The Human Brain
And Cosmic Radiation

—

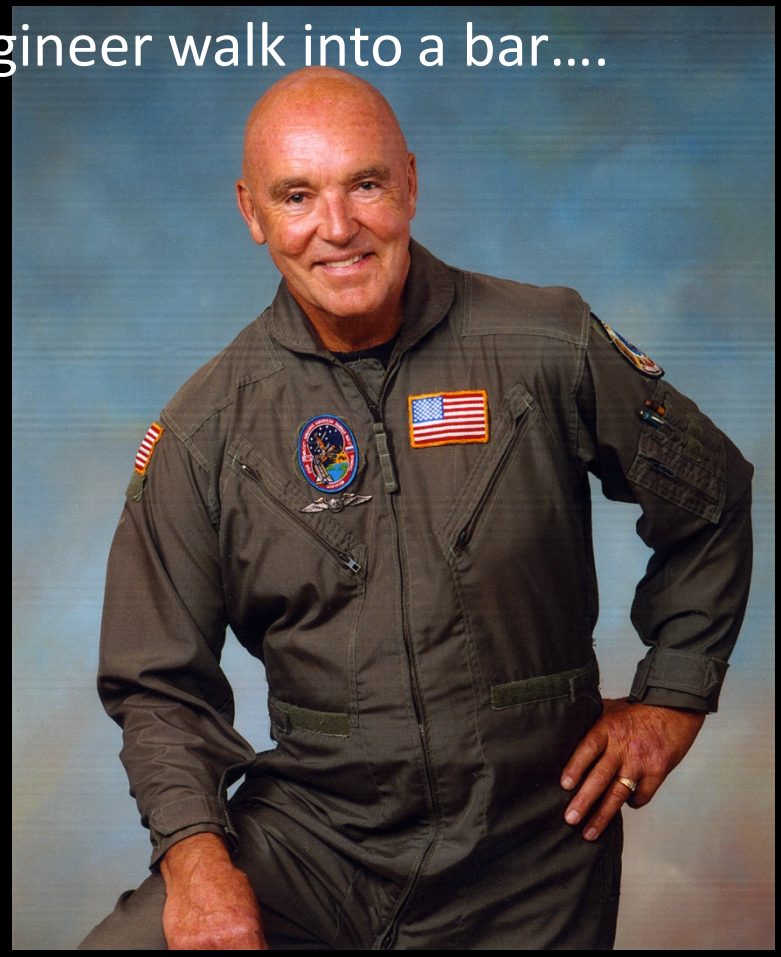
Introducing: RINC

Dennis Chamberland, PhD

…and so our story begins with a common myth…

So…

… a Skylab astronaut physician and a NASA engineer walk into a bar….



Duane Graveline, MD

Effects of some cancer treatments yielded first hints of the effects of therapeutic gamma radiation on the brain.

Suddenly, the concern was far more than therapeutic radiation increasing the risk for cancer!

So what about the effects of cosmic radiation on astronaut cognition? How will it affect them under a chronic dose as in a typical Mars mission profile?

Ask the expert:

Dr. Dennis Steindler

Director of McKnight Brain Institute
University of Florida Shands Medical Center

…. And Dr. Steindler said, ‘”Remember this guy from college?”

… well, it was all lies.

Neurogenesis

- The birth of neurons. It is the process by which neurons are generated from neural stem cells and progenitor cells.

Neurogenesis

- **5 Steps in Neuron Development**

Proliferation

Production of New Cells

Migration

Movement of Primitive Neurons & Glia to Final Destination

Differentiation

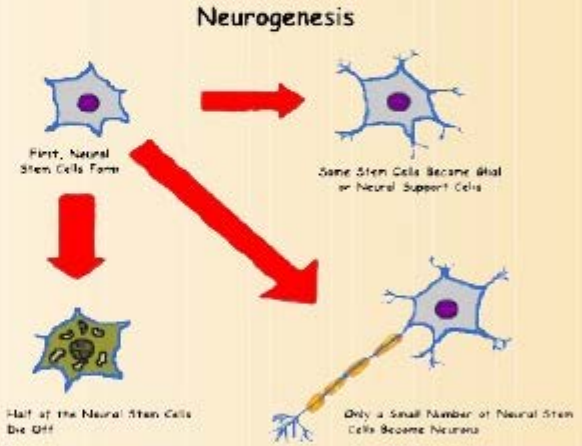
Neurons Develop Axons & Dendrites

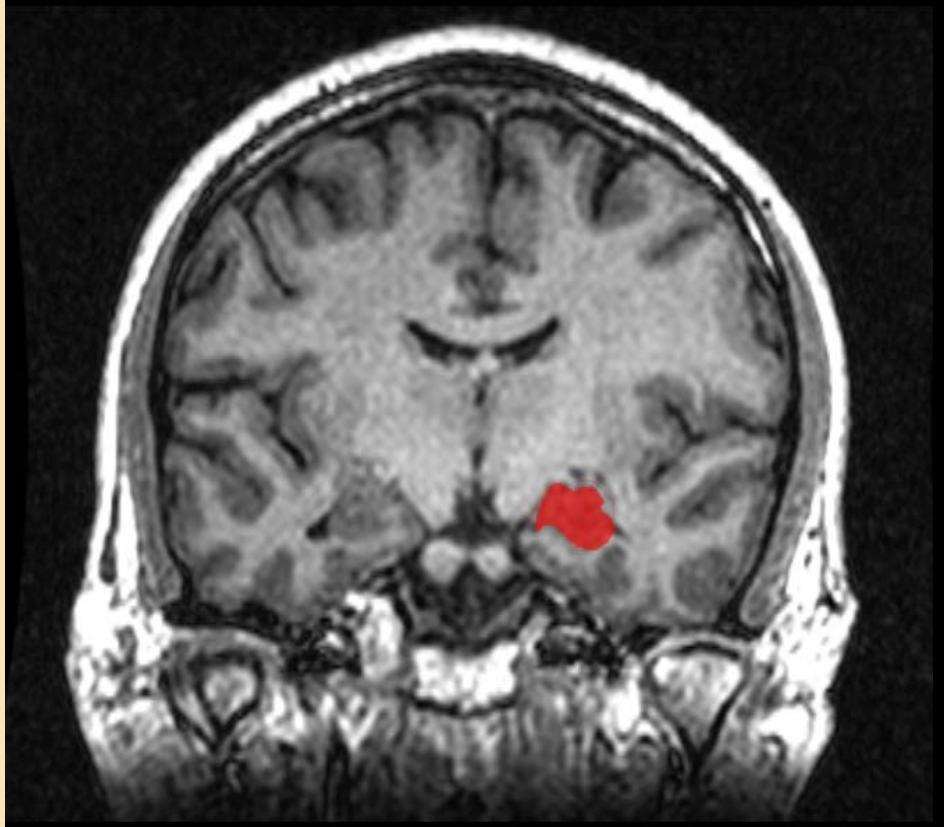
Myelination

Glial Cells Produce Myelin Sheaths Around Axons

Synaptogenesis

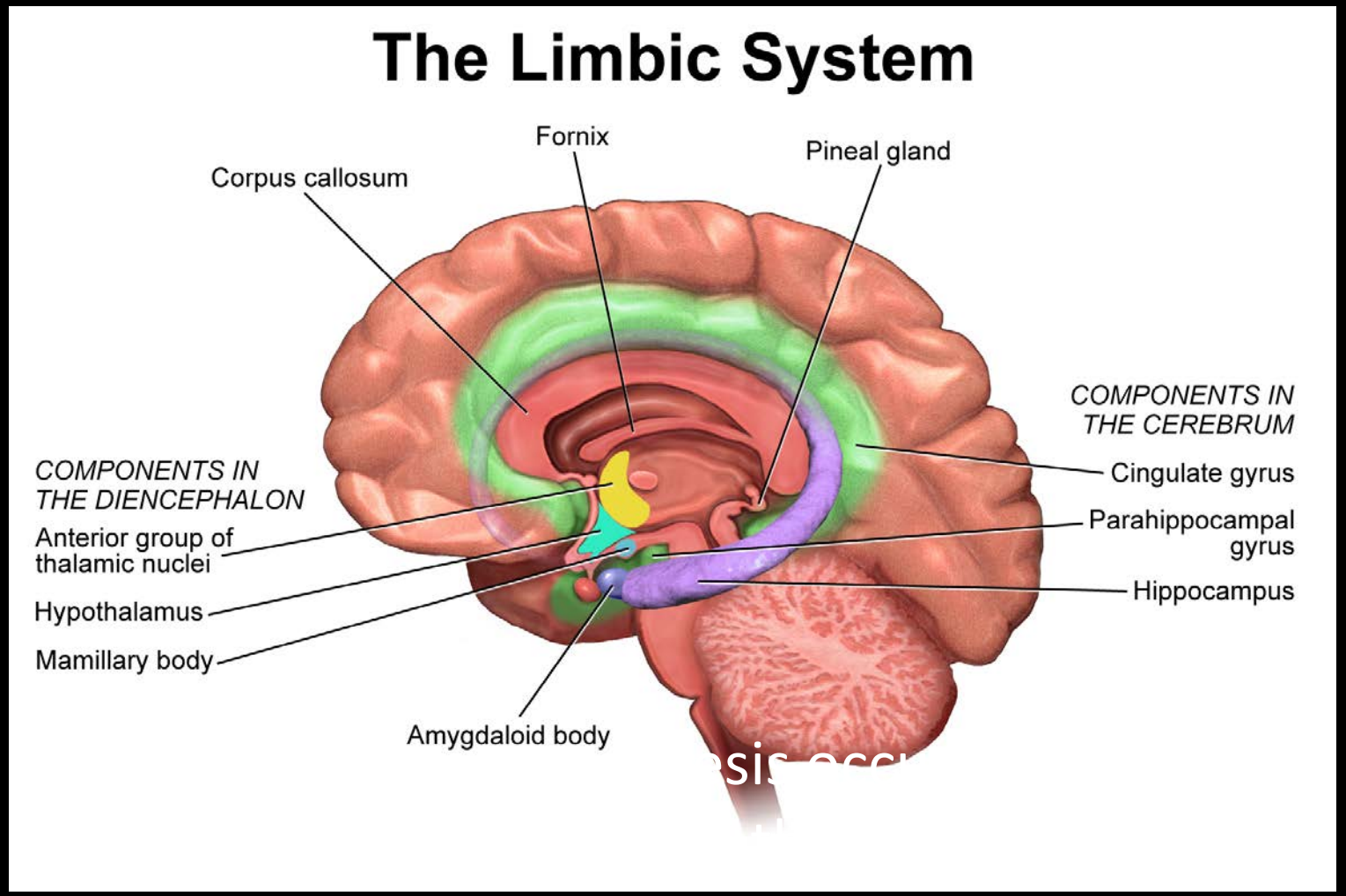
Formation of Synapses





MRI Section of human brain
Showing right section of hippocampus

Neurogenesis in the adult brain occurs in and near the limbic hippocampus.



The structures of the limbic system are involved in motivation, emotion, learning, and memory and pleasure. Humans and other mammals have two hippocampi, one in each side of the brain.

So the team was born.

Large Hadron Collider
Intersecting storage ring particle accelerator.

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NATIONAL LABORATORY

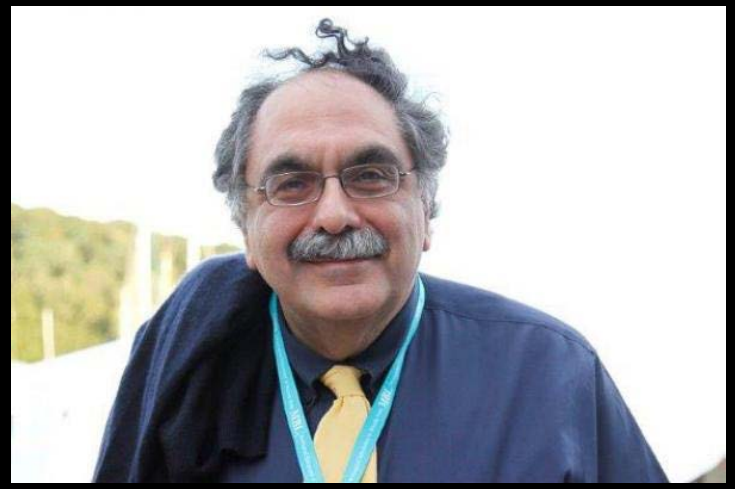
Cold Spring Harbor Laboratory

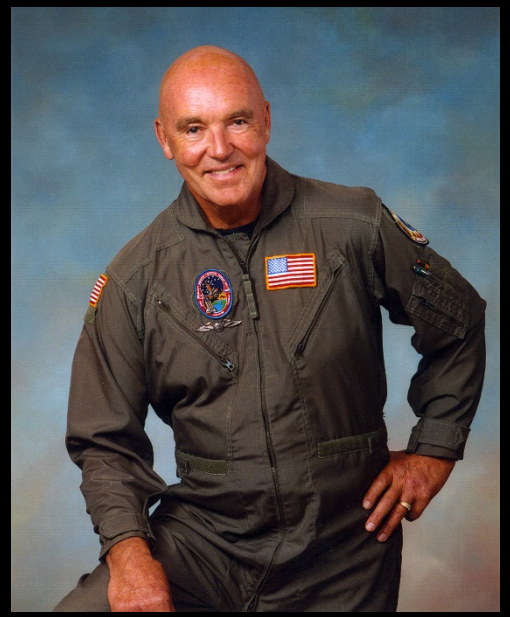
Brookhaven National Laboratory

Neuroscience Associates Inc.

NASA Kennedy Space Center

McKnight Brain Institute of the University of Florida





Juan M. Encinas, Marcelo E. Vazquez, Robert C. Switzer, Dennis W. Chamberland, Harry Nick, Howard G. Levine, Philip J. Scarpa, Grigori Enikolopov, and Dennis A. Steindler

From the beginning … and please speak English.
What is cosmic radiation?

"**Cosmic rays** are high-energy radiation particles, mainly originating outside the Solar System. **Composed primarily of high-energy protons and atomic nuclei**, they are of mysterious origin. Data from the *Fermi* space telescope (2013) has been interpreted as evidence that **a significant fraction of primary cosmic rays originate from the supernovae of massive stars**. However, this is not thought to be their only source. Active galactic nuclei probably also produce cosmic rays.

Why should we worry?

The energies of the most energetic ultra-high-energy cosmic rays have been observed to approach 3×10^{20} eV, about 40 million times the energy of particles accelerated by the Large Hadron Collider.

Most cosmic rays, however, do not have such extreme energies; the energy distribution of cosmic rays peaks at 0.3 gigaelectronvolts. ($300 \text{ X}10^{6}$ eV)

A standard medical x-ray energy by comparison: range 100 eV to 100 keV

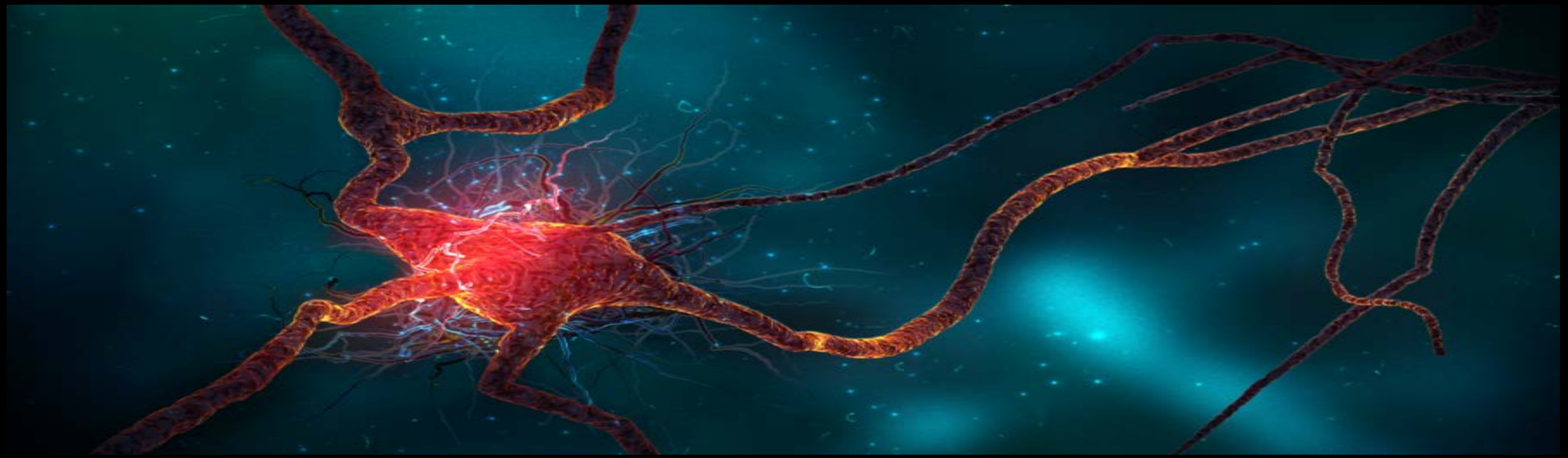
How massive is it?

Comparing Sizes

BB

Basketball

1,832.15267 X
more massive

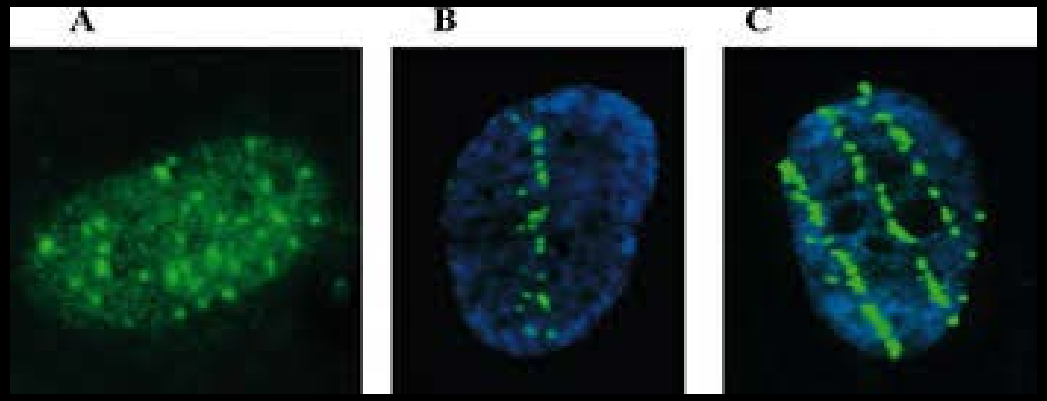


Cosmic Radiation is a stripped down atomic nuclei – usually a proton.

The atomic mass of a typical cosmic particle is

1,832.15267 times that of a gamma.

Both particles are traveling at >90% light speed.

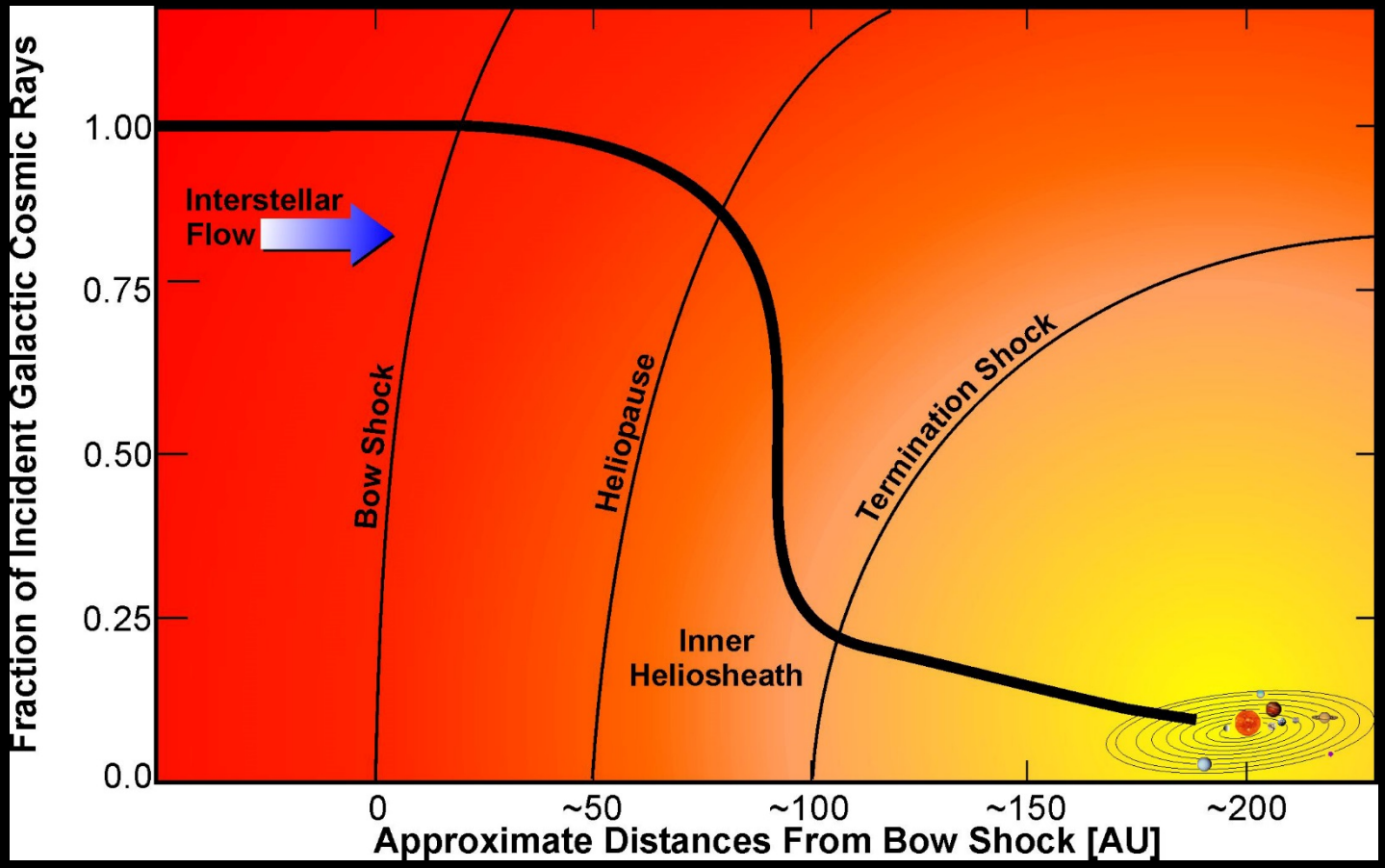


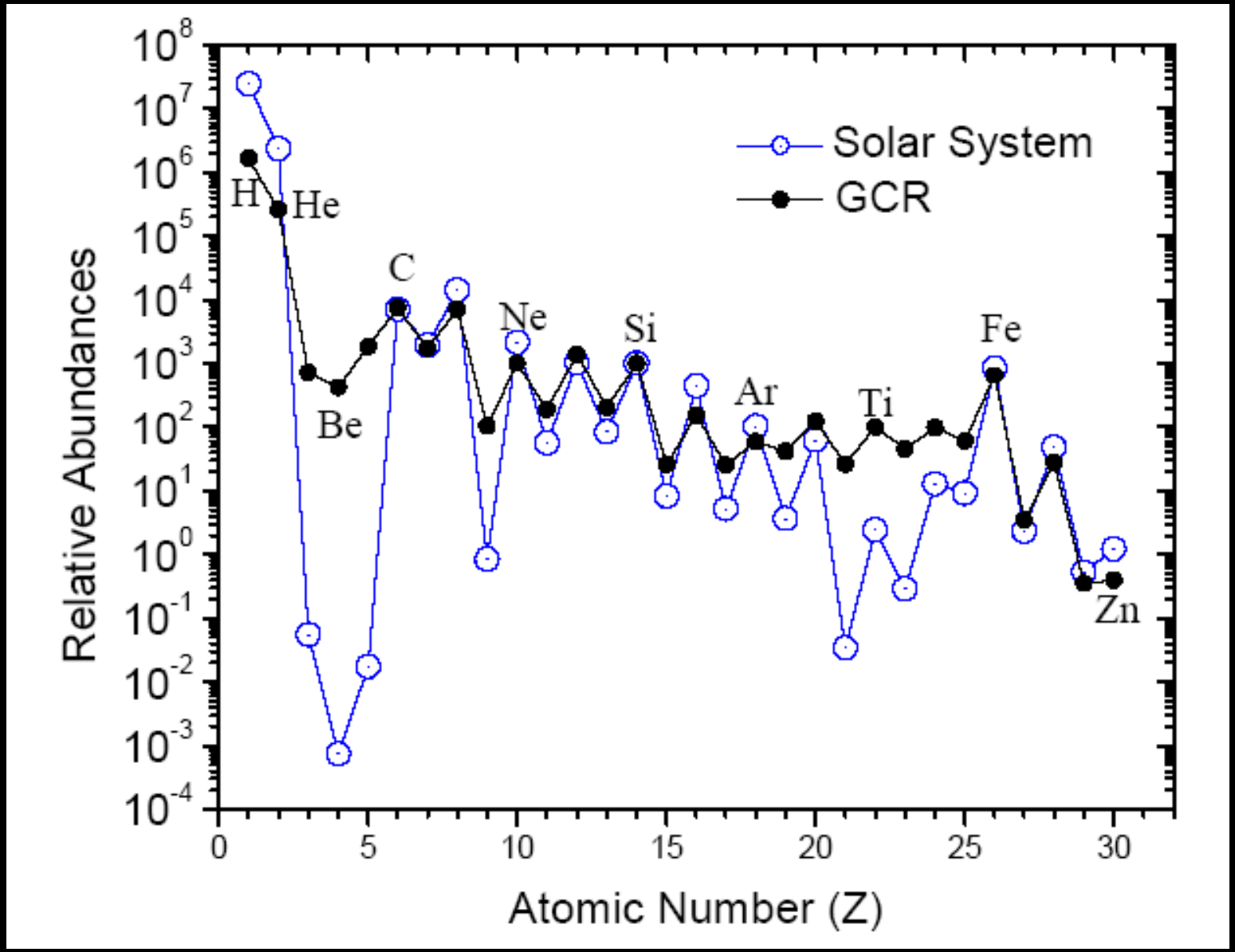
The potential damage to tissue is quantified by Linear Energy Transfer - LET

Cosmic Radiation on and Off Planet

Two Shields Sources – Solar and Terrestrial

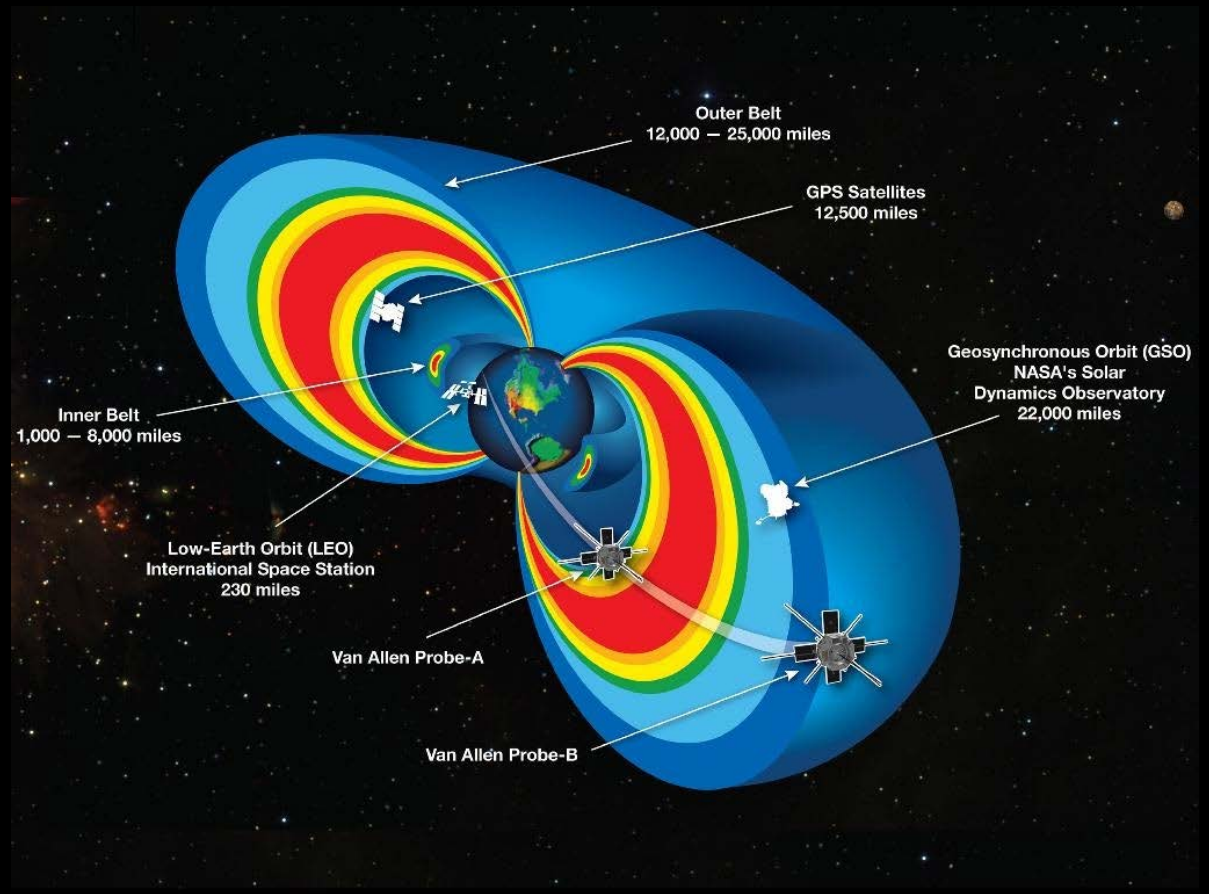
The Solar Shield



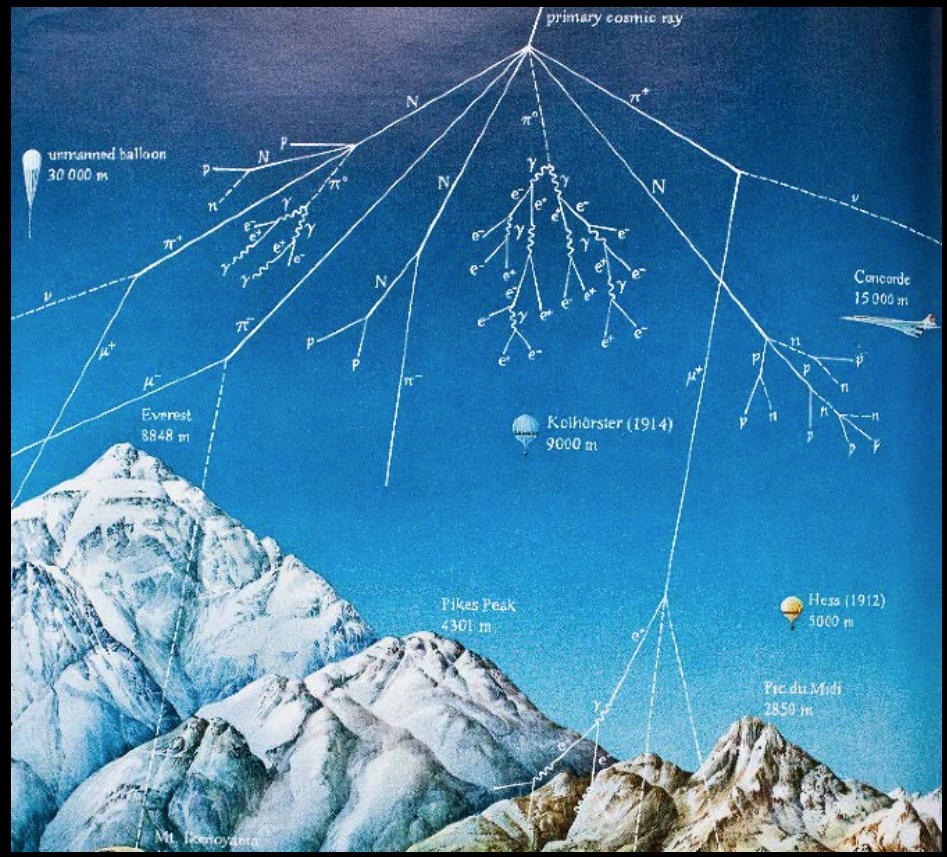


Cosmic Ray Abundance

The Terrestrial Shields



Magnetic

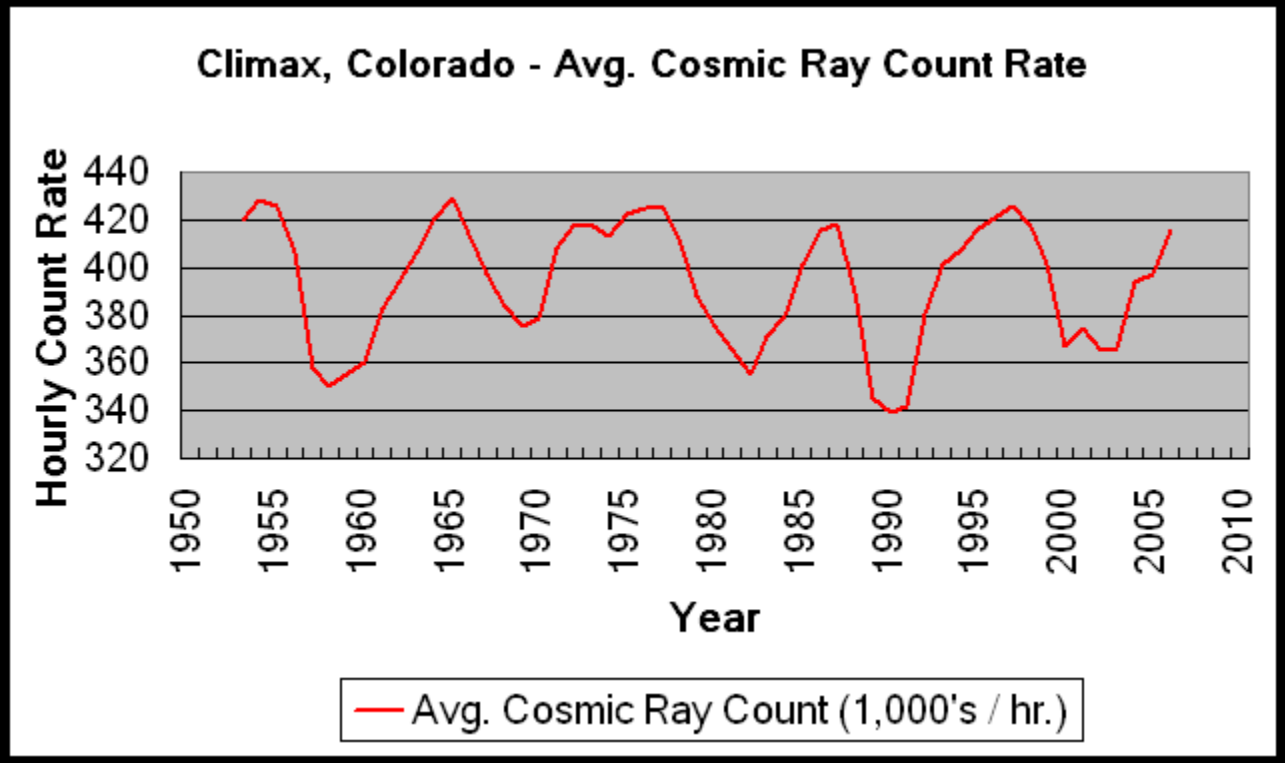


Atmospheric

But it’s Not Perfect!

Cloud Chambers Track Cosmic Ray Tracks on Earth

How Many Actually Cosmic Particles Reach the Surface?
Data from Climax, Colorado – 11,360 feet



* Note that the cycles match the solar activity cycle.

So then how do we experiment with cosmic radiation on earth under the shield?

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We make our own!
Nuclei of Iron
- 1 GeV/n Fe ions

The Animal Model

Nestin-CFPnuc reporter mouse line

We have recently developed a novel reporter mouse line designed to help identify neural stem and progenitor cells in the adult nervous system and accurately quantify changes in selected classes of precursor cells induced by pro- or anti-neurogenic stimuli.

In our model, **only** the healthy limbic neural cells fluoresced for investigation.

This enabled quantification by pifluorescence/bright field microscope equipped with a digital camera and the corresponding software

Statistical analysis (Student's t-test) and graph plotting was performed using Sigmaplot 8.0

Experimental design:

Two-month old nestin-CFPnuc mice were irradiated head alone under anesthesia (isofluorane) at the NASA Space Radiation Laboratory, Upton New York.

Mice were placed under the supercollider beam - exposed to 0 or 100 cGy of 1 GeV/n Fe ions (LET: 148 keVp/µm; these doses correspond to an average fluence of 1–3 hits per cell)

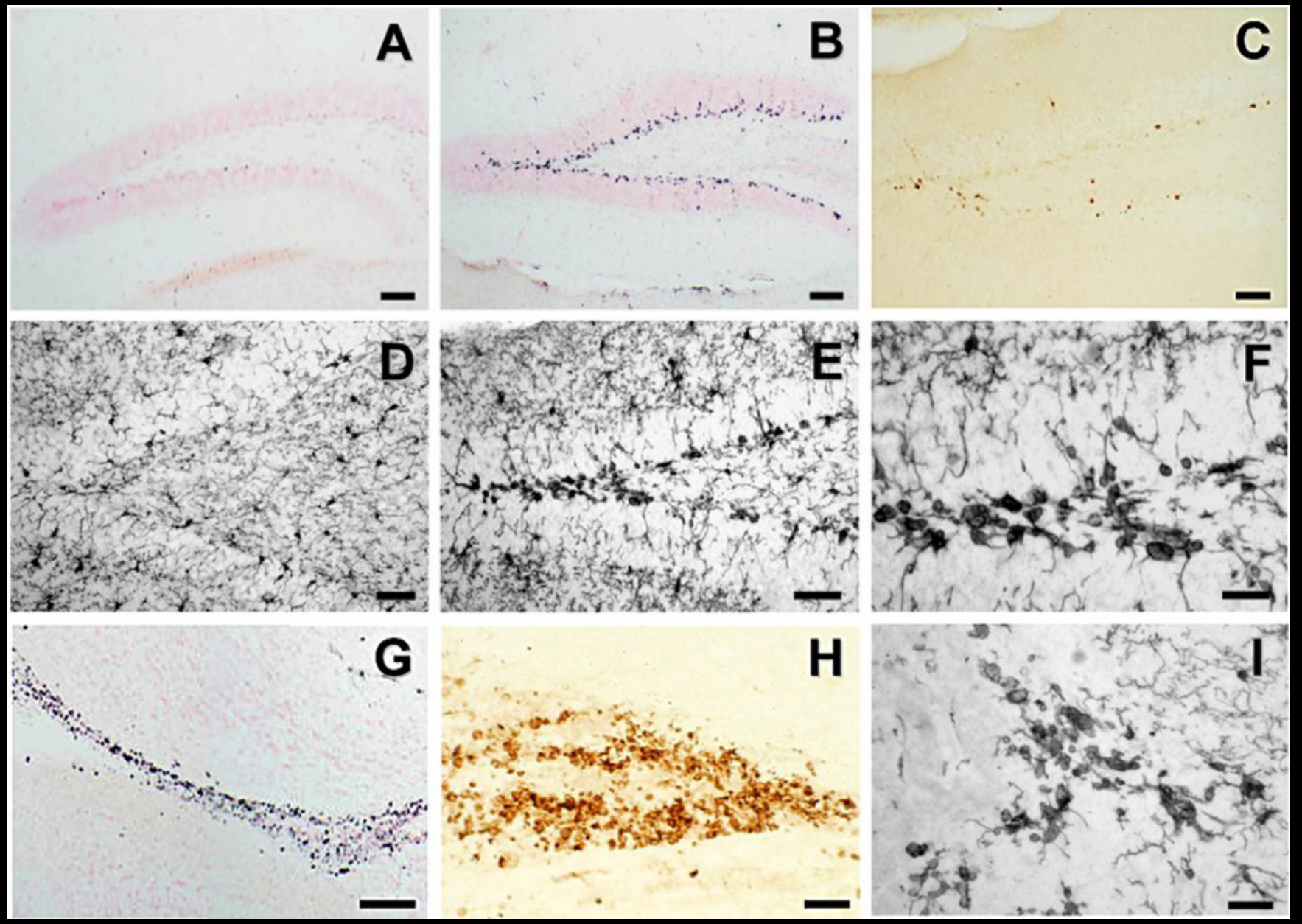
All animal activities were reviewed by the Brookhaven and Kennedy Space Center Animal Use Committee in pursuant to the requirements of the Animal Welfare Act of 1966.

The results were surprising:

1. All previous data came from using terrestrial gamma ray medical sources. The hypothesis was that the models would respond similarly. They did not.

2. "^{56}Fe radiation drastically decreased the number of dividing cells and neural progenitor (stem) cells in the DG (hippocampus), having the greatest effect on the quiescent population of neural progenitors (stem cells).

*Published in the Journal of Experimental Neurology – Feb. 24, 2012
"**Quiescent adult neural stem cells are exceptionally sensitive to cosmic radiation**"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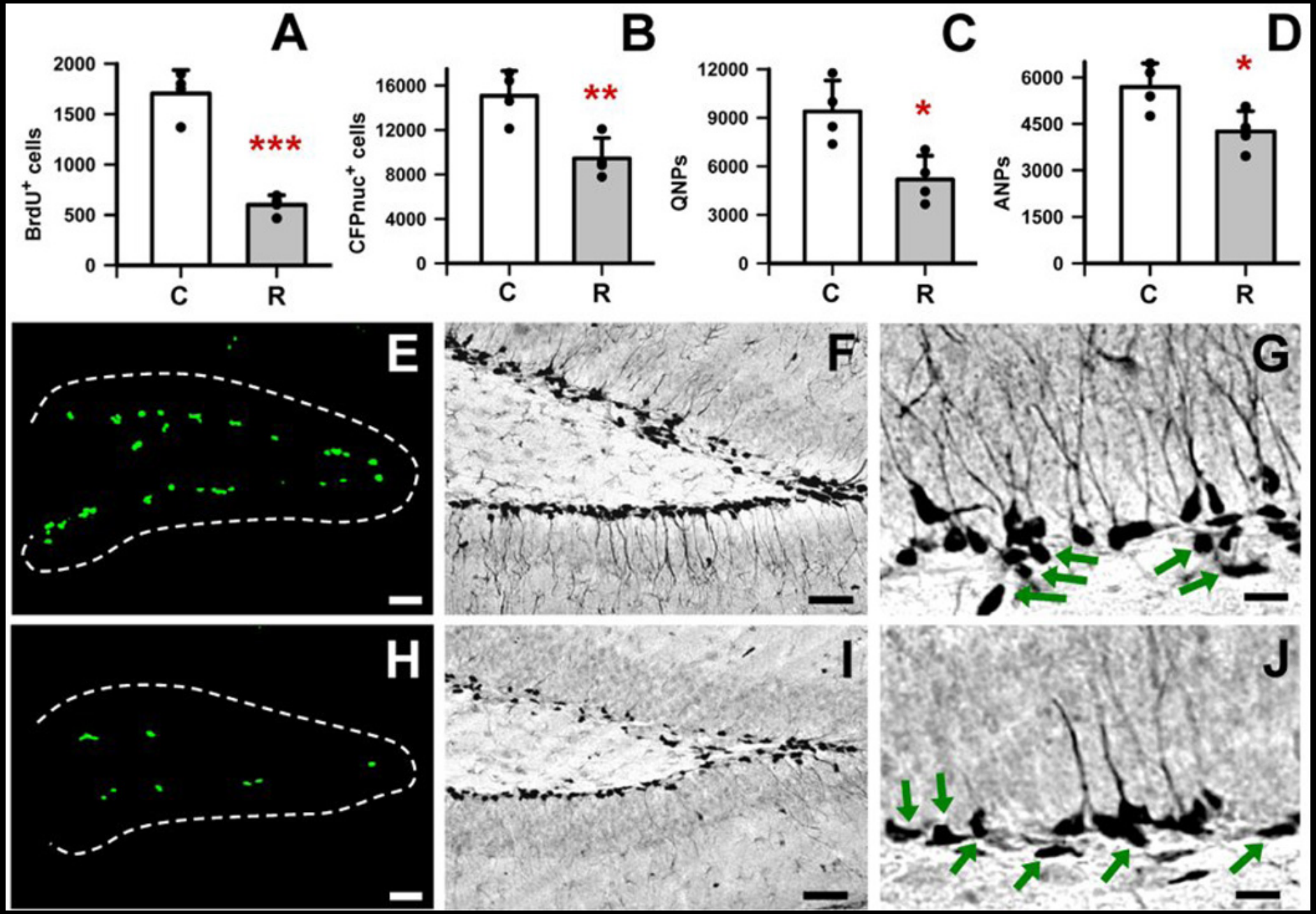
A
BrdU+ cells
2000
1500
1000
500
0
***
C
R
B
CFPnuc+ cells
16000
12000
8000
4000
0
**
C
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C
QNPs
12000
9000
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3. Unexpectedly, our results demonstrate that in the hippocampus, the quiescent stem-like cells, rather than their rapidly dividing progeny, constitute the most vulnerable cell population. This finding underscores a previously unappreciated risk to neural stem cells and raises concerns about the risks facing astronauts on long duration space missions. (The process seriously disrupted neurogenesis.)

4. The carcinogenic and neurodegenerative risks of space radiation have been widely recognized; however, as with therapeutic radiation in the hospital setting, the association of impaired neurogenesis with diminished cognitive and emotional function in astronauts has not been sufficiently appreciated.

New Questions – New Concerns:

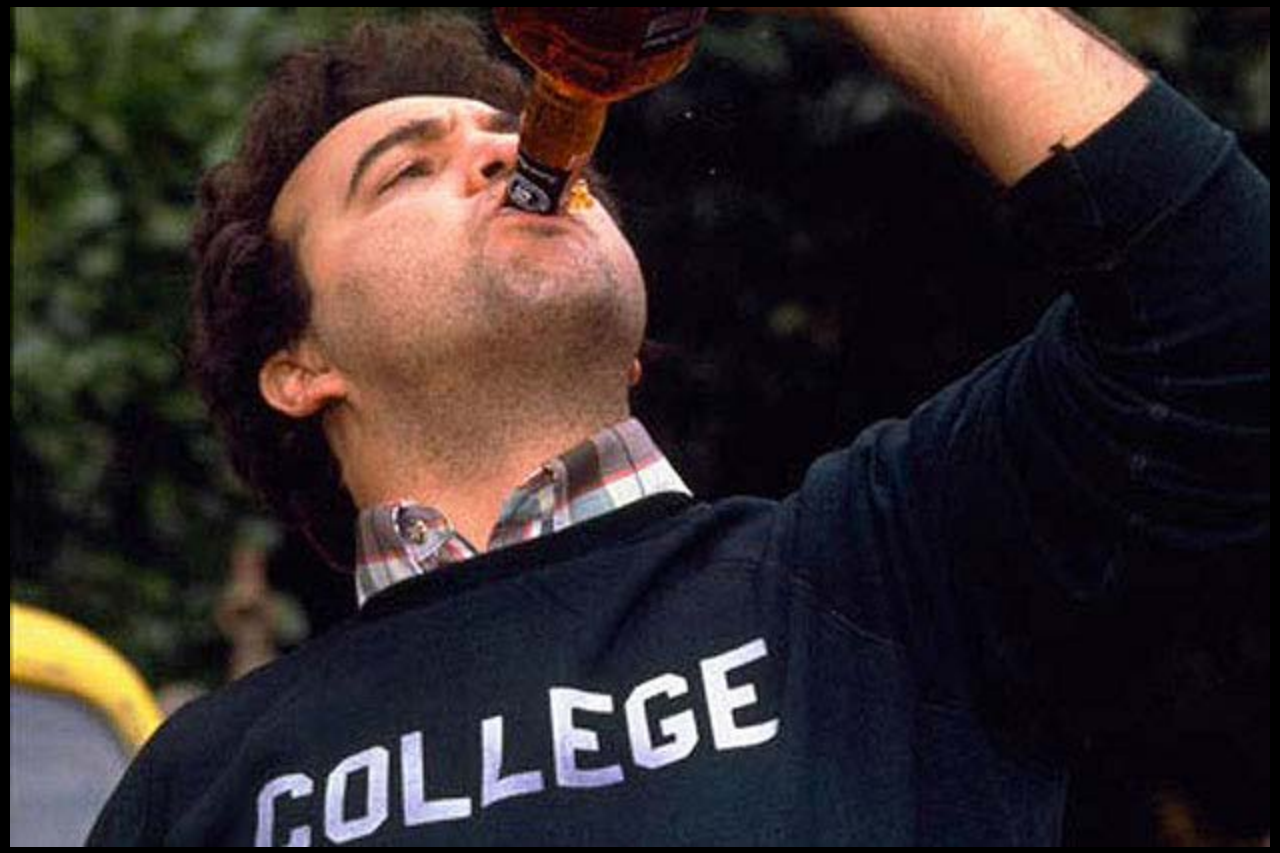
> What would the effect be if the same dose were spread out over 300 days? Could the brain repair the damage fast enough?

- Answer: unknown. There is no way to get that data with our current limitations.

> How can we obtain a better living model since using a particle collider for 300 days is not practical or even feasible?

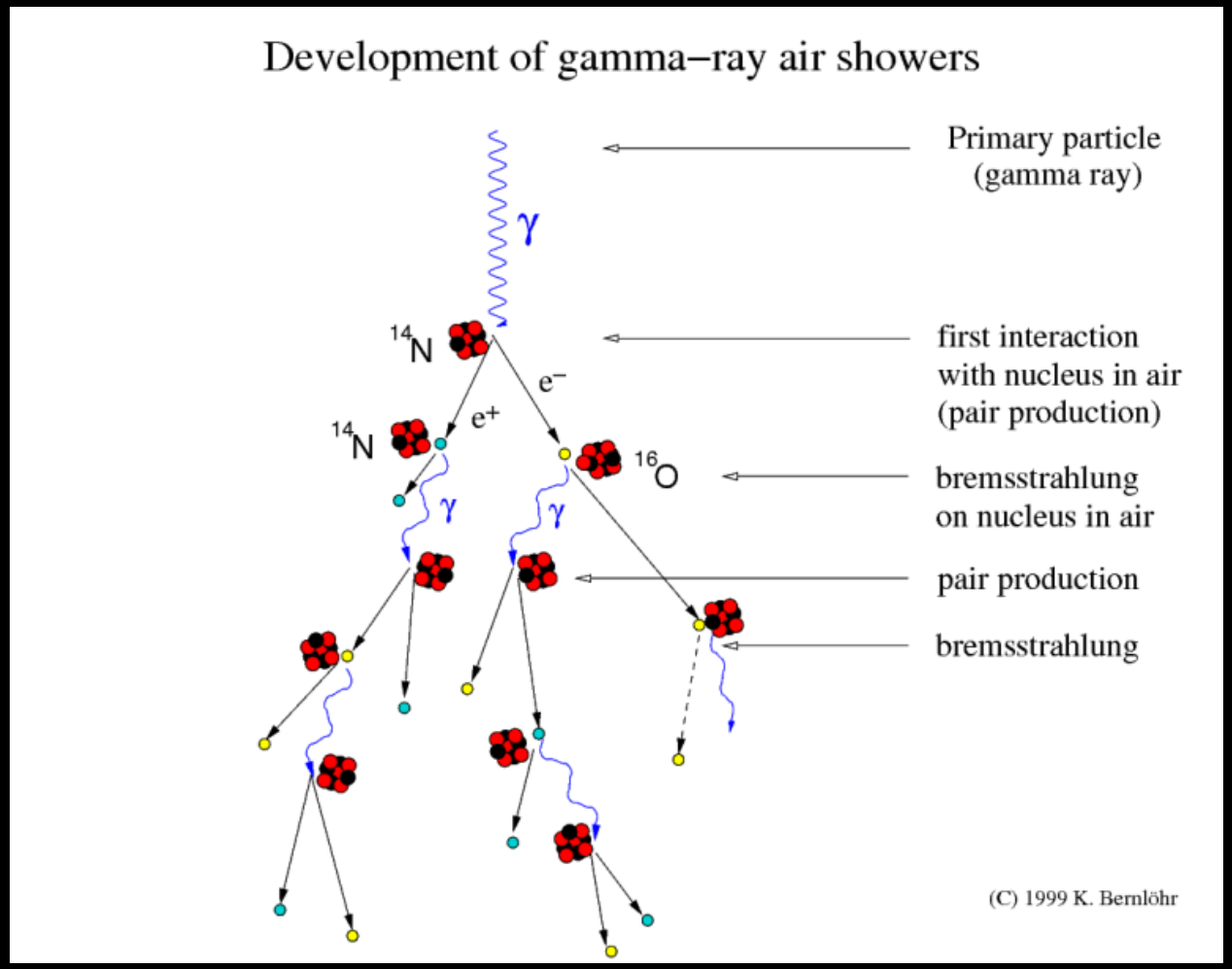
- The author suggests dedicated animal model payloads launched to Lagrange Point 5 (L5) for a suite of 100, 200, 300 and 500 day missions. This is the only way to reliably get the data other than taking a chance with committing human astronauts to Mars.

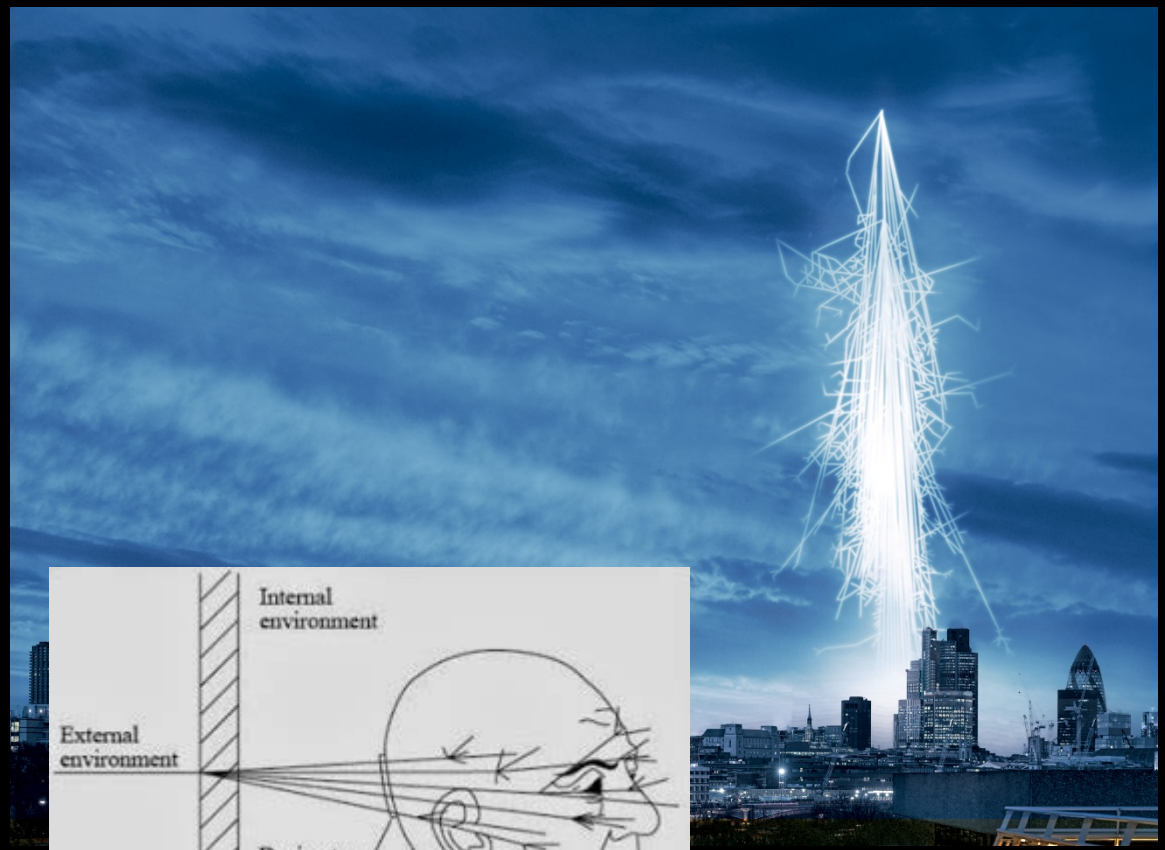
Suggested Cosmic Ray Countermeasures



Appropriate Preflight Premedication

Shielding – and Shielding Problems





Adequate Shielding on Mars - Moon

- The Mars rover Curiosity has allowed us to finally calculate an average dose over the 180-day journey. It is approximately 300 mSv, the equivalent of 24 CAT scans. In just getting to Mars, an explorer would be exposed to more than 15 times an annual radiation limit for a worker in a nuclear power plant.

- The Mars One habitat will be covered by a necessary layer of soil that provides shielding even against galactic cosmic rays. **Sixteen feet (5 meters) of Martian soil provides the same protection as the Earth's atmosphere**. The Mars One habitat can support a soil layer 36 feet (11 m) thick. If the settlers spend, on average, **two hours per day outside the habitat, their individual exposure adds up to 22 mSv per year.**

Introducing

RINC

Radiation Induced Neurogenic Changes

Introduced by Steindler – Chamberland in January 2016
to avoid confusion between diagnostic etiology of:

“Nonspecific Dementia”

and

“Alzheimer's Disease”

Conclusion:

When you have a science question –

ASK THIS GUY

Conclusion:

When you have a science question –

ASK THIS GUY

DEFINITELY NOT THIS GUY!

Questions?