


# Biophysical modelling for space radiation risks assessment

Ricardo Ramos

A space shuttle is shown in the process of launching, ascending from the Earth's surface. The shuttle is white with orange external tank and boosters. The Earth's atmosphere and clouds are visible below, and the Moon is in the upper left corner of the frame. The background is a deep blue space filled with stars.

“We go to the Moon now to  
build a community on and  
around the  
Moon capable of proving  
how to live on other worlds”



<https://www.nasa.gov/specials/artemis>



**Earth**  
**2 mGy (650 days)**



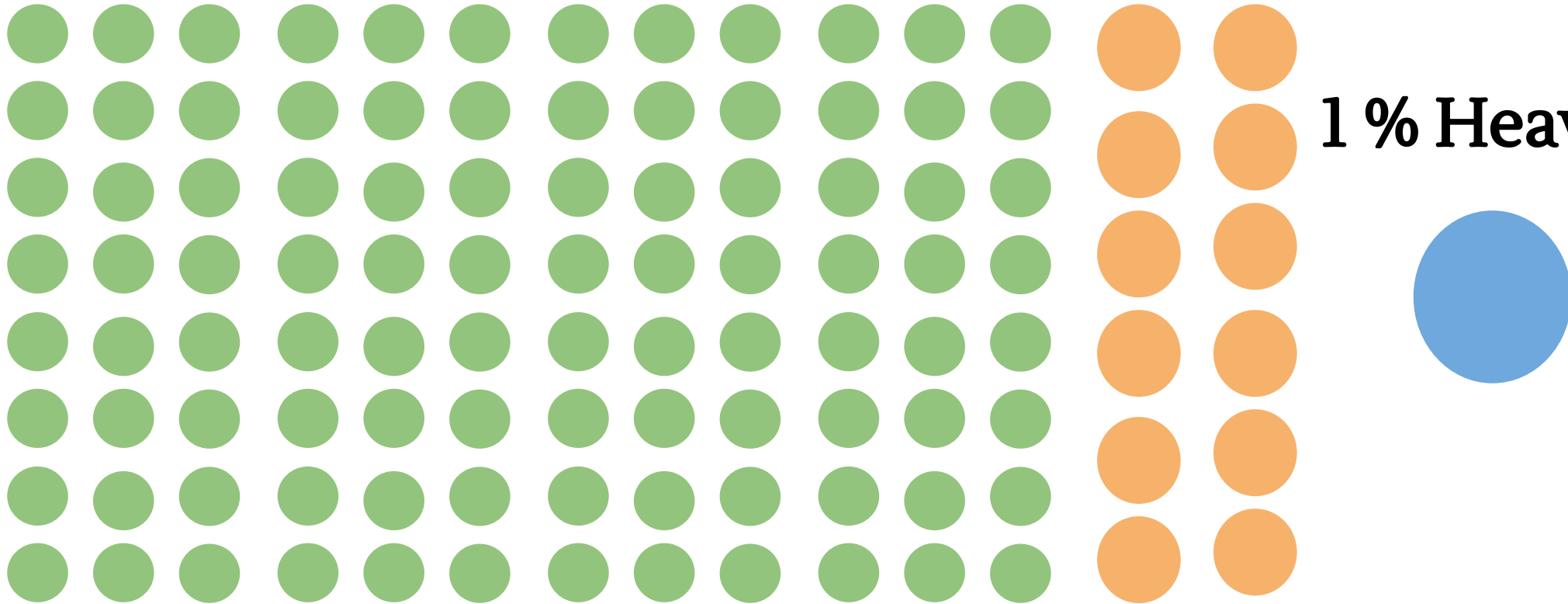
**Mars**  
**350 mGy (650 days)**

# Galactic Cosmic Rays (GCR)

87 % protons

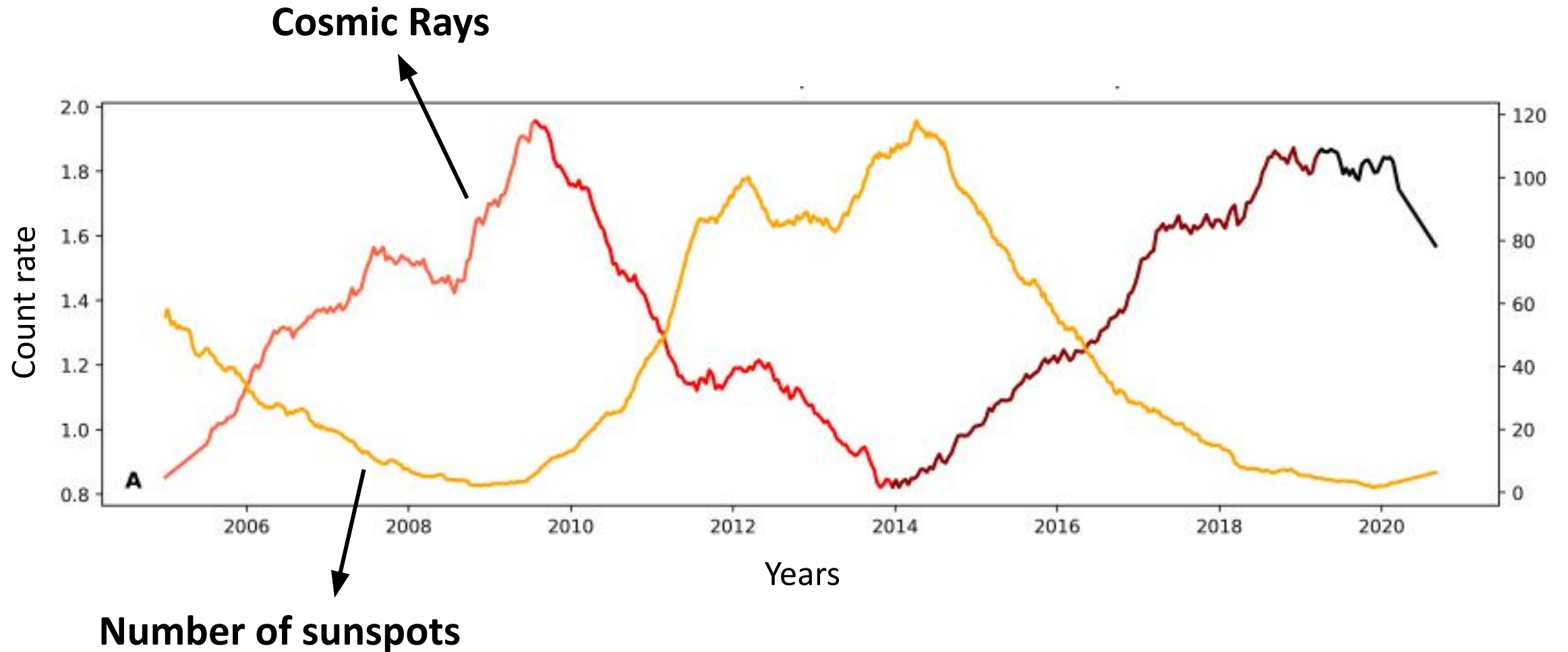
12 % He-ions

1 % Heavy-ions



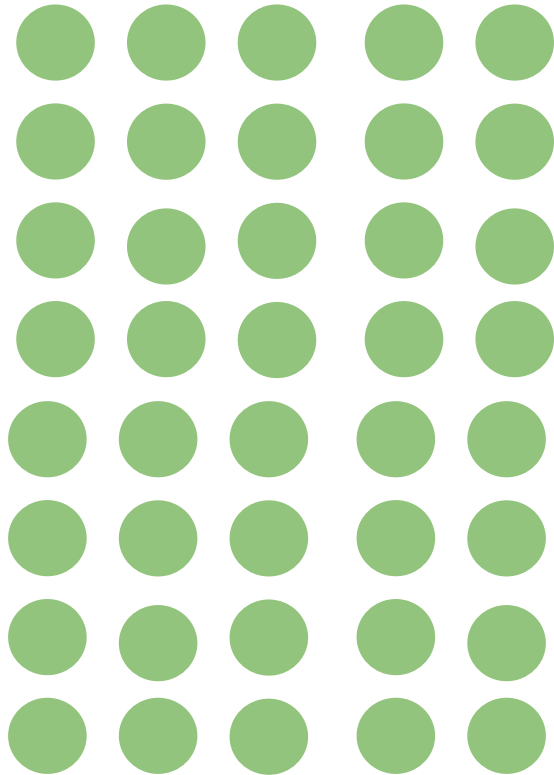
Maximum Dose Rate = 0.5 mGy/day

# GCR and solar activity



# Solar Particle Events (SPE)

protons

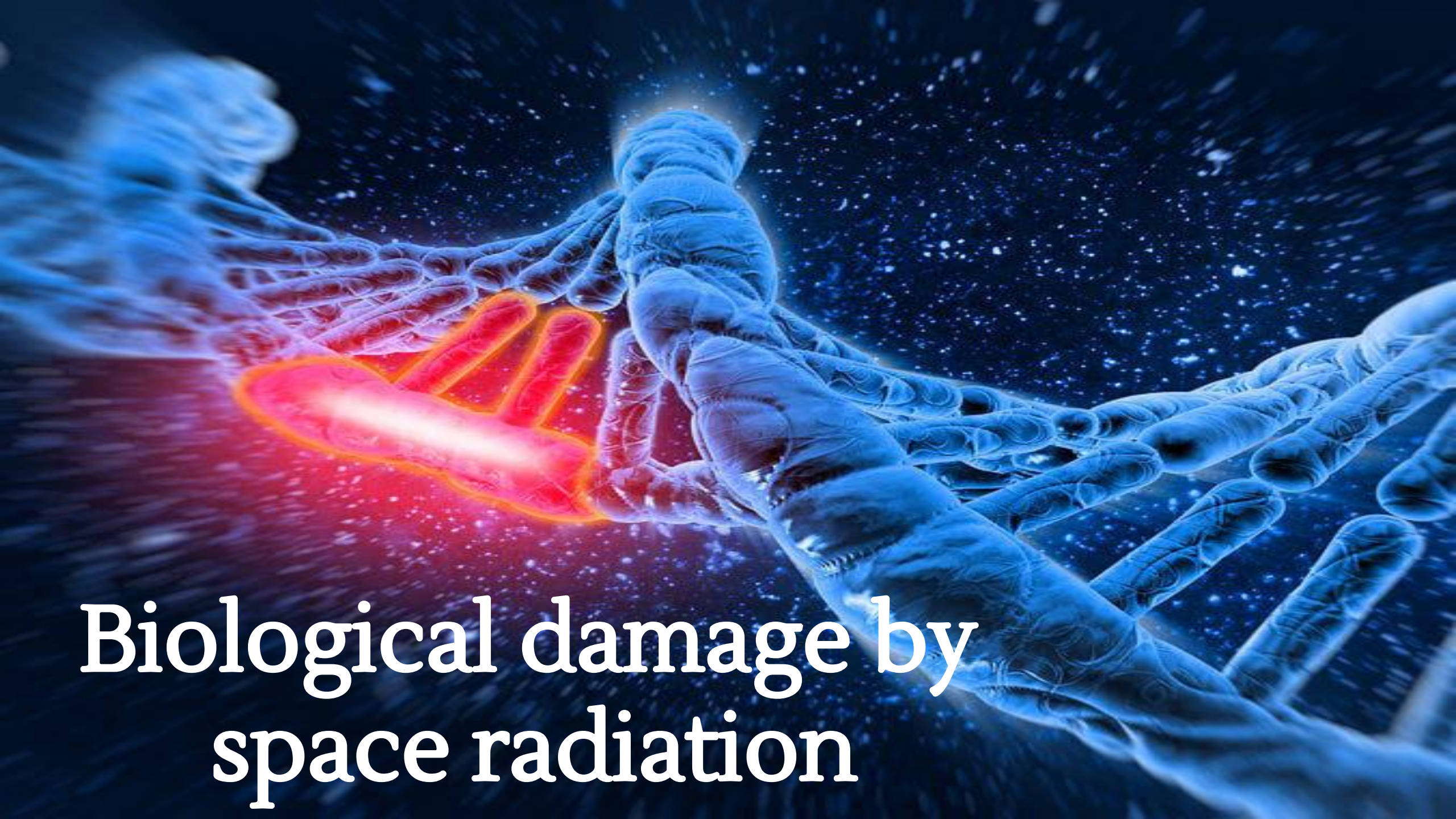


He-ions



Up to  $10^{11}$  particles.cm<sup>-2</sup> in  
few hours, mainly protons

Dose → Gy/event



**Biological damage by  
space radiation**

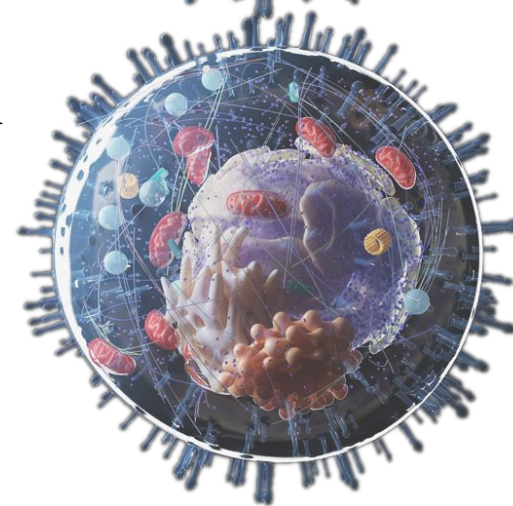
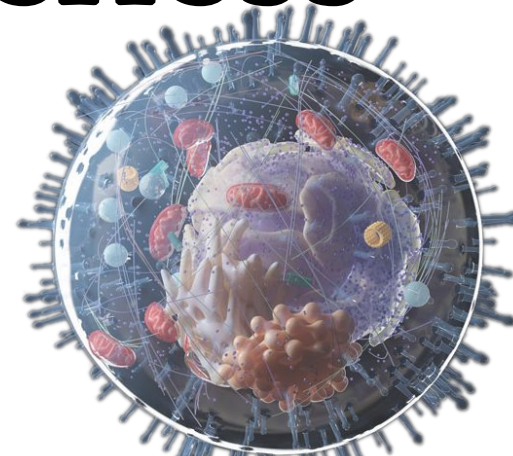
# Limits

NASA limits for **non-cancer** effects

	30-Day Limit (Gy-Eq)	1-Year Limit (Gy-Eq)	Career Limit (Gy-Eq)
Skin	1.5	3.0	6.0
Eye	1.0	2.0	4.0
BFO	0.25	0.5	N.A.
Heart	0.25	0.5	1.0
CNS	0.5	1.0	1.5
CNS ( $Z > 9$ )	N.A.	0.10 Gy	0.25 Gy

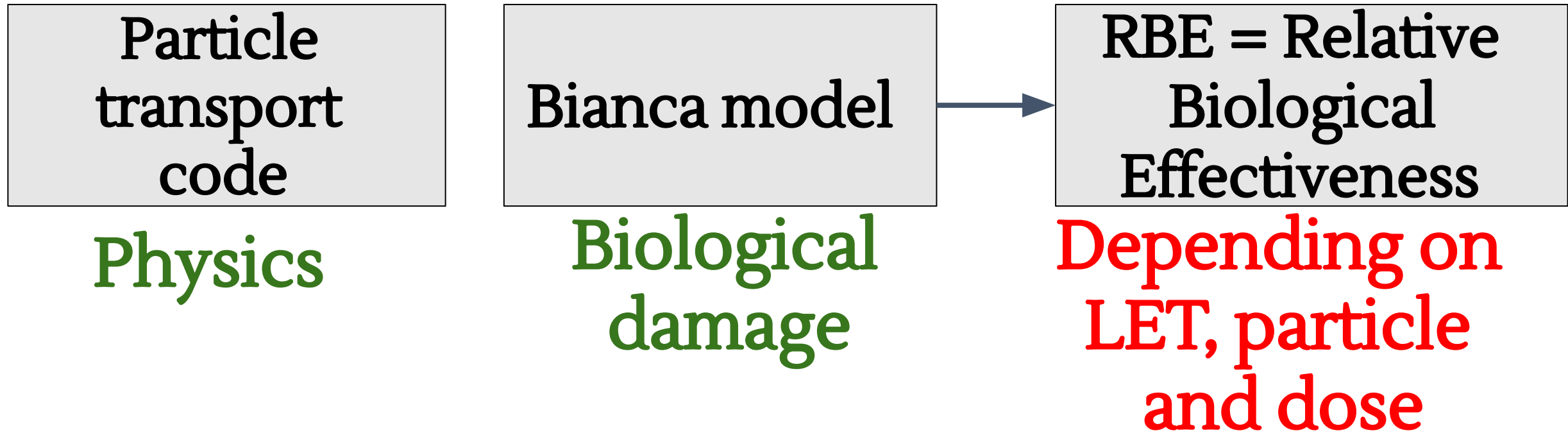
# Relative biological effectiveness

$$\text{RBE} = \frac{\text{Dose}_{\text{photons}}}{\text{Dose}_{\text{space radiation}}}$$



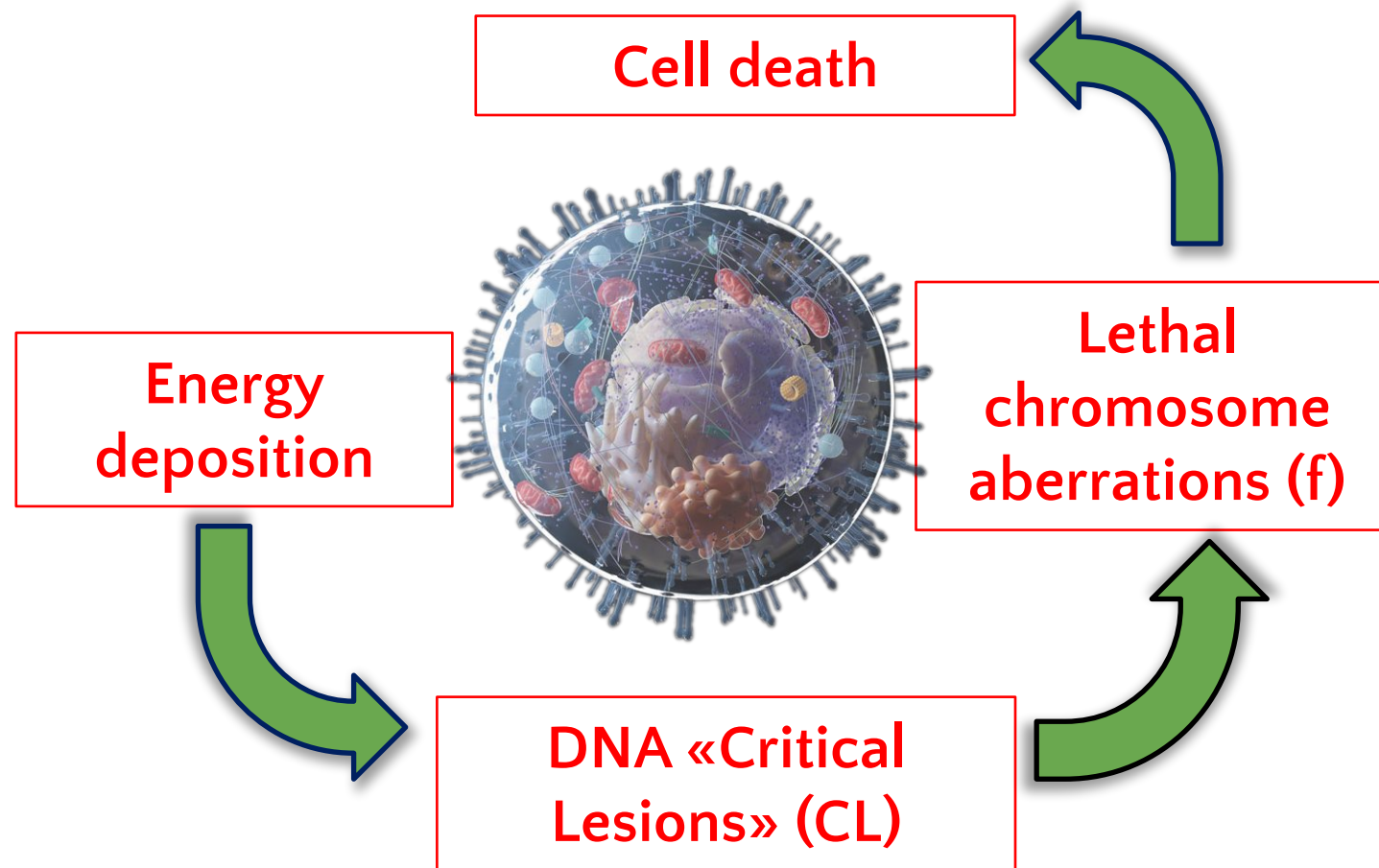
Same biological effect

# Space radiation effects computational studies



# BIANCA model developed in Pavia

Main assumption: DNA “critical lesions” lead to **chromosome aberrations**, and some chromosome aberrations (e.g., dicentrics) lead to cell death



# BIANCA model


Example of radiobiological database for cells V79:

Z=1	A=1,2,3		
LET	alfa		beta
5	0.161168003608071	0.034227925863557	
7.5	0.219155512347106	0.031807059167825	
10	0.277730304065006	0.026062986984213	
12.5	0.324223249128924	0.031963531745716	
15	0.370061833526514	0.032195025167274	
17.5	0.421451839190716	0.031121716722449	
20	0.482515824349661	0.028525693688078	
22.5	0.560520033338037	0.018863044675061	
25	0.613244623202487	0.019486893814967	
27.5	0.670278414247874	0.018719108913174	
30	0.723636950773347	0.019048357687813	

Z=2	A=3 (He3)		
LET	alfa		beta
5	0.134484868252636	0.033328267759041	
10	0.144914045351193	0.039167916406686	
20	0.195309536204132	0.055766427339300	
30	0.254263496879065	0.086614721872234	
40	0.346232798363745	0.110820821623133	
50	0.461751927355611	0.125899692117198	
60	0.577156328111620	0.149414730517834	
70	0.688177599469057	0.170307321062664	
80	0.831202131850177	0.173711239896555	
90	0.958976414546513	0.178987749762615	

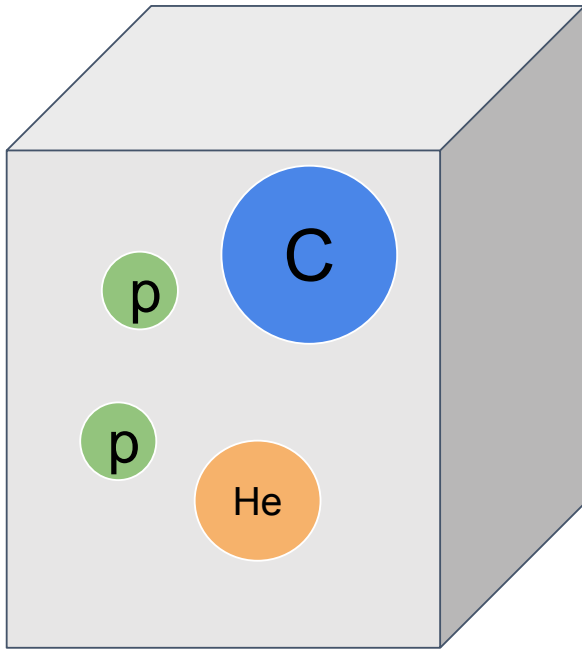
Z=2	A=4 (He4)		
LET	alfa		beta
5	0.122919965474113	0.0282243396663055	
10	0.164742642147497	0.0320256389518587	

Cell death for each ion and LET:


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

# Interface BIANCA - FLUKA

Particle Transport Code: particle  $i$ , dose ( $D_i$ ), LET



**VOXEL**

BIANCA ( $\alpha_i, \beta_i$ )

$$\alpha = \frac{\sum_{i=1}^n \alpha_i D_i}{\sum_{i=1}^n D_i} \quad \sqrt{\beta} = \frac{\sum_{i=1}^n \sqrt{\beta_i} D_i}{\sum_{i=1}^n D_i}$$

$$D_x = \frac{-\alpha_x + \sqrt{\alpha_x^2 - 4\beta_x \ln S(D)}}{2\beta_x}$$

$$RBE = \frac{D_x}{D}$$

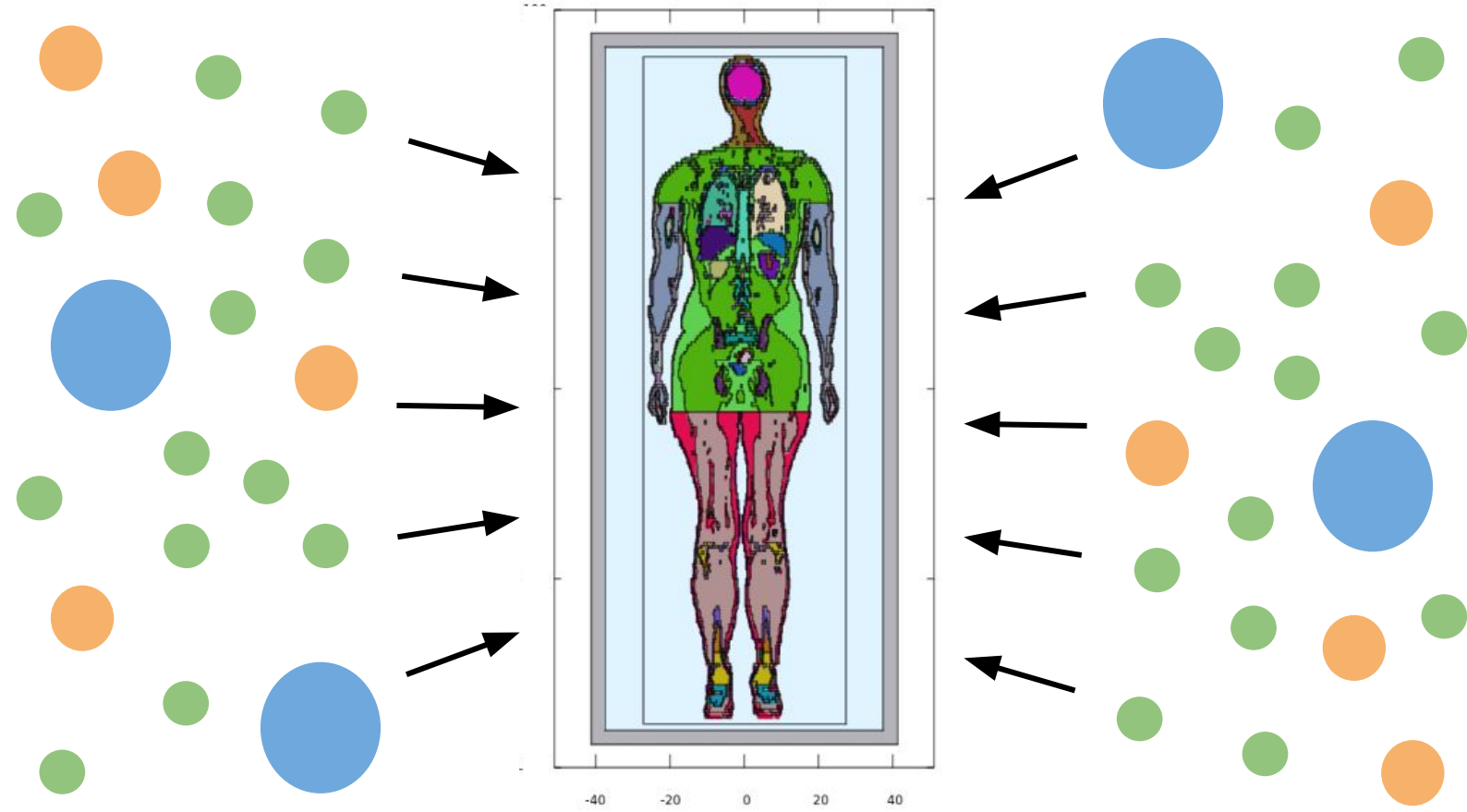
**VOXEL**

# Space radiation calculations

FLUKA + BIANCA

Male and female  
ICRP phantoms

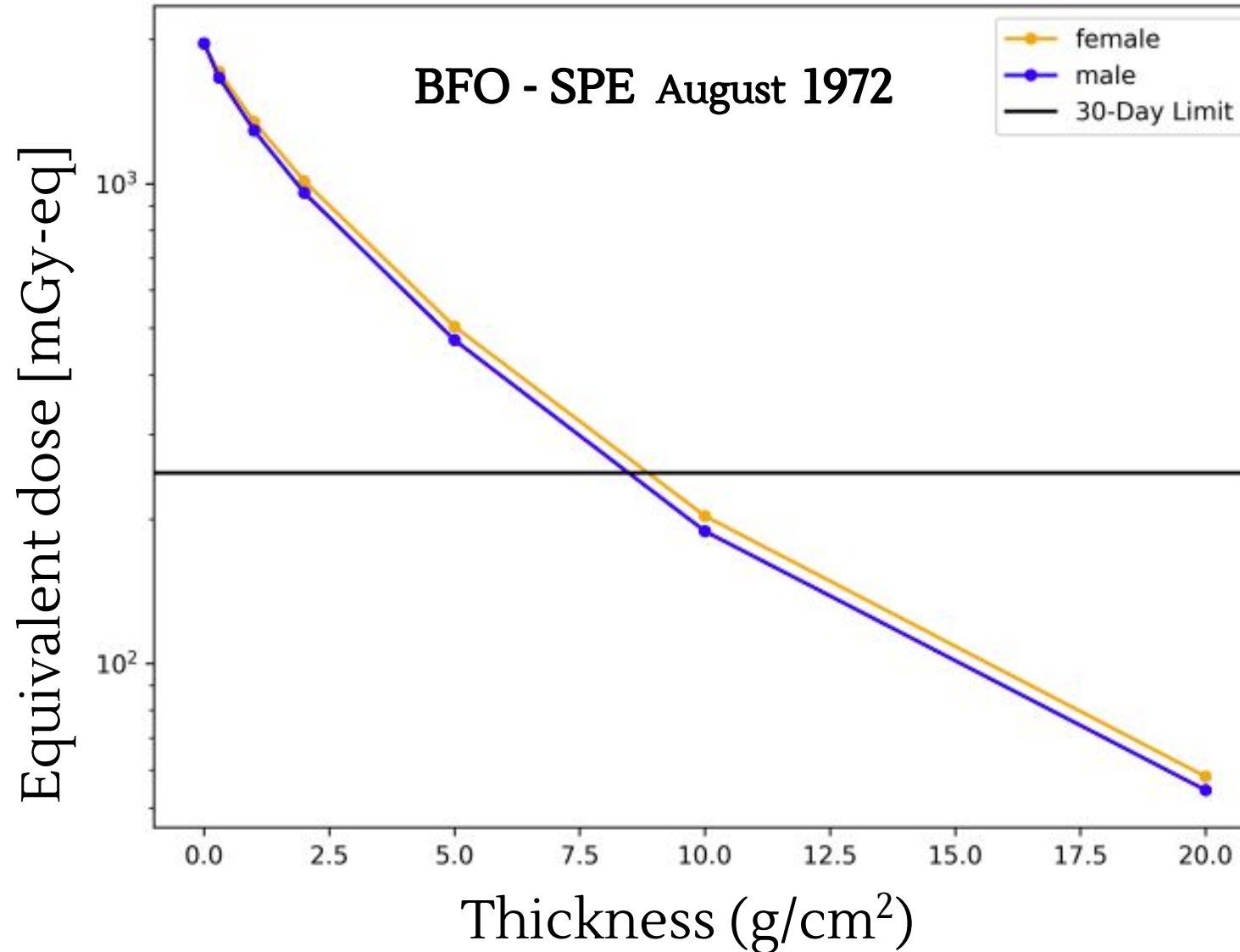
GCR, SPE sources



Cylindrical  
shielding

Variable  
thickness

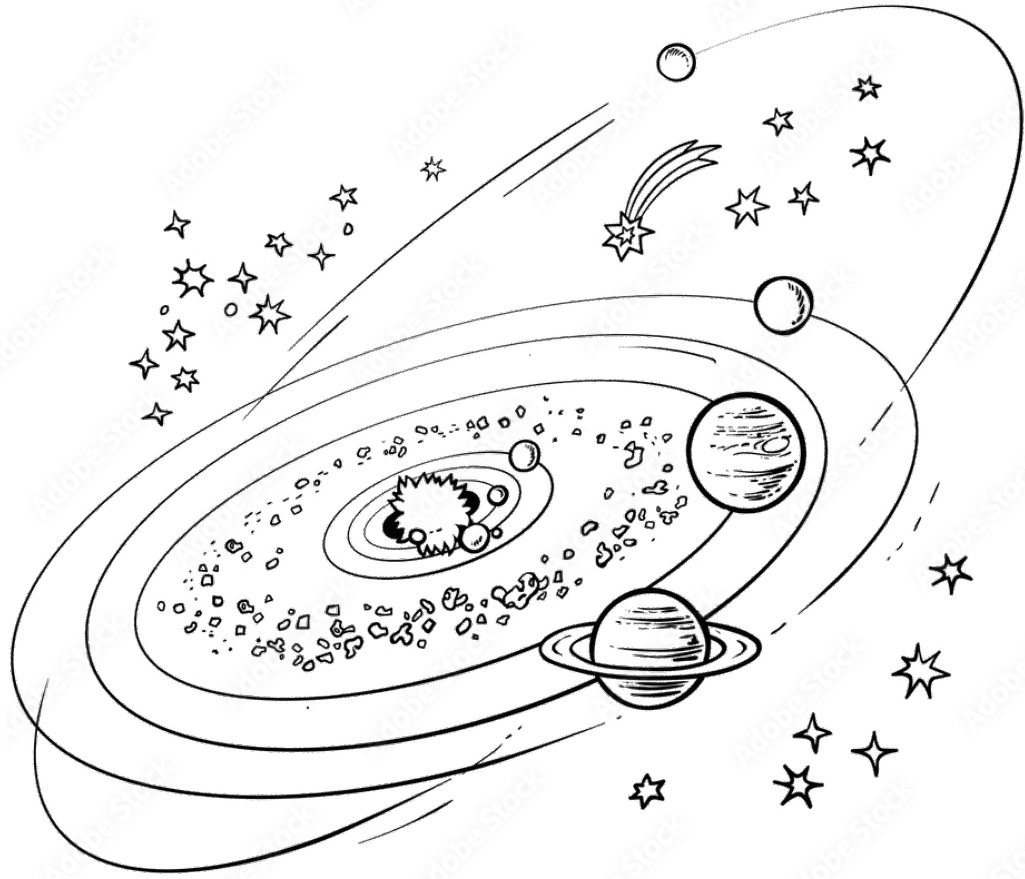
# Space radiation calculations



Limit for  
BFO

RBE (LET, D, particle)!!!

[Ramos et al](#), Journal of  
Radiological Protection, 2024  
[Bernardini... & Ramos](#), LSSR,  
submitted



**Thanks!**

[ricardoluis.ramos@unipv.it](mailto:ricardoluis.ramos@unipv.it)