

Workflow based Guide to using AstroImageJ

for Exoplanet Transit Photometry

Part 2 (Short-form Guide)



Model transit plots WASP104 on UT2020-02-27

Richard Lee

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1. Introduction

Part 2 provides short form instructions for using AIJ v5 with a WASP104 transit dataset hosted on Dropbox. The instructions are intended for users familiar with AIJ and assumes all required software, including Planner plugin and ansvr plate solving software, have been installed. If necessary, refer to Part 1 for instructions to install and configure software.

The WASP104 dataset was acquired on UT2020-02-27 from ICA Astronomy site in Oria, Spain. Compared to the Part 1 WASP12 dataset, additional processing tasks are:

- WASP104 images are not plate solved instructions refer to default ansvr plate solver.
- Meridian flip images were acquired with a GEM mount tracking across the meridian
- Saturated reference star demonstrates re-running photometry with a modified radec file

AIJ Configuration File

AIJ settings are saved to the AIJ_Prefs.txt file located in Users Settings folder C:\Users\<user>\.astroimagej. The BAA WASP104 Dataset Files package (see Appendix), includes a custom settings file BAA.AIJ_Prefs.txt. Section 2 details replacing an existing AIJ_Prefs.txt with the BAA version then setting observatory and camera parameters to process the WASP104 dataset. Parameters to process WASP104 dataset are tabulated in an Appendix in Part 1.

BAA Dataset Files

Treating the WASP104 as a potential 'BAA campaign' object, the supplied file BAA.DATASET.WASP104.TXT contains target J2000, V-mag and data required for user input to the Fit Settings window. Refer Appendix for details.

Transit Results

Table transit times and depth are computed in the Fit Settings window from a five-parameter model fit, including manual entry of the u1 and u2 limb darkening terms.

2. Configuration and Dataset Files

Refer to Part 1 | section 1 for a link to download BAA support files.

Download and import configuration and WASP104 dataset files

- 1. From the BAA web site (link BAA_AIJ in Part 1 | section 1), download and save 'BAA.AIJ Guide Part 2.zip' in folder C:\Astro\Downloads.
- 2. Extract zip file to C:\Astro\Downloads folder; path to the uncompressed folder is: C:\Astro\Downloads\BAA.Files for AIJ Guide Part 2.
- In C:\Astro\Downloads\ BAA.Files for AIJ Guide Part 2 folder, open BAA.README.AIJ_GUIDE_2.TXT in a text editor and follow instructions to copy configuration and other files to respective folders.
- 4. Download WASP104 dataset from Dropbox links detailed in BAA.README.AIJ_GUIDE_2.TXT; unzip and save in:
 C:\Astro\Datasets\WASP104.V.2020_02_27\Raw Science Files (200 files)
 C:\Astro\Datasets\WASP104.V.2020_02_27\Calibration Files (30 files)

Overwrite BAA AIJ_Prefs configuration file

- 1. Navigate to AIJ User Settings folder (C:\Users\<user>\.astroimagej).
- 2. In User Settings folder, rename AIJ_Prefs.txt to AIJ_Prefs.bak and rename BAA.AIJ_Prefs.txt to AIJ_Prefs.txt.

3. Short-form Procedure

3.1. Set up Software

Set up DP Coordinate Converter

1. Open AIJ | DP Coordinate window, select Observatory ID = ICAstronomy, Oria and set UTC offset to 1.

Note: Refer Part 1 | section 2 for instructions to setup a custom observatory.

- 2. Run a SIMBAD query on ObjectID: WASP104.
- 3. Close and re-open AIJ and confirm new DPCC settings have registered.

Set up Aperture Photometry Settings

- 1. Open AIJ | CCD Data Processor window, in Control Panel click to open the Aperture Photometry Settings window.
- 2. Confirm Keywords list includes 'EXPTIME' and not 'EXPOSURE'; edit list as necessary.
- 3. Edit three CCD fields for ICAstronomy values listed in Part 1 | Appendix.
- 4. Close and re-open AIJ and confirm settings have registered.

Set up CCD Data Processor for WASP104 dataset

- 1. Open AIJ | CCD Data Processor window.
- 2. Science Image Processing | Directory: navigate to and Select folder C:\Astro\Datasets\WASP104.V.2020_02_27\Raw Science Files
- 3. Science Image Processing | Filename/Pattern: enter *_LIGHT_V_*.FIT and confirm Totals = 200.
- 4. Bias Subtraction | Filename/Pattern: enter *_BIAS_*.FIT, confirm Totals = 10
- 5. Dark Subtraction | Filename/Pattern: enter *_DARK_*.FIT, confirm Totals = 12.
- 6. Flat Division | Filename/Pattern: enter *_FLAT_V_*.FIT, confirm Totals = 8.
- 7. Change master flat filename from m_flat_FILTER.fits to m_flat_V.fits.
- 8. Confirm CCD DP window settings against the following figure:

Control	Options	Directory	Filename/Pattern	Total
Filename Pattern	Matching			
Enable	Sort Num	C:\Astro\Datasets\WASP104.V.2020_02_27\Raw Science Files\	*_LIGHT_V_*.FIT	20
Filename Numbe	er Filtering			
Enable	-	Min: 0 🔺 Max. 100000000 🔹	*_LIGHT_V_*.FIT	20
lias Subtraction-				_
Build C) ave) 🖲 med	\Calibration Files\	*_BIAS_*.FIT	1
Enable		Waster Calibration Files\	m_bias.fits	
Dark Subtraction				
Build C) ave 🔘 med	\Calibration Files\	*_DARK_*.FIT	1
🗹 Enable 🛛	🖉 scale 🗹 deBias	Waster Calibration Files\	m_dark.fits	
lat Division				
Build C) ave) e med	\Calibration Files\	*_FLAT_V_*.FIT	
Enable 🗹	Remove Gradient	Waster Calibration Files\	m_flat_Vļfits	
mage Correction				
Enable Linea	arity Correction	New pixel value = 0.0E0 + 1.0E0 + (PixVal) + 0.0E0 +	× (PixVal) ² + 0.0E0 × (PixVal) ³	
	illers 🖂 Bright 🗹	Dark Radius. 2 - Theshold. 50 -		
FITS Header Upda	ates	r Target Coordinate Source	bservatory Location Source	
General 🗸	Plate Solve	Coordinate Converter manual entry C	oordinate Converter manual entry	
Save Calibrated In	mages			
🗹 Enable	16 (1) 32	Sub-dir: Reduced Science Files Suffix _bdf Format		
Post Processing				
M-Ap	Save Image	Macro 1 C:\Users\rlee1\		
M-Plot	Save Plot	Macro 2 C:\Users\rlee1\		
		1		
control Panel —				

Set up DP Astrometry Settings for WASP104 dataset

- 1. Open CCD Data Processor | DP Astrometry Settings window 🚺.
- 2. Enable Use Custom Server option and enter server address. In example below this is configured for port 9123.

Note 1: Plate Scale is set to 0.87 arcsec / pixel, image scale for 2x2 binned WASP104 image set. Note 2: Custom Sky Location text boxes are automatically populated from DP CC J2000 Equatorial fields.

DP Astrometry Setting	S			_		\times
User Key:		(Get key from:	nova.astrometry.net)			
Use Custom Server:	Enable	http://127.0.0.1:9123				
Re-save Raw Science:	Enable		WARNING: may	re-write	s raw scie	ence file
Skip Images With WCS:	Enable					
Annotate:	Enable	Radius (pixels)				
Add To Header:	Enable	30.00 ≑				
		Filter Radius (pixels)				
Median Filter:	Enable	2 ≑				
		Max Peak (ADU)	Noise Tol (StdDev)	Ма	x Num Star	rs
Peak Find Options:	Limit Max Peaks	50000 🌲	1.00 🜩			50 🗘
		Radius (pixels)	Sky Inner (pixels)	Sky	Outer (pixe	els)
Centroid Near Peaks:	Enable	20.00 🗘	30.00 🔹		4(0.00
		Plate Scale (arcsec/pix)	Tolerance (arcsec/pix)			
Constrain Plate Scale:	Enable	0.870 🜩	0.250 🔹			
	_	Center RA (Hours)	Center Dec (Degrees)	Rad	lius (arcmi	n)
Constrain Sky Location:	Enable	10:42:24.602	+07:26:06.29		4	40.0 🜩
	_	SIP Order				
SIP Distortion Correction:	Enable	2 ≑				
		SAVE AND EXIT	SAVE			

- 3. Optional: enable option to Skip Images with WCS to bypass plate solve if repeating WASP104 image reduction.
- 4. Click [SAVE AND EXIT] to close window.

3.2. Run AIJ Photometry

Run CCD Processor for WASP104 dataset

- 1. In CCD Data Processor window, click [START] to run image reduction process on WASP104 Raw Science images.
- 2. When image reduction process is finished, move the Reduced Science Files folder up one level as follows:

From: C:\Astro\Datasets\WASP104.V.2020_02_27\Raw Science Files\Reduced Science Files

To: C:\Astro\Datasets\WASP104.V.2020_02_27\Reduced Science Files

Run visual inspection for WASP104 dataset

- AIJ toolbar | File |Import Image Sequence: ensure Use virtual stack is checked, then navigate to and open folder C:\Astro\Datasets\WASP104.V.2020_02_27\Reduced Science Files.
 First reduced image opens in Image Viewer window.
- 2. Viewer | View: select 'Invert' option from View menu to orientate image N-E => up-left as below.



- 3. Click 'Play' icon (left side of horizontal scroll bar) and review image quality; click 'Pause' icon to pause at current displayed image.
- To delete any poor-quality images from the image stack, pause at the defective image and click
 in the Viewer toolbar.

Option: since the fits file is *not* deleted, note the fits filename of any reject image and manually remove the file from the Reduced Science Files folder.

Set up aperture radii for WASP104 dataset

- 1. Alt-Left click on a bright non-saturated star image to open the Seeing Profile window and click [Save Aperture].
- 2. In Viewer window, open the Multi-Aperture Measurements window and confirm that the aperture radii match.
- 3. Close the Multi-Aperture Measurements and Seeing Profile windows and clear aperture overlay on current image.

Import radec apertures for WASP104 dataset

- Viewer | File | Import apertures from RA/Dec list: navigate to and select C:\Astro\AstroImageJ\radec\WASP104.V.018.radec.txt to import and overlay aperture set on current image. Zoom image to fit screen to as necessary.
- 2. Ensure group of toolbar aperture buttons (5) are selected as shown in figure below
- 3. Open Multi-Aperture Measurements window, then click [Place Apertures] to close window, lock apertures to object centroids and open Multi-Aperture Help window.



Run photometry for WASP104 dataset

- 1. Click Viewer title bar to ensure window is active then press <Enter> to start processing.
- When processing is finished, activate the Measurements window, File | Save As: C:\Astro\Datasets\WASP104.V.2020_02_27\Measurements.tbl
 Option: to assist importing data into a spreadsheet, save measurements data to second file: Measurements.txt

Review reference star selection for WASP104 dataset

 Activate the Multi-Plot Reference Star Settings window. The red checkbox is coloured red, indicating that the peak count has exceeded the saturation limit.

Note: linearity and saturation limits are set in the Aperture Photometry Settings window.

None All Save Recall Cycle Enabled Stars Less One Cycle Individual Stars T1 C2 C3 C4 C5 C6 C7 Image: Carrier C	elect reference Show Magnit	stars to include in udes Hide	tot_C_cnts a Magnitudes	nd rel_flux calculatio	ns			
T1 C2 C3 C4 C5 C6 C7 Image: Comparison of the com	None	All Save	Recall	Cycle Enabled St	ars Less One	Cycle Ind	ividual Stars	
Image: Constraint of the state of	Т1	C2	C3	C4	C5	C6	C7	
11.159 12.587 12.309 12.708 12.86 13.304 Green checkbox border - aperture peak count under linearity limit Yellow checkbox border - aperture peak count over linearity limit			\checkmark		\checkmark	\checkmark	\sim	
Green checkbox border - aperture peak count under linearity limit Yellow checkbox border - aperture peak count over linearity limit		11.159	12.587	12.309	12.708	12.86	13.304	
Red checkbox border - aperture peak count over saturation limit	Green checkbo Yellow checkbo Red checkbox b	x border - apertur x border - apertur	re peak count re peak count peak count o	under linearity limit over linearity limit ver saturation limit		22.30	101001	
	ave/Show Curre	ent Configuration						

Option: Run photometry with updated radec apertures

Optional section to demonstrate updating photometry results with C2 removed from radec aperture set.

- 1. Close and re-open AIJ, then from the toolbar, Plugins | Astro Apps | Run Planner App.
- 2. In Planner | Catalogs tab: click [Import Radec File], and open WASP104.V.018.radec.txt (i.e., the radec file for the current MP Reference Stars).
- 3. Uncheck 'USE' for C2 (ObjectId : 10422444+07263510), then click the following button sequence: [Update], [Save Radec File], [Clear], [Import Radec File].
- 4. Re-open WASP104.V.018.radec.txt and confirm ObjectId: 10422444+07263510 is deselected in the aperture table.
- 5. Close the Planner app and VSP Star chart.
- 6. Run photometry for WASP104 Reduced Science Files as above, again using (the now updated) aperture set: WASP104.V.018.radec.txt
- 7. When photometry run is finished, activate the Multi-Plot Reference Star Settings window and confirm all reference star checkboxes are green.

Hulti-plot Refere	ence Star Setting	IS		_		×
Select reference stars	s to include in tot. s Hide Mag	_C_cnts and rel_flu	ux calculations			
Reference Star Selec	tion					_
None All	Save	Recall Cycle	Enabled Stars Less	One Cycle In	ndividual Star	s
T1	C2	C3	C4	C5	C6	
	\checkmark			\checkmark	\checkmark	
	12.587	12.309	12.708	12.86	13.304	
Green checkbox bo Yellow checkbox bo Red checkbox bord	rder - aperture pe rder - aperture pe er - aperture peal	eak count under lin eak count over line k count over satur	earity limit arity limit ation limit			
Save/Show Current C	Configuration					
Save Table	Save Apertures	Send to M	ulti-aperture	Show Apertures		

 In Multi-Plot Main | File | Save data to file, save photometry results to: C:\Astro\Datasets\WASP104.V.2020_02_27\Measurements.tbl, confirm replacing existing file.

Meridian flip time (BJD_TDB) for WASP104 dataset

 Compute the fractional BJD_TDB time of meridian flip as detailed in Appendix. Result: Flip Time = 0.532.

3.3. AIJ Multi-Plot and Transit Analysis

Configure Multi-Plot for WASP104 dataset

- 1. Close and re-open AIJ, in the click toolbar icon 📴 , MultiPlot Tool, to open Multi-plot Main and other Multi-plot windows.
- 2. Activate the Multi-plot Main window, select MP Main | File | Open table from file... then navigate to and select: C:\Astro\Datasets\WASP104.V.2020_02_27\Measurements.tbl.
- 3. MP Main | File | Open plot configuration from file...: navigate to and select C:\Astro\AstroImageJ\plotcfg\BAA.transit_amass_flip.plotcfg.
- 4. Enter MP Main Title: WASP104 on UT2020-02-27
- 5. Enter MP Main Subtitle: ICAstronomy, Oria | V-Filter | 60s
- 6. V. Marker 1: click on scroll-up control to move chart data left until it reaches the 'Predicted Ingress' marker line.
- 7. V. Marker 2: click on scroll-down control to move chart data right until it reaches the 'Predicted Egress' marker line.
- 8. In the Fit and Normalize Region section, click where to copy V. Marker values into the Left and Right textboxes.
- In the Meridian Flip section, enable Show and enter Flip Time = 0.532 (see previous section). The WASP104 plot below feature:
 - Left and Right marker lines coincide with the Predicted Ingress / Egress lines.
 - The solid red line is an initial transit fit to the WASP104 dataset.
 - The dashed cyan line marks the time of the meridian flip.



10. MP Main | File | Save plot configuration: save as: C:\Astro\AstroImageJ\plotcfg\WASP104.transit_amass_sky.plotcfg.

Set up Fit Settings for WASP104 dataset

- 1. Open file C:\Astro\Datasets\WASP104.V.2020_02_27\BAA.DATASET.WASP104.TXT in a text editor.
- 2. Activate the Fit Settings window and enter the following data into Fit Settings | User Specified Parameters text boxes:

	Orbital Parameters Period (days):	1.755	<= README NAS	A EXOPLANET	Р
	Host Star Parameters R*(Rsun):	0.965	<= README NAS	A EXOPLANET	R*/Rsun
3.	Enter the following data into Fit Set	tings 1	ransit Parameters	Prior Center to	ext boxes:

- Linear LD u1: 0.601 <= README | EXOFAST | U1 Linear LD u2: 0.164 <= README | EXOFAST | U2
- 4. If necessary, enable the Linear LD and Quad LD check boxes.

Tabulate model results for WASP104 dataset

- 1. Activate and position the Plot of Measurements window and MP Main windows to view windows side-by-side.
- 2. In MP Main, using scroll control, move V. Marker 1 to mark the Predicted Ingress in the Plot of Measurements

- Repeat with V Marker 2 to mark transit egress.
 Note: For fine control of line marker positions, right-click in one of the V. Marker text boxes to open a small dialog, then set the Stepsize to 0.001.
- 4. Activate Fit Settings window: Fit Settings | File | Save fit results as text file, navigate to C:\Astro\Datasets\WASP104.V.2020_02_27 and save as WASP104.transit_results.txt.
- MP Main | File | Save plot configuration: save as: C:\Astro\AstroImageJ\plotcfg\WASP104.transit_amass_sky.plotcfg, confirm replacing existing file.
- 6. Fit Settings | Transit Parameters, complete results table for WASP104 transit (typical results, your values may slightly differ):

WA	ASP104 Transit	Parameters
Parameter	Units	Value
Тс		2458907.56530
Depth	ppt	12.64
T14	hms	01:55:04

Final Multi-plots for WASP104 dataset

-													
🖶 Multi-plot Main											-		×
File Preference	s Table	X-axis	Y-axis	Help									
Data (Measureme	ents.tbl) —												_
Default X-d	ata	Y-dat	tasets	Detrend	Vars	Rel. Mag.	Reference	v	. Marker 1 🔺	Сору	V. Ma	rker 2 🔺	
BJD_TDB	~		5 🔹 sets		2 🔹		10 🔹 sample	s 🖂	0.5252 🔹	MP		0.6055	•
	Title					Subtitle				Le	aend		
O None Custom				O None	Custom				Align: 🔾 Left 🔘	Center	Right		
WASP 104 on UT 2020-	02-27			ICAstronomy	, Oria V-Fi	lter 60s				Po	sition		
Тор	Middle		Bottom	Тор		Middle		Bottom	Тор	м	iddle	Во	ttom
Left	Center		Right	Left		Center		Right	Left	 G	enter	 R	light
	X-Axis	Label					Y-Axis I	abel			-Trim Data	a Samples-	
O None Column	Label O	ustom Label			O None (Column L	abel 🔿 Cus	tom Label	1	~	Head		0
											Tail		0
		X-Axis So	aling					Y-Axis	Scaling		Ple	ot Size	
Auto X-range	O First X-	value as min	1	O Custom	X-range	0	uto Y-range	(Custom Y-range				
	X-width		0.3 🔹)	(-max	c	A	\leq	Y-max		1.02 🜲	Height	1,00	0
X x 1E 0 🔹				X-min	c	Yx:	E 0 🔹	Y-min		0.9 🗘	Width	80	0 🗘
					Ph	ase Foldi	ng						
					-TO (Days)		Period	l (Days) —	Duratio	on (Hours))		
Unphased O Da	iys Since Tc() Hours Sin	ce Tc O Ph	ase		0			1 -		3 🛓 🔤 2	xP odd/e	ever
Meridian Fli	p			Fit and	Normalize	e Region	Selection –				Other P	anels	_
Show Flip Tir	me	Show	Left Trim		Left	Сору	Right		Right Trim	Red	raw Plot	Add Data	
0.5	33 🜩			D 🗘	0.495 🔹	حاله	0.655	÷	1 🔹 🗆	Y	-data	Ref. Stars	

Multi-Plot Main

🔁 М	ulti-	plot	t Y-d	ata																			-		×
Data Set	C No	ew I	Plot	Auto Scale	X-da	ita	Input in Mag		Y-data	1		Auto Error	Fu	nction		Y-opera	and	c	olor	Symt	ool	Lines	Input Average	Smo- oth	Len- gth
1				\checkmark	default	~		rel_flu	ux_T1		\sim		none	~			~	blue	~	dot	~		1 -		31 🔹
2	1			\checkmark	default	~		rel_flu	IX_T1		\sim		none	~			~	red	~	dot	\sim		1 +		31 🔹
3	ľ			\checkmark	default	~		rel_flu	JX_C2		\sim		none	~			~	purpl	e ~	circle	~		1		31 🔹
4				\checkmark	default	~		AIRM	ASS		\sim		none	~			~	gray	~	dot	~		1		31 🔹
5				\checkmark	default	~		Sky/P	ixel_T1		\sim		none	~			~	black	~	x	~		1		31 🔹
Data Set		Fit Mod	le	Trend Select	Trend Coefficient	T Da	rend taset		Norm/ Mag Re	Out f Mag		Page Rel	Scale	then	Shift	Out Bin	Bin Size (minutes))	egend Type			Custo	om Legend	1	٩
1			\sim	• 0	0.0014461	AIRMASS		~	-		\$			1	0		5	X	<u>a</u>	Legen	d1				
2		v	\sim	• •	0.0002233 🔹	Meridian_Fl	Þ	~	-		\$			1 🔹 🚽	0.015		5	×		Legen	d2				
3		off	~	• •	-0.0000136			~	off v		\$			1 -	0.055		5	×		Legen	d3				
4		off	~	• •	1 +			~	off v		\$		-1	0 🗣	-25 🔹		5	×		Legen	d4				
5		off	\sim	• •	0			~	off v		\$		1	5	-40 🔹		5	X	<u>æ</u>	Legen	dS				

Multi-plot Y-data

2	• O O O.0122597 → AIRMASS	~	· ·
2	• • • • • • • • • • • • • • • • • • •	~	· ·

MP Y-data: AIRMASS & Meridian_Flip Detrend

Detr	end Parameters	
Use	Parameter	Best Fit L
	AIRMASS ~	0.012259799365
	Meridian_Flip ~	-0.001198151179 🖒

Fit Settings: AIRMASS & Meridian_Flip Detrend



Plot of Measurements

Hear Considered Deserves	terrs (math fitterd)		rei_nux_r1				
Orbital Parameters Period (days) 1.755		(deg) 0.0	Host Star Parame	ters (en (K) 42 🐺	ter one) J-K R* (Rsun) 0.397 0.965 0.965	M* (Msi 0.953	n) ρ* (cgs) • 1.090 •
Transit Parameters							
Enable Transit Fit	Auto Update Priors		Extract Prior Center	Values Fr	om Light Curve, Orbit, an	i Fit Marker	s
Parameter	Best Fit	Lock	Prior Center	Use	Prior Width	Cust	StepSize
Baseline Flux (Raw)	0.461851701) 🗆 [0.462472		0.0924944		0.1
$(R_{p} / R_{*})^{2}$	0.013827869		0.009409139 🔹		0.004704569 🔹		0.009409139
a / R.	5.413396437		3.883007246 粪		7.0 🔶		1.0
T _C	2458907.565300815		2458907.575		0.015		0.01
Inclination (deg)	81.322861586		81.2 🔺		15.0 🔹		1.0
Linear LD u1	0.601000000		0.601 🛖		1.0 💂		0.1
Quad LD u2	0.154000000		0.164		1.0 🔹		0.1
Calculated from model	Depth (ppt) b		t14 (d)t14 (hr	ns)	t23 (d) tau (d)	ρ*	(cgs) Rp (Rju
Detrend Parameters	Best Fit	Lock	0.079911 D1:55:	Use	0.034903 0.022504	Cust	StepSize
Detrend Parameters Use Parameter AIRMASS AIRMASS	Best Fit	Lock	0.079911 01555	Use	Prior Width	Cust	5tep5ize
Detrend Parameters Use Parameter AIRMASS Meridan_Flip Th Opening	Best Fit ✓ 0.003505676974 € ✓ 0.000223380495 €	Lock	0.079911 22555 Prior Center 0.0 * 0.0 *	Use	0.02250 Prior Width 1.0 + 1.0 +	Cust	5tepSize 0.1
Detrend Parameters Use Parameter AIRMASS Meridian_Flip Fit Statistics	Best Fit	Lock	0.079911 21555 Prior Center 0.0 + 0	Use	0.034903 0.02250 Prior Width 1.0 ÷ 1.0 ÷	Cust	0.1 0.1 0.1
Detrend Parameters Vise Parameter AIRMASS Meridian_Flip Fit Statistics	Best Fit	Lock	0.079911 21555 Prior Center 0.0 + 0.0 +	Use 	0.034903 0.02250-	Cust	0.1 0.1 049-0052
Detrend Parameters Use Parameter ARPMASS Meridan_Fip Fit Statistics Fit Statistics Fit Statistics Fit Other Removal O Clean N × 0: S ©	Best Fit 0.003505676974 0.00022380495 0.00022380495 RMS (pot) 4.096365 0 0 Dhaustive Optimize 0	Lock	0.079911 21555 Prior Center 0.0 € 0.0 € 1085 1085 1085 1085 Cton Start N/A Max De Mn. E	Use	Prior Width 1.0 </td <td>Cust</td> <td>StepSize 0.1</td>	Cust	StepSize 0.1
Detrend Parameters Use Parameters ✓ Arameter ✓ Arameter ✓ Arameters Mendam, Flap Fit Statistics Fit Statistics ✓ Clean ✓ Other Removal ✓ Other Removal ✓ Other Removal ✓ Other Removal ✓ Other Removal ✓ Detrestings ✓ Show Model	Best Fit 0.003505/76974 0.0023306/76974 0.0022306/76974 0.0022306/76974 0.0022306/76974 0.00505/76974 0.00505 0.0022306/76974 0.0022307 <td>Lock</td> <td>0.079911 0.0 0.</td> <td>Use Use C C C C C C C C C C C C C</td> <td>0.034603 0.02280- Prior Width 1.0 1.0 0 daf 193 Detrend Parameter 19 st: 2 12 g Opterszation ymbol</td> <td>Cust</td> <td>StepSize 0.1 0.1 0.1 0.1 0.1 web.0052 0.1</td>	Lock	0.079911 0.0 0.	Use Use C C C C C C C C C C C C C	0.034603 0.02280- Prior Width 1.0 1.0 0 daf 193 Detrend Parameter 19 st: 2 12 g Opterszation ymbol	Cust	StepSize 0.1 0.1 0.1 0.1 0.1 web.0052 0.1
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Fit Settings

APPENDIX A: Compute BJD_TDB Time of Meridian Flip

Identify pre- and post-meridian flip images

- AIJ toolbar | File |Import Image Sequence: ensure Use virtual stack is checked, then navigate to and open folder containing *unprocessed* image files: C:\Astro\Datasets\WASP104.V.2020_02_27*Raw Science Files*. The first unprocessed (raw) science image opens in an Image Viewer window.
- Scroll through the image stack and identify the image pair where the star fields rotate 180°. In the example below, the immediate pre- and post-flip filenames end with '..._W.FIT' and '..._E.FIT' respectively.



Compute meridian flip JD time

- Open photometry measurements file C:\Astro\Datasets\WASP104.V.2020_02_27\Measurements.txt (or Measurements.tbl) in Excel or other spreadsheet; import data with <tab> delimiter.
- Referring to the figure below, search the Label column to find the last pre-flip image filename (.._883.FIT) and note this row and the next row fractional BJD_TDB values, 0.5304 and 0.5330 respectively in this example.

153	\cdot : \times \checkmark f_x 1.159286		~
	А	Н	
1	Label	BJD_TDB	
48	GSC_260608_LIGHT_V_60s_BIN215C_047_20200228_013230_607_W_bdf.FIT	2458907.5295	1.
49	GSC_260608_LIGHT_V_60s_BIN215C_048_20200228_013342_883_W_bdf.FIT	2458907.5304	1.
50	GSC_260608_LIGHT_V_60s_BIN215C_049_20200228_013733_367_E_bdf.FIT	2458907.5330	1.
51	GSC_260608_LIGHT_V_60s_BIN215C_050_20200228_013848_099_E_bdf.FIT	2458907.5339	1. 🔻
	Measurements +	1	•
Rea	dy 🔚 😋 Accessibility: Unavailable 🛛 🗖 Display Settings 🗮 🗉 🖳 —	+ 1	00%

3. Taking the average of these BJD_TDB values, rounded to 3 places, the fractional meridian flip time is **0.532** (= (0.5304 * 0.5330) / 2).

Note: when prompted in the Guide, enter this value in Multi-plot Main | Meridian Flip | Flip Time field.

APPENDIX B: BAA WASP104 Dataset Files

Example files for WASP104

File	Notes
BAA.DATASET.WASP104.TXT	Data for BAA 'Campaign Target' object. J2000 coordinates, mag data, NASA EXOPLANET & EXOFAST transit fit data
BAA.AIJ_Prefs.txt	Standard BAA photometry settings; user updates observatory and camera data
WASP104.V.018.radec.txt	AlJ radec format aperture file, V-mag, 18 arcmin FOV
BAA.transit_amass_flip.plotcfg	Multi-plot configuration file with airmass & meridian flip detrend

Fit Settings Window – user inputs for V-mag filter

NASA EXOPLANET: <u>https://exoplanetarchive.ipac.caltech.edu/</u>

- 1. Search on WASP104 in the NASA EXOPLANET Home Page
- 2. Read the following Planetary and Stellar Parameters

-	WASP-104 b	P(days)	1.755
-	WASP104	R∗(R⊙)	0.965
-	WASP104	T _{eff} (K)	5306
-	WASP104	Metallicity (dex)	0.320
-	WASP104	log g (log10(cm/s2))	4.43

Source	TICv8	Gaia DR2	Bonomo et al. 2017 🔷 🗞
7_{eff} (К)	5306.0000 ^{+164.1340} -97.2841	5123.500 +216.367 -123.067	5450±130
Metallicity (dex)			0.320±0.090
γ (km/s)			
∨sin i (km/s)			0.40±0.70
Age (Gyr)			3.0±2.0
ρ ★ (g/cm ³)	1.4266737 ^{+0.4007445} -0.2671875		
<i>M</i> ★ (M _☉)	0.9100000 +0.1080450 -0.1116850		1.076±0.049
R ★ (R _☉)	0.96522200 +0.06423370 -0.04865080	1.0202371 ^{+0.0508368} -0.0810033	0.963±0.027
log <i>g</i> (log ₁₀ (cm/s ²))	4.4278500 +0.0656373 -0.1013030		
Sp. T			
L_{\bigstar} (log ₁₀ (L _{\odot}))	$-0.1769817 \begin{array}{c} ^{+0.0109338} \\ _{-0.0178067} \end{array}$	-0.1896361 ^{+0.0049116} -0.0049678	

EXOFAST: https://astroutils.astronomy.osu.edu/exofast/limbdark.shtml

- Open EXOFAST page. Note that WASP104 is not listed in Select Planet drop down
- 2. Select or enter:
 - BAND
 - Teff 5306
 - [Fe/H] 0.320
 - Log g 4.43

EXOFAST - Quadratic Limb Darkening This applet interpolates the Claret & Bloeman (2011) quadradic limb darkening tables. Selecting a planet will attempt to retrieve the Teff, [Fe/H], and log(g) from exoplanets.org. Our database is synced to theirs daily; check the bottom of this page for the most recent update. If you use this code for your research, please cite our paper (Eastman et al, 2013). Select Planet v V v Teff [Fe/H] 5306 0.320

Submit Query -- User inputs are NOT logged

V

3. Click [Submit Query] to compute Quadratic Limb Darkening coefficients:

0.60185147	0.16401032

u1 = 0.601 u2 = 0.164