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A Guide to AstroImageJ Differential Photometry

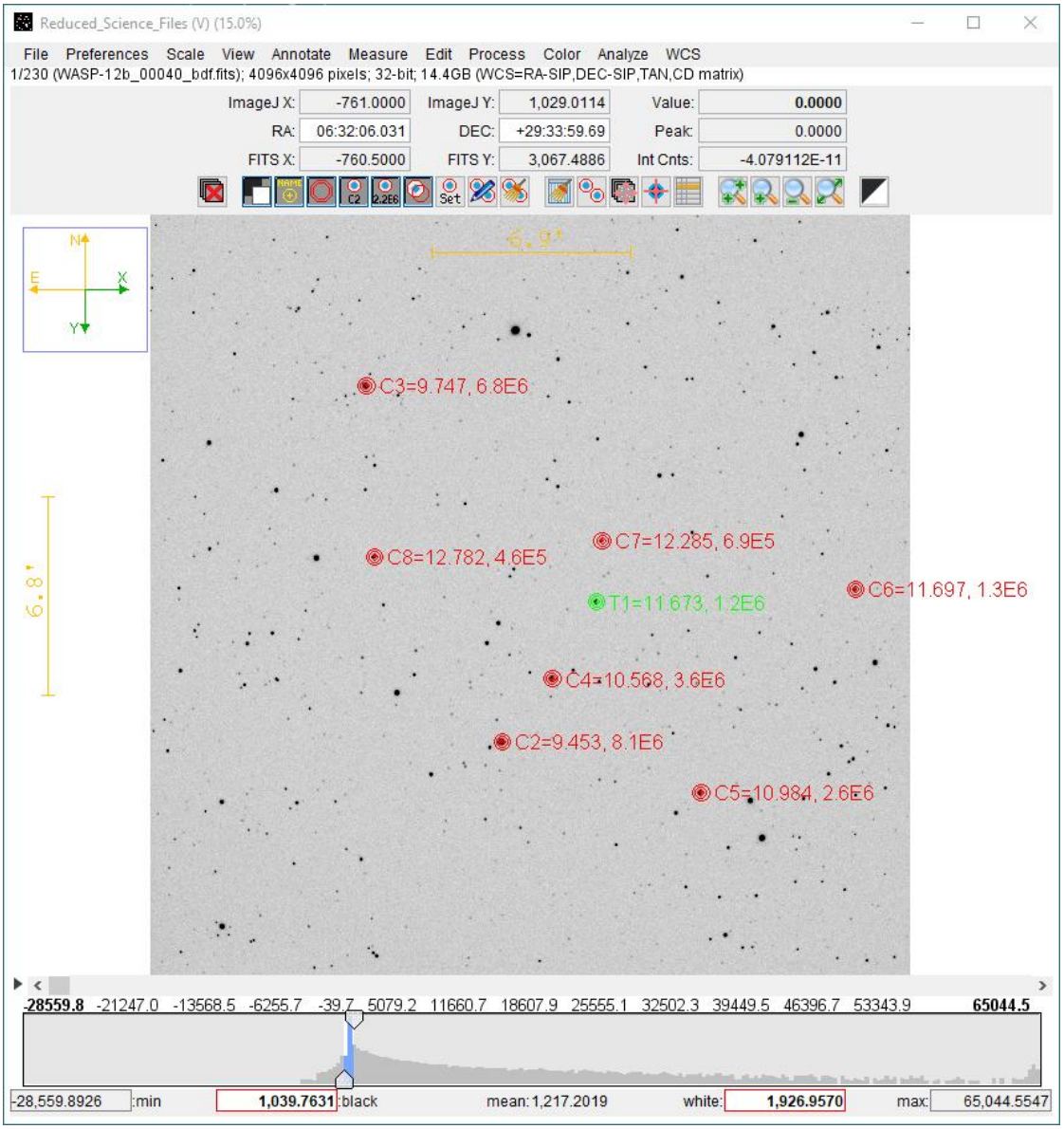

Image Display Interface with WASP-12b Target and Comparison Aperture overlay

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21 October 2018

Contents

1. Introduction

The *BAA VSS Guide to AstroImageJ Photometry* covers:

- Image reduction and photometry processing in AstroImageJ (AIJ)
- Steps in creating BAA VSS Report files from an AIJ measurements data file
- Demonstrate importing AIJ RA/Dec coordinate-based apertures into plate solved images

Chapter 10 in the AstroImageJ User Guide is a step-by-step guide to differential photometry in AstroImageJ (AIJ) based on the WASP-12b example files and is the first step in learning to use the software. The WASP-12b FITS files can be downloaded from the AIJ web site. The chapter is self-contained and can be followed without reading the entire User Guide.

This guide follows on from my article Introduction to AstroImageJ (AIJ) in the June 2018 VSS Circular. The aim is to assist BAA VSS members with some familiarity with AIJ in creating VSS report files using the example WASP-12b FITS files. The guide covers image reduction, importing photometry results and creating a BAA VSS report file using the VSS_Photometry spreadsheet.

1.1. Software Summary

Software	Version	Notes
AstroImageJ	db3.2.1	AIJ User Guide is the main software reference; there are also a number of on-line tutorials
VSS_Photometry	V2.05 (or later)	Excel spreadsheet converts AIP4WIN and AstroImageJ photometry results to BAA VSS Report files.
WASP-12b FITS files	N/A	4GB+ download of raw image and calibration FITS files. From FITS header, these images were exposed with a red filter.

AIJ performs image reduction, photometry processing and calculation of target ensemble magnitude. Results are saved to a text file, *measurements.txt*. Measurements.txt is imported into VSS_Photometry for conversion to VSS Report format.

Software, example files and documentation can be downloaded from the AstroImageJ web page http://www.astro.louisville.edu/software/astroimagej/

1.2. Comments on AIJ Tutorial Guide

1. The VSS_Photometry spreadsheet was designed for AIP4WIN photometry files and recently extended to import AIJ data. For the user, one obvious difference is how the two programs label the comparison star apertures, starting with C1 in AIP4WIN and with C2 in AIJ. For example, AIP4WIN would label four comparison apertures in sequence C1, C2, C3 and C4 while in AIJ the target aperture is labelled T1 then C2, C3, C4 and C5. VSS_Photometry follows the AIP4WIN format and in the Results sheet Comparisons are labelled C1, C2 ...
2. The aperture file used in this guide, *radec.txt,* lists J2000 coordinates and Comparison star Johnson V band magnitudes. These values were downloaded from the AAVSO VSP for WASP-12. The WASP-12b images were exposed with a red filter and, because of filter mismatch, the Results sheet in VSS_Photometry shows large (Calc-Quote) differences in the Data Checks section. In section 5, a second set of results for Landolt field SA113, exposed with a Johnson-V filter, report 'OK' Magnitude Checks for each Comparison.

2. Overview

Fig 2.1 illustrates the exchange of time-resolved photometry data between AIJ and VSS_Photometry.

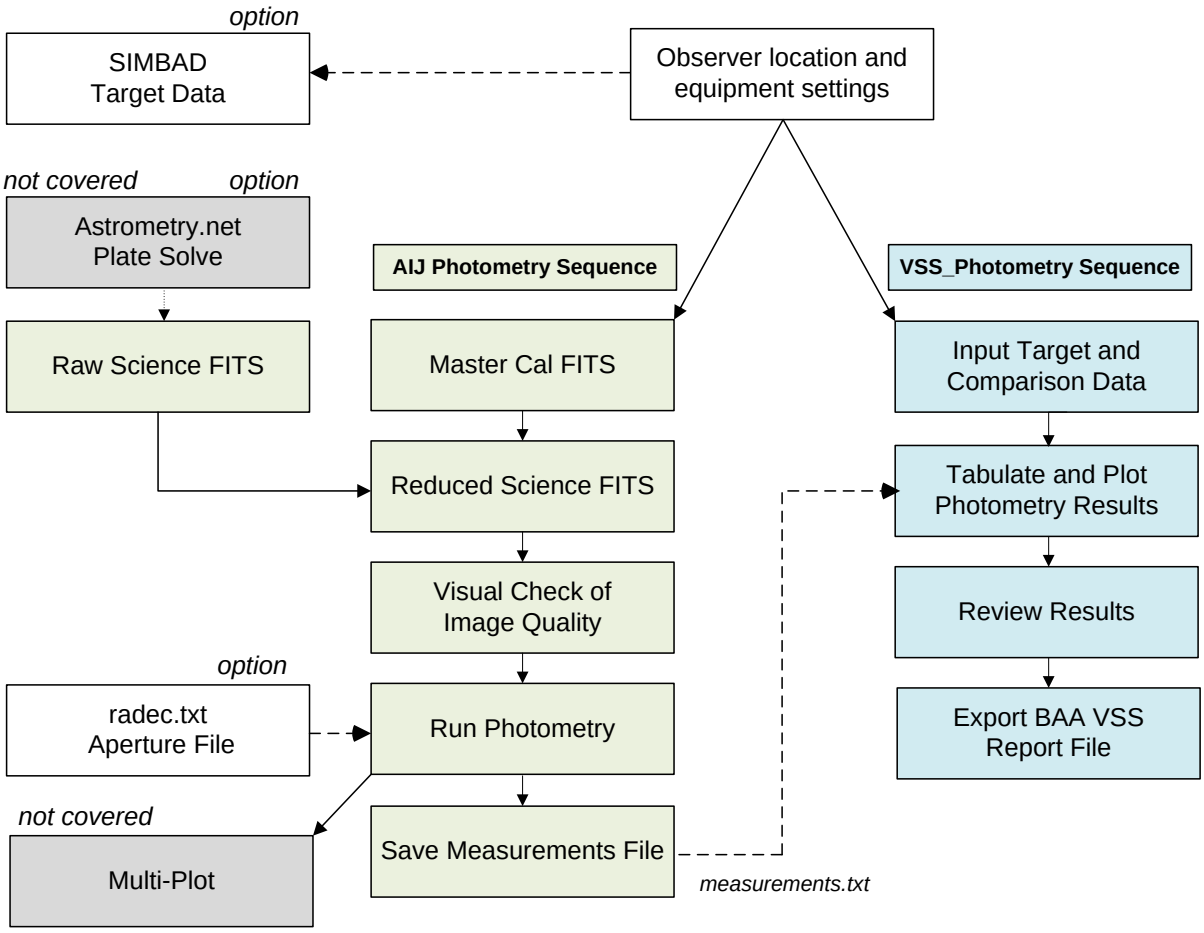


Fig 2.1:Overview of AstroImageJ + VSS_Photometry Analysis Sequence

Observer settings are covered in Appendix B. The main text walks the user through each stage from initialising target data through to creating a BAA-VSS format report file.

Plate solve option: Chapter 7 of the AstroImageJ Users Guide covers set-up and running Astrometry.net to plate solve FITS images through AIJ. The aperture file *radec.txt* comprises a list of target and comparison star RA/Dec coordinates. Importing these coordinates into AIJ enables the software to place apertures on a plate-solved image.

The WASP-12b example files are already plate solved so this step is not required to follow this guide.

Manual aperture option: Refer to the AstroImageJ User Guide and other tutorials for placing apertures on star images based on finder charts.

AIJ photometry results are saved in text file *measurements.txt*. VSS_photometry imports measurements.txt, computes target magnitude and exports a BAA VSS format results file.

While not required for BAA VSS photometry, AIJ also computes heliocentric (HJD) and barycentric (BJD) times taking DP Coordinate Converter observer and target parameters (see section 3.2 and Appendix B for setting up DP Coordinate Converter data).

3. Science Image Reduction

3.1. Software Setup

Setup directories and configure AIJ to follow this guide as detailed in the following appendices:

Appendix A: recommended directory set-up for example files.

Appendix B: configure AIJ and VSS_Photometry for Moore Observatory (University of Louisville) and equipment parameters

3.2. SIMBAD Coordinates

This section illustrates importing SIMBAD coordinates into the DP Coordinate Convert dialog.

1. Open AIJ and from the Toolbar and click DP to open the CCD Data Processor and DP Coordinate Converter windows.
2. In DP Coordinate Converter window Fig 3.1, enter "WASP-12b" in the SIMBAD Object ID text box and press <Enter> to populate Standard Coordinates fields.

   Optional: click the SIMBAD icon SIMBAD to open the SIMBAD web page for WASP-12b (Extra-solar Confirmed Planet)

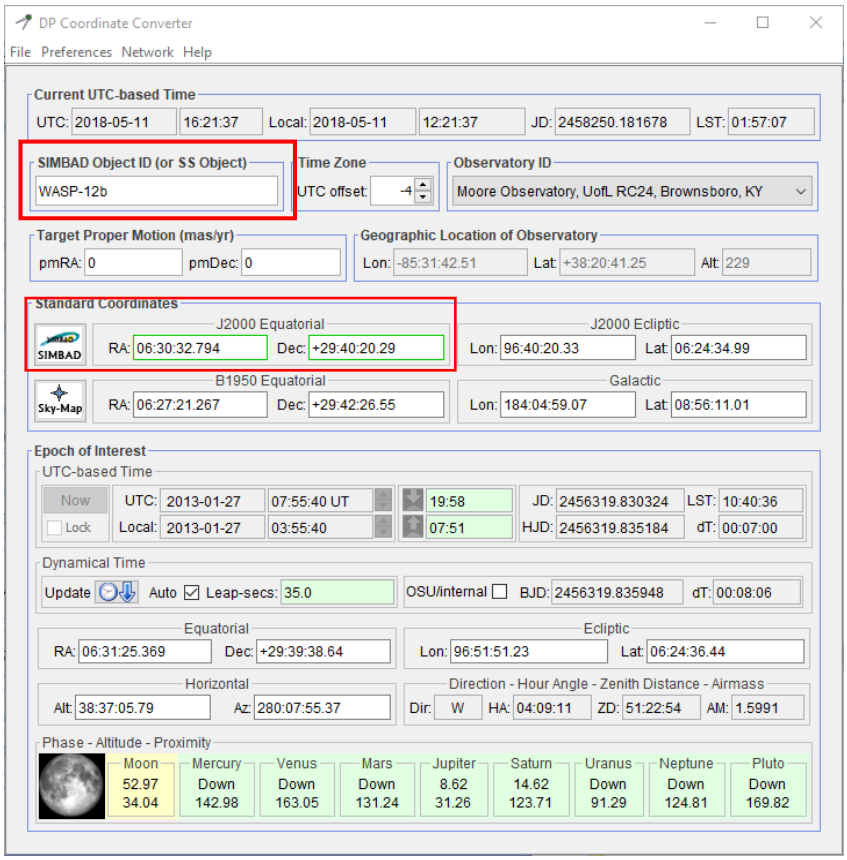


Fig 3.1: WASP-12b Coordinates in DP Coordinate Converter

3.3. Aperture File

Create *radec.txt* aperture file and save in WASP-12b folder as detailed in Appendix C.

3.4. Reduce Science FITS Files

Image reduction steps in AIJ are:

(i) build master calibration files and

(ii) run science image reduction process

1. Select the AIJ / CCD Data Processor window and configure for building master calibration files as fig 3.2
   Bias / Dark / Flat: Build and Enable selected, med (median) combine
   Dark: scale and deBias selected to enable exposure time scaling
   Note: the Science Image Processing Enable checkbox is *not* selected

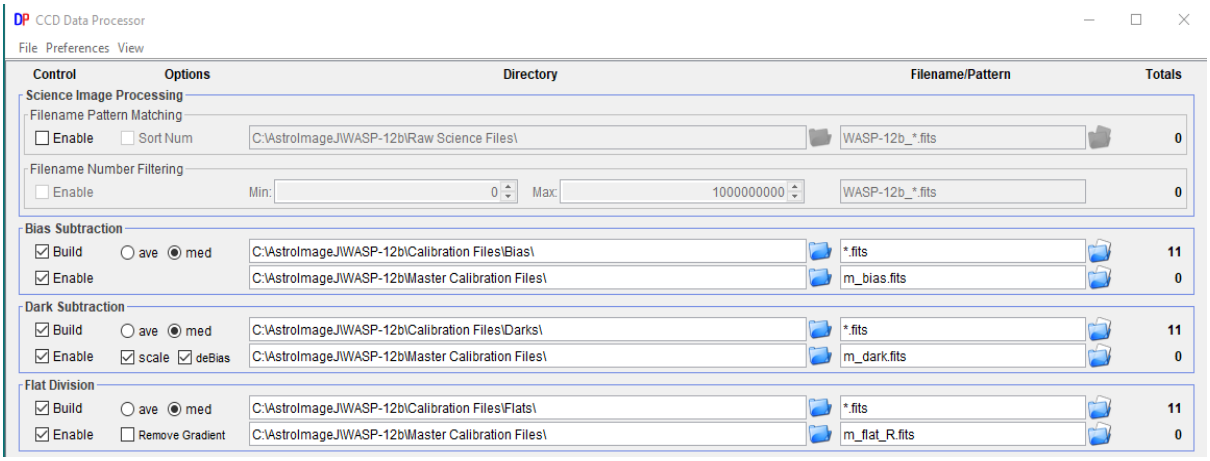


Fig 3.2: CCD Data Processor Master Calibration File Settings
Disable Science Image Processing

2. To import raw calibration files, click the folder icon and navigate to the respective calibration file directory, e.g. C:\AstroImageJ\WASP-12b\Calibration Files\Bias\, etc.
   A simple file pattern (*.fits) is sufficient if each directory contains only single file type.
   Fig 3.2 shows 11 bias, dark and flat FITS files.
3. To specify master calibration files, select the master calibration directory e.g. C:\AstroImageJ\WASP-12b\Master Calibration Files\.
   In Fig 3.2 the master calibration filenames are m_bias.fits, m_dark.fits and m_flat_R.fits.
   Totals = 0 indicates that no master calibration files have been saved yet.
   Refer section 6.5 AIJ Users Guide for details of AIJ Data Reduction Algorithms
4. Click [START] to initiate processing of calibration files; a Log window opens detailing offset and scaling corrections.
   When the process is finished, totals = 1 indicates that the master calibration files have been saved.
5. Deselect Bias, Dark and Flat Build check boxes and select the Enable checkbox in Science Image Processing section. Specify the raw image file directory and matching pattern, Fig 3.3.

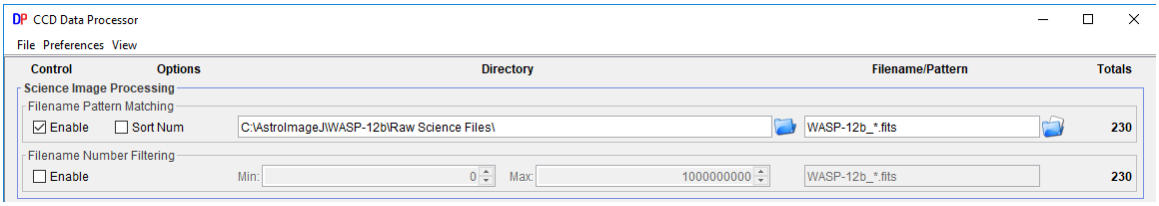


Fig 3.3: Enable Science Image Processing

6. Enable Save Calibrated Images and select 32 bit option.
   Enter “Reduced_Science_Images” and “_bdf” in the Sub-dir and Suffix textboxes respectively, Fig 3.4.
   NOTE: Option to select Plate Solve (on-line Astrometry.net plate solve, refer chapter 7 in AIJ Users Guide). Not required for WASP-12b files which are already plate solved.

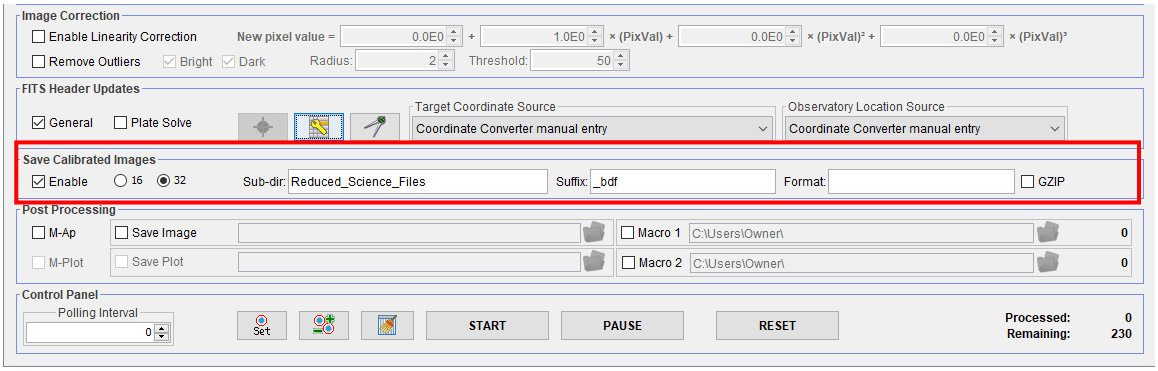


Fig 3.4: Calibrated image options

7. Click [START] to commence processing of science images. The AIJ Image Display interface opens with the first science image then cycles through each image. The Processed and Remaining counts in the CCD DP dialog monitor progress and a Log window documents the image reduction process (several minutes for WASP-12b files).
8. When processing science images is finished, close AIJ and move the reduced image files:
   From: C:\AstroImageJ\WASP-12b\Raw Sciences Files\Reduced_Science_Files
   To: C:\AstroImageJ\WASP-12b\Reduced_Science_Files

3.5. Referencing Target File Path

As an alternative to specifying full file paths, the Bias, Dark and Flat directories can be referenced to the Science Image Directory detailed in the tooltip in fig 3.5.

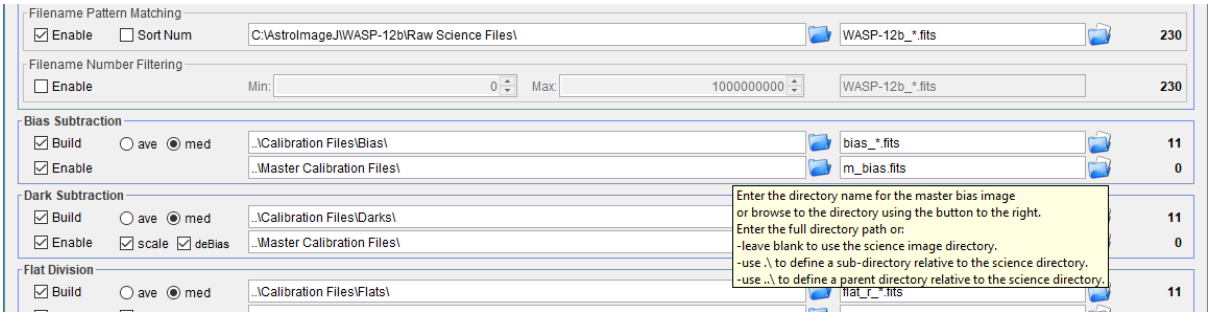


Fig 3.5: Referencing Calibration Directories

4. AIJ Photometry

4.1. Configure Measurement Apertures

1. Open AIJ and from the AIJ Toolbar, import image sequence *Toolbar | File | Import | Image Sequence* .. navigate to the Reduced_Science_Folder and select the first file (WASP-12b_00040_bdf.fits).
2. The Sequence Options dialog opens, select Sort names numerically and Use virtual stack options. Click [OK] to open the first reduced science image in the AIJ Image Display Interface, Fig 4.1.
   The yellow N-E pointers indicate this is a plate-solved image.
   Refer to chapter 5 in the AIJ Users Guide for a detailed description of available functions.

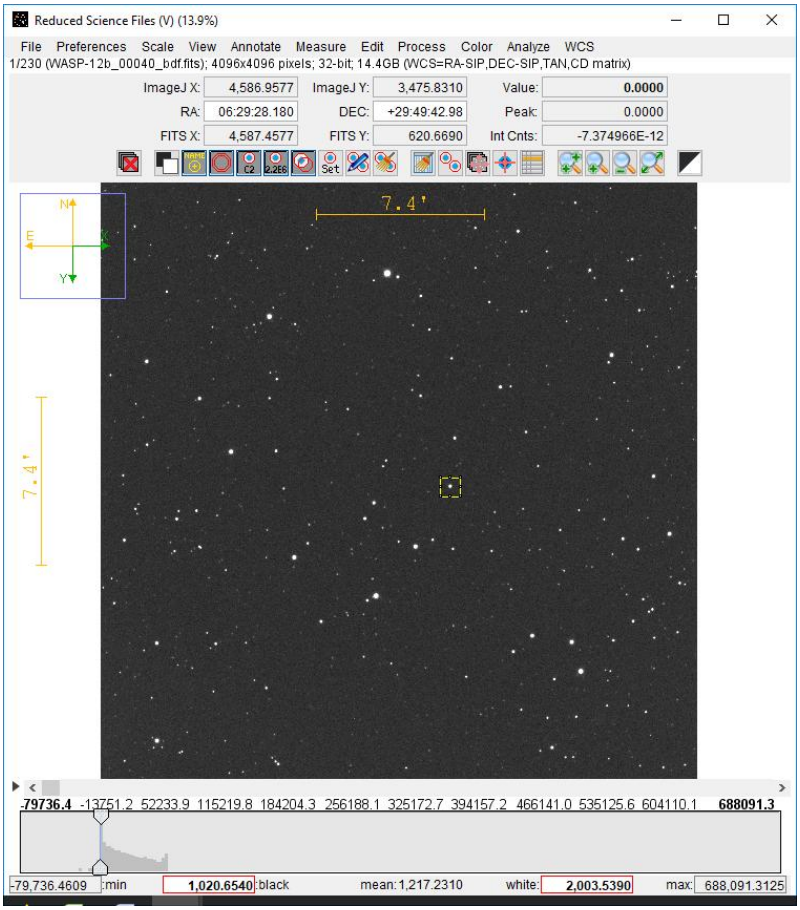


Fig 4.1: Image Display Interface: WASP-12b_00040_bdf.fits

3. Option: select View and the appropriate *Invert..* option so that N-E is orientated up and left as Fig 4.1.
4. Initial set-up of apertures sizes to measure Seeing Profile:
   Click change aperture settings  to open the Aperture Photometry Settings window.
   Enter object / inner / outer radius = 20 / 24 / 30 in and [OK] to close the window.
   Although the exact values are not critical, the object aperture must be large enough to fully enclose the image of a single star.
5. Click toggle aperture display  as necessary to *de-select* the sky background apertures so that the "Live Photometer" is a single circle overlay as shown in Fig 4.2a

6. Alt-Left click on a bright non-saturated star image – the star highlighted in Fig 4.1 is a good candidate. The Seeing Profile for the selected star opens in a new window, Fig 4.2b

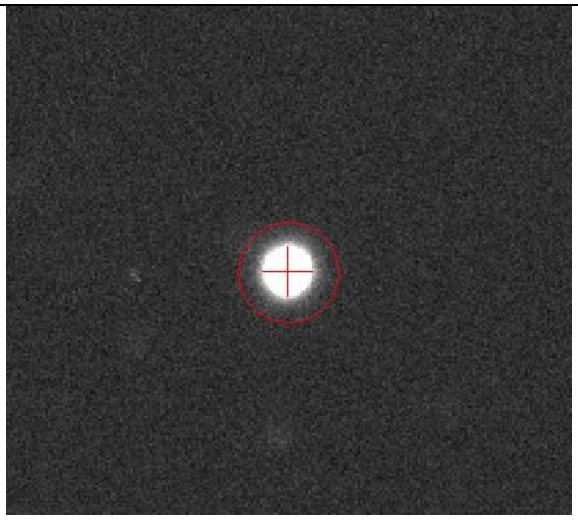


Fig 4.2a Object aperture (R = 20 pix) enclosing a non-saturated star image

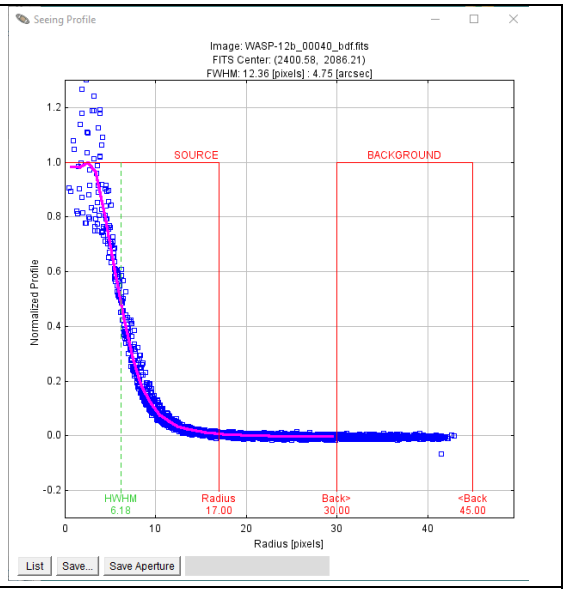


Fig 4.2b: Seeing Profile window
FWHM = 12.36 [pixel] 4.75 [arcsec]
SOURCE Radius = 17
BACKGROUND Radius = 30 | 45

7. Click [Save Aperture] in the Seeing Profile window to select the suggested aperture sizes then click 

in the Image Display window to confirm as shown in Fig 4.3.
Optionally, edit Seeing Profile generated aperture radius values to preferred values relative to FWHM ≈ 12.5 pixel.

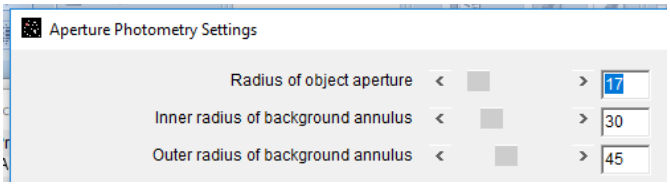


Fig 4.3: Final radius values

8. Click [OK] to close Aperture Photometry Settings window, click clear apertures ..  to clear any aperture overlays and click  to toggle display of sky apertures.

4.2. Visual Check of Image Quality

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

1. Use the scroll bar controls highlighted in Fig 4.4 to inspect individual images.
2. Click on  control left of the scroll bar to start / pause image animation.
Right click on this control to set animation speed and other options.

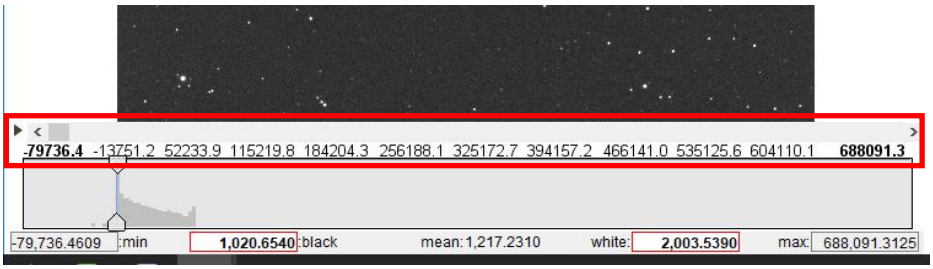


Fig 4.4: Image inspection controls

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

4.3. Run AIJ Photometry

1. In the Image Display window, select *File | Import apertures from RA / Dec list* .. , navigate to and select radec.txt file to import the aperture set. Click zoom to fit .. to re-centre the image. As shown in Fig 4.5a, initial placement will probably be offset from star centroids.

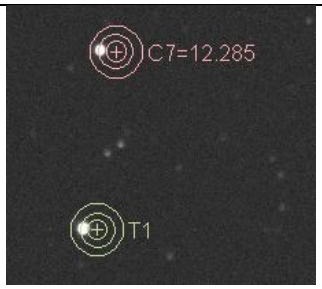


Fig 4.5a:Imported apertures

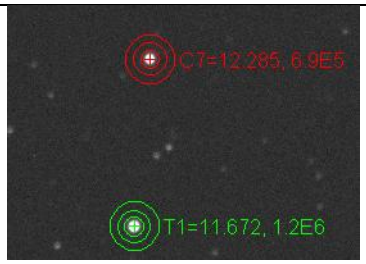


Fig 4.5b: Apertures centred on star images after [Place Apertures] in multi-aperture window

Fig 4.5: Apertures Before / After locking to star centroid
Display of aperture sky background regions is enabled

2. Open the Multi-Aperture Measurements window (in Image Display), click [Place Apertures] to centre the apertures on star centroids (Fig 4.5b); the Multi-Aperture Help dialog opens.
3. Press <Enter> to start AIJ time resolved photometry processing.
   Several windows open, including:
   Plot of Measurements: can be configured to plot relative flux and other parameters during processing. Refer section 10.2.1.10 in the AIJ Users Guide for more details about Multi-plot.
   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.
4. When processing is complete, select *Measurements | File | Save As* .. navigate to WASP-12b director and save as “Measurements.txt”, replacing existing file.
5. Close AIJ

5. Processing Results in VSS_Photometry

5.1. Setup VSS_Photometry Spreadsheet

1. Open VSS_Photometry.XLSM and select the Buttons tab.
2. Click [Select Photometry Import File] button, navigate to and select measurements.txt in the WASP-12b directory.
   The software automatically detects the photometry file format and the Type field displays: 'AstroImageJ'.
3. Click [Select Export Directory] button, navigate to and select the WASP-12b directory.
4. In BAA VSS report file name textbox, enter "BAAVSS WASP-12b.txt".
   Fig 5.1 shows the Buttons sheet with WASP-12b directory and file names, including AAVSO report file.

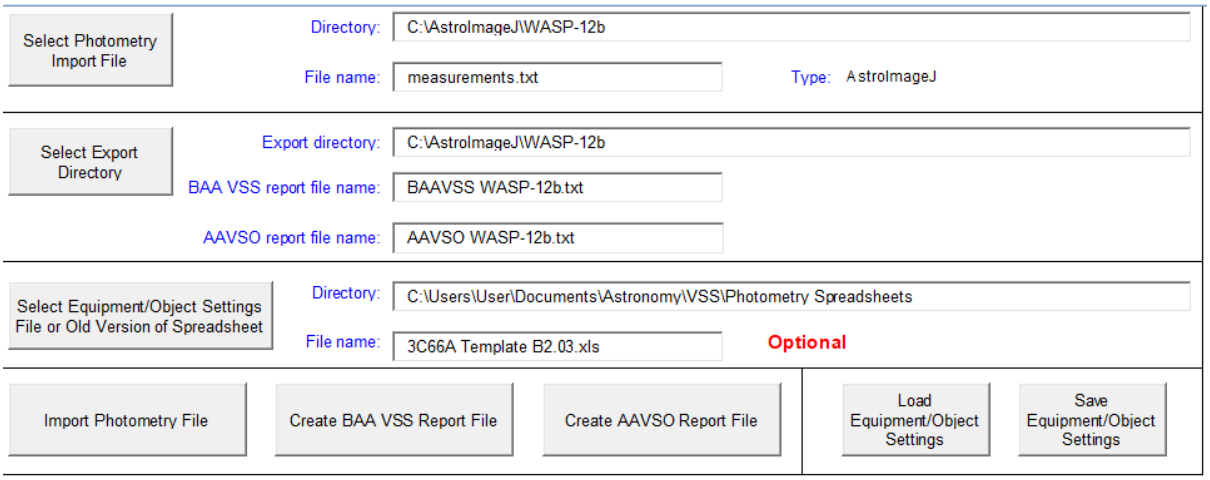


Fig 5.1: Buttons sheet configured for WASP-12b

5. Select the Results sheet, clear previous entries and enter *red-text* data as shown in Fig 5.2.
   Star Designation and Reference Magnitude values taken from *radec.txt*, see Appendix C.

Observation Summary — See columns W and X for filter explanation — Red - Required, Blue - Optional,

Chart	AAVSO WASP-12b	Star Aperture		Airr
Filter	V	Sky Annulus Inner Radius		Observa Block
Photometry Time Stamp	Start Exposure	Sky Annulus Outer Radius		Julian D
Timing Error	1.00			

Automatically populated — Check for AAVSO only

Star Data & Summary Calculations (Individual Variable Measurements to Right)

		User Input			
Type	Star Designation	AIP4WIN Star	Include in Analysis	Reference Magnitude	Error
AAVSO Results	WASP-12b	Var			
BAAVSS Results	WASP-12b	Var			
Comparison	000-BKG-164	C1	Yes	9.453	
Comparison	000-BKG-165	C2	Yes	9.747	
Comparison	000-BKG-166	C3	Yes	10.568	
Comparison	000-BKG-420	C4	Yes	10.984	
Comparison	000-BKG-421	C5	Yes	11.697	
Comparison	000-BKG-167	C6	Yes	12.285	
Comparison	000-BKG-168	C7	Yes	12.782	

Fig 5.2: Results sheet: Header and Comparison data

5.2. Import Results in VSS_Photometry

1. Select the Buttons sheet, click [Import Photometry File] button and close dialogs when data import is finished.
2. Select Results sheet Fig 5.3
   Note: The large Calc-Quoted Differences (red coloured cells) resulting from a mismatch between V-band Reference magnitudes and WASP-12b imaged with red filter (see comments in section 1.2). Refer to Appendix F for an example of reference star photometry results

Star Data & Summary Calculations (Individual Variable Measurements to Right) delete not space)

	User Input				Results				Data Checks
Type	Star Designation	AIP4WIN Star	Include in Analysis	Reference Magnitude Error	Average Magnitude	Average Error	Std Dev Magnitude	Average Weight	Calc - Quoted Difference
AAVSO Results	WASP-12b	Var			11.683	0.041	0.009		
BAAVSS Results	WASP-12b	Var			11.683	0.041	0.009		
Comparison	000-BKG-164	C1	Yes	9.453	9.556	0.041	0.002	0.395	0.103
Comparison	000-BKG-165	C2	Yes	9.747	9.739	0.041	0.004	0.323	-0.008
Comparison	000-BKG-166	C3	Yes	10.568	10.464	0.041	0.003	0.139	-0.104
Comparison	000-BKG-420	C4	Yes	10.984	10.791	0.041	0.003	0.092	-0.193
Comparison	000-BKG-421	C5	Yes	11.697	11.539	0.041	0.004	0.033	-0.158
Comparison	000-BKG-167	C6	Yes	12.285	12.257	0.041	0.004	0.011	-0.028
Comparison	000-BKG-168	C7	Yes	12.782	12.697	0.041	0.005	0.006	-0.085

Fig 5.3: Results sheet for WASP-12b photometry
V-band reference / R-filter exposures

3. To remove a comparison star from photometry analysis, click on the 'Yes' entry in the 'Include in Analysis' column and select 'No' from the drop down options
4. To select a Check star for submitting AAVSO report, click on 'Yes' entry then select 'Check'.
   In Fig 5.4, 000-BKG-420 is de-selected from analysis and 000-BKG-421 selected as the AAVSO check star.

Star Data & Summary Calculations (Individual Variable Measurements to Right)

	User Input			
Type	Star Designation	AIP4WIN Star	Include in Analysis	Reference Magnitude Error
AAVSO Results	WASP-12b	Var		
BAAVSS Results	WASP-12b	Var		
Comparison	000-BKG-164	C1	Yes	9.452
Comparison	000-BKG-165	C2	Yes	9.747
Comparison	000-BKG-166	C3	Yes	10.568
Comparison	000-BKG-420	C4	No	10.984
Comparison	000-BKG-421	C5	Check	11.697
Comparison	000-BKG-167	C6	Yes	12.285
Comparison	000-BKG-168	C7	Yes	12.782

Fig 5.4: Results sheet Yes / No / Check selections

5.3. Export BAA VSS or AAVSO Report Files

To create a BAA VSS formatted report file, select the Buttons sheet and click [Create BAA VSS Report File] button to save e.g. ..\WASP-12b\BAAVSS WASP-12b.txt.

To create an AAVSO formatted report file, select the Buttons sheet and click [Create AAVSO Report File] button to save e.g. ..\WASP-12b\AAVSO WASP-12b.txt.

6. Summary

Analysing time series photometry images in AstroImageJ is relatively straightforward: the more complex software features, including multi-plot, de-trending data and multivariate transit fit analysis, are not required for creating VSS Report files.

In addition to variable star photometry, other cases where BAA members might consider using AstroImageJ include:

- For observers who are new to stellar photometry, AstroImageJ is free to down-load with several sets of example data on the AIJ home page and other sites.
- AAVSO recommends AstroImageJ for exoplanet photometry. Chapter 7 in A Practical Guide to Exoplanet Observing (Dennis Conti) describes using AIJ for this application. This chapter also works with a WASP-12b data set and covers Multi-plot functions in detail.
- Asteroid light curve photometry: in the Multi-plot Main window, select File | Create Minor Planet Centre (MPC) format .. to create MPC formatted data.
- More experienced observers might consider AstroImageJ as an alternative to AIP4WIN, for example. The user forum is well supported by Karena Collins at the University of Louisville. AstroImageJ release notes are listed here.

Users familiar with other photometry software should find the transition to AIJ fairly straightforward. All users are encouraged to check out the AIJ website referenced in the Introduction section for a functions list, tutorials and link to the AIJ forum.

Appendix A: Example File Directories

After downloading WASP-12b raw image and calibration example files (over 4GB) set up directories as Fig A1.1.

Create and save a blank text file *measurements.txt* in the WASP-12b folder.

radec.txt is the WASP-12b aperture file used in this guide, see Appendix C.

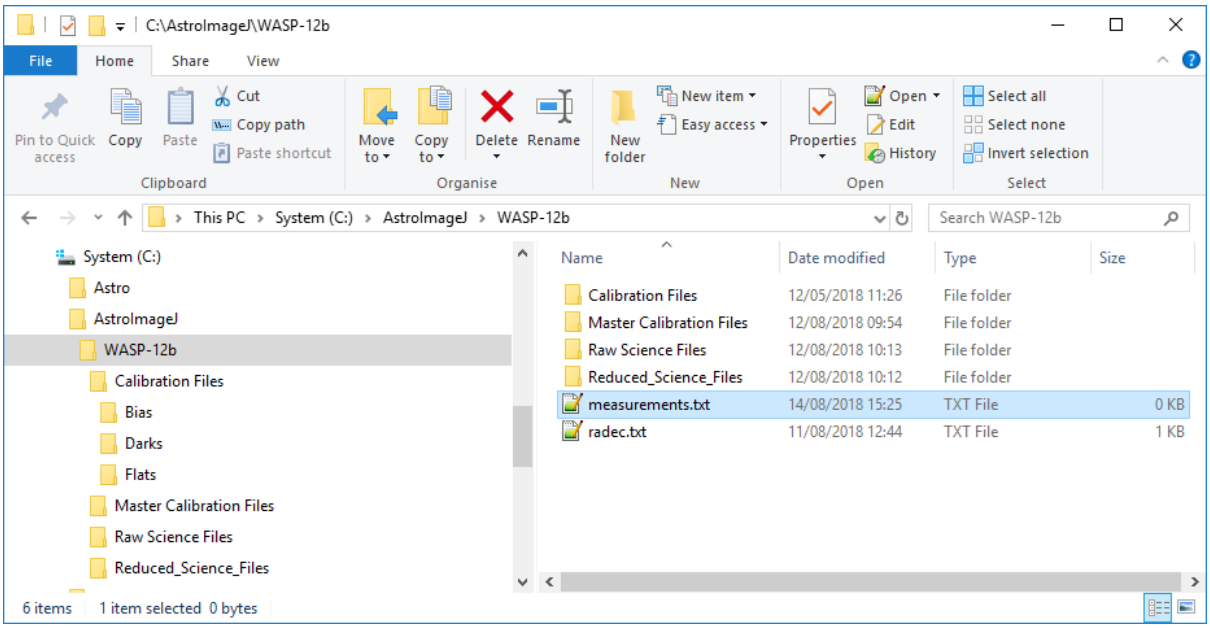


Fig A1.1: WASP-12b directories used in text

Appendix B: Configure Software

Set up observer location and equipment parameters in AIJ and VSS_Photometry, and configure multi-aperture settings in AIJ.

NOTE: Boxed sections detail important instructions for configuring AstroImageJ software.

1. Open VSS_Photometry and select ObsvEqmt sheet
2. To follow the tutorial using WASP-12b example files, input University of Louisville into Observer & Equipment fields shown in Fig B1.1 and save changes:

Observer & Equipment Details — Red - Required, Blue - Optional

Observer Details				
BAAVSS Observer Code	UOL			
AAVSO Observer Code				
Observer Name	University of Louisville, KY			
Location Details				
Location Code	No longer used			
	Deg	Min	Sec	Hem
Latitude	38	20	41	N
Longitude	85	31	42	W
Height (m)	230			
Telescope Details				
Telescope Short Description	RC 0.6m f/8			
Description	RC Optical Systems UofL MORC24			
Aperture (mm)	610			
Focal Length (mm)	4900			
Camera Details				
Observation Method	CCD			
Camera	U16M			
Pixel Size (arcsec)	0.38	0.38		
Gain (e-/ADU)	1.25			
Dark Current (e-/pixel)	0.20			
Readout Noise (e-/pixel)	9			

Fig B1.1: Details for WASP-12b example files

3. Open AIJ and from the Toolbar click DP to open the DP Coordinate Converter window.
4. In the DP CC window, click Preferences and select Use custom observatories list (...). Close AIJ then re-open AIJ and the AIJ / DP CC window
5. Click on Observatory ID and select *Moore Observatory, UofL, RC24, Brownsboro, KY*, Fig B1.1a.
6. Informative only: Edit Time Zone / UTC offset for Eastern Standard Time.

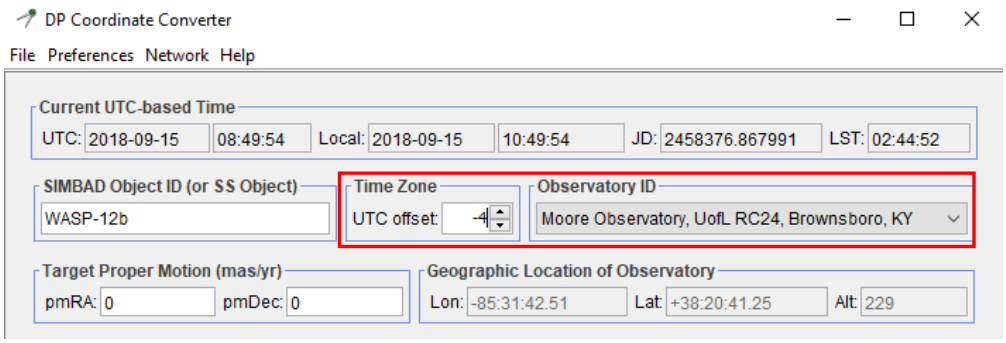


Fig B1.1a: Observatory ID and Time Zone

7. To set up a custom observatory, navigate to the AIJ home directory and edit *observatories.txt* to add a new entry formatted as specified in the file header. Close observatories.txt and save changes. The new observatory should now be available from the Observatory ID drop-down.
8. Select the CCD Data Processor window. In the FITS Header Updates section, select options:
   Target Coordinate Source: Coordinate Converter manual entry
   Observatory Location Source: Coordinate Converter manual entry

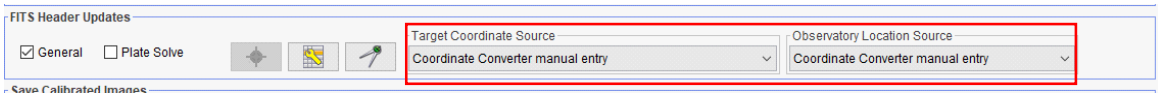


Fig B1.2: Target and Observatory data imported from DP CC settings

9. Click  to open the General FITS Header Settings panel Fig B1.3

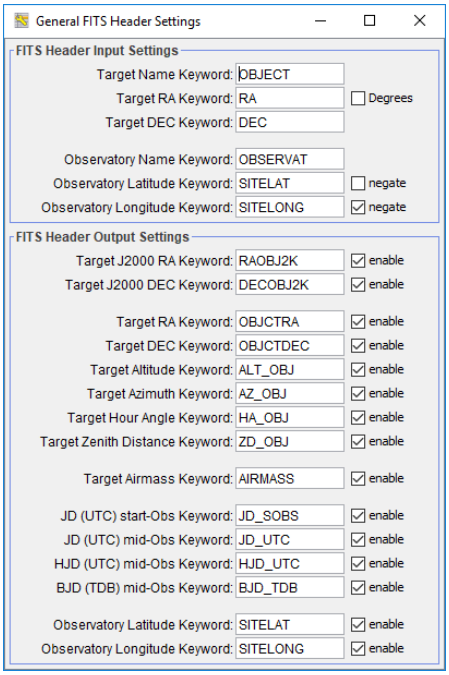


Fig B1.3: Setup FITS Header Keywords

10. 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
11. Close the FITS Header Settings dialog.

12. Click 

in the Control Panel row (bottom row) of the CCD DP window to open the first of two rather busy dialog windows, Fig B1.4.

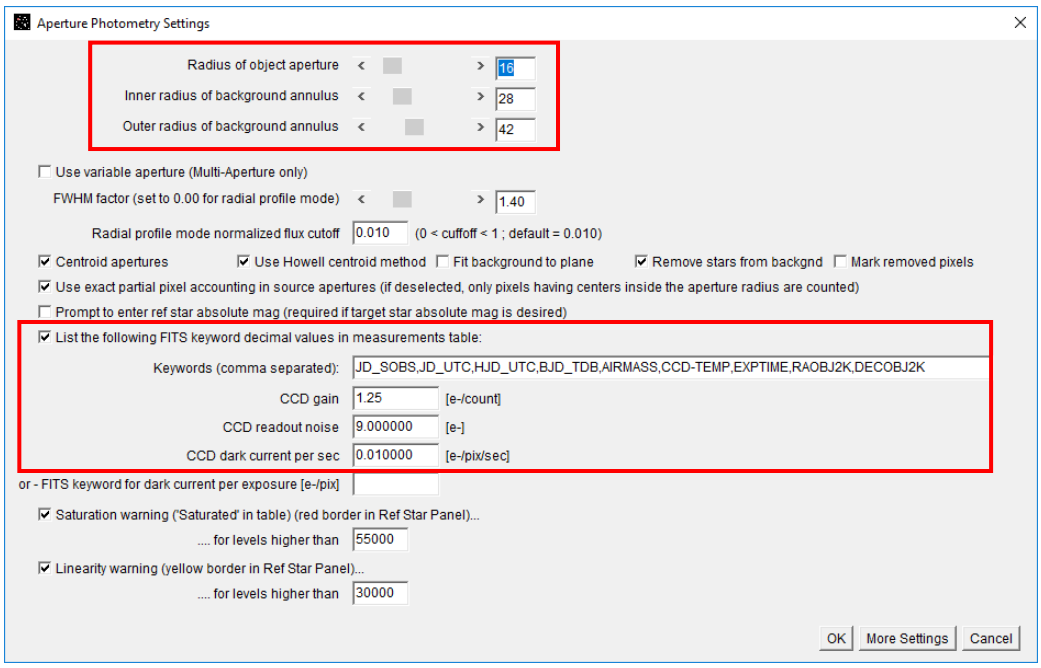
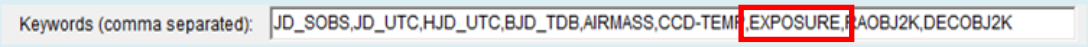


Fig B1.4: Page 1 of 2 Aperture Photometry Settings

Image Exposure time keyword:

Either **EXPTIME** *or* **EXPOSURE** are valid exposure time keyword, refer section *6.3.2.6.2 Exposure Time Source* in the AstroImageJ User Guide.

In Fig B1.4, EXPTIME is shown as the selected exposure time keyword.
If the camera software saves exposure time as EXPOSURE, then *overwrite* EXPTIME with EXPOSURE in the 'Keywords (comma separated)' text entry box as below



NOTE: VSS_Photometry v2.06 does *not* support '**TM-**' or '**UT-**' keyword options.

13. Enter values for CCD gain, CCD readout noise and pixel dark current (e-/pix/sec) listed below, estimate values for the U16M camera used for WASP-12b test images.
14. Check FITS keywords in measurements table include:
    JD_SOBS, JD_UTC,HJD_UTC,BJD_TDB,AIRMASS,CCD-TEMP,EXPTIME (***or*** EXPOSURE), RAOBJ2K,DECOBJ2K
15. Confirm check boxes are selected as indicated
    Other settings:
    Aperture radii settings in the upper section, these are set in main text.
    Below that are a number of options with default selections.
    Keywords to include in FITS header correspond to the General FITS Header settings dialog.
16. Click [More Settings] to open the second window. All except the last item are selected (Clear overlay before use).
17. Close the Aperture Photometry Settings dialog.

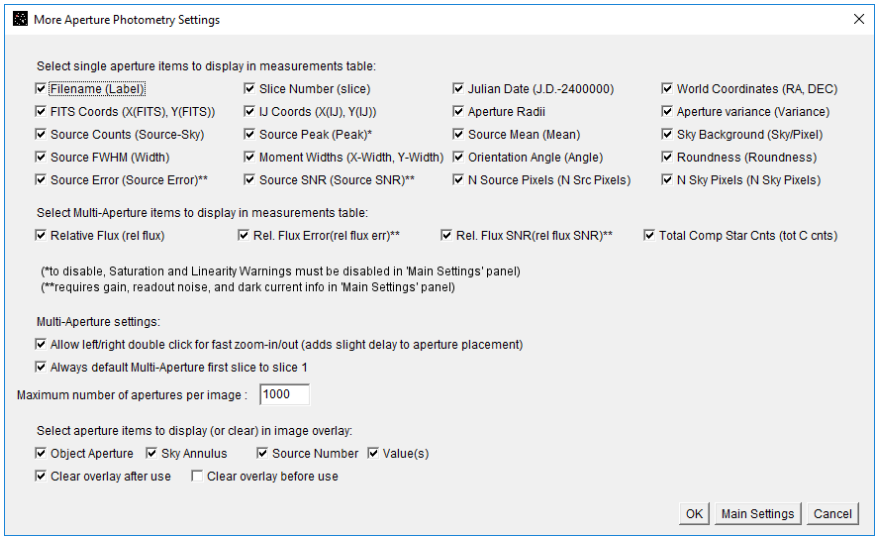


Fig B1.5: More Aperture Photometry Settings dialog

Note: Single and Multi-Aperture selections (24)

Appendix C: Target and Comparison Aperture File

Copy / Paste box text into a text editor and save as *radec.txt* in WASP-12b folder.

```
#WASP-12b, 06:30:32, +29:40:20, 0, 1, 99.999
#000-BKG-164, 06:30:47, +29:35:30, 1, 1, 9.453
#000-BKG-165, 06:31:09, +29:47:47, 1, 1, 9.747
#000-BKG-166, 06:30:39, +29:37:40, 1, 1, 10.568
#000-BKK-420, 06:30:16, +29:33:45, 1, 1, 10.984
#000-BKK-421, 06:29:51, +29:40:46, 1, 1, 11.697
#000-BKG-167, 06:30:31, +29:42:27, 1, 1, 12.285
#000-BKG-168, 06:31:08, +29:41:53, 1, 1, 12.782
#
#RA, Dec, Ref Star, Centroid, Magnitude
06:30:32, +29:40:20, 0, 1, 99.999
06:30:47, +29:35:30, 1, 1, 9.453
06:31:09, +29:47:47, 1, 1, 9.747
06:30:39, +29:37:40, 1, 1, 10.568
06:30:16, +29:33:45, 1, 1, 10.984
06:29:51, +29:40:46, 1, 1, 11.697
06:30:31, +29:42:27, 1, 1, 12.285
06:31:08, +29:41:53, 1, 1, 12.782
#
```

File format:

1st character :	'#' => comment line ignored by AIJ
RA, Dec:	J2000 coordinates in HH:MM:SS and +/-dd:mm:ss formats
Ref Star:	0 => Target, 1 => Comparison
Centroid:	1 => centre aperture on star centroid
Magnitude:	99.999 => no magnitude (target star)
	otherwise catalog magnitude (comparison star)

Appendix D: Required FITS Header Terms

The AIJ results file Measurements.txt must contain the following fields. If any are missing then attempts to import measurements data will be aborted with appropriate error message :

	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

[1] EXPTIME or EXPOSURE are valid FITS header fields for AstroImageJ data processing; VSS_Photometry v2.06 or later can import data containing either keyword.

Appendix E: AstroImageJ Windows Installation Packages

Link to AIJ installation packages (if this link fails, then an internet search for "AstroImageJ" should locate the home page and download links):

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

NOTE: Boxed sections detail important instructions for installing AstroImageJ software.

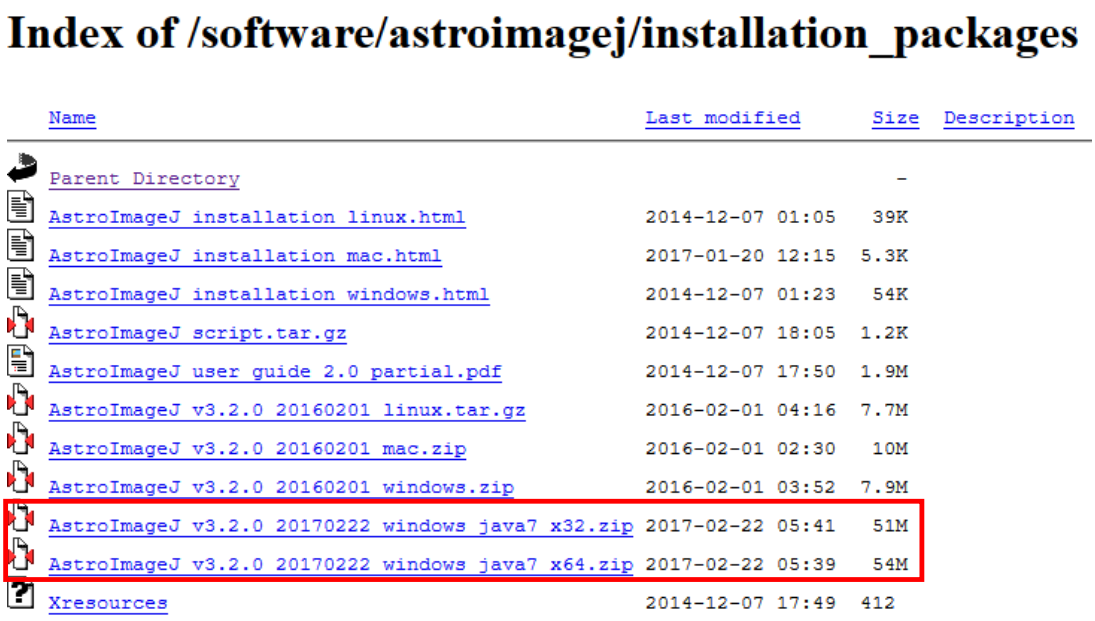


Fig E1: AstroImageJ Installation Packages

The highlighted links will download either Windows 32 or 64 bit versions plus a copy of the Java runtime engine. The next figure shows a typical installation:

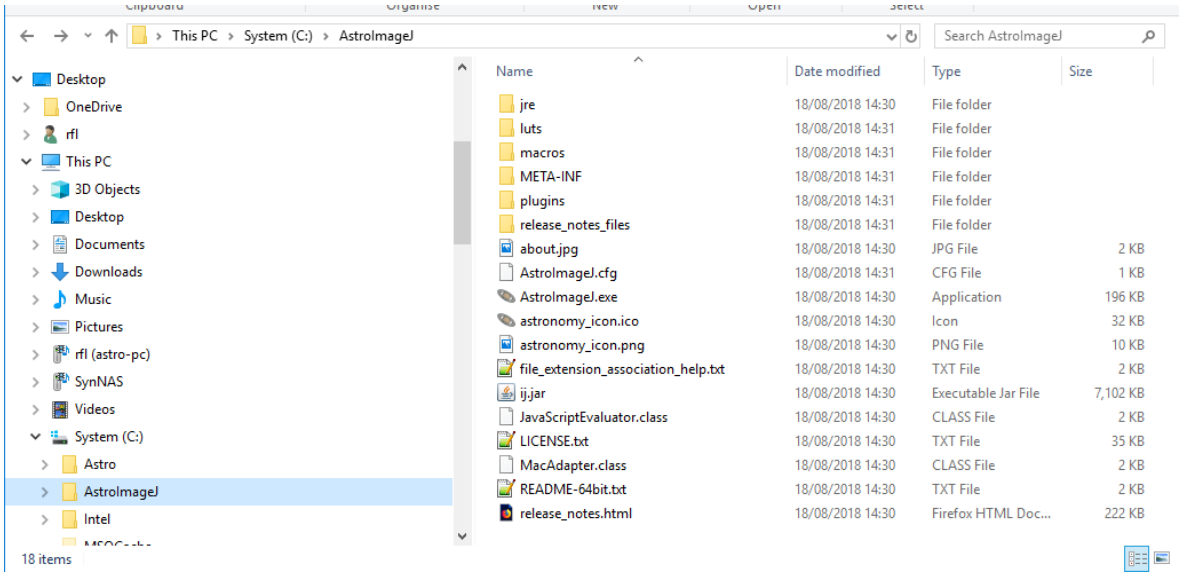


Fig E2: AIJ Installation

Folder jre contains the java runtime engine. File AstroImageJ.cfg is a short text file which is created when AIJ is run for the first time. A Windows Defender Firewall dialog may open, select [Allow access], close and re-open the AstroImageJ toolbar.

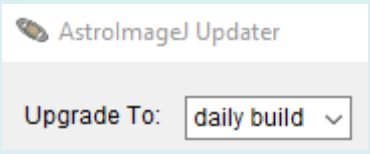
Update AstroImageJ to db3.2.1 or later:

Installed version:

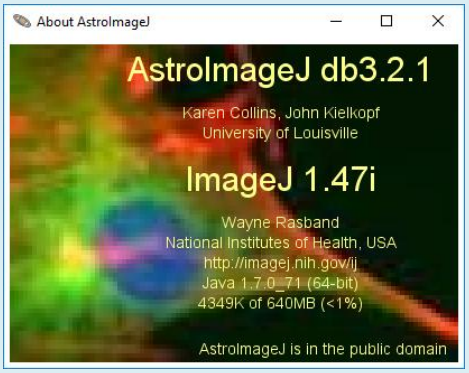
AstroImageJ Toolbar => Help => About AstroImageJ ... to open dialog with installed version

Update to the latest daily build:

AstroImageJ Toolbar => Help => Update AstroImageJ... scroll the Upgrade drop-down **UP** to select daily build option



Close and re-open AIJ, and confirm version upgrade.



Link to the WASP-12b example files; Windows users can download the large *WASP-12b example uncalibrated images.zip* file (4.4GB)

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

Note: AIJ can run from a USB memory stick configured with the installation files and directories in Fig E2

Appendix F: V-Band Photometry of Landolt Reference Stars

Fig F1 shows the results of an imaging series taken with a V-Johnson filter. The Calc-Quoted Differences are less than 0.015 mag and all Magnitude Checks are flagged 'OK'.

The SA113 objects are Landolt reference stars with mmag uncertainties in catalog V-band magnitudes.

Star Data & Summary Calculations (Individual Variable Measurements to Right) delete not space) BAAVSS sheet and AAVSO sheet

	User Input					Results				Data Checks (Cells Turn Red when Limit Exceeded)			
Type	Star Designation	AIP4WIN Star	Include in Analysis	Reference Magnitude	Error	Average Magnitude	Average Error	Std Dev Magnitude	Average Weight	Calc - Quoted Difference	Min Magnitude	Max Magnitude	Magnitude Check
AAVSO Results	SA113-339	Var				12.241	0.004	0.005			12.248	12.231	
BAAVSS Results	SA113-339	Var				12.241	0.004	0.005			12.248	12.231	
Comparison	SA113-259	C1	Yes	11.742		11.745	0.004	0.002	0.445	0.003	11.748	11.743	OK
Comparison	SA113-233	C2	Yes	12.398		12.407	0.004	0.004	0.198	0.009	12.412	12.398	OK
Comparison	SA113-260	C3	Yes	12.406		12.393	0.004	0.003	0.202	-0.013	12.399	12.388	OK
Comparison	SA113-239	C4	Yes	13.038		13.041	0.005	0.005	0.084	0.003	13.048	13.029	OK
Comparison	SA113-250	C5	Yes	13.160		13.154	0.005	0.007	0.071	-0.006	13.167	13.140	OK
Comparison													

Fig F1: Results sheet for SA113 photometry
V-band reference / V-filter exposures

Appendix Z: Document Change Record

Revision Date	Notes
15 Sept 2018	Initial release
20 Oct 2018	Changes to Appendices to assist installing AstroImageJ, updating to db 3.2.1 and Aperture settings required to import data into the VSS_Photometry spreadsheet. Key instructions are highlighted in blue-shaded text boxes, including EXPTIME / EXPOSURE conversion implemented in VSS_Photometry v2.06 Extended list of FITS header terms in Appendix D
21-Oct-2018	Changes following user comments: Section 2: clarify plate solve is optional and highlight manual aperture placement (latter option is covered in AIJ Users Guide) Section 4.1, optional setting N-E orientation Section 5.2: Add Fig 5.4 and text to illustrate Yes / No / Check selections in 'Include in Analysis' column. Add option to save AAVSO report file and move Landolt reference star photometry to Appendix F