

Long-Duration Radiation Biology Studies in Space and in Simulated Microgravity: *From ISS to Moon and Mars*

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Prairie View A&M University
www.pvamu.edu/raise

29th WRMISS (Prague)
Session-01: Saganti

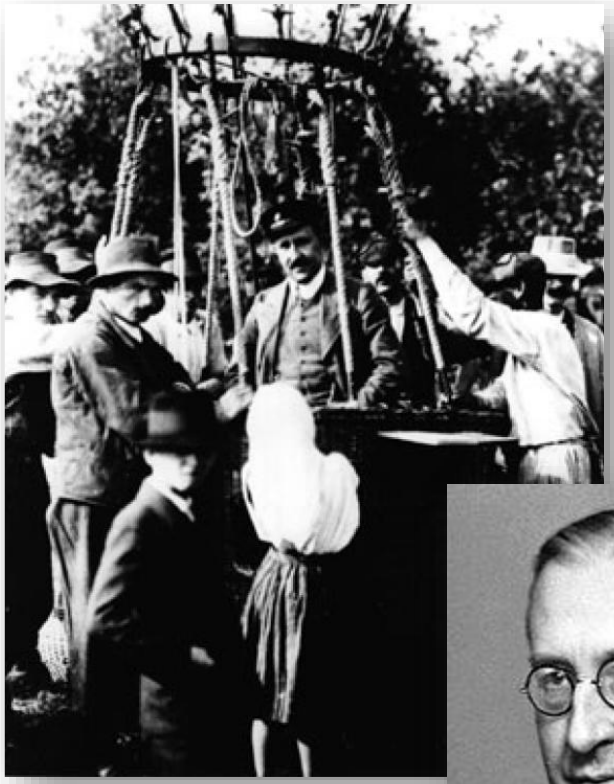
Contributors: Radiation in μG

USA	Japan	Greece
Premkumar Saganti Megumi Hada Paulina Malatesta Seth Saganti **Francis Cucinotta**	Kayo Yoshida Hiroko Ikeda Akane Kizu Kiyomi Eguchi-kasai Toshiaki Kokubo Takeshi Teramura Sachiko Yano Hiromi Suzuki Hitomi Watanabe Gen Kondoh Aiko Nagamatsu Masafumi Muratani Akihisa Takahashi **Takashi Morita**	Alexandros G. Georgakilas **Ioannis Michalopoulos**

BACKGROUND

Historical and Current

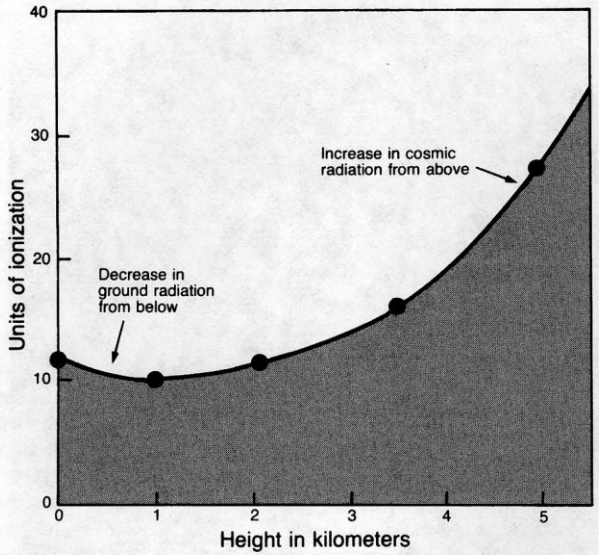
100+ Years of History: 1912-2012
Discovery of Cosmic Rays - **Victor Hess**





Victor Francis Hess
B 1883 Peggau, Austria
D 1964 New York, USA

- Victor Hess - 1912
  - Investigated sources of radiation – a balloon trip to 5300 m (risking life)
  - Radiation levels to be higher after 2500 m
  - Attributed to the fact that there was less atmosphere above to shield from radiation – source outside
- Concluded - radiation is coming from space ... **“cosmic radiation”**
- Won Nobel Prize - 1936



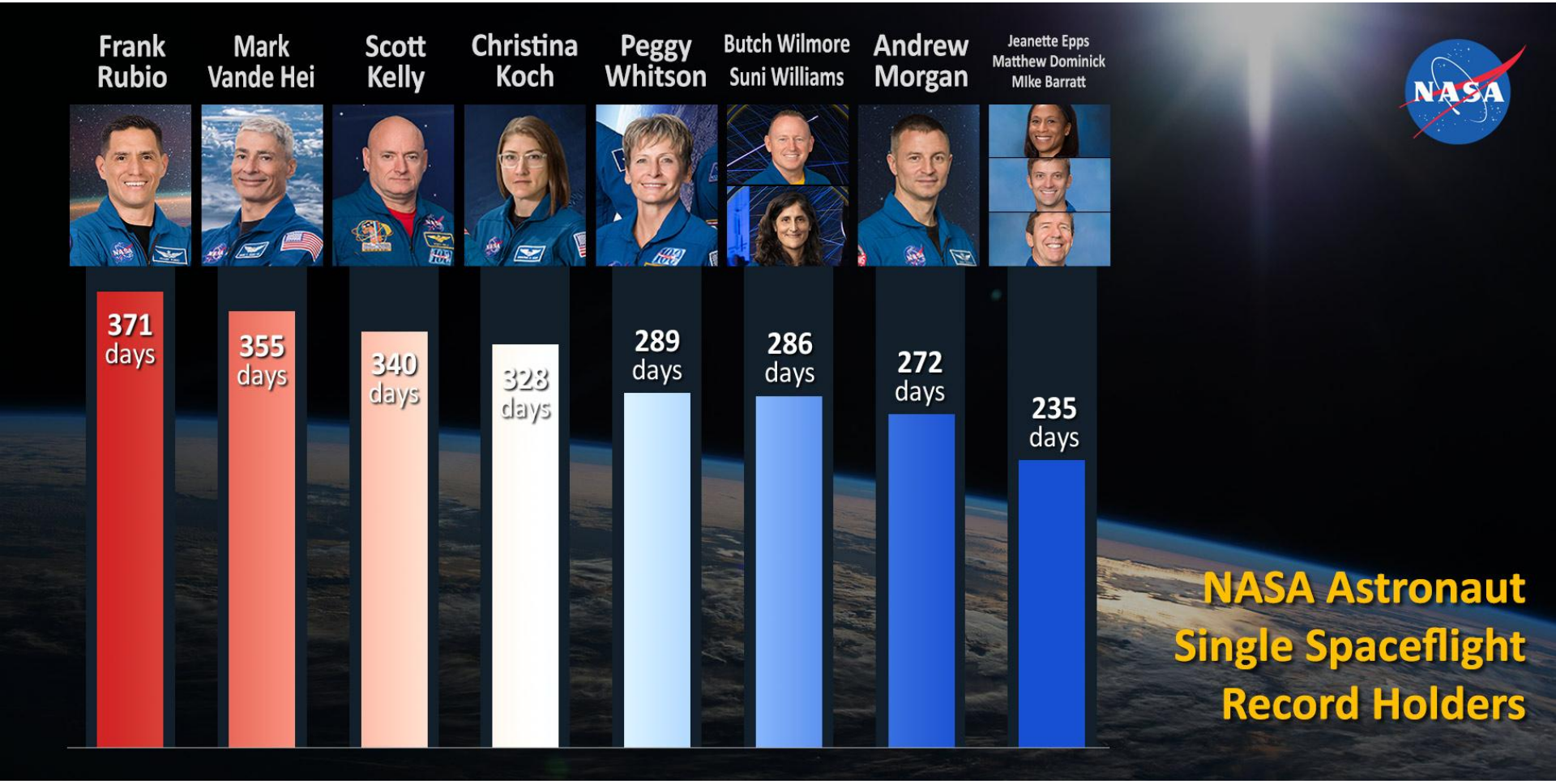
Readings on ionization chamber Victor Hess carried aloft in the Böhmen. Above four kilometers the ionization rose rapidly indicating "that rays of very great penetrating power are entering our atmosphere from above". These cosmic rays contain the only modern samples of matter from outside our solar system which can be investigated directly.

September 27, 2023: Astronaut **Frank Rubio** lands on Earth after **371 days on ISS** – longest US record with 5,963 orbits around the Earth, travelling 157.4 million miles (or 253.3 million km).

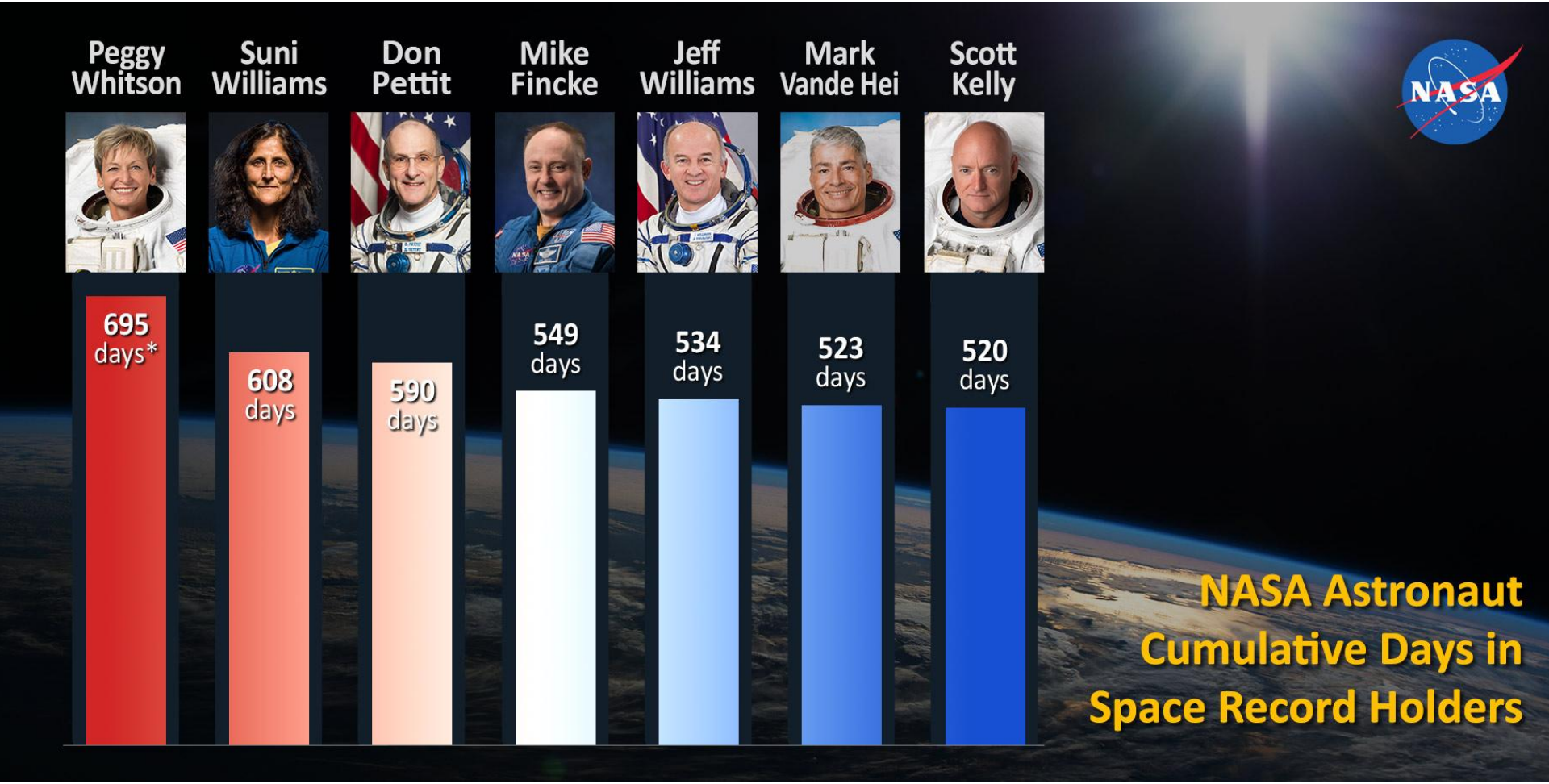


Nasa astronaut Frank Rubio has just returned from a record-breaking 371 days in space onboard the ISS, but the trip ***may have altered his muscles, brain and even the bacteria*** *living in his gut*

https://www.bbc.com/future/article/20230927-


Frank Rubio
371 days
Mark Vande Hei
355 days
Scott Kelly
340 days
Christina Koch
328 days
Peggy Whitson
289 days
Butch Wilmore
Suni Williams
286 days
Andrew Morgan
272 days
Jeanette Epps
Matthew Dominick
Mike Barratt
235 days
NASA
NASA Astronaut
Single Spaceflight
Record Holders

nasa.gov


Peggy Whitson
Suni Williams
Don Pettit
Mike Fincke
Jeff Williams
Mark Vande Hei
Scott Kelly
695 days*
608 days
590 days
549 days
534 days
523 days
520 days
NASA Astronaut Cumulative Days in Space Record Holders

nasa.gov

September 4, 2024

Rank	Name	Days	Flights	Status	Nationality
1	Oleg Kononenko	1092	5	(on ISS now)	Russia
2	Gennady Padalka	878	5	Retired	Russia
3	Yuri Malenchenko	827	6	Retired	Russia
4	Sergei Krikalev	803	6	Retired	Soviet Union / Russia
5	Aleksandr Kaleri	769	5	Retired	Russia
6	Sergei Avdeyev	748	3	Retired	Soviet Union / Russia
7	Anton Shkaplerov	709	4	Retired	Russia
8	Valeri Polyakov	679	2	Deceased	Soviet Union / Russia
9	Peggy Whitson	675	4	Active	United States
10	Fyodor Yurchikhin	673	5	Retired	Russia

As of today (Sept 4, 2024)
50 people spend more than **365** days in space

Source: *Wikipedia*

September 1, 2026

Rank	Name	Days	Flights	Status	Nationality
1	Oleg Kononenko	**1110**	5	(on ISS now)	Russia
2	Gennady Padalka	878	5	Retired	Russia
3	Yuri Malenchenko	827	6	Retired	Russia
4	Sergei Krikalev	803	6	Retired	Soviet Union / Russia
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As of today (Sept 1, 2026)
50 people spend more than **365** days in space

Source: *Wikipedia*

There are more than **225** people with more than **100** days in space from around the World

Country	Total Days	Total Flights
Belgium	198	2
Canada	572	6
China	5,351	40
Denmark	208	2
France	605	4
Germany	888	5
Italy	1,049	7
Japan	2,292	18
Netherlands	203	2
Russia	16,804	95
UAE	185	1
United Kingdom	185	1
USA	21,701	223
USSR	16,917	131
Grand Total	**67,158**	**537**

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September 1, 2026

Authors - Principals

Kayo Yoshida [1], Megumi Hada [2], Masami Hayashi [1], Akane Kizu [1], Kohei Kitada [1], Kiyomi Eguchi-Kasai [3], Toshiaki Kokubo [3], Takeshi Teramura [4], Hiromi Suzuki [5], Hitomi Watanabe [6], Gen Kondoh [6], Aiko Nagamatsu [7], Sachiko Yno[7], Premkumar Saganti [2], Masafumi Muratani [8], **Francis A. Cucinotta [9] and Takashi Morita [1]**

[1]Graduate School of Medicine, Osaka Metropolitan University, Osaka 545-8585, Japan;

[2]Radiation Institute for Science and Engineering, Prairie View A&M University, Prairie View, TX 77446, USA;

[3]QST National Institute of Radiation Sciences (NIRS), Chiba 263-0024, Japan;

[4]Faculty of Medicine, Kindai University, Osaka 577-8502, Japan;

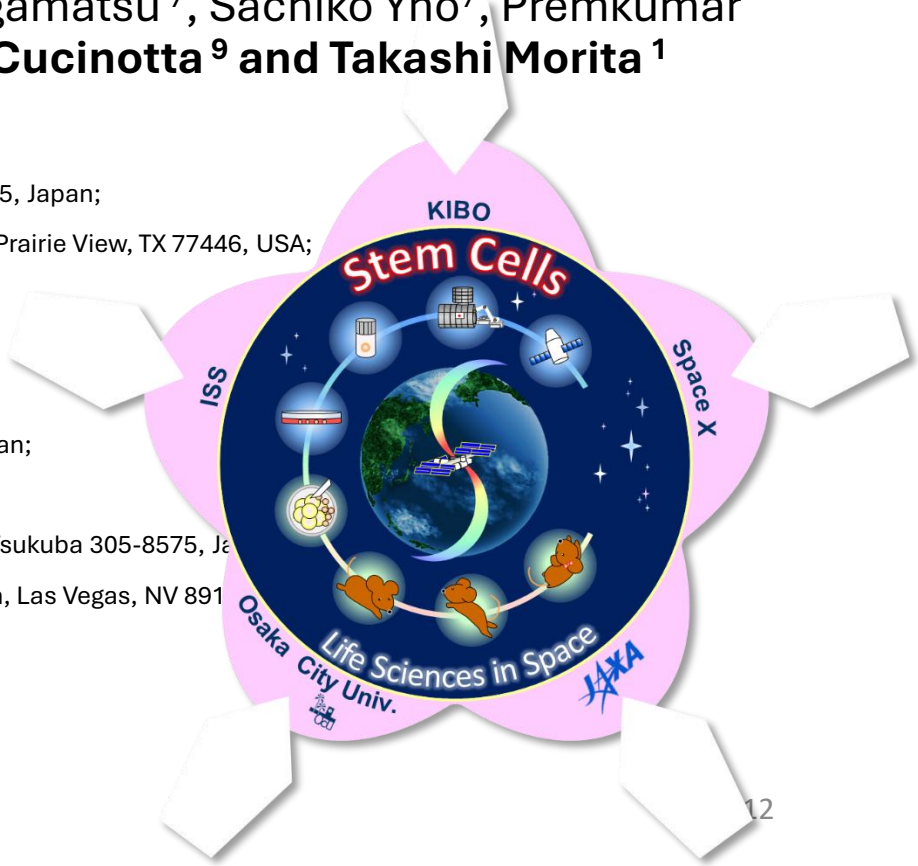
[5]Japan Space Forum (JSF), Tokyo 101-0062, Japan;

[6]Institute for Frontier Medical Sciences, Kyoto University, Kyoto 606-8501, Japan;

[7]Japan Aerospace Exploration Agency (JAXA), Tsukuba 305-8505, Japan;

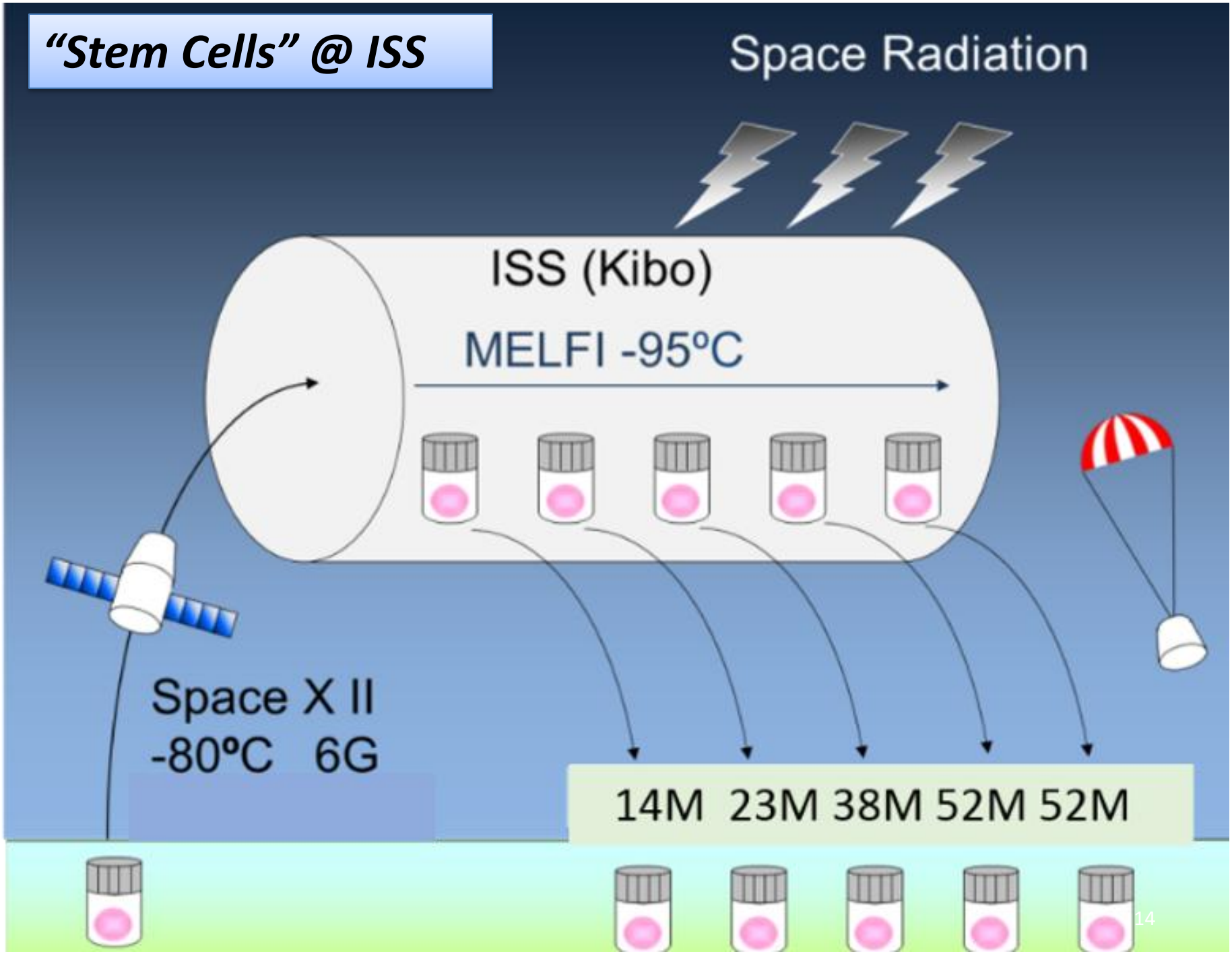
[8]Department of Genome Biology, Faculty of Medicine, University of Tsukuba, Tsukuba 305-8575, Ja

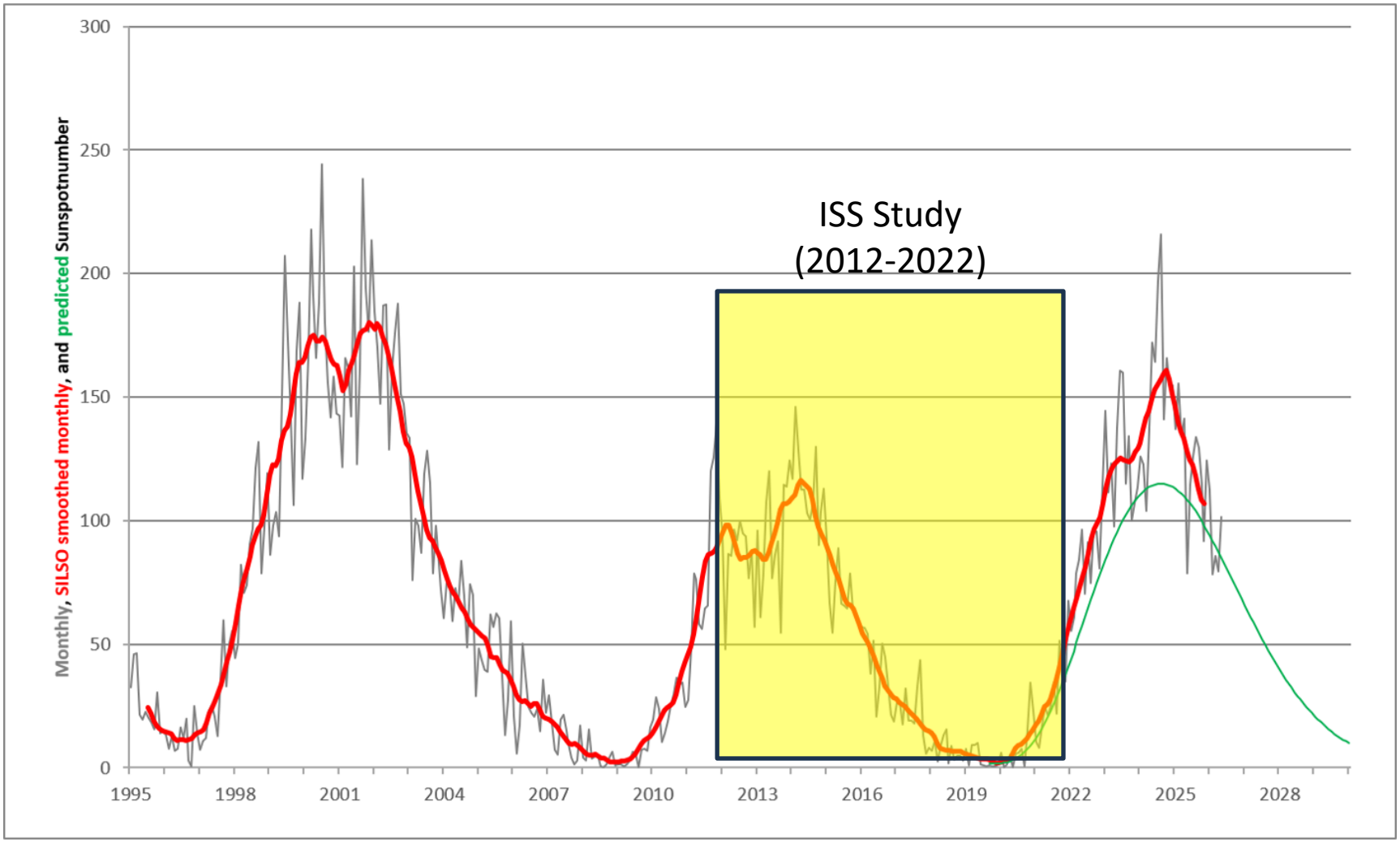
[9]Department of Health Physics and Diagnostic Sciences, University of Nevada, Las Vegas, NV 891



Overview

- A joint collaborative space project between JAXA and NASA
  - “Stem Cells - Study on the Effect of Space Environment to Embryonic Stem Cells to their Development” in the Kibo Module.
- Frozen Embryonic Stem (ES) cells were launched to ISS in
  - Stored in the Minus Eighty Degree Laboratory Freezer for ISS (MELFI) March 2013 through July 2017.
- Four different sets of cell samples were retrieved back to earth
  - After periods of 443 days, 711 days, 1167 days, and 1584 days on the ISS
  - Along with the PADLES (Passive Dosimeter for Life-science Experiments in Space)
  - PADLES consisting of CR-39 and TLDs) dosimeters attached to the tubes (ES cells).
- After these ES cell stacks were brought back to the ground, they were thawed and cultured, and their gene expressions were comprehensively analyzed to elucidate the early response of the cells to long-time exposure to space radiation in microgravity conditions.


"Stem Cells" @ ISS
Space Radiation
ISS (Kibo)
MELFI -95°C
Space X II
-80°C 6G
14M 23M 38M 52M 52M

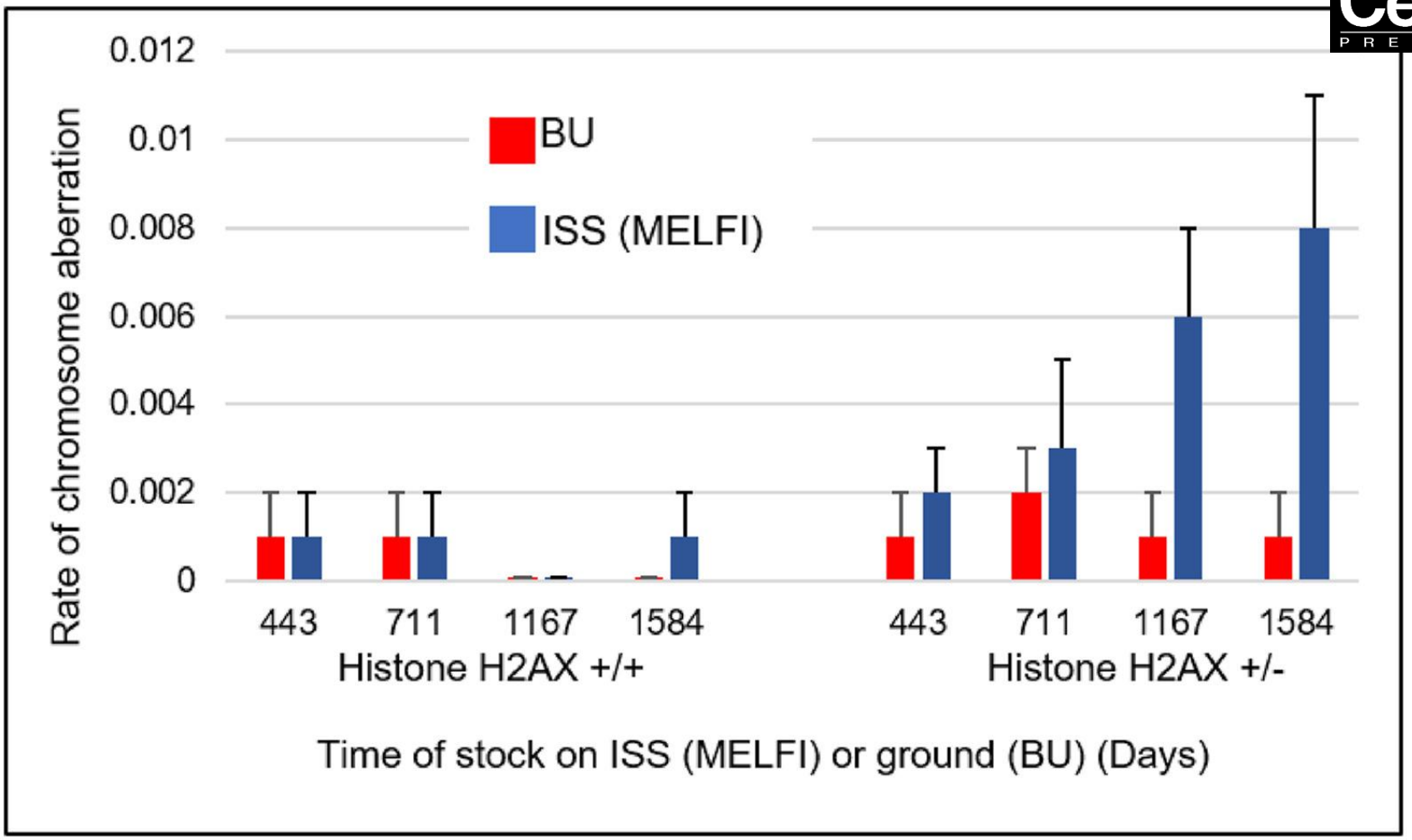


www.stce.be/content/sc25-tracking

Accessed on Aug 5, 2026

Observations

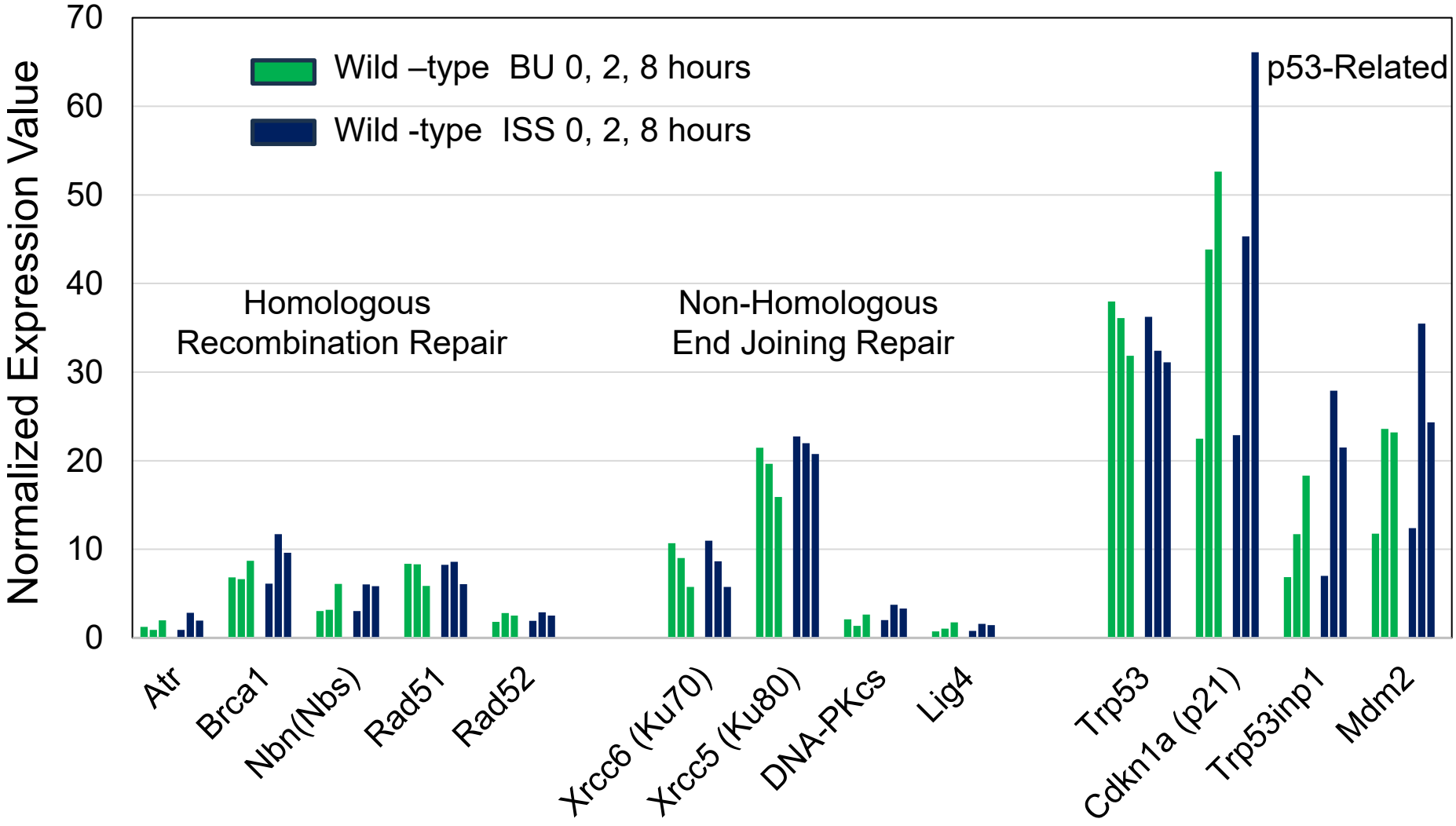
- The comparisons of gene expression involved in double-stranded break (DSB):
  - Also, the expressions of most of the genes that were involved in homologous recombination (HR) and non-homologous end joining (NHEJ) were studied and compared between the ISS-stocked cells and ground-stocked control cells.
- It was noted that the transcription of Trp53inp1 (tumor protein 53 induced nuclear protein-1), Cdkn1a (p21), and Mdm2 genes increased in ISS-stocked cells.
  - This phenomenon is similar to the cells that were exposed to the Fe ions in ground-based experiments at HIMAC Facility.
  - This suggests that accumulated DNA damage caused by space radiation exposure would activate these genes.
- The PADLES measured dose-equivalent values on ISS:
  - 250 mSv (for 443 days),
  - 375 mSv (for 711 days),
  - 575 mSv (for 1167 days), and
  - 830 mSv (for 1584 days) between 2013 and 2017



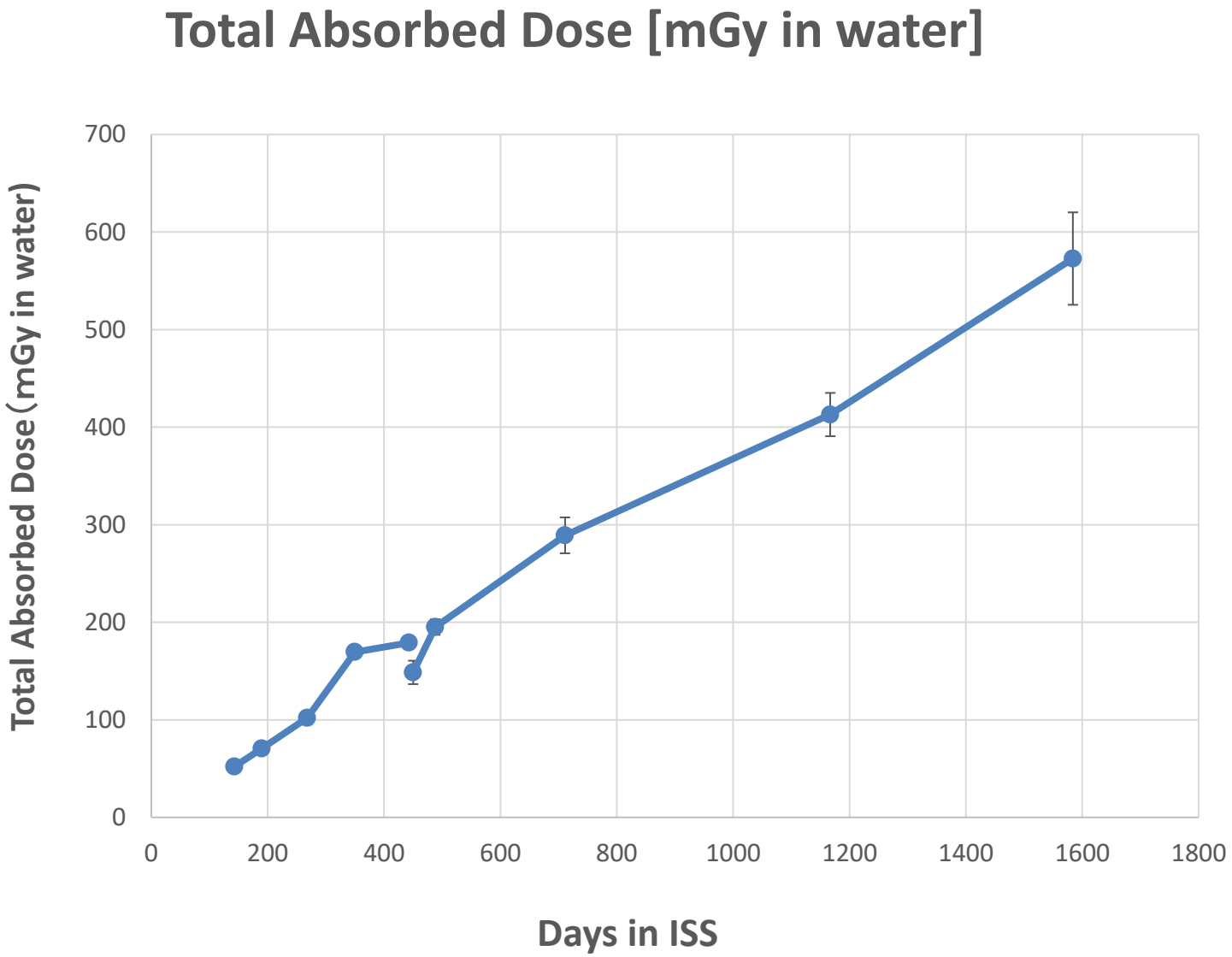
Comparison of the incidence of chromosomal aberrations of wild-type and histone H2AX gene heterozygous-deficient ES cells on the ground (BU) and on the ISS (MELFI) chromosomes were analyzed by FISH method.

The wild-type embryonic stem (ES) cells showed no differences in chromosomal aberrations between the ground control and ISS exposures. However, we detected an increase of chromosome aberrations in radio-sensitized histone H2AX heterozygous-deficient mouse ES cells and found that the rate of increase against the absorbed dose was 1.54-fold of proton irradiation.

Expression of DNA Repair Genes on ISS and Ground(BU)



Yoshida K. et al., *Int J Mol Sci*; *25 (6)*



Nagamatsu et al., JAXA - 2020

Chromosome Aberration Studies on ISS: 2012-2022



Morita (JAXA) / Cucinotta (NASA) (PIs)

A CELL Press 2022 Publication

***Heliyon* 8, no. 8 (2022) e10266**

Dr. Morita (JAXA) and Dr. Cucinotta (NASA) – A Study on ISS

Published in 2022 and Recognized as a NASA Science Discovery on ISS

Heliyon 8 (2022) e10266

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon



Research article

Comparison of biological measurement and physical estimates of space radiation in the International Space Station

Kayo Yoshida [a], Megumi Hada [b], Akane Kizu [a], Kohei Kitada [a], Kiyomi Eguchi-Kasai [c], Toshiaki Kokubo [c], Takeshi Teramura [d], Sachiko Yano [e], Hiromi Hashizume Suzuki [f], Hitomi Watanabe [g], Gen Kondoh [g], Aiko Nagamatsu [e], Premkumar Saganti [b], Francis A. Cucinotta [h], Takashi Morita [a,*]

[a] Osaka City University, Graduate School of Medicine, Osaka, Japan
[b] Radiation Institute for Science and Engineering, Prairie View A&M University, TX, USA
[c] QST National Institute of Radiation Sciences (NIRS), Chiba, Japan
[d] Kindai University, Faculty of Medicine, Osaka, Japan
[e] Japan Aerospace Exploration Agency (JAXA), Tsukuba, Japan
[f] Japan Space Forum (JSF), Tokyo, Japan
[g] Kyoto University, Institute for Frontier Medical Sciences, Kyoto, Japan
[h] University of Nevada, Las Vegas, NV, USA

Heliyon 8 (2022) e10266

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- ISS Study - This work is a result of experiments on board the ISS from 2012-2022 spanning over 10 years and 10 Expeditions
  - Dr. Morita, JAXA-Japan and Dr. Cucinotta, NASA-USA as the PIs
  - From 2016, through our CRI / RaISE, we analyzed samples and data from ISS and contributed to this unique work.
- ISS Discovery – Included for 2022
  - Results from the ISS provide new contributions to the body of scientific knowledge in the physical sciences, life sciences, and Earth and space sciences to advance scientific discoveries in multi-disciplinary ways.
- ISS Publication - This publication made its presence on ISS Research Explorer's Page of the NASA Website (2022)
  - As part of the ongoing radiation biology / biotechnology research work - Stem Cells (nasa.gov)

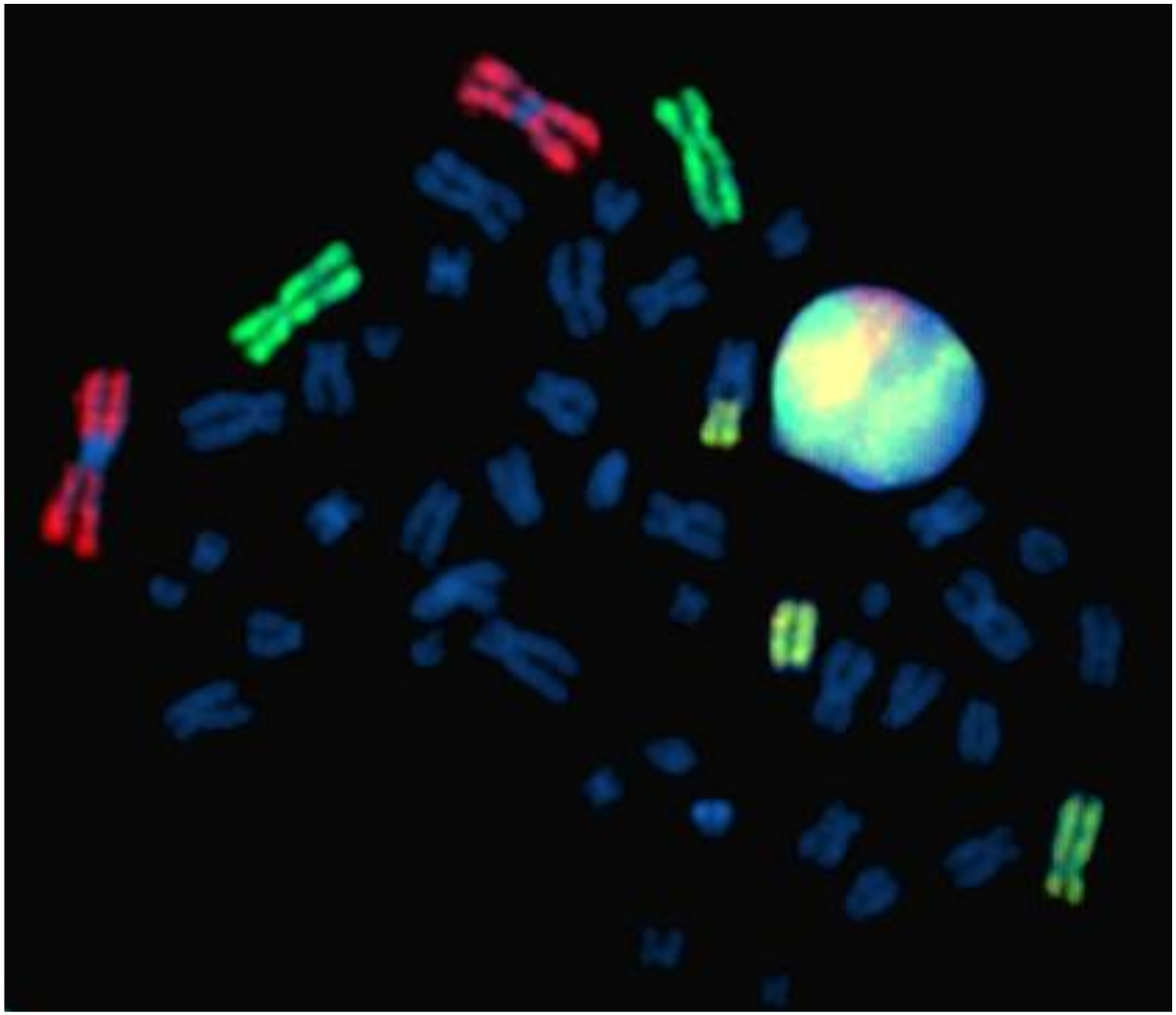
Microgravity + Radiation

SYNEGESTIC EFFECTS

Japan + USA

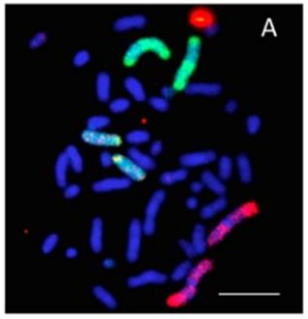
ICRR 2023
Montréal, Quebec
August 29, 2023
Hada / Saganti

S25-05

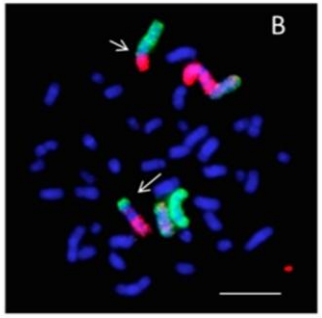


RaISE
RADIATION INSTITUTE FOR SCIENCE & ENGINEERING

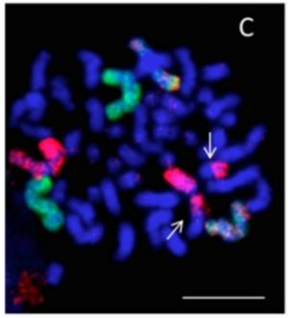
3-color fluorescent *in situ* hybridization method



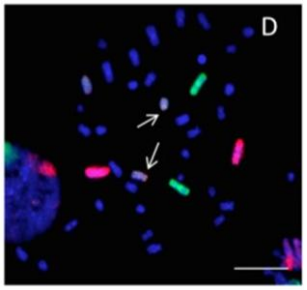
Normal



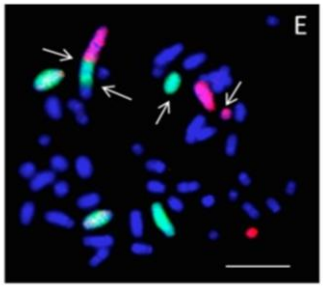
Simple exchange (1 & 2)



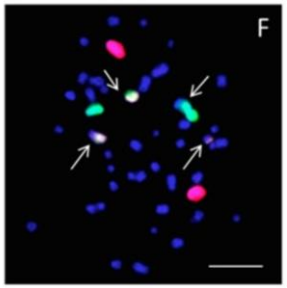
Simple exchange (1 & other)



Break in chromosome 4



Complex exchange (1 and 2 & other)

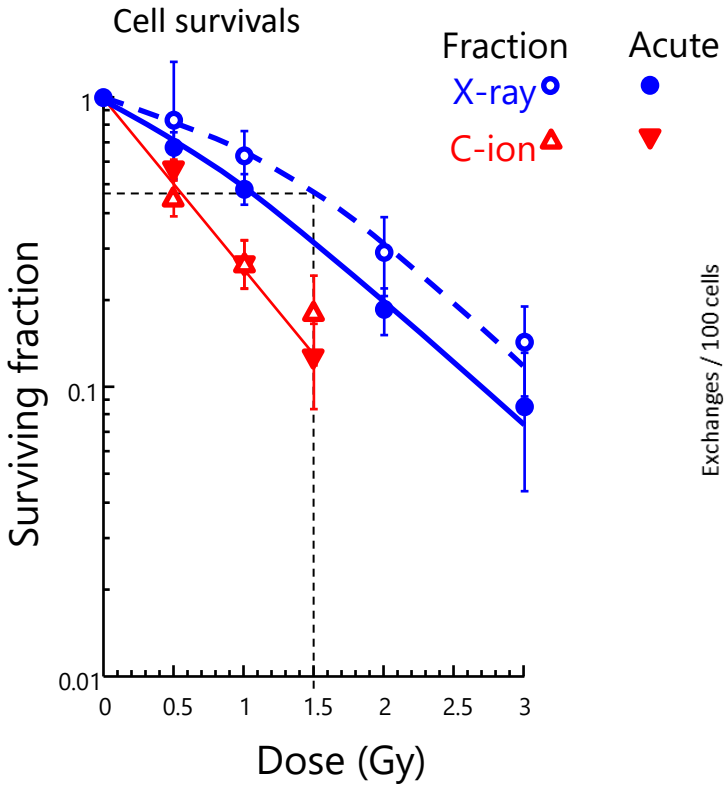


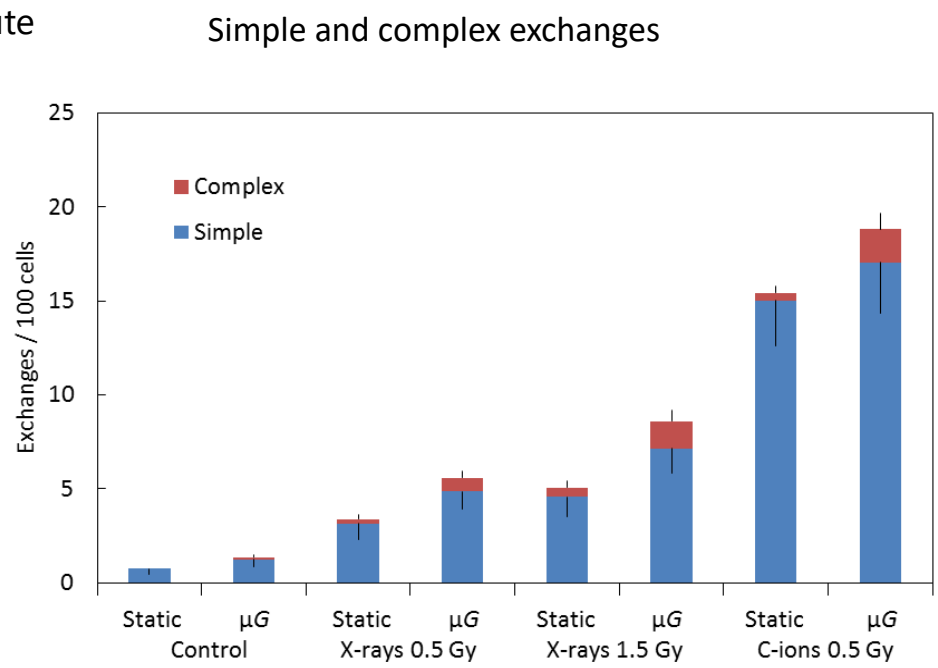
Complex exchange (2, 4 & other)

Chromosomes 1: red
Chromosomes 2: green
Chromosomes 4: yellow

Complex exchanges: An exchange involved a minimum of three breaks in two or more chromosomes
Simple exchanges: Two breaks in two chromosomes (dicentrics and translocations)

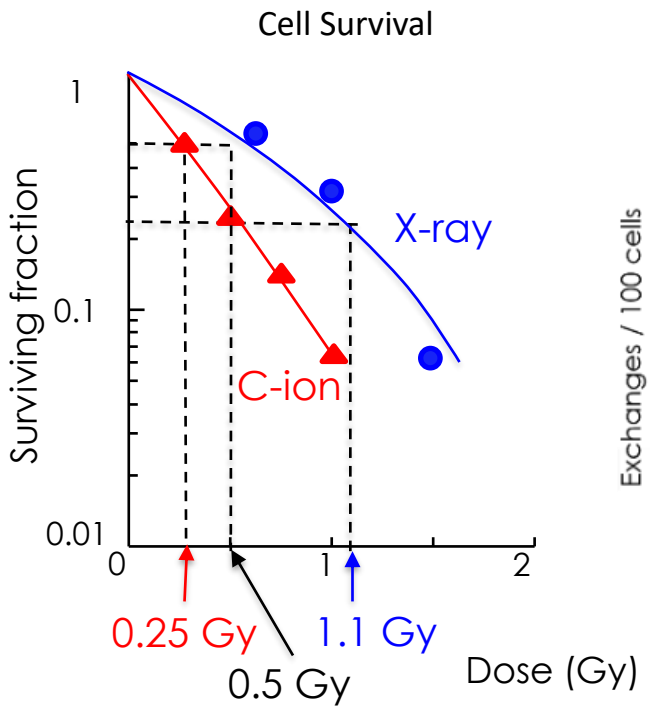
Cell survival and chromosome aberration - Fibroblasts

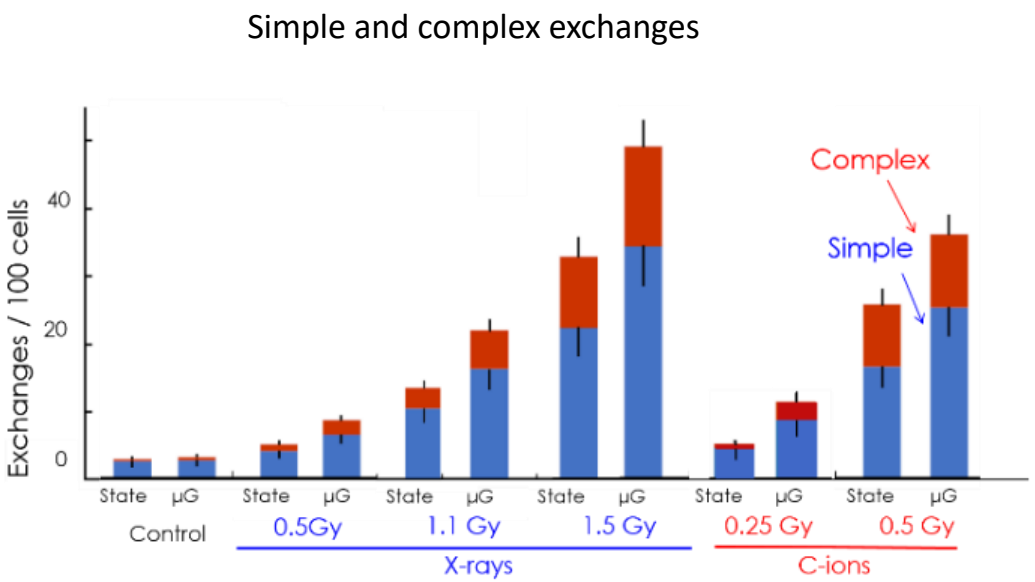




Hada M et al. Int. J. Mol. Sci. 2019; 20:43

Cell survival and chromosome aberration – Lymphoblast TK6



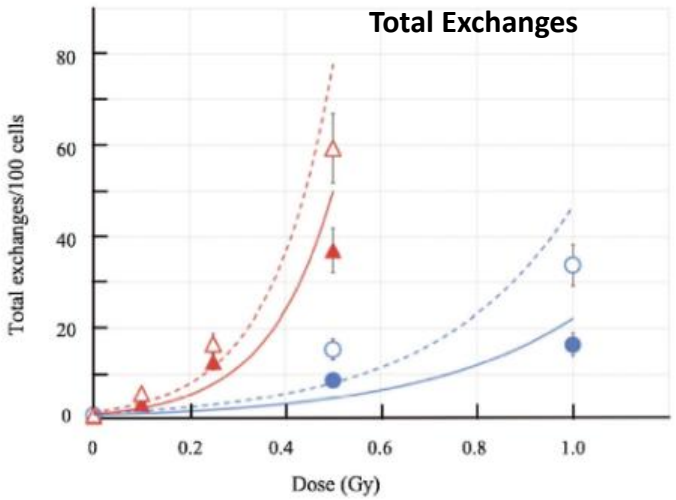


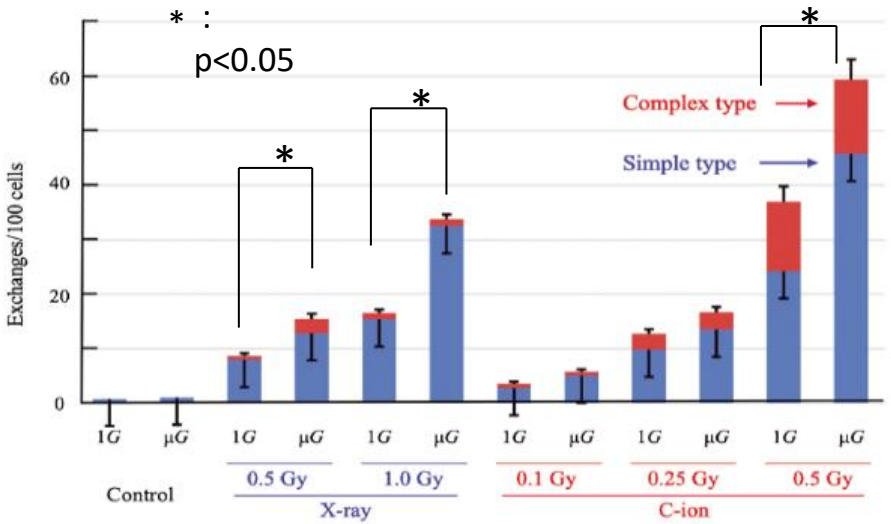
Simulated µG + Irradiation

→ Higher frequency of CA

Yamanouchi S et al. Life 2020;10:0187

Chromosome aberration – Blood Lymphocytes





The logistic regression analysis of the effect of radiation dose and gravity on total exchanges

Radiation	Factor	Coefficient	SE* of coefficient	p-value	OR**	95%CI*** for OR	
						Lower	Lower
X-ray	Dose	2.732	0.203	3.65×10^{-41}	15.370	10.318	22.895
	Gravity	0.760	0.150	4.00×10^{-7}	2.138	1.594	2.868
	Constant	–5.247	0.178	1.85×10^{-191}			
C-ion beam	Dose	6.284	0.355	3.13×10^{-70}	535.886	267.397	1073.961
	Gravity	0.466	0.124	1.66×10^{-4}	1.594	1.250	2.031
	Constant	–5.490	0.146	$<1.00\times10^{-191}$			

*SE, standard error; **OR, odds ratio; ***CI, confidence interval.

Yamanouchi S et al.
Biol Sci Space 2021; 35:15-23

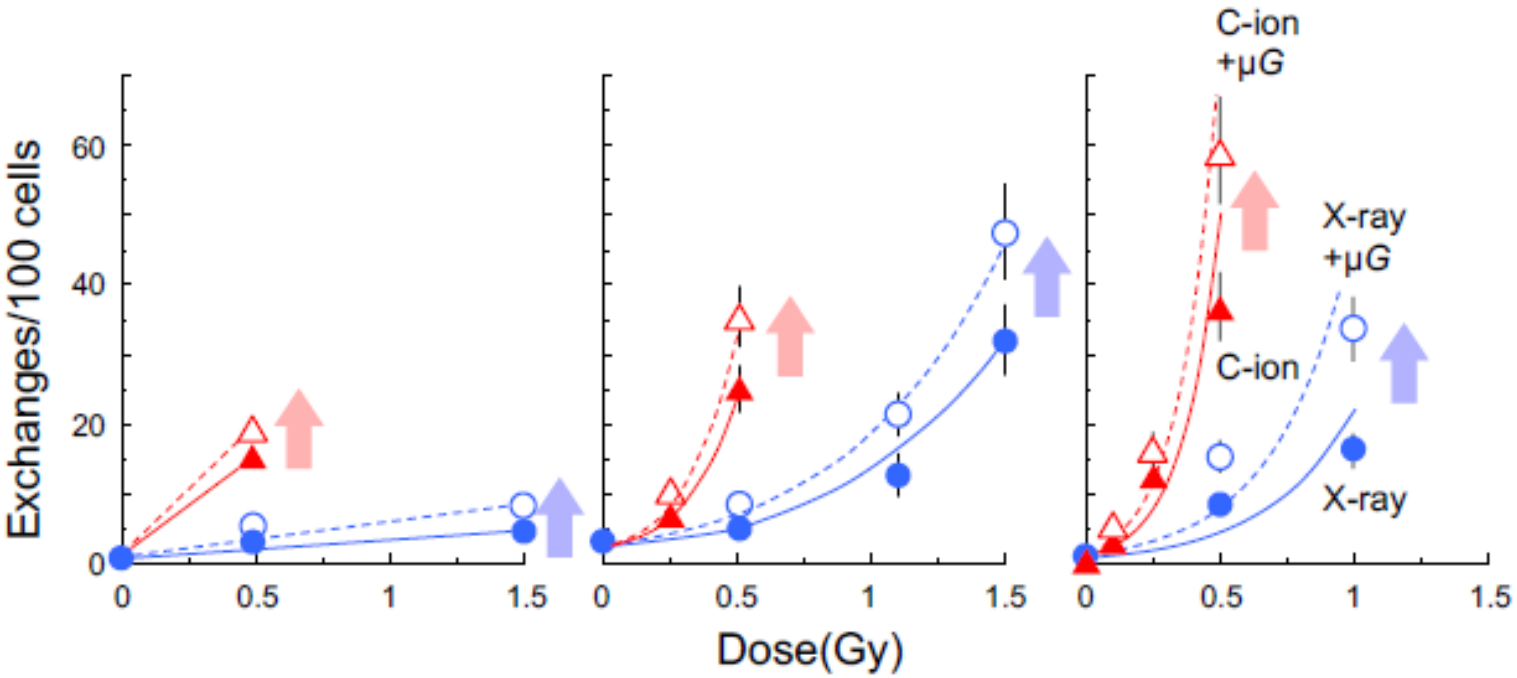
Both dose and gravity significantly contribute to total exchanges.

Comparison of cells

Fibroblast (1BR-hTERT)

Lymphoblastoid cells (TK6)

Blood lymphocytes



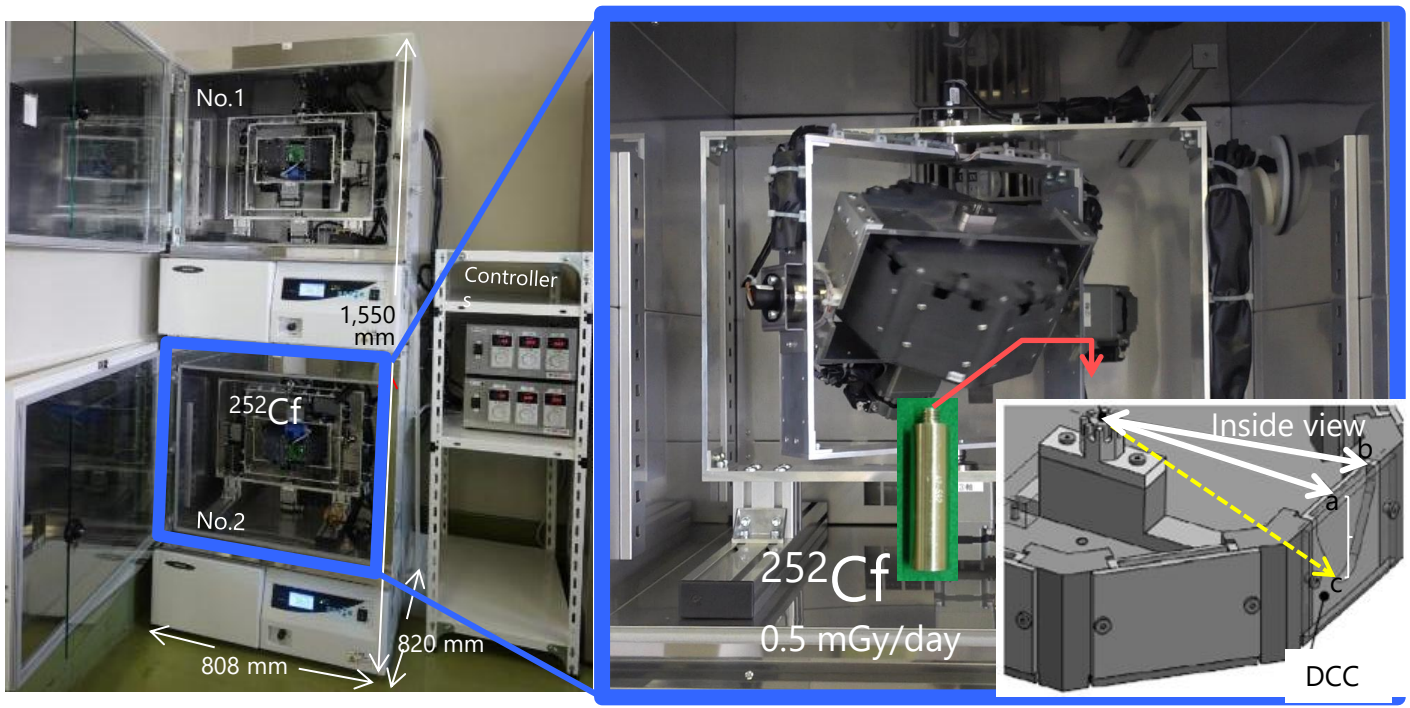
Hada M et al. Int J Mol Sci 2019; 20:43

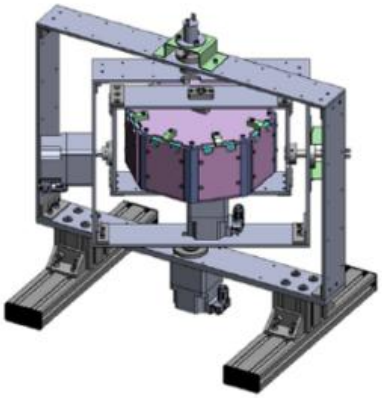
Yamanouchi S et al. Life 2020; 10:187

Yamanouchi S et al. Biol Sci Space 2021; 35:15-23

SwiNG

Simulator of the environments on the Moon and Mars
with **N**eutron-irradiation and **G**ravity-change

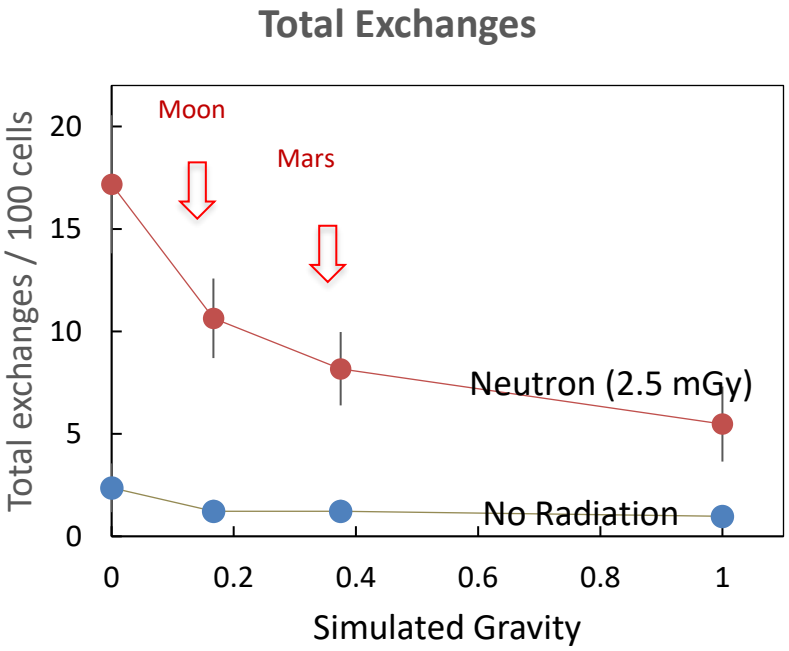


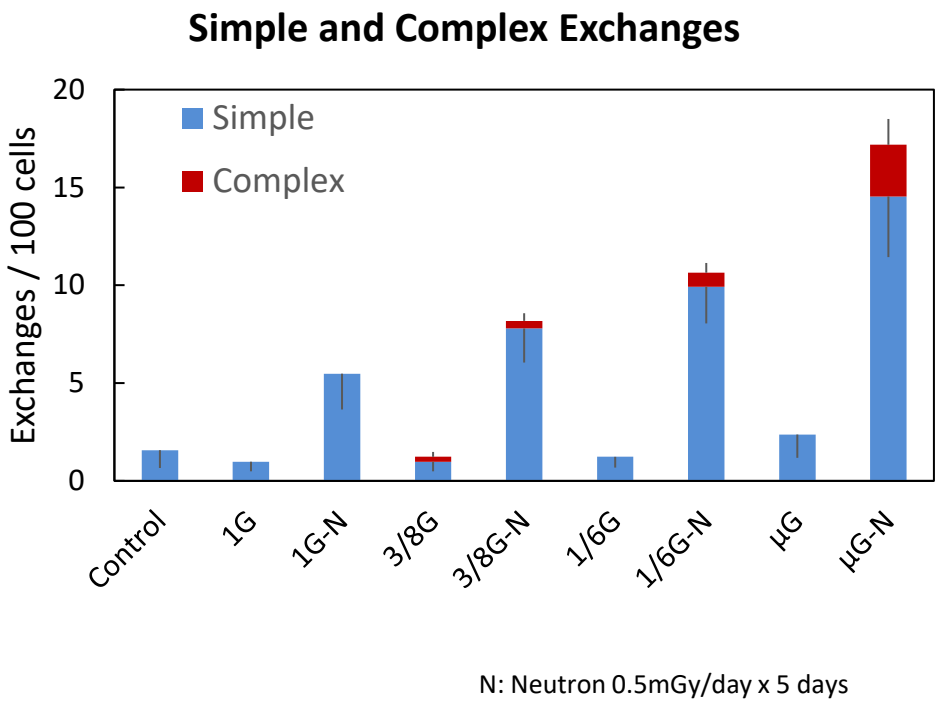


Takahashi A, *et al*. Life 10: 274, 2020

The X:Y ratios of clino-rotation were set at 11:13 rpm.
The rotary speed of motor 1 was 0-133 rpm (0-2*G*).

Chromosome aberrations with low dose neutron exposure





N: Neutron 0.5mGy/day x 5 days

Frequencies of CA induced by neutron exposure is depending on the gravity condition

RECENT BIOINFORMATICS STUDIES

Greece

biomolecules

MDPI

Article

Differential gene expression in human fibroblasts simultaneously exposed to ionizing radiation and simulated microgravity

Polina Malatesta [1,2], Konstantinos Kyriakidis [1,3,4], Megumi Hada [5], Hiroko Ikeda [6], Akihisa Takahashi [7], Premkumar B. Saganti [5], Alexandros G. Georgakilas [2,*] and Ioannis Michalopoulos [1,*]

1 Center of Systems Biology, Biomedical Research Foundation of the Academy of Athens, Athens, Greece
2 DNA Damage Laboratory, Physics Department, School of Applied Mathematical and Physical Sciences, National Technical University of Athens, Athens, Greece; ge18814@ntua.gr (P.M.)
3 Laboratory of Pharmacology, School of Pharmacy, Aristotle University of Thessaloniki, Thessaloniki, Greece
4 UC Santa Cruz Genomics Institute, Santa Cruz, CA, USA; kkyriaki@ucsc.edu (K.K.)
5 Radiation Institute for Science & Engineering, Prairie View A&M University, Prairie View, USA; mehada@pvamu.edu (M.H.); pbsaganti@pvamu.edu (P.B.S.)
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Biomolecules **2024**, *14*(1), 88; https://doi.org/10.3390/biom14010088

Table 1. Names and combinations of the type of radiation (C-ion or X-ray), collection time points (0 (sham irradiated), 3 or 24 h) and gravity (1G or simulated μG) for the 12 conditions studied.

Name	Irradiation		Maintenance Time			Gravity	
	C-ion	X-ray	0 h	3 h	24 h	1G	μG
C0G	–	–	+	–	–	+	–
C0μG	–	–	+	–	–	–	+
C3G	+	–	–	+	–	+	–
C3μG	+	–	–	+	–	–	+
C24G	+	–	–	–	+	+	–
C24μG	+	–	–	–	+	–	+
X0G	–	–	+	–	–	+	–
X0μG	–	–	+	–	–	–	+
X3G	–	+	–	+	–	+	–
X3μG	–	+	–	+	–	–	+
X24G	–	+	–	–	+	+	–
X24μG	–	+	–	–	+	–	+

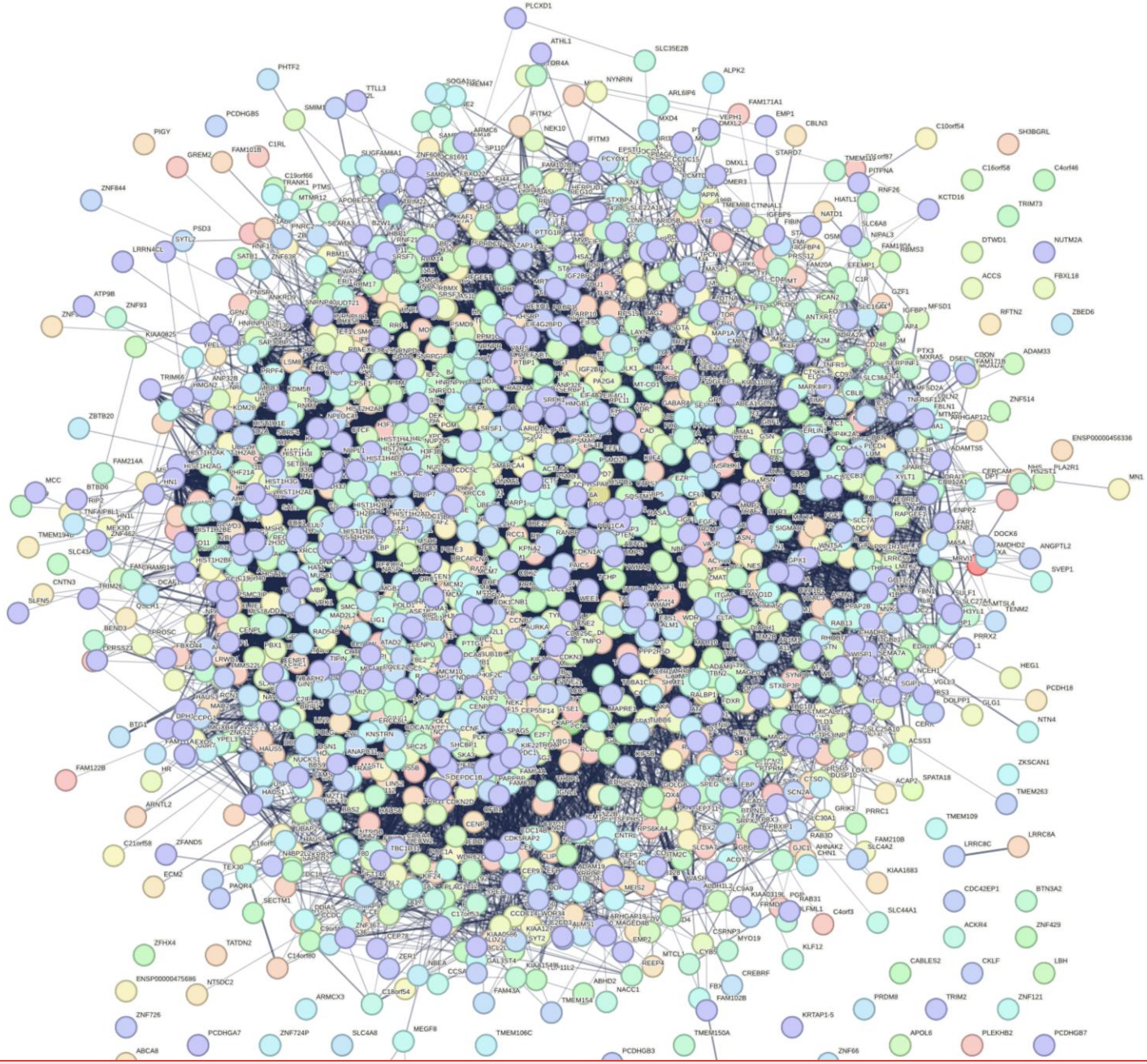


Figure 3. Protein–protein interaction network for DEGs from the comparison between **X-ray irradiated cells** collected 24 h post-irradiation and sham-irradiated ones **under 1G.**

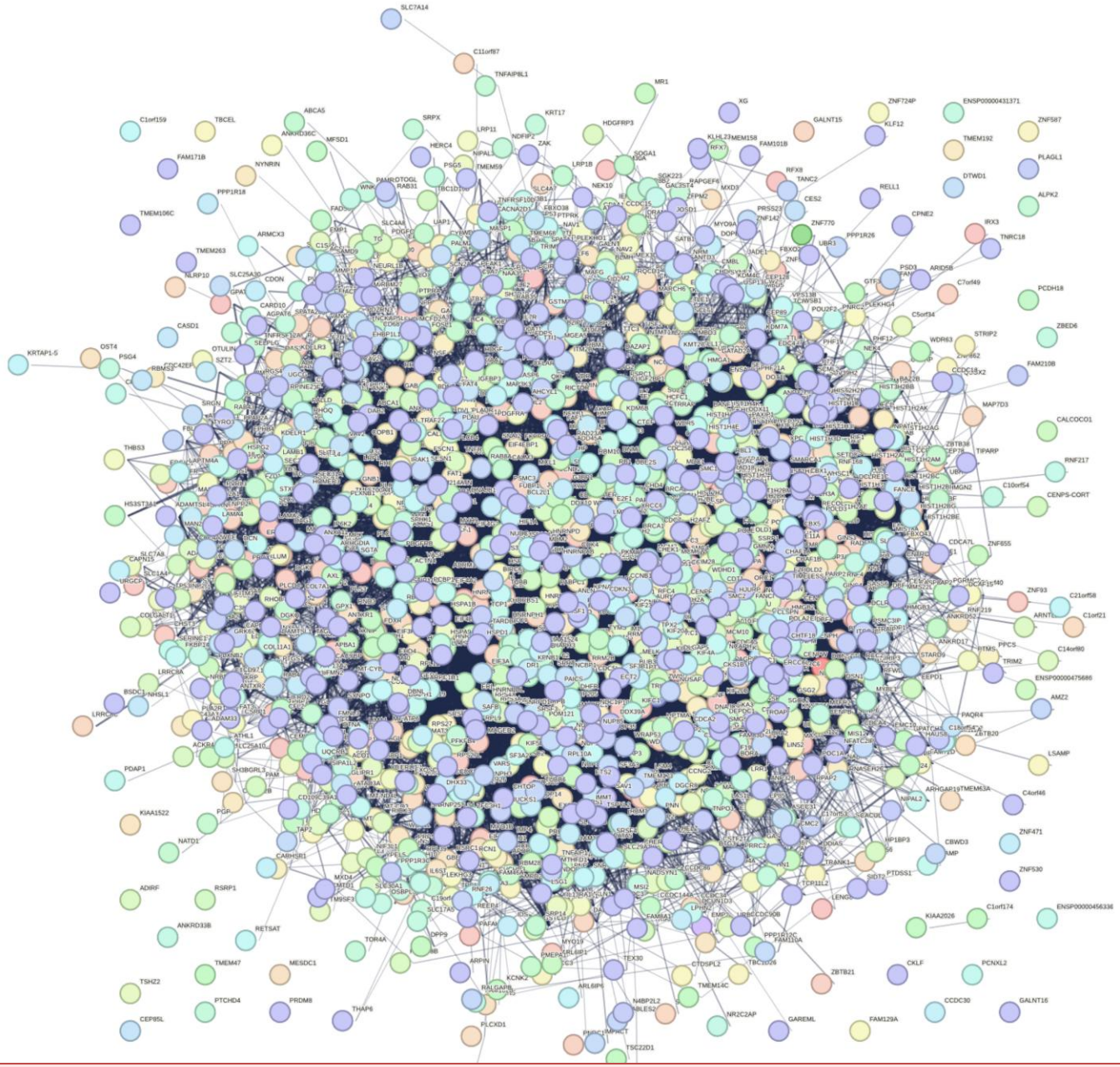


Figure 4. Protein–protein interaction network for DEGs from the comparison between **C-ion irradiated cells** collected 24 h post-irradiation and sham-irradiated ones **under 1G**

Table 3. Common up-regulated genes between early- and late-response genes to X-ray and C-ion radiation under 1G.

Ensembl Gene ID	Gene Name	Description
ENSG00000136542	GALNT5	Polypeptide n-acetylgalactosaminyltransferase 5
ENSG00000196576	PLXNB2	Plexin b2
ENSG00000134574	DDB2	Damage specific dna binding protein 2
ENSG00000131080	EDA2R	Ectodysplasin a2 receptor
ENSG00000163071	SPATA18	Spermatogenesis associated 18
ENSG00000173846	PLK3	Polo like kinase
ENSG00000135679	MDM2	Mdm2 proto-oncogene
ENSG00000244509	APOBEC3C	Apolipoprotein b mrna editing enzyme catalytic subunit 3c
ENSG00000120889	TNFRSF10B	Tnf receptor superfamily member 10b
ENSG00000048392	RRM2B	Ribonucleotide reductase regulatory tp53 inducible subunit m2b
ENSG00000127241	MASP1	Mbl associated serine protease 1
ENSG00000182752	PAPPA	Pappalysin 1
ENSG00000172667	ZMAT3	Zinc finger matrin-type 3
ENSG00000244694	PTCHD4	Patched domain containing 4
ENSG00000174307	PHLDA3	Pleckstrin homology like domain family a member 3
ENSG00000171444	MCC	Mcc regulator of wnt signaling pathway
ENSG00000124762	CDKN1A	Cyclin dependent kinase inhibitor 1a
ENSG00000250337	PURPL	P53 up regulated regulator of p53
ENSG00000164938	TP53INP1	Tumor protein p53 inducible nuclear protein 1
ENSG00000132274	TRIM22	Tripartite motif containing
ENSG00000080546	SESN1	Sestrin 1
ENSG00000159388	BTG2	Btg anti-proliferation factor 2
ENSG00000164125	GASK1B	Golgi associated kinase 1b
ENSG00000154767	XPC	Xpc complex subunit, dna damage recognition and repair factor
ENSG00000167196	FBXO22	F-box protein 22
ENSG00000161513	FDXR	Ferredoxin reductase

1G

Ensembl Gene ID	Gene Name	Description
ENSG00000156802	ATAD2	ATPase family AAA domain containing 2
ENSG00000175305	CCNE2	Cyclin E2
ENSG00000162063	CCNF	Cyclin F
ENSG00000094804	CDC6	Cell division cycle 6
ENSG00000167513	CDT1	Chromatin licensing and DNA replication factor 1
ENSG00000106462	EZH2	Enhancer of zeste 2 polycomb repressive complex 2 subunit
ENSG00000189057	FAM111B	FAM111 trypsin like peptidase B
ENSG00000184357	H1-5	H1.5 linker histone, cluster member
ENSG00000196747	H2AC13	H2A clustered histone 13
ENSG00000286522	H3C2	H3 clustered histone 2
ENSG00000278828	H3C10	H3 clustered histone 10
ENSG00000273983	H3C8	H3 clustered histone 8
ENSG00000197061	H4C3	H4 clustered histone 3
ENSG00000137807	KIF23	Kinesin family member 23
ENSG00000065328	MCM10	Minichromosome maintenance 10 replication initiation factor
ENSG00000112118	MCM3	Minichromosome maintenance complex component 3
ENSG00000104738	MCM4	Minichromosome maintenance complex component 4
ENSG00000116062	MSH6	Muts homolog 6
ENSG00000085840	ORC1	Origin recognition complex subunit 1
ENSG00000161800	RACGAP1	Rac gtpase activating protein 1
ENSG00000168411	RFWD3	Ring finger and WD repeat domain 3
ENSG00000171848	RRM2	Ribonucleotide reductase regulatory subunit M2
ENSG00000140534	TICRR	TOPBP1 interacting checkpoint and replication regulator
ENSG00000120802	TMPO	Thymopoietin
ENSG00000276043	UHRF1	Ubiquitin like with PHD and ring finger domains 1
ENSG00000162607	USP1	Ubiquitin-specific peptidase 1
ENSG00000092470	WDR76	WD repeat domain 76

Table 4. Common down-regulated genes between early- and late-response genes to X-ray and C-ion radiation under 1G.

Table 5. Three up-regulated genes whose expression increased with irradiation alone, while simulated μG in combination with irradiation results in a lower gene expression increase.

Ensembl Gene ID	Gene Name	Description
ENSG00000120889	TNFRSF10B	TNF receptor superfamily member 10b
ENSG00000244694	PTCHD4	Patched domain containing 4
ENSG00000250337	PURPL	P53 up-regulated regulator of p53

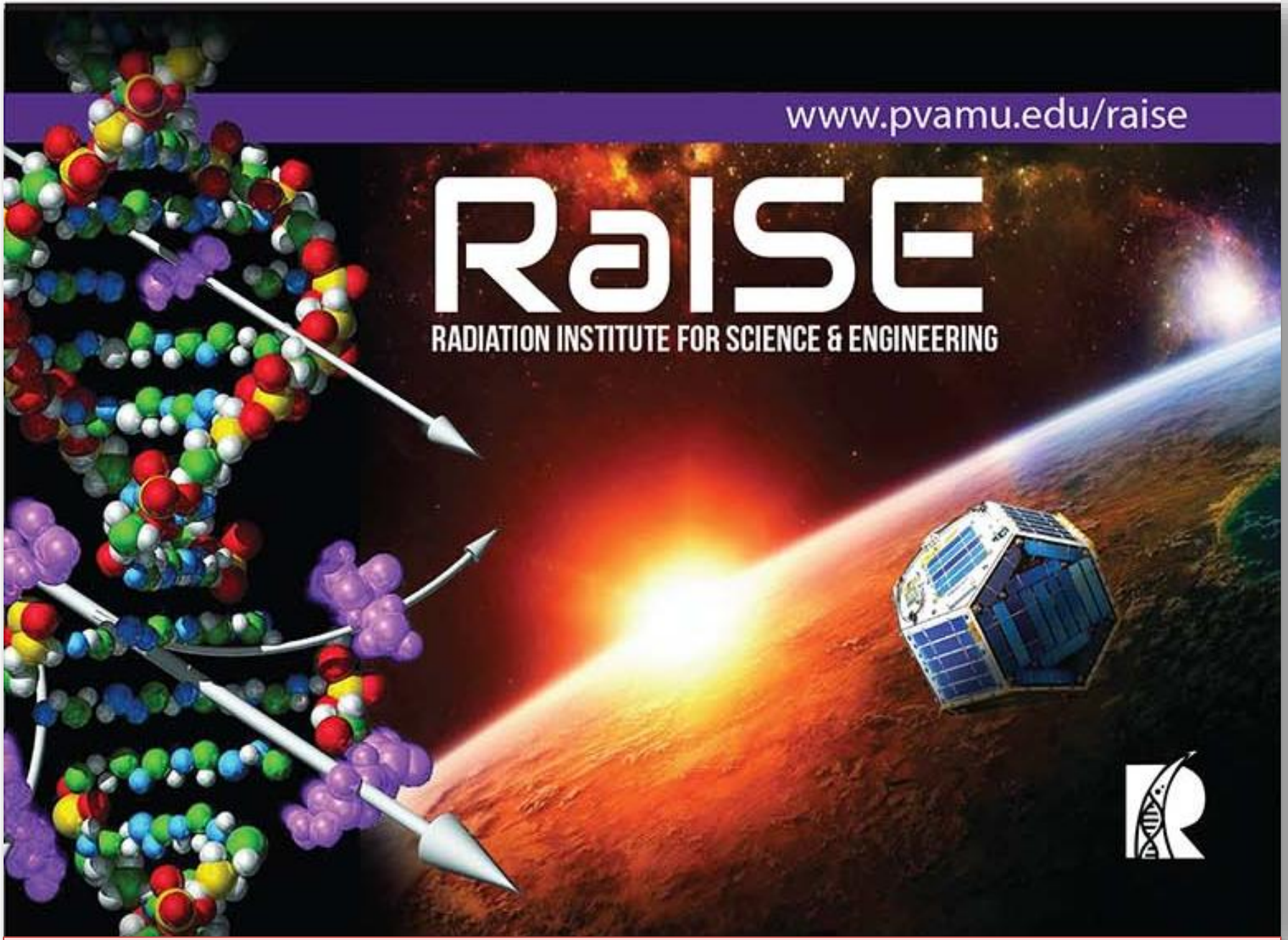
μG

Ensembl Gene ID	Gene Name	Description
ENSG00000162063	CCNF	Cyclin F
ENSG00000184357	H1-5	H1.5 linker histone, cluster member
ENSG00000196747	H2AC13	H2A clustered histone 13
ENSG00000286522	H3C2	H3 clustered histone 2
ENSG00000273983	H3C8	H3 clustered histone 8
ENSG00000197061	H4C3	H4 clustered histone 3
ENSG00000120802	TMPO	Thymopoietin
ENSG00000137807	KIF23	Kinesin family member 23
ENSG00000168411	RFWD3	Ring finger and WD repeat domain 3
ENSG00000276043	UHRF1	Ubiquitin like with PHD and ring finger domains 1
ENSG00000171848	RRM2	Ribonucleotide reductase regulatory subunit M2
ENSG00000140534	TICRR	TOPBP1 interacting checkpoint and replication regulator

Table 6. 12 down-regulated genes whose expression decreased with irradiation alone, while simulated μG in combination with irradiation results in a lower gene expression decrease.

Conclusions

- We identify that PLK1, BRCA1, CCNB1, AURKB, CDK1, CHEK1, RAD51, CCNA2, TOP2A are hub genes in protein interaction networks for DEGs from the comparison between X-ray or C-ion irradiated cells collected 24 hrs post-irradiation and sham-irradiated ones under 1G condition and μG conditions.
- Also, BRCA1 and RAD51 are associated with damage repair of DNA breaks. We note that PLK1, CCNB1, AURKB, CDK1, CHEK1, CCNA2 and TOP2A play a critical role in the process of mitosis.
- We conclude that this bioinformatics approach will certainly help to gain better understanding on the overview of the biological response mechanisms to the combined stressors in space missions and potentially for the establishment of the countermeasures.
- The dose of X-ray and C-ion exposure in this experiment was relatively high compared to the radiation dose astronauts are typically exposed to in Space. This study indicates that further research is needed to comprehend the combined effects of different gravitational conditions and radiation environments.
- Samples exposed to low-dose chronic exposure under simulated μG and partial gravity are currently being studied that simulate prospective future space mission scenarios


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UPDATED: X-RAY MEASUREMENTS WITH "SHARP-CPD" PAYLOAD IN THE POLAR ORBIT ONBOARD THE TEN-KOH SPACECRAFT

Seth Edward Saganti

S. Saganti*, M. Rahman, S. Kolluri, S. Holland, I. Fajardo, R. Rodríguez, K. Okuyama, T. Dachev, G. Erickson, F. Cucinotta, and P. Saganti

Radiation Institute for Science and Engineering (RaISE)
Prairie View A&M University
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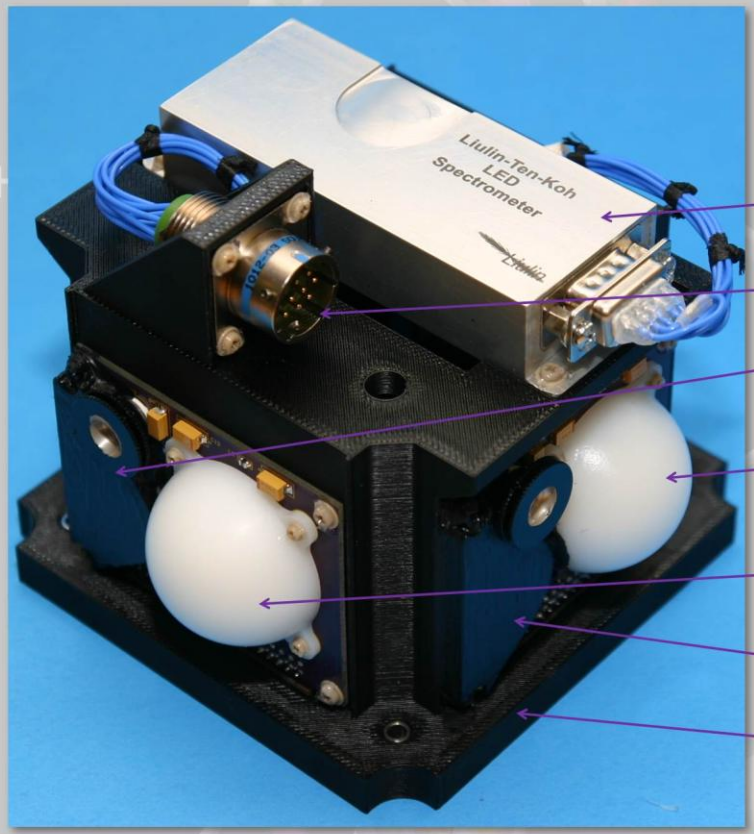
F2.3-0020-26 (Seth Saganti)
August 7, 2026 – Florance, Italy

Contributors: SHARP-CPD (Ten-Koh)

USA	Japan	Bulgaria
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A Radiation Payload to Earth's Polar Orbit in 2018



Solar and Heliospheric Assessment of Radiation Particles (SHARP) – Charge Particle Detector (CPD)

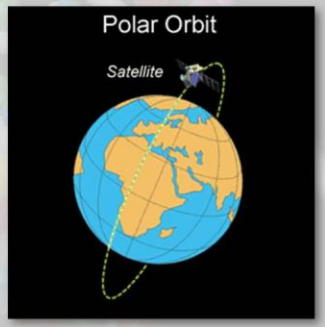
6 Radiation Sensors + 2 X-Ray Detectors + 1 Particle Spectrometer

- Liulin Spectrometer – Similar Instrument on ISS, MIR, and Chandrayaan
- Communication with In-Flight Programming Capability
- 2 Open Sensors for Ambient Radiation Measurements
- 2 Polyethylene Covered Sensors for Shielding Assessment
- 2 Polystyrene Covered Sensors for Skin Dose Assessment
- 2 X-ray Detectors
- PEKK Material for Static Guard









A radiation payload is being developed as part of efforts by the Texas A&M University (TAMU) Chancellor's Research Initiative (CRI) at Prairie View A&M University, Radiation Institute for Science and Engineering (RaISE) in collaborative partnership with NASA Johnson Space Center for the Ten-Koh spacecraft of the Kyushu Institute of Technology (KIT) for a polar orbit launch by the Japan Aerospace Exploration Agency (JAXA), Japan.

Ten-Koh Satellite of KIT-Japan will be launched by JAXA into Low Earth Polar Orbit of 93^0 and about 600 km altitude with PVAMU payload as a primary radiation science investigation instrument and in-flight command control capability.

RaISE
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This research, envisioned in part by NASA Grants (PI-Saganti) NNJ04HD93G, NNJ06JD37G, NNX07AL91G, NNX07AT25A, NNX09Q92G, and NNX10AQ14A; is currently supported through the TAMU Chancellor's Research Initiative – CRI / R aISE at PVAMU

Conclusions / Comments

SHARP-CPD on Ten-Koh in 2018

- Open Sensor Particle Energies
  - During the month of December 2018, we have seen the energy of the particles (primarily protons) **between 60 MeV and 240 MeV**
- Covered Polyethylene / Polystyrene Shielding
  - During the month of December 2018, we have seen the energy distribution behind the uniform shielding block **between 20 and 120 MeV**
- **X-Ray Measurements**
  - We have our first measurements with a simple device (luminescence from x-rays)
  - We measured x-ray energies **between 10 and 120 kV** (potential up to 200 kV)
- Liulin Dose-Rates
  - Polar orbit (93 deg and 600 km altitude) **average dose rate is 1.72 mGy/hr**
  - Compared to ISS (51.6 deg and 400 km altitude) average dose rate is 1.57 mGy/hr
- **Suggestions:**
  - Polar regions (~ 600 km) do have high potential for greater incidence of x-rays
  - Future radiation data measurements may also include x-rays as they contribute a lot

NEUTRONS

Studies at LANL



Mutation Research 701 (2010) 67–74

Contents lists available at ScienceDirect

Mutation Research/Genetic Toxicology and Environmental Mutagenesis

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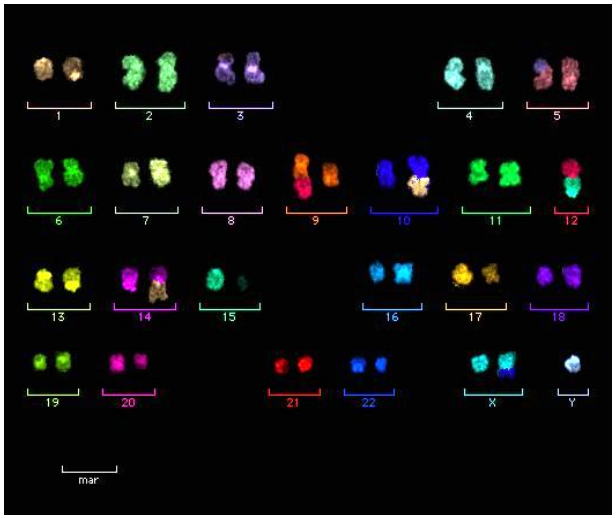
mBAND analysis of chromosome aberrations in human epithelial cells induced by γ-rays and secondary neutrons of low dose rate

M. Hada[a,b], B. Gersey[c], P.B. Saganti[c], R. Wilkins[c], F.A. Cucinotta[a], H. Wu[a,*]

[a] NASA Johnson Space Center, Houston, TX 77058, USA
[b] Universities Space Research Association, Houston, TX 77058, USA
[c] Prairie View A&M University, Prairie View, TX 77446, USA

Chromosome painting with Multicolor fluorescence in Situ Hybridization

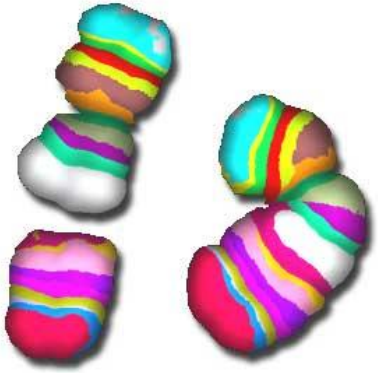
mFISH



Multicolor Fluorescence *in situ* Hybridization

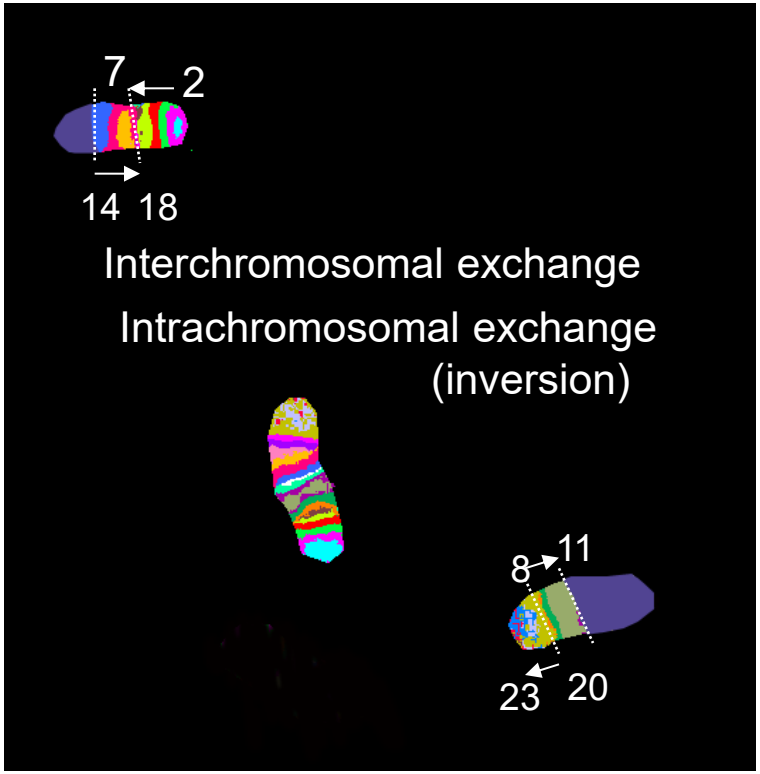
- simultaneous presentation of all 24 different human chromosomes with one single hybridization
- analysis of hidden or complex chromosome aberrations
- composition of marker chromosomes

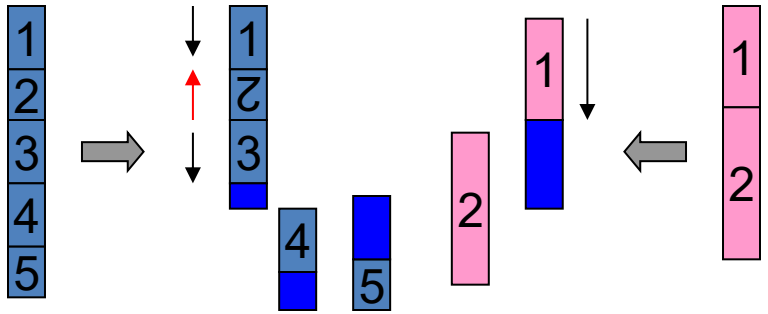
mBAND

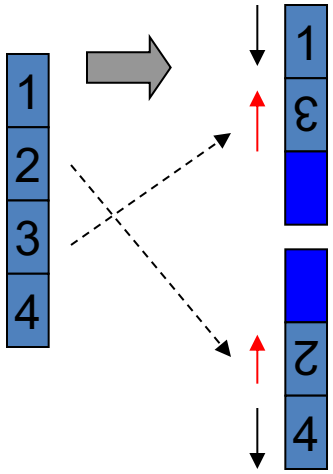


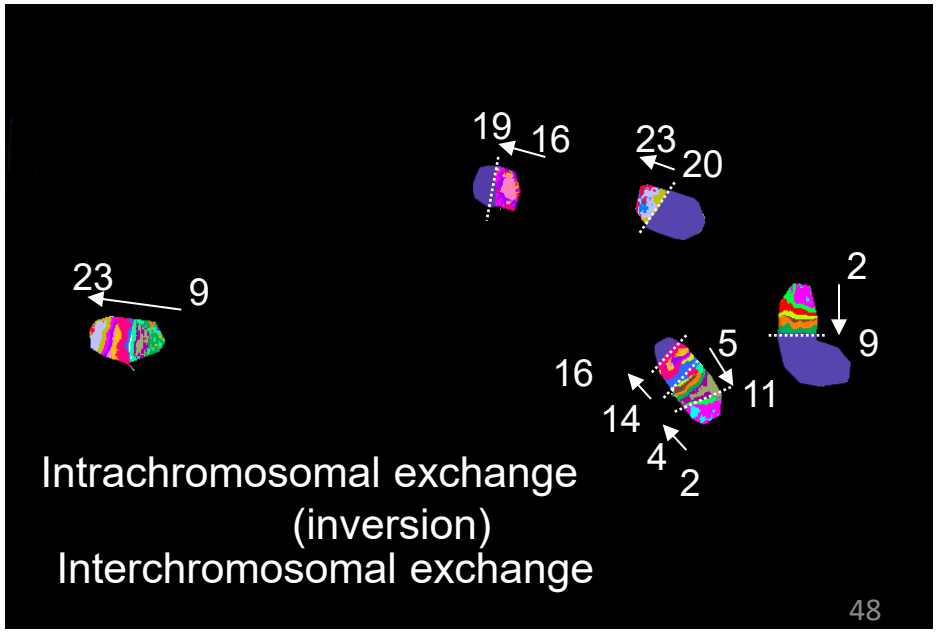
Multicolor Banding *in situ* Hybridization

- color banding pattern along one chromosome
- higher level of precision within one chromosome
- detection of intrachromosomal rearrangements
- detection of break points

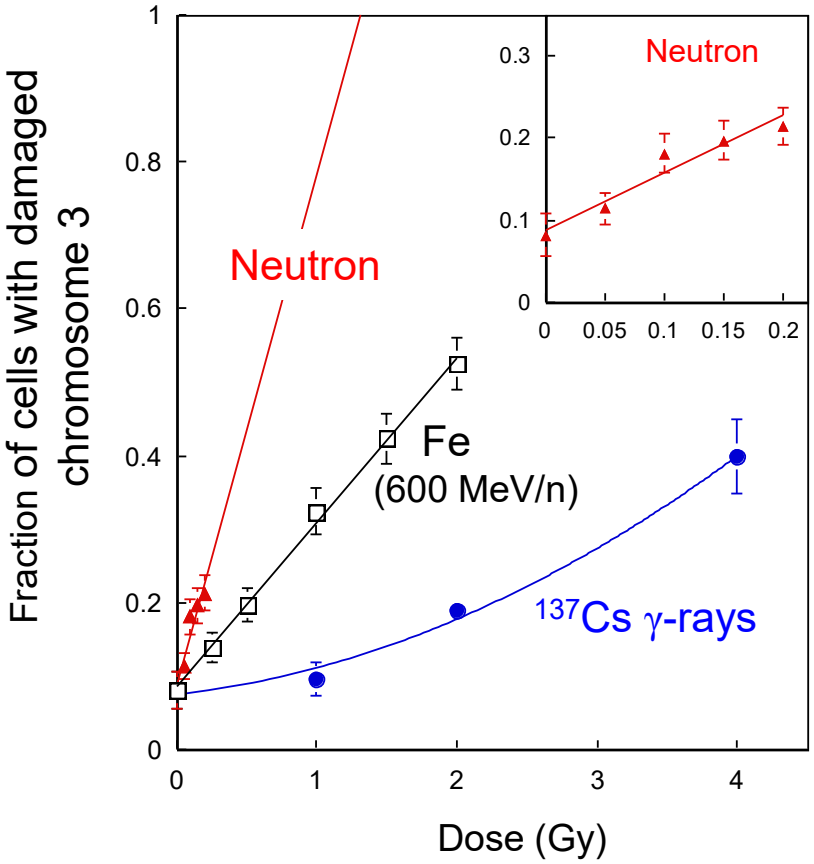

7
2
14
18
Interchromosomal exchange
Intrachromosomal exchange
(inversion)
8
11
23
20


1
2
3
4
5


1
2
3
4


19
16
23
20
23
9
2
9
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4
2
Intrachromosomal exchange
(inversion)
Interchromosomal exchange

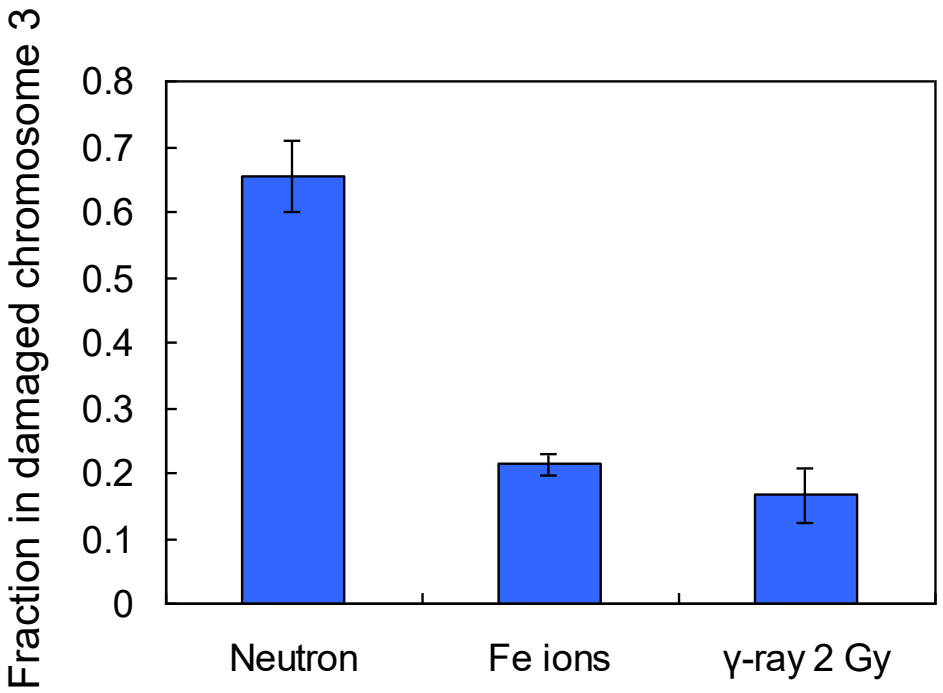
Induction of chromosome 3 aberration in human cells by Neutron, Fe-ions or γ-rays



RBE for 20% of cells with damaged chromosome 3
Fe: 4.5
Neutron: 14.7

Fe-ions induced more aberrations in chromosome 3 compared to γ-rays, and neutron induced more aberration than Fe ions.

Induction of terminal deletion in human chromosome 3 by neutron, Fe ions or γ-rays irradiation



Neutron induced more terminal deletion compare to Fe ions and γ-rays irradiation.