How Harmful is Space Radiation? 
Jeff Daniel & Sabrina Troncoso

Sources of Space Radiation

- **Active Galactic Nuclei**
  - Cosmic rays thought to be emitted by the accretion of matter by black holes at centers of AGNs.
  - These rays are in all parts of the EM spectrum, but most harmfully in gamma, x-ray, and UV wavelengths.
  - Two of the types of AGNs are quasars and blazars (quasars pointed directly at Earth).

- **Supernova Remnants**
  - After a massive star goes supernova, what’s left behind can have strong magnetic fields that accelerate atomic nuclei (mostly alpha particles) to extreme velocities, i.e. GCR.

What is radiation?

- **2 broad types:**
  - **Non-Ionizing Radiation**
    - Low energy
    - Not damaging but easier to shield
    - Radio frequencies, microwaves, IR, visible light, UV
  - **Ionizing Radiation**
    - High energy
    - Very damaging
    - Alpha & beta particles, gamma rays, x-rays, GCR

http://chandra.harvard.edu/resources/em_radiation.html

- Use it to learn about the world around us
  - X-rays, telescopes, spectroscopy, hyperspectral imaging, visible light, radiation oncology

Space in the News: New Horizons Team Prepares for Epic Flyby of Ultima Thule

Presented by: Amanda Alexander

Why is Space Important?

- Exploration of space
- Understanding the universe
- Advancements in technology
- Economic opportunities

How does space exploration impact society?

- Scientific advancements
- Technological innovations
- Economic growth
- Cultural influence

The Planetary Science Decadal Survey

- Read the Executive Summary of Planetary Science Decadal Survey which is linked to the class website for Nov. 7.
- Interview paper due on Wednesday!
**Cosmic Ray discovery**
- 1900s Henri Becquerel discovered radioactive decay
- early 20th century: electrosopes
- 1912 Victor Hess measured radiation in the atmosphere
- found ionization rate increases by ~4x in ~5000m altitude
- won Nobel Prize in 1936

**Sources of Space Radiation**
- **The Sun**
  - Thermal emission: Sun emits EM radiation at all wavelengths, but mostly in the visible, infrared, and ultraviolet ranges.
  - Also emits ionizing radiation via solar wind, coronal mass ejections, and solar flares

**Solar Radiation**
- Solar Wind:
  - solar particles ejected at ~1.6 million km/hour
  - Primarily protons and electrons

**Solar Flares**:
- Concentrated explosive release of magnetic energy
- X-rays
- Relatively low flux

**Coronal Mass Ejections**:
- Huge bubbles of plasma
- Can carry a billion tons of matter
- Can create shock waves in solar wind which accelerate ions
- ~3/day during solar max
- ~1/every 5 days during solar min

**Solar Particle Events**:
- CME + solar flare
- Particles arrive to Earth as fast as 10 minutes after an event
- Create geomagnetic storms
- Radiation penetrates to low altitudes in polar regions

**Van Allen Belts**
- **Discovery**
  - Discovered by Explorer 1, the first American satellite
  - Launched in 1958
  - James Van Allen
  - Micrometeorite detector & cosmic ray experiment

**Van Allen Belts (trapped radiation)**
- Inner belt:
  - ~2 E radii
  - Mostly energetic protons
  - Energies from keV to >100 MeV

**Outer belt**
- ~10 E radii
- Mostly 0.1-10 MeV electrons
- Influenced by solar activity
Radiation and Earth’s Magnetic Field

- Sun’s B field can interact with Earth’s, compressing it... can cause:
  - Aurora: fluorescence
  - Magnetic storms
  - Geomagnetically induced current
  - Ionospheric disturbances
  - Communication/navigation/power disruption

Effect on the Human Body

- Measurements
  - Radiation exposure is measured in Sieverts (Sv), usually millisieverts (mSv) for normal astronaut exposure levels
  - 1 Sv represents a 5.5% increase in cancer risk
  - For comparison, Apollo astronauts received an average of 1.4 mSv per day in space
    - In space for 8 days 3 hrs, Apollo 11 crewmen received a total of ~11.3 mSv, and a ~0.0062% increase in risk of cancer.

Effect on the Human Body

- Cancer
  - Umbrella term for diseases involving out-of-control multiplication and spread of body cells
  - Originates when a cell’s DNA altered, such as by ionizing radiation
  - DNA is changed in such a way that the cell keeps dividing, forming tumors
  - Radiation is the cause of up to 10% of cancer cases

Effect on the Human Body

- Central Nervous System Effects
  - Damage to the nervous system can cause:
    - Impaired cognition
    - Impaired motor functions
    - Behavioral changes
  - Latent effects can include:
    - Premature aging
    - Alzheimer’s Disease
    - Dementia

Tissue Degeneration

- Exposure to ionizing radiation can also directly damage tissue, causing:
  - Cataracts
  - Digestive diseases
  - Heart disease and other circulatory issues

Shielding Methods

- Earth's shielding
  - The magnetosphere deflects the vast majority of solar wind particles (rest is trapped in Van Allen belts or contribute to auroras) as well as cosmic rays
  - Whatever space radiation gets through magnetosphere is at least partly absorbed by the atmosphere

Exercise:

What possible space radiation shielding methods can you think of?
Shielding Methods

- **International Space Station**
  - Partially protected by Earth's magnetic field
  - Aluminum hull of station blocks most alpha, some beta rays
  - Astronauts still receive relatively high exposures

- **Apollo missions**
  - Crews traveled outside magnetosphere
  - Passed through Van Allen belts
  - Spacecraft also used aluminum hull
  - Main protection was short mission duration

Theoretical Methods

- Liquid Hydrogen
  - Can be used as fuel; low secondary radiation
  - Problem: Fuel consumption decreases shielding

- Magnetic field
  - Required for life support anyway
  - Problem: doesn't block gamma rays very well
  - Use a strong electromagnet to produce a field encompassing spacecraft
  - Problem: requires a lot of energy to sustain

Effect on satellites

- **3 categories:**
  1. **Total ionizing dose:**
     - Complete failure
     - Damage builds up over time
  2. **Displacement damage:**
     - Instrument wears down
     - Can fail
     - Also happens over time
  3. **Single event:**
     - Single particle passes through sensitive region
     - Can be destructive or non-destructive

Parker Solar Probe

- **Objectives:**
  - Study energy flow that heats corona and accelerates solar wind
  - Study plasma dynamics and magnetic field

- **Designed in 2015, launched August 12 of this year on Delta IV Heavy rocket**
- **Reaches first perihelion tonight at 8:27 PM MST**
- **Mission planned to operate until June 2025 (24th perihelion)**
- **Closest perihelion to be just 8.86 R₅ from surface**
- **End goal:**
  - Improve our forecasting of solar weather events

Sources:

- [https://www.nasa.gov/sites/default/files/pdf/radiationchallenge.pdf](https://www.nasa.gov/sites/default/files/pdf/radiationchallenge.pdf)
- [https://solarprobe.jhuapl.edu/index.php](https://solarprobe.jhuapl.edu/index.php)
- [https://www.nasa.gov/content/solar-wind](https://www.nasa.gov/content/solar-wind)
- [https://solarsystem.nasa.gov/missions/ulysses/in-depth/](https://solarsystem.nasa.gov/missions/ulysses/in-depth/)