Calendars and Time

One of the earliest and most important functions of astronomy is to provide information for a calendar. Most civilizations want to keep track of the seasons, which depend in turn on the declination of the Sun. But the declination of the Sun changes slowly and it is not always obvious when the Sun gets to one or another extreme of its motion. On the other hand, changes in the Moon's phase are very obvious and easy to keep track of. It would be nice if these changes could both be used to keep track of things.

Alas, the moon requires 29.53… days to go through its cycle of phases, while the seasons (including accounting for precession) repeat every 365.2419…days, every **tropical year**. The **lunar synodic period** (as the time for phases is called) will not divide into the tropical year evenly, without a fraction of remainder. The tropical year is between 12 and 13 lunar months. Worse yet, neither the lunar month nor the tropical year is an integer number of days. But no one wants to start the year in the middle of the day (like 11 AM for example) and then try to keep track of the date.

Ancient civilizations generally tried to reconcile the lunar and solar cycles.

In Egypt, it was most important to keep track of the flooding of the Nile. This occurs on a yearly basis, due to rains flowing into the southern parts of the river. Seed had to be sowed before the flood covered the fields, providing the only water of the year. So it was necessary to know when the Nile would flood, well in advance of the actual event.

The Egyptians used a 365-day solar year for the civil calendar. It was constructed by using 12 months of 30 days each plus 5 extra holiday days. This preserved the idea of the 29.5-day lunar month, but does not keep the lunar phases aligned with days of the month.

As the ~1/4 day difference between the civil and tropical year accumulated, the Egyptians realized that they had a problem. They decided to use the **heliacal** rising of Sirius to trigger the year. Heliacal rising is when the body rises just before the glare of sunlight makes it impossible to see. The next day, the same celestial body will normally rise ~3min 56 seconds EARLIER and will be visible during the night for a while. This method of keeping the calendar IS affected by precession, but on a much longer time scale.

Q 1) If you used the Egyptian 365 day calendar, about how long would it take for the calendar to get 30 days out of alignment with the Sun?

2) If you used the Egyptian 365 day calendar, about how long would it take for the calendar to get a whole year out of alignment with the Sun?

3) What date would you estimate that Sirius rises just before the Sun these days? (Make a horizon for the Earth and move the earth around until the dawn horizon just touches the Sun. Now estimate the date?)

4) What date would you estimate that Arcturus rises just before the Sun these days?

In 238 BCE the Egyptian calendar was reformed by including leap years, with 366 days, every fourth year, bring the average length of the year to 365.25days.

Lunar calendars were in use in the Middle East at the same time. To keep the seasons aligned with the lunar months, some years need to have 12 lunar months, and others need to include 13. This is done by having another, intercalary month, every 2.8 years on the average. Calendars like the Chinese, Vietnamese, and Jewish ceremonial calendars all work this way. Each of these calendars has its own distinct new year time and scheme for intercalation. These calendars are never allowed to slip far from the seasons.

The early Roman calendar also used lunar months, with additional intercalary months in the winter. By the time of Julius Caesar, several intercalary months had been skipped and the traditional March 25 new year had drifted far from the vernal equinox. Caesar reformed the calendar by introducing two intercalary months for that year and by adopting the scheme of 365 days (some 30 and some 31 day months) with one leap year every 4th year. This is called the Julian calendar.

The Julian calendar has an average year of 365.25 days, assuming that the leap year is properly observed. But the tropical year, the year that stays aligned with the seasons, is only 365.2419…. days, some 0.008 days shorter. On the average the Julian calendar runs 1 full day behind the tropical year after 1/. 008 = 125 years. After 1500 years, the Julian Calendar would predict vernal equinox 12 days later than it actually occurred.

Perhaps no one would have cared, but the Catholic Church needed to compute when Easter would occur. Traditionally, Easter is on the Sunday, following the Full Moon, which follows the Vernal Equinox. This would make it 2 days after the Passover Seder (when the Last Supper would have occurred).

It would be easy to observe the vernal equinox, then the full moon, and then have Easter (assuming that there was a way to correct for bad weather). But people wanted to predict when Easter should be celebrated years in advance. Many numerical schemes were tried, and recorded. But the discrepancy between the Julian calendar and the Jewish lunar calendar, made it obvious that there was a problem. According to the Julian calendar, the vernal equinox got earlier and earlier in the year.

Several attempts were made to correct the problem. People were not even certain that the tropical year was constant. Eventually in 1582 Pope Gregory declared a solution based on the findings of a commission he had called. In February 1582, a papal bull was sent instructing people on how to revise the calendar. At that time, January 1 became the start of the year. The decision was that the day following October 4, 1582 would be October 15, 1582. At that time the current leap year scheme was adopted

> **Gregorian Calendar** Leap Years
> February 29 occurs in years
> -divisible by 4 (with no remainder) EXCEPT
> -century years if they are not also divisible by 400

As you may imagine, it was hard for countries to respond to a calendar change within the same year, even if a country meant to do it. Some Catholic countries adopted the Gregorian calendar immediately. Others adopted it later. The history timeline includes some of the dates.

Non-Catholic countries weren't about to do what the Pope said, regardless of whether it was right or wrong. For many years different countries used different dates. So if you read European history, the dates may be in OS, old style (Julian Calendar) or NS (new style) Gregorian dates. Countries switched to NS one by one. Britain and the colonies changed in 1752; Russia changed in 1917. When each area switched, the number of days skipped was altered to bring the calendars all together with the same dates.

The Gregorian calendar isn't perfect. It is still 26 seconds too short. But the day is getting longer as the Moon spirals away. So the discrepancy is getting smaller.

There are several calendars in use that don't use the tropical year as a base or reference.

The Islamic calendar uses 12 lunar months and never 13. So the year is complete in less than a solar year and the holidays slip backward through all seasons. The month traditionally begins with the actual sighting of the crescent moon as soon after new moon as is possible. To keep a calendar that approximates this month, the 12 months have 29 and 30 days.

The Mayans kept at least three different calendars. One was a 365-day solar calendar, consisting of 18 months with 20 days each. Another was made of 13 cycles of 20 days each for a total of 260 days. These two calendars come into alignment every 52 years, called a calendar round. The Mayans also kept a long count consisting of a cycle of 5130 years. It is composed of shorter 20-day cycles with repeats of 20's and 13's.

Traditionally, classical period Mayans cosmology states that 3 of these great cycles had been completed before their current cycle (which started in 3114 BCE and ends in 2012). The entire world is supposed to end and be renewed at that time.

By this time, you may be wondering how astronomers put up with all this complexity. When we want to find the orbit of a comet, for example, we may have data from previous years. But to know how long ago that really was, we would need to take into account the number of February 29's etc. that have occurred in between, whether daylight savings time was in place and how many time zones between the observation locations.

Astronomers don't mess with this. They use a system called Julian Day. It has not months, weeks or years. It just counts days since noon on Jan 0 at Greenwich England in 4713 BCE. This day was chosen based on the idea that it is unlikely that a historic account will be found (on Earth) which occurs before then. Jan 1, Midnight of 2000 (at Greenwich) was 2451544.5. Within each day, astronomers use decimals (like JD 2451544.03).

The second, based on vibrations of a Cesium atom, is the way absolute time is measured. The Earth's orbit and the spin are not exactly constant. The length of the nominal day was set in the 1870's, so the reference day is not changing due to tides.