Observability of temperate exoplanets with ARIEL

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Abstract

- The first objective of the ARIEL mission is to characterize all kinds of exoplanets with a temperature higher than 500 K.
- In this study, we address the following question: under which conditions could a temperate exoplanet, with equilibrium temperatures of 350-500 K, be detectable with ARIEL ?
- We first consider a temperate Jupiter. Its infrared transmission spectrum of a temperate Jupiter is calculated, and its expected amplitude signal through a primary transit is estimated for several classes of stars.
- Calculations show that temperate Jupiters around M stars could have an amplitude signal higher than 10^{-4} in primary transits, with revolution periods of a few tens of days and transit durations of a few hours.
- In order to enlarge the sampling of exoplanets to be observed with ARIEL, such objects could be considered as additional possible targets for the mission.
- In a next step, we will consider the conditions of observability for temperate super-Earths (ex: TRAPPIST-1 b)
- This study is a follow-up of "Transit spectroscopy of temperate Jupiters with ARIEL: A feasibility study" (Exp. Astr. 46:31-44, 2018)

A typical transmission spectrum for a temperate Jupiter

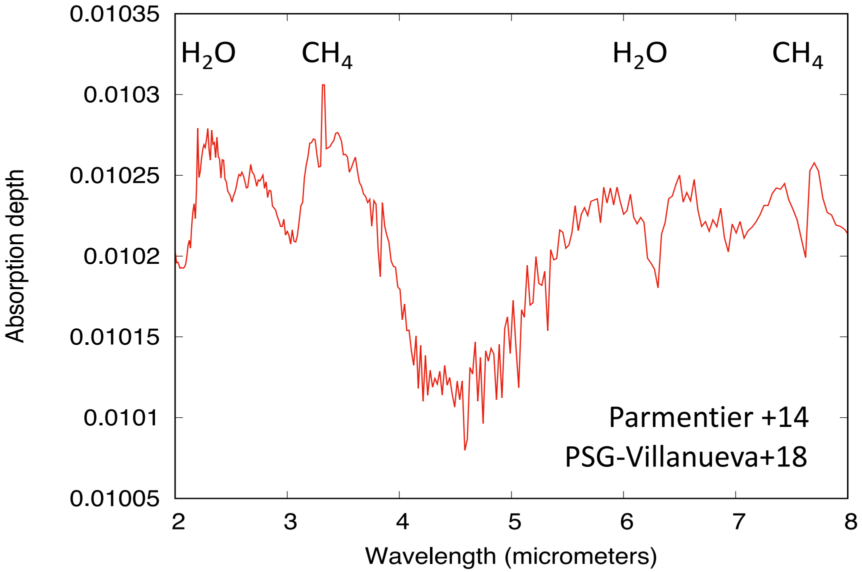

Table 2

Estimated semi-major axis (D), rotational period (P), amplitude of primary transit signal (A) and transit time (t) for a Jovian-like exoplanet transiting around a star of spectral type between G2 and M8, with an albedo a = 0.03, assuming either a fast rotator (columns 6 and 8) or a tidally locked object (columns 7 and 9).
Two cases are considered: T_P = 350 K and T_P = 500 K. The fast rotator case is favoured for G2 to M0 stars (M0 stars are actually an intermediate case); the tidally locked object case is favoured for M5 and M8 stars.

1	2	3	4	5	6	7	8	9	10	11
Spectral type	R (Rs)	M (Ms)	L (Ls)	T* (K)	D (AU) fast rot.	D (AU) slow rot.	P(d) fast rot.	P(d) slow rot.	A	Transit time (h)
G2 (T_P= 350 K) G2 (T_P= 500 K)	1.0	1.0	1.0	5770	**0.625** **0.306**	0.880 0.431	**180** **61**	301 103	6.78 10^{-5} 9.69 10^{-5}	**10.3** **7.1**
G5 (T_P= 350 K) G5 (T_P= 500 K)	0.93	0.93	0.79	5641	**0.561** **0.274**	0.790 0.386	**159** **54**	266 91	7.84 10^{-5} 1.12 10^{-4}	**9.4** **6.6**
K0 (T_P= 350 K) K0 (T_P= 500 K)	0.85	0.78	0.40	4977	**0.431** **0.211**	0.607 0.297	**117** **40**	195 67	9.38 10^{-5} 1.34 10^{-4}	**8.3** **5.8**
K5 (T_P= 350 K) K5 (T_P= 500 K)	0.74	0.69	0.16	4242	**0.358** **0.175**	0.504 0.246	**94** **32**	157 54	1.24 10^{-4} 1.77 10^{-4}	**7.0** **4.9**
M0(T_P= 350 K) M0(T_P= 500 K)	0.63	0.47	0.063	3642	**0.201** **0.099**	0.282 0.139	**48** **17**	80 28	1.71 10^{-4} 2.44 10^{-4}	**5.4** **3.9**
M5(T_P= 350 K) M5(T_P= 500 K)	0.32	0.21	0.008	3041	0.06 0.03	**0.08** **0.04**	12 4	**18** **6**	6.64 10^{-4} 9.50 10^{-4}	**2.6** **1.7**
M8(T_P= 350 K) M8(T_P= 500 K)	0.13	0.10	0.001	2691	0.02 0.01	**0.03** **0.015**	3 1	**6** **2**	3.98 10^{-3} 5.70 10^{-3}	**1.0** **0.6**

Sensitivity study

We use as a calibrator the exoplanet WASP-76 b (0.92 M_J, 1.83 R_J, Te = 2200 K, d = 0.033 AU, period = 1.81 d, A = 10^{-3}, t = 3.4 h. A summation of 25 transits (corresponding to 85 hours of total observing time) is needed to achieve a S/N of about 10 for the nominal ARIEL spectral resolution (100 @ 2-4 µm, 30 @ 4-8 µm).

Table 3

(1) Estimated S/N in 100h of integrating time; (2) number of transits required to obtain 100 hours of integration time on a temperate Jupiter (T = 400 K); (3) total time required to accumulate these transits; (4) Estimated distance of the star for Φ(*)=Φ(WASP-76).

				(1)				(2)	(3)	(4)
Etoile	T* (K)	R* (Rsol)	A	S/N in 100 hours	a (AU)	Period (day)	t(h)	Nb of transits	Total time needed for tint = 100 h (days/year)	Distance for F(*) = F(WASP-76)(pc)
WASP-76	6250	1.73	1 (-3)	12	0.03	1.81	3.4	30	54/0.15	120
G2	5770	1.00	0.8(-4)	1.0	0.47	118	9.0	11	1298/3.56	111
G5	5641	0.93	0.9(-4)	1.1	0.43	110	8.5	12	1320/3.61	100
K0	4977	0.85	1.2(-4)	1.4	0.33	88	8.1	13	1144/3.13	80
K5	4242	0.74	1.3(-4)	1.6	0.27	74	7.3	14	1036/2.84	50
M0	3642	0.63	2.0(-4)	2.4	0.15	45	6.8	15	675/1.85	45
M5	3041	0.32	7.0(-4)	8.4	0.06	25	4.8	21	525/1.44	17
M8	2691	0.13	4.8(-3)	58	0.02	10	2.3	44	440/1.20	7

It can be seen that all classes of objects can be considered within a lifetime of 3 years; however, temperate Jupiters around M5 to M8 dwarfs should be favoured for a higher S/N ratio and a shorter required time of observation. Degrading the spectral resolution will be needed to increase the S/N for M0 stars and to enlarge the distance of observable M5 and M8 stars.