Investigating unusual inbound/outbound asymmetries in energetic particles in the Voyager 2 observations of Uranus' magnetosphere. I. J. Cohen[1], G. B. Clark[1], P. Kollmann[1], and D. L. Turner[1], 1The 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 to fundamental space physics processes like wave-particle interactions. Radiation belts have been observed at Earth and all of the Giant planets, 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 of Uranus' Radiation Belts: The radiation belts of Uranus, in particular, present unique outlying data points when compared to the other Giant Planets (*Fig. 1*) [1, 2]. Current understanding of planetary magnetospheres dictates that in order for particles to accumulate to high intensities at MeV energies, the radiation belts need to quickly draw from a large reservoir of lower-energy plasma and/or lose the accumulated accelerated particles very slowly. However, neither appeared to be the case at Uranus, which was observed by *Voyager 2* to possess a "vacuum magnetosphere" lacking an apparent robust population of low-energy plasma [3] and where the most intense whistler-mode hiss and chorus waves observed by *Voyager 2* were observed [4]. These waves were determined to lead to net losses [5] even though they both could in principle lead to acceleration. 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 [1, 6].

Additionally, since the magnetospheric processes that shape ion and electron radiation belts share many fundamental characteristics, it is also puzzling why Uranus' electron radiation belts appear surprisingly intense up to MeV energies (e.g., compared to those of Saturn & Neptune [6]; Fig. 1) whereas its ion belts show much lower intensities [7]. 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.

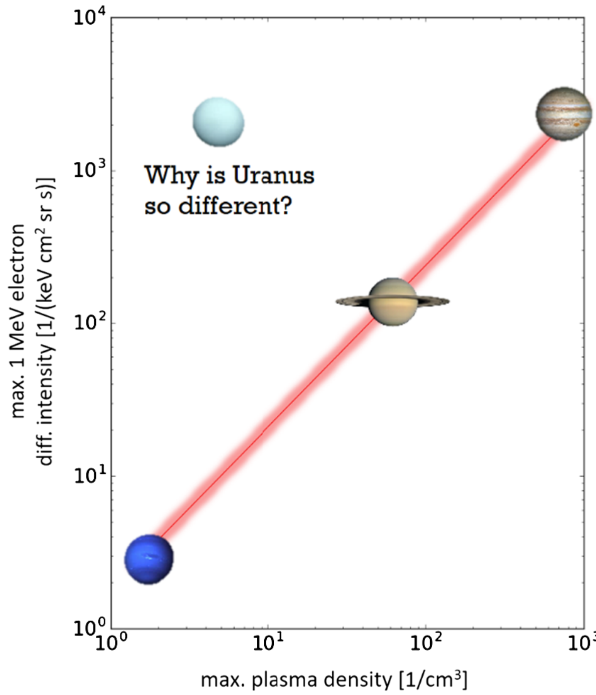

Figure 1. The intensity of Uranus' electron radiation belts at 1 MeV energy is surprising compared to that at the other Giant planets, especially given the apparent lack of lower-energy source plasma in the planet's magnetosphere (from [1]).

Revisiting the *Voyager 2* observations: Unfortunately, in-situ observations of the Uranian magnetosphere are limited to those obtained during the brief flyby encounter of *Voyager 2* in 1986 [8], which makes it difficult to determine whether the snapshot obtained represents the true nature of the planet's magnetosphere or the dominance of transient phenomena [1]. However, even the limited Voyager 2 observations hold glimpses of peculiarities that spawn questions that remain unanswered to this day.

In particular, a significant and abnormal asymmetry in energetic particle intensities was observed (*Fig. 2*) between the inbound and outbound passes of the planet in the regions between Umbriel and Ariel (blue shaded regions) and Ariel and Miranda (green shaded regions) [9]. The magnetic latitudes traversed by *Voyager 2* were very similar (within ~10°) between the inbound and outbound legs around closest approach and thus does not present an immediate solution to this significant discrepancy in the fluxes. Pitch angle coverage in that region is limited but the available data suggest an unusually steep distribution. Though this inbound/outbound asymmetry was previously interpreted as evidence for substorm-like injections similar to those observed at Earth [9-10], we investigate several alternate explanations. In particular, it remains unclear whether such a significant inbound/outbound asymmetry could be maintained by magnetospheric processes without the presence of an active source.

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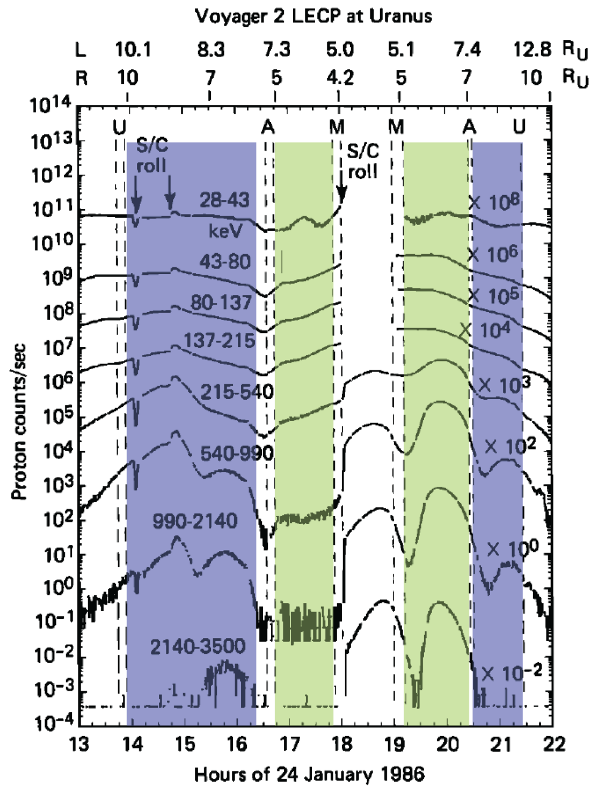

Figure 2. Count rates versus time for the Voyager 2/LECP proton channels (from [9]) show a significant (multiple orders of magnitude) discrepancy between the inbound and outbound legs of the flyby in the regions between Umbriel and Ariel (blue shaded regions) and Ariel and Miranda (green shaded regions). The vertical dashed lines indicate the times when the spacecraft encountered the expected minimum L-shell positions of the satellites.