ASTR 230 ASTRONOMICAL LABORATORY - SPRING 2023

LAB#1
INTRODUCTION TO TELESCOPES AND OBSERVING TECHNIQUES

Due: Tuesday, February 28, 2023 in class

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 your projects. Being able to use a small telescope to find objects and to explain what you see is an essential skill to have when interacting with the public. Many people purchase small telescopes, and you, as the astronomy expert, should be able to use them well. An expert like yourself should be able to glance up in the sky and tell the eight-year-olds and their parents what that bright object is up there without the embarrassment of having it then fly over you before it lands at the airport or the pathetic shame of having them watch while you helplessly wave your phone in some direction and hope the app tells you what star or planet may be there. You need to be able to see the solar system and galaxy in your mind every time you walk outside and look up. These skills also translate to professional observing in many ways. For an observer, there is no substitute for really knowing the sky well. That knowledge will guide you to make the correct decisions and to make the most of the telescope time you have when observing runs do not go as planned, as they usually don't.

In the process of doing this lab you will learn to identify constellations, planets and stars, and get practice finding and observing them with our telescopes. Once you have received the basic training required to use the equipment safely, you will do the observing and writeup. Students can observe together in small groups (typically two people), 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 identifying constellations 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. Alternatively, we will have at least one night where the class may come to the prof's house in Manvel to observe with the Meade 10". These sessions where someone finds the objects for you do not count for that part of the lab writeup, but they are a fun way to see a lot of different objects in one observing session. If you happen to be taking ASTR 360 this semester you should consider looking for some of the objects you are studying in the first part of that class.

Before you begin, you will need to read the material assigned in class, and work with the computer program Stellarium (get whatever the current version is on-line).

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 of the relevant section *before* you go out.

• Do the portions of the lab that don't require a telescope – working with Stellarium, and constellation identification.

• Study the star charts in your reference book of choice to 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 small flashlight and lab record book and be sure someone in your group has a watch/phone with a working timer (or analog equivalent). Note many people use their phones as flashlights. That's ok, but phones are usually very bright and will wreck your night vision and everyone else's in the vicinity. Please be considerate. *Red* light is what you want, as it still allows you to see without these problems. Tape red cellophane to your phone if you can't live without it.

• 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 the object (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 exercises that first familiarize you with the performance of the C-8, and then develop your observing skills by identifying various objects. Section 3.1 can be done without a telescope, and you should do this first. Sections 3.2 & 3.3 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. Observations that require dark skies may be done at George Observatory or in Manvel south of Houston.

Many small telescopes are now equipped with computers that are supposed to find things for you. The ones you will be using are no exception. However, half the time these don't work very well or at all. You'll learn how to set these up, but not be reliant upon them. 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 Stellarium (telescope not required)

Stellarium is a very useful 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 time 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 generally self-explanatory, and you simply need to spend some time with it so you know where to look for the feature you want. When you first open the program it will launch a full-screen window that depicts what it thinks the sky should look like at the time and location it inferred from your computer. You may need to set these as described below. First though, familiarize yourself with the two menu bars. The *bottom menu* can be found by sliding your cursor to the bottom-left of the window. A horizontal bar will appear there detailing about a dozen options. Hover your cursor over the icons. Briefly, these are from left to right:

• Constellation Lines: Toggles lines on-and-off between stars to help you see constellation patterns. I usually turn this on.

• Constellation Labels: Toggles the names of the constellations. There are 88 of them in all. I leave this on as well usually.

• Constellation art: This is rather amusing, but allows you to see, for example, what Hercules is supposed to look like. Hmmm. Somebody 3000 years ago had a good imagination. I find this distracting and leave it off, but it is a fun thing to toggle.

• Equatorial grid: This is the key coordinate system used to identify objects in the sky. It is what we will spend time learning, and it essential to know when at the telescope in order to determine what is up in the sky at any given time. The visibility of any object depends on the time, date, year, and location on the Earth. It looks a lot like longitude and latitude. I always leave this on.

• Azimuthal grid: Another spherical coordinate system. This one determines how far above the horizon an object is situated, and its azimuth (e.g., north, south, northeast). Either on or off.

• Ground: The horizon of the Earth. Remove to get view from space or if you want to see where something is located when it is not up.

• Cardinal Points: Labels N, S, E, and W. Up to you.

• Atmosphere: A haze layer simulating the atmosphere near the horizon. Usually leave this on. Makes the sky blue during the day. Shut it off to see the stars during the day.

• Deep Sky Objects: Labels bright clusters and nebulae in small orange symbols. These are all candidates for you to discover this semester! Click on them to learn more about the object.

• Planet Labels: Does what you'd think.

• Switch between equatorial and azimuthal mount: Silly thing related to telescope orientation. Ignore for now.

• Center on selected object: You should be able to select an object by clicking on it. Hitting space-bar or clicking this button will rotate the field to center the object.

• Night mode: Turns everything red. Good when observing so your eyes stay dark-adapted.

• Full screen: Toggles this mode.

• Time controls: To set current time, speed things up so you can watch objects rise and set (key J), slow them down (key L), or return rate to normal. Note how the clock changes as you speed up and slow down.

• Quit: Ends program.

• Navigation: On a Mac, the arrow keys allow you to move around the sky. A click-drag does the same. Select an object with a click, and deselect with a right-click (side of keypad). To zoom in and out use command-arrow-up or command-arrow-down. Don't use the two-finger scroll to zoom in and out - at least on my laptop that freezes the click and I have restart it.

Similarly, the *side menu* is accessed by sliding your cursor to the left. Here you will find menus for location, time, search, and various configuration menus as to how bright stars appear, how many to display, and so on. Go to the Sky and Viewing Options window and choose the Markings tab. Turn on the Meridian (a green line between north and south) and the Ecliptic (plane of the solar system and path of the Sun, marked as a red line).

If you click 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, its coordinates, spectral type, distance, and other information should appear on the left. 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.

Use the arrow keys to rotate the display to face south, and use command-arrow-down to zoom out a bit so the horizon looks curved and you can almost see both east and west. Use the up-arrow keys to look up until the ground is near the bottom of the display. Turn off the atmosphere, and click 'L' until the stars start to move. Watch as objects rise and set and note the time and date in the lower right corner of the bottom menu bar. Stop the fast rotation with 'K' or reverse it with 'J'. Return to the current time and normal speed using the bottom menu bar.

Zoom out a bit, be sure the the ecliptic is visible, and set the time to be around noon so the Sun is up. Right-click to remove any star information you may be currently highlighting. We want to move forward and backward one day at a time. Go forward with the '=' key, and backward with the '-' key. 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 planets that circle the Sun? Do they all do that? Do all the planets move relative to the stars? Isn't this neat? You have a celestial time machine here, or more properly, a computer planetarium.

Back to business; reset the date and time to some time tonight, say 9:00 pm Is the Moon out? If not, try command-= to move ahead one hour at a time until it rises? What phase is it? Try clicking on the Moon, and then type / to zoom in (and to zoom back out). 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" using the search menu on the left. You will notice there are two coordinate systems, one for 2000.0 and another for 2023.0. They are very similar to one-another, and you simply need to be consistent with what you use. Usually we work with 2000.0 coordinates for convenience. We will learn about the difference in the lectures. 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)? Follow the same procedure as you did with Algol. Once you find M42 you can zoom in and out to get an idea of where it lies relative to bright stars you can see with your unaided eye.

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 animated the display by changing the time.
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. You should turn on the constellation boundaries for this part.
3. Can you identify sometime in the future when Jupiter, Saturn and the Moon are separated by less than 5 degrees from one-another while still being easily visible (say, $> 30°$ from the Sun)? How common are close conjunctions of Jupiter and Saturn?
4. You are on a quest to observe Mercury. You are willing to travel anywhere on Earth. Where and when would you go next year, in 2024? You'll want Mercury as high as possible in the sky as the Sun sets or rises. Explain why some times and elongations are better than others, and why some locations are better than others.

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!

3.2 Constellations (telescope not required)

Use the starmaps in your book or just Stellarium, 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. The patterns will not change over your lifetime - once you learn the constellations they will become your permanent companions. Their locations in the sky tell you directions, herald the dawn and the coming and going of seasons, and even give your location on the Earth.

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 (both Houston and at a darker site).

3.3 Basic Observing Setup

We will start using the telescopes in small groups the second week of class. Most of the telescopic work in this first lab will be done with one of our two 8-inch Celestron (C-8) telescopes. No more than two people will be working with one of these at a time, so we can accomodate a total of four at a time for the first part of the lab where you are learning to set up the telescope and start observing. The goal is to get you comfortable observing with the C-8s so that later in the semester, you can use them on your own. It will almost certainly be necessary to need 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. Sometimes equipment doesn't work because it has a problem or because you are using it wrong. Expect to have some failures.

3.3.1 Setting up the Telescope

The telescopes and other observing equipment are kept in a storage room (room 401) on the 4th floor of Brockman Hall. You will need to take what you need from this room out onto the 4th floor observing deck (room 400) of Brockman Hall to do your observations. There are power outlets on the deck to plug in extension cords for the telescopes. We will try to keep the equipment near the front of the storage room, but through the course of the semester, things often get moved around. Your professor will help you find the equipment you need:

Essentials: Two Celestron-8 telescopes and essential accessories that you should normally need to observe – a silver box of recently cleaned eyepieces, and filters, and a box of power cords for the telescope, and extension cords.

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.

The most important items for this part of the lab activity are the orange C-8 telescopes. There is a larger C-11 telescope you can use for most of the parts of the lab also. The storage room also contains other telescopes such as a solar telescope we won't be using now.

C-8 Telescopes (2): The two C-8s are both mounted on tripods and equatorial mounts. These telescopes have fully computer driven mounts; however, the point of this first lab is to get you aquainted with how the sky and telescopes move, so you will be doing most of the work manually. There are triple castor wheels that kind of look like drones you can use to roll the telescopes from the work room to the outside door. Simply place the tip of each tripod leg into the hole in the wheel assembly and slowly roll out the telescope. You'll have to lift the telescope over the threshold. The wheels don't work too well on the terrace. I think you are better off lifting there, but it is up to you.

We will discuss the correct way to lift the telescopes. Do not lift using the telescope tube, the finders (small telescopes on the side) or the eyepieces. You will break them. *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" whenever the corrector plat on the end of the tube needs to be cleared.*

Note on moving (slewing) the C-8 optical tube (the main scope): The C-8 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 clamps are located near each axis of rotation. The appropriate clamp *must be loosened* when slewing the telescope and tightened when you find the object in the finder. These mounts do not have slow motion knobs. You will need to use the arrows on the hand paddle to make fine adjustments, so you will need to power up the telescope and go through some menu items to be able to do this. Note that when using the paddle controls to move the telescope, the clamps must be tightened to properly engage the motors. If you have computer alignment, slewing is much slower, and if you loosen the clamps you'll lose the computer pointing.

Powering Up the Telescope for Movement and Tracking: There is a power adapter (like a laptop power supply) for each telescope. Plug it into a power strip once you are outside. We have had a lot of trouble with these and have reengineered them. Leave the 'cigarette lighter' power attached, and just plug or unplug the main cord into the power strip. Then switch the mount on. The hand paddle will start displaying a number of messages, asking you to verify positions and set the date, time, and time zone. None of this matters for what you are doing in this lab, so simply hit the "enter" key each time it prompts you for something until you get to the menu for "Select Alignment." At this point, use the up and down arrow keys (also marked "scroll" which are the # 6 and 9 keys) to select "Last Alignment" and then press "enter." This will get the mount and hand paddle all ready to use. You should see the heading "Advanced GT" on the paddle. You can now use the 4 direction arrows to move the telescope. By default, you will be in a relatively slow speed, but you can change this by hitting the "Motor Speed" button and then pressing a number (9 is fastest) to select a speed. With this setup you are now ready to observe. The only thing that is not operational is the computer alignment.

The C-11: This is a lovely, mostly manual telescope. It will give you better views of the planets. This one is a lot more reliable overall, as it doesn't have all the computer programming in it. Power up the mount and it starts tracking. Click the top button to move the light down to the end or your paddle slew rates will be awfully slow. Main slewing is done manually. You simply loosen the two silver-colored 'ships wheel' knobs for RA and DEC, get close enough or use the terrific setting circles, and get the object in the finder. Use the paddle to drive it to the crosshairs (assuming it is aligned), and you are done. When you are done, just unplug it.

Moving the C-11 requires patience as it is a bit of a beast. The mount has wheel locks on it and the whole thing is heavy. Beware! Do *not* push on the tripod so much that the telescope tips out of the wheely bar assembly at the bottom. The only thing that keeps the telescope on the wheely bar is the weight of the telescope. Push on the tripod when the wheels are stuck and you *will* flip the whole thing over! Instead, gently roll it out and ease the wheels over the door threshold and the terrace tiles. Never try to lift the C-11. It is too heavy for you. As you are rolling it slowly, think about how much easier this is than lifting it. Expect to take 5 minutes rolling it in and out.

Remember to ensure the telescopes are stored and work room door is shut before you leave!.

3.3.2 Finder Alignment (can be done at dusk)

Before you power up the C-8s or C-11 it is wise to check to see that the finder scope and the main scope are aligned. Put a low magnification eyepiece in the C-8 (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 alignment is something you must check at the beginning of the night or if you bump the finder scope during the night.

You must learn how to align finders. If they are already aligned well, deliberately misalign it and practice getting them realigned.

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!

3.3.3 Pole Alignment

Now you have to align the polar axis of the C-8 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. The mount has a very handy system for aligning the telescope. First, check to make sure the tripod is setup so that the telescope mount is level. There is a bubble level built into the base of the mount. You may need to adjust the tripod legs in order to get the bubble centered properly. The mount has a small telescope mounted inside it looking through the RA axis of the mount. There is a small dust cover on the front. Remove this if it is there, and rotate the mount 90 degrees to allow you to sight along the axis. Physically adjust the mount (moving the tripod or adjusting the tilt of the mount itself using its set screws) until you have Polaris properly placed while looking through the small telescope. When looking through this, you should see a small crosshair in the center, with a ring around that and a small circle in the ring.

When the manufacturers made this gizmo, I'm sure they had something in mind. But it can be quite confusing because the constellations you see in the markings are not going to appear like that in the field of view. The actual field of view is maybe 10 degrees or so, and the constellations drawn look more like 60 degrees to me. Moreover the location of the ring, which is where Polaris is supposed to go, is on the opposite side of the constellations as they have drawn them. I think their idea was you'd look up at the sky, spin the dial to align with the constellations as you see them when you are looking outside the small telescope, and then align Polaris in the circle, which is on the opposite side of the constellations because the small telescope flips the field of view. Not only is this confusing, you can't easily rotate the dial to line up the constellations without loosening everything so much that the setting circles do not work.

Instead, I suggest the following. Ignore their constellation drawings. The crosshairs in the small telescope are really useful in that they show where the telescope thinks the pole is located. You want Polaris on the circle. But where? Well, the RA of Polaris is about 2 hours. Look up in the sky and see where Polaris is with respect to the pole. Then move the telescope mount accordingly. Make note of which way Polaris moves if you shift the mount slightly up/down or left/right. You will need to think carefully about the minus signs here.

Once you've done this right and Polaris is on the circle in the right location, the mount's RA axis will now be aligned to the pole. You can check this by moving the telescope in DEC so that you can see Polaris in the finder. If you place Polaris close to center of the finder, you can rotate the telescope around in RA and Polaris should move in a tight circle around the center of the finder. If this does not happen, try moving the telescope to place Polaris a little closer or further from the center of the finder (or on the other side of the crosshairs) until you can rotate the telescope in RA and see Polaris move around the center of the finder (this of course will only work if the finder and the telescope are aligned). If you are unable to get this to work, double check the alignment of your mount. Once this is done, everything is now aligned. You can then check the DEC cordinate on the telescope. It should read 90°. If it does not, you can move the DEC setting circle until it does, or, if it is close, just remember the offset from 90° and apply that to the DEC coordinates for each object.

Note that Polaris will not go around in a tight circle when you move in RA unless the telescope points exactly at 90 degrees DEC. The circle part of the exercise is meant as a check and to help you visualize the setup. The only actions that affect pole alignment are moving the tripod (azimuth), and tweaking the elevation (altitude). If you are off a little bit it is going to mean it doesn't point or track as well, but the telescope may still be usable.

Think a bit about what you just did. Visualize the Earth turning, and the celestial sphere. See the sky spinning, put Polaris in the sky and now think how you have aligned the telescope. See in your mind how everything is moving, and how it changes if you are at a different longitude or latitude. You will need these insights when it comes time for your oral exam, and it is this level of awareness that is one of the goals for the lab.

Once the finder and C-8 optical axis are aligned, you can power the internal drive that moves the telescope to compensate for the Earth's rotation. To do this, press the "Menu" (# 7) key on the hand paddle. By default, you should see "Tracking" appear on the paddle display unless you have previously been in some other submenu. If you see "Tracking," press enter. If you do not see this, use the scroll arrows to select "Tracking" and then press enter. You should now see "Mode" displayed. Press enter again. At this point there are 3 options. You want to select "EQ-North." If this is displayed, press enter, otherwise use the scroll buttons to bring this selection up and then press enter. When you need to turn tracking off, go through the same menus and select "off" instead of "EQ-North."

But how much does it matter, really? Let's find out. With your absolute best attempt at alignment, find a nice bright star we'll call 'A' up in the east or west, and another one around the meridian in the south we'll call 'B'. Center them in a medium-power eyepiece (record which one you use). Let it track for 10 minutes. Does it move out of the field? Is there drift? If so, record which way for stars A and B.

Now wreck your pole alignment by deliberately rotating your tripod so the polar axis aligns roughly with the axis of the building, i.e., somewhere in the NNW, maybe 20 degrees off. Redo the experiments with the same stars and see how long it takes them to drift out of view.

3.3.4 Setting Circles

Once you think that the C-8 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 Stellarium, center one of them in the C-8, 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 C-8 or C-11) 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 mount while completing the rest of your observations.* If you do move the mount 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.
2. Results from your experiments of drift with an aligned and misaligned system for stars A and B.

3.4 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. Your phone may or may not have accurate time.

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 that 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 (Stellarium). Center the star in the eyepiece of the C-8 or C-11. Adjust the RA circle so that it reads the RA of the star (use 2023 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 long rod holding the counter weight is parallel with the ground (use the small blue level to determine this). 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 look up the Stellarium value of the LST by seeing what the RA was on the meridian when you observed, and compare it to the value you read off of the C-8 or C-11 RA dial.

What to turn in with your report: 1. Description as to how you measured LST experimentally. 2. Comparison of the Stellarium LST with your observed value.

3.5 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 C-8 is 2032 mm, and the C11 is 2800 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 C-8 or C-11 and find a star relatively high above the horizon and as close as possible to the celestial equator where DEC=0° (check The Sky 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 (via Menu → Tracking → Mode → Off) and see how it moves. With the drive still off then use the handpaddle to move the star in RA 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 the equivalent of 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.

Find an emission nebula, such as the Orion Nebula (M 42) (use circles and coordinates if necessary) using a low magnification eyepiece. 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 C-8 (or C-11) what is its f/ratio? Suppose the f/ratio of the C-8 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 C-8 a f/5.6 telescope. Attach this (carefully) to the back of the C-8, 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.

3.6 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 = 1.22λ/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 C-8 in arc seconds? By the way, if you plan on an astronomy career you absolutely need to understand and remember RP $\sim$ λ/D, something I'm sure you learned in PHYS 201.

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 ($\sim$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?

While we have the color filters out, let's see what they actually do. Point the Project Star spectrometer (get one from me) at some light source like a fluorescent or incandescent bulb. You can even try this in daylight - do not look at the Sun though! Taking great care to not drop the filter or get fingerprints on it, hold it in front of the slit entrance and compare the spectrum with what you get with no filter. Try this for the narrow, nebular filter and at least two of the broad band ones. This exercise is meant to get you thinking about the differences between continuum and emission line spectra, and what it means to have magnitude measurements in different bandpasses.

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.
6. Effect of color filters on spectra of lights.

3.7 Lunar and Solar System Observing

You should observe the Moon with the C-8 at your earliest opportunity. *Look in the Peterson Field Guide or Stellarium 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. Record the features you see through the low power eyepiece and at least one region through the high power eyepiece. Describe the features as you observe. Discuss their color, shading and sharpness, sketch if you are so inclined. 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?)?

Pity the poor majors who took this class in 2022, staring forlornly through murky skies barren of planets. But not you! In the first few months of 2023, Jupiter is an early evening object gradually disappearing in the dusk sky. Venus on the other hand, continues to rise out of the dusk, and will be a brilliant evening star for you by semester's end. Mars is wonderful all night, but Saturn is the opposite, sulking near the Sun and effectively invisible. Your only reasonable chance is to get it very early in the semester. Mercury bounces around the Sun like always. You may be able to catch him, especially from the observatory terrace before dawn, where we have a very good eastern horizon. We will discuss why all these things happen in the lectures.

The four brightest asteroids (Ceres, Vesta, Pallas, and Juno), are all visible to some degree in the spring of 2023. Two of them are sort of close together in the sky, and one of them for sure is going to surprise you as to where it is (how did *that* happen? Hmmm.). For a challenge, try to find some of these and watch them move over the course of a few nights to be sure you have found the right object. There may be a couple of nights when the asteroid is reasonably close to the Moon, so that may help you to find it from the surrounding star patterns. Sometimes you'll be in luck and the asteroid will lie close to another familiar object, and other times it is located in some remote corner of the sky with nothing bright around.

Oooh, Oooh!! COMET! Yes, you guys get a comet this year! Must be all that clean living and good karma. Or a cosmic sign. Or something. Comet C 2022 E3 ZTF last visited Earthly environs before humans existed, but it is coming to say hello to you this semester. The comet is going to be well-placed from Houston as it moves around from night to night in January and February. And it happens to be brightest and easiest to see just when you are doing this part of the lab, not buried in twilight like comets usually are. You'll need to find its coordinates and use your skills to find it. This is a perfect example of the use of skills in this lab. The comet will probably be too faint for your unaided eye to see, but it should look nice in the C-8 and C-11. Use adverted vision to help bring out the tail, and try out some of the color filters.

Draw a picture to scale of how the solar system looks right now as viewed from the north ecliptic pole; it will show why certain planets are visible in the morning and others in the evening. Sketch what you see for each planet you observe, such as its phase, moons, and any markings on the surface. Measure the angular diameter of each either from the drift method or by knowing the field of view of your eyepiece. Now look at your picture of the solar system, and make a rough estimate of the distance to the object in au. Now convert that to a diameter in units of the Earth's diameter (12656 km). Don't look these up from Stellarium or another source. Measure them from your observations and your diagram. What about Uranus and Neptune (either one visible)?

What to turn in with your report:

1. Description of your lunar observations, what you found using the different powers.
2. Identification of some of the features you observed.
3. Draw the solar system picture.
4. Observations of any planets/asteroids/comets you found, sketches.
5. Angular diameter measurement of each planet and its size estimate.
6. Answer the twinkle question.

3.8 Observing Objects with Computer Alignment

Deep sky observing (galaxies, nebulae, clusters and such) can be done with the C-8, but is far more exciting to do with the computerized Meade 10-inch (especially at a dark site) or with the Campus Observatory 16-inch. At the end of this writeup in Appendix I is a list of several such objects. Identify a few of these you'd like to see, and we will try to find them if you come down to my house to observe.

It is often quite a challenge to find low-surface brightness objects like nebulae and galaxies with small telescopes. It can be impossible in light-polluted skies, depending on the object. In this section you will get practice with setting up the computer on the C-8 to find targets. Don't pick anything too difficult - a cluster of stars is a good choice, or maybe the Orion Nebula. Align with the pole as you did previously. But now go through the menu on the hand paddle. It should ask you to align index marks, insert the correct date and time. If it doesn't ask for this, make sure you are choosing EQ-ALIGN for the northern hemisphere. Try doing a two-star alignment. Based on the date, time, and location, the computer is going to pick some stars it will want you to center. Sometimes it makes odd choices. Before you slew to any make sure they are actually above the horizon.

Once you have an alignment, use the paddle to input M42 and see if it finds the nebula. If so, you are all set! You should be able to dial in other objects and it will find them for you. A lot of the time it is going to sort of point in the right direction, but will be off by some amount you can calibrate by looking in the finder. You absolutely want the finder aligned for this section.

Give it a try for five objects and see how you do. If skies are too murky, verify your setup by having it find the Moon, or bright stars you did not use for the alignment.

What to include in your report:

1. Stars it asked you to use for alignment. Did you find them?
1. Objects you attempted to find. Success?
3. Specifics of the observation, did it look like it's supposed to?

3.9 Exoplanets

Exoplanets are all the rage these days. Hundreds of stars have been found that exhibit periodic radial velocity variations indicative of a planetary companion, and many more from transiting planets. While you will not be able to see any of these planets, you can find their host stars and imagine the planetary systems there.

Go to exoplanets.org and identify three stars *fainter than magnitude 4.0* with exoplanets that you can find with the C-8. Here is where knowledge of star names comes in handy. You'll want brighter stars to make your job easier! At the same time, I don't want you to just point to some first magnitude star you can see with your eye, I want you to use some of the skills you have now. Find the star in the eyepiece using setting circles, star-hopping, or the computer. Describe how it is that you know that you have the correct star and not some imposter nearby (or far away if you messed up the pointing somehow).

What to include in your report:

1. A brief description of the planetary system(s) around your star of choice.
2. Visual magnitude, spectral type and distance to the stars, date and time of observation, eyepiece used, appearance of the star.
3. Some rationale as to why you think each of the three stars you found were the right ones.

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. GOALS

– 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.

6. EVALUATION

– Projects like this one evolve and hopefully improve. We have ramped down the observations of faint objects, as that is just too hard to do from Houston's light-polluted skies, but we can still see enough things here to train you to use these types of instruments. Any suggestions on improving the project and/or the writeup? These do not affect your grade, so feel free to be frank in your evaluation of the project and suggestions.

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 Stellarium 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 8.9")
α Gem (1.9, 3.0, 5.4")
γ Leo (2.4, 3.6, 4.7")
λ Ori (3.5, 5.5, 4.3")
ϵ Boo (2.6, 4.8, 2.9")
γ Vir (3.5, 3.5, 2.5")
ζ Ori (1.9, 3.7, 2.4")
η Ori (3.6, 4.9, 1.9")

–

Beautifully colored double: γ And (2.3, 5.1, 9.8")

Moon:

• First Quarter: Jan 28th, Feb 27th, Mar 28th, Apr 27th Full: Jan 6th, Feb 5th, Mar 7th, Apr 5th, May 5th Third Quarter: Jan 14th, Feb 13th, Mar 14th, Apr 13th, May 12th New: Jan 21st, Feb 20th, Mar 21st, Apr 19th, May 19th

Comets: These are fun to watch from night to night as they move among the stars. It is *much* easier to spot comets from a dark site where the surface brightness of the sky is lower so don't be disappointed if you don't find them right away under the city lights of Houston.

Planets for 2023:

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

• Venus: Emerging from the dusk in the west. Fun to watch this semester

• Mars: Perfectly situated in the night sky for you this semester!

• Jupiter: Also nicely placed now in the southwest at dusk

• Saturn: Available, but barely, at the beginning of the lab in the west.

• Uranus, Neptune: ...find out where using Stellarium!

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

• Some 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 objects available ... explore with the Field Guide!

→ see if you can find an asteroid or comet

→ or for a real challenge... Pluto!