

Remotely operated robotic telescopes – the MicroObservatory Robotic Telescope Network

Updated 2023 March 11

Please note that while you may use HOPS and ExoClock on-line analysis to process MicroObservatory observations do not submit your observations to the ExoClock database. The reason for this is that multiple observers may submit results of their analysis of the same set of observations which is causing some confusion.

However you can upload your results to the Exoplanet Transit Database (ETD)

To do so;

- Select ‘How to contribute to ETD on the above mentioned page
- Select ‘Use on-line protocol’
- Follow the instructions to load data to both TRESCA and the ETC

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- 1.0 Accessing the network
- 2.0 Target selection
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- 5.0 MicoObservatory data

1.0 Accessing the network

I must thank Martin Fowler for his considerable help with this project.

The network is operated by the [Harvard and Smithsonian Center for Astrophysics](#) and can be found [here](#). The exoplanet section is accessed by clicking on the ‘DIY Planet Search’ button in the bottom right-hand corner of the home page – Figure 1.1

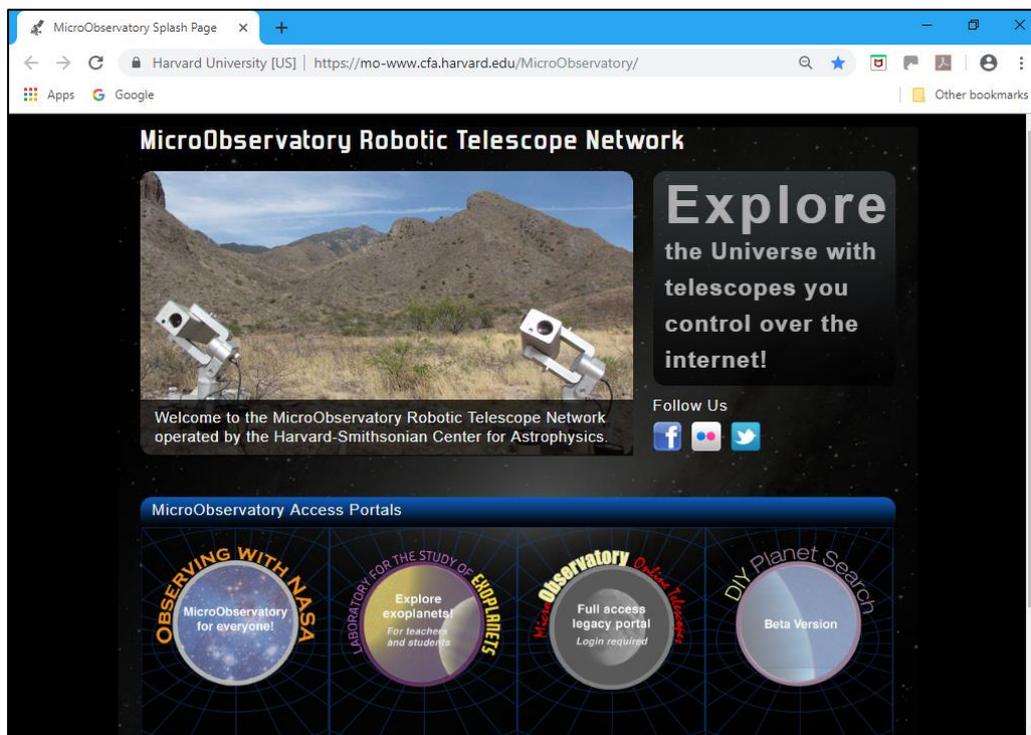


Figure 1.1 Robotic telescope home page.

This brings up the Log in/Register screen – Figure 1.2

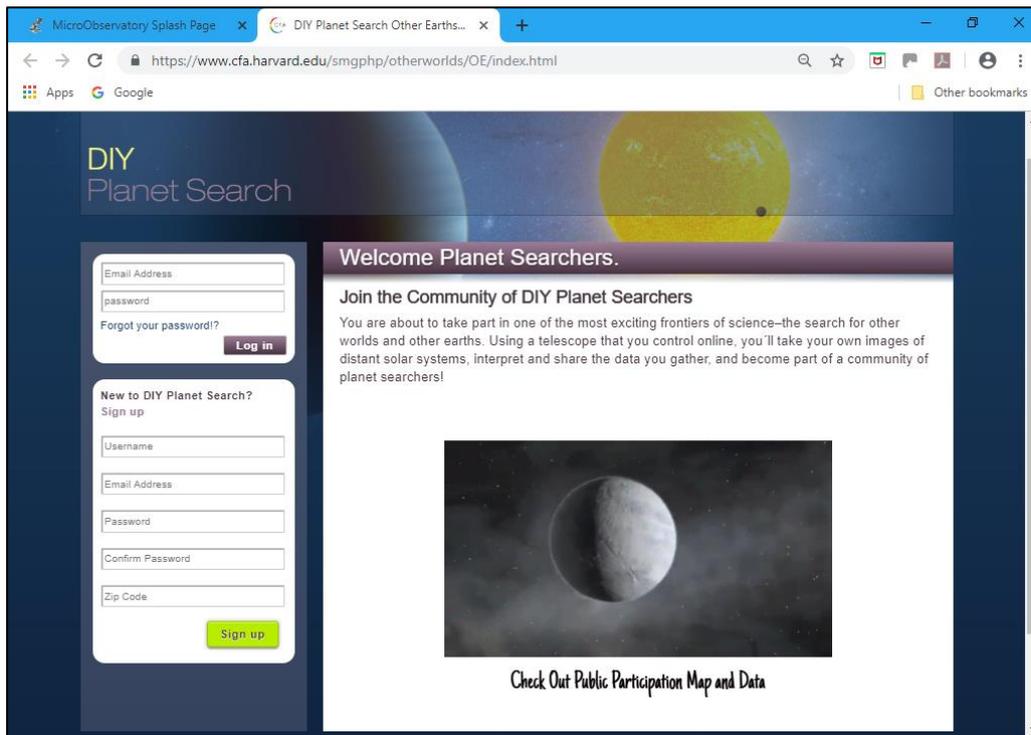


Figure 1.2. Log in/Register screen

2.0 Target selection

After logging in the screen shown in Figure 2.1 is presented which shows targets for the next few days.

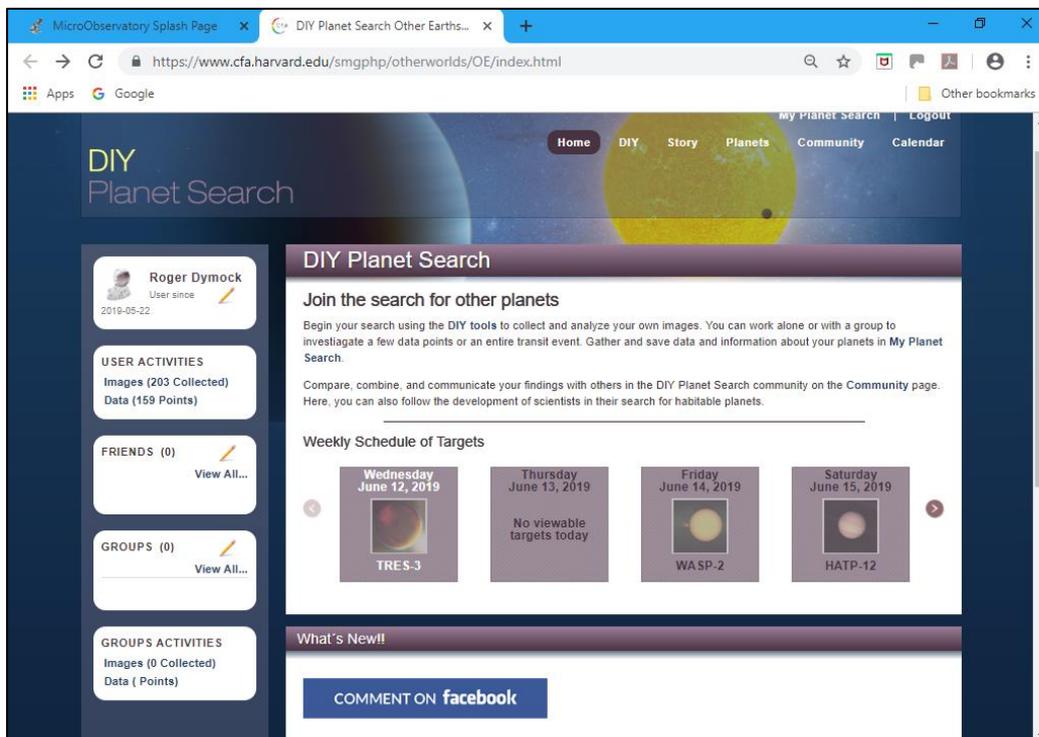


Figure 2.1.

To see the targets for the whole month, Figure 2.2, select 'DIY' at the top of the screen.

Choose a target which is shown on the MicroObservatory pages as shown in Figures 2.1 and 2.2.

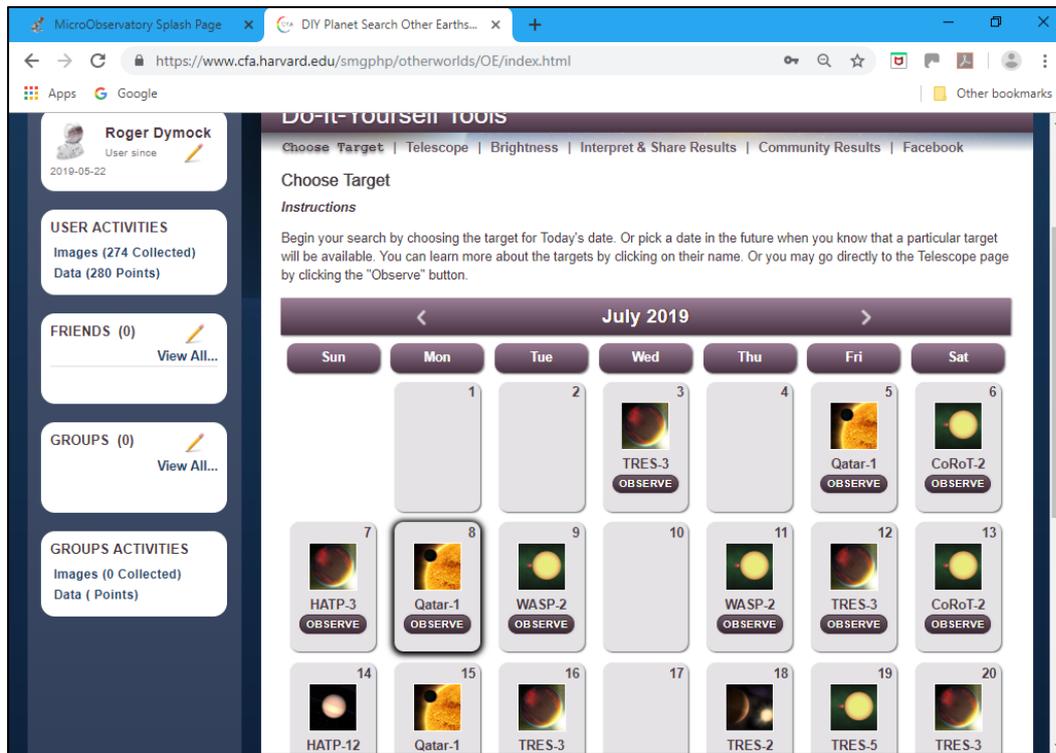


Figure 2.2. Targets for the month.

The target for 2019 July is TRES-3 and the next step is to set up the observing run by clicking on 'Observe' for that object. This opens the Do-it-Yourself Tools page – Figure 2.3.

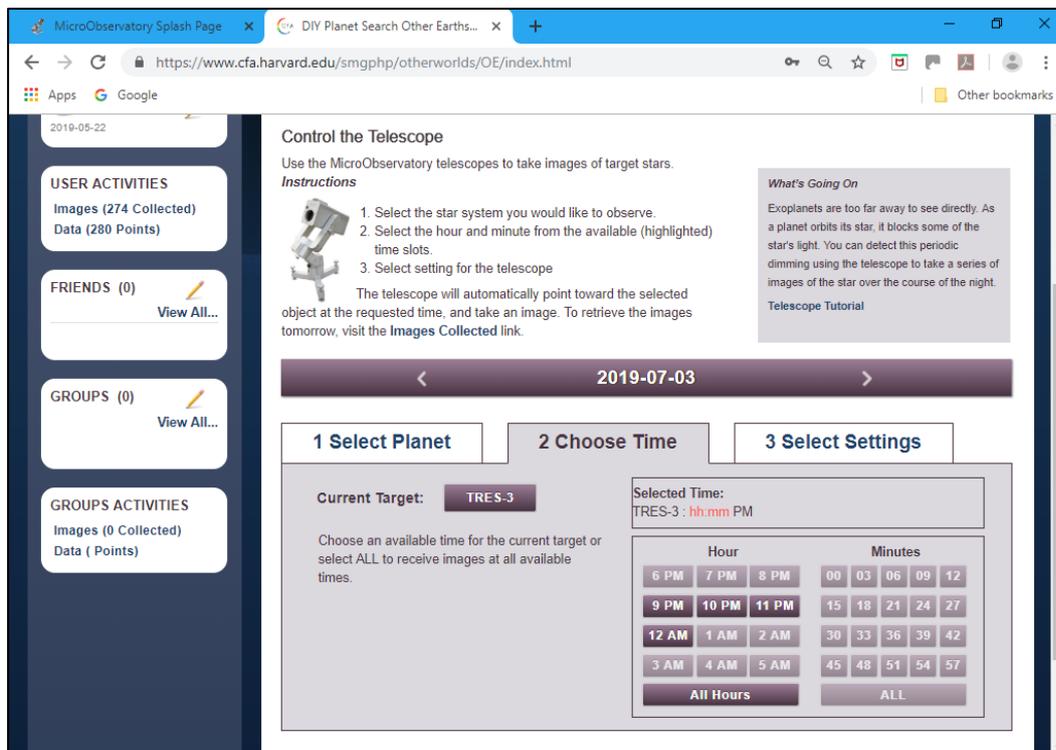


Figure 2.3. DIY Tools page '2 Choose Time' tab.

Under the '2 Choose Time' tab select 'All Hours' which switches to the '3 Select Settings' tab – Figure 2.4. Input the Exposure time and Filter as suggested (they may already be set to the appropriate values).

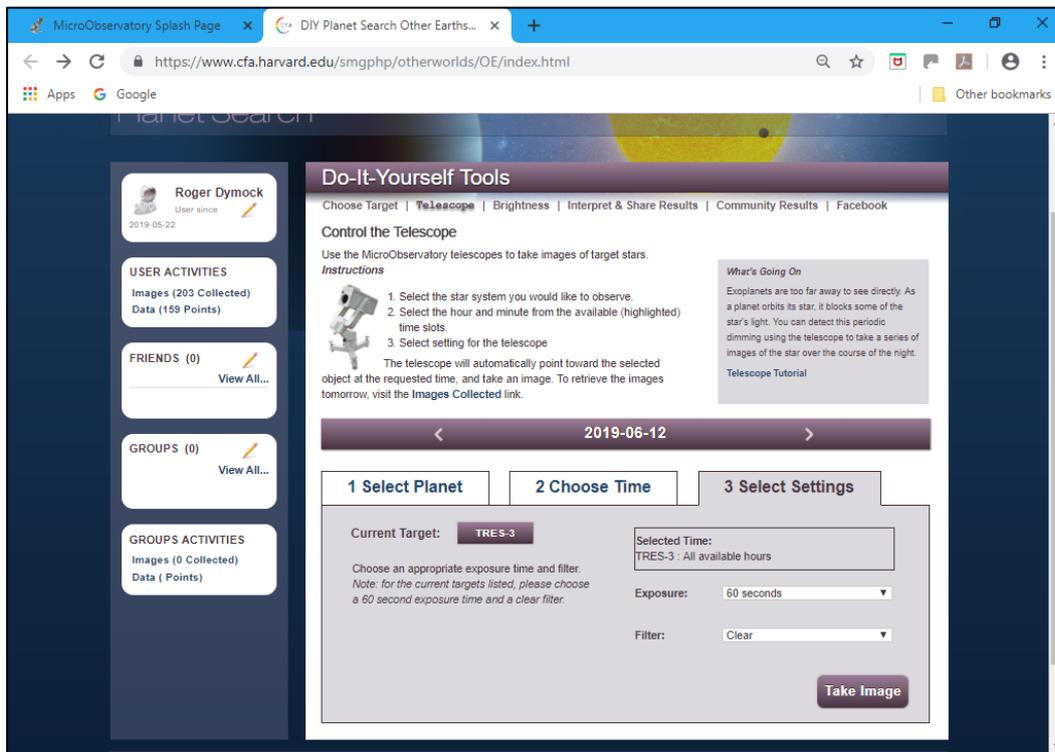


Figure 2.4. DIY Tools page '3 Select Settings' tab.

Clicking on 'Take Image' in the bottom right-hand corner of the screen displays the target and number of images to the left of that button. Images should be available within three days. Selecting 'My Planet Search' at the top of the page opens the page shown in Figure 2.5.

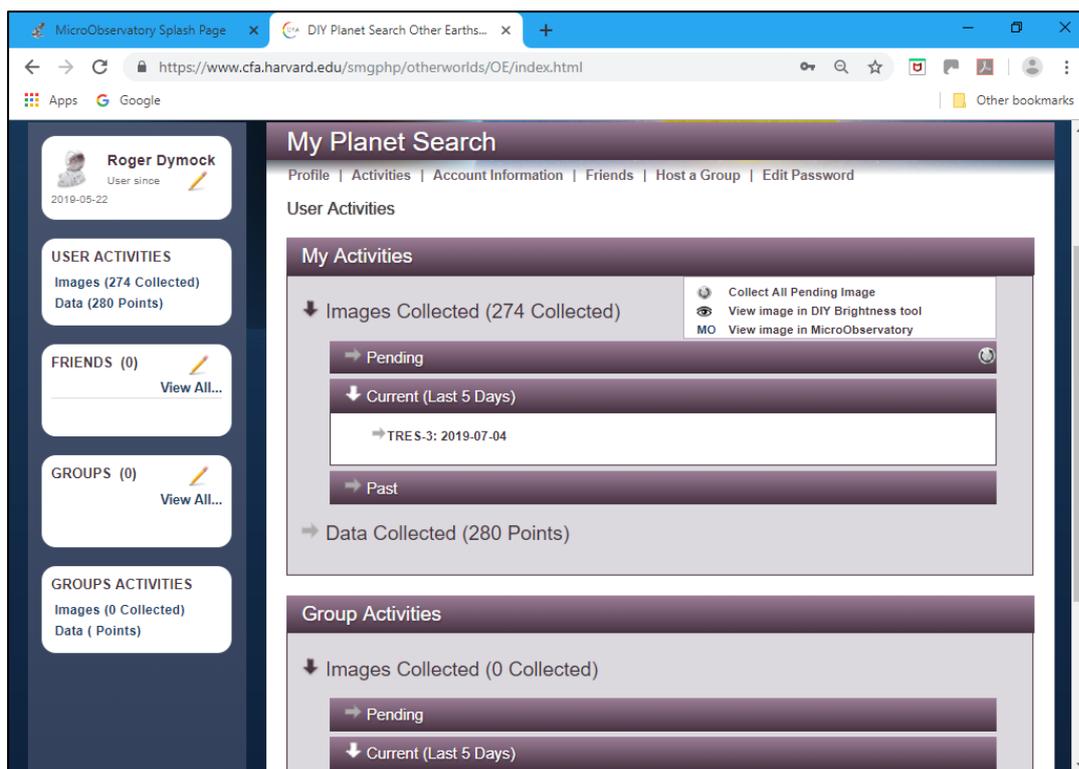


Figure 2.5. Activity status page.

In this case, images of TRES – 3 obtained on the 2019 July 3 are shown under the ‘Current (Last 5 Days)’ heading. Clicking on the arrow next to TRES-3 2019-07-04 opens a list of the images obtained – Figure 2.6.

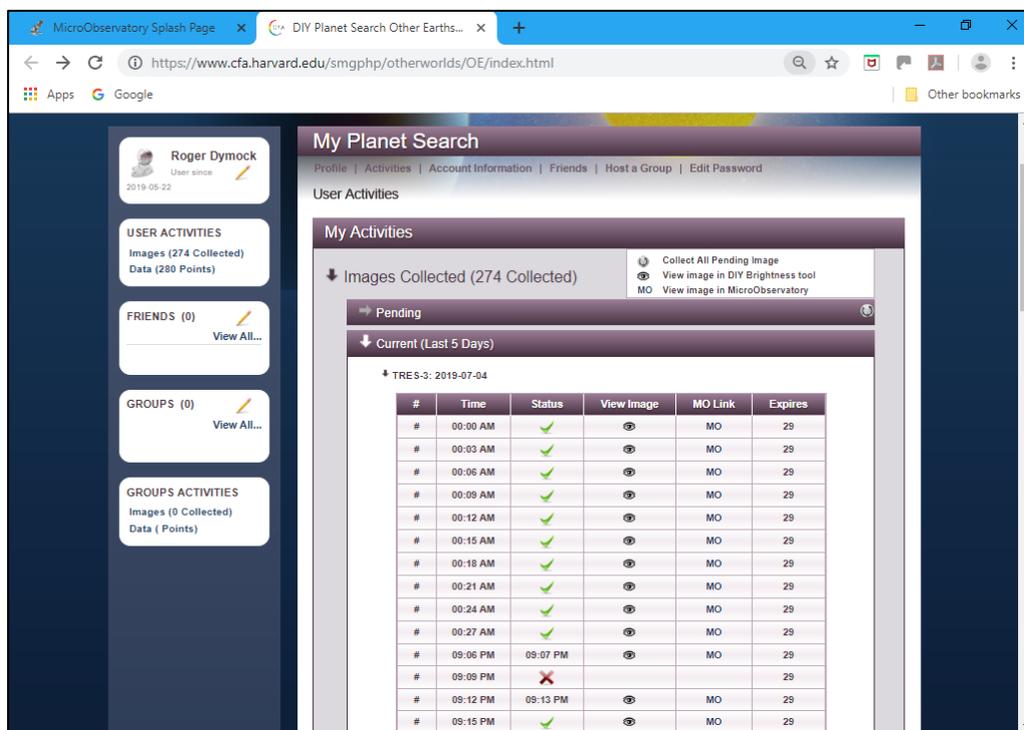


Figure 2.6. (Partial) list of images of TRES 3 obtained on 9th June 2019

3.0 On-line analysis

Select each image in turn, example in Figure 3.1, by clicking on the eyeball icon next to the one to be analysed in the 'View Image' column.

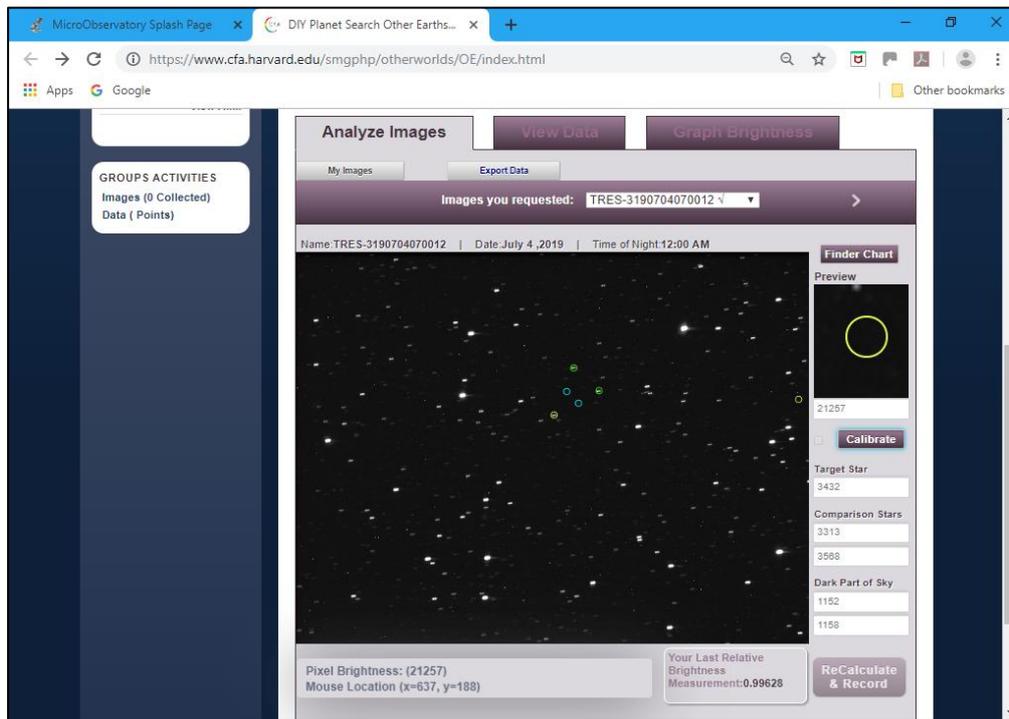


Figure 3.1. Example image of TRES-3

Clicking on the 'Finder chart' button displays a chart with the two comparison stars indicated by yellow circles and the target star by a green circle – Figure 3.2.

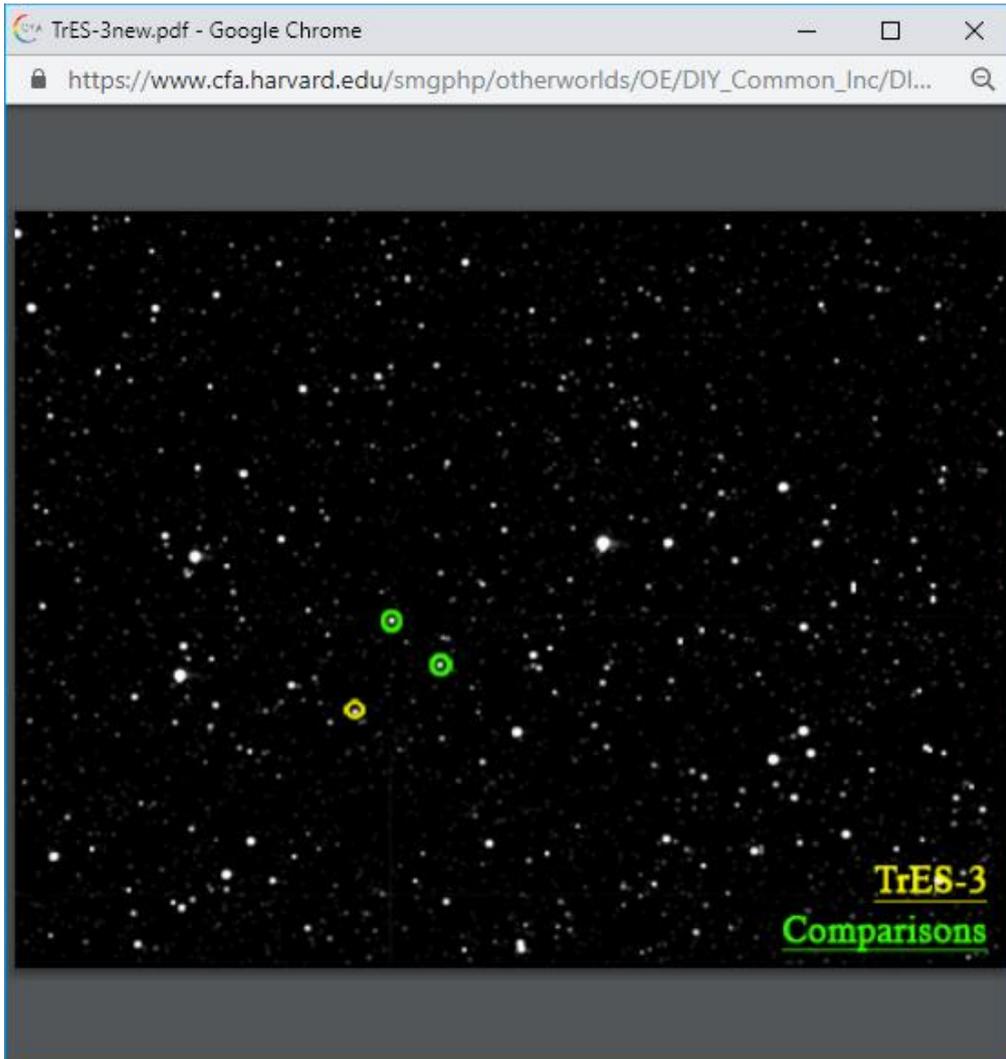


Figure 3.2. Finder chart.

If you want confirmation of the position of TrES-3 you might find this [website](#) useful. Fill in the relevant boxes and this will bring up the page shown in Figure 3.3.

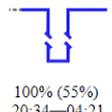
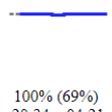
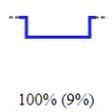
Local evening date	Name	V or Kepler mag	Start—Mid—End	Duration	BJDTDB start—mid—end	Elev. at start, mid, end ±5.0 hrs	% of transit (baseline) observable, Suggested obs. start, end	Depth (ppt)
Wed. 2019-07-03 Nautical twilight 20:34 – 04:21 (America/Phoenix)	TrES-3 b Finding charts: Annotated , SkyMap ; Info: Exoplanets.org , Simbad , Gaia DR2 , TIC , VSX , Vizier phot. ; Airmass plot , ACP plan	12.40 Moon 3% @113°	17:25 22:25—23:06 —23:46 04:46 ±0:49	1:21	8668.726 8668.754 8668.782	18° 76° 83° 83° 26°	 100% (55%) 20:34—04:21	27.4
Wed. 2019-07-03 Nautical twilight 20:34 – 04:21 (America/Phoenix)	Kepler-78 b Finding charts: Annotated , SkyMap ; Info: Exoplanets.org , Simbad , Gaia DR2 , TIC , VSX , Vizier phot. ; Airmass plot , ACP plan	11.72 Moon 3% @115°	17:46 22:46—23:11 —23:35 04:35 ±0:01	0:48	8668.741 8668.758 8668.775	8° 59° 63° 67° 48°	 100% (69%) 20:34—04:21	0.2
Wed. 2019-07-03 Nautical twilight 20:34 – 04:21 (America/Phoenix)	WASP-113 b Finding charts: Annotated , SkyMap ; Info: Exoplanets.org , Simbad , Gaia DR2 , TIC , VSX , Vizier phot. ; Airmass plot , ACP plan	11.77 Moon 3% @83°	16:05 21:05—23:14 —01:23 06:23 ±0:02	4:17	8668.671 8668.760 8668.850	37° 74° 56° 34° -6°	 100% (9%) 20:34—01:49	8.1

Figure 3.3. Data for TrES-3b on 2019 July 3

The predicted transit times are given for the selected location – ingress 22:25, mid-point 23:06, egress 23:46 each +/- 0:49 - local (Phoenix, Arizona) times, 05:25, 06:06, 07:46 UT

Selecting Finding charts/Annotated produces Figure 3.4 with TrES-3 circled.

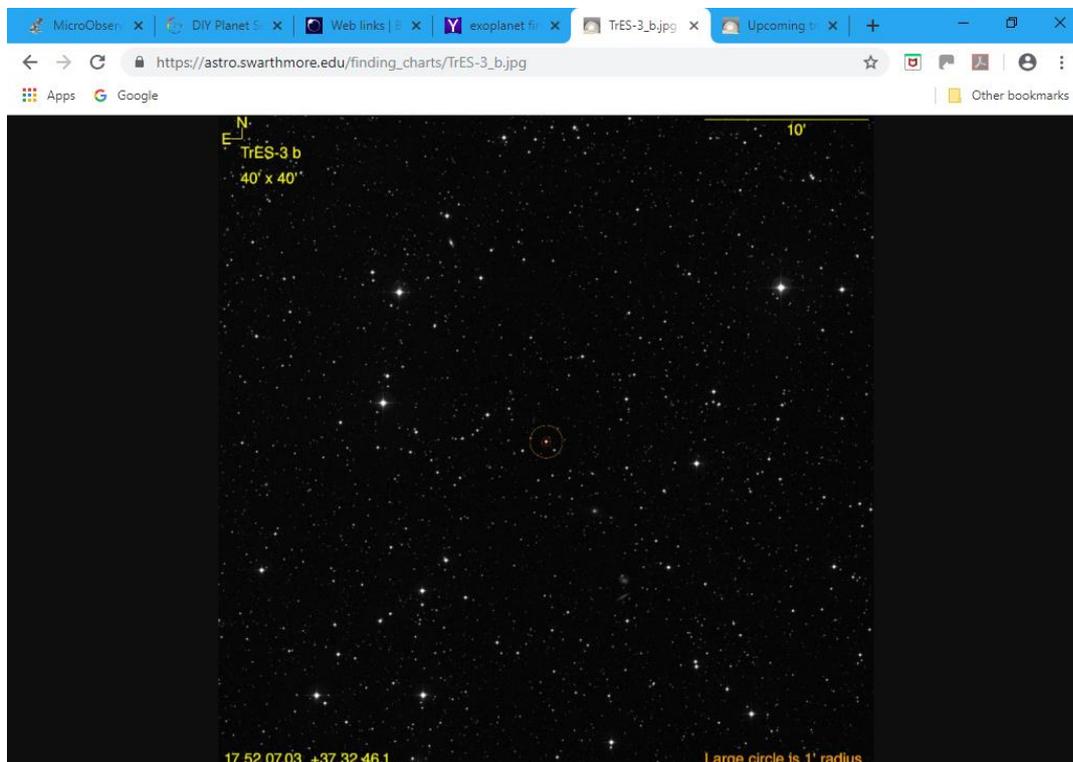


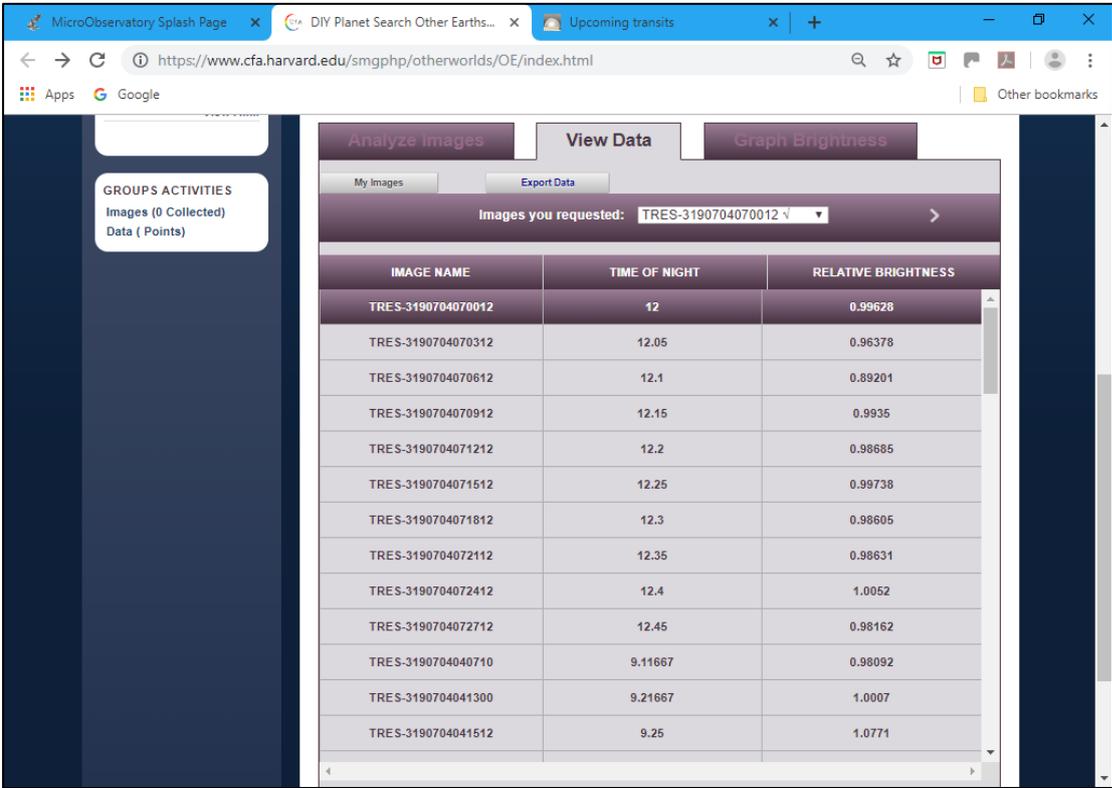
Figure 3.4. TrES finder chart

To measure the brightness of the target star;

- calibrate by clicking on the 'Calibrate' button – a check mark appears next to the button
- in turn click on the target star and two calibration stars as shown on the finder chart
- click in two areas devoid of stars near the above
- click on 'Calculate and Record'. Figure 3.1 shows 'ReCalculate and Record' as this image has been previously measured
- if the overlays are poorly positioned recalibrate and redo the selection sequence
- outliers on the transit light curve shown in Figure 10 can be redone as, again, the overlays may not have been correctly positioned

Images which are trailed or of poor quality can be ignored.

Selecting the 'View Data' tab in Figure 3.1 displays the brightness measurements – Figure 3.5.



The screenshot shows a web browser window with the URL <https://www.cfa.harvard.edu/smgphp/otherworlds/OE/index.html>. The page has three main tabs: 'Analyze Images', 'View Data', and 'Graph Brightness'. The 'View Data' tab is active, showing a table of brightness measurements for the star TrES-3190704070012. The table has three columns: 'IMAGE NAME', 'TIME OF NIGHT', and 'RELATIVE BRIGHTNESS'. The data is as follows:

IMAGE NAME	TIME OF NIGHT	RELATIVE BRIGHTNESS
TRES-3190704070012	12	0.99628
TRES-3190704070312	12.05	0.96378
TRES-3190704070612	12.1	0.89201
TRES-3190704070912	12.15	0.9935
TRES-3190704071212	12.2	0.98685
TRES-3190704071512	12.25	0.99738
TRES-3190704071812	12.3	0.98605
TRES-3190704072112	12.35	0.98631
TRES-3190704072412	12.4	1.0052
TRES-3190704072712	12.45	0.98162
TRES-3190704040710	9.11667	0.98092
TRES-3190704041300	9.21667	1.0007
TRES-3190704041512	9.25	1.0771

Figure 3.5. TrES-3 data

Selecting the 'Graph Brightness' tab displays the transit curve – Figure 3.6 - but the reduction in brightness can be discerned between approximately 20 hrs on Jul 3 and 00:30 hours on July 4 (Arizona time).

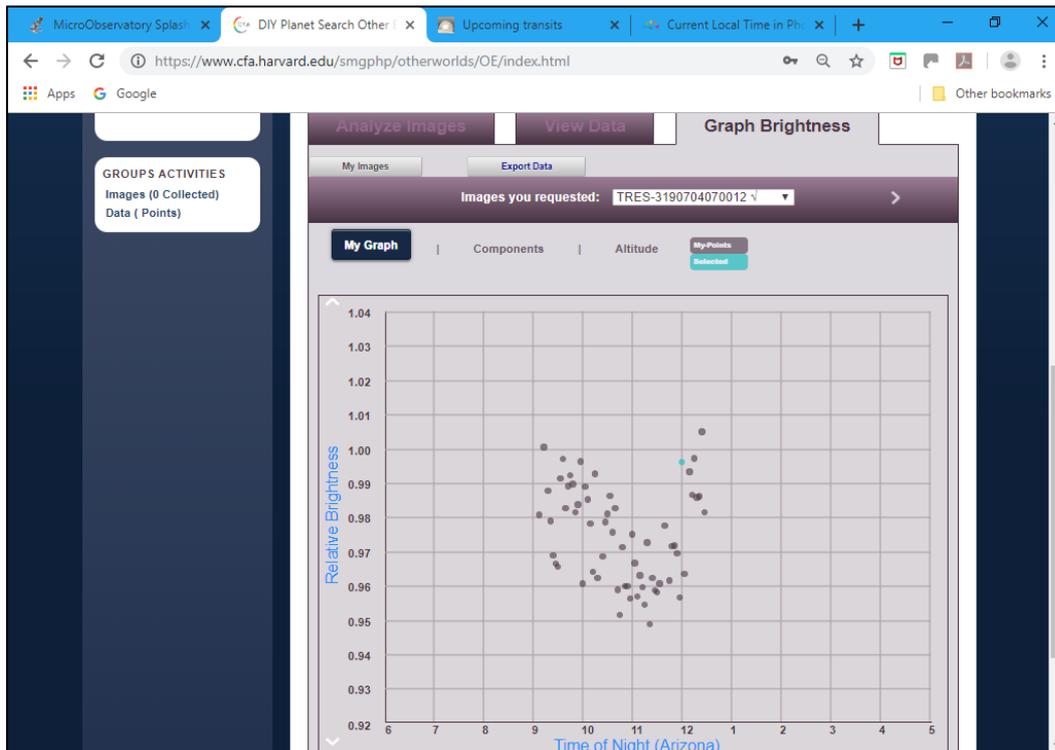


Figure 3.6. Transit light curve

To overlay your results with a reference graph, select 'Interpret and Share Results' -see Figure 6, choose the star in the box 'Data you analyzed' and then 'View Reference Graph'. Also select 'See Predicted Transit' to overlay the predicted times – Figure 3.7.

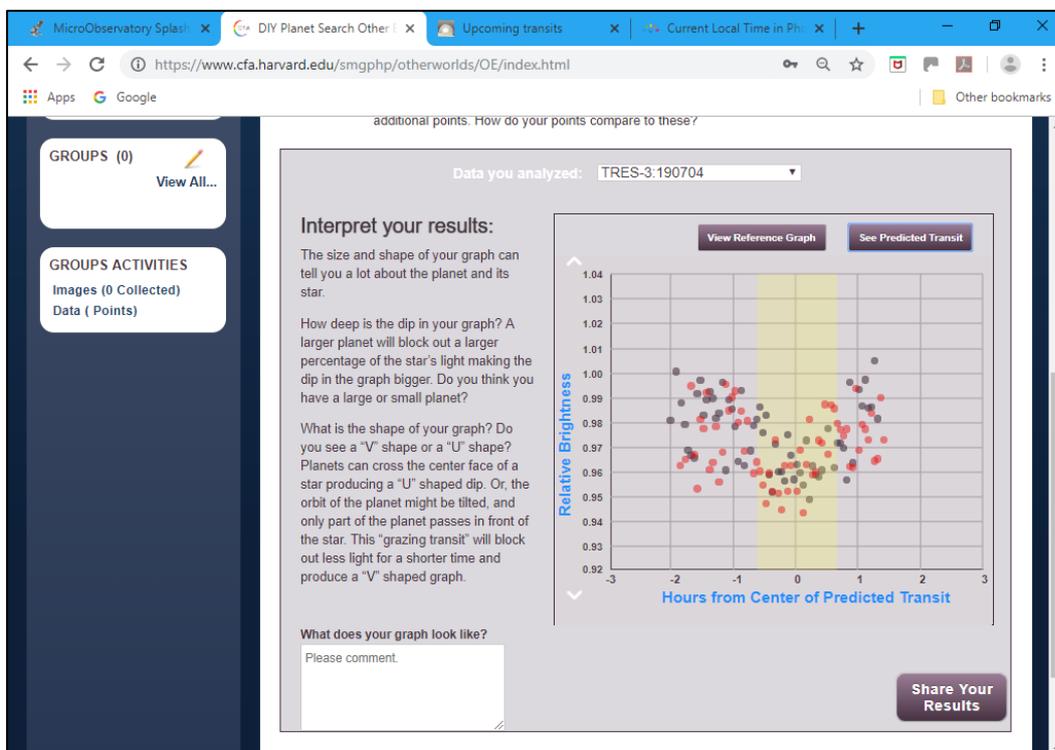


Figure 3.7. Results plus Reference Graph and predicted times.

My results and the reference data are in line with the predicted times of ingress and egress
The points on the curve are as scattered as they are because the on-line calibration includes dark frame subtraction but not flat fielding.

The results can be copied and pasted into Excel and a graph drawn – Figure 3.8

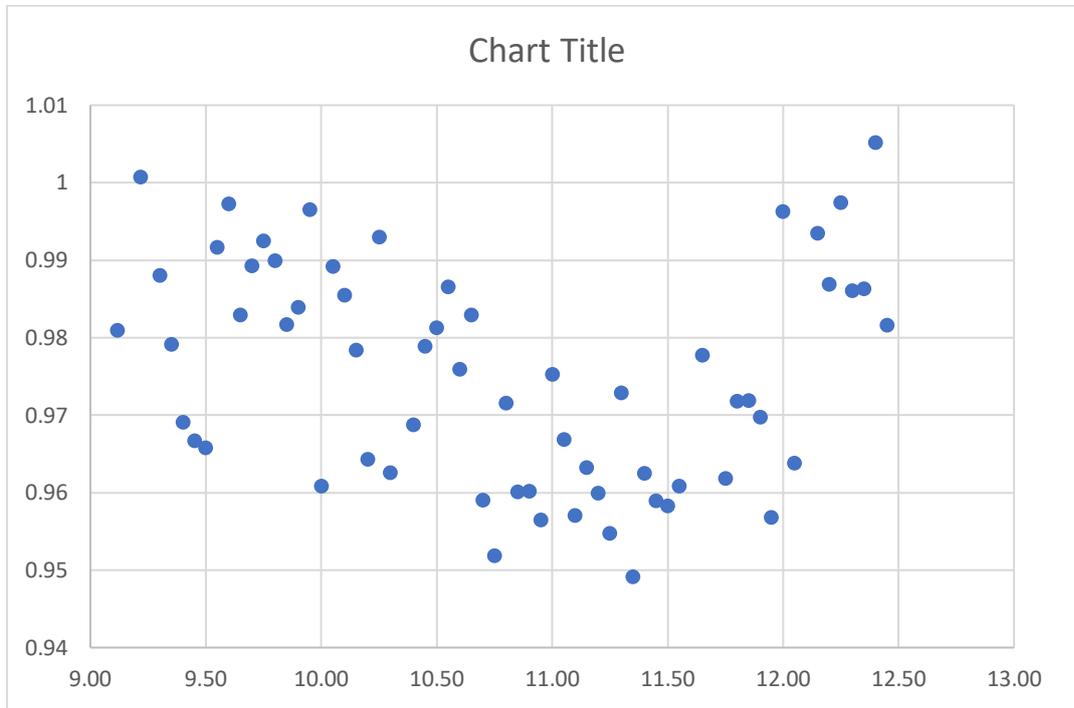


Figure 3.8. Excel transit light curve

4.0 Downloading images and dark frames (for off-line analysis)

4.1 Downloading images

There are time consuming (4.1.1) and somewhat less time consuming (4.1.2) methods. For the former a strong wrist is required as this requires a considerable number of mouse clicks!!!
My thanks to Martin Fowler for his advice as on the latter.

4.1.1 The time-consuming method

Images should be available within three days. Selecting ‘My Planet Search’ at the top of the page opens the page shown in Figure 4.1.1

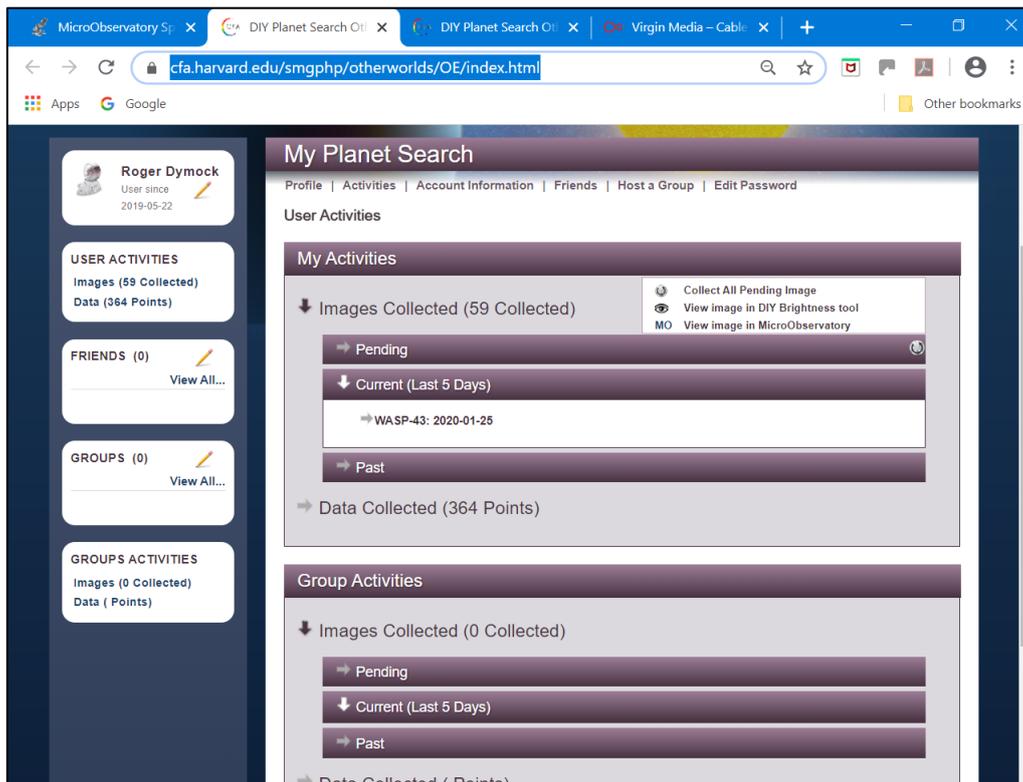


Figure 4.1.1. Activity status page

In this case, images of WASP-43 obtained on the 2020 January 21 are shown under the 'Current (Last 5 Days)' heading. Clicking on the arrow next to WASP-43: 2020-01-25 opens a list of the images obtained – Figure 4.1.2.

The screenshot shows a web browser window with the URL `cfa.harvard.edu/smgphp/otherworlds/OE/index.html`. The page is titled "User Activities" and "My Activities". It displays a list of images collected for WASP-43 on 2020-01-25. The table below shows the details of these images.

#	Time	Status	View Image	MO Link	Expires
#	00:27 AM	✓	👁️	MO	26
#	00:30 AM	✓	👁️	MO	26
#	00:33 AM	✓	👁️	MO	26
#	00:36 AM	✓	👁️	MO	26
#	00:39 AM	✓	👁️	MO	26
#	00:42 AM	✓	👁️	MO	26
#	00:45 AM	✓	👁️	MO	26
#	00:48 AM	✓	👁️	MO	26
#	00:51 AM	✓	👁️	MO	26
#	00:54 AM	✓	👁️	MO	26
#	00:57 AM	✓	👁️	MO	26
#	01:00 AM	✓	👁️	MO	26
#	01:03 AM	✓	👁️	MO	26
#	01:06 AM	✓	👁️	MO	26
#	01:09 AM	✓	👁️	MO	26
#	01:12 AM	✓	👁️	MO	26

Figure 4.1.2. (Partial) list of images of WASP-43 obtained on 2020 January 25

Selecting an image by clicking on 'MO' in the 'MO Link' column links to the page shown in Figure 4.1.3.

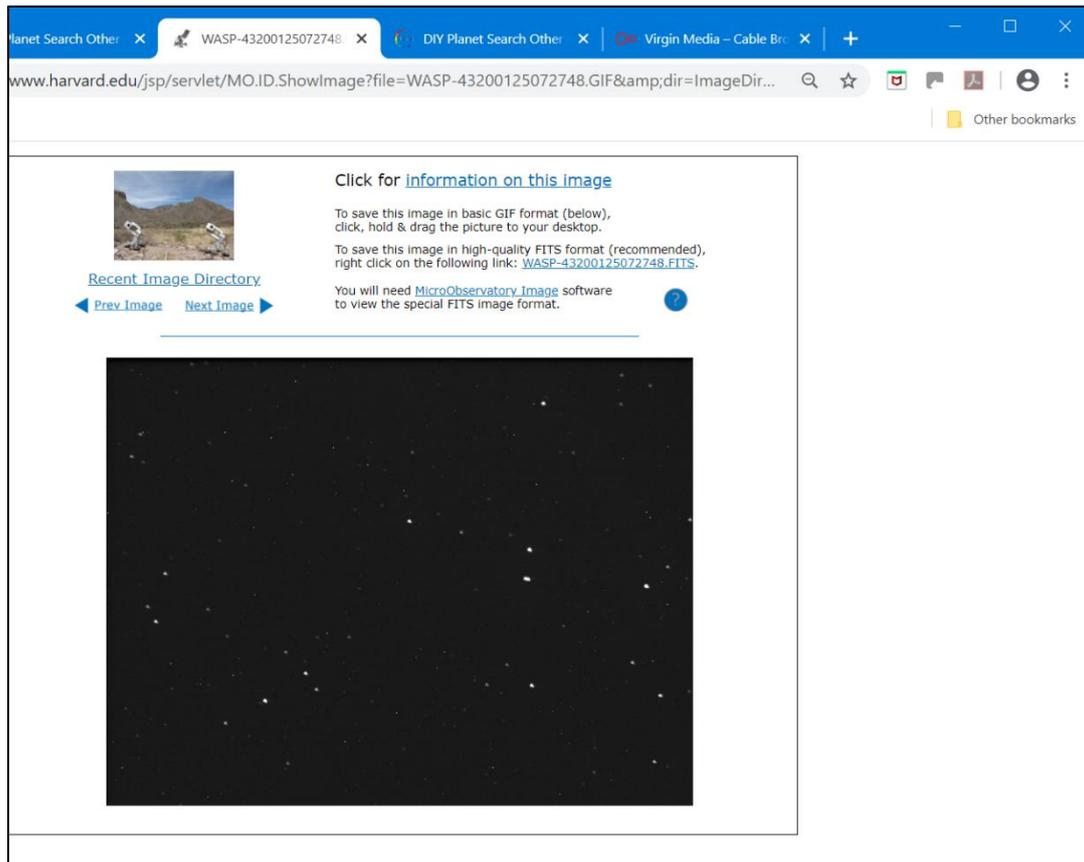


Figure 4.1.3. Image for download

As stated on the page download the image by right-clicking on the link and then ‘Save link as...’ in the pop-up window. Next Image does not work so you will need to return to the list shown in Figure 4.2 by closing the window shown in Figure 4.3.

Now all you have to do is repeat the above sequence for each image you wish to download. Any marked with an X in the ‘Status’ column can be ignored.

To download dark frames see below.

4.1.2. The less time-consuming method

A list of images and dark frames can be found at (<http://mo-www.cfa.harvard.edu/MicroObservatoryLegacy/ControlCenter/index.html>) – Figure 4.1.4

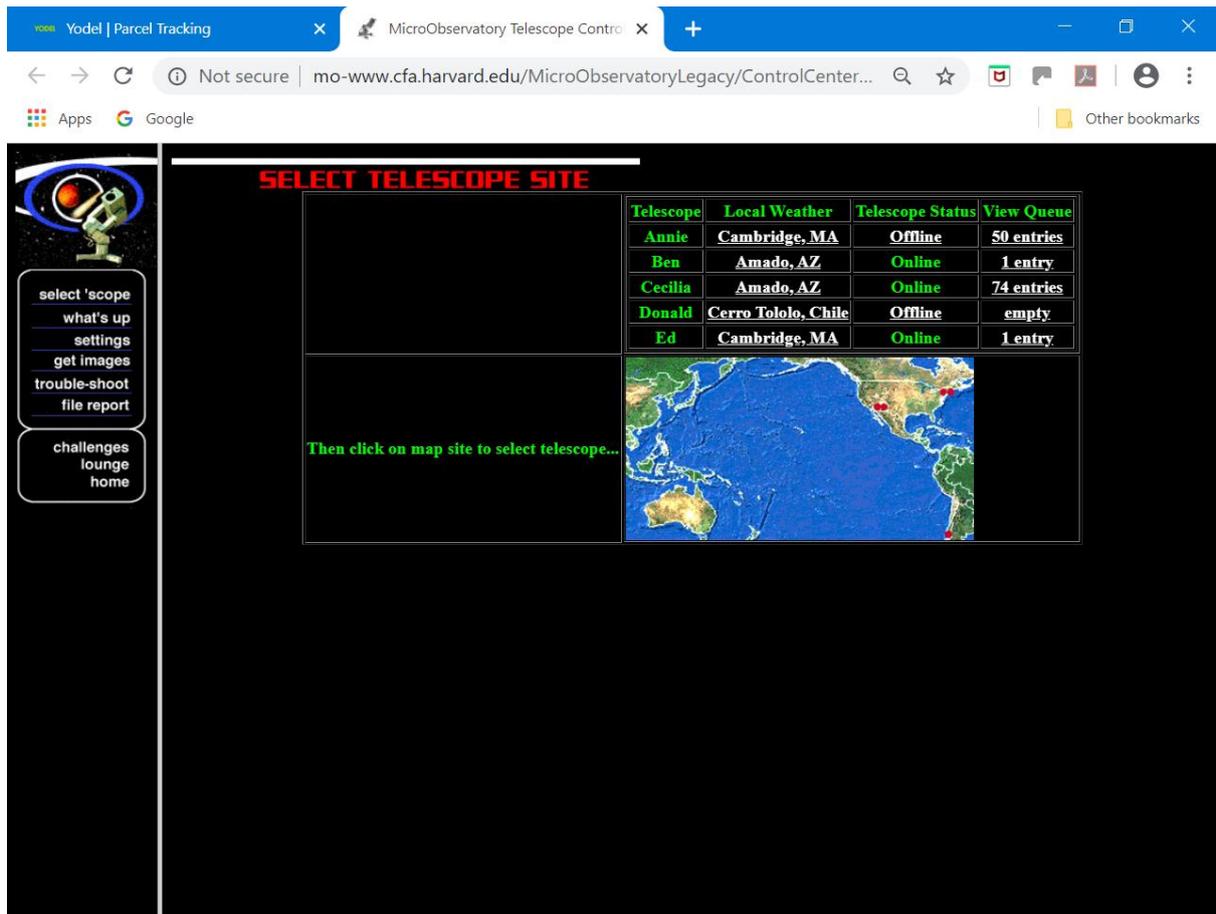


Figure 4.1.4 Control center

To obtain your images select 'get images' from the list on the left of the page. Under Data Range select the required object - in this example HAT-P-36b – Figure 4.1.5.

The screenshot shows the MicroObservatory Telescope Control Center interface. At the top, there are tabs for 'Virgin Media - Cable Broadband', 'Cowplain Bowling Club, Cowplain', and 'DIY Planet Search Home Page'. The browser address bar shows 'mo-www.cfa.harvard.edu/MicroObservatoryLegacy/ControlCenter/index.html'. On the left sidebar, there are links for 'select scope', 'what's up', 'settings', 'get images', 'trouble-shoot', 'file report', 'challenges', 'lounge', and 'home'. The main content area features a 'Date Range' filter with buttons for 'Past 10 Days', 'Past 20 Days', and 'Past 30 Days'. Below this is a dropdown menu set to 'HATP-36'. The main table lists 13 observation records for HATP-36, each with a 'FITS Image' icon for download and a 'Clear' link for weather status.

Image Filename	Date & Time (UT)	Open JS9/4L	FITS Image	Field of View	Exposure Time (sec)	Filter	Object	Telescope	Site	User	Size (KB)	Weather
HATP-36230308090015	08-Mar-2023 09:00:15	JS9/4L		Main	60.00	Clear	HATP-36	Cecilia	AZ	moguest	265	47% Clear
HATP-36230308085716	08-Mar-2023 08:57:16	JS9/4L		Main	60.00	Clear	HATP-36	Cecilia	AZ	moguest	256	47% Clear
HATP-36230308085415	08-Mar-2023 08:54:15	JS9/4L		Main	60.00	Clear	HATP-36	Cecilia	AZ	moguest	255	47% Clear
HATP-36230308085115	08-Mar-2023 08:51:15	JS9/4L		Main	60.00	Clear	HATP-36	Cecilia	AZ	moguest	261	47% Clear
HATP-36230308084515	08-Mar-2023 08:45:15	JS9/4L		Main	60.00	Clear	HATP-36	Cecilia	AZ	moguest	258	47% Clear
HATP-36230308084215	08-Mar-2023 08:42:15	JS9/4L		Main	60.00	Clear	HATP-36	Cecilia	AZ	moguest	253	47% Clear
HATP-36230308083915	08-Mar-2023 08:39:15	JS9/4L		Main	60.00	Clear	HATP-36	Cecilia	AZ	moguest	255	47% Clear
HATP-36230308083615	08-Mar-2023 08:36:15	JS9/4L		Main	60.00	Clear	HATP-36	Cecilia	AZ	moguest	262	47% Clear
HATP-36230308083015	08-Mar-2023 08:30:15	JS9/4L		Main	60.00	Clear	HATP-36	Cecilia	AZ	moguest	253	47% Clear
HATP-36230308082715	08-Mar-2023 08:27:15	JS9/4L		Main	60.00	Clear	HATP-36	Cecilia	AZ	moguest	269	47% Clear
HATP-36230308082415	08-Mar-2023 08:24:15	JS9/4L		Main	60.00	Clear	HATP-36	Cecilia	AZ	moguest	250	47% Clear

Figure 4.1.5. Image list

Unfortunately the images still have to be downloaded one at a time but the number of mouse clicks required is much reduced.

To download images;

- click on the icon in the FITS image column
- save to the required folder
- click on the next image and etc.

To review images before download

- click on the icon in the Image File name column to bring up the image shown in Figure 4.1.6
- click on the image name at top right
- save to your desired folder

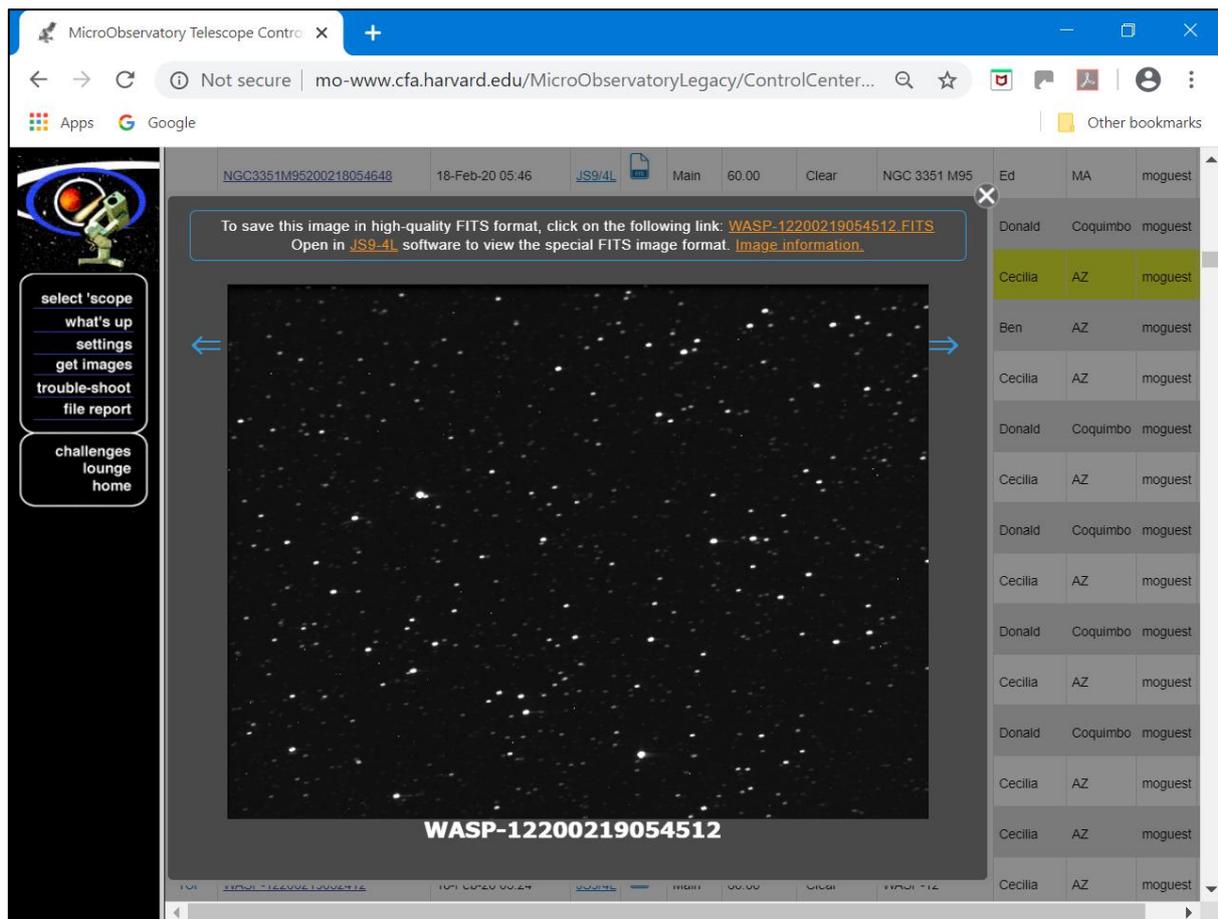


Figure 4.1.6. FITS image

To download dark frames;

- scroll up/down around the date of your images
- select five dark frames ensuring they have the same exposure times as your images and are listed as 'Opaque
- click on the icon in the FITS image column
- save to the required folder
- click on the next image and etc.

The ExoClock project HOPS software may be used – see appendices A and B at <https://britastro.org/sites/default/files/ARIEL%20Space%20Mission%20V2.pdf>

While you may use HOPS and ExoClock on-line analysis to process MicroObservatory observations, please do not submit your observations to the ExoClock database. The reason for this is that multiple observers may submit results of their analysis of the same set of observations which is causing some confusion.

5.0 MicroObservatory data

Telescope

Name;	Cecilia
Type;	5.25", f/3.6, 152mm Maksutov reflector
Focal length	550 mm (Note 1)
Camera;	KAF 1402ME, 1317x1035 binned 2x2 to 650 x 500 pixels
ADUs	12 bit CCD therefore max ADU is 4096 (Note 2)

Pixel size	6.8x6.8 microns binned 2x2 to 13.6x13.6 microns
Plate scale	5.17"/pixel
Image size	56' wide x 43' high
Filter;	Clear
Note 1	FL set to 542mm using Astrometrica
Note 2	Image FITS header states 16 bit as 12 bit is not a valid
parameter	

Location

Whipple Observatory;	Lat 31.68N (+31 40 48N), Long -110.88 (110 52 48W)
Time Zone;	-7