Radio Morphology: Both Uranus and Neptune possess substantial planetary-scale magnetic fields describable (in a simplified form) as highly offset and tilted-dipoles relative to the rotational system of the planet. These dipole systems generated auroral radio emission that was relatively complex in morphology compared to Earth and Saturn. Specifically, these bodies each emitted different forms of ‘smooth’ and ‘bursty’ radio components from a few kHz to 1.3 MHz as observed by the Voyager-2 Planetary Radio Astronomy (PRA) instrument sampling the radio spectrum from 1.2 kHz to 40 MHz [1,2] and Plasma Wave System (PWS) sampling between 10 Hz and 56 kHz [3,4].

As defined previously by these radio astronomy teams, ‘smooth’ emission is one that is typically quasi-continuous over a large fraction of a rotation period (smooth for hours) and does not possess large temporal fluctuations. In contrast, ‘bursty’ emissions have large isolated fluctuations in RF activity over time periods as short as six seconds up to 10’s of minutes. Figure 1 shows a PRA radio spectrogram of Uranus’ dominant bursty and smooth radio components.

![Figure 1 – Voyager 2 closest approach period at Uranus showing the bursty and smooth emissions as observed by the Planetary Radio Astronomy (PRA) instrument.](image)

Given the offset in the magnetic dipole, each planet has a dominant magnetic pole at close to 1G in strength. The most intense radio emissions were generated from the dominant pole. For Uranus, combining the extreme tilt in rotation axis and magnetic axis, this dominant pole was located on the planet’s nightside hemisphere. As such, the strongest high frequency emissions were not observed until Voyager moved behind the planet. In contrast, at Neptune, the stronger pole located at southern mid-latitudes rotated into both day and night hemispheres, allowing observations of emissions for a week before and after closest approach.

Common Bursty Components. Comparing both planetary radio systems, there are bursty emissions that appear to be common to both planets. Specifically, the broadband bursts (n-bursts) at Neptune are each [5]: 1) Emitted from the planet’s stronger pole, 2) have source locations at relatively high latitudes within a few degrees of the magnetic pole (high L-shell), and 3) beamed into a relatively thin (5-10°) but very wide (> 80°) hollow emission cone from their source. As such, due to the near-pole source and very wide hollow emission cone, the bursts tended to be observed when Voyager 2 transited the magnetic equator at both planets.

Implications for the Auroral Regions. The wide, thin hollow cone of these bursty emissions was argued [5] to be indicative of regions where the plasma density is extremely low, with the ratio of electron plasma frequency to electron cyclotron frequency, fpe/fce, having values as low as 0.002. If there was substantial electron content in the source region, then the emission would undergo near-source refraction that would create a narrowing emission beam angle. The low electron density observed at high latitudes (large L-shell) suggests that the near-pole region is evacuated of plasma.

It remains unclear if these emissions are generated at the boundary of open and closed field lines. We leave open the possibility that the emission is driven from an internal source, albeit located at distant regions in the magnetosphere. The temporal burstiness suggests that the source region is undergoing strong modulation: dormant for periods, then generating intense bursts of current to the auroral region. The exact source of this highly-variable energy remains unknown.

Future Missions. Assuming a mission to Uranus orbit arriving in 2025, the stronger magnetic pole may now be located on the dayside, and the planet may have an entirely new radio morphology. Given the magnetic pole positions relatively near the ecliptic, auroral measurements could be obtained (sample activity on high L-shells) thereby tracing the source of any impulsive magnetospheric activity to its auroral ‘hot spot’. We suggest the inclusion of a fast-sampling auroral suite consisting of an electron spectrometer system sampling field-aligned flowing electron bursts (like Wind’s Strahl detector) and nadir-pointing UV spectrometer and radio to remote-sense electron-correlated impulsive auroral activity. This system could be fast sampling in a ‘burst’ mode during polar overpasses.