Instructor's Guide for

The Path of the Sun

Notes

Description

In this activity, student explore the pattern of the Sun's paths across the sky throughout the year as seen by observers in Vancouver (latitude 49° N). To collect the observations needed to sketch the path, students use the Nebraska Astronomy Applet Project (NAAP) "Paths of the Sun Simulator". 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 20), Summer Solstice (Jun 20), Autumnal Equinox (Sep 22) and Winter Solstice (Dec 22). 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:

- Lab computer (or their own laptop) capable of running Flash through a web browser. The tutorial uses the NAAP simulator "Motions of the Sun" found at

  `http://astro.unl.edu/naap/motion3/animations/sunmotions.html`

- The TA will demonstrate how to collect data from the simulator so a digital projector is needed. There are fewer technical problems if the TA can connect his/her own laptop to the projector.
- (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
- an overhead of the sky diagram with no paths drawn. 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 "today"

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. It works nicely to give one version to the West half of the room, one version to the East half. Be sure the students with worksheets asking for Sep and Dec have the sky diagrams with path for Mar and Jun, and vice versa. This way, when the activity is complete, all groups will have data for all four dates.
- (1 per student) Part 3 (page 4)

Before the tutorial, set out the 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.

The two patterns explored in this activity are **when** the Sun rises and sets and **where** the Sun rises and set. Ask them a few questions to get them realizing such observations even exist, and perhaps why we care.

1. 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.
2. "Does anyone know what time the Sun rose this morning"

   You're unlikely to get a correct answer. After all, what impact did it have on them?

   "If you don't know, that's alright. Does the time that the Sun rose really have any impact on you? Probably not. What about this: What time will the Sun set on October 31?"

   This question (or make up your own question whose answer matters to you) matters because kids want to know when they can go out for Halloween and when you can expect people at the door. If nothing else, you can suggest

   "...there are certain events, like some religious festivals that start at teh moment the Sun sets. There are people who care about that time so they can prepare. There has to be a way to **predict** these times."
3. "Does anyone know **where** the Sun set last night? No, no just 'in the West' but exactly where? Was it North of West? South of West? How many degrees?"

   Again, we're not expecting students to have the "right" answer. We want them to realize that this question and observation exists. But why should anyone care?

   "When does the Sun set **exactly** in the West? Right, on the equinoxes. That's an important day for religious festivals and other events so this was a test for equinox: the day the Sun set exactly in the West."

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Emphasize the point for these questions

> It's important to be able to predict **when** and **where** the Sun rises and sets. By watching sunrises and sunsets and figuring out the pattern, **we can predict the future**

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 "armillary sphere ("ARM-i-larry" or "ar-MIL-ary") ("armillary" means "rings") or an actual computer for predicting the motion of the Sun, planets and stars across the sky.

Part 1: Orientation	10 minutes

Obviously, students need to learn how to use the NAAP simulator. Education research demonstrates quite clearly that students do not learn the scientific concepts behinds simulations if they are simply given a recipe to follow. Likewise, saying, "Here's a sim. Explore it for 10 minutes..." doesn't work very well, either. A better approach is to challenge them with a couple of tasks. This approach gets them exploring the features of the simulation while constantly watching the outcome of each change they make, watching the connections between the properties of the underlying concepts.

Invite the students to follow the web address on Page 1 to the NAAP simulation and to answer the 2 questions we pose, the altitude of the Sun on July 1 and the location of the most northerly sunrise.

While they're working on these tasks, wander around the room. Be available to help but be careful not to give the answers ("64.0 degrees") or how exactly how to find the answer ("Spin the clock hands until 12 noon and read the altitude here.") Instead, ask questions that will guide them to the solution, for example, "As you change the time, what properties of the Sun are changing? Where is that recorded?"

In the past, most students have been able to figure out the answers to the two questions (the Sun's altitude is 64° at noon on July 1 and its most northerly rise is around azimuth 52.7°, or $90 - 52.7 = 37.3°$ North of West on June 20).

Part 2: The Path of the Sun	20 min

When it looks like everyone has finished the tasks, or are close, hand out Page 2 and gather their attention so you can demonstrate how to use the simulator to collect data and sketch the Sun's path. You can reassure them that even if they didn't figure out all the features of the simulation, they know enough to proceed.

hand out Page 2

Using the computer hooked up to the projector, demonstrate how to collect the observations needed to trace the path of the Sun "today". That is, do it for whatever date you're running the activity. Ask them to follow along at their own computers.

location and date Check that the location is set to Vancouver (latitude 49° North) either by dragging the latitude bar on the map or typing 49 into the latitude text box. Set the day to today's date, by draggin the bar or entering the date into date text box.

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time of sunrise There are a couple of ways to simulate sunrise. You can drag the Sun in the "animation" window over to the Eastern horizon (you can click-and-drag the celestial sphere to change the point-of-view.) You're watching for the moment when the Sun's altitude is 0.0. Notice the clock hands spin. You can also grab those clock hands and spin them around until the Sun rises. When you've got the time for sunrise, write it on your copy of Page 2, ask them to write it on theirs.

location of sunrise With the Sun on the Eastern horizon, read off the azimuth, also given in the window below the animation. Convert that to degrees North or South of (due) East at azimuth 90°. We do this conversion because azimuth is not very intuitive. It is much easier to visualize angles North or South of East.

highest altitude The time used in the simulation is local time, not standard or daylight saving time. So, the Sun reaches it's maximum altitude close to 12 noon. Students might not know that fact (yet) so it might be better to drag the Sun up from the horizon, watching for the location when the azimuth is exactly 180.0° and then "noticing" that it occurs at about 12 noon. Record the maximum altitude and have them record it, too.

Notice this is the moment when the Sun crosses the gray circle, the meridian, in the animation window. In the morning, the Sun is "before the meridian" or in Latin, "ante meridiem" "a.m." while in the afternoon and evening, the Sun is past the meridian, "post meridiem", "p.m."

time of sunset Drag the Sun down to the Western horizon or spin the clock hands. Watch for the time when the Sun's altitude drops to 0. Record the time...

location of sunset ...and location, again converting from azimuth to degrees North or South of due West at azimuth 270°.

Sun's path Switch to the overhead of the celestial sphere. Ask the students to follow along with you: Mark the location of sunrise, the maximum altitude and the location of sunset, and connect the dots with a nice curve. Label the sunrise and sunset times and put the date on the curve.

(It might be possible to project an image of the celestial sphere and then draw the curve on the projection. Be sure, of course, that you're projecting onto the whiteboard, not the projector screen.)

With this demonstration complete, ask the students to do the same thing for the 2 dates on their worksheets.

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

1. This question asks for the length of the day, which means the number of hours of sunlight during the day, not 24 hours. They'll use their own data for 2 dates and read the data off their diagrams for the other 2 dates.
2. The days are longer in the summer and shorter in the winter but they are "balanced" or "symmetric". They should shade in 1/2 of the graph: over the course of a year, half the time is day and half the time is night.

3. In the short, 50-minute tutorials, we don't have time to fully-explore the role that latitude plays in the path of the Sun. However, students have likely heard, in class and elsewhere, about the strange pattern at the North Pole, the "Land of the Midnight Sun." This question asks them to simulate the Sun's motion there. Depending on exactly when this activity runs, the Sun may or may not rise (or set). It certainly doesn't set on June 20 ("midnight Sun"). The Sun does rise, in a way, on the Vernal equinox around March 20.

4. This question explores a "break" in the pattern. They're likely to learn that on the equinoxes, the Sun rises at 6:00 a.m. and sets at 6:00 p.m. That's a good approximation but it's not correct. The students observe slight variations from this ideal pattern that are due to the Earth's variable speed around the Sun and the Sun's analemma. Though this lab doesn't discuss the analemma, it could prime the students to watch for it in an upcoming class or reinforce it if the analemma has already been discussed in class.

Clean-up	5 minutes

After the tutorial, be sure to return the projector to the Main Office.