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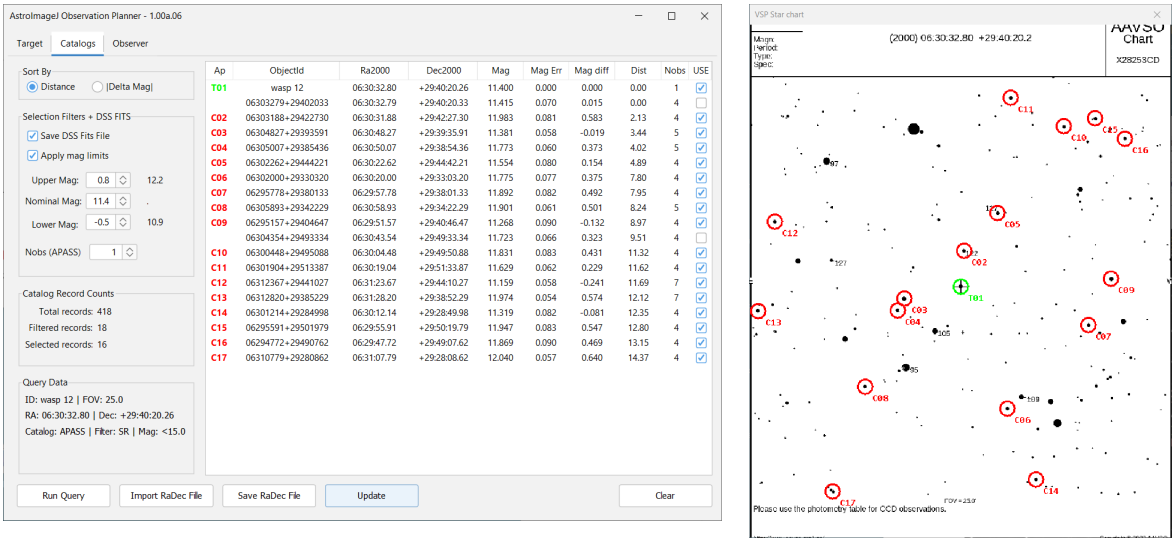
Workflow based Guide to using Observation Planner for AstroImageJ



Selected WASP12 APASS records
Observation Planner | Catalogs Tab.

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07 November 2022

Contents

1. Introduction

Observation Planner is a Java plugin for AstroImageJ (AIJ) which runs from the AIJ toolbar. The main function is to download and select comparison star data from an on-line star catalog. Planner converts selected data into radec file format to import aperture coordinates into AIJ. Candidate comparison stars can be filtered based on magnitude and the software plots apertures on a VSP chart for visual inspection. The user interface comprises three tabs for observer, target and catalogs functions, described in the context of a AstroImageJ-based photometry workflow sequence.

Overview

Section 2 steps through the workflow for a given target star, from observation night planning through to AIJ transit analysis.

Section 3 covers observation planning. The section walks through running the Observation Planner plugin to generate a radec file to import aperture coordinates into AIJ.

Section 4 covers image reduction in AIJ. The user configures the CCD Data Processor window to import WASP12 raw science and calibration fits files, then runs the image reduction process. Fits image files can be plate solved using ANSVR or ASTAP software.

Section 5 covers photometry analysis in AIJ. The user imports the image set and, based on visual inspection, may remove poor quality images from the processing stack. This section is largely based on Section 4 in ref [1].

Section 6 covers AstroImageJ Multi-plot (MP) windows configured to plot transit and other data sets. The three plot configuration windows are complex and Dennis Conti's Guide (ref [2]) was invaluable in preparing this section.

Section 7 briefly covers modelling transit data in AIJ to compute transit timing and depth parameters. This section also leans rather heavily on ref [2].

Section 8 provides a brief summary and describes some enhancements in AIJ v5. Finally, a short list of potential features for Observation Planner is considered.

Best Practice: Closing AstroImageJ toolbar after parameter changes

On closing, AIJ saves current configuration data to AIJ_Prefs.txt file. On my PC the path to this file is C:\Users\rlee1\.astroimagej\AIJ_Prefs.txt.

To ensure any changed settings are saved:

- Close any open windows, DP Coordinate Converter, CCD DP Data Processor, etc
- Close the AIJ toolbar through either Toolbar | File | Quit or Toolbar | Close icon
- Re-open AIJ and confirm the new settings have been retained.

APPENDIX A - Download and install software

Refer to APPENDIX A to download, install and configure software.

Software Licence

Planner.jar and astro_plugins-x.jar are open-source software licensed under GPL-3.0

References:

Ref	Title	Link
[1]	A Guide to AstroImageJ Differential Photometry, Richard Lee	BAA Guides
[2]	A Practical Guide to Exoplanet Observing, Dennis Conti	AIJ Home
[3]	AstroImageJ: Image Processing and Photometric Extraction for Ultra-Precise Astronomical Light Curves (Expanded Edition), Karen Collins, et al	AIJ Home
[4]	AstroImageJ 2.4.1 User Guide	AIJ Home
[5]	BAA Photometry Spreadsheet (version 2.10)	BAA Spreadsheet

On-line Resources

Title	Link
AAVSO Variable Star Plotter	VSP
AAVSO Photometric All Sky Survey	APASS Home
SIMBAD Astronomical Database - CDS (Strasbourg)	SIMBAD
Digitized Sky Survey	DSS Wiki
NASA Exoplanet Archive	NASA Exo
EXOFAST - Quadratic Limb Darkening	EXOFAST

2. Workflow Sequence

This section outlines an AstroImageJ-based photometry sequence to process WASP12 example fits files. These images were captured with a red filter at the University of Louisville's MORC24 observatory. Where practical, the workflow excludes one-off items such as downloading and installing software.

Workflow output is a best fit transit model to a normalised and detrended photometry data set.

Refer to Appendix A for (most of) the one-off software configuration steps.

Section	Process	Software
3	**Observation Planning**	
	Configure observer location for WASP12 example images	AIJ | DP CC
	Specify ObjectID and observation parameters Plot overnight target altitude	Planner
	Run on-line query of VSP or APASS catalog for selected filter band Save filtered and selected table rows to radec file	Planner
	Option to download a DSS fits image of specified region	Planner
	View DSS image with aperture overlay; review aperture selection	AIJ | Image Viewer
4	**Science Image Reduction**	
	DP Coordinate Converter for WASP12	AIJ | DP CC
	Option: Plate solve raw images [1]	ANSVR / ASTAP
	Compile master calibration files Reduce science files	AIJ | CCD DP
5	**AstroImageJ Photometry [2]**	
	Import image stack	AIJ | toolbar
	Visual check of image quality	AIJ | Image Viewer
	Set measurement aperture radii Import radec apertures	AIJ | Image Viewer
	Run AIJ Photometry Save measurements.tbl results file	AIJ | CCD DP
6	**AstroImageJ Multi-Plot [3]**	
	Import measurements.tbl into Multi-Plot Main	AIJ | MP Main
	Configure Multi-plot Main window [3]	AIJ | MP Main
	Configure Multi-plot Y-data window [3]	AIJ | MP Y-data
	Configure Data Fit Settings window	AIJ | Fit Settings
	View plot of measurements	AIJ | PM
7	**Transit Analysis**	AIJ | Fit Settings
	Download and input user specified parameters	NASA Exoplanet Archive
	Download and input limb darkening fit parameters	EXOFAST
	Extract model-based transit depth and timing results	

AIJ AstroImageJ

DP CC	DP Coordinate Converter window
CCD DP	CCD Data Processor window
MA	Multi-Aperture Measurements window
MP xxx	Multi-plot xxx window
PM	Plot of Measurements

[1] Optional step, the WASP!2 fits files are plate solved.

[2[Configuring Multi-Aperture Measurements window will be moved to Appendix A in a later edition.

[3] Multi-Plot configurations are saved in plotcfg files

3. Observation Planning

This section covers configuring observer details in AIJ, running on-line database queries, and creating radec file with aperture coordinates to import into AIJ. To demonstrate, the final sub-section describes how to overlay apertures onto a DSS image.

Refer Appendix A to download and install software:

- AstroImageJ version 5 or later
- Planner.jar and astro_plugins-1.0a.jar, GitHub repository
- Option: plate solving software, ANSVR or ASTAP (GitHub)
- WASP12 example fits files

Refer to Appendix B for one-time configuration of AIJ settings.

3.1. Setup Observer Location

3.1.1. Configure observatory location in AstroImageJ

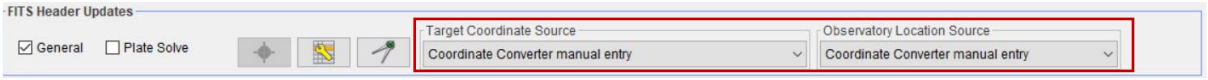
AIJ determines the Observatory Location either from manual entry in the DP Coordinate Converter dialog or by extracting from FITS header. Setup manual location as follows:

1. Open AIJ and from the toolbar click on the CCD Data Processor Tool  (third icon from right). Two windows open:

   The larger CCD Data Processor is the 'control centre' for AIJ image processing..

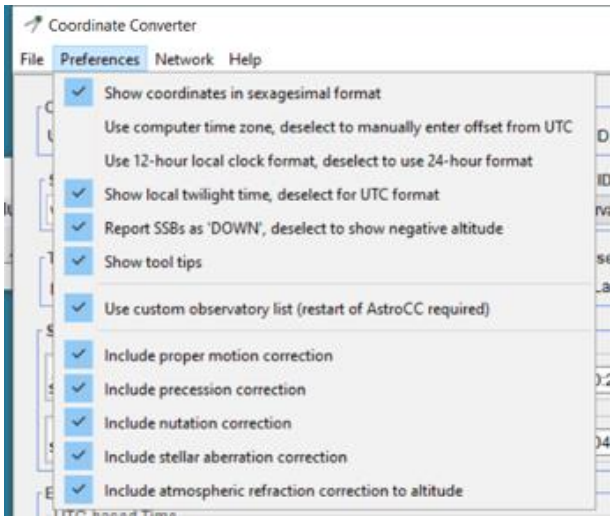
   The DP Coordinate Converter (DPCC) contains Observatory and Object ID fields.

2. In the CCD Processor | FITS Header section, set both drop-down controls to: 'Coordinate Converter manual entry'

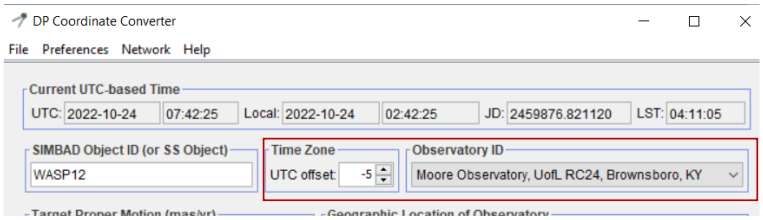


   The caliper icon  in this figure toggles visibility of the DP Coordinate Converter window.

3. In the DPCC window, click on 'Preferences' menu header then check / uncheck the Preference settings as below.



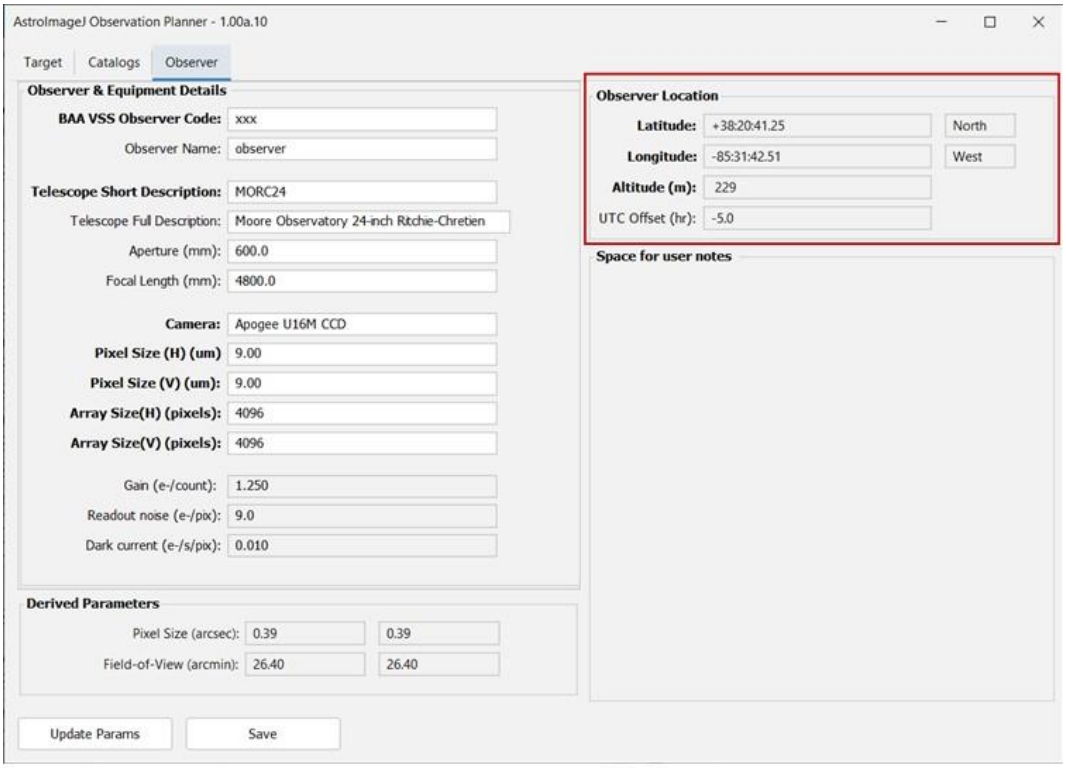
4. To register changes, close and re-open the AIJ toolbar, click  to open the DPCC window and confirm Preferences menu settings are as shown above
5. In the DPCC window, select Moore Observatory, UofL, RC24 from the drop down, (note two Moore Observatory entries are listed).
6. Set the UTC offset to -5 (EST, Eastern Standard Time). Close and reopen the CC dialog to register changes and leave the dialog open for the next section.



3.1.2. Configure observatory location in Observation Planner

The Observer Location data is imported from AIJ. Observer and Equipment Details section contains manual entry data fields. The Observer tab is usually a one-time setup.

1. From AIJ toolbar, select Plugins => Astro Apps => Run Planner App to open the AstroImageJ Observation Planner dialog then click on 'Observer' tab.



Observer Location

Observer Location details are imported from AIJ; confirm by cross-checking with DPCC dialog then close the DPCC dialog.

Observer and Equipment Details

This section Is largely based on the BAA spreadsheet (Ref [5]). Bold highlighted labels are required fields for submitting results to the BAA database. The default values are selected to process the WASP12 example images.

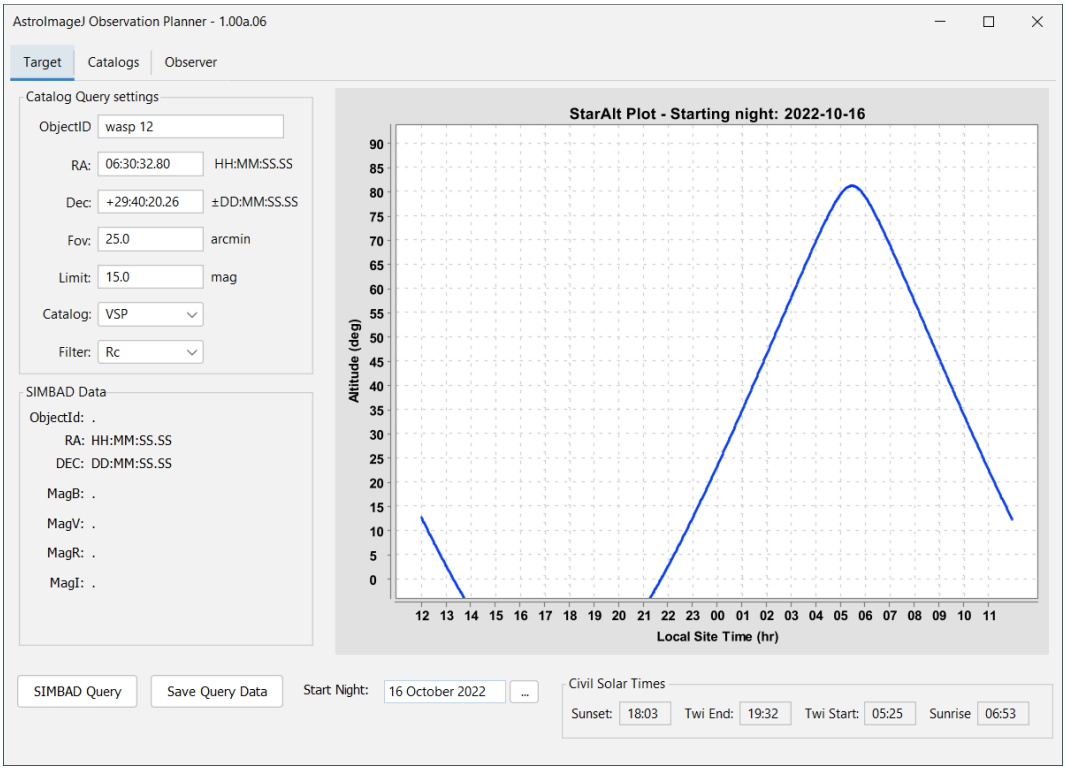
Dark current and Readout noise data is imported from AIJ Aperture Photometry Settings.

Derived Parameters

Pixel size (“/pixel) and field-of-view (arcmin) computed from telescope and camera parameters.

3.2. Specify Target in Observation Planner

In the Planner dialog, click the Target tab configured on first use for WASP12 example images.



Catalog Query settings

Target object parameters to run a query on an on-line database, VSP (Variable Star Plotter) in this figure. Tooltips provide a short description and acceptable data range for each field.

SIMBAD Data

Lists results of ObjectId-based query on the SIMBAD database.

StarAlt Plot

Object altitude plot over 24 hr at observer’s location, runs from Start Night noon to next day noon.

Civil Solar Times

Local times for Sunset and Sunrise, plus Twilight for current Start Night; default Start Night is today’s date (16 October 2022 in this figure).

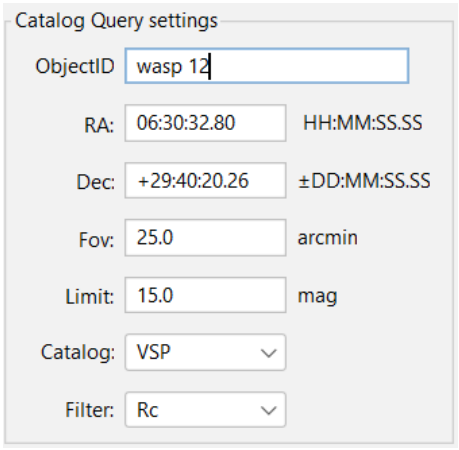
Controls

Button controls run and save results of SIMBAD queries; click ... to change the Start Night.

The StarAlt plot shows the maximum altitude of WASP12 target is about 6 am local time on 16 October 2022, with UTC offset = -5 hr. Maximum altitude advances by 2 hr / month (= 24 hr / 12 month), so in January, WASP12 should reach maximum altitude around midnight at Moore Observatory.

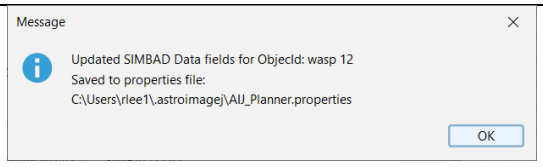
3.2.1. Setup WASP12 Parameters

1. Enter Catalog Query settings fields as below:



   RA and Dec coordinates values automatically update after a SIMBAD query (*but see Alert below*). The FOV is slightly smaller than the derived value in Observer tab. The VSP catalog is the AAVSO Variable Star Plotter database and the WASP12 images were exposed with a red filter.

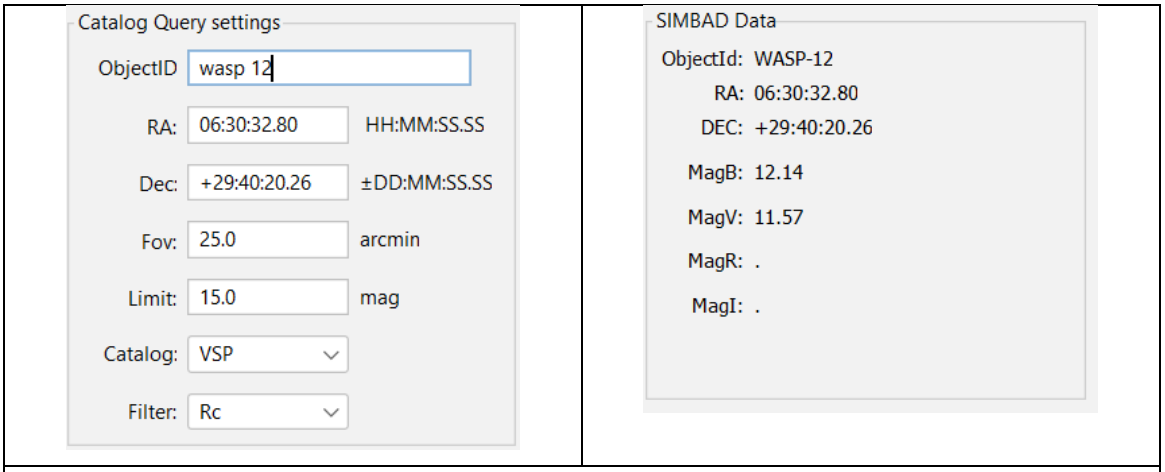
2. Click [SIMBAD Query] to run a name-based query on the SIMBAD database. After a short delay, a message dialog opens confirming updates to SIMBAD Data fields. The second dialog is for a failed query based on ObjectID = wasp 12x (i.e., wasp12x was not found).



Message dialogs for successful and unsuccessful SIMBAD queries
ObjectID = wasp 12 and wasp 12x respectively

3. Close the message dialog, the Catalog Query settings and SIMBAD Data section should be updated with SIMBAD results.

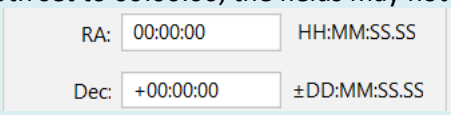
   Note: MagV = 11.57, implies probable value for MagR ≈11.5.



Catalog Query and SIMBAD Data after a succesful WASP12 SIMBAD database query

4. Click [Save Query Data] to save settings to properties file and close the message dialog.

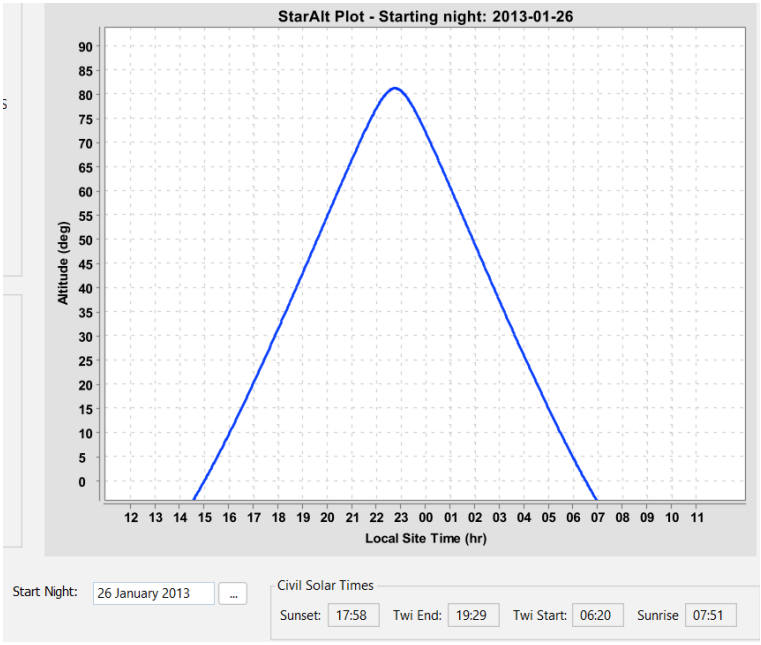
Intermittent bug alert:
When RA and Dec fields are both set to 00:00:00, the fields may not update after a SMBAD query.



This is an intermittent bug. Please try entering non-zero values in both fields (e.g., 01:00:00) and repeat the SIMBAD query

3.2.2. Start Night

1. In the Planner | Target tab, click the ellipsis control ... to open the calendar and set Start Night to 26 January 2013. Note: clicking 'Clear' resets to the date today.

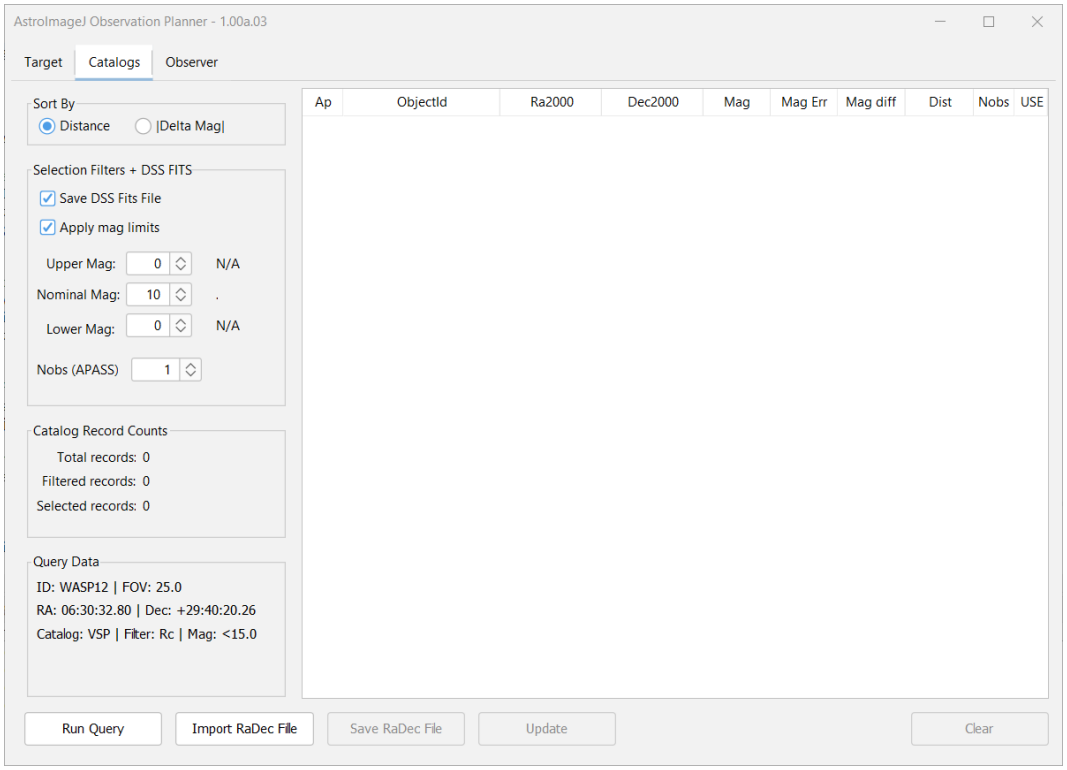


Wasp12 | Start Night: 2013-01-26

Observed from the Moore Observatory, WASP12 reaches maximum altitude at about 23:00, local time.

3.3. Run On-Line Database Query

Click the Catalogs tab to open the catalogs interface with an empty data table:



Sort By

Options to sort table data in order of increasing:

- radial distance (in arcmin) from target object position. or
- increasing absolute difference (Δ) between comparison magnitude (m) and nominal target magnitude (m_0) $\Delta = |m-m_0|$.

Selection Filters + DSS Fits

Option to download a DSS fits file for specified coordinates and field-of-view (default = checked)

Option to apply mag limits to filter table data (default = checked).

Spin controls to set upper and lower mag bands to filter table data. 'N/A' implies limit is disabled.

Nobs (APASS) filters table data by minimum number of observations, applicable to APASS catalog only.

Catalog Record Counts

Displays total number downloaded records plus counts for filtered and user-selected records.

Query Data

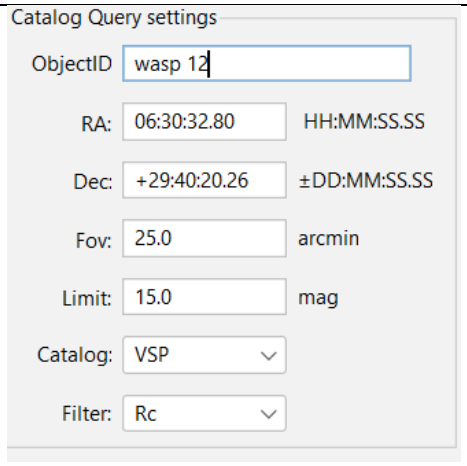
Summary of last saved Target | Catalog Query Settings data. This data is used to compile a query on selected catalog.

Data Table

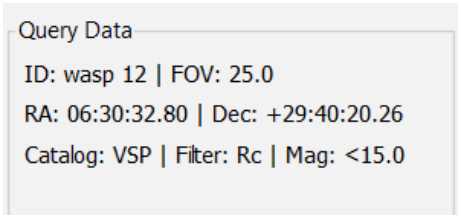
Tabulates target and filtered comparison star data, currently empty.

3.3.1. Run WASP12 | VSP Database Query

1. Confirm Query Data values are as below, with Catalog: VSP and Filter: Rc. Also check that 'Save DSS Fits File' option is checked.



VSP Query settings in Target Tab

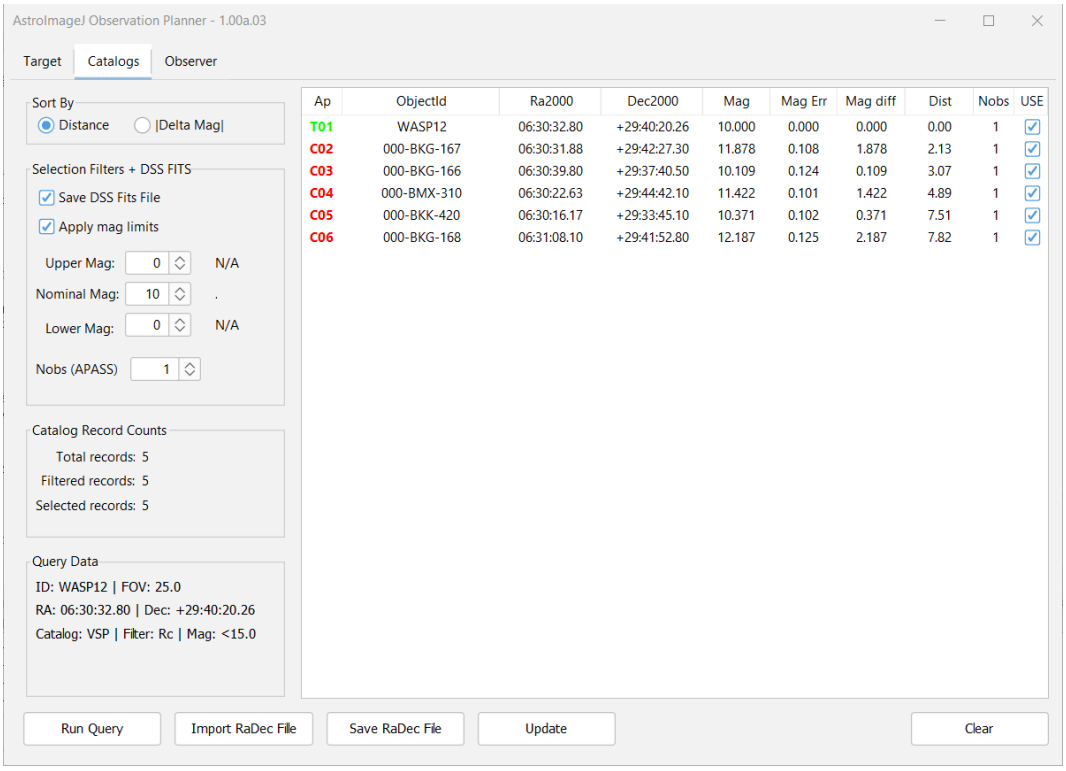


VSP Query settings in Catalogs Tab

If necessary, switch back to the Target tab and edit Catalog Query settings to these values. Click [Save Query Data] and return to Catalogs page.

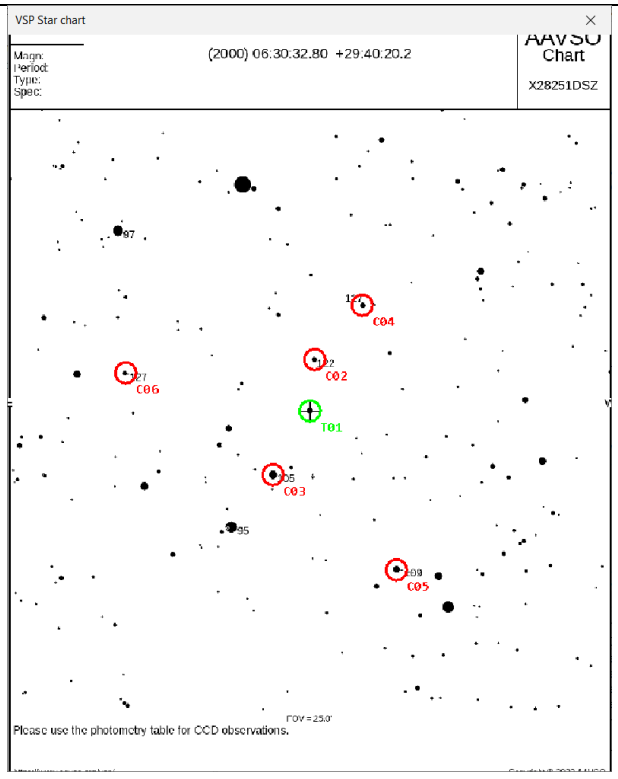
2. Click [Run Query] to run a query on the VSP and DSS databases – note that the queries can take a few seconds. Close the confirmation dialog(s).

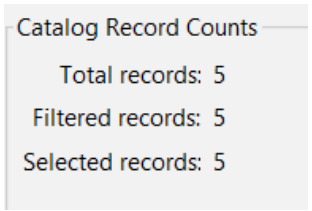
3. The data table is populated with 5 comparison star records and a chart opens displaying apertures centred on database stars.



Header	T01	Cnn
Ap	Green T01 aperture identifies the target object	Red Cnn apertures identify the database comparison star objects
ObjectId	User name for target object	Database object names
Ra2000, Dec2000	Target J2000 coordinates, image centre	Database J2000 coordinates
Mag	Target Nominal Mag	Database mag for selected filter or magnitude band
Mag Err	N/A	Database mag error for selected mag band
Dist	N/A	Radial distance to target coordinates in arcmin
Nobs	N/A	Number of observations (APASS catalog)
USE	Checked	Default state is checked; user unchecks to de-select table row

The next Figure shows the AAVSO chart centred on target, extent defined by the Catalog Query FOV. The over-lay set of apertures correspond to table coordinates.





VSP catalog: Record counts = 5 | 5 |5

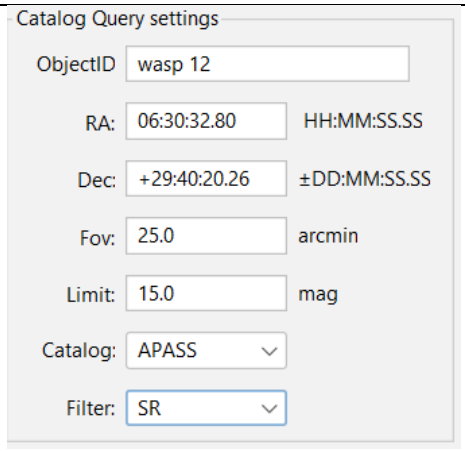
3.3.2. Run WASP12 | APASS Database Query

Run APASS query with no applied filters

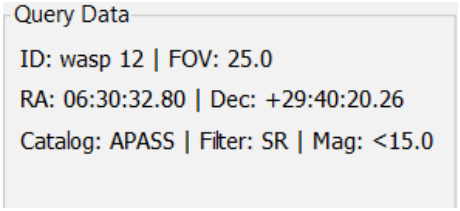
1. Click [Clear] to clear the data table and close the chart.

2. Click the Target tab, from the Catalog Query settings drop-downs, first select the APASS catalog then select SR filter. Click [Save Query Data] to save selections and close confirmation message dialog.

   The Catalogs tab query data should match the Catalog Query settings user inputs as below.

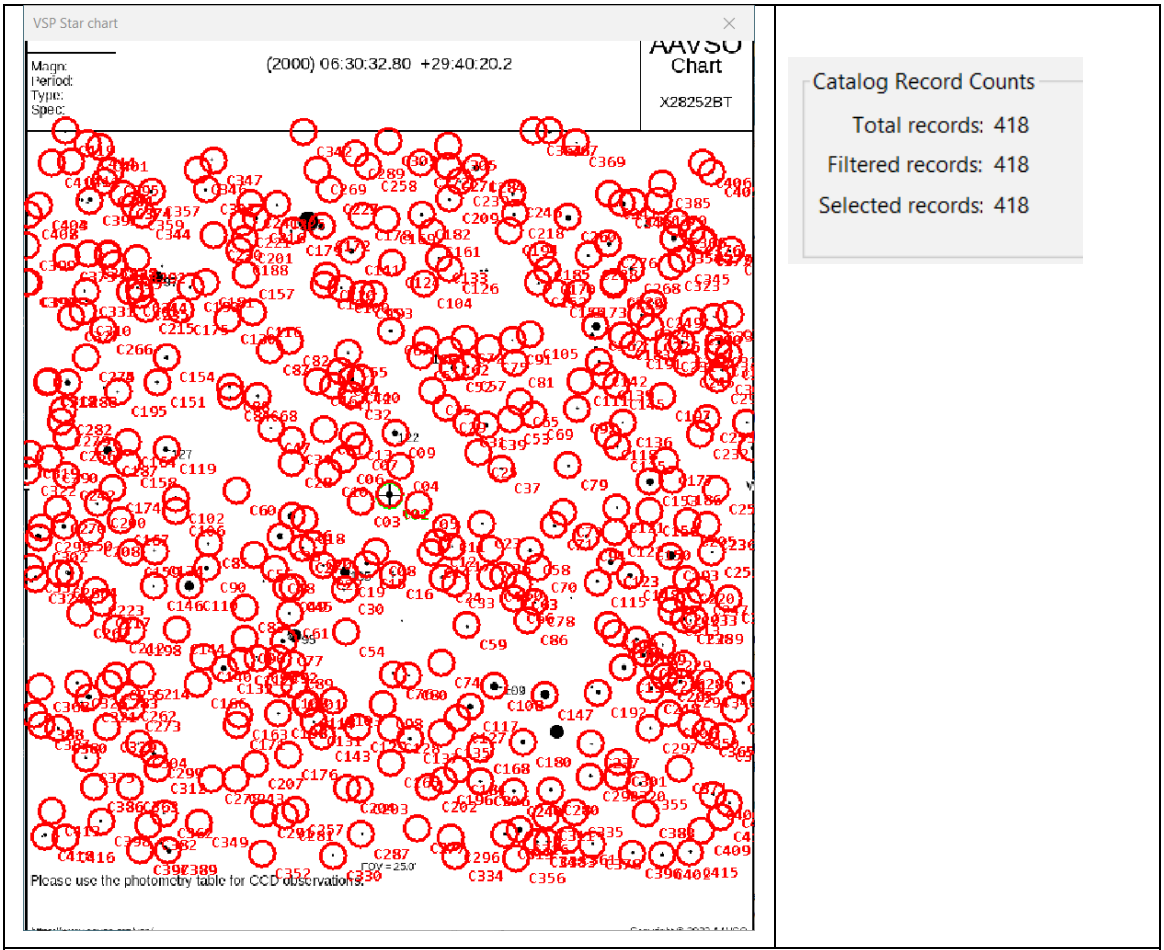


APASS Query settings in Target Tab



APASS Query settings in Catalogs Tab

3. In the Catalogs tab, click [Run Query] to run a query on the APASS database. The query returns more than 400 records matching the Catalog Query settings.



Total records = 418, no filters applied

Note: APASS records do not include an object identifier. The Planner app generates a unique identifier based on Ra and Dec coordinates, with name format HHMMSSSS±DDMMSSSS.

Formatting example for Ap C02:

Ap	ObjectId	Ra2000	Dec2000
T01	WASP12	06:30:32.80	+29:40:20.26
C02	06303279+29402033	06:30:32.79	+29:40:20.33

Apply magnitude filter to WASP12 records

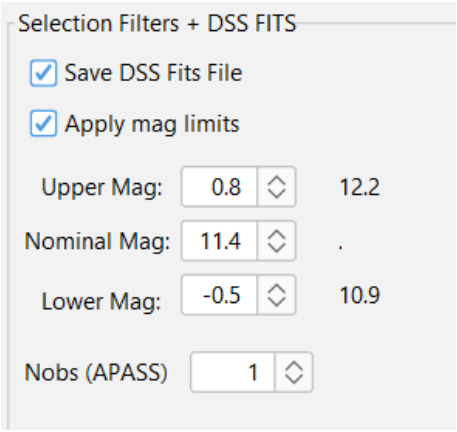
1. Select Sort By: Distance; the table automatically sorts in order of increasing distance from target coordinates.

Ap	ObjectId	Ra2000	Dec2000	Mag	Mag Err	Mag diff	Dist	Nobs	USE
T01	WASP12	06:30:32.80	+29:40:20.26	10.000	0.000	0.000	0.00	1	☑
C02	06303279+29402033	06:30:32.79	+29:40:20.33	11.415	0.070	1.415	0.00	4	☑

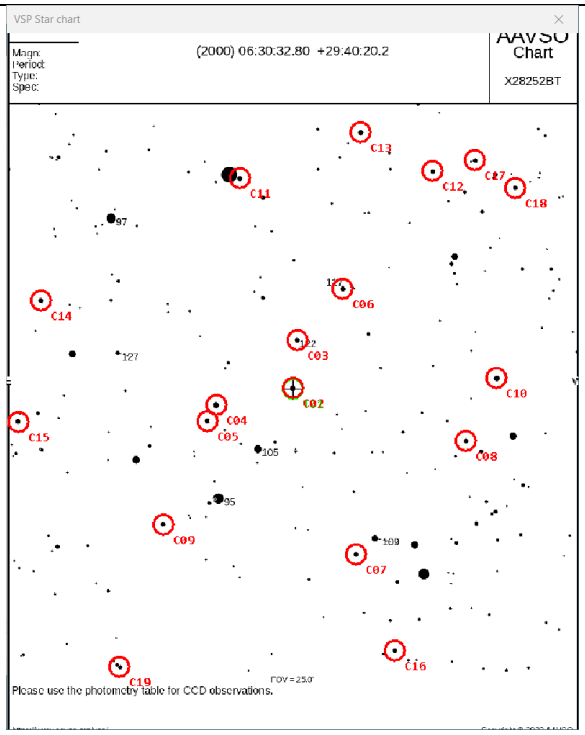
Duplicate Table Records

Note that aperture C02 (id = 06303279+29402033), the Dist field is 0.00, indicating T01 and C02 are duplicate records. Taking the catalog mag value (11.415) for this row should be a good estimate for the Nominal Mag field.

2. Enter Nominal Mag = 11.4 (roughly equal to C02 catalog mag in the previous figure).
3. Type or use spin controls to set mag limits: Upper Mag = 0.8 and Lower Mag = -0.5. The 'N/A' labels change to display upper and lower magnitude limits. Note: these settings are loosely based on recommendations in section 6.4.2 in Ref [2].



4. Click [Update], the Filtered records count drops from 418 to 18.



Catalog Record Counts

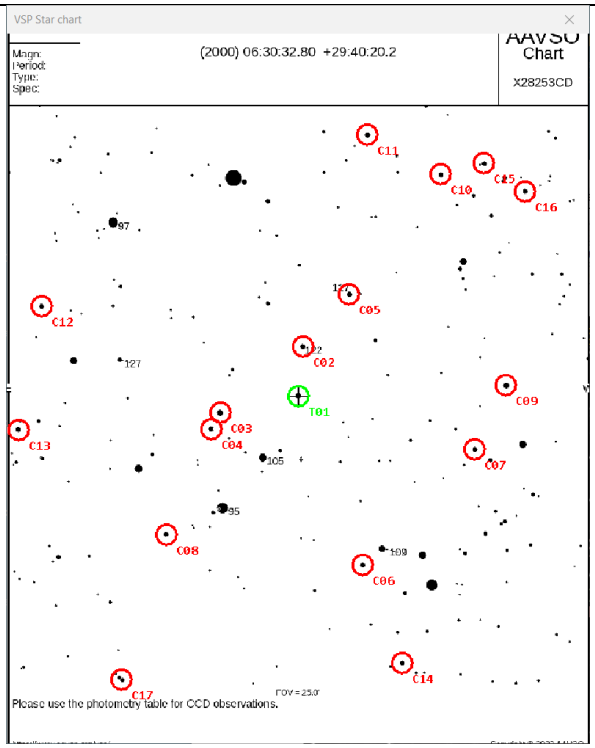
Total records: 418

Filtered records: 18

Selected records: 18

Mag filter applied: Record counts = 418 | 18 |18

5. De-select rows C11 (proximity to bright neighbour) then de-select C02 (duplicate target star). Click [Update] to update counts and chart; the Selected records count drops from 18 to 16. Note that the Ap column updates automatically when a USE cell is selected or de-selected



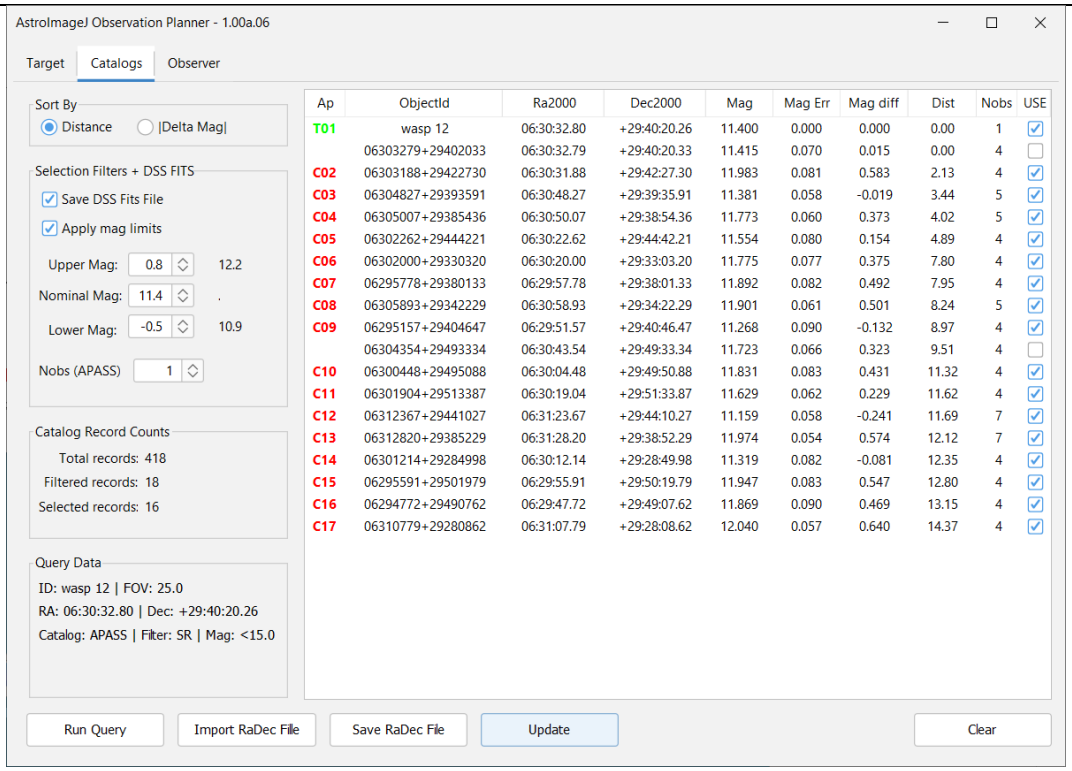
Catalog Record Counts

Total records: 418

Filtered records: 18

Selected records: 16

Mag filter plus 2 de-selected rows: Record counts = 418 | 18 |16



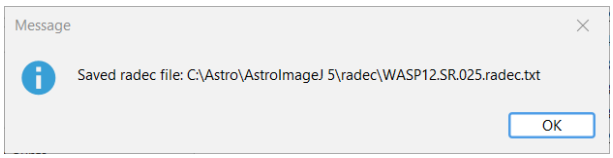
Ap	ObjectId	Ra2000	Dec2000	Mag	Mag Err	Mag diff	Dist	Nobs	USE
T01	wasp 12	06:30:32.80	+29:40:20.26	11.400	0.000	0.000	0.00	1	☑
	06303279+29402033	06:30:32.79	+29:40:20.33	11.415	0.070	0.015	0.00	4	☐
C02	06303188+29422730	06:30:31.88	+29:42:27.30	11.983	0.081	0.583	2.13	4	☑
C03	06304827+29393591	06:30:48.27	+29:39:35.91	11.381	0.058	-0.019	3.44	5	☑
C04	06305007+29385436	06:30:50.07	+29:38:54.36	11.773	0.060	0.373	4.02	5	☑
C05	06302262+29444221	06:30:22.62	+29:44:42.21	11.554	0.080	0.154	4.89	4	☑
C06	06302000+29330320	06:30:20.00	+29:33:03.20	11.775	0.077	0.375	7.80	4	☑
C07	06295778+29380133	06:29:57.78	+29:38:01.33	11.892	0.082	0.492	7.95	4	☑
C08	06305893+29342229	06:30:58.93	+29:34:22.29	11.901	0.061	0.501	8.24	5	☑
C09	06295157+29404647	06:29:51.57	+29:40:46.47	11.268	0.090	-0.132	8.97	4	☑
	06304354+29493334	06:30:43.54	+29:49:33.34	11.723	0.066	0.323	9.51	4	☐
C10	06300448+29495088	06:30:04.48	+29:49:50.88	11.831	0.083	0.431	11.32	4	☑
C11	06301904+29513387	06:30:19.04	+29:51:33.87	11.629	0.062	0.229	11.62	4	☑
C12	06312367+29441027	06:31:23.67	+29:44:10.27	11.159	0.058	-0.241	11.69	7	☑
C13	06312820+29385229	06:31:28.20	+29:38:52.29	11.974	0.054	0.574	12.12	7	☑
C14	06301214+29284998	06:30:12.14	+29:28:49.98	11.319	0.082	-0.081	12.35	4	☑
C15	06295591+29501979	06:29:55.91	+29:50:19.79	11.947	0.083	0.547	12.80	4	☑
C16	06294772+29490762	06:29:47.72	+29:49:07.62	11.869	0.090	0.469	13.15	4	☑
C17	06310779+29280862	06:31:07.79	+29:28:08.62	12.040	0.057	0.640	14.37	4	☑

Filtered WASP12 APASS records in Catalogs tab: 418 | 18 |16

The Ap cell is blanked when the USE column is unchecked

Save Radec File

Click [Save RaDecFile] to save current data table to AIJ compatible radec text file. A dialog opens confirming WASP12.SR.025.radec.txt is saved in radec sub folder. Note that saving a radec file over-writes an existing file without warning.



Import Radec File

1. Close message dialog and click [Clear] to clear the data table.
2. Click [Import Radec File] to open 'Select radec file' dialog.
3. Open WASP12.SR.025.radec.txt to populate the data table with the filtered and selected data set. The data table should be the same as previous table figure except record counts are now 18 | 18 |16.

File Paths

Paths to radec and dss files, based on AIJ installed in folder AstroImageJ 5. The software automatically creates radec and dss folders as needed.

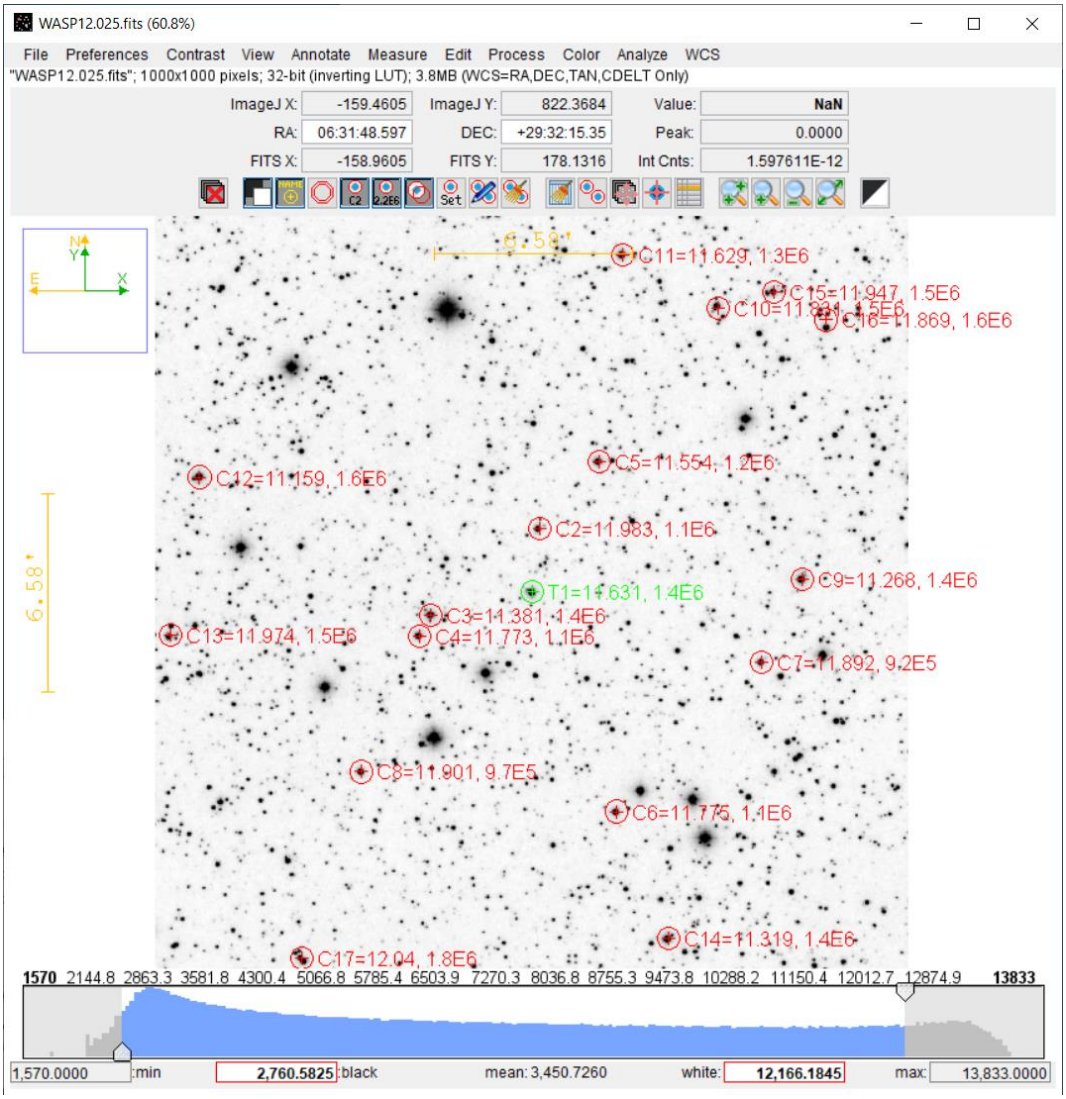
Path to radec txt file	.\AstroImageJ 5\radec\WASP12.SR.025.radec.txt
Path to dss fits file	.\AstroImageJ 5\dss\WASP12.025.fits

3.4. Overlay DSS Image with radec Apertures

1. From the AIJ toolbar, select File | Open, then navigate to and open dss fits file WASP12.025.fits' (path as above). The dss image opens in a new AIJ Image Viewer window.
2. In the Image Viewer, select menu item File | 'Import apertures from RA/Dec list...' to open the Import apertures dialog. Navigate to and open 'WASP12.SR.025.radec.txt' to import the aperture set created in section 3.3.2 (16 apertures)
3. If necessary, click 'zoom to fit image to window' icon in the viewer toolbar to centre image.

   Note 1: To display negative image as below, click 'display as image negative' icon in the Viewer toolbar. Click again to revert to normal image display.

   Note 2: The WASP12 DSS image is crowded with faint, high mag stars. The WASP12 example images are much 'cleaner', so we defer further aperture selection / de-selection until section 4.



4. AstroImageJ Image Reduction

Refer to Appendix A for instructions to download the WASP12 example files. The raw science files are already plate solved.

Copy raw science files to: C:\Astro\AstroImageJ 5\WASP12.SR.2013_01_26\Raw Science Files

Copy calibration files to: C:\Astro\AstroImageJ 5\WASP12.SR.2013_01_26\Calibration Files

The root folder for the WASP12 unzipped image set is WASP12.SR.2013_01_26, based on imaging with a red filter and observation starting on 26th January 2013.

The bias, darks and flats calibration files are copied into a single folder (Calibration Files). An alternative is to copy bias, darks and flat fits files into individual sub-folders:

.\WASP12.SR.2013_01_26\Calibration Files\Bias*bias*.fits

.\WASP12.SR.2013_01_26\Calibration Files\Darks*darks*.fits

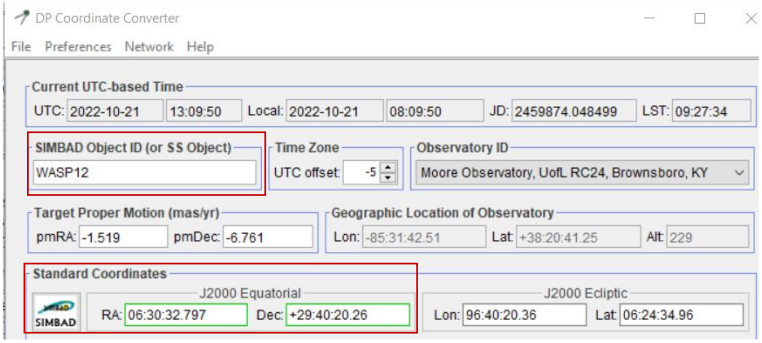
.\WASP12.SR.2013_01_26\Calibration Files\Flats*flats_r*.fits

In section 4.3, change the relative paths to Bias, Dark and Flat sections in CCD Data Processor window accordingly.

4.1. DP Coordinate Converter Target Data

Note that the Target and Observation Sources should be set to 'Coordinate Convert manual entry'.

1. From the AIJ toolbar, click  to open the CC Data Processor and DP Coordinate Converter (DPCC) windows.
2. Enter WASP12 in the DPCC | SIMBAD Object ID text field and press [Enter] to run a SIMBAD query. The dialog should update with WASP12 J2000 coordinates.



4.2. Plate Solve Options

Optional section: The WASP12 example fits files are already plate solved and this section can be skipped in a first reading.

If not already installed, refer to Appendix A for instructions to download ANSVR or ASTAP plate solving software.

4.2.1. ANSVR

ANSVR is fully integrated into AIJ with Plate Solver option in CC Data Processor | FITS Header Updates.

Select Plate Solve checkbox to run ANSVR solver when processing fits files in CCD Data Processor.

Click  icon to open DP Astrometry Settings window. Constrain Sky Local option should be checked; the Center RA and Dec fields should already be populated with WASP12 coordinates.

4.2.2. ASTAP

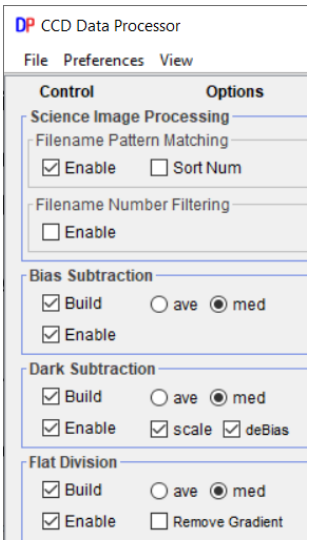
ASTAP is a popular alternative to ANSVR, with faster solve times and potentially smaller disk footprint for small FOV images. I have developed a Java plugin to run ASTAP from the AIJ toolbar – refer link in Appendix A for user instructions and example tutorial.

4.3. Set up CCD Data Processor Window

Image reduction in AIJ consists of building master calibration files then running the science image reduction process. Master file and image reduction can be done in a single sequence. Note that the following screenshots are based on bias, darks and flats fits files being stored in a single calibration folder.

4.3.1. Master Calibration Build Settings

Select Enable, Build med (median) options as shown in the next figure. Select scale and deBias in the Dark Subtraction section to enable exposure time scaling.



4.3.2. Set up Directories and File Wildcards

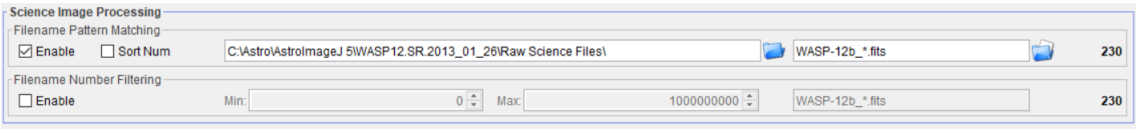
Science Image Processing section

Click the left folder icon  to open a dialog titled 'Select primary directory containing science files'. Navigate to and select the Raw Science Files folder:

C:\Astro\AstroImageJ 5\WASP12.SR.2013_01_26\Raw Science Files.

1. Click the right folder icon  to open 'Select a file' dialog. Select and open the first file in the list (e.g., wasp-12b_00040.fits). The Filename/Pattern field 'WASP-12b_*.fits' is a wild-card filename matching 230 files the Raw Science Files folder.

Note: simple filename pattern '*.FITS' works for any folder containing a single fits file type. In this case the Raw Science File folder contains WASP12 image files only.



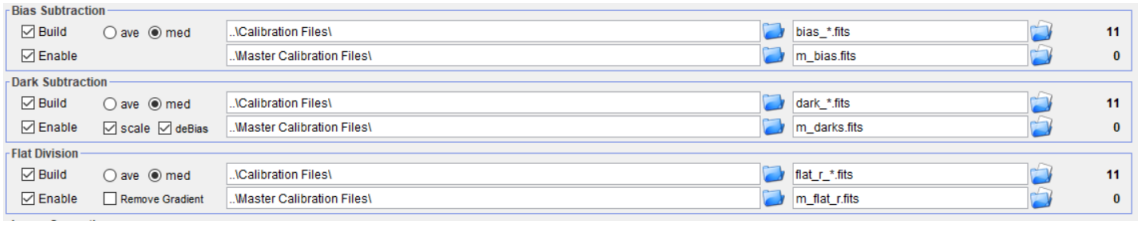
Calibration Processing sections

Set up Bias, Dark and Flat sections as below. The Directory entries are identical and a one-time setting, assuming no changes in the Calibration folder structure.

Unprocessed calibration fits files: ..\Calibration Files\
Processed master fits files: ..\Master Calibration Files\

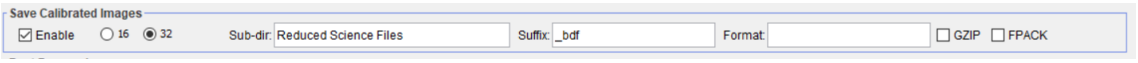
2. Filename/Pattern wildcards are generated by clicking on the right-hand folder icon and selecting a file appropriate to that section; example files are bias_00106.fits, dark_00150.fits or flat_r_00002.fits. Note that AIJ has detected 11 of each fits file type in the common Calibration Files folder.

3. Enter master filenames m_bias.fits, m_darks.fits and m_flat_r.fits in the respective fields.



4.3.3. Save Calibrated (Reduced) Images

In the Save Calibrated Images section, enter Sub-dir: 'Reduced Science Files' and Suffix: '_bdf'.



Processed FITS filenames are appended '_bdf' and saved to a sub-folder in Raw Science Files:
.\Raw Science Files\Reduced Science Files.

4.4. Run Science Image Reduction

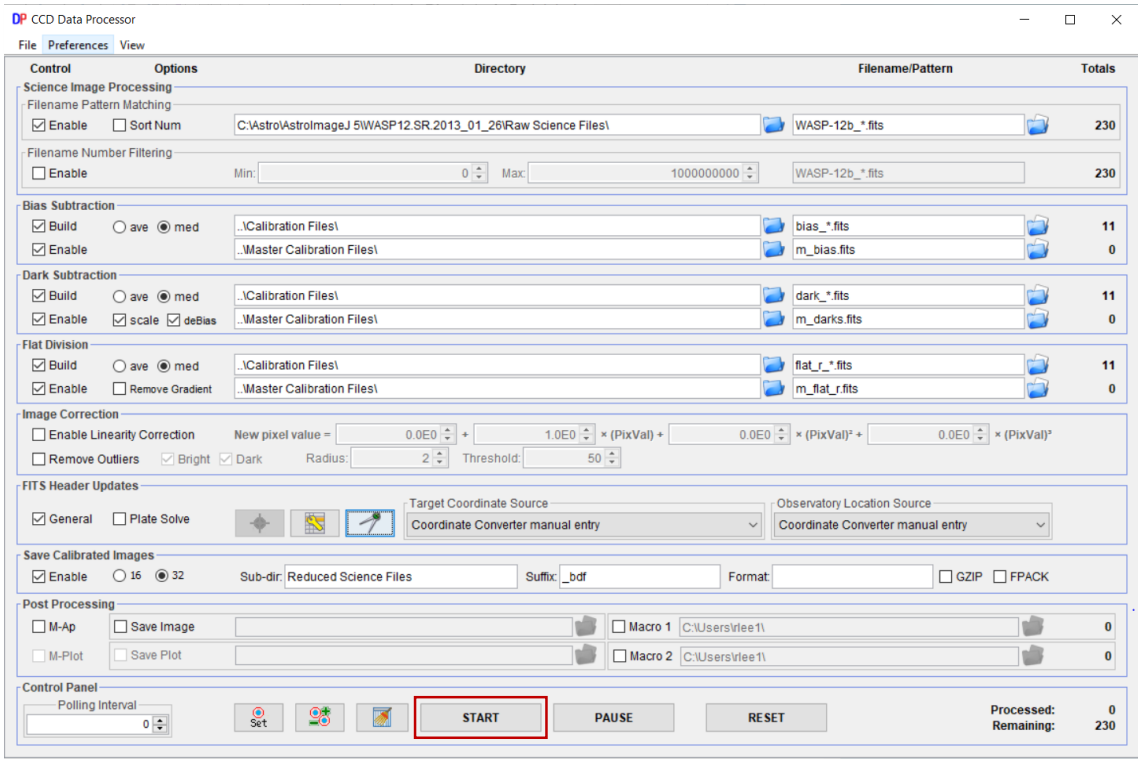
The next figure shows the CCD Processor window prior to running image reduction on 230 raw science files.

Directory entries are based on a single Calibration folder containing bias, darks and flat files. The median-combined calibration files are saved in a Master Calibration Files folder.

Plate Solve (ANSVR) has been disabled, and Target and Observatory are as specified in the DPCC window.

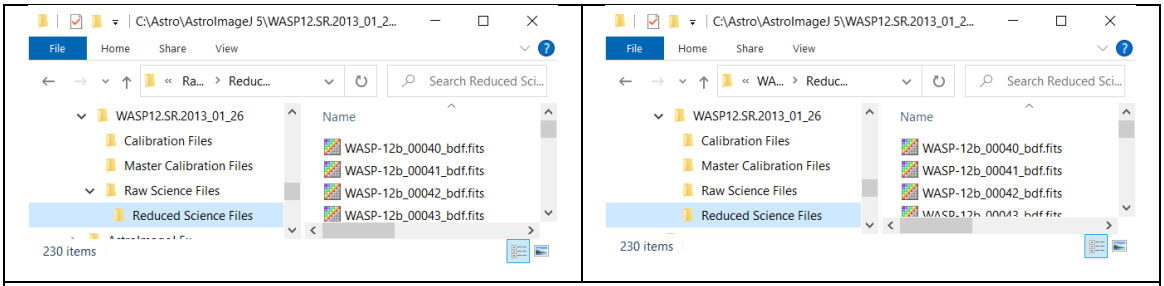
The Processed / Remaining counts in the bottom right corner provide a running tally of processed science files.

1. Click [START] in the Control Panel at the bottom of the CCD Data Processor. A Log window opens, with a running record of each image process. Refer to the log for details.



2. When processing is finished, the master calibration file totals should equal 1, confirming that master bias, darks and flats files were compiled. Uncheck the 'Build' check boxes (3) to prevent AIJ re-building these files in any subsequent runs.

Move the Reduced Science Files folder up one level as below:
From: .\WASP12.SR.2013_01_26\Raw Science Files\Reduced Science Files
To: .\WASP12.SR.2013_01_26\Reduced Science Files



WASP12.SR.2013_01_26 folders
before and after moving the Reduced Science Files up one level.

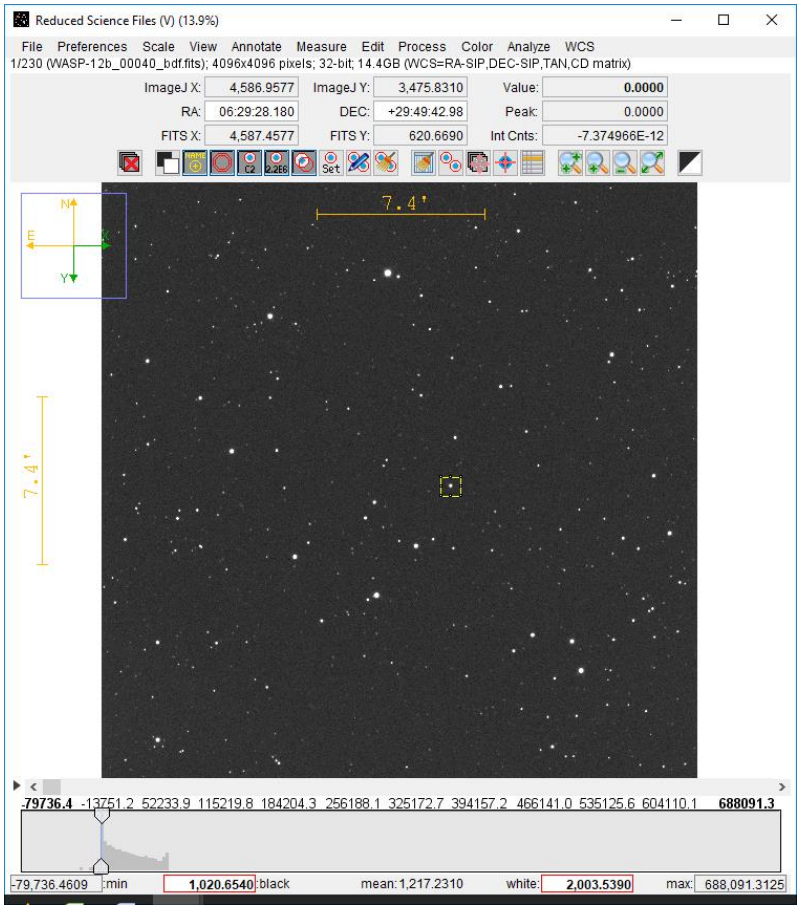
5. AstroImageJ Photometry

5.1. Import Image Stack

1. Open AIJ and from the toolbar, select File | Import | Image Sequence … to open the Import Image Sequence dialog. Ensure the 'Use virtual stack' check box is selected.

2. Click [Browse] navigate to and select the folder containing the reduced WASP12 images: .\WASP12.SR.2013_01_26\Reduced Science Files (Matched files = 230).

   Click [OK] to close the dialog. An Image Viewer window opens displaying the first WASP12 image (WASP-12b_00040_bdf.fits). Note the yellow N-E pointers indicate this is a plate-solved image. Refer to chapter 5 in ref [4] for a more detailed description of available functions in this window.

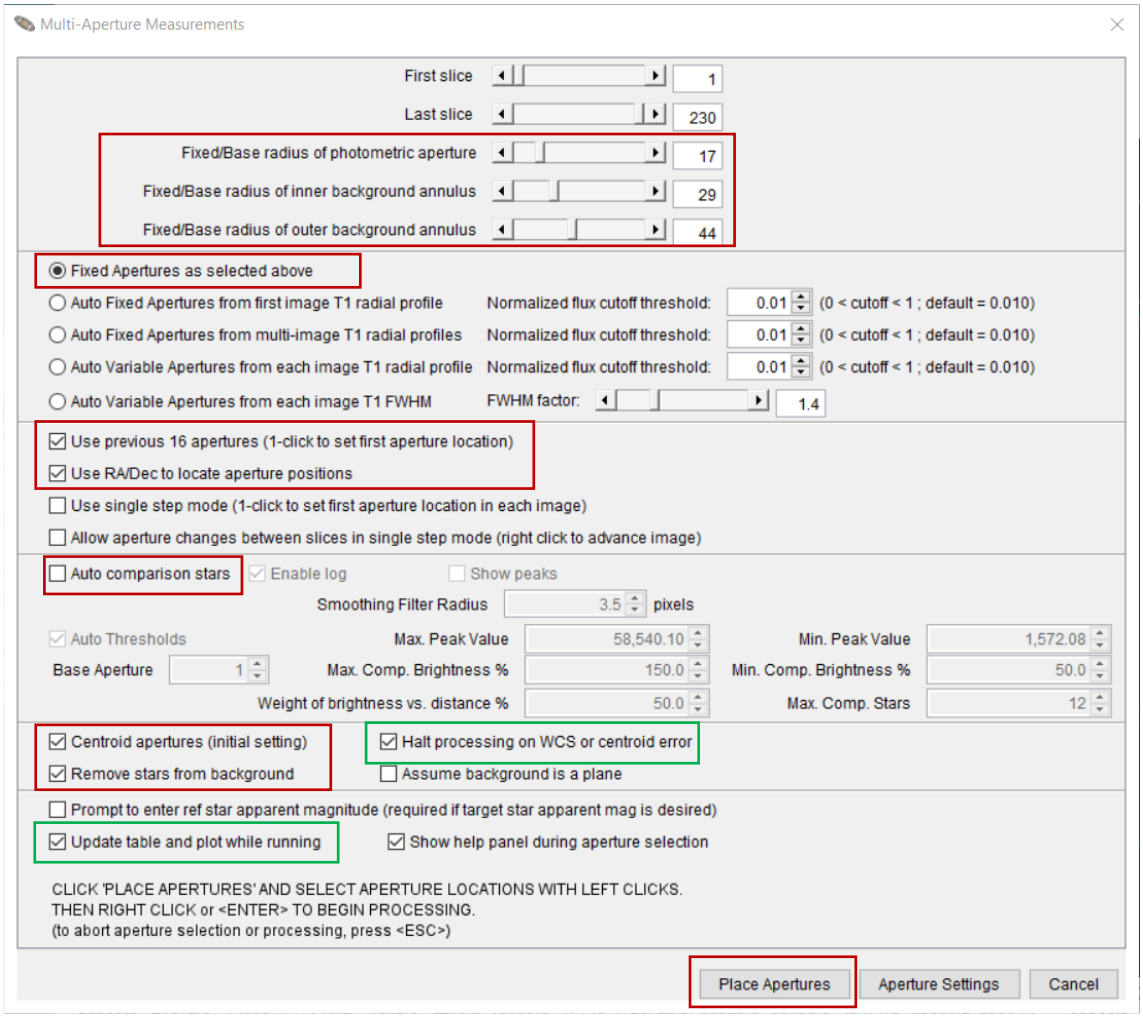


3. Select View then the appropriate Invert … option to orientate image N-E up and left as above.

5.2. Configure Multi Aperture Measurements

This section covers one-time set up of the complex Multi-Aperture window. One-off configuration of this window may be moved to Appendix A in updates to this Guide.

1. In the Image Viewer toolbar, click  'perform multi-aperture photometry' to open the Multi-Aperture Measurements window and configure as indicated in the highlighted sections.



Multi-Aperture Measurements configured for radec Apertures

Highlighted settings

- Aperture radii imported from Seeing Profile window (section 5.4).
- Fixed Apertures located at radec coordinates (on plate solved images)
- Disable option for Auto comparison stars
- Centroid apertures and remove stars from background (see tooltips)
- Green highlighted settings are optional

2. Click [Place Apertures] to save changes and close this window.

3. Click  'clear apertures ..' in the Image Viewer toolbar and close the Multi-Aperture Help window.

5.3. Visual Inspection of Image Quality

The image stack can be inspected by either manually stepping through the stack or running an animation.

1. Use the scroll bar controls highlighted below to inspect individual images.

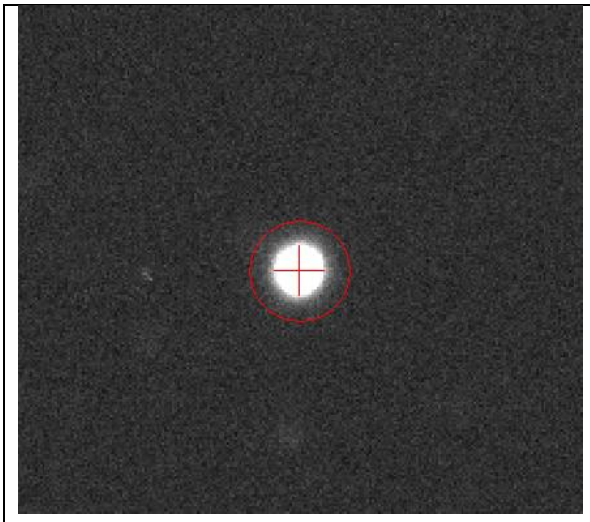
2. Click the Play icon  , left of the scroll bar, to start / pause image animation. Right click on this control to set animation speed and other options.

3. To remove an image from the stack, click , left-most icon. Note: this function only removes the image from current photometry stack. The FITS file is *not* deleted from the Reduced Science Files directory.

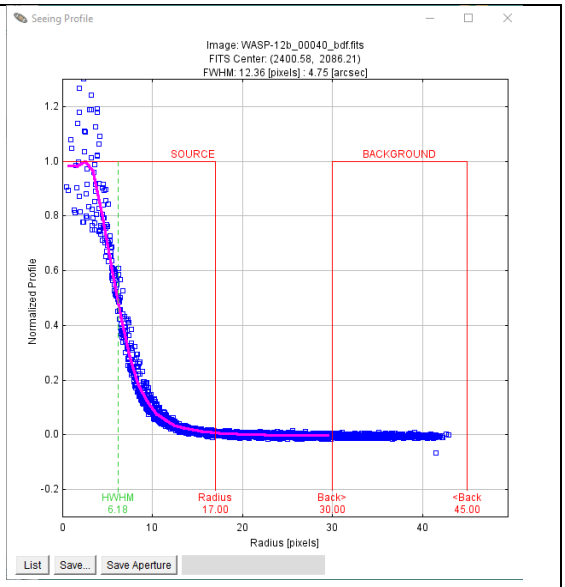
5.4. Photometry Measurement Apertures

5.4.1. Set aperture sizes

1. Click 'change aperture settings' to open the Aperture Photometry Settings window.
2. Enter 20, 24 and 30 in the top three aperture and annulus fields. The exact values are not critical but the object aperture must be large enough to fully enclose the image of a single star. Click [OK] to close this window.
3. Click toggle aperture display as necessary so that the "Live Photometer" is a single circle overlay as shown below.
4. Alt-Left click on a bright non-saturated star image – the star highlighted in the Image Viewer in section 5.1 is a good candidate. The Seeing Profile for the selected star opens in a new window



Object aperture (R = 20) enclosing a non-saturated star image

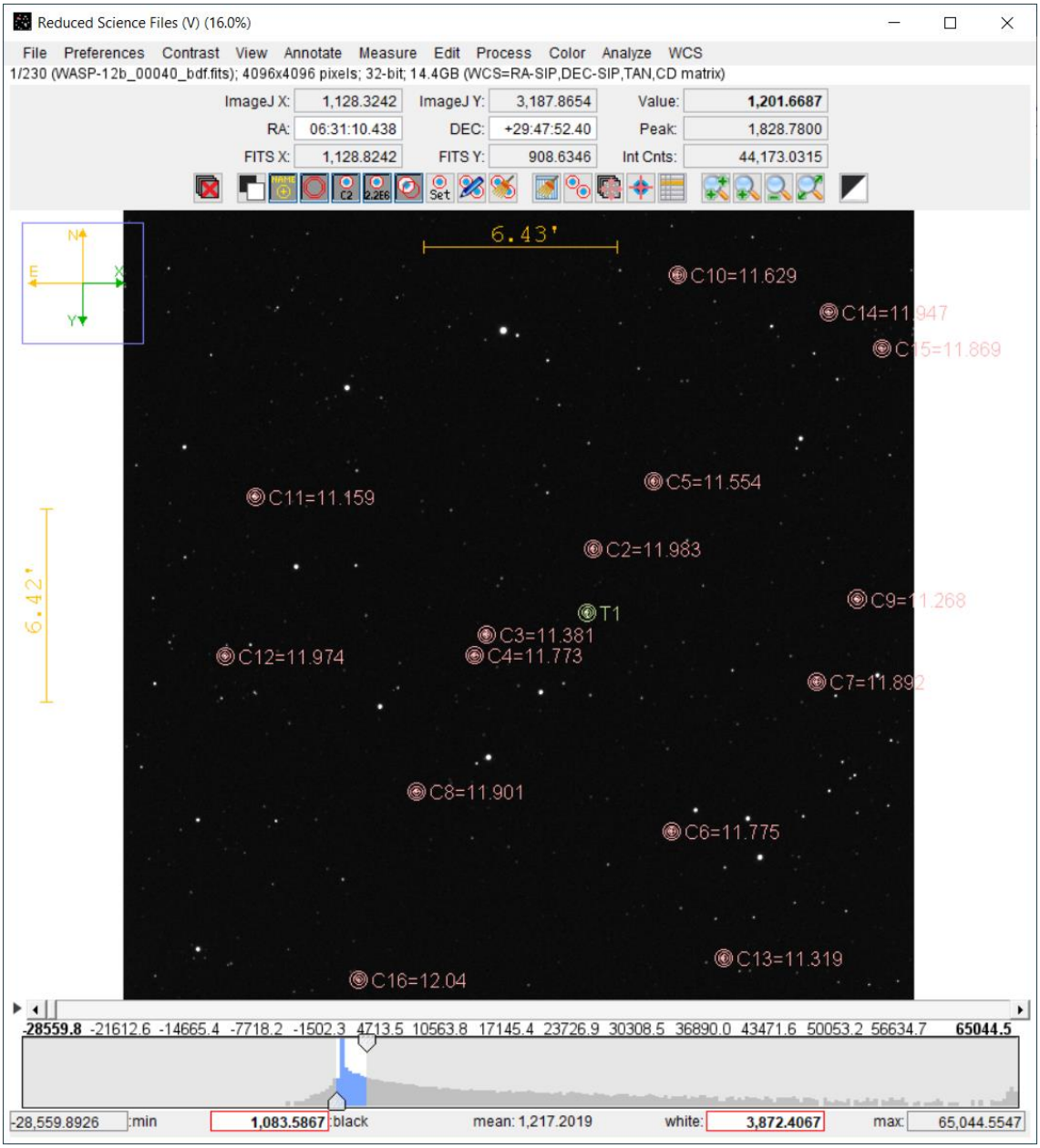


Seeing Profile window
FWHM = 12.36 [pixel] 4.75 [arcsec]
Apertures = 17 | 30 | 45

5. Click [Save Aperture] in the Seeing Profile window to import these aperture sizes.
6. Click in the Image Display window to open the Aperture Photometry Settings window and confirm that aperture sizes are now 17 | 30 | 45. Click [OK] to close the Aperture Photometry window
7. In the Image Viewer, click 'clear apertures ..' to clear any overlays.
8. Click to display sky background apertures. The group of toolbar aperture buttons should all be depressed as shown here:

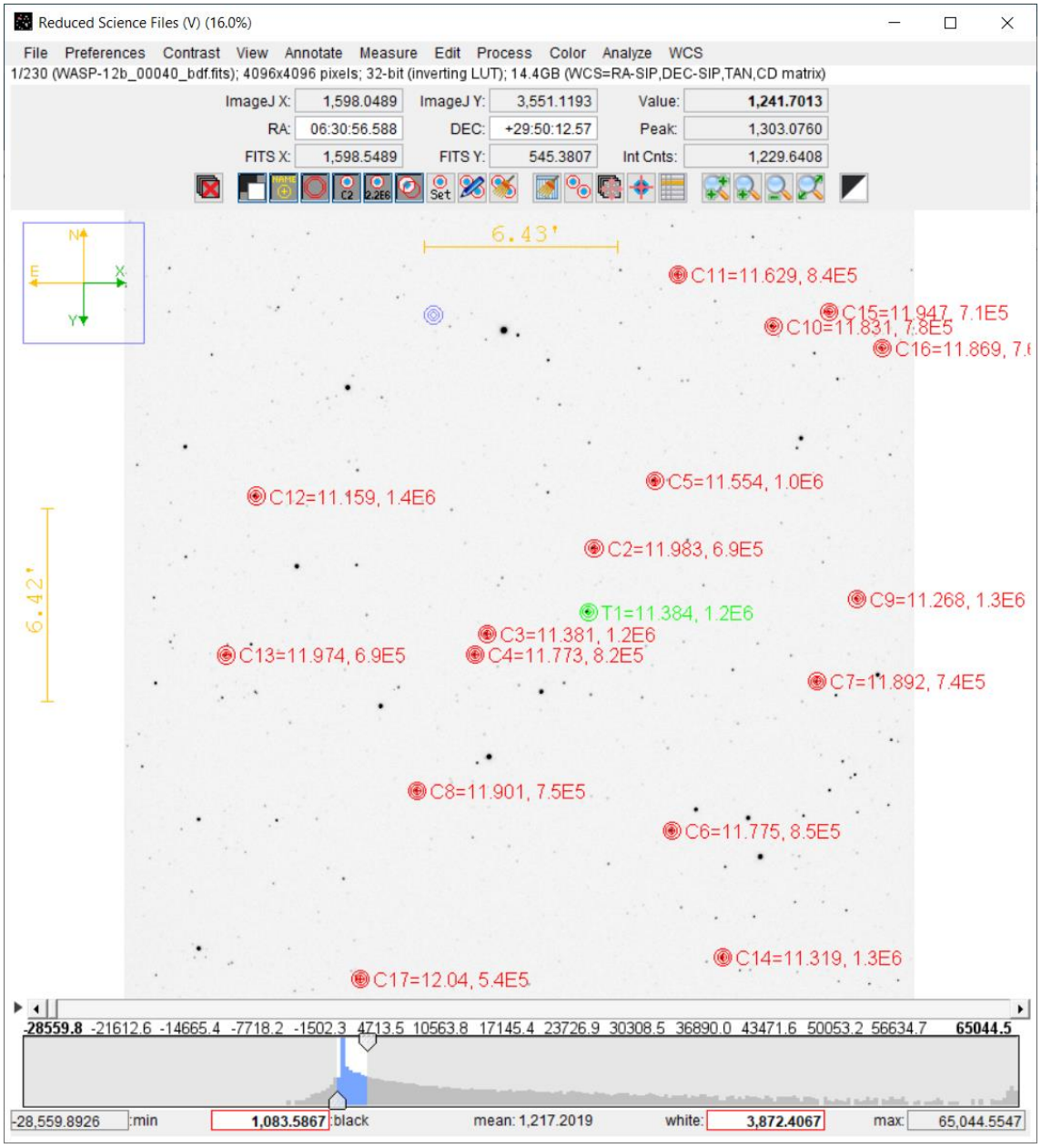
5.4.2. Import radec apertures

1. In the Image Display window, select File | Import apertures from RA / Dec list .. , navigate to and select .\radec\wasp12.SR.025.radec.txt. AIJ imports and overlays the WASP12 image with the APASS set of apertures saved in section 3.3. Click  'zoom to fit ...' to re-centre the image in the Viewer.



2. In the Image Viewer toolbar, click  'perform multi-aperture photometry' to open the Multi-Aperture Measurements window.

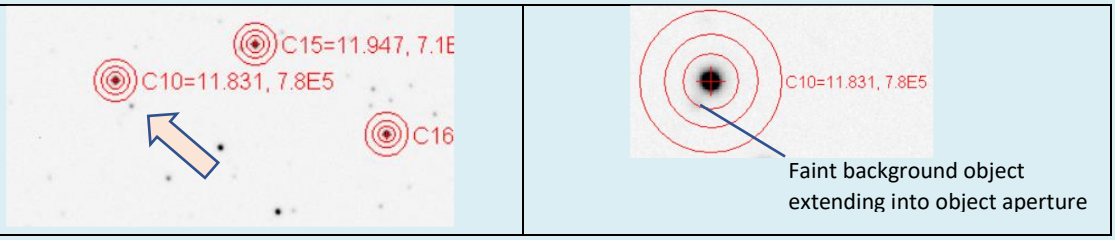
3. Click [Place Apertures] to close this window. In the Image Viewer, the aperture overlay is highlighted and measurement apertures are locked to object centroids.



Aperture overlay after [Place Apertures] in Multi-Aperture Measurements
Negative image to enhance faint details

5.4.3. Remove an aperture from radec set

This is an optional section to demonstrate deleting one aperture from the radec set. In Comparison aperture C10, there is a faint background object that extends into the object aperture.



1. Open Observation Planner | Catalogs tab (AIJ toolbar => Plugins => Astro Apps => Run Planner => App => Catalogs), click [Import Radec File] and open wasp12.SR.025.radec.txt. The data table should be populated with coordinates for T01 to C17 apertures with two rows de-selected.
2. Uncheck 'USE' for Ap C10, aperture numbers for rows that follow update automatically as below.

C10	06300448+29495088	06:30:04.48	+29:49:50.88	11.831	0.083	0.431	11.32	4
C11	06301904+29513387	06:30:19.04	+29:51:33.87	11.629	0.062	0.229	11.62	4
C12	06312367+29441027	06:31:23.67	+29:44:10.27	11.159	0.058	-0.241	11.69	7

	06300448+29495088	06:30:04.48	+29:49:50.88	11.831	0.083	0.431	11.32	4
C10	06301904+29513387	06:30:19.04	+29:51:33.87	11.629	0.062	0.229	11.62	4
C11	06312367+29441027	06:31:23.67	+29:44:10.27	11.159	0.058	-0.241	11.69	7

Change in table row numbering after de-selecting C10 in upper figure

3. Click [Save Radec File] to over-write wasp12.SR.025.radec.txt. To check, click [Clear] then [Import RaDec File] and confirm changes.
4. In the Image Viewer, click  'clear apertures and annotations from overlay'.

Import radec apertures wasp12.SR.025.radec.txt and confirm aperture marked C10 in the above figure has been removed from the aperture set.

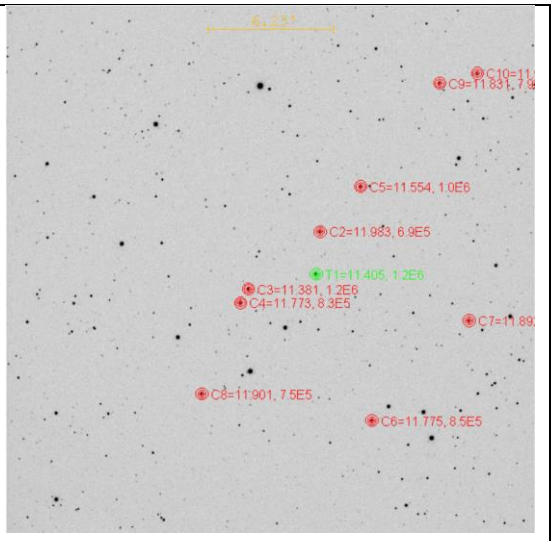
5.5. Run AIJ Photometry

This section covers short form instructions to run AIJ photometry. The section assumes:

- Aperture file: wasp12.SR.025.radec.txt has been saved using the Observation Planner plugin (section 3.3.2),
- Reduced Science Files folder contains processed fits files (section 4)
- Multi-Aperture window is configured as section 5.2,
- A visual check was made of the image stack (section 5.3), and
- Aperture set reviewed and changed as necessary (section 5.4.3). Aperture set C2 – C10 used for Multi-plot charts and transit fit (sections 6 and 7):

Ap	ObjectId	Ra2000	Dec2000	Mag	Mag Err	Mag diff	Dist	Nobs	USE
T01	wasp12	06:30:32.80	+29:40:20.26	11.400	0.000	0.000	0.00	1	☑
	06303279+29402033	06:30:32.79	+29:40:20.33	11.415	0.070	0.015	0.00	4	☐
C02	06303188+29422730	06:30:31.88	+29:42:27.30	11.983	0.081	0.583	2.13	4	☑
C03	06304827+29393591	06:30:48.27	+29:39:35.91	11.381	0.058	-0.019	3.44	5	☑
C04	06305007+29385436	06:30:50.07	+29:38:54.36	11.773	0.060	0.373	4.02	5	☑
C05	06302262+29444221	06:30:22.62	+29:44:42.21	11.554	0.080	0.154	4.89	4	☑
C06	06302000+29330320	06:30:20.00	+29:33:03.20	11.775	0.077	0.375	7.80	4	☑
C07	06295778+29380133	06:29:57.78	+29:38:01.33	11.892	0.082	0.492	7.95	4	☑
C08	06305893+29342229	06:30:58.93	+29:34:22.29	11.901	0.061	0.501	8.24	5	☑
	06304354+29493334	06:30:43.54	+29:49:33.34	11.723	0.066	0.323	9.51	4	☐
C09	06300448+29495088	06:30:04.48	+29:49:50.88	11.831	0.083	0.431	11.32	4	☑
	06301904+29513387	06:30:19.04	+29:51:33.87	11.629	0.062	0.229	11.62	4	☐
	06312820+29385229	06:31:28.20	+29:38:52.29	11.974	0.054	0.574	12.12	7	☐
	06301214+29284998	06:30:12.14	+29:28:49.98	11.319	0.082	-0.081	12.35	4	☐
C10	06295591+29501979	06:29:55.91	+29:50:19.79	11.947	0.083	0.547	12.80	4	☑
	06294772+29490762	06:29:47.72	+29:49:07.62	11.869	0.090	0.469	13.15	4	☐
	06310779+29280862	06:31:07.79	+29:28:08.62	12.040	0.057	0.640	14.37	4	☐

Apertures C2 – C10 in Planner | Catalogs Tab



Aperture overlay in AIJ | Image Viewer

1. Open AIJ and from the toolbar select File | Import | Image Sequence …, navigate to and open the WASP12 Reduced Science Files folder. Confirm there are 230 matched files and click [OK] to close window. The Image Viewer opens with the first reduced science image.

2. Alt-left click on the image of a non-saturated star (section 5.4) and click on [Save Apertures] in the Seeing Profile dialog to import the recommended aperture sizes (17 | 29 | 44).

3. Close Seeing Profile dialog and click  to clear aperture and annotation overlay.

4. Import radec file wasp12.SR.025.radec.txt and  , zoom to fit image to window.

5. Click  , confirm aperture radii same as above, then click [Place Apertures] to close window and return to Image Viewer. The apertures are highlighted and locked onto the object centroids. A Multi-Aperture Help window opens.

6. To ensure Image Viewer is active, click on the title bar, then press [Enter] to start AIJ time resolved photometry processing. If the Multi-Aperture Measurements | Update and plot while running check box is selected, then several windows open:

   - Plot of Measurements: plots relative flux and other parameters during processing.
   - Measurements window: displays a table of photometry results.

   Note: Apertures track frame-to-frame shifts in star centroids including image rotation after a meridian flip.

7. When processing is complete, select Measurements | File | Save As ..., navigate to WASP12.SR.2013_01_26 folder and save as ‘Measurements.tbl’.

   Note: Measurements.tbl can be opened as a tab-delimited text file in Excel or other spreadsheet software. The file comprises a header row then a data row for each image in the image stack (230 data rows for WASP12 data set).

6. AstroImageJ Multi-Plot

The following four setup windows plus graphic window make up AIJ Multi-plot (MP):

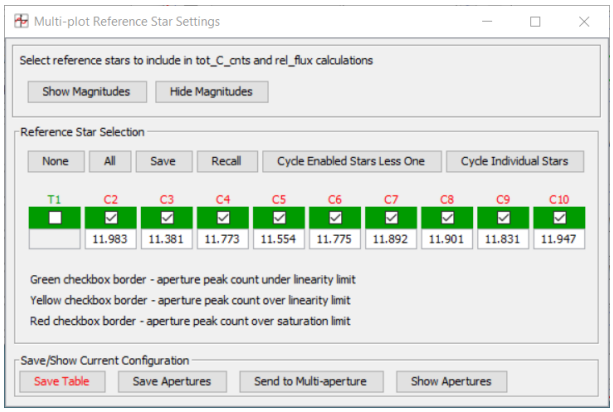
Window	Function
Multi-plot Main	Sets number of plots, plot titles and scales; user sets markers for transit-based normalisation and optional data exclusion
Multi-plot Y-data	Individual plot settings with de-trend and fit mode options
Data Set Fit Settings	Window accessing 7 term transit fit settings
Plot of Measurements	Time-based plot of transit and related data
MP Reference Star Settings	AIJ recomputes photometry results when user changes aperture selection [1]

[1] The Multi-plot Reference Star Settings window is not covered in this Guide

The next sections walk through transit fit and other data plot setups. These instructions refer to two plot configuration files: '**wasp12_transit_amass_sky.plotcfg**' and '**wasp12_transit_comp_amass_sky.plotcfg**'.
Download the plotcfg files from the BAA website (*LINK_TBD*), create sub-folder: .\AstroImageJ 5\plots and save the files in this folder.

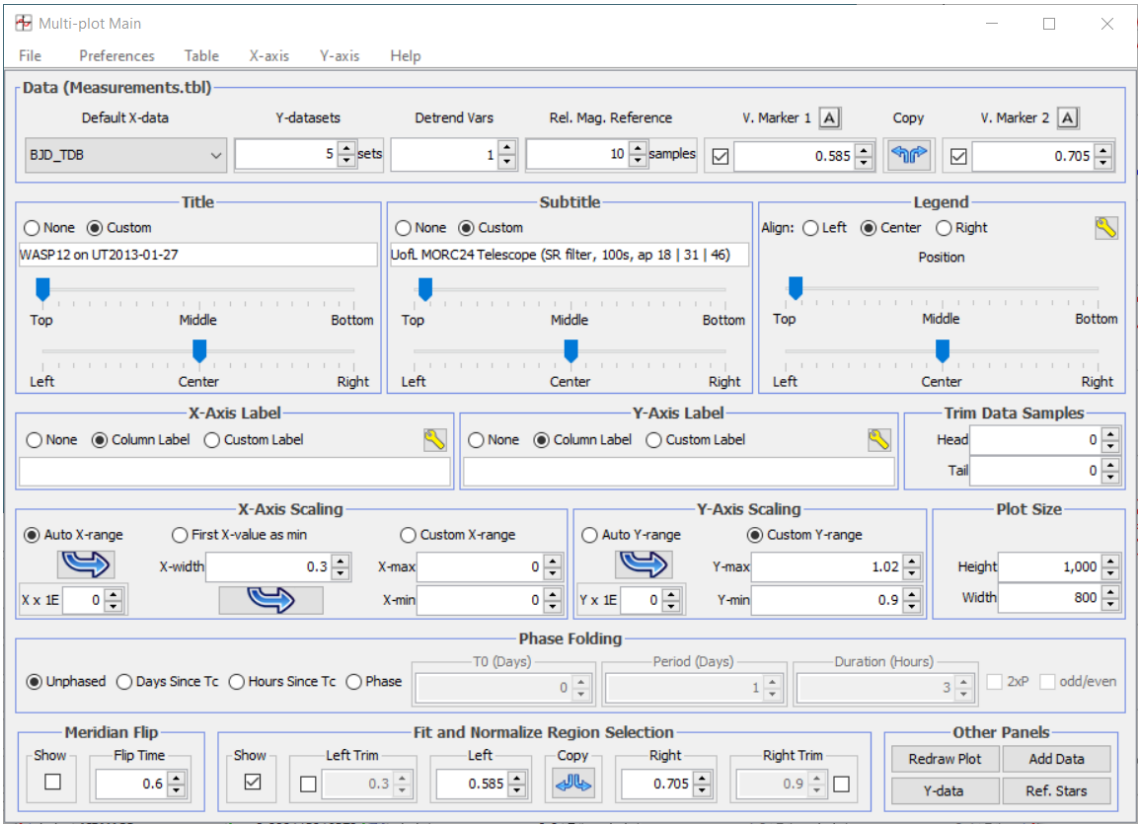
6.1. Open AIJ Plot Windows

1. If AIJ is open, close then re-open and click  'MultiPlot Tool' - several Multi-plot windows open.
2. Locate the Multi-plot Main window, select MP Main | File | Open table from file … to open a dialog titled Select measurement table. Navigate to and open WASP12 measurements.tbl.
3. In MP Main, select File | Open plot configuration from file.. to open dialog, navigate to the plots folder and select 'wasp12_transit_amass_sky.plotcfg'.
4. In MP Main | Other Panels, click [Ref. Stars] to open the Multi-plot Reference Star Settings window (shown below) and close this window.

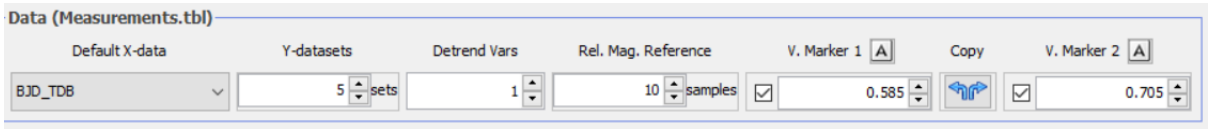


6.2. Multi-plot Main

The following figure shows the Multi-plot Main window configured for 5 Y-datasets and 1 Detrend variable.



Data (Measurements.tbl)

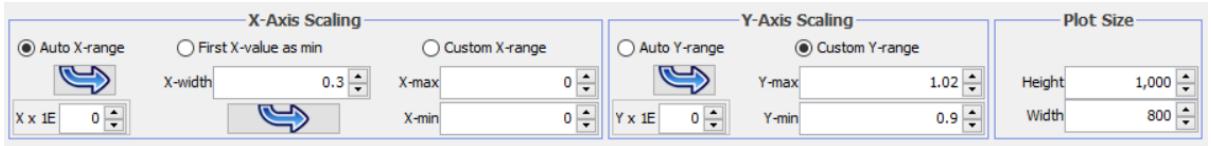


Default X-data	TDB-based barycentric Julian Date at the mid-point of the exposure.
Y-datasets	5 plots, comprising 2 transit, airmass and sky plots, and a blank dataset
Detrend vars	Single detrend (by airmass), note no meridian flip in this dataset
V-Markers	User-sets these markers at transit ingress and egress.

Title and Subtitle

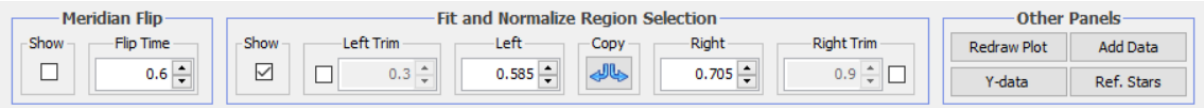
As shown in main figure.

Axis Scaling and Plot Size



X-Axis Scaling	Auto X-range, sizes axis to span the entire time-based dataset.
Y-Axis Scaling	Custom Y-range, scaled to fit plot legend, transit and other plots.
Plot Size	Size of Plot of Measurements window (in pixel).

Meridian Flip, Fit and Normalize, Other Panels



Meridian Flip	Not applicable for WASP12 dataset
Fit / Normalize	Options to trim leading and trailing data, Left and Right Trim fields respectively, are disabled in this figure. Click  to insert V-Marker values into the Left and Right fields
Other Panels	Refresh plot and open other plot windows.

Note: It is easy to get lost in the myriad AIJ plot windows.
[**Redraw Plot**] refreshes the Plot of Measurements chart, and
[**Y-data**] accesses the Multi-plot Y-data window.

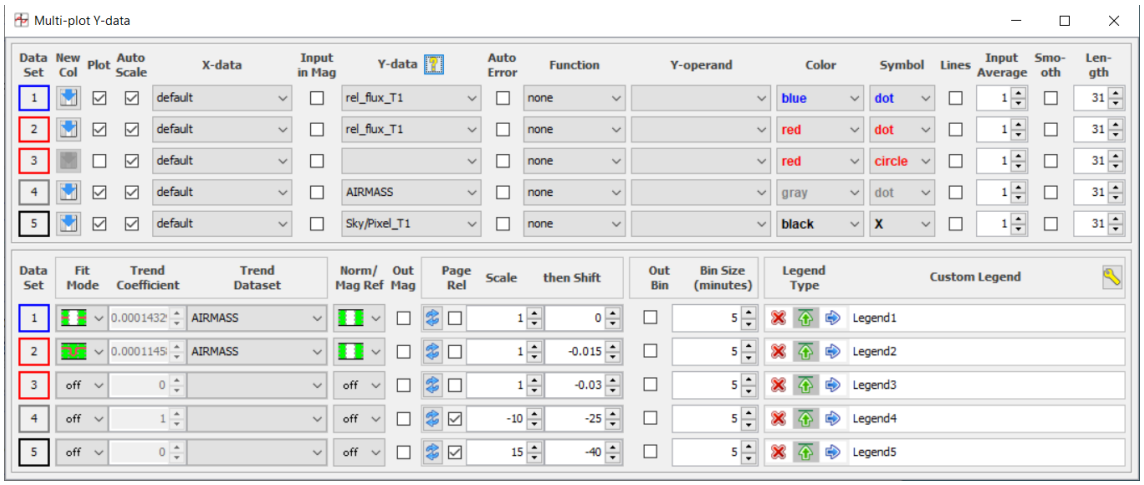
[**Add Data**] this function may corrupt measurements.tbl dataset - recommend to *NOT use* this function

Menu Options

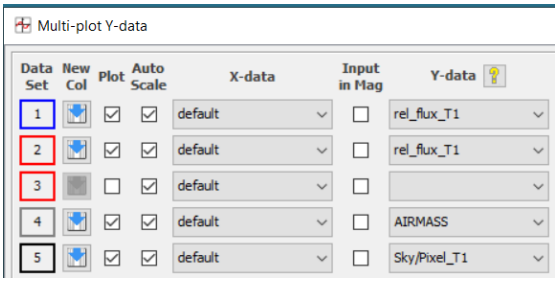
File	Large number of plot configuration and other options
Preferences	Uncheck 'Use –wide—Y-data columns to fold Y-axis rows as in the next section.
Help	Access a general multi-plot help window or a dialog displaying Data Naming Conventions.

6.3. Multi-plot Y-Data

The following figure is a Multi-plot Y-data window in 'folded' state (see MP Main Menu Options) with five data sets. Data sets 1 and 2 are transit plots, data sets 4 and 5 plot airmass and a sky-related parameter. Data set 3 is currently unused and its plot check box is deselected.



Multi-plot Y-data: Upper section



Data Set — Identifier common to upper and lower window sections

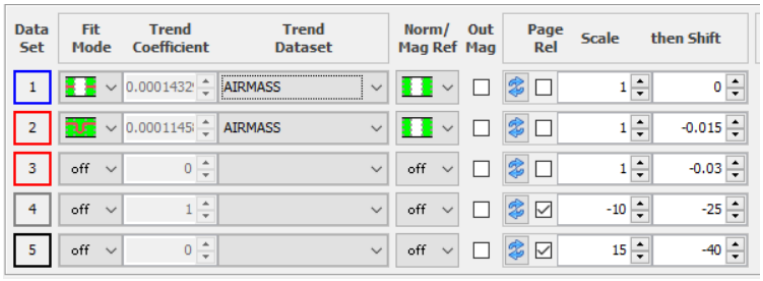
Plot — Check box controls plot visibility

X-data — 'default' is the Multi-plot Main | Default X-data (BJD_TDB in this example)

Y-data — drop-down dataset selections of transit (rel_flux_T1), airmass and sky brightness (Sky/Pixel_T1)

The right-side controls set plot colours and symbols. Input Average combines adjacent data to reduce scatter, set to 1 in this example.

Multi-plot Y-data: Lower section



Fit Mode — Data Set 1: applies an AIRMASS detrend to the green shaded regions. This is the out-of-transit baseline region defined by the Left and Right markers in the Multi-plot Main window.
Data Set 2: AIRMASS detrend and transit fit.
Other Data Sets are 'off'.

Refer to the detailed tooltip for more details. A right-click on opens the Data Set Fit Settings window.

Trend Dataset — Transit datasets (datasets 1 & 2) are 'detrended' by AIRMASS (i.e., each dataset is divided by airmass)

Norm/Mag Ref — Transit datasets are normalised to 1.0 over the baseline regions; see Fit Mode | Data Set 1.

Page Rel, Scale, then Shift

Parameters to control plot placement and scaling. Transit data sets have Scale = 1 and offset for visibility. Data sets 4 and 5 are checked 'Page Rel' to auto-scale and offset towards the bottom of the chart. Refer extensive tooltips for details.

6.3.1. Add Comparison Star to Multi-plot Y-data

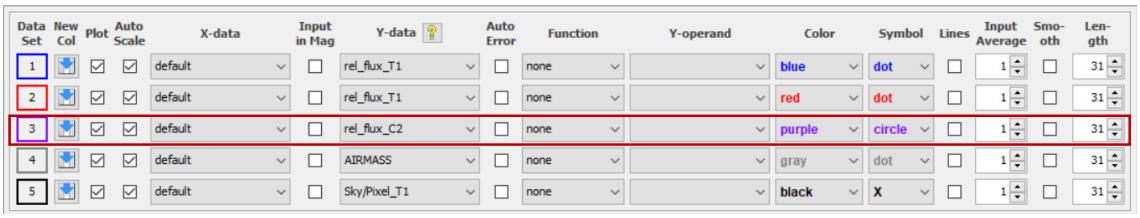
Example of adding rel_flux_C2 as new dataset 3 in the Multi-plot Y-data window.

Data Set 3 - upper window settings

1. Click the Y-data control for Data Set 3 and select 'rel_flux_C2' from the drop-down list. If necessary, select the Plot checkbox for Data Set 3.

2. Change dataset 3 to a distinctive colour and symbol, in this example, purple and circle as below.

Dataset 3 settings in the upper part of the folded Multi-plot Y-data:

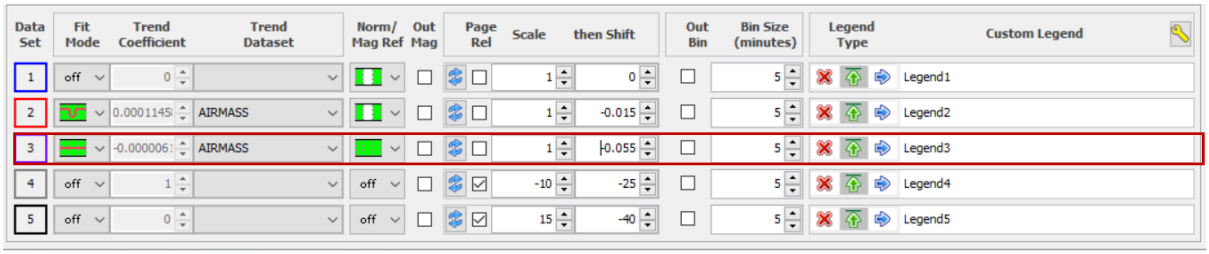


Data Set 3 - lower window settings

3. Data Set 3, Select Fit Mode  , Trend Dataset: AIRMASS and Norm / Mag Ref:  . This combination applies an airmass detrend then a linear fit each over the full data set.

4. Data Set 3, leave Scale = 1 but change 'then Shift' field to offset the plot, offset = -0.055 applied below.

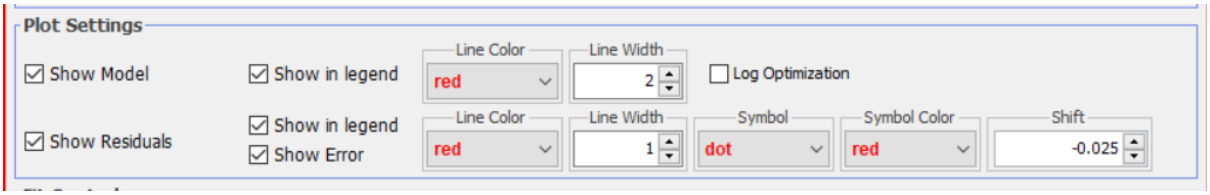
Dataset 3 settings in the lower part of the folded Multi-plot Y-data:



5. To save the current settings, MP Main | File | Save plot configuration …, navigate to the plots folder and save as 'wasp12_transit_comp_amass_sky.plotcfg'.

6.4. Fit Plot Settings

If the Fit Settings window is not already open, right-click on the data set Data Set 2 | Fit Mode icon  to open this window. The Data Fit window handles a 7-parameter fit to the transit dataset. This section covers the Plot Settings section, other sections are covered in a later section.

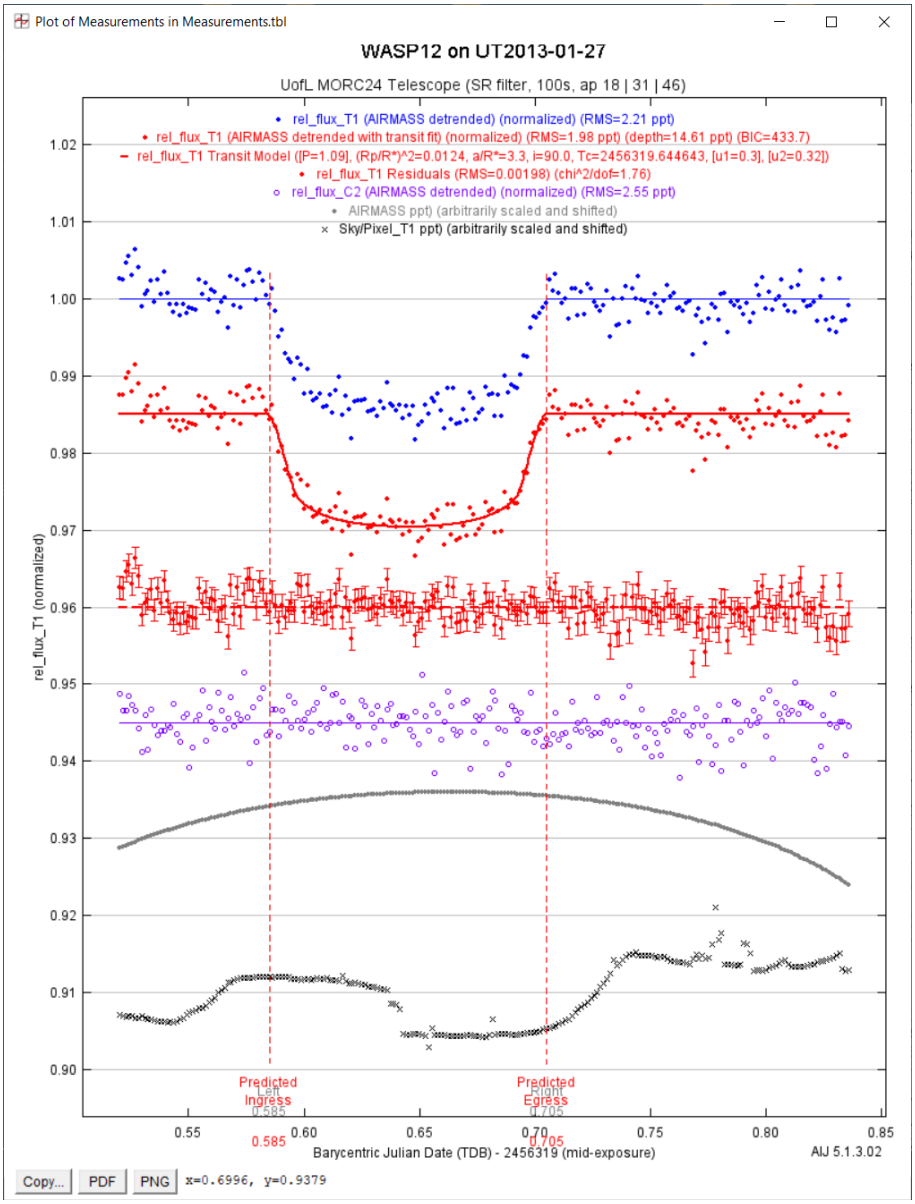


Data Set Fit Settings | Plot Settings section

This section is configured to plot a transit model curve and residuals with error bars. Both plots are red and the residuals are offset by -0.025.

6.5. Plot of Measurements

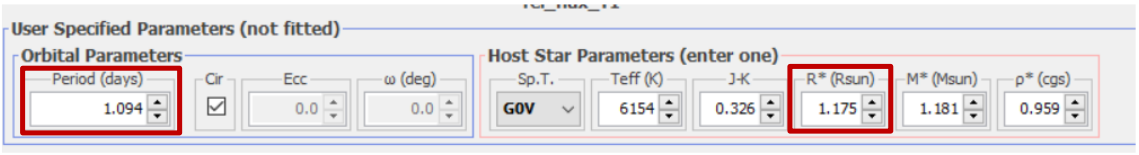
The following Plot of Measurements displays two transit datasets (datasets 1 and 2), fit residuals (dataset 3), the comparison star dataset added in section 6.2 (dataset 4). The bottom two plots, airmass and SkyPixel_T1 show detrend and sky conditions respectively with arbitrary scaling. The header identifies the dataset, any detrend applied (AIRMASS), rms and fit statistics as applicable.



7. Transit Analysis in AstroImageJ

The figure below shows the full Data Set Fit Settings window. The user inputs data into two fields in the Orbital and Host Star Parameter sections. The Transit Parameters section handles a 7-parameter fit to the airmass detrended transit photometry data. In this figure, the user has entered values for the limb-darkening coefficients u1 and u2. Locking these parameters reduces the number of independent fit variables to 5. Transit depth and timing parameters are listed in the 'Calculated from model' row.

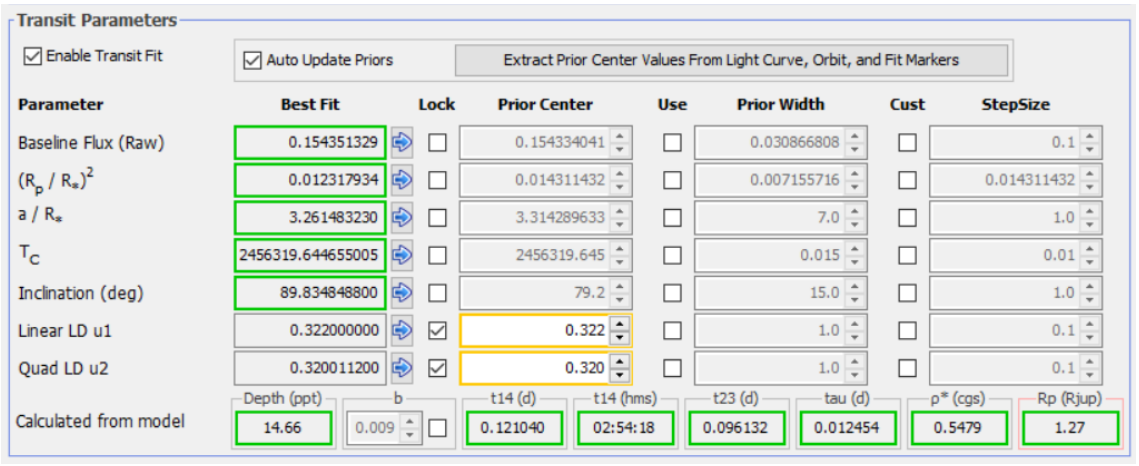
7.1. User Specified Parameters (not fitted)



Orbital and Host Star Parameters can be imported from the NASA Exoplanet Archive: https://exoplanetarchive.ipac.caltech.edu/.

1. Click this link to open the NASA Archive in default browser. Enter WASP12 in the 'Explore the Archive search field and click [Search] to open the WASP-12 Overview page.
2. Click on the WASP-12b Planetary Parameters link, locate orbital period P(days) = 1.0914, and enter this value in the Fit Settings | Orbital Parameters | Period (days) field.
3. In the same web page, click on the WASP-12 Stellar Parameters link, locate the stellar radius $R*(R_\odot)$ = 1.749, and enter this value in the Fit Settings | Host Star Parameters | R*(Rsun) field.

7.2. Transit Parameters



LD terms u1 and u2 can be imported from the EXOFAST - Quadratic Limb Darkening page:

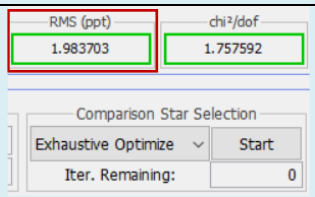
https://astroutils.astronomy.osu.edu/exofast/limbdark.shtml

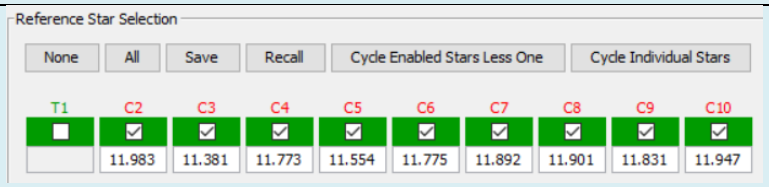
1. Click this link to open the EXOFAST applet in default browser. Select WASP12 and SDSS r' from the 'Select Planet' and 'Band' drop downs respectively and click [Submit Query].
2. Copy the computed LD values u1 = 0.322 and u2 = 0.320 into the respective (yellow highlighted) Prior Center fields. If necessary, select both the Lock check boxes .

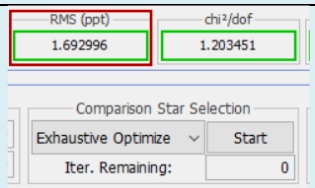
The bottom row lists parameters computed from the transit model, including transit depth = 14.7 ppt (part-per-thousand) and ingress-egress parameters t14 and t23. Refer tooltips for individual parameter descriptions.

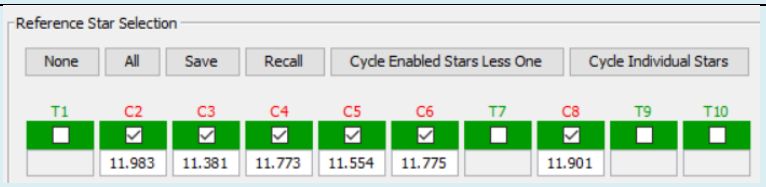
Fit Settings | Fit Optimization | Comparison Star Selection

The Comparison Star Selection optimiser runs about 500 iterations, toggling comparison star selection to find the best transit fit. For the WASP12 data set, starting with 9 comparison stars, fit RMS reduces from 1.98 to 1.69 ppt by de-selecting C7, C9 and C10 from photometry analysis.









Comparison Star Selection	Multi-plot Reference Star Settings

Fit RMS before and after running Comparison Star Selection

8. Summary

Observation planning stages are supported by the Planner java plugin. Planner assists with the selection of suitable Comparison stars from either the VSP or APASS on-line catalogs, saving data in radec format files to import into AIJ.

WASP12 fits files were used to walk-through each processing stage, starting with raw science files, running AIJ image reduction and photometry through to plotting and computing transit fit results. There is no meridian flip in WASP12 data set and airmass is the only detrend applied prior to a 7-term transit model fit. If the host star limb darkening terms u1 and u2 can be downloaded, the model fit reduce to 5 terms.

Multi-plot is probably the most complicated part of using AIJ. Plot configurations can be saved to plotcfg files to assist plotting transit curves. *A Practical Guide to Exoplanet Observing* (Ref [2]) may help with getting to grips with complex plot setup windows. *A Practical Guide …* suggests some alternative processing steps and covers a number of features not discussed in this Guide.

Where practical, one-off software setup procedures are moved to an Appendix to help clarify the data processing sequence.

8.1. AstroImageJ v5

Version 5 was released in January 2022. Link to AIJ forum is an overview of new features introduced in this version: AIJ Forum

Functions to set variable apertures have been enhanced in AIJ v5. In non-crowded star fields, variable apertures would be useful in cases where significant defocus occurs over an observation session. AIJ v5 also introduces Auto comparison star option as an alternative to importing radec coordinate based apertures covered in this Guide. These enhanced or new features can be accessed on the Multi-Aperture Measurements window.

8.2. Observation Planner App

Note that the Planner app requires AIJ 5 or later.

Depending on potential user interest, options to extend the app might include:

- Add an azimuth-altitude plot to assess object visibility
- Plot observing conditions, including sky brightness, telescope tracking, focus parameters etc. extracted from the measurements.tbl file
- Import selected exoplanet and host star parameters from the NASA Exoplanet Archive
- Create BAA database output files, etc.

8.3. WASP104 Example Data Set

As a second set of example data, I hope to make available a set of WASP104 transit images. This dataset includes a meridian flip midway through the transit and unsolved raw science fits files.

This dataset was imaged with a remote telescope on an equatorial mount hosted at ICAstronomy, located in southern Spain https://www.icastronomy.com/. Equipment and observatory details are in an Appendix. The data was processed with HOPS software and accepted for the ExoWorlds project in 2020 https://www.exoworldsspies.com/en/.

Appendix A: Install Software

Install AstroImageJ v5 or later

Link to AstroImageJ installation packages:

https://www.astro.louisville.edu/software/astroimagej/installation_packages/.

If not already installed, download AstroImageJ 5.x windows x64 java18

Index of /software/astroimagej/installation_packages

Name	Last modified	Size	Description
Parent Directory		-	
AstroImageJ_installation_linux.html	2022-06-16 01:39	5.7K	
AstroImageJ_installation_mac.html	2022-01-05 03:40	59K	
AstroImageJ_installation_windows.html	2014-12-07 01:23	54K	
AstroImageJ_script.tar.gz	2022-06-16 01:08	1.0K	
AstroImageJ_v5.1.0.00_linux_x64_java18.tar.gz	2022-07-04 04:48	117M	
AstroImageJ_v5.1.0.00_mac_intel_java18.dmg	2022-07-25 20:43	75M	
AstroImageJ_v5.1.0.00_windows_x64_java18.zip	2022-07-04 04:36	108M	
Older_versions/	2022-07-26 13:51	-	
Xresources	2014-12-07 17:49	412	

Apache Server at www.astro.louisville.edu Port 443

To follow instructions in this guide, copy and rename the uncompressed AstroImageJ folder to: C:\Astro\AstroImageJ 5.

Run AstroImageJ and, if the AstroImageJ Updater dialog opens, click [OK] to upgrade to 'daily build'. To check the installed version, open AIJ and from the toolbar select Help => About AstroImageJ … The About AstroImageJ dialog opens with installed version (5.1.3 at time of writing).

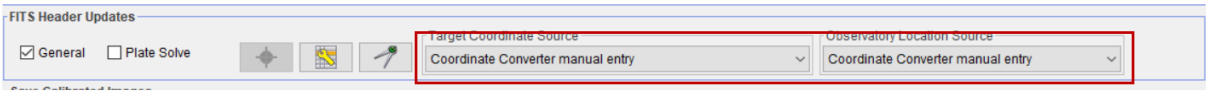
Setup Memory Allocation

Refer to the README.txt file in C:\Astro\AstroImageJ 5 for instructions on changing the physical memory available to AIJ.

Setup DP Coordinate Convert Dialog

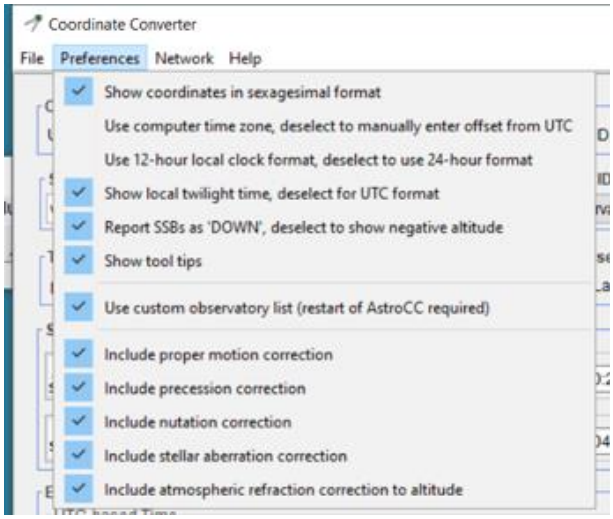
In the toolbar, click  , to open the CCD Data Processor and DP Coordinates Converter windows.

In the CCD Data Processor | FITS Header Updates section, set the Target and Observation Source drop-downs to 'Coordinate Converter Manual Entry'.



The caliper icon  toggles display of the DP Coordinate Converter window.

In the DP Coordinate Converter window, click on 'Preferences' menu header then check / uncheck the Preference settings as below:



Notes:

- Uncheck the 2nd item to manually enter offset from UTC,
- Option to use either 12- or 24-hour clock formats
- Check the 'Use custom observatory list (…)' item.

To register menu selections, close and re-open the AIJ toolbar, and click DP to open the DP Coordinate window. Confirm Preferences menu settings are as shown above.

In Observatory ID drop-down, select 'Moore Observatory, UofL, RC24…' and set UTC offset = -5. Repeat the same closing and open sequence and confirm Moore Observatory is the selected Observatory ID.

Note: AstroImageJ has two nearly identical Coordinate Converter dialogs accessed from the toolbar. Use the **DP Coordinate Converter** window, which links to the Observation Planner plugin software.			
Toolbar icon	**AIJ Toolbar Description**	**Window Title**	**USE ?**
DP	CCD Data Processor Tool	DP Coordinate Converter File Preferences Network Help **DP** Coordinate Converter	✓
	Coordinate Converter Tool	Coordinate Converter File Preferences Network Help Coordinate Converter	✘

Install Observation Planner_for_AstroImageJ

Link to GitHub online repository:
https://github.com/richardflee/observation_planner_for_astroimagej

Follow instructions in GitHub README.md to download application jars

Navigate to AstroImageJ plugins folder and copy planner.jar in the plugins folder

Make a new sub-folder: \AstroImageJ 5\plugins\Astro Apps and copy astro_plugins-1.0x.jar into this folder (x is program version in range a to z).

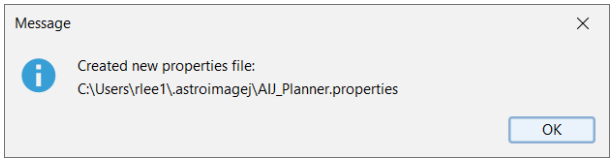
	Folder or File	**Path**	**Notes**

1	AstroImageJ	C:\Astro\AstroImageJ 5	Path referred to in instructions
2	planner.jar	**.\AstroImageJ 5\plugins**	AIJ plugins sub-folder
3	astro_plugins-1.0a.jar	**.\AstroImageJ 5\plugins\Astro Apps**	User creates sub-folder
4	Java install	**.\AstroImageJ 5\jre\bin**	Java 18 or later

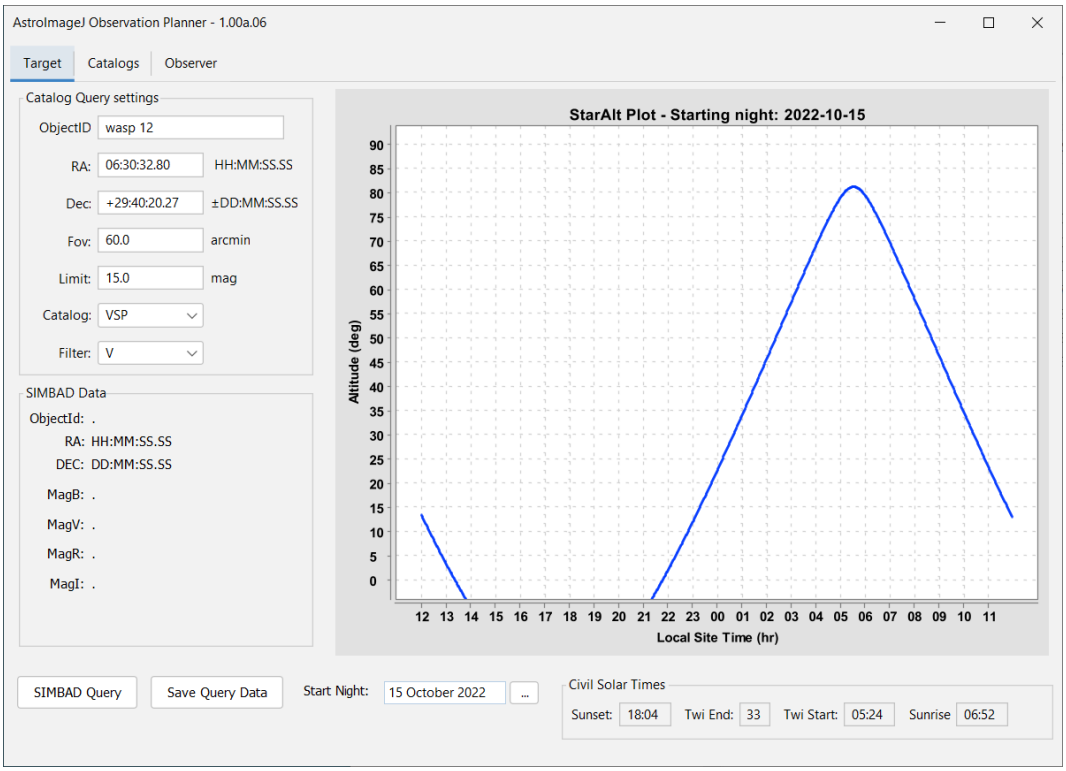
Confirm software install

Run AstroImageJ and from toolbar select Plugins => Astro Apps => Run Planner App. The following message dialog should open stating that a new properties file was created in the AstroImageJ home folder. The path to the properties file in this case is C:\Users\.astroimagej\AIJ_Planner.properties.

Click [OK] to close the dialog box.



The AstroImageJ Observation Planner window opens with default settings (see below). If the dialog fails to open, please check paths to software items 1 - 4 in the installed software table.



AstroImageJ Observation Planner, default settings

Click the Observer tab and verify that Observer Location matches Moore Observatory coordinates.

Observer Location	Moore Observatory, KY
Latitude	+38:20:41.25
Longitude	-85:31:42.51
Altitude (m)	229
UTC Offset (Hr)	-5

Download Plate Solving Software

Importing radec apertures for photometry processing requires astrometric or plate solved fits images. On-line plate solving is relatively slow, and impractical for large images sets.

Two local plate solving options are:

ANSVR https://adgsoftware.com/ansvr/

Runs a local instance of astrometry.net plate solving, ANSVR is fully integrated into AstroImageJ.

- Integrated into CCD Data Processor
- Up to 20 GB download for small field of view
- Typical solve times ~ 5 – 8 s/image

ASTAP http://www.hnsky.org/astap.htm.

Runs as an AstroImageJ plugin, currently Windows only, possible future extension to Linux.

- Partial integration through AstroImageJ plugin
- Database < 1 GB
- Typical solve times < 1.5 s /image
- GitHub online repository: https://github.com/richardflee/astap_solver_for_astroimagej

Disclosure - I developed the ASTAP plugin in Oct 2022. The GitHub link points to instructions to install software and documentation covering use with WASP12 image examples. ASTAP is a good option for processing large numbers of images on an older PC and /or where disk space is at a premium.

Download WASP12b example fits files

Download the uncalibrated example images
https://www.astro.louisville.edu/software/astroimagej/examples/.

Index of /software/astroimagej/examples

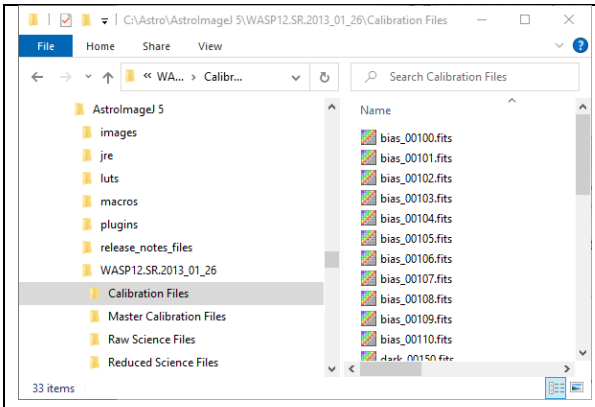
Name	Last modified	Size	Description
Parent Directory		-	
README	2017-02-20 19:02	1.3K	
WASP-12b_example_calibrated_images.tar.gz	2015-06-09 02:52	4.3G	
WASP-12b_example_calibrated_images.zip	2015-02-19 00:04	4.4G	
WASP-12b_example_raw_biases.tar.gz	2017-02-20 18:12	133M	
WASP-12b_example_raw_biases.zip	2[redacted]07:02	136M	
WASP-12b_example_raw_darks.tar.gz	2017-02-20 18:14	135M	
WASP-12b_example_raw_darks.zip	2[redacted]07:05	138M	
WASP-12b_example_raw_flats.tar.gz	2017-02-20 18:13	265M	
WASP-12b_example_raw_flats.zip	2[redacted]06:57	266M	
WASP-12b_example_uncalibrated_images.tar.gz	2017-02-20 18:35	4.3G	
WASP-12b_example_uncalibrated_images.zip	2[redacted]07:01	4.4G	
standard_transit.plotcfg	2016-03-05 02:49	132K	

Apache Server at www.astro.louisville.edu Port 443

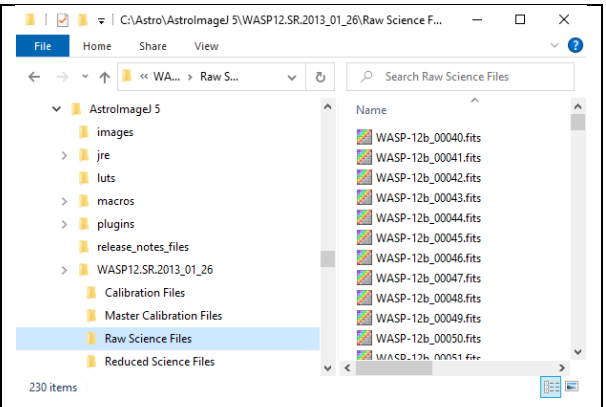
Extract files to folders:

Raw science files: C:\Astro\AstroImageJ 5\WASP12.SR.2013_01_26\Raw Science Files

Calibration files: C:\Astro\AstroImageJ 5\WASP12.SR.2013_01_26\Calibration Files



Calibration files (bias fits listed)



Raw science files

Create two empty folders for processed fits files:

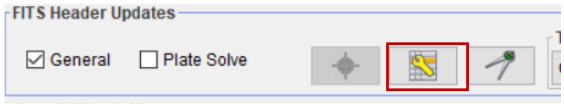
Master Calibration Files: master bias, darks and flats fits files

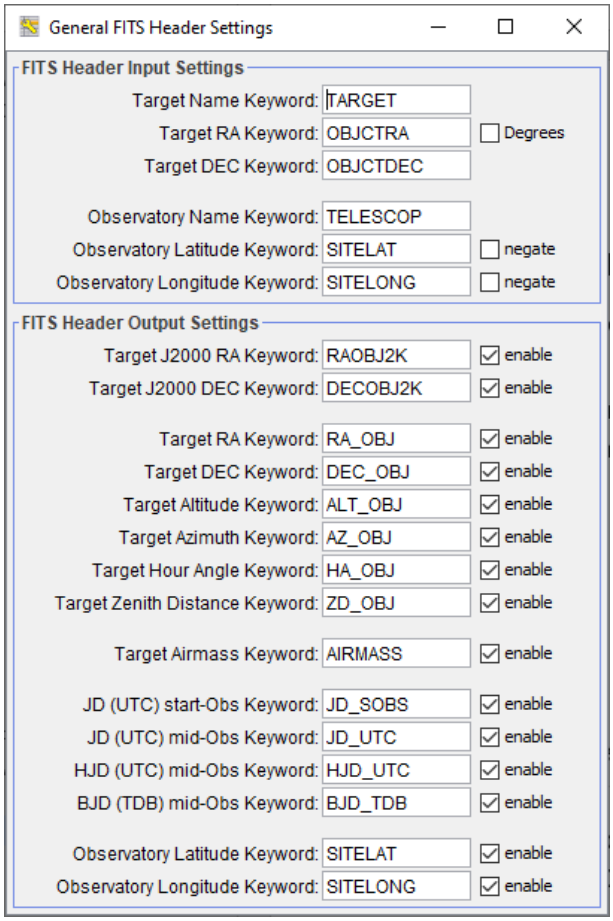
Reduce Science Files contains processed science fits files

Appendix B: Configure AstroImageJ Settings

Appendix A covers setting up Observatory ID in the DP Coordinate Converter dialog. This section covers configuring AstroImageJ to process a sequence of science images.

Open AIJ, from the toolbar, open the CC Data Processor window. In the FITS Header Updates section, click the spanner icon to open the General FITS Header Settings



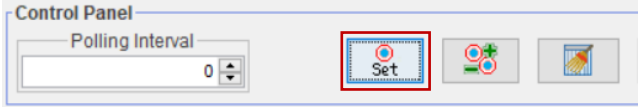


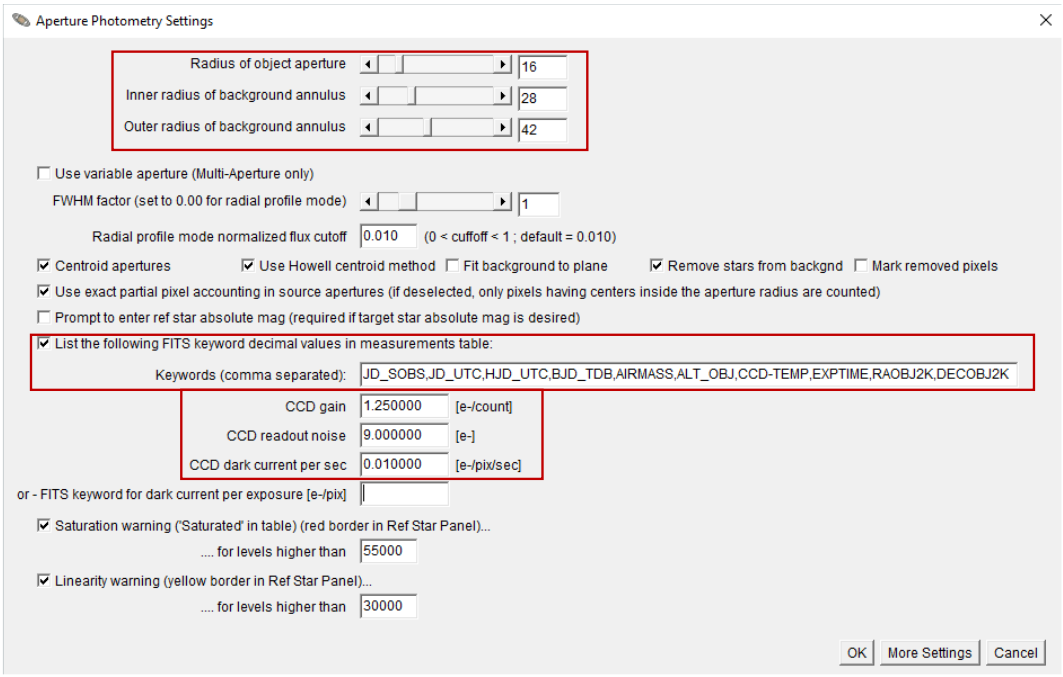
Enable all the FITS Header Output keywords as shown. The important keywords are Airmass and JD-based times, the others are informative.

The FITS Header Input Settings section is not used: Target and Observatory details are imported from the DP Coordinate Converter window.

Close the FITS Header Settings dialog.

Click the Set icon in the Control Panel to open the first of two Aperture Photometry Settings dialogs.





Aperture radius settings	16 | 28 | 42 are set in main text
JD-Keywords	JD_SOBS, JD_UTC, HJD_UTC, BJD_TDB
Exposure Keywords	**EXPTIME** or **EXPOSURE** [1]
J2K Keywords	RAOBJ2K, DECOBJ2K Target J2000 coordinates
Other Keywords	AIRMASS, CCD-TEMP
CCD data	CCD gain, readout noise and dark current, estimated values for Apogee U16M CCD used to acquire WASP12 images [2]

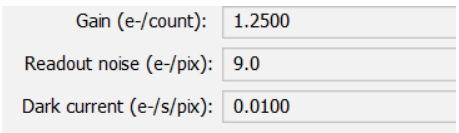
[1] If the camera software saves exposure time with keyword EXPOSURE, then *overwrite* EXPTIME with EXPOSURE in the list of keywords, as below.

[2] Enter CCD values as shown:

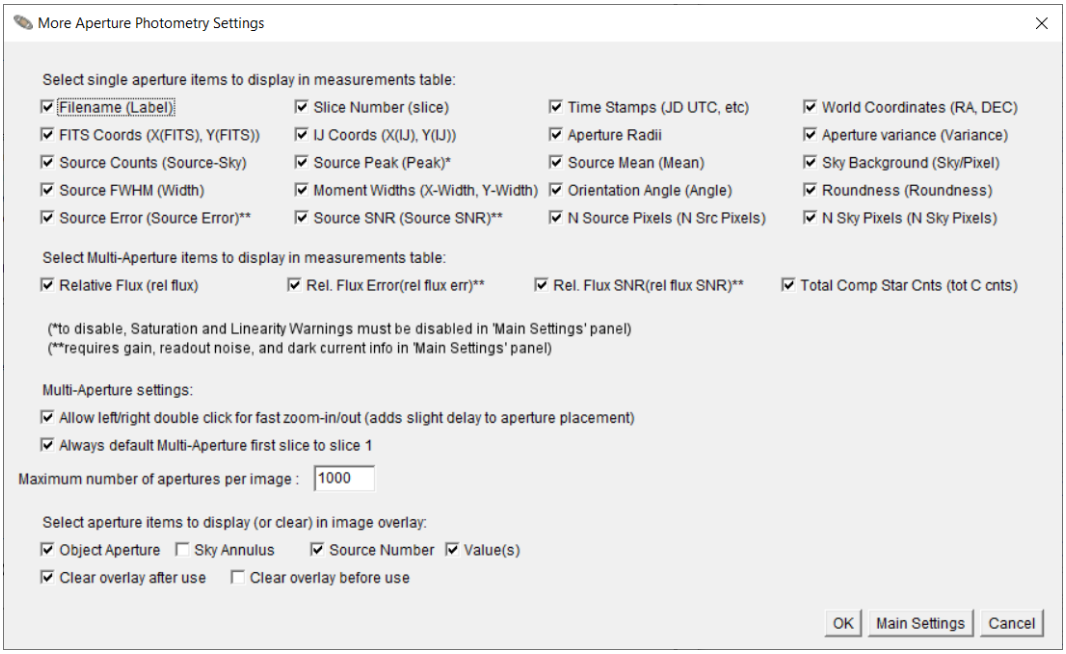
CCD gain: 1.25
CCD readout noise: 9.0
CCD dark current 0.01

Close AIJ toolbar to register these settings, re-open Aperture Photometry Settings window and confirm values have been retained.

Open the Planner plugin, select Obser tab and cross check with entries in Observer | Equipment Details as shown.



In the Aperture Photometry Settings window, click [More Settings] to open the More Aperture Settings dialog. Confirm that the *only unchecked* item is 'Clear overlay before use', all other items are selected.



AstroImageJ saves the results of photometry analysis in the form of a data table saved in measurements.txt file. Table data headers include:

	Field	**Notes**
1	EXPTIME / EXPOSURE	Exposure time in seconds. [1]
2	JD_SOBS	Julian Date at start of exposure
3	JD_UTC	Julian Date at mid-exposure
4	Label	FITS filename
5	N_Sky_Pixels_T1	No. pixels in T1 sky aperture (outer annulus)
6	N_Src_Pixels_T1	No. Pixels in T1 source aperture (centre aperture)
7	Sky/Pixel_T1	Sky background flux / pixel
8	Sky_Rad(Max)	Sky annulus outer radius (pixel)
9	Sky_Rad(Min)	Sky annulus inner radius (pixel)
10	slice	Image stack index
11	Source_Radius	Source aperture radius (pixel)
12	Source_SNR_C2	Computed SNR for first comp star
13	Source_SNR_T1	Computed SNR for target star
14	Source-Sky_C2	Sky-corrected flux for 1st comp star
15	Source-Sky_T1	Sky-corrected target flux

Appendix X: UofL Moore and ICAstronomy Data Sets

Observer Location	**Moore Observatory, KY**	**ICAstronomy, Oria**
Latitude	+38:20:41.25 38.344791	+37:30:03.96 37.5011
Longitude	-85:31:42.51 -85.528476	-02:24:29.88 -2.4083
Altitude (m)	229	1180
UTC Offset (Hr)	-5 (EST)	+1 (CET)
Observer & Equip Details		
Telescope Short Descript	MORC24	ICA_CDK14
Telescope Full Descript.	Moore Observatory 24-inch Ritchie-Chretien	ICAstronomy 14-inch CDK
Aperture (mm)	600	355
Focal Length (mm)	4800	2470
Camera	Apogee U16M CCD	QSI683
Pixel Size (H) (um)	9.0	5.4
Pixel Size (V) (um)	9.0	5.4
Array Size (H)	4096	3320
Array Size (V)	4096	2500
AIJ | Aperture Photometry Settings		
Pixel bin [1]	1 x 1	2 x 2
CCD gain (e-/count)	1.25	1.1 [2]
CCD readout noise (e-)	9.0	8.0
CCD dark current	0.01	0.01
Data set	WASP12B	WASP104
Catalog	APASS	APASS
Filter	SR (SDSS)	V (Johnson)
Start Night	2013-01-27	2020-02-27

[1] QSI683 gain is bin size dependent

[2] QSI683 gain for 2x2 bin

Observatories.txt entries (see file header for data format):

Name		Latitude		Longitude		Alt
Moore Observatory, UofL RC24, Brownsboro, KY	<t>	38.344791	<t>	-85.528476	<t>	229.0
ICAstronomy, Oria	<t>	37.5011	<t>	-2.4083	<t>	1180

<t> => <tab>