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The Ariel Target List: The Impact of TESS and the Potential for Characterizing Multiple Planets within a System

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Abstract

The ESA Ariel mission has been adopted for launch in 2029 and will conduct a survey of around 1000 exoplanetary atmospheres during its primary mission life. By providing homogeneous data sets with a high signal-to-noise ratio and wide wavelength coverage, Ariel will unveil the atmospheric demographics of these faraway worlds, helping to constrain planet formation and evolution processes on a galactic scale. Ariel seeks to undertake a statistical survey of a diverse population of planets; therefore, the sample of planets from which this selection can be made is of the utmost importance. While many suitable targets have already been found, hundreds more will be discovered before the mission is operational. Previous studies have used predictions of exoplanet detections to forecast the available planet population by the launch date of Ariel, with the most recent noting that the Transiting Exoplanet Survey Satellite (TESS) alone should provide over 1000 potential targets. In this work, we consider the planet candidates found to date by TESS to show that, with the addition of already confirmed planets, Ariel will already have a more than sufficient sample to choose its target list from once these candidates are validated. We showcase the breadth of this population, as well as exploring, for the first time, the ability of Ariel to characterize multiple planets within a single system. Comparative planetology of worlds orbiting the same star, as well as across the wider population, will undoubtedly revolutionize our understanding of planet formation and evolution.

Unified Astronomy Thesaurus concepts: Exoplanet atmospheres (487); Exoplanet atmospheric composition (2021); Exoplanet systems (484); Exoplanet catalogs (488); Infrared telescopes (794); Infrared observatories (791); Infrared Astronomical Satellite (785)

1. Introduction

Ariel has been selected as the next ESA medium-class science mission and is due for launch in 2029 (Tinetti et al. 2021). During its 4 yr mission, Ariel will observe 1000 exoplanet atmospheres, aiming to provide a diverse catalog of homogeneous data sets that allow for the large-scale demographics of exoplanet atmospheres to be uncovered for the first time. The planets studied will span a wide range of planetary and stellar parameters, allowing Ariel to probe all corners of the exoplanet population, from temperate terrestrials to ultrahot Jupiters. Data from Ariel will reveal the chemical fingerprints of gases and condensates in the planets' atmospheres, including the elemental composition and thermal structure.

Ariel will simultaneously provide spectral coverage from 0.5 to 7.8 μm, with photometric bands covering the visible and spectrometers providing data at wavelengths longer than 1.1 μm. The mission objective of Ariel is to uncover the chemical diversity of exoplanet atmospheres, with the bulk of the mission being dedicated to a survey constructed of three tiers, where the depth to which the planet is studied increases with each tier.

The list of potential targets for Ariel has been rapidly evolving over recent years and will continue to do so over the period until its launch. The evolution is driven by the plethora of planet detection surveys, each bringing unique parameter spaces to the fore and thus providing a multifarious population from which to select atmospheric targets. Ground-based surveys (e.g., Bakos et al. 2004; Pollacco et al. 2006; Wheatley et al. 2018) have been instrumental in proving the success of the transit detection method, providing a multitude of hot gaseous planets, as well as cooler, rocky worlds, while the Convection, Rotation and planetary Transits (CoRoT; Auvergne et al. 2009) mission was the first to detect exoplanets from space. The Kepler mission (Borucki et al. 2010) has provided the majority of known transiting planets to date, with the extended mission bringing yet more, with a focus on brighter stars along the ecliptic (Howell et al. 2014). The Transiting Exoplanet Survey Satellite (TESS; Ricker et al. 2014) has been operational since 2018 July and is predicted to find thousands of planets (Sullivan et al. 2015; Barclay et al. 2018), many of which will be suitable for atmospheric characterization with Ariel and other facilities.

Here we build upon other works that have explored the potential target list for Ariel (Zingales et al. 2018; Edwards et al. 2019a). The most recent of these, Edwards et al. (2019a, hereafter E19), was conducted as the TESS mission launched and utilized the predictions of Barclay et al. (2018, hereafter B18), in addition to the planets known at the time, to project the expected number of planets that could be studied during the mission's primary life. In the summer of 2020, TESS completed its primary 2 yr mission and moved into extended operations, resurveying parts of the northern and southern hemispheres, as well as covering the ecliptic plane. An updated study of the TESS planet yield was published Barclay (2020; hereafter B20), suggesting the extended mission

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would discover hundreds of additional worlds. Over the last few years, thousands of potential planet signals have been found within TESS data (Guerrero et al. 2021), with 205 planets having been subsequently confirmed to date.[4]

In this work, we compare the current TESS TOIs to the detections predicted by B18 and B20, with a specific focus on those that are suitable for study with Ariel. We explore not only the number of TOIs Ariel could study but the variety in their properties. In E19, a focus was placed upon Ariel's capabilities to study smaller, potentially rocky worlds that could host secondary atmospheres. Here we focus instead on the systems in which there are multiple planets that are suitable for study with Ariel, highlighting the mission's great potential for comparative planetology within a single planetary system, as well as across the vast exoplanet population. Finally, we discuss the efforts that are required to ensure that a robust list of potential targets is chosen for observation with Ariel.

2. Construction of Catalogs

2.1. Currently Known Planets and Those Predicted to Be Found by TESS

The catalog of currently known targets was built in an identical fashion to that of E19, although it was updated to include the detections that have occurred in the intervening years. As described in E19, the catalog is built mainly from the NASA Exoplanet Archive[5] (Akeson et al. 2013). Since E19, the NASA Exoplanet Archive has been updated to include a "Planetary Systems Composite Data" table. The table ensures that as many planetary and stellar properties as possible are reported for a system, which can mean that the data are gathered from multiple studies. Both tables were accessed on 2022 April 26. Where certain parameters were not available, we made further attempts to infer them. These included inferring the stellar mass, radius, or temperature from Pecaut & Mamajek (2013).[6] If the mass had been measured in multiple studies, we took the value from the latest work, assuming that to be the most accurate. If it had not been measured, we estimated it using the relation from Chen & Kipping (2017). We removed any planets that did not have reported uncertainties on the planet radius. Having inferred as many parameters as possible, we also removed any planets that did not have the information required by the Ariel instrument simulator, ArielRad (Mugnai et al. 2020). For the host star, these are the star radius, temperature, log(g), and distance. For the planet, the radius, mass, temperature, and transit duration are needed. Having removed those with insufficient information, the input population consisted of 3488 planets.

Similarly, the B18 sample was the same as that considered in E19, although the phantom inflated planets that were identified within the sample by Mayorga & Thorngren (2018) were removed, reducing the number of predicted planets to 4231. The yield from B20 was not considered in E19, but we include those planets here as an additional means of benchmarking the performance of TESS. These planets were treated in an identical way to those from B18, and the performance of Ariel was modeled for 7603 of them in this study.

[4] NASA Exoplanet Archive, accessed 2022 April 26.

[5] https://exoplanetarchive.ipac.caltech.edu/

[6] http://www.pas.rochester.edu/~emamajek/EEM_dwarf_UBVIJHK_colors_Teff.txt

2.2. TESS Objects of Interest

We accessed the latest TESS objects of interest (TOIs) from both the NASA Exoplanet Archive and the NASA ExoFOP-TESS site,[7] splicing them together using the TOI ID. Both lists were accessed on 2022 April 26. The TOI list contains objects that have been flagged as false positives, such as eclipsing binaries, or as previously known planets (Guerrero et al. 2021). We used the "TOI Disposition" column to determine the current status of a target. We filtered out known planets, which were denoted by "KP." However, we found that, in the "Public Comments" column, references to know systems were still made. Therefore, having made all comments lowercase, we searched this column for the following keywords to identify known planets: "corot," "hat," "hd," "hip," "gj," "kelt," "kepler," "k2," "known," "lhs," "mascara," "ogle," "qatar," "tres," "wasp," and "xo." Furthermore, we searched this same column for "eb" to filter out those identified as eclipsing binaries, as well as comments that contained the phrase "v-shaped." To avoid double counting planets in our analysis, we removed those labeled "CP" in the "TOI Disposition" column, as these denote TOIs that have since gone on to be confirmed planets from the TESS mission. Removing all of those that were flagged by the above process resulted in 4192 remaining TOIs from the initial sample of 5637. Our acceptance rate is consistent with the ∼25% false-positive rate found by Guerrero et al. (2021) for the prime mission.

As mentioned, ArielRad, the instrument simulator used to model the performance of Ariel's photometers and spectrometers (Mugnai et al. 2020), requires a number of input parameters. Some of these were not given in the TOI list and so were inferred using the methods of E19. For instance, the planet mass is obviously not given in the TOI list, as it is only known after further follow-up has been conducted. Hence, we used Forecaster (Chen & Kipping 2017) to estimate the mass. Additionally, we note that an estimate of the planet's temperature is given within the TOI list, but we recalculate it to ensure compatibility between these targets and the predicted targets from B18. Having followed this procedure, 3697 TOIs had enough information to be fed into ArielRad. From this point forward, we refer to these as TESS planet candidates (TPCs).

3. Potential Candidates for Atmospheric Study with Ariel

Ariel aims to undertake a meticulous chemical survey, searching for trends in atmospheric composition and unveiling the demographics of exoplanet atmospheres. Planning of observations with Ariel is based around a tiered approach, which we briefly summarize here. Initially, ∼1000 planets will be studied, with the resulting spectra providing a basic characterization of the atmosphere (presence of clouds, color–color diagrams, etc). From this sample, around half will be studied in more depth, with additional time dedicated to them to build up the signal-to-noise ratio (S/N) of the spectra. These tier 2 observations will provide a more detailed view of the atmosphere, constraining the trace gases, metallicity, and elemental ratios of hydrogen-dominated envelopes. The third tier of Ariel will be devoted to studying the best targets for atmospheric characterization multiple times in search of temporal variations in chemistry or cloud coverage. Finally, a

[7] https://tev.mit.edu/data/

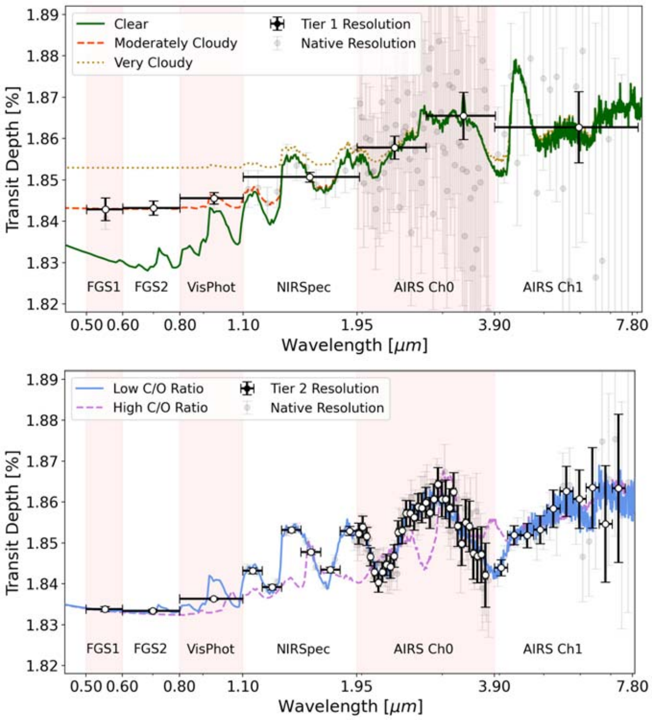

Figure 1. Examples of the spectral binning used to define the science requirements for tiers 1 (top) and 2 (bottom) of the Ariel survey. The reduction in resolution for these tiers is a result of postprocessing; so, for reference, the native spectral resolution at which all observations are taken is also shown. The error bars were computed using ArielRad, and the atmospheric forward models were computed using TauREx 3 (Al-Refaie et al. 2021b). The top panel is a free chemistry model, while the TauREx GGChem plug-in is used for the bottom panel (Woitke et al. 2018; Al-Refaie et al. 2021a). Random Gaussian scatter has been added to each spectrum based on the magnitude of the spectral uncertainties. Ariel's instruments operate simultaneously; therefore, the complete wavelength coverage (0.5–7.8 μm) is provided in a single observation.

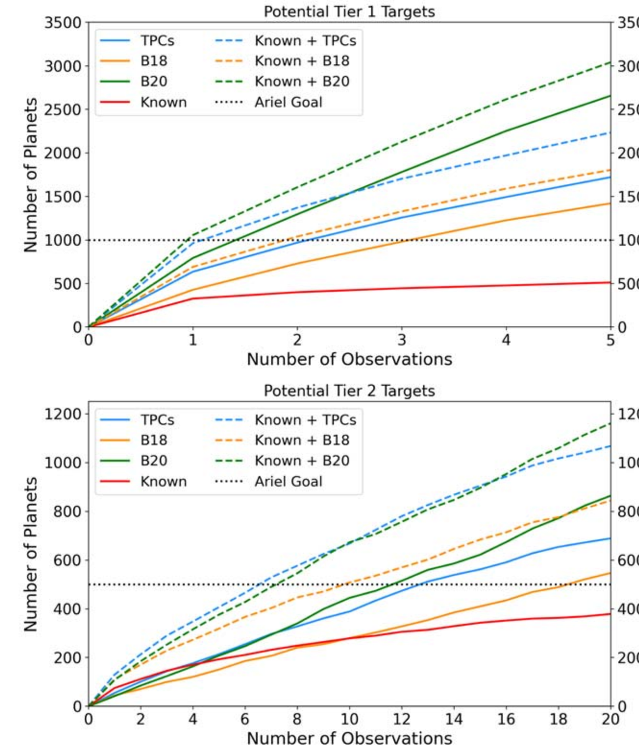

Figure 2. Planets suitable for study in tiers 1 (top) and 2 (bottom). For lines marked by "Known + B18" and "Known + B20," we do not include any confirmed detections made by TESS. "Known" and "Known + TPCs" both include confirmed planets from the TESS mission.

fourth tier will provide time to undertake observations that do not neatly fit into the original three-tier process. Examples could include phase curves or detailed studies of smaller planets that may host secondary atmospheres.

The suitability of a planet for study with Ariel in each of these tiers is defined by a set of science requirements. While the requirements for tier 3 are set at the native resolution of Ariel's instruments, tiers 1 and 2 are set on data with a reduced resolution. The data quality requirement for each tier is that, at the defined resolution, the expected S/N on the atmosphere of the planet is greater than 7. Examples of the data for tiers 1 and 2 are shown in Figure 1. While the ESA science requirements are based upon the resolutions show in Figure 1, the data sets could be analyzed with different spectral binning if required as the reduction in resolution is accomplished during postprocessing. More details on the observation strategy of Ariel can be found in a number of studies (e.g., Tinetti et al. 2018, 2021).

In this work, the performance of the Ariel mission has been modeled using ArielRad (Mugnai et al. 2020). ArielRad is an adapted version of the instrument-independent radiometric simulator ExoRad[8] and accounts for a wide variety of noise sources, including those arising from the detector (readout, gain, dark current), photon noise from the target star, zodiacal background, instrument emission, and jitter noise. For each target, the expected uncertainty on a single transit or eclipse observation is determined at the native resolution of the instruments. It is assumed that Ariel observes for 2.5 times the length of the transit or eclipse. These uncertainties are then utilized to calculate the required number of observations to meet the $S/N > 7$ requirement in each tier. The postprocessing steps include reducing the resolution to those used for the tier 1 and 2 requirements, generating error bars that can be used for more detailed analyses (e.g., spectral retrievals).

3.1. The Mission Candidate Sample

Having derived a list of targets that have all of the parameters necessary for an ArielRad simulation, we use this efficient simulator to determine the number of observations required to reach the required S/N in each tier. The boundary of suitability will not be concrete, with some planets being assessed on a case-by-case basis, but, to broadly understand the entire population, we set upper limits of five observations to achieve tier 1 goals and 20 for tier 2. These limits were also used in E19. We use these requirements to construct the mission candidate sample (MCS), a list of all potential targets for Ariel. Any planets that meet these requirements are henceforth considered suitable for observation with Ariel.

We compare the numbers of potential tier 1 and 2 targets from B18 and B20 to the TPCs in Figure 2, showing the known population as well. From this, we see that the number of TPCs that are suitable for study with Ariel currently lies between the predictions of B18 and B20. The situation is as one would expect given that TESS has finished its prime mission but has not yet completed its first extended mission. Analysis of 2241 TPCs from the prime mission by Guerrero et al. (2021)

[8] https://github.com/ExObsSim/ExoRad2-public

suggested that the yield of targets that were suitable for atmospheric characterization had not been as high as expected, and our results suggest a similar finding but that the extended mission has increased the number beyond the original yield prediction. However, we note that many TPCs may yet turn out to be false positives, and the assumptions we have made, particularly on parameters such as the mass, will also affect the final number of suitable targets.

The large number of TPCs is impressive, given the effects that stray light from the Earth and Moon have had on TESS. Excessive contamination by these sources caused sectors 14–16 and 24–26 to be shifted northward by around 30°, leaving a portion of the sky unobserved during the prime mission (Guerrero et al. 2021). The gap this shift caused can be seen when comparing the sky locations of the tier 1 targets, which are shown in Figure 3. Nevertheless, during the first 3 yr of operation, TESS has undoubtedly provided an enormous number of planet candidates that could be suitable for atmospheric characterization. Additionally, the extended mission is covering the portions of the sky missed previously due to stray light, as well as the ecliptic plane, leading to further detections, some of which may be suitable for study with Ariel.

Currently, around 500 confirmed planets would meet Ariel's tier 1 requirements in five observations or fewer, and, based on our assumptions, over 1700 TPCs could as well. Hence, even if half of these TPCs are false positives, it is likely there will be a copious number of planets to choose from for study with Ariel. Therefore, we now focus on the variety of targets that could be studied. The histograms in Figures 4 and 5 highlight the range of tier 1 targets that are available from the currently known population and the current TPCs. When combining these together, it is appears that a wide parameter space could be probed by Ariel. While the planets studied will generally have a short period (<20 days), their temperatures will vary from 200 to 4000 K and span radii from Earth-sized to superinflated Jupiters. The stellar hosts primarily have temperature between 4000 and 7000 K, but cooler dwarfs, as well as A-type stars, are also present. We note that some targets around cooler or fainter stars have been deemed unsuitable for study due to the brightness requirements of Ariel's FGS channels, which facilitate pointing of the spacecraft. Whether these requirements were reached was assessed by using ArielRad, and those that failed to reach them are not included in our analysis.

In tier 1, Ariel will attempt to study planets in every category of a five-dimensional parameter space. They will be classified by the planet's radius, density, and temperature, as well as the host star's temperature and metallicity. However, as the TPCs do not have measured masses, and their stellar metallicities are not listed in the TPC catalog, we have to overlook these parameters for now. Therefore, we classified the potential tier 1 targets in a three-dimensional parameter space using the classifications shown in Table 1, with the bounds for the stellar types being set by using the values from Pecaut & Mamajek (2013).[9]

In Figures 6 and 7, the distributions of the potential Ariel targets are shown. In each figure, the left column shows the variety of planets available today, which includes those confirmed to date using data from TESS. In the right column, the known population has been combined with the TPCs. While we already known of a diverse sample of planets suitable for atmospheric characterization, these plots highlight the impact TESS will have in increasing this variety yet further. Furthermore, TESS will provide additional planets within each section of the parameter space to allow for more thorough comparisons between planets with similar bulk characteristics. We note that, on the right-hand side of the figures, false positives may still be present, and the removal of these may reduce the overall diversity. For instance, signals indicative of planets with large radii on short periods have a relatively high

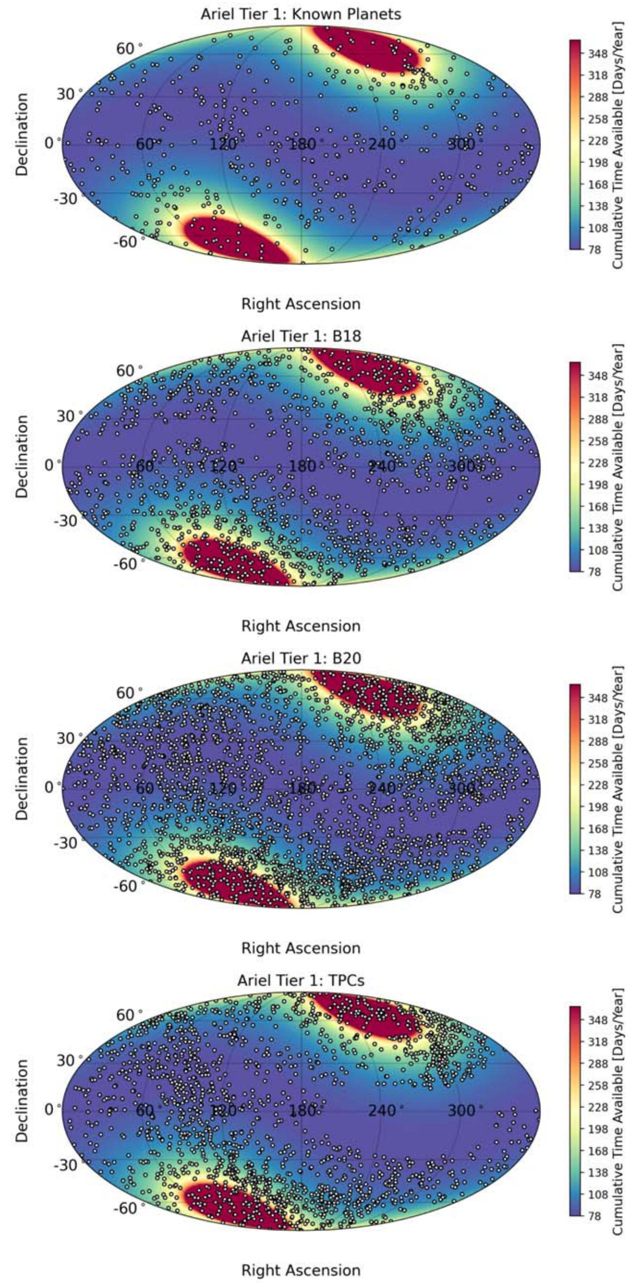

Figure 3. Sky locations of potential Ariel tier 1 targets. First panel: currently known planets; second panel: tier 1 targets from the predicted targets of B18; third panel: tier 1 targets from the predicted targets of B20; fourth panel: potential tier 1 targets from the current TPCs. The sky coverage of Ariel, which offers large continuous viewing zones at the ecliptic poles, was determined using the Terminus code (Edwards & Stotesbury 2021). Ariel's continuous viewing zones have been heavily studied by the TESS mission, leading to many candidates within them.

9 http://www.pas.rochester.edu/~emamajek/EEM_dwarf_UBVIJHK_colors_Teff.txt

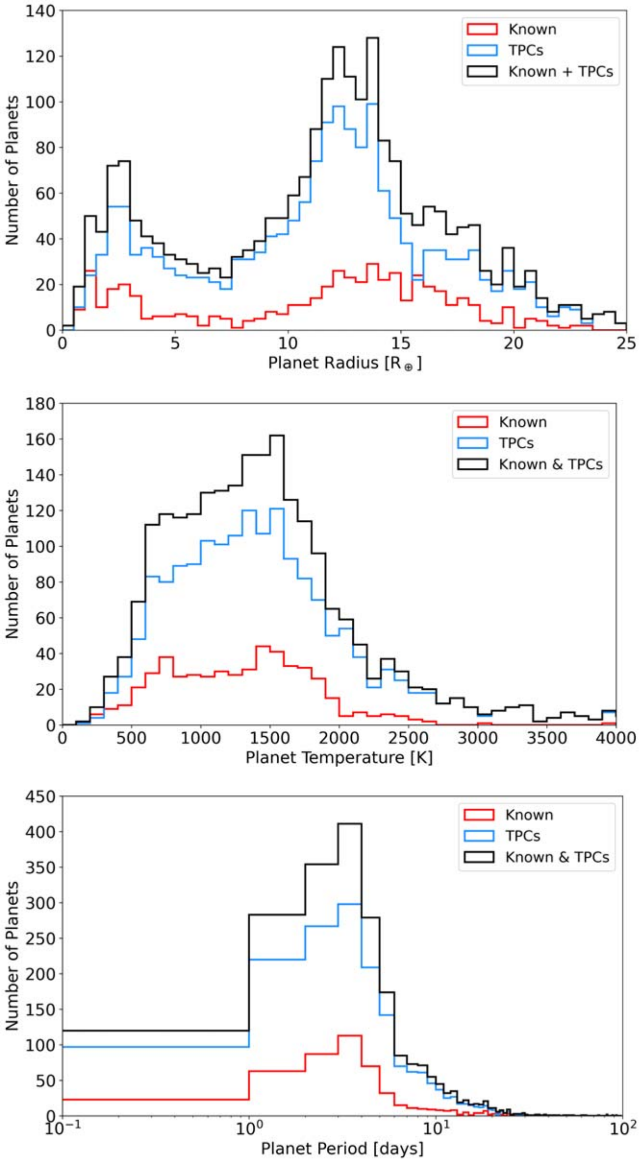

Figure 4. Histograms of the properties of the planets within the potential Ariel Tier 1 Catalog. While the periods of the planets that can be studied are general constrained to <20 days, in terms of planet temperature and radii, the targets will be highly diverse.

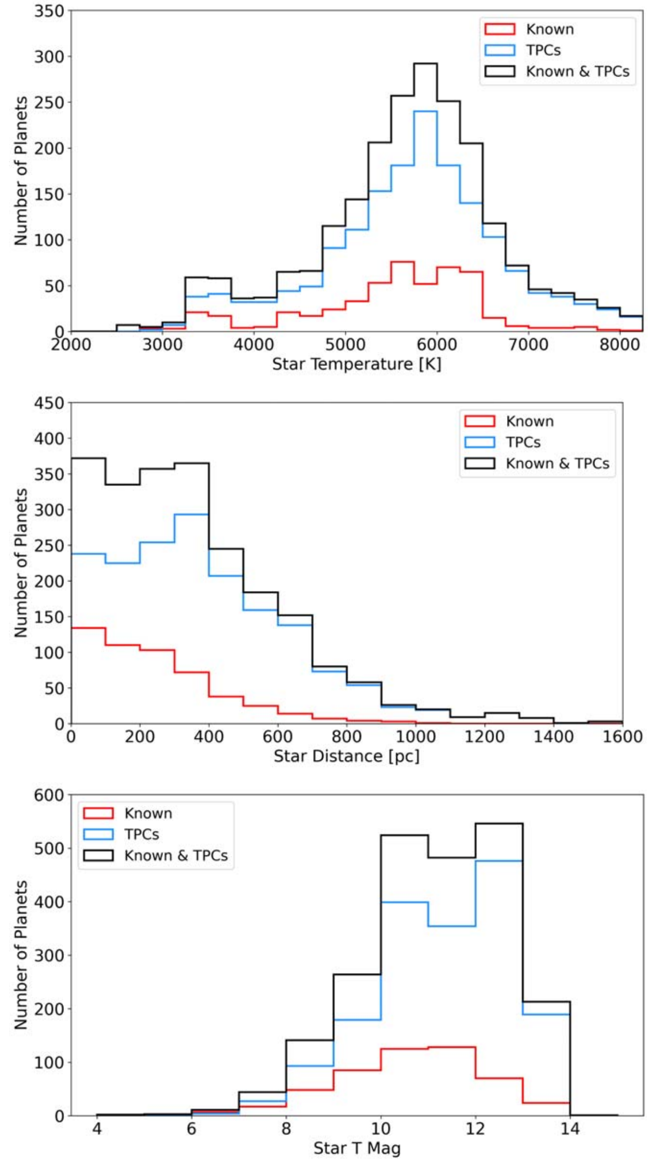

Figure 5. Histograms of the properties of the host stars within the potential Ariel Tier 1 Catalog. Ariel will probe planets around a range of stellar types out to around 1000 pc from the Earth. The host star could be as faint as $T_{\rm mag} \sim 14$.

false-positive rate; therefore, the potential expansion of the parameter space at the top right of each figure may not be real.

In E19, we explored the ability of Ariel to study smaller planets. As these planets may have atmospheres that are not hydrogen-dominated (e.g., Owen & Wu 2017; Fulton & Petigura 2018), or indeed no atmosphere at all, it is likely that a specialized observing plan will need to be devised to ensure that they are studied in an efficient and thorough manner. While we do not go into depth on this here, in Figure 8, we show the radius versus temperature distribution of small planets ($<3\ R_{\oplus}$), highlighting the large number of potential targets, as well as their diversity. Numerous parameters could affect the capability of a small planet to retain it is primordial envelope, including the stellar irradiation and planet mass (e.g., Owen & Wu 2017; Fulton & Petigura 2018; Rogers et al. 2021); thus, a wide range of targets will need to be studied if we are to understand which planets retain hydrogen-dominated envelopes and which do not, as well as the pathways to secondary atmospheres. Hubble observations of sub-Neptunes have had mixed levels of success in detecting atmospheres (e.g., Kreidberg et al. 2014; Benneke et al. 2019; Tsiaras et al. 2019; Guilluy et al. 2021), but spectroscopic observations of rocky planets have yet to yield convincing atmospheric detections (e.g., de Wit et al. 2018; Edwards et al. 2021; Libby-Roberts et al. 2021; Mugnai et al. 2021b). The current lack of detailed atmospheric constraints for these worlds has increased the interest of the community in them. As such, a number of smaller planets will be studied as part of the James Webb Space Telescope (JWST)'s GTO and GO Cycle 1 programs, with over half of the planets observed being smaller than 2.5 $R_{\oplus}$. The JWST will provide data with a wider spectral coverage and higher S/N than Hubble, and, hopefully, these observations and further proposals in future cycles will provide the first detections of atmospheres around small, rocky worlds. Results from these studies will be crucial

Table 1
Bounds Used to Categorize Host Stars in Figures 6 and 7

Star Type	Temperature Bounds	Planet Type	Radius Bounds	Climate	Temperature Bounds
M	$T_s \leqslant 3890$ K	Earth/Super-Earth	$R_p < 1.8\ R_\oplus$	Warm	$T_P \leqslant 500$ K
K	3890 K $< T_s \leqslant$ 5330 K	Sub-Neptune	$1.8\ R_\oplus < R_p \leqslant 3.5\ R_\oplus$	Very warm	500 K $< T_P \leqslant$ 1000 K
G	5330 K $< T_s \leqslant$ 5960 K	Neptune	$3.5\ R_\oplus < R_p \leqslant 6\ R_\oplus$	Hot	1000 K $< T_P \leqslant$ 1500 K
F	5960 K $< T_s \leqslant$ 7300 K	Jupiter	$6\ R_\oplus < R_p \leqslant 16\ R_\oplus$	Very hot	1500 K $< T_P \leqslant$ 2500 K
A	7300 K $< T_s$	Inflated Jupiter	$16\ R_\oplus < R_p \leqslant 26\ R_\oplus$	Ultrahot	2500 K $< T_P \leqslant$ 4000 K

inputs into Ariel's strategy for observing smaller planets, and the mission's potential for studying these worlds will be the subject of a focused manuscript in the future.

3.2. An Example Mission Reference Sample

As in E19, we took the MCS, the list of potential Ariel targets, and created an example mission reference sample (MRS), a selection of planets that could be observed in the prime mission life. In keeping with previous works, we adopt the approach of aiming to choose a very diverse and as complete as possible combination of star/planet parameters while minimizing the number of repeated observations by selecting the planets around the brightest stars. Again, we classify planets using the bounds in Table 1 and ensure that, where possible, at least two planets within each star type/planet temperature/planet radius bin are contained within the MRS. We force 1000 planets to be observed in tier 1, as well as 50 in tier 3, each of which is assumed to be revisited five times in search of variability. We then fill the remainder of the mission time with tier 2 observations, finding that, with the TOIs included in the sample, 600 planets could be observed in tier 2 across the prime mission life under these conditions. We note that, nominally, Ariel will have 10% of its science time dedicated to tier 4 targets and complementary science programs.

The distribution of the planetary radii and temperatures of this example MRS is shown in Figure 9, while the sky locations are given in Figure 10. Ariel target stars will be spread across the entire sky, hopefully helping to alleviate scheduling constraints (Morales et al. 2015, 2022). The MRS derived here requires 21,944 hr, which is 88.5% of Ariel's available science time in the prime mission life (∼24,800 hr), leaving sufficient time for these other programs. However, we also note that much of this tier 4 time may be dedicated to phase curves. Naturally, such observations would acquire transits and eclipses of the planets being studied, and the planets that are suitable for phase curve studies with Ariel are also likely to be excellent targets for atmospheric spectroscopy in tiers 1, 2, or 3. Therefore, this overlap means that primary science can be acquired from these tier 4 observations, blurring the distinction between the two programs and potentially opening up more time to conduct additional observations. In any case, the outcome of this study is clear: assuming that a large portion of the planet candidates within the TOIs are true planets, will we already have a surplus of targets for Ariel, and the mission will be capable of studying 1000 atmospheres during the prime mission life.

The Ariel mission should carry enough fuel for a mission extension to be possible. Hence, we explored the impact on the number of planets that could be studied if the additional operating time were granted. We find that a 2 yr extension would allow for 1400 planets to be studied in tier 1 and 700 in tier 2 across the entire mission life. Again, we assumed roughly 10% of the time was dedicated to additional science observations. Such an extension would be an increase of 57% in terms of science time and, from the currently derived target list, would yield increases of 40% in the number of tier 1 and 2 targets studied.

4. Systems that Contain Multiple Planets for Atmospheric Study with Ariel

While in general, Ariel seeks to conduct comparative planetology across hundreds of targets, comparing the atmospheres of multiple planets within a single system could offer unique insights into their formation and evolution. Therefore, we isolated systems that had multiple planets that could be studied by Ariel, finding 31 known systems, as shown in Figure 11. Within the TPCs, 17 such systems were found, but we note that many multiplanet systems have already been confirmed with TESS (e.g., Dawson et al. 2019; Günther et al. 2019; Huang et al. 2020; Leleu et al. 2021) and thus are included within the known count. The large number of multiple planet systems that have been validated highlights their value as laboratories to study formation processes and, as TESS continues to provide additional data, one hopes further multiplanet systems will be found.

We note that there is disagreement between Lacedelli et al. (2021) and Weiss et al. (2021) about the number of planets in the TOI-561 system (four and three claimed, respectively). As the NASA Archive lists all of these worlds, our methodology of creating a catalog leads to five planets being listed for the system. For a study looking across the whole population, such an error should not affect the overall statistics. Planets b and c are consistently recovered by both studies, so the third planet found by Weiss et al. (2021) is the only controversial world that is suitable for characterization with Ariel within this system (the outer planets found by Lacedelli et al. 2021 are deemed to take too much time to study based on the limits imposed here). Nevertheless, this example provides a warning that must be heeded as Ariel approaches launch and the target list is further refined. The change in parameters between the TOI list and the confirmed catalog is expected given the significant work that goes into confirming the planetary nature of the signal and characterizing the system. However, it again provides an indication that one must be careful in the conclusions drawn from the TPC list, and only once these systems are confirmed will we truly know their suitability for atmospheric studies with Ariel.

In light of this, we provide a first look at Ariel's capabilities to study multiple planets within one system by taking a confirmed system as an example: TOI-1130. The TOI-1130 system contains a warm Jupiter ($R = 1.5\ R_J$) on an 8.4 day orbit but, strangely, also contains a Neptune-sized world on a 4.1 day orbit (Huang et al. 2020). Systems with hot Jupiters rarely host

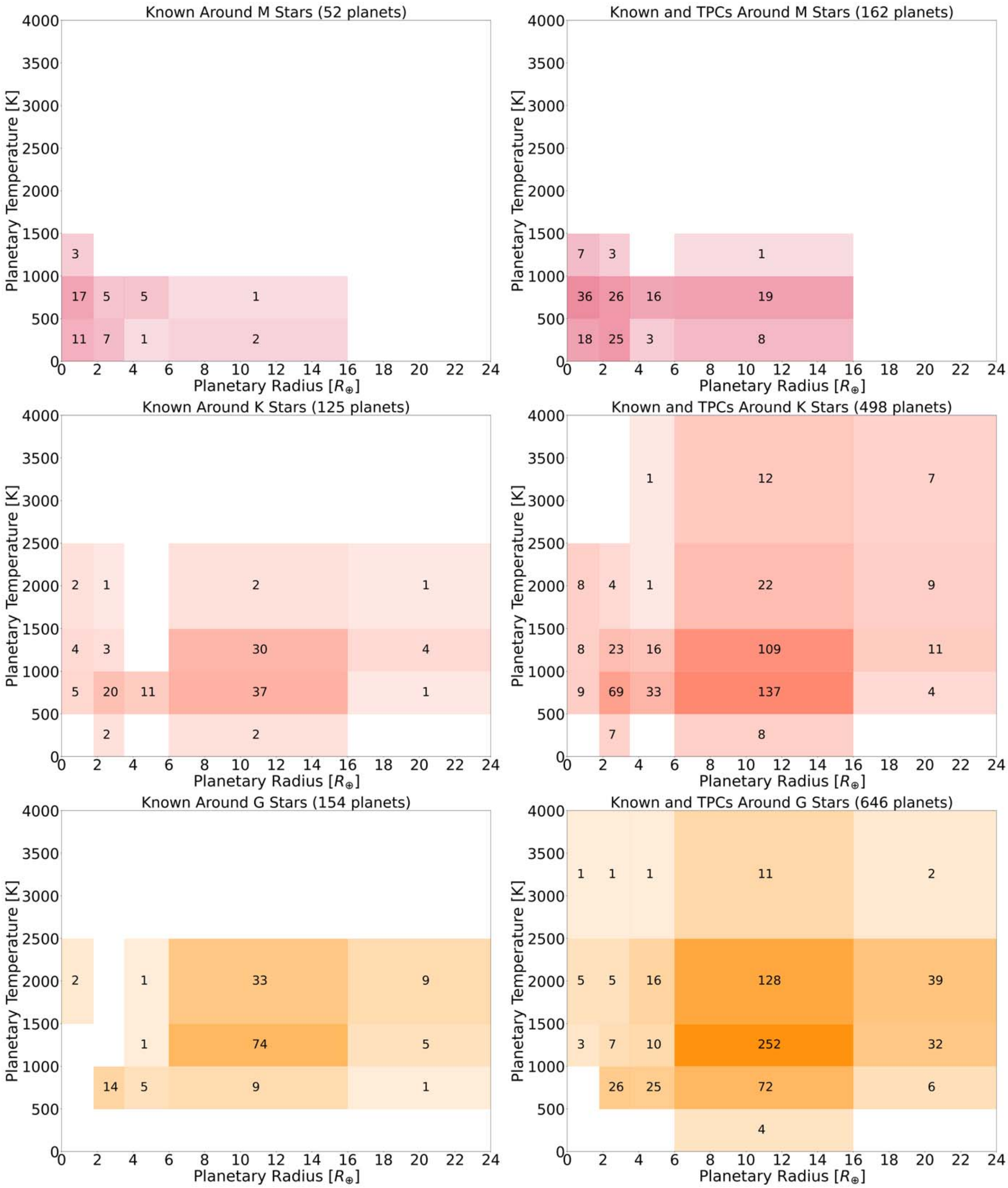

Figure 6. Temperature and radius distribution of known planets, including those found by TESS (left), and these known planets in addition to the current TPCs (right) for M (top), K (middle), and G (bottom) stars that are suitable for tier 1 study with Ariel.

other short-period planets (Steffen et al. 2012), with any companions generally being at much larger orbital distances (Schlaufman & Winn 2016). Given the brightness of TOI-1130 ($K = 8.351$), these planets are ideal targets for atmospheric characterization with Ariel, and constraining their chemistry may provide indicators as to their formation history.

Models suggest that lower-mass planets are incapable of accreting substantial gaseous envelopes, instead preferentially

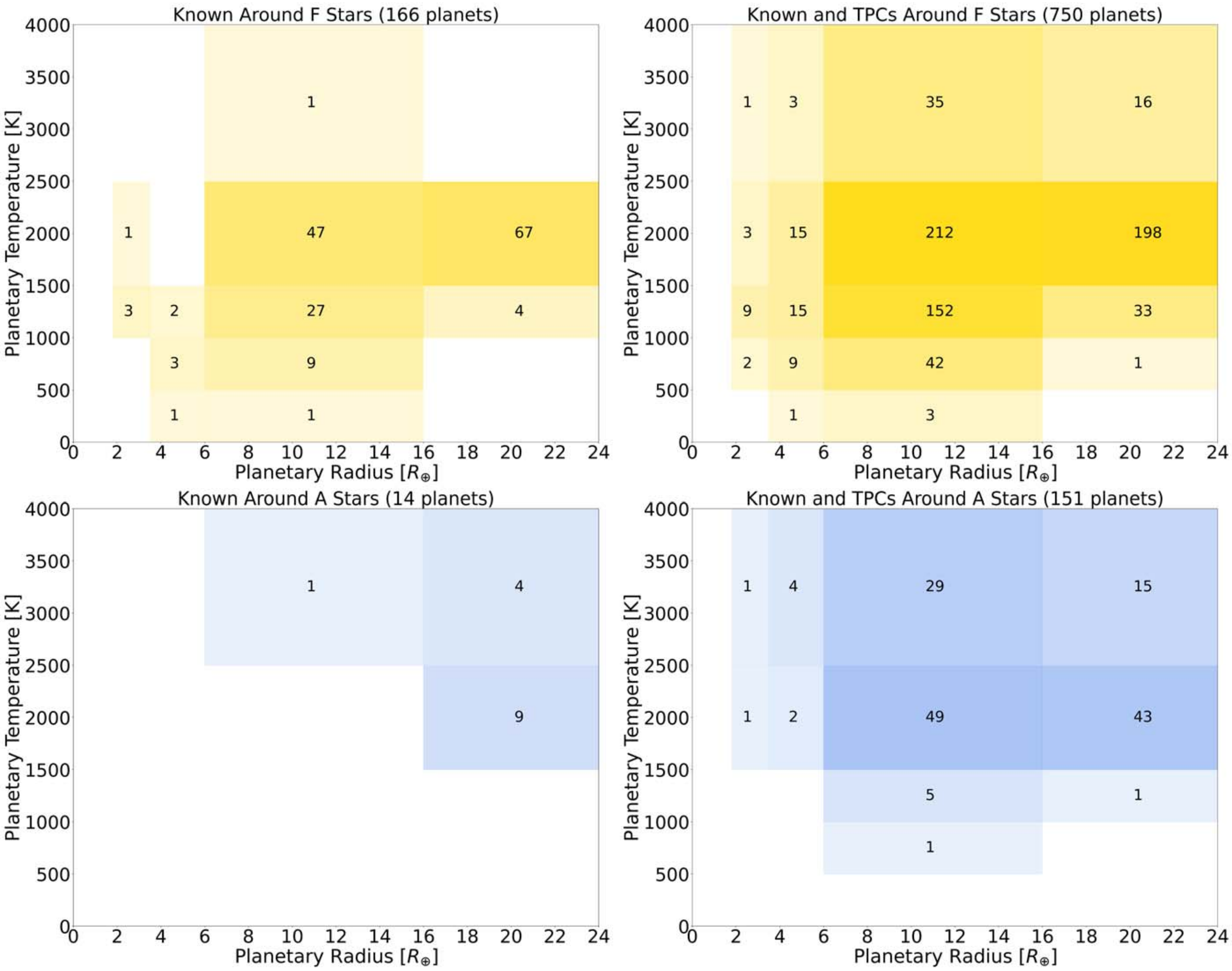

Figure 7. Temperature and radius distribution of known planets, including those found by TESS (left), and these known planets in addition to the current TPCs (right) for F (top) and A (bottom) stars that are suitable for tier 1 study with Ariel.

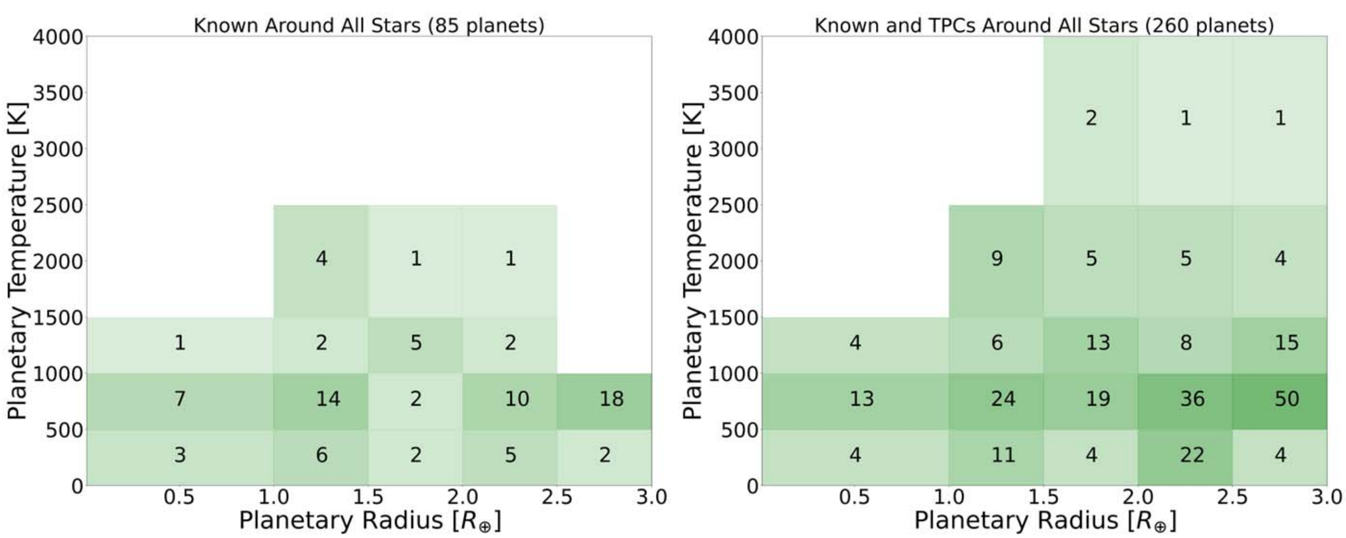

Figure 8. Temperature and radius distribution of known planets, including those found by TESS (left), and these known planets in addition to the current TPCs (right) for worlds with radii smaller than 3 $R_\oplus$ that are suitable for tier 1 study with Ariel.

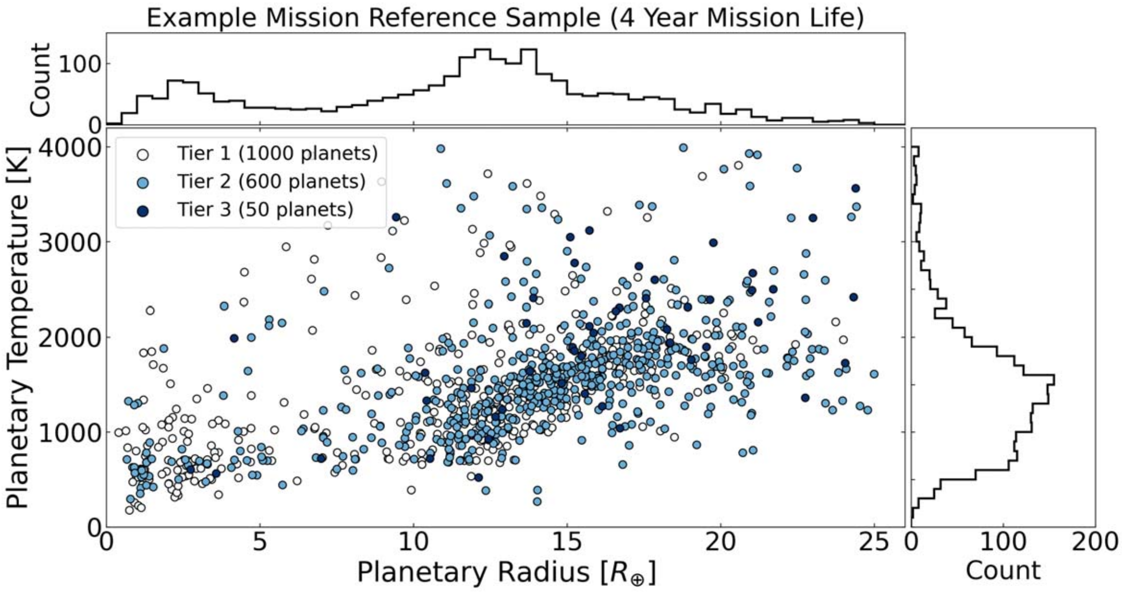

Figure 9. Example MRS derived from currently known planets and the TPCs. The observing campaign shown would require 21,944 hr of telescope time, equivalent to 88.5% of Ariel's available science time in the prime mission life (∼24,800 hr). We note that around 10% of the time is expected to be left for tier 4 observations and complementary science.

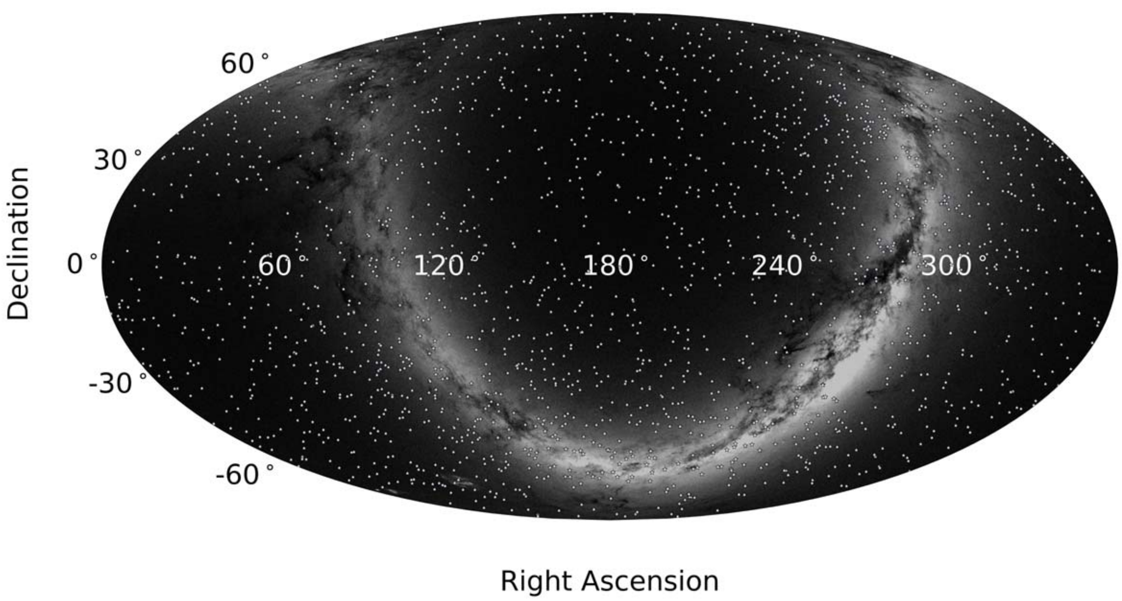

Figure 10. Sky locations of the example MRS, indicated by stars, with the brightest 35 million stars from the Gaia database (Gaia Collaboration et al. 2016, 2018) plotted in the background. The host stars are spread across the sky but with a lower density in the galactic plane. Transit searches here are harder due to the dilution of sources, but this will also be true of Ariel observations; thus, targets in this plane may be less advantageous anyway.

accreting higher-metallicity solids (e.g., Mordasini et al. 2012; Fortney et al. 2013). As the primordial elemental abundances of giant, gaseous planets are expected to remain largely unchanged, measuring these can provide insights into the formation mechanisms of these planets. Studies of the methane content of the gaseous planets within our own solar system are in agreement with the predictions of the core-accretion scenario. By comparing the bulk characteristics of exoplanets to structural evolution models, there is evidence that a exoplanet mass–metallicity trend is likely but could differ for that seen in our own system (Thorngren et al. 2016).

Furthermore, elemental ratios are expected to be a key indicator of where in the disk the planet formed. By constraining these ratios, such as that of carbon to oxygen, one may be able to uncover the formation and migration mechanisms governing the planet's evolution to its current state (e.g., Öberg et al. 2011; Turrini et al. 2018; Shibata et al. 2020). Shorter-period planets, which will form the bulk of the population studied by Ariel, are likely to have formed far further out than they currently orbit, having migrated inward over time (e.g., Lin & Papaloizou 1986; Tanaka et al. 2002). The C/O ratio could be a tracer of whether the planet formed beyond the snow line; if the planet was originally outside the snow line, it should have preferentially accreted carbon-rich gases, leading to a high C/O ratio. Alternatively, if the planet accreted most of its material from inside the snow line, it should be more oxygen-rich and thus have a lower C/O ratio. However, modeling by Turrini et al. (2021) suggests that other

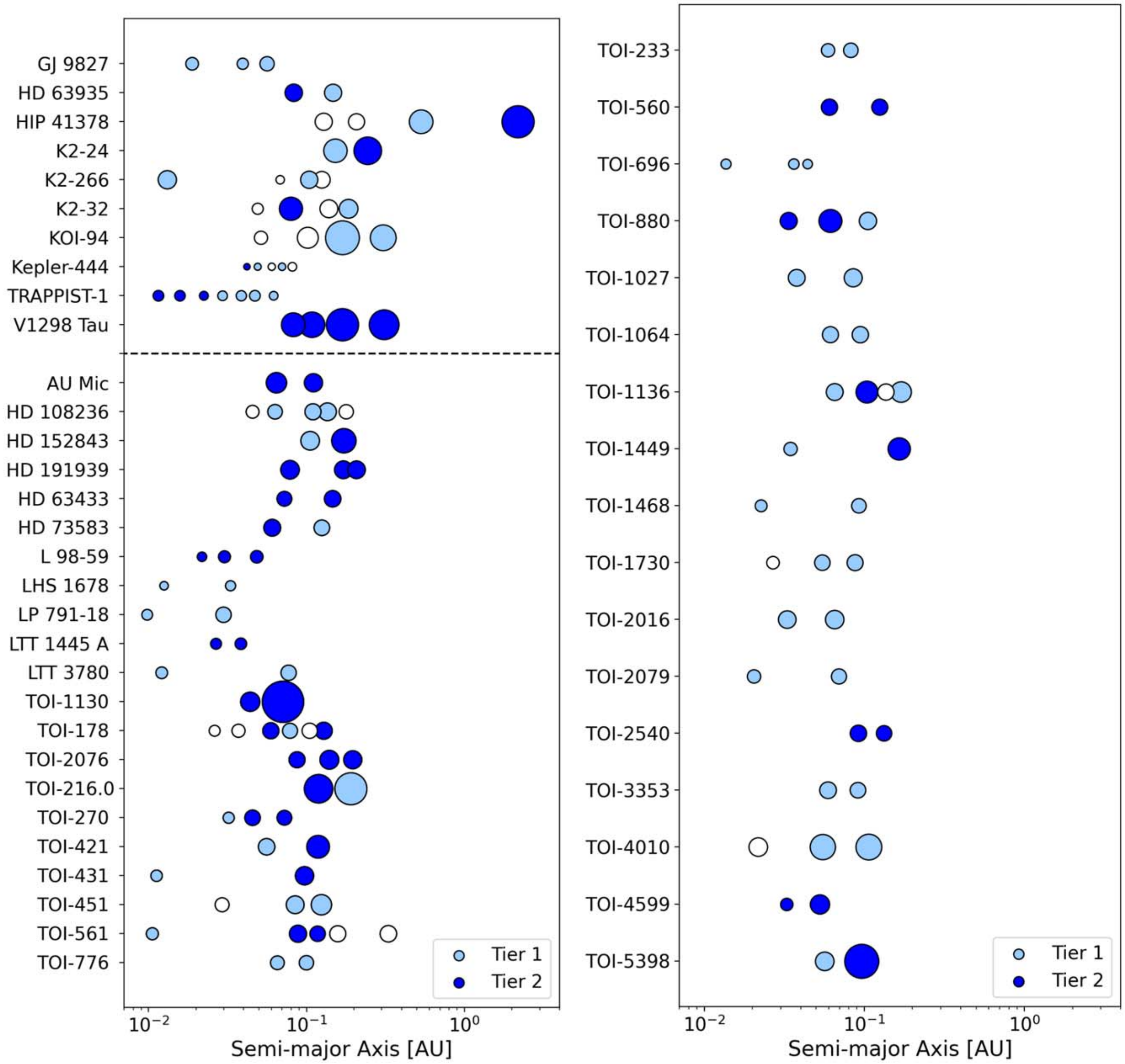

Figure 11. Known (left) and TPC (right) systems that host at least two worlds that could be studied in tier 1 with Ariel. Colors indicate the suitability of characterization (white: not suitable; light blue: tier 1; dark blue: tier 2), while the size of the circles reflects the planet's radius. Those below the dotted line were listed as having been discovered by TESS in the NASA Exoplanet Archive.

elemental ratios, such as S/O or N/O, may provide a better opportunity to constrain where in the disk a planet formed. Nevertheless, as the C/O ratio is the most widely discussed ratio, we stick to using it for this study.

We explored Ariel's capability to constrain these two key parameters, the C/O ratio and the metallicity, for the TOI-1130 system. We used the trend derived in Thorngren et al. (2016) to model the metallicities of TOI-1130 b and c. While Thorngren et al. (2016) found a trend between an exoplanet's mass and its metallicity, a stronger correlation was found when comparing the mass to the planet-to-star metallicity ratio. Hence, we utilized their best-fit model to this, which was

$$\frac{Z_P}{Z_S} = 9.7 M_P^{-0.45}, \tag{1}$$

where the metallicity of the star is determined from

$$Z_S = 0.014 \times 10^{[\mathrm{Fe/H}]}. \tag{2}$$

While TOI-1130 appears to be a metal-rich star, the Fe/H has not yet been measured, with current observations suggesting Fe/H > 0.2 for the star (Huang et al. 2020). As in our case the value is a multiplicative term applied to both planets, we use Fe/H = 0.2. Furthermore, we note that the mass of TOI-1130 b has not yet been constrained, with only a 3σ upper limit of 0.17 M_J placed upon it. Hence, we utilized the relation from Chen & Kipping (2017) to estimate the mass as 0.0407 M_J (12.935 $M_\oplus$). We also note that the relation from Thorngren et al. (2016) did not extend to such small masses. Therefore, the trend within the TOI-1130 system and the population of sub-Neptunes may not reflect the one modeled

Table 2
Input Parameters for the Retrieval Study of the TOI-1130 System

	TOI-1130	
T_S [K]	4250[a]	
R_S [$R_\odot$]	0.684[a]	
Fe/H	0.2[b]	
	TOI-1130 b	**TOI-1130 c**
T_P [K]	780	650
R_P [R_J]	0.326[a]	1.5[a]
M_P [M_J]	0.0407[b]	0.974[a]
C/O	0.5	0.85
log(met)	−0.041	−0.662
Cloud pressure [Pa]	1e3	1e3
No. transits	20	3

Notes.
[a] Denotes parameters taken from Huang et al. (2020).
[b] Denotes basic parameters that have not been yet measured and have been selected based on assumptions described in the text.

here. However, we seek here only to present a proof of concept and leave a detailed study for future work.

As well as modeling differing planet metallicities, we imposed different C/O ratios for the planets. We based these on the modeling in Turrini et al. (2018), assuming a ratio of 0.5 and 0.85 for planets b and c, respectively. We then modeled the spectra for these planets assuming equilibrium chemistry using the ACE package (Agúndez et al. 2012; Venot & Agúndez 2015), which is a plug-in for the TauREx 3.1 retrieval code (Al-Refaie et al. 2021a, 2021b). We assumed isothermal temperature–pressure profiles and introduced a gray cloud deck at 5e2 Pa (0.005 bar) and 1e3 Pa (0.01 bar) for TOI-1130 b and c, respectively, to produce spectral features in the Hubble Space Telescope WFC3 band that are equivalent in size to those seen in similar planets studied with this instrument (e.g., Guilluy et al. 2021). We generated the error bars using ArielRad, assuming 20 observations for TOI-1130 b and three for TOI-1130 c, and our inputs are summarized in Table 2.

We find that, in the case presented here, the atmospheric constituents of TOI-1130 b and c would generally be well constrained, as shown in Figures 12 and 13. We find that the metallicities of these planets could be distinguished (Figure 13), providing evidence for a mass–metallicity trend in the system if one should exist. Additionally, for the assumed C/O ratios, the solutions can be distinguished but are less convincing than the metallicities. From Figure 12, we note that CH_4 and CO_2 are less well constrained than H_2O and CO. Modeling a greater number of observations of TOI-1130 c in particular might help further distinguish the C/O ratios. However, we leave an in-depth analysis of this to a future detailed study of comparative planetology within multiplanet systems with Ariel, aiming here to only motivate the idea with a simple example and set forth the best systems with which to conduct such a study.

5. Discussion, Conclusions, and Future Work

The Ariel target list, in the forms of an MCS and MRS, will continue to evolve as new systems are found, the instrument performance is refined, and the observing strategy is adjusted to maximize the science yield of the mission. We have shown here that TESS has already provided a plethora of planet

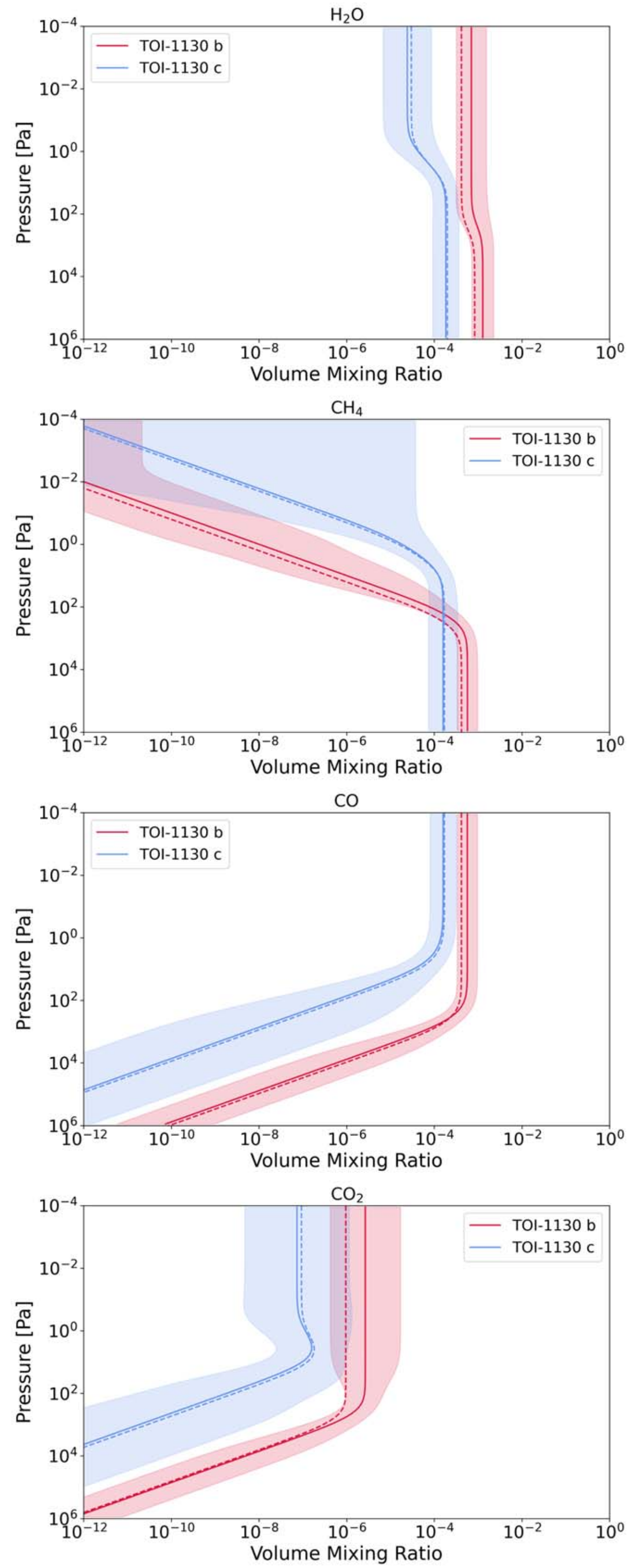

Figure 12. Constraints on the main carbon- and oxygen-bearing species from our retrievals for TOI-1130 b (red) and c (blue). The solid lines show the best-fit model, while the 1σ uncertainties are highlighted by the shaded regions. The input values are given by the dotted lines. While the H_2O and CO abundances are well constrained, the CO_2 profile is less so, as is CH_4 in the upper atmosphere. Increasing the number of observations might improve our knowledge of these molecules and thus elemental ratios such as C/O. Ariel probes from the cloud deck at 1e3 Pa up to roughly 1e1.

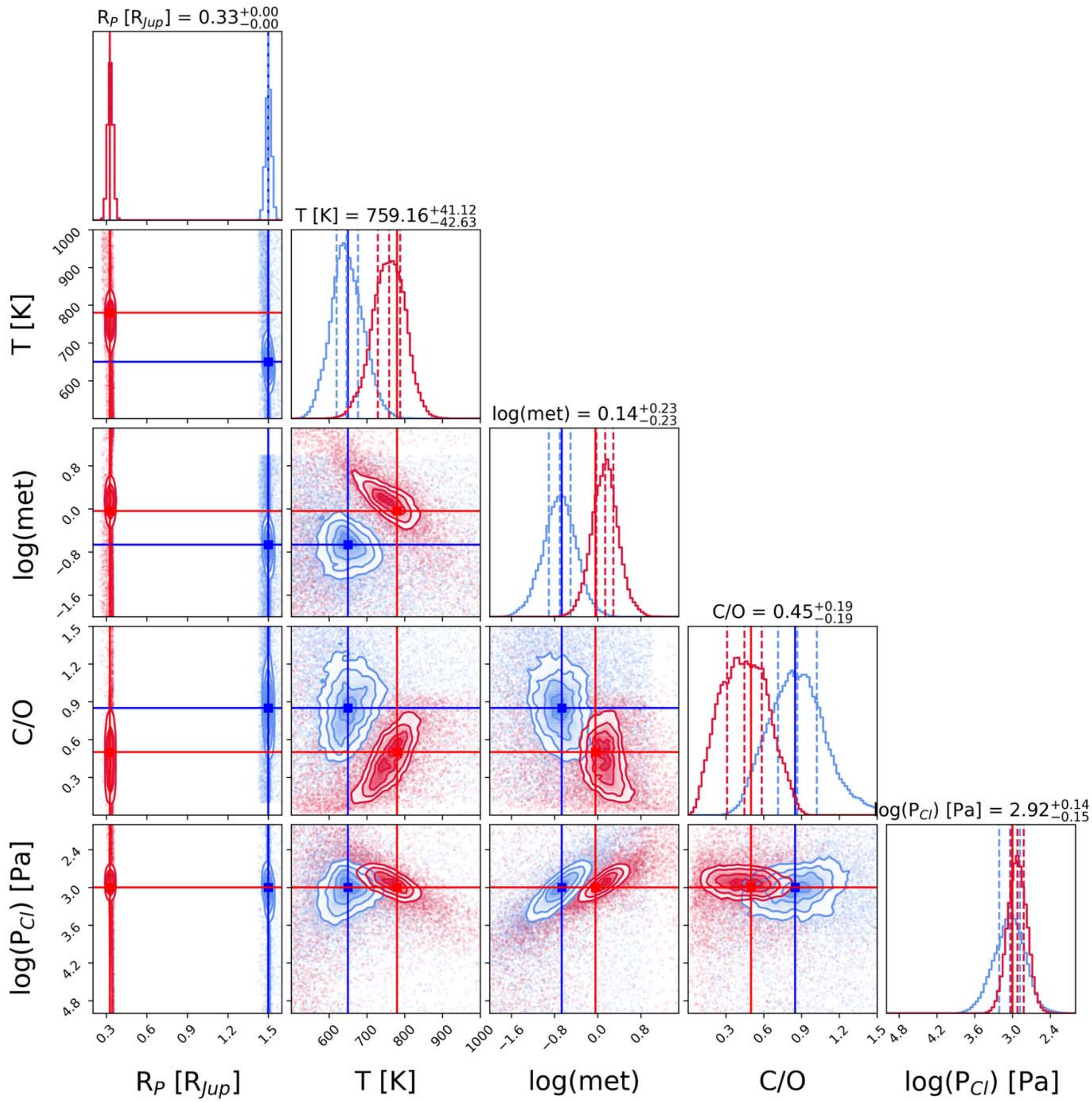

Figure 13. Posterior distributions for our retrievals of TOI-1130 b and c. For the assumed atmospheric metallicities and C/O ratios, Ariel would be able to distinguish between them and thus uncover a mass–metallicity trend in the system, as well as inferring differences in their formation.

candidates that are suitable for study with Ariel, and, when combined with the currently known population, its success will mean that the MCS could contain 2000 planets.

While the majority of these candidates still require confirmation, the continued persistence and devotion of those involved in following up these potential planetary signals, as well as the extension to the TESS mission, will ensure that a large and diverse population of planets are available for Ariel to characterize. The metrics derived in Kempton et al. (2018) are being widely used to direct the TESS follow-up of potential atmospheric targets. In Figure 14, one can see the number of Ariel observations needed to reach the tier 1 and 2 requirements plotted against the transit spectroscopy metric (TSM) from Kempton et al. (2018) for the TPCs analyzed here. Overplotted are the suggested quartiles for larger planets from Kempton et al. (2018), with the scaling factor removed. Kempton et al. (2018) suggested that the cutoff TSM for a statistical sample of gaseous planets should be placed at around 90, a value often quoted and benchmarked against in TESS discovery papers. While this value seems applicable to Ariel tier 2, we suggest that the boundary should be lower for tier 1, with Ariel being capable of potentially studying planets with a TSM $\sim$ 40 or above. However, we note that this metric was designed specifically for JWST NIRISS and thus utilizes the star's magnitude in the *J* band. If one takes two stars that have the same *J*-band magnitude but different temperatures, the stellar flux at longer wavelengths will be greater for the cooler star. Therefore, as Ariel's science requirements are driven by the

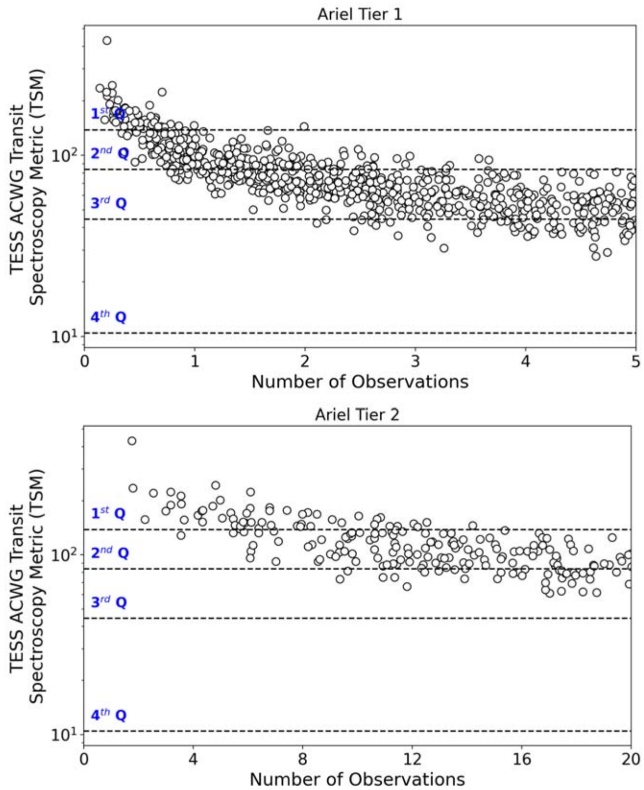

Figure 14. The TSM used by the TESS Atmospheric Characterization Working Group to classify the suitability of atmospheres for characterization (Kempton et al. 2018) for TPCs that are potential targets for Ariel's tier 1 and 2 surveys. In tier 1, Ariel will be capable of observing planets with far lower TSMs than the statistical sample considered in Kempton et al. (2018; TSM > 90), with some planets that have TSM ~ 40 still being considered suitable for the mission. We note that the metric was designed only for JWST NIRISS and, therefore, is not a robust method for assessing the suitability for study with Ariel.

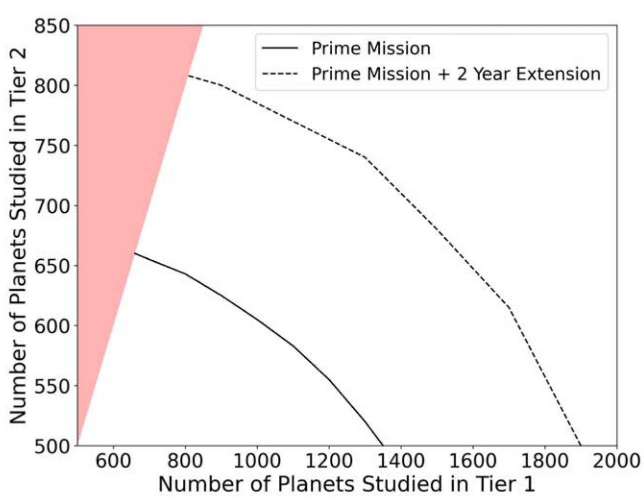

Figure 15. Relationship between the number of tier 1 and 2 planets that can be observed during the prime mission life. The red region is forbidden; by their very definition, one cannot observe more targets in tier 2 than in tier 1. We also show what could be achieved with a 2 yr mission extension. In all cases, 50 planets are assumed to be studied in tier 3, and 10% of Ariel's science time is left for tier 4 observations and complementary science programs.

performance at longer wavelengths (1.95–7.8 μm), its use in this context may not be valid, and the performance for planets around cooler stars may be underrepresented with respect to those around hotter ones. Hence, we recommend the use of ArielRad (Mugnai et al. 2020) to truly assess the suitability of a target for study.

In addition to the multitude of TESS discoveries, the sustained analysis of Kepler/K2 data (e.g., Castro-González et al. 2021; de Leon et al. 2021; Valizadegan et al. 2022; Zink et al. 2021), ongoing ground-based surveys (e.g., Wheatley et al. 2018; Sebastian et al. 2021), and ESA's PLATO mission (Rauer et al. 2016) will also add to the population of exoplanets from which the Ariel sample will be derived. Moreover, other space-based facilities, such as CHEOPS (Benz et al. 2021) and Twinkle (Edwards et al. 2019b), can be expected to find a handful of targets by searching for transits of planets detected by radial velocity (e.g., Delrez et al. 2021) or conducting observations of systems with transiting worlds in search of additional bodies (e.g., Bonfanti et al. 2021).

Such an overabundance of potential targets is undoubtedly beneficial, yet it offers many challenges. While much of the final MRS will be selected based upon which targets occupy the most sparsely populated regions of parameter space or are best placed to answer key questions on the nature of exoplanet atmospheres, prioritization may also be based upon how well characterized the planet's bulk parameters and host star are. If we are to seek trends between atmospheric composition and the bulk characteristics of planets, we must first know both of these. While Ariel will give us the former, the latter knowledge must generally be acquired before launch to ensure that the sample of planets selected allows for these comparisons to be drawn. The key parameters needed include the stellar metallicity and the planet's mass and transit ephemerides.

Luckily, a large cohort of researchers[10] are working to ensure that this is the case. For instance, stellar parameters such as age and metallicity must be known, and work is underway to homogeneously derive such parameters (Brucalassi et al. 2021; Danielski et al. 2021; Magrini et al. 2022). Furthermore, the ephemerides of the potential planets must be well known to ensure efficient scheduling. Here again, work is underway to refine the periods of these worlds using citizen science, with thousands of light curves being observed by amateur facilities as part of the ExoClock project (Kokori et al. 2021, 2022) and by secondary-school students through the ORBYTS program (e.g., Edwards et al. 2021). Planets with nonlinear ephemerides, such as those within multiplanet systems that experience transit timing variations due to the gravitational interaction of the planets, will require particular care and attention (e.g., Dawson et al. 2019; Kipping et al. 2019; Ducrot et al. 2020). By highlighting these key systems in Figure 11 and continuing to update this list, we hope to motivate such follow-up in a timely manner.

Accurately knowing the planet's mass is also useful, particularly for smaller or cloudier worlds (Batalha et al. 2019; Changeat et al. 2020b). Several studies have explored the time needed to provide the radial velocity measurements necessary to constrain planet masses for Ariel (e.g., Barnes & Haswell 2021; Demangeon et al. 2022), and the ongoing work of the radial velocity teams, both within the Ariel consortium and outside of it (e.g., Lillo-Box et al. 2020; Nielsen et al. 2020; Chontos et al. 2021; Kaye et al. 2021; Van Eylen et al. 2021), is ensuring that the best targets for atmospheric characterization are followed up. Nevertheless, it may not be

[10] The Ariel consortium is currently composed of over 500 scientists.

Table 3
Currently-known exoplanets which are considered here to be potential targets for Ariel

Planet Name	Tier	Method	Planet Name	Tier	Method	Planet Name	Tier	Method
55 Cnc e	2	Transit	HAT-P-31 b	1	Eclipse	HATS-27 b	1	Transit
AU Mic b	3	Transit	HAT-P-32 b	3	Eclipse	HATS-29 b	1	Eclipse
AU Mic c	2	Transit	HAT-P-33 b	3	Eclipse	HATS-3 b	2	Eclipse
CoRoT-11 b	1	Eclipse	HAT-P-34 b	2	Eclipse	HATS-30 b	2	Eclipse
CoRoT-2 b	3	Eclipse	HAT-P-35 b	2	Eclipse	HATS-31 b	2	Eclipse
DS Tuc A b	1	Eclipse	HAT-P-36 b	3	Eclipse	HATS-33 b	2	Eclipse
EPIC 211945201 b	1	Transit	HAT-P-37 b	1	Eclipse	HATS-34 b	1	Eclipse
EPIC 246851721 b	1	Eclipse	HAT-P-38 b	1	Transit	HATS-35 b	2	Eclipse
G 9-40 b	1	Transit	HAT-P-39 b	2	Eclipse	HATS-37 A b	2	Transit
GJ 1132 b	2	Transit	HAT-P-4 b	3	Eclipse	HATS-38 b	1	Transit
GJ 1214 b	3	Transit	HAT-P-40 b	2	Eclipse	HATS-42 b	1	Eclipse
GJ 1252 b	1	Transit	HAT-P-41 b	3	Eclipse	HATS-43 b	2	Transit
GJ 3470 b	3	Transit	HAT-P-42 b	2	Eclipse	HATS-46 b	1	Transit
GJ 3473 b	1	Transit	HAT-P-44 b	2	Transit	HATS-48 A b	1	Transit
GJ 357 b	2	Transit	HAT-P-45 b	3	Eclipse	HATS-5 b	2	Transit
GJ 367 b	2	Transit	HAT-P-46 b	2	Eclipse	HATS-51 b	2	Eclipse
GJ 3929 b	2	Transit	HAT-P-49 b	3	Eclipse	HATS-52 b	2	Eclipse
GJ 436 b	3	Transit	HAT-P-5 b	2	Eclipse	HATS-56 b	2	Eclipse
GJ 486 b	2	Transit	HAT-P-50 b	2	Eclipse	HATS-57 b	2	Eclipse
GJ 9827 b	1	Transit	HAT-P-51 b	2	Transit	HATS-58 A b	2	Eclipse
GJ 9827 c	1	Transit	HAT-P-53 b	1	Eclipse	HATS-60 b	1	Eclipse
GJ 9827 d	1	Transit	HAT-P-54 b	1	Eclipse	HATS-62 b	2	Transit
GPX-1 b	2	Eclipse	HAT-P-56 b	3	Eclipse	HATS-65 b	2	Eclipse
HAT-P-1 b	3	Eclipse	HAT-P-57 b	3	Eclipse	HATS-67 b	1	Eclipse
HAT-P-11 b	2	Transit	HAT-P-58 b	2	Transit	HATS-68 b	1	Eclipse
HAT-P-12 b	3	Transit	HAT-P-59 b	2	Eclipse	HATS-7 b	1	Transit
HAT-P-13 b	3	Eclipse	HAT-P-6 b	3	Eclipse	HATS-70 b	1	Eclipse
HAT-P-14 b	2	Eclipse	HAT-P-60 b	3	Eclipse	HATS-72 b	2	Transit
HAT-P-15 b	1	Eclipse	HAT-P-61 b	1	Eclipse	HATS-9 b	1	Eclipse
HAT-P-16 b	3	Eclipse	HAT-P-62 b	2	Eclipse	HD 106315 c	2	Transit
HAT-P-17 b	2	Transit	HAT-P-64 b	2	Eclipse	HD 108236 c	1	Transit
HAT-P-18 b	2	Transit	HAT-P-65 b	2	Eclipse	HD 108236 d	1	Transit
HAT-P-19 b	2	Transit	HAT-P-66 b	1	Eclipse	HD 108236 e	1	Transit
HAT-P-2 b	2	Eclipse	HAT-P-67 b	3	Transit	HD 110082 b	1	Transit
HAT-P-20 b	2	Eclipse	HAT-P-68 b	2	Eclipse	HD 136352 c	2	Transit
HAT-P-21 b	2	Eclipse	HAT-P-69 b	3	Eclipse	HD 1397 b	3	Eclipse
HAT-P-22 b	3	Eclipse	HAT-P-7 b	3	Eclipse	HD 149026 b	3	Eclipse
HAT-P-23 b	2	Eclipse	HAT-P-70 b	3	Eclipse	HD 152843 b	1	Transit
HAT-P-24 b	2	Eclipse	HAT-P-8 b	3	Eclipse	HD 152843 c	2	Transit
HAT-P-25 b	1	Eclipse	HAT-P-9 b	2	Eclipse	HD 17156 b	2	Eclipse
HAT-P-26 b	2	Transit	HATS-1 b	2	Eclipse	HD 183579 b	2	Transit
HAT-P-27 b	2	Eclipse	HATS-13 b	1	Eclipse	HD 189733 b	3	Eclipse
HAT-P-28 b	2	Eclipse	HATS-2 b	2	Eclipse	HD 191939 b	2	Transit
HAT-P-29 b	2	Eclipse	HATS-23 b	2	Eclipse	HD 191939 c	2	Transit
HAT-P-3 b	2	Eclipse	HATS-24 b	2	Eclipse	HD 191939 d	2	Transit
HAT-P-30 b	3	Eclipse	HATS-26 b	2	Eclipse	HD 202772 A b	3	Eclipse
HD 209458 b	3	Eclipse	K2-36 c	1	Transit	LHS 1678 c	1	Transit
HD 219134 b	1	Transit	K2-406 b	2	Transit	LHS 3844 b	2	Transit
HD 219666 b	2	Transit	K2-52 b	1	Eclipse	LP 714-47 b	2	Transit
HD 221416 b	2	Transit	K2-55 b	1	Transit	LP 791-18 b	1	Transit
HD 2685 b	3	Eclipse	KELT-1 b	3	Eclipse	LP 791-18 c	1	Transit
HD 332231 b	3	Transit	KELT-10 b	3	Eclipse	LTT 1445 A b	2	Transit
HD 63433 b	2	Transit	KELT-11 b	3	Transit	LTT 1445 A c	2	Transit
HD 63433 c	2	Transit	KELT-12 b	3	Eclipse	LTT 3780 b	1	Transit
HD 63935 b	2	Transit	KELT-14 b	3	Eclipse	LTT 3780 c	1	Transit
HD 63935 c	1	Transit	KELT-15 b	3	Eclipse	LTT 9779 b	2	Eclipse
HD 73583 b	2	Transit	KELT-16 b	3	Eclipse	MASCARA-1 b	3	Eclipse
HD 73583 c	1	Transit	KELT-17 b	3	Eclipse	MASCARA-4 b	3	Eclipse
HD 89345 b	2	Transit	KELT-18 b	3	Eclipse	NGTS-11 b	1	Transit
HD 97658 b	1	Transit	KELT-19 A b	3	Eclipse	NGTS-12 b	2	Transit
HIP 41378 e	1	Transit	KELT-2 A b	3	Eclipse	NGTS-2 b	2	Eclipse
HIP 41378 f	2	Transit	KELT-20 b	3	Eclipse	NGTS-5 b	2	Transit
HIP 65 A b	3	Eclipse	KELT-21 b	3	Eclipse	NGTS-6 b	2	Eclipse

Table 3
(Continued)

Planet Name	Tier	Method	Planet Name	Tier	Method	Planet Name	Tier	Method
HIP 67522 b	2	Transit	KELT-23 A b	3	Eclipse	Qatar-1 b	3	Eclipse
HR 858 b	2	Transit	KELT-24 b	3	Eclipse	Qatar-10 b	2	Eclipse
K2-107 b	1	Eclipse	KELT-3 b	3	Eclipse	Qatar-2 b	3	Eclipse
K2-121 b	2	Transit	KELT-4 A b	3	Eclipse	Qatar-4 b	2	Eclipse
K2-132 b	1	Eclipse	KELT-6 b	2	Transit	Qatar-5 b	1	Eclipse
K2-136 c	1	Transit	KELT-7 b	3	Eclipse	Qatar-6 b	2	Eclipse
K2-138 f	2	Transit	KELT-8 b	3	Eclipse	Qatar-7 b	2	Eclipse
K2-139 b	1	Transit	KELT-9 b	3	Eclipse	Qatar-8 b	2	Transit
K2-140 b	1	Eclipse	KOI-13 b	3	Eclipse	Qatar-9 b	2	Eclipse
K2-141 c	3	Transit	KOI-94 d	1	Transit	TIC 257060897 b	2	Eclipse
K2-155 c	1	Transit	KOI-94 e	1	Transit	TOI-1064 c	2	Transit
K2-19 b	1	Transit	KPS-1 b	2	Eclipse	TOI-1075 b	1	Transit
K2-198 b	1	Transit	Kepler-105 b	2	Transit	TOI-1130 b	2	Transit
K2-232 b	2	Transit	Kepler-12 b	2	Transit	TOI-1130 c	3	Transit
K2-237 b	3	Eclipse	Kepler-1314 b	1	Transit	TOI-1201 b	1	Transit
K2-238 b	1	Eclipse	Kepler-16 b	1	Transit	TOI-1227 b	2	Transit
K2-24 b	1	Transit	Kepler-18 d	1	Transit	TOI-1231 b	2	Transit
K2-24 c	3	Transit	Kepler-25 c	1	Transit	TOI-125 c	1	Transit
K2-260 b	2	Eclipse	Kepler-444 b	2	Transit	TOI-1259 A b	2	Transit
K2-261 b	2	Transit	Kepler-444 c	1	Transit	TOI-1266 c	1	Transit
K2-266 b	1	Transit	Kepler-444 e	1	Transit	TOI-1268 b	2	Transit
K2-266 d	1	Transit	Kepler-447 b	2	Eclipse	TOI-1296 b	2	Transit
K2-287 b	2	Transit	Kepler-468 b	1	Transit	TOI-1333 b	3	Eclipse
K2-289 b	1	Transit	Kepler-6 b	1	Eclipse	TOI-1411 b	1	Transit
K2-29 b	2	Eclipse	Kepler-7 b	1	Transit	TOI-1431 b	3	Eclipse
K2-295 b	1	Transit	L 98-59 b	2	Transit	TOI-1478 b	2	Eclipse
K2-31 b	3	Eclipse	L 98-59 c	2	Transit	TOI-150.01	2	Eclipse
K2-32 b	2	Transit	L 98-59 d	2	Transit	TOI-1518 b	3	Eclipse
K2-32 d	1	Transit	LHS 1140 c	1	Transit	TOI-157 b	2	Eclipse
K2-329 b	1	Transit	LHS 1478 b	1	Transit	TOI-1601 b	2	Eclipse
K2-34 b	2	Eclipse	LHS 1678 b	1	Transit	TOI-163 b	2	Eclipse
TOI-1670 c	1	Transit	TOI-640 b	3	Eclipse	WASP-132 b	2	Transit
TOI-1685 b	1	Transit	TOI-674 b	2	Transit	WASP-133 b	1	Eclipse
TOI-169 b	1	Eclipse	TOI-677 b	2	Eclipse	WASP-135 b	2	Eclipse
TOI-1693 b	1	Transit	TOI-700 c	1	Transit	WASP-136 b	3	Eclipse
TOI-1728 b	2	Transit	TOI-776 b	1	Transit	WASP-138 b	2	Eclipse
TOI-1759 b	2	Transit	TOI-776 c	1	Transit	WASP-139 b	2	Transit
TOI-178 d	2	Transit	TOI-905 b	2	Eclipse	WASP-14 b	3	Eclipse
TOI-178 e	1	Transit	TOI-954 b	2	Transit	WASP-140 b	3	Eclipse
TOI-178 g	2	Transit	TRAPPIST-1 b	2	Transit	WASP-141 b	1	Eclipse
TOI-1789 b	3	Eclipse	TRAPPIST-1 c	2	Transit	WASP-142 b	2	Eclipse
TOI-1807 b	1	Transit	TRAPPIST-1 d	2	Transit	WASP-145 A b	2	Eclipse
TOI-1842 b	2	Transit	TRAPPIST-1 e	1	Transit	WASP-147 b	2	Transit
TOI-1860 b	1	Transit	TRAPPIST-1 f	1	Transit	WASP-15 b	3	Eclipse
TOI-1899 b	1	Transit	TRAPPIST-1 g	1	Transit	WASP-151 b	2	Transit
TOI-201 b	2	Transit	TRAPPIST-1 h	1	Transit	WASP-153 b	2	Transit
TOI-2076 b	2	Transit	TrES-1 b	2	Eclipse	WASP-156 b	1	Transit
TOI-2076 c	2	Transit	TrES-2 b	3	Eclipse	WASP-159 b	1	Eclipse
TOI-2076 d	2	Transit	TrES-3 b	3	Eclipse	WASP-16 b	2	Eclipse
TOI-2109 b	3	Eclipse	TrES-4 b	2	Eclipse	WASP-160 B b	2	Transit
TOI-216.01	1	Transit	TrES-5 b	2	Eclipse	WASP-161 b	2	Eclipse
TOI-216.02	2	Transit	V1298 Tau b	2	Transit	WASP-163 b	2	Eclipse
TOI-2337 b	1	Eclipse	V1298 Tau c	2	Transit	WASP-164 b	2	Eclipse
TOI-2411 b	1	Transit	V1298 Tau d	2	Transit	WASP-165 b	1	Eclipse
TOI-2427 b	1	Transit	V1298 Tau e	2	Transit	WASP-166 b	2	Transit
TOI-257 b	2	Transit	WASP-1 b	2	Eclipse	WASP-167 b	3	Eclipse
TOI-2669 b	2	Eclipse	WASP-10 b	2	Eclipse	WASP-168 b	2	Transit
TOI-269 b	1	Transit	WASP-100 b	3	Eclipse	WASP-169 b	1	Eclipse
TOI-270 b	1	Transit	WASP-101 b	3	Eclipse	WASP-17 b	3	Transit
TOI-270 c	2	Transit	WASP-103 b	3	Eclipse	WASP-170 b	2	Eclipse
TOI-270 d	2	Transit	WASP-104 b	3	Eclipse	WASP-172 b	2	Transit
TOI-421 b	1	Transit	WASP-105 b	1	Eclipse	WASP-173 A b	3	Eclipse
TOI-421 c	2	Transit	WASP-107 b	3	Transit	WASP-174 b	2	Transit

Table 3
(Continued)

Planet Name	Tier	Method	Planet Name	Tier	Method	Planet Name	Tier	Method
TOI-431 b	1	Transit	WASP-11 b	2	Transit	WASP-175 b	1	Eclipse
TOI-431 d	2	Transit	WASP-110 b	2	Transit	WASP-176 b	2	Eclipse
TOI-4329 b	2	Eclipse	WASP-113 b	2	Eclipse	WASP-177 b	3	Transit
TOI-451 c	1	Transit	WASP-114 b	2	Eclipse	WASP-178 b	3	Eclipse
TOI-451 d	1	Transit	WASP-117 b	3	Transit	WASP-18 b	3	Eclipse
TOI-481 b	2	Eclipse	WASP-118 b	2	Eclipse	WASP-180 A b	2	Eclipse
TOI-530 b	1	Transit	WASP-119 b	2	Eclipse	WASP-181 b	2	Transit
TOI-540 b	2	Transit	WASP-12 b	3	Eclipse	WASP-182 b	2	Transit
TOI-544 b	1	Transit	WASP-120 b	2	Eclipse	WASP-183 b	2	Transit
TOI-559 b	2	Eclipse	WASP-121 b	3	Eclipse	WASP-185 b	2	Eclipse
TOI-561 b	1	Transit	WASP-123 b	3	Eclipse	WASP-186 b	2	Eclipse
TOI-561 c	2	Transit	WASP-124 b	1	Eclipse	WASP-187 b	3	Eclipse
TOI-561 f	2	Transit	WASP-126 b	2	Eclipse	WASP-189 b	3	Eclipse
TOI-564 b	2	Eclipse	WASP-127 b	3	Transit	WASP-19 b	3	Eclipse
TOI-620 b	2	Transit	WASP-13 b	3	Eclipse	WASP-192 b	1	Eclipse
TOI-628 b	3	Eclipse	WASP-131 b	3	Transit	WASP-2 b	2	Eclipse
WASP-20 b	3	Transit	WASP-5 b	2	Eclipse	WASP-80 b	3	Eclipse
WASP-21 b	2	Transit	WASP-50 b	3	Eclipse	WASP-81 b	2	Eclipse
WASP-22 b	2	Eclipse	WASP-52 b	3	Eclipse	WASP-82 b	3	Eclipse
WASP-23 b	2	Eclipse	WASP-53 b	2	Eclipse	WASP-83 b	2	Transit
WASP-24 b	2	Eclipse	WASP-54 b	3	Eclipse	WASP-84 b	2	Transit
WASP-25 b	2	Eclipse	WASP-55 b	2	Eclipse	WASP-85 A b	3	Eclipse
WASP-26 b	2	Eclipse	WASP-58 b	2	Eclipse	WASP-87 b	3	Eclipse
WASP-28 b	2	Eclipse	WASP-6 b	2	Eclipse	WASP-88 b	2	Eclipse
WASP-29 b	2	Transit	WASP-61 b	2	Eclipse	WASP-89 b	1	Eclipse
WASP-3 b	3	Eclipse	WASP-62 b	3	Eclipse	WASP-90 b	2	Eclipse
WASP-31 b	2	Transit	WASP-63 b	3	Transit	WASP-91 b	2	Eclipse
WASP-32 b	2	Eclipse	WASP-64 b	2	Eclipse	WASP-92 b	2	Eclipse
WASP-33 b	3	Eclipse	WASP-65 b	2	Eclipse	WASP-93 b	2	Eclipse
WASP-34 b	2	Eclipse	WASP-66 b	2	Eclipse	WASP-94 A b	3	Transit
WASP-35 b	3	Eclipse	WASP-67 b	2	Transit	WASP-95 b	3	Eclipse
WASP-36 b	2	Eclipse	WASP-68 b	3	Eclipse	WASP-96 b	1	Eclipse
WASP-37 b	1	Eclipse	WASP-69 b	3	Transit	WASP-97 b	3	Eclipse
WASP-38 b	3	Eclipse	WASP-7 b	3	Eclipse	WASP-98 b	1	Eclipse
WASP-39 b	3	Transit	WASP-70 A b	2	Eclipse	WASP-99 b	2	Eclipse
WASP-4 b	3	Eclipse	WASP-71 b	2	Eclipse	Wolf 503 b	1	Transit
WASP-41 b	2	Eclipse	WASP-72 b	2	Eclipse	XO-1 b	2	Eclipse
WASP-42 b	2	Transit	WASP-73 b	2	Eclipse	XO-2 N b	2	Eclipse
WASP-43 b	3	Eclipse	WASP-74 b	3	Eclipse	XO-3 b	3	Eclipse
WASP-44 b	1	Eclipse	WASP-75 b	2	Eclipse	XO-4 b	2	Eclipse
WASP-45 b	1	Eclipse	WASP-76 b	3	Eclipse	XO-5 b	2	Eclipse
WASP-46 b	2	Eclipse	WASP-77 A b	3	Eclipse	XO-6 b	3	Eclipse
WASP-47 b	2	Eclipse	WASP-78 b	2	Eclipse	XO-7 b	3	Eclipse
WASP-48 b	2	Eclipse	WASP-79 b	3	Eclipse	pi Men c	2	Transit
WASP-49 b	2	Eclipse	WASP-8 b	2	Eclipse			

Note. The list will continue to evolve as surveys discover more planets

possible to conduct detailed follow-up of all of the TPCs that may be of interest to the Ariel mission.

The formation of the Ariel MRS will also need to account for the knowledge gained through previous spectroscopic studies of exoplanetary atmospheres. Ground- and space-based spectroscopy is constantly providing new insights into exoplanetary atmospheres. High-resolution spectroscopy from the ground is becoming ever more fruitful (e.g., Pino et al. 2020; Giacobbe et al. 2021; Tabernero et al. 2021; Wardenier et al. 2021). At lower resolutions, transit and eclipse studies with ground-based facilities and Hubble continue to deliver new views of atmospheres (e.g., McGruder et al. 2020; Braam et al. 2021; Saba et al. 2021; Yip et al. 2021), with a recent focus on smaller planets (e.g., de Wit et al. 2018; Benneke et al. 2019; Tsiaras et al. 2019; Diamond-Lowe et al. 2020; Edwards et al. 2021; Gressier et al. 2022), and findings from these studies will further our understanding of exoplanetary atmospheres.

Through its GTO and Cycle 1 GO programs, a significant amount of time has been attributed for JWST to study exoplanets via transit and eclipse spectroscopy. The high-precision data that will be acquired, on top of a wider wavelength coverage with respect to current space-based instruments, will unlock new avenues for exoplanet characterization (e.g., Changeat et al. 2021b; Phillips et al. 2021; Pidhorodetska et al. 2021). The lessons learned from these

Table 4
TESS planet candidates which are considered here to be potential targets for Ariel

TOI	Tier	Method	TOI	Tier	Method	TOI	Tier	Method	TOI	Tier	Method
119.01	1	Transit	341.01	1	Transit	533.01	1	Transit	696.01	1	Transit
133.01	1	Transit	344.01	1	Transit	544.01	1	Transit	696.02	1	Transit
139.01	2	Transit	351.01	1	Transit	559.01	2	Transit	696.03	1	Transit
145.01	1	Transit	352.01	2	Eclipse	560.01	2	Transit	697.01	1	Transit
148.01	1	Transit	354.01	3	Eclipse	560.02	2	Transit	716.01	1	Transit
153.01	1	Transit	360.01	2	Eclipse	575.01	2	Eclipse	733.01	1	Transit
155.01	2	Transit	363.01	1	Transit	577.01	2	Eclipse	735.01	1	Transit
159.01	3	Eclipse	368.01	3	Eclipse	579.01	2	Eclipse	738.01	1	Transit
166.01	2	Transit	375.01	1	Eclipse	585.01	3	Eclipse	741.01	2	Transit
168.01	1	Transit	376.01	1	Transit	587.01	3	Eclipse	742.01	1	Transit
170.01	1	Eclipse	383.01	2	Transit	592.01	1	Transit	746.01	1	Transit
171.01	3	Eclipse	392.01	3	Eclipse	599.01	3	Eclipse	757.01	1	Transit
172.01	1	Transit	393.01	1	Transit	601.01	1	Eclipse	759.01	1	Transit
173.01	2	Transit	399.01	1	Transit	603.01	2	Transit	761.01	1	Transit
174.04	1	Transit	406.01	1	Transit	610.01	1	Transit	762.01	2	Transit
177.01	2	Transit	411.01	1	Transit	611.01	1	Transit	763.01	1	Transit
179.01	2	Transit	412.01	3	Eclipse	614.01	1	Eclipse	771.01	1	Transit
181.01	2	Transit	422.01	1	Transit	615.01	3	Eclipse	772.01	2	Transit
198.01	1	Transit	424.01	1	Transit	618.01	2	Transit	776.02	1	Transit
199.01	2	Transit	426.01	1	Transit	620.01	1	Transit	777.01	2	Transit
210.01	1	Transit	431.01	2	Transit	621.01	3	Eclipse	778.01	3	Eclipse
213.01	1	Transit	431.02	1	Transit	622.01	3	Transit	782.01	1	Transit
214.01	1	Transit	432.01	1	Eclipse	623.01	2	Transit	783.01	1	Transit
217.01	2	Transit	435.01	1	Transit	627.01	3	Eclipse	784.01	1	Transit
233.01	1	Transit	438.01	1	Transit	628.01	3	Eclipse	790.01	1	Transit
233.02	1	Transit	444.01	2	Transit	629.01	2	Transit	791.01	1	Transit
238.01	1	Transit	445.01	3	Eclipse	633.01	2	Transit	802.01	1	Transit
240.01	1	Transit	450.01	3	Transit	634.01	1	Transit	811.01	1	Transit
242.01	2	Eclipse	456.01	3	Eclipse	635.01	1	Transit	812.01	1	Transit
243.01	1	Eclipse	459.01	1	Eclipse	638.01	1	Transit	815.01	1	Transit
245.01	1	Transit	462.01	1	Transit	640.01	3	Eclipse	821.01	1	Transit
260.01	1	Transit	469.01	2	Transit	641.01	1	Transit	823.01	1	Transit
261.01	1	Transit	470.01	1	Transit	642.01	2	Eclipse	829.01	1	Transit
268.01	1	Transit	475.01	1	Transit	645.01	2	Eclipse	836.02	1	Transit
275.01	3	Eclipse	476.01	3	Eclipse	648.01	1	Eclipse	841.01	1	Transit
277.01	2	Transit	478.01	3	Eclipse	649.01	3	Eclipse	842.01	1	Transit
278.01	1	Transit	480.01	1	Transit	654.01	1	Transit	845.01	2	Eclipse
287.01	2	Eclipse	486.01	2	Transit	658.01	2	Transit	846.01	1	Transit
299.01	1	Transit	493.01	1	Transit	659.01	2	Eclipse	847.01	2	Eclipse
302.01	1	Transit	500.01	1	Transit	663.02	1	Transit	852.01	1	Transit
310.01	1	Transit	517.01	1	Transit	672.01	2	Transit	853.01	2	Eclipse
312.01	1	Transit	523.01	2	Transit	682.01	2	Transit	856.01	1	Eclipse
317.01	1	Eclipse	525.01	1	Transit	687.01	1	Transit	857.01	2	Eclipse
322.01	3	Eclipse	526.01	2	Transit	689.01	3	Transit	858.01	2	Eclipse
326.01	2	Eclipse	528.01	2	Transit	691.01	1	Transit	859.01	1	Transit
330.01	1	Transit	532.01	1	Transit	694.01	2	Transit	880.01	2	Transit
880.02	2	Transit	1027.02	1	Transit	1171.01	1	Eclipse	1316.01	1	Transit
880.03	1	Transit	1028.01	2	Transit	1173.01	2	Transit	1317.01	3	Eclipse
882.01	1	Eclipse	1036.01	2	Transit	1176.01	2	Transit	1319.01	2	Transit
883.01	2	Transit	1047.01	2	Transit	1180.01	1	Transit	1321.01	2	Eclipse
885.01	2	Eclipse	1053.01	2	Eclipse	1181.01	3	Eclipse	1325.01	2	Transit
887.01	2	Eclipse	1058.01	2	Eclipse	1182.01	2	Eclipse	1329.01	1	Transit
888.01	1	Transit	1059.01	2	Eclipse	1184.01	1	Transit	1331.01	2	Eclipse
892.01	2	Transit	1061.01	1	Transit	1185.01	1	Transit	1333.01	3	Eclipse
899.01	1	Transit	1064.01	1	Transit	1186.01	3	Eclipse	1343.01	1	Transit
902.01	1	Transit	1064.02	1	Transit	1193.01	3	Eclipse	1345.01	1	Eclipse
907.01	2	Transit	1074.01	1	Transit	1194.01	2	Transit	1350.01	2	Eclipse
909.01	2	Transit	1075.01	1	Transit	1195.01	1	Eclipse	1352.01	2	Eclipse
910.01	2	Transit	1077.01	1	Transit	1196.01	2	Eclipse	1353.01	1	Transit
911.01	3	Eclipse	1080.01	1	Transit	1197.01	2	Eclipse	1355.01	3	Eclipse
912.01	1	Transit	1081.01	2	Transit	1199.01	2	Eclipse	1359.01	2	Eclipse
913.01	1	Transit	1083.01	1	Transit	1215.01	1	Transit	1361.01	2	Eclipse
926.01	1	Transit	1086.01	1	Eclipse	1224.01	1	Transit	1362.01	2	Eclipse
931.01	2	Eclipse	1087.01	1	Eclipse	1232.01	1	Transit	1364.01	1	Eclipse

Table 4
(Continued)

TOI	Tier	Method	TOI	Tier	Method	TOI	Tier	Method	TOI	Tier	Method
933.01	1	Transit	1088.01	1	Transit	1234.01	2	Transit	1367.01	1	Transit
934.01	2	Transit	1090.01	3	Eclipse	1239.01	1	Transit	1369.01	2	Transit
938.01	1	Transit	1091.01	3	Eclipse	1243.01	1	Transit	1370.01	2	Transit
939.01	2	Transit	1094.01	1	Eclipse	1245.01	1	Transit	1371.01	3	Eclipse
941.01	1	Transit	1095.01	2	Eclipse	1246.01	1	Transit	1381.01	1	Transit
942.01	1	Transit	1099.01	2	Transit	1248.01	2	Transit	1382.01	3	Eclipse
943.01	2	Transit	1101.01	2	Eclipse	1250.01	2	Transit	1383.01	2	Transit
947.01	2	Eclipse	1102.01	1	Transit	1263.01	1	Transit	1384.01	1	Eclipse
948.01	1	Transit	1105.01	1	Transit	1264.01	2	Transit	1387.01	1	Transit
950.01	2	Transit	1107.01	2	Eclipse	1270.01	1	Transit	1391.01	1	Transit
954.01	2	Eclipse	1108.01	2	Eclipse	1272.01	1	Transit	1392.01	1	Transit
961.01	3	Eclipse	1110.01	2	Eclipse	1274.01	2	Transit	1394.01	2	Transit
963.01	2	Transit	1111.01	2	Eclipse	1275.01	1	Transit	1396.01	2	Transit
965.01	1	Transit	1113.01	3	Transit	1276.01	2	Transit	1397.01	2	Transit
966.01	3	Eclipse	1119.01	2	Eclipse	1277.02	1	Transit	1399.01	1	Transit
969.01	1	Transit	1120.01	2	Eclipse	1279.01	2	Transit	1400.01	1	Transit
970.01	1	Transit	1123.01	3	Eclipse	1280.01	1	Transit	1401.01	3	Eclipse
978.01	2	Transit	1126.01	1	Transit	1285.01	1	Transit	1410.01	1	Transit
985.01	3	Eclipse	1130.01	3	Transit	1288.01	2	Transit	1411.01	1	Transit
987.01	2	Eclipse	1130.02	1	Transit	1292.01	3	Eclipse	1412.01	2	Transit
990.01	2	Transit	1133.01	1	Transit	1293.01	1	Transit	1415.01	1	Transit
991.01	2	Transit	1135.01	2	Transit	1294.01	1	Transit	1416.01	1	Transit
996.01	2	Eclipse	1136.01	2	Transit	1295.01	2	Eclipse	1420.01	2	Transit
1007.01	2	Eclipse	1136.02	1	Transit	1297.01	2	Eclipse	1423.01	2	Transit
1015.01	2	Eclipse	1136.03	1	Transit	1303.01	3	Eclipse	1424.01	1	Transit
1017.01	3	Eclipse	1143.01	2	Transit	1306.01	2	Eclipse	1431.01	3	Eclipse
1018.01	3	Eclipse	1158.01	3	Eclipse	1310.01	2	Eclipse	1434.01	1	Transit
1019.01	3	Eclipse	1166.01	1	Transit	1312.01	2	Transit	1438.01	1	Transit
1022.01	1	Transit	1168.01	3	Eclipse	1313.01	2	Transit	1448.01	1	Transit
1027.01	1	Transit	1170.01	1	Eclipse	1314.01	1	Eclipse	1449.01	2	Transit
1449.02	1	Transit	1568.01	3	Eclipse	1694.01	2	Transit	1843.01	1	Transit
1454.01	2	Eclipse	1569.01	1	Eclipse	1697.01	1	Transit	1845.01	1	Transit
1460.01	3	Eclipse	1570.01	2	Transit	1700.01	1	Transit	1848.01	1	Transit
1461.01	3	Eclipse	1575.01	3	Eclipse	1702.01	1	Transit	1849.01	1	Transit
1467.01	1	Transit	1577.01	2	Transit	1703.01	2	Eclipse	1850.01	2	Eclipse
1468.01	1	Transit	1578.01	3	Eclipse	1708.01	2	Transit	1853.01	1	Transit
1468.02	1	Transit	1585.01	1	Eclipse	1709.01	2	Eclipse	1854.01	1	Transit
1470.01	1	Transit	1586.01	2	Eclipse	1710.01	2	Transit	1858.01	2	Eclipse
1471.01	2	Transit	1588.01	2	Eclipse	1712.01	2	Eclipse	1859.01	1	Transit
1472.01	1	Transit	1592.01	1	Transit	1717.01	3	Eclipse	1860.01	1	Transit
1473.01	1	Transit	1593.01	1	Eclipse	1718.01	2	Transit	1861.01	1	Transit
1478.01	2	Transit	1594.01	1	Eclipse	1722.01	1	Transit	1873.01	1	Transit
1482.01	2	Eclipse	1596.01	2	Eclipse	1724.01	1	Transit	1883.01	1	Transit
1483.01	1	Transit	1597.01	1	Transit	1730.01	1	Transit	1884.01	1	Transit
1484.01	1	Eclipse	1600.01	2	Eclipse	1730.03	1	Transit	1886.01	1	Transit
1486.01	1	Transit	1601.01	2	Eclipse	1732.01	1	Transit	1890.01	1	Transit
1489.01	1	Eclipse	1602.01	1	Transit	1758.01	1	Transit	1898.01	2	Transit
1490.01	2	Eclipse	1603.01	2	Eclipse	1759.01	2	Transit	1938.01	2	Transit
1492.01	1	Transit	1604.01	3	Eclipse	1765.01	1	Transit	1943.01	1	Transit
1493.01	3	Eclipse	1605.01	2	Transit	1768.01	1	Transit	1944.01	3	Eclipse
1496.01	3	Transit	1606.01	1	Transit	1774.01	1	Transit	1945.01	1	Eclipse
1501.01	3	Eclipse	1608.01	3	Eclipse	1775.01	2	Transit	1949.01	3	Eclipse
1507.01	2	Eclipse	1613.01	1	Transit	1783.01	1	Transit	1951.01	3	Eclipse
1508.01	1	Eclipse	1615.01	3	Eclipse	1786.01	2	Eclipse	1952.01	2	Transit
1511.01	3	Eclipse	1622.01	2	Transit	1788.01	2	Transit	1954.01	2	Transit
1513.01	1	Transit	1623.01	1	Transit	1792.01	2	Transit	1955.01	2	Transit
1515.01	1	Transit	1625.01	1	Transit	1797.01	1	Transit	1956.01	1	Transit
1516.01	3	Eclipse	1634.01	1	Transit	1801.01	1	Transit	1963.01	2	Eclipse
1518.01	3	Eclipse	1635.01	2	Transit	1803.01	1	Transit	1968.01	2	Eclipse
1519.01	2	Transit	1637.01	2	Eclipse	1806.01	1	Transit	1969.01	1	Transit
1521.01	3	Eclipse	1638.01	2	Eclipse	1807.01	1	Transit	1970.01	2	Eclipse
1522.01	1	Transit	1639.01	1	Transit	1808.01	1	Eclipse	1975.01	1	Transit
1527.01	2	Eclipse	1640.01	1	Transit	1811.01	2	Transit	1980.01	2	Eclipse

Table 4
(Continued)

TOI	Tier	Method	TOI	Tier	Method	TOI	Tier	Method	TOI	Tier	Method
1531.01	3	Eclipse	1641.01	1	Eclipse	1815.01	3	Eclipse	1982.01	2	Transit
1532.01	2	Transit	1647.01	2	Eclipse	1818.01	1	Transit	1991.01	2	Eclipse
1533.01	1	Transit	1649.01	3	Eclipse	1820.01	2	Transit	1994.01	2	Eclipse
1535.01	2	Eclipse	1650.01	1	Transit	1822.01	2	Eclipse	1995.01	1	Eclipse
1538.01	2	Transit	1655.01	1	Transit	1823.01	2	Transit	1996.01	3	Eclipse
1541.01	2	Eclipse	1658.01	1	Eclipse	1824.01	1	Transit	1998.01	1	Transit
1543.01	1	Transit	1660.01	1	Transit	1825.01	1	Transit	2000.01	2	Transit
1548.01	1	Transit	1662.01	3	Eclipse	1827.01	2	Transit	2001.01	3	Eclipse
1549.01	3	Eclipse	1663.01	2	Eclipse	1828.01	1	Transit	2005.01	1	Transit
1550.01	2	Eclipse	1668.01	1	Transit	1830.01	3	Eclipse	2008.01	1	Transit
1551.01	1	Transit	1671.01	1	Eclipse	1832.01	1	Transit	2013.01	1	Transit
1553.01	2	Eclipse	1673.01	1	Transit	1835.01	2	Transit	2015.01	1	Transit
1555.01	2	Transit	1683.01	1	Transit	1836.01	2	Transit	2016.01	1	Transit
1556.01	2	Eclipse	1685.01	1	Transit	1837.01	1	Transit	2016.02	1	Transit
1566.01	1	Transit	1691.01	1	Transit	1839.01	1	Transit	2018.01	2	Transit
2019.01	1	Transit	2190.01	1	Eclipse	2373.01	1	Transit	2516.01	3	Eclipse
2023.01	1	Transit	2192.01	1	Transit	2374.01	2	Transit	2521.01	1	Transit
2025.01	1	Transit	2194.01	2	Transit	2378.01	1	Transit	2522.01	1	Transit
2030.01	2	Eclipse	2195.01	2	Transit	2383.01	2	Eclipse	2524.01	1	Transit
2031.01	2	Transit	2200.01	1	Transit	2384.01	2	Transit	2526.01	2	Transit
2033.01	1	Transit	2203.01	2	Eclipse	2385.01	1	Transit	2527.01	1	Eclipse
2040.01	2	Transit	2207.01	1	Transit	2391.01	1	Eclipse	2528.01	1	Transit
2045.01	2	Transit	2212.01	1	Transit	2395.01	1	Transit	2531.01	1	Transit
2046.01	3	Eclipse	2215.01	1	Transit	2397.01	1	Transit	2532.01	1	Transit
2047.01	2	Transit	2217.01	1	Transit	2398.01	1	Transit	2533.01	1	Transit
2057.01	2	Transit	2222.01	1	Eclipse	2401.01	3	Eclipse	2535.01	1	Transit
2058.01	2	Eclipse	2223.01	1	Transit	2402.01	1	Transit	2538.01	1	Eclipse
2062.01	1	Eclipse	2226.01	1	Transit	2404.02	1	Transit	2540.01	2	Transit
2066.01	3	Eclipse	2234.01	1	Eclipse	2407.01	1	Transit	2540.02	2	Transit
2068.01	1	Transit	2236.01	2	Eclipse	2408.01	1	Transit	2543.01	1	Transit
2072.01	1	Transit	2241.01	2	Eclipse	2411.01	1	Transit	2546.01	1	Eclipse
2076.01	2	Transit	2244.01	2	Eclipse	2413.01	1	Transit	2550.01	1	Transit
2076.02	2	Transit	2247.01	2	Eclipse	2416.01	1	Transit	2552.01	1	Transit
2079.01	1	Transit	2248.01	1	Transit	2418.01	2	Transit	2553.01	2	Transit
2079.02	1	Transit	2249.01	2	Eclipse	2420.01	1	Eclipse	2554.01	2	Eclipse
2099.01	1	Transit	2274.01	1	Transit	2421.01	2	Eclipse	2555.01	1	Eclipse
2106.01	2	Transit	2283.01	1	Transit	2422.01	3	Transit	2556.01	2	Transit
2107.01	2	Eclipse	2300.02	1	Transit	2424.01	2	Eclipse	2557.01	2	Eclipse
2108.01	3	Eclipse	2303.01	2	Eclipse	2425.01	1	Transit	2558.01	1	Transit
2114.01	2	Eclipse	2308.01	1	Transit	2427.01	1	Transit	2561.01	2	Eclipse
2117.01	2	Transit	2310.01	1	Transit	2429.01	1	Transit	2562.01	1	Transit
2119.01	3	Transit	2312.01	1	Transit	2431.01	2	Eclipse	2563.01	1	Transit
2123.01	2	Transit	2313.01	1	Transit	2443.01	2	Transit	2564.01	1	Transit
2133.01	1	Transit	2316.01	2	Eclipse	2446.01	1	Transit	2566.01	1	Transit
2134.01	2	Transit	2325.01	1	Transit	2449.01	3	Transit	2567.01	1	Transit
2136.01	1	Transit	2328.01	1	Transit	2450.01	1	Transit	2568.01	1	Eclipse
2141.01	1	Transit	2329.01	1	Transit	2457.01	1	Transit	2569.01	1	Transit
2142.01	1	Transit	2331.01	1	Transit	2463.01	2	Eclipse	2570.01	2	Eclipse
2143.01	2	Eclipse	2332.01	1	Transit	2469.01	3	Eclipse	2571.01	2	Transit
2145.01	2	Eclipse	2336.01	2	Transit	2473.01	3	Eclipse	2576.01	2	Transit
2146.01	2	Eclipse	2337.01	2	Eclipse	2476.01	1	Eclipse	2577.01	1	Transit
2147.01	1	Transit	2338.01	1	Transit	2484.01	1	Transit	2578.01	2	Eclipse
2150.01	1	Transit	2346.01	2	Eclipse	2485.01	2	Transit	2580.01	3	Eclipse
2152.01	3	Eclipse	2350.01	1	Transit	2486.01	1	Transit	2581.01	1	Transit
2154.01	2	Eclipse	2357.01	1	Transit	2488.01	1	Transit	2582.01	1	Transit
2155.01	1	Transit	2359.01	2	Eclipse	2489.01	2	Transit	2583.01	1	Eclipse
2157.01	2	Eclipse	2361.01	2	Transit	2491.01	2	Eclipse	2586.01	1	Transit
2158.01	2	Transit	2363.01	1	Transit	2492.01	2	Eclipse	2587.01	1	Transit
2159.01	2	Transit	2364.01	2	Transit	2494.01	2	Transit	2588.01	1	Transit
2169.01	1	Transit	2366.01	1	Transit	2497.01	2	Transit	2589.01	1	Transit
2171.01	2	Eclipse	2368.01	2	Transit	2500.01	1	Eclipse	2591.01	2	Eclipse
2183.01	3	Eclipse	2369.01	1	Transit	2504.01	1	Eclipse	2594.01	1	Eclipse
2185.01	1	Transit	2371.01	1	Transit	2511.01	1	Eclipse	2596.01	1	Transit

Table 4
(Continued)

TOI	Tier	Method	TOI	Tier	Method	TOI	Tier	Method	TOI	Tier	Method
2597.01	1	Eclipse	2768.01	1	Transit	2927.01	1	Eclipse	3078.01	1	Eclipse
2598.01	2	Eclipse	2778.01	2	Eclipse	2928.01	1	Transit	3082.01	1	Transit
2600.01	2	Eclipse	2779.01	1	Transit	2929.01	1	Transit	3089.01	1	Transit
2602.01	2	Eclipse	2783.01	3	Eclipse	2932.01	1	Eclipse	3091.01	2	Eclipse
2614.01	2	Eclipse	2784.01	1	Eclipse	2937.01	2	Eclipse	3095.01	1	Transit
2615.01	1	Transit	2786.01	1	Eclipse	2938.01	2	Transit	3097.01	1	Transit
2619.01	1	Transit	2790.01	2	Eclipse	2941.01	2	Eclipse	3098.01	2	Eclipse
2624.01	1	Transit	2797.01	1	Transit	2943.01	2	Eclipse	3099.01	2	Transit
2626.01	2	Transit	2798.01	1	Eclipse	2946.01	2	Transit	3106.01	1	Eclipse
2631.01	1	Transit	2799.01	2	Eclipse	2949.01	1	Transit	3107.01	2	Eclipse
2632.01	1	Transit	2800.01	1	Transit	2950.01	1	Transit	3114.01	1	Transit
2635.01	1	Eclipse	2803.01	2	Eclipse	2952.01	1	Transit	3118.01	1	Eclipse
2636.01	2	Eclipse	2809.01	2	Transit	2955.01	1	Eclipse	3122.01	1	Transit
2645.01	3	Eclipse	2813.01	1	Transit	2956.01	1	Transit	3126.01	2	Eclipse
2646.01	1	Eclipse	2814.01	2	Eclipse	2958.01	2	Transit	3127.01	2	Transit
2649.01	1	Transit	2816.01	2	Transit	2962.01	1	Eclipse	3129.01	2	Eclipse
2654.01	1	Transit	2817.01	1	Transit	2964.01	1	Transit	3130.01	2	Eclipse
2659.01	2	Eclipse	2818.01	2	Eclipse	2974.01	1	Eclipse	3132.01	1	Transit
2661.01	1	Transit	2819.01	2	Eclipse	2975.01	1	Eclipse	3134.01	1	Eclipse
2665.01	1	Transit	2820.01	1	Transit	2981.01	1	Transit	3135.01	2	Transit
2668.01	1	Transit	2827.01	1	Transit	2984.01	2	Transit	3136.01	2	Eclipse
2672.01	1	Eclipse	2832.01	1	Transit	2987.01	1	Transit	3138.01	1	Transit
2676.01	1	Eclipse	2834.01	2	Transit	2989.01	2	Transit	3145.01	2	Eclipse
2677.01	2	Eclipse	2835.01	1	Eclipse	2991.01	1	Transit	3146.01	2	Eclipse
2679.01	1	Transit	2836.01	2	Transit	2992.01	1	Eclipse	3151.01	1	Eclipse
2687.01	1	Transit	2839.01	1	Eclipse	2995.01	2	Eclipse	3155.01	2	Transit
2693.01	1	Transit	2840.01	2	Eclipse	2997.01	2	Eclipse	3156.01	2	Eclipse
2700.01	1	Transit	2841.01	1	Eclipse	3001.01	1	Eclipse	3160.01	1	Eclipse
2710.01	1	Transit	2842.01	1	Transit	3004.01	1	Eclipse	3161.01	1	Eclipse
2711.01	1	Transit	2847.01	2	Transit	3006.01	1	Eclipse	3162.01	1	Eclipse
2713.01	1	Transit	2856.01	1	Eclipse	3010.01	1	Eclipse	3163.01	1	Eclipse
2714.01	1	Transit	2866.01	1	Transit	3017.01	1	Eclipse	3164.01	1	Eclipse
2716.01	1	Transit	2870.01	2	Eclipse	3023.01	2	Eclipse	3167.01	1	Eclipse
2718.01	1	Transit	2876.01	1	Transit	3037.01	1	Eclipse	3168.01	2	Transit
2721.01	1	Transit	2879.01	1	Transit	3039.01	1	Eclipse	3174.01	1	Eclipse
2724.01	2	Eclipse	2886.01	3	Eclipse	3040.01	1	Transit	3176.01	1	Transit
2728.01	1	Eclipse	2892.01	1	Transit	3041.01	2	Eclipse	3177.01	2	Transit
2729.01	2	Transit	2896.01	1	Eclipse	3045.01	2	Eclipse	3179.01	1	Eclipse
2735.01	2	Transit	2901.01	2	Eclipse	3053.01	2	Transit	3181.01	1	Transit
2741.01	2	Eclipse	2906.01	1	Transit	3054.01	1	Eclipse	3184.01	1	Transit
2745.01	3	Eclipse	2912.01	1	Transit	3056.01	1	Eclipse	3185.01	1	Eclipse
2746.01	1	Transit	2913.01	1	Transit	3058.01	2	Eclipse	3187.01	1	Eclipse
2749.01	2	Eclipse	2916.01	1	Transit	3062.01	1	Transit	3192.01	2	Eclipse
2757.01	1	Eclipse	2919.01	1	Transit	3065.01	1	Transit	3194.01	1	Transit
2758.01	1	Transit	2920.01	1	Eclipse	3066.01	1	Transit	3195.01	1	Eclipse
2762.01	1	Transit	2921.01	1	Transit	3070.01	1	Eclipse	3196.01	1	Transit
2766.01	2	Eclipse	2923.01	1	Transit	3073.01	1	Transit	3198.01	1	Eclipse
2767.01	1	Eclipse	2925.01	1	Transit	3077.01	1	Transit	3203.01	1	Transit
3206.01	1	Eclipse	3331.01	2	Transit	3492.01	2	Eclipse	3587.01	2	Eclipse
3208.01	1	Transit	3334.01	1	Eclipse	3493.01	1	Transit	3589.01	2	Eclipse
3210.01	2	Eclipse	3341.01	1	Transit	3494.01	1	Transit	3591.01	1	Transit
3212.01	2	Transit	3342.01	2	Transit	3498.01	1	Transit	3593.01	2	Transit
3214.01	2	Eclipse	3344.01	3	Eclipse	3503.01	2	Eclipse	3595.01	2	Transit
3228.01	1	Eclipse	3345.01	1	Eclipse	3504.01	2	Eclipse	3597.01	2	Transit
3231.01	1	Eclipse	3351.01	2	Eclipse	3505.01	1	Transit	3599.01	1	Transit
3233.01	1	Eclipse	3353.01	1	Transit	3506.01	1	Transit	3600.01	1	Eclipse
3237.01	1	Eclipse	3353.02	1	Transit	3507.01	1	Transit	3602.01	2	Eclipse
3240.01	1	Transit	3358.01	1	Transit	3508.01	2	Eclipse	3605.01	2	Eclipse
3241.01	2	Eclipse	3362.01	1	Transit	3510.01	1	Transit	3609.01	1	Transit
3242.01	1	Eclipse	3364.01	2	Transit	3511.01	2	Eclipse	3613.01	1	Transit
3244.01	1	Eclipse	3365.01	2	Transit	3514.01	2	Eclipse	3616.01	1	Eclipse
3245.01	1	Eclipse	3371.01	1	Transit	3515.01	1	Transit	3618.01	1	Transit
3248.01	1	Transit	3374.01	2	Eclipse	3516.01	1	Eclipse	3619.01	1	Eclipse

Table 4
(Continued)

TOI	Tier	Method	TOI	Tier	Method	TOI	Tier	Method	TOI	Tier	Method
3250.01	1	Transit	3388.01	1	Eclipse	3519.01	1	Eclipse	3625.01	1	Eclipse
3252.01	1	Transit	3397.01	1	Transit	3522.01	1	Transit	3626.01	1	Transit
3253.01	1	Transit	3398.01	2	Transit	3523.01	2	Eclipse	3628.01	2	Transit
3255.01	1	Transit	3400.01	2	Eclipse	3524.01	1	Transit	3629.01	2	Transit
3259.01	1	Transit	3404.01	1	Transit	3525.01	1	Eclipse	3630.01	1	Transit
3266.01	1	Transit	3407.01	1	Eclipse	3526.01	1	Eclipse	3632.01	1	Eclipse
3268.01	1	Transit	3422.01	1	Eclipse	3527.01	1	Eclipse	3633.01	1	Eclipse
3271.01	2	Eclipse	3433.01	1	Transit	3529.01	1	Eclipse	3635.01	1	Eclipse
3273.01	2	Transit	3436.01	1	Eclipse	3531.01	3	Eclipse	3636.01	1	Eclipse
3274.01	1	Transit	3437.01	1	Transit	3539.01	1	Transit	3639.01	1	Transit
3275.01	1	Transit	3443.01	2	Eclipse	3542.01	1	Eclipse	3640.01	1	Eclipse
3276.01	1	Transit	3444.01	2	Eclipse	3543.01	2	Eclipse	3642.01	1	Transit
3277.01	2	Transit	3445.01	2	Eclipse	3545.01	2	Eclipse	3643.01	1	Transit
3281.01	1	Transit	3447.01	1	Transit	3546.01	1	Transit	3645.01	1	Transit
3283.01	1	Eclipse	3451.01	1	Transit	3548.01	3	Eclipse	3646.01	2	Eclipse
3285.01	1	Eclipse	3455.01	1	Eclipse	3551.01	1	Eclipse	3652.01	2	Eclipse
3288.01	2	Transit	3456.01	2	Transit	3553.01	1	Eclipse	3662.01	1	Transit
3290.01	1	Transit	3458.01	2	Transit	3559.01	1	Eclipse	3664.01	1	Transit
3294.01	2	Eclipse	3460.01	3	Eclipse	3560.01	1	Transit	3666.01	2	Transit
3296.01	1	Transit	3464.01	1	Transit	3563.01	1	Transit	3668.01	2	Eclipse
3298.01	1	Eclipse	3466.01	2	Eclipse	3564.01	2	Eclipse	3670.01	1	Transit
3304.01	1	Transit	3467.01	1	Eclipse	3565.01	1	Transit	3672.01	1	Eclipse
3305.01	1	Transit	3469.01	2	Eclipse	3566.01	1	Eclipse	3673.01	1	Eclipse
3306.01	1	Transit	3471.01	1	Transit	3567.01	1	Transit	3674.01	1	Transit
3307.01	1	Transit	3472.01	2	Transit	3568.01	1	Transit	3675.01	1	Transit
3309.01	2	Transit	3474.01	2	Transit	3569.01	2	Eclipse	3677.01	2	Eclipse
3314.01	2	Eclipse	3475.01	1	Eclipse	3571.01	2	Eclipse	3678.01	2	Eclipse
3315.01	1	Transit	3476.01	1	Eclipse	3573.01	1	Transit	3679.01	1	Transit
3321.01	2	Eclipse	3478.01	2	Eclipse	3576.01	1	Transit	3682.01	2	Eclipse
3322.01	1	Eclipse	3484.01	2	Eclipse	3577.01	1	Transit	3683.01	1	Eclipse
3326.01	1	Eclipse	3489.01	2	Eclipse	3580.01	2	Transit	3686.01	2	Eclipse
3329.01	2	Transit	3490.01	1	Transit	3585.01	1	Transit	3688.01	2	Transit
3330.01	2	Eclipse	3491.01	3	Eclipse	3586.01	2	Transit	3691.01	1	Transit
3693.01	2	Transit	3789.01	1	Transit	3910.01	2	Transit	4059.01	2	Transit
3698.01	1	Eclipse	3790.01	2	Transit	3912.01	2	Eclipse	4065.01	1	Transit
3699.01	1	Eclipse	3791.01	1	Eclipse	3913.01	1	Transit	4067.01	1	Transit
3700.01	1	Transit	3796.01	2	Transit	3914.01	2	Transit	4069.01	1	Transit
3703.01	2	Eclipse	3797.01	1	Transit	3915.01	2	Transit	4074.01	1	Eclipse
3704.01	1	Transit	3798.01	1	Transit	3921.01	2	Transit	4077.01	1	Transit
3705.01	1	Transit	3799.01	1	Transit	3924.01	1	Eclipse	4079.01	2	Eclipse
3708.01	2	Transit	3801.01	1	Transit	3926.01	1	Transit	4080.01	1	Transit
3713.01	1	Transit	3805.01	1	Transit	3927.01	1	Eclipse	4081.01	1	Transit
3714.01	2	Transit	3807.01	1	Transit	3929.01	2	Eclipse	4082.01	1	Transit
3715.01	3	Eclipse	3809.01	2	Transit	3932.01	1	Eclipse	4084.01	1	Transit
3717.01	1	Transit	3812.01	2	Transit	3937.01	2	Transit	4085.01	2	Transit
3718.01	1	Transit	3815.01	2	Eclipse	3939.01	2	Transit	4086.01	1	Transit
3719.01	2	Eclipse	3822.01	2	Transit	3940.01	2	Transit	4087.01	2	Eclipse
3720.01	1	Eclipse	3826.01	1	Eclipse	3948.01	1	Transit	4088.01	1	Transit
3721.01	1	Transit	3827.01	1	Transit	3951.01	1	Transit	4092.01	1	Transit
3726.01	1	Eclipse	3829.01	2	Transit	3952.01	2	Eclipse	4103.01	2	Transit
3727.01	1	Transit	3835.01	2	Eclipse	3955.01	1	Eclipse	4104.01	1	Eclipse
3731.01	1	Transit	3837.01	1	Transit	3958.01	1	Transit	4116.01	1	Eclipse
3732.01	1	Eclipse	3842.01	2	Transit	3960.01	1	Transit	4118.01	1	Transit
3733.01	2	Eclipse	3845.01	1	Eclipse	3962.01	1	Eclipse	4121.01	2	Eclipse
3735.01	2	Transit	3847.01	1	Transit	3965.01	2	Eclipse	4124.01	2	Eclipse
3736.01	1	Eclipse	3848.01	1	Transit	3972.01	2	Transit	4127.01	1	Transit
3737.01	2	Eclipse	3849.01	2	Eclipse	3976.01	1	Transit	4129.01	1	Transit
3738.01	1	Transit	3850.01	1	Transit	3977.01	2	Transit	4130.01	1	Transit
3741.01	2	Eclipse	3852.01	1	Transit	3980.01	1	Transit	4131.01	1	Transit
3745.01	1	Transit	3855.01	1	Transit	3984.01	1	Transit	4137.01	2	Eclipse
3746.01	1	Transit	3856.01	2	Eclipse	3986.01	1	Eclipse	4140.01	2	Transit
3749.01	1	Eclipse	3857.01	1	Transit	3988.01	1	Eclipse	4144.01	2	Transit
3750.01	1	Transit	3862.01	1	Transit	3991.01	1	Eclipse	4147.01	1	Transit

Table 4
(Continued)

TOI	Tier	Method	TOI	Tier	Method	TOI	Tier	Method	TOI	Tier	Method
3751.01	1	Transit	3863.01	1	Transit	3998.01	2	Eclipse	4149.01	1	Transit
3754.01	1	Eclipse	3866.01	1	Transit	4000.01	2	Eclipse	4153.01	2	Eclipse
3755.01	1	Transit	3868.01	1	Transit	4002.01	1	Eclipse	4160.01	1	Transit
3756.01	1	Transit	3870.01	1	Transit	4003.01	1	Transit	4162.01	2	Eclipse
3758.01	2	Eclipse	3871.01	1	Transit	4007.01	2	Transit	4168.01	1	Transit
3763.01	2	Eclipse	3872.01	1	Transit	4010.01	1	Transit	4170.01	2	Eclipse
3764.01	1	Eclipse	3877.01	1	Transit	4010.02	1	Transit	4173.01	1	Transit
3765.01	2	Eclipse	3881.01	1	Transit	4012.01	2	Transit	4176.01	3	Eclipse
3767.01	2	Eclipse	3883.01	2	Transit	4013.01	1	Eclipse	4177.01	2	Eclipse
3768.01	1	Eclipse	3884.01	2	Transit	4014.01	1	Transit	4180.01	1	Transit
3769.01	2	Transit	3888.01	1	Transit	4015.01	2	Eclipse	4186.01	1	Transit
3772.01	1	Transit	3889.01	2	Transit	4029.01	1	Transit	4188.01	2	Transit
3778.01	1	Transit	3892.01	2	Transit	4034.01	2	Eclipse	4193.01	1	Transit
3780.01	2	Eclipse	3894.01	2	Eclipse	4041.01	2	Transit	4196.01	2	Eclipse
3781.01	1	Transit	3900.01	1	Transit	4043.01	1	Transit	4197.01	2	Transit
3785.01	1	Transit	3905.01	1	Transit	4044.01	1	Transit	4198.01	1	Transit
3786.01	1	Eclipse	3907.01	1	Transit	4047.01	1	Transit	4199.01	2	Eclipse
3788.01	2	Eclipse	3909.01	1	Transit	4056.01	1	Transit	4201.01	2	Transit
4204.01	1	Transit	4406.01	1	Transit	4603.01	1	Transit	4823.01	2	Eclipse
4205.01	2	Transit	4409.01	1	Transit	4605.01	2	Transit	4826.01	1	Transit
4207.01	1	Eclipse	4412.01	1	Transit	4609.01	3	Eclipse	4831.01	1	Eclipse
4209.01	1	Eclipse	4416.01	2	Eclipse	4615.01	2	Eclipse	4833.01	1	Transit
4214.01	2	Eclipse	4417.01	1	Transit	4617.01	2	Eclipse	4836.01	1	Transit
4218.01	1	Eclipse	4422.01	2	Eclipse	4626.01	1	Transit	4841.01	1	Transit
4223.01	1	Transit	4423.01	1	Transit	4635.01	2	Transit	4844.01	1	Transit
4224.01	1	Eclipse	4425.01	2	Transit	4641.01	2	Transit	4846.01	1	Transit
4236.01	2	Eclipse	4427.01	2	Transit	4642.01	1	Transit	4849.01	1	Transit
4242.01	1	Eclipse	4429.01	1	Transit	4645.01	3	Eclipse	4852.01	1	Transit
4243.01	1	Eclipse	4436.01	3	Eclipse	4646.01	2	Transit	4871.01	1	Eclipse
4245.01	1	Transit	4438.01	1	Transit	4652.01	1	Transit	4877.01	1	Transit
4246.01	1	Transit	4441.01	2	Eclipse	4660.01	2	Eclipse	4882.01	1	Transit
4247.01	1	Eclipse	4443.01	1	Transit	4663.01	1	Transit	4887.01	1	Transit
4248.01	1	Eclipse	4451.01	2	Transit	4664.01	1	Transit	4890.01	2	Eclipse
4251.01	1	Eclipse	4458.01	1	Eclipse	4666.01	2	Transit	4899.01	1	Eclipse
4252.01	1	Transit	4461.01	2	Transit	4672.01	1	Eclipse	4903.01	1	Transit
4254.01	1	Eclipse	4462.01	1	Eclipse	4678.01	1	Transit	4909.01	2	Eclipse
4262.01	2	Transit	4468.01	1	Transit	4702.01	2	Eclipse	4911.01	1	Transit
4272.01	1	Transit	4477.01	2	Eclipse	4707.01	1	Eclipse	4914.01	1	Transit
4273.01	1	Eclipse	4478.01	1	Transit	4719.01	2	Transit	4917.01	2	Transit
4274.01	2	Eclipse	4481.01	2	Transit	4721.01	1	Transit	4920.01	1	Transit
4279.01	2	Eclipse	4487.01	2	Eclipse	4726.01	2	Transit	4921.01	1	Transit
4280.01	1	Transit	4491.01	1	Transit	4727.01	1	Eclipse	4928.01	1	Eclipse
4283.01	2	Eclipse	4492.01	3	Transit	4728.01	2	Transit	4929.01	1	Transit
4289.01	2	Eclipse	4495.01	1	Transit	4730.01	1	Transit	4934.01	1	Transit
4292.01	1	Transit	4504.01	1	Transit	4738.01	1	Eclipse	4935.01	1	Transit
4293.01	2	Eclipse	4505.01	2	Eclipse	4739.01	2	Eclipse	4938.01	2	Transit
4324.01	1	Transit	4507.01	1	Transit	4749.01	2	Eclipse	4941.01	1	Transit
4327.01	1	Transit	4515.01	2	Transit	4750.01	1	Transit	4946.01	1	Transit
4329.01	2	Eclipse	4527.01	2	Transit	4754.01	1	Transit	4947.01	1	Transit
4330.01	3	Eclipse	4529.01	1	Transit	4766.01	2	Eclipse	4949.01	2	Eclipse
4335.01	2	Eclipse	4537.01	1	Transit	4768.01	2	Eclipse	4950.01	1	Transit
4336.01	1	Transit	4546.01	2	Eclipse	4770.01	1	Eclipse	4951.01	1	Transit
4341.01	1	Transit	4548.01	1	Transit	4771.01	1	Transit	4960.01	2	Eclipse
4342.01	1	Transit	4552.01	1	Transit	4773.01	1	Eclipse	4961.01	2	Transit
4364.01	1	Transit	4553.01	2	Transit	4775.01	2	Eclipse	4968.01	1	Eclipse
4377.01	2	Eclipse	4557.01	1	Transit	4776.01	1	Transit	4969.01	1	Transit
4379.01	2	Eclipse	4559.01	1	Transit	4778.01	1	Transit	4970.01	1	Transit
4381.01	3	Eclipse	4564.01	2	Transit	4784.01	1	Transit	4972.01	1	Transit
4384.01	1	Transit	4576.01	1	Transit	4787.01	1	Transit	4977.01	1	Transit
4385.01	1	Eclipse	4596.01	1	Transit	4788.01	1	Transit	4979.01	1	Transit
4386.01	1	Transit	4597.01	3	Eclipse	4791.01	2	Eclipse	4981.01	2	Eclipse
4387.01	2	Eclipse	4598.01	1	Transit	4792.01	1	Transit	4987.01	2	Eclipse
4394.01	1	Eclipse	4599.01	2	Transit	4794.01	1	Transit	4994.01	1	Transit

Table 4
(Continued)

TOI	Tier	Method	TOI	Tier	Method	TOI	Tier	Method	TOI	Tier	Method
4395.01	1	Transit	4599.02	3	Transit	4798.01	1	Transit	4998.01	1	Transit
4399.01	1	Transit	4600.01	1	Transit	4811.01	2	Eclipse	4999.01	1	Transit
4400.01	2	Eclipse	4602.01	1	Transit	4822.01	1	Eclipse	5001.01	1	Transit
5003.01	1	Transit	5148.01	2	Eclipse	5263.01	1	Eclipse	5371.01	2	Eclipse
5004.01	1	Transit	5149.01	1	Eclipse	5264.01	2	Eclipse	5375.01	2	Transit
5005.01	1	Transit	5150.01	2	Eclipse	5266.01	1	Eclipse	5378.01	1	Eclipse
5007.01	1	Transit	5153.01	1	Transit	5269.01	1	Transit	5379.01	2	Eclipse
5008.01	1	Transit	5169.01	1	Transit	5270.01	1	Eclipse	5383.01	2	Transit
5009.01	1	Eclipse	5172.01	1	Transit	5273.01	1	Transit	5385.01	2	Eclipse
5015.01	2	Eclipse	5174.01	1	Transit	5276.01	1	Eclipse	5386.01	2	Eclipse
5019.01	1	Transit	5179.01	1	Eclipse	5285.01	2	Transit	5387.01	1	Transit
5022.01	1	Transit	5180.01	1	Eclipse	5287.01	2	Eclipse	5388.01	1	Transit
5025.01	1	Eclipse	5181.01	1	Eclipse	5288.01	2	Transit	5390.01	1	Transit
5026.01	1	Transit	5185.01	1	Eclipse	5291.01	1	Transit	5398.01	3	Transit
5028.01	1	Eclipse	5186.01	2	Eclipse	5295.01	1	Transit	5398.02	1	Transit
5029.01	2	Transit	5189.01	1	Transit	5296.01	2	Transit	5401.01	3	Eclipse
5035.01	1	Transit	5190.01	1	Transit	5297.01	1	Transit	5403.01	1	Transit
5038.01	2	Eclipse	5191.01	2	Eclipse	5298.01	1	Transit	5404.01	1	Transit
5043.01	2	Eclipse	5195.01	1	Eclipse	5299.01	1	Eclipse	5408.01	1	Eclipse
5044.01	1	Transit	5196.01	1	Transit	5300.01	2	Transit	5410.01	1	Transit
5047.01	2	Transit	5197.01	1	Transit	5301.01	1	Transit	5412.01	2	Eclipse
5048.01	1	Eclipse	5198.01	1	Transit	5302.01	1	Transit	5416.01	1	Transit
5049.01	1	Transit	5204.01	1	Eclipse	5305.01	1	Transit	5417.01	1	Eclipse
5051.01	2	Eclipse	5205.01	2	Transit	5307.01	1	Transit	5422.01	1	Transit
5052.01	2	Eclipse	5207.01	1	Transit	5308.01	2	Eclipse	5427.01	2	Eclipse
5053.01	2	Transit	5208.01	1	Transit	5310.01	1	Transit	5432.01	1	Eclipse
5054.01	1	Transit	5209.01	2	Transit	5314.01	1	Transit	5438.01	1	Transit
5056.01	1	Transit	5210.01	2	Transit	5319.01	1	Transit	5440.01	1	Transit
5057.01	2	Eclipse	5211.01	1	Eclipse	5321.01	1	Eclipse	5448.01	1	Transit
5059.01	2	Transit	5217.01	1	Eclipse	5322.01	2	Eclipse	5451.01	1	Eclipse
5060.01	1	Eclipse	5220.01	1	Eclipse	5323.01	1	Eclipse	5452.01	1	Eclipse
5066.01	1	Transit	5222.01	1	Transit	5324.01	1	Transit	5466.01	1	Eclipse
5070.01	1	Transit	5226.01	2	Eclipse	5326.01	1	Transit	5467.01	1	Transit
5075.01	1	Transit	5227.01	1	Transit	5327.01	2	Transit	5472.01	1	Transit
5076.01	1	Transit	5230.01	1	Transit	5328.01	2	Eclipse	5474.01	1	Transit
5079.01	1	Transit	5231.01	1	Eclipse	5330.01	1	Transit	5477.01	1	Transit
5082.01	2	Transit	5232.01	1	Transit	5331.01	1	Transit	5483.01	1	Eclipse
5088.01	2	Transit	5235.01	1	Transit	5334.01	1	Transit	5484.01	1	Transit
5091.01	2	Eclipse	5237.01	1	Eclipse	5337.01	1	Eclipse	5486.01	1	Transit
5092.01	1	Transit	5240.01	1	Eclipse	5338.01	1	Eclipse	5492.01	1	Transit
5099.01	2	Transit	5241.01	1	Transit	5339.01	1	Transit	5493.01	1	Transit
5100.01	2	Eclipse	5242.01	1	Transit	5340.01	1	Transit	5494.01	1	Transit
5108.01	2	Transit	5246.01	1	Eclipse	5341.01	1	Transit	5496.01	1	Transit
5109.01	1	Eclipse	5248.01	1	Eclipse	5342.01	1	Eclipse	5498.01	1	Transit
5110.01	1	Transit	5249.01	1	Transit	5344.01	1	Transit	5499.01	1	Transit
5112.01	1	Transit	5250.01	1	Eclipse	5350.01	2	Transit	5500.01	2	Eclipse
5120.01	2	Transit	5251.01	1	Eclipse	5354.01	1	Transit	5505.01	1	Transit
5124.01	1	Eclipse	5254.01	1	Eclipse	5355.01	1	Transit	5507.01	1	Transit
5126.01	1	Transit	5255.01	1	Transit	5357.01	1	Transit	5510.01	2	Eclipse
5128.01	2	Transit	5259.01	1	Transit	5364.01	1	Eclipse	5511.01	1	Transit
5143.01	2	Transit	5261.01	1	Transit	5368.01	1	Eclipse	5512.01	1	Transit
5518.01	2	Transit	5540.01	3	Eclipse						

Note. The list will continue to evolve as TESS discovers more potential planets.

studies, particularly those of smaller worlds, will influence the choices made to ensure that the scientific yield of Ariel is maximized.

While thus far, we have assumed that 1000 planets would be studied in tier 1, this is by no means fixed. We varied the number of tier 1 planets studied, experimenting with the impact this would have on the number of targets that could be observed in tier 2. Assuming that at least 500 planets are required in tier 2, it could be possible to study around 1350 planets from the list derived here during the primary mission life. Reducing the required number of tier 1 targets increases the time available for tier 2, but the returns are quickly diminishing. The optimal strategy, purely from an efficiency perspective, occurs when the change in the gradient is sharpest.

From Figure 15, this is currently at around 1050 tier 1 planets, which corresponds to 595 tier 2 targets if one assumes that 10% of the Ariel science time is reserved for tier 4 and complementary science. These numbers are based on a 4 yr primary mission life, but if a 2 yr extension were granted and the time utilized to extend the observing strategy of the primary mission life, we could potential study a far greater number of worlds. However, the results from the primary mission may suggest alternative lines of inquiry. The tiering system of Ariel has been designed to account for our general lack of knowledge around the properties of exoplanet atmospheres and their correlation with the bulk characteristics of a system. Given that the primary mission will provide us with the first demographic study of exoplanet atmospheres, the extended mission could then be utilized to study specific populations of interest. The strategy could involve delving deep into trends uncovered in the prime mission, giving extra time to targets or correlations that were not fully explored, conducting more time-intensive observations, or pursuing observing strategies that are high risk/high reward.

In reality, the Ariel Mission Consortium (AMC) and Ariel Science Team (AST) will decide the observing plan of Ariel based upon the scientific yield, which is dependent upon a number of parameters, many of which are qualitative in nature. Studies of the impact of altering the number of planets in each tier will be required, with population-level studies needed to ascertain the science loss/gain from adopting different strategies (e.g., Changeat et al. 2020a; Mugnai et al. 2021a). While not discussed here, Ariel has a fourth tier to account for targets or observations that do not fit into the main structure of the survey. Much of this time might be dedicated to exoplanet phase curves, observing a planet throughout its entire orbit (e.g., Stevenson et al. 2017; Changeat et al. 2021a; Dang et al. 2022; May et al. 2021), and studies are underway to find the best targets for phase curve studies with Ariel (Charnay et al. 2021; Moses et al. 2021). Additionally, this time could be utilized to observe small, rocky worlds that may host secondary atmospheres, as outlined in E19. Further in-depth studies of Ariel's capabilities across specific populations will be needed (e.g., Encrenaz et al. 2021; Ito et al. 2021) to provide meaningful constraints on the potential science yield. These studies, alongside community engagement, will act as guides for the AMC and AST as they construct an ideal MCS. The final MCS will be endorsed by the AST and reviewed under the responsibility of the ESA Advisory Structure before launch. More details on this procedure can be found in the Ariel Science Management Plan.

The confirmed planets and TPCs that are considered potential targets for Ariel using the methodology described here are given in Tables 3 and 4. To guide the studies described above and facilitate engagement with the wider community, an Ariel Target List website, which will be maintained by the AMC, is being constructed (A. Al-Refaie 2022, in preparation). The site will allow users to keep track of all of the planets that are potential viable targets for Ariel, motivating further preliminary follow-up, as well as theoretical studies of Ariel's capabilities. Through this collaborative platform, we hope to ensure that the Ariel mission delivers data sets of value to the entire extrasolar community and that their interests are reflected in the final observing strategy.

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Software: ArielRad (Mugnai et al. 2020), TauREx3 (Al-Refaie et al. 2021b), TauREx3 ACE plug-in (Venot & Agúndez 2015; Al-Refaie et al. 2021a), Astropy (Astropy Collaboration et al. 2018), h5py (Collette 2013), Matplotlib (Hunter 2007), Multinest (Feroz et al. 2009; Buchner et al. 2014), Pandas (McKinney 2010), Numpy (Oliphant 2006), SciPy (Virtanen et al. 2020), corner (Foreman-Mackey 2016).

Linelists: H_2O (Polyansky et al. 2018), CH_4 (Yurchenko & Tennyson 2014), CO (Li et al. 2015), CO_2 (Rothman et al. 2010), CIA (Abel et al. 2011, 2012; Fletcher et al. 2018).

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