

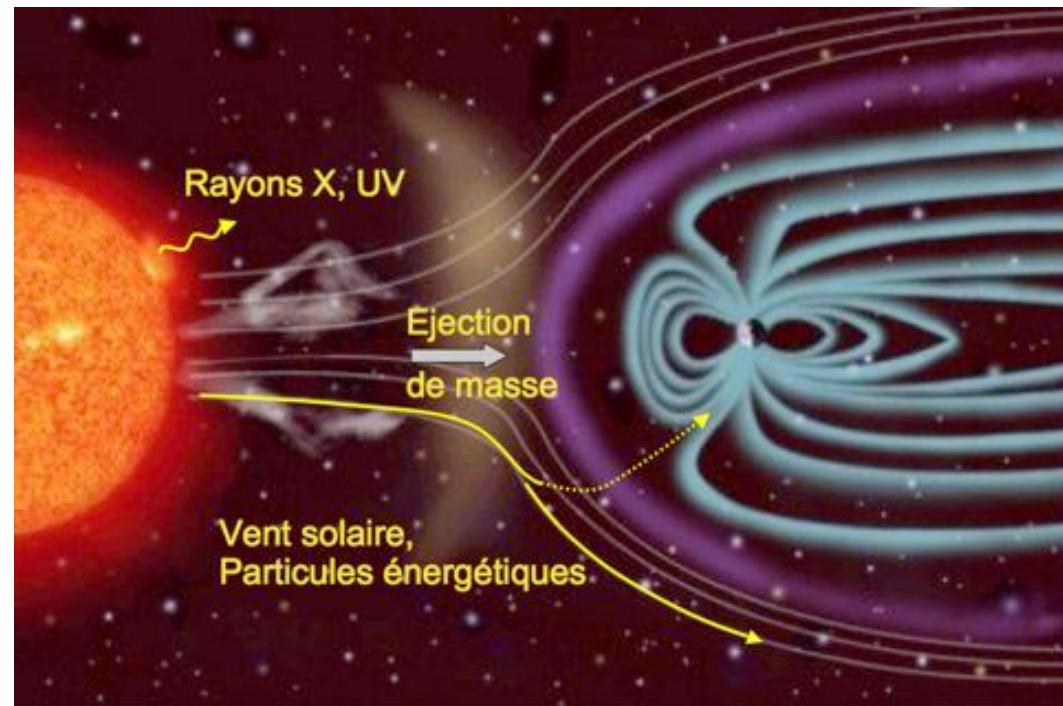
# Space weather: a glimpse of the physical processes

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Pôle de physique solaire, LESIA, Meudon

# The Sun and the Heliosphere

## The visible Sun: « photosphere »

<http://solaire.obspm.fr/pages/galerie/couchers.html>

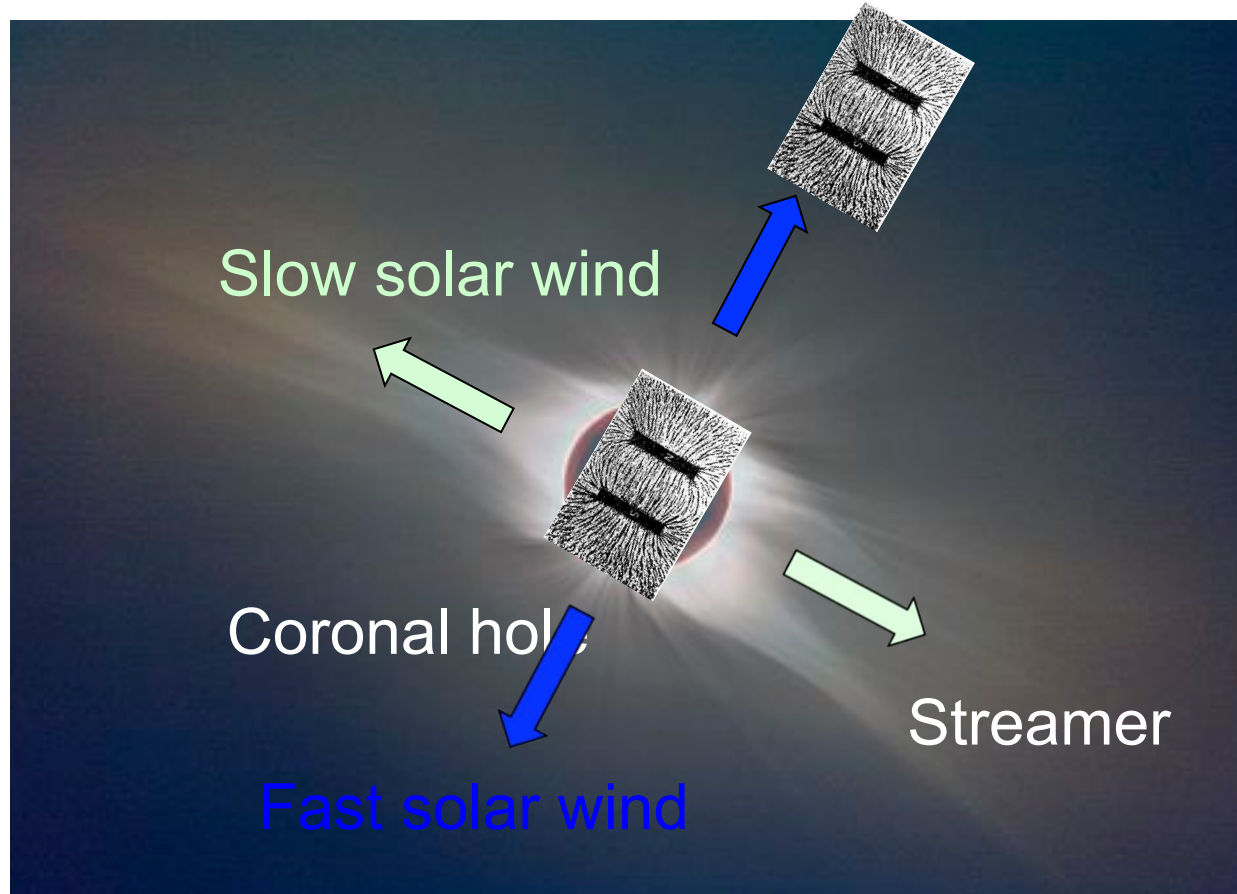


- Gas  $T \approx 6000$  K
- structured by gravity
- gas motions induced by convection in the sub-photospheric layers

# The Sun and the Heliosphere

## The solar corona

© C. Viladrich, IAP & SAF



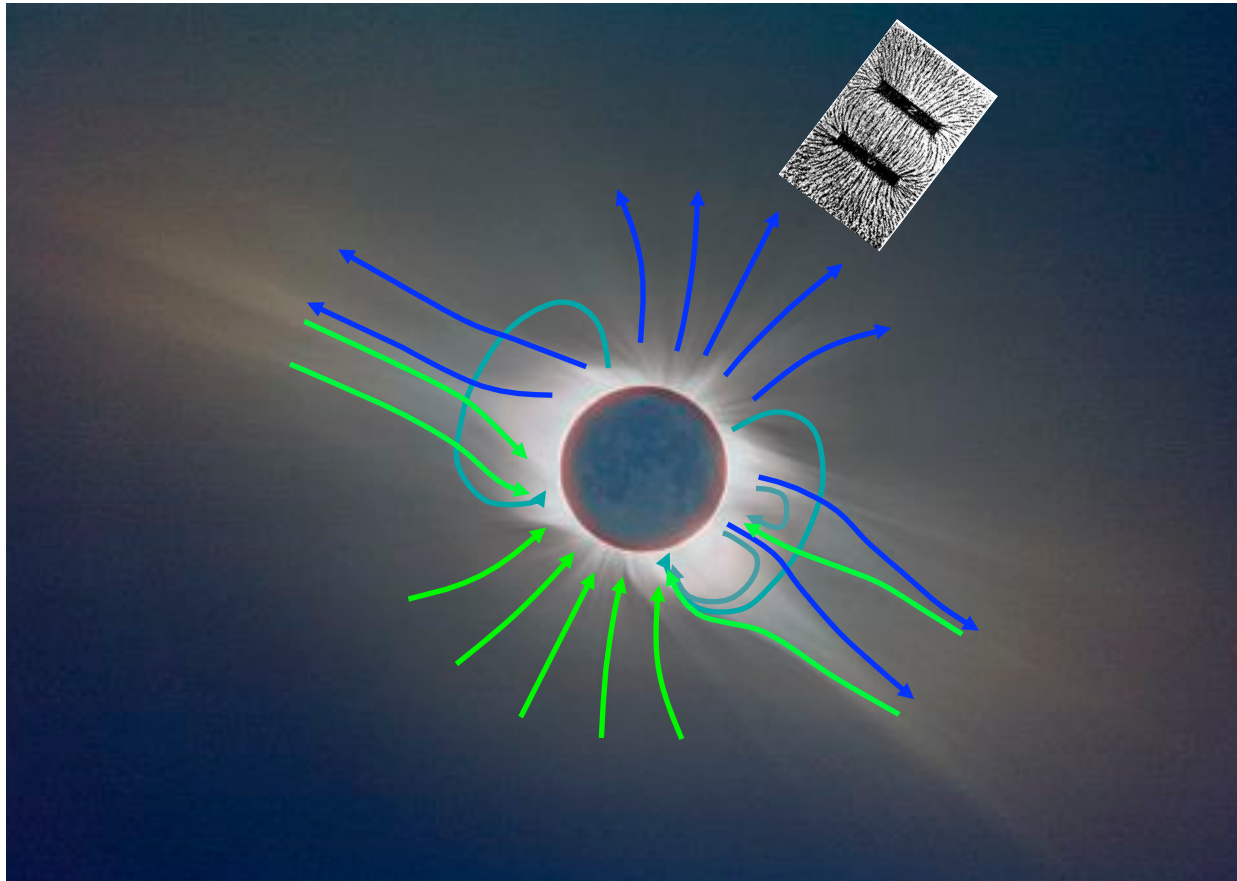
- Hot gas ( $>10^6$  K),
- strongly ionised,
- structured by magnetic fields at low altitude ( $< 1 R_s$  above the surface).

- Consequences of the hot corona (1): high pressure  $\rightarrow$  expansion
- Solar wind escaping
  - along « open » magnetic field lines (coronal holes): fast solar wind,  $\sim 800$  km/s
  - everywhere from the high corona: slow solar wind,  $\sim 400$  km/s

# The Sun and the Heliosphere

## The solar corona

© C. Viladrich, IAP & SAF



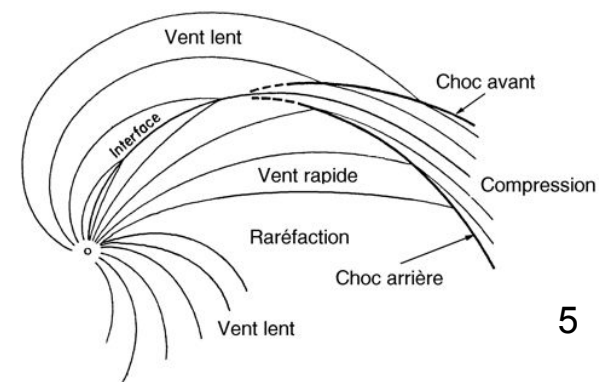
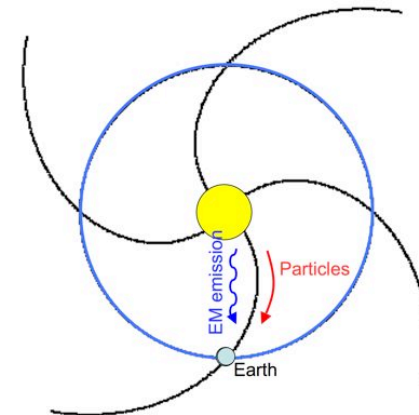
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# The Sun and the Heliosphere

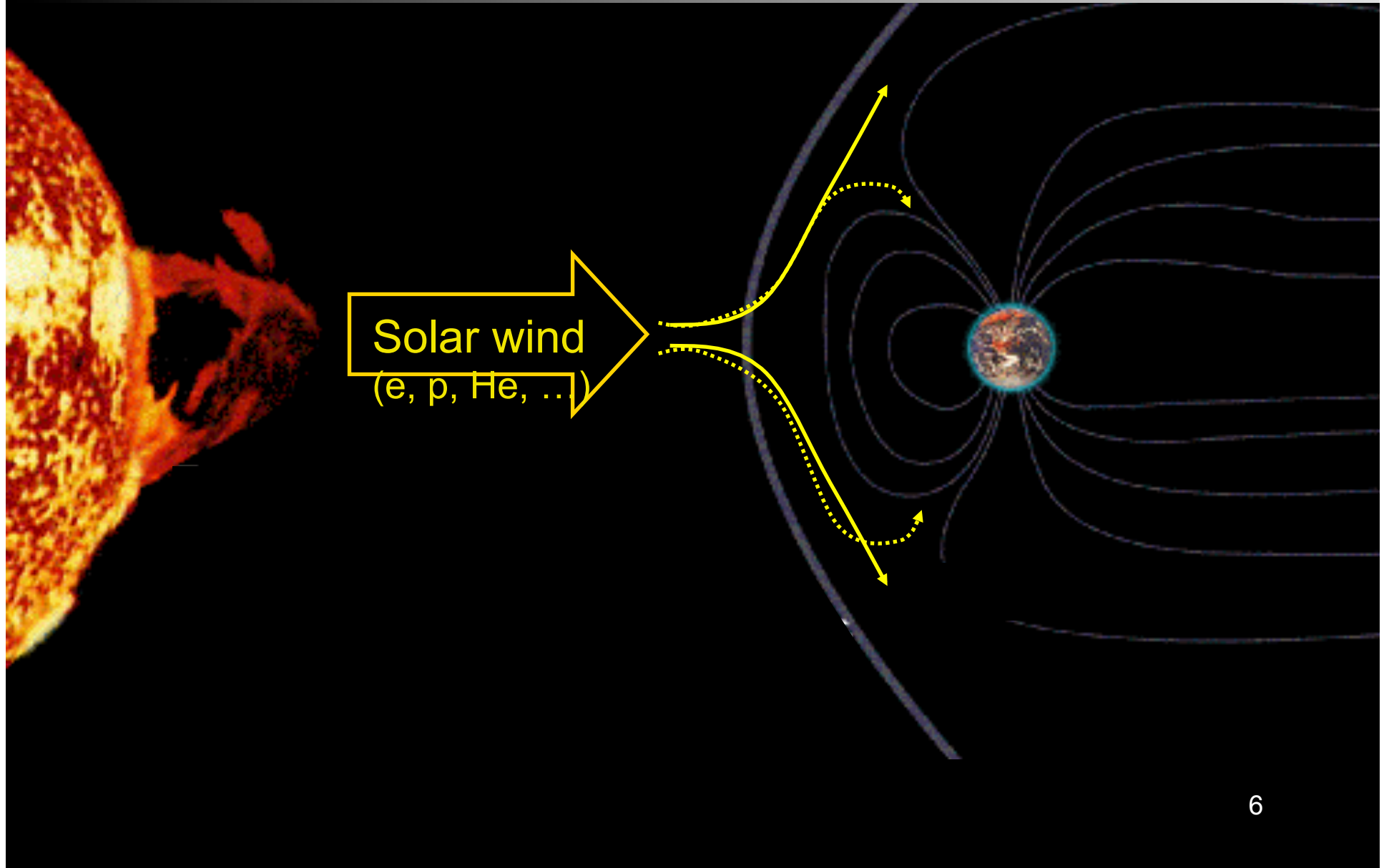
## The solar wind

- The ~ radially streaming solar wind draws the coronal magnetic field lines out into the interplanetary (IP) space.
- When projected onto the solar equatorial plane, an IP field line has a spiral shape :
  - Radial flow (solar wind)
  - + rotation of the footpoint, rooted in the Sun
  - = archimedian spiral (« Parker spiral »),
  - Curvature the stronger, the slower the wind speed
- At the interface between a slow and a fast wind stream an interaction region is formed that rotates with the Sun (« stream interaction region » or « corotating interaction region »).



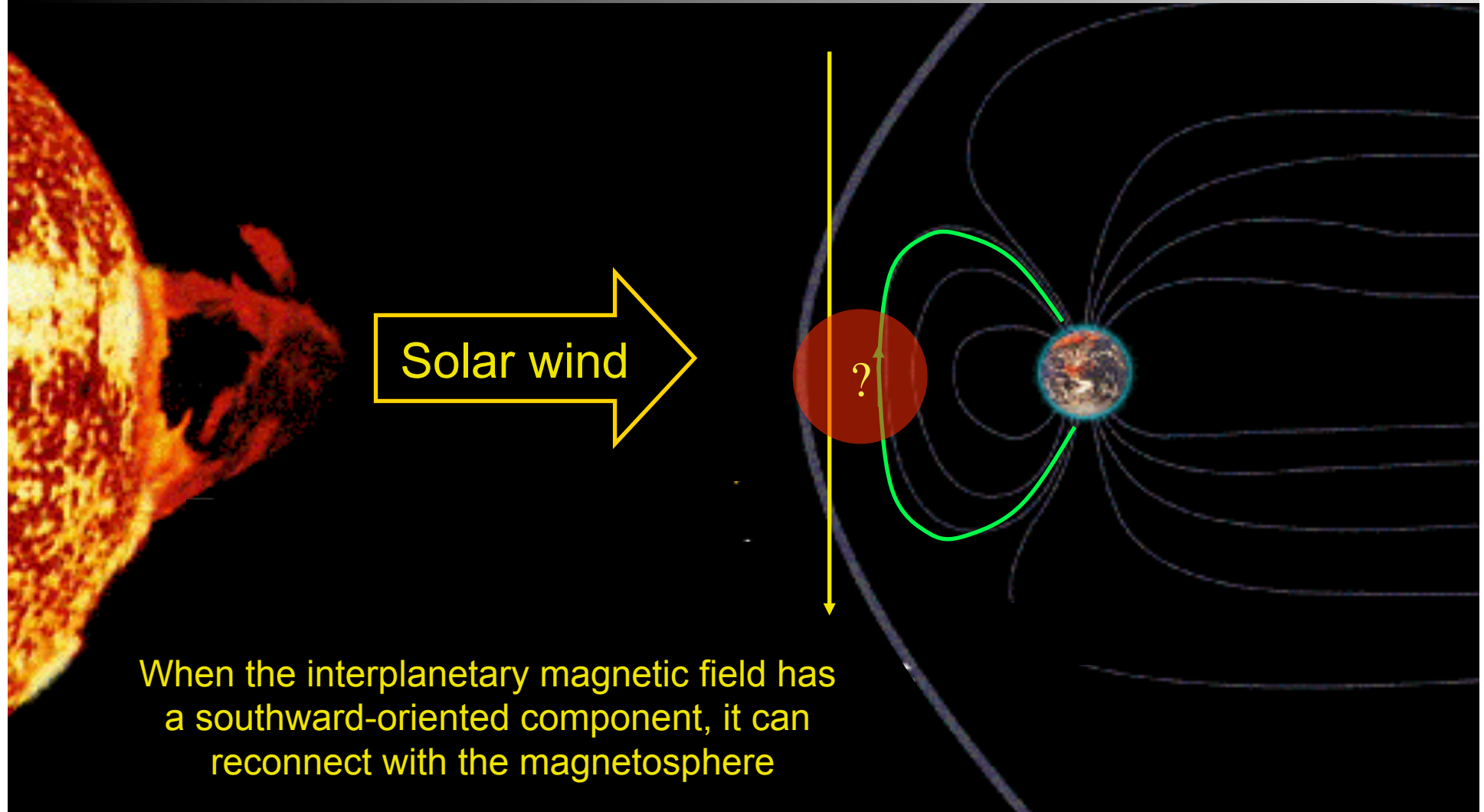
# The Sun and the Heliosphere

## Solar wind and Earth's magnetosphere



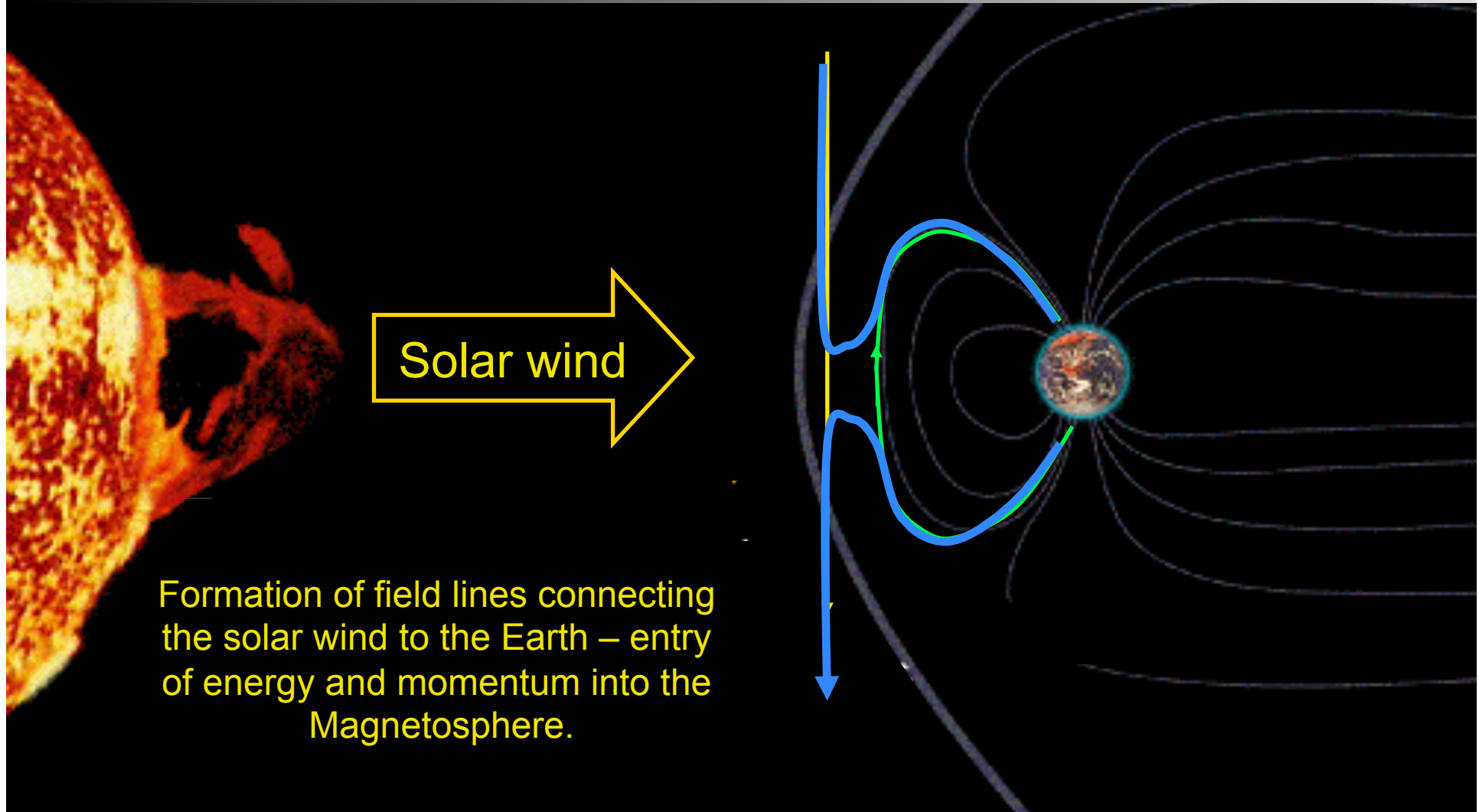
# The Sun and the Heliosphere

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# The Sun and the Heliosphere

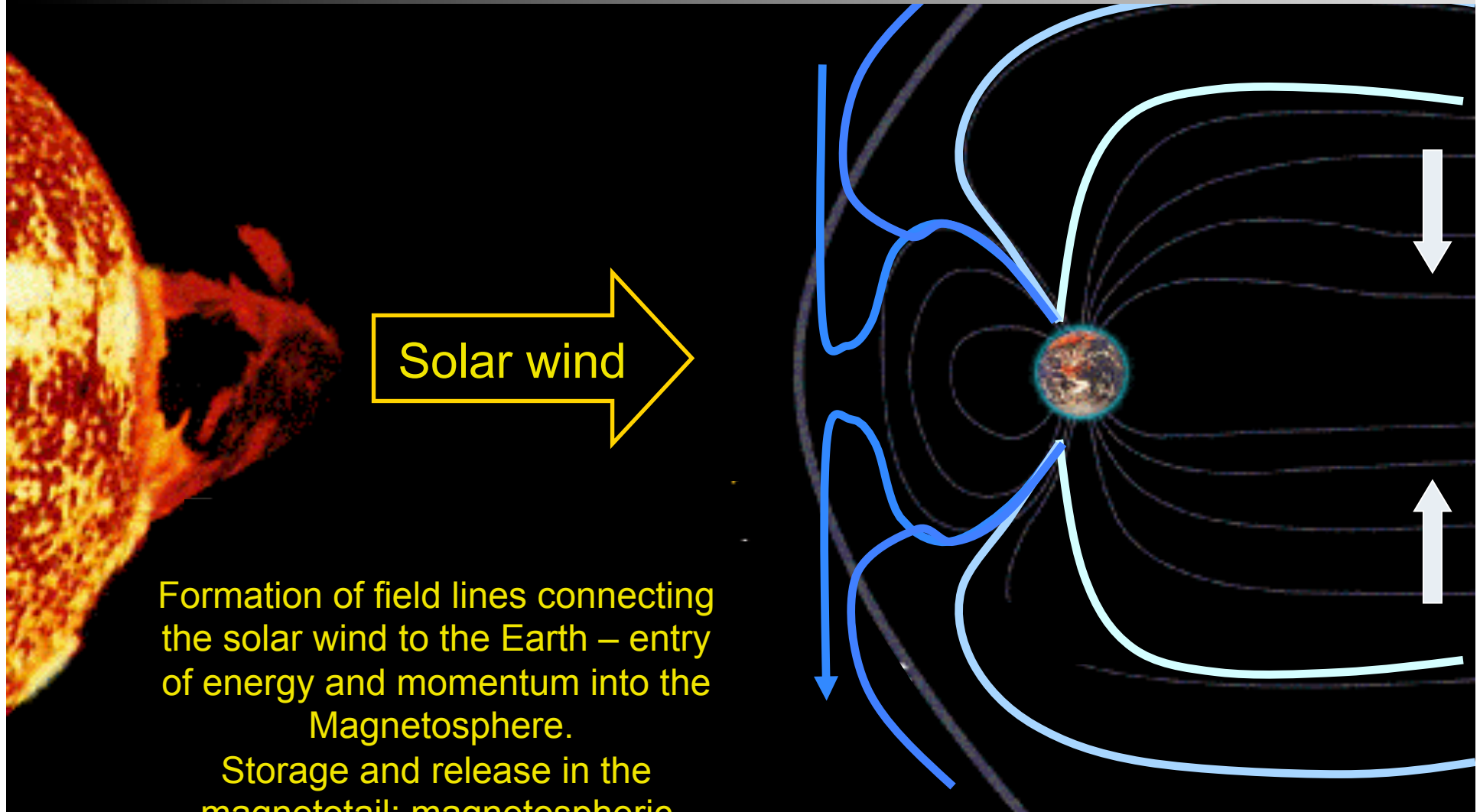
## Solar wind and Earth's magnetosphere





# The Sun and the Heliosphere

## Solar wind and Earth's magnetosphere



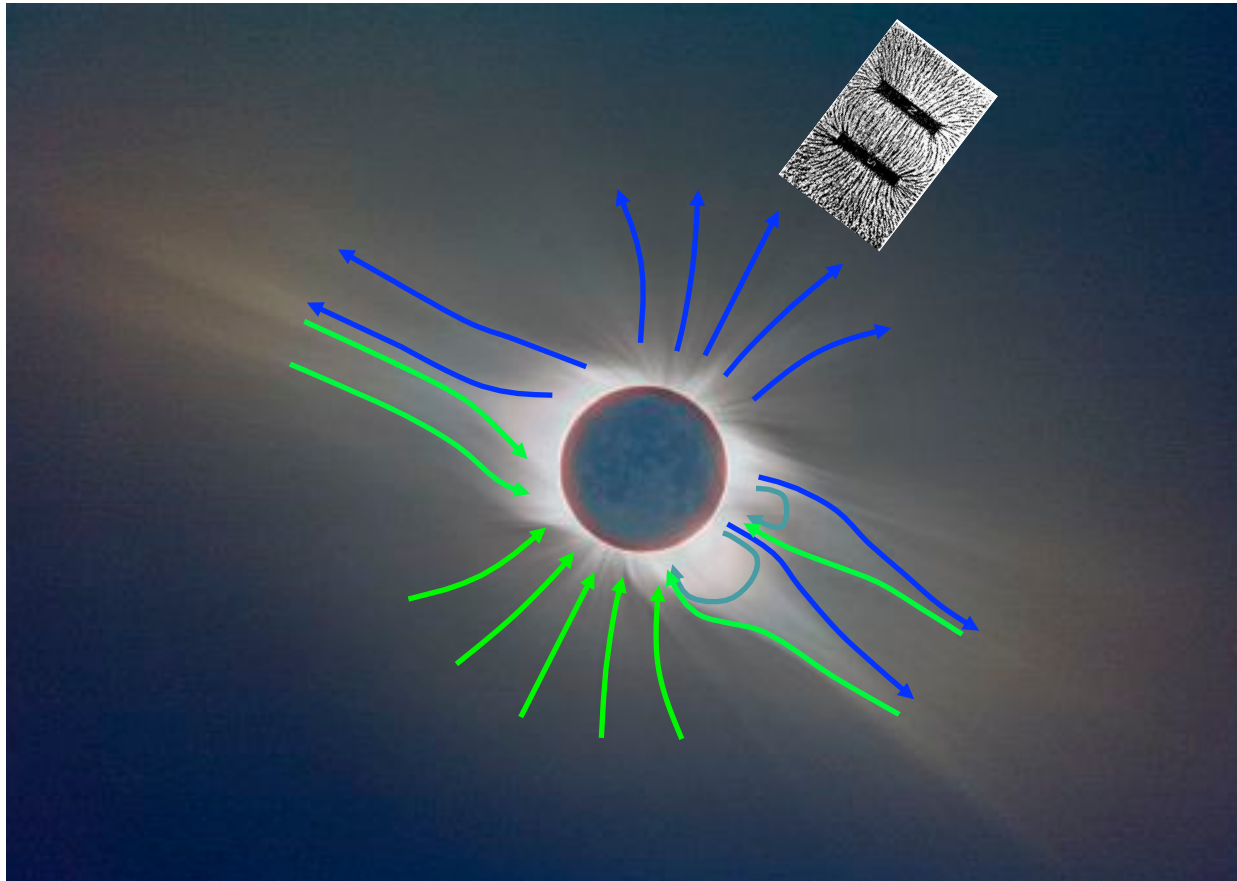
Formation of field lines connecting the solar wind to the Earth – entry of energy and momentum into the Magnetosphere.

Storage and release in the magnetotail: magnetospheric substorms (aurorae).

# The Sun and the Heliosphere

## Flares and coronal mass ejections (CMEs)

© C. Viladrich, IAP & SAF

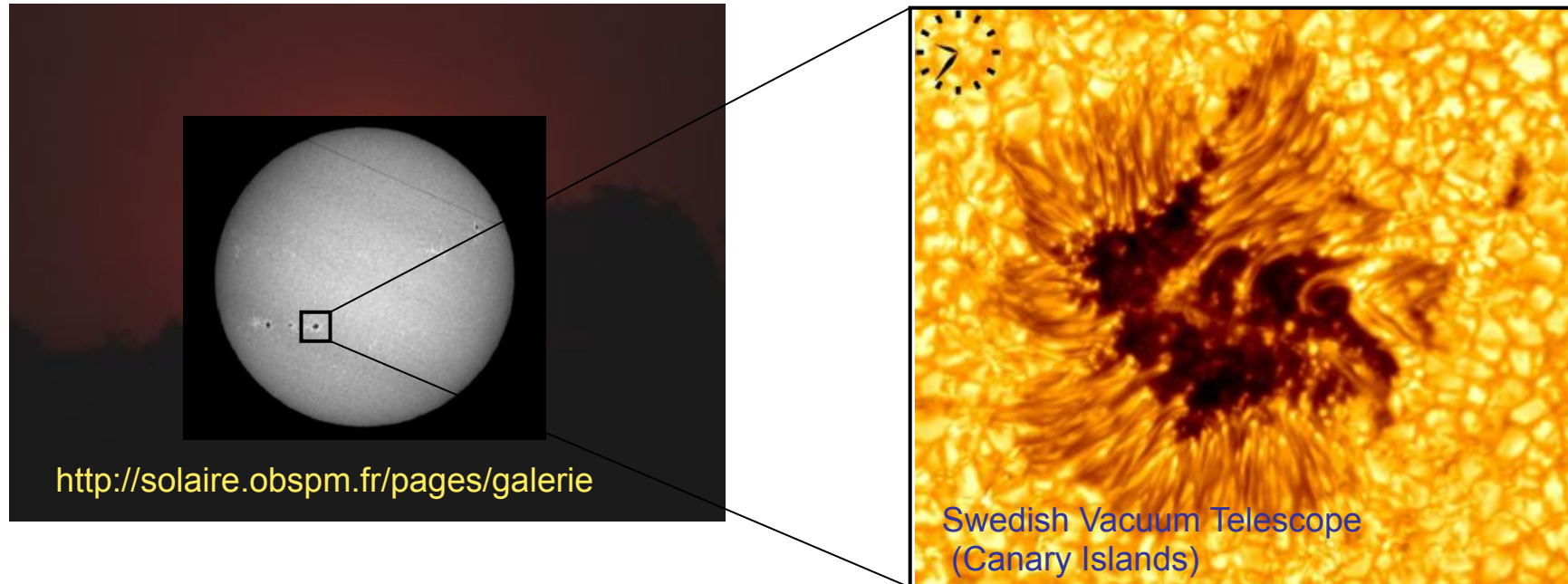


- Corona:
  - hot gas ( $>10^6$  K),
  - strongly ionised,
  - structured by magnetic fields at low altitude ( $< 1 R_s$  above the surface).

- Consequences of the corona: (2) Magnetic field rooted in/below the dynamic photosphere -> Instability -> energy release
  - Heating, particle acceleration: flares
  - Bulk motion: coronal mass ejections (CMEs)

# The Sun and the Heliosphere

## The magnetic field in the photosphere: sunspots



- Sunspot = region with intense magnetic field rooted below the photosphere (convection zone)
- magnetic field concentrated by motions of the ionised gas in the ambient photosphere

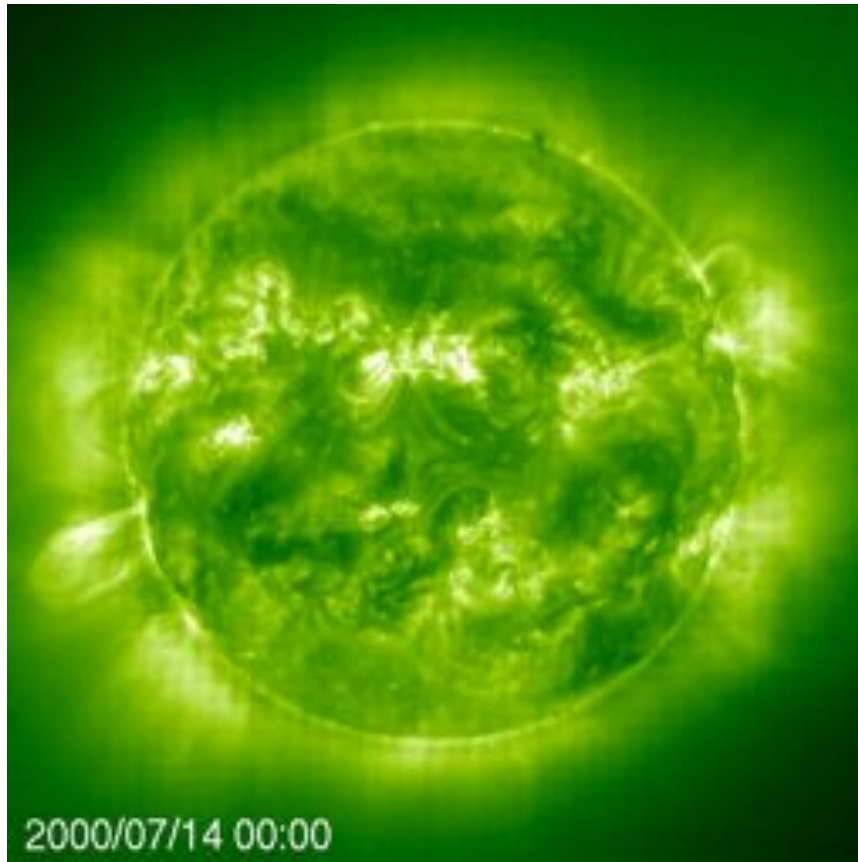
Obs. Paris, Meudon; <http://bass2000.obspm.fr>

Swedish Vacuum Telescope (Iles Canaries); <http://www.solarphysics.kva.se/>

# The Sun and the Heliosphere

## Flares

<http://soho.esac.esa.int/>

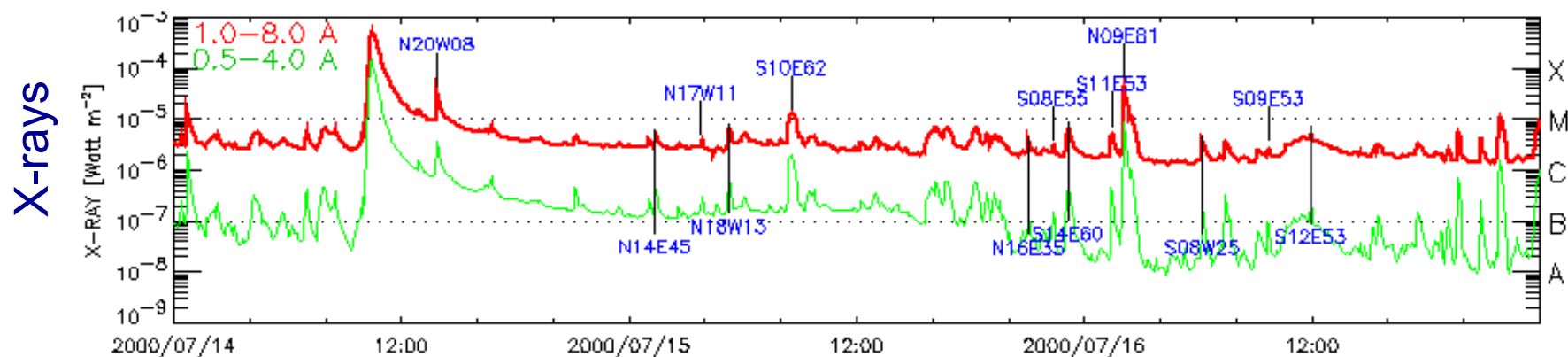


- EUV (~20 nm) emission of the solar corona
- Bright regions: hot gas confined in magnetic fields rooted in the Sun (« active regions »)
- Daily movie (SoHO/ EIT): flare
  - burst of emission,
  - heating of the plasma in an active region
  - acceleration of electrons, protons ...
  - energy  $\rightarrow 10^{25}$  J, in  $\sim 1000$  s

# The Sun and the Heliosphere

## Flares

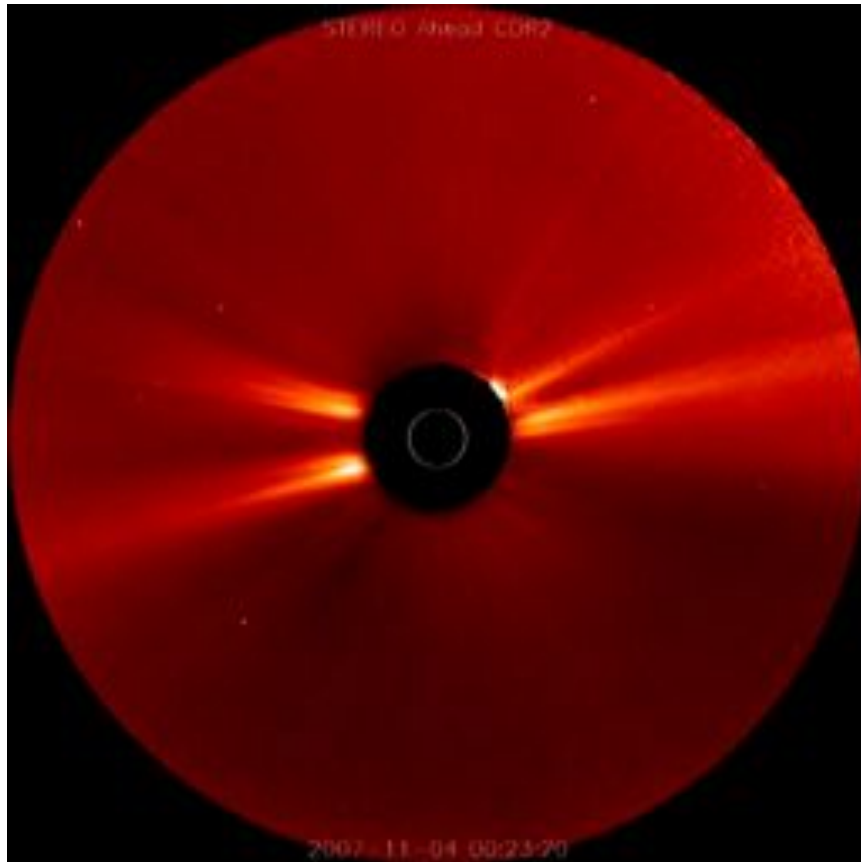
- Monitoring satellites GOES (NOAA): 3 days, 2000 Jul 14-16
- « Soft » X-rays from an active region suddenly heated to  $T \approx 10^7$  K
- Classification as a fct of peak flux in the 0.1-0.8 nm band
  - X class:  $\geq 10^{-4}$  W/m<sup>2</sup>
  - M class:  $\geq 10^{-5}$  W/m<sup>2</sup> etc. pour les classes C, B, A



- E.g., flare of importance X3.5: peak flux =  $3,5 \times 10^{-4}$  W/m<sup>2</sup>

# The Sun and the Heliosphere

## Coronal mass ejections (CMEs)

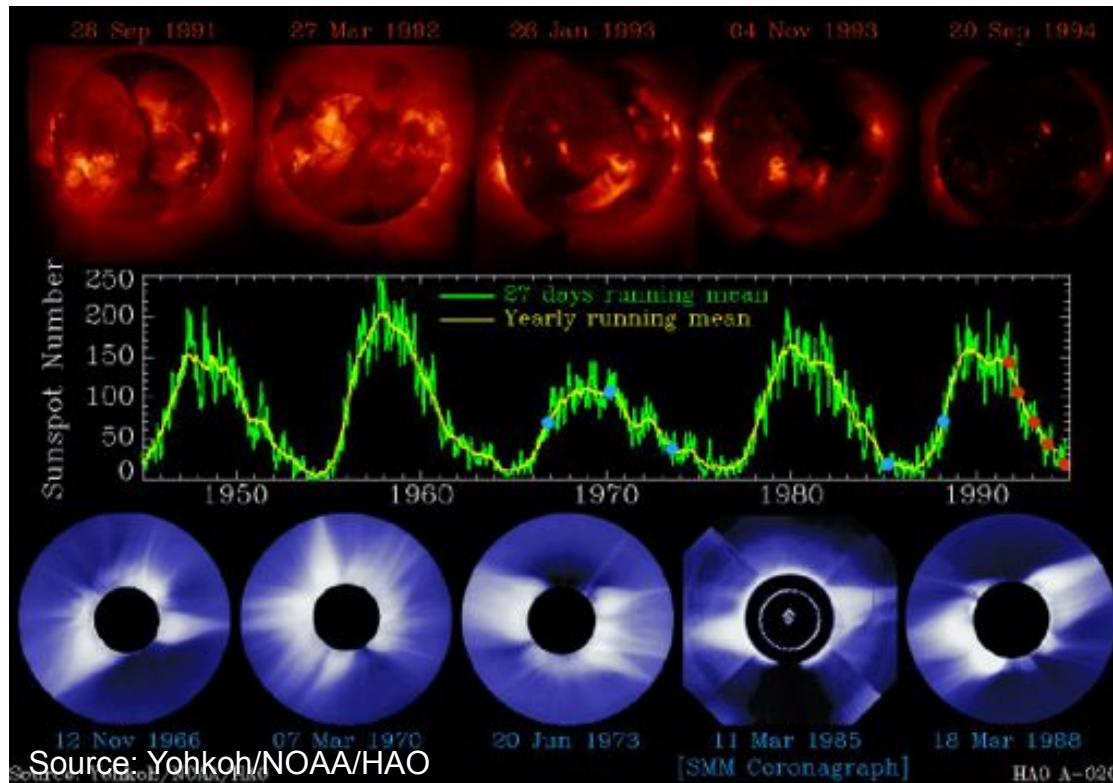


- White-light coronagraph (artificial eclipse) + inserted EUV image
- Extended streamers
- Movie (STEREO/ SECCHI): coronal mass ejection (CME),
  - ejection of a coronal structure (plasma+confining magnetic field)
  - energy  $\rightarrow 10^{25}$  J

# The Sun and the Heliosphere

## The solar activity cycle

Corona in X-rays



Sunspot index

Corona (white light; eclipse)

- All magnetic manifestations (sunspots, structure of the corona) vary in a cyclic way (period 9-14 years, mean 11 years)
- The numbers of eruptive events (flares, CMEs) follow this variation
- Amplitude of the cycle varies (~100 yr period)

# The Sun and the Heliosphere

## Impact on the Earth's space environment

