Report of HIMAC experiments granted by "Living in Space”

(A03-1) “Multidisciplinary Analysis of the Effect of Low Fluence Particle Radiation on Animals and Biological Adaptations”
Research Group Leader: Mitsuru Nenoi
Visit duration: 3rd to 15th of July 2017

Experiment / project name: Intercomparison study of astrobiological model systems in their response to major components of the galactic cosmic radiation (STARLIFE project) [HIMAC Project no. 13J301]

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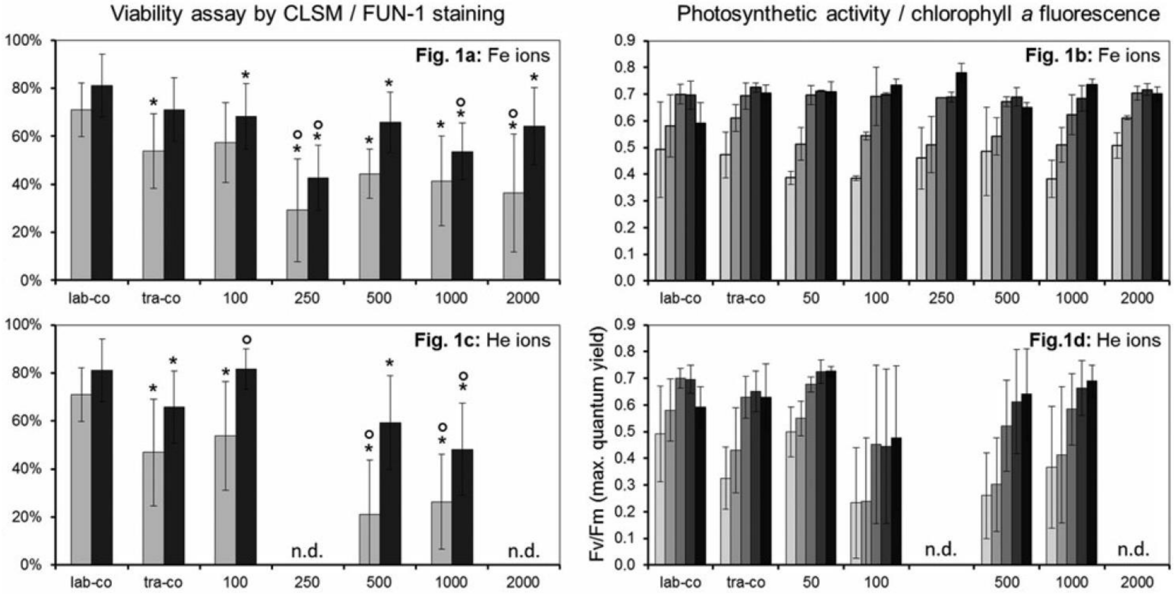
Beam time (date and heavy ions):
1) July 4th, 2017 (22:00 – 30:00 (10:00 p.m. – 06:00 a.m.)), Argon Ar 500 MeV/n (LET 90 keV/µm)
2) July 5th, 2017 (22:00 – 30:00 (10:00 p.m. – 06:00 a.m.)), Helium He 150 MeV/n (LET 2 keV/µm)

Aim and scope of experiment: The majority of experiments on microorganisms in space were performed using Earth-orbiting robotic spacecraft, human-tended spacecraft or space stations. In-depth knowledge regarding the biological effects of the radiation field in space is required for assessing the radiation risks in space. *To obtain this knowledge, microorganisms and different biomolecules have been studied as radiobiological model systems in space and at heavy ion accelerators on the ground*. The proposed research project *STARLIFE is aimed to compare the response of astrobiological model systems* (i.e., archaea, bacteria, lichens, viral and fungal species as well as selected biomolecules), which have been and/or will be in previous, ongoing or intended future space experiments, to heavy ion irradiation experiencing in space. The STARLIFE project is an international consortium of different research groups coordinated by DLR’s Astrobiology Research Group. With this project, selected astrobiological model systems will be exposed under identical conditions to low and high LET heavy ions. Since the advent of space flight, the ability of microorganisms to survive exposure to outer space conditions e.g. parts of the galactic cosmic rays has been investigated to examine the following questions: How far can we stretch the limits for life (metabolism and growth or survival)? Is interplanetary transport of microorganisms by natural processes feasible? To what extent does the space environment sterilize spacecraft during interplanetary travel between planets?

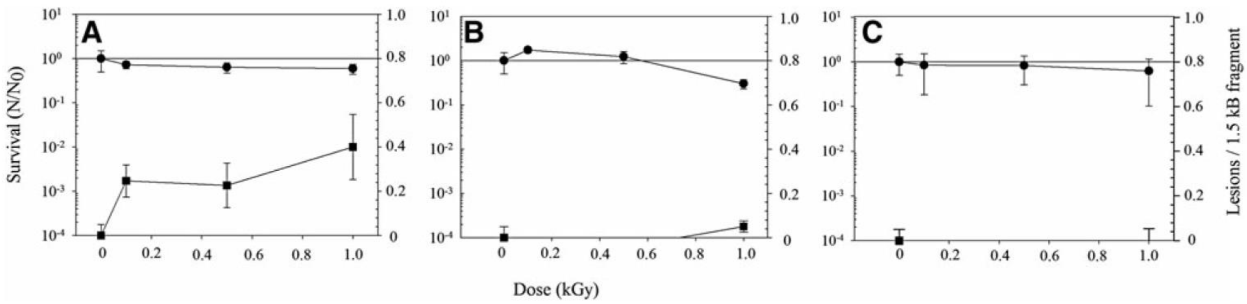
The aim of the STARLIFE group is to investigate the responses of different astrobiological model systems to the different types of ionizing radiation (X-rays, γ-rays, heavy ions) representing major parts of the galactic cosmic radiation spectrum. Low- and high-energy charged particle radiation experiments have been conducted at the Heavy Ion Medical Accelerator in Chiba (HIMAC) facility at the National Institute of Radiological Sciences (QST/NIRS) in Chiba, Japan. All samples were exposed under identical conditions to the same dose and qualities of ionizing radiation (i) allowing a direct comparison between the tested specimens and (ii) providing information on the impact of the space radiation environment on currently used astrobiological model organisms.

Selected results and overview of STARLIFE
The objective of STARLIFE was to study the responses of different model systems to increased doses of heavy ions, mimicking representatives of the HZE component of galactic cosmic radiation. They included six irradiations with heavy ions at the HIMAC facility of the QST/NIRS, using helium (150 MeV/n), argon (500 MeV/n), and iron (500 MeV/n), covering an LET range in water from 2 to 200 keV/µm and doses up to 3 kGy.
Highlight results: The STARLIFE campaign complements the results of the LIFE experiments at the EXPOSE-E facility on the International Space Station by testing the **model organism *Xanthoria elegans*** on its resistance to hazardous radiation that might be accumulated during long-term space exposure. Since previous astrobiological experiments were mostly performed with **anhydrobiotic lichen**, these experiments will **broaden our knowledge on the correlation of physiological state and astrobiological stressors**.



Metabolic activity and photosynthetic quantum yield (QY) of *Xanthoria elegans* after irradiation. Iron ions (a, b), and helium ions (c, d). Left panels: mean percentage (– SD) of metabolically active cells in irradiated samples and untreated controls achieved by live/dead staining.

Three **halophilic archaea**, *Halobacterium salinarum* NRC-1, *Halococcus hamelinensis*, and *Halococcus morrhuae*, have been exposed to different regimes of simulated outer space ionizing radiation. Exposure to 1 kGy of argon or iron ions at the HIMAC did not lead to a detectable loss in viability; only after exposure to 2 kGy of iron ions a decline in survival was observed. This research presents novel data on the **survival and genetic stability** of three halophilic archaea following exposure to simulated **outer space radiation**



Survival (CFU) and relative lesions per 1.5 kB DNA of (A) *Hcc. hamelinensis*, (B) *Hbt. salinarum* NRC-1, and (C) *Hcc. morrhuae* following exposure to Ar ions up to 1 kGy were evaluated. Organisms were incubated for 7 days (*Hbt. salinarum* NRC-1) or 14 days (*Hcc. morrhuae* and *Hcc. hamelinensis*), respectively. The y axis on the left shows survival (filled circles), and the y axis on the right refers to relative lesions induced in 1.5 kB DNA fragments (filled squares).

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