How the Geometry of the Rotation and Revolution of the Earth and Sun Influence the Acceleration of Electrons to Relativistic Energies

Robert L. McPherron Institute of Geophysics and Planetary Physics, University of California Los Angeles

The Earth's magnetosphere is a particle accelerator. Solar wind electrons enter the magnetotail with energies of order 1000 Volts. Within a few days they are observed close to the Earth with energies exceeding one million volts! These electrons penetrate the skin of spacecraft and imbed themselves in insulators such as circuit boards or cables. The accumulation of too many electrons can result in a discharge that destroys an essential electronic component and hence the spacecraft. A surprising fact is that very weak magnetic storms produced by high-speed solar wind streams rotating with the Sun are much more effective accelerators of electrons than strong magnetic storms associated with coronal mass emissions. In fact, three quarters of all high-speed streams hitting the Earth increase the flux or relativistic electrons. Besides spacecraft effects relativistic electrons penetrate deep into the ionosphere producing various oxides of nitrogen. The fate of these oxides is not known but if they are transported lower in the atmosphere they could interact with ozone. Major factors influencing the acceleration of electrons to relativistic energies are the time of year, the time of day, and the polarity of the interplanetary magnetic field (IMF) imbedded in the solar wind. If at equinox the IMF in the high-speed stream satisfies the rule "Spring To and Fall Away', i.e. the direction of the IMF is toward or away from the Sun, then geomagnetic activity is enhanced and electrons are accelerated to high energies. However, most high speed streams create a "snow plow" effect ahead of their arrival that sometimes causes the Earth to pass through the heliospheric current sheet a little ahead of the high-speed stream. This allows four different situations to occur: II, EE, IE, and EI. Here "I" means ineffective (opposite) by the preceding rule and "E" means effective (in agreement), and the order of letters refers to the low-speed stream ahead of the stream interface and to the high-speed after the interface. It is observed that only the case EI results in a decrease in electron fluxes. The explanation for these effects depends on the tilt of the Earth's dipole moment relative to its rotation axis, the tilt of the Earth's rotation axis to the ecliptic pole, and the tilt of the Sun's rotation axis relative to the ecliptic pole. At equinox at about 10 and 22 UT the dipole is nearly orthogonal to the solar wind but tilted ~34° to the ecliptic pole. If the IMF has the orientation given by the preceding rule it will have a component antiparallel to the IMF and magnetic reconnection will occur and cause geomagnetic activity. Because the antiparallel fields persist for days it is possible to generate continuous activity and accelerate electrons.