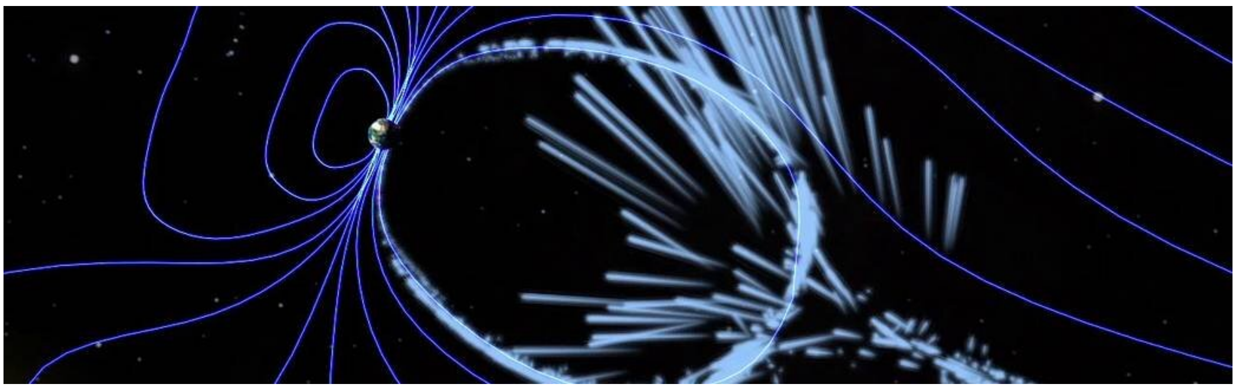
# Three ways to travel at (nearly) the speed of light

May 31 2019, by Mara Johnson-Groh



Credit: NASA

One hundred years ago today, on May 29, 1919, measurements of a solar eclipse offered verification for Einstein's theory of general relativity. Even before that, Einstein had developed the theory of special relativity, which revolutionized the way we understand light. To this day, it provides guidance on understanding how particles move through space—a key area of research to keep spacecraft and astronauts safe from radiation.

The theory of special relativity showed that particles of light, photons, travel through a vacuum at a constant pace of 670,616,629 miles per hour—a speed that's immensely difficult to achieve and impossible to surpass in that environment. Yet all across space, from black holes to our near-Earth environment, particles are, in fact, being accelerated to incredible speeds, some even reaching 99.9% the speed of light.

One of NASA's jobs is to better understand how these particles are accelerated. Studying these superfast, or relativistic, particles can ultimately help protect missions exploring the solar system, traveling to the Moon, and they can teach us more about our galactic neighborhood: A well-aimed near-light-speed particle can trip onboard electronics and too many at once could have negative radiation effects on space-faring astronauts as they travel to the Moon—or beyond.

Here are three ways that acceleration happens.

## 1. Electromagnetic Fields

Most of the processes that accelerate particles to relativistic speeds work with electromagnetic fields—the same force that keeps magnets on your fridge. The two components, electric and magnetic fields, like two sides of the same coin, work together to whisk particles at relativistic speeds throughout the universe.

In essence, electromagnetic fields accelerate charged particles because the particles feel a force in an electromagnetic field that pushes them along, similar to how gravity pulls at objects with mass. In the right conditions, electromagnetic fields can accelerate particles at near-light-speed.

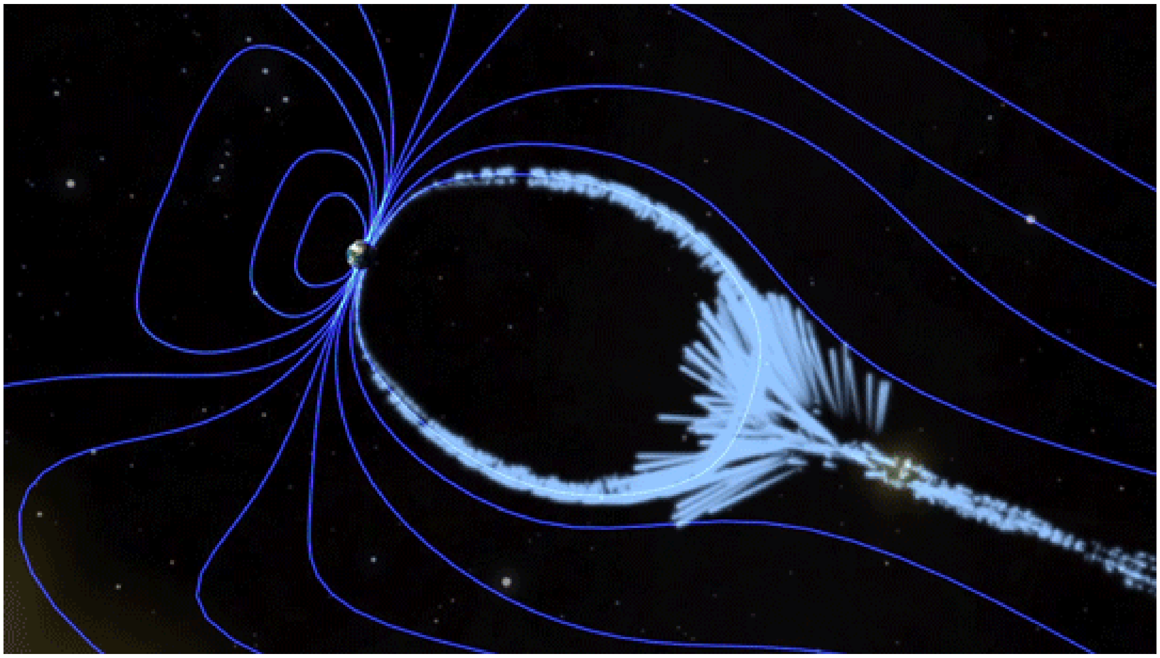
On Earth, electric fields are often specifically harnessed on smaller scales to speed up particles in laboratories. Particle accelerators, like the Large Hadron Collider and Fermilab, use pulsed electromagnetic fields to accelerate charged particles up to 99.99999896% the speed of light. At these speeds, the particles can be smashed together to produce collisions with immense amounts of energy. This allows scientists to look for elementary particles and understand what the universe was like in the very first fractions of a second after the Big Bang.

## 2. Magnetic Explosions

Magnetic fields are everywhere in space, encircling Earth and spanning the solar system. They even guide charged particles moving through space, which spiral around the fields.

When these magnetic fields run into each other, they can become tangled. When the tension between the crossed lines becomes too great, the lines explosively snap and realign in a process known as magnetic reconnection. The rapid change in a region's magnetic field creates electric fields, which causes all the attendant charged particles to be flung away at high speeds. Scientists suspect magnetic reconnection is one way that particles—for example, the solar wind, which is the constant stream of charged particles from the sun—is accelerated to relativistic speeds.

Those speedy particles also create a variety of side-effects near planets. Magnetic reconnection occurs close to us at points where the sun's magnetic field pushes against Earth's magnetosphere—its protective magnetic environment. When magnetic reconnection occurs on the side of Earth facing away from the sun, the particles can be hurled into Earth's upper atmosphere where they spark the auroras. Magnetic reconnection is also thought to be responsible around other planets like Jupiter and Saturn, though in slightly different ways.



Huge, invisible explosions are constantly occurring in the space around Earth. These explosions are the result of twisted magnetic fields that snap and realign, shooting particles across space. Credit: NASA's Goddard Space Flight Center

NASA's Magnetospheric Multiscale spacecraft were designed and built to focus on understanding all aspects of magnetic reconnection. Using four identical spacecraft, the mission flies around Earth to catch magnetic reconnection in action. The results of the analyzed data can help scientists understand particle acceleration at relativistic speeds around Earth and across the universe.

## 3. Wave-Particle Interactions

Particles can be accelerated by interactions with electromagnetic waves, called wave-particle interactions. When electromagnetic waves collide, their fields can become compressed. Charged particles bouncing back and forth between the waves can gain energy similar to a ball bouncing between two merging walls.

These types of interactions are constantly occurring in near-Earth space and are responsible for accelerating particles to speeds that can damage electronics on spacecraft and satellites in space. NASA missions, like the Van Allen Probes, help scientists understand wave-particle interactions.

Wave-particle interactions are also thought to be responsible for accelerating some cosmic rays that originate outside our solar system. After a supernova explosion, a hot, dense shell of compressed gas called a blast wave is ejected away from the stellar core. Filled with magnetic fields and charged particles, wave-particle interactions in these bubbles can launch high-energy cosmic rays at 99.6% the speed of light. Wave-particle interactions may also be partially responsible for accelerating the solar wind and cosmic rays from the sun.

Provided by NASA's Goddard Space Flight Center

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