EFFECT OF IMPACT ANGLE ON THE SIZE OF SMALL DARK IMPACT HALOS ON MARS.

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Introduction: Observations show that small impactors continue to hit Mars up to and including in the present day [1, 2]. In fact, scientists have discovered more than 700 new impact sites at which craters formed within the last ~two decades. Some of the new martian impact craters have a roughly circular, low-albedo "halo" feature. This halo is distinct from the usual discrete ejecta deposits and ray patterns because the halo's albedo changes slowly and smoothly from the dark center to the edge of the halo (**Figure 1**). The martian halos have been mentioned in past work as part of the "dark spot" or "blast zone" surrounding the new craters [2-4]. A preliminary analysis of these features was performed by Ivanov et al. (2010) [5] and another analysis was performed by Bart et al. (2019) [6]. Because the halo's albedo varies slowly and smoothly throughout the halo, and because halos are not observed on other bodies such as the Moon, it has been proposed [1, 7] that these features form as a result of interaction between the atmosphere and some aspect of the impact process. Therefore, the halos present a unique opportunity to study current impact/atmosphere interactions, which will enable a better understanding of the underlying physical processes involved.

Previous Work: We define a "halo" as quasi-circular, smoothly-varying albedo feature that surrounds an impact crater (or cluster of craters) and is much larger than the crater and its ejecta [6]. A halo's albedo is lower than that of the surrounding terrain and the albedo increases slowly and smoothly from the center to the indistinct edge of the halo, where it gradually blends in with the background albedo.

For several possible mechanisms (such as atmospheric shock wave propagation), we expect that halo sizes should be correlated with crater diameter because the overall energy of the impact also scales with crater diameter [8]. To test this idea, we therefore made quantitative halo and crater measurements. We measured XX craters and halos at YY impact sites and found a relationship between the crater diameter and the halo diameter [6]. We found that halo diameter generally increases with increasing crater diameter. Although there is considerable scatter, the trend with size can be quantified with a power law, $D_H = 8.20\ D_C^{1.75}$ (R^2=0.82) (**Figure 2**). The increase in halo diameter with crater diameter is reasonable because larger impacts have more kinetic energy available to disrupt larger areas of the martian surface and/or affect larger volumes of atmosphere.

This Study: We continue our study of the martian halos in order to develop a complete understanding of the mechanism by which these halo features form. As a next step in this process, we will examine the effect of impact angle on the size and location of the martian halos. Work by Shuvalov et. al. (2017) [9] shows that impact angle can have a strong effect on the horizontal extent of the maximum overpressure of the atmospheric impact shock wave. Our current work compares the halo diameter and relative offset to the impact angle of new martian impact craters as measured for clusters by [10]. A strong correlation between the two would suggest that the atmospheric shock wave plays a strong role in creating the halos and would significantly constrain potential halo formation mechanisms. This hypothesis can be further tested with computational modeling.

Conclusion: Although we have shown that impact energy is important in driving halo sizes [6], we are continuing to study the halos to determine their specific formation mechanism. These results contribute to understanding the effects of atmospheric-impact interactions that occur on planets with atmospheres.

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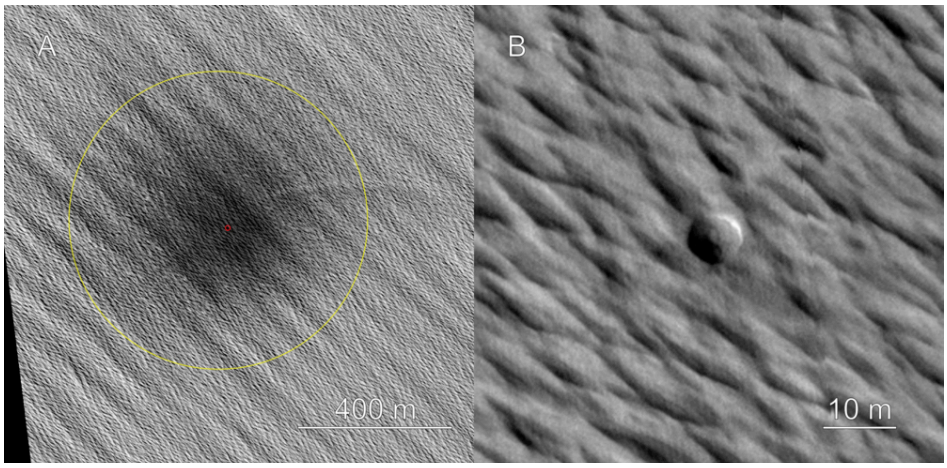

Figure 1: (A) An 8 m diameter crater (outlined in red) formed a 790 m diameter halo (outlined in yellow), observed in HiRISE image ESP_013893_1755. (B) The crater from frame A.

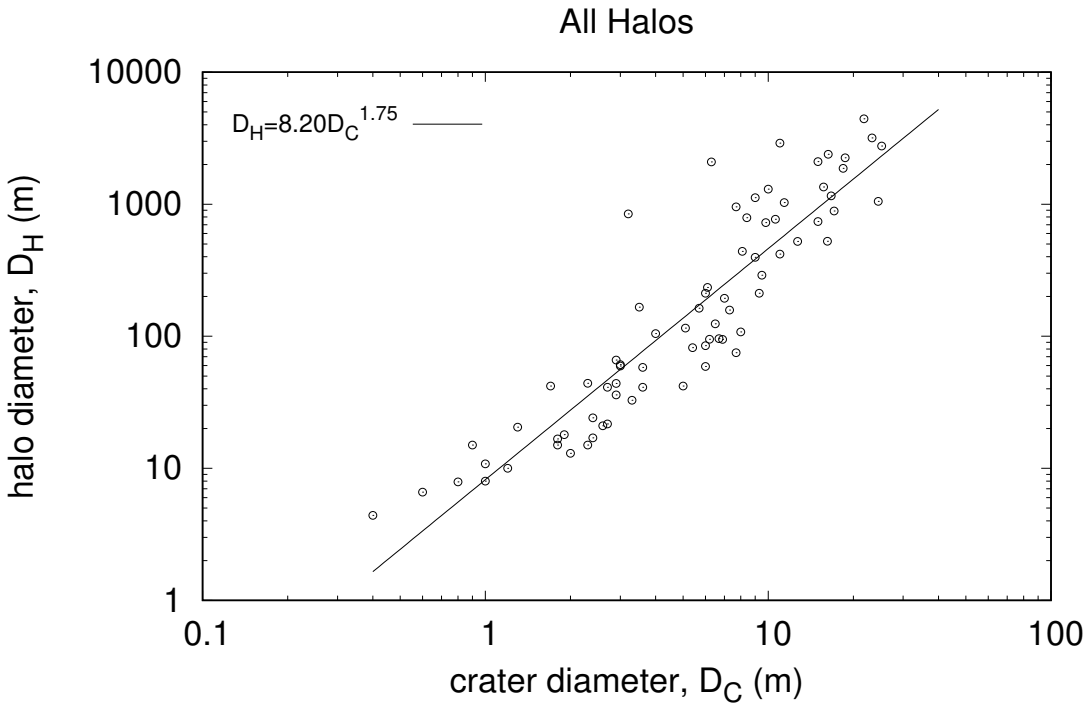

Figure 2: Plot of halo diameter (m) vs. crater diameter (m) for each of the halos measured in this study. The best fit line is also plotted. This plot shows that halo diameter does increase with increasing crater diameter.