

## ***Interactive comment on “Observation of 2nd Schumann eigenmode on Titan’s surface” by C. Béghin et al.***

**C. Béghin et al.**

cbeghin@cnrs-orleans.fr

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REPORT ON GI-2013-1 “Observation of 2nd Schumann eigenmode on Titan’s surface”  
by C. Béghin G, Wattieaux, R. Grard, M. Hamelin and J.P. Lebreton Report 1 Submitted  
on 04 Mar 2013

The paper deals with a very relevant issue and it is suitable for publication, after taking  
into account the following remarks:

1. It would be very important to make a summary of the methods used in the analysis  
made for several years.
2. The authors should indicate if there is a special reason to select the strategy analysis

considered in the paper.

3. It would clarify the used method by indicating the relevant parameters that provide confidence in the obtained results.

4. Did the authors consider other analysis algorithms like the tomographic ones but they realized that they were not suitable?.

5. From the physical point of view it would be very enlightening to use a table to compare the peculiarities of the Schumann resonances in the Earth and Titan? Is it expected some universal behaviour?. REPORT ON GI-2013-1 "Observation of 2nd Schumann eigenmode on Titan's surface" by C. Béghin G, Wattieaux, R. Grard, M. Hamelin and J.P. Lebreton Report # 1 Submitted on 04 Mar 2013

Authors reply

Point 1 – We agree with the reviewer's comment that it is important to emphasize why the usual processing techniques of space-wave data, which are limited most of the time to show colour time-frequency spectrograms, did not allow us extracting a weak signal from noise. We have introduced in the revised manuscript several paragraphs relevant to that important issue, as mentioned below and first of all in the Abstract as: "The usual depicting methods of space-wave data used so far could not allow retrieving the presence of weak signals when Huygens was at rest for 32 minutes on Titan's surface. Whereas the expected signal seems hidden within the instrumental noise, we show that a careful statistical analysis of the amplitude distribution of the 418 spectral density samples of the 36 Hz line reveals abnormal characteristics compared to other frequencies."

Point 2 –We develop now more precisely the reasons which justify our strategy of data analysis at the beginning of Section 2, lines 20-28, as: "The mathematical treatments of the wave field data were designed at least ten years before Huygens landing so as to be performed automatically onboard. The ELF power spectral density (PSD)

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was computed onboard by applying a DFT after a 16-bit analog-digital conversion of two consecutive waveform samples of 333 ms duration each. The square root of the composite DFT modulus, i.e., the amplitude spectral density (ASD) was logarithmically compressed, and the lower byte (8 bits) was transmitted without the phases to Earth by the telemetry system via the Cassini orbiter (Lebreton et al., 2005). Therefore, this study is constrained by the limited performances of usual techniques of wave-data processing of space experiments by taking, nevertheless, the best advantage of the proper peculiarities of the PWA-ELF instrument, as briefly described here below.”

Point 3- The relevant parameters are now summarized at the end of Section 2, as: “Summarizing the above survey, we retain that the probable presence of a natural signal on Titan’s surface should be identified by three indicators observed only with bin 36 Hz, that are respectively by order of significance: (i) a reversal of skew while the major part of the sample distribution lies in the vicinity of a step of the transfer function, (ii) an excess of smallest values compared to the distribution of other bins, (iii) a weak although noticeable increase of the nominal average amplitude. We propose then to reproduce such a behavior and to confirm the fact that the involved mechanism is due to the peculiarities of the onboard data processing and TM transmission. Two different numerical simulations of the entire loop were performed, starting from the ADC input, to the DFT process up to the ground data decommutation”. Point 4- As anticipated by the reviewer, the tomographic algorithms, which are extensively used for solutions of linear equations in 2D and 3D imaging processing, are found inadequate for one-dimension, onboard pre-processed and log compressed data, that is the case of the 36 Hz line samples of the Huygens experiment.

Point 5- A brief comparison between parameters of Earth’s and Titan’s Schumann resonances is shown in Table 1 that is introduced in the revised version, and the relevant following paragraph is added in the Introduction ( Section 1), as:

“A clearly identified signal at around 36 Hz was received for about 2 h 25 min of descent and furthermore interpreted as the second eigenmode of an atypical Schumann reso-

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nance (Béghin et al., 2007, 2009; Simões et al., 2007). The main differences between Earth's and Titan's Schumann resonances (hence referred as SR) are summarized in Table 1 according to most recent studies (Béghin et al., 2012). Other planets such as Venus, Jupiter and Saturn, had been proposed well before Huygens-Cassini mission by Nickolaenko and Rabinowicz (1982) as potential candidates to experience lightning triggered Earth-like SRs. However, Titan revealed itself as a unique case, because the only source of available energy could presumably result from the Saturn's magnetosphere interaction with Titan's atmosphere (Béghin et al., 2007), a view furthermore supported by the established absence of any lightning in Titan's atmosphere (Fischer and Gurnett, 2011)."

Report #2 Submitted on 27 Mar 2013

Suggestions for technical corrections The paper sounds quite good, bibliography seems accurate and the topics falls completely inside the journal scope. The only correction i would point are in the are of the mathematical aspects of the data processing. For me some parts are a bit confusing and lack some standards processing methods. I also miss (in this case is only a suggestion), not only a frecuency study of the magnetic dada, but also a time-frecuency study.

Authors reply

The main concern expressed by the Reviewer # 2 overlaps the items detailed by Reviewer # 1 involving the mathematical aspects of the data processing. For this item, we hope to have produced the best justifications and explanations we can, with the few excerpts proposed in our reply to the suggestions of Reviewer # 1 which are furthermore developed in more details in the revised version of the manuscript. As concerning the Reviewer's suggestion about frequency study of magnetic data, there was unfortunately no measurement of magnetic field performed onboard the Huygens Probe, which is extremely damageable for the understanding, not only of natural waves, but also about the possible existence of some induced steady magnetic field. About the

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time-frequency study of measured ELF electric field, we got a global profile of the field strength throughout the descent from 140 km of altitude down to landing for about 2 hours 25 min, plus 32 min at the surface, as written in the paper. The time resolution was varying between 4 and 10 sec for each successive ELF frequency spectrum. As one can see in our paper, there was no noticeable time evolution at the surface, except a random dispersion that is the main subject of this study, and off-course, the singular first spectrum received 4 s after touch-down.

General message from the authors to both reviewers – Most of comments and remarks expressed by the reviewers have not only led to the corrections reproduced in this brief report, but they rose up directly or indirectly few complementary changes, visible by several yellow highlighted areas in the revised text.

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Interactive comment on *Geosci. Instrum. Method. Data Syst. Discuss.*, 3, 157, 2013.

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