The Great Big Astro Lab Manual

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Cow Canyon Saddle, Mt. Baldy, Los Angeles, CA, USA. Yvonne Ban, 24 Oct 2014.
Model: Emily Schooley

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Hello friend! Welcome to my masterwork.

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1 Introduction

Astronomy is the study of the heavens. As such, a fundamental limitation of the subject is that we do not, in general, conduct *experiments*, only *observations* where we snatch jealously at the sparing scraps of information tantalisingly offered by nature. One could argue that astronomy lives at the very cutting edge of our knowledge, where the scientific exercises of hypothesis formulation and testing are most active and challenging.

Such lofty heights of intellectual endeavour are difficult to convey to the next generation of scientists; astronomy draws on physics, chemistry, mathematics, engineering, programming and computer science at an ever increasing rate, and sometimes even biology. Overwhelmingly, astronomy in the academic institution is presented either in lectures or in research projects involving data from observations. The lucky few may even get the opportunity to personally participate in a physical observation run at one of the awe-inspiring cathedrals of science that are the observatories. None of these formats apply to the Astronomy Lab.

Instead, Astronomy Lab is not so much about *experiments* but more about the *models* that we use in astronomy, which play a larger part in the formation of knowledge in astronomy as compared to other subjects. The in-class activities of the course provide an opportunity to teach students about astronomical models in a more engaged and hands-on manner than can be accomplished in a lecture. Using a variety of excellent pedagogical materials, ranging from web apps and planetarium software to experiments and physical models that the students construct themselves, the goal of the course is to use kinesthetic and self-guided exploration to let students learn and internalise the concepts and models of astronomy.

This manual was precipitated by the COVID-19 pandemic, which caused schools to transition to remote learning. Through adapting this course for this mode, sometimes being as remote as the other side of the Earth, and then adapting it back to in-person classes, we drew from the trials and experiences therewith to formalise a robust programme that will minimise the work needed to plan and oversee the conduction of the course.

2 Setup

2.1 Course setup

The Astronomy 100/1 Lab is conducted in tandem with the Astronomy 100 and(/or) 101 courses and is required to be taken simultaneously.

2.1.1 Schedule

Each semester, 6 independent sections are held on Monday, Wednesday, and Friday of every school week at 12:20-1:10pm (1220-1310) and 1:25-2:15pm (1325-1415). Generally, a lead teaching assistant (TA) and assistant TA is assigned for each section. The workload can be split up amongst the assigned TAs so that each section is covered. There may also be assistance from undergrad TAs.

2.1.2 Scripting

I have arranged it such that most of the script for each class can be essentially read off the slides. You can also reference the teaching notes for more details.

2.1.3 Technical details

Every class is held in the Integrated Learning Center (ILC) room S220. The room consists of:

- 11 round tables at which students sit with power points (and table microphones)
- 3 physically secured Macbooks at each table that can be accessed with one's NetID and have Stellarium installed
- 1 central instructor's (standing) desk ("lectern") with elevated chair
- 1 lectern computer controlling lights and A/V of room
- Lights with 3(?) brightness settings
- 2 wireless microphones, one handheld, one wired clip-on

- 2 HDMI and VGA feeds each, “Lectern Laptop” and “Lectern Aux”
- Digital document projector on left side of instructor’s desk, “Document Cam”
- Whiteboards that wrap around the room
- 11 eye-level screens with 2 separate feeds, “A” and “B”, one located nearest each table
- 4 screens located above instructor’s desk, “Stadium”

2.2 Materials

Every student gets an individual lab worksheet for each lab. Activities that involve teamwork at each table may have a table worksheet for each table. Copies of the syllabus and Stellarium guide may also be provided in hard copy. All materials and instructor presentations are copied on the class webpage on Moodle (Moonami, or Moodle in the Cloud).

All individual student submissions, including all end-of-class quizzes, are administered on Moodle. Table teams fill out and submit table worksheets in class.

Demo materials for specific labs are listed for each lab and can be found in the class supply room.

2.3 Grade breakdown

The total Astronomy Lab grade makes up 25% of the overall Astronomy 100/1 course grade, and does not have a separate grade. The remaining 75% of the Astronomy 100/1 course grade comes from lecture assignments and exams. Within Astronomy Lab, the grade assignment is broken down as shown in Table 1.

2.3.1 Manual grading rubrics

Sunset(/sunrise) photo project (20+2)

1. 1st photo (10+1)
   a. Auto (3)
      i. Photo policy (1)
      ii. Calibration photos (2)
   b. Manual (7+1)
      i. Photos (7)
         1. 1st sunset photo (5)
            a. Photo exists and correct format (1)
            b. Sun location (3)
               i. Azimuth discernible (1)

Table 1: Breakdown of grade assignments for Astronomy 100/1 Lab

Lab	Component	%
1	Background knowledge survey	7
	Quiz	3
	Total	10
2	Quiz	10
	Total	10
3	Survey	2
	Quiz	8
	Total	10
4	Survey	2
	Quiz	8
	Total	10
5	Survey	2
	Quiz	8
	Total	10
6	Survey	2
	Quiz	8
	Total	10
7	Survey	2
	Quiz	8
	Total	10
8	Survey	2
	Quiz	8
	Total	10
Sunset photo project	Photo policy	1
	Calibration photos	2
	1st sunset photo and location	9+1
	2nd sunset photos	8+1
	Total	20+2
Extra credit project	Photos	5
	Report	5
	Total	10

                - -1 Sun's position along the horizon is unclear
            ii. Altitude discernible (1)
                - -1 Sun's position is unclear
            iii. Altitude within 5 to -1 deg above horizon (1)
                - -1 Sun is too far above the horizon
                - -1 Sun is below the horizon
        c. Horizon (1)
            i. Visible (0.5)
                - -0.5 Horizon is not visible
            ii. Features (0.5)
                - -0.5 Horizon has no features
    2. Location photo (2)
        a. Location discernible (1)
            - -1 Location unclear
        b. Location repeatable (1)
            - -1 Location not accurately enough indicated
ii. Early (on-time) submission (+1)

2. 2nd and 3rd photos (8+1)
    a. Auto (2)
    b. Manual (6+1)
        i. Photos (2+1)
            1. 2nd photo (2)
                a. From exact same spot (0.5)
                    - -0.5 Location changed
                b. Date is $\geq$ 1 week after 1st sunset (0.5)
                    - -0.5 Too close to 1st photo
                c. Sun can be located (0.5)
                    - -0.5 Sun cannot be located
                d. Horizon visible + Sun close enough to horizon (0.5)
                    - -0.5 Horizon cannot be seen or too far from sunset
            2. 3rd photo (+1)
                a. Attempt (0.5)
                b. Successful (0.5)
    c. Quiz (4)
        i. Short essay (1)
            1. Agrees with annotated picture (0.5)
                - Sunset locations

        - Picture scale
      2. Sensible (0.5)
  d. Annotated picture (3)
    i. $\geq$ 3 Locations marked (1)
      - -0.5 Location missing
      - 2 locations missing means 0
    ii. Annotations (1)
    iii. Locations reasonable (1)
      1. Summer (winter) solstice sunset(/-rise) is East (West) of earlier sunsets(/-rises) (0.5)
        - -0.5 Summer (winter) solstice sunset(/-rise) location wrong
      2. To scale (0.5)
        - -0.5 Locations not marked to scale

3. End-of-lab quiz (2)

  a. Auto (2)

Extra credit Moon photo project (10)

1. Auto (1)

  a. Quiz question (1)

2. Manual (9)

  a. Photos (5)
    i. Uploaded pictures in readable format (1)
    ii. Zoomed-out daytime picture of Moon with horizon visible (2)
      1. Horizon can be behind something as long as they make clear what's level to camera and use that to estimate Moon's altitude
        - -2 Picture not taken in daytime
        - -1 Picture taken just after sunset
    iii. Zoomed-in picture of Moon taken with same camera at same time (1)
    iv. Stellarium screenshot makes sense and lists moon parameters (1)
      - N.B.: Auto question also asks for Moon parameters
  b. Essay (4)
    i. Clear explanation of Moon's altitude relative to the calibration picture (1)
      - values don't have to be correct, but see if they compare numerically
    ii. Reasonable explanation for how they found size of Moon based on calibration photo (1)
    iii. Reasonable explanation of comparison to golf ball (1)
    iv. Attached photo of golf ball (1)

3 Labs

3.1 Lab 1: Astronomical Angles and Stellarium

3.1.1 Overview

Topics covered:

- Angular measurements
- Using Stellarium
- Azimuths and Altitudes of astronomical objects

Watch out for:

-

3.1.2 Materials needed

Instructors:

-

Students:

- Computer

3.1.3 Script

Prep

1.

Class

1.

Wrapup

1.

3.1.4 Submissions

None.

3.1.5 Astronomy Background Survey

This survey is given before any instruction is given, and questions 1-11 are surveyed again at the end of the course.

1. As seen from Amherst, MA, when will an upright flagpole cast no shadow because the Sun is directly above the flagpole?
   - Everyday at noon.
   - Only on the first day of summer.
   - Only on the first day of winter.
   - On both the first days of spring and fall.
   - <u>Never.</u>
2. When the Moon appears to completely cover the Sun (an eclipse), the Moon must be at which phase?
   - Full
   - <u>New</u>
   - First quarter
   - Last quarter
   - At no particular phase
3. Imagine that you are building a scale model of the Earth and the Moon. You are going to use a 12-inch basketball to represent the Earth and a 3-inch tennis ball to represent the Moon. To maintain the proper distance scale, about how far from the surface of the basketball should the tennis ball be placed?
   - 4 inches (1/3 foot)
   - 6 inches (1/2 foot)
   - 36 inches (3 feet)
   - <u>30 feet</u>
   - 300 feet
4. Imagine that the Earth's orbit were changed to be a perfect circle about the Sun so that the distance to the Sun never changed. How would this affect the seasons?
   - We would no longer experience a difference between the seasons.
   - We would still experience seasons, but the difference would be much LESS noticeable.
   - We would still experience seasons, but the difference would be much MORE noticeable.
   - <u>We would continue to experience seasons in the same way we do now.</u>

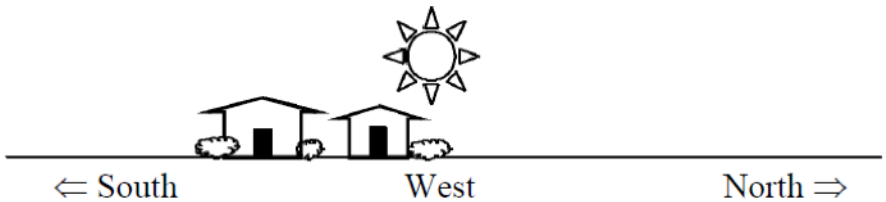


Figure 1:

5. On about September 22, the Sun sets directly to the west, as shown on the diagram below (Fig. 1). Where would the Sun appear to set two weeks later?
   - Farther south
   - In the same place
   - Further north

6. As viewed from our location, the stars of the Big Dipper can be connected with imaginary lines to form the shape of a pot with a curved handle. What is the closest point you would have to travel to in order to observe a substantial change in the shape formed by these stars?
   - Across the country
   - A distant star
   - Europe
   - Moon
   - Pluto
   - A distant star

7. With your arm held straight, your little fingernail is just wide enough to cover up the Sun. If you were on Saturn, which is 10 times farther from the Sun than the Earth is, which of the following objects could you use to just barely cover up on the Sun?
   - Your wrist
   - Your thumb
   - A pencil
   - A strand of spaghetti
   - A hair

8. If you could see stars during the day, this is what the sky would look like at noon on a given day (Fig. 2). The Sun is near the stars of the constellation Gemini. Near which constellation would you expect the Sun to be located at sunset?
   - Leo

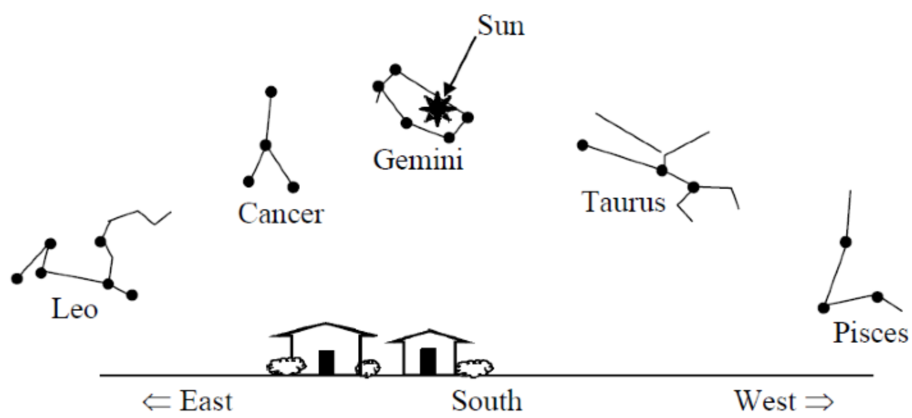


Figure 2:

- Cancer
- <u>Gemini</u>
- Taurus
- Pisces

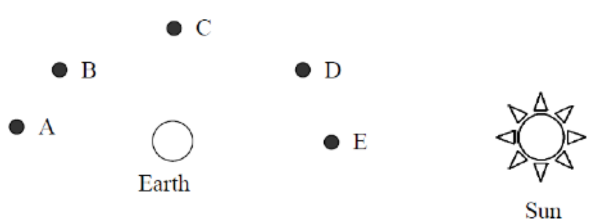


Figure 3:

Figure 4:

9. The diagram below (Fig. 3) shows the Earth and Sun as well as five different possible positions for the Moon. Which positions of the Moon would cause it to appear like the picture of the Moon below (Fig. 4) when viewed from Earth?

   - A
   - B
   - C

- D
- E

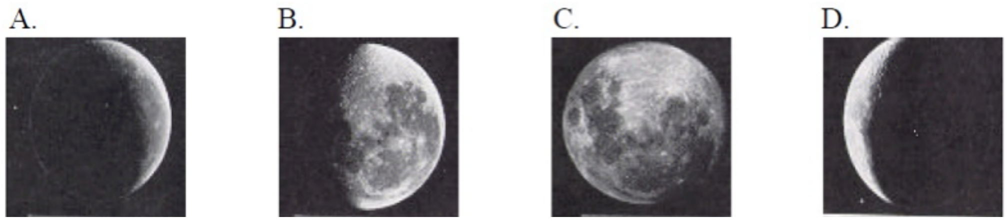


Figure 5:

10. You observe a full Moon rising in the east. How will it appear in six hours? See Fig. 5 for the options.
    - A
    - B
    - C
    - D
11. In general, how confident are you that your answers to this survey are correct?
    - Not at all confident (just guessing)
    - Not very confident
    - Not sure
    - Confident
    - Very confident
12. Which Astronomy Class are you signed up for?
    - Astronomy 100 (10936), TuTh at 10:00am
    - Astronomy 100 (10937), TuTh at 1:00pm
    - Astronomy 101 (23073), TuTh at 2:30pm
13. What time zone do you call home?
    - Eastern
    - Central
    - Mountain
    - Pacific
    - Other: []
14. What computer operating system do you use for homework?

- Apple MacOS
- Microsoft Windows
- Apple iOS (e.g., iPad)
- Chromebook
- Linux
- Other: []

15. For the purpose of the project this semester, what is the model of the phone or camera that you will be using? (Example: iPhone X, Samsung Galaxy S8, Nikon D3500 camera, etc.)

    *Note: you definitely do **not** need a state-of-the-art camera for these projects – you just need to be able to take basic photos.*

16. Over the course of these labs you will be taking pictures of sunsets (or sunrises) with your camera. To do this you will need to have access to a spot where you can view the western horizon for sunsets (eastern for sunrises). It's fine if these pictures are taken through a window.

    If you believe you need special accommodations for taking these photos or that the project will be impossible for you, please explain your circumstances below, and we will work out alternatives with you. (Otherwise, leave blank.)

3.1.6 Quiz

1. What was the approximate altitude of Jupiter at 6:00pm on January 31, 2022? *(choose closest)*

    - 11°
    - 34°
    - 67°
    - 145°
    - 260°

2. From the northern hemisphere, how do the azimuth and altitude of an object in the southeastern sky change with time?

    - Both decrease.
    - <u>Both increase.</u>
    - The azimuth decreases while the altitude increase.
    - The azimuth increases while the altitude decreases.

3. From the northern hemisphere, how do the azimuth and altitude of an object in the southwestern sky change with time?

- Both increase.
- Both decrease.
- The azimuth decreases while the altitude increases.
- <u>The azimuth increases while the altitude decreases.</u>

4. How do you predict the Sun's azimuth and altitude change as it sets in the western sky?

   - Unlike stars, it goes straight down, so its azimuth is constant.
   - <u>Its altitude and azimuth change much like those of any other setting star.</u>
   - You can't measure altitudes or azimuths for the Sun.

3.2 Lab 2: Angular Sizes on the Sky (equiv. to Project pt. 1)

3.2.1 Overview

Topics covered:

- Estimating angular sizes and separations
- Determining the field of view of your camera
- Angles on the sky

Watch out for:

-

3.2.2 Materials needed

Instructors:

- Calibration grids

Students:

- Fingers and arms
- Camera

3.2.3 Script

Prep

1.

Class

1.

Wrapup

1.

3.2.4 Submissions

1. Calibration photos
   - Zoomed-out: $1\times$
   - Zoomed-in: $n\times$

3.2.5 Quiz

1. What is the approximate angular size of the Moon?
   - $0.2°$
   - $0.5°$
   - $3°$
   - $8°$
   - $15°$
2. What is the approximate angular separation between Aldebaran and the Pleiades?
   - $0.2°$
   - $0.5°$
   - $3°$
   - $8°$
   - $15°$
3. Four billion years ago, the Moon was half as far away from Earth as it is now. What was the angular size of the Moon back then?
   - $2\times$ bigger
   - $4\times$ bigger
   - $2\times$ smaller
   - $4\times$ smaller
   - the same
4. Suppose that you have an emergency and have to go home so you can't take your final sunset picture later in the semester. What should you do?
   - Try photoshopping the Sun on another picture you took
   - Ask a friend to take the picture for you
   - Use a friend's photo instead.
   - Take a photo from home.
   - Contact your lab instructor about what you might do instead.
5. From the picture in part 3 of the lab, what were your estimates of the Sun's azimuth and altitude?
   - Azimuth: [x] $°$ (enter a number only)
   - Altitude: [y] $°$ (enter a number only)

3.3 Lab 3: Angular Size vs. Distance

3.3.1 Overview

Topics covered:

- Observing angular size of an object at different distances
- Interpreting the inverse relationship
- The Sun's angular size throughout the year

Watch out for:

-

3.3.2 Materials needed

Instructors:

- Volleyball/"volleyball"
- Tripod/something to hold up volleyball e.g. lab stands $\times 3$
- Blue tape to secure

Students:

-

3.3.3 Script

Prep

1.

Class

1.

Wrapup

1.

3.3.4 Submissions

None.

3.3.5 Quiz

1. What is your team's table number?
    - 1
    - 2
    - 3
    - 4
    - 5
    - 6
    - 7
    - 8
    - 9
    - 10
    - 11
2. a. When does Mars have the largest angular size?
    - Oct 2021
    - Nov 2021
    - Dec 2021
    - Jan 2022
    - Feb 2022
    - Mar 2022
    - Apr 2022
    - May 2022
    - Jun 2022
    - Jul 2022
    - Aug 2022
    - Sep 2022
    - Oct 2022
    - Nov 2022
    - Dec 2022
    - Jan 2023
    - Feb 2023
    - Mar 2023
    - Apr 2023
    - May 2023
    - Jun 2023
    - Jul 2023

- Aug 2023
- Sep 2023
- Oct 2023

b. What was its angular size in arcseconds? [17 ± 4] $''$ (enter number only)

c. Was it undergoing retrograde motion at this time? Yes

3. Even though the Sun is physically much bigger than the Moon, they both have angular diameters of about 0.5°. This is because:
   - the Sun is so much brighter that we can't look at it directly.
   - the Moon has a solid surface, but the Sun is a transparent gas.
   - the Sun is as many times farther away as it is larger.
   - our eyes cannot distinguish such small sizes, so they look the same.
   - All of the above.
4. Which of the following is a significant cause of Amherst's summers being warmer than its winters?
   - Earth is closer to the Sun in the summer than in the winter.
   - The northern hemisphere is closer to the Sun in the summer than in the winter.
   - The ground faces the Sun more directly in the summer than in the winter.
   - All of the above.
5. Suppose you see two friends across campus who you know are the same height as each other. Adam is 2° tall and Beth is 6° tall by your estimate.

   Therefore, [Adam] must be [3] times **further away** from you.
6. When does the Moon have the largest angular size?
   - When it is near the horizon.
   - When it is in the part of its orbit closest to Earth.
   - When it is full
   - When Earth is in the part of its orbit farthest from the Sun.
   - All of the above.

3.4 Lab 4: Phases of the Moon

3.4.1 Overview

Topics covered:

- Relative size of Earth and Moon
- Modelling phases
- Relationship of moon phase to position in orbit and in our sky

Watch out for:

-

3.4.2 Materials needed

Instructors:

- Golf balls (box)
- Lightbulbs on stands ($\times$11)
- Tape measure
- Golf ball on stand

Students:

- Computer

3.4.3 Script

Prep

1.

Class

1.

Wrapup

1.

3.4.4 Submissions

None.

3.4.5 Quiz

1. The Moon's shape appears to change over the course of each month because:
    - dark and bright spots come into view as the Moon rotates.
    - parts of it become hidden as it passes into the Earth's shadow.
    - the part of its sunlit side facing us depends on its orbital position.
    - the Moon's light is generated by internal volcanic processes.
2. If we see the Moon is a crescent this evening from Amherst, what phase will it be when observed from Australia?
    - It will also be seen in the evening as a crescent.
    - It will appear to be nearly full.
    - It will be seen as a crescent in the morning sky.
    - The Moon can't be seen from Australia.
3. If you see the Moon rising at about 9pm tonight, what time should you expect to see it rising a week from now?
    - 9pm
    - 3am
    - 9am
    - 3pm
    - None of these is correct-the Moon always rises at sunset.
4. When can a lunar eclipse occur?
    - Only when the Moon is full.
    - Only when the Moon is new.
    - When the Moon is at one of the quarter phases.
    - At any phase but only at midnight.
5. In the image below (Fig. 6), showing the Moon just above the eastern horizon, what is the phase of the Moon?
    - new
    - first quarter
    - full
    - third (last) quarter
6. In the same image as the previous question, about what time is it?

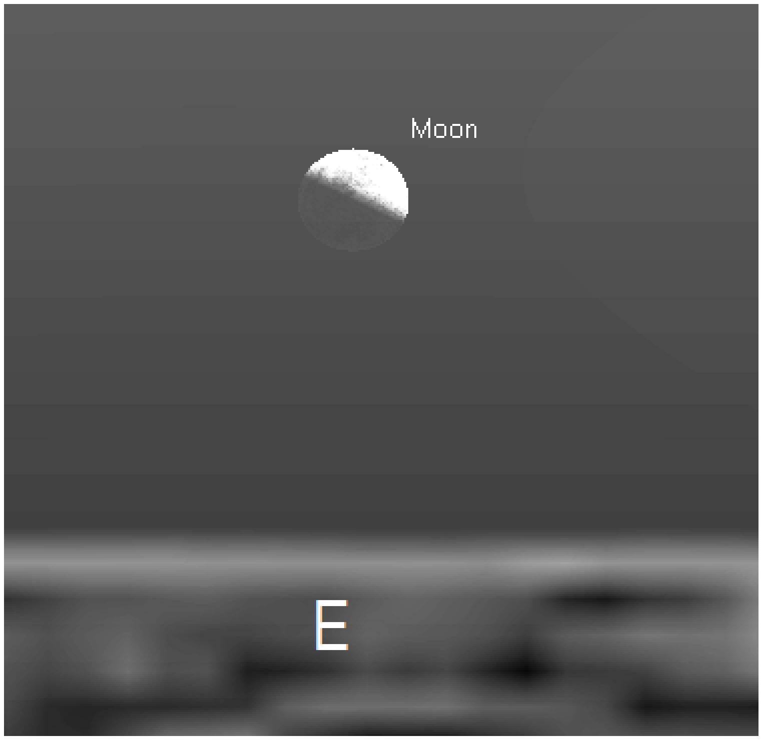


Figure 6:

- midnight
- sunrise
- noon
- sunset

7. If it is a third quarter moon tonight, about how long will it be before the Moon is full?
   - A few days
   - About a week
   - About two weeks
   - <u>About 3 weeks</u>
   - About a month

8. When the Moon is gibbous, what phase would the Earth be in as seen from the Moon?
   - new
   - <u>crescent</u>
   - quarter
   - gibbous

- full

3.5 Lab 5: Motions of the Sun

3.5.1 Overview

Topics covered:

- The Sun's altitude at noon throughout the year
- The path of the Sun through the sky on different dates
- And at different latitudes

Watch out for:

-

3.5.2 Materials needed

Instructors:

-

Students:

-

3.5.3 Script

Prep

1.

Class

1.

Wrapup

1.

3.5.4 Submissions

None.

3.5.5 Quiz

1. What is your table number?

   - 1
   - 2
   - 3
   - 4
   - 5
   - 6
   - 7
   - 8
   - 9
   - 10
   - 11

2. a. What is the latitude of your city in Section 2.b) of the worksheet? [x] ° South (enter number only)

   b. At this location, what is the maximum altitude the Sun reaches during the year? [y] ° (enter number only)

   c. At this location, what month does the Sun reach its maximum altitude at noon?

   - January
   - February
   - March
   - April
   - May
   - June
   - July
   - August
   - September
   - October
   - November
   - <u>December</u>

3. Where can you see the Sun pass straight overhead at noon? (see screen for options)

   - Everywhere on Earth.
   - Everywhere between the arctic circles sometime during the year.
   - <u>Everywhere within the topic latitudes sometime during the year.</u>

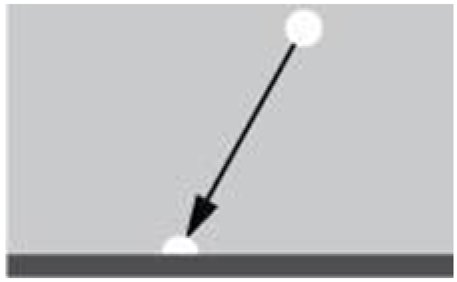


Figure 7:

- Only on the equator.
- Nowhere on Earth.

4. If you were marooned on an island, and you saw a sunset angle as pictured below (Fig. 7), what latitude would you likely be at?
   - N 60°
   - N 30°
   - 0°
   - S 30°
   - S 60°

5. On what day does the Sun appear highest in the sky at noon in Amherst?
   - Vernal Equinox
   - Summer Solstice
   - Autumnal Equinox
   - Winter Solstice

6. What month does the Sun appear highest in the sky at noon in Sydney, Australia (S 34°)? (see screen for options)
   - March
   - June
   - September
   - December

3.6 Lab 6: Solar Power

3.6.1 Overview

Topics covered:

- Experiments using flashlights to model the effect of distance on brightness of sunlight
- The effect of angle
- Solar heating and seasons

Watch out for:

-

3.6.2 Materials needed

Instructors:

- Table worksheets ($\times$11)
- Metre rules ($\times$11)
- Protractors ($\times$11)
- Flashlights ($\times$11)

Students:

-

3.6.3 Script

Prep

1.

Class

1.

Wrapup

1.

3.6.4 Submissions

1. Table worksheets

3.6.5 Quiz

1. What is your team's table number?
    - 1
    - 2
    - 3
    - 4
    - 5
    - 6
    - 7
    - 8
    - 9
    - 10
    - 11
2. In what month is Earth closest to the Sun?
    - Jan
    - Feb
    - Mar
    - Apr
    - May
    - Jun
    - Jul
    - Aug
    - Sep
    - Oct
    - Nov
    - Dec
3. When you double the distance from a light source, the intensity of the light:
    - gets 4 times smaller
    - gets 2 times smaller
    - stays the same
    - gets 2 times bigger
    - gets 4 times bigger

4. Rate each of the following for its importance in explaining why we have cold temperatures in winter here in Amherst. There are three choices for each: important, unimportant/minor and has almost no effect, or works counter to the resulting temperature differences.

   a. Earth's Northern Hemisphere is farther from the Sun than the Southern Hemisphere. unimportant

   b. Earth's orbit is elliptical and we get further away from the Sun in part of our orbit. counter

   c. The angle of Earth's axis results in the Sun having a low altitude and its light spread out. important

5. In part 3, what distance did your group estimate had the same intensity as light shining from an angle of 24°? [1.5] ft (enter number only)

6. List the values (last column in tables) your group measured at:

   - 2.0 ft and 90°: [x] (enter number only)
   - 1.0 ft and 47°: [y] (enter number only)

3.7 Lab 7: Calendars, Horoscopes, and Precession

3.7.1 Overview

Topics covered:

- Movement of the Sun and Moon through the zodiac
- Understanding lunisolar calendars
- What's your sign?
- Precession and the pole star

Watch out for:

-

3.7.2 Materials needed

Instructors:

-

Students:

-

3.7.3 Script

Prep

1.

Class

1.

Wrapup

1.

3.7.4 Submissions

None.

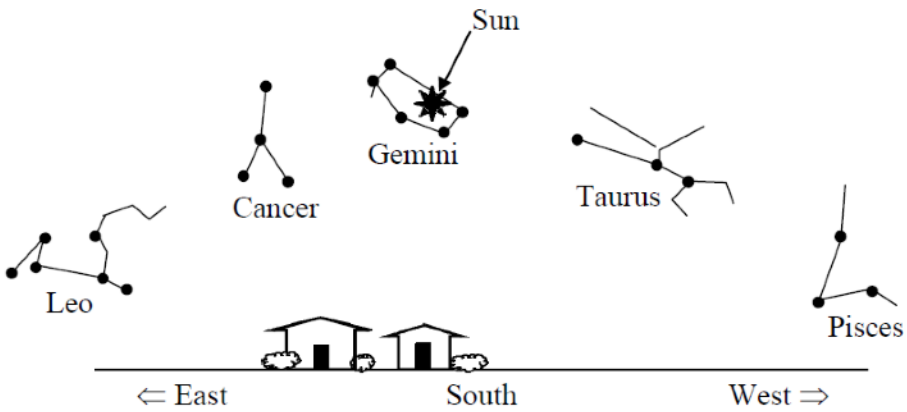


Figure 8:

3.7.5 Quiz

1. What determines that your horoscope sign is, for example, Taurus?

   a. Characteristics that are common among people born on those dates (like being bullish).
   b. The constellation (Taurus) the Moon is in on your birthday.
   c. The constellation (Taurus) the Sun is in on your birthday.
   d. <u>None of the above.</u>

2. If you could see stars during the day, this is what the sky would look like at noon on a given day (Fig. 8). The Sun is near the stars of the constellation Gemini. Near which constellation would you expect the Sun to be located at sunset?

   a. Leo
   b. Cancer
   c. <u>Gemini</u>
   d. Taurus
   e. Pisces

3. For most people living today who, according to popular horoscopes, believe they are ”a Gemini”, the Sun was in the constellation [] on the day they were born.

   a. Leo
   b. <u>Cancer</u>
   c. Gemini
   d. Taurus
   e. Pisces

4. Suppose it is just after sunset, and you see the constellation Gemini just above the horizon where the Sun set. If you were looking just after sunset a month later, what constellation would be in that position?

    a. Leo

    b. Cancer

    c. Gemini

    d. Taurus

    e. Pisces

5. How many lunar months are there between Chinese New Years?

    a. 12

    b. 13

    c. 14

    d. 12 or 13

    e. 13 or 14

3.8 Lab 8: Motions of the Planets in the Sky

3.8.1 Overview

Topics covered:

- Morning and evening stars
- The motion of Mars
- How retrograde motion varies among the planets

Watch out for:

-

3.8.2 Materials needed

Instructors:

-

Students:

-

3.8.3 Script

Prep

1.

Class

1.

Wrapup

1.

3.8.4 Submissions

None.

3.8.5 Quiz

1. When is Mars brightest?

   a. Just at the beginning or end of retrograde motion, when Mars appears stationary.
   b. In July, when Earth is farthest from the Sun.
   c. When it is on the far side of the Sun, so we see its fully-lit face.
   d. <u>In the middle of going through retrograde motion.</u>

2. Which planets undergo retrograde (backward) motion on the sky?

   a. Mars only.
   b. Just Mars, Jupiter, Saturn, Uranus, and Neptune.
   c. Venus only.
   d. Just Venus and Mercury.
   e. <u>All of the planets.</u>

3.9 Lab 9: The HR Diagram

3.9.1 Overview

Topics covered:

- Stellar temperatures and luminosities from colour and magnitude
- Finding stellar radii
- Bright stars vs. nearby stars

Watch out for:

-

3.9.2 Materials needed

Instructors:

- Table worksheets ($\times$11)

Students:

-

3.9.3 Script

Prep

1.

Class

1.

Wrapup

1.

3.9.4 Submissions

1. Table worksheets

3.9.5 Quiz

1. What is your team's table number?
   - 1
   - 2
   - 3
   - 4
   - 5
   - 6
   - 7
   - 8
   - 9
   - 10
   - 11

2. Enter the data you found for your bright star. (enter number only)

   Distance: [d] ly (light-years)

   Temperature: [T] K (Kelvin)

   Size: [D] $\times$ diameter of Sun

3. Which of the following is true about the Sun? (select all that apply)
   - <u>The Sun is a star.</u>
   - The Sun is bigger than most stars.
   - The Sun is more luminous than most stars.
   - <u>The Sun is less luminous than most of the brightest stars we see at night.</u>

4. Which of the following is true about the brightest stars you can see by eye at night? (select one)
   - <u>Most are giant stars, much more luminous than the Sun.</u>
   - Most are very nearby, making them look so bright.
   - Most are small, red stars, which are the most common.
   - Most are young, so they have a lot of fuel to burn.

5. What does absolute magnitude measure?
   - A star's distance in parsecs.
   - How bright a star appears to be.
   - The brightness of a star if observed from above Earth's atmosphere.

- The power output from a star in starlight.

6. Which of the following would you need to know to find a star's surface temperature? (select all that apply)

   - Distance to star
   - Radius of star
   - Absolute magnitude of star
   - B-V color of star

3.10 Lab 10: Distances of Stars in Space

3.10.1 Overview

Topics covered:

- Building a 3D constellation
- Understanding spectral type and luminosity class
- Understanding parallax

Watch out for:

-

3.10.2 Materials needed

Instructors:

- Table worksheets (×11)
- Tribbles (in box)
- Clips (in box)
- Metal poles with sightlines (×11)

Students:

-

3.10.3 Script

Prep

1.

Class

1.

Wrapup

1.

3.10.4 Submissions

1. Table worksheets

3.10.5 Quiz

1. What is your team's table number?
   - 1
   - 2
   - 3
   - 4
   - 5
   - 6
   - 7
   - 8
   - 9
   - 10
   - 11
2. What constellation did your table work on?
3. Light from the Sun takes about 8.5 minutes to reach Earth. About how long does light take to reach us from most of the brighter stars we see at night?
   - Several hours
   - Several months
   - 3-10 years
   - 100-1000 years
   - Millions of years
4. Most constellations are collections of stars that:
   - are not physically associated with each other.
   - are members of a group of stars gravitationally attracted together.
   - were born together out of a cloud of gas, now drifting apart.
   - were born out of the same interstellar cloud as the Sun.
5. Suppose star A has a parallax shift 10 times larger than star B. Which of the following is true?
   - Star A is 10 times closer than star B.
   - Star A is 10 times farther than star B.
   - Star A is 100 times closer than star B.
   - Star A is 100 times farther than star B.

6. If you spot a bright reddish colored star in a constellation tonight, it is most probably:

   - <u>a distant red giant star.</u>
   - a nearby low-mass main-sequence star.
   - either A or B with about equal probability.

7. As viewed from Massachusetts, the stars of the Big Dipper can be connected with imaginary lines to form the shape of a bowl with a curved handle. What is the closest point you would have to travel to in order to observe a substantial change in the shape formed by these stars?

   - Across the country
   - Another continent
   - The Moon
   - Pluto
   - <u>A distant star</u>

8. If you lived on Mars, how would the parallax of stars differ from its value seen from Earth?

   - <u>It would be bigger.</u>
   - It would be smaller.
   - It would be the same.

3.11 Lab 11: Structure of the Local Group

3.11.1 Overview

Topics covered:

- Using angular sizes to estimate nearby galaxy sizes
- Building a scale model of the Local Group of galaxies

Watch out for:

-

3.11.2 Materials needed

Instructors:

- Colour paper (green, yellow, blue)
- Scissors (multiple)
- Galaxy info strips
- Milky Way scale paper disc
- Tripod/chair/something to put the Milky Way on e.g. lab stand

Students:

-

3.11.3 Script

Prep

1.

Class

1.

Wrapup

1.

3.11.4 Submissions

None.

3.11.5 Quiz

1. What is the number of the galaxy you worked on?
2. What was the distance of your galaxy (in light years)? [d] ly (enter number only)
3. What diameter did you estimate for your galaxy (in light years)? [D] ly (enter number only)
4. Approximately how far away is the nearest galaxy that is the size of the Milky Way or larger?
    - About 25,000 light years
    - About 2,500,000 light years
    - About 250,000,000 light years
    - About 2,500,000,000 light years
5. What is the most common type of galaxy in the Local Group of galaxies?
    - Spiral
    - Elliptical
    - Irregular
    - Dwarf
6. What information is needed to find the physical diameter of a galaxy? (select only those items that are necessary)
    - Angular diameter
    - Distance
    - Classification
    - Magnitude
    - Color
7. Which of the following best describes the Milky Way galaxy as compared to the other galaxies in the Local Group?
    - One of the largest galaxies in the Local Group.
    - One of the smaller galaxies in the Local Group.
    - The only spiral galaxy in the Local Group.
    - The only large galaxy in the Local Group.
    - One of the only dwarf galaxies in the Local Group.

3.12 Project: Movement of the Sunset

3.12.1 Overview

Topics covered:

•

Watch out for:

•

3.12.2 Materials needed

Instructors:

- Calibration grids

Students:

- Camera

3.12.3 Script

Prep

1.

Class

1.

Wrapup

1.

3.12.4 Photo Policy Acknowledgement

You will need to take several photos of the setting Sun over the course of the semester following specific directions. Taking these photos is not difficult, but it does require some advance planning. Picture requirements will be described in lab and on Moodle, but a cell phone camera is fine.

You will need to upload your own original pictures taken this semester into Moodle over the course of the semester. Submitting pictures you didn't take yourself this semester, or helping someone else to submit pictures that are not their own, is considered plagiarism and/or academic dishonesty and will be handled in accordance with the UMass Academic Honesty Policy, and may result in penalties up to a zero for the entire project.

You are responsible for saving backups of your pictures immediately, so a lost or broken phone/camera/computer is not an excuse for failing to submit your pictures on time.

You can upload your pictures into Moodle as you take them and save backups of your pictures using UMass OneDrive, for example.

If you have any special circumstances that will not allow you to take sunset photos for your project. You must contact your lab instructor right away to explain the circumstances and come to alternative arrangements with them.

Please indicate that you understand these policies by typing "Y" or "yes":

3.12.5 Submissions

1. 1st sunset(/sunrise) photo
2. 2nd sunset(/sunrise) photo
3. 3rd sunset(/sunrise) photo

3.12.6 Quiz

1. Specifics of photos
   a. First photo:
   Date: [dd/mm] and time: [hh:mm:ss]
   Azimuth of sunset/sunrise: [x] $^\circ$ (enter number only)
   b. Second photo:
   Date: [dd/mm] and time: [hh:mm:ss]
   Azimuth of sunset/sunrise: [x] $^\circ$ (enter number only)
   c. Third photo:
   Date: [dd/mm] and time: [hh:mm:ss]
   Azimuth of sunset/sunrise: [x] $^\circ$ (enter number only)
   d. Comparisons
      i. Days between 1st and 2nd picture: [x] days (enter number only)
      Sunset/sunrise shift in degrees per day: [v] $^\circ$/day (enter number only)
      ii. Days between 2nd and 3rd picture: [x] days (enter number only)
      Sunset/sunrise shift in degrees per day: [v] $^\circ$/day (enter number only)
   e. Dimensions of zoomed-in calibration photo (in degrees): Width: [w] $^\circ \times$ Height: [h] $^\circ$ (enter number only)
   f. Use Stellarium to find the answer. What is the predicted azimuth for the sunset/sunrise on 21 June(/December)? [z] $^\circ$ (enter number only)
2. In the essay box below, explain the procedure you used for predicting the position of the setting(/rising) Sun on 21 June(/December) in your photo, and attach an annotated photo showing the entire horizon covering all of your sunset(/sunrise) pictures and your predicted sunset(/sunrise) position for 21 June(/December).

The picture can be one of your sunset(/sunrise) pictures or a new picture, and it should be taken with the same zoomed-out settings as your original calibration grid photo. On the photo, mark the position of your two best measurements of the setting(/rising) Sun's position, which you will use to predict the sunset(/sunrise) position on 21 June(/December). Write the azimuth of the Sun on the picture at all three positions (two observed sunset(/sunrise) positions and predicted sunset(/sunrise) position). Also, mark on the photo the total width of your photo in degrees, based on your calibration photo.

3.13 Extra Credit Project: Photo of the Moon in the Daytime a.k.a. The Curious Incident of the Moon in the Day-time

3.13.1 Overview

Topics covered:

-

Watch out for:

-

3.13.2 Materials needed

Instructors:

- Moon model golf ball
- Mount for golf ball
- Measuring tape

Students:

- Camera

3.13.3 Script

Prep

1.

Class

1.

Wrapup

1.

3.13.4 Submissions

1. Photos of Moon in daytime
   - Zoomed-out with horizon
   - Zoomed-in on Moon
2. Zoomed-in photo of golf ball at to-scale distance

3.13.5 Quiz

1. Specifics of photos

   a. Date: [dd/mm] and time: [hh:mm:ss]

   b. Dimensions of zoomed-out calibration photo (in degrees): Width: [w] $^\circ$ $\times$ Height: [h] $^\circ$ (enter number only)

   c. Dimensions of zoomed-in calibration photo (in degrees): Width: [w] $^\circ$ $\times$ Height: [h] $^\circ$ (enter number only)

   d. Obtain the answers for this and the following sections using Stellarium. In your photos, what was the:

      - Azimuth of Moon: [x] $^\circ$ (enter number only)
      - Altitude of Moon: [y] $^\circ$ (enter number only)

   e. What time did the sun rise on this date? [hh:mm:ss]

      What time did the sun set on this date? [hh:mm:ss]

2. In the essay box below:

   (1) Compare the altitude of the Moon to the height (in degrees) of your zoomed-out calibration picture. Do these values make sense? Explain how they make sense or what might explain any discrepancy.

   (2) For the zoomed-in picture, how big is the Moon compared to the width (in degrees) found in your zoomed-in calibration photo? Do you get approximately 0.5° for the width of the Moon? Explain how you are making your estimate and/or any problems you had in making the measurement.

   (3) Remember that picture we asked you to take of the golf ball in Lab 3?* Place it alongside your zoomed-in photo of the Moon in a document and upload it here. Comment in the essay box how similar or different are the sizes in the two photos and discuss any difficulties.

   *If you need to redo your photo of the golf ball, you can repeat it by taking a photo of a golf ball from 15 ft 5 in away. Remember that you must use exactly the same settings in your camera as for the zoomed-in photo you took of the Moon.

4 sumner's thoughts

5 sarah's thoughts

6 Past schedules and notes

6.1 Fall 2020

6.2 Spring 2021

6.3 Fall 2021

6.4 Spring 2022

7 Materials

7.1 General

7.1.1 Syllabus

7.1.2 Stellarium Guide

20 July 2022

ASTR100/1 Lab: Stellarium Installation and Usage Guide

You can download Stellarium for your own computer (Mac, Windows, Linux) at `http://www.stellarium.org`

The software is free, and there are links to extensive documentation on the website. After installing it, use the following walk-through to familiarise yourself with the basics of how the program works.

N.B.: If pressing the function keys (F1 – F12) isn't working, press down the Fn key (keyboard lower left corner) and press the function key.

1. Open Stellarium.
2. The default location is Paris (seen in the lower left corner). For observations made from Amherst, we need to change the location.
   i. Move the cursor to the lower-left side of the window and click on "Location Window", or press F6.
   ii. In the "Location" window, in the entry field next to the magnifying glass (for searching), type "Amherst". Then, click on "Amherst Center, United States". (**DO NOT** type "Amherst" into Name/City. It will just rename Paris to Amherst, but won't change the location. Also **DO NOT** select "Amherst, United States".)
   iii. Close the window by clicking on the cross (×) in the upper right corner.
3. Change the Date/Time to a value, e.g. 2015/09/01, 14:00:00.
   i. Move the cursor to the lower-left side of the window and click on "Date/Time Window", or press F5.
   ii. Change the date and time either by entering the values directly or using the arrow keys to increase or decrease the values.
   iii. Close the window by clicking on the cross (×) in the upper right corner.
4. Click and hold the cursor on a spot in the window, and drag it around to look in various directions.
5. Zoom in by scrolling **UP** and zoom out by scrolling **DOWN** (on touchpad, mousepad, mouse, etc.)
6. Zoom out till you see the full sky in your screen. You should see only the Sun.

i. To turn on and off the atmosphere visualisation, move the cursor to the bottom of the window on the left side and click on the cloud icon, or press A.
ii. To turn on and off the ground visualisation, move the cursor to the bottom of the window on the left side and click on the trees icon, or press G.
iii. To turn on and off the constellation lines, move the cursor to the bottom of the window on the left side and click on the "N"-shaped icon, or press C.
iv. To turn on and off the constellation names, move the cursor to the bottom of the window on the left side and click on the mirrored "N"-shaped icon, or press V.
v. To turn on and off the constellation art, move the cursor to the bottom of the window on the left side and click on the person-shaped icon, or press R.
vi. To turn on and off the stars, press S.

7. Click on Saturn. Notice that some information about Saturn pops up at upper left corner of the window.
   i. Press the space bar to center the view on the selected object, Saturn.
   ii. Zoom in until the field of view (FOV at the bottom of screen) is 0.1°. What objects other than Saturn can you see?
   iii. To start and stop the progression of time, move the cursor to the bottom of the window on the left side, move to the right end of the toolbar, and click on the "play" icon, or press K.
   iv. To increase the progression of time, move the cursor to the bottom of the window on the left side, move to the right end of the toolbar, and click on the "fast forward" icon, or press L.
   v. To decrease the progression of time, move the cursor to the bottom of the window on the left side, move to the right end of the toolbar, and click on the "rewind" icon, or press J.
   vi. To return to the present time, move the cursor to the bottom of the window on the left side, move to the right end of the toolbar, and click on the "hourglass" (2 triangles vertically stacked, points facing each other) icon, or press 8.
8. Search for an object, e.g. the Sun.
   i. Move the cursor to the lower-left side of the window and click on "Search Window", or press F3.
   ii. Enter the name of the object you are searching for.
   iii. Close the window by clicking on the cross ($\times$) in the upper right corner.
9. Play around and familiarise yourself with the software. For help, press F1.

7.2 Lab 1: Astronomical Angles and Stellarium

7.2.1 Worksheet

ASTR 100/1 Lab 1: Astronomical Angles and Stellarium

1. Background Survey on Moodle

Log in to Moodle (on smartphone, laptop, or one of the computers at the table). Go to the section for Astronomy Lab 1 and complete the Astronomy Background Survey. Don't worry if you don't know the answers, just answer every question as best you can and you will receive full credit.

2. Stellarium

Stellarium is a planetarium software that helps us visualise the sky over time. We'll use it to begin our exploration of astronomy.

1. Go to `http://stellarium.org/` and download and install the correct version for your operating system. If you can't find it, use Stellarium Web.
2. Open the Location Window from the left-hand menu panel or by pressing F6. In the search bar under the top right menu type "Amherst" and select "Amherst Center, United States".
   - Make sure it's "Amherst Center", not "Amherst" (that's in NY somewhere).
   - **Do not type** into the "Name/City" box. That renames the location.
3. Close the Location Window and open the Date/Time Window from the left-hand menu panel or by pressing F5. Set the time to 7:00pm tonight. Close the window.
4. Look at what the sky will look like tonight. Drag the view and scroll up or down to zoom in or out respectively.

3. Positions of Astronomical Objects

In astronomy, we use angles to measure positions and separations of objects in the sky. From your point of view, an object's position is given by **azimuth** and **altitude**. Answer the following questions.

1. How many degrees are in a circle?
2. How many degrees are in a right angle?
3. What are longitude and latitude?
4. What is the azimuth/altitude system?

Astronomers use the **sexagesimal** system for recording angles. Each degree is divided into 60 **arc minutes** ($'$), and each arc minute is divided into 60 **arc seconds** ($''$). An azimuth of $240°38'12''$ is read as 240 degrees, 38 arc minutes, and 12 arc seconds.

Set the time to 2022/1/31 at 6:00pm. Locate the object and click on it, then answer the following. At this time, what is the azimuth and altitude of:

Object	Azimuth	Altitude
Betelguese		
Jupiter		
Sirius		

Now advance the time by a few minutes. Do the azimuths and altitudes increase or decrease?

4. Lab Quiz on Moodle

Go to the Lab 1 section on the Moodle page and complete the End-of-Lab Quiz.

If you logged into your Moodle account from a classroom computer, be sure to log back out!

7.3 Lab 2: Angular Sizes on the Sky

7.3.1 Worksheet

7.4 Lab 3: Angular Size vs. Distance

7.4.1 Worksheet

ASTR 100/1 Lab 3: Angular Size vs. Distance

In groups at each table, you will investigate how the angular diameter of a spherical body (a ball) depends on its distance from you.

1. Data and Graph

1. At your table, discuss and agree on a plan for how to make measurements of the sphere to explore the relationship between its angular size and distance. Consider:

   a. What distances will you make measurements from?

   b. How will you measure the distances?

   c. Will you repeat the measurement with different people? (This is called replication.)

d. What will you do if points disagree?

2. Make sure each person makes **at least one** measurement of the ball's angular size and distance. Record your measurement below.

   (a) Angular diameter of ball (to nearest half-degree): ______

   (b) Distance from ball: ______

   Record all your measurements on the table worksheet. Mark the the position of your measurements at your table to **graph all the points in the table worksheet.**

3. Select someone at your table to **graph all the points in the table worksheet.**

2. Interpreting the Graph

Look over the points plotted by your group and discuss the following:

1. Do the points exhibit a pattern? How would you describe that pattern in words?
2. How might you describe the relationship mathematically?
3. Do all the points agree with each other? What factors might explain the differences we see?

3. Angular Size of Astronomical Objects

1. Let's consider the Sun.

   a. Does the Sun's angular size changes during the year?

   b. What month is it the smallest? ______

2. Now let's look at the Moon.

   a. Is the Moon larger when it's full?

   b. What is a supermoon?

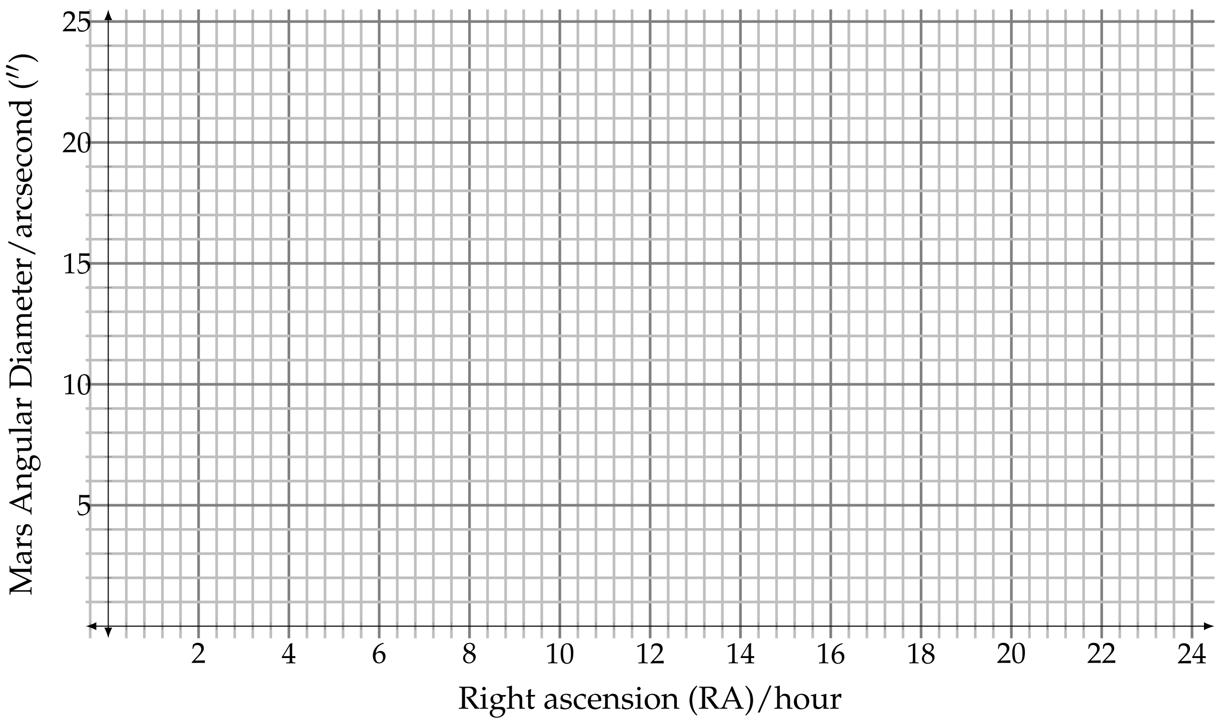
   c. Is the Moon larger when it's near the horizon?

The planet Mars shows the greatest variation in size of all the planets, which we will explore here.

1. In groups of 2-3, start up Stellarium. Find where Mars is today. You can turn off the atmosphere (hit A) and ground (hit G) to help.
2. Once you have found Mars, you can click on it and center the view (by pressing the space key). Take note of Mars's angular diameter (given as "Apparent diameter" in the left-hand side info panel.
3. Zoom in until Stellarium renders some surface features.

4. You are going to look at how Mars's **angular diameter** and **right ascension ("RA")** values each change over time. To do this, open the Date/Time window and vary the date from October 2021 to October 2023, one month at a time. At each date, take note of Mars's **angular diameter** and **right ascension ("RA")**. These are the values you will plot (**NOT** the date!).

5. Plot Mars's angular diameter vs. right ascension in the grid below and answer the following questions.



a. How big is Mars in October 2021? __________ arcseconds
b. Where is it in its orbit in October 2021?
c. In what month is Mars largest? __________
d. How big is it that month? __________ arcseconds
e. What explains the pattern of sizes you find in your graph?

4. Lab Quiz on Moodle

Go to the Lab 3 section on the Moodle page and complete the End-of-Lab Quiz. Write your name on the Table Worksheet and hand it in.

7.5 Lab 4: Phases of the Moon

7.5.1 Worksheet

ASTR 100/1 Lab 4: Phases of the Moon

1. Actual Scale of the Earth and the Moon (Class demo)

1. Suppose the Moon is the size of a golf ball. On this scale, how big is the Earth? **Lower** your hand when you think the demo balloon is at the right size.
2. On this scale, how far would the golf ball Moon be from Earth? **Lower** your hand when you think the demo balloon is at the right distance.

   Relative to the size of the golf ball, this distance is the same as the as the distance from the Earth to the Moon, relative to the size of the real Moon. Hence, **the angular sizes are the same.** If you take a zoomed-in picture of the golf-ball at this distance and compare it to your zoomed-in calibration grid, you will find the golf ball has the same angular size as the real Moon.
3. As part of the extra credit project, take a picture of the golf-ball Moon from the to-scale distance.

2. Modelling the Moon's Phases

You will each get a golf ball with a hole in it so you can put it on a pen or pencil and hold it up. Each table will have a light source that will represent the Sun.

1. To first understand Earth's rotation in relation to the Sun, begin by picturing your head as the Earth. Imagine the top of your head is the North Pole, with Boston at your left eye, and San Francisco your right eye. Take the light bulb on the table to be the Sun.
   a. Which way does your head face when it is noon in Boston?
   b. Which way does your head face when it is noon in San Francisco?
   c. Which way does your head turn to go from noontime in Boston to noontime in San Francisco?
2. Let's examine the Moon's phases as it orbits the Earth. Make sure that you can see the portion of the Moon lit by the "Sun" in your table.
   a. Look for the **crescent** phase, and estimate the angle between the Sun and the Moon (with the Earth at the vertex) when the Moon is a crescent.
   b. Can you ever see a crescent Moon at midnight?
   c. Where is the Moon when it is **new**?
   d. Where is the Moon when it is **full**?

e. Where is the Moon when it is **gibbous**?

3. Suppose the Moon is at **first quarter**.

   a. When should it cross your **meridian**?
   b. When does it rise, and when does it set?

3. Observing the Moon's Phases

1. In groups of 2-3, start up Stellarium.
2. Set up Stellarium for Amherst Center (F6) on 23 February 2022 (F5). Look toward the **east** and adjust the time until you see the Moon rising.

   a. What time does the Moon rise?
   b. Press the semicolon ";" key to turn on the meridian line. What time does the Moon cross the meridian?
   c. What time does it set?

3. If you were taking a picture of the Moon in the daytime, what is the range of times you could take a picture on 23 February 2022?
4. Zoom in on the Moon and look at its shape.

   a. What is its phase on 23 February 2022?
   b. Turn off the ground and center the view on the Moon. Advance the day by opening the Date/Time window, and then clicking the up-arrow (↑) above the day's date, until the Moon is next at first quarter. What is the date?
   c. How can you tell whether a "half-lit" Moon is in the first or third quarter?

5. On this new date,

   a. What time does the Moon rise?
   b. What time does the Moon cross the meridian?
   c. What time does it set?

6. Advance the date by 1 day. What time does the Moon rise? Cross the meridian? Set on this date?

   a. What is the Moon's phase?
   b. What time does the Moon rise?
   c. What time does the Moon cross the meridian?
   d. What time does it set?
   e. What are the differences from Part (6)?

7. Keeping the same time, change your location to Australia (hit **F6** and click on Australia in the location window). What phase is the Moon in?
8. Now, change your location to the Moon and look back at the Earth (search for and select "Moon" in the Location window). What phase is the Earth in?

4. Lab Quiz on Moodle

Go to the Lab 4 section on the Moodle page and complete the End-of-Lab Quiz.

7.6 Lab 5: Motions of the Sun

7.6.1 Worksheet

ASTR 100/1 Lab 5: Motions of the Sun

1. The Sun's Position at Noon

In groups of 2-3, follow along the steps demonstrated by the instructor.

a. Set up Stellarium
    i. Open the Location window and set the location to Amherst Center.
    ii. Open the Sky and Viewing Options window.
        a) Under the "Sky" tab,
            1) Set "Stars Absolute Scale" to 0.0 (or the lowest it will go)
            2) Uncheck "Show Atmosphere"
            3) Under "Projection", select "Cylinder"
        b) Under the "Markings" tab,
            1) Check "Azimuthal Grid"
            2) Check "Meridian"
    iii. Zoom all the way out while staying centered on the South horizon point.
    iv. Open Date/Time window and change the date to 21 September.
    v. Find the time (to within a few minutes) when the Sun is crossing the meridian (azimuth $0°00'$ or $180°00'$, running from due north to due south). What time is it? What might cause it to **not** be 12:00 noon?

b. Plot the **altitude** of the Sun as it **crosses the meridian** on the 21st of each month throughout the year.

2. The Sun's Path during the Day

Watch the Sun's path across the sky on 21 June and 21 December (the summer and winter solstices) over the whole day. On these dates, the Sun reaches its extreme north and south positions respectively. You can advance time faster or slower (or reverse it) using the and buttons in the bottom menu bar, or by **pressing the L and J keys**. Discuss what you see in your groups and answer the following questions:

a. The Sun does not always set due west! What azimuth range do you see it setting over?

____

b. The Sun doesn't approach the horizon going straight down! Sketch what you see in Stellarium. Is the angle the same at both solstices?

____

c. What is the Sun's azimuth at sunset on the equinoxes (22 September and 20 March)? (If there is "landscape" in the way, look for when the Sun's altitude is near zero.)

____

d. Suppose there are mountains rising to an altitude of 10° to the west. How would that affect the azimuth of sunset (when the Sun passes behind the landscape, including mountains) on the equinox?

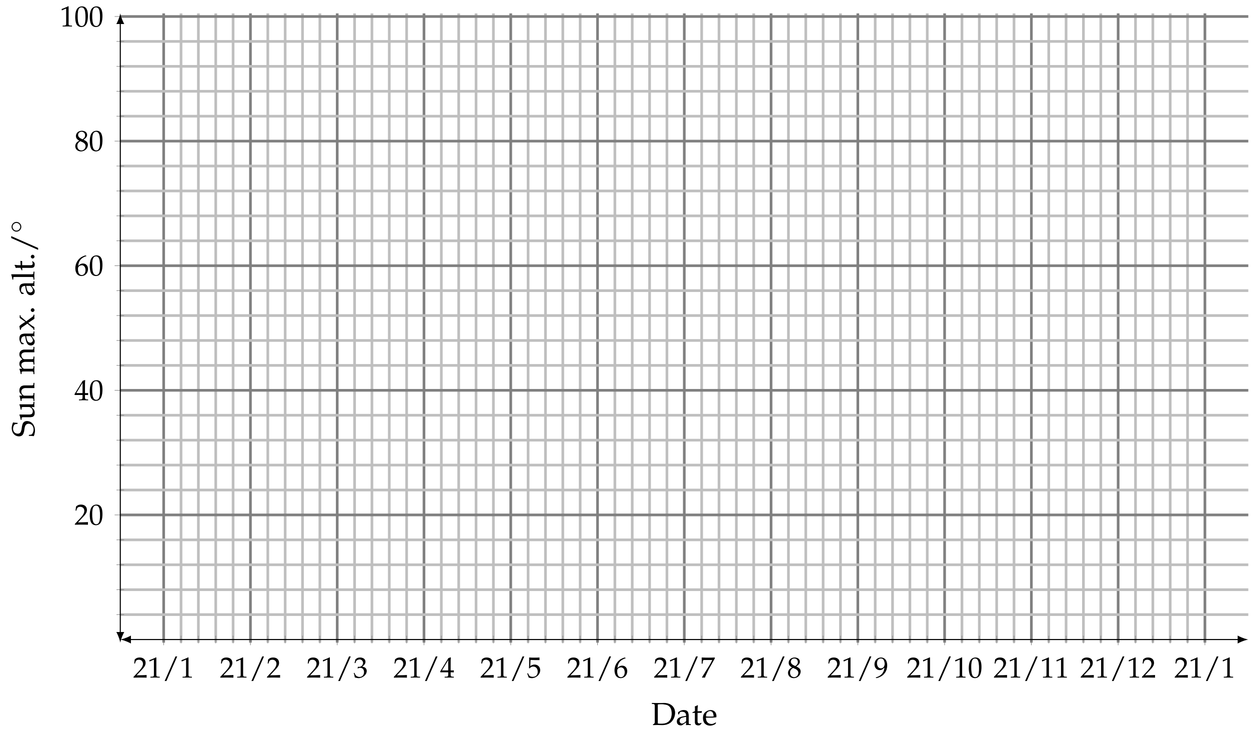
____

3. The Sun's Position at Different Latitudes

Work in pairs and have one person do each part. Then, plot the Sun's noontime altitude throughout the year for both parts in the grid. (Make sure to record the values for the quiz.)

Note: when seen from the southern hemisphere, the Sun crosses the meridian in the **northern** sky!

City	Latitude	Sun max. altitude	Month
Pick a city between S 24°–60°:			
Pick a city in the tropics (between N 23° and S 23°):			



4. The Sun's Path at Different Latitudes

Now, let's look at how the Sun moves across the sky from different locations on Earth. Follow along with your instructor as below:

Open the Location window and type into the "Latitude" entry "N 66d 30m" (note where the spaces are). You should see the red arrow on the map jump to a location north of Amherst Center. (Leave the longitude unchanged from Amherst Center (W 72°) so the time zone stays the same.)

a. At the Arctic Circle (N 66° 30′) and northward, you can sometimes get 24 hours of daylight, and vice versa. Note how the Sun's path becomes more horizontal closer to the North Pole.

b. At the Equator (N 0°), notice how the Sun moves straight up and down as it approaches the horizon. Why would this make twilight shorter in the tropics?

c. From locations at mid latitudes in the Southern Hemisphere, the Sun approaches the horizon at an opposite angle from what we see, and the Sun spends most of the day in the **northern** sky. Note: Does this mean that the Sun is travelling in the opposite **direction** (east or west)?

5. Lab Quiz on Moodle

Go to the Lab 5 section on the Moodle page and complete the End-of-Lab Quiz. Note that some of the questions will depend on what city your team picked for part (3), so be sure to enter the correct latitude of that city.

7.7 Lab 6: Solar Power

7.7.1 Worksheet

ASTR 100/1 Lab 6: Solar Power

1. Power vs. Distance

Working in your table groups, you will carry out two experiments to measure how distance and angle affect the amount of sunlight energy absorbed by the ground. Each group has a flashlight, meter stick, and protractor for these experiments.

a. You should first spend some time deciding what your roles will be in the experiments. Some possibilities are experimentalist, note taker, calculations, number checker, graphing, etc. Discuss and agree on your role, with your team members and write down your role on the table worksheet.

b. Get your flashlight ready by shining it on the white board. Find the edge of the beam, which may be faint and somewhat confusing because of reflections inside the flashlight. Get a clear agreement in your group of where the edge of the beam is.

c. Next you will shine the flashlight on the white board and measure the area of the circle from several different distances. Make measurements of a and **b** (should be approximately the same) with the light bulb at 0.5, 1, 1.5, and 2 meters. *The idea here is the flashlight at 1 meter is analogous to sunlight at 1 AU. Earth's distance varies just slightly throughout its orbit, between 0.983 and 1.017 AU, less than a 2% variation. Mars on the other hand is about 50% farther from the Sun (and its distance varies by 10%), and Venus about 30% closer to the Sun (and its distance varies by ¡1%). From your graph you can see how the intensity of sunlight varies with distance.*

d. Fill in a and b in the table then carry out the calculations to find the area the light is spread over. To simplify the calculations a bit, we will imagine that the flashlight produces 10,000 watts of light output. What we want you to determine is the number of watts per square centimeter at each distance. The *area* of your beam equals $0.79 \times a \times b$. Measure a and b in centimeters to find the area in square centimeters, and then calculate 10,000 watts/*area* to find the watts per square centimeter. (Fill in the table.)

e. Plot you results versus the distance between the board and the flashlight's light bulb. Pick one other distance to fill in a gap in your graph or to check one of the first measurements if it seems inconsistent with the others.

2. Power vs. Angle

You will next repeat the previous experiment, but now you will measure the effect of changing the angle while keeping the flashlight bulb at a constant distance of 1 meter from the whiteboard. *This models what happens on different parts of Earth's surface while the Sun is shining on the ground at an angle. (Mar's axis is tilted a little more than Earth's and is highly variable, while Venus's is very small, just a few degrees, but it spins backward.)*

a. Change your role in this experiment, and write down your new role on the table worksheet.

b. This time you will use the meter stick to keep the flashlight's light bulb at a fixed distance of 1 meter from the board, and a protractor to measure the angle. Note that you can use markers to outline the dimensions a and b of the ellipse created by the flashlight. Try to keep the ellipse of the beam centered on the base of the meter stick so b stays about the same.

c. You will calculate the area of the beam for several angles. In addition to 90°, which you can copy over from the first experiment. Make measurements at 71°, 47°, and 24°. These correspond to the altitude of the Sun in Amherst at noon on the summer solstice, the equinoxes, and the winter solstice respectively.

d. As before, divide 10,000 watts by the area you measured at each angle, determine your y-axis scale, and fill in the table with your measurements and calculations and graph the data.

e. From your graph, at what angle does the intensity of light match the intensity at 1.5m (50% farther away)? Try to estimate that angle then carry out one last measurement at that angle and fill it in the your table.

3. Distance vs. Angle

The angle you measure relative to the whiteboard is like the "altitude" of the Sun. So when the flashlight is shining straight at the board, it is like having the Sun at the zenith, 90° from the horizon.

At noon on the winter solstice in Amherst the Sun has an altitude of about 24°. Compare your graphs to estimate the distance at which the watts per square centimeter (at 90°) is the same as the watts per square centimeter at an angle of 24°. **What distance do you estimate matches the light intensity at 24°? ________ (record this for the end-of-lab quiz**)

4. Lab Quiz on Moodle

Go to the Lab 6 section on the Moodle page and complete the End-of-Lab Quiz. Write your name on the Table Worksheet and hand it in.

7.7.2 Table worksheet

7.8 Lab 7: Calendars, Horoscopes, and Precession

7.8.1 Worksheet

7.9 Lab 8: Motions of the Planets in the Sky

7.9.1 Worksheet

7.10 Lab 9: The HR Diagram

7.10.1 Worksheet

ASTR 100/1 Lab 9: The HR Diagram

1. Stellar Properties

Sitting in groups of 3 or fewer at a computer. Start up *Stellarium*, and put yourself in Amherst. Search for the star *Procyon*, and if necessary adjust the time until it is above the horizon, then work *carefully* through the following together.

Note: It is easier to find the data we need in Stellarium if you limited the information it displays. Open up the configuration window (F2), then click the information tab and click "None" at the top. Select the following to display: Name, Catalog number, Visual magnitude, Absolute magnitude, Distance, and Additional information.

a. What is the star's magnitude? What is its absolute magnitude? Why do these differ?

   A reminder of magnitude scale is shown below. ADD IMAGE

b. Fill in the first 5 columns below using the information in Stellarium:

2. Stellar Sizes

Start up a web browser, and go to the following address (or click on the link in Moodle): **http://astronomy.nmsu.edu/geas/labs/hrde/hrd_explorer.html** Under **Options**, change the x-axis scale to "**B-V color index**" and the y-axis scale to "**magnitude**," and **check** all but "Instability Strip" box. This shows an interactive "Hertzsprung-Russell Diagram" that helps us to examine the properties of stars.

a. **Adjust the Temperature slider** so that the red arrow on the bottom axis of the graph matches the star's B-V color value. Enter the star's temperature in the table.

b. **Adjust the Luminosity Slider** so the red arrow on the left axis of the graph matches the star's absolute magnitude. The program calculates the star's luminosity in solar luminosities (L). Enter the star's luminosity value above.

c. ***With both the Temperature and Luminosity sliders*** set to the values you just found, the program calculates the star's radius in solar radii (R)-in other words, how many times larger or smaller than the star is. Enter the value in the table. This tells you how many times bigger the star's diameter is than the Sun's diameter.

d. Which region does your star fall closest to in the H-R diagram?

3. The Stars We See

In *Stellarium* turn on constellation boundaries (B) and labels (V). Each table will be assigned a constellation: : 1 Boötes, 2 Canis Major, 3 Cassiopeia, 4 Centaurus, 5 Cygnus, 6 Lyra, 7 Orion, 8 Sagittarius, 9 Scorpius, 10 Ursa Minor, 11 Virgo.

a. Find the temperature, radii, and other properties of as many of the brightest stars in your constellation as there are people at your table-break up the work between everyone at the table by writing the names of the stars on your Table worksheet and assigning them to your group members. Write the information for your own star below, and copy this into the Table Worksheet after you have finished.

b. On the whiteboard corresponding to the distance of your star, draw a circle to represent your star. The circle should have a **diameter** in centimeterse equal to the size factor of your star. Use a marker color matching the following scale depending on the spectral type: O, B, A – blue; F, G – green; K, M – red. Write the spectral type of your star next to the star.

4. Nearby Stars

For this activity you are going to examine nearby stars in your constellation. To find them go to Wikipedia's List of Stars in [Your Constellation] or follow the link in Moodle. Sort the stars in order of distance, and look at the nearest stars, one for each person at your table.

In the H-R Diagram Explorer, change the X-Axis Scale to "spectral type." Now when you adjust the Temperature slider you should get the arrow along the x-axis positioned in your star's spectral type (O,B,A,F,G,K,M) and the arabic numeral (0-9) following that letter indicates where in the range the star lies. For example, the Sun, a G2 star, is toward the left (hotter) side of the range of G-type stars, G0 would be at the left edge, G9 at the right edge.

a. Enter the information for the closest star found at your computer below and copy the information into the Table Worksheet, and compare your results at your table.

b. In the H-R Diagram Explorer web app, and click on "the nearest stars" and "the brightest stars." Why do these look so different?

c. How do the stars you can see by eye at night compare to the Sun?

d. How do the nearby stars compare to the Sun?

e. Is the Sun a "typical" star

5. Lab Quiz on Moodle

Go to the Lab 9 section on the Moodle page and complete the End-of-Lab Quiz. Write your name on the Table Worksheet and hand it in.

To learn more about the H-R diagram, visit https://sci.esa.int/gaia-stellar-family-portrait/

7.10.2 Table worksheet

7.11 Lab 10: Distances of Stars in Space

7.11.1 Worksheet

ASTR 100/1 Lab 10: Distances of Stars in Space

1. Building a Constellation

Each table will construct a 3-dimensional model of a constellation. You will be assigned one of the constellations: Aquila, Bootes, Capricornus, Centaurus, Gemini, Hercules, Leo, Pegassus, Taurus, Virgo. You should select at least as many of the brightest stars in the constellation as you have people at your table. Try to pick stars that let you make out the shape of the constellation.

a. Find your constellation in Stellarium. Then sketch it oriented so that it fills most of the white board. Copy the bright stars of the constellation onto the whiteboard with lines connecting them as in the stick figure version in *Stellarium*. (Tap **C** for constellation lines.)

b. Write the Name, Spectral Type, and Parallax next to each of the stars that you are using on the whiteboard. You can find this information by clicking on each star in *Stellarium*. Add this information to your table worksheet.

c. The table will get a bundle of strings, tape, and clips. While holding the tied end of the bundle of strings about 2 meters from the board at about eye level, tape the free end of each piece of string onto the whiteboard at the position of each star. Adjust the strings so that a gentle pull on the bundle keeps all the strings fairly straight and untangled.

d. Each person should calculate the distance of at least one star in parsecs according the the distance formula:

   distance (in parsecs)=1/parallax (in arc seconds)= __________

   also enter this value on the table worksheet.

e. Each person should select a colored ball for the star whose distance they calculated according to the following scheme:

(i) Type: O or B-violet; A-blue; F-green; G-yellow; K-orange; M-red.

(ii) Luminosity class: I-large; II or III-medium; IV or V-small

If your star has an unusual classification try googling it for more information and choose the closest representation for it that you can. Write down the color and size of the ball you decide best represents your star on the table worksheet.

f. From the point where all the strings are tied together, which represents the position of the Sun, measure out a distance of 1 centimeter per parsec distance of each star and fasten the correct color and size ball in place. If the calculated distance is larger than the length of the string, put the ball at the board and write its distance beside it.

g. **When everything is in place, call over an instructor to check your work.**

2. Changing Perspective

Examine the stars in your constellation from the position of the Sun. Their pattern should look very similar to the constellation you see in the sky. Go around the room to look at the other constellations.

a. On the scale of the model, about how far apart are your eyes?__________
Move 10 or 20 parsecs to either side of the Sun and sketch the pattern of stars from the new position. How does it compare to the original pattern?
Copy one of your group's better examples to the table worksheet.

b. Which star appears to change position most relative to its original position as you move to the side? ***Discuss this at your table and answer on the table worksheet.***

c. On the scale of your model, how far away from the Sun is Neptune, roughly speaking? Should star pattern change at all? ***Discuss.***

3. Lab Quiz on Moodle

Go to the Lab 3 section on the Moodle page and complete the End-of-Lab Quiz. Write your name on the Table Worksheet and hand it in.

Extra-credit Moon Project

Try to get a picture of the Moon during the daytime. You can do this from anywhere, and take two pictures one zoomed out so you can see the Moon and the horizon, and the other zoomed in on the Moon. You will need to submit three things:

a. A picture zoomed-out as much as possible showing the horizon and the Moon. (The Moon will look very small in this picture.)

b. A second picture of the Moon zoomed-in as much as possible with your camera.

c. A screen-shot of Stellarium set up to the same location and time as when you took your picture showing the Moon's information at that time.

One of the goals of this project is to learn ***when*** you can see the Moon during the daytime, and ***where*** to look. This changes according to the phase of the Moon. You will also have to plan around the weather. Stellarium can be very helpful in figuring this out. You can also search on the internet for moonrise and moonset times, and then you need to think about where the Moon will be as it goes from east to west.

7.11.2 Table worksheet

7.12 Lab 11: Structure of the Local Group

7.12.1 Worksheet

8 Acknowledgements