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DOCUMENT

The EChO Design Reference Mission

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General update of text	10/12/2013	All	
Update of figures/appendix to reflect targets known as of December 2013 (tables 2 and 3 remain as of Sept 2013)	18/12/2013		

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1 EXECUTIVE SUMMARY

A Design Reference Mission, hereafter the *EChO Core Survey*, has been constructed for the Exoplanet Characterisation Observatory in order to determine the mission lifetime required to fulfil the science requirements. The EChO science requirements call for the observation of at least 100 exoplanets of diverse type and environment to provide a "Chemical Census" of exoplanet atmospheres. A proportion of these are required to be observed at high signal to noise ratio to provide an Origin sample and "Rosetta Stones" giving a deeper understanding of the physics and chemistry of their atmospheres. Two target samples lists have been derived: one using catalogues of real targets as known today, and a second using a statistical approach to predict how many targets will be available by the time EChO is operational in the 2020's. These lists have been evaluated using mission performance models to test the observing time required to fulfil the *EChO Core Survey*. We find that a nominal mission lifetime of four years is sufficient to fulfil the science requirements and a mission of six years will fulfil the ambitious goals for EChO. The use of separate target lists and performance models gives confidence that the Core Survey can be undertaken within the mission lifetime and that will result in a revolution in understanding the origin and evolution of planets.

2 INTRODUCTION

The EChO mission is designed to observe a large sample of stars known to have transiting exoplanets. To fulfil the science objectives set out in the Science Requirements Document (SciRD AD1) and described in detail in the Phase A assessment study "Yellow Book" [AD2], a target list will be constructed by the ESA EChO science team following consultation with the Community. The target list will be known as the EChO Core Survey and will consist of three tiers:

- Chemical census - a shallow tier comprising the largest number of targets that will be used to establish the major chemical constituents of exoplanetary atmospheres, exploring the existing chemical diversity. Measurements of albedo and thermal emission will also determine/constrain the energy budget of those planets.

- Origin – a deeper tier which will provide the means with which to determine the molecular abundances of key atmospheric components as well as trace gases (e.g. H_2O, CO, CO_2, CH_4, NH_3, HCN etc.), to constrain the physical and chemical mechanisms causing the observed diversity (e.g. non equilibrium chemistry, atmospheric dynamics, formation processes etc.)

- Exo-meteo/mapping/Rosetta Stones – a third, ultra-deep tier which will focus on a small and select number of the brightest and most favourable targets to determine very accurate molecular abundances for trace gases, horizontal and vertical thermal profiles and chemical gradients as well as temporal variability.

Observation of the Core Survey is intended to fill a very large fraction of the science observing time available to EChO over its mission lifetime. In this regard EChO is somewhat different from a typical “observatory” type mission, where the observations are typically selected from proposals solicited from the wider community and subjected to peer review via a Time Allocation Committee (TAC). In the case of EChO, it is anticipated that ~10-15% of the mission lifetime will be allocated to such an observatory mode, with proprosals anticipated from across all branches of astrophysics including exoplanet studies.

In this document we present two scenarios for the Core Survey target list, one based on targets known as of today (section 4.1), and the second based on a statistical approach that estimates the number and diversity exoplanets in the local neighbourhood based on stellar counts and the occurrence frequency of different planet types observed by Kepler (section 4.2). In section 5 we describe two different tools that are used to establish the target lists - one based on the requirements for the mission performance set out in [AD3] (section 5.1) and a second based on a realistic assessment of the expected performance [section 5.2). We take these two target lists and, using simulations of the performance of the mission, calculate the mission lifetime required to fulfil the core science requirements of EChO (section 6).

We conclude the document with a short summary and an outline of the next steps to be taken in future mission phases.

3 OVERVIEW OF REQUIREMENTS

The science requirements/goals which define the three tiers (Chemical Census, Origin, Rosetta Stones) are detailed in [AD1] and are listed below:

- R-SCI-001: EChO shall observe a core sample of > 100 exoplanet targets, known as the EChO core survey.
- G-SCI-002: EChO should observe a core sample of > 200 exoplanet targets, known as the EChO core survey.
- R-SCI-003: The mission design shall allow observations to be carried out of a wide range of planetary sizes from gas giants to super-Earths. These will have a range of temperatures from hot (up to 3000K) to temperate (350 K) and are found orbiting a range of stellar types and magnitudes from cool M-dwarfs to hot F-stars. The mission design shall encompass both the faintest and brightest expected targets.

Nominally these are exemplified by the systems GJ1214 (faint cold dwarf star) and 55Cnc (bright G star).

- R-SCI-004: The survey will be divided into three survey tiers: the names, characteristics and description of the each of the tiers are given in Table 2 in the SciRD

- R-SCI-005: More than 25 (TBC) of the planets observed in Chemical Census tier shall be observed in the Origin tier.

- G-SCI-006: More than 50 (TBC) of the planets observed in Chemical Census tier should be observed in the Origin tier.

- R-SCI-007: More than 10 (TBC) of the planets observed in Chemical Census tier shall be observed in the Rosetta Stone tier.

- G-SCI-008: More than 20 (TBC) of the planets observed in Chemical Census tier shall be observed in the Rosetta Stone tier.

- R-SCI-055: The average SNR achieved per spectral element for targets defined in the Chemical Census tier shall either be ≥5 at R=50 averaged over the 2 micron ≤ λ ≤ 5 micron wavelength interval, or shall be ≥5 at R=30 over the 5 micron < λ ≤ 11 micron wavelength: whichever is less demanding. The planet shall be observed in primary transit or eclipse, whichever is less demanding.

- R-SCI-056: The average SNR achieved per spectral element for targets defined in the Origin tier shall be either ≥10 at R=100 averaged over the 2 micron ≤ λ ≤ 5 micron wavelength interval, or ≥10 at R=30 over the 5 micron < λ ≤ 11 micron wavelength interval: whichever is less demanding. The planet shall be observed in primary transit and eclipse.

- R-SCI-057: The average SNR achieved per spectral element for targets defined in the Rosetta Stone tier shall either be ≥20 at R=300 averaged over the 1 micron ≤ λ ≤ 5 micron wavelength interval, or shall be ≥20 at R=30 over the 5 micron < λ ≤ 11 micron wavelength: whichever is less demanding. The planet shall be observed in primary transit or eclipse, whichever is less demanding.

- G-SCI-058: The average SNR achieved per spectral element for targets defined in the Rosetta Stone tier shall either be ≥20 at R=300 averaged over the 1 micron ≤ λ ≤ 5 micron wavelength interval, or shall be ≥20 at R=30 over the 5 micron < λ ≤ 11 micron wavelength: whichever is less demanding. The planet shall be observed in primary transit and eclipse.

4 DEFINTION OF THE ECHO SAMPLES

In this section we describe the two approaches taken to derive a possible target list for the EChO mission. We emphasise that these target lists are designed to allow at best a prediction of the required lifetime for the mission given what is known today about the existence of transiting exoplanets and their host stars. We fully anticipate that future surveys will continue to uncover new targets and that further measurements of both the transiting planets and their host systems will be used to further refine the lists.

4.1 Known Targets

To produce a sample of potential targets for EChO using known systems we first drew up a "long list" of known targets with well characterised stellar and planetary parameters. For a target to be included in the list, it needs to be possible to attain the SNR requirements as defined for the Chemical Census tier for the target within a 3.1 year period. This list has been generated using the EChO Target List Observation Simulator (ETLOS) [RD3] and EChOSim described in section 5.3 and will be updated as new transiting exoplanets are discovered. ETLOS extracts the star/planet information from the Open Exoplanet Catalogue (Rein et al., 2013, [RD4]); further verifications are done using SIMBAD, the 2MASS catalogue and exoplanet.eu (Schneider, 2013 [RD5]) where appropriate. Known transiting exoplanets that are candidate targets for the *EChO Core survey* are given in the appendix. A pared down list was prepared by excluding targets missing fundamental parameters and planets around binary star systems that need to be treated separately. The Core Survey targets were then selected to ensure as diverse a range of stellar types, metallicities and temperatures as possible to fulfil the requirements of the Chemical Census tier. Suitable targets for the Origin and Rosetta stone tiers were further selected to fulfil the SNR requirements expressed in the SciRD (see section 3). The contents of this target list are discussed further in section 6.1.

4.2 A Statistical Sample

A comprehensive exercise has been run to establish a goal statistical sample of transiting targets for EChO that would cover the widest possible range of exoplanet/host star parameter space. This is an evolution of the Mission Reference Sample (MRS) described in [RD6]. As a first step, star counts were estimated using (a) the new catalogue of Lepine et al [RD7] making cuts based on spectral type and magnitude directly, and (b) using the combination of the stellar mass function derived from the 10-pc RECONS sample [RD8] and the mass-luminosity-K-band relationship from [RD9]. Estimates were then made of the maximum number of exoplanets of a given exoplanet class, namely Jupiter, Neptune, Small Neptune and Super-Earth, and fiducial equilibrium temperature, namely hot, warm and temperate, that transit a selection of stellar spectral types from K to M. This was done using statistics from the Kepler mission determined by Fressin [private communication], and adopting a methodology similar to that described in a recent paper by Fressin et al. [RD10]. The boundaries of the classification and the mean planet properties of the different types are given in Table 1.

Planet type	Radius ($R_{\oplus}$)	<Radius> ($R_{\oplus}$)	<Mass> ($M_{\oplus}$)	<μ> (g/mol)
Super-Earth (SE)	1.4-2.2	1.8	7	28
Small Neptune (SN)	2.2-3.0	2.6	6	8
Neptune (N)	3.0-6.0	4.0	15	2.6
Jupiter (J)	6.0-22.0	10.0	300	2
Planet type	**Temp (K)**	**Bond albedo**		
Hot (H)	1500	0.1		
Warm (W)	600	0.3		
Temperate (T)	320	0.3		

Table 1: Definition of planet types.

Planet occurrence rates based on Kepler results were calculated for all spectral types. These rates are weighted towards solar-like stars because of the predominance of FGK hosts in the Kepler survey itself. An analysis of the planet occurrence rates for M hosts observed by Kepler indicates that the rates are consistent with those found for earlier spectral types, albeit at low statistical significance (e.g. [RD11]). Star counts, planet temperatures and types, and the transiting planet occurrence rate were then used to determine the numbers and types of transiting exoplanets around host stars down to a K-band magnitude of 9, with the overall total number in good agreement with estimates from HARPS [RD12] as well as other estimates based on Kepler data [RD13]. Orbital periods and transit times (adopting an impact parameter of 0.5) were then derived for each exoplanet target.

Further details on the MRS and its definition can be found in [RD6].

5 PERFORMANCE MODELLING APPROACH

In order to assess the time needed to observe the required number of targets in the three survey tiers we have undertaken simulations of the mission and instrument performance. Two different approaches have been taken to do this - the so-called static radiometric model approach and the so-called dynamic model approach. These are described in the following sections.

5.1 The Static Radiometric Model

The static radiometric model, hereafter the RM, approach is a simulation of the detection chain applied to targets defined by a number of characteristic quantities. The main hypotheses made in the radiometric description are:

- That the photometric signal from the star, planet, thermal contributions, zodiacal emission etc. are linear and stable with time – i.e. it is a static model.
- The detection chain is linear and can be described by a set of simple parameters such as optical transmission, quantum efficiency of the detectors, linear electronics gain etc.
- All noise contributions (stellar noise, detector noise, thermal noise etc.) are stochastic and independent – i.e can be described by a Gaussian distribution
- The post processing of the data is able to remove all systematic biases at the level of the noise.

Each contributor can described by its characteristics, for instance:

- Stars are described by their effective temperature (and associated SED), radius and distance to the observer.
- Planets are described by their radius, surface temperature, atmospheric molecular density.
- The payload can be described by a number of fixed parameters including the telescope effective area, the telescope and instrument optical transmission, working temperatures, a field of view, the spectral resolution, the spectral range etc.
- The detector can be described by its physical parameters - including the pixel angular field of view on the sky, the full well capacity, the quantum efficiency, the dark current, the readout noise and the readout time.

The model approach provides a description of the source and payload in the simplified case in which noise sources can be considered as Gaussian, and therefore provides a theoretical measure of performance that can be achieved by the observatory. Unaccounted for noise sources such as variation of the source signal, the variation of the temperature of the payload etc. can also be included by through an allocation in the noise budget.

The model provides the means to calculate, for a given host star/exoplanet target:

- The SNR that can be achieved in a single primary transit
- The SNR that can be achieved in a single occultation
- The number of transit/occultation revisits necessary to achieve a specified SNR

The total number of revisits that could be achieved during the proposed mission lifetime

The approach is described in more detail in the EChO radiometric model description document [SRE-PA/2011.040].

5.2 The ESA Radiometric Model (RM) – mission sizing

Several versions of the static radiometric model for EChO have been implemented, including one by ESA in the form of an Excel spread sheet that we refer to as the ESA-RM. In this implementation, a noise budget has been set which includes the noise contributors listed above. Conservative performance estimates have been adopted as appropriate to this early phase of the mission study. As such, the observing time estimates that are derived using the ESA-RM are at the upper end of those expected from EChO by time of launch.

The ESA-RM version used for the calculations reported here was issued in September 2013. The critical parameters assumed are listed in ***Figure 1***. Here the "noise floor" and the "Nmin" values are set to allow some margin for the performance of the system with respect to the ideal situation where the measurement is photon noise limited. The "QE" is the quantum efficiency of the detectors, η the optical transmission from the telescope entrance aperture to the detectors and "R" the resolving power evaluated at the lowest wavelength in each of the spectrometer bands.

SNR CALCULATION PARAMETERS						
Channel limits [μm]	*Relative noise floor X*	*Absolute noise floor Nmin*	*QE*	*η*	*R*	*Aeff [m2]*
0.4	[%.(N0+zodi)]	[e-/s/spectral bin]	[p/e-]			1.131
1	200%	20	60%	10%	300	*1+1/Y*
5	50%	20	70%	23%	300	2
11	30%	200	50%	23%	30	
16	30%	200	50%	23%	30	

Figure 1: Parameters used in the ESA-RM (September, 2013)

5.3 EChOSim

When estimating the real performance of the mission, one needs to take into account all expected effects from the astrophysical scene to the final pipeline products and adopt the most accurate description of each step. This is the purpose of the end-to-end simulation software EChOSim which allows the simulation to go beyond the classical radiometric description and to study the impact of specific effects and/or optimise the choices during the instrument design. The philosophy of EChOSim and its realisation are fully described in the EChOSim User Requirement Document [ECHO-TN-0001-CDF] and EChOSim Software Requirement Document [ECHO-TN-0002-CDF]. EChOSim can also be run as a static model. Extensive comparisons have been made of the results from EChOSim run in this mode, and those from the ESA-RM: the two models are in agreement in terms of SNR achieved when run under controlled conditions [RD14]. EChOSim is presently used as a predictive model, but will evolve during future phases of EChO into a real model of the instrument and spacecraft, which will include measured performance and/or calibration data. In this way the model elements used for the detection process description will be replaced, one by one, by an actual description of the process based on laboratory measurements. Additionally, simulated parameters will be refined as and when accurate models of the payload are available (e.g. thermal and mechanical model of each module, global architecture of the instrument, model of the satellite pointing performance etc).

EChOSim is a fully dynamic end-to-end simulator from the astrophysical scene to a preliminary ground-based data reduction pipeline, encompassing a full simulation of the telescope and instruments [*EChOS*im URD/SRD]. More specifically, it undertakes a time domain simulation of the observation taking into account as many time-varying parameters in the observation as possible. The design goal is to provide "as realistic as possible" simulation of current engineering considerations. *EChOSim* simulates the astrophysical scene (star and transiting planet) as well as the stationary and dynamic characteristics of the instrument and observing strategy. The goal is determine the best overall observing strategy as well as at the same time validating and setting benchmarks for the instrument parameters and calibration strategy under realistic observing conditions.

5.4 Scheduling

Scheduling of the EChO mission is especially critical as it entails a succession of time-critical events. The targets (>100) need to be observed on several occasions (of the order of 25 on average) in either transit or occultation, or both, which occur in specific time windows (of order of 100 per year on average). It can be readily estimated that the total number of possible combinations is phenomenal. Building a mission schedule consists of creating a succession of observations that fulfil the required number of events for all objects. When the sum of all the time needed for the observations is comparable to the total mission lifetime, conflicts arise, scheduling turns into a complex exercise, and optimization becomes essential. Note also that the schedule should consider additional aspects such as spacecraft slew time, downlink and station keeping activities, calibration observations, mildly time-critical observations in the exo-meteo survey (phase maps), and possible observations from additional science programs.

The main goal of the mission schedule is to provide efficient scheduling of the science observations and so to maximize science return. This can be translated into: 1) maximizing the duty cycle (i.e., minimizing the number of gaps or "idle time"); 2) maximizing the number of objects observed; 3) ensuring that the targets observed belong to a broad variety of planet classes. There are other parameters that could eventually be considered (such as minimizing spacecraft slews or setting different priorities for specific objects or events), but those would necessarily imply some level of trade off with the two science return parameters defined above. There are different approaches to the scheduling optimization problem and Artificial Intelligence-based algorithms have shown to be a well-suited and efficient method to explore the vast parameter space of the possible solutions.

Detailed scheduling simulations have been run and are described in [RD15]. The tests basically show that both the real target sample and the statistical MRS can be scheduled to fulfil the mission requirements and thus guarantee the science return of EChO. The planning efficiency (defined as the ratio of the number of scheduled hours to the number or requested hours) can be guaranteed to reach 80% and often values above 90%. Target completeness (i.e., fraction of targets for which at least 80% of the requested events is observed) reaches 95%. The tests also show that downlinks, station keepings, calibration observations and phase maps of Rosetta Stone targets can be placed within the main transit/occultation events and thus be treated as gaps fillers to a large extent. Eventual mild conflicts that may arise can be easily resolved and have negligible impact on the mission efficiency.

6 RESULTS

6.1 Known Target Samples

The list of targets (as of mid-September 2013) as described in section 4.2 and reported in Table 2 was run through the ESA–RM and *EChOSim* performance models. Although some differences are expected due to the different parameterisation of the instrument and other model assumptions (see RD6 for a detailed comparison), the results spread over the Core Survey are quite consistent, and the discrepancies for specific targets are understood and traceable. We are therefore confident of the robustness of estimates made of the observing time that are needed to reach the SNR requirements, and that are reported here.

The selected Chemical Census, Origin and Rosetta Stones samples populating the Core Survey are listed in Table 2 and Table 3, comprising a total of 131 targets (as of mid-September 2013). This does not represent a unique list of targets as the requirements can be reached in a number of ways by increasing and diversifying the Chemical Census, Origin and Rosetta Stones samples. Rather, this is a representative sample that meets the minimum SciRD requirements and so fulfils the science objectives of the EChO mission. In the period between mid-September and mid-December a further 36 targets suitable for observation with EChO in the Chemical Census tier have become available: the pool of targets is shown in the Appendix. In figure 2 we illustrate the diversity in the pool of targets showing how the targets are distributed between stellar type, metallicity, orbit type and planetary temperature.

Observation of all the planets listed in Tables 2 and 3 was also simulated with EChOSIM to assess the number of transits required to reach the baseline and goal SNRs. The integration times needed for each target and survey tier, as well as the detectability of key molecular species are reported in [RD3]. We conclude from both the ESA-RM and *EChOSim* simulations that the Minimum Mission Lifetime estimated to cover the Core Survey and to fulfil the science requirements and the science objectives is **3 years and 1**

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month. The 6 months of commissioning and PV and the open time are not included in this estimate. A nominal four year total mission lifetime is therefore proposed for EChO to include all required observations, commissioning, performance verification and operational overheads.

Planet's name	*Stellar mass (solar masses)*	*Stellar T (K)*	*Stellar radius (solar radii)*	*K mag.*	*Planetary period (days)*	*Planetary Temperature (k)*	*Planet's radius (Earth radii)*
55 Cnc e	0.905	5196	0.943	4.015	0.7365417	1780.9	1.9
HD 189733 b	0.8	4980	0.788	5.54	2.21857312	1099.7	12.5
GJ 436 b	0.452	3684	0.464	6.073	2.6438986	650.3	4.0
HD 209458 b	1.148	6075	1.146	6.308	3.52474859	1316.1	15.1
HD 17156 b	1.275	6079	1.508	6.807	21.2163979	790.5	12.
HD 149026 b	1.3	6147	1.497	6.819	2.8758916	1601.5	7.9
HAT-P-11 b	0.81	4780	0.75	7.009	4.887804	790.9	4.9
KELT-2A b	1.31	6148	1.842	7.346	4.1137914	1565.7	14.3
HAT-P-2 b	1.36	6290	1.64	7.603	5.6334729	1343.6	10.4
HAT-P-22 b	0.916	5302	1.04	7.837	3.21222	1171.7	11.8
GJ 3470 b	0.539	3600	0.568	7.989	3.33671	603.5	4.8
WASP-38 b	1.23	6150	1.35	7.998	6.87188	1152.9	12
WASP-8 b	1.033	5600	0.953	8.086	8.158715	846.5	11.3
WASP-18 b	1.24	6400	1.23	8.131	0.9414518	2187.5	12.8
WASP-80 b	0.57	4145	0.571	8.351	3.0678504	800	10.4
WASP-7 b	1.276	6400	1.432	8.396	4.9546416	1359.5	14.6
WASP-77A b	1.002	5500	1.12	8.408	1.3600309	1816.7	13.3
HAT-P-17 b	0.857	5246	0.837	8.544	10.338523	707.1	11.1
HAT-P-20 b	0.756	4595	0.694	8.601	2.875317	888.3	9.5
WASP-14 b	1.211	6475	1.306	8.621	2.2437661	1718.8	14.06
BD+30 1138 b	1.282	6304	1.482	8.662	2.70339	1667.7	14.9
Gliese 1214 b	0.153	3026	0.21	8.782	1.58040482	519.6	2.7
WASP-29 b	0.825	4800	0.846	8.783	3.922727	910.6	8.7
XO-3 b	1.213	6429	1.377	8.791	3.1915239	1554.5	13.3
WASP-34 b	1.01	5700	0.93	8.792	4.3176782	1058.7	13.4
HAT-P-14 b	1.386	6600	1.468	8.851	4.627657	1445.9	13.17
HAT-P-1 b	1.133	5975	1.115	8.858	4.4652934	1182.1	13.3
WASP-62 b	1.25	6230	1.28	8.944	4.411953	1305.2	15.2
HAT-P-8 b	1.192	6200	1.475	8.953	3.0763402	1713	14.5
HAT-P-13 b	1.22	5638	1.56	8.975	2.916243	1504.3	14.04

WASP-54 b	1.15	6100	1.4	9.035	3.6936411	1759	18.14
WASP-79 b	1.56	6600	1.64	9.056	3.6623817	1958.7	18.6
WASP-13 b	1.09	5826	1.559	9.119	4.353011	1203.3	15.2
HAT-P-30 b	1.24	6304	0.898	9.151	2.810595	1552.5	14.7
HAT-P-34 b	1.392	6442	1.535	9.247	5.4527	1335.3	13.13
WASP-43 b	0.717	4520	0.667	9.267	0.81347753	1317.6	11.37
XO-2 b	0.98	5340	0.964	9.308	2.615838	1203.3	10.7
HAT-P-6 b	1.29	6570	1.46	9.313	3.853003	1529.9	14.6
WASP-71 b	1.21	6050	1.27	9.32	2.9036747	1888.1	16.4
HAT-P-7 b	1.415	6350	1.9	9.334	2.204737	2733	16.01
WASP-3 b	1.24	6400	1.31	9.361	1.8468372	1825.6	15.9
XO-4 b	1.32	5700	1.55	9.406	4.1250823	1328.2	14.7
WASP-11 b	0.82	4980	0.81	9.421	3.722469	943.2	11.5
HAT-P-3 b	0.917	5224	0.799	9.448	2.899703	1047.2	9.1
XO-1 b	1	5940	0.928	9.527	3.9415128	1168	13.
HAT-P-16 b	1.218	6158	1.237	9.553	2.77596	1485.9	14.
HAT-P-26 b	0.816	5079	0.788	9.581	4.234516	907.4	6.2
WASP-16 b	1.022	5550	0.946	9.589	3.1186009	1160	11.06
WASP-72 b	1.23	6250	1.37	9.617	2.21672	2210	11.1
WASP-2 A b	0.89	5150	0.84	9.632	2.15222144	1170.7	12.2
WASP-41 b	0.95	5450	1.01	9.677	3.052394	1207.5	13.3
WASP-26 b	1.12	5950	1.34	9.69	2.7566004	1521.3	14.06
WASP-15 b	1.18	6300	1.477	9.693	3.7520656	1511.3	15.7
WASP-59 b	0.719	4650	0.613	9.723	7.919585	666.7806018	8.5
HAT-P-41 b	1.418	6390	1.683	9.728	2.69404	1689.7	18.5
HAT-P-4 b	1.26	5890	1.59	9.77	3.0565114	1550.7	13.9
TrES-1 b	0.88	5250	0.85	9.819	3.0300722	1180.5616	12.06
TrES-2 A b	0.983	5850	1.003	9.846	2.47	1502.25	12.8
WASP-50 b	0.89	5400	0.84	9.969	1.955096	1289.9	12.6
WASP-21 b	1.01	5800	1.06	9.982	4.322506	1154.6	13.3
WASP-10 b	0.71	4675	0.783	9.983	3.0927616	946.8	11.8
HAT-P-32 b	1.176	6001	1.387	9.99	2.150009	1677.4	22.3
HAT-P-33 b	1.403	6401	1.777	10.0	3.474474	1675.2	20.05
HAT-P-40 b	1.512	6080	2.206	10.01	4.457243	1614.8	19.
HAT-P-31 b	1.218	6065	1.36	10.08	5.005425	1324.7	11.7
HAT-P-12 b	0.73	4650	0.7	10.11	3.2130598	875.4	10.5
HAT-P-27 b	0.92	5300	0.87	10.11	3.039577	1102.7	11.2
HAT-P-21 b	0.947	5588	1.105	10.11	4.124461	1161.5	11.24

WASP-67 b	0.87	5200	0.87	10.13	4.61442	940.6	15.36
WASP-24 b	1.129	6075	1.147	10.15	2.3412083	1514.1	12.11
WASP-32 b	1.07	6100	1.09	10.16	2.718661	1427.6	12.07
WASP-25 b	1	5750	0.95	10.17	3.76483	1135	13.8
WASP-12 b	1.35	6300	1.599	10.19	1.0914222	2319.7	19.05
WASP-47 b	1.084	5400	1.15	10.19	4.1591399	1119.7	12.6
WASP-39 b	0.93	5400	0.895	10.20	4.055259	1021.8	13.9
WASP-17 b	1.2	6650	1.38	10.22	3.735438	1517.8	21.8
HAT-P-18 b	0.77	4803	0.749	10.23	5.508023	774.9	10.9
WASP-1 b	1.24	6200	1.382	10.27	2.5199464	1644.3	16.3
WASP-45 b	0.909	5140	0.945	10.29	3.1260876	1094.2	12.73
HAT-P-29 b	1.207	6087	1.224	10.3	5.72318	1149.1	12.15
CoRoT-2 b	0.97	5575	0.902	10.31	1.7429964	1392.7	16.07
WASP-22 b	1.1	6000	1.13	10.32	3.5327313	1297.5	12.71
WASP-6 b	0.888	5450	0.87	10.32	3.361006	1092.2	13.43
TrES-4 A b	0.88	5338	0.85	10.33	3.5539268	1782	18.72
WASP-48 b	1.19	5990	1.75	10.37	2.143634	1882.7	18.32
WASP-55 b	1.01	5900	1.06	10.4	4.465633	1160.1	14.26
Qatar-1 b	0.85	4910	0.8	10.41	1.42002504	1389	12.77
WASP-66 b	1.3	6600	1.75	10.45	4.086052	1647.5	15.25
HAT-P-5 b	1.163	5960	1.137	10.48	2.788491	1387.4	13.74
WASP-19 b	0.97	5500	0.99	10.48	0.78884	1911.5	15.21
HAT-P-38 b	0.886	5330	0.923	10.50	4.640382	987	9.05
WASP-23 b	0.78	5150	0.765	10.53	2.9444256	1024	10.56
WASP-56 b	1.03	5600	0.99	10.53	4.617101	1216	12.
HAT-P-24 b	1.191	6373	1.317	10.54	3.35524	1495	13.6
HAT-P-19 b	0.842	4990	0.82	10.55	4.008778	922.7	12.4
HATS-1 b	0.986	5870	1.038	10.58	3.446459	1250.3	14.29
WASP-60 b	0.514	5900	0.86	10.58	4.3050011	1148.07466	9.44
WASP-5 b	1	5700	1.084	10.6	1.6284246	1584	12.85
HAT-P-36 b	1.022	5580	1.096	10.60	1.327	1669.2	13.87
TrES-3 b	0.88	5338	0.85	10.61	1.30618608	1582.7529	14.3
Qatar-2 b	0.74	4645	0.713	10.62	1.3371182	1179.7	12.5
HAT-P-42 b	1.179	6455	1.528	10.63	4.641876	1427	14.01
WASP-31 b	1.16	6200	1.24	10.65	3.405909	1410.6	16.86
WASP-28 b	1.08	6100	1.05	10.73	3.408821	1291.9	12.3
WASP-4 b	0.93	5500	1.15	10.746	1.33823187	1710.4	14.96
HAT-P-23 b	1.13	5905	1.203	10.791	1.212884	1873.6	15.01

HAT-P-25 b	1.01	5500	0.959	10.81	3.652836	1100.1	13.06
WASP-64 b	0.98	5400	1.03	10.96	1.57329	1689	13.95
WASP-78 b	2.02	6100	2.31	11.01	2.17517656	2006.7	19.20
HAT-P-9 b	1.28	6350	1.32	11.01	3.922814	1397.3	15.36
HAT-P-28 b	1.025	5680	1.103	11.10	3.257215	1262.4	13.3
HAT-P-39 b	1.404	6430	1.625	11.16	3.54387	1601.9	17.24
CoRoT-11 b	1.27	6440	1.37	11.25	2.994325	1593.4	15.25
WASP-36 b	1.02	5881	0.943	11.3	1.5373653	1554.5	13.9
WASP-44 b	0.917	5410	0.865	11.34	2.4238133	1304	11.
HATS-2 b	0.88	5227	0.89	11.39	1.354133	1577	12.82
WASP-46 b	0.956	5620	0.917	11.40	1.43037	1516.6	14.37
TrES-5 b	0.88	5171	0.85	11.6	1.4822446	1473.91	13.27
Kepler-18 d	0.972	5383	1.108	11.75	14.85888	729.8	6.8
HAT-P-43 b	1.048	5979	1.104	11.76	3.332688	1361	14.08
Kepler-12 b	1.166	5947	1.483	12.07	4.4379637	1354.2	18.6
CoRoT-1 b	0.95	6298	1.11	12.15	1.5089557	1898	16.35

Table 2: List of currently known targets (as of mid-September 2013) with key planetary and stellar parameters, that can be observed in the Chemical Census (black) or Origin (green) tiers of the EChO Core Survey within a nominal 4 year mission lifetime.

Planet's name	*Stellar mass (solar masses)*	*Stellar T (K)*	*Stellar radius (solar radii)*	*K mag.*	*Planetary period (days)*	*Planetary Temperature (k)*	*Planet's radius (Earth radii)*
55 Cnc A b	0.905	5196	0.943	4.015	0.7365417	1780.9	1.989462298
HD 189733 b	0.8	4980	0.788	5.54	2.21857312	1099.7	12.48763428
Gliese 436 b	0.452	3684	0.464	6.073	2.6438986	650.3	4.005260556
HD 209458 b	1.148	6075	1.146	6.308	3.52474859	1316.1	15.1431769
HD 149026 b	1.3	6147	1.497	6.819	2.8758916	1601.5	7.878841312
HD 80606 b	0.98	5370	0.98	7.316	111.43637	1000	10.10642458
Gliese 3470 b	0.539	3600	0.568	7.989	3.33671	603.5	4.830004057
WASP-80 b	0.57	4145	0.571	8.351	3.0678504	800	10.44659739
WASP-54 b	1.15	6100	1.4	9.035	3.6936411	1759	18.13889232
TrES-4 A b	0.88	5338	0.85	10.33	3.5539268	1782	18.7204781

Table 3: List of currently known targets with key planetary and stellar parameters observable as *Rosetta Stones*. Exoplanets identified in red will be observed both in transit and eclipse, and are optimal objects to investigate the spatial/temporal variability of the atmosphere (weather and 2D/3D maps).

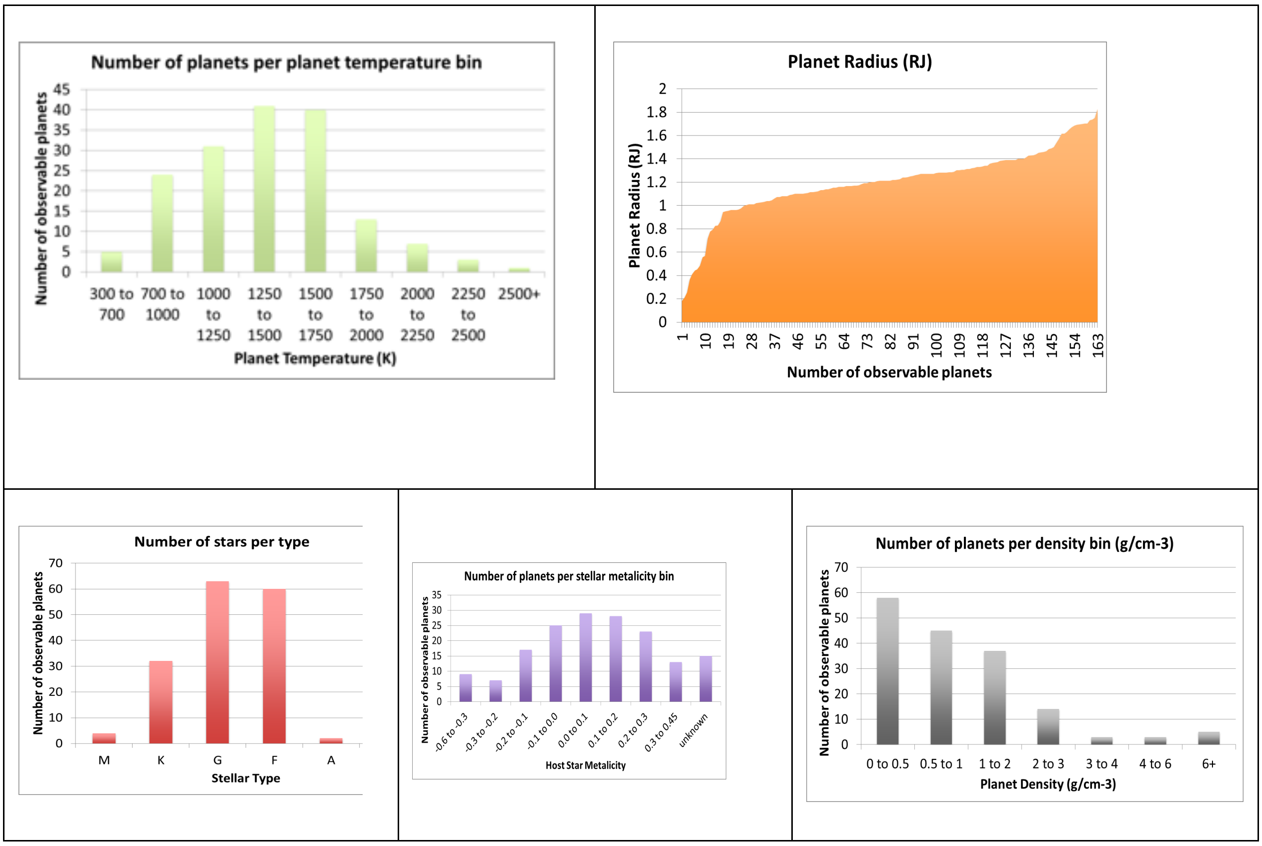

Figure 2: Diversity of the current sample of transiting exoplanets which could be observed in the Chemical Census tier of the EChO Core Survey (as of December, 2013).

6.2 Statistical Sample

The ESA-RM was used to evaluate the MRS discussed in section 4.2, according to the SNR requirements corresponding to the Chemical Census and Origin tiers of the Core Survey. Mean parameters for the different planet classes were adopted as listed in Table 1, with several key additional parameters given in Table 4. The corresponding stellar properties, including spectral energy distribution and the mapping between spectral type and effective temperature, were adopted as presented in [AD1]. The total mission lifetime was assumed to be the goal 6-yr value and the sample was sized to employ 90% of the lifetime (the remaining 10% was retained for the Rosetta Stone tier). A trade-off exercise was run to optimize a sample of objects. This procedure considered factors such as the breadth of the probed parameter space, the time spent observing the different object classes, the total mission lifetime and the number of required events. In this trade-off process, an effort was made to consider for the Chemical Census volume-limited samples of planet types, so that the statistical value of the observations could be enhanced.

Parameter	Value
Number of scale heights in calculations	5
Transit impact parameter	0.5
Orbital eccentricity	0
Heat redistribution factor	1.0

Table 4: General planet parameters.

The resulting hypothetical so-called Mission Reference Sample (MRS), listed in Tables 5 and 6, and illustrated in Figure 3, illustrates the "maximal" parameter space that EChO can potentially cover in the Chemical Census and Origin tiers, according to current SNR requirements and conservative assumptions on instrument performance (Figure 1). The tables also include information on the technique best used to observe the planet (i.e., transit/transmission or occultation/emission) for optimal results. The total number of targets is 238, with the following distribution:

- 10 Super-Earths (hot), complete out to 30 pc
- 20 Small Neptunes (hot and warm), complete out to 40 pc
- 59 Neptunes (hot and warm), complete out to 70 pc
- 149 Jupiters, complete out to 150 pc (hot) and 100 pc (warm)

Of the hot Jupiters, those 33 objects with brighter host stars will be observed in the Origin tier. Note that the MRS as defined here is consistent with our current statistical knowledge of stars and planets, but it represents only one possible realization. Other samples still compatible with statistical constraints and considering a different mixture of planet types and limiting distances/magnitudes are certainly possible.

Class		d (pc)	Kmag	T_{eq} (K)	#obj	Type
HSE	M2	30	8.8	1000	1	Occultation
HSE	M0	30	7.6	1200	2	Occultation
HSE	K1	30	6.5	1500	3	Occultation
HSE	G1	30	5.7	1500	4	Occultation
HSN	M0	40	8.2	1200	1	Transit
HSN	K1	40	7.1	1500	2	Transit
HSN	G1	40	6.3	1500	4	Transit
HSN	F8	40	5.8	1500	5	Transit
WSN	M2	37	9.2	600	2	Transit
WSN	M0	40	8.2	600	4	Transit

WSN	K1	40	7.1	600	2	Transit
HN	M0	70	9.4	1200	3	Transit
HN	K1	70	8.3	1500	7	Transit
HN	G1	70	7.4	1500	10	Transit
HN	F8	70	7.0	1500	13	Transit
WN	M2	37	9.2	600	1	Transit
WN	M0	70	9.4	600	11	Transit
WN	K1	70	8.3	600	7	Transit
WN	G1	70	7.4	600	4	Transit
WN	F8	70	7.2	600	3	Transit
HJ	K1	150	10.0	1500	36	Occultation
HJ	G1	150	9.1	1500	44	Occultation
HJ	F8	150	8.7	1500	54	Occultation
WJ	K1	100	9.1	600	5	Transit
WJ	G1	100	8.2	600	5	Transit
WJ	F8	100	7.8	600	5	Transit

Table 5: Mission Reference Sample for the Chemical Census tier of the EChO Core Survey. For each planet type, an effort has been made to define a volume-limited sample (column labeled d). Kmag is the limiting K-band magnitude for the class. "hot" and "warm" planet types have temperatures as defined in section 3, with the exception of the classes HSE M2, HSE M0, and HSN M0, for which lower temperatures have been adopted so that the resulting orbital periods are above 0.5 days. #obj is the number of targets in the class, in accordance with the mission performance estimates and the number of available transiting planets.

Class		d (pc)	Kmag	T_{eq} (K)	#obj	Type
HJ	K1	100	8.8	1500	9	Occultation
HJ	G1	100	7.9	1500	11	Occultation
HJ	F8	100	7.5	1500	13	Occultation
HJ	K1	100	8.8	1500	9	Transit
HJ	G1	100	7.9	1500	11	Transit
HJ	F8	100	7.5	1500	13	Transit

Table 6: Mission Reference Sample for the Origin tier of the EChO Core Survey. For each planet type, an effort to define a volume-limited sample (column labeled d) has been made. Kmag is the limiting K-band magnitude for the class. #obj is the number of targets in the class, in accordance with the mission performance estimates and the number of available transiting planets. #events is the number of occultations or transits to be observed in order to fulfill the SNR requirements.

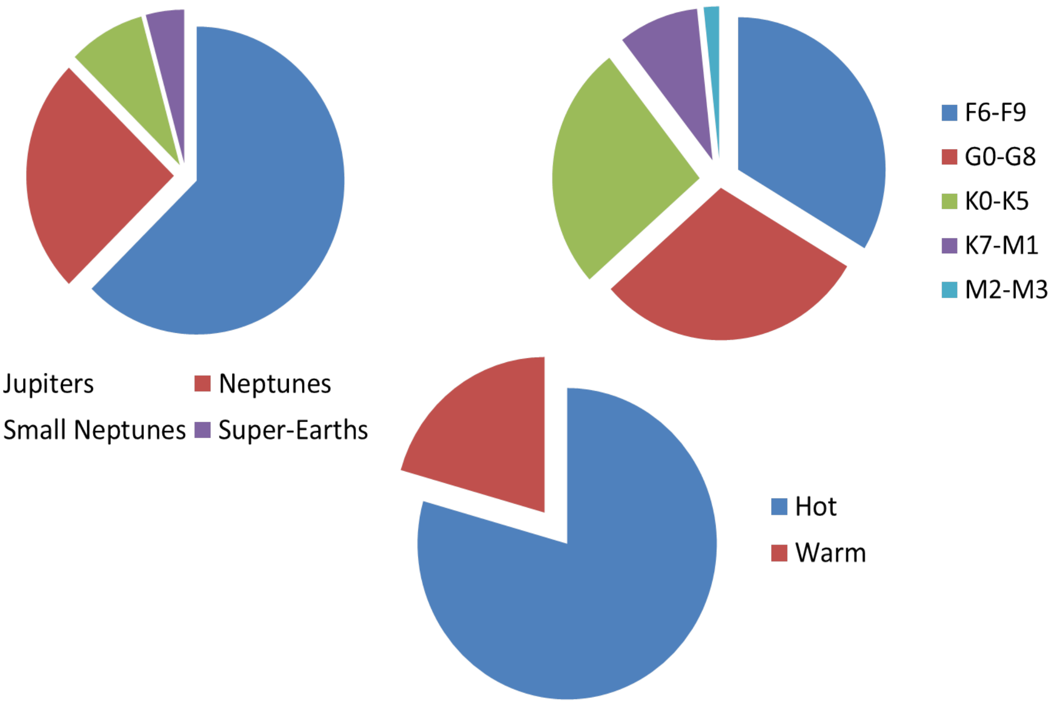

Figure 3: Pie charts illustrating the different planet classes in the Mission Reference Sample of the Chemical Census listed in Table 5.

7 DISCUSSION

TBD

8 APPLICABLE AND REFERENCE DOCUMENTS

[AD1] EChO Science Requirements Document (SciRD),v3.2, SRE-PA/2011.037
[AD2] EChO Phase A Study Assessment Report (Yellow Book), ESA/SRE(2013)2
[AD3] ECHO MRD (Mission Requirements Document), V3.1, SRE-PA/2011.038/

[RD1] EChO radiometric model description, V3.1, SRE-PA/2011.040
[RD2] EChO Sim URD issue 3.0 September 2013

[RD3] Varley et al., Generation of a target list of observable exoplanets for EChO, ECHO-TN-0001-UCL
[RD4] Rein, H. et al., http://www.openexoplanetcatalogue.com/
[RD5] http://www.exoplanet.eu
[RD6] Ribas et al., "EChO targets: the Mission Reference Sample and Beyond", EChO-SRE-SA-PhaseA-001
[RD7] Lepine, S. et al., "A Spectroscopic Catalog of the Brightest (J<0) M Dwarfs in the Northern Sky", AJ, 145, 102 (2013)
[RD8] RECONS website, http://www.recons.org, (2012)
[RD9] Baraffe, I., Chabrier, G., Allard, F., Hauschildt, P. H., "Evolutionary models for Solar metallicity low-mass stars: mass-magnitude relationships and color-magnitude diagrams" A&A, 337, 404 (1998)
[RD10] Fressin, F. et al, "The False Positive Rate of Kepler and the Occurrence of Planets", ApJ, 766, 81 (2013)
[RD11] Dressing, C.D., Charboneau, D., "The Occurrence Rate of Small Planets around Small Stars", ApJ, 767, 95 (2013)
[RD12] Mayor, M., et al. "The HARPS search for southern extra-solar planets XXXIV. Occurrence, mass distribution and orbital properties of super-Earths and Neptune-mass planets", arXiv:1109.2497 (2011)
[RD13] Howard, A., et al. "Planet occurrence within 0.25 AU of solar-type stars from Kepler", ApJS, 201, 15 (2012)
[RD14] Waldmann et al., Comparison between EChOSim 3.0 and ESA Radiometric model, ECHO-TN-0002-UCL
[RD15] Ribas et al. "ECHO-TN-0001-ICE_Technical Note_Planner_v3"

APPENDIX

Complete list of planetary data used for selection of the “real target” list.

Table A-1: List of the pool of EChO target candidates as generated using ETLOS and EChOSim as of mid-December, 2013. In columns 15-16, 18-19 we indicate the numbers of transits needed to achieve the SNR and R requirements for the Chemical Census (blue columns) and Origin Tier (green columns) respectively: in columns 17 and 20 we indicate the feasibility of including the targets in the EChO Core Survey in primary (P), secondary (S) or primary and secondary (P+S) transit.

Planet Name	Planet Type	density	eccentricity	Planet Temp	Planet Radius	Planet Mass	Period	Albedo	Star Type	Metallicity	magK	magV	Distance	Prim.	Sec.	Feasibility Chem. Census	Prim.	Sec.	Feasibility Origin
55 Cnc e	Hot Super-Ea	6.01005818	0.06	1780.9	0.1813	0.027	0.7365417	0.1	K0V	0.31	4.015	5.95	12.3	34	4	P+S	277	13	P+S
BD+30 1138 b	Hot Jupiter	0.77438403	0	1667.7	1.358	1.462	2.70339	0.1	F2	0.047	8.662	9.82	178	2	1	P+S	16	5	P+S
CoRoT-1 b	Hot Jupiter	0.4130349	0	1898	1.49	1.03	1.5089557	0.1	G0V	-0.3	12.149	13.6	460	3	2	P+S	26	13	P+S
Gliese 436 b	Warm Neptu	2.01046825	0.15	650.3	0.365	0.0737	2.6438986	0.3	M3.5V	-0.32	6.073	10.59	10.2	1	8	P+S	4	32	P+S
HAT-P-1 b	Hot Jupiter	0.38562739	0.067	1182.1	1.217	0.524	4.4652934	0.1	G0V	0.13	8.858	10.4	139	1	3	P+S	4	20	P+S
HAT-P-11 b	Hot Neptune	1.16353122	0.198	790.9	0.452	0.081	4.887804	0.1	K4	0.31	7.009	9.47	38	1	18	P+S	5	69	P+S
HAT-P-13 b	Hot Jupiter	0.53764714	0.0142	1504.3	1.28	0.85	2.916243	0.1	G4	0.43	8.975	10.42	214	3	2	P+S	19	14	P+S
HAT-P-22 b	Hot Jupiter	2.26083622	0.016	1171.7	1.08	2.147	3.21222	0.1	G5	0.24	7.837	9.76	82	3	2	P+S	20	5	P+S
HAT-P-24 b	Hot Jupiter	0.47427923	0.067	1495	1.242	0.685	3.35524	0.1	F8	-0.16	10.543	11.76	306	3	4	P+S	19	27	P+S
HAT-P-30 b	Hot Jupiter	0.39197966	0.035	1552.5	1.34	0.711	2.810595	0.1	F	0.13	9.151	10.35	193	1	2	P+S	8	11	P+S
HAT-P-32 b	Hot Jupiter	0.14768108	0.163	1677.4	2.037	0.941	2.150009	0.1	F/G	-0.16	9.99	11.44	320	1	1	P+S	2	3	P+S
HAT-P-33 b	Hot Jupiter	0.16596527	0.148	1675.2	1.827	0.763	3.474474	0.1	F	0.05	10.004	11.03	419	1	2	P+S	6	9	P+S
HAT-P-36 b	Hot Jupiter	1.20335169	0.063	1669.2	1.264	1.832	1.327	0.1	G	0.26	10.603	12.26	317	12	2	P+S	95	14	P+S
HAT-P-4 b	Hot Jupiter	0.44035819	0	1550.7	1.27	0.68	3.0565114	0.1	F	0.24	9.77	11.12	310	3	3	P+S	22	23	P+S
HAT-P-40 b	Hot Jupiter	0.1575597	0.095	1614.8	1.73	0.615	4.457243	0.1	F	0.22	10.009	11.34	501	2	3	P+S	10	19	P+S
HAT-P-41 b	Hot Jupiter	0.22181893	0	1689.7	1.685	0.8	2.69404	0.1	F	0.21	9.728	11.36	344	1	1	P+S	6	6	P+S
HAT-P-45 b	Hot Jupiter	0.40805115	0.049	1652	1.426	0.892	3.128992	0.1	nan	0.07	nan	3.75	305	2	2	P+S	14	15	P+S
HAT-P-6 b	Hot Jupiter	0.59597548	0	1529.9	1.33	1.057	3.853003	0.1	F	-0.13	9.313	10.47	200	2	2	P+S	13	10	P+S
HAT-P-7 b	Hot Jupiter	0.7302358	0	2733	1.4588	1.709	2.204737	0.1	F6	0.26	9.334	10.48	320	6	1	P+S	48	7	P+S
HAT-P-8 b	Hot Jupiter	0.7336857	0	1713	1.321	1.275	3.0763402	0.1	F	0.01	8.953	10.36	230	3	2	P+S	23	9	P+S
HATS-3 b	Hot Jupiter	0.30889086	0.253	1816	1.697	1.138	3.547849	0.1	F	-0.157	10.694	12.44	556	5	4	P+S	37	26	P+S
HD 149026 b	Hot Jupiter	1.27580703	0	1601.5	0.718	0.356	2.8758916	0.1	G0IV	0.36	6.819	8.14	78.9	2	2	P+S	12	9	P+S
HD 189733 A b	Hot Jupiter	1.02429205	0.0041	1099.7	1.138	1.138	2.21857312	0.1	K2V	-0.03	5.54	7.68	19.3	1	1	P+S	1	1	P+S
HD 209458 b	Hot Jupiter	0.36038713	0.0004	1316.1	1.38	0.714	3.52474859	0.1	G0V	0.02	6.308	7.63	47	1	1	P+S	1	1	P+S
KELT-2A b	Hot Jupiter	0.88490694	0.185	1565.7	1.306	1.486	4.1137914	0.1	F7V	-0.015	7.346	8.77	128.9	2	1	P+S	11	3	P+S
Qatar-1 b	Hot Jupiter	1.11866751	0	1389	1.164	1.33	1.42002504	0.1	K	0.2	10.409	12.84	233.35	9	4	P+S	70	32	P+S
TrES-1 b	Hot Jupiter	0.7605012	0	1257.11429	1.099	0.761	3.0300722	0.1	K0V	0.001	9.819	11.42	157	2	7	P+S	15	46	P+S
TrES-2 A b	Hot Jupiter	1.04043718	0	1599.66016	1.169	1.253	2.4706134	0.1	G0	0.001	9.846	11.25	213	6	4	P+S	46	27	P+S
WASP-1 b	Hot Jupiter	0.34906401	0	1644.3	1.484	0.86	2.5199464	0.1	F7V	nan	10.276	11.79	408	3	2	P+S	19	16	P+S
WASP-10 b	Hot Jupiter	3.22224445	0.057	946.8	1.08	3.06	3.0927616	0.1	K5	0.03	9.983	12.7	90	4	4	P+S	33	16	P+S
WASP-100 b	Hot Jupiter	0.55788444	0.1	2190	1.69	2.03	2.849375	0.1	F2	-0.03	nan	10.8	316.23	3	1	P+S	26	5	P+S
WASP-101 b	Hot Jupiter	0.23660341	0.03	1560	1.41	0.5	3.585722	0.1	F6	0.2	nan	10.3	181.97	1	2	P+S	3	10	P+S
WASP-11 b	Hot Jupiter	0.53470874	0	943.2	1.045	0.46	3.722469	0.1	K3V	0.13	9.421	11.89	125	1	13	P+S	7	57	P+S
WASP-12 b	Hot Jupiter	0.35598055	0	2319.7	1.736	1.404	1.0914222	0.1	G0	0.3	10.188	11.69	250	1	1	P+S	6	1	P+S
WASP-13 b	Hot Jupiter	0.23611304	0	1203.3	1.389	0.477	4.353011	0.1	G1V	0	9.119	10.42	155	1	1	P+S	2	8	P+S
WASP-15 b	Hot Jupiter	0.24690108	0	1511.3	1.428	0.542	3.7520656	0.1	F7	-0.17	9.693	10.9	308	1	3	P+S	7	18	P+S
WASP-17 b	Hot Jupiter	0.08168284	0.028	1517.8	1.991	0.486	3.735438	0.1	F4	-0.19	10.224	11.6	400	1	1	P+S	2	6	P+S
WASP-18 b	Hot Jupiter	8.75013708	0.0088	2187.5	1.165	10.43	0.9414518	0.1	F6	nan	8.131	9.3	100	9	1	P+S	73	1	P+S
WASP-19 b	Hot Jupiter	0.58191758	0.0046	1911.5	1.386	1.168	0.78884	0.1	G8V	0.02	10.481	12.3	250	3	1	P+S	18	4	P+S
WASP-2 A b	Hot Jupiter	0.86995142	0	1170.7	1.117	0.914	2.15222144	0.1	K1V	-0.08	9.632	11.98	165.8	4	4	P+S	26	33	P+S
WASP-25 b	Hot Jupiter	0.38461364	0	1135	1.26	0.58	3.76483	0.1	G4	-0.05	10.174	11.9	169	1	4	P+S	5	28	P+S
WASP-26 b	Hot Jupiter	0.64871516	0	1521.3	1.281	1.028	2.7566004	0.1	G0	-0.02	9.69	11.3	250	4	3	P+S	33	19	P+S
WASP-29 b	Hot Jupiter	0.65151228	0.03	910.6	0.792	0.244	3.922727	0.1	K4V	0.11	8.783	11.3	80	1	10	P+S	5	40	P+S
WASP-3 b	Hot Jupiter	0.88896022	0	1825.6	1.454	2.06	1.8468372	0.1	F7V	nan	9.361	10.64	223	3	1	P+S	22	4	P+S
WASP-31 b	Hot Jupiter	0.1746283	0	1410.6	1.537	0.478	3.405909	0.1	F	-0.19	10.65	11.7	400	1	5	P+S	7	34	P+S
WASP-33 b	Hot Jupiter	2.04759637	0	2451.5	1.438	4.59	1.21986967	0.1	A5	0.1	7.468	8.3	116	2	1	P+S	13	1	P+S
WASP-34 b	Hot Jupiter	0.43100355	0.038	1058.7	1.22	0.59	4.3176782	0.1	G5	-0.02	8.792	10.4	120	1	7	P+S	7	34	P+S
WASP-35 b	Hot Jupiter	0.41525898	0	1450	1.32	0.72	3.161575	0.1	G0	-0.15	9.525	10.94	177.01	1	2	P+S	5	11	P+S
WASP-4 b	Hot Jupiter	0.58751646	0	1710.4	1.363	1.1215	1.33823187	0.1	G8	-0.03	10.746	12.6	300	3	1	P+S	25	8	P+S
WASP-41 b	Hot Jupiter	0.68887439	0	1207.5	1.21	0.92	3.052394	0.1	G8V	-0.08	9.677	11.6	180	2	4	P+S	15	24	P+S
WASP-43 b	Hot Jupiter	2.42649839	0.0035	1317.6	1.036	2.034	0.81347753	0.1	K7V	-0.01	9.267	12.4	80	3	1	P+S	23	4	P+S
WASP-45 b	Hot Jupiter	0.85578334	0	1094.2	1.16	1.007	3.1260876	0.1	K2V	0.36	10.294	12	131.83	3	5	P+S	21	38	P+S
WASP-49 b	Hot Jupiter	0.3617225	0	1369	1.115	0.378	2.7817387	0.1	G6	-0.23	9.749	11.36	170	1	4	P+S	6	30	P+S
WASP-52 b	Hot Jupiter	0.29788936	0	1315	1.27	0.46	1.7497798	0.1	K2V	0.03	nan	12	140	1	2	P+S	3	11	P+S
WASP-54 b	Hot Jupiter	0.1867871	0.067	1759	1.653	0.636	3.6936411	0.1	F9	-0.27	9.035	10.42	200	1	1	P+S	2	6	P+S
WASP-62 b	Hot Jupiter	0.28153914	0	1305.2	1.39	0.57	4.411953	0.1	F7	0.04	8.944	10.3	160	1	2	P+S	3	10	P+S
WASP-63 b	Hot Jupiter	0.17237878	0	1540	1.43	0.38	4.37809	0.1	G8	0.08	9.393	11.2	330	1	4	P+S	6	29	P+S
WASP-64 b	Hot Jupiter	0.82114003	0	1689	1.271	1.271	1.57329	0.1	G7	-0.08	10.956	12.29	350	9	4	P+S	74	27	P+S
WASP-68 b	Hot Jupiter	0.66094736	nan	1490	1.24	0.95	5.084298	0.1	G0	0.22	8.9	10.7	158.49	2	2	P+S	12	11	P+S
WASP-69 b	Hot Jupiter	0.29204966	nan	963	1.057	0.26	3.8681382	0.1	K5	0.15	7.46	9.87	50	1	1	P+S	1	4	P+S
WASP-7 b	Hot Jupiter	0.54128331	0	1359.5	1.33	0.96	4.9546416	0.1	F5V	nan	8.396	9.51	140	1	2	P+S	6	7	P+S
WASP-70A b	Hot Jupiter	0.496251	0.067	1387	1.164	0.59	3.7130203	0.1	G4	-0.006	nan		245	2	5	P+S	15	33	P+S
WASP-71 b	Hot Jupiter	0.88747982	0	1888.1	1.5	2.258	2.9036747	0.1	F8	nan	9.32	10.56	200	4	2	P+S	31	11	P+S
WASP-75 b	Hot Jupiter	0.69291656	0	1710	1.27	1.07	2.484193	0.1	F9	0.07	10.062	11.45	260	6	3	P+S	42	22	P+S
WASP-76 b	Hot Jupiter	0.19913284	0.05	2160	1.83	0.92	1.809886	0.1	F7	0.23	8.243	9.52	120	1	1	P+S	1	1	P+S
WASP-77 A b	Hot Jupiter	1.31784666	nan	1934.4983	1.21	1.76	1.3600309	0.1	G8 V	0	8.408	10.3	93	2	1	P+S	9	2	P+S
WASP-78 b	Hot Jupiter	0.28711254	0	2006.7	1.75	1.16	2.17517656	0.1	F8	-0.35	11.008	12	550	4	2	P+S	32	11	P+S
WASP-79 b	Hot Jupiter	0.24299877	0	1958.7	1.7	0.9	3.6623817	0.1	F3	0.03	9.056	10.1	240	1	1	P+S	2	2	P+S
WASP-80 b	Hot Jupiter	0.85174039	0.07	800	0.952	0.554	3.0678504	0.1	K7V	-0.14	8.351	11.88	60	1	5	P+S	4	20	P+S
WASP-82 b	Hot Jupiter	0.35316739	0.06	2190	1.67	1.24	2.705782	0.1	F5	0.12	nan	10.1	200	1	1	P+S	5	2	P+S
WASP-88 b	Hot Jupiter	0.15119923	nan	1772	1.7	0.56	4.954	0.1	F6	-0.08	10.3	11.4	302	1	1	P+S	3	7	P+S
WASP-90 b	Hot Jupiter	0.19296834	0.5	1840	1.63	0.63	3.916243	0.1	F6	0.11	nan	11.7	340	1	2	P+S	8	14	P+S
WASP-95 b	Hot Jupiter	0.84611746	0.04	1570	1.21	1.13	2.184673	0.1	G2	0.14	nan	10.1	104.71	1	1	P+S	7	4	P+S
WASP-96 b	Hot Jupiter	0.36847313	0.27	1285	1.2	0.48	3.4252602	0.1	G8	0.14	nan	12.2	208.93	2	7	P+S	10	52	P+S
WASP-97 b	Hot Jupiter	1.21351996	0.05	1555	1.13	1.32	2.07276	0.1	G5	0.23	nan	10.6	120.23	2	1	P+S	16	6	P+S
XO-1 b	Hot Jupiter	0.71927626	0	1168	1.184	0.9	3.9415128	0.1	G1V	nan	9.527	11.3	200	3	7	P+S	17	47	P+S
XO-2 b	Hot Jupiter	0.89281503	0.045	1203.3	0.973	0.62	2.615838	0.1	K0V	0.45	9.308	11.18	149	3	5	P+S	19	36	P+S
CoRoT-2 b	Hot Jupiter	1.39644374	0	1392.7	1.465	3.31	1.7429964	0.1	G7V	nan	10.31	12.57	300	9	2	P+S	78	14	P+S
CoRoT-5 b	Hot Jupiter	0.23166307	0.09	1316.3	1.388	0.467	4.0378962	0.1	F9V	-0.25	12.546	14	400	2	8	P+S	11	59	P+S
Gliese 1214 b	Warm Super-	1.59467946	0.27	519.6	0.254	0.0197	1.580405	0.3	M4.5	0.39	8.782	14.71	13	6	77	P+S	48	307	P+S
Gliese 3470 b	Warm Neptu	0.68016091	0	603.5	0.440159	0.04372523	3.336649	0.3	M1.5	0.2	7.989	12.3	30.7	1	43	P+S	3	171	P+S
HAT-P-12 b	Hot Jupiter	0.31734741	0	875.4	0.959	0.211	3.2130598	0.1	K5	-0.29	10.108	12.84	142.5	1	34	P+S	4	201	P+S
HAT-P-16 b	Hot Jupiter	2.59701486	0.036	1485.9	1.289	4.193	2.77596	0.1	F8	0.17	9.553	10.91	235	15	2	P+S	122	14	P+S
HAT-P-17 b	Hot Jupiter	0.6875202	0.346	707.1	1.01	0.534	10.338523	0.1	K	nan	8.544	10.38	90	1	17	P+S	6	67	P+S
HAT-P-18 b	Hot Jupiter	0.26528049	0.084	774.9	0.995	0.197	5.508023	0.1	K	0.1	10.234	12.76	166	1	114	P+S	4 /		P
HAT-P-19 b	Hot Jupiter	0.26702498	0.067	922.7	1.132	0.292	4.008778	0.1	K	0.23	10.546	12.9	215	1	37	P+S	6	265	P+S
HAT-P-2 b	Hot Jupiter	13.4796373	0.5171	1343.6	0.951	8.74	5.6334729	0.1	F8	0.14	7.603	8.69	118	28	3	P+S	224	13	P+S
HAT-P-20 b	Hot Jupiter	14.7485513	0.015	888.3	0.867	7.246	2.875317	0.1	K7	0.35	8.601	11.34	70	13	7	P+S	98	25	P+S
HAT-P-23 b	Hot Jupiter	1.08291986	0.106	1873.6	1.368	2.09	1.212884	0.1	G5	0.15	10.791	11.94	393	13	2	P+S	110	12	P+S
HAT-P-25 b	Hot Jupiter	0.44632427	0.032	1100.1	1.19	0.567	3.652836	0.1	G5	0.31	10.815	13.15	297	3	19	P+S	23	138	P+S
HAT-P-26 b	Hot Neptune	0.43392532	0.124	907.4	0.565	0.059	4.234516	0.1	K1	-0.04	9.581	11.76	134	1	242	P+S	6 /		P
HAT-P-3 b	Hot Jupiter	1.38605121	0	1047.2	0.827	0.591	2.899703	0.1	K	0.27	9.448	11.86	130	5	17	P+S	36	135	P+S
HAT-P-39 b	Hot Jupiter	0.2049305	0	1601.9	1.571	0.599	3.54387	0.1	F	0.19	11.157	12.42	642	3	7	P+S	22	51	P+S
HAT-P-44 b	Hot Jupiter	0.24795021	0.072	1126	1.28	0.392	4.30134856	0.1	nan	0.33	11.275	5.34	374	2	35	P+S	15	267	P+S
HAT-P-46 b	Hot Jupiter	0.30893006	0.123	1458	1.284	0.493	4.46587643	0.1	nan	0.3	9.924	3.79	296	2	7	P+S	13	53	P+S
HAT-P-9 b	Hot Jupiter	0.3238911	0	1397.3	1.4	0.67	3.922814	0.1	F	0.12	11.015	12.34	480	4	9	P+S	29	73	P+S
HATS-2 b	Hot Jupiter	1.11970104	0	1577	1.168	1.345	1.354133	0.1	K	0.15	11.386	13.62	360	16	6	P+S	133	45	P+S
Kepler-12 b	Hot Jupiter	0.11740227	0.01	1354.2	1.695	0.431	4.4379637	0.1	G0	0.07	12.066	13.4	600	1	8	P+S	8	58	P+S
Kepler-7 b	Hot Jupiter	0.13661099	0.1	1486.8	1.614	0.433	4.885525	0.1	G0	0.11	11.535	12.95	445.66	1	4	P+S	7	30	P+S
Kepler-76 b	Hot Jupiter	1.35833935	nan	2273.81424	1.25	2	1.54492875	0.1	G2V	-0.1	12.092	13.55	513.33	60	7	P+S	/	53	S
KOI-13 b	Hot Jupiter	4.01238234	0	3648.02879	1.4	8.3	1.7635892	0.1	A5-7V	nan	8.425	9.95	604	109	2	P+S	/	10	S
OGLE2-TR-L9 b	Hot Jupiter	1.36926486	nan	2154.6	1.614	4.34	2.4855335	0.1	F3	-0.05	13.12	14.03	900	71	4	P+S	/	29	S
Qatar-2 b	Hot Jupiter	2.20346439	0	1179.7	1.144	2.487	1.3371182	0.1	K	nan	10.619	13.3	288.4	29	9	P+S	238	67	P+S
TrES-3 b	Hot Jupiter	1.14001393	0	1685.38548	1.305	1.91	1.30618608	0.1	K0V	0.001	10.608	12.4	400	23	7	P+S	187	47	P+S
TrES-5 b	Hot Jupiter	1.33463091	nan	1569.48817	1.209	1.778	1.4822446	0.1	K0V	0.2	11.591	13.58	360	24	8	P+S	193	58	P+S
WASP-14 b	Hot Jupiter	4.6325078	0.087	1718.8	1.281	7.341	2.2437661	0.1	F5V	nan	8.621	9.75	160	12	1	P+S	95	4	P+S
WASP-21 b	Hot Jupiter	0.22463295	0	1154.6	1.21	0.3	4.322506	0.1	G3V	-0.4	9.982	11.6	230	1	9	P+S	4	61	P+S
WASP-22 b	Hot Jupiter	0.50229629	0	1297.5	1.158	0.588	3.5327313	0.1	G	-0.05	10.318	12	300	3	9	P+S	23	63	P+S
WASP-32 b	Hot Jupiter	3.44831053	0	1427.6	1.1	3.46	2.718661	0.1	G	-0.13	10.161	11.3	208.93	22	4	P+S	181	26	P+S
WASP-36 b	Hot Jupiter	1.47933926	0	1554.5	1.269	2.279	1.5373653	0.1	G2	-0.31	11.294	12.7	450	36	7	P+S	298	52	P+S

WASP-38 b	Hot Jupiter	2.7758636	0.028	1152.9	1.09	2.71	6.87188	0.1	F8	-0.12	7.998	9.42	110	5	3	P+S	40	12	P+S
WASP-39 b	Hot Jupiter	0.18132396	0	1021.8	1.27	0.28	4.055259	0.1	G8	-0.12	10.202	12.11	230	1	14	P+S	3	100	P+S
WASP-42 b	Hot Jupiter	0.52651053	0.06	995	1.08	0.5	4.9816872	0.1	K1	0.05	10.033	12.57	160	2	27	P+S	10	137	P+S
WASP-46 b	Hot Jupiter	1.2397111	0	1516.6	1.31	2.101	1.43037	0.1	G6V	-0.37	11.401	12.9	326.09	14	3	P+S	113	23	P+S
WASP-47 b	Hot Jupiter	0.99430507	0	1119.7	1.15	1.14	4.1591399	0.1	G9V	0.18	10.192	11.9	200	5	9	P+S	40	66	P+S
WASP-5 b	Hot Jupiter	1.35234132	0	1584	1.171	1.637	1.6284246	0.1	G5	0.09	10.598	12.26	297	13	3	P+S	108	21	P+S
WASP-50 b	Hot Jupiter	1.28213022	0.009	1289.9	1.15	1.47	1.955096	0.1	G9	-0.12	9.969	11.6	230	10	5	P+S	71	36	P+S
WASP-55 b	Hot Jupiter	0.34415424	0	1160.1	1.3	0.57	4.465633	0.1	G1	-0.2	10.396	11.8	330	2	12	P+S	15	91	P+S
WASP-56 b	Hot Jupiter	0.5816698	0	1216	1.092	0.571	4.617101	0.1	G6	nan	10.532	11.48	255	4	26	P+S	27	200	P+S
WASP-58 b	Hot Jupiter	0.45913101	0	1270	1.37	0.89	5.01718	0.1	G2V	-0.45	nan	11.66	300	3	8	P+S	22	63	P+S
WASP-6 b	Hot Jupiter	0.36385811	0.054	1092.2	1.224	0.503	3.361006	0.1	G8	-0.2	10.325	12.4	307	2	17	P+S	16	123	P+S
WASP-65 b	Hot Jupiter	1.4952908	0	1480	1.112	1.55	2.3114243	0.1	G6	-0.07	10.35	11.9	310	17	7	P+S	137	50	P+S
WASP-66 b	Hot Jupiter	1.14591369	0	1647.5	1.39	2.32	4.086052	0.1	F4	-0.31	10.452	11.6	380	15	3	P+S	122	23	P+S
WASP-67 b	Hot Jupiter	0.20303622	0	940.6	1.4	0.42	4.61442	0.1	K0V	-0.07	10.129	12.5	225	1	22	P+S	6	175	P+S
WASP-72 b	Hot Jupiter	1.81536232	0	2210	1.01	1.41	2.21672	0.1	F7	-0.06	9.617	10.88	340	31	7	P+S	252	48	P+S
WASP-73 b	Hot Jupiter	1.59768886	nan	1790	1.16	1.88	4.08722	0.1	F9	0.14	9	10.5	165.96	7	2	P+S	55	9	P+S
WASP-8 b	Hot Jupiter	2.6615775	0.31	846.5	1.038	2.244	8.158715	0.1	G6	0.17	8.086	9.9	87	4	6	P+S	25	24	P+S
WASP-99 b	Hot Jupiter	2.77060788	0.02	1480	1.1	2.78	5.75251	0.1	F8	0.21	nan	9.5	104.71	6	2	P+S	43	6	P+S
XO-3 b	Hot Jupiter	8.67661635	0.26	1554.5	1.217	11.79	3.1915239	0.1	F5V	-0.177	8.791	9.8	260	63	3	P+S	/	23	S
CoRoT-11 b	Hot Jupiter	1.22988151	0	1593.4	1.39	2.49	2.994325	0.1	F6V	-0.03	11.248	12.8	560	86	17	P+S	/	137	S
CoRoT-19 b	Hot Jupiter	0.48297794	0.047	1515.3	1.45	1.11	3.89713	0.1	F9V	-0.02	11.837	14.01	800	21	18	P+S	178	141	P+S
CoRoT-4 b	Hot Jupiter	0.56676097	0	975.6	1.19	0.72	9.20205	0.1	F8V	0.05	12.29	13.7	724.44	29	/	P	/	/	No
HAT-P-14 b	Hot Jupiter	1.68883518	0.095	1445.9	1.2	2.2	4.627657	0.1	F	0.11	8.851	9.99	205	22	8	P+S	180	58	P+S
HAT-P-15 b	Hot Jupiter	2.09539935	0.19	819.9	1.072	1.946	10.863502	0.1	G5	0.22	9.641	12.41	190	12	89	P+S	96	/	P
HAT-P-21 b	Hot Jupiter	5.01944011	0.228	1161.5	1.024	4.063	4.124461	0.1	G3	0.01	10.111	11.46	254	53	18	P+S	/	132	S
HAT-P-27 b	Hot Jupiter	0.77499607	0	1102.7	1.02	0.62	3.039577	0.1	G8	0.14	10.109	12.19	204	6	20	P+S	42	160	P+S
HAT-P-28 b	Hot Jupiter	0.46641746	0.051	1262.4	1.212	0.626	3.257215	0.1	G3	0.12	11.104	13.03	395	5	14	P+S	40	102	P+S
HAT-P-29 b	Hot Jupiter	0.76075543	0.095	1149.1	1.107	0.778	5.72318	0.1	F8	0.21	10.297	11.83	322	9	31	P+S	72	238	P+S
HAT-P-31 b	Hot Jupiter	2.35080613	0.245	1324.7	1.07	2.171	5.005425	0.1	F	0.15	10.083	11.67	354	43	15	P+S	/	116	S
HAT-P-34 b	Hot Jupiter	2.57400384	0.441	1335.3	1.197	3.328	5.4527	0.1	F8	0.22	9.247	10.4	257	24	7	P+S	199	48	P+S
HAT-P-35 b	Hot Jupiter	0.59161103	0.025	1442.8	1.332	1.054	3.6467	0.1	F	0.11	11.03	11.59	535	13	12	P+S	112	92	P+S
HAT-P-38 b	Hot Jupiter	0.6307507	0.067	987	0.825	0.267	4.640382	0.1	G	0.06	10.501	12.56	249	5	116	P+S	40	/	P
HAT-P-42 b	Hot Jupiter	0.62106957	0	1427	1.277	0.975	4.641876	0.1	G	0.27	10.626	12.17	447	10	10	P+S	84	74	P+S
HAT-P-43 b	Hot Jupiter	0.41454558	0	1361	1.283	0.66	3.332688	0.1	F	0.23	11.764	13.36	543	7	20	P+S	58	147	P+S
HAT-P-5 b	Hot Jupiter	0.71647527	0	1387.4	1.252	1.06	2.788491	0.1	G	0.24	10.481	11.95	340	7	6	P+S	54	44	P+S
HATS-1 b	Hot Jupiter	1.11485731	0.12	1250.3	1.302	1.855	3.446459	0.1	G2V	-0.06	10.58	12.05	303	11	8	P+S	89	55	P+S
HD 97658 b	Warm Super-	3.38308906	0.064	689.2	0.213245	0.024731	9.4909	0.3	K1V	-0.3	5.734	7.714	21.1	47	/	P	/	/	No
Kepler-15 b	Hot Jupiter	0.98955186	nan	1027.9	0.96	0.66	4.942782	0.1	G	0.36	12.216	13.8	660.69	92	/	P	/	/	No
Kepler-17 b	Hot Jupiter	1.43904013	0.011	1622.7	1.312	2.45	1.4857108	0.1	G2V	0.26	12.585	14	800	132	19	P+S	/	148	S
Kepler-25 c	Hot Neptune	nan	nan	959.7	0.410086	nan	12.72	0.1	F	nan	9.493	10.77	191	18	/	P	/	/	No
Kepler-63 b	Hot Jupiter	2.90064883	0.45	963.479414	0.556806	0.377484	9.4341505	0.1	nan	0.05	9.997	12.02	200	56	/	P	/	/	No
KOI-254 b	Hot Jupiter	0.75715711	0.11	956.496834	0.96	0.505	2.455239	0.1	M	0.13	12.89	16.88	333	19	344	P+S	152	/	P
KOI-2672 b	Warm Neptu	0.63276936	nan	413	0.482991	0.053747	88.51658	0.3	nan	nan	nan		263.4	14	/	P	/	/	No
KOI-94 d	Hot Jupiter	0.40829263	0.022	806	1.0270384	0.33344427	22.342989	0.1	F	0.0228	10.926	11.63	426.2	7	/	P	58	/	P
WASP-16 b	Hot Jupiter	1.10737023	0	1160	1.008	0.855	3.1186009	0.1	G3V	0.01	9.589	11.3	176.47	7	11	P+S	49	87	P+S
WASP-23 b	Hot Jupiter	1.31715042	0.062	1024	0.962	0.884	2.9444256	0.1	K1V	nan	10.53	12.7	199.53	8	24	P+S	63	185	P+S
WASP-24 b	Hot Jupiter	1.01737439	0	1514.1	1.104	1.032	2.3412083	0.1	F8-9	0.07	10.148	11.3	330	14	8	P+S	112	57	P+S
WASP-28 b	Hot Jupiter	0.85920273	0.046	1291.9	1.12	0.91	3.408821	0.1	F8-G0	-0.29	10.732	12	334	9	12	P+S	67	87	P+S
WASP-37 b	Hot Jupiter	1.53461408	0	1213.5	1.136	1.696	3.577471	0.1	G2	-0.4	11.093	12.7	338	19	14	P+S	153	106	P+S
WASP-44 b	Hot Jupiter	1.14584253	0	1304	1.002	0.869	2.4238133	0.1	G8V	0.06	11.341	12.9	288.4	14	19	P+S	114	152	P+S
WASP-59 b	Hot Jupiter	2.45931417	0.1	710.017534	0.775	0.863	7.919585	0.1	K5V	-0.15	9.723	13	125	11	/	P	86	/	P
WASP-61 b	Hot Jupiter	1.43321218	0	1417.5	1.24	2.06	3.8559	0.1	F7	-0.1	11.008	12.5	480	36	12	P+S	306	95	P+S
WASP-84 b	Hot Jupiter	1.10132396	0.077	797	0.942	0.694	8.5234865	0.1	K0	0	8.86	11.64	125	3	84	P+S	23	/	P
WASP-98 b	Hot Jupiter	0.82719588	0.24	1180	1.1	0.83	2.96264	0.1	G7	-0.6	nan	13	321.12	9	30	P+S	72	240	P+S
XO-4 b	Hot Jupiter	0.94824896	0	1328.2	1.34	1.72	4.1250823	0.1	F5V	-0.04	9.406	10.7	293	9	5	P+S	74	36	P+S
XO-5 b	Hot Jupiter	1.30741166	0	1133.5	1.03	1.077	4.1877537	0.1	G8V	0.18	10.345	12.13	255	13	21	P+S	104	154	P+S