OUTER PLANETS

MINOR MEMBERS OF THE SOLAR SYSTEM

SUN
Jupiter
(Earth for Scale)
Jupiter’s bands are clouds

- Dark clouds (belts)
- Bright clouds (zones)
- Strong winds
Hubble view of Jupiter

- Arrow shows entry point of Galileo probe, Dec. 1995


- [http://www2.jpl.nasa.gov/galileo/hstimages.html](http://www2.jpl.nasa.gov/galileo/hstimages.html)
Galilean moons

- http://photojournal.jpl.nasa.gov/catalog/PIA00743
Io

- True color on top
- Enhanced color on bottom
- Surface covered with calderas (like Crater Lake…without the water!)

Volcanic Plume on Io
EUROPA — Surface-feature examples

- http://photojournal.jpl.nasa.gov/catalog/PIA00746
Ganymede
Callisto

Four Inner moons of Jupiter

- Metis, Adrastea, Amalthea, Thebe
- Amalthea is 247 km across
- Photos by Galileo probe, 1996-97

[http://www2.jpl.nasa.gov/galileo/ganymede/PIA01076.html](http://www2.jpl.nasa.gov/galileo/ganymede/PIA01076.html)
Jupiter’s outermost ring

- Discovered by Voyager 1
- This photo by Galileo space probe--November 9, 1996

[http://www2.jpl.nasa.gov/galileo/callisto/p48188.html]
Saturn

- Voyager I, II went there in 1980, 81
- This photo by Cassini in 2004

True-color image of Saturn’s rings

Saturn and some of its moons
Titan

- http://ciclops.lpl.arizona.edu/view.php?id=575
River system on Titan

http://www.esa.int/SPECIALS/Cassini-Huygens/SEMHB881Y3E_1.html
Enceladus

- [http://pds.jpl.nasa.gov/planets/captions/saturn/encelads.htm](http://pds.jpl.nasa.gov/planets/captions/saturn/encelads.htm)
Uranus (by Hubble)

- http://hubblesite.org/newscenter/newsdesk/archive/releases/1996/15/image/a
Neptune
Minor Members of Solar System

- Asteroids
- Meteoroids
- Comets
- Kuiper Belt Objects
- Dwarf Planets
“Planet”

- Orbits Sun
- Not a satellite
- Dominates its orbital path
“Dwarf Planet”

- is in orbit around Sun
- has sufficient mass for its self-gravity to pull itself into near-spherical shape
- has not cleared the neighborhood around its orbit
- is not a satellite
Pluto and Charon

HST image

Pluto and Charon

- Pluto does not dominate its orbit
- Pluto is the first discovered Kuiper Belt Object
  - “Plutonian objects” of which it is the original example
- Pluto’s moon is Charon
Orbits of outer planets

- Notice Pluto is sometimes closer to Sun than Neptune

http://www.nineplanets.org/plutodyn.html
Inclination of Planetary orbits

- Notice Pluto’s large inclination to Sun’s equator
  - http://www.nineplanets.org/plutodyn.html
Kuiper Belt

- Donut shaped area containing numerous icy bodies of various sizes
- Eris is the largest discovered
- Pluto and Charon are some
- Triton, moon of Saturn, is likely one that was captured by Saturn’s gravity
- Origin of numerous comets that orbit Sun in periods less than 200 years
- A division of Trans-Neptunian Objects
Eris

- Kuiper Belt Object
- Larger than Pluto
- Discovered in 2003

http://en.wikipedia.org/wiki/Eris_(dwarf_planet)
Eris (2003 UB 313)
Orbit of Orcus (2004 DW)
Kuiper Belt Object

In red
Compare to Pluto in black

http://www.gps.caltech.edu/~chad/2004dw/
Inclination of Orbit of Orcus

- Pluto in red
- Orcus in blue
- Neptune in gray

wikipedia, Orcus-transNeptunian object, 2008-1013
Earth for scale

More Info:
http://solarsystem.nasa.gov/planets/profile.cfm/Object=KBOs&Display=OverviewLong
Orbits of Makemake (blue), Haumea (green), contrasted with the orbit of Pluto (red) and the ecliptic (grey). The perihelia (q) and the aphelia (Q) are marked with the dates of passage. The positions on April 2006 are marked with the spheres illustrating relative sizes and differences in albedo and colour.
Dwarf planets

- Large Kuiper Belt Objects
  - Pluto
  - Eris
  - Makemake
  - Haumea

- The asteroid Ceres

- Other KBOs likely to be discovered that are also dwarf planets
Ceres composition

Asteroids

Asteroid belt

Mars

Earth

Jupiter
Asteroids

Ida, Gaspra, Deimos, Phobos

• http://www.nineplanets.org/asteroids.html
Detail of Comet

- Tail of ionized gases
- Coma
- Nucleus
- Tail composed of dust
Major Impact Structures
Meteor Crater, Arizona

- [http://www.xtec.es/recursos/astronom/craters/METEOR.jpg](http://www.xtec.es/recursos/astronom/craters/METEOR.jpg)
Manicouagan, Quebec
Impact of Fragment G of Comet Shoemaker-Levy on Jupiter
The fireball is seen 12 minutes after impact at 2.34 microns. The impact A site is seen on the opposite limb of the planet.

Image at 2.34 microns with CASPIR by Peter McGregor
ANU 2.3m telescope at Siding Spring

- http://nssdc.gsfc.nasa.gov/planetary/sl9/image/sl9g_hst5.gif
Electromagnetic Spectrum

- Gamma rays
- X rays
- Ultraviolet
- Visible light
- Infrared
- Microwaves
- Television, FM radio
- Short-wave radio
- Standard AM radio
- Broadcast band
- Long radio waves

- 0.001 micrometer
- 1 micrometer
- 1000 micrometers
- 1 meter
- 1000 meters

- Short-wave radiation
- Long-wave radiation
Spectrum

Visible light

Prism

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TABLE 23.1  Colors and corresponding wavelengths.

<table>
<thead>
<tr>
<th>Color</th>
<th>Wavelength (nanometers*)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Violet</td>
<td>380–440</td>
</tr>
<tr>
<td>Blue</td>
<td>440–500</td>
</tr>
<tr>
<td>Green</td>
<td>500–560</td>
</tr>
<tr>
<td>Yellow</td>
<td>560–590</td>
</tr>
<tr>
<td>Orange</td>
<td>590–640</td>
</tr>
<tr>
<td>Red</td>
<td>640–750</td>
</tr>
</tbody>
</table>

*One nanometer is \(10^{-9}\) meter.
Continuous Spectrum

- From glowing gas under pressure
- Like the interior of Sun
Dark Line Spectrum

- White light passing through cold, low pressure gas
- Gas absorbs its elemental wavelength signature
Incandescent hot gas emits its elemental wavelength signature
3 types of spectra

A. Incandescent solid (filament) - Continuous spectrum
B. Incandescent solid (filament) - Dark-line spectrum
C. Incandescent (hot) gas - Bright-line spectrum
Sunspot Variation over time

![Graph showing annual number of sunspots from 1700 to 2000. The graph displays a periodic pattern with peaks and troughs.](https://example.com/sunspot-graph.png)

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Solar wind blows comet tails

http://www.astro.uva.nl/demo/sun/inter.htm
Solar Prominence


http://www.astro.uva.nl/demo/sun/aarde.htm
Solar Interior

- Nuclear Fusion of 4 Hydrogen to 1 Helium
- Difference in atomic mass is released as energy
- Released as photons—light particles
- Convection brings photons to photosphere
- Sun will last about another 5 billion years
Sun Structure

- **Photosphere**: most visible part—“Surface”
  - Hydrogen and helium
  - Granules, sunspots

- **Chromosphere**: lower atmosphere
  - Spicules from granules of photosphere
  - Prominences

- **Corona**: outer atmosphere
  - Ionized gases
  - Solar wind

- **Solar flares**
  - Create auroras
  - Associated with sunspots
Now: hot core + warm surface; small size.

Future: very hot core + cool surface. Large size but less mass; very bright.
Red Giant Betelgeuse

HST view of Betelgeuse in the ultraviolet. Even though Betelgeuse is very large, its distance is too great to resolve details smaller than about 1/4th of its diameter (small gray circle).
http://www.astro.uva.nl/demo/sun/leven.htm
Main Sequence to Red Giant to White Dwarf

http://imagine.gsfc.nasa.gov/docs/science/know_l2/dwarfs.html
Lagoon Nebula