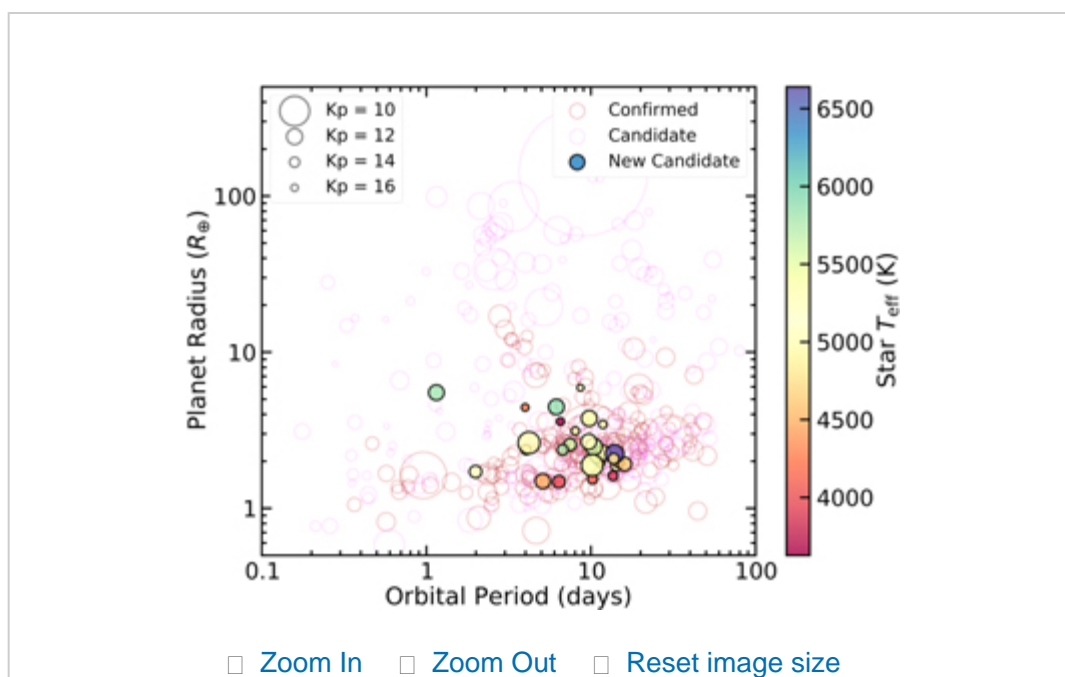
3. Fit Method

Utilizing the EMCEE algorithm (Foreman-Mackey et al. 2013), we maximize and sample the posterior of the 8 transit parameters. The fitted parameters are as follows: $R_{pl}/R_{\star}$ (the radius ratio of the planet and star), planet period, T_0 (the center of the first detected transit), $a_{pl}/R_{\star}$ (the ratio of the semimajor axis to stellar radius), b (the impact parameter), two quadratic limb darkening parameters, and a floating flux normalization parameter. Each parameter is fit using a uniform prior, with the exception of the semimajor axis ratio ($a_{pl}/R_{\star}$) and the two limb darkening parameters. Assuming a perfect initial measurement of period from the from the TERRA grid search, Kepler's law is used to derive a Gaussian prior for $a_{pl}/R_{\star}$. The independent information of stellar radius and stellar mass are provided by Huber et al. (2016) with *Gaia* radius updates from Bailer-Jones et al. (2018). Since the uncertainty in mass and radius are non-negligible, this constraint is rather weak. The priors for the limb darkening parameters are calculated using a Monte Carlo interpolation of the appropriate Claret et al.

([2012](#)) table.

We use the `BATMAN` transit model (Kreidberg [2015](#)) to fit the processed `K2Phot` light curves. Here a Gaussian likelihood function is implemented to fit the photometric data to the transit model. This transit fitting procedure is similar to that of Crossfield et al. ([2016](#)). The resulting parameters are provided in our supplementary blog.[15]

4. Results

In Figure [1](#) we provide 28 new planet candidates that have been vetted by citizen scientists and expert astronomers. This catalog contains 9 likely rocky candidates ($R_{pl} \leq 2.0\ R_\oplus$) and 19 gaseous candidates ($R_{pl} > 2.0\ R_\oplus$). Within this list we find one multi-planet system (EPIC 246042088). These two sub-Neptune ($2.99 \pm 0.02\ R_\oplus$ and $3.44 \pm 0.02\ R_\oplus$) planets exist in a near 3:2 orbital resonance. The discovery of this multi-planet system is important in its addition to the list of known multi-planet systems within the *K2* catalog, and more broadly in understanding the multiplicity distribution of the exoplanet population (Zink et al. [2019](#)). The candidates on this list are anticipated to generate RV amplitudes of 0.2–18 m s^{-1}, many within the range accessible to current facilities.

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Figure 1. Planet orbital period vs. planet radius for our new candidate sample (filled circles) compared to previous *K2* planet candidates (violet open circles) and confirmed planets (brown open circles) from the NASA Exoplanet Archive. Circle size indicates *Kepler* bandpass magnitude, and

color of the new candidates indicates host star effective temperature. An interactive version of this plot is available at http://www.kevinkhu.com/ee.html. The data used to create this figure are available.

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Footnotes

12 https://exoplanetarchive.ipac.caltech.edu

13 https://www.zooniverse.org/projects/ianc2/exoplanet-explorers

14 https://exofop.ipac.caltech.edu/k2/

15 http://www.jonzink.com/blogEE.html

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