Exoplanet Atmospheric Characterization Project:

Updated: 5/5/17

**The Standard Procedure**

**1) Make a good target list**

'Good' is as defined by standard astronomical restrictions (RA/Dec, star brightness) and specific project restrictions (confirmed planet status, planet/star radius ratio, planet period, total planets in system).

A good resource for vetting project candidates is on the web at:

exoplanetarchive.ipac.caltech.edu/ in the "Confirmed Planets" link under the "Working with Data" header.

A good resource for calculating the observable transit times is also on the web at: astro.swarthmore.edu/transits.cgi

**2) Take multi-filter photometry of an exoplanet transit event**

General rules to follow are:

i) Clear sky is the highest preference for target selection

ii) Ideally observe for twice the length of the transit centered on the midtransit time, but partial transit observations are worthwhile

iii) Switch filters every new exposure on a target (gruzigruzi...) (repeated observations in one filter severely hinder other filter analysis)

iv) Target aquisition and defocusing is required for all targets. For a how-to guide please see defocusing\_notes.txt

v) See the WIRO Supplement, supplement.txt, for guidance on WIRO specific questions (weather limits for the project and how-to's for observatory control)

vi) Make sure that in the log file for the night's observations that each image has both the filter and exposure time recorded

**3) Calibration of the Science Images**

*Warning: never cut or mv original data from horatio, only copy (cp) it.*

Always name directories of data with the date observed, target, and filter as applicable

Copy all images taken in the night to a local directory and seperate them into subdirectories by filter (putting any bais, darks, and seperated flats in independent directories also).

[If new calibration images have been created use the python routine bias\_run.py in the directory of bias images (biases must be named bias###.fit). After the masterbias is created copy that into the darks directory and run dark\_run.py in the directory (darks must be named dark###.fit). After the masterdark is created copy the masterdark and master bias into each flat directory and run fltmkr.py (flats must be named flat###.fit).]

Copy the most recent masterbias.fit, masterdark.fit, and the normalizedflat.fit of the correct filter to the corresponding filter directory for the science images. Then run justscience.py (science images must be named a###.fit). a###bdft.fit are the calibrated science images that are ready to be put in AIJ, for simplicity move them to a subdirectory named 'filter\_name'\_calibrated.

To rename images use the rename command. An example of renaming all files in a given directory that start with 'image' to 'bias' is shown here: >>rename image bias image\*.fit

**4) AIJ data reduction**

*Always save a screenshot example of each filter's final AIJ comparison stars and target star arrangement*

Open AstroImageJ with the terminal command >>aij. Load in the images by going to the File tab>Import>File Sequence and double-clicking on any calibrated image in your calibrated directory. Press OK on the 'Sequence Options' popup\*.

A new popup of the set of images will appear, if needed manually input the black/white (typically 0/10,000) inputs to actually see the image features (this adjustment will not stay if/when you switch images).

If the telescope was moved at all during the exposure use the 'align stack using apertures' button (grey boxes behind red arrows) to help AIJ out before doing photometry. The important points of the 'Stack Aligner' popup are the aperture and annulus sliders and the 'Use previous n apertures' box. The alignment happens by finding a set of star psf's in each image so set the aperture and background annulus based on your target and comparison star psf sizes. If your previous alignement/photometry was on the same target+night click the 'Use previous' box to hasten the next step. Click OK when you are ready to move on from the 'Stack Aligner' popup and left-Click to add target/comparisons interactively on the image and enter to run the alignment. (If the alignment cannot find the solution for an image, restart the alignment from the unsolved image with the 'align stack using apertures' button and click on the target star again. This will continue the solving uninterupted.) When the solving ends all aligned images will be in a subdirectory named 'aligned'.

To do the photometric reduction click on the 'preform multi-aperture photomety' button (two red circles with blue circles inside). The 'Multi-Aperture Measurements' popup will come up and the most important points are again the object aperture, background annuli and the 'Use previous n apertures' box. Click 'Place Apertures' and left-click the target star and then comparison stars before pressing enter to let the photometry run.

The first thing you have to do is find the 'Multi-plot Main' popup and change the Left and Right boxes under the 'Fit and Normalize Region Selection' section. Left and Right correspond to the ingress and egress of the transit in fractional Julian Day. Once this has been done you can look at the 'Plot of Measurements' popup. Go to the 'Multi-plot Y-data' popup and make sure the 'Fit Mode' for your target star is |- -| (normalizing out of transit) and trend selected for AIRMASS and X(FITS)\_T1 and Y(FITS)\_T1. Once you have updated the ingress/egress and the transit looks appropriate you can change the ‘Fit Mode’ to |-u-| (the full in & out transit fit). In the new popup tab, “Data Set 1 Fit Settings” change the orbital parameters and host star parameters to approximate values so the transit displays correctly in the Plot tab. Once you are happy with your data click the blue down arrow under 'New Col' in the target star row in the 'Multi-plot Y-data' popup. Press OK in the popup and then find the 'Measurements' popup and copy the data to a calc file. Before saving/closing the calc file make a copy the JD\_UTC (always 6th column) and rel\_flux\_T1\_dn & rel\_flux\_err\_T1\_dn (always last two) columns just below the left side of the data square with a record of the 'Midtransit=xxxxxx' just above this 3xn array. The data files must be saved as '(filter)\_yymmdd.(txt/ods)'.

Finally make a text copy of this lower data with the Midpoint line commented out with a '#'. Examples of the calc and txt files can be found in example\_data.ods and example\_data.txt.

\*If you have sets of images in the directory that you do not want to include (ie. non-calibrated images or images of another filter) use the rename command to distinguish them by name from your desired images and the Sequence Options popup "File name contains" input box to only include desired images.

**5) BatHammer mcmc analysis**

First create a priors text document of 7x3 guesses with one-sided range of allowed space (tiff, period, r, a, inc, ecc, w) with labels as 1st column, values as 2nd column, and one-sided range as 3rd column. Find the priors by looking them up in a trusted data source (eg. caltech exoplanet catalog) and giving the exoplanet radius a "large" allowed space. An example prior is in this directory.

Once the prior, and all desired text data files are located in a directory use the command:

>>python BatHammer.py (filter)

to combine all nights of a given filter.