Section IV. The Stars.

Chapter 18. The Sun

Figure 18.1. The Sun in visible light.

Note. In this section we survey physical properties and activity of the Sun.

Note. Some general facts about the Sun include:

Diameter	110 times Earth's diameter
Mass	333,000 times Earth's mass
Surface Temperature	6,500° K
Rotation Period	25 days

Note. The Sun is a ball of hot gas. Its *luminosity* (amount of energy emitted per second) is 4×10^{33} ergs per second. The intensity of sunlight reaching the Earth is the *solar constant* of 1.4×10^6 erg/cm^2/sec.

Note. The interior is gaseous, not solid. The temperature at the center is $(1.0 \times 10^7)^\circ$ K. The gas is partially ionized in the outer layers and completely ionized in the core.

Note. Gas that is hot exerts pressure. A balance is reached between the gravitational pull and the pressure of hot gas. This is called the *hydrostatic equilibrium.*

Note. The is 73% H and 25% He, much like the solar nebula and outer planets. The inner 25% of the Sun undergoes nuclear reactions, producing γ-ray wavelength radiation. The photons are absorbed and re-emitted over and over. It takes a single photon one million years to reach the outer surface.

Note. The Sun undergoes differential rotation. It rotates faster at the equator.

Note. A big question of the late 1800s was to explain the amount of energy emitted by the Sun. With Einstein's theory of special relativity is was found that matter and energy are interchangeable, "$E = mc^2$."

Note. Following the work in *quantum theory* by Max Plank, Niels Bohr, and (reluctantly) Einstein, the idea of nuclear reactions emerged. There can be *fusion* reactions in which nuclei merge (fuse) to make heavier elements, or *fission* reactions in which a single nucleus splits into smaller nuclei.

Note. The steps in the *proton-proton chain* (in which 4 H nuclei combine to create one helium nucleus, resulting in a difference in mass of 0.7%) are:

1. Two protons (H^+) combine to form deuterium [(proton + neutron) + neutrino],

2. the deuterium combines with another proton to create ^{3}He (two protons and one neutron) and a photon of γ-ray light, and

3. two ^{3}He nuclei combine to form ^{4}He (two protons):

$$\text{proton} + \text{proton} \xrightarrow{\mathbf{1}} \text{proton} + \ \text{neutron} + \text{neutron} + \text{K.E.}$$
$$\xrightarrow{\mathbf{2}} 2 \text{ protons} + \text{neutron} + \text{K.E.} + \gamma - \text{ray} \xrightarrow{\mathbf{3}} {}^4\text{He} + 2 \text{ protons} + \text{K.E.}$$

Note. Simple calculations reveal that, given the Sun's mass,it should keep shining for another 5 billion years.

Note. We now discuss the solar atmosphere. The "surface" of the sun is the *photosphere* at a temperature of 4000–6500° K. Outside of this is the *chromosphere* at a temperature of 6,000–10,000° K. Next is a *transition zone* where temperature rapidly increases. Then there is the *corona* at a temperature of 1 to 2 million °K.

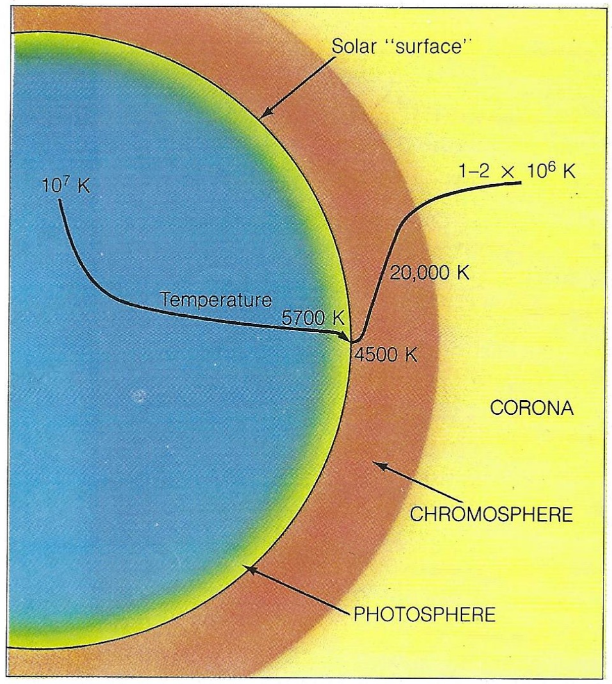
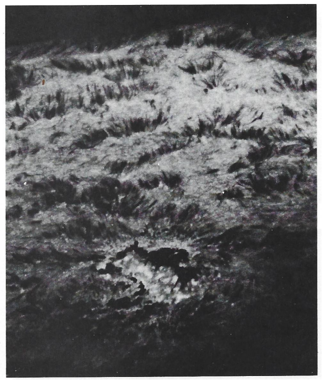


Figure 18.4. The structure of the Sun's outer layers.

Note. The coolest part of the Sun is the photosphere. This is where *absorption lines* in the spectrum are produced. Some additional features include: *Spicules*, which are spikes of glowing gas that interacts with the magnetic field, *coronal holes* are areas in the corona where the gas density is less than surrounding areas (these are dark in X-ray pictures of the Sun), and *prominences* are geysers of hot gas that are arc shaped.




Figures 18.8 and 18.12. Spicules (left) and a prominence (right)

Note. The *solar wind* is a stream of charged particles emanating from the Sun. The Earth is protected by its magnetosphere, but *magnetic storms* (strong solar wind activity) disturbs the ionosphere and affects radio communications and auroras.

Note. *Sunspots* are relatively cool regions (4000° K) in the photosphere, thought to be a result of the strong magnetic field inhibiting convection. Sunspot activity undergoes an 11 year cycle. In fact, the magnetic field of the Sun reverses every 22 years.

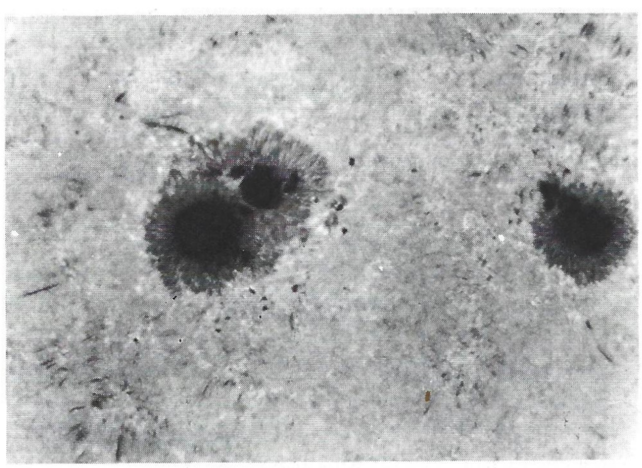


Figure 18.18. Sunspots.

Note. *Solar flares* are outbursts of charged particles accompanied by X-ray emissions and hot spots of gas (see Figure 18.21). These are most common around peaks in sunspot activity.

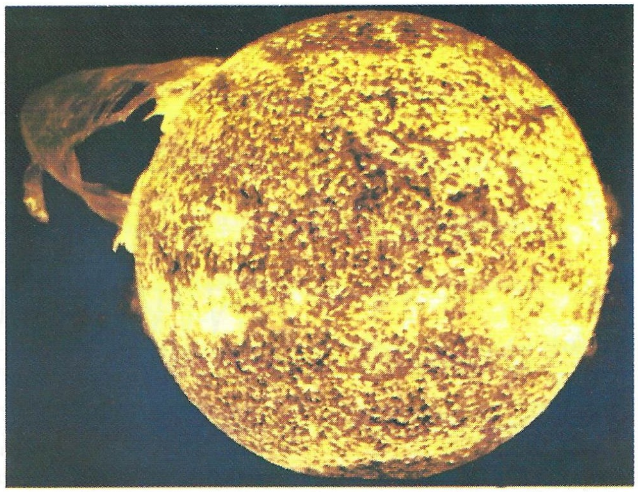


Figure 18.21. A major solar flare.

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