Nanodosimetric Study of Radiation in the Brain and Eyes of Astronauts on the Lunar Surface

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Background: Understanding the biological impact of space radiation is vital to guide proposed long-term human space missions. Several approaches such as average organ doses and microdosimetry are used to quantify the radiation protection of astronauts. The brain and eyes are of particular interest due to the cognitive impact of high energy radiation [1] and high occurrence of cataracts observed in astronauts [2]. The rate and complexity of strand breaks in DNA due to primary galactic cosmic rays (GCR) up to ^{56}Fe and secondary lunar radiation are quantified in the organs using Geant4 and Geant4-DNA physics simulations. Such methods could be used to assess short and long-term impacts of space radiation.

Material and Methods: A three-stage multiscale approach is used to simulate the biological impact of primary and secondary lunar radiation in Geant4: 1) The secondary radiation field on the lunar surface is obtained by simulating a multilayer lunar volume. 2) Separate primary and secondary radiation simulations are used to determine the radiation field in organs of interest in the ICRP145 mesh phantom [3]. 3) Radiation incident on organs is simulated in a cell model containing DNA strands using combined Geant4 and Geant4-DNA physics models. Strand breaks are considered through both direct ionisation of the DNA as well through chemical interactions with induced hydroxyl radicals. Single strand breaks (SSBs) and double strand breaks (DSBs) are classified according to existing schemes [4,5].

Preliminary results: The normalized rate of strand breaks for primary GCR protons and secondary lunar radiation produced by GCR protons have been obtained for lunar radiation in the human brain using only Geant4-DNA physics. Extension of the simulated physics to higher energies using a hybrid Geant4 and Geant4-DNA physics model will allow better quantification of such nanodosimetric quantities, which will be useful for future cosmic radiobiological investigations.

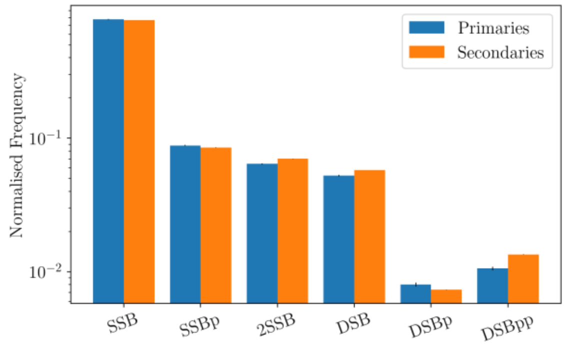

Figure 1: Relative probability of single and double strand breaks of various complexity for primary GCR protons and secondary lunar radiation in the brain, using the classification scheme outlined by Lampe et. al. [4].

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