Introductory Astronomy

Week 4: Stars

Clip 5: Solar Structure

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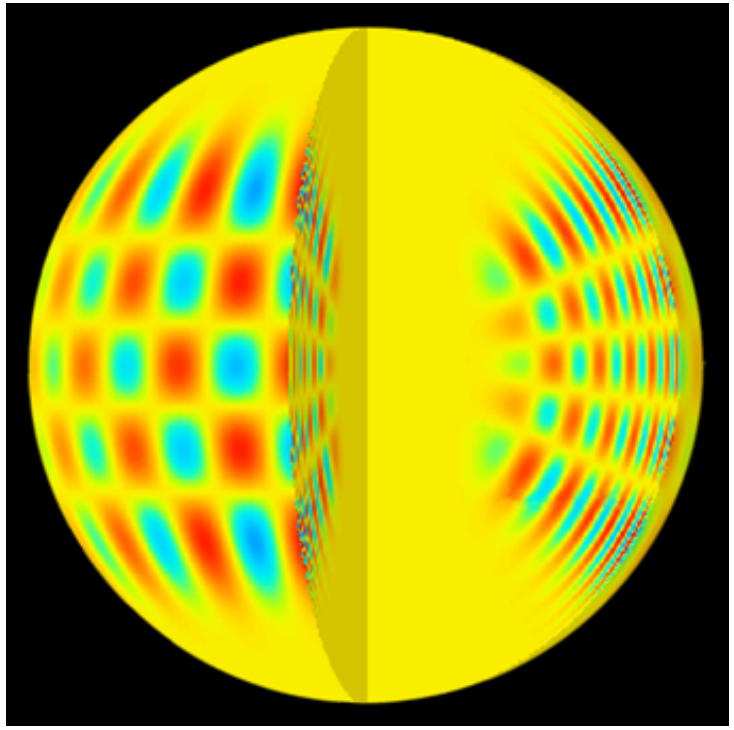
Studying the Sun

- Solar models together with helioseismology provide interior structure between core and photosphere
- Density, pressure, temperature increase with depth for hydrostatic equlibrium



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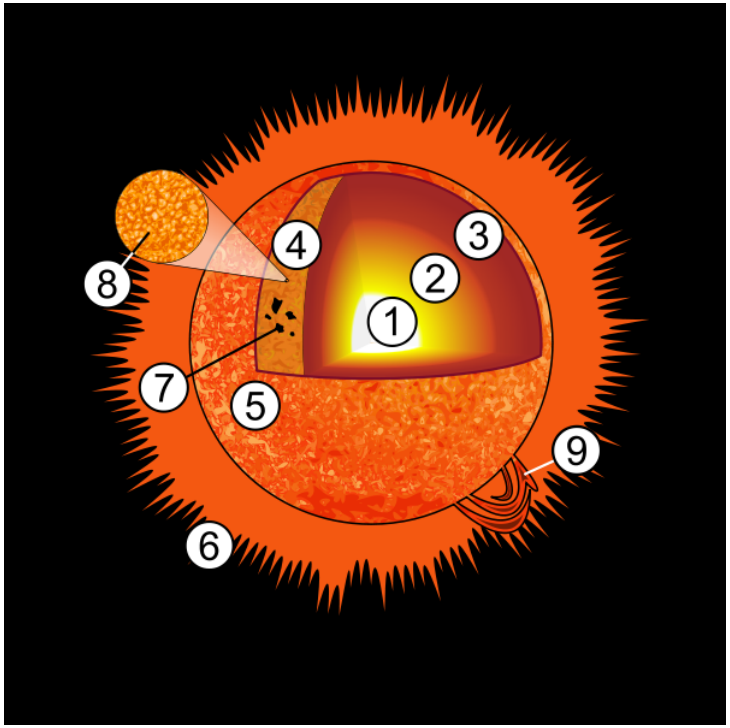
Solar Structure - Core

- Core: $R \leq .25 R_\odot$

$$1.57 \times 10^7\,\mathrm{K} \geq T \geq 7 \times 10^6\,\mathrm{K}$$
$$1.5 \times 10^5\,\mathrm{kg/m^3} \geq \rho \geq 2 \times 10^4\,\mathrm{kg/m^3}$$
$$M \sim 0.4 M_\odot$$

- Stable equilibrium: fusion rate decreases/increases: core contracts/expands increasing/decreasing rate
- Luminosity determined by mass



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Solar Structure – Inner Mantle

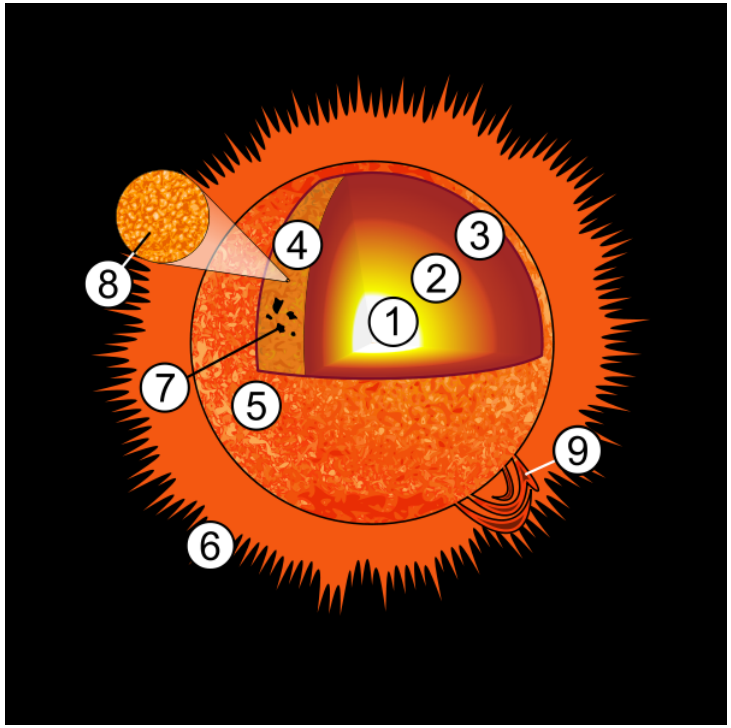
- Radiation Zone:

$$.25R_\odot \leq R \leq .7R_\odot$$

$$7 \times 10^6\,\mathrm{K} \geq T \geq 2 \times 10^6\,\mathrm{K}$$

$$2 \times 10^4\,\mathrm{kg/m^3} \geq \rho \geq 10^3\,\mathrm{kg/m^3}$$

- Heat transfer: Radiation diffusion in charged plasma
- Transit time: $1.7 \times 10^5\,\mathrm{y}$



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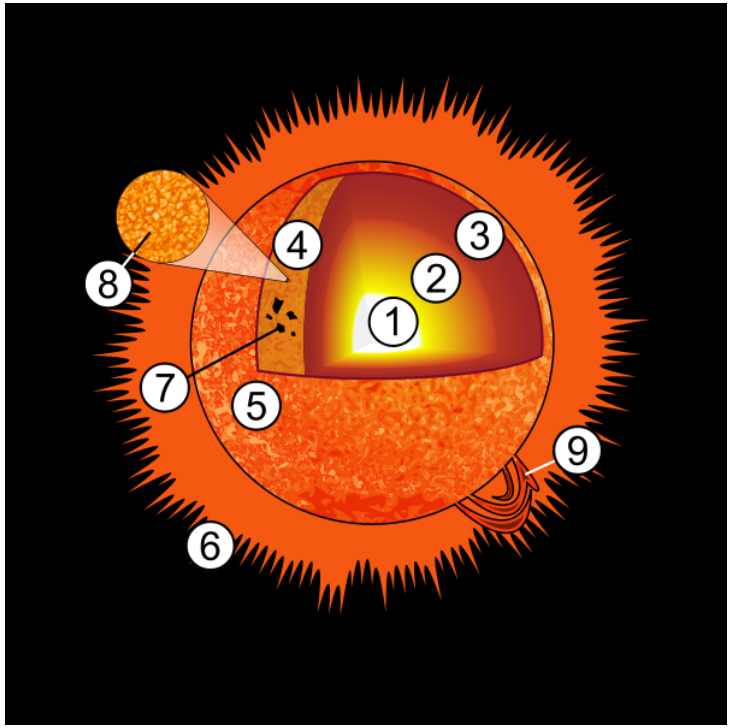
Solar Structure – Outer Mantle

- Convection Zone:

$$.7R_\odot \leq R \leq R_\odot$$
$$2 \times 10^6\,\mathrm{K} \geq T \geq 5780\,\mathrm{K}$$
$$10^3\,\mathrm{kg/m^3} \geq \rho \geq 2 \times 10^{-4}\,\mathrm{kg/m^3}$$

- Heat Transfer: Convection produces granular structure of photosphere



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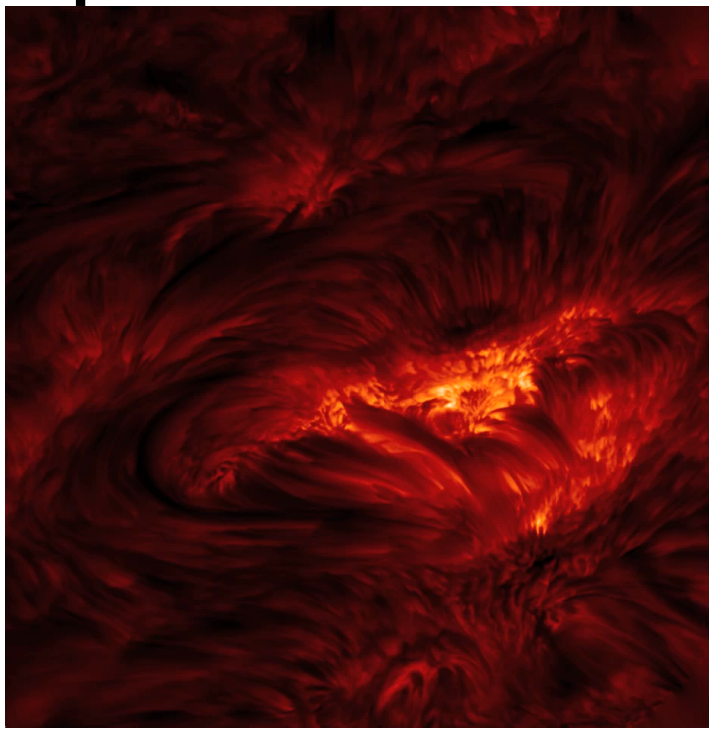
Solar Atmosphere

- Sun extends beyond photosphere
- Density low but temperature increases with altitude
- Chromosphere:

$$h \leq 2000\,\mathrm{km}$$
$$5780\,\mathrm{K} \leq T \leq 50,000\,\mathrm{K}$$
$$2 \times 10^{-4}\,\mathrm{kg/m^3} \geq \rho \geq 10^{-10}\,\mathrm{kg/m^3}$$

Observe by H_α line



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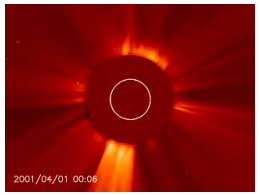
Corona

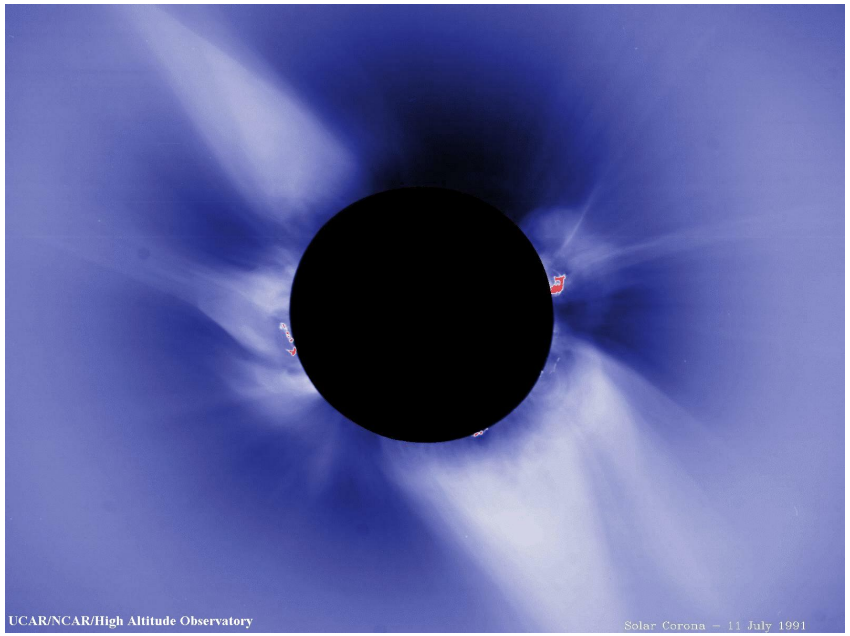


- Corona:

  $2000\,\mathrm{km} \leq h \leq 1.3\,R_\odot$

  $T \sim 2 \times 10^6\,\mathrm{K}$

  $\rho \sim 3 \times 10^{-12}\,\mathrm{kg/m^3}$
- Visible during Eclipse or with coronagraph
- Observed in UV, X-Ray
- High temperature allows escape: Solar wind



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Credits

- Helioseismic p-mode: Wikimedia Commons http://en.wikipedia.org/wiki/File:Helioseismology_pmode1.png
- Solar Structure: Wikimedia Commons/Pbroks13 http://en.wikipedia.org/wiki/File:Sun_diagram.svg
- Photosphere Movie: Bruno Sanchez-Andrade Nuño, (IAG & MPS, NRL) http://apod.nasa.gov/apod/ap090405.html
- Chromosphere Movie: Luc Rouppe van der Voort, Oslo/Royal Swedish Academy of Sciences http://www.solarphysics.kva.se/
- Corona: UCAR/NCAR High Altitude Observatory http://solarscience.msfc.nasa.gov/images/Ecl1991a.jpg
- CME Movie: SOHO (ESA & NASA) http://sohowww.nascom.nasa.gov/gallery/Movies/series.html