

ASTR 1040 Recitation: The Sun

Ryan Orvedahl

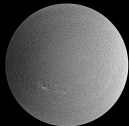
Department of Astrophysical and Planetary Sciences

February 19 & 20, 2019

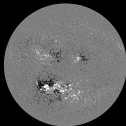
Announcements

- Next Observing: Wed, Feb 20 (8pm or 9pm at SBO)

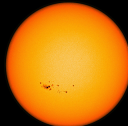
The Sun using SDO



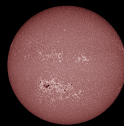
HMI Dopplergram
Surface movement
Photosphere



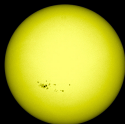
HMI Magnetogram
Magnetic field polarity
Photosphere



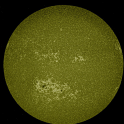
HMI Continuum
Matches visible light
Photosphere



AIA 1700 Å
4500 Kelvin
Photosphere



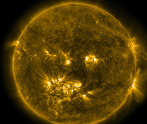
AIA 4500 Å
6000 Kelvin
Photosphere



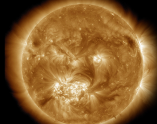
AIA 1600 Å
10,000 Kelvin
Upper photosphere/
Transition region



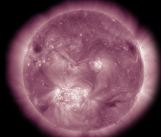
AIA 304 Å
50,000 Kelvin
Transition region/
Chromosphere



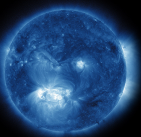
AIA 171 Å
600,000 Kelvin
Upper transition
Region/quiet corona



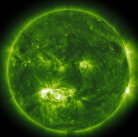
AIA 193 Å
1 million Kelvin
Corona/flare plasma



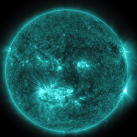
AIA 211 Å
2 million Kelvin
Active regions



AIA 335 Å
2.5 million Kelvin
Active regions

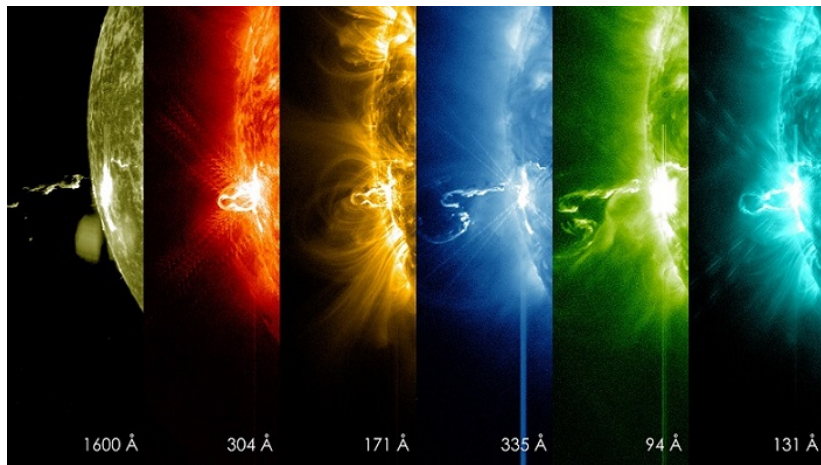


AIA 094 Å
6 million Kelvin
Flaring regions



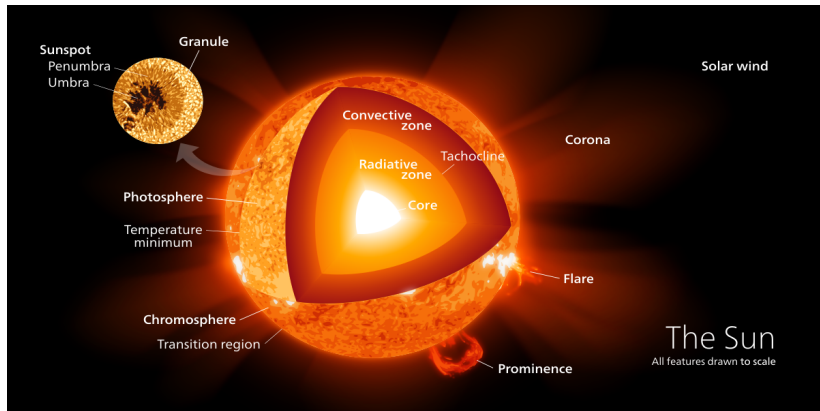
AIA 131 Å
10 million Kelvin
Flaring regions

The Sun using SDO/AIA

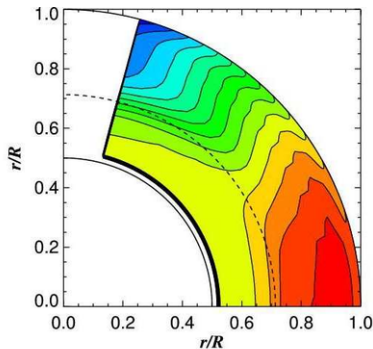
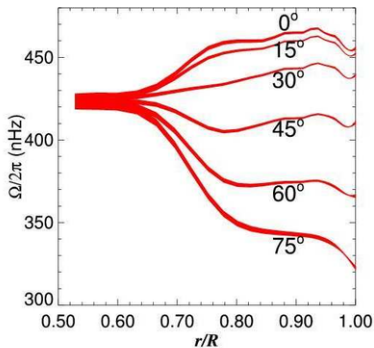


The Sun using SDO/AIA

The Solar Interior

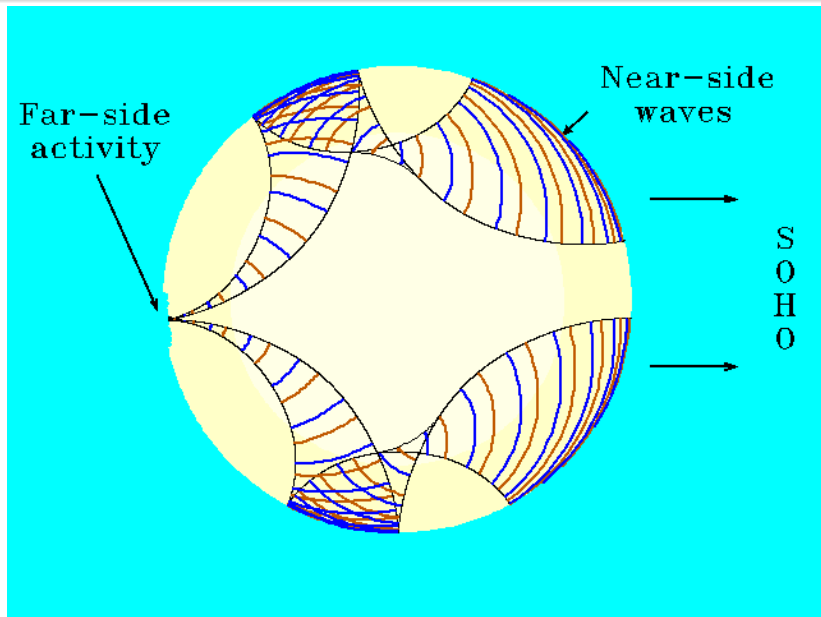


Differential Rotation



Fast equator, slow poles. Constant in radiative zone.

How Do We Know?



What Stops a Star From Collapsing?

Pressure

- Pressure = Force per area, $F = \int P \, dA$
- Each particle has momentum, hits the wall (or particles)
- A change in momentum \Rightarrow Force
- Acts in all directions

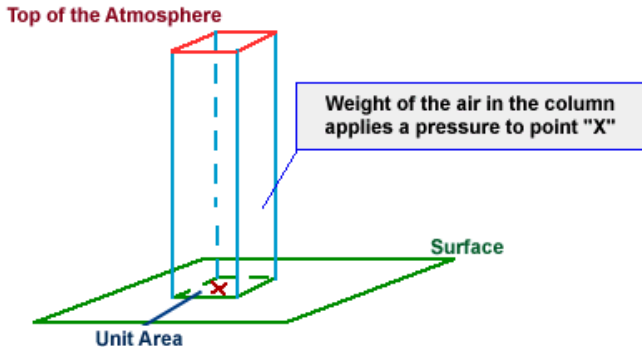
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- Can you move a car with a laser pointer?
 - Not quite, maybe only a grain of sand. But photons carry momentum, thus exert a pressure

Stars are Static, Most of the Time

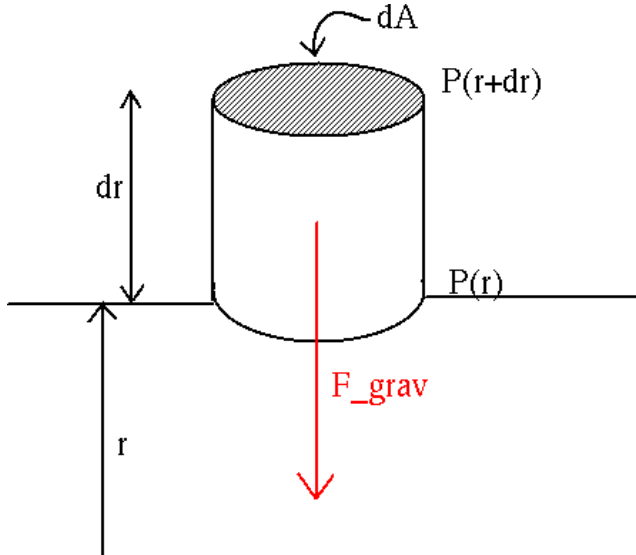


$$F = PA$$

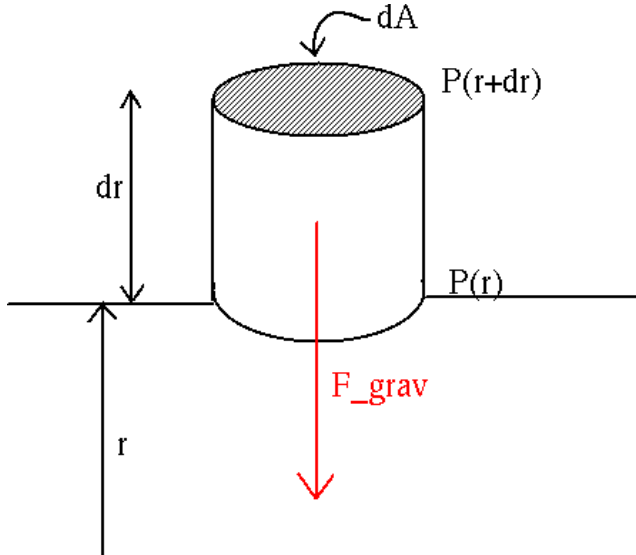
Stars are Static



Hydrostatic Equilibrium



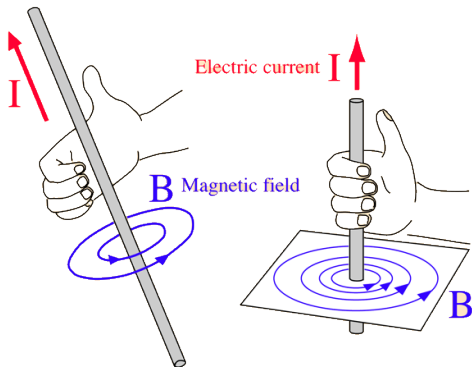
Hydrostatic Equilibrium



$$\frac{dP}{dr} = -\rho g$$

Only changes in P give Force

Quick Aside: Magnetic Pressure



$$P_{\text{mag}} = B^2 / 2\mu_0$$



What Happens at the Top of the Atmosphere?

- Temperature \sim average KE
- Higher temperatures \Rightarrow higher velocities \Rightarrow higher P

What Happens at the Top of the Atmosphere?

- Temperature \sim average KE
- Higher temperatures \Rightarrow higher velocities \Rightarrow higher P
- Beyond the atmosphere is the vacuum of space, much less material means lower pressure
- Pressure difference means particles escape

Practice Problem: Solar Wind Mass Loss

Satellites in orbit around the Earth constantly measure the solar wind. They find that the solar wind is mainly composed of protons with a velocity of $v \approx 500$ km/sec and a number density of about $n \approx 7$ cm⁻³.

$$M_{\odot} = 2 \times 10^{30} \text{ kg} \quad m_p = 1.67 \times 10^{-27} \text{ kg}$$

- How much mass is lost due to the solar wind, in M_{\odot}/yr ?
- How many years until the Sun loses all of its mass?

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- What is the mass element dM for a thin spherical shell?

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- How much mass is lost? $\approx 2.6 \times 10^{-14} M_{\odot}/\text{yr}$
 - $dM = \rho dV = \rho 4\pi r^2 dr = mn 4\pi r^2 dr$
 - $dM/dt = mn 4\pi r^2 dr/dt$
- How many years until it's all lost? $\approx 3.9 \times 10^{13}$ yr
 - $t = M/(dM/dt)$