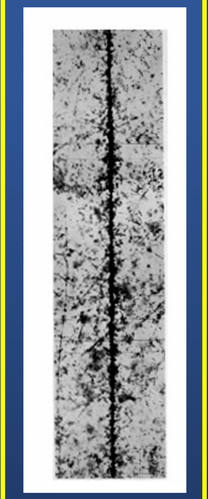
Space Science 101 – Space Radiation Environment



Schaefer & Sullivan, 1976

Why are Ground Radiation Studies Important to Space Research?

- Radiation is considered one of the most critically important risks to astronaut health for long duration missions beyond low Earth orbit. Adequate shielding technologies for long-term missions currently do not exist.
- Long-term consequences of exposure to the space radiation environment are mostly unknown.
- Because this work is not possible with human subjects conducting statistically significant analyses are a limiting factor. Ground studies allow large sample sizes using animal models.
- Deep space radiation analogs, such as those at the NASA Space Radiation Laboratory at the Brookhaven National Laboratory, greatly expand the science that can be conducted.

Why is Space Research Important to Ground Radiation Studies?

- When compared to ground based radiation studies, space will help differentiate between radiation and microgravity effects.
- Enables identifying synergistic mechanisms and processes that govern and/or respond to radiation & gravity.
- Long-duration, low dose rate exposures to high energy particle space radiation is currently not feasible on Earth.

Why is Space Radiation Research is Important to Earth?

- Space radiation-associated physiological effects are similar to those associated with human disease and aging (e.g. oxidative stress, inflammation).
- Information gathered in space is comparable to similar situations on the ground such as radiological disaster (e.g. Fukushima), attack (e.g. dirty bomb) or medical diagnostics (e.g. medical x-rays, CT scans, etc.).
- Data from space radiation studies may lead to new biomarkers applicable to first responders and medical diagnostics, as well as identifying new targets for biomedical and pharmaceutical countermeasures.

Important Questions – What do we need to know about space radiation to engage in long duration space exploration?

Central Nervous System - How does radiation impact the CNS (e.g. behavior, cognitive function, neurodegenerative disease)?

Retina - What role does radiation play in spaceflight-induced deficits in vision?

Heart & Vasculature - Does space radiation have a significant impact on cardiovascular health?

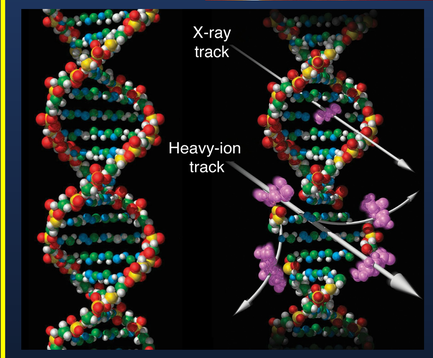
Microbiomes - How does chronic exposure to the space radiation environment impact astronaut microbiome and ISS microbe ecology?

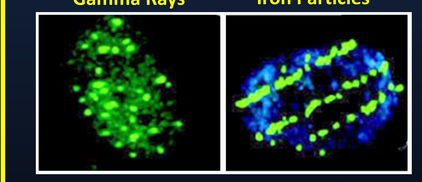
Communication between Physiological Systems - How does radiation impact sympathetic nervous system control of other physiological systems (e.g. immune, cardiopulmonary, musculoskeletal)? What happens to the radiation environment at the interface between hard and soft tissues (e.g. bone-bone marrow, skull-brain-vasculature, biofilms)?

Synergy with other Space Environment Factors - How does space radiation effects interact with those of microgravity, vibration, high CO_2, circadian rhythm, etc.?

Timing - What are the immediate vs. late effects of radiation?

Energy - How do biological effects differ across different radiation types and energies? How do the biological effects of the space radiation environment differ between low earth orbit and deep space?





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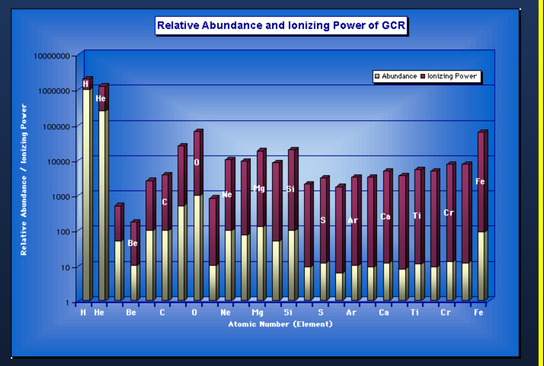
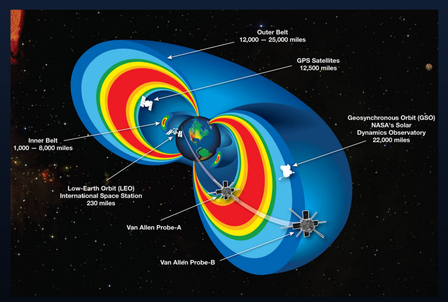
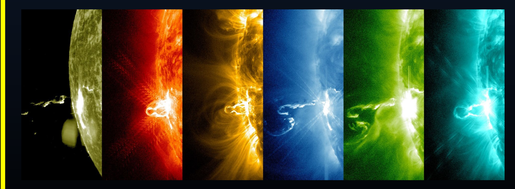
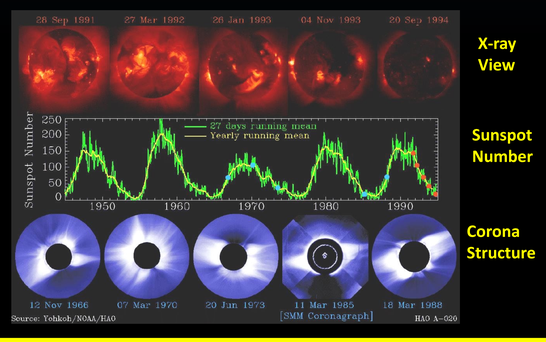
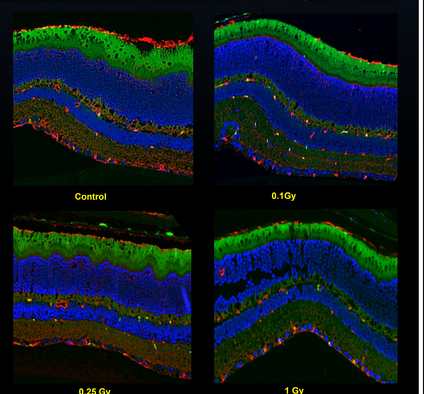






Cyclical Variation of Solar Activity





Mao XM, 2018

Selected Important Answers – What have we learned that could only be revealed in space?

Types of Damage – Radiation-induced damage is not limited to cell death. Many effects are due to functional changes in surviving cells. Furthermore, some changes in function are due to the so-called "by-stander effect" whereby cells not directly hit by radiation also undergo changes.

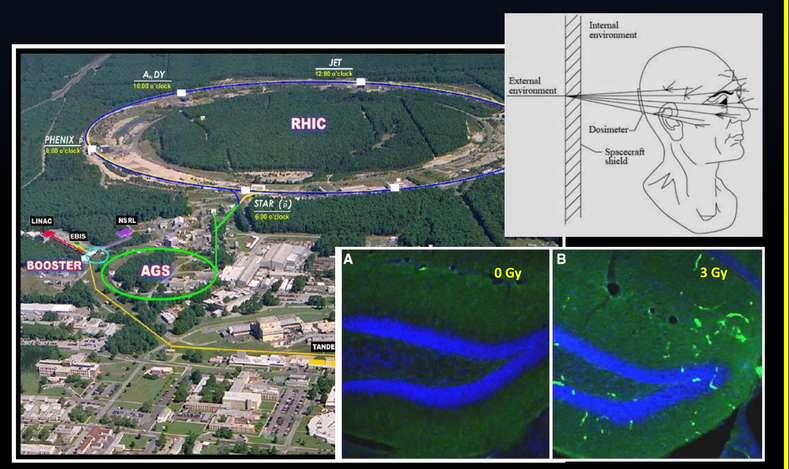
Central Nervous System – Even low doses of high energy particle radiation can have an impact on behavior and cognitive function, including memory and anxiety. At least some of these effects may be progressive over time.

Retina – Radiation is known to have an impact on the vascular integrity of the retina.

Cardiovascular Disease – Although controversial, there is some evidence that the space radiation may have some increased risk for CVD.

Inflammation – Space radiation impacts several measures of immune function. It is known to induce long-term, low levels of oxidative stress and inflammation, which can initiate a cascade of cellular and physiological changes.

Bone – Radiation has been found to have a surprisingly fast and pervasive impact on bone characteristics.



Lipid peroxidation marker 4-HNE at 90 days post irradiation Limoli, 2007

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