INFN Istituto Nazionale di Fisica Nucleare Sezione di Roma

POLICLINICO DI SANT'ORSOLA

SERVIZIO SANITARIO REGIONALE EMILIA-ROMAGNA
Azienda Ospedaliero - Universitaria di Bologna

ALMA MATER STUDIORUM UNIVERSITÀ DI BOLOGNA

FUTURE NEUROLOGY 2022
3RD GLOBAL CONGRESS

Dose-Effects Models for Space Radiobiology:

An Overview on Central Nervous System Dose-Effect Relationship

L.Strigari[1], A.N. Guracho[2], S. Strolin[1], A.G. Morganti[3] and A.Bartoloni[2*]

[1]Department of Medical Physics, Istituto di Ricovero e Cura a Carattere Scientifico (IRCCS) Azienda Ospedaliero-Universitaria di Bologna, Bologna, Italy

[2]Radiation Oncology Center, School of Medicine, Department of Experimental, Diagnostic and Specialty Medicine - DIMES, University of Bologna, Bologna, Italy

[3]Istituto Nazionale di Fisica Nucleare (INFN) Sezione di Roma 1, Roma, Italy

Space radiobiology is an interdisciplinary science that examines the biological effects of ionizing radiation on humans involved in aerospace missions. The dose-effect models are one of the relevant topics of space radiobiology. Their knowledge is crucial for optimizing radioprotection strategies, the risk assessment of the health hazard related to human space exploration, and reducing damages induced to astronauts from galactic cosmic radiation. Dose-effect relationships describe the observed damages to normal tissues or cancer induction during and after space flights. They are developed for the various dose ranges and radiation qualities characterizing the actual and the forecast space missions.

Based on a Pubmed search including 53 papers reporting the collected dose-effect relationships after space missions or in ground simulations, 7 significant dose-effect relationships (e.g., eye flashes, cataract, ***central nervous systems***, cardiovascular disease, cancer, chromosomal aberrations, and biomarkers) have been identified.

For each considered effect, the absorbed dose thresholds and the uncertainties/limitations of the developed relationships are summarized and discussed. The current knowledge on this topic can benefit from further in vitro and in vivo radiobiological studies, an accurate characterization of the quality of space radiation, and the numerous experimental dose-effects data derived from the experience in the clinical use of ionizing radiation for diagnostic or treatments with doses like those foreseen for the future space missions.

The growing number of pooled studies could improve the prediction ability of dose-effect relationships for space exposure and reduce their uncertainty level. Novel research in the field is of paramount importance to reduce damages to astronauts from cosmic radiation before Beyond Low Earth Orbit exploration in the next future.

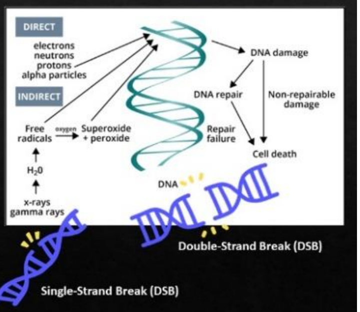
In that sense **an innovative approach could come from state of the art instrumentation and detectors operating in space**, built for astroparticle measurements, allows for the estimation of GCR properties and absorbed dose with a greater accuracy, **thanks to the recent availability of the Alpha Magnetic Spectrometer (AMS) detector, installed on the International Space Station, that measures charged components of cosmic rays since 2011 and is approved to be operative for all the life cycle of the ISS**.

Ionizing Radiation risk for CNS

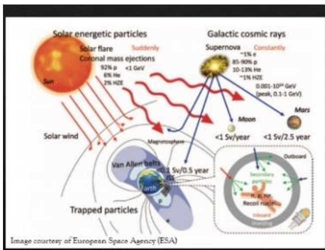
Ionizing radiation particles have in the physical ability to generate free radicals that may cause direct or indirect DNA damage

also provide a source of metabolic stress to which the central nervous system (CNS) is particularly susceptible as compared to other tissue types.

The precise mechanism of neurotoxicity and neurodegeneration produced by the IR are not yet understood from a biological point of view.



Origin of Space Radiation and Consequent Risk



Space Radiation composition
- Galactic Cosmic Rays (GCR)
- Particle emitted by the Sun (SEP) during isolated events
- Particle trapped in Earth's magnetic field (Radiation Belt)

None of the 3 components is constant in time, mainly due to the solar activity

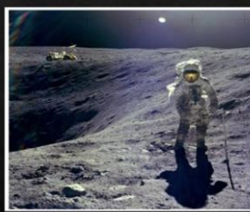
Human Space activities must cope with the high radiation environment of outer space.

Space Radiation effects on CNS

The potential acute and late risk from GCR and SPEs for astronauts on board the ISS are not considered a major concern.

Instead, deep space exploration and long term (>1 year) mission are under consideration.

This was clear from the first Apollo space missions in the 60s/70s



«I'm having these light flashes. I'm seeing this , like, flashing in my eyeballs. It was like fireworks in your eyeballs. It was spectacular.»

Charles Duke –Lunar Module Pilot of Apollo 16

Dose-effects Relationship for CNS

On exploratory BLEO missions' astronauts will be exposed to a variety of particles (HZE) which differ in terms of particle energy and particle linear energy transfer (LET)

Possible CNS risks are :

Early - detriments in short-term memory, reduced motor function, behavioral changes)

Late - neurological disorders, such as premature aging and Alzheimer's disease.

Studies on the effects of radiation on CNS has been done only on ground at the accelerator facility or through simulations

This studies provide evidence for the CNS health risk for missions outside of LEO for example :

- Britten et Al have shown that doses as low as 20 cGy of simulated GCR radiation (1 GeV/u 56Fe particles) can significantly impair learning and memory in a rodent model
- Hienz et al. demonstrated that proton radiation caused marked neurocognitive deficits at doses as low as 25 cGy.
- Rabin et al , showed, using different ions, that the threshold dose (TD) for the disruption of operant respond in mouse model was order tens of cGy
- In general CNS effects threshold appear to be order 0 10 cGy for many endpoints and target

Further investigation are required to produce dose-effects models that will allows to predict the risk of CNS damage due to radiation during the space exploration

For further info visit the following web page
[AMS02 INFN ROMA and Sapienza University [INFN wiki]]
or email to **Alessandro.Bartoloni@cern.ch**