CAN IMPACTORS FROM THE MAIN ASTEROID BELT ERASE A COMETARY CRATERING RECORD ON THE MOON? D. A. Minton, R. G. Strom, and R. Malhotra, Lunar and Planetary Laboratory, The University of Arizona, 1629 E. University Blvd, Tucson AZ (daminton@lpl.arizona.edu)

Introduction The Late Heavy Bombardment (LHB) was a period of intense meteoroid bombardment of the inner solar system that ended approximately 3.8 Ga [e.g., 1–3]. It has been suggested that the LHB was initiated by the migration of Jupiter and Saturn, causing Main belt asteroids (MBAs) to become dynamically unstable [4, 5]. Models for the LHB involving planet migration invoke gravitational interactions between the giant planets and a massive primordial icy planetesimal disk [4, 6–8]. This process inevitably leads to a large number of cometary impacts (from impactors originating from the outer icy disk) onto the inner planets that is comparable to or exceeds the number of asteroidal impacts (from impactors originating from the main asteroid belt) [4]. However, the cratering record on Mercury, the Moon, and Mars suggests that the craters associated with the LHB were caused by impactors originating from the main asteroid belt [9]. Gomes et al. (2005) showed that under the "Nice model" of giant planet migraion, the majority of the cometary impactors struck the Moon prior to the arrival of the asteroidal impactors. It is possible that there were enough asteroidal impacts to erase an earlier cometary cratering record, however this hypothesis has never been tested. Here we use attempt to quantify the amount of asteroidal material needed to erase a preexisting cometary cratering record.

Constructing a comet size frequency distribution The size frequency distribution of KBOs is poorly constrained. Observationally, the visual magnitude distribution of KBOs is reasonable well characterized for visual magnitudes $\lesssim 28$ [10]. Assuming a mean semimajor axis of 42 AU and a geometric visual albedo of 0.04, a visual magnitude $R \lesssim 28$ corresponds to objects diameters $D \gtrsim 30$ km. From Pi-group scaling, a 30 km diameter comet impacting the moon at $50\ \mathrm{km\,s^{-1}}$ would leave a ~ 640 km diameter basin [11]. As there are very few basins of this size on the Moon, the size distribution of objects with sizes much smaller than 30 km will be important in order to distinguish between cometary and asteroidal impactor populations.

In the absence of observational data for $D < 30$ km KBOs, there are other ways in which the KBO size frequency distribution may be estimated. One way is though collisional evolution modeling of the Kuiper belt population, and another is through the cratering record of the icy satellites of the outer solar system. It also may be possible to use the observed size distribution of Jupiter's Trojan asteroids as a proxy for the Kuiper belt size distribution, as it is possible that the Trojans originated in the Kuiper Belt [12].

In a collisionally evolved population, the size distribution will consist of two regimes; a strength-dominated regime where the energy required to disrupt the body decreases as a function of size, and a gravity-dominated regime where the energy required to disrupt the body increases as a function of size [13]. Differences in the resultant steady-state size distributions in the two regimes will cause waves to propagate through the size distribution in the gravity-dominated regime [14]. The waves will oscillate about the gravity-dominated steady-state size distribution, which can be approximated as a power law with an index $-q_g$. The steady-state size distribution strength-dominated regime can be approximated as a power law with an index $-q_s$, which will typically be different than power law index for the gravity-dominated regime. The power law indices, wave amplitudes, wave peak locations, and the transition diameter between the strength and gravity-dominated regime for the population size distribution will depend on several parameters, such as material strength and density, average impact velocity between objects in the population, the population spatial density, and population age [14]. Many of these parameters may be estimated, and a model KBO size distribution can be constructed that can match the observed size distribution for $D \gtrsim 30$ km objects [15].

The cratered surfaces of the icy satellites currently offer the best direct record of the Kuiper belt size frequency distribution for $D \lesssim 30$ km. It is unlikely that asteroids are an important source of impactors in the outer solar system, so outer solar system impactors are likely to be dominated by Kuiper belt objects [17]. However there are several factors that contribute toward complicating the cratering record of the icy satellites. Many of the icy satellites have experienced some amount of surface tectonic activity in their history that has partially or completely erased much of their cratering histories. Of the largest icy satellites, Callisto and Rhea appear to offer the most pristine cratered surfaces relatively free from recent tectonic activity.

Planetocentric debris may be an important component to the icy satellite impactor population, including the formation of "sesquinary" craters (craters produced on one satellite by ejecta thrown out by an impact on another satellite in the same system) [16]. Planetocentric debris may be an important source of cratering in the saturnian and uranian systems, and possibly also on Europa and Triton and [17, 18]. Planetocentric impactors would presumably have a different size distribution than primary impactors from the Kuiper belt, and so would obscure the signature of KBOs on the cratering record of the icy satellites.

Model Kuiper belt size frequency distributions Due to the uncertainties in Kuiper belt size distribution, we choose two model KBO size distributions to compare with the main asteroid belt size distribution.

Model I is the size frequency distribution given by Pan & Sari (2005) [15], from their Fig. 3. It is based on a collisional model of the Kuiper belt that attempted to fit the KBO observational data of Bernstein et al. (2004) [10].

Model II is a hybrid of two size distributions. For $D < 60$ km it is based on the model Callisto crater size distribution derived from crater counts of Galileo imagery [18]. The craters were converted to projectiles using Pi-group scaling [11] and assuming an impact velocity of $16\ \mathrm{km\ s^{-1}}$, projectile density of $1.5\ \mathrm{gm\ cm^{-3}}$, target density of $1.0\ \mathrm{gm\ cm^{-3}}$, and impact angle of $45°$. For $D > 60$ km model II is identical to model I.

The main belt asteroid (MBA) size distribution is a hybrid of three size distributions. For $D > 10$ km it is based on cataloged main belt asteroids taken the Lowell Observatory Asteroid Orbital Elements Database (ftp://ftp.lowell.edu/pub/elgb/astorb.html). This represents the range of asteroid diameters that are likely to be observationally complete for the main asteroid belt [19]. The catalogued asteroid diameters were used if given, otherwise an albedo of 0.09 was assumed to convert magnitude H into diameter. For $0.25\ \mathrm{km} < D < 10\ \mathrm{km}$ the MBA model is based on the lunar highlands impactor SFD [see 9]. For $D < 0.25$ km the MBA model is based on the strength-dominated regime of a collisional evolution asteroid belt model [20].

The two model KBO size distributions are plotted in the style of an R-plot (normalized by a D^{-3} size distribution) along with the model MBA size distribution in Fig. 1. With these model size distributions and estimates of the impact velocities and projectile densities of the various populations, we will simulate the cratering of the lunar surface first by the equivalent of 5×10^{21} gm of cometary material, then subsequently by an equivalent amount of asteroidal material, consistent with estimates of the impact flux onto the lunar surface under the "Nice model" [4]. The simulation will be performed using a

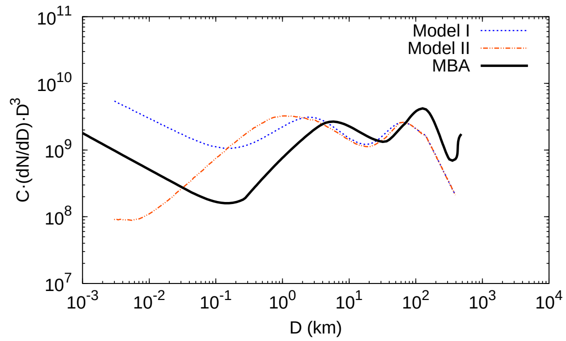

Figure 1: Normalized differential plot of model outer solar system impactor populations compared with a model main belt asteroid population.

stochastic cratering model which simulates crater production and subsequent erasure due to overlying craters and crater ejecta blanketing [21].

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