

Space Weather Forecasting

Planet Hack 2026 Workshop #1

with Prof Helmut Jerjen (ANU)



Australian
National
University

Overview

1. Physics of the Sun
2. Space weather and threats to Earth
3. ISECG's Deep Space Satellite System
4. Forming an efficient Planet Hack research team



Physics of the Sun

Our sun is one of 100 billion stars that make up the Milky Way galaxy

4.5 billion years old



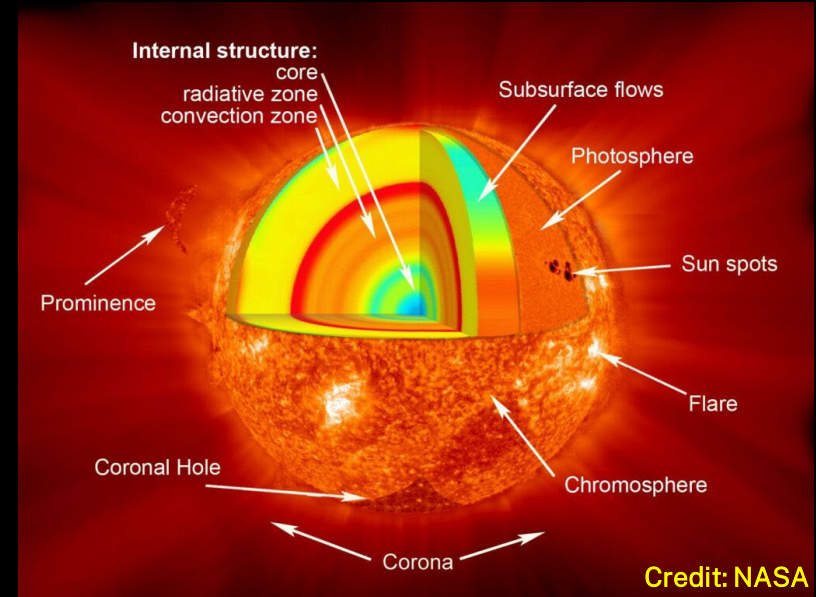
Physics of the Sun

The only star close enough we can see in 2D
Diameter about 109 Earth diameters
Travel time to Earth (150 million km) is 8 min
Provides heat and light for our solar system
Essential for all life on Earth



Physics of the Sun

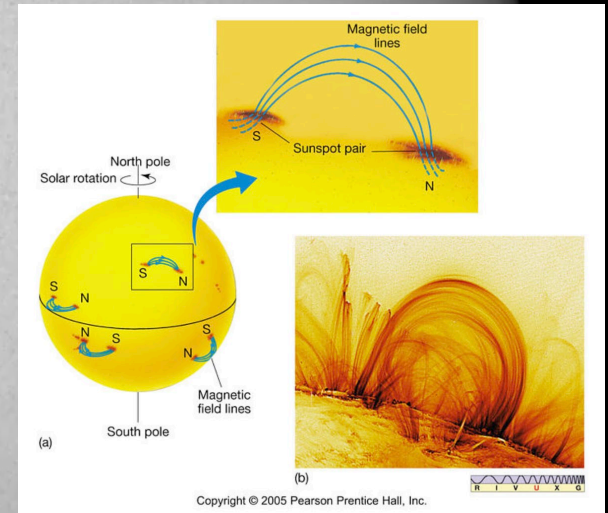
- Giant sphere of rotating hot gas hold together by gravity
- Mostly hydrogen and helium
- Generates enormous amount of energy every second by nuclear fusion: H to He in the core (15 million deg C), equivalent to detonating 400 billion 1Mt nuclear bombs every second!
- Relatively quiet. Sun will continue producing energy for another 4.5 billion years.



Physics of the Sun

SUNSPOTS

Plasma made from charged particles rises to the surface and cools. The magnetic field prevents the plasma from sinking back down. Spots of plasma remain on the surface, cool and dim the light.



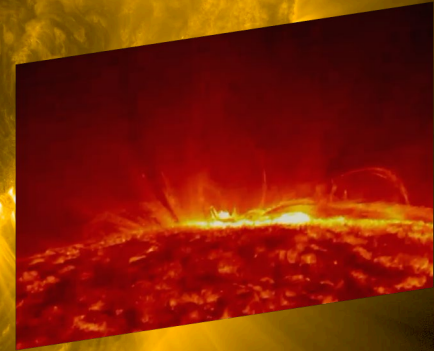
Credit: ESA/NASA



Physics of the Sun

SOLAR FLARES

Magnetic fields around sunspots store large amounts of energy like a spring. They can snap and release the energy in an event called solar flare. Electromagnetic radiation is launched off the surface at high speed, sending it into interplanetary space. A kind of solar lightning occurs.



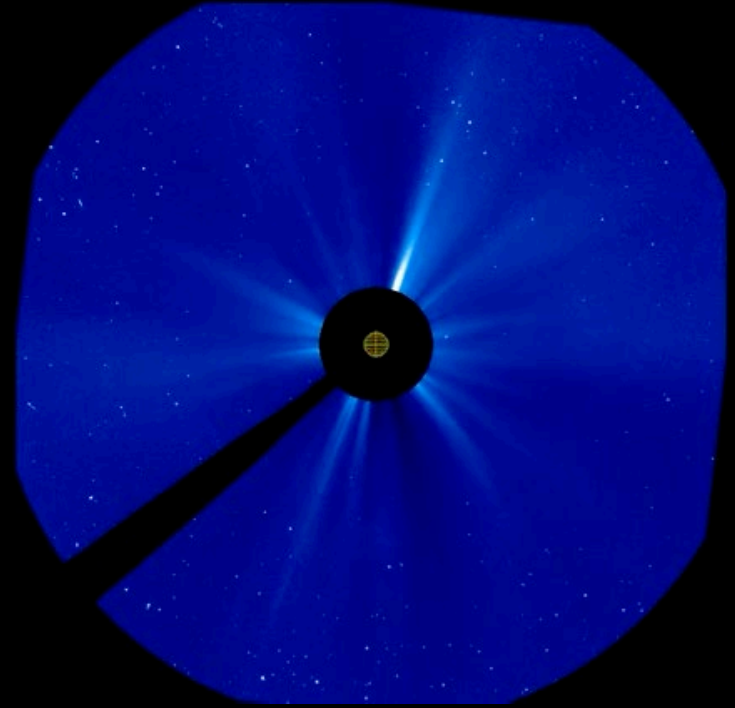
Credit: ESA/NASA



Physics of the Sun

CORONAL MASS EJECTION

Solar flares can be accompanied by a coronal mass ejection (CME). This blasts off billions of tons of plasma (electrons and protons) into the interplanetary space and can hit the Earth. When it does, there can be profound effects.



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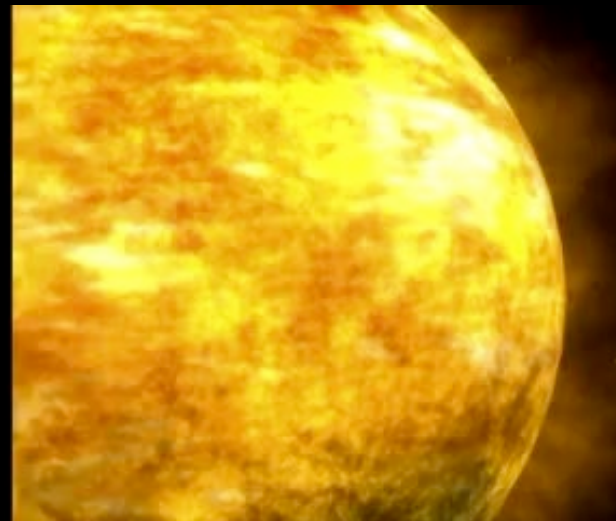


Threats to Earth

Earth's atmosphere absorbs the high-energy photons while the electrically charged particles are deflected by the Earth's magnetic field.

They are funneled down near the geographic poles, interact with O and N, causing the air to glow. This is what we call the aurora, or the northern and southern lights.

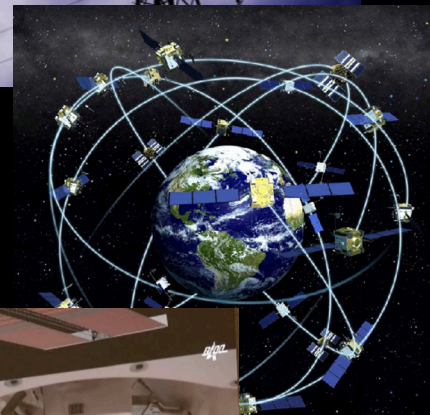
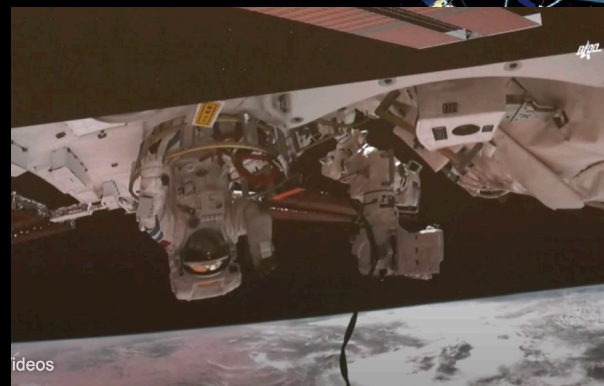
As the magnetic fields interact, they can induce very strong electric currents in the Earth's crust.



Threats to Earth

Radiation and charged particles from CMEs

- disrupt power grids that provide our electricity, leading to blackouts: Geomagnetically Induced Currents (GICs) through long high-voltage transmission lines.
- damage satellites we use for communications, navigation, space exploration.
- dangerous for health of astronauts in space.

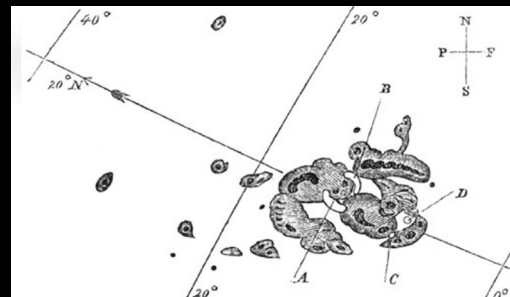


Threats to Earth

Carrington Event (1859): first documented event of a solar flare impacting Earth. The most intense recorded geomagnetic solar storm in the last 500 years.

May 23, 1967: solar storm nearly led to a nuclear war. Fortunately, space-weather forecasters intervened in time.

The Seahorse solar flare (August 1972) knocked out long-distance phone communication across some US states. Tele-communication company redesigned its power system for transatlantic cables.



(Wikipedia)



(National Solar Observatory)



(Big Bear Observatory)



Threats to Earth

March 1989: power blackout in Canada that left six million people without electricity for nine hours.

July 2000: Bastille Day event in France. Most powerful flare since 1989.

Halloween Storms (Oct 2003): aircrafts had to be re-routed, power outages in Sweden, SOHO satellite temporarily failed.

December 2006: GPS disrupted, damage to the solar X-ray imager instrument on the GOES 13 satellite.



Threats to Earth

February 2022: geomagnetic storm destroyed almost 40 Starlink satellites worth over \$50 million shortly after deployment.

July 2026: NASA had to launch an emergency mission to save the SWIFT space telescope.

This is why monitoring the Sun is so important. We depend on it for light and heat. It is the very basis of life itself, but it is entirely capable of knocking our society to its knees.



Solar Activity Forecasting

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Solar Conditions

Solar Wind Speed 	X-Ray Flux C1.0	X-Ray Flares 	Latest Learmonth Spectrograph 	Latest Learmonth H-Alpha Image 
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Geophysical Conditions

Geomagnetic Warning Warning	GEOSTAT Alert No Alert	Geomagnetic Alert No Alert	Aurora Alert No Alert	K-Index 2	pc3-Index 1	AusDst-Index > -20	GIC-Index 
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HF Propagation Conditions

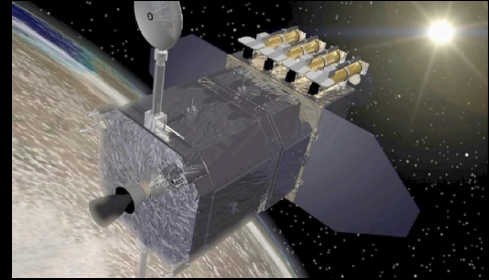
HF Comms Warning Warning	Current HF Fadeout No Event	HF Fadeout Warning Warning	Polar Cap Absorption 0.0dB AT 22:58 UT
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Space Weather Data

Monitoring Of The Sun Is Fundamental For The Future Of Humanity

Launch of dedicated space observatories to monitor and predict solar activities.



Space weather satellites:

Solar and Heliospheric Observatory (SOHO): ESA/NASA, 1995

Michelson Doppler Imager image archive, May 1996 to December 2011

Solar Dynamics Observatory (SDO): ESA/NASA, 2010

Helioseismic and Magnetic Imager archive, May 2010 to today

The Atmospheric Imaging Array (AIA) captures high-definition images of the solar atmosphere every 12 seconds across several wavelength bands. It transmits roughly 1.5 TB of real-time solar data back to Earth every day



Planet Hack 2026 - The Mission



The year is 2028. The International Space Exploration Coordination Group (ISECG) is preparing to launch a \$100 billion deep-space satellite system in 2035.

Every electronic component on board is delicate. Every one of them is vulnerable to solar weather.

ISECG cannot afford a repeat at one hundred times the scale.

Your Planet Hack team has been called in as scientific advisors. Your task is to analyse space weather data, develop your own findings, and pitch your recommendation to the ISECG launch panel on video.



Junior Challenge

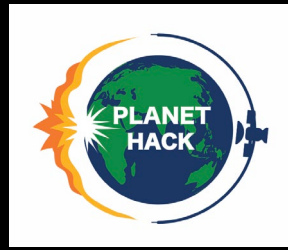


ISECG needs to understand how dangerous the Sun is likely to be at the time of launch. The Sun follows a sunspot activity cycle. Sunspots are the underlying drivers of geomagnetic storms on Earth. While sunspots themselves do not reach our planet, they act as launchpads for massive eruptions of energy and plasma that travel through space and disrupt Earth's magnetic field. These events threaten satellites, GPS, weather systems, communications, and power infrastructure.

Your team has been asked to predict sunspot activity in the year of the Rabbit, 2035 and advise ISECG on the implications for the planned launch. Make a compelling, evidence-based video proposal recommending whether the 2035 launch should proceed. Identify potential hazards, analyse what could happen if a disaster or hazard occurs, and evaluate the risks.



Junior Challenge: Hack



Use SDO/HMI imaging data to identify the solar maximum years between 2012 and 2024.

- Download a high-resolution image from the SDO/HMI archive. Use an image analysis program of your choice to determine the centre coordinates and pixel diameter of a large sunspot.*
 - Compare the sunspot's size to Earth's diameter using a pixel-to-kilometre conversion. Make this scale comparison the visual centrepiece of your pitch.*
 - Track a sunspot across a time series. How many days does it remain visible on the solar disk?*
- Bonus credit if you identify one that lasts at least 30 days and present it as a short time-lapse for the panel.*
- Investigate whether there is a correlation between sunspot size and lifespan. Does size influence longevity?*
 - Make a prediction of solar flare activity for the 2035 launch year.*
 - Pitch your video proposal to the ISECG launch panel. Present your sunspot analysis, scale comparison, time-lapse, and solar activity predictions. If your predictions advise against the launch, clearly justify your reasoning and propose an alternative launch year*



Senior Challenge



Unlike a solid planet, the Sun rotates at different speeds depending on latitude — a phenomenon known as differential rotation. This uneven motion twists magnetic field lines until they snap, producing solar flares and coronal mass ejections.

These events can induce powerful electrical currents in power grids and disrupt satellite electronics at Earth's distance. The 2035 launch window is fixed. ISECG needs to understand how active the Sun will be at launch, and how to respond if a major event occurs during deployment.



Senior Challenge: Hack



Track at least two sunspots at significantly different solar latitudes using a time series of SDO/HMI images. Record their x and y pixel positions and Julian Date timestamps.

- Use trigonometric methods to determine the rotation period at each latitude. Plot x and y as functions of time, fit a sine curve, and estimate the rate of motion.*
- Quantify differential rotation. Derive an equation describing rotation speed as a function of solar latitude, clearly stating any assumptions.*
- Construct your own butterfly diagram across the two most recent solar cycles using sunspot latitude data over time. Use it to estimate the cycle period and identify when the next solar maximum is likely to occur.*

Forecast solar activity for the 2035 launch window. Cross-check your prediction against historical links between solar activity and radio blackout events on Earth (e.g. reported incidents).

- Recommend a mission protection strategy based on your forecast. This could include launch timing, orbital design, hardware shielding, or power grid management for supporting ground stations.*
- Pitch your forecast and strategy to the ISECG launch panel on video. Show the maths. Show the butterfly diagram. Present the decision you would make if the final call were yours.*



Project Planning - Team

1. Planet Hack 2026 challenge is an interdisciplinary project that requires students to collaborate across Astronomy, Computer Science, Mathematics, Physics, Engineering, and Science Communication.
2. Teams need to combine existing knowledge and results from their own data analysis.
3. Identify the questions you want to answer and present to ISECG.
4. Hacks provide a guide to start the process
5. Find credible sources on the internet
6. Conduct a preliminary assessment of SDO research data
7. Develop hypothesis



Project Planning - Team

8. Build an effective team based on the skills and strengths of each group member. What tools, knowledge, and expertise are needed to achieve the project goals? Who is best suited to each task?
9. SMART timeline. Have regular short group meetings to discuss progress, roadblocks and milestones (total project time is short)



Project Planning -Analysis

SDO imaging data:

which type of images is best suited for your tasks?

how many images do you need and at what cadence?

What format do the images have?

Do you need to write Python code or are there image processing packages available for the analysis? E.g. Fiji or JHelioviewer. Think about what you need versus available time. It might be too time consuming to learn how to use a software.



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