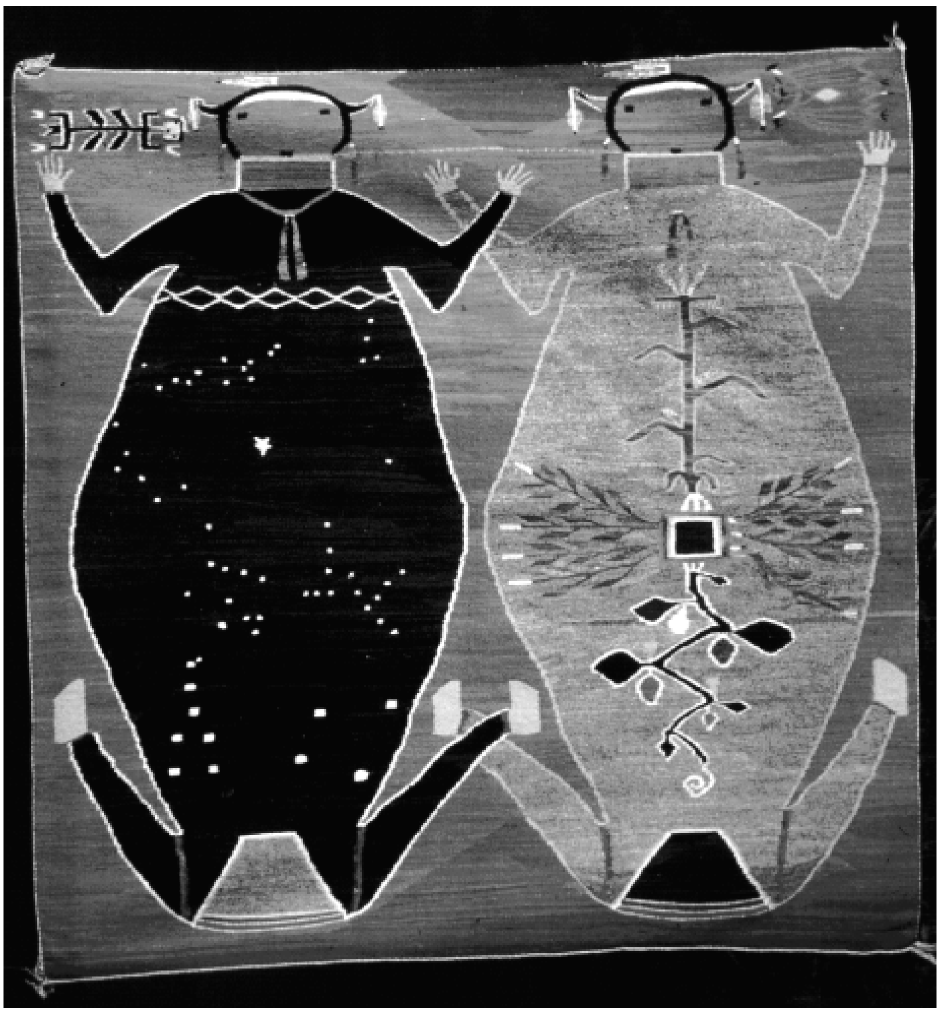
ASTRONOMY OF THE AMERICAS

A PROGRAM FROM THE HOLT PLANETARIUM



by Kevin Cuff, Edna DeVore, John Erickson, Alan Gould, John Hewitt, Steve Luntz, JohnMichael Seltzer, Cary Sneider, and Gregory Steerman

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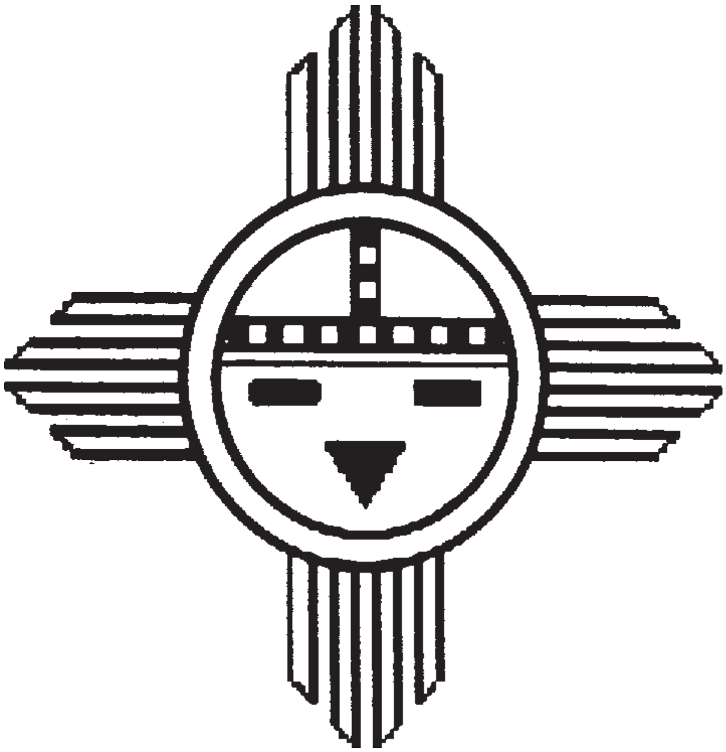

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For latest information, valuable links, and resources relating to the PASS series, visit: https://gss.lawrencehallofscience.org/planetariums

Acknowledgments

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Astronomy of the Americas was developed as both a participatory planetarium program and series of classroom lessons. Staff members who conducted the basic research for *Astronomy of the Americas*, designed the activities and special effects, wrote and edited this volume, and tested the program with audiences at the Lawrence Hall of Science were: Edna DeVore (Project Coordinator), Alan Gould, Greg Steerman, John Hewitt, Kevin Cuff, Steve Luntz, Melinda Santos, Debra Sutter, JohnMichael Seltzer, and Nina Serrano.

Key consultants who contributed ideas and expert advice on this program include: Clara Sue Kidwell, Professor in the Native American Studies Department, University of California at Berkeley; Lee Davis, Director of the California Indian Project, Lowie Museum of Anthropology, University of California at Berkeley; Lee Sprague, Native American Performer with the Turtle Island Ensemble, San Francisco; Dennis Jennings, Native American Health Center, San Francisco; David Dearborn, Physicist and Ethnoastronomer, Lawrence Livermore National Laboratory; Woodrow Bora, Professor Emeritus, History Department, University of California at Berkeley; William Simmons, Department of Anthropology, University of California at Berkeley; Patricia Amlin, Film maker, Berkeley, California; and Ed Krupp, Ethnoastronomer and Director of the Griffith Observatory, Los Angeles, California.

We are also grateful to the entire Hupa Community, who live in Hoopa Valley, California, and especially to Dale Risling, Chairman of the Tribal Council; Ralph Miguelena, Curator, Hupa Tribal Museum; and Jill Fletcher, Educator. Lee Davis, of the Lowie Museum of Anthropology at University of California in Berkeley, provided valuable research data on Hupa astronomy and put us in contact with Hupa community leaders. We obtained their permission to include their traditions in our program. Hupa tribal leaders invited us to visit Hoopa Valley, and even to view the sacred Jump Dance. In the early stages of our program development, staff member Debra Sutter returned to Hoopa Valley to present the program to several hundred school children and many tribal leaders. They provided guidance as to the program's accuracy.

Our special thanks to Carlos Nakai, who composed and performed the music for this program, *Earth Spirit*, and to Canyon Records for their kind permission to use the music.

Photos & Illustrations

We are also thankful to the following individuals and institutions who contributed visual images: Patricia Amlin, filmmaker of Popul Vuh, Berkeley, California; Edward Curtis, *North American Indians*, UC Berkeley Archives; David Dearborn, Lawrence Livermore National Laboratory; Edna DeVore, Lawrence Hall of Science; Alan Gould, Lawrence Hall of Science; Hale Observatory, Mt. Palomar, California Institute of Technology; Hansen Planetarium, Salt Lake City, UT; National Geographic Society, Washington, DC; Ralph Miguelena, Hoopa Tribal Museum; Richard Norton, Science Graphics, Inc.; California Department of Parks and Recreation, State Indian Museum; R. Robert Robbins, University of Texas, Austin, TX; Cary Sneider, Lawrence Hall of Science; Larry Toy, Chabot College, Hayward, CA.

Planetarium Activities for Student Success (PASS)

Series Editors: Cary Sneider, Alan Friedman, and Alan Gould

If you have access to a planetarium for teaching about astronomy, space science, and other subjects, this series of books is for you. Designed for both experienced planetarium professionals and teachers who will be using a planetarium for the first time, these volumes provide a wealth of field-tested strategies and practical suggestions for presenting entertaining and educationally effective programs for students.

The first four books provide a general orientation to astronomy and space science education with applications for both the planetarium and classroom settings. Each of the remaining volumes presents a complete planetarium program and related classroom activities. We hope you will find the materials useful in your work with students and teachers, as well as springboards for your imagination and creativity.

Volume 1: Planetarium Educator's Workshop Guide

Participatory planetarium programs involve students actively in the planetarium environment. The most effective programs are both entertaining **and** educational. This guide introduces the theory and practice of developing effective planetarium programs through a series of thought-provoking activities and discussions.

Volume 2: Planetarium Activities for Schools

This volume provides a wealth of effective planetarium activities for elementary and middle school students, as well as ideas for developing new activities for students of any age.

Volume 3: Resources for Teaching Astronomy & Space Science

There is a wide spectrum of resources for teaching astronomy and space science in elementary and middle schools. This annotated resource guide has the best resources that we have found, including school curricula, books, periodicals, films, videos, slides, professional organizations, planetariums, and telescopes.

Volume 4: A Manual for Using Portable Planetariums

Primarily a "how-to" manual for setting up and using a portable planetarium, this guide has many suggestions useful for teaching school programs in **any** planetarium.

Volume 5: Constellations Tonight

In this participatory version of a classic night sky planetarium program, students receive star maps and have an opportunity to use them to find constellations in the planetarium sky. Classroom activities include creating constel-lations and using star maps.

Volume 6: Red Planet Mars

Students discover Mars three different ways during this planetarium program. They find the red planet by observing it over a period of several nights as it moves against the background stars. Then they view it through a telescope and try to map its surface. Finally they see Mars via space probes. Classroom activities involve students in modeling the solar system, and creating creatures that could survive under different planetary conditions.

Volume 7: Moons of the Solar System

This program begins with observations of the Earth's Moon and a modeling activity that shows why the Moon goes through phases and eclipses. Then the students look at Jupiter's four major moons on a series of nights and figure out how long it takes each one to circle Jupiter. Finally, the students journey through the Solar System to see many moons through the "eyes" of modern spacecraft. Classroom activities involve students in performing experiments in crater formation, using moon maps, and designing lunar settlements.

Volume 8: Colors and Space

What can we learn about the stars and planets from their colors? Answering this question requires a fundamental understanding of why we see color. During this program, students deepen their understanding through a series of activities in which they "travel" to an imaginary planet circling a red sun, and experiment with color filters and diffraction gratings. Related classroom activities include making secret messages that can only be decoded with color filters, and then using the same filters to view nebulae and planets.

Volume 9: How Big Is the Universe?

Based partly on ideas from the short film *Powers of Ten*, this program surveys distances and sizes of things in the universe. Starting with ordinary things on Earth that students are familiar with, they move to progressively more distant astronomical objects: the Moon, the Sun, the Solar System, nearby stars, the Milky Way galaxy, and clusters of galaxies. Students use various methods to determine distance: parallax, "radar," and comparing brightness of objects. Classroom activities include students writing their complete galactic address, making a parallax distance finder, finding the distance to the "Moon," and activities about the expanding universe.

Volume 10: Who "Discovered" America?

Students ponder the meaning of the word *discover* in this program. Can one "discover" a land where people are already living? Students learn the reasons and methods by which Columbus navigated to the "New World," and some of the impacts of his voyages on Native Americans. They also find that certain myths about Columbus are untrue. He was not, for example, alone in believing that the Earth is round. Students also learn about other explorers who "discovered" America long before Columbus's time. Classroom activities include determining the shape and size of the Earth, using quadrants to determine latitude, and modeling lunar eclipses.

Volume 11: Astronomy of the Americas

There are hundreds of Native American cultures, each with distinctive views of the heavens. There are also common threads in many of those cultures. In this program students visit five cultures: the Hupa people of Northern California, plains and mountain tribes that have used Medicine Wheel in Northern Wyoming, the Anasazi of Chaco Canyon in New Mexico, the Mayan people in Mexico and Central America, and the Incan people in Peru. Students observe moon cycles and changes in the sunrise and sunset positions on the horizon and learn how solar observations help Native Americans stay in tune with the harmonies of nature. Classroom activities include the Mayan and Aztec number systems, observing changes in real sunset positions, and learning how Venus can appear as either the "Morning Star" or "Evening Star."

Volume 12: Stonehenge

In this program, students learn what Stonehenge is and how it could have been used by its builders as a gigantic astronomical calendar. They also learn how astronomer Gerald Hawkins discovered Stonehenge's probable function, by actively formulating and testing their own hypotheses in the planetarium. Along the way, they learn a lot about apparent stellar, solar, and lunar motion, and the creation of the research field of "archeoastronomy." Classroom activities include constructing a special sundial to represent the entire yearly cycle of solar motion.

Astronomy of the Americas

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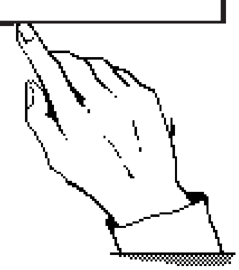
Planetarium Program

Classroom Activities



Astronomy of the Americas

Planetarium Program

Preface

As with people everywhere in the world, Native Americans look at sky above and observe the Sun, Moon, stars and planets. In many places in the Americas, the original astronomical knowledge of the sky has been preserved and passed on to Native Americans who are alive today. In other places, Native American astronomy has been rediscovered through the efforts of archaeologists, ethnologists, astronomers, and others. Altogether, Native American astronomy presents to us today a vision of living in harmony with the cycles of the Earth, Sun, Moon, stars and planets.

In all of the Native American astronomies included in this program, there is a common theme: horizon astronomy. Watching for the rising and setting of astronomical objects allows us to track time, keep calendars, follow the seasons, and better understand our place in the cycles of the cosmos.

You will notice that the words *Sun*, *Moon*, and *Earth* are always capitalized. In most text materials you will sometimes find these words capitalized and sometimes not. Our decision to capitalize here is for the special reason that Grandfather Sun, Grandmother Moon, and Mother Earth are never viewed as objects by Native Americans. They are as important as our brothers, sisters, and cousins, and not simply large objects floating in space. This is consistent with what all of our Native American consultants have taught us—that although there are large cultural differences among different Native American peoples, they all share certain important convictions about the relationship between humankind and the natural environment.

Astronomy of the Americas explores the astronomical concepts of five cultures:

❖ the Hupa of northern California

❖ the Plains people and Medicine Wheel, Wyoming

❖ the Anasazi of Chaco Canyon, New Mexico

❖ the Maya of Mexico and Central America

❖ the Inca of Peru

It would be very difficult to include all five cultures in a 50-minute program. Although the time of presentation will vary greatly according to the particular class of students and style of the teacher, the first section on the Hupa is longest, taking from 30 to 40 minutes. Here are some possible presentation strategies:

1. Present two short programs (30–40 minutes each). The first one could be just on the Hupa and the second one on the other four cultures.

2. Present only astronomies of North America, including just three sections: the Hupa, the tribes that frequented Medicine Mountain, and the Anasazi.

3. Another North American astronomy program sequence could be: the Hupa, the Anasazi, and the Maya. [The Medicine Mountain section reinforces horizon astronomy concepts already presented in the Hupa section.]

4. For a single program that is astronomy of "all the Americas," the Incan section must be included, since it is the only section on South America. Such a program could include either
a. the Hupa, the Anasazi, and the Inca, or
b. the Hupa, the Maya, and the Inca.

Astronomy of the Americas offers an opportunity to sample the astronomy from five different Native American tribes. There is much more to learn about this topic than can be included in a single planetarium program. You may wish to tie *Astronomy of the Americas* into further lessons about Native Americans or astronomy. The classroom activities in this volume were designed to complement activities in the planetarium program. The GEMS Teacher's Guide, *Earth, Moon and Stars,* published by Lawrence Hall of Science, offers a further related set of lessons for grades 5–9. A bibliography for children and adults is included in this book to guide your continued exploration of Native American astronomy, science, and culture.

Objectives

In this planetarium program, the students will be able to:

1. Describe how cycles of the Moon are used to keep a calendar.

2. Tell how the sunrise and sunset positions change throughout a year and how features on one's horizon can be used in conjunction with sunrise and sunset to define a yearly calendar.

3. Recognize the "Rabbit in the Moon."

4. Make a drawing to represent an astronomical event—a supernova.

5. Tell how the movements of the planet Venus correspond to elements of the Mayan creation myth, the Popol Vuh.

6. Appreciate the astronomical achievements of Native Americans, the diversity of Native American cultures, and the values of living in harmony with nature shared by nearly all Native Americans.

Materials

1. Clipboards and Hupa Calendar Stones handout. Make one copy of "The Hupa Calendar Stones" handout, page 9, for each student. Provide clipboards or other surfaces for the students to write on during the program.

2. Moon Phases. Be prepared to project each phase of the Moon.

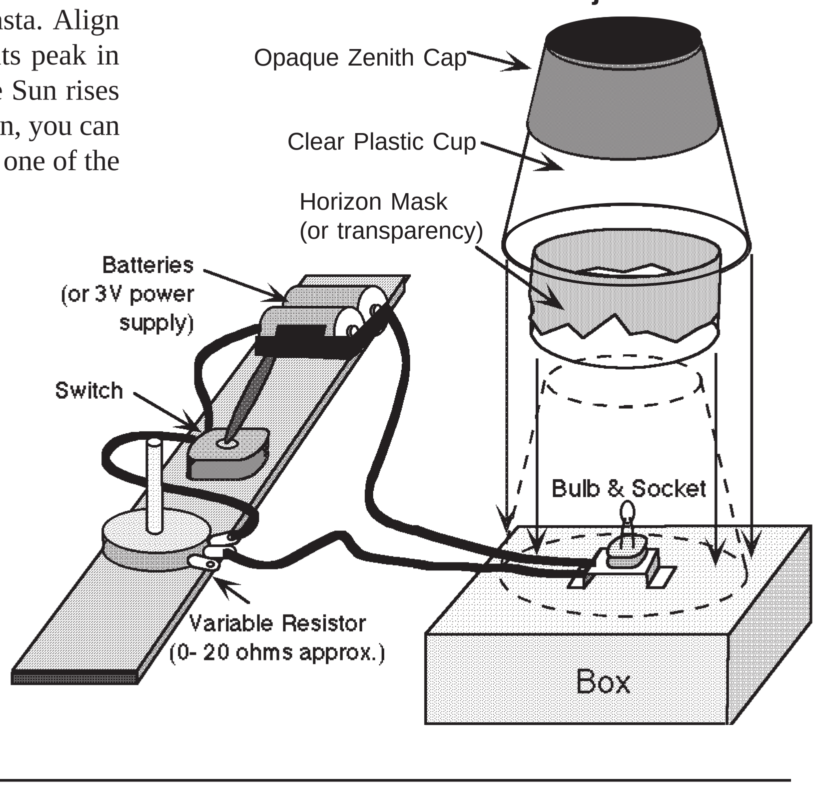
3. Eastern Horizon Mountain Ridge.
Prepare an Eastern Horizon Mountain Ridge with two high peaks, Mount Lassen and Mount Shasta. Align Mount Lassen so that the Sun rises over its peak in December. Align Mount Shasta so that the Sun rises over its peak in May. To prepare the horizon, you can use the artwork on the following page with one of the following methods:

a. Make cardboard cutouts and hang them on the horizon. This technique is especially good for portable planetariums, with the cardboard attached by means of Velcro.

b. If your planetarium has a panorama projection system, make slides of artwork on page 7 and make the proper alignments of the two peaks to match the December and May sunrise positions on your horizon.

c. Make a "mini-brute-force" horizon projector using a #605 light bulb, a Mini-mag lite® flashlight bulb, a STARLAB main star bulb, or other suitable light bulb with a very small filament. Photocopy the artwork on a transparency and form it in a cylindrical shape to make a horizon mask. (See illustration below. The variable resistor is optional.)

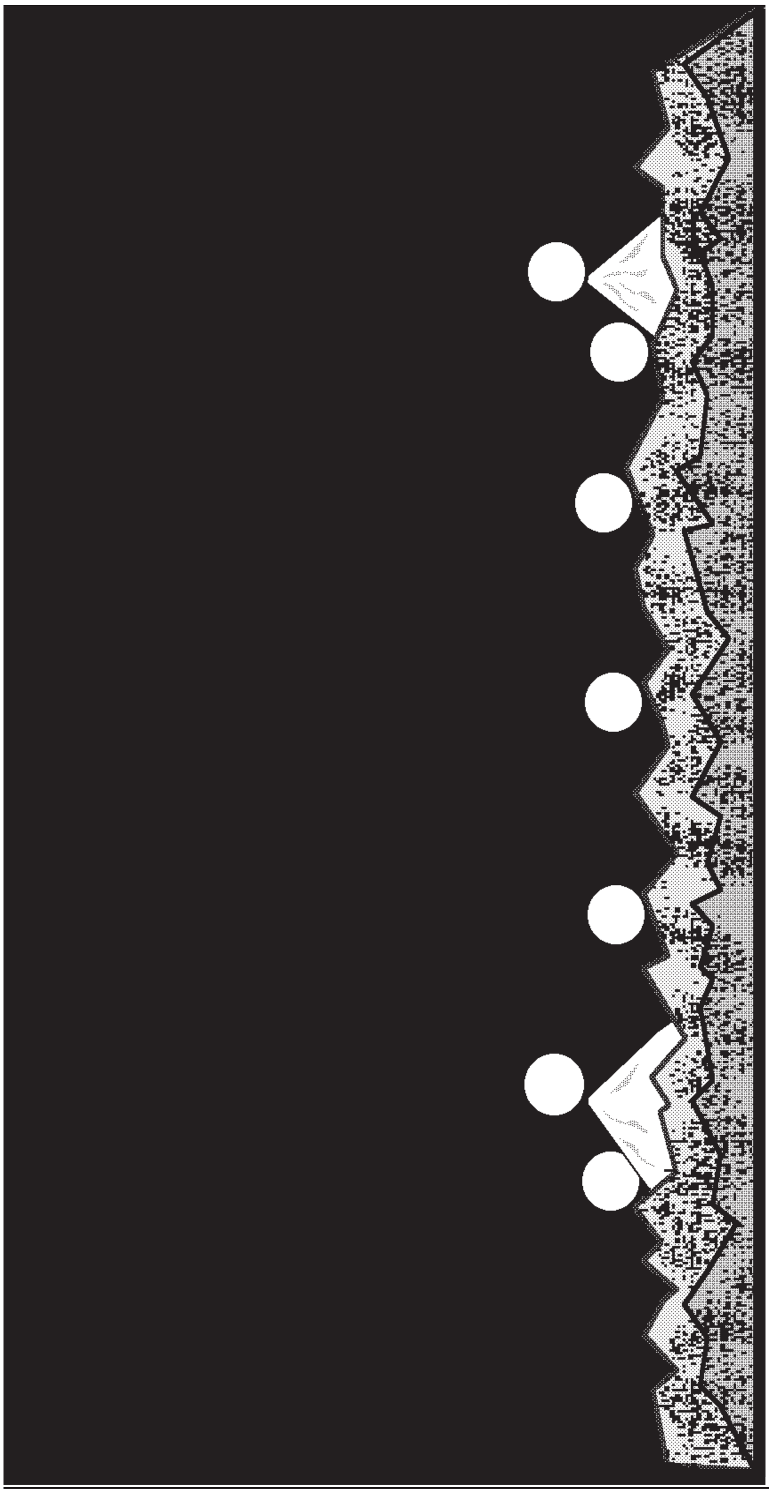
Mini-Brute-Force Projector



Monthly Sunrises

Eastern Horizon Mountain Ridge

Master for Panorama or Overhead Transparency



December
(Mount Lassen)

January &
November

February &
October

March &
September

April &
August

May & July
(Mount Shasta)

June

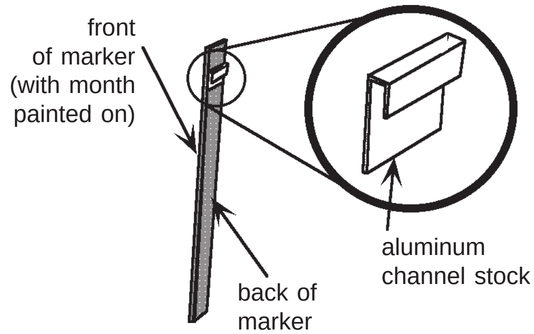
Master for
Mini-Brute-Force
projector

Note: The monthly positions of sunrise are not equally spaced along the horizon. It changes slowly near the solstices (December and June) and rapidly near the equinoxes (March and September).

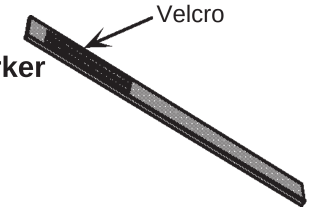
4. Horizon markers. You will need 12 horizon markers labeled for each month of the year for marking the rising sun. These can be wood or cardboard markers with hooks or Velcro to hang on your horizon. In a portable planetarium, you can even use Post-its™. You also need two sunset markers for the solstices in June and December.

5. Medicine Wheel Cairns. Using the artwork below, make either cardboard cutout cairns, panorama projection slides, or a photocopied transparency for "brute-force" projection. Make two cairns and be ready to show them positioned at the summer solstice sunrise and sunset points.

Horizon Marker Design 1

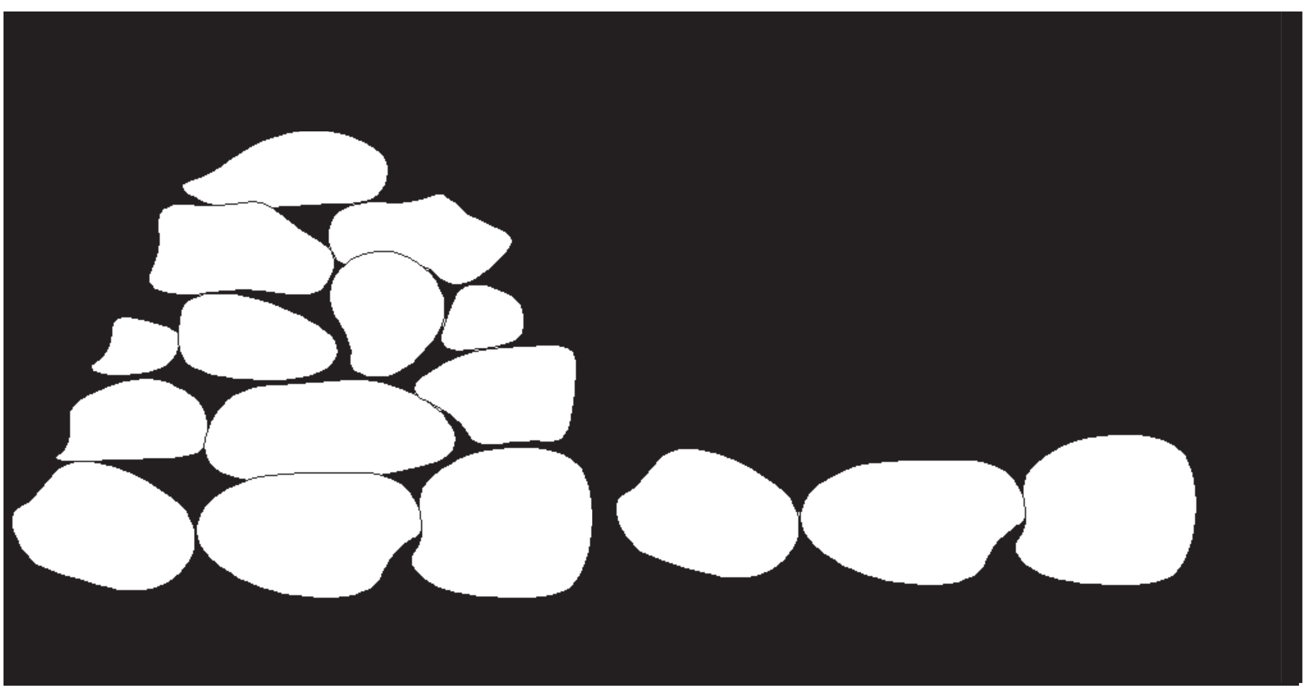


Horizon Marker Design 2



Photocopy Master for Mini-Brute-Force horizon projector:

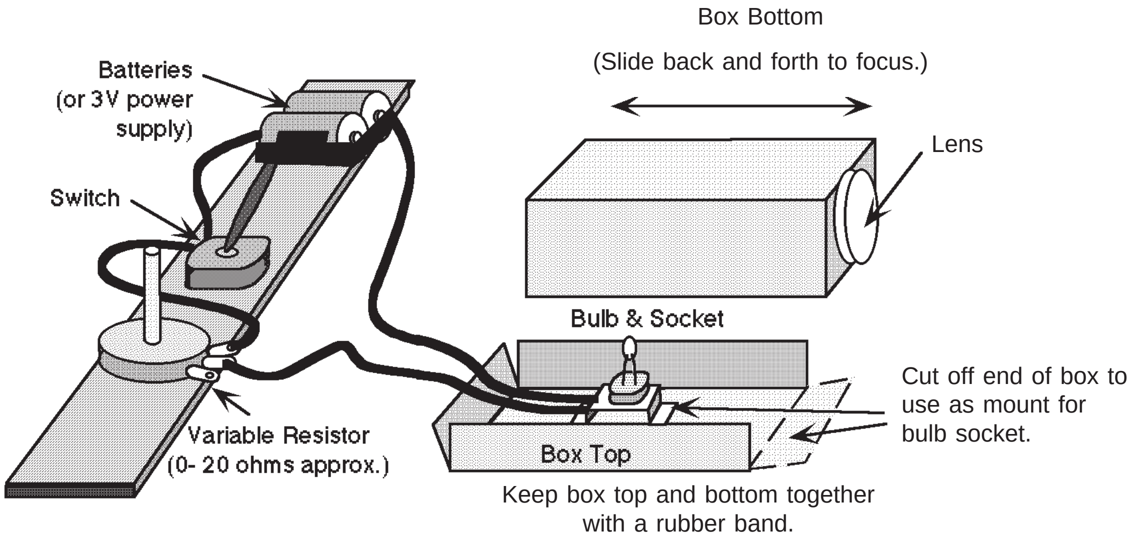
Artwork for panorama projection (and pattern for larger posters):



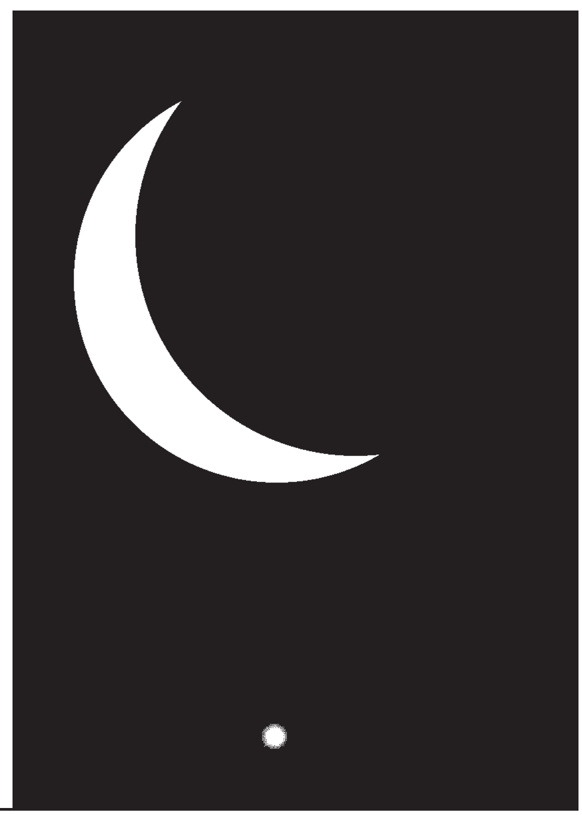
(For posters, make black outline rocks on white background)

6. Supernova Projector. You will need to be able to project a dot and vary its brightness from "dim star" to something rivaling the Moon in brightness. This can be accomplished using a "dot projector" light source with a variable voltage (potentiometer) control.

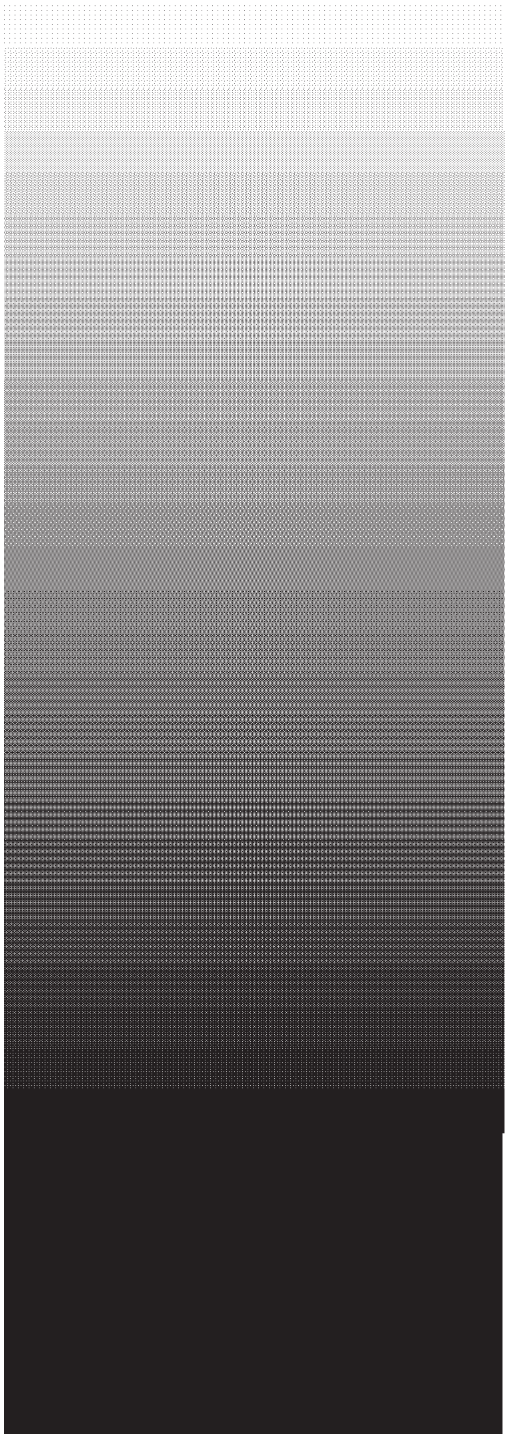
Use as small a filament bulb as possible (see list under 3c on page 10). The longer the focal length of the lens, the smaller and brighter the "star" will be.



The supernova can also be accomplished using an overhead projector covered with opaque cardboard that has a small hole in it and covered by a photocopy of the Supernova Dimmer on the following page. The Supernova Dimmer is simply a graduated gray scale which, when moved over the hole in the cardboard, controls the amount of light that can pass. Start with the darkest end of the Supernova Dimmer transparency and slowly slide the Supernova Dimmer over the small hole until the "supernova" is as bright as possible. Stop at the clear end of the Supernova Dimmer, or remove it entirely. At right is an optional supernova with waning crescent moon for use in making an overhead projector transparency.



Supernova Dimmer



7. Black construction paper and chalk for supernova drawing. Optional: Use fluorescent chalk if you have UV lights (blacklights) in your planetarium.

8. Venus Projector. You will need to be able to switch rapidly from Venus as an "evening star" to Venus as a "morning star." The easiest way to do this is to use any two of your planet projectors positioned on opposite horizons of the sky, east and west. To create the "morning star" you can move diurnal motion forward to make the eastern planet rise. To create the "evening star" you can move the diurnal motion in reverse to make the western planet appear above the western horizon.

During the program, use diurnal motion in forward or reverse to make Venus appear as the bouncing ball in the game played by the twins in the Popol Vuh, as described in the script. The "bouncing ball" motion being portrayed is Venus's motion over a period of many weeks, not just a single night.

In a portable planetarium, you can use the supernova projector described on the previous page. Mount it on a stand so you can point it at the eastern horizon or western horizon, as well as higher in the sky.

9. Optional Audio Tape and Lighting: For lighting during the transitions, we arrange four silhouettes of trees with colored lights behind them, one at each of the four cardinal directions. North is white; East, yellow; South, red; and West, blue. The lights are all wired through a single dimmer so they can be faded in and out in each transition time. Have a stereo cassette tape player and tape of Native American music to play as a transition when traveling to the next location of interest. We have used the album *Earth Spirit* by Carlos Nakai, produced by Canyon Records. There are also sections of narration which can be taped and played instead of being given live by the presenter, specifically, the Mayan creation myth (Popol Vuh), and the concluding paragraph.

10. Slide projector. Optional: have an extra slide projector that you can crossfade from the full moon slide to the "rabbit moon" image.

11. Slides

Image Source

Introduction:

1. "Astronomy of the Americas" .... LHS
2. Navajo Weaving .... NGS: Bob Sacha
3. Man in cave with stars on ceiling .... NGS: Bob Sacha

The Hupa People

4. Map with Hoopa marked .... LHS
5. Hupa Valley from ridge top .... Sneider
6. Sacred House with calendar stones .... Parks
7. Hupa woman with a child .... Curtis
8. Hupa girls in brush dance clothing .... Miguelena
9. Hupa children in jump dance clothing .... Miguelena

The Plains People

10. Map with Medicine Wheel marked .... LHS
11. Big Horn Medicine Mountain .... LHS
12. Medicine Wheel .... LHS
13. Close up at Medicine Wheel .... LHS

The Anasazi People

14. Map with Chaco Canyon marked .... LHS
15. Sun Watcher at Chaco Canyon .... NGS: Tom T. Hall
16. Person next to butte at sunrise .... NGS: Bob Sacha
17. Full Moon .... Hale
18. Rabbit outline on Moon .... LHS
19. Petroglyph at Chaco Canyon .... Norton
20. Drawings of petroglyphs in southwest USA & Mexico .... LHS
21. Rabbit with star at foot bowl, Mimbres Indians .... Robbins
22. Crab Nebula .... Hale

The Mayan People

23. Map with Chichen Itza marked .... LHS
24. Aztec Calendar .... Hansen
25. Caracol at Chichen Itza .... Toy
26. Day keeper painting Mayan text .... NGS: B.D'Andrea
27. Day keeper writing in Latin .... Amlin
28. Boys Playing Ball .... Amlin

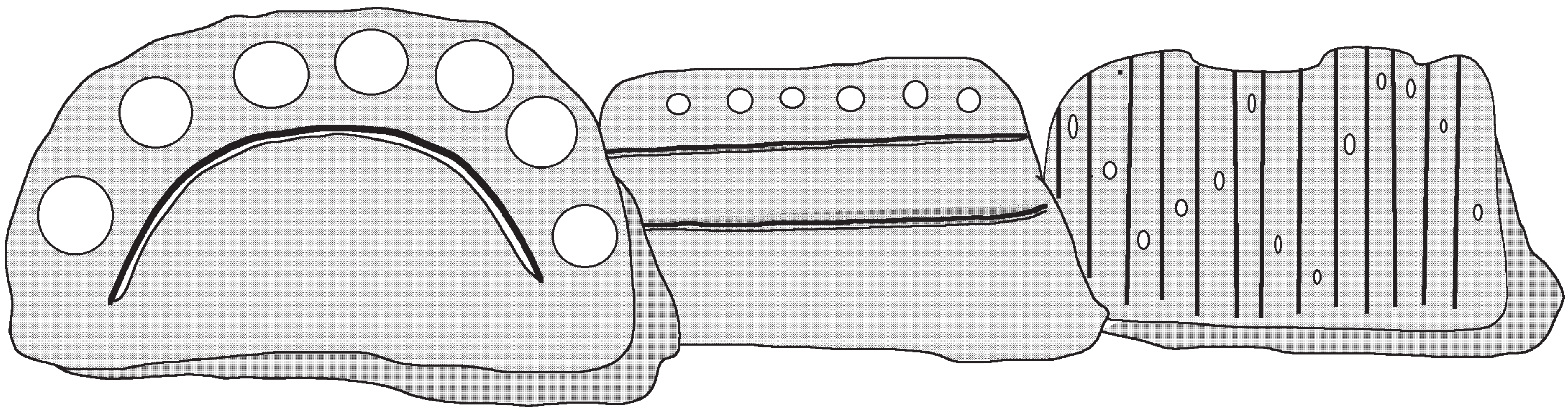
29.	Men playing ball	NGS: Bob Sacha
30.	Blood woman riding deer	Amlin
31.	Dresden Codex: Venus Ephemeris	Hansen
The Inca People		
32.	Map with Machu Picchu marked	LHS
33.	Torreon oblique view	Dearborn
34.	Shadow on bedrock stone	Dearborn
35.	Intimachay entrance	Dearborn
36.	Horizon through window of Intimachay	Dearborn
37.	Machu Picchu from distance	Dearborn
38.	Modern Peruvian peasant marker	Dearborn
Conclusion		
39.	Hupa girls in brush dance clothing	Miguelena
40.	Credits	LHS

Slide Sources

Amlin: Patricia Amlin, Berkeley, California
Curtis: Edward Curtis, *North American Indians*, Univ. of Calif. Berkeley Archives
Dearborn: David Dearborn, Lawrence Berkeley Labs, UC Berkeley
Hale: Hale Observatories, Mt. Palomar, California Institute of Technology
Hansen: Hansen Planetarium, Salt Lake City, Utah
LHS: Lawrence Hall of Science, University of California at Berkeley
NGS: National Geographic Society, Washington, DC
Miguelena: Ralph Miguelena, Hoopa Tribal Museum, Hoopa Valley, CA
Parks: State Indian Museum, California Department of Parks and Recreation
Robbins: Robbins, University of Texas, Austin, Texas
Sneider: Cary Sneider, Lawrence Hall of Science, University of California at Berkeley
Toy: Larry Toy, Chabot College, Hayward, CA

Slides of Medicine Wheel are also available from Richard Norton—Set 7400: Archaeoastronomy (46 slides) available from Science Graphics, Inc. P. O. Box 7516, Bend, OR 97708. 503-389-5652.

The Hupa Calendar Stones



The Moon Stone

Each shallow hole represents a time interval between 3 and 4 days. The eighth position marks the time of the dark (new) Moon. This Moon is in the land of the dead and is imagined to be underground, below the Moon stone. The month begins at the first thin crescent Moon and is marked in the far right hole.

The Universe Stone

Shadows falling on the shallow holes may have confirmed key sunrise observations in the high country. The stone is divided into three parts, representing the Sky, the Earth, and the Underworld.

The Year Stone

There are thirteen vertical bars. The bar at the far right represents the first month. It begins with the first thin crescent moon after the Winter Solstice. Since twelve complete lunar cycles ($29^1/_2$ days each) is less than a solar year, a short thirteenth month is added to adjust the lunar year to the solar year. The short thirteenth month averages just 11 days.

Setup

Instrument and Special Effects:

1. **Annual motion**: Set the Moon as a thin waxing crescent with the Sun at around November 20 on the ecliptic.
2. D**iurnal motion**: Place the Sun at sunrise position on the southeastern horizon.
3. **Lighting:**
   a. Blue dome lighting for people to enter.
   b. Turn on title slide.
   c. Optional: four-color lights and cardinal point projectors.
   d. Optional: check **black lights** for use in Chaco Canyon segment.
4. **Special Effect Projectors:**
   a. Panorama of eastern horizon skyline.
   b. Monthly sun projector aimed at eastern horizon (7 sun positions).
   c. Month hangers for marking sunrises and sunsets: one complete set for 12 months plus one additional for June and December solstice sunsets.
   d. Panorama of Medicine Wheel cairns.
   e. Supernova projector.
5. **Latitude**: 42° North.
6. **Pointers:** Check for working light pointers.
7. **Planets:** Two planets are permanently positioned along the ecliptic. One is in “May” and the other in “August” for the Popol Vuh Venus effects.
8. **Slides**: Cue up to first slide.

   Optional: Cue up extra slide projector with the single slide of the red, Rabbit Moon and align it with the Full Moon in the other projector.

Recommendations for Using the Script

We don’t expect the script that follows to be memorized as an actor might memorize a part. Use it as a guide in learning, rehearsing, and improving presentations. We recommend that you read the script once or twice; then work with it in the planetarium, practicing the projector controls, slides, special effects, and music. You should be able to imagine yourself presenting information, asking questions, and responding to participants. For your first few presentations, you can have the script on hand, using major headings as reminders of what to do next.

The script is organized in blocks or sections. The purpose of these separations is only to help you learn and remember what comes next. Once you have begun a section, the slides or special effects and your own train of thought will keep you on track.

Directions for the instructor are printed in italics, the instructor’s narrative is printed in regular type, and ***directions and questions to which the students are expected to respond are printed in bold italics.*** There is no point in memorizing narration word-for-word, since what you need to say will depend upon the students. The language you use and the number and kinds of questions you ask will depend on how old the students are, how willing they are to respond, and how easily they seem to understand what is going on.

We believe the most important elements of the program are the questions and the activities, since these involve the students in active learning. If you must shorten your presentation, we recommend that you borrow time from the narration.

Script: Astronomy of the Americas

Introduction

Music: Native American music.

Optional Effect: Four colored lights on at cardinal points.

Image 1: Title Slide

Welcome. My name is ______________ and I would like to welcome you to the__________ Planetarium. Native Americans of long ago had extensive knowledge of the sky. In hundreds of different Native American cultures, this knowledge has been passed on from generation to generation and is still in use today. Each culture has a unique viewpoint, but there are some common themes among most of them.

Fade four colored lights and title slides, and turn on stars.

First, let's imagine we are far from the city. It is late November, and we are viewing the sky just before sunrise. Native Americans know that the position of sunrise is intimately linked with the rhythms of the seasons.

Darken the sky. Bring up stars. Moon in young waxing crescent phase, late November.

Please tell me when you see the Sun in the sky. I will hang a marker for this November sunrise position.

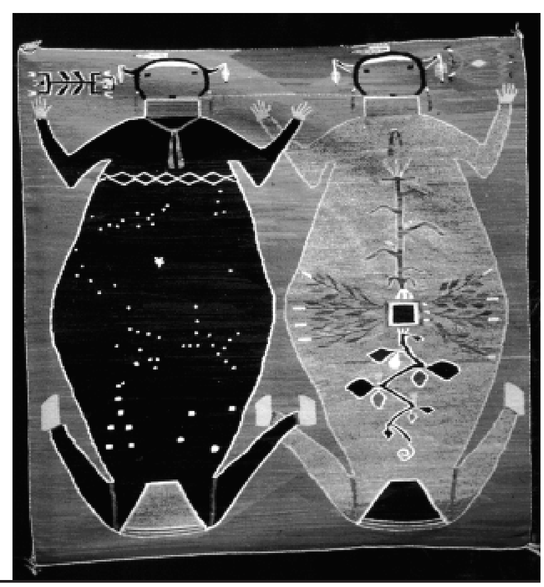
Turn on diurnal motion. Stop at sunrise: when the Sun is about one foot above the springline of the dome. Bring up blue sky, and turn stars off as the Sun rises.

Hang marker to show sunrise point.

The planetarium is like a time machine that allows us to magically speed up the Sun's daily crossing.

Turn on diurnal motion. As the Sun crosses the sky, show the next two images and describe them.

Image 2: Navajo Mother Earth, Father Sky



This is a Navajo weaving depicting the sacred buckskins of Mother Earth and Father Sky.

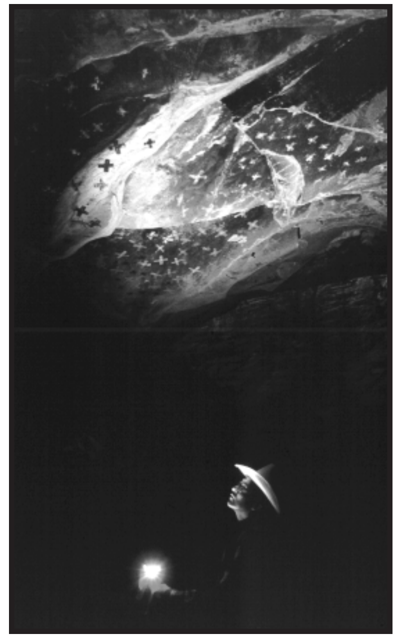


Image 3: Man in cave with stars painted on the ceiling

Like you, Native Americans observe Grandfather Sun, Grandmother Moon, and their relatives: the stars and planets. They help them live in harmony with natural events on Mother Earth. The slow changes of the sky provide a natural calendar that helps determine when to hunt, when to plant and harvest, and when to celebrate rituals and ceremonies. We keep time with paper calendars on the wall, and digital watches on our wrists, but the sky provides a clear calendar for the careful observer, as you will soon see. We are now at sunset.

Turn on the stars as the Sun sets. Crescent Moon should be visible low in the southwest. Stop diurnal motion with Sun below southwestern horizon.

Look around the planetarium sky. Perhaps you can find the stars we call the Big Dipper.

Option: Allow a student to point out the stars of the Big Dipper.

As many of you know, the two pointer stars in the bowl of the Big Dipper point to the North Star.

Point it out for the group.

Throughout the Americas, the sky helps Native people to find the directions: north, east, south and west. These four directions have spiritual as well as physical meaning for Native Americn cultures. East, where the Sun rises, is connected with the idea of birth and the beginnings of cycles. West, where the Sun sets, is connected with death and the ends of cycles.

Turn on Cardinal Points. Turn on four colored lights at cardinal directions. Transition music.

Many tribes associate a color with each of the four directions, which you now see in the sky.

The Hupa People: Who Live Where The Trails Lead Home

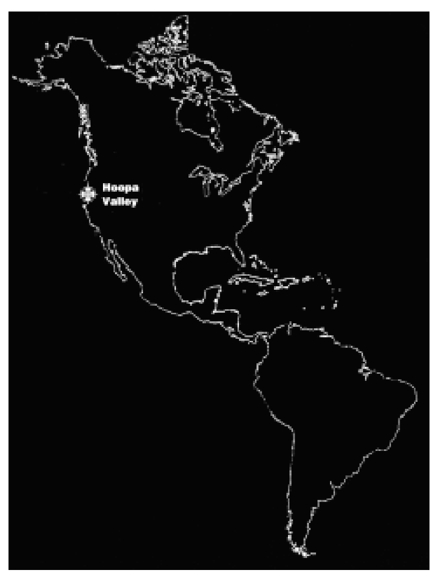
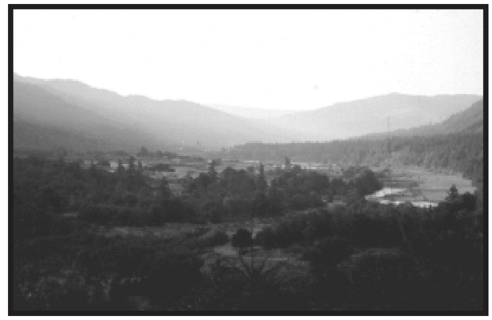


Image 4: Map of Northern Calif. with Hoopa Valley

Let’s first visit Hoopa Valley in Northern California. This is the home of the Hupa people who call themselves *Na Tin Ukxwe* (na-**din**-o-hwe), which means “people who live where the trails lead home.”

Image 5: Hoopa Valley from ridge top



The Hupa live along the Trinity River. To keep their lives attuned to the natural world and to know the seasons of fishing, hunting, and harvesting, the Hupa developed a precise calendar system based on the Sun, Moon, and stars.

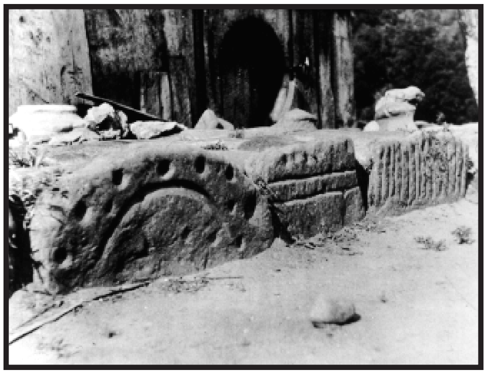


Image 6: Calendar Stones

These stones were the public calendar of the Hupa people before contact with Europeans. The stones, about 18 inches high, are sacred objects left by the immortals for the people.

The photograph of these Calendar Stones was taken early this century. They are the Moon Stone, the Universe Stone, and the Year Stone

Point out, left to right.

The stone on the right is the Year Stone. The stone in the center is the Universe Stone, which shows the Hupa idea of the universe. The top band is the sky;, the center band is the Earth, and the bottom band is the underworld.

The stone on the left is called the Moon Stone. In 1970, a tragedy occurred. The Moon Stone was stolen and has not been recovered! If you discover where the Moon Stone is, please let us know and we will report it to the Hupa so they can get back their sacred stone. I'll show you how the Moon Stone is used to keep a calendar.

Look at the Moon in the planetarium sky. What do you call the Moon in this phase? *(Invite students to stand up to look for the Moon if they are sitting directly beneath it.)*

Take responses until someone says Crescent*.*

That's right, we call this the *crescent Moon*. The Hupa people call it *the New Moon*, because it is the first time they see the Moon after it has been gone for a few days. Its appearance begins the lunar month as it does for many people worldwide.

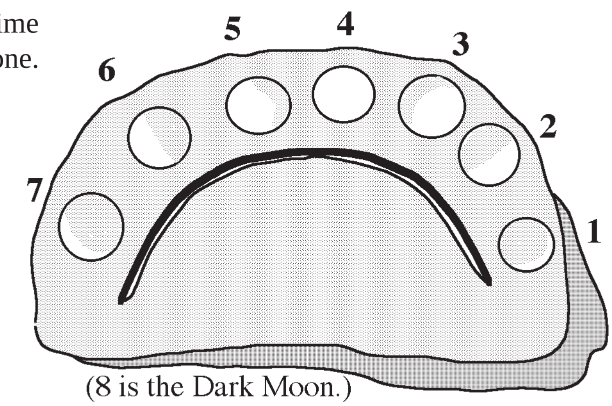
Please take a clipboard and clip the handout in place so that you can see the drawing of the three stones.

Have students get clipboards. Hand out Calendar Stone drawing, and have students take a look at them. Turn on the Calendar Stone photo again (#8).

Let's look at the Moon Stone again. There are 7 shallow holes across the top of the stone that are used to track the Moon as it changes. When the First Moon appears, as we see in the sky now, the Hupa mark the first shallow hole on the right side of the stone. *(Point to it.)* We think they used a natural paint to mark the stone, and washed it off at the end of a complete cycle.

On your drawing, please draw the Moon in the first circle by darkening in the part you cannot see. You can use the outline of the circle as the outline for the Moon. You will have just a thin white crescent left.

Each hole on the Moon Stone is used to mark theappearance of Moon about every 3 to 4 days. Let's use the planetarium as a time machine to look at the Moon for each position on the Moon Stone. We are looking at the Moon just after sunset each day.



(8 is the Dark Moon.)

Turn on annual motion and stop at $3^1/_2$-day intervals to display the Moon. Young children enjoy counting off the days out loud. Turn off the Moon lamp while advancing the Moon between each position.

Phases on the Stone:

1st circle — waxing crescent
2nd circle — first quarter
3rd circle — waxing gibbous
4th circle — full

For each phase, ask:

Do you know what we call this Moon phase today? Please draw the Moon in the next circle.

At the full Moon:

The full Moon is just rising at sunset. ***Where will the Moon be 3–4 days from now?*** *(It will be below the eastern horizon—not visible at sunset.)* After full Moon, it cannot be seen in the evening; it can only be seen after midnight.

We will watch the Moon cross the sky as it does in just one evening, and we will observe the remainder of the Moon phases every 3–4 days at sunrise instead of sunset.

Note: The phrase *first quarter* can be confusing. Many people say it looks like a *half* Moon. The term *quarter* can refer to the fact that you can see a quarter of the entire surface of the spherical Moon. Alternatively, *quarter* can refer to the fact that the moon has gone through one quarter of its monthly cycle.

Turn on music. Diurnal motion to sunrise with full Moon in west. While the Moon crosses the sky, you can mention that the Hupa also keep a private calendar at home. It is a set of Moon markers, which are moved one each day from one basket to another to keep track of the Moon. This is useful in bad weather as well.

Show the remaining Moon phases very quickly, ending with waning crescent Moon. Give students time to draw in the remaining circles at each phase.

5th circle — waning gibbous

6th circle — third (last) quarter

7th circle — waning gibbous

8th (no circle) — new (dark) Moon

After the waning crescent phase, ask:

What will the Moon look like 3–4 days from now? *(It gets dark.)*

The Hupa people call it *the Dark Moon* and say that it is shining underground in the land of the dead. The whole lunar cycle that you have just observed is about 29$^1/_2$ days long, including the Dark Moon, about one month. The Hupa word for a lunar month is *mining* (min-**ning**) which literally means "its face," and begins when Crescent Moon reappears at sunset. You can see the Moon in the sky during about 28 days of the whole cycle. The Moon's cycle of changes makes a natural calendar that everyone can see.

Optional: To save time, you can go through the last half of the lunar cycle very quickly. Students need not draw the remain-ing phases. Students can be invited to keep their Moon Stone handouts and draw in the remaining holes when they watch the cycles of the Moon in the real sky.

Image 8 (again): Calendar Stones

Now, we can understand the Year Stone. (*Point to it on the slide.)* Each time a new lunar cycle begins, one bar on the Year Stone is marked. ***There are 13 bars on the Year Stone, but how many months does* your *calendar have?*** *(Only 12.)* ***And, how many days long are those months?*** *(Some are 30, some are 31 days.)* All the days of all the months in your calendar add up to 365 days, which is the length of a year. The first twelve Hupa months are each 29$^1/_2$ days. This adds up to only 354 days, 11 days short of the yearly Sun cycle, which is 365 days. Rather than making every month longer than a true lunar cycle, the Hupa have a thirteenth month which is about 11 days long. The 13th month is called by the Hupa the "bad luck, spoiled Moon" month.

Hupa Cultural Calendar

The three stones together are a public community calendar for all to share. There is a natural event or ceremony during each Moon cycle. During the first three moons (January through March), it is winter, a time of rain and snow, when food is scarce. During this time, the men and boys live separately from the women and girls, which has the effect of timing childbirth to the time of year when there is plenty of food for the mothers and the newborn children.

During the fourth Moon cycle (our April), the frost ends, eel runs start, and fishing begins. Fishing continues in the fifth Moon cycle, when the spring salmon appear in the Trinity River. People also harvest food from the meadows and forests.

Image 7: Hupa Woman with a child

Also during the fifth Moon cycle (our May), the time of courtship and weddings begins. Men and women live together at this time.

Image 8: Hupa girls in Brush Dance clothing

In the sixth and seventh Moon cycles (June and July), the Hupa perform the Brush Dance Ceremony. It is a time to heal and a time to have fun. It is the most social of the Hupa ceremonies. As summer ends, a second salmon run occurs; and the fall harvest of grains, tobacco, and acorns begins.

Between the eighth and ninth Moon cycles (August and September), there are "The World Renewal Ceremonies," the most important event in Hupa society today. First is the 10-day-long White Deerskin Dance followed by ten days of rest.

Image 9: Hupa children in Jump Dance clothing

Then there is the Fall Jump Dance, a 10-day spiritual ceremony that establishes harmony with the natural world. These children are dressed for the Fall Jump Dance. It is said that the Moon comes to Earth to participate when you cannot see it in the sky. This is a time to focus on our responsibilities as human beings to keep the world a safe place for future generations.

As the year ends, it is time for the final months of harvesting food and game; once again, the men and boys live apart from the women and girls.

Hupa Sunrise Watching—The Solar Year

Religious leaders called *World Walkers* or *Cosmic Net Weavers* watch the position of sunrise along the eastern horizon to establish the beginning of the year. This renews harmony between the Moon cycles and the Sun cycle.

Let's travel with the World Walker up to the mountains on the border of the Hupa homeland.

Turn on music. Mountain range skyline projected around horizon. Sunrise at the winter solstice (December 21).

After a long hike, we are standing in a special place in the Trinity Alps, near Hoopa Valley. A high mountain is a doorway to the world of "Sky Above," which helps us to understand life on earth. To the northeast is Mt. Shasta and to the southeast is Mt. Lassen, an active volcano in northern California *(point them out)*.

It is now late December. We can see our first marker for the late November sunrise.

Diurnal Motion: Sunrise on December 21. Stop when Sun is at top of Mt. Lassen in southeast.

May I have a volunteer to mark the position of sunrise today?

Have a student mark the December 21 sunrise.

What seems special to you about this sunrise? *(The Sun rose over the peak of Mt. Lassen.)* Let's watch where the Sun sets as well. **As the Sun crosses the sky today, please raise your hands (vote) to tell me where you think the Sun will set today.** *(Use pointer to indicate southwest, west, and northwest.)*

Diurnal motion: Sunset in southwest. Stop the Sun above the horizon so that everyone can see where it is at sunset.

May I have a volunteer to mark the position of sunset today?

Have all students stand up. (This is a good time to stretch.) Hand out monthly markers for January through October. Hand them out in order to make it easier for students to know who will be marking next. Save the extra June marker for the Medicine Wheel segment.

Move the Sun to the next month.

Please mark where the Sun rises on this day in January.

Optional: Assign two students per marker. One guesses where the Sun will rise, and the other adjusts the marker after the Sun appears.

Is anyone surprised? In the month before and the month after December, the sunrise position is farther north. On a special day in December, the Sun rises further south than it does the whole rest of the year. That special day is also the shortest day of the year. It marks the beginning of the Hupa year. After the World Walker observes the Sun rise over Mt. Lassen, she proclaims to the people that the next "first Moon" is the first Moon cycle of the new year.

We have a special name for that day when the sunrise is farthest south, which is also the shortest day of the year. ***Does anyone know our name for that day?*** *(Winter solstice.)*

Continue to have students mark sunrise at monthly intervals, around the 21st of each month. For each month, it can speed things along if you ask the student who has the marker for the next month to "get ready."

To save time, you may omit February and April, but be sure to mark March, the equinox, for later discussion.

Just before June, ask:

What has been happening to the position of sunrise along the horizon? *(It moves further north each month.)* In May, the Sun rises over Mt. Shasta. That is when the Hupa social season begins, an important time of year.

After marking June sunrise:

Where do you think the Sun will rise in July? *(Take predictions.)* **Is anyone surprised?** As in May, the Sun rises over Mt. Shasta again. The June sunrise marks the "longest day of the year." It is another special day. It has the most northerly sunrise of the year. ***Does anyone know our name for that day?*** *(Summer solstice.)*

Have a student mark September sunrise.

To save time, you may omit marking August and October. You will still have the solstices and equinoxes marked. The pattern for the year will be apparent. November and December were previously marked.

The pattern of changes in sunrises *(and sunsets)* is the same each year**.** There is a northern extreme sunrise *(and sunset)* in June at the summer solstice. There is a southern extreme sunrise *(and sunset)* in December at the winter solstice. Halfway in between the solstices, in March and September, are equinoxes. On the equinoxes, length of day and night are equal.

As a solstice approaches, the sunrise (or sunset) position changes more and more slowly. The Sun appears to rise and set in nearly the same position for many days in a row. The word *solstice* means "Sun stop." The Hupa say "the Sun stands still."

Optional: ***If we marked a sunset calendar along the western horizon throughout a year, what would it look like?*** *(A mirror image of the sunrise calendar.)*

Together, the lunar calendar on the stones and the sunrise observations over the mountain ridges are the basis of the annual calendar for the Hupa. Like many people, the Hupa follow the motions of the Sun along the horizon, and the Moon across the sky to be in accord with the annual cycles of Mother Earth.

Four color lights on.

Darken sky, turn on stars. Play music for 15–20 seconds as a transition.

Medicine Wheel

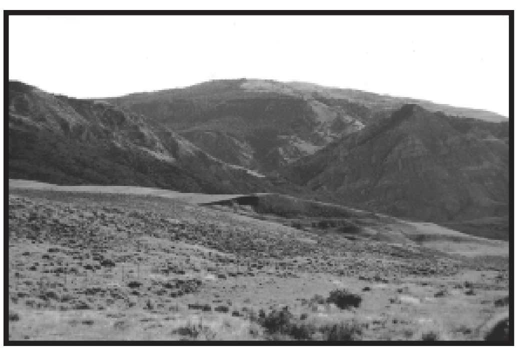
Sun at sunrise position, June 21, summer solstice.

We have found that observing Grandmother Moon and Grandfather Sun can help us not only to stay in touch with Mother Earth and Father Sky, but can help us in maintaining vital aspects of living such as hunting, farming, and social life.

Image 10: Map with Medicine Wheel marked

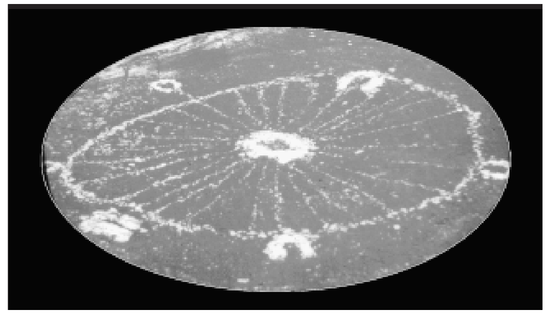
In some places, Native Americans built structures that mark points along the horizon where events of interest occur. Now we will leave Northern California and journey to the high mountains in northern Wyoming.

Image 11: Big Horn Medicine Mountain



It is late spring at the summit of Medicine Mountain in the Big Horn Mountains of Wyoming. We are at an altitude of nearly 10,000 feet. It is pretty cold here on this mountain top. There is snow on the ground much of the year, but this is an excellent location for sky watching. The top is above timberline and offers a clear view of the horizon.

Image 12: Medicine Wheel



On top of the mountain is a wheel-like pattern made of piled up stones that were gathered from the area. There are many of these stone circles in North America. We call this particular stone circle "Big Horn Medicine Wheel." The Crow people call it "The Sun's Tipi." Some stone circles in North America may be over 2000 years old.

At the center of the circle is a doughnut-shaped pile of stones connected to the rim by 28 spoke-like lines of stones. ***Can you think of any reason that there are 28 spokes?*** *(Perhaps because the Moon can be seen for about 28 days of its monthly cycle. The number 28 is sacred among the Plains people.)*

Six more piles of stones are around the outside of the circle. Archaeologists call the piles of stones ***cairns***.

Turn on Medicine Wheel panorama projector. Fade up stars.

If you sight from one cairn to another, certain points on the horizon are marked. Here are some of those horizon points. We are here in the chilly, early morning just before sunrise on the "longest day of the year." We saw the special sunrise position for this day with the Hupa world walker. ***Let's watch this special sunrise here at Medicine Wheel.***

Diurnal motion: sunrise over the northwestern cairn. Blue lights on, stars off.

The Sun rises over this cairn on the "longest day of the year." ***Can you guess where the Sun will set?***

Let diurnal motion continue slowly to sunset as you explain more about Medicine Wheel:

For the Northern Cheyenne, Lakota, Dakota, Nakota, Crow, Arapahoe and other Northern Plains people, the stone circle is a religious site, an altar on the top of a sacred mountain. No one knows exactly who constructed the wheel.

Because Medicine Wheel is visited by many tribes, it has more than one purpose. Some individuals use it as a place to seek visions. Seeking a vision requires great self discipline: meditation, abstinence, and fasting. At one time, the cairns were stacked higher, and had simple roofs that formed an enclosure for the individual seeking a vision.

It is also said that Medicine Wheel was built to allow the observance of the Sundance ceremony. The design of the stone wheel is similar to the Sundance Lodge, which has 28 poles reaching to the center tree.

Stop diurnal motion with the Sun above the lone, western cairn.

Is there anyone who would like to mark the sunset?

At Medicine Wheel, the sunrise **and** sunset positions are marked in alignments of cairns for the "longest day of the year," the summer solstice. But there is no cairn alignment for the "shortest day of the year," the winter solstice. ***Why do you think that is?*** *(The 10,000-foot-high mountain in northern Wyoming is inaccessible in the winter time—too much snow.)*

Let the Sun set. Darken the sky. Turn on stars and four colors at cardinal points.

The four directions of the solstice extremes have spiritual meaning just as the four cardinal directions have meaning of their own. Some Native American cultures align buildings and roads to the four solstice extremes to help them stay in tune with the yearly rhythms of Grandfather Sun.

Image 13: Close-up of Medicine Wheel

Before we leave, look one more time at the Medicine Wheel. Here you see a cloe-up of one of the rock cairns. ***What's the white stuff?*** (Snow.) ***Can you see anything wrong with this picture? Anything that does not belong?*** (*The fence*.) Native Americans today maintain that the Medicine Wheel is a place for sacred ceremonies. This fence was placed around Medicine Wheel to protect it from being destroyed by tens of thousands of summer tourists each year. The U.S. Forest Service does not allow anyone to cross the fence, including Native Americans wishing to perform traditional ceremonies at the site. Several recent Supreme Court decisions have denied Native Americans access and control of other sacred sites as well.

Four color lights on. Darken sky, turn on stars, transition music.

Diurnal motion to just before sunrise. Make the Moon a Waning Crescent about 20° above the western horizon. Fade four colored lights. Stars on.

The Anasazi People: Ancient Ones

Image 14: Map with Chaco Canyon marked.

Now we travel several hundred miles south to Chaco Canyon in northwest New Mexico.

Image 15: Sun watcher at Chaco Canyon

Here we see an Anasazi (On-a-**sazz**-ee) Sun watcher as he may have appeared in an-cient times, observing the sunrise at the sum-mer solstice. A rock painting or petroglyph, on the rock wall behind the Sun watcher, marks the precise place to stand to observe this summer solstice sunrise.

Image 16: Person next to butte at sunrise.

Today at Chaco Canyon we can observe the same sunrise. Chaco Canyon is a National Historical Monument. The people who live nearby say that Chaco Canyon was built by the Anasazi, which means "Ancient Ones." At Chaco Canyon, there are 13 prehistoric towns and hundreds of minor ruins carefully constructed to align with the four cardinal directions and the four solstice directions of sunrise and sunset.

Like many other sky watchers, the Anasazi looked for signs in the sky as guidance. ***What could they have seen in the sky at night?*** *(Constellations, comets, planets, Moon, …)*

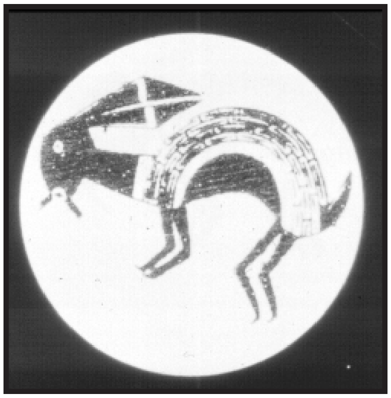
Optional: Meteor or bolide effect.

What was that? (Meteor.) Do you often see them? Meteors are common, but are not often seen from the city because they are faint. Undoubtedly, the Anasazi sky watchers would have seen them often. Today many Native Americans regularly observe meteor showers as a part of their cultural activities.

They certainly would have observed Grandmother Moon and, like people everywhere, seen familiar shapes on the face of the Moon.

Image 17: Full Moon

What shapes do you see on the face of the Moon? *(A man, a woman, two frogs?)* Some people see a rabbit on the Moon. ***Can anyone see a rabbit in the Moon?***



Let a student point out the Rabbit in the Moon.

Image 18: Red rabbit Moon

This is the Anasazi figure of the Moon Rabbit. Many southwestern tribes tell stories about the rabbit. In their paintings and pottery, the rabbit represents the Moon.

Cross fade several times the Full Moon (#17), with the red Moon Rabbit overlay (#18).

Imagine you are an Anasazi sky watcher about 900 years ago. The date is A.D. July 5, 1054. You can see the Moon just before sunrise.

Create supernova using supernova projector.

Suddenly, you notice a new star near the Moon. The star is brightening, but not moving. It is not a big meteor or a comet. It is a very bright star that you have never seen before.

Effect: Dawn sky; brighten horizon

By dawn, the star near the Moon outshines all others in the sky and it is even brighter than the Moon! The new star is so bright you can see it in the daytime sky for 23 days.

Fade out the Moon (it will not stay in the same place from day to day). Brighten sky (blue) lights to daylight levels with supernova projector and Moon still on. Pulse the daylight to indicate the passage of days.

The strange new star's appearance is amazing, and we think it is important enough to make a permanent record to celebrate the new star.

Let's draw what we saw the first night near the Moon. Use your artistic imagination to represent what you saw.

Hand out black paper and fluorescent chalk to record the Moon and the star together. After a minute or two of drawing, turn on black lights. After about 2–3 minutes, continue:

As you finish drawing, you may wish to tell future sky watchers who you are. Can you think of a way to "sign" your drawing without

using writing? Perhaps you can make up a special symbol that is uniquely yours.

Show your drawing to the people near you and explain how you identified yours.

Have students put away the chalk. Turn off the black lights.

Image 19: Chaco Canyon petroglyph of supernova.

Now, let's look at a rock painting found at Chaco Canyon. ***Does it look like your drawing?*** Perhaps this petroglyph is a record of the new star of A.D. 1054. Today, we call the new star a ***supernova and believe a supernova is actually an old star exploding***.

At many sites in the southwestern United States and northern Mexico, people painted a Crescent Moon and a bright star. Perhaps these look like your drawing.

Image 20: Chalk renderings of petroglyphs.

Some people argue that the petroglyphs cannot be tied to the supernova. But this bowl was found among the pottery from the Mimbres Indians of southwestern New Mexico. It has been dated to the approximate time of the supernova of A.D. 1054. Supernovae are visible only about once each century.

Image 21: Rabbit with star bowl.

What do you think it shows? (*A rabbit and a star?*) Perhaps it is the Rabbit Moon in Crescent phase with the new star near its foot. Interestingly, the star has 23 points. ***What could that symbolize?*** (*The number of days the supernova was visible in the sky.*)

Image 22: Crab Nebula.

Today, if we look with a large telescope toward the place of the new star, we find this beautiful sight: an expanding cloud of gas called the Crab Nebula. It is the remains of the star that exploded 900 years ago and certainly could have been seen over the quiet deserts of Chaco Canyon.

We do not know why the Anasazi deserted Chaco Canyon almost 600 years ago. Their descendents, the Hopi and Zuni people, live in the same area and carry on the traditions of watching the Sun, Moon and stars. Many of the same symbols appear in their art today.

Four colored lights on at cardinal points. Music for transition.

The Maya: First People

Image 23: Map with Chichen Itza marked.

We travel south to Mexico.

Image 24: Aztec calendar.

Many people immediately think of Mexico when they see the Aztec calendar. It is a record of the Aztec creation story, as well as a complex 52-year calendar. Aztec astronomers could accurately predict solar eclipses.

We now visit the Maya, who developed a most sophisticated astronomy and a precise time-keeping system using the Sun, Moon, planets and stars. The Maya called themselves the “First People.”

Image 25: The Caracol at Chichen Itza.

This building might have been an observatory where Mayan astronomer-priests kept watchful vigil on the cycles of the Sun, Moon, and especially the planet Venus. The coiled shape gives the building its modern name “Caracol” which means “snail” in Spanish. We do not know the Mayan name for the structure.

Caracol has windows that line up with rising and setting positions along the horizon. Four of the most important directions match the extreme rising and setting points of Venus. Mayan astronomers were capable of predicting the position of Venus with great accuracy. In their daily lives, the people placed great importance on what part of the cycle Venus was in to decide what actions were necessary on any occasion.

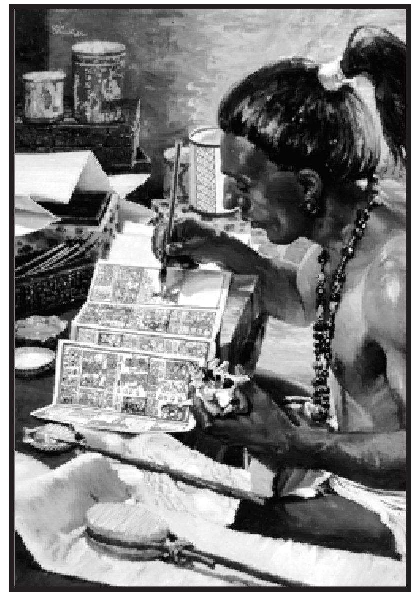
Has anybody here seen Venus? People have seen it at times in the morning when it is often called the “morning star,” or in the evening, when it is often called the “evening star.” It is often the brightest object in the sky other than the Sun or Moon.

Fade out starlight, bring up daylight, leave a few stars. Venus is visible above the eastern horizon.

It is almost dawn now. ***Does anyone see Venus?***

Give someone the pointer to point out Venus.

Image 26: Day Keeper writing in book.



Prior to European contact, the Maya recorded their knowledge of Venus. Here we see the Day Keeper writing a text to record the position of Venus, as well as the Sun and Moon. Using this book as a record of celestial events, Day Keepers measure time extremely accurately. They could predict the timing of Venus's 584 day cycle to within two hours in five hundred years! When the Spaniards came, the invaders destroyed almost all these books, and they outlawed the Mayan language, both written and spoken.

Image 27: Day Keeper writing in Latin.

The Spaniards forced the Day Keepers to learn Latin. So this Day Keeper is writing in Latin instead of using his traditional glyphs and images, which were forbidden.

The Day Keepers' book is also an outline of the creation story, the Popol Vuh, which involves Venus, the Sun, and the Moon.

Turn off all lights and sound. Planetarium is dark and silent.

Either narrate or play a recording of the following story; show images and move Venus as required.

Popol Vuh

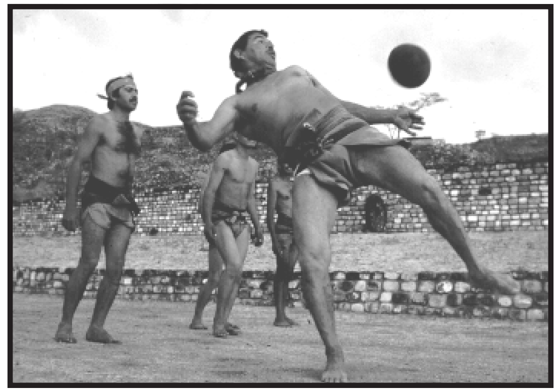
Let's start at the beginning of the Mayan story, the Popol Vuh, when there is nothing but Venus as a morning star.

Early morning is the time when life begins and, in the beginning, the first humans are made out of corn. They are twins named One Hunter and Seven Hunter.

Image 28: Boys playing ball.

It is not long before the boys are old enough to play ball.

*Image 29:
Men playing ball.*



From ancient times to the present, the Maya play a game that is a combination of soccer and basketball. In the Popol Vuh story, the ball represents Venus.

If we watch Venus for several months at dawn, it will appear higher and higher for a while, and then lower and lower each morning. Since Venus goes up and then comes down over the months, it behaves like the ball in the twin boys' ball game!

Use Venus projector to slowly move Venus up and down like a ball. Then make it go back below the eastern horizon.

But there are evil beings, the Lords of the Underworld.

Optional: have all the students stamp their feet to make the sound of thunder to announce the "Lords of the Underworld."

They are the evil lords of disease and death who live in the Underworld, Shi-Bal-Ba. They make people sick. They make people die. They live below the Earth, and it is not safe for anything to go below the Earth. The twins' ball game has disturbed the evil lords and they are angry and jealous. They summon the boys to the Underworld to play ball. They want to play ball, too. But theirs is a game of death.

When the boys take their ball to the Underworld, Venus no longer appears as a morning star, and it will not be seen at all for many days. It is in the Underworld.

Optional: Have all the students stamp their feet to make the sound of thunder to announce the "Lords of the Underworld."

When the boys go to the Underworld they are confused. The evil lords trick them into sitting on a hot seat. When they play ball against the evil lords, the twins are defeated. Because they lost the game, the twins are murdered by the evil lords. To celebrate the victory, the evil lords hang the twins' heads up in a tree.

Diurnal motion to sunset; show Venus in the west as the evening star.

Now, Venus reappears, but in the west after sunset as the evening star. When Venus is in the west, it is in a place associated with death.

Image 30: Blood Woman riding Deer to Earth.

Blood Woman is the daughter of an evil lord. She hears that there is a tree with delicious forbidden fruit that looks like a human head. When she goes to sample the fruit, the head spits a seed into her hand. This is the first pregnancy and the first birth will soon occur. From this day on, the people's death is not the end because their children will carry on the family traits and traditions as the cycle of life continues. Blood Woman carries the seed from the tree up to the surface of the Earth. The seed will become her twin sons, Hunter and Jaguar-Deer, the heroes of the story.

Venus appears as a morning star again when these twins are born. The East is a place associated with life and birth and light.

Make Venus rise in the eastern sky before sunrise again. Fade up morning sounds again.

These newborn twins must destroy the evil lords to make the Earth a safe place for people. They must make the sky safe for the Sun, Moon, and planets to make their journeys below the Earth.

Like their fathers, the boys grow up and play the ball game again.

Move Venus up and down again in the East. Optional: reverse slides to image 28—boys playing ball.

The cycle of Venus continues. Venus again gets higher and higher each morning just like at the beginning. Again, the Lords of the Underworld hear the ball game and summon the boys to play. Again, Venus is not visible in the sky.

Show that Venus has disappeared.

Optional: Have all the students stamp their feet to make the sound of thunder to announce the "Lords of the Underworld."

But this time, the boys are not fooled by the evil Lords. The Lords cannot trick the boys. When the Lords try to freeze the boys they start a fire. But the evil Lords cut off Hunter's head and use it as a ball in the game. The evil Lords believe they have won again.

This is a time of death, and Venus appears as the evening star in the west.

Show Venus as the evening star.

But the evil Lords are tricked because Jaguar-Deer substitutes a pumpkin for Hunter's head and returns the head to Hunter's body. In the end, the evil lords' desire for death is so strong that the twins trick the evil lords into killing themselves.

Finally, the triumphant twins go to the grave of their father. They open the earth, and the spirit of their father becomes Venus. They tell him, “Now the world is a safe place for your children ... safe for all people to be born, live their lives and die in peace. Now the world is a safe place for the Sun and the Moon to rise and set without being disturbed.”

Venus rises again as a morning star to mark the beginning of a new cycle. One of the boys becomes the Sun and the other becomes the Moon, which can now appear in the sky safely. Deer carries the Sun, and Rabbit carries the Moon.

Make Venus, Moon, and then Sun rise in the east.

Fade in flute and drum music. End of recorded story.

Image 31: Dresden codex: Venus ephemeris.

These pages are from a Mayan book about Venus. The book shows that the Mayan people knew with precision the 584-day cycle between reappearances of Venus as a morning star. They knew that five Venus cycles equaled eight solar years. They integrated all this into their calendars and lives. Although most of their written records were destroyed by the Spanish invaders, some of their knowledge survived. It is still passed on by Mayan people living in Central America today.

The people continue to watch the cycles of the Sun, Moon, and Venus in the sky as they rise and set to mark the passage of time. For the Maya, Venus is a guide, and future generations continue creating the story in cycles of birth and death, forever. Understanding the sky is an essential element in the complex web of interactions through which we weave our life paths.

Allow Sun to set, and turn on stars.
Four colors at cardinal points.

The Inca of Machu Picchu: People of the Sun

Image 32: Map with Machu Picchu marked.

Throughout the Americas, people tracked the Sun as it rose and set along the horizon to keep calendars. In Peru, we find evidence of a complex and sophisticated astronomy practiced by the Inca in their worship of their most important deity, *Inti*, the Sun, and to keep a calendar for civil and religious purposes. The Inca call themselves "People of the Sun."

We are in Machu Picchu. There are a variety of buildings here.

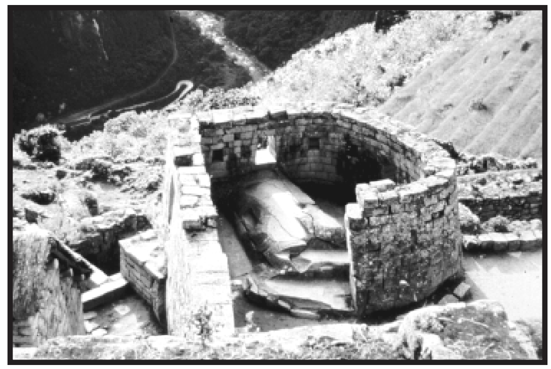


Image 33: Oblique view of Torreon.

One building stands out: the Torreon. It is fitted carefully to the bedrock stone. Inside, there is a straight edge cut into the bedrock platform that dominates the floor of the Torreon.

There are no other curved buildings at this site. Many people speculated about what the Torreon might have been: a palace, a tomb, a special chamber for an important person? No one was sure.

About ten years ago, a team of astronomers carefully surveyed the building. They discovered that one window points toward the northeast. Beginning in May, the light from the rising Sun enters this window and shines on the stone. On the summer solstice (which is in December in the southern hemisphere), the sunlight lines up exactly with the edge of the carved ledge on the bedrock stone as the shadow of a plumb bob suspended in front of the window shows us.

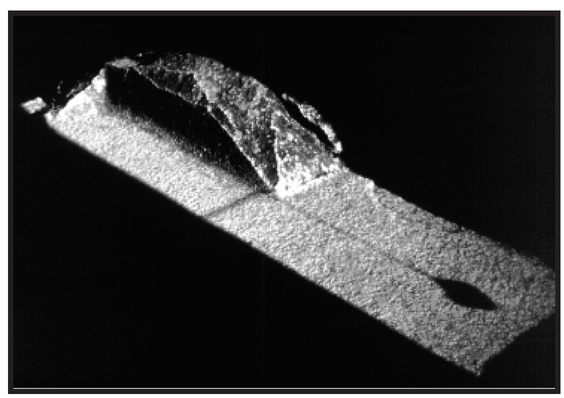


Image 34: Shadow on bedrock stone.

The Torreon is a place to predict and observe the summer solstice. It is the time of the most important Incan celebration, **Inti Raymi,** when all peoples in the Incan empire paid homage to the Sun and to their rulers. From historical records we know that ceremonial offerings were made throughout the month leading to the solstice.

If the summer solstice was an important time of celebration for the Inca, can you think of another time of year when they would celebrate Inti, the Sun? *(The winter solstice or the equinoxes, or zenith passage.)* At the winter solstice, there was another celebration, **Capac Raymi**, to initiate the sons of the high born class and celebrate the Incan creation story.

Image 35: Entrance of Intimachay.

Use pointer to show where the window is located in the image.

The astronomers looked for some other structure that might be used to observe the winter solstice for the celebration of Capac Raymi. They found an unusual structure at Machu Picchu, a modified cave with a single small window. The window faces the point on the southeastern horizon where the Sun rises on the winter solstice.

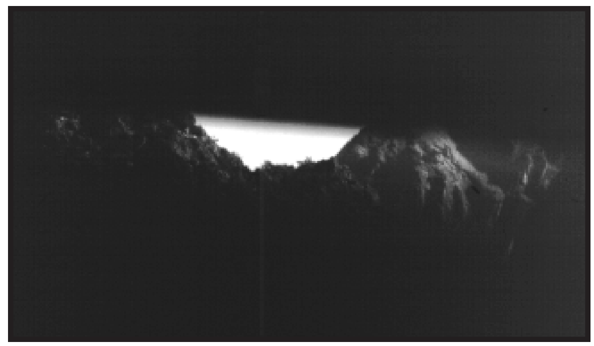


Image 36: Horizon through window.

Through the window, you can see only a small piece of the horizon, about twice the width of the disc of the Sun. This structure could be a winter solstice observatory.

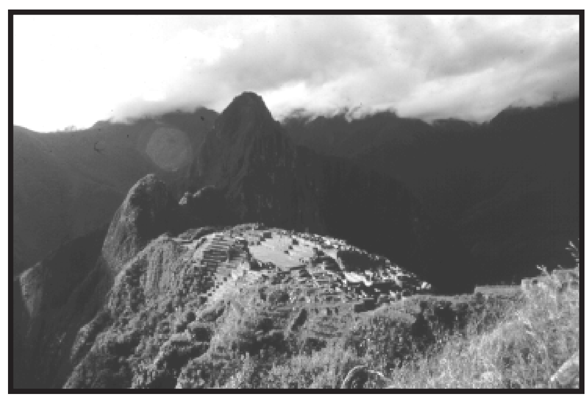


Image 37: Machu Picchu from a distance.

At Machu Picchu, the evidence in the stone buildings indicates Incan knowledge of the sky, which is separately confirmed in historical accounts.

Image 38: Modern Peruvians—market scene.

Today, the descendants of the Inca live, work the land, and continue to track the Sun along the horizon to keep a planting calendar. They continue a tradition of Sun watching that is thousands of years old.

Conclusion:

Image 39: Hupa girls in brush dance clothing.

Dark sky with stars, slow diurnal motion. Either narrate or play a tape of the following paragraph.

The sky turns and, in turning, measures out our lives. To live in harmony with the world and its cycles is the goal of traditional Native Americans. Their patterns for living derive from a deeply held attention to the rhythms of the sky and Earth. The lessons we learn instruct us that whether as architects, weavers, hunters, potters, or storytellers, traditional Native American men and women weave their perceptions of the celestial patterns into their lives in order to participate directly in the ways of the universe. (Adapted from *Living the Sky* by Ray Williamson)

(End of recorded narration.)

The Native Americans are not people of yesterday, gone from the continents. Today, the Inca struggle for control of their lands. The Maya strive to preserve their way of life in the diminishing rain forests of Guatemala and Mexico. The Hopi and Zuni repeat the cycle of the year in their everyday lives to maintain a traditional life style. The Plains people seek to maintain Medicine Wheel, Bear Bluff, and other places as a sacred sites in order to continue their religious practices. On their ancestral lands in Northern California, the Hupa watch the sky and teach their children the cycle of the year.

All of these people have knowledge and lessons that can teach people worldwide to better understand and respect the way in which the sky and Earth, plants and animals, mountains and rivers, and people can walk in harmony with one another and with Mother Earth.

Images 40: credits.

Native American Sky Tales

Annotated bibliography by Marian Drabkin, Science Education Library,

Lawrence Hall of Science, University of California, Berkeley

To Native Americans, for whom the relationship between the human world and the world of nature was central, stories about the natural world were of great importance. Joseph Bruchac, an Abenaki poet and storyteller, has said, "Stories are the life of a people .... They affirm and help to sustain the values of a culture." In a classroom, stories can be a way of introducing children to the way a culture perceives itself, the way it gathers and processes information, the way it lives. These are some of the many collections of Native American stories currently in print and including tales of the Sun, Moon, or stars:

Bruchac, Joseph. *Return of the Sun: Native American Tales from the Northeast Woodlands.* The Crossing Press, 1989. Grade 4 and up.

Almost all these tales came (at least in part) from living oral tradition, and many are here translated from their original languages. There is a great variety of stories, including "The Return of the Sun" (Onondaga), which tells how the Sun came to be fastened up into the sky so that it can give light and life to the people.

Caduto, Michael J. and Joseph Bruchac. *Keepers of the Earth: Native American Stories and Environmental Activities for Children.* Fulcrum, 1988, 1989.

Designed for adults to use with children, each story is accompanied by suggestions for activities related to the theme or the subject matter of the story. "How Coyote Was the Moon" includes activities demonstrating the phases of the Moon and lunar eclipses; "How Fisher Went to the Skyland: the Origin of the Big Dipper" has information and activities about the Solar System. Many suggestions for teachers are included in this very useful collection whose 24 stories are beautifully written and irresistible for reading aloud or telling.

Clark, Ella E. *Indian Legends of the Pacific Northwest.* University of California Press, 1953. Grade 7–Adult.

This classic collection of tales from the many peoples of the Northwest includes eight stories about the Sun and the stars. Most stories have appended notes telling how the story was collected, or how it was told, or what variations exist in other tribes in other areas. Its format is not inviting to younger readers, with quite small print and crowded pages, but the selection of tales on every topic is excellent, and illuminates the lives and concerns of the Northwest peoples.

Curry, Jane Louise. *Back in the Beforetime: Tales of the California Indians.* Margaret K. Mc-Elderry Books, 1987. Grades 4–7.

In a collection whose level of language and humor make it attractive and accessible to younger readers, there are tales about everything from how the stars got up into the sky to the tricky way Coyote managed to steal the Sun, but then had to find a way to make it rise and set.

Erdoes, Richard and Alfonso Ortiz. *American Indian Myths and Legends.* Pantheon, 1984. Grade 7–Adult.

This encyclopedic collection of Native American tales includes a section of 19 tales of the Sun, Moon, and stars, representing many native cultures and regions. Grandmother Spider steals the Sun (Cherokee), the trickster Coyote puts the stars in their places (Wasco), a young couple who do not follow tradition are put up into the sky to become stars (Tewa), and many others. This collection is a must for anyone interested in Native American lore.

Gifford, Edward W. and Gwendoline Harris Block. *Californian Indian Nights.* University of Nebraska Press, 1930, 1990. Grade 5 and up.

Star stories were common in southern California; though, according to the compilers of this collection, they were rare in northwestern and central California. Several interesting tales about the Pleiades and other stars are included here. Seven stories about the Sun and Moon are included.

Krupp, Ed. *Beyond the Blue Horizon.* Harper Collins Publishing, New York, 1991. Grade 9 and up.

This exploration of sky stories and mythology encompasses the human view of the sky worldwide. Krupp includes many Native American ideas in his survey. It is a well written and generously illustrated book that includes basic astronomical concepts to illuminate the stories and myths.

Lavitt, Edward and Robert E. McDowell. *Nihancan's Feast of Beaver: Animal Tales of the North American Indians.* Museum of New Mexico Press, 1990. Grade 4 and up.

This accessible, attractive collection is arranged by tribe, with a small insert map for each showing where they lived. In this collection are the Wintu tale of the first dawn and the Haida recounting of how Raven stole the Sun, as well as many others from all over North America. The stories are short, and each is prefaced by an introductory note about the tribe from which it came.

Lankford, George E. *Native American Legends: Southeastern Legends: Tales from the Natchez, Caddo, Biloxi, Chickasaw, and Other Nations.* August House, 1987. (Native American Folklore Series). Grade 9–Adult.

These stories are all unusual, from sources not readily available and from tribes not always represented in collections. It is perhaps less readable (because containing more scholarly material) than the other collections represented here, but few others represent this region so thoroughly.

Martin, Fran. *Raven-Who-Sets-Things-Right: Indian Tales of the Northwest Coast.* Harper & Row, 1975. Grade 4 and up.

Raven, the trickster, sometime creator, sometime changer, is a culture hero of Northwest Coast peoples. Among other tales here is the account of how Raven stole back the Sun, Moon, and stars from the Old-One-At-The-Source-Of-The-River and released them for the use of humans and animals. The lively style begs for reading aloud or telling. These are favorites with listeners of all ages.

Mayo, Gretchen. *Star Tales: North American Indian Stories About the Stars*. Walker & Co., 1987. Grade 5 and up.

Well-chosen tales about various stars, constellations, and the Milky Way are included here. Introductory paragraphs to each story explain something about the beliefs of the tribe from which the story came, and something about the way other tribes have viewed the same star or constellation. All are inviting to younger readers, and some contain irresistible humor. Good for reading aloud.

Monroe, Jean Guard and Ray A. Williamson. *They Dance in the Sky: Native American Star Myths*. Houghton Mifflin, 1987. Grade 5 and up.

This collection of well chosen and easily readable stories brings together tales from all regions about the Pleiades, the Big Dipper, and other stars and constellations. Native American star patterns are listed, their European-named equivalents are given, and the beliefs of many Native groups about the stars are discussed.

Williamson, Ray A. *Living the Sky*, University of Oklahoma, Norman, 1984. Grade 9 and up. Williamson brings the viewpoint of Native Americans to the reader through his exploration of several sites and cultures throughout the Americas. He portrays carefully the understanding and relationship between Native Americans and the natural world — including the cosmos. This book is a delight to read, with gracefully written text and appropriate line-drawn illustrations. For parents and teachers seeking more information, this may be considered a companion volume for *They Dance in the Sky: Native American Star Myths.*

Worldwide Web Connections

and update information may be found at
http://www.lhs.berkeley.edu/pass

Sky Challenger is a set of star charts, one of which is a Native American constellation star wheel. It is available from Eureka! at Lawrence Hall of Science, University of California, Berkeley, CA 94720. (510) 642-1016

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Astronomy of the Americas

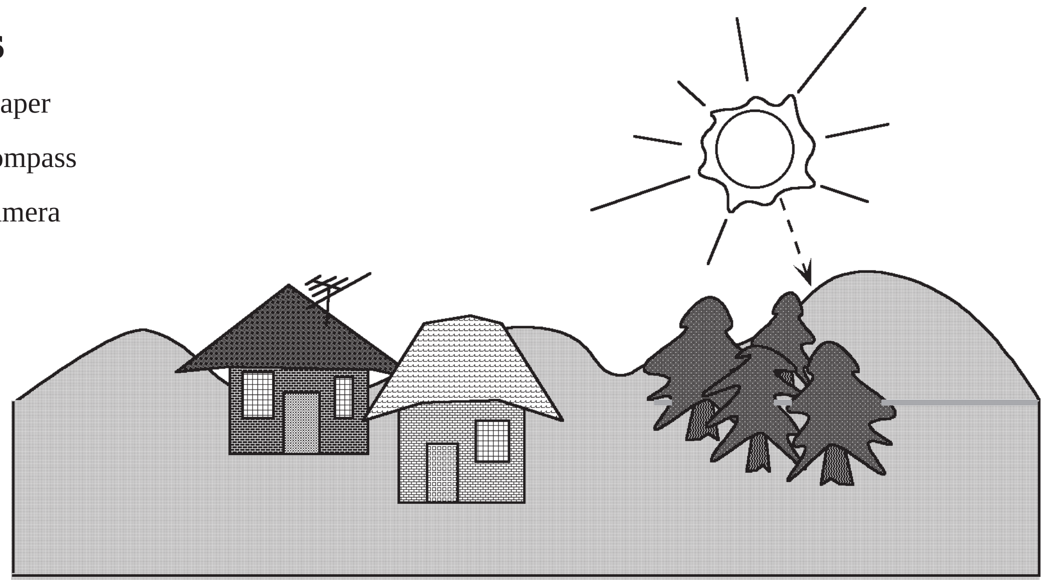
Classroom Activities

Observing Where the Sun Sets

This activity is for students to do at home. When they complete it, they will have created a horizon Sun calendar much like ones that were used in many Native American tribes.

Materials

- ❑ Pencil and Paper
- ❑ Magnetic Compass
- ❑ Optional: Camera



What to Do at Home

1. Select a position where you can observe the setting Sun. Note where on the horizon the sun sets on a given night. Make a drawing or take a picture of the horizon in that general area.

2. Using a magnetic compass, mark the compass directions northwest, west, and southwest on your picture or drawing.

3. Once or twice a week for the next month, mark the location where the Sun sets for each clear day, and record the date and time of the sunset. **Be sure to always make your observations from the same spot.**

4. Discuss results in class. ***Does the sun set further to the south, further to the north, or in the same place on later days as compared with the first day?***

Going Further

1. Observe the same star set each night for a period of about a week. **Be sure to always observe from the same spot.** ***Does its setting point change in the same way that the Sun's does?***

2. Try to guess where the Sun would set three months later. How about six months later? Mark those guesses on your horizon picture (in pencil). Check your guesses after the months have gone by.

3. Could you devise a way to make a calendar using the information in this activity?

4. Make the same type of observations of the rising point of the Sun.

5. Can you find any relationship between the location of sunset and the time of sunset?

Morning Star and Evening Star

This activity will help your students to see why Venus appears to us sometimes as the morning "star" and sometimes as the evening "star."

Materials

- ❑ A white light with no shade or reflector. This will represent the Sun.
- ❑ A small white ball to represent Venus. Mount the ball on a stick or pencil.
- ❑ A way to make the Venus stick stand up. It could be stuck into a lump of clay, or taped to the edge of the table.

Preparation

Set up the white light on a table in the front of the class. Make sure there is room for you to move the "Venus" ball in a small orbit (less than one meter radius) around the "Sun."

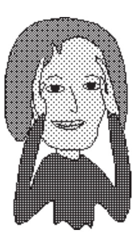
In Class

Turn on the white light and turn off the room lights.

Let's pretend that this bright white light is the Sun, the small white ball is the planet Venus, and your head is the Earth.

Since your head is the Earth, you can imagine people living on "Mt. Nose." What time of day is it on Mt. Nose when you look directly toward the Sun? *(Noon.)* ***What time of day is it when you are facing directly away from the Sun?*** *(Midnight.)*

Put your hands up to form blinders on the sides of your eyes. *(Demonstrate, as shown in the picture).*



Your hands form an eastern horizon and a western horizon. ***Now, turn around to face directly away from the Sun, and then start turning slowly to your left.*** This is the way the Earth turns. You should see the "Sun" during your day. It is night when the Sun "sets" behind your (western) horizon hand and you are facing away from the Sun. When the Sun "rises" from your other (eastern) horizon hand it's morning. ***Behind which hand does your Sun "set," the left hand or the right?*** *(Right.)*

For younger groups, stop and make sure students recall which hand is their right by asking them all to raise their right hands. Help any students who have trouble recalling.

On which horizon does the Sun set, the West or the East? *(West.)* ***Which of your horizon hands represents your western horizon, your left hand or your right hand?*** *(Right hand.)* ***Turn a couple more times slowly so you see the Sun rise and set a couple more times, and then stop at your "noon" position facing the Sun and rest your "horizons." You may put your hands down.***

Hold the white Venus ball about 1/2 meter to the right of the Sun (as seen by your students).

Now we will add Venus to our model. This white ball is Venus. As you turn, you will see Venus and the Sun. When the real Sun is above the horizon, it is so bright that it is very difficult for you to see the real Venus. So in our model, imagine you can see Venus only when the Sun is below the horizon (behind your hand or behind your head). Venus will be visible to you just before sunrise, just after sunset, or it won't be visible to you at all. ***Now, put your horizons back on and start turning slowly to find out if you can see Venus just before your sunrise, or just after your sunset.***

Let the students turn a few times.

Raise your hand if you saw Venus just before sunrise. *(Most of the students will raise their hands.)* ***If you saw Venus just before sunrise, would you call it the "morning star" or the "evening star?"*** *(Morning star.)* ***Turn around a couple of more times to make sure you can see the "morning star" just before "sunrise."*** *(Help any students who need help.)*

Now stop turning and rest your "horizons." Venus orbits around the Sun and so can appear to be on either side of the Sun.

Make Venus orbit the Sun and finally, put Venus on the other side of the Sun, on the left side from your students' perspective.

If you put up your "horizon" hands and let your "Earth" turn again, do you think you will be able to see Venus before sunrise or after sunset? (After sunset.) ***Try it. Raise your hand if you saw Venus just after sunset. (Most*** *of the students will raise their hands.)* ***Was Venus a morning star or evening star for you?*** *(Evening star.)* ***Turn around a couple more times to make sure you can see the "Evening Star" just after "sunset."***

Help any students who need help.

Do you think that there is any time when you cannot see Venus at all? *(Yes.)* ***When would you not be able to see Venus?*** *(When Venus is either behind the Sun and blocked or in front of the Sun and is drowned out by the sun's brightness.)*

Walk around the Sun with Venus to show its orbit. While you are orbiting...

Raise your hand if Venus is not visible to you because it is behind the Sun.

Go around for at least two orbits.

Now raise your hand when Venus would not be visible to you because it is in front of the Sun, and the sun's brightness would hide it. (Remember, the real Sun is much brighter than this light!)

Go around another two orbits or so.

What you have just modeled is the modern explanation for why Venus is sometimes the "evening star," sometimes the "morning star," and sometimes not visible at all.

Optional:

Venus's cycle is as follows:

1. Venus appears as a morning star for about 263 days.

2. Venus is not visible when it goes behind the Sun for about 50 days.

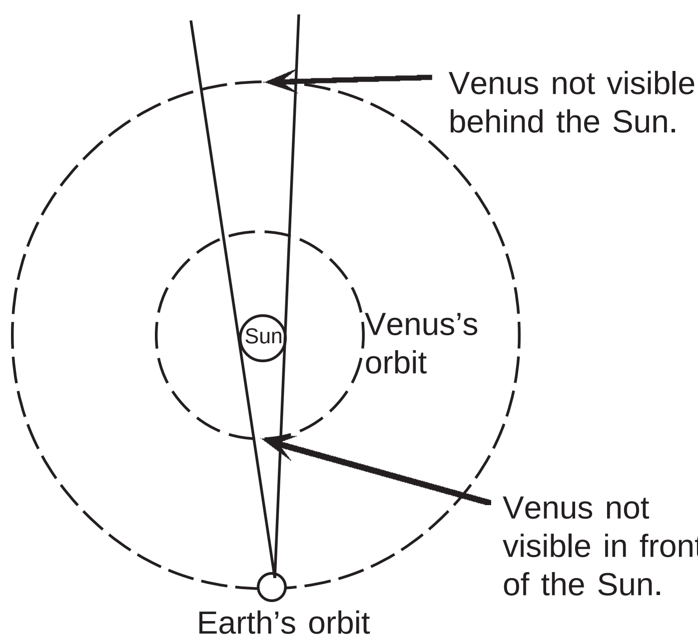
3. Venus appears as the evening star for about 263 days.

4. Venus is not visible when it goes in front of the Sun for about 8 days.

5. The entire cycle of Venus is 584 days long.

Why do you think that Venus's time of non-visibility is longer when it goes behind the Sun than when it goes in front of the Sun?

A diagram helps to answer this question:



Aztec and Mayan Math

The Aztecs and Maya developed a complex and sophisticated mathematics. In recent decades anthropologists have learned a great deal about Native American mathematics from archaeo-logical excavations and from people who still use mathe-matical methods developed by their ancestors.

Among the many examples of Native American mathematics we might have selected, we chose to present some elementary aspects of the Aztec and Mayan numbering systems. These concepts were chosen primarily because they are interesting and accessible to middle school and high school students. They provide insight into how various cultures have addressed the need to express large numbers as well as insight into the base-10 system that is so important in our own culture.

In the set of slides for *Astronomy of the Americas* is a picture of a Mayan scribe writing a book. The slide includes some of the number symbols your students will learn to interpret in this activity. Anthro-pologists were able to use these symbols to decode the Mayan books.

Materials

- ❏ 1 Styrofoam meat tray for each student. You can get them from supermarkets, or students can bring them in.
- ❏ 1 dull pencil or ballpoint pen for each student to "engrave" the styrofoam
- ❏ One copy of each of four handouts for each student, using the masters on pages 44–47:

Base-10 and Base-20 Number Systems	How to Write Aztec Numbers
Who "Invented" Zero (0)?	How to Read and Write Mayan Numbers

Preparation

Use scissors to trim the edges of the Styrofoam meat trays to produce flat pieces about 4" x 6".

In Class

1. Hand out the first activity page, "Base-10 and Base-20 Number Systems." Read outloud the information, explaining base-10 and base-20 number systems. You may wish to use the chalkboard or overhead projector to explain the examples. Help your students as necessary while they work out the two sample problems on the page.

2. You may want to ask your students why they think we use the base-10 number system. Why not a base-5 system or a base-20 system? Possibly it's because we have ten fingers. You may want to tell students that computers use a base-2 number system.

3. Hand out the second activity page, "How to Write Aztec Numbers." Explain how to write numbers as an Aztec would. Then distribute the pieces of Styrofoam and dull pencils or ballpoint pens to make Aztec number rubbings. Encourage your students to create number rubbings that challenge their classmates.

4. Hand out the third activity page, "Who "Invented" Zero (0)?" Discuss how the Maya made numbers with dots, bars, and a leaf symbol. Then, allow students to practice writing Mayan numbers with these symbols. Encourage students to make up numbers for their classmates to decipher.

5. Hand out the fourth activity page, "How to Read and Write Mayan Numbers." This sheet provides additional challenges in using Mayan numbers.

6. You may want to tell the students that the Maya used these symbols for many different purposes, including keeping track of goods for religious offerings and business transactions. They also used these symbols to keep track of the Sun, Moon, and the planet Venus; and to create a calendar and number the days, weeks, and years. The Mayan calendar was many thousands of years old when the Spanish explorers arrived. In the years that followed, Christian missionaries burned many Mayan books because they wanted to convert the Maya to Christianity.

Long before Columbus and other Europeans came to the Americas, the ancient Aztecs and Maya developed advanced number systems. They used base 20 for their systems. The number system most used throughout the world today is a base-10 system.

Base 10	**Base 20**
" 7 5 " In base 10, the number **" 7 5 "** is figured like this: (**7** x 10) + (**5** x 1) = 75 (70) + (5) = 75	**" 3 15"** In base 20, the number " **3 15** " **(which means the same as "75" in base 10)** is figured like this: (**3** x 20) + (**15** x 1) = 75 (60) + (15) = 75
Show how the number 225 is figured in base 10: (__ x 100) + (__ x 10) + (__x 1) = 225 (_____) + (_____) + (_____) = 225	Show how the equivalent number to 225 in base 10 is figured in base 20: (__ x 20) + (__ x 1) = 225 (____) + (__) = 225

The upper limits of counting vary considerably among Native American Peoples. The Dakota, Cherokee, Ojibway, Navajo, Winnebago, Wyandot, Micmac, and others could all count into the millions; the Choctaw and Apache to the hundred thousands; and many other Native Peoples to 1,000 or more. For example, the Ojibway word for one billion is *me-das-wac me-das-was as he.*

The Pomo of California have a particularly interesting system of counting. While the eastern Pomo use a system similar to base 20, the southwestern Pomo use a variation of a base-40 system. This system probably developed because the Pomo were the principal suppliers of long strings of clam shell beads used in trade throughout north central California.

Native Peoples often express numbers in mathematical sentences. For example, 400 might be expressed as "20 times 20," just as in Lincoln's address at Gettysburg he expressed the number 87 as "Four score and seven...." A "score" is 20, so "Four score and seven..." is (4 x 20) + (7 x 1).

The Aztecs used these hieroglyphs to record numbers.

The finger  represented numbers from 1 to 19.

The flag  represented 20.

The feather  represented 400.

So, the number 468 would look like this:

400 + 60 + 8

(1 x 400) + (3 x 20) + (8)

How to Make Aztec Number Rubbings

What to Do

Use a dull pencil or ballpoint pen to draw the three Aztec number symbols onto the smooth side of a Styrofoam meat tray. Leave plenty of space between the symbols.

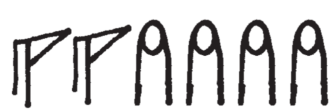
Make an Aztec number by placing paper over the heiroglyph and rubbing the paper with a crayon.

Challenge

Create Aztec herioglyphic rubbings for the following numbers:

1. Your age
2. 23
3. 121
4. 882
5. 1,225

What are these Aztec numbers?

6.  = ________

7.  = ________

Make up five Aztec numbers on the back of this paper for a friend to decode.

The Maya used the zero many years before the Europeans learned about it from Arab mathematicians in the thirteenth century. Having the zero as a place holder allowed the Maya to keep complex records of long sequences of numbers; not having a zero limited the mathematical abilities of Europeans and the ancient Greeks.

The Maya recorded numbers with a series of dots and bars.

A dot (•) equals 1.

A bar (—) equals 5.

This symbol  represents zero (0).

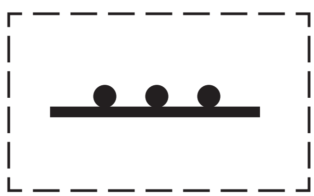
The Maya made many other important contributions to mathematics. For example, they were among the first people to use place value. In the system we use, place values represent multiples of 10. For example, in the number 25, the 5 represents five ones. The 2 represents two tens, or twenty.

In the Mayan system, place values represent multiples of 20, not 10. Another difference is that value in the Mayan number system increases from bottom to top, instead of from right to left as in the system we use. Since the Mayan system uses base 20, a number placed above, but not touching another number represents a multiple of 20.

How to Read and Write Mayan Numbers

For example, the number 8 looks like this:

Ones Row



3 dots = (3 x 1) = 3

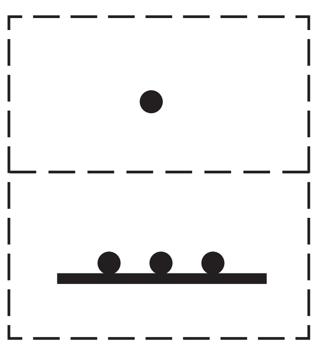
1 bar = (1 x 5) = 5

8

The number 28 looks like this:

20s Row

Ones Row



1 dot = (1 x 20) = 20

3 dots = (3 x 1) = 3

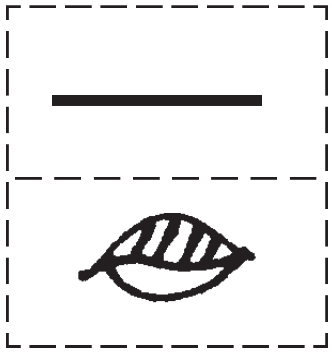
1 bar = (1 x 5) = 5

28

Notice that the bars and dots in the same row are in contact with each other.

The number 100 looks like this:

20s row



1s row

1 bar = 5 x 20 = 100

1 shell = 0 x 1 = 0

100

Challenge: Use the Mayan number system to write these numbers

7 20 19 92

247

Your Age

Make one up

Make one up

Make up five more Mayan heiroglyphic numbers on the back of this paper for a friend to decode.