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DOCUMENT

EChO targets: the Mission Reference Sample and beyond

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1 INTRODUCTION

One of the main objectives of the EChO mission is to measure the physical and chemical properties of a broad and diverse sample of exoplanets. These should span a range of masses, densities, equilibrium temperatures, orbital properties, host star parameters, etc. Among all the available transiting exoplanets at the time the mission starts, efforts will be focused on those that pose the best observing circumstances, most importantly the nearest and brightest. Over 300 transiting planets have been discovered to date, including super-Earth, Neptune and Jupiter type planets, mostly with hot and warm temperatures. But it is expected that the numerous ongoing and future transit search experiments will keep on discovering new targets of EChO interest and improve on those presently available.

The statement above and the need to size the mission according to the targets that EChO will observe roughly 10 years in the future motivated an effort to estimate the sample of transiting planets expected. This effort is described in the current document and has led to the definition of a Mission Reference Sample (MRS) that provides a general flavour of the parameter space that the mission will cover. Of course, the list of EChO observable planets will evolve over the coming years by expanding into the variety of star/planet configurations as defined by the MRS. The current fainter targets will be replaced by brighter counterparts and objects covering new parameter space will be added.

The details of the methodology followed to define the EChO MRS and the corresponding results are explained below. Also, we present a census of the known transiting planets today and a summary of the projects that are aimed at discovering transiting planets that can be of potential interest to EChO.

2 ESTIMATING STAR COUNTS

Two complementary and independent approaches based on 1) direct star counts, and 2) a projection of an available volume-limited stellar catalogue were carried out. A new catalog of M dwarfs has been recently released by Lépine et al. (2013; hereafter L13). This catalog is based on spectroscopic spectral types and covers the Northern Hemisphere down to magnitude J=9 and the claimed completeness is better than 90%. A first cut considered only K<8 to ensure no bias when changing the reference magnitude band from J to K magnitude. Then, two different magnitude limits (K<7,8) were considered and stars classified in different spectral type bins (K7-M1, M2-M3, M4 and later) were counted. Stars classified as K7 were included in the early M bin, as done also by L13. Also, the resulting numbers have been multiplied by 2 so that they reflect the expected counts over the full sky. The results are given in Table 1.

Table 1: Star counts considering different spectral type intervals and K-band magnitude limits for the Lépine et al. (2013) catalog.

Mass ($M_\odot$)	Spectral type	Nstars (K<7)	Nstars (K<8)
0.65-0.41	K7-M1	330	1226
0.41-0.25	M2-M3	194	778
0.25-0.10	M4-lateM	58	224

We also used the observed stellar mass function as obtained from the 10-pc RECONS sample to model star counts as a function of apparent magnitude. The Baraffe et al. (1998) models were used to provide the required mass-luminosity-K magnitude conversions. Star counts were binned to the same mass/spectral type intervals as defined for the L13 catalogue, namely K7-M1, M2-M3 and M4-lateM, plus F, G and K dwarfs. The same magnitude limits as in L13 (K<7,8) were considered. Note that a possible incompleteness of the 10-pc RECONS sample for the coolest M dwarfs might lead to underestimated star counts for these stars. However, early M-dwarf counts should not be affected. The star counts resulting from this method are presented in Table 2.

Table 2: Star counts considering different spectral type intervals and K-band magnitude limits calculated using the RECONS sample and theoretical models.

Mass ($M_\odot$)	Spectral type	Nstars (K<7)	Nstars (K<8)
1.25-1.09	F6-F9	5646	22,585
1.09-0.87	G0-G8	3356	13,360
0.87-0.65	K0-K5	1167	4647
0.65-0.41	K7-M1	386	1535
0.41-0.25	M2-M3	81	323
0.25-0.10	M4-lateM	28	112

As shown by the tables, the values yielded by the two approaches differ significantly for the mid & late M bins (being the L13 counts a factor of 2 higher, as expected) but are within 20% for the early Ms. By merging the results from the two methods and scaling the number of stars using the formula $N \propto 10^{(3/5)Kmag}$, we predict the star counts in Table 3 down to a magnitude limit K=9.

Table 3: Adopted star counts down to K=9.

Mass ($M_\odot$)	Spectral type	Nstars (K<9)
1.25-1.09	F6-F9	90,000
1.09-0.87	G0-G8	53,200
0.87-0.65	K0-K5	18,500
0.65-0.41	K7-M1	6000
0.41-0.25	M2-M3	3000
0.25-0.10	M4-lateM	800

3 FRACTION OF TRANSITING PLANETS

Prior to estimating the number of transiting planets, we classified them in terms of planet type and equilibrium temperature. Classification into temperature bins is quite difficult as it depends on a number of factors and becomes even more uncertain when we consider wide bins of stellar spectral types (e.g., the temperatures of a planet at a given orbital distance around an M4 and an M9 star are very different yet we count them in the same overall bin). We have carried out the exercise of defining ranges of orbital period but this has to be regarded as a very crude approximation. The starting point to calculate the temperatures is the definition of the Habitable Zone by Selsis et al. (2007). To scale the temperatures we considered that $T_{eq} \propto S^{1/4} \propto a^{-1/2} \propto P^{-1/3}$, where S, a, and P are the total stellar flux, the orbital semi-major axis, and the orbital period, respectively. The resulting ranges are shown in Table 4. Again, this is a very crude approximation since the actual temperature of the atmosphere depends strongly on the chemical composition.

Regarding planet physical properties, the boundaries of the classification and the mean planet parameters of the different types are given in Table 5. Fiducial values for "hot", "warm" and "temperate" planets are adopted as equilibrium temperatures of 1500 K, 600 K, and 320 K, respectively. These categories were defined based on commonly-used planet classes that mainly reflect the bulk composition of the object (from hydrogen dominated to iron/silicates dominated).

Table 4: Temperature classification of planets for different host stars as a function of orbital period.

Spectral type	Orbital period (days)		
	Hot (T_{eq} > 700 K)	Warm (700 > T_{eq} > 400 K)	Temperate (400 > T_{eq} > 250 K)
F6-F9 (F8)	<60	60-200	>200
G0-G8 (G1)	<30	30-100	>100
K0-K5 (K1)	<12	12-40	>40
K7-M1 (M0)	<5	5-18	>18
M2-M3 (M2)	<2	2-6	>6
M4-late M (M4)	<1	1-3	>3

Table 5: Definition of planet types as s function of radius and mean parameters for each type.

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		

To estimate the planet counts we made use of the statistics of the Kepler mission as determined by F. Fressin (private communication). Fressin has used a methodology similar to that described in a recent paper (Fressin et al. 2013) but further refined to include the catalog by Burke (in preparation) and a new Kepler detection model. The calculations correspond to direct transiting planet counts without geometric bias correction. The transiting planet rates for the different planet types as a function of orbital period are

Figure 1: Number of transiting planets per star for different planet types (see Table 5) as a function of orbital period (geometric bias included). The statistics have been calculated from the Kepler mission candidate list by F. Fressin (priv. comm.) using a methodology similar to that described in Fressin et al. (2013).

shown in Figure 1.

An important assumption in our estimations is that the overall Kepler detection statistics apply to stellar hosts from F type to M type. Although this will definitely need future proof, the statistical study of Dressing & Charbonneau (2013) indicates that the planet occurrence rate around M dwarfs and around solar-type stars are fundamentally not very different, although the available statistics for the former is still insufficient to draw definitive conclusions.

Using the star counts in Table 3, the planet temperature definitions in Table 4, the planet types in Table 5 and the transiting planet occurrence rates shown in Figure 1, we calculate the number of transiting planets for the different classes considered. These are shown in Table 6 and in Figure 2 for a limiting magnitude K=9. Note that the predicted total number of planets is 3584, which corresponds to a total overall transiting planet occurrence of 2.09%. Such overall number is in good agreement with HARPS estimates (Mayor et al. 2011) and other estimates based on Kepler data (Howard et al. 2012).

Table 6: Total number of transiting planets expected for each of the planet classes down to a limiting magnitude K=9.

HSE	M4	0.15	HSN	M4	0.01	HN	M4	0.01	HJ	M4	0.01
HSE	M2	1.62	HSN	M2	0.16	HN	M2	0.11	HJ	M2	0.14
HSE	K7	13.90	HSN	K7	2.93	HN	K7	1.88	HJ	K7	1.61
HSE	K0	100.03	HSN	K0	36.04	HN	K0	18.92	HJ	K0	9.22
HSE	G0	444.55	HSN	G0	199.24	HN	G0	99.34	HJ	G0	38.71
HSE	F8	879.44	HSN	F8	429.29	HN	F8	217.45	HJ	F8	82.96
WSE	M4	0.67	WSN	M4	0.12	WN	M4	0.06	WJ	M4	0.07
WSE	M2	7.00	WSN	M2	1.89	WN	M2	1.23	WJ	M2	0.75
WSE	K7	27.23	WSN	K7	13.54	WN	K7	6.51	WJ	K7	2.02
WSE	K0	62.65	WSN	K0	38.48	WN	K0	19.00	WJ	K0	4.94
WSE	G0	99.96	WSN	G0	69.24	WN	G0	41.20	WJ	G0	16.10
WSE	F8	87.65	WSN	F8	54.68	WN	F8	44.93	WJ	F8	30.63
TSE	M4	7.94	TSN	M4	4.24	TN	M4	2.36	TJ	M4	1.09
TSE	M2	24.23	TSN	M2	14.32	TN	M2	7.78	TJ	M2	3.47
TSE	K7	24.55	TSN	K7	16.27	TN	K7	9.84	TJ	K7	5.08
TSE	K0	39.85	TSN	K0	26.46	TN	K0	18.32	TJ	K0	12.72
TSE	G0	37.91	TSN	G0	21.91	TN	G0	21.18	TJ	G0	22.48
TSE	F8	18.22	TSN	F8	7.30	TN	F8	11.20	TJ	F8	17.17

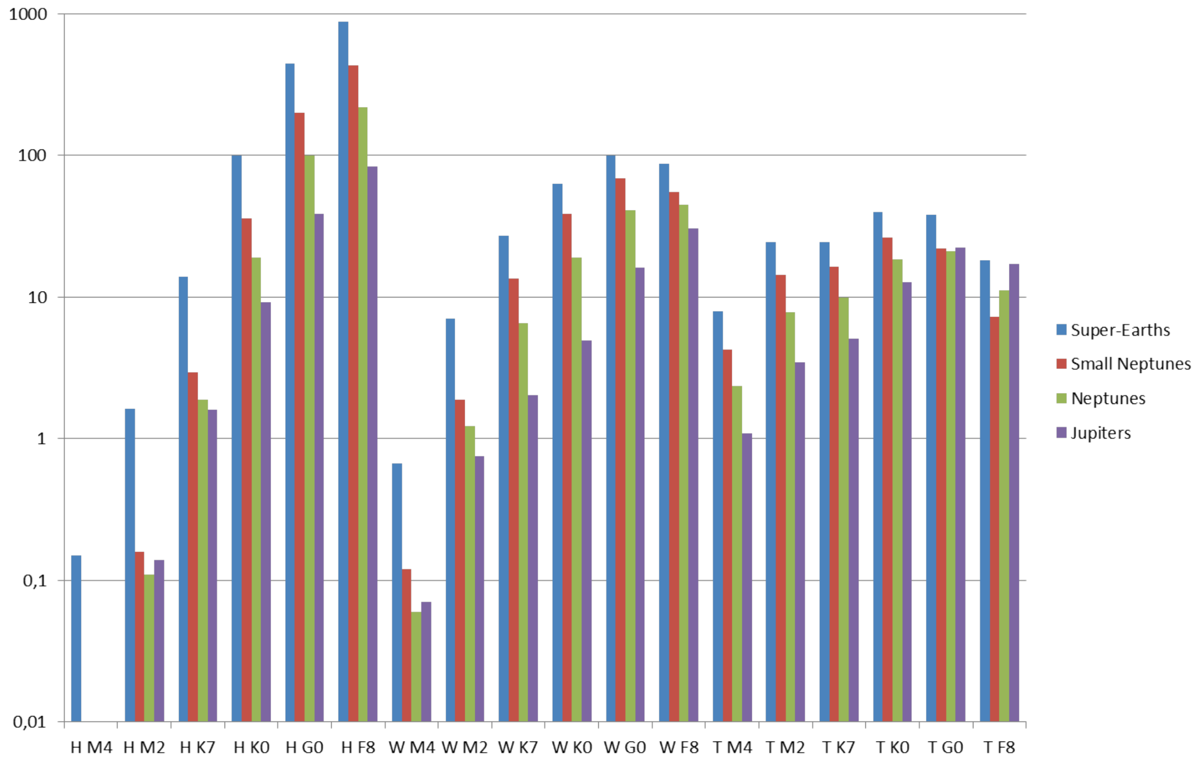

Figure 2: Bar diagram of the transiting planet estimates in Table 6.

4 THE MISSION REFERENCE SAMPLE: CHEMICAL CENSUS

ESA's radiometric model (SRE-PA/2011.040) was used to evaluate the parameters of the exoplanet/host star combination that could eventually be observed by a 1 m-class telescope operating in the vis-thermal IR waveband with state-of-the-art detectors. The SNR requirements for the Chemical Census are: <SNR>=5, with R=50 in the short-wavelength IR (SWIR) channel (1 to 5 μm) or <SNR>=5 with R=30 in the mid-wavelength IR (MIR) channel (5 to 11 μm), whichever is less demanding. The requirement is to observe either the transit (primary eclipse) or the occultation (secondary eclipse) depending on which one requires the least events. Mean planet parameters, as defined in Tables 4 and 5, were adopted, and several key additional parameters are given in Table 7. The corresponding stellar properties, including spectral energy distribution and the mapping between spectral type and effective temperature, were adopted as presented in [AD1]. The radiometric model was used to calculate the number of events needed to reach the required SNR for different kinds of host star/planet combinations with brightnesses compatible with the estimated population of transiting planets. We imposed a restriction by which we did not consider objects fainter than the current limiting case in the visible (GJ 1214), as defined in the 0.55-1 μm band. A trade-off exercise was then 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 volume-limited samples of planet types, so that the statistical value of the observations could be enhanced.

The resulting hypothetical so-called Mission Reference Sample (MRS), listed in Table 8, covers the full range of exoplanetary host systems that EChO can potentially observe in the Chemical Census according to current SNR requirements and conservative assumptions on instrument performance. The table also includes information on the technique best used to observe the planet (i.e., transit/transmission or occultation/emission) for optimal results. In the current scenario, the Chemical Census takes up approximately 70% of the total mission lifetime. 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)

The distribution of the targets into the different classes according to host star type, planet type and equilibrium temperature is shown in Figure 3.

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.

Table 7: General planet parameters.

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

Table 8: Mission Reference Sample for the Chemical Census. 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. "hot" and "warm" planet types have temperatures as defined in Sect. 3, except for 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. #events is the number of occultations or transits to be observed in order to fulfill the SNR requirements.

Class		d (pc)	Kmag	T_{eq} (K)	#obj	Type	#events
HSE	M2	30	8.8	1000	1	Occultation	307
HSE	M0	30	7.6	1200	2	Occultation	192
HSE	K1	30	6.5	1500	3	Occultation	127
HSE	G1	30	5.7	1500	4	Occultation	167
HSN	M0	40	8.2	1200	1	Transit	61
HSN	K1	40	7.1	1500	2	Transit	41
HSN	G1	40	6.3	1500	4	Transit	40
HSN	F8	40	5.8	1500	5	Transit	38
WSN	M2	37	9.2	600	2	Transit	112
WSN	M0	40	8.2	600	4	Transit	129
WSN	K1	40	7.1	600	2	Transit	109
HN	M0	70	9.4	1200	3	Transit	9
HN	K1	70	8.3	1500	7	Transit	6
HN	G1	70	7.4	1500	10	Transit	6
HN	F8	70	7.0	1500	13	Transit	6
WN	M2	37	9.2	600	1	Transit	6
WN	M0	70	9.4	600	11	Transit	20
WN	K1	70	8.3	600	7	Transit	17
WN	G1	70	7.4	600	4	Transit	15
WN	F8	70	7.2	600	3	Transit	16
HJ	K1	150	10.0	1500	36	Occultation	5
HJ	G1	150	9.1	1500	44	Occultation	6
HJ	F8	150	8.7	1500	54	Occultation	8
WJ	K1	100	9.1	600	5	Transit	34
WJ	G1	100	8.2	600	5	Transit	30
WJ	F8	100	7.8	600	5	Transit	27

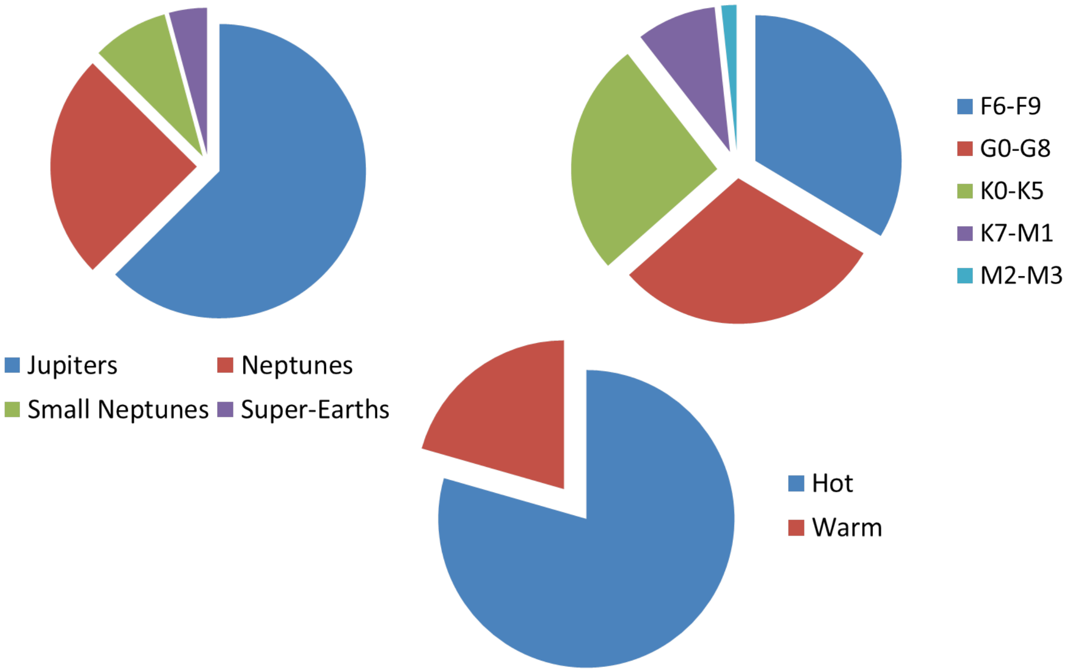

Figure 3: Pie charts illustrating the different planet classes in the Mission Reference Sample of the Chemical Census listed in Table 7.

5 THE MISSION REFERENCE SAMPLE: ORIGINS SURVEY

A similar procedure to that described in Section 4 was followed to define the Origins Survey sample. The sample considers only bright hot Jupiter-type planets around stars within 100 pc of the Sun. The SNR requirements for the Origins Survey are: <SNR>=10, with R=100 in the SWIR channel (1 to 5 μm) or <SNR>=10 with R=30 in the MIR channel (5 to 11 μm), whichever is less demanding. The requirement is to observe both the transit (primary eclipse) and the occultation (secondary eclipse). Mean planet parameters, as defined in Tables 4 and 5, were adopted, and several key additional parameters are given in Table 7. The corresponding stellar properties, including spectral energy distribution and the mapping between spectral type and effective temperature, were adopted as presented in [AD1]. The radiometric model was used to calculate the number of events needed to reach the required SNR for different kinds of host star/planet combinations. The Mission Reference Sample for the Origins Survey is shown in Table 9. In the current scenario, the Origins Survey uses some 30% of the total mission lifetime, with a total of 33 targets.

Table 9: Mission Reference Sample for the Origins 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.

Class		d (pc)	Kmag	T_{eq} (K)	#obj	Type	#events
HJ	K1	100	8.8	1500	9	Occultation	10
HJ	G1	100	7.9	1500	11	Occultation	9
HJ	F8	100	7.5	1500	13	Occultation	10
HJ	K1	100	8.8	1500	9	Transit	93
HJ	G1	100	7.9	1500	11	Transit	82
HJ	F8	100	7.5	1500	13	Transit	85

6 THE MISSION REFERENCE SAMPLE: ROSETTA STONES

Rosetta Stone targets are key selected planets that provide the best observing circumstances. In general, these transiting planets are among the brighter objects in their classes and will allow EChO to address a variety of science cases, e.g. the dynamic behaviour and the 2D mapping of their atmospheres. The Rosetta Stone sample will be defined as the best examples of transiting planets are being discovered. But already today we can design a number of objects that would compose such sample, and some of them are so favourable that are very likely to stay by the time EChO begins operations.

Selected hot Jupiters are prime Rosetta Stone targets for which EChO could carry out spectral mapping, spectrophotometric orbital phase curves and exo-meteorological observations (a number of snapshots). Examples of such objects known today are: HD 189733 b, HD 209458 b, HAT-P-32 b, WASP-13 b, WASP-17 b, WASP-41 b, WASP-54 b, WASP-79 b, and WASP-80 b. For other planet classes the main objective is to carry out observations for spectral mapping and obtaining spectrophotometric orbital phase curves, and representative objects already available are: 55 Cnc e, GJ 436 b, and GJ 1214 b. Rosetta Stone targets will also include eccentric planets with different properties to investigate the dynamical behaviour of atmospheres subject to strongly-varying stellar irradiance. Examples of such objects are HD 80606 b and HAT-P-11 b. Finally, EChO is planning to observe prime transiting planets of strong scientific interest whenever available, for example, a transiting temperate super-Earth orbiting a (bright) nearby late M-type star.

In the current scheme, Rosetta Stone observations (i.e., phase curves and multiple visits) make up a relatively small subset of the total observing time of EChO. It is being investigated if such observations can be treated as “fillers” and make use of the gaps left by the Chemical Census and Origins Survey.

7 KNOWN TRANSITING EXOPLANET TARGETS

As of July 2013, the number of confirmed transiting planets (according to the exoplanet.eu database) is 312. We have collected all the relevant parameters from such transiting planets (making use of the exoplanet.eu database, literature searches and cross-matching with eh 2MASS catalog) and run them through the Radiometric Model, as done for the MRS planet classes. The calculations provide the number of events needed to fulfil the Chemical Census SNR requirements (see Section 4). In addition, we exclude those targets that are fainter than the limiting case (GJ 1214) in the visible (integrated over 0.55-1 μm) band. Out of the 312 initial targets, we find 122 objects that can be observed by the EChO mission, plus 2 additional objects that are likely to meet the SNR requirements but have effective temperatures above the interval covered by the Radiometric Model. The full list of observable transiting planets, with the estimated number of events required to reach the target SNR ratio, is shown in Appendix A. In summary, the distribution into target types is as follows:

- 2 hot Super-Earths
- 1 warm Small Neptune
- 3 Neptunes (1 hot, 2 warm)
- 116 Jupiters (114 hot, 2 warm)

Figure 4 illustrates this distribution in schematic form.

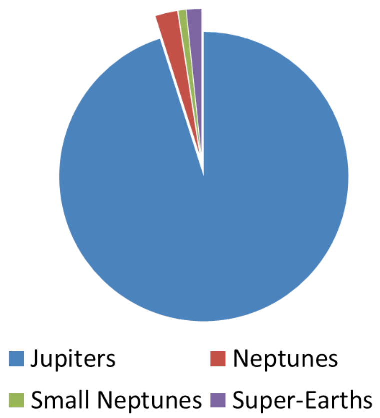

Figure 4: Pie chart illustrating the planet type distribution of known targets observable by EChO.

8 FINDING ADDITIONAL TARGETS

If launched today, EChO would be able to observe a large (> 100) and diverse sample of exoplanets that would fulfill the mission objectives of studying population-wide properties of exoplanets and understanding their origins. The probed parameter space is multi-dimensional and includes in particular planet size, temperature and stellar host type. The EChO science return can be further improved by identifying additional targets that occupy sparsely-populated areas of this parameter space. We discuss here the observational efforts that will lead to these new discoveries between today and the launch of EChO.

Broadly speaking, two strategies have been successfully developed to find transiting exoplanets:

- Find exoplanets through a dedicated radial velocity (RV) survey and subsequently search for potential transits through a high-precision photometric follow-up

- Find transiting exoplanet candidates through a dedicated transit survey and subsequently obtain RV measurements to confirm the candidates as real planets and measure their masses

The first strategy has been at the origin of most "benchmark" transiting planets known today orbiting nearby bright stars: HD 189733 b, HD 209458 b, Gl 436 b, 55 Cnc e, GJ 3470 b, HD 149026 b, HD 17156 b, HD 80606 b. The second strategy has led to the detection of more than 150 Hot Jupiters and the benchmark super-Earth GJ 1214 b.

To optimize the science return of any exoplanet characterization mission, it is important to be able to observe the most favourable objects in each planet category of interest, i.e. those which are closest to the Sun and orbit bright stars. This means that an all-sky exoplanet search is required. From various RV surveys (HARPS, CORALIE, HIRES, etc) and the NASA Kepler mission, relatively precise data are now available regarding planet occurrence around F, G, K and M main-sequence stars. Two numbers are particularly useful to keep in mind: the occurrence rate of transiting Hot Jupiters is about $7\ 10^{-4}$ (1 every 1400 stars), and the occurrence rate of transiting Neptunes and super-Earths is about 0.02 (1 every 50 stars). The typical orbital periods of these objects range from 2 to 20 days, driven by the combination of the intrinsic period distribution of exoplanets and the geometric transit probability. It must be noted that the period distribution of the presently-known Hot Jupiters is biased towards short periods due to the window function of ground-based transit surveys, whose sensitivity drops sharply beyond 5-10 days.

Finding the nearest transiting exoplanets represents a difficult challenge both for RV surveys and transit surveys. RV surveys require a significant number of observations per star (between 10 and 50) to detect a planet and measure its orbital parameters to sufficient accuracy to trigger a photometric search for potential transits. Moreover, relatively large telescopes are required to reach the RV precision of 1 m/s required to detect super-Earths and Neptunes. On the other hand, transit surveys must continuously monitor thousands of stars simultaneously to catch the rare transit events. Doing that over the whole sky is extremely demanding, especially from the ground where the day-night cycle, weather downtime and limited photometric precision conspire to reduce the sensitivity of transit searches. In both cases, long-term programs over several years are required to detect a significant sample of transiting planets.

We give below an overview of the presently-known transiting planets, split into three categories: Hot Jupiters, Neptunes and super-Earths. In each case we briefly mention the present and future surveys and missions that will add new detections of great value for EChO before its expected launch in 2022-2024. The list is not exhaustive. For more details on these various projects we refer to the Technical Note led by G. Micela.

Hot Jupiters:

- About 30 Hot Jupiters are known with host star magnitude K < 9, mostly coming from the WASP and HAT surveys, plus some bright objects from RV surveys
- About 100-120 are predicted to exist based on star counts and occurrence rates
- Existing surveys have already done a good job of finding the nearest Hot Jupiters; therefore EChO benefits already today from a relatively optimized sample of Hot Jupiters (which represent the majority of EChO targets by numbers)
- Ongoing transit surveys are expected to further improve these numbers within the next few years (WASP, HAT, ...)

Neptunes and Small Neptunes:

- 6 transiting (small) Neptunes are known with K < 9: Kepler-68 b, HD 97658 b, GJ 1214 b, GJ 3470 b, GJ 436 b, HAT-P-11 b
- Up to 500-1000 are predicted to exist based on star counts and occurrence rates
- More optimized surveys are needed to increase the discovery rate
- RV surveys: HARPS, HARPS-N, Keck (ongoing), ESPRESSO (2017), CARMENES (2016), SPiROU (2017?)
- Use CHEOPS (2017) to search for transits of RV-detected planets
- Ground-based transit searches: Next Generation Transit Survey (2014), MEarth (ongoing), APACHE (ongoing)
- Space-based transit searches: Transiting Exoplanet Survey Satellite (2017)

Super-Earths:

- 3 transiting super-Earths are known with K < 9: Kepler-21 b, Kepler-37 d, 55 Cnc e
- Up to 1000-1500 are predicted to exist based on star counts and occurrence rates
- More optimized surveys are needed to increase the discovery rate
- RV surveys: HARPS, HARPS-N, Keck (ongoing), ESPRESSO (2017), CARMENES (2016), SPiROU (2017?)
- Use CHEOPS (2017) to search for transits of RV-detected planets
- Ground-based transit searches: Next Generation Transit Survey (2014), MEarth (ongoing), APACHE (ongoing)
- Space-based transit searches: Transiting Exoplanet Survey Satellite (2017)

The exoplanet parameter space that EChO will probe can be developed along three main dimensions: host star properties, planet mass/size, and planet equilibrium temperature. We discuss below to what extent these dimensions will be explored by some major planet search surveys (the list is not exhaustive):

- The search for transiting Hot/Warm Jupiters around bright FGK stars is well under way and is expected to be completed by the end of the decade (WASP, HAT, …)
- RV surveys together with CHEOPS will find transiting Hot/Warm Neptunes and super-Earths around nearby FGK and M dwarfs. At least 10-15 very bright candidates are expected from these searches.
- NGTS will find transiting Hot/Warm Neptunes and super-Earths around bright K and M dwarfs. About 50 of them will be orbiting stars with I < 11.
- TESS will in principle be able to find most of the transiting hot/warm Neptunes and super-Earths around nearby FGK and M dwarfs with orbital periods < 10-50 days. Super-Earths around late-M dwarfs could also be found if the faint limit can be lowered to I=13-14 for these stars.
- MEarth will continue its search for transiting Neptunes and super-Earths of various temperatures around late-M dwarfs. An optimized observing strategy should yield several more planets like GJ 1214 b or smaller.

In conclusion, one can say that the path towards an optimal planet sample for EChO appears to be well defined. Thanks to the combination of many existing and planned missions and surveys, the sample of known transiting planets is expected to converge towards the EChO Mission Reference Sample by 2020.

9 CONCLUSIONS

The main conclusions from this report can be summarized in the following points:

- The reference sample for the EChO mission is well defined and consistent with state-of-the-art statistical knowledge of planets and stars
- Plenty of targets exist to make it possible for EChO to survey a variety of planet configurations
- A realistic sample of transiting planets is already available today, although over a still fairly restricted area of the parameter space
- As new planets keep being discovered, fainter targets will be dropped and increase the size of the sample
- Also, the new additional detections of transiting planets will allow EChO to cover other planet classes and further enhance the mission's science value

10 REFERENCES

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A. APPENDIX A: LIST OF KNOWN TRANSITING PLANETS OBSERVABLE BY ECHO IN CHEMICAL CENSUS MODE

Name	Class	Kmag	T_{eq} (K)	P (d)	Rpl ($R_\oplus$)	Mpl ($M_\oplus$)	Type	#events
55Cnce	HSE K1	4.02	1781	0.74	2.0	8.6	Occultation	11
HD189733b	HJ K1	5.54	1100	2.22	12.5	361.7	Occultation	1
Gliese436b	WN M0	6.07	650	2.64	4.0	23.4	Transit	1
Gliese436c	HSE M0	6.07	814	1.37	0.7	0.3	Transit	374
HD209458b	HJ G1	6.31	1316	3.52	15.1	226.9	Transit	1
HD17156b	HJ G1	6.81	791	21.22	12.0	1014.2	Occultation	8
HD149026b	HJ F8	6.82	1602	2.88	7.9	113.1	Transit	3
HAT-P-11b	HN K1	7.01	791	4.89	5.0	25.7	Transit	1
HD80606b	HJ K1	7.32	1000	111.44	10.1	1252.3	Occultation	1
KELT-2Ab	HJ F8	7.35	1566	4.11	14.3	472.3	Occultation	1
HAT-P-2b	HJ F8	7.60	1344	5.63	10.4	2777.8	Occultation	8
HAT-P-22b	HJ K1	7.84	1172	3.21	11.9	682.4	Occultation	2
Gliese3470b	WN M2	7.99	604	3.34	4.8	13.9	Transit	1
WASP-38b	HJ F8	8.00	1153	6.87	12.0	861.3	Occultation	6
WASP-8b	HJ G1	8.09	847	8.16	11.4	713.2	Occultation	8
WASP-18b	HJ F8	8.13	2188	0.94	12.8	3315.0	Occultation	1
WASP-80b	HJ M0	8.35	800	3.07	10.4	176.1	Transit	1
WASP-7b	HJ F8	8.40	1360	4.95	14.6	305.1	Transit	3
WASP-77Ab	HJ G1	8.41	1817	1.36	13.3	559.4	Occultation	1
HAT-P-17b	HJ K1	8.54	707	10.34	11.1	169.7	Transit	2
HAT-P-20b	HJ K1	8.60	888	2.88	9.5	2303.0	Occultation	10
WASP-14b	HJ F8	8.62	1719	2.24	14.1	2333.2	Occultation	2
KELT-3b	HJ F8	8.66	1668	2.70	14.9	464.7	Occultation	3
Gliese1214b	WSN M4	8.78	520	1.58	2.7	6.4	Transit	52
WASP-29b	HJ K1	8.78	911	3.92	8.7	77.6	Transit	2
XO-3b	HJ F8	8.79	1555	3.19	13.4	3747.2	Occultation	8
WASP-34b	HJ G1	8.79	1059	4.32	13.4	187.5	Transit	2
HAT-P-14b	HJ F8	8.85	1446	4.63	13.2	699.2	Occultation	37
HAT-P-1b	HJ G1	8.86	1182	4.47	13.4	166.5	Transit	1
WASP-62b	HJ F8	8.94	1305	4.41	15.3	181.2	Transit	1
HAT-P-8b	HJ F8	8.95	1713	3.08	14.5	405.2	Occultation	3
HAT-P-13b	HJ G1	8.98	1504	2.92	14.0	270.2	Transit	7
WASP-54b	HJ G1	9.04	1759	3.69	18.1	202.1	Occultation	1

WASP-79b	HJ F8	9.06	1959	3.66	18.7	286.0	Transit	1
WASP-13b	HJ G1	9.12	1203	4.35	15.2	151.6	Transit	2
HAT-P-30b	HJ F8	9.15	1553	2.81	14.7	226.0	Transit	2
HAT-P-34b	HJ F8	9.25	1335	5.45	13.1	1057.7	Occultation	35
WASP-43b	HJ K1	9.27	1318	0.81	11.4	646.5	Occultation	4
XO-2b	HJ K1	9.31	1203	2.62	10.7	197.1	Transit	7
HAT-P-6b	HJ F8	9.31	1530	3.85	14.6	335.9	Transit	8
WASP-71b	HJ G1	9.32	1888	2.90	16.5	717.7	Occultation	1
HAT-P-7b	HJ F8	9.33	2733	2.20	16.0	543.2	Occultation	1
WASP-3b	HJ F8	9.36	1826	1.85	16.0	654.7	Occultation	2
WASP-63b	WJ G1	9.39	443	4.38	15.7	120.8	Transit	16
XO-4b	HJ G1	9.41	1328	4.13	14.7	546.7	Occultation	22
WASP-11b	HJ K1	9.42	943	3.72	11.5	146.2	Transit	2
HAT-P-3b	HJ K1	9.45	1047	2.90	9.1	187.8	Transit	16
XO-1b	HJ G1	9.53	1168	3.94	13.0	286.0	Transit	5
HAT-P-16b	HJ F8	9.55	1486	2.78	14.1	1332.7	Occultation	11
HAT-P-26b	HJ K1	9.58	907	4.23	6.2	18.8	Transit	2
WASP-16b	HJ G1	9.59	1160	3.12	11.1	271.7	Transit	21
WASP-72b	HJ F8	9.62	2210	2.22	11.1	448.1	Occultation	4
WASP-2Ab	HJ K1	9.63	1171	2.15	12.3	290.5	Transit	9
HAT-P-15b	HJ G1	9.64	820	10.86	11.8	618.5	Transit	112
WASP-41b	HJ G1	9.68	1208	3.05	13.3	292.4	Transit	7
WASP-26b	HJ G1	9.69	1521	2.76	14.1	326.7	Transit	14
WASP-15b	HJ F8	9.69	1511	3.75	15.7	172.3	Transit	2
WASP-59b	WJ K1	9.72	667	7.92	8.5	274.3	Transit	46
HAT-P-41b	HJ F8	9.73	1690	2.69	18.5	254.3	Transit	2
HAT-P-4b	HJ G1	9.77	1551	3.06	13.9	216.1	Transit	8
TrES-1b	HJ K1	9.82	1181	3.03	12.1	241.9	Transit	6
TrES-2Ab	HJ G1	9.85	1502	2.47	12.8	398.2	Occultation	13
WASP-50b	HJ K1	9.97	1290	1.96	12.6	467.2	Occultation	22
WASP-21b	HJ G1	9.98	1155	4.32	13.3	95.3	Transit	1
WASP-10b	HJ K1	9.98	947	3.09	11.9	972.6	Occultation	39
HAT-P-32b	HJ G1	9.99	1677	2.15	22.4	299.1	Transit	1
HAT-P-33b	HJ F8	10.00	1675	3.47	20.0	242.5	Transit	2
HAT-P-40b	HJ G1	10.01	1615	4.46	19.0	195.5	Transit	3
HAT-P-31b	HJ G1	10.08	1325	5.01	11.7	690.0	Occultation	110
HAT-P-12b	HJ K1	10.11	875	3.21	10.5	67.1	Transit	1
HAT-P-27b	HJ K1	10.11	1103	3.04	11.2	197.1	Transit	16
HAT-P-21b	HJ G1	10.11	1162	4.12	11.2	1291.4	Occultation	117

WASP-67b	HJ K1	10.13	941	4.61	15.4	133.5	Transit	1
WASP-24b	HJ G1	10.15	1514	2.34	12.1	328.0	Occultation	35
WASP-32b	HJ G1	10.16	1428	2.72	12.1	1099.7	Occultation	43
WASP-25b	HJ G1	10.17	1135	3.76	13.8	184.3	Transit	3
WASP-12b	HJ F8	10.19	2320	1.09	19.0	446.2	Occultation	1
WASP-47b	HJ K1	10.19	1120	4.16	12.6	362.3	Transit	42
WASP-39b	HJ K1	10.20	1022	4.06	13.9	89.0	Transit	1
WASP-17b	HJ F8	10.22	1518	3.74	21.8	154.5	Occultation	5
HAT-P-18b	HJ K1	10.23	775	5.51	10.9	62.6	Transit	1
WASP-1b	HJ F8	10.28	1644	2.52	16.3	273.3	Transit	5
WASP-45b	HJ K1	10.29	1094	3.13	12.7	320.1	Transit	33
HAT-P-29b	HJ G1	10.30	1149	5.72	12.1	247.3	Transit	35
CoRoT-2b	HJ G1	10.31	1393	1.74	16.1	1052.0	Occultation	8
WASP-22b	HJ G1	10.32	1298	3.53	12.7	186.9	Transit	9
WASP-6b	HJ G1	10.33	1092	3.36	13.4	159.9	Transit	3
TrES-4Ab	HJ K1	10.33	1782	3.55	18.7	291.5	Transit	1
XO-5b	HJ G1	10.35	1134	4.19	11.3	342.3	Transit	70
WASP-48b	HJ G1	10.37	1883	2.14	18.3	311.5	Occultation	7
WASP-55b	HJ G1	10.40	1160	4.47	14.3	181.2	Transit	4
Qatar-1b	HJ K1	10.41	1389	1.42	12.8	422.7	Occultation	15
WASP-66b	HJ F8	10.45	1648	4.09	15.3	737.4	Occultation	34
HAT-P-5b	HJ G1	10.48	1387	2.79	13.7	336.9	Transit	24
WASP-19b	HJ G1	10.48	1912	0.79	15.2	371.2	Occultation	2
HAT-P-38b	HJ K1	10.50	987	4.64	9.1	84.9	Transit	15
WASP-23b	HJ K1	10.53	1024	2.94	10.6	281.0	Transit	40
WASP-56b	HJ G1	10.53	1216	4.62	12.0	181.5	Transit	11
HAT-P-24b	HJ F8	10.54	1495	3.36	13.6	217.7	Transit	14
HAT-P-19b	HJ K1	10.55	923	4.01	12.4	92.8	Transit	2
HATS-1b	HJ G1	10.58	1250	3.45	14.3	589.6	Transit	63
WASP-60b	HJ G1	10.59	1148	4.31	9.4	163.4	Transit	34
WASP-5b	HJ G1	10.60	1584	1.63	12.8	520.3	Occultation	21
HAT-P-36b	HJ G1	10.60	1669	1.33	13.9	582.3	Occultation	11
TrES-3b	HJ K1	10.61	1583	1.31	14.3	607.1	Occultation	7
HAT-P-42b	HJ F8	10.63	1427	4.64	14.0	309.9	Transit	47
WASP-31b	HJ F8	10.65	1411	3.41	16.9	151.9	Transit	3
WASP-28b	HJ G1	10.73	1292	3.41	12.3	289.2	Transit	37
WASP-4b	HJ G1	10.75	1710	1.34	15.0	356.4	Occultation	8
HAT-P-23b	HJ G1	10.79	1874	1.21	15.0	664.3	Occultation	7
HAT-P-25b	HJ G1	10.82	1100	3.65	13.1	180.2	Transit	12

KOI-94d	HJ F8	10.93	806	22.34	11.3	106.0	Transit	48
WASP-64b	HJ K1	10.96	1689	1.57	13.9	404.0	Occultation	11
WASP-78b	HJ G1	11.01	2007	2.18	19.2	368.7	Occultation	18
HAT-P-9b	HJ F8	11.02	1397	3.92	15.4	212.9	Transit	15
HAT-P-35b	HJ G1	11.03	1443	3.65	14.6	335.0	Transit	57
WASP-37b	HJ G1	11.09	1214	3.58	12.5	539.0	Transit	155
HAT-P-28b	HJ G1	11.10	1262	3.26	13.3	199.0	Transit	22
HAT-P-39b	HJ F8	11.16	1602	3.54	17.2	190.4	Transit	10
WASP-57b	HJ G1	11.24	1251	2.84	10.1	213.6	Transit	296
Kepler-5b	HJ F8	11.77	1652	3.55	15.7	671.9	Occultation	172
CoRoT-19b	HJ G1	11.84	1515	3.90	15.9	352.8	Transit	157