Notes

TA Guide for

ASTR 310 Tutorial: The Path of the Sun

ver. 100916

Description

In this activity, explore the pattern of the Sun's paths across the Vancouver sky throughout the year. To find these paths, they use a "computer", the armillary sphere. The tutorial moves back and forth between TA-lead explanations and demonstrations, student exploration and data collection The TA has to keep track of the time and "drive" the activities forward.

Learning Goals

After this tutorial, together with lecture materials, students should be able to

- trace the motion of the Sun on the celestial sphere throughout the year

Set-up — 20 minutes

The students will work together in groups of 2 or 3. We want them to compare the path of the Sun on 4 different days throughout the year: Vernal Equinox (Mar 21), Summer Solstice (Jun 22), Autumnal Equinox (Sep 23) and Winter Solstice (Dec 22). (By the way, the actual date of the equinoxes and soltices can vary by a day or two. The dates given here are the one labelled on the armillary sphere.) There is not enough time for them to collect data on all 4 dates so half the class will work on 2 dates (Mar, Jun) and we give them Sep, Dec, and the other half of the class collects Sep, Dec and we give them Mar, Jun.

Materials:

- (1 per group) armillary sphere. Make sure each sphere has brass fastener attached to the ecliptic ring at Oct 24, an angle-measuring gauge, and that the spring-clips have the latitude locked at 49°N (the green dot on the meridian ring should be right on the Northern horizon,)
- (1 per group) diagram of the sky, photocopied onto 11×17 paper. There are 2 versions of the diagram: one has Oct, Sep, Dec and the other has Oct, Mar, Jun.
- (1 or 2 per group) coloured markers
- **overheads** Please us a dry erase marker, not an overhead pen, to mark on the overheads. You might want a narrow, black one for writing answers on the overhead and thick, coloured one for tracing the Sun's path on October 24.
  1. time of sunrise/sunset multiple-choice questions
  2. location of sunrise/sunset multiple-choice questions
  3. Stonehenge
  4. armillary sphere
  5. Part 1: Orientation
  6. sky diagram (with Oct path only)

Notes

- When we hand out all the pages for a tutorial at the beginning, students often rush thru important steps because they think they have to get the last page ASAP. A better strategy for the students is to hand out pages as needed:
  - (1 per group) Intro and Part 1 (page 1)
  - (1 per group) Part 2 (pages 2,3 double-sided) There are 2 versions of Page 3: one asks students to find Sep, Dec and the other asks for Mar, Jun.
  - (1 per student) Part 3 (page 4)

Before the tutorial, set out the armillary spheres, coloured pens, Part 1 (Orientation) and sky graphic. We'll distribute the two versions of Part 2 later. Even though they don't need the sky graphic yet, the longer they sit looking at it, the more familiar they'll be with what the picture is showing and simpler it will be for them to imagine themselves standing at the center of the diagram.

As usual, invite the students to form groups of 2–3 as they arrive.

Part 0: Introduction and Motivation	5–10 minutes

It's never a bad idea to let the students know why they are doing this, or any other, tutorial. Why should they care? Why should they invest the time and energy? The answer should be more than the marks they'll receive.

First do a quick orientation to the room, asking the students to imagine they're outside. Trace out the horizon and directions North, East, South and West. Ask them where the Sun rises (East) and sets (West) and trace the path of the Sun (with your arm or maybe with a laser pointer?) across the Southern sky.

The next 2 overheads are to motivate why astronomers care about this topic: to predict the future. Don't tell the student that yet, though. Let them see it from the multiple-choice questions.

Put up overhead, "When did the Sun rise this morning?" The Sun rose around 5:56 a.m. or 6:00 a.m. depending on when you run the tutorial. But clocks will read 6:56 or 7:00 because of daylight saving time. Whatever – the answer we're looking for is, "E I don't really care..." This morning's sunrise is over, it's in the past. Do they really care exactly when it rose? Next ask them "When will the Sun set on October 31?" The answer is "A 5:54 p.m." Why should they care now? Because October 31 is Halloween and people (especially parents!) want to know when the Sun goes down and the kids come out trick-or-treating. overhead 1

Put up overhead, "Where did the Sun rise today?" Depending on when the tutorial runs, compared to the equinox, the answer will change. Again, the answer we're looking for is "E I don't really care..." It's already happened so what can it possibly matter anymore? Now ask, "When does the Sun rise due East?" Here, the answer is "B September 23". That's a very important thing to know because when the Sun rises due East (in the Spring), it's the Autumnal Equinox. Before everyone had calendars on their walls, this is how we knew important dates. overhead 2

Emphasize the point for these questions

> by watching sunrises and sunsets and figuring out the pattern, **we can predict the future**

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Tell them about the "computers" they'll be using for the rest of the tutorial:

> The pattern is not simple because it depends on the daily rotation of the Earth on its tilted axis and the yearly revolution of the Earth around the Sun. No one can do it in their heads. We need a computer like Stonehenge or this "computer". It's called an armillary sphere ("ARM-i-larry" or "ar-MIL-ary") ("armillary" means "rings") and it's a computer for predicting the motion of the Sun, planets and stars across the sky.

Stonehenge, armillary sphere overheads

For the rest of the tutorial, the students will learn how to use the armillary sphere – not all the features, just the basics for now – and then predict the future.

Part 1: Orientation	10 minutes

It's important students see the basic parts/motions of the sphere but you have to keep things moving along here. Reassure the students that if they don't catch everything the first time, they'll see it again later in Part 2. Hold up an extra armillary sphere at the front and work your way through the Orientation to the armillary sphere. Be sure to write the answers/responses on the Orientation overhead.

bead We need to refer to the armillary sphere overhead, so don't put the Orientation overhead up yet. From previous versions of this tutorial, we've discovered students are confused throughout the activity if they miss the key fact: the bead represents the Earth and they have to imagine they are **standing on top of the bead at all times.** Refer back to armillary sphere and point to the little stick man standing on the Earth at the center of the rings. Then put up the Orientation overhead so you can work your way through it together.

keep the armillary sphere overhead up

axis To emphasise the bead is the Earth, the wooden dowel is like the axis of the Earth. If you followed the dowel up into space, it would point to Polaris, the North Star.

Orientation overhead

horizon The directions N, E, S, W are marked on the horizon. From the point of view of the stick man, everything above the horizon is visible in the sky; everything below the horizon is not visible.

meridian The **green meridian ring** is marked by angles/degrees that measure the height of objects above the Southern horizon.

equator The numbers on the **blue equator ring** go from 0 to 24. They have something to do with hours/time (as they'll see later.)

ecliptic There's lots written on the **red ecliptic ring**: angles, signs of the zodiac and dates. It's the dates we're looking for. Those dates mark the location of the Sun in the celestial sphere. Remind them that the Sun moves/slides Eastward along the ecliptic at about 1 degree per day.

brass fastener Get them to check there is a brass fastener attached at Oct 24. Ask them to imagine that it's the Sun shining down on them on the bead. Get them to spin the inner sphere so the Sun goes from the Eastern horizon, up above the horizon and the back down to the Western horizon. What does it show? The path of the Sun across the Vancouver sky on October 24.

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a.m., p.m. Ask them to spin the sphere so the Sun is on the meridian. What time of day is it when the Sun (a) crosses the meridian, (b) is at the highest point of the day, (c) is due South? It's noon. Spend an extra moment now describing how in the morning, the Sun is still rising up to the meridian: it's before the meridian or (in Latin) *ante meridiam* or a.m. and in the afternoon, the Sun is past the meridian or *post meridiam* or p.m. A lot of students will probably say, "Ohh! That's what the means!"

While going over the last few of these points, the other TA can start handing out the worksheet for Part 2: the worksheet with Sep, Dec goes with the sky diagram containing Mar, Jun (the dates they *don't* have to collect), and vice versa.

hand out Part 2

Part 2a: How to use the armillary sphere	10 min

First, you'll demonstrate how to use the armillary sphere to collect data and sketch the Sun's path, using October 24. Then the students will do it for their own two dates.

sky diagram overhead

Hold up an armillary sphere and demonstrate how to move the inner sphere and where to look to make the measurements. Get the students to follow along on Page 2 with the same movements and measurements:

location at sunrise Line up the brass fastener on the Eastern horizon. Demonstrate using the angle gauge to measure the location of the sunrise, about 18°South of East. By saying it out loud, "South of East", you model the language that astronomers use. Trace over the dot on the sky diagram.

highes point Rotate the Sun to the meridian. Again, use the angle gauge to measure the height of the Sun in degrees (just a little less than 30°, about 29°). Trace over the point on the sky diagram.

location at sunset Rotate the brass fastener to sunset. Use the angle gauge to measure it's location (about 18° South of West). Trace over the sunset point on the sky diagram.

You can now "connect the dots" on the sky diagram and trace out the path of the Sun across the sky. Emphasise this is *where* the Sun moves across the sky on October 24. But *when* does it happen?

sunset (We start with sunset, rather than sunrise, because it's easier to make the conversion from hours of rotation into an actual time of day.)

Remind them that the Earth takes 24 hours to rotate once. Now remind them that the equator ring is divided into 24 intervals, so rotating by one interval means 1 hour has passed.

To find the time of sunset, first put the Sun at noon. Read the hour on the **blue** equator ring at the point where it crosses the **green** meridian, about 14. Check that each group is doing this measurement.

When it looks like everyone has found 14, get them to spin to sunset. And **here's the key step**: look back at the **blue** equator ring at the **green** meridian – not where the equator ring crosses the Western horizon. **Always read times at the meridian** At the meridian, the hour is about 19.

Okay, now the easy part: how many hours did it take for the Sun to move from noon to sunset? $19 - 14 = 5$ hours. So the Sun sets 5 hours after noon, or 5 p.m. Write that time (actually, circle that time) on the sky diagram.

By the way, some students might not follow this "measure twice, find the difference" method. Instead, they'll carefully count the intervals that pass as they slowly rotate the sphere. Of course, that method works just fine.

sunrise Finding the time of sunrise is very similar, except for the slightly more difficult calculation at the end. Spin back to noon (hour 14 again) and then spin backwards to sunrise. Again look at the equator ring where it **crosses the meridian** at about hour 9. How many hours does it take for the Sun to go from sunrise to noon? $14-9 = 5$. So when did the Sun rise? 5 hours before noon, or 7 a.m. Some students might say 5 a.m. so remind them they have to subtract from noon. Circle that time on the sky diagram.

Now the path on the sky diagram is complete. Emphasise that this is the path the Sun follows on October 24. They've just predicted the future!

Part 2b: The path of the Sun across the sky	10 minutes

Invite the students to repeat these steps to find the path of the Sun on 2 important dates, shown in the Table on Page 3. Remind them to draw and label the Sun's paths on their sky diagram.

Part 3: Questions	Remainder of tutorial

As groups finish Part 2 and draw their 2 paths on the sky diagram, hand out the Question sheet.

hand out Part 3 as needed

The first question asks for the length of the day, which means the number of hours of sunlight during the day, not 24 hours.

The second question makes the link between the pattern of sunrises and sunsets and the seasons. Student 1 correctly remembers that the height of the Sun is important. And Student 3 is (partly) correct because the length of the day is important. Student 2 is incorrect but it is a widely-held misconception that the seasons are caused by the changing distance between the Earth and the Sun. That response is here to get the students to confront their misconceptions. The correct answer, then, is "Students 1 and 3".

We ask the students to take off the black clips and rotate the sphere so the ARCTIC POLE is straight up (the wooden axis is vertical.) This sets the armillary sphere to show the celestial sphere for observers at the North Pole. They'll be a bit confused at first, but the Sun **never** rises on October 24 – it's always below the horizon because we're past the Autumnal Equinox. Simlilary, there is no "sunrise" on June 22 because the Sun is always up. So when does the sun rise at the North Pole? On the Vernal Equinox, March 21.

Point out the group has to hand in the sky diagram with their worksheets so ask them to put their names on the diagram.

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Clean-up	10–20 minutes

After the tutorial, reset all the armillary spheres: each one needs to be set to 49° (in case the clips got moved) and the brass fastener needs to be attached to Oct 24. Make sure there is an angle gauge with each sphere.

Collect all the overheads, in order would be great, and wipe off everything you wrote.