

**Introduction:** The size-frequency distribution (SFD) of Solar System objects is diagnostic of the formational and collisional history of those objects. As smaller objects impact larger ones, craters form which can be used to infer the impactor population through the use of various scaling laws. The lunar crater population is well studied and forms the basis and model for inner solar system bodies, while near-Earth asteroids (NEAs) provide a present-day comparison population. Combined, these can be used to model the main asteroid belt’s (MBA’s) SFD (e.g., [1]).

The outer solar system (OSS) likely underwent a distinct collision and dynamic history, which should be reflected in differences in the SFD of impact craters and small bodies that formed them. However, the OSS is much more difficult to observe: Many fewer spacecraft have imaged solid OSS surfaces, and ground- or near-Earth-based telescopic surveys of comet nuclei are much more difficult than asteroid surveys reaching down to the same size.

Recent advances from telescopic surveys (e.g., [2-3]) have offered at least two independent estimates of the SFD of Jupiter-family comet (JFC) and short- and long-period comet (SPC, LPC) nuclei from the Kuiper Belt. Independently, NASA’s New Horizons spacecraft in the past five years has provided unprecedented imaging of Pluto, Charon, their satellite Nix, and Kuiper Belt Object (KBO) Arrokoth that spatially resolved impact craters. The Pluto-Charon system provides an important crater population because the giant planets’ satellite systems likely exchange material, such that their crater populations are likely contaminated by planetocentric impactors.

This work seeks to answer two very broad questions: Given these recent surveys and spacecraft data, (1) is there convincing evidence for distinct inner and outer solar system impactor populations, and (2) is there convincing evidence that the cometary SFD is the source of OSS impact craters?

**Inner Solar System and Asteroids:** Numerous datasets need to be assembled.

**Mercury:** The most complete Mercury crater database [4] was designed to eliminate secondary impact craters. However, examination shows that that effort might have eliminated too many craters, for the SFD shows a substantial decrease – instead of maintaining – the slope at crater diameters where secondary impacts are thought to dominate. Therefore, we have measured impact craters in a few young regions of Mercury and similarly attempted to exclude secondaries.

**Moon:** Maria unit craters were extracted from [5]; a general, spoken (uncitable) rule-of-thumb for lunar impacts is that secondaries tend to dominate near \(D \approx 1–3\) km, so craters \(D < 3\) km were removed.

**Mars:** The largest Mars crater database is outdated relative to modern imagery, so we used new, unpublished data in young, Amazonian terrains, assembled from CTX imagery that excluded secondary impacts. This database should be complete to \(D \geq 0.75\) km.

**Vesta:** Data from both [6] and [7] do not match other crater data (Fig. 1) and we are investigating this.

**Ceres:** Unpublished data from [8] was used that had a stated completeness limit of 1 km; to be conservative, we clipped this dataset at \(D \geq 2\) km.

**NEA:** Data from [9] was used.

**MBA:** The latest models based on [1] were used.

**ISS Results:** Preliminary analysis in Fig. 1 shows an RSFD normalized such that the different crater and impactor populations are visible in a narrow vertical range. From this preliminary work, most of the different bodies show the same basic trend, indicating a similar source-impact population. The primary outlier is Vesta, which we are further investigating.

**Outer Solar System Craters:** For this work, we chose to focus on well-imaged craters in the Saturn and Pluto-Charon systems, in addition to Arrokoth.

**Mimas, Iapetus, Rhea:** Craters by [10] were used, which are complete for \(D \geq 3\) km, 3 km, and 1 km in regions they cover, respectively. The best coverage around Inktomi crater on Rhea was removed to avoid secondary craters, and there is no good evidence of resolved secondary crater populations elsewhere on these bodies.

**Tethys, Dione:** Craters by [11-12] were used, which should be complete for \(D > 5\) km.

**Charon:** To avoid resurfacing effects on Pluto, Charon’s craters on Vulcan Planum were used based on new counts which closely match those by [13]. The counts should be complete for \(D \geq 3\) km.

**Nix:** Craters from [14] were used which should be complete for \(D \geq 1–2\) km.

**Arrokoth:** Craters from [15] were used which, based on the highest spatial scale imaging, should be complete down to \(\sim 100\)s of meters. Completeness estimates are important to understand.
Some researchers have based completeness upon a SFD transition to shallower power-laws based on the ISS, where the SFD is well known to continue with a $\approx 3$ power-law slope (differential SFD) from kilometers through meters of size. When using this assumption for Saturnian system craters, completeness limits have been placed near $D \approx 5$–$10$ km. However, using a limit of $\approx 8$–$10$ pixels, completeness would be closer to $\approx 1$–$3$ km.

**Comets— JFCs, SPCs, LPCs:** Today’s JFCs likely originated from scattered KBs that were once in the trans-Neptunian region. There have been many recent attempts to measure the JFC SFD based on telescopic surveys. Most attempts have derived sizes using optical photometry of sunlight scattered by the nucleus and an assumed albedo, but newer work using Spitzer and WISE infrared photometry can directly measure sizes, for thermal emissivities vary little. The IR studies demonstrate cometary SFDs are different from inner solar system asteroid and crater SFDs: Asteroid SFDs follow a reasonably constant power-law at diameters from $\sim 10$ km to at least $\sim 10$ m. By contrast, the JFC SFD appears to have an inflection point to a shallower SFD slope starting at $\sim 1$–$4$ km. However, de-biasing these surveys based on observational limitations is difficult, and past authors have tended to propose ad hoc mechanisms for removing small nuclei to reconcile the SFDs. However, *is this necessary?*

For our comparison to the OSS crater population, we used the JFC survey from [2] coupled with the SPC and LPC survey from [3] – two independent surveys that arrived at similar observed SFDs. However, like OSS craters, some authors have assumed that some form of SFD de-biasing is needed in order to match the inner solar system or asteroid SFDs.

**Outer Solar System Synthesis:** Figure 2 shows a preliminary synthesis of the OSS comet and moon SFDs. Regarding the general SFD shapes, the Saturnian satellites follow similar SFDs, though the shallower slopes (that some interpret as completeness issues) are different. However, Charon, Nix, and Arrokoth have extremely similar – and shallower – slopes that closely match Mimas and Iapetus. Additionally, the comet slopes are similar to the shallow SFD components of these three bodies. The mismatch at $\sim 10$s of km crater diameters vs comets that would produce $\sim 10$s of km craters is still a subject we are investigating.

However, this clearly demonstrates not only that the shallow slopes on Saturnian satellite crater populations is likely real, but by extension, the Charon, Nix, and Arrokoth data indicate that comet surveys likely are sampling the true SFD on $\sim$km-scale nuclei.

**Ongoing Work:** At the LPSC2020 conference, we expect to have more accurate scaling between craters and impactors, and to have more quantitative comparisons between the different populations.