EPSC Abstracts
Vol. 12, EPSC2018-203-1, 2018
European Planetary Science Congress 2018

Observational constraints on the distribution and temperature dependence of H_2O_2 on the surface of Europa

S. K. Trumbo (1), M. E. Brown (1), K. P. Hand (2), and K. de Kleer (1)
(1) Division of Geological and Planetary Sciences, California Institute of Technology, Pasadena, CA, 91125, USA (strumbo@caltech.edu) (2) Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, 91109, USA

Abstract

We present L-band Keck NIRSPAO and NASA IRTF SpeX observations of hydrogen peroxide (H_2O_2) on the surface of Europa. We map H_2O_2 across the surface at a spatial resolution of ~300 km and investigate the geographic variability in its abundance. We find elevated concentrations at low-latitudes, potentially correlated with chaos terrain, and relative depletions toward the cold poles. We also examine the temperature effects on Europa's H_2O_2 abundance by examining changes in the H_2O_2 band strength before and after eclipse.

1. Introduction

Hydrogen peroxide (H_2O_2) is part of an important radiolytic cycle on Europa. The bombardment of surface water ice by magnetospheric ions and electrons converts H_2O to H_2O_2, losing H_2 in the process and creating an oxidizing surface [1, 2, 4]. Understanding this cycle is not only important to our knowledge of the chemical composition of Europa's surface and to the study of surface-magnetosphere interactions throughout the solar system, but it is also critical for our understanding of the potential chemical energy sources to Europa's ocean [3, 6]. Water-rock interactions at the seafloor can be a source of reductants, but the energy available for redox chemistry will likely depend on the supply of oxidants, such as H_2O_2, from the radiolytically processed surface environment [3, 6].

Spectroscopic observations of potentially endogenous salts suggest that low-latitude chaos regions on the leading and anti-Jovian hemispheres may be important sites of exchange between the surface and subsurface environments [5]. However, laboratory experiments [8, 9] and disk-integrated spectroscopic observations of Europa's surface [7] suggest that the local H_2O_2 concentrations are controlled by the local temperature and availability of water ice, leading to the prediction that the highest H_2O_2 concentrations would lie at the cold, icy high-latitudes of the leading hemisphere, rather than the warm, salty equatorial regions. If these predictions are correct, such a spatial separation of H_2O_2 and the most likely locations of surface-subsurface exchange could limit the delivery of oxidants to the subsurface ocean. A definitive understanding of the distribution and controls of H_2O_2 across the surface of Europa is therefore crucial for understanding its potential habitability.

2. Observations and results

We present L-band observations of Europa taken with the near-infrared spectrograph NIRSPEC and adaptive optics (AO) system (hereby combined to NIRSPAO) on the Keck II telescope, as well as with the near-infrared spectrograph SpeX of the NASA Infrared Telescope Facility (IRTF). Our NIRSPAO observations map the 3.5 µm H_2O_2 feature across the surface of Europa at a nominal spatial resolution of ~300 km, thereby testing the expectation that H_2O_2 is concentrated in the coldest, iciest regions. Figure 1 shows representative NIRSPAO spectra of the high- and low- latitudes on the leading hemisphere. Contrary to expectations, our NIRSPAO data exhibit a depletion of H_2O_2 at the high latitudes and higher abundances near the warm equator. Intriguingly, as demonstrated in the mapped silt of Figure 2, these data also suggest a potential concentration of H_2O_2 within the salty chaos terrains, which may imply a compositional control on abundance.

Our SpeX data examine the strength of the 3.5 µm H_2O_2 feature in disk-integrated spectra taken before and after Europa's daily eclipse and are therefore sensitive to temperature controls that are independent of geographic location. A simple thermal model of Europa's surface [10] predicts a temperature drop of 10–20 K during eclipse. Comparison of H_2O_2 band strengths before and after this temperature change will investigate the importance of temperature in the equilibrium concentrations of H_2O_2 on Europa.

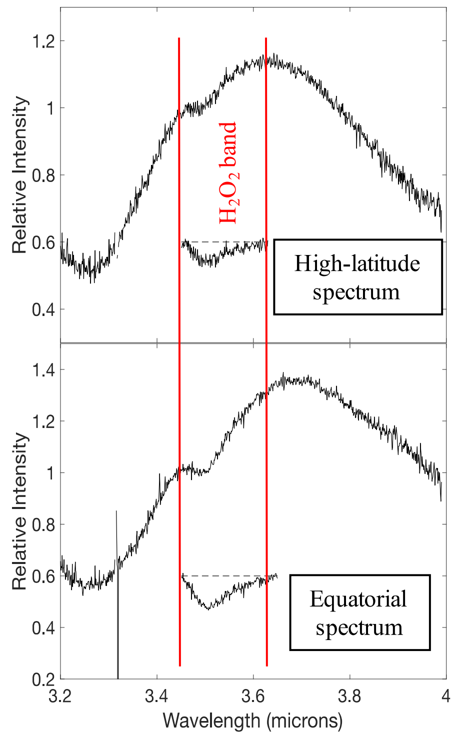

Figure 1: Two representative spectra from a NIRSPAO N/S slit across Europa. The high-latitude spectrum exhibits a smaller H_2O_2 absorption than the equatorial spectrum. This observation is contrary to the expectation that H_2O_2 be concentrated in the coldest and iciest regions on Europa's surface.

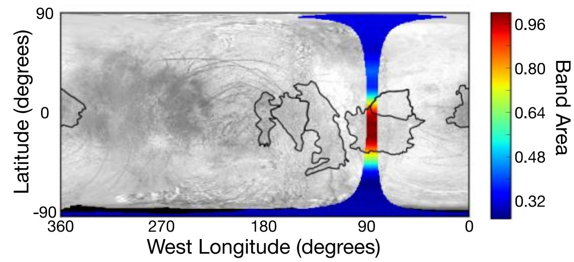

Figure 2: A NIRSPAO N/S slit across the leading hemisphere of Europa. The H_2O_2 abundance appears to be lowest at high latitudes and most concentrated in the salty chaos region, Tara Regio. This implies a potential compositional, rather than temperature, control on H_2O_2 abundance.

Acknowledgements

S. K. Trumbo is supported through a NASA Earth and Space Sciences Fellowship (NESSF). K. de Kleer is supported via the *51 Pegasi b* Fellowship Program.

References

[1] Carlson, R. W., Anderson, M. S., Johnson, R. E., Smythe, W. D., Hendrix, A. R., Barth, C. A., Soderblom, L. A., Hansen, G. B., McCord, T. B., Dalton, J. B., Clark, R. N., Shirley, J H., Ocampo, A. C., and Matson, D. L.: Hydrogen Peroxide on the Surface of Europa, Science, Vol. 283, pp. 2062-2064, 1999.

[2] Carlson, R. W., Calvin, W. M., Dalton, J. B., Hansen, G. B., Hudson, R. L., Johnson, R. E., McCord, T. B., and Moore, M. H.: in Europa, University of Arizona Press, 2009.

[3] Chyba, C. F. : Energy for microbial life on Europa, Nature, Vol. 403, pp. 381-382, 2000.

[4] Cooper, P. D., Johnson, R. E., Quickenden, T. I.: Hydrogen peroxide dimers and the production of O2 in icy satellite surfaces, Icarus, Vol. 162, pp. 444-446, 2003.

[5] Fischer, P. D., Brown. M. E., Hand, K. P.: Spatially resolved spectroscopy of Europa: the distinct spectrum of large-scale chaos, AJ, Vol. 150, pp. 164.

[6] Hand, K. P., Chyba, C. F., Priscu, J. C., Carlson, R. W., and Nealson, K. H.: in Europa, University of Arizona Press, 2009.

[7] Hand, K. P. and Brown, M. E.: Keck II observations of hemispherical differences in H$_2$O$_2$ on Europa, ApJ Letters, Vol. 766, pp. L21.

[8] Hand, K. P. and Carlson. R. W.: H_2O_2 production by high-energy electrons on icy satellites as a function of surface temperature and electron flux, Icarus, Vol. 215, pp. 226-233.

[9] Loeffler, M. J., Raut, U., Vidal, R. A., Baragiola, R. A., and Carlson, R. W.: Synthesis of hydrogen peroxide in water ice by ion irradiation, Icarus, Vol. 180, pp. 265-273.

[10] Trumbo, S. K., Brown, M. E., and Butler, B. J.: ALMA thermal observations of a proposed plume source region on Europa, AJ, Vol. 154, pp. 148.