

# Today's Topics

Monday, March 2, 2026 (Week 6, lecture 16) – Chapters 15, 16.

A. Surface of the Sun

B. Internal structure

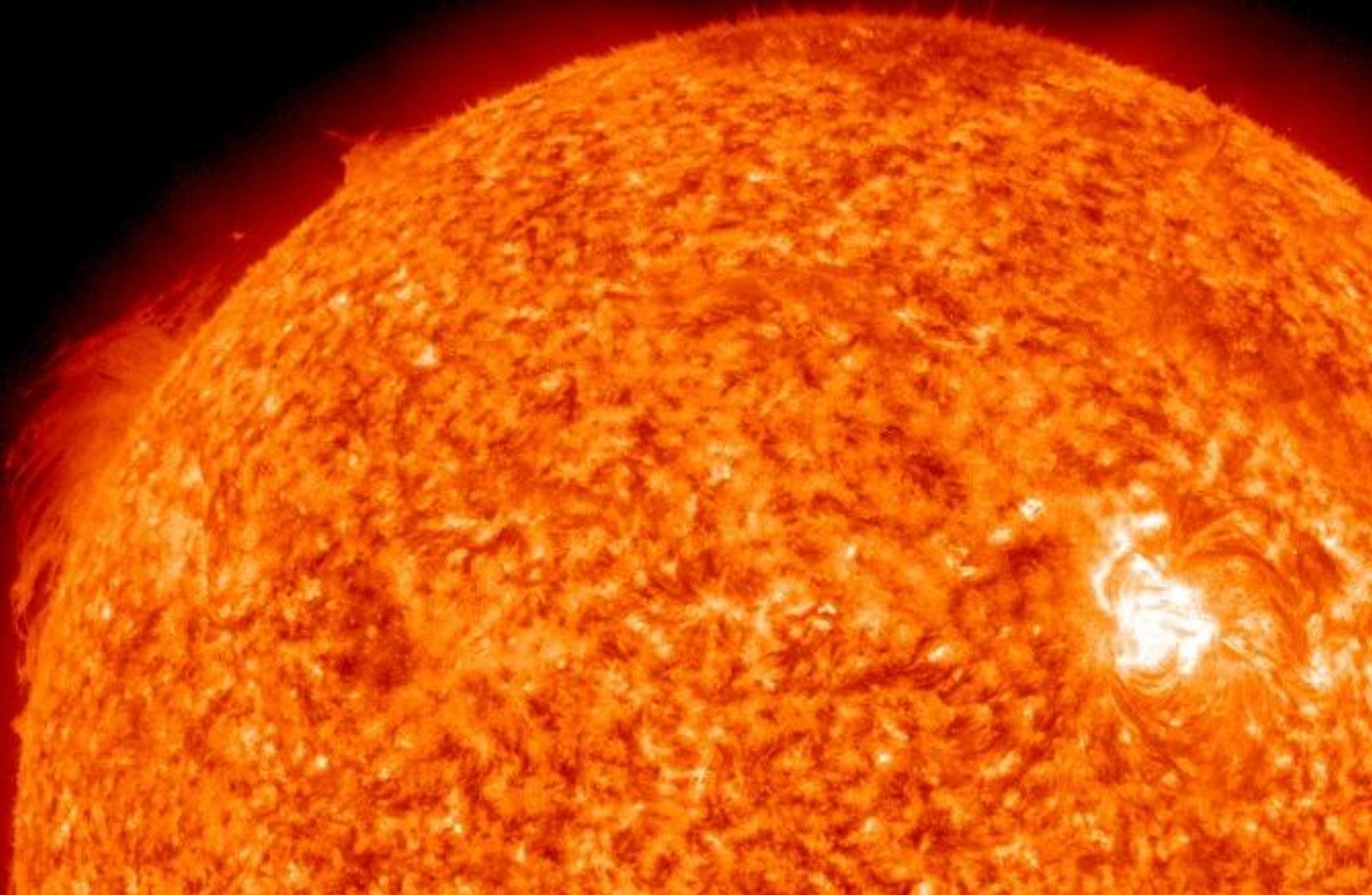
C. Solar fusion

D. Interlude 1 activity *(essay topic and title due today)*

**Reminder: Problem Set #5 part 1** is due on ExpertTA on Friday, March 6, by 9:00 am.  
**Problem Set #5 part 2** is due in class on Friday, March 6 (hardcopy).

# Our Sun's Surface

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



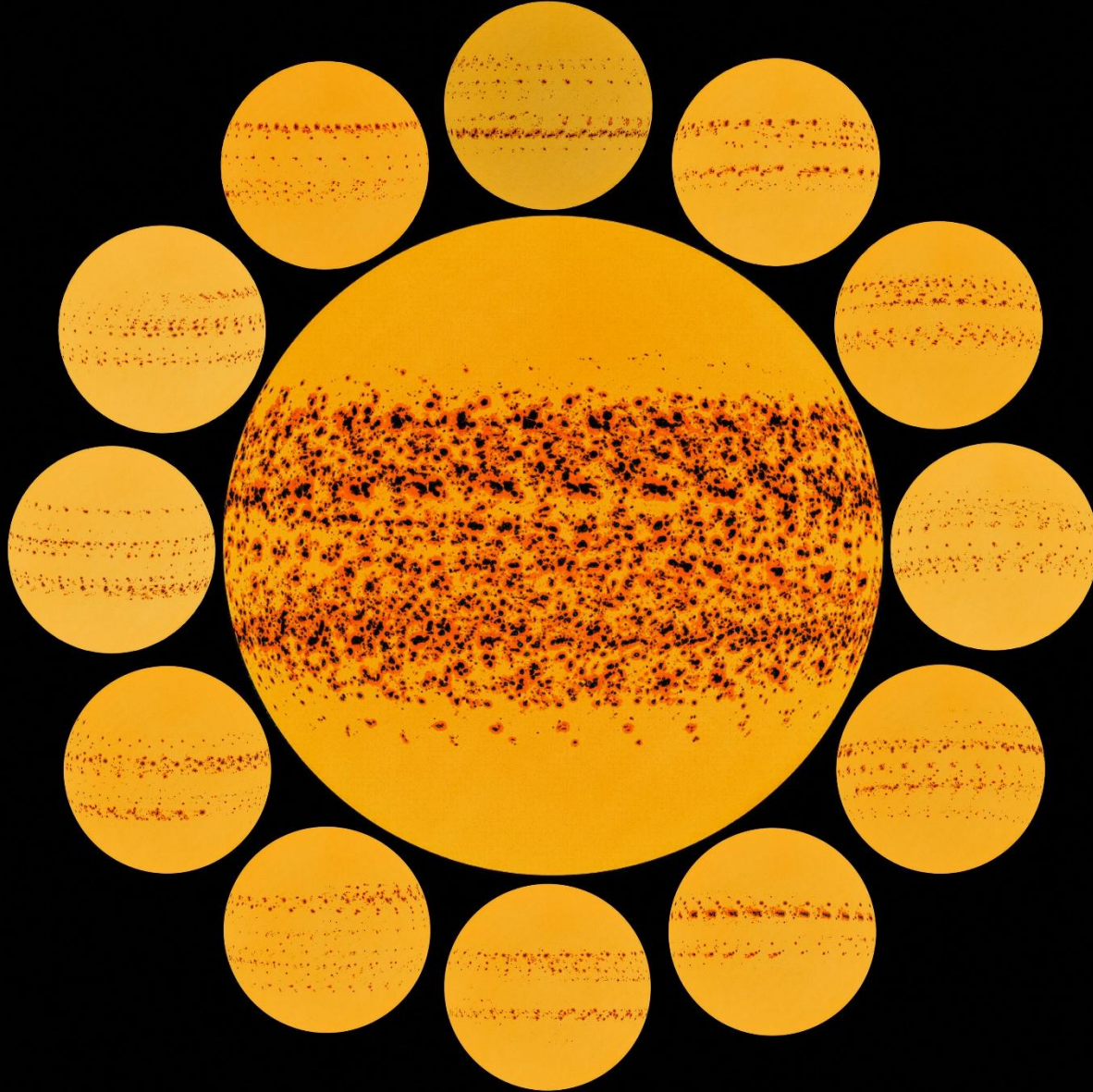
# Sunspots



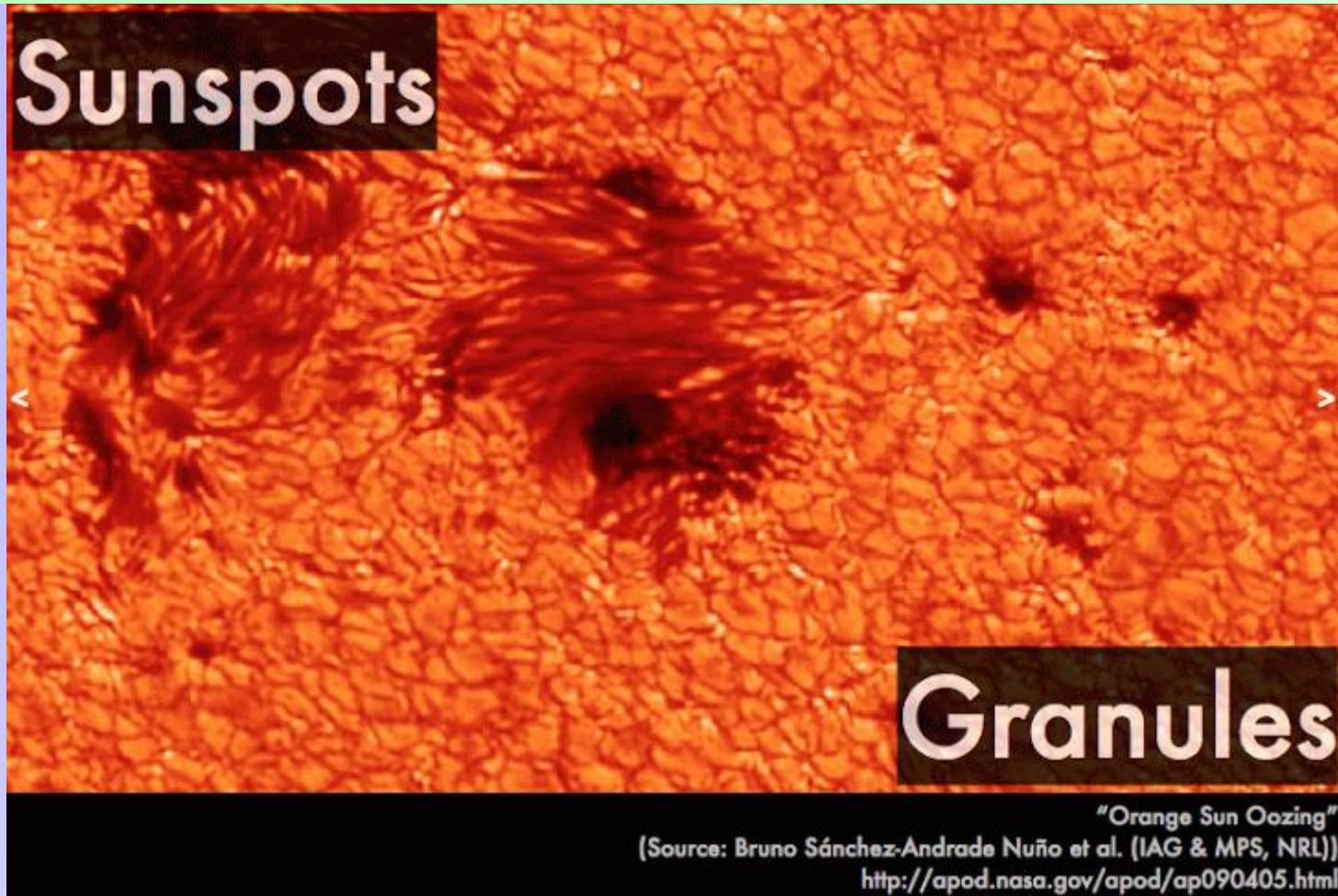
[February 3, 2026]

Daniel Korona

# 2025 TOTAL SUNSPOTS



# Our Sun: Sunspots & Granules



Sunspot size ~ 10,000-20,000 km

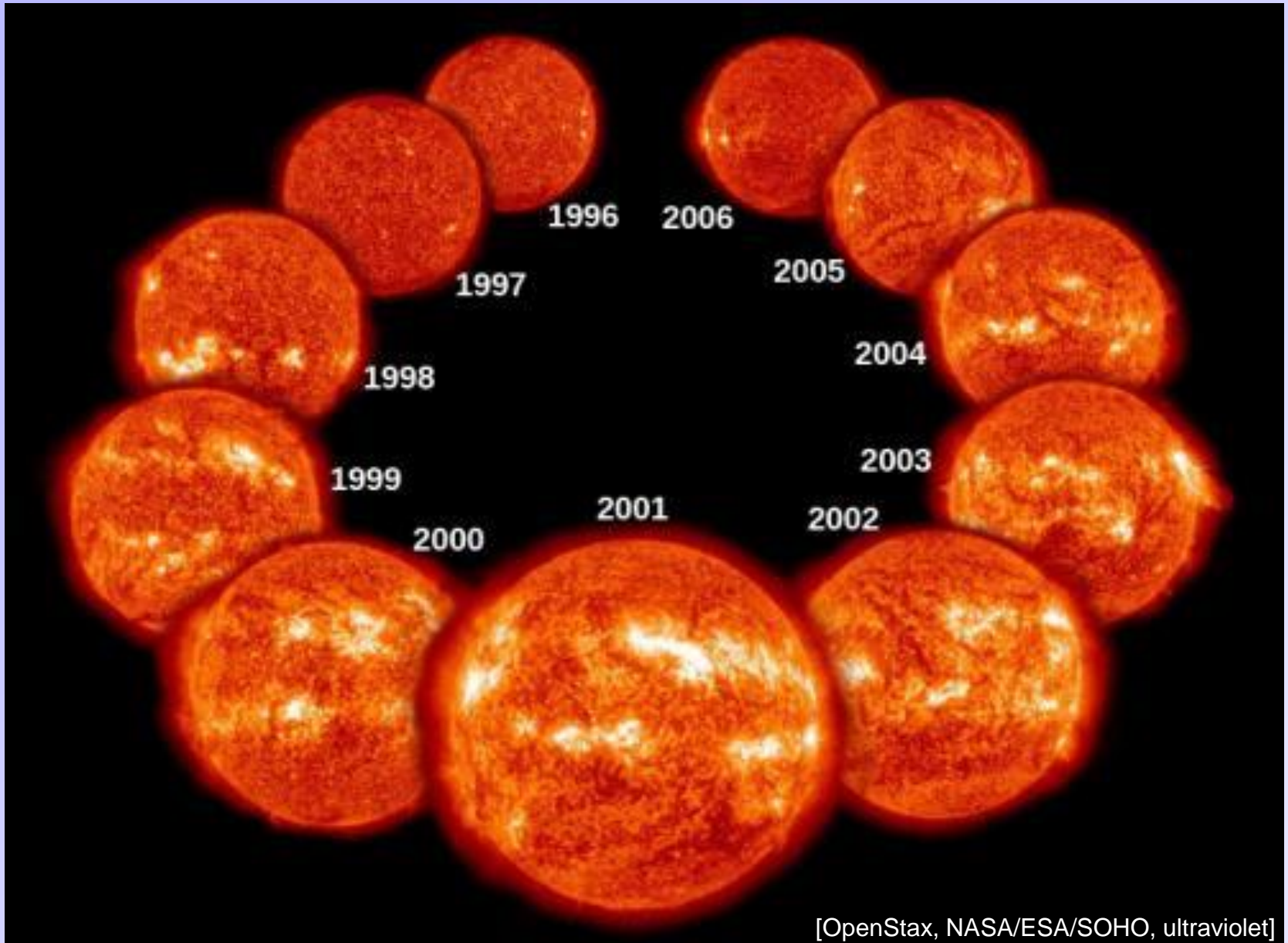
*Sunspot = cooler surface region with strong magnetic field.*

*→ convection is impede by magnetic field.*

Granule size ~ 1500 km

*granule = convective cell*

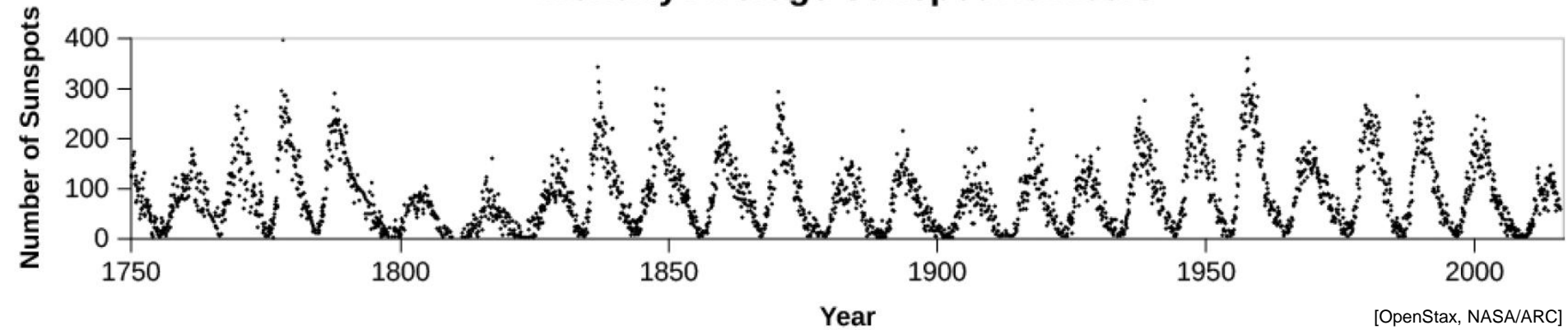
# Solar Cycle: 11 year period



[OpenStax, NASA/ESA/SOHO, ultraviolet]

# Sunspots: 11 year cycle

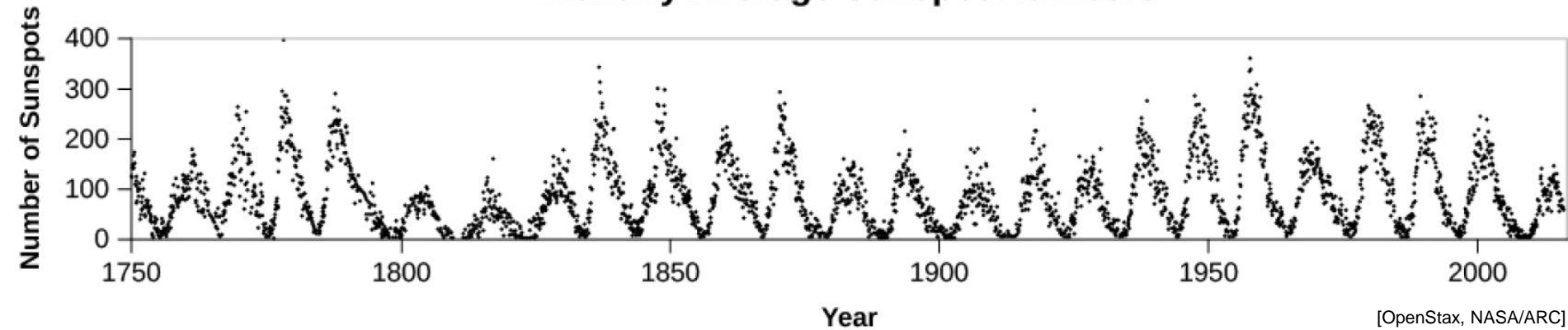
Monthly Average Sunspot Numbers



[OpenStax, NASA/ARC]

# Sunspots: 11 year cycle

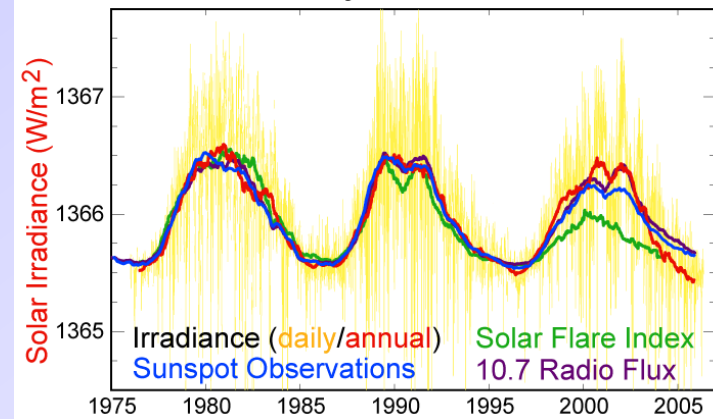
## Monthly Average Sunspot Numbers



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

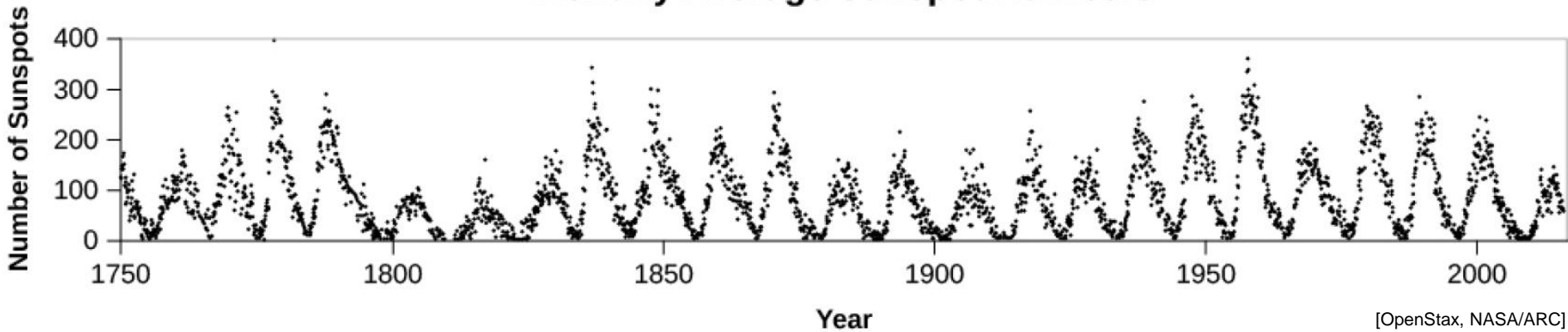
- Number of **sunspots**.
- Solar **flares** and **coronal mass ejections**.
- Total solar irradiance (but only by 0.1 %).
- Solar **UV irradiance**.

## Solar Cycle Variations



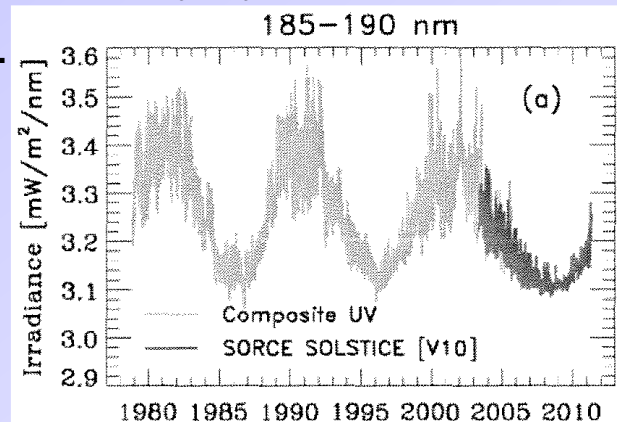
# Sunspots: 11 year cycle

## Monthly Average Sunspot Numbers



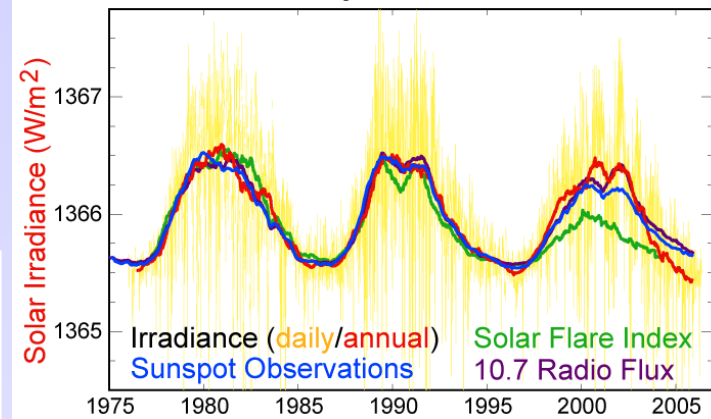
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[M. T. DeLand and R. P. Cebula, "Solar UV Variations during the decline of cycle 23", *J. Atmos. Sol.-Terr. Phys.* **77**, 225 (2011)]

## Solar Cycle Variations



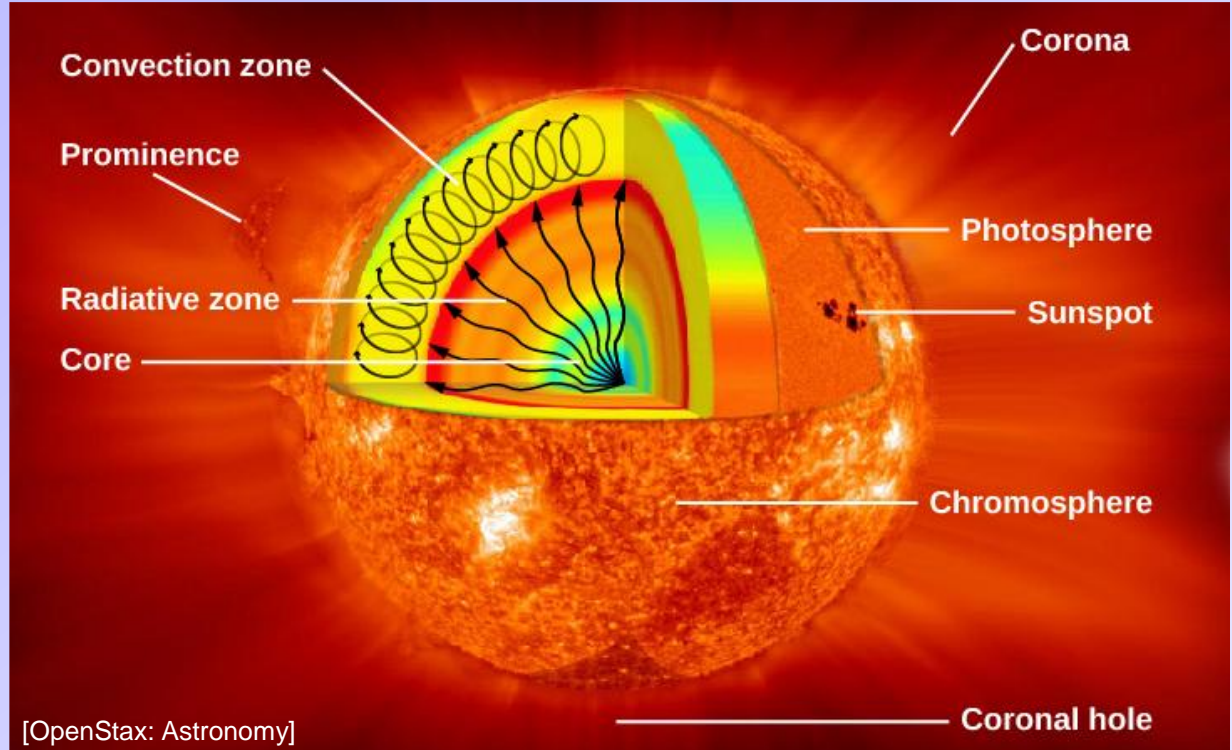
[Wikipedia]

**PolleEv Quiz: [PolleEv.com/sethaubin](http://PolleEv.com/sethaubin)**

# Our Sun: Structure

Structure determined from:

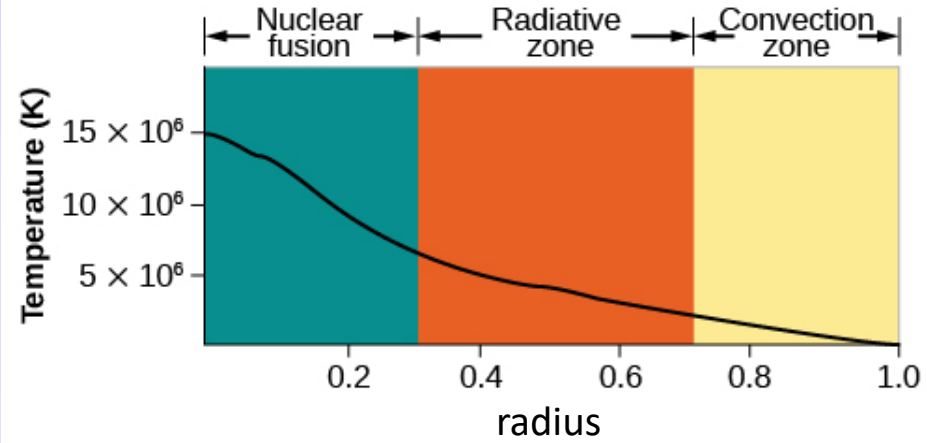
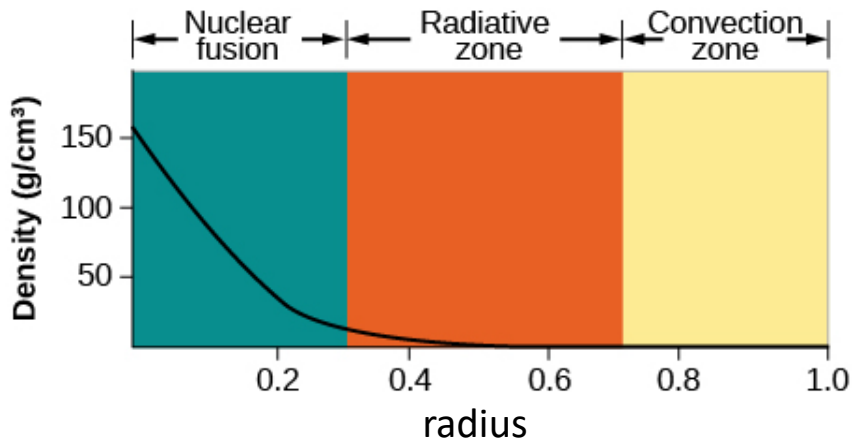
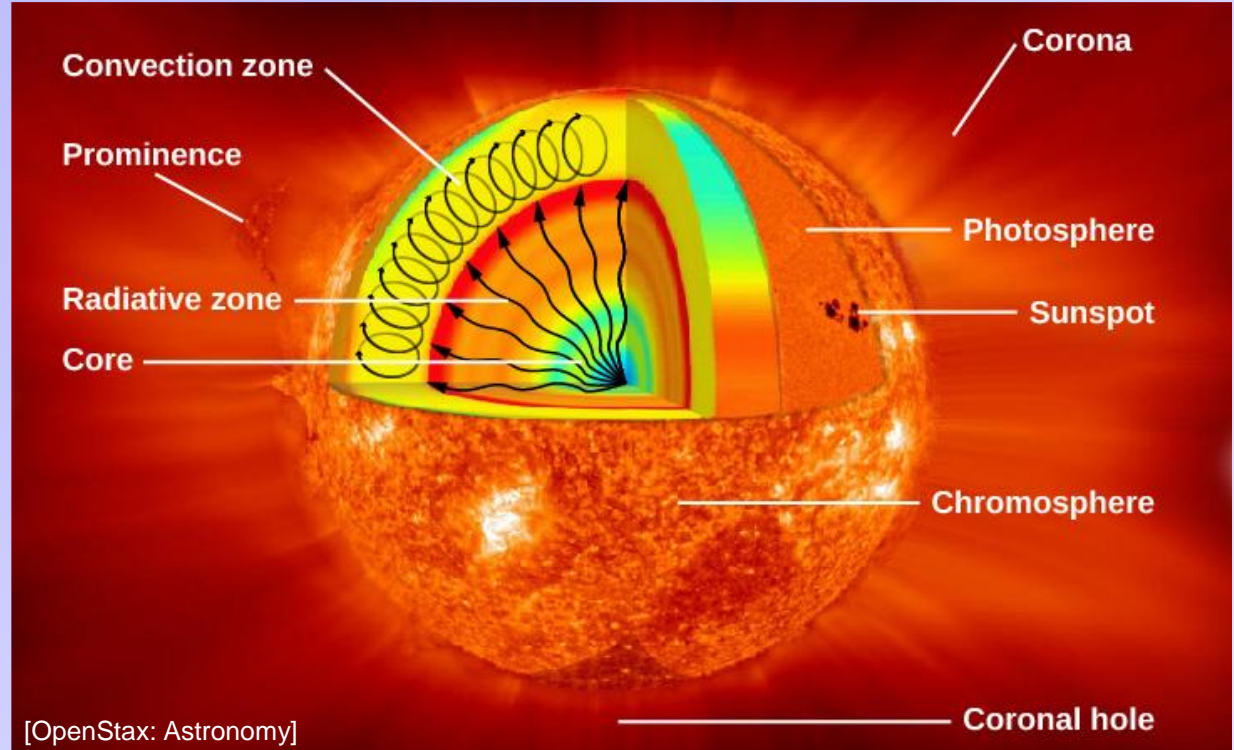
- Computer modelling.
- Helioseismology.
- **Neutrino** measurements.



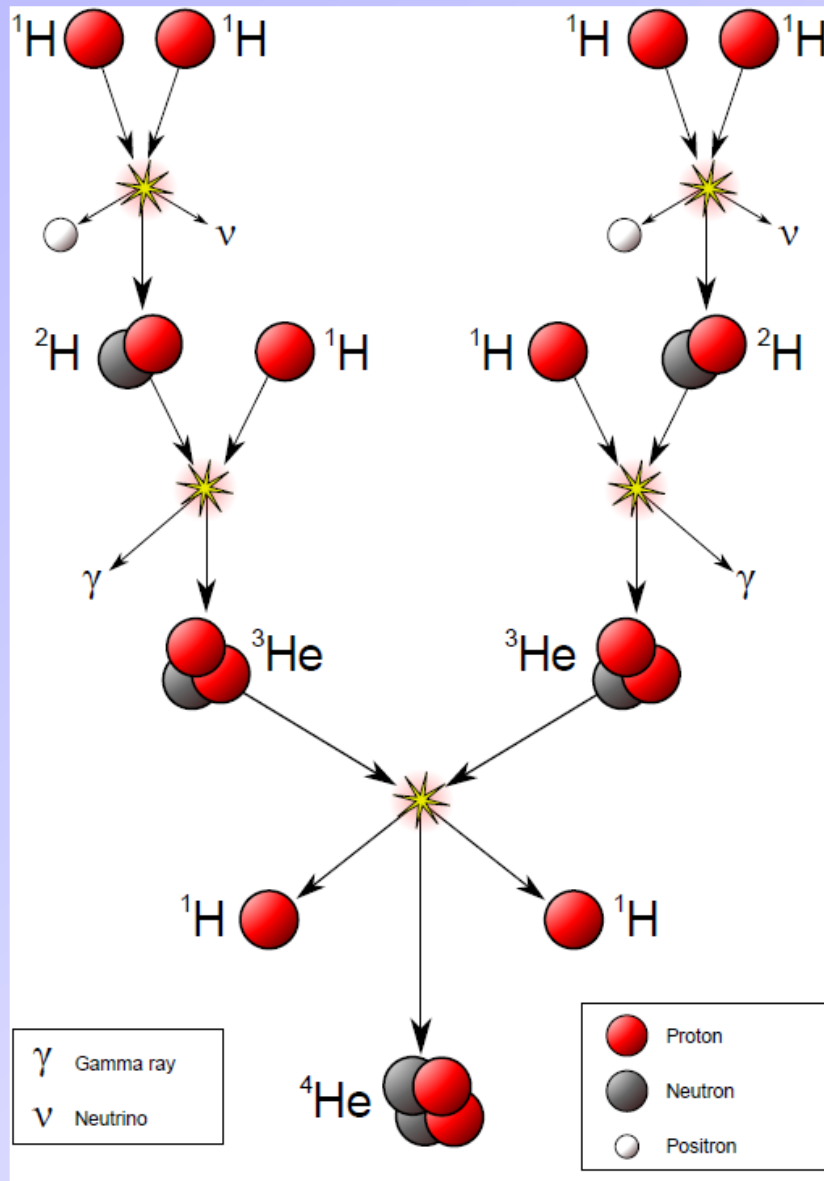
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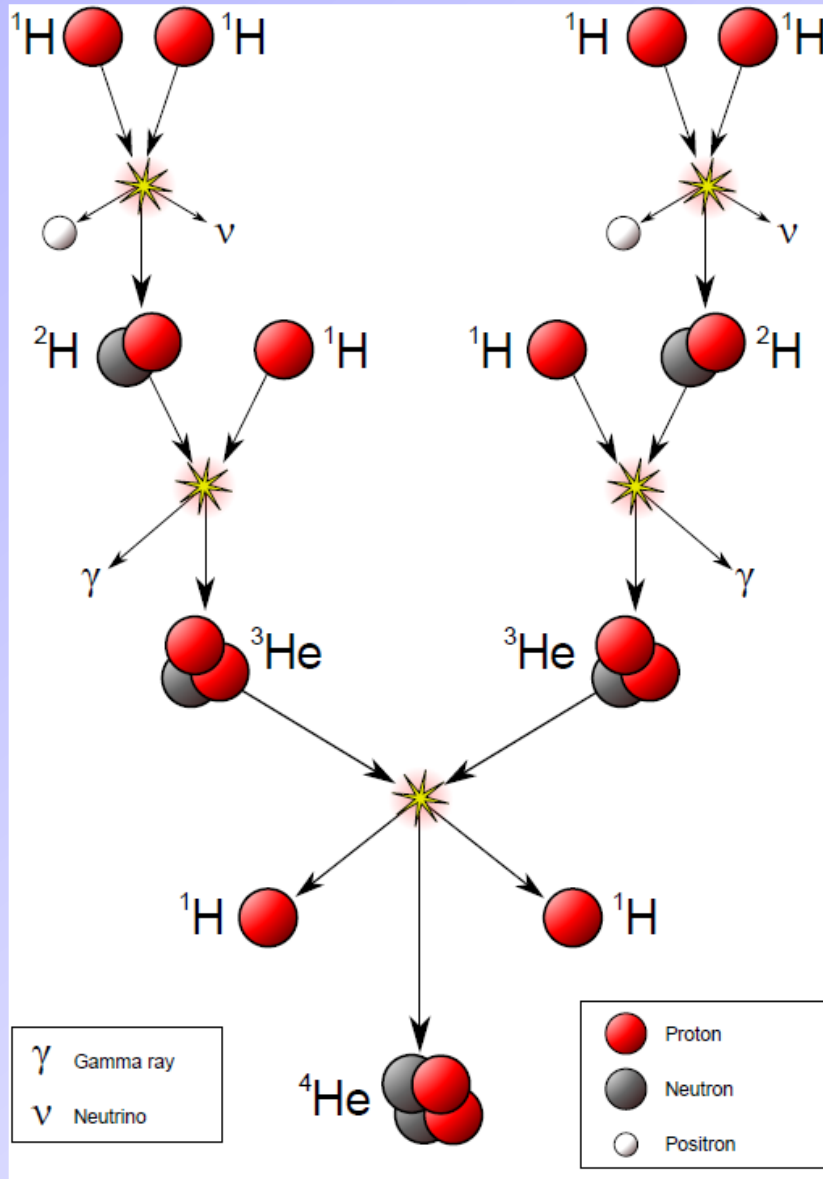
# Solar Fusion: proton-proton chain



(see also Feb. 16 lecture)

# Solar Fusion: proton-proton chain

9 billions years  
*weak force*

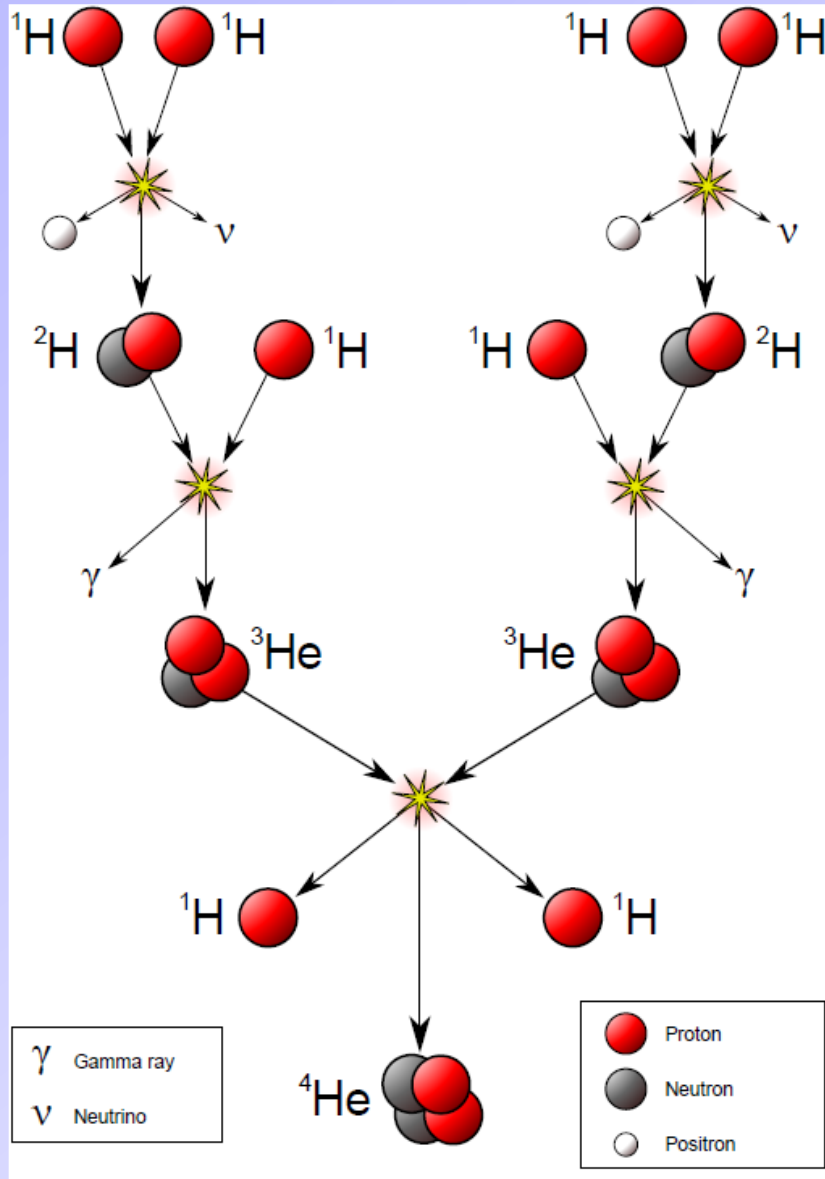


(Note:  $1 \text{ eV} = 1.602 \times 10^{-19} \text{ J}$ )

$2 \times 1.442 \text{ MeV}$

(see also Feb. 16  
lecture)

# Solar Fusion: proton-proton chain



9 billions years  
*weak force*

4 seconds  
*strong force*

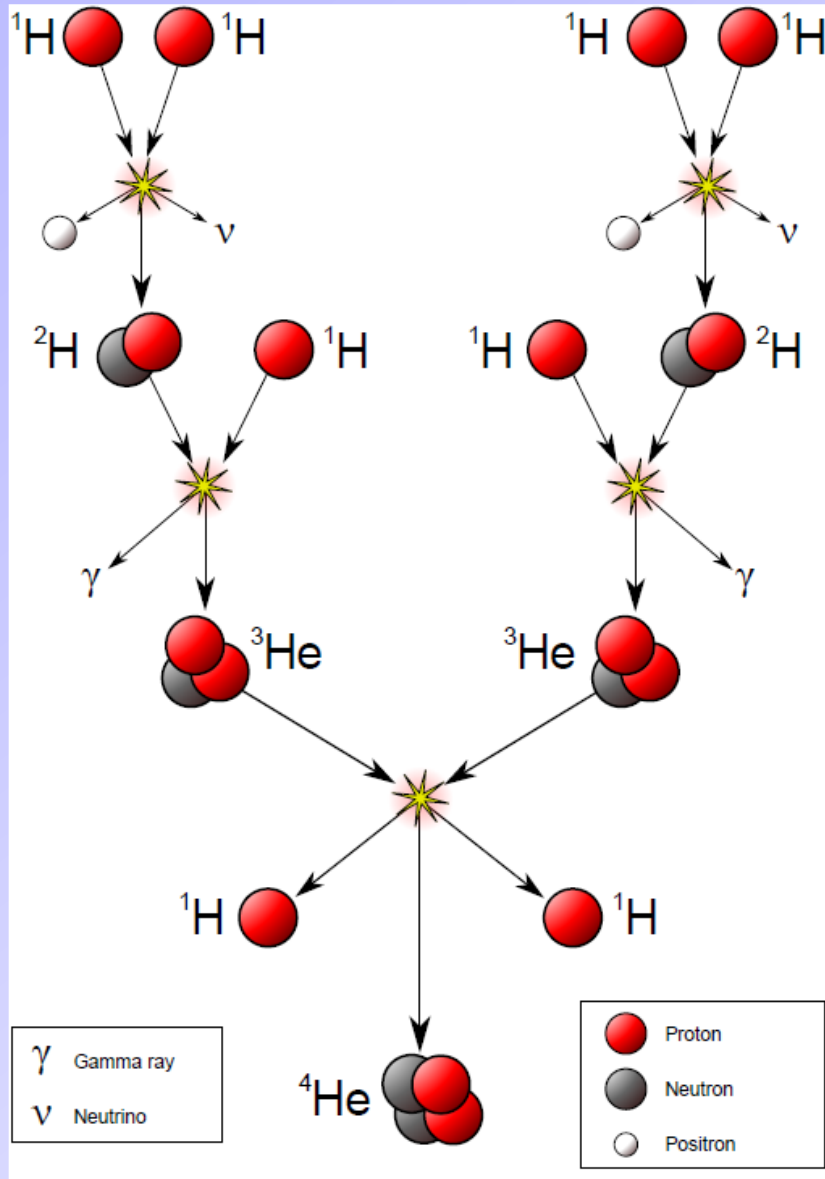
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$$2 \times 1.442 \text{ MeV}$$

$$+ 2 \times 5.49 \text{ MeV}$$

(see also Feb. 16  
lecture)

# Solar Fusion: proton-proton chain



9 billions years  
*weak force*

4 seconds  
*strong force*

400 years  
*strong force*

(see also Feb. 16  
lecture)

(Note:  $1 \text{ eV} = 1.602 \times 10^{-19} \text{ J}$ )

$$2 \times 1.442 \text{ MeV}$$

$$+ 2 \times 5.49 \text{ MeV}$$

$$+ 12.86 \text{ MeV}$$

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$$= 26.7 \text{ MeV total}$$

$$= 4.28 \times 10^{-12} \text{ J}$$

# Einstein: Mass & Energy

$$\textit{Energy} = E = mc^2$$

↑  
*mass*

↑  
*c = speed of light*

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**Example:** Mass converted to energy in p-p fusion

$$m = \frac{E}{c^2} = \frac{4.28 \times 10^{-12}}{(3 \times 10^8)^2} = 4.76 \times 10^{-29} \text{ kg}$$

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Mass of a proton:  $m_p = 1.6726 \times 10^{-27} \text{ kg}$

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*= 0.7 % of the mass of 4 protons*

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Mass of 4 protons:  $4 \times m_p = 6.6905 \times 10^{-27} \text{ kg}$

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Mass of 4 protons:  $4 \times m_p = 6.6905 \times 10^{-27} \text{ kg}$

Mass of  $^4\text{He}$  nucleus:  $m_{\text{He}} = 6.6447 \times 10^{-27} \text{ kg}$

**Note:**

$$4m_p - m_{\text{He}} = 4.65 \times 10^{-29} \text{ kg}$$

*difference is due to two positrons !*

# Interlude 1 ACTIVITY

1. Astronomy in ancient civilizations
2. Constellations in various cultures
3. Stars for navigation: The longitude problem
4. Black hole time machine
5. Sketch how humanity will first explore a nearby star system
6. The art of scientific astrophotography
0. Pick your own topic