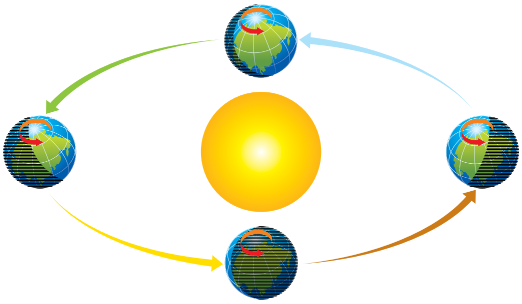
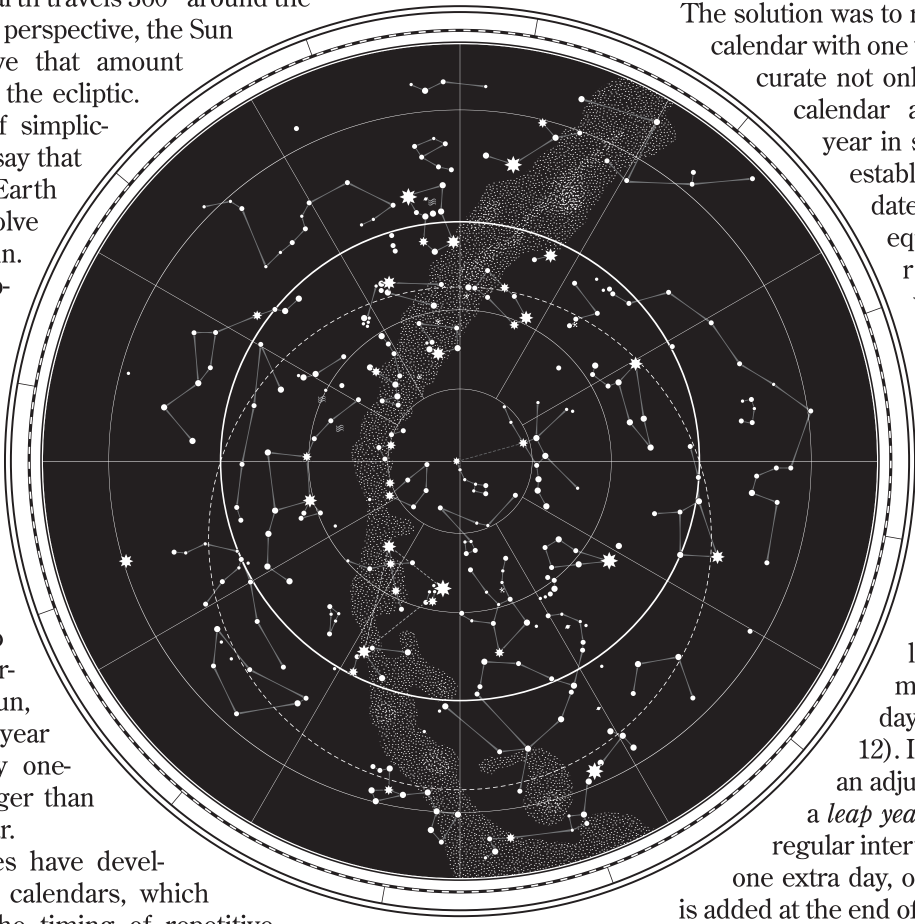
A year in time

by Bob Riddle



Every year around this time, winter officially becomes spring on a day appropriately called the March equinox. Most students know this fact, but few of them know the type of calendar year used to measure the change of seasons.

A *tropical year* is used to measure how long it takes the Earth to complete one revolution around the Sun, using the March equinox as the starting point. During each year, the Earth travels 360° around the Sun or, from our perspective, the Sun appears to move that amount each year along the ecliptic. For the sake of simplicity, we typically say that it takes the Earth 365 days to revolve around the Sun. With this approximation, the Earth would need to move approximately 0.99° each day. This is known as a *common year*. However, the Earth actually takes about 365.24 days to complete one orbit around the Sun, so the tropical year is approximately one-quarter day longer than the common year.



Many cultures have developed their own calendars, which are based on the timing of repetitive astronomical events. Some calendars, such as the Gregorian calendar, use the tropical year, whereas the Jewish calendar uses both the tropical year and the lunar cycle, and the Islamic calendar is based on the lunar cycle. The first widely used calendar was the Julian calendar, which was introduced in 45 BCE and made up of 365.25 days per year. Though close to the actual length of the tropical year, it was off enough that an error of one full day occurred every 128 years. Although this might not seem like much, over time, dates shifted backward with respect to the calendar. In other words, the tropical year and the human-made calendar were out of synch with each other.

The solution was to replace the Julian calendar with one that was more accurate not only in keeping the calendar and the tropical year in synch but also in establishing a specific date for the March equinox. The 1582 replacement was the Gregorian calendar, which is still in use today. The Gregorian calendar is made up of 365.2425 days and includes 12 months where the average length of each month is 30.44 days (365.2425 / 12). In either calendar, an adjustment known as a *leap year* is included at a regular interval, during which one extra day, or *intercalary day*, is added at the end of February. In the Julian calendar, the leap year was every fourth year, so an extra day was added every fourth year to make up for the quarter day not counted each year. The Julian calendar took things one step further by skipping the leap year in years that were evenly divisible by 100.

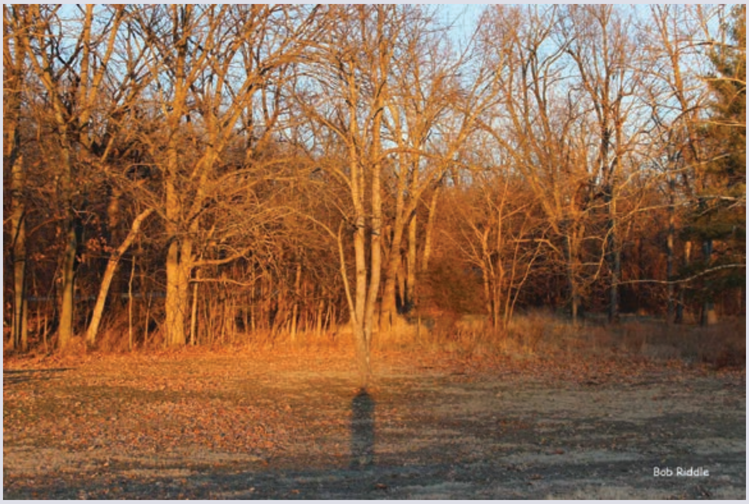
This adjustment was necessary because more accurate calculations of the tropical year revealed that it was approximately 11 minutes shorter than the 365.25 days used by the Julian calendar

All calendars need an established starting point from which to measure the length of the year. In the Julian and Gregorian calendars, the starting point is the March equinox. Another method using a different starting point is the *anomalistic year*, a year whose length, 365.2596 days, is measured from the time of one perihelion to the next. *Perihelion* is the minimum distance that can separate the Earth and the Sun and occurs around the first week of July.

More commonly used after the calendar year is the *sidereal year*, a year with a length of 365.2564 days (365 days, 6 hours, 9 minutes, 13 seconds). *Sidereal*, meaning "time by the stars," is measured with reference to the fixed stars in the background and times how long it takes for a reference star, other than the Sun, to return to the same position in the sky. However, if the Sun were used for this measurement, then it would be called a tropical year and would be measured from the time the Sun is at the March equinox to when it returns to that same equinox. This method would amount to a year length of 365.2422 days (365 days, 5 hours, 48 minutes, 46 seconds).

Calendars, as artificial time-keeping methods, probably resulted from the need to keep track of longer time spans than the more familiar natural day-and-night cycle and the monthly cycle of Moon phases. The seasonal year was a logical next step, but without specific dates established to mark the changing of the seasons, this calendar was somewhat irregular in that the changes in seasons were more subtle in some areas of the world than in other areas. Regardless of the circumstances, all time-keeping methods we follow have their roots in, and are based on, motions of the Earth and Moon, such as their respective rotation and revolution. Historically, many calendars have been developed in different parts of the world, and students could conduct some research into the different calendars in addition to the currently used Gregorian calendar. This activity could include calendars developed and used in China, India, early Greece, Rome, and Egypt, as well as present-day calendars used in Islam and Judaism (see Resources for a link to a NASA website about calendars).

FIGURE 1 Casting a long equinox shadow



Cast an infinite shadow

On March 20, the day of the March equinox, the Sun rises exactly east at the complementary angle to your latitude. At the equator, which is 0° latitude, the Sun

FIGURE 2 Students in Quito, Ecuador, measuring the Sun's altitude angle at midday on the equinox

rises at a 90° angle, straight up, in relation to the horizon. At midday on the equator, the Sun is directly overhead and shadows have no length, but rather look like shapeless blobs at your feet (Figure 1). At 40° latitude, the Sun would rise at the complementary angle of 50°. At midday when the Sun is due south and at its highest point above the horizon, your shadow is at its shortest length for the day and would point directly north. At sunset, the opposite of what occurs at sunrise would happen as your shadow again is infinite in length and points directly east. Interestingly, at the time of local sunrise on the March equinox, if no obstructions were present, your shadow would be infinite in length and would point directly west (Figure 2).

An equinox eclipse

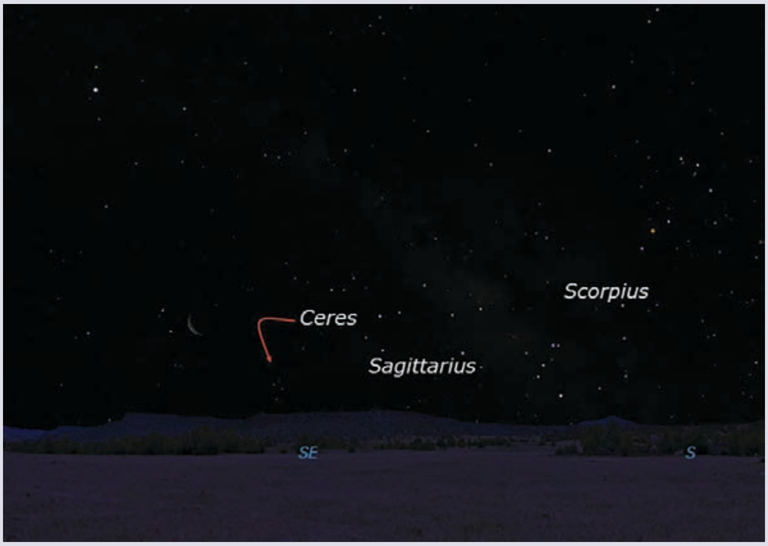
The first of the two eclipse pairs for this year, a total solar eclipse, will occur on March 20, the day of the equinox. Coincidentally, this full Moon has the greatest *apogee* distance, or most distant orbital point from the Earth, of the year, making it a “super mini-Moon.” The eclipse path, or the *path of totality*, crosses the north Atlantic Ocean, with the greatest duration of the eclipse—2 minutes, 47 seconds—visible near the Faroe Islands east of Iceland. This eclipse will not be visible from the United States, but as with all solar eclipses, the path the Moon’s shadow follows allows for a virtual trip to other countries with your students to give them the opportunity to learn more about these countries. Students can use the map at the eclipse website to follow the path of totality (see Resources).

End of the line

This month, some space missions will come to their endings. At the time of this writing, the *MESSENGER* orbiter at Mercury is scheduled for impact with the surface of the planet. *MESSENGER* is a mission to study Mercury and has been active since its arrival at the planet in March 2011. The impact date will more than likely be known by the time you receive this issue of *Science Scope*. An x-ray–observing satellite, *Suzaku*, operated by the Japanese Space Agency (JAXA), is scheduled to shut down, signaling the end of its extended mission. The *Suzaku* mission involved the study of the structure and evolution of black holes and galaxy clusters. Another x-ray–observing satellite, the XMM-Newton, operated by the European Space Agency, will also be ending its extended mission. This mission examines x-ray emissions from a variety of sources, including galaxies and black holes.

The *Dawn* mission is not ending its mission; rather, its journey across the main asteroid belt continues when it enters orbit around the dwarf planet Ceres this month. At the end of this month or early next month, NASA will be launching the *Jason 3* satellite. This is an Earth-observing mission to record sea levels to gather data about ocean circulation and climate changes (see Resources for mission websites). ■

FIGURE 3 Location of dwarf planet Ceres at 5 a.m. EDT on March 15, 2014



Visible planets

Mercury will be low over the eastern horizon before sunrise but will be difficult to see.

Venus will be visible over the western horizon at sunset.

Mars will be visible over the western horizon at sunset.

Dwarf planet Ceres will rise about

For students

1. On the day of the equinox: What is the rising or setting angle for the Sun at the North Pole? In what direction would your shadow point at midday on the equator? *(The Sun rises and sets at the complementary angle to the latitude, so at the North Pole, the Sun rises or sets at 0°. At the equator at midday, your shadow would point straight down toward the ground.)*
2. Why use *midday* instead of *noon*? (Midday *is the moment when the Sun is halfway between rising and setting and is different for each longitude position.* Noon *is a standard clock time and is the same east or west across each time zone, regardless of the Sun's position.)*
3. On the equinox, does the Sun really rise exactly east for all locations on the Earth? *(The Sun rises exactly east and sets exactly west only for those on the longitude where the time of local sunrise or sunset coincides with the time of the equinox. So if you are not at that longitude, then the Sun rises and sets a little bit away from due east or due west, respectively.)*

two hours before the Sun and will be low over the southeast horizon at sunrise (see Figure 3).

Jupiter will be high above the southern horizon at sunset and will be visible all night.

Saturn will rise around midnight local time and will be high above the southern horizon at sunrise.

March

2 Waxing gibbous Moon near Jupiter
3 Waxing gibbous Moon near Regulus
4 *Dawn* spacecraft arrives at Ceres
5 Moon at apogee: 406,400 km (243,840 mi.)
Full Moon (smallest of the year—a super mini-Moon)
6 *Dawn* spacecraft arrives at dwarf planet Ceres
7 Moon at ascending node
8 Daylight saving time begins
9 Waning gibbous Moon near Spica
12 Waning gibbous Moon near Saturn
13 Last quarter Moon
Mars near Uranus
14 *Cassini* distant flyby of Helene and Calypso
16 Waxing crescent Moon near dwarf planet Ceres
Cassini flyby of Titan
19 Moon at perigee: 357,600 km (214,560 mi.)
20 New Moon
Total solar eclipse
Vernal equinox: 6:45 p.m. EDT
Moon at descending node
21 Thin waxing crescent Moon near Mars
Dwarf planet Makemake at opposition (51.5 AU)
22 Thin waxing crescent Moon near Venus
24 Waxing crescent Moon near Aldebaran
27 First quarter Moon
30 Waxing gibbous Moon near Jupiter
31 Launch of *Jason 3*

Resources

Calendars—*http://eclipse.gsfc.nasa.gov/SEhelp/calendars.html*
Cassini Saturn mission—*http://saturn.jpl.nasa.gov*
Dawn mission—*http://dawn.jpl.nasa.gov*
Daylight saving time—*www.timeanddate.com/time/dst/2015.html*
Jason 3 mission—*www.jpl.nasa.gov/missions/jason-3*
MESSENGER mission—*http://messenger.jhuapl.edu*
Project SunShIP—*http://sunship.currentsky.com*
Suzaku x-ray satellite—*http://global.jaxa.jp/projects/sat/astro_e2*
Total solar eclipse of March 20, 2015—*http://moonblink.info/Eclipse/eclipse/2015_03_20*
XMM-Newton mission—*www.esa.int/Our_Activities/Space_Science/XMM-Newton_overview*

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