THE FEASIBILITY OF DETECTING ERUPTIVE VENTING ON EUROPA. Lynnae C. Quick[1], Olivier S. Barnouin[2], G. Wes Patterson[2] and Louise M. Prockter[2]. [1]Dept. of Earth and Planetary Sciences, Johns Hopkins University, Baltimore, MD, lquick5@jhu.edu, [2]Johns Hopkins University Applied Physics Laboratory, Laurel, MD.

Introduction: Resurfacing processes, including (cryo) volcanism, play a key role in maintaining the youthful surfaces of Io, Triton, and Enceladus [1,2,3,4,5,6,7, 8,9]. Europa also has a relatively young surface [9] and previous studies suggest that cryovolcanic processes may be responsible for the production of low-albedo deposits surrounding lenticulae and along triple band margins, ridges and lineae on this distinctive satellite [10, 11] (Fig. 1). Here, we consider the feasibility of spacecraft cameras to detect cryovolcanic venting that may produce these deposits. Our model assumes that plume particles follow ballistic trajectories that are governed by the same physical parameters and equations as those indicated in [11,12]

A variety of factors constrain our ability to detect cryoplumes on Europa, including, timescale of eruptive venting and spacecraft camera exposure time. Using these factors as constraints, we explore conditions under which we might observe eruptive venting on Europa. The results of our model could be employed in the search for cryovolcanic venting on Europa during NASA's planned Jupiter Europa Orbiter Mission [13].

Model: We employ ballistics to determine the velocity of plume particles and plume heights [11,12]. Volatiles may also contribute to plume optical depths at visible wavelengths. However in this conservative model, we consider only the particulate component of potential cryoplumes. We will explore the effects of volatiles on this model in the future.

Using the scattering cross section of particles within a plume, we have computed optical depths for timescales over which plumes might be observed by spacecraft. The scattering cross section of particles within the plume is given by:

$$\sigma_{scattering} = \frac{2\pi^2 K}{\lambda} r_p{}^3 \qquad (1)$$

where $K \approx 1$ [14]. We take λ= 0.6μm, in accordance with a camera that operates in the visible part of the spectrum. The optical depth of the plume is:

$$\tau = (\sqrt{2} H P_{flux} \sigma_{scattering}) t_{\exp} \qquad (2)$$

$t_{\exp}$ is the exposure time, in seconds, of the camera that is observing the plume. P_{flux}, the particle number density flux, is the number of particles in the plume per m^3 per second and is dependent upon the volume of the plume. From the point of view of the spacecraft, the greatest number density of particles, which will control the maximum optical depth, will be in an area surrounding the vent that we reasonably model as a cone (Fig. 2). Assuming that particulates are ejected between 45° and 90°, the maximum extent of observed deposits, R, determines the horizontal scale of the plume, and thus the cone (Figs. 1 and 2).

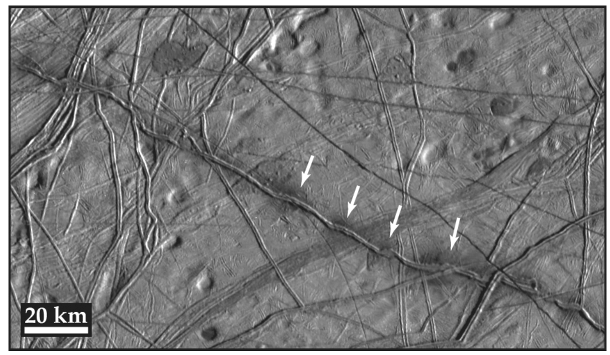

Fig. 1. Dark deposits along Rhadamanthys Linea. Here, the horizontal range, R, of dark deposits is measured from the center of Rhadamanthys to the edge of the deposits on either side of the linear feature. See Fig. 2 also.

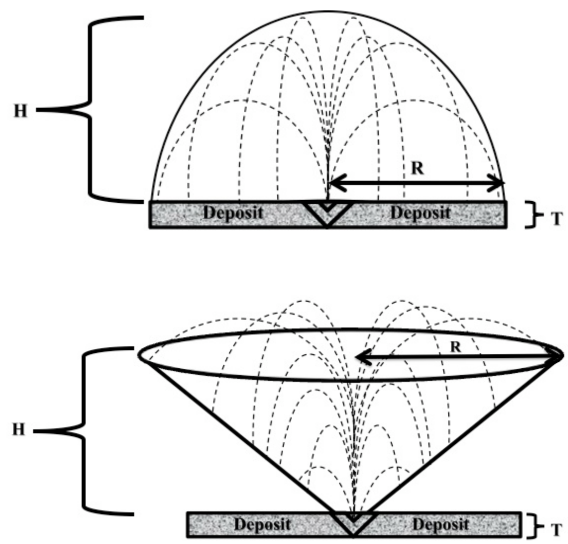

Fig. 2. Top. The ballistic path of plume particles as they leave the vent. H is the maximum height that plumes reach above the surface, T is the thickness of the dark deposit the plume leaves behind, R is the horizontal range of plume particles from the vent. **Bottom.** We approximate the envelope of plume particles to a cone of erupting material that will be visible to spacecraft cameras.

Analysis: To determine reasonable particle number densities of potential cryoplumes, estimates of the densities and thicknesses of low-albedo deposits that may have been formed by these plumes are needed. Most unconsolidated granular deposits, which cryoplumes are likely to form, usually have porosities ranging from 40-50% [15]. Any subsequent coalescence of the grains, which might occur during deposition, would further decrease this porosity. We thus constrain the number of particles in the plumes by assuming that low-albedo deposits will have porosities between 25 and 50%. Based on the dynamic range of Europa's topography [16] and observations that suggest relatively thin plume deposits on Enceladus [3], we expect plume deposits on Europa to be no more than 10 meters thick. However, because direct measurements of the thickness of dark deposits on Europa are not possible at this time, our model considers a range of deposit thicknesses between 1 and 10 meters.

Time of eruption also plays a significant role in the number density of plume particles and hence in the determination of plume optical depth. We have considered cryoplume eruptions that last anywhere between 0.01 and 10,000 years. The minimum optical depth needed to detect cryoplumes on Europa has also been constrained by observations of plumes on Triton [7,17], null observations of the Ionian plume Pele at visible wavelengths [18,19], and minimum values from optical depth models of particles in Saturn's E-ring near the orbit of Enceladus [20]. These studies suggest that plume optical depths must be at least ~ 0.06 for detection at visible wavelengths. Cryoplumes with particle densities of at least $3x10^{-6}$ kg/m^2 have been detected on Enceladus. [3,21]. Conversion of this density to optical depth values confirms that optical depths of at least 0.06 are needed for cryoplume detection. Experiences with New Horizons and Galileo at Io suggest that reasonable spacecraft camera exposure times could range between 0.005 and 50s.

Results: Under these conditions, a plume with R=5km, that leaves behind a 1m thick surface deposit, and is being observed by a camera with an exposure time of 1 second, would have an optical depth ≥0.06 for approximately 10 years. Thicker deposits yield longer possible eruption times, i.e. 100-200 years for a 10-meter thick deposit (Fig. 3). Longer exposure times, on the order of 5-50 s, make the detection of cryoplumes much more likely, while shorter exposure times significantly decrease the probability of detection. Plumes that have been erupting for 10 years or less would be visible to spacecraft cameras with exposure times of at least 1 second. The timescale of visibility increases if we assume that plumes emplace thicker, less porous deposits. Null detections of cryoplumes at Europa's limb by New Horizons at resolutions of 12-15km/pixel suggest that reasonable plume heights must be less than 30 km [12]. Therefore, observations of Europa's limb at resolutions greater than 500 m/pixel may be necessary for their detection.

The potential for cryoplumes with low vertical extents on Europa suggests that the best chance of observing eruptive venting would occur if we continuously observed specific areas on the surface at resolutions on the order of a hundred meters per pixel, with exposure times between 0.5 and 1 seconds for at least one to two months (Fig. 3), in areas where dark deposits have previously been observed.

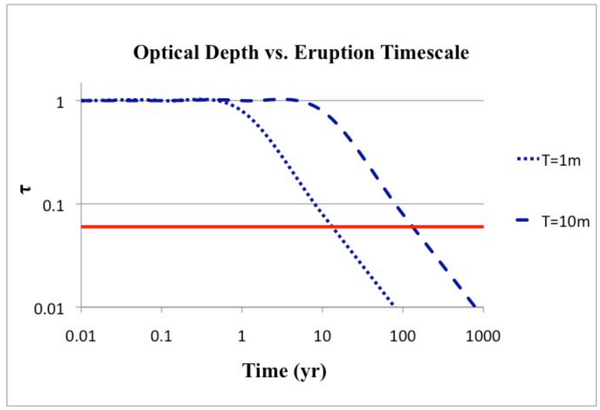

Fig. 3. Plot of optical depth as a function of eruption timescale constrained by thickness of deposits plumes leave behind. Here, plume particle porosity is 25% and t_{exp}= 1s. The horizontal line at $\tau = 0.06$ represents the lowest optical depth at which plumes would be visible to spacecraft cameras at visible wavelengths. Logarithmic scales have been used on both axes.

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