Instructions for CPM

Before Running:

You need to have a software installed that will measure the FWHM of any candidates. Caltech's Aperture Photometry tool (APT) is recommended for this (which is a bit like IRAF, but has an interface and is actually intuitive to use). It can be downloaded from here:

https://www.aperturephotometry.org/downloads/

You will need java installed for the windows version. It is also a good idea to watch the following tutorial, especially the initial setup (0:00 to 5:52) otherwise your window may be configured differently to how it is described below:

https://www.youtube.com/watch?v=5lXAWfBW_NQ&ab_channel=LuisaRebull

The rest of the video is extremely useful as well, but only if you are using APT for something other than APT. Using APT on your computer means that you also need to have the data you are analysing on your computer rather than analysis, if you navigate to the file you want the data to be in and then type:

scp abc123@analysis.astro.ex.ac.uk:/data/shinkley/Keck_Data/completed_stars/(etc) **.**

where etc is the route to where the data is and it ends with the name of the file eg: 'llsg.fits. and a space and decimal ' .'

FWHM instructions:

1. I will assume at this point that you have downloaded APT and configured it as per the video, also you will need the script
2. Open APT, click "**open image**" and open the image you want to examine
3. A window called "Aperture correction tool" will open, click "**compute**" and then "**close window**" when it finishes
4. Find the candidate in the image and click on it to centre the aperture on it, as long as you click decently near it the aperture will detect and centre on the candidate.
5. Click on the button marked "**5/5/0_>Alter**"
6. Use the slider the increase/decrease the size of the aperture so it contains the entire candidate signal, click "**Apply**" and "**close**" on both boxes
7. Click "**Recompute photometry**"
8. Now click on "**Aperture slice**" and ensure the candidate's signal is properly centred in the aperture (Note: it does not need to be perfect, as long as it is close the Gaussian fitting will still work)
9. Finally click on "**Radial profile**" and look on the far right of the window for "FWHM (pixels)=…." this is the value of the FWHM of the object and should be equal to or greater than $\frac{\lambda}{D}$ (The expected FWHM of a point source). If this is the case, then the candidate is likely to be something more than just correlated speckle noise

Position estimation instructions:

1. You will need the script **cpm.py** and images from each epoch of the candidate you want to do CPM on, if the image is part of a cube, there is another script: **cube_splitter.py** that can copy individual images from the cube. Just make sure to type the number of the image from the cube that you want to copy on line **35** of the code, the number should be the number as it appears in ds9 **minus 1**, for example if you want to use image '6' from ds9, type in '5' in the script
2. Check if CPM has already been done by logging onto analysis:
   ssh -XY abc123@analysis.astro.ex.ac.uk
   And navigate to the astrometry folder:
   cd ../../data/shinkley/Keck_Data/completed_stars/DangerZone/astrometry

   Type "**ls**" to see a list of all the stars that have had CPM done, if your star is not there, it has not undergone CPM

3. (Assuming CPM has not been done)Use ds9 to make a note of the rough positions of the candidate and the star (if it is not centred on (512,512))
4. Run the cpm script using:

   python cpm.py or **run cpm.py** if you are using jupyter notebook

5. The cpm script will ask for the name of the image, the minimum SNR of the object to look for and the minimum sigma value.
6. Having inputted this, the script will output a list of coordinates of the objects that fulfil these criteria and an image showing where these objects are, use the rough ds9 coordinates to find the accurate coordinates of your candidate/star
7. If there are too many objects in the list, only part of it will be displayed, in this case increase SNR and/or decrease sigma until you find the coordinates you need. If there are too few objects; decrease SNR and/or increase sigma
8. Repeat this for all the epochs
9. Find the difference between x and y values of the candidate and the star to get the position of the candidate relative to the star for each epoch (note in the CPM code the +- coordinates are a little odd, (+,+) is in the top left quarter of the image). Multiply this by the pixel scale; 9.952mas/pix before 2015ap13, 9.971mas/pix after
10. If you are using raw data, the coordinates of the candidate will have to be rotated by the value 'PARANG' (positive direction is anticlockwise): refer to:
    https://github.com/jluastro/nirc2_distortion/wiki?fbclid=IwAR0u1ypp7HzGZqmAQ1fUL_vZMeaOe7WI0ErANCyiyktV_7IlZ0tYIYT5T_c#dist_post2015
    for more information, there may be other angular corrections to apply in this case, **Never forget to rotate your images by β,** This is the keck angular correction and is 0.252° clockwise for images before 2015apr13, 0.262° after
11. Having obtained positions for the candidate in each epoch log on to analysis:

    ssh -XY abc123@analysis.astro.ex.ac.uk

    And navigate to the astrometry folder:

    cd ../../data/shinkley/Keck_Data/completed_stars/DangerZone/astrometry

    Create a new file for your star:

cp Jake/HIP96718 . (The decimal is required)

mv HIP96718 HIPxxxxx (where 'xxxxx' is the number of your star)

12. Enter your file:
    cd HIPxxxxx
13. Edit the information in the filestar file:
    nano filestar_HIP96718_hannah_2.txt
    DO NOT CHANGE THE NAME OF THE STAR AT THE TOP OF THE FILE, YOU WILL CAUSE SO MANY PROBLEMS
14. The inputs going down are: J2000 stellar right ascension (RA) (hours), J2000 declination (dec) (degrees), RA proper motion (mas/year), RA proper motion error, dec proper motion (mas/year), dec proper motion error, distance (Pc) and error in distance.
15. Fill in all these for your star using eg: simbad and find the distance and error on the 6th page of the keck observing spreadsheet "**Parallaxes + distances**"
16. Keep the next two lines as '0.000'
17. The next line is the number of epochs that the star has
18. In each column under this input; the date of observation, x position of the candidate relative to the star (mas), error, y position of the candidate (mas) and error for that. (Assume an error of 4.976mas (half a plate scale))
19. Input the values for each epoch in a separate column, then save and close:
    <Control> o, <enter>, <control> x
20. Run CPM using:
    bash
    idl
    @journal_hip89925.idl
21. An image (diagastroHIP96718_2.png) of the CPM plot will appear, close this and run step 20 again to ensure any changes you made to filestar are fully registered
22. On the image: the blue points are your measured positions of the candidate, the red are where the candidate is predicted if it is a background object, and these red points follow the black line. If the blue points also appear to follow this line, then your candidate is most likely a background object. If they cluster together, then it is likely to be gravitationally bound to the star. (Note there may still be some scatter due to orbital motion, the point is whether the blue points line up with the red or not)
23. (Optional-and advised): download the image to your computer (type this into your computer, not analysis):
    scp
    abc123@analysis.astro.ex.ac.uk:/data/shinkley/Keck_Data/completed_stars/DangerZone/astrometry/HIPxxxxx/diagastroHIP96718_2.png .

    The decimal is needed
24. If you want to adjust the scale on the plot, open the movement file (in analysis):
    nano mouvement_v3_hip16095.pro
    navigate to line 264 (under displays, sky plane diagram, count 22 lines from sky plane diagram), scroll right to find the values 'nmaxx', 'nminx', 'nmaxy' and 'nminy' and adjust them to your liking
    If the angular positions don't appear on the third plot, go into the movement file and change the '+180' on line 233 to '-180'. If the angles exceed 360° or go below 0°, they do not loop around and will instead stop the graph plotting.