



Exoplanets Catalogue Analysis: The Distribution of Exoplanets at FGK Stars by Mass and Orbital Period Accounting for the Observational Selection in the Radial Velocity Method

Vladislava Ananyeva, Anastasiia Ivanova, Inna Shashkova, Oleg Yakovlev, Ale ander Tavrov, Oleg Korablev, Jean-Loup Bertaux

► To cite this version:

Vladislava Ananyeva, Anastasiia Ivanova, Inna Shashkova, Oleg Yakovlev, Ale ander Tavrov, et al.. Exoplanets Catalogue Analysis: The Distribution of Exoplanets at FGK Stars by Mass and Orbital Period Accounting for the Observational Selection in the Radial Velocity Method. Atmosphere, 2023, 14, pp.353. 10.3390/atmos14020353 . insu-03989389

HAL Id: insu-03989389

<https://insu.hal.science/insu-03989389>

Submitted on 14 Feb 2023

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.


L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons Attribution 4.0 International License

Article

Exoplanets Catalogue Analysis: The Distribution of Exoplanets at FGK Stars by Mass and Orbital Period Accounting for the Observational Selection in the Radial Velocity Method

Vladislava Ananyeva ¹, Anastasiia Ivanova ¹, Inna Shashkova ^{1,*} , Oleg Yakovlev ¹, Alexander Tavrov ¹, Oleg Korablev ¹ and Jean-Loup Bertaux ²

¹ Space Research Institute (IKI), Russian Academy of Sciences, Moscow 117997, Russia

² LATMOS/IPSL, Université de Versailles Saint-Quentin, 11, Boulevard d'Alembert, F-78280 Guyancourt, France

* Correspondence: shi@iki.rssi.ru

Abstract: When studying the statistics of exoplanets, it is necessary to take into account the effects of observational selection and the inhomogeneity of the data in the exoplanets databases. When considering exoplanets discovered by the radial velocity technique (RV), we propose an algorithm to account for major inhomogeneities. We show that the de-biased mass distribution of the RV exoplanets approximately follows to a piecewise power law with the breaks at ~ 0.14 and ~ 1.7 M_J . FGK host stars planets group shows an additional break at 0.02 M_J . The distribution of RV planets follows the power laws of: $dN/dm \propto m^{-3}$ (masses of 0.011–0.087 M_J), $dN/dm \propto m^{-0.8 \dots -1}$ (0.21–1.7 M_J), $dN/dm \propto m^{-1.7 \dots -2}$ (0.087–0.21 M_J). There is a minimum of exoplanets in the range of 0.087–0.21 M_J . Overall, the corrected RV distribution of the planets over the minimum masses is in good agreement with the predictions of population fusion theory in the range (0.14–13 M_J) and the new population fusion theory in the range (0.02–0.14 M_J). The distributions of planets of small masses (0.011–0.14 M_J), medium masses (0.14–1.7 M_J), and large masses (1.7–13 M_J) versus orbital period indicate a preferential structure of planetary systems, in which the most massive planets are in wide orbits, as analogous to the Solar system.

Keywords: extrasolar planets radial velocity; mass and orbital period distribution; FGK host stars planets group; account for observational selection



Citation: Ananyeva, V.; Ivanova, A.; Shashkova, I.; Yakovlev, O.; Tavrov, A.; Korablev, O.; Bertaux, J.-L.

Exoplanets Catalogue Analysis: The Distribution of Exoplanets at FGK Stars by Mass and Orbital Period Accounting for the Observational Selection in the Radial Velocity Method. *Atmosphere* **2023**, *14*, 353. <https://doi.org/10.3390/atmos14020353>

Academic Editor: Elizabeth A. Silber

Received: 21 December 2022

Revised: 1 February 2023

Accepted: 3 February 2023

Published: 10 February 2023



Copyright: © 2023 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

1. Introduction

The statistics of existing exoplanets are modified by observational biases, and differ from the statistics of detected exoplanets, e.g., as it is directly obtained from exoplanet catalogue [1] (other active catalogs such as <http://exoplanet.eu/> (accessed on 30 June 2022) include the same confirmed planets, with a few exceptions. We chose the NASA Exoplanet Archive, and other catalogs can be used. We hope some differences in data content will be irrelevant for the presented analysis, but the verification is left for future work). The detection capability of a particular survey does not have the same response for all planet types and for all host star types. The observational bias factor for a certain type of planet depends mainly on the characteristics of the instrument dedicated to a given survey and on the duration of the survey. When making and studying the statistics of exoplanets, one should take into account the inhomogeneity of the data of the various surveys in the published archives (open databases). For exoplanets discovered with the radial velocity (RV) technique, the data inhomogeneity is mainly caused by differences in the sensitivity of spectrographs, the activity level of host stars, the duration of observations, the number of RV measurements (coverage of the RV orbital phase), the efficiency of applied data processing technique, and planets' multiplicity (detectability in multi-planet systems is significantly harder than in single-planet systems).

We start our de-biasing principle at the upper level: we accept the exoplanet detection event as it is listed in the catalogue [1]. We understand a possible discussion about whether the catalogue detection fact by most RV surveys could provide the necessary input needed to support the completeness of statistical analysis de-biasing. Logically, the proposed de-biasing on a *catalogue* level cannot be complete, perhaps it cannot resolve important fine details, but surely it can recover important statistical inhomogeneities at the top level and drastically improve the raw catalogue statistics. To validate our approach, we shall refer the reader to compare both the biased and the obtained de-biased dependencies with alternative (i) cosmogony models of, e.g., the population synthesis [2,3] and (ii) with the transit exoplanets statistics, e.g., [4]. We intend to demonstrate here a reasonably good correspondence (with both (i) and (ii)) for the obtained de-biased mass distribution, while the raw (biased) distribution falls short of the number of light mass planet more than in two orders.

Operating with the catalogue data, we have to account for the overall statistical distribution of planetary masses and periods which are dependent on the mass of host star. This concerns both overall planet abundance and the architecture of planetary systems (e.g., [5–7]). Therefore, we select the group of FGK host stars for additional analysis.

Second, we do not want to mix the host stars that were targeted in blind RV surveys with those that were chosen only because of follow-up of transiting planets, e.g., WASP-8, Kepler-56, Kepler-94, and Kepler-424. These host stars and planets were excluded from the analysis to improve such an inhomogeneity for the de-biased statistics.

Transiting planets whose masses have been measured by the radial velocity technique are subject to other observational selection biases (in particular, (i) the probability of a transiting configuration is reciprocally proportional to the distance between the planet and the star, (ii) transiting planets discovered by ground surveys are mostly giant planets because the Earth's atmosphere makes shallow transits invisible). Obviously, the transiting planets with measured mass should be considered separately.

Consequently, within some observational surveys, planets with certain properties (e.g., the orbital period and the minimum mass ($M \cdot \sin i$, where M is the *true* mass of a planet and i is the angle between the perpendicular to the orbital plane of a planet and the line of sight) can be detected, while the other surveys fail to find them. For example, a low-mass planet orbiting a low-active star can only be detected with a high-precision spectrograph rather than with a less sensitive instrument. At the same time, a low-mass planet orbiting a quickly rotating active star cannot be detected even with a high-precision spectrograph. Finally, to detect long-period planets, the radial velocity of a host star should be measured over a long period of time, sufficient for the planet to cover a large part of its orbit. Massive planets on close orbits around their host stars may be detected within almost any observational survey. At the same time considerable efforts are required to detect planets with low masses or large orbital periods, these planets can be observed only by a few surveys, while the other surveys will miss them. As a consequence, the real (unbiased) joint statistical distribution of RV planets over minimum masses $m = M \cdot \sin i$ and orbital periods P (i.e., on the m – P plane) will differ from the observed (biased) distribution.

The purpose of our study is to propose and study a method to simultaneously homogenize several published surveys, in order to retrieve (or approach as much as possible) the true de-biased mass/period distribution of exoplanets.

We derived the observed and regularized exoplanet mass distribution from a sample of known planets detected through the RV method from a variety of different surveys, which are considered initially sufficiently inhomogeneous. The methodology adopted to compute the regularizing detectability-window matrix (**W**) is inherently simplistic, taking into account only the total time of observations and the scatter of the RV measurements (Equations (5a) and (5b)). The proposed methodology remains affected by numerous factors, which impacts the dependences in fine detail, but these do not affect the conclusions. To analyze such a large sample of data, we used a simplified approach based on the planet detectability event recorded in the exoplanet database. While specific methods reflecting planetary signals in the detection pipelines techniques, such as using Lomb-Scargle peri-

odogram, to measure RVs in time series, remain superfluous for us, planned for future analysis, so currently they are not captured in detail.

Within a certain degree of precision, the mass distribution of the transiting planets does not depend on the spectral class of their parent stars if one considers planets in stars of spectral classes F, G, and K. [8], so we combine a group of FGK host stars RV planets for an additional study.

In some studies of exoplanetary statistics, the inhomogeneity of observational data was ignored. For example, Butler et al. (2006) [9] constructed the projective-mass distribution of 167 exoplanets known at that time and approximated it with a power law $dN/dm \propto m^{-1.1}$ but did not take into account the difference in detectability between the various surveys. Marchi, 2007 [10] studied the taxonomy of 183 planets ignoring any observation selection. Tabachnik and Tremaine (2002) [11] analyzed 72 planets, looking for a solution in the form of a power law using the maximum likelihood method. They found that the distribution of planets by masses and orbital periods follows $dN = C m^{-\alpha} P^{-\beta} (dm/m)(dP/P)$, with $\alpha = 0.11 \pm 0.10$, $\beta = -0.27 \pm 0.06$, but poorly describes the distribution of massive planets and brown dwarfs. Marcy et al. (2005) [12] attempted to solve this problem by considering only the planets which were detected at the Lick and the Keck observatories with the spectrographs of nearly equal instrumental errors in single RV-measurements (about 3 m/s); as a result, they eventually examined 104 planets out of 152 known at that time. Marcy et al. (2005) [12] found that the distribution follows a power law $dN/dm \propto m^{-1}$. When considering the distribution of planets with orbital periods P from 2 to 2000 days and minimum masses m from 0.3 to 10 Jupiter masses (M_J), Cumming et al. (2008) [13] introduced the survey-completeness factor and found that the joint distribution of 182 RV planets by masses and orbital periods obeys a power law $dN = C_1 \times m^{-0.31 \pm 0.2} \times P^{0.26 \pm 0.1} d\ln(m)d\ln(P)$ (where C_1 is a constant), which corresponds to a projective-mass distribution $dN/dm \propto m^{-1.31 \pm 0.2}$. To analyze the mass distribution of planets orbiting 166 Sun-like stars observed at the Keck observatory with the High Resolution Echelle Spectrometer (HIRES), Howard et al. (2010) [14] introduced the completeness function $C(m, P)$ as a fraction of stars that for sure do not have nearby planets with specified values of the period and the minimum mass. They found that the projective-mass distribution of planets with periods shorter than 50 days can be approximated by the power laws $dN/d\log(m) \propto m^{-0.48+0.12/-0.14}$ or $dN/dm \propto m^{-1.48+0.12/-0.14}$. Jiang et al., 2010 [15] mentioned the need to correct for the observational selection associated with the detection limit of the different surveys. They resumed the coupled mass-period exoplanets' distribution as a power law $dN \propto m^{0.099 \pm 0.055} \times P^{0.13 \pm 0.04} dm/m dP/P$.

We study the de-biasing method against observational selection of RV exoplanets in mass and orbital period statistics. The de-biasing method based on exoplanet catalogue data accounts for major essential selection factors in RV exoplanet detection. Alternatively, a more logical and straightforward de-biasing method is based on raw data analysis from host star observation used to determine Keplerian residuals (taken not from a catalogue but from spectroscopic data). These residuals can be used to determine an “overall” de-biased exoplanet occurrence rate. Thus, from the raw data, one claims the completeness function of a star and, therefore, a detection fact of an exoplanet in a star system. For example, this procedure can be implemented using a Lomb-Scargle periodogram math algorithm, as constructed on RV data by adding and subtracting a real or a dummy planet with a given minimum mass m and period P .

We have tested this approach and summarized a difficulty with reliable exoplanet non-detection criterion. Not on the level of mathematics but on the level of raw data. The uncertainty is caused by the following: (i) Only a limited number of radial velocity measurements is available from various spectrographs. (ii) Need to filter star activity (rotation accounting). (iii) Need to filter observing biases factors, such as an inducement of possible planets and unique observational samplings. It is not uncommon for planets discovered by one research group not to be confirmed by another one (alfa Cen B b, Gliese 581 d, g, f, HD 41248 b, c, etc.).

Indeed, the detection of exoplanets remains a “piecemeal” product. Often it is derived from an original unique hypothesis, often from a non-unified combination of several random factors. Therefore, the de-biasing and homogenization of datasets proposed here is based on a much simplified, surely imprecise model: we analyze exoplanet detection event on catalogue basis. One of the aims why we generalise analysis within $\{K/\oplus(O-C), P/T\}$ parametric space is not only to exclude random factors but to account for systematic factors (where K is reflex motion, $\oplus(O-C)$ is residual “observation minus calculation”, P is orbital period, T is time span.) We extrapolate a detection event over other planets with generic characteristics $\{K/\oplus(O-C), P/T\}$, and using that, we state whether the planet can or cannot be detected.

Let us consider a possible criticism of how to account for the number of RV observations in a given periodogram. One of the parameters of the proposed model (γ , see Section 2.1.1, Formula (5b)) is actually the threshold value of $K/\oplus(O-C)$ at which a planet can still be detected in a given set of radial velocity measurements. We have relied on the formula for identifying a periodic signal in noise $S/N = \sqrt{n} \cdot \dots K/\Delta V$, where S/N is the signal-to-noise ratio, which must be 10 or higher for reliable detection, n is the number of measurements, ΔV is the error of a single measurement. Sources of noise are also the star activity and the possible presence of other planets, so instead of ΔV value we use $\oplus(O-C)$, which is a measure of the total noise. Hence the threshold value $K/\oplus(O-C) = \gamma = 10/\sqrt{n}$, which does depend on the number of radial velocity measurements. However, in most cases the number of radial velocity measurements leading to the discovery of a low mass planet (<0.14 Jupiter masses) is in the range 100–400, which corresponds to the value of $\gamma = 0.5 \dots 1.0$, on average 0.75, which is accepted in our model. On the other hand, massive planets correspond to a large value of K (tens and hundreds of meters per second), so 20–30 measurements of radial velocity are sufficient to detect such planets. For $N = 25$ $\gamma = 2$, which is accepted in the model for massive planets. It is possible to calculate an individual threshold value $K/\oplus(O-C) = \gamma$ for each star. However, at this stage we believe that determining the exact value of γ for each star is redundant. The fact of a publication presenting a new RV planet also depends on random factors. In addition, authors may take their time to publish a reliable RV signal, seeking to make sure of its planetary nature, or, on the contrary, rush to publish it and present an unreliable planet, which will not be confirmed later.

Therefore, the number of RV observations is encoded in catalogue data if one considers detection event. Several random factors remain averaged on overall statistics. Additional signals in the RV data from stellar activity, inducement of possible planets, observational sampling are similarly encoded.

The de-biasing based only on stars with planets is evidently incomplete. To account for stars without planets, we use the mathematic approach in Section 2.1.1. We analyzed the observed stars without planets considering the ratio of the sum of stars in which a planet with a given mass and orbital period $\{m, P\}$ can be detected to the total sum of all observable stars.

From Tuomi et al. (2019) [16] (published online in arxiv.org), we borrowed the method of combining single “windows” (completeness functions of each star) into a common “window” (matrices \mathbf{W} and \mathbf{V} , Section 2.1.1). Hence, Tuomi et al. (2019) [16] applied this method to the actual radial velocity data of stars and carefully considered other factors, including stellar activity indicator data, which we apply in our proposed method.

We borrowed from Petigura et al. (2013a) [17] the methodology for calculating the true number of planets with a known observed number of planets and the completeness function. The detailed calculation of the completeness function in Petigura et al. (2013) [17] and this paper differ because Petigura et al. (2013) [17] considers the distribution by radii and orbital periods of the transiting Kepler planets but not the distribution by the minimum masses of the RV planets (Section 2.1.1).

2. Materials and Methods

2.1. Method for Considering Several Surveys

2.1.1. The Concept of a Detectability Window Algorithm

Among the approaches used to regularize the inhomogeneous data on RV exoplanets from the NASA Exoplanet Archive [1,18], there is one method which we called the “detectability window” regularization algorithm. Presently, we are developing this approach, which was proposed by Tuomi et al. (2019) [16] to study the occurrence rate of planets of different types around M-dwarf stars.

Tuomi et al. (2019) [16] analyzed 23,473 individual measurements of the radial velocity of 426 M dwarfs, which were performed with the High Accuracy Radial velocity Planet Searcher (HARPS), HIRES, Planet Finder Spectrograph (PFS), Ultraviolet and Visual Echelle Spectrograph (UVES), and other instruments.

To account for the differences between the surveys in duration and sensitivity, Tuomi et al. (2019) [16] have introduced the detection probability function $p_i(\Delta m, \Delta P)$ for each of the data sets (in fact, for each observed star). This function takes discrete values of 1 or 0 depending on whether the obtained data would allow a planet with the minimum mass and the orbital period in a range of $(\Delta m, \Delta P)$ to be detected near a specified host star or not, respectively. This calculation must consider the host star’s mass and the accuracy (in m/s) achieved by the survey. The non-detection of a planet occurs either because the amplitude of the reflex motion K (in m/s) is below the accuracy of the survey, or because the duration of the monitoring survey is too short w.r.t. the period. The overall planet detection probability function $f_p(\Delta m, \Delta P)$ was finally determined by summing up all $p_i(\Delta m, \Delta P)$ over the observed stars ($N = 426$) and dividing the latter by N (In [16], the probability function of detection was determined as $f_p(\Delta m, \Delta P) = 1 - \frac{1}{N} \sum_{i=1}^N p_i(\Delta m, \Delta P)$. This is because they have used the reverse definition of p_i : $p_i = 0$ for detection, $p_i = 1$ for non-detection.)

$$f_p(\Delta m, \Delta P) = \frac{1}{N} \sum_{i=1}^N p_i(\Delta m, \Delta P). \quad (1)$$

The ranges of the minimum masses and the orbital periods $(\Delta m, \Delta P)$ were represented within a grid of, e.g., 8×8 , where they cover the intervals $m = 1\text{--}10^3$ Earth masses (M_E) and $P = 1\text{--}10^4$ days, respectively.

Tuomi et al. (2019) [16] were focused on determining the occurrence rate of exoplanets at M dwarfs rather than analyzing their distribution over masses or orbital periods. However, we have modified their proposed method the study of the joint distribution over masses and orbital periods for RV planets orbiting stars of all types as well as in the selection of FGK host-star group.

For the explanation and, therefore, some generalization of Tuomi et al. (2019) [16] methodology, we refer the reader to Appendix A.

The amplitude K of the sinusoidal variation of RV (in the case of circular orbits) is a function of M_{star} , the mass of the planet M_{planet} , and its period P_{planet} :

$$K(\text{m/s}) = 203.25 M_{\text{planet}} M_{\text{star}}^{-2/3} P_{\text{planet}}^{-1/3} \sin i, \quad (2)$$

where the numerical constant 203.25 is needed when the M_{planet} is in units of Jupiter mass M_J and M_{star} is in units of solar mass, and K is needed in m/s to be compared to the accuracy (or threshold detection limit) of a particular spectrometer and survey. The angle inclination of the system is angle i with the line of sight. For RV surveys, the product $M_{\text{planet}} \cdot \sin i$, the minimum mass, is determined. This equation shows that for a given planet with a given period, the amplitude K of the reflex motion is smaller for a heavier star. Therefore, the same planet (mass, period and inclination) may be detected by a particular survey around a light host star, and escape detection around a heavier host star with the same instrument and survey. This introduces a bias that we are able to estimate (see below) and, therefore, correct for it (de-biasing). This bias depends on the particular sample of stars monitored by a survey (the mass distribution of host stars in the survey) and RV performances of this

survey. Our procedure also allows accounting for different performances of the different surveys (homogenization). It relies on the assumption that the true mass distribution of planets is independent of the host star's mass.

2.2. Method to Construct a Detectability Window

2.2.1. The Concept of a Detectability Window Algorithm

To take into account the data inhomogeneity in the archives of RV-exoplanets, we introduce the notion of a “detectability window”. The detectability window is a matrix of dimension $(n \times n)$ in the m – P plane, the elements of which represent the probability of detecting a planet with the desired values of the minimum mass and the orbital period $\mathbf{W}(m, P)$. The \mathbf{W} matrix dimension $(n \times n)$ can be chosen by Sturges' rule [19] to compute the histogram bins number. In other words, the matrix \mathbf{W} describes for one given survey (for observed star) or for the merged ensemble of surveys, the fraction of existing planets that are actually detected with given values depending on m and P . The observed (biased) distribution of planets in the m – P plane (a two-dimensional histogram) $\mathbf{N}_0(m, P)$ can be obtained by element-by-element scalar multiplication of the real (unbiased) distribution $\mathbf{N}(m, P)$ by the detectability window $\mathbf{W}(m, P)$:

$$\mathbf{N}_0(m_i, P_j) = \mathbf{N}(m_i, P_j) \times \mathbf{W}(m_i, P_j), \quad (3)$$

where i and j run from 1 to n .

Consequently, the real (unbiased) distribution can be obtained from the observed (biased) distribution by dividing each element of the observed two-dimensional histogram by the corresponding element of the detectability window, if the latter is not zero:

$$\mathbf{N}(m_i, P_j) = \mathbf{N}_0(m_i, P_j) \times (1/\mathbf{W}(m_i, P_j)), \text{ if } \mathbf{W}(m_i, P_j) \neq 0. \quad (4)$$

In other words, to construct a distribution less distorted by the observational selection, we take each of the actually detected RV planets in the m – P plane with a statistical weight inverse to the corresponding value of the planet detection probability, i.e., the matrix element $\mathbf{W}(m, P)$ of the detectability window. This method of correcting the observations from a known bias factor is similar to the approach of Petigura et al. (2013a) [17] for the size distribution of transiting planets, the similar de-biasing of RV planets was used in [20]. In the case of transiting planets, for a circular orbit of radius a , it is simply the angle R_*/a at which the host star with radius R_* is seen from the orbit. Hence, one detected planet may be counted as a number larger than several tens. (Note the similarity to our problem: for transiting planets, the radius of the star R_* is taken into consideration; for RV planets, it is the mass of the star which is necessary to be known).

It may not be very obvious that the results of several surveys with different sensitivities may be merged rather simply. The demonstration is given in Appendices A and B.

To construct the detectability window matrix $\mathbf{W}(m, P)$, we consider RV planets with orbital periods and minimum masses ranging from 1 to 10^4 days and from $0.011 M_J$ to $13 M_J$, respectively (The window's boundaries may be set arbitrarily. In the following, we use the windows with the other boundaries as well).

We divided each of the domains into twelve bins, equal widths when expressed in logarithms so that the resulting m – P plane was split into 144 cells. In the middle of each of these cells, we place an artificial (dummy) planet, i.e., 144 artificial planets are assumed. For each cell with the dummy planet we compute the probability of its detection, the method for calculating which is given below.

To estimate whether each of the artificial planets could have been detected by the considered surveys we need two additional characteristics—total observation time T and average deviation from the best Keplerian curve $\sigma(\text{O} - \text{C})$ in m/s—which are absent in the NASA Exoplanet Archive [1], but would give an estimate of the actual accuracy of the instrument/survey (in m/s). For each of the real RV planets or planetary systems (in the case of multiplanetary systems), we take as a basis the source (published study) where

the time T of observations is longest while the average deviation from the best Keplerian curve $\sigma(O - C)$ is smallest. All sources are listed in Table A2. For each of these sources, we estimate whether it could detect each of the 144 artificial planets. We assume that an artificial planet will definitely be detected if two conditions are fulfilled simultaneously:

$$\left. \begin{aligned} P &\leq \delta T \\ K &\geq \gamma \sigma(O - C) \end{aligned} \right\} \quad (5a)$$

$$(5b)$$

These conditions mean the following. According to inequality (5a), the orbital period P of an artificial planet should be less than the product $\delta \times T$, where T is the total time of observations and δ is a numerical multiplier of the order of unity, which will be defined in Section 2.2. According to inequality (5b), the semi-amplitude K of the reflex motion (in m/s) induced by an artificial planet in the radial velocity of a host star should be greater than the product $\gamma \times \sigma(O - C)$, where γ is another numerical factor of the order of unity, which will also be defined in Section 2.2.2.

In [20], the detectability-window matrix \mathbf{W} was constructed for 547 stars, each of them has at least one RV planet. For each star we calculated the reflex motion K by Equation (2) that each artificial exoplanet could induce on the star. If the artificial exoplanet satisfies both conditions (5a) and (5b), the value in the corresponding cell of the matrix $\mathbf{W}(m, P)$ is increased by one, and the algorithm proceeds to the next host star of the surveys (out of 547 stars in total). Once the examination of observations of all host stars has been accomplished, the resulting matrix was normalized by the number of stars (547), and the values in cells of the matrix \mathbf{W} take values between 0.0 to 1.0, corresponding to the detection probabilities, where zero or unity means an absolutely opaque window or an absolutely transparent one, respectively (i.e., the planet cannot be detected, or would be certainly detected by the surveys, respectively).

Figure 1 shows an example of the detectability window \mathbf{W} in the form of a map with cells of different brightness corresponding to the planet detection probability w_{ij} . The probability values w_{ij} and the numbers of planets from the NASA Exoplanet Archive [1], which occur in a specified cell $\mathbf{W}(\Delta m, \Delta P)$, are indicated in each of the cells by the lower and upper numbers, respectively. In addition, the positions of these detected planets in the m - P plane are shown by red dots. In Figure 1, the detectability window was constructed for the coefficient values $\delta = 2$ and $\gamma = 0.8$ in (5a) and (5b), respectively, i.e., by assuming that an artificial planet will be detected if its half of orbital period is less than the total time of observations T and the semi-amplitude of the induced reflex motion in the radial velocity is greater than eight-tenths of the average deviation from the best Keplerian curve $\sigma(O - C)$. For a more accurate δ and γ choice, we refer the reader to Section 2.2.2.

However, the *detectability* window proposed above by the \mathbf{W} matrix is not constructed for all observed stars but only for stars with planets. Therefore, the correction by \mathbf{W} is neither complete nor accurate, as it does not account for possible low-mass planets orbiting stars by which no planets have been detected.

Without loss of generality, we can relax this inconsistency by the following algebra.

We consider L - number of observation programs (surveys), where: The 1-st one can only detect the heaviest of the artificial planets with minimum mass m_1 ; The 2-nd survey detects planets with masses: m_1 and m_2 ($m_1 > m_2$); etc.; Finally, the L -th survey is able to detect planets of all masses: m_1, m_2, \dots, m_L . Assume, the 1-st survey observes N_{*1} stars, the 2-nd— N_{*2} stars, etc., the L -th survey— N_{*L} stars. The corresponding occurrence rates of planets with masses m_1, m_2, \dots, m_L are denoted by f_1, f_2, \dots, f_L .

Logically, the 1-st survey finds $f_1 \cdot N_{*1}$ planets with mass m_1 , the 2-nd survey finds $f_1 \cdot N_{*2}$ planets with mass m_1 and $f_2 \cdot N_{*2}$ planets with mass m_2 , and so on, until the L -th survey detects $f_1 \cdot N_{*L}$ planets with mass m_1 , $f_2 \cdot N_{*L}$ planets with mass $m_2, \dots, f_L \cdot N_{*L}$ with mass m_L .

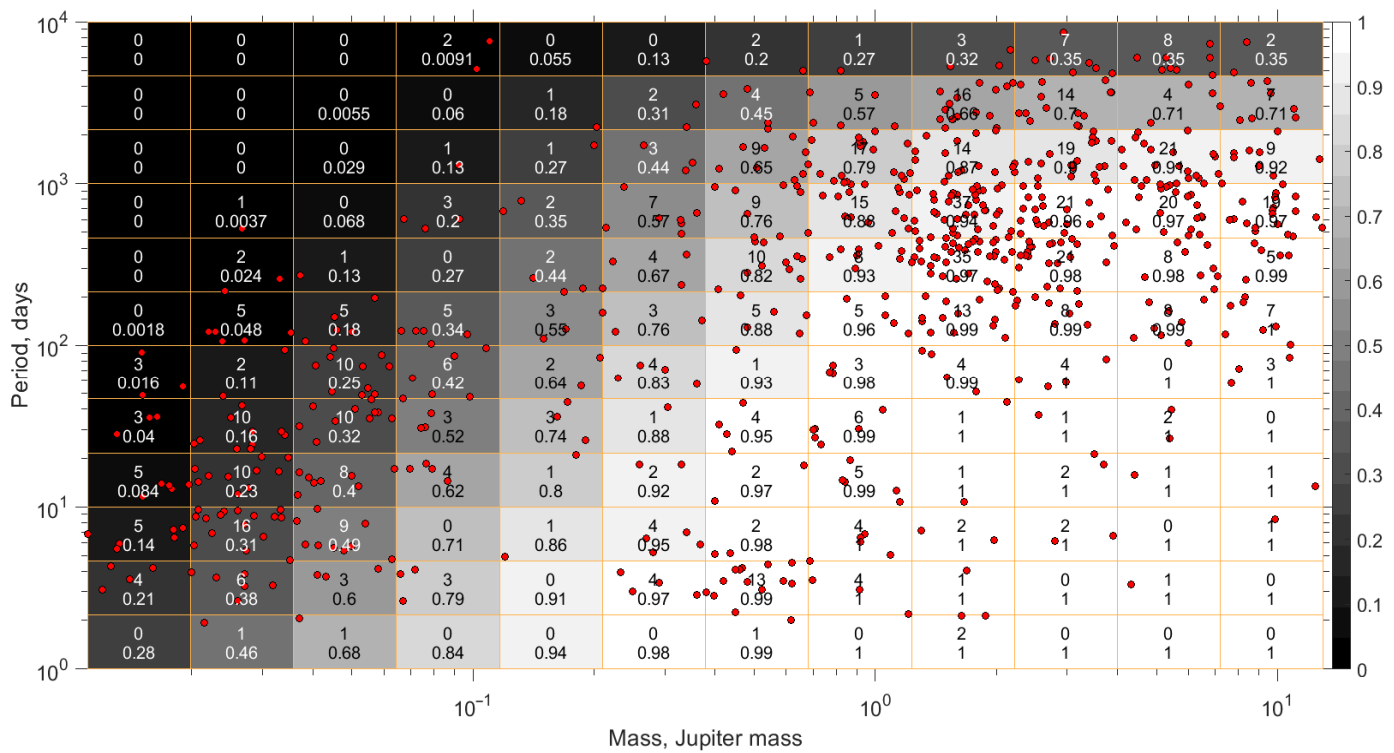


Figure 1. The detectability window \mathbf{W} in the form of a map in the m – P plane obtained with the coefficients $\gamma = 0.8$ and $\delta = 2.0$ in (5a) and (5b). The upper and lower numbers in each of the cells (Δm , ΔP) present the number of known planets with the minimum mass and the orbital period in the corresponding interval and the probability of detecting planets with these parameters, respectively. The degree of shading a cell corresponds to the detection probability for this cell according to the scale on the right. The red dots show the positions of actually detected RV planets in the m – P plane.

Counting the number of detected planets results in: The heaviest planets with mass m_1 will be detected $f_1 \cdot N_{*1} + f_1 \cdot N_{*2} + \dots + f_1 \cdot N_{*L} = f_1 \cdot (N_{*1} + N_{*2} + \dots + N_{*L})$ times. The number of planets with m_2 mass is $f_2 \cdot (N_{*2} + \dots + N_{*L})$. Finally, the number of lightest planets with m_L mass is $f_L \cdot N_{*L}$.

However, it is important that in reality, the quantity of planets with m_1 mass will be $f_1 \cdot (N_{*1} + N_{*2} + \dots + N_{*L})$, the quantity of planets with m_2 mass will be $f_2 \cdot (N_{*1} + N_{*2} + \dots + N_{*L})$, and so on, and the quantity of m_L mass planets will be $f_L \cdot (N_{*1} + N_{*2} + \dots + N_{*L})$.

To convert the observed numbers of planets into their real numbers, the detection efficiency values (elements of the *detectability* window matrix $\mathbf{V}(\leftarrow \mathbf{W})$) shall be following:

$$v_1 = 1, \text{ (for planets with } m_1 \text{ mass);} \quad (6a)$$

$$v_2 = f_2 \cdot (N_{*2} + \dots + N_{*L}) / (f_2 \cdot (N_{*1} + N_{*2} + \dots + N_{*L})) = (N_{*2} + \dots + N_{*L}) / \sum N_{*}, \text{ (for planets with } m_2 \text{ mass);} \quad (6b)$$

...

$$v_L = N_{*L} / \sum N_{*}, \text{ for planets with } m_L \text{ mass.} \quad (6c)$$

In other words, each coefficient of the *detectability* window matrix \mathbf{V} is the ratio of the sum of stars in which a planet with a given minimum mass and orbital period can be detected to the total sum of all observed stars.

Directly from the NASA Exoplanet Archive [1], we know neither the number of observed stars in each *artificial* survey N_{*i} nor the occurrence rates of planets f_i in the mass domain between m_{i-1} – m_{i+1} . However, instead, we do know the number of stars with de-

tected planets of masses m_1, m_2, \dots, m_L . The number of stars that have the planets detected in the i -st survey (denoted as) S_i :

$$S_1 = d_1 \cdot f_1 \cdot N_{*1}, \text{ (detected by the 1-st survey);} \quad (7a)$$

$$\begin{aligned} S_2 &= d_2 \cdot (f_1 \cdot N_{*2} + f_2 \cdot N_{*2}) = \\ &= d_2 \cdot N_{*2} (f_1 + f_2), \text{ (detected by the 2-nd survey);} \end{aligned} \quad (7b)$$

...

$$S_L = d_L \cdot N_{*L} \dots (f_1 + f_2 + \dots + f_L), \text{ (detected in the L-th survey).} \quad (7c)$$

By definition, the coefficient d_i is the ratio of the number of stars to the number of observed planets orbiting these stars. For small f , the coefficient d is close to 1 (as a rule, a star has only one known planet), but as f increases, d decreases, and it tends to the value inverse to the average number of planets per star. For giant planets of 2–13 Jupiter masses considered in this paper, $d = 0.931$ (248 planets in 231 stars), and for planets with masses less than 0.1 Jupiter masses $d = 0.676$ (145 planets in 98 stars). To exclude the additional factor d , when constructing the detectability window matrix for a multiplanet system $\tilde{\mathbf{W}}$, we further consider the star as many times as it has known planets. In this case, Equation (7) can be re-written as:

$$\tilde{S}_1 = f_1 \cdot N_{*1}, \text{ (detected by the 1-st survey);} \quad (8a)$$

$$\begin{aligned} \tilde{S}_2 &= f_1 \cdot N_{*2} + f_2 \cdot N_{*2} = \\ &= N_{*2} \cdot (f_1 + f_2), \text{ (detected by the 2-nd survey);} \end{aligned} \quad (8b)$$

...

$$\tilde{S}_L = N_{*L} \cdot (f_1 + f_2 + \dots + f_L), \text{ (detected in the L-th survey).} \quad (8c)$$

It follows from the statements above, that is possible to re-write the *detectability* window matrix $\tilde{\mathbf{W}}$ (see below (9a)–(9c)) that accounts only for detected planets, into the *detectability* window matrix \mathbf{V} , which takes into account all the observable stars (6a)–(6c). One can realize that $\tilde{\mathbf{W}}$ had the matrix elements $\tilde{w}_1 \dots \tilde{w}_L$ along the minimum mass m direction, which are:

$$\tilde{w}_1 = 1, \text{ (for planets with } m_1 \text{ mass);} \quad (9a)$$

$$\begin{aligned} \tilde{w}_2 &= (\tilde{S}_2 + \dots + \tilde{S}_L) / (\tilde{S}_1 + \tilde{S}_2 + \dots + \tilde{S}_L) \\ &= (\tilde{S}_2 + \dots + \tilde{S}_L) / \Sigma \tilde{S}, \text{ (for planets with } m_2 \text{ mass);} \end{aligned} \quad (9b)$$

...

$$\tilde{w} = \tilde{S}_L / \Sigma \tilde{S}, \text{ for planets with } m_L \text{ mass.} \quad (9c)$$

The corresponding Formulas (6a)–(6c) and (9a)–(9c) for v_i and \tilde{w}_i are structurally identical, but they have the different N_{*i} and \tilde{S}_i metrics, where N_{*i} counts observed stars, while \tilde{S}_i counts detected planets.

We further express \tilde{S}_i through the matrix elements \tilde{w}_i (from (8b));

$$\tilde{S}_1 = (1 - \tilde{w}_2) \cdot \Sigma \tilde{S}, \quad (10a)$$

$$\tilde{S}_2 = (\tilde{w}_2 - \tilde{w}_3) \cdot \Sigma \tilde{S}; \quad (10b)$$

$$\dots \tilde{S}_i = (\tilde{w}_i - \tilde{w}_{i+1}) \cdot \Sigma \tilde{S}, \dots \quad (10c)$$

$$\tilde{S}_L = \tilde{w}_L \cdot \Sigma \tilde{S}, \text{ (from 7b, at boundaries we assume } w_1 = 1 \text{ and } w_{L+1} = 0). \quad (10d)$$

From (8a)–(8c), we express the number of observed stars N_{*i} through the number of the planets detected in the i -st survey \tilde{S}_i :

$$N_{*i} = \tilde{S}_i / \sum_{k=1}^i f_k. \quad (11)$$

Finally, v_i is found via \tilde{w}_i :

$$v_1 = \tilde{w}_2 = 1, \text{ (for planets with } m_1 \text{ mass)} \quad (12a)$$

$$v_1 = 1 - 1 / (1 + N_{*2} / N_{*1} + \dots + N_{*L} / N_{*1}), \text{ for planets with } m_2 \text{ mass} \\ = 1 - 1 / (1 + (\tilde{w}_2 - \tilde{w}_3) / (1 - \tilde{w}_2) \cdots f_1 / (f_1 + f_2) + \dots + \tilde{w}_L / (1 - \tilde{w}_2) \cdot f_1 / \sum f); \quad (12b)$$

$$\dots v_{i+1} = v_i - N_{*i} / \sum N_* = v_i - 1 / \sum_{j=1}^L \frac{N_{*j}}{N_{*i}}, \text{ (where } N_{*j} / N_{*i} = \tilde{S}_j / \sum_{k=1}^j f_k / \tilde{S}_i \sum_{k=1}^i f_k, N_{*j} / N_{*i} = \tilde{S}_j / \tilde{S}_i \cdot \sum_{k=1}^i f_k / \sum_{k=1}^j f_k = (\tilde{w}_j - \tilde{w}_{j+1}) / (\tilde{w}_i - \tilde{w}_{i+1}) \cdot \sum_{k=1}^i f_k / \sum_{k=1}^j f_k) \quad (12c)$$

...

$$v_{L+1} = \tilde{w}_{L+1} = 0 \quad (12d)$$

For example, if $f_i = \text{constant}$ (that makes “flat” distribution on a logarithmic scale $\frac{dN}{d \log(m)}$, corresponding to the mass distribution $\frac{dN}{dm} \propto m^{-1}$), then $\sum_{k=1}^i f_k / \sum_{k=1}^j f_k = i/j$.

If $dN/d \log m \propto m^{-\alpha}$ (which corresponds to the mass distribution of $\frac{dN}{dm} \propto m^{-\alpha-1}$), $f_i = f_1 \cdot m_{\text{step}}^{i-1}$,

$$\sum_{k=1}^i f_k / \sum_{k=1}^j f_k = (m_{\text{step}}^{i+1} - 1) / (m_{\text{step}}^{j+1} - 1),$$

where m_{step} is $(m_i / m_{i+1})^\alpha$.

Without knowing N_{*i} (which defines the total number of observed stars in each survey, including those without planets), we cannot determine the f_i occurrence rate. However, since f_i enters expressions for v_i only as relations of the form $\sum_{k=1}^i f_k / \sum_{k=1}^j f_k$, we can compute v_i by restoring the distribution of planets by mass \tilde{w}_i , by a $f(m)$ guess, as a function of planetary mass in a fixed orbital period domain.

Examples of detectability windows $\tilde{\mathbf{W}}$ (for multiplanet systems) and \mathbf{V} (for stars with and without planets) are shown in Figure 2a,b, respectively.

In aid of understanding, a *toy model* simplified with $L = 2$ (with two types of planets observed by two surveys) is discussed and illustrated in Appendix B.

The approach above of Equations (6)–(12) is applicable if all the surveys can be arranged in a monotonic sequence according to increasing (or decreasing) detection efficiency of exoplanets. It is possible if the detection efficiency depends monotonically on only one parameter, e.g., the planet mass m (determined by single condition). However, in the general case, the detection efficiency of exoplanets is a function of several variables, hence, in the present paper, we stretch them to the two major parameters (m, P) in (5). We note that for some set of regions on the plane (m, P) , one of the conditions accounting for the survey arranged either along planet mass m or orbital period P as the only parameter is always fulfilled, to make the approach described above (6–12) is applicable. Let us comment that (6)–(12) approach is also applicable by replacing m to P , where it is required. Suitable here one more comment is that all the notations, such as those used by forming the detectability windows $\mathbf{V}(m, P)$ (for stars with and without planets, Equation (6)), $\mathbf{W}(m, P)$ (accounting for a single planet in systems, Equation (8)) and $\tilde{\mathbf{W}}(m, P)$ (for multiplanet systems, Equation (8)) can be similarly determined as well for the discrete (centered) m_i and P_i values as for their sets collected in intervals $\Delta m = [m_i \dots m_{i+1}]$ and $\Delta P = [P_i \dots P_{i+1}]$.

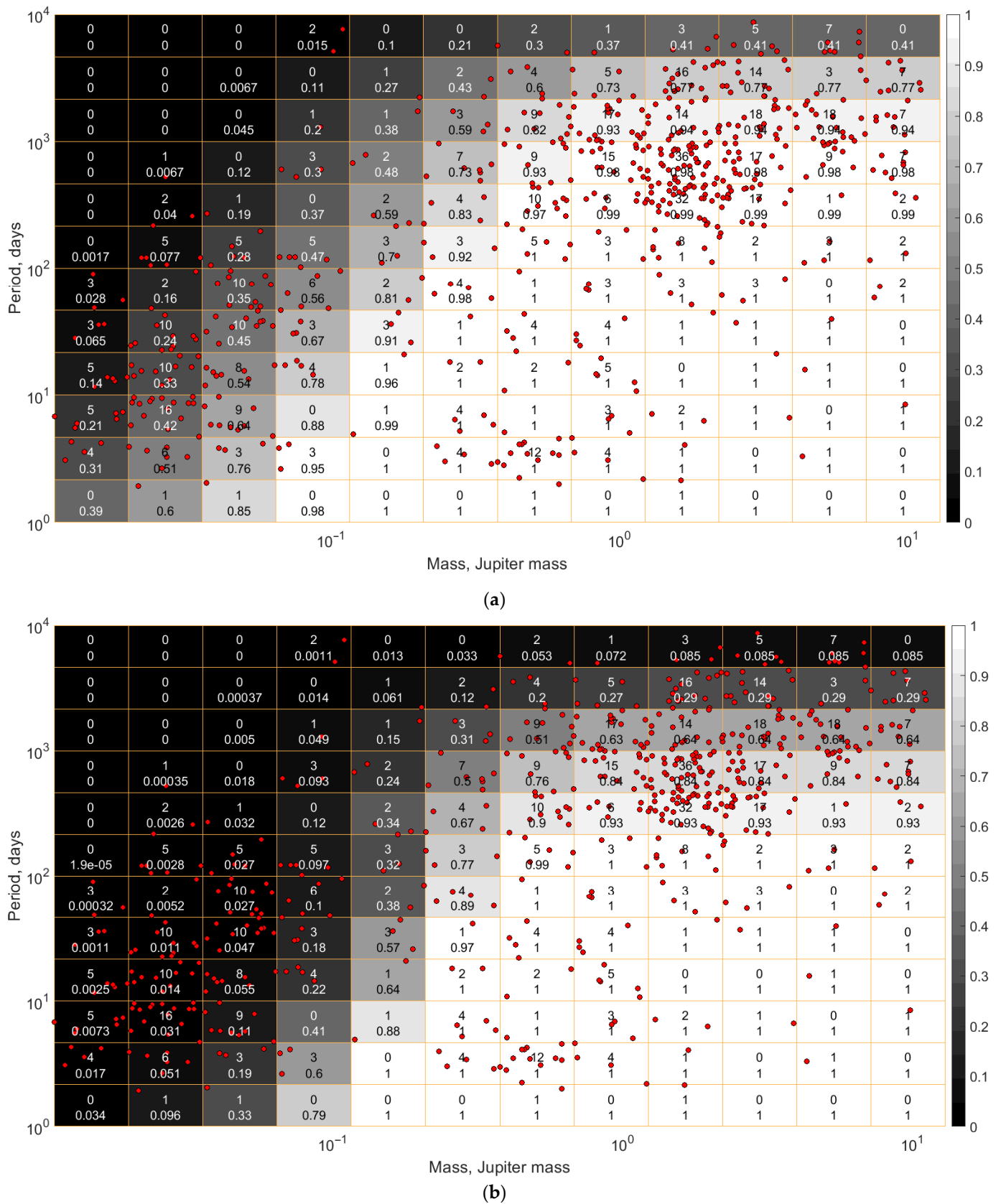


Figure 2. The detectability windows: (a) \tilde{W} (for multiplanet systems) and (b) V (for stars with and without planets) in the format of maps in the m – P plane obtained with the coefficients $\gamma = 0.8$ and $\delta = 2.0$. The designations are the same as those in Figure 1.

To ensure that the constructed various detectability windows $\mathbf{W}(m, P)$, $\tilde{\mathbf{W}}(m, P)$ (8) and $\mathbf{V}(m, P)$ (6) do actually reflect the current ability of the RV technique to detect exoplanets, we should specify the parameters γ and δ (5) more accurately in each mass- and orbital period domain.

2.2.2. Parameters of the Detectability Window Regularization Algorithm

The values initially assumed for the coefficients in (5a) and (5b) (and illustrated in Figures 1 and 2) $\gamma = 0.8$ and $\delta = 2.0$, do characterize the majority of discovered planets, the orbital periods of which are longer than the full time of their observations T (e.g., HD 181234 b [21]). Moreover, some planets induce sinusoidal fluctuations in the radial velocity of a host star with a semi-amplitude K smaller than $\sigma(O - C)$ (e.g., GJ 433 d [22] and HD 26965 b [23]), which implies $\gamma < 1.0$.

To determine the coefficient δ , we plot the distribution of RV planets over the ratio P/T in the form of a histogram (see Figure 3).

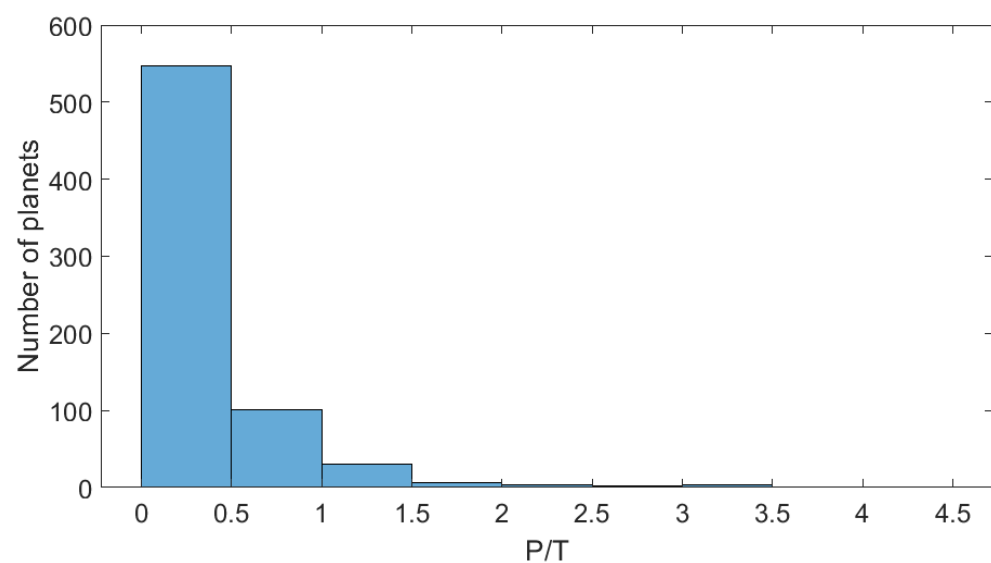


Figure 3. The distribution of RV planets over the ratio of the orbital period P to the total time of observations T .

According to Figure 3, $P/T < 1.5$ for the majority of RV-planets (97.7%), and $P/T < 2.5$ for 99.1% of them. When choosing a value for the coefficient δ , we should take into account that those planets which have passed only a part of their orbit around host stars during the time of observations may also be detected. The smaller the fraction of the orbit the planet has passed, the less reliably its minimum mass and orbital period can be determined. If this fraction of the orbit is small, the Kepler curve degenerates into a linear or quadratic drift of the star's radial velocity, which indicates the presence of long-periodic bodies in the system, but does not allow their period and mass to be determined. For example, planets with $P/T > 2.5$ (HD 221420 b, Pr0211 c, HAT-P-17 c, HR 5183 b, HD 190984 b, and HD 133131 B b) are in highly eccentric orbits. During the observational period, they have already passed through pericenters, when the orbital velocity changes rapidly. If the same planets had been observed during their apocenter passages, they would have been apparently missed as a poorly defined source of a linear drift in the radial velocity of their host stars. For most planets with $P/T > 2.5$, the orbital periods and the semi-major axes of orbits are poorly determined.

It is also worth noting that the variation of the coefficient δ mostly influences the detection probability of planets with the longest periods, while the influence of coefficient δ on the detection probability of short- or medium-period planets is very weak. We will further set $\delta = 2.0$; i.e., we accept the condition that a planet can be detected if it has completed at least a half revolution on the orbit around its host star for the entire period of observations.

Next, let us consider whether it is possible to choose a universal value for the coefficient γ that would be valid for detecting most RV planets so that $\gamma < \frac{\sigma(O-C)}{K}$.

The distribution of RV planets over the ratio $K/\sigma(O-C)$ in the form of a histogram is shown in Figure 4.

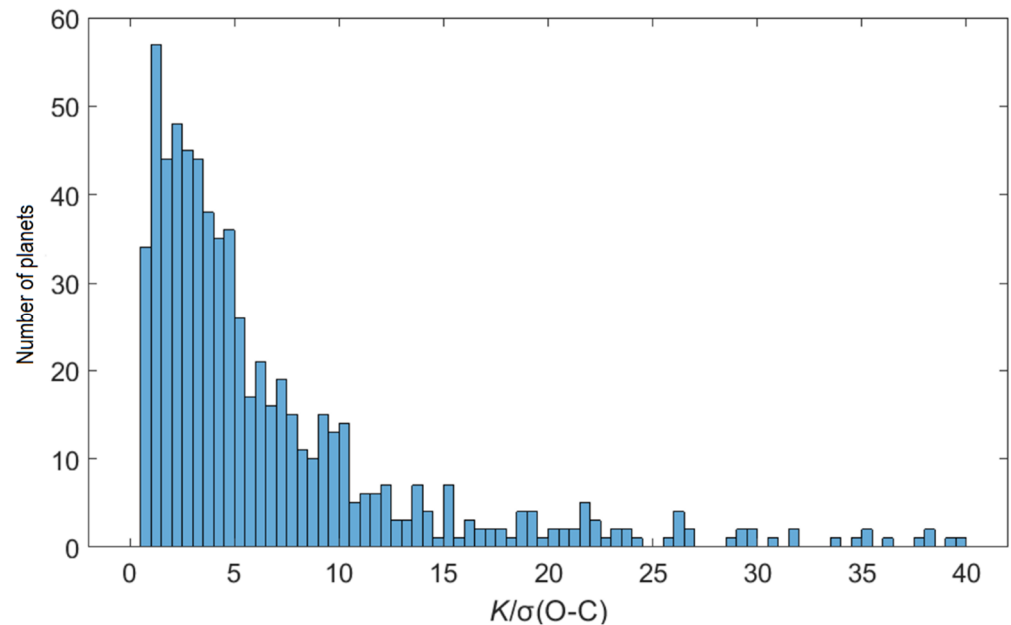


Figure 4. The distribution of RV planets over the ratio of the semi-amplitude K of the radial velocity oscillations of a host star to the average deviation $\sigma(O-C)$ from the best Keplerian curve.

For the majority of planets (95.1%), $K/\sigma(O-C) > 1.0$, i.e., the semi-amplitude K of fluctuations in the radial velocity of a host star, which are caused by the gravitational influence of the planet, is greater than the average deviation $\sigma(O-C)$ from the best Keplerian curve. However, for 34 planets out of 695 (4.9%), $0.5 < K/\sigma(O-C) < 1.0$. As a universal approximation, we may set $\gamma = 0.8$; although, in Section 3, for each of the intervals of the minimum masses m , optimal values of γ will be chosen.

Nevertheless, the detectability window matrix \mathbf{W} (in Figure 1) contains zero probability $f_p = 0$ in the following eight elements (or the map cells with numbers i and j along the horizontal and vertical axes, respectively): W_{11} , W_{21} , W_{31} , W_{12} , W_{22} , W_{13} , W_{14} , and W_{15} . These “degenerate” cells correspond to planets of small masses and large orbital periods. We call this degenerate region “a blind spot”. It is impossible to detect planets from the blind spots (with the corresponding parameters Δm_i and ΔP_j) even with state-of-the-art tools, and unfortunately, their number remains unknown for constructing statistical patterns.

Note that since for $w_{ij} = 1$ $\tilde{w}_{ij} = 1$ and $v_{ij} = 1$, and for $w_{ij} = 0$ $\tilde{w}_{ij} = 0$ and $v_{ij} = 0$, the blind spot area does not change when moving from the imprecise matrix \mathbf{W} to the refined matrix \mathbf{V} (see Figure 2).

3. Results

3.1. De-Biased Histograms of the Projective-Mass Distributions of RV Planets

3.1.1. The Technique for Constructing the Projective-Mass Distributions of RV Planets and Their Histograms

We analyze the projective-mass distribution of RV planets $N(m) = dN/dm$ with the example of the detection probability matrices—the detectability windows \mathbf{W} , $\tilde{\mathbf{W}}$, and \mathbf{V} —shown in Figures 1 and 2a,b, correspondingly.

First, using the detectability windows \mathbf{W} (accounting for stars with single planets), we write the numbers of planets \mathbf{N} in the map cells (the upper numbers shown in the cells) as

the matrix $N_0(12 \times 12)$ and use Equation (4) to regularize the data and correct the observational selection. To pass from the two-dimensional non-corrected (biased) distribution $N_0(\Delta m, \Delta P)$ to the corrected mass distribution of RV planets in the form of a histogram $N(m) = dN/dm$, we sum up the elements of the matrix $N_0 \times (1/W)$ (see (4)) by columns, i.e., by orbital periods:

$$N(m) = N(\Delta m) = \sum_{j=1}^{12} N_0(\Delta m, \Delta_j P) \times (1/W(\Delta m, \Delta_j P)). \quad (13a)$$

However, in the blind spot (cells $W_{11}, W_{21}, W_{31}, W_{12}, W_{22}, W_{13}, W_{14}$, and W_{15}), the elements of the matrix N cannot be defined due to the division by zero. Because of this it is impossible to construct a mass distribution for the whole $m-P$ plane, i.e., for i and j both running from 1 to 12. There are two ways to overcome this problem:

(A). We cover the planets of all masses, but limit ourselves to those with short orbital periods, i.e., $i = 1-12$ and $j = 7-12$:

$$N_A(m) = N(\Delta_{i=1...12} m) = \sum_{j=7}^{12} N(\Delta_i m, \Delta_j P) \times (1/W(\Delta_i m, \Delta_j P)). \quad (13b)$$

(B). We cover planets with all periods, but limit ourselves to more massive planets, i.e., $i = 4-12$ and $j = 1-12$:

$$N_B(m) = N(\Delta_{i=4...12} m) = \sum_{j=1}^{12} N(\Delta_i m, \Delta_j P) \times (1/W(\Delta_i m, \Delta_j P)). \quad (13c)$$

In Figure 5a,c we show the distribution of planets as a histogram $N_A(m)$ for all considered masses with the orbital periods $\Delta_{j=7...12} P$ ranging from 1 to 100 days. This distribution was obtained according to Equation (13b) for several values of γ and δ ($\gamma = 0.65, 0.80, 0.95$; $\delta = 1.5, 2.0, 2.5$). Figure 5d show the distribution of planets $N_B(m)$ for all considered orbital periods and the masses exceeding $0.065 M_J$ ($21 M_E$); it was calculated according to Equation (13c).

When passing from the integer numbers of planets N_0 in Equation (6a) (see the upper numbers in the map cells in Figure 1) to the fractional numbers of planets N in Equations (6b) and (6c), we took into account the error in determining planetary masses by the kernel density estimation (KDE). In this procedure, we used a Gaussian profile or a skewed normal distribution, depending on whether the upper and lower errors are equal (the smoothing technique was described in [24] and presented at length by [25]) or differ in magnitude [26], respectively.

As a first approximation, the mass distribution of RV planets in Figure 5 follows a piecewise continuous power law with breakpoints approximately located at $0.14 M_J$ and $1.7 M_J$ (see Figure 5b,d for more precise positions). It is important that the breakpoint positions are independent of selected values of the coefficients γ and δ . The breakpoint positions are determined within an accuracy of the bin width in the histogram.

It should be noted that the projective-mass distribution for planets with periods of 1–100 days significantly differs from that for planets with periods of $1-10^4$ days even in the projective-mass domain, which is common for the both distributions (i.e., $(0.063-13) M_J$). While the positions of minima ($0.14 M_J$) coincide in the both distributions, the positions of the maxima are different ($\sim 0.5 M_J$ and $\sim 1.7 M_J$ for the short-periods planets and the planets with all periods observed, respectively). As it will be shown in Section 4, this suggests that the most massive planets are on wide orbits with periods exceeding 100 days.

As can be seen in Figure 5c, the distribution of planets with periods of 1–100 days does not depend on the choice of the value for δ either (the distributions are the same for $\delta = 1.5, 2.0$, and 2.5). This is due to the fact that, for short-period planets, the whole time of observations always exceeds their orbital periods, i.e., $P/T < 1$.

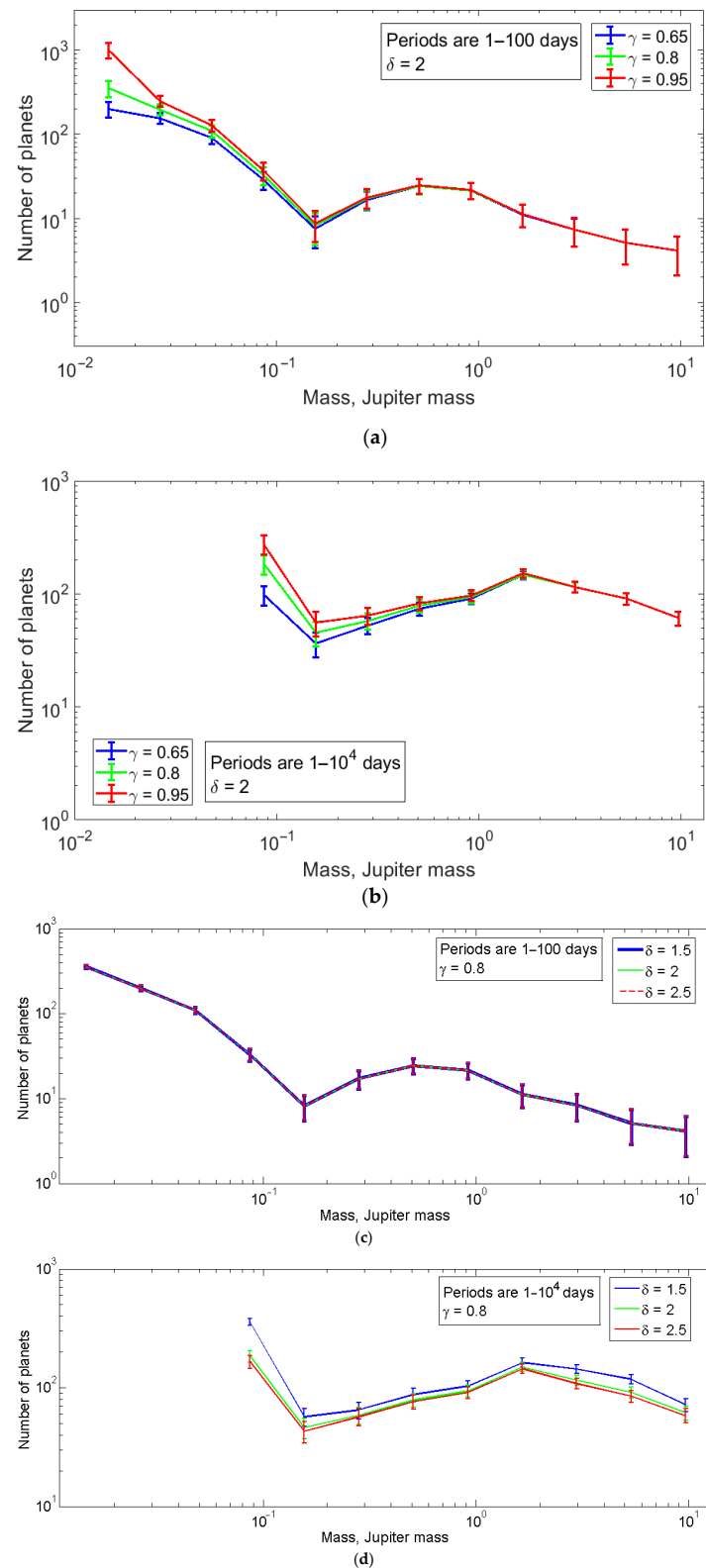


Figure 5. The corrected (de-biased) mass distributions of planets $N(m)$. The coefficients are set at $\delta = 2.0$ and $\gamma = 0.65, 0.8$, and 0.95 for the planets with $m = (0.011\text{--}13) M_J$ and $P = 1\text{--}100$ days (panel (a)) and with $m = (0.065\text{--}13) M_J$ and $P = 1\text{--}10^4$ days (panel (b)). The coefficients are set at $\delta = 1.5, 2.0$, and 2.5 and $\gamma = 0.8$ for the planets with $m = (0.011\text{--}13) M_J$ and $P = 1\text{--}100$ days (panel (c)) and with $m = (0.065\text{--}13) M_J$ and $P = 1\text{--}10^4$ days (panel (d)). The error bars were estimated according to the Poisson distribution.

Let us state that the breakpoint positions at 0.14 M_J and 1.7 M_J do not depend on the values of the coefficients γ and δ . The slopes of the mass distributions of planets in three mass intervals slightly depend on γ choice. Therefore, we better determine the parameters γ and the power indices α (in $N(m) \propto m^{-\alpha}$ approximation) in each of the mass intervals. We have analyzed these intervals separately.

The power indices of de-biased mass dependencies within optimal parameters for the intervals between the breakpoint positions are summarized in the Table 1.

Table 1. Optimal parameters and power law approximation for three mass intervals.

Parameters, Approximation Coefficients	Low-Mass Planets	Intermediate Masses	Massive Planets
m , mass domain, M_J	0.011–0.12	0.12–1.2	1.2–13
δ , in Equation (5a)	2	2	2
γ , in Equation (5b)	0.75	1.6	2
Planets numbers	122	185	355
α , in approx. by $N(m) \propto m^{-\alpha}$ de-biased by \mathbf{W}^*	−2	−0.7 ... −0.8	−1.7 ... −2 **
α , in approx. by $N(m) \propto m^{-\alpha}$ de-biased by \mathbf{V}^{***}	−3	−0.8 ... −1.0	−2

* accounting for the stars with planets. ** −1.7 for all systems and −2 for systems with $\sigma(\text{O} - \text{C}) < 15$ m/s. *** accounting for the stars with planets (with planets multiplicity) and the stars without detected planets.

3.1.2. The Composite Projective-Mass Distribution of Planets—Comparison to the Mass Distributions from Population Synthesis Theory

In Figure 4, the projective-mass distribution of RV planets corrected with the detectability window regularization algorithm rather accurately follows a power law piecewise. In a domain of (0.011–0.087) M_J (or (3.5–28) M_E), the exponent is −3, i.e., $dN/dm \propto m^{-3}$. In a domain of (0.087–0.21) M_J (or (28–67) M_E), the distribution exhibits a minimum, which is deepest in a range of (0.12–0.16) M_J (or (37–50) M_E), where the number of planets is 7.7 times smaller than that predicted by the power law with an exponent of −3. In a mass domain of (0.21–2.2) M_J , the distribution follows a power law with an exponent ranging from −0.8 to −1, i.e., $dN/dm \propto m^{-0.8 \dots -1}$. In a mass domain of (2.2–13) M_J , the distribution may be approximated by a power law with an exponent ranging from −1.7 to −2.0, i.e., $dN/dm \propto m^{-1.7 \dots -2.0}$.

Due to the presence of the blind spot (zeroed W_{11} , W_{21} , W_{31} , W_{12} , W_{22} , W_{13} , W_{14} , and W_{15}), it is impossible to plot the mass distribution of RV exoplanets in the entire mass range of 0.011–13 Jupiter masses and orbital periods of 1– 10^4 days. However, we obtained a composite mass distribution of the RV exoplanets by putting on one plot the distribution of light planets (0.011–0.21 Jupiter masses) with orbital periods of 1–100 days and the distribution of medium and heavy planets (0.21–13 Jupiter masses) with orbital periods of 1–3981 days. For greater uniformity, we considered only systems with a noise level $\sigma(\text{O} - \text{C}) < 15$ m/s (598 planets). When constructing the distribution of medium and large masses planets, we considered only systems whose total observational time T exceeded 1990.5 days.

In Figure 6a, we superimpose the overlapping parts for the host stars in the mass domain of the distributions in a range of (0.156–0.378) M_J (the right end of the blue curve and the left end of the green one) by 3.75. The coefficient 3.75 was chosen as the ratio of the number of planets in the mass interval 0.156–0.378 of the Jupiter mass with orbital periods of 1–3981 days and 1–100 days.

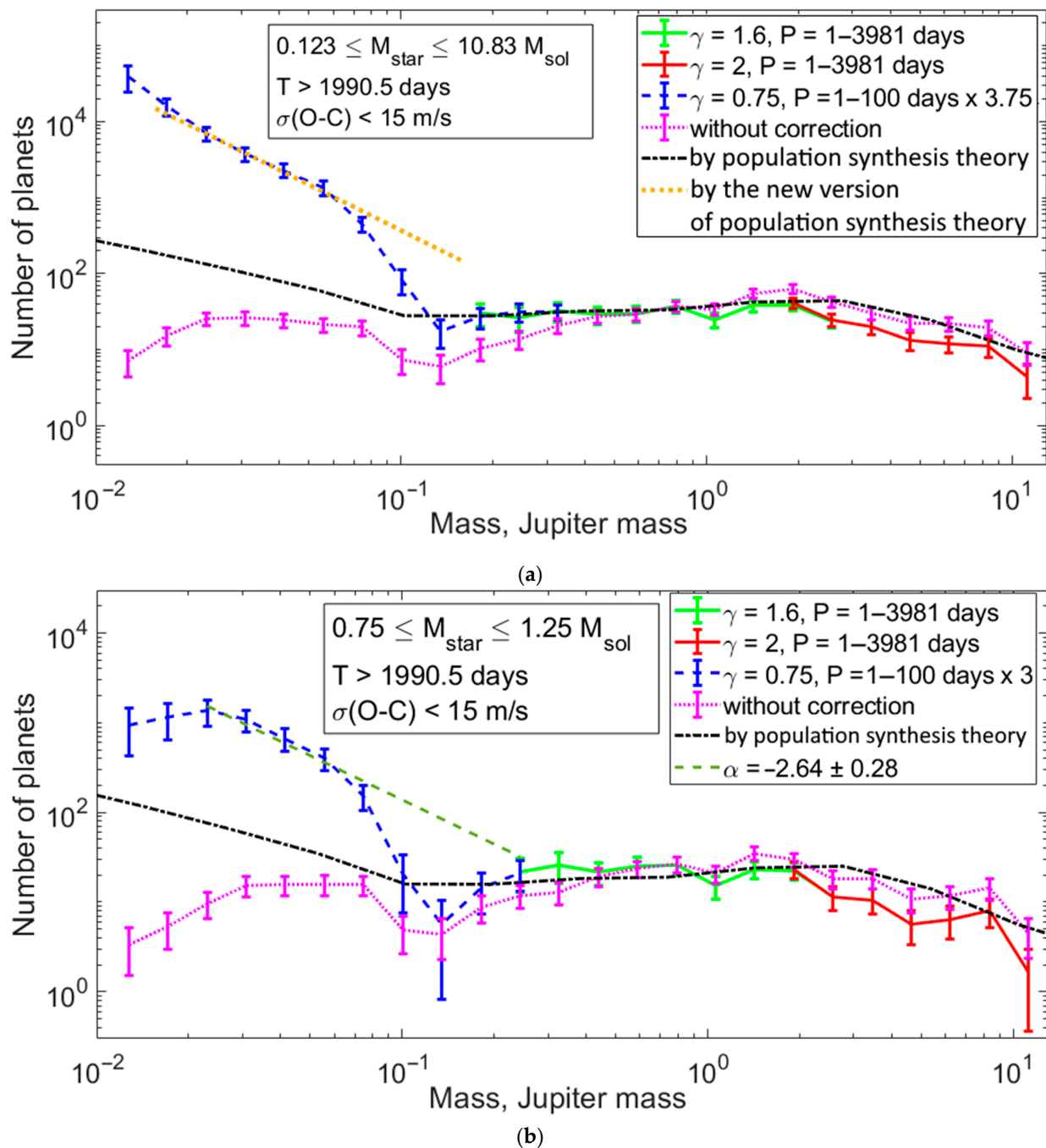


Figure 6. (a) The composite de-biased (via \mathbf{V}) distribution for the minimum masses of 598 RV planets with masses of 0.011–13 Jupiter masses that are part of systems with a noise level $\sigma(\text{O} - \text{C}) < 15$ m/s. For all sections of the distribution, $\delta = 2.0$ was assumed. The blue solid line shows the distribution of planets with orbital periods of 1–100 days ($\gamma = 0.75$), the blue dashed line shows the same distribution multiplied by 3.75. The green and red solid lines show the corrected distribution of planets with periods of 1–3981 days with $\gamma = 1.6$ and 2.0, respectively. The dotted magenta line shows the biased distribution of RV planets with periods of 1– 10^4 days (from the NASA Exoplanet Archive [1]). The black dashed line shows the distribution of exoplanets by mass predicted by population synthesis theory [2], the orange dotted line shows the distribution of planets with masses 5–50 Earth masses according to the new version of population synthesis theory [3]. (b) The similar dependencies for FGK host stars (with the star masses 1.00 ± 0.25 solar mass).

With the planetary population synthesis, Mordasini (2018) [2] established a theoretical model of the formation and evolution of planets; consequently, the theoretically derived mass distribution of planets may be compared to observations: therefore, both the biased and the de-biased distributions. The predicted mass distribution of planets displayed (by [2] in Figure 10 (top left panel)) is reproduced here in Figure 6 by a dashed black line. In a mass domain of $(1\text{--}30) M_E$ (or $(0.003\text{--}0.1) M_J$), the distribution follows a power law with an exponent of -2 , i.e., $dN/dm \propto m^{-2}$. In a mass domain of $(0.1\text{--}5) M_J$, the predicted mass distribution follows a power law with an exponent of -1 , i.e., $dN/dm \propto m^{-1}$ (which results in a plateau or even a slight increase along the mass bins expressed in logarithm), and in the domain above $5 M_J$ the power exponent approaches -2 again. The projective-mass distribution of RV planets corrected with the detectability window regularization algorithm is well consistent with the population synthesis theory [2] in the range of $0.21\text{--}13$ Jupiter masses. However, in the region of masses less than 0.21 Jupiter masses, the corrected distribution does not agree with the distribution predicted in [2]. However, a new generation of population synthesis models (e.g., [3]) predicts a $dN/dm \propto m^{-3}$ distribution for planets with masses $5\text{--}50$ Earth masses. In the mass range $0.087\text{--}0.21 M_J$ there is a deficit of observed planets w.r.t. the theory (the hot Neptunes desert).

In Figure 6b, we analyzed the similar graph as in Figure 6a, but only for FGK host star group in stellar mass domain of $1.00 \pm 0.25 M_{\text{sol}}$. Both graphs show a similarity, but the graph corresponding to solar-like (FGK) host stars shows a decreasing planet number in $(0.011\text{--}0.02) M_J$ mass domain. Additionally, the mass distribution slope of planets orbiting FGK host stars fits to $m^{-2.64 \pm 0.28}$ in comparison to m^{-3} for all planets (orbiting host stars with the masses $(0.123\text{--}10.8) M_{\text{sol}}$).

3.1.3. The Minimum in the $(0.087\text{--}0.21) M_J$ Domain of Masses

The de-biased projective-mass distribution of RV planets exhibits a contrasting minimum in the mass range $(0.087\text{--}0.21) M_J$. In this range, planets are robustly detected: for planets of lower masses, $\gamma = 0.75$, while more massive planets require $\gamma = 1.6$. We find reasonable to check whether the observed minimum may be explained by the incorrectly estimated detectability efficiency of planets with masses of $(0.087\text{--}0.21) M_J$, i.e., the incorrectly estimated coefficient γ (the transition from $\gamma = 0.75$ to $\gamma = 1.6$).

We construct the distribution of RV planets over the ratio $K/\sigma(O - C)$, i.e., the ratio of the half-amplitude K of the radial-velocity oscillations of a host star to the mean deviation from the best Keplerian curve $\sigma(O - C)$, for a mass range of $(0.087\text{--}0.38) M_J$ (58 planets).

Though it is clear that $\gamma = 0.75$ in this domain, we modeled the influence of changes in the coefficient γ on the minimum depth in the projective-mass distribution of RV planets, for which the corrections with $\gamma = 0.75$ and 1.6 were used. We considered planets with periods of $1\text{--}100$ days from systems with a noise level $\sigma(O - C) < 8$ m/s. The result is presented in Figure 7a.

As can be seen from Figure 7a, changes in the coefficient γ do not basically change the distribution pattern. In the minimum domain $((0.108\text{--}0.135) M_J$ or $(34\text{--}43) M_E$), the number of planets predicted by the power law fitting the range of small masses is seven times larger than the number of planets corrected by the detectability window with $\gamma = 0.75$. Moreover, the number of planets in the same domain corrected by the detectability window with $\gamma = 1.6$ is in 3.6 times smaller than the number of planets predicted by the power law. Consequently, we conclude that the minimum in the $(0.087\text{--}0.21) M_J$ range cannot be explained only by a jump in the γ value.

In Figure 7b, we examined the dependence of the distribution of planets by mass, depending on the orbital period coverage: $10\text{--}1000$ days, $4.64\text{--}464$ days, $2.15\text{--}215$ days, and $1\text{--}100$ days (we used period ranges equal in logarithmic scale and equal to 100). We can see that the minimum becomes deeper as the orbital periods decrease, suggesting that the mass values in the minimum range correspond to the so-called “desert of hot-Neptunes” (e.g., [27,28]).

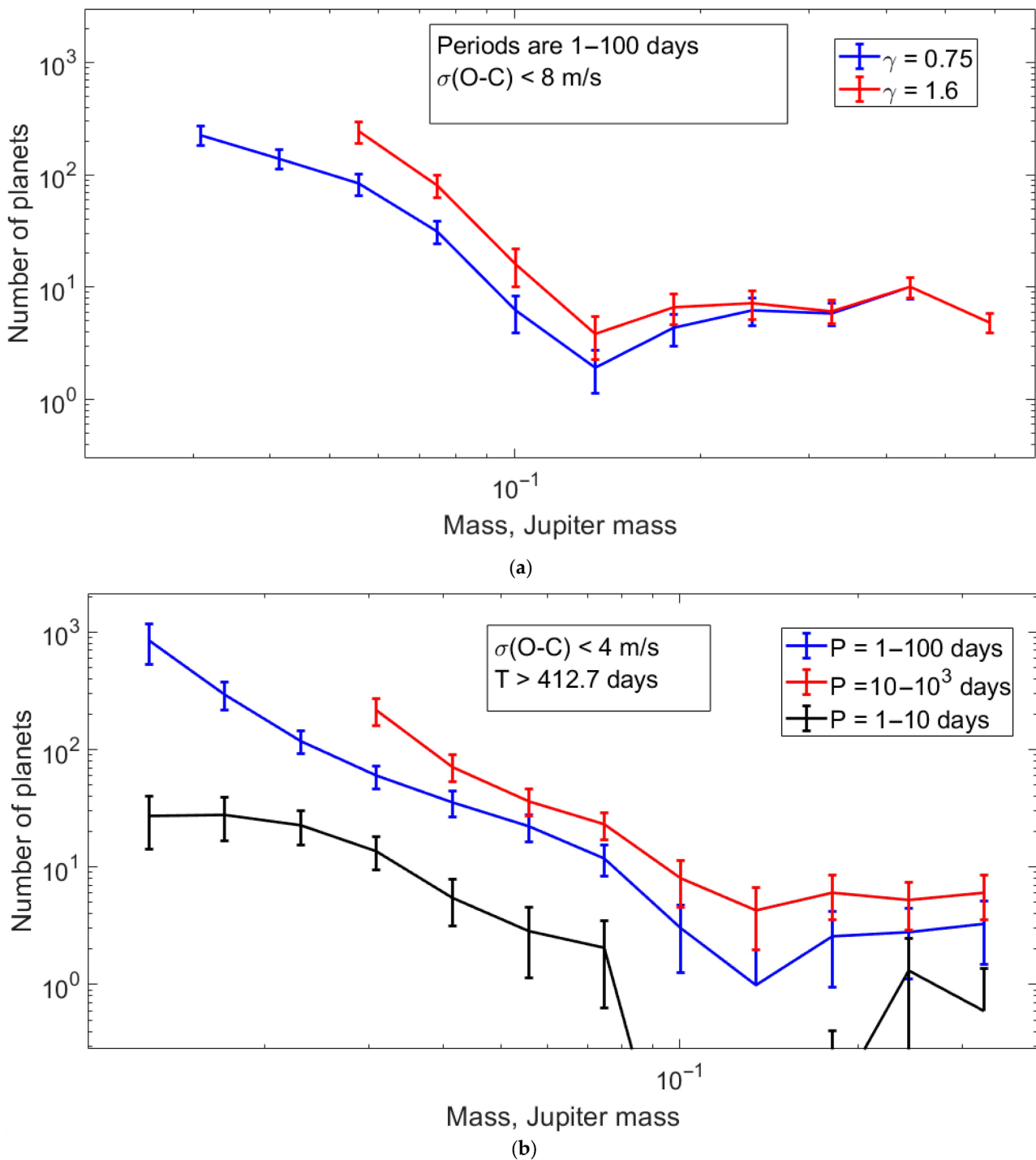


Figure 7. (a) The de-biased mass distributions of planets with masses $m = (0.036-0.38) M_J$ and orbital periods $P = 1-100$ days for $\gamma = 0.75$ and 1.6 . The planets with $\sigma(O - C) < 8$ m/s are considered. (b) The de-biased mass distributions of the planets having the orbital periods of 1–100 days (blue line), 10–1000 days (red line), and 1–10 days (black line). The planets of low-noise systems (with $\sigma(O - C) < 4$ m/s) are considered. By guess, the minimum is caused by planets in tight orbits.

It seems possible that if planets of all orbital periods were detected, including periods longer than 1000 days, this minimum would completely disappear and the de-biased mass distribution of RV planets would agree with the population synthesis theory. On one hand, we note that adding de-biased distributions 1–10 days and 10–1000 days of Figure 7b (therefore, complete 1–1000 days) will certainly still show a deficit in this mass range. On the other hand, Neptune and Uranus in the Solar system still could not be detected from

outside, because of their large orbit, long period, small induced K reflex motion and very low transit probability. Therefore, this issue deserves a more rigorous separate analysis, deleted to future for the time being.

3.1.4. The Maximum in the (6–9) M_J Domain of Masses

The projective-mass distribution of planets with masses in a domain of (1.7–13) M_J can be represented as a sum of the power law and the maximum (bump) in a range of (6–9) M_J (Figure 6a,b). This peculiarity can also be seen in the composite de-biased distribution, the de-biased distribution of planets from low-noise systems ($\sigma(O - C) < 15$ m/s) and the biased distribution (the dotted magenta line in Figure 6), because in this domain there is just no-correction, matrix elements equal to 1.

This peculiarity may be explained by the contribution of planets formed due to the gravitational instability in the protoplanetary cloud [29], while the other giants were formed due to the nucleus accretion [30,31]. However, a lengthy discussion of this issue is beyond the scope of this paper.

3.2. Histograms of the Orbital-Period Distributions of RV Planets

In Section 2, we have described how to construct and translate the detectability window matrixes $\mathbf{W}(m, P)$, $\tilde{\mathbf{W}}(m, P)$, and $\mathbf{V}(m, P)$, which made it possible to correct the observed two-dimensional histogram $\mathbf{N}_0(m_i, P_j)$ for the distribution of RV planets over the orbital periods and minimum masses and obtain the corrected histogram $\mathbf{N}(m_i, P_j)$.

To derive the mass distribution of RV planets, we summed the matrix elements over orbital periods. The summation can also be made over masses, which will result in the distribution over orbital periods $N(P)$.

Due to the blind spot (zero elements) in the \mathbf{W} , $\tilde{\mathbf{W}}$, and \mathbf{V} matrixes, this summation cannot be made over the entire m – P plane (see Section 3.1). For example, it is possible to construct the distribution of planets $N_A(P)$ covering all masses and the orbital periods $P = 1$ – 10^4 days analogously to Equation (13b) or to construct the distribution of planets $N_B(P)$ covering all orbital periods and the masses larger than $0.12 M_J$ ($37 M_E$) analogously to Equation (13c).

$$N_A(P) = N(\Delta_{j=1\dots 6} P) = \sum_{i=2}^{12} \mathbf{N}(\Delta_i m, \Delta_j P) \times (1/V(\Delta_i m, \Delta_j P)). \quad (14a)$$

To derive the distribution $N_B(P)$ we consider the planets with minimum masses $m = (0.011$ – $13) M_J$ and orbital periods $P = 1$ – 10^4 days, also divide each of these domains into 12 bins and sum up the matrix elements over minimum masses starting from the fifth column (i.e., sum up the planets with $m > 0.12 M_J$).

$$N_B(P) = N(\Delta_{j=1\dots 12} P) = \sum_{i=5}^{12} \mathbf{N}(\Delta_i m, \Delta_j P) \times (1/V(\Delta_i m, \Delta_j P)). \quad (14b)$$

To describe the distribution $N_A(P)$ more accurately we consider the planets with minimum masses $m = (0.011$ – $13) M_J$ and orbital periods $P = 1$ – 10^4 days, divide each of these domains into 12 bins, and sum up the first 6 the matrix elements over minimum masses, (Figure 8a).

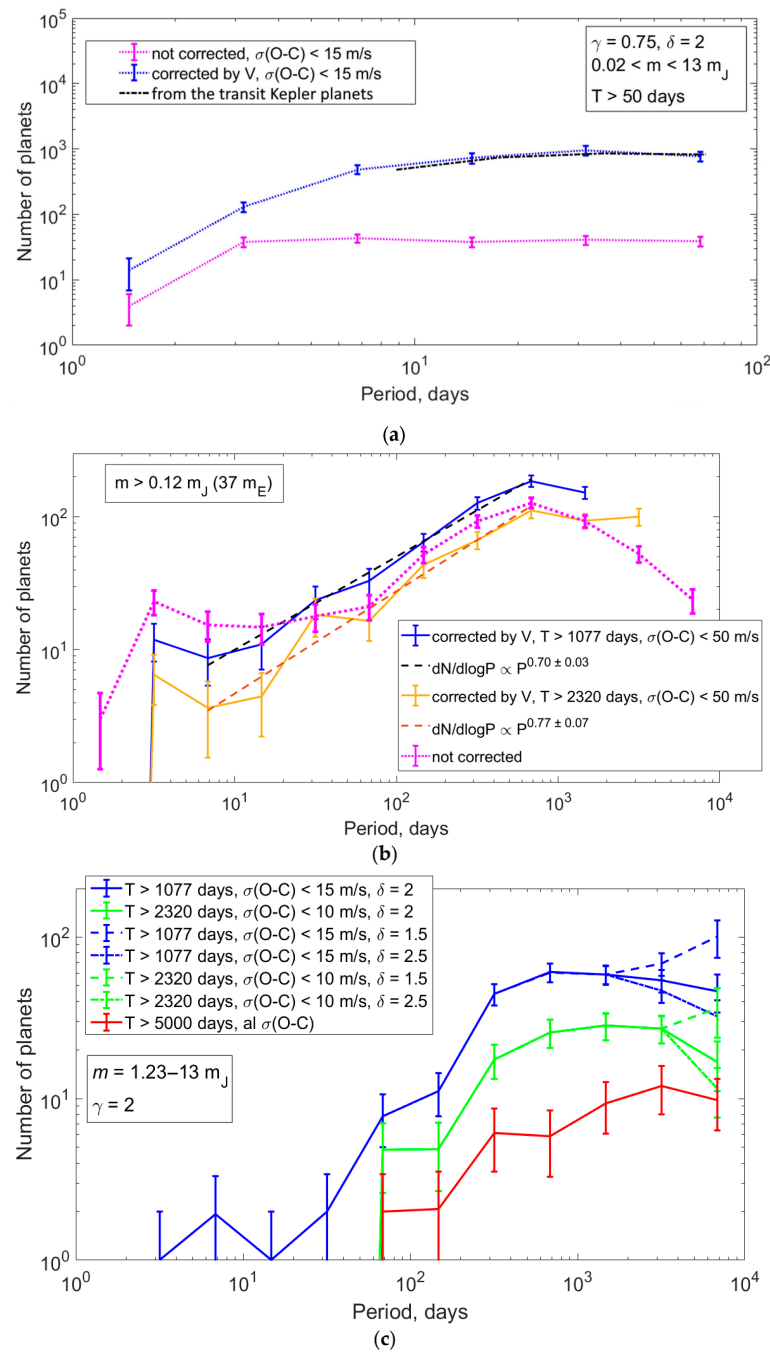


Figure 8. The orbital-period distribution of RV planets. **(a):** $N_A(P)$ (14a)—de-biased distribution of planets with masses $m = (0.02–13) M_J$ and orbital periods $P = 1–100$ days for $\gamma = 0.75$; the dotted blue line shows the distribution of planets with $\sigma(O-C) < 15$ m/s. The orbital-period distribution of the transit *Kepler* planets with radii of $(1–16) R_E$ and orbital periods of $6.25–100$ days is shown by black dash-dot line [17]. **(b):** De-biased $N_B(P)$ (14b)—distributions of planets with masses $m = (0.12–13) M_J$ for $\gamma = 1.6$: blue line— $\sigma(O-C) < 50$ m/s, the orange line— $\sigma(O-C) < 50$ m/s, $T > 2320$ days. The dashed lines in black and brown show approximations by power laws with exponents 0.70 and 0.77 , respectively ($dN/d\log P \propto P^{0.70 \pm 0.03}$ and $dN/d\log P \propto P^{0.77 \pm 0.07}$). Initial from NASA Exoplanet Archive [1] (biased) distribution is shown by dotted magenta line. **(c):** The de-biased distributions of planets with $m = (1.23–13) M_J$, $P = 1–10^4$ days for $\gamma = 2$ and $\delta = 1.5, 2.0$, and 2.5 . Red line— $T > 5000$ days, green lines— $T > 2320$ days and $\sigma(O-C) < 10$ m/s, blue lines— $T > 1077$ days and $\sigma(O-C) < 15$ m/s. Solid lines show the distributions corrected by $\delta = 2.0$, dash lines—by $\delta = 1.5$, dotted lines—by $\delta = 2.5$.

We excluded the lightest planets with the masses of 0.011–0.02 masses of Jupiter, because the \mathbf{V} matrix values for them are very small (e.g., $v(1,6) = 4.9 \cdot 10^{-4}$), while the statistical errors are high. The small number of real planets after the correction becomes very large due to small values of the \mathbf{V} matrix elements. In addition, in the region of masses less than five Earth masses (less than 0.016 Jupiter masses), the distribution of planets by masses may not follow the power law with an exponent of degree -3 [3], so the calculation of the \mathbf{V} matrix elements made under this assumption becomes incorrect.

For planets with masses $m > 0.12 M_J$, the planet detection efficiency depends both on the noise level $\sigma(O - C)$ (affects masses m (5b)) and on the observation duration T (affects periods P (5a)), so we cannot define a final detectability window $\mathbf{V}(m, P)$, as described in Section 2.1, (6–12). To construct the distribution of the long-period planets, we can either consider planets discovered by surveys with long observation times T (for them condition (5a) will always be satisfied, and we can apply formalism (6)–(12)), or consider planets of large masses, for which condition (5b) will always be satisfied, and different observation times T . In the latter case, the corrected distribution of the long-period planets will depend on the assumed dependence dN/dP .

Figure 8b shows the distribution of planets with masses 0.12–13 M_J , from the surveys with a total observation time T exceeding 1077 days, here (5a) is satisfied for planets with periods less than 2154 days. The distributions of the planets from the surveys with noise level $\sigma(O - C) < 50$ m/s and $\sigma(O - C) < 15$ m/s are shown. The obtained distributions display a monotonic increase in the number of planets with increasing orbital periods from 6.8 to 680 days, which can be approximated by a power law with a power index of 0.69 ± 0.03 ($dN/d\log P \propto P^{0.69 \pm 0.03}$) and 0.70 ± 0.03 ($dN/d\log P \propto P^{0.70 \pm 0.03}$), respectively.

Moreover, Figure 8b shows the distribution of planets with $m = 0.12$ –13 M_J with a total observational time exceeding 2320 days and noise level $\sigma(O - C) < 50$ m/s, planets with $P < 4640$ days obey the condition (5a). In the range of $P = 6.8$ –680 days, this distribution can be approximated by $dN/d\log P \propto P^{0.77 \pm 0.07}$, whereas in the range of $P = 680$ –4640 days it becomes flat ($dN/d\log P \approx 0$). For comparison, the biased distribution (from the NASA Exoplanet Archive [1]) of planets with $m = 0.12$ –13 M_J discovered by surveys with any total observation time $T = 40$ –11,314 days is shown.

The choice of the coefficient δ in (5a) affects the distribution on the orbital period distribution only in the region of periods δ times the total observing time T . To avoid this uncertainty associated with the choice of δ , we consider only planets discovered by surveys with long observing times T , but they are few. Thus, the number of planets discovered by surveys with a total observation time $T > 5000$ days is 107 out of 695. To cover as many planets as possible, we considered (i) planets discovered by surveys with full observing time $T > 2320$ days and noise level $\sigma(O - C) < 10$ m/s (316 planets), and (ii) planets discovered by surveys with full observing time $T > 1077$ days and noise level $\sigma(O - C) < 15$ m/s (523 planets). In this case, for planets with $m = 1.2$ –13 M_J condition (5b) is always fulfilled (i) for planets with $P < 4640$ days, (ii) for planets with $P < 2154$ days.

Figure 8c shows the orbital period distributions for planets $m = 1.2$ –13 M_J (columns 9–12), at different values of the parameter δ ($\delta = 1.5, 2.0, 2.5$) and the minimum total observation time T ($T > 1077, 2320, 5000$ days).

From Figure 8c, one cannot draw conclusions about the distribution of the planets over orbital periods of more than twice the minimum total observing time since, in this region, the type of distribution is strongly influenced by choice of coefficient δ . Nevertheless, all three distributions in Figure 8c show similar behavior: in the region of periods of less than 46.4 days, there are very few or no planets of 1.2–13 Jupiter masses, in the region of 46.4–464 days, there is a steady increase in the number of planets, in the region of 464–4640 days the distribution becomes flat. There is a hint of a decrease in the number of planets in the last bin (4640– 10^4 days), but it is not yet clear how much of this decrease is real and how much is caused by the observational selection.

The de-biased orbital-period distributions of RV planets were compared to the distribution of the *Kepler* planets with radii of (1–16) R_E and orbital periods of 6.25–100 days [17],

it is shown by a dash-dotted black line (Petigura et al. (2013) [17] reduced the orbital-period distribution to a single star, i.e., it represents the occurrence rate. To pass from the occurrence rate to the distribution, one should multiply it by a constant, which is equivalent to a vertical shift). As can be seen from Figure 8a, the orbital-period distributions of the *Kepler* planets and the RV planets are in good agreement in a domain of 6.25–100 days.

We compared the de-biased orbital-period distributions of RV planets with a similar distribution of *Kepler* planets with periods of 1–300 days from [6], Figure 12, and found good agreement. The distribution of planets with radii (1–16) R_E (shown by the black line in Figure 12 in [6]) looks similar to the blue dotted line in Figure 8a, and the distribution of planets with radii (8–16) R_E (shown by the red line in Figure 12 in [6]) looks similar to the distribution of planets with masses (0.12–13) M_J in Figure 8b.

We compare the result in (Figure 8b,c) with ([32], Figure 2), which is based on the orbital period distribution of 155 RV planets with masses of 0.1–20 M_J orbiting 822 stars detected by HARPS and CORALIE. In the range of 7–1000 days, there is a similar increase in the number of planets, which transitions to a roughly flat distribution in the ~1000–4000 day range. For planets with periods in the range of $4 \cdot 10^3$ – 10^4 days [32] show a sharp decrease in the number of planets. Figure 8c does not show such a strong decrease. Perhaps the observed decrease in [32] is due to the reduced detection efficiency of light gas giants (0.1–0.3 M_J) with large orbital periods. The semi-amplitude of their induced radial velocity K is less than ~3 m/s (for stars of Solar mass), and such planets are not detected in most cases.

Since the projective-mass distribution of RV planets exhibits different behavior in mass domains of (0.011–0.14) M_J , (0.14–1.7) M_J , and (1.7–13) M_J , we constructed the orbital-period distributions for the planets from each of these mass domains (Figure 9).

Figure 9 shows that the orbital-period distributions of planets with small, intermediate, and large masses ((0.02–0.12) M_J , (0.12–1.2) M_J , and (1.2–13) M_J) differ from each other, which suggests a dominating structure of planetary systems. The most massive planets, with $m > 2.2 M_J$, are mainly on wide orbits with orbital periods longer than 100 days. Only 18 (7.9%) out of 227 massive planets have orbital periods shorter than 100 days. The analogous portion of planets with intermediate masses is $65/233 = 27.9\%$. The distribution of planets with intermediate masses exhibits a two-fold peak in a range of 2.15–4.64 days, which is not observed in the distributions of planets with small and large masses.

Both distributions of planet numbers versus orbital period agree well within error bars.

We compared the de-biased orbital-period distributions of RV planets with masses of (0.02–0.12) M_J (Figure 9, blue line) with the same distribution of *Kepler* planets with radii (1–6) R_E from ([33], Figure 15, top panel). Although the two sets of planets considered do not match completely, we found good agreement between both distributions (a rapid increase in the number of planets as orbital periods increase from 1 to 10 days and then an approximately flat distribution for orbital periods of 10–100 days).

We compared the de-biased orbital-period distributions of RV planets with masses of (0.02–0.12) M_J with the distribution of *Kepler* planets with radii (1.7–4) R_E (Sub-Neptunes) with periods 1–300 days from ([34], Figure 7) and also found good agreement. The distribution of planets with radii (8–24) R_E (Jupiters) and periods 1–300 days from [34] agrees with the distribution of planets with masses (1.23–13) M_J inside the matched interval of orbital periods we obtained.

For this analysis, the detectability matrices \mathbf{W} , $\tilde{\mathbf{W}}$ were calculated by $\delta = 2.0$ for all planets and $\gamma = 0.75, 1.6$, and 2.0 for planets with small, intermediate, and large masses, respectively, same for FGK host stars. Matrix \mathbf{V} was calculated assuming that the distribution of the masses of the light planets follows the power law $dN/dm \propto m^{-3}$, the medium-mass planets follow $dN/dm \propto m^{-1}$, and the heavy planets follow $dN/dm \propto m^{-2}$. Heavy planets do not require any correction because the corresponding matrix elements were equal to 1.

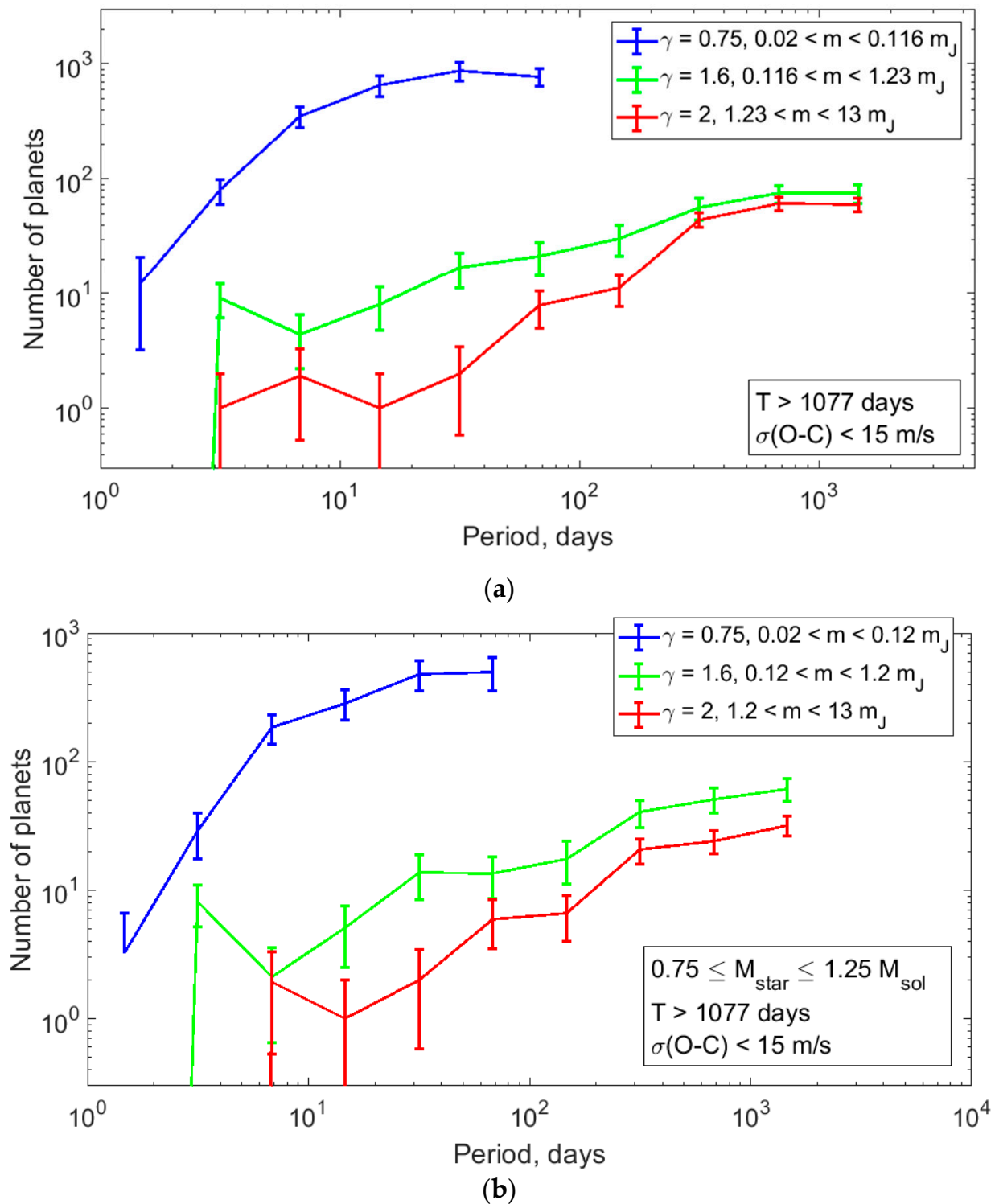


Figure 9. The de-biased orbital-period distributions for the planets from mass domains of $(0.02\text{--}0.12) M_J$, $(0.12\text{--}1.2) M_J$, and $(1.2\text{--}13) M_J$ are shown by blue, green, and red lines, respectively. Planets with a total observation time $T > 1077$ days in systems with a noise level $\sigma(O - C) < 15$ m/s are represented. (a) All types of host stars were considered, (b) FGK host stars were considered.

4. Discussion and Conclusions

The observed distributions of RV exoplanets over minimum masses $m = M \cdot \sin i$ and orbital periods P were initially distorted (biased) by the observational selection. We have corrected important selection factors as caused by differences in the sensitivity of spectro-

graphs, the activity level of host stars, the mass of the host star, and the duration of the surveys. The results presented here on the mass and period distributions of planets are related to the particular (observed) mass distribution of the 547 stars. Their choice was eventually mixed over different host star types, it may not be well representative of the true and full star distribution in the Galaxy. The overall distribution of planetary masses and periods of the host stars of all types can be artificial because the host star mass or its spectral class possibly determines a planetary interior to be compact or Solar system close analogue or different.

Separately we have considered planets distribution of FGK host stars in stellar mass domain of $M_{\text{star}} = 1.00 \pm 0.25$. Most of the host stars of the known RV planets are sun-like.

Evidently, the mass distribution of transiting planets can be dependent on the spectral class of their parent stars. However, if the giant planets in stars of spectral classes F, G, K were considered in [8], a certain independence was shown.

To account for the observational selection, the “detectability window” regularization algorithm was used. The method is based on a concept of the detectability window matrix $\mathbf{V}(m, P)$ in the m – P plane, the components of which are determined as the probabilities of detecting planets in each of the intervals of minimum masses and orbital periods. When constructing the corrected distributions over minimum masses and orbital periods in the form of a histogram, each detected RV planet was accounted for with a statistical weight inverse to the value of the \mathbf{V} matrix component for specified values of P and m .

We considered planets with minimum masses $m = (0.011\text{--}13) M_J$ (or $(3.5\text{--}4131) M_E$) and orbital periods $P = 1\text{--}10^4$ days. Within these limits, some elements of the \mathbf{V} matrix contain zeros, which means that planets of low masses and large orbital periods cannot be detected. We obtained the distributions of planets with all masses and orbital periods of 1–100 days (Equation (13b)) or the distributions of planets with all orbital periods and masses larger than $0.12 M_J$ (Equation (13c)).

The composite projective-mass distribution of RV planets obeys a piecewise power law with two breakpoints at $\sim 0.12 M_J$ and $\sim 2.2 M_J$ (Figure 6). The distribution of RV planets with $m = (0.02\text{--}0.087) M_J$ (or $(6.3\text{--}28) M_E$) follows a power law with an exponent of -3 , $dN/dm \propto m^{-3}$. The distribution of RV planets with $m = (0.21\text{--}2.2) M_J$ follows a power law with an exponent ranging from -0.8 to -1.0 , $dN/dm \propto m^{-0.8 \dots -1.0}$. The distribution of RV planets with $m = (2.2\text{--}13) M_J$ is fitted by a power law with an exponent ranging from -1.7 to -2.0 , $dN/dm \propto m^{-1.7 \dots -2.0}$. In general, the composite projective-mass distribution of RV planets partly agrees with the predictions of the population synthesis theory [2,3].

At the same time, the corrected projective-mass distribution exhibits some peculiarities. In a mass domain of $(0.087\text{--}0.21) M_J$ (or $(28\text{--}67) M_E$), there is a minimum, the depth of which exceeds a 7.7-fold for planets with $P = 1\text{--}100$ days and $m = (0.11\text{--}0.14) M_J$ (or $(34\text{--}43) M_E$).

When considering samples of planets with large orbital periods, this minimum becomes smaller and just disappears for planets with orbital periods of 10–1000 days (Figure 7b). We assume that this minimum is caused by a lack of this kind of planets in tight orbits and corresponds to the so-called desert of hot Neptunes [27,28].

In a mass domain of $(6\text{--}9) M_J$, the distribution of RV planets exhibits a maximum. Probably, this maximum appears due to the contribution of planets formed due to the gravitational instability in the protoplanetary disk, while the other giant planets were formed due to the core accretion.

We have directly compared true mass distributions (from theory of formation [2,3]) with observed minimum mass distributions. Is this legitimate? If the true mass distribution follows a power law with exponent α , does the minimum mass distribution has the same exponent α ? and vice-versa? To the best of our knowledge, this question has not yet been cleared in the literature. However, using a particular geometrical representation of an ensemble of exoplanets, Bertaux et al. (2021) [35] have shown that this is indeed the case. In addition, Bertaux et al. (2021) have performed forward simulations of true mass distributions for various values of a power law exponent, giving minimum mass distribu-

tions. They were then fitted by a power law. For a true mass distribution with a power law with exponents $\alpha = -1.5$, $\alpha = -2$, and $\alpha = -2.5$, we found, respectively, for the minimum mass distribution: -1.57 , -2.03 , and -2.498 . The small differences are due to edge effects. Therefore, we think it is fully legitimate to compare directly the exponents of power laws of a true mass distribution (coming from theory) and an observed minimum mass distribution (See also [4,36]).

We also analyzed the orbital-period distributions of planets. Due to the blind spot, the distribution of RV planets cannot be obtained for the entire m – P plane. We derived the orbital-period distribution of planets with masses of $(0.02\text{--}13) M_J$ with $P = 1\text{--}100$ days and the distribution of planets with all considered orbital periods but with masses exceeding $0.12 M_J$.

The de-biased distribution of planets with masses $(0.02\text{--}13) M_J$ and orbital periods of $1\text{--}100$ days displays a rapid increase in the number of planets with increasing periods from 1 to 10 days and a close to flat distribution in the region of $10\text{--}100$ days. The distribution shape is well consistent with that for the *Kepler* (transiting) planets with radii of $(1\text{--}16) R_E$ and orbital periods of $6.25\text{--}100$ days [6,17,33]).

The distribution of planets with masses larger than $0.12 M_J$ ($37 M_E$) shows a local maximum at $P = 2.15\text{--}4.64$ days. In the domain of $6.8\text{--}680$ days, the distribution follows a power law with an exponent of -0.3 ($dN/dP \propto P^{-0.3}$), in the region of $680\text{--}4640$ days the distribution becomes flat ($dN/dP \propto P^{-1}$) (Figure 8b,c). The orbital-period distributions of RV planets from three mass domains, where the projective-mass distributions behave differently ($(0.02\text{--}0.12) M_J$, $(0.12\text{--}1.2) M_J$, and $(1.2\text{--}13) M_J$), also differ (Figure 9). Specifically, most massive planets, with $m > 2.2 M_J$, are mainly on wide orbits with orbital periods longer than 100 days. This may suggest that there is a prevailing structure of planetary systems, within which low-mass planets are on orbits close to host stars, while massive planets are on wide orbits, analogous to the situation in the Solar System.

Author Contributions: Conceptualization, V.A.; methodology, V.A.; software, O.Y.; validation, O.K. and J.-L.B.; investigation, V.A.; resources, V.A. and A.I.; data curation, V.A.; writing—original draft preparation, I.S.; writing—review and editing, V.A. and A.T.; visualization, I.S.; supervision, A.T. All authors have read and agreed to the published version of the manuscript.

Funding: The authors acknowledge the support of Ministry of Science and Higher Education of the Russian Federation under the grant 075-15-2020-780 (N13.1902.21.0039).

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A. Method for Merging Together Several Surveys

Let us consider one particular RV survey of exoplanets containing N stars, with its own sensitivity and duration. Within a particular bin $(\Delta m, \Delta P)$, this survey detected $f_{\text{obs}}(\Delta m, \Delta P)$, while the exercise of checking the “detectability” of a dummy planet (m, P) around all N stars yielded $N f_p(\Delta m, \Delta P)$. Therefore, we can say that the true occurrence rate $f_{\text{occ}}(\Delta m, \Delta P)$ of this type of planet around stars, in units of “planets per star”, is given by:

$$f_{\text{occ}}(\Delta m, \Delta P) = \frac{f_{\text{obs}}(\Delta m, \Delta P)}{N f_p(\Delta m, \Delta P)} \quad (\text{A1})$$

This is exactly the Equation (13) of Tuomi et al. (2019) [16].

We can describe this Equation (A1) by stating that the occurrence rate of planets in a certain bin is simply the ratio of the number of actually detected planets to the number of “detectable” planets, given the particular characteristics of the survey (accuracy of RV, period covered).

Now, we describe how can be simply merged the results of two surveys S_1 and S_2 with different sensitivity ((O – C) threshold), different durations (which will impact the coverage of periods) and different numbers of planets monitored, respectively, n_1 and n_2 .

Let us call q_1 and q_2 the number of “detected” dummy planets in the bin $(\Delta m, \Delta P)$. We have, by definition of $f_p(\Delta m, \Delta P)$:

$$q_1 = n_1 f_{p1}(\Delta m, \Delta P); q_2 = n_2 f_{p2}(\Delta m, \Delta P) \quad (A2)$$

Therefore, we have two estimates of the occurrence rate of planets $(m, P) f_{occ}(\Delta m, \Delta P)$:

$$f_{occ1}(\Delta m, \Delta P) = f_{obs1}(\Delta m, \Delta P)/q_1; f_{occ2}(\Delta m, \Delta P) = f_{obs2}(\Delta m, \Delta P)/q_2 \quad (A3)$$

In order to obtain an estimate from the combination of the two surveys, one could make an average of $f_{occ1}(\Delta m, \Delta P)$ and $f_{occ2}(\Delta m, \Delta P)$, or some kind of weighted average. However, there is a simpler way to obtain a combined estimate. Indeed, we note that (dropping $(\Delta m, \Delta P)$ for simplicity):

$$f_{occ} = \frac{f_{obs1}}{q_1} = \frac{f_{obs2}}{q_2} = \frac{f_{obs1} + f_{obs2}}{q_1 + q_2} \quad (A4)$$

The numerator of the last fraction is simply the sum of the planets detected in the two surveys. The denominator is the sum of dummy planets detected (detectable planets) in the two surveys. This can be extrapolated to any number of surveys with different characteristics, and we can state:

Regardless of the different characteristics of the various surveys, the (true) occurrence of planets (number of planets per star) in a certain bin is simply the ratio of the total number of actually detected planets in all surveys to the total number of “detectable” planets in all surveys, when detectability is computed for each survey given the particular characteristics of each survey (accuracy of RV, period covered).

$$f_{occ} = \frac{\sum_k f_{obsk}}{\sum_k q_k} \quad (A5)$$

and therefore the true number of planets $N(m, P)$ in this bin for all Q stars ($Q = 547$ in the present study) of the combined surveys is:

$$N(m, P) = Q f_{occ} = Q \frac{\sum_k f_{obsk}}{\sum_k q_k} \quad (A6)$$

We then define the *detectability window* for a particular bin as:

$$W = \frac{\sum_k q_k}{Q} \quad (A7)$$

and therefore the true number of planets $N(m, P)$ in this bin for all Q stars of the combined survey is:

$$N(m, P) = Q f_{occ} = \frac{\sum_k f_{obsk}}{W(m, P)} \quad (A8)$$

Coming back to one particular single survey, Figure A1 is a sketch of the Detectability window in a diagram Period P /amplitude K of the reflex motion of a star influenced by the presence of one planet around the host star. The solid lines result from Equation (2) for a planet of $0.1 M_J$ and two masses of the host star. Within a given survey, the planet will be or will not be detected according to the mass of the host star and the sensitivity limit of the survey.

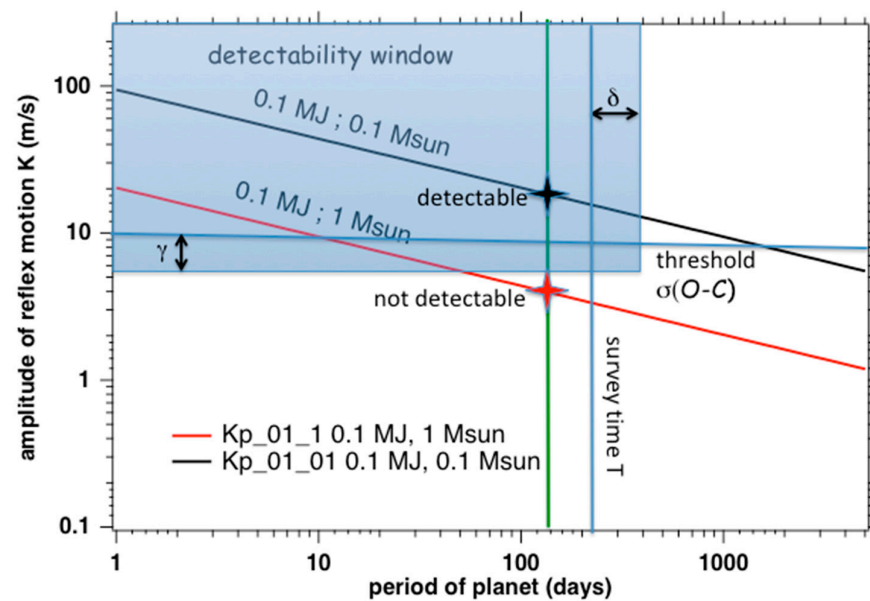


Figure A1. This is a sketch of the Detectability window, in a diagram of observables in one RV survey: the period and the amplitude K (m/s) of a sinusoidal variation of RV induced by a planet. The two solid lines represent the relation for a planet of $0.1 M_J$ around a host star with $1 M_{\text{sun}}$ (red) and 0.1 solar mass M_{sun} (black). The same planet will be detected around a host star with mass $0.1 M_{\text{sun}}$ and not detected around a host star with mass $1 M_{\text{sun}}$. The rectangular blue-shaded area represents the area of the detectability window; γ and δ are two multiplicative factors affecting the boundaries of the detectability window that can be adjusted simultaneously to all surveys, for a more homogeneous treatment (see text).

Appendix B

Here we discuss an artificial example in which only two types of planets are considered: the heavy (1) and light (2) planets. Their occurrence rates are f_1, f_2 , correspondingly. We consider, therefore, two surveys, the first can detect only heavy planets, and the second can detect all the planets. Let the first survey observe N_1 stars, while the second survey observe N_2 stars.

The first survey detects $f_1 \cdot N_1$ heavy planets and zero light planets. The second survey detects $f_1 \cdot N_2$ heavy planets and $f_2 \cdot N_2$ light planets. The number of heavy planets detected is $f_1 \cdot N_1 + f_1 \cdot N_2 = f_1 \cdot (N_1 + N_2)$. The number of light planets detected is $f_2 \cdot N_2$.

However, the true number of light planets orbiting all observed stars is $f_2 \cdot (N_1 + N_2)$.

For de-bias, the detectability window matrix \mathbf{V} consists of the following 2 cells:

v_2	v_1
Here $v_1 = 1$ (means that all surveys detect the heavy planets), $v_2 = (f_2 \cdot N_2) / (f_2 \cdot (N_1 + N_2)) = N_2 / (N_1 + N_2)$.	
$N_2 / (N_1 + N_2)$	1

To check and visualize it we assume some casual numeric, $f_1 = 0.05, f_2 = 3, N_1 = 1000, N_2 = 20$. Then the first survey detects $f_1 \cdot N_1 = 50$ heavy planets. The second survey detects $f_1 \cdot N_2 = 1$ heavy planets and $f_2 \cdot N_2 = 60$ light planets. The total number of detected heavy planets is $f_1 \cdot N_1 + f_1 \cdot N_2 = 51$, the total number of detected light planets is 60. However, while the true number of light planets is $f_2 \cdot (N_1 + N_2) = 3060$.

If one corrects the number of light planets by $v_2 = N_2 / (N_1 + N_2) = 20 / 1020 = 1 / 51$, then resumed the corrected number of light planets is $f_2 \cdot N_2 / v_2 = 60 / (1 / 51) = 3060$.

From here we complicate our de-biasing technique a bit, we assume we do not know the numbers of observed stars in surveys: N_1 and N_2 (e.g., due to the lack of a proper

criterion of planet non-detection). However, oppositely, we know the numbers of the stars denoted by S_1 and S_2 with detected planets corresponding to the surveys.

The first survey detects $f_1 \cdot N_1$ heavy planets orbiting $S_1 = d_1 \cdot f_1 \cdot N_1$ stars, the second survey detects $f_1 \cdot N_2$ heavy planets and $f_2 \cdot N_2$ light planets orbiting $S_2 = d_2 \cdot N_2 \cdot (f_1 + f_2)$ stars. The coefficient d_i defines the ratio of the number of stars to the number of observable planets in those stars. For small f_i $d_i \rightarrow 1$ (for small f_i every star with planets has only one planet). For big f_i $S_i \rightarrow N_i$ (every observed star has planets).

The detectability window matrix **W** also consists of 2 cells:

w_2	w_1
-------	-------

$$w_1 = 1.$$

$$w_2 = S_2/(S_1 + S_2) = 1/(1 + S_1/S_2).$$

$$\text{If } S_1 = 50, S_2 = 20, \text{ then } w_2 = 2/7.$$

The corrected number of light planets is 210. Thus, one counts only stars with planets results in underestimate the number of light planets.

$$\text{We express } S_1/S_2 \text{ through } w_2: S_1/S_2 = 1/w_2 - 1.$$

$$\text{We express } N_i \text{ through } S_i: N_1 = S_1/(d_1 \cdot f_1), N_2 = S_2/(d_2 \cdot (f_1 + f_2)).$$

$$\text{Then } v_2 = N_2/(N_1 + N_2) = 1/(1 + N_1/N_2) = 1/(1 + S_1/S_2 \cdot d_2/d_1 \cdot (f_1 + f_2)/f_1) = 1/(1 + (1/w_2 - 1) \cdot d_2/d_1 \cdot (f_1 + f_2)/f_1).$$

In order to exclude the unknown factors d_i , further we consider the star as many times as the number of the orbiting planets are known, that in the case of a multiplanet system when constructing the detectability window matrix: $\mathbf{W}(S) \rightarrow \hat{\mathbf{W}}(\hat{S})$. Then \hat{S}_1 is the number of planets detected by the first survey and \hat{S}_2 is the number of planets detected by the second survey.

$$N_1 = \hat{S}_1/f_1,$$

$$N_2 = \hat{S}_2/(f_1 + f_2), \text{ and}$$

$$v_2 = N_2/(N_1 + N_2) = 1/(1 + (\hat{S}_1/\hat{S}_2 - 1) \cdot (f_1 + f_2)/f_1).$$

$$\text{To calculate } v_2 \text{ through } \hat{w}_2, \text{ we have to know the relation } f_2/f_1.$$

$$\text{In our case } f_2/f_1 = 60 \text{ and } (f_1 + f_2)/f_1 = 61.$$

Let us check it out.

$$\hat{w}_2 = \hat{S}_2/(\hat{S}_1 + \hat{S}_2) = 61/(50 + 61) = 61/111$$

$$v_2 = 1/(1 + (111/61 - 1) \cdot 61) = 1/51.$$

Finally, we have to estimate the unknown ratio f_2/f_1 . We consider it from the ratio of light and heavy planets discovered by second survey \hat{S}_2/\hat{S}_1 . If one underestimates f_2/f_1 , (e.g., accepts $f_2/f_1 = 50$ and $(f_1 + f_2)/f_1 = 51$), then the number of light planets is underestimated: $v_2 = 1/(1 + (111/61 - 1) \cdot 51) \approx 0.0234$, and the corrected number of light planets is 2568. If one overestimates f_2/f_1 , (e.g., accepts $f_2/f_1 = 70$ and $(f_1 + f_2)/f_1 = 71$), then the number of light planets is overestimated: $v_2 = 1/(1 + (111/61 - 1) \cdot 71) \approx 0.0169$, and the corrected number of light planets is 3558. Let us claim that these inaccuracies are not critical.

Figure A2 shows the ratio between w_2 и v_2 depending on the f_2/f_1 . The Table A1 shows de-biased number of light planets by applied method (by **W** and by **V**).

Table A1. De-biased number of light planets depending on applied method (**W** or **V** matrices).

Parameters	Low-Mass Planets	Intermediate Masses	Massive Planets
Without correction	60		51
Correction by W	210		14.57
Correction by V (true f_2/f_1)	3060	3060	1
Correction by V (underestimated f_2/f_1)	2568		1.19
Correction by V (overestimated f_2/f_1)	3552		0.86

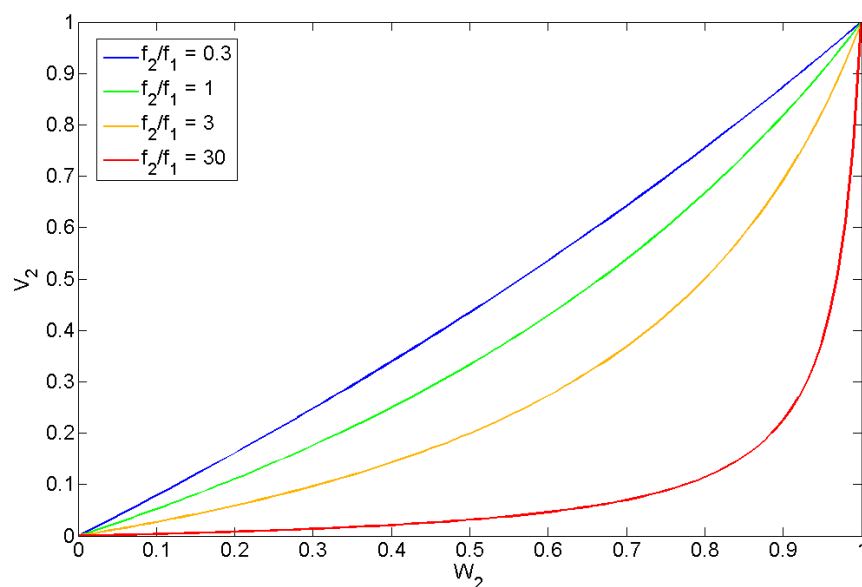


Figure A2. The ratio between w_2 и v_2 versus of f_2/f_1 .

Table A2. List of considered RV planets (shading at FGK stars).

N	Planet Name	Orbital Period, Day	Span, Day	Planet Mass, M_J	Host Star Mass, m_\odot	$\sigma(\text{O-C})$, m/s	RV K, m/s
1	HD 24064 b	535.6	1921	$12.89^{+2.89}_{-2.89}$	1.61	34.5	251.00
2	HATS-59 c	1422	1742	$12.70^{+0.87}_{-0.87}$	1.038	100.00	224.00
3	BD+20 2457 c	622	1833	$12.47^{+0.56}_{-0.56}$	10.83	60.00	160.03
4	HD 87646 b	13.481	2500	$12.4^{+0.7}_{-0.7}$	1.12	270.00	956.00
5	HIP 67537 b	2556.5	4419	$11.10^{+1.1}_{-0.4}$	2.41	8.00	112.70
6	HD 220074 b	672.1	1374	$11.10^{+1.8}_{-1.8}$	1.2	57.40	230.80
7	HD 110014 b	835.477	2950	11.09^{+1}_{-1}	2.17	45.80	158.20
8	HD 106270 b	2890	1484	$11^{+0.8}_{-0.8}$	1.32	8.40	142.10
9	HD 13189 b	471.6	1300	$10.95^{+2.92}_{-2.92}$	2.24	54.50	173.30
10	TYC 4282-00605-1 b	101.54	1200	$10.78^{+0.12}_{-0.12}$	0.97	23.02	495.20
11	HD 114762 b	83.915	6901	$10.69^{+0.56}_{-0.56}$	0.8	27.40	612.50
12	HD 156846 b	359.51	2686	$10.67^{+0.74}_{-0.74}$	1.38	6.06	464.30
13	HD 95127 b	482	2929	$10.63^{+8.06}_{-8.06}$	3.7	50.90	116.00
14	18 Del b	993.3	1772	$10.30^{+0.11}_{-0.11}$	2.3	15.40	119.40
15	HD 17092 b	359.9	1200	$10.13^{+2.29}_{-2.29}$	6.73	16.00	82.40
16	HD 39091 b (pi Men b)	2093	6570	$10.02^{+0.15}_{-0.15}$	1.094	5.50	192.60
17	TYC 1422-614-1 c	559.3	3651	10.00^{+1}_{-1}	1.15	18.94	233.00
18	HD 208527 b	875.5	1352	$9.9^{+1.7}_{-1.7}$	1.6	39.30	155.40
19	HD 156279 b	131.05	254.2	$9.880^{+0.69}_{-0.69}$	0.95	9.08	578.00
20	HD 162020 b	8.428	842	$9.840^{+2.75}_{-2.75}$	0.75	13.60	1813.00
21	Kepler-94 c	820.3	800	$9.836^{+0.629}_{-0.629}$	0.81	13.90	262.70
22	BD-13 2130 b	714.3	1529	$9.78^{+4.56}_{-4.56}$	2.12	18.30	137.60
23	HD 139357 b	1125.7	1287	$9.76^{+2.15}_{-2.15}$	1.35	14.14	161.20
24	HD 221420 b	22482	6500	$9.70^{+1}_{-1.1}$	1.67	3.93	54.70
25	HD 38801 b	685.25	1143	$9.70^{+0.59}_{-0.57}$	1.207	11.00	197.30
26	HD 141937 b	653.22	882	$9.690^{+0.4}_{-0.4}$	1.09	8.70	234.50
27	HD 106515 A b	3630	4800	$9.610^{+0.14}_{-0.14}$	0.97	9.63	158.20
28	WASP-8 c	4323	2099	$9.450^{+1.04}_{-2.26}$	1.34	2.91	115.00
29	HIP 63242 b	124.6	1025	$9.180^{+0.24}_{-0.24}$	1.54	23.70	287.50
30	HD 33564 b	388	417	$9.10^{+0.2}_{-0.2}$	1.25	6.70	232.00

Table A2. Cont.

N	Planet Name	Orbital Period, Day	Span, Day	Planet Mass, M_J	Host Star Mass, m_\odot	$\sigma(\text{O-C})$, m/s	RV K, m/s
31	HD 23596 b	1561	2100	$9.030^{+0.74}_{-0.74}$	1.47	9.20	127.00
32	HD 175167 b	1290	1828	$8.970^{+3.32}_{-3.32}$	1.37	6.91	161.00
33	HIP 75458 b (iota Dra)	511.1	678	$8.82^{+0.72}_{-0.72}$	1.05	10.00	307.60
34	HD 1690 b	533	2547	$8.790^{+3.63}_{-3.63}$	1.86	29.00	190.00
35	gam 1 Leo b	428.5	2195	8.780^{+1}_{-1}	1.23	43.00	208.30
36	HD 30177 b	2527.8	6300	$8.62^{+0.13}_{-0.13}$	1.053	10.00	125.98
37	HD 156279 c	4191	4225	$8.60^{+0.55}_{-0.5}$	0.93	2.20	110.20
38	HD 191806 b	1606.3	3616	$8.520^{+0.63}_{-0.63}$	1.14	10.00	140.50
39	HD 181234 b	7462	6794	$8.37^{+0.36}_{-0.34}$	1.01	20.00	126.80
40	HD 222582 b	572.38	683	$8.370^{+0.4}_{-0.4}$	1.12	3.36	276.30
41	HD 89744 b	256.78	5186	$8.35^{+0.18}_{-0.18}$	1.86	16.40	269.66
42	HD 104985 b	199.505	1932	$8.300^{+0.07}_{-0.07}$	2.3	26.60	166.80
43	HIP 105854 b	184.2	1279	$8.20^{+0.2}_{-0.2}$	2.1	23.60	178.10
44	HD 102329 b	778.1	1484	$8.160^{+2.19}_{-2.19}$	3.21	7.20	84.80
45	HD 74156 c	2473	3408	$8.060^{+0.37}_{-0.37}$	1.238	12.8	116.50
46	HD 178911 B b	71.484	3392	$8.030^{+2.51}_{-2.51}$	1.24	9.10	343.30
47	bet Cnc b	605.2	3460	$7.800^{+0.8}_{-0.8}$	1.7	47.20	133.00
48	HD 203473 b	1552.9	1553	$7.80^{+1.1}_{-1.1}$	1.12	7.00	133.60
49	HD 14067 b	1455	2302	$7.800^{+0.7}_{-0.7}$	2.4	12.70	92.20
50	Pr0211 c	4850	791	$7.790^{+0.33}_{-0.33}$	0.935	26.00	138.00
51	HD 168443 b	58.112	5360	$7.659^{+0.0975}_{-0.0975}$	0.995	3.81	475.13
52	HD 5891 b	177.11	1392	$7.630^{+1.43}_{-1.43}$	1.93	28.40	178.50
53	eps Tau b	594.9	938	$7.600^{+0.2}_{-0.2}$	2.7	9.90	95.90
54	HD 30177 c	11,613	6300	$7.600^{+3.1}_{-3.1}$	1.053	7.17	70.80
55	70 Vir b	116.688	9480	$7.416^{+0.057}_{-0.057}$	1.09	6.10	316.20
56	HD 81040 b	1001.7	2227	$7.270^{+0.98}_{-0.98}$	1.05	26.00	168.00
57	HD 125612 d	3008	2016	$7.2^{+0.35}_{-0.35}$	1.091	3.70	98.37
58	HD 111232 b	1143	1181	$7.140^{+0.19}_{-0.19}$	0.84	7.50	159.30
59	4 UMa b	269.3	890	$7.100^{+1.6}_{-1.6}$	1.234	28.80	215.55
60	HD 86264 b	1475	2952	$7.00^{+1.6}_{-1.6}$	1.42	26.20	132.00
61	Kepler-424 c	223.3	653	$6.970^{+0.62}_{-0.62}$	1.01	20.00	246.00
62	HD 106252 b	1531	3682	$6.930^{+0.27}_{-0.27}$	1.01	12.20	138.80
63	HD 59686 A b	299.36	4500	$6.920^{+0.24}_{-0.18}$	1.9	19.49	136.90
64	HD 183263 c	4684	4908	$6.90^{+0.12}_{-0.12}$	1.12	3.68	77.50
65	HD 196067 b	3638	4900	$6.900^{+1.1}_{-3.9}$	1.29	9.92	104.00
66	GJ 676 A c	7337	3535	$6.8^{+0.1}_{-0.1}$	0.73	2.46	88.70
67	HD 98649 b	6023	5771	$6.79^{+0.31}_{-0.53}$	1.03	10.30	140.10
68	eps CrB b	417.9	2503	$6.700^{+0.3}_{-0.3}$	1.7	25.00	129.40
69	HD 233604 b	192.00	2956	$6.575^{+0.16}_{-0.16}$	1.5	19.13	177.80
70	HD 147018 c	1008	2290	$6.560^{+0.32}_{-0.32}$	0.927	7.39	141.20
71	HD 11977 b	621.6	3864	$6.5^{+0.2}_{-0.2}$	2.31	11.20	105.00
72	alf Tau b	628.96	11,314	$6.470^{+0.53}_{-0.53}$	1.13	98.00	142.10
73	HD 1666 b	270.0	3165	$6.430^{+0.22}_{-0.31}$	1.5	35.60	199.40
74	BD+03 2562 b	481.9	4159	$6.400^{+1.3}_{-1.3}$	1.14	69.80	155.70
75	HD 10697 b	1075.7	4057	$6.383^{+0.078}_{-0.078}$	1.13	8.10	116.90
76	IC 4651 9122 b	734.0	3284	$6.300^{+0.5}_{-0.5}$	2.1	25.00	89.50
77	HD 113996 b	610.2	3994	6.300^{+1}_{-1}	1.49	39.30	120.00
78	HD 2039 b	1120	1337	$6.290^{+1.16}_{-1.16}$	1.23	15.00	153.00
79	bet UMi b	522.3	2920	6.100^{+1}_{-1}	1.4	40.50	126.10

Table A2. Cont.

N	Planet Name	Orbital Period, Day	Span, Day	Planet Mass, M _J	Host Star Mass, m _☉	σ(O-C), m/s	RV K, m/s
80	HD 70573 b	851.8	1100	6.100 ^{+0.4} _{-0.4}	1	18.70	148.50
81	HD 145377 b	103.95	1106	6.020 ^{+0.48} _{-0.48}	1.2	15.30	242.70
82	HIP 65891 b	1084.5	1733	6.00 ^{+0.49} _{-0.49}	2.5	9.30	64.90
83	HD 66141 b	480.5	2605	6.00 ^{+0.3} _{-0.3}	1.1	38.80	146.20
84	HD 238914 b	4100	3944	6.00 ^{+2.7} _{-2.7}	1.47	19.80	71.00
85	HIP 67851 c	2131.8	4017	5.980 ^{+0.76} _{-0.76}	1.63	8.90	69.00
86	HD 224538 b	1189.1	4128	5.970 ^{+0.42} _{-0.42}	1.34	5.20	107.00
87	HD 33142 c	834	2573	5.97 ^{+0.8} _{-1.04}	1.62	5.00	11.40
88	HD 28185 b	379	2971	5.900 ^{+0.24} _{-0.24}	1.02	7.33	163.50
89	HD 5583 b	139.35	3225	5.780 ^{+0.53} _{-0.53}	1.01	69.50	225.80
90	HD 99706 c	1278	2418	5.69 ^{+0.96} _{-1.43}	1.46	4.20	13.80
91	HD 11755 b	433.7	1716	5.630 ^{+0.92} _{-0.92}	0.72	27.70	191.30
92	Kepler-56 d	1002	1490	5.610 ^{+0.38} _{-0.38}	1.32	1.80	95.21
93	HD 75784 c	5040	3694	5.60 ^{+1.2} _{-1.2}	1.41	4.63	57.00
94	HD 213240 b	882.7	770	5.580 ^{+0.31} _{-0.31}	1.57	11.00	96.60
95	HIP 8541 b	1560.2	2194	5.50 ⁺¹ ₋₁	1.17	9.10	87.40
96	HD 72892 b	39.475	1486	5.450 ^{+0.37} _{-0.37}	1.02	4.50	318.40
97	HD 27894 d	5174	4748	5.415 ^{+1.214} _{-0.239}	0.8	2.04	79.76
98	TYC 3667-1280-1 b	26.468	2844	5.400 ^{+0.4} _{-0.4}	1.87	28.30	242.40
99	HD 132406 b	974	1078	5.380 ^{+1.31} _{-1.31}	1.03	7.50	115.00
100	HD 154672 b	163.94	3693	5.370 ^{+0.39} _{-0.39}	1.18	3.60	225.00
101	HD 142 c	6005	5067	5.300 ^{+0.7} _{-0.7}	1.232	11.20	55.20
102	81 Cet b	952.7	1638	5.300 ^{+0.13} _{-0.13}	2.4	9.20	62.80
103	HD 240210 b	501.75	1655	5.210 ^{+0.11} _{-0.11}	0.82	38.90	161.89
104	HD 148164 c	5062	4383	5.16 ^{+0.82} _{-0.82}	1.21	5.62	54.28
105	HD 147873 b	116.596	3995	5.140 ^{+0.34} _{-0.34}	1.38	2.60	171.50
106	HD 13908 c	931	1589	5.130 ^{+0.25} _{-0.25}	1.29	9.60	90.90
107	HD 16175 b	990	3988	5.100 ^{+0.81} _{-0.81}	1.63	9.20	94.00
108	BD-17 63 b	655.6	1760	5.10 ^{+0.12} _{-0.12}	0.74	4.10	173.30
109	HD 50554 b	1293	2000	4.954 ^{+0.389} _{-0.389}	1.04	12.00	104.00
110	HD 102272 b	127.58	1450	4.940 ^{+0.64} _{-0.64}	1.45	15.40	155.50
111	HD 67087 c	2374	3423	4.850 ^{+3.61} ₋₁₀	1.36	11.80	93.30
112	HD 11506 b	1622	3574	4.83 ^{+0.52} _{-0.52}	1.24	4.80	78.17
113	14 And b	185.84	1486	4.800 ^{+0.06} _{-0.06}	2.2	20.30	100.00
114	GJ 676 A b	1051.1	3535	4.733 ^{+0.01} _{-0.011}	0.73	2.46	124.50
115	HD 40979 b	264.15	3588	4.670 ^{+0.34} _{-0.34}	1.45	20.30	119.40
116	14 Her b	1773.4	4428	4.660 ^{+0.15} _{-0.15}	0.9	13.00	90.00
117	gam Lib c	964.6	5234	4.580 ^{+0.43} _{-0.45}	1.47	16.41	73.00
118	HD 111998 b	825.9	2989	4.510 ^{+0.5} _{-0.5}	1.18	17.35	87.60
119	HD 120084 b	2082	3530	4.500 ^{+0.93} _{-2.8}	2.39	5.80	53.00
120	HD 25015 b	6019	6428	4.48 ^{+0.28} _{-0.30}	0.86	30.00	60.10
121	Kepler-454 c	523.9	1750	4.460 ^{+0.12} _{-0.12}	0.85	5.00	110.44
122	HD 142022 A b	1928	2170	4.440 ^{+3.17} _{-3.17}	0.9	10.80	92.00
123	GJ 86 b	15.765	1090	4.420 ^{+0.2} _{-0.2}	0.93	7.00	376.70
124	HD 111591 b	1056.4	3796	4.400 ^{+0.4} _{-0.4}	1.94	21.90	59.00
125	HD 80606 b	111.4367	3480	4.380 ^{+0.74} _{-0.74}	1.15	13.30	472.00
126	tau Boo b	3.312	3287	4.320 ^{+0.04} _{-0.04}	1.34	13.90	471.73
127	BD+20 274 b	578.2	2548	4.200 ^{+0.22} _{-0.22}	0.8	35.80	121.40
128	ups And d	1276.46	7383	4.132 ^{+0.029} _{-0.029}	1.3	13.76	56.26

Table A2. Cont.

N	Planet Name	Orbital Period, Day	Span, Day	Planet Mass, M_J	Host Star Mass, m_\odot	$\sigma(\text{O-C})$, m/s	RV K, m/s
129	omi UMa b	1630	2625	$4.100^{+0.26}_{-0.26}$	3.09	7.60	33.60
130	HD 76920 b	415.4	3028	$3.930^{+0.15}_{-0.14}$	1.17	9.74	186.80
131	HIP 14810 b	6.674	1112	$3.90^{+0.49}_{-0.49}$	1.01	3.29	423.34
132	42 Dra b	479.1	1209	$3.880^{+0.85}_{-0.85}$	0.98	26.00	110.50
133	55 Cancri d	4825	8476	$3.878^{+0.068}_{-0.068}$	0.905	16.30	48.29
134	HD 55696 b	1827	1827	$3.87^{+0.72}_{-0.72}$	1.29	7.18	76.70
135	HD 24040 b	3668	6392	$3.860^{+0.36}_{-0.36}$	1.11	7.50	47.40
136	HD 72659 b	3658	4515	$3.850^{+0.23}_{-0.23}$	1.43	4.20	41.00
137	HD 128311 c	921.538	4566	$3.789^{+0.432}_{-0.924}$	0.828	9.37	74.80
138	HD 35759 b	82.467	1261	$3.760^{+0.17}_{-0.17}$	1.15	6.00	173.90
139	HD 92788 b	325.8	6867	$3.76^{+0.15}_{-0.16}$	1.15	5.00	108.24
140	HD 95872 b	4375	4080	$3.740^{+0.93}_{-0.93}$	0.7	7.90	59.00
141	KELT-6 c	1276	567	$3.710^{+0.21}_{-0.21}$	1.42	17.00	65.70
142	HD 195019 b	18.202	2240	$3.70^{+0.3}_{-0.3}$	1.21	16.00	272.80
143	HD 92788 c	11,611	6867	$3.67^{+0.25}_{-0.3}$	1.15	5.00	33.29
144	HD 183263 b	625.1	4908	$3.635^{+0.034}_{-0.034}$	1.12	3.68	86.16
145	HD 86950 b	1270	2594	$3.600^{+0.7}_{-0.7}$	1.66	6.10	49.00
146	HD 169830 c	1834.3	5155	$3.54^{+0.1}_{-0.1}$	1.4	8.90	39.70
147	HD 143361 b	1039	4417	$3.532^{+0.066}_{-0.065}$	0.968	2.80	73.89
148	HD 166724 b	5144	4010	$3.530^{+0.11}_{-0.11}$	0.81	3.76	71.00
149	HD 17156 b	21.217	40	$3.510^{+0.21}_{-0.21}$	1.41	3.62	279.80
150	HD 108341 b	1129	3770	$3.500^{+1.2}_{-3.4}$	0.843	1.50	144.00
151	HD 1605 c	2111	3281	$3.48^{+0.11}_{-0.13}$	1.31	6.40	46.50
152	HD 204313 b	1920.1	3006	$3.460^{+0.21}_{-0.21}$	1.03	7.80	57.00
153	HD 95089 c	1785	2422	$3.45^{+0.14}_{-0.14}$	1.54	7.60	45.10
154	TYC 3318-01333-1 b	562	3514	$3.420^{+0.35}_{-0.35}$	1.19	15.00	75.42
155	HD 18742 b	766	2995	$3.4^{+1.2}_{-1.2}$	1.36	7.90	61.00
156	HAT-P-17 c	5584	1869	$3.400^{+0.7}_{-1.1}$	0.99	5.00	48.80
157	GJ 3021 b	133.71	462	$3.370^{+0.09}_{-0.09}$	0.9	19.20	167.00
158	HD 13167 b	2613	3105	$3.31^{+0.16}_{-0.16}$	1.35	4.00	48.20
159	eps Indi A b	16,510	9000	$3.25^{+0.65}_{-0.39}$	0.754	1.00	29.22
160	HR 5183 b (HD 120066 b)	27,000	8200	$3.23^{+0.14}_{-0.15}$	1.07	3.40	38.25
161	HD 66428 b	2263	5200	$3.204^{+0.043}_{-0.043}$	1.083	4	54.03
162	91 Aqr b	181.4	4150	$3.200^{+0.001}_{-0.001}$	1.4	18.90	91.50
163	HD 37605 c	2720	2841	$3.19^{+0.38}_{-0.38}$	0.94	6.44	48.51
164	WASP-41 c	421	1581	$3.180^{+0.2}_{-0.2}$	0.81	20.00	94.00
165	HD 220842 b	218.47	997	$3.180^{+0.15}_{-0.15}$	1.13	4.50	108.10
166	HD 196050 b	1378	1364	$3.180^{+0.3}_{-0.3}$	1.31	7.20	49.70
167	HD 18015 b	2278	3105	$3.18^{+0.23}_{-0.23}$	1.49	8.40	38.00
168	HD 190984 b	4885	1950	$3.100^{+0.065}_{-0.065}$	0.91	3.44	48.00
169	HD 73267 b	1245	1586	$3.097^{+0.043}_{-0.044}$	0.9	1.70	64.65
170	HD 221287 b	456.1	1130	$3.090^{+0.79}_{-0.79}$	1.25	8.50	71.00
171	HD 68402 b	1103	2050	$3.070^{+0.35}_{-0.35}$	1.12	5.30	54.70
172	HD 142245 b	1299	1465	$3.070^{+0.42}_{-0.42}$	3.5	4.80	24.80
173	HD 67087 b	352.2	3423	$3.060^{+0.2}_{-0.22}$	1.36	11.80	73.60
174	HD 32518 b	157.54	1215	$3.040^{+0.68}_{-0.68}$	1.13	18.33	115.83
175	HD 125612 b	559.4	2016	$3.0^{+0.09}_{-0.09}$	1.091	3.70	80.00
176	75 Cet b	691.9	3609	$3.00^{+0.16}_{-0.16}$	2.49	10.80	38.30
177	HD 12484 b	58.83	865	$2.98^{+0.14}_{-0.14}$	1.01	25.20	155.00

Table A2. Cont.

N	Planet Name	Orbital Period, Day	Span, Day	Planet Mass, M _J	Host Star Mass, m _☉	σ(O-C), m/s	RV K, m/s
178	HD 153950 b	499.4	1791	2.95 ^{+0.29} _{-0.29}	1.25	3.90	69.20
179	HD 50499 c	8620	7268	2.93 ^{+0.18} _{-0.73}	1.25	10.00	24.23
180	HD 165155 b	434.5	2740	2.89 ^{+0.23} _{-0.23}	1.02	5.80	75.80
181	HD 169830 b	225.62	1506	2.88 ^{+0.03} _{-0.03}	1.4	8.90	80.70
182	HD 113337 b	324	2193	2.83 ^{+0.24} _{-0.24}	1.4	24.80	75.60
183	xi Aql b	136.75	1152	2.80 ^{+0.07} _{-0.07}	2.2	22.30	65.40
184	HD 118203 b	6.134	402	2.79 ^{+0.25} _{-0.25}	1.84	18.10	217.00
185	HD 1502 b	428.5	1167	2.75 ^{+0.16} _{-0.16}	1.46	11.30	57.50
186	HD 171238 b	1532	2491	2.72 ^{+0.49} _{-0.49}	0.96	11.60	50.70
187	HD 150706 b	5894	5150	2.71 ^{+0.66} _{-1.14}	1.17	15.30	31.10
188	HD 75898 b	422.9	4800	2.71 ^{+0.36} _{-0.36}	1.26	5.82	63.39
189	HD 81688 b	184.02	1945	2.70 ^{+0.045} _{-0.045}	2.1	24.00	58.58
190	HD 40956 b	578.6	1818	2.70 ^{+0.6} _{-0.6}	2	23.60	68.00
191	HD 173416 b	323.6	1278	2.70 ^{+0.3} _{-0.3}	2	18.5	51.80
192	HD 37605 b	55.013	2841	2.69 ^{+0.3} _{-0.3}	0.94	6.44	203.47
193	HIP 109600 b	232.08	2496	2.68 ^{+0.12} _{-0.12}	0.87	3.30	98.60
194	HD 152079 b	2919	4032	2.66 ^{+0.046} _{-0.046}	1.147	4.08	40.76
195	HD 171028 b	550	1320	2.62 ^{+0.16} _{-0.16}	1.53	2.30	60.60
196	HD 23079 b	730.6	1358	2.61 ^{+0.11} _{-0.11}	1.12	4.80	54.90
197	HD 217107 c	4270	3470	2.60 ^{+0.15} _{-0.15}	1	11.00	35.70
198	HD 155233 b	818.8	1828	2.60 ^{+0.3} _{-0.3}	1.69	10.00	40.50
199	HD 196885 A b	1333	3780	2.58 ^{+0.16} _{-0.16}	1.28	14.70	53.90
200	HD 154857 c	3452	4109	2.58 ^{+0.16} _{-0.16}	1.96	3.20	24.20
201	HD 43691 b	37	821	2.55 ^{+0.34} _{-0.34}	1.32	12.49	130.06
202	HD 181342 b	564.1	1367	2.54 ^{+0.19} _{-0.19}	1.69	7.20	44.10
203	HD 41004 A b	963	1140	2.54 ^{+0.74} _{-0.74}	0.95	10.00	99.00
204	47 UMa b	1078	7175	2.53 ^{+0.06} _{-0.07}	1.03	6.5	48.40
205	HD 60532 c	600.1	1960	2.51 ^{+0.16} _{-0.16}	1.5	4.66	46.10
206	TYC 1422-614-1 b	198.4	3651	2.50 ^{+0.4} _{-0.4}	1.15	18.94	82.00
207	HD 133131 B b	5769	1840	2.50 ^{+0.05} _{-0.05}	0.93	1.59	37.41
208	GJ 317 b	692	3708	2.50 ^{+0.4} _{-0.7}	0.42	8.5	75.20
209	HD 154857 b	408.6	4109	2.45 ^{+0.11} _{-0.11}	1.96	3.20	48.30
210	Kepler-432 c	406.2	437	2.43 ^{+0.24} _{-0.22}	1.32	50.00	62.10
211	HD 290327 b	2443	1986	2.43 ^{+0.42} _{-0.42}	0.84	1.6	41.30
212	HD 108863 b	437.7	1488	2.414 ^{+0.078} _{-0.078}	1.59	5.1	47.40
213	mu Leo b	357.8	3443	2.40 ^{+0.4} _{-0.4}	1.5	14.2	52.00
214	HIP 74890 b	822.3	1429	2.40 ^{+0.3} _{-0.3}	1.74	6.5	36.50
215	HD 29021 b	1362.3	1597	2.40 ^{+0.2} _{-0.2}	0.85	3.93	56.40
216	HD 212771 b	380.7	849	2.39 ^{+0.27} _{-0.27}	1.56	5.8	50.00
217	HD 4732 c	2732	2842	2.37 ^{+0.38} _{-0.38}	1.74	7.09	24.40
218	HD 4732 b	360.2	2842	2.37 ^{+0.34} _{-0.34}	1.74	7.09	47.30
219	HD 73526 b	188.9	5226	2.25 ^{+0.12} _{-0.12}	1.14	6.54	82.70
220	HD 98736 b	968.8	4850	2.33 ^{+0.78} _{-0.78}	0.92	3.08	52.00
221	HD 82886 b	705	1507	2.33 ^{+0.33} _{-0.33}	2.53	7.7	28.70
222	HD 62509 b (beta Gem)	589.64	9100	2.30 ^{+0.45} _{-0.45}	2.1	20.6	41.00
223	HD 47366 b	359.15	2719	2.30 ^{+0.18} _{-0.13}	2.19	14.7	39.01
224	HD 147873 c	491.54	3995	2.30 ^{+0.18} _{-0.18}	1.38	2.60	47.90
225	GJ 328 b	4100	3753	2.30 ^{+0.13} _{-0.13}	0.69	6.00	40.00
226	HD 145934 b	2730	6135	2.28 ^{+0.26} _{-0.26}	1.748	7.8	22.90

Table A2. Cont.

N	Planet Name	Orbital Period, Day	Span, Day	Planet Mass, M_J	Host Star Mass, m_\odot	$\sigma(\text{O-C})$, m/s	RV K, m/s
227	GJ 876 b	61.117	4600	$2.2756^{+0.0045}_{-0.0045}$	0.32	2.96	214.00
228	HR 810 b (HD 17051 b)	302.8	1976	$2.27^{+0.25}_{-0.25}$	1.34	10.4	57.10
229	HD 145457 b	176.3	1389	$2.23^{+0.42}_{-0.42}$	1.23	9.7	70.60
230	HD 216437 b	1334	6055	$2.223^{+0.058}_{-0.058}$	1.165	10.00	39.08
231	HD 159868 b	1184.1	3400	$2.22^{+0.059}_{-0.059}$	1.19	5.8	37.92
232	HD 163607 c	1272	4840	$2.201^{+0.037}_{-0.037}$	1.12	2.00	38.37
233	HD 180053 b	213.72	2812	$2.194^{+0.064}_{-0.064}$	1.75	13.8	51.50
234	HD 13931 b	4218	4394	$2.20^{+0.21}_{-0.21}$	1.3	3.31	23.30
235	HD 73526 c	379.1	5226	$2.19^{+0.12}_{-0.12}$	1.14	6.54	65.10
236	NGC 2682 Sand 978 b	511.21	1826	$2.18^{+0.17}_{-0.17}$	1.37	12.9	45.48
237	HD 4203 c	6700	4715	$2.17^{+0.52}_{-0.52}$	1.25	3.93	22.20
238	HD 136418 b	464.3	1040	$2.14^{+0.15}_{-0.15}$	1.48	5.00	44.70
239	HD 222155 b	3999	4847	$2.12^{+0.5}_{-0.5}$	1.21	11.00	24.20
240	HD 147018 b	44.236	2290	$2.12^{+0.07}_{-0.07}$	0.927	7.39	145.33
241	HIP 79431 b	111.7	179	$2.10^{+0.035}_{-0.035}$	0.42	3.9	149.50
242	HD 192699 b	340.94	1845	$2.096^{+0.093}_{-0.093}$	1.38	10.5	49.30
243	Kepler-48 e	982	1135	$2.067^{+0.079}_{-0.079}$	0.88	3.00	45.83
244	HD 206610 b	673.2	875	$2.036^{+0.065}_{-0.065}$	1.55	4.8	35.40
245	HD 8574 b	227	3609	$2.03^{+0.14}_{-0.14}$	1.34	14.2	58.30
246	HD 65216 c	5370	5371	$2.03^{+0.11}_{-0.11}$	0.874	2.84	26.00
247	6 Lyn b (HD 45410 b)	934.3	1826	$2.01^{+0.077}_{-0.077}$	1.44	9.31	32.80
248	HD 82943 c	219.3	2300	$2.01^{+0.001}_{-0.001}$	1.08	7.88	43.60
249	HD 89307 b	2199	4818	$2.00^{+0.4}_{-0.4}$	1.03	8.4	32.40
250	HD 164604 b	641.5	3100	$2.00^{+0.26}_{-0.26}$	0.77	8.2	60.66
251	HD 70642 b	2125	6300	$1.99^{+0.018}_{-0.018}$	1.078	3.99	30.40
252	HD 187123 c	3810	3543	$1.99^{+0.25}_{-0.25}$	1	2.5	25.50
253	HD 20868 b	380.85	1705	$1.99^{+0.05}_{-0.05}$	0.78	1.7	100.34
254	24 Sex b	452.8	1907	$1.99^{+0.38}_{-0.26}$	1.54	6.8	40.00
255	HD 190647 b	1176	3500	$1.985^{+0.033}_{-0.033}$	1.069	2.00	37.51
256	ups And c	241.258	7383	$1.981^{+0.019}_{-0.019}$	1.3	13.76	68.14
257	HIP 107773 b	144.3	1674	$1.98^{+0.21}_{-0.21}$	2.42	12.00	42.70
258	HD 68988 b	6.277	513	$1.97^{+0.1}_{-0.1}$	1.28	4.36	184.40
259	HD 210702 b	354.1	1739	$1.97^{+0.18}_{-0.11}$	1.85	8.82	37.45
260	HD 98219 b	433.8	1484	$1.964^{+0.1}_{-0.1}$	1.41	3.6	42.00
261	HD 33844 b	551.4	2408	$1.96^{+0.12}_{-0.12}$	1.78	7.3	33.50
262	HD 12648 b	133.6	1693	$1.96^{+0.22}_{-0.22}$	1.2	29.80	102.00
263	HD 4313 b	356.21	911	$1.927^{+0.09}_{-0.09}$	1.63	3.7	40.30
264	HD 117207 b	2621.75	6364	$1.926^{+0.034}_{-0.034}$	1.053	3.4	27.78
265	HD 159243 c	248.4	767	$1.90^{+0.13}_{-0.13}$	1.125	12.40	56.60
266	Pr0211 b	2.146	791	$1.88^{+0.03}_{-0.03}$	0.935	26.00	309.70
267	HD 47366 c	682.85	2719	$1.88^{+0.14}_{-0.12}$	1.81	14.7	25.86
268	HD 152581 b	686.5	1478	$1.869^{+0.071}_{-0.071}$	1.3	4.7	36.20
269	gam Cep b	903.3	10,800	$1.85^{+0.16}_{-0.16}$	1.4	7.70	31.10
270	7 CMa b	735.1	6791	$1.85^{+0.04}_{-0.06}$	1.34	8.20	34.30
271	HD 9446 c	192.9	851	$1.82^{+0.17}_{-0.17}$	1	15.10	63.90
272	HD 4203 b	437	4715	$1.82^{+0.05}_{-0.05}$	1.25	3.93	52.82
273	HD 160691 c	4205.8	2987	$1.814^{+0.19}_{-0.19}$	1.08	3.34	21.79
274	kap CrB b (HD 142091 b)	1285	3353	$1.811^{+0.057}_{-0.057}$	1.5	4.8	26.18
275	HD 131496 b	896	1465	$1.8^{+0.1}_{-0.1}$	1.34	6.3	31.60
276	alf Ari b	380.8	2320	$1.80^{+0.2}_{-0.2}$	1.5	17.80	41.10

Table A2. Cont.

N	Planet Name	Orbital Period, Day	Span, Day	Planet Mass, M_J	Host Star Mass, m_\odot	$\sigma(\text{O-C})$, m/s	RV K, m/s
277	HD 158038 b	521	1465	$1.80^{+0.2}_{-0.2}$	1.65	4.7	33.90
278	HD 45350 b	963.6	2265	$1.79^{+0.14}_{-0.14}$	1.02	9.10	58.00
279	HD 74156 b	51.638	3408	$1.78^{+0.04}_{-0.04}$	1.238	12.8	108.00
280	HD 87883 b	2754	3833	$1.78^{+0.34}_{-0.34}$	0.82	9.2	34.70
281	HD 233832 b	2058	5569	$1.78^{+0.06}_{-0.08}$	0.71	5	38.29
282	16 Cyg B b	798.5	2899	$1.78^{+0.08}_{-0.08}$	1.08	10.6	50.50
283	HD 128311 b	453.019	4566	$1.769^{+0.023}_{-0.023}$	0.828	9.37	55.60
284	HD 72490 b	858	2922	$1.768^{+0.08}_{-0.08}$	1.21	6.43	33.50
285	HD 5319 b	641	3574	$1.76^{+0.07}_{-0.07}$	1.51	7.18	31.60
286	HD 33844 c	916	2408	$1.75^{+0.18}_{-0.18}$	1.78	7.3	25.40
287	HD 82943 b	441.2	2300	$1.75^{+0.001}_{-0.001}$	1.08	7.88	66.00
288	ome Ser b	277.02	4217	$1.70^{+0.12}_{-0.12}$	2.17	17	31.80
289	HD 167042 b	420.77	1925	$1.70^{+0.12}_{-0.09}$	1.5	7.68	32.16
290	BD+48 740 b	733	3492	$1.70^{+0.7}_{-0.7}$	1.09	21.7	54.00
291	HD 149143 b	4.072	286	$1.69^{+0.14}_{-0.14}$	1.73	4.72	149.60
292	HD 160691 b	643.25	2987	$1.68^{+0.001}_{-0.001}$	1.08	3.34	37.78
293	HD 142415 b	386.3	1529	$1.67^{+0.12}_{-0.12}$	1.07	10.6	51.30
294	TAP 26 b	10.79	72	$1.66^{+0.31}_{-0.31}$	1.04	51	149.00
295	HD 86081 b	2.138	87	$1.64^{+0.09}_{-0.09}$	1.39	4.38	207.70
296	HD 23127 b	1214	5959	$1.64^{+0.18}_{-0.18}$	1.42	11	27.50
297	47 UMa d	14002	7175	$1.64^{+0.48}_{-0.29}$	1.03	6.5	13.80
298	HD 4917 b	400.5	3307	$1.615^{+0.093}_{-0.093}$	1.32	7	37.10
299	HD 221585 b	1173	3983	$1.61^{+0.14}_{-0.14}$	1.19	4.04	27.90
300	HD 100655 b	157.6	1599	$1.61^{+0.34}_{-0.34}$	2.28	11.2	35.20
301	HD 134987 b	258.18	4195	$1.59^{+0.02}_{-0.02}$	1.07	3.3	49.50
302	HD 180902 b	479	830	$1.60^{+0.2}_{-0.2}$	1.52	3.3	34.25
303	HD 42012 b	857.5	4400	$1.60^{+0.1}_{-0.1}$	0.83	8.61	39.00
304	HD 129445 b	1840	2153	$1.60^{+0.6}_{-0.6}$	0.99	7.3	38.00
305	BD+49 828 b	2590	3134	$1.60^{+0.2}_{-0.4}$	1.52	11.6	18.80
306	HAT-P-11 c	3407	3614	$1.60^{+0.08}_{-0.09}$	0.809	4.98	30.90
307	HD 200964 b	606.3	1862	$1.599^{+0.067}_{-0.067}$	1.39	7.6	30.90
308	NGC 2682 Sand 364 b	120.95	3729	$1.57^{+0.11}_{-0.11}$	1.35	15.93	56.94
309	HIP 109384 b	499.48	2776	$1.56^{+0.08}_{-0.08}$	0.78	5.8	56.53
310	HD 4113 b	526.62	2922	$1.56^{+0.04}_{-0.04}$	0.99	8.4	97.10
311	HD 27442 b	428.1	1096	$1.56^{+0.14}_{-0.14}$	1.23	6.5	32.20
312	HD 222076 b	871	2330	$1.56^{+0.11}_{-0.11}$	1.07	5.9	31.90
313	HD 6718 b	2496	2028	$1.56^{+0.1}_{-0.11}$	0.96	1.79	24.10
314	eps Eri b	2502	8784	$1.55^{+0.24}_{-0.24}$	0.83	11.7	18.50
315	HD 30856 b	847	1294	$1.547^{+0.091}_{-0.091}$	1.17	5.2	29.90
316	HD 28678 b	380.2	1294	$1.542^{+0.073}_{-0.073}$	1.53	6.1	32.90
317	GJ 317 c	5312	2535	$1.54^{+0.57}_{-1.26}$	0.42	8.50	30.00
318	psi 1 Dra B b	3117	6233	$1.53^{+0.1}_{-0.1}$	1.19	7.05	21.00
319	HD 48265 b	778.51	3834	$1.525^{+0.05}_{-0.05}$	1.312	3.38	28.65
320	HD 102329 c	1123	2421	$1.52^{+0.25}_{-0.3}$	1.3	3.3	27.40
321	HD 121504 b	63.33	1496	$1.51^{+0.13}_{-0.13}$	1.18	11.6	55.80
322	omi CrB b	187.83	3504	$1.50^{+0.13}_{-0.13}$	2.13	16.4	32.25
323	HD 33142 b	326.6	1294	$1.50^{+0.22}_{-0.22}$	1.78	8.3	30.40
324	HD 188015 b	461.2	1322	$1.50^{+0.13}_{-0.13}$	1.09	4.3	37.60
325	HD 190360 b	2868	4346	$1.495^{+0.1542}_{-0.1542}$	0.98	3.1	23.39

Table A2. Cont.

N	Planet Name	Orbital Period, Day	Span, Day	Planet Mass, M_J	Host Star Mass, m_\odot	$\sigma(\text{O-C})$, m/s	RV K, m/s
326	HD 27631 b	2198	5550	$1.494^{+0.042}_{-0.042}$	0.944	5.29	24.51
327	HD 132563 b	1544	3645	$1.49^{+0.09}_{-0.09}$	1.081	12.7	26.70
328	HD 177830 b	406.6	5180	$1.49^{+0.03}_{-0.03}$	1.47	3.85	31.60
329	HD 20782 b	597.06	4111	$1.488^{+0.107}_{-0.105}$	1.02	2.34	118.43
330	HD 10442 b	1032.3	3386	$1.487^{+0.076}_{-0.076}$	1.01	5.98	29.90
331	HD 216536 b	148.6	2756	$1.47^{+0.12}_{-0.2}$	1.36	23	50.00
332	BD+14 4559 b	268.94	1265	$1.47^{+0.06}_{-0.06}$	0.86	11.43	55.21
333	HD 50499 b	2483.7	7268	$1.45^{+0.08}_{-0.08}$	1.31	10	18.94
334	HD 220773 b	3724.7	3311	$1.45^{+0.3}_{-0.3}$	1.16	6.57	20.00
335	HD 133131 A b	649	4460	$1.42^{+0.04}_{-0.04}$	0.95	9.38	36.52
336	HIP 5158 b	345.72	1901	$1.42^{+0.274}_{-0.274}$	0.78	2.47	59.00
337	HD 5608 b	792.6	3190	$1.40^{+0.095}_{-0.095}$	1.55	6.3	23.50
338	HD 208897 b	352.7	2760	$1.40^{+0.08}_{-0.08}$	1.25	18.13	34.70
339	HD 116029 b	670	1487	$1.40^{+0.29}_{-0.29}$	0.83	6.9	36.60
340	HD 99706 b	868	2418	$1.39^{+0.24}_{-0.24}$	1.7	4.2	22.40
341	HIP 67851 b	88.9	4017	$1.38^{+0.15}_{-0.15}$	1.63	8.9	45.50
342	XO-2 S c	120.8	384	$1.37^{+0.053}_{-0.053}$	0.98	3.1	57.68
343	HD 2952 b	311.6	3219	$1.37^{+0.26}_{-0.26}$	1.97	12.4	26.30
344	HD 205739 b	279.8	1209	$1.37^{+0.09}_{-0.07}$	1.22	8.67	42.00
345	HD 19994 b	466.2	3367	$1.37^{+0.12}_{-0.12}$	1.365	14	29.30
346	HD 79498 b	1966.1	2661	$1.34^{+0.07}_{-0.07}$	1.06	5.13	26.00
347	HD 141399 c	201.99	2566	$1.33^{+0.08}_{-0.08}$	1.07	4.8	44.20
348	HD 231701 b	141.6	1095	$1.31^{+0.18}_{-0.18}$	1.52	5.9	39.00
349	8 UMi b	93.4	1888	$1.31^{+0.16}_{-0.16}$	1.44	17.2	46.10
350	HD 217107 b	7.127	3470	$1.30^{+0.05}_{-0.05}$	1	11	139.20
351	HD 148427 b	331.5	2748	$1.30^{+0.17}_{-0.17}$	1.64	7	27.70
352	HD 108874 b	395.8	2850	$1.29^{+0.06}_{-0.06}$	1	4.1	37.00
353	HIP 14810 c	147.747	1112	$1.31^{+0.18}_{-0.18}$	0.81	3.29	50.91
354	HD 116029 c	907	2252	$1.27^{+0.15}_{-0.15}$	1.33	5	20.70
355	HD 94834 b	1576	3100	$1.26^{+0.17}_{-0.17}$	1.11	6.32	20.70
356	HD 216435 b	1391	1560	$1.26^{+0.18}_{-0.18}$	1.25	6.69	20.00
357	HD 95089 b	507	2422	$1.26^{+0.085}_{-0.085}$	1.54	7.6	25.00
358	WASP-47 c	588.5	494	$1.253^{+0.029}_{-0.029}$	1.04	3.7	30.00
359	HD 142 b	349.7	5067	$1.25^{+0.15}_{-0.15}$	1.232	11.2	33.20
360	HD 210277 b	442.1	433	$1.29^{+0.05}_{-0.05}$	1.01	6.1	38.90
361	HD 148164 b	328.55	4383	$1.23^{+0.25}_{-0.25}$	1.21	5.62	39.60
362	HD 30562 b	1157	3691	$1.22^{+0.14}_{-0.14}$	1.12	7.58	33.70
363	HD 200964 c	852.5	1862	$1.214^{+0.072}_{-0.072}$	1.39	7.6	21.50
364	HD 147513 b	528.4	1690	$1.21^{+0.074}_{-0.074}$	1.07	5.7	29.30
365	HD 143105 b	2.197	422	$1.21^{+0.06}_{-0.06}$	1.51	10.6	144.00
366	HD 52265 b	119.27	509	$1.21^{+0.05}_{-0.05}$	1.204	10.1	42.97
367	HD 73534 b	1770	1765	$1.20^{+0.1}_{-0.1}$	1.4	3.36	16.20
368	HD 65216 b	613.1	5371	$1.18^{+0.06}_{-0.06}$	0.88	2.84	33.70
369	HD 141399 d	1069.8	2566	$1.18^{+0.08}_{-0.08}$	1.07	4.8	22.63
370	HD 28254 b	1116	1989	$1.16^{+0.06}_{-0.1}$	1.06	2.19	37.30
371	HD 100777 b	383.7	857	$1.16^{+0.03}_{-0.03}$	1	1.7	34.90
372	HD 5319 c	886	3574	$1.15^{+0.08}_{-0.08}$	1.56	7.18	18.80
373	HD 75784 b	341.7	3694	$1.15^{+0.3}_{-0.3}$	1.41	4.63	26.70
374	HD 130322 b	10.709	5178	$1.15^{+0.025}_{-0.025}$	0.92	14.6	112.50

Table A2. Cont.

N	Planet Name	Orbital Period, Day	Span, Day	Planet Mass, M _J	Host Star Mass, m _☉	σ(O-C), m/s	RV K, m/s
375	HD 114386 b	937.7	1550	1.14 ^{+0.13} _{-0.13}	0.6	10.2	34.30
376	HD 159243 b	12.62	767	1.13 ^{+0.05} _{-0.05}	1.125	12.4	91.10
377	HD 14787 b	676.6	3287	1.121 ^{+0.069} _{-0.069}	1.43	5.3	20.70
378	HD 220689 b	2266.4	5200	1.118 ^{+0.035} _{-0.035}	1.016	4.85	17.12
379	HD 9174 b	1179	1723	1.11 ^{+0.14} _{-0.14}	1.03	2.2	20.80
380	BD+15 2940 b	137.48	2362	1.11 ^{+0.11} _{-0.11}	1.1	17.89	42.70
381	HD 114783 b	493.7	3208	1.10 ^{+0.06} _{-0.06}	0.853	6.3	31.90
382	HIP 91258 b	5.05	146	1.09 ^{+0.21} _{-0.21}	0.97	5.97	130.90
383	BD+15 2375 b	153.22	4103	1.061 ^{+0.27} _{-0.27}	1.08	22.82	38.30
384	HD 60532 b	201.9	1960	1.06 ^{+0.08} _{-0.08}	1.5	4.66	29.10
385	rho CrB b	39.846	3360	1.045 ^{+0.024} _{-0.024}	0.889	2.57	67.28
386	gam Lib b	415.2	5234	1.02 ^{+0.14} _{-0.14}	1.47	16.41	22.00
387	HD 219415 b	2093.3	2653	1.00 ^{+0.12} _{-0.12}	1	8.8	18.20
388	HD 154345 b	3538	6511	1.00 ^{+0.3} _{-0.3}	0.88	4	17.00
389	HD 108874 c	1624	2850	0.99 ^{+0.06} _{-0.06}	1	4.1	18.20
390	HD 1605 b	577.9	3281	0.96 ^{+0.04} _{-0.06}	1.31	6.4	19.80
391	HD 185269 b	6.838	749	0.94 ^{+0.046} _{-0.046}	1.28	10.1	91.00
392	HD 10647 b	989.2	4748	0.94 ^{+0.08} _{-0.08}	1.11	8.92	18.10
393	HD 113538 c	1818	3771	0.93 ^{+0.06} _{-0.06}	0.585	3.5	22.60
394	HD 86226 b	1695	4680	0.92 ^{+0.1} _{-0.1}	1.06	6.88	15.30
395	HD 102956 b	6.495	1164	0.92 ^{+0.07} _{-0.07}	1.59	6	73.40
396	HD 285507 b	6.088	194	0.917 ^{+0.033} _{-0.033}	0.734	15	125.80
397	HD 179949 b	3.093	735	0.916 ^{+0.076} _{-0.076}	1.21	7.7	112.60
398	HD 25171 b	1802.3	4100	0.915 ^{+0.012} _{-0.011}	1.076	2.4	14.56
399	GJ 849 b	1924	6210	0.911 ^{+0.036} _{-0.036}	0.49	3.72	23.96
400	BD+48 738 b	392.6	2480	0.91 ^{+0.074} _{-0.074}	0.74	16	31.90
401	24 Boo b	30.35	4808	0.91 ^{+0.1} _{-0.13}	0.99	26.51	59.90
402	HD 96063 b	361.1	1398	0.90 ^{+0.1} _{-0.1}	1.02	5.4	25.90
403	HD 128356 b	298.2	2633	0.89 ^{+0.07} _{-0.07}	0.65	3.9	36.90
404	7 Cma c	996	6791	0.87 ^{+0.06} _{-0.06}	1.34	8.2	14.90
405	HD 17674 b	623.8	6709	0.87 ^{+0.06} _{-0.07}	0.98	8.24	21.10
406	HD 13908 b	19.382	1589	0.865 ^{+0.035} _{-0.035}	1.29	9.6	55.30
407	24 Sex c	883	1907	0.86 ^{+0.22} _{-0.35}	1.54	6.8	14.50
408	HD 155358 b	194.3	3723	0.85 ^{+0.05} _{-0.05}	0.92	6.14	32.00
409	HD 148156 b	1027	2168	0.85 ^{+0.05} _{-0.06}	1.22	3.69	17.50
410	Kepler-68 d	625	1207	0.84 ^{+0.05} _{-0.05}	1.19	4	19.06
411	HD 38529 b	14.31	3745	0.839 ^{+0.03} _{-0.03}	1.477	11.8	56.10
412	HD 187085 b	1019.74	5811	0.836 ^{+0.011} _{-0.011}	1.189	5.51	15.39
413	55 Cancri b	14.652	8476	0.8306 ^{+0.0033} _{-0.0033}	0.905	3.5	71.40
414	HD 114729 b	1121.79	6500	0.825 ^{+0.007} _{-0.007}	0.936	3.93	16.91
415	HD 155358 c	391.9	3723	0.82 ^{+0.07} _{-0.07}	0.92	6.14	24.90
416	HD 134987 c	5000	4195	0.82 ^{+0.03} _{-0.03}	1.07	3.3	9.30
417	GJ 179 b	2288	3626	0.82 ^{+0.07} _{-0.07}	0.357	9.51	25.80
418	HD 4208 b	832.97	6562	0.81 ^{+0.015} _{-0.014}	0.883	6.36	19.03
419	HD 197037 b	1035.7	3924	0.79 ^{+0.05} _{-0.05}	1.11	8	15.50
420	HIP 65407 c	67.3	1517	0.784 ^{+0.054} _{-0.054}	0.93	7.5	41.50
421	HD 163607 b	75.22	4840	0.784 ^{+0.01} _{-0.01}	1.12	2	52.34
422	HD 109246 b	68.27	1120	0.77 ^{+0.09} _{-0.09}	1.01	7.7	38.20
423	HD 159868 c	351	3400	0.768 ^{+0.044} _{-0.044}	1.19	5.8	20.00

Table A2. Cont.

N	Planet Name	Orbital Period, Day	Span, Day	Planet Mass, M _J	Host Star Mass, m _☉	σ(O-C), m/s	RV K, m/s
424	HD 156411 b	842.2	2231	0.74 ^{+0.04} _{-0.05}	1.25	2.94	14.00
425	HD 192263 b	24.356	4799	0.733 ^{+0.015} _{-0.015}	0.807	12.42	59.30
426	HD 207832 c	1155.7	2722	0.73 ^{+0.05} _{-0.18}	0.94	8.43	15.30
427	GJ 876 c	30.088	4600	0.71 ^{+0.0039} _{-0.0039}	0.32	2.96	88.34
428	HD 224693 b	26.73	562	0.71 ^{+0.035} _{-0.035}	1.33	4.07	40.20
429	HD 9446 b	30.052	851	0.70 ^{+0.06} _{-0.06}	1	15.1	46.60
430	HD 32963 b	2372	5838	0.70 ^{+0.03} _{-0.03}	1.03	2.64	11.10
431	HD 209458 b	3.525	1885	0.699 ^{+0.007} _{-0.007}	1.23	14.9	85.10
432	HD 37124 d	1862	4810	0.696 ^{+0.059} _{-0.059}	0.85	4.03	12.80
433	GJ 832 b	3660	5570	0.689 ^{+0.16} _{-0.16}	0.45	1.6	15.40
434	ups And b	4.617	7383	0.6876 ^{+0.0044} _{-0.0044}	1.3	13.76	70.51
435	HD 96167 b	498.9	1832	0.68 ^{+0.18} _{-0.18}	1.31	4.6	20.80
436	HD 8535 b	1313	2220	0.68 ^{+0.04} _{-0.07}	1.13	2.49	11.80
437	HD 37124 b	154.378	4810	0.675 ^{+0.017} _{-0.017}	0.85	4.03	28.50
438	HD 211810 b	1558	4052	0.67 ^{+0.44} _{-0.44}	1.03	2.55	15.60
439	Kepler-65 e	258.7	2229	0.653 ^{+0.055} _{-0.056}	1.248	6.05	19.10
440	HD 27894 b	18.02	4748	0.665 ^{+0.007} _{-0.009}	0.8	2.04	59.80
441	HD 170469 b	1145	2544	0.66 ^{+0.11} _{-0.11}	1.1	4.18	12.00
442	HD 141399 e	5000	2566	0.66 ^{+0.1} _{-0.1}	1.07	4.8	8.80
443	HD 45364 c	342.85	1583	0.658 ^{+0.013} _{-0.013}	0.82	1.417	21.92
444	HD 37124 c	885.5	4810	0.652 ^{+0.052} _{-0.052}	0.85	4.03	15.40
445	HD 216770 b	118.45	827	0.65 ^{+0.04} _{-0.04}	0.9	7.8	30.90
446	HD 63765 b	358	3934	0.64 ^{+0.05} _{-0.05}	0.865	3.41	20.90
447	HD 181433 c	962	1757	0.64 ^{+0.016} _{-0.016}	0.78	1.06	16.20
448	HD 34445 b	1056.7	6830	0.629 ^{+0.028} _{-0.028}	1.07	3.43	12.01
449	HD 11964 b	1945	4378	0.622 ^{+0.056} _{-0.056}	1.08	3.1	9.41
450	HD 330075 b	3.388	204	0.62 ^{+0.004} _{-0.004}	0.7	2	107.00
451	HD 103720 b	4.556	3353	0.62 ^{+0.025} _{-0.025}	0.794	13.1	89.00
452	WASP-94 B b	2.008	625	0.618 ^{+0.029} _{-0.028}	1.24	7.16	86.48
453	HD 175541 b	297.3	3685	0.61 ^{+0.87} _{-0.087}	1.65	5.6	14.00
454	HD 43197 b	327.8	1943	0.60 ^{+0.04} _{-0.12}	0.96	1.44	32.40
455	BD-10 3166 b	3.488	414	0.59 ^{+0.07} _{-0.07}	1.47	5.7	60.90
456	HD 44219 b	472.3	1988	0.58 ^{+0.04} _{-0.06}	1	2.39	19.40
457	HIP 14810 d	981.8	1112	0.59 ^{+0.1} _{-0.1}	0.81	3.29	12.17
458	HD 207832 b	161.97	2722	0.56 ^{+0.03} _{-0.06}	0.94	8.43	22.10
459	Pr0201 b	4.426	101	0.54 ^{+0.12} _{-0.12}	1.24	26	58.10
460	HD 181433 d	2172	1757	0.54 ^{+0.043} _{-0.043}	0.78	1.06	11.30
461	47 UMa c	2391	7175	0.54 ^{+0.073} _{-0.066}	1.03	6.5	8.00
462	BD-11 4672 b	1667	3271	0.53 ^{+0.05} _{-0.05}	0.571	2.9	13.40
463	HIP 57274 d	431.7	1004	0.5267 ^{+0.03} _{-0.03}	0.73	3.15	18.20
464	HD 187123 b	3.097	3810	0.523 ^{+0.043} _{-0.043}	1	2.5	14.91
465	HD 160691 e	310.55	2987	0.522 ^{+0.001} _{-0.001}	1.08	3.34	14.91
466	HD 7449 b	1255.5	4452	0.508 ^{+0.111} _{-0.111}	1.053	4.21	21.90
467	HD 99109 b	439.3	2575	0.502 ^{+0.07} _{-0.07}	0.93	6.28	14.10
468	HD 31253 b	466	4461	0.50 ^{+0.07} _{-0.07}	1.23	4.23	12.00
469	HD 210193 b	649.9	3161	0.482 ^{+0.073} _{-0.073}	1.04	2.9	11.40
470	HD 2638 b	3.444	401	0.48 ^{+0.003} _{-0.003}	0.93	3.3	67.40
471	HD 164509 b	282.4	2153	0.48 ^{+0.09} _{-0.09}	1.13	4.9	14.20
472	HD 114613 b	3827	5637	0.48 ^{+0.04} _{-0.04}	1.364	3.9	5.52

Table A2. Cont.

N	Planet Name	Orbital Period, Day	Span, Day	Planet Mass, M _J	Host Star Mass, m _☉	σ(O-C), m/s	RV K, m/s
473	HD 30669 b	1684	3799	0.47 ^{+0.06} _{-0.06}	0.92	3.6	8.60
474	HD 45652 b	43.6	484	0.47 ^{+0.035} _{-0.035}	0.83	8.9	33.10
475	51 Peg b	4.231	3278	0.468 ^{+0.007} _{-0.007}	1.12	11.8	57.30
476	GJ 3512 b	203.59	867	0.463 ^{+0.023} _{-0.022}	0.123	3.27	71.84
477	NGC 2682 YBP 401 b	4.087	2493	0.46 ^{+0.05} _{-0.05}	1.14	12.74	49.06
478	HD 141399 b	94.44	2566	0.451 ^{+0.03} _{-0.03}	1.07	4.8	19.23
479	HD 212301 b	2.246	723	0.45 ^{+0.005} _{-0.005}	1.27	6.7	59.50
480	HD 208487 c	909	2650	0.45 ^{+0.13} _{-0.11}	1.05	4.4	10.10
481	HD 102195 b	4.114	435	0.45 ^{+0.014} _{-0.014}	0.87	6.1	63.00
482	HD 6434 b	22.017	5444	0.44 ^{+0.01} _{-0.01}	0.89	7.77	35.00
483	DMPP-2 b	5.207	4508	0.437 ^{+0.059} _{-0.03}	1.44	17.35	40.26
484	HIP 65407 b	28.125	1517	0.428 ^{+0.032} _{-0.032}	0.93	7.5	30.50
485	HD 133131A c	3568	4460	0.42 ^{+0.15} _{-0.15}	0.95	9.38	6.89
486	HD 75289 b	3.51	335	0.42 ^{+0.008} _{-0.008}	1.15	7.44	54.00
487	HD 126614A b	1244	4029	0.41 ^{+0.06} _{-0.06}	1.26	3.99	7.30
488	HD 208487 b	129.97	2650	0.48 ^{+0.06} _{-0.06}	1.05	4.4	19.30
489	HIP 57274 c	32.03	1004	0.409 ^{+0.009} _{-0.009}	0.73	3.15	32.40
490	HD 11506 c	223.41	3574	0.408 ^{+0.057} _{-0.057}	1.24	4.8	12.10
491	NGC 2682 YBP 1514 b	5.118	1506	0.40 ^{+0.11} _{-0.11}	0.96	14.6	52.29
492	HD 108147 b	10.901	1065	0.40 ^{+0.011} _{-0.011}	1.27	9.2	36.00
493	HD 181720 b	956	2239	0.40 ^{+0.06} _{-0.06}	1.03	1.37	8.40
494	HD 63454 b	2.818	2215	0.398 ^{+0.01} _{-0.01}	0.84	6.84	64.19
495	HD 83443 b	2.986	1455	0.38 ^{+0.003} _{-0.003}	0.9	9	58.10
496	HD 34445 g	5700	6830	0.38 ^{+0.13} _{-0.13}	1.07	3.43	4.08
497	HD 93083 b	143.58	383	0.37 ^{+0.01} _{-0.01}	0.7	2	18.30
498	HD 103774 b	5.888	2734	0.367 ^{+0.022} _{-0.022}	1.335	11.43	34.30
499	HD 149026 b	2.877	277	0.36 ^{+0.03} _{-0.03}	1.3	3.8	43.30
500	HD 113538 b	663.2	3771	0.36 ^{+0.04} _{-0.04}	0.585	3.5	12.20
501	HIP 12961 b	57.435	2226	0.36 ^{+0.07} _{-0.07}	0.69	3.9	24.70
502	HD 102843 b	3090	3009	0.3584 ^{+0.0456} _{-0.0456}	0.95	1.6	5.24
503	HD 47186 c	1353.6	1583	0.3506 ^{+0.075} _{-0.075}	0.99	0.91	6.65
504	NGC 2682 YBP 1194 b	6.958	1889	0.34 ^{+0.05} _{-0.05}	1.01	11.55	37.72
505	HD 219134 h	2247	6837	0.34 ^{+0.02} _{-0.02}	0.794	2.223	6.10
506	HD 38283 b	363.2	3013	0.34 ^{+0.02} _{-0.02}	1.085	4.3	10.00
507	HD 164922 b	1201	7017	0.3385 ^{+0.0151} _{-0.0154}	0.874	2.63	7.15
508	HD 33283 b	18.179	738	0.33 ^{+0.026} _{-0.026}	1.24	3.6	25.20
509	HD 564 b	492.3	4008	0.33 ^{+0.03} _{-0.03}	0.961	2.9	8.79
510	HD 215497 c	567.94	1855	0.33 ^{+0.02} _{-0.02}	0.872	1.75	10.10
511	BD-08 2823 c	237.6	1826	0.33 ^{+0.03} _{-0.03}	0.74	4.3	13.40
512	GJ 649 b	598.3	3702	0.328 ^{+0.032} _{-0.032}	0.54	4.2	12.40
513	GJ 1148 b	41.38	6158	0.3043 ^{+0.0032} _{-0.0044}	0.344	3.71	38.37
514	HD 101930 b	70.46	382	0.30 ^{+0.007} _{-0.007}	0.74	1.8	18.10
515	HD 88133 b	3.415	185	0.29 ^{+0.02} _{-0.02}	1.20	5.3	35.70
516	HD 7199 b	615	2579	0.29 ^{+0.023} _{-0.023}	0.89	2.63	7.80
517	HD 109749 b	5.24	537	0.28 ^{+0.016} _{-0.016}	1.23	2.77	28.30
518	HD 168746 b	6.404	880	0.27 ^{+0.02} _{-0.02}	1.07	9.8	28.60
519	HD 204941 b	1733	2180	0.266 ^{+0.032} _{-0.032}	0.74	1.31	5.90
520	HD 16141 b	75.523	1220	0.26 ^{+0.02} _{-0.02}	1.11	3.24	12.00
521	XO-2S b	18.157	384	0.259 ^{+0.014} _{-0.014}	0.98	3.1	20.64

Table A2. Cont.

N	Planet Name	Orbital Period, Day	Span, Day	Planet Mass, M _J	Host Star Mass, m _☉	σ(O-C), m/s	RV K, m/s
522	HD 46375 b	3.024	516	0.249 ^{+0.03} _{−0.03}	1	2.59	35.20
523	HD 126525 b	960.4	4323	0.237 ^{+0.002} _{−0.002}	0.897	2.5	5.26
524	Kepler-25 d	122.4	2945	0.226 ^{+0.031} _{−0.031}	1.19	6.14	9.67
525	HD 76700 b	3.971	1244	0.233 ^{+0.024} _{−0.024}	1.13	6.2	27.60
526	HD 3651 b	62.218	7376	0.229 ^{+0.008} _{−0.008}	0.882	6.3	15.90
527	HD 137388 b	330	2054	0.223 ^{+0.029} _{−0.029}	0.86	2.39	7.90
528	GJ 1148 c	532.58	6158	0.2141 ^{+0.0069} _{−0.0154}	0.344	3.71	11.34
529	HD 218566 b	225.7	5053	0.21 ^{+0.02} _{−0.02}	0.85	3.48	8.30
530	HD 8326 b	158.991	3152	0.21 ^{+0.062} _{−0.062}	0.8	2.4	9.36
531	HD 21411 b	84.288	3217	0.207 ^{+0.081} _{−0.081}	0.89	3.5	11.48
532	HD 10180 h	2222	2428	0.203 ^{+0.014} _{−0.014}	1.06	1.27	3.04
533	HD 220197 b	1728	1887	0.20 ^{+0.04} _{−0.07}	0.91	2.62	3.78
534	HD 117618 b	25.827	6264	0.19 ^{+0.04} _{−0.04}	1.17	6.16	12.80
535	HD 45364 b	226.93	1583	0.1872 ^{+0.0036} _{−0.0036}	0.82	1.417	7.22
536	HD 104067 b	55.806	2272	0.186 ^{+0.013} _{−0.013}	0.791	4.6	11.56
537	HD 102117 b	20.8	2299	0.18 ^{+0.03} _{−0.03}	0.95	3.3	12.00
538	55 Cancri c	44.418	8476	0.1714 ^{+0.0055} _{−0.0055}	0.905	3.53	10.18
539	BD-06 1339 c	125.94	2955	0.17 ^{+0.03} _{−0.03}	0.7	4.3	9.10
540	HD 34445 c	214.67	6830	0.168 ^{+0.016} _{−0.016}	1.07	3.43	5.45
541	HD 27894 c	36.07	4748	0.162 ^{+0.04} _{−0.011}	0.8	2.04	11.57
542	HD 177830 c	110.9	5180	0.15 ^{+0.02} _{−0.02}	1.47	3.85	5.10
543	55 Cancri f	262	8476	0.141 ^{+0.012} _{−0.012}	0.905	6.343	4.87
544	HD 85390 b	788	2374	0.132 ^{+0.011} _{−0.011}	0.76	1.15	3.82
545	HD 49674 b	4.948	452	0.12 ^{+0.02} _{−0.02}	1	5.55	14.00
546	HD 34445 f	676.8	6830	0.119 ^{+0.021} _{−0.021}	1.07	3.43	2.74
547	GJ 15A c	7600	7310	0.11 ^{+0.06} _{−0.08}	0.38	3.08	2.50
548	HD 206255 b	96.045	3099	0.108 ^{+0.022} _{−0.022}	1.42	2.3	3.92
549	GJ 433 c	5094	7305	0.102 ^{+0.02} _{−0.02}	0.48	2.1	1.75
550	HD 103197 b	47.84	2235	0.098 ^{+0.006} _{−0.006}	0.9	1.4	5.90
551	HD 34445 d	117.87	6830	0.097 ^{+0.013} _{−0.013}	1.07	3.43	3.81
552	GJ 163 d	604	3068	0.0925 ^{+0.0091} _{−0.0091}	0.4	2.02	4.42
553	HD 134060 c	1291.56	4083	0.0922 ^{+0.0133} _{−0.0139}	1.095	1.64	1.65
554	HD 147379 b (GJ 617A)	86.78	2185	0.08984 ^{+0.046} _{−0.0047}	0.6	3.87	5.83
555	HD 179079 b	14.476	1580	0.0866 ^{+0.008} _{−0.008}	1.15	3.88	6.64
556	HD 10180 e	49.747	2428	0.079 ^{+0.0038} _{−0.0038}	1.06	1.27	4.19
557	HD 99492 b	17.054	6756	0.079 ^{+0.006} _{−0.006}	0.85	4.33	6.98
558	HD 11964 c	37.91	4378	0.0788 ^{+0.0097} _{−0.0097}	1.08	3.1	4.65
559	rho CrB c	102.54	3360	0.0787 ^{+0.0063} _{−0.0063}	0.889	2.57	3.74
560	HD 38677 b (DMPP-1 b)	18.57	763	0.0764 ^{+0.005} _{−0.0037}	1.21	1.1	5.16
561	HD 192310 c	525.8	2348	0.076 ^{+0.016} _{−0.016}	0.8	0.92	2.27
562	HD 109271 c	30.93	2683	0.076 ^{+0.007} _{−0.007}	1.047	2.05	4.90
563	HD 10180 f	122.72	2428	0.0752 ^{+0.0044} _{−0.0044}	1.06	1.27	2.98
564	GJ 3293 b	30.599	2300	0.0741 ^{+0.0028} _{−0.0028}	0.42	2.78	8.60
565	61 Vir d (HD 115617 d)	123	1571	0.072 ^{+0.008} _{−0.008}	0.942	2.17	3.25
566	HD 47186 b	4.085	1583	0.0717 ^{+0.0014} _{−0.0014}	0.99	0.91	9.12
567	Kepler-19 d	62.95	867	0.0708 ^{+0.0176} _{−0.0038}	0.936	2.9	4.00
568	HD 16417 b	17.24	3874	0.0696 ^{+0.0063} _{−0.0063}	1.2	2.6	5.00
569	HD 10180 g	602	2428	0.0673 ^{+0.0107} _{−0.0107}	1.06	1.27	1.59
570	GJ 436 b	2.644	1645	0.067 ^{+0.007} _{−0.007}	0.41	5.26	18.10

Table A2. Cont.

N	Planet Name	Orbital Period, Day	Span, Day	Planet Mass, M_J	Host Star Mass, m_\odot	$\sigma(\text{O-C})$, m/s	RV K, m/s
571	HD 219134 d	46.71	6837	$0.067^{+0.004}_{-0.004}$	0.794	2.223	4.40
572	GJ 3293 c	122.6	2300	$0.0664^{+0.004}_{-0.004}$	0.42	2.78	4.89
573	HD 219828 b	3.835	5169	$0.0661^{+0.0044}_{-0.0044}$	1.23	1.64	7.53
574	HD 190360 c	17.119	4346	$0.0638^{+0.01}_{-0.01}$	0.98	3.1	5.20
575	Kepler-20 g	34.94	2262	$0.0628^{+0.0114}_{-0.0097}$	0.948	5.39	4.10
576	HD 213885 c	4.785	3728	$0.0628^{+0.0043}_{-0.0043}$	1.068	5	7.26
577	GJ 96 b	73.94	1896	$0.0619^{+0.0072}_{-0.0076}$	0.6	3.37	4.69
578	HIP 71135 b	87.19	3009	$0.0592^{+0.0129}_{-0.0129}$	0.66	3.1	3.71
579	GJ 687 b	38.14	6077	$0.058^{+0.007}_{-0.007}$	0.413	6.62	6.40
580	HD 125612 c	4.155	2016	$0.058^{+0.01}_{-0.01}$	1.091	3.7	6.46
581	HD 90156 b	49.77	1607	$0.057^{+0.005}_{-0.005}$	0.84	1.23	3.69
582	61 Vir c (HD 115617 c)	38.021	1571	$0.057^{+0.003}_{-0.003}$	0.942	2.17	3.62
583	HD 69830 d	197	826	$0.057^{+0.005}_{-0.005}$	0.86	0.81	2.20
584	HD 64114 b	45.791	2633	$0.056^{+0.011}_{-0.011}$	0.95	1.6	3.33
585	HD 204313 c	34.905	4748	$0.0553^{+0.0053}_{-0.0053}$	1.03	1.32	3.42
586	HD 21693 c	53.736	4106	$0.0547^{+0.0056}_{-0.0056}$	0.8	2.05	3.44
587	HD 109271 b	7.854	2683	$0.054^{+0.004}_{-0.004}$	1.047	2.05	5.60
588	HD 192310 b	74.72	2348	$0.0532^{+0.0028}_{-0.0028}$	0.8	0.92	3.00
589	HD 34445 e	49.175	6830	$0.0529^{+0.0089}_{-0.0089}$	1.07	3.43	2.75
590	GJ 4276 b	13.352	774	$0.052^{+0.003}_{-0.003}$	0.406	2.46	8.79
591	HD 164595 b	40	809	$0.0508^{+0.0086}_{-0.0086}$	0.99	2.3	3.05
592	HD 77338 b	5.736	2636	$0.05^{+0.017}_{-0.015}$	0.93	1.74	6.00
593	HD 4308 b	15.56	680	$0.05^{+0.0025}_{-0.0025}$	0.93	1.3	4.10
594	HD 102365 b	122.1	4545	$0.05^{+0.008}_{-0.008}$	0.85	2.53	2.30
595	GJ 581 b	5.368	6509	$0.0478^{+0.0009}_{-0.0007}$	0.31	2.91	12.35
596	GJ 876 e	124.26	4600	$0.046^{+0.005}_{-0.005}$	0.32	2.96	3.42
597	HD 20003 c	33.924	4063	$0.0454^{+0.0044}_{-0.0046}$	0.875	1.65	3.15
598	HD 42618 b	149.61	6967	$0.0453^{+0.0076}_{-0.0079}$	1.015	2.34	1.89
599	HD 51608 c	95.945	4158	$0.045^{+0.005}_{-0.005}$	0.8	1.6	2.36
600	BD-08 2823 b	5.6	1826	$0.045^{+0.007}_{-0.007}$	0.74	4.3	6.50
601	HD 31527 c	51.205	4135	$0.0445^{+0.004}_{-0.004}$	0.96	1.41	2.51
602	HD 20781 e	85.507	4093	$0.0442^{+0.0049}_{-0.0049}$	0.7	1.45	2.60
603	CoRoT-7 c	3.7	109+25	$0.043^{+0.003}_{-0.003}$	0.9	1.96	6.01
604	LSPM J2116+0234 b	14.44	882	$0.0418^{+0.0035}_{-0.0031}$	0.43	4.14	6.26
605	HD 10180 c	5.76	2428	$0.0412^{+0.0017}_{-0.0017}$	1.06	1.27	4.50
606	HD 125595 b	9.674	2075	$0.041^{+0.004}_{-0.004}$	0.756	3.22	4.79
607	GJ 378 b	3.822	880	$0.041^{+0.0063}_{-0.0064}$	0.56	4.86	7.96
608	HD 211970 b	25.201	3102	$0.0409^{+0.0079}_{-0.0079}$	0.61	2.7	4.02
609	HD 164922 c	75.765	7017	$0.0406^{+0.005}_{-0.005}$	0.874	2.63	2.22
610	HD 51608 b	14.073	4158	$0.0402^{+0.0037}_{-0.0038}$	0.8	1.6	3.95
611	HIP 35173 b	41.516	3269	$0.04^{+0.0085}_{-0.0085}$	0.79	2	2.80
612	HIP 54373 c	15.144	3064	$0.03914^{+0.00664}_{-0.00664}$	0.57	4.2	4.84
613	HD 45184 b	5.885	4160	$0.0384^{+0.0032}_{-0.0033}$	1.03	2.15	4.26
614	HD 180617 b	105.9	6100	$0.0384^{+0.0044}_{-0.0031}$	0.45	2.66	2.85
615	HD 31527 d	271.7	4135	$0.0372^{+0.0053}_{-0.0053}$	0.96	1.41	1.25
616	HD 69830 c	31.56	826	$0.0371^{+0.0022}_{-0.0022}$	0.86	0.81	2.66
617	HD 24085 b	2.046	3162	$0.0371^{+0.0098}_{-0.0098}$	1.22	2	5.40
618	HD 10180 d	16.357	2428	$0.037^{+0.002}_{-0.002}$	1.06	1.27	2.86
619	HD 20003 b	11.848	4053	$0.0367^{+0.0033}_{-0.0033}$	0.875	1.65	3.84
620	HIP 57274 b	8.135	1004	$0.0365^{+0.0041}_{-0.0041}$	0.73	3.15	4.64

Table A2. Cont.

N	Planet Name	Orbital Period, Day	Span, Day	Planet Mass, M_J	Host Star Mass, m_\odot	$\sigma(\text{O-C})$, m/s	RV K, m/s
621	HD 103949 b	120.88	3064	$0.0352^{+0.0072}_{-0.0072}$	0.77	1.4	1.77
622	GJ 674 b	4.694	820	$0.035^{+0.0008}_{-0.0008}$	0.35	3.27	8.70
623	GJ 422 b	20.129	5200	$0.0348^{+0.0035}_{-0.0035}$	0.35	4.5	4.47
624	HD 219134 g	94.2	6837	$0.034^{+0.004}_{-0.004}$	0.794	2.223	1.80
625	HD 136352 c	27.582	3993	$0.034^{+0.0033}_{-0.0034}$	0.81	1.35	2.65
626	HD 20781 d	29.158	4093	$0.0334^{+0.0038}_{-0.0038}$	0.7	1.45	2.82
627	GJ 163 b	8.632	3068	$0.0334^{+0.0019}_{-0.0019}$	0.4	2.02	6.13
628	HD 160691 d	9.639	2987	$0.0332^{+0.001}_{-0.001}$	1.08	3.34	3.06
629	GJ 3138 d	257.8	2932	$0.033^{+0.0066}_{-0.0072}$	0.681	2.6	1.47
630	HD 31527 b	16.554	4135	$0.0329^{+0.0028}_{-0.0028}$	0.96	1.41	2.72
631	HD 69830 b	8.667	826	$0.0321^{+0.0014}_{-0.0014}$	0.86	0.81	3.51
632	HD 134060 b	3.27	4083	$0.0318^{+0.0024}_{-0.0025}$	1.095	1.64	4.61
633	DMPP-1 c (HD 38677 c)	6.584	763	$0.0302^{+0.005}_{-0.0017}$	1.21	1.1	2.88
634	HD 40307 d	20.432	1912	$0.0299^{+0.0047}_{-0.0053}$	0.77	1.16	2.75
635	HD 176986 c	16.819	4821	$0.0289^{+0.0031}_{-0.0031}$	0.789	2.5	2.63
636	HD 285968 b (GJ 176 b)	8.776	4832	$0.0285^{+0.0022}_{-0.0048}$	0.485	2.95	4.49
637	GJ 685 b	24.16	1605	$0.0283^{+0.0057}_{-0.0053}$	0.55	1.5	3.00
638	HD 175607 b	29.01	3390	$0.0283^{+0.0035}_{-0.0035}$	0.71	2	2.37
639	HD 219134 f	22.805	6837	$0.028^{+0.003}_{-0.003}$	0.794	2.223	2.30
640	HD 45184 c	13.135	4160	$0.0277^{+0.0032}_{-0.0034}$	1.03	2.15	2.36
641	HD 7924 b	5.398	4775	$0.0273^{+0.0016}_{-0.0016}$	0.832	2.5	3.59
642	HIP 54373 b	7.76	3064	$0.0271^{+0.0058}_{-0.0058}$	0.57	3.1	4.19
643	HD 136352 d	107.6	3993	$0.027^{+0.0036}_{-0.0037}$	0.81	1.35	1.35
644	HD 39855 b	3.25	2271	$0.027^{+0.005}_{-0.005}$	0.87	1.8	4.08
645	BD-06 1339 b	3.873	2955	$0.027^{+0.004}_{-0.004}$	0.7	4.3	4.40
646	GJ 229A b	526.115	7262	$0.0267^{+0.0064}_{-0.0064}$	0.58	2.4	1.37
647	HD 26965 b	42.378	5550	$0.0266^{+0.0015}_{-0.0015}$	0.78	2.6	1.81
648	HD 97658 b	9.494	2016	$0.026^{+0.004}_{-0.004}$	0.78	2.78	2.90
649	GJ 3082 b	11.949	2678	$0.026^{+0.005}_{-0.005}$	0.47	2.5	3.94
650	GJ 3634 b	2.646	462	$0.026^{+0.005}_{-0.013}$	0.45	2	5.59
651	HD 21693 b	22.679	4106	$0.0259^{+0.0033}_{-0.0034}$	0.8	2.05	2.20
652	55 Cancri e	0.737	8476	$0.0256^{+0.0007}_{-0.0007}$	0.905	5.95	5.97
653	GJ 676 A e	35.39	3535	$0.025^{+0.002}_{-0.002}$	0.73	2.46	2.00
654	HD 7924 c	15.299	4775	$0.0247^{+0.0022}_{-0.0023}$	0.832	2.5	2.31
655	Wolf 1061 d (GJ 628 d)	217.21	4136	$0.0242^{+0.0033}_{-0.0035}$	0.294	2.34	2.23
656	HD 181433 b	9.374	1757	$0.024^{+0.002}_{-0.002}$	0.78	1.06	2.57
657	GJ 3293 d	48.135	2300	$0.0239^{+0.0033}_{-0.0033}$	0.42	2.78	2.42
658	GJ 180 d	106.3	6182	$0.0238^{+0.0034}_{-0.0034}$	0.43	3.1	2.08
659	K2-18 c	8.962	758	$0.0236^{+0.0042}_{-0.0042}$	0.359	2.89	4.63
660	GJ 1265 b	3.651	782	$0.023^{+0.002}_{-0.002}$	0.178	3	9.89
661	GJ 229A c	121.995	7262	$0.0229^{+0.004}_{-0.004}$	0.58	2.4	1.93
662	GJ 3942 b	6.905	1203	$0.0225^{+0.0019}_{-0.0019}$	0.63	2.36	3.29
663	GJ 686 b	15.532	7442	$0.022^{+0.003}_{-0.003}$	0.42	2.9	3.29
664	Kapteyn c (GJ 191 c)	121.54	3750	$0.022^{+0.003}_{-0.004}$	0.281	2	2.27
665	HD 3167 d	8.509	152	$0.0217^{+0.0022}_{-0.0022}$	0.87	3.16	2.39
666	GJ 876 d	1.938	4600	$0.0215^{+0.0013}_{-0.0013}$	0.32	2.96	6.56
667	GJ 163 c	25.63	3068	$0.021^{+0.003}_{-0.003}$	0.4	2.02	2.75
668	HD 40307 c	9.618	1912	$0.0208^{+0.0031}_{-0.0035}$	0.77	1.16	2.45
669	GJ 3341 b	14.207	1456	$0.0208^{+0.0003}_{-0.0003}$	0.47	2.86	3.04
670	GJ 536 b	8.708	4677	$0.0205^{+0.0013}_{-0.0022}$	0.506	2.91	3.12

Table A2. Cont.

N	Planet Name	Orbital Period, Day	Span, Day	Planet Mass, M_J	Host Star Mass, m_\odot	$\sigma(\text{O-C})$, m/s	RV K, m/s
671	GJ 180 b	17.133	6182	$0.0204^{+0.0021}_{-0.0021}$	0.43	3.1	3.25
672	HD 1461 b	5.773	3725	$0.0203^{+0.0019}_{-0.0019}$	1.02	2.26	2.28
673	HD 7924 d	24.451	4775	$0.0203^{+0.0025}_{-0.0025}$	0.832	2.5	1.65
674	HD 215497 b	3.934	1855	$0.020^{+0.0023}_{-0.0023}$	0.872	1.75	3.00
675	GJ 3998 c	13.74	869	$0.0197^{+0.0024}_{-0.0025}$	0.5	2	2.67
676	GJ 357 d	55.66	7779	$0.019^{+0.003}_{-0.003}$	0.342	2.66	2.09
677	GJ 433 b	7.371	7305	$0.019^{+0.002}_{-0.002}$	0.48	2.1	2.86
678	HD 176986 b	6.49	4821	$0.0181^{+0.0021}_{-0.0021}$	0.789	2.5	2.56
679	GJ 667 C b	7.2	2201	$0.018^{+0.001}_{-0.001}$	0.33	1.84	3.90
680	GJ 581 c	12.919	6509	$0.0178^{+0.0008}_{-0.0012}$	0.31	2.91	3.28
681	HD 1461 c	13.505	3725	$0.0176^{+0.0023}_{-0.0023}$	1.02	2.26	1.49
682	HD 20781 c	13.89	4093	$0.0168^{+0.0021}_{-0.0022}$	0.7	1.45	1.81
683	GJ 433 d	36.059	7305	$0.0164^{+0.0029}_{-0.0029}$	0.48	2.1	1.46
684	61 Vir b (HD 115617 b)	4.215	1571	$0.016^{+0.002}_{-0.002}$	0.942	2.17	2.12
685	GJ 832 c	35.67	5570	$0.0157^{+0.0098}_{-0.0098}$	0.45	1.6	1.79
686	Kapteyn b (GJ 191 b)	48.616	3750	$0.0151^{+0.0031}_{-0.0028}$	0.281	2	2.25
687	HD 136352 b	11.582	3993	$0.0151^{+0.0018}_{-0.0018}$	0.81	1.35	1.59
688	HD 20794 d	90.309	2610	$0.015^{+0.002}_{-0.002}$	0.7	0.82	0.85
689	GJ 676 A d	3.601	3535	$0.014^{+0.001}_{-0.001}$	0.73	2.46	2.40
690	GJ 3138 c	5.974	2932	$0.0132^{+0.0019}_{-0.0019}$	0.681	2.6	1.93
691	HD 38677 e (DMPP-1 e)	5.516	763	$0.013^{+0.0036}_{-0.0021}$	1.21	1.1	1.30
692	GJ 667 C c	28.1	2201	$0.013^{+0.002}_{-0.002}$	0.33	1.84	1.90
693	HD 40307 b	4.312	1912	$0.0126^{+0.0022}_{-0.0025}$	0.77	1.16	1.94
694	HD 219134 b	3.093	6837	$0.012^{+0.001}_{-0.001}$	0.794	2.223	1.90
695	HD 219134 c	6.765	6837	$0.011^{+0.002}_{-0.002}$	0.794	2.223	1.40
696	GJ 357 c	9.125	7779	$0.0107^{+0.0014}_{-0.0014}$	0.342	2.66	2.13
697	Wolf 1061 c (GJ 628 c)	17.872	4136	$0.0107^{+0.0013}_{-0.0014}$	0.294	2.34	2.70
698	HD 38677 d (DMPP-1 d)	2.882	763	$0.0105^{+0.0011}_{-0.0012}$	1.21	1.1	1.33
699	GJ 3293 e	13.254	2300	$0.0103^{+0.002}_{-0.002}$	0.42	2.78	1.66
700	GJ 15A b	11.441	7310	$0.00953^{+0.00138}_{-0.00145}$	0.38	3.08	1.68
701	HD 20794 b	18.315	2610	$0.0085^{+0.0009}_{-0.0009}$	0.7	0.82	0.83
702	GJ 3998 b	2.65	869	$0.0078^{+0.0009}_{-0.0009}$	0.5	2	1.82
703	HD 20794 c	40.114	2610	$0.0076^{+0.0013}_{-0.0013}$	0.7	0.82	0.56
704	HD 20781 b	5.314	4093	$0.0061^{+0.0011}_{-0.0012}$	0.7	1.45	
705	Wolf 1061 b (GJ 628 b)	4.887	4136	$0.006^{+0.0008}_{-0.0008}$	0.294	2.34	
706	GJ 3138 b	1.22	2932	$0.0056^{+0.001}_{-0.001}$	0.681	2.6	
707	GJ 581 e	3.153	6509	$0.0052^{+0.0005}_{-0.0008}$	0.31	2.91	1.55
708	HD 10180 b	1.178	2428	$0.0044^{+0.0008}_{-0.0008}$	1.06	1.27	

References

1. Archive: NASA Exoplanet Archive. 2021. Available online: <https://exoplanetarchive.ipac.caltech.edu/> (accessed on 30 June 2022).
2. Mordasini, C. Planetary Population Synthesis. In *Handbook of Exoplanets*; Deeg, H.J., Belmonte, J.A., Eds.; Springer International Publishing: Cham, Switzerland, 2018; pp. 2425–2474. [CrossRef]
3. Emsenhuber, A.; Mordasini, C.; Burn, R.; Alibert, Y.; Benz, W.; Asphaug, E. The New Generation Planetary Population Synthesis (NGPPS). II. Planetary population of solar-like stars and overview of statistical results. *Astron. Astrophys.* **2021**, *656*, A70. [CrossRef]
4. Yakovlev, O.Y.; Ananyeva, V.I.; Ivanova, A.E.; Tavrov, A.V. Comparison of the mass distributions of short-period exoplanets detected by transit and RV methods. *Mon. Not. R. Astron. Soc.* **2022**, *509*, L17–L20. [CrossRef]
5. Dressing, C.D.; Charbonneau, D. The occurrence of potentially habitable planets orbiting M dwarfs estimated from the full Kepler dataset and an empirical measurement of the detection sensitivity. *Astrophys. J.* **2015**, *807*, 45. [CrossRef]

6. Kunitomo, M.; Matthews, J.M. Searching the Entirety of Kepler Data. II. Occurrence Rate Estimates for FGK Stars. *Astron. J.* **2020**, *159*, 248. [CrossRef]
7. Pinamonti, M.; Sozzetti, A.; Maldonado, J.; Affer, L.; Micela, G.; Bonomo, A.S.; Sánchez, R.Z. HADES RV Programme with HARPS-N at TNG. XV. Planetary occurrence rates around early-M dwarfs. *Astron. Astrophys.* **2022**, *A65*, 21. [CrossRef]
8. Ananyeva, V.I.; Ivanova, A.E.; Venkstern, A.A.; Tavrov, A.V.; Korablev, O.I.; Bertaux, J.L. The Dependence of the Mass Distribution of Exoplanets on the Spectral Class of Host Stars. *Sol. Syst. Res.* **2020**, *54*, 175–186. [CrossRef]
9. Butler, R.P.; Wright, J.T.; Marcy, G.W.; Fischer, D.A.; Vogt, S.S.; Tinney, C.G.; Penny, A.J. Catalog of Nearby Exoplanets. *Astrophys. J.* **2006**, *646*, 505. [CrossRef]
10. Marchi, S. Extrasolar Planet Taxonomy: A New Statistical Approach. *Astrophys. J.* **2007**, *666*, 475. [CrossRef]
11. Tabachnik, S.; Tremaine, S. Maximum-likelihood method for estimating the mass and period distributions of extrasolar planets. *Mon. Not. R. Astron. Soc.* **2002**, *335*, 151–158. [CrossRef]
12. Marcy, G.; Butler, R.P.; Fischer, D.; Vogt, S.; Wright, J.T.; Tinney, C.G.; Jones, H.R. Observed Properties of Exoplanets: Masses, Orbits, and Metallicities. *Prog. Theor. Phys. Suppl.* **2005**, *158*, 24–42. [CrossRef]
13. Cumming, A.; Butler, R.P.; Marcy, G.W.; Vogt, S.S.; Wright, J.T.; Fischer, D.A. The Keck Planet Search: Detectability and the Minimum Mass and Orbital Period Distribution of Extrasolar Planets. *Publ. Astron. Soc. Pac.* **2008**, *120*, 531. [CrossRef]
14. Howard, A.W.; Marcy, G.W.; Johnson, J.A.; Fischer, D.A.; Wright, J.T.; Isaacson, H.; Valenti, J.A.; Anderson, J.; Lin, D.N.C.; Ida, S. The occurrence and mass distribution of close-in super-Earths, Neptunes, and Jupiters. *Science* **2010**, *330*, 653–655. [CrossRef] [PubMed]
15. Jiang, G.; Yeh, L.C.; Chang, Y.C.; Hung, W.L. On the Fundamental Mass-Period Functions of Extrasolar Planets. *Astrophys. J. Suppl. Ser.* **2010**, *186*, 48. [CrossRef]
16. Tuomi, M.; Jones, H.R.A.; Butler, R.P.; Arriagada, P.; Vogt, S.S.; Burt, J.; Barnes, J.R. Frequency of planets orbiting M dwarfs in the Solar neighbourhood. *Astrophys. J. Suppl. Ser.* **2019**, *1906*, 04644. Available online: <https://arxiv.org/pdf/1906.04644.pdf> (accessed on 20 April 2022).
17. Petigura, E.A.; Howard, A.W.; Marcy, G.W. Prevalence of Earth-size planets orbiting Sun-like stars. *Proc. Natl. Acad. Sci. USA* **2013**, *110*, 19273–19278. [CrossRef]
18. Akeson, R.L.; Chen, X.; Ciardi, D.; Crane, M.; Good, J.; Harbut, M.; Zhang, A. The NASA exoplanet archive: Data and tools for exoplanet research. *Publ. Astron. Soc. Pac.* **2013**, *125*, 989–999. Available online: <https://iopscience.iop.org/article/10.1086/672273/pdf> (accessed on 24 June 2022). [CrossRef]
19. Sturges, H.A. The choice of a class interval. *J. Am. Stat. Assoc.* **1926**, *21*, 65–66. Available online: https://www.jstor.org/stable/2965501?origin=JSTOR-pdf#metadata_info_tab_contents (accessed on 24 June 2022). [CrossRef]
20. Ivanova, A.E.; Yakovlev, O.Y.; Ananyeva, V.I.; Shashkova, I.A.; Tavrov, A.V.; Bertaux, J.L. The “Detectability Window” Method to Take into Account Observational Selection in the Statistics of Exoplanets Discovered through Radial Velocity Measurements. *Astron. Lett.* **2021**, *47*, 43–49. [CrossRef]
21. Rickman, E.L.; Ségransan, D.; Marmier, M.; Udry, S.; Bouchy, F.; Lovis, C.; Wyttenbach, A. The CORALIE survey for southern extrasolar planets. XVIII. Three new massive planets and two low-mass brown dwarfs at greater than 5 AU separation. *Astron. Astrophys.* **2019**, *625*, A71. [CrossRef]
22. Feng, F.; Butler, R.P.; Shectman, S.A.; Crane, J.D.; Vogt, S.; Chambers, J.; Thompson, I.B. Search for Nearby Earth Analogs. II. Detection of Five New Planets, Eight Planet Candidates, and Confirmation of Three Planets around Nine Nearby M Dwarfs. *Astrophys. J. Suppl. Ser.* **2020**, *246*, 11. [CrossRef]
23. Ma, B.; Ge, J.; Muterspaugh, M.; Singer, M.A.; Henry, G.W.; González Hernández, J.I.; Ealey, B. The first super-Earth detection from the high cadence and high radial velocity precision Dharma Planet Survey. *Mon. Not. R. Astron. Soc.* **2018**, *480*, 2411–2422. [CrossRef]
24. Jorissen, A.; Mayor, M.; Udry, S. The distribution of exoplanet masses. *Astron. Astrophys.* **2001**, *379*, 3. [CrossRef]
25. Ananyeva, V.I.; Tavrov, A.V.; Venkstern, A.A.; Churbanov, D.V.; Shashkova, I.A.; Korablev, O.I.; Bertaux, J.L. The Distribution of Giant Exoplanets over True and Minimum masses: Accounting for Observational Selection. *Sol. Syst. Res.* **2019**, *53*, 124–137. [CrossRef]
26. Ivanova, A.E.; Ananyeva, V.I.; Venkstern, A.A.; Shashkova, I.A.; Yudaev, A.V.; Tavrov, A.V.; Bertaux, J.L. The mass distribution of transiting exoplanets corrected for observational selection effects. *Astron. Lett.* **2019**, *45*, 687–694. [CrossRef]
27. Szabó, G.M.; Kiss, L.L. A short-period censor of sub-jupiter mass exoplanets with low density. *Astrophys. J. Lett.* **2011**, *727*, L44. [CrossRef]
28. Mazeh, T.; Holczer, T.; Faigler, S. Dearth of short-period Neptunian exoplanets: A desert in period-mass and period-radius planes. *Astron. Astrophys.* **2016**, *589*, A75. [CrossRef]
29. Boss, A. Giant Planet Formation by Gravitational Instability. *Science* **1997**, *276*, 5320. [CrossRef]
30. Pollack, J.B.; Hubickyj, O.; Bodenheimer, P.; Lissauer, J.J.; Podolak, M.; Greenzweig, Y. Formation of the Giant Planets by Concurrent Accretion of Solids and Gas. *Icarus* **1996**, *124*, 1. [CrossRef]
31. Moe, M.; Kratter, K.M. Impact of binary stars on planet statistics—I. Planet occurrence rates and trends with stellar mass. *Mon. Not. R. Astron. Soc.* **2021**, *507*, 3. [CrossRef]
32. Fernandes, R.B.; Mulders, G.D.; Pascucci, I.; Mordasini, C.; Emsenhuber, A. Hints for a turnover at the snow line in the giant planet occurrence rate. *Astrophys. J.* **2019**, *874*, 81. [CrossRef]

33. Mulders, G.D.; Pascucci, I.; Apai, D.; Ciesla, F.J. The Exoplanet Population Observation Simulator. *I. Inn. Edges Planet. Syst. Astron. J.* **2018**, *156*, 1. [[CrossRef](#)]
34. Petigura, E.A.; Marcy, G.W.; Winn, J.N.; Weiss, L.M.; Fulton, B.J.; Howard, A.W.; Johnson, J. A The California-Kepler Survey. IV. Metal-rich Stars Host a Greater Diversity of Planets. *Astron. J.* **2018**, *155*, 2. [[CrossRef](#)]
35. Bertaux, J.-L.; Ivanova, A. A numerical inversion of $m \sin i$ exoplanet distribution: The sub-Saturn desert is more depleted than observed and hint of a Uranus mass gap. *Mon. Not. R. Astron. Soc.* **2022**, *512*, 4. [[CrossRef](#)]
36. Ho, S.; Turner, E.L. The Posterior distribution of $\sin(i)$ values for exoplanets with $M \sin(i)$ determined from radial velocity data. *Astrophys. J.* **2011**, *739*, 26. [[CrossRef](#)]

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.