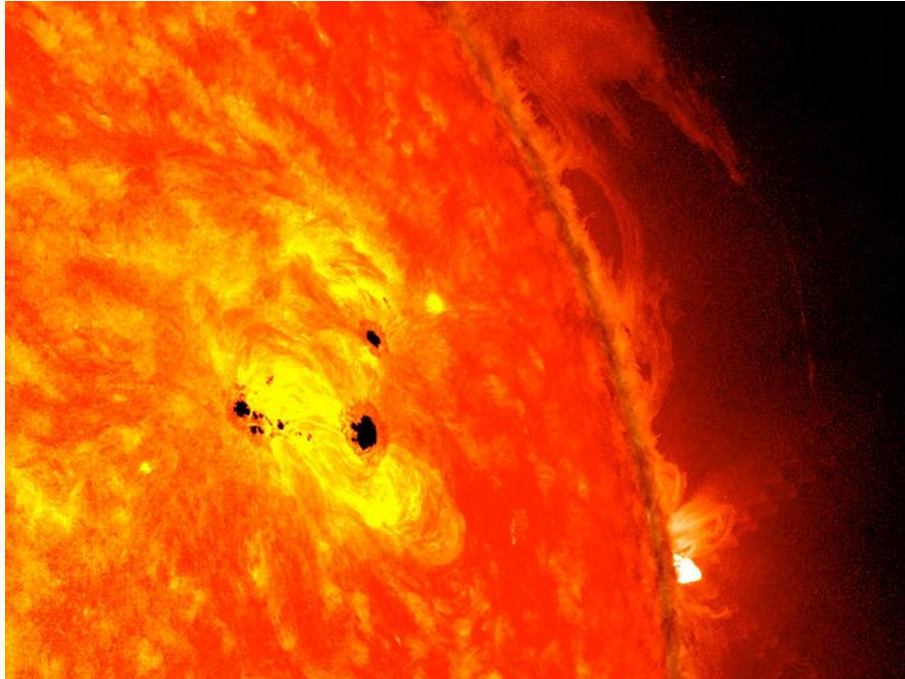


Into Orbit Possible FLL Project

—

Sunspots and Solar Flares



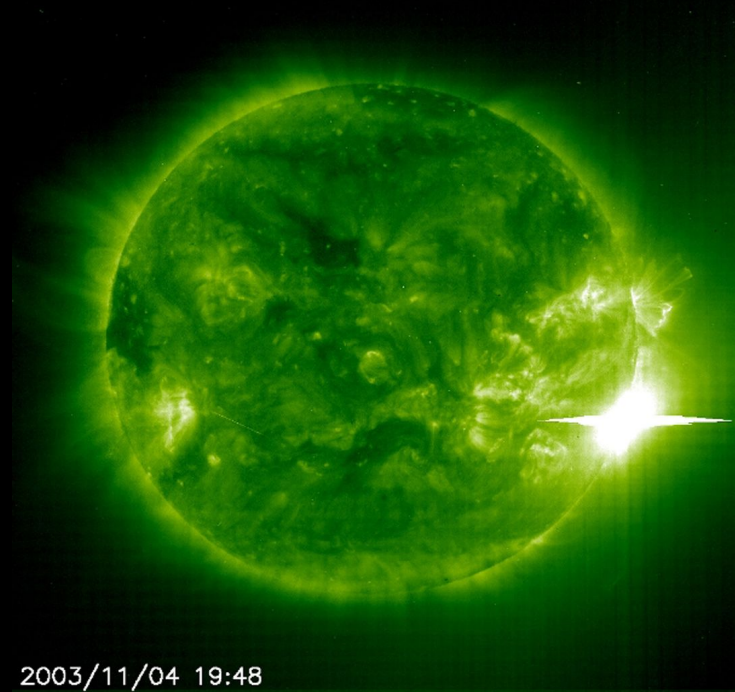
- The Sun's surface has electrically charged gases that generate areas of powerful magnetic forces, i.e. magnetic fields
 - The Sun's gases are constantly moving, which tangles, stretches and twists the magnetic fields, i.e. solar activity
 - Some areas have magnetic fields so strong that they keep some of the heat within the Sun from reaching the surface => Sunspots, i.e. dark areas on the surface of the Sun (only 6,500 F),
 - Near sunspots the magnetic field lines often tangle, cross, and reorganize causing a sudden explosion of energy, i.e. solar flare
-

Solar Flares-

Our solar system largest explosive events

- An intense burst of radiation coming from the release of magnetic energy associated with sunspots.
- Bright areas on the sun that can last from minutes to hours.

We see a solar flare by the photons (or light) it releases, at almost every wavelength of the spectrum.
We monitor flares in x-rays and optical light.



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Space Weather

Created by the activity on Sun's surface

- Solar flares can be accompanied by a coronal mass ejection (CME): enormous bubbles of superheated gas – called plasma
 - A plasma is a gas so hot that some or all of its atoms are split up into electrons and ions moving independently of each other
 - In a few hours, a billion tons of material are lifted off the sun's surface and accelerated to speeds of a 1,000,000 mph (1.6 million km/h), creating the solar wind.
-

The Solar Wind creates the Solar Weather

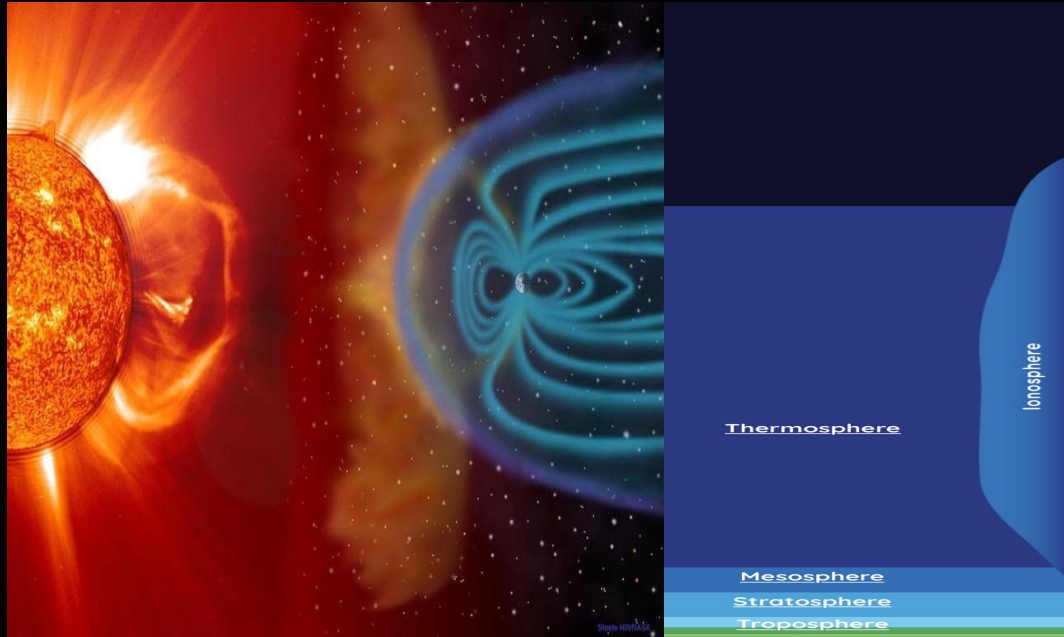
-
- CMEs take 1–3 days to propagate, flare-related space weather impacts Earth within minutes of flare onset

So ...

**The sun is a mess of tangled magnetic fields
that can snap like a rubber bands and hurl
dangerous electrified plasma out into space.**



Earth's Superhero Shield



- Earth's magnetic field: most of the charged particles crash into it and flow around it.
 - The particles squish and flatten the side of the magnetic field facing the Sun.
 - The other side of the magnetic field stretches into a long, trailing tail.
- In the Van Allen radiation belt energetic charged particles are captured and held around Earth by the magnetic field
- the ionosphere: swells with the charged particles sneaking past Earth's magnetic field. Auroras happen as the high-energy particles from the sun interact with its atoms

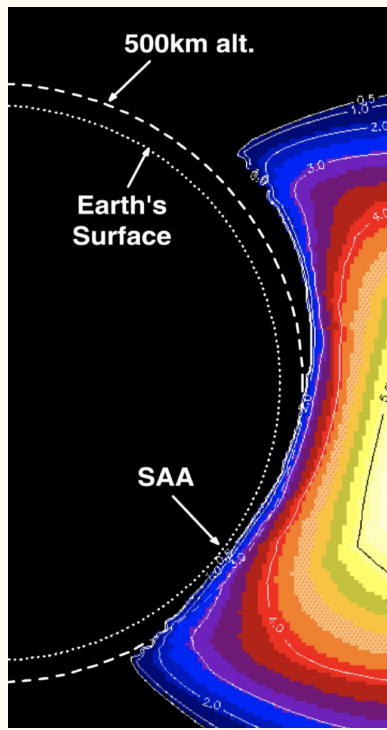
Prisoners of Earth's Superhero Shield

- In the Van Allen radiation belts the Earth's magnetic field captures and holds around the planet energetic charged particles
- there are 2 such belts and sometimes others may be temporarily created
- the South Atlantic Anomaly: above S. America, 200 - 300 km off the coast of Brazil the Earth's inner Van Allen radiation belt comes closest to the Earth's surface, dipping down to an altitude of 200 kilometres (120 mi).

Radiation impacts on space missions



Sources of radiation



Particles accelerated to near the speed of light mostly protons, and some heavier elements => can knock apart atoms of humans=> radiation sickness

- cosmic rays (supernova explosions)
 - less intense during solar CME/flares
- Solar Particle Events (flare/CME)
 - swollen Van Allen belts descend at lower latitudes
- trapped high energy particles in the South Atlantic Anomaly (SAA)
 - bombards ISS with protons energies > 10 million electron volts at a rate of 3000 'hits' per cm²/s

“...a trip to interplanetary space carries more radiation risk than working in low-Earth orbit,” said J. Pellish, a space radiation engineer at Goddard.

Effects on Humans

The focus of NASA's Human Research Program

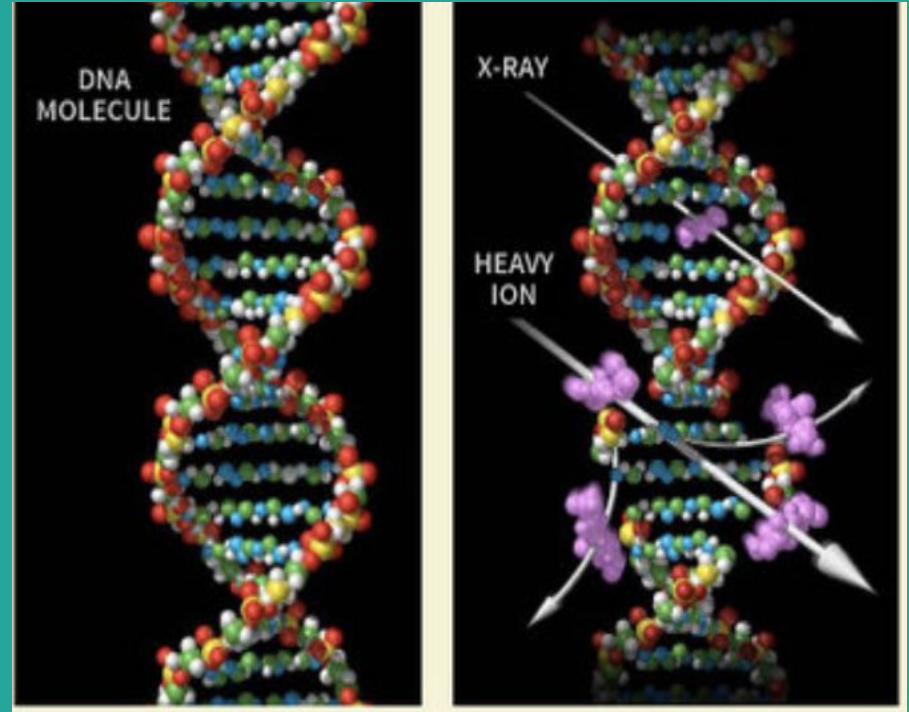


Damage to DNA

Tony Slaba, Ph.D., NASA research physicist. “It’s difficult to quantify exactly how radiation is interacting with tissues and cells – and more complicated to quantify and determine what long-term outcomes are going to be”

Breaks in the DNA strands =>

- No repair=> radiation sickness
- Cells attempt to repair the damage=> Errors lead to mutations and abnormal (cancer) cells



Effects on Aircraft

- **miniaturization/digitization of electronics and logic circuits made satellites more vulnerable to radiation (the total electric charge in these circuits is comparable with the charge of incoming ions)**



Spacecraft anomalies

- **Spacecraft internal electrostatic discharge** caused by high-energy electrons (> 100 keV) of the outer radiation belt of the Earth.
- **Single event effect**, i.e. measureable effect in a circuit caused by a single incident high-energy ion (> 10 MeV)
 - Non-destructive: Bit flipping or other hard drive errors
 - Destructive: logical gate rupture or burnout



● Other anomalies

- **Increased spacecraft drag** caused by the expansion of the Earth's upper atmosphere during space weather storms
 - more re-boots to adjust the spacecraft orbit
- **Communication disruptions** due to ionospheric irregularities
- **Altitude control disruptions** caused by magnetic field fluctuations

International Space Station (ISS)

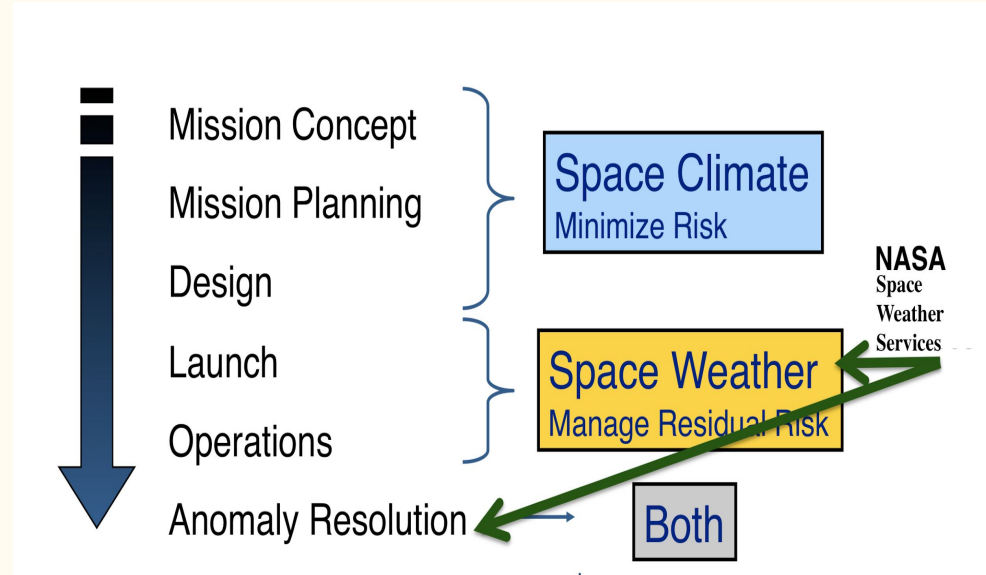
and
Low Earth Orbit
satellites

- NOAA monitors the radiation levels
- "safe zone", the region between the Van Allen belts

- ISS monitors the short-term and lifetime radiation doses for each astronaut
- The Hubble Space Telescope turn off its sensors in intense radiation regions
- Space Shuttle's modern laptops crashed when flights passed through the SAA
- The SAA disabled the direction-finding mechanism of Hitomi, Japan's most powerful X-ray observatory, causing the satellite to rely solely on gyroscopes and leading to its destruction

Space Weather Services

- Alerts/forecasts of adverse conditions throughout the solar system, such as significant CME events, elevated radiation levels
- Assistance in spacecraft anomaly resolution by determining whether space weather has any role in causing the observed anomaly



Solar Weather Prediction Models

- **Automated** based on machine learning which extracts features shared by previous flares and tries to identify them in the current solar activity.
- **“First-principles”** based on the fundamental physics theory of the event – i.e. the plasma properties, electromagnetics- guiding a CME’s movement through space.

Active regions data analyzes the 3 phases of a solar flare:

- energy build-up, energy release, energy transport
- collected by

American Geostationary Operational Environmental Satellites (GOES),
Solar Dynamics Observatory's Helioseismic and Magnetic Imager (SDO), etc.

Better databases- A tedious necessary task

Flares HUGE database used by Stanford researchers in 2017:

2,071 active regions with 1.5×10^6 active region patches characterized by > 25 parameters

Crowdsourced sun flare photos processing: draws the solar flares edge

- Involves more people=> faster
- Can help point researchers towards images that may be of interest
- <https://www.zooniverse.org/projects/shannon-/solar-stormwatch-ii/classify>
- We classified more than 100 images **Solar Stormwatch**

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