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On The Magnetospheric Engine Behind Saturn's Periodic Radio Emissions and Astrophysical Implications

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Periodic planetary radio emissions have been used as diagnostic, not only as proxies for a planet's rotation period, but are foremost becoming powerful remote diagnostics of magnetospheric processes and large-scale current systems in action. With the increasing abundance of discovered exoplanets and recent detection of periodic radio emissions from brown dwarfs, the potential held by radio observatories in development, such as the Square Kilometer Array (SKA) systems, fuels the importance to understand the larger-scale magnetospheric and solar-wind driver that planetary radio emissions represent.

Here, we present the groundbreaking discoveries Cassini has made of the large-scale, magnetospheric processes that accompany periodic radio emissions, providing important insights in to their global drivers. The periodic Saturn Kilometric Radiation (SKR) in the range of approximately 20-500 kHz has been used to define a saturnian longitude system adopted by the IAU. An unexpected change from 10h39min to about 10h47min (Gurnett et al., 2005) came as one of the biggest surprises of the Cassini mission. Even more mysteriously, two slightly different periods were found originating from different hemisphere (Gurnett et al., 2009). To this day this behavior remains unexplained. The SKR period and phase have not only been found to be correlated with variations in the magnetic-field and in-situ particle-intensity variations measured by Cassini, but more strikingly found to be intimately related to the appearance and evolution of vast regions of heated plasma beyond 9 Saturn radii (RS) in the night side magnetosphere using Energetic Neutral Atom (ENA) observations. In addition, these large-scale magnetospheric "injections" are closely tracked, both in intensity and rotation phase, also by auroral intensifications (Mitchell et al., 2009). These periodic, large-scale injections are driven by magnetotail reconnection resulting in fast plasma flows that heat charged particles up to 10 MK as they propagate in to the inner magnetosphere. What ultimately causes the periodicity of the injections is still an outstanding question, but observations and modeling point to a possible ionospheric asymmetry.

Narrow-band radio emissions at 5 and 20 kHz also display highly periodic features around the same periods as observed in SKR (Louarn et al., 2007; Wang et al., 2010). Recently, a different type of periodic magnetospheric injection appearing down to 6 Rs in the pre-midnight magnetosphere was found to correlate with the narrow-band emission periodicity (Brandt et al., 2019). This type of injection appears in close relation to the larger-scale injections, either contributing to their triggers, or being a result thereof.

Both Earth, and in particular Jupiter display similar type of radio emissions, but with its unique and diverse instrumentation, Cassini has been the first mission to reveal direct insight in to the large-scale magnetospheric dynamics that radio emissions represent. Its results have far-reaching implications for interpreting the space environment around brown dwarfs and in particular when the first detections of exoplanetary radio signals are expected with the deployment of SKA.