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# Plasma Events in the South Atlantic Anomaly: Correlations with the Interplanetary Magnetic Field Reconnection Processes

Adelson de Brito[a] and Premkumar B. Saganti[b]
*(a) Universidad Privada San Pedro,Chimbote, Peru( Office in Japan),432-8021 6-18-5 Sanarudai Hamamatsu, Shizuoka, Japan*
*(b) Department of Physics and NASA-CARR, Prairie View A&M University, Pairie View, TX- 77446, USA*
Presenter: A. de Brito (abrito@physnotes.net), jap-debrito-AS-abs1-sh35-oral

The South Atlantic Anomaly (SAA) bounds a region in the Earth's magnetosphere in which both protons and electrons are trapped at much lower altitude and this SAA region behaves as an "open bubble/well shaped dent" in the magnetosphere. In this paper, we present an approach to understand the correlations between high radiation indices in the SAA and the Interplanetary Magnetic Field (IMF) reconnection processes.

## 1. Introduction

### The South Atlantic Anomaly (SAA)

The Earth's magnetosphere protects us from the constant bombardment solar particle events (SPE) and galactic cosmic rays (GCR). It is estimated that the Sun is blowing several radiation particles, in many directions, around one billion kilograms of electrons, protons and other forms of dense matter per second. The Earth's magnetosphere is almost a spherical shaped magnetic field that surrounds the planet except in a region known as the South Atlantic Anomaly (SAA). The SAA is located over the South Atlantic Ocean, off the coast of Brazil and covers a region from – 90º through + 40º geographical longitude and - 50º and 0º geographical latitude in an average altitude of 500 km, permitting the influence of the lower van Allen belt to impart high energetic protons and electrons in to the SAA region.

The presences of energetic protons above the 50 MeV level shows a 1000 times increase when compared to other regions exterior to the SAA. The SAA region is an important feature due to its highly unusual concentration of plasma and consequent high indices of radiation that transforms the region of concern for radio wave communications and harmful for spacecrafts as well as human exploration including the crew on the Space Shuttle and the International Space Station (ISS)

The region of the space between the bow shock of the Earth and the magnetopause is referred to as the magneto sheath. Considering a Sun-Earth cross section we would perceive that during the moments that precedes the 'shock' the solar wind is Supersonic 400 km/s to 'slow down' in the after the shock development.

The downstream inner to the bulk of its vicinity is essentially subsonic and the plasma becomes thermalized. The Earth's magnetosphere is the portion of the space that bounds the interaction between the solar wind and the Earth's dipole-like magnetic field and its extension varies roughly from 100 km above the Earth's surface to about several Earth radii (~ 63,800 km).

## 2. Discussion

The interaction of the supersonic solar wind with the geomagnetic field will shape a kind of 'belt' that will hold at the sunward side the actual bulk interaction that takes place. At this region as a consequence of the interaction the solar wind will absorb energy and thus will become 'thermalized' at the time it assumes subsonic velocities. The 'belt' is actually the 'bow shock'. In the inner side of the 'bow shock' a collision less zone results created. The flow that crosses the 'bow shock' proceeds in its path around the magnetosphere as magneto sheath plasma towards rejoining the undisturbed solar wind somewhere outwards the end tip of the so-called 'magneto tail'. In the anti-solar direction, show that the magnetosphere is stretched in the shape of a geomagnetic tail very similar to a comet's tail.

One of the further consequences of this solar wind – magnetosphere interaction is the creation of a plasma environment at the earthward side of the magnetopause. Characteristic values of particle concentration range between 0.001 and 1.00 $cm^{-3}$ and flow velocities into the range of 100 km/s in that part of the region. The *Neutral Sheet* is the region where the most inner core of the magnetosphere is located. One of the theoretical approach remounts to the *Chapman and Ferraro* Cavity Theory (1930-31) that claims "the existence of a current sheet (in the magneto sheet) playing the role of a separation between the Earth Magnetosphere and the solar wind plasma. The "Open Magnetosphere" Models have in *Dungey* (1961) one of its pioneers when he proposed a model based on a "reconnection process" that takes place at the front (dayside) of the Magnetosphere to produce field lines with one end at the Earth and the other in distant space.

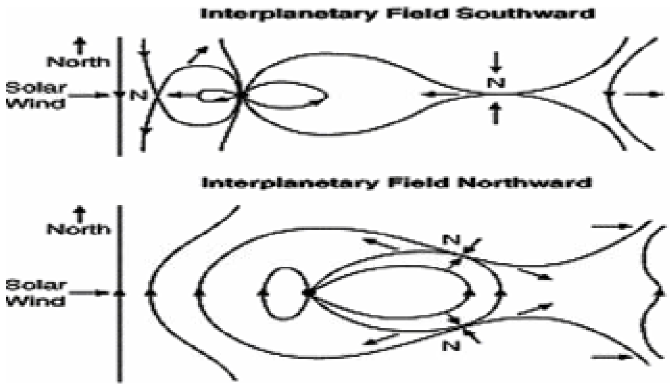


**Figure-1:** Schematic model of the interplanetary fields taken from Dugney, 1961

We consider the phenomenological approach for this study and assume the plasma content as a three dimensional region comprised into the SAA. We consider the highly unusual radiation indices due to high concentration of particles that result deposited in the site as a consequence of the magnetic reconnections of the IMF that will take place in this site. The coupling-decoupling process under which the IMF evolves and carries out the task of transporting mass, momentum and energy to the very corners of our universe will remain an unknown variable.

## 3. Proposition

In our current approach, a rationalistic explanation for the unusually large particle flux present in regions characterized by low indices of magnetic activity and in particular of "neutral sheet" is assumed to be closely associated with the magnetic reconnection process. The resultant plasma thermal pressure forms a stationary equilibrium with the opposing magnetic fields [*Yamada et al*., 1997, 1999]. This team also performed a Magnetic Reconnection Experiment (MRX) in 1995 for developing a comprehensive study of magnetic reconnection in a controlled environment.

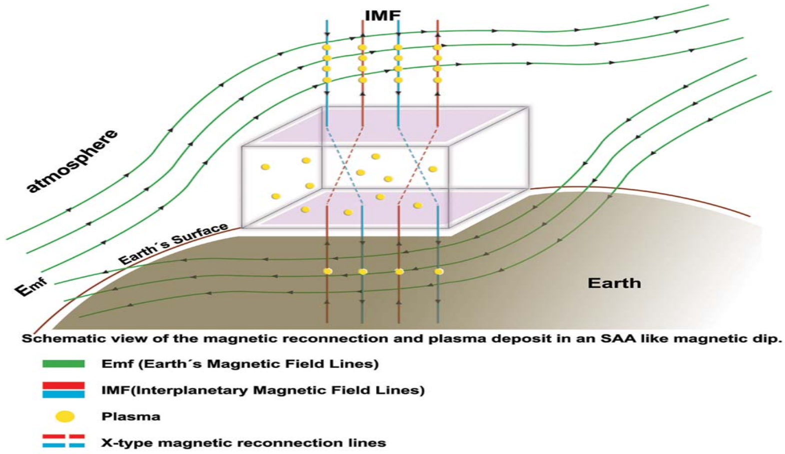


**Figure-2:** Illustration of plasma events in the SAA magnetic dip

Badhwar et al showed the variation of the particle flux of the trapped elemental composition over time in the SAA through their Space Shuttle based radiation measurements and expressed as dose-rates. They also observed the geomagnetic field leads to *drift*. The dose rates measured on two manned spacecrafts, Skylab (50 degrees inclination @ 438 km orbit) and Mir orbital station (51.65 degrees inclination @ 400 km orbit), were used to determine the drift rate of the SAA. The longitude and latitude drift rates between 1973 and 1995, were estimated to be 0.28 ± 0.03 degrees W per year, and 0.08 ± 0.03 degrees N per year, respectively. In Figure-3, dose-rate (µSv/hr) through the SAA as measured from the Space Shuttle is shown prior to an SPE and the enhanced dose-rate (µSv/hr) during an SPE in April 2001. Data is taken from the National Space Development Agency of Japan (NASDA), *Quick report of BBND data analysis.*

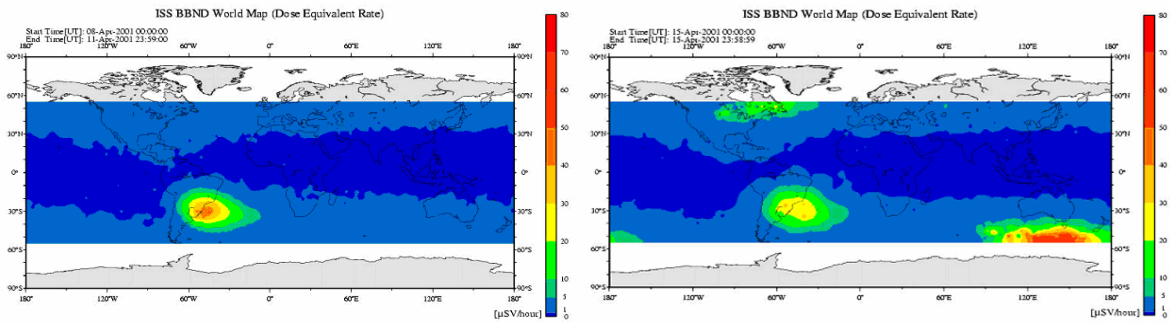


**Figure-3(A):** Dose equivalent (µSv/hr) rate measured during quiet solar conditions, April 8-11, 2001(left)
**Figure-3(B):** Dose equivalent (µSv/hr) rate measured during a solar flare on April 15, 2001(right)

## 4. Conclusion

This work indicates the possibility of relationship between the SAA and the IMF. In our preliminary approach, we have shown the possibility for such a phenomenon to be explored and studied with future measurements and developments of theoretical approaches in particular of the SAA drift. Understanding the nature of the SAA variations during an SPE is a concern for human explorations in the Low Earth Orbit and these studies will provide the opportunities for such studies.

## 5. Acknowledgments

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