

Solar activity through observations & modelling

Jasmina Magdalenić Zhukov

The Sun

$$M_{\odot} \approx 2 \times 10^{30} \text{ kg} \\ \approx 330\,000 M_{\text{Earth}}$$

$$n_{\odot} \approx 1.08 \text{ kg/m}^3 \\ \approx 0.26 n_{\text{Earth_mean}}$$

$$R_{\odot} \approx 6.69 \times 10^8 \text{ m} \\ \approx 109 R_{\text{Earth}}$$

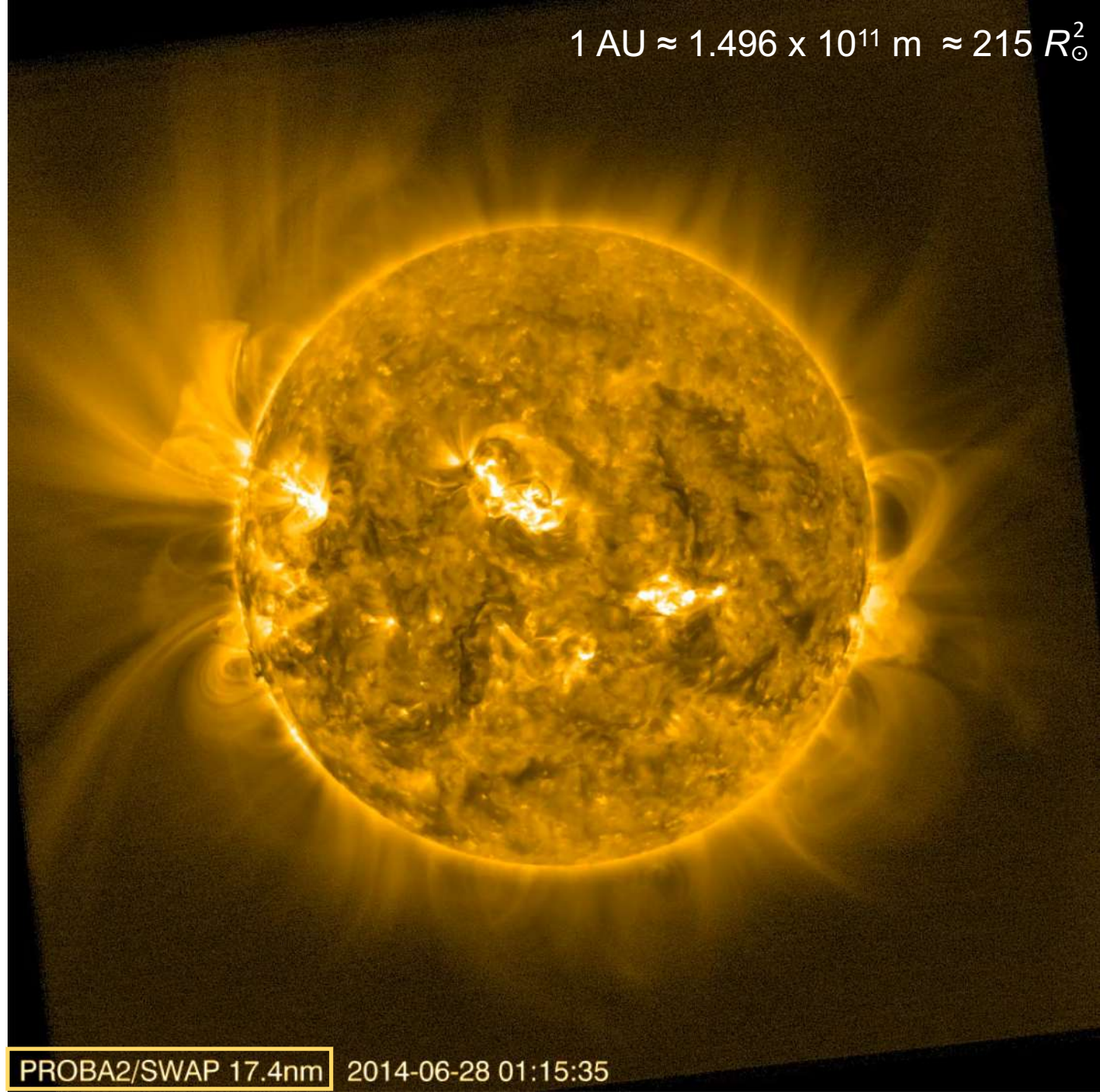
$$\text{Age} \approx 4.5 \times 10^9 \text{ years}$$

Composition:

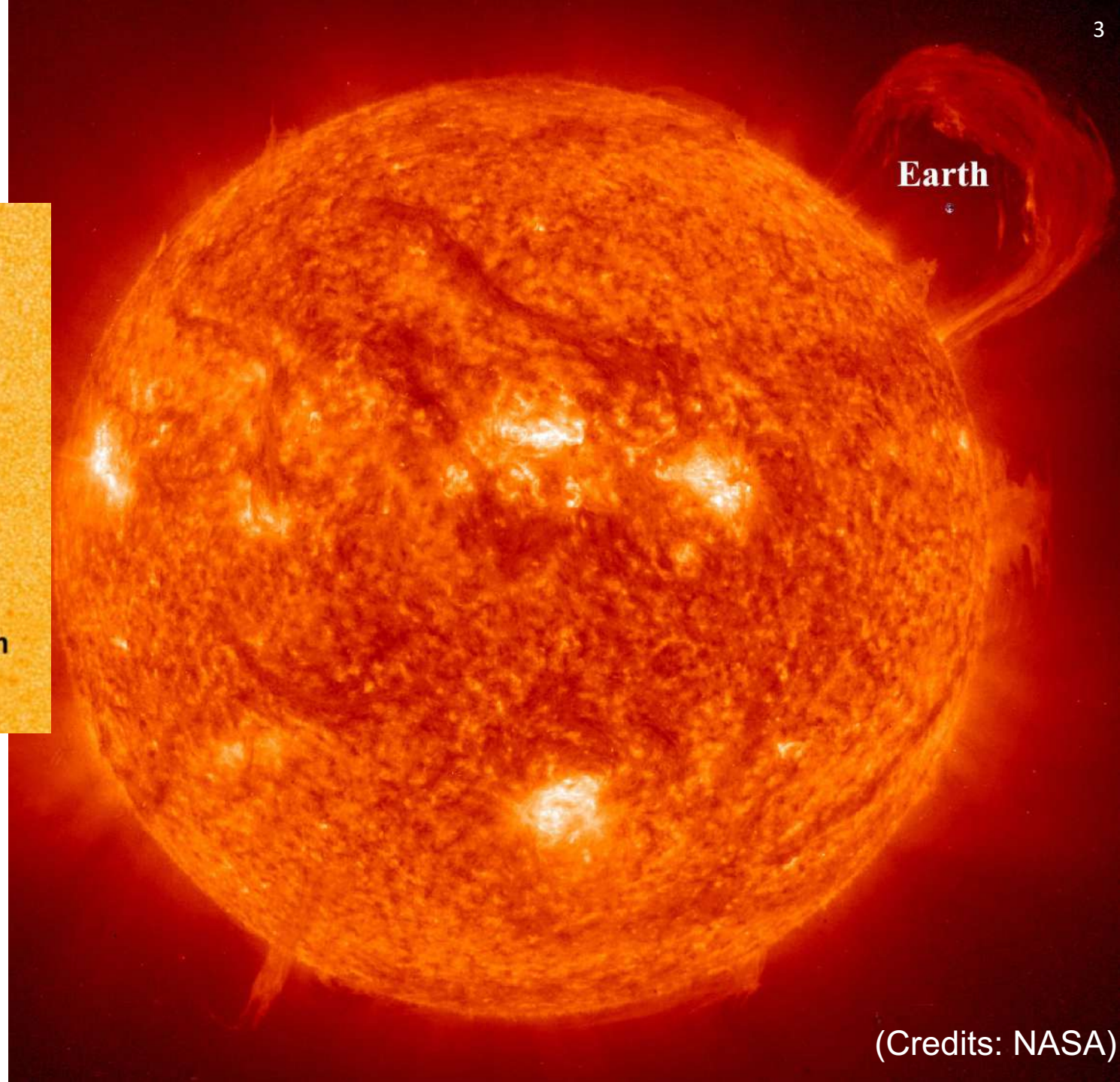
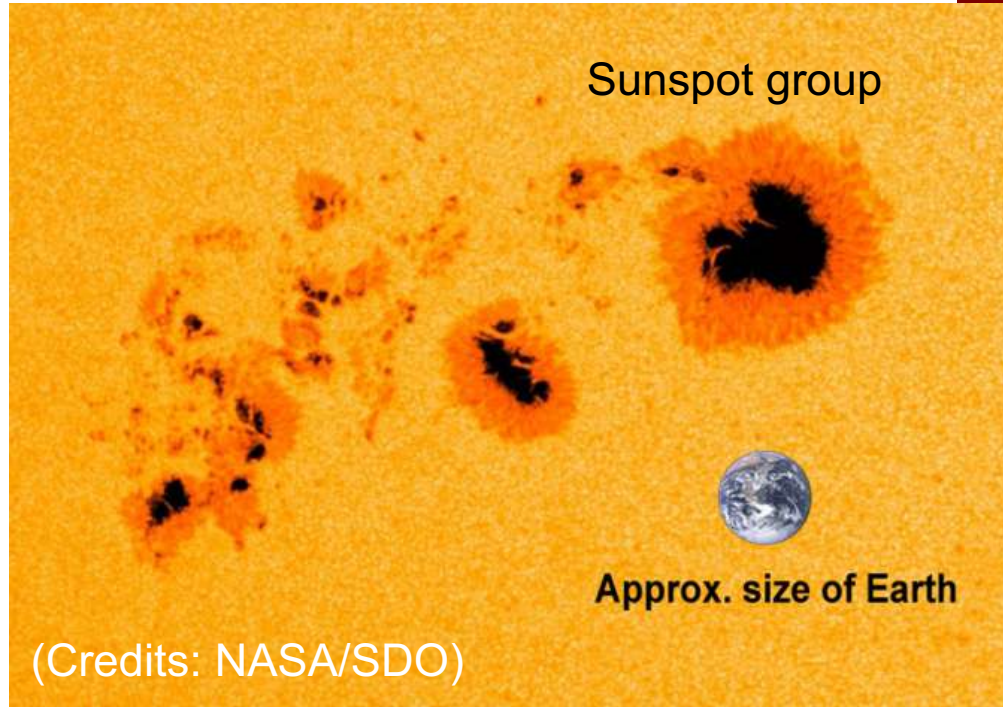
\approx 92% of hydrogen,

\approx 7.8 % helium,

\approx 0.1 % oxygen, carbon, nitrogen

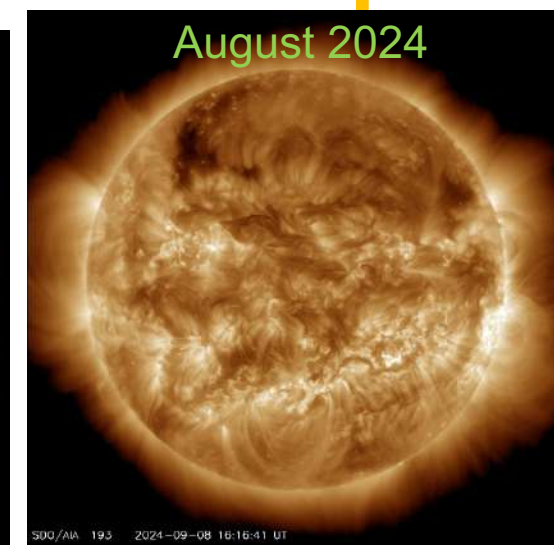
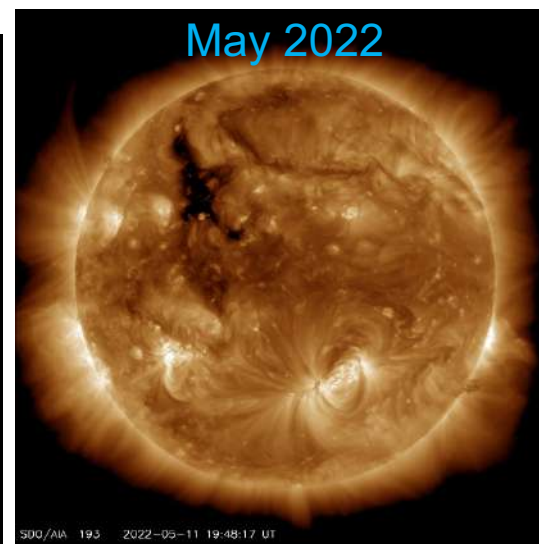
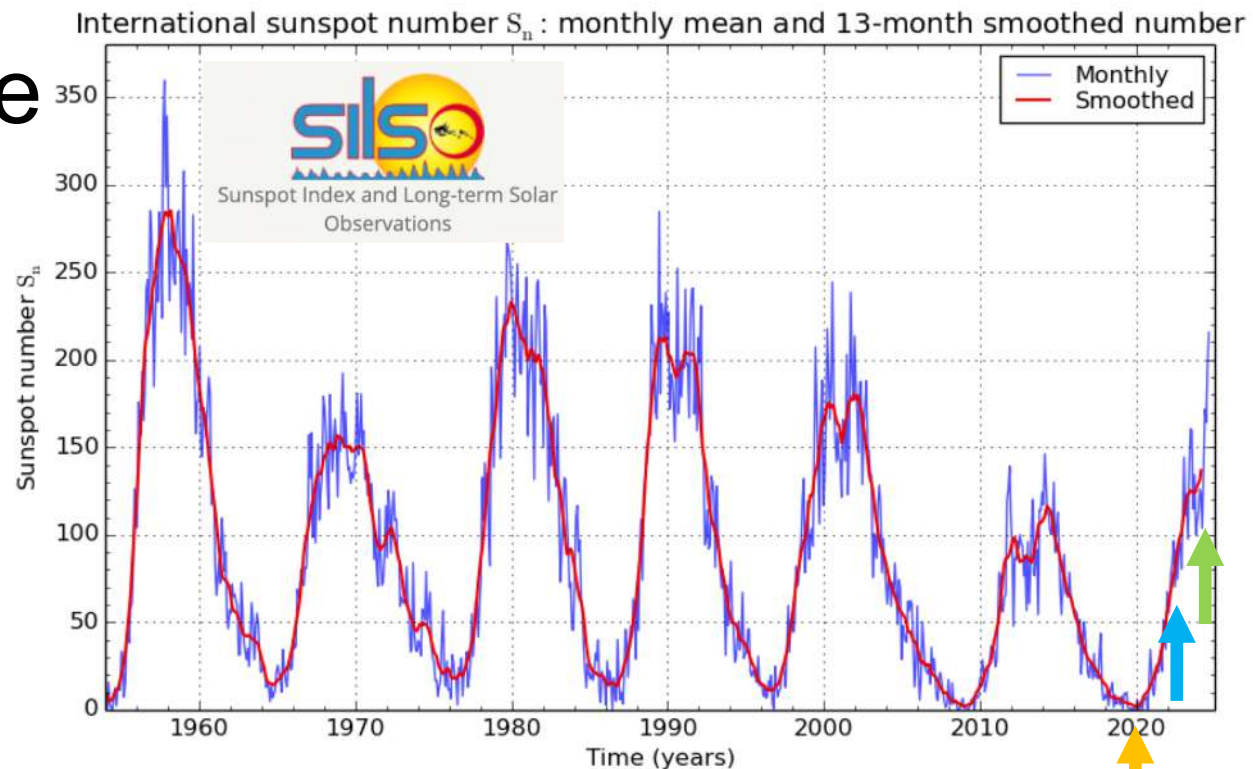


How big is the Sun?

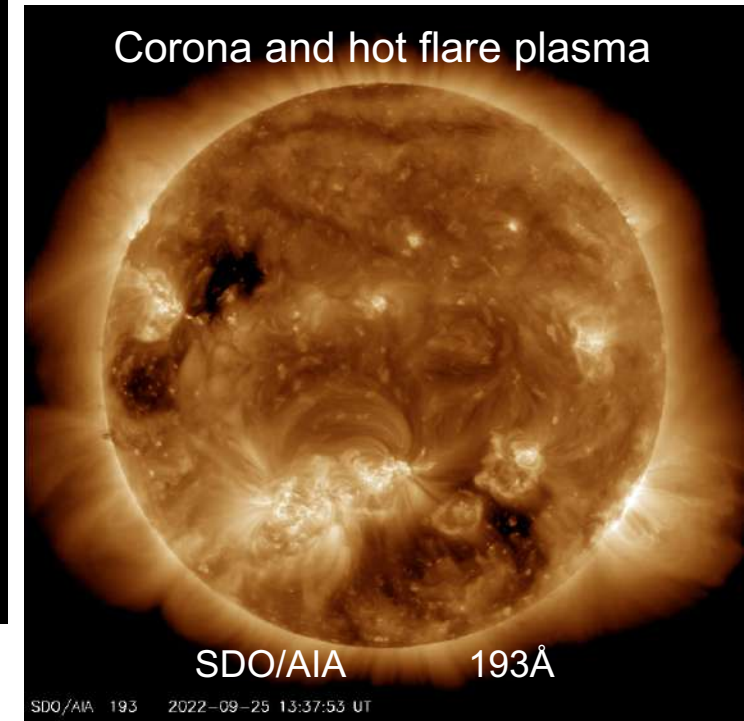
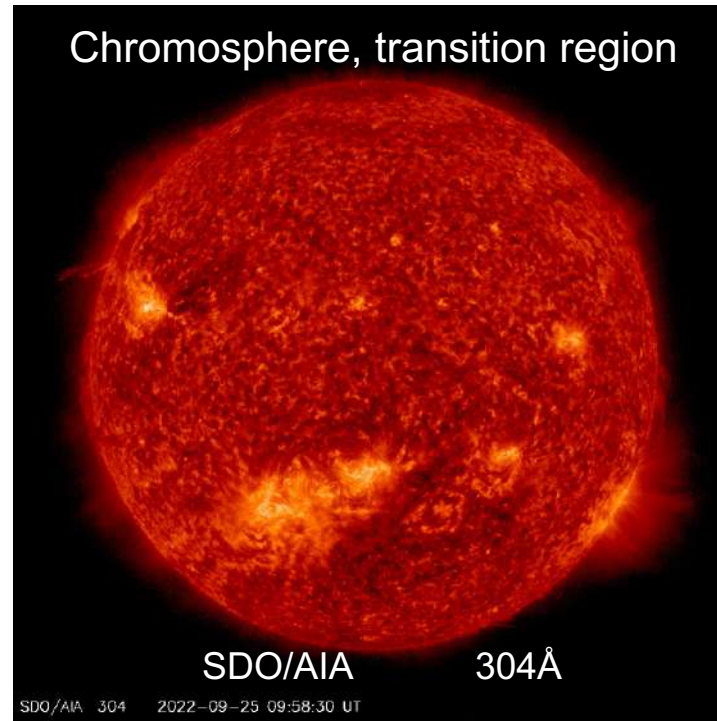
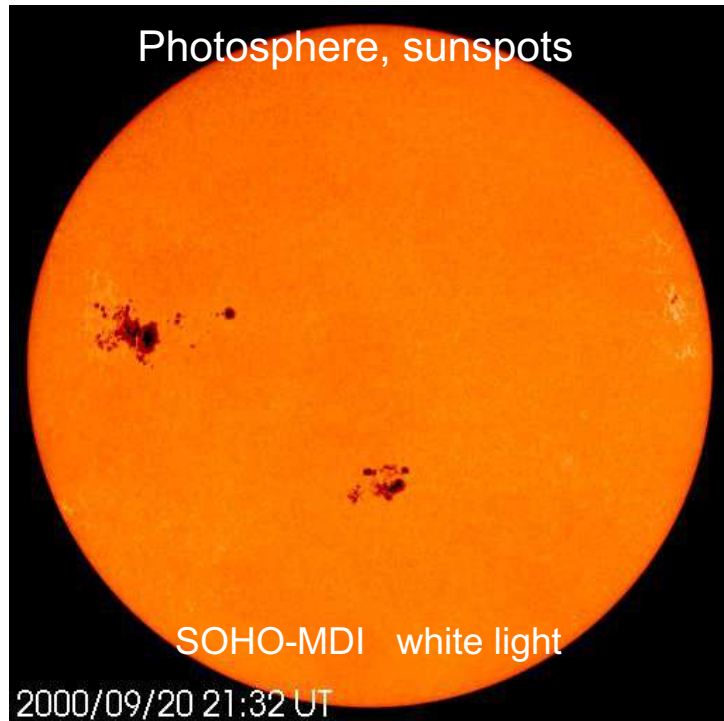


Solar activity & solar cycle

- Solar activity varies with an **average period of 11 (22) years.**
- Magnetic poles of the Sun flip every 11 years.
- Sun's activity is mainly visible in the solar corona.



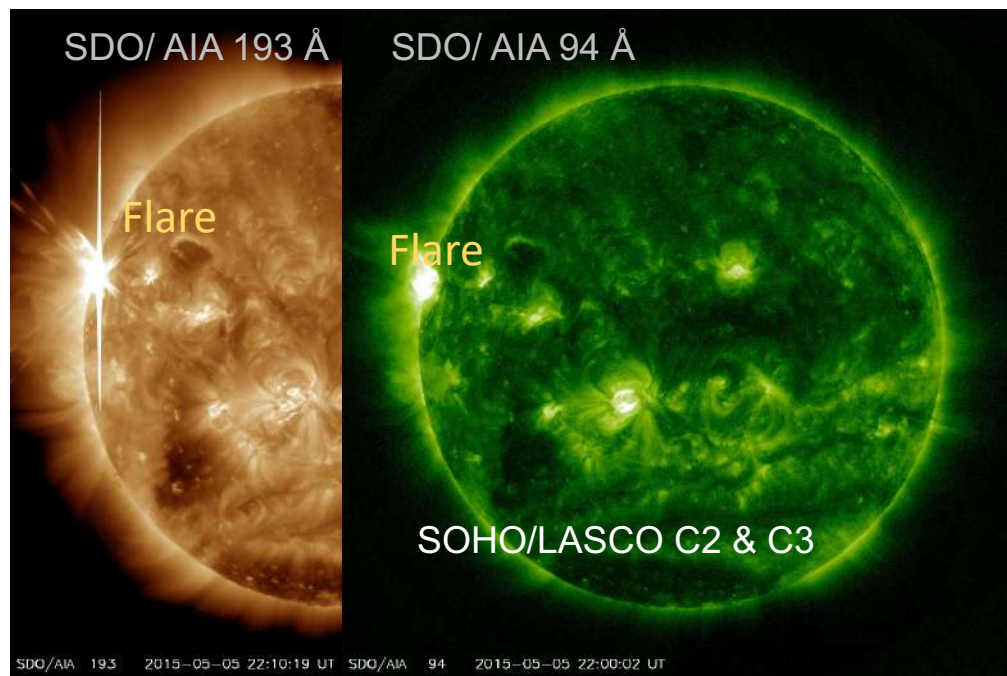
Observing the Sun at different wavelengths



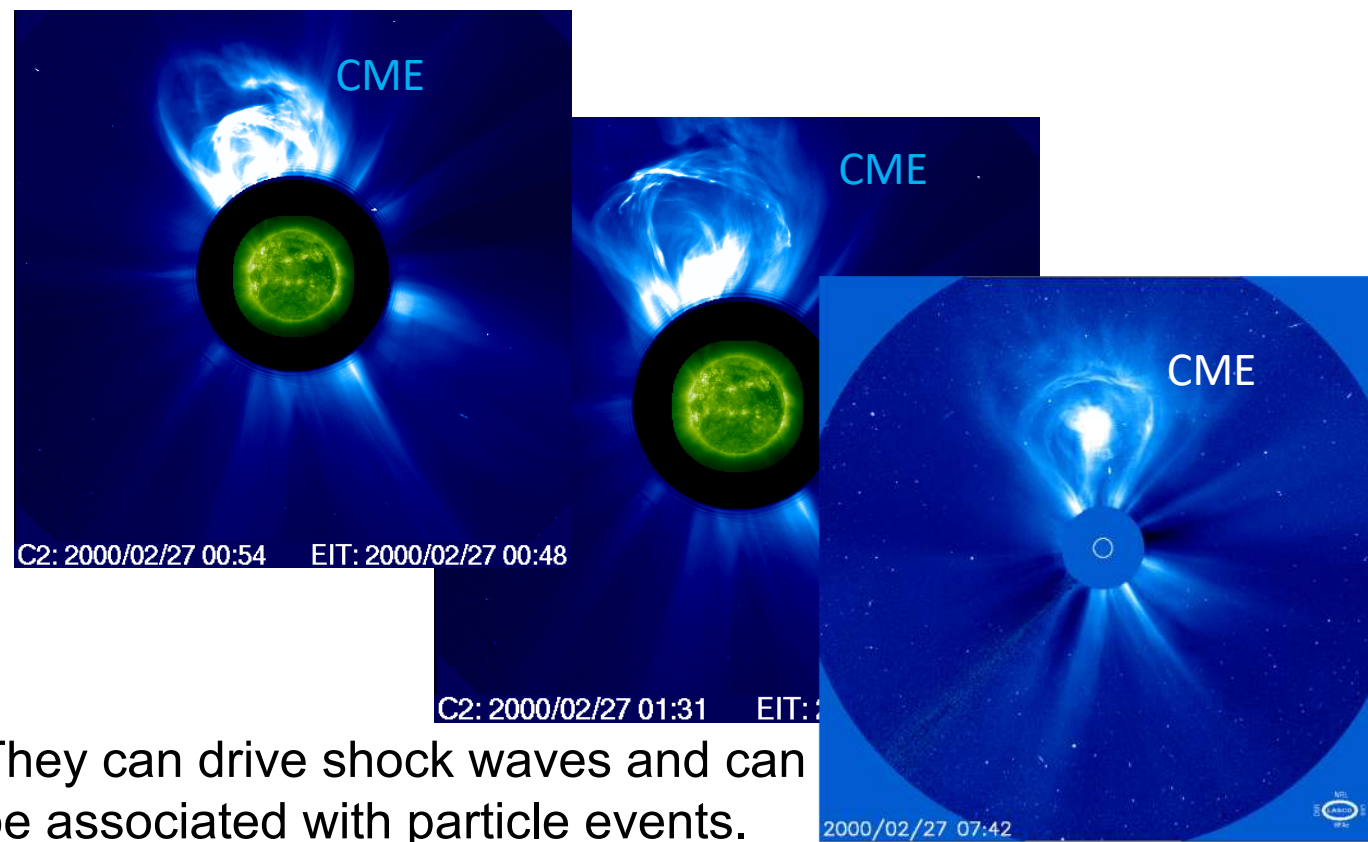
Different wavelengths map the processes at different temperatures, and in different layers of the solar atmosphere.

Solar activity: Solar Flares & Coronal Mass Ejections

- **Solar flares** are large and abrupt release of the energy stored above the sunspot groups.
- **Coronal mass ejections - CMEs** are large expulsions of the plasma and magnetic energy from the Sun into the heliosphere.

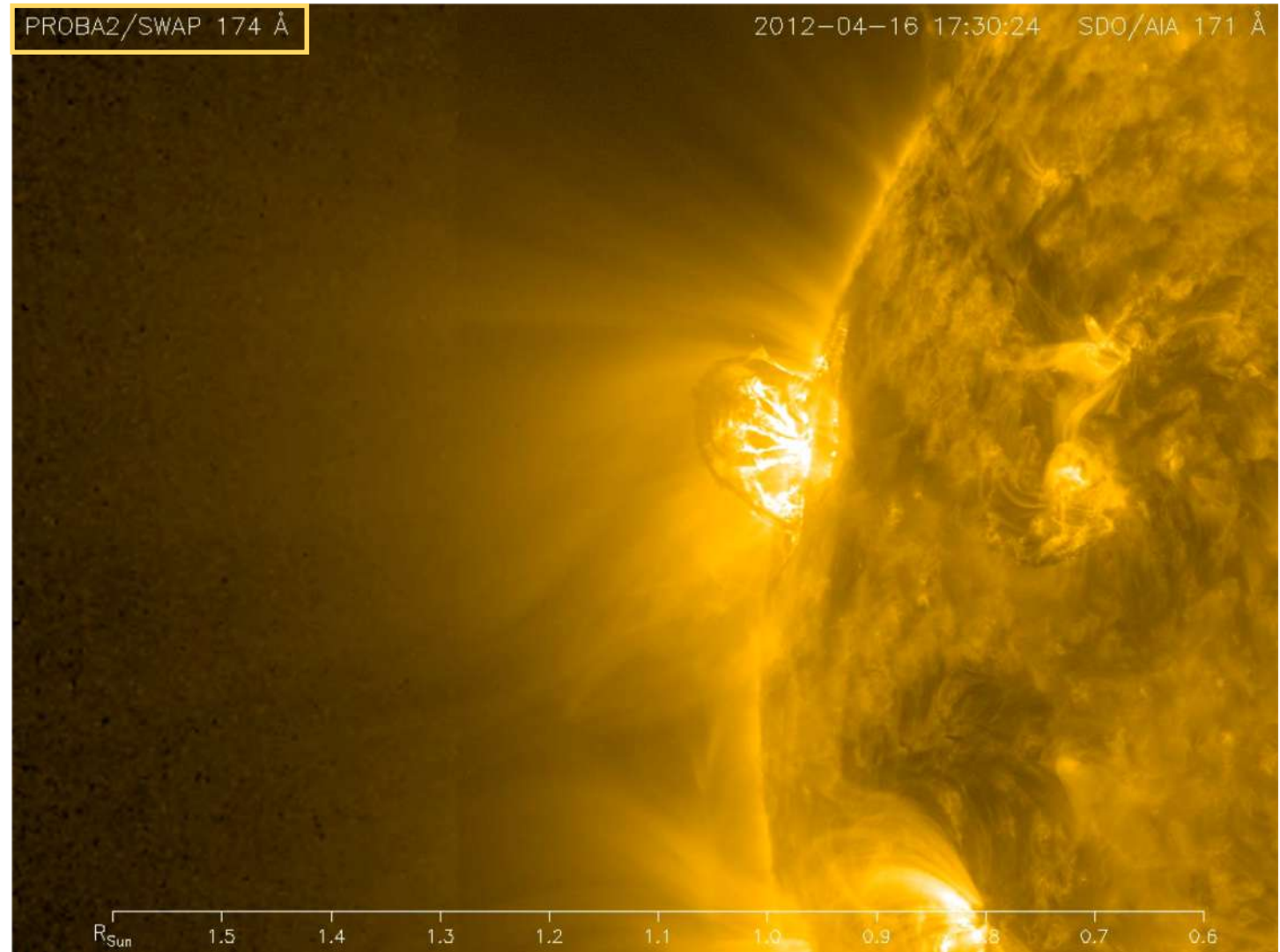
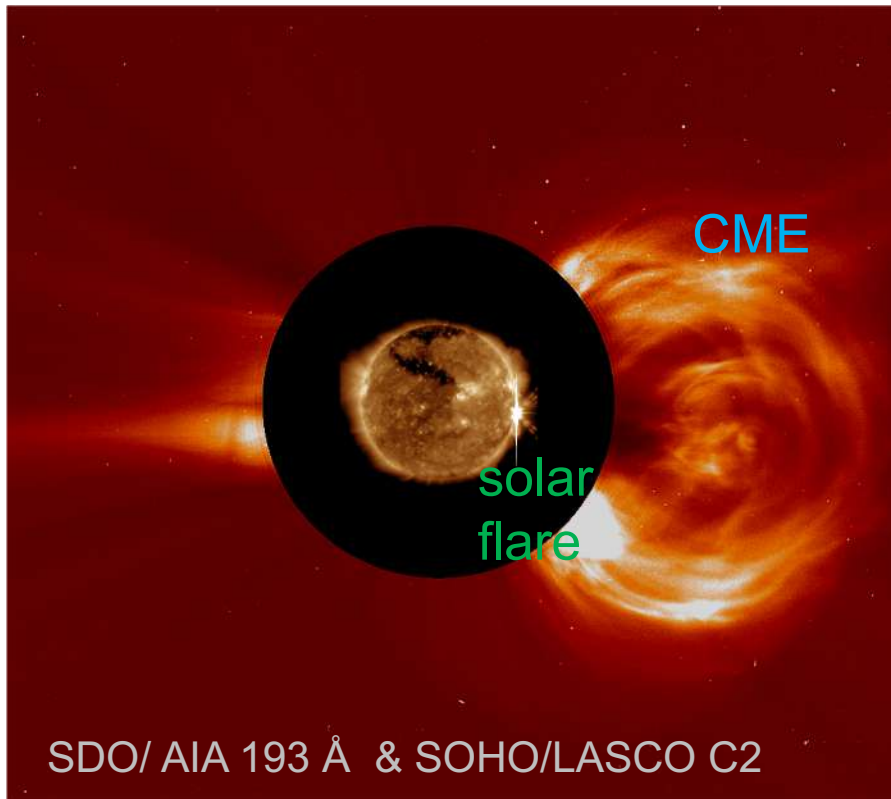


During solar flares: energy is released, plasma is heated, waves are generated & particles are accelerated.



They can drive shock waves and can be associated with particle events.

Association between Solar Flares & Coronal Mass Ejections - CMEs



Solar wind

A continuous flow of charged particles propagating from the Sun into the interplanetary space.

Fast solar wind:

High speed: 500-800 km/s

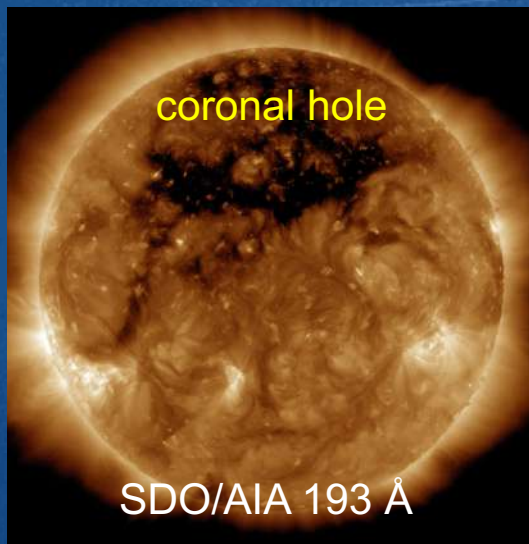
Low density: 3 – 4 particles/cm³

Source: coronal holes

Slow solar wind:

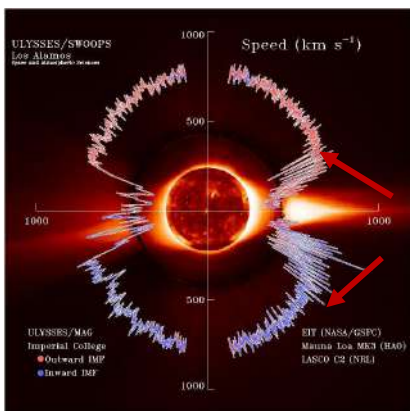
Low speed: 250 – 400 km/s

High density: 10.7 particles/cm³

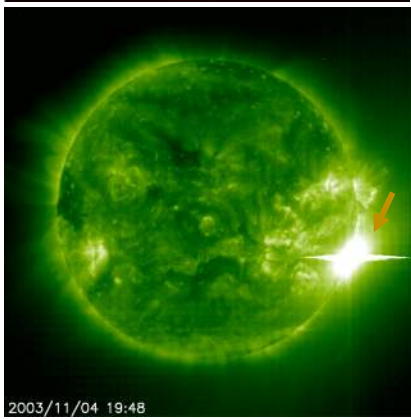


Why is solar activity important?

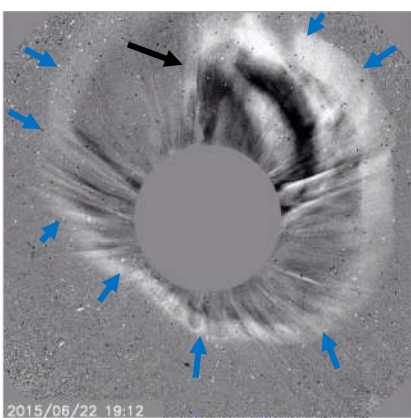
Solar activity can impact Earth in form of so-called space weather events.



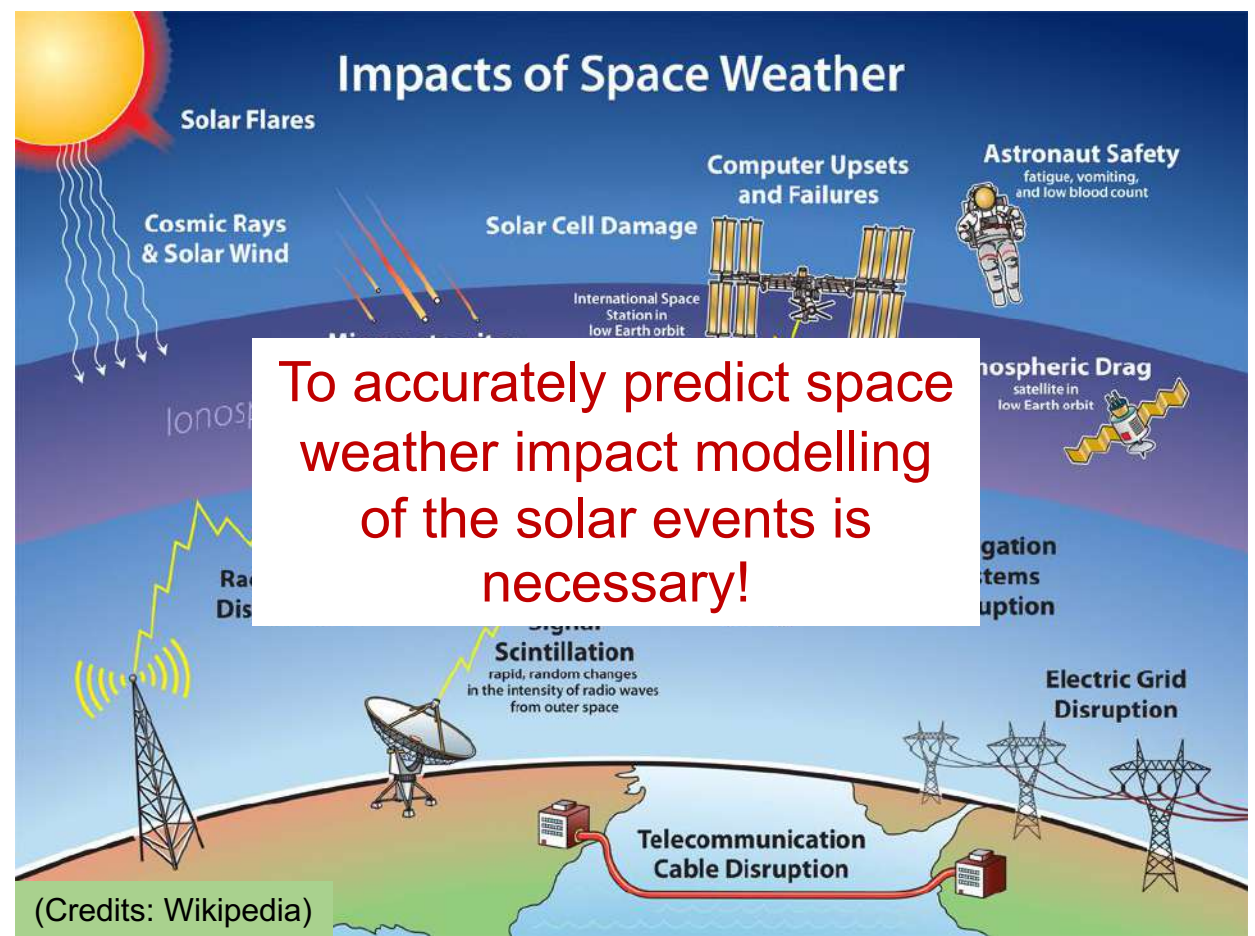
- Fast solar wind



- Solar flares → Solar energetic particle events (SEPs)

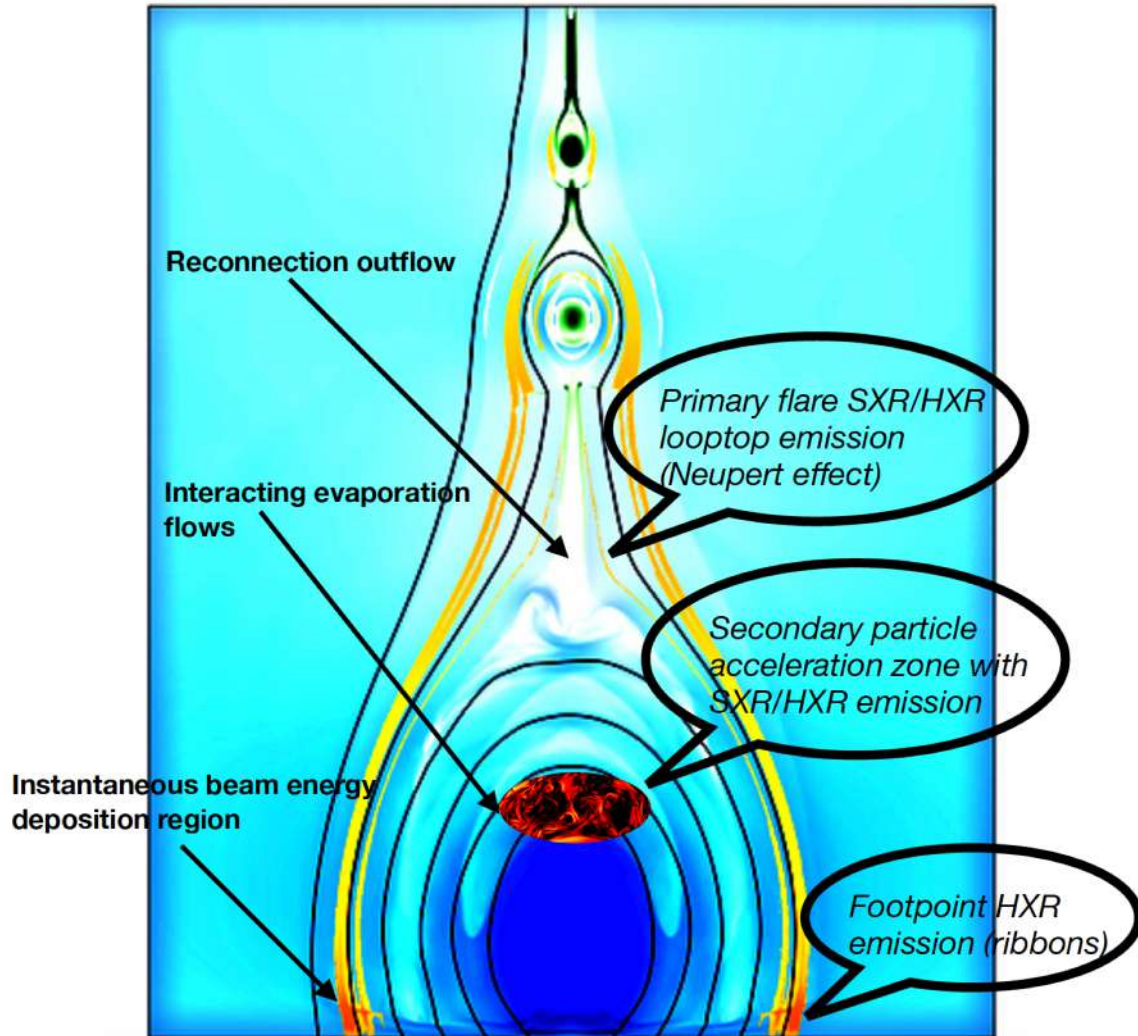


- CMEs → Shock waves → SEPs

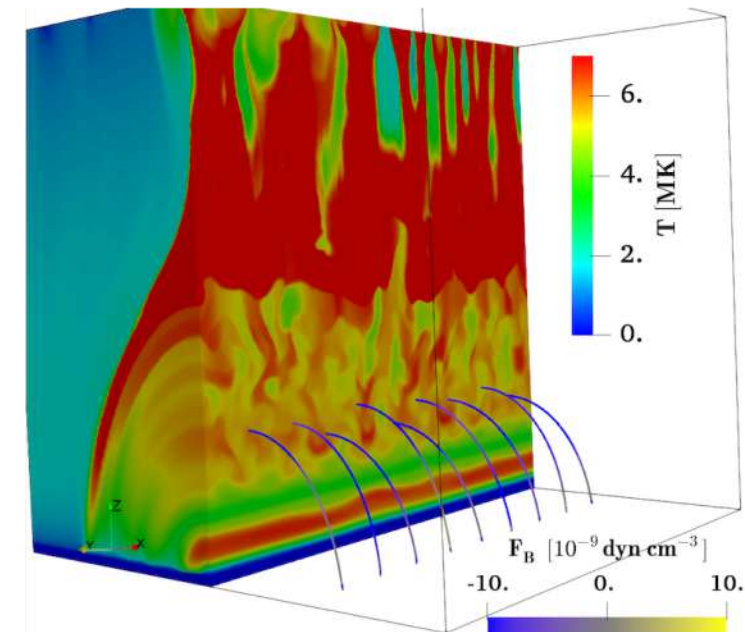


(Credits: Wikipedia)

Modelling of flares & particle acceleration



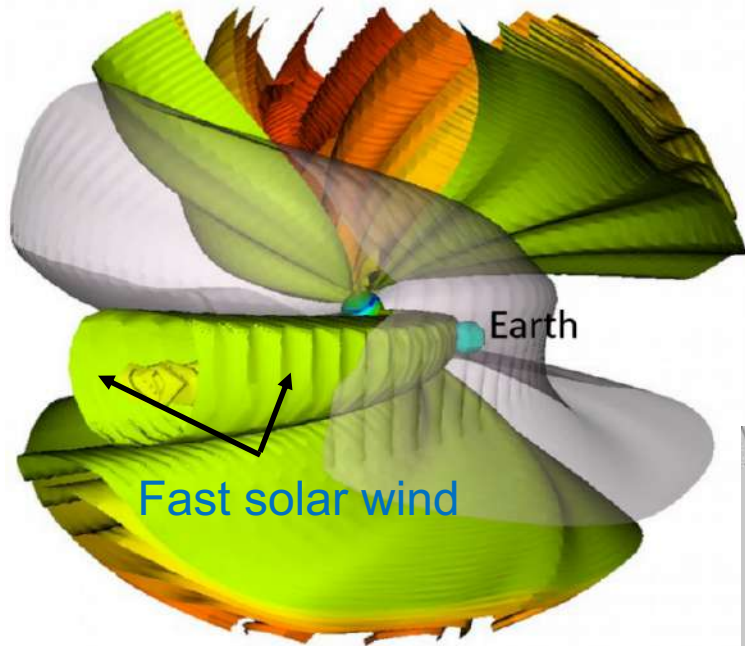
- Solar flare simulations in 2D & 3D combined with particle beam models provide information on particle trapping and acceleration during solar eruptions.



Self-consistent MHD+particle beam models (Bacchini, Ruan, Keppens 2024, submitted; Druett et al. 2023)

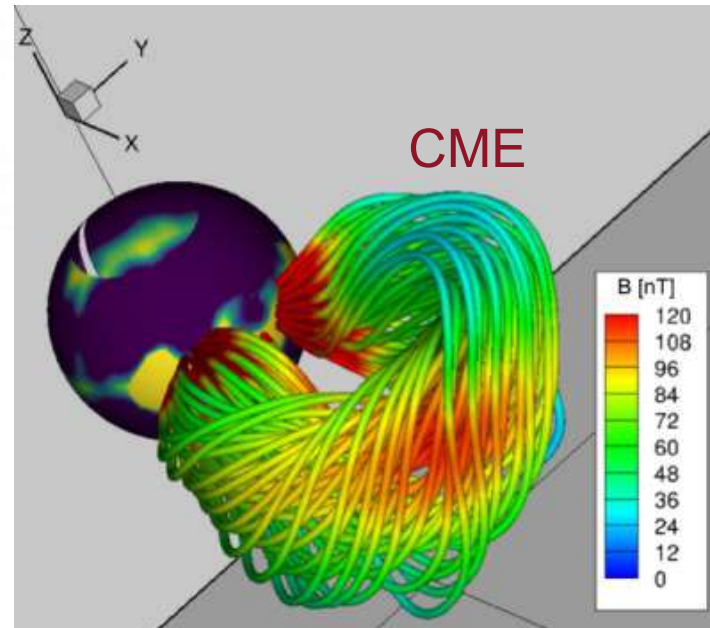
Test-Particle simulations.

Modelling of solar wind & CMEs



Credits: E. Samara

- 3D presentation of the modelled solar wind by EUHFORIA.
- Colorful isosurfaces map solar wind of different speed & gray isosurface defines the heliosphere current sheet.



A FRi3D flux rope in EUHFORIA.
(Maharana et al., 2022)

- Some of the state-of-the-art solar wind & CME models at KU Leuven:
 EUHFORIA, COCONUT, Icarus; FRi3D, Torus, Horseshoe

Solar Physics in Belgium: Observations & Modelling



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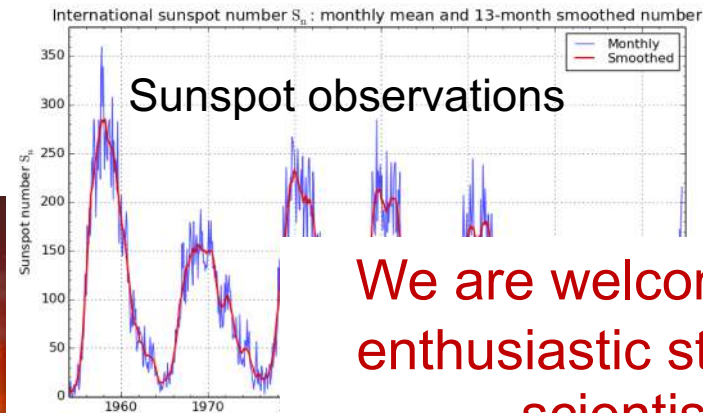
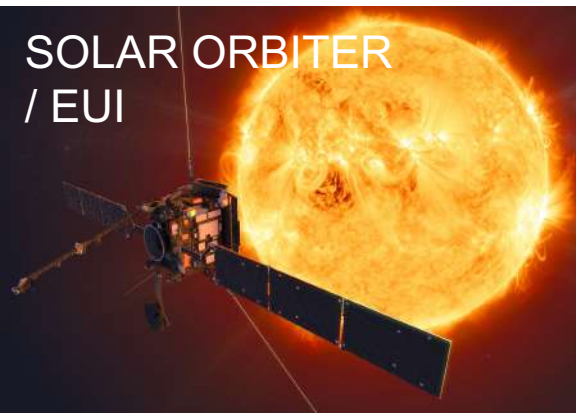
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Solar Physics in Belgium



Instruments &
observations

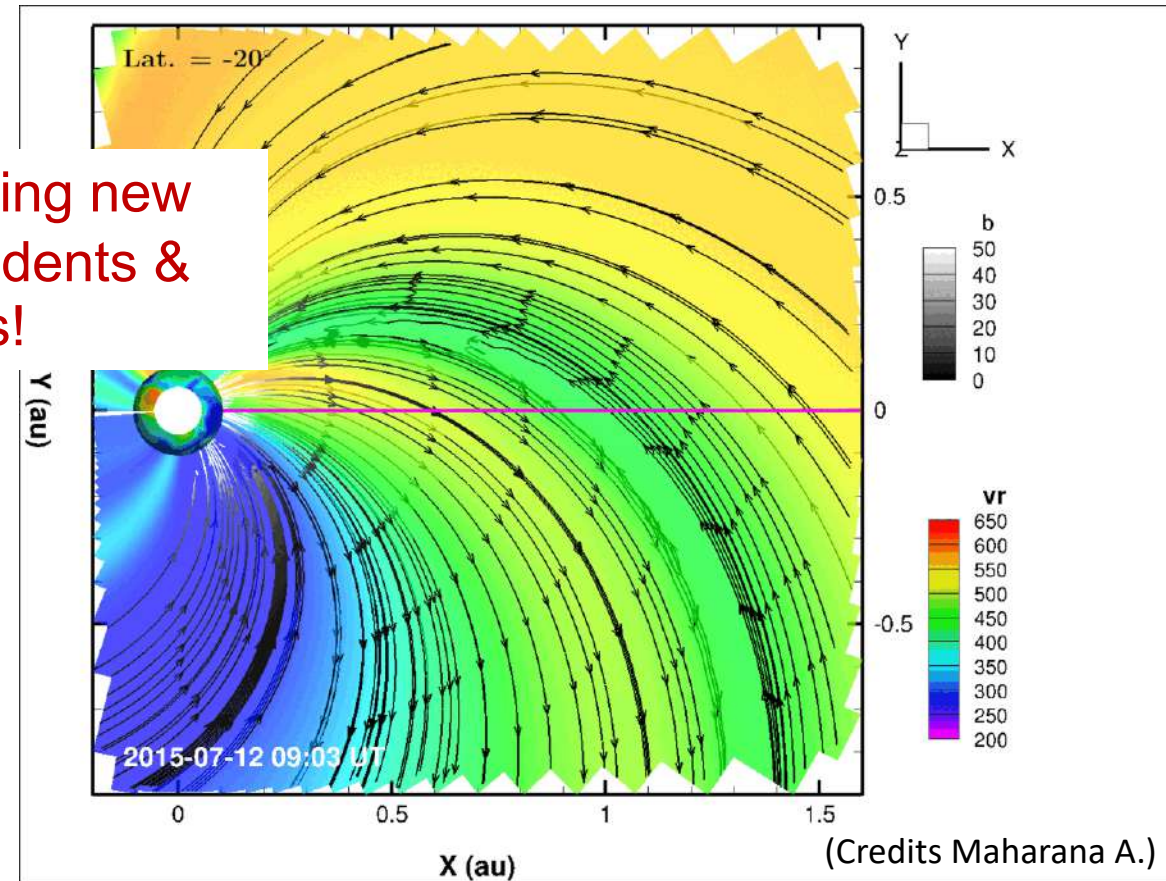


We are welcoming new
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scientists!



Modelling

Flares, CMEs & solar wind, particle acceleration



Thank you for your
attention!

