Department of Physics
Umeå University

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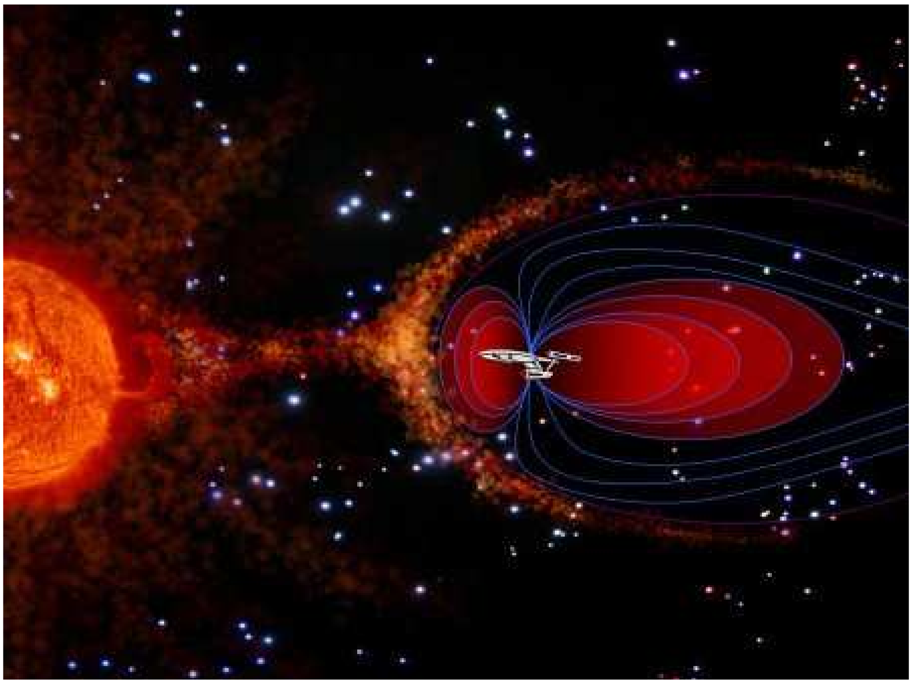
Radiation protection in space

By: Daniel Holmberg



Project in Space Physics 7,5hp

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Introduction

When looking toward the idée to travel long distances in space the problem with cosmic radiation increases. In a low orbit surrounding earth human are relatively protected by the magnetosphere but when leaving earths bounds the particles of space create a very deadly scenario. When the duration and exposure of radiation increases with increased time in space the probability of biological damage also increases. The chance of creating a deadly scenario for long traveling astronauts must be minimized in order to succeed in such endeavors as a mission to mars. In order to protect the astronauts we also must understand the radiation problem. Due to the short nature of this project both alpha and neutron interactions are omitted as well as pair production.

Space radiation

In space; radiation can be defined as energy packages of particles traveling at a very high speed. Radiation can be divided in two parts ionizing and non ionizing radiation. [1]

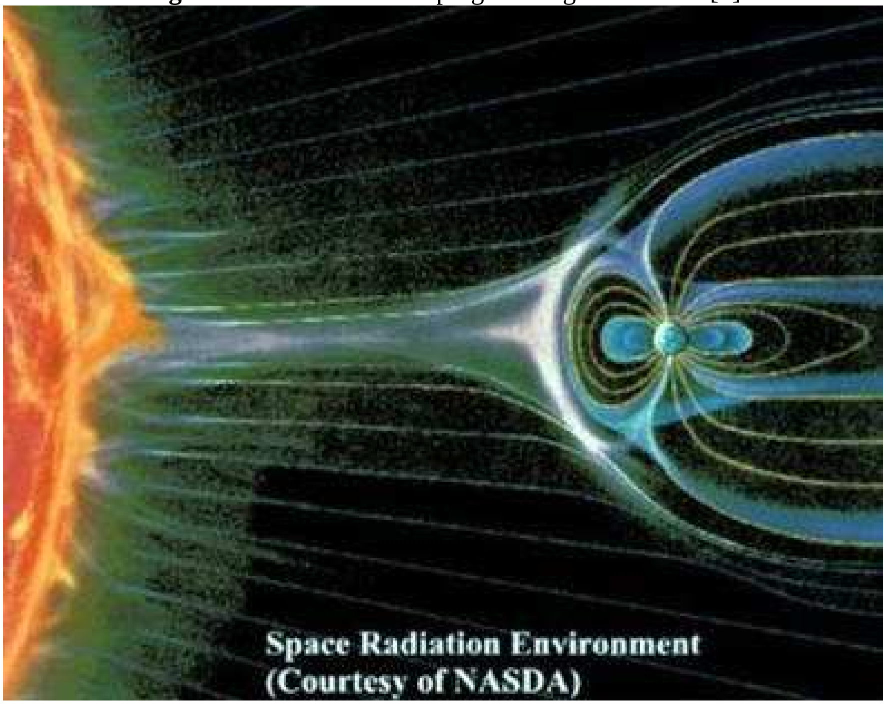
- Ionizing radiation is radiation with sufficient energy to remove electrons from the orbits of atoms resulting in charged particles, and it is this type of radiation that is evaluated for purposes of radiation protection. Examples of ionizing radiation include gamma rays, protons, and neutrons. Ionizing radiation is different from ion formation that occurs in ordinary chemical reactions, such as the generation of table salt from sodium and chlorine. In such a reaction, only the outermost electron is removed to form a positively charged ion. With ionizing radiation, if the energy is sufficient, electrons other than those in the outermost orbits can be released; this process renders the atom very unstable, and these ions are very chemically reactive.
- Non-ionizing radiation is radiation without sufficient energy to remove electrons from their orbits. Examples are microwaves, radio waves, and visible light.

In the subject of radiation protection in space the electromagnetic waves or non-ionizing radiation have little importance so we will focus on the particle radiation. There are three naturally occurring sources of particle radiation in space: trapped radiation, galactic cosmic radiation (GCR), and solar particle events (SPE).[1]

Trapped Radiation [2]

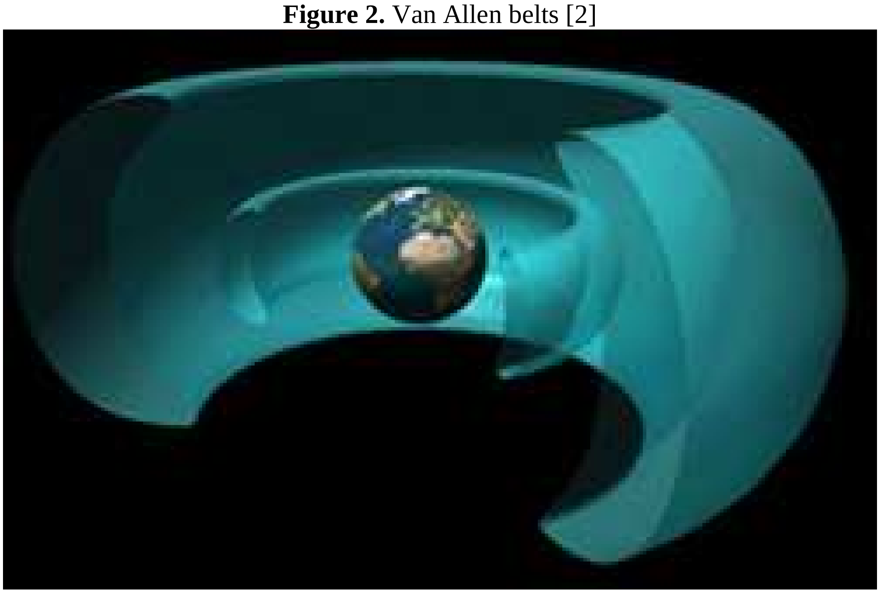
The rotation of earths iron core creates electrical currents inside the planet; these in turn create a magnetic field around earth which is very similar to a dipole field. This field extends several earth radiuses out from the surface of the planet. The most steadily source of ions and charged particles comes from the burst of solar wind created at the surface of the sun. The solar wind contains ions from almost every element in the periodic table; however, it consists primarily of protons and electrons. These particles can not easily penetrate the magneto sheath of earth. The interaction of the particles and the magnetic field forms a shock front around which the particles are deflected. The solar wind compresses and confines the magnetic field on the side toward the Sun and stretches it out into a long tail on the night side *figure 1*.

Figure 1. Solar wind is shaping the magneto sheath. [1]



Some particles manage to enter the magnetosphere and become trapped; these trapped particles are contained in two doughnut-shaped magnetic rings around earth called the Van Allen radiation belts *figure 2*. Inner belt is mainly made up of protons and the outer belt electrons. Now nearly all space missions so far done by humans except Apollo missions to the moon has stayed below the Van Allen belts. The main part of today's spaceflight missions receive there maximum dose from passing through the South Atlantic Anomaly. Due to the tilt in the earth axis the geographic and magnetic poles are not centered in one point. The inner belts lowest point is not at the poles but around 200km over Brazil.

Figure 2. Van Allen belts [2]



Galactic Cosmic Radiation (GCR)

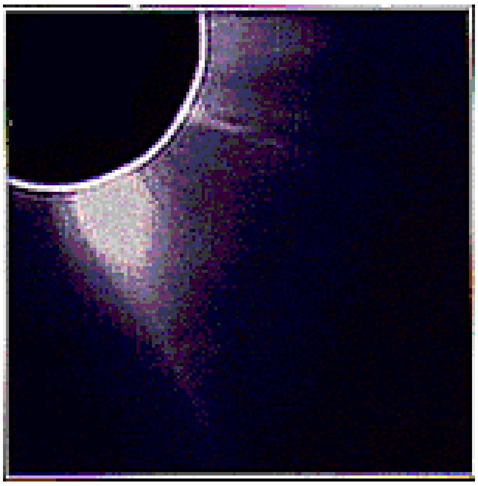
The (GCR) originates from outside our solar system. It consists of ionized particles from the entire element table. The flux of these particles are relatively low compared to (SPE) source, also the direction of the incident radiation is random and not distributed equally over a volume. [2] However, since they travel very close to the speed of light, and because some of them are composed of very heavy elements such as iron, they produce intense ionization as they pass through matter. The long duration of space flight to a destination as mars will likely expose astronauts to a larger dose from (GCR) then today's space flights.

Solar Particle Events (SPE)

Solar particle events are injections of energetic electrons, protons, alpha particles, and heavier particles into interplanetary space. These particles are accelerated to near relativistic speeds by the interplanetary shock waves which precede fast coronal mass ejections and which exist in the vicinity of solar flare sites. The most energetic particles arrive at Earth within tens of minutes of the event on the Sun. [3]

Some of the most dramatic space weather effects occur in association with coronal mass ejections (CMEs) *figure 3*. These are huge bubbles of plasma filled with magnetic field lines that are ejected from the Sun's corona [4]. Near solar maximum, the Sun produces about three CMEs per day, whereas near solar minimum, it produces about one every five days. The faster CMEs have outward speeds considerably greater than that of the normal solar wind, and they produce large shock waves in the solar wind as they plow through it. Some of the solar wind ions are accelerated by the shock wave, and they become a source of intense and long-lasting energetic particle source in space.

Figure 3. Coronal mass ejections [3]



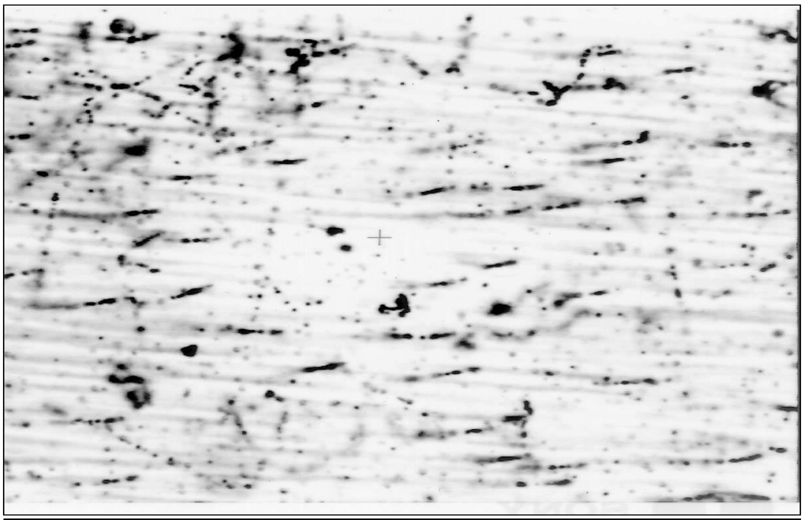
Radiation interaction of charged particles

Here we only look at Beta particles who are charged particles with relatively light mass (electron or positron).There are 2 main interactions that are of importance.

Excitation and Ionization

The interaction between the electric field of a beta particle and the orbital electrons of the absorbing medium leads to inelastic collisions that generate electron excitation and ionization. Because of the continuous spectrum of beta particles, the specific ionization (the number of ion pairs created per cm of air) can be recorded on a special film, the charged interactions when the beta particles ionize the material is shown in *figure 4.*

Figure 4. Ionization tracks for beta particles



Bremsstrahlung

The second important mechanism of reducing energy of beta particles is "bremsstrahlung". When a high-speed charged particle passes through a medium, it occasionally undergoes a substantial nuclear scattering, which results in the emission of continuous electromagnetic energy called bremsstrahlung or "braking radiation"[5]. This energy is in the range of X-rays and becomes more energetic if the stopping material is made of heavy materials such as heavy metals the Z dependence is high. The use of light materials reduces "bremsstrahlung". This is why light materials such as Plexiglas are used to absorb beta radiation. When gamma emission follows beta disintegration, protection against gamma rays is also required. In this situation, we need to stop the beta particles first with low Z material materials and then gamma and bremsstrahlung radiation with high Z material.

Radiation interaction of uncharged particles

Gamma rays are photons [6] (quanta of light) and have no electric charge and no rest mass. Therefore, the interaction of gamma rays with matter is weak compared to the charged particles. But this makes the gamma rays more inert to most shielding material low or high in Z.

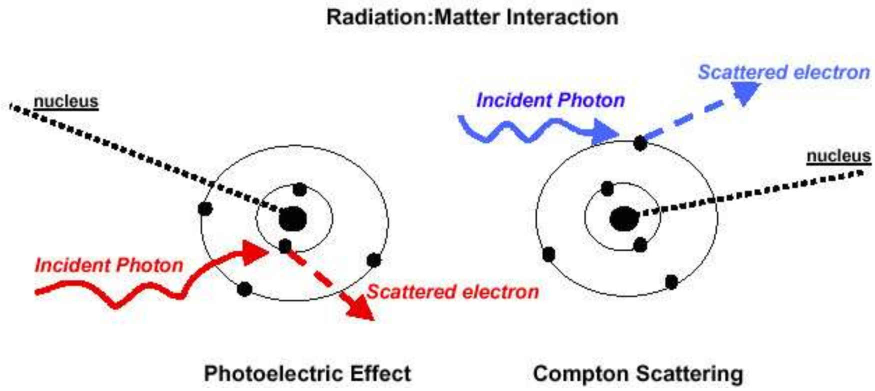
Photoelectric Effect

An electron is emitted from an atom (ionization process) with energy equal to the energy of the gamma ray. The electron then moves through matter and loses its energy as described for beta interactions. This is the predominant effect at low gamma energies.

Compton Scattering

The gamma ray interacts with an electron, causing an increase in the electron's energy. A new gamma ray with a smaller energy is then emitted. The electron interacts as explained earlier. The new gamma ray can escape from the matter or can be absorbed through the photoelectric effect. The Compton effect is the predominant effect at intermediate gamma energies.

Figure 5. Gamma interaction [4]



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Radiation protection solutions

Shielding

By using different shielding material one may lower the effect of (GCR) in some energy ranges, but for some types of radiation this will only increase the secondary radiation. The aluminum walls of the ISS, for example, are believed to have a net beneficial effect. In deep space however it is believed that thin aluminum shielding would have a negative net effect due to the higher energies of the particles. There is currently three main ides at work in NASA.

- Spacecraft can be constructed out of hydrogen-rich plastics, rather than aluminum.
- Material shielding has been considered. Liquid hydrogen, which would be brought along as fuel in any case, tends to give relatively good shielding, while producing relatively low levels of secondary radiation. Therefore, the fuel could be placed so as to act as a form of shielding around the crew. Water, which is necessary to sustain life, could also contribute to shielding.
- Electromagnetic fields may also be a possibility.

Special provisions would also be necessary to protect against an SPE, which could increase fluxes to levels that would kill a crew in hours or days rather than months or years. Potential strategies/ideas include providing a small habitable space behind a spacecraft's water supply or providing an option to abort to the protective environment provided by the Earth's magnetosphere. Most shielding problems will increase the payload of the space crafts and that is one major problem in long duration flight.

Drugs

Another line of research is the development of drugs that mimic and/or enhance the body's natural capacity to repair damage caused by radiation. Some of the drugs that are being considered are retinoids, which are vitamins with antioxidant properties, and molecules that retard cell division, giving the body time to fix damage before harmful mutations can be duplicated.

Timing of missions

Due to the potential negative effects of astronaut exposure to cosmic rays, solar activity may play a role in future space travel. At NASA the space weather has been monitored since the days before the Apollo program[7]. Because galactic cosmic ray fluxes within the solar system are lower during periods of strong solar activity interplanetary travel during solar maximum should minimize the average dose to astronauts.

EM shielding

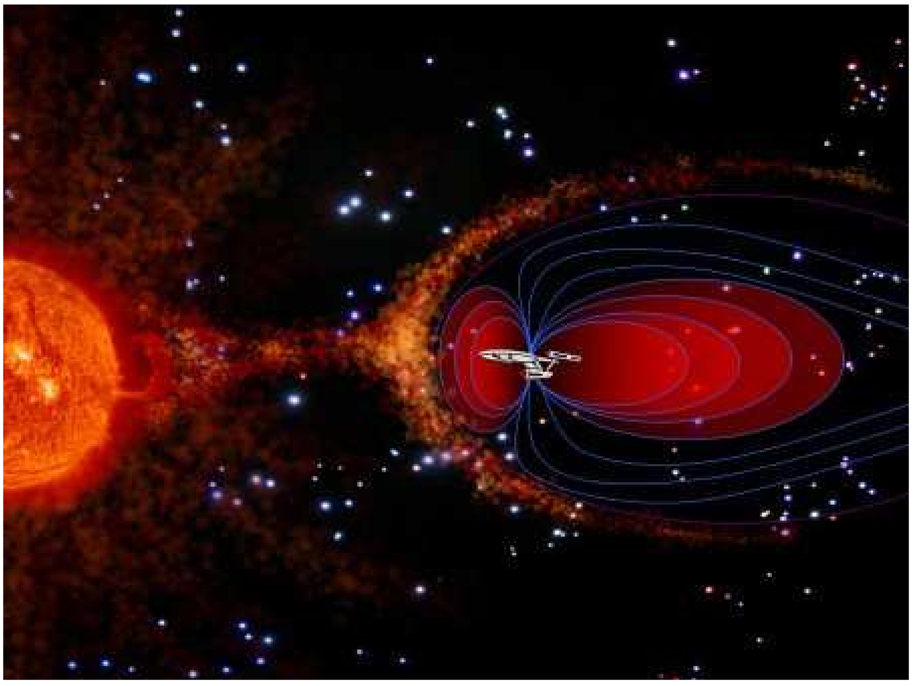
The idea to mimic earths magnetic protection *figure 6* has been in the loop over the last two decades, at NASA the development has created more problems then solutions[8]. Some of the most common errors with this type of solution are:

1 the fields act in opposite directions on positively and negatively charged particles, so shielding that excludes positively charged galactic cosmic rays will tend to attract negative ions.

2 a very large power supply would be required in order to run the electrostatic and magneto static generators, and superconducting materials might have to be used for magnetic coils.

3 the possible field patterns might tend to dump charged particles into one area of the spacecraft.

Figure 6. EM shielding [5]



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Pictures

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