

Safe Havens and Hot Spots: Ionizing Radiation in Martian Permafrost and its Influence on the Survival of Ancient Life



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Abstract

Permafrost on Mars is considered a primary target for the search for life. On a microscopic scale permafrost is highly non-uniform and the effective radiation dose absorbed by a microorganism, and thus its survival probability, depends strongly on its microscopic location and its environment. Current values for survival rates on Mars are estimates based on the average expected dose rate in the subsurface. Average values can over- and underestimate the true survival probabilities by an order of magnitude and more. The goal of my research is to understand how microscopic safe havens and hot spots in the radiation environment impact the potential for (1) the presence of extinct or extant life on Mars and (2) the preservation of biological information in extreme environments on Mars and Earth.

Therefore I propose to carry out the first quantitative study of ionizing radiation in permafrost and its influence on ancient life using 3D modelling of Martian regolith based on Monte Carlo simulations. To validate the computer models, Mars-analog samples will be investigated through laboratory-based measurements and computer simulations

Introduction and Objectives

- ❑ Currently, Mars is cold, dry, has a thin atmosphere, oxidation hazards and scarcity of organic molecules
- ❑ There is compelling evidence that billions of years ago Mars was warmer and wetter just like current Earth (presence of liquid water)
- ❑ If there has been life, do these ancient organisms still exist in the deeper subsurface of Mars 3.5 billion years later. in the deeper subsurface of Mars are they dormant or active?
- ❑ Good news: below 3 m, organisms will have to contend with only the low-level background radiation due to radioactivity.
- ❑ The Martian subsurface is basically a regolith type sediment that is made up of mineral matrix.
- ❑ Reported dose rate on Martian regolith ranges from (0.1 - 0.8) mGy/yr and represents average dose rates, yet are used to predict survival of microbes.

Research Questions

- ❑ How does radiation vary microscopically in sediments?
- ❑ How long will ancient microorganisms survive in situ under the influence of the variation in radiation?
- ❑ How fast will radiation destroy traces of extinct life?

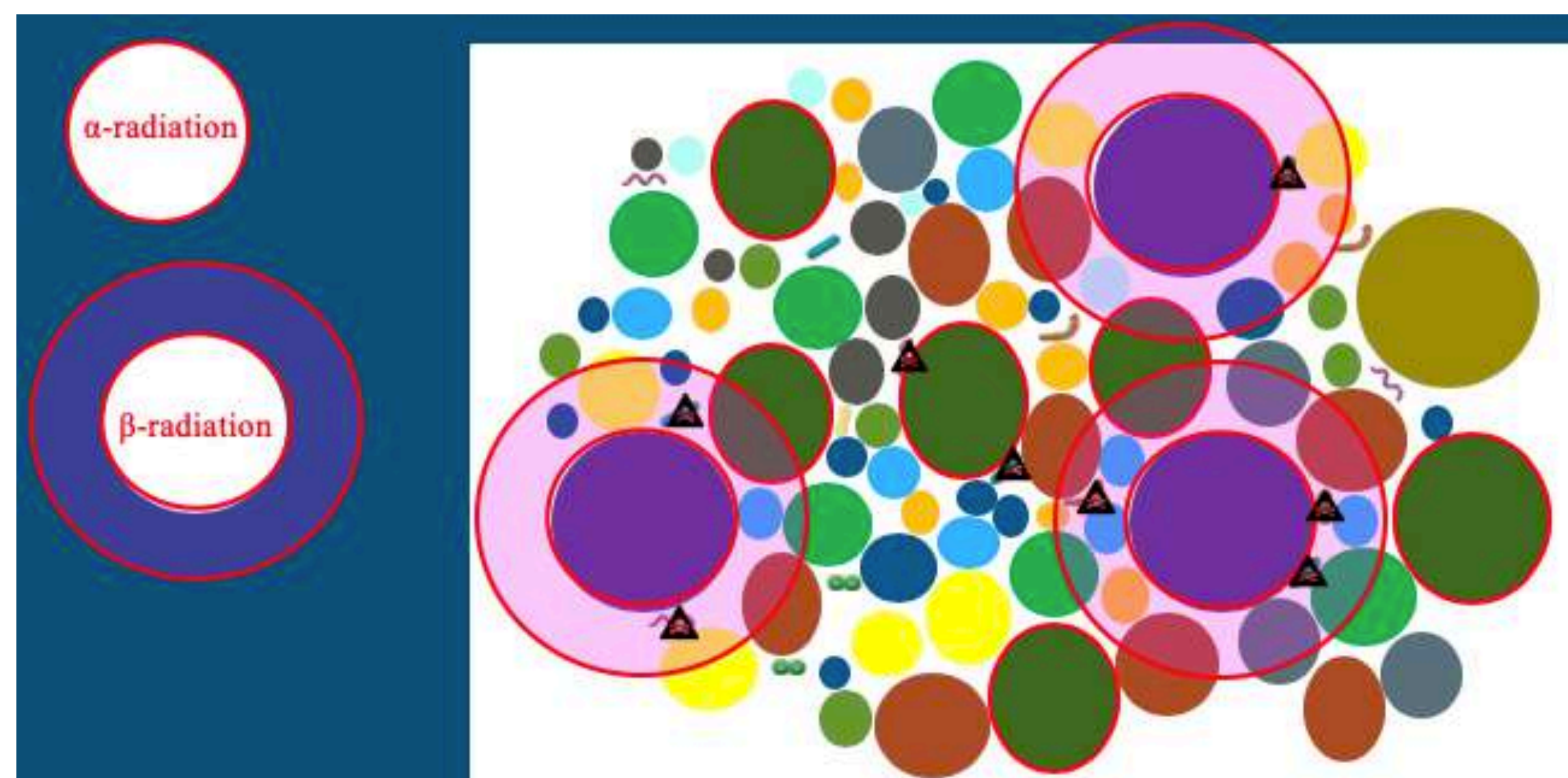
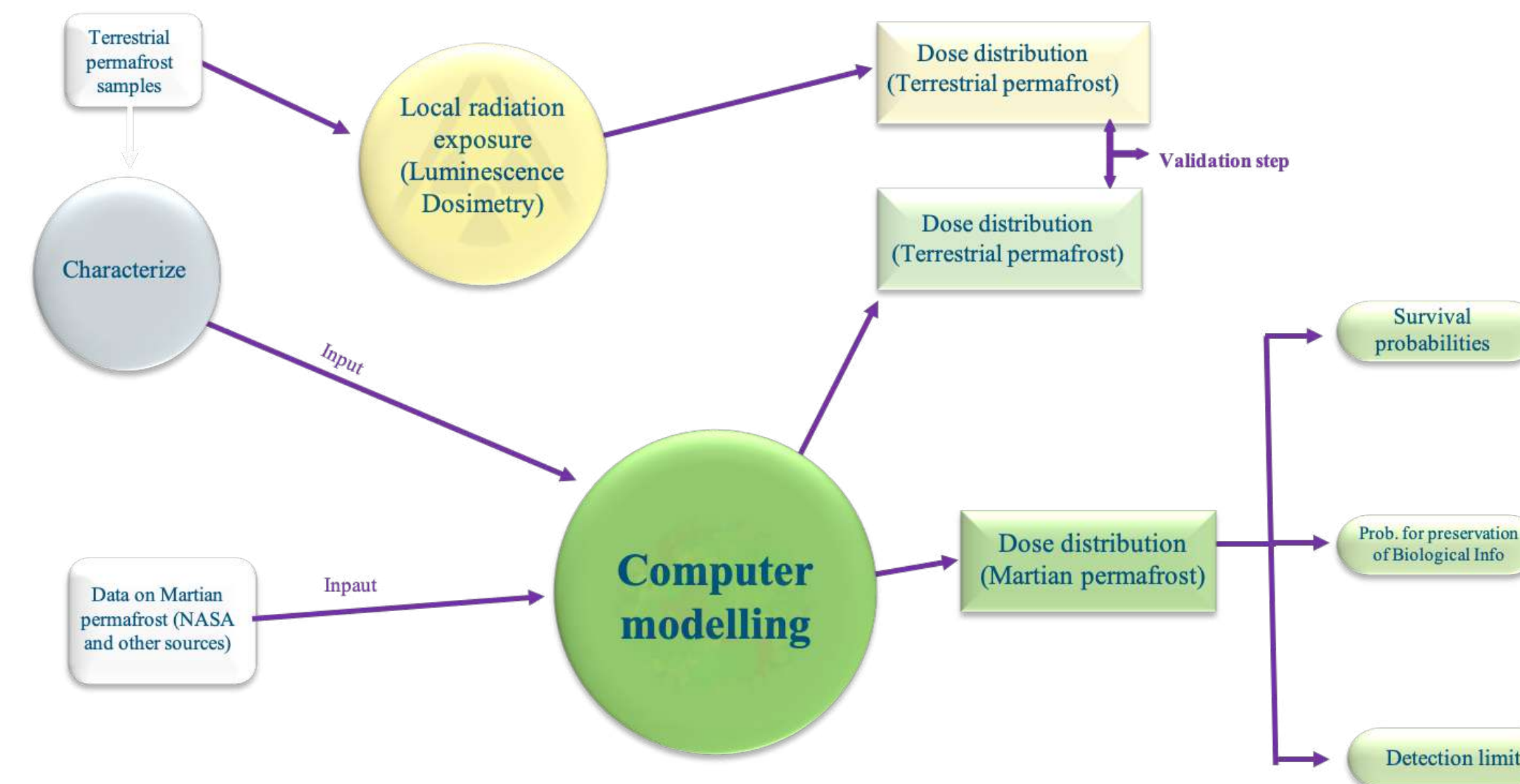


Fig.1. Simple modelling of Martian regolith as spherical grain of different sizes and different minerals (color coded). Where represents various microbes and the sign, represents exposure of microbes to radiation based on its location. The range of alpha and beta particles are ~ 20 µm and ~ 2 mm respectively.

Work-Flow



Materials and Methods

- ❑ DosiVox, a C++ code based on Geant4 toolkit
- ❑ Mars analog samples
- ❑ Risø TL/OSL-DA-20 automated luminescence reader
- ❑ α - $\text{Al}_2\text{O}_3\text{:C}$ grains, chips, and Luxel badges

Luminescence Dosimetry/M Measurement

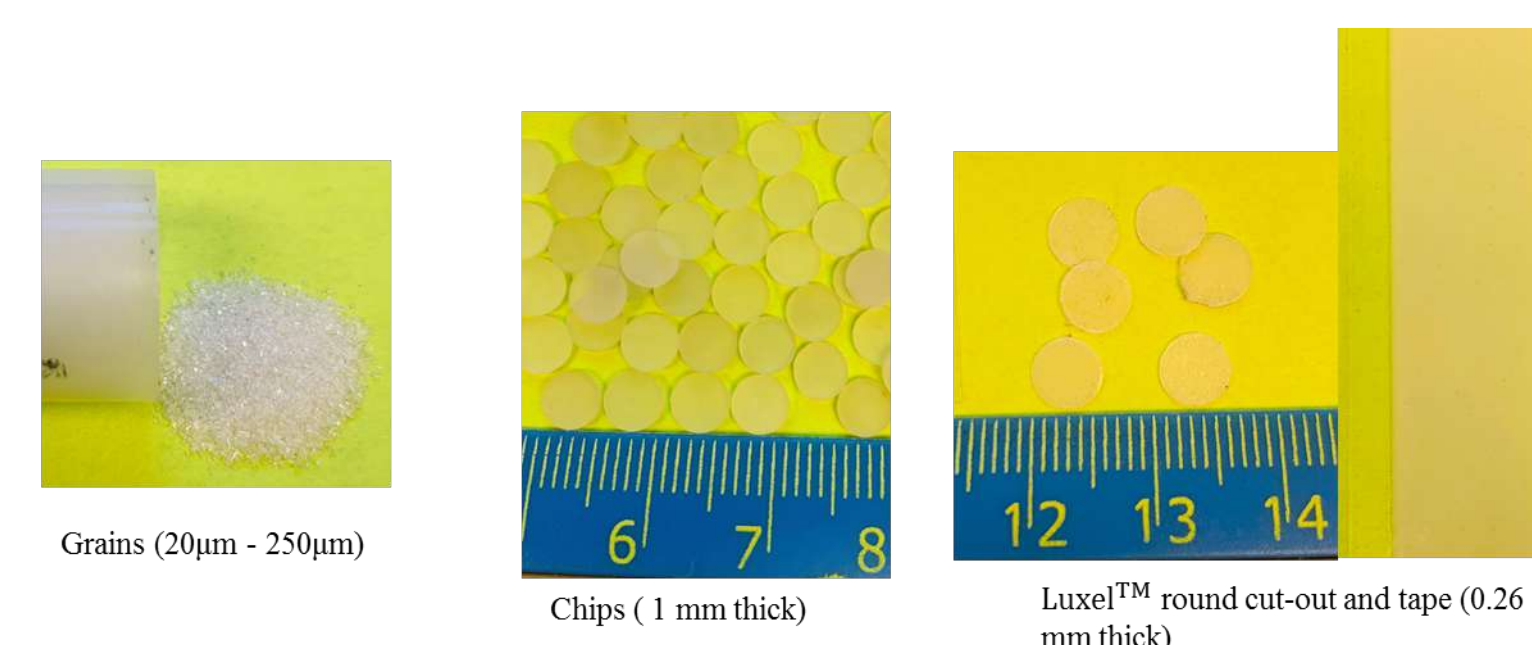


Fig. 2. α - $\text{Al}_2\text{O}_3\text{:C}$ grains, chips, and Luxel badges. These crystals are used as dosimeter to measure radiation

Alpha radiation measurement:

- ❑ smaller sized grains will be used due to the range of alpha particles
- ❑ grains will be mixed with permafrost sample and left for a minimum period of 6 months
- ❑ grains will be exposed to α , β , and γ radiation from permafrost sample
- ❑ two sets of samples will be prepared. (1) with alpha sensitive grains and (2) the other with alpha desensitized grains.

Beta radiation measurement:

- ❑ Luxel dosimeters will be used.
- ❑ Luxel dosimeter consist of polyester sheets on both sides of the tape that are thick enough to absorb alpha radiation without attenuating the beta component
- ❑ exposure will be around 5-6 week
- ❑ the gamma component can be neglected due to the small soil sample volume

Reading of dosimeter:

- ❑ Each dosimeter will be read and analyzed based on the principle of luminescence dosimetry.

Computer Simulation Code: DosiVox

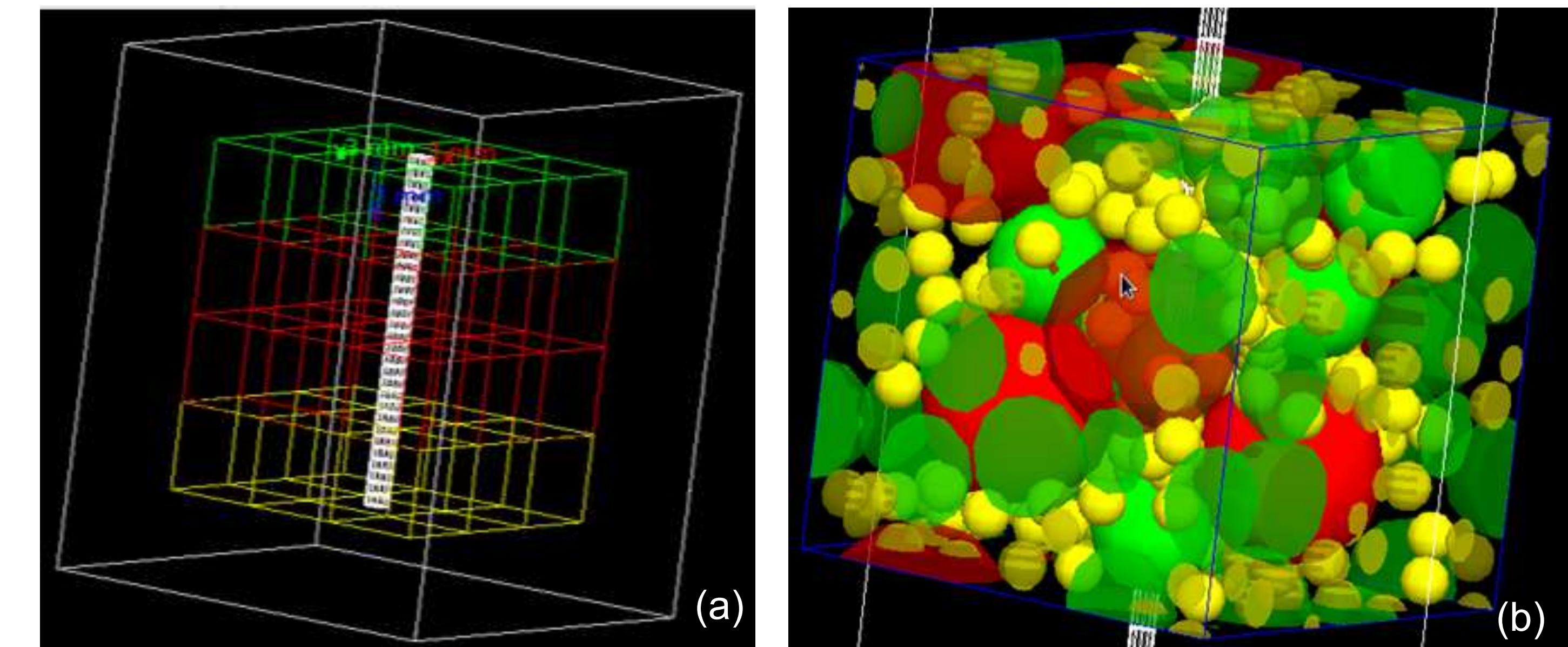


Fig. 3. DosiVox allows modelling samples by constructing a voxelized 3D volume where materials and associated radioactivity can be defined for each voxel. (a) is a 3x3x4 voxel volume with the probe detector at the center. (b) an alternative representation, where the voxels are filled with grains of different minerals and sizes and the grains can also act as detectors.

Preliminary Result: Beta dose rate model in a hypothetical regolith from Thorium series only

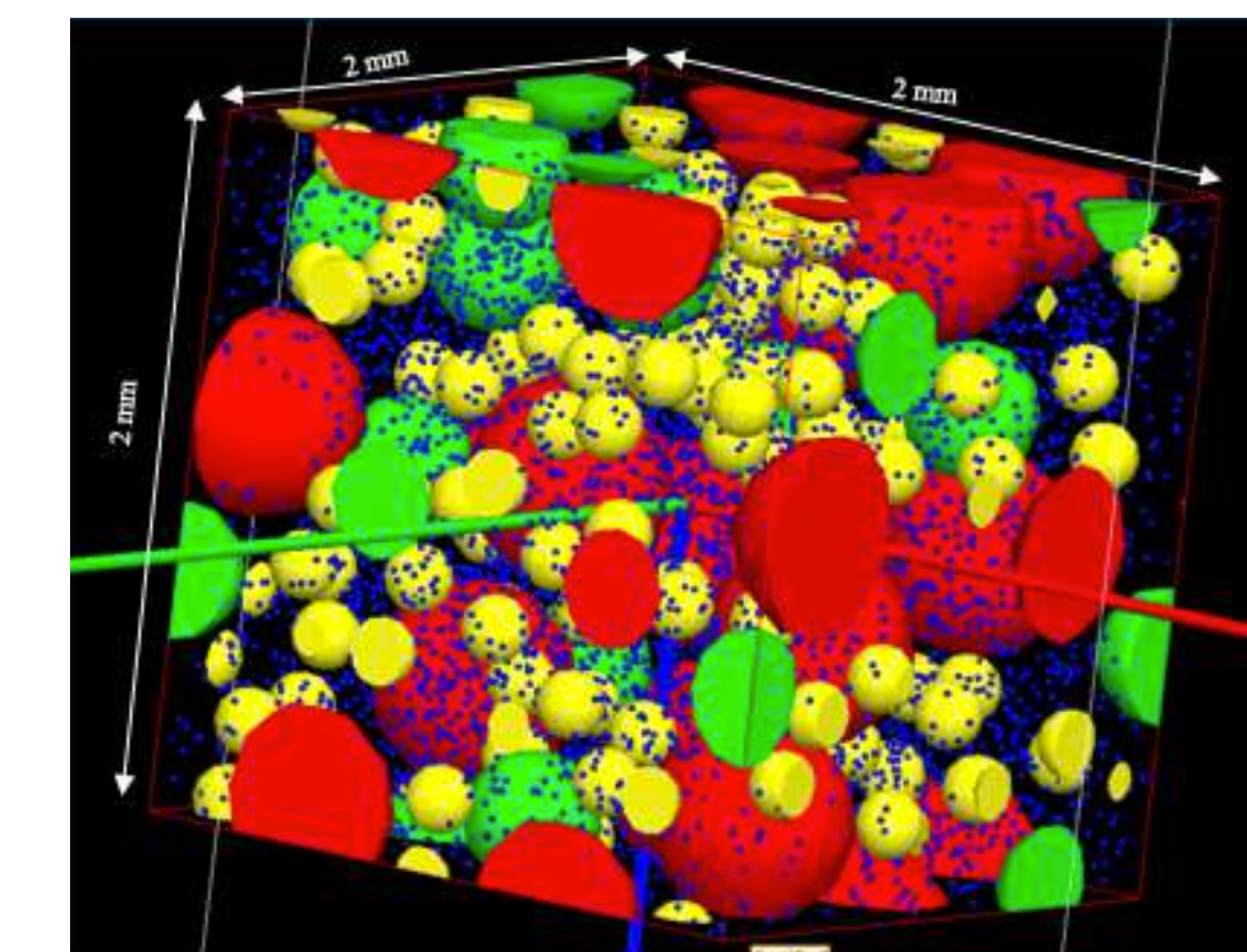


Fig. 4. In this model, four grains were arranged randomly in a 3x3x3 voxelized 3D volume. The image above represents the central voxel used as a detector. The volume was filled with water so the pre spaces is filled with water. The grains accounts for 30 % of the total volume. The blue tiny grains (diameter 10 micrometer) represent bacterial cells modelled with the formula ($\text{C}_{60}\text{H}_{87}\text{O}_{23}\text{N}_{12}\text{P}$) having a density of 1.1 g/cm^3 . The red, green and yellow grains represents zircon ($300 \mu\text{m}$, density of 4 g/cm^3), quartz ($200 \mu\text{m}$, density of 2.65 g/cm^3), and feldspar ($100 \mu\text{m}$, density of 2.60 g/cm^3) respectively. The dose deposited on the blue grains represents dose absorbed by the bacteria cells.

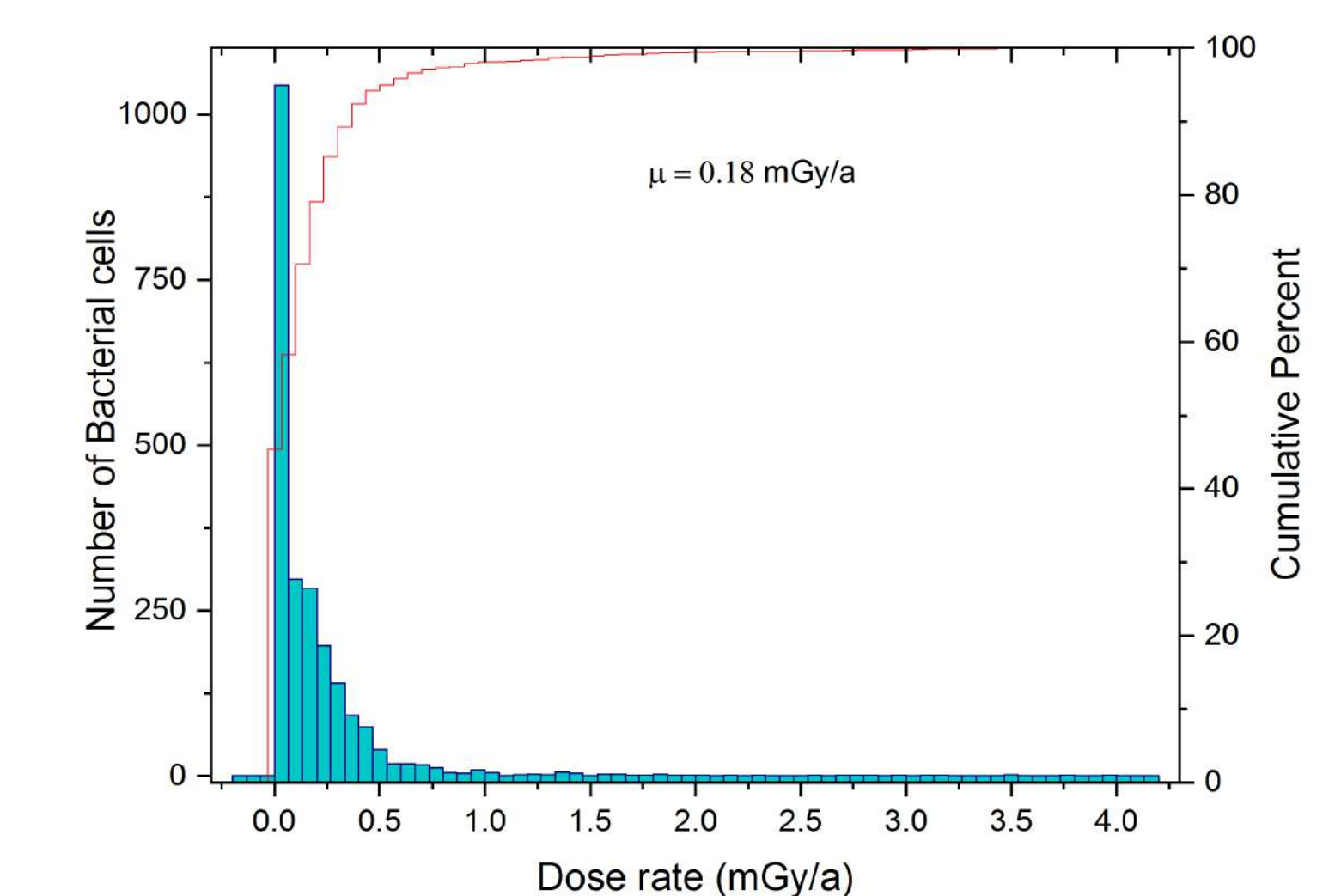


Fig. 5. β -dose (Th series) distribution histogram for the model in Fig 4. The dose distribution represents the dose rates absorbed by the bacterial cells. There were about 2301 bacteria cells. The average dose rate is 0.18 mGy/yr and from the distribution, about 45 % of the bacterial cells receives a dose rate less than or equal to 0.03 mGy/yr. (Min. dose rate = 10^{-4} mGy/yr, Max. dose rate = 4.2 mGy/yr)