EPSC Abstracts
Vol. 13, EPSC-DPS2019-1033-2, 2019
EPSC-DPS Joint Meeting 2019

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

Global measurements of water on Europa at infrared wavelengths

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Abstract

The presence of water plumes on Europa was first hypothesized more than 10 years ago [1] and has been inconclusively debated ever since regardless of detection of hydrogen and oxygen in 2012[2]. We present results from direct measurements of water and organics, covering most of Europa's terrain with the Keck Observatory. Our global measurements on 17 dates in 2016 and 2017 suggest mostly quiescent activity, except for one night where we measure water vapor release and obtain upper limits for methanol and ethane (relative to water).

1. Introduction

In 2012, ultraviolet observations with the Hubble Space Telescope (HST) found plume-like emission features of hydrogen (H) and oxygen (O) in the southern hemisphere, at abundances 100–1000x above the expected values resulting from exogenic effects [2]. This was the first detection and characterization of plume chemical content at Europa. The 2012 plume-like H and O emissions, however, have eluded confirmation regardless of numerous attempts, making detection of plume water an elusive endeavor. Recent transit imaging and reanalysis of Galileo magnetic and plasma field data have provided further evidence of plume activity [3,4], yet the intrinsic characteristics of these observations preclude direct determination of water in plumes.

The fate of the released plume particles will depend on the solar radiation, the Jovian plasma field, and Europa's gravitational field, leading to one (or more) of the following mechanisms: excitation, ionization, dissociation, return (freeze out), and/or escape. In the nearly collision-less plume environment, solar excitation of molecules (water and organics) results in emission of infrared photons through decay to the ground vibrational state, either directly (resonant fluorescence) or through branching into intermediate vibrational levels (non-resonant fluorescence), allowing high-resolution spectroscopy (e.g. with Keck's Near-InfraRed SPECtrograph, NIRSPEC) to detect these signatures.

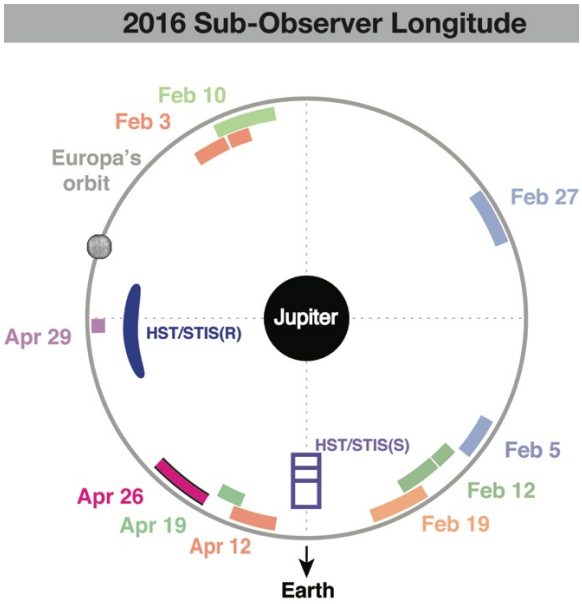

Figure 1. Orbital parameters. This orbital plot shows the longitudinal coverage of our 2016 observations (colored bars). Characteristics of the HST/STIS detections are labelled and included for comparison.

In 2016, we started a sensitive search for water and organics through temporal observations of Europa's disk with NIRSPEC at the 10m Keck Observatory. Using high-resolution infrared spectroscopy, we were able to target radiative excitation of water molecules via solar excitation (fluorescence pumping) in the 2–5.5 μm region. The key advantage of observations at infrared wavelengths is the ability to measure water vapor directly (not H and O), which represents a direct

and independent assessment of water resulting from plume activity.

2. Results

Our program was aimed towards characterizing, and strongly constraining, the chemical composition of potential Europan plumes near Jupiter's opposition, with a strong focus on detecting activity through measurements at different longitudes (Fig. 1). This survey consisted of 17 observations that yielded full longitudinal coverage, spanning dates from February 2016 through March 2017. Multiple visits were needed to provide temporal coverage sufficient to probe possible cadence, including some back-to-back observations of a particular region after a single orbital period (3.55 days). Furthermore, observations at different orbital positions with respect to Jupiter (true anomaly) allowed the study of tidal effects on the presumed activity.

We obtained disk average measurements of Europa, as defined by the instrument slit of 0.4″ width (or 0.7″; depending on the night seeing) and spatial extract of ~1″ along the North-South or East-West direction. We targeted lines of water vapor and organics, which ultimately permitted a unique and complementary effort to characterize the chemical composition of Europa in preparation for in situ observations. Of the 17 water vapor measurements, 16 measurements indicated no detection within sensitivity limits, thus establishing the quiescent state. One measurement yielded an indication of surplus emission suggesting the presence of water vapor (3.1σ). Even though the limited signal-to-noise ratio of the possible H_2O emission feature prevents us from establishing a definitive detection, cross-correlation analyses (e.g. [5]) of the data favor the existence of water activity.

3. Conclusions

Our ground-based survey represents a unique characterization of the molecular properties of Europa's tenuous atmosphere, providing direct measurements of water vapor and using rather unexplored wavelengths in the study of plumes with high-resolution IR spectroscopy. While several models have estimated the global escape rates for different molecules [6,7], observational astronomy has gathered only limited information on Europa's atmosphere, especially in regards to measurements of water release. The individual detection strategies and wavelength regimes used to date provide independent tests that together support the view that plume activity on Europa is rather transient (given the large number of non-detections), yet activity at lower levels should not be ruled out. If plumes are present, questions remain as to what mechanisms are responsible for their sporadic nature.

Acknowledgements

We thank the staff of the W. M. Keck Observatory for their exceptional support throughout our long Europa observing program. L.P. acknowledges support from NASA's Keck PI Awards (RSA 1541943, 1466335), Solar System Observations (NNX17AI85G), and Solar System Workings (80NSSC19K0027). The authors recognize and acknowledge the very important cultural role and reverence that the summit of Maunakea has always had within the indigenous Hawaiian community. We are most fortunate to have the opportunity to conduct observations from this mountain.

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