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TITAN'S SCHUMANN RESONANCE : A CRITICAL REASSESSMENT OF HUYGENS PROBE CONSTRAINTS ON AN INTERNAL OCEAN, AND PROSPECTS FOR DRAGONFLY

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Introduction: The Schumann resonance [1] is a set of electromagnetic propagation modes in the cavity between the lower part of the ionosphere, and the electrically conductive surface of the Earth, and has a characteristic frequency structure with multiple peaks in vertical electric field strength at 7,14, 20 Hz etc.. The resonance is excited by impulsive lightning discharges. It was recognized that Titan might have a similar activity (although with an interior water ocean ~100 km beneath the dielectric ice crust acting as the lower bound of the cavity – see figure 1), and the Huygens probe detected a 36 Hz signal (via a nominally horizontal electric field antenna) that was interpreted (e.g. [2,3]) as a Schumann-like resonance. An excitation by Saturn's magnetosphere was postulated to explain the existence of the signal in the absence of observed lightning. We have re-examined the data and its context, and challenge the Schumann interpretation [4], while recognizing that other Cassini data on Titan's rotation state and tidally-varying gravity field robustly indicate a subsurface water ocean expected from thermal evolution models.

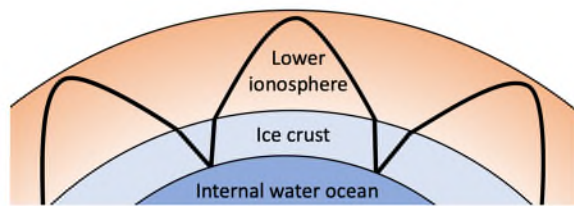


Figure 1: Schematic of a Schumann mode on Titan, bounded by the (likely temporally- and perhaps spatially-variable) lower ionosphere and the ice-ocean interface. In principle the propagation is affected by (and measurements of the Schumann resonance could diagnose) the thickness of the ice crust.

Huygens Schumann Detection: As reviewed in [4] most Schumann detections on Earth have required post-processed spectral analysis of long time series (10s of minutes) of data acquired with vertical antennas that are long and/or rigid (to avoid mechanical vibrations introducing a signal from the ~100V/m DC 'fair weather' electric field [1]). Expectations of detecting of a Schumann signal from a 2m hinged boom horizontal antenna, with real-time spectral analysis of <1s data samples, on a platform moving at 5-50 m/s through a turbulent atmosphere, must be considered optimistic.

The Plasma and Wave Analyzer (PWA) element of the Huygens Atmospheric Structure Instrument (HASI) included Extremely Low Frequency (ELF) electric field sensing. The most prominent feature of the data from this instrument was signal power in a '36 Hz' frequency bin (two instrument modes with slightly different center frequencies were used during descent). This frequency is actually rather high, and was interpreted as a second mode of the Schumann resonance. Suppression of the fundamental mode can occur in some propagation geometries, but there was certainly no a priori expectation of this spectral characteristic. The signal varied during descent and declined towards the surface, with this later altitude variation being interpreted (by extrapolation to zero E-field amplitude at an – unexpectedly small – depth of 45km beneath the surface) as a measure of ice thickness [3].

Although mechanical oscillation of the antenna booms was considered and dismissed [2], in fact, a review of the full descent profile (fig. 2) shows that the buffeting of the probe during its parachute descent has a time history very similar to the ELF data. The sudden onset of the signal at 900s (parachute exchange) and cease at impact (8869s) is particularly striking.

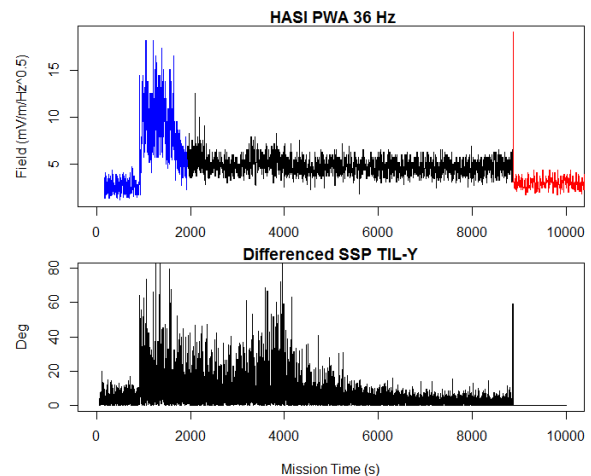


Figure 2: HASI/PWA ELF 36 Hz power (top, different colors indicate different instrument modes, usually plotted separately). Lower panel is sample-to-sample difference in reading of an electrolytic tilt sensor in the Huygens Surface Science Package – the values do not represent real tilts, but rather that the sensor responded to very short period (sub-second) oscillations that might be expected to excite antenna

motion. The time histories are overall rather similar, suggesting a possible mechanical origin for the ELF signal.

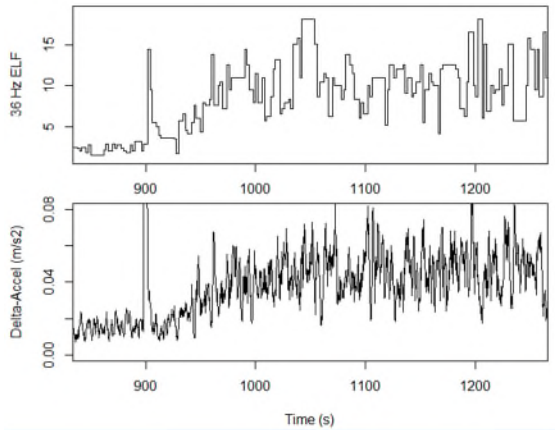


Figure 3: A close view of the minutes of descent just before and sometime after the release of the main parachute at 900s. The probe accelerated under near-free-fall for about 50s until a new faster terminal velocity under the small ‘stabilizer’ parachute was asymptotically reached. Considerable buffeting occurred, as indicated in the lower plot (differenced HASI accelerometer readings) which mirror the evolution of the ELF signal.

Further support for a mechanical origin is seen in the evolution immediately after parachute exchange (figure 3). Indeed, the behaviour is the exact opposite of what an idealized Schumann detection would see – the signal should be most easy to identify in the most dynamically-quietest parts of the mission, under the large, stable main parachute, or at rest on the surface.

Thus we consider that the 36 Hz signal – which in any case has several characteristics not expected in the classic Schumann model – was an artifact of the probe dynamics.

Future Detection of Schumann Resonance on Titan: Our refutation of the claimed Huygens detection does not assert that a Schumann resonance was not present on Titan during the descent, only that the data do not require it and it had a low a priori expectation. We furthermore stress that since rainstorms on Titan are rare, lightning is also (at best) rare, and so the Schumann signal is likely sporadic. The best chance of detecting it is therefore via long-term observations. The Dragonfly mission [5], selected as NASA’s next New Frontiers mission for launch in 2026 with Titan arrival in 2034, offers prospects for such observations. The mission will

feature over 2 years of geophysical observations, including electric field sensing to detect possible Schumann signals.

Interpretation of Schumann Resonance: Many papers modeling possible Schumann resonances on Titan were published before and after the Huygens descent, as reviewed in [4], and yield a range of predictions of the frequency and relative intensity of different Schumann modes. Indeed, the model variation is such that a frequency considered to be a second mode in one model might be the third mode in another. The model parameters that influence the spectrum are the desired unknown (the ice thickness), the excitation mechanism, the effective dielectric constant of the crust (often assumed to be the observed near-surface value of 2-2.5, but more realistically the bulk value for ice, 3.1) and critically, two scale height parameters defining the bottomside ionosphere profile. These latter parameters in particular are not well-constrained by data, and are likely (as on Earth) variable with space weather conditions.

While possible detection of a Schumann resonance at Titan will surely be interesting, its interpretation to derive ice thickness will likely not be straightforward.

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