SEARCHING FOR PLUMES AND ONGOING GEOLOGIC ACTIVITY ON EUROPA  C. B. Phillips, Carl Sagan Center for the Study of Life in the Universe, SETI Institute, 189 Bernardo Ave, Mountain View, CA 94043. phillips@seti.org.

Introduction: The recent discovery of an apparent plume erupting from Europa’s surface using data from the Hubble Space Telescope [1] has prompted renewed interest in the possibility of recent or ongoing geologic activity on Europa. Here we summarize previous searches for plumes and changes on Europa’s surface, and make recommendations for future efforts.

Plume searches from the Galileo Spacecraft: While the plume detection by [1] was the first solid evidence for the existence of plumes venting material off the surface of Jupiter’s moon Europa, such plumes were theorized from the Voyager era, when observations were made of Europa’s young, icy surface and of active volcanic activity on Io. No definitive evidence of plume activity on Europa was found during the Voyager mission, however. The Galileo spacecraft provided renewed evidence for the existence of an ocean of liquid water beneath Europa’s icy surface, leading in turn to renewed interest in the possible presence of active venting of material from Europa.

The Galileo spacecraft was in orbit around Jupiter from 1995 to 2003. While Galileo was a capable Flagship-level mission, it had two factors that hindered its ability to search for plumes. First, the available data downlink from the Galileo spacecraft was severely constrained by the failure to deploy of the high gain antenna, resulting in a total Europa data volume from the Solid State Imager (SSI) instrument of less than 1 gigabyte. Second, the SSI instrument had no ultraviolet filter, which might have been more sensitive to scattering from small plume particles. Instead, the shortest wavelength filter on the SSI instrument was the violet filter, with a central wavelength of 0.41 microns. (In comparison, the Voyager spacecraft had a UV filter with a central wavelength of 0.35 microns, but the spatial resolution and number of observations were limited by the flyby trajectory).

Despite the limited available data downlink, we were able to design and implement a few observation sequences from the Solid State Imager (SSI) instrument specifically targeted to search for plumes on Europa. The most comprehensive of these was a 30-image observation taken in 1999 to observe the limb and the dark sky just off the limb in a search for active plumes.

The plume search image sequence is shown in Figure 1. This observation sequence was taken on Galileo orbit E19 in February 1999, and consists of 15 images which followed parallel to the limb, and 15 in the dark sky just off the limb. The 30 images were taken at a resolution of 72 meters per pixel, which is high for Galileo. The images were taken at a Longitude of about 215° and a Latitude range between about 2° S to 15° N. The observation sequence was taken at a high phase angle of about 150° to enhance the probability of plume detection through forward scattering.

The images were carefully analyzed, but no plumes were observed [2]. We found no diffuse glows seen off the limb of Europa, and no anomalously bright regions on the surface. However, despite our attempts to take this observation at a favorable tidal geometry, it was suggested that this image sequence actually occurred under unfavorable tidal stress conditions [3].

In addition to this observation sequence, plume searches were also performed in eclipse images on orbits G7 and C20. In eclipse, we searched for glowing material above the limb of Europa. While this method works well on Io, we again found no Europa plumes.

Change detection on Europa: In addition to looking for active plumes venting material above Europa’s surface, we can also look for new deposits on the surface due to plume fallout. Assuming that the plume material would primarily be composed of water, such surface deposits would most likely be frost patches that at bright at visible wavelengths. The deposit would need to be optically thick to be detectable.

Such plume deposits are readily seen on Io surrounding active volcanoes. Io’s plume deposits vary in color, and these variations are thought to indicate the different chemistry of various volcanoes – we have seen dark flows interpreted to be silicate-rich, bright yellow and red deposits thought to be due to various forms of sulfur, and bright white deposits thought to be due to fallout from plumes rich in SO2 ice.

We have searched for changes on Europa’s surface due to ongoing geologic activity, plume deposits in particular, by comparing images taken by the Voyager spacecraft to later ones taken by Galileo [2]. Such comparisons are aided by the 20-year time interval between the observations, but hindered by the low resolution and areal coverage of the Voyager data.

Our comparison (Figure 2) involves the selection of overlapping Voyager and Galileo images that are as well-matched in resolution, filter, and viewing geometry as possible. We reproject the images to the same map projection, align them using an interactive coregistration process, and take a ratio image to highlight changes. In the case of the Voyager / Galileo comparisons, we found no changes that we could attribute to plume deposits or other signs of geologic activity.

We performed a similar comparison between images taken on different orbits during the Galileo mission, and again found no evidence of ongoing activity. We also used images of Europa taken during the 2007 New
Horizons flyby of the Jupiter system on its way to Pluto, and compared them with simulated surface views of the appropriate hemisphere of Europa from the combined Voyager-Galileo basemap (Figure 3; [4]). While the New Horizons images, taken with the LORRI camera, were at low resolution, similar images of Io did detect changes on its surface due to ongoing volcanic activity – both new dark lava flows and new bright plume deposits were visible on Io. For Europa, however, no surface changes were detected.

**Summary:** Our attempts to detect active plumes or plume deposits on Europa during the Galileo era have so far been unsuccessful. One possibility is that the plumes are episodic in nature and were not active from 1995-2003, but were active in 2012 when detected by [1]. Another possibility is that the plumes are tenuous and leave no detectable surface deposits, at least none observable with Galileo’s ultimately limited spectral resolution and spatial coverage. To aid with plume detection and the search for ongoing surface changes, we suggest that a future mission be equipped with filters which are matched as closely as possible to those on previous missions such as Galileo to ease comparisons, and that the filters include UV if possible. Observations well-matched in lighting and viewing geometry, taken at comparable resolution to our existing observations, will also aid in the search for surface changes.