



HAL
open science

Where should amorphous water ice be observed on Ganymede?

Audrey Moingeon, Eric Quirico, Olivier Poch, Dominique Bockelée-Morvan, Thierry Fouchet, François Leblanc, Emmanuel Lellouch, Pablo Rodriguez-Ovalle, Bernard Schmitt, Vladimir Zakharov

► **To cite this version:**

Audrey Moingeon, Eric Quirico, Olivier Poch, Dominique Bockelée-Morvan, Thierry Fouchet, et al.. Where should amorphous water ice be observed on Ganymede?. Europlanet Science Congress 2024, Sep 2024, Berlin, Germany. EPSC Abstracts, 17, pp.EPSC2024-926, 2024, 10.5194/epsc2024-926 . insu-04679497

HAL Id: insu-04679497

<https://insu.hal.science/insu-04679497v1>

Submitted on 27 Aug 2024

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Where should amorphous water ice be observed on Ganymede?

Audrey Moingeon¹, Eric Quirico¹, Olivier Poch¹, Dominique Bockelée-Morvan², Thierry Fouchet², François Leblanc³, Emmanuel Lellouch², Pablo Rodriguez-Ovalle², Bernard Schmitt¹, and Vladimir Zakharov²

¹Univ. Grenoble Alpes, CNRS, IPAG, 38000 Grenoble, France (audrey.moingeon@univ-grenoble-alpes.fr)

²LESIA, Observatoire de Paris, Université PSL, Sorbonne Université, Université Paris Cité, CNRS, 92195 Meudon, France

³LATMOS/CNRS, Sorbonne Université, UVSQ, Paris, France

The surface of Ganymede is dominated by crystalline water ice, but amorphous water ice has been observed at the poles of both hemispheres [1]. Recent hyperspectral data from the James Webb Space Telescope have confirmed the presence of amorphous water ice in the north polar region of the leading hemisphere [2]. Because Ganymede is embedded in the Jovian magnetosphere, its surface is continuously irradiated by charged particles (ions and electrons), which induces radiolysis, chemistry, sputtering of surface molecules, and likely amorphization of water ice [3,4]. However, the irradiation flux is not uniform across Ganymede's surface due to its own magnetic field [5], and the equatorial region is partially shielded from ion and electron irradiation. This fact, along with higher temperatures at lower latitudes that efficiently promotes recrystallization, may explain that the presence of amorphous water ice is restricted to the polar regions.

Here, we question the presence of amorphous water ice in the north polar region using a numerical approach. The ion and electron fluxes impinging on the polar and equatorial regions are taken from a number of previous publications [6,7]. We first estimate the erosion rate of water ice at the surface for different case models using sputtering yields of H₂O and O₂ [8,9,10]. The nuclear and electronic doses deposited in the subsurface with depth were calculated using the stopping powers generated by the SRIM software (<http://www.srim.org/>) [11]. The contribution of bremsstrahlung emission from decelerating electrons was not included in this calculation. The erosion rate mitigates the actual doses accumulated in the surface, and our numerical code included a moving surface front.

Our calculations show that water ice erosion is dominated by O and S ions, and the contribution of electrons is 3 orders of magnitude smaller. Although sputtering is more efficient at high temperatures [12], we found that the polar regions are more eroded due to a higher ion flux. The doses accumulated in the surface reach a steady state within ~ 100000 years and are in the range of 100-1000 eV/atom. These values are underestimates, corresponding to a maximum erosion rate where no sputtered water molecules sink back to the surface. The fraction of crystalline water ice transformed into amorphous water ice was estimated using the kinetics reported in [13]. Since amorphous water ice crystallization competes with radiolytic amorphization, we also considered this process and used the kinetic parametric equation of [14]. Finally, our calculations show that amorphous water ice is essentially formed in the polar regions, where temperatures are < 100 K, to a depth of ~600 μm. This result is consistent with the detection of amorphous water ice at the north

pole of Ganymede by the JWST telescope, but not with the lack of detection at the south pole. Our analysis of experimental data in the literature shows that the kinetics of water ice amorphization is not well constrained in the temperature range 90-120 K for low energy projectiles. This issue is being addressed through irradiation experiments. Ongoing simulations also include more realistic erosion rates.

- [1] Ligier et al. (2019), *Icarus* 333, 496–515.
- [2] Bockelée-Morvan et al. (2024), *Astronomy and Astrophysics* 681, A27
- [3] Cooper et al. (2001), *Icarus* 149, 133-159
- [4] Johnson et al. (2004), *Jupiter. The Planet, Satellites and Magnetosphere*, 485-512
- [5] Kivelson et al. (1996), *Nature* 384, 537-541
- [6] Poppe et a. (2018), *Journal of Geophysical Research* 123, 389-391
- [7] Liuzzo et al. (2020), *Journal of Geophysical Research* 125, e28347
- [8] Fama et al. (2008), *Surface Science* 602, 156-161
- [9] Johnson et al. (2009), *Europa*, 507
- [10] Teolis et al. (2017), *Journal of Geophysical Research* 122, 1996-2012
- [11] Ziegler et al. (2010), *Nuclear Instruments and Methods in Physics Research B* 268, 1818-1823
- [12] Brown et al. (1980), *Physical Review Letters* 45, 1632-1635
- [13] Fama et al. (2010), *Icarus* 207, 314-319
- [14] Schmitt et al. (1989), *Physics and Mecanics of Cometary Materials* 302, 65-69