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FINAL REPORT

for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

# ANALYSIS OF ENERGETIC PROTON AND ELECTRON DATA IN NEPTUNE'S MAGNETOSPHERE

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submitted by

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# Final Report for Grant NAGW-2402

"Analysis of Energetic Proton and Electron Data in Neptune's Magnetosphere"

This grant was for the analysis and interpretation of data obtained by the cosmic ray system (CRS) on Voyager 2 in the magnetosphere of Neptune. The research goals included the following: characterize the distribution and intensity of trapped electrons and protons; relate them to theoretical models of particle transport; study the particle absorption signatures of Neptune's moons and rings; develop planetary magnetic field models based on the particle data; and study Neptune's cosmic ray cutoff. Significant progress was made in each of these areas.

The trapped electrons were described through the use of a model based on radial diffusion and satellite absorption. By parameterizing the model and fitting it to the electron counting rate data, we obtained good estimates of the radial diffusion coefficient as well as the electron phase space densities through most of the high intensity regions. These results also illustrated the strong role of the moons in controlling the intensity of the outer planet radiation belts. They have been described in a journal article [1] and letter [2]. In addition to the radial diffusion models, we have begun to study the role of pitch-angle diffusion and flux limiting by whistler mode waves. These effects appear to be significant at the lower electron energies, and we have described preliminary results at an AGU conference.

Similar studies of the trapped protons proved to be considerably more difficult due to the low intensities encountered and the large proton gyro-radii in the planetary magnetic field. It was necessary to develop new methods for converting the proton data to the physically meaningful gyro-center coordinates, and for calculating the absorption effects of the moons. The results showed that the protons are even more strongly depleted by Neptune's moon Proteus than are the electrons, and that the radial diffusion coefficients for protons and electrons are each consistent with expectations based on the model of thermospheric wind-driven diffusion. This work was carried out under our supervision by a graduate student, Mark Looper, and led to his PhD thesis [3]. Two conference presentations were given and a manuscript for a journal article is in preparation.

In order to understand the complex role of the Neptune's moons and rings in controlling the structure of the radiation belts, which we outlined in a conference article [4], a general study of satellite signature formation was initiated. It led to a description of the transient microsignature and steady-state macrosignature formation. The results were applied to the Proteus signatures at Neptune (described in [1] and at an AGU conference). They were also applied to to the Mimas signatures at Saturn and published in a conference article [5]. They led to a more quantitative determination of the relationship between signature formation and filling-in by diffusion than was previously available.

A related topic was the development of planetary magnetic field models. Due to the limitations of the Voyager trajectory, the model derived from the Voyager magnetometer was not detailed enough to accurately predict the locations of the satellite absorption signatures. By adjusting the model to predict locations that agree with our interpretations of the various particle signatures, we derived a field model that is consistent with both the field and particle data. However, due to the limited number of signatures the model is still not unique. These results were published in a journal article [6].

The close approach of Voyager 2 over the north pole of Neptune provided a unique opportunity to study the cosmic ray cutoff in a non-terrestrial planetary magnetic field. From the depth and shape of a decrease in the counting rate of galactic cosmic ray protons, we were able to infer the fraction of excluded trajectories along the Voyager trajectory. This led to constraints on the magnetic field geometry close to the planet where the field models are highly uncertain. It also led to the interpretation of a deep signature in the trapped electrons as resulting from a drift shadow of the planet. These results were described in a journal letter [7].

Publications:

[1] R. S. Selesnick and E. C. Stone, The electron absorption signature of 1989N1, *J. Geophys. Res.*, *96*, 19137-19147, 1991.

[2] R. S. Selesnick and E. C. Stone, Radial diffusion of relativistic electrons in Neptune's magnetosphere, Submitted to *Geophys. Res. Lett.*, 1994.

[3] M. D. Looper, Energetic protons in the magnetosphere of Neptune, Ph.D. thesis, California Institute of Technology, 1993.

[4] R. S. Selesnick and E. C. Stone, Energetic particle signatures of satellites and rings in Neptune's magnetosphere, *Adv. Space. Res*, *12*, (11)71-79, 1992.

[5] R. S. Selesnick, Micro- and macro-signatures of energetic charged particles in planetary magnetospheres, *Adv. Space. Res*, *13*, (10)221-230, 1993.

[6] R. S. Selesnick, Magnetic field models from energetic particle data at Neptune, *J. Geophys. Res.*, *97*, 10857-10863, 1992.

[7] R. S. Selesnick and E. C. Stone, Neptune's cosmic ray cutoff, *Geophys. Res. Lett.*, *18*, 361-364, 1991.