Physics SURVEY

The Physics Department is surveying all students who take physics courses to assess the department's "human climate." (e.g. inclusivity issues, participation in activities, etc)

http://bit.ly/physUGsurvey

(I will send out an e-mail to the class with the link)

Today's Topics

Monday, November 11, 2019 (Week 11, lecture 26) – Chapters 15, 16.

0. The Sun: a visual introduction

1. Sun's surface

2. Sun's internal structure

3. Solar fusion

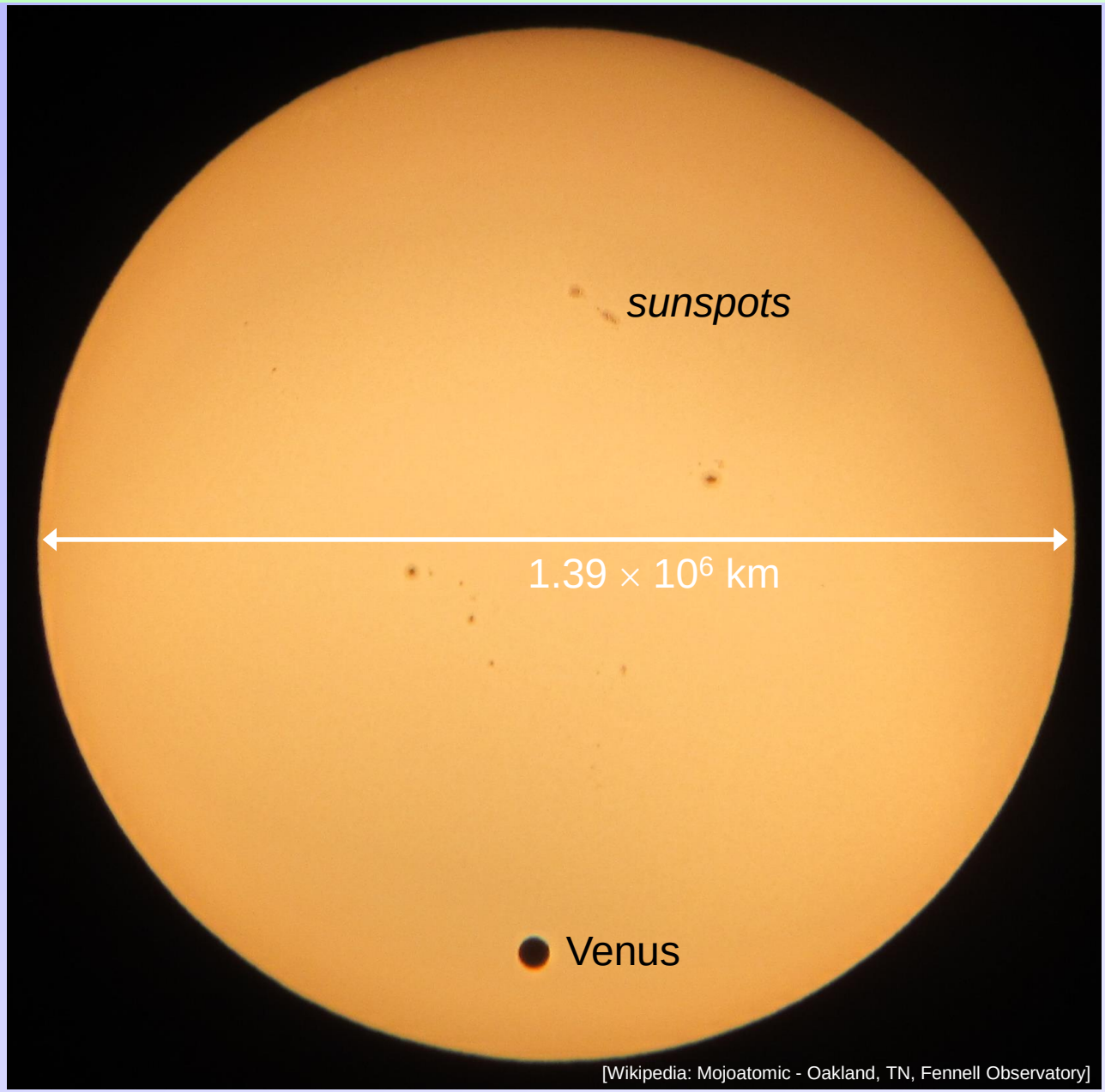
Our Sun

[OpenStax: Astronomy]

Our Sun

[Wikipedia: Mojoatomic - Oakland, TN, Fennell Observatory]

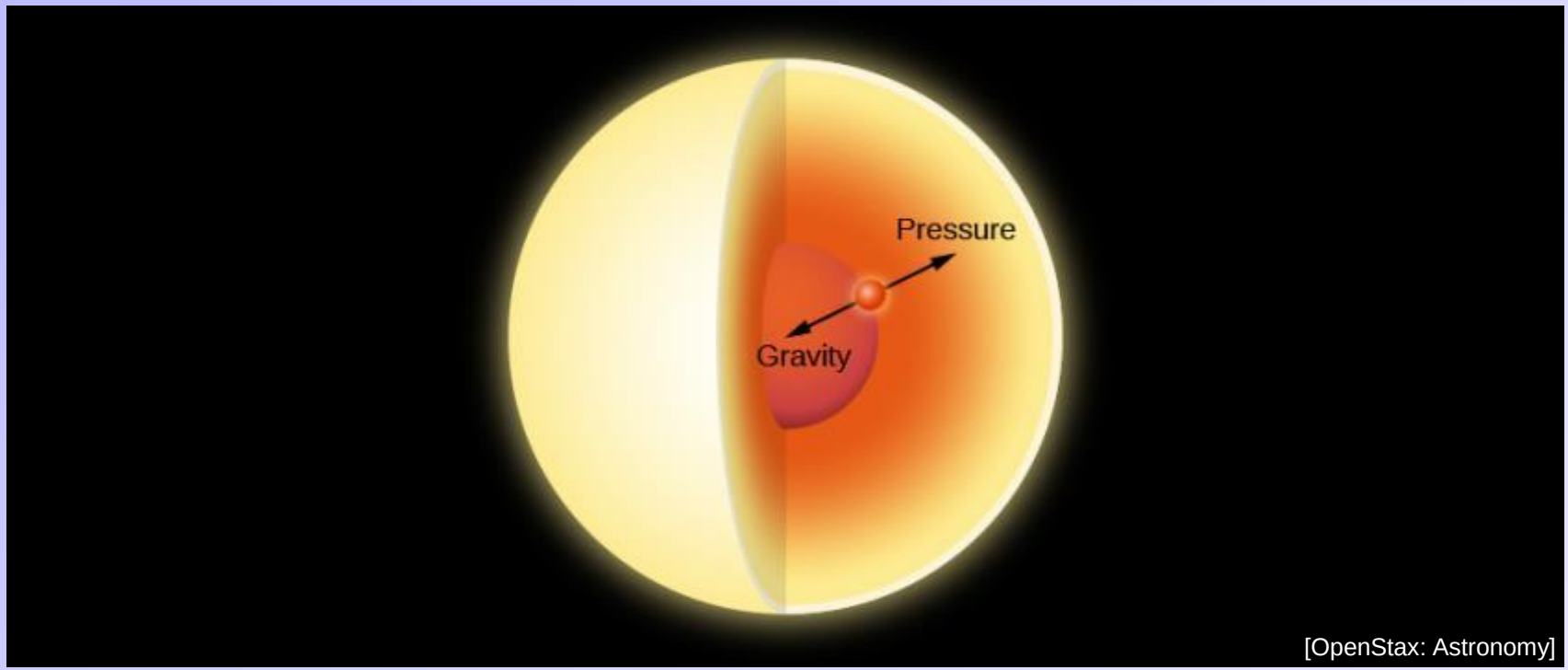
Our Sun



Transit of Venus, 2012. *(visible light)*

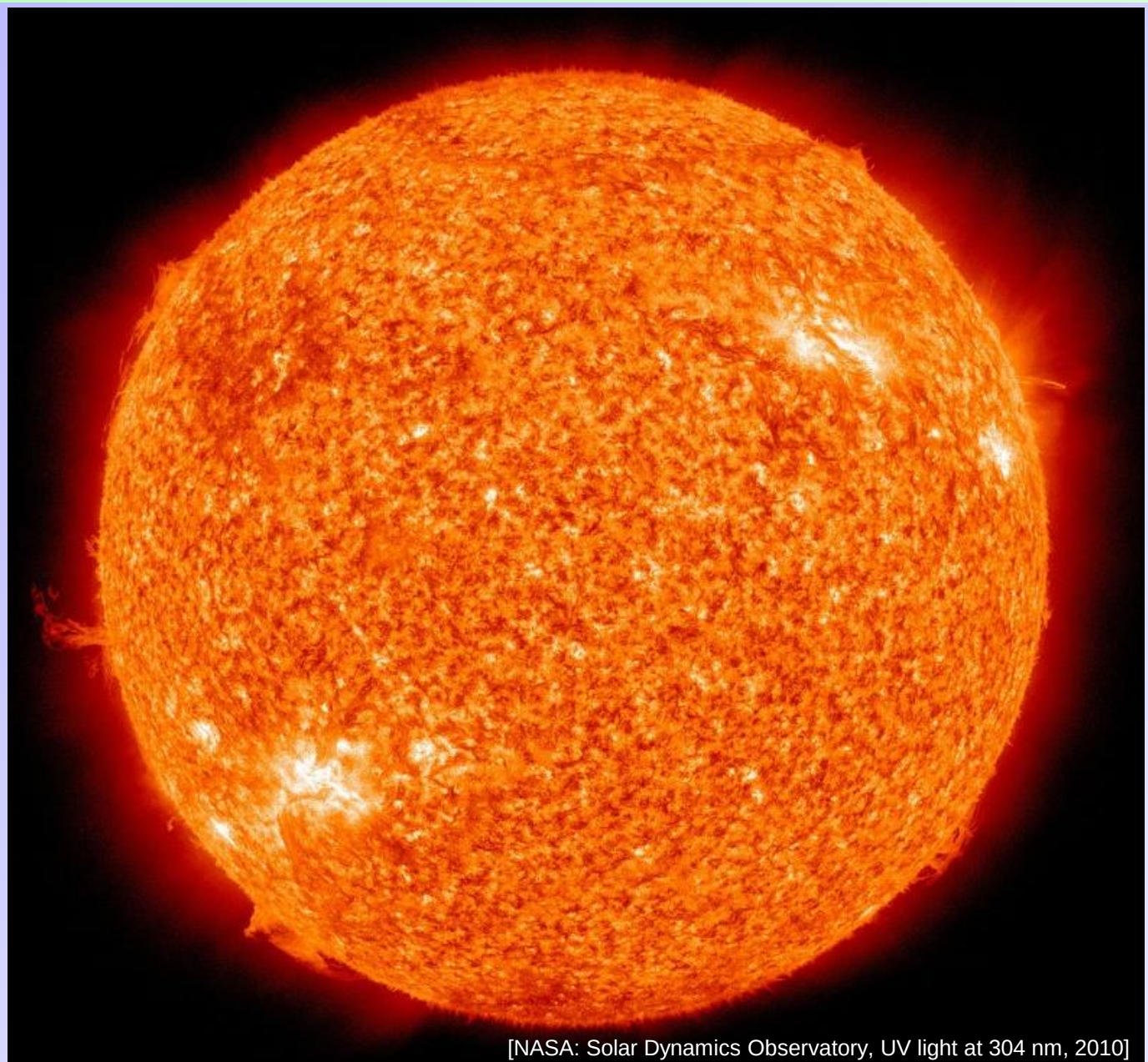
Solar Equilibrium

Gravity vs Fusion Heat



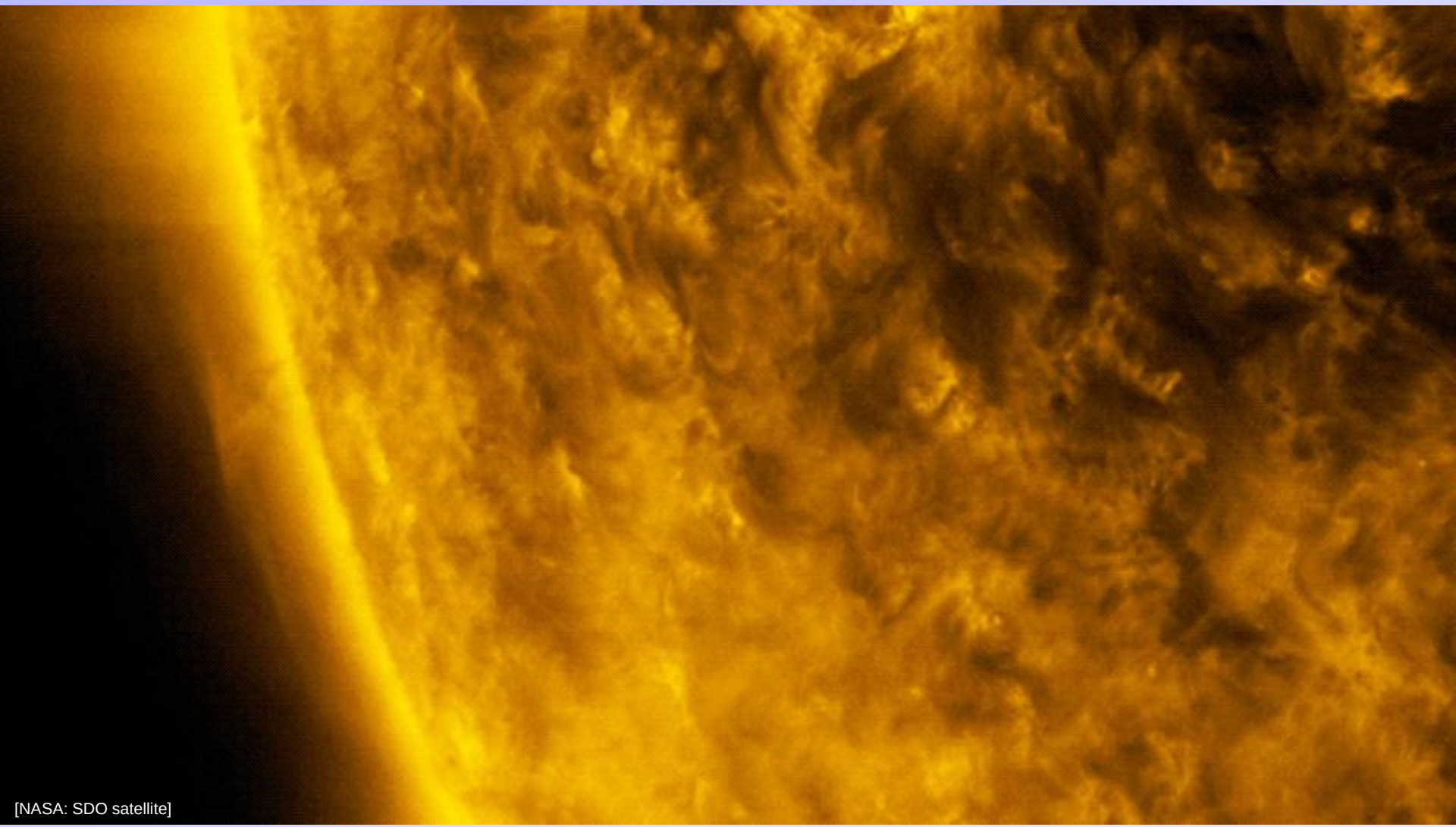
Hydrostatic Equilibrium: In the Sun (and any star), the **inward force of gravity** is ***exactly balanced*** at each point by the **outward force of gas pressure** due to **heat** from nuclear fusion.

Our Sun



[NASA: Solar Dynamics Observatory, UV light at 304 nm, 2010]

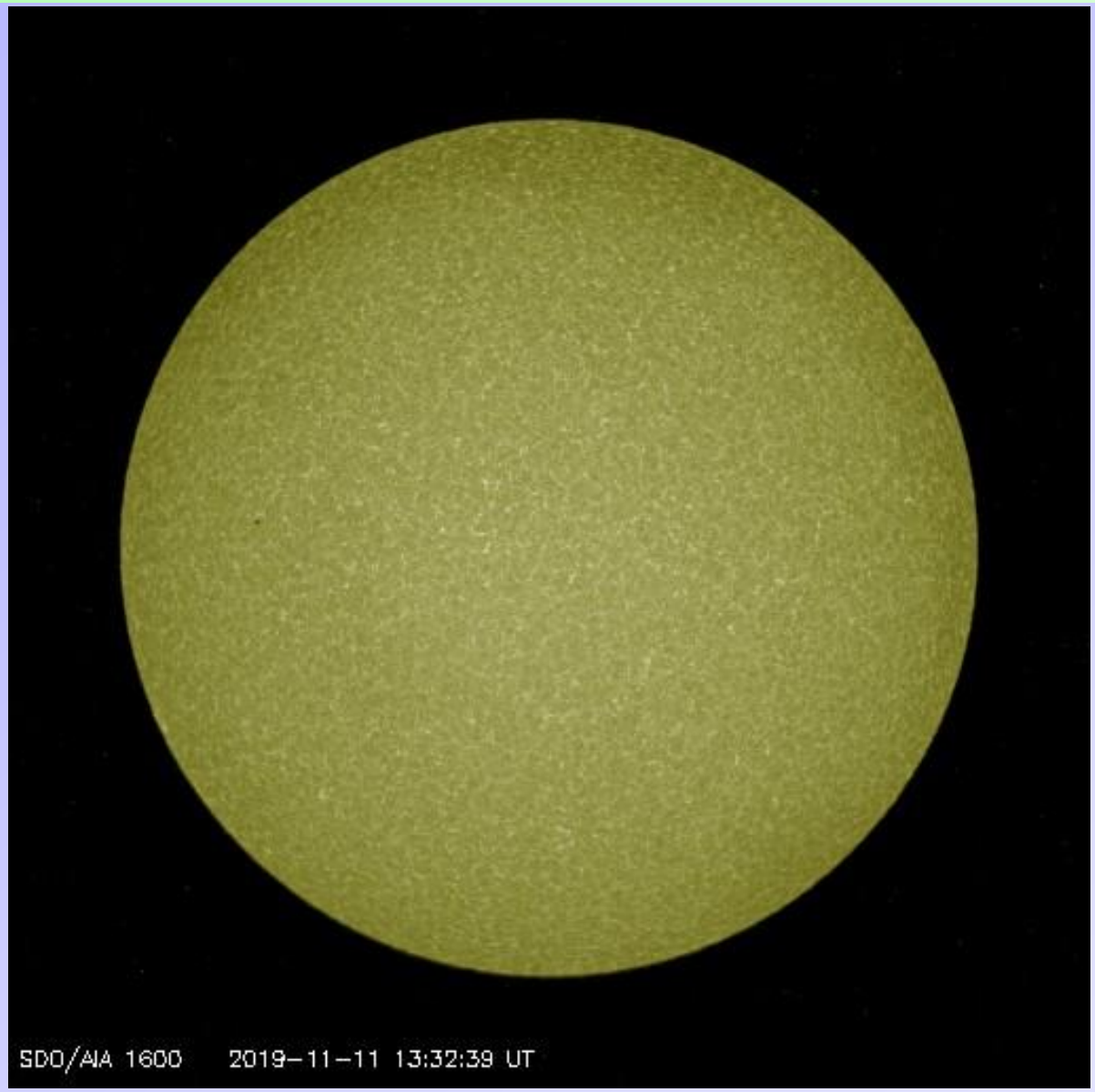
The Sun is Gigantic



[NASA: SDO satellite]

Transit of Mercury, May 9, 2016

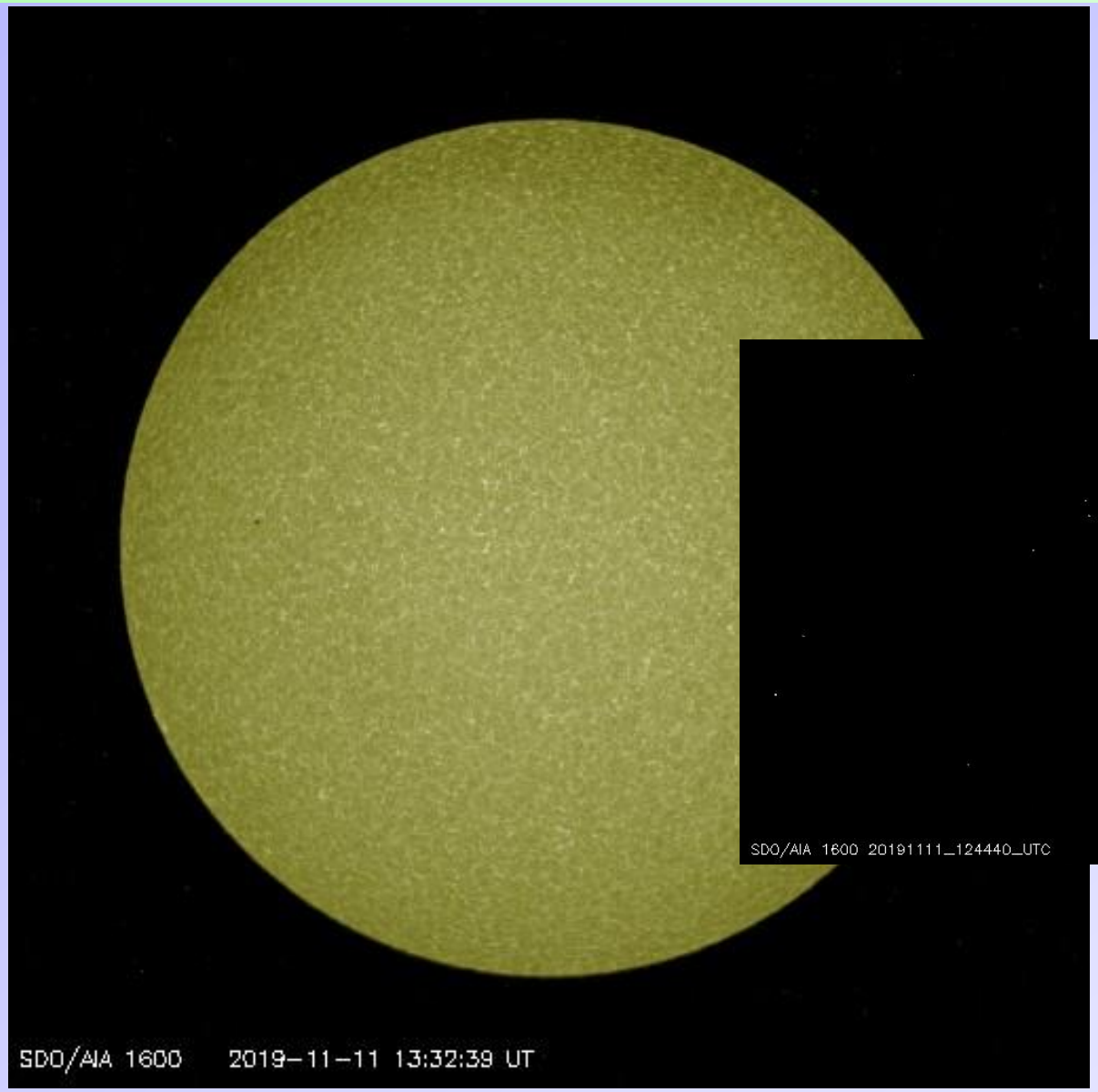
The Sun is Gigantic



Transit of Mercury, November 11, 2019 (i.e. right now)

Sun view at 1600 nm.

The Sun is Gigantic



Transit of Mercury, November 11, 2019 (i.e. right now)

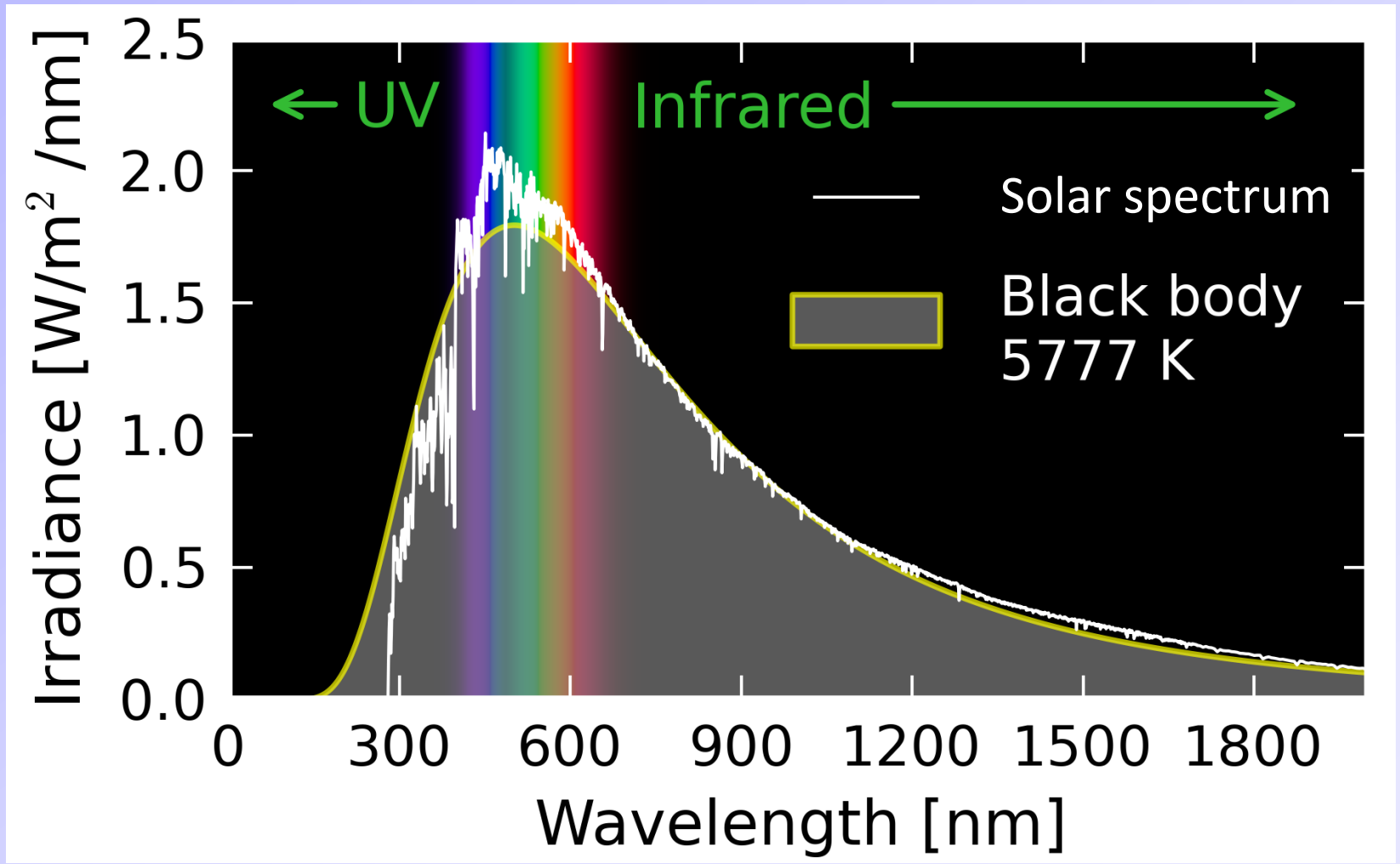
Sun view at 1600 nm.

The Sun is Gigantic

June 26, 2019 | The International Space Station passes in front of the sun as seen from Gyöngyös, Hungary. (Peter Komka/EPA-EFE/Shutterstock)

Our Sun

Blackbody Radiation Source

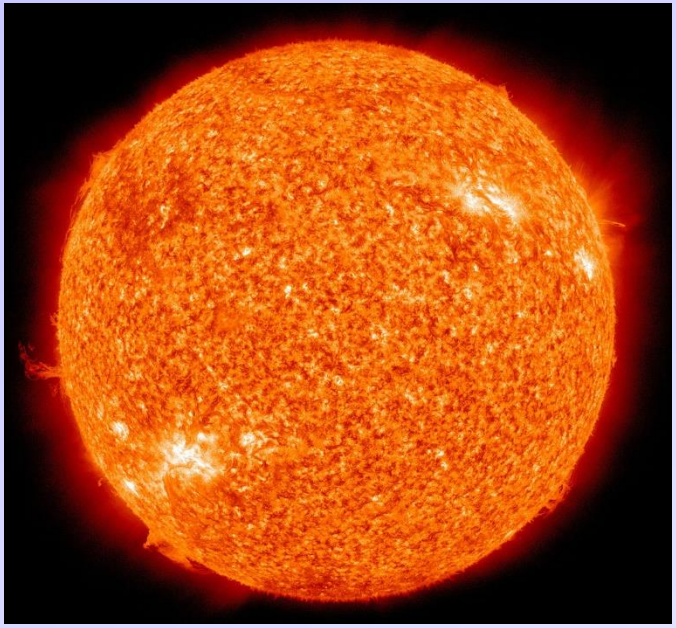


[Wikimedia Commons: Danmichaelo,public domain]

Our Sun: Surface (photosphere)

Properties

- Temperature = 5777 K (surface/photosphere)
- Substance: Plasma (electrons & nuclei are dissociated).
- Magnetosphere: ~ 1 Gauss at surface.
  (exception: sunspots at 3000 G)
- Rotation period: $T_{equator}$ = 25 days, T_{poles} = 34 days.
- Rotation axis tilt: 7.25° with respect to ecliptic.



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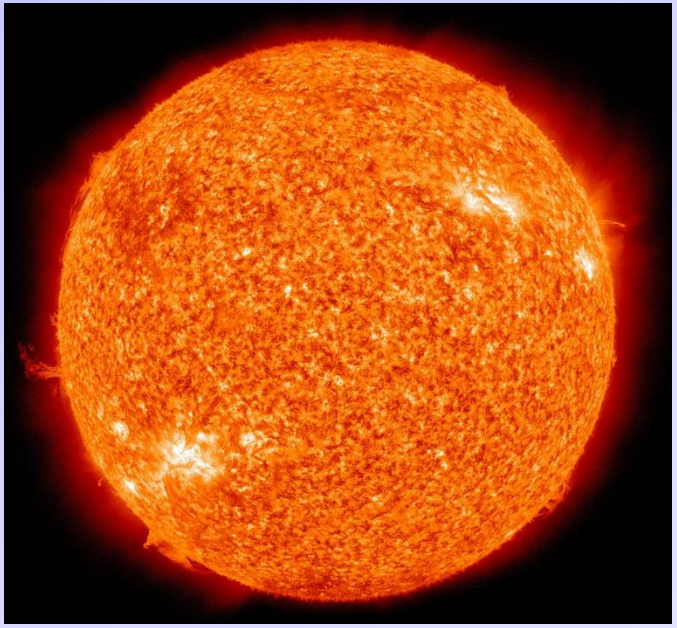

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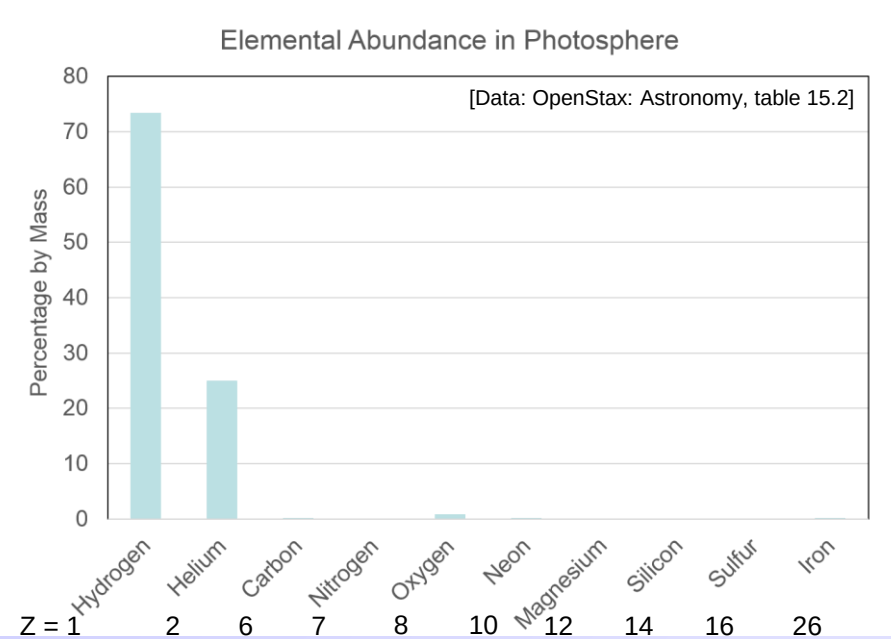
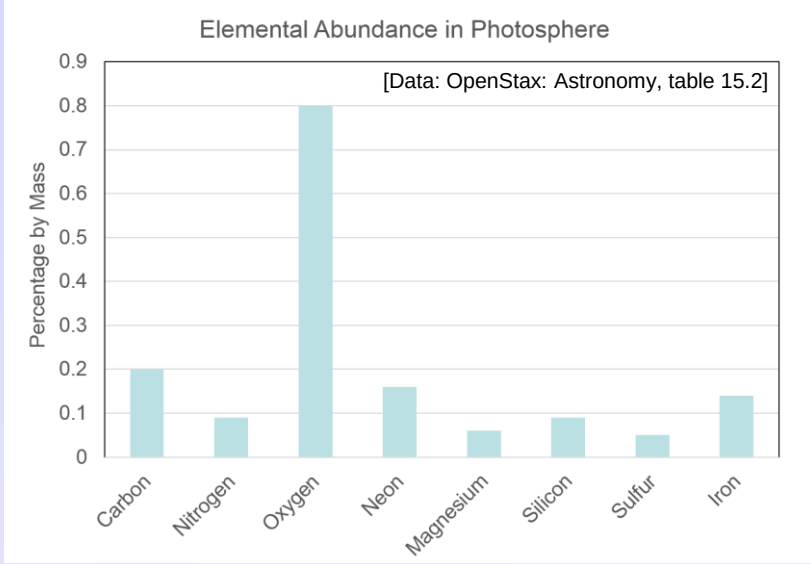


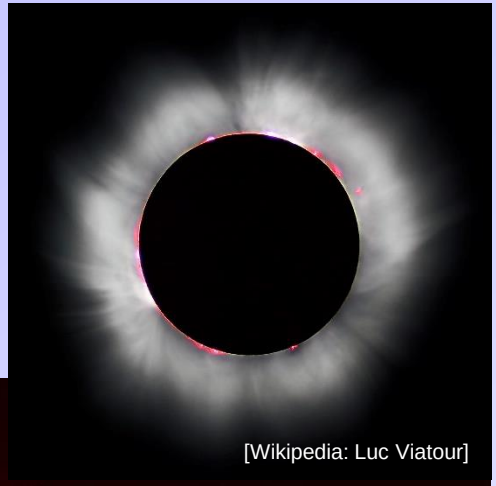


Solar Wind

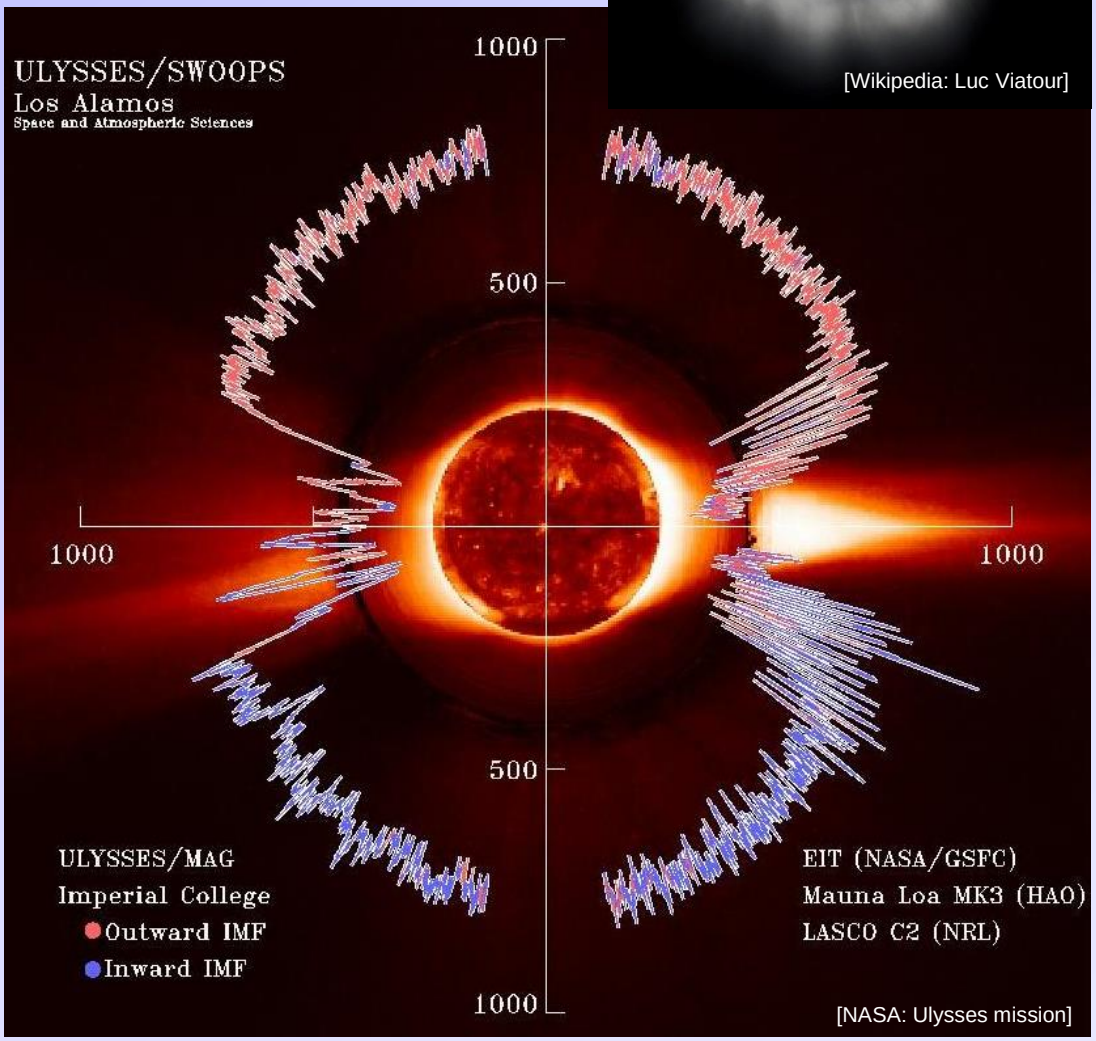
Extension of the Corona

Solar Wind

Extension of the Corona


[Wikipedia: Luc Viatour]

- Corona is very hot (1 million Kelvin)
- Solar wind consists of:
  - protons
  - electrons
  - alpha particles (He nuclei)
- Energy range: 0.5 – 10 keV
- Solar wind speed: 400 – 750 m/s
- Strongest emission is from coronal holes.

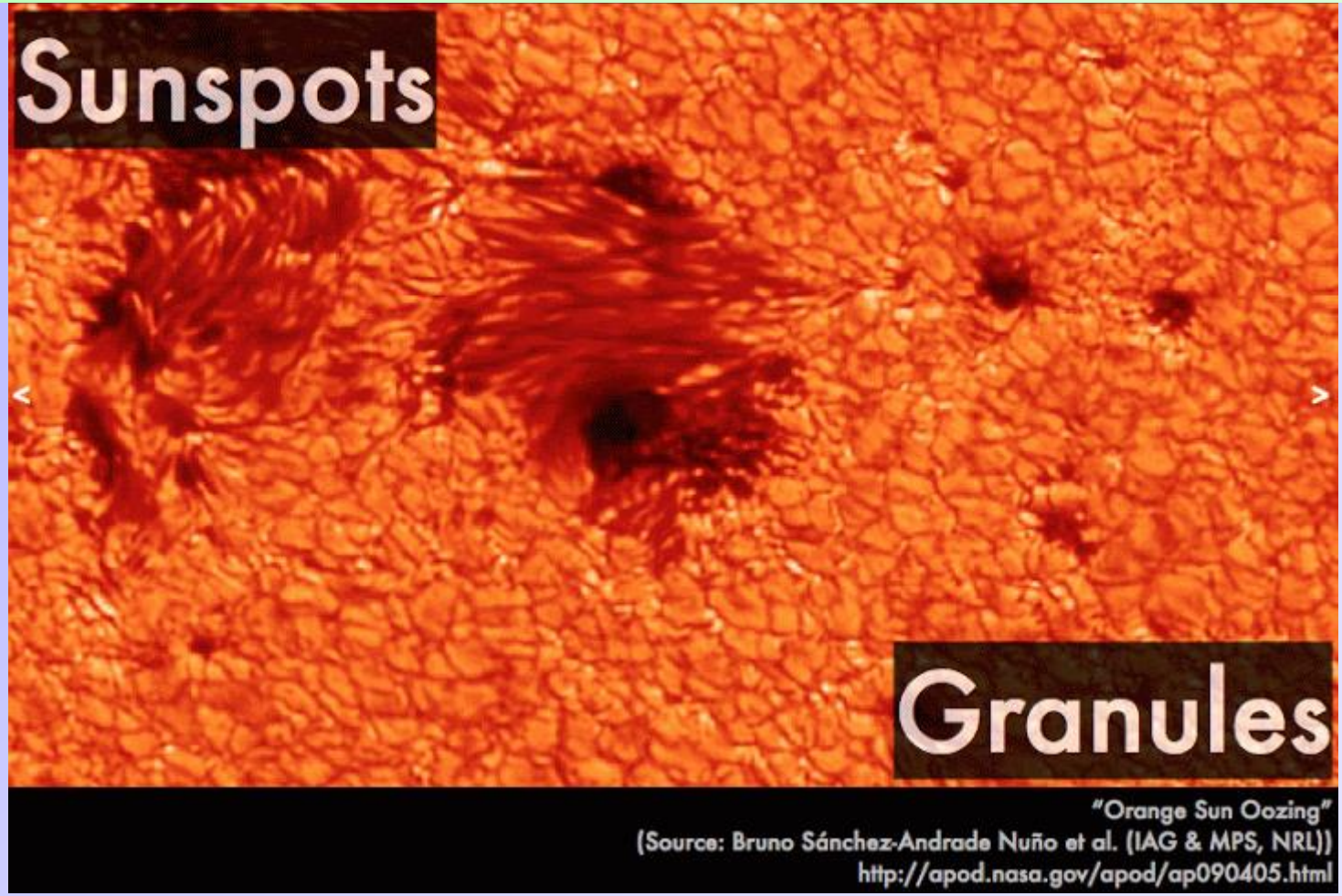


[NASA: Ulysses mission]

Our Sun's Surface

[NASA: Solar Dynamics Observatory, October 18, 2010]

Our Sun: Sunspots & Granules



Sunspot size ~ 10,000-20,000 km

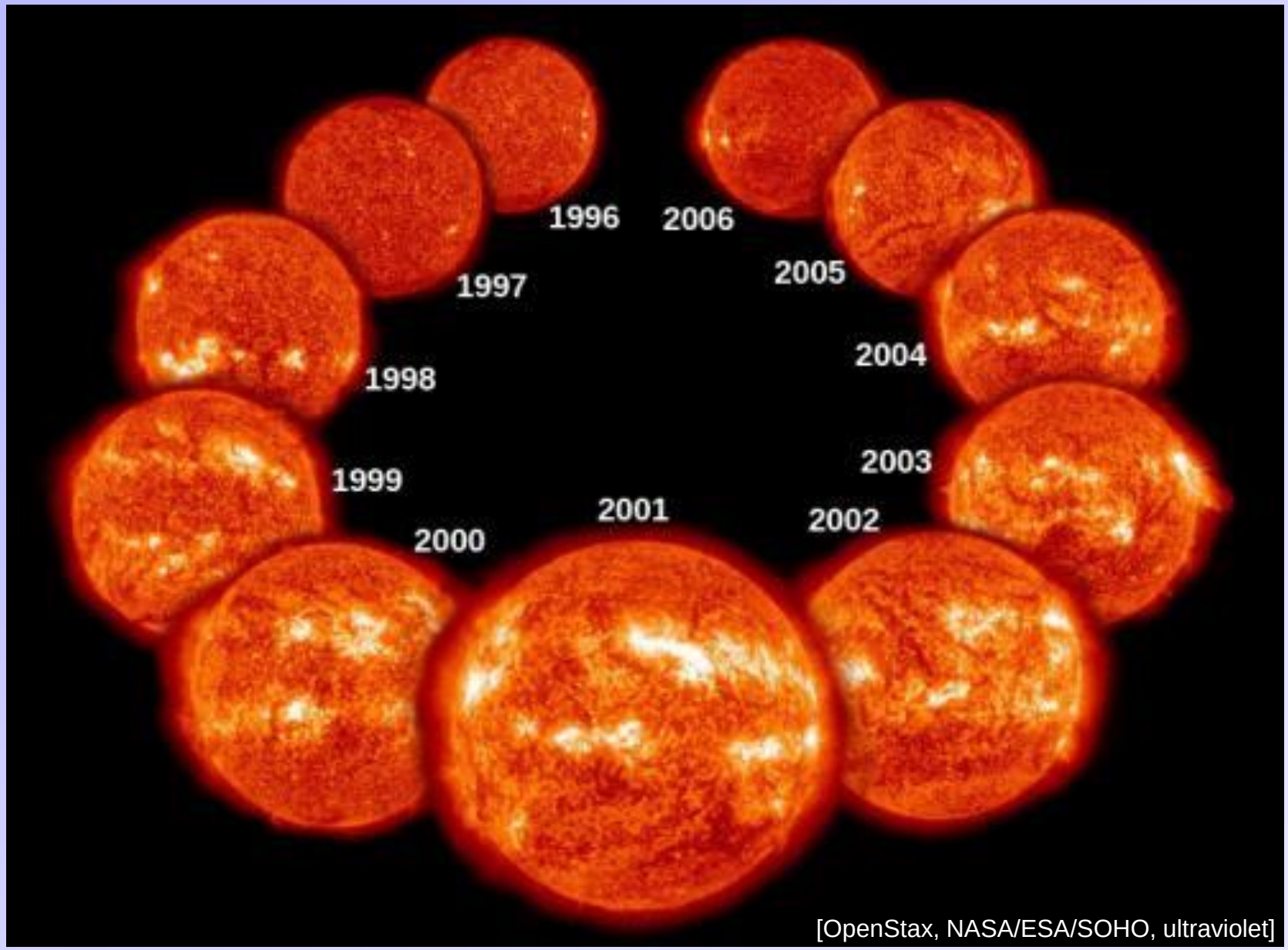
Sunspot = cooler surface region with strong magnetic field.

→ convection is impede by magnetic field.

Granule size ~ 1500 km

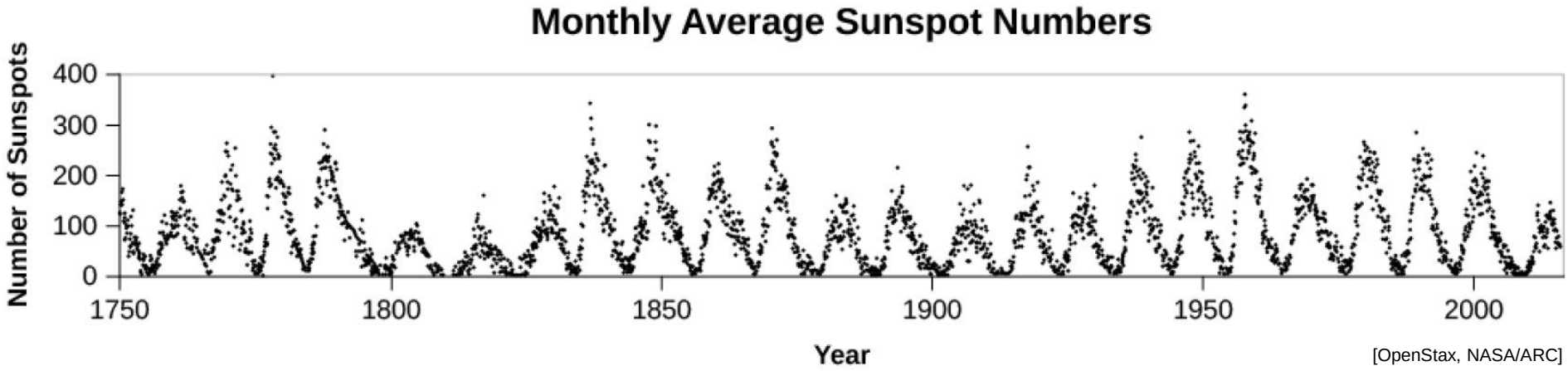
granule = convective cell

Solar Cycle: 11 year period



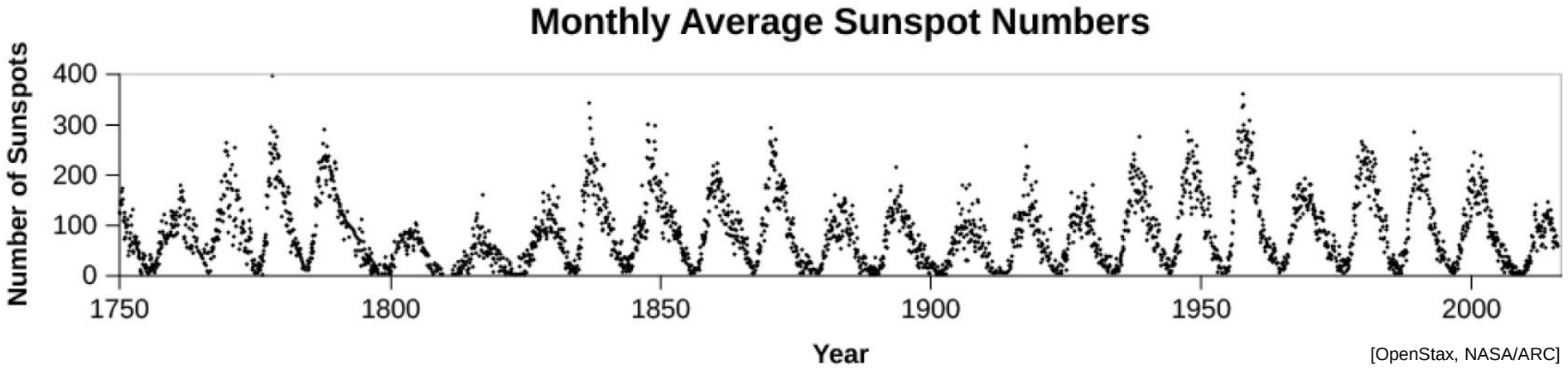
[OpenStax, NASA/ESA/SOHO, ultraviolet]

Sunspots: 11 year cycle



[OpenStax, NASA/ARC]

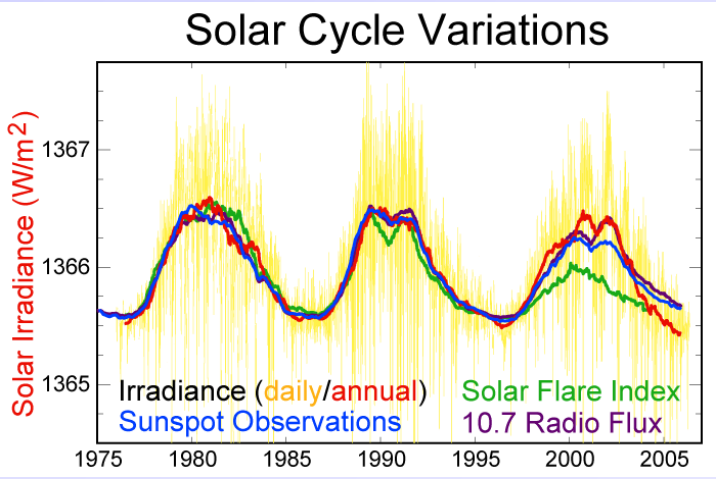
Sunspots: 11 year cycle



[OpenStax, NASA/ARC]

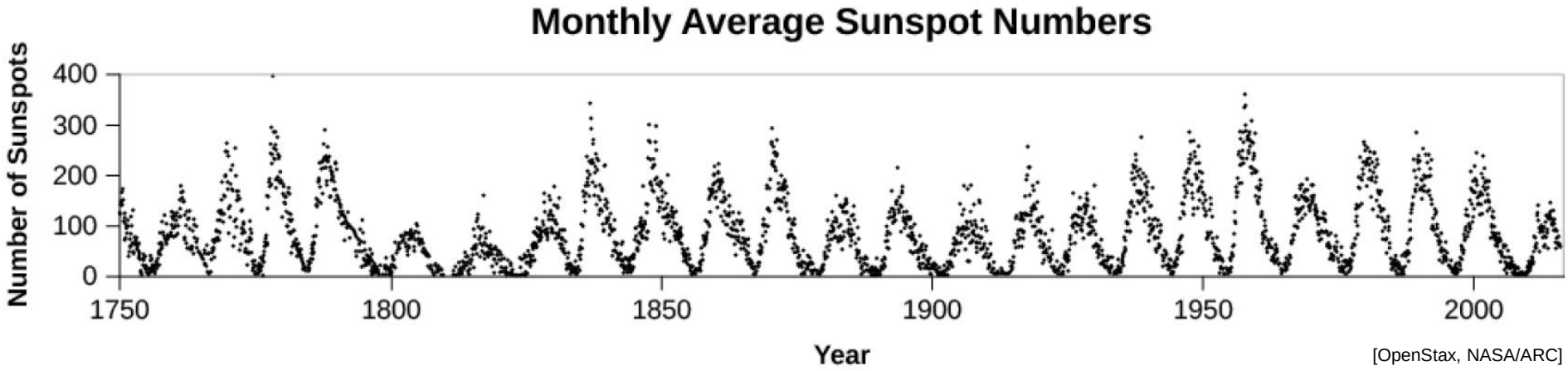
The following all vary in-sync with the solar cycle:

- Number of **sunspots**.
- Solar **flares** and **coronal mass ejections**.
- Total solar irradiance (but only by 0.1 %).
- Solar **UV irradiance**.



[Wikipedia]

Sunspots: 11 year cycle



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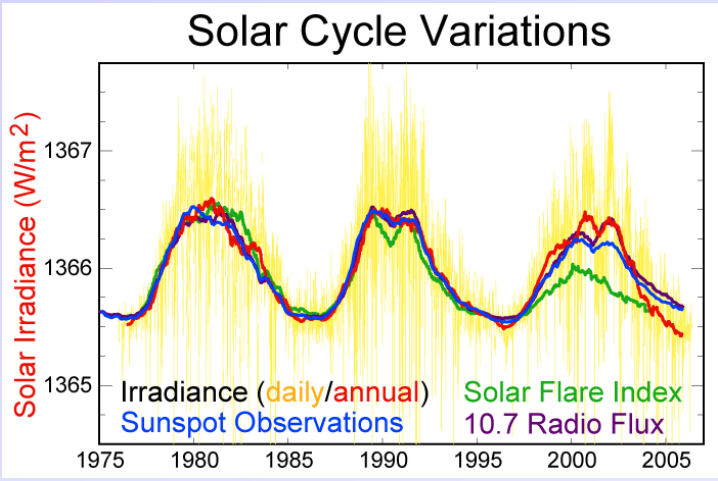
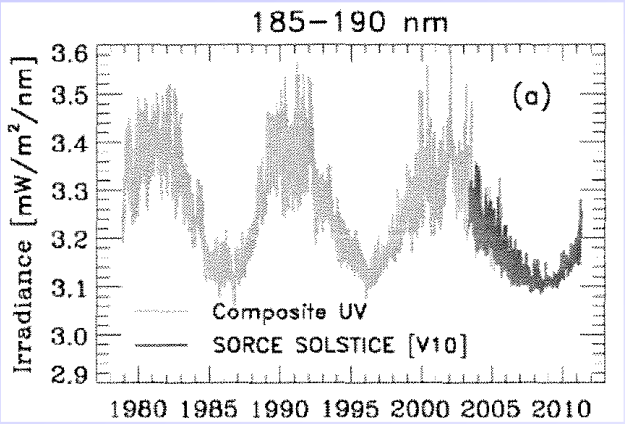


[Wikipedia]

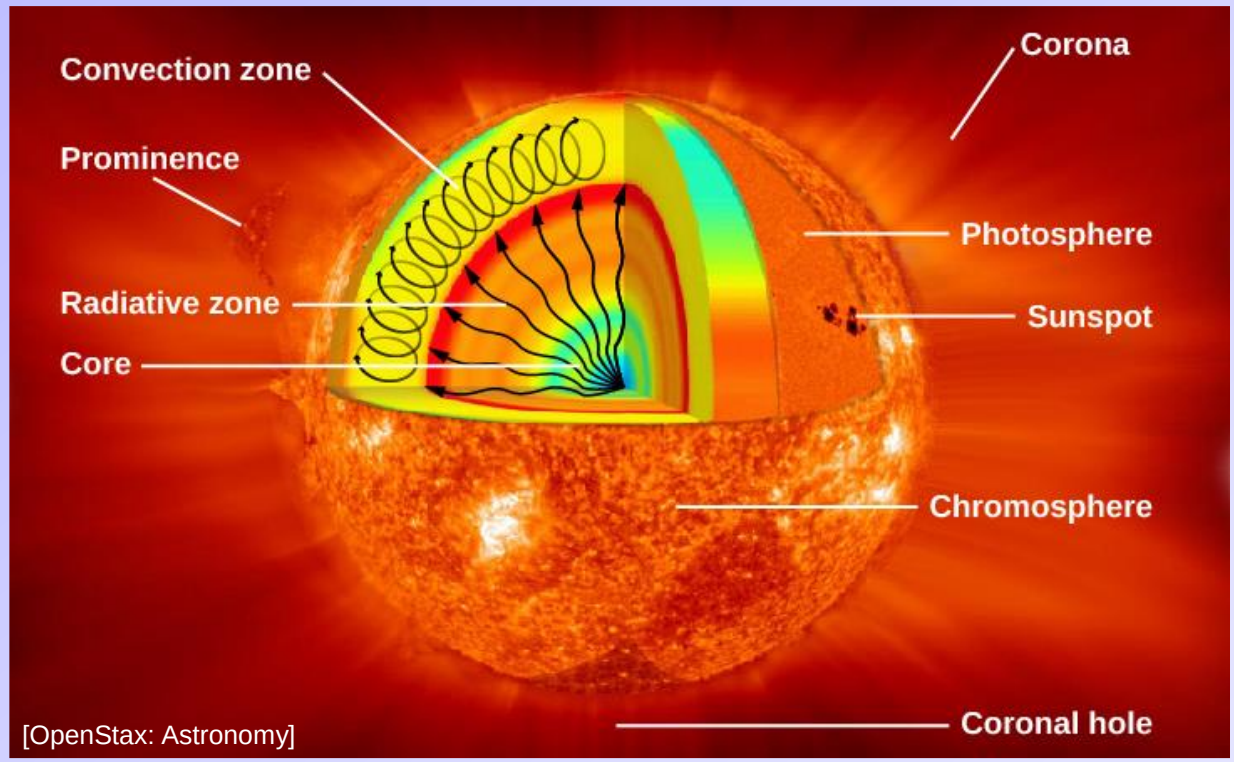


[M. T. DeLand and R. P. Cebula, "Solar UV Variations during the decline of cycle 23", *J. Atmos. Sol.-Terr. Phy.* **77**, 225 (2011)]

Our Sun: Structure

Structure determined from:

- Computer modelling.
- Helioseismology.
- **Neutrino** measurements.



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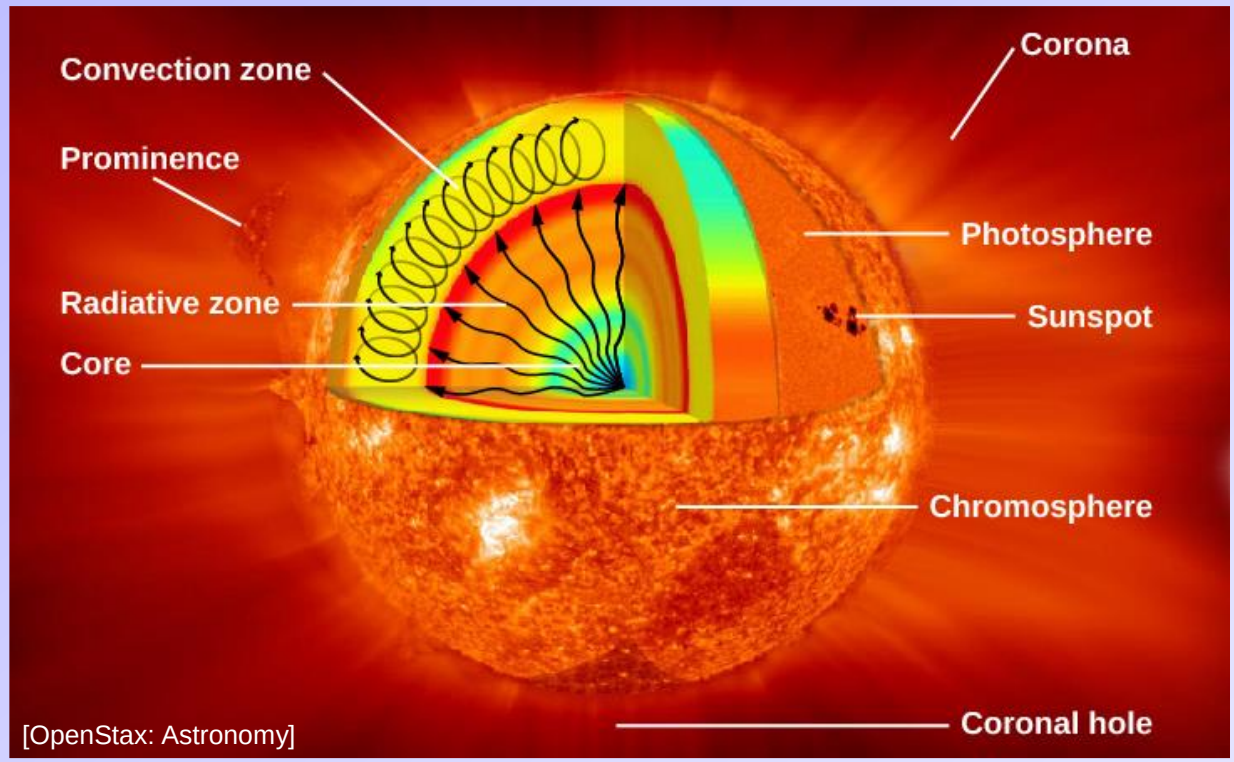
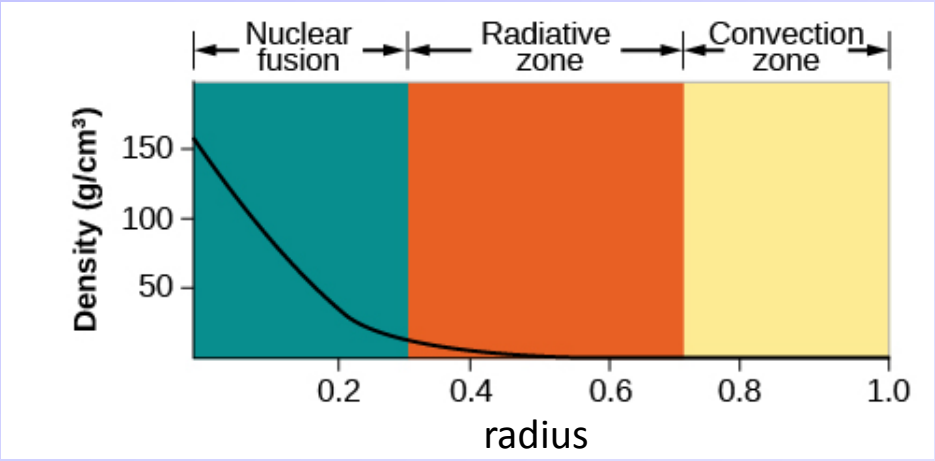
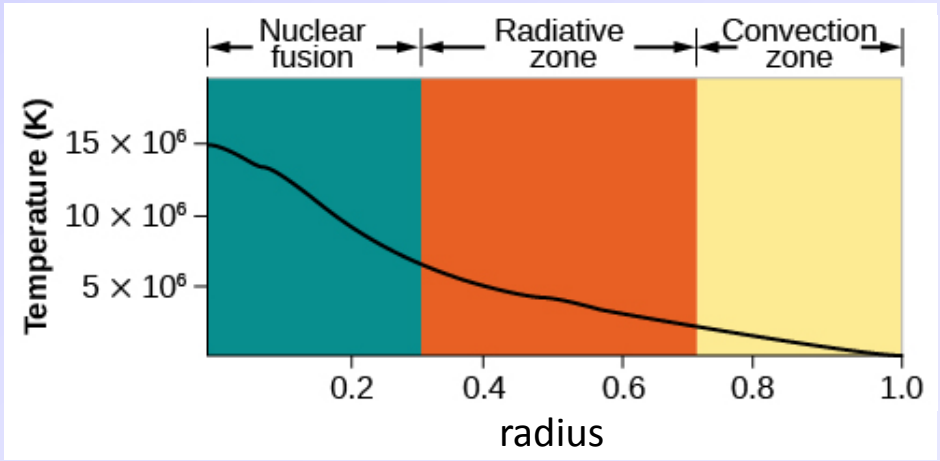
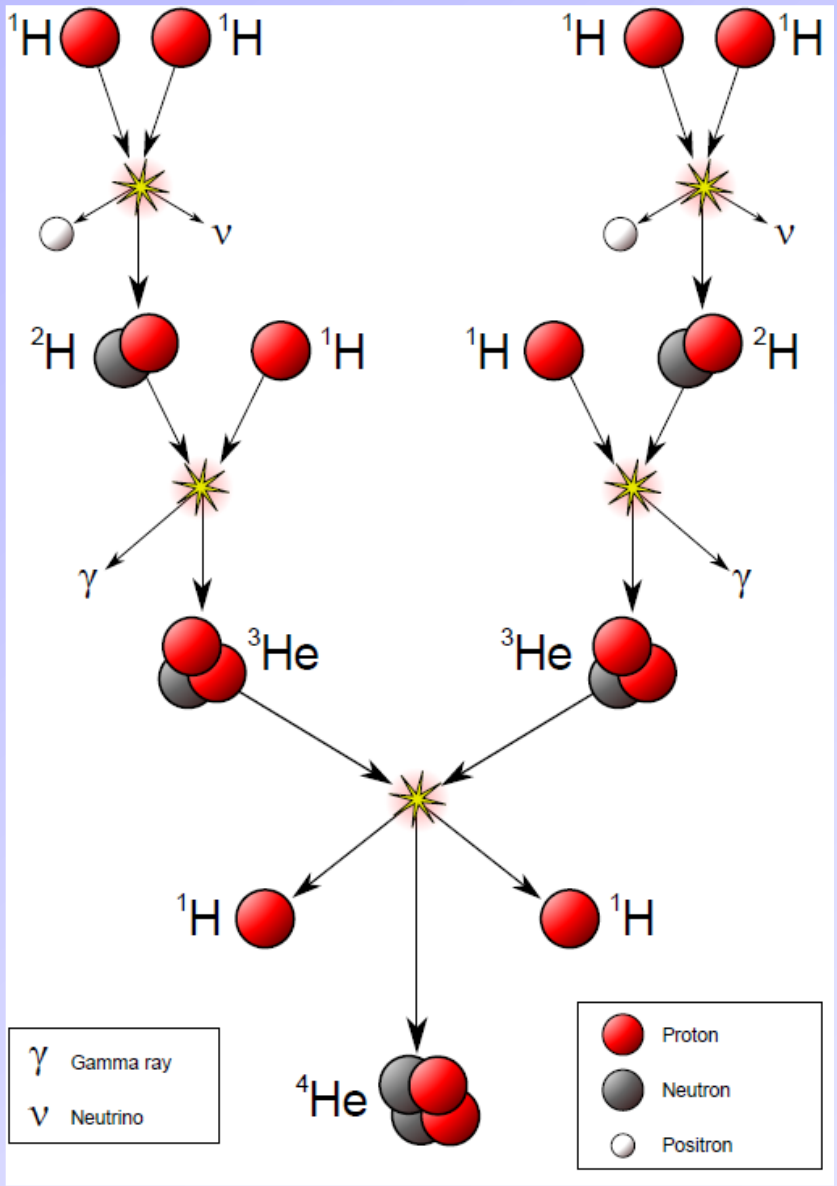






Solar Fusion: proton-proton chain



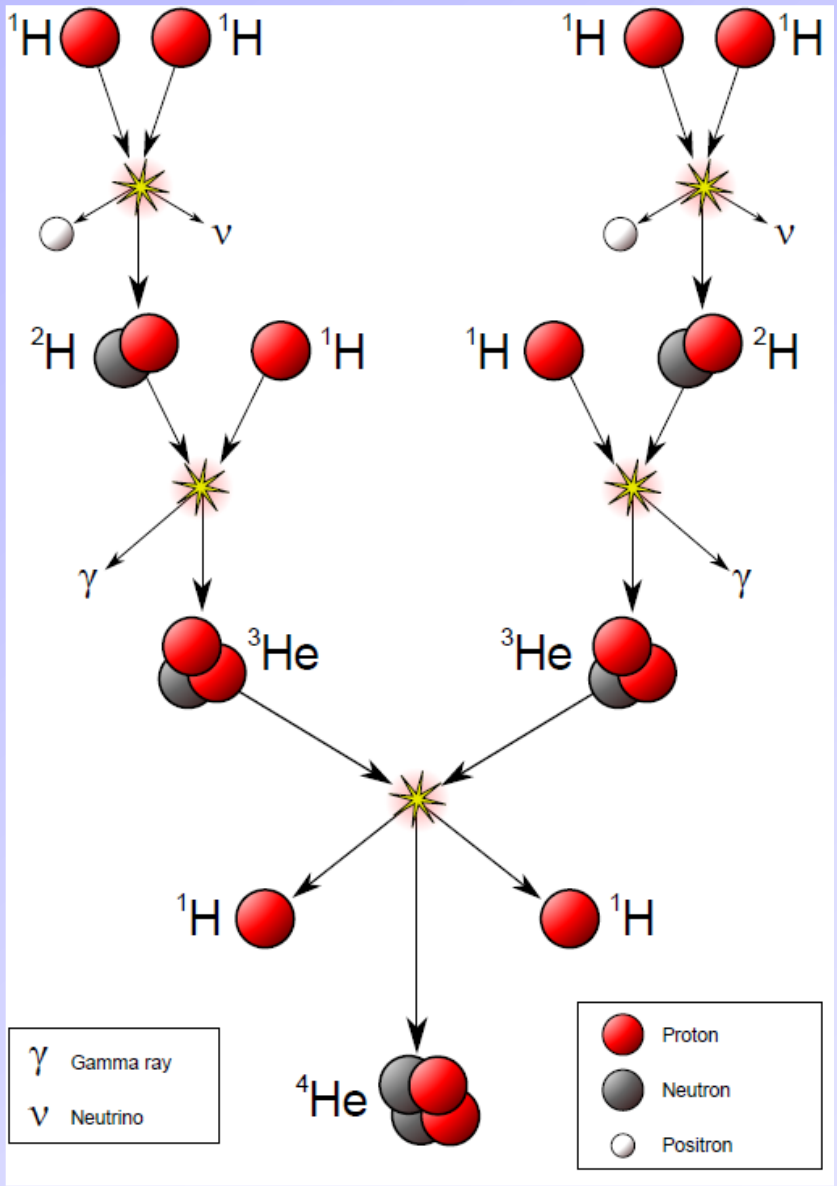
(see also Sept. 20 lecture)

By Sarang - Own work, Public Domain, https://commons.wikimedia.org/w/index.php?curid=51118538

Solar Fusion: proton-proton chain

(Note: 1 eV = 1.602×10^{-19} J)

9 billions years
weak force



2×1.442 MeV

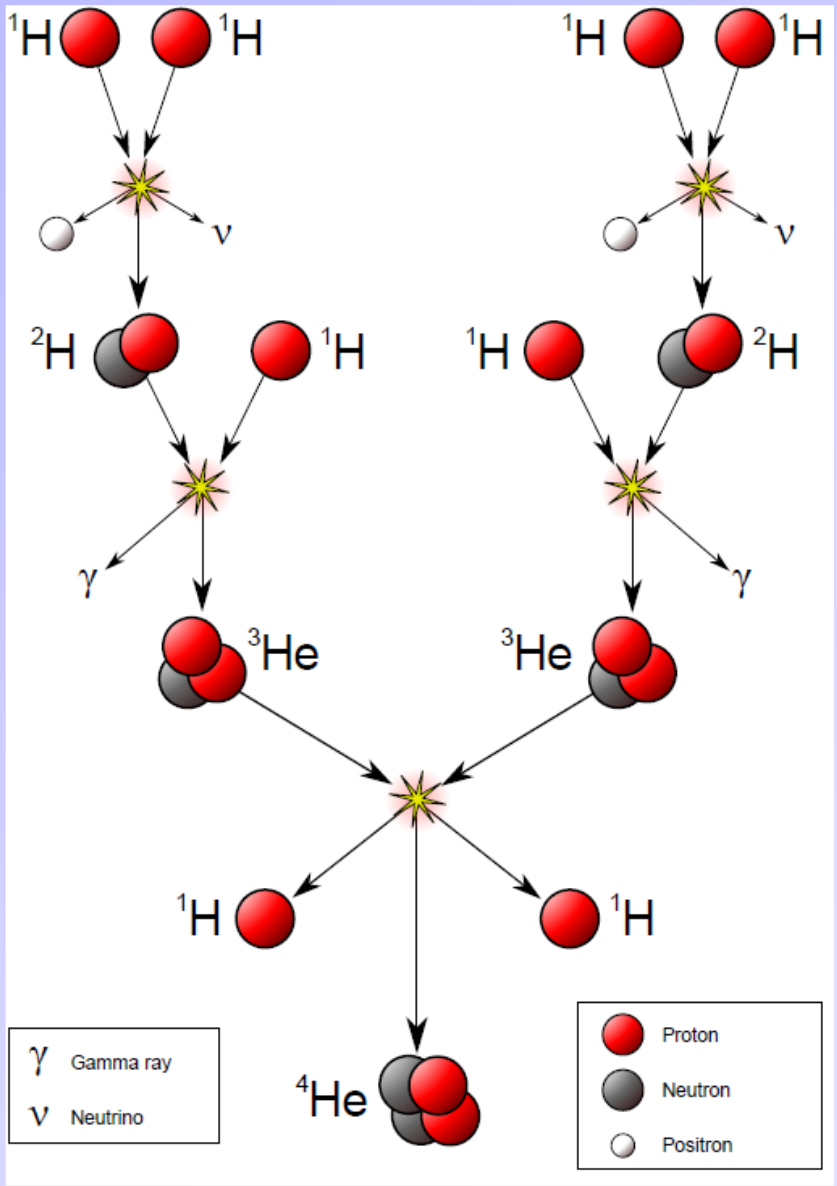
(see also Sept. 20 lecture)

Solar Fusion: proton-proton chain

(Note: 1 eV = 1.602×10^{-19} J)

9 billions years
weak force

4 seconds
strong force



2×1.442 MeV

\+ 2×5.49 MeV

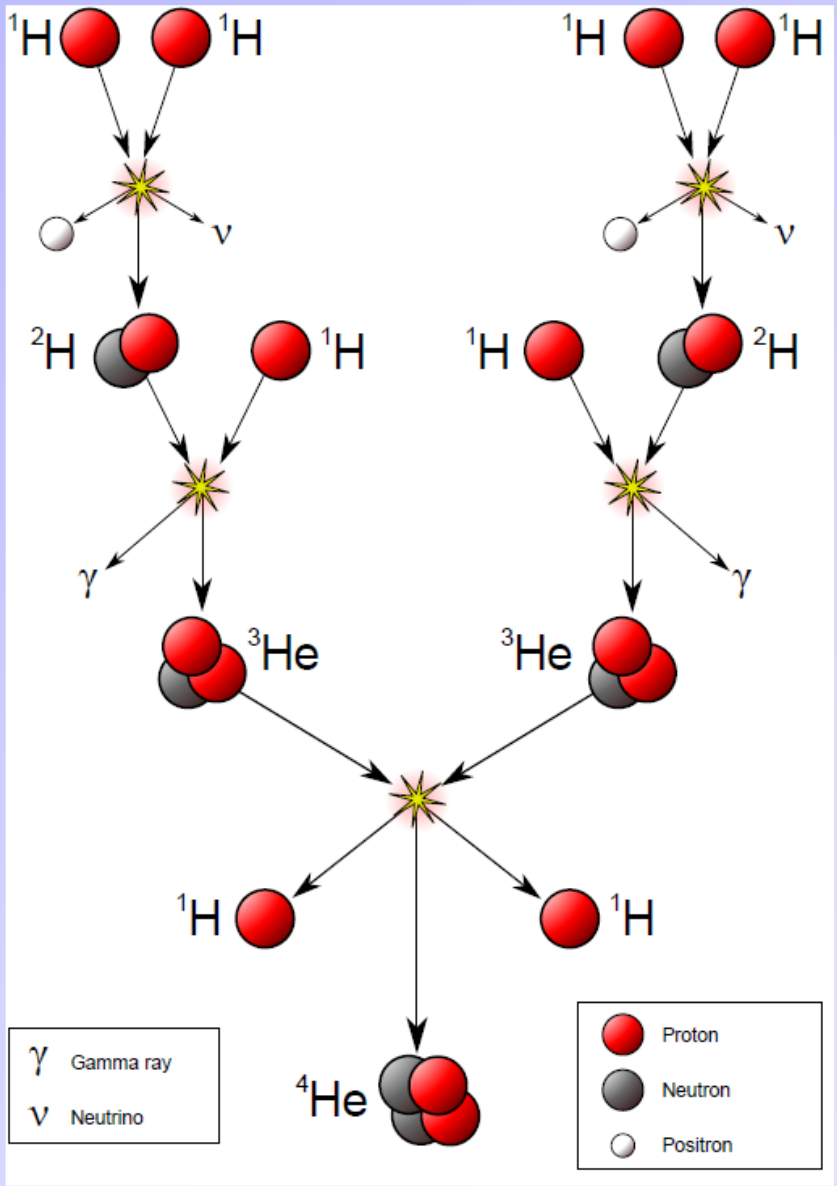
(see also Sept. 20 lecture)

Solar Fusion: proton-proton chain

9 billions years
weak force

4 seconds
strong force

400 years
strong force



(Note: 1 eV = 1.602×10^{-19} J)

2×1.442 MeV

\+ 2×5.49 MeV

\+ 12.86 MeV

= 26.7 MeV total

= 4.28×10^{-12} J

(see also Sept. 20 lecture)

Einstein: Mass & Energy

$$Energy = E = mc^2$$

mass

c = speed of light