

Infinite Worlds



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ARIEL Space Mission Special Issue

The e-magazine of the Exoplanets Division Of the Asteroids and Remote Planets Section Issue 5

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Introduction to this special issue

This issue is devoted to the ARIEL Space Mission's ExoClock Project. Observers are invited to participate in ground-based observations of exoplanet transits in support of the project.

Please do let me have your comments and whether or not you have found the information included here of use.

This document plus related presentations from the ARPS meeting held recently will be uploaded to the Exoplanets website.

ARIEL Space Mission

The ExoClock Project

Originated 2019 December 5

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1.0 Introduction

The Exoplanet Division is participating in a pro-am project supporting the ARIEL space mission with ground-based exoplanet observations. This is a great opportunity to get started in exoplanet transit observations and make a significant contribution to the mission.

The objective of this document is to encourage participation in this project and provide help in installing the Python/HOPS software, imaging and generating transit light-curves.

Data for an initial selection of target stars is shown in the appendices. More can be found on the ExoWorlds Spies Transit Scheduler.

Mark Salisbury is our contact point with Ariel for this project.

2.0 The ARIEL space mission

The mission website is at ARIEL Space Mission - <u>https://arielmission.space/</u> ARIEL will use transit spectroscopy to characterise the atmospheres of ~1000 exoplanet.

Relevant documentation;

ESA Assessment Study Report - <u>https://sci.esa.int/documents/34375/36249/1567260310680-</u> ESA_SCI-2017-2_ARIEL.pdf

A chemical study of exoplanets with ARIEL - <u>https://link.springer.com/article/10.1007/s10686-</u>018-9598-x

Those interested in astrobiology may find much of interest in the above-mentioned documents. The presentation, 'An Introduction to Astrobiology' given by Peta Bosley at the ARPS meeting held on 2019 September 29 can be found here (link to be added when this document is finalised and uploaded to Exoplanets website).

2.1 The ExoClock project

Ground-based exoplanet observations in support of the ARIEL space mission - <u>https://ariel-gbfu.azurewebsites.net/</u>

There is a need to confirm the ephemerides, transit times, of the approximately 1000 ARIEL targets. Some of these targets will not have been observed for a several years, therefore their predicted transit times could be in error and thus missed by ARIEL when imaging that particular event.

The project offers observers;

- ephemerides
- target prioritisation with alert system
- personalised observation schedule
- direct publications for participants
- continuous feedback to observers

To participate;

- register you telescope and sign up/login at https://ariel-gbfu.azurewebsites.net/users/login/
- check your schedule at https://ariel-gbfu.azurewebsites.net/schedule/today
- observe a transit; beginners guide at <u>https://exoworldsspies.com/en/observers/</u>
- analyse your observation; software at https://exoworldsspies.com/en/software/
- upload your light curve; login required

A transit light-curve of WASP-52b obtained by Steve Futcher, Hampshire Astronomical Group, and Portsmouth University students is shown in Figure 2.1.1. It can also be viewed on the ExoClock Observations webpage at

https://ariel-gbfu.azurewebsites.net/database/observations



Figure 2.1.1. WASP-52b transit light-curve

You don't have to own your own telescope to participate. Martin Fowler uses the <u>MicroObservatory robotic telescope</u> to obtain a light-curve of HAT-P-32b – Figure 2.1.2. It can also be viewed on the ExoClock Observations webpage at <u>https://ariel-gbfu.azurewebsites.net/database/observations</u>



Figure 2.1.2. HAT-P-32b transit light-curve

2.2 ExoWorlds Spies

Website at <u>www.exoworldsspies.com</u>. Here observers can find information on;

- installation and use of HOPS software (Software and For observers) see Appendix B
- practice targets (NAV/For observers) see Appendix C

3.0 Imaging and analysis process

The ExoWorlds Spies website <u>Observing an exoplanet transit webpage</u> describes the ExoClock projects preferred imaging process. There is a link to the <u>HOPS user manual</u> – HOPS is the software to be used for image analysis.

The forthcoming workshop – section 4.0. may bring about some modifications to these processes – as they say, watch this space.

It may help observers to obtain consistent results if comparison stars are defined for the ARIEL targets - <u>https://ariel-gbfu.azurewebsites.net/database/</u>See appendix A for finder charts

(Guide) and comparison stars plus a link to the relevant entry in the Exoplanet Transit Database. Transit times can be obtained from the ExoWorlds Spies Transit Scheduler, the Exoplanet Transit Database or Find Exoplanet Transits

4.0 Workshop

A workshop, hosted by ARIEL personnel, is planned for 2020 January, Topics under consideration include;

- ARIEL mission update
- understanding of how amateurs can assist the ARIEL mission
- coordination of observing programs of suggested targets
- targets. A list is available at https://ariel-gbfu.azurewebsites.net/database/
- comparison stars
- timing e.g. Barycentric Julian Date (BJD) or Heliocentric Julian Day (HJD)
- equipment requirements; e.g. 8in reflector, 6in refractor
- use of robotic telescopes e.g. the MicroObservatory robotic telescope
- imaging techniques
- use of filters e.g. R (Cousin Rc or Sloan r' for example) or Clear
- the photometry process
- familiarisation with HOLomon Photometric Software (HOPS)

5.0 **ARIEL** targets

5.1 **Target selection**

Plan is to select a number of targets suitable for UK observers and provide finder charts and comparison star data. See appendices for data for stars listed in Table 5.5.1. If this proves successful, then more charts and data will be generated.

The **ExoWorlds Spies Transit Scheduler** can be used to provide targets depending on location and telescope size. The targets listed in Table 5.5.1 were selected using;

- latitude; 54 degrees
- (Approx UK centre) - longitude; -1.0 degrees (Approx UK centre)
- telescope aperture; 8 ins
- preferred time zone; 0 hrs
- Next 12 Months

From the list Targets were selected using the following criteria;

- high priority (prediction uncertainty higher than 10 minutes for 2020) A1 to A8
- medium priority (prediction uncertainty lower than 10 minutes for 2020 but higher than 10 minutes for 2028, or reference older than 2016) - A8 to A10
- V mag brighter than 13
- transit depth >=10
- altitude >30 degrees during transit

For transit times for a specific planet access;

- Exoworlds Spies Transit Scheduler

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or
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- Exoplanet Transit Database

or

- Find Exoplanet Transits

Appendix no.	Target	RA	Dec	V mag	Depth (mmag)
A1	HAT-P-20b	07 27 39.95	24 20 11.9	11.34	20
A2	<u>XO-6b</u>	06 19 10.39	73 49 39.7	10.25	14
A3	HAT-P-6b	23 39 05.81	42 27 57.5	10.44	10
A4	WASP-13b	09 20 24.71	33 52 56.8	10.42	10
A5	<u>XO-4b</u>	07 21 33.17	58 16 05.2	10.67	10
A6	HAT-P-8b	22 52 09.86	35 26 49.6	10.30	11
A7	<u>HAT-P-17b</u>	21 38 08.74	30 29 19.4	10.54	20
A8	HAT-P-3b	13 44 22.59	48 01 43.2	11.58	16
A9	WASP-11b	03 09 28.55	30 40 24.9	11.60	23
A10	HAT-P-12b	13 57 33.48	43 29 36.7	12.84	28

The link under Target in Table 5.5.1 takes you to the relevant appendix. The link in the table at the beginning of each appendix is to the Exoplanet Transit Database.

Table 5.5.1. Selected targets

Clicking on 'More' displays a finder chart and star and transit data – included in appendices.

STScI DSS charts are obtained from <u>http://archive.stsci.edu/cgi-bin/dss_form</u> using the HST Phase 2 (GSC1) option.

The best time of the year to observe the selected targets can be ascertained using the Object Visibility facility at <u>http://catserver.ing.iac.es/staralt/</u> using the Starobs option.

5.2 Comparison stars

Comparison star were selected to be close to the target star in both magnitude and colour i.e.; V mag +/- 1.5 and (B-V) +/- 0.2. Stars may be selected outside these ranges to give a spread of comparison stars across the image and if there are few that meet these criteria. Data extracted from Vizier/APASS catalogue at <u>http://vizier.u-strasbg.fr/viz-bin/VizieR-3?-source=II/336/apass9&-out.max=50&-out.form=HTML%20Table&-out.add=_r&-out.add=_RAJ, DEJ&-sort=_r&-oc.form=sexa The AAVSO Variable Star Plotter at <u>https://www.aavso.org/apps/vsp/</u> was accessed to check for variable and comparison stars near the target.</u>

Appendix A1

Target	RA	Dec	V mag	g E	B-V De	epth (m	mag)	
<u>HAT-P-20b</u>	07 27 39.95	24 20 11.9	11.34	-	1.2	20		
Table A1.1. Ta	rget data							
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\leftrightarrow \rightarrow C $\widehat{\mathbf{n}}$ ari	el-gbfu.azurewebsites.net/	/database/planets/HAT-P-2	20b/		Q 🕁		R e	•
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CREC European Space	Agency M4 Mission	Ехослоск 👻 Ерһете	rides					
		HAT	F-P-20b					
The	Ephemeris - Bakos et al	2011		Th	Star			
T (D.1)		0.00001	DA (12000)	7.27.20.05	Transmitter (K)	4505		
10 [BJ]	OTDBJ 2455080.92661	± 0.00021	RA [J2000]	/:2/:39.95	Temperature [K]	4595		
Period	[days] 2.875317 ±	4e-06	DEC [J2000]	24:20:11.9	Log(g) [cgs units]	4.64		
J2000 T	07-27-39.953+24-20-11.87	77	V magnitude	11.34	Metallicity [dex Fe/H	0.35		
		3		The	Transit			
Q			Depth [mmag]	20.03	Duration [hours]	1.85		
1.1			R _n /R _s	0.12898551				
	+	ä	2/P	11.25	Inclination [dos]	96.9		
			d/R _s	11.25	mennation [deg]	00.0		
			Eccentricity	0.015	Periastron [deg]	317.0		
-		Ø	1	Discovered by	Bakos et al. 2010			
LOVETING								

Figure A1.1. Star and transit data



Figure A1.2. Finder chart



Figure A1.3. STScI DSS chart

Nominal criteria for comparison star selection (can exceeded to obtain spread and number of comparison stars).

1.0<(B-V=1.2)<1.4 9.84<(V=11.34)<12.84

Comparison star	RA	Dec	V	B-V
1	07 27 50.80	+24 19 04.82	11.481	0.526
2	07 27 24.40	+24 24 36.64	11.891	1.291
3	07 27 27.88	+24 14 23.82	11.770	1.264
4	07 27 09.47	+24 17 38.48	13.128	0.769
5	07 27 57.44	+24 13 29.72	12.089	0.771

Table A1.2. Comparison star data



Figure A1.4. Object visibility

Appendix A2

Target	RA	Dec	V mag	B-V	Depth (Mmag)
<u>XO-6b</u>	06 19 10.39	73 49 39.7	10.25	0.360	14

Return to target list

Table A2.1. Target data

🐞 ETD - Exoplanet Transit Database 🗙 🛛 🧕 ExoWorlds Spies 🛛 🗙	S ExoClock		× +		- 0 X
\leftarrow \rightarrow C (a ariel-gbfu.azurewebsites.net/database/planets/XO-6b/			Q \$		
🔛 Apps 🕝 Google					Other bookmarks
ARIEL SPACE MISSION ExoClock - Ephemer	rides				*
X	0-6b				
The Ephemeris - Crouzet et al. 2017		The	Star		
T ₀ [BJD _{TDB}] 2456652.71245 ± 0.00055	RA [J2000]	6:19:10.39	Temperature [K]	6720	
Period [days] 3.7650007 ± 8.1e-06	DEC [J2000]	73:49:39.7	Log(g) [cgs units]	4.03	
J2000 🔻 06 19 10 202-73 49 59 56	V magnitude	10.25	Metallicity [dex Fe/H]	-0.07	
		The	Fransit		
	Depth [mmag]	14.15	Duration [hours]	2.9	
	R_p/R_s	0.11036269			
	a/R _s	9.08	Inclination [deg]	86.0	
	Eccentricity	0.0	Periastron [deg]	0.0	
674-17-44	D	iscovered by C	Crouzet et al. 2017		

Figure A2.1 Star and transit data



Figure A2.1. Finder chart



Figure A2.2. STScI DSS chart

Nominal criteria for comparison star selection. 0.160<(B-V=0.360)<0.560 8.75<(V=10.25)<11.75

Comp star	RA	Dec	V mag	B-V
1	06 18 26.80	+73 50 02.07	12.012	0.996
2	06 19 50.99	+73 53 02.01	12.510	0.657
3	06 20 07.82	+73 53 29.85	9.843	0.471
4	06 19 10.14	+73 56 09.75	13.302	0.960
5	06 17 47.11	+73 43 20.58	9.450	0.995

Table A2.2. Comparison star data



Figure A2.3. Object visibility

Appendix A3

Target	RA	Dec	V mag	B-V	Depth (mmag)				
HAT-P-6b	23 39 05.81	42 27 57.5	10.44	0.469	14				
Table A3.1. 7	Table A3.1. Target data								

Return to target list



Figure A3.1 Star and transit data





Figure A3.3. STScI DSS chart

Nominal criteria for comparison star selection. 0.269<(B-V=0.469)<0.669 8.94<(V=10.44)<11.94

Comp star	RA	Dec	V mag	B-V
1	23 38 59.06	+42 24 38.09	11.710	0.736
2	23 39 15.75	+42 20 47.60	12.752	0.724
3	23 39 36.79	+42 34 51.92	11.826	0.377
4	23 39 37.67	+42 26 49.11	11.450	0.339
5	23 38 47.40	+42 31 44.1	12.451	1.028

Table A3.2. Comparison star data

Note. Data for Comparison star 4 are from Guide and Comparison star 5 from the AAVSO



Figure A3.4. Object visibility

Appendix A4

Target	RA	Dec	V mag	B-V	Depth (mmag)
WASP-13b	09 20 24.71	33 52 56.8	10.42	0.459	10

Table A4.1. Target data

Return to target list



Figure 4.1





Figure A4.3. STScI DSS chart

Nominal criteria for comparison star selection. 0.259<(B-V=0.492)<0.659 8.92<(V=10.42)<11.92

Comp star	RA	Dec	V mag	B-V
1	09 20 23.48	+33 59 16.04	13.872	0.565
2	09 20 02.97	+33 55 45.60	13.240	0.933
3	09 19 51.49	+33 52 23.82	13.867	0.385
4	09 20 33.07	+33 46 36.50	11.653	0.467
5	09 21 08.51	+33 48 20.72	11.092	0.939

Table A4.2. Comparison star data



Figure A4.4. Object visibility

Appendix A5

Target	RA	Dec	V mag	B-V	Depth (mmag)
<u>XO-4b</u>	07 21 33.17	58 16 05.20	10.67	0.492	10

Table A5.1. Target data

Return to target list



Figure A5.1







Figure A5.3. STScI DSS chart

Nominal criteria for comparison star selection. 0.292<(B-V=0.492)<0.692 9.162<(V=10.662)<12.162

Comp star	RA	Dec	V mag	B-V
1	07 21 27.73	+58 18 38.25	12.319	0.665
2	07 21 09.31	+58 16 05.17	10.510	0.719
3	07 21 57.40	+58 15 10.08	11.622	0.412
4	07 21 39.81	+58 11 20.18	10.318	1.553
5	07 20 45.90	+58 17 18.44	11.512	1.106

Table A5.2. Comparison star data



Figure A5.4. Object visibility

Appendix A6

Target	RA	Dec	V mag	B-V	Depth (mmag)
HAT-P-8b	22 52 09.86	35 26 49.60	10.30	0.506	11

Table A6.1. Target data

Return to target list

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H Apps G Google					Other bo	okma <mark>rk</mark> s
ARIEL SPACE MISSION ExoClock - Ephemerides						
HAT-I	P-8b					
The Ephemeris - Mancini et al. 2013 HIGH PRIORITY		The	Star			
	RA [J2000]	22:52:09.86	Temperature [K]	6200		
Pariad Idaws 2 0762459 + 2 4a.06	DEC [J2000]	35:26:49.6	Log(g) [cgs units]	4.15		
renou (uays) 5.0/03436 ± 2.4e-00	V magnitude	10.3	Metallicity [dex Fe/H]	0.01		
12000 🔻 (2015) S. Maria - S. Alandaria		The 7	Fransit			
	Depth [mmag]	10.73	Duration [hours]	4.1		
	R _p /R _s	0.09171975				
1. · · · · · · · · · · · · · · · · · · ·	a/R _s	6.14	Inclination [deg]	87.8		
	Eccentricity	0.0	Periastron [deg]	0.0		
	D	iscovered by L	atham et al. 2009			
160V:17:04						
© 2019 ExoCle	ock Project					
XO-4b.gif					Show a	II ×

Figure A6.1





Figure A6.3. STScI DSS chart

Nominal criteria for comparison star selection. 0.306<(B-V=0.506)<0.706 8.80<(V=10.30)<11.80

Comp star	RA	Dec	B-V	V mag
1	22 52 16.18	+35 28 19.57	0.464	12.430
2	22 51 58.98	+35 22 00.86	0.557	12.612
3	22 52 38.29	+35 27 13.96	0.745	12.704
4	22 51 43.33	+35 33 00.20	0.541	12.394
5	22 52 50.66	+35 31 58.99	0.452	10.904

Table A6.2. Comparison star data

Note. Data for Comparison star 5 is from Guide



Figure A6.4. Object visibility

Appendix A.7

Target	RA	Dec	V mag	B-V	Depth (mmag)
<u>HAT-P-17b</u>	21 38 08.74	30 29 19.4	10.54	0.802	20

Table A7.1. Target data

Return to target list



Figure A7.1





Figure A7,3

Nominal criteria for comparison star selection. 0.602<(B-V=0.802)<0.1.002 9.04<(V=10.54)<12.04

Comp star	RA	Dec	V mag	B-V
1	21 38 21.99	+30 33 22.11	11.921	0.270
2	21 38 28.25	+30 26 11.03	11.322	0.400
3	21 37 57.21	+30 34 33.34	12.494	0.598
4	21 38 22.39	+30 36 03.02	9.050	0.503
5	21 38 12.33	+30 24 09.88	9.397	0.301

Table A7.2





Appendix A.8

Target	RA	Dec	V mag	B-V	Depth (mmag)
HAT-P-3b	13 44 22.59	48 01 43.2	11.58	0.817	16

Table A8.1

Return to target list



• 1 3h 45.	• 3 ^{13h44m3(}	13h44;	• 4	+5
- <u>+ 48 05'</u>			·. ·	+ 48 0 5
	•1		•	
		+ ⊤		
+ 40	•			+ 48
•5	*			Ð
11 ● 15 • 12 ● 16 • N 13 ● 17 ·			•	
14 18 E 13h44m22.59s J2000.0 +48 01'43.2" UMa Alt 85.532 Az 332.177 43 15.000' 25 Nov 2019 14:20:14 UTC	130s	• 2 [#]	1308 1308 1308	+ 47 55

Figure A8.2



Figure A8.3

Nominal criteria for comparison star selection. 0.617<(B-V=0.817)<1.017 10.08<(V=11.58)<12.08

Comp star	RA	Dec	V mag	B-V
1	13 44 36.38	+48 03 52.56	12.770	0.807
2	13 44 11.84	+47 55 08.00	10.694	0.684
3	13 44 35.66	+48 08 33.94	13.193	0.606
4	13 43 40.61	+48 08 30.29	11.178	0.560
5	13 45 21.80	+47 58 24.41	12.575	1.154

Table A8.2





Appendix A9

Target	RA	Dec	\mathbf{V}	B-V	Depth (mmag)
WASP-11b	03 09 28.55	30 40 24.9	11.60	0.964	23

Table A9.1

Note. No ETD entry for this target

Return to target list

📴 ExoWc 🗙 🧶 ExoClc 🗙 🧔 ETD - 🗙 🛛 🕅 The ST 🗙 🗍 🧰 Object 🗙 🛛 🕰 VizieR	× 🌏 AAVSC × 🕂	– 0 ×
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ARIEL SPACE MISSION ExoClock - Ephemerides		•
WASP-11b		
The Star	The Planet	
Simbad (VASP-11 GAIA DR 2123376685084303360 2MASS J03092855+3040249	Discovered by West et al. 2009 Ephemeris by Mancini et al. 2015 Priority MEDIUM	
RA 03:09:28.5427 DEC +30:40:24.868	Mid-time	
7.992 mas 3.856 mas/y -44.826 mas/y	$2454729.9072 \pm 0.0002 \text{ BJD}_{\text{TDB}}$	
V _{mag} R _{mag} I _{mag} [*] J _{mag} H _{mag} K _{mag} 11.57 11.42 10.508 10.015 9.56 9.421	Period 3.72247967 ± 4.5e-07 days	
G _{mag} G _{BP mag} G _{RP mag} 11.554 12.101 10.885	Rband Depth*Duration*22.88 mmag2.51 hours	
22000 ▼ 003 09/28/04403/09/86/07/	* calculated from the parameters below, using PyLightcurve	
	Limb Darkening Parameters	
	T _{eff} Log(g) Fe/H 4800 K 4.69 cm/s ² 0.0 dex	
	Transit Parameters	
	Rp/Rs a/Rs 0.12808989 12.765	- 17
FaV: 17.94	i e ω 89.8 deg 0.0 0.0 deg	

Figure A9.1



Figure A9.2



Figure A9.3

Nominal criteria for comparison star selection. 0.764<(B-V=0.964)<1.164 10.90<(V=11.60)<12.90

Target	RA	Dec	V mag	B-V
1	03 09 14.81952	+30 41 29.0436	12.625	0.716
2	03 09 32.07264	+30 44 02.4324	13.567	0.746
3	03 09 51.18816	+30 37 11.2548	12.480	1.120
4	03 09 12.08064	+30 33 33.1380	13.456	1.311
5	03 09 01.28328	+30 46 52.3704	13.853	1.257

Table A9.2



Figure A9.4

Appendix A10

Target	RA	Dec	V mag	Depth (mmag)
<u>HAT-P-12b</u>	13 57 33.48	43 29 36.7	12.84	28

Table A10.1

Return to target list 🧕 ExoW: X 🕺 ExoCl: X 😓 ExoCl: X 🖉 S ETD - X 🛛 🧰 Objec: X 🖓 🐳 Vizier X 🖉 S AAVS: X 👌 🕂

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ARIEL SPACE MISSION ExoClock ~ European Space Agency Mill Mission	Ephemerides HAT-P-12b		Logn
Т Simba 1818-91 GAAA DR2 19951-7986 2014-2015 RA 13:57:334-4680 Parallax PR 6.976 mas -134.7 Va 12:52 11:572 12:44 12:152 11:572 Gmag Gr 12:42 12: 12:42 12:42 12: 12:42 12:42 12: 12:42 12:42 12: 12:42 12:4	he Star 19116540 3 DEC +43:29:36.602 M.RA P.N.DEC 791 masiy -44.294 masiy 9 10:794 10:236 10:108 BPmag GRPmag 3021 11:698 Tathate Housenance	For PlanceBits own of the presention o	
	© 2019 ExoClock Project		
WASP-11b.gif ^			Show all

Figure A10.1





Figure A10.3

Nominal criteria for comparison star selection. 0.886<(B-V=1.086)<1.286 11.266<(V=12.766)<13.266

Comp star	RA	Dec	V mag	B-V
1	13 57 24.99	+43 31 33.60	13.130	0.921
2	13 57 22.64	+43 35 48.35	12.626	0.771
3	13 58 00.95	+43 22 39.54	13.197	1.005
4	13 57 04.84	+43 22 36.07	12.811	0.893
5	13 58 09.52	+43 36 21.46	13.305	0.678

Table A10.2





Appendix B

Python/HOPS installation notes

1.0 Python Installation

See https://exoworldsspies.com/en/software/

Installation has been problematic for some, including myself, so these notes and screenshots will help you through the process. Please follow the installation instructions exactly as described on the above website.

Visit the Anaconda website



Figure B1.1

Click on "Download" under Python 3.7 version and choose 64 or 32 bits to suit your system and save (in Downloads for example).

Open file



 Anaconda3 2019.10 (64-bit) Setup 						
	License Agreement Please review the license term 2019.10 (64-bit).	ns before installing Ar	naconda3			
Press Page Down to see th	e rest of the agreement.					
Anaconda End User Licens	e Agreement		^			
Copyright 2015, Anacond	a, Inc.					
All rights reserved under t	he 3-dause BSD License:					
Redistribution and use in s permitted provided that th	source and binary forms, with or ne following conditions are met:	without modification,	are			
			- ×			
If you accept the terms of the agreement, click I Agree to continue. You must accept the agreement to install Anaconda3 2019.10 (64-bit).						
Anaconda, Inc						
	< <u>B</u> ack	I <u>A</u> gree	Cancel			
Figure B1.3						

Select 'I Agree'

O Anaconda3 2019.10 (64-	-bit) Setup — 🗆 🗙						
	Select Installation Type Please select the type of installation you would like to perform for Anaconda3 2019.10 (64-bit).						
Install for:							
Just Me (recommended)	Just Me (recommended)						
O All Users (requires adm	in privileges)						
Anaconda, Inc. ————	< <u>B</u> ack <u>N</u> ext > Cancel						

Figure B1.4

Select 'Just Me (recommended) and then 'Next'

Anaconda3 2019.10 (64-bit) Setup				<
	Choose Install Location Choose the folder in which to instal	l Anaconda3 20	19.10 (64-bit).	
Setup will install Anaconda3 folder, click Browse and selec	2019. 10 (64-bit) in the following fold ct another folder. Click Next to conti	er. To install in a nue.	a different	
Destination Folder	Anaconda3	Brow	/se	
Space required: 2.9GB Space available: 18.5GB Anaconda, Inc.	< <u>B</u> ack	Next >	Cancel	

Figure B1.5

Suggest you use whatever destination folder is shown and then select 'Next'

 Anaconda 	3 2019.10 (64-	bit) Setup		—		×
	ACONDA	Advanced Installation Customize how Anacono	Options da integrate	es with Windows		
Advanced A Not r menu Anac cause This PyCh deter	d Options dd Anaconda to ecommended. I u and select "An onda get found e problems requ egister Anacono will allow other p arm, Wing IDE, ct Anaconda as	my <u>P</u> ATH environment var nstead, open Anaconda wi aconda (64-bit)". This "add before previously installed ring you to uninstall and re a as my default Python 3. rograms, such as Python 3 PyDev, and MSI binary pa the primary Python 3.7 on	iable ith the Wind I to PATH" d I software, einstall Ana 7 Fools for Vis ckages, to the system	dows Start option makes but may conda. sual Studio automatically n.		
Anaconda, Inc		<	<u>B</u> ack	Install	Cance	el

Figure B1.6

Very important - check both boxes (Don't leave blank as in this screen

shot) and then select 'Install'

This next bit takes several minutes to complete.

Anaconda3 2019.10 (64-bit) Setup	
Setup was completed successfully.	
Completed	
Processed C: \Users \RogerDymock \Anaconda3 \Menu \notebook.json successfully. Processed C: \Users \RogerDymock \Anaconda3 \Menu \powershell_shortcut.json succe Processed C: \Users \RogerDymock \Anaconda3 \Menu \spyder_shortcut.json successfu Execute: "C: \Users \RogerDymock \Anaconda3 \pythonw.exe" -E -s "C: \Users \RogerD Running post install Execute: "C: \Users \RogerDymock \Anaconda3 \pythonw.exe" -E -s "C: \Users \RogerD Execute: "C: \Users \RogerDymock \Anaconda3 \pythonw.exe" -E -s "C: \Users \RogerD Execute: "C: \Users \RogerDymock \Anaconda3 \pythonw.exe" -E -s "C: \Users \RogerD Execute: "C: \Users \RogerDymock \Anaconda3 \pythonw.exe" -E -s "C: \Users \RogerD Execute: "C: \Users \RogerDymock \Anaconda3 \pythonw.exe" -E -s "C: \Users \RogerD Execute: "C: \Users \RogerDymock \Anaconda3 \pythonw.exe" -E -s "C: \Users \RogerD Created uninstaller: C: \Users \RogerDymock \Anaconda3 \pythonw.exe" -E -s "C: \Users \RogerD	^
Completed	*
Anaconda, Inc	el
Figure B1.7	

Select 'Next'



Anaconda is the most popular Python data science platform.

Share your notebooks, packages, projects and environments on Anaconda Cloud!

Learn more about Anaconda Cloud

Learn how to get started with Anaconda

< <u>B</u>ack

Finish

Cancel



ANACONDA.

Tick or untick two boxes as required and then select 'Finish'

2.0 HOPS Installation

Download the code from GITHUB

🧿 Save As								×
$\leftarrow \rightarrow \checkmark \uparrow \blacksquare$	> 1	This PC → Downloads	√ Ū	Se	earch Downlo	bads		Q
Organise 🔻 Nev	v fol	der				 	= •	?
💻 This PC	^	Name			Date mo	dified		Туре
🗊 3D Objects		✓ Last month (1) ———						
📃 Desktop		Astrometrica.zip			07/09/20	19 16:41		Comp
🔮 Documents								
👆 Downloads								
👌 Music								
Pictures								
🚆 Videos								
L WINDOWS (C:)							
👝 DATA (D:)		1						
r	*	×						
File <u>n</u> ame:	hop	os-master.zip						~
Save as <u>t</u> ype:	Con	npressed (zipped) Folder (*.zip)						\sim
∧ Hide Folders				C	<u>S</u> ave		Cancel	

Figure B2.1

Select 'Save'

Unzip by right-clicking on the 'hops-master.zip file and selecting Extract all.

	×
🔶 😫 Extract Compressed (Zipped) Folders	
Select a Destination and Extract Files	
Files will be extracted to this <u>f</u> older:	
C:\Users\RogerDymock\Downloads\hops-master Brows	e
Show extracted files when complete	
Extract	Cancel

Figure B2.2

Select 'Extract'

In the folder 'hops-master double' click 'windows_installer.cmd'. This brings up a window similar to that below. Not the actual one but that disappears on completion of installation so couldn't capture it.

🔤 Command Prompt		×
Microsoft Windows [Version 10.0.18362.418] (c) 2019 Microsoft Corporation. All rights reserved.		î
C:\Users\RogerDymock>		
		v

Figure B2.3



The hops.cmd icon,

, is placed on your desktop.

Double clicking on that opens two windows, Figures B2.5 and B2.6.

S C:\WINDOWS\system32\cmd.exe		×
C:\Users\RogerDymock\Desktop>python "C:\Users\RogerDymock\Anaconda3\lib\site-packages\hops-2.4.1-py3.7.egg\ no display found. Using non-interactive Agg backend gzip was not found on your system! You should solve this issue for astroquery.eso to be at its best! On POSIX system: make sure gzip is installed and in your path!On Windows: same for 7-zip (http://www.7-zip. Loading Please wait for the main window to appear.	hops" org)!	^
		~

Figure B2.5

🖉 Reduction & Alignment			– 🗆 X
HOlomon	Reduct	ion & Alignment	MY PROFILE
	Directory	Choose Directory	
	Name identifier for observation files	Autosave	ſ
E Contraction	Name identifier for bias files	bias	
etric 9	Name identifier for dark files	dark	
Convright (c) 2017-2019	Name identifier for flat files	flat	
Angelos Tsiaras	Bin fits files (reduced only)	1	
atsiaras@star.ucl.ac.uk		Show files	
USER MANUAL			
	Detected target RA DEC	None detected	✓ Use detected values
OBSERVATION PLANNER	Manual target RA DEC (hh:mm:ss +/-dd:mm:ss)	hh:mm:ss +dd:mm:ss	[
	Exposure time header keyword	EXPTIME	
	Observation date header keyword	DATE-OBS	
	Observation time header keyword	TIME-OBS	
		Show header	
	RUN REDU	CTION & ALIGNMENT	N

Figure B2.6

That's about it for installation.

Appendix C

The HOPS User Manual and Data Analysis video at <u>https://exoworldsspies.com/en/software/</u> provide detailed instructions on running HOPS but this example may be of help.

1.0 Data download

Go to <u>https://exoworldsspies.com/en/observers/</u> and choose a dataset – in this example HAT-P32b. The screen shot in Figure C1 will be displayed.



Figure C1.1. Selected target

Click on the arrow below 'Observations' – resulting in Figure C2.

** Drophox - wasp2h 20160711 ho			– n x
← → C	jeeuwt8/AACegYvS6w2HK33Zz7ckBO8	Da?dI=0	€ 4 7 8
🚻 Apps 🕒 Google			Other bookmarks
¥			Sign in Download •
wasp2b_20160711_holomon_cg	epro_c11xatik4000_rec	I	
Sorted by name			:=
reduction-001bias.fit reduction-001c	ark.fit reduction-001flat.fit	reduction-002bias.fit	reduction-002dark.fit
reduction-002flat.fit reduction-003	ias.fit reduction-003dark.fit	reduction-003flat.fit	reduction-004bias.fit

Figure C1.2. Selected data

Select Download/Direct download and save to a convenient folder.

Examine the images and delete those of poor quality or with satellite trails. If there is a meridian flip, as in this case, then reorient the later images to coincide with the earlier ones.

It is convenient to organise your data as per the instructions at <u>https://exoworldsspies.com/en/observers/</u> i.e.

- Keep all scientific and reduction frames in one folder without subfolders
- Use a specific identifier for the scientific frames e.g.WASP-10b-001.fits etc
- Use a specific identifier for the bias frames, not containing the same identifier as the scientific frames e.g. bias-001.fits etc
- Use a specific identifier for the dark frames, not containing the same identifier as the scientific frames e.g. dark-001.fits etc
- Use a specific identifier for the flat frames, not containing the same identifier as the scientific frames e.g. flat-001.fits etc

2.0 Target data and selection of comparison stars

RA	Dec	B-V	V mag
20 30 54.14	+06 25 45.90	0.894	11.798
Table C2.1			



Figure C2.2

Nominal criteria for comparison star selection (data from Vizier/APASS) 0.694<(B-V=0.894)<1.094, 10.298<(V=11.798)<13.298

Comp star	RA	Dec	B-V	V
1	20 30 51.73	+06 28 01.14	0.631	12.028
2	20 30 46.52	+06 20 56.90	0.821	13.046
3	20 30 41.49	+06 30 54.58	0.652	12.985
4	20 31 22.21	+06 26 28.26	0.928	11.924
5	20 31 02.21	+06 32 40.58	0.718	12.663

Table C2.2

3.0 Analysis

There is a video at <u>https://exoworldsspies.com/en/software/</u> a User Manual below the video window.

Double click on the hops.cmd icon and wait until the window in Figure C3 is displayed.

🦸 Reduction & Alignment			– 🗆 🗙
HOlomon	Reduct	ion & Alignment	MY PROFILE
	Directory	Choose Directory	
	Name identifier for observation files	Autosave	
E and the second	Name identifier for bias files	bias	
ciric 0	Name identifier for dark files	dark	
Convright (c) 2017-2019	Name identifier for flat files	flat	
Angelos Tsiaras	Bin fits files (reduced only)	1	
atsiaras@star.ucl.ac.uk		Show files	
USER MANUAL			
	Detected target RA DEC	None detected	Use detected values
OBSERVATION PLANNER	Manual target RA DEC (hh:mm:ss +/-dd:mm:ss)	hh:mm:ss +dd:mm:ss	[
	Exposure time header keyword	EXPTIME	
	Observation date header keyword	DATE-OBS	
	Observation time header keyword	TIME-OBS	
		Show header	
	RUN REDU	CTION & ALIGNMENT	[

Figure C3.1. Reduction and Alignment window

Select he directory in which the images (observation files in HOPS terminology) are stored by clicking on the Directory box and navigating to the relevant folder. Enter the Name identifier for observation files, wasp-2, bias, dark and flat files and the quantities of images and calibration frames will now be listed. The Reduction and Alignment window is now populated – Figure C3.2.



Figure C3.2

Select My Profile, fill in the observatory data and click on Update – Figure C3.3 shows as much as could be gleaned from the FITS header and a web search. For the purposes of this exercise do not leave 'None' in any of the boxes as this will cause an error later.

🧳 My Profile			
	UPDATE		
observer kev	OBSERVER	flat files	flat
observatory key	OBSERVAT	bin fits	1
telescope key	TELESCOP	observatory	Holomon Station
camera key	INSTRUME	observatory lat	+40 25 58
filter_key	FILTER	observatory_long	23 30 19
observation_date_key	DATE-OBS	observatory_elev	850
observation_time_key	TIME-OBS	observatory_time_zone	2
target_ra_key	OBJCTRA,RA	observer	Dymock
target_dec_key	OBJCTDEC,DEC	telescope	2800 FL scope
exposure_time_key	EXPTIME	camera	CCD
observation_files	Autosave	filter	R
bias_files	bias		
dark_files	dark		

Figure C3.3

Select Run Reduction and Alignment. On completion the window in Figure C3.4 is displayed in which some images were deselected.



Figure C3.4

Select RUN ALIGNMENT. On completion the Photometry window is displayed - Figure C3.5.

Photometry

 \times



Click Show FOV and orientate the image to match the chart in Figure C3.2 – Figure C3.6





Select Target and Comparison stars as listed in Table C2.2 – Figures C3.7 and C3.8

Photometry



Figure C3.7

Select Run Photometry to calculate the light curve – Figure C3.8 is displayed.



Figure C3.8

Close the window shown in Figure C3.8 and select Proceed to Fitting – Figure C3.9 is displayed which shows observatory, host star and exoplanet data. This data can be verified by referring to, for example, the <u>Extrasolar Planets Encyclopaedia</u>



Figure C3.9

Select the Light-curve file from your various attempts and aperture or Gauss (psf) fitting you wish to use. Click on Show Preview to see a preview of the fitted light-curve – Figure C3.10.

The raw light-curve and model fit (red line) are shown at the top while the detrended light curve and model fit (red line) and the expected model, cyan line, are shown at the bottom.



Figure C3.10

If the result is satisfactory click on RUN FITTING to obtain the final result, Figure C3.11. Data included is shown in Figure C.12. obtained from the User Manual.

Other data and images available are itemised in the User Manual PP30-32.





Figure C.12

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