THE APEX-ANTAPEX CRATERING ASYMMETRY ON JOVIAN SATELLITES: IMPLICATIONS FROM RAY CRATERS ON CALLISTO AND GANYMEDE

L. Y. Xu[1], H. Miyamoto[1] and N. Hirata[2], [1]The University of Tokyo, Hongo, Tokyo 113-8565, Japan (luyuanxu@seed.um.u-tokyo.ac.jp), [2]Kobe University.

Introduction: The definite sources of impactors on Jovian satellites are still uncertain. Zahnle et al. [1-2] summarized the possible origins as heliocentric comets (centered by the Sun) and planetocentric debris. Heliocentric comets are furthermore classified as ecliptic comets, which mainly come from Kuiper belt, and nearly isotropic comets (NICs), which primarily come from Oort cloud. Most of the impactors on Jupiter are currently recognized to origin from ecliptic comets in their studies.

Apex-antapex cratering asymmetry is an important indicator for determining the sources of impactors. For a synchronously rotating satellite, heliocentric comets preferentially hit the leading hemisphere. As a result, a strong decreasing apex-antapex asymmetry (e. g. a factor of ~70 for Ganymede and ~40 for Callisto) is theoretically expected under the assumption of ecliptic comets origin. However, none of the observations on Jovian satellites show such a strong tendency. Schenk and Sobieszczyk [3] and Zahnle et al. [1] examined all craters using Voyager and Galileo image data and reported that Ganymede exhibits a slight apex-antapex (~4) asymmetry on the bright terrain, while Callisto shows no obvious asymmetry. In the case of Io and Europe, no impact craters identified on Io, and scarcely found on Europa because of their endogenic activities caused by tidal heating [4].

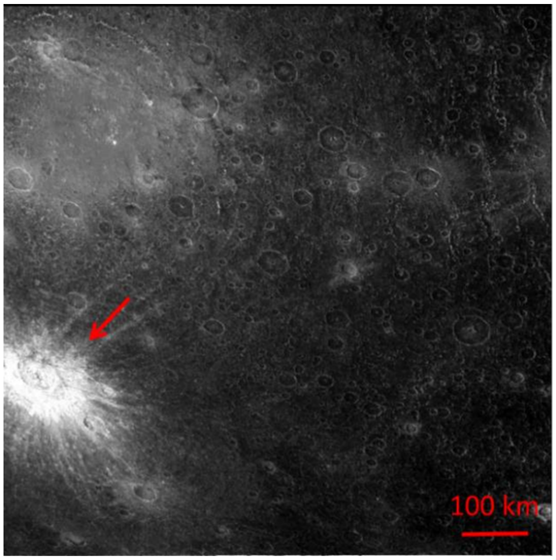

Figure 1. Galileo image (ID: 0368293101R) showing a large bright ray crater Burr, located inside the multi-ring structure Utgard, and neighboring the second largest multi-ring structure Asgard on Callisto.

Ray craters, the impact craters surrounded by radial ejecta patterns with relatively higher albedo (Figure 1), are recognized to be the youngest features on a planetary body [5], and thus the distribution of ray craters serves as a more accurate indicator for studying the sources of recent impactors than that of all craters. However, no decreasing asymmetry have been identified on any of the Jovian satellites at all. Passey and Shoemaker [6], by examining Voyager images, reported an increasing asymmetry on Ganymede and no obvious asymmetry on Callisto. Also, there are no ray craters on Io and few ray craters on Europa for the same reason of endogenic activities [4].

Data and Methods: We measured the locations and diameters of ray craters as well as the related areas using the global maps of Callisto and Ganymede. These maps, available via USGS Astrogeology Science Center, were mosaicked by combining Voyager and Galileo images with a global resolution of 1 km/pixel. Since the crater rays are sensitive to photographic conditions, we carefully examined the raw images of both Voyager and Galileo data and excluded those with unsatisfactory solar and emission angles. These raw images are available via Planetary Data System of NASA.

The identification of ray craters was based on their circular raised rims accompanying bright albedo rays that extend radially from the center of the craters (Figure 1). Considering the resolution of the raw images, we only measured the ray craters with D > 10 km within the region of resolution higher than 5.0 km/pixel for Callisto and higher than 4.0 km/pixel for Ganymede. Ultimately, we obtain unbiased density distributions of ray craters on Callisto and Ganymede corresponding to angular apex distances and varying resolutions.

Apex-antapex cratering asymmetry on Callisto and Ganymede: Although the Galileo images still do not provide reliable observations near apex and antapex regions of Callisto, the same case as the previous observations of Passey and Shoemaker [5], the revised density of ray craters (D > 10 km) under varying resolutions prominently decreases with increasing angular apex distances on Callisto (20-160°, Figure 2) and on the bright terrain of Ganymede (Figure 3). Considering the density of all craters on Callisto shows no asymmetry [1, 3], the density distributions of ray craters demonstrate that the apex-antapex cratering asymmetry does exist on Callisto as well as Ganymede, and the older craters (without rays) on Callisto lost the asymmetry distribution because of various possible reasons such as crater saturation or/and nonsynchronous rotation.

Comparisons between Callisto and Ganymede: The distribution of ray craters on Callisto shows significant distinctions to that on Ganymede. 1) Contrary to the distribution of ray craters on the bright terrain of Ganymede, whose trends to angular apex distances are size-dependent [7], the density of ranging sizes of ray craters on Callisto uniformly decreases with increasing angular apex distances. 2) The degree of asymmetry of ray craters on Callisto is similar to that on the bright terrain of Ganymede, and the decreasing curve is less scattered [6], although Callisto is expected to have a lower degree of cratering asymmetry than Ganymede because of its relatively lower orbital velocity (8.2 km/s for Callisto and 10.9 km/s for Ganymede). These suggest that Callisto, compared to Ganymede, suffered milder preferential surface alterations which are dependent on crater sizes, latitudes and angular apex distances.

Implications for Jovian system by combined analyses of Callisto and Ganymede: We found that in both cases − the density of ray craters (D > 10 km) on Callisto in this study, or the results of ray craters (D > 25 km) and all craters (D > 10 km) identified on the bright terrain of Ganymede [7] − they exhibit much lower degree of asymmetries than the theoretical estimation of Zahnle [1] for ecliptic comets. Therefore, we propose that nearly isotropic comets, instead of ecliptic comets, may be the dominant impactors on Jovian system, at least for the large craters (D > 25 km).

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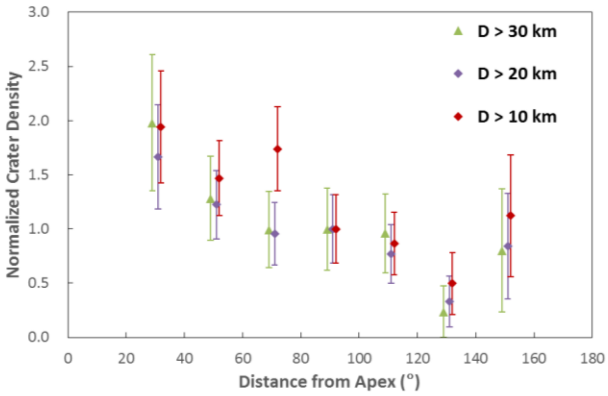
References: [1] Zahnle K. et al. (2001) Icarus, 153, 111–129. [2] Zahnle K. et al. (2003) Icarus, 163, 263–289. [3] Schenk, P. and S. Sobieszczyk (1999) AAS, 31, 1182. [4] Zahnle et al. (1998) Icarus, 136, 202-222. [5] Shoemaker E. M. et al. (1982) Satellites of Jupiter: 435-520. [6] Passey Q. R. and Shoemaker E. M. (1982) Satellites of Jupiter: 379-434. [7] Xu L. Y. et al., in preparation.

(a) Callisto (Res < 2.0 km/pixel)



(b) Callisto (Res < 5.0 km/pixel)

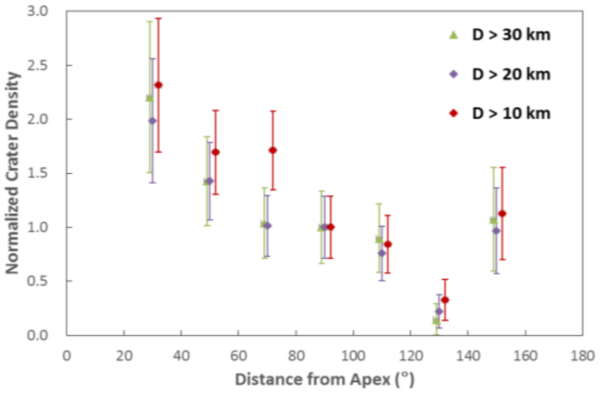
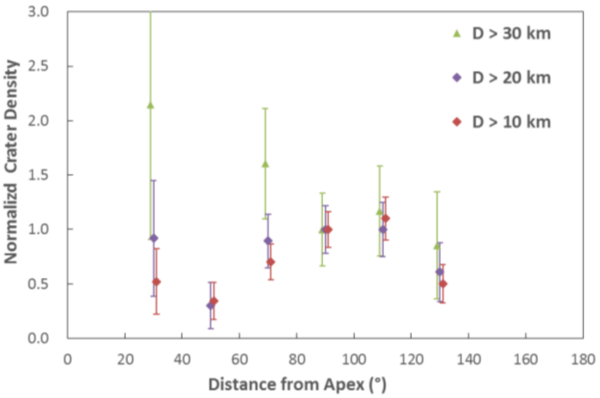


Figure 2. Normalized densities of ray craters on Callisto as a function of the distance measured in degrees from the apex of motion for areas of varying resolutions. The error bars are defined by ±density * $N^{-0.5}$

(a) Ganymede (Res < 2.0 km/pixel)



(b) Ganymede (Res < 4.0 km/pixel)

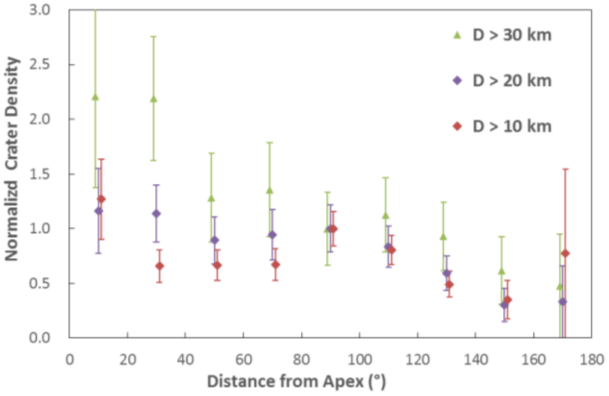


Figure 3. Normalized densities of ray craters on the bright terrain of Ganymede as a function of the distance measured in degrees from the apex of motion for areas of varying resolutions. The error bars are defined by ±density * $N^{-0.5}$