Van Allen belts and polar auroras

The spectacular phenomenon of polar auroras

The Van Allen belts are responsible for polar auroras, one of the most fascinating phenomena that we can see on the Earth. Polar auroras consist of coloured belts that stretch across the sky giving the impression of seeing the setting of a celestial show.

Photograph of an aurora borealis, or northern lights, in Alaska, about 75 km south of the Arctic Circle. Credits: Dick Hutchinson

Let us understand what the Van Allen belts are, and let us take a look at the history of their discovery, which marks an important point in the space race, which began around the middle of the XX century.

An infinity of charged particles

The Van Allen belts are areas or belts with a large number of high energy particles (plasma) that surround the Earth. They are a true torus of charged particles, as James Van Allen the American physicist who discovered them liked to define them. They consist essentially of protons, electrons and heavier ions (electrically charged atoms), imprisoned in the Earth's magnetic field.

These particles move constantly and at times they hit each other reciprocally, and lose their kinetic energy with a consequent emission of radiation. The particles can reach high energies, over 30 kilo-electron volt (in physics electron volt – symbol eV – is the unit of measure of energy, which is commonly used in the atomic and subatomic field), and therefore can be a risk for spacecraft and equipment orbiting the Earth, but also for human beings on the planet.

The discovery

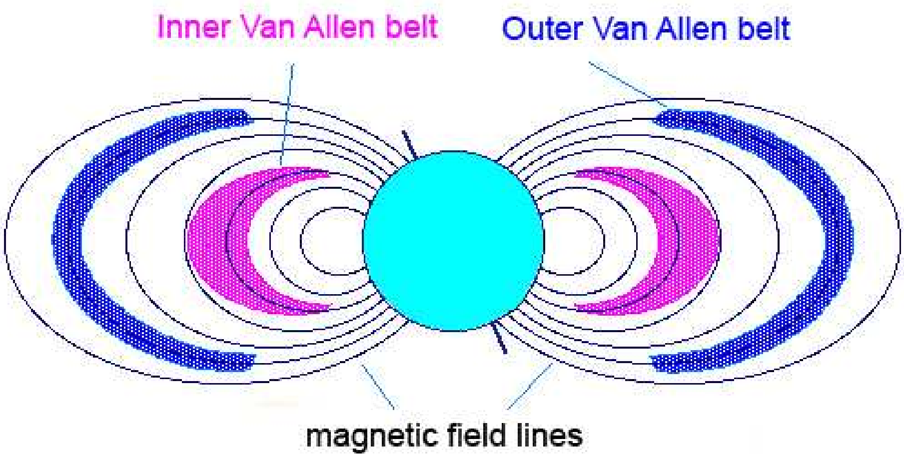
The history of scientific discoveries is studded with cases in which luck played an important role. The serendipic nature of scientific research allowed the discovery of X rays, fundamental cosmic radiation and many other phenomena. The same occurred in case of the Van Allen belts.

During the Cold War, the Americans and Russians also battled in the field of aerospace. At the time, the winners of the conflict were the Russians who sent the Sputnik, the first artificial satellite, into space.

In response the United States began the biggest campaign of space studies which led to the Apollo 11 mission and the first man on the moon in 1969. During those years, in 1958, the American physicist James Van Allen followed the work on the first American satellite, Explorer I, which orbited the Earth. The aim of the satellite was to verify how the flow of cosmic rays varied on Earth and in space.

On the satellite also a Geiger counter (an instrument used to measure ionizing radiations), and an altimeter were installed in order to measure the radiation levels of the atmosphere at different altitudes. The experiment showed that at high altitudes the Geiger counter was unable to detect the particles. Some time later Explorer III was launched, and it led to the discovery that the particles were not recorded because of the presence of an intense area of energetic particles. In this way Van Allen discovered the presence of two distinct areas of the magnetosphere that contained different types of particles.

He understood that these regions were made up of highly energetic particles that were confined by the Earth's magnetic field. A torus of particles subdivided into two separate regions surrounding the Earth, which at times could also meet.



The classic structure of the Van Allen belts, consisting of two particle belts at different distances from the Earth's surface.
Source: www.bo.astro.it

The inner belt, situated at a distance between 700 and 10,000 kilometres, consists essentially of high energy electrons and protons. The outer belt, at a distance between 13,000 and 65,000 kilometres, consists of even higher energy electrons than those of the inner belt.

The nature of the particles of the Van Allen belts

The particles of the belts come from cosmic rays and the solar wind. The former are high speed protons that hit the Earth in all directions, they are present in the entire Galaxy and they transport high energies. When they hit the Earth's atmosphere they give rise to a secondary cluster of cosmic rays that propagates in all directions. Some reach the Earth, while others, with energies ranging between 10 and 100 MeV, are "reflected" into space and at times they remain trapped in the inner Van Allen belt.

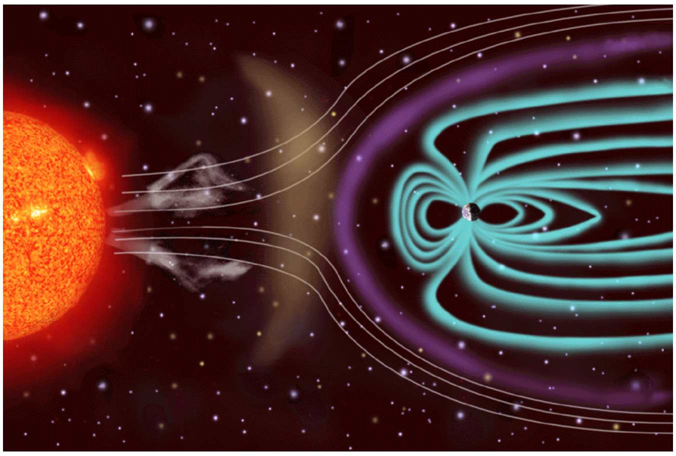


Diagram of the interaction of the solar wind and the Earth's magnetosphere.

Particles that are so heavily loaded with energy can cause significant problems to instruments orbiting around the Earth, and can be very dangerous for astronauts on board the International Space Station (ISS).

The outer belt was studied in greater detail by the following mission, Explorer III and by the space probes Pioneer III and

IV. It was proved that its presence is mainly due to the solar wind, a flow of charged particles from the Sun that strike the Earth's magnetosphere.
Due to the presence of the Earth's magnetic field, the particles coming from the Sun are channelled along the magnetic field lines and are trapped, thus forming the outer belt, with its characteristic elongated banana shape.

The Van Allen belts are dangerous for humans

The presence of particle belts is dangerous mainly for astronauts orbiting the Earth at a height of 400 km. They are subjected to a dose of radiations that is hundreds of times greater than the amount typically absorbed on Earth.
This involves a high risk of tumours, damage to the nervous system and genetic modifications. The annual dose of radiations that a human being can absorb is expressed in REM (Roentgen Equivalent Man) units. For astronauts it is approximately 50 REM. After a period of less than three months on the International Space Station, an astronaut can absorb up to 18 REM, on an intercontinental route an airline pilot can absorb up to 0.004 REM and an X-ray can reach up to 0.01 REM.
Therefore it is easy to understand the need to protect astronauts in space better.

Polar auroras

At times the flow of particles from the Sun is very intense. In this case particles can penetrate up to the lower layers of the atmosphere and interact with the atoms and molecules of the same. The charged particles hit the atoms of the atmosphere and this excites the latter, and when they drop back to a ground state, they emit a light that is visible at various wavelengths, which gives rise, near the poles, to spectacular flashes and clouds of many colours: the polar auroras. When seen from space, the auroras look like two coloured rings positioned above the Earth's magnetic poles.

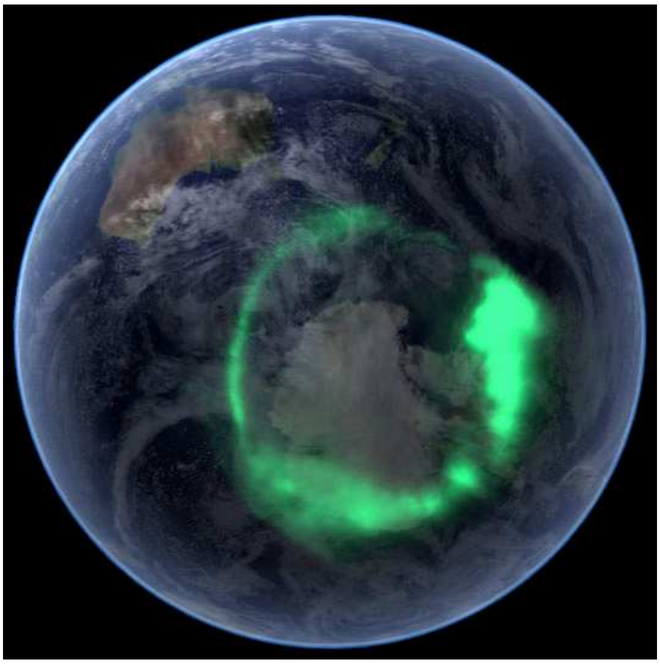


Image of a polar aurora seen from Space.
Credits: NASA

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