Survey of the Solar System

The Sun

Giant Planets

Terrestrial Planets

Minor Planets

Satellite/Ring Systems
The Sun

Mass, $M_\odot$ $\sim 2 \times 10^{30}$ kg

Radius, $R_\odot$ $\sim 7 \times 10^8$ m

Surface Temperature $\sim 5800$ K

Density $\sim 1.4$ g/cm$^3$

*First light SDO -- 2010*
Solar Structure

- Core: $r < 0.3 \, R_\odot$
- Radiative Zone: $0.3 \, R_\odot < r < 0.7 \, R_\odot$
- Convective Zone: $r > 0.7 \, R_\odot$
- Photosphere: ‘Surface’ of the sun
- Corona: Solar Atmosphere
Core: Nuclear Fusion

\[ {^1\text{H} + ^1\text{H} \rightarrow ^2\text{H} + e^+ + \nu_e} \]
\[ e^- + e^+ \rightarrow 2\gamma \]
\[ ^2\text{H} + ^1\text{H} \rightarrow ^3\text{He} + \gamma \]
\[ ^3\text{He} + ^3\text{He} \rightarrow ^4\text{He} + ^1\text{H} + ^1\text{H} \]

Overall Reaction:
\[ 4^1\text{H} + 2e^- \rightarrow ^4\text{He} + 2\nu_e + 6\gamma \]

\[ \Delta E = [4(1.007825u) - 4.002603u] \times [931\text{MeV/u}] \]
\[ \Delta E = 26.7 \text{ MeV} \]
Solar Structure

The Radiative Zone is a region of highly ionized gas where the energy transport is primarily by photon diffusion where photons are absorbed and re-emitted.

At the base of the Convection Zone, lower efficiency of photon diffusion leads to thermal gradients where convection becomes the dominant mechanism for energy transport.

Image modified from: UCB's Center for Science Education
Solar Structure

In the Photosphere the plasma becomes transparent to the optical spectrum, allowing for the escape of most of the electromagnetic energy reaching that layer. Hence, the Photosphere is the visible ‘surface’ of the sun.

Below the photosphere the plasma is so dense that we cannot see through it, but evidence of the convection zone are visible as ‘granules’.
Solar Structure

The Solar Atmosphere:
- Photosphere
- Chromosphere
- Transition Zone
- Corona
- Heliosphere
Solar Wind (at 1 AU)
Density ~ 5-10 cm⁻³
Speed ~ 450 km/s
Magnetic field ~ 6 nT

Temperature ~ $10^5$ K
At the heliopause the solar wind merges with the interstellar medium, forming the boundary of the heliosphere (the radial extent of the solar atmosphere).

Neutrals in the interstellar medium are unaffected by the solar wind and pass directly into the solar system, enabling relative speed determination.
The termination shock marks the inner edge of the heliopause. This boundary is in dynamic pressure balance between the solar wind and interstellar medium is characterized by a slowing of the solar wind (variable due to the solar cycle).

Both Voyagers 1 and 2 are believed to have crossed the termination shock.

2004- Voyager 1 @ 94 AU (solar max)
2007 Voyager 2 multiple crossings @ ~84 AU (solar min)
In 2012, Voyager 1 indicated that it finally ‘cleared’ the Solar System and has ventured into interstellar space!

How do we know?

2012- Voyager 1 @ 120 AU

Non-Sun Material

Terrestrial Planets

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Asteroids

Minor Planets

Comets

Ring Systems

Satellites
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**Giant Planets**

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**Gas Giants: Jupiter**

- **Mass**: $\sim 1.900 \times 10^{27} \text{ kg}$
- **Radius**: $\sim 71500 \text{ km}$
- **Orbit**: $\sim 5.2 \text{ AU}$
- **Rotation**: $\sim 10 \text{ hr}$
Giant Planets

Gas Giants: Jupiter
Composition mostly H & He, but
with a heavy element core
~ 3% of total mass
Strong Atmospheric Dynamics
Several large satellites
Strong magnetic field
Thin Rings
Plasma Torus
Aurora

Clarke et al., 1998
Giant Planets

Gas Giants: Saturn

Mass \( \sim 5.7 \times 10^{26} \text{ kg} \)
Radius \( \sim 60300 \text{ km} \)
Orbit \( \sim 9.5 \text{ AU} \)
Rotation \( \sim 10.5 \text{ hr} \)
Giant Planets

Gas Giants: Saturn
Composition mostly H & He, but with a heavy element core ~ 10% of total mass
Strong Atmospheric Dynamics
Several satellites
Strong magnetic field
Complex Rings
Neutral Cloud
Aurora

Clarke et al., 2005
Giant Planets

Ice Giants: Uranus
Mass $\sim 8.7 \times 10^{25}$ kg
Radius $\sim 25600$ km
Orbit $\sim 19.2$ AU
Rotation $\sim -17.4$ hr
**Giant Planets**

**Ice Giants: Uranus**
Composition mostly H$_2$O, NH$_3$, & CH$_4$, but with a small rocky core
Strong Atmospheric Dynamics
Several satellites
Strong off-axis magnetic field
Several Thin Rings
Aurora ?? -- Yes!

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Clarke et al., 1998
**Giant Planets**

**Ice Giants: Neptune**

- Mass: $\sim 1.02 \times 10^{26}$ kg
- Radius: $\sim 24800$ km
- Orbit: $\sim 30$ AU
- Rotation: $\sim 16.1$ hr

Giant Planets

Ice Giants: Neptune
Composition mostly H$_2$O, NH$_3$, & CH$_4$, but with a small rocky core
Strong & Seasonal
   Atmospheric Dynamics
Several satellites
Off centered/ off axis
   Magnetic field
Interesting Rings
Aurora ??

Voyager 2 encounter