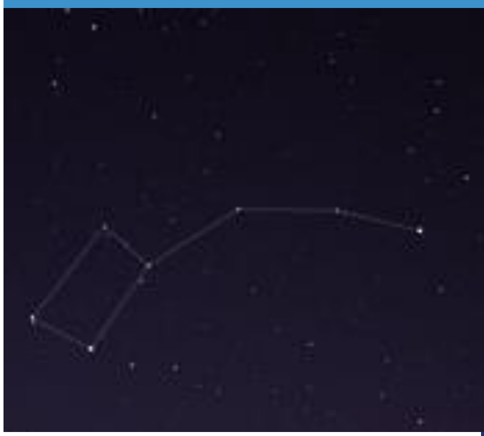
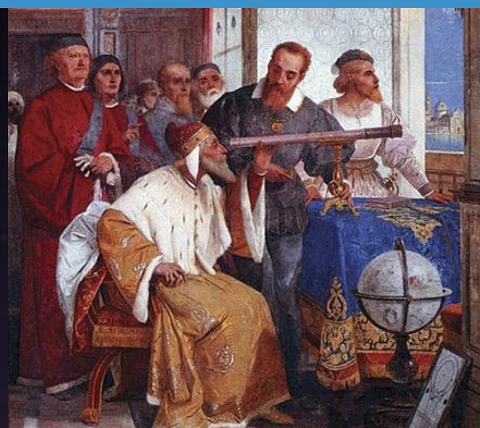
All Of The Above

YOUR MONTHLY DOSE OF SPACE AND TIME





Observe

HOW DARK IS IT?

This month we learn how to use one of the best-known constellations to quickly determine how dark the sky is at your observing site on a given night before you drag out the telescope.

Remember

REFUTING GALILEO

In 1610, Galileo discovered the 4 large moons of Jupiter using one of the first telescopes. In 1611, Francesco Sizzi published a book proving that these moons simply could not exist.

Explore

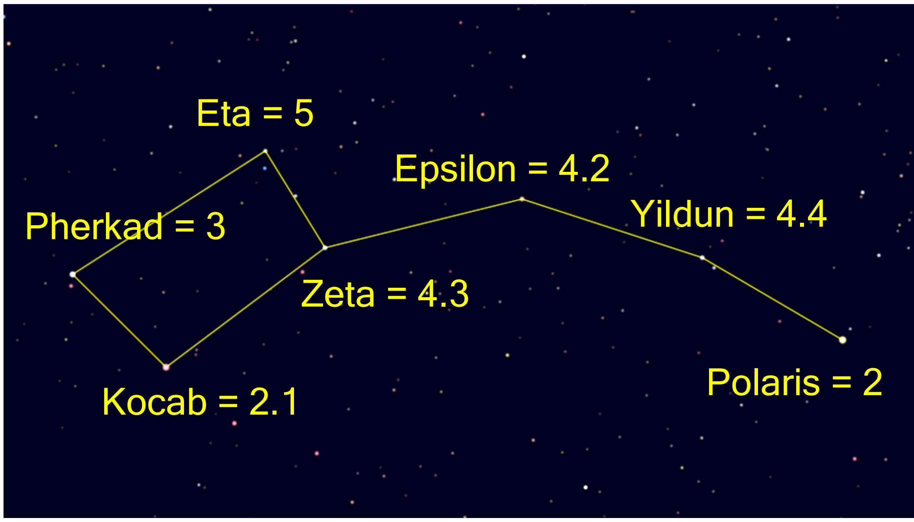
NEW SHEPARD #9

Blue Origins launched its 9th test flight of the New Shepard suborbital space tourism craft. Their first manned flight may occur late this year.

Consider

DO YOU HAVE THE TIME?

We all have an internal sense of time, which most of us have never explored beyond our daily experience. The nature and experience of time have been a recurrent fascination of mine. Very recently (as those in the most recent session of classes may recall), this interest has surged again, bringing yet more realizations about this exceedingly complex topic.



Magnitude	X Brighter than 0	# Stars
0	1	6
1	2.5	14
2	6.25	71
3	15.6	190
4	39	610
5	98	1929
6	244	5946

The magnitude scale, devised by the ancient Greeks, was meant to range from 1 for the brightest stars to 5 for the dimmest, with the brightest stars 100x brighter than the dimmest. In reality, in the darkest of skies, most humans can see to magnitude 6, and the brightest star, Sirius, is at magnitude -1.46

RATE THE NIGHT SKY WITH URSA MINOR

You've been waiting to observe, and it looks like tonight is a clear, dark night. But just how dark is the sky you are looking at? Even in a clear sky, what you can see depends on a number of factors. Haze in the atmosphere dims the stars – we measure that as "transparency". The presence of the Moon washes out the sky the closer we are to a full Moon. And artificial lighting both near you and dozens of miles away casts a "light dome" that makes the sky a dark to light grey.

One way to rate the darkness of the sky is to determine how dim of a star you can see with the naked eye. Star brightness is measured on the magnitude scale, summarized in the table above. From even the worst locations, a clear sky at night will show magnitude 1 stars.

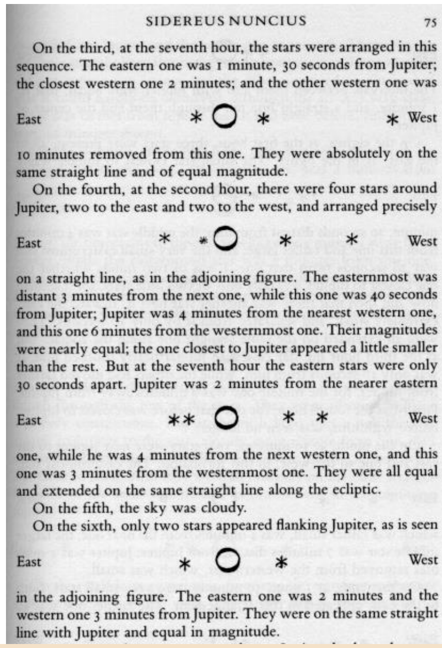
To get a quick assessment of just how dark your location is that night, you can use the constellation Ursa Minor (the "Little Dipper") as a guide. Once you are sure twilight has ended, use Ursa Major to find the North star. Polaris is the tail star of Ursa Minor (or the end of the handle), at magnitude 2. Then, look for the upper star at the opposite end of the dipper, which is a magnitude 3 star. Next, see if you can find all of the stars of the handle, ranging from 4.2 to 4.4 magnitude. Lastly, try to find the star at the inner top edge of the bowl of the dipper, Eta, which is magnitude 5.

Here in my yard in Southbury, on an average night with no Moon visible, I can see Eta – sometimes clearly, sometimes barely. On the best of nights, my "limiting magnitude" with naked eye is about 5.5. On a more typical night, with the Moon at an early phase, the limit is somewhere around 4.5.

WHAT IS "SEEING"?

When we observe any astronomical object, we must look through at least 60 miles of our atmosphere. Earth's atmosphere contains variable amounts of water vapor at different heights above the surface, moving at different speeds on any night. The effect of observing a point of light through moving water vapor is commonly called the "twinkle" of the stars – in fact what is happening, is the apparent position of the star is constantly shifting as the rays of light are bent randomly as they pass through the moving water vapor.

On a larger object, such as the Moon or a planet, it is like looking at the object through a pool of water. The more water and motion involved, the harder it is to see the object clearly. Astronomers call the effect "seeing". Even on a clear, very dark, transparent night, the seeing can be awful. On the other hand, some of the best seeing occurs when there are very thin clouds present.



SIDEREUS NUNCIUS 75

On the third, at the seventh hour, the stars were arranged in this sequence. The eastern one was 1 minute, 30 seconds from Jupiter; the closest western one 2 minutes; and the other western one was

East * ○ * * West

10 minutes removed from this one. They were absolutely on the same straight line and of equal magnitude.

On the fourth, at the second hour, there were four stars around Jupiter, two to the east and two to the west, and arranged precisely

East * *○ * * West

on a straight line, as in the adjoining figure. The easternmost was distant 3 minutes from the next one, while this one was 40 seconds from Jupiter; Jupiter was 4 minutes from the nearest western one, and this one 6 minutes from the westernmost one. Their magnitudes were nearly equal; the one closest to Jupiter appeared a little smaller than the rest. But at the seventh hour the eastern stars were only 30 seconds apart. Jupiter was 2 minutes from the nearer eastern

East ** ○ * * West

one, while he was 4 minutes from the next western one, and this one was 3 minutes from the westernmost one. They were all equal and extended on the same straight line along the ecliptic.

On the fifth, the sky was cloudy.

On the sixth, only two stars appeared flanking Jupiter, as is seen

East * ○ * West

in the adjoining figure. The eastern one was 2 minutes and the western one 3 minutes from Jupiter. They were on the same straight line with Jupiter and equal in magnitude.

ΔΙΑΝΟΙΑ
ASTRONOMICA,
OPTICA, PHYSICA,

Qua Syderei Nuncij rumor de Quatuor Planetis à Galilæo Galilæo Mathematico Celeberrimo recens perspicilli cuiusdam ope conspectis, vanus redditur.

AVCTORE FRANCISCO
SITIO FLORENTINO.

Theognidis Sententia.

Μωμεῦνται δέ με πολλοὶ ὁμῶς κακοὶ ἠδὲ καὶ ἐσθλοί
Μιμεῖσθαι δ' οὐδεὶς τῶν ἀσόφων δύναται.

CVM PRIVILEGIIS.

VENETIIS, M DCXI.

SCIENTIFIC REVOLUTIONS ARE HARD

"There are seven windows given to animals in the domicile of the head, through which the air is admitted to the tabernacle of the body, to enlighten, to warm, and to nourish it. What are these parts of the microcosmos? Two nostrils, two eyes, two ears, and a mouth. So, in the heavens, as in a microcosmos, there are two favourable stars, two unpropitious, two luminaries, and Mercury, undecided and indifferent. From this and many other similarities in Nature, such as the seven metals, etc., which it were tedious to enumerate, we gather that the number of planets must necessarily be seven. Moreover, these satellites of Jupiter are invisible to the naked eye and therefore can exercise no influence on the Earth, and therefore would be useless, and therefore do not exist. Besides, the Jews and other ancient nations, as well as modern Europeans, have adopted the division of the week into seven days, and have named them after the seven planets. Now, if we increase the number of planets, this whole and beautiful system falls to the ground."

To clarify a bit, seven planets: Sun, Moon (luminaries), Venus, Mars (unpropitious), Jupiter, Saturn (favorable), and Mercury. Seven metals: gold, silver, copper, tin, lead, iron, and mercury.

Francesco's Sizzi's argument against the existence of the Galilean moons of Jupiter is often used as an example of a fallacy based on correlation and analogy. However, that is not its major flaw. Correlation and analogy can be useful tools in explaining new phenomena. The real flaw here is in the final sentence – accepting Jupiter's moons will destroy the *beauty* of the known natural order. Although we laugh at Sizzi, consider the following quote from a NY Times review of the book "Fearful Symmetry" (by Anthony Zee, review by Ronald Kahn) from 1987:

BEAUTY and simplicity are the religious beliefs of modern physics. The belief that fundamental laws of nature exist rests upon the belief that the universe exhibits a grand design. Religion enters science in the assumption of this grand design - what governs nature is not just a haphazard collection of rules, but one beautiful and simple law.

THE DAWN OF A NEW AGE APPROACHES

The race among private companies to accomplish human spaceflight continues to accelerate this year. Virgin Galactic launched the first powered unmanned flight of SpaceShip Unity in April, SpaceX and Boeing have delivered their first man-rated Dragon and CST space capsules to Cape Canaveral for unmanned test flights and plans for new spaceports in California and Scotland have been announced. But the company that may become the first to reach an operational manned spaceflight for hire condition is Blue Origins, which completed its 3rd test flight of the year, 9th test flight overall, on July 18th.

Showing the maturity of the design and testing of their vehicle, Blue Origins has been intentionally testing recovery systems by putting their craft into various failure modes. On one test flight, one of three parachutes was intentionally disabled. In another, the booster was intentionally separated from the capsule prematurely, at "max Q" to test the emergency recovery system. All flights have resulted in the safe return of the crew capsule to Earth, and in all but one, the safe recovery of the booster.

In the July 18th test flight, the emergency recovery system was activated after nominal separation from the booster. The firing of the solid fuel escape rocket shot the capsule to its highest altitude to date, 74 miles, and would have subjected a crew to a load of 10gs – a straining but safe acceleration for healthy astronauts.

Both the booster and capsule were recovered successfully, with a total flight time of just over 11 minutes.

HIGHER GROUND

While Blue Origins and Virgin Galactic race to the suborbital thrill-ride space flight market, SpaceX and Boeing-Bigelow continue their march toward resuming American-launched crew service to the International Space Station. Both Boeing's CST-100 (discussed last month), and the Crew Dragon space capsule from SpaceX are in final preparations for unmanned test launches later this year, reaching the ISS. By late 2019 both companies should achieve NASA certification for manned flights to ferry ISS astronauts, after one or more manned test flights during the year. Here we see the Crew Dragon entering a space environment test chamber at a NASA facility earlier this year.

In an atomic clock, such as the one shown here, a gas of caesium atoms is produced and sorted to contain only those of the proper atomic mass and in their lowest energy state. Lasers then supercool the gas to approach absolute zero. A microwave signal oscillating at about 9192631770 times a second is then tuned to maximize its absorption in the cavity, caused by the caesium atoms transitioning to their second lowest energy state. Precise measurement of the tuned microwave frequency becomes the tick of the clock.

MEASURING TIME

How do we measure time? Throughout history there have been a wide variety of time systems in different cultures, always tied to one or more astronomical motions – the rotation of the Earth, Earth's orbit about the Sun, the phases of the Moon. However, each of these astronomical motions is not truly constant. Laying aside the practical problems of the calendar, caused by the simple fact that the rotation of Earth (the day) is not related at all to its orbit about the Sun (the year), which forced the adoption of the very complex leap year system, the rotational period of Earth constantly varies due to weather, earthquakes, and volcanic shifts in the distribution of mass in the planet.

In an attempt to define a unit of time based on a natural phenomenon that never varies, in 1967 the scientific community adopted a definition of 1 second such that the light emitted when an electron changes between the second lowest to the lowest orbit in an atom of the element caesium (when at absolute zero and in a perfect vacuum) has a frequency of 1/9192631770 seconds. Ok then, problem solved?

Hardly. Setting a fixed unit (which the caesium definition may have accomplished) does not mean we have a method of measurement. The most accurate atomic clocks, which attempt to directly measure the frequency of the emissions of light from caesium atoms, will disagree at the level of about one billionth of a second (a nanosecond) after a day. Although this may seem meaningless, we know of phenomena that occur in far shorter time periods than a nanosecond.

Human perception of time is nowhere near as accurate. Two very short sounds that occur less than 2 thousandths of a second apart cannot be distinguished by the human brain. Most interestingly, however, if those two sounds are of different pitches, a test subject cannot determine which of the two tones (higher or lower) came first. Only when the sounds are separated by 20 thousandths of a second or longer can the order of the sounds be reliably detected. The bothersome conclusion? It takes time to detect time!

But the underlying problem in measuring time is subtler, and more disturbing. Any time measurement relies upon a "clock", and a clock is always a device or phenomenon that repeats its behavior with a fixed period (ticking of a mechanical clock, vibrations of a quartz crystal in a modern watch, or the period of light from a caesium atom's lowest energy transition). But how do we know that these clocks are periodic? Oh, by measuring the time between events with a … clock. And how do we know that second clock is a clock? By measuring it with another clock. And so on. Very quickly we conclude that there is no way to measure time with arbitrary accuracy. The best we can hope for is agreement to within some precision between multiple clocks, and then taking an average to get to a value of time between two events. That is precisely what is done to establish International Atomic Time – an average of 400 atomic clocks located throughout the world.

That's enough for now, though the concept of "now" is worth its own lengthy discussion. Maybe next, uh, time.