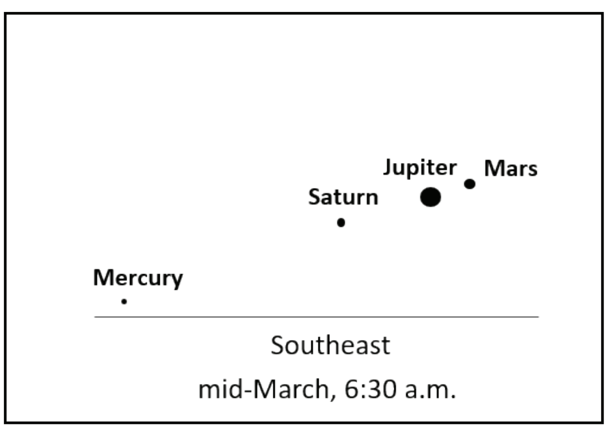
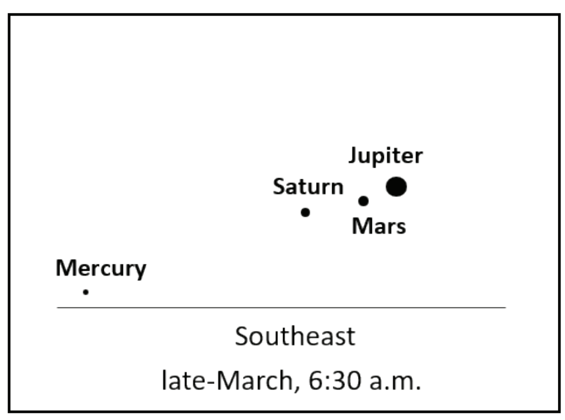
Hello!

As far as the planets go, not much has changed in the evening sky. Venus still shines brightly in the Southwest after sunset. In the morning though, things are changing in a visible way. Below are diagrams of the mid-March and late-March morning horizons. Playing "find what's different between these drawings", take a look and notice any changes.





Time's up. Correct! In just a couple of weeks, Mars has moved to the left of Jupiter in the sky. If you saw my last article, you might remember that because it is closer to the Sun, Mars orbits the Sun more quickly than Jupiter does (Kepler's Third Law of Planetary Motion). The result is that as we look above our southeastern horizon before dawn, we see a change in their relative positions. And, if you have been watching each morning, you've also noticed the Moon moving along past all of these planets and shrink from its third-quarter phase, to a crescent, then disappear into the sunlight. Evening watchers will see it show up again around March 25th and begin moving up to meet Venus.

In the last *What's Up?* I talked about where the planets are in their orbits relates to where we see them in the sky. It has generated a lot of discussion, so in this and the next couple of articles, I'll try to explain planetary motion a bit more fully. Here, I'm taking the approach that if you give someone a fish, they can eat dinner that day, but if you teach them to fish, they can always get dinner. I can keep showing you where to find the planets in the sky (and I will!), but if you have a sense for how they move, you can track and find them yourself. First, some historical background on all of this.

Without getting too deep into it, by the 4th century B.C.E., the model of the cosmos was one that had the Earth at the center of eight concentric spheres (one each for the Moon, Sun, the five (at that time) known planets, and the stars). This is called a*geocentric* model. This didn't completely explain the motions and appearances of the planets though. The 3rd century B.C.E. saw the addition of *epicycles*. These were small circles which carried the planets and which moved along another circle that carried the epicycle around the Earth. This came closer to accounting for the changing speeds of the planets, the change in brightness of the planets, and the apparent backwards motion (retrograde motion) that the planets made from time to time. These models got to be quite complicated as epicycles were added upon epicycles as needed, but they still didn't precisely match the planets' motions. Of course, all of these motions needed to be circular motions because the circle represented the perfection of shape and the heavens must be perfect, in the world view of the very intelligent and influential thinker, Aristotle. These model systems remained the accepted explanation. About 500 years later, in the 2nd century C.E., Ptolemy came along and tweaked the model a bit more by adding the *equant* into the mix. The equant was a point in space a distance away from the center of the Earth around which the circles and epicycles moved. This allowed for the motions to be explained better while keeping the planets moving with constant circular motions (again, an Aristotelian concept of perfection). Ptolemy's text, the *Almagest* (or Great Book), contains 13 books covering all aspects of astronomy. Ptolemy's model of the cosmos held sway for 1200 years. Why did we care about getting the movements of the Sun, Moon, and planets right? It was a combination of religious reasons (certain feasts are based on knowing just where the Sun and/or Moon is and when it is where it is) and astrological reasons (to cast horoscopes for people).

Jump ahead to the 16th century. In his 1543 publication, *De Revolutionibus Orbium Coelestium* (*On the Revolution of the Heavenly Spheres*), Nicolaus Copernicus proposed a *heliocentric* model – a model with the Sun at the center of the Solar System. Such a system had been proposed back in the ancient days, but never gained traction because the writings of Aristotle had so much influence. Still, though the Sun was at the center, Copernicus kept to the notion of circular orbits and required his own set of epicycles to try to fully explain planetary motions. Later that century, the Danish astronomer Tycho Brahe proposed a modification that blended the Ptolemaic and Copernican systems. Tycho postulated that yes, the planets circled the Sun (heliocentric view) but still the Sun (and the Moon) circled the Earth (geocentric view). Tycho's geoheliocentric system had its shortcomings as well. So…

…enter Johannes Kepler! Some of Kepler's notions of the Solar System's arrangement were a bit out there too, by what we know today. For instance, instead of the planets arranged on concentric spheres around the Sun – yes this at least was a heliocentric model – they moved on spheres bounded, inside and outside, by a series of the regular polyhedral shapes: tetrahedron, cube, octahedron, dodecahedron, and icosahedron. These are 4-, 6-, 8-, 12-, and 20-sided figures. To prove his theories, he needed better data. Who had that? Tycho did. Though Tycho worked mostly in the days before the telescope, he built and ran an astronomical research facility that was the best in the world (a story in itself!). For political reasons, Tycho moved his works from Denmark to Austria. There, Kepler was able to secure employment under Tycho and gained partial access to his data – Tycho's data was jealously guarded. The data consisted of precisely-measured positions of stars and the planets. Of particular interest to Kepler were the data showing where Mars was located at different times over the years. Eventually, after Tycho's death, Kepler got to study all of the data. He tried fitting the data on Mars' position to various types of curves. After many failures, he tried an ellipse and found that motion along an ellipse fit the data perfectly (the First Law). Along the way to this, he hit upon the relationship that as the planets move in their orbits, they sweep out equal areas in equal times (the Second Law). After these two relationships, the relationship between a planet's distance from the Sun and the time it takes for the planet to orbit the Sun once was worked out (the Third Law).

I'm going to stop here and pick up again next time. For now, in addition to keeping an eye on Mercury, Saturn, Jupiter, and Mars in the mornings and on Venus in the evening, don't forget that the Earth is also constantly in motion around the Sun and that motion combined with the Earth's tilt, causes our seasons. The Vernal Equinox, the beginning of Spring in the northern hemisphere, occurred at 11:49 p.m. on March 19th this year. And around and around we go.

Happy Spring! Keep looking up!

Barry

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