Astronomy 1 – Introductory Astronomy
Spring 2014

Lab 5: Observing the Sky pt. 2

Quick overview

Meet at 8 p.m. in Science Center Room 187. We will go up to the roof from there, and make several different observations, some of which will complement observations you made in the first observing lab: you will be looking at how some things have changed in the sky since you did that lab in February. You will also be doing some simple observations with small telescopes.

Before coming to lab

Review your notebook from the first observing lab, to remind yourself what you observed then. Pay special attention to the observations of Polaris and Betelgeuse.

Read "What are the two most important properties of a telescope" on pp. 174-177 (but you can skip the Mathematical Insight) and also read "How does Earth's atmosphere affect ground-based observations?" on pp. 182-184.

Goals

To see how the sky has changed since the first observational lab.

To understand the pattern behind those changes, and the reason for it.

To see the effect of increasing aperture size on astronomical observations.

To operate a telescope to view objects invisible to the naked eye and take digital
images through the telescope.

Your write-up should include answers to all bold-faced, numbered questions.

Part I: Light Gathering Power

In this part of the lab, you will try to get some understanding of the factors that determine how *deep* a given observation can reach, i.e. what is the faintest object detectable in a given observation. Astronomers refer to an observation that reaches very low brightness levels as a *deep* observation, which explains the name of the Hubble Deep Field.

To reach very faint objects, we need to maximize the amount of energy we collect in a given observation. Three ways to increase the energy collected are

1. to use a bigger aperture (or "light bucket" in astronomical slang) to catch the photons, or

2. to take a longer exposure in order to give more time for photons to arrive, or

3. to change to a different detector that is more efficient at detecting light.

Aperture Size

To see the effect of changing aperture size, first look at the stars of the Pleiades, a cluster of stars near Taurus that the ancient Greeks called the "Seven Sisters."[1] This cluster is in the western sky in early spring.

Q1. How many stars can you see in the Pleiades with your naked eye? Take your time and observe carefully.

Now, find a pair of binoculars. There are two focus adjustments you can make. The first is a knob between the two oculars that focuses both the left and the right side. Use this to get the **left** eye in focus. Next, there is a ring around the right eyepiece that will separately focus the right eye.

Q2. How many stars can you see in the Pleiades using binoculars? Again, take your time and observe carefully. Count every star in your field of view; even the very faint ones.

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[1] **This group of stars is also called "Subaru" in Japanese; a representation of it can**

The binocular objective lens (the one collecting the light) is 5 cm in diameter. On average, the pupil of a dark-adapted eye is about 1 cm in diameter.

Q3. How many times bigger is the *area* of the lens of the binoculars than the area of the pupil of your eye? Does this match the number of times more stars you saw with binoculars? If not, can you explain why?

Our telescopes are 8 inches (20 cm) in diameter, so can collect even more light than with the binoculars. We would expect to see many more stars in the Pleiades using our telescope. However, we won't try to count them. As you may have noticed with the binoculars, even though increased light-gathering and magnification help you see fainter objects, the *amount* of sky you can see decreases. The unaided eye can see a view approximately 120° across, while the binoculars give a view only about 5° across. The amount you are able to see is called the **field of view**. The telescopes have a much smaller field of view than the binoculars. Since the binoculars can just fit the Pleiades in the field of view, we won't be able to see the entire star cluster in the telescopes. Therefore, we tend to use the telescopes to see dim objects, or to see small detail on large objects.

So, looking through the eyepiece of the telescope should show us even fainter objects than our binoculars.

Exposure Time

In addition, we can attach a camera to the telescope in place of an eyepiece. By collecting light for an extended period of time, it is possible to see fainter and fainter objects. (Note that the human eye has a natural "exposure time" of about 1/20 or 1/30 of a second…no matter how long you keep your eyes open.) We have a CCD (digital) camera attached to the 24" telescope. In groups of three or four, go up to the 24" telescope to acquire some images of the Orion Nebula (M42). There will be a student helper or instructor there to guide you through the procedure. Your goal is to observe the effect of increasing exposure time on the image.

Q4. First, take a relatively short exposure of a few seconds (0.1 s). What exposure time did you choose? Describe the resulting

image (and make a sketch in your notebook if it helps). How many stars do you see? Can you see the nebula clearly?

Q5. Now, increase the exposure time to (5 to 30 seconds). (Record this number.) How does this image compare to the previous one?

Part II: Angular resolution

Besides gathering light to see fainter objects, another of the important jobs of a telescope is to provide better **angular resolution**, or ability to distinguish fine detail, than your eye can provide. The theoretical angular resolution of a telescope, called the diffraction limit, depends on its diameter.

diffraction limit (in arc seconds) = 2.5 X 10^5 (diameter of telescope/wavelength of light)

The diffraction limit of our 8-inch telescopes is around 0.6 arc seconds for visible light. In practice, turbulence of the atmosphere causes the image in the telescope to jump around, making the actual angular resolution larger than this. The actual angular resolution is called **astronomical seeing**, and changes from night to night depending on local atmospheric conditions. (This is also the reason for star "twinkling".)

In this part of the lab you will observe three pairs of closely-spaced binary stars in order to see whether or not you can distinguish that there are two stars there, or whether they simply look like a single star. The smallest angular separation at which two stars can be distinguished from a single star is called the *resolution* of the observation. This resolution can be influenced by the optics of the telescope, and (primarily) by blurring of the images as they pass through Earth's atmosphere.

There will be telescopes set up and pointed to three binary stars of different angular separations. Look at these binary pairs and see whether or not you can see that two stars are present. (When you are right at the limit, you may see an elongated blob rather than two cleanly separated stars. For our purposes, this counts as resolving the stars.) Record the names of the stars, their different angular separations (see below for a list), and whether or not you could resolve the two stars from each other. Compare the angular separation of the stars – and your ability to see two separate stars in each binary pair – to the resolution limit imposed by the atmosphere (in Swarthmore, it's about 3 to 5 arc seconds, depending on the humidity, temperature, and other factors).

The binaries we will look at are:

iota Cancri (SAO 80416), with a separation of 30.8 arc seconds;
38 Geminorum (SAO 96265), with a separation of 7.3 arc seconds;
Castor (α Geminorum), with a separation of 3.9 arc seconds.

Q6. Make a table in your notebook of the binary stars, their angular separations, and whether you could resolve the binary. Based on your observations, estimate the resolution limit tonight. (i.e. Is it greater than 3.9" but less than 7.3"? Is it less than 3.9"? etc.)

Part III: Changes in the Sky

First, use your sky map to identify as many constellations as possible. The table below lists the brighter constellations, some of which were visible earlier in the semester. In the notes to yourself, you might want to comment on how their location has changed since the first observing lab. Turn in this table, or a copy, with your lab write-up.

Name	**Found?**	**Notes to yourself**
Gemini		
Orion		
Leo (The constellation of Regulus)		
Virgo (The constellation of Spica)		
Hydra		

Draco		
Cassiopeia		
Big Dipper/Ursa Major		
Little Dipper/Ursa Minor		

The final part of this lab will be to complete a second pair of sketches for the northern and southern skies. You will use all four sketches (two from this lab and two from earlier in the semester) to answer the lab questions. These sketches need to be made as close as possible to the time you made the original sketches. Be sure to adjust for daylight savings time! (If you made your original sketch at 9:00 p.m. standard time, and the clocks have changed, you should make this one at 10:00 p.m. daylight time.)

Q7. Use an angle ruler to measure the angle of Polaris from the northern horizon. As usual, also record an uncertainty in the value. This measurement should agree with the angle you found in the first lab. If it does not, offer an explanation.

Q8. Use your ruler to measure the altitude and azimuth of Betelgeuse. Remember, azimuth is measured along the horizon from North. You may find it easiest to measure the angle from North toward the West to Betelgeuse (i.e. the short path), then subtract that angle from 360°. Record measurement uncertainties in both measurements.

Q9. Northern Sky Sketch: Center your sketch on Polaris, and carefully note the position of Ursa Major (the Big Dipper). Draw as much of it and of Ursa Minor (the Little Dipper) as you can see. Remember to draw in the constellation lines and label the constellations, but don't draw stars and constellations that were invisible to you, that you are only copying from the star chart.

The scale and viewing direction of your sketch should match those of your old Northern Sky Sketch, from the first observing lab, as closely as possible (A good way to check for this is to see if foreground objects are at the same places and have the same size on both sketches). Try to make your sketch at about the same time of evening as your previous sketch also (with a correction for Daylight Savings Time, if applicable). In any case note the time on your sketch, along with location, date, and sky conditions.

Q10. Southern Sky Sketch: Make your sketch facing directly south. Be sure to show Sirius and the meridian, marking exactly where due south is on your horizon. Draw in the same landmarks, and match the scale and viewing direction and time of your previous Southern Sky Sketch. Note whether Betelgeuse, which should be prominent on your old sketch, still fits on this one. Be sure to include the time, location, date, and sky conditions.

The following questions can be answered indoors after you finish your observations.

Q11. Comparing your two sketches of the southern sky, which direction has the sky appeared to move over the course of the semester, east-to-west or west-to-east? Does this observation confirm what you learned in the first Observing lab?

Q12. Explain why the motion you see between your two southern-sky sketches cannot be caused by the rotation of the Earth on its axis every 24 hours.

Q13. Looking at your two northern sky sketches, describe in words the motions of the stars in the northern sky and how they differ from the motions of the stars in the southern sky. (For example, do all of the stars move? Do all the stars rise and set?)

Q14. Compare your measurements of the position of Betelgeuse between now and earlier in the semester. When was Betelgeuse closest to the Western horizon? Since you made each

measurement at about the same time of night, then the angular distance of the Sun below the Western horizon is about the same for each case. Is Betelgeuse getting closer to the sun in the sky, or farther away from it?

Q15. Is Betelgeuse really changing its position relative to the Sun in actual (linear) distance? Draw a picture showing why Betelgeuse appears to move closer to (or farther away from) the Sun in the sky between your two observations. (Your picture should be from a perspective looking down on the Solar System, rather than based on Earth. Include the Sun, the Earth at two different times of year, and Betelgeuse. Draw a stick figure on each Earth at 9PM and indicate the angle between the Sun and Betelgeuse for each stick figure.) Also explain in words what is happening. Your answer must include both a picture and written explanation to receive full credit.

The answer to the previous question applies not just to Betelgeuse, but to all of the stars in the sky. This is the fundamental reason for the changes in the sky you have seen this semester.

To hand in:

- A short introduction/abstract (just one paragraph);
- Answers to all the numbered questions (and any associated sketches and tables);
- A concluding paragraph or two