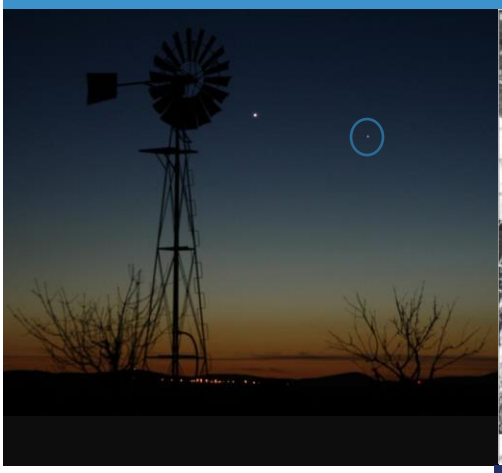
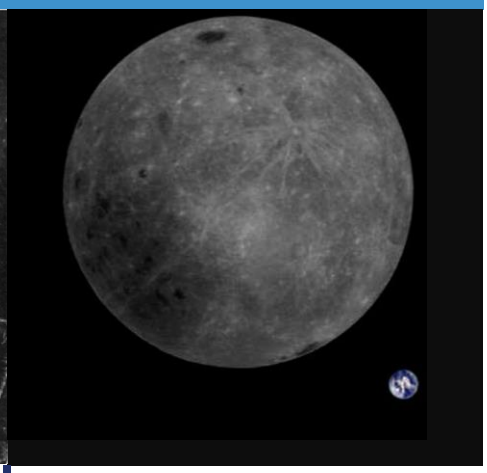
All Of The Above

YOUR MONTHLY DOSE OF SPACE AND TIME





Observe

A MONTH FOR MERCURY

On February 27, the planet Mercury reaches its greatest separation from the Sun in the evening sky. In late February and early March, Mercury can be glimpsed in a clear sky just after sunset. All you need to do is look!

Remember

19th CENTURY COMETS

In the 1800s, six fantastically bright comets with massive tails were observed. Since 1930, only three, possibly four comets came close to rivaling these earlier comets in brilliance and size.

Explore

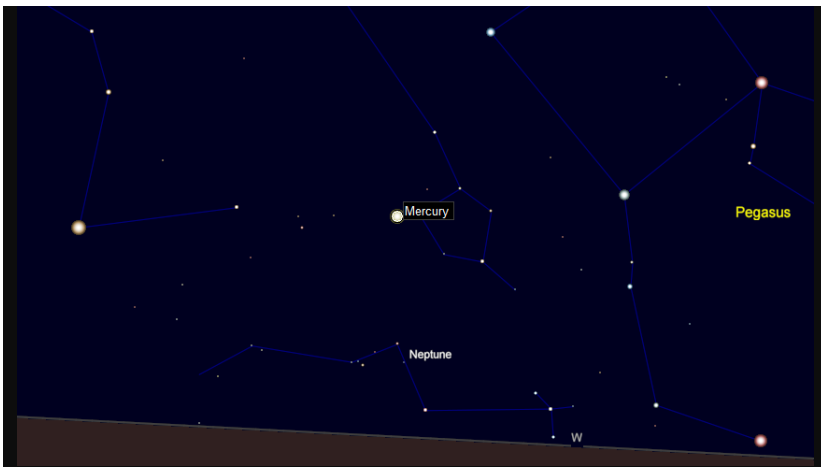
BACK TO THE MOON

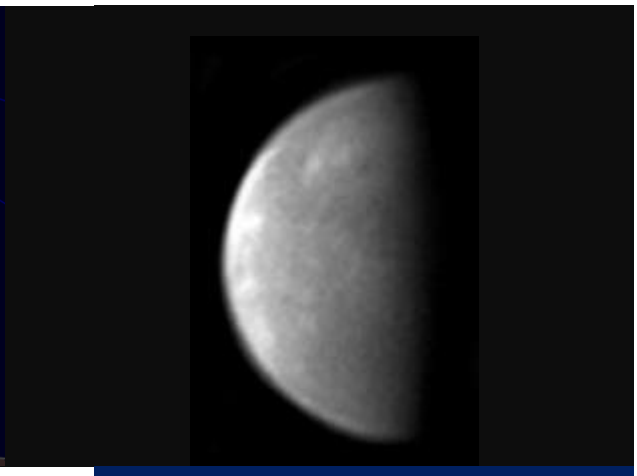
As the focus of NASA and SpaceX turns toward the moon as a step toward Mars, other countries have and are planning to land robotic missions in preparation for their own human exploration projects.

Consider

THE MUSIC OF THE SPHERES

The relationship between science and music has been known for over 2500 years, and has pervaded the history of science down to the present day. As we continue to improve our understanding of the Universe, we continue to find analogies between the theory of the music and the theories of physics. Let's explore this relationship, and see how widely it can be applied.





OBSERVE MERCURY THIS MONTH

Mercury, being the closest (known) planet to the Sun, orbits in the least amount of time of all the planets, with a period of only 88 days. Mercury's location in the sky relative to the Sun consequently changes rapidly, with noticeable changes at times happening from one day to the next. On February 1st, Mercury will set within a minute of the Sun, making it impossible to observe. By February 27th, Mercury will remain above the horizon for 90 minutes after sunset.

Mercury is notoriously difficult to observe, again because of its closeness to the Sun. The planet can never appear more than 18° above the horizon at sunset, which means it never is visible after twilight ends. By the 27th, Mercury will be about 17° away from the Sun, making this a particularly good opportunity. By eye, Mercury will appear as one of the brighter stars in the twilight, though it can still be hard to see. At sunset, holding your outstretched hand at arm's length, Mercury will be about the distance from your thumb to pinky above the horizon, falling closer to the horizon as twilight deepens.

If you look at Mercury through a pair of binoculars, or with a telescope, you will encounter the second problem in observing Mercury. Because you are seeing it near the horizon, Mercury's light needs to pass through a much larger thickness of Earth's atmosphere than objects appearing overhead. As a result, Mercury's image will remain blurry – as if it is underwater. Nonetheless, if you are lucky enough to spot it in binoculars, you should be able to see that it has a phase.

Our best photographs of Mercury taken from Earth (example shown above) show very little surface detail. Seeing the craters of Mercury from Earth is nearly impossible, even though the planet is only 90 million miles distant at its best appearance. Although the planet does come within 57 million miles of Earth, it is at its "new" phase then, with the side not lit by the Sun facing us.

If you do plan to see Mercury at the end of the month, you will want to catch it within a week of the 27th, as it moves very rapidly back toward the Sun and is lost once again in its glare.

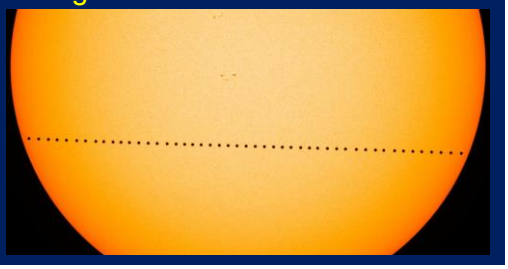
MERCURY TRANSITS

On November 11, 2019 Mercury will pass directly between the Earth and the Sun, an event known as a "transit". A transit is visible only through telescopes, and, of course, requires the use of an appropriate filter, or projection of the image of the sun on to a screen that can be safely viewed.

Transits of Mercury are uncommon, but not what I would call "rare". There have been seven transits in my lifetime (1964), the most recent in 2016. The next after this coming event will be in 2032.

For a transit to occur, Earth must be in the plane of Mercury's orbit. Because the orbits of Mercury and Earth are slightly titled with respect to each other, we are only in Mercury's plane near two days of the year – May 8th and November 10th, with these dates slowly advancing as Mercury's orbital tilt slowly rotates.

The image below is a combination of multiple images taken by NASA during the 2016 transit.



MASSIVE COMETS OF THE 19TH CENTURY

On March 25, 1811, a comet was discovered at a distance between the orbits of Mars and Jupiter, and was soon predicted to become exceedingly bright. "Napoleon's Comet" as it became known, remained visible to the naked eye for an amazing 260 days. This comet came close to neither Earth nor the Sun – its incredible brightness was due entirely to its massive size – a coma over 1 million miles in diameter, 3 times the diameter of the Sun, a tail 25° in length, and a central core thought to be an incredible 22 miles in diameter.

The Great Comet of 1843 was discovered in February of that year, very rapidly brightened as it approached to within a mere 500,000 miles of the Sun three weeks later, becoming visible in broad daylight with a tail measured to be nearly 200 million miles long. Calculation of the orbit indicated a period of about 700 years, and that it is one of a family of "sungrazing" comets that formed after the breakup of an enormous parent comet observed in 1106AD.

Another massive comet was discovered by the astronomer Donati in June of 1858. This was the first comet to be photographed, and had an orbit taking it far into the north sky, entering Ursa Major shortly after its discovery, and reaching an intense brilliance with a 60° tail by October.

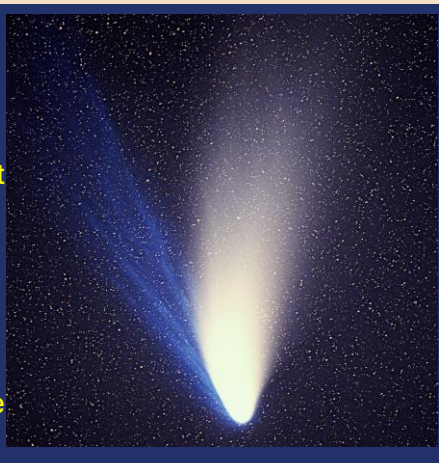
Only three years later, in May, 1861 a rapidly evolving comet was discovered which reached its closest approach to the Sun a day before it passed within 13 million miles of Earth. This comet became sufficiently bright to cast shadows, and was extremely unusual as Earth passed through its tail for two days, creating a surreal appearance of streams of material converging across 90° of sky converging to the comet's head. By mid-August the comet was no longer visible to the naked eye.

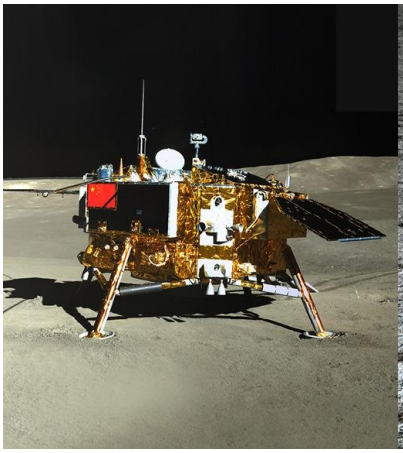
In 1874, Coggia's Comet was discovered in April, became visible to the unaided eye in June, and grew an enormous but unusually narrow tail 70° long, but only 1-2°in width. On the night of July 21st, four days after its closest approach to the Sun, the brightness of the comet became oddly unstable, going from easily visible throughout the length of its tail to barely visible several times over the period of an hour, and showing waves of structure rapidly flowing through the tail.

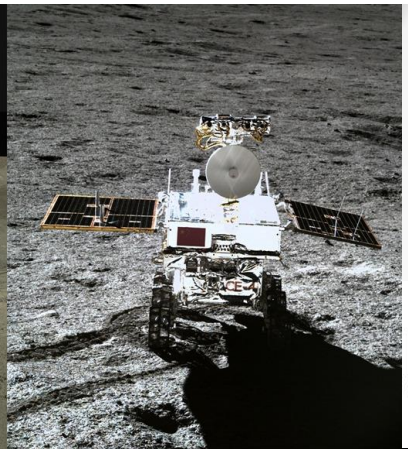
The final massive comet in the 19th century was visible without aid from September, 1882 until February. A member of the same family as the 1843 comet, it passed within only 300,000 miles of the Sun, reaching the incredible magnitude of -17, easily visible next to the Sun. It then transited the Sun, and subsequently broke into 5 fragments as it passed back through the Solar System.

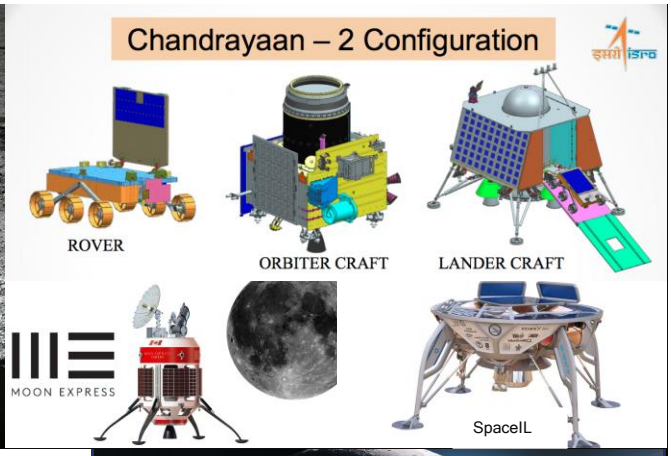
THE MONSTER COMET OF '97

On July 23, 1995 two amateurs, Alan Hale and Thomas Bopp independently observed a dim comet in telescopes, while it was still between Jupiter and Saturn's orbits – where most comets are undetectable. Achieving naked eye visibility in May 1996, as it approached the Sun it became an amazingly bright object in the northern hemisphere, and at its closest approach to the Sun in April it was barely within Earth's orbit, and remained visible throughout most of the night, with a tail over 45° in length. The final naked eye observations were in December, 1997, nearly doubling the record for visibility previously set by the 1811 comet. The nucleus is estimated at 100 miles in diameter – over 6 times the size of Halley's comet. In 2012, 15 years after perihelion, the comet was observed at 30 times the distance of Earth from the Sun.









THE RETURN TO THE MOON

On January 3rd, the People's Republic of China successfully landed the Change'4 spacecraft on the far side of the Moon near its south pole. This is the first spacecraft to land on the far side of the Moon, requiring the use of a second spacecraft in the Moon's orbit about Earth to act as a communications relay to maintain contact between the Earth and the lander, which is forever blocked from directly contacting Earth by the Moon itself. The 2600lb lander carries the 310lb Yutu-2 rover, which deployed within 12 hours of the landing, and is hoped to function for several years, examining surface material, and using ground-penetrating radar to study the subsurface structure. The lander also contains a biological chamber in which several plant species seeds sprouted, but subsequently failed when the external temperature plummeted after lunar sunset, and the onboard heaters failed to maintain a survivable temperature.

The Change' series of missions (-1, impacted moon in 2007, -2, orbited moon in 2010, -3, landed on near side of the Moon in 2013), is planned to culminate in sample return missions from the area of the south pole in 2019-2023.

Meanwhile, the Indian space agency is planning the launch of a lander/rover on April 1, 2019, continuing the series of Chandrayaan missions, which included a successful impactor in 2008. The future plans of India are uncertain.

At least two private missions to land on the Moon are also reaching milestones in 2019. The Israeli company SpaceIL will launch a small lander on February 18th, expected to last only two days on the lunar surface as it lacks any internal thermal control systems. The American company Moon Express is planning to launch a demonstration lander in late 2019, containing a shoebox sized telescope and laser retroreflector. Moon Express plans a sample return mission as soon as 2020, with the ultimate goal of constructing a robotic mining facility near the south pole.

Two additional international companies, TeamIndus based in India, and Synergy Moon planned to launch rovers in 2019, though their current status is less well known.

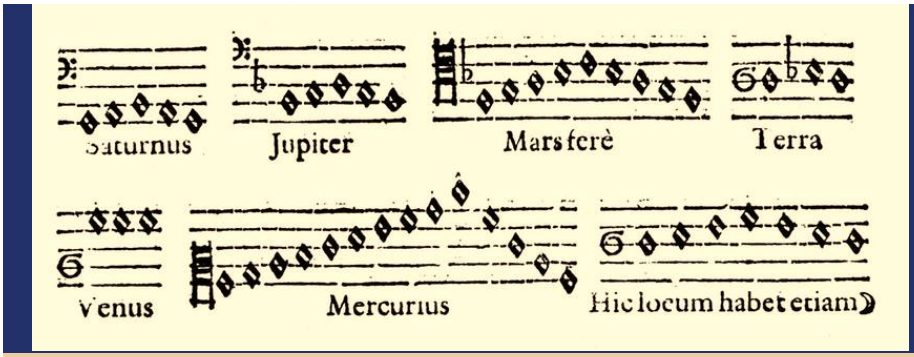
By the end of 2020, at least two additional organizations plan to reach the lunar surface – the American Astrobotic Technology company and PTScientists of Germany.

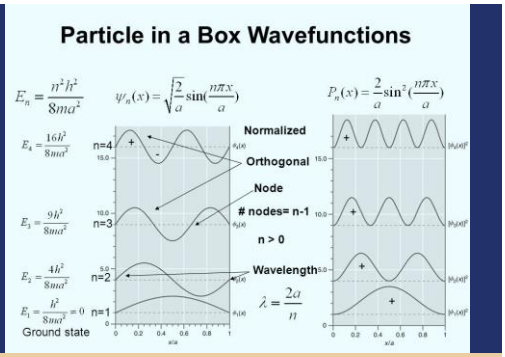
MANNED MISSIONS

The prospects for landing men on the Moon any time soon is far less certain. NASA continues to pursue development of the Orion crew vehicle, with an unmanned flyby of the Moon notionally scheduled for 2020, and a crewed mission to complete a single lunar orbit no sooner than 2022. However, many observers, including NASA engineers on the Orion program, have doubts that the Space Launch System that launches Orion will ever reach a launch.

SpaceX plans a launch of the BFR in 2023, but only as a stepping stone to reach Mars, and this mission would not include landing on the surface. No other private company appears to be considering lunar manned missions at the current time.

Other countries are even less likely to bring man to the surface of the Moon in the near term, though Russia, China, and Japan all have plans on paper to reach this milestone in the 2030s.





MUSICA UNIVERSALIS

The “Music of the Spheres” was originally proposed by followers of Pythagoras, who had first come to understand that the pitch of a note produced by a stretched string varies inversely with its length, and that certain mathematical ratios of string lengths produced harmonic sounds. From this observation came the conjecture that the planets, being massive bodies in motion, must produce incredibly loud sounds, each at its own pitch, and that the harmony of these sounds would affect the quality of life on Earth. We would not be able to hear this sound because we would have been accustomed to it from birth and would ignore it as background noise. This idea of celestial harmony persisted through Kepler (his music of the planets is shown above), who was convinced that the orbits of the planets must follow a “perfect” geometrical pattern. To the end of his life, though he had discovered the true laws of the planetary orbits, he felt that these were only approximations of an underlying perfection that he had been unable to grasp.

Though we now know no “sound” in the conventional sense is produced by objects moving in the vacuum of space, there remains some truth in the concept of the *musica universalis*. A pure musical tone is produced by a repeating pattern of air motion following a specific mathematical shape – the sine wave, in turn created by the sinusoidal vibration of some object (strings of a violin, lips of a trumpet player, wooden reed of a clarinet). Adding different sine waves together produces harmonies when the periods of vibration “resonate” with each other to produce smoothly varying repetitive patterns, and disharmonies when the patterns become more complex and only repeat over longer periods.

The mathematical field of Fourier analysis (from physicist Joseph Fourier around 1800) is based on the fact that any periodic pattern can be represented as an infinite sum of sine waves. From Galilean and Newtonian physics, we find sine wave motions in pendulums, water waves, the vibration of springs, and rotating objects. Most of modern mechanical analysis of structures relies upon Fourier analysis to determine how the structure will vibrate when it interacts with its surroundings, and what sinusoidal “modes” can dominate this vibration, become resonant, and either amplify slight signals beneficially, or lead to uncontrollably large motions that destroy the structure.

The propagation of light is known to occur in sine waves, driven by the interaction of electrical and magnetic fields – the classical theory of optics and optical engineering is based in sinusoidal oscillations of these fields. We generate radio and microwave (forms of light) sinusoidal waves at specific frequencies – the mathematical inverse of periods – to allow the simultaneous broadcast of dozens of different messages, and receive them by “tuning” receivers to the specific frequency we want to detect.

In the use of quantum mechanics to describe the properties of atoms and the energy states of electrons, the sinusoidal wave appears again, with only specific allowed periods of the wave (representing the “quanta”) occurring within a given atomic structure. These allowed periods are in fixed mathematical ratios to each other, as in the harmonics of music.

In the late 1990s it was discovered that the very surface of the Earth rings in sinusoidal waves at an extremely low frequency (long period), with each location on the surface rising and falling by less than a millimeter about every 4 and a half minutes. (The actual cause of this is an active area of research).

Even the formation of our Sun is tied to a sinusoidal vibration. The arms of our galaxy represent pressure waves in the interstellar gas from which stars form. As these waves of pressure travel around the galaxy’s center, new stars are formed, and these mark the “arms” of the galaxy.

And so, at every scale of the Universe – from atom to galaxy – we are surrounded by the “music” of sine waves. If you want to hear the best representation, in my opinion, of this universal music, listen to any of Bach’s music.