THE SCOPE

GT Astronomy Club

No Room for Error:

The story of the immense calculations behind the landing of NASA's Curiosity Rover.

By Joanna Wedemeyer

Six years ago NASA launched the Mars Science Laboratory (MSL), a robotic space probe, with the intention of landing the rover Curiosity on the surface. Seven years prior, in 2004, the Mars Exploration Rovers (Spirit and Opportunity) had landed in a sequence of events referred to as the "Six Minutes of Terror". Curiosity's EDL (Entry, Descent, and Landing) was designed with the utmost caution and detail; there was zero margin for error. The mission had looked through six vehicle configurations, had 76 pyrotechnic devices, and over 500,000 lines of code. The EDL was carried out slightly differently from the previous methods and is referred to as the "Seven Minutes of Terror".

The trip from Earth to Mars takes approximately 300 days depending on the alignment of the two planets and the speed of the spacecraft. The MSL was launched from Cape Canaveral on November 26, 2011, and reached the atmosphere of Mars on August 6, 2012. Given the distance between the two planets it takes approximately fourteen minutes for a signal from Mars to reach Earth. When the scientists received word that the MSL had reached the atmosphere, it had already been on the ground (dead or alive) for seven minutes. It takes seven minutes for the spacecraft to pass through the atmosphere and reach the surface. During those few minutes, the speed of the MSL must decrease from 13,000mph to 0. The computer, which was on its own at this point, had to execute everything perfectly. If any one thing were to go wrong, the 2.5 billion dollar mission would be a failure.

When the MSL hits the atmosphere it receives an enormous amount of drag that heats the spacecraft's heat shield up until it glows like the Sun. While it is falling through the atmosphere, rockets have to be turned on at just the right time in order to guide the craft to the determined landing area. However, the atmosphere of Mars is 100 times thinner than Earth's which means it doesn't do anything to help slow the descent. So, once the MSL has slowed to about 1000mph it will release a parachute. The largest supersonic parachute, weighing approximately 100lbs, must withstand 65,000lbs of force. The opening of the parachute is a "neck-snapping" moment, so the ropes have to be able to handle the tension of "9G's".

United Launch Alliance Image of the Launching of the Mars Science Laboratory

The heatshield is now blocking the radar of the MSL from seeing the surface, so it is released and begins to plummet separately towards the surface. The radar and computer of the MSL have to make accurate calculations of the velocity and surface or else the rest of the programmed landing sequence won't work. It is at this point that the parachute has slowed it to about 200mph. This is still too fast to land, so the interior of the MSL is ejected from the capsule which the parachute is attached to. The interior ignites rockets in order to slow its descent, and move it to the side so that it doesn't collide with the capsule it left. The MSL now makes its horizontal velocity zero and works to decrease its vertical velocity.

The radar now begins to scan the surface for its landing site. The MSL begins to make a trajectory straight down to the bottom of a crater which is sitting right next to a 6km high mountain. The rocket engines can't get too close to the ground though, or else they would cause a dust cloud to form around the rover which could damage the equipment. Approximately 20m above the surface the MSL executes the "Skycrane Maneuver": it slowly releases a 21ft long tether attached to the rover. As it's lowered, the rover extends its wheels and once it is safely on the ground the MSL immediately detaches from the rover and flies off a safe distance away to crash on the planet.

NASA/JPL-Caltech/MSSS Image of the Curiosity Rover on the Surface of Mars

The Curiosity Rover has been exploring the surface of Mars ever since, and because of its discoveries new missions are being put together. NASA and the Georgia Institute of Technology have partnered together on many such missions and projects: three GT Alumni were on the EDL team for the MSL, our very own Dr. Britney Schmidt from the School of EAS is part of a team proposing a mission to Europa to take samples above and below the icy surface, and Dr. Robert Braun of the School of AE has worked on the review board of many NASA missions, including the MSL and Curiosity Rover. Indeed, due to the success of the Mars Science Laboratory Mission more and more opportunities to explore the universe are being made.

Comets: The Icy Rocks of the Cosmos

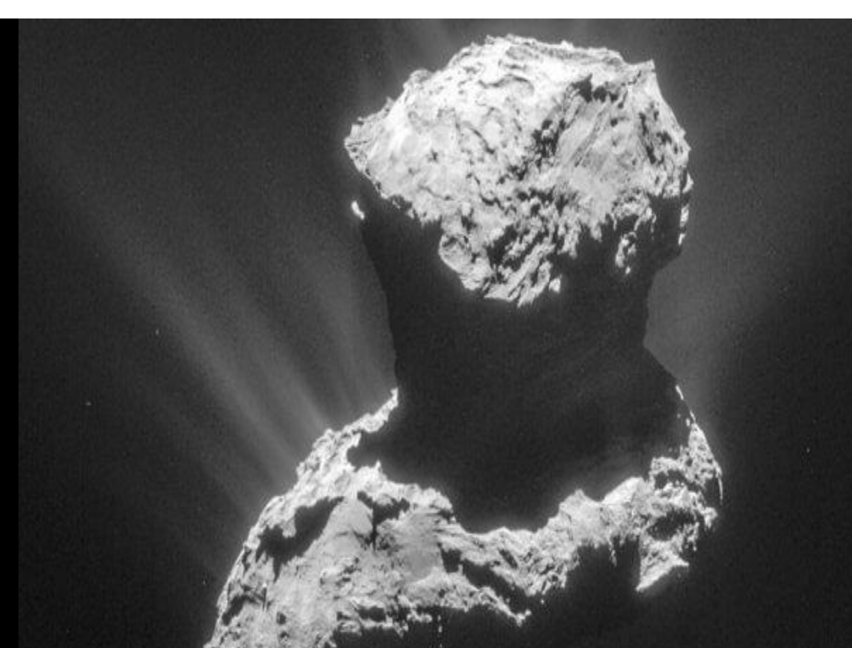
By Will Thompson

The formation of the solar system, and solar systems like ours, has always been a question of great interest to astronomers. Specifically, the development of life in our own solar system has continued to be a topic of great interest in many fields. It is a subject that has influenced the field of space exploration to the point that several of the space missions launched throughout our solar system have gone with the express intent of analyzing organic molecules and their origins. Among the key objects of study when it comes to organic molecules are comets, which are primarily composed of ice, carbon dioxide, ammonia, and methane.

Comets present us with a unique view of the early solar system, as they are some of the leftover remains from our solar system's formation. These remains never became big enough to become planets or moons and are left to orbit the Sun for the entirety of the existence. However, unlike asteroids, comets are composed primarily of dust, ice, and other organic molecules, like carbon dioxide and methane. Although they exist primarily in the regions of the outer solar system, far from the Sun, in a region known as the scattered disc. A few comets get pulled into the inner solar system because orbits are disrupted by the gravitational pull of large objects. These large objects range from the planets in our outer solar system, like Neptune, to neighboring stars passing close enough to our solar system to exert a significant gravitational influence over the orbits of smaller objects at the edge of the solar system. After their orbits change, comets have orbits that bring them close enough to the Sun for some of the ice to melt. Heat causes the ice to convert into gases, some of which actually become ionized, and radiation pushes the dust off of the core of the comet. These make comets distinct from asteroids as the ion trail and the gases left behind, known as the coma, distinguish comets visibly from asteroids. Although they are faint, comets passing close enough to the Earth can be seen in the night sky as an object a spectacular trail flowing out behind a point across the night sky.

Due to the fact that they originate in the outer solar system, comets have extremely elliptical orbits, which means that they spend most of their time in the outer solar system, far from the Earth. The most famous comet, Halley's comet, only passes near the Earth every 74 to 79 years. After passing sloe to the Earth and having its outer layers break down near the Sun, it travels out to the very edge of our solar system where the surface freezes up again and regains much of the structure that was lost during its time near the Sun. However, not all comets are as regular as Halley's comet. Some break down as they pass too close to the Sun, whereas others are not gravitationally bound to the Sun and pass through our solar system only once before being flung back out into interstellar space.

The highly elliptical nature of a comet's orbit also makes it a particularly difficult astronomical body to send actual missions to. However, in March of 2004, the European Space Agency launched the Rosetta probe and the Philae lander to study the comet 67P/Churyumov-Gerasimenko. 67P/Churyumov-Gerasimenko is a comet that was discovered 1969 by Klim Churyumov and Svetlana Gerasimenko. 67P/Churyumov-Gerasimenko is part of a group of comets known as short period comets, as an orbital period of less than 20 years. This particular comet's orbit is controlled primarily by the gravitational pull of Jupiter and is part of a group called the Jupiter Family set of comets.



Left: Illustration of Rosetta and the Philae Lander at 67P/Churyumov-Gerasimenko

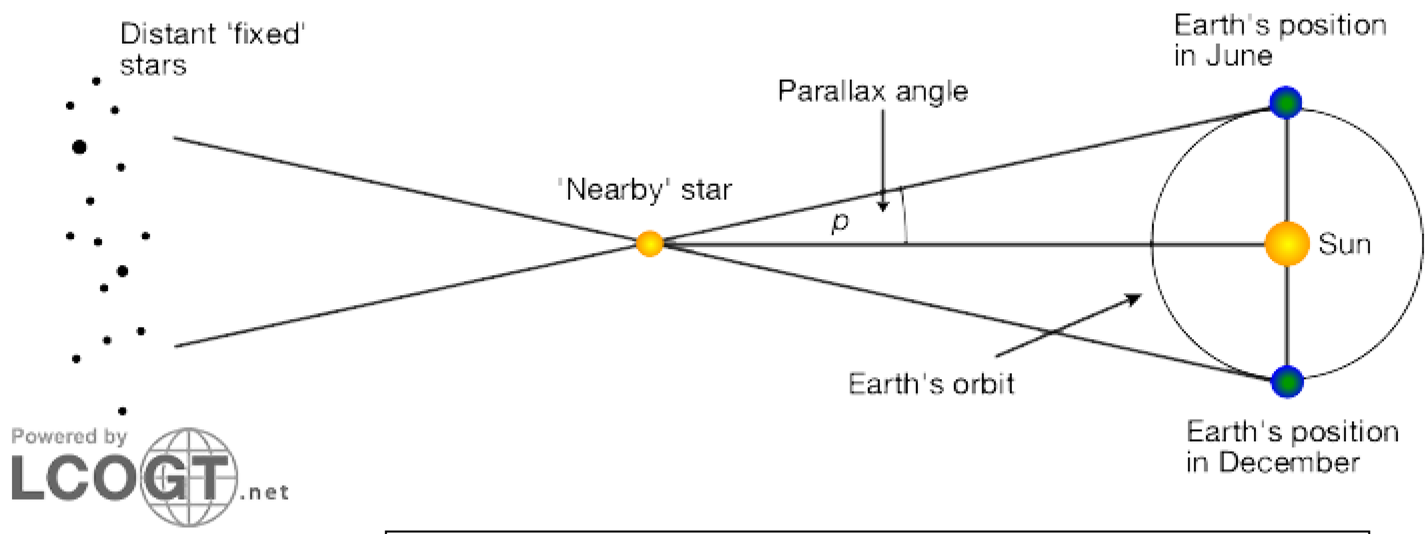
Right: ESA/Rosetta Image of 67P/Churyumov-Gerasimenko

Below: Comet West Image by John Laborde

On November 6, 2014, the Rosetta probe arrived at the comet and the Philae lander touched down on the comet 6 days later on November 12. The primary mission for the Rosetta probe and Philae lander was to collect data and information about the dynamic properties of comets in addition to a determination of the chemical and mineralogical compositions within the nucleus of the comets. Upon its initial touchdown, the Philae lander bounced off the comet's surface and ended up touching down at another location on the comet called Abydos. This new position blocked a substantial amount of light needed for Philae to generate power, and the lander went into hibernation after three days. Rosetta continued to orbit the comet and gather data until September 30, 2016, when it crashed into 67P/Churyumov-Gerasimenko.

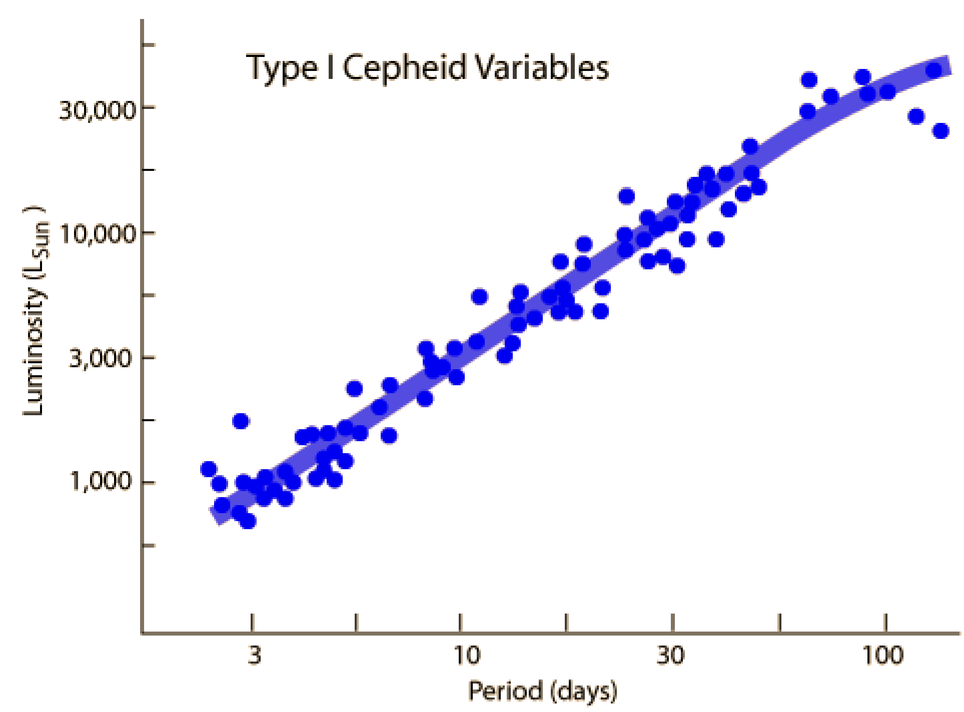
Beginner’s Guide: How We Observe Space

By James Li



Above: Las Cumbres Observatory illustration of stellar parallax measurements

Below: Graph of the Luminosity of Type I Cepheid Stars vs. the Period Between Pulses. Credit for the Graph Goes to the Georgia State University Website Hyperphysics, which is maintained by the University’s Physics and Astronomy Department



Whenever you hear about a star or nebula ten, fifty, or ten thousand light years away, how did we figure that out? It’s not like an astronomer has a ruler that long, so we use some clever methods instead.

For objects relatively close to us (tens of light years at best), we use something called parallax. To explain, take your thumb at arm’s length and look at it with one eye, then with the other. That jump you see your thumb do is called parallax. The farther away something is, the smaller the jump will be, so you can estimate its distance from the jump.

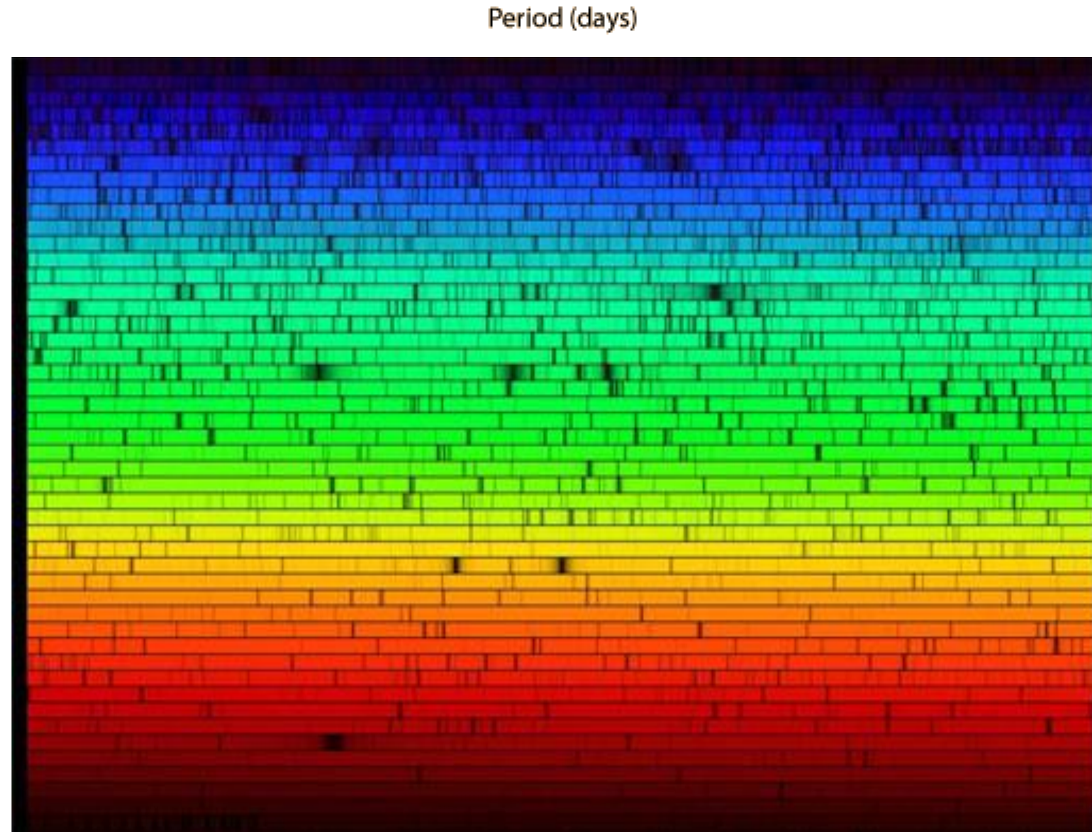
When we’re looking at stars, we use opposite points in Earth’s orbit, as far apart as possible, to maximize the jump we see. We measure this in arcseconds, a tiny unit of distance in the sky: your pinky at arm’s length is about 1 degree, which is 60 arcminutes, and each arcminute has 60 arcseconds. So an arcsecond is really tiny, but how far is something if it jumps an arcsecond? It’s 3.26 light years, but we also call this a parsec. An arcsecond is really small, our closest neighbor, Alpha Proxima is 4.24 light years away, so its parallax is even less. If we’re really careful, this method works out pretty well; but even things in our own galaxy will be thousands of light years away, so another yardstick is needed.

Cepheid variables are weird stars that regularly pulse in size and brightness, but it turns out that luminosity (total energy output) and the period between pulses are directly related. If we can time the period, we can then guess how luminous the actual star is. Things look dimmer the further away you are from it, so we can then gauge distance to these stars. This works pretty well even to nearby galaxies tens of millions of light years away.

But what if we want to go further, out to the distant galaxies in the Hubble Ultra-Deep Field that are literally billions of light years away? We then have to use the expansion of the universe. In 1929, Edwin Hubble measured galaxies moving away from each other by measuring their Doppler shift. A Doppler shift is when a wave (like light or sound) is stretched to a higher or lower frequency when the source is moving closer or further from an observer. It’s the same effect when hearing an ambulance siren pitch up, then down as it passes by. The same happens with light where things look “redder” when moving away and “bluer” when approaching.

What Hubble showed was that the speed was proportional to the distance to the object due to the expansion of space. What this all means is that if we take the speed we see a galaxy leave us, calculated from the Doppler shift, we can divide by Hubble’s Constant to get its distance. With this we can measure basically to the edge of the observable universe.

Knowing how far things are isn’t interesting science by itself. How would we know what the things we’re looking at are made of? This is where spectroscopy comes in. Elements and compounds hit by light sometimes absorb certain kinds of light. The wavelengths of light absorbed act like fingerprints for chemicals, and based on how strong these patterns are we can measure what chemicals are there and roughly how much of each kind.



Spectrum of the Sun Taken by a High-Resolution Echelle Spectrograph.

Source: Nigel Sharp, National Optical Astronomical Observatory/National Solar Observatory at Kitt Peak/Association of Universities for Research in Astronomy, and the National Science Foundation. Copyright Association of Universities for Research in Astronomy Inc. (AURA), all rights reserved.

Remembering Carl Sagan for his 83rd Birthday

By Will Thompson

Carl Sagan was an American astronomer, astrophysicist, author, and science popularizer/science communicator who was born on November 9, 1934 and died on December 20, 1996. His contributions to the study of space lie both in the scientific studies that he conducted in addition to the efforts he made to raise public interest in space exploration. He published over 600 scientific papers and was the author of multiple books throughout his lifetime.

Sagan is arguably most famous for his work as a science popularizer on the PBS television series *Cosmos: A Personal Voyage*. The 13 part series, which Sagan co-wrote, aired in 1980 and served to educate people at large about a variety of scientific topics. The ultimate goal of the program was to raise an awareness in the world about the significance of scientific endeavors and the education of people in technical fields. As Carl Sagan put it, “We live in a society exquisitely dependent on science and technology, in which hardly anyone knows anything about science and technology,” which, to him at least, was a great tragedy in a world where the rapid advancement of technology was constantly reshaping almost every facet of human life. Beyond *Cosmos*, Carl Sagan also appeared on nighttime talk shows and wrote books, such as *Pale Blue Dot* and *Contact*. *Contact* was successful enough to even be adapted into a film bearing the same name.

However, Sagan’s accomplishments in creating a great sense of curiosity about the universe in the minds of the public should not cause one to overlook his significant contributions to scientific discoveries through his own research. He was among the first to hypothesize that that one of Saturn’s moons, Titan, could have liquid on its surface and contributed significantly to the Mariner missions to Venus as he had correctly theorized the nature of Venus’ surface as extremely hot, dry, and barren. He also made substantial contributions to the Search for Extraterrestrial Life (SETI) as conducted an experimental demonstration of amino acid generation from basic chemicals exposed to radiation. The contributions that Carl Sagan made to the field of space exploration go far beyond what can be mentioned in this article, but he is without a doubt one of the most significant people to have worked in the field of astronomy.

Carl Sagan at the Very Large Array in New Mexico on the Documentary Series *Cosmos*

Astronomical Events Calendar

- November 24: Mercury at Greatest Eastern Elongation - Mercury will reach its highest elevation above the horizon in the evening, making it the best time to see the planet.
- November 30: GT Observatory Public Night at the Howey Physics Building
- December 3: Full Moon - In addition to being a regular full moon, this full moon will also be a supermoon.
- December 13-14: Peak of the Geminids Meteor Shower – Considered to be one of the biggest meteor showers, the Geminids peak on the night of 13th and morning of the 14th at an average of 120 meteors per hour during its peak. The meteors will be primarily seen around the constellation Gemini.
- December 18: New Moon
- December 21: Winter Solstice – This is the first day of Winter and marks where the Southern pole of the Earth is the most tilted towards the Sun
- December 21-22: Ursids Meteor Shower: This is a small meteor shower that produces around 5 to 10 meteors per hour on average. It peaks on the night of the 21st and occurs around the constellation of Ursa Minor.
- January 1: Mercury at Greatest Western Elongation – On this day, Mercury will reach its highest elevation above the horizon in the morning.
- January 2: Full Moon – In addition to being a regular full moon, this full moon will also be a supermoon.
- January 3-4: Quadrantids Meteor Shower – This particular meteor shower produces around 40 meteors per hour at its peak and occurs around the constellation of Bootes.

Photos of the Month

These photos were taken by student astrophotographer Jack Casey on the semesterly Astronomy Club Stargazing trip. The above photo is of the Orion Nebula and the photo to the left is of the Andromeda Galaxy.