The Ice Giant Radiation Belts. I. J. Cohen[1], B. H. Mauk[1], P. Kollmann[1], G. B. Clark[1], M. Gkioulidou[1], A. Y. Ukhorskiy[1], R. L. McNutt, Jr.[1], H. T. Smith[1], A. M. Rymer[1], P. C. Brandt[1], D. L. Turner[1], [1]The Johns Hopkins University Applied Physics Laboratory (11100 Johns Hopkins Road, MS 200-E254, Laurel, MD 20723; Ian.Cohen@jhuapl.edu)

Introduction: Planetary radiation belts are regions of space in planetary magnetospheres where high-energy (including relativistic) charged particles are quasi-trapped in predominantly dipolar magnetic fields. As net products of processes acting on the ions and electrons throughout the magnetosphere, study of radiation belt composition, energy content and spatial profiles can relate certain processes back to the global distribution of gas and dust as well as wave-particle interactions. Radiation belts have been observed at Earth and all of the Giant planets (*Fig. 1*), allowing for comparative studies into the processes that source, sculpt, and govern these significant regions of planetary magnetospheres. Radiation belts can also have significant effects within planetary systems, including weathering of satellite surfaces, potentially darkening them significantly, and charging dust particles within rings, which may contribute to ring dynamics.

Mysteries at the Ice Giants: The radiation belts of the Ice Giants, Uranus and Neptune, present unique data points in particular. Uranus' radiation belts are especially interesting as *Voyager 2* observations [1] did not confirm our expectations. Our current understanding dictates that in order for the particles to accumulate to high intensities at such high energies, the radiation belts need to quickly draw from a large reservoir of lower energy plasma and/or lose the accelerated particles very slowly. However, neither appeared to be the case at Uranus, which possesses a vacuum magnetosphere [2] (i.e. lacks a source of low energy plasma) and where the most intense whistler-mode chorus waves observed by *Voyager 2* were observed [3] (such waves would provide efficient acceleration but also potentially significant particle losses [4]). Thus, it remains a mystery how Uranus' electron radiation belts can be as significant in intensity at 1 MeV energy as those of Earth and Jupiter [5].

Furthermore, since radiation belt ions and electrons share several physical processes, it is also puzzling why Uranus' electron radiation belts appear surprisingly intense (e.g., compared to those of Saturn & Neptune [5]) whereas its ion belts show low intensities [6] (*Fig. 2*). Uranus may behave so unexpectedly because its unique magnetospheric configuration results in the dominance of processes that have been observed to play lesser roles at other planets. Likewise, it remains unclear how Neptune's uniquely dynamic magnetosphere, which may globally reconfigure on a diurnal timescale of only hours, affects the lifetime and variability of its radiation belts.

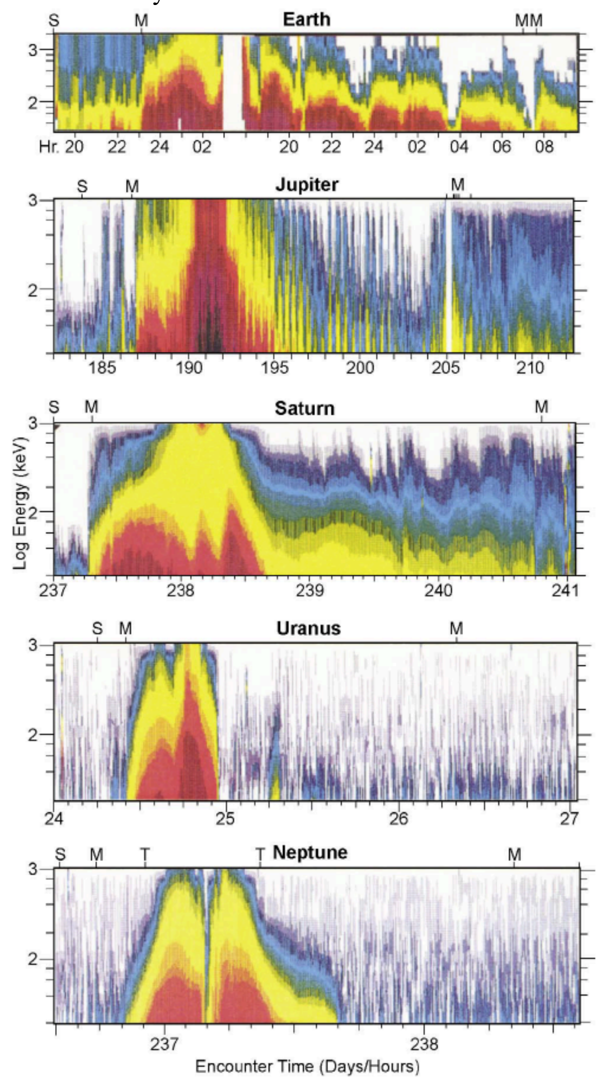

Figure 1. Spectrograms (from [5]) of energetic electron intensities (color scale) versus energy (vertical scale) and time (horizontal scale). The Earth data were obtained by the International Sun Earth Explorer (ISEE) mission, and the other data were obtained by the Voyager encounters of the various outer planet magnetospheres. The time scales encompass both inbound and outbound magnetopauses ("M" character above each plot). Energy spans roughly 20 keV to ~1 MeV. The intensity scale is fixed for all of the panels to allow for comparison between intensities at the different planets.

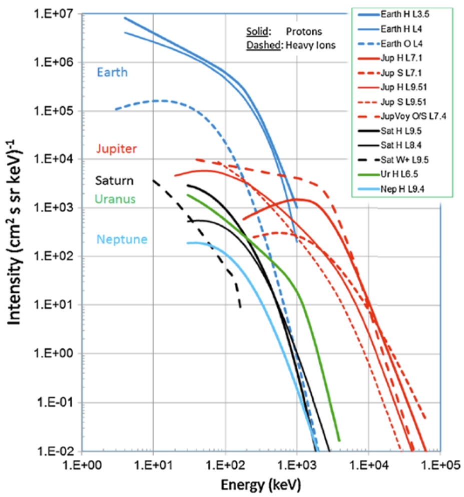

Figure 2. Energetic ion spectra sampled within the ring current regions of the five strongly magnetized planets of the solar system with best fits (from [6]). The spectra are the most intense observed within these systems specifically at 100 keV and 1 MeV, or both. Solid line spectra are protons, and dashed line spectra are heavy ions (O, S, or Water Group [W^+]).

New Insights From Earth and Jupiter: Fortunately, observations obtained over the last decade from the *Van Allen Probes* mission [7] at Earth and the *Juno* mission at Jupiter [8] have provided new understanding of radiation belt processes that may provide some insight and answers for addressing the mysteries of the Ice Giants' radiation belts.

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