# COMBINING SATURNIAN CRATERS AND KUIPER BELT OBSERVATIONS TO BUILD AN OUTER SOLAR SYSTEM IMPACTOR SIZE-FREQUENCY DISTRIBUTION.

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**Motivation.** Recently, it has been suggested that there are two distinct populations of small bodies responsible for the majority of impact craters on inner solar system [1]. These two populations are distinguished by the size-frequency distributions (SFDs), and through impact crater scaling relationships it was shown that SFDs of ancient craters appear to match the expected SFDs of impactors originating in the Main Asteroid belt, while young craters appear to match that of the Near Earth Asteroids. In contrast, the cratering record of outer solar system bodies has proved more difficult to understand.

Here we use results of a powerful new tool, the Cratered Terrain Evolution Model (CTEM) [2], to illuminate the outer solar system impactor population. Using *Cassini* mission imagery of the icy satellites of Saturn (see Richardson et al., this meeting), we show that both ancient and young terrains on these icy satellites were bombarded by a common, heliocentric impactor population. Using N-body simulations of a model Main Asteroid Belt [3], as well as a model of the Scattered Disk subpopulation of the Kuiper belt [4], we show that the most likely source region of impactors in the saturnian system is the Kuiper Belt. We therefore use observations of the Kuiper belt luminosity function in combination with our derived size-frequency distribution of icy satellite impactors to produce a model Kuiper belt SFD that spans from tens of meter-sized comets up to thousand kilometer-sized Dwarf Planets such as Pluto and Eris. We apply our model Kuiper Belt SFD toward the development of a new impact crater chronology for the outer solar system.

**The scaled impactor size distribution from craters on icy satellites of Saturn** Using CTEM and crater counts based on imagery data from the *Cassini* mission, we are able to derive a common size frequency distribution for heliocentric impactors onto icy satellites of Saturn (see Richardson et al., this meeting for more details). Based on our N-body simulation results, we assume that this common population originates in the scattered disk of the Kuiper belt. Like the main asteroid belt SFD, the derived Kuiper belt SFD can best be described as "wavy," but its the shape is distinguishable from that the main asteroid belt (see Figs. 1 and 2). The wavy shape can be approximated as a broken power law, with $N_{>D} \propto D^{-q_i}$, where $q_i$ is the logarithmic slope of the cumulative size distribution in the range of $D_i < D < D_{i+1}$ There is a distinct transition at impactor size $\sim 15$ km between a steep slope ($q \sim 3.5$ for $1 \text{ km} \lesssim D \lesssim 15 \text{ km}$) to a shallow slope ($q \sim 1.0$ for $15 \text{ km} \lesssim D \lesssim 60$ km, with an uncertain upper bound on diameter due to poor crater statistics). The increase in the relative abundance of larger impactors above the steep-to-shallow transition of impactors at $\sim 15$ km may be responsible for some distinct and seemingly unusual large basins on small satellites, such as Herschel on Mimas, Odysseus on Tethys, and the largest basin on Hyperion.

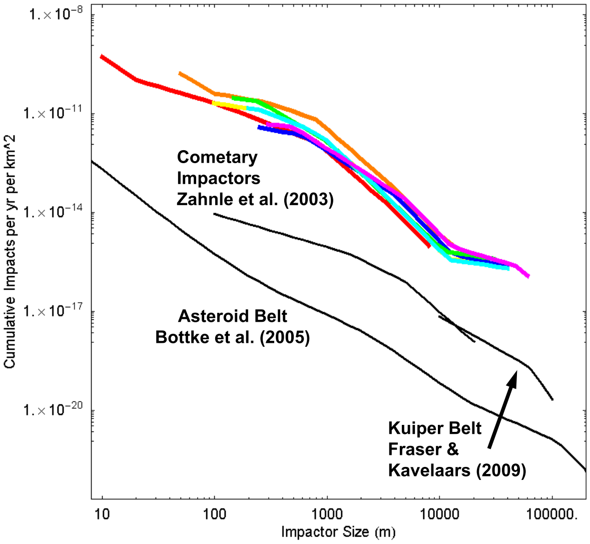

Figure 1: Size frequency distribution comparisons. Color lines are the results from CTEM presented by Richardson et al. (this meeting). Solid lines are model small body populations, including comets (inferred from both comet observations and impact crater scaling for jovian satellites) estimated by Zahnle et al. (2003) [5], observation of the Kuiper belt (dominated by the cold classical population) from Fraser and Kavelaars (2009) [6], and the main asteroid belt from Bottke et al. (2005) [7]. Colors: red=Phoebe, orange=Hyperion, yellow=Mimas, green=Tethys,cyan=Dione,blue=Rhea,purple=Iapetus.

**The size distribution of Kuiper belt objects from observations** Numerous telescopic surveys of Kuiper belt objects have uncovered some basic characteristics of the Kuiper belt luminosity function.a Converting a luminosity function to a size-frequency distribution is a task that requires many assumptions, including the mean distance of the surveyed objects and their albedos. For our purpose we will assume a distance of 35 AU and an albedo of 6%. We take results for the combined Kuiper belt lu-

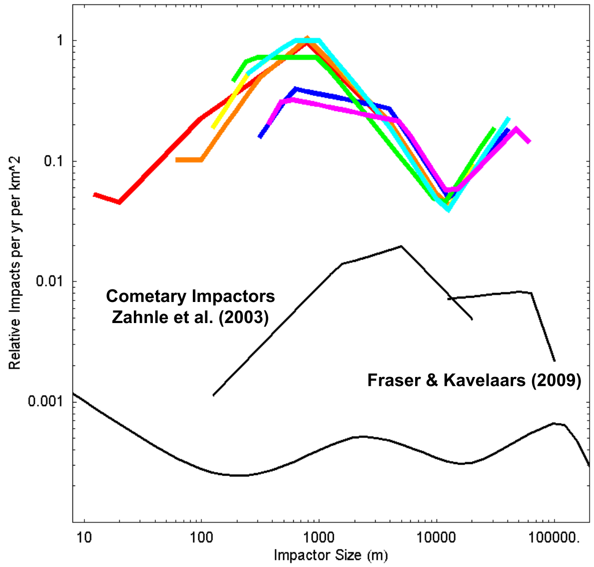

Figure 2: Same as Fig. 1, but in a relative plot format (arbitrary y-axis).

minosity function reported by Fraser et al. (2008) [8] and following a similar procedure outlined in Fraser and Kavelaars (2009) [6] we convert this to a SFD, shown in Fig. 3. The results overlap somewhat, and in fact the KBO observations show a shallow branch to the SFD where we see a shallow branch in the derived impactor SFD. However, Fraser and Kavelaars (2009) [6] found that the slope in the shallow branch was $q = 1.9$, compared to our derived slope of $q = 1.0$. We note, however, that this was derived for the entire Kuiper belt, which is dominated by the cold classical component. The hot component of the Kuiper belt (KBOs with inclinations greater than $\sim 5°$) have been observed to have a shallower sloped SFD than the cold component at all sizes [9, 10]. If the saturnian system impactors are derived primarily from the dynamically hot Kuiper belt population, than the impactors will likely reflect their shallower slope compared with observations of the cold classical belt.

**Implications.** By combining size distributions derived for saturnian system impactors with those of Kuiper belt observations, we can put better constraints on the absolute number of small comets. This will have implications for models of the cometary contribution during the Late Heavy Bombardment [12]. Using flux estimates of comets, we can also use our derived impactor size-frequency distribution toward a crater count chronological system for the outer solar system. We compare results from our system with those of Zahnle et al. (2003) [5] and those based on asteroid impacts onto bodies in the inner solar system, such as Ivanov et al. (2002) [13].

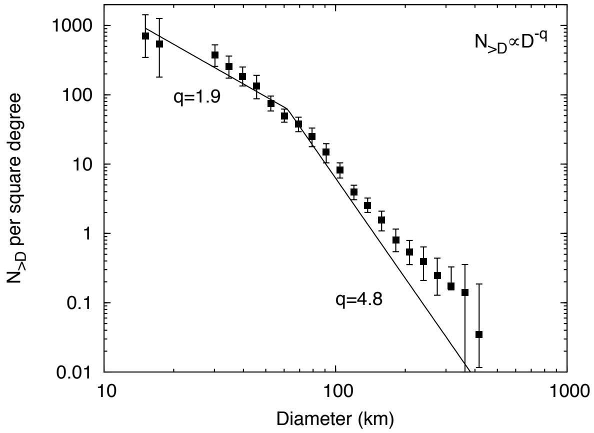

Figure 3: Kuiper Belt size-frequency distribution from Fraser and Kavelaars (2009) [6]. Luminosity function converted to diameter by assuming a 6% albedo. The deviation of the SFD from a single power law at large sizes is likely due to the known dependence of KBO albedo and size, with large KBOs having a higher albedo on average than small ones [11].

## References

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