EPSC Abstracts
Vol. 13, EPSC-DPS2019-59-1, 2019
EPSC-DPS Joint Meeting 2019

EPSC
EPSC-DPS Joint Meeting 2019
15–20 September 2019 | Geneva, Switzerland

Investigating Ganymede's water vapor exosphere with JUICE/MAJIS

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Abstract

Ganymede's exosphere is the actual interface between the moon's icy surface and Jupiter's magnetospheric environment. Its characterization is of key importance to achieve a full understanding of the ice alteration processes induced by the radiation environment. Several scientific instruments that will operate on board JUICE have the potential to study Ganymede's environment. Among them, the Moons And Jupiter Imaging Spectrometer (MAJIS) will have the chance to investigate the moon's water vapor exosphere by measuring its IR emission. In this work, we estimate the expected non-LTE photon emission from exospheric water molecules and speculate on the detection possibilities with JUICE/MAJIS. First, we provide a rough comparison of the existing models of Ganymede's water vapor exosphere and discuss the derived characteristics of the neutral environment. We then use these model outputs to estimate different scenarios for the expected non-LTE emission from water molecules. Our results can be of help during the JUICE observation planning phase.

1. General concept and motivation

Ganymede's magnetosphere is capable of slowing down the incident Jovian plasma [1], nevertheless, a non-negligible flux impacts the moon's icy surface activating different release processes, such as sputtering and radiolysis [2], [3]. The EPD instrument onboard Galileo, indeed, revealed the entry of charged particles in the moon's magnetosphere, most likely through tail reconnection [4]. The sputtering-and-radiolysis induced exosphere, consisting mainly of H_2O, O_2, and H_2, therefore, is expected to be generated through a complex process driven by the Jovian plasma and energetic ion energy and spatial distribution, and depending on the moon surface characteristics (e.g. temperature, composition). A number of numerical models have been developed to understand the plasma circulation around this moon as well as the generation of its surface-bounded exosphere (e.g., [5], [3], [6], [7]). Although there are not yet observational evidences, Ganymede's water vapor exosphere is believed to be locally collisional (around the subsolar region) and collisionless elsewhere. The understanding of the dynamics of Ganymede's water vapor exosphere along the moon's orbit around Jupiter is of significant importance for obtaining information on the way the icy surface interacts with the planet's magnetospheric environment. MAJIS onboard JUICE [8], will investigate the composition of water and non-water-ice components in both Ganymede's surface and exospheric environment. The observed spectral emission signatures, such as the non-LTE emissions from water molecules, is a potential tracer of the spatial distribution of the H_2O exosphere.

2. Models

Several modelling efforts have advanced our understanding of the generation of Ganymede's exosphere providing important constraints for the involved processes. As in the Europa case, exospheric models are based on very different approaches (e.g. collisional or collisionless environment assumption). For a general comparison of the available techniques see [9]. Models depend on a series of physical parameter assumptions which are currently poorly known, mainly due to the absence of an adequate quantity of in situ data. Figure 1 presents a comparison between the H_2O density profiles calculated by different models. We note that around the subsolar point and up to an altitude of at least ~250 km, all models (apart [2], who ab inizio consider a low sublimation rate) have the same trend. Models begin to diverge at higher altitudes (substantially above ~550 km). In that region, the density of the sublimated exosphere is significantly lowered, as shown in the collisionless model by [3] hence any diversion of a model from a strictly thermal profile is the result of the assumed chemistry taking place.

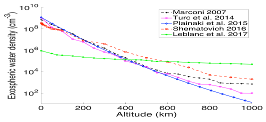

Figure 1: Modeled Ganymede's H_2O density profiles around the subsolar point.

3. Detection

In general, the MAJIS measurements of water gas are relevant to the search for the sputtered water vapor exosphere or for the occurrence of possible plumes or plume-material (possibly scattered from condensates). Such measurements can be made in the dayside due to non-LTE photon emissions from water or minor components (CO_2, CO, Na, H_2O). The MAJIS instrument [8] covers the H_2O non-LTE photon emission spectral range (2.4-3μm). Following the approach suggested by [10] and [11] for the estimation of the non-LTE radiance measured from a spectrometer onboard a spacecraft in limb viewing, we are able to simulate the MAJIS observations of Ganymede's H_2O exosphere. We use the HITRAN database [12] to compute the cross-sections for the ro-vibrational lines of the ν1, ν2 and ν3 H_2O band and we assumed a g-factor gf = 3.349×10^{-4} s^{-1}, gf = $3.33\times10-5$ s^{-1} and gf = 2.67 x 10^{-4} s^{-1} (at an heliocentric distance of 5.2 AU) for the H_2O ν3, ν1 and ν2 bands, respectively [11]. The estimated radiance was convolved with the MAJIS instrumental function and compared with the expected noise level (see Figures 2 and 3).

4. Discussion – Conclusions

Our simulations using the models by [5], [3], [6], and [7], evidence that MAJIS has the necessary sensitivity to observe Ganymede's exosphere with a SNR higher than 1 during limb observations with tangent altitude below 100 Km from the surface. The current study considers as inputs the results of numerical simulations hence the obtained SNR differences cannot be rigorously attributed to specific parameters within each model (future work). In this study, we considered different theoretical models of the H_2O exosphere. The extent at which the plasma-neutral interactions has been considered in each case (reaction efficiencies, geometries, composition, etc..) is a crucial parameter determining the characteristics that distinguish one model from another [see also [13]). The upcoming measurements with JUICE of Ganymede's exosphere will provide proof of the most realistic scenario among the ones currently proposed. At a larger perspective, future exploration of the Outer Solar System requires knowledge on the planetary space weather conditions near and within the system under investigation [14].

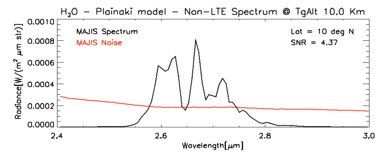

Figure 2: Simulated MAJIS spectrum of the H_2O Non-LTE emission between 2.4 and 3 microns for the Ganymede exosphere model by [3] at lat~10°N and tangent altitude ~ 10 km.

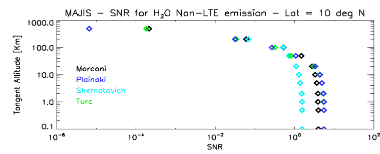

Figure 3: Comparison of the MAJIS signal-to-noise ratios (SNR) computed for different exospheric models and different observation tangent altitudes.

References

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