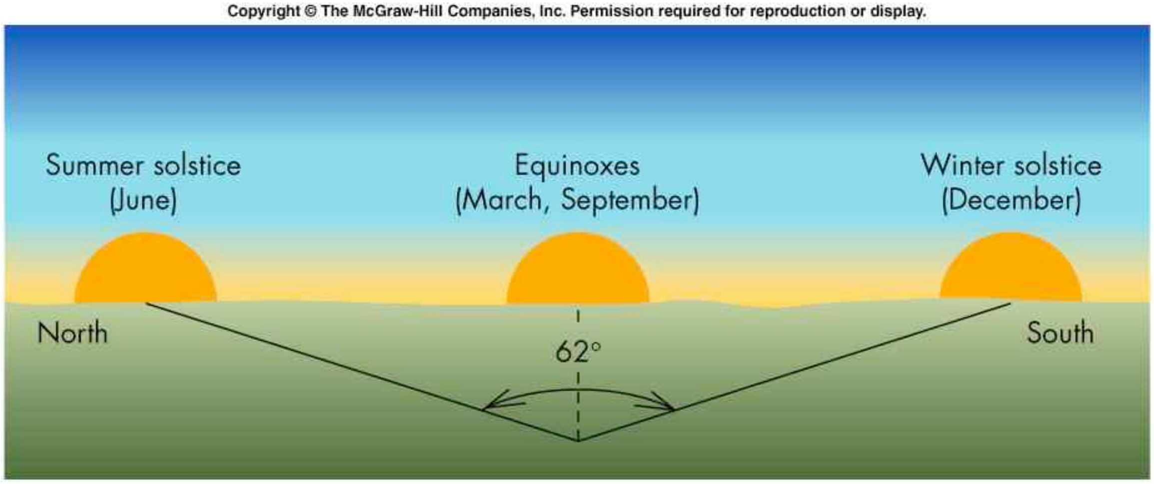
29:52 Exploration of the Solar System
Notes for February 4, 2008
The Sun: Seasons and Time

In last lecture noted that the right ascension and declination of the Sun changed throughout the year.

1. You can tell this from observations of the sky.
2. We can explain this physically by the orbital motion of the Earth around the Sun (revolution) plus the tilt of the Earth's axis (obliquity of the ecliptic).

We discussed two consequences of this.

3. There is a change through the year of the azimuth of the Sun at rising and setting (see Figure 2.12 below).
4. There is a change of the length of daylight; the amount of time the Sun is above the horizon.



Today we discuss a *third* consequence, which is the change in the *altitude angle of the Sun at transit.*

Below is a formula for the altitude angle at transit of any astronomical object. Let LC be the complement of the latitude (the latitude is L), and D is the declination of the object. The altitude angle at transit is

$$ALT=LC+D$$

At its furthest north, the declination of the Sun is +23.5; at its furthest south, it is -23.5. Look at the difference in the altitude angle. Take Iowa City, which has a latitude of about 41.5 degrees north. Since L=41.5 degrees, LC=48.5.

1. On the summer solstice D=23.5 and ALT=48.5+23.5=72degrees
2. On the winter solstice, D= -23.5 and ALT=48.5-23.5=25 degrees.

This is a large change in the angle at which the Sun's rays come in.

Highly oblique sunlight is less effective at heating the ground. As a result, the colder winter months correspond to times when the Sun's rays are more oblique, and the Sun is above the horizon for fewer hours.

The Arctic Circle.

The above equation also tells us where on the Earth the Sun would not rise at all. If ALT=0 for the Sun at transit, it is sitting right on the southern horizon at noon. For a negative ALT, it doesn't rise at all. Our equation says that if LC=23.5, ALT =0 on the winter solstice. LC=23.5 corresponds to a latitude of 66.5 degrees. For latitudes greater than 66.5 degrees, the Sun doesn't rise for at least some days during the year. At those times, it would be dark 24 hours per day.

At the north pole, the Sun never rises between September 21 (autumnal equinox) and March 21 (the vernal equinox).

Summary of Terms for the Sun's Motion in the Sky

Here are some important terms for the position of the Sun in the sky, and how it relates to the seasons.

1. Vernal equinox; first day of Spring; D=0 degrees.
2. Summer solstice; first day of summer, longest day of year, D=+23.5 degrees.
3. Autumnal equinox; first day of autumn, D=0 degrees (again).
4. Winter solstice; shortest day of year, first day of winter, D=-23.5 degrees.

Note that the seasons are reversed in the southern hemisphere. Be sure you understand why this is so. Right now, it is late summer in Australia.

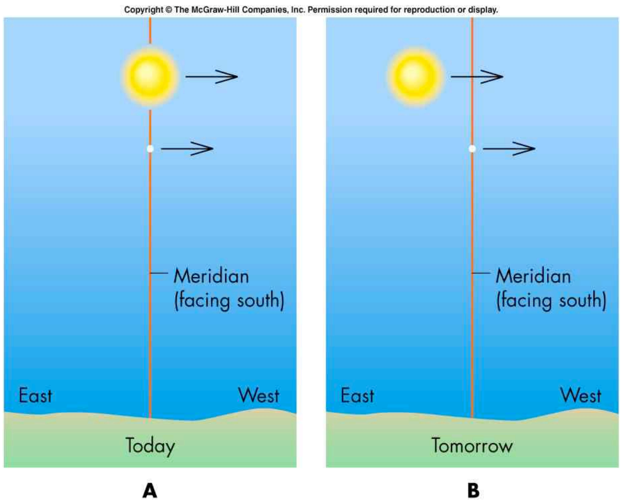
Time

Probably the original motivation for the development of astronomy was to keep time. You can base clocks and calendars on the motions of the Sun or the Moon. Let's start with the Sun (the basis for modern timekeeping).

To keep track of time, we need a fundamental unit or interval of time. That is the day. The day is defined astronomically. There are two kinds of days in astronomy.

1. The *solar day*: this is the interval of time between successive transits of the Sun.
2. The *sidereal day:* this is the time between successive transits of a star.

You would think that these are the same, but they aren't. The average solar day is longer. The sidereal day is 23h56m4s in length. An illustration of the difference between the solar day and the sidereal day is given in Figure 2.17 of the book.



The reason for this is that the Sun is moving eastward relative to the stars (caused by the Earth's orbital motion), so the Earth has to rotate a little more to "line up" the Sun on the meridian after one day.

Interestingly enough, the length of the solar day is not the same during the year. If you have an accurate enough clock, you can measure that the time between successive transits of the Sun is not the same in, say, September as it is in May. The reason for this is that the rate of eastward motion of the Sun against the background stars varies through the year. This is mainly due to properties of the Earth's orbit around the Sun that we will discuss a little later.

This would make a mess out of civil timekeeping, so the length of the day our clocks run on is the *mean solar day,* or average length of time between successive transits of the Sun.

Apparent solar time is the time you would measure by where the Sun is relative to transit. When you observe the Sun transiting, the apparent solar time is 12 noon. 12 hours before is apparent solar midnight, and 6 hours after is apparent 6PM. Due to changes in the length of the apparent solar day, the difference between apparent solar time and mean solar time can be as great as 16 minutes. Apparent solar time is what you measure with a sundial.

Time depends on your longitude. This is easiest to understand if you think of apparent solar time, but it works for mean solar time as well. Let's say it is 12 noon apparent solar time for you. Obviously it will be 12 midnight for someone on the other side of the Earth. For a person 15 degrees of longitude to the east, it will be 1PM apparent solar time. Think about it and make sure it makes sense to you. This fact is the basis of ways of determining longitude from astronomical observations.

You can't have different times for each longitude (Wayland and Olds, Iowa, for example, which are about 5 miles apart), so we define time to be the same within 15 degree zones called time zones. We are in the central time zone. Read about it in your textbook and look at Figure 2.18.

Next time, we talk about the year, another main unit of time.