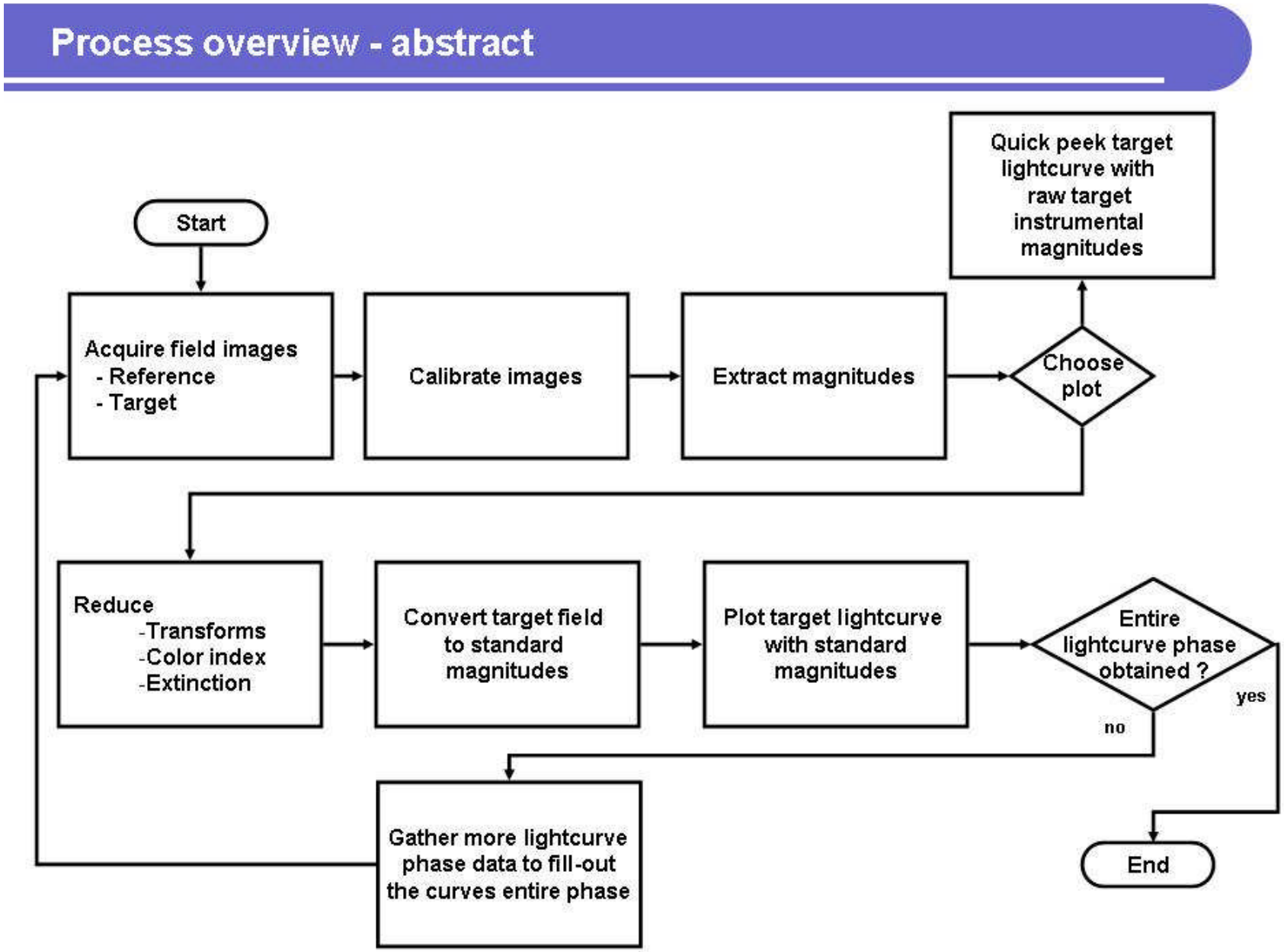
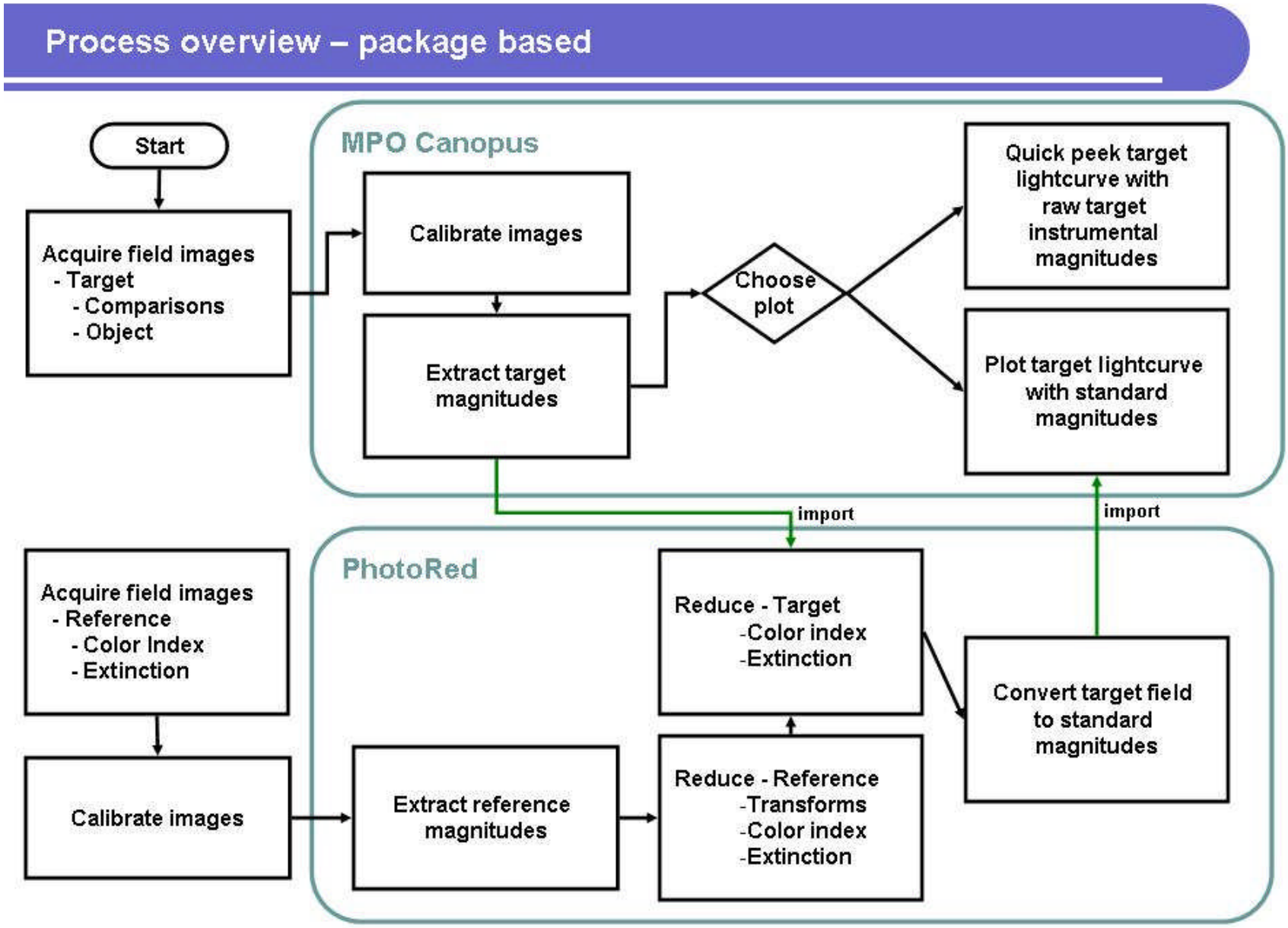

Process overview - abstract
Start
Acquire field images
- Reference
- Target
Calibrate images
Extract magnitudes
Choose plot
Quick peek target lightcurve with raw target instrumental magnitudes
Reduce
-Transforms
-Color index
-Extinction
Convert target field to standard magnitudes
Plot target lightcurve with standard magnitudes
Entire lightcurve phase obtained ?
yes
no
Gather more lightcurve phase data to fill-out the curves entire phase
End


Process overview – package based
Start
Acquire field images
- Target
- Comparisons
- Object
MPO Canopus
Calibrate images
Extract target magnitudes
Choose plot
Quick peek target lightcurve with raw target instrumental magnitudes
Plot target lightcurve with standard magnitudes
import
import
PhotoRed
Acquire field images
- Reference
- Color Index
- Extinction
Calibrate images
Extract reference magnitudes
Reduce - Reference
-Transforms
-Color index
-Extinction
Reduce - Target
-Color index
-Extinction
Convert target field to standard magnitudes

Dialogue option; Operates on; Sets	Operates on	Sets	Plots

Acquiring images with your telescope, camera and software for basic rigorous method

Uses: Camera and telescope

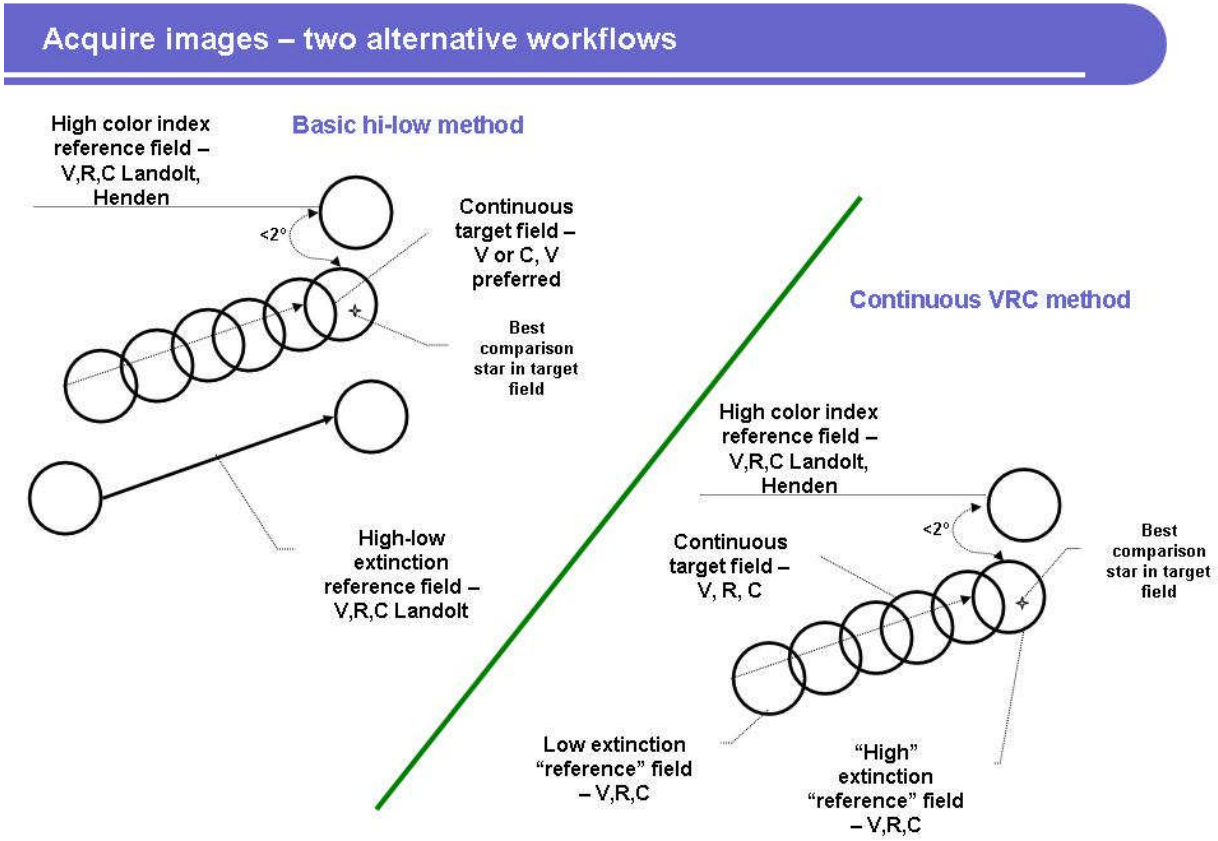
Sets: High color index reference field taken at the end of session, a continuous target field, and the high-low reference extinction field taken once at the beginning and once at the end of the session.

The high color index field and continuous target field should be within 2 degrees of each other.

Images can be obtained using one of shooting orders. For beginners, the left-hand basic method is recommended – because data manipulation is more explicit and easier to follow.

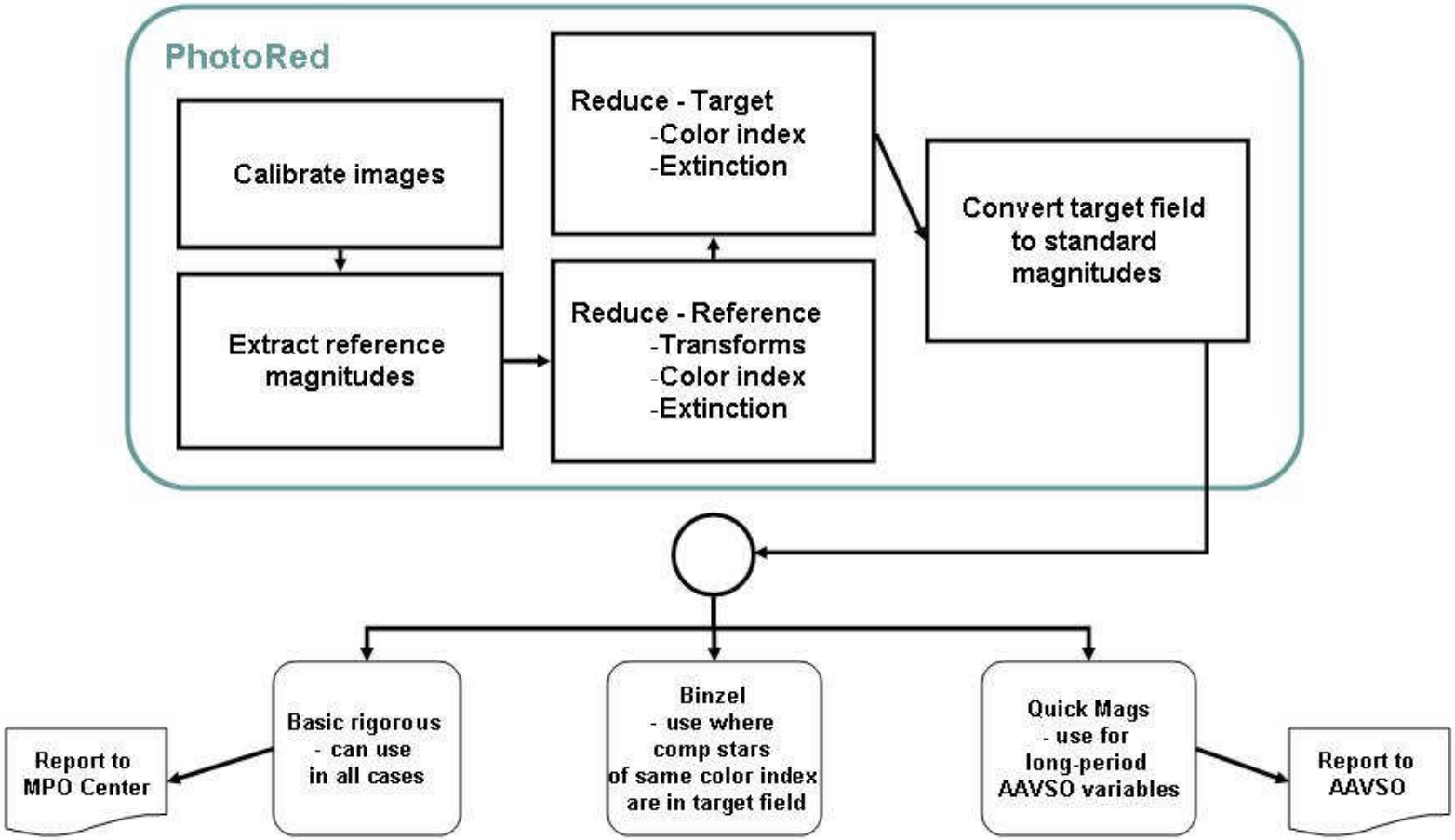
The high color index reference field is used to set the initial transforms and color index. The high low reference extinction field is used to set the initial extinction coefficients. The continuous target field is used to set the fine tuned extinction coefficient.

For practice purposes, it is possible to shoot only a continuous target field and only plot a raw instrumental "quick peek" lightcurve, remaining only MPO Canopus.



Process – overview – Three methods to convert to standard magnitudes

- **Only one of the three methods – the basic "rigorous" method is graphed here, using only the basic "high-low" imaging method.**



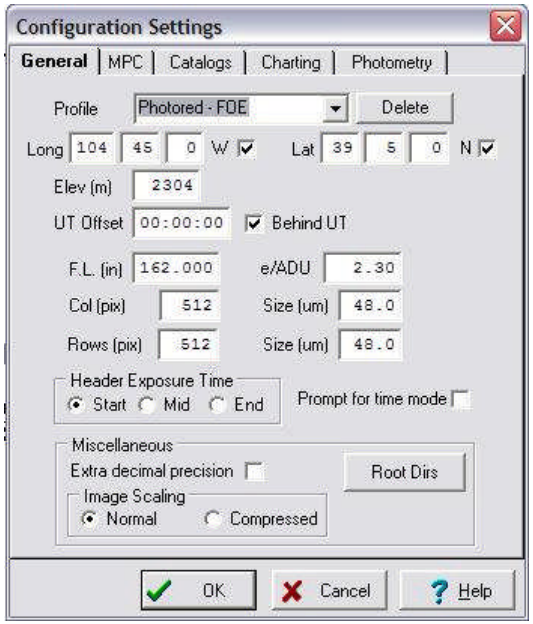
Dialogue option; Operates on; Sets	Operates on	Sets	Plots

In MPO Canopus, make a configuration for the imaging sessions. UserGuide v9.2, Lesson 1; MPO Canopus Manual v9.2 at 51-67.

A configuration is a pairing of an observer, location and telescope.

Use and assumed value of 2.3 for the e/ADU if you do not have software that computes the photos to analogue conversion rate from your images. Manual at 52.

The **effective focal ratio** (telescope plus reducer or Barlow) should be within 10-20% of its true value in order for the key "Automeasure" feature to work properly. Manual v9.2 at 52.



Dialogue option; Operates on; Sets	Operates on	Sets	Plots
Build directory structure to store data. MPO Canopus software upgrades generally require recompilation of *.FF2 files. Leave the original of these files in the c:\mpo\udata directory. Store copies in your archival project directory.	c:\mpo\udata\ [asteroid name]\ c:\mpo\canopus\ [asteroid name]\		In your personal project directories: [asteroid name]\ [session date]\ Raw\ Processed\ Dark frames\ White flats\ Images\ High ref\ Target\ Low extinction\ Session data\ (*.obs, *.FF2 archive) Reports\ Plots\ Project Notes\ <shortcut to c:\mpo\>

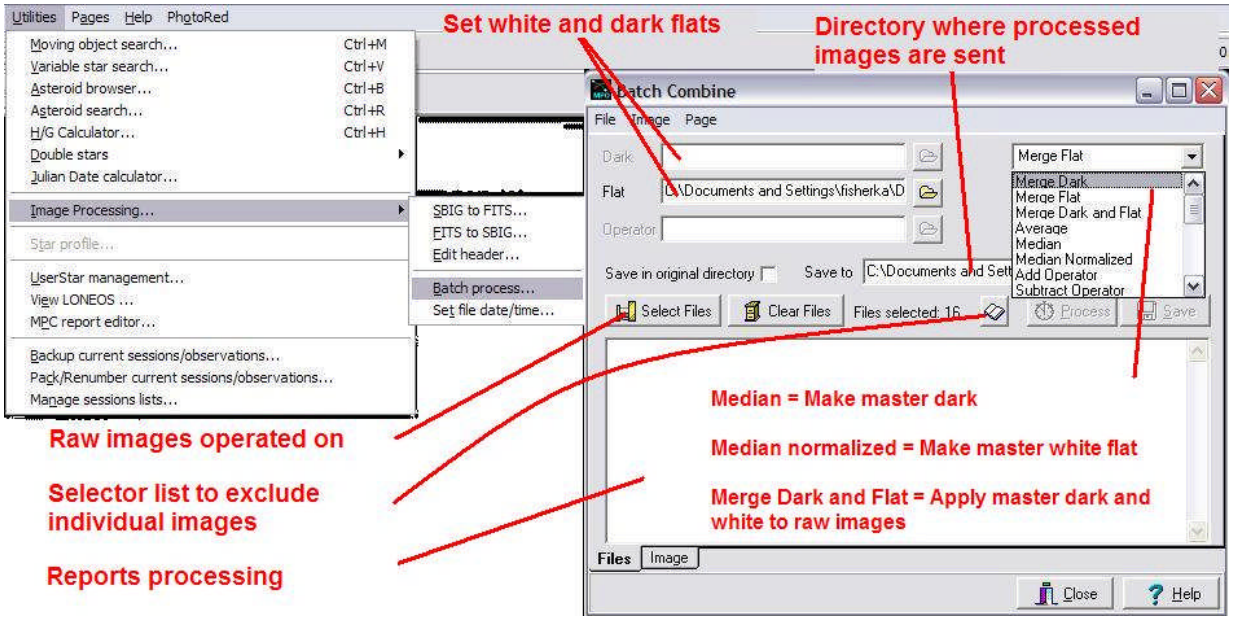
Dialogue option; Operates on; Sets **Operates on** **Sets** **Plots**

In MPO Canopus, calibrate the images.

Combine your white flats, dark flats and raw images. MPO Canopus Manual v9.2 at 68-91.

See Manual v9.2 at 286 for meanings of image operations.

Images can calibrated using other software, *e.g.* Maxim DL or AIP4WIN.



If necessary, adjust headers. To operate, MPO Canopus needs a few key FITS fields. See FITS field list at MPO Canopus Manual v9.2 at 381-382.

DATE-OBS - Date time of the exposure

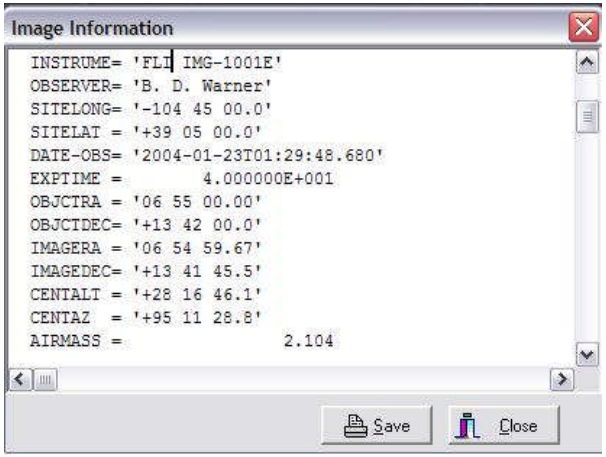
FILTER - filter applied

IMAGEDEC - Declination of the image center

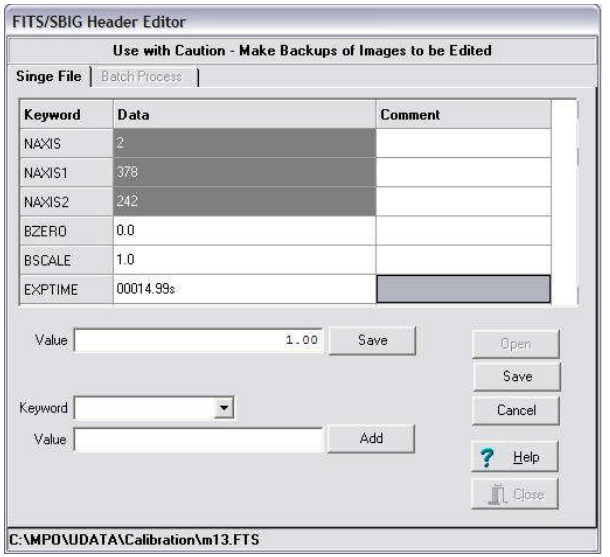
IMAGERA - Right ascension of the image center

If necessary, manually adjust your FITS image fields. MPO Canopus Manual v9.2 at 291-296.

Inspect images with Image | Header info



Edit single or batch images with Utilities | Image Processing | Edit Header



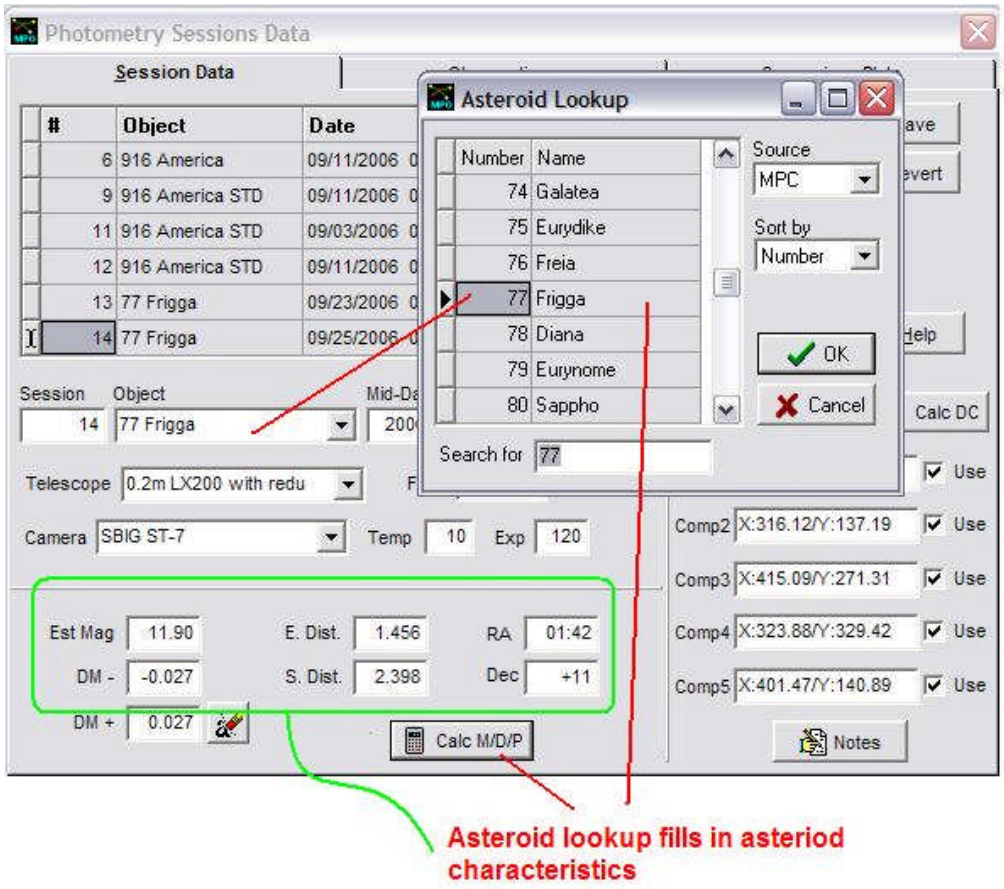
Dialogue option; Operates on; Sets	Operates on	Sets	Plots

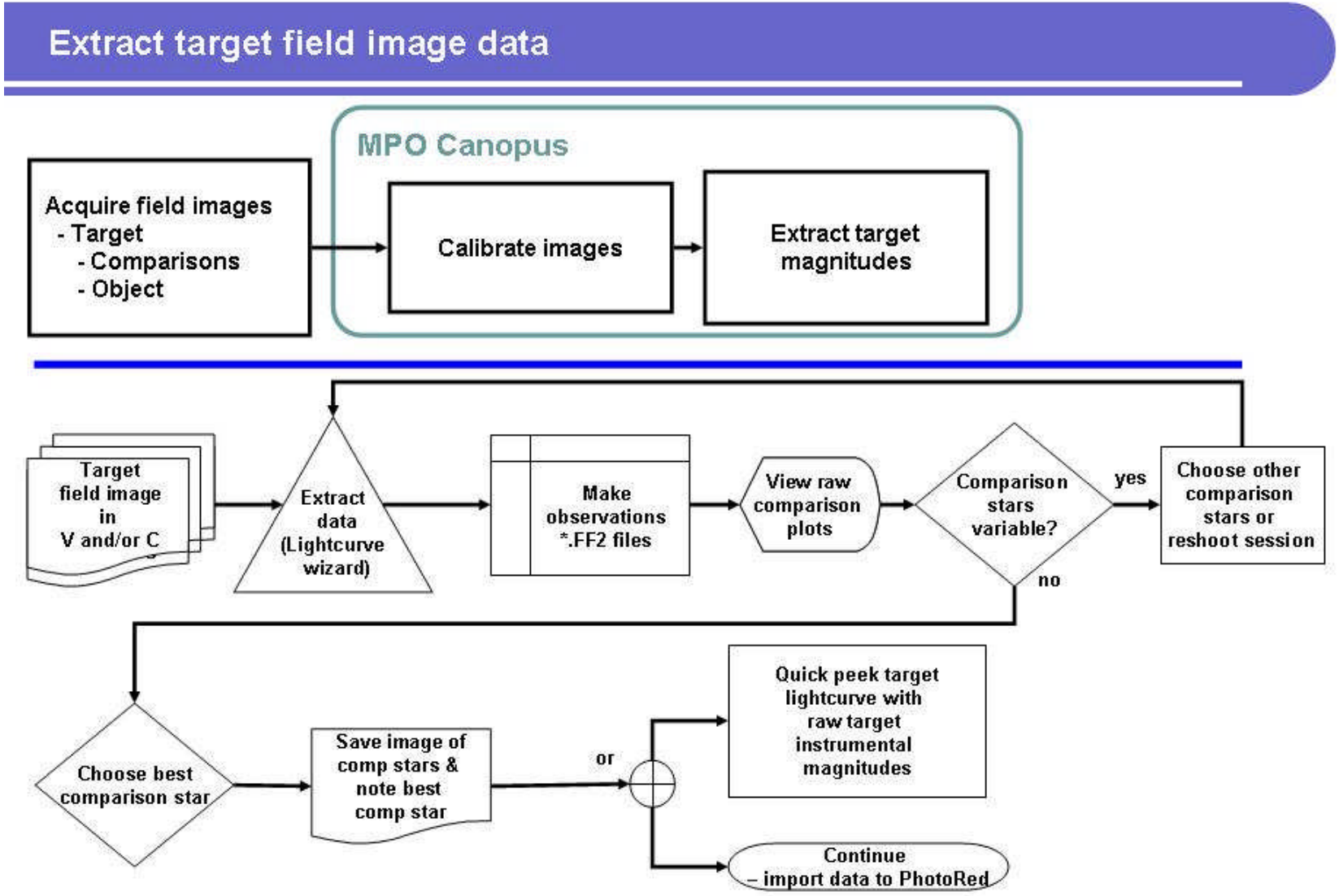
When creating a session in MPO Canopus to measure an asteroid target field, set the asteroid characteristics. User Guide v9.2 at Lesson 11, p. 33-34; MPO Canopus Manual v9.2 at 51-67.

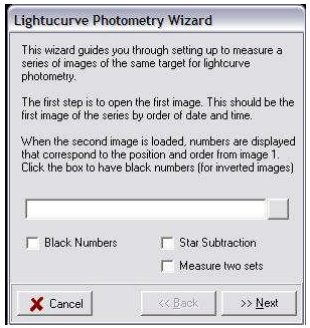
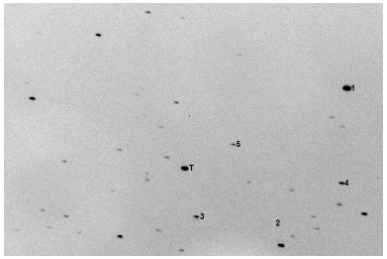
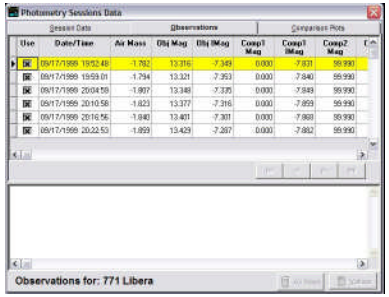
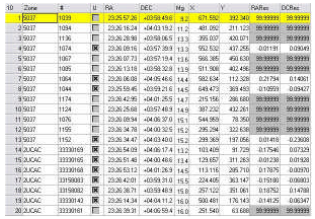
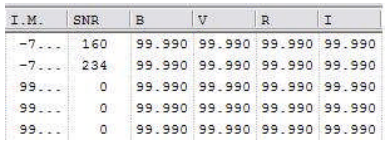
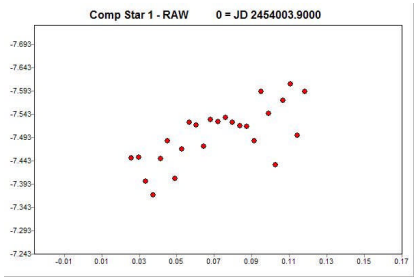
Uses: MPO Canopus Sessions Tab.

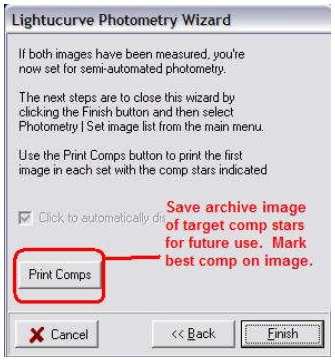
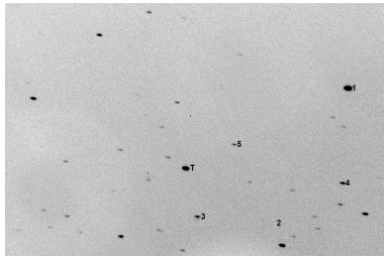
Sets: New session characteristics.

A "Session" is a unique series of images taken of one object with a set of filters at nearly the same time. It is paired with a "Configuration" – a unique observer, telescope, camera and location.

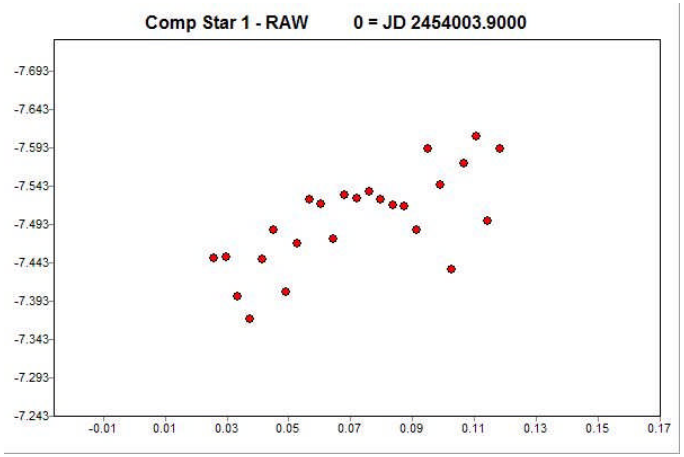



Extract target field image data
MPO Canopus
Acquire field images
- Target
- Comparisons
- Object
Calibrate images
Extract target magnitudes
Target field image in V and/or C
Extract data (Lightcurve wizard)
Make observations *.FF2 files
View raw comparison plots
Comparison stars variable?
yes
Choose other comparison stars or reshoot session
no
Choose best comparison star
Save image of comp stars & note best comp star
or
Quick peek target lightcurve with raw target instrumental magnitudes
Continue – import data to PhotoRed

Dialogue option; Operates on; Sets	Operates on	Sets	Plots
In MPO Canopus, **measure target fields** that contains a target within MPO Canopus. Use either continuous V,R,C target images paired with one high reference field, or continuous V or C paired with high-low reference fields.  (Reference fields are measured below in PhotoRed.) Uses: Target field images. Sets: MPO Canopus Observations Table.	Target images in MPO Canopus  Color-coding in observations table and astrometry display are: If the cell is red, the Red magnitude of the star is being reported from the source catalogue; if the cell is blue, the Blue magnitude of the star is being reported; if green, then the V magnitude is being reported. These may be Johnson or Cousin's values depending on the source catalogue. A checked box means the comparison star is used in the intensity/magnitude solution equations. Nature of grey highlight is unknown.	Sessions – observations table and astrometry table. Makes archive files (*SESS.FF2 and *.AST):  - Astrometry display and file (*.AST)  Does not extract standard magnitudes in data table when imported to PhotoRed:  	Comparison star plots to detect variable comparison stars 

Dialogue option; Operates on; Sets	Operates on	Sets	Plots
Save target comp stars image. Note down for later use in First Order (Comps) reduction, the best comparison star in target field on criteria: (a) linear response, (b) low noise, and (c) optionally nearest brightness to target. On the saved target field image, edit and mark the best comparison star for later use during target extinction reduction.		Archive image of target field with comp stars marked. 	"Low noise" means a good signal to noise ratio (SNR). The MPO Canopus Manual refers to a good SNR as "more than 100" (Manual v9.2 at 130) and a poor SNR as 30-40 (Manual v9.2 at 137). *Lightcurves* at Sec. 4.5.4.

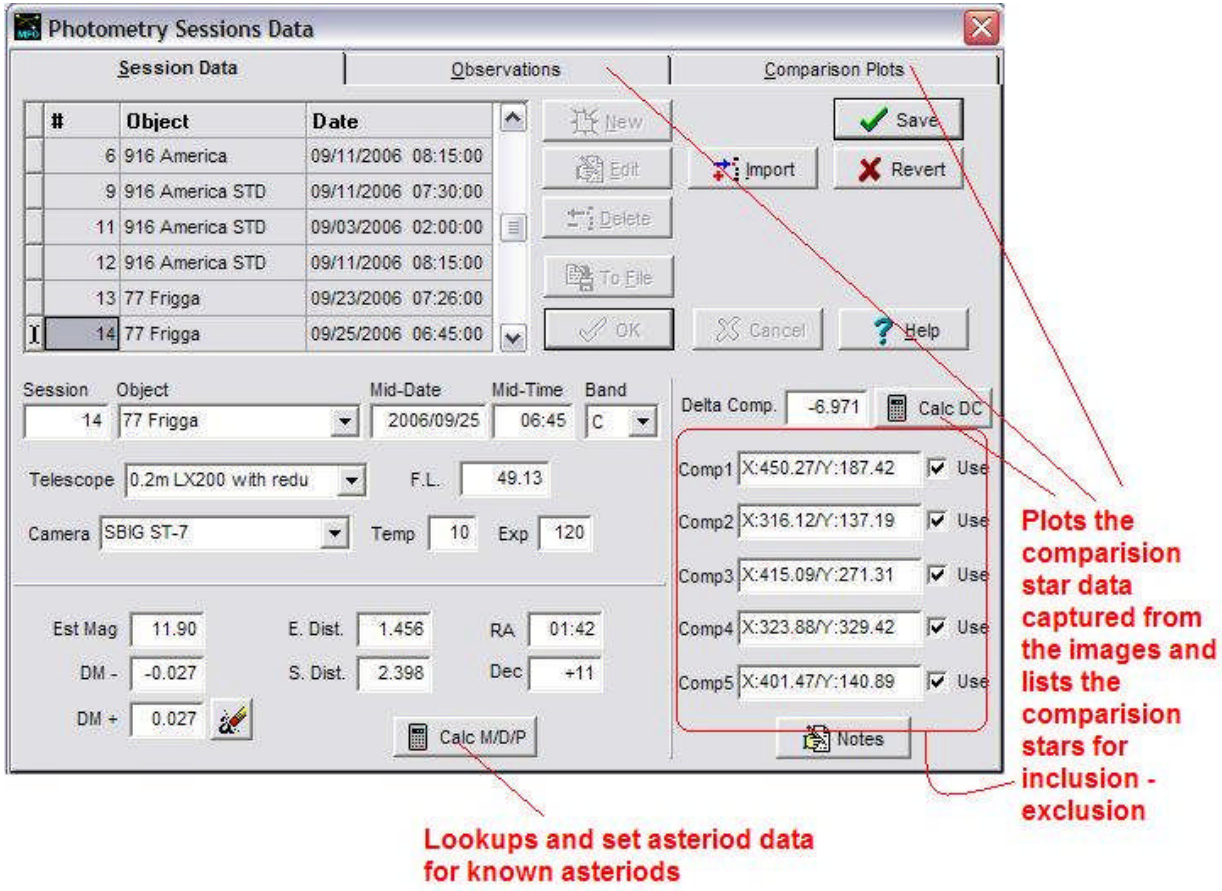
In MPO Canopus, after target field images are measured, plot and adjust the comparison stars:



Uses: MPO Canopus Photometry Sessions Tab.

Sets: Plots comparison graphs.

Exclude/include comparison stars based on criteria: (a) linear response, (b) low noise, and (c) optionally nearest brightness to target.

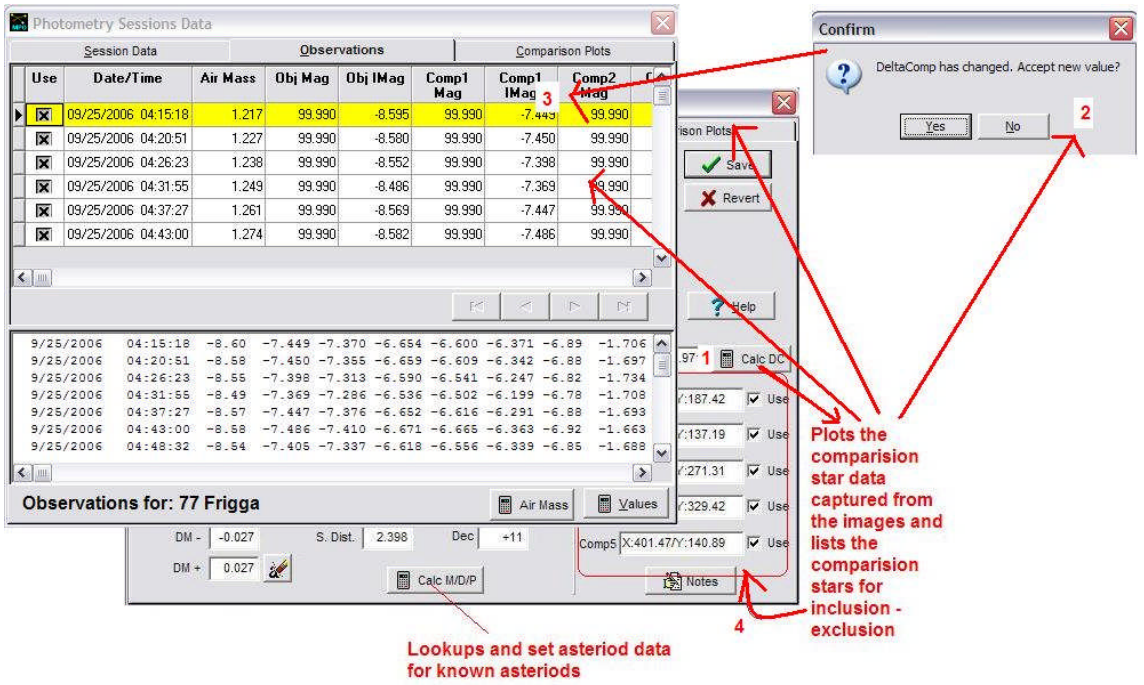


Dialogue option; Operates on; Sets	Operates on	Sets	Plots

(con . . . .) In MPO Canopus, after the images are measured, plot and adjust the comparison stars:

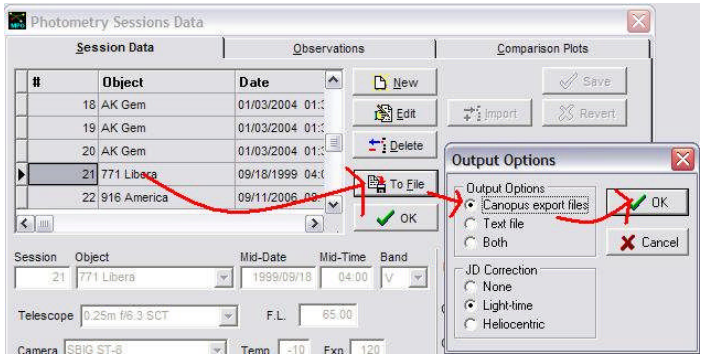
Uses: MPO Canopus Photometry Sessions Tab.

Sets: Plots comparison graphs.



In MPO Canopus, optionally, export an *.FF2 archive data file.

Bring up the Sessions Data dialogue (Crtl+S) and use the “To File” option to generate an *.FF2 archival file.

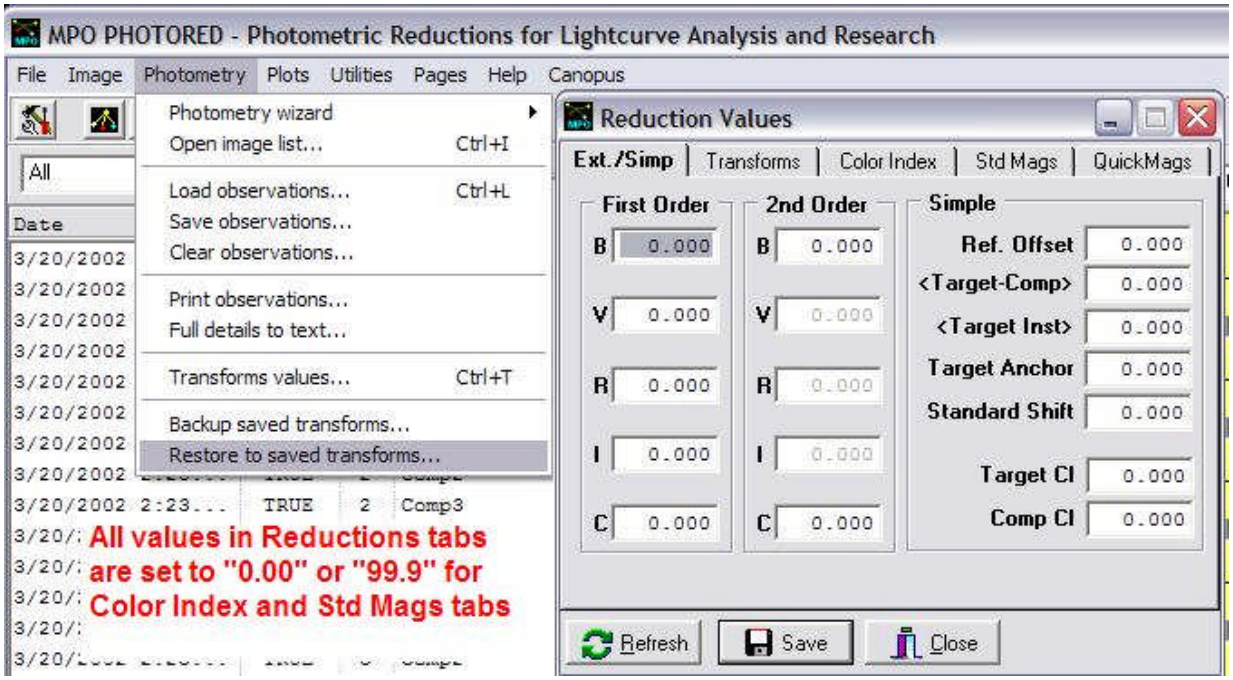


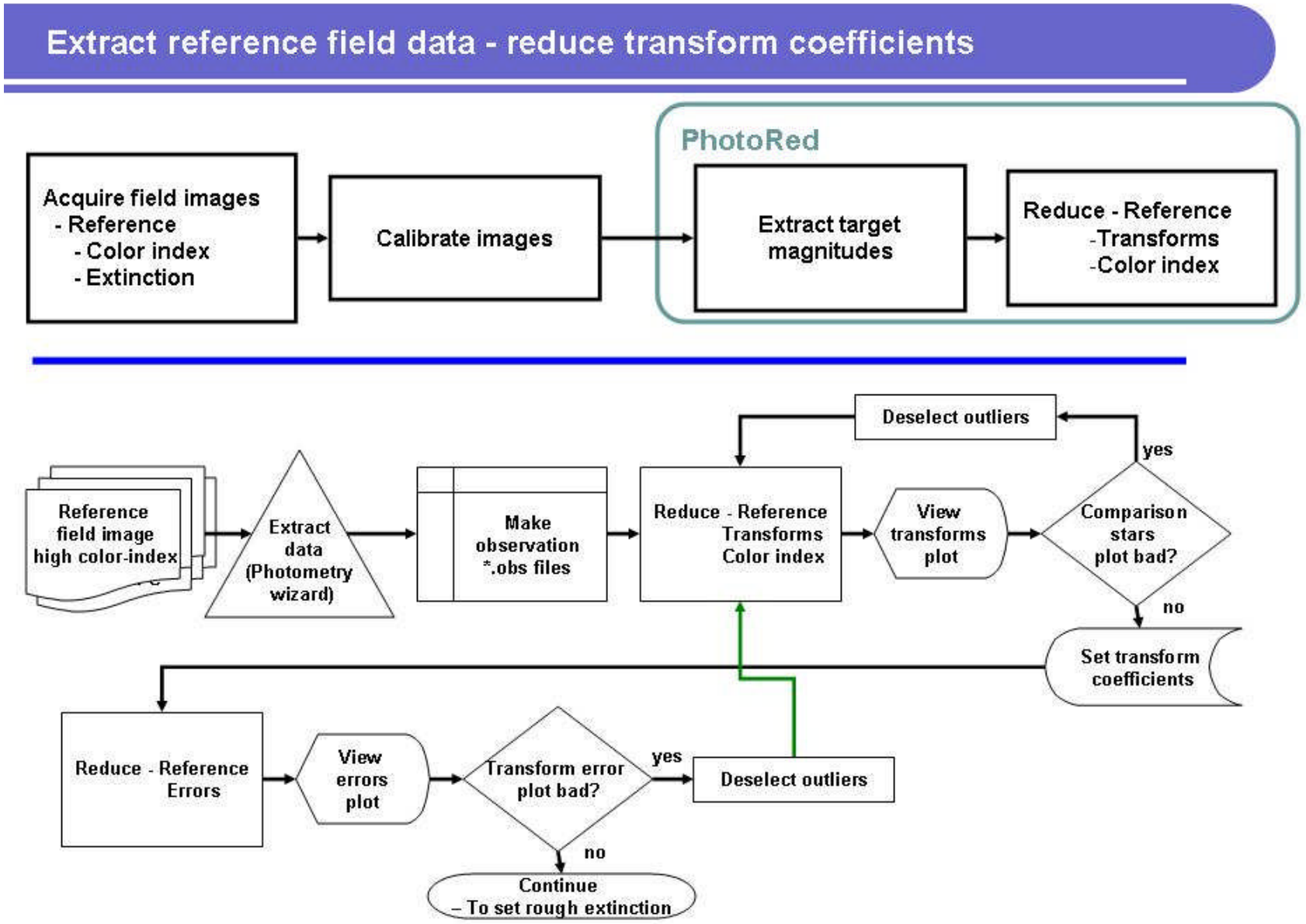
Dialogue option; Operates on; Sets	Operates on	Sets	Plots

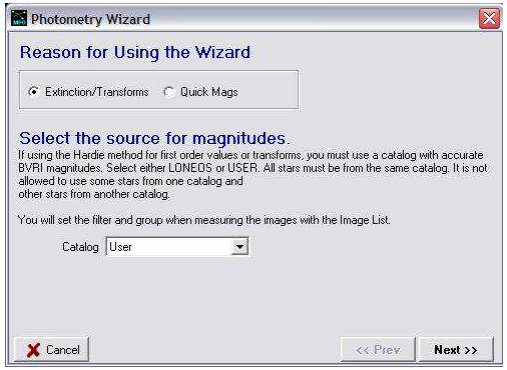
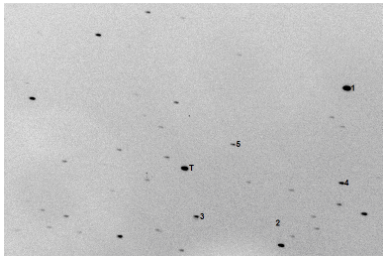
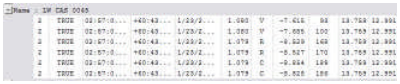
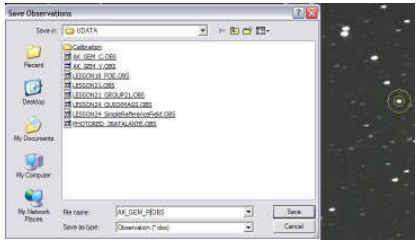
In PhotoRed, make and retrieve a “zero-based” Reductions dialogue so you can follow the changes in the coefficients throughout the process.

Make the zero-based reductions tab by zeroing out all the entries (or changing them to 99.9 as applicable). On the menu bar, use | Photometry | Backup saved transforms. This creates a “*.prr” file.

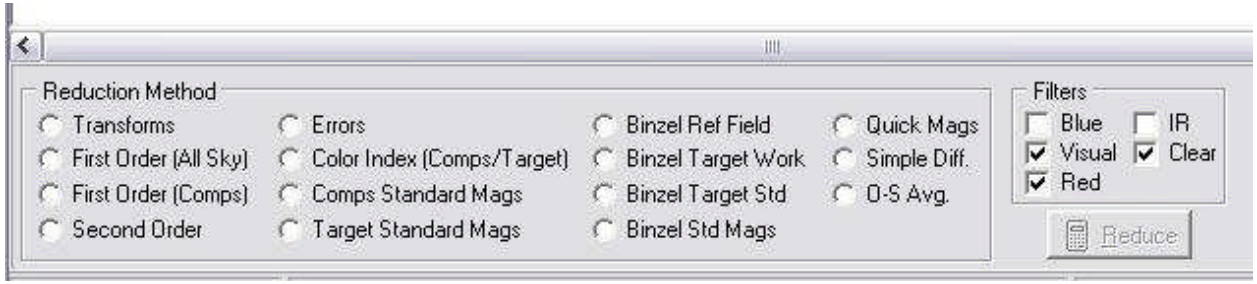
At the start of a new PhotoRed project, retrieve this zero-based Reductions tab with | Photometry | Restore saved transforms.

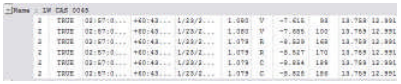
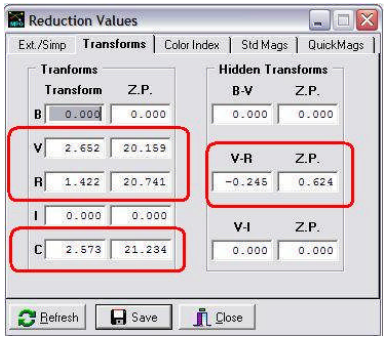
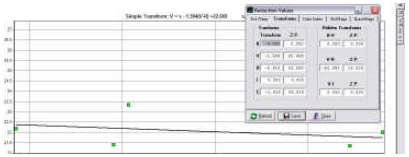
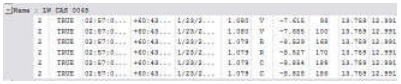
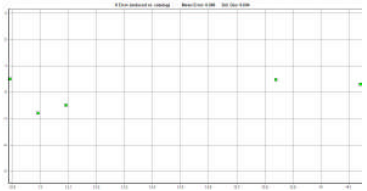


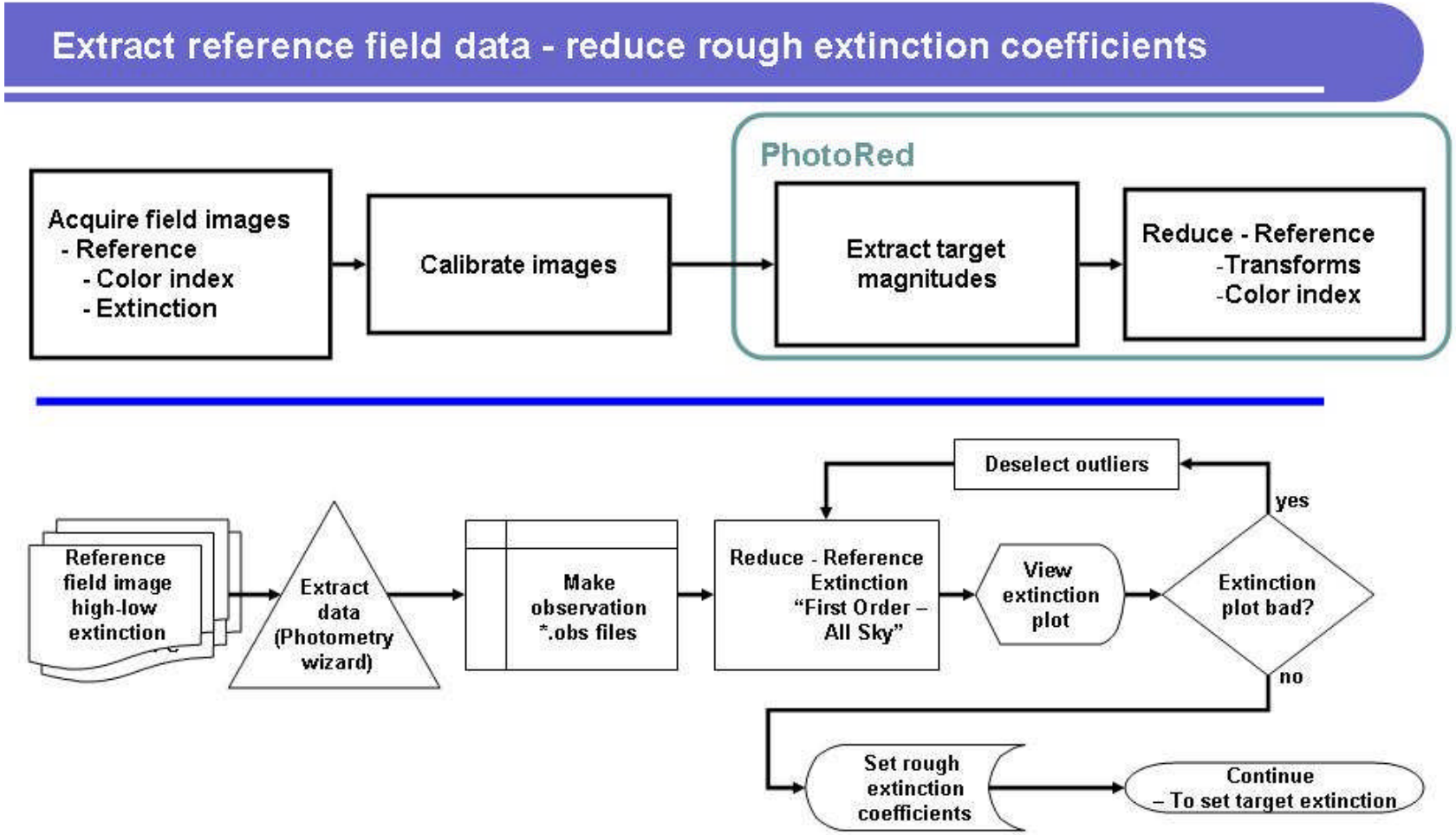

Extract reference field data - reduce transform coefficients
PhotoRed
Acquire field images
- Reference
- Color index
- Extinction
Calibrate images
Extract target magnitudes
Reduce - Reference
-Transforms
-Color index
Deselect outliers
yes
Reference field image high color-index
Extract data (Photometry wizard)
Make observation *.obs files
Reduce - Reference Transforms Color index
View transforms plot
Comparison stars plot bad?
no
Set transform coefficients
Reduce - Reference Errors
View errors plot
Transform error plot bad?
yes
Deselect outliers
no
Continue – To set rough extinction

Dialogue option; Operates on; Sets	Operates on	Sets	Plots
In PhotoRed, measure high and low reference-extinction field and high reference transforms field near target that do not contain a target per User Guide v9.2 at 55-59, Lesson 18:  Measures only one filter group (V, R or C) at a time. Uses: High-low extinction reference field; high color index reference field. Sets: PhotoRed transforms table and *.obs file.	Reference field images in PhotoRed: 	PhotoRed Transforms tables (*.obs)  Extracts standard magnitudes in data table: I.M. SNR B V R I -9... 488 13.199 12.118 11.538 11.004 -9... 488 13.971 13.458 13.151 12.849 -9... 488 12.016 11.530 11.239 10.950 -9... 488 12.623 12.309 12.123 11.906 -9... 488 12.483 11.467 10.922 10.433 Save to *.obs files – one for extinction with high-low data in extinction field and one for transforms/color index using the high reference field near target.	Nothing 

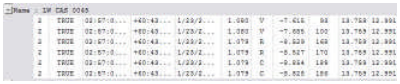
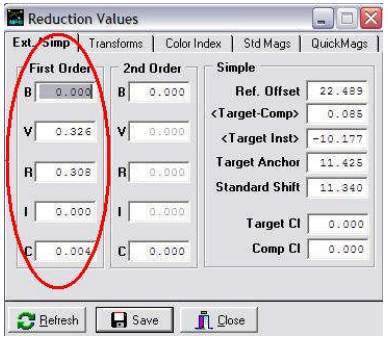
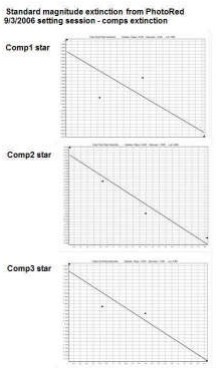
PhotoRed Reductions Menu Options:

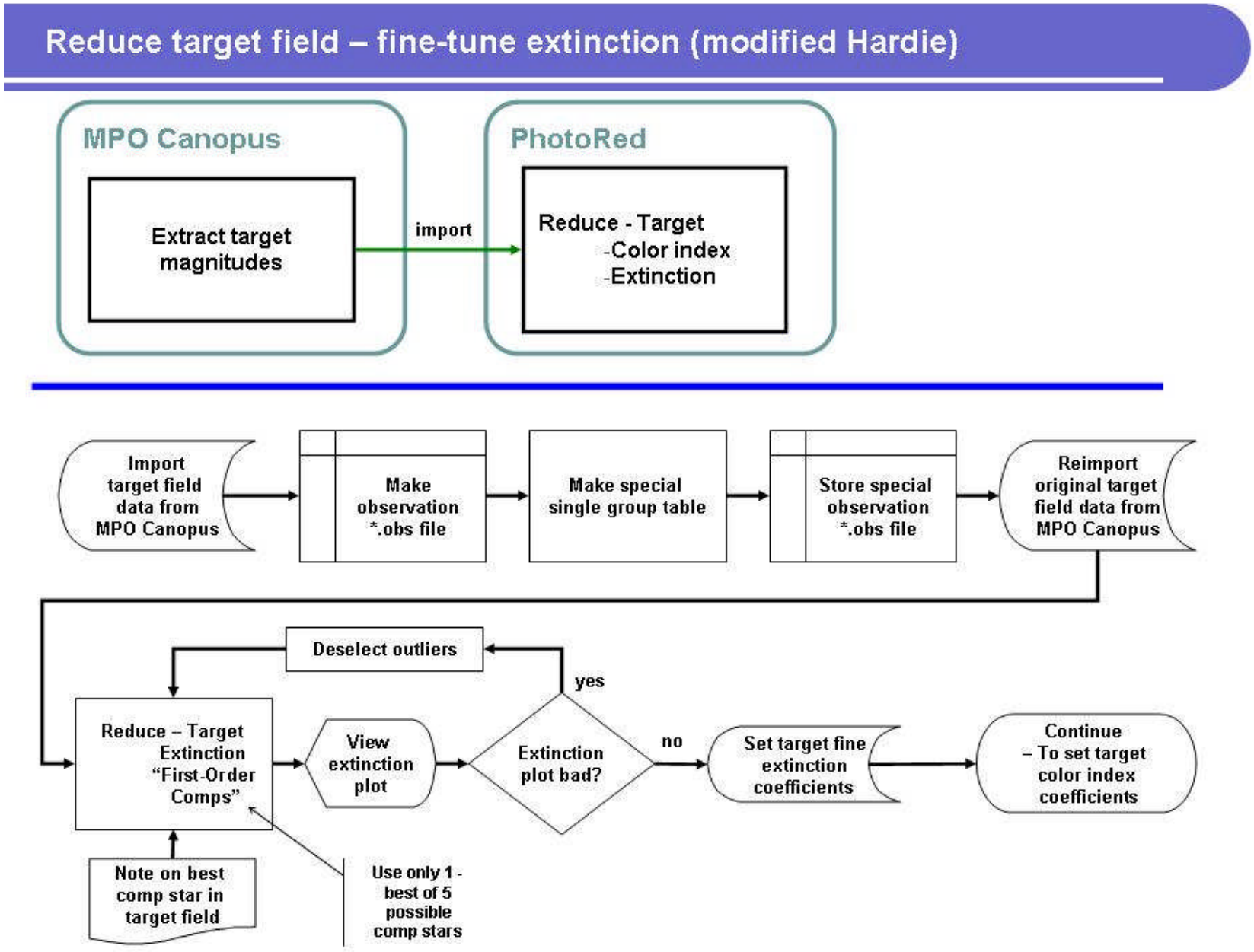


Dialogue option; Operates on; Sets	Operates on	Sets	Plots
"Transforms" – Reduction Method Option - PhotoRed Uses: V, R & C images of high reference field Sets: Rough coefficients to transform instrumental to standard magnitude using reference fields. *Lightcurves* at Sec. 5.7; *User Guide* v9.2 Lessons 18 (first half at pp. 60-62 – "Transforms" option) Also sets: Hidden color index coefficients to transform instrumental to standard magnitudes using a reference field. *Lightcurves* at Sec. 5.8; *User Guide* v9.2 Lesson 18 (first half at pp. 60-62 – "Transforms" option)	PhotoRed Lightcurve wizard data on high color index reference field – stored in *.obs file 	Transform Tab – Reductions 	Transform coefficients 
"Errors" – Reduction Method Option - PhotoRed Uses: V,R & C data from reference fields Sets: Check the transform errors in the reference fields. Lightcurves at Sec. 5.8; User Guide v9.2 Lesson 19 ("Errors" option).	PhotoRed Lightcurve wizard data on high color index reference field – stored in *.obs file 	Sets nothing; plot is read to confirm that transform coefficients are useable	Transform coefficient errors 



In PhotoRed, extract extinction reference field observations, as shown above with respect to the high reference field.

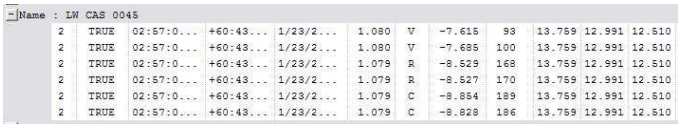
Dialogue option; Operates on; Sets	Operates on	Sets	Plots
"First Order – All Sky" – Reduction Method Option - PhotoRed Uses: V, R & C images of extinction reference fields. Sets: Initial rough estimate for first order extinction coefficients and nightly set point – a predicate for finding refined first order extinction using the Modified Hardie Method from the reference fields. *Lightcurves* at Secs. 5.9-10 and *User Guide* v9.2 Lesson 18 (last half at pp. 62-63 – "Comps - All Sky" option).	PhotoRed Lightcurve wizard data – high and low extinction reference fields – stored in *.obs files 	Ext/Simp Tab – Reductions 	Extinction coefficients – reference fields 


Reduce target field – fine-tune extinction (modified Hardie)
MPO Canopus
Extract target magnitudes
import
PhotoRed
Reduce - Target
-Color index
-Extinction
Import target field data from MPO Canopus
Make observation *.obs file
Make special single group table
Store special observation *.obs file
Reimport original target field data from MPO Canopus
Deselect outliers
yes
Reduce – Target Extinction "First-Order Comps"
View extinction plot
Extinction plot bad?
no
Set target fine extinction coefficients
Continue – To set target color index coefficients
Note on best comp star in target field
Use only 1 - best of 5 possible comp stars

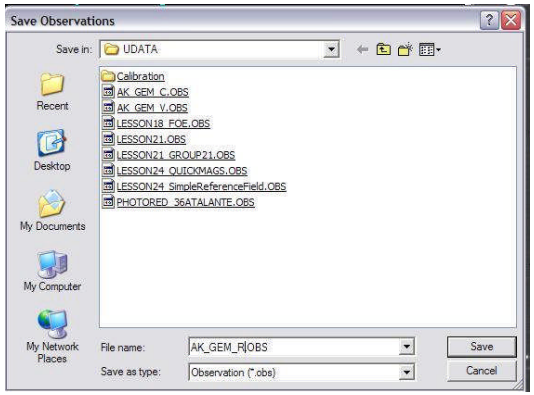
Dialogue option; Operates on; Sets	Operates on	Sets	Plots

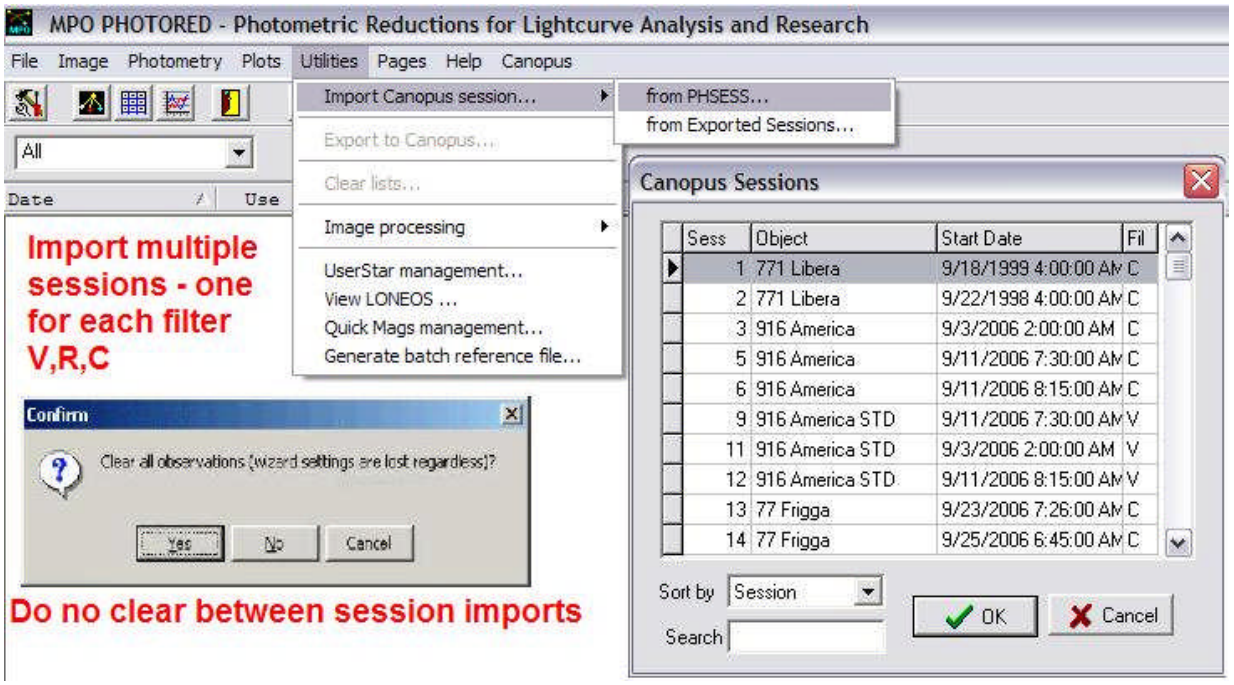
In PhotoRed – pull-import MPO Canopus target field data for V, R and C filters forward into PhotoRed's reduction table. User Guide v9.2 at 75-76, Lesson 20.

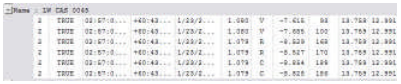
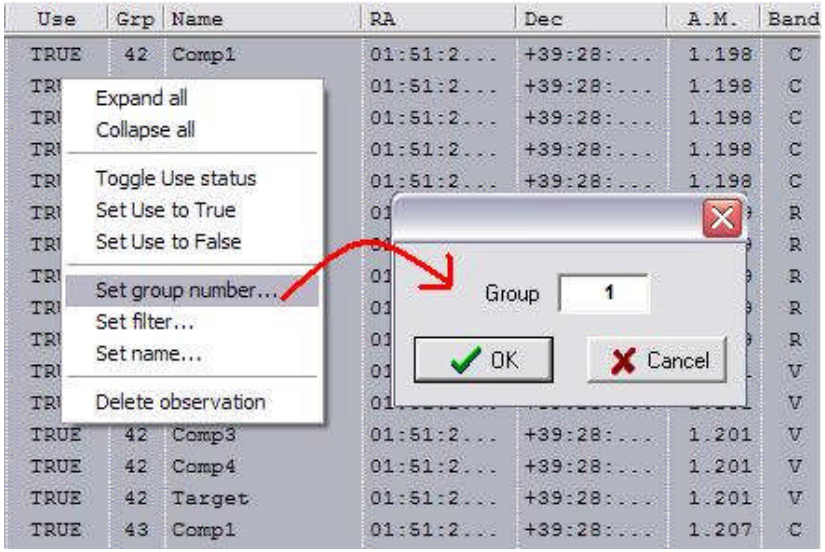
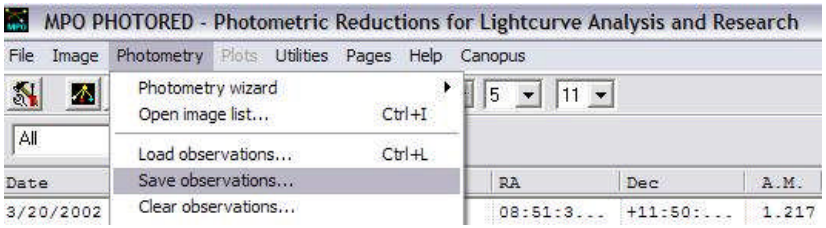
Or measure images using Differential Photometry using special "group" settings per User Guide at User Guide v9.2 at 69-74, Lesson 20.

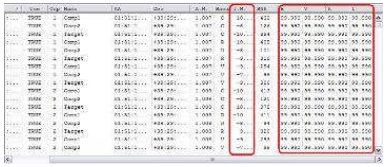
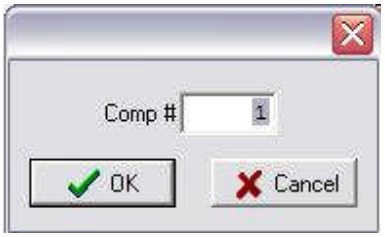
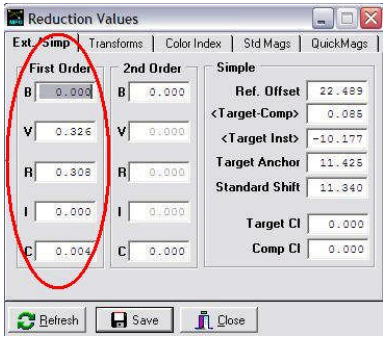
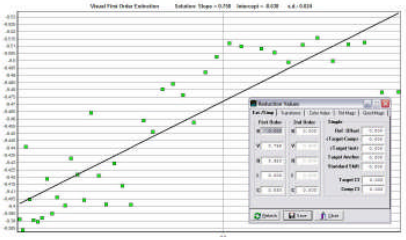


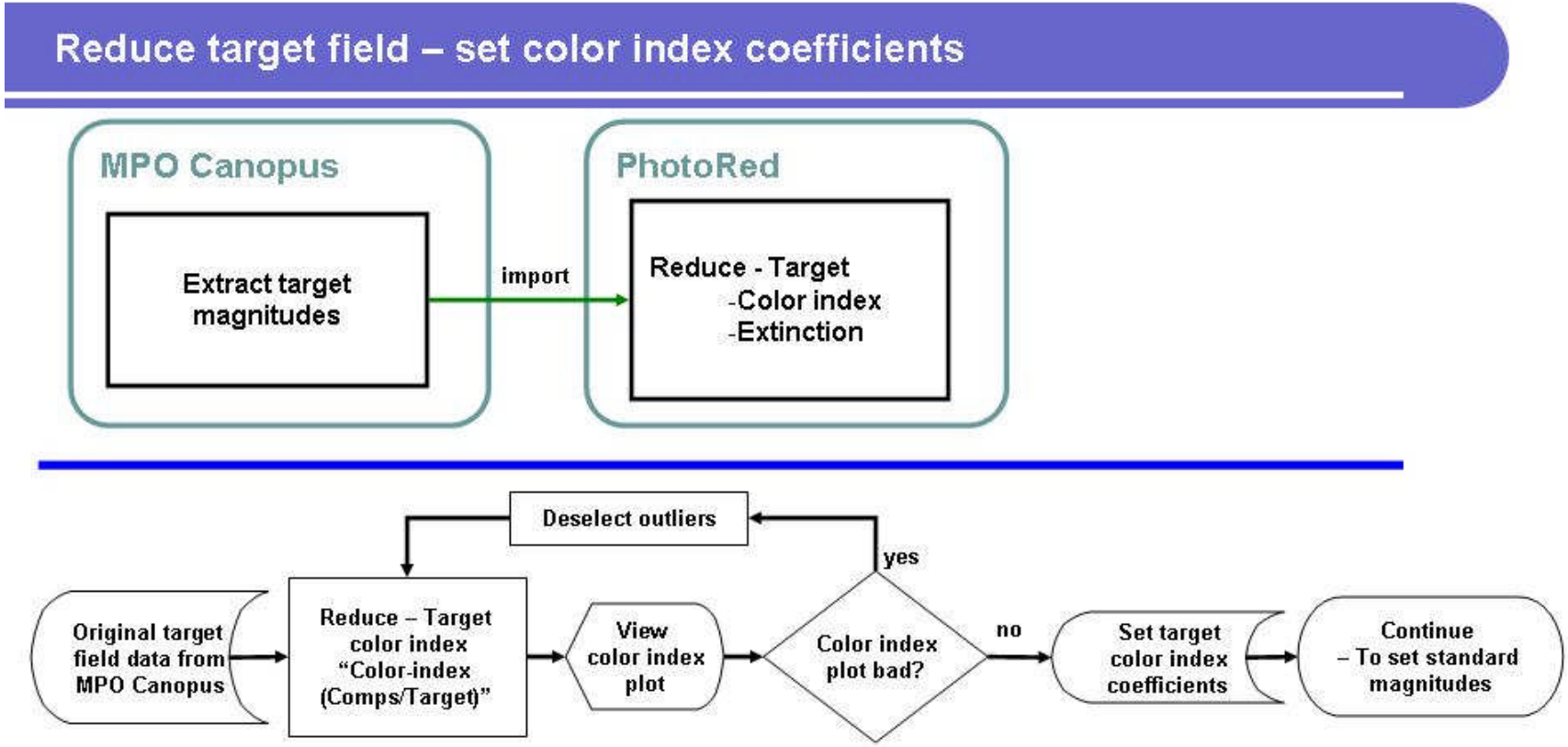
Save the combined filter data into a working *.obs file.

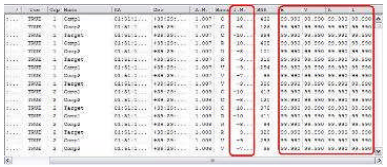
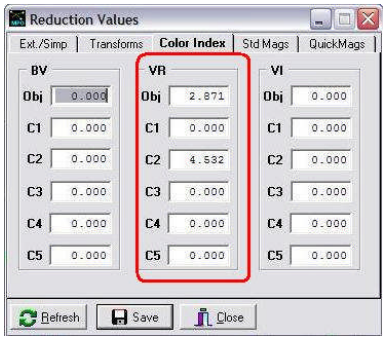
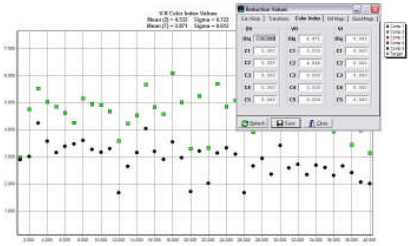




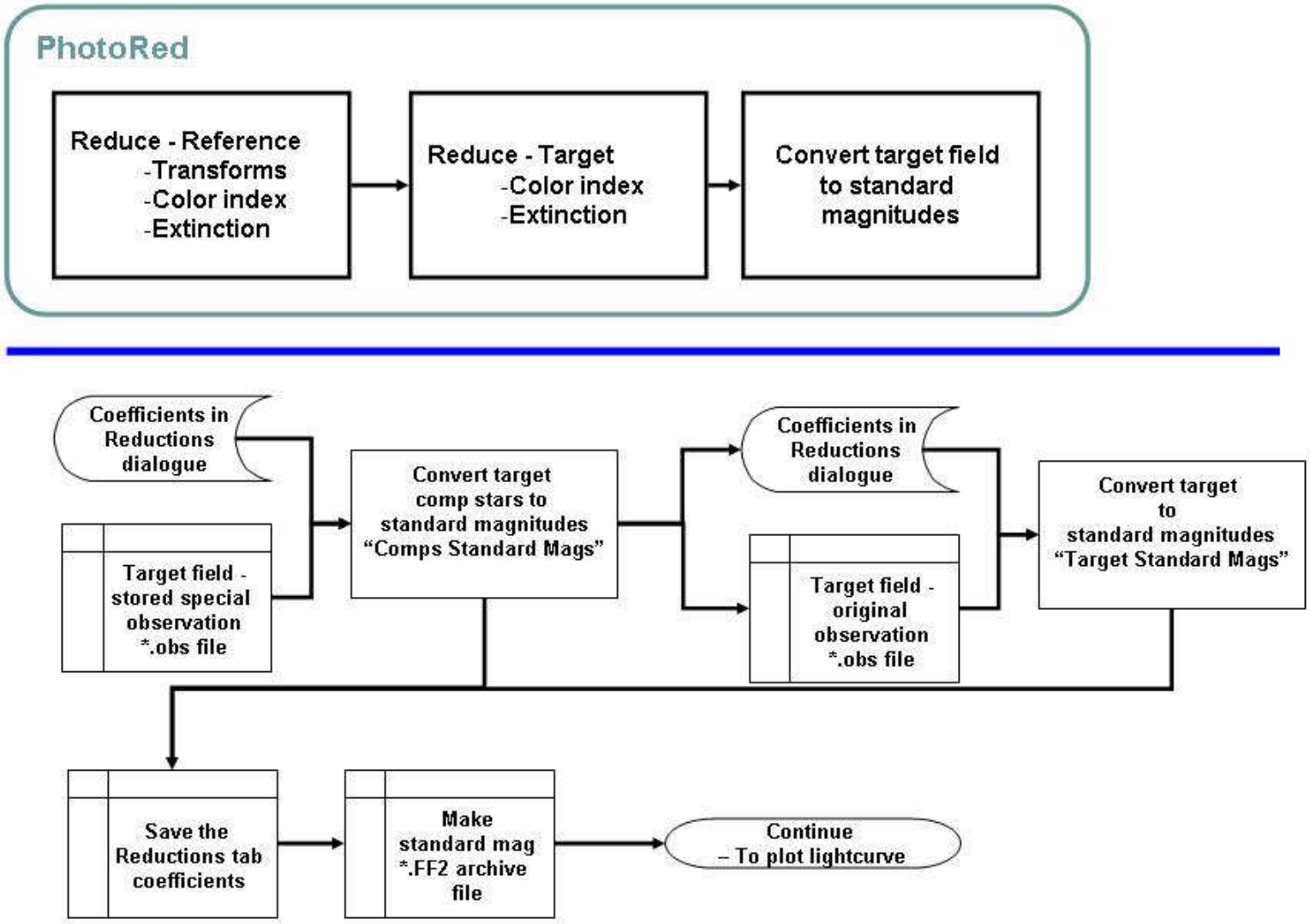
Dialogue option; Operates on; Sets	Operates on	Sets	Plots
In PhotoRed - Make special 2nd observation file list using the target data field with just one group number for all observations. UserGuide v9.2 at 85-86. Uses: Reductions table. Sets: Special *.obs file From UserGuide v9.2 at 85: "Here comes the time saving trick. The Color Index (Comps/Target) method requires three groups of data in order to calculate a standard deviation of the derived values. On the other hand, the Comps Standard Mags method, which uses the exact same data, must have the data arranged so that there is one and only one group but with at least three observations in each filter per group to compute the standard deviations. You don't want to remeasure the images, keeping the Group number at 1 and you don't have to."	Reductions observation table in PhotoRed.  On the menubar – Photometry | Save observations	Makes special "obs" file with one group for later use by the "Comps Standard Mags" Reduction routine.  
Reload and re-pull the MPO Canopus target field data for V, R and C filters forward into PhotoRed's reduction table. User Guide v9.2 at 75-76, Lesson 20. You can also reload the saved *.obs data from the temporary working file.	Reductions table – loads. On the menubar – Photometry | Load observations	See illustrations above. This reloads the original target field data; not the special *.obs file.	

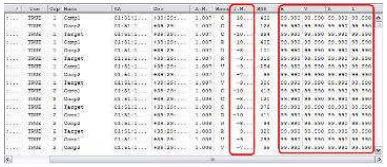
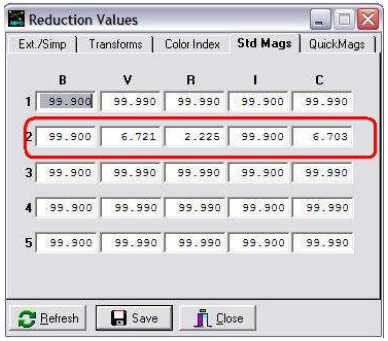
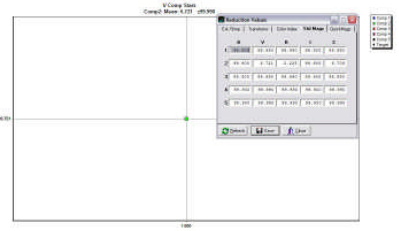
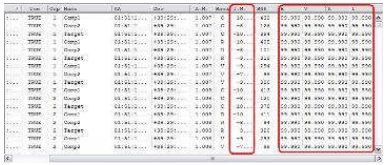
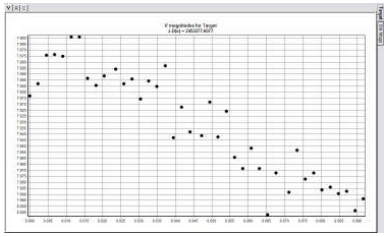
Dialogue option; Operates on; Sets	Operates on	Sets	Plots
"First-Order Comps" – Reduction Method Option – PhotoRed. User Guide v9.2, Lesson 20 Uses: V & C continuous images of the target field – or – V, R & C continuous images of the target field - and using the reference field transform and extinction coefficients set above. Uses only 1 comp star – the best of 5 possible comp stars found when measuring field in MPO Canopus. See above in MPO Canopus where the best comp star was noted down for future reference. Sets: For the target field refine the first order coefficients, readjust the nightly extinction and set the transformation equation nightly zero-point. Now that you have an initial rough estimate of the transform and extinction coefficients from the reference field, a more refined estimate for the target field can be obtained. Use the target field and Lightcurves Sec. 5.12 (continuous target field images – "First-Order Comps") and User Guide v9.2 Lesson 20	Imported PHESSES data or export *FF2 file or saved *.obs file - on original target field from MPO Canopus  Run extinction reduction by selecting the best comp star: 	Ext/Simp Tab – Reductions 	Extinction coefficients – target field 


Reduce target field – set color index coefficients
MPO Canopus
Extract target magnitudes
import
PhotoRed
Reduce - Target
-Color index
-Extinction
Deselect outliers
yes
Original target field data from MPO Canopus
Reduce – Target color index "Color-index (Comps/Target)"
View color index plot
Color index plot bad?
no
Set target color index coefficients
Continue – To set standard magnitudes

Dialogue option; Operates on; Sets	Operates on	Sets	Plots
"Color Index (Comps/Target)" – Reduction Method Option - PhotoRed Uses: V & C continuous images of the target field – or – V, R & C continuous images of the target field Sets: Find the color index coefficients for comparison stars in the target field. Lightcurves at Secs. 5.13 and 5.14 and User Guide v9.2 Lesson 21 (option "Color Index (Comps/Target)").	Imported PHESSES data or export *FF2 file - on target field from MPO Canopus 	Color index coefficients for target field 	Color indices for comps and target in target field 

Reduce target field – standard magnitudes of comparison stars



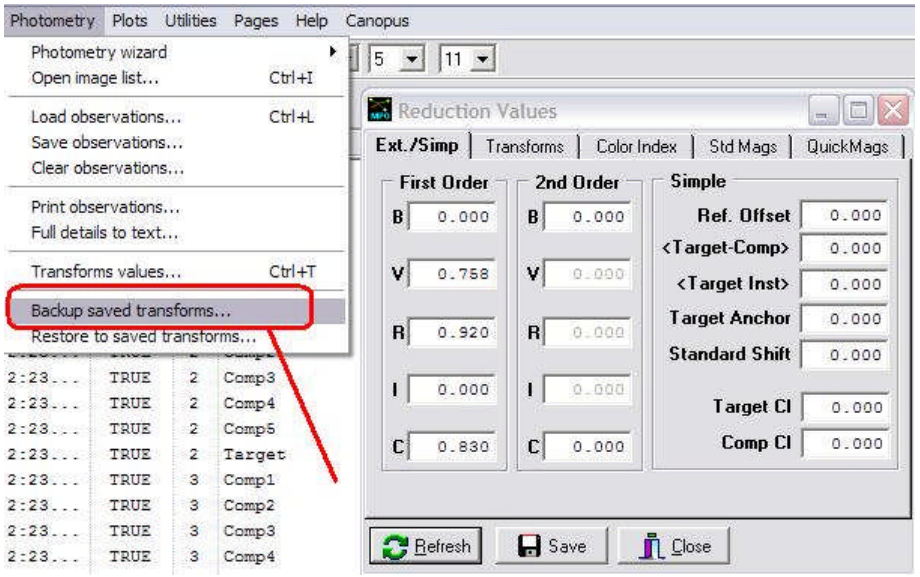
Dialogue option; Operates on; Sets	Operates on	Sets	Plots
"Comps Standard Mags" – Reduction Method Option - PhotoRed Uses: Special single group *.obs file" created above Sets: Find the standard magnitudes of target in the target field by the alternative "basic" instrumental to standard magnitudes method. In the target field, convert the instrumental magnitudes for the comparison stars to standard magnitudes. Lightcurves at Secs. 5.15 and 5.16 and User Guide v9.2 Lesson 22 (option "Comp Standard Mags").	Special single group *.obs file" created above  Does not reset the observation values in the table. Sets reduction coefficients only	Standard magnitude coefficients for comp stars 	Standard magnitude conversion indices for all available comps 
"Target Standard Mags" – Reduction Method Option - PhotoRed Uses: Target field data on one filter and coefficients set above in Reductions dialogue tabs. Sets: Find the standard magnitudes of target field comparison stars by the alternative "basic" instrumental to standard magnitudes method. In the target field, convert the instrumental magnitudes for the target to standard magnitudes. Lightcurves at Secs. 5.17 and 5.18 and User Guide v9.2 Lesson 23 (option "Target Standard Mags").	Imported PHESSES data or export *FF2 file - on target field from MPO Canopus (original *.obs file)  Does not reset the observation values in the table. Sets reduction coefficients only	Data text table for export listing target standard magnitudes by Julian date. 	List of target standard magnitudes VISUAL ------ J.D. Mag. Err ---------- ----- ----- 2452277.60771 7.908 7.908 2452277.60998 7.898 7.898 2452277.61225 7.874 7.874 2452277.61451 7.874 7.874 2452277.61679 7.875 7.875 2452277.61906 7.859 7.859 2452277.62133 7.859 7.859 2452277.62360 7.894 7.894 2452277.62587 7.899 7.899 2452277.62814 7.892 7.892 2452277.63128 7.886 7.886 2452277.63355 7.898 7.898 2452277.63581 7.894 7.894 2452277.63809 7.911 7.911 2452277.64037 7.896 7.896 2452277.64264 7.900 7.900 2452277.64491 7.883 7.883 2452277.64718 7.943 7.943 2452277.64946 7.918 7.918 2452277.65174 7.938 7.938 2452277.65490 7.941 7.941 2452277.65716 7.913 7.913 2452277.65943 7.942 7.942 2452277.66170 7.921 7.921 2452277.66397 7.959 7.959 2452277.66625 7.969 7.969 2452277.66852 7.952 7.952 2452277.67080 7.969 7.969 2452277.67307 8.007 8.007 2452277.67534 7.972 7.972 2452277.67890 7.989 7.989

Dialogue option; Operates on; Sets	Operates on	Sets	Plots

In PhotoRed, save the Reductions tab.

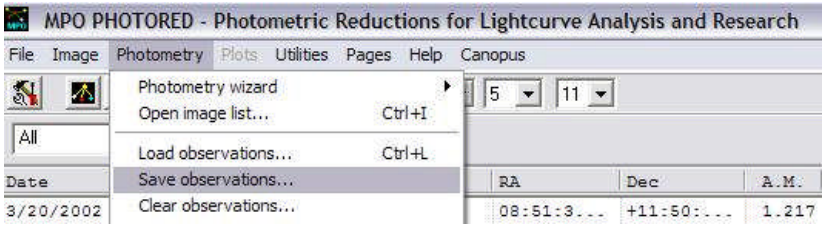
Uses: Reductions tab coefficients and completed reduction.

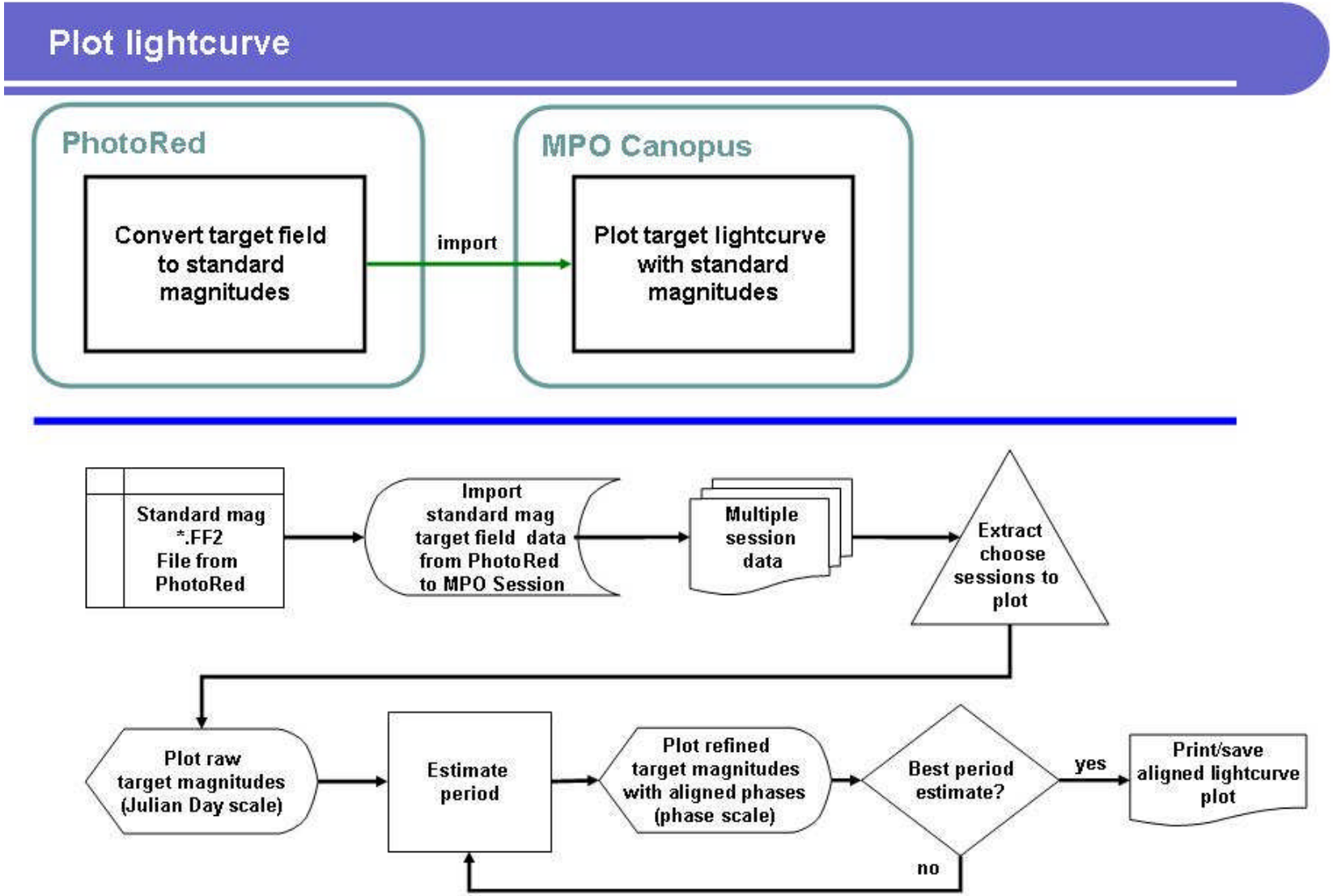
Sets: The coefficients in the Reduction tab to a "*.prr" file.



In PhotoRed, optionally, make an archival export file - *.obs

On the menubar – Photometry | Save observations.



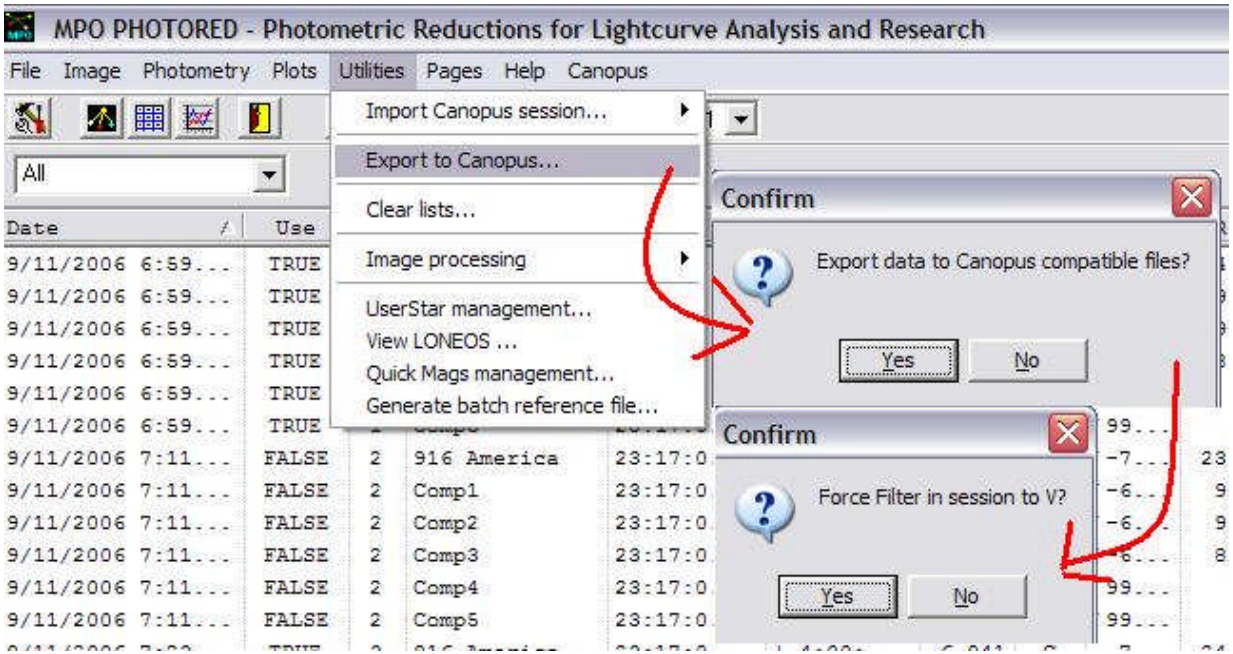

Plot lightcurve
PhotoRed
Convert target field to standard magnitudes
import
MPO Canopus
Plot target lightcurve with standard magnitudes
Standard mag *.FF2 File from PhotoRed
Import standard mag target field data from PhotoRed to MPO Session
Multiple session data
Extract choose sessions to plot
Plot raw target magnitudes (Julian Day scale)
Estimate period
Plot refined target magnitudes with aligned phases (phase scale)
Best period estimate?
yes
Print/save aligned lightcurve plot
no

Dialogue option; Operates on; Sets	Operates on	Sets	Plots

Loop back (export) standard magnitude data for target field back to MPO Canopus. MPO Canopus v9.2 Reference Guide at 311-312. Make an archival *.FF2 file of standard magnitudes.

If you have imported/pulled your target data from MPO Canopus, you can loop back the standard V magnitudes of your target as a new session in MPO Canopus that contains standard V magnitudes. With target brightness in standard V magnitudes, multiple sessions across several days can be plotted.

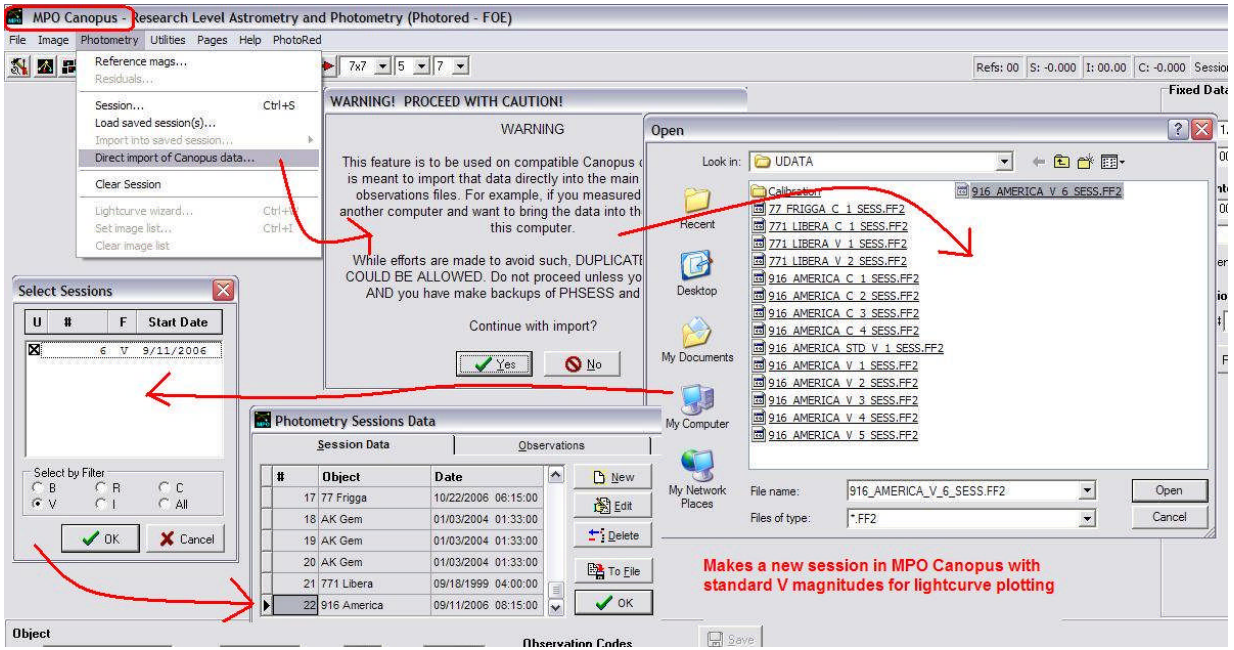
1) Export standard magnitudes from PhotoRed.



Dialogue option; Operates on; Sets **Operates on** **Sets** **Plots**

2) **Working in MPO Canopus, import PhotoRed standard magnitudes** into MPO Canopus.

MPO Reference Manual, v9.2 at 175-177.

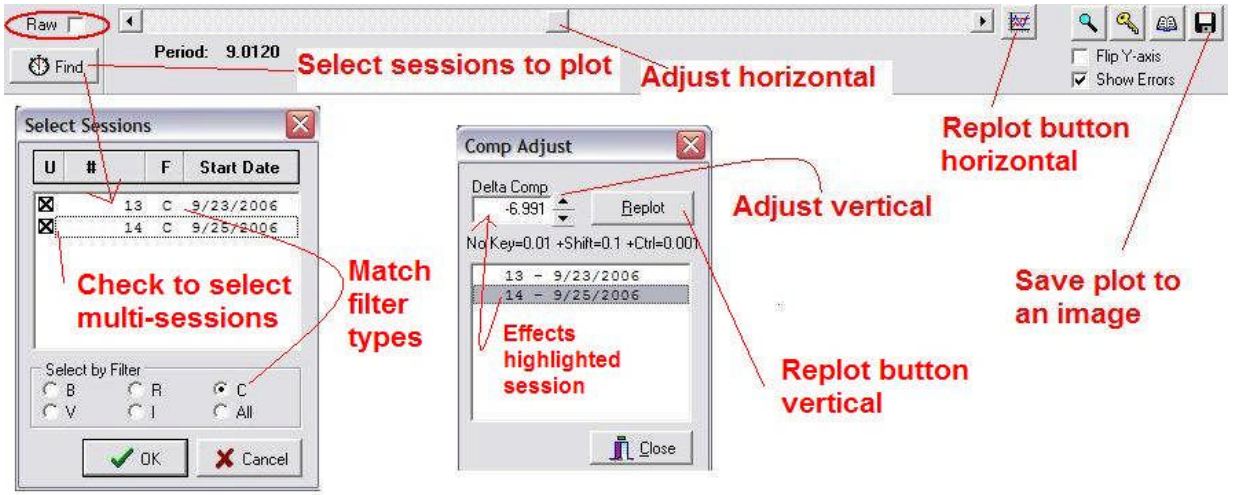


In MPO Canopus, plot the lightcurve using target standard magnitudes imported from PhotoRed session.

User Guide v9.2 at Lessons 12 through 17.

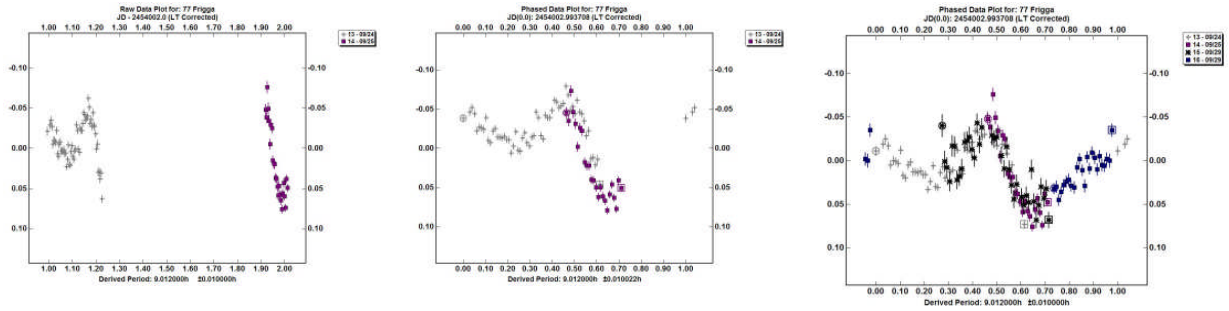
"Raw" button toggles between reading raw magnitude data from file or refining an existing plot in memory. When "raw" is checked, the lightcurve fragments plot based on the absolute Julian date.

When "raw" is unchecked, the lightcurve plots based on a computed light curve phase between 0.0 and 1.0 in tenths of a phase.



Dialogue option; Operates on; Sets	Operates on	Sets	Plots

Example screen shots using MPO Canopus lightcurve plot page to move several partial lightcurves so they form an overlapping major lightcurve period.



In PhotoRed, use the Root Mean Square (RMS) errors plotted in the Residuals dialogue to find the period.

Uses: "Raw" and refined curve plots, above. Initial estimate of period.

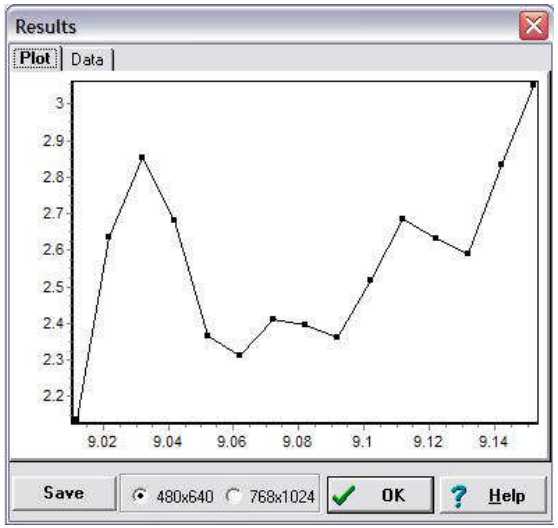
Sets: Refined curve plots.

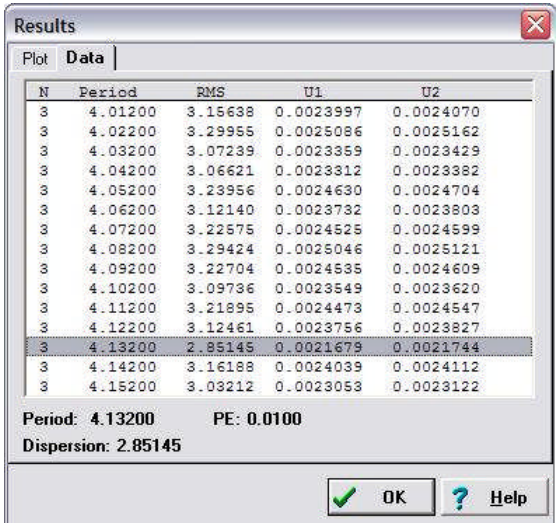
The initial period guess can be based on your knowledge gained from imaging the target. For known comets estimated periods can be found from the Harvard Minor Planet Center asteroid data archive, from the MPO Bulletin or from journal literature.

Harvard Lightcurve-Asteriod Data Archive
http://cfa-www.harvard.edu/iau/lists/LightcurveDat.html

Minor Planet Observer Bulletin
http://www.minorplanetobserver.com/mpb/

NASA-ADS
http://adsabs.harvard.edu/abstract_service.html





Itinerate the light curve plots to minimize the unexplained periodicity in the plot – as indicated in the Residuals plot window. User Guide v9.2 at Lesson 16; MPO Canopus Manual v9.2 at 148; *Lightcurves* at Chap. 11.

Here, the initial Residuals plot shows a high degree of residual unexplained periodicity (left-side) and estimates the next itineration period (right-side) based on the initial guess.

Dialogue option; Operates on; Sets	Operates on	Sets	Plots

Plot the initial period "raw" guess. The working example are raw "C" images of 77 Frigga. Initial "raw" search is based on the following settings (MPO Canopus Manual v9.2 at 148):

Orders: If more than 25 points - 4; "sparse coverage" – 2. I use one for this.

Min.: Make initial guess based on rough plot of magnitudes standard magnitudes in spreadsheet.

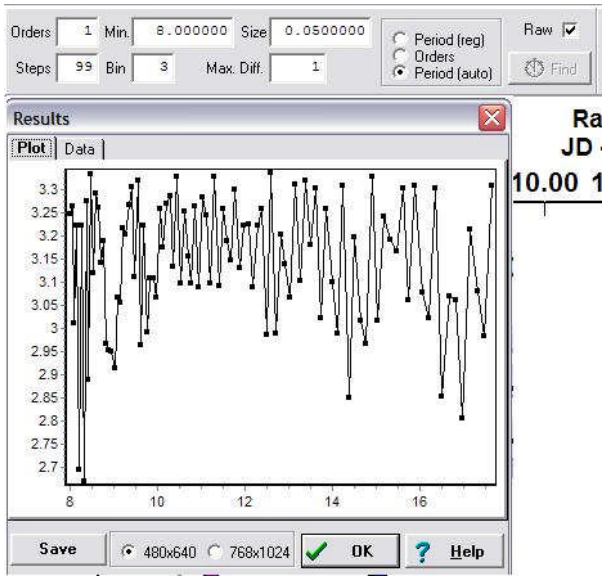
Size: Time in hours between two data points.

Steps: Number of periods to search across - try 100.

Bins: 3 for 1..10; number of points to be binned together for computation - I use 1.

Max Diff.: Average time between images – 1.

Period: Auto.



The initial test – based on a period 8.00 hours – shows minimum residual error at around 8.5 hours.

Dialogue option; Operates on; Sets	Operates on	Sets	Plots

Plot the refined data (not raw).

The refined search is based on the last itineration plot and the following plot settings (MPO Canopus Manual v9.2 at 148-149):

Orders: If more than 25 points - 4; "sparse coverage" – 2.

Min.: Make initial guess based on rough plot of magnitudes standard magnitudes in spreadsheet.

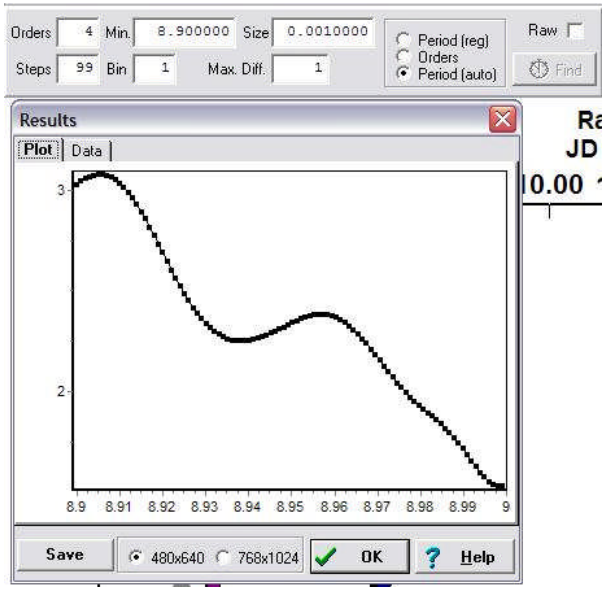
Size : Set time to 0.001.

Steps: Number of periods to search across - try 99.

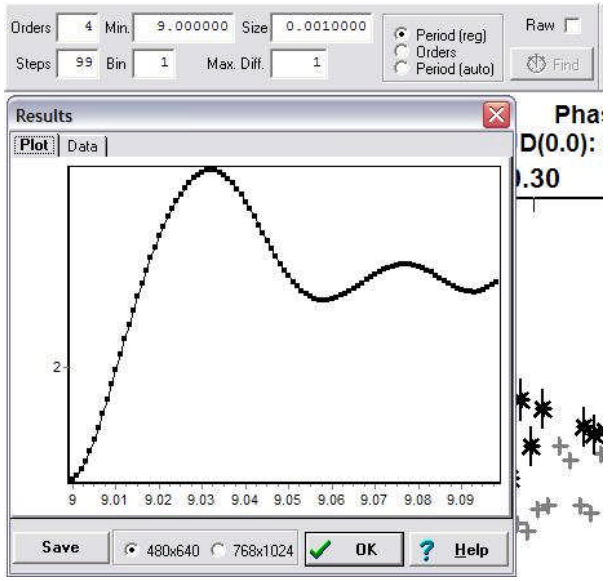
Bins: 3 for 1..10; number of points to be binned together for computation - I use 1.

Max Diff.: Average time between images – 1.

Period: Auto or Regular.



A period of 8.9 hours is tested and the residuals decreases toward 9.0 hours.

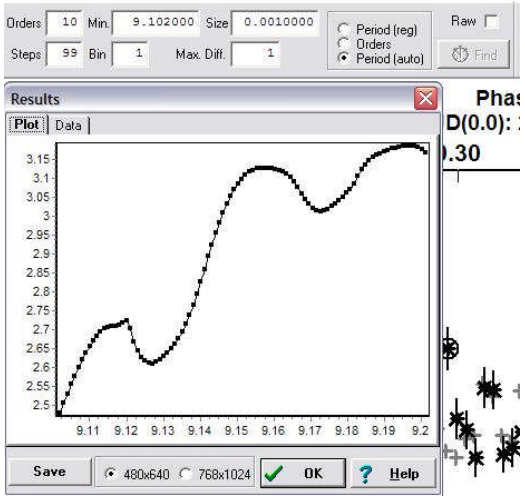


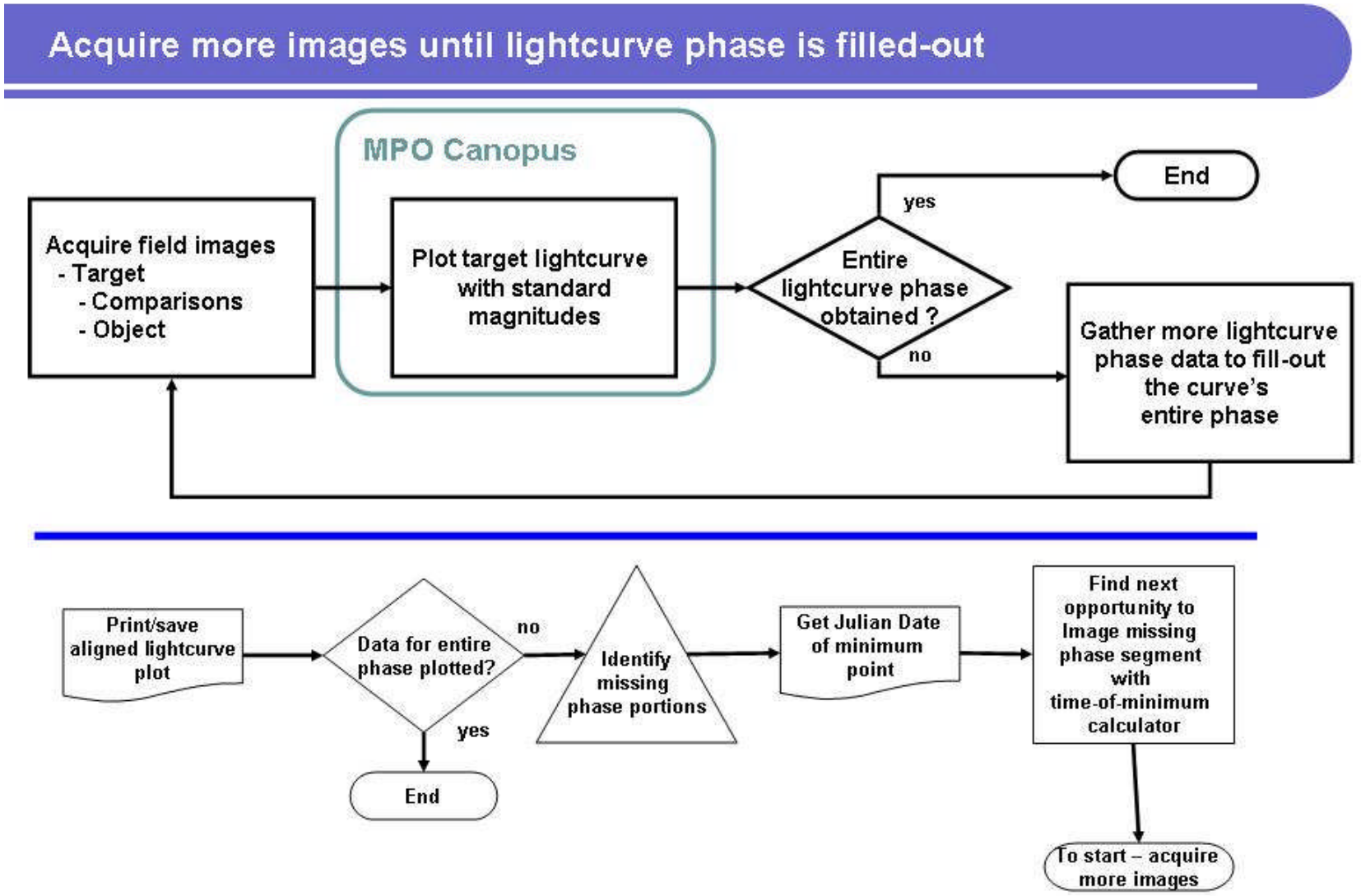
The residuals for a period of 9.0 hours increase away from about 9.0 hours. The true period is between these values.

Narrow in on a minimized residual period.

After a few more refined search period guesses, a minimum residual curve is plotted. Because the working example was from rough "C" filter images, some residual periodicity remains (left-hand screen shot).

The right-hand screen shot is the residuals curve for the final 771 Libera asteroid data from the MPO Canopus distribution disk and User Guide example. Because the image and data extraction is high quality, almost all the periodicity is removed from the Residuals plot. The residual error is linear.



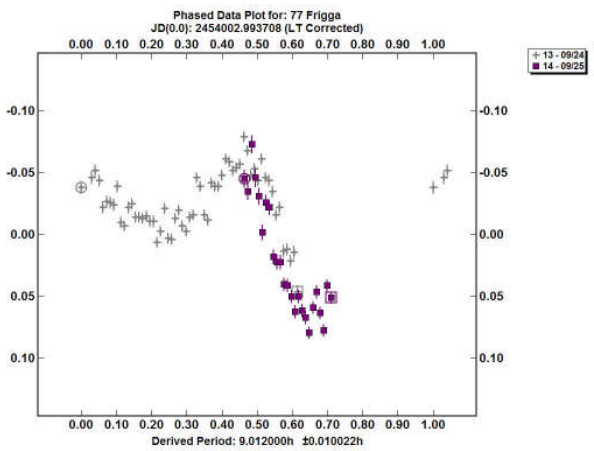

Acquire more images until lightcurve phase is filled-out
MPO Canopus
Acquire field images
- Target
- Comparisons
- Object
Plot target lightcurve with standard magnitudes
Entire lightcurve phase obtained ?
yes
End
no
Gather more lightcurve phase data to fill-out the curve's entire phase
Print/save aligned lightcurve plot
Data for entire phase plotted?
no
yes
End
Identify missing phase portions
Get Julian Date of minimum point
Find next opportunity to Image missing phase segment with time-of-minimum calculator
To start – acquire more images

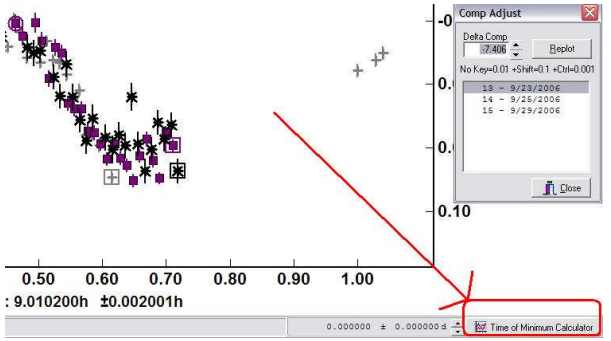
Dialogue option; Operates on; Sets **Operates on** **Sets** **Plots**

In MPO Canopus, if you have not captured images and extracted data, you will need to **gather more lightcurve phase data** to fill-out the curve's entire phase.

In the left-hand illustration, no phase data has been collected for asteroid 77 Frigga between phase 0.75 and 0.95.

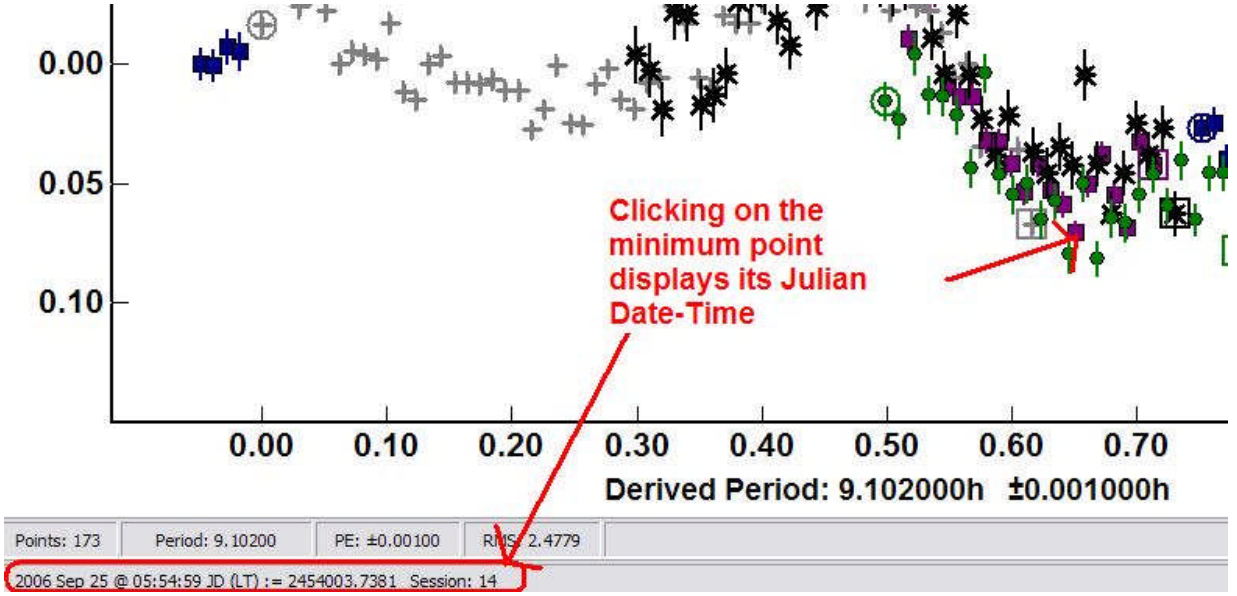
Find the next imaging opportunity to capture the missing portion of the phase using the "Time-to-Minimum Calculator" (right-hand figure). The "Time-of-Minimum Calculator" feature button is in the lower-right hand corner of the Lightcurve plotting window.





Get Julian Date of minimum point.

For the Time-of-Minimum Calculator to work, it needs the Julian Date-Time of a minimum point on the light-curve. Clicking on a point displays the Julian Date-Time of the point (from an image) in the lower-left-hand status bar of the Lightcurve plotting window.



Dialogue option; Operates on; Sets	Operates on	Sets	Plots

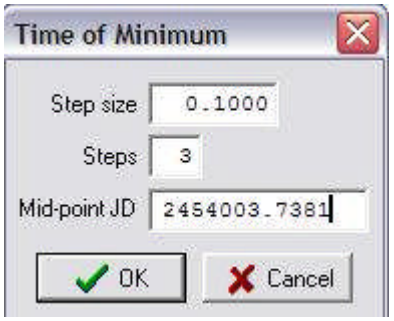
Find next opportunity to image the missing lightcurve phase segment with time-to-minimum calculator.

The Time-of-Minimum calculator works by examining the curve of points around the Julian Date-Time of the minimum point. MPO Canopus Manual v9.2 at 165-168.

mid-point JD: Enter the minimum JD date-time found above.

Step size: Is the binning time frame around which the algorithm searches. Generally, use 0.1 for one-tenth of the phase curve.

Steps: The number of steps used by the algorithm – 3.



After pressing Okay, the Time-of-Minimum Ephemeris dialogue displays. Plot an imaging phase opportunity using these settings:

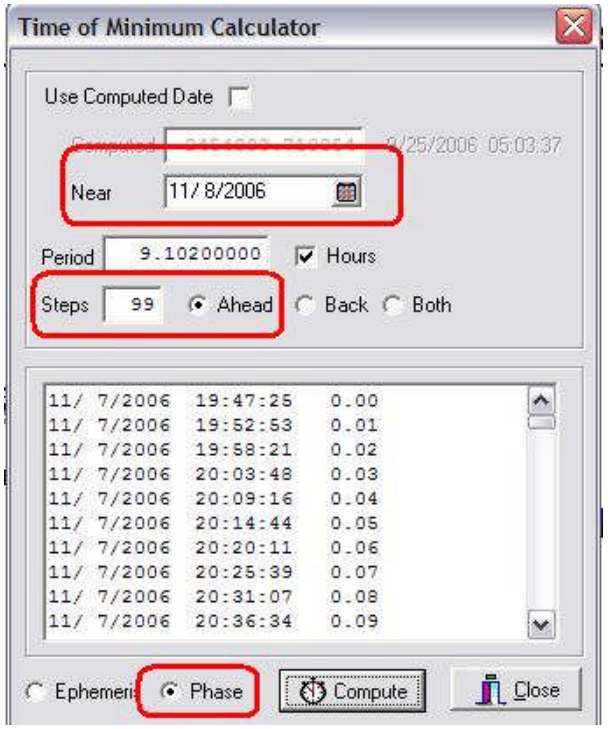
Near: The date of your planned observation.

Period: The light curve plotted period.

Steps: Use 99. **Ahead:** Checked.

Phase: Checked.

The report window now estimates the lightcurve's phase (right-hand column) at various date-times after the "Near" date.



END OF PROCESS

I.

Misc notes on other items in MPO Canopus/PhotoRed

Reductions Table B,V,R,I standard magnitudes: Normally, the "Basic rigorous method" does not change the 99.99 B,V,R, I values in the PhotoRed Reductions window or Reductions table.

In the Reductions table, the right-hand B,V,R,I standard magnitude columns are not changed.

In the Reductions table, the right-hand B,V,R,I standard magnitude columns are changed by the "Quick mags" reference field measurement routine.

The "Quick mags" method, which is used to reduce AAVSO long-period variable measurements to standard magnitudes, is not covered here.

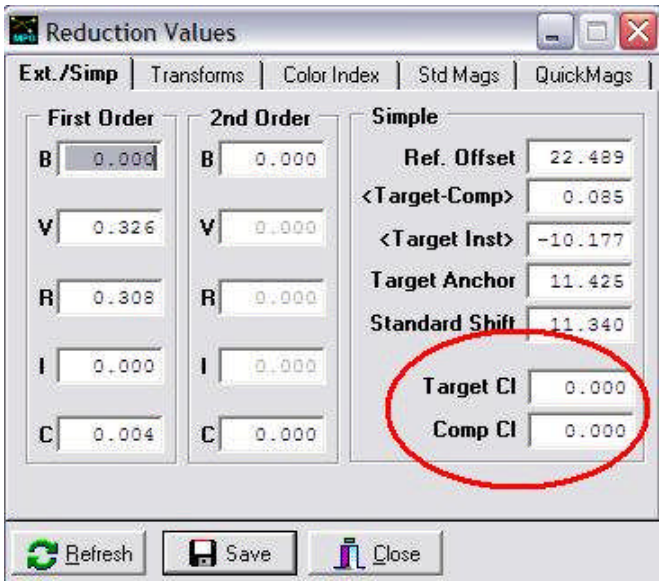
Misc. Binzel method coefficients: On the Reductions dialogue, Ext/Simp. Tab, the right-hand "Simple" or "Binzel" method will change two fields: Target CI and Comp CI.

These fields appear to be estimated and are hand-entered.

The Binzel method of reducing observations to standard magnitudes is not covered here.

Use	Grp	Name	RA	Dec	A.M.	Band	I.M.	SNR	B	V	R	I
TRUE	6..	Comp1	01:51:1...	+39:29:...	1.007	C	-10...	432	99.990	99.990	99.990	99.990
TRUE	6..	Comp2	01:51:1...	+39:29:...	1.007	C	-10...	510	99.990	99.990	99.990	99.990
TRUE	6..	Comp3	01:51:1...	+39:29:...	1.007	C	-10...	290	99.990	99.990	99.990	99.990
TRUE	6..	Comp4	01:51:1...	+39:29:...	1.007	C	-10...	427	99.990	99.990	99.990	99.990
TRUE	6..	Target	01:51:1...	+39:29:...	1.007	C	-10...	393	99.990	99.990	99.990	99.990

Name : LW CAS 0045											
2	TRUE	02:57:0...	+60:43...	1/23/2...	1.080	V	-7.615	93	13.759	12.991	12.510
2	TRUE	02:57:0...	+60:43...	1/23/2...	1.080	V	-7.685	100	13.759	12.991	12.510
2	TRUE	02:57:0...	+60:43...	1/23/2...	1.079	R	-8.529	168	13.759	12.991	12.510
2	TRUE	02:57:0...	+60:43...	1/23/2...	1.079	R	-8.527	170	13.759	12.991	12.510
2	TRUE	02:57:0...	+60:43...	1/23/2...	1.079	C	-8.854	189	13.759	12.991	12.510
2	TRUE	02:57:0...	+60:43...	1/23/2...	1.079	C	-8.828	186	13.759	12.991	12.510



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