THE BIG HEAT: ALBEDO CHANGES AS CAUSE OF DESTRUCTION OF NEAR-SUN ASTEROIDS.

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Introduction: The apparent dearth of low perihelion asteroids in debiased estimates of the near-Earth object population was discovered in [1] and proposed to be the result of full disintegration of those objects, or “super catastrophic disruption.” Darker and smaller asteroids disrupt further from the Sun than brighter ones. The exact details of *how* these asteroids fall apart and *why* it happens at these distances is unclear [2]. The clear albedo and size relationships are indicative of a possible thermal origin. Yarkovsky drift, YORP spin changes [3], and thermal breakdown of surface materials all increase in effectivity with lower perihelion distance and are all thought to play a role: the question is understanding the relative importance of these effects and what other processes are at play. **Understanding ‘super catastrophic disruption’ is critical to understanding the modern NEO population and the end-states of many small bodies.**

Understanding how the near-Sun environment affects the evolution of small bodies is of particular interest, especially with the upcoming launch of DESTINY$^+$ to the near-Sun object and parent of the Geminids Meteor Shower (3200) Phaethon [4] later this decade. Phaethon’s ongoing mass loss, though insufficient to re-supply the Geminids [5], is thought to be driven by thermal breakdown of surface materials, loss of material near its equator due to its relatively rapid rotation, and through radiation pressure directly stripping grains from the surface (see, e.g. [5,6,7].) While thermal breakdown of larger rocks and boulders should resupply the regolith, the other two processes should act to remove these grains, and preferentially the smaller ones. Phaethon’s surface could plausibly retain thermally altered materials [8], indicating that at least the larger grains can be retained long enough to have their surfaces altered through heating.

While Phaethon and 322P/SOHO [9] are the only near-Sun objects observed to lose mass without an obvious cometary origin, the processes invoked to explain their ongoing mass loss should be generically applicable to the near-Sun object population.

Hypothesis: We propose here that relatively rapid changes in albedo facilitate the thermal breakdown of surface materials, faster Yarkovsky drift, and faster rotational disruption of these near-Sun objects. These albedo changes are to be expected on near-Sun objects through two processes: thermal alteration of surface materials (heating of surface materials, not thermally driven mechanical breakdown), and loss of finer grains through rotational shedding and radiation pressure. Darker surfaces causing faster radial drift and rotational spin-up would generally act to enhance further thermal degredation or rotational mass loss, suggesting that a feed-back loop could be possible under certain circumstances.

Thermal Alteration: In laboratory experiments where CM [10,11] and CI [12,8] Chondrites were heated and then cooled back to ambient temperature, it was found for both that albedo decreased with increasing peak heating temperature until some critical temperature (800-1000 Kelvin depending on meteorite), after which they brightened back to their initial albedos. Thus for at least many of the carbonaceous chondrites, they are expected to darken as they approach the Sun and warm up. The laboratory data of albedo vs. temperature for CIs and CMs is shown in **Figure 1**.

Grain Size Effects: For many kinds of meteorites (HEDs, ordinary chondrites, carbonaceous chondrites, see, e.g., [13,14,15,16]), increasing the average grain size decreases the average albedo. Smaller grains should be preferentially lost over larger ones due to their smaller mass, but also due to their higher surface area to mass ratios in the case of radiation pressure driven mass loss. Radiation pressure also increases in strength rapidly as the asteroids approach the Sun, such that any fine-grained regolith can be increasingly easily removed, and the albedo can then decrease as a result. A simplified model of grain loss by radiation pressure based on [5] is shown in **Figure 2**.

Regardless of the relative importance of these processes, it is likely that asteroids injected into a near-Sun orbit could darken with decreasing perihelion distance, especially those in the C-complex. If these processes are effective at significantly changing the albedo, then the Yarkovsky drift rate of these objects would increase and the rate of spin change from YORP would also speed up due to their dependence on albedo. Faster orbital evolution would result in a more rapid removal from the NEO population (impacts onto planets, the Sun, etc.), and faster YORP spin up would make fragmentation and full disruption more frequent as objects can more quickly reach rapid spin states. **Finally, a lower albedo for any of these objects would also make them harder to detect, and thus decrease the number discovered.**

Other Considerations: [17] recently proposed that the destruction of near-Sun objects could be through erosion by repeated meteoroid impacts. While not a natural explanation of the albedo dependence of the dearth of near-Sun objects [1], the near-Sun meteoroid environment could very well play a significant role in the evolution and destruction of some objects. It is also expected that smaller or rapidly rotating asteroids should have fewer small grains even before entering the near-Sun region, so it is unclear the magnitude of grain size loss that could be estimated for a particular asteroid when its perihelion distance is lowered.

Ongoing and Future Work: We are currently pursuing several inquiries into the effectiveness and interaction of these multiple ongoing processes. In particular, we will present a model that creates an initial population of small NEOs with a reasonable size-frequency distribution, various perihelion distances, rotation states, and taxonomic classes and will evolve their albedos in response to thermal alteration (if a C-complex object) and in response to changes in their grain sizes (radiation pressure stripping modulated by rotational state and size) We will use this to explore how these proposed changes in albedo change the observability of these asteroids and the peak temperatures reached by them. It is expected that as both grain size loss and thermal alteration act to lower the albedos of these objects, fewer would be observable (e.g. they fall below sensitivity limits of discovery surveys). As future work we will explore observational tests to these hypotheses through targeted observations and the efforts of discovery surveys.

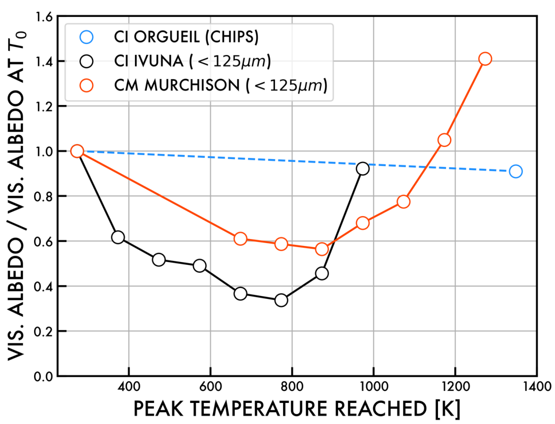

Figure 1. The trend of decreasing albedo with temperature (until a crossover point) is shown for powders of the CI Ivuna [12] and the CM Murchison [10,11], with two data points for chips of the CI Orgueil [8]. Ivuna reaches less than 1/3 of its original albedo when heated to 800 Kelvin, while Murchison reaches slightly above ~1/2. All three samples generally became bluer in color with heating before reddening around temperatures where their albedos began to increase again. Their measured visible (0.55-micron) albedos before heating were all 0.048-0.049.

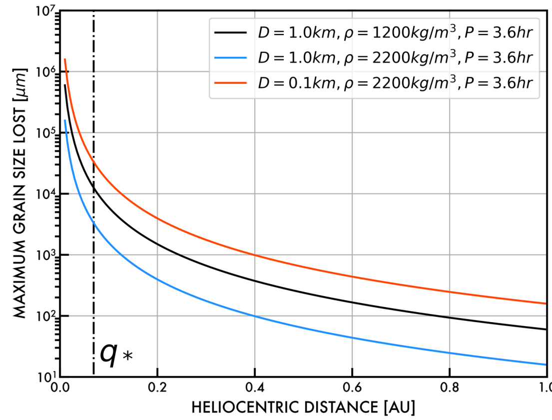

Figure 2. The maximum grain size that could be lost due to radiation pressure stripping is plotted as a function of heliocentric distance for three example small asteroids. The model is based on the derivation of [5]. Also plotted is the critical disruption distance q_* defined in [1]. Cohesion is neglected for the purposes of this toy model but will be discussed in the presentation. For minimally cohesive surfaces it is clear that fine grains can be stripped rapidly, and especially so for less massive or faster rotating asteroids.

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