Tamap Journal of Physical Science
http://www.tamap.org/

TJOPS-2005-28
Volume 2020, Article ID 1
Research Article

Radius Study of Ten Transiting Hot Jupiter Exoplanets with Ground-Based Observations

Fatemeh DAVOUDI[1], Atila PORO[1,*], Ehsan PAKI[2], Pegah MIRSHAFIE[2], Farzaneh AHANGARANI FARAHANI[2], Ahmad FARAHANI[1], Mojtaba ROSHANA[2], Faezeh ABOLHASANI[2], Shiva ZAMANPOUR[2], Elaheh LASHGARI[1], Sima MODARRES[1], and Amirreza MOHANDES[2]

[1] *International Occultation Timing Association (IOTA) - Middle East Section, Tehran, IRAN*
[2] *Exoplanet Transit Project (ETP), Transit department, IOTA-ME, Iran*

Received: 11.05.2020 • **Accepted**: 25.05.2020 • **Published Online:** 28.05.2020

Abstract: In this research, 14 light curves of 10 hot Jupiter exoplanets available on Exoplanet Transit Database (ETD) were analyzed. We extracted the transit parameters using EXOFAST software. Finally, we compared the planet's radius parameter calculated by the EXOFAST with the value at the NASA Exoplanet Archive (NEA) using the confidence interval method. According to the results obtained from this comparison, there is an acceptable match for the planet's radius with NEA values. Also, based on the average value of 350 mm optics in this study, it shows that the results obtained using small telescopes can be very significant if there is appropriate observational skill to study more discovered planets.

Keywords: Photometry, Exofast, Hot Jupiter, NEA

1. INTRODUCTION

Throughout the transit of an exoplanet passing in front of the disk of its' host star, it blocks a small portion of light from the star with the change in flux at mid-transit known as the transit depth [1]. Therefore, photometric observation of transit and the data of the transit light curve can then be used to deduce the orbital and physical parameters of the exoplanets. Ground-based observations have great scientific potential in the discovery of new exoplanets and also have the follow-up potential in providing system parameters as well as mid-transit times [2].

It is possible to get ground-based observation raw data from Exoplanet Transit Database (ETD)[†] that is preserved by the Czech Astronomical Society (CAS). The ETD has been established to collect all available transit data with different qualities which then classify them. This online portal provides some useful information for observers such as time of the transit start, center, end, duration, and the depth of each transit that named as transit prediction. Moreover, it has an algorithm for processing photometric data which fits them to a light curve. The planetary transit measured in the light curve is mostly described by three parameters: depth, duration, and its' mid-transit time [3].

Throughout this study, we investigated 10 exoplanets and their light curves in proportion to the ETD. The exoplanets that we chose to discuss in this paper are alone in their planetary system or have distant companions. They also all belong to hot Jupiter type planets with an apparent magnitude between 9.8 and 14.07. We have studied Corot-12 b [4], HAT-P-52 b [5], HAT-P-57 b [6], HATS-28 b [7], HATS-34 [8], KELT-3 b [9], WASP-61 b [10], WASP-67 b [10], WASP-122 b [11] and WASP-140 b [12], their detections are primary transit and their light curves are taken from ETD.

We know hot Jupiter as a class of giant gassy exoplanets. They are the easiest planets to detect because of their large size (with masses greater than or equal to 0.25 Jupiter mass) and short orbital period (with period between 0.8 - 6.3

[*] Correspondence: info@iota-me.com
[†] http://var2.astro.cz/ETD/

days [13]. There are several mechanisms to explain some of the observational properties of hot Jupiters. The main properties can be summarized as follows: a) orbital periods about three days, b) variety of obliquity, c) solitary host stars, d) distinct mass functions from other types of exoplanets, e) narrow range of stellar mass**.** For more information about the hot Jupiters, you can refer to the following paper [14].

The ETD adopts the parameter uncertainties from a Levenberg-Marquardt optimization algorithm [3], which is believed to be unreliable in the presence of parameter correlations [15]. So we reanalyzed ETD light curves using an exact method. The activity described in this study is done in two sections. In the first part, we chose some exoplanets and then analyzed and reduced observational data from their light curves. In the next section, we compared values of the output parameters of planets from a web-based tool (A Fast Exoplanetary Fitting Suite in IDL) with the parameters from the Extrasolar Planets Encyclopedia[‡] database. EXOFAST[§] as a fast transit parameter fitter takes flux and time in BJD_{TDB} (Barycentric Julian Dates in Barycentric Dynamical *Time*) as inputs and provides Stellar, planetary, and primary transit parameters.

EXOFAST is an IDL library for transit and radial velocity modeling and portrays the parameter uncertainties with a differential evolution Markov Chain Monte Carlo method (MCMC), which is presented by Eastman, Gaudi, and Agol [16]. The authors acquire noteworthy improvement in the evolution speed of the quadratic MA model by swapping the modern way including the calculation of elliptic of integral of the third kind with a faster one. The transit method has been highly significant for this revolution. It can be utilized to find out orbital inclination, planet radius, mass, and average density of the planet [17][18][20][21]. Moreover, we can obtain some information about their atmospheres [22][23], thermal emission [20][24], and also provide a probe of exoplanetary structures [25][26].

2. OBSERVATION

The first step to derive the orbital and physical parameters of exoplanets is observation. In this project, we collected light curves of ground-based observations that are available on the ETD website. So, we found the raw dataset of the exoplanets and then data reduction was done.

Star Name	RA_{2000}	Dec_{2000}	D. (pc)	Spect.	App. Mag.	Planet	Discovered
CoRoT-12	06 43 03.76	-01 17 47.14	1150	G2V	15.52	CoRoT-12 b	2010
HAT-P-52	02 50 53.20	+29 01 20.52	385	-	14.07	HAT-P-52 b	2015
HAT-P-57	18 18 58.42	+10 35 50.12	303	-	10.47	HAT-P-57 b	2015
HATS-28	18 57 35.92	-49 08 18.55	521	G	-	HATS-28 b	2016
HATS-34	00 03 05.87	-62 28 09.61	532	-	13. 85	HATS-34 b	2016
KELT-3	09 54 34.38	+40 23 16.97	178	F	9.8	KELT-3 b	2012
WASP-61	05 01 11.91	-26 03 14.96	480	F7	12.5	WASP-61 b	2011
WASP-67	19 42 58.52	-19 56 58.52	225	K0V	12.5	WASP-67 b	2011
WASP-122	07 13 12.35	-42 24 35.11	251.93	G4	11.0	WASP-122 b	2015
WASP-140	04 01 32.54	-20 27 03.91	180	K0	11.1	WASP-140 b	2016

Table-1. Specifications of the host stars and the planets. All of these exoplanets detected by Primary Transit method.

In Table 1, we present the characteristics of the host stars and the planets, which is based on the Extrasolar Planets Encyclopaedia. We put the observation's information in Table 2 which includes the planet's name, the planet's celestial coordinates (Right Ascension (RA.) and Declination (Dec.)), the observer's name and the date on which the mid-transit happened. Also, we put some information about the observation tools the observers used to collect the exoplanet's transit data; they include optical telescope which we wrote its' optic size, Charged Couple Device (CCD) model and also the filter which is used up to the observer's choice.

[‡] http://exoplanet.eu/
[§] https://exoplanetarchive.ipac.caltech.edu/cgi-bin/ExoFAST/nph-exofast

Planet	RA_{2000} - DEC_{2000}	Observer	Observation date	Filter	Optic size (mm)	CCD
CoRot-12 b	06:43:03.76 -01:17:47.14	F. Grau Horta	2014-12-23	R	305	FLI PL1001E-1
HAT-P-52 b	02:50:53.20 29:01:20.52	F. Campos	2018-01-21	Clear	350	ST-8XME
HAT-P-52 b	02:50:53.20 29:01:20.52	R. Naves	2016-12-02	Clear	305	Moravian G4
HAT-P-52 b	02:50:53.20 29:01:20.52	Y. Jongen	2019-01-03	Clear	425	STLX11002
HAT-P-57 b	18:18:58.43 10:35:50.13	A. Wünsche	2019-06-29	V	820	FLI PL230
HAT-P-57 b	18:18:58.43 10:35:50.13	F. Lomoz	2019-07-03	V	300	ST2000XM
HATS-28 b	18:57:35.93 -49:08:18.56	P. Evans	2016-07-02	Clear	250	ST9XE
HATS-34 b	00:03:05.87 -62:28:09.62	Y. Jongen	2020-01-23	Clear	425	Moravian 4G
KELT-3 b	09:54:34.38 40:23:16.98	A. Ayiomamitis	2013-03-09	Clear	305	ST-10XME
KELT-3 b	09:54:34.38 40:23:16.98	S. Gudmundsson	2014-02-27	Clear	300	STL-11k
WASP-61 b	05:01:11.92 -26:03:14.97	C. Quiñones, et al.	2014-10-19	B	1540	-
WASP-67 b	19:42:58.52 -19:56:58.52	P. Evans	2014-05-20	Clear	250	ST9XE
WASP-122 b	07:13:12.35 -42:24:35.12	Y. Jongen	2020-01-14	V	425	Moravian 4G
WASP-140 b	04:01:32.55 -20:27:03.91	F. Lomoz	2017-01-01	Clear	254	G2-8300

Table-2. Initial data information for planets.

3. METHOD AND ANALYSIS

We used the raw data for 10 exoplanets that consist of three columns of time in Julian Dates (JD) or Heliocentric Julian Dates (HJD), Delta Magnitude, and its' error. JD or HJD time frame was converted to BJD _TDB through Time Utilities[**], applying RA, DEC of the host star from the Simbad website[††]. Then we used Phoebe software to turn Delta Magnitude to normalized flux.

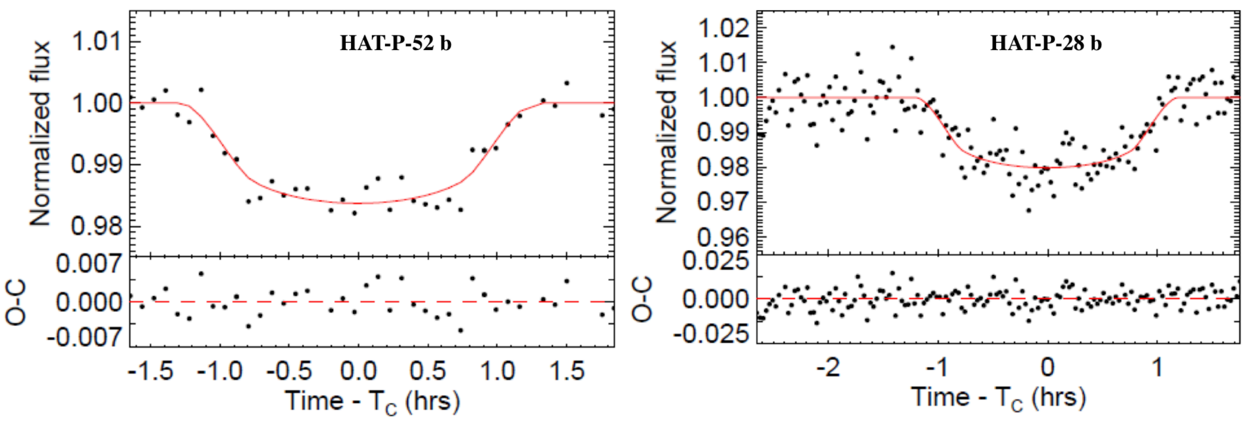


Figure-1. The observational and theatrical light curves of HAT-P-52 b (left) and HAT-P-28 b (right) extracted by EXOFAST software.

We prepared a file including time in BJD_{TDB}, Flux, and its' Error and then used it as an input for EXOFAST. After importing the data file to EXOFAST, the filter type of each observation was selected. Then, we disabled the Include all Detrending Columns section. Three parameters of metallicity, effective temperature, and Log g are necessary for EXOFAST. EXOFAST has done the best fit on light curves (Figure 1) and calculated the parameters of transit based on the given data. The whole light curves were displayed in the Appendix. The horizontal axis is Time (BJD_{TDB})-T_c based on hours. The vertical axis in the top panel is based on the normalized flux of the star and the O-C which means the residuals between observed and fitted data points.

[**]http://astroutils.astronomy.ohio-state.edu/time/
[††]http://simbad.u-strasbg.fr/simbad/

Planets	$R_P(R_J)$	K	$T_C(BJD_{TDB})$	T_{FWHM}	δ	τ
CoRot-12 b	1.8058 (±0.2109)	0.1685 (±0.0055)	2457014.58 (±0.0022)	0.1055 (±0.0045)	0.0284 (±0.0018)	0.0223 (±0.0078)
HAT-P-52 b	1.0964 (±0.0750)	0.1241 (±0.0021)	2458140.343 (±0.0010)	0.0852 (±0.0020)	0.0154 (±0.0005)	0.0206 (±0.0034)
HAT-P-52 b	1.1418 (±0.0874)	0.1293 (±0.0032)	2457724.553 (±0.0012)	0.0950 (±0.0024)	0.0167 (±0.0008)	0.0123 (±0.0042)
HAT-P-52 b	0.8778 (±0.0687)	0.0994 (±0.0026)	2458520.336 (±0.0009)	0.0754 (±0.0018)	0.0098 (±0.0005)	0.0081 (±0.0032)
HAT-P-57 b	1.2333 (±0.0602)	0.0937 (±0.0010)	2458663.509 (±0.0006)	0.1398 (±0.0013)	0.0087 (±0.0002)	0.0132 (±0.0022)
HAT-P-57 b	1.4751 (±0.1124)	0.1122 (±0.0039)	2458668.44 (±0.0023)	0.1353 (±0.0045)	0.0126 (±0.0009)	0.0153 (±0.0079)
HATS-28 b	1.2139 (±0.0750)	0.1337 (±0.0025)	2457571.884 (±0.0010)	0.0822 (±0.0020)	0.0179 (±0.0006)	0.0171 (±0.0035)
HATS-34 b	1.3289 (±0.0950)	0.1364 (±0.0034)	2458871.602 (±0.0013)	0.0315 (±0.0026)	0.0186 (±0.0009)	0.0315 (±0.0046)
KELT-3 b	1.4832 (±0.0747)	0.1023 (±0.0007)	2457126.464 (±0.0005)	0.1157 (±0.0011)	0.0104 (±0.0001)	0.0235 (±0.0019)
KELT-3 b	1.3706 (±0.1032)	0.0945 (±0.0030)	2456715.552 (±0.0019)	0.1092 (±0.0038)	0.0089 (±0.0005)	0.0155 (±0.0066)
WASP-61 b	1.1478 (±0.0474)	0.0873 (±0.0016)	2456950.747 (±0.0013)	0.1612 (±0.0025)	0.0076 (±0.0003)	0.0141 (±0.0044)
WASP-67 b	0.9970 (±0.0676)	0.0986 (±0.0034)	2456798.021 (±0.0009)	0.0619 (±0.0019)	0.0097 (±0.0007)	0.0061 (±0.0033)
WASP-122 b	1.7442 (±0.0802)	0.1208 (±0.0013)	2458862.643 (±0.0007)	0.0508 (±0.0013)	0.0146 (±0.0003)	0.0390 (±0.0024)
WASP-140 b	1.1990 (±0.0735)	0.1406 (±0.0022)	2457755.319 (±0.0006)	0.0423 (±0.0012)	0.0197 (±0.0006)	0.0175 (±0.0021)

Table-3. Exofast's results for 10 hot Jupiter exoplanets in this study.

The output parameters of EXOFAST and their uncertainties were listed in Table 3. The second column represents the planet's radius R_p (R_J), the third column contains the ratio of the planet radius to the stellar radius $k = R_p/R_*$, the fourth column is transit center time T_C (BJD_{TDB}), the fifth column is FWHM duration (days) $T_{FWHM,}$ transit depth δ, and τ, Ingress/egress duration are shown in the sixth and seventh columns respectively. We calculated the uncertainties of k and R_p from the following equations:

$$\sigma_k = \frac{\sigma_{depth}}{2k}, \qquad \sigma_{R_p} = k\sigma_{R_*} + R_*\sigma_k \qquad (1)$$

where R_* and its uncertainty extracted from NEA[‡‡] in Table 4.

Planets	$R_P(R_J)$
CoRot-12 b	1.44±0.13 [4]
HAT-P-52 b	1.009±0.072 [5]
HAT-P-57 b	1.413±0.054 [6]
HATS-28 b	1.194±0.07 [7]
HATS-34 b	1.43±0.19 [8]
KELT-3 b	1.345±0.072 [9]
WASP-61 b	1.24±0.03 [10]
WASP-67 b	$1.4^{+0.3}_{-0.2}$ [10]
WASP-122 b	1.743 ± 0.047 [28]
WASP-140 b	$1.44^{+0.42}_{-0.18}$ [12]

Table-4. The radius of the exoplanets from NEA.

The positions of all host stars in this study, in which the theoretical Zero Age Main Sequence (ZAMS) and Terminal Age Main Sequence (TAMS), are shown in the H-R diagram in Figure 2 and the calculation are shown in Table 5. As can be seen in the diagram, most of the stars in this study are in the middle or second part of their lifetime, and the planets were discovered by primary transit at the time when star's temperature is cooler than the first part of their lifetime.

‡‡https://exoplanetarchive.ipac.caltech.edu/

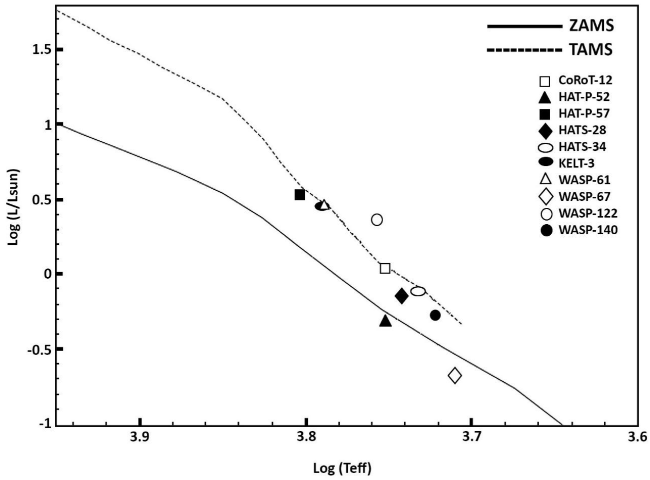


Figure-2. The position of the host stars on the H-R diagram.

Planet Name	T(K)	R(R_{Sun})	L(L_{sun})	LogT	Log(L/L_{sun})
CoRoT-12 b	5675±80 [4]	1.116 (+0.096 -0.092) [4]	1.1590±0.11	3.7539	0.0640
HAT-P-52 b	5131±50 [5]	0.893 (±0.047) [5]	0.4959±0.13	3.7102	-0.3046
HAT-P-57 b	6330±124 [19]	1.85 (±0.39) [19]	3.2410±0.09	3.8014	0.5106
HATS-28 b	5498±84 [7]	0.922 (±0.040) [7]	0.6969±0.11	3.7402	-0.1568
HATS-34 b	5380±73 [8]	0.98 (± 0.047) [8]	0.7219±0.15	3.7307	-0.1415
KELT-3 b	6304±49 [19]	1.70 (±0.12) [19]	3.1120±0.19	3.7996	0.4930
WASP-61 b	6250±15 [19]	1.55 (±0.24) [19]	2.5320±0.13	3.7958	0.4034
WASP-67 b	5200±10 [19]	0.88 (±0.08) [19]	0.4965±0.08	3.7160	-0.3040
WASP-122 b	5720±13 [28]	1.52±0.03 [28]	2.3584±0.10	3.7573	0.3726
WASP-140 b	5260±10 [12]	0.87 (± 0.04)[12]	0.5198±0.17	3.7209	-0.2841

Table-5. Calculations of host stars and parameters determining their position in the H-R diagram.

4. CONCLUSION

In order to compare the parameters of exoplanets obtained from the analysis of data related to ground observations with small telescopes to the parameters available in the NASA archive (NEA), we analyzed 14 transit light curves for 10 hot Jupiter exoplanets from the ETD database.

The telescopes used in the observations have an average aperture of 350 mm. The observations were used CCD method of observation. After the raw data reduction, we prepared a file including time in BJD_{TDB}, Flux, and its' Error and then used it as an input for EXOFAST and extracted the parameters of exoplanets. The radius of the exoplanet is the most important parameter determined by the transit method. Using the confidence interval method, the radius of exoplanet has a good agreement with NEA in 1σ to 3σ.

The results show that the radius of exoplanets obtained from ground-based observation with small telescopes are comparable to its value in the NEA in this study. This is important because it can show the role of observations with small telescopes to study more discovered planets.

ACKNOWLEDGMENTS

This manuscript was prepared by the International Occultation Timing Association Middle East section (IOTA/ME) and with participants at a project was held as a scientific activity on exoplanets during winter and spring of 2020.

REFERENCES

[1] Rice, K., 2014. The detection and characterization of extrasolar planets. Challenges, 5(2), pp.296-323.

[2] Davoudi, F., Jafarzadeh, S.J., Poro, A., Basturk, O., Mesforoush, S., Harandi, A.F., Gozarandi, M.J., Mehrjardi, Z.Z., Maley, P.D., Khakpash, S. and Rokni, K., 2020. Light curve analysis of ground-based data from exoplanets transit database. *New Astronomy*, 76, p.101305.

[3] Poddaný, S., Brát, L. and Pejcha, O., 2010. Exoplanet Transit Database. Reduction and processing of the photometric data of exoplanet transits. *New Astronomy*, 15(3), pp.297-301.

[4] Gillon, M., Hatzes, A., Csizmadia, S., Fridlund, M., Deleuil, M., Aigrain, S., Alonso, R., Auvergne, M., Baglin, A., Barge, P. and Barnes, S.I., 2010. Transiting exoplanets from the CoRoT space mission-XII. CoRoT-12b: a short-period low-density planet transiting a solar analog star. *Astronomy & Astrophysics*, 520, p.A97.

[5] Hartman, J.D., Bhatti, W., Bakos, G.Á., Bieryla, A., Kovács, G., Latham, D.W., Csubry, Z., de Val-Borro, M., Penev, K., Buchhave, L.A. and Torres, G., 2015. HAT-P-50b, HAT-P-51b, HAT-P-52b, and HAT-P-53b: Three Transiting Hot Jupiters and a Transiting Hot Saturn From the HATNet Survey. *The Astronomical Journal*, 150(6), p.168.

[6] Hartman, J.D., Bakos, G.Á., Buchhave, L.A., Torres, G., Latham, D.W., Kovács, G., Bhatti, W., Csubry, Z., de Val-Borro, M., Penev, K. and Huang, C.X., 2015. HAT-P-57b: a short-period giant planet transiting a bright rapidly rotating A8V star confirmed via Doppler tomography. *The Astronomical Journal*, 150(6), p.197.

[7] Espinoza, N., Bayliss, D., Hartman, J.D., Bakos, G.Á., Jordán, A., Zhou, G., Mancini, L., Brahm, R., Ciceri, S., Bhatti, W. and Csubry, Z., 2016. HATS-25B THROUGH HATS-30B: A HALF–DOZEN NEW INFLATED TRANSITING HOT JUPITERS FROM THE HATSOUTH SURVEY. *The Astronomical Journal*, *152*(4), p.108.

[8] de Val-Borro, M., Bakos, G.Á., Brahm, R., Hartman, J.D., Espinoza, N., Penev, K., Ciceri, S., Jordán, A., Bhatti, W., Csubry, Z. and Bayliss, D., 2016. HATS-31b through HATS-35b: five transiting hot Jupiters discovered by the HATSouth survey. *The Astronomical Journal*, *152*(6), p.161.

[9] Pepper, J., Siverd, R.J., Beatty, T.G., Gaudi, B.S., Stassun, K.G., Eastman, J., Collins, K., Latham, D.W., Bieryla, A., Buchhave, L.A. and Jensen, E.L., 2013. KELT-3b: A Hot Jupiter Transiting AV= 9.8 Late-F Star. *The Astrophysical Journal*, *773*(1), p.64.

[10] Hellier, C., Anderson, D.R., Collier Cameron, A., Doyle, A.P., Fumel, A., Gillon, M., Jehin, E., Lendl, M., Maxted, P.F.L., Pepe, F. and Pollacco, D., 2012. Seven transiting hot jupiters from wasp-south, euler and trappist: Wasp-47b, wasp-55b, wasp-61b, wasp-62b, wasp-63b, wasp-66b and wasp-67b. *Monthly Notices of the Royal Astronomical Society*, *426*(1), pp.739-750.

[11] Rodriguez, J.E., Colón, K.D., Stassun, K.G., Wright, D., Cargile, P.A., Bayliss, D., Pepper, J., Collins, K.A., Kuhn, R.B., Lund, M.B. and Siverd, R.J., 2016. KELT-14b and KELT-15b: an independent discovery of WASP-122b and a new hot Jupiter. *The Astronomical Journal*, *151*(6), p.138.

[12] Hellier, C., Anderson, D.R., Cameron, A.C., Delrez, L., Gillon, M., Jehin, E., Lendl, M., Maxted, P.F.L., Neveu-VanMalle, M., Pepe, F. and Pollacco, D., 2016. WASP-South transiting exoplanets: WASP-130b, WASP-131b, WASP-132b, WASP-139b, WASP-140b, WASP-141b and WASP-142b. *Monthly Notices of the Royal Astronomical Society*, *465*(3), pp.3693-3707.

[13] Becker, J.C., Vanderburg, A., Adams, F.C., Rappaport, S.A. and Schwengeler, H.M., 2015. WASP-47: A hot Jupiter system with two additional planets discovered by K2. *The Astrophysical Journal Letters*, *812*(2), p.L18.

[14] Martin, E.L., Spruit, H.C. and Tata, R., 2011. A binary merger origin for inflated hot Jupiter planets. *Astronomy & Astrophysics*, *535*, p.A50.

[15] Mallonn, M., Von Essen, C., Herrero, E., Alexoudi, X., Granzer, T., Sosa, M., Strassmeier, K.G., Bakos, G., Bayliss, D., Brahm, R. and Bretton, M., 2019. Ephemeris refinement of 21 hot Jupiter exoplanets with high timing uncertainties. *Astronomy & Astrophysics*, *622*, p.A81.

[16] Eastman, J., Gaudi, B.S. and Agol, E., 2013. EXOFAST: A fast exoplanetary fitting suite in IDL. *Publications of the Astronomical Society of the Pacific*, *125*(923), p.83.

[17] Guillot, T., 2005. The interiors of giant planets: Models and outstanding questions. *Annu. Rev. Earth Planet. Sci.*, *33*, pp.493-530.

[18] Sato, B.E., Fischer, D.A., Henry, G.W., Laughlin, G., Butler, R.P., Marcy, G.W., Vogt, S.S., Bodenheimer, P., Ida, S., Toyota, E. and Wolf, A., 2005. The N2K consortium. II. A transiting hot Saturn around HD 149026 with a large dense core. *The Astrophysical Journal*, *633*(1), p.465.

[19] Stassun, K.G., Collins, K.A. and Gaudi, B.S., 2017. Accurate empirical radii and masses of planets and their host stars with Gaia parallaxes. The Astronomical Journal, 153(3), p.136.

[20] Charbonneau, D., Winn, J.N., Latham, D.W., Bakos, G., Falco, E.E., Holman, M.J., Noyes, R.W., Csák, B., Esquerdo, G.A., Everett, M.E. and O'donovan, F.T., 2006. Transit photometry of the core-dominated planet HD 149026b. *The Astrophysical Journal*, *636*(1), p.445.

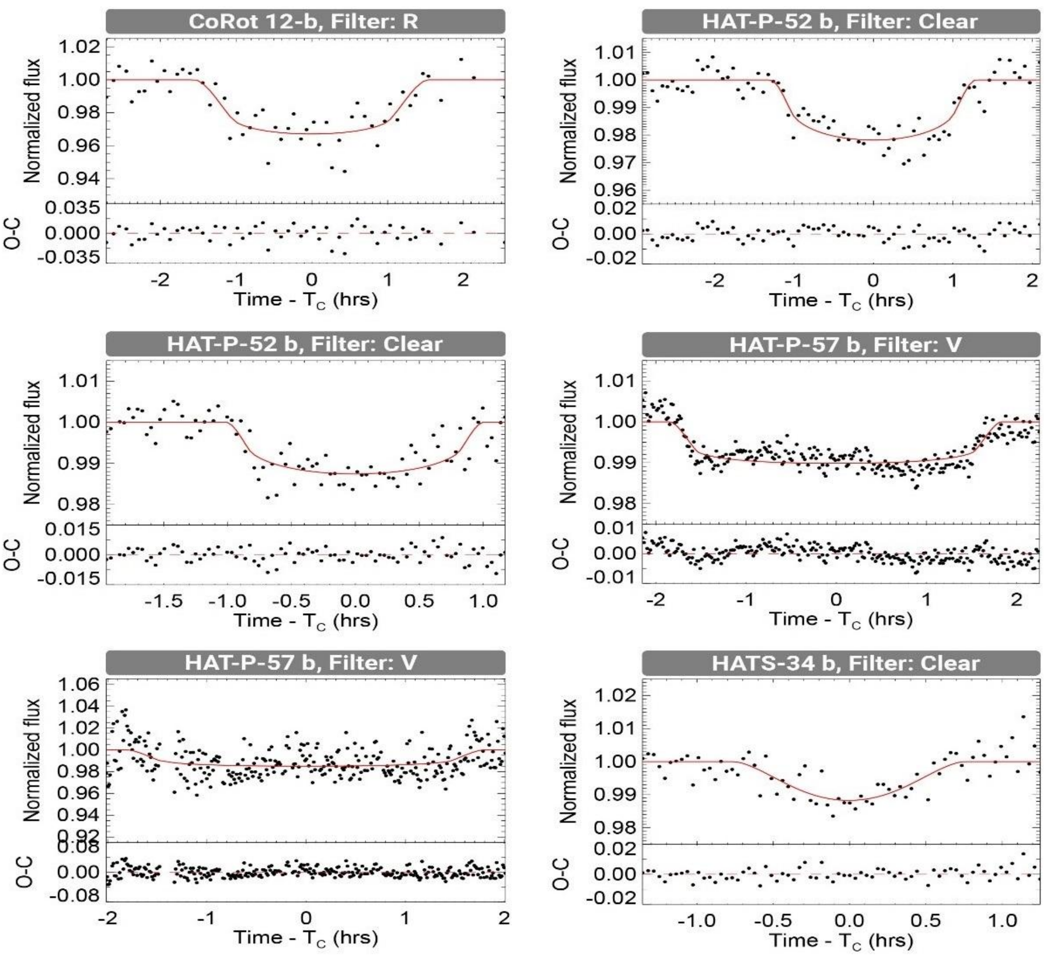
[21] Fortney, J.J., Saumon, D., Marley, M.S., Lodders, K. and Freedman, R.S., 2006. Atmosphere, interior, and evolution of the metal-rich transiting planet HD 149026b. *The Astrophysical Journal*, *642*(1), p.495.

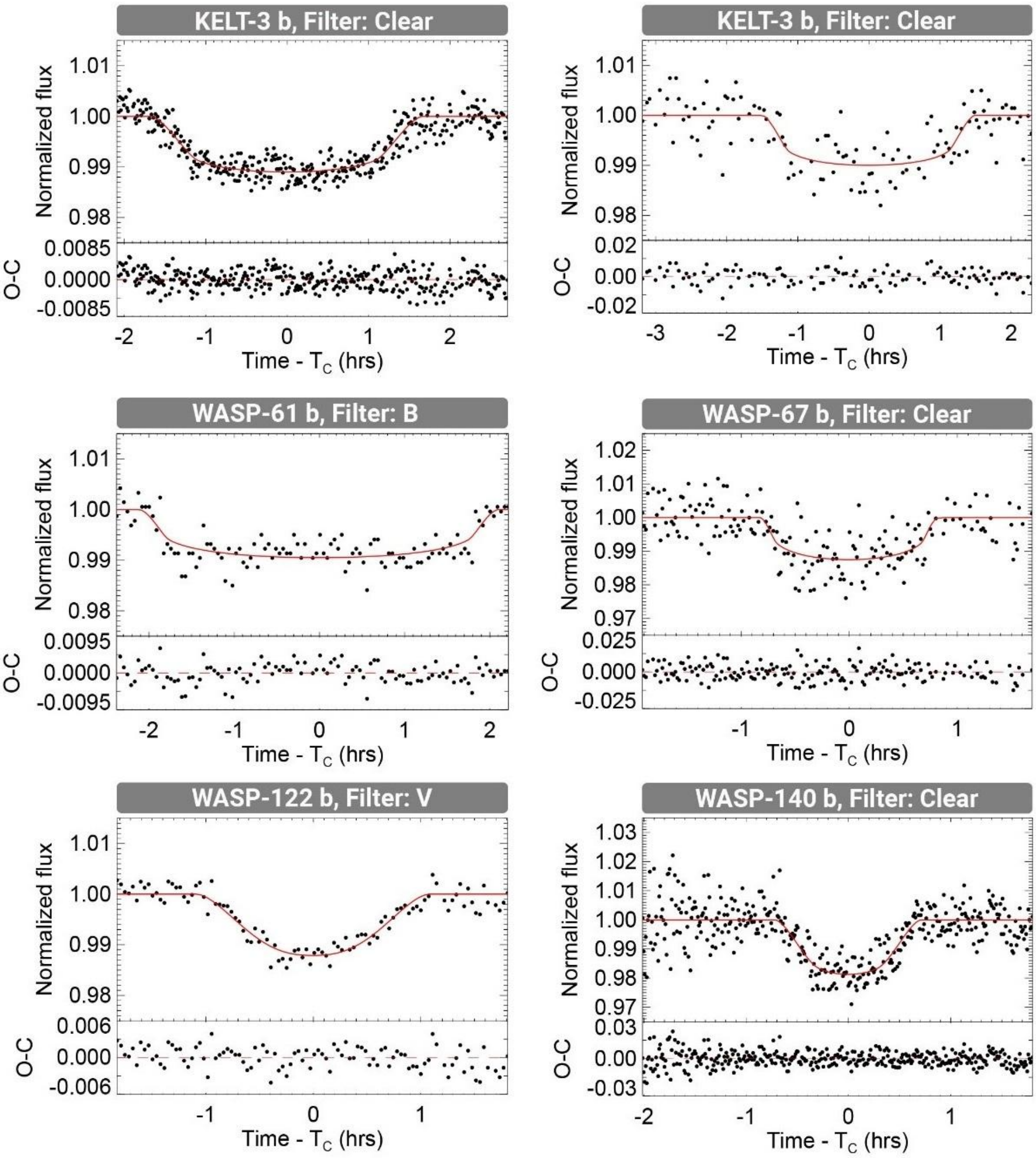
[22] Charbonneau, D., Brown, T.M., Noyes, R.W. and Gilliland, R.L., 2002. Detection of an extrasolar planet atmosphere. *The Astrophysical Journal*, *568*(1), p.377.

[23] Vidal-Madjar, A., Des Etangs, A.L., Désert, J.M., Ballester, G.E., Ferlet, R., Hébrard, G. and Mayor, M., 2003. An extended upper atmosphere around the extrasolar planet HD209458b. *Nature*, *422*(6928), pp.143-146.
[24] Deming, D., Seager, S., Richardson, L.J. and Harrington, J., 2005. Infrared radiation from an extrasolar planet. *Nature*, *434*(7034), pp.740-743.
[25] Ragozzine, D. and Wolf, A.S., 2009. Probing the interiors of very hot Jupiters using transit light curves. *The Astrophysical Journal*, *698*(2), p.1778.
[26] Carter, J.A. and Winn, J.N., 2010. The detectability of transit depth variations due to exoplanetary oblateness and spin precession. *The Astrophysical Journal*, *716*(1), p.850.
[27] Buchhave, L.A., Bakos, G.Á., Hartman, J.D., Torres, G., Latham, D.W., Andersen, J., Kovács, G., Noyes, R.W., Shporer, A., Esquerdo, G.A. and Fischer, D.A., 2011. HAT-p-28b and HAT-p-29b: Two sub-Jupiter mass transiting planets. *The Astrophysical Journal*, *733*(2), p.116.
[28] Turner, O.D., Anderson, D.R., Cameron, A.C., Delrez, L., Evans, D.F., Gillon, M., Hellier, C., Jehin, E., Lendl, M., Maxted, P.F.L. and Pepe, F., 2016. WASP-120 b, WASP-122 b, and WASP-123 b: Three Newly Discovered Planets from the WASP-South Survey. *Publications of the Astronomical Society of the Pacific*, *128*(964), p.064401.

APPENDIX

In the figures, the light curves of planets were displayed in different bands extracted by EXOFAST software. The horizontal axis is Time (BJD_{TDB})-T_c based on hours. The vertical axis in the top panel is based on Normalized flux of the star and the O-C which means the Residuals between observed and fitted data points.




KELT-3 b, Filter: Clear
KELT-3 b, Filter: Clear
WASP-61 b, Filter: B
WASP-67 b, Filter: Clear
WASP-122 b, Filter: V
WASP-140 b, Filter: Clear
Normalized flux
O-C
Time - T_C (hrs)