Chapter 2
Effects of Celestial Motions on Human Activities

Our ancestors were curious about the effects of celestial objects on Earth. Heaven and nature touched every aspect of ancient culture and sky stories are woven into myth, religion and astrology. People also noted the contrast between the beauty and stability of the heavens and the insecurity and grim realities of terrestrial life. For early humans on Earth, survival was a daily struggle. They were constantly scraping by to gather enough food to eat and seek shelter from wind, rain, and cold. At times, they were at the mercy of unpredictable elements such as storms, and floods. But the heavens appeared permanently peaceful. By watching the heavens, our ancestors found consolation. Through the Sun, the Moon and the stars, they believed that they had access to the supernatural and satisfied their spiritual needs.

There were also practical reasons that the ancients cared about the heavens. Even the most primitive people realized that their lives were governed by the Sun. Light and warmth provided by the Sun were essential for survival. Human activities were confined to the day because darkness made outdoor activities such as hunting and fishing difficult, if not impossible. It was also much harder to spot and evade predators at night. By watching the position of the Sun in the sky, ancient people knew the amount of daylight left to finish their tasks and return to their caves or huts safely. The Sun was their natural clock.

About 10,000 years ago, humans began to change from gathering and hunting to farming. Plants grow in the summer, and food is more plentiful during the warm season. Surviving the winter was a major challenge. In fact, before modern times, starvation during the winter season was common. Since agriculture depends on the seasons, there were practical reasons to better understand the heavens. By noting the positions of sunrise, people learned how soon winter would arrive and could prepare accordingly. It was only in the last hundred years that advances in technology (in particular artificial lighting) made us less aware of the heavens.

S. Kwok, *Our Place in the Universe*, DOI 10.1007/978-3-319-54172-3_2

2.1 Daily Motion of the Sun

Let us begin to study the daily motion of the Sun. We know qualitatively that every day the Sun rises on one side of the horizon and sets on the other side. Sometime between the rising and setting, it reaches a highest point in the sky. The fact that the Sun rose at a different time every day has been for known for thousands of years. Around 500 B.C., Babylonian timed the Sun's rising and setting to an accuracy of about one minute using water clocks.

In the following paragraphs, we will describe the movement of the Sun as it would appear to an observer in a northern temperate zone. This would apply to most ancient civilizations—the Babylonians, the Egyptians, the Greeks, and the Chinese. First, they see the Sun rises earlier and earlier; after reaching the earliest time, it rises later and later. After the latest sunrise time is reached, the Sun begins to rise earlier and the cycle repeats. When the Sun rises earlier, it also sets later. The length of the day (time between sunrise and sunset) is therefore different every day. The date of the longest day is called summer solstice, and the date of the shortest day is called winter solstice.

Every day after sunrise, the Sun gets higher and higher in the sky, reaching a maximum altitude during the day (the local noon). It then begins setting and gets lower and lower until it reaches the other side of the horizon. The next day, the maximum altitude reached by the Sun at noon is different. During part of the year, the Sun will get higher and higher at noon until it reaches a maximum height on a certain date; after that the maximum altitude of the Sun at noon will decrease. This decrease continues until it reaches its lowest point at noon about a half a year later, and then reverses itself and increases again.

2.2 The Annual Motion of the Sun

It would be simple if that was all the Sun did. However, in addition to its daily motion, the Sun follows a different path in the sky each day. Not only does the Sun rise at different times and to a different height every day, it also rises from a different location on the horizon. As we go from spring to summer, the Sun rises each day a bit more to the north of east, until it rises at the northern most point on the day of the summer solstice (June 20 or 21; solstice means "sun stand" in Latin).[1] After the summer solstice, the rise point of the Sun moves south, and it rises exactly in the east on autumnal equinox (~September 22 or 23). After that, the Sun rises in the southeast and reaches the southernmost point on winter solstice (~December 21 or 22). Then the Sun turns back to the north and rises exactly in the east again on

[1]The date of June 21 for summer solstice is only applicable in the northern hemisphere. In the southern hemisphere, the dates of the summer and winter solstice are interchanged.

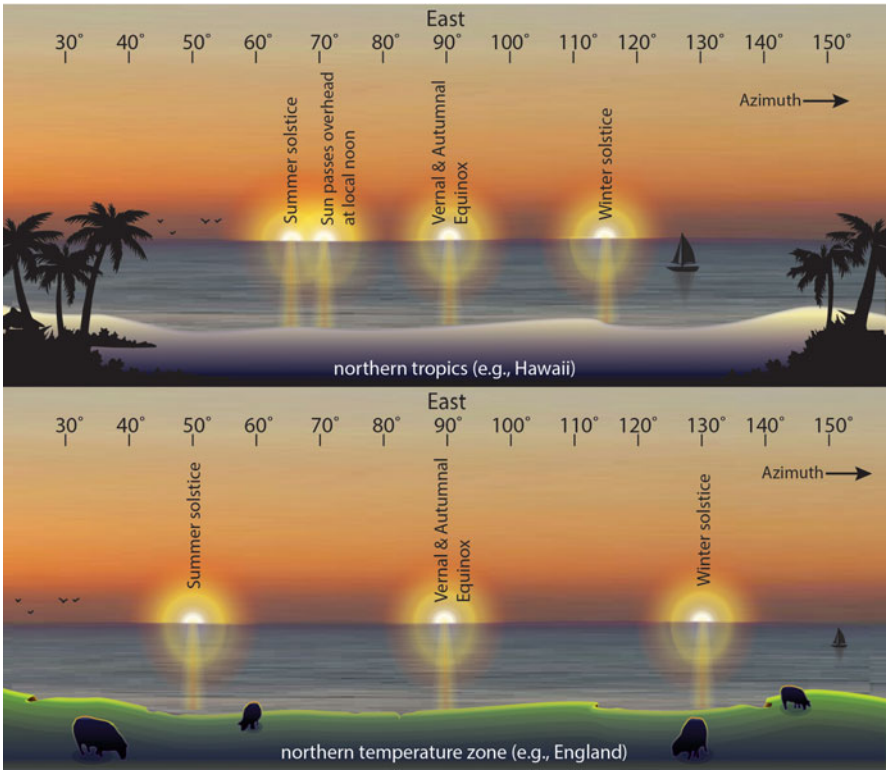

Fig. 2.1 Positions of sunrise vary with the time of year and observing location. The Sun rises in the northeast in the summer and in the southeast in the winter. For an observer in the northern tropics (*top panel*), there are days when the Sun can pass directly overhead, and the sunrise positions for those days are marked. The positional spread of the sunrise point on the horizon is larger in more northern locations (*bottom panel*). At 50° latitude, the spread of the sunrise point between summer and winter solstices is 77°

the vernal equinox (~March 20 or 21). This shift in the position of sunrise with the seasons is illustrated for two locations in Fig. 2.1.

In a northern location such as England, the swing of the position of the rising Sun is quite large (~80°). This is easily noticeable even to the casual observer. In a house with a north-facing window, the Sun shines through the window in the summer but not in the winter. Using mountains as markers, Native American Indians used the shifting position of the rising Sun as a calendar. The shift is most rapid when the Sun is near the equinoxes (about a degree a day) but slows down considerably near the solstice. The rising Sun reverses directions at the most northern (summer solstice) and the most southern (winter solstice) points.

2.3 The Seasons

The annual motion of the Sun directly relates to the seasons. Every year, the weather changes from warm to cold and back to warm again. Seasons greatly affect human activities. In the winter, it may not be possible to grow crops. Outdoor activities may be hampered by cold temperatures, ice, and snow. Farmers require accurate information on the coming and going of the seasons to know when to sow and harvest. Winter solstice was a major festival in many cultures because it was the time to stock up food supplies for the difficult months ahead and to celebrate the beginning of the lengthening of daylight.

Another aspect of seasonal variation is the changing length of the day. In the summer, day light hours are longer, and in the winter, nights are longer. The longer days allow more time to work in the field. In extreme northern regions such as northern Scandinavia, the Sun can be up all day in the summer and the sky is dark almost all day in the winter.

Since ~1000 B.C., the Babylonians, Egyptians, Greeks, and Chinese knew that the maximum height attained by the Sun was different every day of the year. They noted that the minimum length of the Sun's shadow varies from day to day. As people traveled, they also realized that the Sun's daily path was different when observed from different locations. The Sun generally rises every day in the eastern direction, climbs to a maximum altitude, and sets in the western direction. As one travels south, the length of the noon shadow shortens as a result of the Sun going higher in the sky. The Sun does not swing as far north and south along the horizon during the year. If one goes far enough south (e.g. to southern Egypt), the shadow of the Sun completely disappears at noon sometime in the summer.

This pattern of annual motion of the Sun gives certain places on Earth special significance. People who lived in northern temperate zones never saw the Sun directly overhead. However, when they began to travel south, they found that on two days of the year, the Sun did pass overhead. The demarcation line was later named the Tropic of Cancer (the reason for this name will be explained later). More precisely, they found that on the Tropic of Cancer, the Sun at noon is directly overhead on the summer solstice (~June 21).

Most ancient civilizations did not travel much farther south than the Tropic of Cancer. But if they had, they would have found another special line where the Sun passes directly overhead on the equinoxes. This line is what we now call the equator. It is quite possible that this special line was known to the African and Polynesian people. If they had proceeded even farther south, they would have found another line where the Sun is directly overhead at noon on the winter solstice (~December 21–22). This line is called the Tropic of Capricorn.

2.4 Regular But Not Simple

In addition to the motions of the Sun, a number of celestial events were easily observable and recognized by all ancient peoples. Like the Sun, the Moon and the stars rise and set every day. The phases of the Moon change on time scales of about 29 days. From time to time, there are eclipses of the Sun and the Moon. Comets and shooting stars (meteors) appear at random times.

However, the heavens were not easy to understand. The Sun generally rises in the east and sets in the west, *but not exactly*. Over the course of a year, the rise and set positions move north to south and back along the horizon. The Sun also rises to different maximum altitudes every day. The Moon sometimes appears during the day and sometimes during the night, which contradicts the idea that the Sun and the Moon are two gods governing different domains. Different stars are seen at different times of the year, and the timing of eclipses was not easily predictable.

But does it have to be this way? Can the motion of the Sun be simpler? It could always rise and set at the same place and rise to the same height every day. In fact, it could even stay in the same place in the sky and not move at all. Why are its movements so complicated? What would our world be like if they were simpler?

However, our ancestors were not satisfied to just stand in awe of the magnificence of the heavens. With incredible patience and diligence, they observed and recorded the movement of celestial objects. Why did the Sun, the Moon, and the stars move this way? They first came to the important conclusion that celestial objects had regular, periodic motions and that their future behavior was predictable. However, the pattern was not simple.

Was God trying to hide messages in these patterns? If the Sun was there to serve humans, why were its movements so complicated? If the purpose of the Sun was to separate day and night, why did God just switch daylight on and off and make every day the same length? If the Sun was *not* created for our convenience, then why was it there? Was God playing games with us? All these mysterious events seemed to signify the omnipotent power of the Creator.

Celestial objects made people wonder about their existence. How was the world created? What was the structure of the cosmos? What was our place in the Universe? Our answers to these questions have changed greatly over millennia, and our quest is ongoing. These changes happened despite great bias and prejudice, and pioneers were subjected to ridicule and persecution. The triumph of reason over dogma represents the greatest achievement of mankind.

2.5 Questions to Think About

1. Why do humans need to define a place for themselves in the Universe?
2. Can you imagine living in a world that has no day or night or a world without seasons? Are day/night/seasons necessary? Does their existence suggest a creator? If so, why did God create them for us? Are they just coincidences?

3. At the beginning of this chapter, we said that "even the most primitive people realized that their lives were governed by the Sun". Is the word "govern" too strong? How does the Sun affect the Earth, and in what ways do humans depend on the Sun for their existence?
4. For thousands of years, we accepted plants and animals as they were, and the question of the origin of species did not arise until much later (the nineteenth century). Why did ancient people feel the need to understand the movement of celestial bodies and the origin of the universe? Why didn't they accept celestial bodies as they were? Why were they more curious about the Sun and the stars than about plants and animals?
5. Can you imagine a physical model that could lead to a chaotic heaven—for example, with sunrise and sunset occurring at seemingly random times? What would it be like to live in such a world?

http://www.springer.com/978-3-319-54171-6

Our Place in the Universe
Understanding Fundamental Astronomy from Ancient Discoveries
Kwok, S.
2017, XXV, 267 p. 100 illus. in color., Softcover
ISBN: 978-3-319-54171-6