Physics 344 Lab 1

Getting to Know *The Sky* and *IDL*

Due: Thursday, September 13
Text Reference: Chapters 1, 2 and 3

Purpose: Computers are ubiquitous in astronomy today – they control telescopes and instruments and are required to display, manipulate, and analyze images from detectors. We will be using a number of programs in this course, including *The Sky* to control the telescope, *CCDSoft* to operate the CCD cameras, and *IDL* for imaging processing and analysis. This lab introduces you to *The Sky* running on windows PCs and *IDL* running on the Linux computer Astrolab.

Interactive Data Language (IDL) is a commercial program designed for working with images, and is widely used in astronomy, especially in space sciences. It will be our primary tool for both display and quantitative analysis of the images that we will obtain in this course. As its name implies, *IDL* is interactive – you can type commands into it one at a time and see the results. It is also a programming language – you can define new commands by writing programs using the basic commands of the language. Some of the "basic" commands are quite complex and most commands are equally able to operate on scalars or one, two, or three-dimensional numeric arrays. This makes it possible to perform complex operations simply. For example, the command **c = a + b** adds image **a** to image **b** and put the result into a new image **c** by carrying out the operations c(1,1) = a(1,1)+b(1,1), c(1,2)=a(1,2)+b(1,2), …, c(n,m)=a(n,m)+b(n,m), where **a** and **b** are two dimensional arrays of numbers, each of size n x m. If **a** and **b** were simple numbers, or one or three-dimensional arrays, the same command would add them appropriately and create an output object **c** of the correct type and size.

IDL is used by astronomers around the world and a number of freeware program packages are available to perform common astronomical tasks. We have included some of the most popular and useful of these packages in our IDL libraries. These tasks often involve extracting quantitative information from images, such as "how big is a feature in an image?" or "how bright is the image of a star?". This is rather different from the kinds of image manipulation performed by packages such as Photoshop, which are primarily concerned with manipulating the visual appearance of an image (contrast, color balance, *etc*.).

Procedure: Each student should work independently on this assignment.

The first part of the lab uses the computers in the classroom or the dome. I have requested that you get key-card access to these locations (and the building) for the rest of the course. I will keep you posted on progress. If you have problems during the semester, see Ms. Cascio in Physics & Astronomy room 326 during normal working hours (8:30 AM – noon, 1:00 – 4:30 PM).

The second part of the lab uses the computer Astrolab, which lives in the machine room of the Serin Physics Lab. You will connect to this computer using the VNC program, which gives you remote access to a desktop on Astrolab. You can use VNC on the computer in the classroom, but you will probably find it more convenient to set up VNC on other computers (there is also a web-browser option). So, the first step for this part is to follow the instructions on the VNC write-up handed out in class and available on the class websites.

Part I:
Carry out the following steps on either the computer in dome or the computer in room 401 below. Your report should answer all of the questions below and also state the date and time that you carried out these exercises.

1) Log into one of the computers with username "ph344" and password "orion".
2) Start *The Sky* by clicking on the icon on the desktop. Note that a large number of options can be set using the menus, with some of the more common ones also available using the buttons on the toolbars at the top of the window (note that if you leave the mouse stationary over a button for a short time, a tooltip describing the button will pop up). Start by checking that The Sky is reasonably set up for the class. It should be OK, but you never know if someone has left it in an odd state…. When exiting *The Sky,* you should always answer NO to the question about saving changes that have been made in order to preserve the reasonable default state.
    a. Pull down the *View* menu, and click on *Status Bar*; make sure that the *Visible* box is checked. If they are not already set, check the *Equatorial* box in *Cursor Position,* and the *Field width, Date*, and *Time* boxes in *Other Options*. Then click on *OK* – this will display the date and time on the status bar at the bottom of *The Sky*'s window.
    b. Pull down the *Data* menu, and click on *Location*. On the *Predefined List* tab, select the Schommer Observatory under the *User-Defined Locations* item and then click on *Set Location*. Under the *Data* menu, click on *Time* and set the date to September 13, 2018, and the time to 8:00 pm. Note that the sky display will adjust to the selected location and time. (After you have completed this assignment, you may want to experiment with different sites and/or dates and times – for example, to see what is happening at the Southern African Large Telescope (SALT) observatory, use the South African Astronomy Observatory location from the Observatories database.)
    c. **Q1)** What is the latitude, longitude, and altitude adopted for the Schommer Observatory in *The Sky*?
    d. Open the *Display Explorer* item on the *View* menu. Under *Solar system*, make sure that *Planets, Sun,* and *Moon* are checked to display these objects. You can look at what kinds of *Stellar* and *Non-stellar* objects can be displayed, though most of these are more conveniently turned on or off with buttons on the toolbar. When you are done, dismiss the *Display Explorer* to get it out of the way.
    e. Open the *Reference lines* item on the *View* menu. Make sure that *Constellation Lines*, *Ecliptic*, *Local Horizon,* and *Meridian* are checked. You can turn these on and off to see what lines these are (you have to click OK for the change to take effect). Also be sure that the *North/East indicator* is turned on (it is useful for indicating the orientation of the display when very zoomed in). Most of the reference lines can also be turned on and off with the *Reference objects → Reference lines* item in the *Display Explorer* – this is less convenient, but there the properties of the lines are also alterable. Dismiss the panel when done.
3) Use the toolbar buttons to experiment with displaying different classes of objects, selecting the various display viewpoints (N, E, S, W, and Z – this last for zenith-centered, the default at startup), zooming and panning, and displaying various grids. Note that as you zoom in to greater levels of detail (in smaller fields of view), more objects are displayed. The default stellar display for the whole sky (Z viewpoint) shows more stars than are visible in our light-polluted skies. The faint magnitude limit of the stars displayed is adjustable in the *Display Explorer* (expand *Stellar* and use

Display Properties under the *Star* item to vary the faint magnitude limit), however I have found that it is generally best to just use the defaults.

4) Note how clicking on an object in the display brings up a panel of information on it. Return to the zenith-centered display (Z button), if necessary. If the date and time are set to the 8:00 PM on September 13, 2018, then there will be a bright star (bigger dot), Vega, near the zenith (the center of the circular display). Click on it and make sure that the "More Information" mode of the Object Information box is selected.
    a. **Q2)** List all of the names of Vega (Flamsteed-Bayer is a name). List the equatorial and horizon coordinates. Finally, list the magnitude, spectral type, and distance (in parsecs) of the star.
    b. **Q3)** Locate the other two bright stars that, along with Vega, form the famous "summer triangle": Deneb and Altair. You can either click on the stars if you recognize them or use the *Find* tool (binocular button). For each of Vega, Deneb, and Altair, are they east or west of the meridian at 8:00 PM? This is important because our telescope mount requires a large movement to change its pointing from slightly west to slightly east of the meridian (the reason will become apparent when observing). Also identify the stars Arcturus and Antares and list what side of the meridian these are on.
    c. **Q4)** With the display, date, and time set as at the beginning of the problem. Start zooming in. Continue until a rectangular red box with a ring around it appears. This is the footprint of the telescope's CCD camera on the sky. The smaller rectangle in the ring is the field of view of the guide CCD. Click on the brightest star in the big rectangle (biggest dot, though check magnitudes if you are unsure). What is the name of this star and is it east or west of the meridian. Zooming in like this will be the first step in setting up the telescope for observing (more on this later).
5) Continue on to answer the questions below. Remember that, after you are done with *The Sky* and exit the program, always answer NO to the question about saving the changes that you have made. Everyone is using the same version of the program and life is much simpler if we maintain a uniform setup. If you use the computer in the dome, shut it down since it is still getting hot in there during the day. You can leave the computer in room 401 on (though log off).

Q5) What planets are observable from the Schommer Observatory at 8:00 pm on September 13, 2018? List the constellation in which each appears. You can turn on constellation name labels in the *Display Explorer* under *Reference Objects* → *Reference Lines* → *Constellation Figure*. If a planet seems to be between two constellations, turn on *Constellation Boundaries* in that panel or the *Reference lines* panel.

Q6) Set the time to 9 pm (21:00:00) – you can either do this directly or by setting the time step to 1 hour and using the *Step Forward* button. Make a sketch of the full sky with the five bright stars from Q3 on it along with Mars, Jupiter, and Saturn. Label each with its name, magnitude, and, for the stars, spectral type. Make sure that your sketch includes labels of the cardinal directions along the horizon. On a clear night, find these objects in the real sky and note their relative apparent brightness and color. Include the date and time of this visual observation in your report.

Q7) Adjust the time step to 1 hour and advance the display with the *Step Forward* button. Describe how the appearance of the sky changes. What major solar system objects (i.e., excluding comets and asteroids) are visible on September 14, 2018 at 6:00 am, just before sunrise?

Q8) What is the first day during the semester (approximately) when the GK Per (which can be searched for as "GCVS GK Per", is 30 degrees above the eastern horizon at 10 PM? At 8 PM? You may need to watch out for the effect of daylight savings time, which ends on November 4^{th} this year.

Q9) Set the date and time to 8:00 PM, September 1, 2018. Turn off the daytime sky mode (if it is on) and select a time step of 23 h 56m 04 s (one Sidereal Day). Use the *Go Forward* button and carefully observe the motion of the planet Jupiter with respect to the stars until September 1, 2019. Describe this motion in detail. Why are the stars stationary in the display when skipping forward by one sidereal day?

Part II

1. Use VNC to connect to your computer account on the "astrolab" computer (see the VNC handout for details). Create a lab1 subdirectory (a folder in Window-speak) and copy the files "moon.fits" and "m31.fits" from the /home/ph344/lab1 directory into your lab1. (For example, you can use the Applications → System Tools → File Browser tool from the menu at the top of your desktop. Or you could issue the appropriate Linux commands in a terminal window, if you know them.)
2. Get a terminal window by clicking on the terminal symbol at the top of your desktop. Start the IDL Developers Environment by typing the command *idlde* (followed by a return). To make an icon on your desktop for easy access, right click on the desktop, and select the "Event Launcher"; click "Browse" and navigate to /usr/local/bin/idlde; click on "OK". Thereafter, clicking on this icon will start idl for you.
3. Set your path in IDL: in IDLDE, click on *window/preferences*, then select *IDL* and *Paths*; click on *Insert*, and then in the Places window navigate to *File System* and double click. Then navigate to */usr/local/src/idl* (make sure *idl* is highlighted) and click *OK*. This path will be added to the path window. Check the box preceding this item to include the subdirectories. Then click *Apply* and *OK*. You only need to do this once, and then the IDL astronomy libraries will be automatically added to your path every time you run IDL.
4. There is a lot to learn about *IDL*. In this lab we focus on the image display tool RUPhAst, which is the local Rutgers version of the PhAst tool and is a program written in IDL. A moderately-useful manual for PhAst is available on the class websites. For mysterious reasons perhaps deeply connected to the level of entropy in the universe, before running RUPhAst issue the command ".run ruphast <return>" − TWICE – at the IDL> prompt in the IDL Console (at the bottom of IDL widget). You will see many messages about modules being compiled but should see no error messages. You can then start the RUPhAst widget by typing "ruphast <return>" at the prompt. The first time you start RUPhAst it will ask to create a directory called output – say yes.
5. Read the image moon.fits from your lab1 subdirectory using "Read Fits File" under "File" in the top menu bar. Change the "Mouse Mode" to "Color". You can then adjust the display contrast and brightness by holding down the left mouse button and dragging: left-right changes the brightness, and up-down changes the contrast. Try zooming the image with the buttons on the PhAst tool, and panning the zoomed image by dragging the green outline in the small window. Note that clicking the right mouse button centers the display on the location of the cursor.
6. Read through the RUPhAst help (rightmost of the RUPhAst menus). See what typing the r, c, and i keys (with the cursor somewhere on the image) does. Use the "i" key to inspect the statistics for the pixel values in an 11 x 11 box centered on the cursor location. You can change the size of the box by typing a number in the "Box Size for Stats" box *and then pressing the enter key*. The number

isn't recognized until you press enter – this is a generic feature of the graphical user interface built into IDL.

7. Find the coordinates (x,y) and brightness value of the brightest pixel in the image of the Moon. You may find the "Pixel Table" in the "ImageInfo" menu useful. Measure the diameter (in pixels) of the bright crater Tycho, which is located at about the (x,y) location (1255, 1350) in the image. Plot a row and a column passing through Tycho. Save these plots using the "Create PS" button on the plot window. Select the "Encapsulated (EPS)", and deselect the "Color Output" settings, and use the "Choose…" button to navigate to your local directory, then change the extension from ".ps" to ".eps" and save the file. You should use a more descriptive file name than the default "phast_plot". The Open Office Writer can insert these .eps files directly into your lab report. If you want to print these plots, you will need to copy them to your local computer (using ftp in ssh) and then use your printer.

   Experiment with the "s" and "t" keys in the vicinity of Tycho. Also include one each of these plots with your lab writeup.

8. Load the m31.fits image using "Read Fits File". This is a field containing (some of) the galaxy M31 taken with our telescope. What was the exposure time of this image and what date and time was it taken? What filter was used? (Hint: use the "ImageInfo/ImageHeader" menu item.) Use the "Full Range" and "Auto Scale" buttons to experiment with changing the display map. (Full Range maps the brightest pixel to white and the faintest to black; Auto Scale maps a smaller range of "most common" pixel values to the grey scales from black to white.) For this image, even autoscale does not do the best job. Set the minimum (black) display value to 1500 and the maximum (white) to 20000 by typing those numbers in the Min and Max boxes (remembering to hit return). Experiment with adjusting the brightness and contrast using the left mouse button. Estimate the (x,y) coordinates of the bright central nucleus of M31. What is the value of the brightest pixel in the center of the galaxy?

9. With the cursor on the star at (750, 1495), press the "p" key. Report the aperture radius, and inner and outer sky radii chosen by the program and reported in the photometry popup window. Press the "Show Radial Profile" button (if it is not already selected) to see the pixel values (yellow points) and a fitted Gaussian (solid line). Report the FWHM (full width at half maximum intensity), the sky level (in ADU), and the object counts (in ADU) for this star. Note that the "object counts" value is the sum of the pixel values within the aperture radius minus the contribution from the "sky" background, estimated from the values of the pixels between the inner and outer sky radii. Finally, also report the SNR (Signal-to-Noise Ratio) of this measurement.

10. Put the cursor on the star at (2245,455) and press the "p" key. Note how the radial profile of this star has a flat top near a value of 64,000. This star is "saturated" – it is so bright that the pixel signal values were larger than the analog electronics of the CCD detector system could handle, and all information about the bright portions of the star has been lost. What is the reported FWHM of this star? Explain why this is different from the FWHM of the star of the previous question. How would you change the way the image was taken to obtain useful information about the brightness of this star?