

Anisotropic proton fluxes in the SAA

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During two years a Radiation Environment Monitor, REM [1] from PSI was mounted outside the Russian space station Mir and measured the charged particle fluxes of the environment. An outstanding result of this campaign was the measurement of the east-west effect of the protons in the South Atlantic Anomaly, SAA and its energy dependence.

The motion of a stably trapped particle in the earth's magnetosphere can be approximately described by its gyration around the local magnetic field line (the center of gyration is denoted as guiding center), its bounce motion along field lines between conjugate mirror points in the northern and southern hemisphere, and its drift around the earth. Its trajectory forms a shell which can be labeled by the so-called L-shell parameter, L , which in a dipole field approximation measures the distance between the center of the earth and the points where the shell crosses the magnetic equator.

At a given point D in space (see figure 1), the guiding centers $GC1$, $GC2$ of particles arriving from different directions have different locations. If the difference in guiding center position is large compared with the spatial flux gradient scale length then the observed flux distribution can be expected to be anisotropic [2].

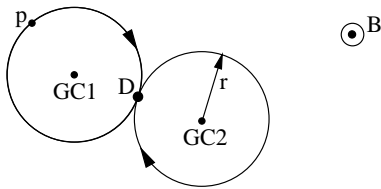


Figure 1: The difference in guiding center position $GC1$, $GC2$ of particles arriving from different directions at a given point D in space can cause anisotropic flux distributions.

The gyro-radius depends on the particle's mass, m and energy, E and on the magnetic field strength, B with $r_{gyro} = p/(q \cdot B)$.

Since the effect scales with the gyro-radius, the anisotropy is best observed with high momentum particles at low magnetic fields. Mir encounters the minimum field strength of approximately 0.2 Gauss in the SAA. There the gyro-radius of 1 MeV electrons and 100 MeV protons (typical energies of particles detected by REM) are of the order of 100 m and 100 km, respectively. The SAA is also the place where the proton fluxes are high and the spatial flux gradients large - thus ideal for observing the anisotropy.

In order to extract the proton flux anisotropy in the Mir-REM data we binned the measurements in the SAA according to L , B , and pointing direction of the detector, and averaged the data in each bin over the entire Mir-REM lifetime.

In the upper panel of figure 2 the proton fluxes from east and west are compared for a number of B - L -bins. It shows the measured 100 MeV proton fluxes as function of L . The B -values correspond to the minimum values encountered by Mir at a given L . The fluxes from west are higher than those from east. The ratio is a function of L , is around 4 at $L=1.1$

earth radii and vanishes above $L \approx 1.7$ earth radii.

A similar behavior is found for the spectral hardness, as shown in the lower panel of figure 2, where the spectral indices γ (the proton spectra, $f_p(E)$ are fitted by a power law $f_p(E) = A_p \cdot (E/E_0)^\gamma$) are plotted versus L . The energy spectra of the protons coming from west are harder than those of the particles from east, and as for the fluxes, the difference vanishes above $L \approx 1.7$ earth radii.

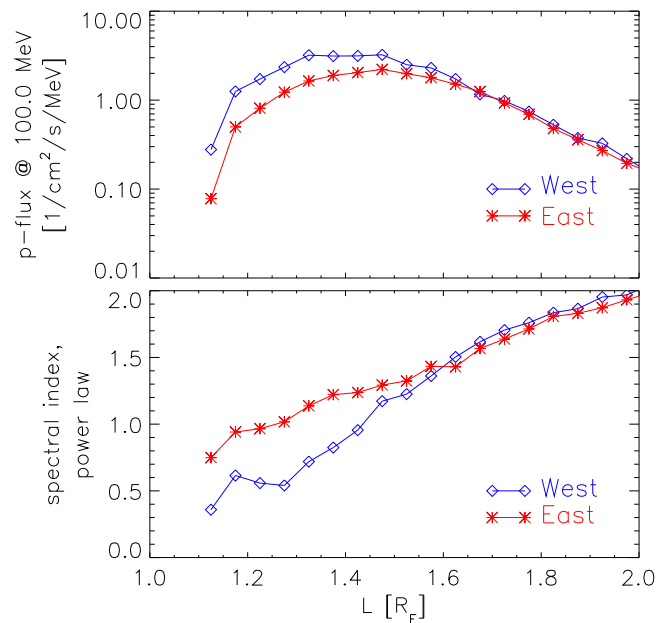


Figure 2: Comparison of proton fluxes from east and west in the SAA. The upper panel show the 100 MeV proton fluxes and the lower panels the spectral power law indices as function of L .

The flux gradients in the SAA are mainly caused by the interaction of the protons with ambient atmospheric particles. The deeper an L -shell dips at the mirror points into the atmosphere the more the particles are absorbed. The fact that the high energy protons arriving from east at a given point in the SAA are members of L -shells dipping on average deepest into the atmosphere explains why the east fluxes are low and their spectra soft.

REFERENCES

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- [2] M. Kruglanski et al., Proton anisotropy, *TREND-3 final report* **chapter 3**, BIRA-IASB, Belgium, 1998