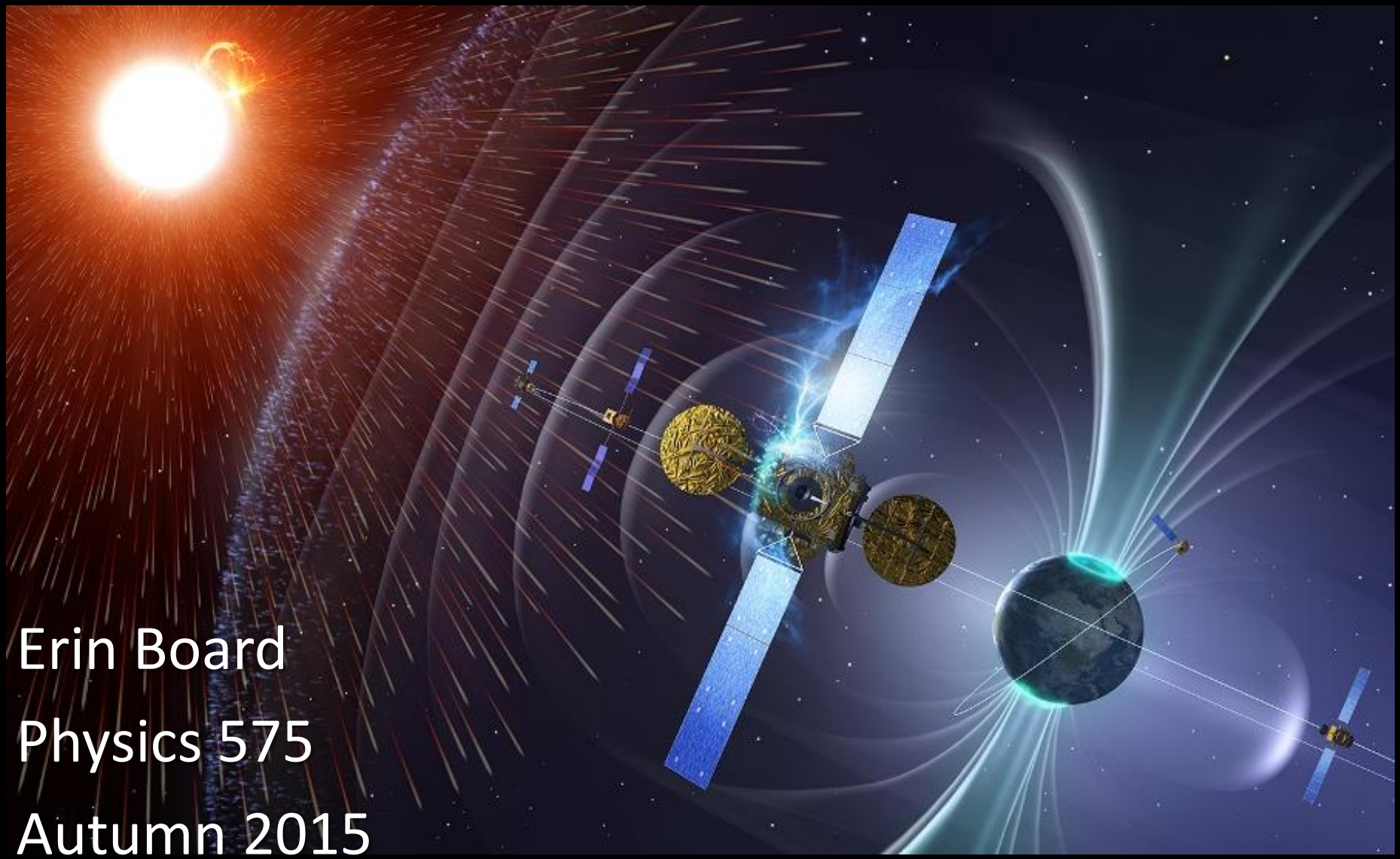
Cosmic Radiation and Shielding



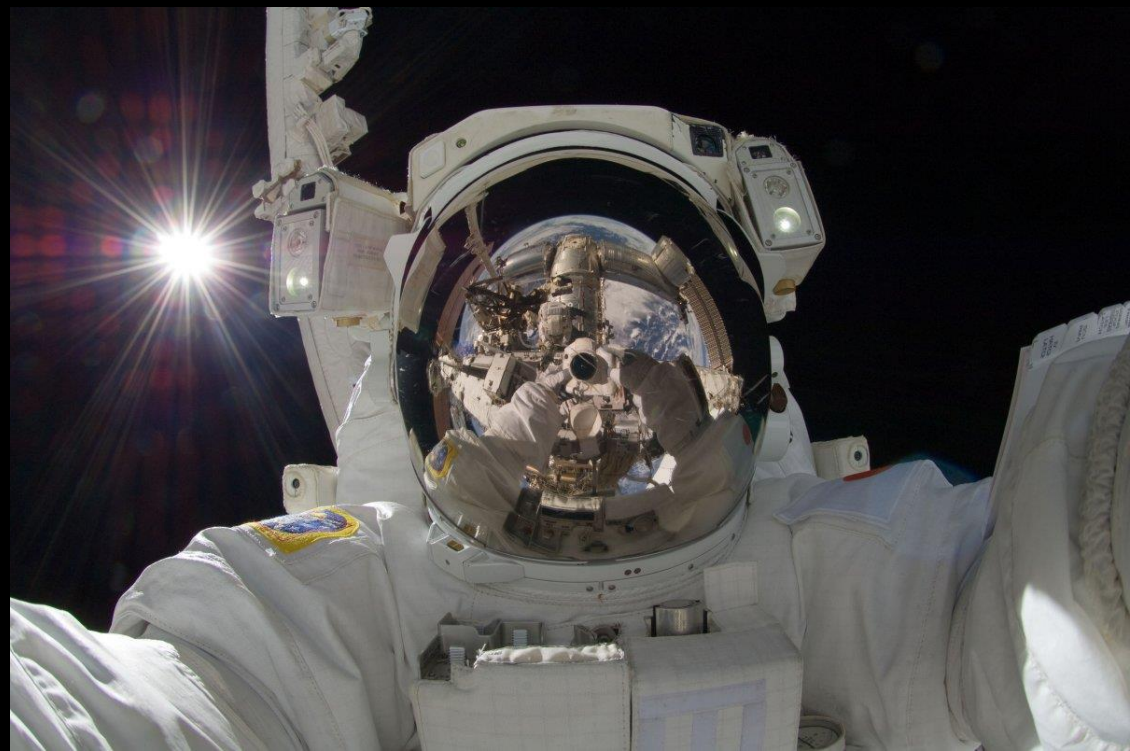
Erin Board

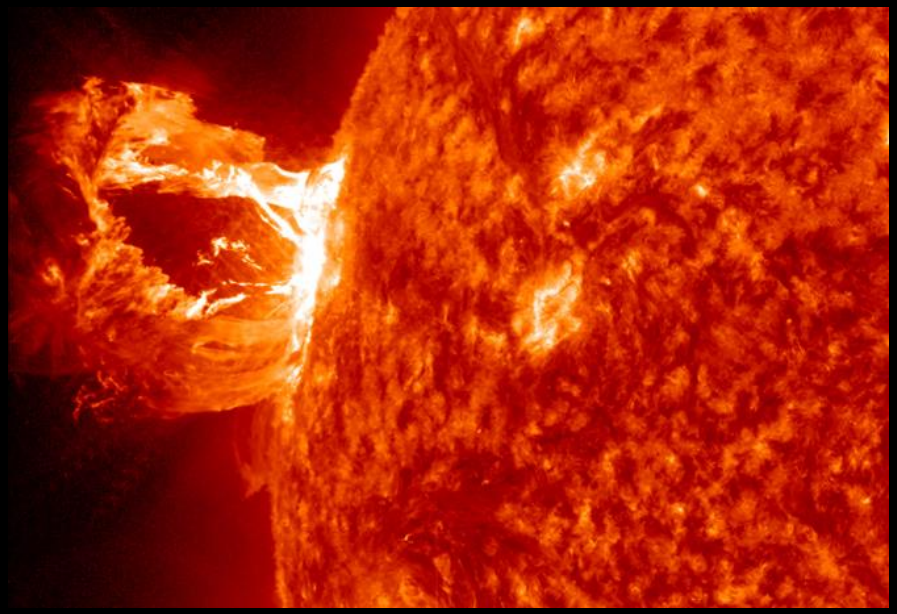
Physics 575

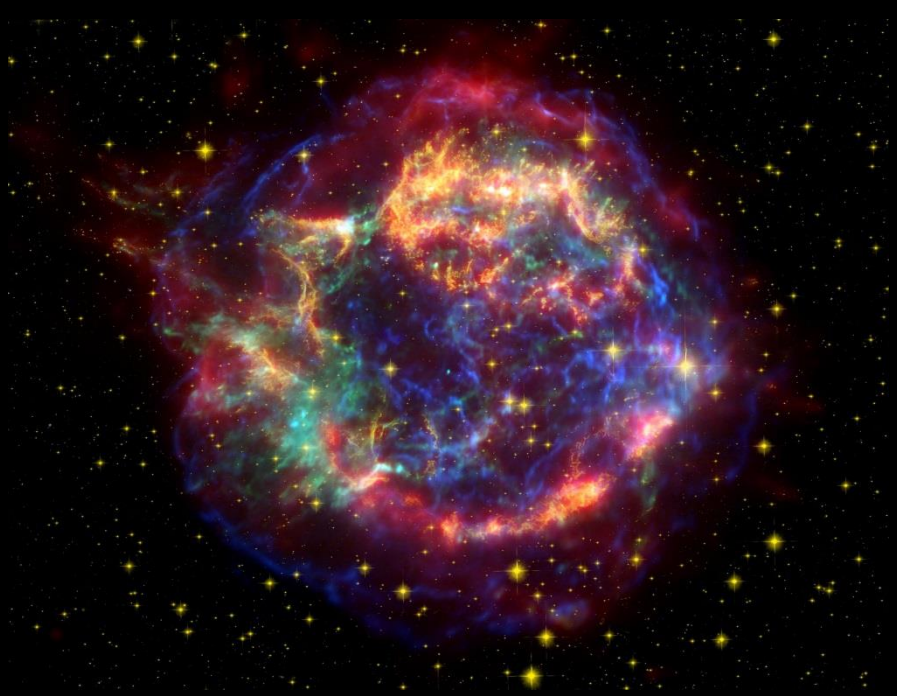
Autumn 2015

Overview

- What is Cosmic Radiation?
- Health Effects
- Detectors in Space
- Shielding
- Questions





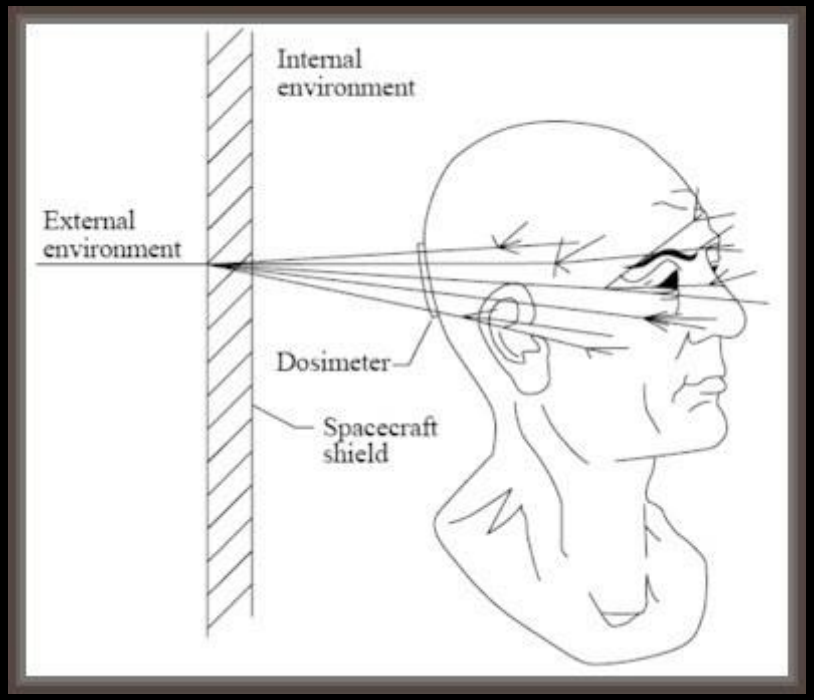


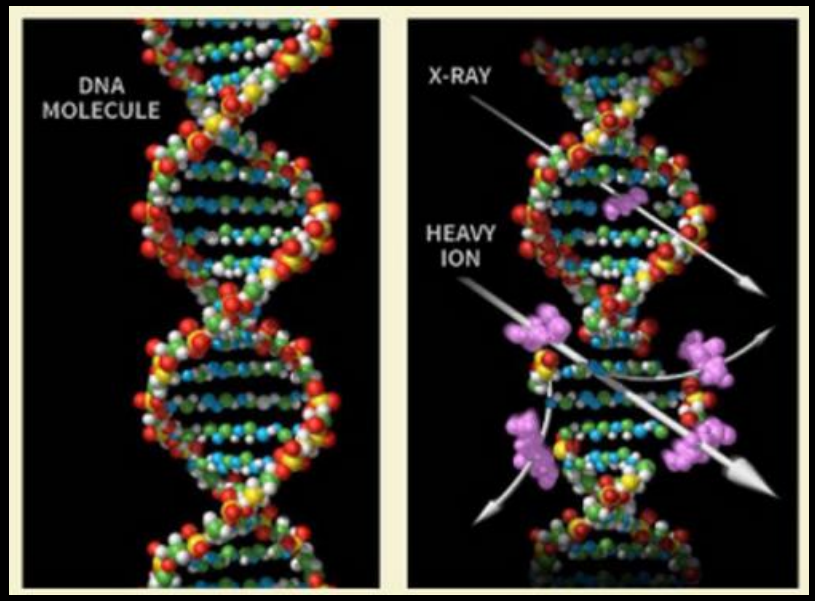
Cosmic Radiation

- High-energy protons and atomic nuclei
- Originate from supernovae and solar events
- Earth’s magnetic field and atmosphere provide shielding
- Inflicts damage on electronics and living organisms

Health Effects

- Astronauts on Apollo mission reported seeing flashes of light
- Sufficient energy to change or break DNA molecules
- Acute: diarrhea, nausea, vomiting, central nervous system damage, death
- Long term: cataracts, cancer, sterility, mutated genes in offspring



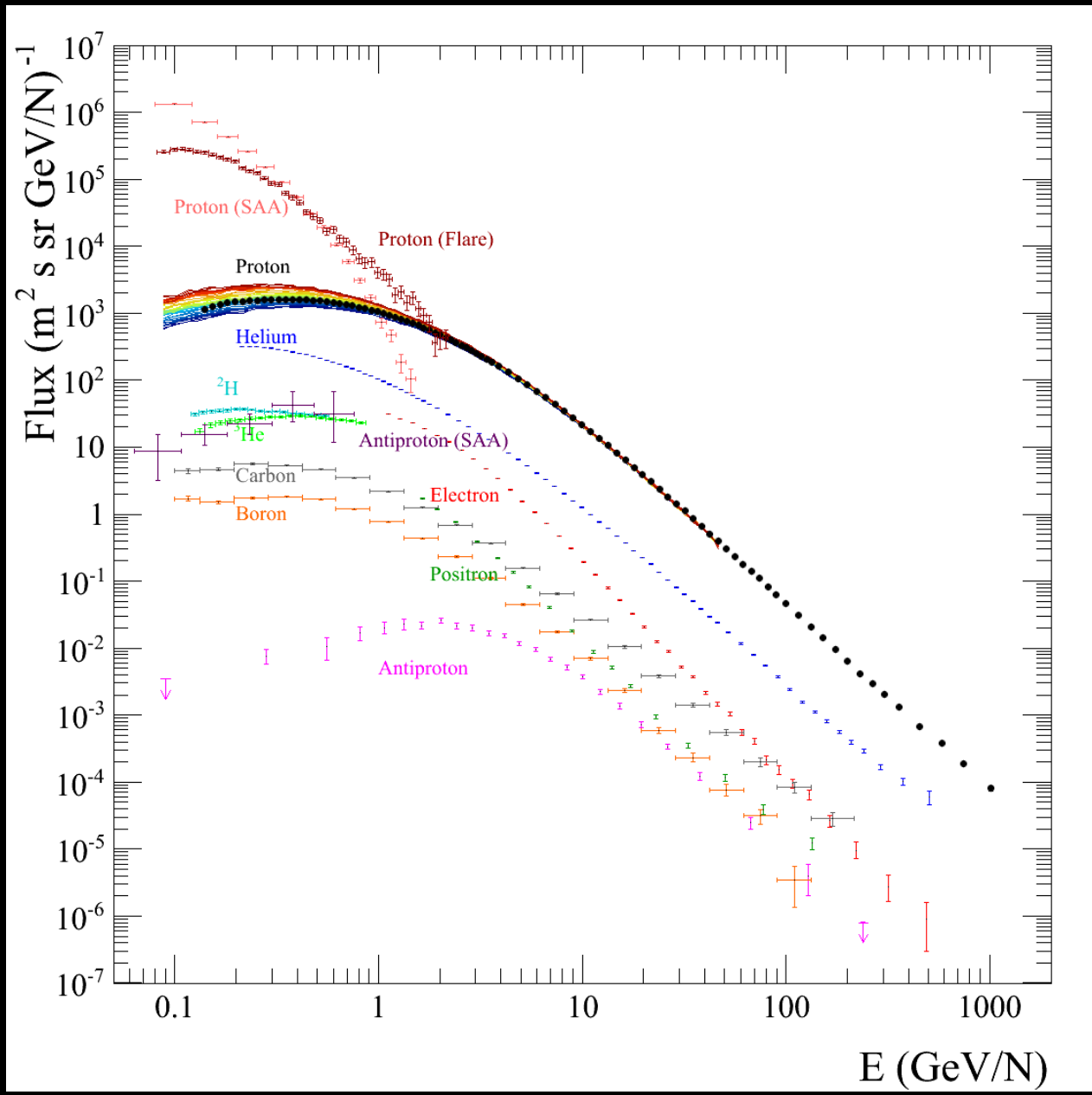


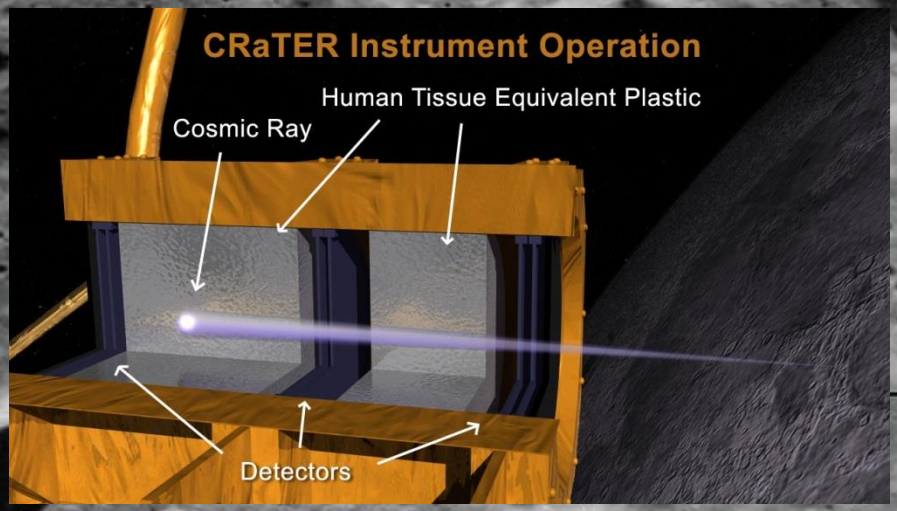
ALTEA

- The Anomalous Long Term Effects in Astronauts' Central Nervous System
- Astronauts on the ISS wore the helmet for 90 minutes during tests
- 6 particle detectors measure the trajectory, energy, and type of particle passing through the brain
- April 2006 – October 2007

PAMELA

- The Payload for Antimatter Matter Exploration and Light-nuclei Astrophysics
- Permanent magnet spectrometer
- High precision and sensitivity
- On board of a Russian satellite launched in 2006
- Circular orbit at 570 km (354 miles)



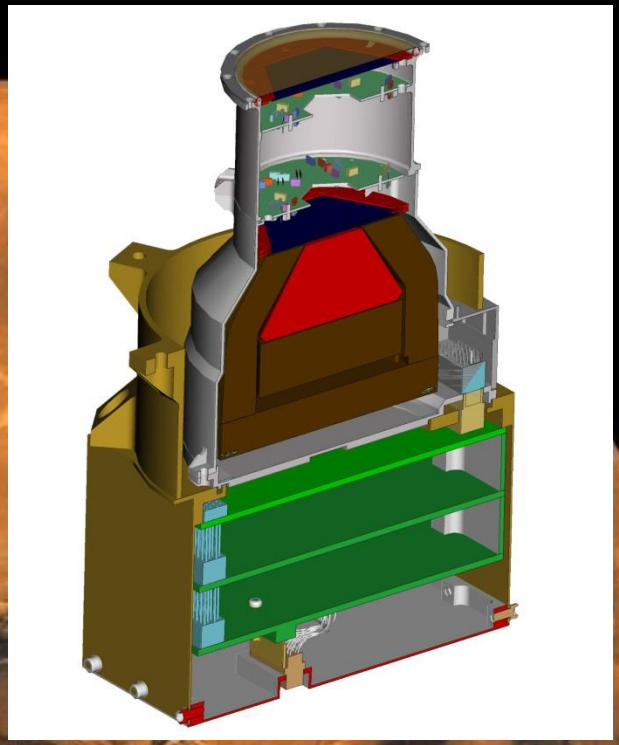


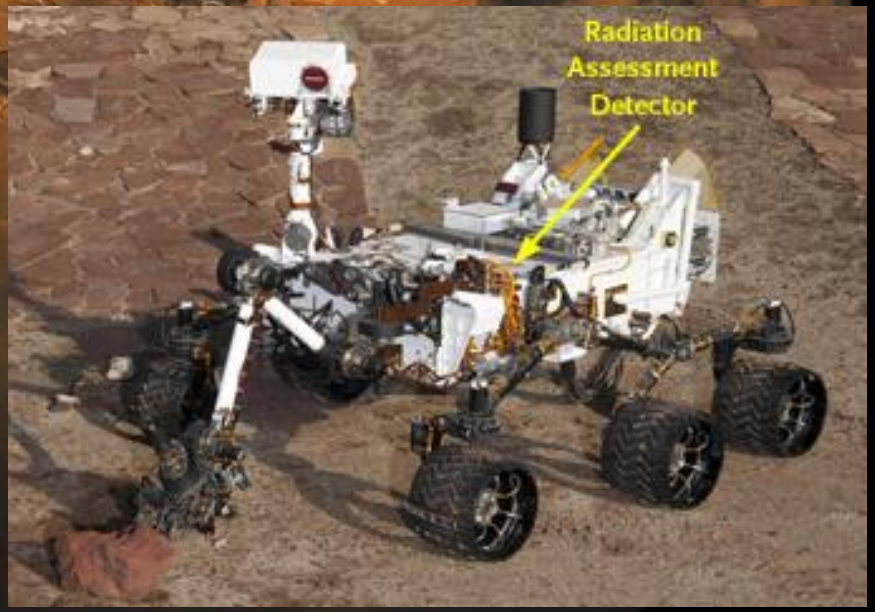
LRO

- The Lunar Reconnaissance Orbiter carries 7 different instruments
- The Cosmic Ray Telescope for the Effects of Radiation (CRaTER) characterizes the lunar radiation environment and biological impacts
- Tests models of radiation effects and shielding
- Launched in June of 2009
- LRO orbits the Moon at 50km (31 miles)

RAD

- NASA's Curiosity rover is equipped with a Radiation Assessment Detector
- Preparation for human exploration
- Measures and identifies all high-energy radiation at the surface of Mars
- Uses a stack of silicon detectors and a crystal of cesium iodide
- Small, lightweight, and energy efficient
- Launched November of 2011
- Landed August of 2012





Results from RAD

RAD Measurement	Mars Surface	MSL Cruise	Units
Charged Particle Flux (A * B)	0.64 ± 0.06	1.43 ± 0.03	$cm^{-2}\ s^{-1}\ sr^{-1}$
Fluence Rate (B)	1.84 ± 0.34	3.87 ± 0.34	$cm^{-2}\ s^{-1}$
Dose Rate (Tissue-like) (E detector)	0.21 ± 0.04	0.48 ± 0.08	mGy/day
Avg. Quality Factor <Q>	3.05 ± 0.26	3.82 ± 0.30	(dimensionless)
Dose Equivalent Rate	**0.64 ± 0.12**	**1.84 ± 0.30**	**mSv/day**
Total Mission Dose Equivalent (NASA Design Reference Mission, DRM)	320 ± 50 (500 days)	662 ± 108 (2x180 days)	mSv

Depth below Surface	Effective Shielding mass (g/cm^2)	GCR Dose Rate (mGy/yr)	GCR Dose Equiv. Rate (mSv/yr)
Mars Surface (RAD)	0	76	232
-10 cm	28	96	295
-1 m	280	36.4	81
-2 m	560	8.7	15
-3 m	840	1.8	2.9

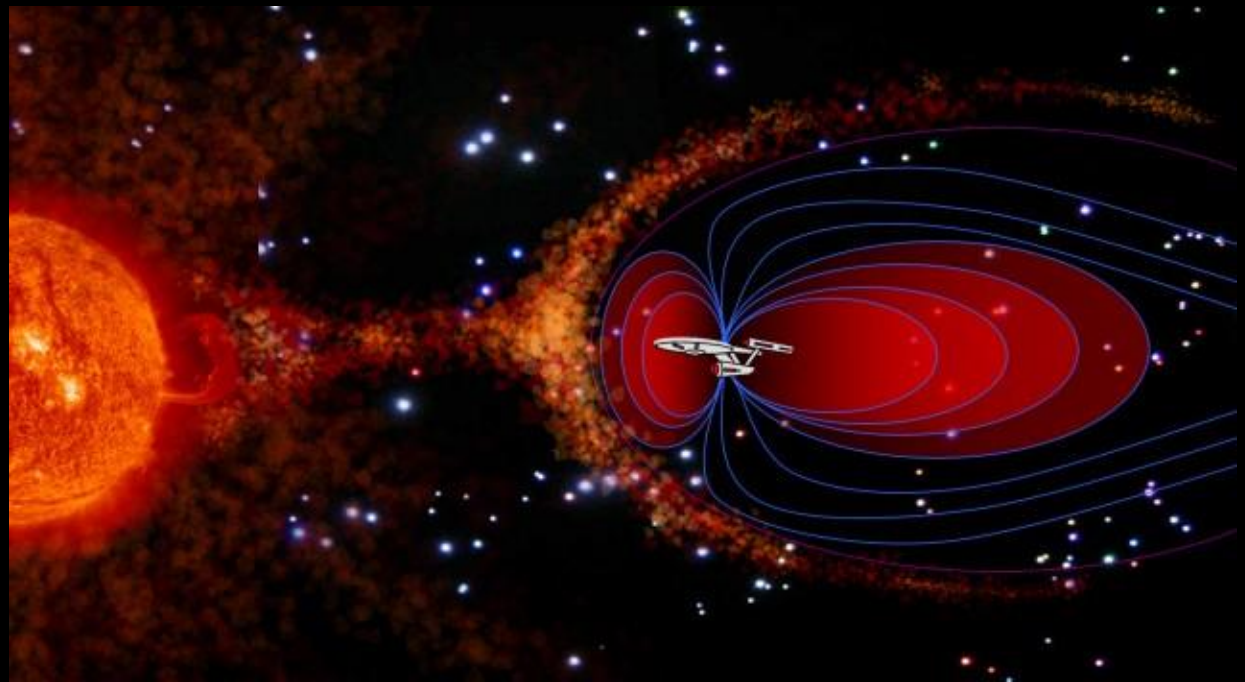
Shielding

Passive

- Use a sufficient amount of material to absorb the energy from the cosmic radiation

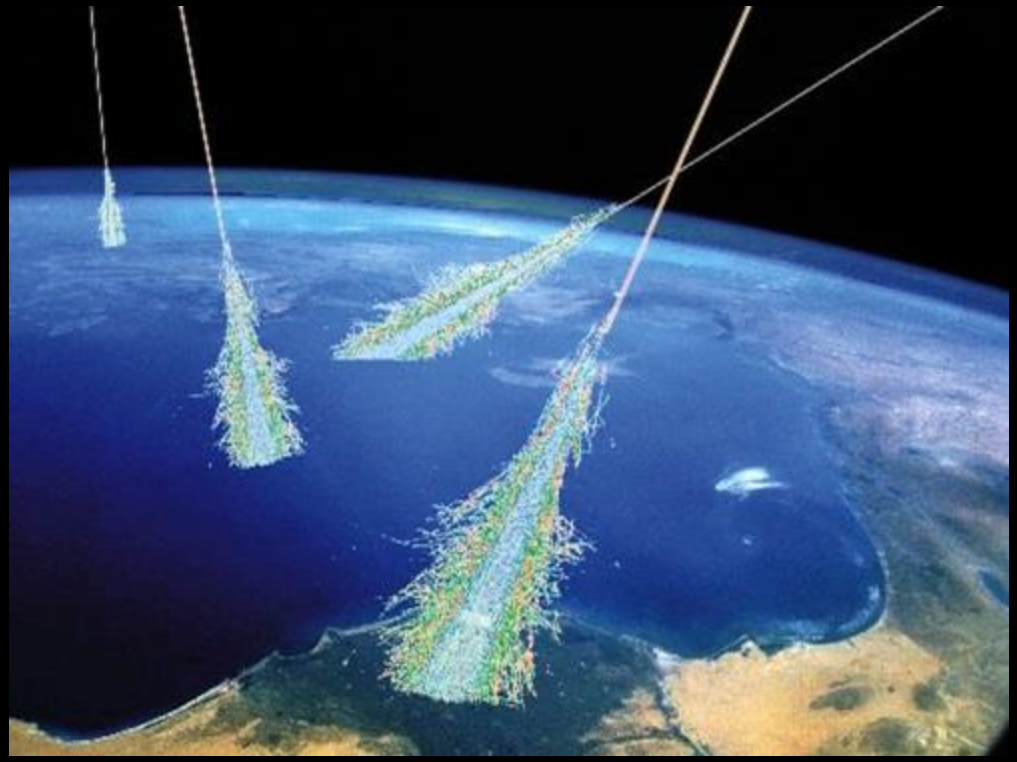
Active

- Produce a magnetic field that is big enough and strong enough to deflect cosmic radiation

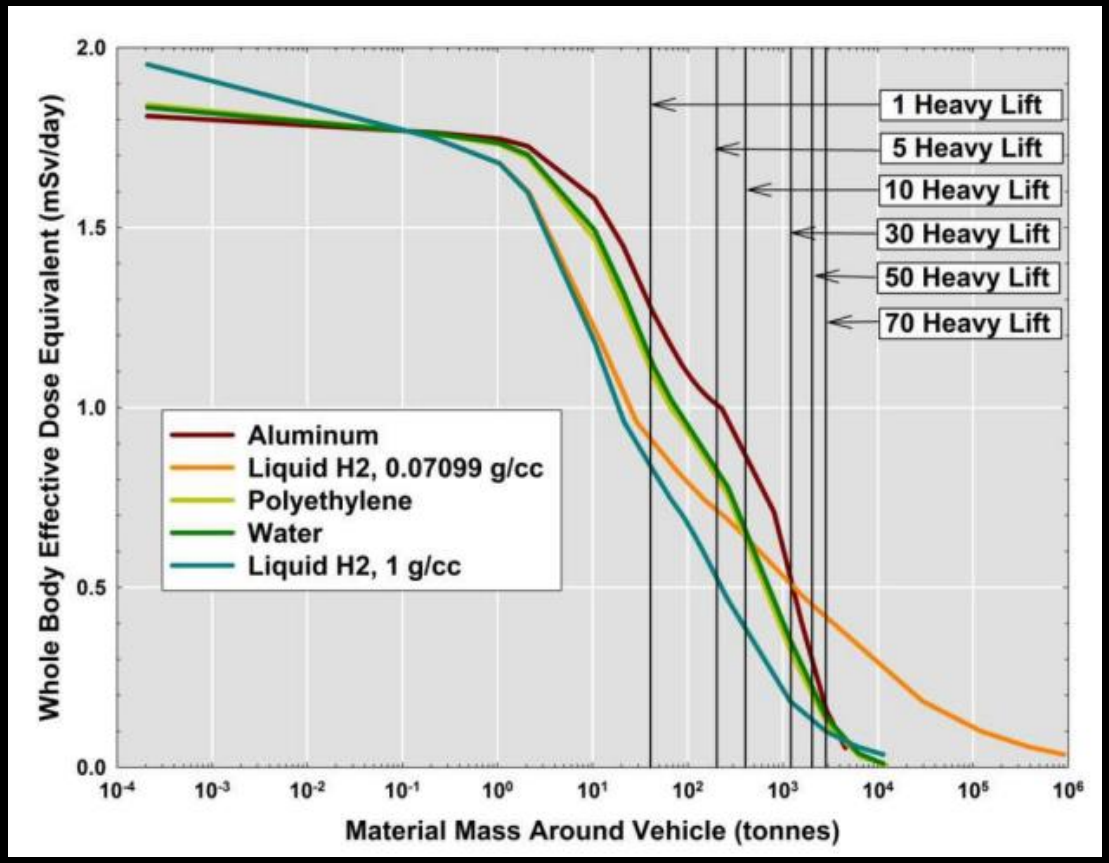


Passive Shielding

- Cannot use materials of high atomic number
- Problem: can generate secondary radiation
- Best materials: liquid hydrogen, water, and polyethylene have high hydrogen count
- Shield effectiveness drops as shield thickness increases



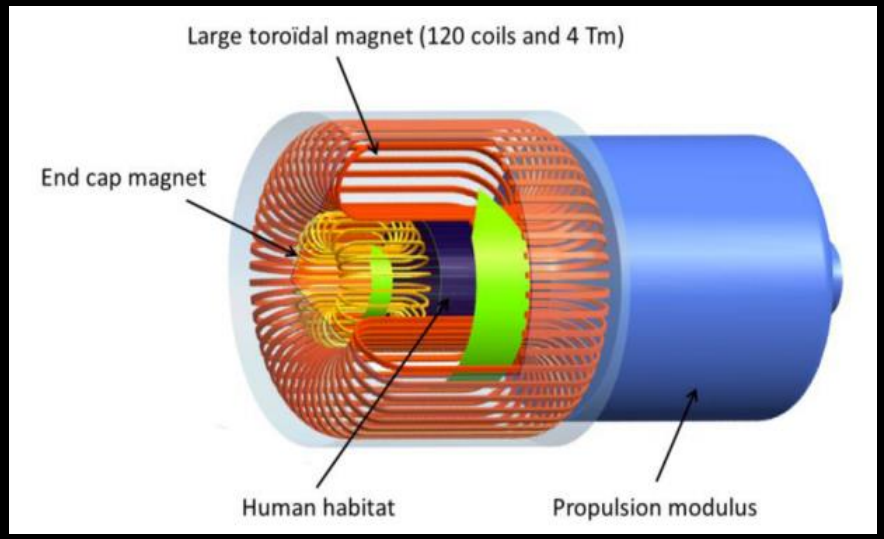
Passive Shielding



- Provides only 130 to 175 days of protection depending on material
- A mission to Mars would be approximately 200 days each direction
- Passive shielding alone will not provide sufficient protection

Active Shielding

- Recent breakthroughs with superconducting magnets make this more attainable
- Smaller and lighter than normal magnets required to produce such a field
- The Space Radiation Superconducting Shield (SR2S) project is working on a superconducting toroid magnet 10 m long and 12.8 m in diameter
- Magnesium diboride superconducts at 10 Kelvin



Solution

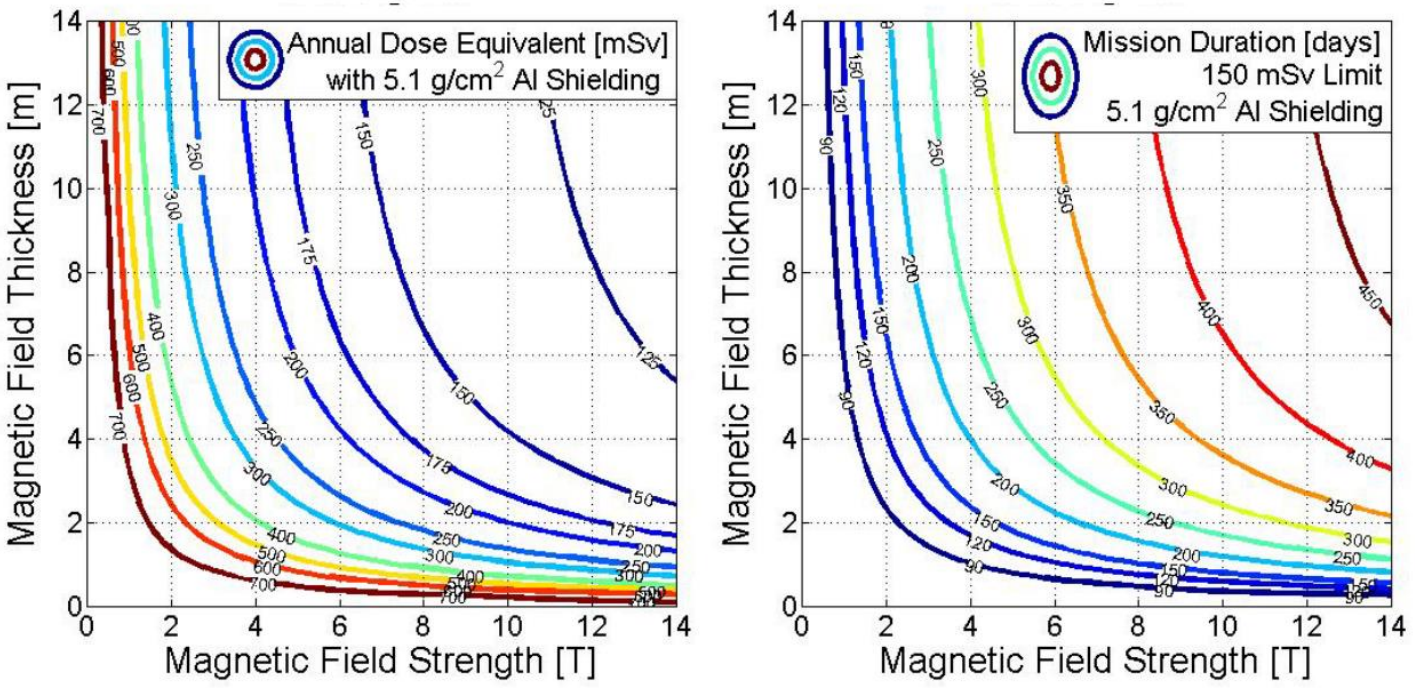


Figure 8.20. Open-Ended Cylinder Model with 5.1 g/cm^2 Al Shielding (r_i = 4m) a) Annual Dose Equivalent, b) Maximum Mission Duration to 150 mSv Limit

- Using both passive and active shielding together may provide the best protection for astronauts

Questions?