THE BOULDER POPULATION OF VESTA. S. E. Schröder[0,1], U. Carsenty[1], F. Schulzeck[1], E. Hauber[1], R. Jaumann[1], C. A. Raymond[2], and C. T. Russell[3], [0]stefanus.schroeder@dlr.de, [1]Deutsches Zentrum für Luft- und Raumfahrt (DLR), Rutherfordstraße 2, 12489 Berlin, Germany, [2]Jet Propulsion Laboratory (JPL), 4800 Oak Grove Drive Pasadena, CA 91109, U.S.A., [3]University of California (UCLA), 603 Charles E. Young Drive, East, Los Angeles, CA 90095-1567, U.S.A.

Introduction: Boulders on the surfaces of small solar system bodies are generally associated with relatively young impact craters. The Framing Camera onboard the Dawn spacecraft observed many boulders on the surface of asteroid Vesta from its vantage point in the Low Altitude Mapping Orbit (LAMO) [1]. We identified, mapped, and measured more than 10,000 boulders. Due to the limited resolution of LAMO images (19 m per pixel), the boulders in our sample are much larger than those typically studied thus far on other small bodies. The largest boulder we identified is a 500 m large block in Marcia crater. The boulder size-frequency distribution (SFD) is generally assumed to follow a power law. Typical power law exponents for other small solar system bodies are found in the range from –3 to –4, [2,3,4]. We study the global SFD of Vesta boulders and compare with published values.

Mapping: We mapped and measured boulders with the J-Vesta GIS tool, which is a version of J-Mars [5]. The example in Fig. 1 shows the boulder population associated with Cornelia crater.

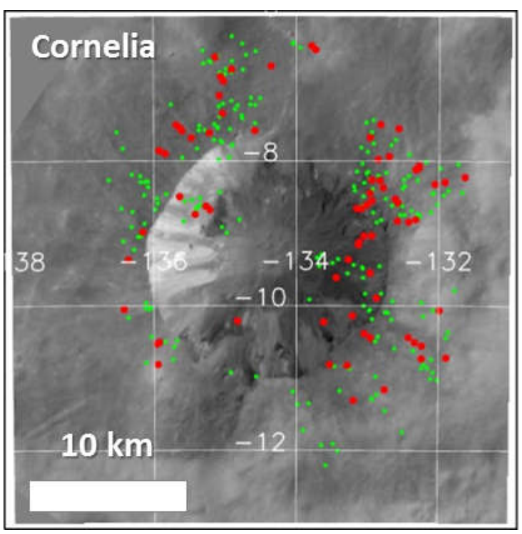

Figure 1: Boulders in and around Cornelia crater. Small green dots represent boulders with a size between 3 and 4 pixels. Large red dots represent boulders larger than 4 pixels.

Cornelia crater is typical in the sense that it shows no clear correlation between boulder size and distance from the crater center. Our count is probably complete for a size of larger than 4 pixels ($d > 76$ m), but not for a size between 3 and 4 pixels ($57 < d < 76$ m).

Size-frequency distribution: The statistically most appropriate way to estimate the power law exponent is through the maximum-likelihood (ML) method [6]. The power law exponent of the global boulder population estimated by means of ML is –4.5. We also estimated the power law exponent of the boulder populations of all craters individually and found large variations, with the boulders around one crater having an exponent of almost –12 (Fig. 2).

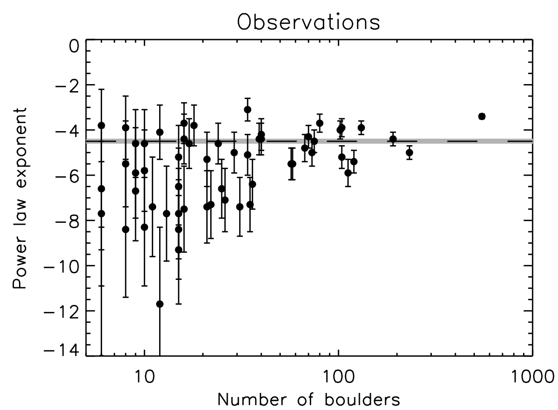

Figure 2: Power law exponents of the boulder SFD of all craters with at least 6 boulders larger than 4 pixels. The dashed line with gray confidence interval indicates the best-fit exponent for the global boulder SFD.

However, the variation in the value of the exponent does not reflect different physical properties of the boulder populations across the surface. Instead, by means of a simulation we found that this variation naturally results from the variation in the number of boulders used for the ML fit, uncovering a hidden bias of the ML method in the process. Our simulations show that a population size of at least 100 boulders is required to estimate the power law exponent with an accuracy of better than unity. In other words, a power law exponent estimated for too small a population may be very different from its true value, purely by chance. This is rarely recognized in the literature, so we evaluated the reliability of published exponents for small bodies, and re-analyzed boulder data with the ML method where possible.

The power law exponent for the global boulder population of Vesta (–4.5) proves to be different from typical values (–3 to –4) [2,3,4]. Furthermore, a statistical test reveals that a power law is actually not a good model for the Vesta data, with an apparent lack of boulders at the large end of the size range. In rock grinding experiments, a Weibull distribution is often adopted to describe the resulting SFD, and results from the fractal nature of the cracks propagating in the rock interior [7]. The Weibull provides a satisfactory fit to the Vesta boulder SFD, whereas a (single) power law does not fit the data (Fig. 3).

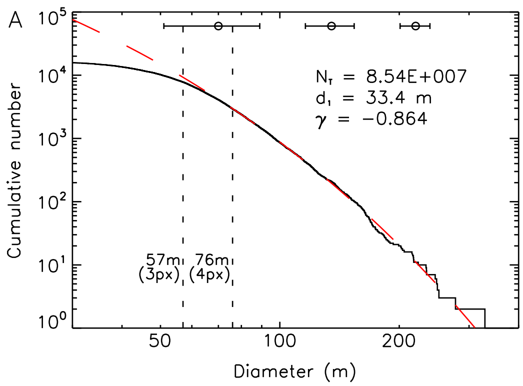

Figure 3: Best fit Weibull distribution (red dashed line) for the SFD (black line) of boulders larger than 4 pixels. The error bars at the top indicate the uncertainty in boulder size at different diameters due to a 1 pixel measurement error. A power law would plot as a straight line.

We can now also understand the apparent discrepancy between the power law exponent of Vesta and that of other small bodies. If we consider the power law as a local slope of the Weibull, it will be steeper for the boulders of Vesta, as they are much larger than typical boulders investigated so far on other small bodies. Our results suggest that, even though the use of the power law is widespread, the SFD of planetary boulders is better described by a Weibull distribution.

References: [1] Russell C. T. et al. (2007) *Earth, Moon and Planets, 101,* 65. [2] Thomas, P. C. et al. (2000) *JGR 105*, 15091. [3] Thomas, P. C. et al. (2001) *Nature 413*, 394. [4] DeSouza, I. et al. (2015) *Icarus 247*, 77. [5] Christensen, P. R. et al. (2009) *AGU Fall Meeting Abstracts*, IN22A–06. [6] Clauset A. et al. (2009) *SIAM Review 51(4),* 661. [7] Brown W. K. and Wohletz K. H. (1995) *Journal of Applied Physics 78*, 2758.