## <u>Remotely operated robotic telescopes – the MicroObservatory Robotic Telescope</u> <u>Network</u>

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 <u>Exoplanet Transit Database (ETD)</u> 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

## Contents

- 1.0 Accessing the network
- 2.0 Target selection
- 3.0 On-line analysis
- 4.0 Downloading images and dark frames (for off-line analysis)
- 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 <u>Harvard and Smithsonian Center for Astrophysics</u> and can be found <u>here</u>. 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

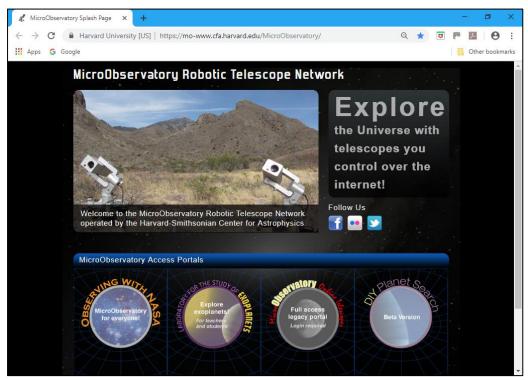
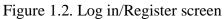


Figure 1.1 Robotic telescope home page.

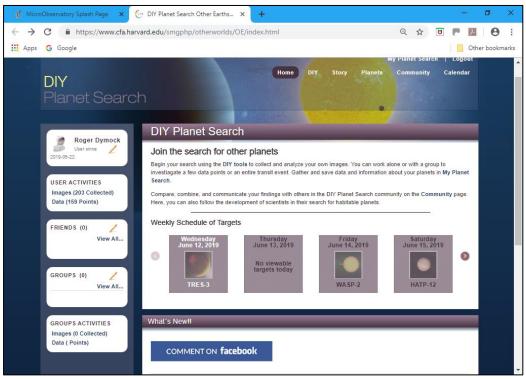
	Planet Search Other Earths × + du/smgphp/otherworlds/OE/index.html	- Q ☆ <b>0 7</b> <u>8</u>	• × •
🔢 Apps 🛛 G Google		Other	bookmarks
DIY Planet Search		online, you'll take your own images of ar, and become part of a community of	

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



## 2.0 Target selection

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





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 MicoObservatory pages as shown in Figures 2.1 and 2.2.

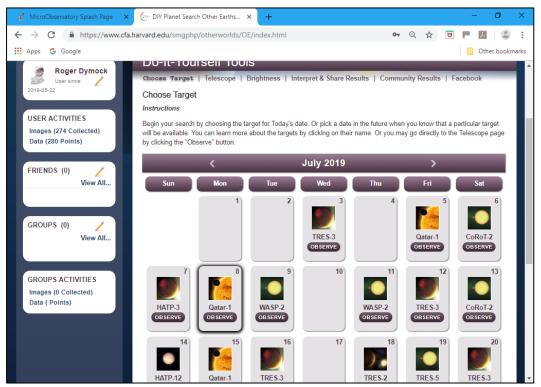


Figure 2.2. Targets for the month.

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.

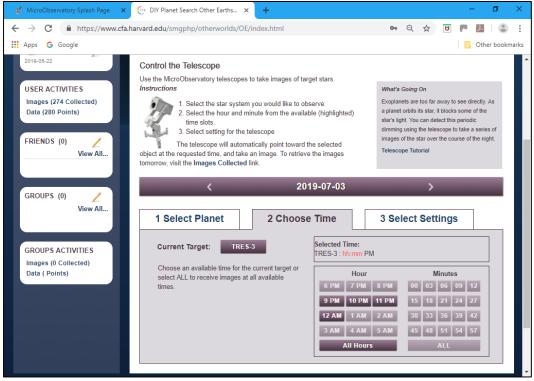


Figure 2.3. DIY Tools page '2 Choose Time' tab.

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).

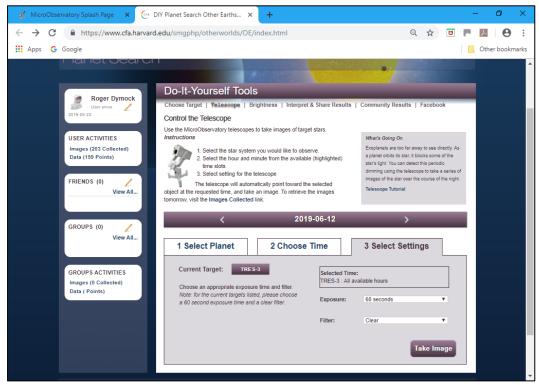


Figure 2.4. DIY Tools page '3 Select Settings' tab.

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.

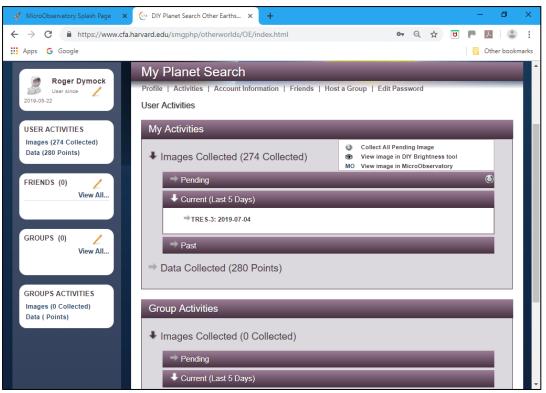


Figure 2.5. Activity status page.

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.

💰 MicroObservatory Splash Page 🛛 🗙	💮 DIY Planet Sea	rch Other Ea	rths ×	+					-	٥	×
← → C ③ https://www.cfa.ha	arvard.edu/smgph	p/otherwo	orlds/OE/ind	ex.html			QL	U		<u>ل</u> ا	:
Apps <b>G</b> Google										Other bool	kmarks
	My DL	anot Co	oroh						_		
💓 Roger Dymock		anet Se		tion I Friends	B   Host a Group						
2019-05-22	User Activ		account information	ation   Friends	s   Host a Group	Edit Passwo	ra				
	User Activ	Vities									
USER ACTIVITIES	My Act	tivities									
Images (274 Collected) Data (280 Points)						llect All Pending					
Data (200 Points)	↓ Ima	ges Colle	cted (274)	Collected)		ew image in DIY B ew image in Micro					
FRIENDS (0)		Pending						٢			
View All		Current (La	ast 5 Davs)								
		+ TRES-3:									
			1	1							
GROUPS (0) / View All		#	Time 00:00 AM	Status	View Image	MO Link MO	Expires 29				
The Aller		#	00:00 AM		•	MO	29				
		#	00:06 AM	Ĵ		MO	29				
GROUPS ACTIVITIES		#	00:09 AM	~		MO	29				
Images (0 Collected) Data ( Points)		#	00:12 AM	~		MO	29				
Data ( Points)		#	00:15 AM	1	۲	MO	29				
		#	00:18 AM	1	۲	MO	29				
		#	00:21 AM	1	۲	MO	29				
		#	00:24 AM	~	•	MO	29				
		#	00:27 AM 09:06 PM	09:07 PM	•	MO MO	29 29				
		#	09:06 PM	U9:07 PM	w	WO	29	_			
		#	09:12 PM	09:13 PM		мо	29				
		#	09:15 PM	1		MO	29				

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.

💰 MicroObservatory Splash Page 🗙 🕑 I	IIY Planet Search Other Earths × +	_	- 0	×
$\leftrightarrow$ $\rightarrow$ C (i) https://www.cfa.harvarc	.edu/smgphp/otherworlds/OE/index.html		* 8	:
👖 Apps 🕒 Google		🖪	Other bookm	narks
	Analyze Images View Data Graph Brightness			^
GROUPS ACTIVITIES	My Images Export Data			
Images (0 Collected) Data ( Points)	Images you requested: TRES-3190704070012 🗸 💌	>		
	Name:TRES-3190704070012   Date:July 4 ,2019   Time of Night:12:00 AM	Finder Chart		
	• • • • • • • • • • • • • • • • • • •	review		
	김 아님, 영양의 영양에 집을 갖	$\bigcirc$		
		0		
	e •	1257 Calibrate		
	1월 1일 - 1일	arget Star		
	그 바람이 있는 것 같은 것을 가지 않는 것을 많이 가지 않는 것 같은 것 같은 것 같아.	432 omparison Stars		
		313		
	그는 것 같은 것 같아요. 이 것 같은 것 같은 것 같은 것 같은 것 같이 지 않는 것 같이 ?	568 ark Part of Sky		
		152		
	Your Last Relative	158		
	Pixel Brightness: (21257) Mouse Location (x=637, y=188) Measurement:0.99628	ReCalculate & Record		•

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.

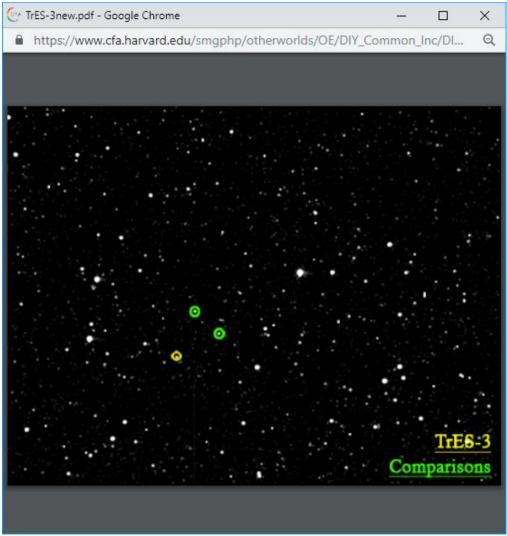


Figure 3.2. Finder chart.

If you want confirmation of the position of TrES-3 you might find this <u>website</u> useful. Fill in the relevant boxes and this will bring up the page shown in Figure 3.3.

s.	MicroObservatory Splash	n Page 🛛 🗙 📔 🔄 DIY Planet Se	arch Other Earth	× 🔯 U	pcoming transits	×	+	-	o ×
←	→ C	://astro.swarthmore.edu/print	_transits.cgi?o	bservatory_stri	ng=31.680944%	3B-110.8775%3	BAmerica		ん   🕃 : Other bookmarks
Sea	rch:	Show if visib	le transit % +	baseline % >	0	V_m	iax:		
	Local evening date 🔻	Name 🔶	V or Kepler ≑ mag	Start— Mid —End	Duration 🔶	BJD <sub>TDB</sub> 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 Finding charts:		12.40	17:25 22:25— 23:06		8668.726	18° 76°,		
	Nautical twilight 20:34 – 04:21 (America/Phoenix) (America/Phoenix)	Moon 3% @113°	-23:46 04:46 ±0:49	1:21	8668.754 8668.782	83°, 83° 26°	100% (55%) 20:34—04:21	27.4	
•	Wed. 2019-07-03 Nautical twilight	Kepler-78 b Finding charts: Annotated, SkyMap;	11.72	17:46 22:46— 23:11		8668.741	8° 59°,		
	20:34 - 04:21 (America/Phoenix)	Info: <u>Exoplanets.org</u> , <u>Simbad</u> , <u>Gaia DR2</u> , <u>TIC</u> , <u>VSX</u> , <u>Vizier phot.</u> ; <u>Airmass plot</u> , <u>ACP plan</u>	Moon 3% @115°	23:35 04:35 ±0:01	0:48	8668.758 8668.775	63°, 67° 48°	100% (69%) 20:34—04:21	0.2
€	Wed. 2019-07-03 Nautical twilight	<u>WASP-113 b</u> Finding charts: <u>Annotated, SkyMap;</u>	11.77	16:05 21:05— 23:14		8668.671	37° 74°,	<b>T</b>	
	20:34 – 04:21 (America/Phoenix)	Info: <u>Exoplanets.org</u> , <u>Simbad</u> , <u>Gaia DR2</u> , <u>TIC</u> , <u>VSX</u> , <u>Vizier phot.</u> ; <u>Airmass plot</u> , <u>ACP plan</u>	Moon 3% @83°	01:23 06:23 ±0:02	4:17	8668.760 8668.850	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.

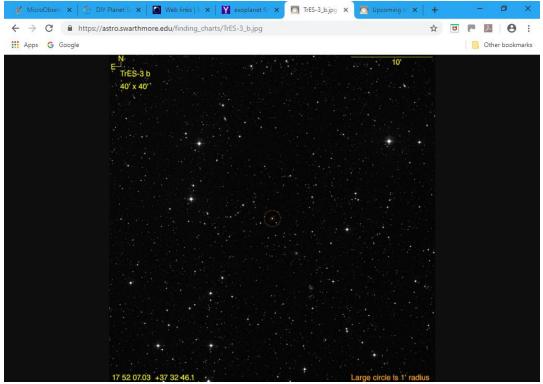


Figure 3.4. TrES finder chart

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.

💰 MicroObservatory Splash Page 🗙 🤄 D	DIY Planet Search Other Earths 🗙	Opcoming transits	×   +	-	٥	×
← → C ③ https://www.cfa.harvard	.edu/smgphp/otherworlds/OE/ind	dex.html	Q ☆	8		:
🗰 Apps 🛛 G Google				Ot	her bookn	narks
	Analyze images	View Data Gra	aph Brightness			<b>^</b>
GROUPS ACTIVITIES	My Images Exp	ort Data				
Images (0 Collected) Data ( Points)	lmages y	pu requested: TRES-3190704070	012√ ▼	>		
	IMAGE NAME	TIME OF NIGHT	RELATIVE BRIGHT	NESS		
	TRES-3190704070012	12	0.99628	<b>^</b>		
	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			
	4			► F		-

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).

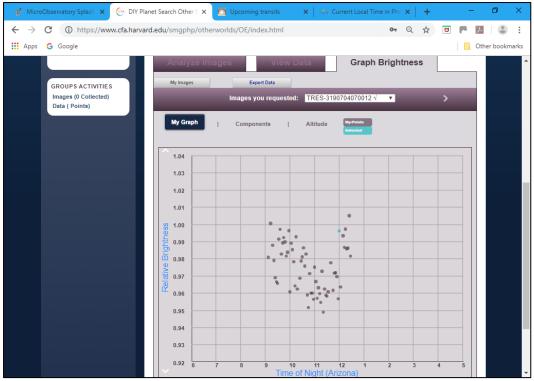


Figure 3.6. Transit light curve

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.

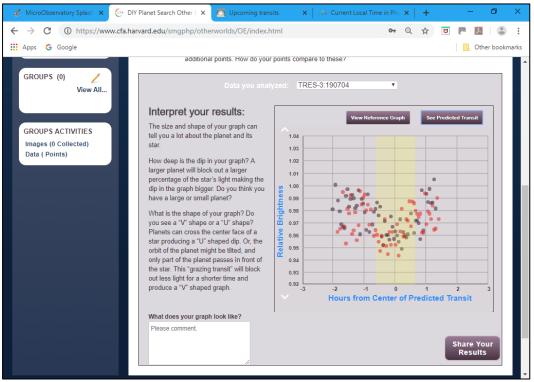
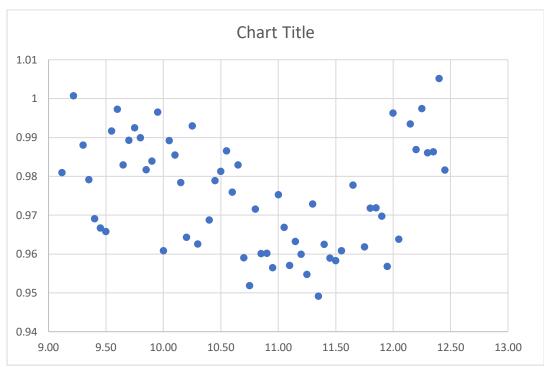


Figure 3.7. Results plus Reference Graph and predicted times.

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

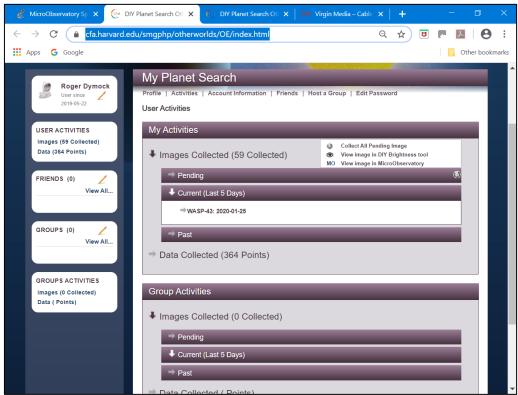


Figure 4.1.1. Activity status page

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.

MicroObservatory Sp 🗙 💮 DIY Planet S		<ul> <li>DIY Planet S</li> </ul>	earch Ot X		edia – Cable 🗙	+		
ightarrow C $rightarrow$ cfa.harvard.edu/smg	ohp/otherworld	ls/OE/index	html		Q	. ☆ 🖸		Θ
Apps 🔓 Google							Cthe	er <mark>bookm</mark>
User	Activities							
	A 100 1 10 10 10 10 10 10							
USER ACTIVITIES My Images (59 Collected)	Activities	_	_			_		
	Images Colle	cted (59 C	ollected)	0	Collect All Pendin View image in DIY			1.15
	inages cone	cied (05 C	onected)		View image in Mic		_	1.15
FRIENDS (0)	Pending						٢	1.15
View All	🕹 Current (La	ist 5 Days)						1.15
								1.15
	* WASP-43	: 2020-01-25						1.15
GROUPS (0) 🖉	#	Time	Status	View Image	MO Link	Expires		1.15
View All	#	00:27 AM	1	6	MO	26		1.15
	#	00:30 AM	1	۲	MO	26		1.15
	#	00:33 AM	~	9	MO	26		1.15
GROUPS ACTIVITIES	#	00:36 AM	~	9	MO	26		1.15
Images (0 Collected) Data ( Points)	#	00:39 AM	~	9	MO	26		1.15
Suu (Tomis)	#	00:42 AM	~	6	MO	26		1.15
	#	00:45 AM	~	6	MO	26		1.15
	#	00:48 AM	~	۲	MO	26		1.15
	#	00:51 AM	~	۲	MO	26		1.8
	#	00:54 AM	~	۲	MO	26		1.8
	#	00:57 AM	~	•	MO	26		
	#	01:00 AM	~	•	MO	26		
	#	01:03 AM	~	۲	MO	26		
		01:06 AM	-	۲	MO	26		
	#	01:09 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.

harvard.edu/jsp/servlet/MO.ID.Sho	wlmage?file=WASP-43200125072748.GIF&dir=ImageDir	Q	☆	U	
					Other boo
and the second second	Click for information on this image				
0 0	To save this image in basic GIF format (below), click, hold & drag the picture to your desktop.				
	To save this image in high-quality FITS format (recommended), right click on the following link: <u>WASP-43200125072748.FITS</u> .				
Recent Image Directory	You will need <u>MicroObservatory Image</u> software to view the special FITS image format.				
	이 없이 많은 것이 여름다. 여름 것				
	- 그는 10 전 전 전 전 전 전 전				
	그는 없는 것이 같은 돈을 다 한다.				
김 경기도 문화	[편집] 이 여행에 가지 않는 것 같은				
그 것은 물질했다.					
	동생 왜 한번에는 것 않는 가슴				
	아이지 않는 것이 같아. 승규는				
에 생각을 만든 것도가 못했다.	성상 것이 많은 것이 같은 것이 다. 그 것은 것 같아?				

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 (<u>http://mo-</u> <u>www.cfa.harvard.edu/MicroObservatoryLegacy/ControlCenter/index.html</u>) – Figure 4.1.4

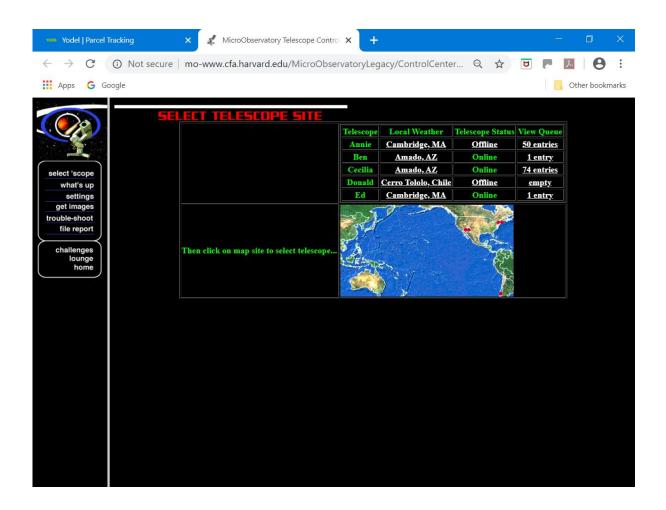


Figure 4.1.4 Control center

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.

💉 MicroObservatory Telescope Contro 🗙 🕻	🔀 Virgin Media - Cable Broadband, Di 🗙	HF Cowplain Bowling Club, C	owplain, V 🗙		lanet Search Ho	me Page	×	+				~	-	- 0	×
$\leftrightarrow$ $\rightarrow$ $\mathcal{C}$ ( A Not secure   mo-w	ww.cfa.harvard.edu/MicroObservator	ryLegacy/ControlCenter/in	ndex.html							E	2 🕁			· 🗆 🌔	: 1
G Google														, Other b	ookmarks
										- M					
	Date Range	Past 10 Da	ays		Past 20	) Days	]	(	Past	30 Days					
select 'scope	HATP-36												•		
what's up settings get images trouble-shoot	Image Filename	<u>Date &amp; Time (UT)</u> ▼ Op JS	en FITS 19/4L Image	Field of View	Exposure Time (sec)	<u>Filter</u>	<u>Object</u>	Telescope	Site	<u>User</u>	Size (KB)	Weather	Ľ		
file report	HATP-36230308090015	08-Mar-2023 09:00:15 JS	:9/4L	Main	60.00	Clear	HATP-36	Cecilia	AZ	moguest	265	47% Clea	¢		
challenges lounge home	HATP-36230308085716	08-Mar-2023 08:57:16 JS	:9/4L	Main	60.00	Clear	HATP-36	Cecilia	AZ	moguest	256	47% Clea	œ		
	HATP-36230308085415	08-Mar-2023 08:54:15 JS	<u>9/4L</u>	Main	60.00	Clear	HATP-36	Cecilia	AZ	moguest	255	47% Clea	c		
	HATP-36230308085115	08-Mar-2023 08:51:15 JS	<u>9/4L</u>	Main	60.00	Clear	HATP-36	Cecilia	AZ	moguest	261	47% Clea	œ		
	HATP-36230308084515	08-Mar-2023 08:45:15 JS	<u>9/4L</u>	Main	60.00	Clear	HATP-36	Cecilia	AZ	moguest	258	47% Clea	c		
	HATP-36230308084215	08-Mar-2023 08:42:15 JS	:9/4L	Main	60.00	Clear	HATP-36	Cecilia	AZ	moguest	253	47% Clea	Ľ		
	HATP-36230308083915	08-Mar-2023 08:39:15 JS	:9/4L	Main	60.00	Clear	HATP-36	Cecilia	AZ	moguest	255	47% Clea	c		
	HATP-36230308083615	08-Mar-2023 08:36:15 JS	<u>19/4L</u>	Main	60.00	Clear	HATP-36	Cecilia	AZ	moguest	262	47% Clea	Ľ		
	HATP-36230308083015	08-Mar-2023 08:30:15	9/4L	Main	60.00	Clear	HATP-36	Cecilia	AZ	moguest	253	47% Clea	£		
	HATP-36230308082715	08-Mar-2023 08:27:15 JS	9/4L	Main	60.00	Clear	HATP-36	Cecilia	AZ	moguest	269	47% Clea	œ		
BACK TO	HATP-36230308082415	08-Mar-2023 08:24:15 JS	9/4L	Main	60.00	Clear	HATP-36	Cecilia	AZ	moguest	250	47% Clea	c		

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

MicroObservatory Te	lescope Contro × +		- 0	i ×
→ C ()	Not secure   mo-www.cfa.harvard.edu/MicroObservatoryLegacy/ControlCenter Q		ト	0
Apps G Google			Other k	bookmar
	NGC3351M95200218054648 18-Feb-20 05:46 JS9/4L <table-cell> Main 60.00 Clear NGC 3351 N</table-cell>	/195 Ed	MA	mogues
<b>Y</b>	To save this image in high-quality FITS format, click on the following link: <u>WASP-12200219054512.FITS</u> Open in <u>JS9-41</u> , software to view the special FITS image format. <u>Image information</u> .	Donald	Coquimbo	mogues
ect 'scope		Cecilia	AZ	mogues
what's up settings	_ 방법 방법 이 여행 방법 방법 수 있는 것이 많이 했다.	Ben	AZ	mogues
et images ple-shoot		Cecilia	AZ	mogues
allenges		Donald	Coquimbo	mogues
lounge home	이 이 것은 것이 같은 것이 되는 것 같아. 이 것이 같아.	Cecilia	AZ	mogues
	에는 것은 것이다. 같은 것은	Donald	Coquimbo	mogues
	신 한 것은 것 같은 것은 것 같아요. 방법이 것 같아.	Cecilia	AZ	mogues
	지 않는 것 같은 것 같은 것 같은 것 같은 것 같은 것이다.	Donald	Coquimbo	mogues
		Cecilia	AZ	mogues
		Donald	Coquimbo	mogues
	- 이상 방법에서 가장 가장 가지 않아 있었다. 이상 가장	Cecilia	AZ	mogues
	WASP-12200219054512	Cecilia	AZ	mogues
		Cecilia	AZ	mogues

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 <u>https://britastro.org/sites/default/files/ARIEL%20Space%20Mission%20V2.pdf</u>

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

#### Location

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