ASTR 230 ASTRONOMICAL LABORATORY - SPRING 2006

LAB#1
INTRODUCTION TO TELESCOPES AND OBSERVING TECHNIQUES

Due: Friday, February 24, 2006 at 5:00 pm

1 Purpose

The purpose of this project is to introduce you to the basic characteristics of telescopes and familiarize you with observing techniques that you will need for subsequent labs. In the process of doing this project you will learn to identify constellations and enjoy observing several celestial objects. Initially the lab assistant or instructor will be present to assist you, explain things, fix things that do not seem to work right, etc., − but in the end you must do the actual observing and writing of the lab report. Students will observe together in small groups (2-4), but each person should make and report their own observations. Watching others is not the way to learn how to observe (though there are some benefits in working with an experienced observer).

This laboratory will take several outside observing periods to complete. An observing period is about 3 hours or more under good (less than 50% cloudy) weather conditions. You are encouraged to observe as long as you can if you have a clear sky and low humidity (rare in Houston!). While all of the observing for the first lab can be done on campus, some of the exercises such as the Deep Sky Observing are much easier to do at a dark site such as George Observatory in Brazos Bend State Park. You are encouraged to make a trip to George for one of their public viewing nights held on the weekends. In addition, you can obtain the telescopes on any given night for a trip on your own or for campus use by checking out the telescopes. You can, for example, take the telescopes on a weekend camping venture with friends into the dark skies of rural Texas.

Before you begin these great adventures, you will need to read the material assigned in class, visit the planetarium on your own and work with the computer program Starry Night (available on the Owlnet Macs).

2 Preparation

Good preparation is essential for success in this and any observing project. An observational astronomer usually has to spend much more time preparing for an observing run than actual observing. Before you touch a telescope, you should:

• Carefully read this entire writeup *before* you go out.

• Do the portions of the lab that don't require a telescope – the planetarium show, working with the Starry Night program, and constellation identification.

• Study the star charts in your book and find out which stars and planets are visible by going outside your home or college if weather permits to check out "what is up there" –

before observing with the telescopes.

• Buy yourself a flashlight and lab record book (preferably with lined or quadrille pages) and be sure someone in your group has a watch with a working second hand for timing purposes.

• Your time at the telescope will be spent more efficiently if you know the basics of telescopes (types, magnification, f-ratio, resolution, etc.), the equatorial coordinate system (right ascension(RA), declination(DEC), sidereal time (ST), universal time (UT), meridian, celestial equator, zenith, etc.), the astronomical stellar magnitude system (apparent magnitude, color index, etc.), and the nature of "what's up there" (the Moon, planets, star clusters, nebulae, galaxies, etc.). Most of this will be explained in our weekly lectures, but you may have to do some outside reading on your own.

3 Lab Assignment

The assignment consists of several activities that don't require a telescope which are meant to introduce you to how celestial objects move in the sky and what types of objects are currently visible. The observing program consists of several exercises that first familiarize you with the performance of the C8, and then develop your observing skills by identifying various objects. Sections 3.1 - 3.3 can be done without a telescope, and you should do these first. Sections 3.4 & 3.5 introduce you to the operation of the telescope and can be completed your first night. The remaining portions of the lab can be done on the second or third nights of observing, while much of the deep sky observing will need to be done at George Observatory south of Houston or at the Campus Observatory during scheduled class observing sessions.

You will need to write up the answers to the questions in each section in a lab report, so take good notes about what you are doing.

3.1 Planetarium (telescope not required)

Attend a "Starry Night Express" show at the Burke-Baker Planetarium. These shows are typically held daily at 2:30 pm and additionally at 5:00 pm on Saturday and Sunday (call 713-639-4629 to verify times). There may be a small fee ($5) for the planetarium show.

What to turn in with your report:

• What date did you attend?

• What constellations did you recognize in the show?

• Compare the shape of the constellations in the planetarium to the real sky. How accurate were they?

• Compare the star colors in the planetarium to the real sky. How accurate were they?

• What advantages are there to learning the night sky in a planetarium versus learning them on the real sky?

• What disadvantages are there to learning the night sky in a planetarium versus learning them on the real sky?

3.2 Starry Night (telescope not required)

Starry Night is a very useful Mac/Windows program for studying the sky and identifying objects for telescopic study. It saves hours of work in preparing finder charts and obtaining current coordinates for both amateur and professional observing. It's also fun to play with, so feel free to explore the night sky via computer simulation beyond what you are directly instructed to do. You can get plots of the night sky at any place and at any time of the year (including thousands of years in the past or the future). It can be used to find many objects by name, show where they are in the sky, make finding charts of the fields where they are located, show pictures of numerous objects, animate the motions of the sun-moon-planets, etc.

You <u>must</u> do this part before you observe. You can work with the computer software at your convenience, but do this before beginning your first outdoor session. You will need about 1-2 hours to do this, so don't wait until the last minute and think you are going to do this while observing. Using the programs is good "cloudy night" astronomy fun...

The program is menu-driven and you should check out the various commands in the lists when you bring the program up. There is one Mac computer in HB 335 which you can use to run Starry Night. There is an icon on the desktop to launch "Starry Night Pro 3.0.3." Additionally, the software is available from Central Mac for those of you who have a Mac running OS 9 or OS X with Classic installed (even earlier versions may be supported but I am not promising). If you wish to install it on your own Mac, go to http://cts.rice.edu/Software/centralmac.html and follow the instructions there. Finally, the professor has a version of Starry Night which runs on a PC and he can write the installation software to CD if you provide him with a blank CD-RW. This version is not the pro, so the windows that appear will not be exactly as described below, but all the same functions are available. Contact the professor and provide him with a CD-RW if wish to pursue this option. Assuming you are using "Starry Night Pro 3.0.3," first, you need to make sure the home location is set to Houston. In the small SN window in the upper left, the current location is given by the latitude and longitude. To verify this is Houston, click on the word "Location." A new window will pop up with a picture of the Earth and a red circle showing where the current location is set to. To verify this is Houston, click on the "Lookup" button and select Houston. Click "OK." Did the red circle move? Then click "Set Location." Once the home location is set properly, also make sure the date and time displayed in the lower left window are correct (if for some reason the time window in the lower left is not visible, click on the "time" button in the upper left window). If necessary, you can click on the date or time and change the values using the up/down arrows that appear. The extra SN windows displaying information disappear if you click on the screen background or some other program, but they should come back if you click on the main Starry Night window.

The sky appears before you as it would for the current time. If the time is during the day, the sky will appear blue with the Sun in yellow. If the time is set to night, you will see a dark sky and a host of stars and other objects. The grond stretches before at the bottom in green to the horizon with a few trees as landmarks (note this is not what Houston really looks like).

The view should startup facing south, with the directions marked on the horizon with little yellow arrows. East is to the left and west is to the right. As the mouse is moved across the field, it appears as a little hand. If you place the hand on one of the brighter stars (try the Sun if the screen comes up displaying a daylight view), the star's (or other type of object) name, the constellation it appears in, its coordinates, and its distance should appear. The coordinates are listed as the RA and Declination of the object, and these are the coordinates you will need to use with the telescope when trying to find things. If the view you have is a daytime view, change the time to sometime tonight, say around 9 pm. Again, you can do this by clicking on the time in the lower left window and using the up/down buttons that appear to change things. Use the mouse to get information on a few stars that you see.

OK, let's put some helpful lines up on the sky. Click on "Guides" and select "Equatorial" and then select "Grid." This should put up a grid of red lines showing lines of constant RA and Dec. Hit "Guides" again and select "Ecliptic" and then select "The Ecliptic." The ecliptic will appear in green, but you may not see it on the screen because it does not pass through the part of the sky currently visible on the screen. Take the mouse (if it does not appear as a hand, click on the hand in the upper left SN window) up to the top center part of the star screen, making sure it is not on any star or other object. Click the mouse and hold it down and drag the mouse toward the bottom. This changes what part of the sky you are looking at. Do this until the ecliptic runs through the center of the screen. Now lets animate the screen. There are a series of buttons in the time window at lower left that look like the play, pause, rewind, etc. button on a VCR. There should be one with a dot and an arrow pointing to the right which is green. This is the button that tells the computer to animate the sky in real time. Next to these buttons in a box with a number and units; it probably reads "003 minutes." This lets you select what time unit to use when doing a fast animation. For example, click on the "minutes" and select "days (solar)." Then click on the number and enter 1 using the up/down arrows. Then click on the "play" button (the single arrow to the right). Make sure the ecliptic is visible before you start playing. Note what's moving and what's not, and what's moving the fastest (why?)...what's that big grayish thing zooming through and changing phases? Do you see any other objects moving relative to the stars? Isn't this neat? You have a celestial time machine here, or more properly, a computer planetarium. You can stop the animation by hitting the "pause" button (the square) before you get too dizzy, but let it play for at least a year or so.

Back to business; reset the date and time to some time tonight, say 9:00 pm by clicking on these quantities and using the arrows which pop up to change them. Using the mouse, move the cursor around and hit the mouse buttons to get data on various objects in the sky, particularly those colored things... Is the Moon out? If so, what phase? This is what you are going to see if you go observing tonight!

Let's get coordinates for the objects in Appendix I...Find "Algol" on the screen starmap and put the mouse cursor on it... WAIT A MINUTE - Algol isn't labeled! No problem, click on "Selection" and select "Find" In the new window that pops up, type "Algol" in the field labelled "Name contains" and hit return. The star field moves until Algol is centered in the field and labelled. You can now use the mouse to get info on Algol, including its coordinates. Write down the coordinates and other information to use when you try to observe it. Do the same thing for all of those other named stars in the Appendix I.

OK, what about those deep-sky “M” objects (from the catalog of Messier – a comet hunter in the 18th century who cataloged 110 nebulous objects that fooled other comet hunters). Click on “Selection” and ”Find” and give it something like “M42” and hit return. We now fly through the sky and zoom in on M42 – it’s the Orion Nebula! The zoomed in view shows what the Nebula looks like through a large telescope. Double click on the little magnifying glass in the upper left window to zoom all the way back out. If you wish, you can do this for all of the other Messier objects, though some may not have pictures stored (try the planets too). So far, we have been looking up info on specific stars and other objects and when selecting them with the mouse, you will see what constellation they appear in. You may also want to show the constellations themselves on the sky. This is done by clicking on “Guides” and selecting “Constellations” and then selecting what it is you want displayed, such as “boundaries,” “labels,” etc. When exiting Starry Night, it will ask you if you want to save changes you have made. This is up to you, but please do not reset any of the program “preferences” since this may make the program behave very differently than described above for the next user.

What to turn in with your lab report:
1. A statement that you have gone through all the steps in the previous paragraphs. Include the coordinates of the bright stars in Appendix I. Describe motions of moving objects when you ‘animate’.
2. A list of the constellations in which each of the planets, Sun, and Moon appeared in on the date and time of your birth, and a description as to where/if each planet was visible in the night sky.

After pursuing this exercise, I hope you now see just how much there is to study “up there” and how convenient it is to prepare for telescope observations using computer software and databases. Now comes the hard (but enjoyable) part: going into the cold dark night and observing the real stuff!

3.3 Constellations (telescope not required)

Use the starmaps in your books to find at least one dozen constellations and the brightest dozen or so stars. Try to find these stars and constellations in the sky. If you were not able to find a particular star or constellation, was it because it never rises from Houston, because it was up at a later or earlier time, or some other reason? Note the date, time, location (campus, George Observatory etc.) the sky conditions including: the % of the sky covered by clouds, any haze, moonlight and interfering street lights. Now locate the faintest star you can see with the naked eye (no telescope). Find it on your star chart and record its magnitude. This will be the limiting magnitude and should be mentioned in your lab writeup. Later, when you go to a dark site outside the city, record and compare the limiting magnitude at this site with the limiting magnitude in Houston. Review the constellations and stars during subsequent observing evenings until you know many of them well.

What to turn in with your report:

1. Your list of constellations and stars, and any specifics related to your observations as described above.

2. The limiting magnitude.

3.4 Basic Observing Setup

We will start using the telescopes in small groups the second week of class. Most of the telescopic work in this 1st lab will be done with one of our 2 8-inch Celestron (C8) telescopes. No more than 2 people will be working with one of these at a time, so we can accomodate a total of 4 at a time for the first part of the lab where you are learning to set up the telescope and start observing. The professors will watch the weather conditions and send out an email announcement when the sky looks promising. The first 4 people to respond will then be able to observe that night. The goal is to get you comfortable observing with the C8s so that later in the semester, you can use them on your own. It will almost certainly be necessary to schedule more than one night to complete all parts of the lab, and nights may well be lost due to weather (a plague for professionals too). Do not leave this to the last week – schedule and observe early.

3.4.1 Setting up the Telescope

In the metal box next to the Campus Observatory dome (keep the combination to the lock confidential please) you will find boxes labeled:

Essentials: Take this box outside along with the telescope. The box contains everything you should normally need to observe – eyepieces, diagonals, telescope bolts and wrenches, a grey power cord for the telescope, and an orange extension cord.

Heaters: A blow dryer in case it is humid and your lenses fog up (try using the large black dewcap over the end of the telescope), and a couple of heater coils if the temperature drops to near or below freezing and the gears no longer move smoothly.

Power Cables and Drives: Extra power cables and extension cords. Also a drive box that can be useful for centering objects at high magnification, but you can use the telescope without this box.

Large Tools & Small Tools: Various tools.

Misc.: Please leave this box alone unless instructed otherwise.

–NOTE– It took some time to organize all this stuff, so please be considerate and return everything to where you got it from. This will help your fellow students who use the facility after you.

`AND`

C-8 Telescope (2): Lift *carefully* from the bottom or hold onto the fat part of the fork. Do not grab hold of the finders (small telescopes on the side) or the eyepieces. *Avoid all contact with the optical surfaces of the telescope (lenses, mirrors, eyepieces). Do not put your hands or fingers on the clear glass corrective plate at the end of the telescope. If dew forms on this surface, do not wipe it off (you could have used our dew caps!). Instead, if you anticipate a high humidity night, use the "hair dryer" on the end of the tube.* Mount the base of the C8 onto the circular ring of the wedge using three screws to secure.

Note on moving (slewing) the C8 optical tube (the main scope): The C8 has RA and DEC clamps such that the telescope should not be "slewed" (moved large distances by hand) in RA or DEC with these clamps tightened. The DEC clamp is located at the top of one of the forks and the RA clamp is located at the base between the forks. The appropriate clamp *must be loosened* when slewing the telescope and tightened when you find the object in the finder. Slow motion knobs for both axes are located at the base of the fork and should be used for fine centering of objects. These knobs are to be used to move the telescope when the RA and DEC clamps are locked. The drive will not work unless the RA clamp is tightened. Note also that you should check that the DEC movement rod (on the inside of one of the forks) is approximately located in the middle of the tread of the DEC slow motion screw (adjust if necessary).

3.4.2 Finder Alignment (can be done at dusk)

Before you power up the C8 it is wise to check to see that the finder scope and the main scope are aligned. Put a low magnification eyepiece in the C8 (25 – 50mm focal length) and find some distant terrestrial light (a street light or the illuminated corner of a building), being careful to loosen the RA and DEC clamps before slewing. First put the object in the center of the finder. Then look through the eyepiece, adjusting the objective's focusing knob if the object is out of focus. Is the object centered in the eyepiece field of view? If yes, then the finder and main scope are aligned. Most of the time they will not be aligned, so while viewing through the main scope's eyepiece, move the telescope around until you can center your object of interest in the main telescope's field of view. Now look back into the finder. The cross hairs should be on the center of the object if the two scopes are aligned. If not, adjust the position of the finder scope until the cross hairs are on the object which is at the center of the field of view in the main telescope eyepiece. Remember if you tighten one screw *you must loosen one of the others* at the same time to move the finder without damaging it. This may take some effort and you might have the lab assistant help the first time. This alignment is something you must check at the beginning of the night or if you bump the finder scope during the night.

Once the finder and C8 optical axis are aligned, you can power the internal drive by: (1) plugging the extension cord into the power outlet at one end and the drive corrector at the other end; (2) plugging one end of the grey C8 power cord into the base of the C8 and the other end into the output of the drive corrector. You should then hear the C8 drive motors humming. Make sure that the drive corrector is set to the sidereal rate. Note that a drive corrector is not absolutely essential for most of the tasks in this lab. If no working drive corrector is available just plug the grey C8 cord directly into a power outlet.

Note that once you start looking at celestial objects you may have to change the focus of the telescope. It is easy to focus on a bright star; you simply adjust the knob next to the center eyepiece tube until the star appears as small as possible. DO NOT FORCE THIS KNOB... if you find resistance, turn it in the other direction!

3.4.3 Pole Alignment

Now you have to align the polar axis of the C8 to the NCP (North Celestial Pole). This is painful at first, but gets easier the more you do it. Find the pseudo-North Star, Polaris (the Pole Star), in the sky. Set the C8 tube parallel to the fork (the DEC setting circle should read 90 degrees or so, but use your eagle-eye to check this). Now move the tripod or wedge with the telescope clamps tightened such that Polaris is approximately centered in the finder. The name of the game here is to adjust the tripod-wedge (and possibly also the telescope tube parallelism to the fork) such that you can rotate the telescope in its polar axis (RA clamp loose please!) through 180 degrees or so such that Polaris stays approximately centered in the finder. To arrive at this result, one may have to adjust the wedge and/or tube parallelism. Think while you are doing this and remember that it really can be done in just a few minutes with practice. If you find that you are getting nowhere, have the lab assistant help you.

Sometimes the DEC dial will not read correctly. If it is only off by a degree or so, simply add the appropriate offset to the coordinates when you are looking for an object. Otherwise, rotate the C8 so the two sides of the fork mount are vertical and move the wedge up and down so Polaris is centered. Then rotate the C8 90 degrees in RA and move the tube to recenter Polaris (after adjusting the azimuth by rotating the base of the wedge so Polaris passes through the center of the finder when you move the tube vertically (in DEC); then using a phillips screwdriver, loosen the DEC circle (screw, don't strip it!) and rotate it to 90 degrees and tighten carefully.

3.4.4 Setting Circles

Once you think that the C8 is satisfactorily aligned to the pole, it is time to set and check the setting circles, the dial readouts in RA and DEC. To do this you will have to find a bright star you can locate with your eye and for which you can get known coordinates. See the suggested list of bright stars in Appendix I and get the coordinates of these stars ahead of time from the Peterson's guide or from Starry Night, center one of them in the C8, check the DEC circle reading and if it is off, adjust or (easier) write down the error and compensate other future settings. Note the DEC circles on the two sides of the fork won't necessarily read exactly the same. Now set the RA circle (move it by hand) to the star's RA. Next carefully move the telescope (blindly) to the DEC and RA coordinates of another bright star about 90 degrees away in the sky (adjusting for the DEC circle error, if necessary). Is it in the finder? Is it in the telescope field (low magnification)? If it is not, you goofed! First try another star pair. If that fails, then you will have to go back to the NCP alignment process (or check to see if the circles are slipping). After you are successful, record the names of the stars you used and mention them in your writeup along with a general discussion of how easy or difficult it was to accomplish the polar alignment.

Once you have confidence in the circles, almost anything that can be seen can be found (in a low magnification eyepiece) by setting the circles to the coordinates of a star (centered in the C8) near an object, then moving to the coordinates of the object. Care and practice is all it takes! *Note that once you have the telescope polar aligned DO NOT move or bump the wedge while completing the rest of your observations.* If you do move the wedge you will have to realign it. At this point, you may continue on if you have time and begin observing the objects listed in each of the following sections. When you finish observing, make sure everything goes back exactly where you found it, nothing is left, and all doors are locked.

It is always a good idea to record in your lab book where you are located, the beginning and ending time of your observing session as well as the conditions of the sky. Estimate the amount (%) of cloud cover, point out the presence or absence of man-made light sources, the temperature (if you know it), humidity (low, medium or high based on the dew on the telescope!) and whether or not the wind was strong enough to rock the telescope. If sky conditions change significantly during the observing session also note that.

What to turn in with your report:

1. Descriptions of your procedure, success/failure with the tasks described in the preceding four subsections.

3.5 Local Sidereal Time

Before you go to the telescope, synchronize your watch with Universal Time or Central Time by using the National Institute of Standard's clock available under the 'assignments' link on the course home page (http://www.ruf.rice.edu/~cmj/astr230/astr230.html).

The local sidereal time (LST) is defined to be the RA of stars crossing the meridian at your location. It varies with location and date (Why?). A rough estimate of the sidereal time can be made by locating a star which is both high up in the sky and which can be identified by you so that its RA and DEC are known from Peterson's book or some other source (Starry Night). Center the star in the eyepiece of the C8. Adjust the RA circle so that it reads the RA of the star (use 1997 or 2000 coordinates depending on what is available in your reference). Now slew the telescope in the Right Ascension axis only (do not change Declination) until the two ends of the fork are horizontal (use the small blue level in the tool box). Record the sidereal time that you found from the RA circle and and the time (CDT, CST or UT) from your watch. Estimate the accuracy with which you were able to determine the local sidereal time based on the accuracy with which you can read the RA dial (± how many min, sec).

When it is time to write up your lab report you will use the UT and local time to calculate the LST, and compare it to the value you read off of the C8 RA dial.

What to turn in with your report: 1. Description as to how you measured LST experimentally. 2. Your calculations of LST, and comparison with your observed value.

3.6 Telescope Parameters (magnification vs. light gathering power)

The magnification of a telescope objective-eyepiece combination is equal to the ratio of the focal length of the telescope divided by the focal length of the eyepiece, where they are both in the same units so their ratio is a dimensionless quantity. The *focal length of the C8 is 2032 mm.* Note that the focal length of eyepieces are always written on them in mm. Calculate and record in your lab book the magnification of each of your eyepieces when used with the telescope. Include these magnification values in your lab report.

Now you are to determine the size of the field of view (in arc seconds) of your highest and lowest magnification eyepiece. Put your lowest magnification eyepiece in the C8 and find a star relatively high above the horizon and as close as possible to the celestial equator where DEC=0° (check Starry Night or another reference ahead of time). Now measure the field of view of your lowest magnification eyepiece by letting the star "trail" through the widest diameter of the eyepiece field. Do this by centering the star in the eyepiece field of view, turn off the drive and see how it moves. With the drive still off then use the RA slow motion knob to move the star so it is just barely outside the eastern edge of the eyepiece field. Time how long it takes to move all the way across the middle of the field of view to the western edge. You will need a watch with a second hand to do this. Now insert the highest magnification eyepiece and repeat the steps, recording how long it takes to move across the field.

For your writeup you will want to calculate the size of the field of view for each of these two eyepieces. You can do this as follows: For a star on the celestial equator, the conversions from time units (units of RA) to angular units (seconds of arc) are 1 hour = 15 degrees; 1 min = 15 arcmin, 1 sec = 15 arc sec. For a star off the equator, you will have to make a declination correction to the above relations (see below). You can quickly do the calculations now or wait to do it during your writeup. In your writeup compare the size of the fields of view of these two eyepieces to their magnifications you calculated above.

If your telescope drive has been off for more than a few minutes, your RA dial will no longer be accurate. Reset the RA dial to the RA of the star you are observing before moving the telescope. The DEC dial should not need adjusting.

Finally, put the low magnification eyepiece in the telescope and go to a star whose coordinates you know and is near declination 60° or as close to that as you can get. Once you have centered the star turn off the drive and repeat the timing procedure for this new star. You only need to do this for one of the eyepieces, either your low or high power ones from above. You should find that the time it takes for the star to drift across the field is noticeably longer. In fact, for stars off the equator with declination (δ), the relation between RA time units and angular units changes (Why?), such that the angular units in the above equatorial relations have to be multiplied by $\cos(\delta)$. In your writeup show this is true by comparing your observations for the star at the equator with the star at a declination of 60°, keeping in mind that your field of view in the eyepiece did not change, so the conversion from time to angular units is different.

Once again, if your drive has been off for more than a few minutes, recalibrate your RA dial to the coordinates of the new star and turn on the drive.

Find an emission nebula, such as the Orion Nebula (M 42) (use circles and coordinates if necessary) using a low magnification eyepiece (the 32 mm Plossel is suggested). Use a sheet of paper or notebook to slowly cover the objective (have a friend hold it) and see how the surface brightness of the nebula decreases. For a fixed focal-length or magnification, the surface brightness should vary with the telescope's light gathering area. Record your observations in your lab book.

Now put in a higher magnification eyepiece (e.g., ~9mm or so) and observe the nebula; notice how much fainter its surface brightness gets and how the stars look (larger? blurrier?).

Record your observations. What does this tell you about the relative importance of telescope light gathering power compared with magnification "power" for observing extended deep-sky objects? Remember this if you ever buy a telescope. Next insert the "nebular" filter, the green eyepiece filter. Compare the appearance of the nebula to what you saw earlier. Is the contrast better? Why? Note that a nebular filter blocks out man-made sodium and mercury emission lines, but lets in light between those wavelengths.

Another important characteristic of a telescope when it comes to viewing or photographing extended objects is the f/ratio = focal length of telescope divided by the objective diameter. From the information you have about the C8 (or C11) what is its (unitless) f/ratio? Suppose the f/ratio of the C8 was f/5 (but it still had an 8-inch objective); would the Ring Nebula and other extended deep-sky objects appear brighter or fainter through a given (say 32 mm) eyepiece? If you were a deep-sky fanatic (that is you were interested in mostly observing faint extended objects such as nebulae and galaxies) would you buy an f/5 or f/10 telescope of a given objective size for observing them? Note that we also have a "focal reducing lens" which makes the f/10 C8 a f/5.6 telescope. Attach this (carefully) to the back of the C8, put in the same eyepiece as above (32mm or so) and reobserve the nebula. Does it look smaller compared to direct viewing with the same eyepiece? Does it look brighter? Record your comments.

What to turn in with your report:
1. Your field of view calculation for both low and high power eyepieces. Calculations of the power for each.
2. Your timings of stars on the celestial equator and at $\delta = 60°$. Appropriate comments.
3. Description as to what happens to the nebula as you a) cover the objective, b) change the magnification, c) use the nebular filter, and d) use the focal reducer.
4. Answer the focal ratio question regarding deep sky objects.

3.7 Resolving Power and Astronomical Seeing

The atmosphere limits the effective resolving power of ground-based telescopes. The theoretical resolving power (RP) of a telescope in radians can be computed by $RP = 1.22\lambda/D$. The wavelength of the observed light, λ, and D, the telescope objective diameter, must be in the same units. If $\lambda = 5500$ Å (green light) and D is the telescope objective diameter in inches, the resolving power of a telescope in seconds of arc (1 radian = 206,265 arc sec) becomes RP(arcsec) = 5.6/D(inches). Derive this result in your writeup. What is the theoretical resolving power (in green light) of the C8 in arc seconds?

Now let us see how close we can get to this theoretical resolving power when limited by the Earth's atmosphere.

When light passes through the atmosphere it is refracted and scattered, such that images are degraded with blue light being affected more than red. To see this, first find a bright star near the horizon and observe it through a high magnification eyepiece (∼9mm or so). See the colors separate (refraction) and how it is blurry and wiggles (scattering). This is why stars "twinkle" (find Sirius or Canopus for the most spectacular examples). Look at the horizon star through blue and red filters attached to the high magnification eyepiece. If the star is bright, it should be definitely larger and more blurry through the blue filter. Is it? Record your observations.

Seeing is defined as the apparent diameter of a stellar disk as viewed through the telescope. Because stars are so far away, they should appear as points of light without size. However, the atmosphere distorts and spreads out the incoming light such that the stars have a diameter called the "seeing disk" or simply "seeing", which is measured in angular seconds of arc ($''$). The better the seeing, the smaller this value. Typical values in the Houston area might be 2-5 arcseconds but you may find the seeing to be better or worse than this depending on the weather.

Quantitative estimates of actual seeing using the eye are very subjective. The best way to determine seeing is to observe a double star of known separation (using their separation as a "ruler" to compare the stellar diameters). Excellent examples that are up in the winter/spring skies are listed at the end of this handout. Observe with a range of eyepieces to see which one works best at separating the close pairs. Can you see the individual stars? What eyepiece magnification gives the best view? What would you estimate the "seeing" (defined as the apparent stellar image size) to be? Try the red and blue filters again and see if the separation is better seen through the red filter. Try observing two or three of the other double stars from your list. Calculate the seeing from each one of them. Do you notice a degradation in seeing for stars lower in the sky? Why would you expect this to happen?

What to turn in with your report:

1. The derivation described above.
2. The seeing estimate and how you measured it.
3. The best choice of eyepieces for the seeing estimate.
4. The effect of seeing as the objects set.
5. The effect of color on seeing.

3.8 Lunar and Planetary Observing

You should observe the Moon with the C8 at your earliest opportunity. *Read Ch. 5 in Muirden and/or look in the Peterson Field Guide before beginning your lunar observations.* The best time to observe details on the Moon is near 1st and 3rd quarter, but do not wait too late in the semester to complete this part of the lab.

Observe the Moon with both low power and high power eyepieces. It might help if you use one of the eyepiece filters, especially the red filter, for improving the seeing and reducing the surface brightness of the Moon. Sketch the features you see through the low power eyepiece and at least one region through the high power eyepiece. Record any comments about the features as you observe. Discuss their color, shading and sharpness. In your lab writeup you should write a paragraph or two about your lunar observations based on these comments.

When you pick out features to observe on the Moon, you may be interested in looking for those that have some geologic significance. For example, large faults called grabens often occur along the edges of the Mare, and are caused when heavy lava in the Mare subsides and the edges of the basin are pulled apart. The Moon also has many rilles, which are lava tubes that may have once fed basaltic lunar basins. Several interesting craters also exist where the impact occurred at a grazing angle and left a highly elliptical scar. Notice how some craters sit on top of rays from other craters, indicating that the rayed crater impacted first. Mare also have 'wrinkle ridges' that form as the lava subsides. You might try magnifying one of the shadows from the lunar mountains to see what the shape of the mountain looks like. Over the course of a few hours you can watch as the shadow gradually changes its length. You are witnessing the sunrise on another world.

Planets usually do not twinkle like the stars do. Locate and observe one of the naked-eye planets. Does it twinkle? Why do you think the planets do not twinkle? If you can not figure this out, think about how a planet appears in a telescope compared to a star. Even distant planets like Uranus and Neptune do not twinkle through a telescope ...why (are they visible now?)?

Currently, among the planets, Jupiter and Saturn are very bright and well placed in the evening sky. Venus and Mars are currently morning objects and are fairly easy to observe around 6 am. Consult the monthly magazines, *Sky and Telescope* or *Astronomy*, in the library or find them on the web or use Starry Night to see where to look for the planets. Check out what Jupiter and the others should look like in the Peterson Guide, then sketch at least two of them in your lab book. What does Venus look like? Comment on the appearance of Jupiter's and/or Saturn's surface, – do you see any belts, spots, polar caps, etc.? Note the subtle colors of features. How many moons of each planet you can observe? How prominent are the rings of Saturn? Draw a picture of how the solar system looks right now as viewed from the north ecliptic pole, and show why certain planets are visible in the morning and others in the evening.

What to turn in with your report:

1. Sketch of your lunar observations, description of what you found using the different powers.
2. Identification of some of the features you observe.
3. Similar observations of the planets you found.
4. Answer the twinkle question.
5. Draw the solar system picture.

3.9 Deep Sky Observing

The deep sky observing can be done with the C8, but is far more exciting to do with the C11 or computerized Meade 10-inch (especially at a dark site) or with the Campus Observatory 16-inch and video equipment.

At the end of this writeup in Appendix I is a list of several "deep sky" objects (star clusters, nebulae, and galaxies). Locate at least five of these and note their appearance including a sketch in your notebook. Observe them with a variety of eyepieces (or with eyepieces and the video equipment for the 16-inch) and note which one seems to give the best view of each object. For nebulae, try using the nebula filter to see if it really does give better contrast between the object and the sky background.

What to include in your report:

1. A paragraph or two on each Deep Sky object as to what it is, how far away, the size, age,

etc.
2. Sketch the object and compare its appearance with the Peterson's picture.
3. Specifics of the observation.

4 Lab Report

Writing good project reports, just like publishing papers for real scientists, is a necessary part of life in order to obtain proper recognition and credit for study or research done. Therefore, don't hurt yourself by turning in poorly-written reports. If you wish, talk with your instructor or lab assistant about pointers on how to write a good report. Furthermore, you are given specific suggestions below about the format and what to include.

Every experiment or research project is different, and so must be the report. Some are very quantitative, others are qualitative and descriptive. Whatever the case may be, the best general advice is to outline what you did and then describe the results that you obtained (including failures), by writing a smoothly flowing narrative. The aim of this narrative should be to provide a complete but concise description of what you did such that a new student who reads it would get an accurate idea of what the lab is about. Do not short-change yourself by doing all the work in the lab and then not spending the time and effort writing up a good report. Remember also that while you should answer all questions and include all relevant material in your writeup, the length of your report is not always an indication of how well it is written.

A suggested report outline for *this* follows.

1. PURPOSE

– State in your own words what do you consider to be the purposes of this project. Be rather specific regarding the various goals and experiments. A well-written paragraph suffices here.

2. EQUIPMENT

– Make a table of the dates, times that you observed and where you were located, with some notes about weather conditions each night (clouds, haze, humidity, etc.).

– Provide a list of the equipment used.

– Describe in detail the basic setup of the telescope(s) using a diagram or drawing if appropriate.

– Note any problems encountered with the equipment.

3. RESULTS & ANALYSIS

– Answer the questions posed above.

4. CONCLUSIONS

– Try to draw conclusions regarding your experiences in using the telescopes and performing the various tasks. Specifically, what worked well and what did not?

– What did you learn and/or discover? Did you fail at anything and why?

5. REFERENCES

– Include a list of references at the end of your narrative of written material and/or "quotes" from your helpful staff.

6. EVALUATION

– Projects like this one evolve and hopefully improve. Any suggestions on improving the project and/or the writeup are solicited. These do not affect your grade, so feel free to be frank in your evaluation of the project and suggestions.

Finally, we urge everyone to try to type or word process the basic text of their report, with drawings, equations, etc. written in as appropriate. The original observational notes and data can be photocopied and attached to the end of the report as an appendix.

APPENDIX I – Suggested Objects for January-February Observing in the Houston area

Below are suggested objects for the various parts of the observing laboratory appropriate for January and February. Use Starry Night to get further information on them (e.g., coordinates, magnitudes, identifications, pictures). You can substitute any other bright stars, binaries, etc., for those listed below.

Bright stars for calibrating setting circles:

– Aldebaran, Algol, Alpherat, Betelguese, Capella, Procyon, Regulus, and Sirius (pick two widely separated in sky)

Double Stars for seeing determination:

θ Ori (in M42; a quadruple with all stars $\sim$ 6th mag, closest separation is 8.7")
λ Ori (3.7, 5.7, 4.4")
γ Leo (2.4, 3.6, 4.4")
α Gem (1.9, 2.9, 3.9")
ζ Ori (1.9, 5.5, 2.6")
η Ori (3.7, 4.8, 1.4")

–

Beautifully colored double: γ And (2.3, 5.1, 10.0")

Moon:

• Third Quarter: Jan 21st, Feb 20th; New: Jan 28th; First Quarter: Feb 4th; Full: Feb 12th.

Planets:

• Jupiter: Visible in the East late night/early morning. Overhead about 7:30 am.

• Saturn: Visible in the East in the evening. Overhead about 1 am.

• Venus: Rises about 6:30 am, the morning star.

• Mars: Overhead about an hour after sunset.

• Uranus, Neptune, and Pluto: ...find out where using Starry Night!

• Mercury: – the "catch me if you can" planet! (why? where is it?)

Deep Sky Objects (clusters, nebulae, galaxies, asteroids):

- Our favorites are:

→ M42 (HII region, the Orion Nebula),

→ M44 (old open cluster; The Beehive),

→ Pleiades (“Seven Sisters”, a young open cluster)

→ h and χ Persei (Young double open cluster)

→ M35, 36, 37, & 38 (nice open clusters in Aur and Gem),

→ NGC 2392 (the “Eskimo” planetary nebula, faint, has visible central star)

→ M31 (The Andromeda Galaxy).

→ M82 (Starburst galaxy in UMa, a late evening object).

→ Many other excellent Messier objects available also... explore!

→ or... see if you can find an asteroid!