

# Space Climate Aurora Forecast

**Shabnam Nikbakhsh**

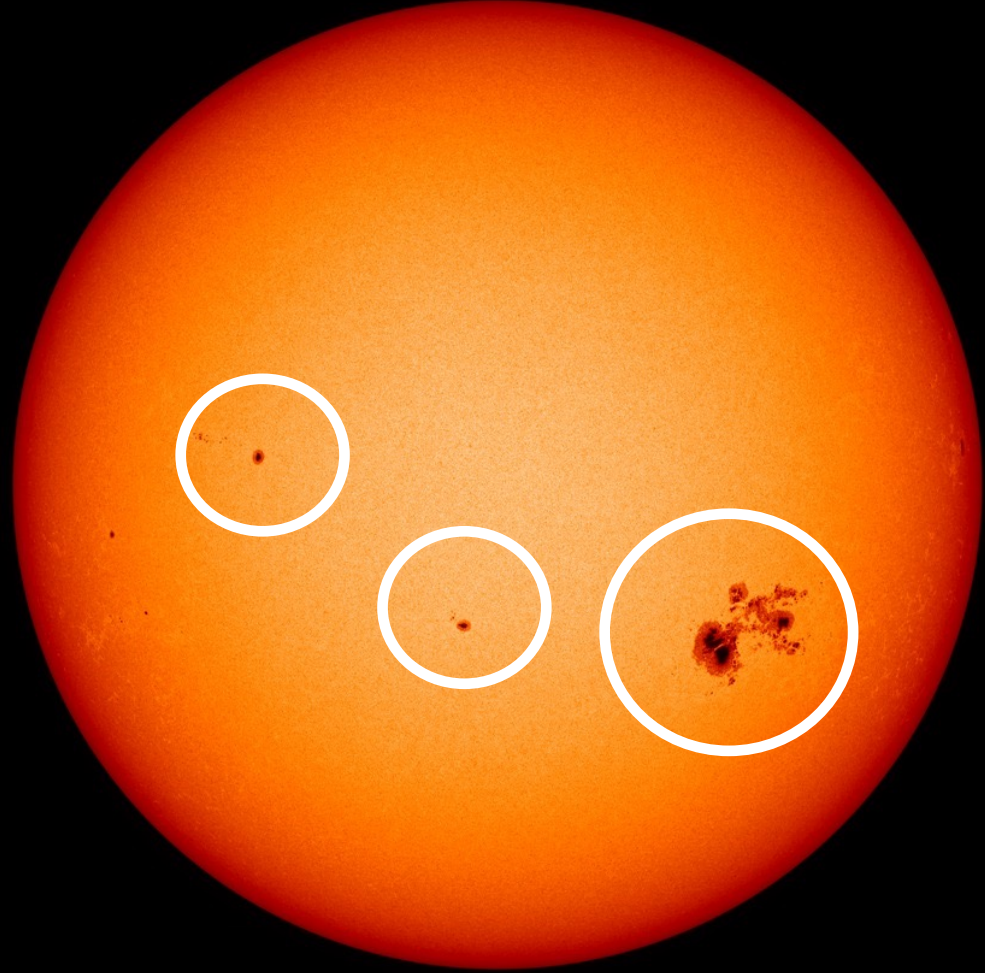
[Shabnam.Nikbakhsh@oulu.fi](mailto:Shabnam.Nikbakhsh@oulu.fi)

# What to do:

- Check the current state of the sun
  - Active regions
  - Solar max/min
  - CME/flare or coronal holes
- Check solar wind data
  - Fast/slow solar wind
- Check geomagnetic data
  - Dst, Kp, AE



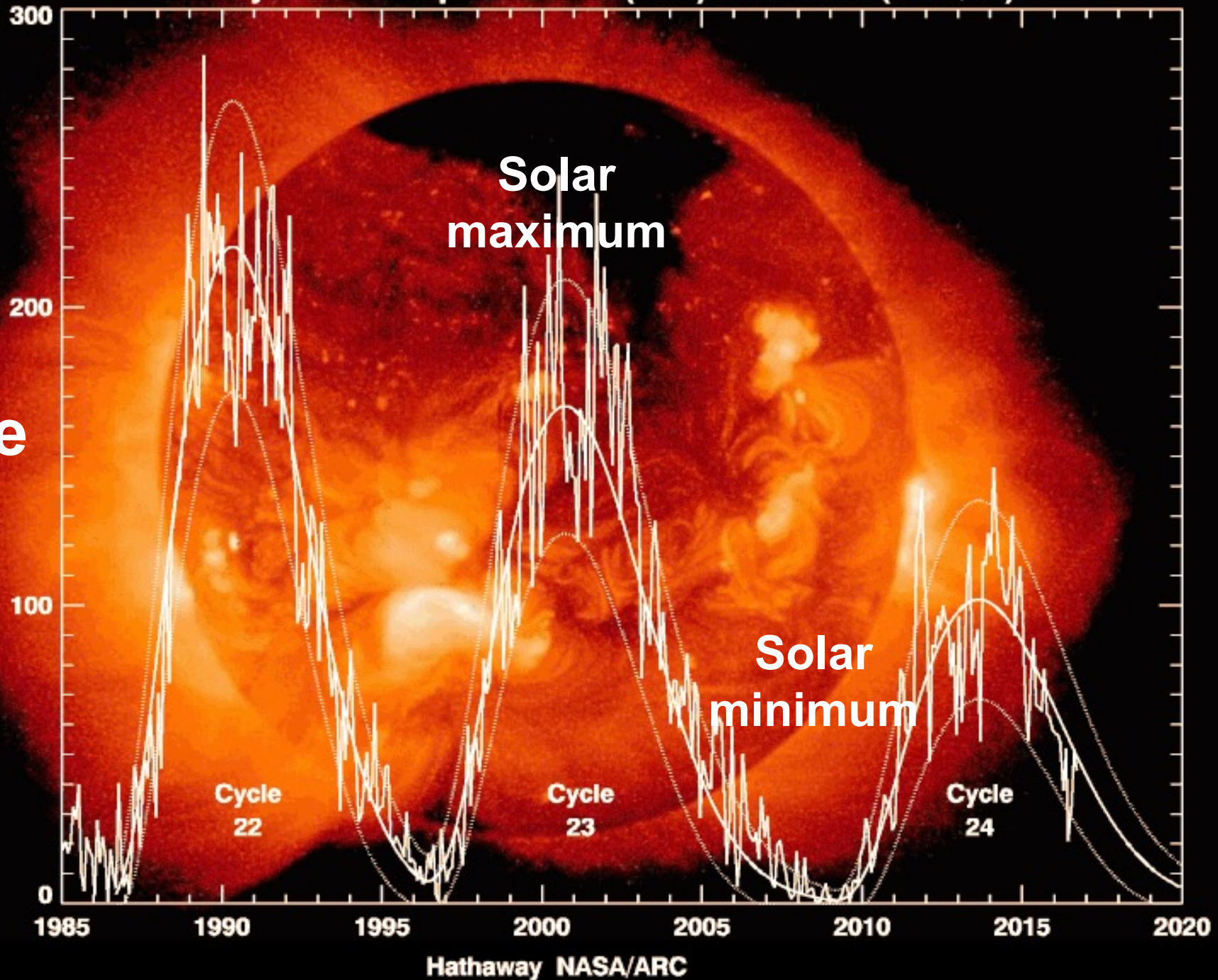
Video credit: ISS/NASA



Sunspot groups  
Credit: SDO/NASA

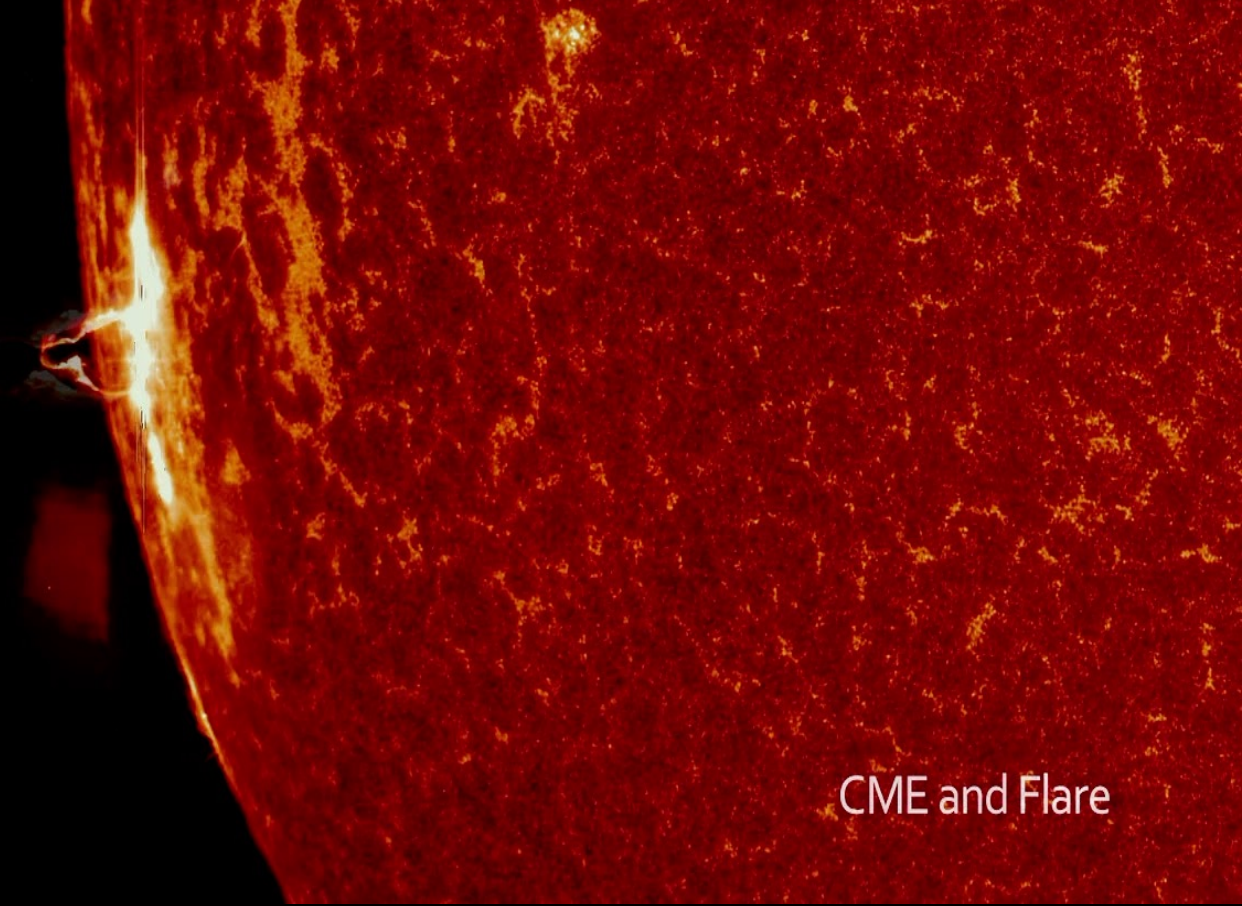
# Cycle 24 Sunspot Number (V2.0) Prediction (2016/10)

**Solar cycle**



# CME and flare

- Coronal mass ejections (CMEs) and solar flare are explosive phenomena that occur on the Sun
- Often occur together but they are not the same
- Often emerge from solar active regions

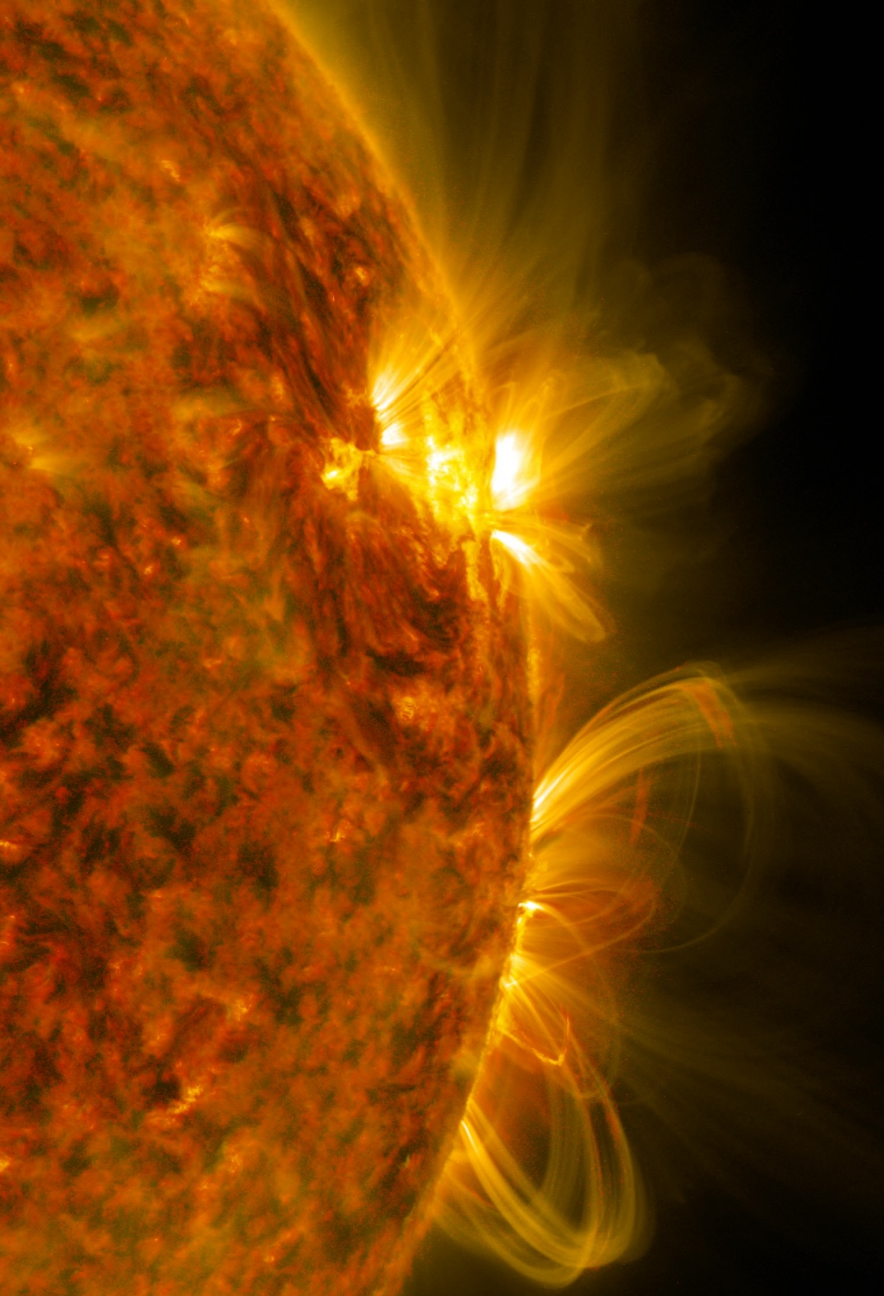


CME and Flare

Video credit: SDO/NASA

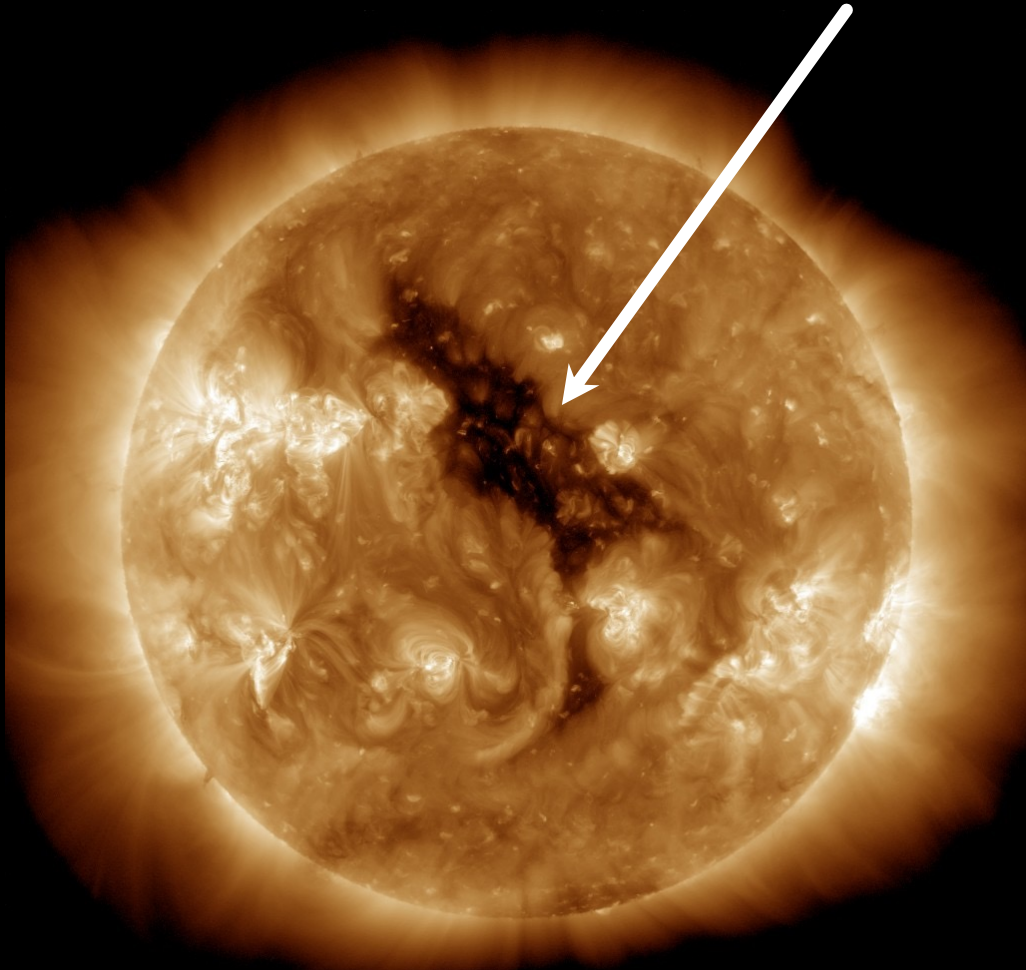
# Solar Flare classification

- Flares produce electromagnetic radiation across the electromagnetic spectrum at all wavelengths, from radio waves to gamma rays
- Solar flares are classified according to their X-ray brightness, in the wavelength range 1 to 8 Angstroms
- Flares classes have names: A, B, C, M, and X, with A being the smallest and X being the largest
- Each category has nine subdivisions ranging from, e.g., C1 to C9, M1 to M9, and X1 to X9. These are logarithmic scales, much like the seismic Richter scale. So, an M flare is 10 times as strong as a C flare

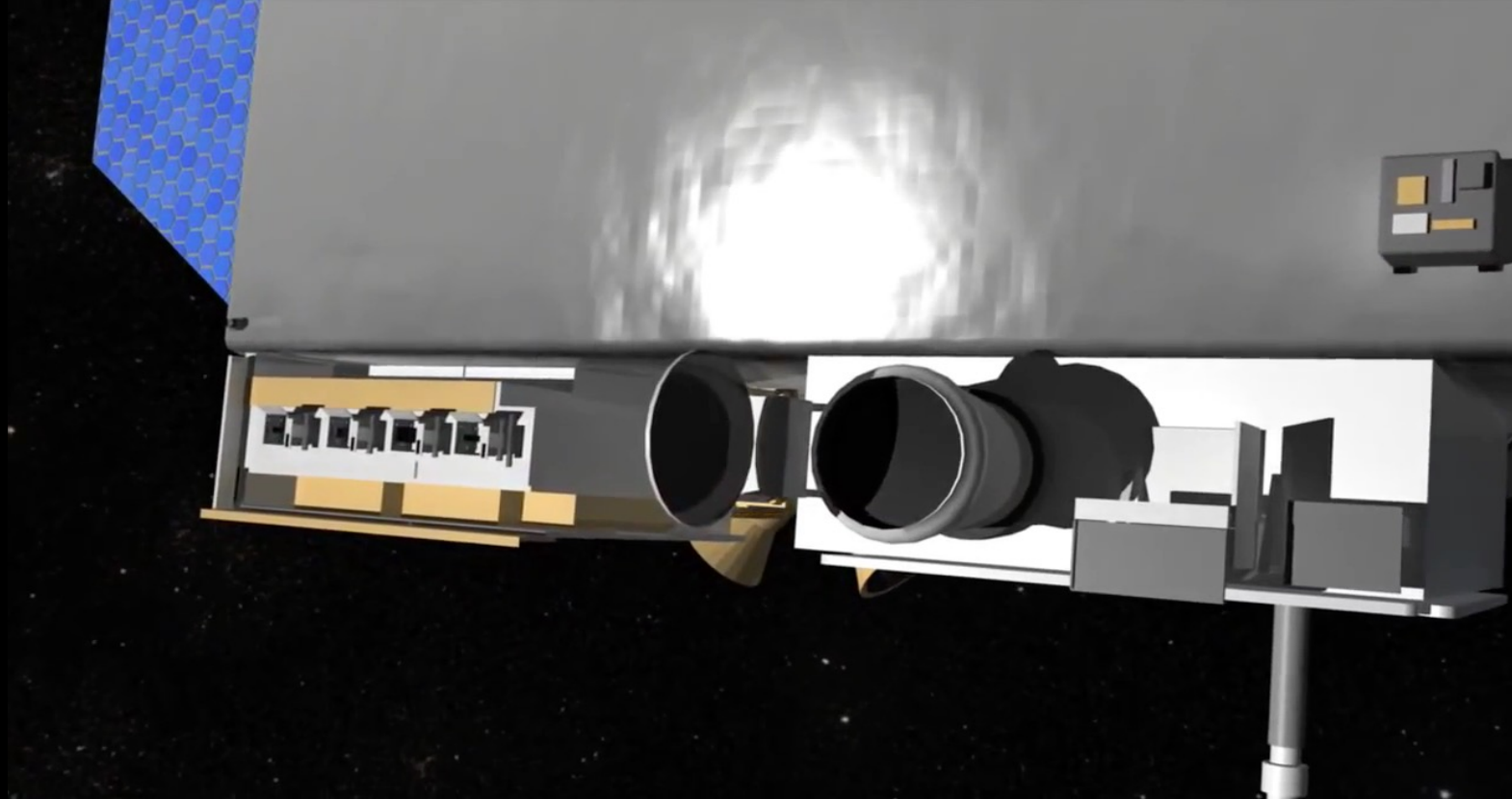


Sept. 10, 2017, X8.2-class solar flare observed by SDO. The video shows a blend of light from the 171- and 304-angstrom wavelengths.  
Image credit: SDO/NASA

# Coronal Holes



- Appear in the Corona
- Observed in the EUV and soft X-ray images
- Cooler and less dense than surrounding plasma
- Associated with open and unipolar magnetic field lines which allows the solar wind to escape more easily to the space
- Produces the fast solar winds, referred to as high-speed streams
- Develop at any time, but more common and persistent during solar minimum



## Near-Earth Space Observation

### Solar Dynamic Observatory (SDO) Satellite

- Launched in : February 2010 Orbit: ~35,000 km
- HMI: Studies oscillation and magnetic field at photosphere
- AIA: Studies the sun in multiple wavelength (white light, Seven EUV & two UV)
  - EVE: Studies solar EUV irradiance

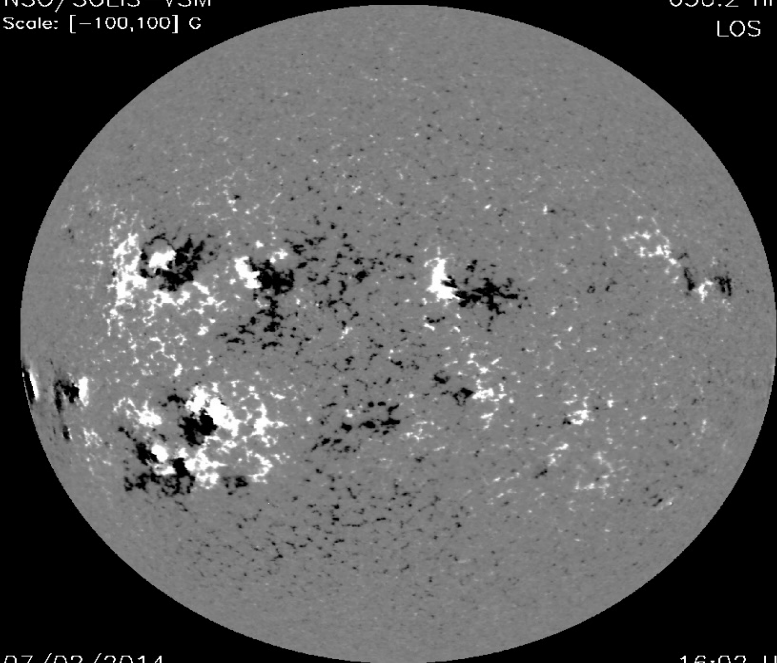


# Zeeman effect

- In the presence of a magnetic field, the energy levels of atoms are split into more than one level
- This causes spectral lines to also be split into more than one line, with the amount of splitting proportional to the strength of the magnetic field
- This effect is called the Zeeman Effect
- A magnetograph is used to measure sunspot's magnetic fields strength and direction

NSO/SOLIS-VSM  
Scale: [-100,100] G

630.2 nm  
LOS B



07/02/2014

16:02 UT

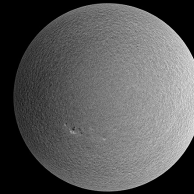
**Magnetogram**

07.02.2014

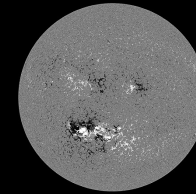
Iron spectral line at 8468 Å

# Solar observations

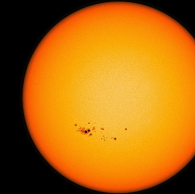
- Solar Cycle, sunspot, flare, CME, coronal holes
- Declining phase or minimum
- <https://heliviewer.org/>
- <https://solarmonitor.org/index.php>



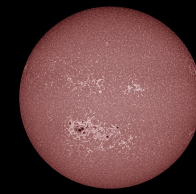
HMI Dopplergram  
Surface movement  
Photosphere



HMI Magnetogram  
Magnetic field polarity  
Photosphere



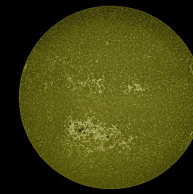
HMI Continuum  
Matches visible light  
Photosphere



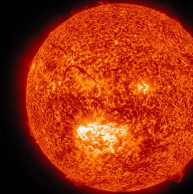
AIA 1700 Å  
4500 Kelvin  
Photosphere



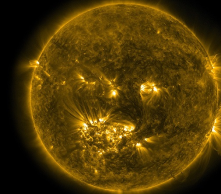
AIA 4500 Å  
6000 Kelvin  
Photosphere



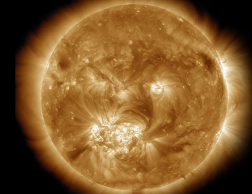
AIA 1600 Å  
10,000 Kelvin  
Upper photosphere/  
Transition region



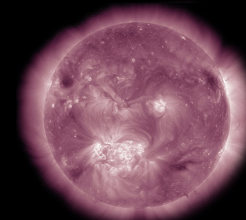
AIA 304 Å  
50,000 Kelvin  
Transition region/  
Chromosphere



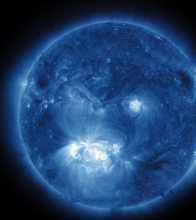
AIA 171 Å  
600,000 Kelvin  
Upper transition  
Region/quiet corona



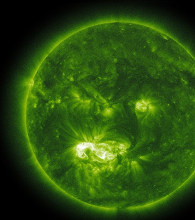
AIA 193 Å  
1 million Kelvin  
Corona/flare plasma



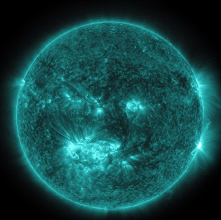
AIA 211 Å  
2 million Kelvin  
Active regions



AIA 335 Å  
2.5 million Kelvin  
Active regions



AIA 094 Å  
6 million Kelvin  
Flaring regions



AIA 131 Å  
10 million Kelvin  
Flaring regions

# Helio viewer website

Helioviewer.org

2023/04/27 17:29:22 UTC ○ NEWEST

Jump: 1 Day

▼ Observation Date

▼ Images + Add Layer

▼ AIA 304 2023/04/27 16:56:29 UTC

Opacity:

Observatory: SDO

Instrument: AIA

Measurement: 304

Difference: No difference ima

▼ Features and Events

▼ HEK 2023/04/27 17:29:22 UTC

check all  check none

- Active Region
- Coronal Cavity
- Coronal Dimming
- Coronal Hole
- Coronal Jet
- CME
- Coronal Rain
- Coronal Wave
- Emerging Flux
- Eruption
- Filament
- Filament Activation
- Filament Eruption
- Flare

Data Sources

Earth Scale

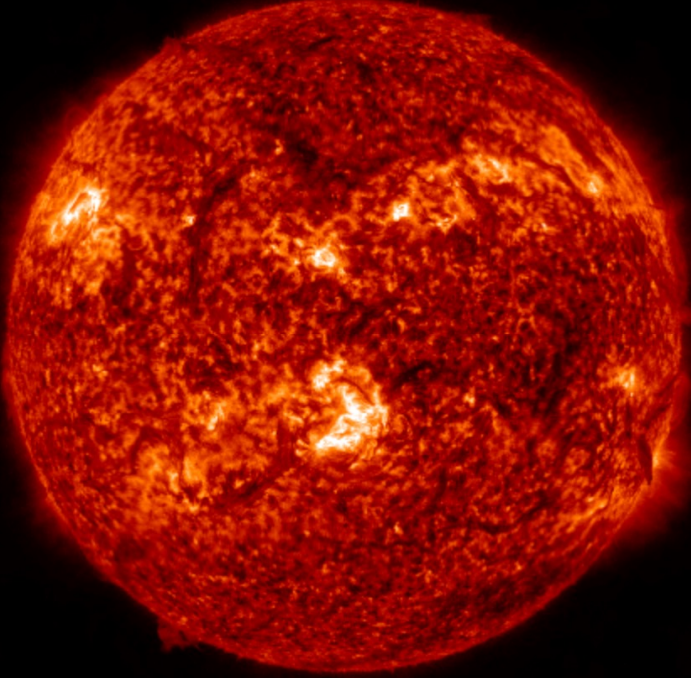


Image Timeline Events Timeline

# Helio viewer website

Helioviewer.org

Observation Date: 2014/10/22 17:29:22 UTC NEWEST

Jump: October 2014

Images	Sun	Mon	Tue	Wed	Thu	Fri	Sat
HMI Mag	28	29	30	1	2	3	4
Obs	5	6	7	8	9	10	11
In	12	13	14	15	16	17	18
Meas	19	20	21	22	23	24	25
Features	26	27	28	29	30	31	1
HEK	2	3	4	5	6	7	8

- Active Region (25)
  - SPoCA (8)
  - HMI SHARP (13)
  - NOAA SWPC Observer (4)
- Coronal Cavity
- Coronal Dimming
- Coronal Hole (10)
  - SPoCA (10)
- Coronal Jet
- CME
- Coronal Rain
- Coronal Wave
- Emerging Flux (1)
  - Emerging flux region module (1)

AR NOAA 12194  $\beta\gamma$

AR NOAA 12192  $\beta\gamma$

AR NOAA 12193  $\beta\gamma$

AR NOAA 12187  $\beta\gamma$

Earth Scale

Image Timeline Events Timeline

Date Search

27 April 2023

NOAA Search

←20230426 ←Week ←Rotation

Today

Rotation⇒ Week⇒ 20230428⇒

Main

Far-side

SDO short-wave

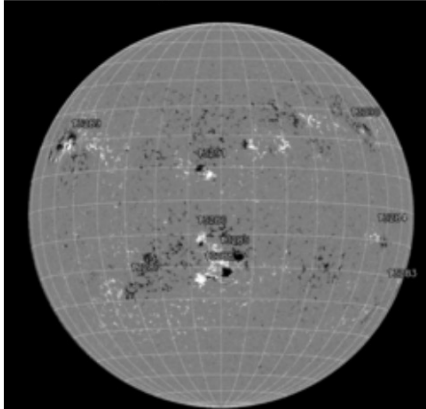
SDO long-wave

NOAA  
9 Active  
Regions

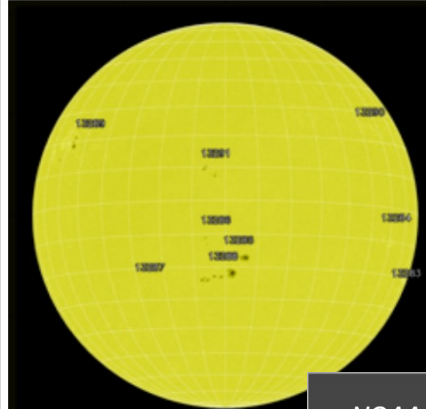
Flare  
Forecast

Coronal  
Holes

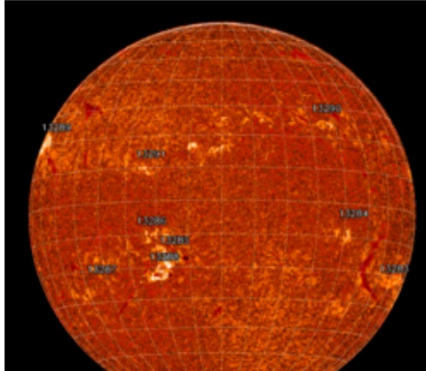
HMI Mag 20230427 13:58



HMI 6173Å 20230427 14:34



GHN Hα 20230426 06:04



GOES  
ACE  
SDO/EVE  
Events

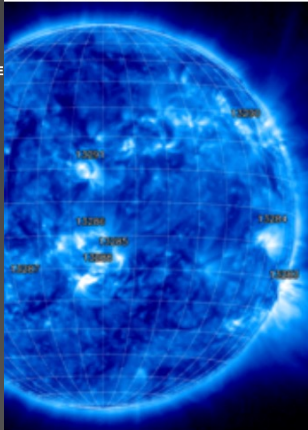
Today's/Yesterday's NOAA Active Regions

NOAA Number	Latest Position	Hale Class	McIntosh Class	Sunspot Area [millionths]	Number of Spots	Recent Flares
13285	S17W04 (63",-206")	β/β	Cso/Cao	0120/0220	04/05	- / C2.7(23:57)
13286	S11E03 (-49",-107")	α/	Axx/	0010/	02/	-
13288	S22E01 (-15",-286")	β/β	Dso/Dso	0140/0180	05/04	M1.8(11:04) C1.4(10:30) C1.2(09:37) C1.0(09:14) C1.2(08:42) / -
13289	N20E49 (-677",372")	β/α	Dso/Hax	0150/0090	03/02	-
13290	N24W54 (705",427")	β/-	Dro/---	0040/---	03/--	-
13291	N09E03 (-49",224")	β/-	Bxo/---	0020/---	04/--	-
13283	S23W91 (876",-372")	/	/	/	/	-
13284	S08W62 (834",-97")	/α	/Axx	/0005	/01	-
13287	S25E26 (-380",-341")	/α	/Axx	/0010	/01	-

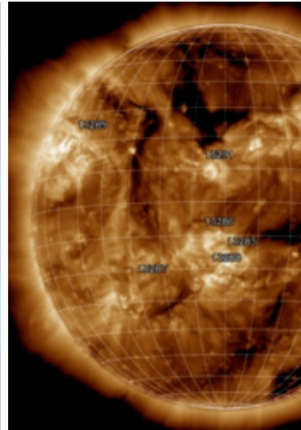
Class (HH:MM) -Today

Class (HH:MM) -Yesterday

CHIMERA 174Å 20230427 12:37



AIA 193Å 20230427



www.SolarMonitor.org

Date Search 27 April 2023 NOAA Search

←20230426 ←Week ←Rotation Today Rotation⇒ Week⇒ 20230428⇒

NOAA 9 Active Regions

Flare Forecast

Coronal Holes

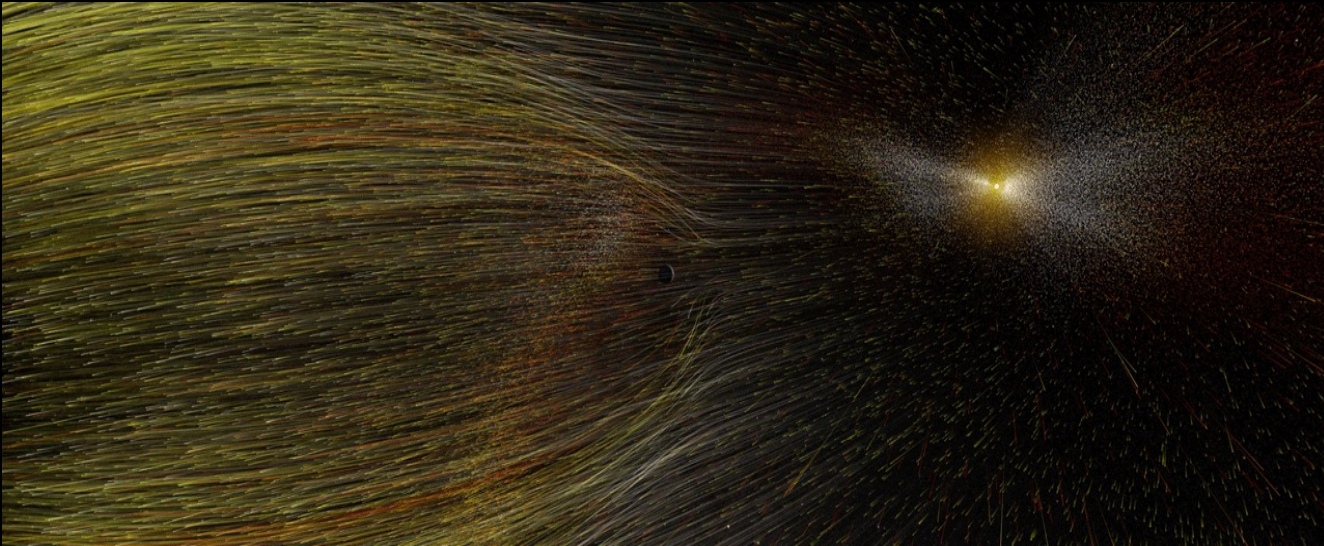
CHIMERA Coronal Holes at 27-Apr-2023 15:24:40.843 UT

GOES ACE SDO/EVE Events

SolarMonitor.org

X (arcsecs)

# Solar wind



Credit: NASA/Goddard

- **Continuous** stream of charge particles, mostly electrons and protons
- Average speed 400 (km/s)
- Fast solar wind (~750 km/s)
- Slow solar wind (~350 km/s)

# Observations at L1:

- Lagrange points: Zones in space where the gravitational and centrifugal force of two bodies balance out
- Lagrange points can be used by spacecraft to reduce fuel consumption needed to remain in position
- L1 ~1.5 million km
- Spacecraft in L1: SOHO, DSCOVR, ACE, Wind

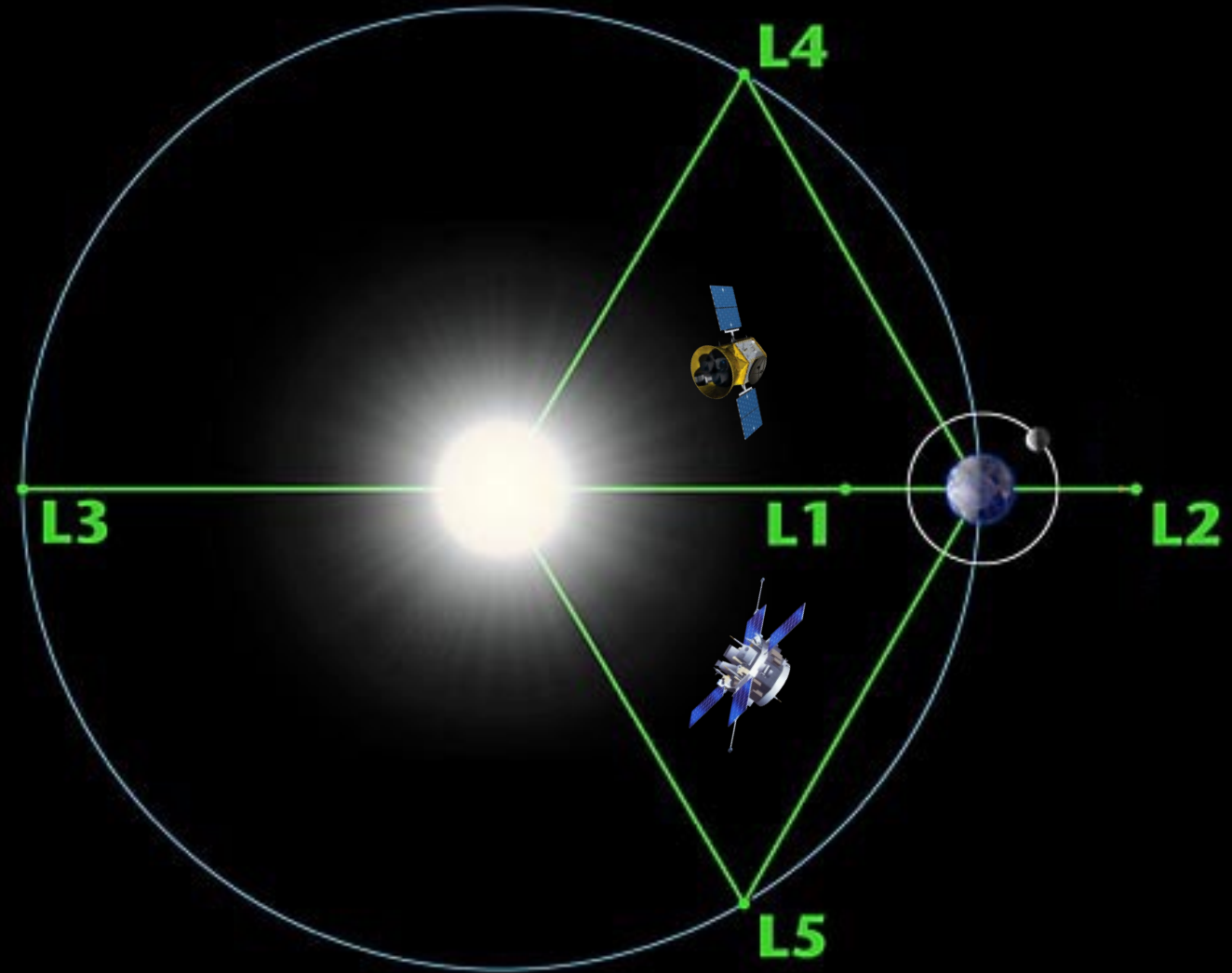
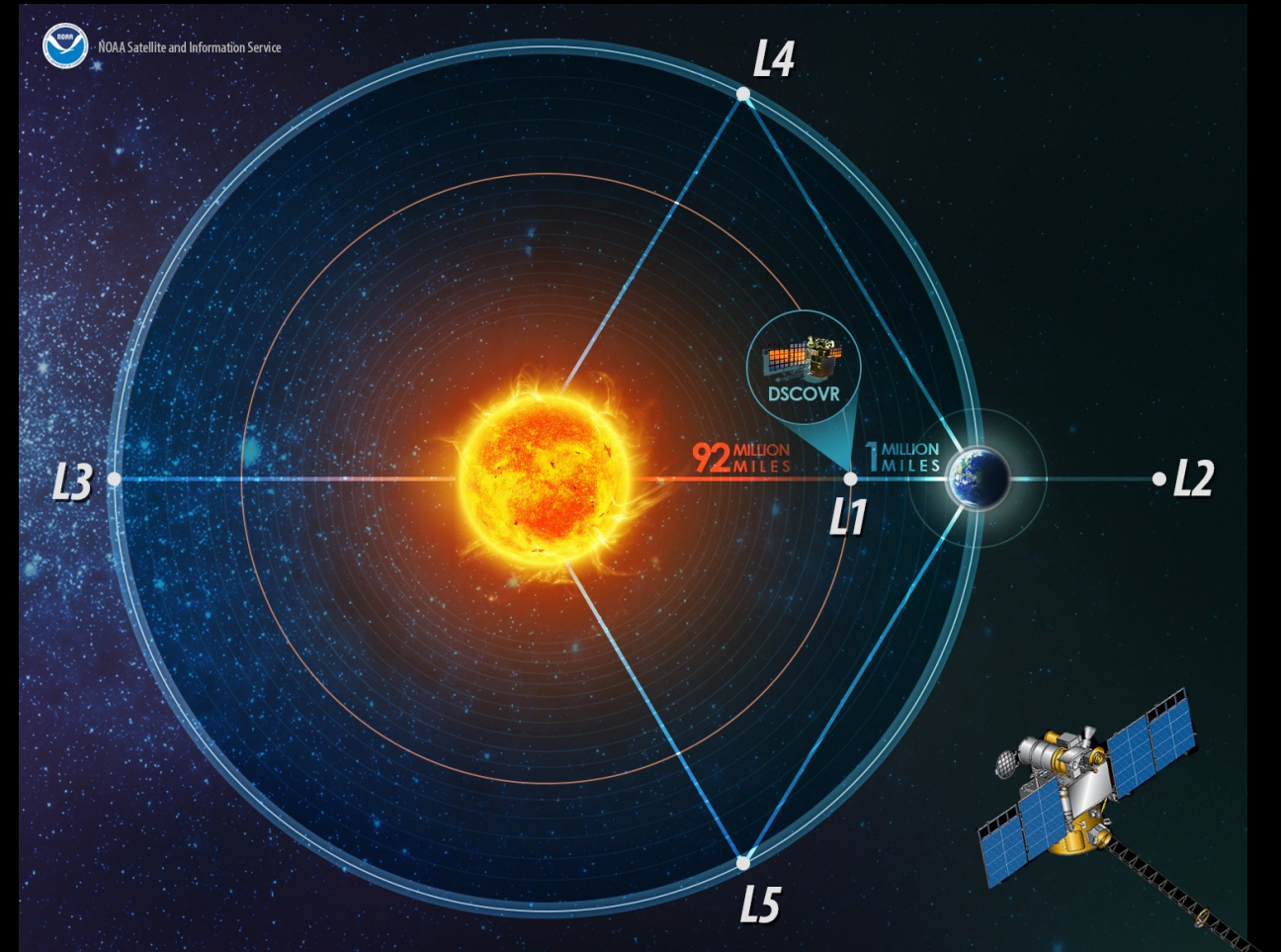


Image credit: NASA/WMAP Science Team

# Solar Wind data

- Deep Space Climate Observatory (DSCOVR) Satellite
- Built in 2001, Launched February 2015
- PlasMag Instrument:
  - Part 1: a vector magnetometer
  - Part 2: a Faraday cup, measures the three-dimensional distribution function of proton and alpha components
  - Part 3: a “top-hat” analyzer, gives 3-D electron velocity distribution functions



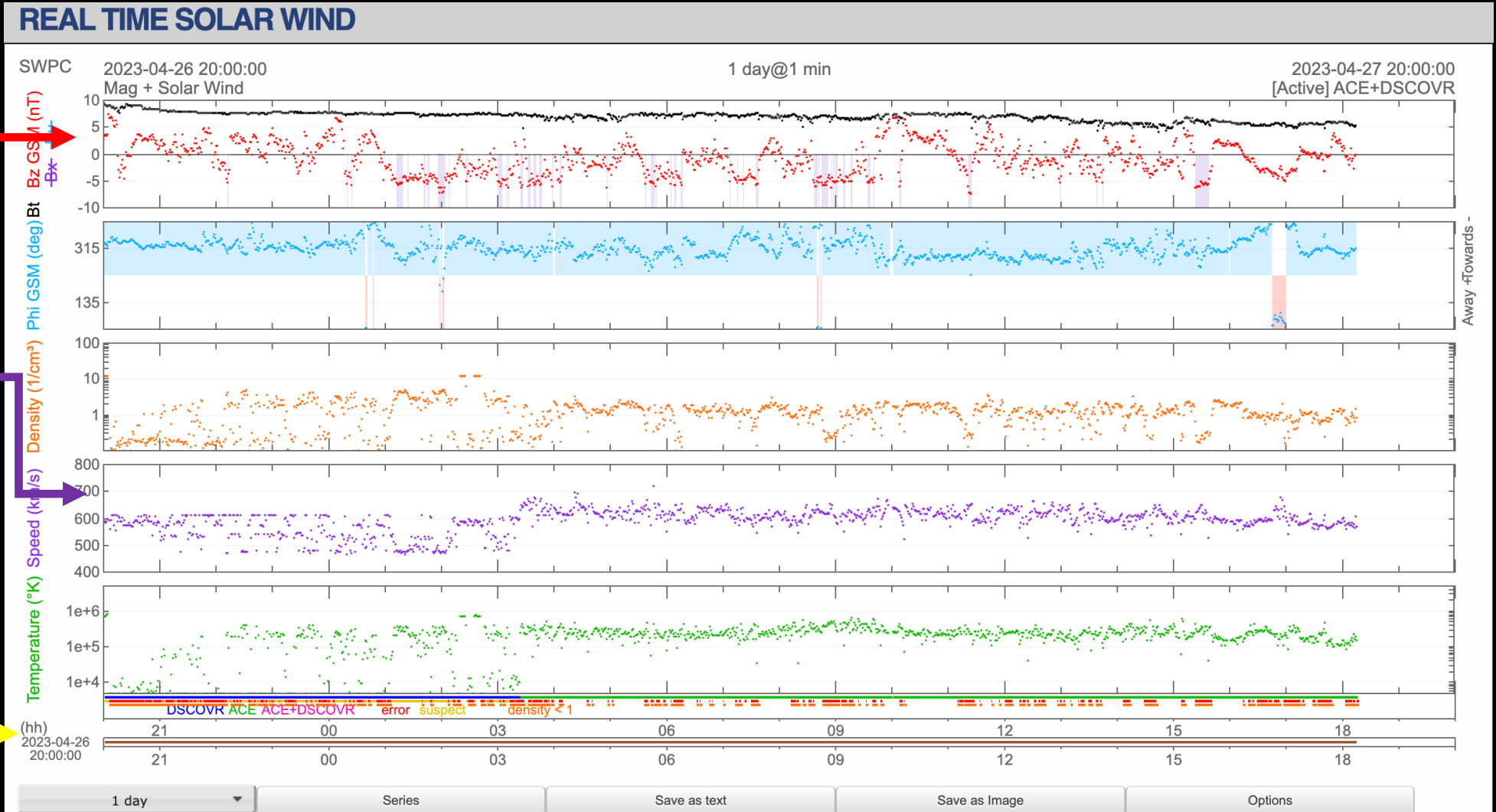


# What to look

**Z**  
component  
of the  
solar wind  
magnetic  
field

Solar wind  
Speed

Note  
Coordinated  
Universal  
Time (UTC)



# You can also find DSCOVR data at this website:

- Space Weather website <http://spaceweather.com/>

The screenshot shows the homepage of spaceweather.com. At the top, there is a navigation bar with links for 'AURORA ALERTS', 'SUBMIT YOUR PHOTOS', 'CONTACT US', 'SUBSCRIBE', 'FLYBYS', and 'EARTH TO SKY'. A search bar is located in the top right corner with the text 'Subscribe to SpaceweatherNews' and a 'go!' button. The main content area is divided into several sections. On the left, there is a 'Current Conditions' section with the following data: Solar wind speed: 320.9 km/sec, density: 12.1 protons/cm<sup>3</sup>, and more data links for ACE and DSCOVR. Below this is the 'X-ray Solar Flares' section, showing a 6-hr max of A3 and a 24-hr max of B4. The 'Daily Sun: 03 Mar 18' section features a large orange sun with a sunspot labeled '2700'. A caption below the sun states: 'Sunspot AR2700 is in an advanced state of decay, and now consists mainly of a white magnetic froth called plage. Credit: SDO/HMI'. The 'Sunspot number: 11' section includes a link 'What is the sunspot number?' and is dated 'Updated 03 Mar 2018'. The 'Spotless Days' section provides statistics for the current stretch and for the years 2018, 2017, 2016, and 2015. On the right side, there is a 'What's up in space' section with the date 'Saturday, Mar. 3, 2018'. It contains three articles: 'Lights Over Lapland' with a 'Ranked #1' badge, 'GEOMAGNETIC OUTLOOK', and 'VENUS-MERCURY CONJUNCTION'. Below the 'VENUS-MERCURY CONJUNCTION' article is a large image showing the sunset sky with Venus and Mercury visible. A smaller inset image shows the two planets more clearly. At the bottom of the page, there are several promotional banners for 'MARIANNE'S HEAVEN ON EARTH Aurora Chaser Tours', 'Tours in Small Groups' (www.gtice.is), 'Averted Imagination', and 'FOR RENT'.

spaceweather.com  
News and information about the Sun-Earth environment

Subscribe to SpaceweatherNews  
go!

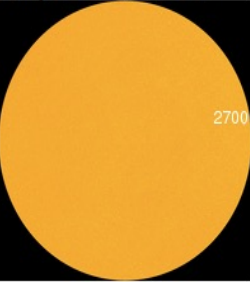
AURORA ALERTS | SUBMIT YOUR PHOTOS | CONTACT US | SUBSCRIBE | FLYBYS | EARTH TO SKY

Current Conditions

Solar wind speed: 320.9 km/sec  
density: 12.1 protons/cm<sup>3</sup>  
more data: [ACE](#), [DSCOVR](#)  
Updated: Today at 1634 UT

X-ray Solar Flares  
6-hr max: A3 1347 UT Mar03  
24-hr: B4 0407 UT Mar03  
[explanation](#) | [more data](#)  
Updated: Today at: 1600 UT

Daily Sun: 03 Mar 18



Sunspot AR2700 is in an advanced state of decay, and now consists mainly of a white magnetic froth called plage. Credit: SDO/HMI

Sunspot number: 11  
[What is the sunspot number?](#)  
Updated 03 Mar 2018

Spotless Days  
Current Stretch: 0 days  
2018 total: 28 days (46%)  
2017 total: 104 days (28%)  
2016 total: 32 days (9%)  
2015 total: 0 days (0%)

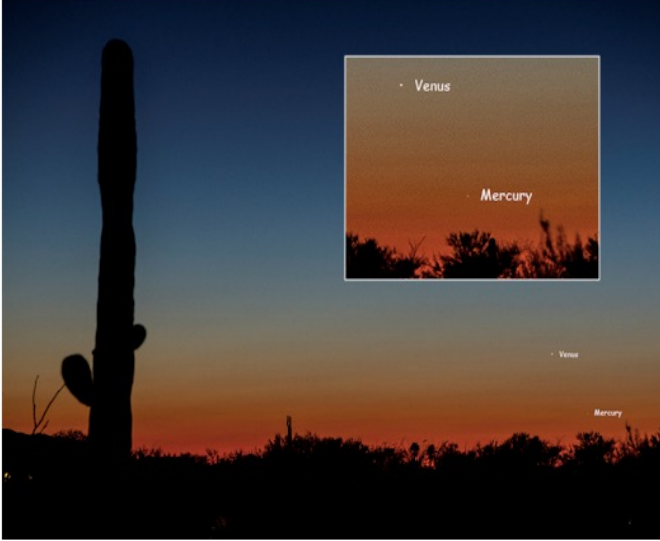
What's up in space  
Saturday, Mar. 3, 2018

Lights Over Lapland is excited to announce that we now have TWO aurora webcams covering nearly a 200° view of Abisko National Park in Sweden! Watch the auroras dance live, all season long [here](#).

**Ranked #1**

**GEOMAGNETIC OUTLOOK:** Earth's magnetic field is expected to be mostly undisturbed for the first three days of March. Geomagnetic activity might increase, however, on **March 4th** when solar wind flowing from [a northern hole](#) in the sun's atmosphere grazes our planet. Arctic sky watchers should be alert for auroras at that time. Free: [Aurora Alerts](#)

**VENUS-MERCURY CONJUNCTION:** Returning to the evening sky after a nearly 11 month absence, Venus is once again beaming through the twilight, low in the western sky after sunset. This weekend, Mercury is there, too. Eliot Herman photographed the two planets converging over Tucson, Arizona:



"Last night, I made this test exposure of Mercury and Venus after sunset," says

archives  
March  
3  
2018  
view

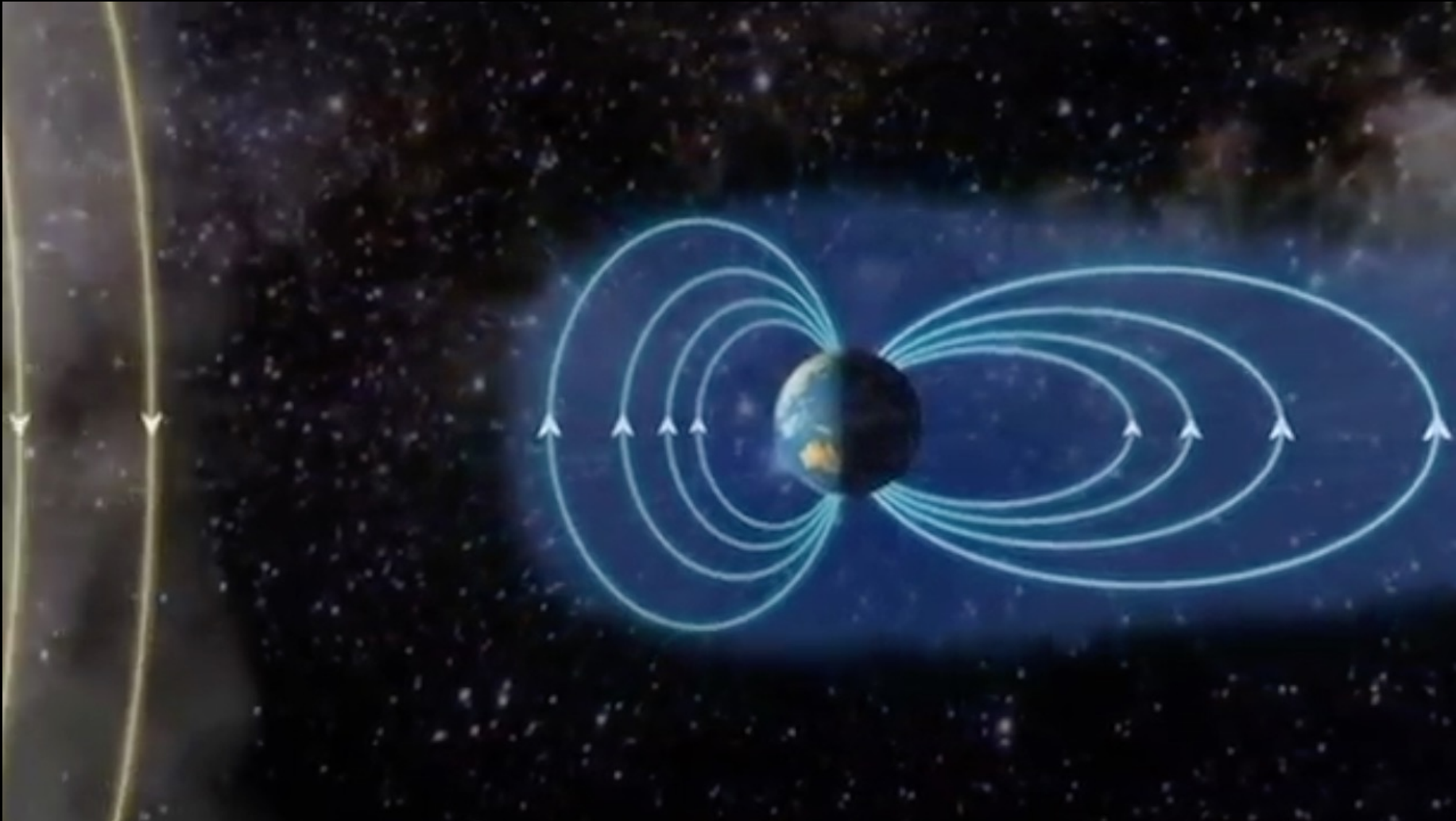
MARIANNE'S HEAVEN ON EARTH  
Aurora Chaser Tours

Tours in Small Groups  
www.gtice.is

Averted Imagination

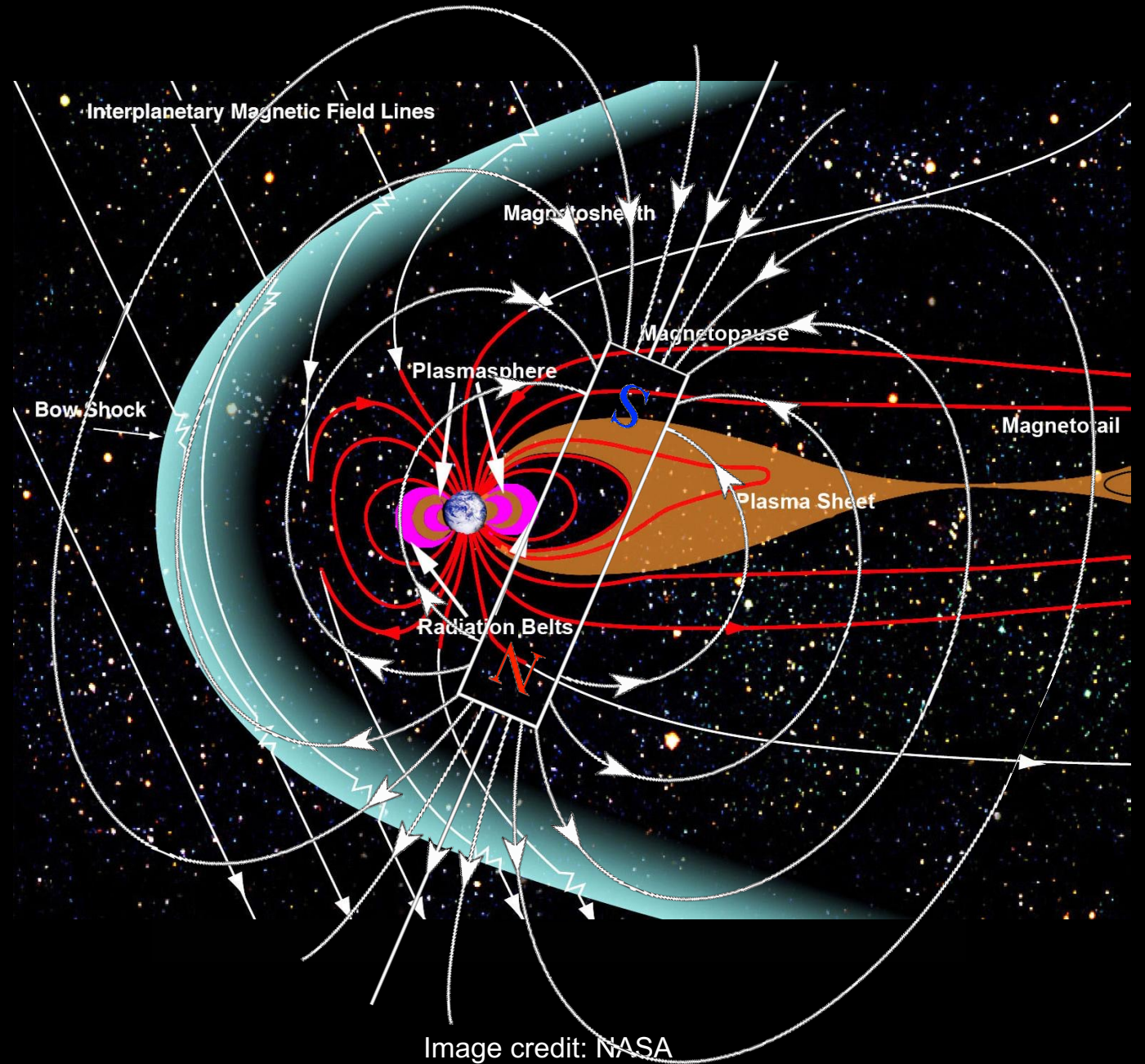
FOR RENT

# How Auroras Are Formed



# Magnetosphere

- When you look at the Earth from space, it looks like it is floating in a black void
- The Earth's core is surrounded by an ocean of liquid metal. The flow of this material creates electric currents, which in turn creates the magnetic field
- The Earth is surrounded by a complex system formed by the interaction of the solar wind with the Earth's magnetic field
- The solar wind compresses the sunward side of the magnetosphere to a distance of  $\sim 10 R_{\oplus}$  and its nightside to possibly  $1000 R_{\oplus}$
- The magnetosphere is highly dynamic



# Magnetopause

- Magnetopause is the boundary between the magnetosphere and solar wind
- Total pressure = thermal + dynamic + magnetic

$$P = n k_B T_i + n m_i V^2 + \frac{B^2}{2\mu_0}$$

$$k_B \sim 10^{-23}$$

Parameters	Solar Wind	Magnetosphere
$k_B T$ [keV]	0.01	5
$n$ [ $\text{cm}^{-3}$ ]	5	0.1
$V$ [km/s]	400	50
$B$ [nT]	5	55
$P_{\text{TH}}$ [nPa]	0.01	0.08
$P_{\text{DYN}}$ [nPa]	1.3	0.0004
$P_B$ [nPa]	0.01	1.2

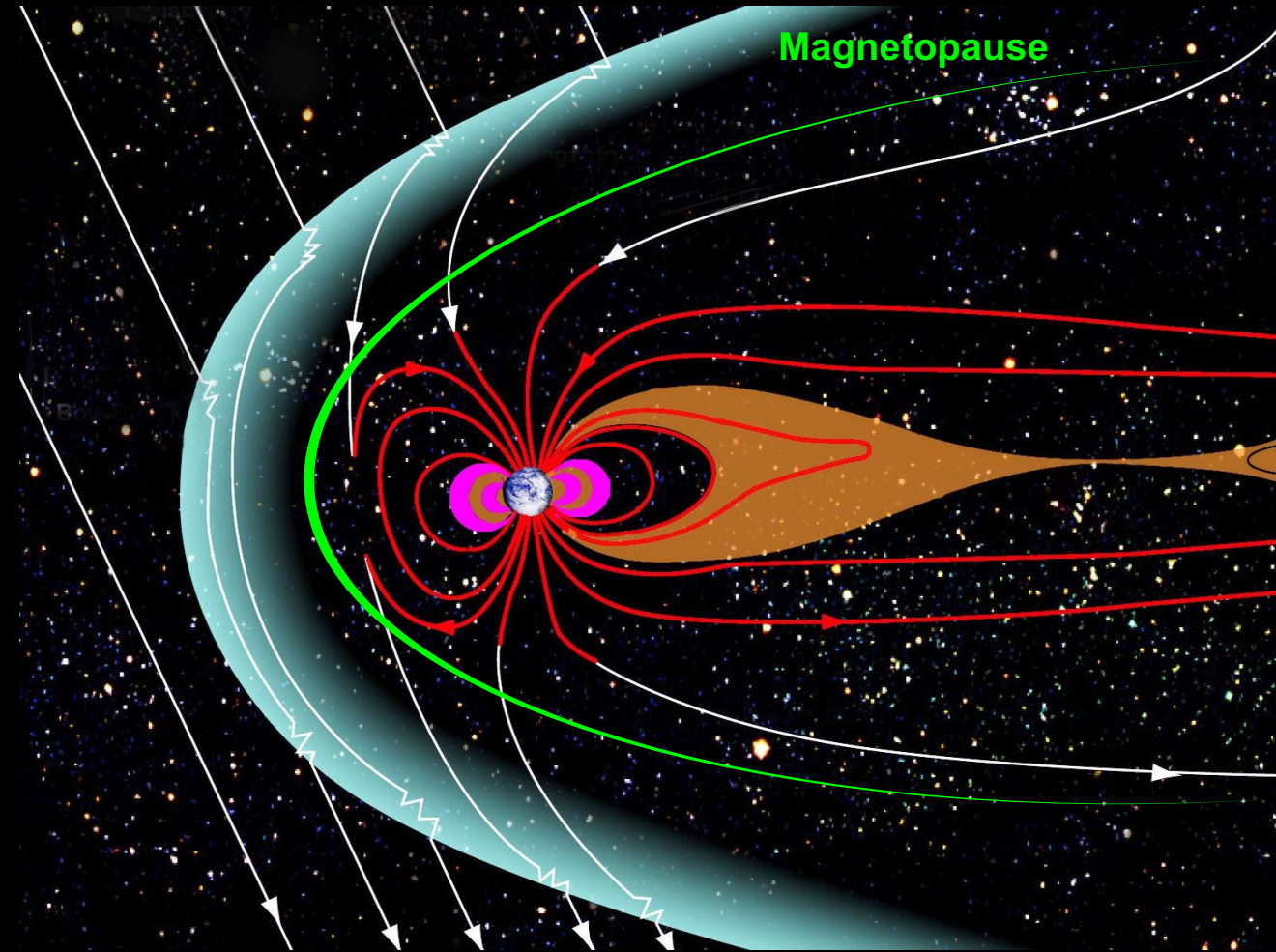


Image credit: NASA/Goddard

# Estimate the magnetopause location

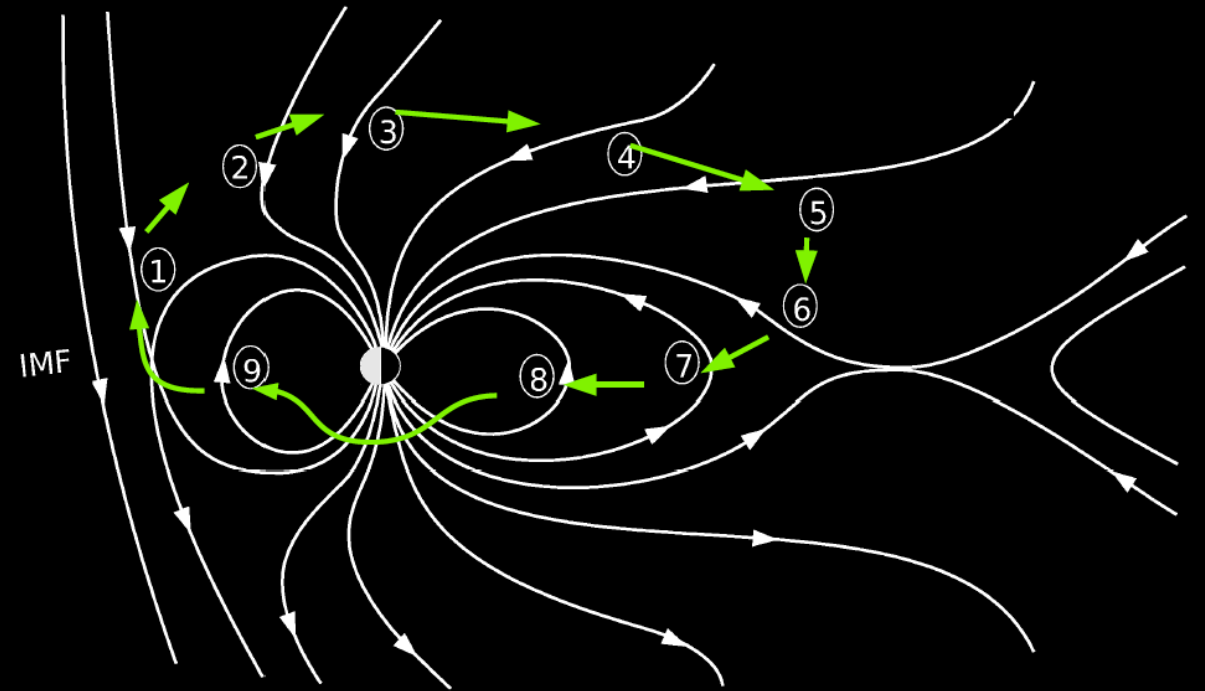
- Remember we are dealing with solar wind which is carrying magnetic field and charged particles
- So the total the pressure will be:

$$P = \underbrace{n k_B T_i}_{\text{Thermal pressure}} + \underbrace{n m_i V^2}_{\text{Dynamic pressure}} + \underbrace{\frac{B^2}{2\mu_0}}_{\text{Magnetic pressure}}$$

- Now read again the definition of the magnetopause
- Note: Inside the magnetopause,  $B_{\text{inside}} \sim 2B_{\text{dipole value}}$

# Consider the Dungey Cycle

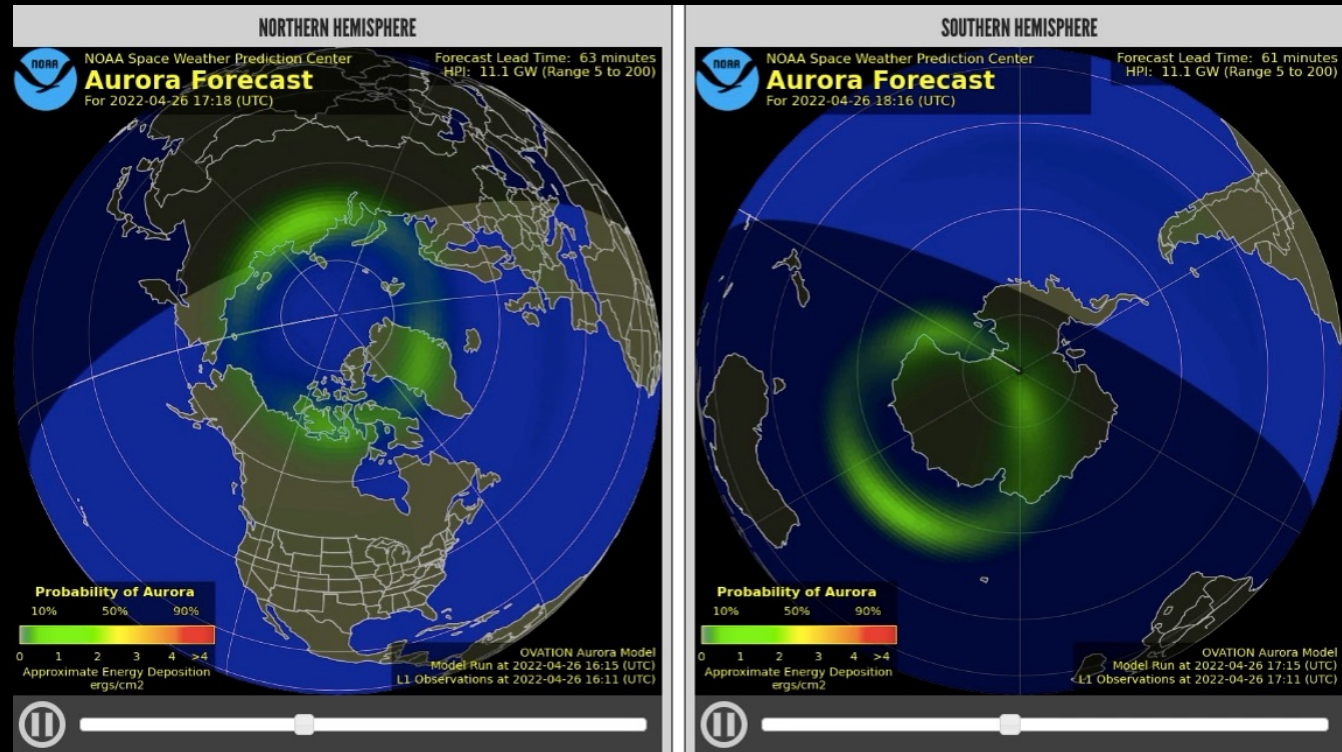
- If IMF has a southward component
- Magnetic reconnection opens the dayside magnetopause
- IMF connects to the Earth magnetic field
- Solar wind flow around the magnetosphere drives a global convective motion



The Dungey cycle. After Dungey, 1961

# OVATION Aurora Forecast

- 30-minute forecast, based on the current solar wind condition at L1
- Remember: The model uses a fixed 30 minutes delay time between L1 and Earth
- You can make better prediction based on the real-time solar wind speed
- <https://www.swpc.noaa.gov/products/aurora-30-minute-forecast>





# Database for the Geomagnetic indices

Check these indices

- Dst index
- AL/AU or AE index
- Kp index

World Data Center for Geomagnetism

- <https://wdc.kugi.kyoto-u.ac.jp/wdc/Sec3.html>

World Data Center for Geomagnetism, Kyoto  
Our website is now always-on SSL; http access will be redirected to https.  
<http://wdc.kugi.kyoto-u.ac.jp/> --> <https://wdc.kugi.kyoto-u.ac.jp/> (April 1, 2022)

operated by  
Data Analysis Center for Geomagnetism and Space Magnetism  
Graduate School of Science, Kyoto University  
Kitashirakawa-Oiwake Cho, Sakyo-ku  
Kyoto 606-8502, JAPAN

TEL: +81-75-753-3929 (075-753-3929, inside Japan)  
FAX: +81-75-722-7884 (075-722-7884, inside Japan)

Home Page | WDC for Geomag, Kyoto | E's magnetic field? | Data Service | I-Magnet | Link

- 1. World Data Center for Geomagnetism, Kyoto**  
Data Analysis Center for Geomagnetism and Space Magnetism,  
Research, Publication list, Staff, Access Guide and Map, WDC system and others
- 2. What is the Earth's magnetic field?**  
Magnetic north, geomagnetic and magnetic pole, Geomagnetic elements,  
Geomagnetic field observation and collection of the data (Geomagnetic observatories on the Google Earth),  
International Geomagnetic Reference field and others
- 3. Geomagnetic Data Service**  
Indices, Geomagnetic Field Data at the Observatories, Models, Data Catalogue and others
- 4. INTERMAGNET Kyoto GIN Home Page**  
QL monitor of INTERMAGNET data, about INTERMAGNET and others
- 5. Link to other sites**  
Kyoto University, ICSU/WDS's, Geomagnetic Observatories, Societies and others

# Ring current

$$R_{\oplus} = 6,371 \text{ (km)}$$

- The **Ring current** is located at  $\sim 3$  to  $8 R_{\oplus}$ , circulates clockwise (when viewed from the north )
- The current produces a B-field in opposition of  $B_{\oplus}$
- Dst index measures the intensity of the ring current
- Dramatic enhancement during geomagnetic storm

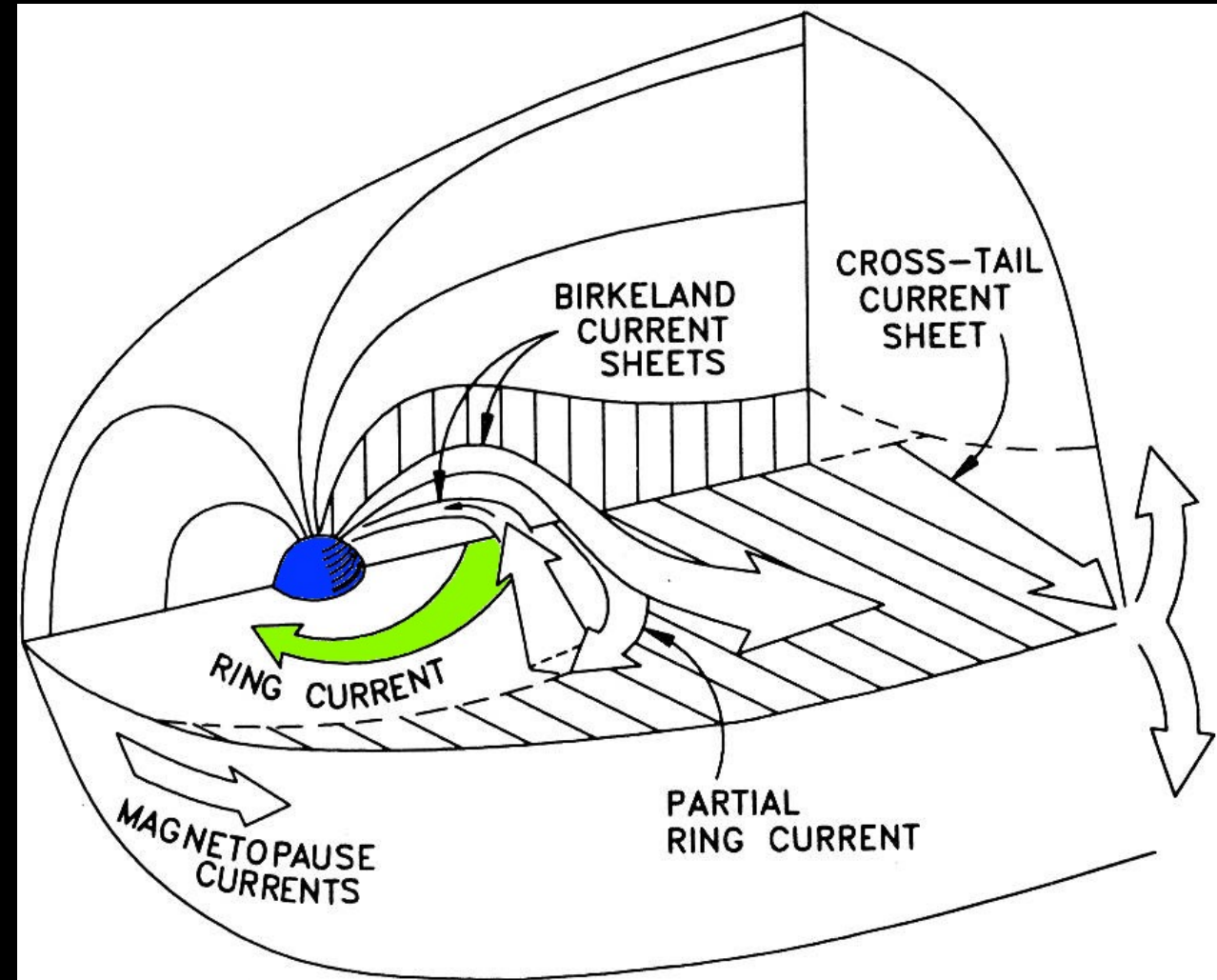
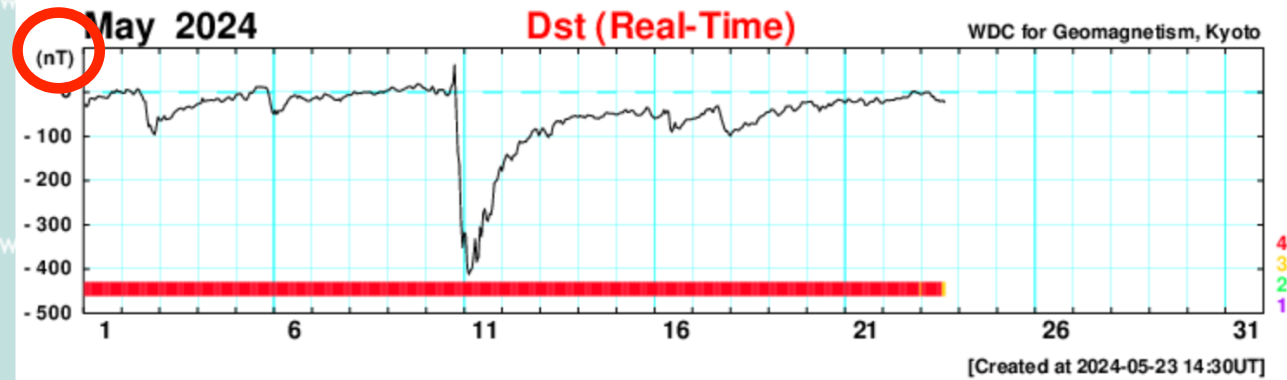


Illustration credit: David P. Stern

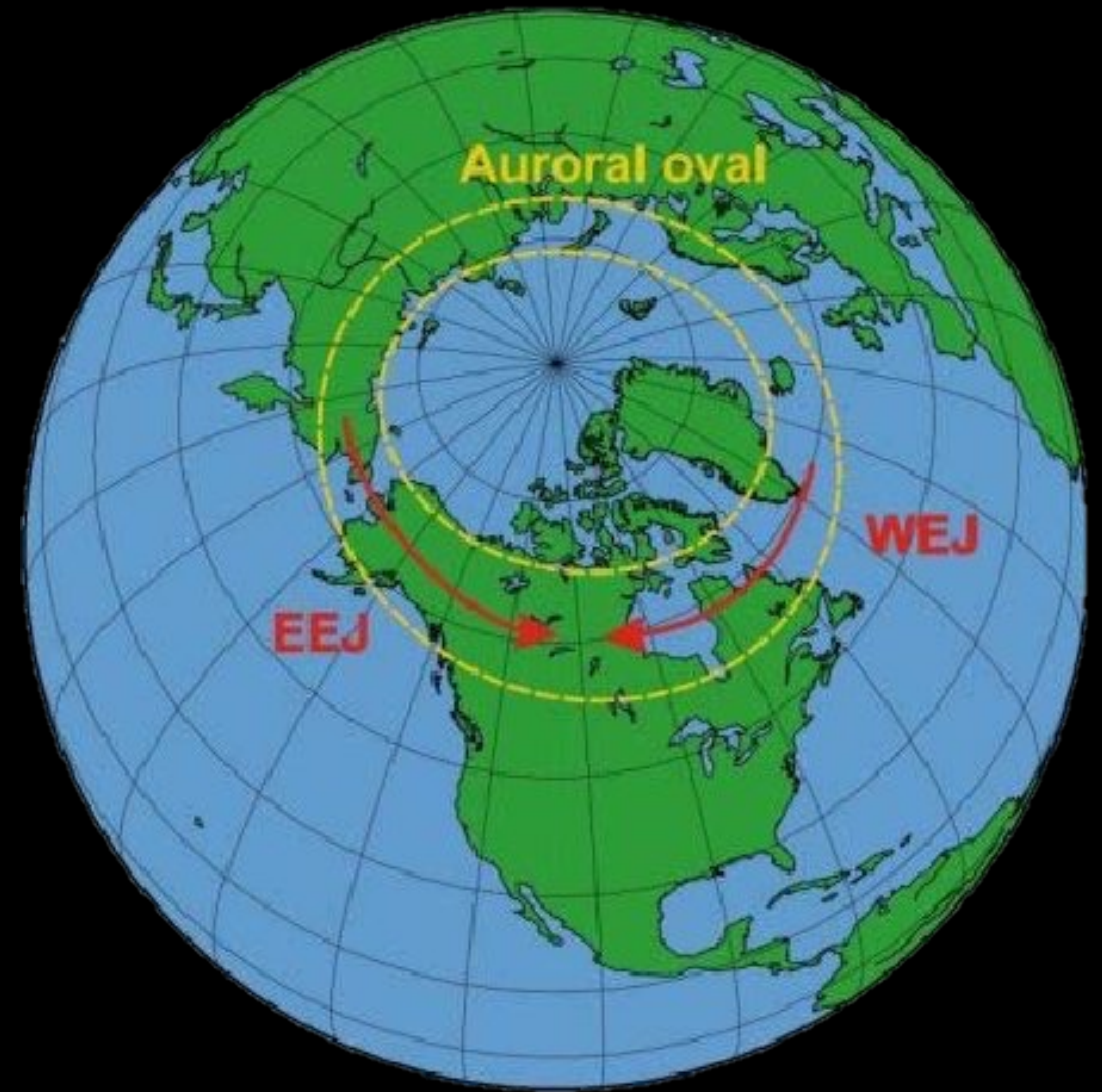


(The data for this month in the wdc-like format is [here](#).)

WDC for Geomag. KYOTO Hourly Equatorial Dst Values (REAL-TIME) MAY 2024																								
DAY	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	-27	-33	-28	-15	-14	-14	-17	-14	-10	-9	-11	-11	-12	-13	-14	-9	-4	1	-2	1	5	1	2	-1
2	-2	-2	6	5	3	2	-4	-4	2	7	5	-4	-9	-19	-21	-54	-78	-74	-85	-93	-96	-77	-56	-63
3	-64	-60	-54	-62	-61	-60	-59	-54	-47	-44	-41	-38	-37	-37	-40	-37	-34	-33	-33	-36	-35	-32	-29	-27
4	-26	-25	-14	-21	-20	-19	-19	-18	-18	-19	-18	-15	-15	-19	-22	-21	-18	-15	-12	-12	-16	-18	-14	-8
5	-4	-5	-3	-8	-14	-17	-17	-9	-1	-2	0	6	12	11	11	12	11	10	11	6	-8	-28	-44	-50
6	-41	-50	-42	-42	-42	-38	-29	-26	-18	-14	-10	-10	-7	-8	-13	-9	-11	-14	-15	-17	-20	-20	-19	-16
7	-14	-13	-10	-14	-16	-14	-10	-4	-5	-7	-8	-10	-13	-16	-18	-18	-16	-20	-14	-12	-10	-8	-6	-7
8	-6	-2	1	-3	-3	-2	-3	-1	0	0	-1	0	0	-3	-5	-5	-2	-2	1	1	-1	2	3	4
9	6	10	11	8	5	3	2	3	5	7	8	11	12	13	10	8	12	16	19	17	14	10	9	6
10	4	3	5	13	6	-4	-3	6	4	6	5	-3	-7	-7	0	13	18	62	-36	-135	-165	-287	-351	-318
11	-322	-397	-412	-403	-399	-369	-332	-384	-373	-306	-326	-274	-264	-287	-292	-275	-277	-253	-206	-202	-197	-179	-169	-178
12	-159	-149	-141	-145	-148	-154	-144	-142	-140	-122	-111	-114	-114	-112	-112	-106	-103	-98	-89	-86	-83	-86	-98	-92
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14	-53	-55	-55	-58	-55	-52	-53	-53	-54	-58	-59	-59	-60	-56	-56	-54	-48	-46	-48	-48	-48	-48	-50	-51
15	-50	-48	-46	-47	-42	-40	-45	-45	-42	-41	-44	-50	-52	-52	-52	-50	-46	-42	-35	-36	-43	-52	-56	-59
16	-58	-58	-55	-54	-49	-40	-49	-42	-46	-82	-90	-80	-69	-81	-81	-83	-76	-72	-67	-62	-62	-62	-62	-60
17	-60	-59	-57	-57	-53	-48	-51	-44	-39	-39	-37	-41	-46	-36	-33	-31	-42	-57	-69	-81	-88	-88	-96	-99
18	-91	-88	-84	-85	-87	-83	-81	-76	-70	-71	-75	-74	-71	-71	-72	-72	-64	-58	-55	-54	-52	-48	-45	-45
19	-43	-39	-40	-44	-48	-53	-51	-47	-44	-40	-32	-33	-31	-32	-38	-43	-41	-38	-35	-31	-23	-23	-24	-23
20	-22	-22	-21	-27	-32	-30	-32	-43	-37	-32	-35	-36	-31	-26	-31	-29	-24	-22	-19	-17	-18	-19	-20	-24

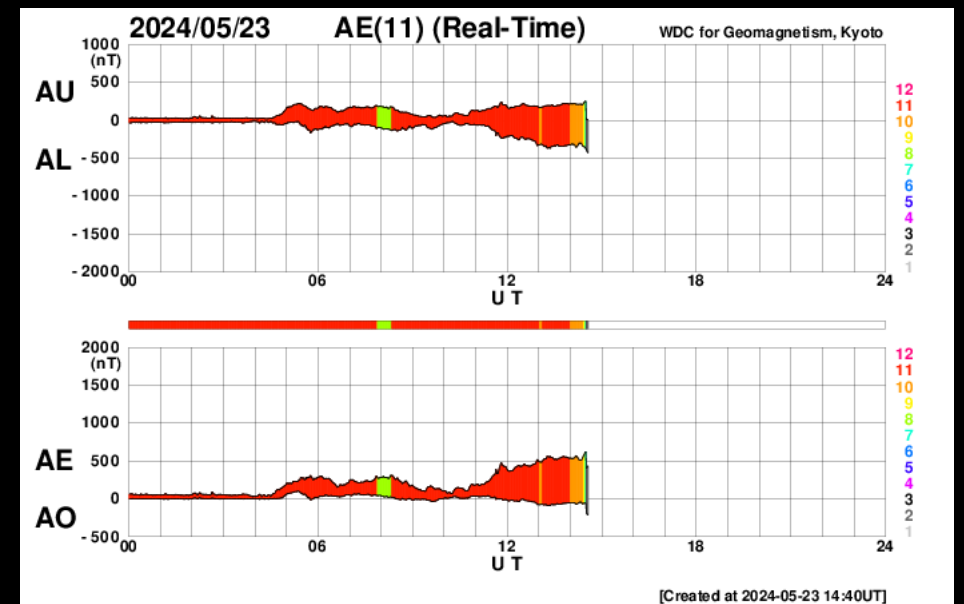
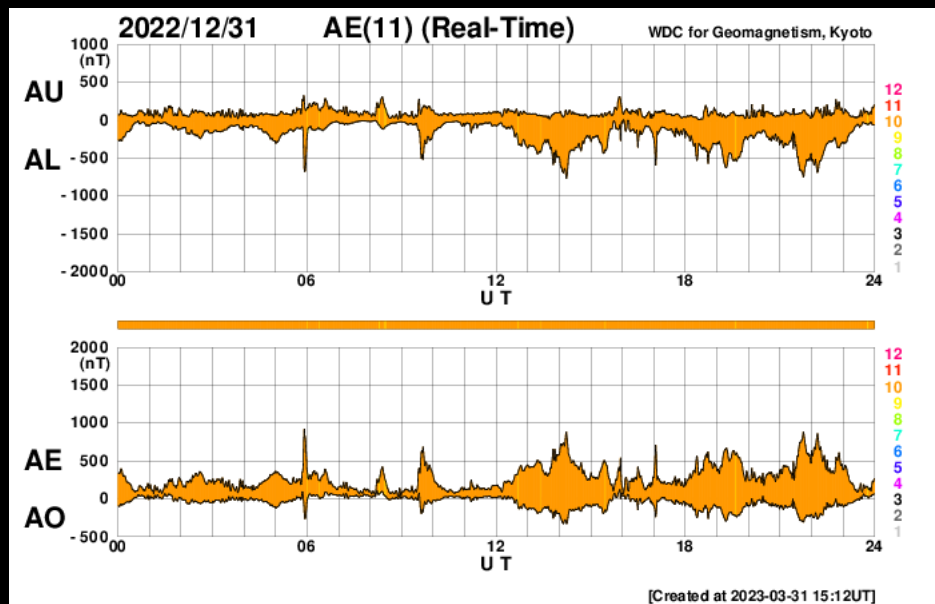
# Auroral Electrojets

- An electrojet is an electric current which travel around the Earth's ionosphere
- Near the Northern and Southern Polar circles
- Enhancement during substorm



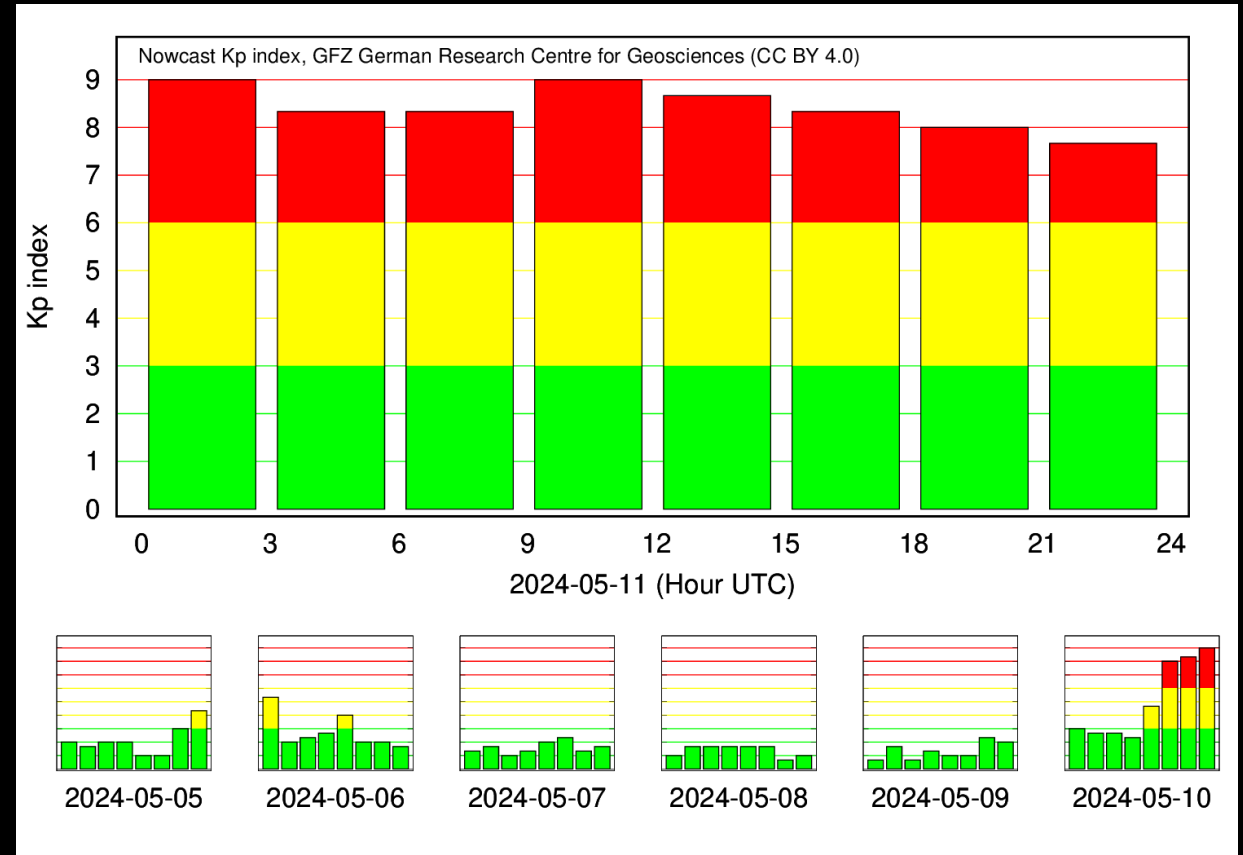
Representation of the East (EEJ) and West (WEJ) auroral electrojet  
Image credit: Piccinelli et al. 2014

# Auroral Electrojet (AE) index



# Kp index

- The  $K_p$  is used to characterize the magnitude of geomagnetic storms,
- Quantifies disturbances in the horizontal component of earth's magnetic field
- <https://kp.gfz-potsdam.de/en/figures/kp-daily-plots>



K<sub>p</sub> index  
Credit: GFZ Helmholtz Centre Potsdam


# All sky camera

Longyearbyen all-sky camera

National Institute of Polar Research



ScreenCast-O-Matic.com

2013/03/02  
18:50'10" 

- Used in meteorology, astronomy and visual observation of auroras
- Capture a photograph of the entire sky
- All-sky cameras that are used for imaging auroras have special optical elements such as fish-eye lenses or spherical mirrors to acquire an image of the whole sky in one shot

# All sky camera data



Tromso, Norway  
Oct. 27, 2010

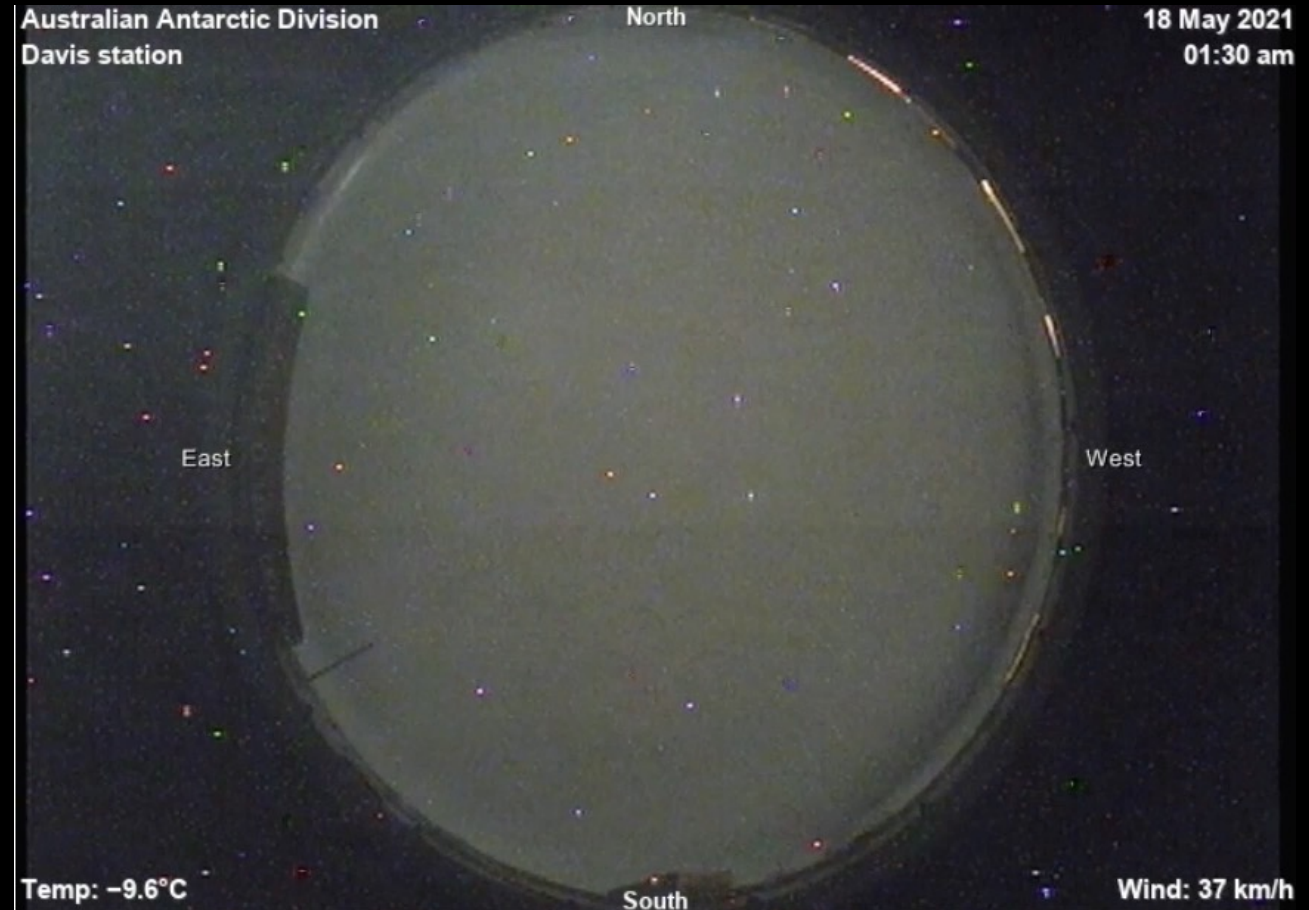
Photo Credit: Terence Murtagh & Nicholas  
Cades Observatory, Kingston, TAS, Australia  
Holdsworth

- Sodankylä Geophysical Observatory  
<http://www.sgo.fi/Data/RealTime/allsky.php>
- Skibotn Observatory, Norway:  
<https://fox.phys.uit.no/ASC/ASC01.html>
- Kiruna station, Sweden:  
[https://www2.irf.se/Observatory/?link=All-sky\\_sp\\_camera](https://www2.irf.se/Observatory/?link=All-sky_sp_camera)
- Syowa (or Showa) station, South Pole:  
<http://polaris.nipr.ac.jp/~acaaurora/aurora/Syowa/> **Not working!**



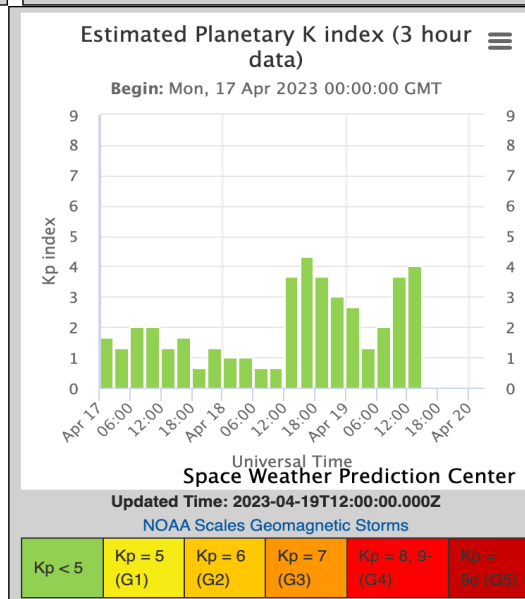
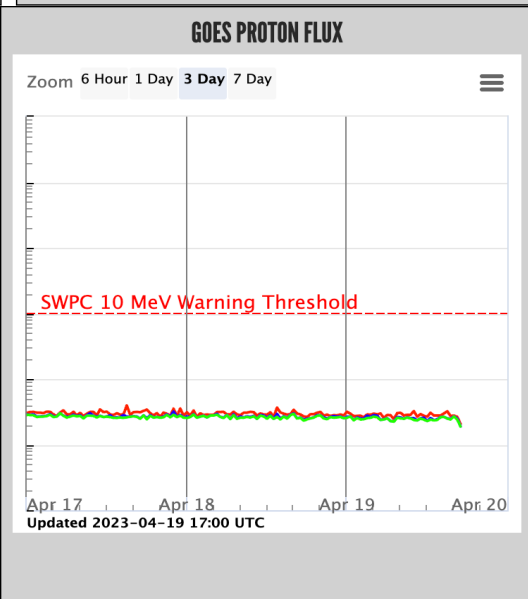
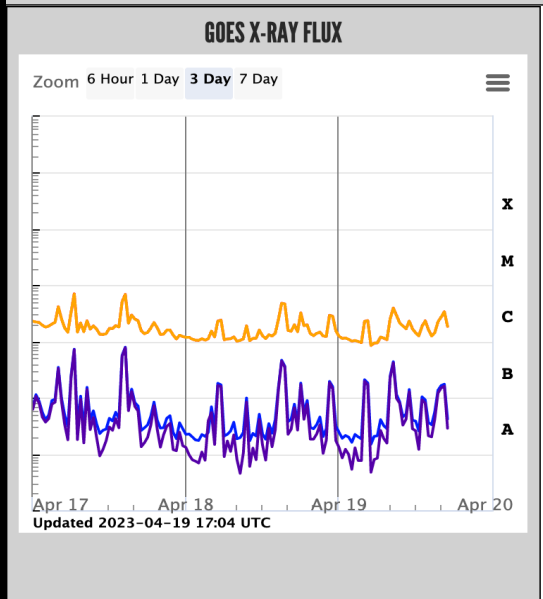
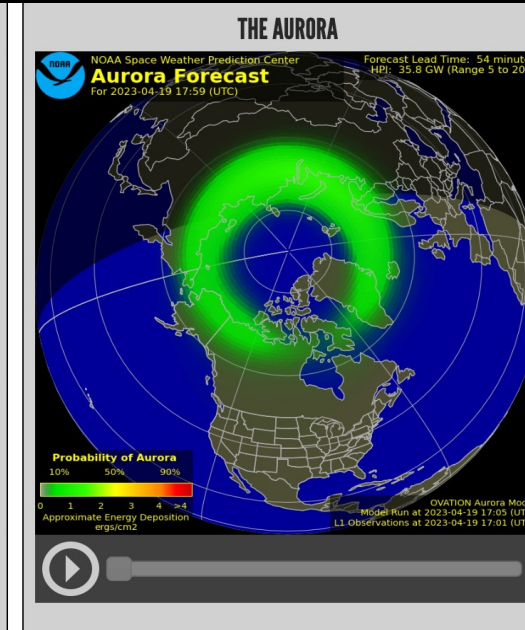
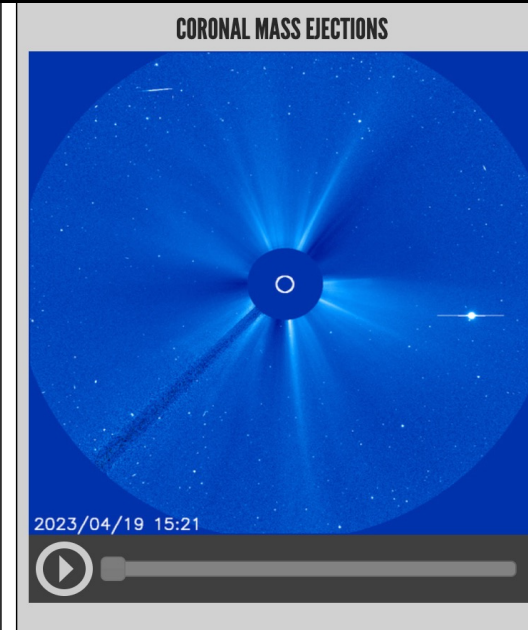
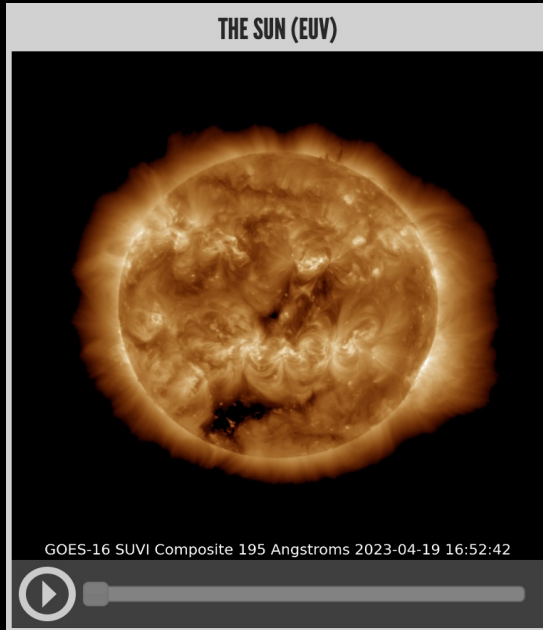
# Davis Station Sky-cam

- Davis station is one of the permanent research center in Antarctica
- Operated by Australian Antarctic Division
- Coordinates:  $68^{\circ} 34' 36''$  S,  $77^{\circ} 58' 3''$  E
- Sky-cam produces images of the full sky and provides a view for the study of Antarctic clouds with similar sensitivity to the naked eye
- <https://www.antarctica.gov.au/antarctic-operations/webcams/davis/>



Sky-cam at the Davis station  
Video credit: Australian Antarctic Division

# NOAA Space Weather Prediction Center



**Summary of what you need to report**

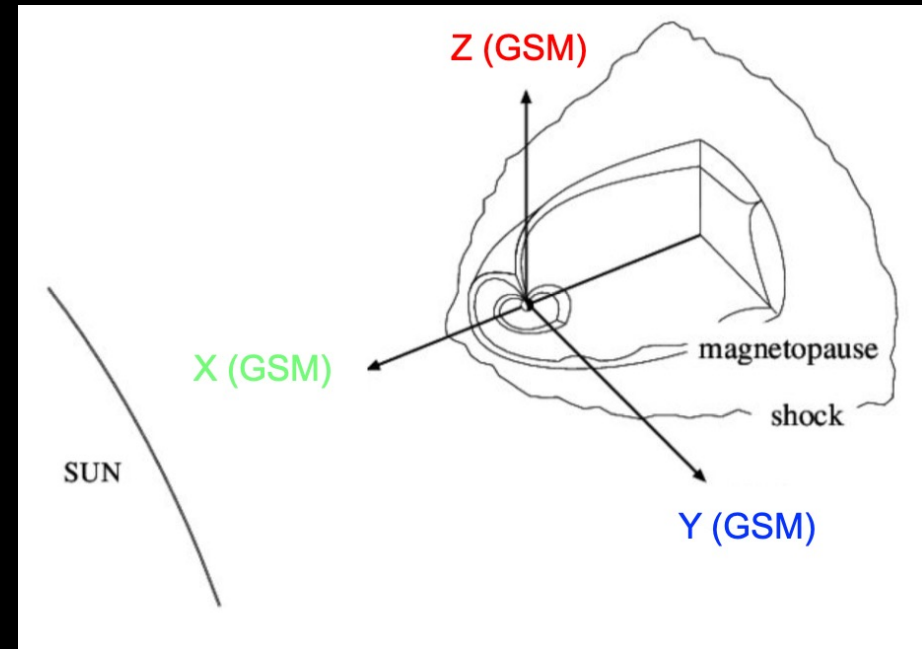
# i. Theory

- **Calculate the location of the magnetopause**
  - Explain the theory and all approximations you need to make
- **Estimate solar wind travel time from L1 to the magnetopause based on your observation**
  - You need to check solar wind data (for example DSCOVR satellite) and pick an average speed
- **Explain which geomagnetic data are more suitable for your forecast and why**
- **Explain the Dungey Cycle**
  - Find a scientific article that estimate the duration of the Dungey cycle and use that estimation for your forecast. Please mention your reference as well.

## ii. Observation

- **Pick a date for your forecast**
- **Find these Solar observations and discuss your findings:**
  - Ground-based and space-based data:
    - Magnetogram data
    - SDO short and long-wave
    - Active regions
    - Coronal holes
    - Solar wind data
    - Flaring activity
- **Show plots of these geomagnetic indices and discuss your findings:**
  - Dst, Kp, and AE
- **Image from all Sky camera data:**
  - North/South Hemisphere

- Phi is the angle of the interplanetary magnetic field that is being carried out by the solar wind
- It is measured in the GSM (geocentric solar magnetospheric) coordinate system
- In this system the X-axis points from the Earth to the Sun and the Z-axis is pointing along the direction of the Earth's north magnetic pole. This puts the Y-axis roughly pointing to the left as one looks at the Sun from the Earth
- Phi is the angle made by the field in the XY plane. This means that Phi would be  $0^\circ$  if it were pointing at the Sun and  $180^\circ$  if it were pointing from the Sun to the Earth. Sudden and rapid changes in the Phi angle in conjunction with increased solar wind speeds and  $B_z$  fluctuations is common during a CME impact



Credit: Eija Tanskanen