

Continue



A Coronal Mass Ejection, or CME, is when the sun suddenly releases a lot of matter and energy from its surface, flinging it outwards into space. To understand why it would do this, we need to know a bit more about how the surface of the sun works.The Sun is a miasma of incandescent plasma, and it rotates around its axis once every 30 days (roughly). But because the sun isn't a solid body like the Earth, the entire Sun does not have to rotate at the same rate. If the equator of the Earth tried to rotate faster than the poles, the rocks that make up the surface of our planet would have to shear apart. But because the Sun is just gas, it can have an equator that rotates a few days faster than its poles - a gas doesn't have the same resistance to shear as rock does. The Sun also has a pretty intense magnetic field, which normally would start at the top pole, and travel smoothly downward to the bottom pole, as it does on the Earth. However, since the equator of the Sun is travelling a little bit faster than the poles, the magnetic field gets dragged along with the faster material, which pulls the magnetic field into a twist. After enough twisting, the magnetic field begins to form little loops that pop out of the surface. You can replicate this effect by taking a bit of string or cable and twisting it - at some point, the cable will want to make a twisted loop if you give the line some slack. These little loops tend to be associated with sunspots. As the years go by, the magnetic field of the sun gets increasingly twisted, and these loops get bigger and more common on the surface of the sun. As the magnetic fields get increasingly tangled up in themselves, if the bases of the magnetic fields (or, in our cable analogy, some of the cable closer to your hands, not in the loop itself) touch, they snap together and create a new magnetic line, without the loop. This then leaves the loop in the lurch - but it doesn't just hover over the surface of the sun. The snapping together generates a lot of energy, which is all dumped into flinging the material which was trapped in the loop outwards, into the solar system.These particles have extremely high energies, which means they leave the sun's surface at an extremely high temperature and at an extremely fast pace. Since these can occur at any point on the Sun's surface, (although they don't tend to form at the exact poles, since the magnetic field doesn't get very twisted there) and the Sun is constantly rotating, the probability of a CME being headed straight for the Earth would be pretty low, if they shot directly out from the surface. However, CMEs are notable because they eject particles over a wide swath of space, so our odds of running into this stuff is much higher than you would expect. So what happens when they head for us? Fortunately, the Earth's magnetosphere takes the brunt of the blow from these particles. The magnetosphere can be thought of as a giant magnetic shield, deflecting charged particles that come our way. This protects us from most of this kind of radiation from the sun. Our magnetic field sinks into the planet at the magnetic north and south poles (close to, but not exactly the same as, the rotational north pole). This means that theres a bit of a divot in our magnetic field, and particles can get stuck in here, and go around bombarding the atmosphere with radiation, causing the atmosphere to glow. This is what causes the Northern and Southern lights - also known as the aurora. If you're in the far north and you hear that theres a solar storm coming, head outside when it hits - theres a good chance of seeing the aurora any time a CME comes our way.Less aesthetically pleasing is the fact that CMEs can do a fair amount of damage to some of our satellites in orbit. Satellites are built to be able to handle slightly more than an average amount of radiation under normal circumstances. But if they're getting hit with the kinds of energies that CMEs bring, even after 93 million miles, some satellites cant handle the dosage. The constant bombardment of the satellite by charged particles can cause the satellite itself to become charged. This is very similar to becoming electrically charged by shuffling around in socks on carpet. If the satellite gains enough charge, it can short-circuit itself, which will kill the satellite, if a crucial part fails. (In space based satellites, most parts are crucial.) This kind of thing mostly affects satellites that are in very high, particularly geocentric orbits, like GPS satellites. The International Space Station is usually unaffected since its in a lower orbit, although in the case of strong storms, the astronauts can take shelter in more highly shielded portions of the ISS.On the surface of the Earth, most of the time the most noticeable part of a CME is the aurora; most of the other consequences of a coronal mass ejection just dont make it to the surface.That said, in 1989, a solar storm knocked out power to 6 million people living in Quebec because there was so much turbulence in the magnetic field of the Earth that it induced a current in the power lines, and overloaded a set of circuit breakers. In the face of extremely large coronal mass ejections, we can have problems on Earth. Fortunately, as long as we have telescopes observing the sun, we will always have several days warning.Have your own question?Curious about something I wrote here? Feel free to ask!The corona is the outermost layer of the Sun. It is extremely hot but so tenuous that it is visible only when a solar eclipse blocks the brighter photosphere. Coronal holes are less dense regions of the corona where coronal matter streams outward into interplanetary space. Coronal mass ejections occur when magnetic field lines in the solar corona snap and eject large clumps of solar material into interplanetary space.Overview The outermost layer in the Suns atmosphere is the corona (which means crown). Gas in the corona can reach temperatures of a few million kelvins. This gas is very thin, however, with a density on the order of 10-12 kilograms/meter3. Thus, the corona is faint, so faint that it cannot normally be seen because its feeble light is overwhelmed by the much brighter photosphere. The corona must be observed optically either during a total solar eclipse or by using a coronagraph. The latter is a disk, blocking the photosphere, in the focal plane of the telescope. The chromosphere is the layer of the suns atmosphere between the photosphere and corona. The chromosphere is only a few thousand kilometers thick. The temperature of the gas in the chromosphere is slightly higher than that in the photosphere. In the approximately 100-kilometer-thick transitional region between the chromosphere and corona, the temperature rapidly increases from about 6,000 kelvins to a few hundred thousand kelvins. The Sun is a ball of gas without anything that could be considered a solid surface. The suns photosphere, however, is the closest the sun has to a surface. The photosphere is relatively opaque and blocks our view of the solar interior, so most photographs or observations of the solar disk show the suns photosphere. It is also the coolest layer of the sun. The bottom layer of the photosphere is at a temperature of 5,800 kelvins. The photospheric temperature drops with increasing height to a temperature of about 4,500 kelvins at the top of the photosphere, begins to increase in the chromosphere, and is extremely high in the corona.Relatively cool stars are reddish in color, while hot stars are bluish. The suns corona, at a few million kelvins, is much hotter than most stars, so it emits most of its energy in the extreme ultraviolet (the shortest ultraviolet wavelengths) to X-ray region of the electromagnetic spectrum. The photosphere is not hot enough to emit significant amounts of energy in this spectral region. Fortunately for human beings, Earths atmosphere blocks most extreme ultraviolet and X radiation, so astronomers study the sun at these wavelengths from satellites.Extreme ultraviolet and X-ray pictures of the sun show a bright corona and dark photosphere, which is the reverse of optical pictures showing a bright photosphere and much fainter corona. Solar astronomers therefore study the solar corona using extreme ultraviolet or X-ray images. At these wavelengths the corona shows structures that are not visible at optical wavelengths.One common structure in the X-ray corona is the coronal hole. On X-ray images of the suns corona, coronal holes show up as dark areas because they are regions where the corona is much more tenuous than normal. In the coronal holes, the corona does not show up in X rays and the photosphere below is very dark at X-ray wavelengths. Gas density in the coronal holes is typically about one-tenth the density of the normal part of the corona. Near the north and south poles the coronal holes tend to be relatively stable. Near the equatorial and midlatitude regions of the sun, coronal holes are less stable. Coronal hole activity varies with the suns magnetic activity cycle. Coronal holes are therefore in some way related to the suns magnetic field. The largest coronal holes, which are a few hundred thousand kilometers in diameter, can last for months. More typical coronal holes are tens of thousands kilometers in diameter. These smaller coronal holes typically last only for hours rather than months.Most of the corona contains coronal loops, which are magnetic field structures. The solar magnetic field lines come up from the lower layers of the sun, loop into the corona, then flow back down into the solar interior. Charged particles, such as protons and electrons, in strong magnetic fields generally travel in spiral paths around the magnetic field lines. The magnetic forces do not allow these particles to travel across the magnetic field lines. Solar material is a plasma in which electrons are separated from the atomic nuclei; it is composed of charged particles and flows along these coronal loops.Coronal loops do not exist in coronal holes. In coronal holes the magnetic field lines from the suns interior do not loop back into the sun. They extend outward into interplanetary space. In the coronal holes, solar material moves upward from the suns lower layers along these magnetic field lines. Rather than falling back down into the sun, this materialwhich is mostly protons (hydrogen nuclei) and electrons with occasional heavier, ionized atomstreams out into interplanetary space and leaves a low-density coronal hole. Coronal holes therefore contain solar matter flowing into interplanetary space and are a major source of the solar wind.The solar wind consists of charged particles from the sun flowing outward into space. Were it not continually replenished from the lower layers of the sun, the solar wind would evaporate the corona in about a day. A few billion kilograms of solar material flow outward in the solar wind every second. The sun permanently loses this mass. It would seem that the sun might quickly evaporate from the cumulative effect of the coronal holes and solar wind, but the sun is very much more massive than Earth. Hence, in the nearly five billion years of its existence, the sun has lost less than one-tenth of 1 percent of its mass to the outflow of the solar wind.Coronal mass ejections occur when coronal loops break. Normally solar material flows along the coronal loops into the corona, and back into the interior. However, occasionally the magnetic field lines in a coronal loop break. When this happens, the loop more or less explodes. The solar material in the loop is no longer confined by the magnetic field; it shoots outward into space. These events are called coronal mass ejections, or CMEs.A typical CME flings about 1012 to 1013 kilograms of solar material into space. Typically a CME releases 1024 to 1025 joules of energy. Because CMEs are related to the suns magnetic field, they occur more frequently during the maxima of the solar activity (sunspot) cycle. CMEs happen as often as a few times a day. When a CME is pointed toward Earth, the resulting magnetic storm can severely disrupt long-distance communications on Earth and cause increased auroral activity.Knowledge GainedIn contrast to the suns photosphere, the spectrum of the suns corona contains emission lines, which form from a hot, thin gas. Many of the emission lines in the suns coronal spectrum are lines not visible from Earth. Astronomers originally thought these lines might be a new element, but they turned out to be what scientists call forbidden lines. The existence of these forbidden lines was an early clue to the extremely low density of the corona.Although the corona can be studied optically from the ground during eclipses, much of our knowledge of the corona, coronal holes, and coronal mass ejections comes from satellites, particularly those equipped to observe the sun at extreme ultraviolet and X-ray wavelengths as well as optically. Such studies started in earnest in the 1970s using X-ray telescopes on the Skylab mission. During this crewed mission, solar astronomers first noticed the connection between coronal holes and the solar wind.Other satellites have been important to understanding coronal phenomena. The Japanese Yohkoh Satellite was launched in 1991 and fell back to Earth in 2005. Yohkoh for the first time allowed daily images of the corona allowing solar astronomers to study rapid changes in the coronal structure. The joint European and National Aeronautics and Space Administration (NASA) Solar and Heliospheric Observatory, SOHO, mission launched in 1995, and the NASA Transition Region and Coronal Explorer (TRACE) mission, launched in 1999, also made many contributions to our understanding of coronal and other solar phenomena. SOHO discovered a magnetic carpet on the suns surface that plays a major role in providing the energy needed to heat the corona. TRACE takes very high-resolution, extreme ultraviolet images of the corona. Although TRACE could image only a small region of the corona at one time, it did allow very detailed studies of coronal phenomena. TRACE was retired in 2010. In 2006, NASA launched the Hinode Mission to study the suns magnetic field. As of 2022, the spacecraft was still in orbit. In 2018, NASA launched the Parker Solar Probe, which became the first spacecraft to touch the sun by flying into its corona. By 2021, the craft had made fourteen of a planned twenty-four orbits of the sun, sending back valuable information about the solar wind. ContextCoronal mass ejections as well as variations in the solar wind can affect Earth, causing geomagnetic storms. These geomagnetic storms are often referred to as space weather. The aurora borealis and aurora australis, also known as the northern and southern lights, are caused by these geomagnetic storms. Hence they are more likely to be visible when a coronal mass ejection reaches Earth. Other geomagnetic effects are less benign. Earths upper atmosphere expands a little and disrupts long-distance radio communications that depend on radio waves reflecting off the ionosphere or communication satellites. The expanded upper atmosphere can cause some friction on low-Earth-orbit satellites leading to orbital decay and eventually falling back to Earth. Geomagnetic storms caused by coronal mass ejections can also disrupt the electrical power grid.Coronal holes and coronal mass ejections are part of the complex magnetic phenomena of the suns corona. Coronal holes seem to play a still poorly understood role in the suns magnetic activity cycle, though they occur during periods of lower activity in the suns eleven-year cycle. These phenomena do not exist in isolation. The corona and its magnetic fields interact with the suns chromosphere, photosphere, interior, and their magnetic fields. Via the solar wind, originating in coronal holes, and coronal mass ejections, the suns corona also interacts with Earth. To understand any facet of this complex sun-earth system completely, astronomers need to understand all the other facets.BibliographyBuckley Michael, "NASA Gives Green Light for Johns Hopkins APL to Begin Building Solar Probe Plus Spacecraft," National Aeronautics and Space Administration, 9 Apr. 2015, www.nasa.gov/content/goddard/nasa-gives-green-light-for-johns-hopkins-apl-to-begin-building-solar-probe-plus-spacecraft. Accessed 20 Jan. 2023.Chaisson, Eric, and Steve McMillan. Astronomy Today, 8th ed. New York: Addison, 2013.Freedman, Roger A., and William J. Kaufmann III. Universe, 9th ed. New York: Freeman, 2010.Print.Golub, Leon, and Jay M. Paschosf. Nearest Star: The Surprising Science of Our Sun. Cambridge: Harvard UP, 2001.Print.Heckert, Paul A. Solar and Heliospheric Observatory. In *USA in Space*, 3rd ed. Edited by Russell Tobias and David G. Fisher. Pasadena,: Salem, 2006.Print.Hester, Jeff, et al. Twenty-first Century Astronomy. New York: Norton, 2007. Print."Parker Solar Probe." National Aeronautics and Space Administration, 8 Feb. 2021, www.nasa.gov/content/goddard/parker-solar-probe. Accessed 20 Jan. 2023.Schrijver, Carolus J. The Science Behind the Solar Corona. Sky and Telescope 111.4 (2006): 28-33. Print.Zeilik, Michael. Astronomy: The Evolving Universe. 9th ed. Cambridge: Cambridge UP, 2002. Print.Zeilik, Michael, and Stephen A. Gregory. Introductory Astronomy and Astrophysics. 4th ed. Fort Worth,: Saunders, 1998. Print.Coronal Mass Ejections, or CMEs, are explosive bursts of solar plasma and magnetic field that fly away from the Sun at thousands of kilometers an hour. CMEs are frequently (but not always) associated with solar flares. These eruptions occur when large, looming coronal loops or filaments (gases trapped by magnetic fields, a bit like iron filings) are buffeted or disturbed in some way. This causes the whole loop system to become unstable, so the trapped material can burst free, dragging some of the magnetic field with it.CMEs are most common during solar maximum during times when the sunspot cycle is most active. Sometimes Earth lies in the path of a Coronal Mass Ejection. Because they contain highly charged particles, CMEs can be dangerous to astronauts and cause serious damage to satellites. However, they can also cause the most spectacular lightshow on earth the aurora!The fast-moving CMEs can, if they are in the correct orientation, actually force the Earths magnetic field to restructure itself. This restructuring (called magnetic reconnection) energizes particles in space, launching them along the Earths magnetic field towards the poles. Once they hit the Earths atmosphere, which appears like a brick wall to these particles, they come to a screeching halt, dumping their excess energy into the atmosphere. This extra energy causes the Earths atmosphere to glow. Different atoms in the atmosphere glow different colors. For example, oxygen glows red and green, and nitrogen glows blue and purple all colors we see in the aurora! Share copy and redistribute the material in any medium or format for any purpose, even commercially. Adapt, remix, transform, and build upon the material for any purpose, even commercially. The licensor cannot revoke these freedoms as long as you follow the license terms. Attribution You must give appropriate credit , provide a link to the license, and indicate if changes were made . You may do so in any reasonable manner, but not in any way that suggests the licensor endorses you or your use. ShareAlike If you remix, transform, or build upon the material, you must distribute your contributions under the same license as the original. No additional restrictions You may not apply legal terms or technological measures that legally restrict others from doing anything the license permits. You do not have to comply with the license for elements of the material in the public domain or where your use is permitted by an applicable exception or limitation . No warranties are given. The license may not give you all of the permissions necessary for your intended use. For example, other rights such as publicity, privacy, or moral rights may limit how you use the material. Coronal mass ejection on February 27, 2000. A disk blocks out the light of the sun. The white circle indicates the suns surface. Learn more about coronal mass ejections here. Image via SOHO. Every so often, the sun burps with the power of 20 million nuclear bombs. These hiccup, known as coronal mass ejections, are powerful eruptions near the surface of the sun, driven by kinks in the solar magnetic field.The resulting shock ripples through the solar system and can interrupt satellites and power grids on Earth.During a CME, enormous bubbles of superheated gas called plasma are ejected from the sun. Over the course of several hours, a billion tons of material launch off the suns surface and accelerate to speeds of a million miles per hour (1.6 million kilometers per hour).This can happen several times a day when the sun is most active. During its quieter periods, CMEs occur only about once every five days.How do they form?The underlying cause of CMEs is not well understood. Astronomers agree, however, that the suns magnetic field plays a major role. Because the sun is a fluid, turbulence tends to twist the magnetic field into complex contortions.When the field twists too much and it kinks, much like a phone cord or toy Slinky, then these kinks snap the magnetic field and can potentially drive vast amounts of plasma into space.The plasma itself is a cloud of protons and electrons that the solar wind carries aloft.Traveling at a million miles per hour (1.6 million kph), the ejecta can cross the 93-million-mile (150-million-km) distance to Earth in just a few days.A jet moving that fast would get you from Los Angeles to New York in only 18 seconds.Do all coronal mass ejections reach us?Because CMEs blow off the sun in all directions, most dont come anywhere near Earth.But every so often, an eruption aims right at us. When the plasma cloud hits our planet, a geomagnetic storm follows. Then, the shock wave of moving particles compresses the Earths dayside magnetic field while it stretches out the nightside.Like an ejected rubber band, the terrestrial magnetic field eventually snaps back with the same amount of energy as a bolt of lightning.The video below shows the particle flow around Earth as solar ejecta associated with a coronal mass ejection strike.The onslaught of charged particles and the temporary restructuring of the Earths magnetic field has observable effects.Auroral displays, usually only seen near the poles, can drift to lower latitudes and become more brilliant.The disturbance of the magnetic field can also expose Earth to deadly cosmic rays.The atmosphere still provides enough protection for everyone on the ground.But astronauts in space may receive lethal doses of radiation.During a solar storm in 1989, cosmonauts aboard the Mir space station received their maximum yearly radiation dose in just a few hours!Are they dangerous for humans?The real long-lasting danger comes from the storms effect on technology. The flurry of magnetic activity and induced electric currents have the potential to severely disrupt power grids, satellites, communication networks that is, anything that uses electricity.When the sun aimed a CME at us in that 1989 event mentioned above the resulting storm collapsed the Hydro-Quebec power grid for six million people without power for nine hours. But the 1989 storm is nothing compared to the geomagnetic storm of 1859. Known as the Carrington Event, after amateur astronomer Richard Carrington, who observed the flares that triggered the storm, it was the most powerful geomagnetic storm ever recorded. People as far south as Hawaii and the Caribbean observed auroras.Witnesses at higher latitudes reported being able to read newspapers by the light of the aurora alone.Telegraph networks around the globe catastrophically failed; operators received shocks and telegraph paper caught on fire.A repeat of the Carrington Event in todays far more interconnected world would be devastating.Cascading failures could quickly shut power down to millions of people in a matter of minutes.Communication networks would fail and GPS satellites, upon which the entire air traffic system relies, would shut down. Becoming better preparedBut, obviously, we dont want to be surprised by a powerful Earth-directed CME.Thats why astronomers study the sun.Besides the joy of discovering how stars work, a better understanding of solar activity can help us be better prepared.With even just a few hours warning before an impending CME strike, we could safely shut down and protect essential services. Disruptions may then only last a few hours, rather than the days, weeks and months that might otherwise occur.CMEs are just another reminder of how fragile our pale blue dot is as it races around the sun.On August 31, 2012, the Solar Dynamics Observatory (SDO) caught the sun launching streams of plasma into space at nearly 900 miles (about 1,400 km) per second. Image via NASA/ GSF/ SDO.Bottom line: Coronal mass ejections (CMEs) are powerful eruptions on the suns surfacecaused by instabilities in the suns magnetic field.When they aim at Earth, the resulting magnetic storm can disrupt electrical systems and produce brilliant auroral displays.Watch: 25 years of solar activity Chris Crockett got his Ph.D. in astronomy from UCLA in 2011 and worked at Lowell Observatory and the U.S. Naval Observatory. He then realized he enjoyed talking about astronomy a lot more than actually doing it. After being awarded a Mass Media Fellowship in 2013 by the American Association for the Advancement of Science, he spent a summer writing for Scientific American, then went on to become the staff astronomy writer at Science News from 2014 - 2017. These days, he freelances, focusing on stories about astronomy, planetary science, and physics. His work has appeared in Science News, Scientific American, Smithsonian Magazine, Knowable, Sky & Telescope, and the American Physical Society's online magazine Physics. Coronal mass ejections (CMEs) are large expulsions of plasma and magnetic field from the sun's atmosphere the corona.Compared to solar flares bursts of electromagnetic radiation that travel at the speed of light, reaching Earth in just over 8 minutes CMEs travel at a more leisurely pace, relatively speaking. At their highest speeds of almost 1,900 miles per second (3,000 kilometers per second), CMEs can reach Earth in about 15 to 18 hours whilst slower CMEs traveling around 155 mi/s (250 km/s) can take several days to arrive, according to the Space Weather Prediction Center of the National Oceanic and Atmospheric Administration (NOAA).These relatively slower travel times are useful as they give us more time to prepare for such an arrival. CMEs can wreak havoc with power grids, telecommunication networks and orbiting satellites and expose astronauts to dangerous doses of radiation. Conversely, CMEs are a welcomed visitor for skywatchers worldwide as they can trigger impressive auroral displays that are visible at latitudes beyond their "normal" polar range. You may like Related: How hot is the sun?Coronal mass ejections form similarly to solar flares a result of the twisting and realignment of the sun's magnetic field, known as magnetic reconnection, according to NOAA. When magnetic field lines "tangle" they produce strong localized magnetic fields which can break through the surface of the sun at active regions, subsequently generating CMEs.CMEs usually take place around sunspot groups and are often accompanied by a solar flare, though the two don't always occur in tandem. In fact, scientists are still not entirely sure how the two events are related, and according to Univ. of Colorado Boulder's Space and Atmospheric Research's (UCAR) Center for Science Education CMEs like solar flares are most common during solar maximum a period in the sun's 11-year cycle of activity when the star is at its most active. After CMEs are released, they swell in size as they travel away from the sun. "Larger CMEs can reach a size comprising nearly a quarter the space between Earth and the sun by the time it reaches our planet", said NOAA in a statement. If a CME is large enough and travels faster than the solar wind it generates a shock wave whereby accelerated charged particles travel ahead of the CME further disturbing space weather conditions and intensifying geomagnetic storms according to NOAA.Effects of CMEs on EarthExtensive auroral displaysCMEs can trigger large geomagnetic storms that result in impressive auroras like this one pictured in Alaska. (Image credit: Noppawat Tom Charoenpinth via Getty Images)Aurora displays are formed when disturbances in Earth's magnetic field funnel ions down towards Earth's poles where they collide with atoms of oxygen and nitrogen in Earth's atmosphere, creating dazzling aurora light shows around the polar regions. In the Northern Hemisphere the phenomenon is called the northern lights (aurora borealis), while in the Southern Hemisphere, it's called the southern lights (aurora australis).Usually, these dazzling light shows are confined to the polar regions but during large magnetic disturbances triggered by a CME auroras can be seen at much lower latitudes than they're normally observed according to ESA.In 1859, the Carrington Event a colossal solar storm triggered by a CME resulted in aurora displays observed near tropical latitudes over Cuba, the Bahamas, Jamaica, El Salvador, and Hawaii, according to NOAA. That being said, CMEs don't always trigger extraordinary auroral displays, the degree of magnetic disturbance from a CME depends on the CME's magnetic field and Earth's. If the CME's magnetic field is aligned with Earth's, pointing from south to north the CME will pass on by with little effect. However, if the CME is aligned in the opposite direction it can cause Earth's magnetic field to be reorganized, triggering impressive aurora light shows. Technological malfunctionsLarge CMEs can cause technological malfunctions that are especially problematic in the Carrington Event in 1859 caused worldwide telegraph system failures. According to History.com there were even reports of operators receiving electric shocks and sparks showering from telegraph machines, setting papers ablaze. In 1989, a CME accompanied a solar flare that hit Earth, plunging the entire province of Quebec, Canada, into an electrical blackout that lasted 12-hours, according to a NASA statement. The event cost Quebec's utility company Hydro-Quebec at least \$10 million in damages. But just how do CMEs cause all this disruption?CMEs can also cause surges in electrical currents which overload power grids causing widespread blackouts. Also, according to NASA, CMEs can jostle Earth's magnetic field which can impair radio transmissions and increase radio static in Earth's ionosphere.GPS systems are particularly vulnerable to disturbances in the ionosphere and GPS coordinates have been known to stray by tens of feet during a CME event. The disruption occurs because GPS uses radio signals to relay information between a satellite and a ground receiver. The radio signal passes through the ionosphere layer containing charged plasma that bends the path of the GPS signal in a similar fashion to lenses bending light, according to NOAA's Space Weather Prediction Center. Normally, GPS systems can compensate for this bending of the radio signal, leaving the accuracy of GPS unaffected. However, during a CME event, the ionosphere can be so severely disturbed that the GPS models cannot keep track of such changes and receivers can no longer calculate an accurate position.Effects of CMEs in spaceCMEs can wreak havoc on satellites in high geosynchronous orbits. (Image credit: MARK GARLICK/SCIENCE PHOTO LIBRARY via Getty Images)How do CMEs affect satellites?Earth-orbiting satellites are vulnerable to CMEs, particularly those in high geosynchronous orbits which is where most communications satellites are found, according to NASA's Goddard Space Flight Center. When a CME triggers a geomagnetic storm, satellites can be struck by a high current discharged into the satellite or damaged when high-energy particles penetrate the satellite. As such, vulnerable satellites can be placed in "safe mode" to prevent damage to electronics. A direct hit of a colossal geomagnetic storm like the one observed in 1859 the Carrington Event could take a heavy toll on our satellite fleet according to the research described in a NASA statement."A worst-case solar storm could have an economic impact similar to a category 5 hurricane or a tsunami," said Dr. Sten Odenwald of NASA's Goddard Space Flight Center, Greenbelt, Md."There are more than 900 working satellites with an estimated replacement value of \$170 billion to \$230 billion, supporting a \$90 billion-per-year industry. One scenario showed a 'superstorm' costing as much as \$70 billion due to a combination of lost satellites, service loss, and profit loss. "SpaceX has already witnessed firsthand the damage space weather can do when a geomagnetic storm destroyed up to 40 Starlink satellites worth over \$50 million, in Feb. 2022.Can CMEs harm astronauts?In low-Earth orbit, astronauts receive higher doses of radiation than we do on Earth but they are still mostly protected by the magnetosphere according to a statement from NASA.The real danger to astronauts comes if they stray from the safety of the magnetosphere, for example, to explore the surface of the moon or Mars. Upon such an expedition outside Earth's "protective shields" they are vulnerable to dangerous space weather events such as CMEs. According to NASA, if a CME-driven shock wave were to hit an unprepared astronaut exploring the lunar or martian surface, they would be hit with as much radiation as 300,000 simultaneous chest X-rays. This would have lethal consequences as it would only take 45,000 simultaneous chest X-rays to kill you. How can we forecast CMEs?The Solar and Heliospheric Observatory's coronagraph is used to observe CMEs. (Image credit: NASA/Solar weather can have drastically expensive consequences. It is, therefore, important to increase our understanding, monitoring and predictions of such events.Luckily for us, CMEs take several hours, sometimes days, to reach Earth. This gives us some time to prepare for their arrival.Various organizations keep a watchful eye on the sun and report any changes in surface characteristics that could infer a CME ejection such as an increase in solar activity and solar flare ejections. If a strong M or X-class solar flare is detected it is likely that it will be accompanied by a CME, but not always, according to SpaceWeather.Live.com.SWPC forecasters use various parameters size, speed and direction inferred by orbital satellites' coronagraph imagery to determine the likelihood of a CME hitting Earth.A coronagraph is a specialized instrument used to block out the light of the sun so scientists can observe the outermost layer of the corona. It mimics the natural phenomenon of a solar eclipse when the moon's shadow covers the bright center allowing the corona to be observed.According to NOAA, forecasters primarily use NASA and ESA's Solar and Heliospheric Observatory's (SOHO) coronagraph the Large Angle and Spectrometric Coronagraph (LASCO) to analyze CMEs and determine the likelihood of an Earth impact.A coronal mass ejection (CME) captured by NASA and ESA's Solar and Heliospheric Observatory (SOHO). (Image credit: NASA/GSFC/SOHO/ESA)On the front line of CME detection is the Deep Space Climate Observatory (DSCOVR) satellite that is stationed at the first Lagrange point L1 between Earth and the sun at about 1 million miles (1.6 million km) from Earth.DSCOVR monitors any changes in the interplanetary magnetic field (IMF) strength and solar wind speed which are vital to the accuracy and responsiveness of NOAA's space weather alerts and forecasts.From its parking spot at L1, the DSCOVR satellite can provide between 15 to 60 minutes of advanced warning before a CME reaches Earth. When an Earth-bound CME is detected, the SWPC alerts vulnerable groups such as power companies, satellite companies and airlines to take appropriate measures. With advanced warning, utility companies can redirect power loads to protect the grids from being overloaded when the CME hits, satellites can be placed into "safe" mode and planes can be redirected.ESA's Vigil mission hopes to add another solar defender to Earth's aid by the mid-2020s according to ESA. Vigil will monitor the sun from Lagrange 5, approximately 93 million miles (150 million kilometers) from Earth. The spacecraft will be positioned so it can keep an eye on the "side" of the sun. It will monitor solar conditions before they rotate around to face Earth in a bid to give us advanced warning of possibly hazardous solar activity.Additional resourcesInterested in reading more about what impacts large solar flares and CMEs might have on astronauts on the moon, check out this article from NASA. Explore more effects of energized space weather and the hazards of space travel with Tufts University. Want to keep an eye on current geomagnetic activity levels for yourself? The British Geological Survey has got you covered you can also sign up for their geomagnetic disturbance alert emails. BibliographyCoronal mass ejections. NOAA / NWS Space Weather Prediction Center. Retrieved May 20, 2022.DSCOVR. Deep Space Climate Observatory. NESDIS. Retrieved May 20, 2022.Mendez, B., Petcolas, L., & Hauck, K. (August 12, 2004). Solar flares and coronal mass ejections. NASA. Retrieved May 20, 2022.NASA. The impact of flares. NASA. Retrieved May 20, 2022.Odenwald, S. (March 13, 2009). The Day the Sun brought darkness. NASA. Retrieved May 20, 2022.Solar Orbiter images first coronal mass ejections. ESA. (May 17, 2021.). Retrieved May 20, 2022.Steigerwald, B., & Weintraub, R. A. (April 1, 2006.). Safeguarding our satellites from the sun. NASA. Retrieved May 20, 2022.UCAR Center for Science Education. Coronal Mass Ejection (CME) | Center for Science Education. Retrieved May 20, 2022.What is a coronal mass ejection (CME)? SpaceWeather.Live. Retrieved May 20, 2022. Coronal Mass Ejections, or CMEs, are massive bursts of solar wind and magnetic fields that are ejected from the Sun's corona, the outermost layer of the Sun's atmosphere. These ejections can contain billions of tons of solar material and can travel at speeds of up to several million miles per hour. When a CME reaches Earth, it can interact with the Earth's magnetic field and atmosphere, producing a variety of effects.II. How are Coronal Mass Ejections formed?Coronal Mass Ejections are typically associated with solar flares, which are sudden releases of energy on the Sun's surface. During a solar flare, magnetic energy that has built up in the Sun's atmosphere is suddenly released, causing a burst of radiation across the electromagnetic spectrum. This burst of energy can also trigger the release of a CME, which is a much larger and more powerful event.The exact mechanism by which CMEs are formed is not fully understood, but it is believed to involve the reconfiguration of magnetic fields in the Sun's corona. As the magnetic fields become twisted and tangled, they can eventually snap and release huge amounts of solar material into space.III. What are the effects of Coronal Mass Ejections on Earth?When a Coronal Mass Ejection reaches Earth, it can have a number of effects on our planet. One of the most noticeable effects is the creation of geomagnetic storms, which can disrupt the Earth's magnetic field and cause disturbances in the ionosphere. These disturbances can lead to disruptions in radio communications, GPS systems, and power grids.CMEs can also produce stunning displays of auroras, or northern and southern lights, as the charged particles from the Sun interact with the Earth's atmosphere. These auroras can be seen at high latitudes and are a beautiful reminder of the powerful forces at work in our solar system.In extreme cases, CMEs can also pose a threat to astronauts in space, as the increased levels of radiation can be harmful to human health. Space agencies closely monitor solar activity to ensure the safety of astronauts on the International Space Station and other spacecraft.IV. How are Coronal Mass Ejections monitored and predicted?Scientists use a variety of instruments to monitor and predict Coronal Mass Ejections. One of the most important tools is the Solar and Heliospheric Observatory (SOHO), a satellite that orbits the Sun and provides real-time data on solar activity. SOHO can detect solar flares and CMEs before they reach Earth, giving scientists valuable time to prepare for any potential impacts.In addition to SOHO, other spacecraft and ground-based observatories also contribute to the monitoring of CMEs. These instruments provide data on the speed, direction, and strength of CMEs, allowing scientists to make more accurate predictions about when and where they will impact Earth.V. What is the relationship between Coronal Mass Ejections and space weather?Coronal Mass Ejections are a key component of space weather, which refers to the conditions in space that can affect satellites, spacecraft, and other technology. When a CME reaches Earth, it can create disturbances in the Earth's magnetosphere, ionosphere, and atmosphere, leading to a variety of space weather effects.These effects can include disruptions in satellite communications, increased radiation levels in space, and potential damage to spacecraft electronics. Space agencies and satellite operators closely monitor space weather conditions to protect their assets and ensure the safety of astronauts in space.VI. How can Coronal Mass Ejections impact technology on Earth?Coronal Mass Ejections can have a significant impact on technology on Earth, particularly on our power grids and communication systems. When a CME interacts with the Earth's magnetic field, it can induce electrical currents in power lines, transformers, and other infrastructure, leading to power outages and equipment damage.In 1859, a massive solar storm known as the Carrington Event caused widespread disruptions to telegraph systems around the world. If a similar event were to occur today, it could have devastating effects on our modern technology-dependent society.To mitigate the risks posed by CMEs, power companies and other critical infrastructure operators are working to improve their resilience to space weather events. By implementing protective measures and developing emergency response plans, we can reduce the impact of Coronal Mass Ejections on our technology and infrastructure.

Coronal.mass ejection. How often does a coronal mass ejection occur. What is a coronal mass ejection quietest. Coronal mass ejection effects on humans. Why do coronal mass ejections occur. Coronal mass ejection effects.