Link of the day


**Solar Dynamics Observatory (SDO)**

Standard Solar Model

• 4 basic assumptions:
  ▪ Hydrostatic Equilibrium
  ▪ Energy transport: radiation, conduction, convection
  ▪ Nuclear reactions the only source of energy
  ▪ Composition at start was homogeneous and primordial
4 equations, 4 unknowns

\[ \frac{dP}{dr} = -\frac{Gm\rho}{r^2} \quad \text{or} \quad P = \frac{\rho T \mathcal{R}}{\mu} \]

\[ \frac{dT}{dr} = -\frac{3\kappa\rho L}{16\pi acr^2 T^3} \quad \text{or} \quad \frac{dT}{dr} = \left(1 - \frac{1}{\gamma}\right) \left(\frac{T}{P}\right) \frac{dP}{dr} \]

\[ \frac{dL}{dr} = 4\pi r^2 \rho \varepsilon \]

\varepsilon = \varepsilon_\gamma - \varepsilon_\nu \quad \text{nuclear energy generation rate per unit mass minus the luminosity of nutrinos}

Convection becomes important when the star cannot transport all of its energy via radiation.
Fig. 1. Structure of two model convection zones with depth. Figure adapted from Gough and Weiss (1976), who computed models based on formulation of Böhm-Vitense (1958), solid lines, and on that of Öpik (1950), dashed lines. Curves from these two formulations coincide except within 10^3 km of outer boundary of convection zone. Arrows labelled H, He I, He II denote 10–9% ionization zones for hydrogen and helium.
Schematic example

\[ T \]

\[ \frac{dT}{dr} \]

Convection

Parallel

Radiation

Using lowest \( \frac{dT}{dr} \) gets lower temperature at center of sun

Surface temperature \( \approx \times 10^3 + \text{K} \)

Center of sun
Temperature as a function of Radius
ATOMS form, convection starts

- Composition
- Hydrogen Energy Levels
- Convection Cells (granulation, supergranulation)
- TRACE/SDO movie samples
Fig. 2-5. Term diagram for hydrogen according to the Bohr theory, showing the transitions responsible for some of the spectral series of this element.
Energy level diagram for Helium

For more info see http://hyperphysics.phy-astr.gsu.edu/hbase/atomic/atstruct.html#c1
\[ \frac{dP}{dr} = - \frac{Gm\rho}{r^2} \]

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\[ \frac{dT}{dr} = - \frac{3\kappa \rho L}{16\pi acr^2 T^3} \quad \text{or} \quad \frac{dT}{dr} = \left( 1 - \frac{1}{\gamma} \right) \left( \frac{T}{P} \right) \frac{dP}{dr} \]

\[ \frac{dL}{dr} = 4\pi r^2 \rho \varepsilon \]

\( \kappa \) is the Opacity

Fig. 9. Rosseland opacity for $X = 0.75$, $Y = 0.2321$, $Z = 0.0179$ vs temperature with density as a parameter. Densities (g cm$^{-3}$) are logarithmically spaced, three per decade.
Fig. 1. Structure of two model convection zones with depth. Figure adapted from Gough and Weiss (1976), who computed models based on formulation of Böhm-Vitense (1958), solid lines, and on that of Öpik (1950), dashed lines. Curves from these two formulations coincide except within $10^3$ km of outer boundary of convection zone. Arrows labelled H, He I, He II denote 10–9% ionization zones for hydrogen and helium.
Fig. 1

Hinode SOT First Light image

Sun’s diameter ~1,400,000 km

Above: The sun in white light (420 nm). Above-right and right: From SOT showing in detail solar granulation (convection cells), and bright points between granules that are locations of concentrations of magnetic field.

From: http://science.nasa.gov/science-news/science-at-nasa/2006/02nov_firstlight/
The image shows a 121,000 km square region at the center of the Sun's disk. The Sun has a diameter of 1,400,400 km so that this picture covers only about 1% of the disk. To display the entire Sun at the same scale would require a poster 7 meters (23 feet) square. About 100 images of the Earth could be placed in the area shown in such a poster.
supergranules

Magnetic field $>15\text{G}$ (color)

Light: upflow
Dark: downflow

Figure 11 - Flow within solar granulation cells. (a) Top view; downflow is concentrated at vertices of cells. Direction of flow is indicated as upward (+), downward (−), and horizontal (arrow). (b) Vertical section of flow in region of vertex of several cells. Length of arrow denotes magnitude of velocity.

More about convection: http://hyperphysics.phy-astr.gsu.edu/hbase/thermo/heatra.html#c3
THE SOLAR SPECTRUM

FREQUENCY

10^{21} Hz 10^{20} Hz 10^{19} Hz 10^{18} Hz 10^{17} Hz 10^{16} Hz 10^{15} Hz 10^{14} Hz 10^{13} Hz 10^{12} Hz 10^{11} Hz 10^{10} Hz 10^{9} GHz 10^{8} GHz 10^{7} GHz 10^{6} GHz 10^{5} GHz 10^{4} MHz 10^{3} MHz

GAMMA-RAY X-RAY ULTRA-VIOLET INFRARED RADIO

NASA-GOOGAR SPACE FLIGHT CENTER GREENBELT, MARYLAND AUGUST, 1976

QUIET SUN OUTLINE OF LARGEST BURST REPEATER (RATHERMALL)

28 FLARE POST-FLARE 18 FLARE

NON-FLARE CONDITIONS

SPECTRAL IRRADIANCE (erges cm^{-2} s^{-1} Ω^{-1} m^{-2})

WAVELENGTH

10^{-1} m 10^{-2} m 10^{-3} m 10^{-4} m 10^{-5} m 10^{-6} m 10^{-7} m 10^{-8} m

COMPILED BY H.H. MAULTER FROM THE FOLLOWING SOURCES:


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