Occurrences and Wave Properties of Pc1 Pearl Pulsations Relative to Plasma Boundaries

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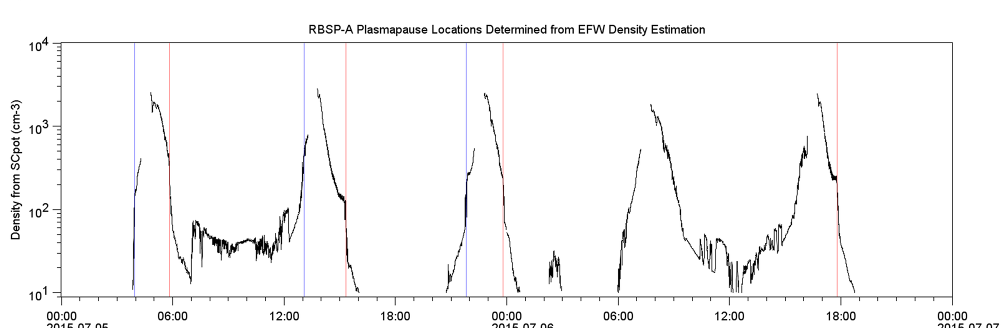
Abstract

Pc1 pearl pulsations, a subset of electromagnetic ion cyclotron (EMIC) waves modulated in time, have become a nearly commonplace observation in the Van Allen Probes era. While this population had previously been only rarely observed in situ, the large number of recorded wave events using the Van Allen Probes and MMS missions have allowed us to identify wave properties and characteristics which differentiate them from traditional “unstructured” EMIC waves. The previously observed independence of their excitation and modulation frequencies from the changing background field across L implies the wave generation mechanism is not constrained to a small area. Instead, an external source carrying this frequency and modulation information appears to interact with some refraction boundary, where the waves couple to the transverse mode.

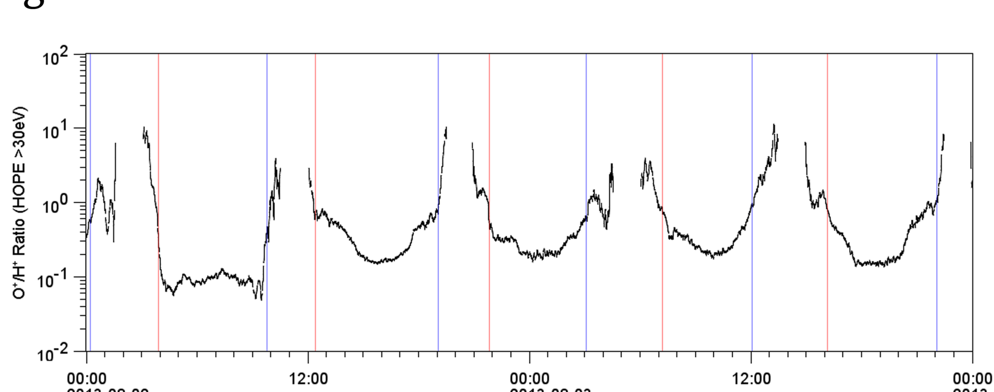
Here we examine the occurrence rates and various wave properties in relation to the observed magnetospheric boundaries given by the electron plasmapause and oxygen/proton ratio. The wave events we use are compiled from the first three years of Van Allen Probes data.

Boundaries

- The plasmapause boundary is defined by a change in electron density by a factor of 5 within $\Delta L \leq 0.5$
- Only the inner density gradient is considered to avoid confusion posed by the plume (this may be added in future iterations)



- The oxygen boundary is taken as the outer edge of a >20% excursion of the O+/H+ density ratio from the median-filtered background for each orbit.



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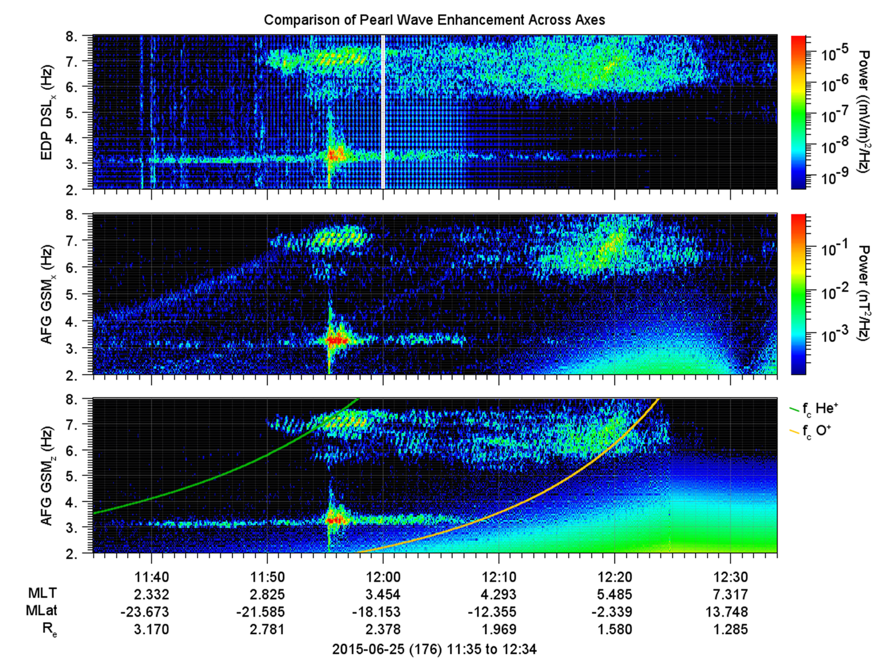
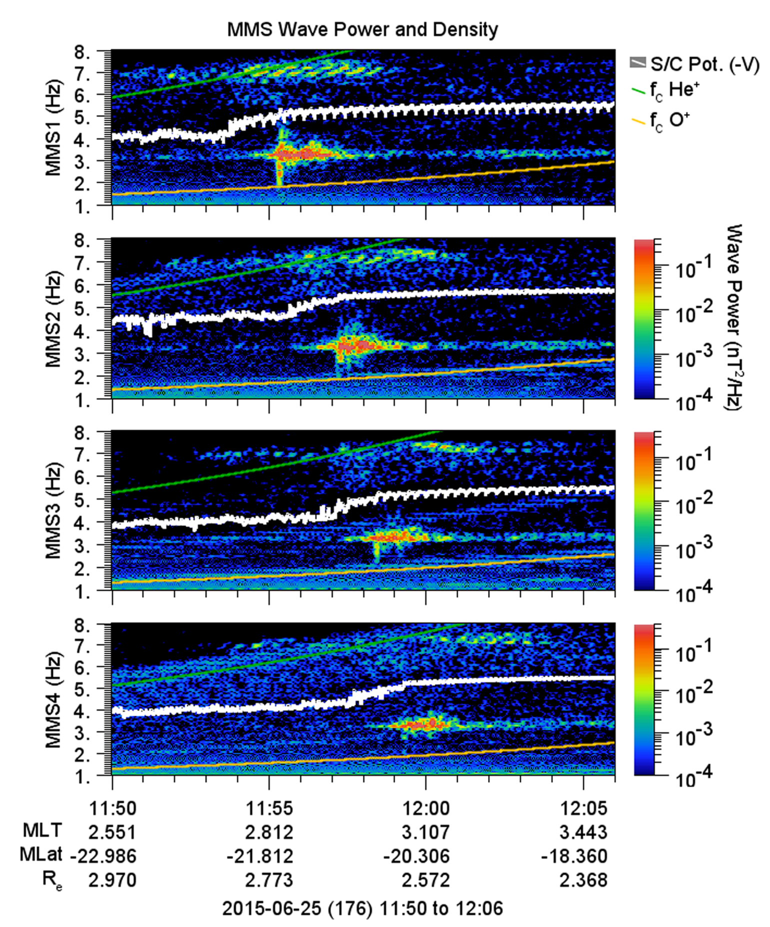
Constant Frequency

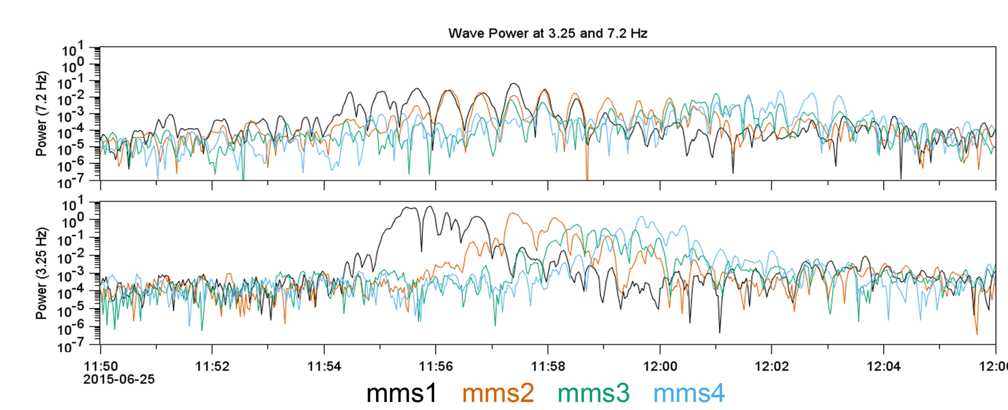
Pc1 pearl pulsations typically occur at a constant excitation frequency and modulation period across L

- Right, He^+ pearl pulsation event in 5-8 Hz band of activity spanning several L and MLT
- Compressional and electric components exhibit wave power over whole duration, transverse component restricted to discrete wave periods.

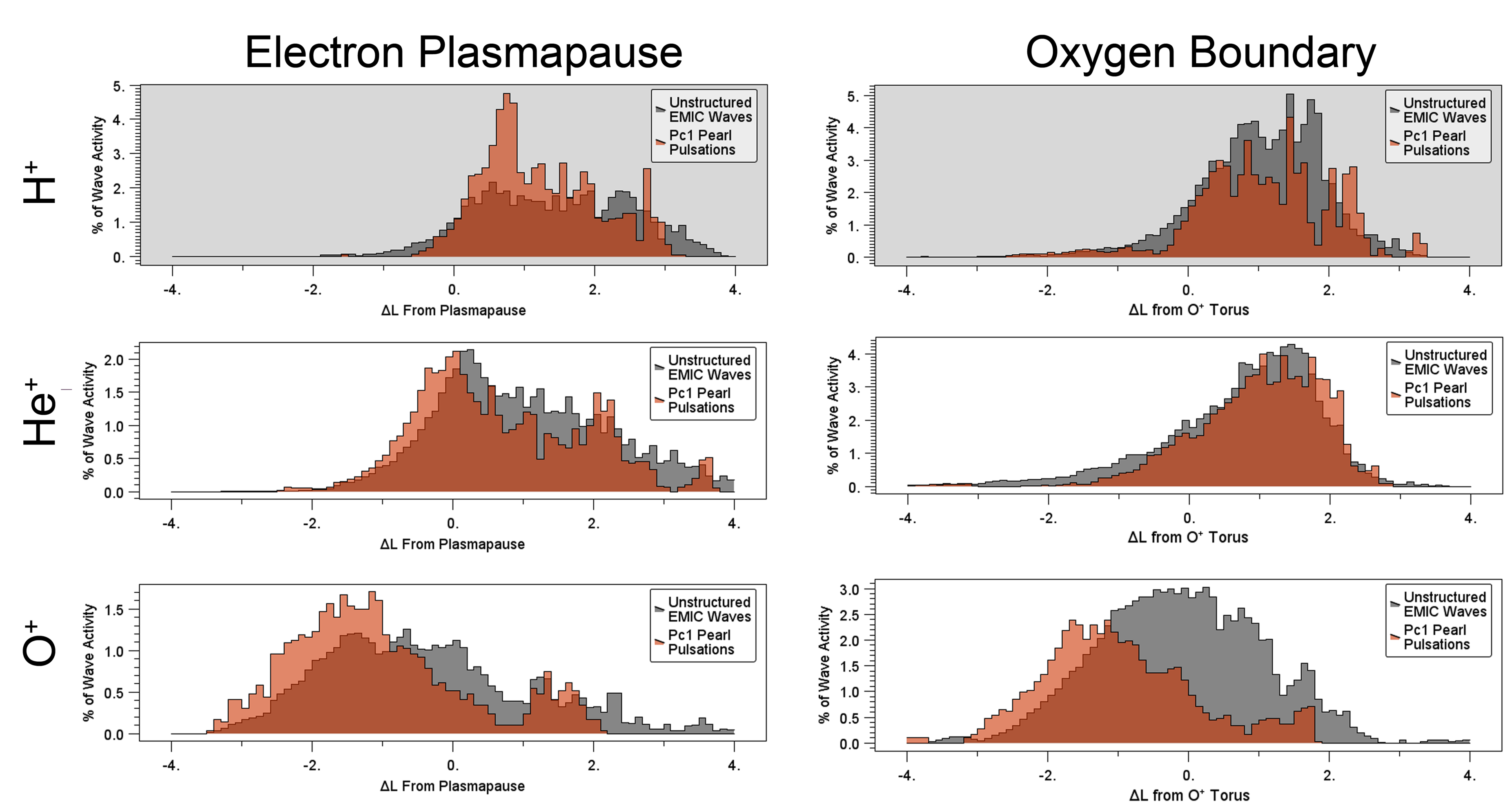




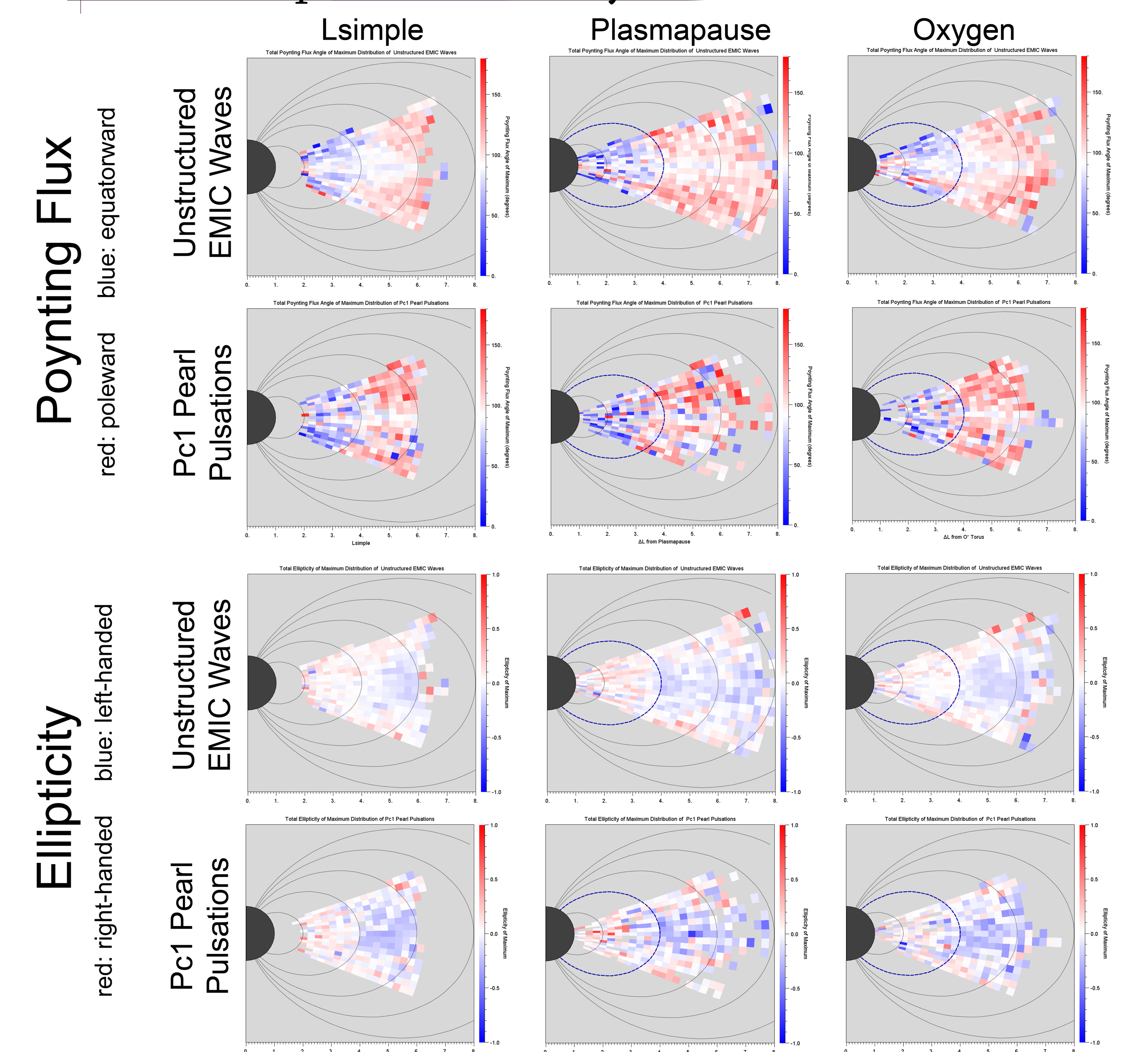
- Left, 4 MMS spacecraft observe wave enhancement at different times as they encounter electron plasmapause
- Below, “background” pearl elements are observed simultaneously, but amplitude of each element changes with boundary



Sorting by L and Ion Species



Wave Properties Sorted by ΔL



Conclusions/Discussion

Our previous observations of Pc1 pearl pulsations have demonstrated a tendency for the wave events to exhibit a constant excitation frequency across L, as well as a constant modulation period. This is at odds with most of the currently proposed generation mechanisms for this wavemode (such as ULF modulation or bouncing wave packets) as these require the excitation frequency to depend to first order on the background field strength. Instead, it appears that an external source carrying the frequency and modulation characteristics interacts with a boundary with a sufficient refractive index to couple the wave energy into the transverse mode.

Our occurrence distributions only show significant differences in occurence between pearl pulsations and unstructured waves in the Oxygen band, which for pearl pulsations are almost exclusively observed within our oxygen boundary.

Sorting wave properties by distance from plasma boundaries reveals propagation and ellipticity properties which were otherwise hidden. Both types of EMIC waves tend to propagate back towards the equator within the plasma gradient, although for unstructured waves this change occurs at the plasmapause, while for pearl pulsations it is more distinctly seen at the oxygen boundary. Similarly, the ellipticity of unstructured waves changes from left- to right-handed at the plasmapause boundary, but there is less of an effect of either boundary on the ellipticity of pearl pulsations.

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