Future HST Observations of Europa and its Plumes: Findings and Recommendations

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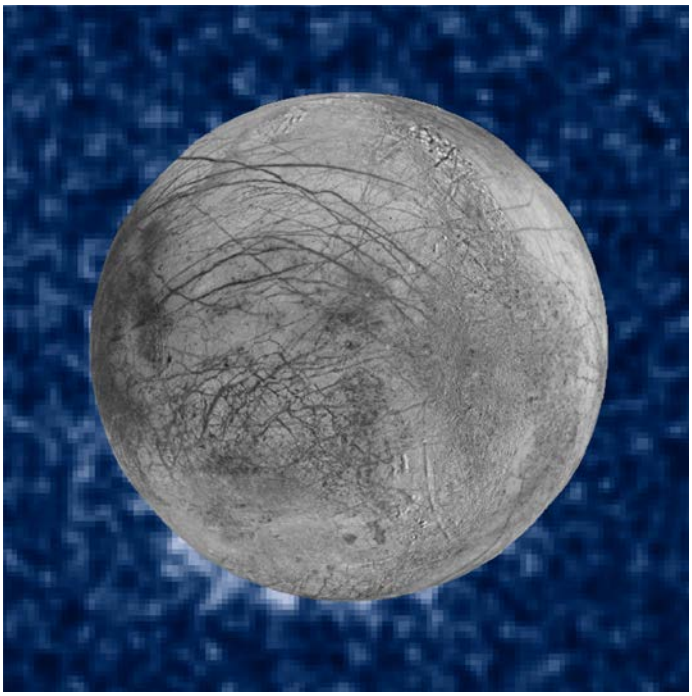
8 Sept. 2017



Left: HST STIS UV images of airglow emissions, possible from plumes on Europa, with visible image of the satellite superimposed. *Right*: Artist's conception of the appearance of a water-based plume. [*NASA press release 16-096, Sept. 2016*].

Overview:

Jupiter's satellite Europa is the target of NASA's flagship mission Europa Clipper, currently in development. Observations with Hubble show evidence for gaseous plumes suggestive of outgassing from the sub-crustal ocean. There is high scientific importance in learning more about potential Europa plumes, their properties and locations, and HST observations may reveal new information that influences the planning for a Europa mission. At the same time, HST observing time is a precious resource, and in prior observations the duty cycle of detections has been low.

In Jan. 2017 the STScI Director constituted a committee to provide advice on how Hubble can best support planning for a future mission. The committee members are Professor John T. Clarke (Boston University), Dr. John Spencer (Southwest Research Institute) and Dr. Amanda Hendrix (Planetary Science Institute). The committee charter is attached in Appendix A. One task of the committee is to recommend an approach that appropriately balances the science priorities against the resource requirements. This document reports on the activities of the committee, the knowledge that has been gained by looking into different approaches to plume detection, and the final recommendations of the committee for future HST observations of Europa.

Committee Activities:

The committee first met by teleconference on 12 Jan. 2017, discussed the charter and how best to proceed. The committee then solicited general inputs from members of the planetary science community, with solicitations for inputs through several newsletters with a submission deadline of February 10th 2017. Specific inputs were also requested from the two primary observing groups that have thus far detected evidence of plumes on Europa using HST, led by Lorenz Roth and William Sparks. Further telecons were held on 26 Jan., 17 Feb., 20 Feb., 24 Feb., 15 March, 19 April, and 3 May. Discussions were also held with representatives from the Europa Clipper project (R. Pappalardo and C. Niebur) to obtain input from the project for the committee recommendations.

The flurry of activity in mid-February involved the review and concentrated discussion of the inputs from the broad community and the two observing groups. In the course of this discussion, it became clear that GO proposals for cycle 25 due in April 2017 would be at a clear disadvantage, in part because the committee report would not be available, and in part due to the unavailability of calibration observations, designed to better understand the feasibility of some types of plume-related observations, taking place near Jupiter opposition in spring 2017. It was agreed with Neill Reid from STScI that a mid-cycle call for Europa observations could be made with a due date of September 30th 2017, coinciding with the first deadline for regular mid-cycle HST proposals, for observations during the Jupiter apparition in spring 2018. *This mid-cycle call for Europa observing proposals is the main recommendation of the committee.* It is proposed that a number of orbits in the range of 50-100 be considered, with the final number of allocated orbits depending on the review of the proposals that are received.

Committee Deliberations:

The guiding principles behind the committee deliberations have been to balance the high value of HST observing time with the high importance of Europa plume science, both in absolute scientific merit and in supporting the planning for the Europa Clipper mission. The committee reviewed the existing set of HST observations, and tabulated the rates of successful plume detection for different techniques. The committee also reviewed proposed new observing methods that might lead to plume detection and characterization, including inputs from both the two primary observing teams and the broader community.

There are basically two methods that have been used to detect what is thought to be plume activity at Europa: a) looking for FUV airglow emissions from a plume, a technique used by the Roth group, and b) looking for absorption or scattering of FUV light from the Jovian disk by a plume when Europa passes in front of Jupiter, a technique used by the Sparks group. There are relative strengths and weaknesses of each approach, and each method has shown a detection rate of the order of 5-10 percent in the prior observations depending on the level of confidence. There are potential methods to increase the detection rates, and to better characterize the properties of plume gas in a given detection. There are also other methods or refinements that could be used that have not been commonly employed to date, for example looking in new wavelength ranges based on the expected composition of the plume, or observing plume emissions Europa in Jupiter's shadow when there is little reflected sunlight background from the Europa disk.

The Europa Committee has studied the value of further test observations of Europa in summer 2017 to assist in characterizing the capabilities of new modes of observations for future proposal cycles. The committee contacted Lorenz Roth and Bill Sparks, who are the PI's for the existing test programs, for which the observations have all been obtained. The question was what, if any, further observations would be appropriate. The committee had already discussed this and reached agreement, and then discussed the responses from Lorenz Roth and Bill Sparks.

In view of the responses and discussion to date, the committee decided that observations of emissions from Europa in Jupiter eclipse had the greatest potential for providing new plume detection techniques, beyond the techniques currently being employed by the Sparks and Roth groups. The committee thus recommended that 4 HST orbits be devoted to test observations in summer 2017 to better understand the potential of these techniques. In every case the goal is to characterize the level of scattered light from Jupiter and the sensitivity to Europa emissions during eclipses. In this case it would be best, although not required, to have Europa in eclipse in the aperture during each sequence of observations. The proposed modes are:

1) 2 orbits with STIS/CCD G750M

2) 1 orbit with STIS/CCD 230MB

3) 1 orbit with WFC3 F656N

The committee declined to approve another test observation at Ly-alpha of Europa in transit. The proposed observations, with one exception, were performed in spring 2017 and the data are available to the public in the STScI archive.

Committee Conclusions:

While Hubble remains the best tool currently available for detecting plume activity on Europa, the observations are challenging. In December 2012, STIS detected 1216 Å Ly-α emission from atomic hydrogen, and 1304 Å emission from atomic oxygen, consistent with electron impact on a water vapor plume, from a localized region near Europa's south pole (Roth *et al*. 2014). However 18 additional visits yielded no further detections (Roth et al. 2015 [AGU abstract]), indicating that a favorable combination of viewing geometry, plume activity, and sufficient magnetospheric electron density to illuminate the plumes is relatively rare. Sparks *et al*. (2016) used STIS to image Europa in transit in front of Jupiter in broadband images centered near 1500 Å, and obtained tentative detections of localized absorption of Jupiter light above Europa's limb, consistent with discrete plumes in several locations, on three out of ten visits. Subsequent transit observations in 2016 showed an apparent plume signature above an identical location on Europa to one of the earlier detections (Sparks *et al*. 2017). This repeat detection is hard to explain as a coincidence or an artifact, and thus provides good evidence for the reality of this particular plume. However, both successful techniques suggest that plume activity is intermittent.

Given the high importance of Europa science, the committee recommends further HST observations of Europa. The detailed observing methods and the amount of time to be allocated were considered to be open questions to be decided by the TAC.

The committee recommended that test observations be performed in spring 2017 to characterize several new observing methods, with the data to be obtained by the two existing teams and made public immediately.

The committee recommends a mid-cycle AO for new Europa observations to be obtained in 2018, with proposals to be submitted by the September 30th 2017 mid-Cycle proposal deadline. The amount of observing time to be allocated in this AO is recommended to be in the range of 50-100 orbits, depending on the amount of time that is found to be justified in a review of the proposals. These proposals may include existing and new observing methods, and the test data from spring 2017 are available to the public to assist in proposal preparation.

The STScI may revisit the science and strategy for further observations after the results from the 2018 observations are known.

Appendix A: Committee Charter from 11 Jan. 2017

An Advisory Committee for Hubble Observations of Europa

Jupiter's moon Europa is defined as a priority target for a NASA Flagship mission in the 2013 Planetary Division Decadal Survey, "Vision and Voyages for Planetary Science in the Decade 2013-2022". Observations with the Hubble Space Telescope show evidence for gaseous plumes suggestive of outgassing from the sub-crustal ocean, possibly similar to that observed in Saturn's moon Enceladus. Such plumes may enable a probe to sample Europa's ocean without landing. The activity, however, is at best sporadic: Europa has been targeted for observation on 55 occasions; gaseous plumes have been tentatively detected on only four occasions. Given the potential importance of these observations, the STScI Director is constituting the present committee to provide advice on how Hubble can best support planning for potential future missions.

The committee is chartered to address the following question:

Is there a suite of observations with Hubble that can provide definitive answers on the frequency of outgassing from the Europan ocean and the characteristics of the associated gaseous plumes?

In answering this question, the committee should consider the following issues:

- What are the pros and cons of observations in different instrumental modes?
- What are optimal observing strategies to determine the frequency of active outgassing?

STScI will provide technical support for these inquiries. The committee will report back to the STScI Director by April 2017.