Before Getting Started...

V12 Tutorial: Fixed Formatting

Forced "U.S.-centric" settings

Ini (text) files are used; mixing formats can cause problems.

- **Time separator ' : ' colon (also used as RA/Dec separator)**
  RA: 12:45:22.6 Dec: +05:32:57.9 UT: 04:52:30 (leading zeros/24-hour)
- **Date separator ' – ' dash Date order yyyy-mm-dd**
  May 12, 2023: 2023-05-12 (leading zeros)
- **Decimal point ' . ' period**
  Value = –0.45587 (leading zero for |x| < 1.0, no thousands grouping)
- **Millimeters for focal lengths; meters for apertures (30 cm = 0.30 m)**

MPO v12 Tutorial

Lightcurve Analysis

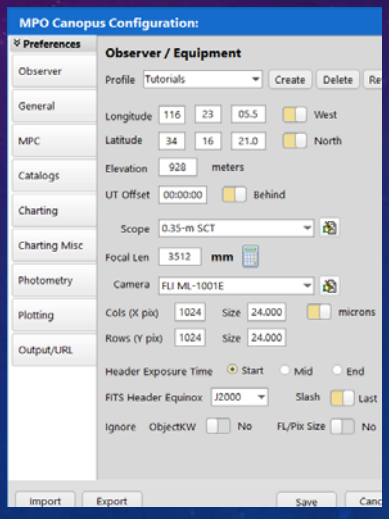
V12 Tutorial: The Tutorials User-Profile

"Must See TV"

Tutorials Profile

- Used in asteroid photometry and other tutorials.

https://YouTube.com/@8734Warner

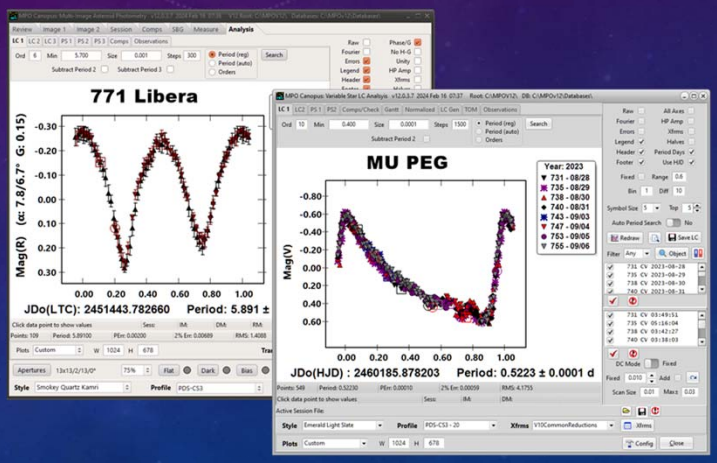


V12 Tutorial: Lightcurve Analysis
One for Four

- **Four Analysis Engines:**
  - **MIAsteroidPhotometry.**
  - **AsteroidLCAnalysis.**
  - **VarStarMIPhotometry.**
  - **VarStarLCAnalysis.**

They look and work exactly the same way.

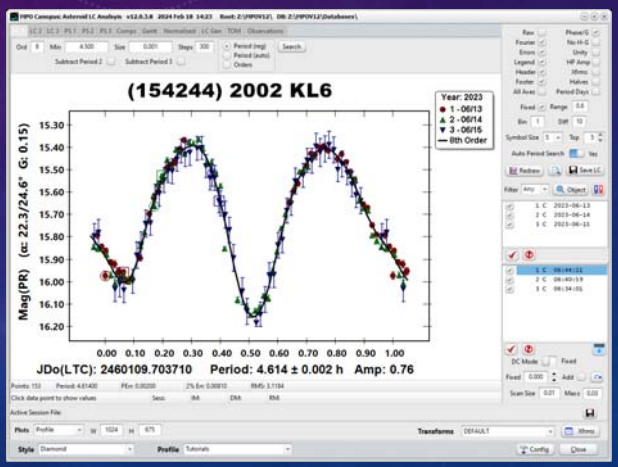
The difference is which options are used and up to 3 periods are allowed for asteroids but only 2 for variable stars.



V12 Tutorial: Lightcurve Analysis
The Stand-alone LC Asteroid Program

The AsteroidLCAnalysis Program

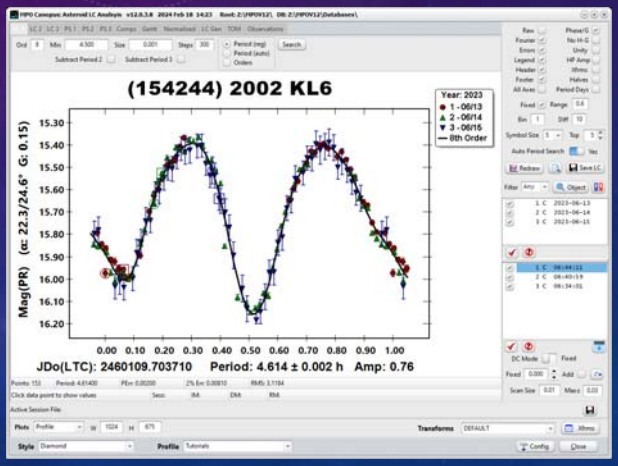
- **Data available for a dual-period search.**
- **Allows for a 3rd period.**
- **H-G and unity corrections not seen and used for variable stars.**



V12 Tutorial: Lightcurve Analysis

What's Lies Ahead

1. Configuration Setup.
2. Taking a Guided Tour.
3. Selecting an Object.
4. Working with the Comp Stars (and Check).
5. Single-period Analysis.
6. Dual-period Analysis.
7. What You Didn't Learn.
8. Asteroid vs. VarStar control, settings, and use.
9. Plot Pointers.

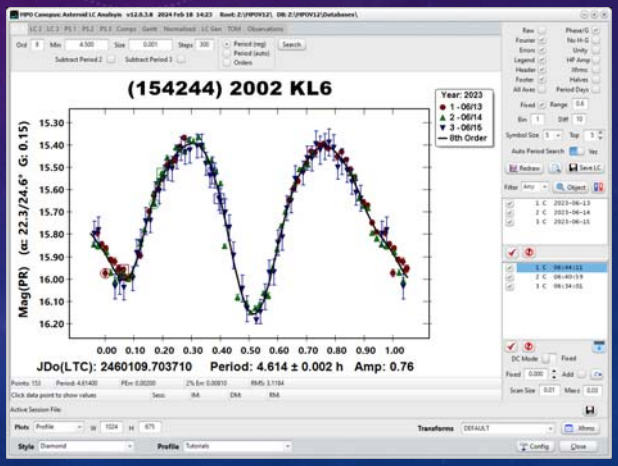


Concentrate on the Process

V12 Tutorial: Lightcurve Analysis
Picking the Right Goal

It's the Process, not the Results

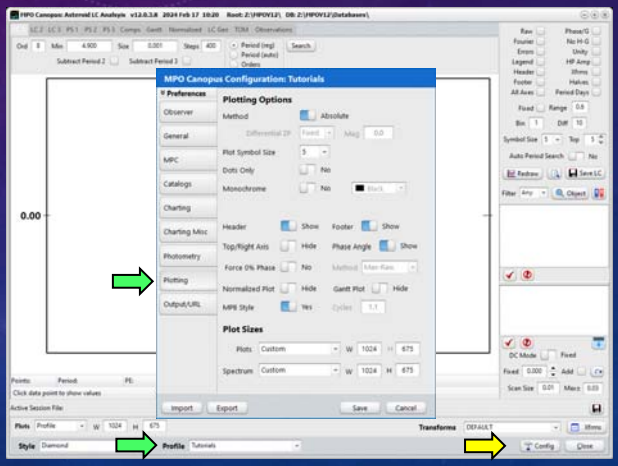
- **This is no "gold star" for duplicating the results. It's unlikely you will.**
- **Success is determined by how well you can use the program on your own.**
- **Practice, practice, practice.**



Configuration Setup

V12 Tutorial: Lightcurve Analysis
Check the Configuration

- Open MPO Launcher.
- Click <Analysis> tab.
- Click <Asteroid Period/TOM>.
- Wait for program to appear.
- Confirm that Profile is "Tutorials."
- Click <Config>.
- Go to Plotting tab.
- Most other settings can be changed during analysis.



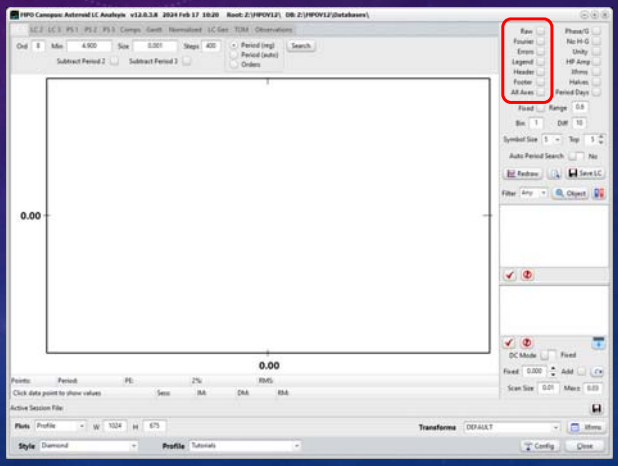
Taking a Guided Tour

V12 Tutorial: Lightcurve Analysis
A Guided Tour of the Analysis Program

The Options Set
Checked / Unchecked

- **Raw: Mag vs. JD / Mag vs. Phase.**
- **Fourier: Show / Hide (phased plots).**
- **Errors: Show / Hide.**
- **Legend: Show /Hide.**
- **Header: Show / Hide.**
- **Footer: Show / Hide.**
- **All Axes: Hide / Show top/right axes.**

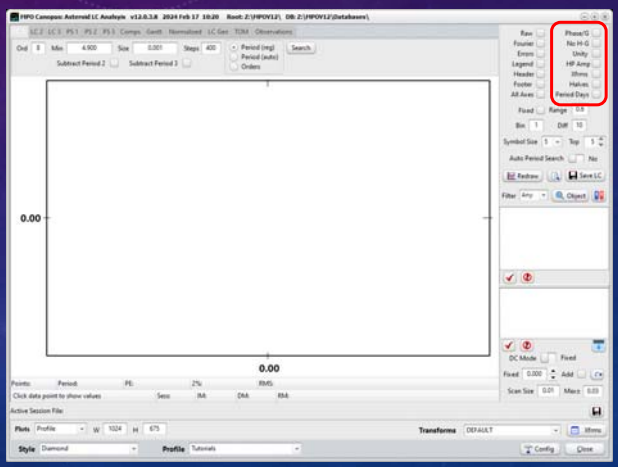
Changing the check immediately updates the plot; a new search is not required.



V12 Tutorial: Lightcurve Analysis
A Guided Tour of the Analysis Program

The Options Set
Checked / Unchecked

- **Phase/G: Show / Hide in Y-axis title.**
- **No H-G: Ignore / Add *H-G* correction.**
- **Unity: Unity Distances / Sky mag.**
- **HP Amp: 3 / 2 decimal place precision.**
- **Xfrms: Include / Ignore color corrections.**
- **Halves: Show / Hide split-halves plot.**
- **Period Days: Hours / Days (new search).**

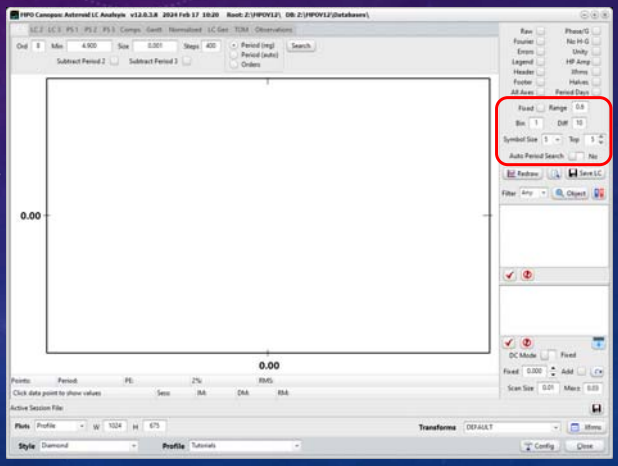


V12 Tutorial: Lightcurve Analysis
A Guided Tour of the Analysis Program

The Options Set

Checked / Unchecked

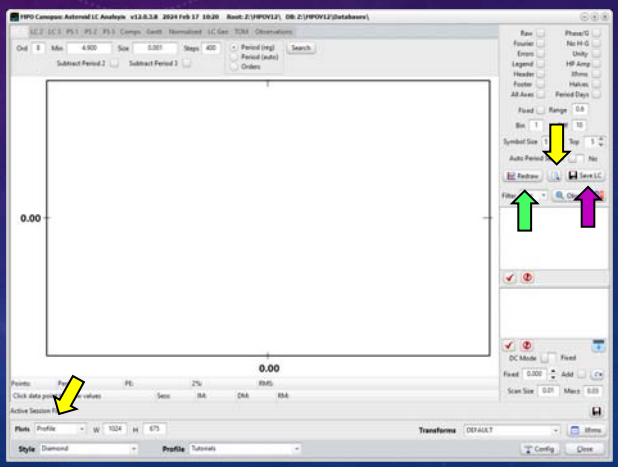
- Fixed: Y-axis range Fixed / Floating.
  - Range: Mags (fixed range)
- Symbol Size: Plot symbol size (3-13, odd).
- Top: Vertical position of legend (> 0).
- Auto Period Search
  - Yes
    Period recomputed each time a data point is included/excluded.
  - No
    <Search> click required to find updated period.



V12 Tutorial: Lightcurve Analysis
A Guided Tour of the Analysis Program

The Options Set

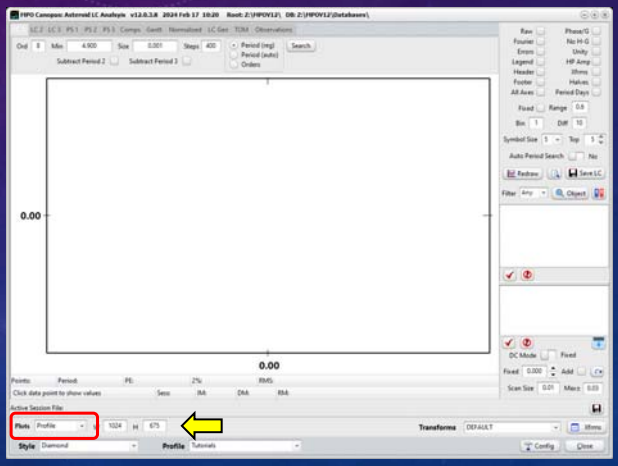
- <Redraw>
  Click to redraw plot without doing a period search.
- <Teeny-tiny magnifying glass>
  Click to resize form so that plot has similar size and the same aspect ratio and the "Plots" setting (WYSIWYG).
- <Save LC>
  Click save the active (showing) lightcurve plot using plot size in "Plots" drop down list.



V12 Tutorial: Lightcurve Analysis
A Guided Tour of the Analysis Program

The Options Set

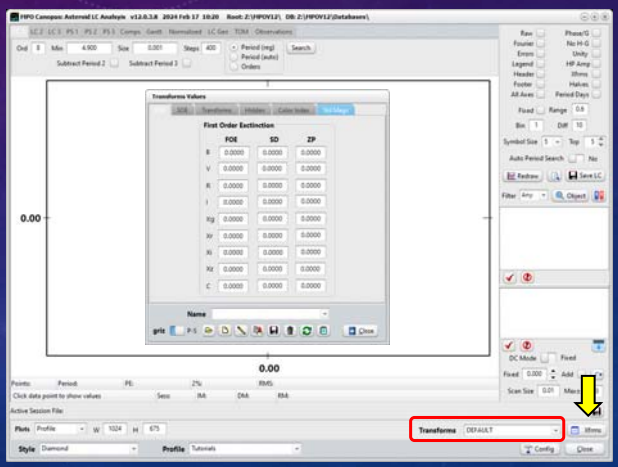
- <Plots>
  - Sets dimension (in pixels) of lightcurve plot 24-bit PNG.
  - "Profile": Use profile setting.
  - Pre-selected sizes: 4:3 aspect ratio.
  - Custom: Use dimensions in entry fields to the right of the control.
  - File save dialog appears with initial default directory \MPOV12\Plots.
    - Selected directory is used the next time.



V12 Tutorial: Lightcurve Analysis
A Guided Tour of the Analysis Program

The Options Set

- "Transforms"
  - Sets dimension (in pixels) of lightcurve plot 24-bit PNG.
  - Select PhotoRed transforms set if color-correcting on-the-fly.
  - Click <Xfrms> to display the PhotoRed transforms form.
    - Watch "PhotoRed" tutorial and refer to v10 Canopus/PhotoRed manual.

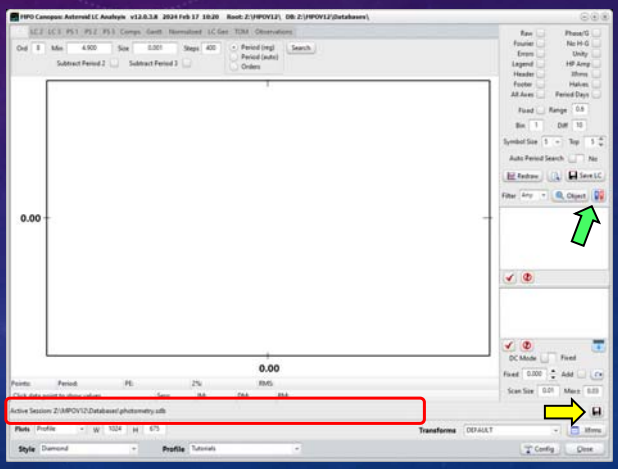


Selecting an Object

V12 Tutorial: Lightcurve Analysis
Object/Sessions Selection

Which Database?

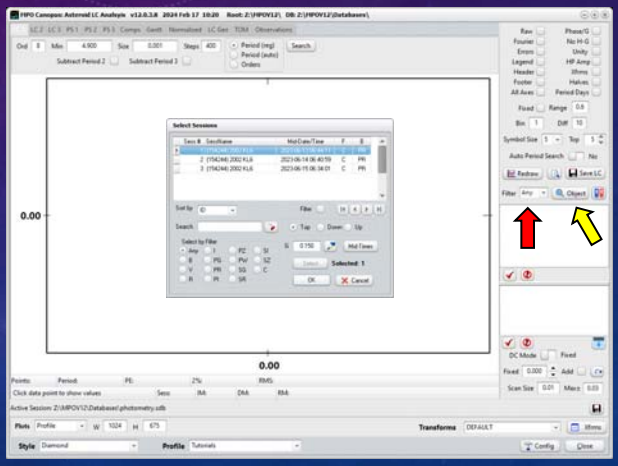
- **"Active Session File"**
  - **Full path of the current photometry database.**
- **<Floppy Disc>**
  - **Opens a file save dialog to backup or save the active database under a different name. The active database does *not* change.**
- **<Blue-Red Computers>**
  - **Select to set the active database to the default photometry.sdb or to another v12 photometry SDB file.**



V12 Tutorial: Lightcurve Analysis
Object/Sessions Selection

Not Your Tutorial Data Set

- There were not enough sessions in the tutorial data for a good demo.
- A personal database with 20000+ sessions is used for the reset of this "chapter."



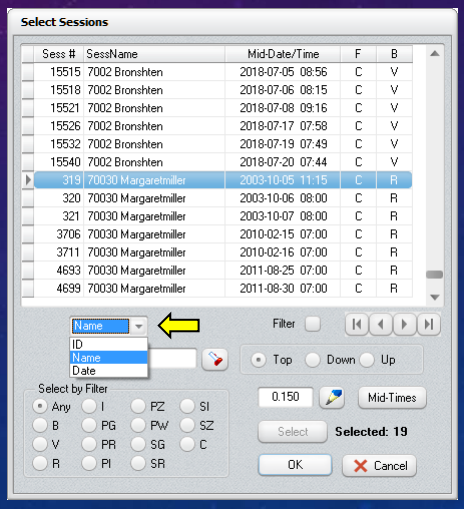
To Select an Object

- Select a filter from "Filter" drop down.
  "Any" includes all sessions for chosen object.
- Click <Object>.

V12 Tutorial: Lightcurve Analysis
The Session Selection Form

Searching for an Object

- Select the Sort Order (search field).
  ID: Session ID
  Name: All or part of a session name.
  Date: All or part of session date.

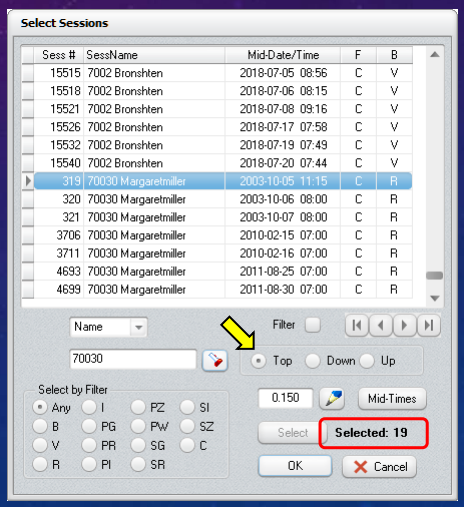


V12 Tutorial: Lightcurve Analysis
The Session Selection Form

Searching for an Object

- Select start location (in current search order).
  - **Top:** From the first record in the table. *Always finds the first matching record.*
  - **Down:** From the current record towards the last.
  - **Up:** From the current record towards the first.
- Enter a full or partial search string
  - Use "%" as a leading wild card (Name and Date).
  - "%" added to end of string by default.

The "Selected" count reflects the number of records matching the name of the highlighted record.



V12 Tutorial: Lightcurve Analysis
The Session Selection Form

Searching for an Object

By Name

These can find "70030 Margaretmiller"

"70030" "Margaretmiller" "%iller" "70%Mil%er"

"%ill% can find...

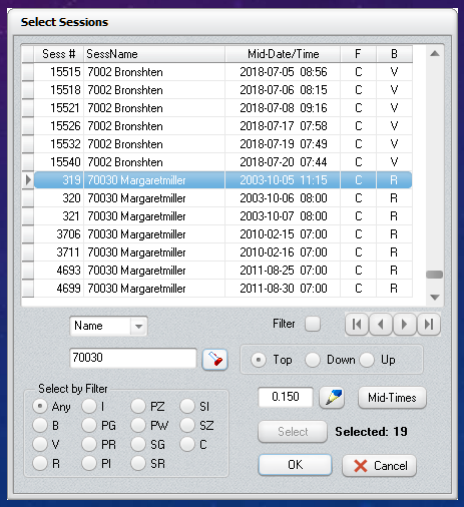
"15964 Billgray" "4368 Pillmore" ...
"70030 Margaretmiller", among others.

By Date (yyyy-mm-dd)

"2000": Any session in 2000.

"2000-08": Any session in 2000 August.

"2000-03-07" finds any session made on that date.



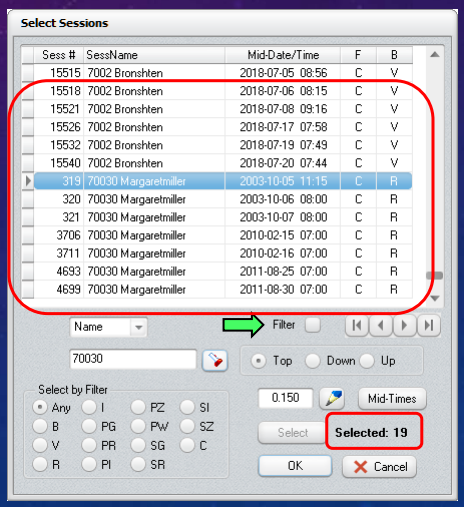
V12 Tutorial: Lightcurve Analysis
The Session Selection Form

Selecting an Object

- **All Sessions for a Target**
  - Click on any record in the table for the object.
  - Click <OK>.

    The "Selected" count reflects the number of records matching the name of the highlighted record.

- **Filter Records to a Single Object**
  - Can select subset of sessions.
  - Click on any record in the table for the object.
  - Check <Filter> box.

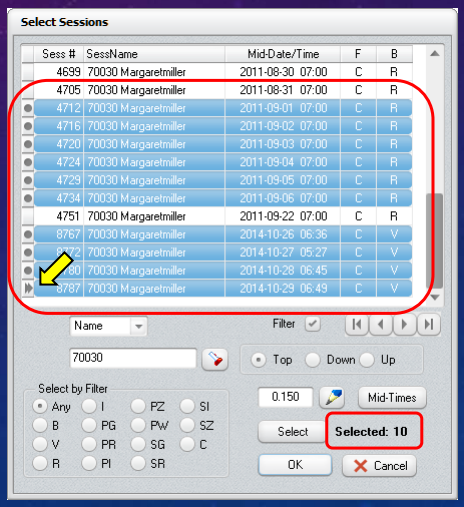


V12 Tutorial: Lightcurve Analysis
The Session Selection Form

Select Only Some Sessions

- Click on the first record that will be selected.
- Ctrl+Click on remaining sessions to be selected.
- Double-right arrow indicates the most recent selection. Others are dots.
- Number of selected records shown at lower-right.
- Click <OK>.

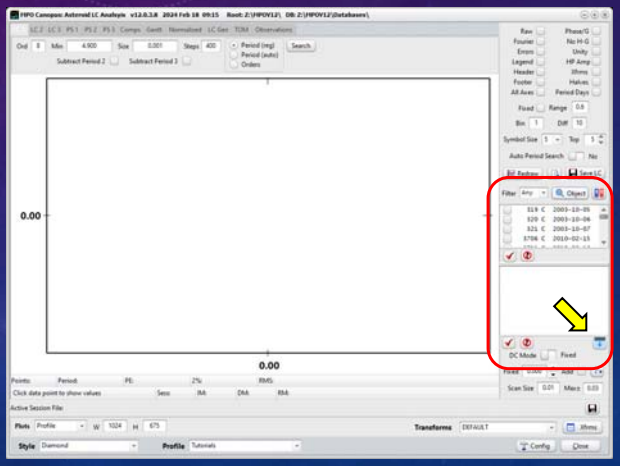
  The "Selected" count shows the subset record count.



V12 Tutorial: Lightcurve Analysis
Make Room for Sessions

See All (or More) Sessions

- With more than a few selected sessions, not all can be seen in the lists.
- Click <Rollup> to cover the controls not directly related to plotting.

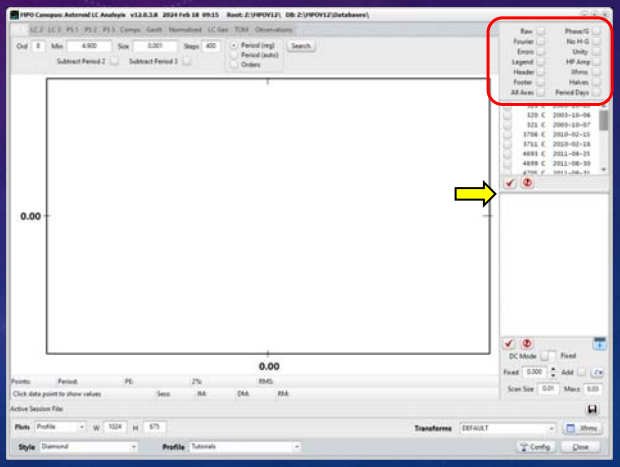


V12 Tutorial: Lightcurve Analysis
Make Room for Sessions

See All (or More) Sessions

- Only the check boxes at the top of the Options panel are visible.
- Click <Rollup> again to show all the controls on the Options panel.
- Splitter Bar
  - Place mouse cursor over the bar.
  - Drag up/down to change the relative sizes of the two lists.

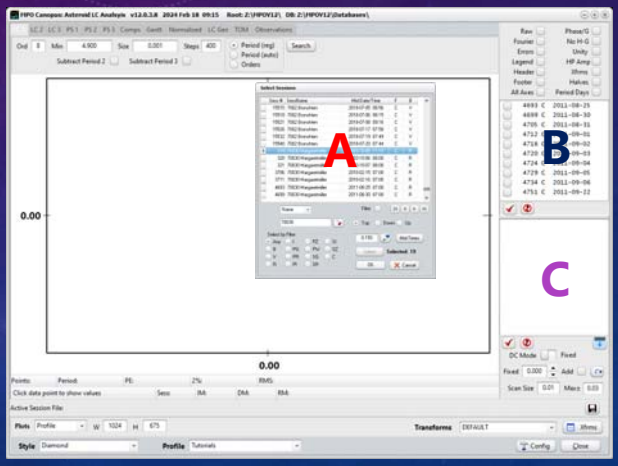
"Drag": Place mouse pointer, depress left button, move mouse, release left button.



V12 Tutorial: Lightcurve Analysis
Choosing the Sessions to Analyze

The Three Stages of Sessions

- **Select Sessions Form (A)**
  All matching sessions in the search.
- **Sessions Pool List (B)**
  All the sessions that can be used in the analysis.
- **Active Sessions List (C)**
  The sessions that will be analyzed.



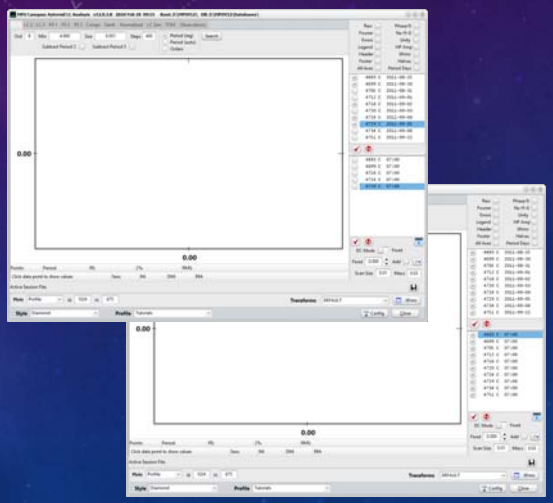
V12 Tutorial: Lightcurve Analysis
Selecting the Sessions to Analyze

Select a Single Session

- **Click on the check box, not the name, of the session.**
- **It is moved to the bottom list.**

Select Multiple Sessions

- **Click on the name, not the check box of a session.**
- **Use Shift+Click and Ctrl+Click to select additional sessions.**
- **Click <RedCheck> under the "B" list to move them to the "C" list.**
- **Click <Abort> under the "B" list to clear all checks.**



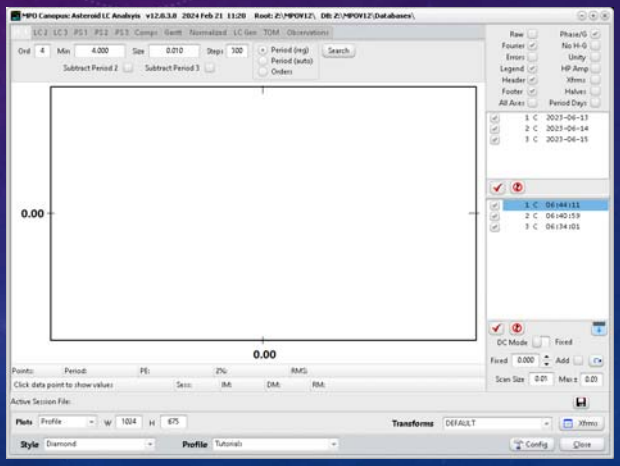
V12 Tutorial: Lightcurve Analysis
Ready, Set...

Back to the Tutorial Data Set

- Using three night's data on (154244) 2002 KL obtained from the example images and the Multi-image Asteroid Photometry program.

Selecting the Analysis Sessions

- Click the check box for a session in the bottom list to include in the analysis.
- Click C List <RedCheck> to check all sessions.
- Click C List <Abort> to clear the checks for all sessions.



V12 Tutorial: Lightcurve Analysis
Who Brought the Donuts?

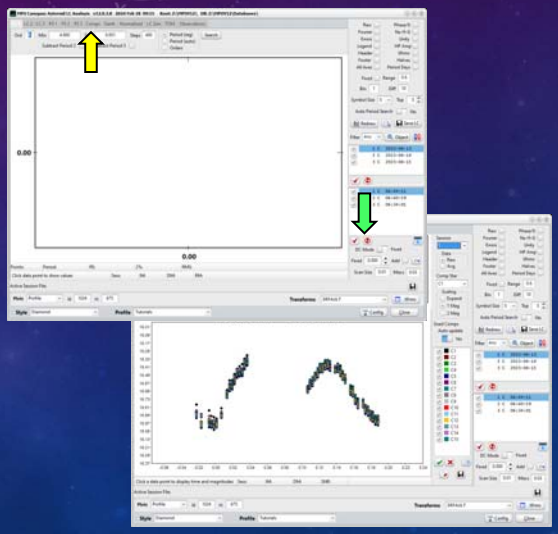
Break Time!

Working with Comps

V12 Tutorial: Lightcurve Analysis
Confirm Comps for Each Session

Back to Tutorials Database

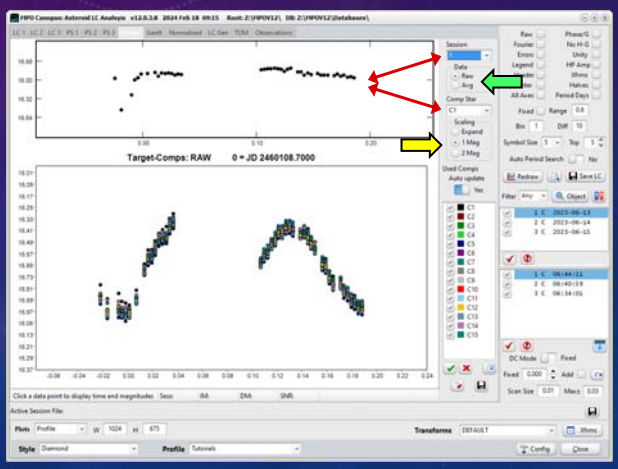
- **Three sessions for (154244) 2002 KL6**
- **Check all sessions that you want to include for plotting and period search.**
- **Click "Comps" tab.**



V12 Tutorial: Lightcurve Analysis
Confirm Comps for Each Session

The Comps Tab

- **Top Plot**
  Selected comp in selected session.
- **Data**
  Raw: Sky mag vs. JD.
  Avg: Sky mag vs average of other comps.
- **Bottom Plot**
  All selected comps in selected session.
- **Scaling (bottom plot)**
  Expand: Fit to data.
  1 Mag: Minimum range of 1 mag.
  2 Mag: Minimum range of 2 mag.



V12 Tutorial: Lightcurve Analysis
Confirm Comps for Each Session

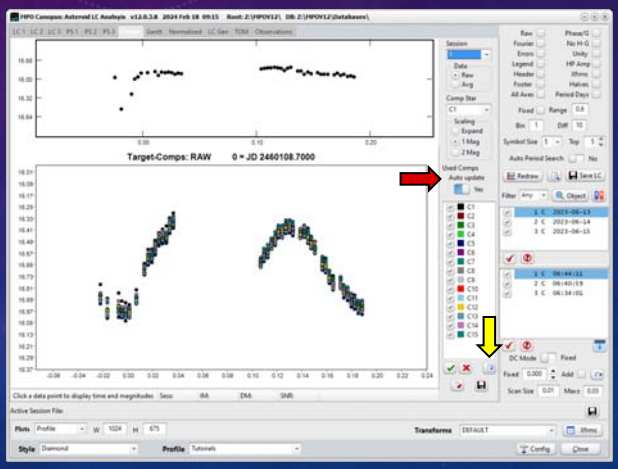
The Comps Tab

- **Auto Update**
  Yes
  Immediately updates the bottom plot to reflect a change in comp star status.

  No
  Registers change but does not update until <Update> is clicked.

If "No" and the changes were not updated, running a new search manually looses the changes.

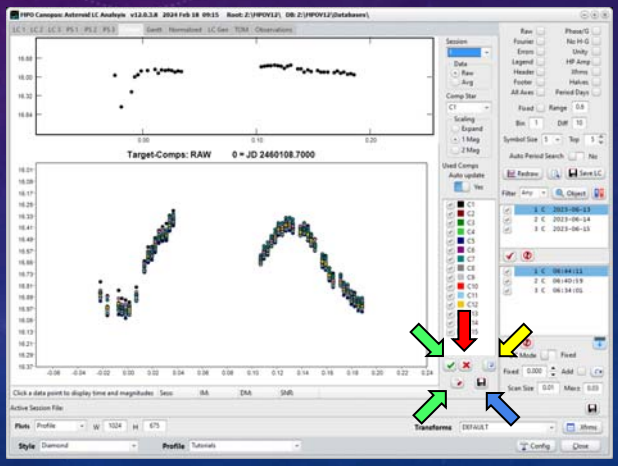
A new period search is done if "Auto Period Search" is set to "Yes".



V12 Tutorial: Lightcurve Analysis
Confirm Comps for Each Session

The Comps Tab

- **<GreenCheck>**
  Checks all *selected* comps in list and clears all other checks. ***Auto update: NO***
- **<X>**
  Clears all checks. ***Auto update: NO***
- **<Update>**
  Updates comp star plot based on checked comp stars but does not run period search.
- **<Flashlight>**
  Switches to "LC1" tab and runs period search using parameters on that tab.
- **<Save>**
  Saves current top and bottom plots.

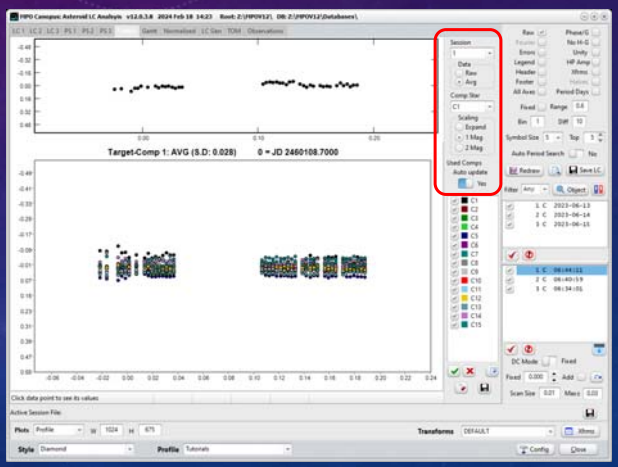


V12 Tutorial: Lightcurve Analysis
Dropping Data Points or a Comp

It's the Process, not the Numbers.

Comp 1, Session 1

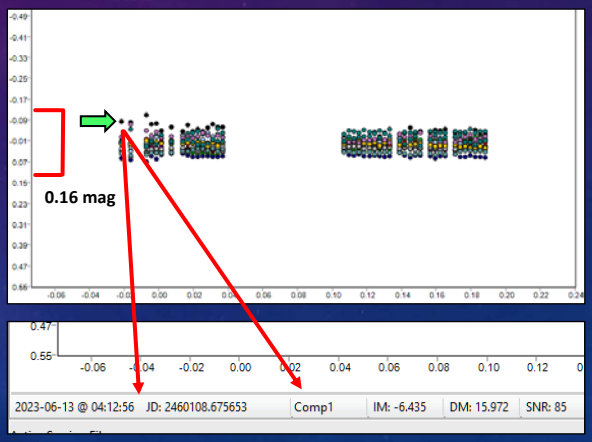
- Set Auto Period Search: **No**
- Select Session 1 in bottom list.
  (line, not check box)
- Session: **1**
- Comp Star: **C1**
- Data: **Avg**
- Scaling: **1 Mag**
- Auto update: **No**
- Comps List: **Check all comps**
- Auto update: **Yes**



V12 Tutorial: Lightcurve Analysis
Dropping a Data Point

- ***Process, not Exact Results!***
- **Exclude apparent outliers.**
  High and low in group
- **Click on a data point of an "outlier" on bottom plot to show its session and data point in the bottom status bar.**
- **Ctrl+Click to remove the *entire observation* from the from calculations.**
  Confirm the request

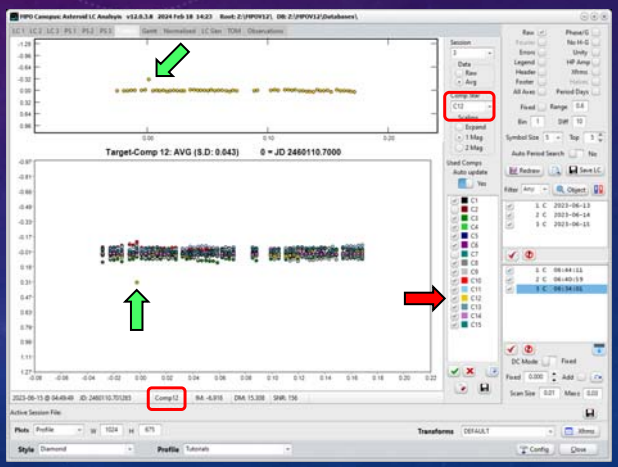
***Auto Period Search:* No**
If a large number of data points.



V12 Tutorial: Lightcurve Analysis
Dropping a Data Point (Comp or Entire Observation?)

All, or One? ***(Session 3)***

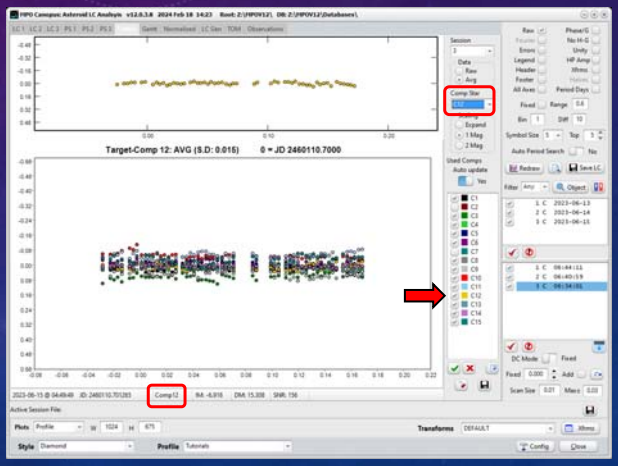
- **Determine the session of the comp on lower plot.**
- **Plot points reflect vertically, e.g., low on the bottom chart is high on the top chart.**
- **Ctrl+Click *on the top plot* to exclude only that comp's data for the one observation.**
- **Check the plots again.**



V12 Tutorial: Lightcurve Analysis
Dropping a Data Point (Comp or Entire Observation?)

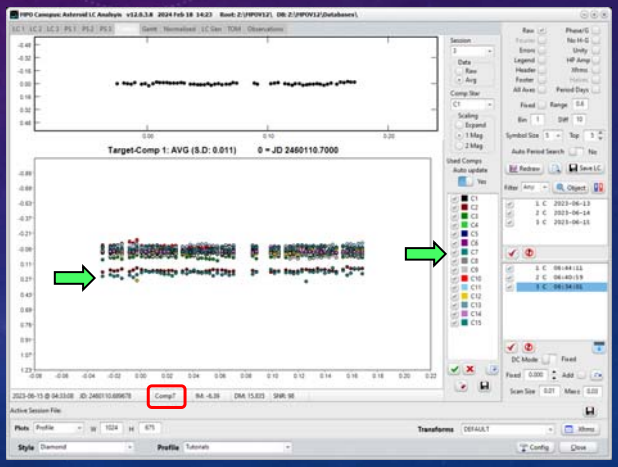
Confirm the Result

- **If Good, continue on.**
- **If not now, or later, comps for the same observation keep popping out, delete the entire observation, i.e., Ctrl+Click on the comp's data point *on the bottom plot* to delete the entire observation.**



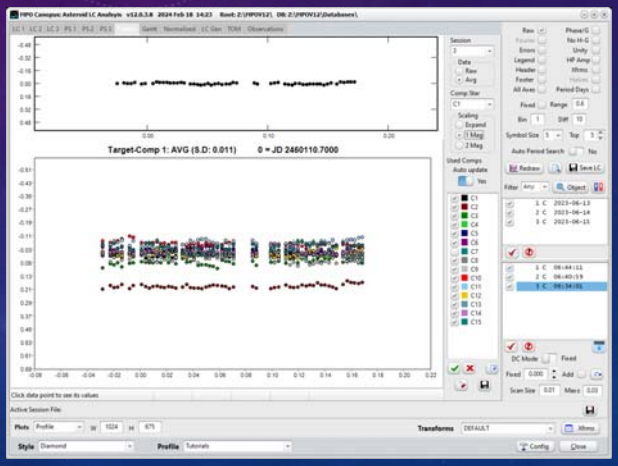
V12 Tutorial: Lightcurve Analysis
Dropping a Comp

- ***On Session 3***
- **Click on a data point of an "outlier" to show its session and data point in the bottom status bar.**
- **Comp 7 is "bad."**
- **Uncheck C7 in the comps list.**



V12 Tutorial: Lightcurve Analysis
Dropping a Comp Entirely

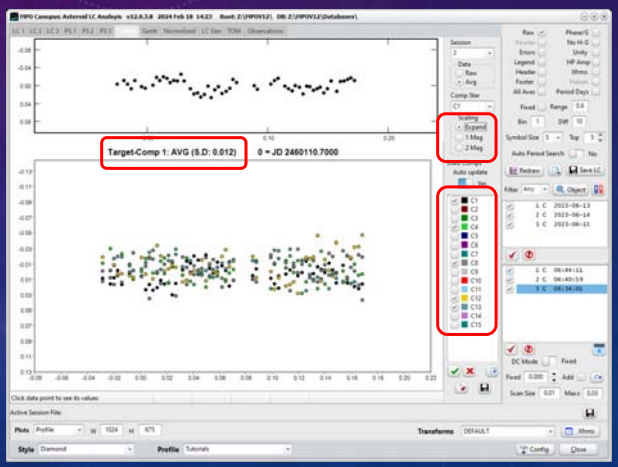
- ***On Session 3***
- **Comp removed entirely.**
- **Comp 2 also "bad" so it was excluded the same way.**



V12 Tutorial: Lightcurve Analysis
Dropping a Comp for a Session

Session 3 Result

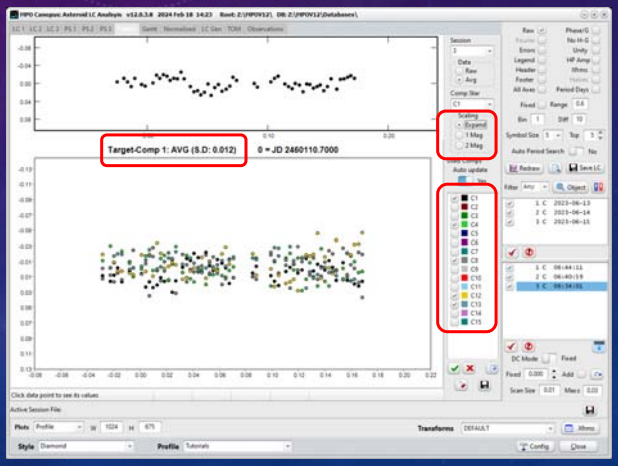
- **Scaling: Expand**
- **Number of Comps: 5**
- **Average Target-CompX: ~ 0.015**
  - **Target: Derived mag using all comps.**
  - **Comp X: Derived mag using only Comp X.**
  - **S.D. Standard deviation of the differences for all observations.**



V12 Tutorial: Lightcurve Analysis
Dropping Comps for a Session

Final Results

- **Session 1**
  - **Comps Used: 8**
  - **Mean S.D.: ~0.006 mag**
- **Session 2**
  - **Comps Used: 8**
  - **Mean S.D.: ~0.010 mag**
- **Session 3**
  - **Comps Used: 5**
  - **Mean S.D.: ~0.015 mag**

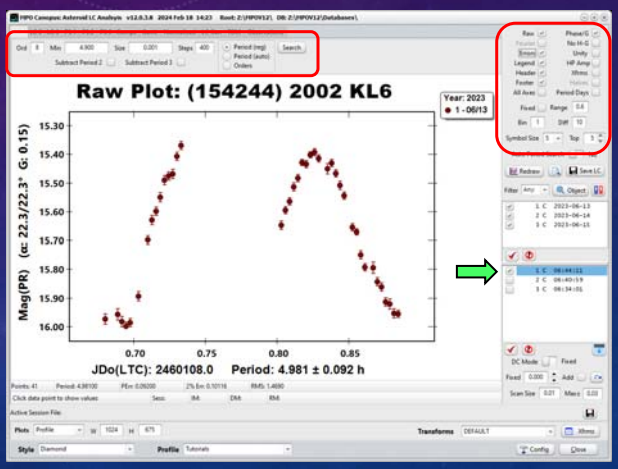


Reviewing Raw Lightcurves

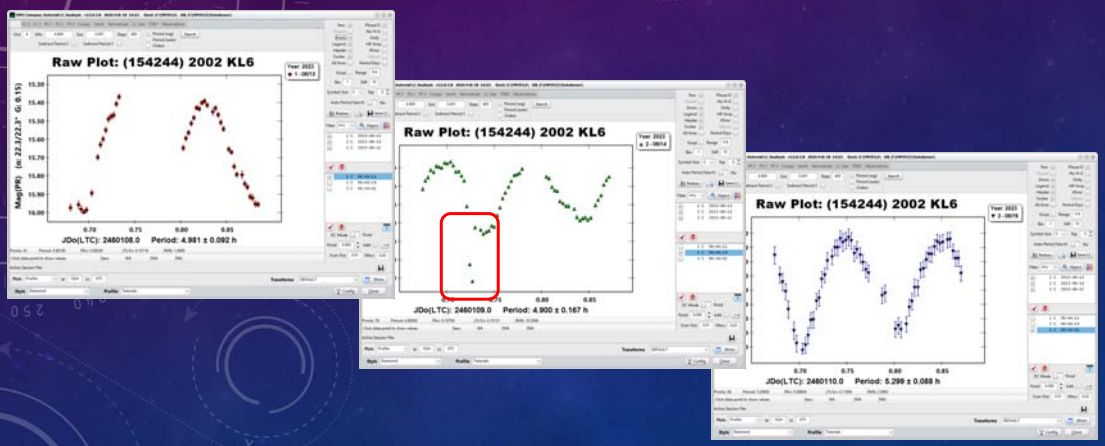
V12 Tutorial: Lightcurve Analysis
Dropping a Comp

Good Comps ≠ Good LC Data Point

- Plot raw data one session one-at-a-time on "LC1" tab.
- Check only one session in lower list.
- Set options check boxes to plot raw data and show the basic parts of the plot.
- Raw: Checked.
- Phased H/G: Checked.
- Period Days: Unchecked.
- Set preliminary search parameters.
  - *Use low orders and set "Steps" = 1.*
- Click <Search>



V12 Tutorial: Lightcurve Analysis
Reviewing the Raw Lightcurves



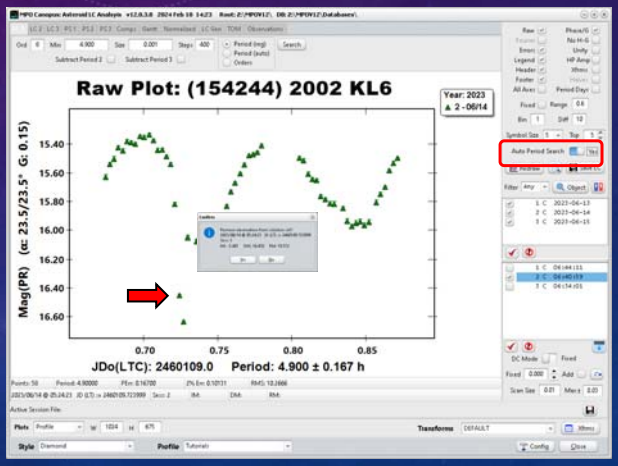
V12 Tutorial: Lightcurve Analysis
Editing Lightcurve Data

One point at-a-time.

- **Auto Period Search:**
  Only a Few: Yes
  More than a Few: No
- **Ctrl+Click on data point.**
- **Confirm request to exclude.**

Caution!

- **Be "surgical" when deleting data points.**
- **You could be losing evidence of a binary.**
- **The points may be good when plotting to the true period.**



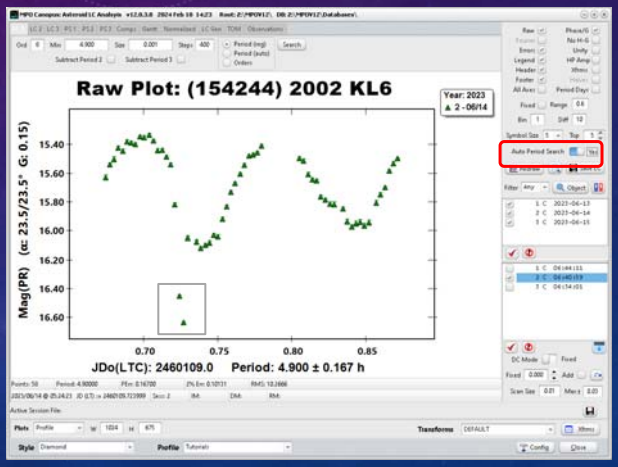
V12 Tutorial: Lightcurve Analysis
Editing Lightcurve Data

Multiple Points, Single Step

- **<Auto Period Search>**
  Yes: Period Search; zooms to 100%.
  No: Plot view unchanged; points visible.
- **Zoom to so that *only points to be excluded are visible*.**
  Drag mouse from upper-left to lower-right of exclusion area.
- **Shift+Ctrl+F12 to exclude all visible data points.**

Caution!

- **Don't delete everything!**



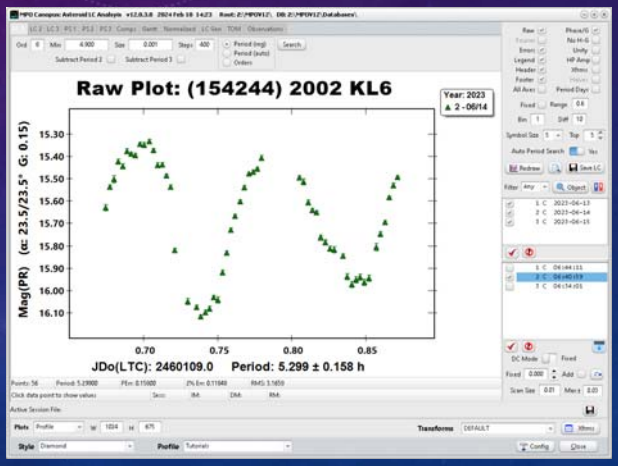
V12 Tutorial: Lightcurve Analysis
Editing Lightcurve Data

Multiple Points, Single Step

- Points have been excluded.
- Raw plot (and period) regenerated.
- Auto Period Search: No
  - Plot and period are not updated.
  - Unzoom and do Period Search.

I Deleted Everything!

- Being fast isn't always good.
- If there are no data points, go to the Observations and check all the observations for the affected session.

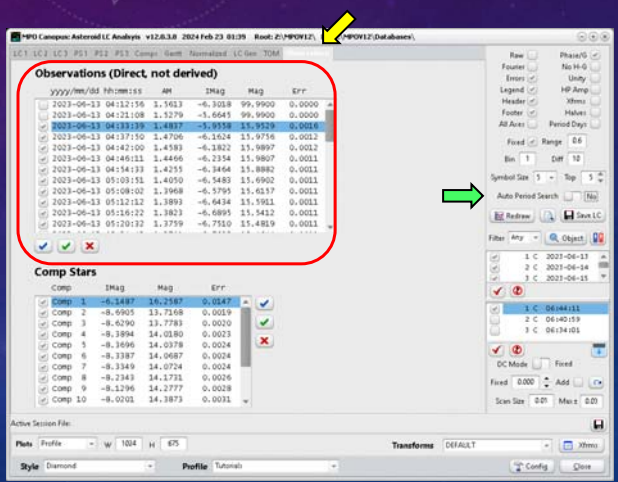


V12 Tutorial: Lightcurve Analysis
Editing Lightcurve Data

Target Observations

Clicking on a check is not same as clicking on the line.

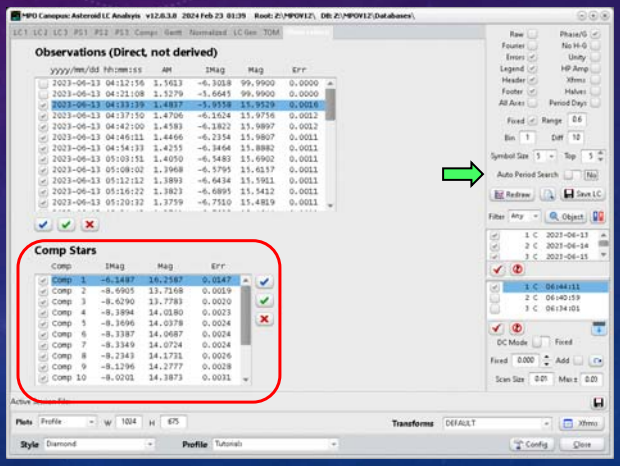
- Multi-select enabled.
- Check box toggles state.
- Click <Left Check> to check *all* (reset).
- Click <Middle Check> to check *selected*.
- Click <X> to uncheck *selected*.
- Auto Period Search
  - Yes: Period search; switch to "LC1".
  - No: No action; manual period search.



V12 Tutorial: Lightcurve Analysis
Editing Lightcurve Data

Comps Observations

- Check box toggles state.
- Click <Left Check> to check *all* (reset).
- Click <Middle Check> to check *selected.*
- Click <X> to uncheck *selected.*
- Auto Period Search
  - Yes: Period search; switch to "LC1".
  - No: No action; manual period search.



V12 Tutorial: Lightcurve Analysis
What's for Lunch?

Break Time!

Single-period Analysis

V12 Tutorial: Lightcurve Analysis
Single-period Analysis

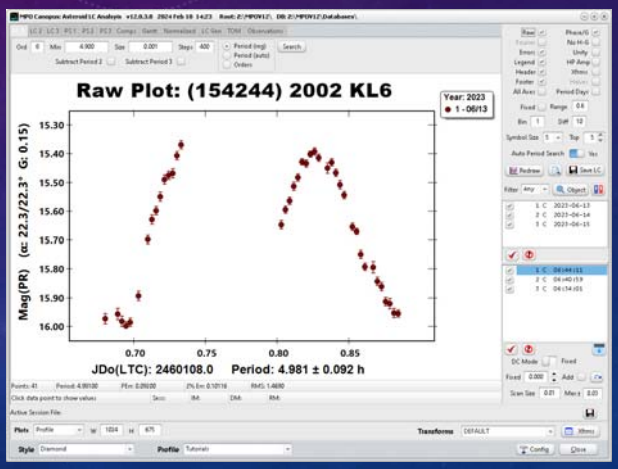
What *is* Covered

- The purpose and effect of period search controls.
- The basic mechanics of doing a period search, but *not every possibility*.

What *is not* Covered

- Judging the quality and/or validity of ambiguous or uncertain results.

A Practical Guide to Lightcurve Photometry.
Analyzing Light Curves: A Practical Guide.
Minor Planet Bulletin. mpbulletin.org
Journal of the AAVSO. aavso.org



V12 Tutorial: Lightcurve Analysis
Single-period Analysis

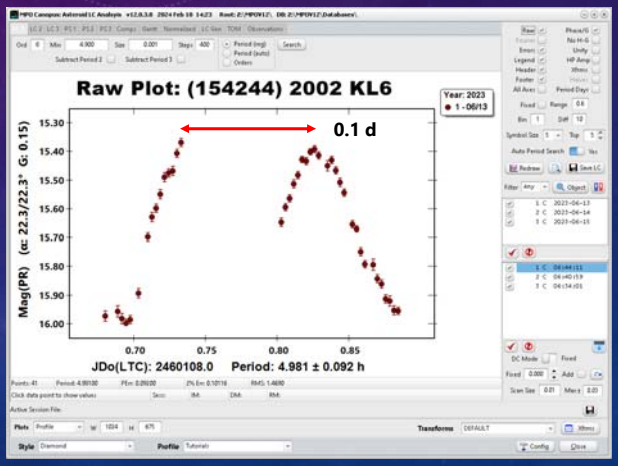
Period Search Overview

- Asteroid data are adjusted for changing viewing aspects and different comp stars. Variables use heliocentric JD.

  To make data seem as if all observations were made at exactly the same time and using a single set of comp stars.

  "Zero-point" is based on the earliest observation.

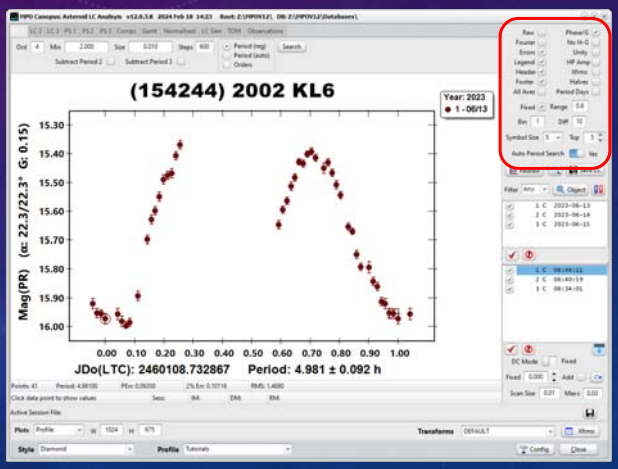
- Review a raw plot for an approximate time between maximums or minimums.
- Assume nothing without sound justification.



V12 Tutorial: Lightcurve Analysis
Single-period Analysis

Options Setup

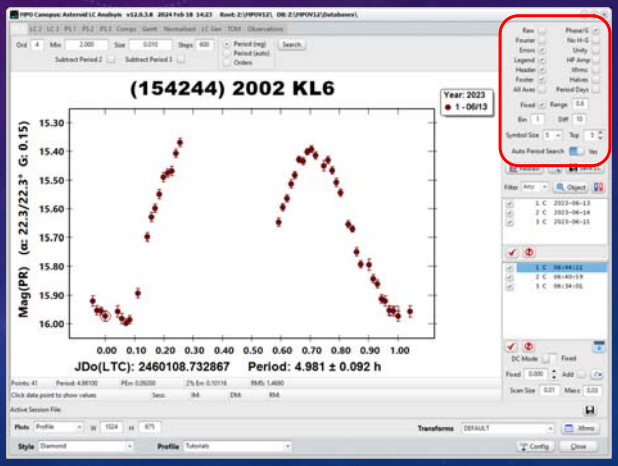
- Raw: **Unchecked**
- Fourier: **Unchecked**
- Errors: **Checked**
- Header and Footer: **Checked**
- Phase H/G: **Checked**
  - **Checked**
    Removes variations due to changing phase angle and Earth/Sun distances.
  - **Unchecked**
    Uncorrected data. Helps when value of *G* uncertain and verify data trend.



V12 Tutorial: Lightcurve Analysis
Single-period Analysis

Options Setup

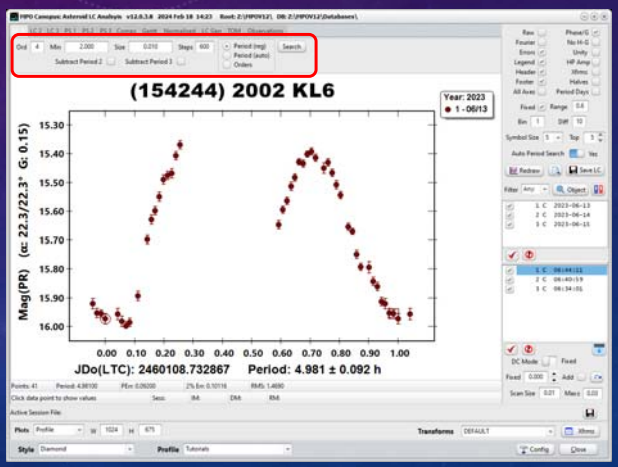
- Period Days: Unchecked
- Fixed: Checked
- Range: 0.6 mag
- Period Days: Unchecked (hours)
- Symbol Size: 5
- Top: 5
- Auto Period Search: Yes



V12 Tutorial: Lightcurve Analysis
Single-period Analysis

Period Search Setup

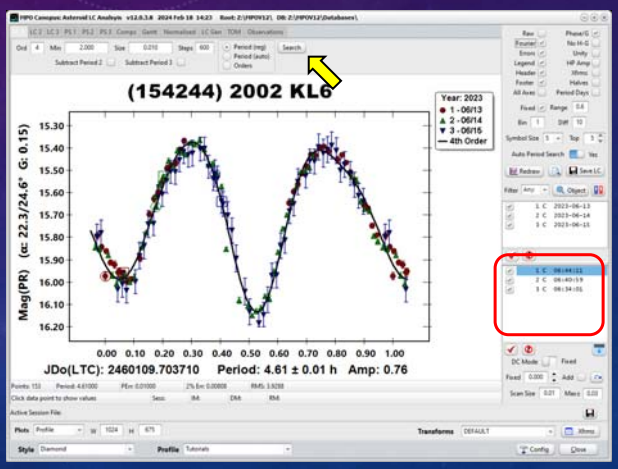
- Ord (Fourier orders): 4
- Subtract Period 2 / 3: Unchecked
- **Likely Period Known or Guessed**
  - Amplitude/phase angle favor a bimodal lightcurve (2 min/max pairs).
  - Time between to maximums is ~0.1 d, so full period is about 0.2 d, or 5 h.
- Period (reg): Checked
- Min: 2.0 (h) Size: 0.01 h
- Steps: 600 (covers 2.0 to 8.0 h).



V12 Tutorial: Lightcurve Analysis
Single-period Analysis

And the Answer is…

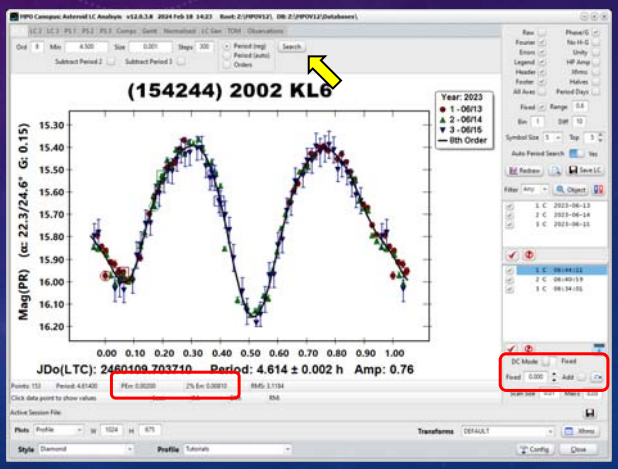
- Check all available sessions.
- Click <Search>.
- If only they were all so easy!
- Fourier: Checked



V12 Tutorial: Lightcurve Analysis
Single-period Analysis

Improving the Result

- Use higher-order fit.
- Narrow search after each try.
  - Don't overdo
    - Too high of order can degrade the fit.
    - Keep precision "reasonable" by using the "2% error."
- Adjust offsets (DeltaComp)

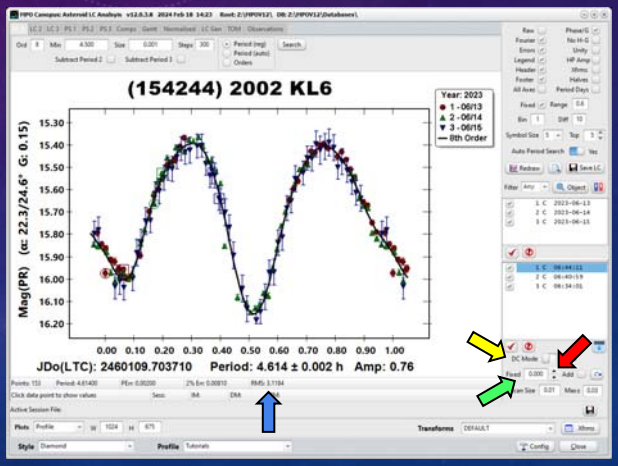


V12 Tutorial: Lightcurve Analysis
Single-period Analysis

Improving the Result

- Adjusting Offsets (DeltaComp – DC)
  - *Select* a session in the lower list.
  - DC Mode: Fixed
  - Fixed: 0.000
  - Click <Up/Down> to shift the Y-axis position.
    Click: 0.01 +Shift: 0.1 +Ctrl: 0.001 mag
- Keep an eye on the RMS value, look for a minimum.

Don't over do. Adjustment for solar-color comps and target should be ≤0.03 mag.



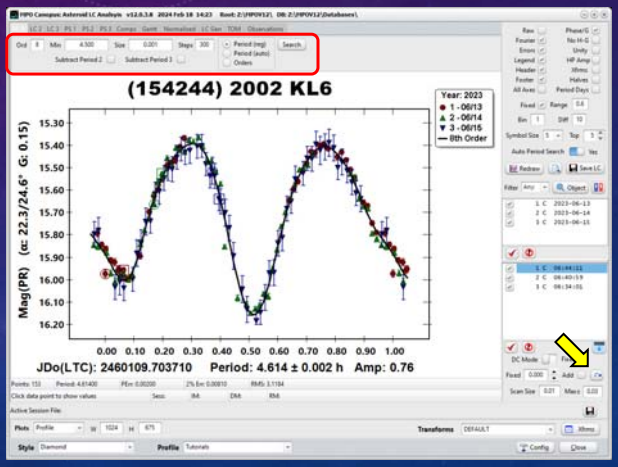
V12 Tutorial: Lightcurve Analysis
Single-period Analysis

Adjusting Offsets

- Changing the value does not automatically update the session data.
- Click <Recycle> next to the DeltaComp value field to apply the new value to the session.
- Auto Period Search sets when the update is shown.

  Yes: The plot updates immediately after clicking <Recycle>.

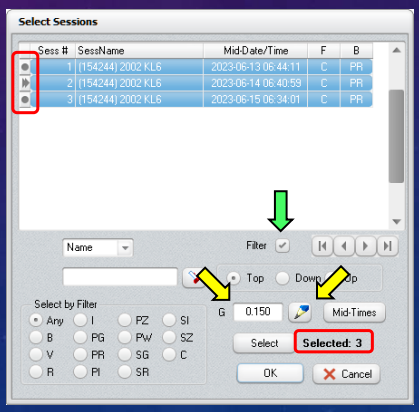
  No: Updates are not seen until running the search again.



V12 Tutorial: Lightcurve Analysis
Single-period Analysis

Adjusting Offsets Using *G (Asteroids Only)*

- Use a different *but same* value for all sessions.
- Works mostly for wide range of phase angles.
- Use with caution. Required calibrated data.
- Locate a session for the asteroid
- Click <Filter>.
- Select one or more sessions.
- Set new value of G in entry field.
- Click <Pencil>.
- Can also adjust mid-date/time of selected sessions.
- Click <OK> to transfer selected sessions.

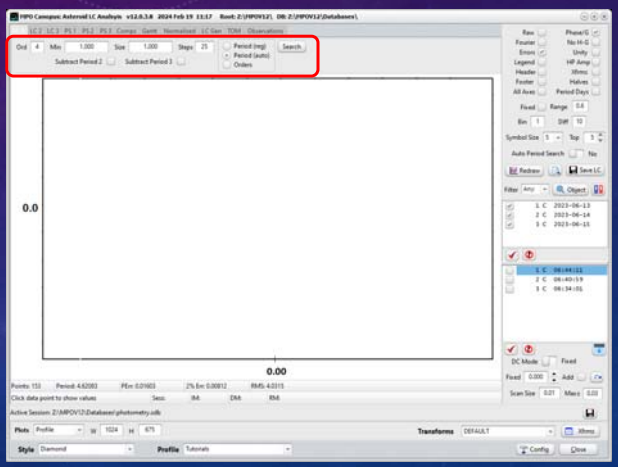


V12 Tutorial: Lightcurve Analysis
Single-period Analysis

Working with an Uncertain Period

- Period (auto): **Checked**
- Min: **2.00 (h)**
- Size: **1 h**
- Steps: **23 (covers 2.0 to ~25 h).**

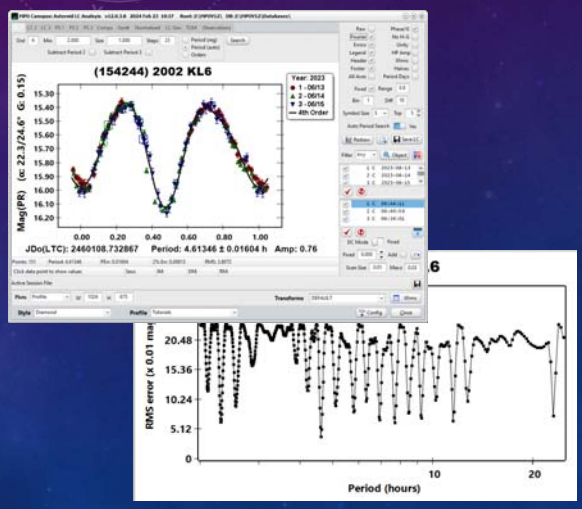
Don't start too small or over a too large a range. One, especially both, can make for a long search time. Have you read "War and Peace" lately?



V12 Tutorial: Lightcurve Analysis
Single-period Analysis

Initial Result

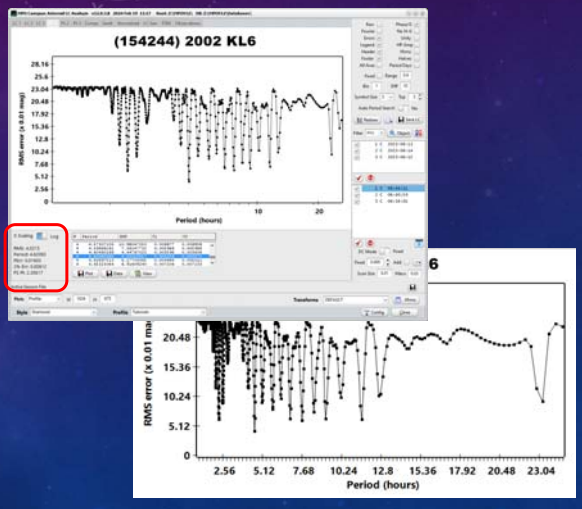
- Period similar to before.
- Each dot on the period spectrum is a trial period. There are hundreds with most being at the short end.
- Precision of period and error "strange" and excessive. Don't use this as the final result.
- Switch to "PS1" tab for period spectrum.
  - Use "Period (reg)".
  - Min: 4.50, size: 0.001, steps: 300.



V12 Tutorial: Lightcurve Analysis
Single-period Analysis

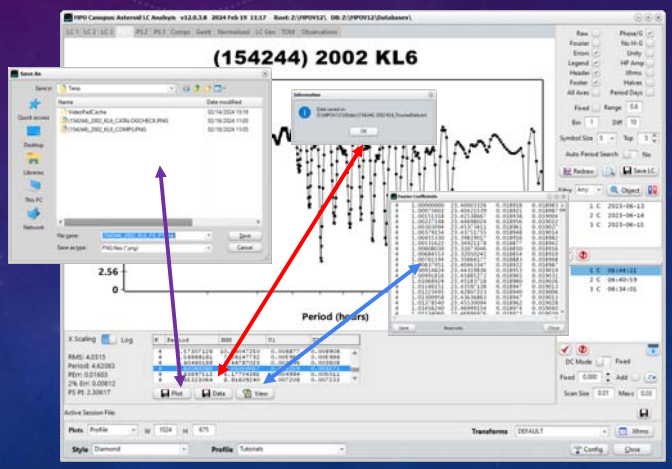
The Period Spectrum

- RMS fit (units of 0.01 mag) vs. Period.
- <X Scaling>: Log
- Analysis Data at lower-left
- "2% Err":
  Period error that would result in a 2% shift of the phase curve.
  $\Delta P = 0.02778 * (P^2) / T$
  P and T in same units
- Click on a point to see its period.



V12 Tutorial: Lightcurve Analysis
Single-period Analysis

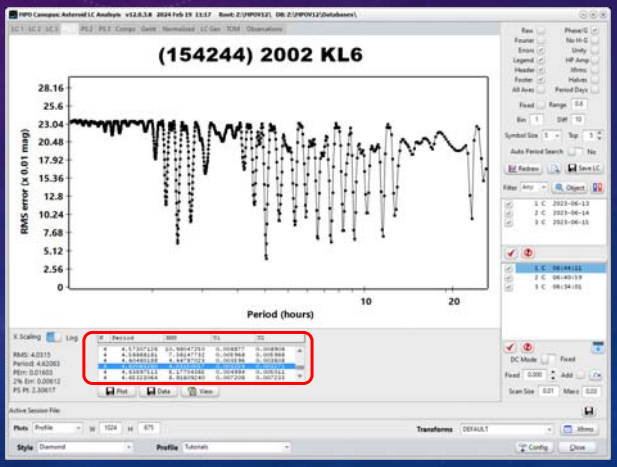
- Click <Plot> to save the period spectrum plot.
- Click <Data> to save the Fourier data (needed for the "LC Gen" tab).
- Click <View> to see and save the data (needed for the "LC Gen" tab).



V12 Tutorial: Lightcurve Analysis
Single-period Analysis

The Period Spectrum

- Fourier analysis values.
- Highlighted row is the "best" solution (lowest RMS value).
- Never trust a computer!
  The "best" solution may not be the correct solution.
- If best solution seems about right, return to "LC1" and do a "Period (reg)" search with parameters that center on the best period on the spectrum.



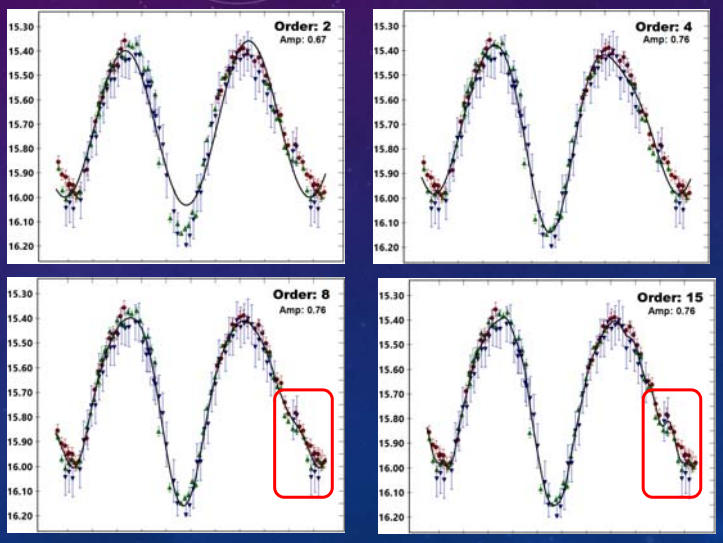
V12 Tutorial: Lightcurve Analysis
Single-period Analysis

How High the Order

- Higher orders often help with large amplitude or unusually-shaped lightcurves.

  2 = 6.5513, 0.67
  4 = 3.9606, 0.76
  8 = 3.3386, 0.76
  15 = *3.3458, 0.76*

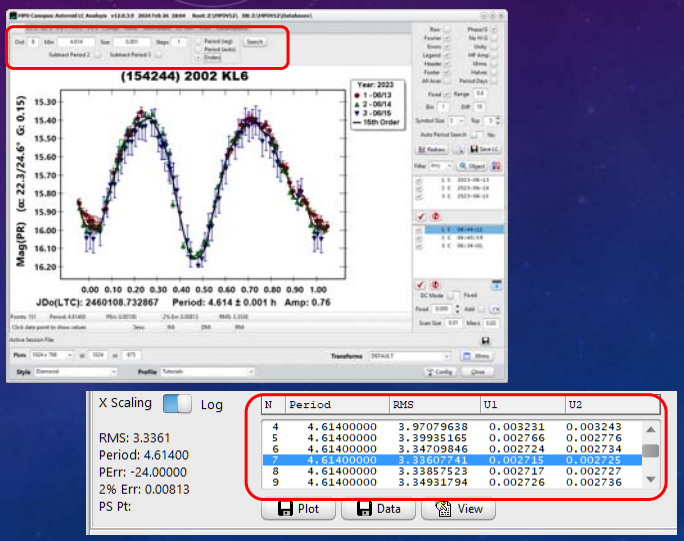
- Higher-orders can "follow the noise" instead of the data.



V12 Tutorial: Lightcurve Analysis
Single-period Analysis

Finding Order

- Period: 4.614 h
- Size: 0.001 h
- Steps: 15
- Search Type: Orders
- Click <Search>.
- Go to "PS1" tab.
- Ignore period spectrum.
- Highlighted line (Order: 7) has lowest RMS.
- Even-order is often adopted when no significant difference.



Dual-Period Analysis

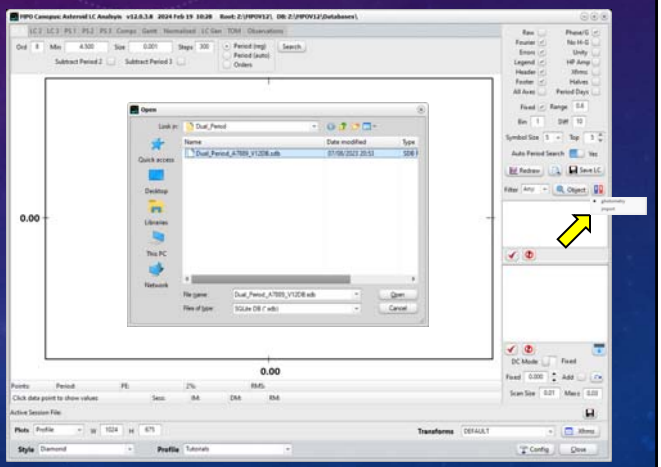
V12 Tutorial: Lightcurve Analysis
Dual-period Analysis

Limitations

- Additive periods only, i.e., not tumblers.

Loading an Export Set

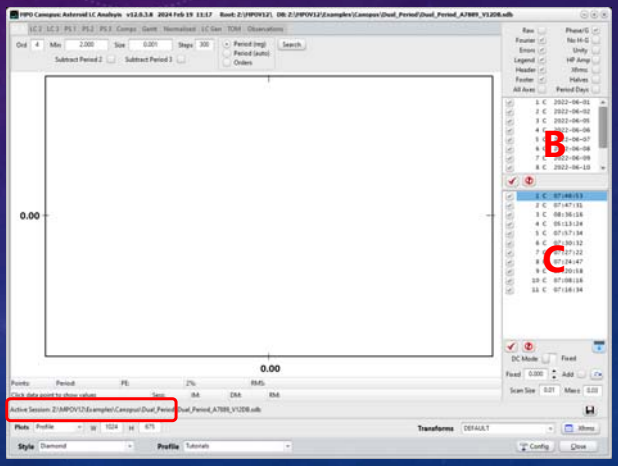
- Click <Red/Blue>.
- Select "Import" from menu.
- Navigate to
  \MPOV12\Examples\Canopus\Dual_Period
- Open "Dual_Period_A7889_V12DB.sdb"



V12 Tutorial: Lightcurve Analysis
Dual-period Analysis

Duplicitous Data

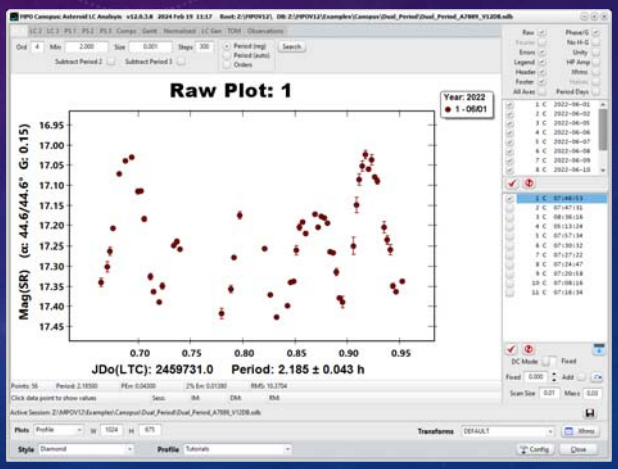
- Path of current database file shown at lower-left.
- Available sessions loaded into top list.
- Transfer all sessions to the lower list.
- Data have been pre-screened.



V12 Tutorial: Lightcurve Analysis
Dual-period Analysis

Find Period 1 ("LC1" tab)

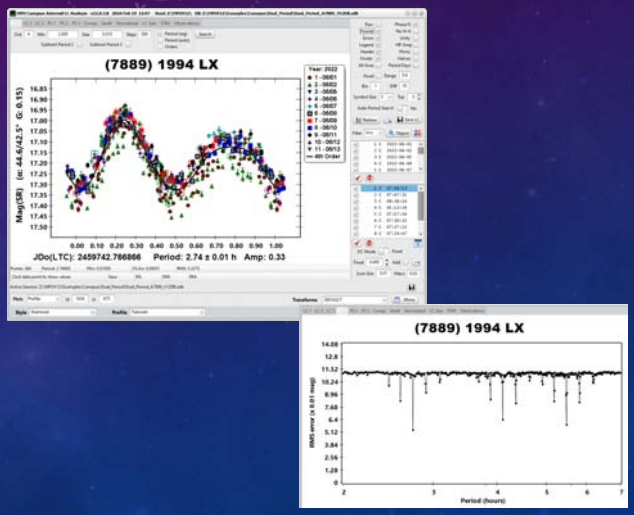
- As in single-period search, plot the raw data of one session to see if a dominant period is apparent. If not, use "Period (auto)" method.
- *Keep selected session and Raw=Checked.*
- Rough guess is 0.12 d (2.88 h)
  - Ord: 4
  - Min: 2.0 (h)
  - Size: 0.01
  - Steps: 500 (2.0 – 7.0 h)
  - Click <Search>.



V12 Tutorial: Lightcurve Analysis
Dual-period Analysis

Initial Result

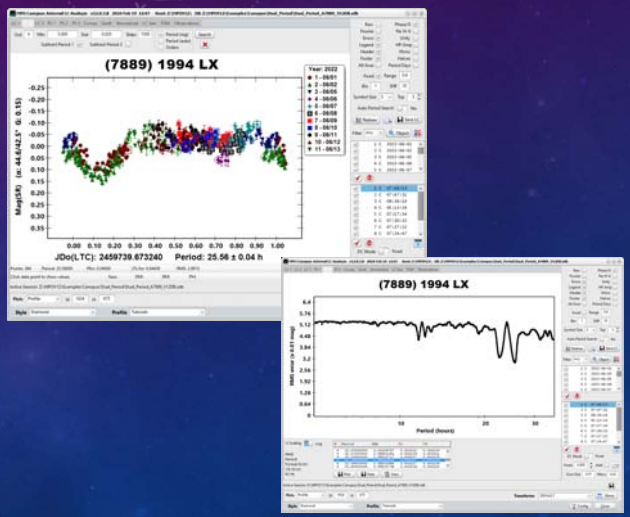
- Shows a good solution but lots of "noise."
- Don't be too quick to exclude data points.
- Click the "LC2" tab.



V12 Tutorial: Lightcurve Analysis
Dual-period Analysis

Secondary Period Search ("LC2")

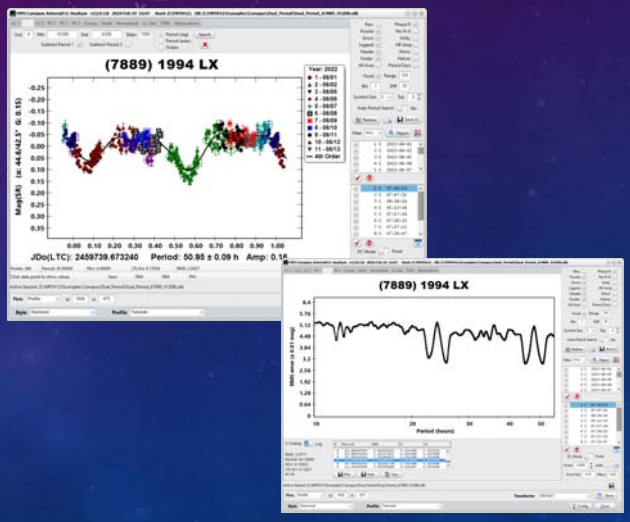
- The orbital periods of asteroid satellites tend to favor 10-50 h; some are much longer (Pravec et al. 2018 + ref therein).
  - <Subtract Period 1>: Checked
  - Order: 4
  - Min: 5.0
  - Size: 0.02 h
  - Steps: 1500 (5 – 35 h)
  - Fourier: Unchecked
  - Fixed: Checked Range: 0.6 mag
- Click <Search> on LC2 tab.



V12 Tutorial: Lightcurve Analysis
Dual-period Analysis

Secondary Period Search

- Double-period possible. Try again.
  - <Subtract Period 1>: Checked
  - Order: 4
  - Min: 10
  - Size: 0.03 h
  - Steps: 1500 (10 - 55 h)
  - Fourier: Checked
- Check solution near 45 h.



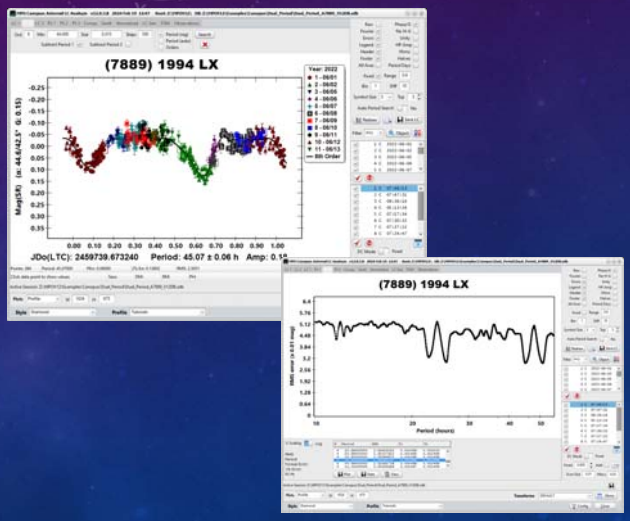
V12 Tutorial: Lightcurve Analysis
Beware of the Fit by Exclusion Under the Bed

Secondary Period Search
Checking Alternate P2

- <Subtract Period 1>: Checked
- Order: 8
- Min: 44.00
- Size: 0.01 h
- Steps: 300 (44.00 – 46.00)
- Fourier: Checked

Better fit, but minimums are not quite 0.5 phase apart.

Return to "LC1"

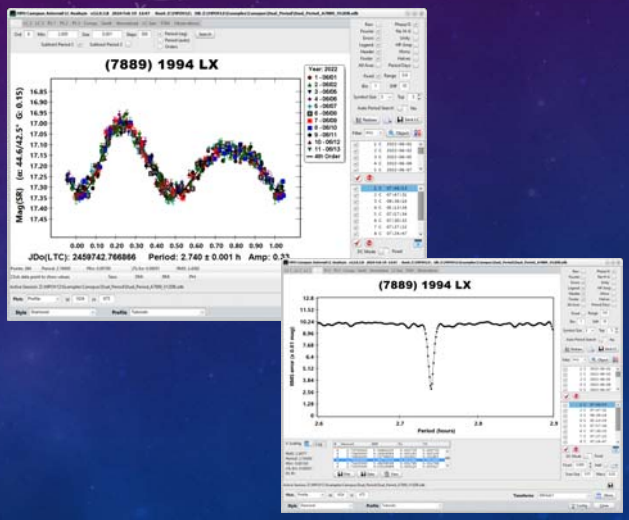


V12 Tutorial: Lightcurve Analysis
Dual-period Analysis

Period 1, Try 2

- <Subtract Period 2>: Checked
- Order: 8
- Min: 2.600
- Size: 0.001 h
- Steps: 300 (2.600 – 2.900 h)
- Fourier: Checked

- Getting very close.
- Go back to "LC2".

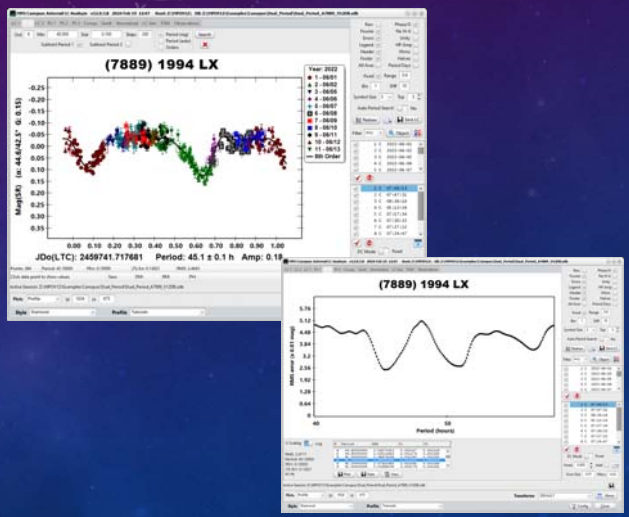


V12 Tutorial: Lightcurve Analysis
Dual-period Analysis

Secondary Period Search

- <Subtract Period 1>: Checked
- Order: 8
- Min: 40.0
- Size: 0.1 h
- Steps: 200 (40 – 60 h)
- Fourier: Checked

- 45-h period slightly favored, but events asymmetrically spaced.
- Try narrow search near 50 h.

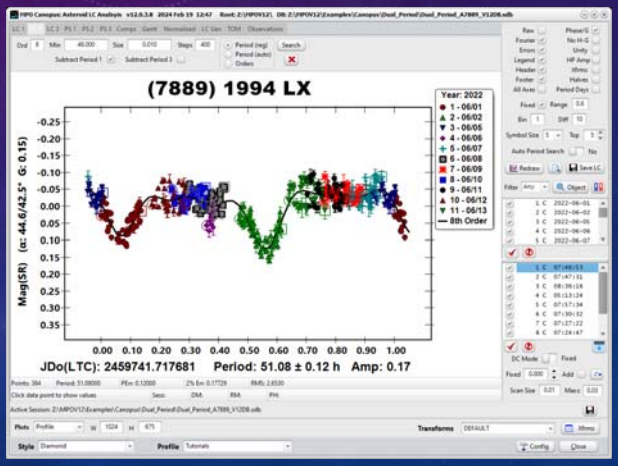


V12 Tutorial: Lightcurve Analysis
Dual-period Analysis

Secondary Period Search

- <Subtract Period 1>: Checked
- Order: 8
- Min: 49.00
- Size: 0.01 h
- Steps: 400 (49.00 – 52.00 h)
- Fourier: Checked

- Events more symmetrical, but poorer fit.
- Reset to near 45 h and search again.
- Return to "LC1" tab.

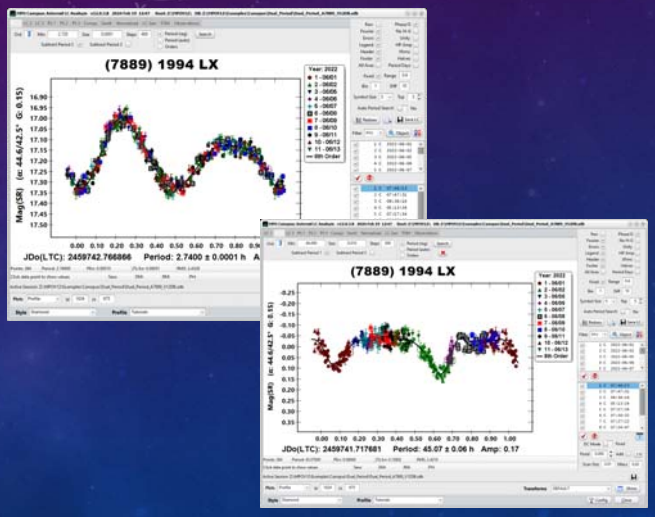


V12 Tutorial: Lightcurve Analysis
Dual-period Analysis

Refine the Periods

- Go between two periods until they stabilize.
- Don't press the precision too much.
  *0.1-0.5 * "2% Err".*

- **Final Results**
  - P1: 2.7400 ± 0.0001 h
    A1: 0.33 ± 0.03 mag
  - P2: 45.07 ± 0.06 h
    A2: 0.17 ± 0.02 mag
  - P2 Alternate: 51.05 ± 0.11 h
    A2: Alternate: 0.17 ± 0.02 mag



V12 Tutorial: Lightcurve Analysis
Dual-period Analysis

About the Satellite (P2: 45.07 h)

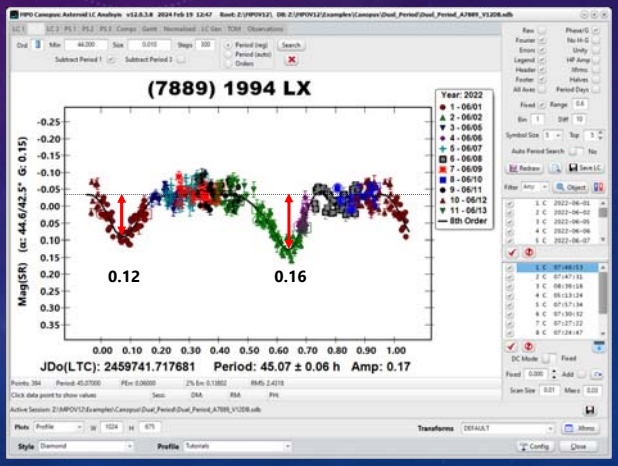
- **Mutual events (occultations/eclipses)**
  0.12 – 0.16 mag

$$\sqrt{10^{(0.4 * 0.12)} - 1.0}$$

- **Effective sat/primary diameter ratio**
  Ds/Dp ≥ 0.34 ± 0.03

Minimum because events not total.

Nearly flat outside the events, so satellite is nearly spheroidal and its rotation is tidally-locked to the orbital period.



V12 Tutorial: Lightcurve Analysis
Work with What You've Seen So Far

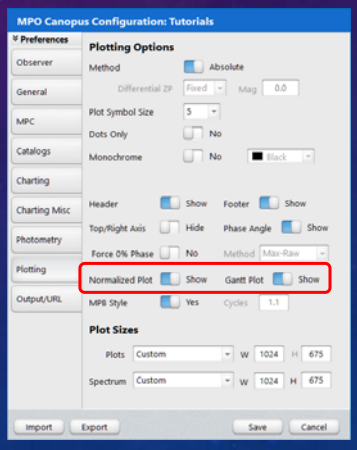
Break Time!

The Other Plots

V12 Tutorial: Lightcurve Analysis
Enabling the Normalized and Gantt Plots

Configuration Setup

- Open configuration form.
- Select profile to be edited.
- Plotting Options Tab.
  - <Normalized Plot>: Show
  - Gantt Plot: Show
- Save any changes.

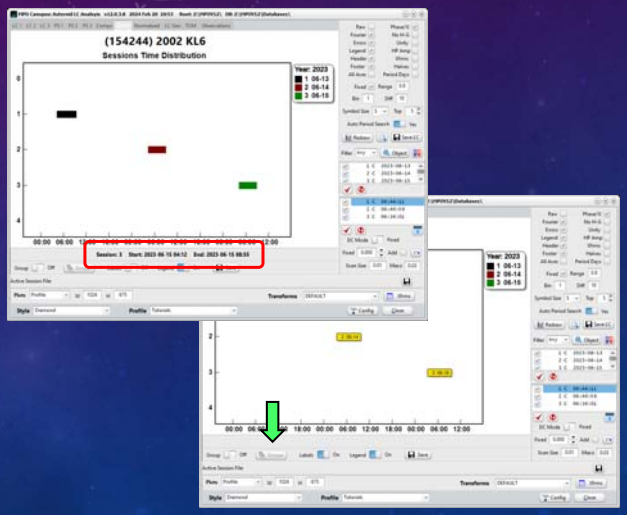


Sessions Gantt Plot

V12 Tutorial: Lightcurve Analysis
The Gantt Plot

Session Spans vs. Date/Time

- **Shows span of observations for each session.**
- **Ideal for collaborations involving different longitudes.**
- **Label gives session number and mm-dd.**
- **Click on a session in the plot to see session number, start/end times.**

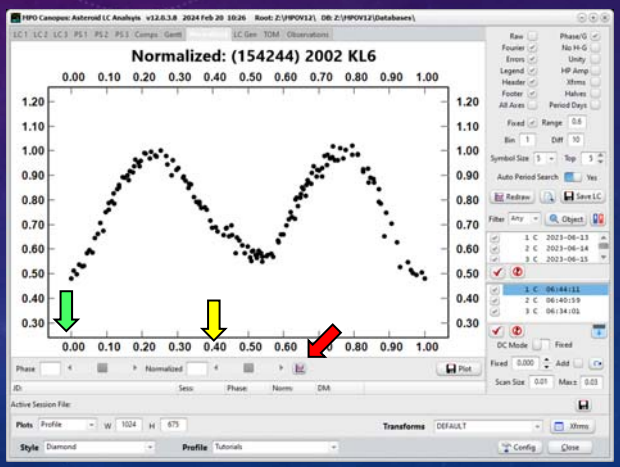


Normalized Data Plot

V12 Tutorial: Lightcurve Analysis
The Normalized Plot

For Binary Star Modelers

- **Compatible with Binary Maker 3.**
- **Converts derived magnitude to flux.**
- **Plots normalized values vs. period phase.**
- **Max Y-value = 1.0.**
- **Uses PeriodSearch 1 data.**

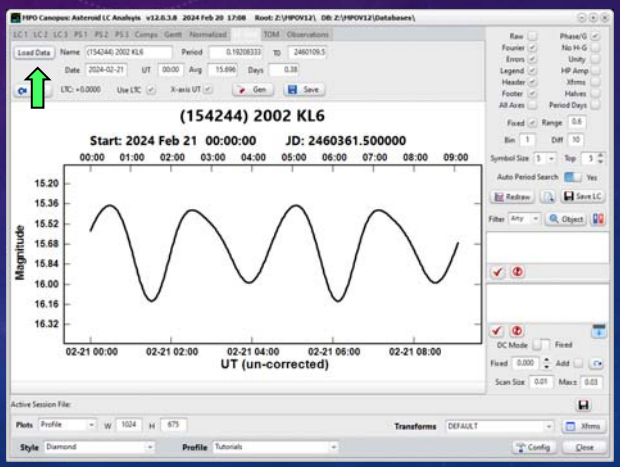


LC Generator (Ephemeris)

V12 Tutorial: Lightcurve Analysis
The Lightcurve Generator (Ephemeris)

Past and Future Predictions

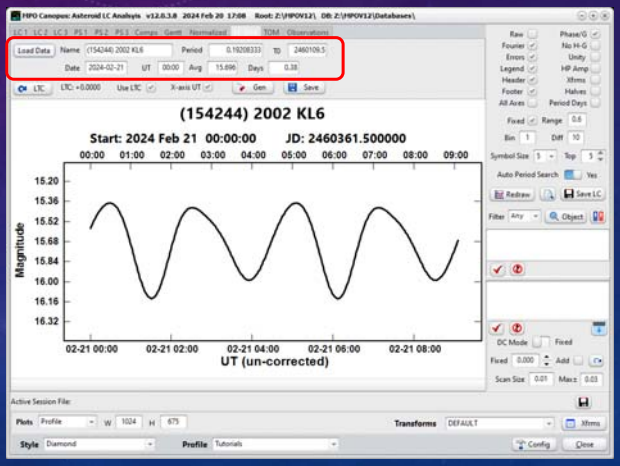
- **Uses Fourier data saved on the Period Spectrum tabs.**
- **Within same apparition and not too far removed from T0 for incoming data.**
- **Click <LoadData> to display file open dialog.**
- **Load previously saved Fourier data.**
- **Ephemeris automatically generated for current date at 00:00 UT.**



V12 Tutorial: Lightcurve Analysis
The Lightcurve Generator (Ephemeris)

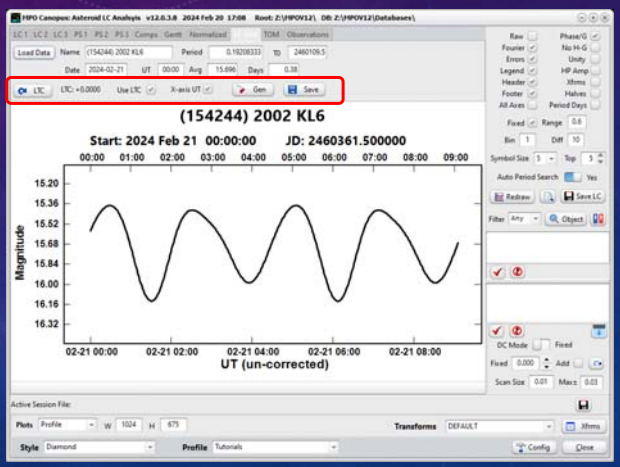
Past and Future Predictions

- **"Period" and "TO" Fourier data**
  Do not change TO. Change period to experiment with small differences.
- **"Date" and "UT"**
  Start date and UT
- **"Avg" Fourier data**
  Should not be edited.
- **"Days"**
  Can be changed to set the range of the ephemeris, in days.



V12 Tutorial: Lightcurve Analysis
The Lightcurve Generator (Ephemeris)

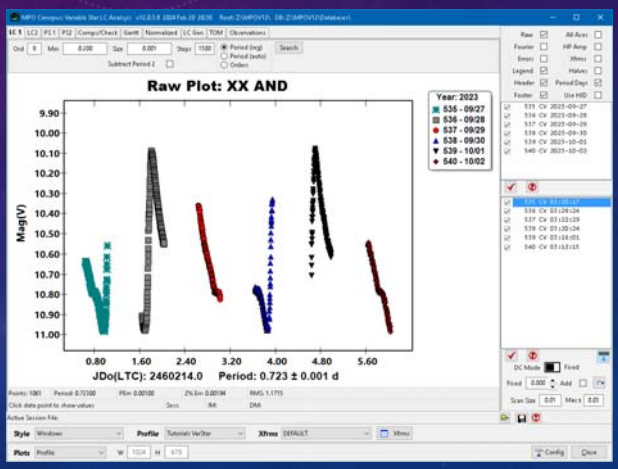
- **<LTC>**
  Compute light-time (Asteroid-Earth) or HJD (to Solar center) correction.
- **Use LTC:**
  Checked: Include light-time correction.
  Unchecked: Use Earth-based date/time.
- **X-axis UT**
  Checked: Date/Time are UT.
  Unchecked: Date/Time Local Time.
- **<Gen>**
  Generate ephemeris.
- **<Save>**
  Save plot.



Time of Minimum/Maximum

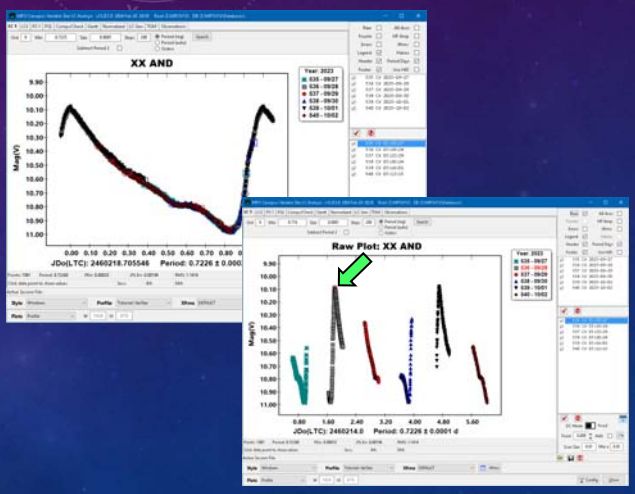
V12 Tutorial: Lightcurve Analysis
Finding Time of Maximum/Minimum

- **The Extreme Limits**
- **Mostly of interest in variable stars.**
- **Minimum for eclipsing binary stars**
- **Maximum for most others.**
- **Can find a TOM for only one session at a time.**
- **Should find accurate period first to extrapolate TOM to past future events.**
- **Combine with LC Generator (Ephemeris).**
- **Two maximums and three minimums in this data set.**



V12 Tutorial: Lightcurve Analysis
Finding Time of Maximum/Minimum

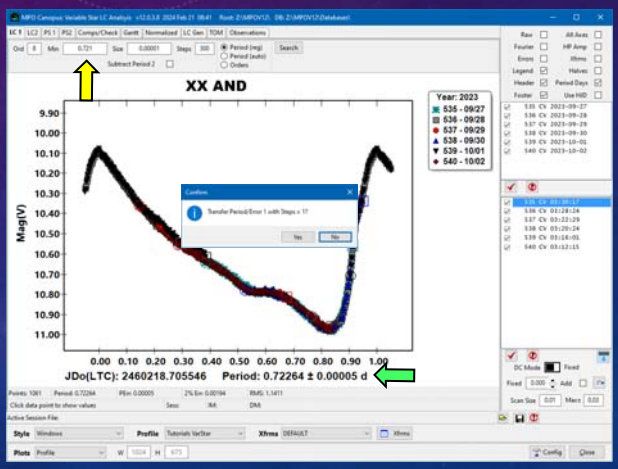
- **The First Time of Maximum**
  - Based on Hertzsprung (1928) as described in *"Astronomical Photometry"* (Henden and Kaitchuck, 1990).
  - Period = 0.7226 ± 0.0001 d (0.1 * 2% Err).
  - Session 536: Sep 28.



V12 Tutorial: Lightcurve Analysis
Finding Time of Maximum/Minimum

The First Time of Maximum

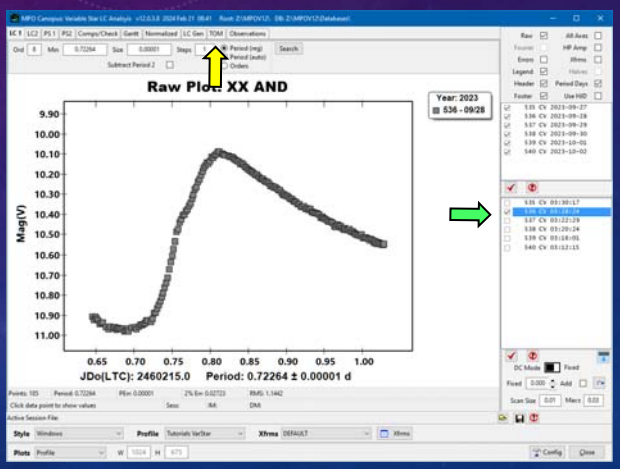
- Find the period using as many sessions as possible to get most precise period.
- Ctrl+Shift+Click on "Min" entry field.
- Click <Yes>.
- Answer "Yes".
  - This freezes the derived period so that it won't change from here on.
  - The period is converted to days; be careful if originally working in hours if you want to do another period search.



V12 Tutorial: Lightcurve Analysis
Finding Time of Maximum/Minimum

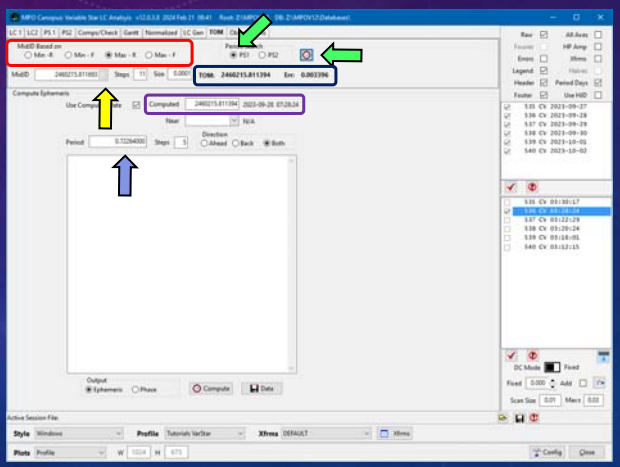
The First Time of Maximum

- Check only session 536.
- Click <Search> on "LC1".
- Click "TOM" tab.



V12 Tutorial: Lightcurve Analysis
Finding Time of Maximum/Minimum

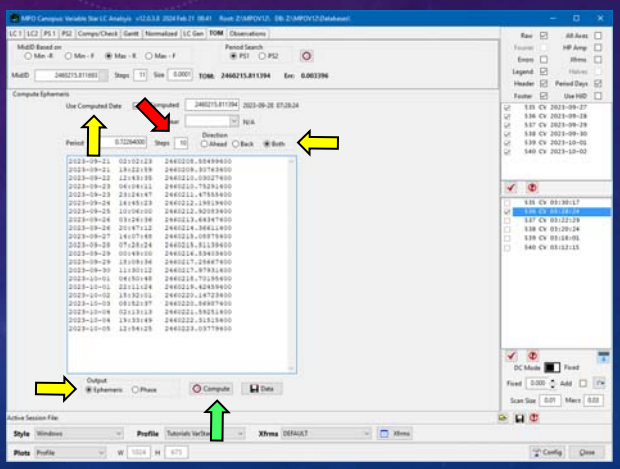
- Period transferred from "LC1".
  Steps = 1 prevents updated period.
- Click <Max – R>.
  - Maximum mag based on raw data, not Fourier curve, which likely has very different shape and gives a false value.
- Click <MidJD> on "MidJD" control.
  The MidJD is for the data or Fourier point indicated by the MidJD Based on setting.
- Set Steps: 11, Size: 0.0001
- Click <PS1>.
- Click <stopwatch>.
- Computed TOM displayed in "Computed".



V12 Tutorial: Lightcurve Analysis
Finding Time of Maximum/Minimum

Using the Computed Date

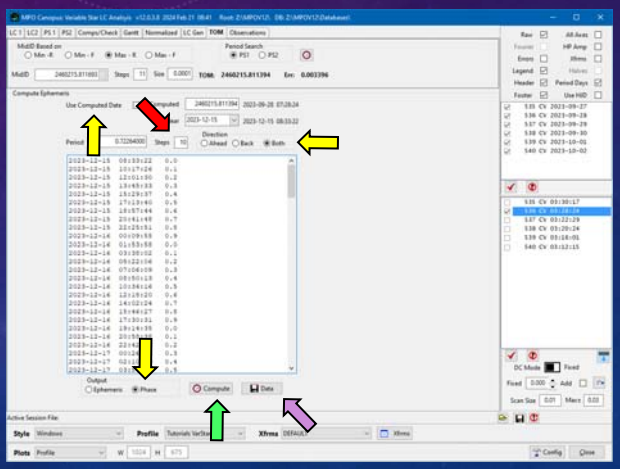
- Used Computed Date: Checked
- Steps: 10
- Direction: Both
- Output: Ephemeris
- Click <Compute>.
- Computes 10 times of maximum before and after computed date.



V12 Tutorial: Lightcurve Analysis
Finding Time of Maximum/Minimum

Using Another Date

- Used Computed Date: Unchecked
- Near: 2023-12-15 *(yyyy-mm-dd)*
  Use button to display popup calendar. Press <Enter> on calendar to accept.
- Steps: 10
- Direction: Both
- Output: Phase
- Click <Compute>.
- Computes times of 0.0 – 0.9 phase for next ten days.
- Click <Data> to save the results.

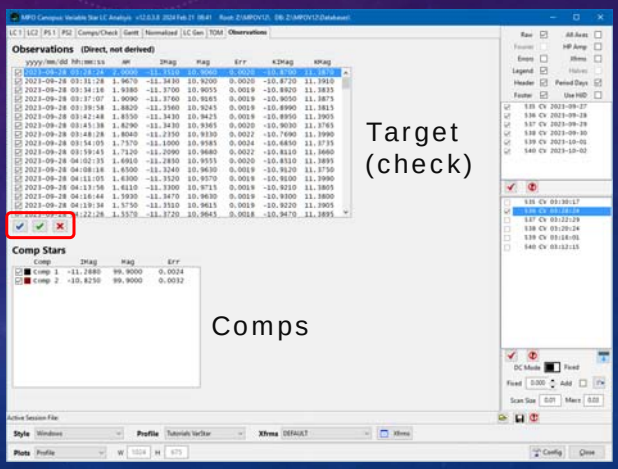


Reviewing the Observations

V12 Tutorial: Lightcurve Analysis
Reviewing/Editing Observations Manually

The Rare Excursion

- Use plots in most cases.
- Use for "en masse" changes, e.g., restore observations after a Ctrl+Shift+F12 with all data points showing.
- Use check box of individual records to toggle Use = True/False.
- <Blue Check>: Checks all records.
- <Green Check>: Checks *selected* records.
- <Red Check>: Unchecks *selected* records.
- Does *not* trigger a period search.

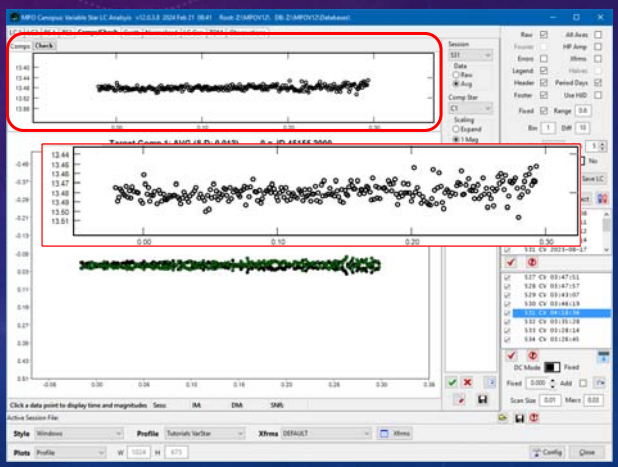


Asteroids vs. Variable Stars

V12 Tutorial: Lightcurve Analysis
Some Differences

Asteroids
- Periods in Hours.
- Asteroid-Earth light-time correction.
- H/G, No HG, Unity corrections.
- Different comp stars.
- Up to 3 periods.

Variable Stars
- Check star plotting and reporting.
- Periods in Days.
- Heliocentric JD correction.
- Up to 2 periods.



You are a Steely-eyed Analyst

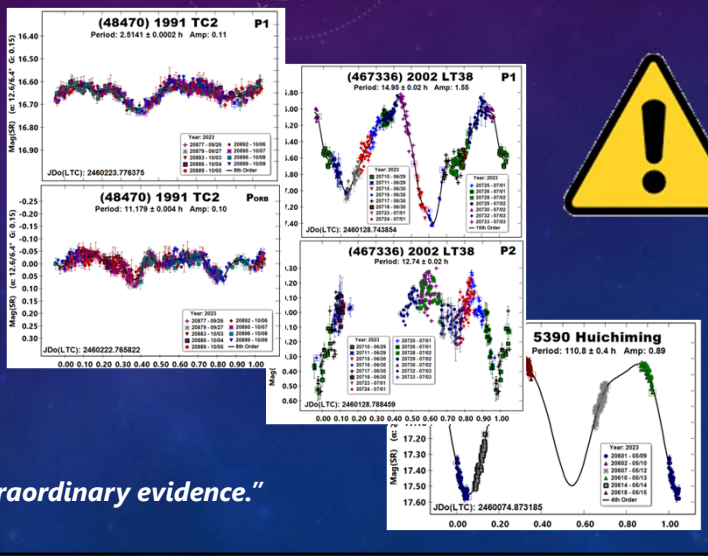
Almost…

V12 Tutorial: Lightcurve Analysis

Pot Holes in the Road to Success

It's Not Always Easy

- **Rotational aliases.**
- **Binary and Trinary.**
- **Tumblers.**
- **Three periods.**
- **Low amplitude (multi-modal?)**
- **Unusual lightcurve shape.**
- **Long and VERY long periods.**
- **Very long period *and* binary.**



Never trust a computer.

"Extraordinary results require extraordinary evidence."

Plot Pointers

V12 Tutorial: Lightcurve Analysis
Plot Secrets

To Zoom In

- Depress left mouse button at upper-right of zoom region.
- Move the mouse to the lower-right of the region.

  "Drag the mouse."
- Release the left button.

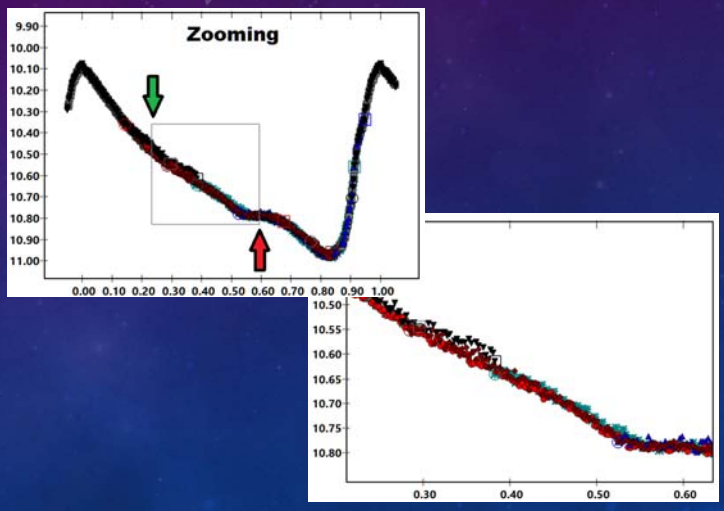
To Unzoom

- Drag up and to the left for a few pixels within the axes and release.

Zoom on Zoom

Same as Zoom.

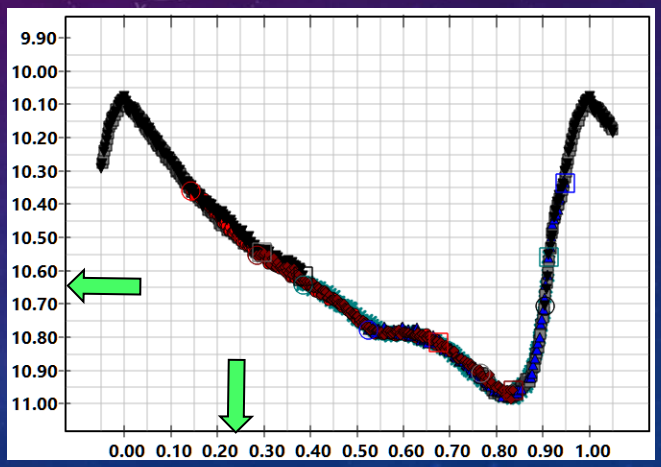
Unzoom until back to 100%.



V12 Tutorial: Lightcurve Analysis
Plot Secrets

Toggle Grid Display

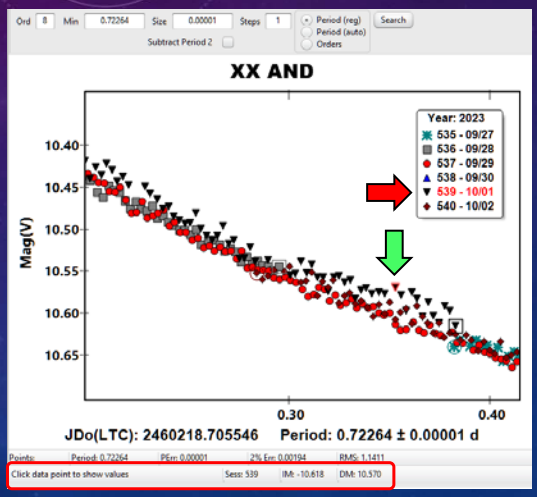
- Click on Left Axis line to show/hide horizontal grid.
- Click on Bottom Axis line to show hide vertical grid.



V12 Tutorial: Lightcurve Analysis
Plot Secrets

Data Point Information

- Orange "hover" outline displayed when hovering over a data point.
- If series in legend, the series turns red.
- Click on a data point on the plot to display information in a status bar under the plot.
- Move the mouse to empty area before saving so that all series are black text.



MPO v12 Tutorial

Lightcurve Analysis

YouTube Channel

https://youtube.com/@8734Warner

Technical Support

https://groups.io/g/MPOSoftware

PowerPoint Slides

https://bdwpublishing.com/php/tutorials.php

Producer/Director/Writer/Editor
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Addison (AI Voice)
Andrew (AI Voice)
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Music
Music from Uppbeat (free for Creators!)
https://uppbeat.io/t/...

prigida/moving-forward
braden-deal/together-we-can
prigida/picture-frames
ra/renewed
simon-folwar/mirrors-and-clouds
ben-johnson/cant-stop-chasing-you
dan-phillipson/the-journey-ahead
zoo/clarity
corinne/ecstatic
hartzmann/purple-lines


Catering
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Caffeination
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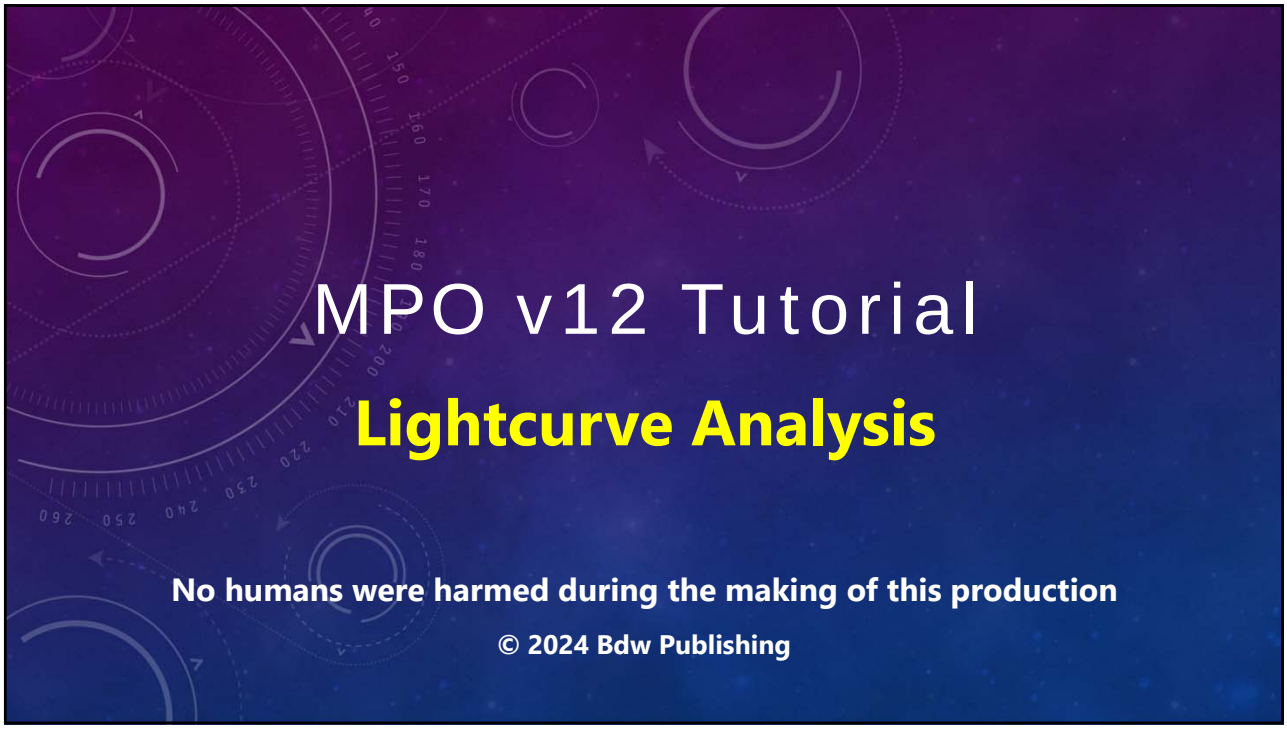
Computers & Network Support
Brian D. Warner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