Remotely operated robotic telescopes – the MicroObservatory Robotic Telescope Network

Updated 2020 February 19

Contents

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

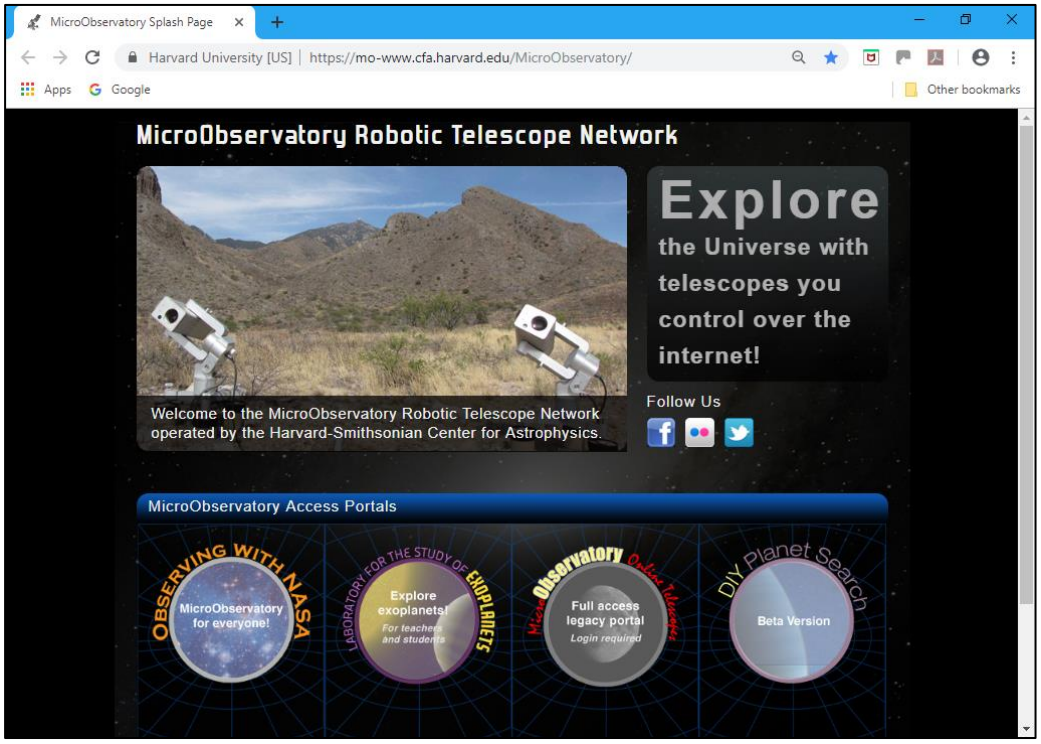


Figure 1.1 Robotic telescope home page.

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

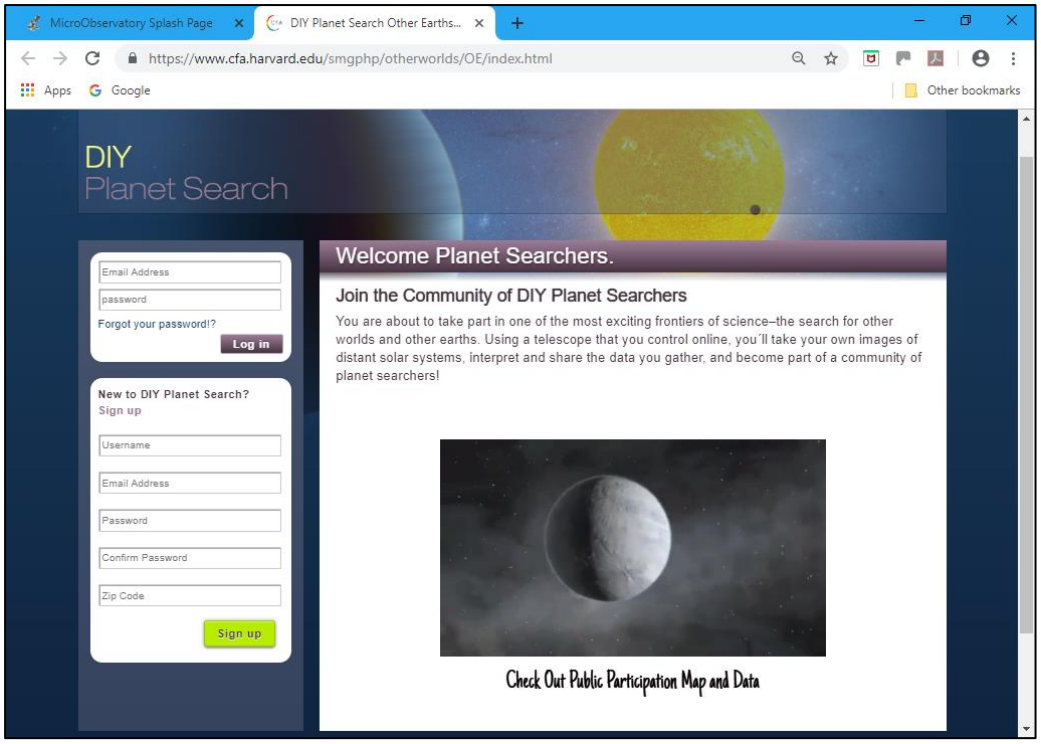


Figure 1.2. Log in/Register screen

2.0 Target selection

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

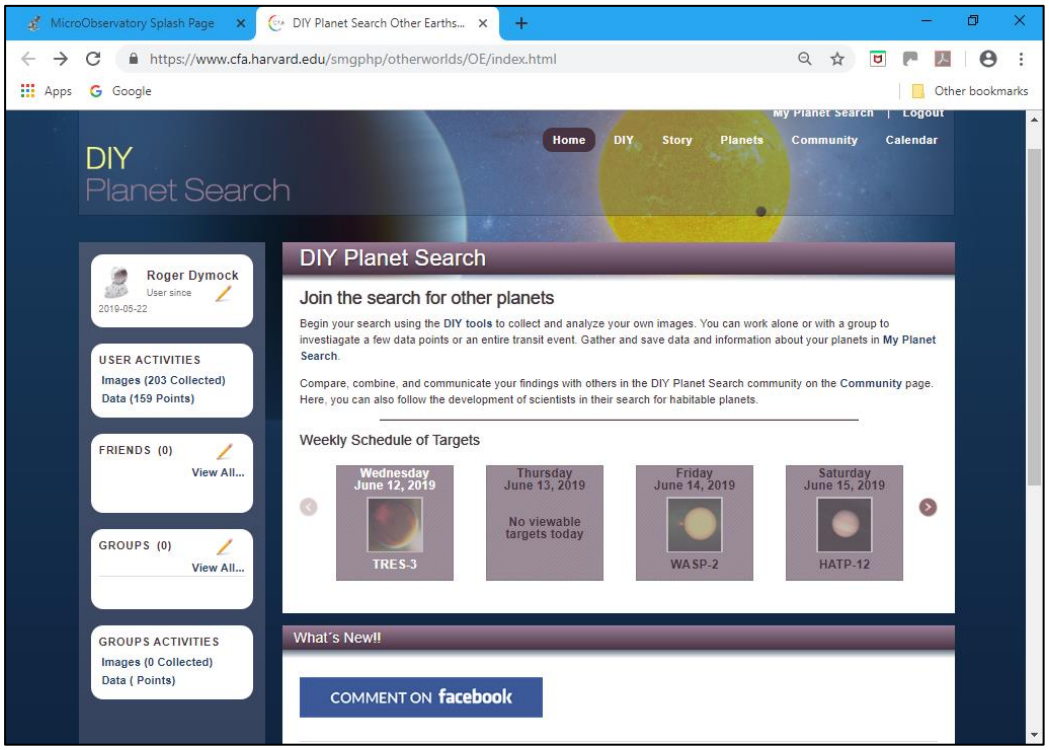


Figure 2.1.

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

If you are participating in the ARIEL ExoClock project access the ExoClock Ephemerides page to choose a target which is shown there and on the MicoObservatory pages as shown in Figures 2.1 and 2.2. MicroObservatory data required when creating an ExoClock account is given in Section 5.

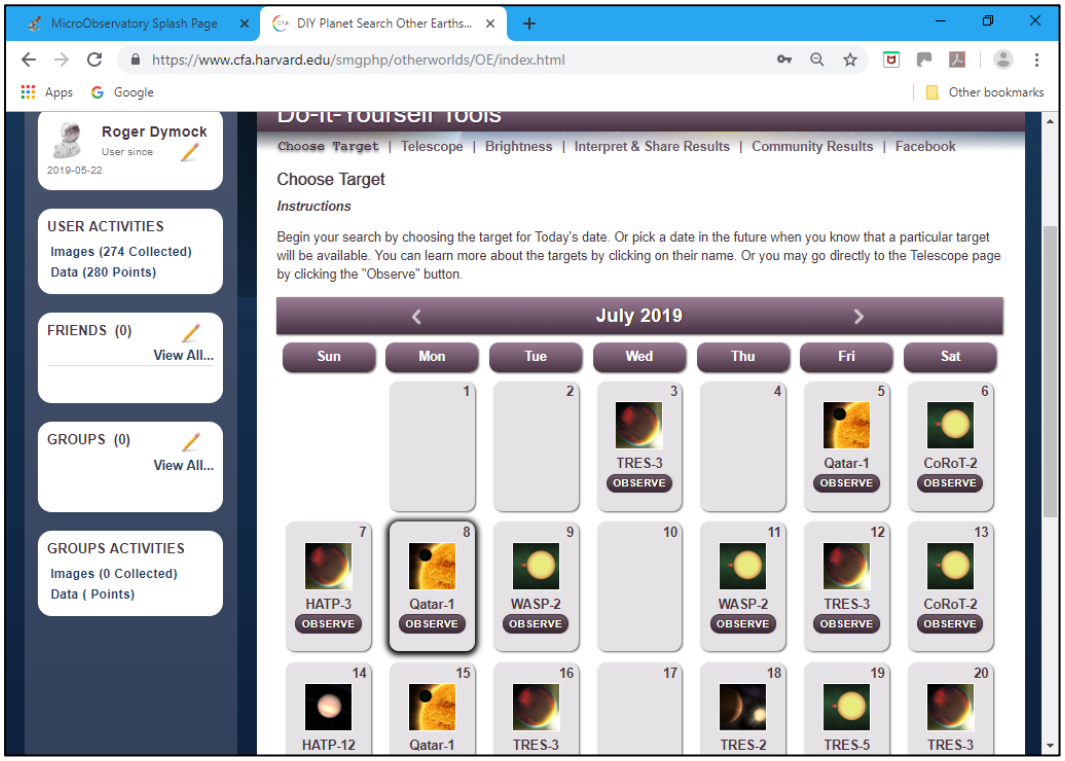


Figure 2.2. Targets for the month.

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.

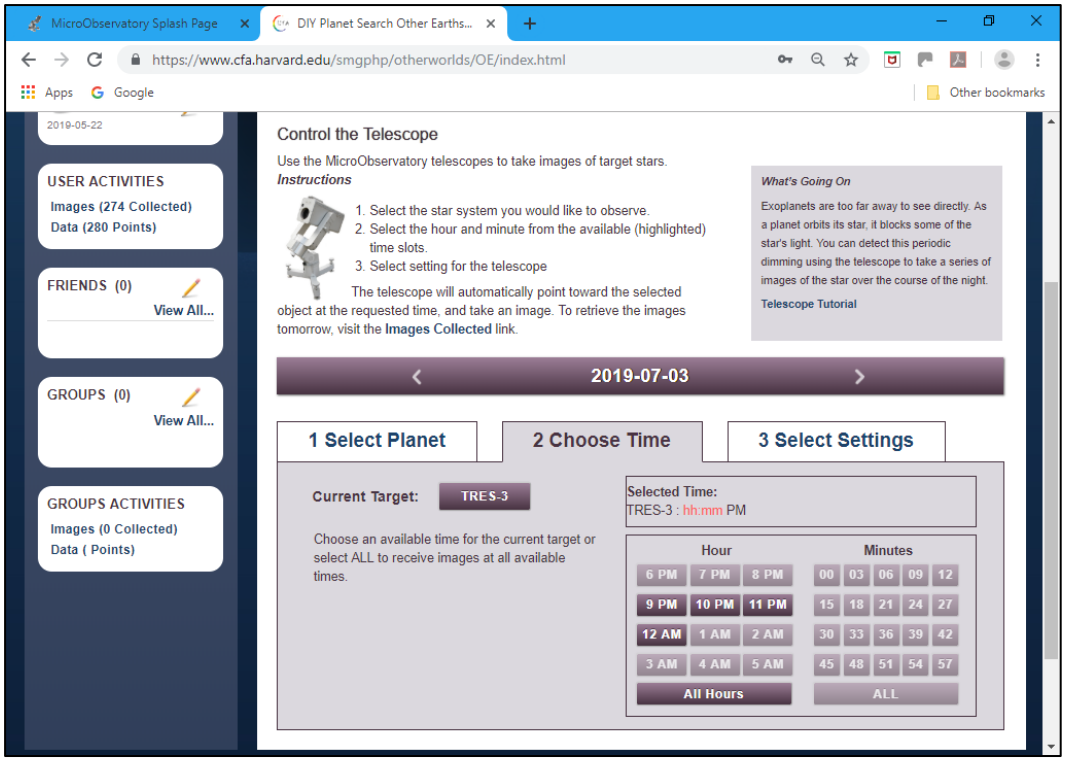


Figure 2.3. DIY Tools page '2 Choose Time' tab.

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).

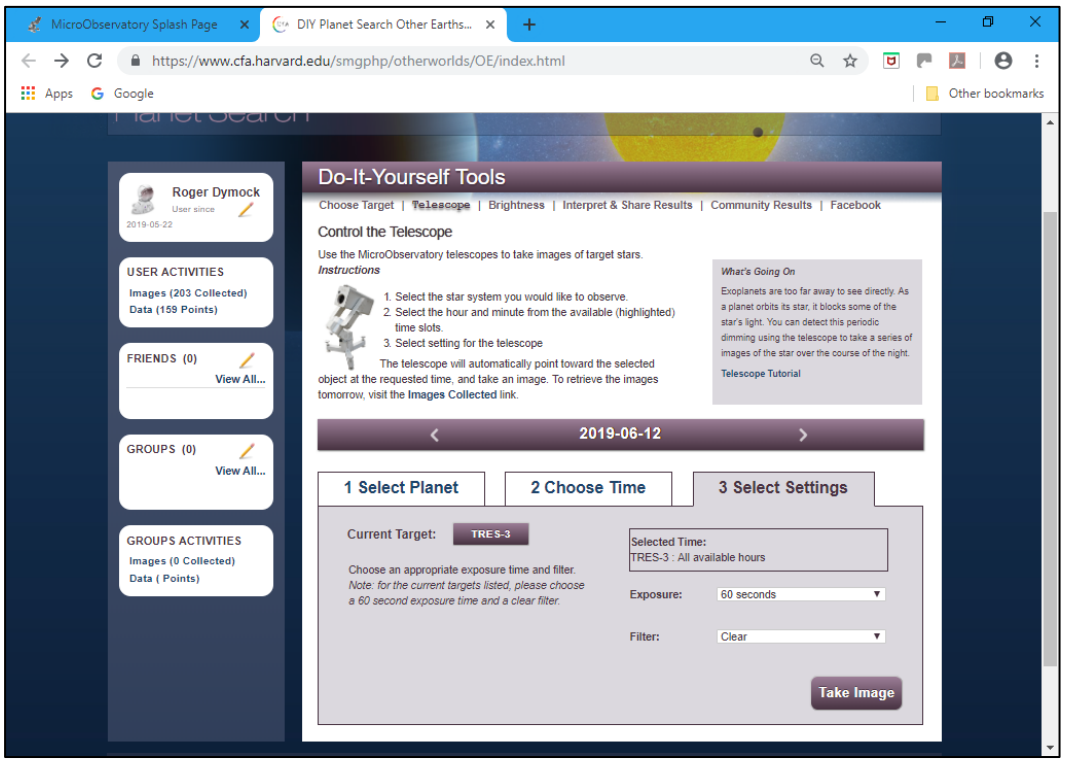


Figure 2.4. DIY Tools page '3 Select Settings' tab.

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.

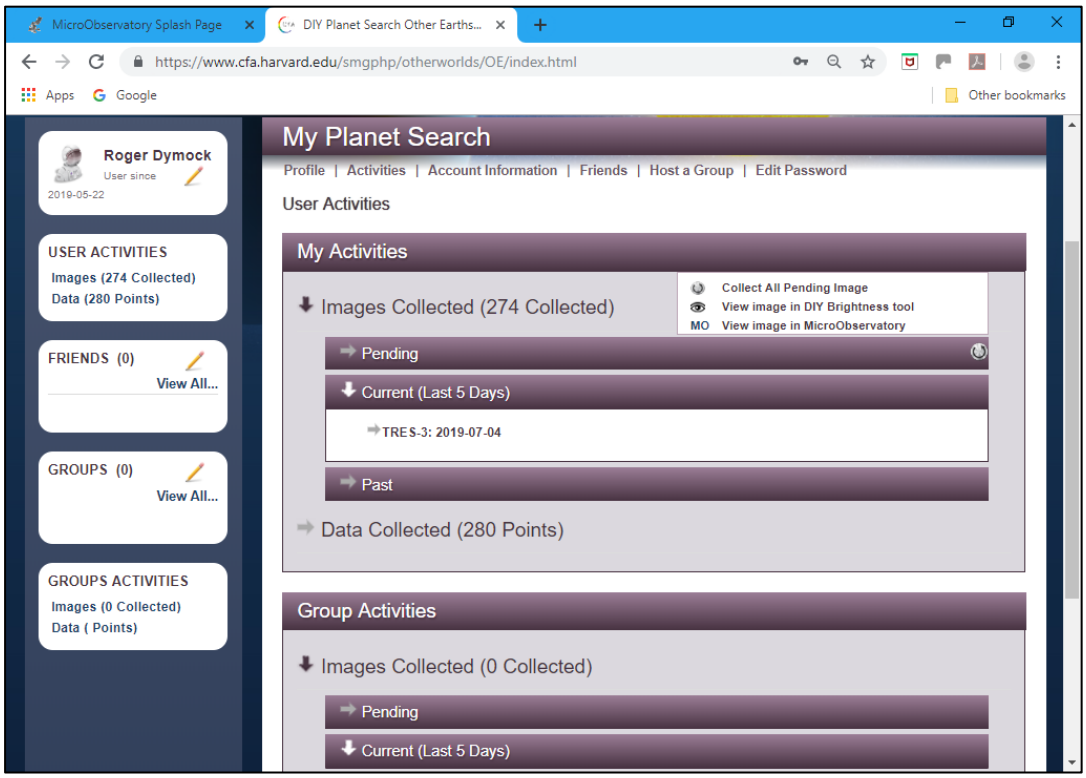


Figure 2.5. Activity status page.

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.

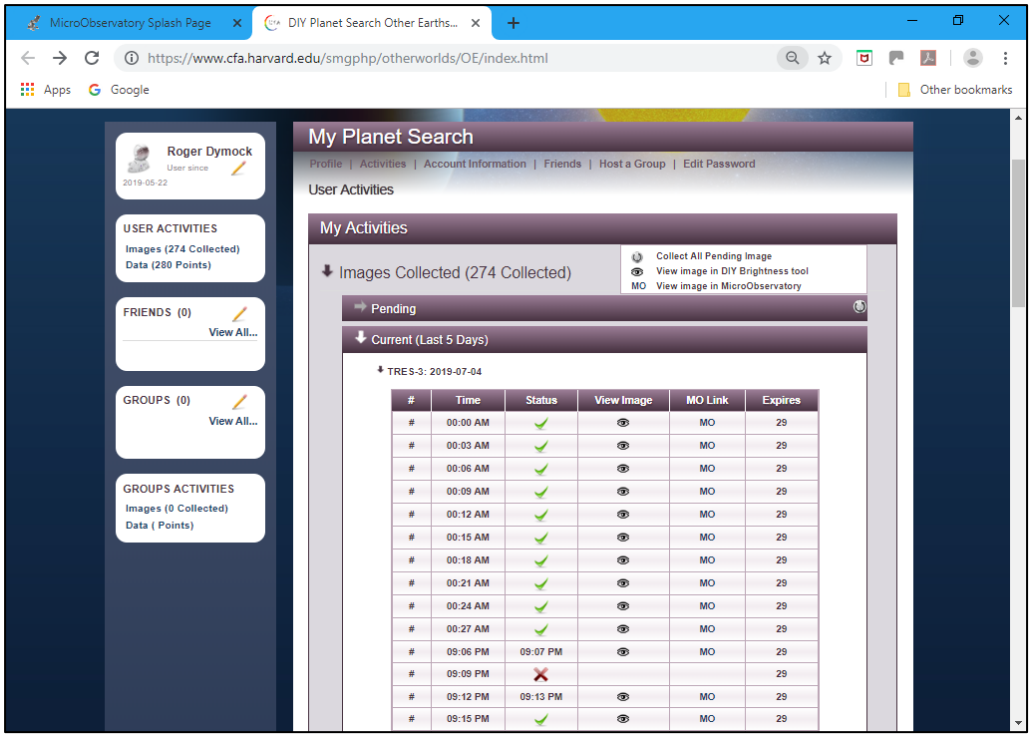


Figure 2.6. (Partial) list of images of TRES 3 obtained on 9th June 2019

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.

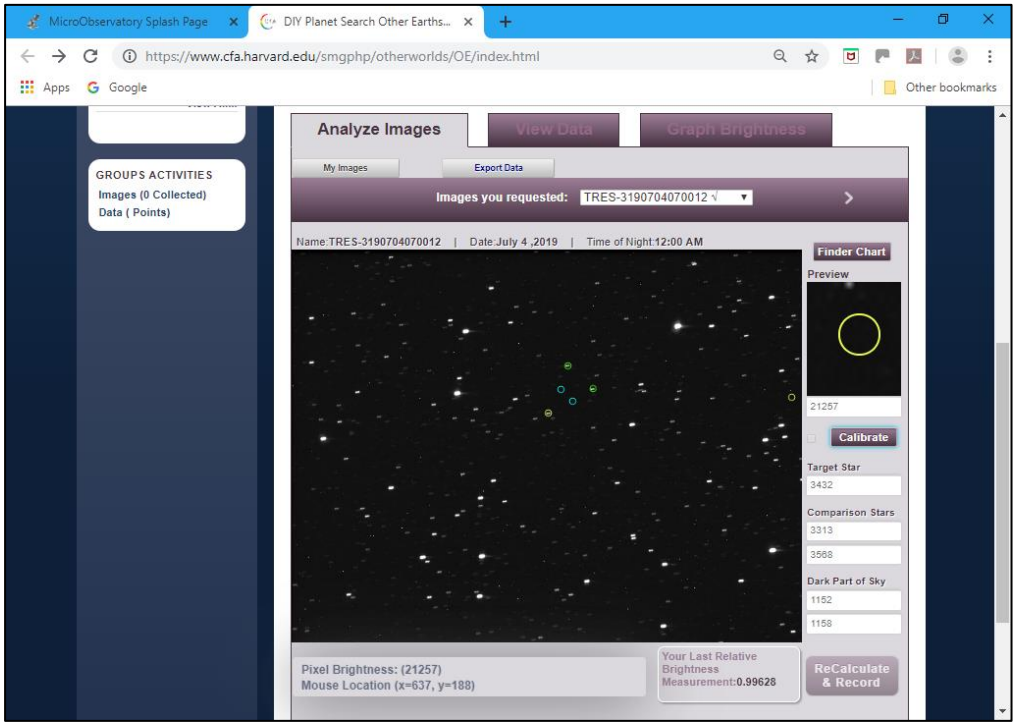


Figure 3.1. Example image of TRES-3

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.

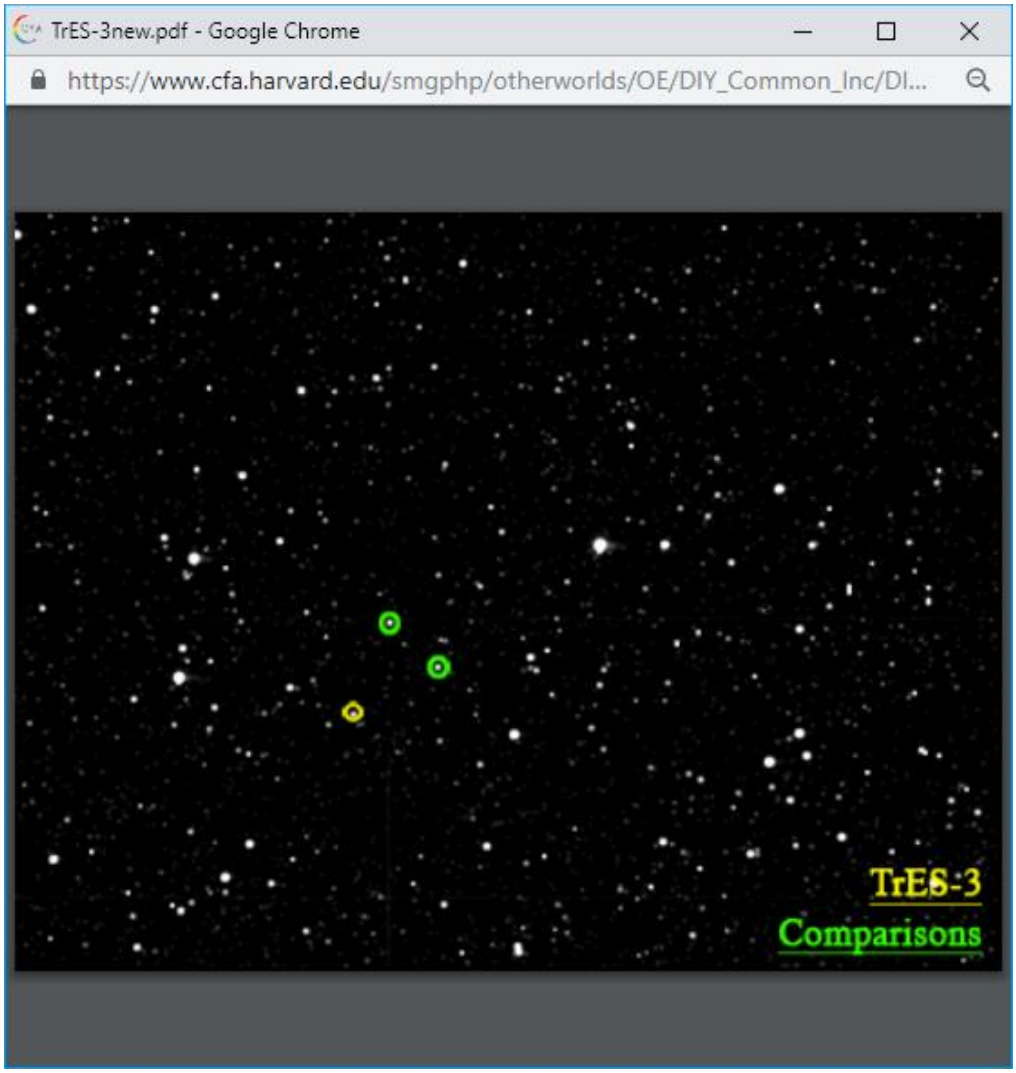
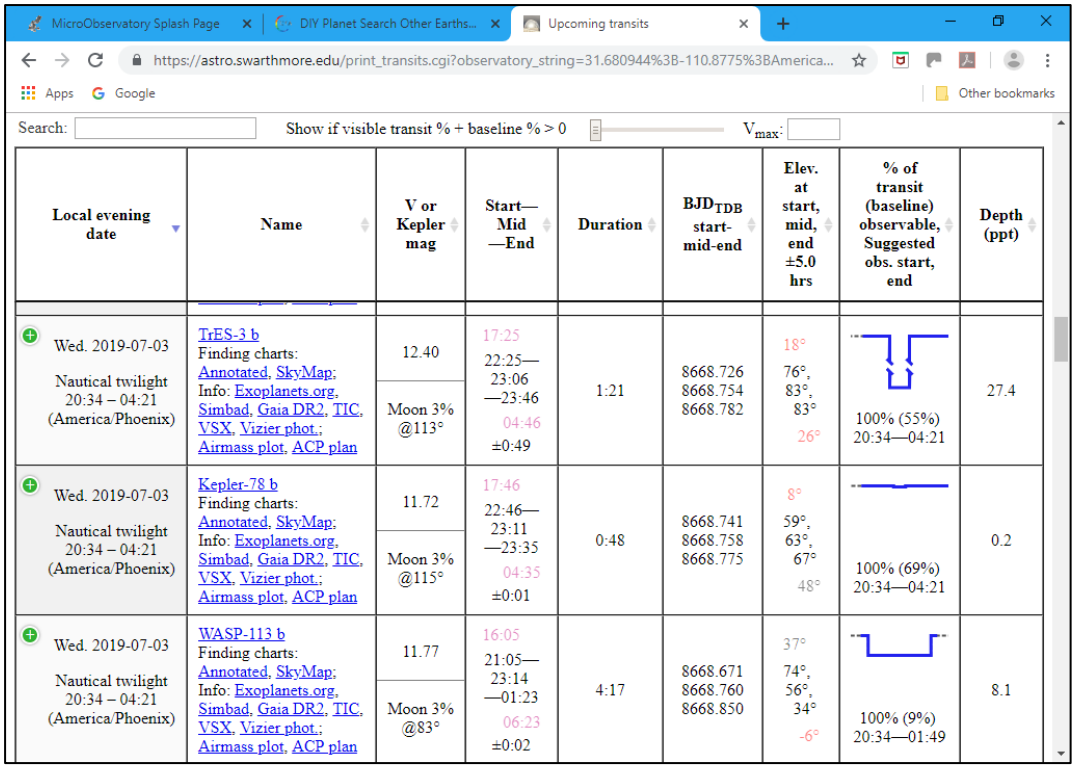


Figure 3.2. Finder chart.

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.



MicroObservatory Splash Page | DIY Planet Search Other Earths... | Upcoming transits

https://astro.swarthmore.edu/print_transits.cgi?observatory_string=31.680944%3B-110.8775%3BAmerica...

Apps | Google | Other bookmarks

Search: | Show if visible transit % + baseline % > 0 | V_{max}:

Local evening date	Name	V or Kepler mag	Start—Mid—End	Duration	BJD_{TDB} 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.

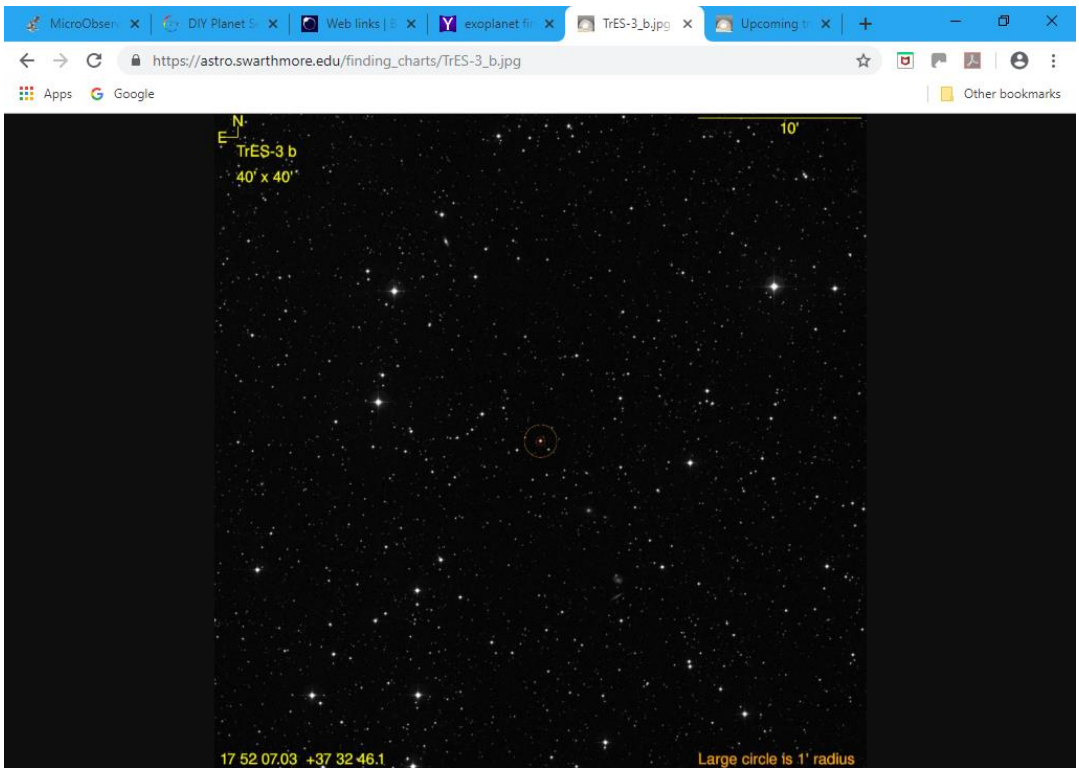


Figure 3.4. TrES finder chart

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.

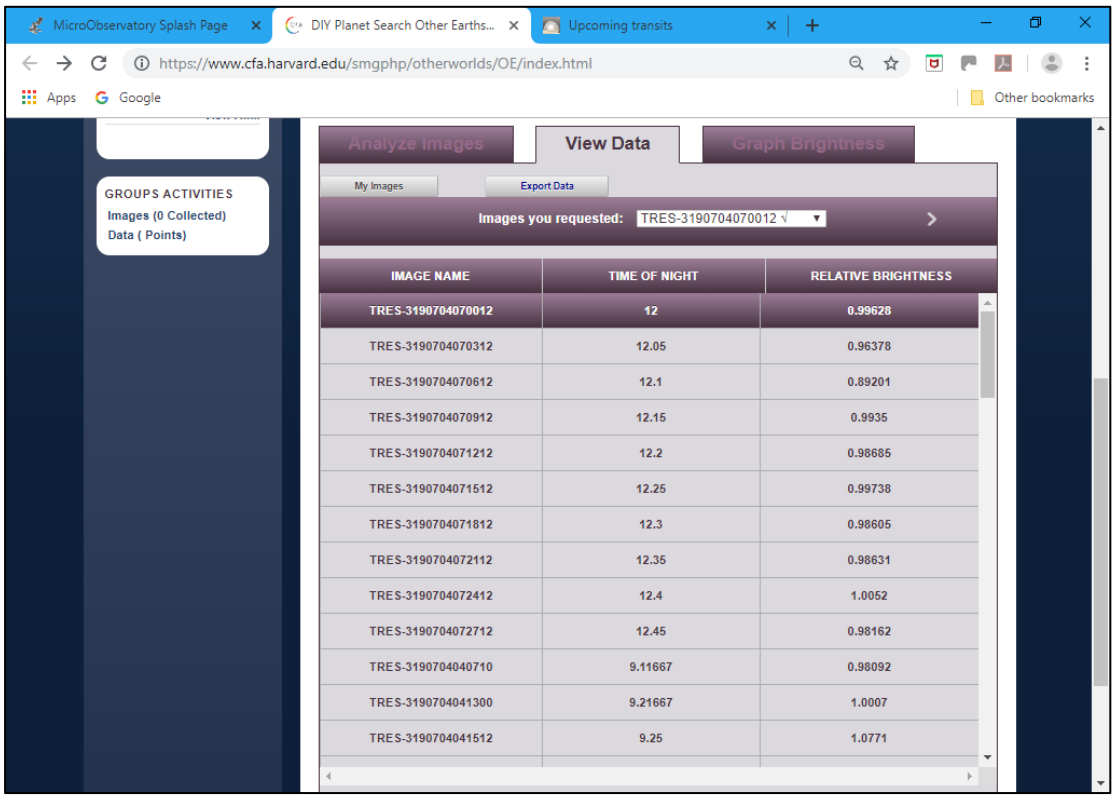


Figure 3.5. TrES-3 data

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).

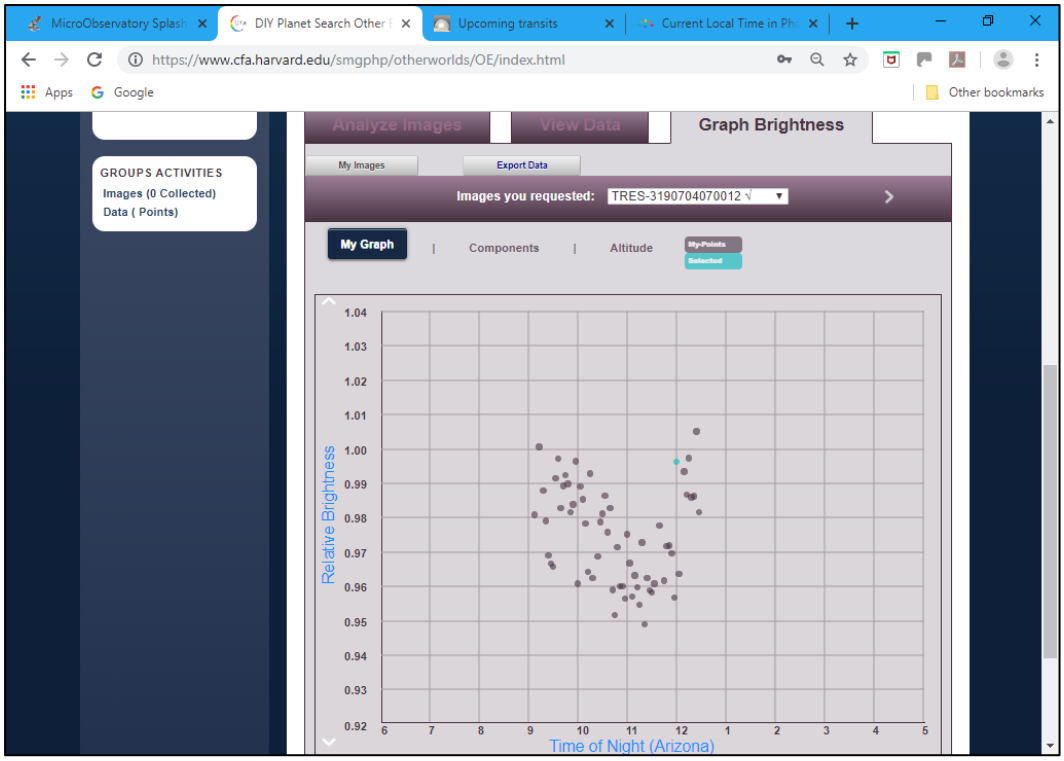


Figure 3.6. Transit light curve

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.

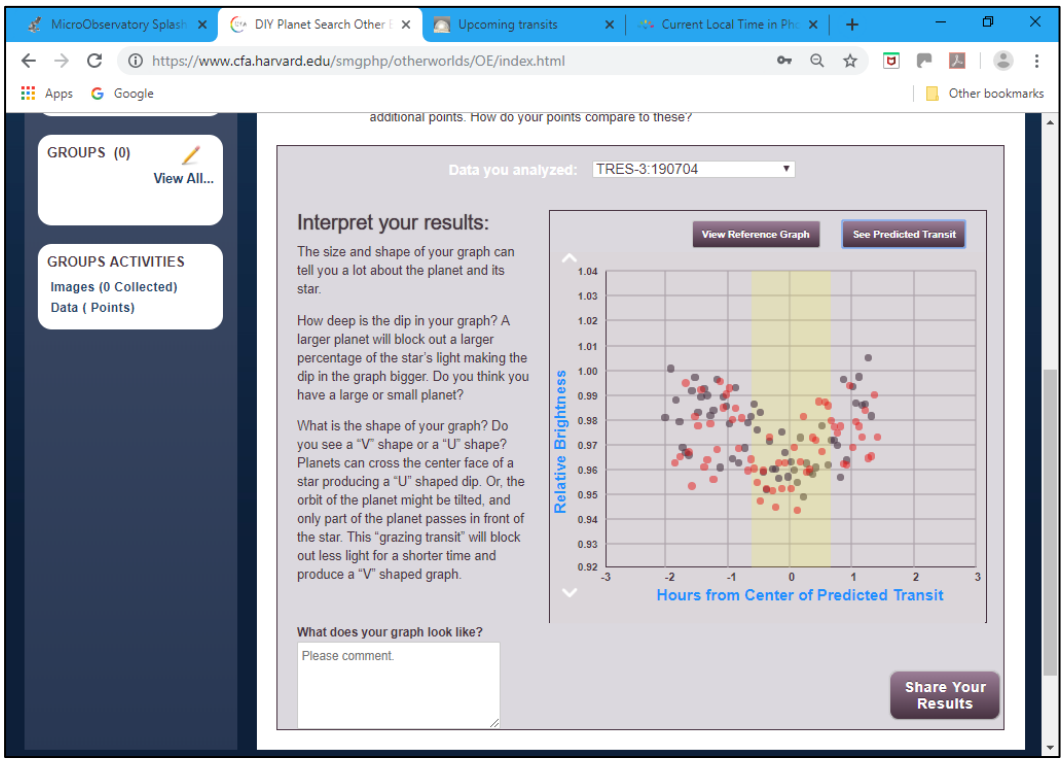


Figure 3.7. Results plus Reference Graph and predicted times.

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

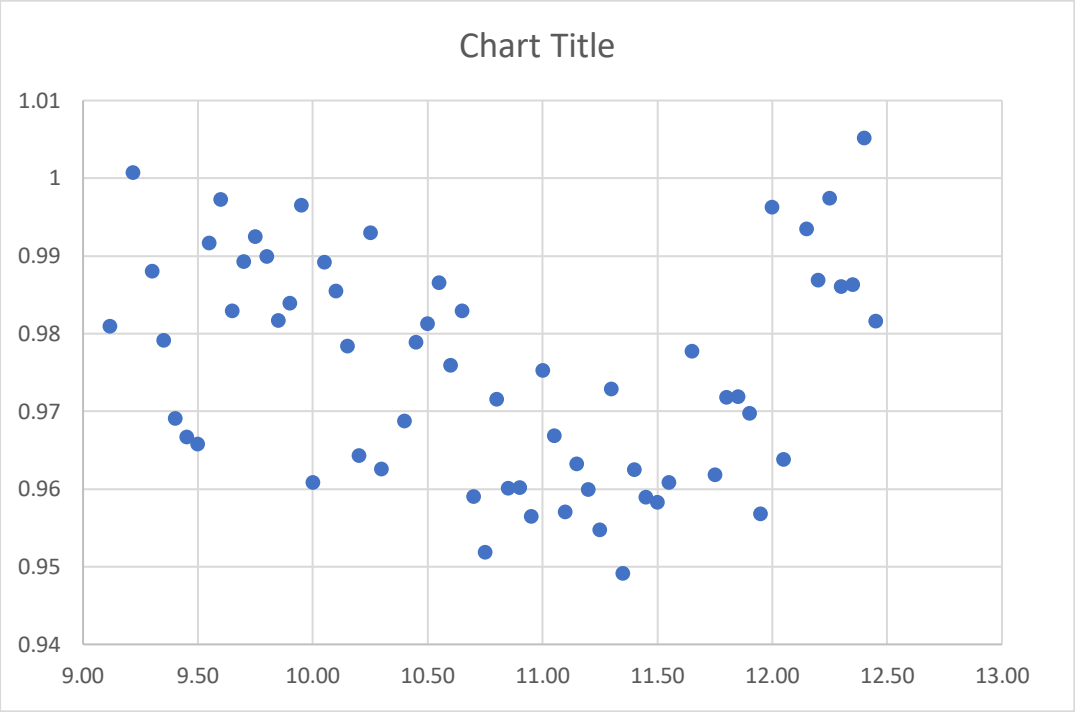


Figure 3.8. Excel transit light curve

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

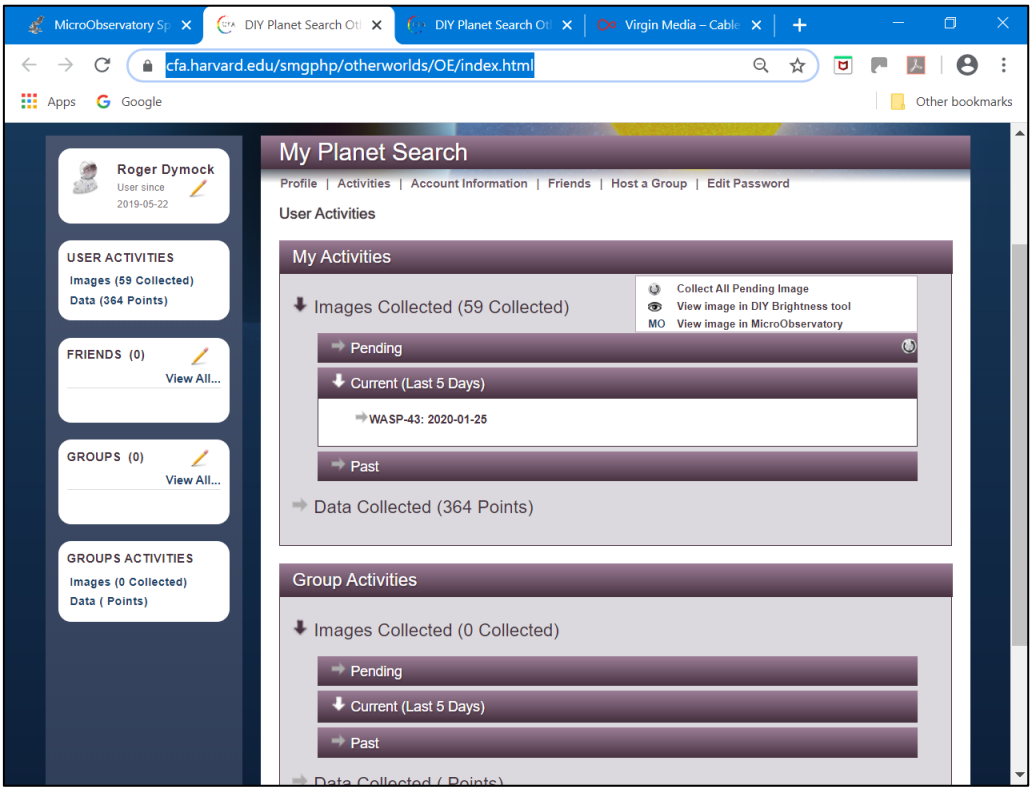


Figure 4.1.1. Activity status page

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.

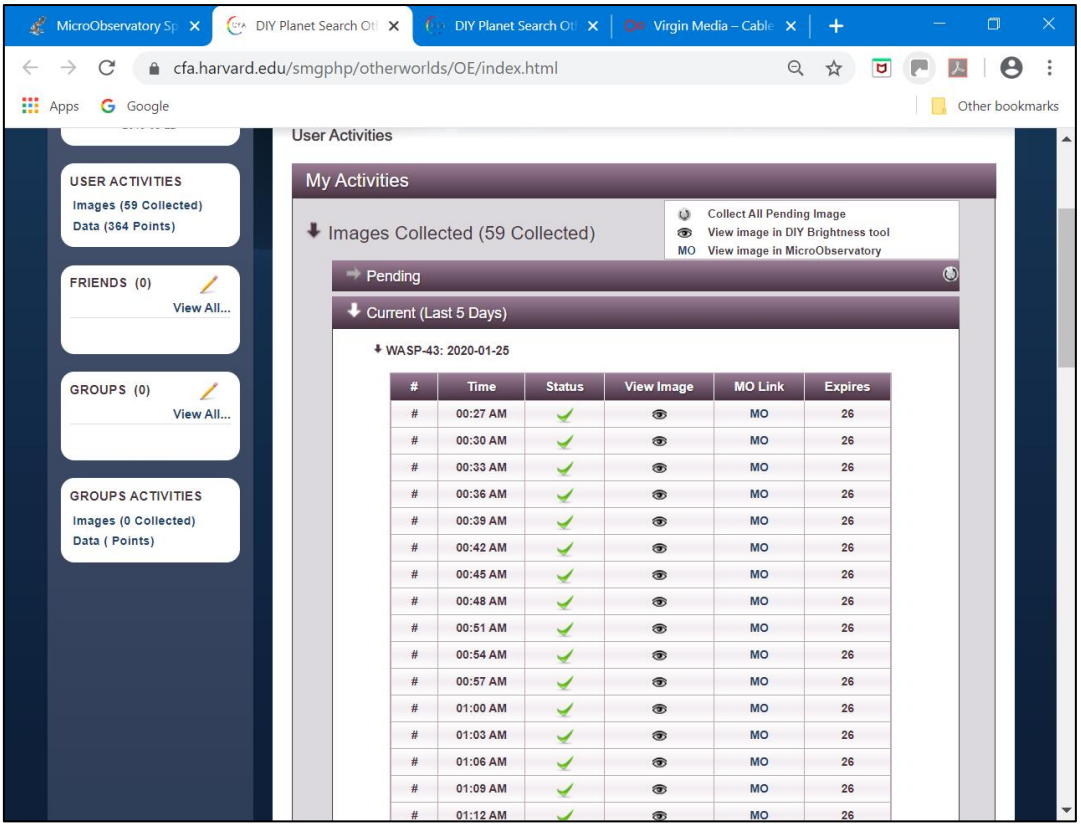


Figure 4.1.2. (Partial) list of images of WASP-43 obtained on 2020 January 25

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

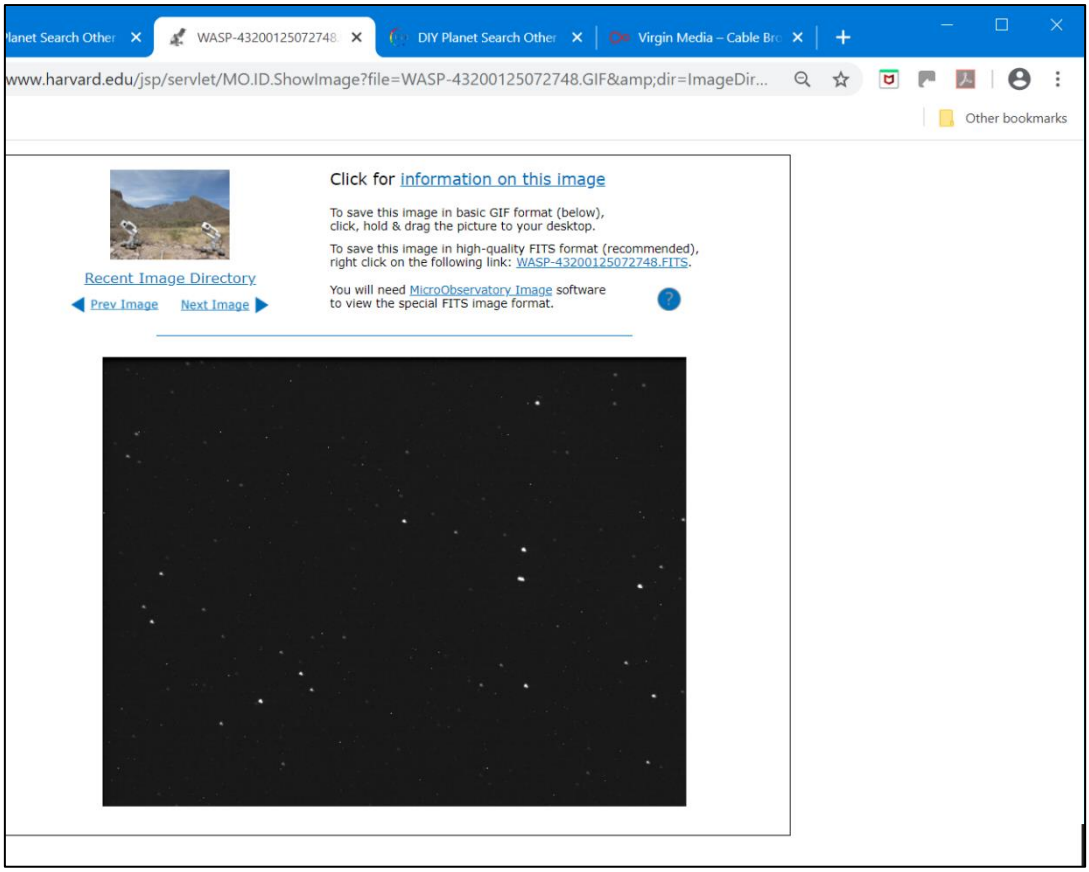


Figure 4.1.3. Image for download

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

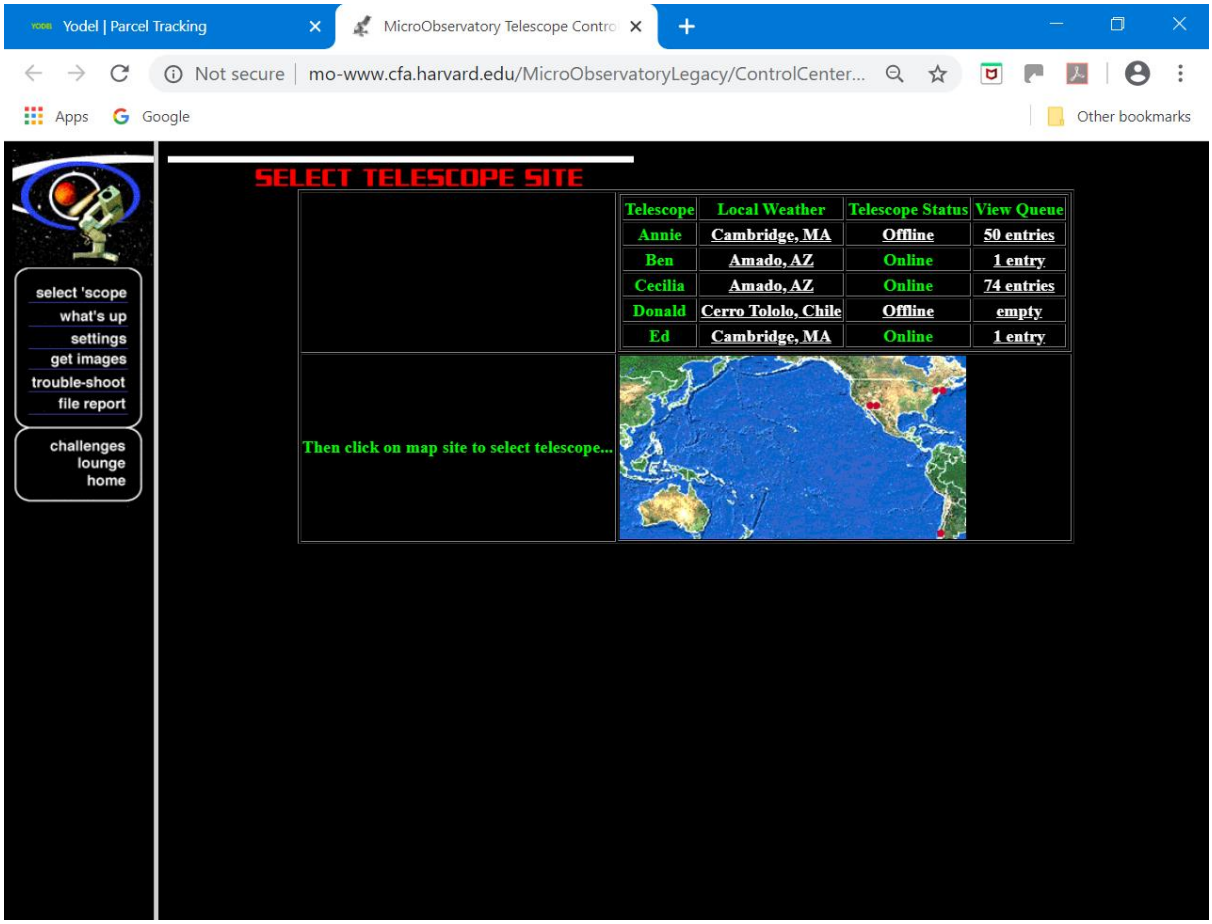


Figure 4.1.4 Control center

To obtain your images select ‘get images’ from the list on the left of the page and scroll down to the required images and date. In this example HAT-P-36b – Figure 4.1.5. Note that the exoplanet images are interspersed with the others taken on that night.

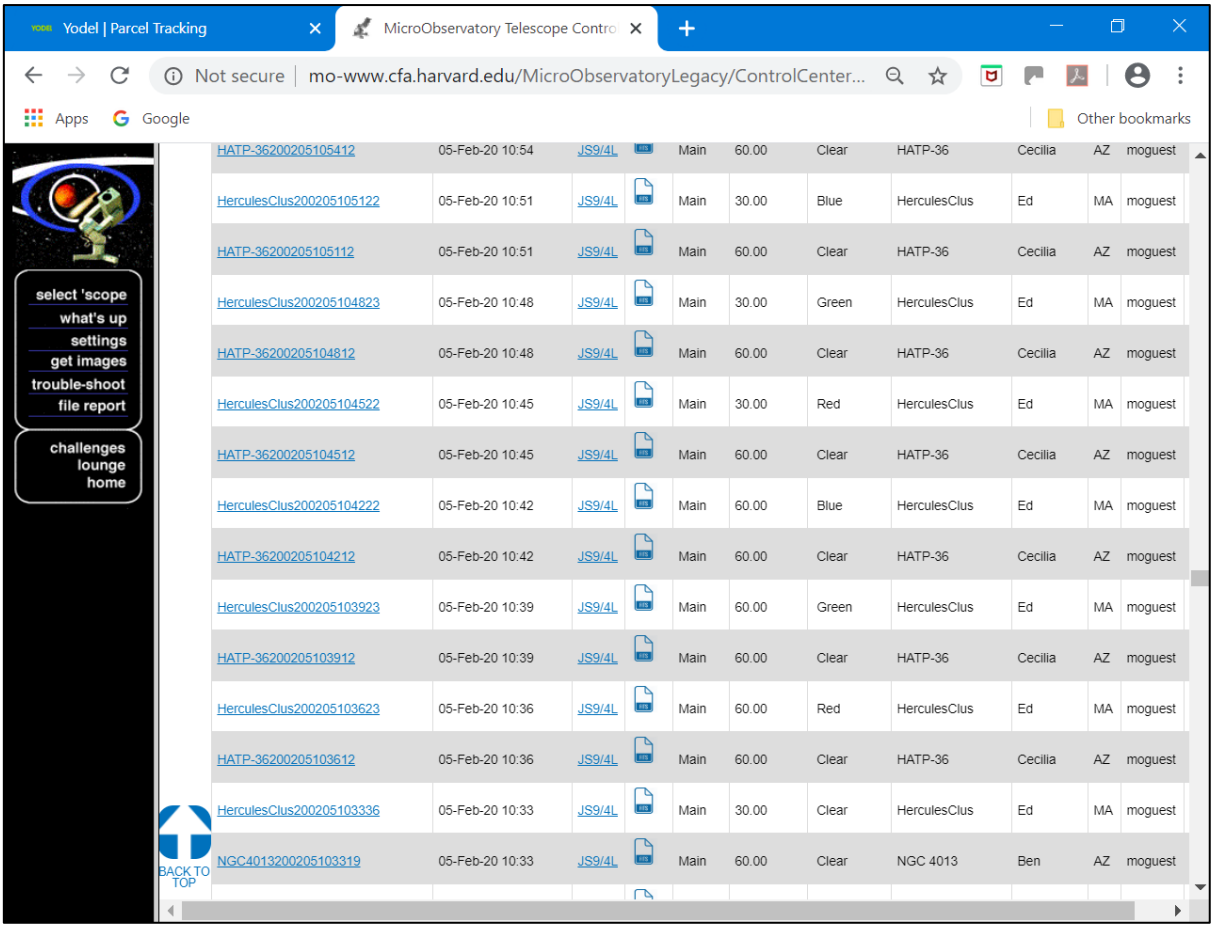


Figure 4.1.5. Image list

Unfortunately the images till 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

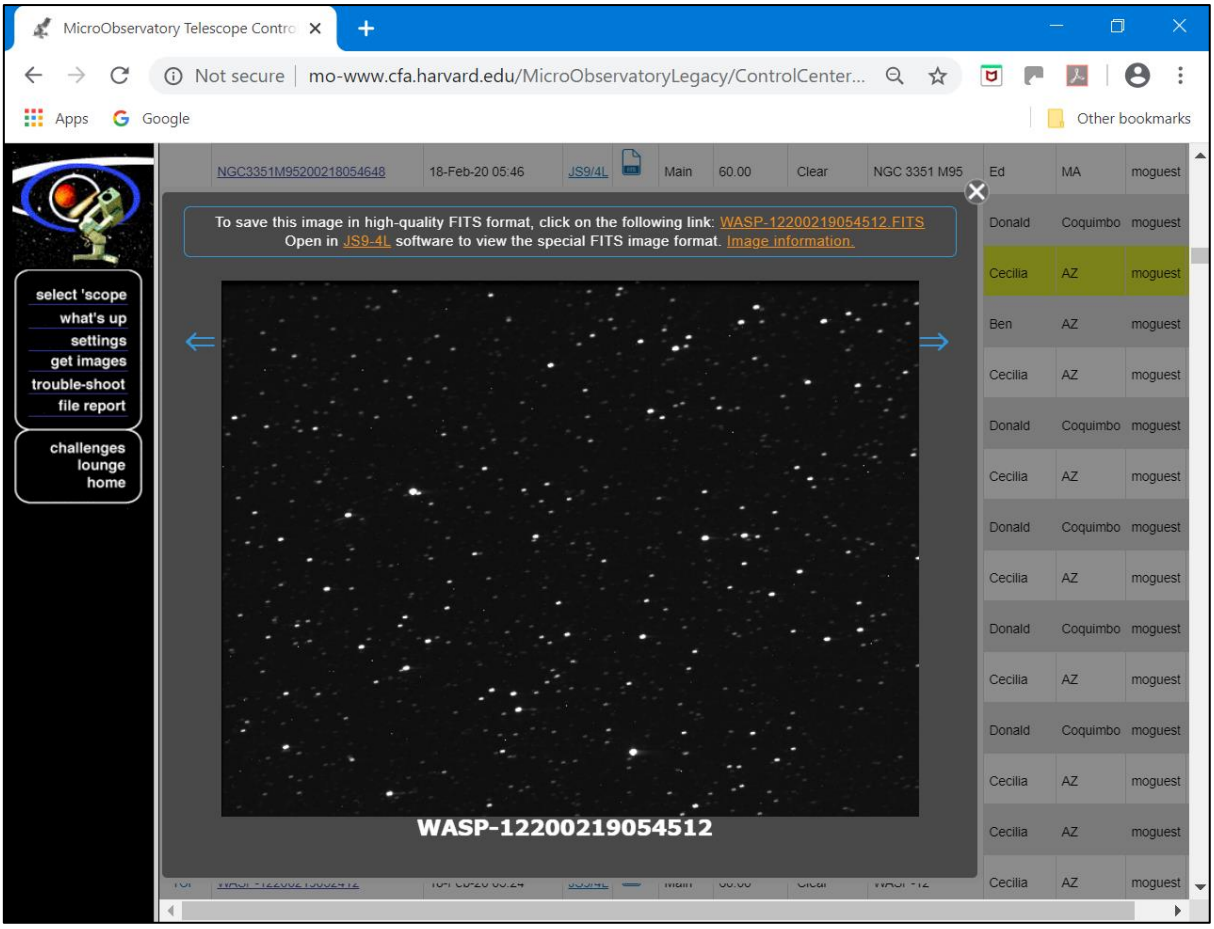


Figure 4.1.6. FITS image

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.

For ARIEL ExoClock participants please use the HOPS software – see appendices A and B at https://britastro.org/sites/default/files/ARIEL%20Space%20Mission%20V2.pdf

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 (110.88, 110 52 48W)
Time Zone;	-7