EPSC Abstracts
Vol. 9, EPSC2014-265, 2014
European Planetary Science Congress 2014

Simulation of Europa's water plume

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Abstract

Plumes on Europa would be extremely interesting science and mission targets, particularly due to the unique opportunity to obtain direct information on the subsurface composition, thereby addressing Europa's potential habitability.

Our aim is to simulate an icy plume on Europa to understand if it could be detectable from ESA's JUICE mission, and in particular from JANUS camera.

1. Introduction

Surface venting is quite common on some outer solar system satellites, as Io and Enceladus, and spacecrafts have observed plumes erupting from their geologically young surface. Europa also possesses a relatively young surface [1], and it has been proposed that many of its surface features are a result of material emplaced via ballistic cryovolcanism (i.e. plumes) [2]. These plumes have been long hypothesized but they were never directly observed until recent discoveries. In fact, spectral images taken by Hubble's Space Telescope Imaging Spectrograph (STIS) taken in 2012 revealed first signs of active water vapor plumes at Europa's south pole [3]. The origin and evolution of plumes and whether or not they are currently active remain unanswered questions. In order to explore the plausible plume detection, we simulate an icy plume on Europa to estimate possible plume characteristics under a variety of conditions. We expect to obtain constraints on imaging requirements necessary to detect potential plumes that could be useful for ESA's JUICE mission, and in particular for the JANUS camera [4].

2. Background

Voyager 1 obtained the first observations of active extraterrestrial volcanism while imaging Io [5] and observations by multiple instruments on Cassini revealed that Enceladus has cryovolcanic plumes that consist of both particle and vapor component [6]. The young surface of these moons may be indicators of volcanic resurfacing accompanied by plume activity.

Europa also has a relatively youthful surface, which cratering statistics suggest is no more than 60 Myr old [7]. The presence of such young surface suggests that Europa has undergone resurfacing in current geological time. Furthermore, with its subsurface water ocean and relatively young icy surface Europa is generally considered a prime candidate in the search for present-day habitable environments in our Solar System. The existence of water plume on the Jupiter's moon Europa has been long speculated until the recent discover. HST imaged surpluses of hydrogen Lyman alpha and oxygen emissions above the southern hemisphere in December 2012 that are consistent with two 200 km high plumes of water vapor [3]. Non-detections in previous observation campaign suggest that plume activity is a highly variable phenomenon.

In previous works ballistic cryovolcanism has been considered and modeled as a possible mechanism for the formation of low-albedo features on Europa's surface [2]. There have been several plume models over the last few decades and our work agrees with the model of [2] even if we consider that material falling after a cryovolcanic plume consists of snow, so we expect to observe high albedo regions in contrast with the background albedo of Europa surface.

3. Method

To simulate an icy plume we assume that particles follow ballistic trajectories and we neglect loss processes of particles. We consider a launch angle cone of particles between 45° and 90° fixing at the beginning a single ejection velocity equal to 200 m/s. This velocity allows particles to reach a maximum range of 30 km and a maximum height of 15 km in agreement with the estimates reported in [2]. Assuming ballistic trajectories for plume particles, the radius of the deposit is defined as:

$$\boldsymbol{R} = \frac{\boldsymbol{v}^2 \sin \boldsymbol{2\vartheta}}{\boldsymbol{g}} \tag{1}$$

where g is the gravity acceleration of Europa, 1,1314 m/s^2. In the Fig. 1 it is shown the landing site particles distribution, or the deposit, that is thicker at the outer edge than in the centre because many launch angles nearly reach the maximum distance. From the particles deposit we will able to estimate its thickness assuming a certain water production rate, the ice density and particle size equal 1µm, in agreement with the range of sizes of plumes particles on Enceladus.

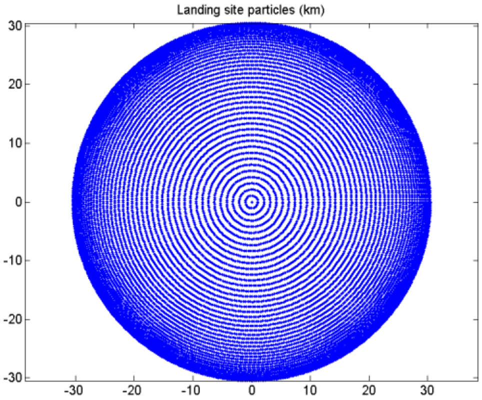

Fig. 1 Landing site particles distribution

Since a single ejection velocity is not a realistic assumption, we assume a Maxwellian velocity distribution of the particles that ranges from 100 m/s to 500 m/s.

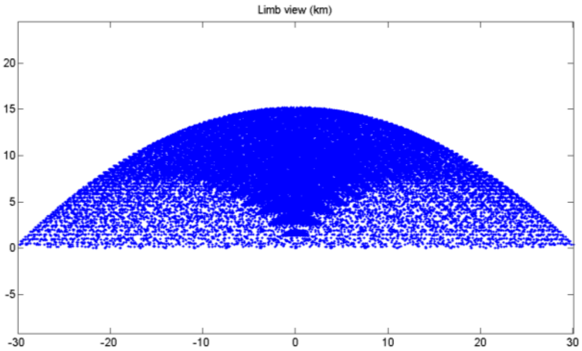

Fig. 2 Limb view of the plume

Furthermore, we have to consider also the limb view of the plume because, even if this detection requires optimal viewing geometry, it is easier detectable in principle against the dark sky (Fig. 2).

4. Results and future works

We expect that the particles deposit is brighter than the Europa surface and so it could be detectable from spacecraft images. We are at the beginning of our simulations and we have to insert other fundamental assumption in our model, as the introduction of the optical thickness that give us further information of the characteristics of the plume. Our purpose is to understand if this feature is detectable from JANUS, the camera on board JUICE mission. In the next future we will be able to compare our results to the technical characteristic of the JANUS instrument considering for example the pixel scales of the different phases of the JUICE mission, in particular the Europa flybys phases.

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