A NEW PERSPECTIVE ON TRAPPED RADIATION BELTS IN PLANETARY ATMOSPHERES. A. Diaz[1], M. A .K. Lodhi[1], and T. L. Wilson[2], [1]Texas Tech University, Lubbock, Texas 79409 USA. [2]NASA, Johnson Space Center, Houston, Texas 77058 USA.

Introduction: The charged particle fluxes trapped in the magnetic dipole fields of certain planets in our Solar System are interesting signatures of planetary properties in space physics. They also represent a source of potentially hazardous radiation to spacecraft during planetary and interplanetary exploration. The Earth's trapped radiation belts have been studied for years [1,2] and the physical mechanisms by which primary radiation from the Sun and Galaxy is captured is well understood. The higher-energy particles [3, 4] (Figure 1) collide with molecules in the planetary atmosphere and initiate large cascades of secondary radiation which itself becomes trapped by the magnetic dipole field of the planet. Some of it is even backscattered as albedo neutrons [1,5].

The spectrum or flux of cosmic rays (CRs) in Figure 1 is a function of energy E, *in vacuo* or in the Galaxy. Based upon recent work [6], we will show that in the presence of a planetary atmosphere, the spectrum is actually bi-variant in energy E and atmospheric density ρ. As a paradigm shift, this new point of view helps clear up some of the historical difficulties associated with understanding trapped radiation belts.

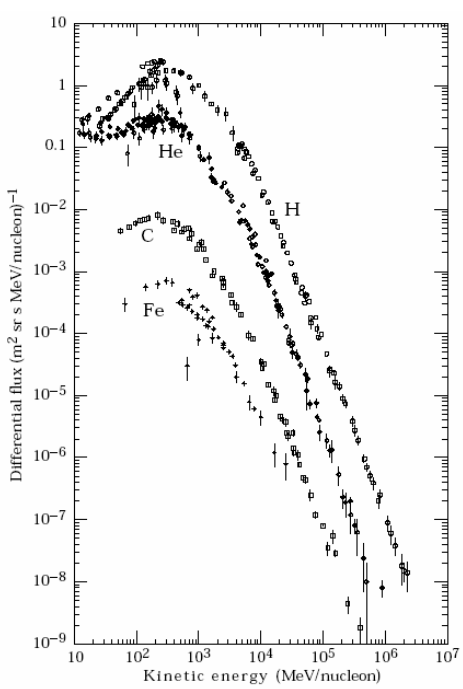

Figure 1. Galactic cosmic-ray spectrum.

General discussion: In an effort to create a simplified solar modulation model of inner trapped radiation belts for the Earth, a regression algortihm technique used in nuclear physics was applied to the proton belt model known as AP8 [6]. The motivation was to determine a formulation of trapped proton flux at random epochs, in particular between solar maximum and minimum since AP8 only applied *at* maximum or minimum.

A key factor was the realization [7-10] that the properties of the upper atmosphere of the Earth are strongly coupled to solar activity, in particular atmospheric density ρ and temperature. Throughout the course of the solar cycle, the Earth's atmospheric neutrals expand and contract the thermosphere in response to the behavior of the Sun. Clearly, density ρ in the concept of a dynamic atmosphere couples to the charged-belt species as these undergo multiple scattering off the neutrals. That in turn reduces their lifetime in the belts. Therefore, it became necessary to understand how atmospheric density *per se* coupled to charged-belt population levels as a function of solar activity. This was the simplified goal of that study [6].

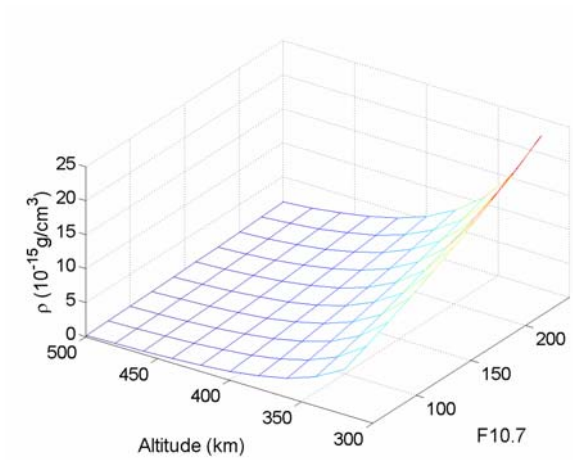

Figure 2. Three-dimensional plot of the variance between density ρ and $F_{10.7}$ for Earth at altitude h.

Simple parametrization of density ρ shows it is a multi-variant function of altitude h and solar activity $F_{10.7}$, shown in Figure 2. The parameter $F_{10.7}$ is the

solar radio flux at 10.7 cm, commonly used to simulate the magnitude of a given solar cycle. $F_{10.7}$ = 110 here for reasons given in [6]. Sometimes referred to as carpets plots, another version is shown in Figure 3.

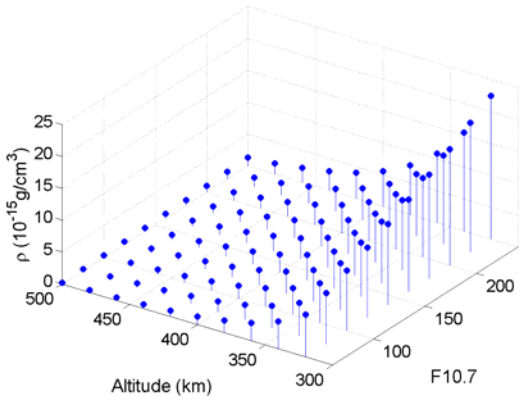

Figure 3. Another illustration of Figure 2.

The AP8 proton flux J is known to be a multi-variant function of h and energy E. However, h is not a definitive parameter as a property of the atmosphere. Directly from the interdependence in Figures 2 and 3, a power-law approximation to AP8 for flux J shows it is bivariant in energy E and density ρ. The resulting relation is $J(E,\rho)\sim\sum A(E^n)\rho^{-n}$, with A itself a power law in E [6].

This is shown in Figure 4 for six altitudes (350, 400, 450, 500, 550, and 600 km), where the solid lines are the regression algorithm and the dashed lines (red) are AP8. The method can be applied to any sophisticated trapped belt model besides AP8, adopted here only for its common useage and utility.

Conclusions: Comparison of the bi-variant flux J in Figure 4 with the flux in Figure 1 (where $\rho=0$) definitely shows how the presence of an atmospheric background or medium of neutrals at density ρ is a three-dimensional surface. Only in the limit as $\rho\rightarrow 0$ does the flux become a mono-variant function of energy E as is usually assumed for flux spectra. For $\rho\rightarrow 0$, Figure 4 is still a trapped flux (not a GCR flux) but the effect of ρ is manifest.

References: [1] W.N. Hess (1968), *The Radiation Belt and Megnetosphere* (Blaisdell, London). [2] B. Rossi and S. Olbert (1970), *Introduction to the Physics of Space* (McGraw-Hill, NY). [3] Simpson J. A. (1983) *Ann. Rev. Nucl. Part. Phys. 33*, 323. [4] Eidelman, S. et al. (2004), *Phys. Lett. B592*, 1. [5] Battiston R. (2002) *Intl. J. Mod. Phys., A17*, 1589. [6] Lodhi, M.A.K. et al. (2005), *Radiation Measurements*, in press. [7] Jacchia L. G. (1960) *JGR, 65*, 2775. [8] Jacchia L. G. (1962) *Nature, 192*, 1147. [9] Harris I. and Priester W. (1962) *JGR, 68*, 4585.

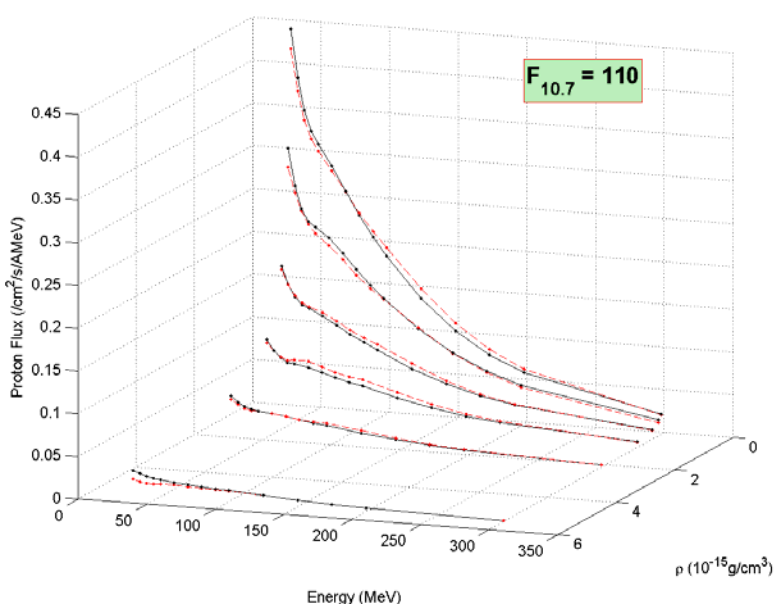

Figure 4. Bi-variant proton flux for a planetary atmosphere (Earth).