Photometry Project

AST 3Y03 Winter 2017
Due January 30, 2017

In this project, you will determine the magnitudes of stars in the open cluster M11. The images were taken in 1996 at the CTIO 0.9m telescope on Cerro Tololo in Chile. This is a research telescope run by a consortium of US universities and institutions called SMARTS (http://www.astro.yale.edu/smarts).

Procedure:

1. Create a directory in your own disk space on phys-ugrad for this project.

2. Change to the class directory /1/home/asills/3Y03_W2017/photometry

3. Copy your two images (e.g. obj719.fits and obj721.fits) from the class directory to your directory.

4. 'ds9' is a program which allows you to look at astronomical images. You can try this out: type `ds9 obj719.fits` This takes a while, as the ds9 program is quite memory-intensive. Don't worry. Once it and the image are loaded into memory, it works much faster. Spend some time playing around with the different buttons and the size of the image (the blue box in the upper left frame). You can, for example, click on 'scale', and the click and hold the right mouse button down, and wiggle your mouse around to change how the image looks. When you are done, click the exit button.

5. The program that we use to analyze astronomical images is called IRAF (Image Reduction and Analysis Facility). This is written and supported by staff at NOAO (National Optical Astronomical Observatories) in Arizona, and distributed to the astronomical community free of charge. Their website is http://iraf.noao.edu

6. The first time you run IRAF, you need to create something called a 'login.cl' file and a 'uparm' directory. Make sure you are in your photometry project directory, and type `mkiraf.` When you are prompted for your terminal type, the correct answer is `xtermjh.` Then you need to make some changes to this file. Edit it (using vi, emacs, pico, or your favourite text editor). Near the top, you need to change one line to read `set imdir = "HDR$".` Towards the middle, there is are lines which look like `task $vi $emacs $w $wc $less $rusers $sync $pwd $gdb = "$foreign"` If you want to add any other linux commands (e.g. `more`)edit those lines and add `$command` e.g. `task $vi $emacs $w $wc $less $rusers $sync $pwd $gdb $more = "$foreign"` You can also add other linux commands to these lines so that you can use those commands inside the iraf environment.

   Remember – you only do this ONE time. Do not use `mkiraf` again.

7. To run IRAF, you must be in a special kind of terminal that can handle graphics output. Type `xgterm &`

8. Change to that window. Start ds9 in the background (ds9 &). To start IRAF, type cl.

9. A useful manual is *A Beginner's Guide to Using IRAF* which is posted on Avenue to Learn. Start by reading the IRAF help page I have written, and then spend some time flipping through the Beginner's Guide.

10. Spend some time looking at the images using imexamine. What do the stars look like? What does the background look like?

11. We are going to do aperture photometry using the DAOPHOT package (written by Peter Stetson at the Dominion Astrophysical Observatory in Victoria in 1987, see Stetson 1987 *PASP* **99**, 111). This is the simplest kind of photometry, in which we will simply count up how many photons hit the CCD detector from the star inside a circle (aperture) of a given size. There are problems with the simple approach, as you will discover, but it will give you a sense of what is done. The images have all been pre-processed (bias subtracted, dark subtracted, flat-fielded, overscan trimmed). They have also been shifted so that the stars are all located at the same pixel coordinates. This will make your life easier in the long term. Load the photometry package by typing noao <return> digiphot <return> daophot <return>.

12. Before we start doing anything with the images, we need to characterize them in a variety of ways. On the next page are a list of values that we need to determine for each image. Some can be found in the FITS header file for the image (imhead *imagename* long+), and some can be found by using imexamine to look at different parts of the image. In particular, you will need to use 'r' to look at a number of stars to determine their sizes (full width half max, the last number in the line that comes up on your screen). Take the average of about 10 stars. Also, put your cursor on a blank piece of sky and type 'h'. Determine the pixel value of the peak of the histogram, and use that to calculate the standard deviation of the background in counts.

13. Now we are going to put all these values into IRAF so that we don't have to keep typing them in. Type epar phot. For each of the lines 'datapar', 'centerp', 'fitskyp', and 'photpar', type ':e' and then type in your values in their required fields. When you are done, type ':q' to get out of that particular parameter.

14. The routine daofind will find all the stars for us, depending on the parameters you gave. Type daofind and answer the questions as prompted. If the value in brackets is the one you want, just hit return; otherwise type in the value you would prefer.

15. You need to check if you have found as many stars as you would like (or if you've found too many!). First, display your image in ds9 using disp *imagename* 1. Then mark each found star using tvmark 1 *filename.coo*. You should have a little red dot on the centre of each star, and no red dots on non-stars. If you have too many or too few stars, you need to change your photometry parameters or your selection criteria.

16. When you are happy with your star choices, you can now do photometry! Run the command `phot`. The input coordinate list is *filename.coo*, and again you can choose the default values of each parameter by hitting return, or change them by typing the value you would prefer.

17. Take a look at the file *filename.mag.* This will give a large amount of information in a not-very-nice format. To extract the most useful information, use the command `txdump.` In particular, if you want to extract the star ID number, the x and y positions, and the magnitude from a file and put them in a file called *frame1.phot*, you would say `txdump` *`filename.mag`* `id,xc,yc,mag yes >` *`frame1.phot.`* This will put your data into a nice convenient format.

18. Now you need to go and do this (from step 11) for the other image. Remember that some of the photometry parameters will change. To make things easier, you can probably use the coordinates file from the first image to do photometry on the second image, but you need to check to be sure.

19. The two images were taken in different filters, and they have been shifted so that the stars all lie at almost the same coordinates. Therefore, you can create a colour-magnitude diagram from your data. Take a look at CMDs in any intro astronomy textbook for more information. Remember – magnitudes are backwards, and colours are always calculated as shorter wavelength minus longer wavelength.

Things to include in your write-up

1. A copy of the sheet called "Quantities needed for each image".

2. A short description of what you did. Do not go into detail, especially where I have outlined the procedure above. Describe what you had to do in a way that your mother (i.e. an intelligent non-astronomer) would understand.

3. Your final colour-magnitude diagram.

4. Answers to the questions below.

5. A statement about who collaborated with you on this project, what they worked on with you, and an estimate of what fraction of the work they did. Also estimate how long this project took you, and assess its relevance, interest level, and appropriateness for an undergraduate project worth 10% of your final mark.

Questions

1. Look at the stars at (970,1137), (817,1124) and (1037, 908) using imexamine. What are the differences between these stars and regular stars? What does a normal star look like (be quantitative)?

2. What are the filters of your two images?

3. What is the exposure time of your two images?
4. Who took these images?
5. Which photometry parameters change from image to image, and which ones stay the same? Why?
6. From looking at your colour-magnitude diagram and comparing it to the CMDs attached below, what can you tell me about the stars in this cluster? Are all the stars you found part of this cluster? If not, what could they be?
7. Estimate how accurate your photometry is, and give a list of possible errors or uncertainties that can affect your photometry. For each error, suggest something that will improve your measurements.

IRAF HELP PAGE

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IRAF consists of a long list of commands ('tasks') organized into packages. You need to load most packages before you can use their commands.

In the following, things that you type exactly as shown are in `courier` font; names of commands, packages, filenames etc that you need to substitute are in *`italics`*.

Useful IRAF commands:
General:

`cl`	log into IRAF
`logout`	log out of IRAF
`bye`	exit from the current IRAF package
`help`	lists the current possible commands/packages
`help` *`command`*	all you ever need to know about the command, including examples
`package`	load that package
`epar` *`command`*	lets you change the parameters of the command before you run it
`:g`	run the command with the new parameters
`:e`	see the secondary list of parameters
`:q`	exit and save changes, but do not run the command

Working with images:

`display` *`image`* `1`

display the image in the first frame in the ds9 window

`imexamine` examine the image. Place the cursor on the image and type a letter:

`r`	show the profile of the cursor position, and print out position, mag, fwhm
`s`	show a 3-D plot of the cursor position
`e`	show a contour plot of the cursor position
`h`	plot a histogram of the pixel values near the cursor position
`q`	quit imexamine

`tvmark 1` *`file.coo`*

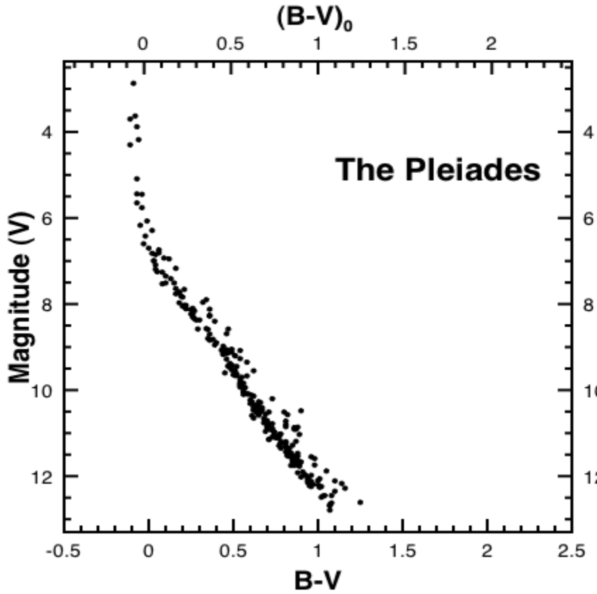
marks the positions of a set of coordinates (from *file.coo)* on the first frame in ds9

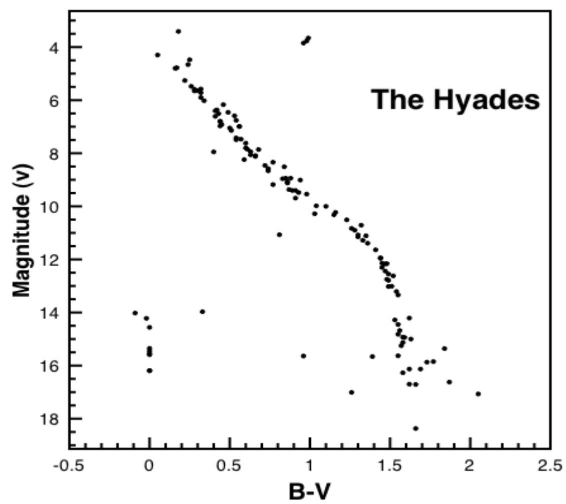
Other things to know about using IRAF:
IRAF is picky about delete and backspace keys. One works, the other doesn't, and it often depends on which computer you are on.

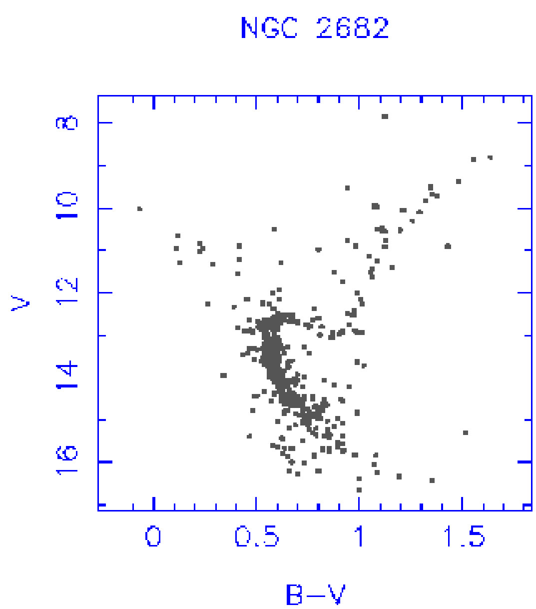
- To go back to a command that you have typed before (and perhaps edit it), type `e`. Then you can use the arrow keys to select your command, or move around in that line to edit the command. This saves lots of typing.
- Sometimes output runs over more than one screen. If this is a problem, type `| less` after the command, and it will keep your output to one page at a time. To see more, hit the space bar.

Quantities needed for each image

Quantity	***IRAF name***	***How to find***	***Value image 1***	***Value image 2***
Full Width Half Max (pixels)	fwhmpsf in datapars	imexamine 'r'		
Read Noise (electrons)	readnoi in datapars	FITS header		
Gain (electrons per count)	epadu in datapars	FITS header		
Min good data value (counts)	datamin in datapars	-3*read noise in counts		
Max good data value (counts)	datamax in datapars		32000	32000
Standard deviation of background in counts	sigma in datapars	$\sqrt{(s + r^2)}$ s = sky value from imexamine 'h'; r=read noise in electrons		
Centroid algorithm	calgori in centerpars		centroid	centroid
Size of centroid box (pixels)	cbox in centerpars	2*FWHM		
Inner radius of sky annulus (pixels)	annulus in fitskypars	Aperture + 5 pixels		
Width of sky annulus (pixels)	dannulu in fitskypars	5 – 10		
Size of aperture (pixels)	apertur in photpars	4*FWHM		


(B-V)$_0$
0
0.5
1
1.5
2
The Pleiades
Magnitude (V)
4
6
8
10
12
-0.5
0
0.5
1
1.5
2
2.5
B-V


The Hyades
Magnitude (v)
4
6
8
10
12
14
16
18
-0.5
0
0.5
1
1.5
2
2.5
B-V


NGC 2682
V
8
10
12
14
16
0
0.5
1
1.5
B−V

Sophie Burley	obj719.fits	obj722.fits
Colin Colterjohn	obj720.fits	obj722.fits
Alex Dalton	obj721.fits	obj722.fits
Christian Dimaria	obj719.fits	obj723.fits
Dillen Dochterty	obj720.fits	obj723.fits
Iggy Doria	obj721.fits	obj723.fits
Nicole Dumont	obj719.fits	obj724.fits
Ian Fare	obj720.fits	obj724.fits
Melanie Gascoine	obj721.fits	obj724.fits
Natalie Gervasi	obj719.fits	obj722.fits
Chris Gubbels	obj720.fits	obj722.fits
Peter Gysbers	obj721.fits	obj722.fits
David Hudson	obj719.fits	obj723.fits
Andrew Hughes	obj720.fits	obj723.fits
David Kelly	obj721.fits	obj723.fits
Hokan Leung	obj719.fits	obj724.fits
Cole Marsh	obj720.fits	obj724.fits
Michael Radica	obj721.fits	obj724.fits
Morgan Richards	obj719.fits	obj722.fits
Derek Savery	obj720.fits	obj722.fits
Jen Scora	obj721.fits	obj722.fits
Tyler Soares	obj719.fits	obj723.fits
Nico Stepan	obj720.fits	obj723.fits
Ingrid Tengs	obj721.fits	obj723.fits
Alex Woodfinden	obj719.fits	obj724.fits