CHARACTERIZING RAYED CRATERS ON MERCURY AND GANYMEDE.

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Introduction: Crater rays are among the most conspicuous features on the Moon, Mercury, and large icy satellites. These distinctive radial to sub-radial lineaments typically extend hundreds of kilometers from their source craters, and are readily identified by a contrast in albedo with respect to the underlying surface materials, especially when viewed at low phase angles (Fig. 1). Rayed craters constitute a group of impact structures least affected by subsequent geological processes. Shoemaker and Hackman [1] first suggested that rayed craters are the youngest of a planetary body's impact features because they superpose all other terrains.

Recently, observations by the MErcury Surface, Space ENvironment, GEochemistry, and Ranging. (MESSENGER) spacecraft have shown that Mercury is extensively cratered globally, with large-scale variations in crater density demarcating terrains by age. Yet its youngest population of impact craters, i.e., its rayed craters, has been little studied so far. Here, to obtain the overview for those craters in the inner and outer Solar System, we present the first comprehensive global catalog of rayed craters on Mercury and Ganymede. We then compare these data with prior studies of rayed craters on the Moon, Mars, Iapetus, Mimas, Dione, and Rhea [2–7], to better understand the similarities and differences in the formation of rayed craters across the Solar System.

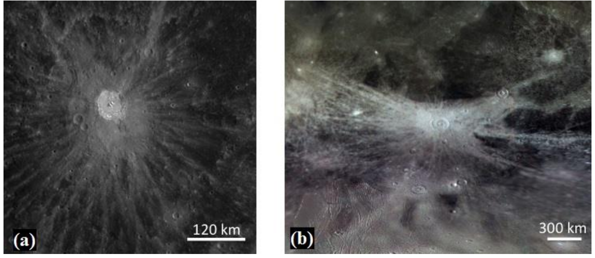

Figure 1: *(a) Kuiper crater on Mercury (62 km in diameter)located at 11°S 31.5°W (b) Rayed crater on Ganymede (143 km in diameter)located at 39.19°S 85.51°W*

Methods: We surveyed the total populations of rayed craters on Mercury (with the MESSENGER 250 m/px and 665 m/px global monochrome and 8-color mosaic base maps, respectively) and on Ganymede (with 1000 m/px global monochrome and color base maps).

We searched the image data for craters that exhibit rayed ejecta with higher albedo than the surroundings extending for multiple crater radii. The rims of positively identified craters ≥2 km in diameter (the limit of our lowest-resolution data) situated between 60°N and 60°S were mapped with Arcmap. Beyond these latitudes, polar projections were used to obtain accurate diameter measurements without projection-induced distortions. In addition to diameter, we recorded rayed crater location (i.e., center latitude and longitude), diameter, crater morphology and bright/dark ray lengths.

Results: We mapped 160 rayed craters on Mercury and 48 on Ganymede. On Mercury there is no clear longitude dependence for craters distribution but the longest rays are located around 0° longitude. On Ganymede, we find that 63% of rayed craters are located on the trailing hemisphere. Ganymede's longest rays are located at -90° longitude. The low number of rayed craters identified near/at the poles (four (~8%) on Ganymede and five (~3%) on Mercury) may result from low solar illumination angles, that make crater identification difficult.

Fig. 3 shows both (i) cumulative crater frequency versus diameter and (ii) R *(number of diameter to the power of three, divided by number of craters multiplied by counted area*) versus diameter plots of our rayed crater catalogs compared with rayed craters on Mimas, Rhea, Dione, Tethys, Mars and the Moon. On Mercury, we also cataloged 461 bright halo craters (which, like rayed craters, are also thought to be relatively young). Mercury rayed craters and craters with bright halos fall into two different populations (Fig. 3). We also found evidence of rays that are kinked, i.e., are not monotonically radial to a suspected source crater, but the reason for this appearance remains unclear.

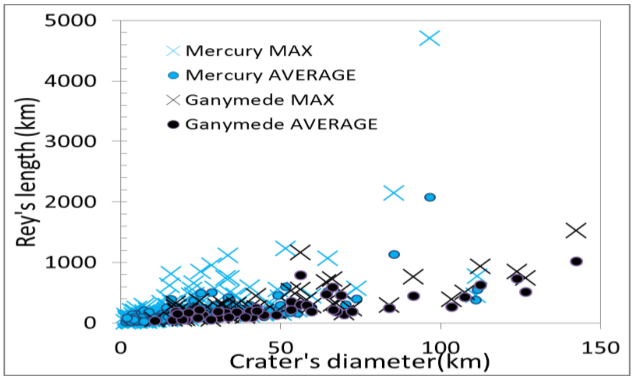

Figure 2: *Diameter vs. length of rays measured on Mercury and Ganymede. Purple squares represent average ray lengths and green diamonds represent maximum ray lengths.*

Ray Lengths: On both Mercury and Ganymede, we found no clear dependence of maximum or average ray length on crater diameter (shown in Fig. 2). On both bodies, rays have similar length distributions. The crater Hokusai with the longest rays (~4,700 km) is located in Mercury's northern hemisphere. Nevertheless, Ganymede has substantially more rayed craters with diameter larger than 60 km. This difference may indicate that rays are erased at different rates on Ganymede than on Mercury, and/or that the population of late-stage impactors in the outer Solar System is different than that at Mercury.

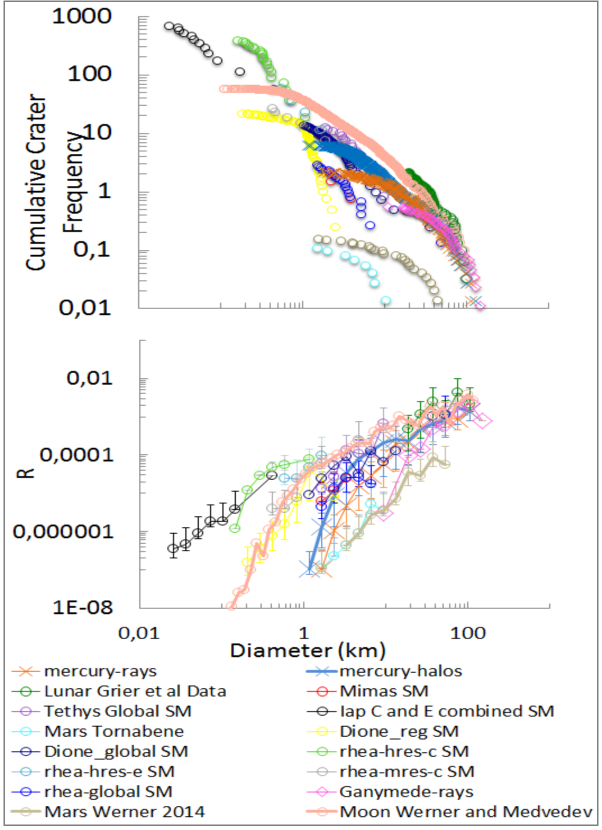

Figure 3: *Top - Cumulative crater frequency vs diameter, Bottom - R vs. diameter comparative plot*

Discussion: We compared our results (in color) with those of Strom et al. [8] (in black) and presented them in Fig. 4.They proposed that young plains surfaces (Mars Young Plains) have a flatter distribution than old surfaces (Mars Old Plains). Our results, combined with data for rayed craters from the Moon and craters on icy moons (including the population of craters on young Europa's surface), show indicate quite the opposite: steeper slope for younger populations. This may indicate steeper production function in current impactor flux.

Great debate has arisen as to the source and flux of comets (and asteroids), the impact of which on these bodies is the sole means of estimating surface ages.

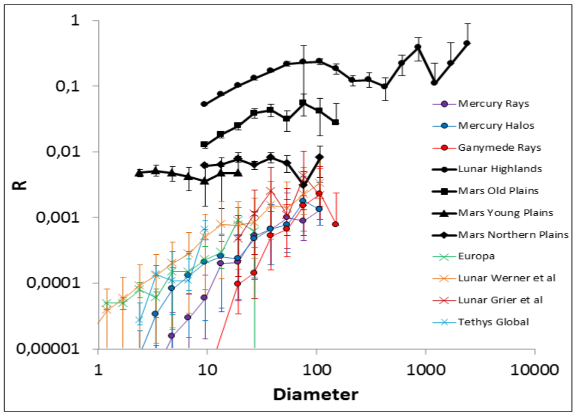

Figure 4*: Crater distribution from Strom et al. compared with our results*

For a moon orbiting one of the outer planets, Zahnle, K. et al. [9] calculated that cratering rates by a heliocentric impactor population should be much greater (by 10–40 times) on the leading than the trailing hemisphere. Conversely, a planetocentric impactor population (dominated by secondary projectiles launched into Saturn orbit from these moons) will mostly return to the originating satellite [10]. Models show a weak 1:2 global cratering asymmetry for this "sesquinary" population, in favor of the hemisphere opposite the original source basin [10]. Such leading/trailing asymmetries in crater distribution have also been observed on Neptune's moon Triton [e.g., 9, 11, 12]. Schenk, P & S.W. Murphy [4] found that Dione and Tethys show considerable enhancement in rayed crater density on the leading hemispheres by a factor of ~4, and a similar enhancement on Rhea (by a factor of 1–2). The factor of 1.67 greater density of rayed craters on the leading side of Ganymede that we find is less than that predicted [10], less than that observed for craters on outer Solar System moons generally, and much less than predicted for heliocentric projectiles [9]. This discrepancy could be from different rates of surface alteration and ray erasure on the trailing and leading hemispheres on Ganymede, which are unknown. Further, small ray crater systems could fade much faster than larger ones.

References: [1] Shoemaker, E.M., and Hackman, R.J., (1962). [2] Tornabene L. L. et al. (2006). [3] Werner, S. et al (2014). [4] Schenk, P & S.W. Murphy, (2011).[5] Grier, J. et al. (2011). [6] Werner, S. & Medvedev, S. (2010. [7] Herrick R. et al. (2011). [8] Strom, R. G. et al. (2005). [9] Zahnle, K. et al. (2001). [10] Alvarellos, J. et al (2005). [11] Shoemaker, E.M. et al (1982). [12] Schenk, P. & Sobieszczyk, S. (1999).