AMS Roma Sapienza Activities
(1/11/2021-31/10/2022)

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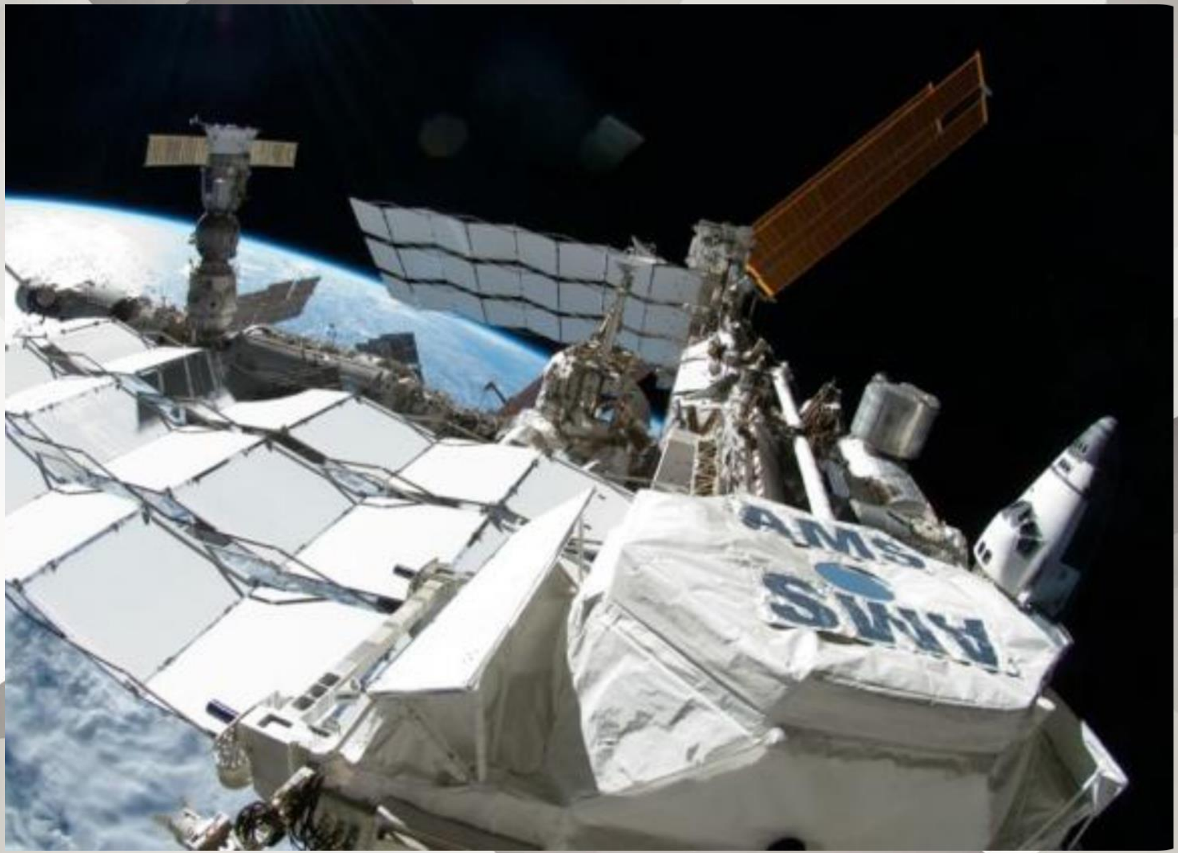
I gratefully acknowledge the strong support from the AMS collaboration and from the Italian Space Agency (ASI) within the agreement ASI-INFN n. 2019-19-HH.0.

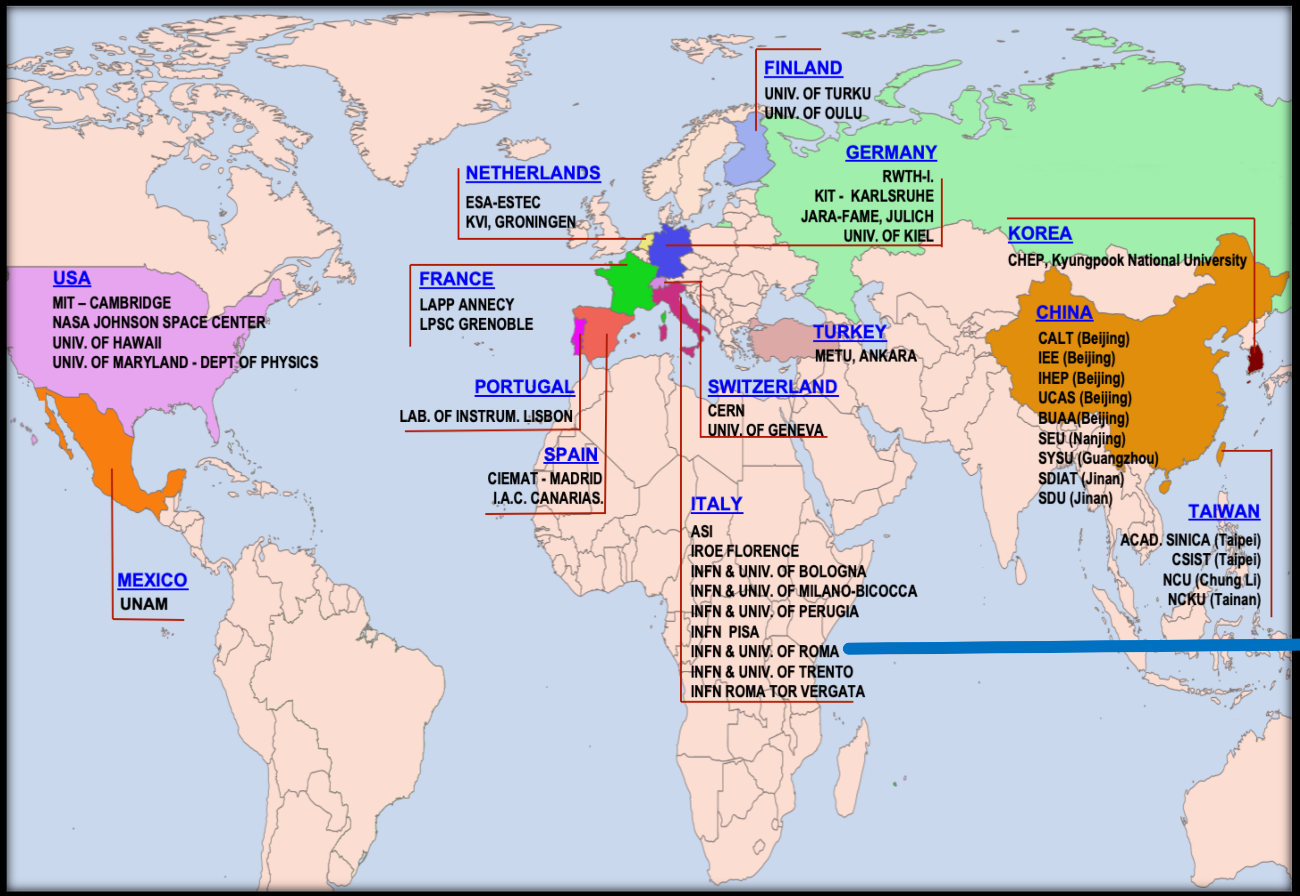


Outline

- AMS INFN Roma Sapienza Research Group
- TRD operations support
- Astroparticle Experiments 4 Space Radiobiology
- Target Effects vs Non Target Effects investigation

INTRODUCTION

INFN ROMA SAPIENZA RESEARCH GROUP



The AMS collaboration

(http://ams02.space)

An international collaboration made of 44 Institutes from America, Asia and Europe

The AMS02 detector has collected so far more than <u>200 billion</u> Cosmic Rays events.

More Info in the AMS-02 webpage:

https://ams02.space

AMS Data taking operations support

I participate by remote in monitoring the AMS data acquisition at the AMS Payload Operation Control Centre (POCC),

I did more than ten shifts in the **TEE** (TRD + Tracker) crew position

(25 – 27/03/2022, 04 – 05/08/2022, 08 – 09/08/2022 and 12 – 14/09/2022).

Transition Radiation Detector Monitoring (TRD)

The INFN Roma and the Sapienza University joined the AMS collaboration in 2001.

The group has taken part to the construction of the Transition Radiation Detector (TRD), having as main task the responsibility to develop the slow control electronics of the GAS System of the TRD (UG-Crate).

The UG-CRATE was part of a safety-critical system, and the group took care of all the phases of the development (Design–Test-Integrate-Fly) following the NASA requirements.

Grafana remote monitoring software

Astroparticle Experiments
4
Space Radiobiology

I Participated in the research activity of the INFN ROMA Sapienza AMS group relating to the use of cosmic ray measurements collected by AMS and in general from astroparticle and dosimetry experiments in space to improve the knowledge of radiobiology in space environment with particular emphasis on the topic of dose-effect models.

Journal articles and conference papers published

Bartoloni A, Della Gala G, Guracho AN, Paolani G, Santoro M, Strigari L, Strolin S (2021)

Space Radiation Field Characterization Using the Astroparticle Operating Detectors

Proceedings of the International Astronautical Congress, IAC Volume A1 2021 IAF/IAA Space Life Sciences Symposium 2021 at the 72nd International Astronautical Congress, IAC 2021 Dubai

72nd International Astronautical Congress (IAC 2021), Dubai, United Arabiean mirates, 25-29 october 2021.

IAF/IAA SPACE LIFE SCIENCES SYMPOSIUM (A1)
Radiation Fields, Effects and Risks in Human Space Missions (5)

IAC-A1.5.1 (ID:63116)

Space Radiation Field Characterization Using the Astroparticle Operating Detectors.

A. Bartoloni [a*], G. Della Gala[a,b], A.N. Guracho[a], G. Paolani[a,b], M. Santoro[a,b] L. Strigari[a,b], S. Strolin[a,b]

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Abstract

The actual and next decade will be characterized by an exponential increase of the exploration of the Beyond Low Earth Orbit space (BLEO). Moreover, the firsts tentative to create structures that will enable a permanent human presence in the BLEO are forecast. In this context a detailed space radiation _eld characterization will be crucial to optimize radioprotection strategies (eg spaceship and lunar space stations shielding, lunar / Mars village design, ...), to assess the risk of the health hazard related to human space exploration and to reduce the damages potentially induced to astronauts from galactic cosmic radiation. On the other side since the beginning of the century many astroparticle experiments, aimed at investigating the unknow universe components (dark matter, antimatter, dark energy,) are collecting an enormous amount of data regarding the cosmic rays (CR) components of the radiation in space. Collected data cover a large period of time and permit to have not only integrated information of CR fluxes but also their variations on time on a daily basis; Also, the energy range are particularly interesting since the astroparticle detectors operates using instruments that allows to measure CR in a very high energy range starting usually from the MeV scale up to the TeV, that are not covered by other space radiometric instruments; Last but not least is the possibility to acquire knowledge in the full range of the CR components and theirs radiation quality. After reviewing the past and still operating astroparticle experiments architectures and instrumentations (PAMELA, AMS02, . . .) it will be illustrated how these data can be used to enhance the space radiation field characterization and consequently to improve the radiobiology issues in space with the respect of one of the most the relevant topics of space radiobiology represented by the dose effect models.

Keywords:; Human Space Exploration; Space Radiation; Space Radiobiology; Cosmic Ray; Astroparticle Physics ;AMS02

Journal articles and conference papers published

Bartoloni A, Paolani G, Santoro M, Strigari L, Strolin S, Guracho AN, Della Gala G (2022)

High Energy Physics Astroparticle Experiments to Improve the Radiation Health Risk Assessment in Space Missions

POS EPS-HEP2021 106 doi:10.22323/1.398.0106

PoS PROCEEDINGS OF SCIENCE

Volume 398 - The European Physical Society Conference on High Energy Physics (EPS-HEP2021) - T01: Astroparticle and Gravitational Waves

High Energy Physics Astroparticle Experiments to Improve the Radiation Health Risk Assessment in Space Missions

A. Bartoloni*, *G. Paolani, M. Santoro, L. Strigari, S. Strolin, A.N. Guracho and G. Della Gala*

Full text: pdf

Pre-published on: February 10, 2022
Published on: May 12, 2022

Abstract

In the near future, all the space agencies are working to restart the human exploration of space outside the Low Earth Orbit (LEO). Crewed space missions in this and the next decade will see the presence of humans on the Moon and Mars surface. One of the main showstoppers to be investigated for safe exploration and colonisation is the biological effects of ionising radiation that can compromise the health of astronauts/space workers. In this vital task, a principal role could be done by the astroparticle experiments presently operating in space. Such experiments are a source of information crucial to improving the knowledge of radiobiology effects in space. In this talk, a review of the past and present astroparticle experiments will be presented and will highlight some of the possible contributions and improvements in the space radiobiology research field.

DOI: https://doi.org/10.22323/1.398.0106

How to cite

Metadata are provided both in "article" format (very similar to INSPIRE) as this helps creating very compact bibliographies which can be beneficial to authors and readers, and in "proceeding" format which is more detailed and complete.

Conference papers

Bartoloni A, Della Gala G, Guracho AN, Morganti A.G., Paolani G, Santoro M, Strigari L, Strolin S (2022)

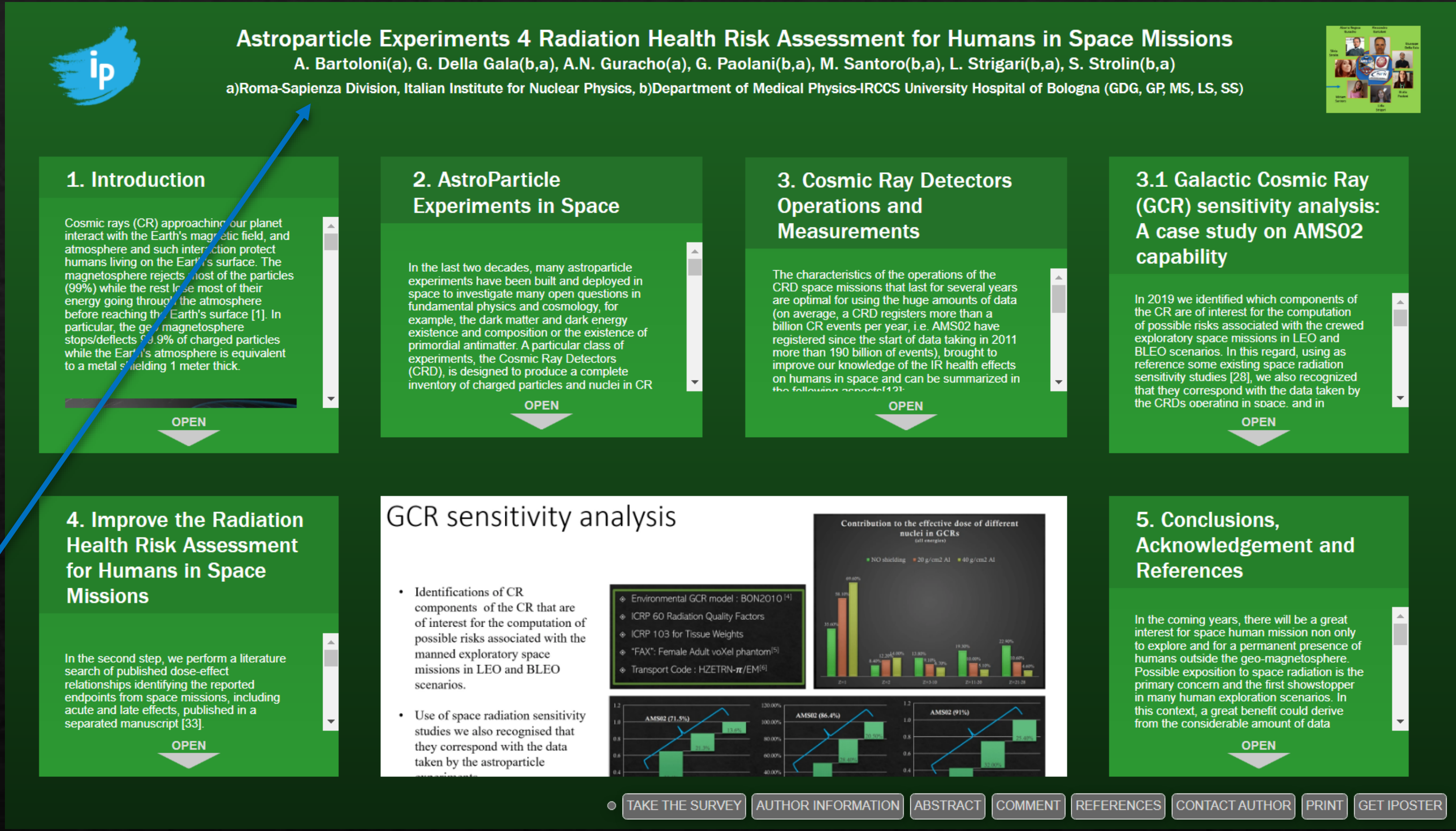
Dose-Effects Models for Space Radiobiology: an overview on Dose-Effect Relationship.

Oral talk

Bartoloni A, Della Gala G, Guracho AN, Paolani G, Santoro M, Strigari L, Strolin S (2022)

Astroparticle Experiments to Improve the Radiation Health Risk Assessment for Humans in Space Missions"

Interactive presentation



[iaf (iPosterSessions - an aMuze! Interactive system)]

Target Effects vs Non Target Effects investigation

I developed a software tool for analyzing AMS02 data for the generation and validation of predictive models of bystander-type non-target effects (NTE / bystander) due to the risk of exposure to ionizing radiation from galactic cosmic rays.

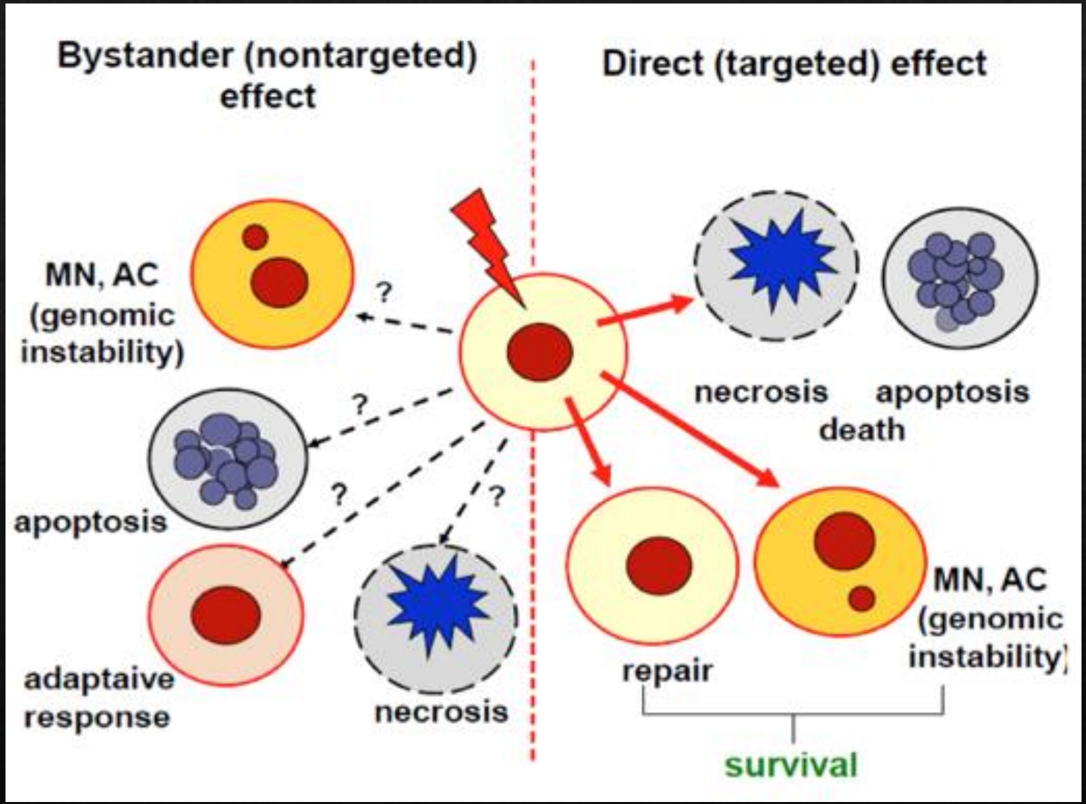
The software, developed in the R-Studio IDE using R-Script language, includes a main program and several libraries for a total of > 10,000 lines of codes. Furthermore, I participated in the production of the software documentations.

I gave a talk in this research activity at the 22nd International Conference of Mechanics in Medicine and Biology (ICMMB-2022)

Bartoloni A, Guracho AN, Strigari L, (2022) **Target Effects vs. Non-Target Effects in Estimating the Carcinogenic risk due to Galactic Cosmic Rays in Exploratory Space Missions** Proceedings of the International Astronautical Congress, IAC Volume A1 2022 IAF/IAA Space Life Sciences Symposium 2022 at the 73rd International Astronautical Congress, IAC 2022 Paris – September 2022

Target Effects vs Non Target Effects

- Non-targeted effects (NTEs) include bystander effects where cells traversed by heavy ions transmit oncogenic signals to nearby cells, and genomic instability in the cell's progeny.
- Studies on the Harderian gland, chromosomal aberrations at low dose and many mechanistic studies support the NTE model, with evidence of a supra-linear effect at low doses of NTE compared to a linear effects for TE .
- These NTEs are expected also at the fluences and for radiation species that occur in space.



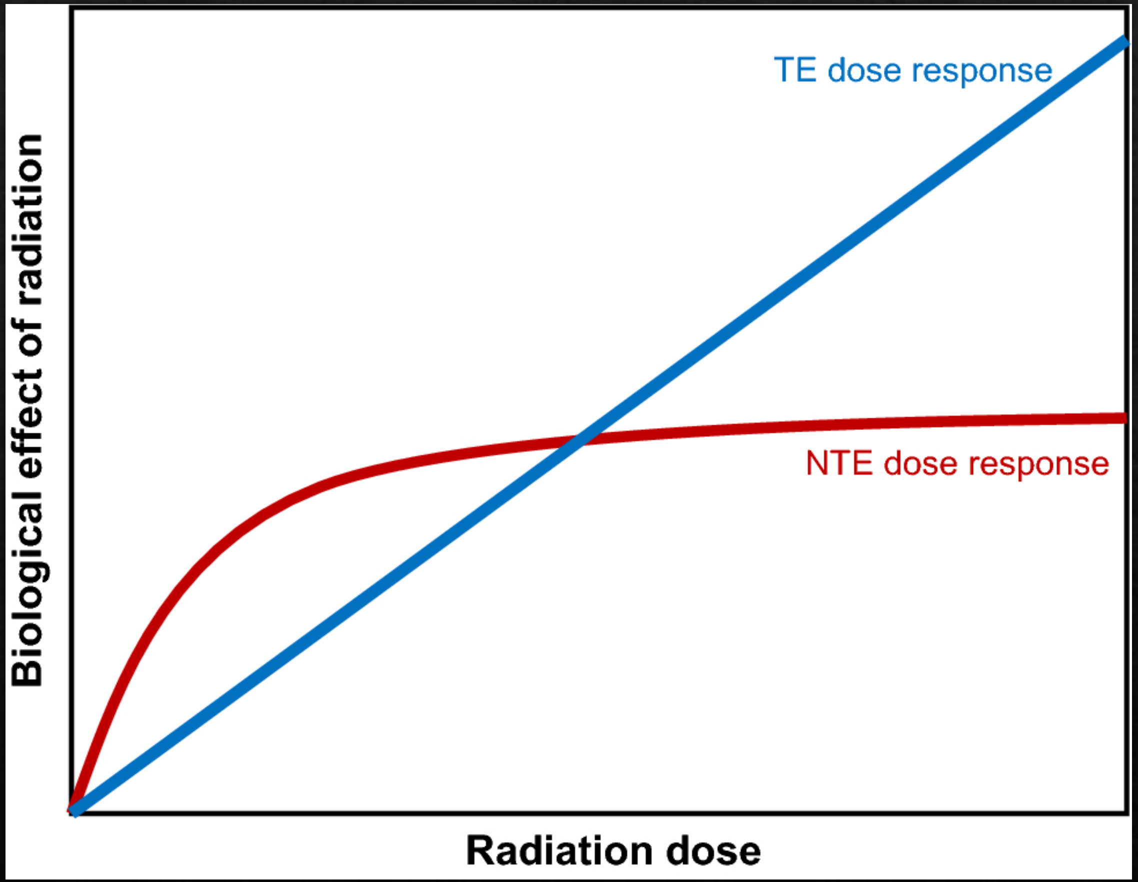
Non-Targeted Effects Models Predict Significantly Higher Mars Mission Cancer Risk than Targeted Effects Models

F. Cucinotta, Eliedonna E. Cacao • Published 12 May 2017 • Biology, Physics • Scientific Reports

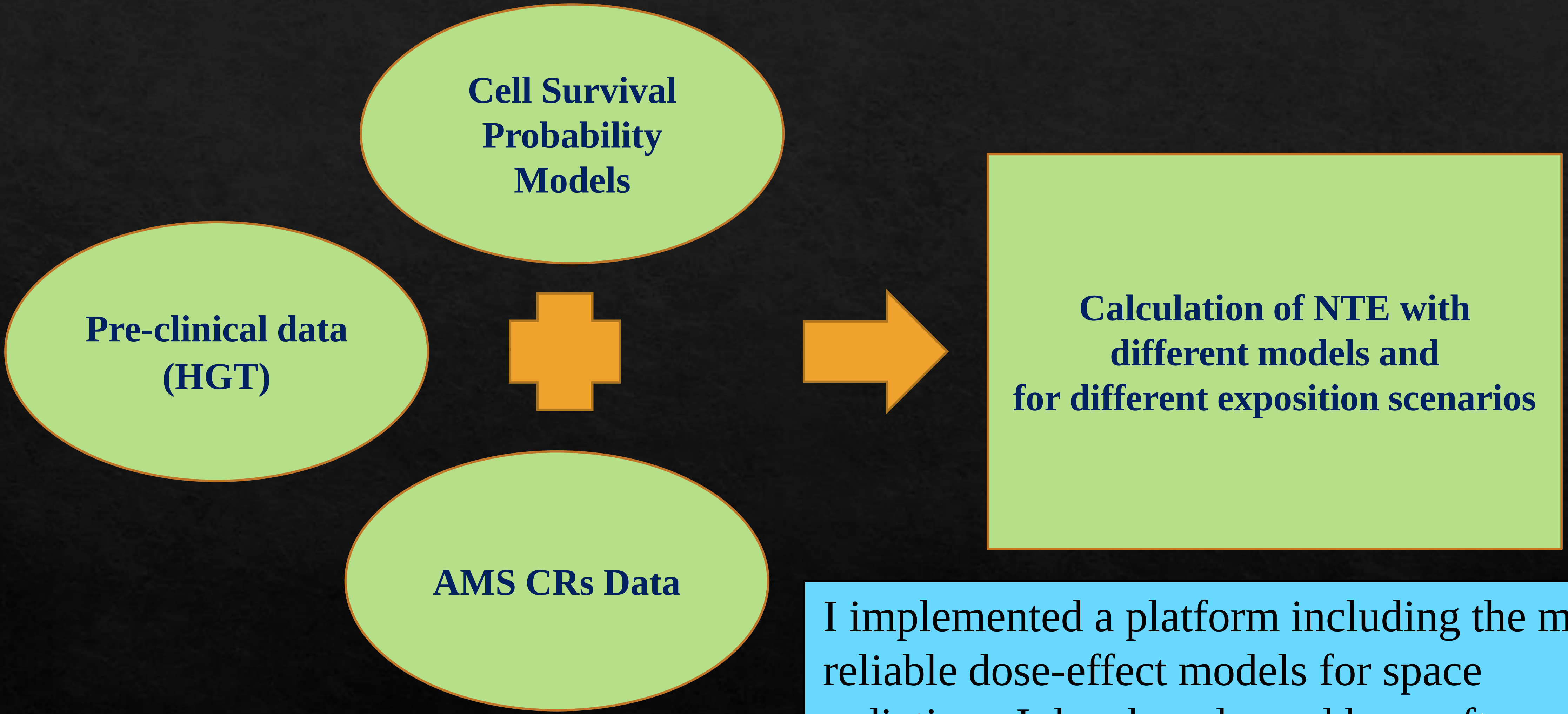
Work in progress at Roma Sapienza AMS group

Dose-Effect Relationship

Crucial point is to predict the toxicity of the space radiation expected for the astronauts/space workers and the creation of reliable ***mathematical models*** that describe the correlation between the exposition to IR and the possible damages to the organs at risk



A Tool for NTE components evaluation



I implemented a platform including the more reliable dose-effect models for space radiation, I developed an ad hoc software in R-script language (> 10,000 code lines).

Hazard Function for Tumor Prevalence (TP)

Prevalence is the number of people/cells with a specific disease or condition in a given population at a specific time. This measure includes both newly diagnosed and pre-existing cases of the disease.

Tumor prevalence (TP) is described by a Hazard function, H, which is dependent on radiation type for γ-rays while for charged particles is dependent on the charge number (Z), kinetic energy (E) and fluence (F).

$$TP = 1 - e^{-H(Z,E,F)}$$

$$H_\gamma = H_0 + [\alpha_\gamma D + \beta_\gamma D^2] * S(D)$$

$$H_{CP}(Z,E,F) = H_0 + [\Sigma F + \beta D^2] * S(D)$$

Where:

- H_0 represents the background prevalence
- α_γ and β_γ are the linear and quadratic coefficient with dose Induction terms
- Σ is pseudo-biological action cross section taking in account the particle track structure models
- ***S(D)*** is the ***Cell Survival Probability.***

R-script Library includes the most used Cells Survival Probability models

To be used in the calculation of hazard functions of Tumor Prevalence.

1. Theory n-target N-hit model (nTNH)
   Two special case of nTNH including:
   - Theory single Target single hit model (sTSH)
   - Theory single Target N-hit model (sTNH)
2. Theory Linear Quadratic Model (LQ)
3. Linear Quadratic Model modified by hyper-radiosensitivity(HRS) effect.
4. Theory Linear Quadratic Cubic Model (LQC) for high dose.
5. Sublesion Theory Repair – misRepair Model (S-RMR)
6. Sublesion Theory Lethal – potentially lethal Model (S-LPL)
7. Sublesion Theory Saturable Repair Model (S-SR)

1. $S(D) = 1 - (1 - B)^n,\ B = e^{\frac{-D}{D_0}}\left[1 + \sum_2^N \frac{\left(D/D_0\right)^{N-1}}{(N-1)!}\right]$

2. $S(D) = e^{-\alpha D - \beta D^2}$

3. $S(D) = exp\left\{-\alpha\left(1 + \left(\frac{\alpha_s}{\alpha} - 1\right) e^{\frac{-D}{D_0}}\right) D - \beta D^2\right\}$

4. $S(D) = e^{-\alpha D - \beta D^2 - \gamma D^3}$

5. $S(D) = e^{-aD}\left[1 + \left(\frac{aD\left(1 - e^{(-\lambda T)}\right)}{\varepsilon}\right)\right]^{\varepsilon\phi}$

6. $S(D) = e^{-(n_L - n_{PL})D}\left[1 + \frac{n_{PL} D}{\epsilon}\left(1 - e^{-\epsilon_{PL} t_r}\right)\right]^{\epsilon}$

7. $S(D) = e^{-\frac{n_0 - C_0}{1 - \frac{C_0}{n_0} e^{kT(C_0 - n_0)}}}$

Space radiation representative pre-clinical data set (Alpen et. al. 1993)

Prevalence of Harderian Gland Tumors

- Gammas 55.5TBq Co60
- Hydrogen with energy 250A MeV, LET 0.4 keV/µm
- Exposition time in between 60 sec. to 120 sec.
- Irradiation field is 3 x 5 cm^2.
- Background Prevalence is $H_0 = 0.026$

Table III

Prevalence of Harderian Gland Tumors after Irradiation with Proton ions

Dose (Gy)	Mice: Number	Mice: At risk	Mice: With tumors	Mice: Prevalence[a]
0	198	155	4	2.6 ± 2.5
0.4	47	44	43	9.3 ± 6.1
0.8	42	41	8	19.5 ± 12.1
1.6	48	43	13	30.2 ± 13.7
3.2	28	24	7	29.2 ± 18.2

[a] ±95% CI

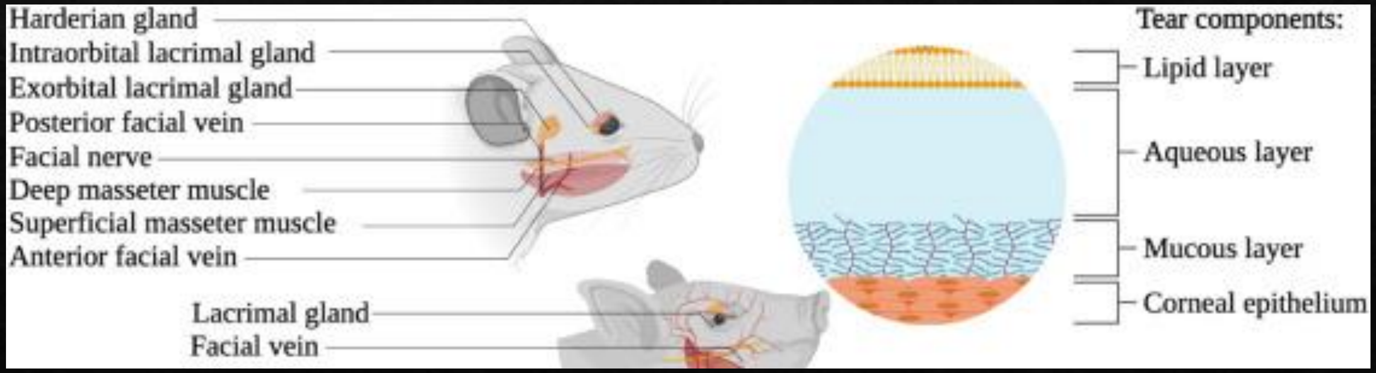
Table II

Prevalence of Harderian Gland Tumors

After 60Co Gamma Irradiation

Dose (Gy)	Mice: Number	Mice: At risk	Mice: With tumors	Mice: Prevalence[a] (%)
0	198	155	4	2.6 ± 2.5
0.4	292	229	11	4.8 ± 2.7
0.8	278	161	15	9.3 ± 4.5
1.6	244	117	16	13.7 ± 6.2
3.2	181	115	37	32.2 ± 8.5
7.0	90	52	24	46.2 ± 13.6

[a] ±95% CI



Hazard Function
Targe Effect (TE) vs Non-Target Effects (NTE)

The NTE model assumes a non-linear type response in addition to the linear dose term at low doses.

The η function represents the NTE contribution, which is parameterized as a function of the particle Linear Energy Transfer (L).

We tuned the radiobiological parameters to reproduce available experimental data

$$H_{TE}(Z,E,F) = H_0 + [\Sigma F + \beta D^2] * S$$

$$H_{NTE}(Z,E,F) = H_0 + [\Sigma F + \beta D^2 + \eta] * S$$

$$\eta = \eta_0 L e^{-\eta_1 L}[1 - e^{-N_{Bys}}]$$

Where:

- L is the Linear Energy Transfer of the particle
- N_{Bys} is the number of bystander
- $N_{Bys} = Fluence * A_{Bys}$
- A_{Bys} is an area corresponding to the number of bystander cells surrounding a cell traversed directly from a HZE particle that receive an oncogenic signal.

An example: TE vs NTE for Protons

Calculation of the TE and NTE TP models showing for 250A MeV protons there is no relevant differences in the tumour Prevalence versus dose as expected (NTE models predict same tumor prevalence at low doses compared to the TE model).

Fig 2.4 Comparison of targeted effects (TE) and non-targeted effects
(NTE) models for proton beams to the experiment of Alpen et al.12 for the dose response
for Harderian gland tumor prevalence. Results show NTE are small for low LET particle beams.
TP = 1-exp(-Hazard(D))
H(D) = (H0 + Sigmaf_NTE*Fluence + Betaf_NTEs*(Dose)^2 + Eta_f)*S_NTEs
KE=250 , Sigma0TE=85.63 , alphagamma=0.055 , BetaH=0.109247184296719 , H0=0.026 ,
D0=2.6 , n=3 , N=1 , m=3 ,
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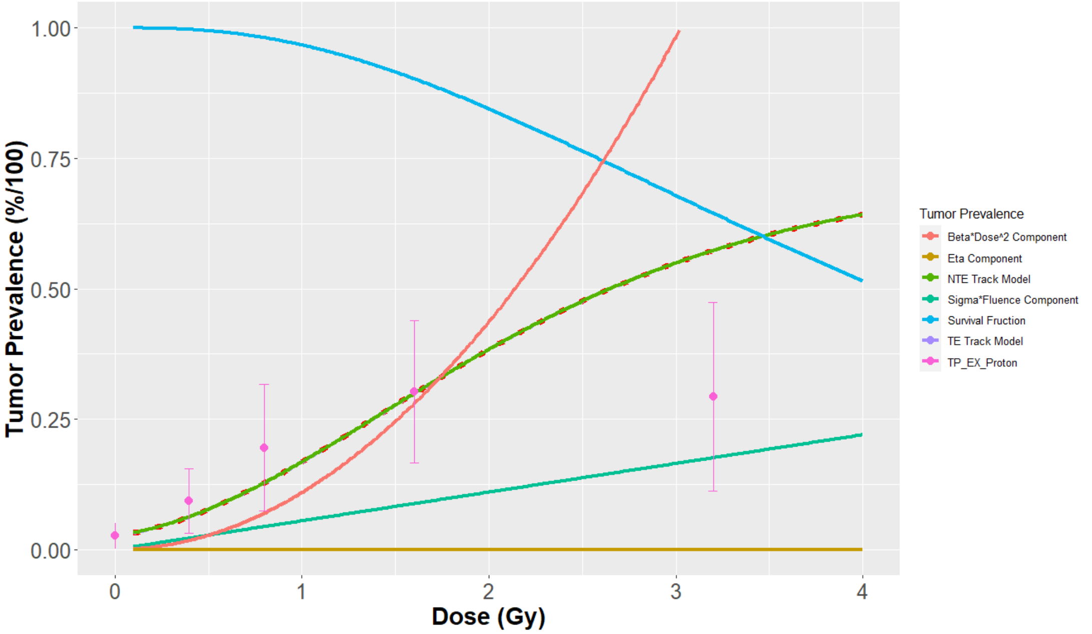

Fig 2.4.1 Comparison of targeted effects (TE) and non-targeted effects
(NTE) models for proton beams to the experiment of Alpen et al.12 for the dose response
for Harderian gland tumor prevalence. Results show NTE are small for low LET particle beams.
TP = 1-exp(-Hazard(D))
H(D) = (H0 + Sigmaf_NTE*Fluence + Betaf_NTEs*(Dose)^2 + Eta_f)*S_NTEs
KE=250 , Sigma0TE=85.63 , alphagamma=0.055 , BetaH=0.109247184296719 , H0=0.026 ,
D0=2.6 , n=3 , N=1 , m=3 ,
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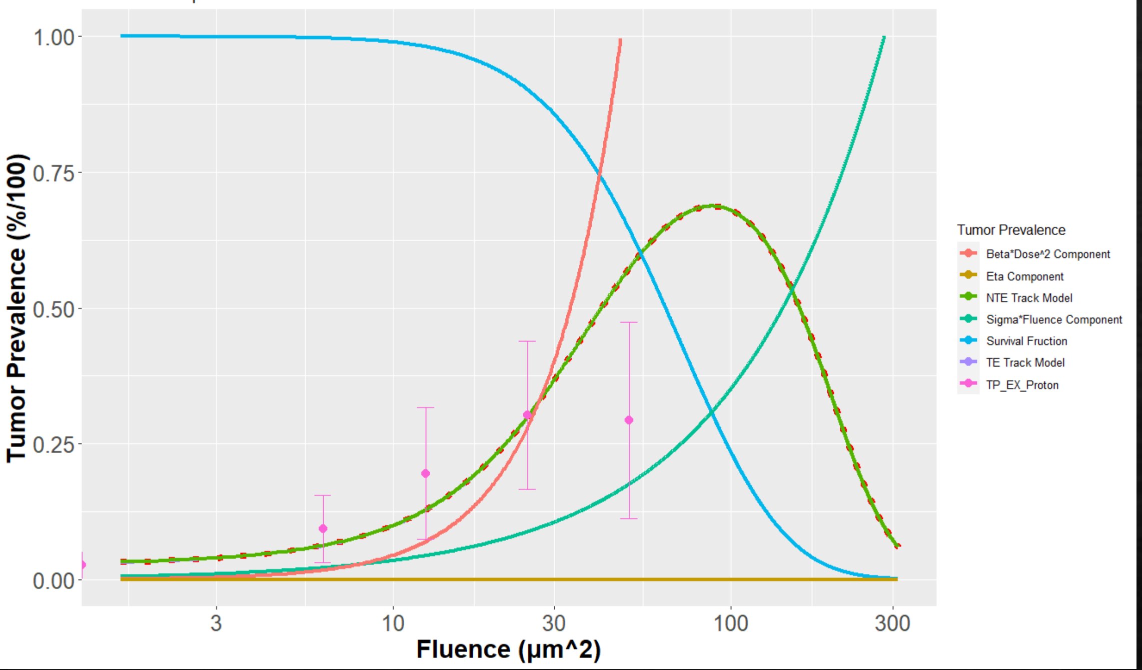
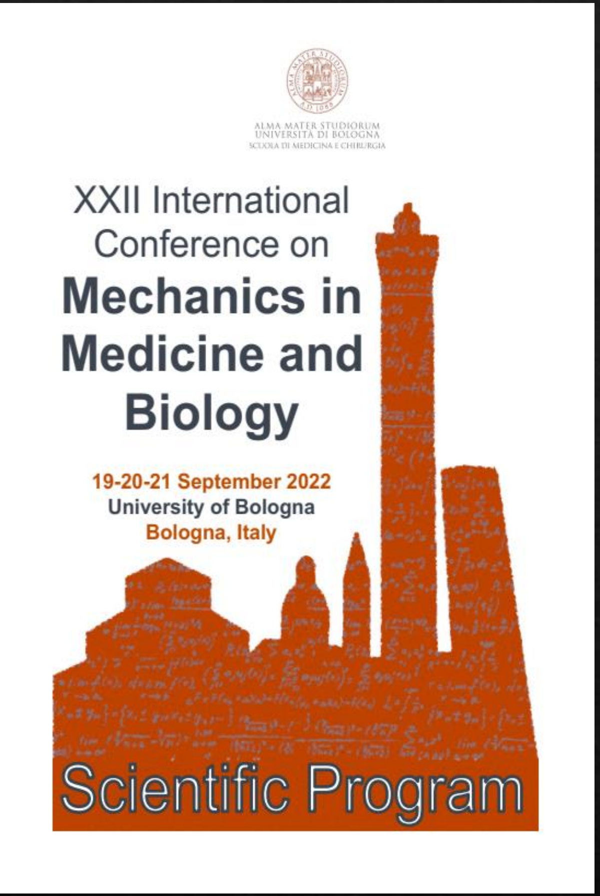


The shape of the tumor response curve found in the NTE model is shallow non-linear dose responses curve.
It has important implications for space travel because would alter how mission design factors such as duration and radiation shielding are analyzed for radiation protection purposes.

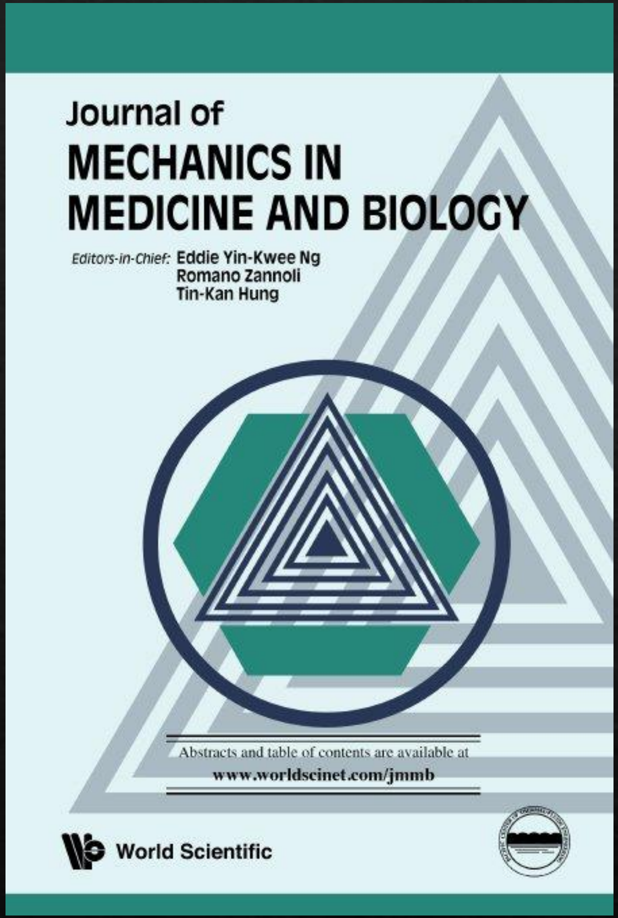


I presented this research work at the XXII International Conference on Mechanics in Medicine and Biology 19-20-21 September 2022 University of Bologna Bologna, Italy;

I gave a talk titled “**Target Effects vs. Non-Target Effects in Estimating the Carcinogenic risk due to Galactic Cosmic Rays in Exploratory Space Missions”** on the “Detectors and Dosimetry» session.

The talk was selected to be published on the [Journal of Mechanics in Medicine and Biology (worldscientific.com)]

I am writing the paper that will be submitted in November

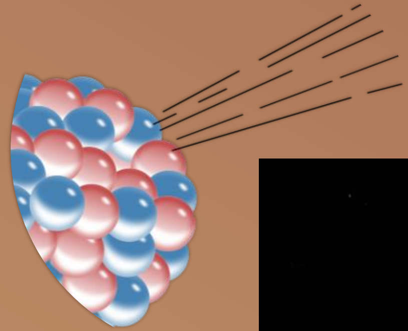


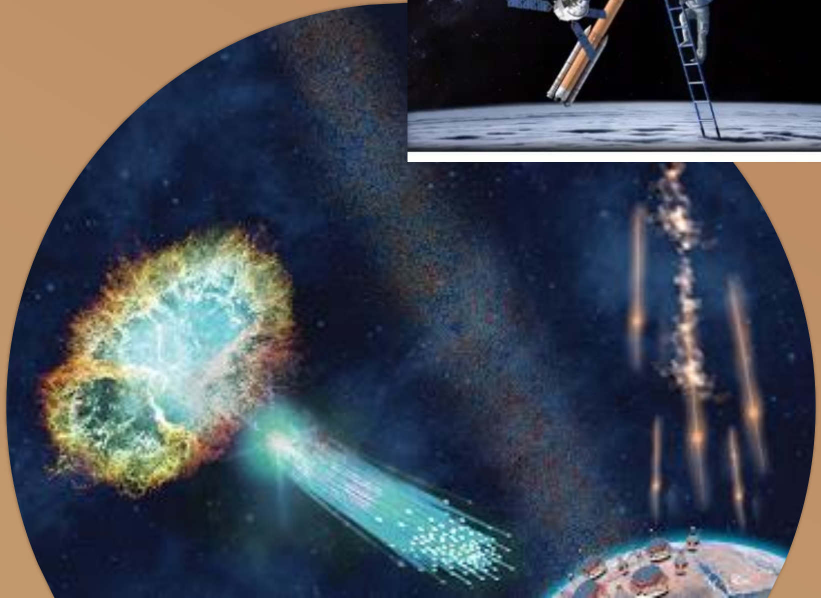
This is the picture of people participated on XXII International Conference on Mechanics in Medicine and Biology, September 19-20-21, 2022, held in Bologna.

Summary

The activity I carried out as part of the research grant in the period under review was focused on three aspects:

- I Participated in the research activity of the INFN ROMA Sapienza AMS group relating to the use of cosmic ray measurements collected by AMS and in general from astroparticle and dosimetry experiments in space to improve the knowledge of radiobiology in space environment with particular emphasis on the topic of dose-effect models.
- I participated in the control and data collection activities of the experiment at the AMS Payload Operation Control Center (POCC).
- I have developed a software tool for analyzing AMS02 data for the generation and validation of predictive models of bystander-type non-target effects (NTE / bystander) due to the risk of exposure to ionizing radiation from galactic cosmic rays.
- I presented this research activity at the ICMMB-2022 and the talk was selected to be published on the **Journal of Mechanics in Medicine and Biology (worldscientific.com)**





THANKS FOR THE ATTENTION!

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AMS02 INFN ROMA and Sapienza University Web Site

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