

**A localized and surprising source of energetic ions in the Uranian magnetosphere
between Miranda and Ariel**

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Introduction

This Supporting Information includes additional figures that support the main text of the article, specifically providing context for several of the original Voyager 2 observations and assumptions made during the radial and pitch angle diffusion modeling.

Text S1. Estimate of Potential Active Moon Source.

An expected source from Ariel, if it is in fact an active ocean world, can be estimated using the source required to sustain the pitch angle distributions shown in the simple diffusion model shown in Fig. 2d. This can be achieved by first compiling a thermal ion distribution using a Maxwellian distribution fit to the average density measured by PLS in the region between Miranda and Ariel. That thermal Maxwellian is then combined with a suprathermal power law for energies ≥ 7 keV using the average spectral index from the 340-1455 keV energy channels in LECP in the same region. Creating this complete ion energy distribution fills the significant energy gap between the PLS and LECP measurements. Assuming the source distribution matches this “measured” flux distribution, then the distribution can be scaled to match the estimated source of protons in the 1.45-MeV ion channel of S0 = $1.26 \times 10^{11} \text{ cm}^{-2}\text{-s}^{-1}\text{-sr}^{-1}\text{-MeV}^{-1}/\text{s}$ (Fig. S4). This scaled source distribution can then be used to calculate an integrated source across the energies measured by the 1.45-MeV LECP ion channel. Assuming a contribution from 10% of Ariel’s surface and a one-day estimate of the residence time of the plasma (lower limit based on Bagenal (2013)) with an assumed distribution (Fig. S4) yields an estimated source of 1.7×10^{30} particles/s within the energy range of the 1.45-MeV LECP ion channel. It must also be emphasized that this is likely an overestimation as it assumes that the entire population of magnetospheric plasma and energetic particles originates from Ariel. If this were true, this would represent a significantly stronger source than would be expected by simply scaling the 1×10^{28} particles/s rate observed at Enceladus (e.g., Smith et al., 2010) to the larger surface area of Ariel.

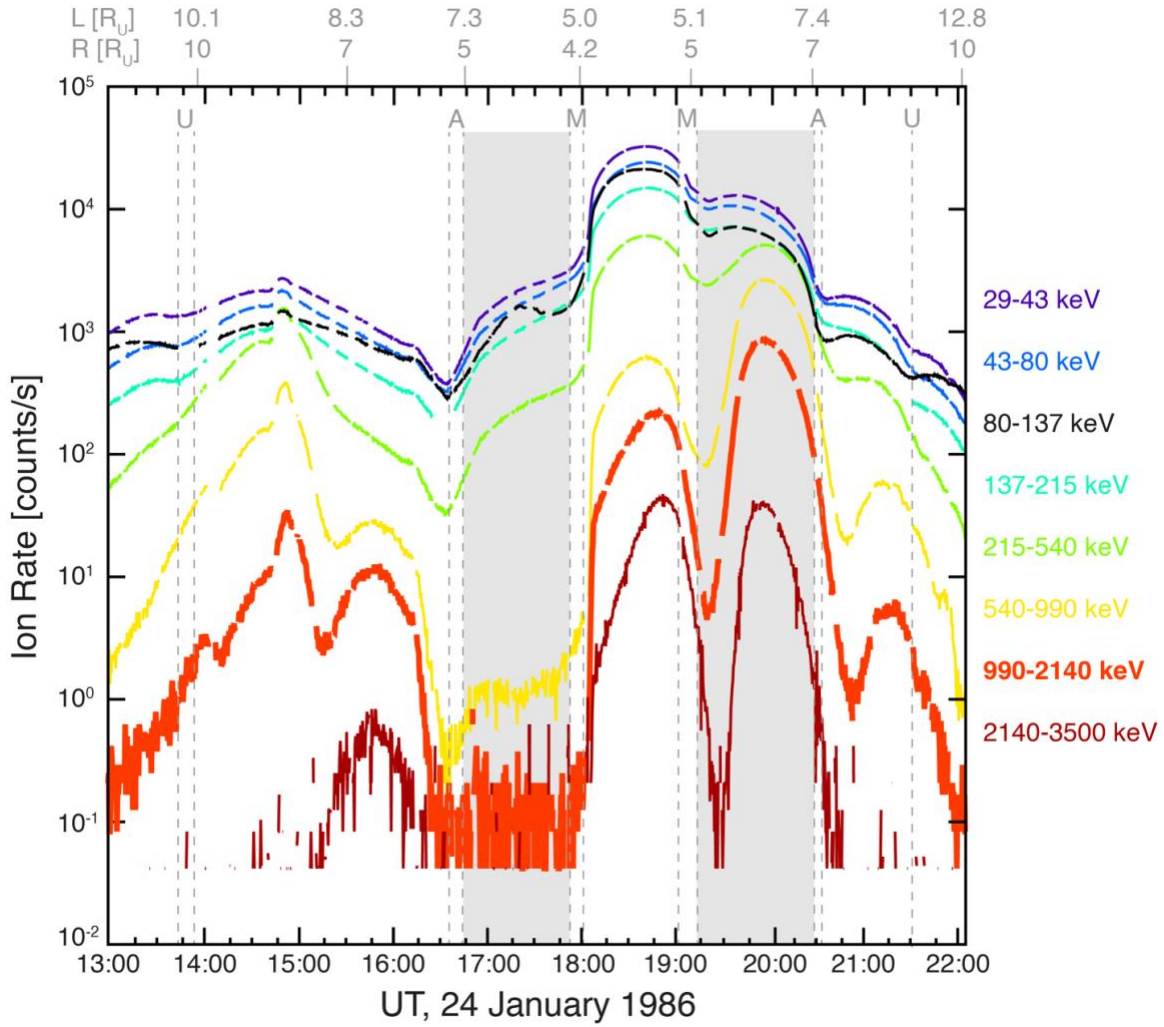


Figure S1. Measured total ion count rates measured by Voyager 2/LECP during the Uranus flyby. The curious and significant “asymmetry” in observed ion rates in the region between Miranda and Ariel (gray shaded regions) when comparing the inbound and outbound legs of the trajectory – first noted by (Mauk et al., 1987) - motivated the present analysis.

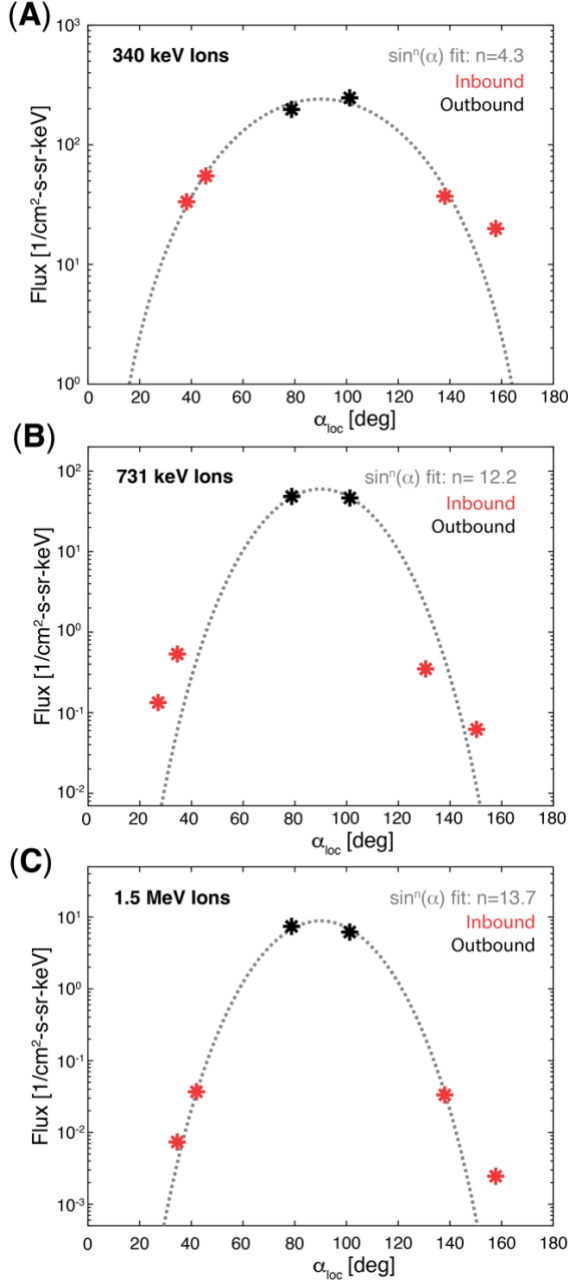


Figure S2. Average PADs measured in three different LECP ion energy channels. These distributions were created by mapping ions at $L = 6 \pm 0.5$ from the inbound leg of the trajectory (24 Jan 1986 17:15-17:30 UT, red) to the corresponding equatorial pitch angle and combining them with the local pitch angle observations from the outbound leg of the trajectory in the same L-shell region (24 Jan 1986 19:45-20:00 UT, black). The gray dashed line shows the $\sin^n(\alpha)$ fit denoted in the upper righthand corner of each panel.

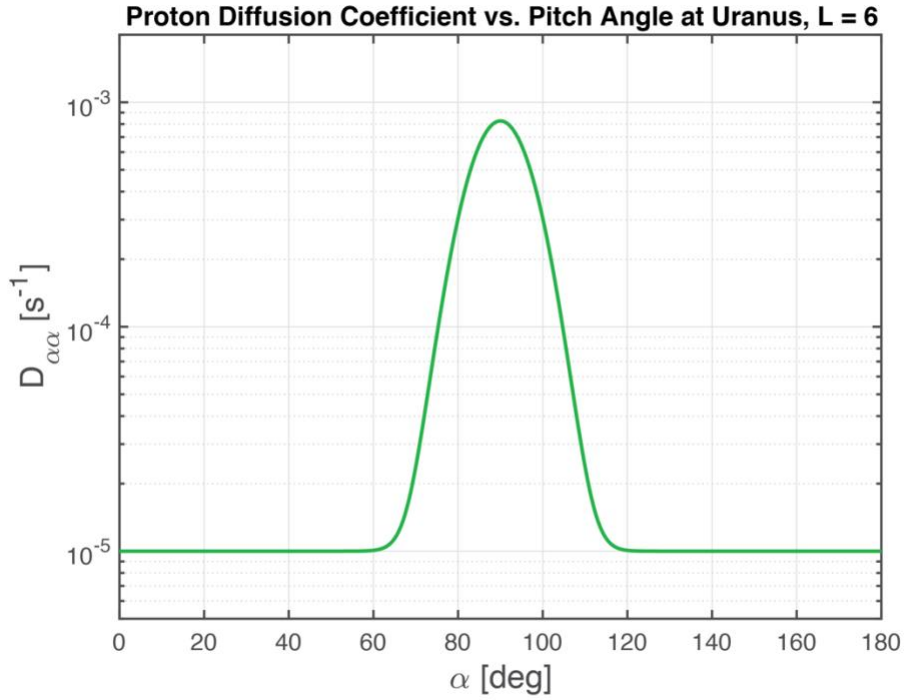


Figure S3. Modeled pitch angle diffusion coefficient distribution versus pitch angle (α) used in the simple one-dimensional model used to generate the results in Fig 2. This distribution is based on 1-MeV protons in electromagnetic ion cyclotron (EMIC) waves at $L = 6$ at Earth, which is a reasonable assumption given the aforementioned strong whistler-mode wave activity observed in this region by Voyager 2 (Kurth & Gurnett, 1991)

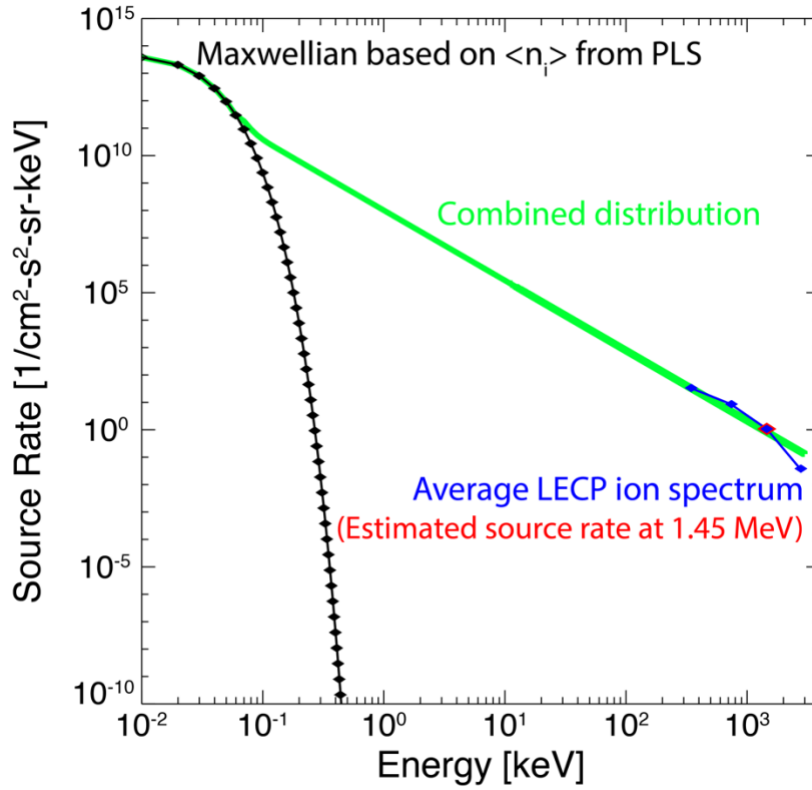


Figure S4. The combined ion source rate estimated from Voyager 2 PLS and LECP observations. The black line shows a Maxwellian distribution using the average density measured by PLS in the region between Miranda and Ariel. This is then combined with a power law for energies ≥ 7 keV (green line) using the average spectral index from the 340-1455 keV energy channels in LECP in the same region (blue line). This distribution is scaled to match the estimated source of protons at 1.45 MeV of $S_0 = 1.26 \times 10^{11} \text{ cm}^{-2}\text{-s}^{-1}\text{-sr}^{-1}\text{-MeV}^{-1}/\text{s}$ (red).