Lecture 15: The Sun
Start reading about: The Sun (Ch. 10), Spectra (Ch. 5), Stars (Ch. 11)

Next week: Stars and Spectra

Midterm: Tuesday, February 18th

UW planetarium: Tuesday, March 4th 3:00pm
The Sun, our star
99.985% of the mass of the Solar System
The source of all the energy on Earth
and light in the Solar system
our model system for studying other stars
Can use the same geometric methods the ancient Greeks used to determine that the Sun is 108x larger than the Earth.
Can use orbit of the planets to find the Sun’s mass

\[(\text{some number})(\text{Distance}^3) / (\text{Period}^2) = 2 \times 10^{30} \text{ kg}\]

About a million times more massive than Earth
The Sun. It’s different. It’s really bright. Even the ancients knew it was the source of light in the Solar system.
Obvious theory: The Sun is burning stuff.

Coal? Oil? Magic cosmic oil?

Calculations showed that this could only support a few thousand years of burning.
19th Century: Slightly less obvious theory: Gravitational contraction

1) Gravity squeezes the Sun into a smaller ball.
2) That heats up the Sun.
3) Heat = light.

Can only provide 25 Millions years of energy
Fossil record rules this out

This is a legitimate mechanism for making heat!
It happens in proto-stars.
It’s just not the one currently making the Sun shine.
This explosion represents about half a gram of mass. Efficient enough energy source to keep the Sun burning for billions of years.
E = MC²
But how?
A proton in a Hydrogen nucleus has a different mass than a proton in a Helium nucleus or a proton in an Iron nucleus or Plutonium nucleus. Weird.
This is what you need to know, not the whole “proton-proton chain”

\[ E = mc^2 \]

\[
\begin{align*}
4^1H & \rightarrow 1^4He + \text{energy} \\
& \quad \text{(gamma rays)}
\end{align*}
\]
The weight of the rest of the Sun compresses the center

Fusion starts in the center and pushes back out

The Sun stays the same size.

Those gamma rays bounce around and leave (after a million years or so and turning into all sorts of different types of light)
Self-regulating process, thankfully

If the rate of fusion slows, the gravity will crush the star and increase the rate again.

If the rate of fusion increases, the core will puff up decreasing the rate of fusion.

“The Solar thermostat”
All fusion happens in core

16 million degrees K

160 g/cm³ (15x density of lead)
85% of the Sun

Electromagnetic radiation tries to escape

Takes about 1 million years for a gamma ray to leave (as a bunch of other longer wavelength types of light)
Convection zone

Hot ionized gas (can’t hold onto electrons) circulates

Edge is 5800 degrees Kelvin

This is where Solar weather comes from
Is the Sun’s surface active?
Yeah, the surface is constantly changing

We see Solar earthquakes “Sunquakes”

The Sun is shaking:
Blue areas bulging outwards
Red areas sagging inwards
Sun’s “atmosphere”: photosphere, chromasphere, corona

Hot ionized gas blows off

Photosphere is the part we “see”

Heats up again
Is the Sun rotating? Fast?

Solar day 25 days at the equator
30 days at the poles

The Sun is a giant ball of plasma (ionized gas where electrons move freely)

Think the Sun has a magnetosphere?
The Sun’s different rate of rotation at the poles and equator causes the magnetic field to get tangled.
Sunspot activity gives warning.
Eventually these tangled field lines bulge and pop out of the surface. A sunspot.
August 28th - Sept. 1st 1859 “The Carrington Event”
-Telegraphs shock operators
-Aurora Borealis visible in Cuba
-Estimated would cause ~$3Trillion in damage if it happened now
Talk more about the Electromagnetic spectrum.
Summary:

Light:
- It moves fast, but not that fast
- There’s a lot more of it than the human eye can see
- The sectors of the Electromagnetic spectrum

The Sun:
- How does it make light
- What types of light does it make
- Anatomy of a star
Start talking seriously about non-visible light.
Light or “Electromagnetic radiation”

All light moves at the same speed through empty space

300,000 kilometers per second
9.46x10^{12} kilometers per year, 9.46x10^{12} km “light year”

Moon: 1.1 light seconds away
Sun: 8 light minutes away
Jupiter: 35-50 light minutes away
Voyager 2: 13.5 light hours away
All light waves move at the same speed, but they can have different spacing in between peaks “wavelength”
For visible light different wavelengths = different colors

“red” is $7.9 \times 10^{-7}$ meters
“blue” is $4.7 \times 10^{-7}$ meters
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<th>X-rays</th>
<th>ultraviolet</th>
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Jupiter in infrared
Art is astronomy
“false coloring”
**Key terms:**
Electromagnetic spectrum, speed of light, Gravitational contraction, nuclear fusion, nuclear fission, core, radiation zone, convection zone, photosphere, chromospheres, corona, solar wind

**Key Ideas:**
What are the basic parts of the electromagnetic spectrum?

Why do we need to “false color” pictures of astronomical objects?

What makes the Sun shine?

What are the parts of the Sun?

How does the Sun regulate the rate of fusion in its core?

http://www.pbs.org/wgbh/nova/space/secrets-sun.html