



# The Sun

Lecture  
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# Outline

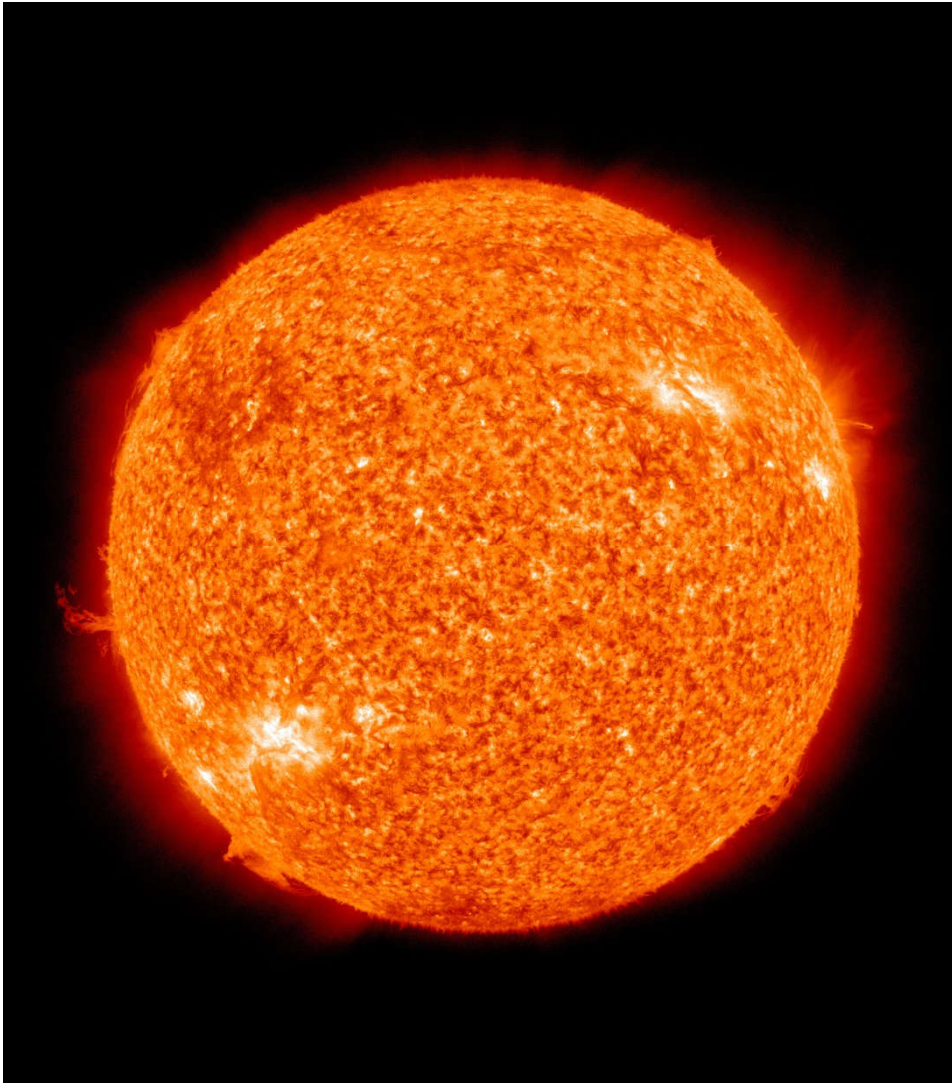
- I. Properties of the Sun
- II. Solar irradiance
- III. Solar activity
- IV. Solar indices and measurements





Part I

# PROPERTIES OF THE SUN

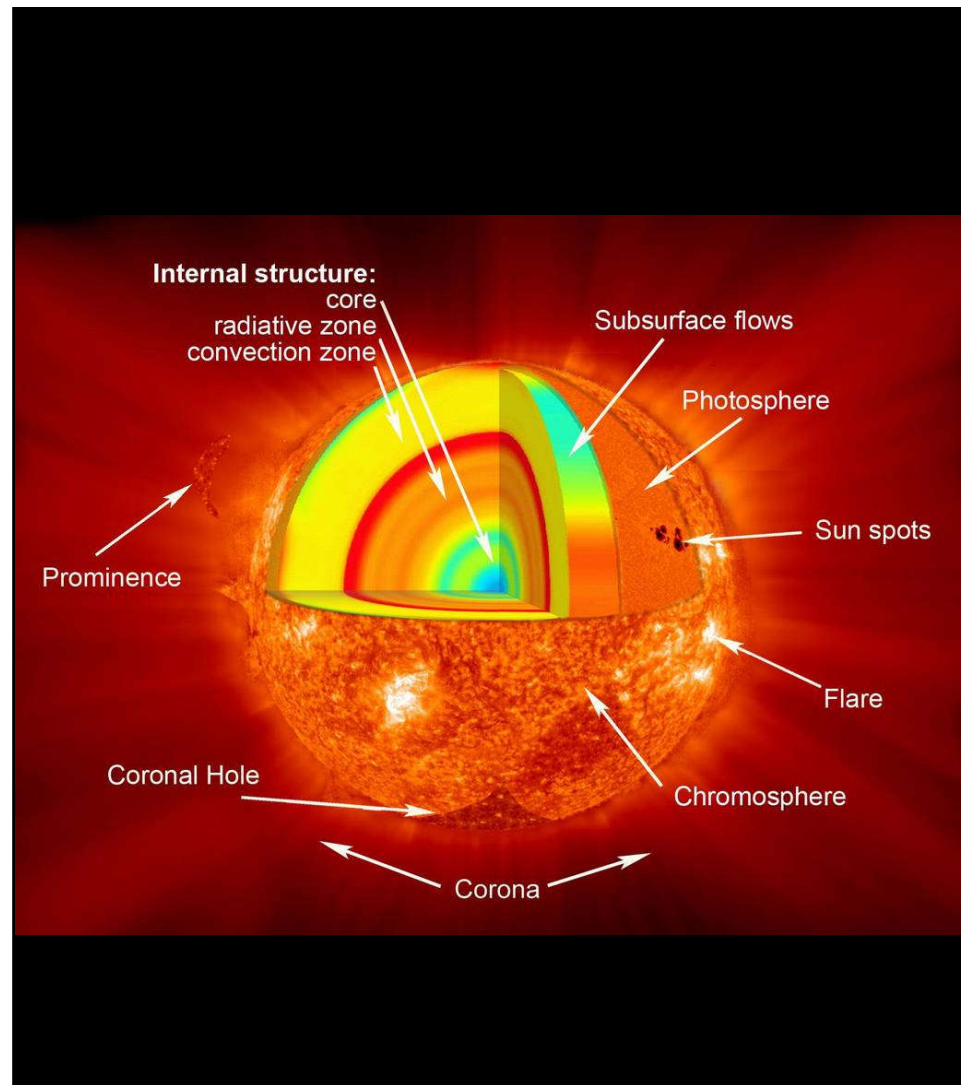


# What is the Sun

- Mass:  $1,989 \times 10^{30} \text{kg}$
- Size:  $\varnothing 1,39 \times 10^6 \text{km}$
- Distance:  $149,6 \times 10^6 \text{km}$
  
- 73,5% H, 25%He  
→ rest 1,5%: O,C,...

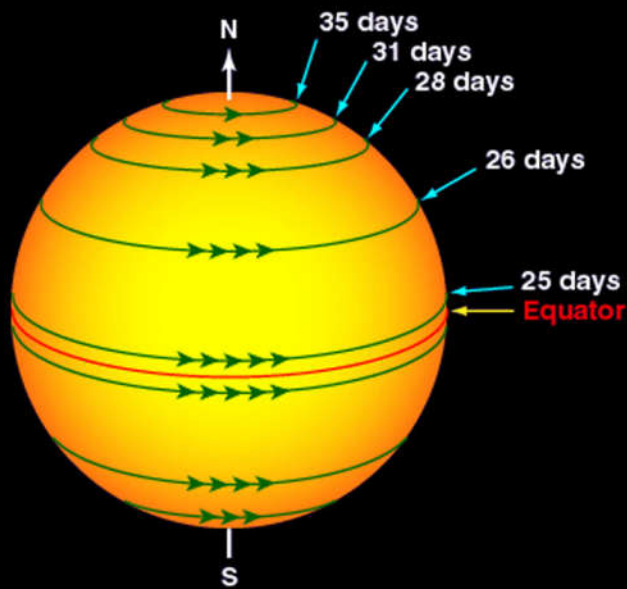
# Structure of the Sun

- **Solar interiors**
  - Core
  - Radiative zone
  - Convective zone
- **Solar atmosphere**
  - Photosphere
  - Chromosphere
  - Transition region
  - Corona



# Differential rotation

- Convective Zone from surface down 30% of radius
- plasma rotates around the Sun
- slowly at poles (33.5 days), faster at equator (25.6 days)
- Mean rotation 27 days



$$\omega = A + B \sin \varphi + C \sin^4 \varphi$$

$$A = 14.713 \pm 0.0491 \text{ } ^\circ/\text{d}$$

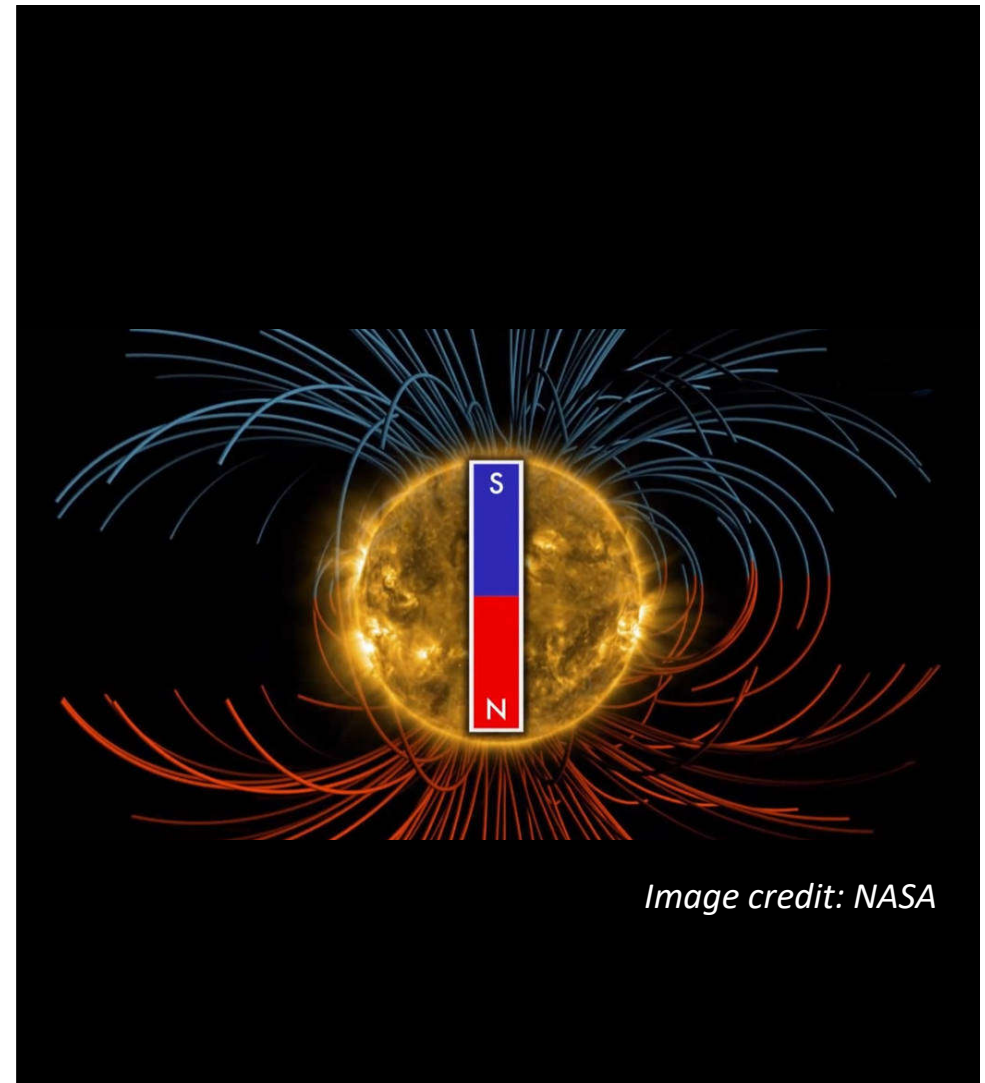
$$B = -2.396 \pm 0.188 \text{ } ^\circ/\text{d}$$

$$C = -1.787 \pm 0.253 \text{ } ^\circ/\text{d}$$



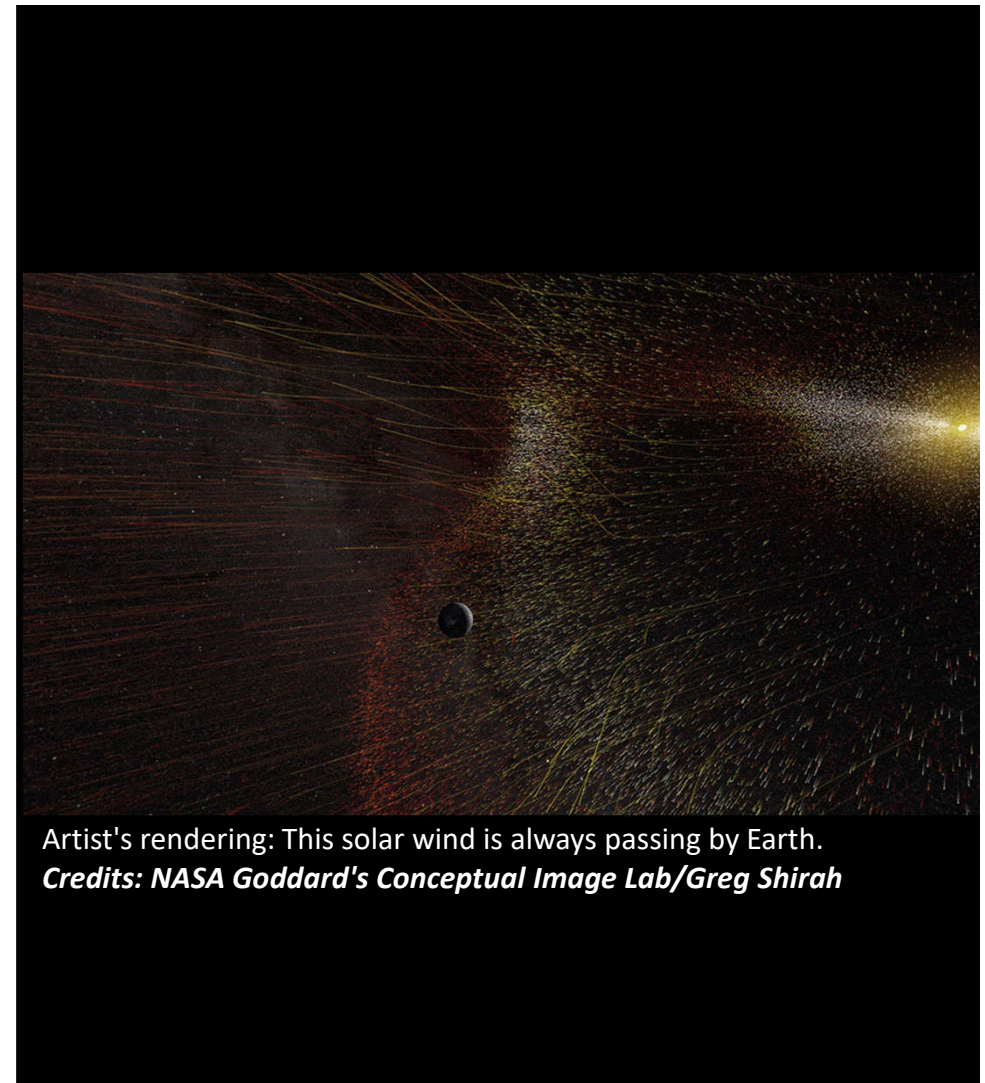
# Solar magnetic field

- Magnetic star
- Dynamo theory
- Generation by the motion (convection) of conductive plasma inside the Sun
- Drives all solar activity
- Open magnetic field lines extend into space → interplanetary magnetic field (IMF)
- Magnetic field fluctuates significantly (times scales ranging from a fraction of a second to billions of years)



# Solar wind

- created by the outward expansion of plasma from the corona
- Sun's gravity can't hold extremely heated plasma down
- carries some of Sun's magnetic field (IMF)
- Forms the heliosphere
- reaches speeds of over one million miles per hour
- "bow shocks" forms whenever it is forced to flow around the planets



Artist's rendering: This solar wind is always passing by Earth.

***Credits: NASA Goddard's Conceptual Image Lab/Greg Shirah***



# Solar wind

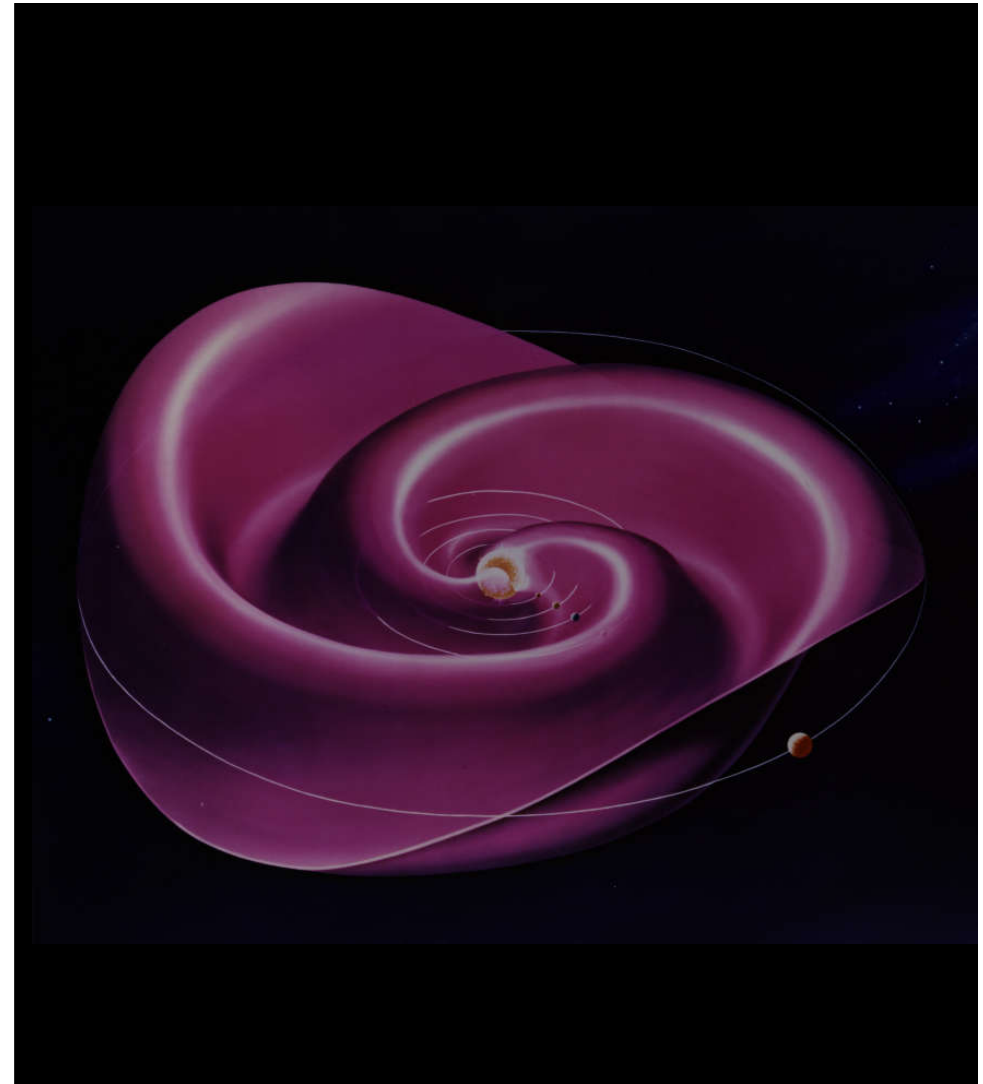
Mean solar wind properties near Earth

Parameter	Property	value
Composition		96% $H^+$ , 4% (0-20%) $He^{++}$ , $e^-$
Density	$n_p \approx n_e$	6 (0.1-100) $cm^{-3}$
Velocity	$u_p \approx u_e = u$	470 (170-2000) km/s
Protonenfluss	$n_p u$	$3 \cdot 10^{12} m^{-2} s^{-1}$
Temperatur	T	$10^5$ (3500- $5 \cdot 10^5$ ) K
Interplanetary magnetic field	B	3.5 (0.2-50) nT

*Prölss (2001)*

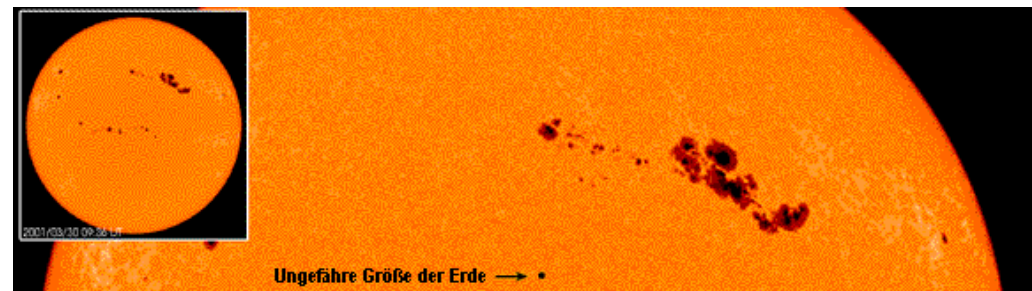
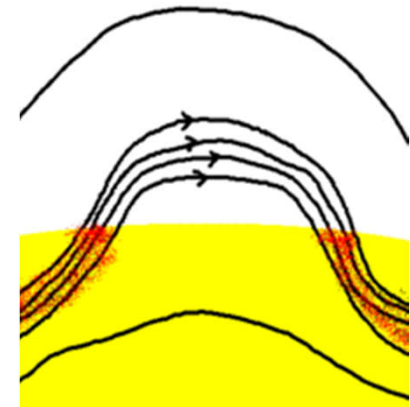
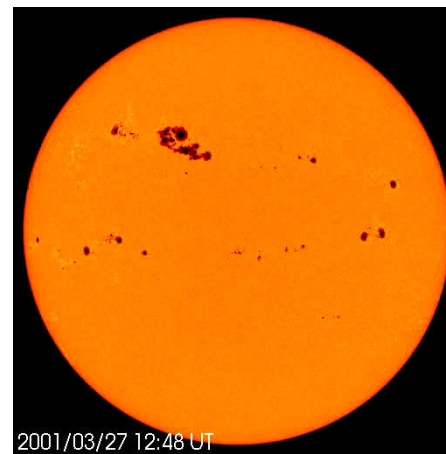
# Parker Spiral

- Solar rotation winds up its magnetic field lines above its polar regions into a large rotating spiral,
- Magnetic current sheet: enormous continuous magnetic wave of ion particles in the Heliosphere
- spiral wavy shape known as Parker Spiral



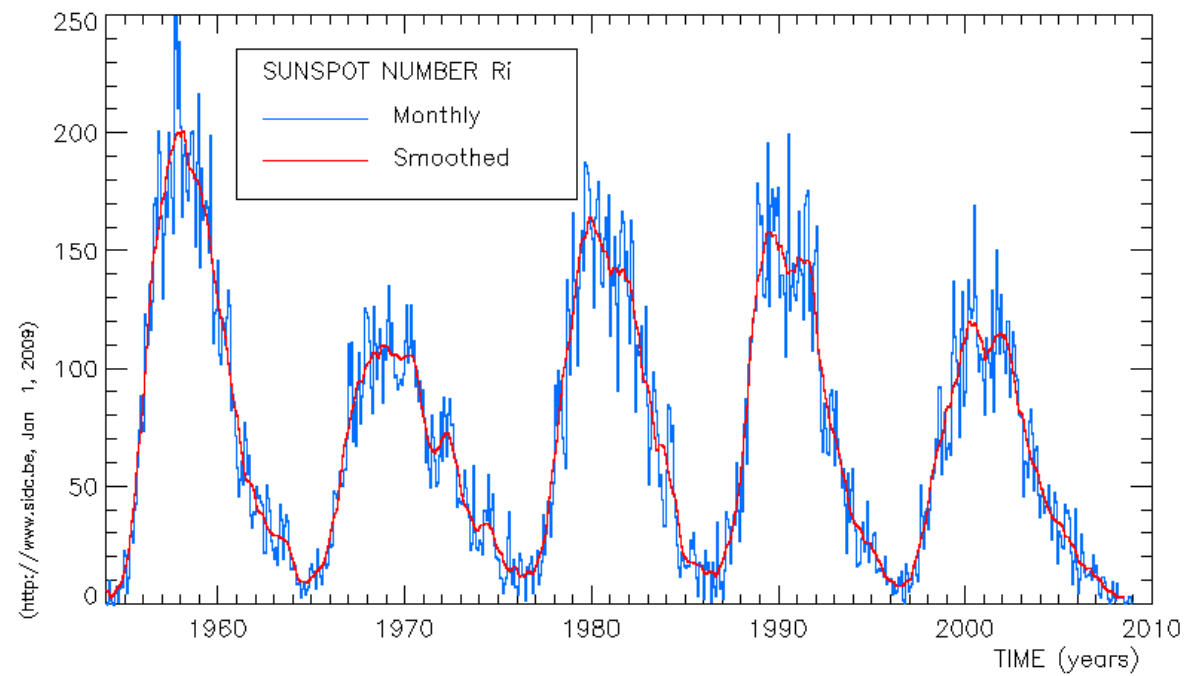
# Sunspots

- areas of lower surface temperatures which appear dark (in Photosphere)
- caused by intense magnetic disturbances
- occur due to the Sun's magnetic field expanding up to the photosphere
- Hot gas travels to the top of the convective zone and cools down
- can last from anywhere between one hour to seven months

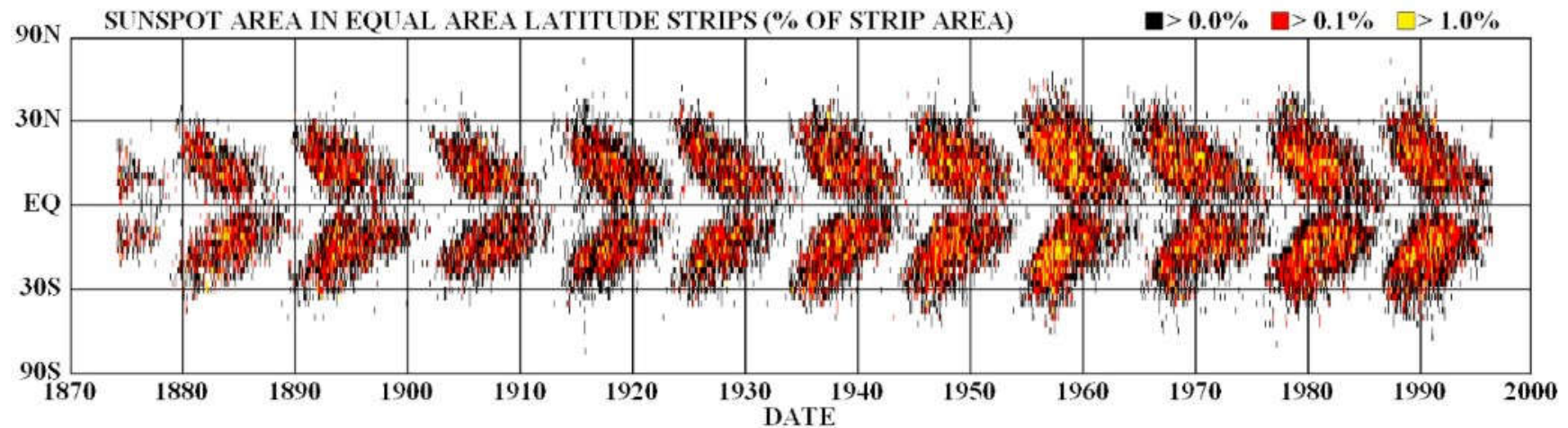




# Solar cycle

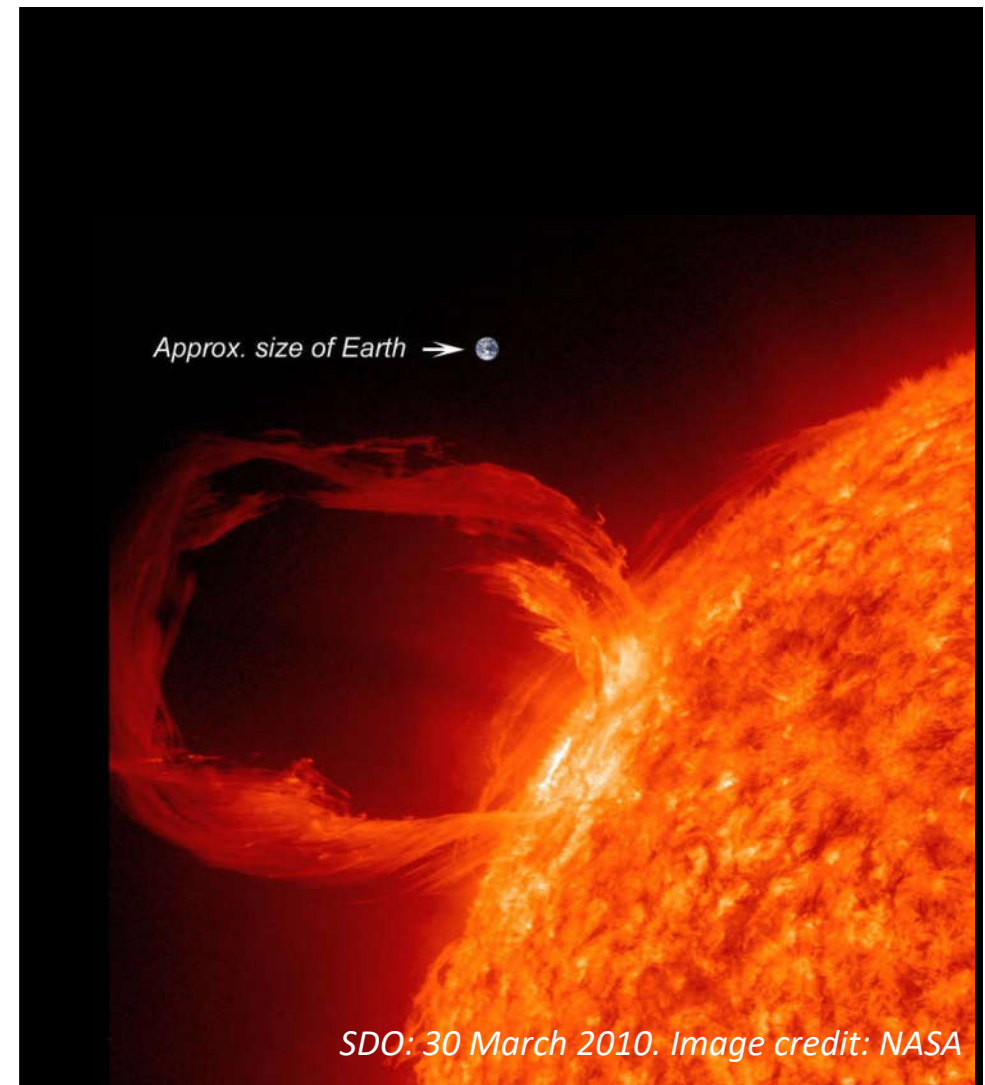


# Maunder butterfly diagram



# Prominences

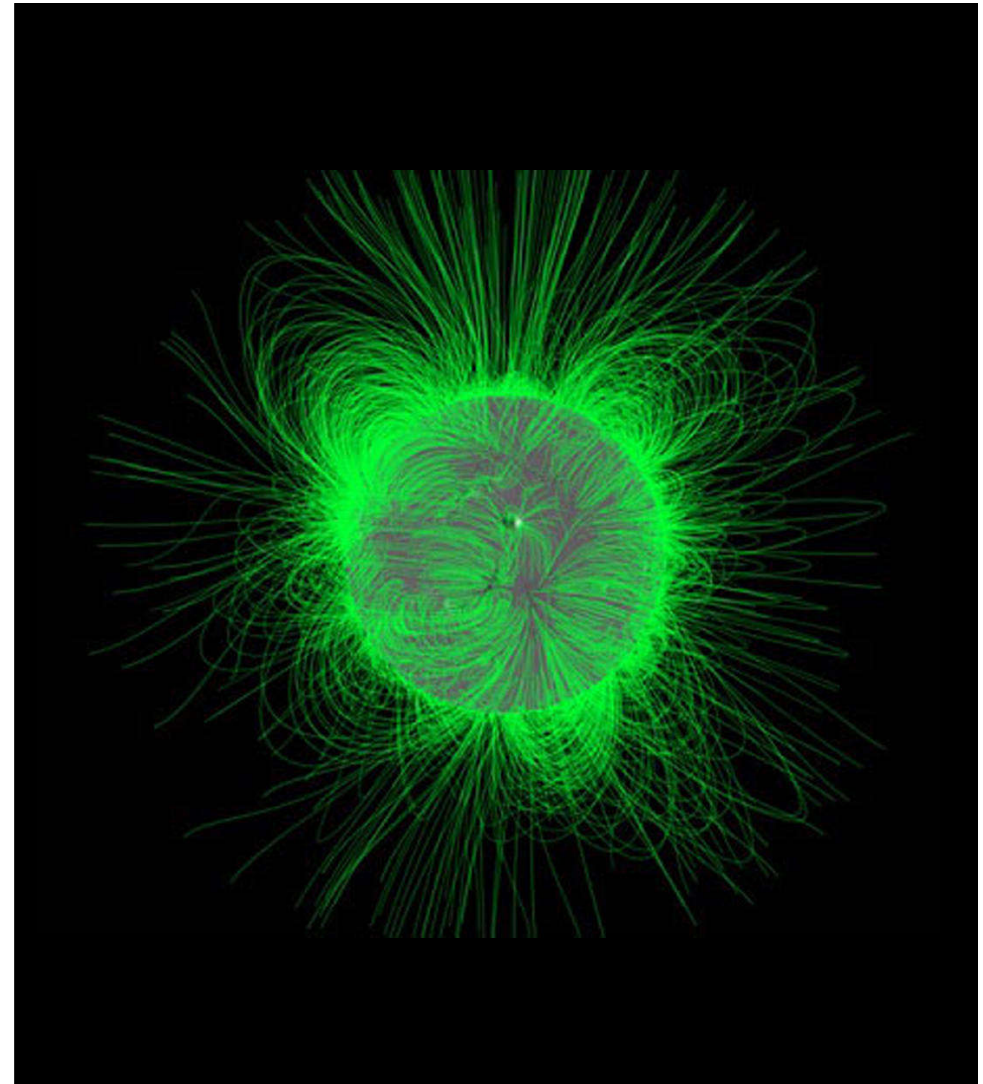
- loops of magnetic field lines trap some solar wind plasma and hold it back from escaping Sun.
- Anchored in the Photosphere
- rise up through the Chromosphere
- Often in a loop shape
- mass within a Prominence is typically on the order of 100 billion tons
- Differential rotation causes magnetic field lines to become twisted
- Eruption occurs when such a structure becomes unstable





# Coronal holes

- Large dark patches in the Sun's corona, which are most prevalent and stable at the poles
- Magnetic field lines extend outwards into space → interplanetary magnetic field
- Emit constant stream of high speed solar wind „streamers“
- Leave regions of low density plasma and
- Lower temperature when compared to their surroundings



# Conveyors belts

- Meridional Plasma Flows in the Convection Zone
- Both branches of the conveyor belt take about forty years to complete one revolution.
- The top of the belts skim the sun's surface, sweeping up knots of solar plasma magnetism and propelling them towards the poles.
- Suppress sunspots by counteracting magnetic diffusion at the sun's equator.

