MAOPhot 1.1.4

Welcome to MAOPhot 1.1.4, a PSF Photometry tool using Astropy 6.1.6 and Photutils 2.0.2

1.1.4 Changes

1) Support for APASS DR10
2) Added Setting: Max qfit , ['qfit' is quality of PSF fit, lower number is better fit]
3) Added Setting Min Separation Factor [this x FWHM = the minimum distance (in pixels) such that any two sources separated by less than this distance will be placed in the same group]
4) Added Setting: "From Fits" checkbox for CCD Filter; when unchecked user can manually override FILTER value in Fits header
5) "Find Peaks" and "Iterative PSF Photometry" now uses DAOStarFinder
6) In APASS DR10, remove any entries with Johnson (V) > maglimit until cgi-bin/apass_dr10_download.pl is fixed
7) Use mouse wheel and shift-mouse wheel to scroll

Introduction

Aperture photometry and Point Spread Function (PSF) photometry are two widely used methods for measuring the magnitude of stars or other stellar objects. Here's how they differ:

1. Aperture Photometry
    a. Definition:
        i. Aperture photometry involves summing the light within a circular (or elliptical) aperture centered on the star and subtracting the background light estimated from an annulus around the aperture
    b. Advantages:
        i. Simple and straightforward to implement
        ii. Works well for isolated stars with little contamination from nearby stars or artifacts
    c. Disadvantages:
        i. Less effective in crowded fields, where light from nearby stars may contaminate the aperture
        ii. Accuracy depends on the choice of aperture size; a large aperture captures more light but also more background noise, while a small aperture might miss some of the star's light
        iii. When stars are blended it is obviously impossible simply to sum the CCD data-numbers corresponding to the image of each star and then to subtract an allowance for the diffuse sky emission. (Stetson 1986)
    d. Usage:
        i. Suitable for relatively uncrowded fields and for stars with a relatively high signal-to-noise ratio (SNR).
2. PSF Photometry
    a. Definition:
        i. PSF photometry models the star's light distribution as a mathematical function called the Point Spread Function (PSF), which describes how the star's light

spreads across the detector. The PSF is then fitted to the star to determine its total flux, accounting for overlaps with nearby stars

ii. If nature has attempted to confuse us by blending the light of two or more stars, we retaliate by fitting a model in which two or more of the expected stellar profiles are superimposed: each model stellar profile is shifted in χ and y and scaled in intensity, and one or more parameters describing the local distribution of diffuse sky light are varied, until a satisfactory fit of the overall model to the image data is achieved. (Stetson 1986)

b. Advantages:
   i. Excellent for crowded fields, as it can deconvolve the light from overlapping stars
   ii. Provides more precise measurements, especially in dense star clusters or regions with significant background contamination
c. Disadvantages:
   i. More computationally intensive and requires accurate modeling of the PSF
   ii. Sensitive to systematic errors if the PSF model does not accurately represent the actual star profiles
d. Usage:
   i. Ideal for dense stellar fields, such as globular clusters or the cores of galaxies

This program was derived from "MetroPSF" by Maxym Usatov. It has been renamed and extended to produce AAVSO reports exclusively and to facilitate generating an effective PSF for PSF photometry.

MAOPhot calculates stellar magnitudes from FIT formatted digital photographs using PSF photometry. It produces an extended AAVSO (American Association of Variable Star Observers) report (https://www.aavso.org/aavso-extended-file-format) which can be submitted to AAVSO using their online tool WebObs (https://www.aavso.org/webobs).

MAOPhot uses the PSF (point spread function) Photometry exclusively.

MAOPhot is written in Python using Astropy (a common core package for astronomy). MAOPhot also uses Photutils. See "PSF Photometry" which describes many of the classes and methods used in MAOPhot. (https://photutils.readthedocs.io/en/stable/user_guide/psf.html)

MAOPhot has been redesigned for AAVSO reporting only and includes, but is not limited to the following enhancements:

- uses Astropy 6.1.6 and Photutils 2.0.2
- generation of an Effective PSF model (EPSF model), and the ability to create a 'rejection list' of stars that the user can select that will not be part of the EPSF model generated
- option to use a Gaussian PRF (Pixel Response Function) as model
- Uses Iterative PSF Photometry, an iterative version of PSF Photometry where new sources are detected in the residual image after the fit sources are subtracted
- PSF Photometry using an ensemble of comparison stars or a single comp star

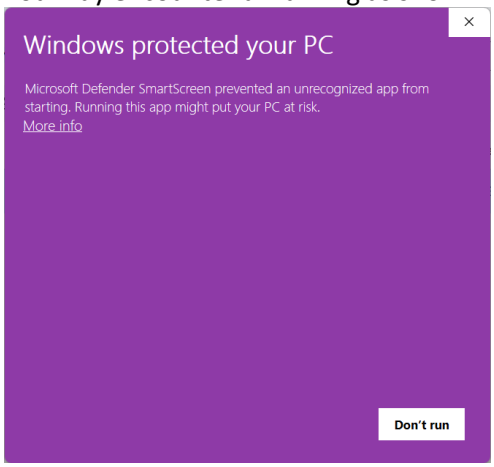
- generation of Two-Color Photometry (B, V), (V, R) or (V, I), and Single Image Photometry reports in AAVSO extended format
- use of telescope Transformation Coefficients (needed for Two Color Photometry)
- user can specify check star and list of comp stars
- manually select a star for measurement
- intermediate results are saved as .csv files
- optionally enter an AAVSO Chart ID when retrieving comparison star data

System Requirements

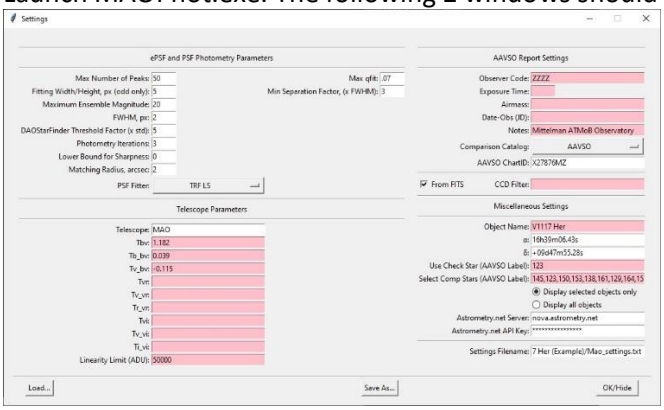
1. MAOPhot presently only runs on Windows 10 or 11
2. 8 GB of memory and 1 GB storage

Installation

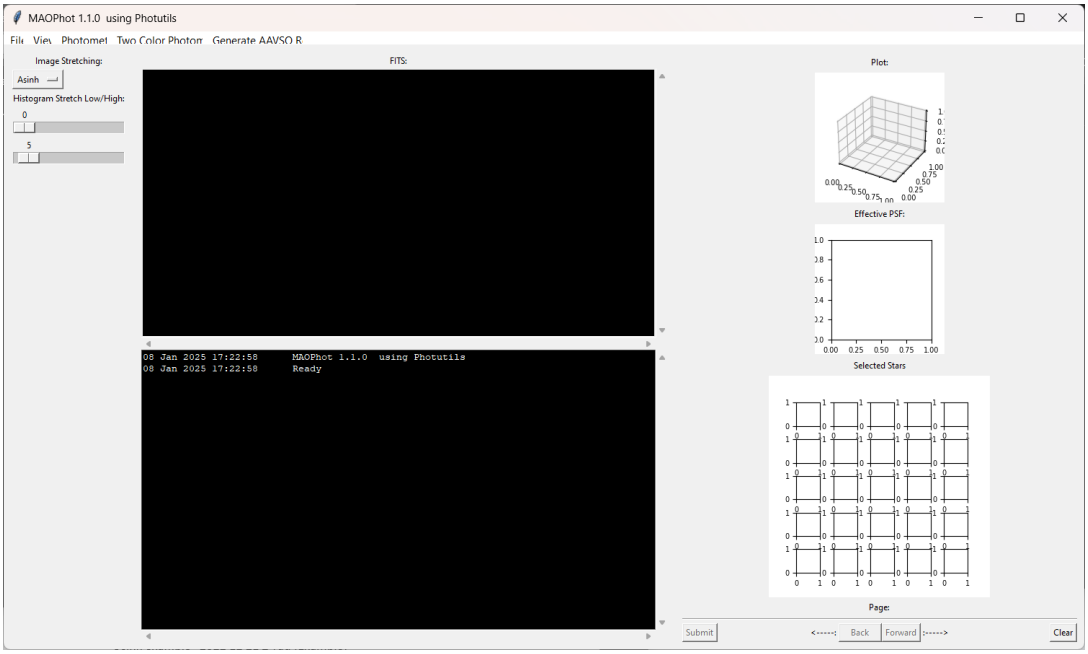
1. Goto https://github.com/petefleurant/PSF-Photometry/releases
    a. Under MAOPhot 1.1.4 scroll down to Assets.
    b. Download file “MAOPhot_SETUP.exe” (override any download warnings)
2. Execute MAOPhot_SETUP.exe on your local machine
    a. You may encounter a warning as shown in the following illustration (Windows 11)



    b. Select More Info, then Run
    c. Allow “Unknown Publisher to make changes to your device”
    d. Accept License agreement (MIT License that comes with most python applications)
    e. Select Destination Directory
    f. Proceed to install MAOPhot
3. Launch MAOPhot.exe. The following 2 windows should appear:



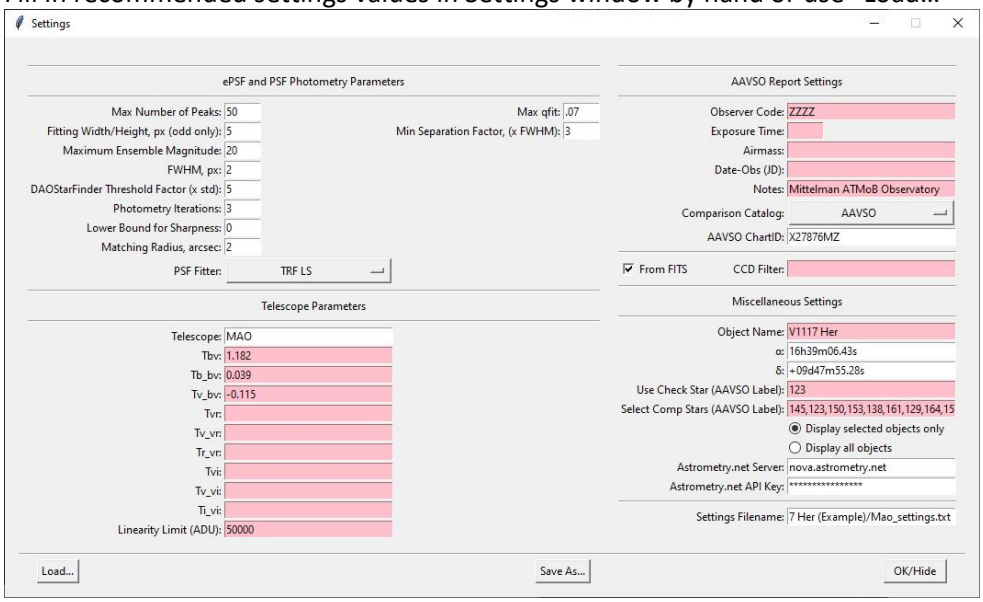
Settings window which contains important parameters for PSF Photometry, telescope specs, and location where var object, comp, and check stars are specified.



Main Window which contains Stretching tools for the images on the left, the image display and console in the center, and the PSF analysis section on the right.

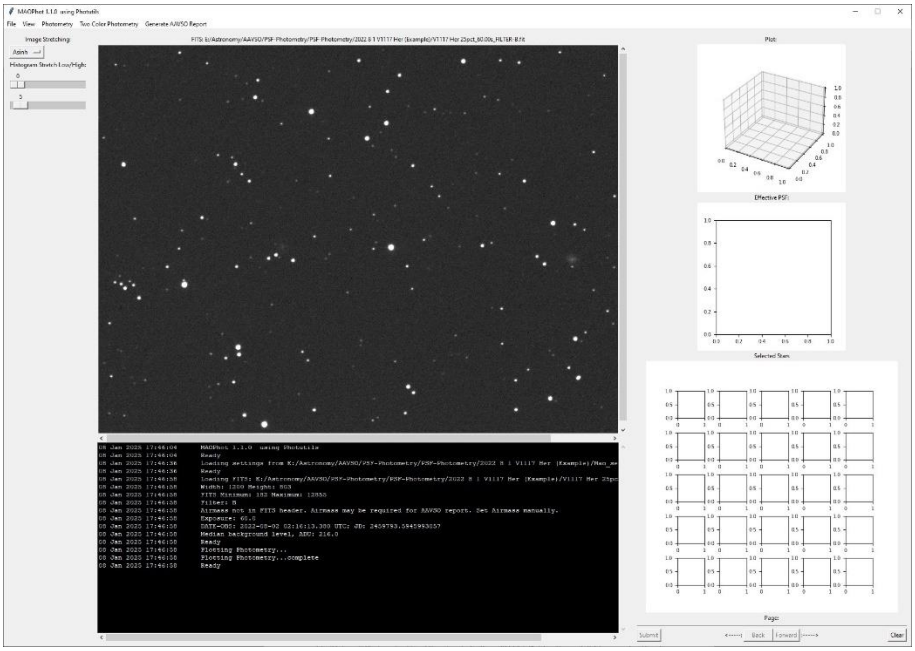
Single Image Photometry Workflow
General Workflow for Single Image Photometry and AAVSO report generation
Using example ”2022 8 1 V1117 Her (Example)”

1) Prepare master images.
   a) The master should be calibrated in proper FIT format. It should be cropped such that no 'black' or zero value ADU exists at the edges. The image need not be plate solved but RA and DEC values should exist for proper plate solving in MAOPhot. (see below for Astronometry.net server settings)
2) Launch MAOPhot by running the following command in the working directory
   a) MAOPhot.exe
3) Fill in recommended settings values in Settings window by hand or use “Load…”



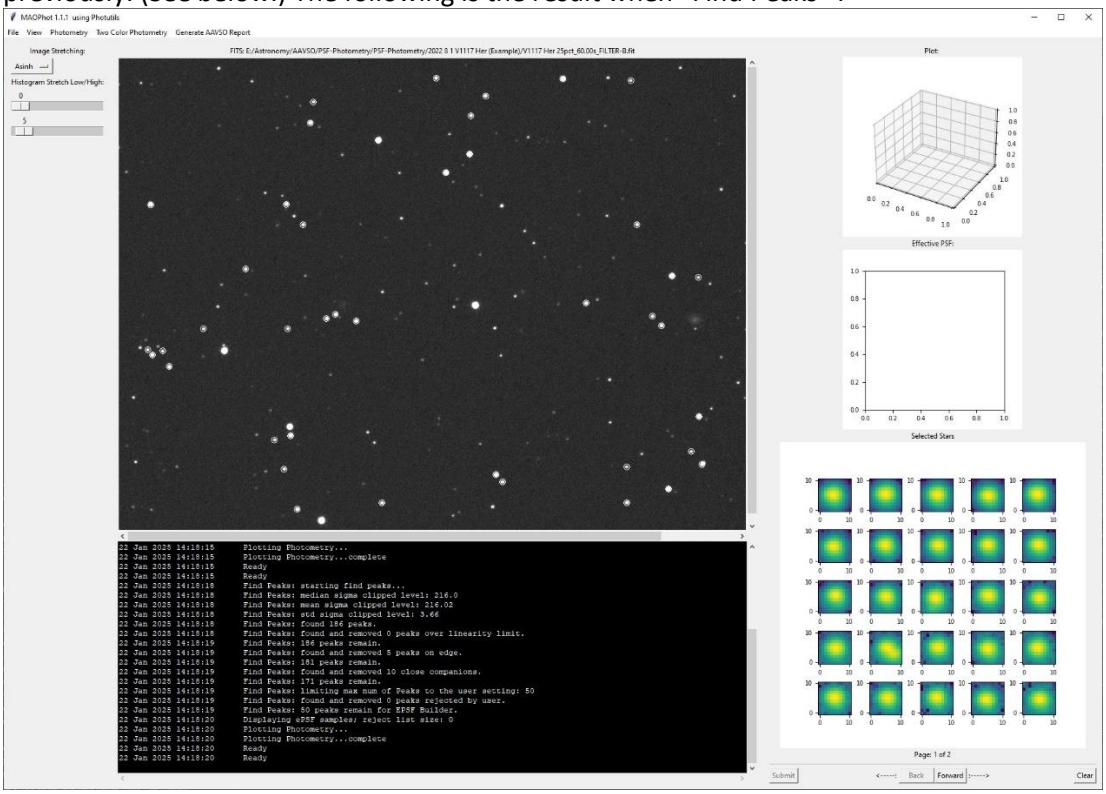
   a) Use ‘Load…’ to load an existing set of settings (E.g., 2022 8 1 V1117 Her (Example)\MAO_settings.txt)
   b) adjust the ‘Fitting Width/Height so that it contains stellar images of target magnitude
   c) adjust FWHM to the average FWHM in image
   d) Close the Settings Window by clicking OK

4) **'File->Open...**' (E.g., 2022 8 1 V1117 Her (Example)\V1117 Her 25pct_60.00s_FILTER-B.fit
   a) Image Stretching uses Asinh by default. Adjust stretch if necessary. (This is only a screen stretch. It does not affect the file.)

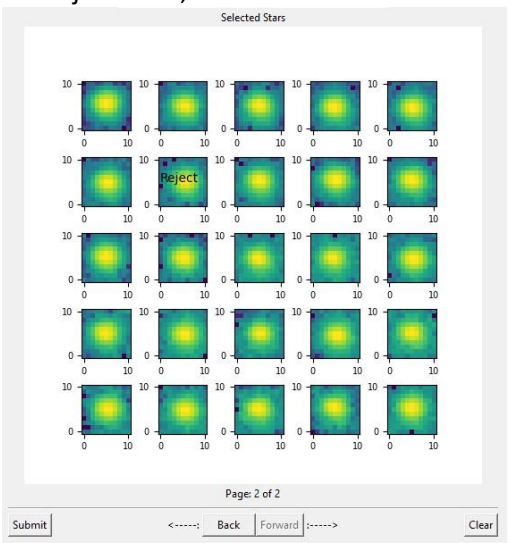


5) [Optional] '**Photometry->Find Peaks**'
   a) MAOPhot looks for peaks in image and removes any over the Linearity Limit, any that are close to edge, and any that have close companions. It also will remove any that the user has specified

previously. (See below.) The following is the result when “Find Peaks” :



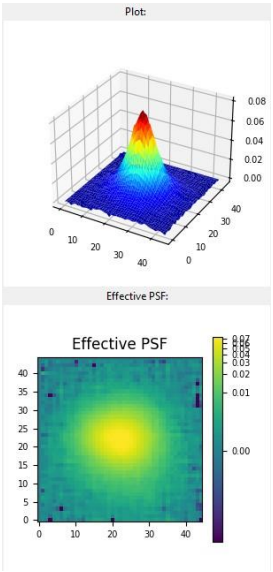
b) 186 peaks were found, 5 peaks on edge were removed, and 10 with close companions were removed. The user specified a ‘Max Num of Peaks” of 50; so, from what is left, the 50 brightest peaks will be used

c) The 50 remaining peaks are shown on the right side. The user can select any to be further rejected. The user pages through and inspect for any peaks not desired for the generation of the ePSF model. To reject stars, click on one or more of them then submit. See the following illustration: 

Note a sample has been rejected after user clicked on it. Click on Submit to remove it from the Selected Stars. To undo a Reject, just click on it again.

6) [Optional] **'Photometry->Create Effective PSF'**

   a) Watch progress bar in output console; (console that first appeared after involving MAOPhot.exe)
   b) [Optional] Select more stars to be rejected, (see step 5)
      i) select stars NOT well isolated from their neighbors (most are done automatically)
      ii) [optional] save rejection list (Photometry-> Save rejection list)
      iii) then select 'Photometry->Create Effective PSF' again and repeat if necessary
      iv) inspect “Effective PSF Plot” for a “reasonable” looking PSF



7) [Optional] **Photometry->Load Rejection List…** (E.g., V1117 Her-B-rejection.csv)
   a) After loading select 'Photometry->Create Effective PSF' again
8) Photometry->Iteratively PSF Photometry
   a) Watch progress bar in output console; (console that first appeared after involving MAOPhot.exe)
   b) After this completes, the photometry is saved to a csv (comma separated values) file that could be inspected in Excel or some other editor. In this example the file save is: “V1117 Her 25pct_60.00s_FILTER-B.fit.csv”. This is referred to as the photometry file.
9) [optional] **Photometry->Solve Image** (example files for Z Tau, V1117 Her, and S Gem already have WCS data)
   a) 'Photometry->Solve Image' to plate solve if FITS file does not contain WCS Header data
   b) [optional] After solving, 'File->Save' or ‘File->Save As…’ to save WCS data in FITs file
   Note: if your input file image already has WCS Header data, there is no need to “Solve Image”
10) **Photometry->Get Comparison Stars** [WCS Header data required]
   a) In this example, chart X27876MZ that was specified in the Settings was used (this is not necessary). MAOPhot found 9 objects in the image, and all the comparison stars that were specified in the Settings.
   b) The photometry file is updated with the objects found, associating the object, comp, and check stars with their photometry data.

c) Once this is done, the user can repeat steps 1 through 10 for another filter or immediately proceed to generate an AAVSO report for this single image. (Transformation coefficients would not be able to be applied in this case.)

11) '**Generate AAVSO Report->Single Image Photometry**'
   a) Select the <fits filename>.csv file that was generated by step 10 (E.g., V1117 Her 25pct_60.00s_FILTER-B.fit.csv)
   b) An AAVSO report is generated in the subdirectory (E.g., 2022 8 1 V1117 Her (Example)/aavso_reports/AAVSO V1117 Her 25pct_60.00s_FILTER-B V1117 Her_single.txt)
   c) The following is a generated report from this example:

Example Single Image Photometry AAVSO report:

```
#TYPE=Extended
#OBSCODE=FPIA
#SOFTWARE=Self-developed; MAOPhot 1.1.4  using Photutils
#DELIM=,
#DATE=JD
#OBSTYPE=CCD
#NAME,DATE,MAG,MERR,FILT,TRANS,MTYPE,CNAME,CMAG,KNAME,KMAG,AMASS,GROUP,CHART,NOTES
V1117 Her,2459793.59460,12.932,0.019,B,NO,STD,145,-6.445,153,-5.769,na,na,X27876MZ,Mittelman ATMoB Observatory|CMAGINS=-
6.445|CREFERR=0.01|CREFMAG=15.174|KMAG=15.85|KMAGINS=-5.769|KREFERR=0.019|KREFMAG=15.878|VMAGINS=-8.687
```

More about Single Image Photometry

Single Image Photometry does not utilize Transformation coefficients. Simple differential photometry is used. Only a single comp star is used (which must be the case if the AAVSO VPhot tool, 'Transform Applier' is to be used).

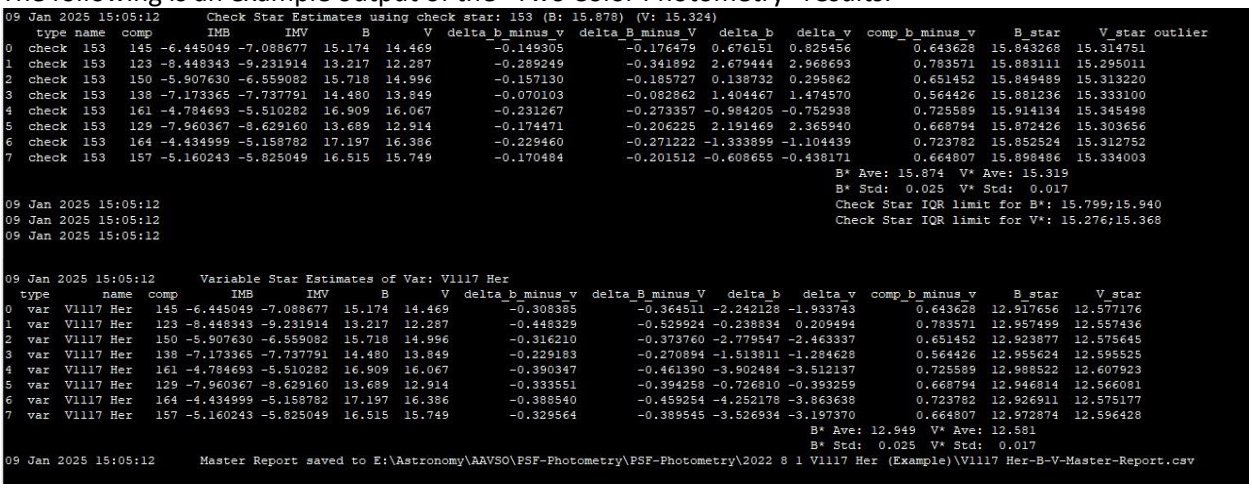
Two Color Photometry Workflow
General Workflow for Single Image Photometry and AAVSO report generation
Using example ”2022 8 1 V1117 Her (Example)”

General Workflow for Two Color Photometry and AAVSO report generation with B and V filters.

Execute steps 1 through 10 above for the B master (if not done already) and then the V master images. Skip step 11.

Then continue with step 12:

12) '**Two Color Photometry->(B-V)**'
   a) Select the 2 csv files that were generated in step 10 (1 for B and 1 for V; (e.g., “V1117 Her 25pct_60.00s_FILTER-B.fit.csv” and “V1117 Her 25pct_60.00s_FILTER-V.fit.csv”)
   (When file selection dialog appears, it will specify the files needed using the default file names.)
   b) The following is an example output of the “Two Color Photometry” results.



```
09 Jan 2025 15:05:12      Check Star Estimates using check star: 153 (B: 15.878) (V: 15.324)
    type name  comp       IMB       IMV       B       V  delta_b_minus_v  delta_B_minus_V   delta_b   delta_v  comp_b_minus_v     B_star     V_star outlier
0  check  153   145 -6.445049 -7.088677  15.174  14.469        -0.149305        -0.176479  0.676151  0.825456        0.643628  15.843268  15.314751
1  check  153   123 -8.448343 -9.231914  13.217  12.287        -0.289249        -0.341892  2.679444  2.968693        0.783571  15.883111  15.295011
2  check  153   150 -5.907630 -6.559082  15.718  14.996        -0.157130        -0.185727  0.138732  0.295862        0.651452  15.849489  15.313220
3  check  153   138 -7.173365 -7.737791  14.480  13.849        -0.070103        -0.082862  1.404467  1.474570        0.564426  15.881236  15.333100
4  check  153   161 -4.784693 -5.510282  16.909  16.067        -0.231267        -0.273357 -0.984205 -0.752938        0.725589  15.914134  15.345498
5  check  153   129 -7.960367 -8.629160  13.689  12.914        -0.174471        -0.206225  2.191469  2.365940        0.668794  15.872426  15.303656
6  check  153   164 -4.434999 -5.158782  17.197  16.386        -0.229460        -0.271222 -1.333899 -1.104439        0.723782  15.852524  15.312752
7  check  153   157 -5.160243 -5.825049  16.515  15.749        -0.170484        -0.201512 -0.608655 -0.438171        0.664807  15.898486  15.334003
                                                                                                                  B* Ave: 15.874  V* Ave: 15.319
                                                                                                                  B* Std:  0.025  V* Std:  0.017
09 Jan 2025 15:05:12                                                                                              Check Star IQR limit for B*: 15.799;15.940
09 Jan 2025 15:05:12                                                                                              Check Star IQR limit for V*: 15.276;15.368
09 Jan 2025 15:05:12


09 Jan 2025 15:05:12      Variable Star Estimates of Var: V1117 Her
  type       name  comp       IMB       IMV       B       V  delta_b_minus_v  delta_B_minus_V   delta_b   delta_v  comp_b_minus_v     B_star     V_star
0  var  V1117 Her   145 -6.445049 -7.088677  15.174  14.469        -0.308385        -0.364511 -2.242128 -1.933743        0.643628  12.917656  12.577176
1  var  V1117 Her   123 -8.448343 -9.231914  13.217  12.287        -0.448329        -0.529924 -0.238834  0.209494        0.783571  12.957499  12.557436
2  var  V1117 Her   150 -5.907630 -6.559082  15.718  14.996        -0.316210        -0.373760 -2.779547 -2.463337        0.651452  12.923877  12.575645
3  var  V1117 Her   138 -7.173365 -7.737791  14.480  13.849        -0.229183        -0.270894 -1.513811 -1.284628        0.564426  12.955624  12.595525
4  var  V1117 Her   161 -4.784693 -5.510282  16.909  16.067        -0.390347        -0.461390 -3.902484 -3.512137        0.725589  12.988522  12.607923
5  var  V1117 Her   129 -7.960367 -8.629160  13.689  12.914        -0.333551        -0.394258 -0.726810 -0.393259        0.668794  12.946814  12.566081
6  var  V1117 Her   164 -4.434999 -5.158782  17.197  16.386        -0.388540        -0.459254 -4.252178 -3.863638        0.723782  12.926911  12.575177
7  var  V1117 Her   157 -5.160243 -5.825049  16.515  15.749        -0.329564        -0.389545 -3.526934 -3.197370        0.664807  12.972874  12.596428
                                                                                                                  B* Ave: 12.949  V* Ave: 12.581
                                                                                                                  B* Std:  0.025  V* Std:  0.017
09 Jan 2025 15:05:12      Master Report saved to E:\Astronomy\AAVSO\PSF-Photometry\PSF-Photometry\2022 8 1 V1117 Her (Example)\V1117 Her-B-V-Master-Report.csv
```

   c) This data is saved in a “Master-Report”: E.g., V1117 Her-B-V-Master-Report.csv
   d) Referring to the above output, note that the column “outlier” is blank. If there was a comp star that was an outlier, then it would be indicated there. MAOPhot checks for values outside the IQR (interquartile range) to detect outliers.
   e) If any outliers (comparison stars) were indicated, delete from 'Select Comp Stars (AAVSO Label)' in the Settings if desired, then select 'Generate AAVSO Report->Two Color Photometry->(B-V)'again.

13) '**Generate AAVSO Report->Two Color Photometry->(B-V)**'
   a) Select the “Master-Report” csv file that were generated in step 12; (e.g., “V1117 Her-B-V-Master-Report.csv”)
   (When file selection dialog appears, it will specify the file needed using the default file names.)
   b) An AAVSO report is generated in the subdirectory (E.g., 2022 8 1 V1117 Her (Example)/aavso_reports/AAVSO V1117 Her 25pct_60.00s_FILTER-V V1117 Her)

c) The following is a generated report from this example:

Example Two Color Photometry AAVSO report:

```
#TYPE=Extended
#OBSCODE=FPIA
#SOFTWARE=Self-developed; MAOPhot 1.1.4  using Photutils
#DELIM=,
#DATE=JD
#OBSTYPE=CCD
#NAME,DATE,MAG,MERR,FILT,TRANS,MTYPE,CNAME,CMAG,KNAME,KMAG,AMASS,GROUP,CHART,NOTES
V1117 Her,2459793.59495,12.949,0.025,B,YES,STD,ENSEMBLE,na,153,15.874,na,na,X27876MZ,Mittelman ATMoB
Observatory|KMAGINS=-5.769|KMAGSTD=15.874|KREFMAG=15.878|Tbv=1.182|VMAGINS=-8.687
V1117 Her,2459793.58465,12.581,0.017,V,YES,STD,ENSEMBLE,na,153,15.319,na,na,X27876MZ,Mittelman ATMoB
Observatory|KMAGINS=-6.263|KMAGSTD=15.319|KREFMAG=15.324|Tv_bv=-0.115|VMAGINS=-9.022
```

More about Two Color Photometry

MAOPhot mimics VPhot's "Two Color Photometry" (for this discussion we use B and V).
See spreadsheet: ProcessingMaoImages_202281V1117Her.xlsx It includes formulas to generate "two color photometry". (See https://github.com/petefleurant/PSF-Photometry)

Error Estimation

MAOPhot mimics VPhot when calculating error estimation.
From VPhot documentation:

> In an ensemble solution with more than two comp stars, the magnitude is estimated as the average of the individual comp stars estimate [of the check star], and the error is taken as the standard deviation of this sample.
>
> If one or two comp stars are used, the error estimate is based on the SNR of each measurement (the target measurement and the comp stars measurements). The standard error of a measurement is defined as 2.5 * np.log10(1 + 1 / SNR) [The errors are added in quadrature.]

Menu Functionality

Menu functions:

File->Open	load a FITs file into MAOPhot for analysis
File->Save	save loaded FITS file
File->Save As…	save loaded FITS file to a file
File-> Edit Settings…	displays ‘Settings’ window
File->Exit	exits application
View->Zoom In	zoom in in +.5 scale increments
View->Zoom Out	zoom out in -.5 scale increments

View->100% Zoom — zoom to normal scale

View->Refresh — Usually used if settings: “Display selected objects only has changed”

Photometry->Find Peaks — Looks for peaks in image that will be used for effective PSF (ePSF) Model generation. It discards any peaks over the Linearity Limit, any that are close to edge, and any that have close companions. It also will discard any that the user has specified previously

Photometry->Create Effective PSF

Analyzes image and generates an ePSF model following the prescription of Anderson and King (2000; PASP 112, 1360)
(Max number of iterations is hardcoded at 50)
Any two peaks within an aperture width/height are rejected.
If a rejection list has been loaded, then peaks in list are also rejected

Photometry->Load Rejection List…

Loads a previously saved rejection list

Photometry->Save Rejection List…

After running “Photometry->Find Peaks “, the user can select peaks to be rejected by mouse clicking on them in the “Selected Stars” area
When user clicks on a peak to be rejected, the word “Rejected” appears. The user can page through the list of peaks and reject (and undo a reject). When Submit button is clicked, the peaks submitted will not be used in the next “Photometry->Create Effective PSF”. Once the rejected peaks are submitted, they can be saved using “Photometry->Save Rejection List…”

Photometry->Clear ePSF Data

clears all ePSF data, ePSF and rejection list.

Photometry->Iterative PSF Photometry

Execute iterative version of PSF Photometry where new sources are detected in the residual image after the fit sources are subtracted

Photometry->Solve Image

Use Astronometry.net server to add WCS Header information.

Photometry->Get Comparison Stars

Queries AAVSO for VSX objects and comparison stars in the field

Two Color Photometry->(B,V) — Executes two color photometry for B and V

Two Color Photometry->(V,R) — Executes two color photometry for V and R

Two Color Photometry->(V,I) — Executes two color photometry for V and I

Generate AAVSO Report->Single Image Photometry

This generates an AAVSO report in extended format for a single Filter.

Generate AAVSO Report->Two Color Photometry->(B,V)

This generates an AAVSO report in extended format for 2 filters, (B,V).

The data is transformed.

Generate AAVSO Report->Two Color Photometry->(V,R)

This generates an AAVSO report in extended format for 2 filters, (V,R).
The data is transformed.

Generate AAVSO Report->Two Color Photometry->(V,I)

This generates an AAVSO report in extended format for 2 filters, (V,I).
The data is transformed.

List of parameters in Setting Window

Parameter	Description	Units	Req*
Max Number of Peaks	The maximum number of peaks that is initially displayed in the Selected Stars area after Photometry->Find Peaks is executed	integer	
Fitting Width/Height	Rectangular shape around the center of a star that will be used to define the PSF-fitting region (must be an odd number)	pixels	
Maximum Ensemble Magnitude	Magnitude limit used when fetching comp stars	magnitude	
FWHM	PSF Photometry searches for peaks with similar FWHM	pixels	
IRAFStarFinder Threshold Factor	The absolute image value above which to select sources in terms in multiples of std.	float	
Photometry Iterations	Number of iterations to perform in Iteratively Subtracted PSF Photometry	integer	
Lower Bound for Sharpness	The lower bound on sharpness for object detection. (Upper bound is fixed at 2.0)	float	
Matching Radius	Tolerance between image coordinate and catalog, if within tolerance than a match is made	arcsecs	

PSF Fitter	Type of fitter used in Interactive PSF Photometry **TRF LS**: Trust Region Reflective algorithm and least squares statistic **Sequential LS Programming**: Sequential Least Squares Programming (SLSQP) optimization algorithm and least squares statistic. **Simplex LS**: Simplex algorithm and least squares statistic.	list selection	
Max qfit	MAOPhot discards any PSF fit with qfit > "Max qfit"; anything below 0.1 is considered good	float	
Min Separation Factor (x FWHM)	Min Separation Factor x FWHM gives minimum separation that defines a distance (in pixels) such that any two sources separated by less than this distance will be placed in the same group. Stars in a group are fitted simultaneously.	float	
Telescope	Name of telescope; for reference only (OPTIONAL not used)	string	
Tbv	Transformation Coefficients	float	yes
Tb_bv		float	yes
Tv_bv		float	yes
Tvr		float	yes
Tv_vr		float	yes
Tr_vr		float	yes
Tvi		float	yes
Tv_vi		float	yes
Ti_vi		float	yes
AAVSO Observer Code	Entered into the report under #OBSCODE	string	yes

Exposure Time	exposure usually found in FITS header; used to calculate instrumental magnitude	float	yes
From FITS	If checked, the CCD Filter value is gotten from the FILTER value in the loaded Fits file header. If unchecked, the user can override the Fits header value by entering it into CCD Filter.	string	
CCD Filter	filter used for image; usually found in FITs header	string	yes
Airmass	Found in FITs header	float	
Date-Obs	Entered into report; usually found in FITs header	JD	yes
Notes	Entered into report under notes	string	yes
Comparison Catalog	**AAVSO**: use comp stars found in AAVSO Variable Star Database **Gaia DR2**: use objects from I/345 Gaia DR2 (Gaia Collaboration, 2018) **APASS DR9**: use objects from II/336 AAVSO Photometric All Sky Survey (APASS) DR9 (Henden+, 2016) (R and I filters are Sloan) Comp names have a 'B', (e.g., 113B_2) **APASS DR10**: use objects AAVSO Photometric All Sky Survey (APASS) DR10 (R and I filters are Sloan) Comp names have an 'A', (e.g., 113A_2)	list selection	
AAVSO ChartID	specific chartID to be used; (e.g., X28484CPQ) (optional)	string	
Object Name	variable star name to be measured	string	yes
α	RA of Object specified by Object Name	hmsdms	
δ	Dec of Object specified by Object Name	hmsdms	

Use Check Star	KNAME	AAVSO label	yes
Select Comp Stars	comma separated list of AAVSO labels specifying comp stars to be used in measurement; if more than 1, then “ENSEMBLE” keyword is entered into report	AAVSO labels	yes
Display selected objects only	Display only objects listed in Comp Stars, Check Star, and Object Name	Radio Button	
Display all objects	Display all objects found by Astronomy.net (redundant ones have .0, .1, …etc. appended to name)	Radio Button	
Astronometry.net Server	URL of astronomy.net server (e.g., nova.astrometry.net or a local one)	string	
Astronometry.net API Key	To use astroquery.astrometry.net you will need to set up an account at astrometry.net and get your API key. The API key is available under your profile at astrometry.net when you are logged in. Copy the key and insert into this field.	string	
Settings File Name	Name of file containing loaded Settings (Not used to load settings. Use “Load…” button)	String	

*Req: these settings are directly inserted into the AAVSO Report; most are automatically filled in from the FIT header (Only some TCs are inserted into AAVSO Report)

Definitions

IRAF	IRAF is a general Image Reduction and Analysis Facility providing a wide range of image processing tools for the user. IRAF is a product of the National Optical Astronomy Observatories and was developed for the astronomical community although researchers in other scientific fields have found IRAF to be useful for general image processing. (see https://iraf-community.github.io/)

Bibliography

Stetson, P. B. (1986). DAOPHOT: A COMPUTER PROGRAM FOR CROWDED-FIELD STELLAR PHOTOMETRY.

Notes

In **optimization algorithms** used in statistics and numerical computing, **gtol (gradient tolerance) and xtol (step tolerance)** are **termination conditions** that determine when an algorithm should stop iterating.

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1. gtol (Gradient Tolerance)

- **Definition**: The optimization stops when the **gradient (first derivative) of the objective function is small**.
- **Interpretation**: The gradient represents the rate of change of the function. A small gradient means the function has reached a local minimum (or is very close to it).
- **Usage**: If $||\nabla f(x)|| < gtol$, the algorithm stops.
- **Common in**: Newton methods, Quasi-Newton methods (e.g., BFGS, L-BFGS), and Conjugate Gradient.
- **Example**:
  If gtol = 1e-6, the optimizer stops when the gradient norm is **smaller than 0.000001**.

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2. xtol (Step Tolerance)

- **Definition**: The optimization stops when **the change in the parameter values (x) is very small**.
- **Interpretation**: If the steps taken in each iteration become very small, the algorithm assumes convergence.
- **Usage**: If $||x\_new - x\_old|| < xtol$, the algorithm stops.
- **Common in**: Trust-region and Line Search methods.
- **Example**:
  If xtol = 1e-8, the optimizer stops when the parameter updates are smaller than **0.00000001**.

Key Differences

Termination Condition	Meaning	Stops when...	Typical Use
gtol	Gradient tolerance	The **gradient is small** (function slope is near 0)	Gradient-based methods (e.g., BFGS, CG)
xtol	Step tolerance	The **parameter change is small**	Trust-region & Line Search

Contact:
P.Fleurant
petefleurant@gmail.com