BY BARRY DECRISTOFANO

Hi. We haven't had many clear nights these past two week to look at the night sky. Well, that just happens sometimes – April showers and all that. I do hope though, that when it has been clear, you've been able to take a moment to look for the constellation of Leo the Lion and to watch the movement of the ever-changing Moon through the evening sky from one night to the next. And, in the morning, that you've been able to notice the shifting positions of Mars, Jupiter, and Saturn. If you were following the evening sky happenings the past couple of months, you might remember that the planet Neptune was close to Venus after sunset for a while; eventually, Neptune's nightly appearances ended and it disappeared from the night sky all together. However, Earth has kept chugging along in its orbit, moving to a new position relative to Neptune, and the planet has reappeared. Only now, it can be found in the morning sky. Just before sunrise, by 5:30 a.m., Neptune can be seen rising above the eastern horizon. The March 27th What's Up? (Installment #16) shows the morning horizon from a couple of weeks ago. Neptune can be found where Mercury is shown in that diagram (but, at 5:30 a.m., not 6:30 a.m.). Mercury is still in the East in the morning, but it appears closer to the Sun now and is lost in its glare.

In a Nutshell: Kepler's Three Laws of Planetary Motion:

- 1st. A planet's orbit arond the Sun is in the shape of an elipse.
- 2nd. As the planets move, they sweep out equal areas of their orbits in equal times.
- 3rd. There is a relationship between a planet's distance from the Sun and the time that it takes to orbit the Sun.

It's time now to finish up our look at Kepler's Laws of Planetary Motion. To recap our efforts thus far, the 1st law tells us that the planets' orbits around the Sun are in the shape of an ellipse. The 2nd Law of Planetary motion says that, as the planets move, they sweep out equal areas of their orbits in equal times. The 3rd Law tells us that the farther away a planet is from the Sun, the longer it takes to orbit the Sun. Conceptually, this might seem like a no-brainer. But the 3rd Law also actually describes a precise mathematical relationship between a planet's distance from the Sun and the duration of its orbit. It says that the value obtained by dividing the cube of the planet's distance from the Sun by the square of the time it takes the planet to orbit the Sun is a constant. This is important because it was useful to Sir Isaac Newton in formulating the law of gravity. Let's look at it in more detail.

As an example, let's use one million miles as our unit of distance, and one Earth-day as our unit of time. The Earth is an average 93 million miles from the Sun and it takes the Earth 365.25 days to orbit the Sun. Dividing 93 cubed (93^3) by 365.25 squared (365.25^2), we get a solution of 6.03 million miles^3/day^2.

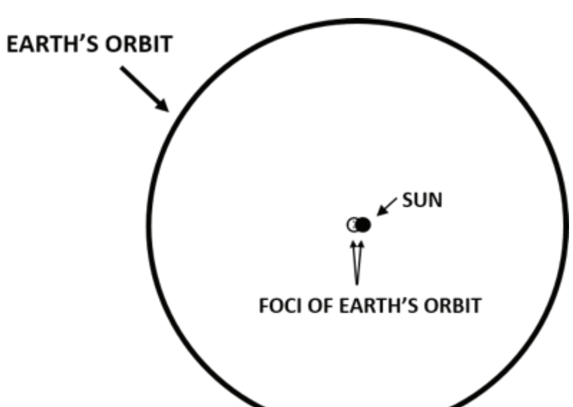
Now let's try it for Jupiter and see if we end up with that same value, as the 3rd Law says we should. Consulting planetary data, we find that Jupiter is, on average, 483.6 million miles from the Sun. Jupiter's orbital period is 4332 Earth-days. Dividing 483.63 by 43322 gives us…6.03 million miles^3/day^2. For all of the planets, this value – 6.03 million miles^3/day^2 – is a constant.

This relationship holds true for all planets because of how gravity works. It is the result of how the force of gravity changes over the different distances that each planet is from the Sun. The force of gravity also depends on the masses of objects. But, in case you are wondering, since the Sun is SO much more massive than any of the planets (the Sun accounts for 99.8% of all of the mass in the Solar System), the fact that some planets are bigger than others doesn't affect the result by very much.

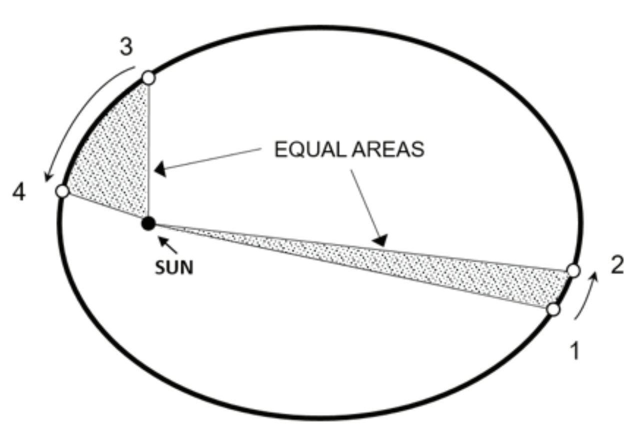
For us observers of the sky, knowledge of this third law is key to understanding what we witness. It tells us a couple of things. First, that Mercury and Venus go around the Sun faster than the Earth does (88 days for Mercury and 225 days for Venus). That helps explain why we see these two planets changing positions in the sky relative to the Sun and the other stars much faster than we see the other planets do. Also, the fact that they both are closer to the Sun than the Earth explains why they never get too far away from the Sun in our skies. In fact, we only see them in the mornings and in the evenings – never in the middle of the night when we are on the side of the Earth that faces completely away from the Sun.

Second, Jupiter, Saturn, Uranus, and Neptune orbit the Sun more slowly than the Earth does (in about 12, 30, 84, and 164 Earth-years, respectively). In the third What's Up? (August 16th, 2019), I wrote about the plane that all of the planets orbit the Sun in (or nearly in) and that the constellations of the Zodiac ring this plane in space. Taking that as a starting point, Jupiter's 12-year orbit of the Sun means that from Earth, Jupiter moves though each of the 12 zodiac constellations in about one year. Saturn spends on average 2 ½ years in each zodiac constellation; Uranus, 7 years in each; and Neptune, about 13 ½ years in each zodiac constellation – they move very slowly across our sky!

Here's a summary of what the 3 Laws tell us:



1st Law – Elliptical Orbits



2nd Law – Equal Areas in Equal Times

PLANET	DISTANCE FROM SUN (millions of miles)	LENGTH OF YEAR (Earth-days)	RATIO: distance³ / year²
Mercury	36	88.0	6.02
Venus	67.2	224.7	6.01
Earth	93.0	365.25	6.03
Mars	141.6	687.0	6.02
Jupiter	483.6	4,332	6.03
Saturn	886.5	10,759	6.02
Uranus	1,783.7	30,687	6.03
Neptune	2,795.2	60,190	6.03

3rd Law – $\frac{\text{distance}^3}{\text{time}^2}$ = a constant

So it is my hope that, armed with a little knowledge of Kepler's Laws, you can gain a feel for how the planets move in our skies and why we see them where and when we do.

You can reach me at astroblog@comcast.net with questions and comments. This is What's Up? Installment #18.

Keep looking up!

Barry

We are repeating last week's "What's Up?" column to correct a bit of math. In translating the typography through several platforms, special figures like superscript numerals, can get "lost in translation". Rather than trying to explain the corrections to Kepler's Laws of Planetary Motion in a correction, we thought it best just to repeat the entire column correctly. We apologise for any confusion this may have caused our stargazers.