

Characterizing K2 Candidate Planetary Systems Orbiting Low-mass Stars. II. Planetary Systems Observed During Campaigns 1–7

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Abstract

We recently used near-infrared spectroscopy to improve the characterization of 76 low-mass stars around which K2 had detected 79 candidate transiting planets. 29 of these worlds were new discoveries that had not previously been published. We calculate the false positive probabilities that the transit-like signals are actually caused by nonplanetary astrophysical phenomena and reject five new transit-like events and three previously reported events as false positives. We also statistically validate 17 planets (7 of which were previously unpublished), confirm the earlier validation of 22 planets, and announce 17 newly discovered planet candidates. Revising the properties of the associated planet candidates based on the updated host star characteristics and refitting the transit photometry, we find that our sample contains 21 planets or planet candidates with radii smaller than $1.25 R_{\oplus}$, 18 super-Earths $(1.25-2 R_{\oplus})$, 21 small Neptunes $(2-4 R_{\oplus})$, three large Neptunes $(4-6 R_{\oplus})$, and eight giant planets $(>6 R_{\oplus})$. Most of these planets are highly irradiated, but EPIC 206209135.04 (K2-72e, $1.29^{+0.14}_{-0.13} R_{\oplus})$, EPIC 211988320.01 $(R_p = 2.86^{+0.16}_{-0.15} R_{\oplus})$, and EPIC 212690867.01 (2.20^{+0.19}_{-0.18} R_{\oplus}) orbit within optimistic habitable zone boundaries set by the "recent Venus" inner limit and the "early Mars" outer limit. In total, our planet sample includes eight moderately irradiated 1.5–3 R_{\oplus} planet candidates ($F_p \lesssim 20 F_{\oplus}$) orbiting brighter stars (Ks < 11) that are well-suited for atmospheric investigations with the Hubble, Spitzer, and/or James Webb Space Telescopes. Five validated planets orbit relatively bright stars (Kp < 12.5) and are expected to yield radial velocity semi-amplitudes of at least 2 m s^{-1} . Accordingly, they are possible targets for radial velocity mass measurement with current facilities or the upcoming generation of red optical and near-infrared high-precision RV spectrographs.

Key words: planetary systems – planets and satellites: fundamental parameters – stars: fundamental parameters – stars: late-type - stars: low-mass - techniques: spectroscopic

Supporting material: machine-readable table

1. Introduction

Since 2014, the NASA K2 mission has been using the Kepler spacecraft to search for transiting planets in 100 sq. deg. fields along the ecliptic plane. K2 observes 10,000-30,000 stars in each field for roughly 80 days before moving onto the next field. The placement of each field is driven by the three primary Requirements of the extended mission design: (1) K2 must look along the ecliptic plane so that the torque from solar radiation pressure is balanced, (2) sunlight must illuminate the solar panels, and (3) K2 cannot look so close to the Sun that sunlight illuminates the detectors (Howell et al. 2014; Van Cleve et al. 2016).

During the main Kepler mission, the planet search targets were primarily selected by the Kepler Science Office with a small contribution from Guest Observer proposals. In contrast, all K2 targets are nominated by members of the community. Although some of the selected target stars are well-characterized, many have poorly estimated properties constrained by only photometry, proper motion, and (when lucky) parallax. The problem of inadequate stellar characterization is particularly dire for the smallest, coolest target stars around which K2

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has the highest sensitivity to transiting planets. In order to improve the characterization of low-mass K2 target stars,²⁰ we are conducting an extensive spectroscopic survey of potentially low-mass stars. In the first paper in this series (Dressing et al. 2017, hereafter D17), we presented near-infrared (NIR) spectra and determined stellar parameters for 144 potentially low-mass stars observed by K2 during Campaigns 0–7 (2014 May 30–2015 December 26).

In this paper, we use our previously determined stellar parameters combined with planet candidate lists to generate a catalog of K2 planetary systems orbiting low-mass stars. The structure of the paper is as follows.

In Section 2, we explain the origins of our planet candidate sample and describe the K2 planet candidate lists from which we selected our targets. We then consult the catalog of stellar parameters presented in D17 and update the host star parameters accordingly in Section 3. Next, we fit the K2 photometry in Section 4 to determine the transit parameters for each candidate. In Section 5, we use the open-source VESPA software (Morton 2015b) to run a false positive analysis to statistically validate planets and identify likely false positives. In Section 6, we combine the information from our various analyses to revise parameters for K2 planet candidates and validated planets orbiting low-mass dwarfs. We highlight particularly noteworthy individual systems in Section 7 before concluding in Section 8.

2. Sources of Planet Candidates

We obtained NIR spectroscopy of all stars in our sample because they were initially believed to host transiting planets or because they were close enough to the candidate host star that they might have been responsible for the transit-like signal observed in the light curve. In some cases, subsequent detailed analyses of the K2 photometry or ground-based follow-up observations revealed that the putative transit signals were actually due to false positives.

The majority of the 74 systems in the cool dwarf sample were selected from unpublished candidate lists provided by A. Vanderburg (53 stars hosting 59 candidates) or the K2 California Consortium (K2C2; 43 stars hosting 54 candidates); several stars appear on both lists and many of the K2C2 targets were later published in Crossfield et al. (2016). The cool dwarf sample also includes 20 single-planet systems from Barros et al. (2016), 16 singles from Pope et al. (2016), 16 stars hosting 18 candidates reported by Vanderburg et al. (2016), three singles from Adams et al. (2016), two singles from Mann et al. (2017), and five singles from Montet et al. (2015), who refined the properties of the planet candidates reported by Foreman-Mackey et al. (2015). Two of the stars in the sample (EPIC 212773309 and EPIC 211694226) are in close proximity to other stars and EPIC 212773309 also displays a clear secondary eclipse.

The 74 systems in our cool dwarf sample host 79 unique K2 Objects of Interest (K2OIs). As of 2016 September 7, 24 of those K2OIs had been confirmed as bona fide planets using the VESPA false positive probability tool (Morton 2012, 2015b, see Section 5), 23 had been previously published as planet candidates, two were classified as false positives, and 30 were new detections. Twenty seven of the new detections were identified by A. Vanderburg,

eight were found by K2C2, and five were discovered by both collaborations. In total, our cool dwarf planet sample consists of 60 single-planet systems, six double-planet systems (EPIC 201549860 = K2-35, EPIC 206011691 = K2-21, EPIC 210508766 = K2-83, EPIC 210968143 = K2-90, EPIC 211305568, and EPIC 211331236 = K2-117), one tripleplanet system (EPIC 211428897) and one quadruple-planet system (EPIC 206209135 = K2-72).

3. Updates to Planet Host Star Characterization

In D17, we applied empirical relations to NIR spectra acquired at IRTF/SpeX and Palomar/TSPEC to revise the classifications of putative low-mass stars harboring potential K2 planet candidates. Of the 144 K2 targets we observed, 49% were actually contaminating giant stars or hotter dwarfs (typically reddened by interstellar extinction) and 74 (51%) were bona fide low-mass dwarfs. For the cool dwarfs, we measured a series of equivalent widths and spectral indices and applied empirically based relations from Newton et al. (2015) and Mann et al. (2013a, 2015) to estimate effective temperatures, radii, masses, metallicities, and luminosities. Our results agree well with those of Martinez et al. (2017), who used lower-resolution NIR spectra from NTT/SOFI to improve the characterization of late-type dwarfs hosting K2 planet candidates.

In general, we found that our new radii were typically $0.13 R_{\odot}$ (39%) larger than the original estimates provided in the Ecliptic Plane Input Catalog (EPIC, Huber et al. 2016). These changes are unsurprising because, as noted by Huber et al. (2016), the EPIC values were determined by comparing photometry to stellar models that have been shown to systematically underestimate the temperatures and radii of cool stars (e.g., Kraus et al. 2011; Boyajian et al. 2012; Feiden & Chaboyer 2012; Spada et al. 2013; von Braun et al. 2014; Newton et al. 2015). In addition, our quest to find potentially habitable planets likely biased our stellar sample toward stars with underestimated radii at the expense of stars with overestimated radii. We adopt the revised stellar classifications from D17 in this paper.

Although the planet candidate catalogs we consulted typically provided their own estimates of stellar properties, we found that the original stellar classifications provided therein also tended to underestimate the radii and temperatures of the cool dwarfs. For most candidates, the amplitude of the suggested radius change is similar to the 15% radius increase found by Newton et al. (2015) for *Kepler* planet candidates orbiting M dwarfs with previous radius estimates based on fits to stellar models (e.g., Muirhead et al. 2012, 2014; Dressing & Charbonneau 2013; Mann et al. 2013b; Huber et al. 2014).

The exceptions to the general trend of underestimated stellar radii are the parameters provided in Vanderburg et al. (2016b) and the associated unpublished Vanderburg lists. Indeed, their estimates are based on empirical relations (Casagrande et al. 2008; González Hernández & Bonifacio 2009; Boyajian et al. 2013; Pecaut & Mamajek 2013). For those two sources, the discrepancies between our revised values and their initial values are likely due to the fact that spectroscopic observations help break the degeneracy between stars that are intrinsically red and stars that appear red due to interstellar extinction.

 $^{^{20}}$ In this series we define "low-mass stars" as M and K dwarfs with $M_{\star} \lesssim 0.75~M_{\odot}.$

4. Improving Transit Fits

Some of the planets in our target list have well-determined properties because they were previously published in other catalogs, but others are new. In order to provide a uniform catalog of properties for all of the planets in our sample, we perform our own fits to the K2 photometry to determine updated properties and errors for the full planet sample.

We began by downloading the K2 Self Flat Fielding (K2SFF) photometry provided by A. Vanderburg.²¹ The K2SFF pipeline processes K2 photometry by recording the roll angle of the spacecraft during each cadence and removing the correlation between flux and roll angle (Vanderburg & Johnson 2014; Vanderburg et al. 2016b). This procedure yields precision within 60% of that achieved during the baseline *Kepler* mission for faint stars (*Kp* > 12.5) and *Kepler*-like performance for brighter stars. Prior to fitting the transits, we re-processed the K2SFF data by simultaneously fitting for the transit light curves, long-term variability, and K2 pointing systematics using the procedure described by Vanderburg et al. (2016b).

Next, we ran a Markov chain Monte Carlo (MCMC) analysis to constrain the time of transit T_0 , orbital period P, planet/star radius ratio R_p/R_* , semimajor axis/stellar radius ratio a/R_* , inclination *i*, quadratic limb darkening, eccentricity *e*, and longitude of periastron ω . We ran our fits in Python and used the emcee package (Foreman-Mackey et al. 2013) to determine the errors on transit parameters. We assessed convergence by measuring the integrated autocorrelation time of our chains and requiring that the MCMC ran for at least ten times longer than the estimated autocorrelation time.

In order to efficiently sample the full allowed parameter space, we fit the limb darkening parameters using the q_1 , q_2 coordinatespace defined by Kipping (2013a). We also assumed that the eccentricity distribution of transiting planets followed the Beta distribution found by Kipping (2013b) for short-period planets $(P < 382 \text{ days}, P_{\beta}(e; \alpha, \beta) = \frac{\Gamma(\alpha + \beta)}{\Gamma(\alpha)\Gamma(\beta)}e^{\alpha - 1}(1 - e)^{\beta - 1}$ where $\alpha = 0.697$, $\beta = 3.27$, and Γ is the Gamma function) and fit for $\sqrt{e} \cos\omega$ and $\sqrt{e} \sin\omega$ to enable more efficient sampling of low-eccentricity orbits (e.g., Eastman et al. 2013).

At each point in the analysis, we computed the likelihood of our transit model by using the BATMAN package written by Kreidberg (2015) to solve the equations of Mandel & Agol (2002) and generate a model transit lightcurve. Our K2 light curves were obtained in "long-cadence" mode using 30 min integration times, which is relatively long compared to total durations of the transits we model. Accordingly, we employed the "supersample" feature of BATMAN to generate sample long-cadence light curves by modeling the brightness of the star at 1 min cadence and recording the average of 30 consecutive modeled fluxes.

We restricted our fits to consider $70^{\circ} < i < 90^{\circ}$, $0 < R_p/R_* < 1$, $a/R_* > 1$, $0 \leq q_1 \leq 1$, $0 \leq q_2 \leq 1$, $0 < \sqrt{e} \cos\omega < 1$, and $0 < \sqrt{e} \sin\omega < 1$. We further required that K2OIs transit their host stars (i.e., impact parameter $b \leq 1 + R_P/R_*$) and imposed priors on the limb-darkening coefficients by interpolating the tables produced by Claret et al. (2012) at the temperatures and surface gravities of the host stars.²² Specifically, we assumed that u_1 and u_2 were drawn from Gaussian distributions with dispersions set by propagating the errors in our stellar parameter

estimates. Despite our attention to limb darkening, we note that the dominant contribution to the shape of ingress and egress is the smearing due to the lengthy exposure times used for long-cadence K2 data.

All of our target stars were spectroscopically characterized by D17. We incorporated our knowledge of the host stars into our transit fits by using Kepler's third law and the estimated host star masses to determine the orbital semimajor axes of planets with the observed orbital periods. We then compared the resulting distances to the estimated stellar radii and set Gaussian priors on the expected a/R_* ratio for each planet (Seager & Mallén-Ornelas 2003; Sozzetti et al. 2007; Torres et al. 2008). The widths of these priors reflect the uncertainties in the stellar radii and masses,²³ but by imposing this prior we implicitly assume that the candidate transit event is indeed caused by the transit of a planet across the target star rather than a blended transit or eclipse of a contaminating star. The VESPA false positive analysis discussed in Section 5 should reveal such scenarios.

For a handful of targets, the transit depths were shallow enough that the MCMC sometimes wandered away from the transit signal under consideration. Accordingly, we required that the transit center must be within 6% of the initial guess (up to a maximum difference of 6 hr) and that the orbital period must be within 0.025 days (36 min) of the initial guess. As discussed in Section 6.3, we later repeated the transit fitting process using k2phot and K2SC photometry to check for systematic offsets in planet parameters.

5. Determining K2OI Dispositions

Early in the Kepler mission, transiting planet candidates were "confirmed" by conducting radial velocity or transit timing variation studies to measure planet masses. However, mass measurements are expensive and not feasible for all systems. As a result, tools like BLENDER (e.g., Fressin et al. 2011; Torres et al. 2011), VESPA (Morton 2012, 2015b), and PASTIS (Díaz et al. 2014) have been adopted to "validate" planet candidates in a statistical sense. These tools simulate the range of astrophysical configurations that could generate the observed lightcurve subject to the constraints placed by indepth analyses of the transit photometry (e.g., shifts in the photocenter during transit, presence or absence of secondary eclipse, variations in the depths of odd and even transits) and subsequent follow-up investigations (e.g., high-contrast imaging, radial velocity searches for additional stars, achromaticity of transit events, analyses of archival observations).

5.1. Identifying Clear False Positives

Four of the K2OIs in our sample displayed clear secondary eclipses when we phase-folded the light curve of the host star to the assumed orbital period: EPIC 212679798.01, 212773272.01, 212773309.01 (also identified as an EB by Barros et al. 2016), and 213951550.01. Consulting the

²¹ https://archive.stsci.edu/prepds/k2sff/; https://doi.org/10.17909/T9BC75

²² Claret et al. (2012) consider multiple methods for computing limbdarkening coefficients; we adopt the coefficients found using the least-squares method.

²³ As discussed in D17, we estimated the stellar radius errors by running Monte Carlo simulations in which we simulated multiple realizations of the noise in our NIR spectra and recomputed the stellar parameters using the H-band relations from Newton et al. (2015). Our radius errors include a 0.027 R_{\odot} intrinsic scatter term added in quadrature to the 1σ errors determined from the Monte Carlo simulations. We determined the masses and associated errors by employing the stellar effective temperature–mass relation from Mann et al. (2013b). In this paper, we enforce a minimum mass error of 10% based on the fractional errors displayed in Figure 5 of Mann et al. (2013b).

ExoFOP-K2 follow-up website,²⁴ we found that three of these stars were flagged by D. LaCourse as possible eclipsing binaries (212773309 and 212679798) or false positives (212773272). K2OIs 212773309.01 and 212773272.01 were identified at exactly the same ephemeris, suggesting that the transit-like events detected in the light curve of EPIC 212773272 are actually due to the eclipses of EPIC 212773309.

In addition to classifying EPIC 212679798.01, 2127732 72.01, 212773309.01, and 213951550.01 as false positives due to the presence of secondary eclipses, we also rejected EPIC 211831378.01, 211970234.01, and 212572452.01 due to blended photometry or inconsistent transit depths when fitting data processed by different K2 pipelines. For instance, the K2SFF photometry of EPIC 211831378 displays 650 ppm transits while that from k2phot and K2SC reveals events with depths of 9000 ppm and 12%, respectively. We attribute this discrepancy in event depth to the use of different apertures for each pipeline. As mentioned on the ExoFOP website, archival photometry from DSS, SDSS, 2MASS, and *WISE* reveals a brighter star 12."3 away from EPIC 211831378; the K2SFF pipeline incorrectly placed the aperture around this star (EPIC 211831539) rather than around the target star.

EPIC 211970234 is also in a crowded field and the assigned K2SFF aperture includes contributions from multiple stars, one of which is much brighter than the target star. Similarly, the photometry of EPIC 212572452 is contaminated by light from EPIC 212572439 (2MASS J13374562-1111331), which is 1 magnitude brighter than the target star and 5."96 away.

Finally, we classified EPIC 212628098.01 as a false positive due to the large implied planet radius of $14-18 R_{\oplus}$ and the presence of a neighboring star only 1."25 from the target star. The nearby star is only 3.8 magnitudes fainter than the target star and was detected both in Gemini-N/NIRI AO images and in speckle images acquired with DSSI at Gemini-S and WIYN.

5.2. Assessing False Positive Probabilities

For the more promising K2OIs, we used the VESPA framework to assess the probabilities that each was truly a transiting planet. We first fit the transit photometry as described in Section 4 and rescaled the photometric errors so that the adopted transit model had a reduced chi squared of 1 for the segment of the light curve centered on the transit event. Prior to rescaling the errors, we clipped the light curves and kept only the points within six durations of the transit center. We then searched for secondary eclipses by phase-folding the full data set to the orbital period of the planet in question and measuring the "eclipse depth" at multiple points in the light curve. We assumed that the eclipse has the same duration as the primary transit, but we allowed the phase of secondary eclipse to vary from phase = 0.3 to phase = 0.7 (i.e., we did not assume that the orbit is circular). We recorded the depth of the deepest event as the maximum allowed secondary eclipse depth ("secthresh" in the VESPA fpp.ini file).

Next, we referred back to the K2SFF photometry and recorded the radius of the selected photometric aperture as the maximum allowed separation between the target and the source of the transit event ("maxrad"). We then consulted previously published K2 papers and the Exo-FOP K2 follow-up website to check whether there are extant speckle or high-contrast images placing limits on the allowed brightness of nearby stars. If so, we included those contrast curves as additional constraints. For reference, we list the adaptive optics observations used in our false positive analysis in Table 1 and display the composite set of contrast curves in Figure 1. These observations were obtained with NIRC2 on the 10 m Keck II telescope, NIRI (Hodapp et al. 2003) on the 8 m Gemini-N telescope, PHARO (Hayward et al. 2001) on the 200 inch Palomar Hale telescope, and DSSI (Howell et al. 2011; Horch et al. 2012) on the 8 m Gemini-N and Gemini-S telescopes and the 3.5 m WIYN²⁵ telescope.

Finally, we filled in the host star properties (coordinates, magnitudes, and spectroscopic fits from D17) and ran VESPA to compute the false positive probability (FPP). Recognizing that VESPA FPPs are statistical and depend on the assumed planet radius, we ran the analysis twice for each planet using R_p/R_{\star} ratios set to the 16th and 84th percentiles of the posterior distribution. As in Crossfield et al. (2016), we adopted a threshold of FPP < 1% for validation, but we adopted a less forgiving FPP cut of FPP > 90%. When classifying K2OIs, we required that both FPP estimates were below 1% or above 90% in order to label K2OIs as validated planets or false positives, respectively. We classified the remaining systems as planet candidates.

We summarize our new K2OI dispositions in Table 2. In total, 44 K2OIs met the formal criteria for validation, but seven orbit stars with nearby companions and therefore cannot be validated with VESPA. Of the remaining 37 K2OIs with low FPPs, 20 were previously validated by Crossfield et al. (2016), eight are new detections, and nine were previously classified as planet candidates. As discussed in Section 5.2, we rejected eight K2OIs as false positives based on visual inspection of their light curves. No additional K2OIs were classified as false positives based on VESPA FPPs alone. The remaining 27 K2OIs had ambiguous FPPs between 1% and 90%. The ambiguous sample included three previously confirmed planets, nine previously announced planet candidates, and 15 new detections. The three confirmed planets that failed to meet our 1% FPP threshold are EPIC 201345483.01 ($R_p = 10.4 R_{\oplus}$, FPP = 15%), EPIC 20163 5569.01 ($R_p = 7.5 R_{\oplus}$, FPP = 4%–7%), and EPIC 210508766.02 $(R_p = 2.1 R_{\oplus}, \text{ FPP} = 1.9\%)$. One other previously confirmed planet (EPIC 201637175.01 = K2-22b, Sanchis-Ojeda et al. 2015) met our FPP cut for validation, but is listed as a planet candidate in Table 2 due to the presence of a nearby star. We do not dispute the previous validation of K2-22b, but our VESPA analysis is not sufficiently sophisticated to validate planets orbiting stars with nearby companions.

The most likely explanation for why we were unable to validate EPIC 201345483.01 is that our estimates of the stellar radius $(0.69^{+0.06}_{-0.04} R_{\odot}, D17)$ and planet radius $(10.4^{+0.9}_{-0.7} R_{\oplus})$ are much larger than the values of $0.445 \pm 0.066 R_{\odot}$ and $6.71 R_{\oplus}$ assumed by Crossfield et al. (2016) when validating the system. In contrast, our estimates agree well with those adopted by Vanderburg et al. (2016b) in their discovery paper ($0.66 R_{\odot}, 11 R_{\oplus}$). Because larger planets are rarer than smaller planets, our larger planet radius estimate led us to adopt a smaller prior probability of planethood than Crossfield et al. (2016) based on their smaller planet radius estimate. In the future, including AO or speckle imaging would be useful for discriminating between

²⁴ https://exofop.ipac.caltech.edu/k2/

²⁵ The WIYN Observatory is a joint facility of the University of Wisconsin-Madison, Indiana University, the National Optical Astronomy Observatory and the University of Missouri and hosts the NASA-NSF NN-EXPLORE program.

				Pixel	PSF		Nearby Star	a	Contrast	Observation	Uploaded
EPIC	Telescope	Instrument	Filter	Scale	(")	Det?	Δ mag	Sep (")	Achieved ^b	Date	Ву
01205469	Keck2_10m	NIRC2	К	0.009942	0.066557	no			$\Delta 7.91 \text{ mag}$ at 0."5	4/7/15	Ciardi
01208431	Keck2_10m	NIRC2	Κ	0.009942	0.079626	no			$\Delta 5.86 \text{ mag}$ at 0."5	2/19/16	Ciardi
01549860	Keck2_10m	NIRC2	Κ	0.009942	0.060571	no			$\Delta 8.10 \text{ mag}$ at 0."5	4/1/15	Ciardi
201617985	Keck2_10m	NIRC2	Κ	0.009942	0.091839	no			Δ 7.84 mag at 0."5	4/1/15	Ciardi
201637175	GeminiN_8m	DSSI	692 nm	0.011410	0.020000	no ^c			$\Delta 4.977 \text{ mag}$ at 0."5	1/15/16	Ciardi
201637175	GeminiN_8m	DSSI	880 nm	0.011410	0.020000	no ^c			$\Delta 4.666$ mag at 0.75	1/15/16	Ciardi
201855371	Keck2_10m	NIRC2	K	0.009942	0.053694	no			$\Delta 8.49$ mag at 0."5	4/7/15	Ciardi
205924614	Keck2_10m	NIRC2	Κ	0.009942	0.058868	no			$\Delta 8.17 \text{ mag}$ at 0."5	8/7/15	Ciardi
206011691	Keck2_10m	NIRC2	Κ	0.009942	0.050896	no			Δ 7.45 mag at 0.75	7/25/15	Ciardi
06209135	Keck2_10m	NIRC2	К	0.009942	0.062750	no			$\Delta 7.74 \text{ mag}$ at 0.75	8/21/15	Ciardi
10448987	GeminiN_8m	NIRI	К	0.021400	0.102616	no			$\Delta 6.86 \text{ mag}$ at 0.75	12/14/15	Ciardi
10489231	Keck2_10m	NIRC2	К	0.009942	0.101436	no			$\Delta 5.78 \text{ mag}$ at 0.75	10/28/15	Ciardi
10508766	Keck2_10m	NIRC2	К	0.009942	0.054223	no			Δ 7.40 mag at 0.75	10/28/15	Ciardi
10508766	GeminiN_8m	DSSI	692 nm	0.011410	0.020000	no			$\Delta 4.994$ mag at 0.75	1/13/16	Ciardi
10508766	GeminiN_8m	DSSI	880 nm	0.011410	0.020000	no			$\Delta 5.248$ mag at 0.75	1/13/16	Ciardi
10508766	Palomar-5 m	PHARO-AO	K_short	0.025000	0.159000	no			$\Delta 4.90$ mag at 0.75	10/20/16	Ciardi
10558622	Keck2_10m	NIRC2	K	0.009942	0.049441	no ^d			Δ 7.86 mag at 0.75	10/28/15	Ciardi
10558622	Keck2_10m	NIRC2	K	0.009942	0.050778	no ^d			$\Delta 8.24$ mag at 0.75	2/17/16	Ciardi
10558622	GeminiN_8m	DSSI	692 nm	0.011410	0.020000	no ^d			$\Delta 5.286$ mag at 0.75	1/13/16	Ciardi
10558622	GeminiN_8m	DSSI	880 nm	0.011410	0.020000	no ^d			$\Delta 5.248 \text{ mag} \text{ at } 0.75$	1/13/16	Ciardi
10558622	WIYN_3.5 m	DSSI	692 nm	0.022000	0.050000	no ^d			$\Delta 3.5 \text{ mag} \text{ at } 0.72$	10/24/15	Everett
10558622	WIYN_3.5 m	DSSI	880 nm	0.022000	0.063000	no ^d			$\Delta 3.5$ mag at 0.2 $\Delta 3.5$ mag at 0.2	10/24/15	Everett
210707130	Keck2_10m	NIRC2	K	0.009942	0.051244	no			$\Delta 7.92 \text{ mag} \text{ at } 0.2$	10/28/15	Ciardi
210707130	Keck2_10m Keck2_10m	NIRC2	K	0.009942	0.053366	no			$\Delta 6.62 \text{ mag} \text{ at } 0.75 \text{ mag}$	2/19/16	Ciardi
210707130	GeminiN_8m	DSSI	692 nm	0.011410	0.020000				$\Delta 5.650 \text{ mag} \text{ at } 0.5^{\circ}$	1/13/16	Ciardi
210707130	GeminiN_8m	DSSI	880 nm	0.011410	0.020000	no no			$\Delta 5.030$ mag at 0. 5 $\Delta 5.719$ mag at 0."5	1/13/16	Ciardi
210750726	Keck2_10m	NIRC2	K	0.009942	0.111601				$\Delta 5.36$ mag at 0.5	10/28/15	Ciardi
210750726	Keck2_10m Keck2_10m	NIRC2 NIRC2	K	0.009942	0.080981	no			$\Delta 6.06 \text{ mag} \text{ at } 0.75$	2/19/16	Ciardi
210750726		DSSI				no		•••	•		
	GeminiN_8m		692 nm	0.011410	0.020000	no	•••		$\Delta 4.901 \text{ mag at } 0.75$	1/15/16	Ciardi
10750726	GeminiN_8m	DSSI	880 nm	0.011410	0.020000	no	•••		$\Delta 5.002 \text{ mag}$ at 0."5	1/15/16	Ciardi
210838726	GeminiN_8m	NIRI	K	0.021400	0.109663	no	•••		$\Delta 6.12 \text{ mag at } 0.75$	11/2/15	Ciardi
10838726	GeminiN_8m	NIRI	K	0.021400	0.099683	no			$\Delta 6.83 \text{ mag at } 0.75$	12/14/15	Ciardi
10968143	Keck2_10m	NIRC2	K	0.009942	0.053846	no			Δ 7.59 mag at 0.75	10/28/15	Ciardi
210968143	Keck2_10m	NIRC2	K	0.009942	0.051648	no			$\Delta 7.91 \text{ mag}$ at 0.75	2/17/16	Ciardi
10968143	GeminiN_8m	DSSI	692 nm	0.011410	0.020000	no			$\Delta 5.279 \text{ mag}$ at 0."5	1/13/16	Ciardi
10968143	GeminiN_8m	DSSI	880 nm	0.011410	0.020000	no			$\Delta 5.089 \text{ mag}$ at 0.75	1/13/16	Ciardi
10968143	Palomar-5 m	PHARO-AO	K_short	0.025000	0.165000	no			$\Delta 4.73 \text{ mag}$ at 0."5	10/20/16	Ciardi
11077024	Keck2_10m	NIRC2	К	0.009942	0.061843	no			Δ 7.41 mag at 0.75	2/19/16	Ciardi
11077024	GeminiN_8m	DSSI	692 nm	0.011410	0.020000	no			$\Delta 4.924$ mag at 0."5	1/15/16	Ciardi
211077024	GeminiN_8m	DSSI	880 nm	0.011410	0.020000	no			$\Delta 5.371 \text{ mag}$ at 0.75	1/15/16	Ciardi
211331236	Keck2_10m	NIRC2	K	0.009942	0.079162	no			$\Delta 6.62 \text{ mag}$ at 0."5	1/21/16	Ciardi
211428897	Keck2_10m	NIRC2	J	0.009942	0.114165	yes			$\Delta 5.41 \text{ mag}$ at 0."5	1/21/16	Ciardi
211428897	Keck2_10m	NIRC2	K	0.009942	0.060653	yes			$\Delta 6.86 \text{ mag}$ at 0."5	1/21/16	Ciardi
11428897	GeminiN_8m	DSSI	692 nm	0.011410	0.020000	yes	1.8	1.1	$\Delta 4.442 \text{ mag}$ at 0.75	1/15/16	Ciardi
211428897	GeminiN_8m	DSSI	880 nm	0.011410	0.020000	yes	1.2	1.1	$\Delta 4.869 \text{ mag}$ at 0.75	1/15/16	Ciardi

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Table 1

					Table (Continu						
				Pixel	PSF		Nearby Star		Contrast	Observation	Uploaded
EPIC	Telescope	Instrument	Filter	Scale	(")	Det?	Δ mag	Sep (")	Achieved ^b	Date	Ву
211509553	GeminiN-8 m	NIRI	open	0.021400	0.098000	yes	3.3	1.9	$\Delta 5.84~\mathrm{mag}$ at $0.^{\prime\prime} 5$	2/20/16	Ciardi
211770795	Keck2_10m	NIRC2	Κ	0.009942	0.065018	no			Δ 7.36 mag at 0.75	2/19/16	Ciardi
211770795	GeminiN-8 m	NIRI	open	0.021400	0.112000	no			$\Delta 5.57$ mag at 0.75	2/20/16	Ciardi
211799258	GeminiN-8 m	NIRI	open	0.021400	0.107000	no			$\Delta 6.61 \text{ mag}$ at 0."5	2/20/16	Ciardi
211818569	Palomar-5 m	PHARO-AO	Ks	0.025000	0.122000	no			$\Delta 5.22$ mag at 0.75	10/20/16	Ciardi
211831378	GeminiN_8m	NIRI	Κ	0.021400	0.125410	no			$\Delta 6.59 \text{ mag}$ at 0."5	1/28/16	Ciardi
211924657	GeminiN-8 m	NIRI	Br-gamma	0.021400	0.101000	no			$\Delta 6.26 \text{ mag}$ at 0."5	2/20/16	Ciardi
211970234	GeminiN-8 m	NIRI	open	0.021400	0.113000	no			$\Delta 5.60$ mag at 0.75	2/20/16	Ciardi
212006344	Keck2_10m	NIRC2	K	0.009942	0.053540	no			$\Delta 8.06$ mag at 0.75	1/21/16	Ciardi
212006344	GeminiN_8m	DSSI	692 nm	0.011410	0.020000	no			$\Delta 5.281 \text{ mag}$ at 0."5	1/14/16	Ciardi
212006344	GeminiN_8m	DSSI	880 nm	0.011410	0.020000	no			$\Delta 5.800 \text{ mag}$ at 0."5	1/14/16	Ciardi
212069861	Keck2_10m	NIRC2	J	0.009942	0.092989	no			$\Delta 6.17 \text{ mag}$ at 0."5	2/17/16	Ciardi
212069861	Keck2_10m	NIRC2	К	0.009942	0.096097	no			Δ 7.63 mag at 0."5	2/17/16	Ciardi
212069861	GeminiN-8 m	NIRI	Br-gamma	0.021400	0.131000	no			$\Delta 4.93$ mag at 0."5	2/20/16	Ciardi
212154564	Keck2_10m	NIRC2	ĸ	0.009942	0.111359	no			$\Delta 6.06 \text{ mag}$ at 0."5	2/19/16	Ciardi
212154564	GeminiN-8 m	NIRI	open	0.021400	0.106000	no			$\Delta 5.52 \text{ mag}$ at 0."5	2/20/16	Ciardi
212354731	GeminiS_8m	DSSI	692 nm	0.011000	0.021000	no			$\Delta 5$ mag at 0.2	6/29/16	Everett
212354731	GeminiS_8m	DSSI	880 nm	0.011000	0.027000	no			$\Delta 5 \text{ mag}$ at 0."2	6/29/16	Everett
212460519	WIYN_3.5 m	DSSI	692 nm	0.022000	0.050000	no			$\Delta 3.5 \text{ mag} \text{ at } 0.72$	4/21/16	Everett
212460519	WIYN 3.5 m	DSSI	880 nm	0.022000	0.063000	no			$\Delta 3.5 \text{ mag} \text{ at } 0.72$	4/21/16	Everett
212554013	GeminiS_8m	DSSI	692 nm	0.011000	0.021000	no			$\Delta 5$ mag at 0.2	6/22/16	Everett
212554013	GeminiS_8m	DSSI	880 nm	0.011000	0.027000	no			$\Delta 5$ mag at 0.2 $\Delta 5$ mag at 0.2	6/22/16	Everett
212565386	GeminiS_8m	DSSI	692 nm	0.011000	0.021000	no			$\Delta 5 \text{ mag} \text{ at } 0.2$	6/22/16	Everett
212565386	GeminiS_8m	DSSI	880 nm	0.011000	0.027000	no			$\Delta 5$ mag at 0.2 $\Delta 5$ mag at 0.2	6/22/16	Everett
212572452	GeminiS_8m	DSSI	692 nm	0.011000	0.021000	no			$\Delta 5$ mag at 0.2 $\Delta 5$ mag at 0.2	6/22/16	Everett
212572452	GeminiS_8m	DSSI	880 nm	0.011000	0.027000	no			$\Delta 5$ mag at 0.2 $\Delta 5$ mag at 0.2	6/22/16	Everett
212628098	GeminiS_8m	DSSI	692 nm	0.011000	0.021000				$\Delta 5$ mag at 0.2 $\Delta 5$ mag at 0.2	6/22/16	Everett
212628098	GeminiS_8m	DSSI	880 nm	0.011000	0.027000	yes	3.8	1.3	$\Delta 5$ mag at 0.2 $\Delta 5$ mag at 0.2	6/22/16	Everett
212628098	—	DSSI	692 nm	0.022000	0.027000	yes			-		Everett
	WIYN_3.5 m WIYN_3.5 m	DSSI	880 nm	0.022000		yes			$\Delta 3.5 \text{ mag at } 0.00\% 2 \Delta 3.5 mag at $	4/20/16	
212628098	—				0.063000	yes		•••		4/20/16	Everett
212628098	GeminiN-8 m	NIRI	Br-gamma	0.021400 0.011000	0.107000	yes			Δ 7.01 mag at 0.75	6/20/16	Ciardi
212679181	GeminiS_8m	DSSI	692 nm		0.021000	yes	1.1	1.2	$\Delta 5 \text{ mag at } 0.00\%$	6/21/16	Everett
212679181	GeminiS_8m	DSSI	880 nm	0.011000	0.027000	yes	1.1	1.3	$\Delta 5 \text{ mag at } 0.072$	6/21/16	Everett
212679181	WIYN_3.5 m	DSSI	692 nm	0.022000	0.050000	yes	1.5	1.5	$\Delta 3.5 \text{ mag}$ at 0."2	4/17/16	Everett
212679181	WIYN_3.5 m	DSSI	880 nm	0.022000	0.063000	yes	1.2	1.5	$\Delta 3.5 \text{ mag at } 0.12$	4/17/16	Everett
212679798	GeminiS_8m	DSSI	692 nm	0.011000	0.021000	yes			$\Delta 5 \text{ mag at } 0.072$	6/22/16	Everett
212679798	GeminiS_8m	DSSI	880 nm	0.011000	0.027000	yes	2.6	0.1	$\Delta 5 \text{ mag}$ at 0."2	6/22/16	Everett
212679798	GeminiN-8 m	NIRI	open	0.021400	0.110000	yes			$\Delta 6.62 \text{ mag at } 0.75$	6/20/16	Ciardi
212686205	WIYN_3.5 m	DSSI	692 nm	0.022000	0.050000	no			$\Delta 3.5 \text{ mag}$ at 0."2	4/20/16	Everett
212686205	WIYN_3.5 m	DSSI	880 nm	0.022000	0.063000	no	•••		$\Delta 3.5 \text{ mag}$ at 0."2	4/20/16	Everett
212773272	GeminiS_8m	DSSI	692 nm	0.011000	0.021000	no	•••		$\Delta 5 \text{ mag}$ at 0."2	6/21/16	Everett
212773272	GeminiS_8m	DSSI	880 nm	0.011000	0.027000	no			$\Delta 5$ mag at 0."2	6/21/16	Everett
212773272	GeminiN-8 m	NIRI	Br-gamma	0.021400	0.109000	no			$\Delta 7.09$ mag at 0."5	6/20/16	Ciardi
212773309	GeminiS_8m	DSSI	692 nm	0.011000	0.021000	yes	2.8	1.0	$\Delta 5 \text{ mag}$ at 0."2	6/21/16	Everett

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		(Continued)											
				Pixel	PSF		Nearby Star	a	Contrast	Observation	Uploaded		
EPIC	Telescope	Instrument	Filter	Scale	(")	Det?	Δ mag	Sep (")	Achieved ^b	Date	By		
212773309	GeminiS_8m	DSSI	880 nm	0.011000	0.027000	yes	2.0	1.0	$\Delta 5 \text{ mag}$ at $0.2''$	6/21/16	Everett		
212773309	WIYN_3.5 m	DSSI	692 nm	0.022000	0.050000	yes	2.8	1.2	$\Delta 3.5 \text{ mag}$ at 0."2	4/24/16	Everett		
212773309	WIYN_3.5 m	DSSI	880 nm	0.022000	0.063000	no	2.0	1.2	$\Delta 3.5 \text{ mag}$ at 0."2	4/24/16	Everett		
213951550	GeminiN-8 m	NIRI	open	0.021400	0.116000	yes		0.2	$\Delta 6.41 \text{ mag}$ at 0."5	7/15/16	Ciardi		
216892056	GeminiS_8m	DSSI	692 nm	0.011000	0.021000	no			$\Delta 5 \text{ mag}$ at 0."2	6/29/16	Everett		
216892056	GeminiS_8m	DSSI	880 nm	0.011000	0.027000	no			$\Delta 5 \text{ mag}$ at 0."2	6/29/16	Everett		
216892056	GeminiN-8 m	NIRI	Br-gamma	0.021400	0.110000	no			$\Delta 6.86 \text{ mag}$ at 0.75	6/15/16	Ciardi		
217941732	GeminiS_8m	DSSI	692 nm	0.011000	0.021000	no			$\Delta 5 \text{ mag}$ at 0."2	6/19/16	Everett		
217941732	GeminiS_8m	DSSI	880 nm	0.011000	0.027000	no			$\Delta 5$ mag at 0."2	6/19/16	Everett		

Table 1

Notes.

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^a We use the "Nearby Star Det?" column to indicate whether any follow-up image revealed a companion to the star. The values in the " Δ mag" and "Sep" columns refer to the magnitude difference and separation measured in the specific image described on the corresponding line of the table.

^b These point sensitivity estimates provide a rough view of whether the image provides deep or shallow limits on the presence of nearby companions. As shown in Figure 1, the contrast achieved improves with increasing separation from the target star. We use the full separation-dependent contrast curves for our false positive probability estimates.

^c The Gemini/DSSI speckle images of EPIC 201637175 did not reveal any companions, but Subaru/HSC imaging displayed a second star roughly 12% as bright as EPIC 201637175. The separation of the two stars is approximately 2" (Sanchis-Ojeda et al. 2015). ^d The follow-up images of EPIC 210558622 did not reveal any companions, but a second set of spectral lines was detected in the Keck/HIRES reconnaissance spectrum (Crossfield et al. 2016).

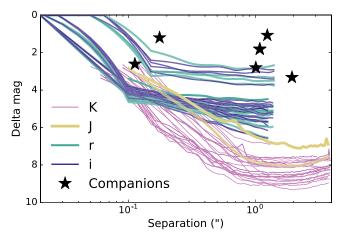


Figure 1. Sensitivity of our follow-up imaging observations as a function of separation. The purple and yellow contrast curves mark the limits achieved for our adaptive optics observations at near-infrared wavelengths, while the teal and navy curves display the limits for our speckle imaging at optical wavelengths. The stars indicate the magnitude difference between the K2 target stars and detected nearby "companion" stars that may or may not be physically associated. The magnitude differences shown here are those in the band used for the follow-up observations; the flux ratio in the K2 bandpass may be different.

 Table 2

 Breakdown of K2OI Dispositions

Previous	Updated Disposition ^a										
Disposition	СР	PC	FP	All							
СР	22	3 ^b	0	25							
PC	9	13	1 [°]	23							
FP	0	0	2	2							
UK	7	17	5	29							
All	38 ^d	33	8	79							

Notes.

^a CP = Confirmed Planet, PC = Planet Candidate, FP = False Positive, UK = Unknown.

^b The previously confirmed planets that we cannot validate with VESPA are EPIC 201345483.01 (FPP = 15%), EPIC 201635569.01 (FPP = 4%-7%), and EPIC 201637175.01 (=K2-22b, nearby star detected). See Section 5.2 for details.

^c The planet candidate rejected as a false positive is EPIC 212572452.01, which was announced by Pope et al. (2016) as a candidate with $R_p/R_{\star} = 0.174$ and an orbital period of 2.6 days. As discussed in Section 5.2, the K2 photometry for this target is contaminated by light from the nearby, brighter star EPIC 212572439.

^d Bold values indicate summations.

the planetary interpretation and remaining false positive scenarios.

EPIC 201635569.01 was previously validated by Montet et al. (2015) as a $4.81 \pm 0.42 R_{\oplus}$ planet with FPP = 4.9×10^{-3} and by Crossfield et al. (2016) as a $4.48 \pm 0.52 R_{\oplus}$ planet with FPP = 0.6%. Our inability to confirm the validation of this planet may be due to our larger estimate of the planet radius, which is in turn caused by the larger stellar radius found by D17. We estimated a revised radius of $0.62 \pm 0.03 R_{\odot}$, which is significantly larger than the values of $0.45 \pm 0.01 R_{\odot}$ and $0.39 \pm 0.04 R_{\odot}$ assumed by Montet et al. (2015) and Crossfield et al. (2016), respectively. Our new FPP estimate of 4%–7% is still consistent with the planetary interpretation of the transit-like

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event, but indicates that additional observations such as AO imaging would be useful to rule out the remaining false positive scenarios.

For EPIC 210508766.02, our initial FPP estimate of 1.9% is only slightly above our validation threshold of 1% and does not consider the fact that transit-like events detected in candidate multiple-planet systems are more likely to be bona fide planets (Lissauer et al. 2012). Given that EPIC 210508766 also hosts 210508766.01, we can apply a multiplicity boost to reduce the FPP for 210508766.02 by a factor of 30 (Sinukoff et al. 2016; Vanderburg et al. 2016a). We therefore support the previous validation of EPIC 210508766.02 (K2-83c) by Crossfield et al. (2016) and classify that K2OI as a validated planet while categorizing all of the other K2OIs with FPP between 1% and 90% as planet candidates. The final disposition breakdown for our K2OI sample is 38 validated planets, eight false positives, and 33 planet candidates.

We list the estimated FPPs and resulting dispositions for individual K2OIs in Table 3. For conciseness, Table 3 also includes estimates of the orbital periods and mid-points of transit-like events. We present the remaining transit parameters and the corresponding physical parameters in Table 4. As part of our classification and transit fitting process, we produced an array of vetting plots for each candidate. We have uploaded all of these plots to the ExoFOP-K2 website and provide examples in the Appendix.

As indicated in Figure 1 and Table 3, six of the planet candidates are associated with K2 targets for which our followup imaging observations revealed nearby companions and Keck/HIRES observations revealed an additional set of stellar lines in the spectrum of EPIC 210558622. The imaged companions might be physically associated with the target star or are simply background stars that fall along the same line of sight. Regardless, the close proximity of additional stars dilutes the depths of the transit-like events in the K2 light curves and causes the planets to appear smaller than their true size. In general, the radii of planet candidates orbiting stars with stellar companions are underestimated by a few percent if they orbit the target stars and by a factor of three if they orbit the companion stars (Furlan et al. 2017). Assessing whether the companion stars are bound to the target stars and determining the source of the transit events will require additional scrutiny of the K2 photometry and follow-up imagery (see Furlan et al. 2017, and references therein). We will discuss these systems in more detail in E. J. González et al. (2017, in preparation), an upcoming catalog paper describing the results of our follow-up images of candidate K2 planet host stars of all spectral types.

6. Revised Planet Properties

After refitting the transit photometry and calculating false positive probabilities, we combined our new transit parameters with updated stellar characterizations from D17 to determine the physical properties of each K2OI. We display the revised planet properties in Figure 2. The panels include the full population of K2 planet candidate, validated planets, and false positives as well as planet candidates and confirmed or validated planets identified during the original *Kepler* mission. In general, the left panel demonstrates that the planet size and orbital period distribution of our K2 planet candidates and validated planets is similar to the distribution of short-period *Kepler* planet candidates. The majority of planets and planet

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		Disp	osition	VESPA	A FPP ^a	Nearby	R_p/R_{\star}				P (days) ^c		t0 (BKJD) ^c			
EPIC	K2OI	Old	New	Small R_p	Big R_p	Star? ^b	K2SFF	k2phot	K2SC	Val	-Err	+Err	Val	-Err	+En	
1205469	1	СР	CP	3.6e-08	3.6e-08	no	0.074	0.072		3.47134	0.00016	0.00016	1976.881	0.002	0.00	
1208431	1	CP	CP	3.7e-07	2.0e-06	no	0.034	0.035		10.00342	0.00100	0.00102	1982.524	0.004	0.004	
)1345483	1	CP	PC	1.5e-01	1.5e-01		0.140	0.136		1.72926	0.00001	0.00001	1976.526	0.000	0.00	
01549860	1	CP	CP	2.3e-05	3.4e-05	no	0.028	0.028		5.60835	0.00034	0.00034	1979.119	0.002	0.002	
01549860	2	CP	CP	1.5e-09	6.9e-08	no	0.019	0.019		2.39996	0.00020	0.00020	1977.584	0.004	0.004	
01617985	1	PC	PC	5.0e-02	8.3e-02	no	0.033	0.033		7.28118	0.00057	0.00055	1979.641	0.004	0.00	
01635569	1	CP	PC	3.6e-02	6.7e-02		0.110	0.104		8.36879	0.00019	0.00019	1978.447	0.001	0.00	
01637175	1	CP	PC	2.4e-03	9.1e-03	yes	0.075	0.074		0.38108	0.00000	0.00000	2034.139	0.000	0.00	
01717274	1	PC	PC	1.1e-01	9.3e-02		0.038	0.039		3.52675	0.00030	0.00030	1976.915	0.004	0.00	
01855371	1	CP	CP	6.2e-06	1.4e-05	no	0.030	0.030		17.96903	0.00142	0.00138	1984.944	0.003	0.00	
)5924614	1	CP	CP	6.0e-11	7.9e–11	no	0.056	0.055	0.056	2.84927	0.00003	0.00003	2150.423	0.000	0.00	
06011691	1	CP	CP	4.1e-07	1.0e-08	no	0.026	0.026	0.026	9.32504	0.00040	0.00038	2156.422	0.001	0.00	
)6011691	2	CP	CP	2.5e-08	8.0e-13	no	0.035	0.033	0.034	15.50192	0.00093	0.00092	2155.471	0.002	0.00	
6119924 ^d	1	PC	CP	2.6e-03	2.2e-03		0.009	0.009	0.009	4.65541	0.00047	0.00092	2146.948	0.002	0.004	
06209135	1	CP	CP	1.2e-04	1.2e-05	no	0.030	0.030	0.030	5.57721	0.00047	0.00042	2177.376	0.004	0.00	
06209135	2	CP	CP	8.4e-05	1.1e-04	no	0.032	0.030	0.030	15.18903	0.00315	0.00313	2156.465	0.002	0.00	
06209135	2	CP	CP	7.2e-04	5.1e-04	no	0.032	0.031	0.029	7.76018	0.00150	0.00150	2150.405	0.003	0.00	
06209135	3 4	CP	CP	7.2e-04 8.4e-05	1.1e-04	no	0.028	0.028	0.030	24.15887	0.00130	0.00130	2151.788	0.007	0.00	
06312951	4	PC	PC	2.3e-02	2.1e-02		0.030	0.038	0.396		0.00017	0.00018	2134.034	0.005	0.00	
	1	PC PC								1.53402						
06318379	1	PC CP	PC CP	1.0e-01	4.6e-02		0.075 0.029	0.076 0.028	0.076 0.027	2.26044	0.00003	0.00003	2147.250 2237.440	0.000 0.002	0.00 0.00	
0448987	1			2.8e-07	7.5e–08	no				6.10233	0.00041	0.00039				
0508766	1	CP	CP	5.1e-04	3.9e-04	no	0.029	0.028	0.028	2.74723	0.00013	0.00013	2234.060	0.002	0.00	
0508766	2	CP	CP	1.8e-02	1.9e-02	no	0.035	0.034	0.034	9.99744	0.00061	0.00062	2233.271	0.002	0.00	
0558622	1	PC	PC	2.2e-06	2.1e-10	no	0.035	0.033	0.033	19.56324	0.00237	0.00255	2250.779	0.003	0.00	
0564155	1	UK	PC	2.0e-02	1.5e-02		0.035	0.034	0.034	4.86407	0.00027	0.00028	2263.759	0.001	0.00	
0707130	1	CP	CP	1.4e-05	3.4e-05	no	0.019	0.019	0.019	0.68456	0.00002	0.00002	2232.367	0.001	0.00	
10750726	1	CP	CP	5.6e-04	3.8e-04	no	0.046	0.045	0.046	4.61228	0.00017	0.00017	2233.218	0.001	0.00	
0838726	1	CP	CP	9.8e-04	8.1e-04	no	0.020	0.018	0.020	1.09598	0.00006	0.00006	2233.008	0.002	0.00	
0968143	1	CP	CP	2.8e-13	9.8e-12	no	0.037	0.036	0.037	13.73491	0.00080	0.00080	2245.659	0.001	0.00	
10968143	2	CP	CP	2.6e-04	1.5e-04	no	0.019	0.017	0.017	2.90071	0.00032	0.00033	2233.740	0.004	0.00	
1077024	1	CP	CP	1.9e-05	4.1e-06	no	0.035	0.032	0.032	1.41960	0.00006	0.00006	2232.430	0.002	0.00	
1305568	1	UK	PC	5.6e-01	1.0e+00		0.041	0.041	0.038	11.55063	0.00112	0.00116	2336.344	0.002	0.00	
11305568°	2	UK	PC				0.015	0.016	0.017	0.19785	0.00001	0.00001	2343.970	0.002	0.00	
11331236 ^f	1	PC	CP	4.7e-08	2.8e-08	no	0.037	0.037	0.036	1.29151	0.00004	0.00004	2309.776	0.001	0.00	
11331236 ⁸	2	UK	CP	2.2e-06	3.5e-06	no	0.038	0.037	0.037	5.44482	0.00042	0.00040	2310.560	0.003	0.00	
11336288	1	UK	PC	1.9e-01	1.2e-01		0.018	0.015	0.017	0.22181	0.00002	0.00002	2344.090	0.002	0.00	
11357309	1	PC	PC	7.6e-02	6.7e-02		0.017	0.018	0.018	0.46394	0.00002	0.00002	2368.458	0.001	0.00	
11428897	1	PC	PC	7.0e-06	5.5e-08	yes	0.024	0.025	0.023	1.61093	0.00006	0.00006	2309.275	0.001	0.00	
1428897	2	UK	PC	7.4e-04	2.5e-05	yes	0.021	0.019	0.021	2.17807	0.00012	0.00012	2310.647	0.002	0.00	
1428897	3	UK	PC	1.2e-03	5.2e-04	yes	0.021	0.021	0.020	4.96883	0.00037	0.00037	2340.523	0.002	0.00	
11509553	1	PC	PC	1.0e-03	1.3e-03	yes	0.181	0.176	0.177	20.35954	0.00032	0.00033	2318.412	0.001	0.00	
1680698 ^h	1	UK	CP	5.6e-03	7.6e-03		0.032	0.029	0.031	50.92092	0.00525	0.00558	2327.473	0.004	0.00	
11694226	1	UK	PC	2.9e-01	6.2e-01	yes	0.020	0.017	0.368	1.91828	0.00017	0.00019	2342.946	0.002	0.00	
1762841	1	UK	PC	9.8e-02	1.2e-01		0.031	0.223	0.185	1.56494	0.00009	0.00009	2343.261	0.001	0.00	
1770795 ⁱ	1	PC	CP	1.2e-05	7.6e-05	no	0.031	0.031	0.029	7.72858	0.00070	0.00073	2315.826	0.003	0.00	
1791178 ^j	1	UK	CP	1.7e-03	1.5e-03		0.028	0.028	0.029	9.56274	0.00067	0.00067	2342.604	0.002	0.00	
1799258	1	UK	PC	9.0e-01	9.4e-01	no	0.264	0.258	0.348	19.53406	0.00077	0.00079	2320.146	0.001	0.00	
1817229	1	UK	PC	3.9e-01	9.5e-01		0.276	0.266	0.176	2.17693	0.00005	0.00005	2342.525	0.001	0.00	
1818569 ^k	1	PC	CP	1.4e-04	6.1e-04	no	0.109	0.108	0.108	5.18575	0.00020	0.00020	2310.561	0.001	0.00	
1822797	1	CP	CP	6.7e-04	7.6e-04		0.032	0.030	0.029	21.16986	0.00169	0.00172	2332.577	0.002	0.00	
1826814	1	UK	PC	5.6e-01	9.6e-01		0.082	0.260	0.029	1.53453	0.00012	0.000172	2343.198	0.002	0.00	
1831378	1	UK	FP	2.4e-05	1.9e-06	no	0.032	0.200	0.579	3.48929	0.00012	0.00048	2310.755	0.002	0.00	
1924657 ¹	1	PC	PC	5.3e-01	6.4e-01	no	0.013	0.074	0.051	2.64484	0.00011	0.00048	2311.641	0.005	0.00	
1924037	1	PC	PC	3.4e-01	3.8e-01		0.032	0.031	0.031	10.55630	0.00066	0.00064	2334.605	0.001	0.00	
11965883	1	PC PC	PC PC	3.4e-01 8.6e-02	3.8e-01 9.5e-02		0.043	0.039	0.039	10.55630	0.00066	0.00064	2342.915	0.001	0.00	
1170700/	1	гC	гC	0.0e-02	9.50-02	•••	0.057	0.050	0.057	1.9/424	0.00011	0.00011	2342.913	0.001	0.00	

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								inued)							
		Disp	oosition	VESP	a FPP ^a	Nearby		R_p/R_{\star}			$P (\text{days})^{c}$			t0 (BKJD) ^c	
EPIC	K2OI	Old	New	Small R_p	Big R_p	Star? ^b	K2SFF	k2phot	K2SC	Val	-Err	+Err	Val	-Err	+Err
211970234	1	UK	FP	1.6e-01	1.9e-01	no	0.069	0.104	0.212	1.48350	0.00004	0.00003	2310.371	0.001	0.001
211988320	1	UK	PC	7.5e-02	7.2e-02		0.041	0.036	0.034	63.84808	0.00588	0.00560	2309.721	0.004	0.005
212006344 ^m	1	PC	CP	1.5e-04	1.7e-04	no	0.020	0.019	0.020	2.21940	0.00007	0.00007	2311.048	0.001	0.001
212069861 ⁿ	1	PC	CP	1.1e-04	2.9e-06	no	0.043	0.042	0.040	30.95676	0.00272	0.00259	2314.492	0.003	0.003
212154564°	1	PC	CP	6.8e-07	9.7e-07	no	0.070	0.067	0.069	6.41354	0.00026	0.00025	2309.183	0.002	0.002
212398486 ^p	1	UK	CP	7.5e-03	1.7e-03		0.050	0.050	0.045	21.75026	0.00196	0.00199	2410.088	0.002	0.002
212443973	1	PC	PC	1.6e-01	8.9e-01		0.024	0.295	0.096	0.77923	0.00005	0.00006	2423.710	0.002	0.002
212460519 ⁹	1	PC	CP	4.2e-13	1.1e-11	no	0.027	0.028	0.027	7.38707	0.00025	0.00025	2390.794	0.001	0.001
212554013 ^r	1	PC	CP	1.0e-03	1.6e-03	no	0.117	0.115	0.117	3.58816	0.00002	0.00002	2390.926	0.000	0.000
212572452	1	PC	FP	3.3e-07	4.3e-08	no	0.072	0.067	0.176	2.58148	0.00001	0.00001	2390.028	0.000	0.000
212628098	1	FP	FP	9.2e-02	3.0e-02	yes	0.228	0.278	0.286	4.35244	0.00003	0.00003	2390.348	0.000	0.000
212634172	1	UK	PC	3.0e-01	1.0e+00		0.093	0.081	0.069	2.85177	0.00009	0.00010	2421.669	0.001	0.001
212679181	1	PC	PC	4.2e-04	6.4e-04	yes	0.026	0.024	0.026	1.05459	0.00002	0.00001	2423.570	0.000	0.000
212679798	1	UK	FP	2.1e-01	9.5e-01	yes	0.482	0.678	0.158	1.83473	0.00002	0.00002	2389.389	0.002	0.002
212686205 ^s	1	UK	CP	1.1e-07	4.2e-06	no	0.017	0.016	0.014	5.67582	0.00041	0.00041	2422.503	0.002	0.002
212690867	1	UK	PC	2.9e-02	3.5e-02		0.049	0.047	0.049	25.86125	0.00309	0.00298	2422.464	0.003	0.003
212773272	1	UK	FP	9.4e-01	9.8e-01	no	0.623	0.203	0.205	4.68189	0.00005	0.00005	2389.666	0.001	0.001
212773309	1	FP	FP	8.5e-01	9.4e-01	yes	0.732	0.738	0.728	4.68199	0.00007	0.00006	2389.665	0.001	0.001
213951550	1	UK	FP	1.0e+00	1.0e+00	yes	0.683	0.625		1.11704	0.00002	0.00002	2478.230	0.001	0.001
214254518	1	UK	PC	9.8e-03	1.2e-02		0.015	0.015		5.05899	0.00054	0.00053	2506.630	0.003	0.003
214522613	1	UK	PC	5.1e-02	4.9e-02		0.024	0.022		10.99041	0.00126	0.00124	2506.314	0.002	0.002
214787262 ^t	1	UK	CP	6.1e-04	1.4e-03		0.027	0.026		8.23949	0.00029	0.00029	2502.009	0.001	0.001
216892056	1	UK	PC	6.1e-01	9.8e-01	no	0.279	0.083		2.78592	0.00005	0.00005	2478.406	0.001	0.001
217941732 ^u	1	UK	CP	1.2e-06	2.9e-07	no	0.015	0.015		2.49412	0.00013	0.00013	2507.612	0.001	0.001

Table 3

Notes.

^a The "Small R_p " and "Big R_p " values refer to VESPA FPP estimates made using the 16th and 84th percentiles of the R_p/R_{\star} posterior probability distribution, respectively. Note that VESPA operates in a statistical fashion and that the reported FPP may occasionally be higher for the small R_p case than for the big R_p case due to changes in the simulated population of stars.

^b Indicates whether a nearby star was revealed in the follow-up AO and speckle imagery (see Table 1). Rows without definitive answers mark stars without follow-up images posted to the ExoFOP-K2 website. Note that planet radius estimates are not corrected for flux dilution due to the presence of nearby stars.

^c Values and errors for orbital period and transit center are from fits using K2SFF photometry.

^d Now validated as K2-116b.

^g Now validated as K2-117c.

^h Now validated as K2-118b.

- ⁱ Now validated as K2-119b.
- ^j Now validated as K2-120b.
- ^k Now validated as K2-121b.

¹ This K2OI displays transit timing variations, but our fits assumed a linear ephemeris.

- ⁿ Now validated as K2-123b.
- ^o Now validated as K2-124b.
- ^p Now validated as K2-125b.
- ^q Now validated as K2-126b.
- ^r Now validated as K2-127b.
- ^s Now validated as K2-128b.
- ^t Now validated as K2-129b.

^u Now validated as K2-130b.

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^e VESPA was unable to calculate an FPP for EPIC 211305568.02. See Section 7.2.5.

^f Now validated as K2-117b.

^m Now validated as K2-122b.

									able 4 Properties	a								The As
				D (D					mb				D (D)					ASTRONOMICAL
EPIC	K2OI	P ^b (days)	Val	$\frac{R_p/R_{\star}}{-\text{Err}}$	+Err	a/R_{\star}	i		tening	е	ω	Val	$\frac{R_p (R_{\oplus})}{-\text{Err}}$	+Err	a (au)	Val	$F_p(F_{\oplus})$ -Err	+Err A
201205469	1	3.47134	0.074	0.002	0.002	13.51	88.90	q_1 0.48	<i>q</i> ₂ 0.30	0.07	-25.11	4.75	0.33	0.34	0.038	46.4	16.3	
201203409	1	10.00342	0.074	0.002	0.002	27.68	88.90 89.54	0.48	0.30	0.07	-23.11 -41.44	2.10	0.33	0.34	0.038	40.4 15.6	6.2	23.0 JOURNAL 9.2 219.7 AL
201200431	1	1.72926	0.140	0.001	0.003	8.02	87.75	0.45	0.43	0.10	59.61	10.44	0.70	0.90	0.025	380.5	150.1	219.7 Ž
201549860	1	5.60835	0.028	0.001	0.001	19.10	88.58	0.55	0.44	0.12	41.16	1.93	0.10	0.13	0.055	68.0	10.5	12.1
201549860	2	2.39996	0.019	0.001	0.001	10.53	88.98	0.54	0.45	0.12	-74.55	1.32	0.08	0.08	0.031	211.0	32.5	37.4 <u>4</u> :207
201617985	1	7.28118	0.033	0.002	0.003	26.16	88.30	0.47	0.27	0.23	62.91	1.77	0.17	0.21	0.060	9.2	2.6	3.3 8
201635569	1	8.36879	0.110	0.004	0.004	22.94	88.19	0.50	0.33	0.14	-70.72	7.49	0.47	0.48	0.069	5.5	3.2	6.1
201637175	1	0.38108	0.075	0.004	0.004	3.19	77.48	0.48	0.30	0.19	46.70	4.75	0.36	0.35	0.009	737.9	196.7	6.1 242.8 4.1 ,26pp),
201717274	1	3.52675	0.038	0.002	0.004	15.20	88.23	0.59	0.29	0.13	23.29	1.32	0.25	0.26	0.026	15.0	3.3	4.1 <u>9</u>
201855371	1	17.96903	0.030	0.002	0.002	40.17	89.08	0.51	0.37	0.18	52.06	2.03	0.16	0.18	0.117	10.5	2.9	3.7 8
205924614	1	2.84927	0.056	0.001	0.002	10.46	88.21	0.53	0.44	0.07	23.94	4.38	0.25	0.29	0.035	141.3	23.5	28.8 5
206011691	1	9.32504	0.026	0.001	0.001	25.37	88.98	0.52	0.41	0.10	34.48	1.84	0.10	0.10	0.076	10.0	1.7	2.1 ^Z
206011691	2	15.50192	0.035	0.002	0.002	35.50	88.85	0.50	0.41	0.21	59.96	2.49	0.19	0.17	0.107	5.1	0.9	1.1 0
206119924	1	4.65541	0.009	0.000	0.000	15.37	89.09	0.54	0.44	0.06	-23.44	0.69	0.04	0.04	0.048	78.6	10.5	2.1 November 1.1 12.2
206209135	1	5.57721	0.030	0.001	0.002	24.16	89.15	0.54	0.27	0.11	7.49	1.08	0.11	0.11	0.040	8.5	1.1	1.2
206209135	2	15.18903	0.032	0.002	0.002	47.82	89.54	0.54	0.27	0.11	16.83	1.16	0.13	0.13	0.078	2.2	0.3	0.3
206209135	3	7.76018	0.028	0.002	0.002	29.91	89.26	0.54	0.27	0.11	14.28	1.01	0.12	0.12	0.050	5.4	0.7	0.8
206209135	4	24.15887	0.036	0.002	0.002	64.53	89.68	0.54	0.27	0.11	11.39	1.29	0.13	0.14	0.106	1.2	0.2	0.2
206312951	1	1.53402	0.022	0.002	0.002	9.41	87.23	0.47	0.27	0.11	32.40	1.13	0.10	0.11	0.021	120.2	16.8	19.0
206318379	1	2.26044	0.075	0.002	0.004	16.21	88.35	0.54	0.27	0.13	42.80	2.30	0.26	0.28	0.020	30.1	3.8	4.5
210448987	1	6.10233	0.029	0.001	0.001	19.77	89.29	0.54	0.45	0.06	-27.89	1.97	0.11	0.13	0.059	62.9	8.4	9.2
210508766	1	2.74723	0.029	0.001	0.001	12.59	88.72	0.46	0.29	0.07	-5.43	1.71	0.10	0.10	0.032	38.8	5.9	6.3
210508766	2	9.99744	0.035	0.001	0.001	29.67	89.51	0.47	0.29	0.06	-19.35	2.11	0.12	0.12	0.076	6.9	1.0	1.1
210558622	1	19.56324	0.035	0.001	0.001	38.50	89.75	0.53	0.43	0.48	-90.15	2.59	0.15	0.17	0.125	13.2	2.1	2.3
210564155	1	4.86407	0.035	0.002	0.002	26.74	89.00	0.53	0.26	0.13	36.10	1.09	0.13	0.13	0.036	7.7	1.0	1.2
210707130	1	0.68456	0.019	0.001	0.001	4.30	80.21	0.56	0.45	0.24	67.59	1.37	0.11	0.11	0.013	1069.1	144.7	163.5
210750726	1	4.61228	0.046	0.003	0.003	19.98	87.75	0.49	0.27	0.26	72.02	2.30	0.21	0.23	0.042	16.4	2.0	2.2
210838726	1	1.09598	0.020	0.001	0.001	7.36	85.77	0.47	0.28	0.15	51.29	1.08	0.08	0.09	0.017	144.4	18.0	20.2
210968143	1	13.73491	0.037	0.001	0.001	33.90	89.40	0.54	0.45	0.07	16.40	2.53	0.13	0.14	0.100	10.2	1.4	1.7
210968143	2	2.90071	0.019	0.001	0.002	12.02	86.94	0.55	0.45	0.19	56.76	1.30	0.11	0.13	0.035	80.8	11.1	13.2
211077024	1	1.41960	0.035	0.001	0.001	11.19	88.62	0.43	0.25	0.09	-23.36	1.22	0.12	0.12	0.018	56.1	6.6	7.4
211305568	1	11.55063	0.041	0.004	0.805	36.12	88.64	0.49	0.26	0.35	10.33	1.99	0.25	39.17	0.078	5.7	0.7	0.8
211305568	2	0.19785	0.015	0.001	0.002	2.50	79.26	0.48	0.26	0.13	33.20	0.72	0.08	0.11	0.005	1292.5	158.3	178.2
211331236	1	1.29151	0.037	0.001	0.001	8.32	88.36	0.46	0.28	0.06	-22.63	1.96	0.12	0.12	0.019	145.8	18.9	21.5
211331236	2	5.44482	0.038	0.001	0.001	20.93	89.49	0.46	0.28	0.15	-77.06	2.03	0.13	0.13	0.051	21.4	2.8	3.2
211336288	1	0.22181	0.018	0.002	0.002	2.28	77.48	0.47	0.33	0.17	54.63	1.14	0.13	0.15	0.006	1140.9	151.6	172.3
211357309	1	0.46394	0.017	0.001	0.001	4.28	86.80	0.47	0.27	0.08	-36.30	0.84	0.06	0.06	0.010	437.3	56.8	63.9
211428897	1	1.61093	0.024	0.001	0.001	12.64	89.08	0.47	0.25	0.15	-71.99	0.75	0.08	0.08	0.021	48.0	5.9	6.8
211428897	2	2.17807	0.021	0.001	0.001	16.36	89.21	0.47	0.25	0.11	-54.04	0.65	0.07	0.07	0.025	32.1	3.9	4.6
211428897	3	4.96883	0.021	0.001	0.001	29.12	89.52	0.47	0.25	0.10	-40.14	0.67	0.08	0.08	0.044	10.7	1.3	1.5
211509553	1	20.35954	0.181	0.002	0.003	47.46	89.61	0.48	0.28	0.09	43.86	10.82	0.58	0.59	0.119	1.8	0.3	0.4
211680698	1	50.92092	0.032	0.002	0.002	71.82	89.50	0.54	0.45	0.20	58.67	2.54	0.20	0.23	0.245	4.3	0.6	0.6 <u>U</u>
211694226	1	1.91828	0.020	0.002	0.002	10.51	86.33	0.49	0.26	0.19	59.28	0.99	0.11	0.13	0.021	75.8	12.1	0.6 Dressing 13.8 29.7 mg
211762841	1	1.56494	0.031	0.004	0.007	7.91	83.60	0.51	0.27	0.17	55.97	2.14	0.30	0.49	0.023	157.6	25.9	29.7 jg
211770795	1	7.72858	0.031	0.001	0.001	21.58	89.40	0.51	0.27	0.07	-37.71	2.29	0.13	0.15	0.070	54.9	8.8	9.6 g
211791178	1	9.56274	0.028	0.001	0.001	24.05	89.57	0.49	0.38	0.14	-81.19	2.01	0.12	0.13	0.078	35.1	5.1	5.9 <u>p</u>

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									able 4 ntinued)									
		P ^b		R_p/R_{\star}					mb ening				$R_p (R_{\oplus})$				$F_p(F_\oplus)$	
EPIC	K2OI	(days)	Val	-Err	+Err	a/R_{\star}	i	q_1	$\frac{q_2}{q_2}$	е	ω	Val	-Err	+Err	a (au)	Val	-Err	+Err
211799258	1	19.53406	0.264	0.021	0.168	77.55	89.26	0.54	0.45	0.48	89.44	9.46	1.93	6.33	0.087	1.0	0.6	1.4
211817229	1	2.17693	0.276	0.208	0.494	17.03	85.82	0.55	0.44	0.08	-4.12	7.13	5.51	12.83	0.019	15.1	11.9	56.6
211818569	1	5.18575	0.109	0.005	0.005	14.71	87.25	0.50	0.27	0.22	72.97	9.12	0.68	0.66	0.052	89.5	11.2	12.5
211822797	1	21.16986	0.032	0.001	0.001	48.67	89.73	0.45	0.25	0.06	-21.51	1.98	0.11	0.11	0.131	3.5	0.5	0.5
211826814	1	1.53453	0.082	0.056	0.520	12.15	85.00	0.56	0.47	0.09	-8.50	2.34	1.65	14.85	0.015	26.0	18.5	63.9
211831378	1	3.48929	0.015	0.001	0.001	14.01	88.89	0.49	0.37	0.08	-22.01	0.91	0.07	0.07	0.037	24.6	7.1	10.5
211924657	1 ^c	2.64484	0.052	0.001	0.002	13.85	88.77	0.48	0.28	0.10	-26.38	1.83	0.21	0.24	0.026	18.8	2.6	2.9
211965883	1	10.55630	0.043	0.004	0.004	29.73	88.32	0.43	0.25	0.23	62.02	2.79	0.30	0.27	0.083	11.4	1.5	1.7
211969807	1	1.97424	0.037	0.001	0.002	9.93	88.00	0.51	0.26	0.09	6.24	1.96	0.15	0.15	0.023	62.1	13.8	16.0
211970234	1	1.48350	0.069	0.003	0.015	12.68	87.70	0.51	0.40	0.12	10.96	1.42	0.30	0.41	0.015	19.2	4.3	5.0
211988320	1	63.84808	0.041	0.001	0.001	92.33	89.80	0.50	0.27	0.07	3.10	2.86	0.15	0.16	0.276	0.9	0.1	0.1
212006344	1	2.21940	0.020	0.001	0.001	10.42	86.39	0.46	0.25	0.21	60.80	1.28	0.08	0.08	0.029	79.9	11.1	13.1
212069861	1	30.95676	0.043	0.001	0.001	61.89	89.79	0.53	0.42	0.06	-33.53	2.65	0.15	0.15	0.167	2.9	0.4	0.5
212154564	1	6.41354	0.070	0.002	0.002	30.09	89.51	0.47	0.33	0.08	-26.80	2.64	0.24	0.24	0.051	8.7	1.1	1.2
212398486	1	21.75026	0.050	0.002	0.002	63.31	89.72	0.45	0.25	0.08	-3.74	2.18	0.18	0.19	0.121	2.0	0.3	0.3
212443973	1	0.77923	0.024	0.005	0.183	7.18	83.37	0.48	0.26	0.12	23.59	0.90	0.19	6.84	0.011	98.7	11.5	13.0
212460519	1	7.38707	0.027	0.000	0.000	22.38	89.40	0.47	0.26	0.06	-33.72	1.84	0.10	0.11	0.066	35.3	5.9	6.6
212554013	1	3.58816	0.117	0.002	0.002	12.02	87.22	0.55	0.27	0.12	-65.74	8.66	0.59	0.68	0.041	105.6	17.8	20.7
212572452	1	2.58148	0.072	0.003	0.003	9.92	86.28	0.58	0.45	0.15	-76.47	5.30	0.37	0.40	0.033	132.0	33.7	41.8
212628098	1	4.35244	0.228	0.006	0.006	17.15	87.29	0.55	0.42	0.18	91.75	14.06	0.78	0.78	0.044	81.2	11.7	13.1
212634172	1	2.85177	0.093	0.028	0.528	14.47	86.15	0.56	0.44	0.12	6.67	3.51	1.12	20.03	0.027	18.8	2.6	2.9
212679181	1	1.05459	0.026	0.003	0.003	8.02	83.74	0.47	0.31	0.18	64.17	1.25	0.18	0.15	0.016	114.7	13.9	16.5
212679798	1	1.83473	0.482	0.231	0.335	8.98	84.65	0.53	0.26	0.52	-91.97	29.52	14.20	20.58	0.024	164.7	28.0	35.0
212686205	1	5.67582	0.017	0.001	0.001	15.46	87.40	0.48	0.26	0.23	62.55	1.42	0.13	0.16	0.056	68.8	9.7	11.1
212690867	1	25.86125	0.049	0.001	0.002	64.68	89.76	0.48	0.29	0.09	-26.75	2.20	0.18	0.19	0.133	1.4	0.2	0.3
212773272	1	4.68189	0.623	0.281	0.259	15.60	85.55	0.56	0.47	0.07	-36.21	29.05	13.26	12.25	0.036	13.8	2.0	2.4
212773309	1	4.68199	0.732	0.348	0.201	16.74	85.66	0.48	0.26	0.14	-79.60	46.96	22.42	13.10	0.048	69.5	8.4	9.8
213951550	1	1.11704	0.683	0.314	0.229	6.71	79.52	0.57	0.28	0.08	-44.84	35.08	16.27	11.98	0.016	166.0	26.5	31.7
214254518	1	5.05899	0.015	0.001	0.001	16.18	89.17	0.50	0.38	0.07	-30.08	1.12	0.07	0.08	0.051	56.1	7.9	9.2
214522613	1	10.99041	0.024	0.002	0.002	36.38	88.90	0.49	0.26	0.22	63.16	1.15	0.12	0.13	0.075	6.9	1.2	1.4
214787262	1	8.23949	0.027	0.001	0.001	34.37	89.21	0.49	0.27	0.13	39.89	1.04	0.09	0.10	0.057	4.5	0.5	0.6
216892056	1	2.78592	0.279	0.232	0.412	15.87	85.50	0.55	0.44	0.06	4.45	12.11	10.13	17.91	0.028	25.5	3.1	3.5
217941732	1	2.49412	0.015	0.001	0.001	9.26	86.53	0.49	0.26	0.17	49.80	1.25	0.14	0.20	0.032	136.4	35.8	45.8

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^a For presentation purposes, this table contains only a subset of the available columns. See the machine-readable version for transit parameters based on fits to k2phot and K2SC photometry as well as errors on all parameters. ^b See Table 3 for errors on P and estimates of the transit center. ^c This K2OI displays transit timing variations, but our fits assumed a linear ephemeris.

(This table is available in its entirety in machine-readable form.)

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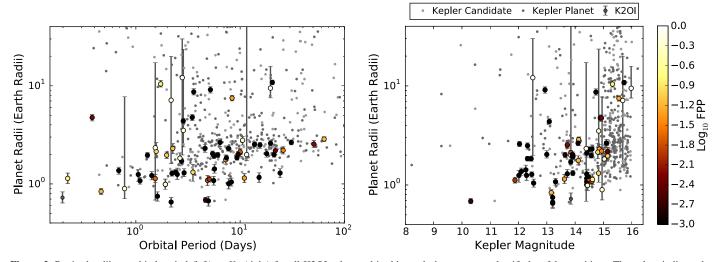


Figure 2. Revised radii vs. orbital period (left) or Kp (right) for all K2OIs observed in this work that were not classified as false positives. The colors indicate the average of the two FPP estimates for each K2OI as shown in the legend. For reference, the smaller circles mark planet candidates (light gray) and validated/confirmed planets (dark gray) detected during the prime *Kepler* mission. We obtained the properties of *Kepler* planets from the NASA Exoplanet Archive (Akeson et al. 2013).

candidates have radii $\lesssim 3 R_{\oplus}$, but both the *Kepler* and K2 radius distributions have tails extending to larger planet radii. As expected, Figure 2 also reveals that K2OIs with high FPPs tend to be larger than those with lower FPPs. Martinez et al. (2017) noted a similar size difference between the radii of their planet candidates and validated planets (see their Figure 9) and remarked that the radius estimates for candidates tend to be more uncertain.

The primary difference between our K2 planet candidates and the Kepler sample is that the K2 sample is biased toward brighter host stars. Considering only stars hosting planet candidates or validated planets, the median Kp of our cool dwarf sample is 14.1. As shown in the right panel of Figure 2, 77% of Kepler planets and planet candidates orbiting stars cooler than 4800K have fainter host stars. The Kepler cool dwarf sample has a median host star brightness of Kp = 15.2, fainter than 93% of our K2 host stars. Interestingly, we note that our false positive sample is biased toward fainter host stars relative to the overall sample: the median Kp of our false positive sample is 14.8. A possible explanation for this trend is that the reduced photon counts for these faint stars cause the signal-to-noise ratio of the putative transit events to be below the threshold required to distinguish between bona fide transits and grazing eclipsing binaries.

In both the *Kepler* and K2 samples, we note a deficit of large planets at short orbital periods. The sole K2 planet with a period shorter than one day and a plotted radius larger than $1.5 R_{\oplus}$ is EPIC 201637175.01 (K2-22b), which is reported to be in the process of evaporating (Sanchis-Ojeda et al. 2015). Although our best-fit transit model uses a radius of $4.75_{-0.36}^{+0.35} R_{\oplus}$, Sanchis-Ojeda et al. (2015) argued that the planet itself is likely significantly smaller and surrounded by large dust clouds. In that interpretation, the deep transits are caused by the clouds of debris and do not reflect the underlying radius of the planet (Sanchis-Ojeda et al. 2015).

In general, the relative lack of larger short-period planets is consistent with results from the *Kepler* mission: Sanchis-Ojeda et al. (2014) observed that all ultra-short-period planets orbiting G, K, or M dwarfs have radii $\leq 2 R_{\oplus}$. The lack of large planets on ultra-short orbital periods may indicate that the envelopes of highly irradiated planets are highly vulnerable to photoevaporation

(e.g., Watson et al. 1981; Lammer et al. 2003; Baraffe et al. 2004; Murray-Clay et al. 2009; Valencia et al. 2010; Sanz-Forcada et al. 2011; Lopez et al. 2012; Kurokawa & Kaltenegger 2013; Lopez & Fortney 2013; Owen & Wu 2013). At longer orbital periods, our sample includes planet candidates and validated planets with estimated radii between $0.7 R_{\oplus}$ and $12.1 R_{\oplus}$.

6.1. Biases in the Planet Sample

Adopting the same planet size categories as Fressin et al. (2013), our sample contains 21 Earths ($<1.25 R_{\oplus}$; 8 validated), 18 super-Earths ($1.25-2 R_{\oplus}$; 13 validated), 21 small Neptunes ($2-4 R_{\oplus}$; 13 validated), three large Neptunes ($4-6 R_{\oplus}$; two validated), and eight giant planets ($>6 R_{\oplus}$; two validated). The size distribution depicted in Figure 3 is not representative of the larger population of planets orbiting low-mass stars. Rather, our sample, like most K2 planet catalogs, is shaped by strong selection biases due to the increased detectability of planets on short-period orbits compared to planets with longer periods and our interest in identifying compelling small planets orbiting bright stars for future follow-up observations.

Looking at Figure 4, the smallest planets are predominantly detected around the coolest target stars (median $T_{\text{eff}} = 3595 \text{ K}$ for $R_p < 1.25 R_{\oplus}$ compared to $T_{\text{eff}} = 3842 \text{ K}$ for the full sample of planet candidates and validated planets), but the observed correlation of planet radius and stellar effective temperature is likely a selection effect due to the $1/(R_*)^2$ scaling of transit depth with stellar radius rather than a reflection of the true underlying occurrence rate of small planets. We further investigate the role of selection biases in Figure 5 by comparing the host star magnitudes and radii for different sizes of planets.

As would be expected if the minimum planet radius were a function of search sensitivity, we find that our smallest planet candidates and validated planets are preferentially associated with the brightest and smallest host stars. We also note that the Neptunes and giant planets in the sample fall along the lower right edge of the distribution, indicating that they tend to orbit stars that are fainter and/or larger than the majority of the stars in our target sample. We interpret both of these results as evidence that our planet sample contains significant selection effects and

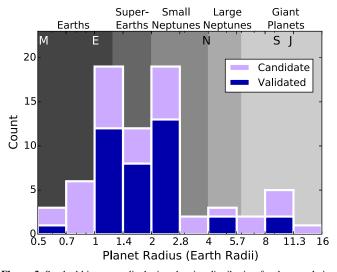


Figure 3. Stacked histogram displaying the size distribution for the population of K2 planet candidates (lilac) and validated planets (navy) characterized in this paper. The background shading denotes the planet size ranges defined by Fressin et al. (2013) and adopted in this paper. Letters mark the radii of Mars, Earth, Neptune, Saturn, and Jupiter.

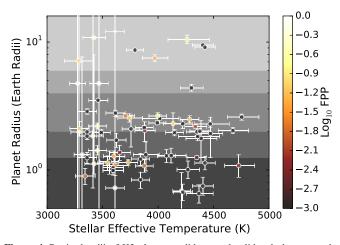


Figure 4. Revised radii of K2 planet candidates and validated planets vs. the effective temperature of their host stars. As in Figure 2, the planets are color-coded according to their FPPs. The shaded regions are the same as in Figure 3 and denote Earths (darkest region; at bottom), super-Earths (second from bottom), small Neptunes (middle), large Neptunes (second from top), and giant planets (lightest region; at top).

therefore cannot be used to estimate planet occurrence rates unless the detection biases are considered as part of the analysis.

6.2. Planet Radii versus Insolation Flux: Photoevaporation and Potentially Habitable Systems

In Figure 6 we plot the insolation flux received by the planet candidates and validated planets in our sample as a function of the effective temperatures of their host stars. We calculate the insolation flux from the stellar luminosities and the orbital semimajor axes, which we derive from the orbital periods and the stellar masses.

Due to the relatively short, 80 day durations of K2 campaigns and the bias of the transit method toward shortperiod planets, the majority of the planets have very short orbital periods and are therefore highly irradiated. The most heavily irradiated planets in our sample receive over

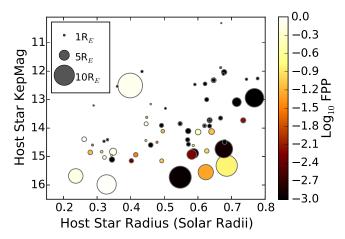


Figure 5. Host star magnitude in the *Kepler* bandpass vs. estimated stellar radius for K2 targets in our low-mass candidate host star sample. Larger circles indicate larger planets and the planets are colored based on their FPPs using the same scaling as in Figure 2.

1000 times the flux received by the Earth (F_{\oplus}) and 21% of the planets receive at least 100 F_{\oplus} .

Although our ability to discern relationships between planet radii and insolation flux environment is complicated by selection effects, Figure 6 reveals that the population of highly irradiated planets is dominated by smaller planets. As previously discussed, the shortage of highly irradiated intermediate-sized planets may be due to photoevaporation. Of the seven validated planets and planet candidates receiving at least 200 F_{\oplus} , the only object with a radius between 2 R_{\oplus} and 10 R_{\oplus} is the evaporating planet EPIC 201637175.01 (K2-22b Sanchis-Ojeda et al. 2015).

At the opposite extreme of the insolation flux distribution, our cool dwarf sample contains 21 planets or planet candidates receiving $<10 F_{\oplus}$. In order to assess whether any of these planets might be habitable, we used the polynomial relations from Kopparapu et al. (2013) to determine the insolation flux boundaries corresponding to conservative habitable zone (HZ) limits of the moist greenhouse inner edge and the maximum greenhouse outer edge and to more optimistic limits of recent-Venus inner limit and early-Mars outer limit. A more sophisticated choice would have been to use the planet-mass-dependent relations from Kopparapu et al. (2014), but we do not know the masses of these planets.

Given the temperature distribution of the host stars in our cool dwarf sample, the median HZ boundaries are $0.26-0.89 F_{\oplus}$ (0.22–0.40 au) for the conservative case and $0.23-1.55 F_{\oplus}$ (0.16–0.42 au) for the more optimistic case. As shown in Figure 6, four of the planets and planet candidates in our sample fall within the optimistic HZ limits (EPIC 206209135.04, 211799258.01, 211988320.01, and 212690867.01). We discuss each of these K2OIs individually in Section 7.

6.3. Comparison of K2 Photometric Pipelines

In order to investigate the influence of systematic effects in the reduced K2 photometry on the derived planet properties, we repeated the transit fits using photometry processed by the K2 Systematics Correction Pipeline^{26,27} (Aigrain et al. 2015, 2016) and the k2phot pipeline (Petigura et al. 2013). We note that

 ²⁶ https://archive.stsci.edu/prepds/k2sc/; https://doi.org/10.17909/T9K591
 ²⁷ https://github.com/OxES/k2sc

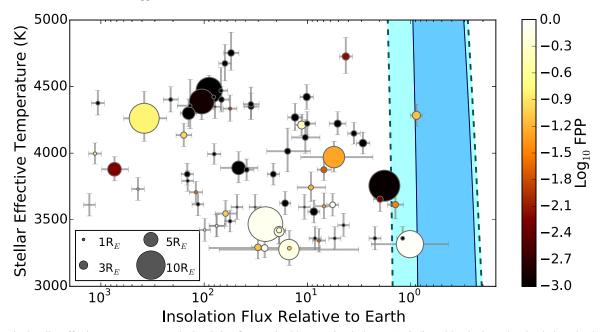


Figure 6. Revised stellar effective temperatures vs. the insolation flux received by associated planets. As indicated by the legend and colorbar, the data points are scaled by planet radius and colored based on FPP. The cyan and blue regions indicate optimistic (early-Venus/recent-Mars) and pessimistic (moist greenhouse/ maximum greenhouse) habitable zone boundaries based as calculated by Kopparapu et al. (2013). The planets plotted within the habitable zone are: EPIC 206209135.04 (small black circle; $1.3 \pm 0.1 R_{\oplus}$, $F_p = 1.2 \pm 0.2 F_{\oplus}$, FPP = $1 \times 10^{-5} - 8 \times 10^{-5}$), EPIC 211799258.01 (large white circle; $R_p = 9.5^{+6.3}_{-1.9} R_{\oplus}$, $F_p = 1.0^{-1.6}_{-0.6} F_{\oplus}$, FPP = 90%-94%), EPIC 211988320.01 (medium yellow-orange circle; $R_p = 2.9 \pm 0.2 R_{\oplus}$, $F_p = 0.9 \pm 0.1 F_{\oplus}$, FPP = 7%), and EPIC 212690867.01 (medium orange circle; $R_p = 2.2 \pm 0.2 R_{\oplus}$, FPP = 3%-4%).

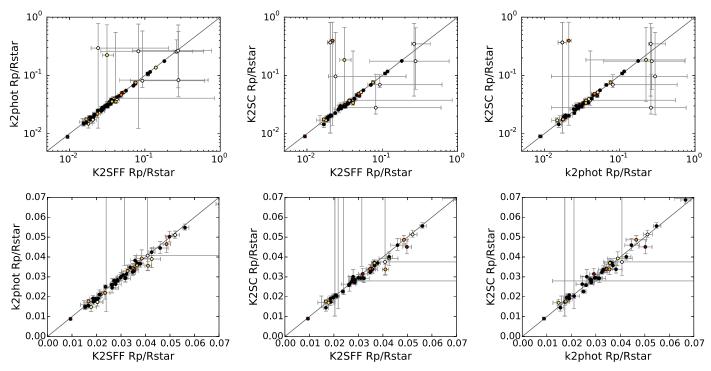


Figure 7. Comparison of planet/star radius ratios found by fitting photometry from different pipelines. The symbols are colored based on FPP using the same color scaling as in Figure 11; K2OIs with lower FPPs have darker colors. The top panels display all K2OIs while the bottom panels zoom in to highlight the K2OIs with small R_p/R_{\star} ratios. Only planet candidates and validated planets are shown. Left: k2phot fits vs. K2SFF fits. Middle: K2SC fits vs. K2SFF fits. Right: K2SC fits vs. k2phot fits.

lightcurves produced using the k2varcat (Armstrong et al. 2014, 2015, 2016) and EVEREST (Luger et al. 2016) pipelines are also available on the MAST, but we did not perform fits using those lightcurves.

Figure 7 compares the resulting planet/star radius ratios found by fitting photometry from the K2SFF, K2SC, and k2phot pipelines. For K2OIs with small R_p/R_{\star} , we find generally consistent planet properties regardless of our choice of photometric pipeline, but the estimates for K2OIs with $R_p/R_{\star} > 0.05$ can be quite discrepant. In general, the K2OIs with the largest radius disagreement are false positives for which the transit model provides a poor fit to the data. In contrast, nearly all of the K2OIs with $R_p/R_{\star} > 0.05$ appear well-fit by a transit model and many were classified as confirmed planets in Section 5 based on their K2SFF lightcurves.

Specifically, the median absolute difference in $R_p/R_{\star,\text{KSFF}}$ and $R_p/R_{\star,\text{k2phot}}$ is $\Delta R_p/R_{\star,\text{K2SFF-k2phot}} = 0.001$ for validated planets, $\Delta R_p/R_{\star,\text{K2SFF-k2phot}} = 0.002$ for planet candidates, and $\Delta R_p/R_{\star,\text{K2SFF-k2phot}} = 0.05$ for false positives. Comparing the KSFF and K2SC fits, we find similar median differences of 0.001 for validated planets and 0.003 for planet candidates, but a higher median difference of 0.12 for false positives. These values are comparable to the median differences of 0.001, 0.002, and 0.06 found when comparing the R_p/R_{\star} fits from the k2phot and K2SC pipelines for validated planets, planet candidates, and false positives, respectively.

Despite the overall agreement between the transit fits produced using distinct sets of photometry, there are a few K2OIs with large R_p/R_{\star} differences across pipelines. For instance, we noticed that the K2SC pipeline appeared to remove the transits of EPIC 211799258.01. Furthermore, our k2phot fits for EPIC 211826814.01 and EPIC 212443973.01 and our K2SC fits for EPIC 206312951.01 and EPIC 211694226.01 failed to converge on the transit midpoint. In general, we found that comparing fits from different pipelines was a convenient way to bolster confidence in borderline detections and reject astrophysical false positives due to blended photometry.

6.4. Updates to Transit Parameters

As shown in Table 2, many of the K2OIs analyzed in this paper were previously announced in other publications. Consulting the NASA Exoplanet Archive (Akeson et al. 2013), we found that 27, 17, 5, and 3 of our K2OIs were included in the candidate catalogs published by Crossfield et al. (2016), Vanderburg et al. (2016b), Montet et al. (2015), and Adams et al. (2016), respectively. In addition, 18 K2OIs were included in the Barros et al. (2016) catalog, 15 appeared in the Pope et al. (2016) catalog, and one (EPIC 205924614.01 = K2-55b) was part of the Schmitt et al. (2016) catalog. While the first set of catalogs included both transit parameters and physical properties like planetary and stellar radii, the second set did not convert transit parameters to physical properties. We compare the available fits for all K2OIs in Figure 8.

As shown in the top left panel, our period and planet/star radius ratio estimates are generally in agreement with past results. The median differences $(R_p/R_*)_{\text{revised}} - (R_p/R_*)_{\text{literature}}$ between our revised planet/star radius ratios and previously published values are 0.0005 (Adams et al. 2016, three K2OIs), -0.001 (Barros et al. 2016, 18 K2OIs, standard deviation $\sigma = 0.003$), 0.002 (Crossfield et al. 2016, 27 K2OIs, $\sigma = 0.072$), 0.002 (Pope et al. 2016, 15 K2OIs, $\sigma = 0.003$), -0.0007 (Montet et al. 2015, five K2OIs, $\sigma = 0.005$), -0.001(Schmitt et al. 2016, EPIC 205924614.01), and -0.0006(Vanderburg et al. 2016b, 17 K2OIs, $\sigma = 0.002$).

The right panels of Figure 8 reveal that our stellar radius estimates tend to be larger than the values used in previous studies. Specifically, we find median differences of $0.04 R_{\odot}$, $0.13 R_{\odot}$, $-0.03 R_{\odot}$, and $0.01 R_{\odot}$ compared to the radius estimates from Adams et al. (2016, three K2OIs), Crossfield et al. (2016, 27 K2OIs, $\sigma = 0.07$), Montet et al. (2015, five

K2OIs, $\sigma = 0.09$), and Vanderburg et al. (2016a, 17 K2OIs, $\sigma = 0.10$). Primarily due to the large difference between our stellar radius estimates, our planet radius estimates are typically $0.5 R_{\oplus}$ (35%) larger than those from Crossfield et al. (2016, $\sigma = 3 R_{\oplus}$). We measure smaller differences of $-0.01 R_{\oplus}$ (-1%), $-0.20 R_{\oplus}$ (-9%), and -0.13 (-5%) between our values and those from Adams et al. (2016, three K2OIs), Montet et al. (2015, five K2OIs, $\sigma = 1 R_{\oplus}$), and Vanderburg et al. (2016a, 17 K2OIs, $\sigma = 0.5 R_{\oplus}$), respectively. In comparison, our typical errors on planet radii are 6%–13%.

The two K2OIs with large changes are EPIC 201617985.01 and EPIC 201637175.01 (K2-22b). Crossfield et al. (2016) reported $P = 1.143201 \pm 0.000012$ days for EPIC 201637175.01 and $R_p/R_{\star} = 0.41^{+0.34}_{-0.34}$ for EPIC 201617985.01 whereas we found P = 0.38 days and $R_p/R_{\star} = 0.033^{+0.032}_{-0.024}$. Our shorter orbital period for EPIC 201637175.01 is one third of the value reported by Crossfield et al. (2016) and matches earlier estimates by Sanchis-Ojeda et al. (2015), Vanderburg et al. (2016b), and Adams et al. (2016). Similarly, our revised planet/star radius estimate for EPIC 201617985.01 is in agreement with previous estimates by Montet et al. (2015, $R_p/R_{\star} = 0.033$) and Vanderburg et al. (2016a, $R_p/R_{\star} = 0.032$).

We attribute the period error for EPIC 201637175.01 to the fact that the TERRA search did not consider threshold-crossing events with periods shorter than a day (Crossfield et al. 2016). For EPIC 201617985.01, the Crossfield et al. (2016) fit favored a large impact parameter ($b = 1.38^{+0.41}_{-0.31}$), which led to a broad posterior distribution of allowed planet radii. Excluding those two candidates does not alter the median differences between our revised values and those published by Crossfield et al. (2016), but considerably shrinks the standard deviations of the differences from 0.072 to 0.002 for the planet/star radius ratios and from 3 R_{\oplus} to 0.8 R_{\oplus} for the planet radii.

7. Discussion

Several of the planets in our sample are particularly interesting because they might be habitable, reside in systems with multiple transiting planets, or orbit particularly bright stars. For reference, we present schematics of all of the multiplanet systems and potentially habitable systems in Figure 9. We also discuss individual systems in the following sections.

For the purpose of planning potential follow-up observations, we first employed the planetary mass-radius relation presented in Weiss & Marcy (2014) to assign masses to the K2OIs and computed the expected radial velocity (RV) signal due to each planet. We display the resulting estimates in Figure 10. We note that the full range of small planet compositions is not well captured by a one-to-one mass-radius relation (Wolfgang & Lopez 2015; Chen & Kipping 2017), but these coarse mass estimates are sufficient for assessing the feasibility of future RV investigations.

In general, we find that these planets would be challenging targets for current RV spectrographs due to the small expected signal (median value = 2.3 m s^{-1}) and the faintness of their host stars at optical wavelengths. In addition, several of the easiest candidates in Figure 10 are unsuitable for RV observations: EPIC 210558622 was identified as an spectroscopic binary (Crossfield et al. 2016), EPIC 212679181 is accompanied by a fainter star 1.75 away,²⁸ and EPIC 216892056.01 is almost certainly a false positive.

²⁸ https://exofop.ipac.caltech.edu/k2/edit_obsnotes.php?id=212679181

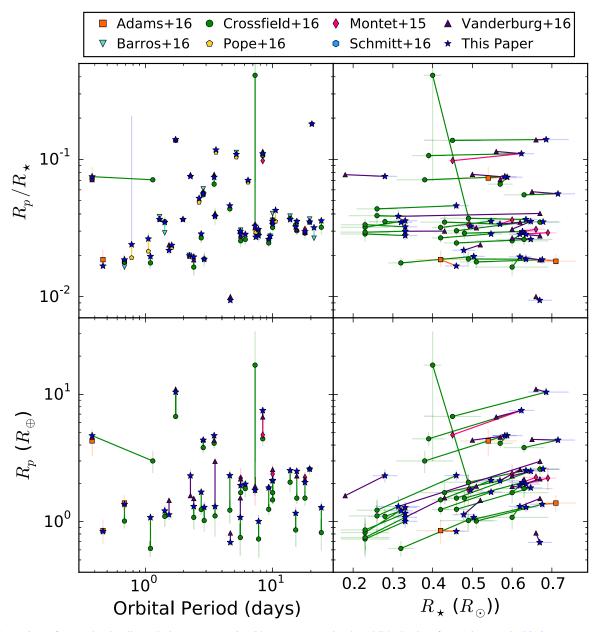


Figure 8. Comparison of our updated stellar and planetary properties (blue stars) to previously published values from Adams et al. (2016, orange squares), Barros et al. (2016, teal downward triangles), Crossfield et al. (2016, green circles), Pope et al. (2016, yellow pentagons), Montet et al. (2015, pink diamonds), Schmitt et al. (2016, light blue hexagons), and Vanderburg et al. (2016a, purple upward triangles). Where available, we display the errors using faded lines in the color assigned to each paper. The darker lines connect our revised values to the previously published estimates. Top left: planet/star radius ratio vs. orbital period. Top right: planet radius vs. orbital period. Bottom right: planet radius vs. stellar radius. Note that not all earlier papers contained estimates of physical planetary and stellar radii.

In contrast, the small Neptune EPIC 205924614.01 (K2-55b) is an ideal follow-up target and has already been observed by both Keck/HIRES and *Spitzer*. The validated small planets EPIC 210707130.01 and 212460519.01 are also attractive RV targets. We discuss K2-55b in detail in a separate publication (C. D. Dressing et al. 2017, in preparation) and consider the two smaller planets in Section 7.3.

Although our targets are generally poorly suited for RV mass measurements, they are more compelling candidates for transmission spectroscopy. The combination of the small sizes and red colors of their host stars produces larger transmission signals than would be expected for similar planets orbiting Sunlike stars with similar brightnesses in the *Kepler* bandpass. While our targets are moderately faint at visible wavelengths, they are modestly bright in the NIR. As shown in Figure 11, several planets should yield detectable transmission signals if our assumptions regarding planet masses and atmospheric compositions are correct.

We approximated the transmission signals shown in Figure 11 by assuming that the planetary atmospheres extend for five scale heights. When calculating the latter, we adopted the same planet masses as for the RV predictions and determined planetary equilibrium temperatures using a fixed planetary albedo of 0.3. We also assumed that each planet possesses a Jupiter-like atmosphere with a mean molecular weight of $2.2m_H$; planets with water-dominated atmospheres would generate transmission

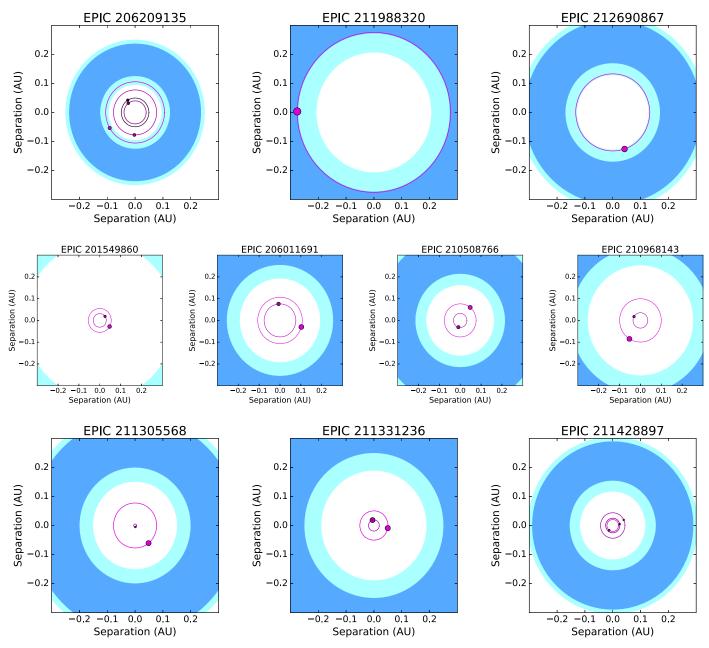


Figure 9. Orbits of potentially habitable planets and planets in multi-planet systems relative to the habitable zones of their host stars. The cyan regions indicate optimistic habitable zones (HZs) extending from the early-Mars outer boundary to the recent-Venus inner boundary while the blue regions denote more conservative HZs set by the maximum greenhouse outer limit and the moist greenhouse inner limit. Planet sizes are to scale relative to other planets, but not relative to the orbits. Each panel covers the same range of semimajor axes. Systems containing planets in the HZ are shown in the top row. Note that EPIC 211799258.01 is omitted because it is almost certainly a false positive (see Section 7.1.2).

signals an order of magnitude smaller. While exciting from a habitability standpoint, the smallest planets in our sample may be bare rocky cores without substantial atmospheres and would therefore be poor targets for transmission spectroscopy.

Consulting Figure 11, the most intriguing targets for atmospheric characterization are EPIC 201205469.01 (K2-43b, Crossfield et al. 2016), 201345483.01 (K2-45b, Crossfield et al. 2016), 201635569.01 (K2-14b, Montet et al. 2015; Crossfield et al. 2016), 205924614.01 (K2-55b, Crossfield et al. 2016), 206318379.01 (K2-28b, Hirano et al. 2016; G. Chen et al. 2017, in preparation), 211509553.01, 211818569.01 (K2-121b), and 212554013.01 (K2-127b). These planets span a broad range in both size and equilibrium temperature: EPIC 211509553.01 is a cool giant planet ($R_p = 10.8 \pm 0.6 R_{\oplus}$, $T_{eq} = 355$ K); EPIC 201345483.01 is a hot giant planet ($R_p = 10.4^{+0.9}_{-0.7} R_{\oplus}$, $T_{eq} = 988$ K); EPIC 201635569.01, EPIC 211818569.01, and EPIC 212554013.01 are warm giant planets ($R_p = 7.5 \pm 0.5 R_{\oplus}$, $T_{eq} = 527$ K; $R_p = 9.2 \pm 0.7 R_{\oplus}$, $T_{eq} = 756$ K; and $R_p = 8.7^{+0.7}_{-0.6} R_{\oplus}$, $T_{eq} = 789$ K, respectively); EPIC 201205469.01 and EPIC 205924614.01 are warm large Neptunes ($R_p = 4.8 \pm 0.3 R_{\oplus}$, $T_{eq} = 676$ K and $R_p = 4.4 \pm 0.3 R_{\oplus}$, $T_{eq} = 861$ K, respectively); and EPIC 20631 8379.01 is a warm small Neptune ($R_p = 2.3 \pm 0.3 R_{\oplus}$, $T_{eq} =$

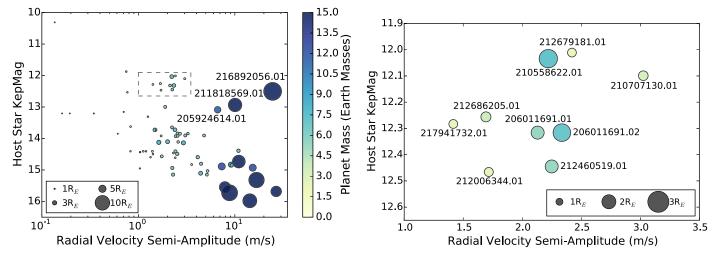


Figure 10. Host star *Kepler* magnitude vs. expected radial velocity (RV) semi-amplitude. The sizes of data points are scaled so that larger planets have bigger data points and the colors indicate the assumed planet masses. Left: estimated RV semi-amplitudes for all of the planets in our sample. Right: estimated RV semi-amplitudes of the small planets most amenable to RV observations. This panel shows a zoom-in of the boxed region in the left panel. We label key planets for ease of reference and discuss the most promising systems individually later in this section.

547 K). Of these planets, EPIC 205924614.01, 20618379.01, and 211818569.01 have the brightest host stars and are therefore the most favorable targets.

7.1. Systems with Planets in or Near the HZ

7.1.1. EPIC 206209135 (K2-72): Validated Four-planet System with an Earth-sized Planet in the HZ

EPIC 206209135 is an M2 dwarf (Kp = 14.407, Ks = 10.962) orbited by four transiting planets with periods of 5.577, 7.760, 15.189, and 24.167 days. All four planets were previously validated by Crossfield et al. (2016) based on careful scrutiny of the K2 photometry, follow-up imaging with Keck/NIRC2, and low FPPs as computed with VESPA (Morton 2015b). In their analysis, Crossfield et al. (2016) assumed a stellar radius of $0.232 \pm 0.056 R_{\odot}$, which is 30% smaller than our revised value of $0.33 \pm 0.03 R_{\odot}$ (D17). Despite the significant change in the assumed stellar parameters, our independent VESPA analysis also returned FPPs low enough to validate all four planets.

The outermost planet (EPIC 206209135.04) has a radius of $1.29^{+0.14}_{-0.13} R_{\oplus}$, a semimajor axis of $0.106^{+0.009}_{-0.013}$ au and an insolation flux of $1.2 \pm 0.2 F_{\oplus}$, placing it within the 0.22–1.52 F_{\oplus} (0.09–0.25 au) boundaries of the optimistic Venus/Mars HZ but outside the 0.28–0.91 F_{\oplus} (0.13–0.24 au) limits of the conservative moist greenhouse/maximum greenhouse HZ. The second outermost planet (EPIC 206209135.02) is slightly smaller ($R_p = 1.16 \pm 0.13 R_{\oplus}$) and lies inside the inner edge of the optimistic HZ ($F_p = 2.2 \pm 0.3 F_{\oplus}$, $a = 0.078^{+0.007}_{-0.010}$). The two innermost planets (EPIC 20 6209135.01 and EPIC 206209135.03) have radii of $1.08 \pm 0.11 R_{\oplus}$ and $1.01 \pm 0.12 R_{\oplus}$ and receive $8.5^{+1.2}_{-1.1} F_{\oplus}$ and 5.4^{+0.8}_{-0.7} F_{\oplus} , respectively. We note that our radius estimates for all four planets are consistent with the revised values found by Martinez et al. (2017), who used NTT/SOFI spectroscopy to characterize the host star and then scaled the R_p/R_{\star} values from Crossfield et al. (2016) accordingly.

The orbital periods of the four planets are in near-resonant configurations, which suggests that the system may have experienced disk-driven migration. Specifically, planets .01 and .03 (5.577 days and 7.760 days) are near the second-order 7:5 mean motion resonance and planets .03 and .02 (7.760 days and 15.189 days) are near the first-order 2:1 mean motion resonance. Planets .01 and .04 (5.577 days and 24.167 days) have an orbital period ratio of roughly 3:13.

Assuming that all four planets have rocky compositions and masses of $1.1-2.6 M_{\oplus}$ as suggested by the Weiss & Marcy (2014) mass-radius relation, the expected radial velocity perturbations from each planet individually would have semi-amplitudes of $0.8-1.4 \text{ m s}^{-1}$. Given that the host star is relatively faint (Kp = 14.407, Ks = 10.962) the system would be a challenging target for RV surveys. Fortunately, the near-resonant architecture of the system may enable planet mass measurements via transit timing variations (TTVs) rather than RVs. These TTV-based masses will be useful for interpreting the results of subsequent atmospheric characterization studies.

7.1.2. EPIC 211799258: New Candidate Cool Jupiter

This previously unknown planet candidate has a high FPP of 90%–94%, suggesting that the system is most likely a false positive. Our Gemini-N/NIRI imaging of the system was sensitive to companions 6.6 (7.6) magnitudes fainter than EPIC 211799258 at 0."5 (1."0) and did not reveal any companions, but our VESPA analysis suggested that the most likely false positive configuration for this system was an eclipsing binary that we would not expect to resolve in our AO imaging. If real, the planet candidate is a $9.5^{+6.3}_{-1.9} R_{\oplus}$ planet with an orbital period of 19.5 days. The host star is faint (Kp = 15.979, Ks = 12.185), but the planet should generate a large RV signal. Given the paucity of cool Jupiters known to transit low-mass stars, this system may warrant further study despite the low likelihood that the planetary interpretation is correct. If this transit-like event is indeed caused by eclipses involving the target star, high-resolution spectra acquired at opposite quadratures should reveal significant RV variation. In contrast, the absence of RV variation would rule out the foreground eclipsing binary scenario and possibly allow us to validate EPIC 211799258.01 as a genuine planet.

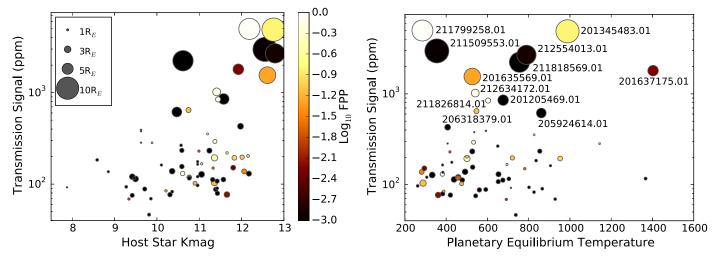


Figure 11. Estimated transmission spectroscopy signal vs. host star *K*-band magnitude (left) and planetary equilibrium temperature (right). As in Figure 10, the points are colored based on FPP and scaled by planet size. In the right panel, we label the planets with approximated transmission signals larger than 500 ppm. Note that these estimates assume that that the mean molecular weight of the atmosphere is $2.2m_H$; planets with heavier atmospheres would generate smaller transmission signals.

7.1.3. EPIC 211988320: New Candidate Small Neptune in the HZ

EPIC 211988320.01 $(2.86^{+0.16}_{-0.15} R_{\oplus})$ was originally identified as a transit-like event with an orbital period of 15 days, but our subsequent inspection of the light curve revealed that the orbital period is actually 63.8 days. The longer orbital period places EPIC 211988320.01 just within the boundaries of the conservative moist greenhouse/maximum greenhouse HZ of its MOV host star. Although this planet is likely too large to be rocky, its host star is bright enough (Kp = 14.122, Ks = 11.36) to enable future atmospheric characterization studies. Our estimated FPP for the candidate is 7%, but our analysis did not include AO or speckle imaging. While the system is too faint for radial velocity (Kp = 14.122, Ks = 11.360), acquiring AO or speckle images would be straightforward. Due to the long orbital period of EPIC 211983320.01, only two transits are visible in the K2 data. We therefore recommend acquiring additional transit observations to refine the orbital ephemeris prior to embarking upon an intensive atmospheric characterization campaign.

7.1.4. EPIC 212690867: New Candidate Small Neptune in the HZ

This small planet $(2.20^{+0.19}_{-0.18} R_{\oplus})$ has an orbital period of 25.9 days around a 3614^{+118}_{-107} K host star. The planet receives an insolation flux of $1.4^{+0.3}_{-0.2} F_{\oplus}$ and would be an intriguing target for atmospheric characterization if its host star were slightly brighter (Kp = 14.936, Ks = 12.061). Our VESPA analysis returned an FPP too large for validation (FPP = 3%-4%), but the planet could likely be validated if we acquired an AO or speckle image to rule out the remaining false positive scenarios.

7.1.5. EPIC 212398486 (K2-125): Newly Validated Mini-Neptune Near the HZ

The EPIC 212398486 system consists of a mini-Neptune orbiting an M2 dwarf on a 21.8 day orbit. The 3654^{+100}_{-92} K, $0.40 \pm 0.03 R_{\odot}$ host star has optimistic HZ boundaries of $0.2-1.5 F_{\oplus}$, just cooler than the $2.0 \pm 0.3 F_{\oplus}$ insolation flux received by the planet. At $R_p = 2.19^{+0.19}_{-0.18} R_{\oplus}$, the planet is very unlikely to be rocky, but it is still an attractive target for follow-up atmospheric characterization studies. The majority of well-

characterized mini-Neptunes are hot; the EPIC 212398486 system provides a complementary example of a cooler small planet. The system is fainter than most of our targets (Kp = 15.147, Ks = 11.802), but follow-up atmospheric studies should be feasible. Our VESPA analysis of the K2SFF photometry yielded an FPP = 0.2%-0.7%, allowing us to validate this previously unknown planet.

7.2. Systems with Multiple Transiting Planets

7.2.1. EPIC 201549860 (K2-35): Validated Two-planet System

The EPIC 201549860 (K2-35) system was validated by Sinukoff et al. (2016) as a 4680 \pm 60 K, 0.72 \pm 0.04 star hosting a 1.40 \pm 0.17 R_{\oplus} inner planet with a period of 2.4 days and 2.09^{+0.43}_{-0.31} R_{\oplus} outer planet with a period of 5.6 days. They characterized the host star by applying the SpecMatch (Petigura 2015) and isochrones (Morton 2015a) packages to optical spectra acquired with Keck/HIRES. Using IRTF/ SpeX NIR spectra, we classified the host star as a K4 dwarf with a cooler temperature of 4402^{+96}_{-93} K and a smaller radius of 0.62 \pm 0.03 (D17). After refitting the transit photometry, we revised the planet radii to 1.32 \pm 0.08 R_{\oplus} for the inner planet and $1.93^{+0.13}_{-0.11} R_{\oplus}$ for the outer planet. Both of these estimates are consistent with the Sinukoff et al. (2016) estimates.

7.2.2. EPIC 206011691 (K2-21): Validated Two-planet System

The NASA Exoplanet Archive describes the EPIC 206011691 system as containing a $1.25 \pm 0.11 R_{\oplus}$ inner planet on a 9.324 day orbit and a $1.53 \pm 0.14 R_{\oplus}$ outer planet with an orbital period of 15.498 days. Both planets were announced by Petigura et al. (2015), independently detected by Vanderburg et al. (2016b) and validated by Crossfield et al. (2016). In addition, Barros et al. (2016) detected the outer planet, but not the inner one.

The two planets are near the second-order 5:3 mean motion resonance, which may be a residual sign of past convergent migration. Neither planet is habitable and at V = 12.316 the host star is a challenging target for precise planet mass measurements via RV, but the system might exhibit TTVs. Accordingly, the system is one of the targets of our ongoing

Spitzer program to conduct follow-up transit observations of K2 planets (Program 10067, PI: M. Werner; Beichman et al. 2016).

Combining our new stellar characterization in D17 with our revised transit fits, we estimate the radii of the planets as $1.85 \pm 0.1 R_{\oplus}$ for the inner planet and $2.49^{+0.17}_{-0.19} R_{\oplus}$ for the outer planet. Our results are larger than the Petigura et al. (2015) estimates ($1.59 \pm 0.43 R_{\oplus}$ and $1.92 \pm 0.53 R_{\oplus}$, respectively), but they agree within the errors.

7.2.3. EPIC 210508766 (K2-83): Validated Two-planet System

The EPIC 210508766 system contains an M1 dwarf orbited by two super-Earths: a $1.71 \pm 0.10 R_{\oplus}$ planet on a 2.747 day orbit and a $2.11 \pm 0.12 R_{\oplus}$ planet on a longer 9.997 day orbit. Neither planet is habitable ($F_p = 39 \pm 6 F_{\oplus}$ and $F_p = 6.9^{+1.1}_{-1.0} F_{\oplus}$, respectively) and the system is too faint for RV mass measurement (Kp = 13.844, Ks = 10.765), but obtaining transmission spectra of both planets would be an interesting exercise in comparative planetology.

Both planets were previously validated by Crossfield et al. (2016). As discussed in Section 5.2, we confirm the validation of both planets as long as we account for the fact that planets in multi-planet systems are less likely to be false positives (Lissauer et al. 2012; Sinukoff et al. 2016; Vanderburg et al. 2016a).

7.2.4. EPIC 210968143 (K2-90): Validated Two-planet System

EPIC 210968143 is a K5 dwarf hosting two planets validated by Crossfield et al. (2016) and re-validated in this paper. The outer planet $(2.53^{+0.13}_{-0.13} R_{\oplus})$ has a 13.734 day orbital period and the inner planet $(1.30^{+0.13}_{-0.11} R_{\oplus})$ has a 2.901 day orbital period. The two planets are far from resonance and the host star is too faint at optical wavelengths for precise mass measurement (Kp = 13.723), but the brighter IR magnitude of Ks = 10.36renders the system amenable to atmospheric investigations. The inner planet EPIC 210968143.02 is highly irradiated ($F_p = 81^{+13}_{-11} F_{\oplus}$), but the outer planet EPIC 210968143.01 receives much less insolation ($F_p = 10.2^{+1.7}_{-1.4} F_{\oplus}$). A transmission spectrum of EPIC 210968143.01 might therefore help improve our understanding of less highly irradiated mini-Neptune atmospheres.

7.2.5. EPIC 211305568: Candidate Two-planet System

This M1V star was observed by K2 during Campaign 5. There are two K2OIs associated with the target, but neither is particularly compelling. The deeper transit-like events are attributed to 211305568.01, a $2.0_{-0.3}^{+39.2} R_{\oplus}$ K2OI with an orbital period of 11.6 days and the shallower events to 211305568.02, a small ($0.7 \pm 0.10 R_{\oplus}$) K2OI with an ultra-short orbital period of 0.2 days. We calculated a high FPP for 211305568.01 (FPP = 55%-100%), but VESPA could not fit the putative transits of EPIC 211305568.02 and therefore did not return an FPP. We classify both K2OIs as planet candidates in this paper, but we urge readers to obtain additional follow-up observations to verify the veracity of these signals. The star is moderately faint at optical wavelengths (Kp = 13.849), but easily observable at redder wavelengths (Ks = 10.608).

7.2.6. EPIC 211331236 (K2-117): Newly Validated Two-planet System

This system contains two short-period super-Earths $(1.96 \pm 0.12 R_{\oplus} \text{ at } 1.292 \text{ days}, 2.03 \pm 0.13 R_{\oplus} \text{ at } 5.444 \text{ days})$ orbiting an M3 dwarf with a temperature of 3842 ± 82 K and a radius of $0.49 \pm 0.03 R_{\odot}$. The star is too faint for RV observations (Kp = 13.905, Ks = 10.589), but the system is amenable to atmospheric characterization (see Figure 11).

7.2.7. EPIC 211428897: Candidate Three-planet System

The M2 dwarf EPIC 211428897 hosts three transiting Earth-sized planets with orbital periods of 1.611, 2.218, and 4.969 days and radii of $0.75 \pm 0.08 R_{\oplus}$, $0.65 \pm 0.07 R_{\oplus}$, and $0.67 \pm 0.08 R_{\oplus}$, respectively. The inner two planet candidates are near the first-order 4:3 mean motion resonance and planet candidates .01 and .03 (1.611 days and 4.969 days) are near the second-order 3:1 mean motion resonance. Due to the small planet sizes, the anticipated RV semi-amplitudes of $0.2-0.3 \text{ m s}^{-1}$ are too small to be detected by current spectrographs (and the Kp = 13.2, Ks = 9.624 host star is too faint at optical wavelengths for high-precision RV observations), but the masses of the planets could be estimated via TTVs. The VESPA FPPs for these planets would be low enough to merit validation in the absence of nearby stars, but the presence of a nearby star precludes the use of VESPA for this system and means that the planets are larger than our estimates would suggest. The nearby star is roughly 1 magnitude fainter than and approximately 1."1 away from the target star. The correction factor for the planet radius estimates depends on which of the targets hosts the planets, but is likely to be on the order of a few (Ciardi et al. 2015, 2017; Furlan et al. 2017).

7.3. Systems Orbiting Bright Stars

7.3.1. EPIC 210707130 (K2-85): Relatively Bright Star Hosting a Validated Earth-sized Planet with an Ultra-short Orbital Period

As shown in Figure 10, EPIC 210707130.01 (K2-85b) is one of the most attractive RV targets in our sample. This ultrashort-period $1.37 \pm 0.11 R_{\oplus}$ planet orbits a moderately bright (Kp = 12.099, Ks = 9.466) K5 dwarf every 0.685 days and was validated by Crossfield et al. (2016). Using the massradius relation from Weiss & Marcy (2014), we estimate a planet mass of $3.3 M_{\oplus}$, which is consistent with the expectation that highly irradiated small planets tend to have rocky compositions (Dressing et al. 2015). Given the estimated host star mass of $0.70 M_{\odot}$, the anticipated RV semi-amplitude is 3.0 m s^{-1} .

7.3.2. 212460519 (K2-126): Moderately Bright Star Hosting a Newly Validated Super-Earth

EPIC 212460519 is a moderately bright star (Kp = 12.445, Ks = 9.712) hosting a $1.84^{+0.11}_{-0.10} R_{\oplus}$ planet with a 7.4 day orbital period. The planet is too hot to be habitable ($F_p = 35^{+7}_{-6} F_{\oplus}$), but might be an interesting target for atmospheric characterization. Assuming $m_p = 5.4 M_{\oplus}$ as predicted by the Weiss & Marcy (2014) mass-radius relation, EPIC 212460519.01 is expected to induce an RV semi-amplitude of 2.2 m s⁻¹.

8. Conclusions

Due to the dependence of planet radius estimates on host star characterization, our recent work improving the classification of cool dwarfs observed by K2 significantly affected the assumed properties of the associated planet candidates. In general, we found that the host star radii were underestimated by 8%-40% (D17), implying that the initial planet radius estimates were also undersized. In this paper, we investigated 79 candidate transit signals in the lightcurves of 74 low-mass K2 target stars and provided an updated catalog of planet properties. Our revisions to the system properties include both improved classifications of the host stars from D17 and our new transit fits. As part of the analysis, we also assessed the credibility of each planet candidate by using the VESPA framework developed by Morton (2012, 2015b) to calculate the probability that each transit-like event was caused by an astrophysical false positive rather than a genuine planetary transit.

In total, we considered 79 putative transit events. We rejected six as false positives, validated 16 as bona fide planets, and classified 17 new planet candidates. We also upheld the previous classifications of two false positives and provided updated planet radius estimates for 16 planet candidates and 22 validated planets announced in earlier publications.

Our cool dwarf planet sample is dominated by small worlds: 55% (39) are smaller than $2R_{\oplus}$ and 85% (60) are smaller than Neptune. Compared to the planets detected during the prime Kepler mission, our candidates tend to orbit brighter stars that are more amenable to follow-up observations. In particular, the thirteen small planets with radii of 1.5–3 R_{\oplus} and host stars brighter than Ks = 11 are likely targets for atmospheric characterization studies with Spitzer, HST, and JWST. Furthermore, radial velocity observations may be feasible for the brightest systems, particularly given the advent of red spectrographs like CARMENES (Quirrenbach et al. 2010), the Habitable Zone Planet Finder (Mahadevan et al. 2010), the Infrared Doppler instrument (Tamura et al. 2012; Kotani et al. 2014), iSHELL (Rayner et al. 2012), and SpiROU (Delfosse et al. 2013; Artigau et al. 2014).

As the K2 mission continues, additional planets will be detected around stars across the ecliptic. We will continue to conduct follow-up observations for future targets and eagerly await the opportunity to characterize the best systems with the *JWST*. Beginning in 2018, we will expand our follow-up program to include planet candidates detected by the Transiting Exoplanet Survey Satellite (Ricker et al. 2014; Sullivan et al. 2015), which is scheduled to launch in 2018 March.

Many of our targets were provided by the K2 California Consortium (K2C2). We thank K2C2 for sharing their candidate lists and vetting products. We are grateful to Tim Morton for making VESPA publicly available and to Jennifer Winters, Nic Scott, and Lea Hirsch for assisting with speckle imaging. We also acknowledge helpful conversations with Chas Beichman, Eric Gaidos, Jessie Christiansen, Michael Werner, and Arturo Martinez. We thank the anonymous referee for providing helpful suggestions to improve the paper.

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Our stellar characterization follow-up observations were obtained at the Infrared Telescope Facility, which is operated by the University of Hawaii under contract NNH14CK55B with the National Aeronautics and Space Administration and at Palomar Observatory. We thank the staff at both observatories and the Caltech Remote Observing Facilities staff for supporting us during our many observing runs. We are grateful to the IRTF and Caltech TACs for awarding us telescope time.

Our contrast curves were based on observations obtained at Gemini Observatory, Kitt Peak National Observatory via the NN-EXPLORE program time allocation at the WIYN telescope, and the W.M. Keck Observatory. Kitt Peak National Observatory, National Optical Astronomy Observatory, is operated by the Association of Universities for Research in Astronomy (AURA) under a cooperative agreement with the National Science Foundation. Gemini Observatory is operated by the Association of Universities for Research in Astronomy, Inc., under a cooperative agreement with the NSF on behalf of the Gemini partnership: the National Science Foundation (United States), the National Research Council (Canada), CONICYT (Chile), Ministerio de Ciencia, Tecnología e Innovación Productiva (Argentina), and Ministério da Ciência, Tecnologia e Inovação (Brazil). The W.M. Keck Observatory is operated as a scientific partnership among the California Institute of Technology, the University of California and the National Aeronautics and Space Administration. The Observatory was made possible by the generous financial support of the W.M. Keck Foundation.

The authors wish to recognize and acknowledge the very significant cultural role and reverence that the summit of Maunakea has always had within the indigenous Hawaiian community. We are most fortunate to have the opportunity to conduct observations from this mountain.

Facilities: Kepler, K2, IRTF (SpeX), Palomar:Hale (TripleSpec, PALM-3000/PHARO), Gemini-N (DSSI, NIRI), Gemini-S (DSSI), Keck:II (NIRC2), WIYN (DSSI).

Appendix Vetting Plots

As discussed in Section 5, we have posted transit fits and false positive assessments for all K2OIs on the ExoFOP-K2 website. Figures 12-14 provide an example set of vetting data products. The K2OIs featured are a newly validated planet (EPIC211680698.01 = K2-118b, Figure 12), a newly detected planet candidate (EPIC 212634172.01, Figure 13), and a newly rejected false positive (EPIC 212679798.01, Figure 14).

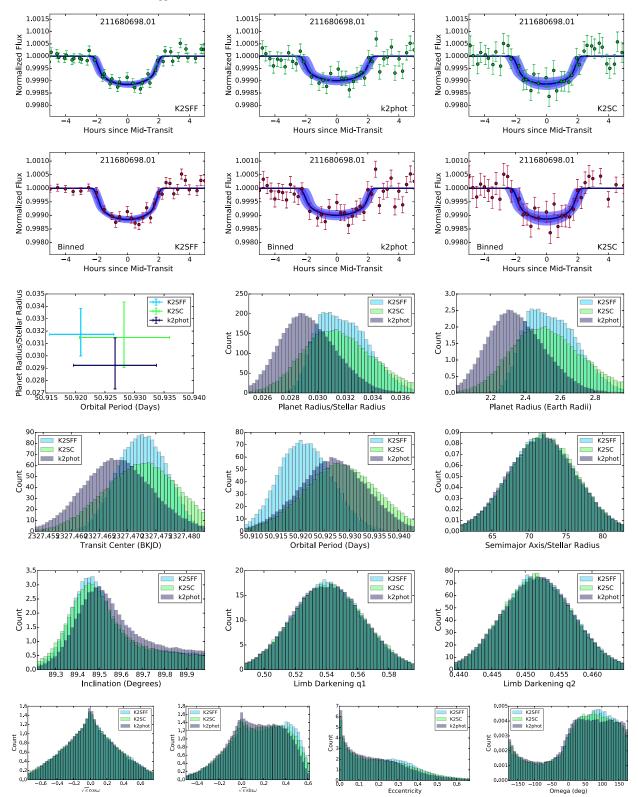


Figure 12. Example set of vetting plots showing transit fits and parameter posterior distributions for EPIC 211680698.01, a previously unknown planet validated in this paper as K2-118b. Top row: K2 data processed by the K2SFF (left), k2phot (middle), and K2SC (right) pipelines and phase-folded to the orbital period of EPIC 211680698.01. The dark blue lines indicate the median transit model fit to each version of the photometry and the medium (light) blue mark 1σ (2σ) contours. Second row: same as top row, but the K2 data points are binned to better reveal the quality of the transit fits. Third row, left column: comparison of the planet/star radius ratios and orbital periods found when fitting K2SFF (light blue), K2SC (green), and k2phot (dark purple) photometry. All remaining panels: posterior probability distributions for the indicated transit parameter. The translucent histograms compare the results produced by fitting K2 photometry processed using K2SFF (light blue), K2SC (light green), and k2phot (gray).

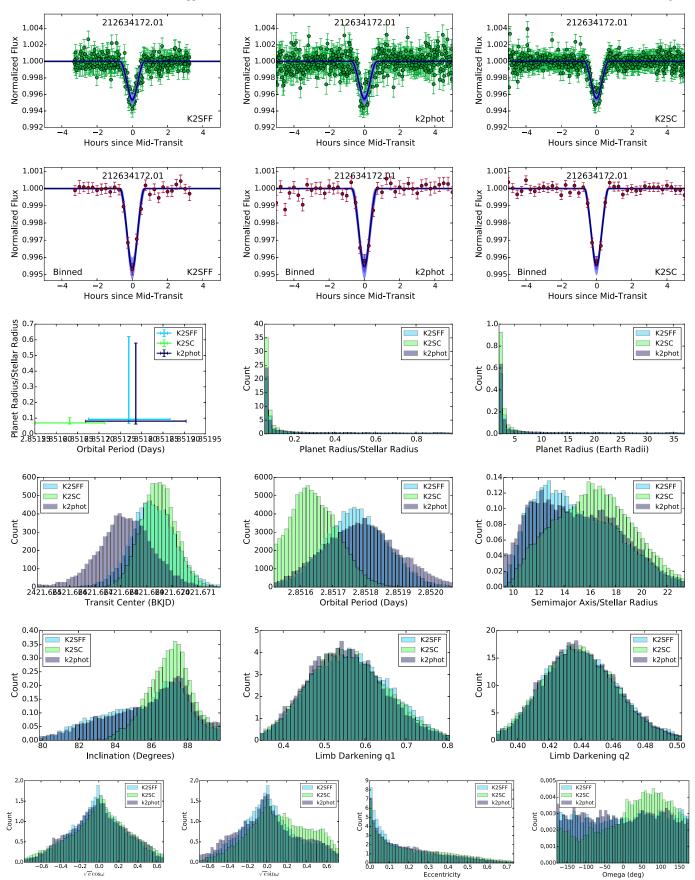


Figure 13. Same as Figure 12 but for the newly detected planet candidate EPIC 212634172.01.

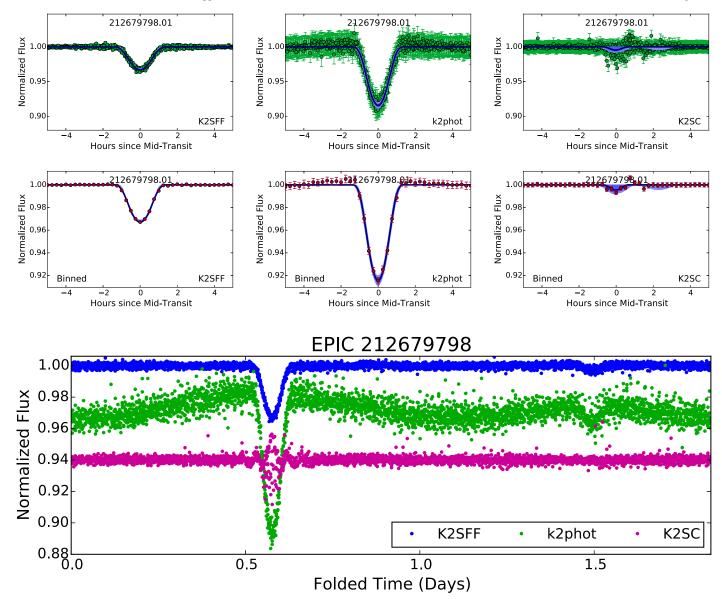


Figure 14. Top two rows: same as Figure 12 but for newly rejected false positive EPIC 212679798.01. Bottom row: phase-folded light curve of EPIC 212679798 shown over the full orbital period of K2OI 212679798.01. The KSFF (blue, top) and k2phot (green, middle) photometry display a clear secondary eclipse near 1.5 days. The K2SC photometry (magenta, bottom) has removed the secondary eclipse and partially flattened the primary eclipse. Note that the depth of the primary and secondary eclipses are also deeper in the k2phot photometry than in the K2SFF photometry. The event depth discrepancy is likely due to the different default photometric apertures used by both pipelines.

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References

Adams, E. R., Jackson, B., & Endl, M. 2016, arXiv:1603.06488 Aigrain, S., Hodgkin, S. T., Irwin, M. J., Lewis, J. R., & Roberts, S. J. 2015,

MNRAS, 447, 2880 Aigrain, S., Parviainen, H., & Pope, B. J. S. 2016, MNRAS, 459, 2408 Akeson, R. L., Chen, X., Ciardi, D., et al. 2013, PASP, 125, 989 Armstrong, D. J., Kirk, J., Lam, K. W. F., et al. 2015, A&A, 579, A19 Armstrong, D. J., Kirk, J., Lam, K. W. F., et al. 2016, MNRAS, 456, 2260 Armstrong, D. J., Osborn, H. P., Brown, D. J. A., et al. 2014, arXiv:1411.6830 Artigau, É, Kouach, D., Donati, J.-F., et al. 2014, Proc. SPIE, 9147, 15 Baraffe, I., Selsis, F., Chabrier, G., et al. 2004, A&A, 419, L13 Barros, S. C. C., Demangeon, O., & Deleuil, M. 2016, arXiv:1607.02339 Beichman, C., Livingston, J., Werner, M., et al. 2016, ApJ, 822, 39 Boyajian, T. S., von Braun, K., van Belle, G., et al. 2012, ApJ, 757, 112 Boyajian, T. S., von Braun, K., van Belle, G., et al. 2013, ApJ, 771, 40

Casagrande, L., Flynn, C., & Bessell, M. 2008, MNRAS, 389, 585

- Chen, J., & Kipping, D. 2017, ApJ, 834, 17
- Ciardi, D. R., Beichman, C. A., Horch, E. P., & Howell, S. B. 2015, ApJ, 805 16
- Ciardi, D. R., Beichman, C. A., Horch, E. P., & Howell, S. B. 2017, ApJ, 834.96
- Claret, A., Hauschildt, P. H., & Witte, S. 2012, A&A, 546, A14
- Crossfield, I. J. M., Ciardi, D. R., Petigura, E., et al. 2016, ApJS, 226, 7
- Delfosse, X., Bonfils, X., Forveille, T., et al. 2013, A&A, 553, A8
- Díaz, R. F., Almenara, J. M., Santerne, A., et al. 2014, MNRAS, 441, 983
- Dressing, C. D., & Charbonneau, D. 2013, ApJ, 767, 95
- Dressing, C. D., Charbonneau, D., Dumusque, X., et al. 2015, ApJ, 800, 135
- Dressing, C. D., Newton, E. R., Schlieder, J. E., et al. 2017, ApJ, 836, 167
- Eastman, J., Gaudi, B. S., & Agol, E. 2013, PASP, 125, 83
- Feiden, G. A., & Chaboyer, B. 2012, ApJ, 757, 42
- Foreman-Mackey, D., Hogg, D. W., Lang, D., & Goodman, J. 2013, PASP, 125, 306
- Foreman-Mackey, D., Montet, B. T., Hogg, D. W., et al. 2015, ApJ, 806, 215
- Fressin, F., Torres, G., Charbonneau, D., et al. 2013, ApJ, 766, 81
- Fressin, F., Torres, G., Désert, J.-M., et al. 2011, ApJS, 197, 5
- Furlan, E., Ciardi, D. R., Everett, M. E., et al. 2017, AJ, 153, 71
- González Hernández, J. I., & Bonifacio, P. 2009, A&A, 497, 497
- Hayward, T. L., Brandl, B., Pirger, B., et al. 2001, PASP, 113, 105
- Hirano, T., Fukui, A., Mann, A. W., et al. 2016, ApJ, 820, 41
- Hodapp, K. W., Jensen, J. B., Irwin, E. M., et al. 2003, PASP, 115, 1388
- Horch, E. P., Howell, S. B., Everett, M. E., & Ciardi, D. R. 2012, AJ, 144, 165
- Howell, S. B., Everett, M. E., Sherry, W., Horch, E., & Ciardi, D. R. 2011, AJ, 142, 19
- Howell, S. B., Sobeck, C., Haas, M., et al. 2014, PASP, 126, 398
- Huber, D., Bryson, S. T., Haas, M. R., et al. 2016, ApJS, 224, 2
- Huber, D., Silva Aguirre, V., Matthews, J. M., et al. 2014, ApJS, 211, 2
- Kipping, D. M. 2013a, MNRAS, 435, 2152
- Kipping, D. M. 2013b, MNRAS, 434, L51
- Kopparapu, R. K., Ramirez, R., Kasting, J. F., et al. 2013, ApJ, 765, 131
- Kopparapu, R. K., Ramirez, R. M., SchottelKotte, J., et al. 2014, ApJL, 787. J.29
- Kotani, T., Tamura, M., Suto, H., et al. 2014, Proc. SPIE, 9147, 14
- Kraus, A. L., Tucker, R. A., Thompson, M. I., Craine, E. R., & Hillenbrand, L. A. 2011, ApJ, 728, 48
- Kreidberg, L. 2015, PASP, 127, 1161
- Kurokawa, H., & Kaltenegger, L. 2013, MNRAS, 433, 3239
- Lammer, H., Selsis, F., Ribas, I., et al. 2003, ApJL, 598, L121
- Lissauer, J. J., Marcy, G. W., Rowe, J. F., et al. 2012, ApJ, 750, 112
- Lopez, E. D., & Fortney, J. J. 2013, ApJ, 776, 2
- Lopez, E. D., Fortney, J. J., & Miller, N. 2012, ApJ, 761, 59
- Luger, R., Agol, E., Kruse, E., et al. 2016, AJ, 152, 100
- Mahadevan, S., Ramsey, L., Wright, J., et al. 2010, Proc. SPIE, 7735, 77356X Mandel, K., & Agol, E. 2002, ApJL, 580, L171

- Mann, A. W., Brewer, J. M., Gaidos, E., Lépine, S., & Hilton, E. J. 2013a, AJ, 145, 52
- Mann, A. W., Feiden, G. A., Gaidos, E., Boyajian, T., & von Braun, K. 2015, ApJ, 804, 64
- Mann, A. W., Gaidos, E., & Ansdell, M. 2013b, ApJ, 779, 188
- Mann, A. W., Gaidos, E., Vanderburg, A., et al. 2017, AJ, 153, 64
- Martinez, A. O., Crossfield, I. J. M., Schlieder, J. E., et al. 2017, ApJ, 837, 72
- Montet, B. T., Morton, T. D., Foreman-Mackey, D., et al. 2015, ApJ, 809, 25
- Morton, T. D. 2012, ApJ, 761, 6 Morton, T. D. 2015a, Isochrones: Stellar Model Grid Package, Astrophysics
- Source Code Library, ascl:1503.010
- Morton, T. D. 2015b, VESPA: False positive probabilities calculator, Astrophysics Source Code Library, ascl:1503.011
- Muirhead, P. S., Becker, J., Feiden, G. A., et al. 2014, ApJS, 213, 5
- Muirhead, P. S., Hamren, K., Schlawin, E., et al. 2012, ApJL, 750, L37
- Murray-Clay, R. A., Chiang, E. I., & Murray, N. 2009, ApJ, 693, 23
- Newton, E. R., Charbonneau, D., Irwin, J., & Mann, A. W. 2015, ApJ, 800, 85
- Owen, J. E., & Wu, Y. 2013, ApJ, 775, 105
- Pecaut, M. J., & Mamajek, E. E. 2013, ApJS, 208, 9
- Petigura, E. A. 2015, PhD thesis, Univ. California
- Petigura, E. A., Marcy, G. W., & Howard, A. W. 2013, ApJ, 770, 69
- Petigura, E. A., Schlieder, J. E., Crossfield, I. J. M., et al. 2015, ApJ, 811, 102
- Pope, B. J. S., Parviainen, H., & Aigrain, S. 2016, MNRAS, arXiv:1606.01264
- Quirrenbach, A., Amado, P. J., Mandel, H., et al. 2010, Proc. SPIE, 7735, 773513
- Rayner, J., Bond, T., Bonnet, M., et al. 2012, Proc. SPIE, 8446, 84462C
- Ricker, G. R., Winn, J. N., Vanderspek, R., et al. 2014, JATIS, 1, 014003
- Sanchis-Ojeda, R., Rappaport, S., Pallè, E., et al. 2015, ApJ, 812, 112
- Sanchis-Ojeda, R., Rappaport, S., Winn, J. N., et al. 2014, ApJ, 787, 47
- Sanz-Forcada, J., Micela, G., Ribas, I., et al. 2011, A&A, 532, A6
- Schmitt, J. R., Tokovinin, A., Wang, J., et al. 2016, AJ, 151, 159
- Seager, S., & Mallén-Ornelas, G. 2003, ApJ, 585, 1038
- Sinukoff, E., Howard, A. W., Petigura, E. A., et al. 2016, ApJ, 827, 78
- Sozzetti, A., Torres, G., Charbonneau, D., et al. 2007, ApJ, 664, 1190
- Spada, F., Demarque, P., Kim, Y.-C., & Sills, A. 2013, ApJ, 776, 87
- Sullivan, P. W., Winn, J. N., Berta-Thompson, Z. K., et al. 2015, ApJ, 809, 77
- Tamura, M., Suto, H., Nishikawa, J., et al. 2012, Proc. SPIE, 8446, 84461T
- Torres, G., Fressin, F., Batalha, N. M., et al. 2011, ApJ, 727, 24
- Torres, G., Winn, J. N., & Holman, M. J. 2008, ApJ, 677, 1324
- Valencia, D., Ikoma, M., Guillot, T., & Nettelmann, N. 2010, A&A, 516, A20
- Van Cleve, J. E., Howell, S. B., Smith, J. C., et al. 2016, PASP, 128, 075002
- Vanderburg, A., Bieryla, A., Duev, D. A., et al. 2016a, ApJL, 829, L9
- Vanderburg, A., & Johnson, J. A. 2014, PASP, 126, 948
- Vanderburg, A., Latham, D. W., Buchhave, L. A., et al. 2016b, ApJS, 222, 14 von Braun, K., Boyajian, T. S., van Belle, G. T., et al. 2014, MNRAS,
- 438, 2413 Watson, A. J., Donahue, T. M., & Walker, J. C. G. 1981, Icar, 48, 150
- Weiss, L. M., & Marcy, G. W. 2014, ApJL, 783, L6
- Wolfgang, A., & Lopez, E. 2015, ApJ, 806, 183