EPSC Abstracts
Vol. 5, EPSC2010-727, 2010
European Planetary Science Congress 2010

Europa's Disk-Resolved Ultraviolet Spectra: Relationships with Plasma Flux and Surface Terrains

A. R. Hendrix (1), T. Cassidy (1), R. E. Johnson (2), and C. Paranicas (3)
(1) JPL/Caltech, Pasadena, CA, arh@jpl.nasa.gov, (2) Univ. Virginia, Charlottesville, VA, (3) APL/Johns Hopkins Univ., Laurel, MD.

1. Introduction

The suite of disk-resolved observations from the Galileo Ultraviolet Spectrometer (UVS) is analyzed to look for spectral trends across the surface of Europa. We focus on the UV albedo and the 280 nm SO_2 absorption strength -- their relationships with sulfur and electron flux distributions as well as surface features and relative surface ages. We compare UV trends with a new model of sulfur ion flux to the surface. Our results have implications for exogenic and endogenic processes.

2. Sulfur Flux Model

In this study, we have repeated earlier calculations [1] with up-to-date plasma parameters from the Galileo spacecraft. Compared to the Voyager era parameters, Galileo found higher plasma densities [2] and provided a much better characterization of the "hot" or "non-thermal" ion population [3]. We assumed that Europa is electromagnetically inert [1]; we did not include the relatively small contribution of the induced magnetic field of the moon. The ion motion is described using the "guiding-center approximation" which, in addition to gyration around the magnetic field lines, includes a guiding center "drift" perpendicular the magnetic field. For sufficiently low energy ions, this drift is simply the co-rotation velocity. With increasing ion energy, positive ions drift faster than co-rotation speed [4], an effect not implemented in earlier studies [1]. The ions are also free to move parallel to the field lines.

3. Results

The Galileo UVS data exhibit two different effects: a global-scale darkening, where the disk-resolved albedo decreases from the leading hemisphere to the trailing, and the SO_2 absorption band, which is confined to the trailing hemisphere and is stronger in dark, younger terrains.

3.1 SO_2 absorption

We find that Galileo UVS-measured SO_2 absorption strengths are greater on the trailing hemisphere; this is as expected from previous disk-integrated observations [5][6] of the UV absorption band itself and from Voyager-era disk-resolved measurements of large-scale UV darkening in the broad-band UV filter [7][8][9]. Absorption strength on the leading hemisphere is negligible.

We compare the measured SO_2 band strengths for each region observed by the Galileo UVS with the sulfur flux model. The SO_2 absorption distribution generally correlates with the sulfur flux to the surface, namely the cold flux (the hot flux is minimal in comparison). However, it is not just the sulfur ions that are important: electrons, which are deposited primarily on the trailing hemisphere [10] are responsible for the radiolysis that converts the deposited S^+ and H_2O to SO_2 and hydrate. The electron flux is roughly constant over the trailing hemisphere, for the low latitudes.

We also note strong variations in SO_2 band depth based on terrain. In particular, the young chaos units show stronger SO_2 absorption than predicted by the cold sulfur model alone, suggesting a local source of SO_2 in those regions.

The SO_2 absorption is also correlated with NIMS-measured hydrate concentration [11]. The correlation between the SO_2 and the dark material is consistent with the sulfur cycle [13][14] where a dynamic equilibrium exists between continuous production and destruction of sulfur polymers S_x, sulfur dioxide SO_2, hydrogen sulfide H_2S and $H_2SO_4*nH_2O$. The sulfur cycle involves an initial sulfurous material on the surface of Europa being exposed to radiolysis.

3.2 UV Albedo

The large-scale pattern in disk-resolved UV albedo (300-310 nm) follows the familiar disk-integrated orbital lightcurve trend, long seen in longer wavelength observations (e.g., [15] [16] [17] [18] [7] [9]), with a minimum at the center of the trailing hemisphere and a maximum at the center of the leading hemisphere – but has a much more dramatic variation between leading and trailing hemispheres compared to longer wavelengths, and compared to IUE disk-integrated measurements. When compared with the longitudinal variation in SO_2 band strength, it becomes clear that different processes drive these two spatial trends. Whereas the SO_2 absorption is not present at all at longitudes <180°W, the albedo is seen to increase steadily from the trailing hemisphere apex at 270°W to the leading hemisphere apex at 90°W.

The primary magnetospheric interaction, the cold sulfur ion implantation, is confined to the trailing hemisphere, as is the electron bombardment [10]. Thus, the interaction between the surface and the incoming cold ions and/or the incoming electrons cannot be the source of the global-scale albedo variation. We find the UV albedo is correlated with the hot sulfur flux and/or the sputtering rate.

Sputtering, caused primarily by hot ions, can darken a regolith by increasing the average grain size [19]. Hot sulfur ions do most of the sputtering, though oxygen ions and cold ions make a significant contribution. Small grains are preferentially destroyed by sputtering by heavy ions (whereas larger grains will tend to be more absorbing due to longer path length). The strong wavelength dependence in the longitudinal albedo variation suggests that a chemical process could also play a role.

The research described here was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.

References

[1] Pospieszalska, M. K. and Johnson, R. E.: Magnetospheric ion bombardment profiles of satellites: Europa and Dione. *Icarus* **78**: 1-13, 1989.
[2] Kivelson, M. G., F. Bagenal, W. S. Kurth, F. N. Neubauer, C. Paranicas, J. Saur. Magnetospheric Interactions with Satellites in Jupiter, eds. F Bagenal, T. E. Cowling, W. B. McKinnon. Cambridge University Press, 2004.
[3] Mauk, B. H., D. G. Mitchell, R. W. McEntire, C. P. Paranicas, E. C. Roelof, D. J. Williams, S. M. Krimigis, and A. Lagg: Energetic ion characteristics and neutral gas interactions in Jupiter's magnetosphere, JGR, 109, 2004.
[4] Thomsen, M. F. and J. A. van Allen: Motion of trapped electrons and protons in Saturn's inner magnetosphere, Journal of Geophysical Research, 85, 5831-5834, 1980.
[5] Lane, A. L., R. M. Nelson, D. L. Matson: Evidence for sulphur implantation in Europa's UV absorption band. *Nature* **292**: 38-39, 1981.
[6] Noll, K. S., H. A. Weaver, A. M. Gonnella: The albedo spectrum of Europa from 2200 Å to 3300 Å. *J. Geophys. Res.* **100**: 19057-19059, 1995.
[7] Johnson, T. V., L. A. Soderblom, J. A. Mosher, G. E. Danielson, A. F. Cook, P. Kupferman: Global multispectral mosaics of the icy Galilean satellites. *J. Geophys. Res.* **88**: 5789-5805, 1983.
[8] Nelson, M. L., T. B. McCord, R. N. Clark, T. V. Johnson, D. L. Matson, J. A. Mosher, L. A. Soderblom: Europa: Characterization and interpretation of global spectral surface units. *Icarus* **65**: 129-151, 1986.
[9] McEwen, A. S.: Exogenic and endogenic albedo and color patterns on Europa, *J. Geophysical Research*, **91**, 8077-8097, 1986.
[10] Paranicas, C., R. W. Carlson, R. E. Johnson: Electron bombardment of Europa. *Geophys. Res. Lett.,* **28**: 673-676, 2001.
[11] Hendrix, Carlson, Smythe, "Europa as Seen by Galileo UVS and NIMS," Jupiter after Galileo/before Cassini, Lisbon, June 2002.
[12] Carlson, R. W., W. M. Calvin, J. B. Dalton, G. B. Hansen, R. L. Hudson, R. E. Johnson, T. B. McCord, M. H. Moore: Europa's surface composition, in *Europa*, eds. Pappalardo *et al.*
[13] Carlson, R. W., R. E. Johnson, M. S. Anderson: Sulfuric acid on Europa and the radiolytic sulfur cycle. *Science* **286**: 97-99, 1999.
[14] Carlson, R. W., M. S. Anderson, R. E. Johnson, M. B. Schulman, A. V. Yavrouian: Sulfuric acid production on Europa: The radiolysis of sulfur in water ice. *Icarus* **157**: 456-463, 2002.
[15] Stebbins, J., Jacobsen, T.S.: Further photometric measures of Jupiter's satellites and Uranus, with tests for the solar constant. Lick Obs. Bull. 13, 180–195, 1928.
[16] Johnson, T.V.: Galilean satellites: narrowband photometry 0.3–1.1 microns. Icarus 14, 94–111, 1971.
[17] Morrison, D., Morrison, N.D., Lazarewicz, A.R.: Four-color photometry of the galilean satellites. Icarus 23, 399–416, 1974.
[18] Buratti, B. and J. Veverka: Voyager photometry of Europa. *Icarus* **55**: 93-110, 1983.
[19] Clark, R. N., F. P. Fanale, A. P. Zent: Frost grain size metamorphism - Implications for remote sensing of planetary surfaces. *Icarus* **56**: 233-245, 1983.