CORONAL MASS EJECTIONS: SCIENCE & TECHNOLOGY

NEWS: IIA team decodes reason behind May 2024 solar eruptions

WHAT'S IN THE NEWS?

A series of intense Coronal Mass Ejections (CMEs) from the Sun in May 2024 caused rare northern lights visible in Ladakh, highlighting the powerful impact of solar storms on Earth. This event, unlike any in two decades, is prompting enhanced space weather forecasting efforts, including data from India's Aditya-L1 mission, to predict and mitigate disruptions to technology.

Solar Storms & Northern Lights: The Science Behind the Spectacle

A powerful series of solar events in May 2024, specifically Coronal Mass Ejections (CMEs), caused rare Northern Lights visible as far south as Ladakh, India, marking an unusual solar storm not seen in two decades.

About Northern Lights (Aurora Borealis):

- **Appearance:** Glowing, shifting curtains of light seen in the night sky, primarily near the Arctic Circle.
- **Formation:**
    - **Solar Wind:** The Sun continuously releases charged particles (electrons and protons).
    - **Magnetic Interaction:** Earth's magnetic field guides these particles towards the polar regions.
    - **Atmospheric Collision:** These particles hit gases (oxygen, nitrogen) in the upper atmosphere, exciting them.
    - **Light Release:** The excited atoms release energy as light, creating the aurora.

About Coronal Mass Ejections (CMEs):

- **Definition:** Large expulsions of plasma and magnetic fields from the Sun's outer atmosphere (corona) into space. They often look like twisted ropes, called "flux ropes."
- **Frequency:** Varies with the Sun's 11-year solar cycle (more frequent during solar maximum, less during solar minimum).
- **Impact on Earth:** When directed towards Earth, CMEs can cause **geomagnetic storms**, which can:
    - Disrupt satellites and communication systems.
    - Affect power grids.
    - Lead to spectacular auroras (Northern and Southern Lights) at high latitudes.

- **Mechanism:** CMEs cause magnetic fields from the Sun (interplanetary magnetic field - IMF) to merge with Earth's magnetic field (geomagnetic field), intensely transferring energy into Earth's magnetosphere. This drives geomagnetic storms and substorms, causing auroras.
- **Plasma Temperature:** CME plasma can range from very cold (chromospheric material) to very hot (coronal plasma).
- **Energy Exchange:** As CMEs travel, they continuously exchange electrical, kinetic, potential, and thermal energy, causing internal heating or cooling of their plasma.
- **Relevance:** Studying CMEs is crucial for predicting and reducing their negative impact on Earth's vital infrastructure (communication, navigation, power).

Key Findings on CME Thermal Behavior (Recent Research):

- **Mid-Journey Thermal Shift:** CMEs initially release heat but then absorb and maintain it, reaching stable temperatures in the middle of their journey.
- **Double Flux Ropes:** Data from the Wind spacecraft showed two intertwined magnetic structures near Earth, with compressed magnetic fields and unusual thermal patterns for electrons and ions.
- **CME-CME Interactions:** When multiple CMEs interact, their thermal structure changes:
    - **Electrons:** Tend to release heat.
    - **Ions:** Show mixed thermal states, but heating is dominant.
- **Pioneering Insight:** This research provides the **first continuous tracking of the thermodynamics of multiple CMEs** across the heliosphere, representing a significant contribution from Indian and global scientists.

Implications for Space Weather Forecasting:

- **Enhanced Models:** This new understanding greatly improves the accuracy of space weather predictions, as published in the Astronomy and Astrophysics Journal.
- **Magnetosphere Impact:** Aids in predicting complex geomagnetic disturbances caused by interacting CMEs.
- **Future Tracking (Aditya-L1):** Upcoming data from India's **Aditya-L1 mission** (specifically its VELC and ASPEX instruments) will help refine these models and explore if thermal changes can act as early warning signs for major space weather events.
    - **Aditya-L1:** India's first dedicated solar mission, carrying seven scientific instruments.
        - **VELC (Visible Emission Line Coronagraph):** Studies the Sun's corona.
        - **ASPEX (Aditya Solar Wind Particle Experiment):** Studies solar wind particles.

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