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The H_2O and O_2 exospheres of Europa and Ganymede

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Abstract

The exospheres of Jupiter's icy satellites Europa and Ganymede are mixtures of H_2O, O_2 and H_2 and some minor constituents, like Na. H_2O is released from the surface mainly through either direct sputtering, caused by the impact of energetic ions of Jupiter's magnetosphere, or sublimation. O_2 and H_2 are produced through chemical reactions among different products of H_2O radiolytic decomposition.
In the present study we investigate at first the Europa's exospheric characteristics under the external conditions that are likely in the Jupiter's magnetospheric environment, applying the Europa Global model of Exospheric Outgoing Neutrals (EGEON, [1]) for different configurations between the positions of Europa, Jupiter and the Sun. We show that the H_2O exosphere around Europa is denser and more extended above the moon's trailing hemisphere. We find that solar illumination and preferable plasma impact direction together determine the spatial distribution of Europa's exosphere and the O_2 release efficiency. We show that the modelled O_2 densities are in good agreement with the analysis results from two HST observations of Europa's leading and trailing hemisphere.
In order to investigate on the O_2 exosphere of Ganymede, we apply the same model, making however some important modifications regarding the impacting ions precipitation regions and the satellite physical characteristics. The map of the ion precipitation to Ganymede's surface, is produced using a single-particle Monte Carlo model the simulates the trajectories of the ions inside the magnetic field, assumed to be described by the model of [2]. We present some first preliminary results on the spatial distribution of the H_2O and O_2 exosphere of Ganymede and discuss the escape.

1. Introduction

The great majority of the released to the exosphere O_2 and H_2O molecules (and also a percentage of the emitted H_2 molecules) re-impact the moons in lack of sufficient energy to overcome gravity; upon impact, H_2O sticks to the surface whereas O_2 and H_2 do not. Instead, O_2 (and H_2) molecules upon impact get thermalized, bounce back and re-impact the moons until some loss process stops their motion. As a result thin (of about some hundreds of km) almost homogeneous thermal exospheric O_2 rings accumulate at small altitudes around Europa and Ganymede surfaces. The existence of these tenuous O_2 exospheres, with column densities in the range 10^{14} -10^{15} cm-2, has been already demonstrated through HST observations and Galileo UV-spectrometer-data modeling.

2. Brief description of EGEON

EGEON is a MC model that simulates the effects of surface irradiation on the generation of Europa's exosphere providing the spatial density distribution of the released species. Ion fluxes originating from the Jovian magnetosphere impact the surface of Europa causing sputtering, ionization and excitation of water-ice molecules. Following electronic excitations and ionizations water-ice molecules can get dissociated; chemical reactions among the water-dissociation products result in the formation of new molecules (e.g. O_2, H_2, OH and minor species) that are finally ejected from the surface to the moon's exosphere. Among all the different species that can be released from the surface in its current version, EGEON considers only H_2O, O_2 and H_2 molecules. As exospheric generation processes, EGEON considers: a) the radiolysis of ice followed by the ejection of new species, and b) the direct sputtering of water-ice molecules, with the release yields described in [3]. As loss processes, the model considers electron-impact ionization and gravitational escape of the generated exospheric molecules [1]. The details of the model can be found in [1] and [4].

2. Results and Discussion

In case that the trailing hemisphere apex and the subsolar point of Europa are in opposite directions (panel (a) in Fig.1), we estimate along the Europa-Sun line, at the leading hemisphere apex of Europa, an O_2 column density of about $1.5 \cdot 10^{19}$ m^{-2}. In the opposite direction, at the trailing side the O_2 column density is estimated to be $3.0\cdot10^{18}m^{-2}$.

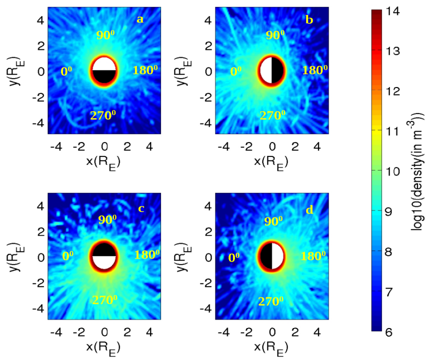

Figure 1: Released O_2 density spatial distribution at Europa due to O^+ magnetospheric ions impacting the surface of the moon obtained by EGEON. Sunlit hemisphere is indicated with white color and dark hemisphere with black. In all four panels the xy-plane is Europa's orbital plane around Jupiter. Jupiter is to the left and trailing hemisphere is down in all four configurations

It results that the O_2 column density at the leading hemisphere of Europa derived from the EGEON results, is in very good agreement with the one derived from the June 28 2008 HST/STIS observations [5], being slightly larger by a factor of 1.5 We note that on the basis of the observations of the OI emission from the leading hemisphere of Europa, [5] concluded that contrary to its trailing side, no Sub-Jovian and anti-Jovian asymmetry is visible. This is consistent with the EGEON results. Moreover, on the basis of the same observations [5] searched for departures from a radially symmetric atmospheric emission and found an emission surplus centered around 90^0west longitude (that is the leading hemisphere apex). Such a surplus of emission is reproduced by EGEON (see panel (a) in Fig.1) and is due to the illumination of the leading hemisphere by the Sun that favors radiolysis, releasing O_2 in the exosphere.

Whereas the spatial distribution of the exosphere of Europa depends mainly on the illumination of the moon's surface and secondarily on the ion flux that impacts the trailing hemisphere more intensively [1], at Ganymede the situation is expected to be more complicated. The intrinsic magnetic field of Ganymede (unique moon in the Solar System to posses a magnetic field), reconnecting to the external Jovian magnetic field, partially shields the surface from the ion impact, especially at the equatorial regions [6]. Due to this phenomenon, the emission of O_2, produced through radiolysis on Ganymede's surface, is expected to depend both on the configuration of the reconnection of the magnetic fields and the illumination of the moon by the Sun. The latter determines the moon's surface temperature responsible for the efficiency of the radiolysis mechanism. Furthermore, the dynamics of the Jovian magnetospheric plasma determine the dynamics of plasma entry and circulation inside Ganymede's magnetosphere and eventually the precipitation towards the surface. Fig. 2 shows that at Ganymede, the O_2 exosphere is denser at the regions of the open-closed magnetic field lines boundaries.

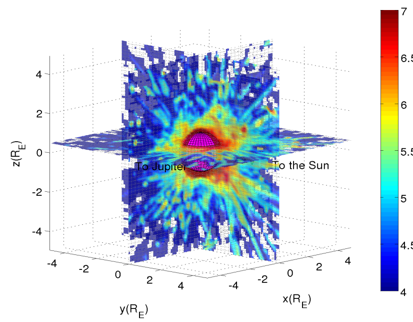

Figure 2: Released O_2 density spatial distribution at Ganymede due to O^+ magnetospheric ions impacting the surface of the moon. Sunlit hemisphere is at the positive y-axis diection.

References

[1] Plainaki, C., Milillo, A., Mura, A., Orsini, S., Massetti, S., Cassidy, T., 2012. The role of sputtering and radiolysis in the generation of Europa exosphere, Icarus, Volume 218, Issue 2, p.956–966, doi: 10.1016/j.icarus.2012.01.023.

[2] Jia, X., R. J. Walker, M. G. Kivelson, K. K. Khurana, and J. A. Linker (2009), Properties of Ganymede's magnetosphere inferred from improved three-dimensional MHD simulations, J. Geophys. Res., 114, A09209, doi:10.1029/2009JA014375.

[3] Famà, M., Shi, J., Baragiola, R. A., 2008. Sputtering of ice by low-energy ions. Surface Science 602, 156-161.

[4] Plainaki, C., Milillo, A., Mura, A., Orsini, S., Cassidy, T. 2010. Neutral particle release from Europas surface. Icarus 210, 385-395.

[5] Saur, J., Feldman, P.D., Roth, L., Nimmo, F., Strobel, D.F., Retherford, K.D., McGrath, M.A., Schilling, N., Gérard, J.C., Grodent, D., 2011. Hubble Space Telescope/Advanced Camera for Surveys Observations of Europa's Atmospheric Ultraviolet Emission at Eastern Elongation, Astroph. J., 738, 2, article id. 153.

[6] Kivelson, M.G., K.K. Khurana, F.V. Coroniti, S. Joy, C.T. Russell, R.J. Walker, J. Warnecke, L. Bennett, and C. Polanskey, The magnetic field and magnetosphere of Ganymede, Geophys. Res. Lett., 24, 2155, 1997