Astronomy 210

Section 1– MWF 1500-1550

134 Astronomy Building

This Class (Lecture 25):

Debris

2nd Hour Exam in 2 weeks!

Next Class:

Birth of the Solar System

Outline

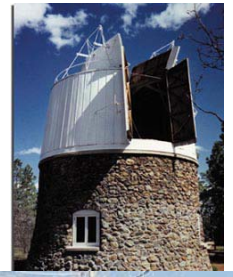
- Pluto– Planet or Largest Kuiper Belt Object?
- Life in our Solar System?
- Comets– You Dirty Iceball
- Asteroids– Spacecraft hazard?
- Meteroids– watch your head

No lunar landscape, no Martian desert can compare to the terrifying solitude of Pluto.

Patrick Moore and David A. Hardy
Challenge of the Stars (1972)

The Discovery of Pluto

- Astronomers calculated that there must be another body perturbing the orbits of Uranus and Neptune
- Percival Lowell calculated that "Planet X" must have a mass 7 times that of the Earth
- Clyde Tombaugh was hired to look for it
- In 1930, he found a planet
- In honor of Lowell, it was named Pluto (P.L.)



Clyde Tombaugh (1906 – 1997)

Fortunate Mistake

- It turned out that Pluto was not Lowell's "Planet X"
- Pluto has only 0.2% the mass of Earth, not 7 times the mass
- Too small to influence Uranus & Neptune's orbits
- Modern observations and calculations show no "Planet X" needed to predict their orbits

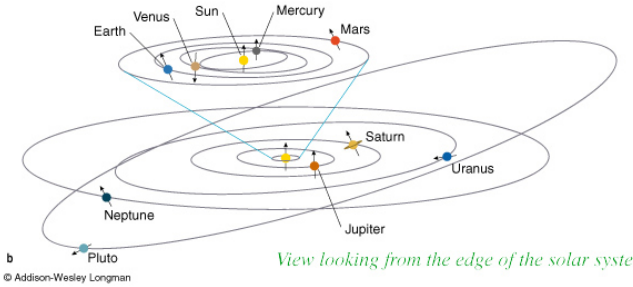
Earth - Pluto Comparison

Radius	0.19 Earth
Surface gravity	0.04 Earth
Mass	0.002 Earth
Average Distance from Sun	39.5 AU
Tilt of Rotation Axis	122 degrees
Orbit eccentricity	0.249
Year	248.6 Earth years
Solar day	6.39 Earth days (backwards)

How Does Pluto Measure Up?

Pluto's Orbit

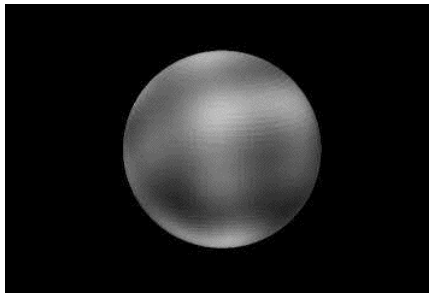
- Highly eccentric
- Highly inclined with respect to the other planets



View looking from the edge of the solar system

- From 1979-1999, Pluto was closer to the Sun than Neptune!
- Never will collide because of 3:2 resonance with Neptune

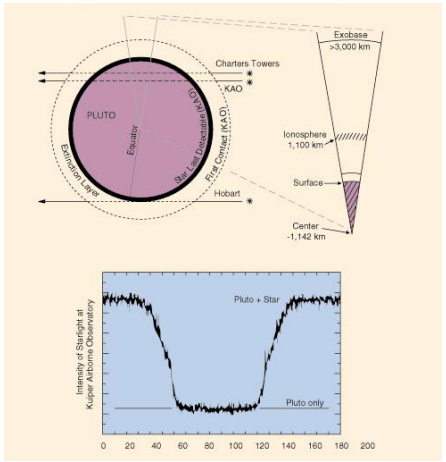
Pluto's Surface



- No spacecraft has ever visited Pluto
- Our best view of Pluto comes from Hubble
- Covered in nitrogen, methane, and carbon monoxide ice
- Current surface temperature - about 40 K (-230 C, -390 F)!

Pluto's Atmosphere

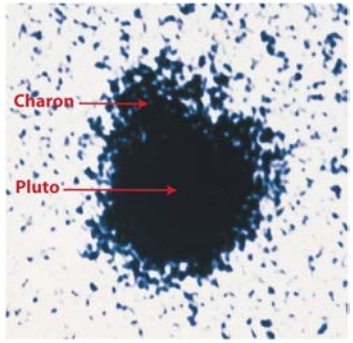
- Observed when Pluto occults background stars
- Consists mostly of nitrogen (90%) and carbon monoxide
  - Similar to Triton
- As Pluto gets farther from the Sun, atmosphere may "freeze out" around 2020



Pluto's Moon, Charon

- In 1977, Pluto was found to have a moon
- Largest moon relative to host planet
  - About 1200 km across
  - About 12% Pluto's mass
- Surface covered in water ice
- Both rotate synchronously
  - Pluto and Charon each keep the same face pointed towards the other

Pluto's Moon, Charon



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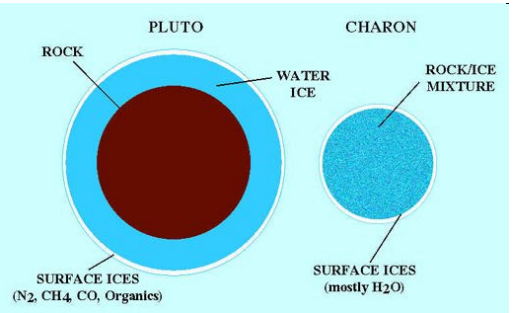
Interiors & Composition

- Pluto is similar in density and size to Neptune's moon Triton
- Likely a similar composition, a rock/ice mix (60/40)



- Rocky core, surrounded by water-ice mantle
- Since it is smaller, Charon is probably not differentiated

New Horizons

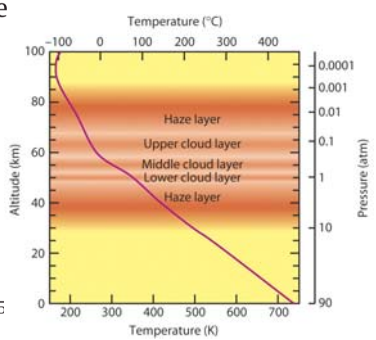
Currently planned for launch in 2006
http://pluto.jhuapl.edu

Life in our Solar System Conclusions

- ***No conclusive evidence exists for life in our solar system besides on Earth***
- But, possibilities exist for life
  - Venus may have life in the clouds that migrated when possible oceans boiled away.

Life on Venus?

- Surface is far too hot
  - If lead is liquid, think of what heat would do to complex organic polymers
  - No cooler polar regions exist
    - Heat is uniform!
    - But, high in the clouds it should be cooler?!
  - Maybe life can still exist in the clouds?



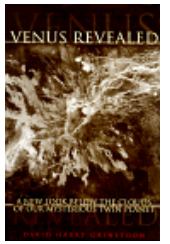
Venus Chemical Disequilibrium

- At 50 km up, the temperature is not too hot and the pressure is 1 atmosphere.
- High clouds in the atmosphere contain chemicals that hint at the presence of some kind of biological activity.
- Hydrogen sulfide and sulfur dioxide - two gases that react with each other– exists in the clouds.
- Something is probably producing them.
- Hardly any carbon monoxide. So something is perhaps removing the gas.

http://www.manson-valley.de/fotogalerie/manson/images/acss/acss_32.jpg

Life on Venus?

- One possibility is that microbes living in the clouds could be combining sulfur dioxide with carbon monoxide and possibly hydrogen sulphide or carbonyl sulphide in a metabolism similar to that of some early terrestrial microorganisms.
- Given that the temperature on Venus was once much cooler, there may once have been oceans on the planet. Life could have started there and retreated to stable niches once the runaway greenhouse effect began.
- Maybe a mission to scoop up some atmosphere?



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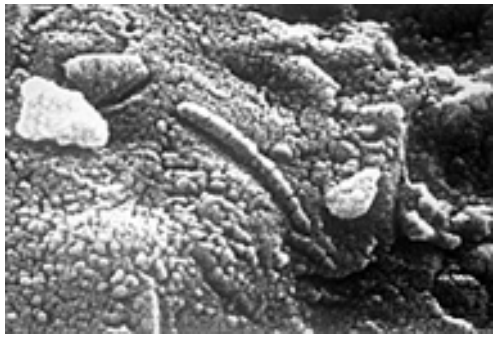
  - Mars may have some microbial history linked to water, and perhaps some subsurface life.

Martian Microbes?

- Microscopic shapes that resemble living and fossil bacteria on Earth– nanobacteria. Perhaps we have meet our first ET?
- With new evidence of once liquid water, we can further speculate what happened when the planet's atmosphere disappeared, perhaps life moved to the subsurface. Going underground.



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  - Jupiter's atmosphere is rich in pre-biotic molecules.

Floating Life

- Maybe similar to whales– mixture between jellyfish and birds?
- Big bags of hyrdrogen gas feeding on smaller microbes.
- Of course, this is all speculative, and there is no way to detect such life.

http://www.epilogue.net/cgi/database/art/list.pl?gallery=3126

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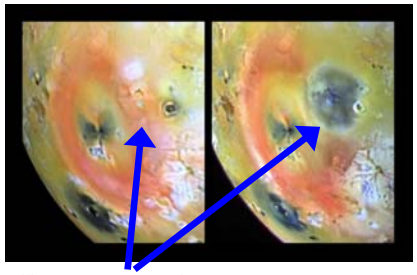
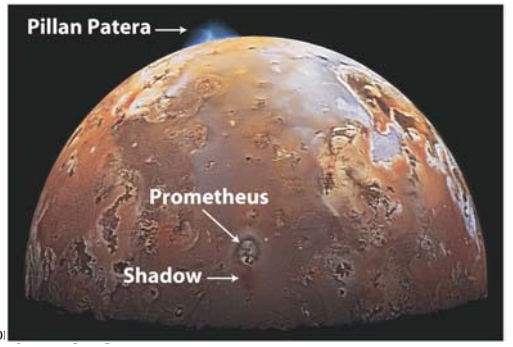
  - Europa's sub-crustal oceans may harbor life, even fish-like life.

Io

- Innermost Galilean moon – the "pizza moon"
- The most volcanically active body in the solar system.
- Voyager 1 discovered presence of volcanoes
- Internal heating by Jupiter's tides
- Atmospheric gases ripped off by Jupiter's magnetic field – ion torus

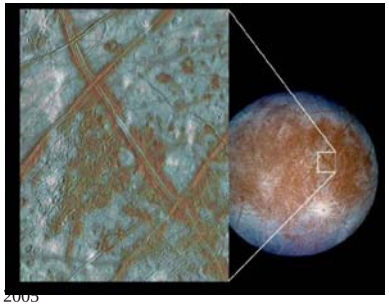


Pillan Patera eruption
Before & after



Europa

- Perhaps like Io, Europa is also heated from within?
- Likely that there is liquid water below the ice surface.
- Life could exist below the surface ice below the surface, around hydrothermal vents.
- Early life on Earth, may have formed around such vents.
- We don't how thick the ice is yet.
- Future missions, will have to employ smash and dive spacecraft.



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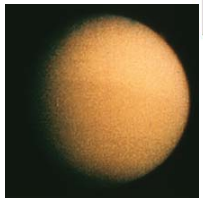
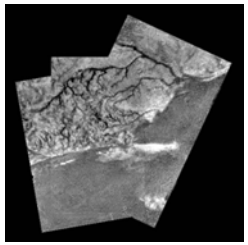
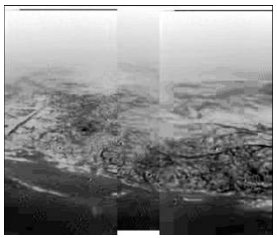
  - Europa's sub-crustal oceans may harbor life, even fish-like life.
  - Titan is very interesting
    - Thick atmosphere
    - Reducing chemistry

Titan

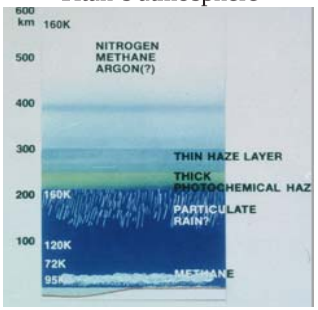
- Liquid/ice hydrocarbons?
- Organic compounds – life?
  - Probably not – too cold: 95 K
  - May be a "deep freeze" of the chemical composition of ancient Earth
- Could there be a "fish" swimming in liquid methane?







Titan's atmosphere



No Intelligent Life

- We might find evidence of some sort of life in our Solar System in the next decade, but very unlikely to find complexity needed for intelligent and communicative life.
- Apparently in our system, Earth's conditions are necessary.
- Other planets may have microbial forms of life, and maybe complex fish-like organisms, but we don't expect communicative beings.

How to search for life?

- How do we search for life in our Solar System and beyond?
- What test will indicate life exclusively?
- Is is clear that future missions need to land as near as possible to sites of subsurface water or other solvents.
- What if the life is still in the protolife stage? Can we detect that?
- The boundary between chemical and biological processes is difficult to distinguish.

Decision Trees– Search for Life

- Wait for it to come to us via meteorites or comets.
- Robotic one-way investigations– Mars rovers.
- Fetch and return with samples.

http://www.ibiblio.org/wm/paint/auth/friedrich/tree.jpg

Problems

- In the last 2 cases, we have the problem of contamination by Earth life.
- Organisms can live in Mars-like conditions on Earth.
- If some Earth life survives the space journey, it could colonize Mars, possibly destroy any Martian life. Think of Kudzu.
- Current missions must be sterilized.

http://www.hope.edu/academic/biology/faculty/evans/images/Angiosperms/CoreEudicots/EurosidsI/Fabaceae/Kudzu.JPG

Biomarkers: How to look for extrasolar life.

- We need to decide how to search for biomarkers or chemical signatures of life.
- On Earth, methane and oxygen are indicators. They normally react. Something is keeping it out of equilibrium. Sort of like Venus disequilibrium.
- The Galileo spacecraft on its way out to Jupiter, turned and looked at the Earth.
- Did it detect life?

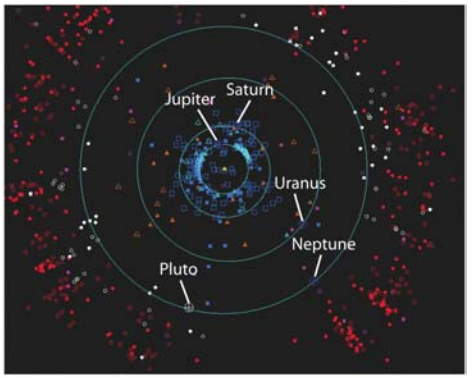
Biomarkers: Looking at Earth.

- Strong "red edge" from reflected light. Absorption from photosynthesis.
- Strong O_2. Keeping oxygen rich atmosphere requires some process. It should slowly combine with rocks.
- Strong methane. Should oxidize. Replenished by life.
- Strange radio emissions that could be intelligent life.
- Recently, researchers have looked at the Earthshine from the moon.
- They agree with Galileo result. There is life on Earth.
  - Water
  - Oxygen
  - Tentative detection of "red edge"

http://epod.usra.edu/archive/epodviewer.php3?oid=56256

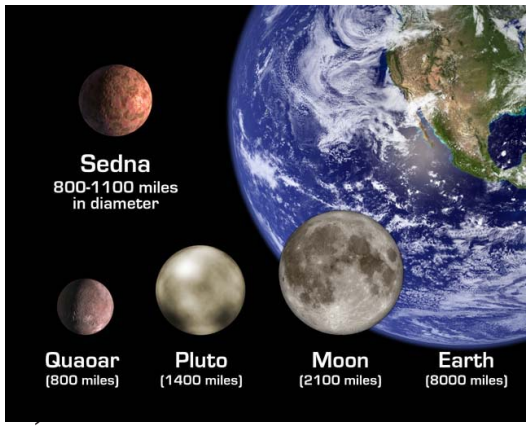
Beyond Pluto – The Kuiper Belt

- A "reservoir" of icy bodies beyond Pluto
- Proposed to explain short-period comets
- The first Kuiper Belt Object (KBO) was detected in 1992
- Typical sizes 10-50 km, very faint
  - Small ones are potential comets
  - A few are large, hundreds of km across



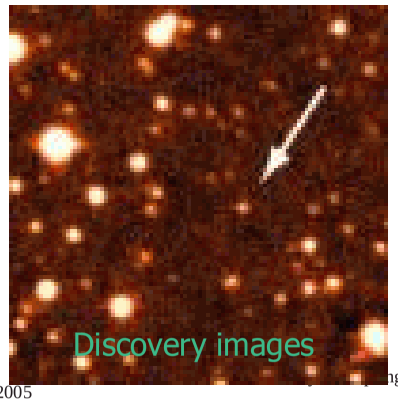
Quaoar & Sedna

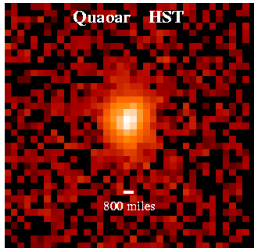
- Currently the largest known KBOs
- Probably similar in composition to Charon
- Surface temperatures around 30 K (-240

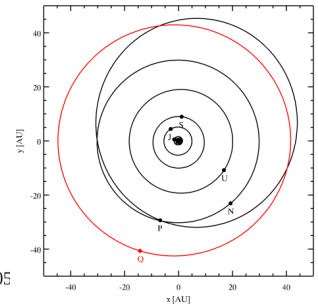


Quaoar

- Orbital distance ~ 42 AU
- About 50% the diameter of Pluto

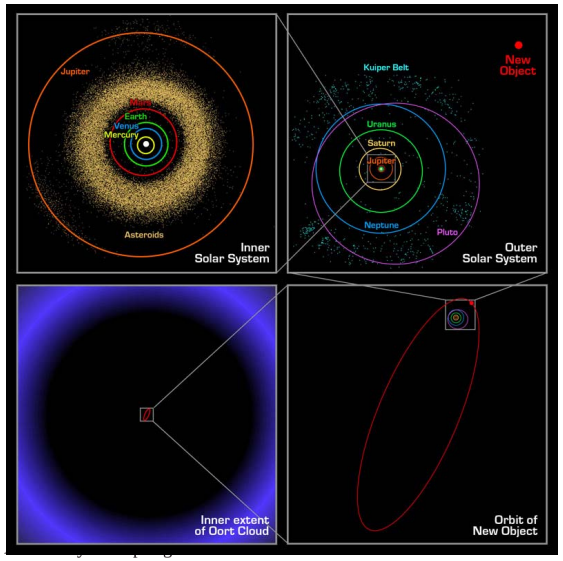






Sedna

- About 75% the diameter of Pluto
- Currently at 67 AU from the Sun
- Orbit takes it over 900 AU away
- 10,500 yr orbit

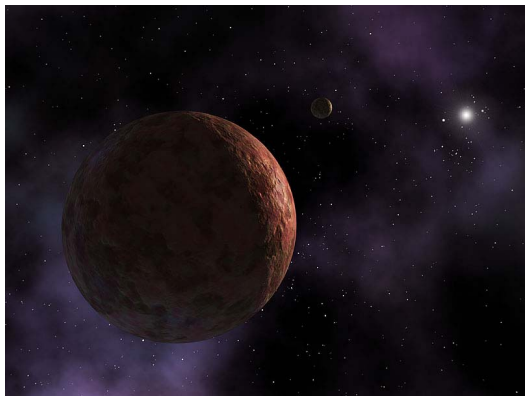


Pluto, Planet or KBO?

- Planet?
  - Odd planet: all other outer planets are giants
  - **Very** eccentric orbit
  - Orbit highly tilted with respect to the other planets
- Kuiper Belt Object?
  - Larger than other KBOs (but close in size to Quaoar & Sedna)
  - Has an atmosphere (like Triton)
    - Because of size & closeness to the Sun
  - Typical KBO composition (icy-rock mix)
  - Orbit typical for a KBO
    - Many KBOs are also in resonance with Neptune

Planet? Undefined!

- We have **no** definition of a planet!
  - Its like art: *We know one when we see it*
- If Pluto is a planet, why not Sedna or Quaoar?



Ways of Defining a Planet

1. Historical
   - Just the original nine!
2. Historical Plus
   - Anything bigger than Pluto
   - …and not something's moon!
3. Gravitationally Round
   - Big enough that its gravity makes it round
4. Population Classification
   - Isolated bodies vs. members of large populations

Class Question

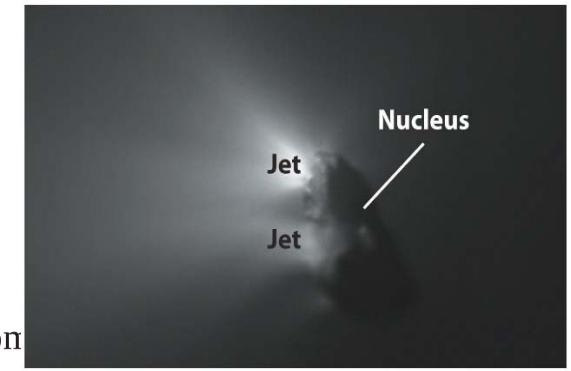
Pluto. Is it a planet, or is it a Kuiper Belt Object? How do you think Pluto should be classified? Discuss this with your classmates and write down your group's conclusion.

Comets

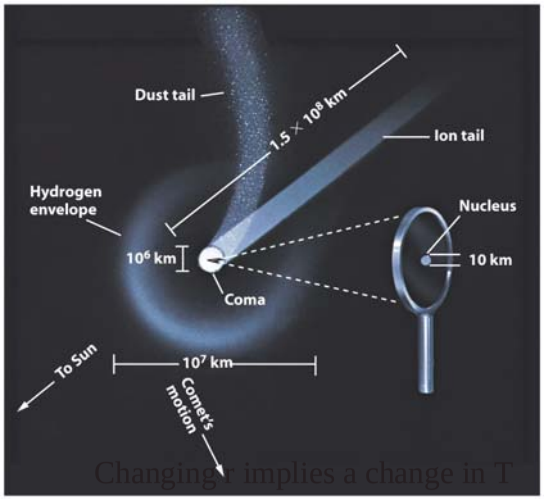
- Apparitions that appear like ghostly fireballs frozen in the sky
- In ancient times, the appearance of a comet was often considered a harbinger of doom
- Ironically, life on Earth may have been impossible without them
- Also comets and meteoroids are the oldest original solar system material! Left over building materials.

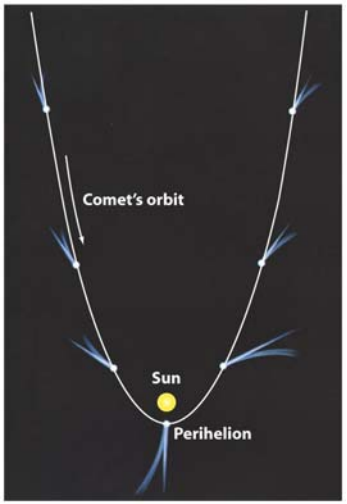
What is a Comet?

- Dirty icebergs in space
  - 10-50 km across
- Composed mostly of water ice (but also CO_2 and CH_4), with some solid dust, rock & metal
  - Dark surfaces!
- Very elliptical orbits $\Rightarrow$ varying r implies varying T



Comets

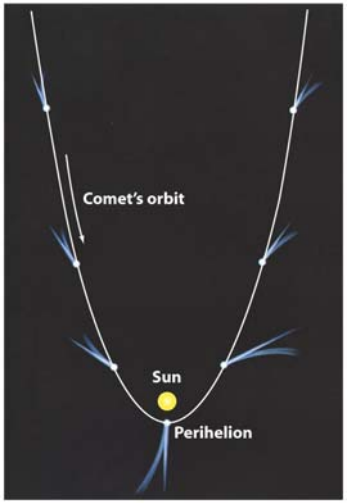




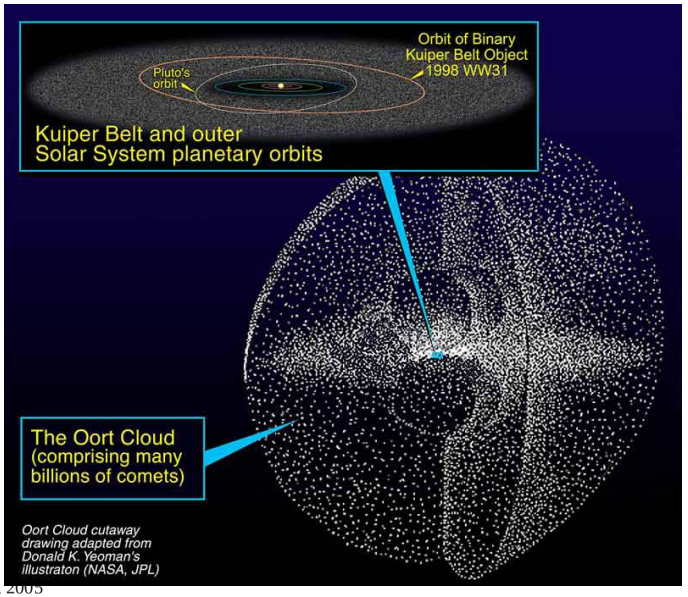
Changing r implies a change in T

Comets

- Coma
  - Sunlight evaporates comet surface
  - Forms a cloud of gas & dust around the nucleus
- Tails
  - Gas is ionized by the sun's UV light
  - Gas & dust pushed away by the solar wind



Where Do Comets Lurk?

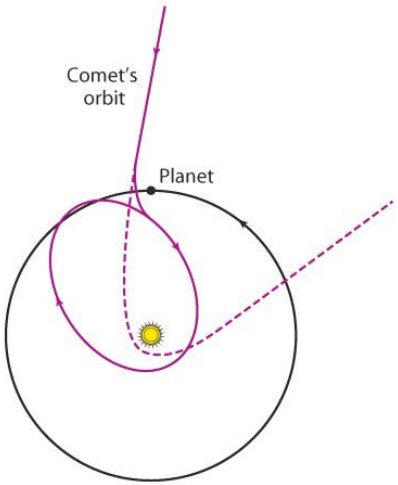


Where Do Comets Lurk?

- The vast majority live far out in the Solar System, beyond the planets
- Short period comets: Kuiper Belt (aka trans-Neptunian)
  - Orbital periods of hundreds of years
  - Around and beyond the orbit of Pluto (30-500 AU), probably formed there.
  - Now about 240ish the size of 10% Pluto
- Long-period comets: Oort Cloud
  - Edge of Sun's gravitational influence
  - Out to 50,000 AU
  - Periods > 10^5 yrs
  - Probably did not form there. Ejected bodies by Jovians.

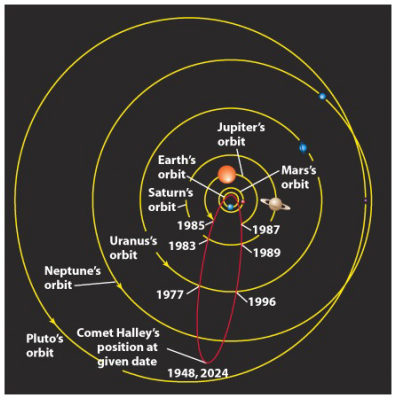
Falling Into the Solar System

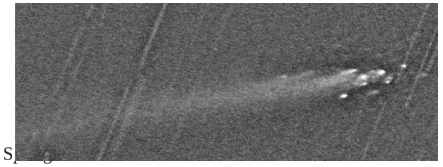
- Occasionally, comet orbits get "perturbed" by passing stars
- They fall into the inner Solar System on highly elliptical orbits
- Interactions with planets can shorten their orbits



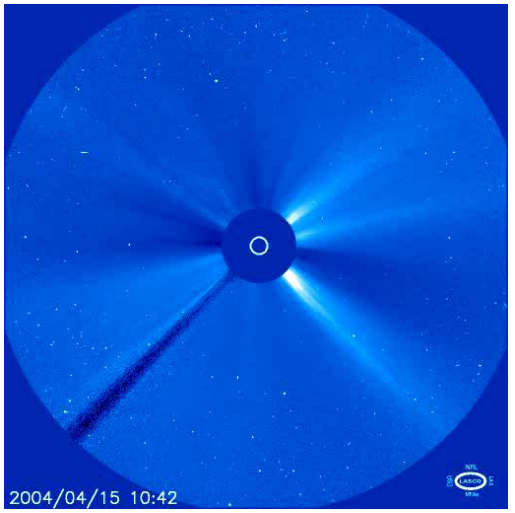
Life & Death of a Comet

- Even comets on shortened orbits live mostly in the outer solar system
- Every orbit, they lose 1% of their masses to solar evaporation
  - Halley's Comet will only last about 5600 more years
- When they become too small, they break apart

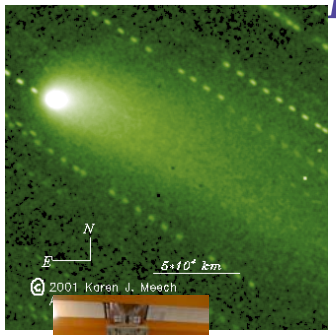




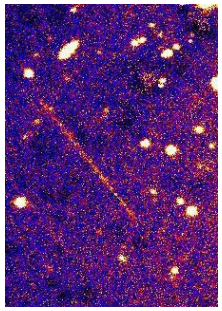
Life & Death of a Comet



Deep Impact



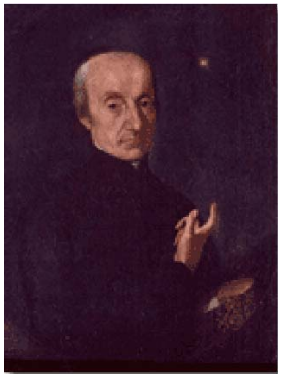
Deep Impact



http://realserver1.jpl.nasa.gov:8080/ramgen/Video-NASA1st-Pesrson-Yeomans-AVC2005-016.rm

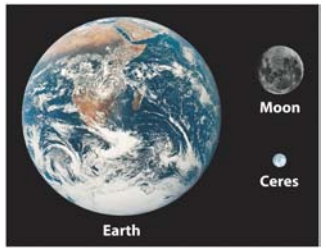
Discovery of the Asteroids

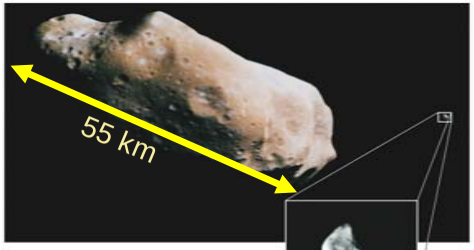
- In 1801, Giuseppe Piazzi noticed an uncharted "star" that shifted position among the stars over several nights
- Could it be another planet?
  - Its orbit was between Mars and Jupiter
  - Very dim, so it must be small
  - Too small to be a planet
- It was an *asteroid*, a "minor planet"



Asteroids

- Small sizes
  - Largest – Ceres: 940 km across
  - Only 3 more than 300 km
  - About 240 bigger than 100 km
  - Millions under 1 km
- Composition
  - Rocks (silicates) and iron/nickel

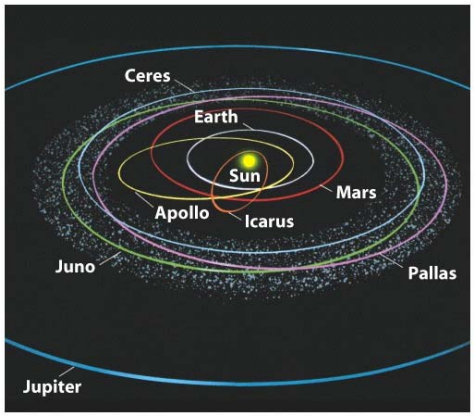




Ida and Dactyl from Galileo

The Asteroid Belt

- Most asteroids are found between 2 to 3.5 AU
  - Between Mars & Jupiter
  - Region is called the **Asteroid Belt**
  - Nearly circular orbits



The possibility of successfully navigating an asteroid field…

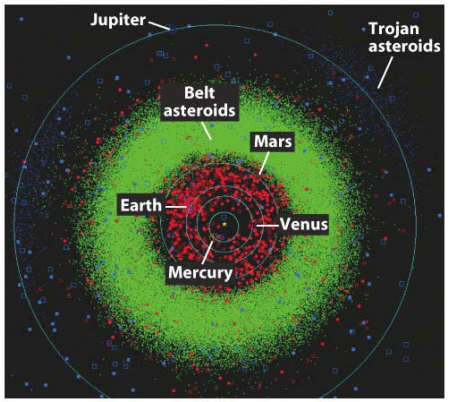
- Actually, NASA has sent many space probes into and through the Asteroid Belt
- Unlike in Star Wars, the Asteroid Belt is not that crowded
- Average separation between sizable asteroids is 10 million km!

Destroyed… by the Empire

- Are the asteroids a destroyed planet? **No**
  - Combined, the asteroids have a mass about 0.1% that of the Earth
  - Less than 10% that of our Moon
- The asteroids might be a *failed* planet
  - Jupiter's gravity kept the asteroids from coalescing into a planet
  - Jupiter probably ejected many asteroids from the Solar System

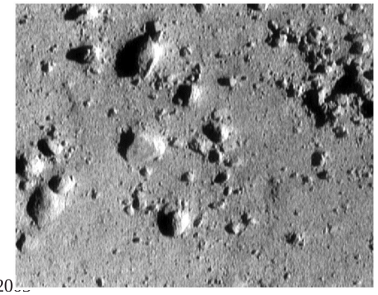
Apollos and Trojans

- Some asteroids are on orbits that cross Earth's orbit
  - Called *Apollo asteroids*
  - At least 1690 are known
  - In 1972, one skipped off the Earth's atmosphere
- Other asteroids share Jupiter's orbit!
  - Called *Trojan asteroids*
  - Lead and trail Jupiter around the Sun



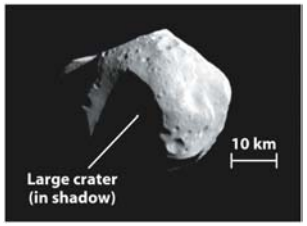
Landing on Eros

- In 2001, NASA landed a spacecraft on the asteroid Eros
- Heavily cratered surface
- Boulders buried in the regolith
- Ancient – 4.6 billion years old



Asteroids - Early Solar System Leftovers

- The asteroids were too small to have much internal heat
  - No differentiation
  - No geologic activity
  - The same as when they formed 4.6 billion years ago
- Fossils of the early solar system!



Meteors

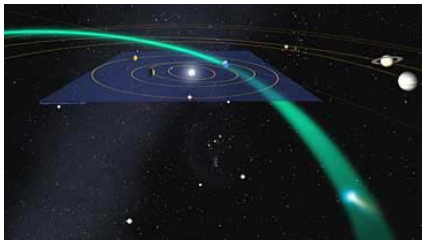
- When you see a "shooting star", that is a **meteor**
  - A piece of solar system debris (a **meteoroid**) interacting with our atmosphere
- Most "burn up" or disintegrate in the upper atmosphere, but some do survive fall
  - These are **meteorites**
- Composition: rock, some metals

Meteor Showers

- Meteors hit Earth all the time
- In the early morning, you can typically see about 3 per hour
- Several times a year, the rate increases
  - Maybe more than a meteor per minute
  - Called **meteor showers**
- Seem to originate from a single point in the sky

Meteor Showers

- When a comet enters the inner Solar System, it leaves a trail of dust
- When Earth passes through this dust, we get a meteor shower
- Meteor showers don't typically produce meteorites
  - Its all dust, not rocks



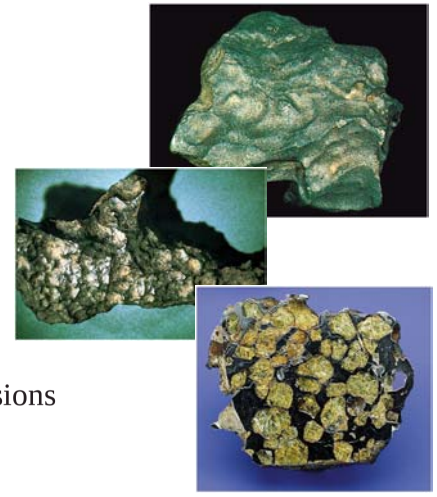
Prominent Yearly Meteor Showers

Shower	Date of maximum intensity	Typical hourly rate	Constellation
Quadrantids	January 3	40	Boötes
Lyrids	April 22	15	Lyra
Eta Aquarids	May 4	20	Aquarius
Delta Aquarids	July 30	20	Aquarius
Perseids	August 12	80	Perseus
Orionids	October 21	20	Orion
Taurids	November 4	15	Taurus
Leonids	November 16	15	Leo Major
Geminids	December 13	50	Gemini
Ursids	December 22	15	Ursa Minor

Peekskill Fireball (October 9, 1992)

Types of Meteorites

- 94% of meteorites are **stony**
  - Made of silicates, hard to distinguish from Earth rocks
- 5% are **irons**
  - Iron-nickel crystals
- 1% **stony-irons**
  - Silicates with iron inclusions



Meteorites are Ancient

- Meteorites are the oldest objects in the Solar System
- Remnants of the Solar System's formation
- The oldest are carbonaceous chondrites (a type of stone)
  - Abundant in carbon and water
  - Contain amino acids - building blocks of life!
  - 4.56 billion years old
- Some have diamonds produced by interstellar shock waves!

Carbonaceous chondrite

Meteorite Observing

- The UofI has a small meteorite collection in the Natural History Building
- Activities:
  - Count the numbers of each type of meteorite, compare to the fractions that exist in space
  - Why do we know when most of the stony meteorites fell, but not the iron ones?
  - Visit a web-site, learn about how to identify meteorites
- Extra Credit Report: Due April 8th, worth 1/3 a homework.