
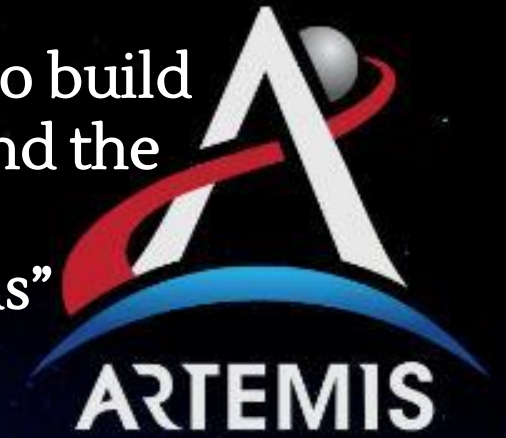


# Il problema delle radiazioni nell'esplorazione spaziale

Ricardo Ramos, Mario Carante



“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>

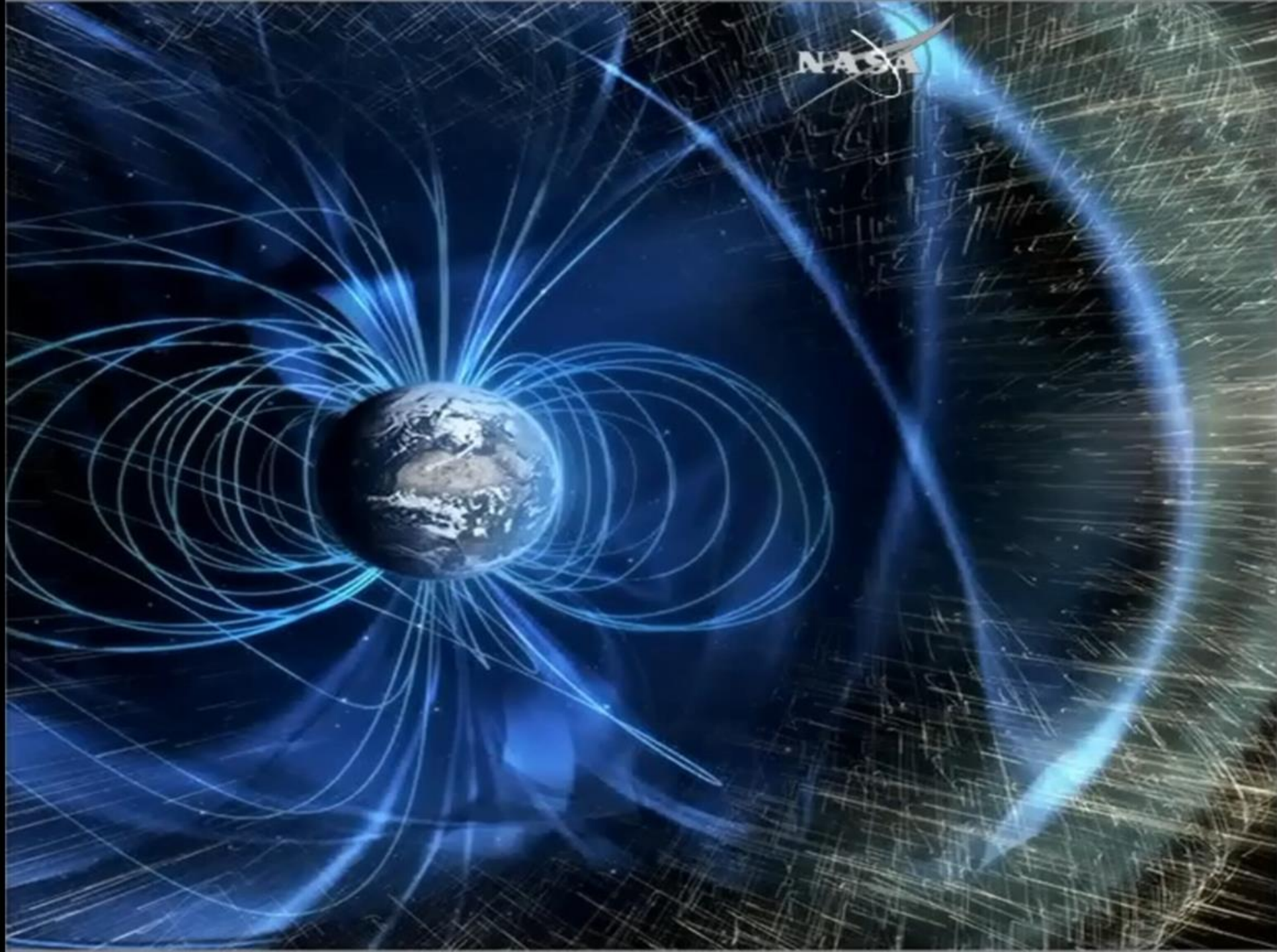
# MISSION TO MARS

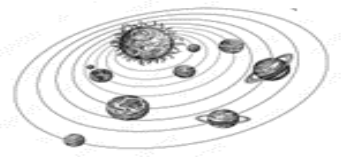


“Then, we will use what we learn on and around the Moon to take the next giant leap: sending the first astronauts to Mars”

*Tanto tempo fa,  
in una galassia lontana lontana.....*





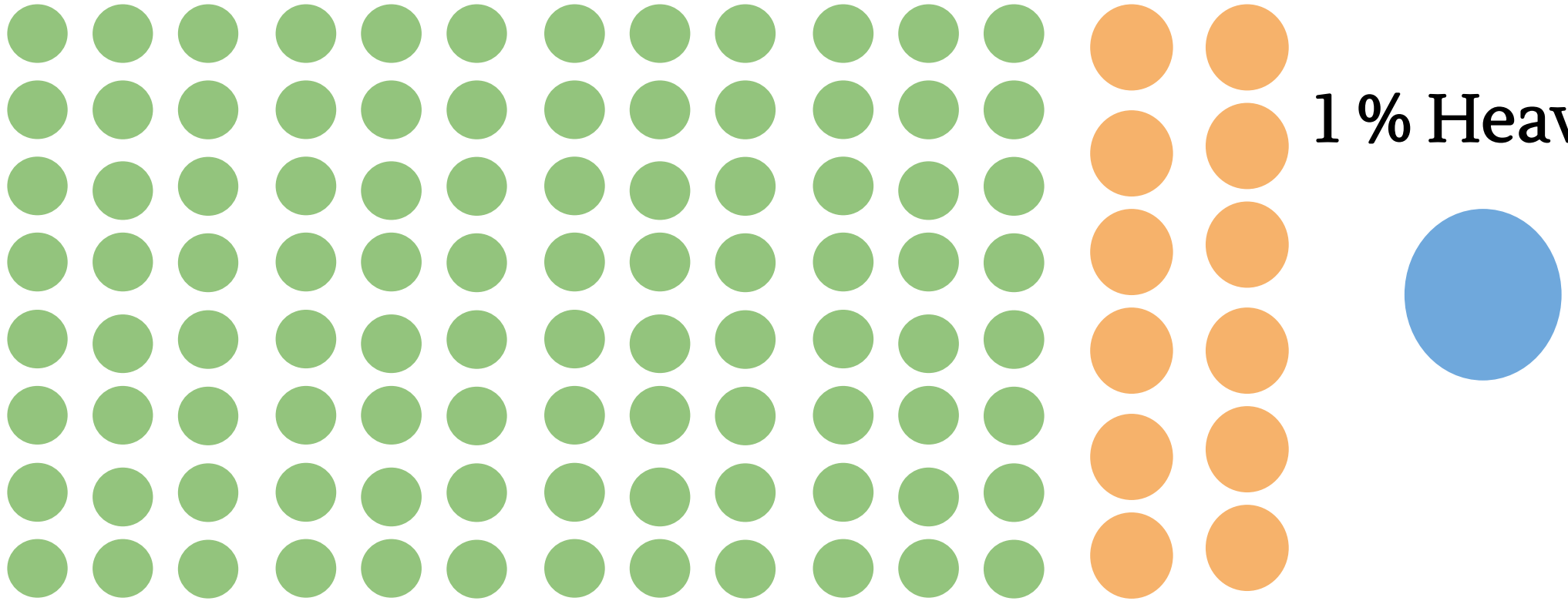


# Galactic Cosmic Rays (GCR)

87 % protons

12 % He-ions

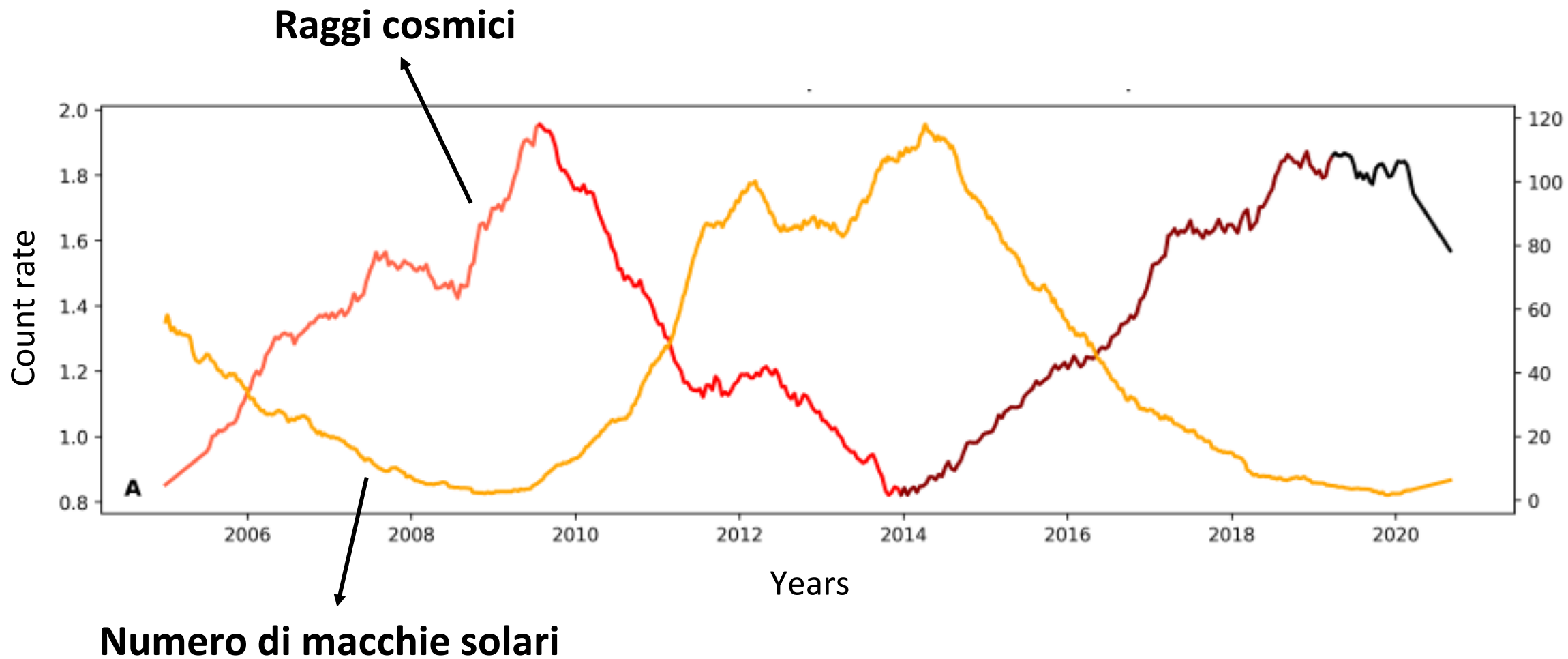
1 % Heavy-ions

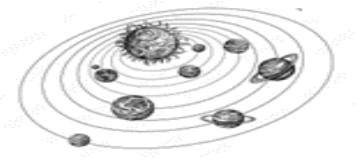


Maximum Dose Rate = 0.5 mGy/day



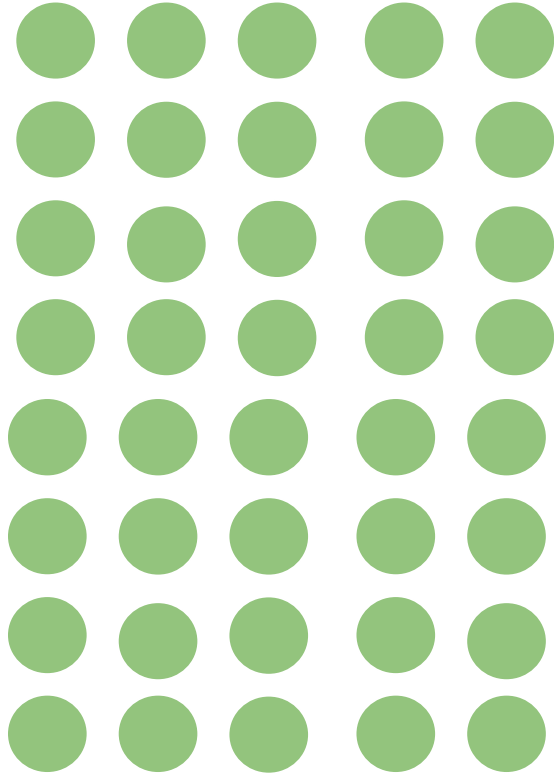
# GCR e attività solare





# Solar Particle Events (SPE)

protons



He-ions



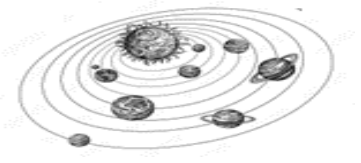
Up to  $10^{11}$  particles. $\text{cm}^{-2}$  in  
few hours, mainly protons

Dose  $\rightarrow$  Gy/event



# Biological damage by space radiation





# Effetto Biologico

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protons



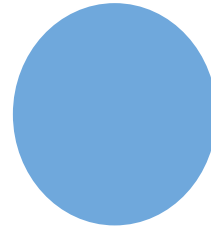
+

He-ions

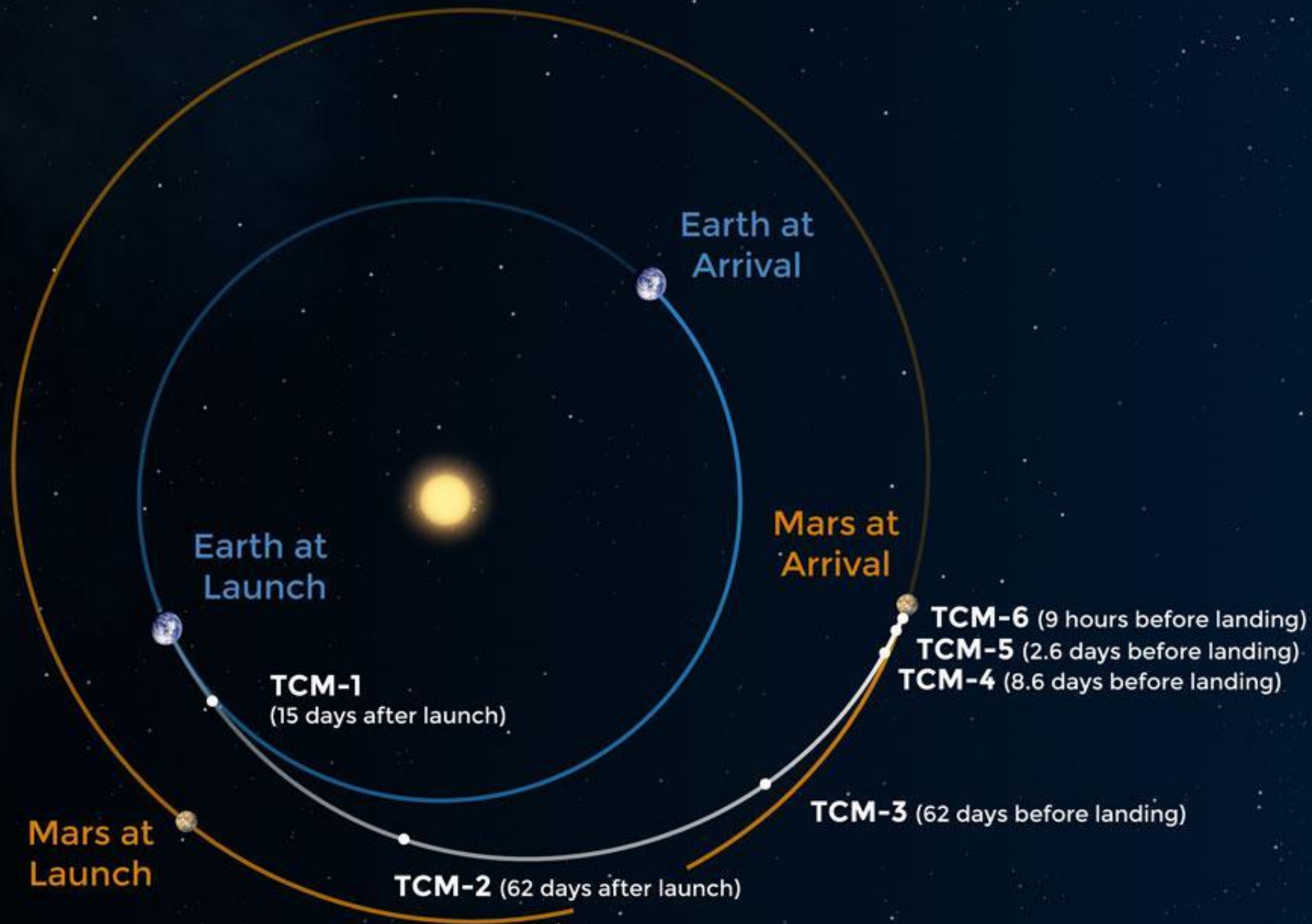


++

Heavy-ions



+++++

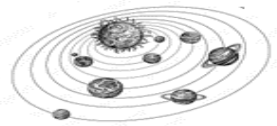




Terra  
2 mGy (650 giorni)



Marte  
350 mGy (650 giorni)



# Per confronto

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Fondo naturale di radiazioni: ordine di grandezza di **1 mGy all'anno**

Banana: **0.1  $\mu$ Gy**

Rx torace: **20  $\mu$ Gy**

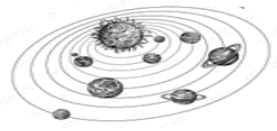
Volo Tokyo-New York: **0.15 mGy**

2 settimane nella zona di esclusione di Fukushima dopo l'incidente: **1 mGy**

TAC total body: **1-10 mGy**

Avvelenamento da radiazione: **0.5 Gy in one shot**

Dose fatale: **alcuni Gy**

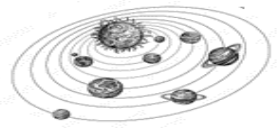


# Limiti

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NASA limits for **cancer** risk – 1 year missions

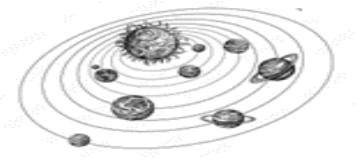
Age	Male (Sv)	Female (Sv)
30	0.78	0.60
40	0.88	0.70
50	1.00	0.82
60	1.17	0.98



# Limiti

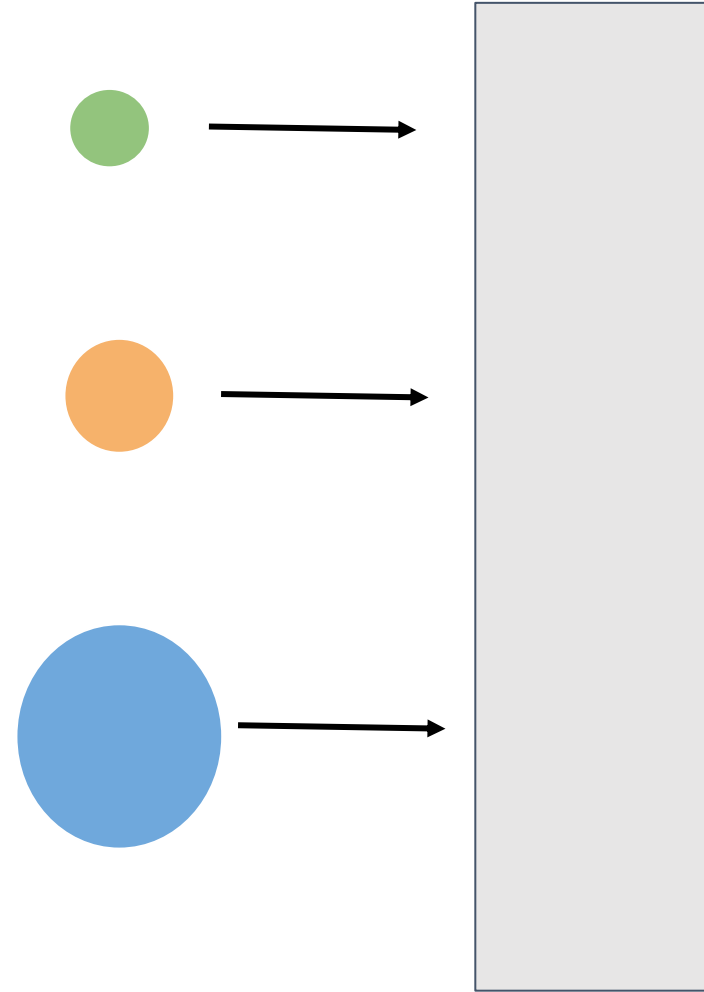
## NASA limits for non-cancer effects

	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



# Schermatura

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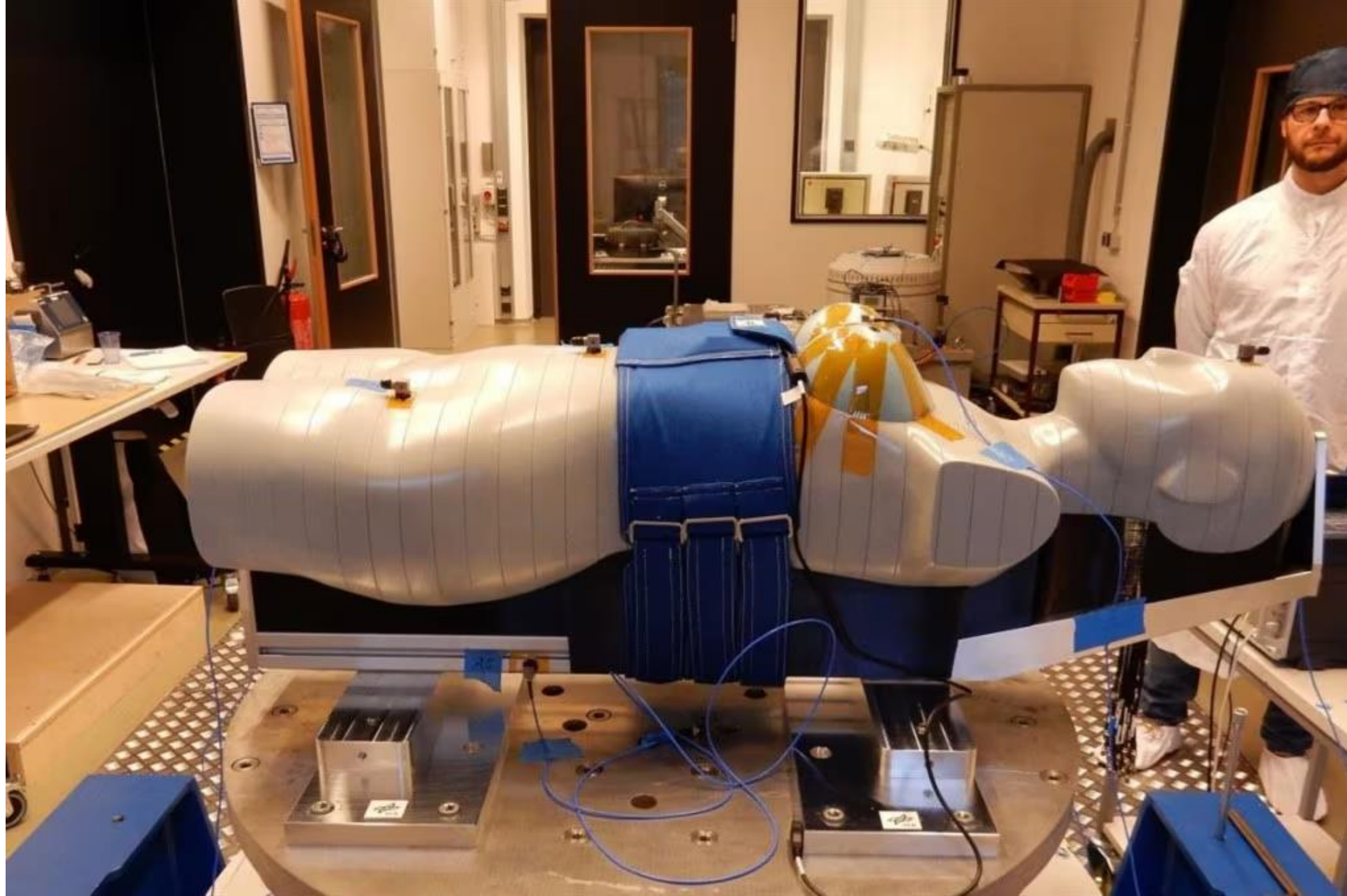


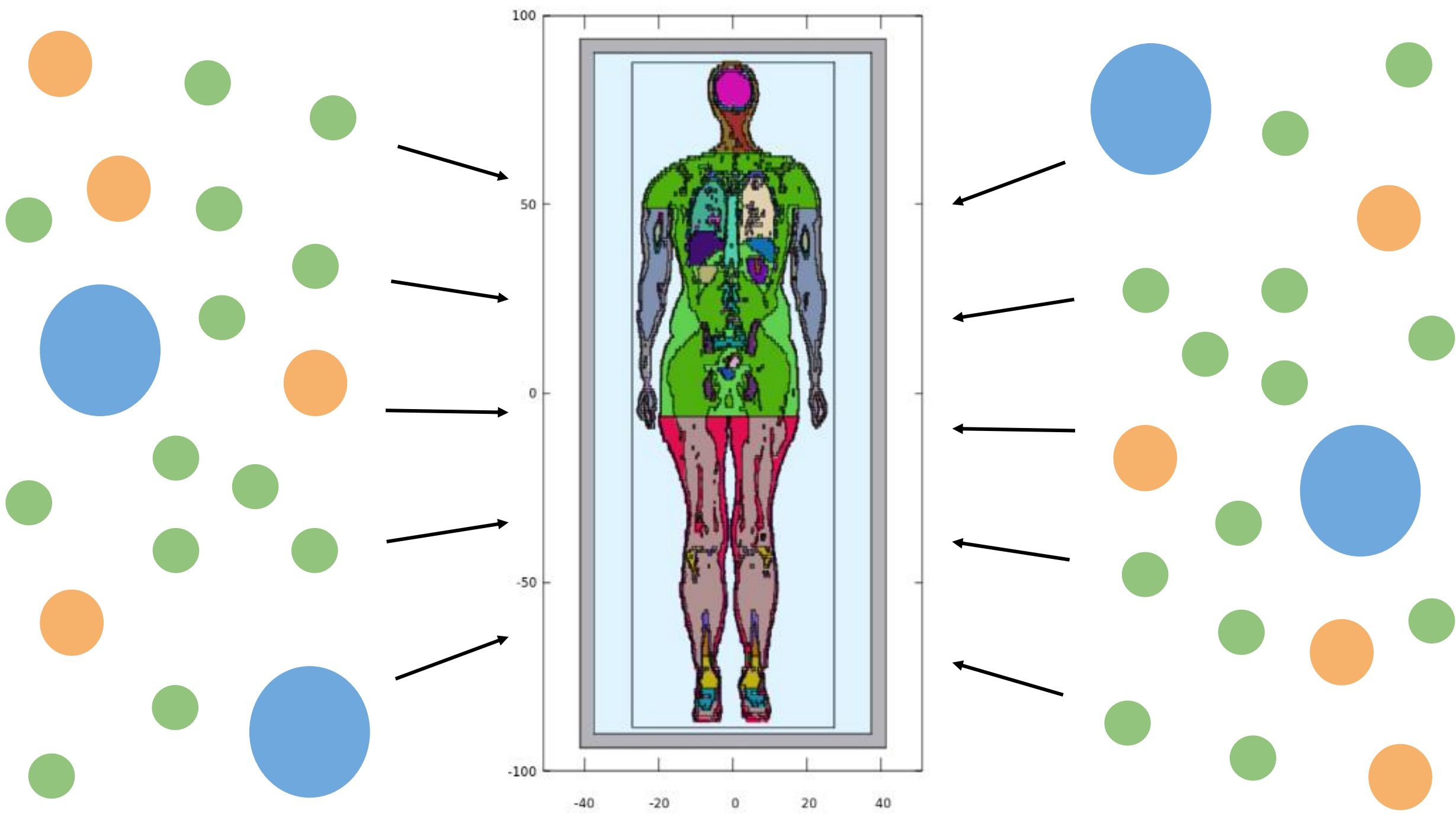




# Tsiolkovsky rocket equation

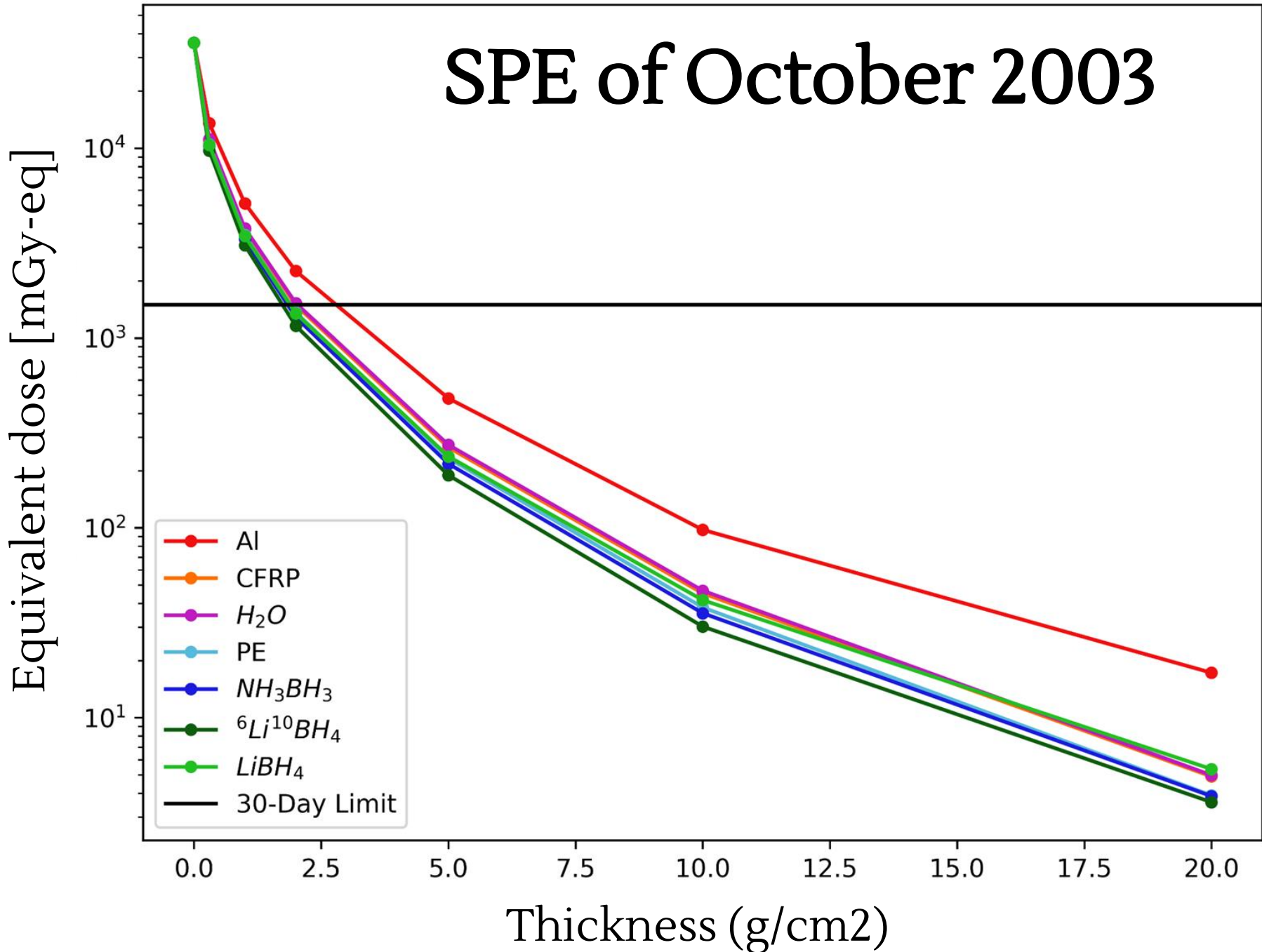
$$\Delta v = v_e \ln \frac{m_0}{m_f}$$







# SPE of October 2003



Limit for  
skin

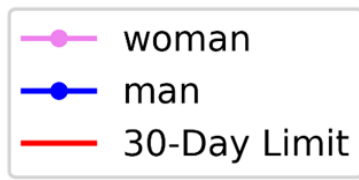
Limit for  
heart

# SPE of October 2003

Equivalent dose [mGy-eq]

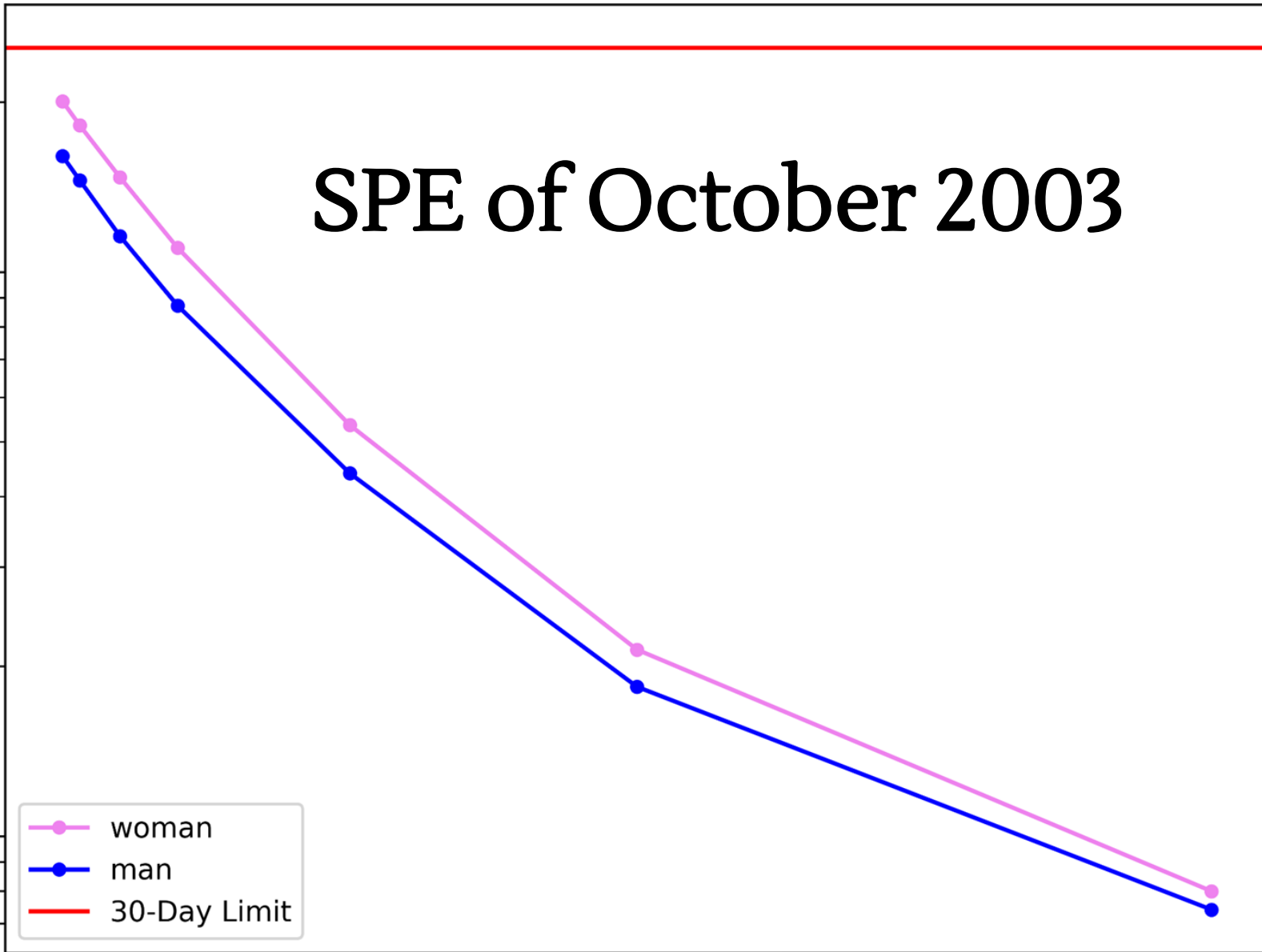
$10^2$

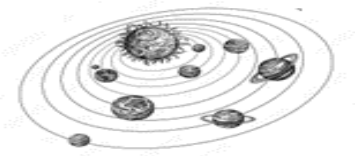
$10^1$



0.0 2.5 5.0 7.5 10.0 12.5 15.0 17.5 20.0

Thickness (g/cm<sup>2</sup>)





# Gruppo e collaborazioni

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**Elena Bernardini**

**Alice Casali**