Sun-Earth Connections

Magnetism Across Time and Space

Sarah Gibson
Magnetism in Comic Books

- Green Lantern
- Magneto: Not a Hero
Magnetism at Home
The magnet is alive!
Magnetism at Home

The magnet is alive!
Magnetism at Home

The magnet is alive!

The magnet is useful...

Magnets
Magnetism at Home

The magnet is alive!

The magnet is useful...
Magnetism at Home

The magnet is alive!

The magnet is useful...

The magnet can be dangerous.
Magnetism across the Universe

Storage and release of magnetic energy
Earth’s magnetic field acts as a shield
Earth’s magnetic field acts as a shield
Earth’s magnetic field acts as a shield
Unfortunately, that shield can break
Unfortunately, that shield can break
Always had potential for beauty...
Begin at the Earth: Space Weather

Always had potential for beauty...

...now has potential for danger
Begin at the Earth: Space Weather

Ordinary....
Begin at the Earth: Space Weather

Ordinary....


Back to the Sun: Magnetic Origins

Solar Storms
Coronal Mass Ejections (CMEs) and Flares

Together, they represent a release of magnetic energy
Inside the Sun
The dance of the dynamo: All together now!
The dance of the dynamo: All together now!
Building magnetic fields by means of turbulent convection, shear, magnetic buoyancy and global circulations
Magnetic fields continuously emerge through the Sun's surface.
Magnetic fields continuously emerge through the Sun’s surface.
Humans have been “seeing” solar magnetic fields for a long time...
3D and Twisted

Back to the Sun: Magnetic Origins

AIA 304 - 2011/09/25 - 10:00:08Z
AIA 171 - 2011/09/25 - 10:00:00Z
AIA 211 - 2011/09/25 - 10:00:00Z
AIA 193 - 2011/09/25 - 10:00:09Z
Back to the Sun: Magnetic Origins

3D and Twisted

AIA 304 - 2011/09/25 - 10:00:08Z
AIA 171 - 2011/09/25 - 10:00:00Z
AIA 211 - 2011/09/25 - 10:00:00Z
AIA 193 - 2011/09/25 - 10:00:09Z
Magnetic energy stored in twisted magnetic field
Magnetic energy stored in twisted magnetic field

Released through solar eruption
Magnetic energy stored in twisted magnetic field

Released through solar eruption

Impacts the Earth
The Solar Butterfly Diagram

DAILY SUNSPOT AREA AVERAGED OVER INDIVIDUAL SOLAR ROTATIONS

Sunspot area in equal area latitude strips (% of strip area)

The 11-year Sunspot cycle

Average daily sunspot area (% of visible hemisphere)

http://solarscience.msfc.nasa.gov/
Magnetism and Space Climate

**Space weather varies with the solar cycle**

**From the Sun...**
Magnetism and Space Climate

Space weather varies with the solar cycle

Through the Solar Wind...
Space weather varies with the solar cycle

Through the Solar Wind...
Space weather varies with the solar cycle

Through the Solar Wind...
Magnetism and Space Climate

*Space weather varies with the solar cycle*

To the Earth.

**Geomagnetic Activity**

![Image of aurora borealis](Image)

**Sunspot Number and AA Index 1868-1992**

<table>
<thead>
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<th>Year</th>
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- AA Index (red)
- Sunspots (yellow)
What about radiation?
What about radiation?

Total Solar Irradiance (TSI)

Froelich et al., 2009
Magnetism and Space Climate

What about radiation?

Total Solar Irradiance (TSI)

Short wavelength radiation (EUV)
Magnetism and Space Climate

**Total Solar Irradiance (TSI)**

- Froelich et al., 2009
- What about radiation?

**Short wavelength radiation (EUV)**

- Solomon et al., 2010

**Thermospheric neutral density**
What about radiation?

Recent solar minimum was unusually deep

Solomon et al., 2010

Froelich et al., 2009

Total Solar Irradiance (TSI)

Magnetism and Space Climate

Short wavelength radiation (EUV)

Thermospheric neutral density
Galactic cosmic rays reached space-age high, in a magnetically weak and quiet heliosphere.
Galactic cosmic rays reached space-age high, in a magnetically weak and quiet heliosphere.
A Deep Solar Minimum

Sunspot Number

Ap Geomagnetic Index (mainly solar wind speed)

Heliospheric Magnetic Field at Earth

Weird for the Century...

Courtesy L. Svalgaard
A Deep Solar Minimum

Yearly averaged sunspot numbers 1610-2015

Not this Weird.

WDC-SILSO
Conclusions
What’s true at home is true across the solar system
Conclusions

What’s true at home is true across the solar system

The magnet is alive!
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Magnetism is a force of nature — neither good nor evil, but its power cannot be ignored.