OSIRIS-REx
ASTEROID SAMPLE RETURN MISSION

Boulder Size Frequency Distribution (SFD) of (101955) Bennu

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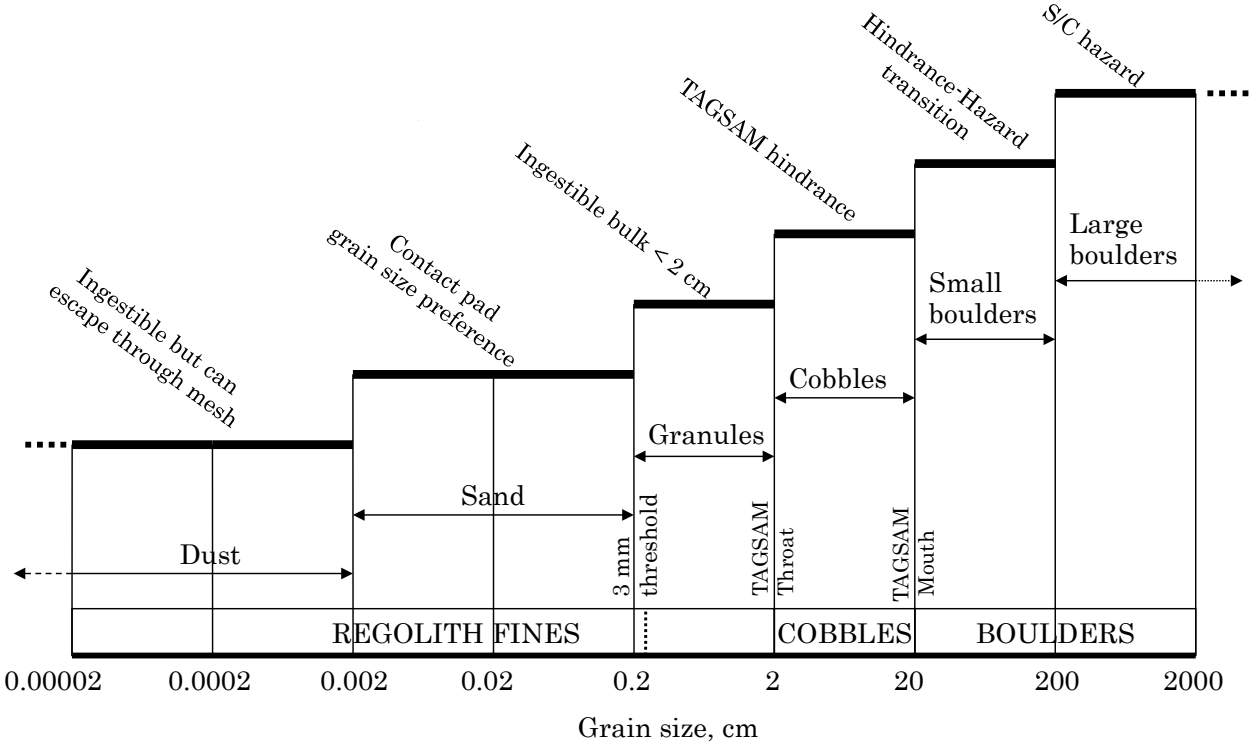
Outline

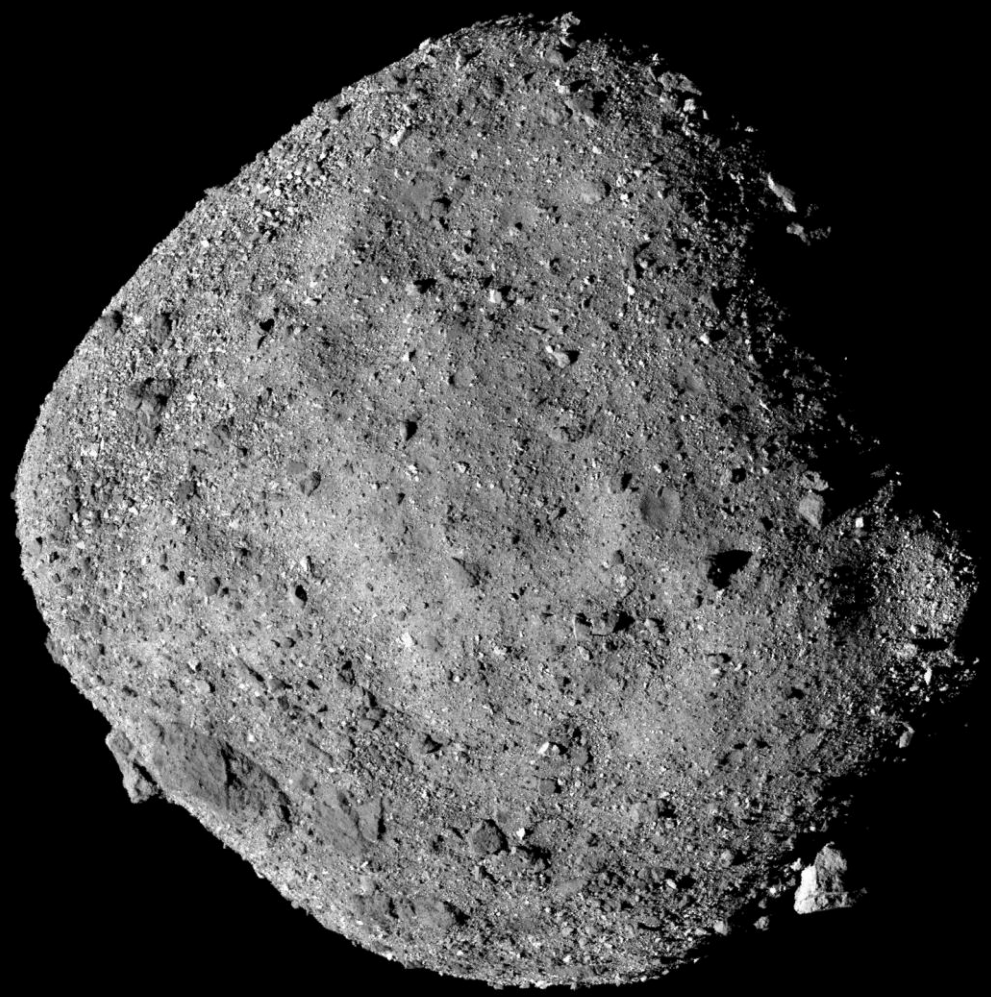
- OSIRIS-REx Specific Nomenclature
- Objective
- Hazard Mapping
  - Data Collection
  - Data Reduction
  - Map of Boulders
- The Size Frequency Distribution
  - Technique
  - Results
  - Comparisons
- Where We Go from Here
- Takeaways

OSIRIS-REx Specific Nomenclature

Term	Definition	In This Talk…
Hazard Mapping	Boulder or crater mapping for spacecraft safety	**Rock Counting**
Boulder	Diameters > 20cm	**Particles**
Cobble	Diameters between 2 – 20cm	



Simplified triumvirate size classification (Fines, Cobbles, Boulders) tying Wentworth scale to mission practicality



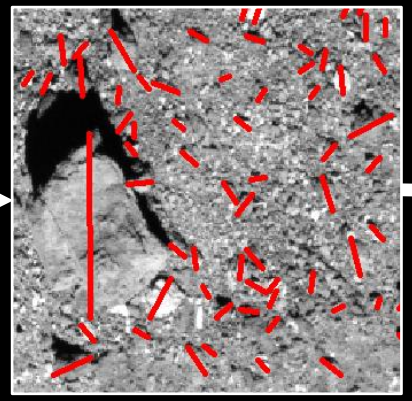
Mosaic of Bennu with 9 images taken on 12-02-2018

For **spacecraft safety** and **science value** we want to identify…

- 80% of boulders ≥ 21 cm diameter globally
- 80% of cobbles ≥ 2 cm diameter locally

Hazard Mapping: Data Collection

Get image

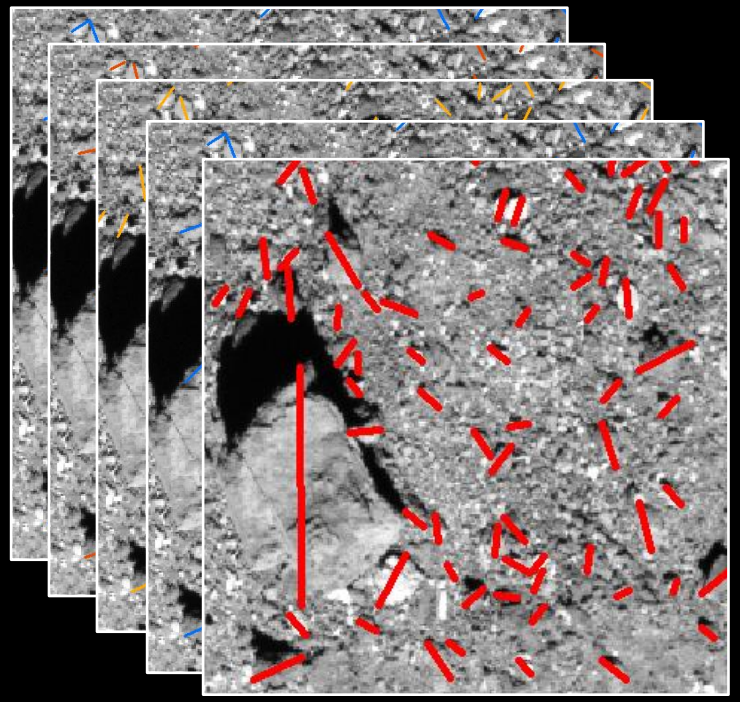


Count rocks

Extract body-fixed XYZ coordinates from ISIS3 cube backplanes

Calculate Lat/Lon coordinates and length

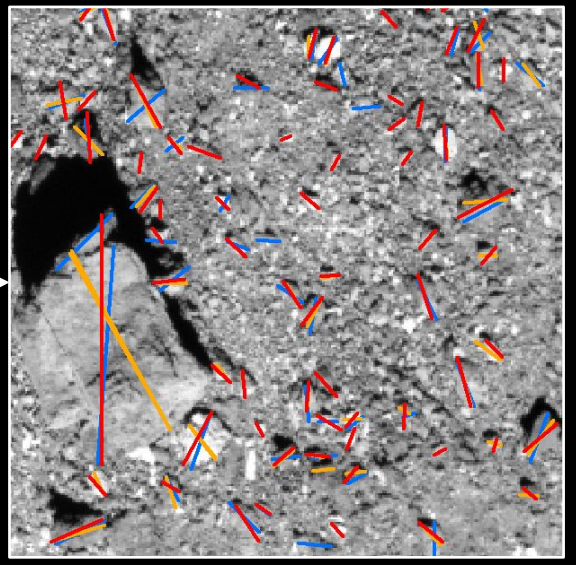
We can update these counts to reflect shape model and pointing improvements.



5 Different People Counting
7 Images from 12/01/18 (~0.41 m/px)

Modified DBSCAN
Clustering Algorithm

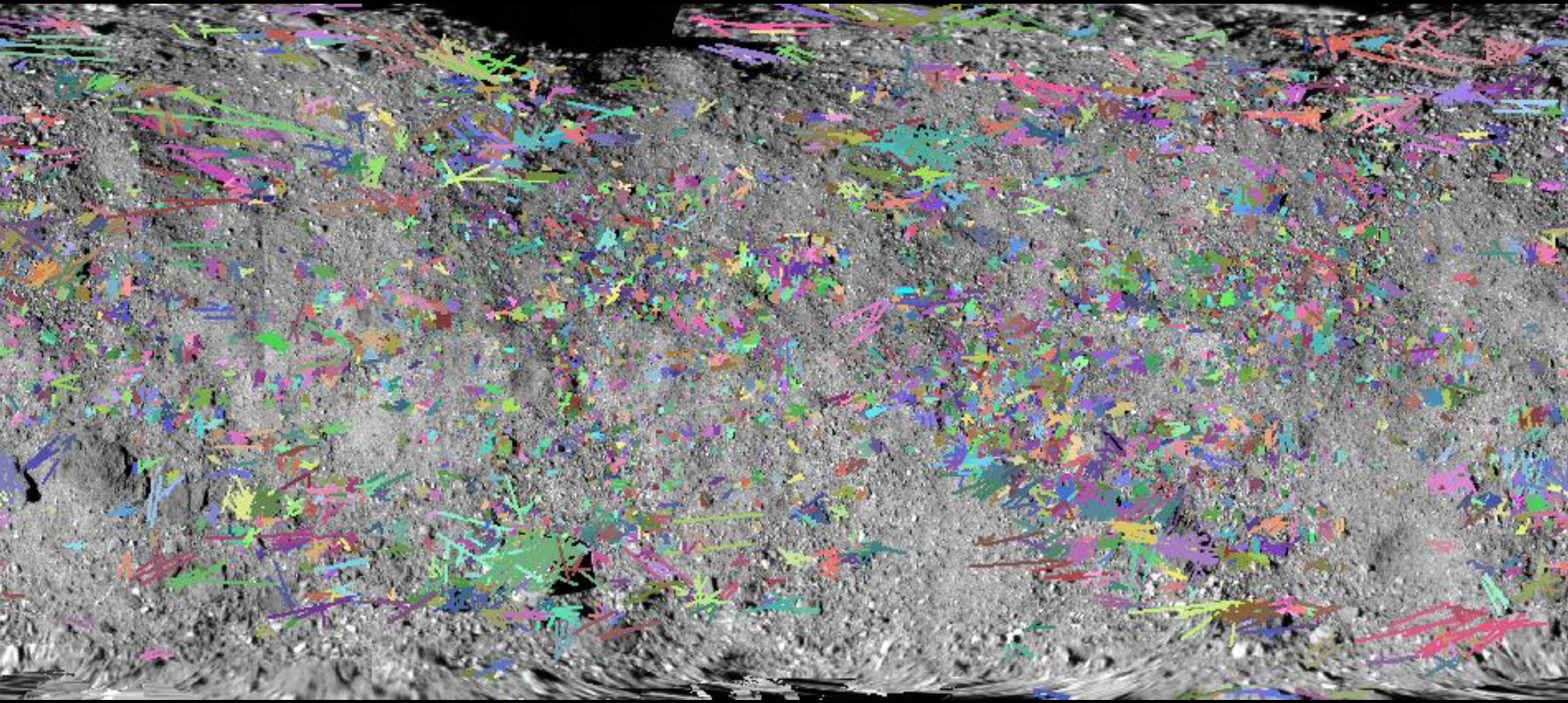
Group counts based on
- Length
- XYZ body-fixed location



Clustered dataset

Surface Mapping: Map of Boulders (as of December 1, 2018)

2750 boulders found



Global Mosaic of Bennu

We employ Robbins et al.'s (2018) revised methods for analyzing crater SFDs.

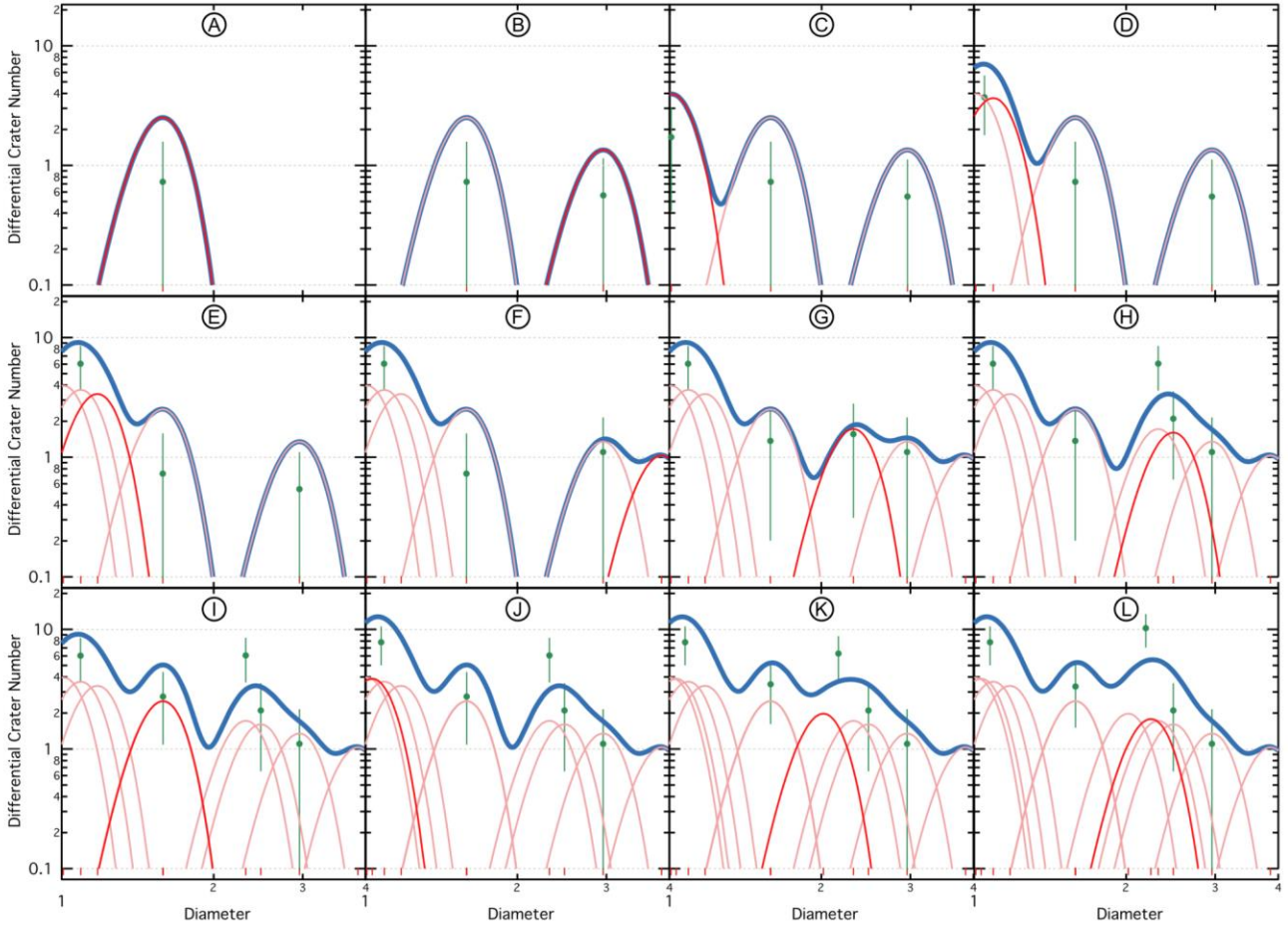


Figure 3 reproduced from Robbins et al. 2018.

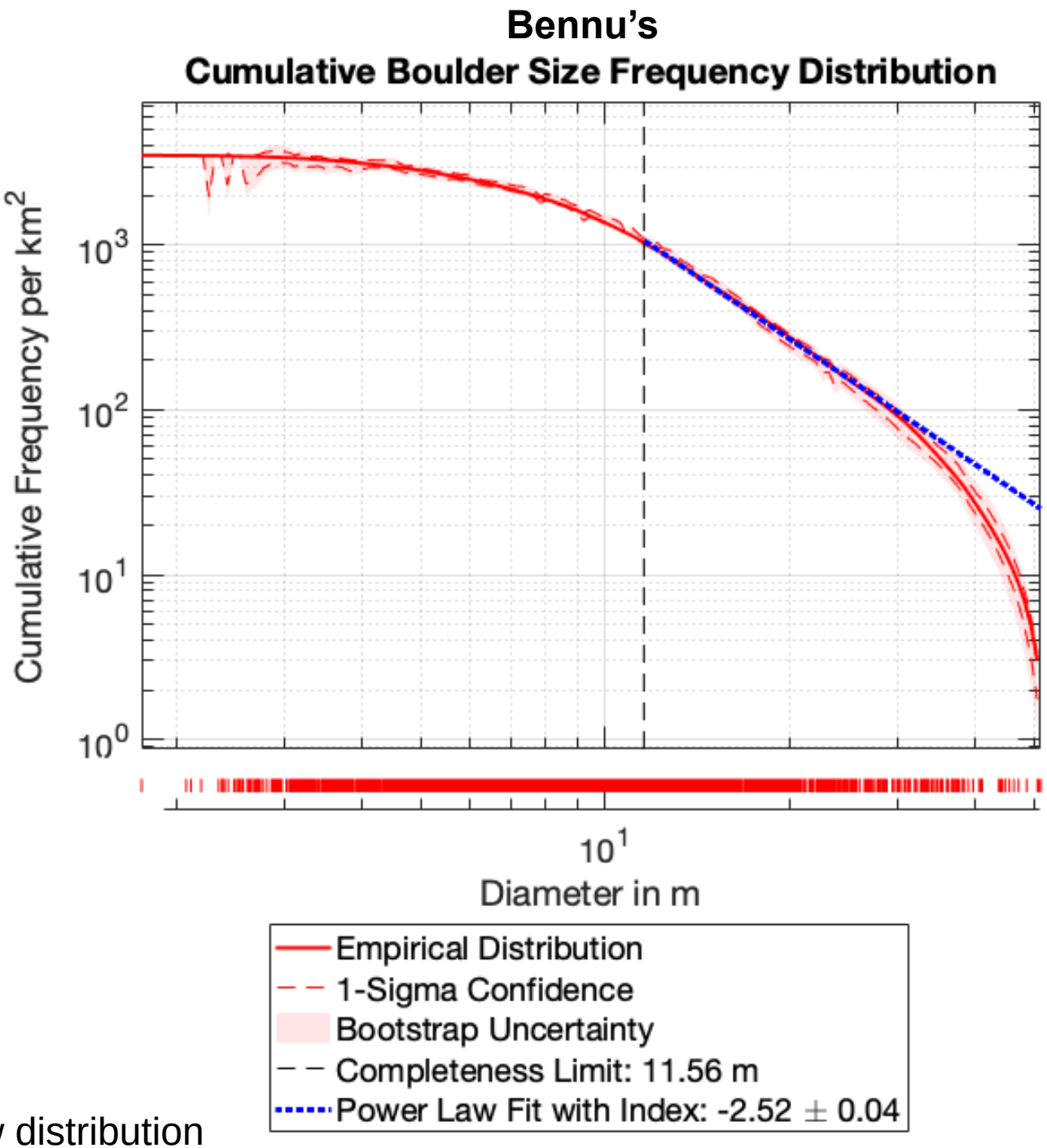
1. Represent each boulder as normal probability distribution function (PDF).
2. Sum all of the PDFs.
3. Convert differential SFD into relative SFD, cumulative SFD, and incremental SFD.
4. Scale all plots to physical values.

Power Law Index

-2.52 ± 0.04

Minimum boulder diameter* used in power law fit

11.56 m



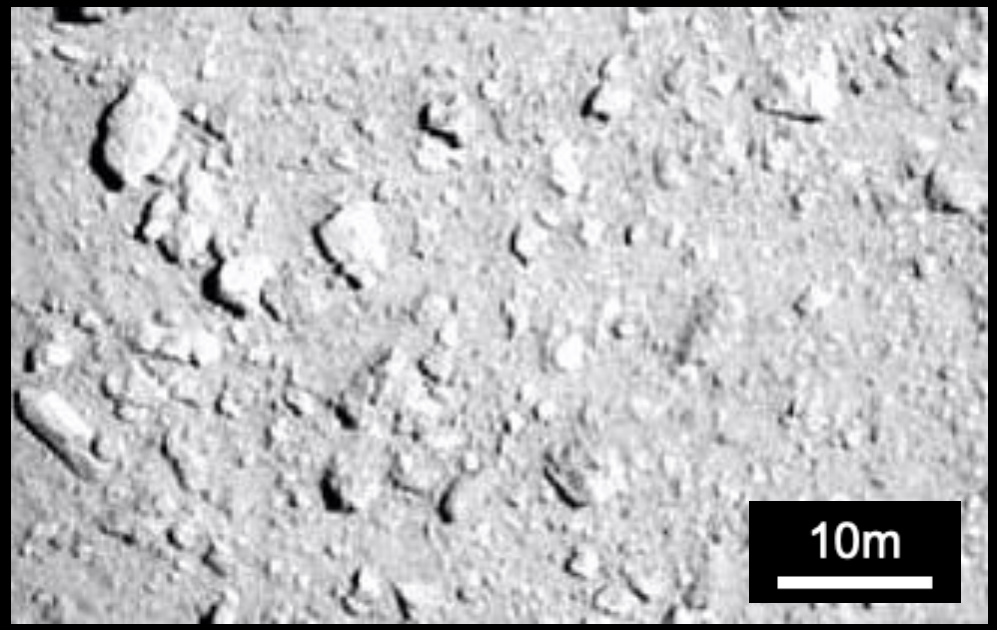
*Calculated by maximizing likelihood of power law distribution

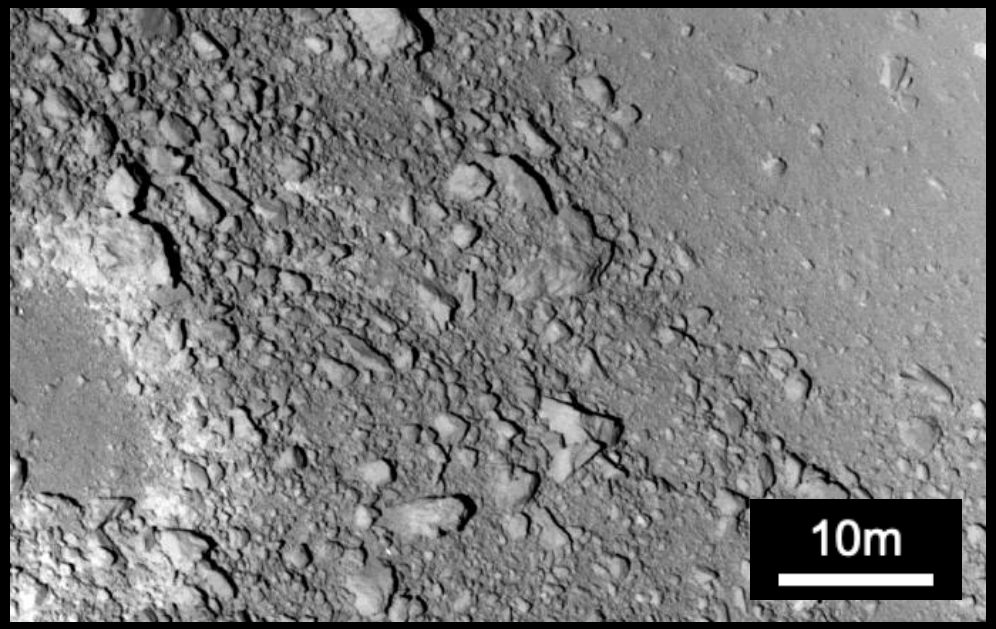
The Size Frequency Distribution: Comparisons

Object	Source	Fitting Technique	Measurement Technique	Global Cumulative Power Law Index	Minimum Boulder 'Size' (m)
Bennu	Burke et al. (This Meeting)	Robbins et al. (2018)	Longest axis diameter	-2.52 ± 0.04	11.56
	Pajola et al. (This Meeting)	Crater Analysis Techniques Working Group (CATWG; 1979)	Longest axis diameter	-3.17 +0.17/-0.24	6
Itokawa	DeSouza et al. (2015)	DeSouza et al. (2015)	Equivalent Spherical Radius	-3.6 ± 0.3	6.8
	Michikami et al. (2008)	CATWG (1979)	Mean horizontal dimension	-3.1 ± 0.1	5
	Mazrouei et al. (2014)	CATWG (1979)	Equivalent Spherical Radius	-3.5 ± 0.1	6
Ryugu	Honda et al. (This Meeting)	CATWG (1979)	Longest axis diameter	-2.5	< 1
67P	Pajola et al. (2015)	CATWG (1979)	Longest axis diameter	-3.6 +0.2/-0.3	7

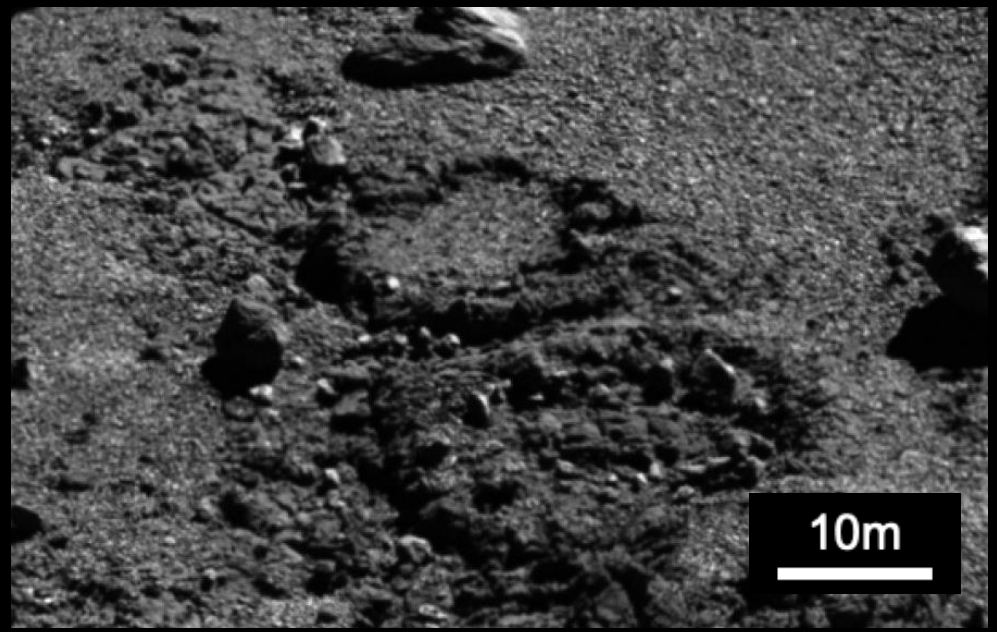
Bennu | Credit: NASA, Goddard, & University of Arizona

Ryugu | Credit: JAXA, University of Tokyo, & Collaborators



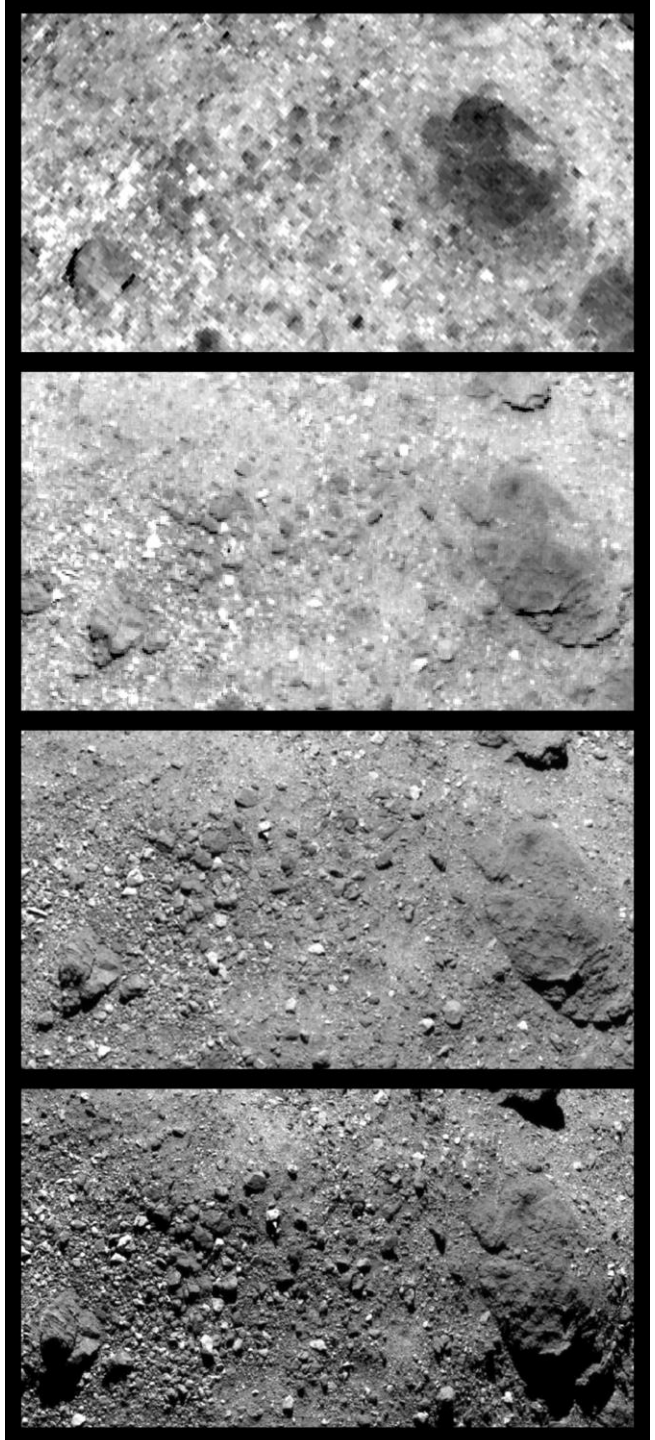


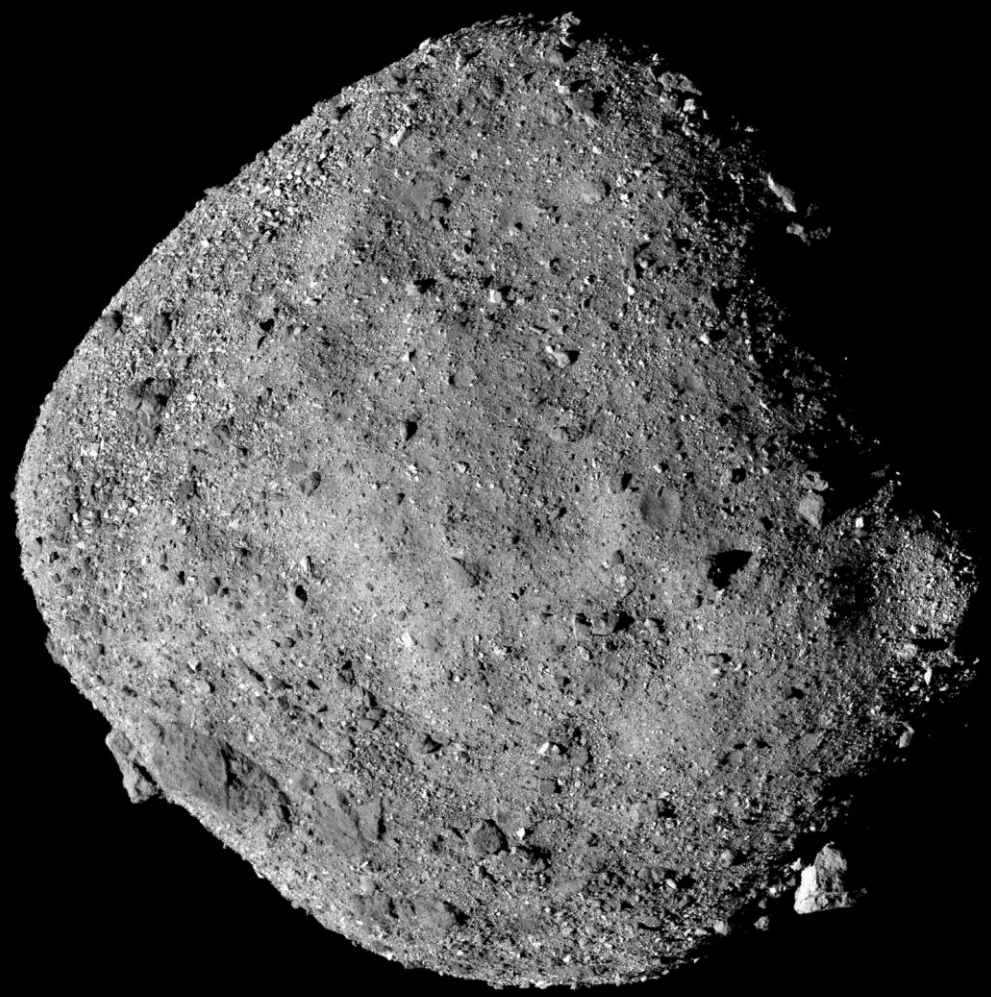
Itokawa | Credit: ISAS, JAXA, & University of Tokyo



67P | Credit: ESA, Rosetta, MPS, & Collaborators

- The SFD and Boulder Map is a work in progress.
  - As image resolution improves, measurement accuracy improves.
  - Eventually we will have 10s to 100s of measurements per boulder for most of the visible boulders on Bennu.
  - We will also incorporate counting efforts from those using SBMT and CosmoQuest's Bennu Mappers.
- SFD will help estimate upcoming workload to meet mission requirements.





What do we know so far?

- Bennu’s SFD slope may be indicative of impact comminution.
- We are well equipped to map boulders.

Thank you to the following people for their help counting rocks:

Dr. Jason P. Dworkin
Dr. Scott A. Sandford
Juliette Brodbeck
Natalie Shultz

Anyone in the world can help us count rocks!
See **Carina Bennett's** poster tomorrow for info.

(Hazard Identification Using CosmoQuest Citizen Science for the OSIRIS-REx Mission)

Backup

Why you should use KS test to obtain completeness limit (xmin) and MLE to obtain scaling parameter (α)

- Underestimating xmin
  - Leads to significant deviation from true scaling parameter (α)
- Overestimating xmin
  - Slower deviation from true scaling parameter (α)

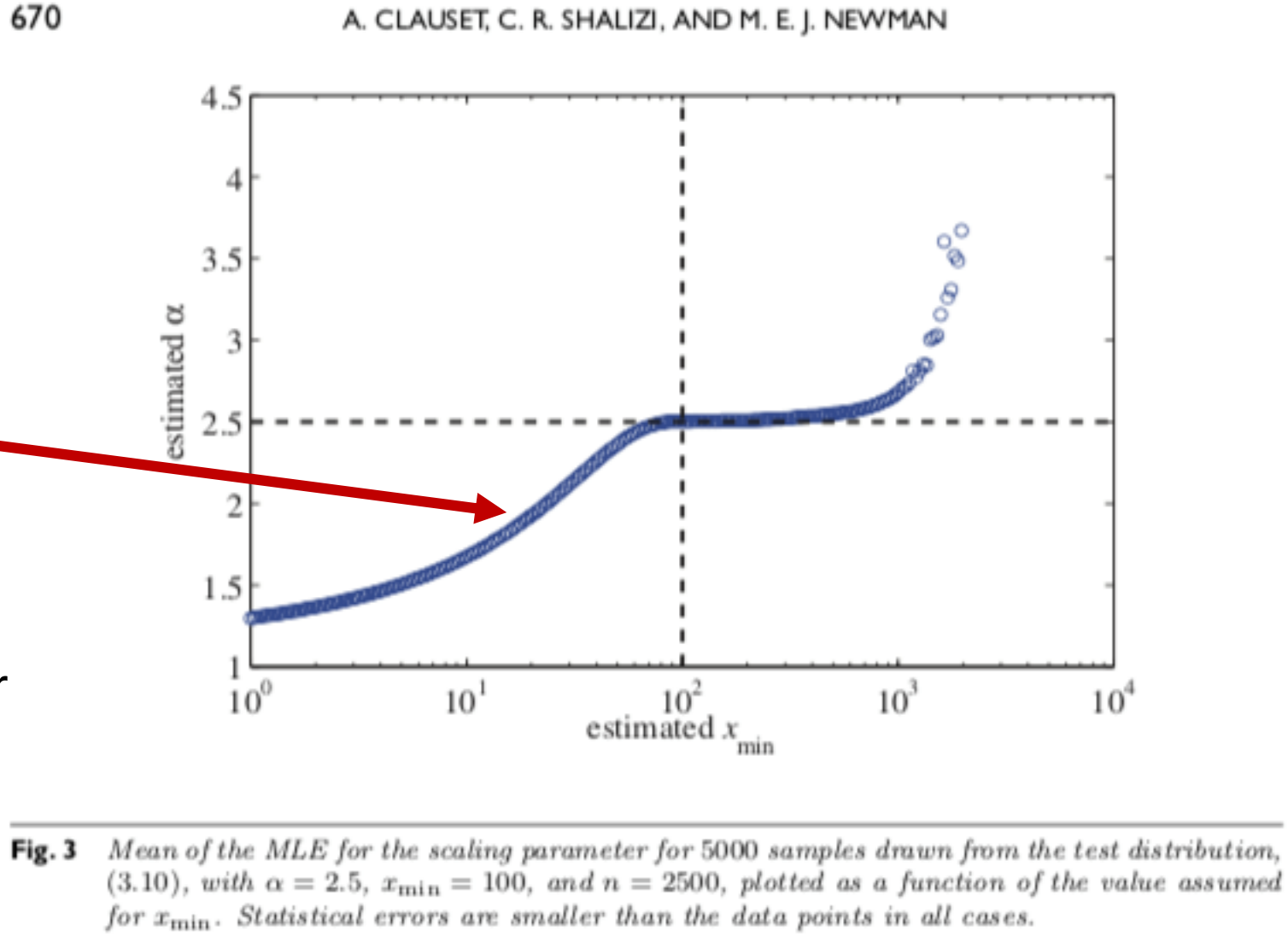


Fig. 3 *Mean of the MLE for the scaling parameter for 5000 samples drawn from the test distribution, (3.10), with* $\alpha = 2.5$, $x_{\min} = 100$, *and* $n = 2500$, *plotted as a function of the value assumed for* $x_{\min}$. *Statistical errors are smaller than the data points in all cases.*

Figure 3 reproduced from Clauset et al. 2009.