Crater Equilibrium as an Anomalous Diffusion Process

So, you think you understand crater equilibrium?

- Observations of heavily cratered terrains define an "empirical equilibrium" level as a cumulative power law with a slope of -1.83 (Hartmann 1984).
- But what is the process that determines the observed crater count equilibrium level?

**History of equilibrium cratering modeling**

**Experimental and Observational**
- Gaut (1970) showed that natural and experimental cratered surfaces (e.g., golf course) reach a maximum crater density of about 5-10% of "geometrical saturation."
- Many early experiments were conducted to understand the relationship between crater density and impact energy.

**Numerical**
- Monte Carlo simulation codes like CTEM are the primary way that cratered surfaces are modeled numerically. Monte Carlo codes can be broadly categorized as either analytic- or topography-based.
- Analytic codes simulate the production of craters and the evolution of cratered surfaces through time.
- Topography-based codes simulate the formation of craters and the evolution of cratered surfaces through the effects of impact cratering and other geological processes.

**How we modeled equilibrium cratering in CTEM**

- We accomplished this with a series of numerical experiments in which we generated a 100 m test crater field and bombarded it with a size-distribution containing a single size of crater, from 1 - 10 m.
- To model this in CTEM we need to know what is the erosive "power" of each crater.
- Using a Poisson model to estimate the number of overlapping craters over the test area, over time, we solved for the intrinsic per-crater erosive power. This tells us how much each crater contributes to the diffusivity of the system.
- We adopt the Neumark Production Function (NPF) as our cratering model. To estimate the effects of unresolved craters, we extrapolate the cumulative slope of the NPF to a 10 m crater size. Based on UEDGE experiment measurements, this likely overpredicts the primary production.

**But what is the process that determines the observed crater count equilibrium level?**

- Very heavily cratered terrains appear to reach an equilibrium in the total cumulative number of countable craters per unit area.
- We used the Cratered Terrain Evolution Model (Richardson, Minton, and Fassett 2015) to investigate crater count equilibrium.
- We found that the observed equilibrium level is a consequence of crater degradation due to downslope diffusion. But classical diffusion is inadequate to capture the process. Downslope movement is instead an anomalous diffusion process, similar to lateral transport as shown by U & Mustard (2000).