DOES SIZE MATTER?

SOME FACTORS INFLUENCING THE RADIATION ROBUSTNESS OF MICROBES VOYAGING THROUGH SPACE

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For decades, many have wondered about the possibility that living organisms can travel through space. Some have speculated that Earth was “seeded” with microbes from Mars, or vice versa. For example, the Allen Hills (Antarctica) meteorite (ALH 84001).
Found live microbes (*Streptococcus mitis*) on pieces of the Surveyor probe returned from the Moon

This was after three years of unprotected exposure to cosmic radiation, vacuum, and the lunar freeze-thaw cycles!

So can living microbes travel through space?
Humans are more resistant to radiation damage than are many other complex organisms.

But many microbes are astonishingly resistant to radiation exposure – why?
BUGS IN SPACE!
So what is important?

- Radiation type and intensity
  - Photons versus particles
  - Energy distribution
- Mode of transport (e.g. ice, dust)
  - Opacity/density
  - Size (shielding and secondary electron buildup)
- The organism
  - Organism size
  - Genome size and activity
IONIZING RADIATION PARAMETERS
Radiation in space

- Photons
  - UV (not very penetrating)
  - X-ray (moderately penetrating)
  - Gammas (most penetrating)

- Particles
  - Electrons (bremsstrahlung)
  - Protons (generate secondary electrons)
  - Higher-Z particles (generate secondary electrons)

- The radiation environment changes according to location in space (i.e. near a star, galactic “outskirts”, proximity to SNe or GRB, etc.)

- Most extreme challenge comes from SNe and GRB
Approximate acute lethal dose

Integrated dose from SN at 10 pc

24-hour dose in space at gamma peak

Lethal dose range (>50%) for humans
Organisms in space

- The most significant effects may be on space-borne organisms.
- Any organism in a piece of rock or ice less than about a few tens of cm across may well become sterilized as it transits space.
- It seems reasonable to think that very small rocks or dust are not healthy abodes for any except the most radiation-resistant bacteria, or for any but the shortest transit times.
MODE OF TRANSPORT
Transport parameters

- Composition (rock, ice, metal)
- Size and opacity
- Time of transit
  - Longer transit time means more chances for high-dose event
Photon shielding

- Photon attenuation increases with depth
  - So the interior of larger objects will be better-shielded than that of smaller ones

- However, much of the radiation dose comes from secondary electrons
  - If there is insufficient thickness for the photons to interact, they can’t deposit energy
  - So if an object is very small, radiation dose may actually drop
Large objects

- Very large objects (say, a meter or more in radius) provide ample radiation shielding for interior organisms.
- There is room for secondary electrons and bremsstrahlung x-rays to be absorbed.
- However, large objects require more energy to reach escape velocity.
- Also have to survive entry into an atmosphere.
Intermediate sizes

- Smaller objects are much more numerous
- Easier to reach escape velocity
- However, they don’t provide as much shielding from direct photon radiation
- Also leave room for secondary electron buildup
- And they have those pesky reentry problems
Dust grains require the least energy to reach escape velocity
  - However, may also be more prone to heating when they are blasted into space

May be too small for photons to interact, reducing absorbed dose and electron buildup

Reentry likely to be gentler than with larger objects

However, UV exposure may be a problem
The largest objects may provide the most reliably hospitable environment for microbes traveling through space (assuming they can survive reentry)

However, the smallest objects (dust) may be a very good second choice

- Assuming that charged particles and UV are not too bad
ORGANISM VARIABLES
More genes provide more targets, and more things that can be damaged
More genes also imply a more complex organism
However, more genes also imply more DNA repair mechanisms
Organism activity levels

- May be reproducing more rapidly
  - Less time to repair damage
- More genes are active
  - more targets that can be damaged
Individual microbes can be exceptionally radiation resistant

In addition to some of the previously mentioned factors, it may also be related to the size of an organism

Small targets are hard to hit
Consider a 2 μm diameter organism with a cross-sectional area of about 3.1x10^-8 cm². An organism receiving integrated dose of 1000 rads (in the form of 1 MeV photons) will experience about 15-20 photons passing through. With a linear attenuation of about 0.08 cm⁻¹ and a depth of 2 μm, these photons will probably not interact at all. Even if one does, the odds are very high that there will be little damage – and that the damage will not be fatal to the cell. This may help explain the radiation resistance of many microbes – especially in the form of spores.
A person is optically thick, even to gamma radiation.

In both humans and microbial colonies, the odds are against any individual cell being killed or mutated.

However, it takes the death of only a small fraction of human cells to cause death.

On the other hand, survival of a microbial colony requires the survival of only a handful of microbes.
SO PUTTING IT ALL TOGETHER
The very largest or the very smallest particles will experience the lowest dose to organisms hitching a ride on the particles.

- And dust may be more likely to survive atmospheric entry.

The very small size of most microbes helps them avoid photon hits.

Thus – microbes on dust grains may be very robust.