

The ExoClock Project

Ground - based exoplanet observations in support of the ARIEL space mission

Anastasia Kokori

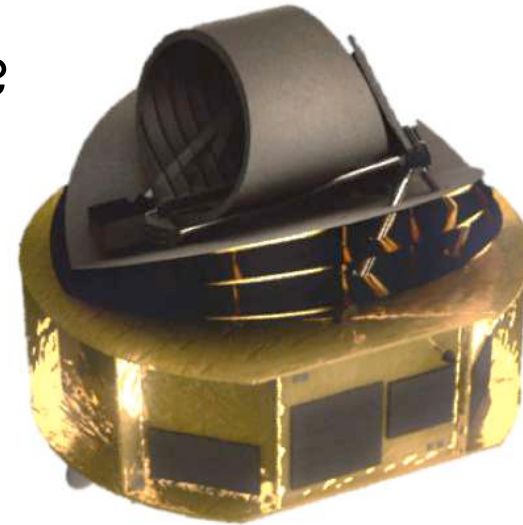
UCL, Birkbeck & Royal Observatory Greenwich

ARPS meeting, 29th September 2019

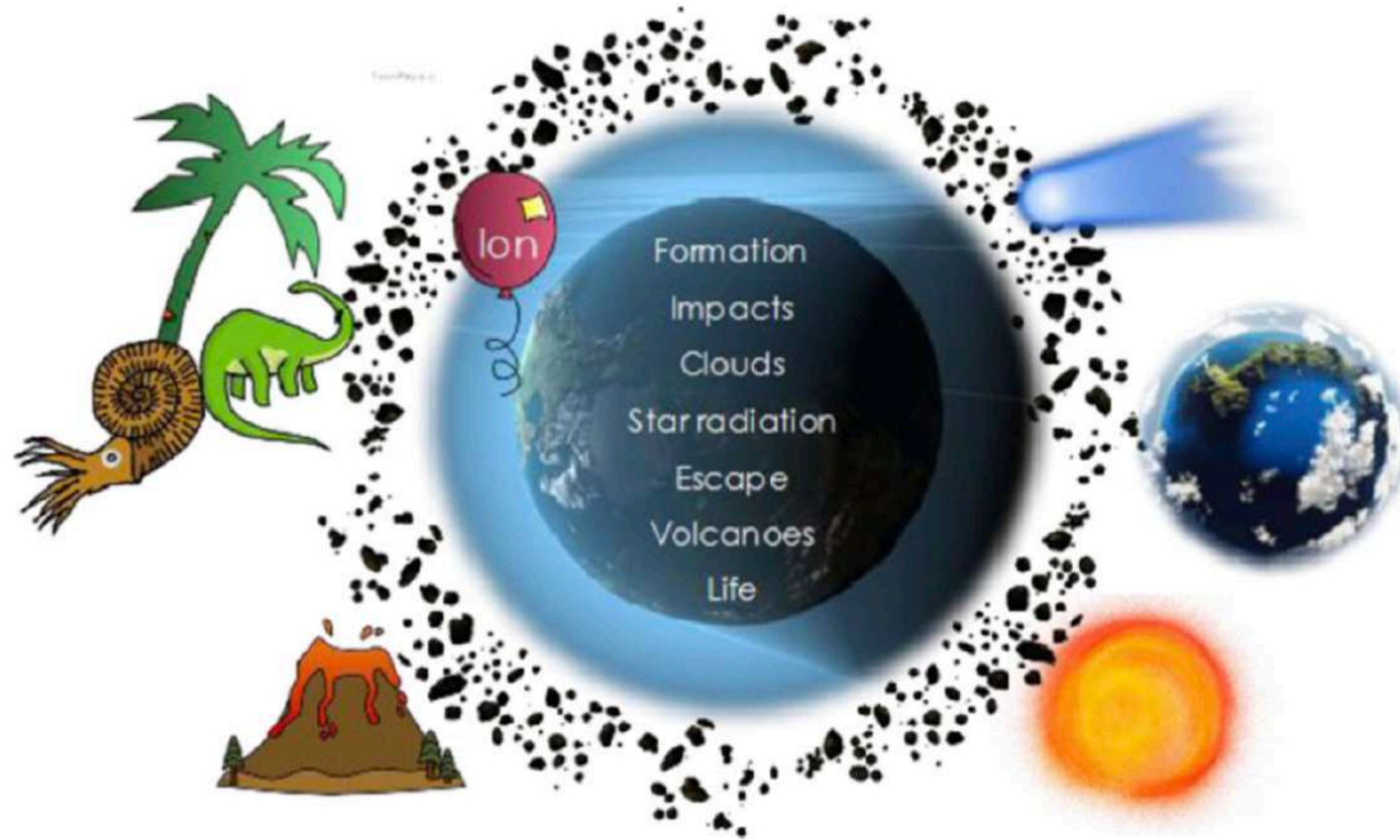


ARIEL space mission

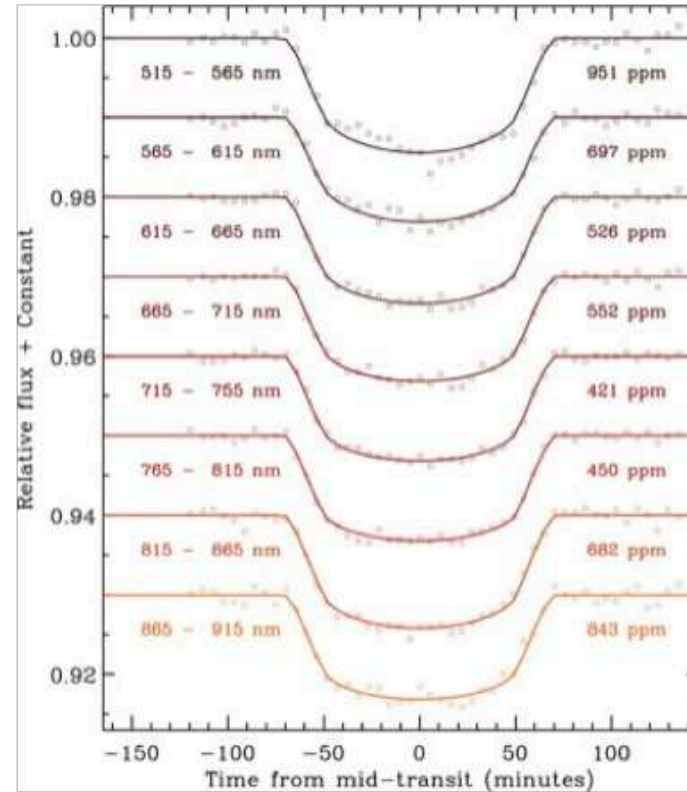
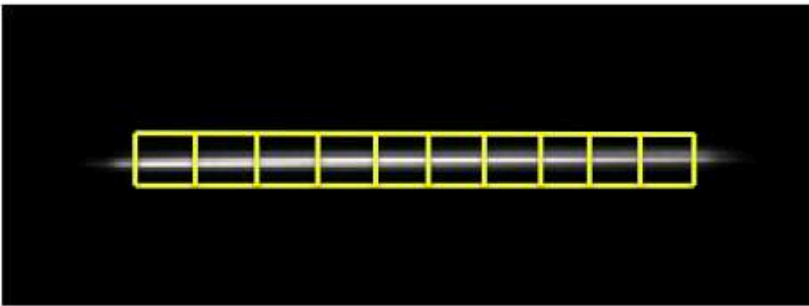
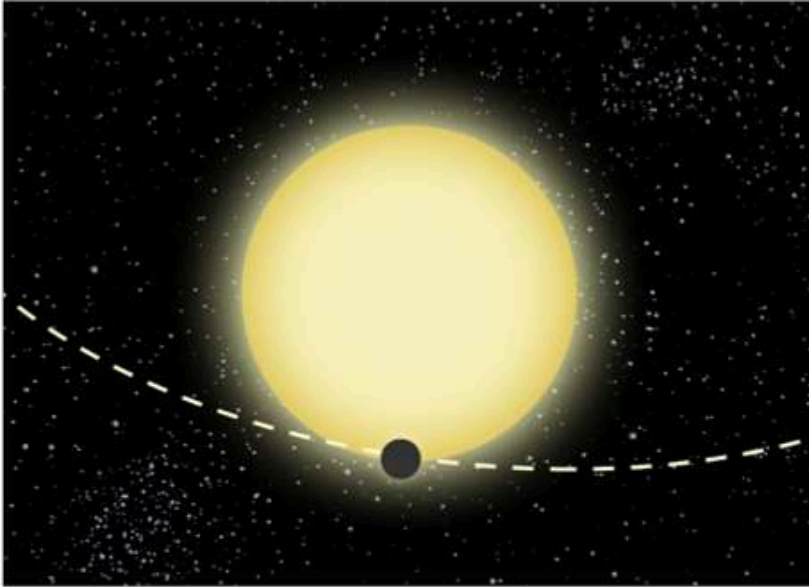
- ESA medium (M4) mission: Launch 2028
- Telescope aperture: 1 m
- Spectrograph
- Wavelength coverage: 0.5 - 7.8 μm
- Key science question:
How chemically diverse are exoplanets?
- Science goal:
Observe ~1000 exoplanet atmospheres



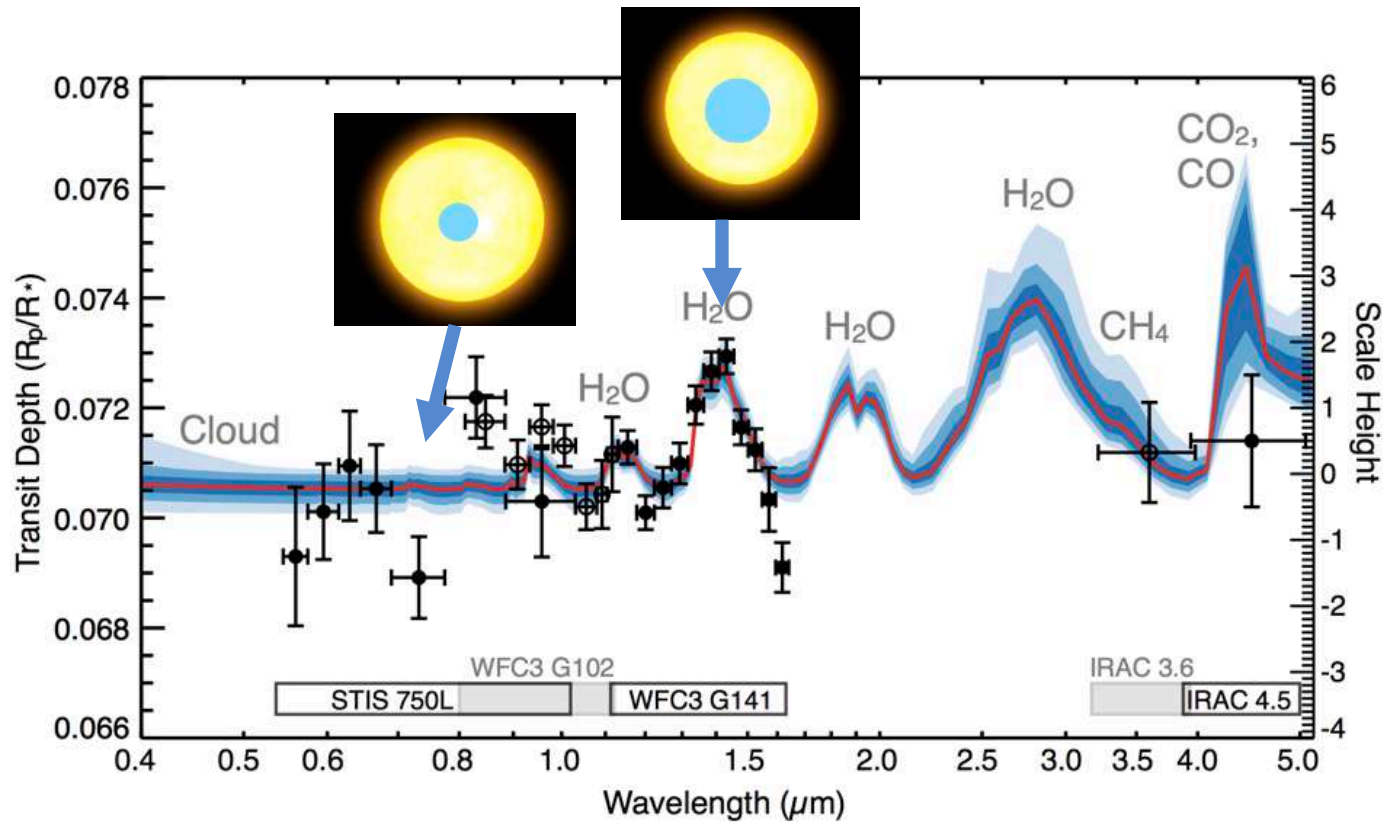
Importance of the atmosphere



Transit spectroscopy

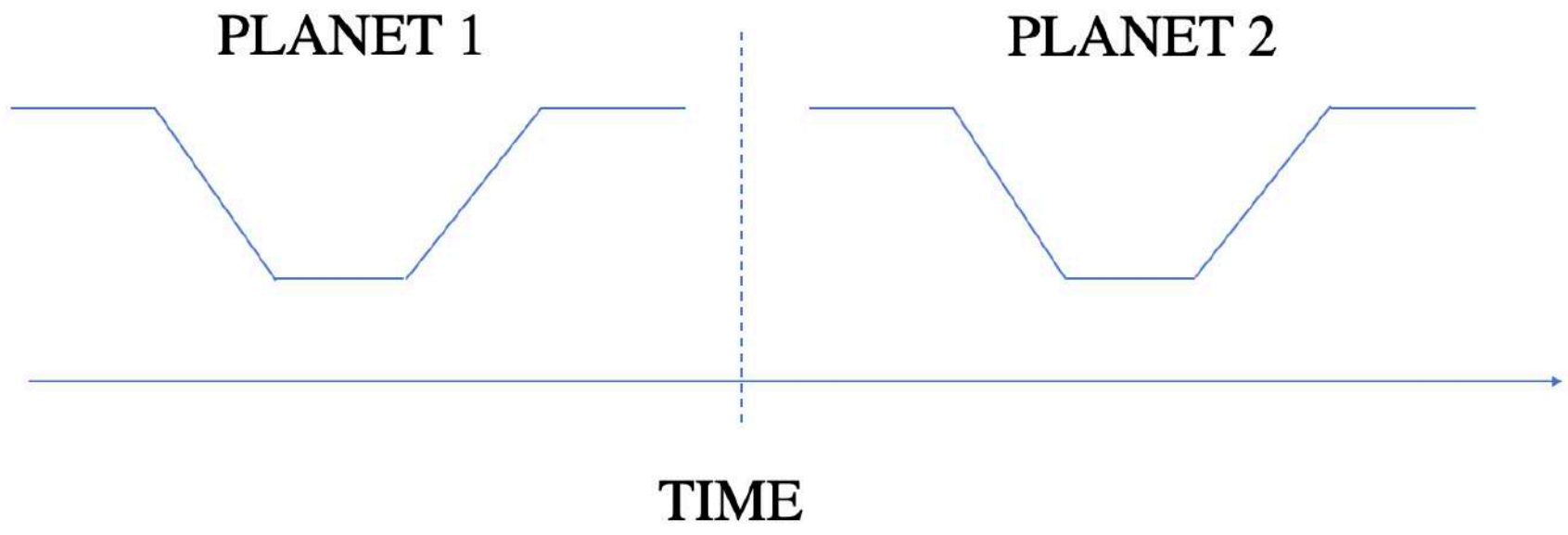


Transit spectroscopy

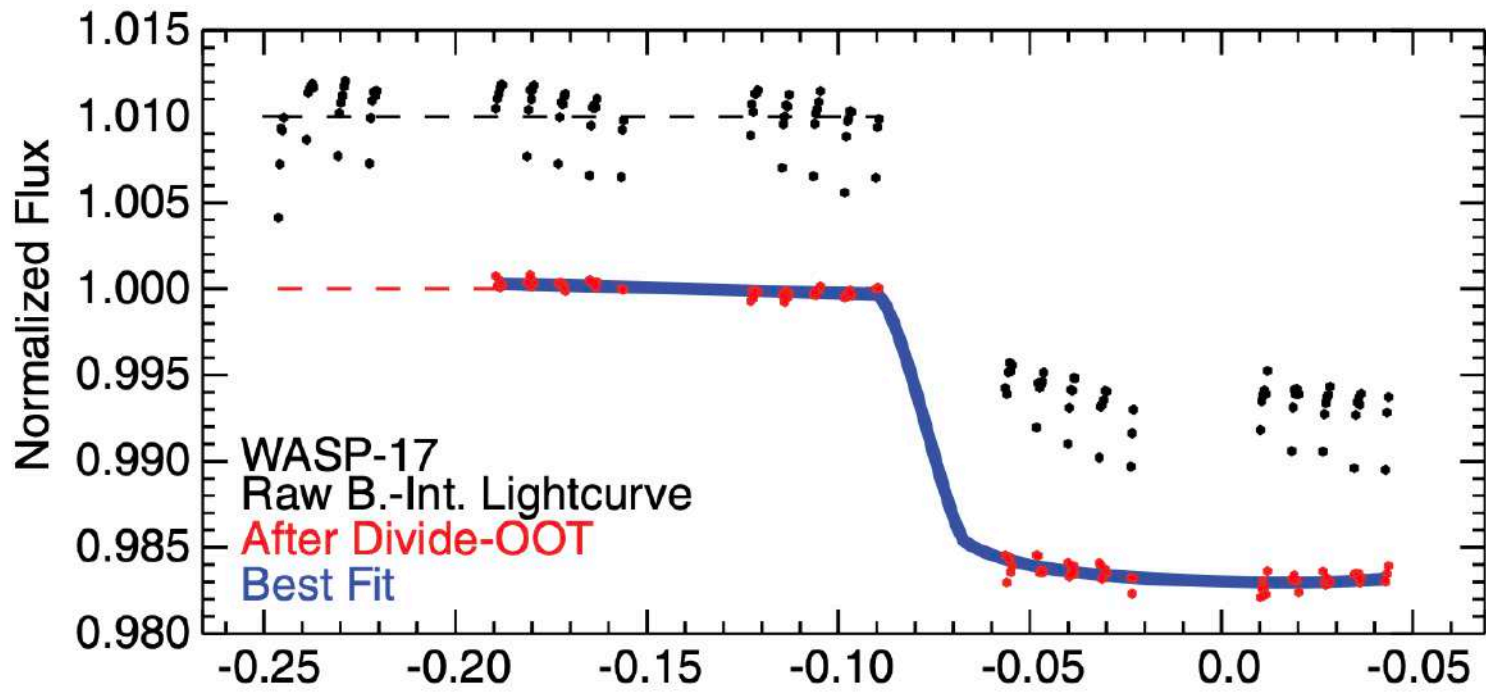


Wakeford et al. 2017

Time-critical



Time-critical



Mandel et al. 2017

Ephemeris refinement: WASP-83 b

Hellier et al. 2015:

$$T_0 = 2455928.8853 \pm 0.0004$$

$$P = 4.971252 \pm 0.000015$$

Last observation Feb. 2012

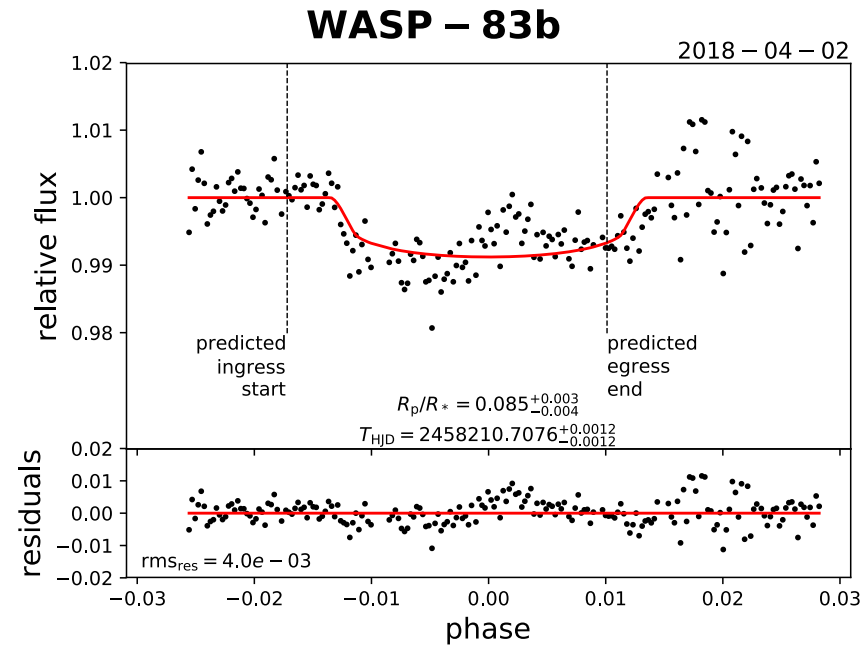
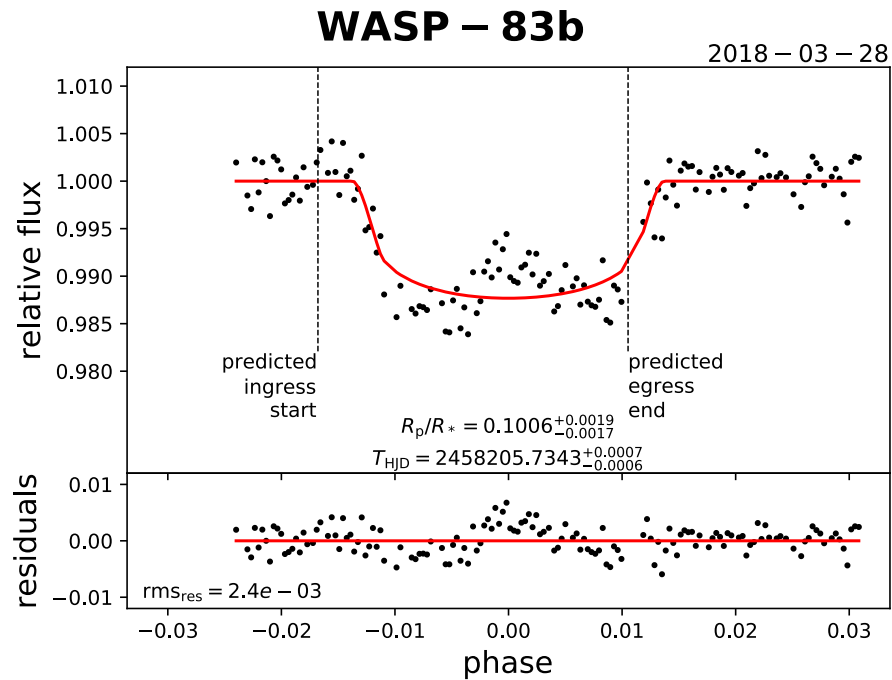
Our observations:

28 / 03 / 2018

02 / 04 / 2018

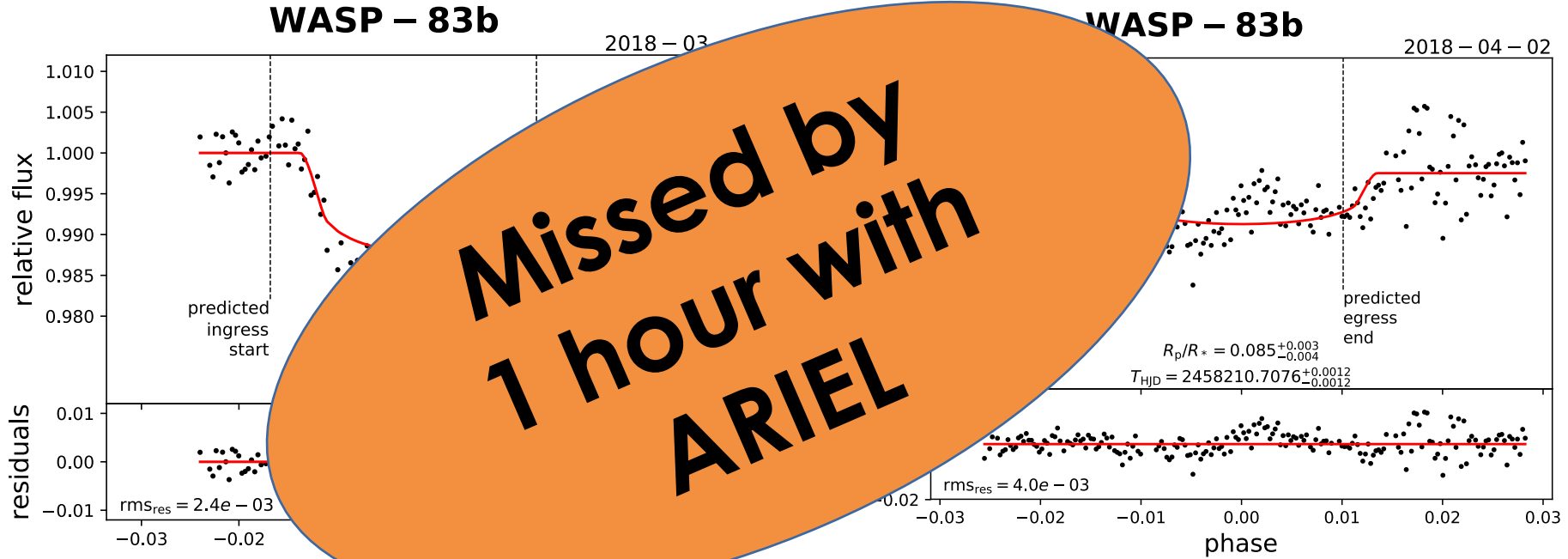
Expected uncertainty: **± 9 minutes**

Ephemeris refinement: WASP-83 b



Confirmed time shift of **25 minutes**

Ephemeris refinement: WASP-83 b



Confirmed time shift of **25 minutes**

The **ExoClock** project

Need for ephemeris confirmation for ~1000 ARIEL targets:

- Not so many observations required: ~1 per 1-2 year(s)!
- But needs to be well organised
- Every transit is a unique opportunity to contribute to the mission
- Observations can be available for further research

What is new in ExoClock

- ◆ Open to everyone
- ◆ Live up-to-date ephemerides
- ◆ Target prioritization with alert system
- ◆ Personalised observation schedule
- ◆ Direct publications for participants
- ◆ Continuous feedback to the observers



Welcome to the ExoClock Project

ExoClock is a project to monitor transiting exoplanets in order to keep their ephemerides up-to-date. Everyone with some basic equipment, including a telescope and a CCD camera, can participate in the effort of monitoring the planets' host stars. If you haven't heard of exoplanet monitoring before, have a look here:

<https://exoworldsspies.com/science>

Step 1: Register your telescopes

Now that you are ready, go to [My Telescopes](#) to register your telescopes. This information is mandatory for us to suggest you which planets to observe, and when. You can always update your telescopes under [My Telescopes](#) and your personal info under [My Profile](#)

Step 2: Check your schedule

After completing this step, go to [My Schedule](#) to see which planets you can observe.

Step 3: Observe a transit

If you don't have any experience on observing transiting exoplanets, all the guidelines on how to record an exoplanet transit are outlined here:

<https://exoworldsspies.com/observing>



Welcome Anastasia!

Logout

My Telescopes

Name	Size [inches]	Observatory	Latitude [degrees]	Longitude [degrees]	Camera	
C11	11.0	Holomon Astronomical Station	43.4	23.5	ATIK 4000	Delete
c8	8.0	Holomon Astronomical Station	40.4	23.5	ATIK 11000	Delete

Add new Telescope:

Telescope model*

Required.

Telescope Aperture in inches (above 6)*



Planet Name & Remarks	Star RA/DEC [h/deg]	Star Vmag [mag]	Transit Depth [mmag]	Transit Duration [h]	Observ. Start [TZ:2.0]	Transit Start [TZ:2.0]	Transit Mid-point [TZ:2.0]	Transit End [TZ:2.0]	Observ. End [TZ:2.0]
WASP-52b LOW PRIORITY NO PRE-TRANSIT	23:13:58.74 8:45:40.5 FOV	12.0	33.51	1.82	2019/09/06 19:31 16° E	2019/09/06 20:31 27° E	2019/09/06 21:26 36° SE	2019/09/06 22:20 44° SE	2019/09/06 23:20 52° SE
TrES-2b MEDIUM PRIORITY	19:07:14.03 49:18:59.0 FOV	11.41	15.44	1.84	2019/09/06 19:59 82° NE	2019/09/06 20:59 82° NW	2019/09/06 21:54 74° NW	2019/09/06 22:49 66° NW	2019/09/06 23:49 56° NW
HAT-P-32b MEDIUM PRIORITY NO PRE-TRANSIT	2:04:10.28 46:41:16.2 FOV	11.29	29.63	3.12	2019/09/06 20:04 19° NE	2019/09/06 21:04 27° NE	2019/09/06 22:38 41° NE	2019/09/07 00:12 56° NE	2019/09/07 01:12 66° E
Qatar-1b LOW PRIORITY	20:13:31.60 65:09:43.3 FOV	12.84	25.33	1.65	2019/09/06 20:25 66° N	2019/09/06 21:25 68° N	2019/09/06 22:15 68° N	2019/09/06 23:04 65° N	2019/09/07 00:04 60° NW



Upload Observations

Telescope*

- IC Astronomy Observatory - Officina Stellare ProRC 700 - FLI PL16803
- Warrambungle Observatory - Meade LX200ACF - SBIG STXL6303E
- El Sauce Observatory - Planewave CDK24 - FLI ProLine PL9000

File*

Choose file No file chosen

This should be a .TXT file containing only two columns: one for the time and one for the flux. If you are using HOPS you will find a file named "ExoClock_info.txt" in your photometry folder, with information on what you need to upload.

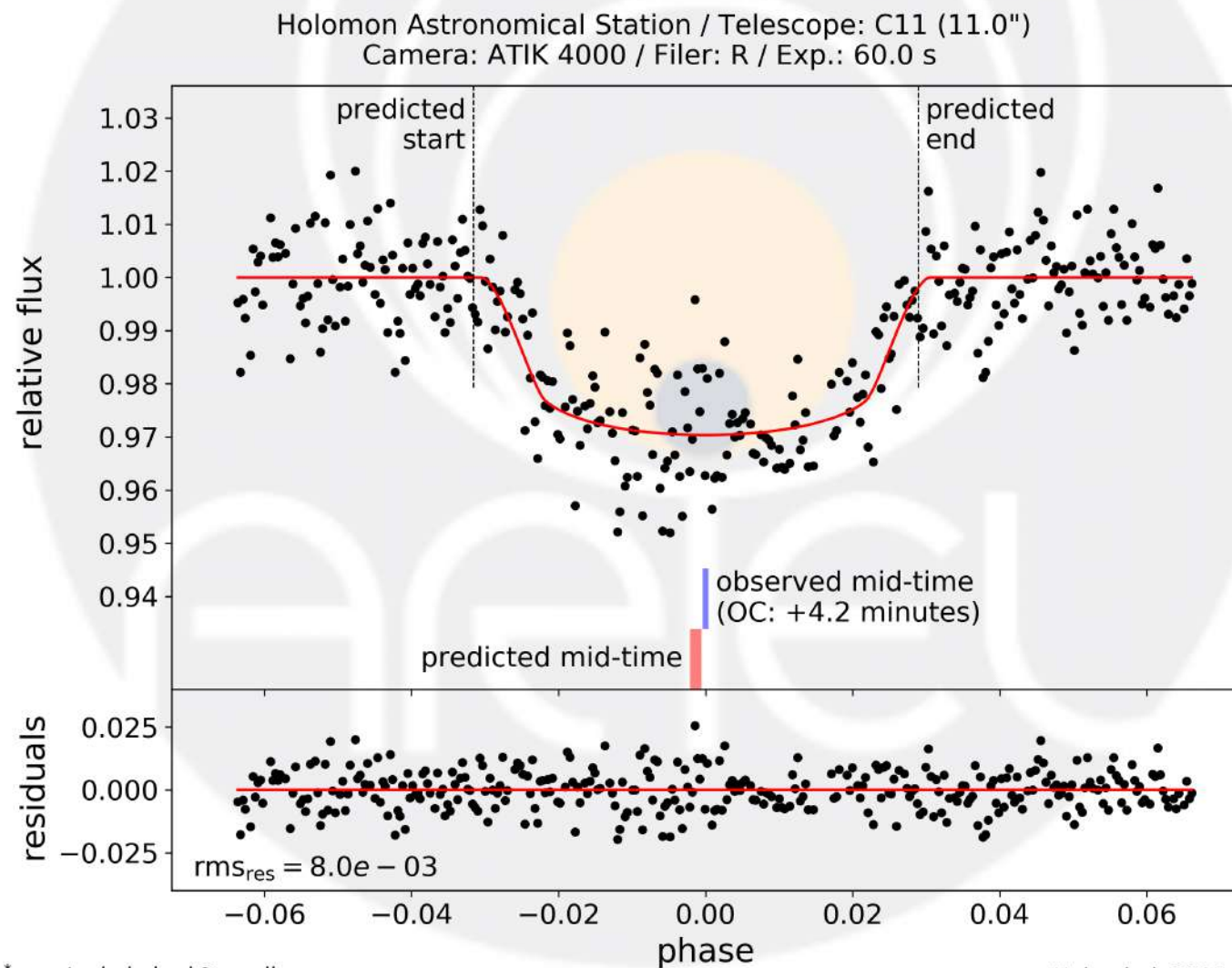
Planet*

55Cnce

HAT – P – 32b

2017-10-05

Anastasia Kokori* (UCL, ROG), Angelos Tsiaras (UCL, AUTh)



The Exoworlds Spies project

ABOUT

SCIENCE

PEOPLE

START TRAINING

DATA BASE

SOFTWARE

BLOG

ΕΛΛΗΝΙΚΑ



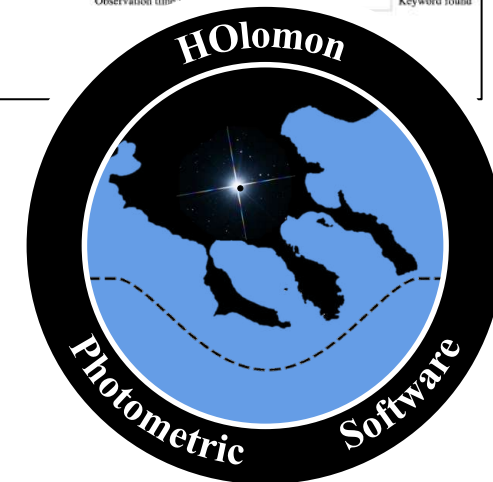
Our strategy

- Education and Research
- Observation toolkit
- Data analysis software
- Educational material (videos, data for training etc)
- Website/ email
- www.exoworldsspies.com



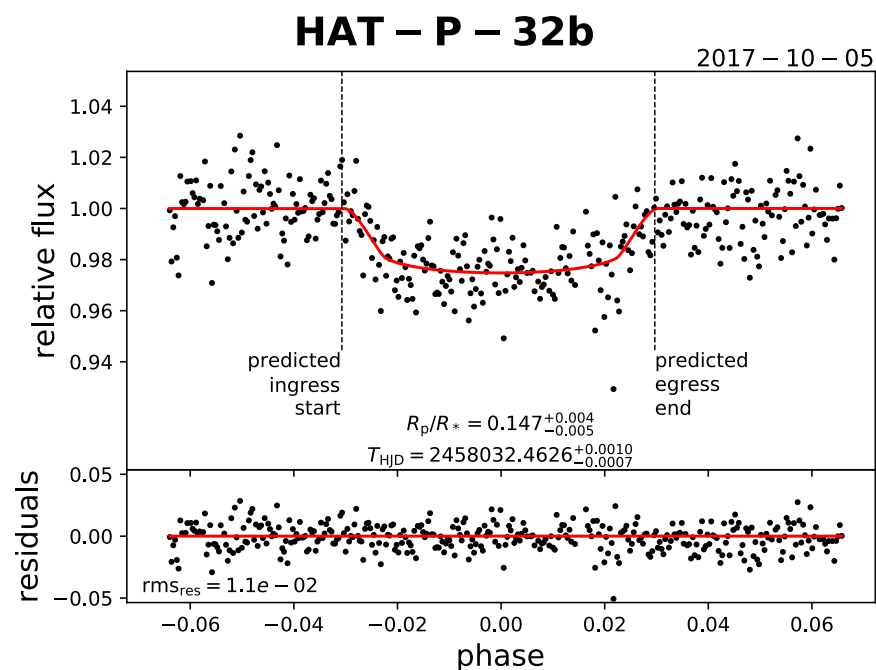
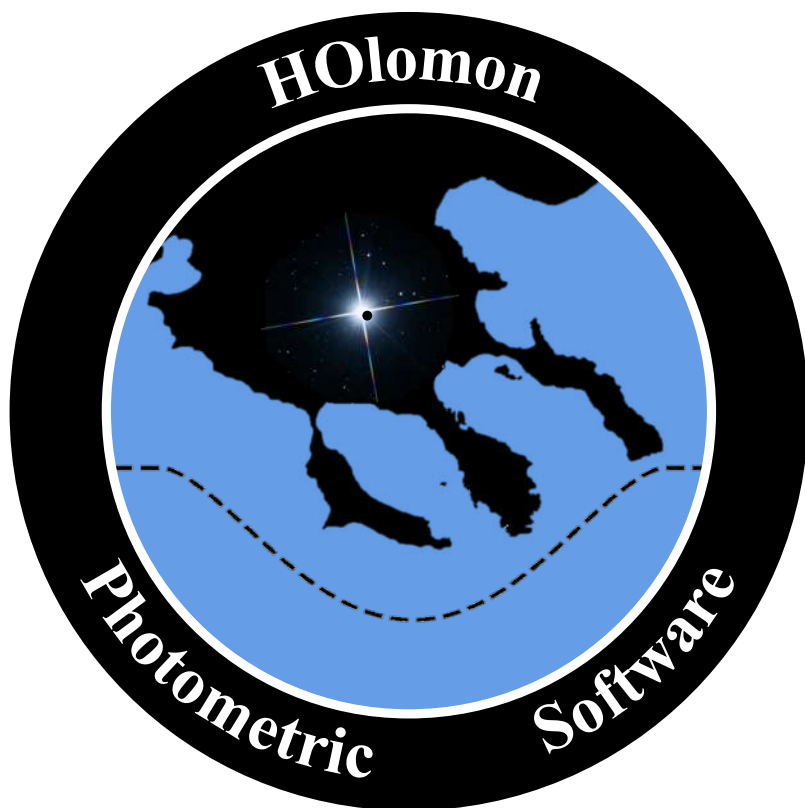
The screenshot shows the 'Reduction & Alignment' window of the Holomon Photometric Software. The interface includes a directory path 'Desktop/WASP85b' and several input fields for file naming conventions. A table lists the number of files found for each identifier. Below this, there are fields for target RA/DEC coordinates, exposure time keywords, and observation date keywords. A 'Show files' button is also visible.

Field	Value	Files Found
Name identifier for observation files	Auto	676 files found
Name identifier for bias files	bias/	35 files found
Name identifier for dark files	dark/	25 files found
Name identifier for flat files	flat/	10 files found
Bin fits files (reduced only)	I	



HOPS – the **H**Olomon **P**hotometric **S**oftware

github.com/ExoWorldsSpies/hops



HOPS – characteristics

Open source code

open to contribution from the pro/am communities

GUI for Linux / Mac OS / Windows

no scientific or coding background needed

Written in Python

easy to implement modern scientific codes

Flexible on data formats

suitable for most small and medium class telescopes



HOPS – features

User profile

The image shows two screenshots of the HOPS software interface. The left window, titled 'My Profile', contains a list of fields for user information, each with a text input field. The right window, titled 'Reduction & Alignment', contains a logo for 'HOlon Photometric Software', copyright information, and various configuration options for file naming and detection.

My Profile

UPDATE

observer_key	OBSERVER
observatory_key	OBSERVAT
telescope_key	TELESCOP
camera_key	INSTRUME
filter_key	FILTER
observation_date_key	DATE-OBS
observation_time_key	TIME-OBS
target_ra_key	OBJCTRA,RA
target_dec_key	OBJCTDEC,DEC
exposure_time_key	EXPTIME
observation_files	Autosave
bias_files	bias
dark_files	dark
flat_files	flat
bin_fits	1
observatory	
observer	
telescope	
camera	
filter	

Reduction & Alignment

HOlon Photometric Software

Copyright (c) 2017-2019
Angelos Tsiaras
atsiaras@star.ucl.ac.uk

Reduction & Alignment

HELP

MY PROFILE

Directory: Desktop/hatp32b_20171005

Name identifier for observation files		No files found
Name identifier for bias files	bias	5 files found
Name identifier for dark files	dark	5 files found
Name identifier for flat files	flat	5 files found
Bin fits files (reduced only)	1	

Show files

Detected target RA DEC: None detected

Use detected values

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 REDUCTION & ALIGNMENT



HOPS – features

Reduction

The screenshot displays the HOPS Reduction & Alignment software interface on the left and a file browser window on the right. The software interface includes a logo for HOlonon Photometric Software, copyright information for Angelos Tsiaras, and various configuration fields for observation files, bias files, dark files, flat files, and bin fits files. It also features a 'Show files' button and a 'RUN REDUCTION & ALIGNMENT' button. The file browser window shows a directory named 'hatp32b_20171005' containing a 'hops.command' file and a list of output files such as 'areduction-001bias.fit', 'breduction-001dark.fit', and 'creduction-001flat.fit'.

Reduction & Alignment

HOlonon Photometric Software

Copyright (c) 2017-2019
Angelos Tsiaras
atsiaras@star.ucl.ac.uk

Reduction & Alignment **HELP** **MY PROFILE**

Directory **Choose Directory**

Name identifier for observation files: Autosave

Name identifier for bias files: bias

Name identifier for dark files: dark

Name identifier for flat files: flat

Bin fits files (reduced only): 1

Show files

Detected target RA DEC: None detected

Use detected values

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 REDUCTION & ALIGNMENT

hatp32b_20171005

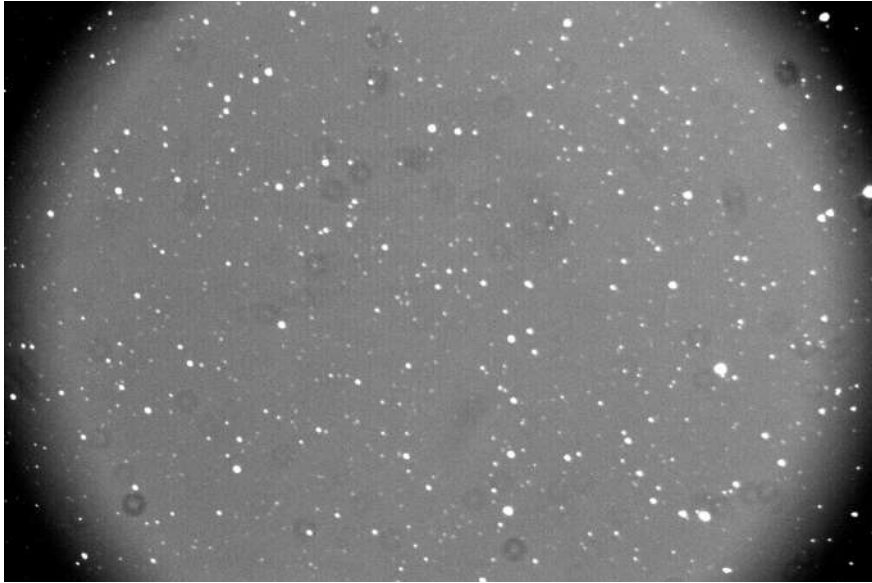
hops.command

- areduction-001bias.fit
- breduction-001dark.fit
- creduction-001flat.fit
- hatp-32b-001.fit
- hatp-32b-002.fit
- hatp-32b-003.fit
- hatp-32b-004.fit
- hatp-32b-005.fit
- hatp-32b-006.fit
- hatp-32b-007.fit
- hatp-32b-008.fit
- hatp-32b-009.fit
- hatp-32b-010.fit
- hatp-32b-011.fit
- hatp-32b-012.fit
- hatp-32b-013.fit
- hatp-32b-014.fit
- hatp-32b-015.fit



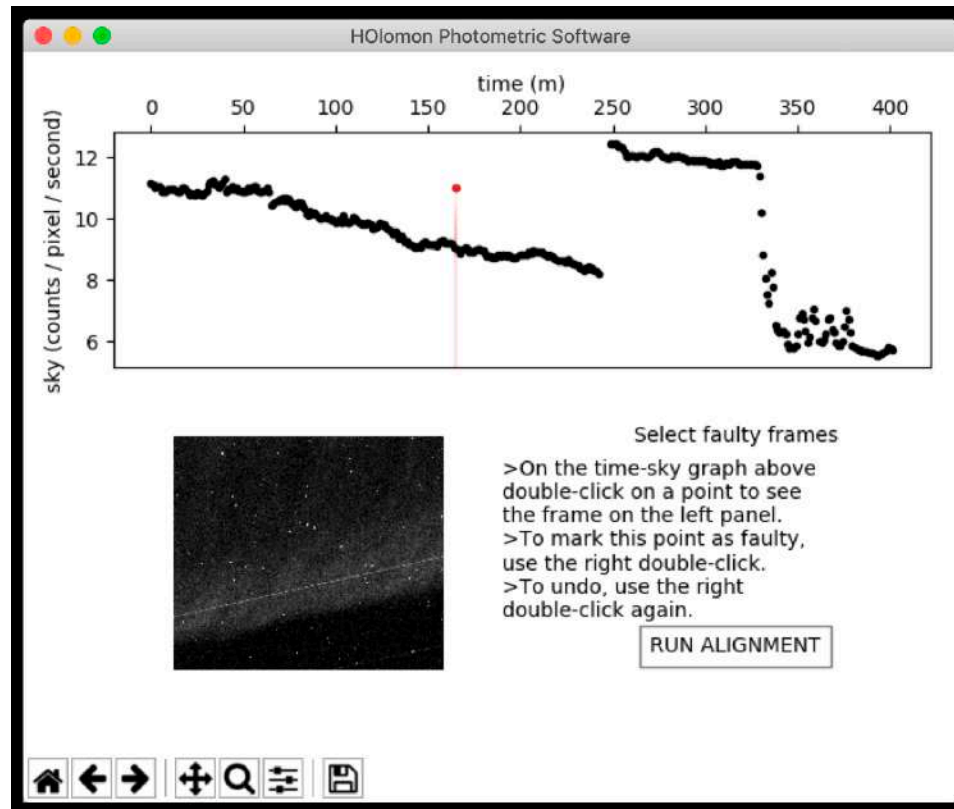
HOPS – features

Reduction



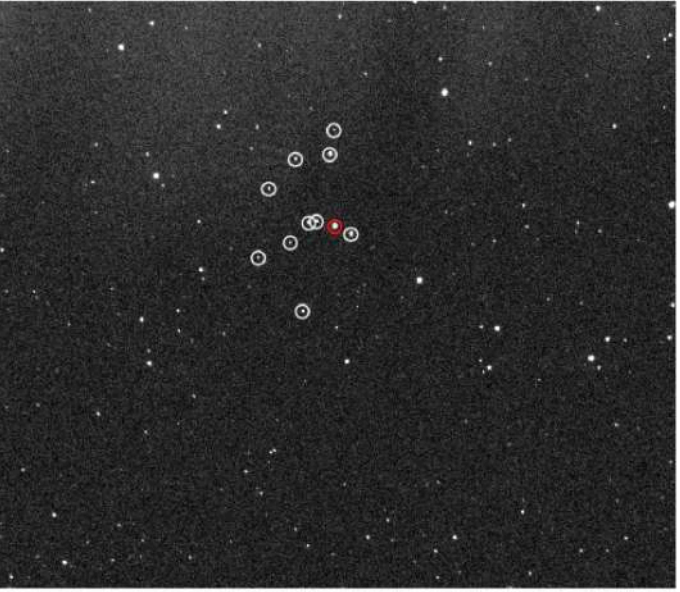
HOPS – features

Frame selection



HOPS – features

Alignment



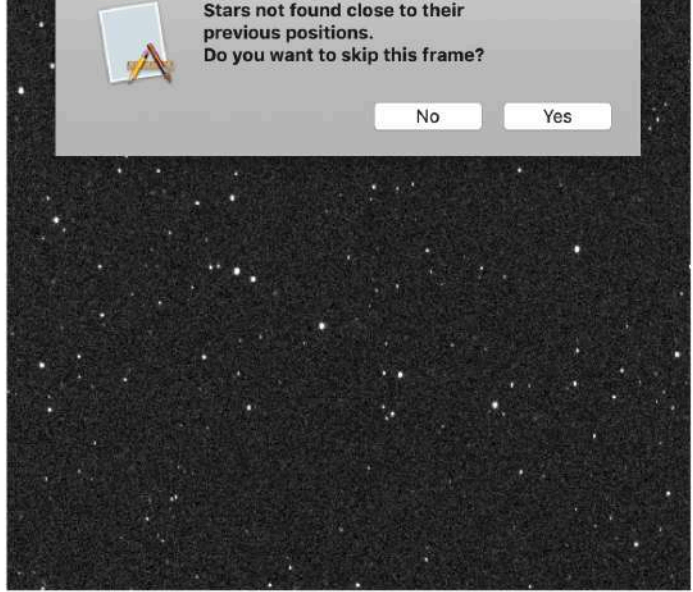
HOlomon Photometric Software

ALIGNMENT

FILE: out_2017_10_05_22_28_22_hatp-32b-159.fit

COMPLETE: 43.1%

TIME LEFT: 0h 00m 23s



HOlomon Photometric Software

Stars not found close to their previous positions.
Do you want to skip this frame?

No Yes

ALIGNMENT

FILE: out_2017_10_05_23_01_52_hatp-32b-190.fit

COMPLETE: -%

TIME LEFT: -h -m -s



HOPS – features

Photometry

The screenshot displays the HOPS Photometry software interface, divided into two main windows: 'FOV' and 'Photometry'.

FOV Window: Shows a star field with a red 'T' target and cyan 'C1' and 'C2' comparison stars. The axes range from 0 to 1000. A toolbar at the bottom includes navigation and zoom controls.

Photometry Window: Contains the 'HOLomon Photometric Software' logo, copyright information (© 2017-2019 Angelos Tsiaras), and a table of comparison stars. The table has columns for 'Position' (X, Y) and 'Box semi-length'. A 'RUN PHOTOMETRY' button is at the bottom.

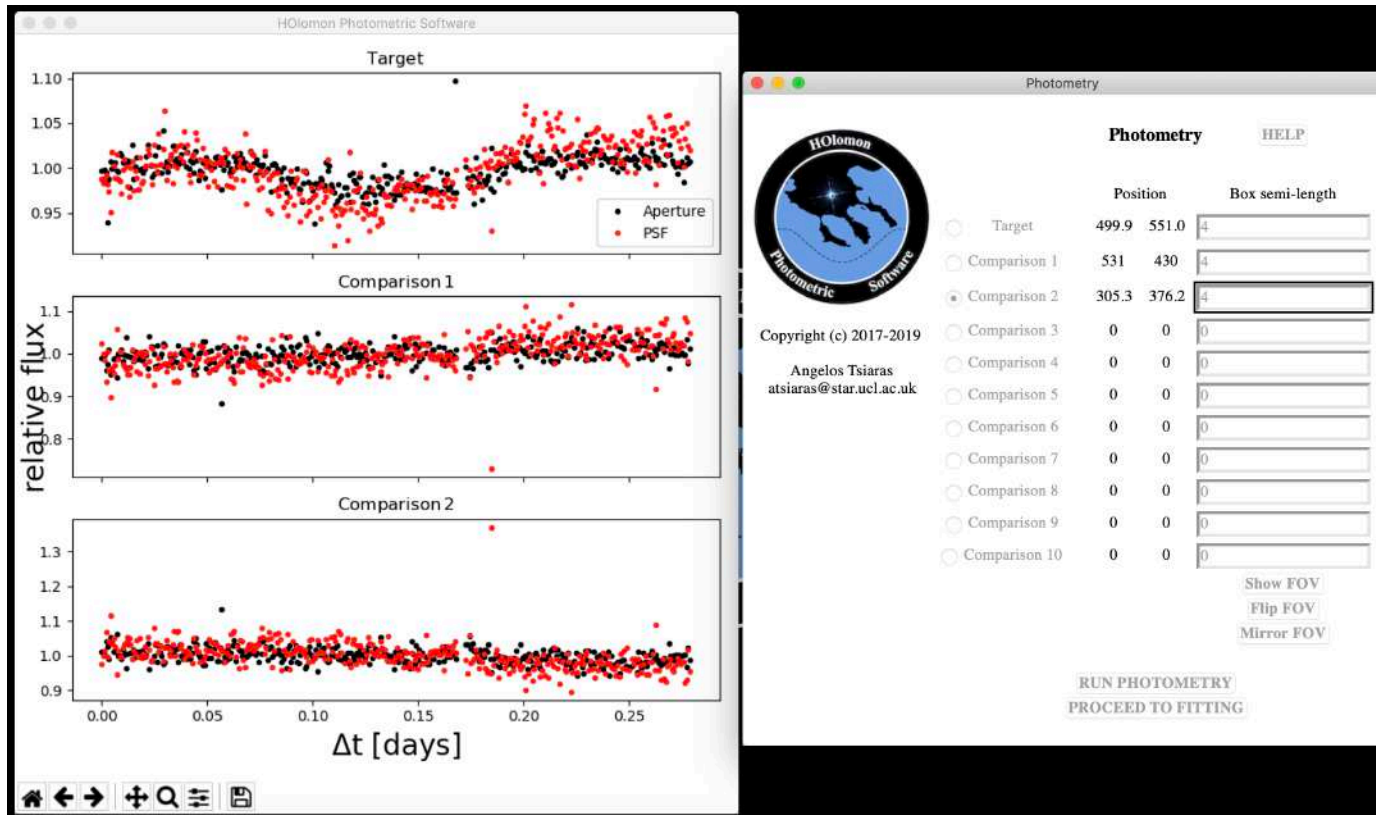
	Position	Box semi-length
<input type="radio"/> Target	499.9 551.0	4
<input type="radio"/> Comparison 1	531 430	4
<input checked="" type="radio"/> Comparison 2	305.3 376.2	4
<input type="radio"/> Comparison 3	0 0	0
<input type="radio"/> Comparison 4	0 0	0
<input type="radio"/> Comparison 5	0 0	0
<input type="radio"/> Comparison 6	0 0	0
<input type="radio"/> Comparison 7	0 0	0
<input type="radio"/> Comparison 8	0 0	0
<input type="radio"/> Comparison 9	0 0	0
<input type="radio"/> Comparison 10	0 0	0

Buttons: Show FOV, Flip FOV, Mirror FOV, RUN PHOTOMETRY, PROCEED TO FITTING



HOPS – features

Photometry



HOPS – features

Photometry – ExoClock_info.txt

The ExoClock Project is an effort to keep the ephemerides of exoplanets as precise as possible for planning future observations. If you have observed an exoplanet you can contribute your observation at:

<https://ariel-gbfu.azurewebsites.net>

File to upload: PHOTOMETRY_APERTURE.txt
(this is a suggestion based on the scatter of your light curves, you can also try uploading PHOTOMETRY_GAUSS.txt)

Planet: HAT-P-32b
(this is the closest known exoplanet found in the catalogue, if this is not the target you observed, please ignore)

Time format: JD.UTC
(UTC-based Julian date)

Flux format: Flux
(flux of target over summed flux of comparisons)

Filter: R

Exposure time in seconds: 60.0



HOPS – features

Fitting

The screenshot displays the HOPS software interface. The main window is titled 'Fitting' and contains a 'Fitting' section with various input fields and a 'Preview' window showing two plots.

Fitting Section:

- Light-curve file: PHOTOMETRY/PHOTOMETRY_APERTURE.txt
- Binning: 1
- Scatter limit: 3.0
- Filter: R
- Camera: ATIK4000
- Planet: HAT-P-32 b
- Period [days]: 2.150009
- Mid-time [days, HJD]: 2454420.44637
- Rp/Rs: 0.14678185211086506
- a/Rs: 5.304197355687062
- Inclination [deg]: 88.7
- Eccentricity: 0.163
- Periastron [deg]: 0.0
- Telescope: C11
- Observatory: Holomon
- Observer: Holomon
- M* [Fe/H, dex]: -0.16
- T* [K]: 6207.0
- log(g*) [cm/s^2]: 4.219936
- Iterations: 130000
- Burned iterations: 30000

Preview Section:

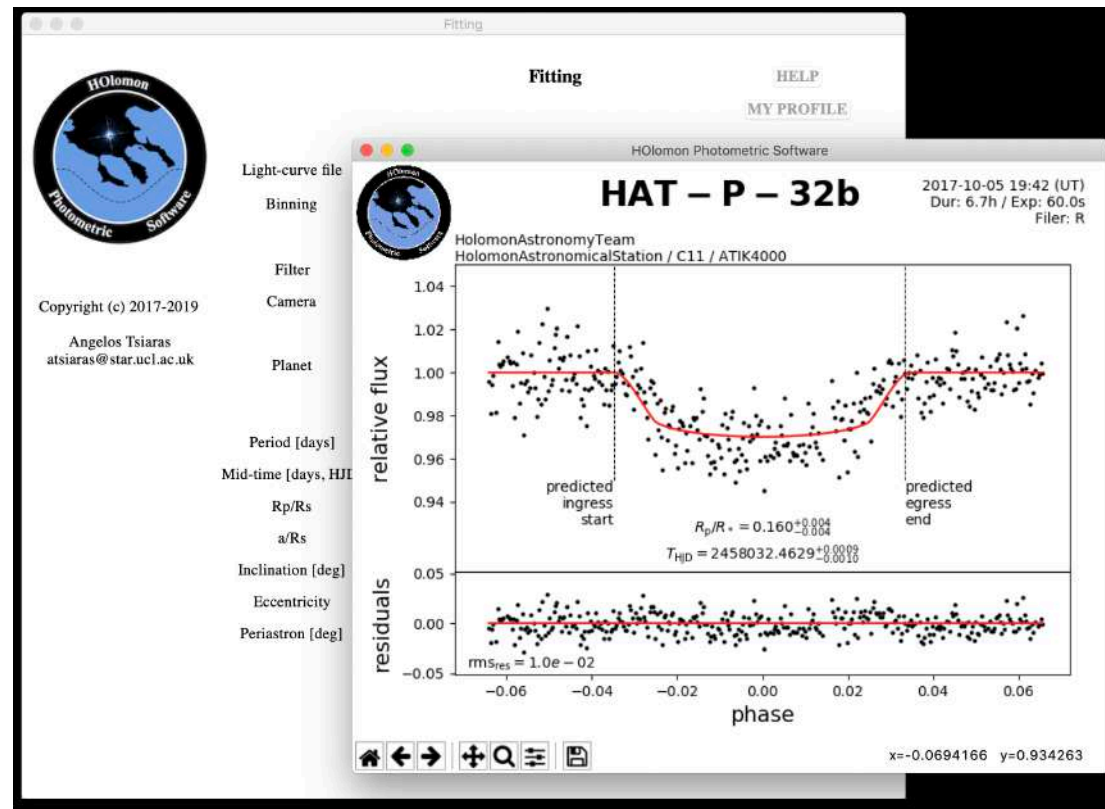
- relative flux: 0.700 to 0.825
- normalised flux: 0.96 to 1.02
- phase: -0.06 to 0.06
- 8.2e-03

Buttons: Show Preview, RUN FITTING, RETURN TO PHOTOMETRY, EXIT



HOPS – features

Fitting



Join us in the ExoClock project!

Register at ExoClock:

exoclock.space

Launched!

Start training at ExoworldsSpies:

www.exoworldspies.com

