Citizen Science Training Modules

The Radio JOVE Project

radiojove.gsfc.nasa.gov

A Partnership Between

Welcome to The Radio JOVE Project Citizen Science Training Modules.

These training modules are a partnership between the SunRISE mission team and The Radio JOVE Project. We acknowledge contributors to these modules as well as our funding sources of support.

This is Training Module 0.0 – Introduction to the Sun

Prerequisites for Training Modules

1. High School Reading Comprehension and General Science
2. Electromagnetic Spectrum
3. Speed, Wavelength, Frequency, and Energy of Waves
4. Graphical Interpretation of Data

This is a list of prerequisites needed to be able to understand the material in this module.

Learning Objectives

1. Locating the Sun in the sky
2. Basic properties of the Sun
3. Energy transport
4. The Sun's power and rotation

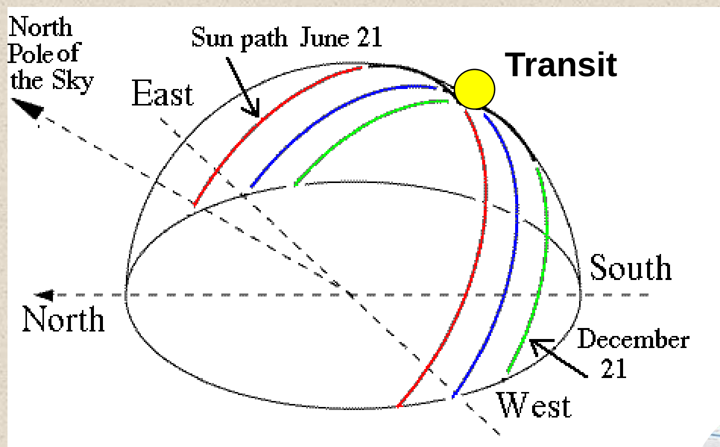
This is a brief summary of the learning objectives for this presentation.
After a brief review of the Sun's motion in the sky, we discuss the basic properties of the Sun, size, density, composition, rotation, etc. We then discuss the three types of energy transport, and then introduce the various layers of the Sun.

Locating the Sun in the Sky

Because of Earth's eastward rotation, the Sun (and Moon, planets, and stars) rises in the East and sets in the West.

On average, the Sun rises at 6 am local time and sets at 6 pm.

The Sun transits when it reaches its highest elevation in the sky, the time it crosses a N-S line in the sky.



Adapted from NASA, https://pwg.gsfc.nasa.gov/stargaze/Secliptc.htm

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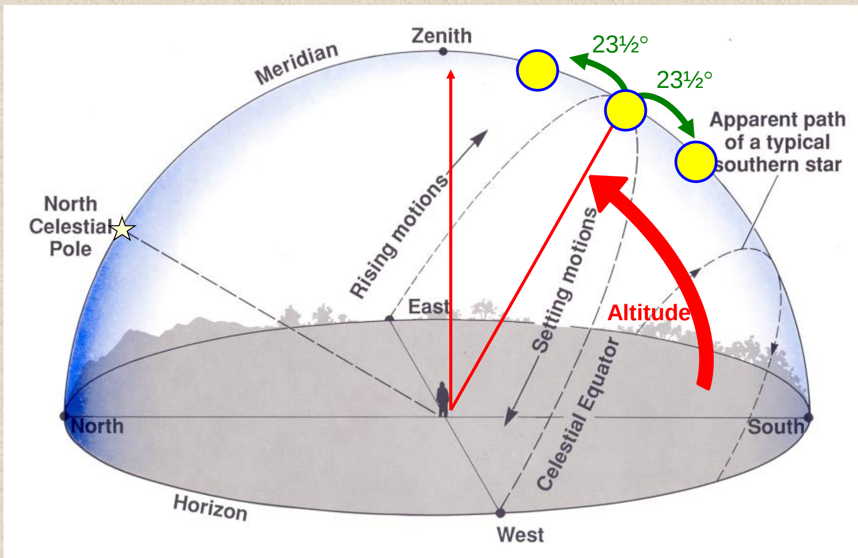
Locating the Sun in the Sky



The altitude of the Sun at noontime on the equinoxes = 90° – latitude angle.

In the northern hemisphere, the latitude = altitude of Polaris (North Celestial Pole).

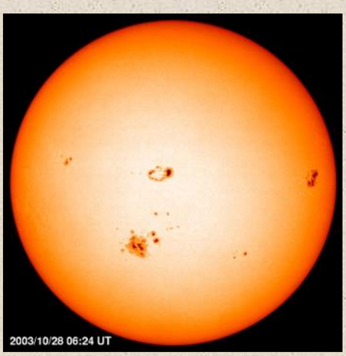
For a person living at latitude 40° North, the noontime altitude of the Sun is 50° on the equinoxes. Simply add or subtract 23.5° to determine the noontime altitude on the solstices.

The altitude of the Sun at noontime on the equinoxes = 90° – latitude angle. In the southern hemisphere where latitude angles are negative, you must subtract your altitude answer from 180 to get the correct noontime altitude.
In the northern hemisphere, the latitude = altitude of Polaris (North Celestial Pole).
Example 1: for a person living at latitude 40° North, the noontime altitude of the Sun on the date of the equinox is 90 – °40 = °50°.
Example 2: for a person living at latitude 30° South, the noontime altitude of the Sun on the date of the equinox is 90- – °30 = °120°. Since altitudes cannot exceed 90°, subtract the answer from 180° to get the correct answer: 180 – °120 = °60°.

Simply add or subtract 23.5° to determine the altitude on the solstices.

Properties of the Sun

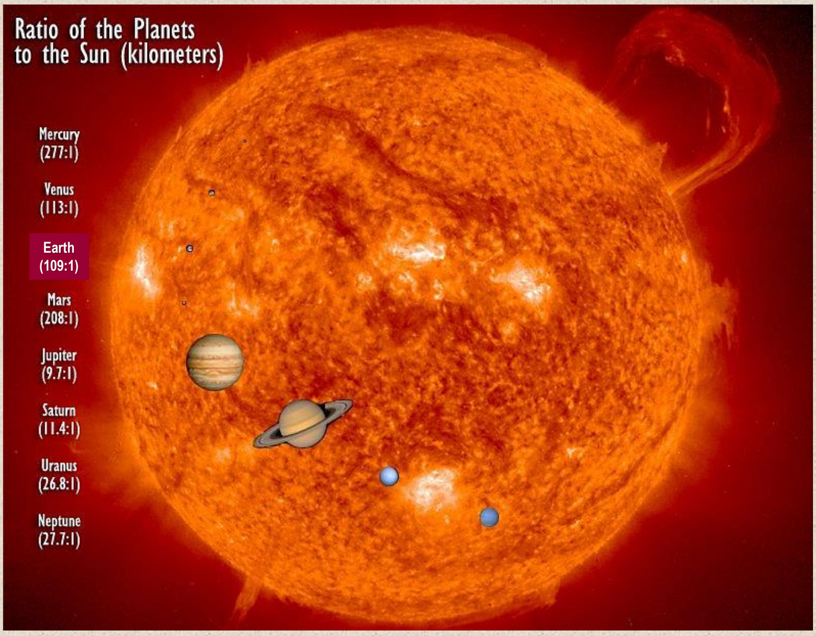
Solar Property	Value
Mean Distance (to Earth)	1.496 x 10^8 km (= 1 Astronomical Unit, AU)
Radius (R_{Sun})	6.96 x 10^5 km (about 109 times the radius of the Earth)
Mass (M_{Sun})	1.99 X 10^{30} kg (about 330,000 times the mass of the Earth)
Average Density	1.41 g/cm^3 (water = 1.0 g/cm^3)
Luminosity	3.8 X 10^{26} Joules/sec = watts
Composition of Photosphere	by Mass / by Number of atoms 73% hydrogen / 91% H atoms 25% helium / 9% He atoms 2% heavier elements / < 1% other atoms
Rotation rate	25 days (equator)
Surface temperature	5800 K
Core temperature	15 million K



SOHO, NASA & ESA

A table shows the basic properties of the Sun.

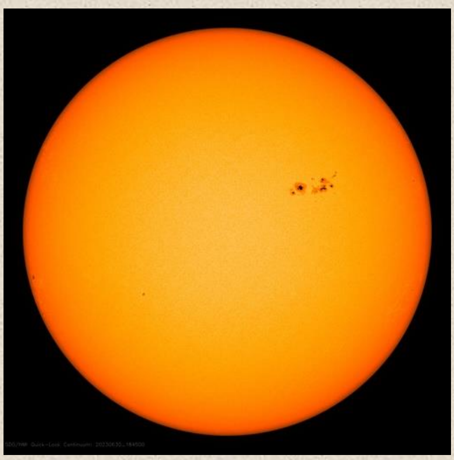
The Size of the Sun



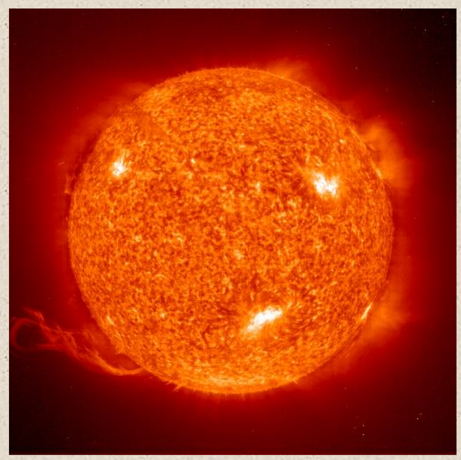
NASA/JPL

A scale drawing shows the Sun's size compared with the major planets. The Sun's diameter is about 109 times larger than the Earth.

Sun's Power



NASA/SDO 06/30/2023



SOHO, NASA & ESA

Luminosity (L) = total amount of energy a star emits per second

Sun's Luminosity (L_{sun}): $L_{sun} = 4 \times 10^{26}$ J/s or Watts

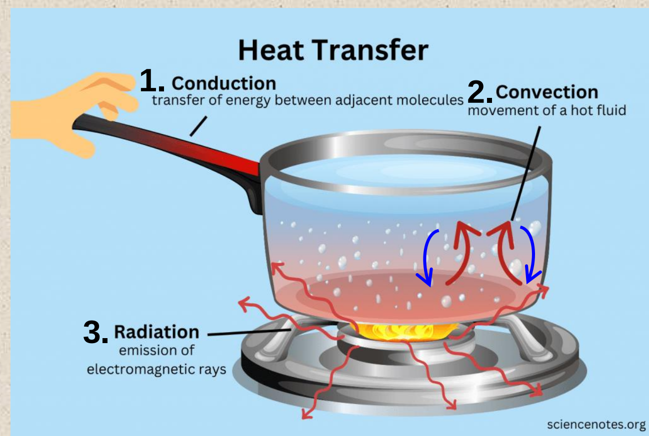
At Earth, the intensity is ~ 1360 Watts/m^2

The Sun's luminosity, or total energy emitted at all wavelengths, is 4×10^{26} Joules/second. The Sun's energy radiates outward in a spherical pattern, and by the time it reaches the Earth, the intensity of the radiation received at Earth's equator is about 1360 Watts per square meter.

Energy Transport

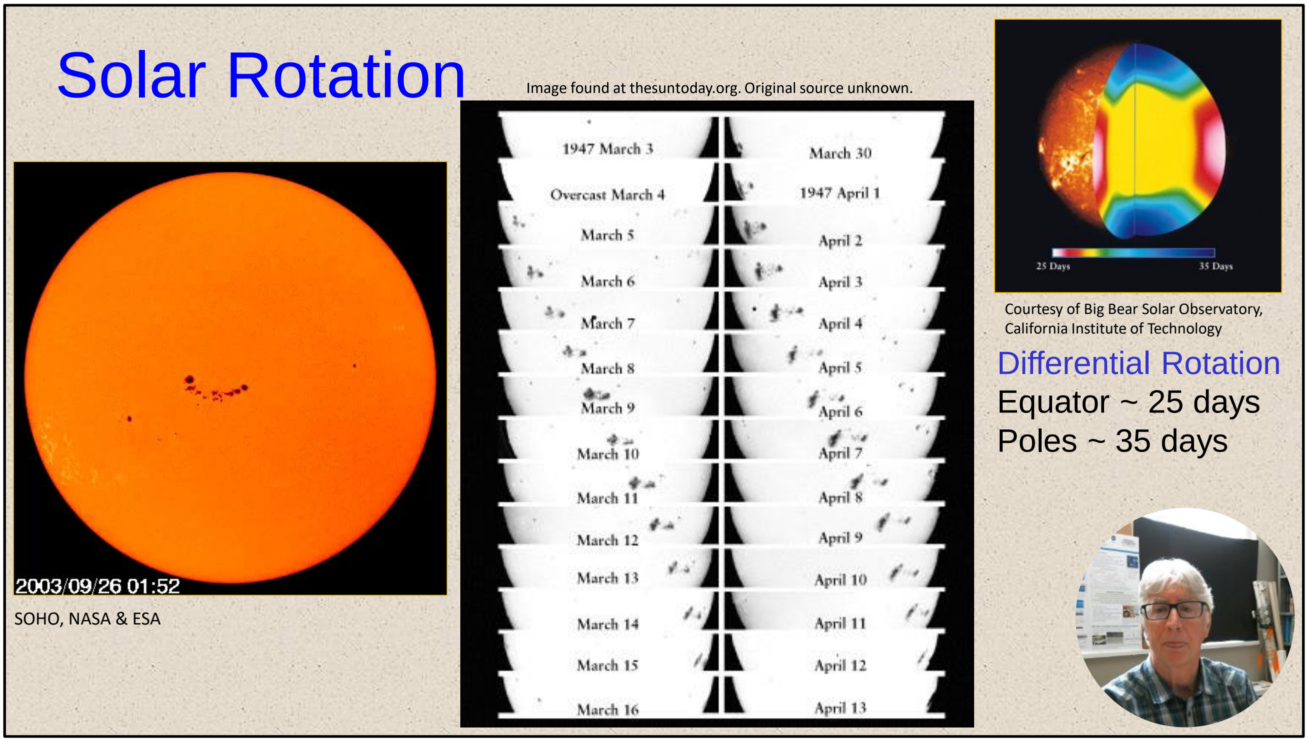
Energy Flow: HOT → Cool

1. Conduction – heat flow from contact
   - Not important for Stars
2. Convection – heat flow from the mixing of fluids (gases)
   - Important for Stars
3. Radiation - energy flow from the electromagnetic waves (light)
   - Most important for Stars!

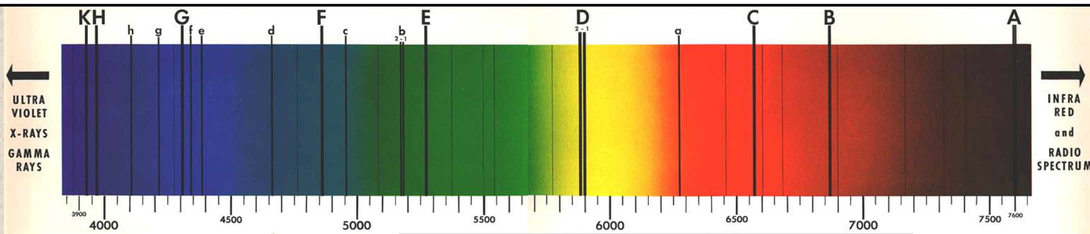


adapted from sciencenotes.org

A brief review of the mechanisms of energy transport. The 2nd law of thermodynamics tells us that heat flows from hotter objects to cooler ones. Conduction is energy transport from contact in liquids and solids. This is not important in stars. Convection causes the transfer of heat from the mixing of gases because hotter gas is less dense than cooler gas. Like a pot of boiling water, the movement is caused from heated material rising to the surface, and then cooling off at the surface to sink back down under the influence of gravity to be reheated. This is an important energy transport mechanism in the interiors of stars. Radiation is energy flow from electromagnetic waves, and it is important in the interior of stars, but also carries much of the energy away from the Sun and warms Earth and the other planets. [Note: The solar wind also carries away energy, but the neutrinos from the nuclear reactions carry away most of the energy.]



First demonstrated by Galileo in about 1612 by observing the sunspot motion over many days, the Sun rotates. As seen in the multiple images from 1947, sunspots take about a month to rotate around the Sun. More modern measurements show that the Sun rotates differentially. That is, it rotates faster at the equator, about 25 days, and more slowly near the poles, about 35 days.



Sun - Composition

Percent Atoms
~ 91% H
~ 9% He
< 1% all other elements

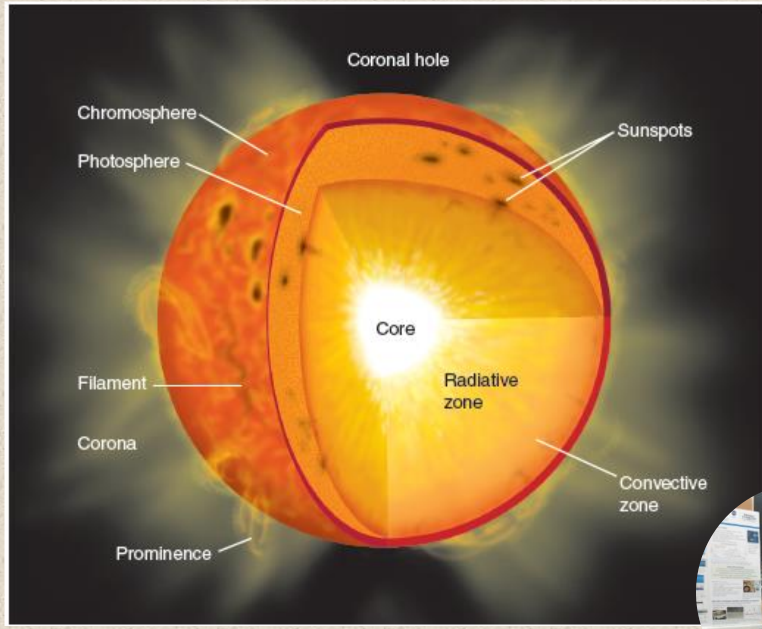
Lines	Due To ...	Wavelengths (Å)
A - (band)	O_2	7594 - 7621
B - (band)	O_2	6867 - 6884
C	H	6563
a - (band)	O_2	6276 - 6287
D - 1, 2	Na	5896 & 5890
E	Fe	5270
b - 1, 2	Mg	5184 & 5173
c	Fe	4958
F	H	4861
d	Fe	4668
e	Fe	4384
f	H	4340
G	Fe & Ca	4308
g	Ca	4227
h	H	4102
H	Ca	3968
K	Ca	3934

Taken from a ground-based telescope, the molecular oxygen (O_2) lines come from absorption by Earth's atmosphere.

The absorption lines seen in the visible solar spectrum are also called the Fraunhofer lines. The spectral lines identify the types of atoms and molecules that make up the gas in the Sun. The composition of the Sun can be determined and shows that the Sun is about 90% hydrogen by number, about 9% helium, and less than 1% of heavier elements like iron (Fe), sodium (Na), calcium (Ca), and magnesium (Mg). The molecular oxygen (O_2) lines come from absorption by Earth's atmosphere.

Sun Structure

Structure
1. Interior
   a. Core
   b. Radiative Zone
   c. Convection Zone
2. Photosphere
3. Atmosphere
   a. Chromosphere
   b. Transition Zone
   c. Corona



This is a cutaway diagram showing the various layers and structure of the Sun. The interior consists of the core where the nuclear reactions happen and the radiative and convective energy transport regions. The “surface” of the Sun is called the photosphere where the gas becomes optically thick, that is, opaque to visible light. Sunspots occur in the photosphere. Above the photosphere are thin layers of the chromosphere and the transition zone. The vast, thin outer layer is called the corona which becomes the solar wind of charged particles leaving the Sun.

Resources

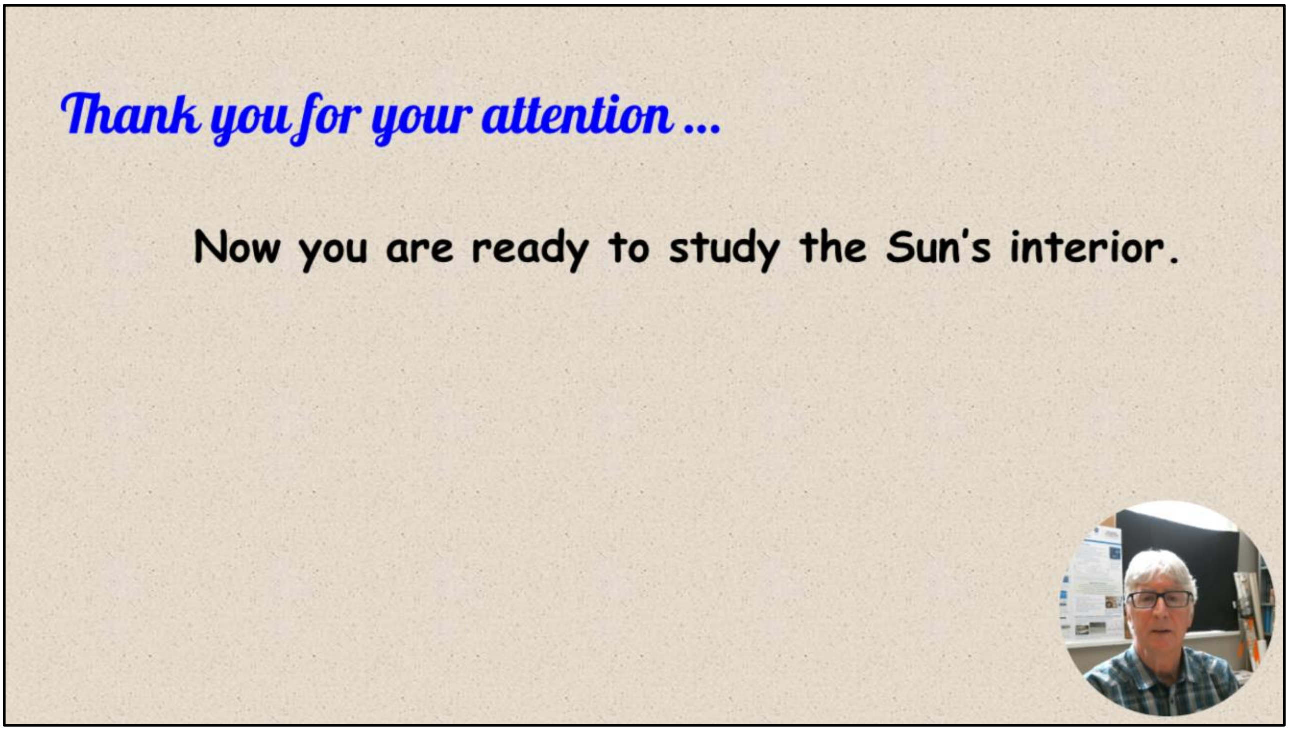
The Sun
https://solarsystem.nasa.gov/solar-system/sun/overview/
https://www.exploratorium.edu/eclipse/our-sun-is-a-star
https://solarscience.msfc.nasa.gov/

NASA Solar and Heliospheric Observatory (SOHO)
https://soho.nascom.nasa.gov/home.html

NOAA Space Weather Prediction Center
https://www.swpc.noaa.gov/

Space weather:
https://spaceweather.com/
https://swe.ssa.esa.int/current-space-weather
https://www.swpc.noaa.gov/

This is a short list of good resources on the Sun and Space Weather.



Thank you for your attention … Now you are ready to study the Sun’s interior.