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# Crater Size Distributions on the Jovian Satellites Ganymede and Callisto: Reassessment of Galileo and Voyager Images, and an Outlook to ESA's JUICE Mission

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## Abstract

The investigation of crater size-frequency distributions on icy satellites has raised intense debates between various groups of investigators about the nature and origin of potential impactor families and cratering chronologies (e.g. [1], and ref's therein). For the Galilean satellites of Jupiter, incomplete image coverage by the cameras aboard Voyager and Galileo impedes to decipher the full cratering record of these bodies. ESA's JUICE mission to Jupiter will provide an excellent opportunity to obtain global high-resolution coverage by the JANUS camera while in orbit about Jupiter's largest moon Ganymede, and during several flybys at Callisto and Europa [2][3]. In this paper we review the current knowledge of the cratering record of the Galilean satellites Ganymede and Callisto and discuss strategies for crater investigations by JUICE.

## 1. Introduction

The primary goal of measuring crater distributions is to obtain information on stratigraphy, chronology, and geologic evolution of a planet or satellite (e.g. [4]). Using crater frequencies on a given surface as a measure for geologic time sounds simple – however, the procedure needs careful consideration to use them as a stratigraphic tool. In this work, we will address the following topics, listed approximately in order of increasing uncertainty: **(1)** Are crater distributions on the Galilean satellites *similar or different from lunar distributions* ? **(2)** Do the most densely cratered surfaces represent *production distributions*, or are they *equilibrium distributions* ? **(3)** Were the Galilean satellites *isotropically cratered*, or do they show *variations in crater frequency* dependent of the distance to the *apex of orbital motion* ? **(4)** Are crater distributions *stable through time* ? **(5)** Are small craters (D < ~ 1 km), mostly *secondaries or primaries* ? **(6)** What is the *cratering rate* on each satellite and its time dependence ? In this work we focus on topics (1) to (5) which are prerequisite to extract **relative ages** from measurements of crater frequencies.

## 2. Cratering record from Voyager and Galileo SSI imaging data

### 2.1 Moon versus Galilean satellites

Our measurements in the most densely cratered units on Ganymede and Callisto show a complex shape rather similar to lunar highland distributions, from crater sizes D ~ 20 m up to ~ 200 km (e.g. [5]). This strongly implies that the craters on the Galilean satellites were formed by impactors from a *collisionally evolved projectile family* – either supporting Main Belt asteroids (MBAs) as preferential impactors (e.g. [5]), or inferring collisional evolution in outer Solar System bodies, e.g. Kuiper Belt Objects (KBOs). These similarities allow that crater distributions on the Galilean satellites can be fitted by the lunar production function polynomial, empirically shifted to impact conditions on Ganymede or Callisto [6] (*Fig. 1*). The cratering record at the smallest sizes (D << 100 m) is not very well known due to insufficient imaging by Galileo SSI. At the largest diameters (D > 100 km), many basins were found to be highly degraded; a significant number of them therefore may have been lost from the cratering record (e.g. [7]).

### 2.2 Production versus equilibrium distributions

The complex shape of crater distributions indicates that most of them are production distributions.

Furthermore, highest crater densities on Ganymede and Callisto were shown to be factors of 2-4 lower than densities in the lunar highlands [6]. In some localities on Callisto, however, equilibrium distributions characterized by a cumulative -2 slope were measured at kilometer-sized craters.

### 2.3 Apex-antapex variations

We found no evidence for an apex-antapex variation in crater frequency on Callisto or Ganymede – provided that crater distributions are production distributions, as has been shown (sec. 2.2). This implies that either the majority of projectiles were impacting from planetocentric orbits, or, alternatively, Ganymede and Callisto have rotated non-synchronously during a period of heavy bombardment.

### 2.4 Stability with time

Imaging data currently available from the Galilean satellites are not sufficient to investigate any significant changes in the slope of crater distributions which indicates changes in the impactor population. For Ganymede, the impactor population appears to have been stable with time for the two major geologic units, at least from the record of craters ranging from ~ 2 – 100 km (*Fig. 1*).

### 2.5 Primary versus secondary craters

Clusters and rays of secondary craters with D < 1 km are well distinguishable and can be excluded from crater measurements to avoid contamination of measuerements with secondaries. However, lack of sufficient coverage at high resolution impedes to identify primary source craters.

## 3. Outlook to the JUICE mission

For the first time, JUICE will take the opportunity to investigate an icy satellite in the outer Solar System from orbit under fairly stable viewing conditions. These observations will help to carry out crater size-frequency measurements, based on detailed global geologic mapping at various spatial resolutions down to highest resolution (e.g., meter per pixel resolution). Potential primary source craters for secondaries can be more easily identified since global imaging at high spatial resolution provides the geologic context. Highly degraded basins and large craters can be located with the help of stereo information [8], supported by laser altimetry data obtained with the GALA instrument, in order to complete investigating the cratering record at the largest sizes.

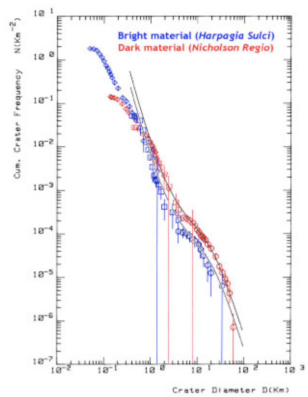


**Figure 1:** Examples for crater distributions of the two major geologic units on Ganymede: younger bright material (blue) and older dark material (red). Measurements in Voyager data for craters with diameters D > 2 km and Galileo SSI data for D < 2 km. Curve shown is the lunar production function (explanation given in text, sec. 2.1).

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