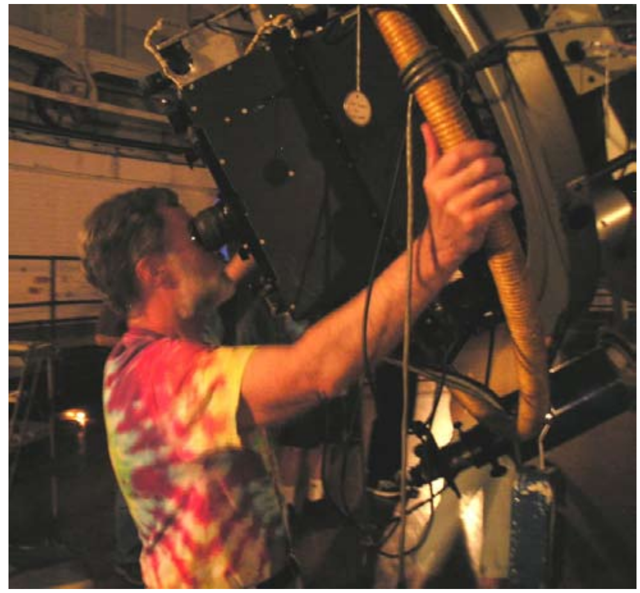
2. Astronomers' Tools

Astronomers are very limited in ability to actually visit and explore their objects of interest. Humans have personally visited only one other body in the cosmos other than Earth: the Moon. We have sent spacecraft to most of the planets in our own solar system and received treasure troves of data and information about those places, including their moons, some asteroids, and comets. But when it comes down to more distant objects—and most of the Universe—we basically have only the light we receive from those objects and our imagination and ingenuity to analyze and interpret that light. Fortunately, we are not restricted to visible light only. We have detectors for all types of electromagnetic radiation: infrared light, ultraviolet light, x-rays, gamma rays, and radio waves.



Kyle Cudworth controlling the Yerkes Observatory 40" telescope—the largest refractor telescope in the world.

Mapping Space and Time

One of the simplest tools of astronomy is something to help find things in the sky: a star map. There are a wide variety of these, ranging from those ideal for beginning stargazers to highly detailed maps and computer programs for advanced amateur or professional astronomers. One kind of star map, the *planisphere*, is adjustable to show what the sky looks like any time of night and any time of year.

Caution—it's common and easy to confuse these terms:

Rotate—think of something spinning on its own axis.

Revolve—think of something orbiting (going around) something else.

These terms are verbs, but similarly, people often confuse the corresponding nouns: ***rotation*** **and** ***revolution*****.**

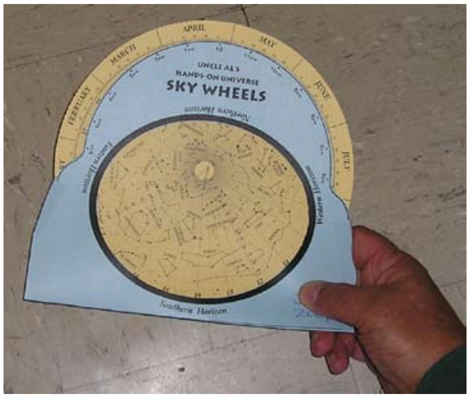
Motion Defines Time

Time often seems so subjective—while listening to a boring lecture, it seems like time drags on endlessly. When spending an enjoyable or exciting evening with friends, time flies. When we need to actually measure time, the sky is a great reference—it seems to move "like clockwork" with the different ways that the Earth is moving:

Rotation—Earth spinning on its axis makes the sky seem to move from east to west.

Revolution—Earth orbiting around the Sun makes the sky seem to shift each day so that the part of the sky is visible to us without the Sun blocking it in daytime

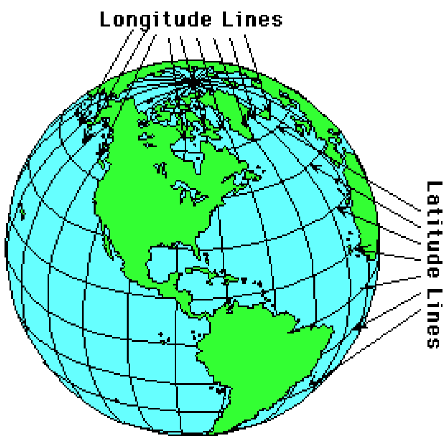
Precession—the wobbling of the Earth's rotation axis, so the direction that Earth's axis points in the sky slowly drifts over thousands of years— 26,000 years for one complete wobble. Earth's axis currently points to within a degree of the star *Polaris* (*North Star*). In about 10,000 years it will point closer to the very bright star Vega, in the constellation Lyra.



In the investigation on the next page, ***Star Maps***, you can construct your own star map and use it not only to find things in the sky, but to show how the sky changes with time.

Coordinates For Earth and Sky

To roughly locate things in the sky, we can identify groups of stars, called *constellations*. But to specify exactly where an object is in the sky, we use *celestial coordinates*. Celestial coordinates are to the sky, as geographical coordinates (latitude and longitude) are to the Earth.



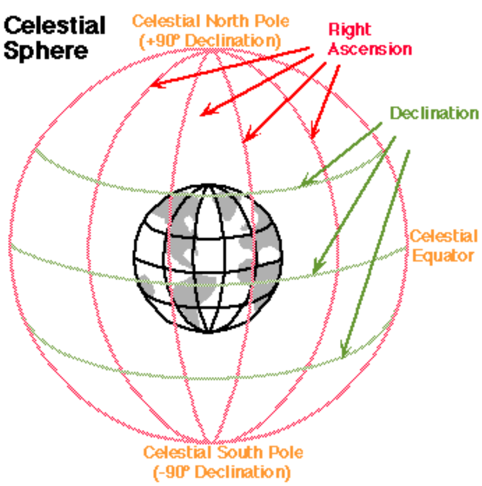
Review of Geographical Coordinates

The Earth's spin determines special locations on Earth. The spin axis goes through the North and South Poles, and midway between them, is the equator.

Latitude—To indicate how far north or south we are on Earth, we use degrees (°) of latitude. The equator is neither north nor south and is 0° latitude. Latitude lines range between 90°S, which is the latitude of the South pole, and 90°North, the latitude of the North Pole.

Longitude—To indicate how far east or west we are, we use longitude in degrees. Longitude lines are perpendicular to the latitude lines and go from the North Pole to the South Pole. As Earth spins, longitude lines swing under the Sun "like clock-work." A zero longitude line was arbitrarily chosen to go through Greenwich, England. Longitude lines are numbered to 180 degrees east of Greenwich and 180 degrees west of Greenwich.

For telling more precise locations, each degree of latitude or longitude is subdivided into 60 minutes, often called *minutes of arc* (measure of angle, not time). Each minute is further divided into 60 *seconds of arc*. An apostrophe (') is the symbol for minutes of arc, and a quote mark (") is the symbol for seconds of arc. Example: San Francisco, California is 122° 26' west of Greenwich and 37°46' north of the equator. These geographical coordinates are abbreviated 37°46' N 122°26' W.



Celestial Coordinates

Long ago, people believed that there was a giant sphere to which the stars were attached—the *celestial sphere*. Imagine extending the Earth's axis infinitely into space, north and south. It would pierce that sphere in two places: the *celestial north pole* and the *celestial south pole*. If Earth's equator were extended infinitely outward to the celestial sphere, it would become the *celestial equator*.

Even though we know there is no physical sphere out there holding up the stars, we still find it convenient to think of an imaginary celestial sphere to specifying locations of things in the sky. The "celestial latitude lines" are called *declination*. As with latitude on Earth, declination in the sky increases from 0°at the celestial equator to 90° at the celestial North or South pole. As with latitude on Earth, each degree has 60 minute divisions (') and each minute is further divided into 60 seconds (").

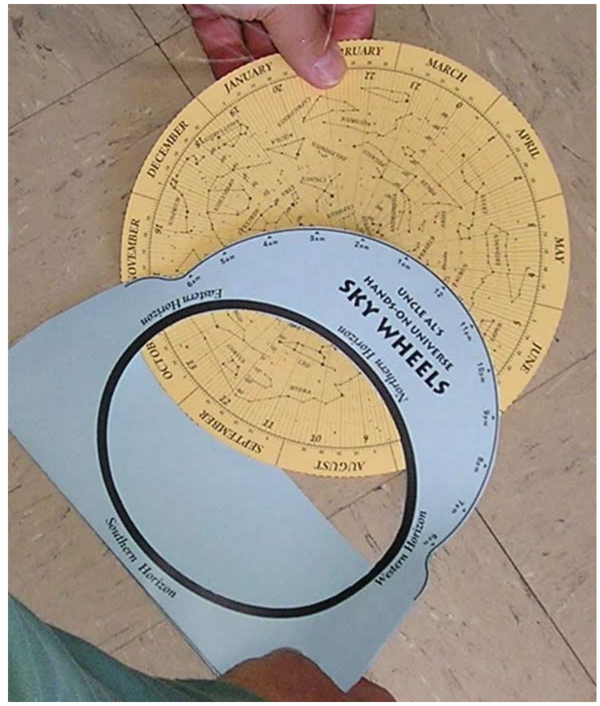
Right Ascension is the name of the celestial coordinate that corresponds to longitude on Earth. Unlike longitude, which is measured in degrees and minutes, right ascension is measured in hours and minutes. There are 24 hours of right ascension corresponding to the full sweep of 360 degrees around the celestial equator. Simple division will tell you that each hour of right ascension must be equivalent to 15 degrees of arc. As you might expect by now, each hour has 60 minute divisions (') and each minute is further divided into 60 seconds (").

Investigation *Developed by HOU Co-Director, Alan Gould (Uncle Al)*

Using Star Maps

Standing here on Earth which is rotating, we see everything in the sky wheeling around us once every 24 hours. Each object in the sky appears to move 15° westward every hour as Earth rotates. (15°/hr = 360°/24 hrs)

Make "Uncle Al's HOU Sky Wheel" to demonstrate this motion. [Print the "Coordinate Sky Wheel" and "Sky Wheel Holder" from http://lhs.berkeley.edu/starclock/skywheel.html.] Follow the instructions on the printed starwheel sheet, and when it is cut out and assembled, set the Sky Wheel for near the end of the school year, June 1, at shortly after sunset, say 9 p.m.



Notice the Big Dipper is high in the sky and the tip of the handle is near Right Ascension 14 hours, which in turn points close to the word "Southern" in "Southern Horizon" on the Star Wheel Holder. The times on the Star Wheel Holder are always standard time, so you may need to take that into account if your clock is set to daylight savings time.

Rotate the Star Wheel FORWARD 2 hours (to 11 p.m. standard time on June 1).

2.1 What Right Ascension line now points to the word "Southern" in Southern Horizon?

2.2 What constellation just rose, almost due east?

2.3 What constellation is setting in the northwest?

2.4 What constellation is closest to the zenith (highest place in the sky; center of the map)?

Rotate the Star Wheel FORWARD by another 2 hours (to 1 am standard time on June 1).

2.5 What Right Ascension line now points to the "Southern" in Southern Horizon?

2.6 What constellation is closest to the zenith?

2.7 What constellation is rising, almost due east?

2.8 What constellation is setting in the west?

Rotate the Star Wheel FORWARD another 2 hours (to 3 am standard time, June 1).

2.9 What Right Ascension line now points to the "S" in Southern Horizon?

2.10 What constellation is closest to the zenith?

2.11 What constellation is rising in the northeast?

2.12 What constellation is setting in the northwest?

Notice that there is one star in the sky which does not seem to change its position ever. It's at the tip of the handle of the Little Dipper, (Ursa Minor) and is called *Polaris*, or the *North Star*.

Now some more questions to test your Star Wheel driving skill:

2.13 What constellation is near the zenith on New Year's Eve at 11 p.m.?

2.14 In what month is the Big Dipper (Ursa Major) highest in the sky at midnight?

2.15 About what time is Leo setting (in the northwest) on the summer solstice (about June 21)?

Earth Rotating on Its Axis and Revolving Around the Sun

Rotating the Star Wheel can represent both rotation (spinning) of Earth and revolution (orbiting) of Earth around the Sun. To imagine Earth's rotation, keep your attention focused on one date and watch the hours go by that date as you turn the wheel. To imagine Earth revolving around the Sun, keep your attention focused on a particular hour of the night and imagine that you are coming out each night to see that sky at that particular hour of night. You can then watch the days and months go by from the perspective of that particular time of night. The Sun appears to creep Eastward in the sky each day by approximately one degree, or about 30 degrees (2 hours right ascension) per month.

2.16 How many degrees does the sky shift in one month?

The Trifid Nebula, the 20th entry in Charles Messier's catalog, commonly referred to as M20. Photo courtesy Richard Bennion, Ewell Observatory, Belmont, CA. http://www.ewellobservatory.com

Find Messier Objects

Charles Messier, a French comet hunter, created a catalog of interesting sky objects that might look a little like comets, but are not. They are actually a variety of objects including star clusters, galaxies, and nebulae (clouds of gas). If you find a table that has the coordinates of the Messier objects, you can mark them on your own star map. For example, the Owl Nebula is a Planetary Nebula 1630LY from us, whose coordinates are RA 11h14.8m; DEC +55°01'

2.17 In which constellation is the Owl Nebula?

You can download the HOU Messier Object Excel spreadsheets at http://www.handsonuniverse.org/activities/uncleal. You might choose to mark the BRIGHTEST Messier objects on your Coordinate Star Wheel, or perhaps the CLOSEST Messier objects.

2.18 Get image(s) of Messier object(s). In book(s) or searching the worldwide web, find Messier objects of the following types: nebulae (gas clouds), globular star clusters, open star clusters, galaxies. Print one for wall decoration or save for a computer screen display.

August 2007: Google announced the roll-out of its Google Sky software for exploring celestial objects.

Moving Planets, Asteroids, and Comets

Most things we see in the solar system—planets, asteroids, and comets—generally move across the sky through the night along with the "fixed" stars. However, most of them very slowly drift relative to stars from west to east as they orbit the Sun. The movements of the planets range from Mercury's fast orbit motion (as much as 2 degrees per day eastward in the sky) to Pluto's slow orbit motion (about 1.5 degree per year eastward against the background stars).

You can mark the positions of planets on your Coordinate Star Wheel, but since they change, it's best if you make those marks in pencil so you can erase and update their positions as needed.

Good ways to find planets include:

- Get a "planetarium program" that computes celestial coordinates of planets. See http://astro.nineplanets.org/astrosoftware.html
- Que Tal in the Current Sky -- http://currentsky.com
- Magazines: *Sky & Telescope* or *Astronomy* magazine
- *Observers Handbook* (Royal Astronomical Society of Canada)
- Guy Ottwell's *Astronomical Calendar* (Dept. of Physics, Furman University, Greenville, S.C.)

You can also get an ***ephemeris*** of the Planet's Coordinates which is a table of celestial coordinates pinpointing the object's location at specific time intervals as it moves in the sky. You can find an Ephemeris generator at the NASA Jet Propulsion Lab (JPL) website, http://ssd.jpl.nasa.gov/horizons.cgi.