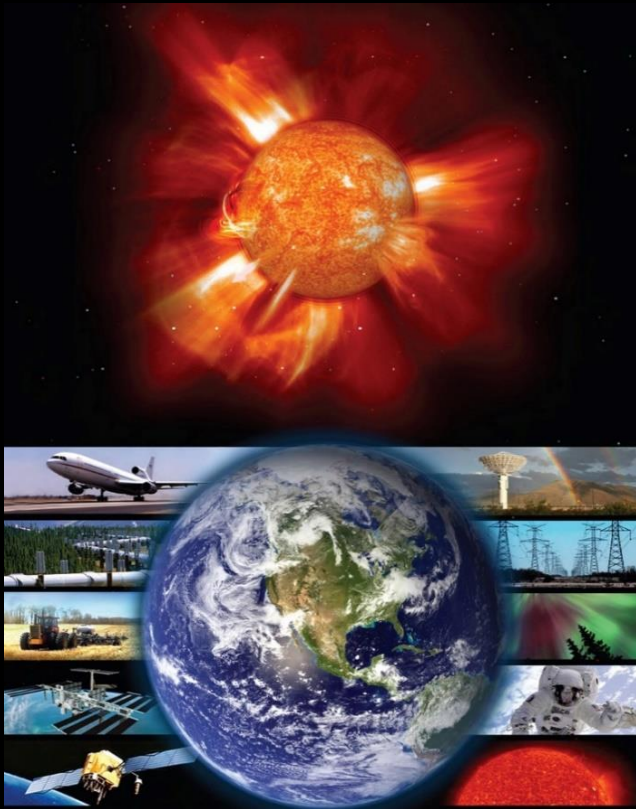


# The physics of Space Weather

*Emiliya Yordanova*



INSTITUTET FÖR RYMFYSIK  
Swedish Institute of Space Physics



*Credit: NASA*

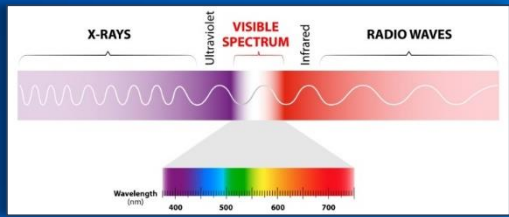


National Space Weather Program

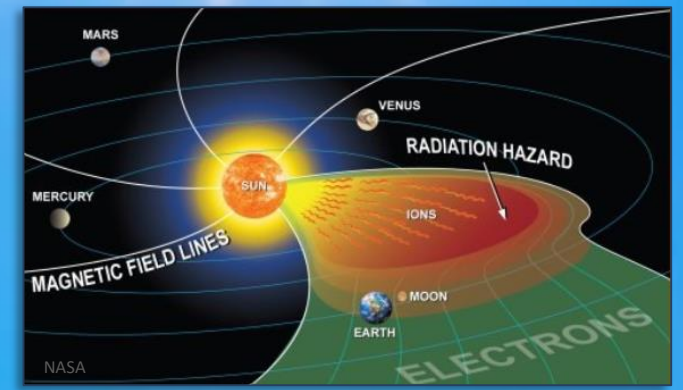
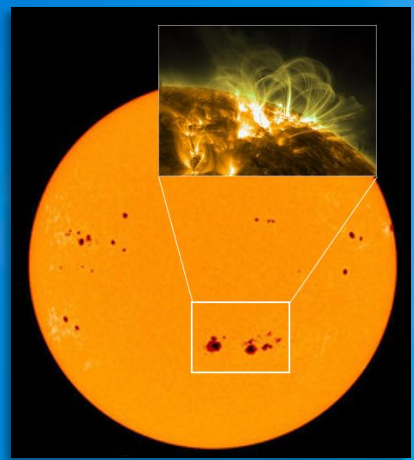
## Outline

- Space weather
- Impact
- Forecast challenges
- Our project
- Community

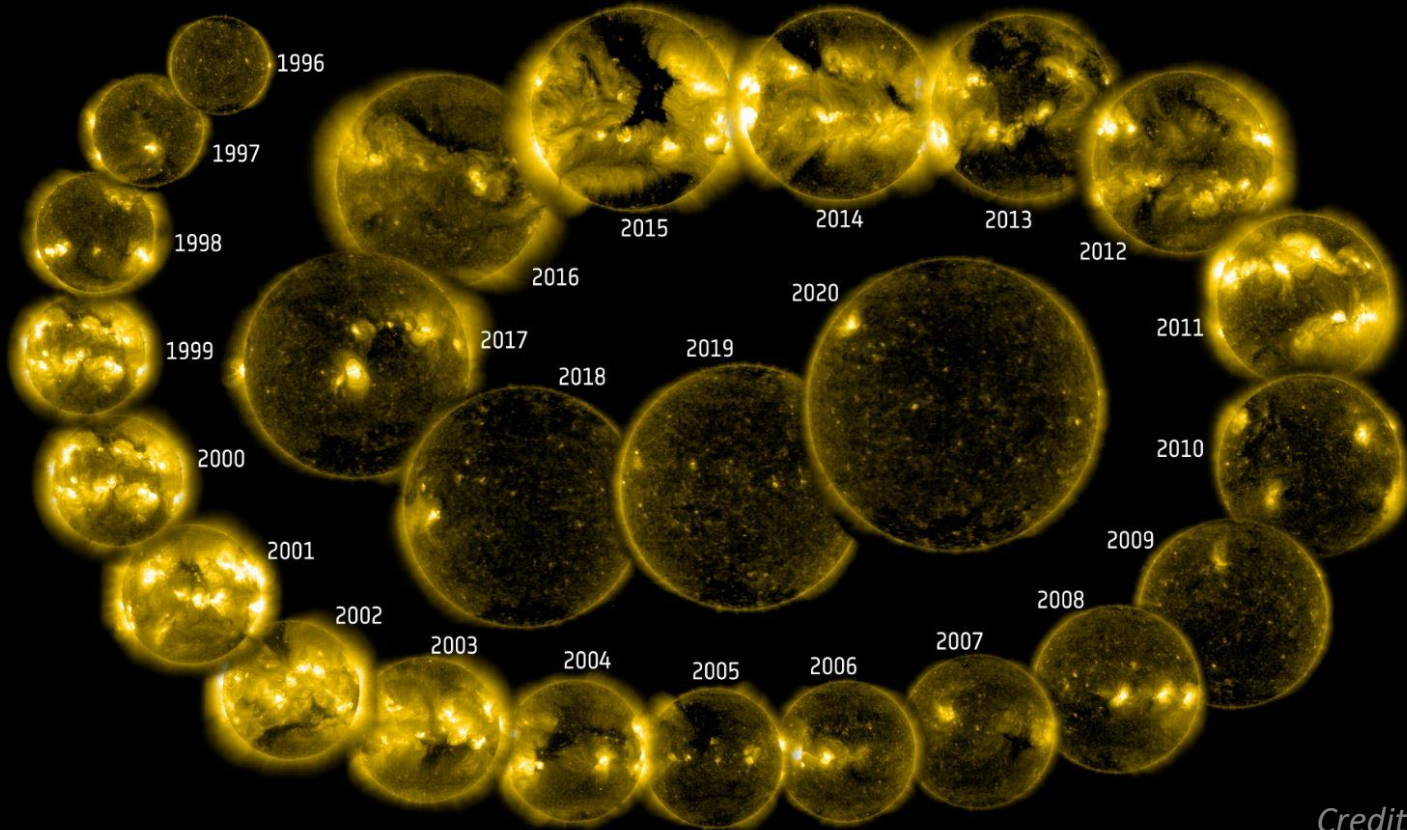
# Sun



- Light (99.9%)
- Magnetized wind
- Radiation



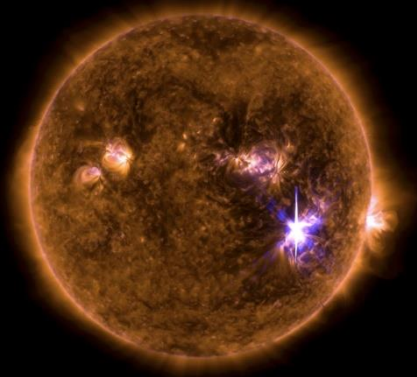
# Solar and Heliospheric Observatory (SOHO)



# Solar storms

## Solar flares

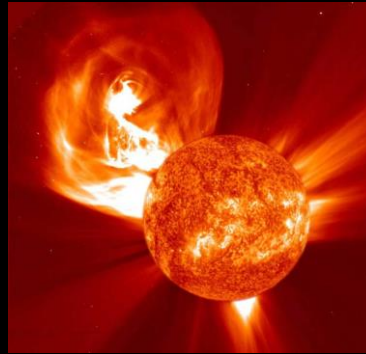
sudden intense brightening



- HF communications disturbances
- Radio blackouts
- GPS navigation errors

## Coronal mass ejection (CME)

Massive explosion of particles and magnetic field

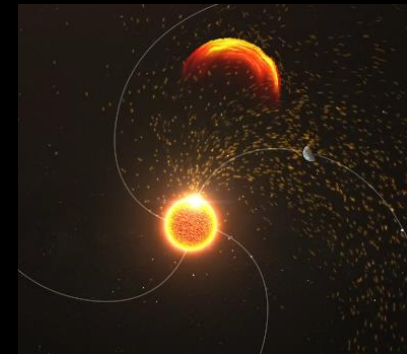


Geomagnetic storms:

- Electrical power loss
- Aurora

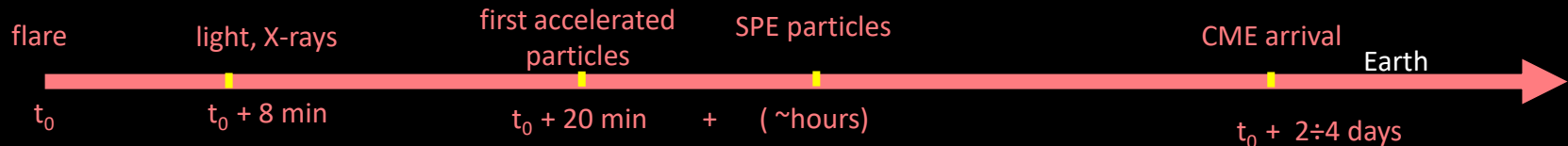
## Solar particle events (SPE)

Accelerated protons and electrons



Solar radiations storm:

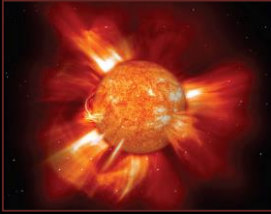
- Astronauts
- Satellite electronic circuits
- Navigation position errors
- High-altitude aircraft





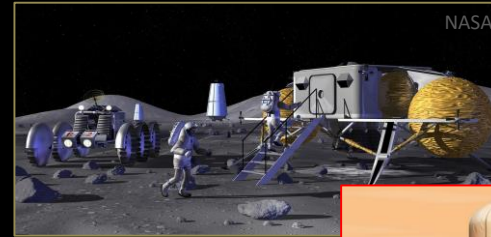
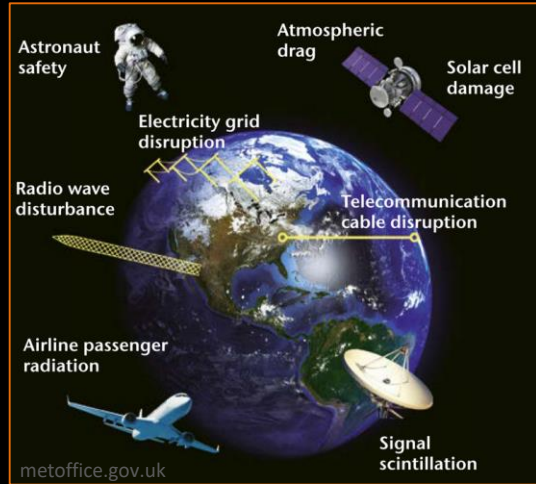
# Space weather scales

Level	Radio blackouts		Proton storms		Geomagnetic storms	
	Scale	X-ray	Scale	Pfu*	Scale	Kp
<b>Extreme</b>	R5	X20	S5	100000	G5	9
<b>Severe</b>	R4	X10	S4	10000	G4	8
<b>Strong</b>	R3	X1	S3	1000	G3	7
<b>Moderate</b>	R2	M5	S2	100	G2	6
<b>Minor</b>	R1	M1	S1	10	G1	5



# Space weather

The behavior of the Sun and the conditions in space that impact human activity and technology both in space and on the ground.



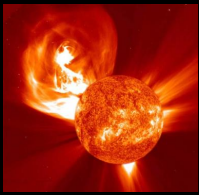
## Why do we care?



[ronntorossianupdate.com](http://ronntorossianupdate.com)



[www.youtube.com/watch?v=4bLz\\_4LKMg](http://www.youtube.com/watch?v=4bLz_4LKMg)



# CMEs ground effect: Geomagnetically Induced Currents (GICs)



## Loss of power impact:

- Water and wastewater distribution systems
- Perishable foods and medications; hospitals
- Heating/air conditioning and electrical lighting systems
- Computer systems, telephone systems, and communications systems (including disruptions in airline flights, satellite networks and GPS services)
- Public transportation systems
- Fuel distribution systems and fuel pipelines
- All electrical systems that do not have back-up power



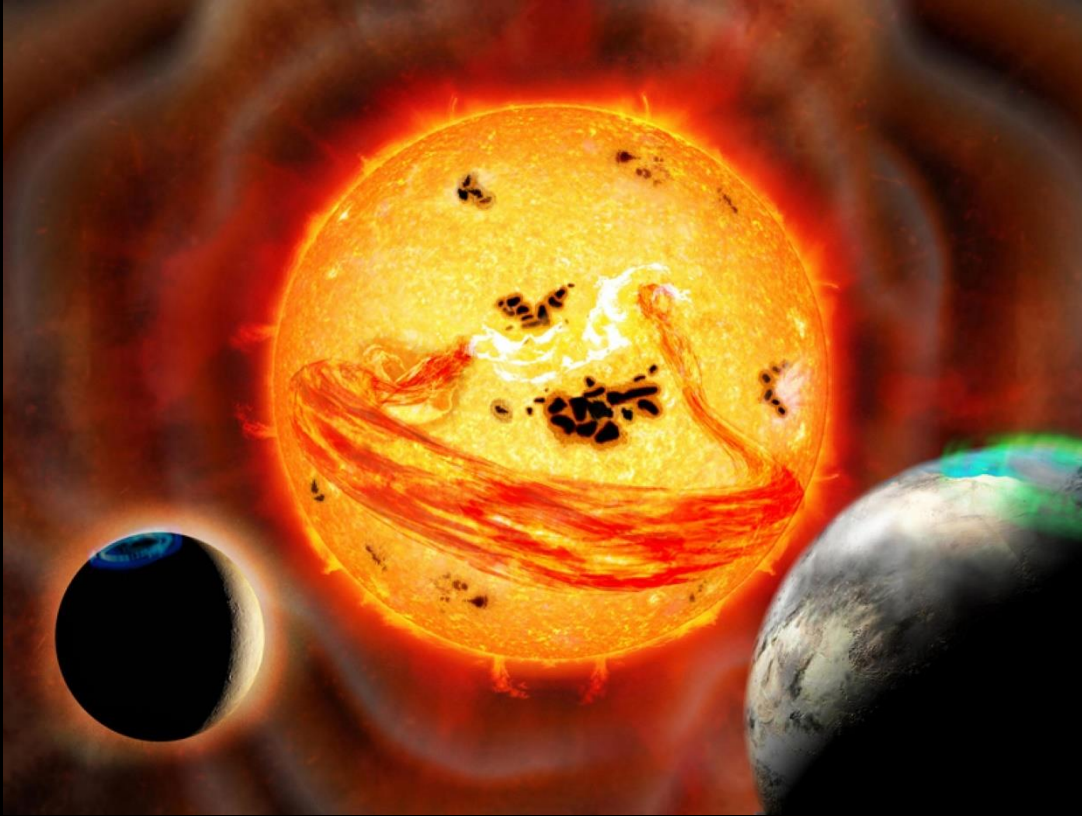
# Historical GIC events



- Malmö power outage 23 Sep 2003
- Quebec power outage 13 March 1989
- New York railway storm 13-16 May 1921
- Carrington event 28 Aug - 2 Sep 1859
- Vietnam war, sea mines spontaneous detonation - 4 Aug 1972

ESKOM (South Africa) 400 kV Transformer Failures, Oct-Nov 2003 storm

# Space weather in Exoplanets

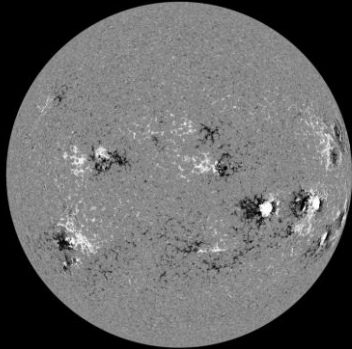


- Observation of stellar filament eruption associated with a superflare at EK Draconis (~ 111 ly)

Doi:10.1038/s41550-021-01532-8

*Artist Impression Credit: National Astronomical Observatory of Japan*

# Forecast challenges I: Solar sources

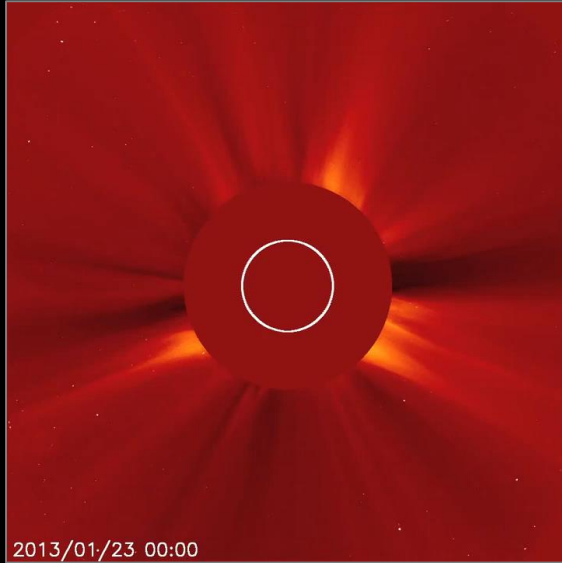


SDO/HMI, 20140710\_203000



- Solar atmosphere – not included in the forecast
- Simulations - computationally too expensive

# Forecast challenges II: CME arrival

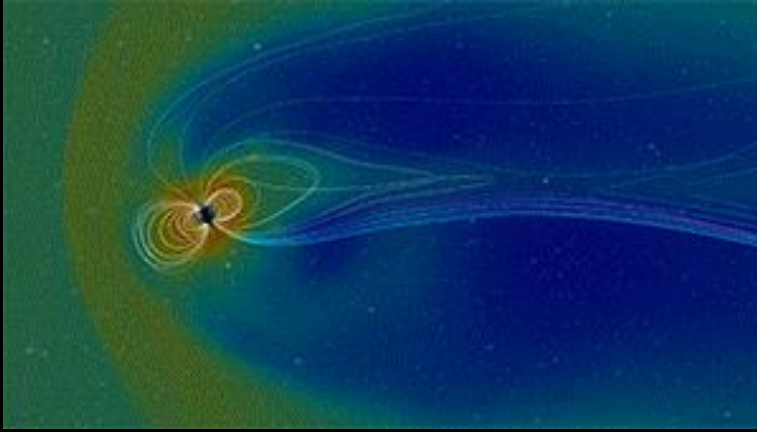


- CMEs interactions with background - trajectory changes
- CMEs geoeffectivity prediction - incomplete

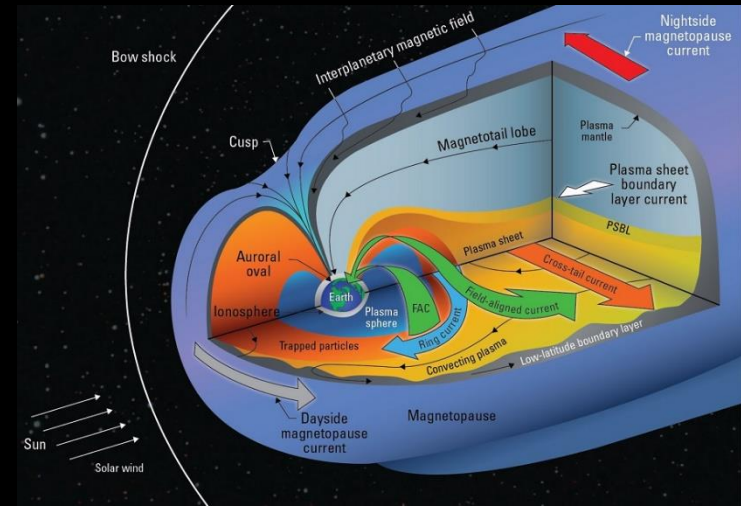


# Forecast challenges III: Magnetosphere

Credit: NASA



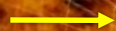
Credit: NOAA



- Prior knowledge of the energy storage in the magnetosphere
- Prediction of the behavior of the ionospheric currents

# Swedish Space Weather Project

Coronal Mass Ejections



CME evolution and interactions



Magnetospheric Dynamics: Currents and GICs  
Magnetosphere



ISP (SU):



*S. Danilovic*  
J. Leenaarts  
J. de la Cruz-Rodríguez  
G. Vissers

IRF(Lead):



*E. Yordanova*  
A. P. Dimmock  
*E. Werner*  
L. Sorriso-Valvo

FOI:



*L. Rosenqvist*  
J. Kjäll  
R. Friström  
*L. Hesslow*

- ✓ Improve forecasting confidence through investigation of the physical processes governing the Space weather chain

A cosmic background image featuring a blue and purple nebula or galaxy structure against a dark space background with scattered stars.

# Frontiers in Astronomy and Space Sciences

## Women in Science: Space Physics

**Topic Editors:** *S. Perri and E. Yordanova*