SIMULATIONS OF THE EARTH'S OUTER RADIATION BELT DURING MAGNETIC STORMS

L. Desorgher, P. Bühler, A. Zehnder (PSI), L. Adams, E. Daly (ESA/ESTEC)

During geomagnetic storms large variations of the trapped relativistic electron fluxes trapped in the earth's outer radiation belt are observed. We numerically simulated these variations by tracing the movement of the trapped particles in a time varying geomagnetic field and compared the results which measurements from the Radiation Environment Monitor, REM from PSI aboard the STRV-1B satellite.

TRAPPED PARTICLES

The movement of the trapped relativistic electrons in the earth's quiet time magnetic field can be described by three cyclic motions, the cyclotron motion around the local magnetic field line, the bounce motion along field lines between magnetic mirror points in the north and south hemisphere, and the drift motion around the earth [1]. The surface defined by the bounce and drift motion of a particle is called its drift shell. Each of the three motions can be associated with an adiabatic invariant. The first adiabatic invariant is the magnetic moment $M=p_\perp/2m_0B$, where $p_\perp$ is the particle's momentum perpendicular to the magnetic field line, m_0 the particles rest mass, and B the magnitude of the magnetic field. The second adiabatic invariant is $J = \oint p_{\parallel} ds$, where the integral is taken along the guiding field line for a complete bounce cycle. The third adiabatic invariant is $\Phi = \oint A dx$ the magnetic flux encompassed by the particle's guiding drift shell (*A* is the magnetic vector potential). The invariants are conserved as long as magnetic field changes are slow compared to the period of the cyclic motion τ_i ($\tau_i B/B \ll 1$). The periods depend on energy and position in space. For a 1 MeV electron at 5 earth radii the period of the cyclotron motion is $\tau_c \approx 10^{-3}$ sec, for the bounce motion $\tau_b \approx 10^{-1}$ sec, and for the drift motion $\tau_d \approx 15$ min. Its is therefore the third invariant which risks first to be violated during magnetically active times. During typical magnetic storms (see previous report in this volume) the magnetic field variations take place over hours thus the assumption of a slow magnetic field variation, and therefore conservation of all three adiabatic invariant, is justified in first approximation. Conservation of the first invariant during magnetic field depression results in a lowering of the particle's moments and therefore a deceleration of the particles. Conservation of the third invariant causes the particle's drift shells to expand (the decreasing magnetic field under the integral in the formula for ϕ is compensated by a stretching of the integration path). Thus during the main phase of a magnetic storm the particles are expected to loose energy, which leads in a detector like REM with a fixed lower energy threshold to a decreasing count rate, and to drift outwards (during the storm recovery phase the inverse process takes place).

SIMULATIONS

The amount of deceleration and drift of a single particle depends on the initial energy and position and on the spatial distribution of the magnetic field. Thus a realistic simulation of the effect must take the initial particle distribution in energy and space, but also a realistic time and spatial dependent magnetic field into account. The figure shows the result of such a simulation for the March 95 storm main phase. Initial conditions were taken from REM measurement and for the magnetic field variations we used one of the available models [2] which takes Dst and solar wind parameters as input. The results were obtained by solving the equations of motion in the guiding centre approximation, which assumes the first adiabatic invariant to be constant.

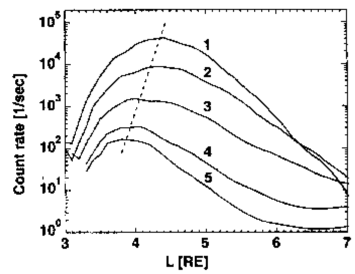

Fig. 1: Simulated count rates in the REM detector versus distance from earth during the main phase of the March 95 magnetic storm. The different radial profiles (1-5) correspond in time with the points 1-5 marked in the figure of the previous report in this volume.

The results of the simulation qualitatively compare very well with the observations. The decrease of the count rate during the storm main phase is of the same order of magnitude and, in a first view surprising, the inward drift of the peak of the radial distribution is also reproduced. Although the single particles drift outwards, the fact that deceleration and radial motion is stronger at larger distances from earth make that the peak of the radial count rate distribution moves inward. If the ring current effect was the only process acting on the trapped electrons, the radiation belt would recover to its initial distribution after the storm. This is clearly not the case, which suggest, especially during the recovery phase, additional losses, acceleration, and injection processes to act.

REFERENCES

[1] J.G. Roederer, Dynamics of Geomagnetically Trapped Radiation, Springer-Verlag (1970).

[2] N.A. Tsyganenko, Planet. Space. Sci., **37** (1989).