Planetary Protection Concerns for Small Bodies

Clark R. Chapman

Southwest Research Institute (retired), Boulder CO, USA

Committee on Planetary Protection 2021 Fall Meeting

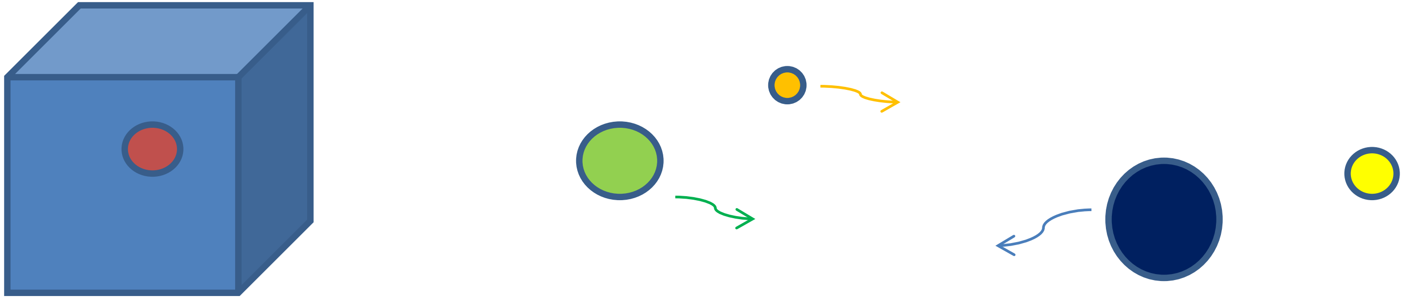
3:35 PM EST, 1 December 2021

A Little Bit About Me

- **My expertise concerns asteroids/small bodies and impact cratering in the solar system.**
- **I know little about biology or the range of extreme environments that life, or evidence of past life, may tolerate or have survived.**
- **I was a member of the last NAS committee that studied planetary protection in the context of small bodies:** NAS/NRC Task Group on Sample Return from Small Solar System Bodies (“**Evaluating the Biological Potential in Samples Returned from Planetary Satellites and Small Solar System Bodies,” 1998**).
- **Its scope was much broader than the narrow scope of this study.**

My Interpretation of the Task (1)

- In the solar system environment where most small bodies are exchanging materials, is there some body(/s) (or part of a body) of biological interest that sits alone, so that its materials can't be found elsewhere, so it should be protected from contamination by robotic spacecraft or astronaut expeditions?
- "Small bodies" = asteroids, comets, KBOs, Oort Cloud bodies & dwarf planets (but not planetary satellites or small meteoroids).



My Interpretation of the Task (2)

- **What is "planetary protection"?**
  - I assume we are discussing biological contamination only.
  - I assume we are NOT discussing physical or chemical damage to the body (note: Edward Teller even proposed bombing and destroying Ceres).
- **What kinds of missions to small bodies are pertinent?**
  - I would guess that scientific or engineering missions with no astrobiological purpose would be minimally affected by contamination.
  - So I will emphasize scientific missions that may have a focus on learning about biology that may be preserved on a small body.
  - How a specific small body with astrobiological interest would be identified and selected for study is mostly a mystery to me.

Size-Frequency Distribution of Near-Earth Asteroids

(There are similar data for other small-body populations, like main-belt asteroids, Trojans, comets, KBOs)

- **From Harris & Chodas (2021)**
- **Cumulative no. > diameter D**
- **Also Earth impact interval (yr)**
- **~ power law due to collisional evolution (many small ones!)**
- **Derived from main asteroid belt**
- **Dynamical duration in inner solar system ~10 Myr**
- **Data from asteroid/bolide surveys** (present day, not before)

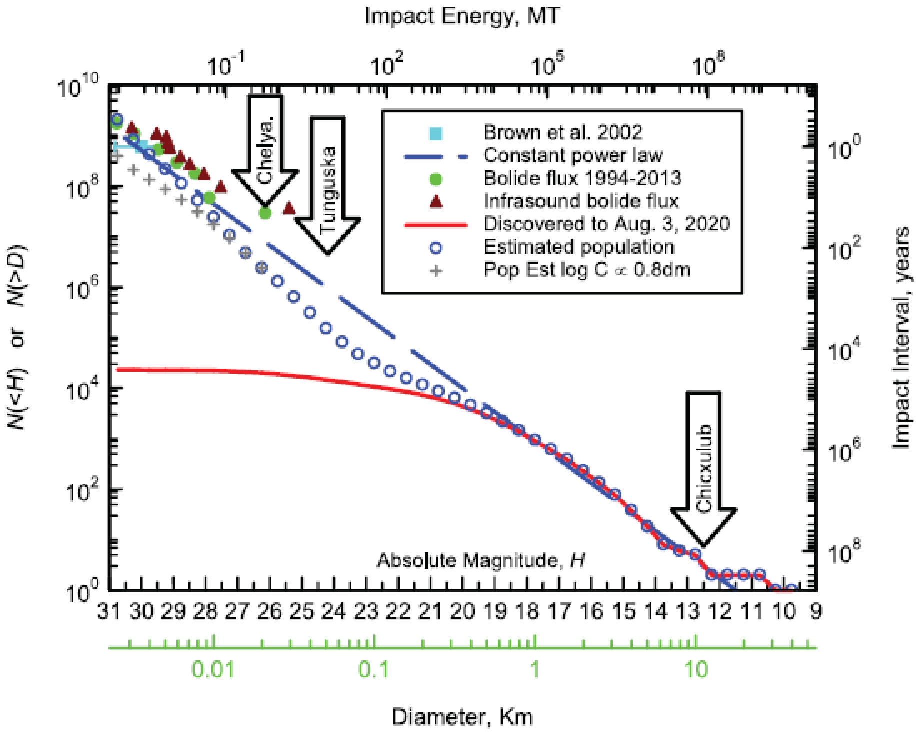
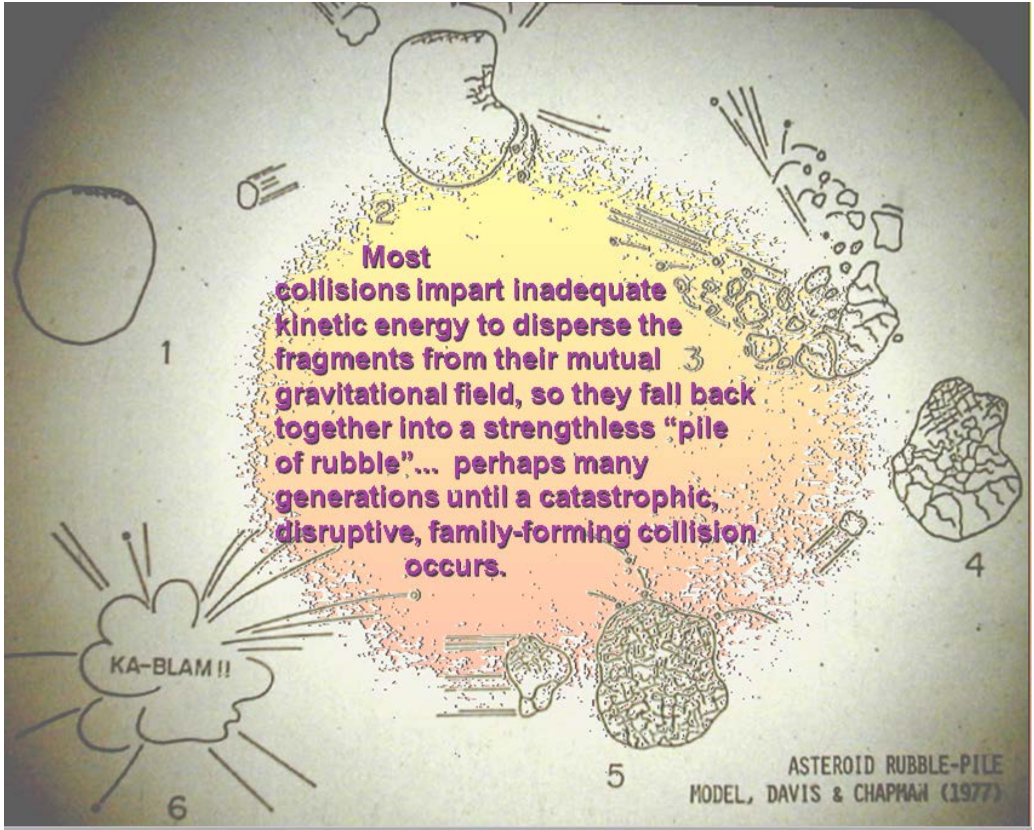


Fig. 8. The cumulative population of NEAs, with the new bin boundaries.

Most Asteroids are "Rubble Piles"

- Because of the "steep" SFD, most asteroid collisions are cratering or produce rubble piles (only modest fraction of ejecta escape).
- Only rare, giant collisions disrupt targets, forming asteroid "families".
- Only largest asteroids (e.g. >200 km diam.) retain unbroken interiors.
- Rubble piles are like lunar "megaregolith" throughout.
- All asteroids have surficial regolith, exposed to impacts/radiation.



My Perspective on Small Bodies

- **Since evidence about astrobiology may well exist mainly in rare rock-sized (vs. >km-sized) locations, I fear that we know very little about small bodies at such scales** (like COSPAR remarks re Mars).
- **Most small bodies (except the largest ones and perhaps new comets) have likely been smashed to bits or are otherwise physically evolved (e.g. “rubble piles”) so that “pristine” samples are rather small and may be rare/non-existent on most bodies.**
- **Due to collisions and orbital evolution, there are likely amounts (order 1%) of exogenous material (“xenoliths”) from other small bodies and even planets (e.g. Venus) on many small bodies, as found on Bennu and Ryugu and in many meteorites on Earth.**

Let Me Amplify a Bit about Venus

- **Venus has presumably been lifeless (except in its atmosphere?) for the last 0.5 Gyr, but maybe had life in much earlier times…and that would be fascinating.**
- **It has been proposed (Armstrong et al. 2002; Cabot & Laughlin 2020) that asteroid impacts may have lofted pieces of ancient Venus (through atmospheric tunnel of the impactor) so samples of biological interest may be on the lunar surface or within regoliths of small bodies.**
- **How would we recognize them? It would be a challenge to find such very rare, ancient fragments.**

Asteroid Taxonomy

- **Chapman, Morrison & Zellner (1975) originated the C,S,M… taxonomy. Taxonomy now uses most of the alphabet and is subdivided even more in the Bus-DeMeo system.**
- **But neither taxonomic classes nor higher resolution spectra are highly diagnostic of unambiguous composition nor do they generally reveal composition of minor constituents.**
- **So to say that a particular Sq-type asteroid is probably like a typical LL chondrite is likely to be true, but it may not be. And certainly spectra of whole objects don’t reveal xenoliths.**
- **And interpretations of spectra are rendered difficult by space-weathering, possible high temperatures, particle sizes, etc.**

What is a Unique Body of Biological Interest?

- **There may be unique asteroids (identified by unusual remote-sensing properties) but I doubt their uniqueness would imply biological interest.**
- **Most asteroids have the same variety of xenoliths on them and we would not be able to identify (in advance) any that are unique.**
- **Because of low spatial density and slow velocities, most comets and KBOs are likely to share fewer bits of other bodies. Some might be quite special. How would a particular body's biological interest be identified?**
- **New comets are more likely to be pristine, but are they similar or not?**
- **Interstellar objects (only two are known but more will soon be discovered) are likely to be unique, so planetary protection would be essential.**
- **Deep interiors of larger bodies are more likely pristine and of biological interest but such places would be very difficult to access.**

What would Make a Body Unique?

- **Deep interior of a large body**
  - There are few large bodies, so each may be unique
  - Their deep interiors have not been mixed onto bodies elsewhere, but access is likely impossible
- **Dynamically isolated bodies (e.g. in stable resonances like Trojans, interior to Mercury's orbit, etc.). But many other bodies likely share such orbits so no such body is likely to be unique.**
- **Very rare bodies (e.g. interstellar objects, very recently created family members exposing an original body's interior, very rare enormous comet).**

Some Concluding Impressions

- **Even a known body with a rare taxonomic type is likely represented by innumerable smaller, similar bodies.**
- **Bits of almost any body may exist on other small bodies, but that doesn't mean such bits would be easily found.**
- **We must not assume that all bodies of the same "type" are the same. Almost every body studied close-up by spacecraft has had unique characteristics, sometimes quite unexpected.**
- **The deeper beneath regoliths, the farther out in the solar system, the larger the body … the more likely we may wish to avoid contamination because:**
  - **They are more likely to be rare, unique, or "pristine" (e.g. no radiation).**
  - **They are more likely to have astrobiological significance.**
  - **However, accessing them may be increasingly difficult.**

Conclusions

- **It is generally doubted that small bodies have harbored life (life hasn't been found in meteorites).**
- **But that is NOT a robust conclusion, so we should be cautious.**
- **Still, small bodies are extremely numerous and almost all are fragments of the same parent bodies or otherwise similar to each other, so few need to be preserved as "national parks."**
- **Planetary protection measures should be retained (or even enhanced) for any mission focused on astrobiology or for a mission going to a rare or unique small body (e.g. interstellar object).**
- **Other small-body missions probably don't require P.P. protocols.**