COOKBOOK HOW TO MEASURE EURONEAR NEA LIGHTCURVE WITH CANOPUS BASED ON IRAF REDUCED IMAGES:

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Amadeo Aznar, 10 February 2016 (added the Appendix 1)

Tested on INT WFC CCD4 10x10' window using 2011WK15 Feb 2015 3-night observations

Download IRAF reduced images:

http://www.imcce.fr/~ovidiu/Canopus/2011WK15-MPO-INT10-n2.zip **(then other two nights n1 and n3)**

Use the IRAF scripts provided by Ovidiu (redwfcbias.cl, redwfcflat.cl and redwfc.cl) and follow EXACTLY the steps in their header! WARNING: IMAGERA/DEC and OBJCTRA/DEC need to be update for at least first field (asteroid and night) in the redwfc.cl script (for INT data at least), otherwise they won't be read correctly.

1. Receive from Ovidiu the reduced images (these need some FITS header updates, besides bias+flat correction) or reduce the raw images using Ovidiu's IRAF scripts

2. Start Canopus and set two important menus for INT WFC 10x10' FOV window case:

  2a. File / Configuration (see next screenshots) with most important in the middle one to reverse N/S only and rotate 90 deg (CW). Create and save this new configuration named "INT-WFC-CCD4-10" (10' central FOV window). Finally press OK to load this new configuration.
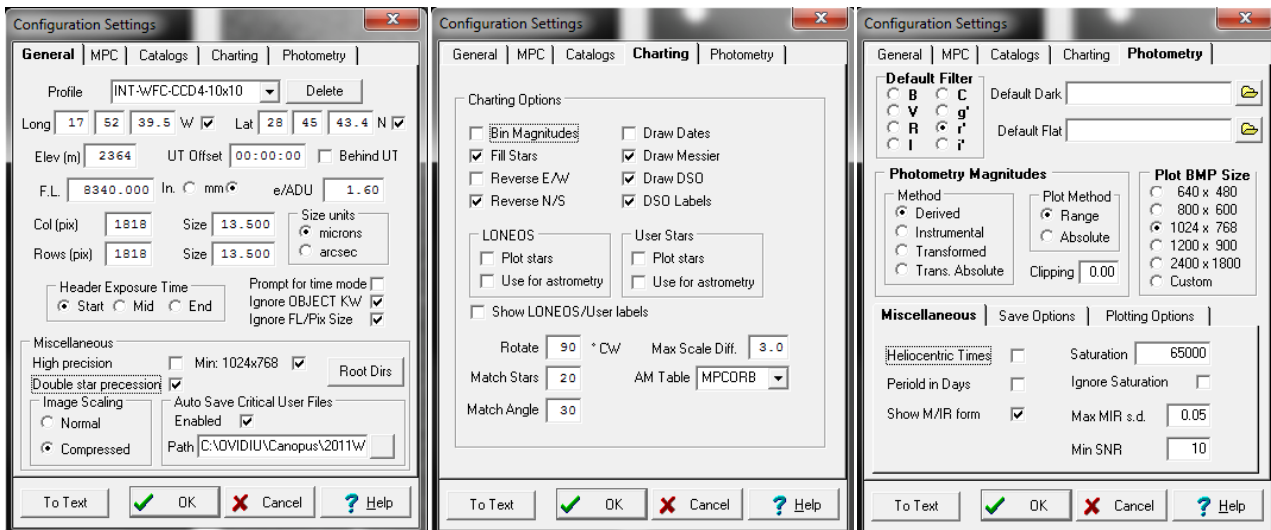
  2b. Under Photometry / Session (see next screenshot) create a new Session Data for the observed object (ex 2011 WK15). After entering all the data, press button Calc M/D/P for Canopus to calculate some needed asteroid parameters for the observed date/time (for ~5:00 UT). Press OK button to accept this photometry session.
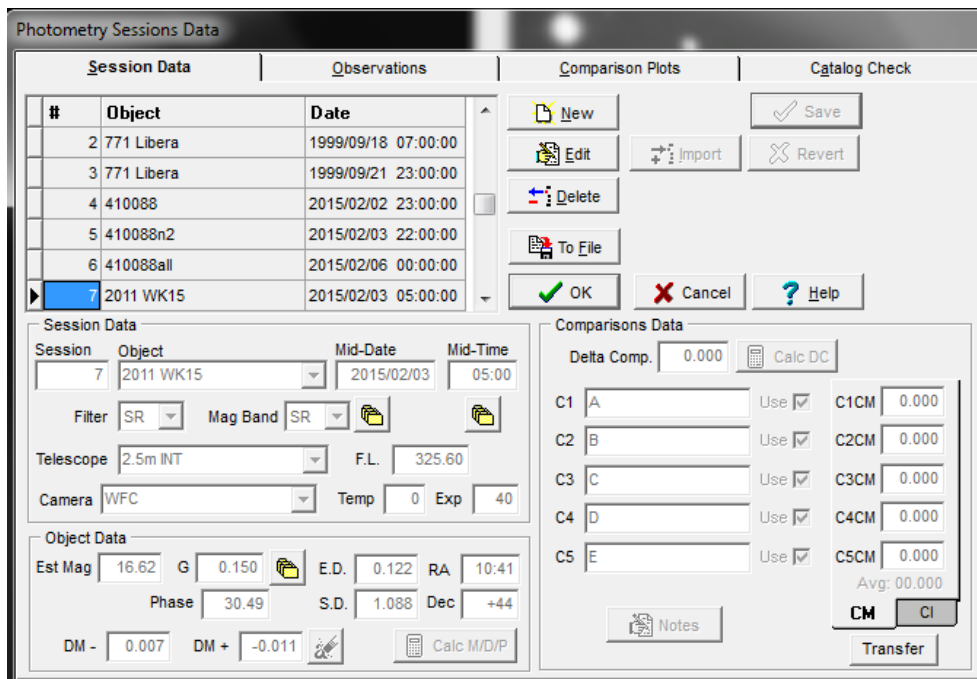
3. Open the first image (r1110525redCCD4.fits) using Image / Open, this will load in the right part of screen

4. Check on the image that you can see fainter stars close to the sky level. This should be the case because in the CFG you selected Image Scale / Compressed. Otherwise, just change this option or adjust the image display scaling factors: right click on the image, then Scaling, then Normal / Normal 2.0 (instead of 3.0) so you can see fainter stars (needed later).

5. Carefully set the best Apertures (upper button) parameters based on the observed seeing (FWHM measured with Canopus by clicking on 2-3 stars, then reading the second value after SN found in the bottom status bar (ex: SN: 142/5.58 gives us FWHM 5.58 pixels which we approximate to 6), and also based on the elongation of the stars and the asteroid (usually we tracked the telescope at miu/2 – half its proper motion, to obtain similarly elongated asteroid and star images) and the direction of this elongation. Set these parameters in Apertures:

5a. Target: to match in the end 5c values

5b. Comparisons: to match in the end 5c values

5c. Astrometry: Check Circular (to measure elongated stars), Width: 19 pix (typically 3xFWHM is recommended, and needs to be odd number, taking measured FWHM=6 pix). Height: 15 pix (some lower value decided after tests, depending on the ellipticity of the stars), Rotation: 120 deg (measured counterclockwise from horizontal upwards), to be decided after testing

Dead: 2 (small ring between star ellipse and sky larger ring)

Sky: 6 (typically measured FWHM)

IMPORTANT: Decide the best values by repeating the Automatch (Ctrl+A) and checking the red apertures to fit nicely around stars to encircle best the light of most stars!

TIP: In case the tracking was normal sidereal, stars will be circles (Width=Height and Rotation=0) and the asteroid will be more elongated (find it and plug in the appropriate numbers for Target). In case we tracked on the asteroid, then for Target Width=Height and Rotate=0, while stars (both Comparisons and Astrometry) will be elliptical.

6a. Load Image / Auto match/measure (see next printscreen). This step is needed to make sure the field is identified correctly and the important FITS keyword and data are read correctly from the image headers (otherwise you can correct important header parameters for the first image only, using Utilities / Image Processing / Edit Header). This should load and test some triangles (automate match) versus the given catalog star and it should successfully finish by showing a stare map in the left panel with some numbers besides the stars (available from the catalog), and the loaded images in the right panel with circled stars (identified on image). It will also show a table listing the identified stars (white lines and marked with X) and stars with errors (grey lines, which can be refined later. Close this small menu.
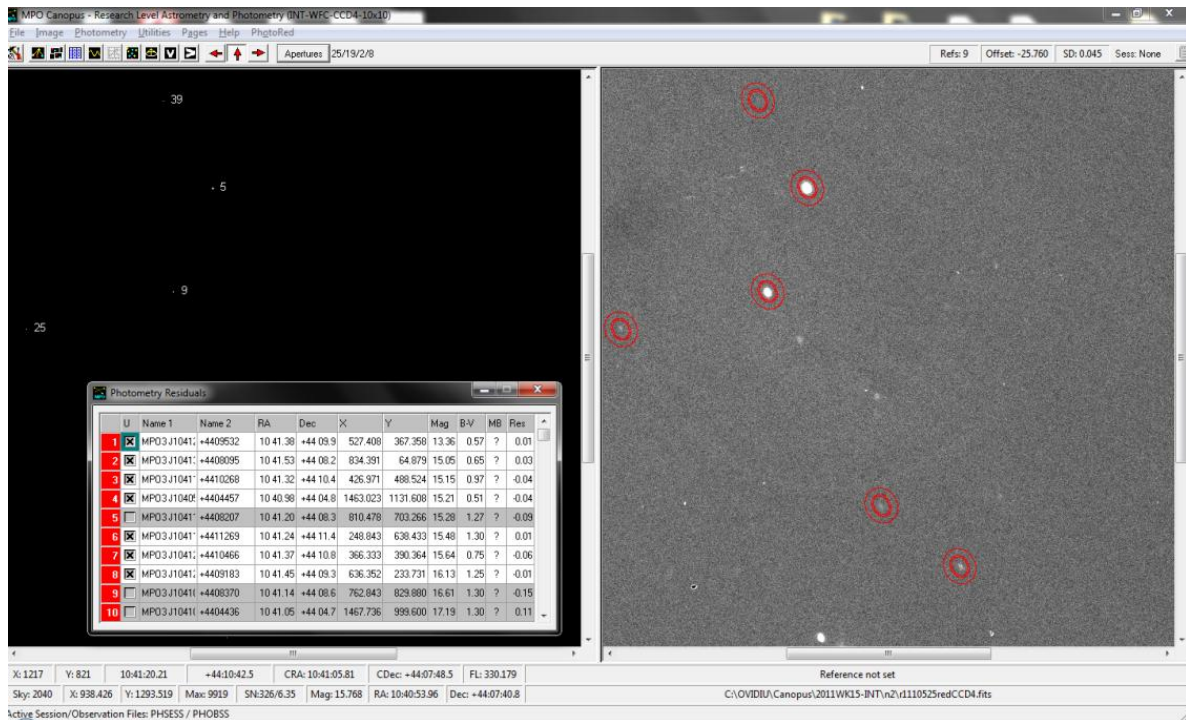
6b. There are two possibilities in case AutoMatch does not work:

First, Image / Close the image, then open it to edit its header, in order to match exactly the centre of the field IMAGERA and IMAGEDEC. You can edit the header using either NASA's "fv" FITS viewer software (http://heasarc.gsfc.nasa.gov/ftools/fv/fv_download.html Windows version) or using Canopus (Utilities / Image Processing / Edit header). To find out the exact centre of the image, you can use Astrometry.net (follow the Use / web links - http://nova.astrometry.net/upload).

Second, if the previous did not work, then in Canopus you can Manually match the image. You load the image first (making sure the Session is correct), then attempt the Auto Match (Ctrl+A) again (which will not work – not produce any numbers on the left star chart image). Then you must Image / Close the image, then re-Open the same image, then chose Image / Generate Manual Chart... then answer NO (for Delete last extracted), then select Chart based on .. position, then you should see RA DEC those found by Astrometry.net (corrected by you in the header), then press OK, and some catalog stars (small points) will populate the left chart image. Here, you should identify two stars, and the image should match quite exactly the chart (and you are free to drag left/right up/down the bars to find better/brighter stars – see the next image as an example).
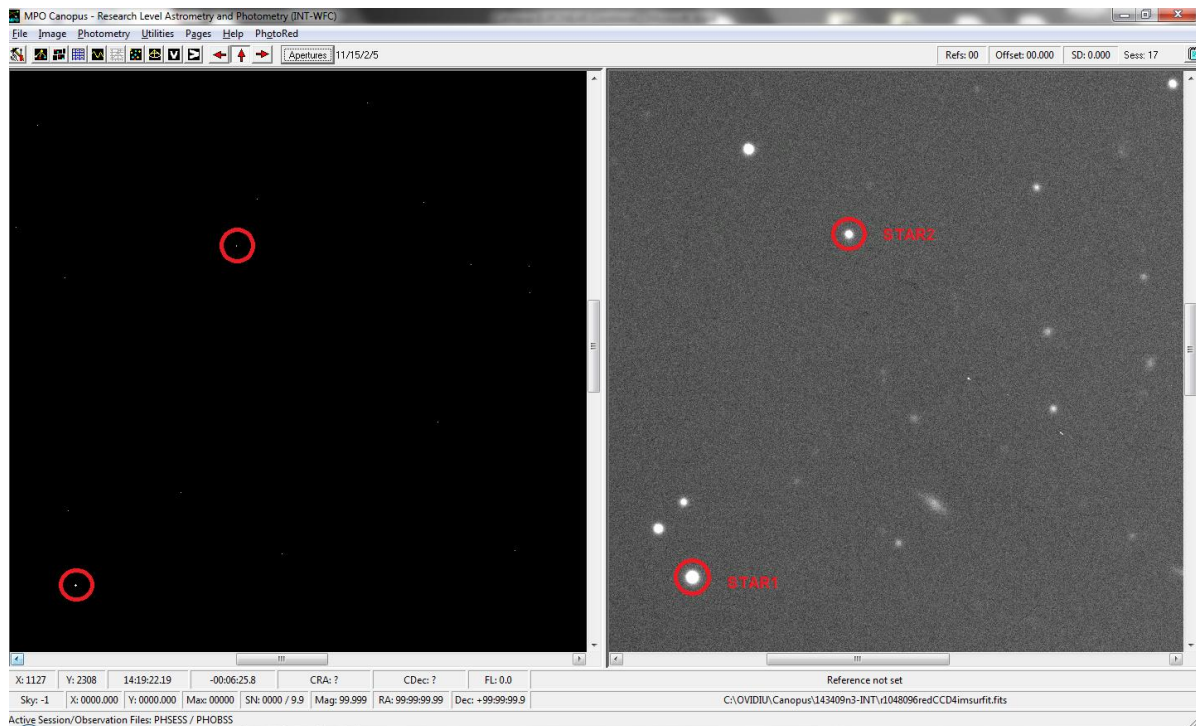
First, click on the first star on the image (right side), then right click Set Image Star / Add Star 1. Then, go on the left side and right click on the first corresponding catalog star, then Set chart star / Add Star 1, to assign the first star. Then, come back on the right-side image, click on the second star then right click, the Set Image Star, then Set Star 2, then go to the left chart on the same star and right click Set chart star / Add Star 2, to assign the second star. Then over the same left-side chart, right click / Match to image / Auto Measure. This should resolve your field, namely populate the chart with identified star numbers from the catalog/s and encircle the identified stars on the righ-side image. If this is not the case, attempt Auto Match (Ctrl+A) again.

7. Load Photometry / Lightcurve Wizard menu, eventually press Clear current data. Basically follow from page 61 of the Canopus Guide manual to the end of the chapter (108) steps, shortly: Press the small "..." button and load again the first image (r1110525redCCD4.fits). Select "Star Subtraction" for subtracting the small stars in the path of the target. Press Next twice.

8. Press "Show Path" and search for your object (chose "Sort by NAME" because this object does not have a number yet) and chose "2011 WK15" (first INT 10x10' test) then a longer red line will appear on the right part of screen, and you should see the asteroid very close to the start of this red line!

9. By doing all the steps above, you are ensured MPO Canopus recognized the images (orientation, coordinates, etc form FITS headers) and you could continue to load all the images in this session - one "session" in MPO Canopus is defined as one night, one star field (using the same few standard stars) and one filter!

10. Click on the asteroid (close to the start of the red path), then click the Target button in the wizard menu. This way Canopus identified the asteroid in the first image.

11a. Click Selector button, then Plot Comps in the small Plot tab, to plot all possible comparison catalog stars (which should show in the field). TIP for ideal reduction: if you click on any point/star on this plot, Canopus will give you info about the star (colors) which ideally should match (be very close to) the color of the asteroid. Also, it's best to pick points sitting closer to the black fitted line.

11b. In case you don't have enough Comp stars to run the Comparison Star selector (due to a small field, lack of catalog stars in that region, g-band filter), then you should skip together the Comparison Star selector (steps 11a-13) and search stars using another external source, example the VizieR, Aladin SDSS DR9 to search for catalog stars (see APPENDIX 1 bellow), by identifying them with your image displayed in DS9.

Then you should only extract their catalog magnitudes and XY positions in DS9 (to be able to identify them later in Canopus and add their magnitudes in the Session / Comparison Data C1CM-C5CM boxes). There is also an alternate way to add User stars imported from a text file (ex extracted via VizieR for the observed region and an appropriate catalog holding enough stars) and still use the CompStar Selector, but the previous method is easier.

12. Choose the anchor star which is also the first comparison star (Comp1), as one star close to the asteroid path which remains visible during all images. This should have a good S/N>100 (check in the lower-left bar) and be non-saturated. Click on that star in the image. Click Set Comp 1 in the Comp Star Selector.

   ATTENTION: do NOT click on the Star 1 button in the wizard!

   Continue by selecting the other Comp stars (visible in all images)!

   IMPORTANT: to attempt reducing all images in one shot (no more groups), then the comp stars should be visible in ALL images, so you need to load in DS9 the first two and last two images, identify the asteroid and possible Comp stars.

   See the next image and choose the same stars Comp1=(366,390), Comp2=(249,638), Comp3=(427,489), Comp4=(810,703) and Comp5=(834,65).
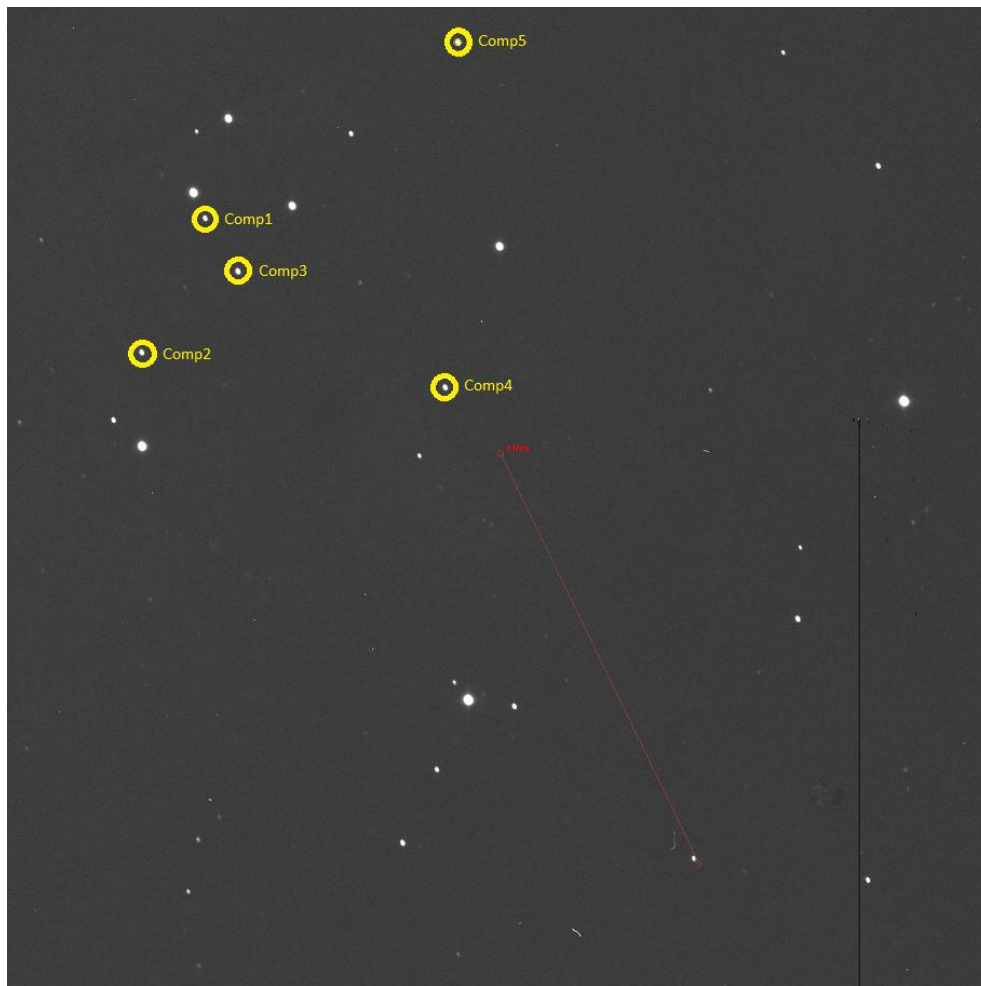
13. Click on the Comps tab in the Comp Star Selector. Check in the Set Comp Mags box, Text to NOTES box and V-R radio button. Click Transfer button. Click Save to Text and accept the name. Press Close to close the CSS (Comp Star Selector). All 5 stars and the asteroid positions should show in the wizard.

14. Click Next, then using the ... small button load the last image in the set/session. These two images (first and last) will be used to align the star field and also to calculate the asteroid expected position based on linear interpolation in time (with UT taken from the header). Click Next two more times. The last image should load with the T (target) and 1-5 numbers overlayed on it) but usually NOT matching the last image (because we usually tracked at miu/2).

15. Correct the positioning by moving the mouse over the anchor star (Comp1) and pressing Ctrl+Click (usually left mouse click). Then the numbers should match the 5 stars! Click the Star 1 button and the numbers will populate the new wizard small window.

16. In DS9, load the last and second last images (OBS: another image, ex the 20-th and 21-th can be used instead of second last), and identify the asteroid in second image (X,Y). Make sure this is the asteroid (ex: danger when observing in ecliptic), and eventually use MPC eph and DSS map to check this! Possible some green circle will show up nearby.

17. Click on the asteroid, then Target button.

18. Click next twice, then Load Image #1 again, which will load in the right panel showing the red path again, this line will help us to select nearby stars close to the asteroid path. TIP: steps 19-21 will be skipped in case you did not choose StarBGone process.

19. Select two Reference stars for StarBGone (this 2 stars concept is different than the five photometry comparison stars chosen before). Choose as Reference Star 1 one of the 5 reference stars! (should be present in ALL images) for example Comp2 star (249, 639), thus Reference Star 1 (StarBGone) = Comp2. Click on Comp2 star in the image, then Set ref Star 1 button on the wizard. Choose as Reference Star 2 a new bright star at (409, 206) (not necessarily from catalog). Press on the star, the press Set Ref Star 2 button.

20. Locate stars near the path [TIP: impossible? if the last fields moved a lot and the red path goes outside the first image – in which case you need to split the images in two groups and allow 2-3 common images in each group which will later help the small shift alignment]. Add these stars close to the path (to be deleted) by clicking on each, then the Add button. TIP: in order to see fainter stars, you should have changed right click (on the image) then Scaling, then change to Mode Compressed (and eventually adjust the two Compressed limits) but this does not seem to work/show the red path anymore at this step!

21. Click Next, then click Save Comps and accept the image name. Click Finish.

22. A Windows menu will appear allowing you to load ALL images in this session. Click on the first, then scroll down, then click Shift+click (to select all). Then click Open. We will try Auto (and AutoMatch button NOT checked). Press AUTO, then in the small menu, chose Simple (AutoMatch optional), then OK.

23. Have your computer volume ON to hear the beeps after each image measurement. Maybe at some point (after many images, at ...678 image in this INT trial) the process might stop with the error "Comp1 apperture placement not correct.." probably due to a telescope jump or shift in position. In this case, accept the error and find the anchor Comp1 star in the image, then Click on the star, so all Comp stars will be re-aligned by the program. If the asteroid is not in the aperture, then Ctrl+Click on the asteroid in the image, so it will become centered in the aperture. Click Accept Auto again, then Yes to re-start from the highlighted image. Also, maybe sometimes the target will drift out from the aperture, in this case your should Abort / Yes the process and re-center the target in the aperture (just Click on it), then reload the process (Auto / Simple) and continue. IMPORTANT: It is mandatory to keep the asteroid well centered in the aperture and do not leave it approach closer than 3-4 pixels from the first red circle/ellipse, otherwise the night plot will artificially start to decrease (less flux from the asteroid being measured in a wrongly placed aperture). You can Abort then re-center and re-start the process as many times as needed.

24. This will end the semi-automated measurement process. Click Close.

25. To see your "birthday" present, Load Pages / Lightcurve analysis, then check (as a first test only) Orders=4, Steps=100, Min=2.0, Size=0.1, Bin=1, Max Diff=10, Period checked only, Raw and R Mag checked, then press Find button, check in your session, then OK, and voila your first light-curve!

26. Check that none of the Comp stars is variable. Click on the upper-right corner Notepad icon (yellow popup "Edit current session") which opens you the Session data form in edit mode. Click on the Calc DC button, then check the Comparison Plots tab to see the instrumental magnitudes of each Comp star.All of them (click on each of the five Comp radio buttons) should show the same behaviour (scatter and trend, with very small variations for some points). By clicking Data / Avg radio button, the CompX star is compared with the average of the remaining comparison stars. These trends should be horizontal with very small scatter (usually < 0.01 mag). Click Comp1, .. Comp5 buttons to check this.

27. Eventually some data points are well outside the horizontal linear trend, and these points (images) can be deleted from reduction simply by pressing Ctrl+Click on the point, then Yes. You can delete 1-2 such above points.

28. Still in edit mode of Session, click on Catalog Check tab to compare stars in a different way. Under the Raw vies, all curves (apparent asteroid magnitudes) should run parallel (the five stars have different colors), with a small possible shift between curves (colors) due to approximate catalog magnitudes (up to usually ~0.2 mag). Also, the Avg plots should ideally sit on top of one another around Y=0.

29. You can also remove outlier points from the light-curve plot (ex bright stars in the trail not removed via StarBGone) by simply clicking Ctrl+Click on the light-curve, then accept Yes.

30. Once you are satisfied with the check, return to "Session Data" tab and click Save and then OK. This ends 2011WK15-n2 (night 2) reduction, you can exit Canopus now.

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31. Start n1 (night 1) reduction now. Re-start Canopus and make sure you load the same Configuration, and define a new Session by entering the same name of the Object (2011 WK15), then the n1 mid-date (2015/02/02) and mid-time (03:30), Filter and Mag Band (SR), Telescope INT, Camera WFC. Press Calc M/D/P, search the Object (by name) "2011 WK15" and accept, then Save the new Session. REMEMBER, each session is defined as a new night and the same star field and filter. Press OK.

32. Load first image (r1109989redCCD4.fits), run Auto Match.

33. Identify possible common comp stars loading in DS9 first and second image (blink and identify the asteroid), then last two images (again identify the asteroid and write its position (X,Y)) then load first and last image, center on a common star and identify (in DS9 click to circle) common possible stars.

34. Eventually adjust the Apertures parameters, based on n1 exp time (the same 40s in this case), measured FWHM, elongation and apparent fit of the stars in the apertures, after Auto Match.

35. Start the Lightcurve Wizard. Clear current settings. Load first image, click Show Path, click exactly on the asteroid (previous right click/Zoom 4:1 to center best), then click on Target button, then select 5 Comp stars among those identified in DS9 (you will need there Invert Y).

36. Press Selector button, then Plot Comps, select the 5 Comp stars and write down their XY positions. Chose the following: Comp1=(380,371), Comp2=(708,250), Comp3=(294,913), Comp4=(1169,674) and Comp5=(694,1020). Click Transfer and Save to Text (in Compstarmags-n1.txt).

37. Load Image#2 one image in the middle (ex r1110051redCCD4.fits) and check in DS9 position of the target (983,1023). Click Next 3 times. Find the anchor = Comp1 star and do Ctrl+Click on it, then the 1..5 numbers will fit the stars again. Click on Star 1 button to let the wizard know.

38. Click on the asteroid (983,1023) then the Target button. Click Next, then click Save Comps (as comps-n1.png image). Click Finish.

39. Load all images in n1. Accept the same values as first time and start the Auto process with AutoMatch button NOT checked and Simple (AutoMatch optional). The process will stop a few times, reposition the apertures (clicking on Comp1 anchor star) and eventually correcting the target in the aperture (press Ctrl+Click on the asteroid), the continue with Auto until the end.

40. Repeat the steps 24-30. This will end n1, you can eventually close Canopus.

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41. Start n3 (night 3) reduction, set the date 2015/02/04, mid-time 06:00, Basically repeat steps 31-40. SKIP the first image (if not tracked correctly), load the first image r1111180redCCD4, identify Comp stars: Comp1=(549,446), Comp2=(340,289), Comp3=(1345,366), Comp4=(1169,880), Comp5=(703,884). Load Image #2 one in the middle (ex r1111251redCCD4) asteroid at (1077,1123). For StarBGone eventually choose ref star 1 = (549,446) = one of the CompX stars and ref star 2 = (1345,365). Delete few points (especially closer to end if observed longer in twilight) from plots, and close the n3 session and eventually Canopus.

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43. Select the three sessions (same object) and fit the 3 nights data! This is another story.

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44. Send your 3 night plots to Ovidiu along with your Canopus export files (use Session, select the reduced object, press To File button, then check Output Options: Canopus export files, and JD Correction light-time, press OK, then select all 3 nights with Ctrl+Click, then press OK and select the folder – usually C:\MPO\UDATA, then send to Ovidiu the two files 2011_WK15_1_OBS.FF2 keeping the observations and 2011_WK15_1_SESS.FF2 keeping the sessions).

APPENDIX 1 - Using catalog magnitudes from other sources

In this appendix you will learn how to get stars magnitudes in different bands (ex. Sloan r or g) using some external (online) source, in case there are no catalog stars in the Canopus catalogs covering your observed field.

1. Run normally the wizard until Canopus demands you to select 5 comparison stars.

Select the 5 comparison stars without using the CSS. If you did run the *auto/match* before the wizard, then the RA/DEC coordinates will be recorded in the session, but not their magnitudes (don't worry about this). Later you will let Canopus know the missing magnitudes of the comparison stars (ex. r or g), after you'll get them from an external source.

Other alternative would be to run the wizard using the CSS but selecting the V filter (from the Comp Star Selector / Filter radio buttons). This way the session will store the celestial coordinates (RA/DEC) of the comparison stars and also their V magnitudes (and remember to transfer the star information to the session by clicking on the *Transfer* button in the *Comps* tag CSS). Then later, after you'll obtain the missing (say, r or g) magnitudes from an external source, you must replace the previous V magnitudes with the the r or g magnitudes.

2. Whichever method you use, run the wizard almost until the end. Stop in last step (I think nr. 12).

Before loading the image list to be reduced, save the comparison star image. This image lets you recognize the 5 comparison stars in the star field of the external source later.

Close the wizard but do not select any image list to be reduced, yet. Before select the image list, it is necessary to enter the r or g magnitudes of your comparison stars.

3. Now it is time to obtain the r and g magnitudes from some external source (ex the digitized sky atlas).

Use the Aladin Sky Atlas to plot a star catalog with Sloan magnitudes. Aladin is the professional interactive sky atlas in which you can visualize digitized sky images plotted with any star catalogs. Also you can access other related data from other archives for knowing all information about the star in the field (magnitudes in several band, proper motion, etc.).

4. Better download and install Aladin in your computer. You can download it from the Aladin website (http://aladin.u-strasbg.fr/java/nph-aladin.pl?frame=downloading). Although there is a "lite versión" which allow online use in a browser, it is strongly recommended to install Aladin in your computer in order to access all the information and use all the Aladin analysis tools.

5. Run Aladin and click on the Open folder icon (upper left side, or File/Open). A server selector will be automatically opened. This server selector will be used in order to get the star field image and also the star catalog information.

6. Let's get the star image field first. Choose an image server using this server selector (icons in left column). Click on 5th left column icon (DSS) and then from the sub-menu, select DSS from STScl (Baltimore/US – DSS.STScl).

7. Write the RA and DEC star field coordinates in the Aladin Target (ICRS, name) line. You can type the coordinates in degree system or sexagesimal system. You can select an specific star image height and width field size (ex 15' is the default size).

8. Click SUBMIT. The star field will be loaded in the Aladin main screen (while a green lamp in Aladin's server selector will flash a few sec).
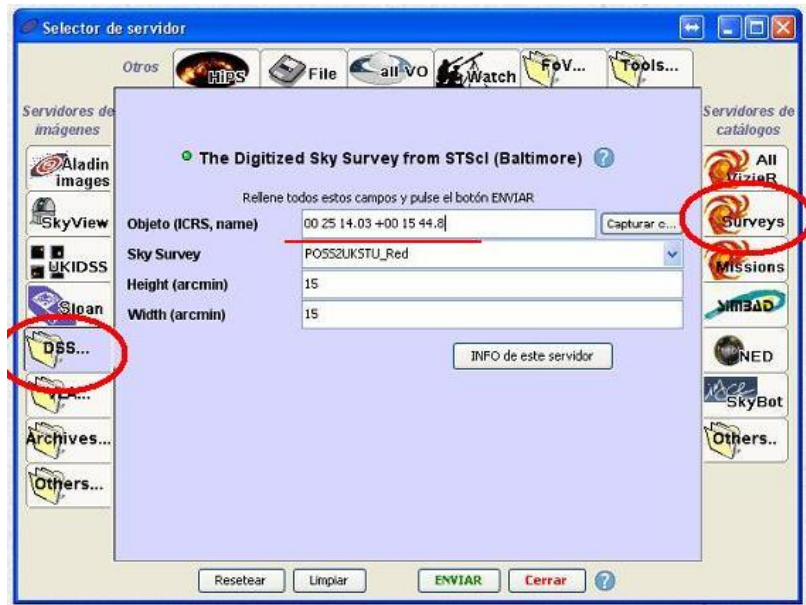
7. Second, select a catalog (from the Survey icon in the right column) to get the information from the catalog.

8. Let's charge the star catalog information. Click on Surveys (second icond in right column). A list of star catalog will appear in the server selector screen.

9. Select the SDSS-DR9 catalog (or any later version of the Sloan SDSS catalogs).

10. Click SUBMIT. A star plot (red dot each star) will appears in Aladin main screen. You will see the star field image with the stars superimposed in main Aladin screen. NOTE: Sometimes it is recommended to load the star catalog first and then the star field image, Aladin could collapse otherwise. If Aladin still refuses to work, try SDSS9 directly (http://skyserver.sdss.org/dr9/en/tools/chart/navi.asp?)

11. Match Aladin chart with your saved image field (in Step 2). Click on your CompStar1 and its astrometric and photometric information should appear at the bottom of the screen. Note that, possibly, your star field could be inverted in relation with the Aladin star field. Write down the r and g comparison star magnitudes.
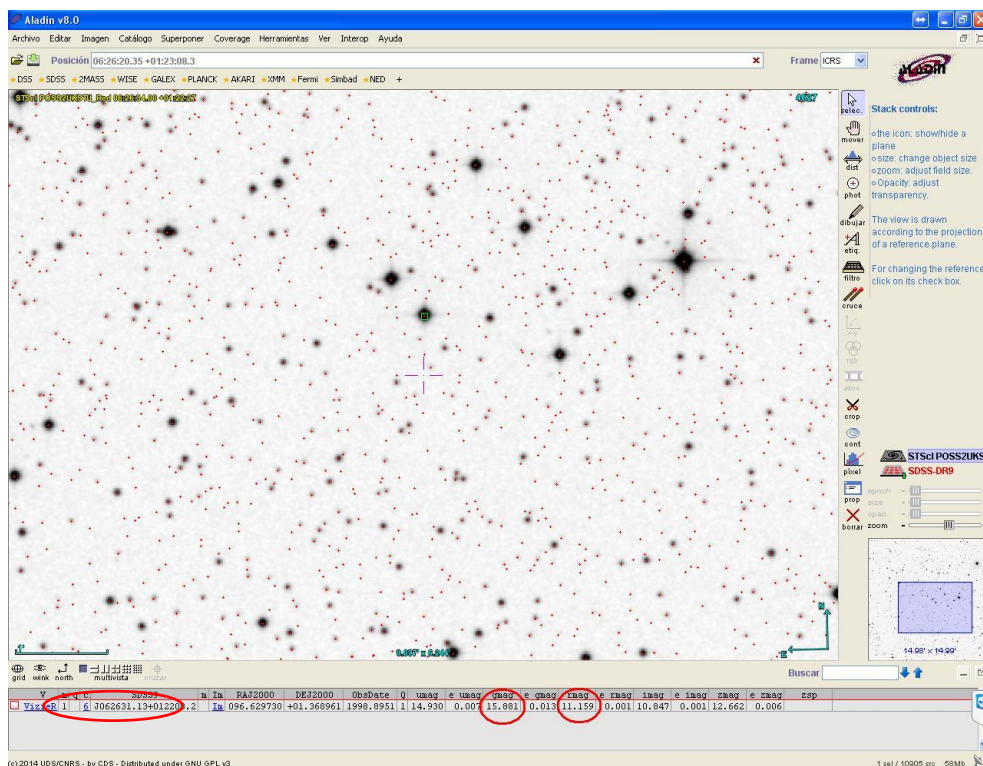
Remember that Sloan Digitized Sky Survey does not cover all sky. If your field is not covered by SDSS8, then you should try another catalog (ex: URAT, APASS9, CMC15). If no catalog covers your star field in the required band, then you must use other source or eventually calibrate the field (by observing a nearby SDSS field during photometric conditions).

12. Go to *photometry > session*. Edit session and replace the X/Y coordinates if necessary. Type them without using spaces. Remember type two decimals in RA coordinates (without coma or point). Type DEC coordinates with one decimal. Replace V magnitude by r or g magnitude. Then save session.
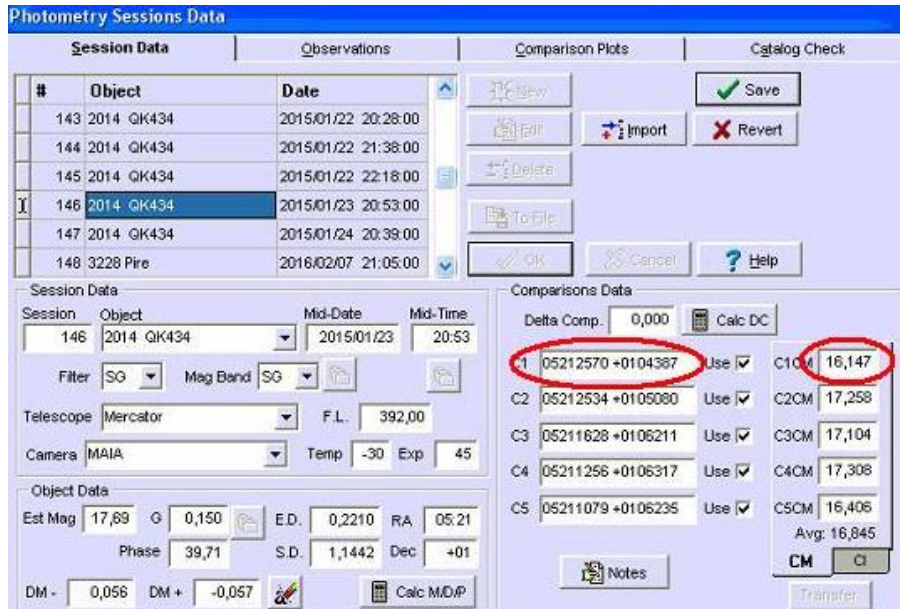
13. Go to *photometry > set image list* and select the image list in order to be reduced. Follow the light-curve process like usually.