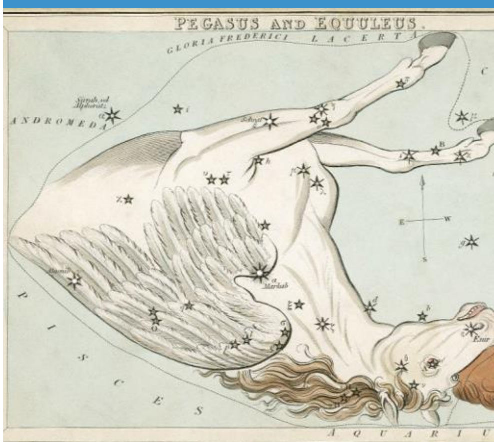
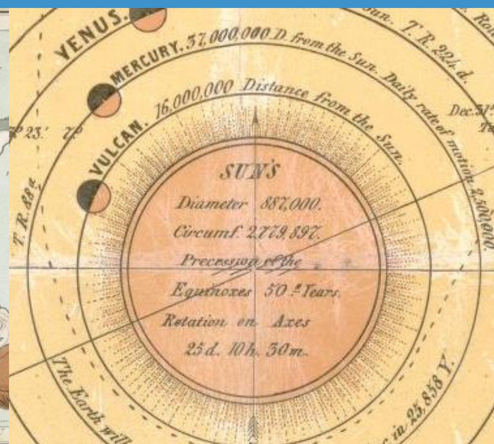
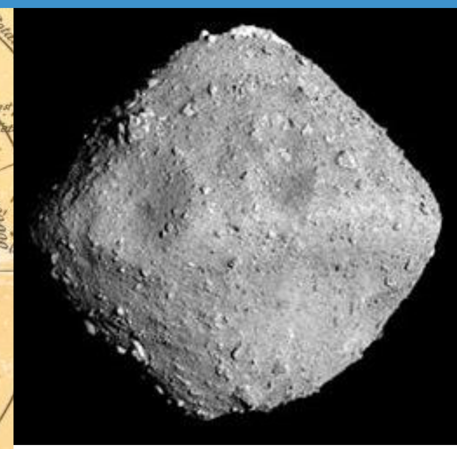
All Of The Above

YOUR MONTHLY DOSE OF SPACE AND TIME







Observe

FLY WITH THE HORSE

October brings the mighty constellation Pegasus into view. His body is easily spotted as a great rectangle in the autumn sky, and legs and neck fairly easy to trace.

Remember

THE FIRST NINTH PLANET

In 1860, only 10 years after discovering Neptune, LeVerrier announced the prediction and observation of a ninth planet orbiting inside Mercury's orbit. The new planet Vulcan was announced across the world.

Explore

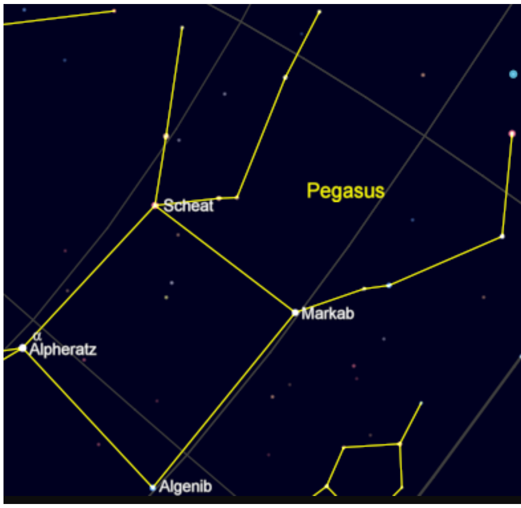
HOP AROUND RYUGU

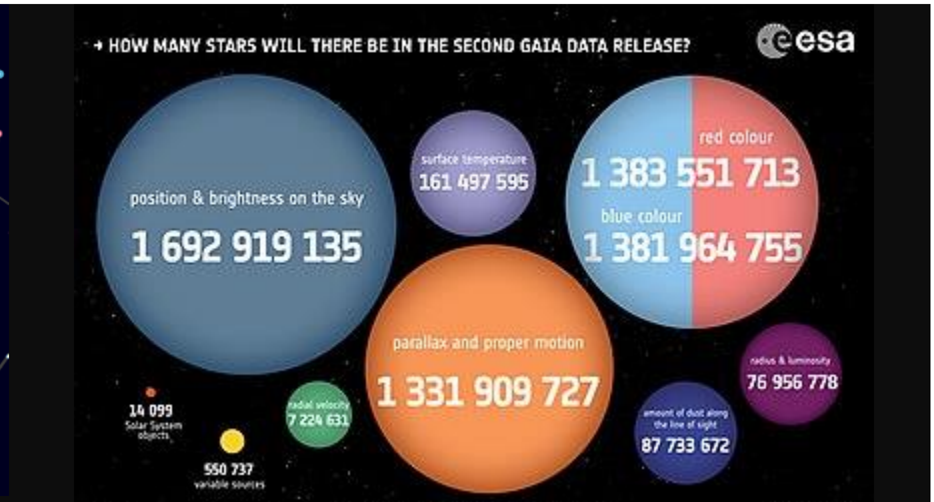
The Japanese Space Agency has landed two hopping rovers on the asteroid Ryugu, in preparation for obtaining samples and returning them to Earth in December, 2020.

Consider

PICK A NUMBER FROM 1-10

Throughout engineering we encounter the need to use "random numbers", and almost always rely on a computer algorithm to generate one when needed. What is true randomness, and can we actually achieve it?





THE GREAT SQUARE OF PEGASUS

Facing east on an October evening, search for a large square marked by four stars, large enough to place two fists laid side by side at arm's length. The square is rotated about 45 degrees, forming a 4 point cross. This is the Great Square of Pegasus. Having found the square, try to trace the horse's legs and neck using the star map above.

The brightest star (left star in the cross) in this square is Alpheratz (Arabic for "navel of the horse"). This young, blue-white star is 97 light years away. It is a binary star, with the larger component having a mass of about 3.6 times the mass of the Sun, and producing 200 times the energy of our Sun. The dimmer companion, impossible to see separately in a telescope, was detected through the motion of absorption lines, showing the main star's velocity away from us varies slightly with a period of 97 days, being pulled by the unseen companion. Its mass is 1.8 times the Sun's mass, and produces about 10 times the Sun's energy.

The star opposite Alpheratz is Markab ("saddle"), and is a middle-aged white star, about triple the mass of the Sun, 5 times its diameter, and is133 light years from us. Other than for its size, this is a rather uninteresting star.

At the top of the cross lies Scheat ("forearm"), a visibly orange star 196 light years distant. Scheat is a red giant of about twice the sun's mass, but with a diameter 95 times greater than the sun's. This vast surface area produces about 1500 times the sun's energy. Scheat loses 1% of its mass every 2 million years into an expanding shell of gas now larger than the orbit of Uranus.

Finally there is Algenib ("wing"). Located 390 light years from Earth, it is the dimmest of the square, yet a massive blue giant, 9 times the mass of the Sun, 5 times its diameter, producing 5500 times its energy. The youngest of the stars of the Square, it is also likely to be the first to reach its end of life due to its enormous mass and is almost certainly destined to become a black hole within the next 100 million years.

ASTRONOMETRY: GAIA

Something to realize from this month's discussion of the stars of the Pegasus Square is that for almost every visible star, modern astronomers have obtained detailed information about its distance, mass, variability, and usually age and stage of life.

One of the keys to unlocking this knowledge is the precise measurement of star location, and tracking very small motions of the stars over time. This is the sub-science of astronometry, and when done manually could be considered the most boring of the sciences. Thankfully, modern technology has rescued astronomers from this tedium.

Orbiting observatories have been used to survey the exact positions of stars, starting with the Hipparcos mission in 1989-93. Hipparcos mapped 2.5 million star positions.

The Gaia mission, launched in 2013 has released two catalogues of processed data to date, the most recent in April, 2018, consisting of 1.6 *billion* star positions and 1.3 *billion* measured motions. Although the sheer quantity of data overwhelms the available astronomical community, we can determine all of the key physical characteristics for most stars visible from Earth in large telescopes.

THE DISCOVERY OF VULCAN.

PROF. WATSON, OF ANN ARBOR, GIVES DETAILS OF HIS OBSERVATIONS—HE IS CERTAIN THAT HIS CONCLUSIONS ARE CORRECT.

Special Dispatch to the New-York Times.

DETROIT, Aug. 7.—The *Post and Tribune* will publish to-morrow a letter from Prof. James C. Watson, the astronomer, of Ann Arbor, giving the details of his discovery of the planet Vulcan during his observations of the recent total eclipse of the sun. After stating his conviction of the correctness of Le Verrier's conclusions as to such a planet, and his own determination to improve the brief duration of totality by thoroughly examining the region near and south of the sun, he proceeds: "Fortunately, however, it was situated in the region which I had determined to sweep over. I found, about a minute before the end of the total eclipse, a star of the 4½ magnitude, which immediately arrested my attention from its general appearance and place, in which there is no known star. It had a disk larger than the spurious disk of a star, and in which there is no known star. It had a disk larger than the spurious disk of a star, and shone with a ruddy light. There was no elongation, such as would be presented by a comet in that position, and hence I feel warranted in announcing it as an interior planet. Its position in reference to the sun and a neighboring star I determined by a method which obviates the possibility of error, so that I am able to assign its position with certainty. At the instant of observation its right ascension was 8 hours 26 minutes, and its declination, 18° north, as derived from an approximate reduction made the next day. I will, however, as soon as possible, measure the circles in which the records were made and get more accurate results. I have heard that the planet was seen by Mr. Lewis Swift, of Rochester, N. Y., who was stationed south of Separation, Wyoming Territory, where I observed. I do not know whether he got more than an estimate of its position, but his observation is valuable as furnishing an independent confirmation of my discovery. I shall make a thorough examination of the record of the observations of the spots seen upon the sun, which may have been this planet in transit across its disk, and if possible determine all the elements of its orbit. Otherwise, it will be necessary to observe it at succeeding total eclipses of the sun in order to derive all the data required."

THE PLANET VULCAN

As you may recall from class, the planet Neptune was first computed from variations in the orbit of Uranus by both John Couch Adams in England and Urbain LeVerrier in France. After this astounding success of Newtonian physics and mathematics, LeVerrier turned his attention to the orbit of Mercury in 1859, whose actual orbit does not match Newtonian predictions. LeVerrier considered the existance a planet between Mercury and the Sun to explain the problem of Mercury's orbit, and set about computing its orbit and mass.

Late in 1860 came a letter from an amateur, Lescarbault, in France who had been casually observing the Sun looking for possible planet transits over the past year, and who claimed to have seen such a transit in March of 1859. LeVerrier (not the most pleasant of individuals) traveled secretly to this country doctor's home with a second witness, and interrogated him sharply on what he had seen. LeVerrier came away convinced his second planet had been observed, and secured Lescarbault France's highest award, the *Légion d'Honneur*t.

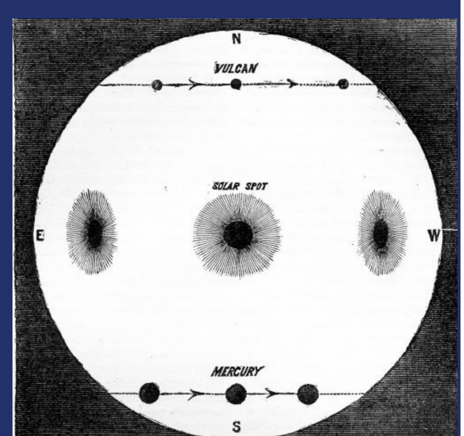
Soon several other observers came forward with reports of observations, some stretching back 40 years. Most of these could be dismissed as observations of sunspots, or lacked enough details to be credible; however, others involved professional astronomers, including 12 separate observations by JW Pastorff, of as many as two transiting objects at once. LeVerrier continued to tweak his calculations based on these reports, and predicted at least two transits, which never were observed. However, in 1862 an amateur with a second witness in England, in 1865 a professional astronomer in Turkey observed transits. Then, in July, 1878 during a total eclipse, two very respected astronomers recorded seeing a planet near the Sun at about the same location in the sky, one from Wyoming, the other from Colorado, both reporting the object to be red in color. That Vulcan was (shall we say) a hot topic at the time is evident, as even Thomas Edison traveled to Wyoming for this eclipse in an attempt to view Vulcan (pictured to the right above, arrow).

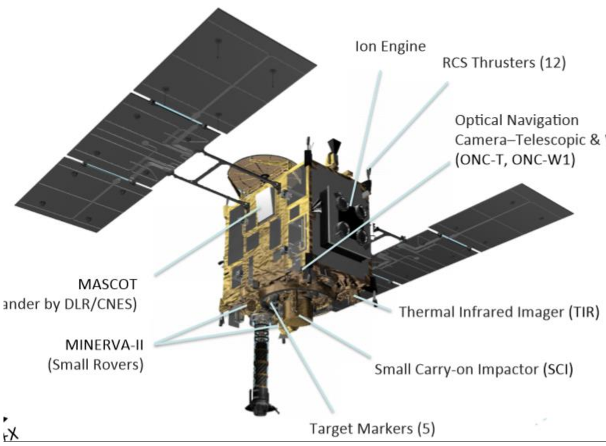
All subsequent attempts at predicting transits failed to result in observations, and surveys during seven eclipses between 1883 and 1908 failed to reveal any observable planets. After Einstein's theory of general relativity precisely predicted the true orbit of Mercury, without needing an additional planet, the search for Vulcan was abandoned.

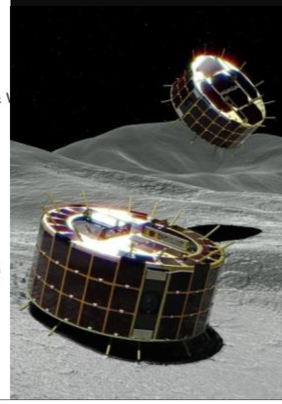
A YOUNG MAN AND HIS BOOKS

In December 1987 a sophomore physics student at the University of Rochester was debating whether to take up a second foreign language, after French, in the interests of scientific research. Remembering the story of Vulcan, and noting that the University's library had copies of Comptes Rendus de l'Académie Des Sciences from the 1800s, he goes to the top of the library's tower where the oldest journals are stored on a Saturday afternoon, and reads through the history of Vulcan as it unfolded.

Five hours later, I had learned several facts. First, 1860s scientific French is not modern French. Second, the Vulcan story remains a significant mystery. Third, when the library closes they turn off the elevator and the heat in the upper tower. I did end up taking about a month of Russian as a junior, but had to drop it when the course on Celestial Mechanics (which wasn't really about planetary motion) started getting out of control on me.







TO TASTE A SPACE DUMPLING

One of the key areas of interest in astronomy is understanding the precise mixture of materials present in the immense gas and dust cloud out of which the solar system was formed. Were complex organic molecules from which life formed created on Earth, or did they exist from the beginning? Precisely what percentages were different elements present in that cloud?

Studying planets cannot easily reveal these answers, as all planets have undergone huge thermal and chemical processes in their formation. However, comets and asteroids, being vastly simpler objects, contain only the original materials within them.

The purpose of the Japanese Hayabusa program is to visit these objects, collect fresh samples of their material, and return these samples to Earth for analysis. The Hayabusa 2 spacecraft, launched in December, 2014, reached its target asteroid Ryugu, in June, 2018 and landed the first two of its 4 miniature “rovers” on the surface on September 21. Both of these 7x3 inch cylindrical rovers operates by “hopping” over the surface, as a wheeled rover would fly off the asteroid, due to the exceptionally low gravity field, about 1/80000th that of Earth’s. (A 200lb man on Ryugu would weigh as much as a honey bee weighs on Earth).

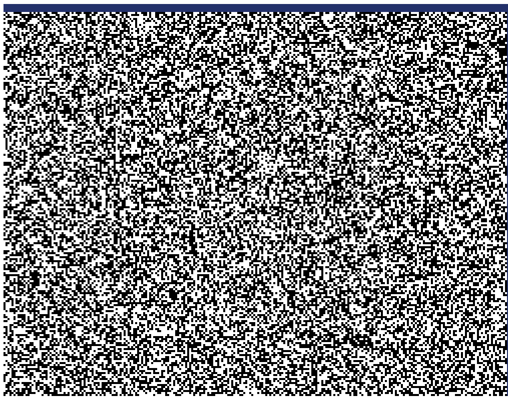
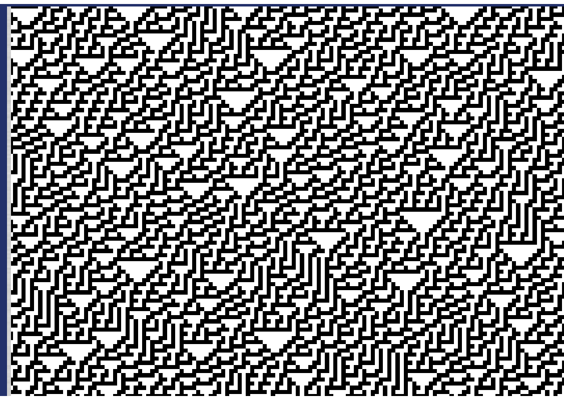
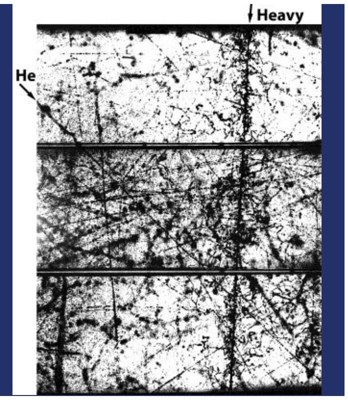
In late October, the main Hayabusa spacecraft will extend a horn and descend, fire a small bullet into the asteroid, and thereby collect surface material into the horn. In the spring of 2019, a 10 lb explosive charge will send a 5 lb copper projectile into the surface from a distance of 1700ft, creating an estimated 6 ft wide crater. After waiting 2 weeks for the dust to settle, the spacecraft will descend again and obtain a sample from the bottom of the crater, capturing pristine material that has never been subjected to solar radiation.

Hayabusa will then restart its ion thrusters and return to Earth, arriving in December, 2020, and dropping a sample capsule to re-enter the atmosphere and be recovered in the Australian outback for study.

THE SPACECRAFT

The spacecraft Hayabusa 2 is an engineering marvel of miniaturization and advanced technology space systems. A roughly 3x4x5 ft box, not including solar panels, and weighing only 1350 lbs, it is propelled by 3 ion thrusters carrying only 145lbs of fuel. The electronics run on less electricity than a typical hair dryer (1250W), powered by two small solar panels.

In this small package are three navigational cameras, near-infrared and thermal-infrared science cameras, a laser radar (LIDAR) system, a near-infrared spectrograph for determining surface chemicals from their absorption lines, plus the communications system. Then there are the 4 rovers, the sample collection horn, the explosive charge and projectiles, and the all-important sample return capsule, plus robotics to move the collected samples into containers, and the containers into the capsule.

THE QUEST FOR RANDOMNESS

Mathematics is often referred to as the “purist” of sciences, because it starts with what is known (or what is asserted to be true) and proceeds through only the application of rigid logic to develop additional truths from these limited number of known (or assumed) truths. There are significant differences between what actually happens in mathematics and what I just stated, but we are going to ignore those for today, and focus on a single field in math that does not follow this pattern – statistics.

Statistics is the science of dealing with randomness in mathematics – seeking to outline the behavior of phenomena in which we do not know the right answer, but may have partial knowledge of what to expect. For example, if I roll a 6-sided dice, I will get an answer between 1 and 6, and not 7. It precisely this clash between the purity of math and the lack of certainty of what is being studied that makes statistics (in my opinion) one of the hardest yet most fascinating fields to master.

But what of this randomness? Thinking of numbers, an infinite list of values in which there are no repeating patterns of any length is a reasonably approximate definition of a random number sequence. Note that individual numbers can repeat, but not in any pattern. Mathematicians attempt to model uncertainty in the real world using such sequences. As uncertainty ultimately means the inability to predict the value of a measurement, this seems a very reasonable model to use.

Where the trouble starts is when we attempt to use a computer to model random numbers. There are many different algorithms that have been invented to create sequences of random numbers, typically lists of integers. All of these use previous values in the list to compute the next value. But there is a fundamental problem. In our current computers, which typically use 32-bit integers, there are only 2^{32}=4,294,967,296 different possible integers that can be represented. If we assume we can compute a random number a billion times a second (quite possible for a modern PC), we will inevitably repeat a random number very 4-5 seconds. Although we can defeat that problem using more bits to store the integers (using the speed argument, a 128-bit integer, which is occasionally used, will not repeat for 10^{23} years, effectively forever), every algorithm using prior values starts with a “seed” value, and using that same seed we can reproduce the random sequence exactly – so, not truly random.

For applications where “true randomness” is absolutely essential, engineers turn to the natural world. Such things as radioactivity, thermal noise of electronics, atmospheric turbulence, radio noise (similar to what you hear by tuning an older radio to a frequency between stations), and even the cosmic radiation background have been used to achieve “randomness”, or at least an increasingly good approximation of randomness – certainly “good enough” for any real-world application.

But, this does not answer the question of whether any of these mechanisms are truly random. *That* discussion rapidly becomes one of philosophy and religion. Are all events in the Universe pre-determined, following the laws of physics, or are there mechanisms to produce randomness? I will simply state my position – the evolution of the Universe is indeed predetermined, with a single, very important exception. Man (and to our knowledge only Man, though alien intelligences may also possess this trait) has free will, and free will by definition is not determined.