The Formation and Contents
of our
Our Solar System

Seminar Outline

Formation of the Solar System

The Sun

The Terrestrial (Rocky) Planets
- Mercury
- Venus
- Earth
- Mars

The Asteroid Belt

The Gas Giants
- Jupiter
- Saturn

The Ice Giants
- Uranus
- Neptune

The Kuiper Belt / Scattered Disk

The Oort Cloud

Our Moon

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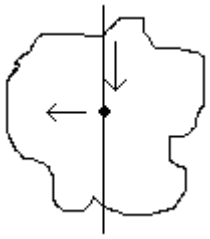
Formation of the Solar System

Pre-Solar Nebula

- Began as a dense, irregularly-shaped giant molecular cloud of dust and gas.
  - Cloud was rotating, causing gas to form "disk."
  - Gravitational attraction begins in "center" of rotating disk.
  - As cloud grew smaller, rotation speeds increased.

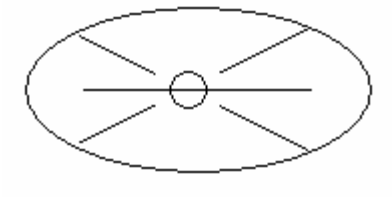


Birth of the Sun

  - Gravitational collapse, fusion starts, the Sun "lights up".
  - Initially, the Sun has a high rotation rate, and high-energy solar wind (charged particles). This wind bleeds off rotational speed and slows it down.
- Solar wind from the Sun pushes matter and (especially) gas outward.

Protoplanetary Disk

- Stuff left over from the formation of the Sun – "debris disk".
- Gas and dust condensed into "planetesimals" (1-100km in size). Growths rate a few cm per year over millions of years.



  - Inner solar system (<4AU) – too hot for water. Mostly made of metals with high melting point (iron, nickel, aluminum, silicates, etc). Gaseous material blown out through solar wind.
  - Outer solar system – ices form, making chunks sticky. Much more gaseous because more gas there.
- Some protoplanets combine (collide); others are tossed out of the disk.

Completing the Process

- Multiple Moon-to-Mars-sized objects in the inner Solar System collided and combined.
- Then-elliptical orbits were made circular by drag from remaining debris.

The Sun

- Class "G" star.
- Lit up 5 billion years ago, and will live 5 billion years more.
- Surface temperature is 6000°K; core temperature is 15M°K.

Mercury

- Very close to the Sun. Only visible at most 1hr before/after sunrise/sunset.
- One Mercury year is 1-1/2 Mercury days.
- Cratered surface, very little atmosphere.
- Surface temperature varies from -170℃ to 430℃.

- Iron-rich core, probably molten, 1800km radius.
- Thin mantle (600km), thin crust (≅ 200km).

Venus

- Evening/morning star – stays close to the Sun.
- "Greenhouse effect on steroids" – atmosphere is 96% CO_2.
- 900°F every day, all the time, everywhere. Melts lead.
- Covered in clouds (sulfuric acid), which is why it's so bright.
- Atmospheric pressure on the surface 90X that of Earth.
- Surface has mountains, valleys, plains and craters.
- No magnetic field.

Earth

Mars

- Red because of rust – Mars has lots of iron compounds.
- Polar ice caps – CO_2 on surface, H_2O underneath.
- Massive dust storms – can cover the planet.
- Volcano Olympus Mons is the size of Arizona.
- The canyon Valles Marineris – as wide as the U.S., 5 miles deep.

The Asteroid Belt

- Likely a planet that failed because of Jupiter's gravitational influence.
- Basically "rubble piles".
- Only 7 larger than 300km (186 miles) in diameter.
- More than half the entire mass is in only 4 objects.
- Ceres, the largest, is a "minor planet", 950km in diameter.

Jupiter

- 2.5X the mass of all other planets *combined*.
- "Vacuum cleaner"
- Rapid rotation gives Jupiter an oblate shape.
- 80% hydrogen, 14% helium.
- No surface – just transparent/opaque gas.
- Color due to ammonia and sulfates.
- Has a thin ring.
- 4 large ("Galilean") moons, 3 bigger than our Moon, 1 bigger than Mercury.
- Io (closest), very volcanic due to tidal pressure of elliptic orbit.
- Europa (smallest) probably has a 10-50km crust of water ice, with a slushy water ocean below.
- Ganymede (largest) is mostly craters 2-4B years old.
- Callisto (farthest) has a cratered surface, mostly hard old ice. The crater Valhalla was a massive meteor strike, with shock waves on the surface still present.

Saturn

- Low density 0.7 g/cm³ and would float in water.
- No surface.
- Winds exceed 1100 mph (1800kph), lightning 1000X that on Earth.
- Rings are only 20m thick. Chunks of ice and rock, probably a disintegrated moon.
- Apparent visible rings are from 2-4 (depending on tilt), with gaps (Cassini, Enke divisions). They should have dissipated by now, unknown why not.
- Largest moon Titan, thick nitrogen atmosphere with lightning which creates hydrocarbons. Probable methane lakes on surface. Greenhouse warming. Huygens probe showed what appear to be shorelines and river channels.
- Moon Enceladus has gas plumes that contain water, possible liquid water below surface, heated by tidal forces.

Uranus

- Rocky core, then ice, then molecular hydrogen (H_2).
- Atmospheric clouds of water and methane.
- Winds can reach over 500mph.
- Axis tipped 98°, magnetic field tipped 60° from axis and off-center, these probably due to a collision.
- 27 known moons, largest Miranda.

Neptune

- In early solar system, orbit inside Uranus.
- First seen by Galileo, but he didn't recognize it as a planet.
- Thin, clumpy rings.
- Icy clouds of methane, storms, winds over 1200 mph.
- Primary moon Titan orbits backwards, probably captured. Past volcanoes.

The Kuiper Belt / Scattered Disk

- Kuiper Belt beyond Neptune, Scattered Disk farther out.
- Pluto first object found (1930),
- 20X wider than the Asteroid Belt, and 200X more massive.
- The Scattered Disk is the source of some long-period comets.

The Oort Cloud

- Nearly 1 light-year away – 1/4 the distance to the closest star (besides the Sun).
- Generally defines the outer edge of the Solar System.
- Inner cloud is in the orbital plane (generally), but the outer cloud is spherical.
- Source of many long-period comets.

Our Moon

- 1/4 the Earth's diameter, 1/6 its gravity.

- Always the same face toward the Earth. Tidal forces caused the Moon to bleed off rotational energy.
- Heavily cratered, most occurring more than 3 billion years ago.
- Probably formed by a collision with Mars-sized Theia.
- Earth's stable axis is due to the Moon's influence.

Credits

- **Prof. Alex Filippenko**, UC Berkeley, and his Teaching Company DVD series "Understanding the Universe: An Introduction to Astronomy"
- **Prof. Neil deGrasse Tyson**, Director of the Hayden Planetarium, and his Teaching Company DVD series "My Favorite Universe"
- **Wikipedia.com**, for more reference material than can be listed.

Reference Tables

Table 1 – Absolute Data Values

	From Sun AU	Orbital Incl. °	Axis Tilt °	Satel-lites	Absolute Mass kg	Density g/cm ³	Surface Temp ℉ Min	Max
Mercury	0.4	7.0	2.2	0	3.30×10^{23}	5.4	-316	800
Venus	0.7	3.4	177.3	0	4.87×10^{24}	5.2	842	896
Earth	1.0	7.3	23.4	1	5.97×10^{24}	5.5	-128	136
Mars	1.5	1.9	25.2	2	6.42×10^{23}	3.9	-125	23
Asteroid Belt	2 - 4	< 30						
Jupiter	5.2	1.3	3.1	63	1.90×10^{27}	1.3	-258	-163
Saturn	9.5	2.5	26.7	60-200	5.68×10^{26}	0.7	-308	-218
Uranus	19.6	0.8	97.8	27	8.68×10^{25}	1.3	-371	-323
Neptune	30.0	1.8	28.3	13	1.02×10^{26}	1.6	-361	-330
Kuiper Belt	30-55	< 30						
Oort Cloud	50,000							
Pluto	39.0	17.1	119.2	3	1.30×10^{22}	2.0	-400	-361
Eris	67.7	44.0		1	1.67×10^{22}		-406	-361

Table 2 – Relative to Earth

	Rotation (Earth Time)	Year (Earth Units)	x Earth Mass	x Earth Gravity	x Earth Radius	x Earth Surface Area	x Earth Volume
Mercury	58.6d	88d	0.055	0.377	0.38	0.108	0.054
Venus	243d	225d	0.815	0.904	0.95	0.902	0.857
Earth	24h	365d	1.000	1.000	1.00	1.000	1.000
Mars	24.6h	687d	0.107	0.377	0.53	0.284	0.151
Asteroid Belt							
Jupiter	9.9h	12y	318.72	2.535	11	122	1321
Saturn	10.5h	30y	95.15	1.064	9	84	764
Uranus	17.25h	84y	14.53	0.904	4.00	16	63
Neptune	16h	165y	17.15	1.140	3.80	15	58
Kuiper Belt							
Oort Cloud							
Pluto		250y	0.002		0.19	0.033	0.006
Eris		557y					