

TODAY

- **ASTEROIDS, METEORITES, COMETS**
- **KUIPER BELT; DWARF PLANETS**
- **IMPACTS**

EVENTS

- **HOMEWORK 3 DUE IN ONE WEEK**
- **EXAM RESULTS:**
 - **MEAN: 76, MEDIAN 78**

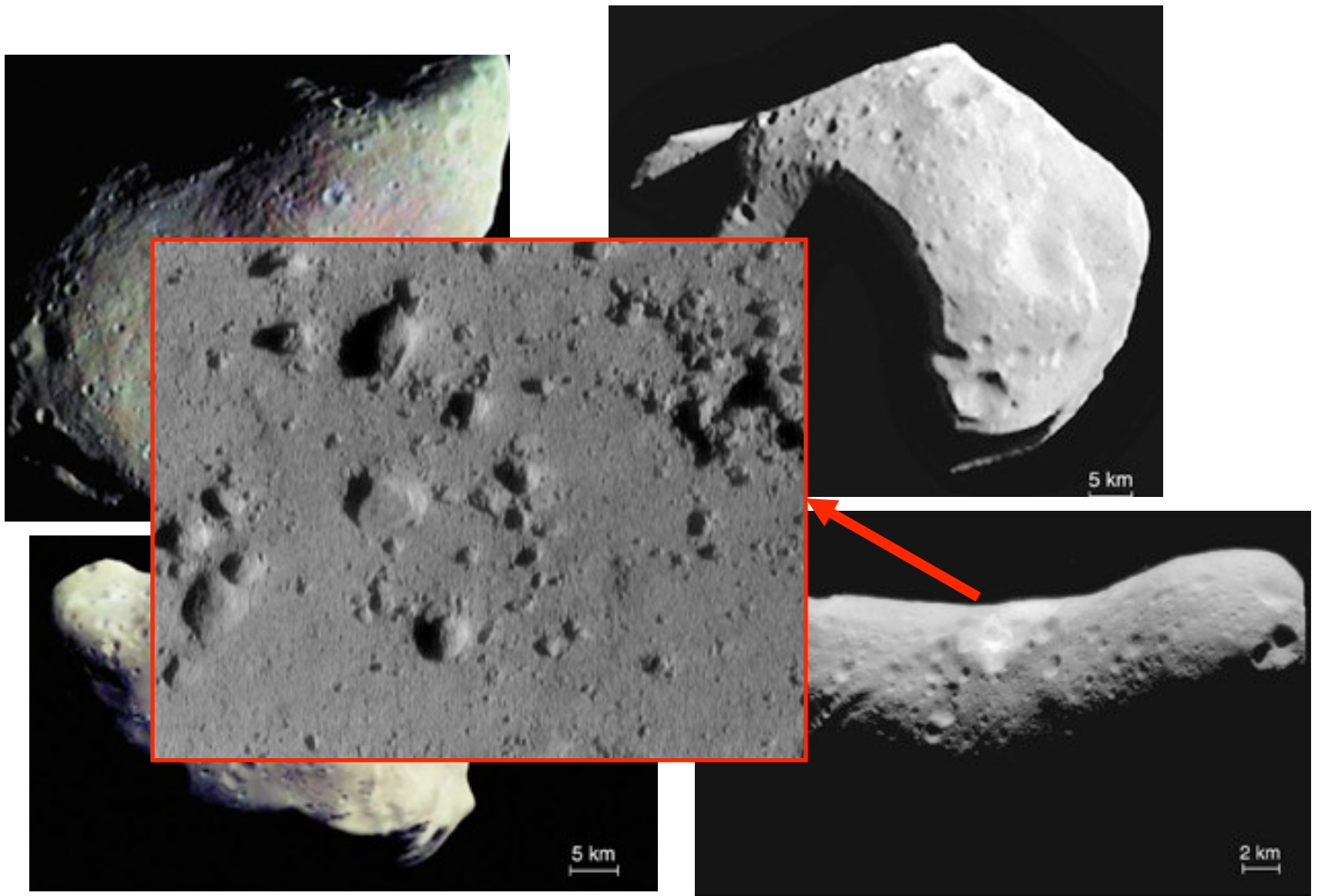
Asteroids



Asteroid Facts

- Asteroids are rocky leftovers of planet formation.
- “Rubble Piles”
 - loose collection of rocks; not one big one.
- The largest is Ceres, diameter $\sim 1,000$ km.
- There are 150,000 in catalogs, and probably over a million with diameter >1 km.
- Small asteroids are more common than large asteroids.
- All the asteroids in the solar system wouldn't add up to even a small terrestrial planet.

Lots of small bodies, but not much mass.



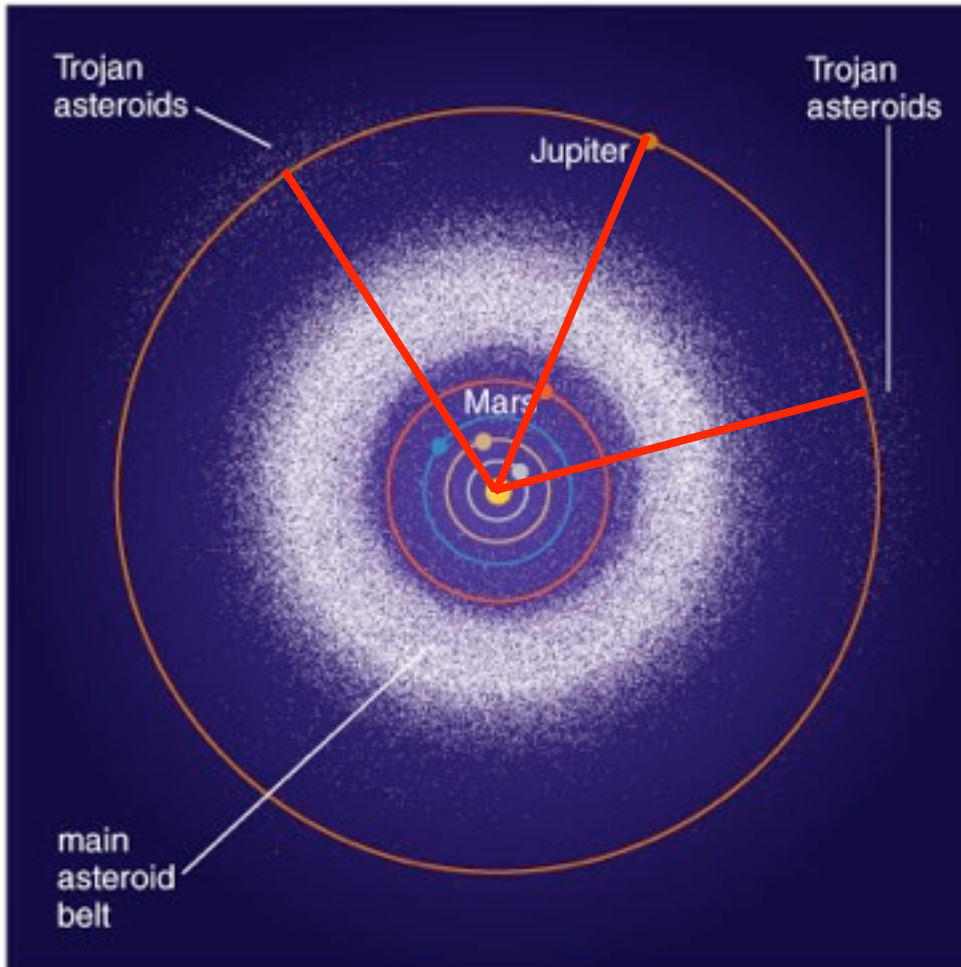
Asteroids are cratered and not round.

Asteroids with Moons



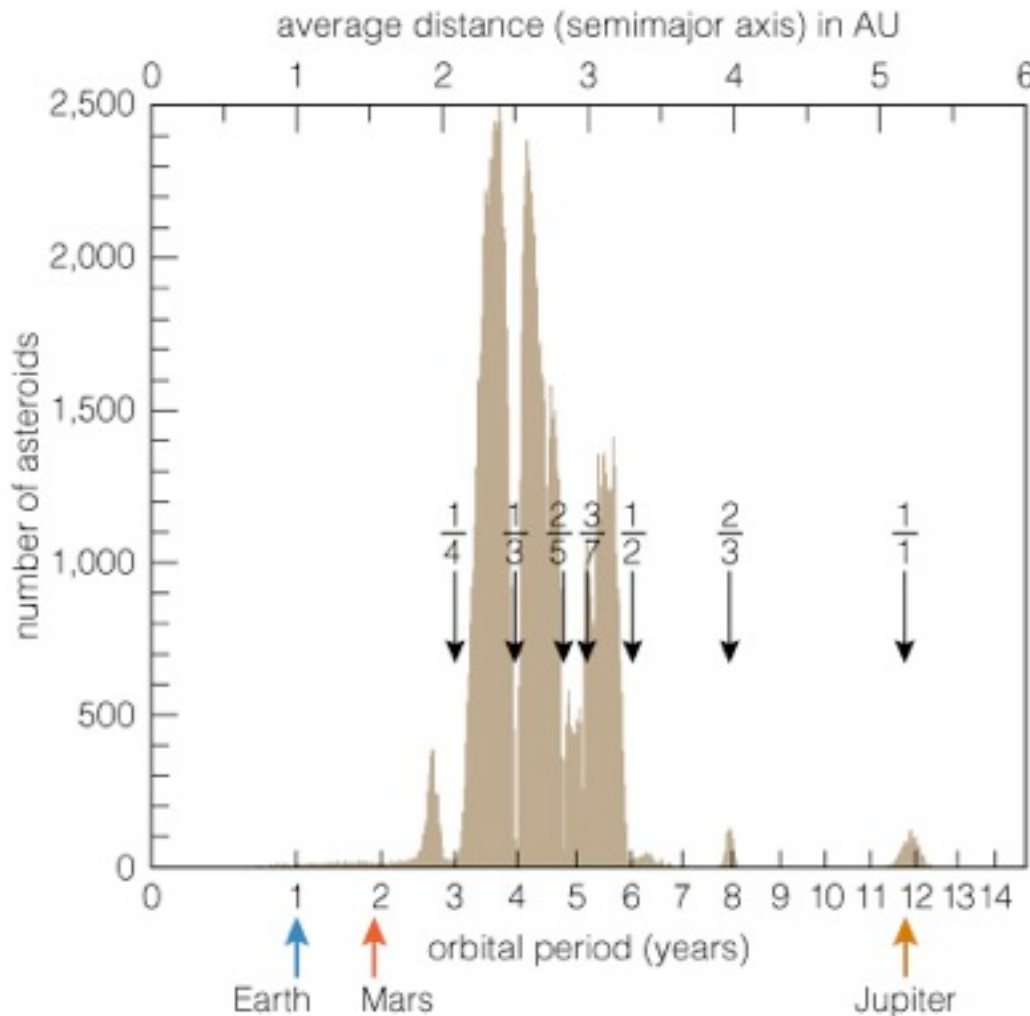
- Some large asteroids have their own moon.
- Asteroid Ida has a tiny moon named Dactyl.
- Sometimes asteroids are binary, with two roughly equal size partners.

Asteroid Orbits



- Most asteroids orbit in a **belt** between Mars and Jupiter.
- *Trojan asteroids* follow Jupiter's orbit.
 - 60 degrees ahead or behind
- *Apollo asteroids* cross Earth's orbit

Orbital Resonances



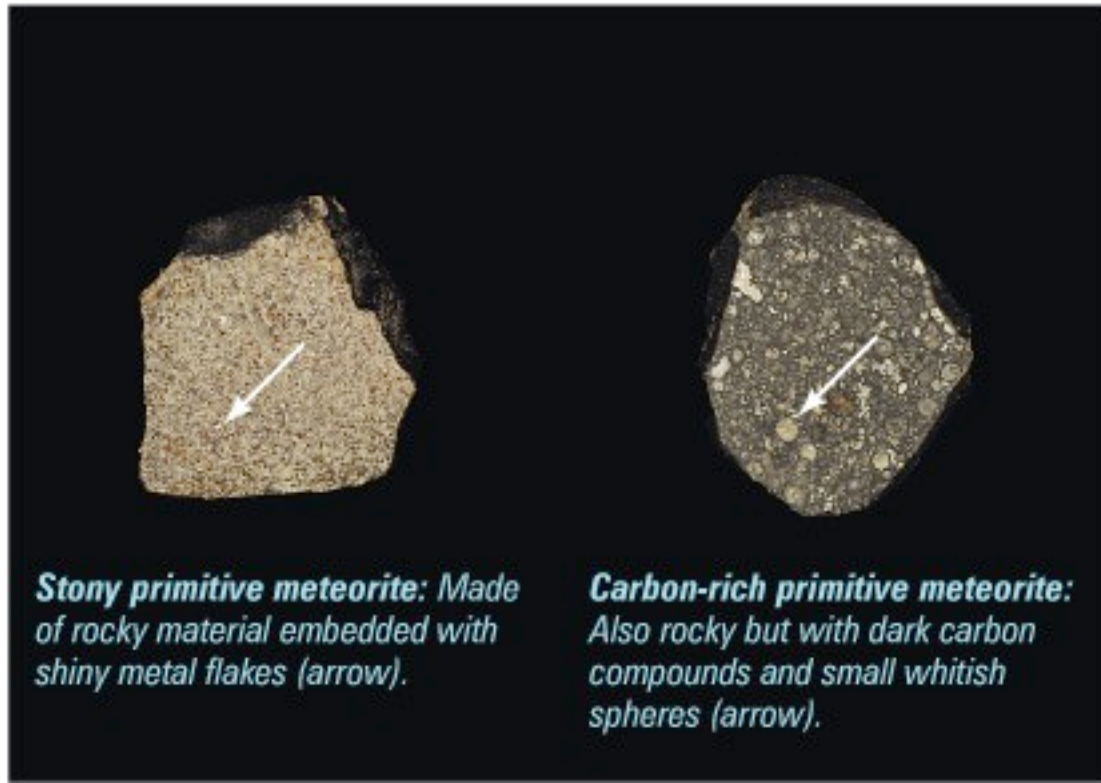
- Asteroids in orbital resonance with Jupiter experience periodic nudges.
- Those nudges clear asteroids out of resonant orbits, leaving gaps in the belt.
- Same physics as rings of Saturn

Rocks that fall from the sky...

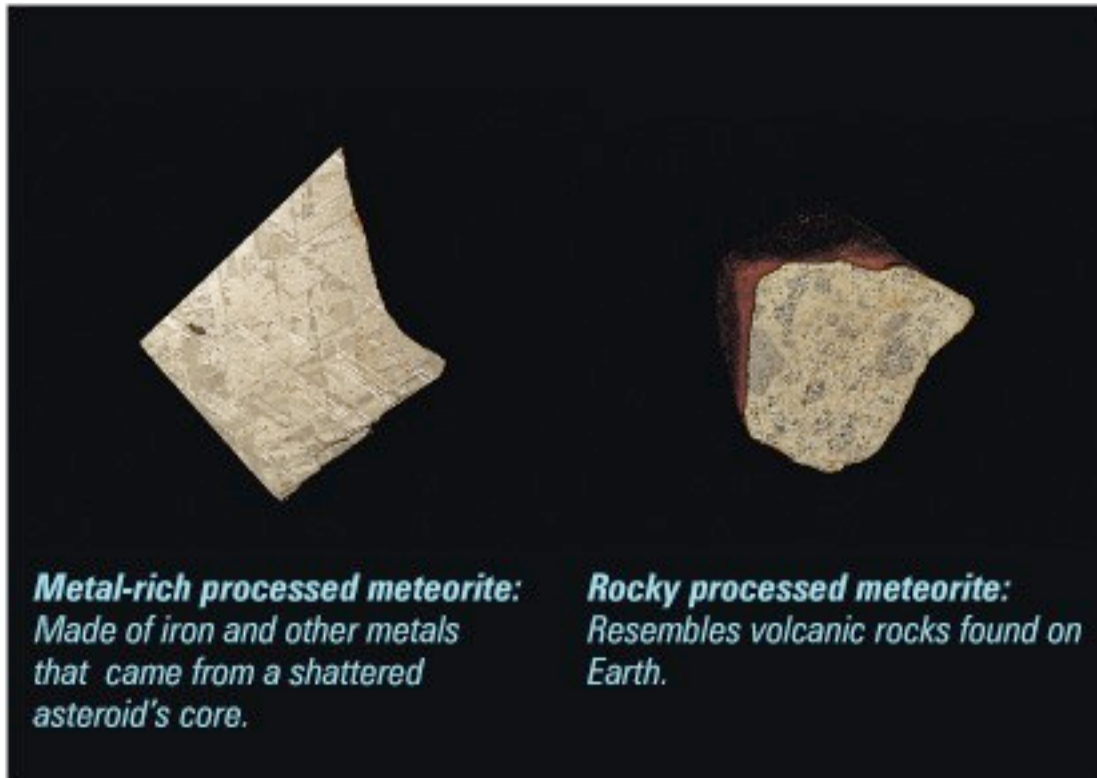
- **Meteorite:** A rock from space that falls through Earth's atmosphere.
- **Meteor:** The bright trail seen as a shooting star.
Typically only a grain of sand.
- **Meteoroid:** A rock in space prone to become a meteor.

Primitive Meteorites

Primitive: Unchanged in composition since they first formed 4.5 billion years ago - key to measuring the composition of the solar system

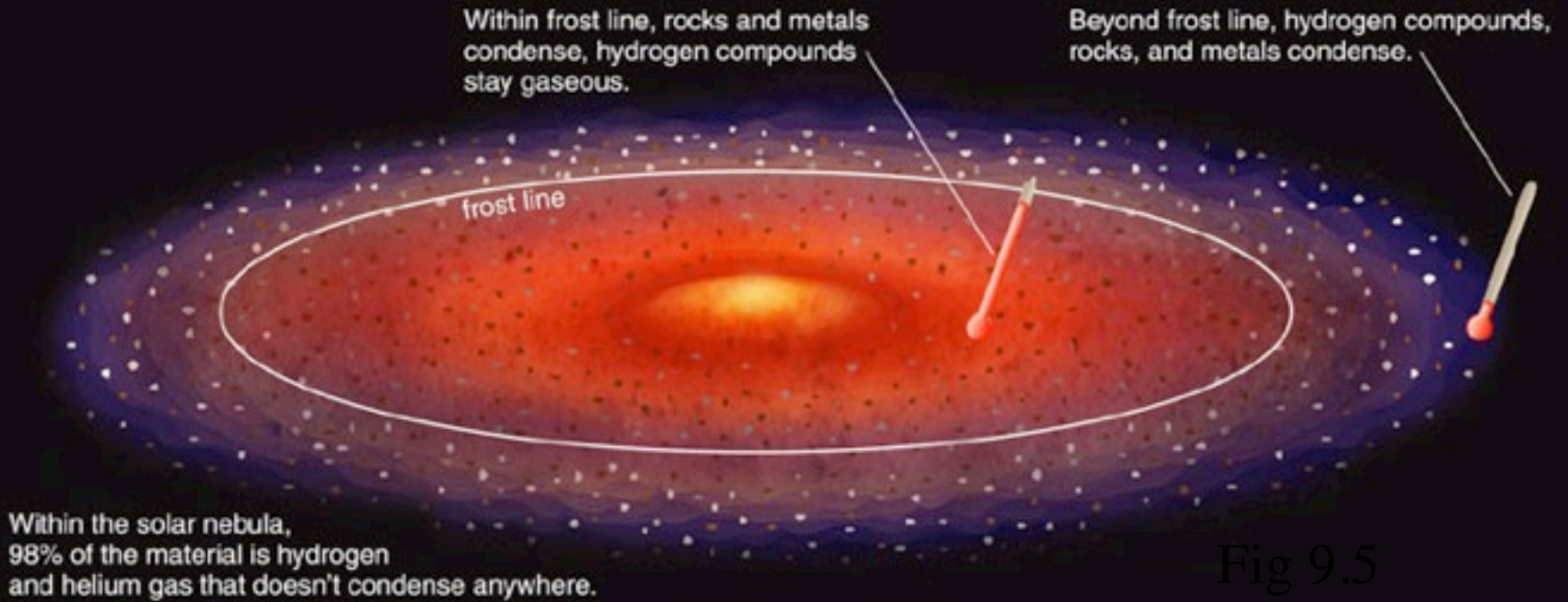


Processed Meteorites



Metal-rich processed meteorite:
*Made of iron and other metals
that came from a shattered
asteroid's core.*

Rocky processed meteorite:
*Resembles volcanic rocks found on
Earth.*



FROST LINE at about 3.5 AU

Inside the *frost line*: Too hot for hydrogen compounds to form ices
- only get rocky asteroids and planets

Outside the *frost line*: Cold enough for ices to form
- get icy moons and comets
- ice is a major component of their total mass

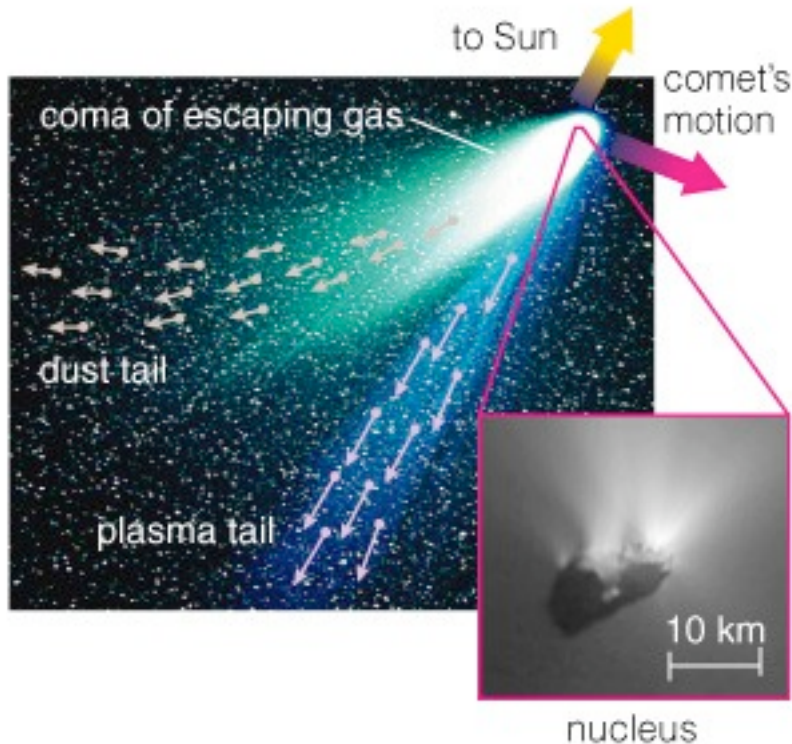
Comets



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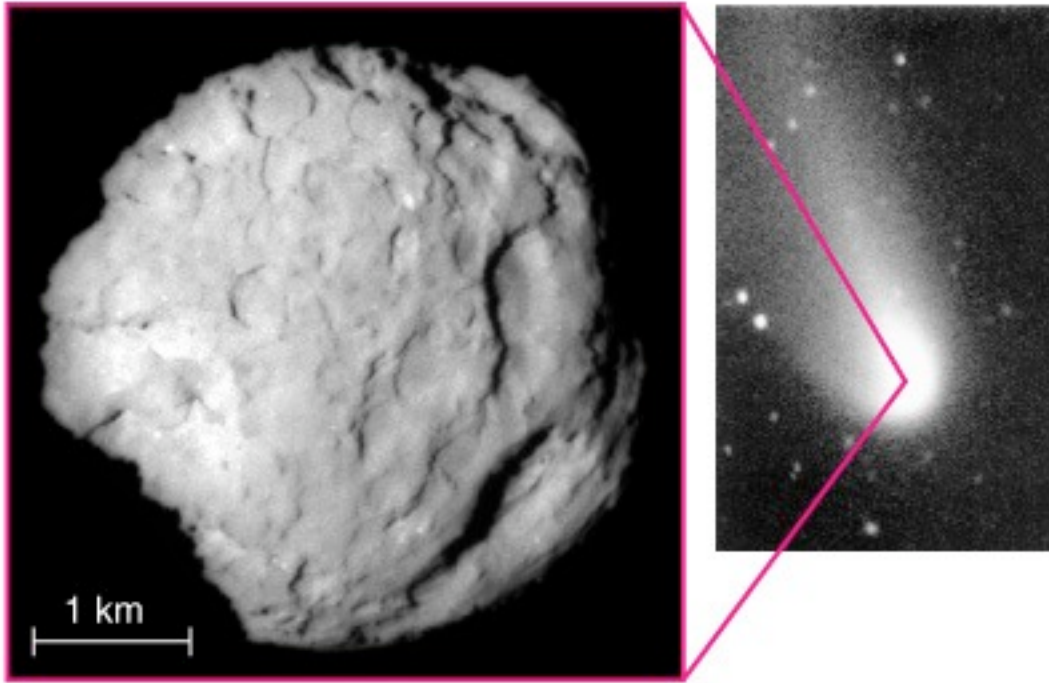
Anatomy of a Comet

- Nucleus: actual object
- Coma is atmosphere that comes from heated nucleus.
- Plasma tail is gas escaping from coma, pushed by solar wind.
- Dust tail is pushed by photons.
- Larger debris follow comet's orbit; source of meteoroids.



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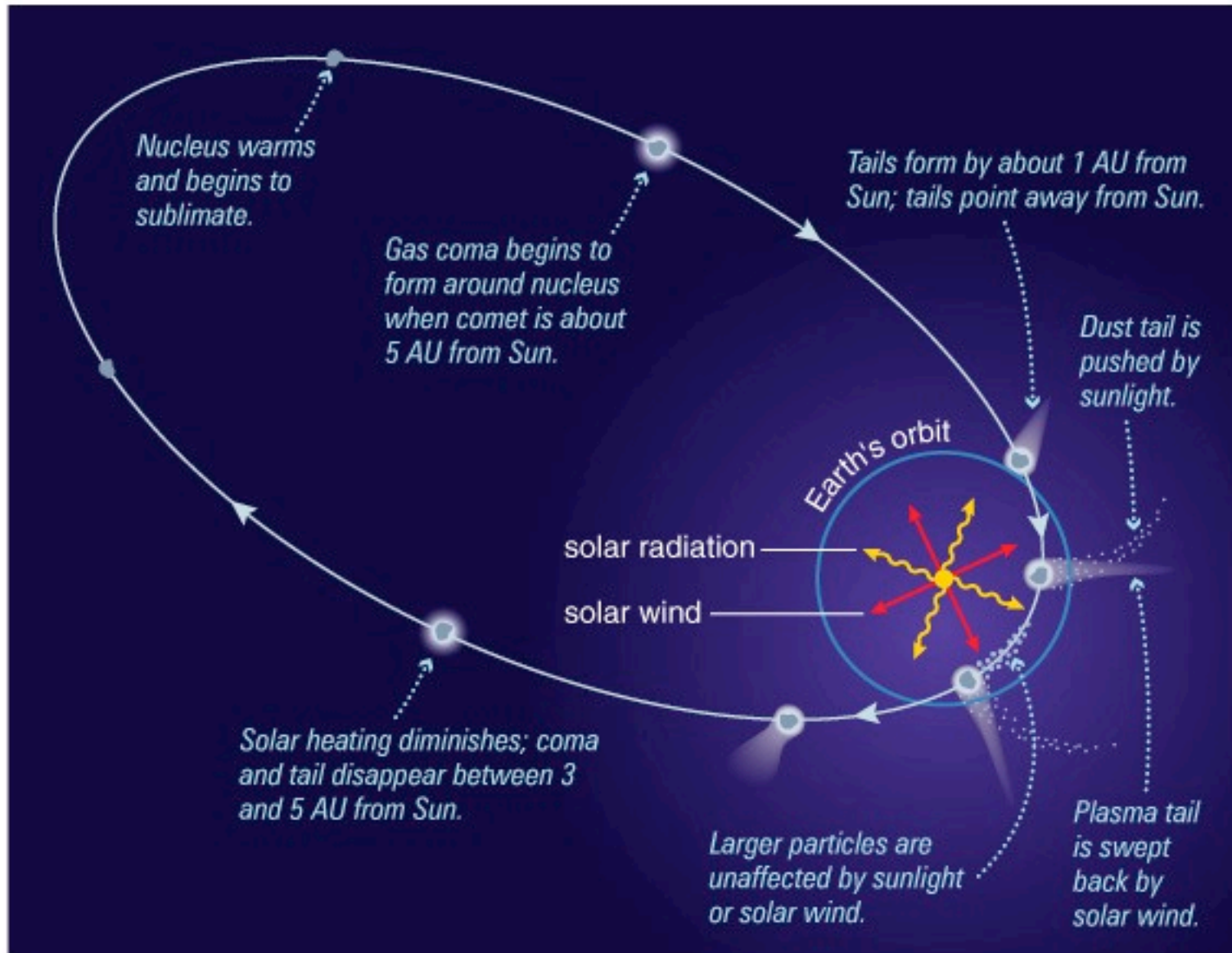
Nucleus of Comet



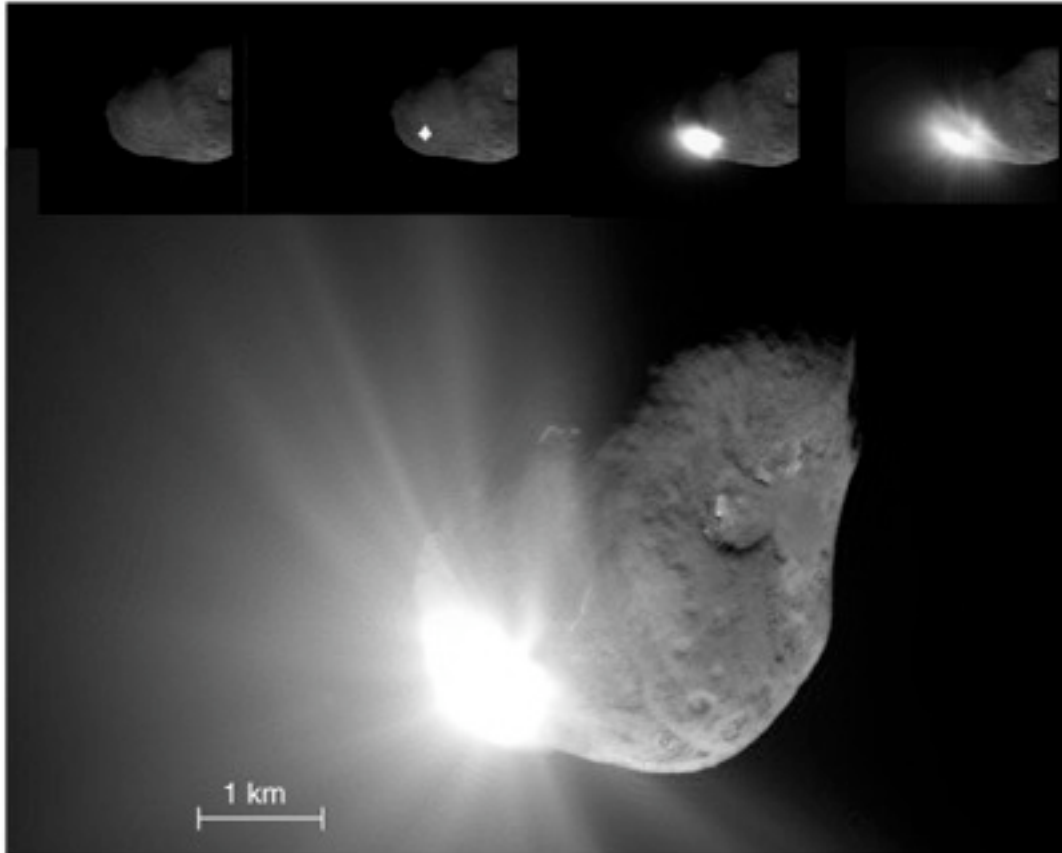
- A “dirty snowball” -
- a combination of rock, ice, and carbon-rich “tar”

- Source of material for comet’s tail -
- Tail only appears when comet nears the sun: ices are heated into vapor, forming coma and tail.

Growth of Tail



Deep Impact (led by UMd)

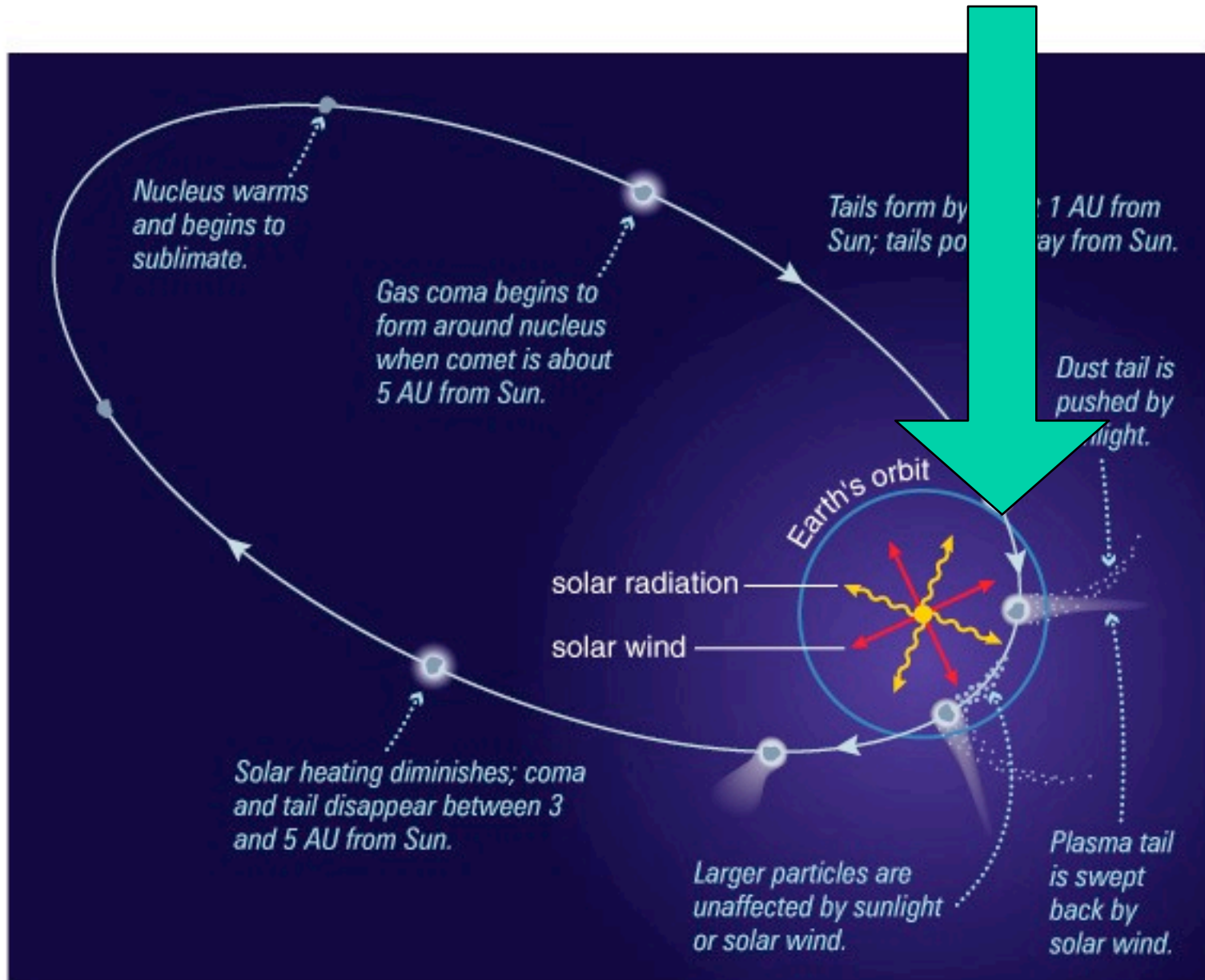


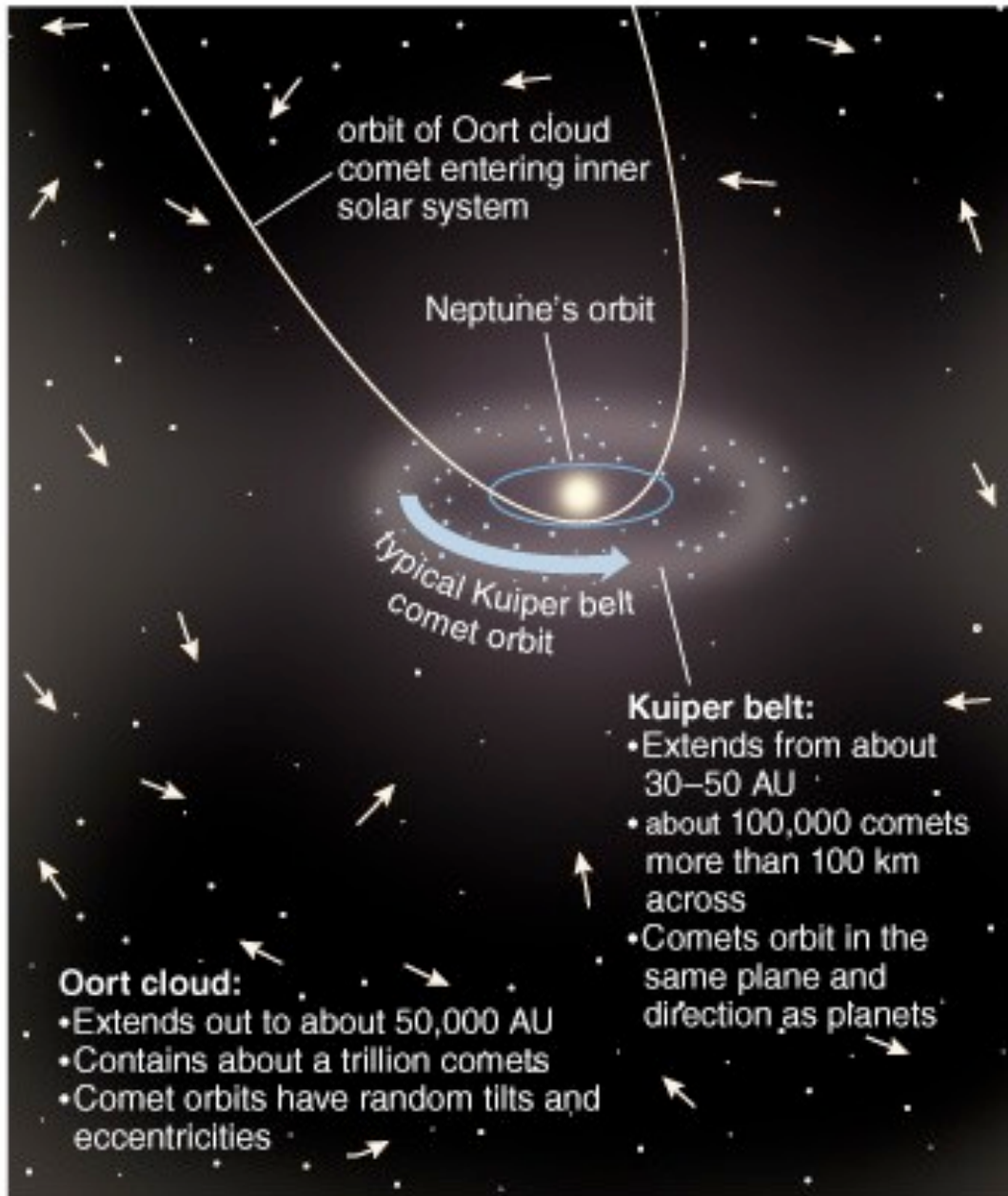
- Mission to study nucleus of Comet Tempel 1
- Projectile hit surface on July 4, 2005
- Lots of ices (as expected) but also a lot of tarry hydrocarbon materials



Comets eject small particles (**meteoroids**) that follow the comet around in its orbit and cause meteor showers when Earth crosses the comet's orbit.

annual meteor shower





Only a tiny number of comets enter the inner solar system; most stay far from the Sun.

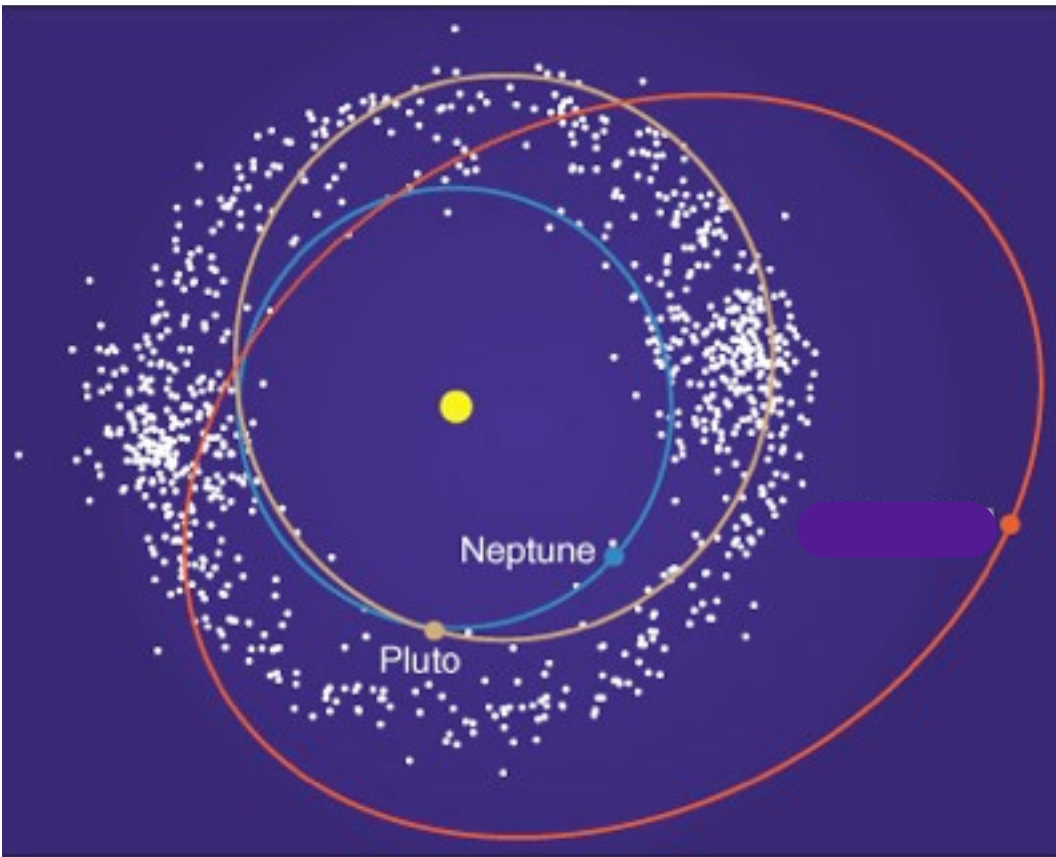
Oort cloud:

On random orbits extending to about 50,000 AU

Kuiper belt:

On orderly orbits from 30–50 AU in disk of solar system

Kuiper Belt



- disk of objects beyond the orbit of Neptune
- Like more distant, icy version of asteroid belt
- Many small objects; some large ones (like Pluto)

Pluto is just the first known example
of large Kuiper Belt objects



What is Pluto like?

- Its largest moon Charon is nearly as large as Pluto itself.
 - Tidally locked: perpetually face each other.
- Pluto is very cold (40 K).
- Pluto has a thin nitrogen atmosphere that refreezes onto the surface as Pluto's orbit takes it farther from the Sun.

Other Icy Bodies



- There are many icy objects like Pluto on elliptical, inclined orbits beyond Neptune.
- The largest ones are comparable in size to Earth's Moon.
- More similar to Jovian moons with icy+rocky compositions

Dwarf Planets

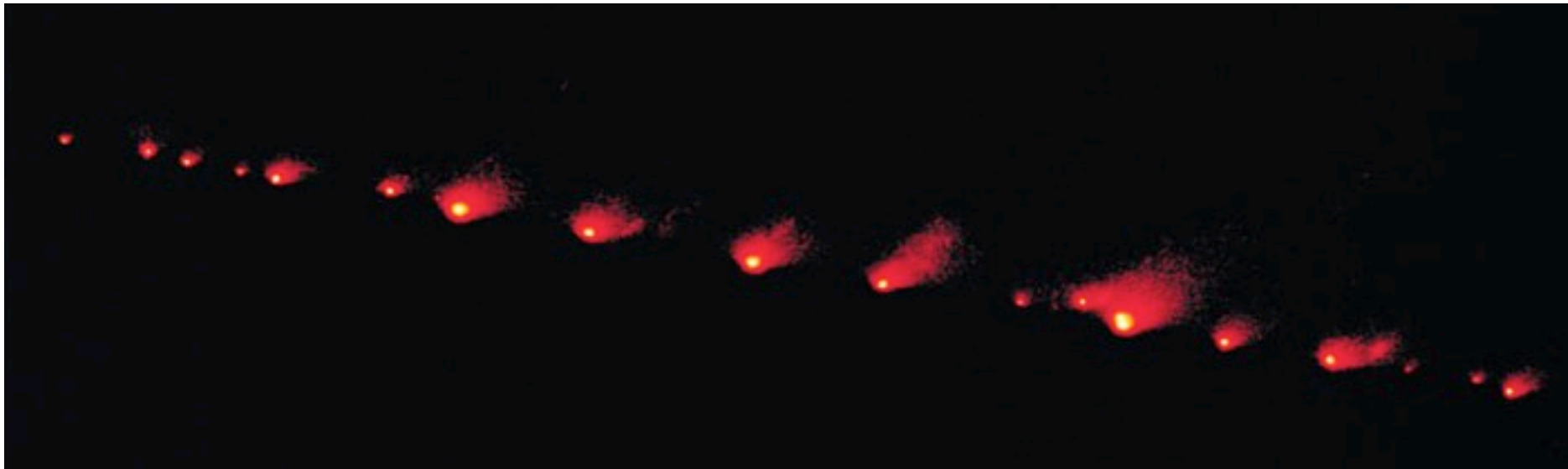
- Large Kuiper Belt objects like Pluto now considered “dwarf planets.”
- Good nomenclature?
 - Are Pluto et al. just really big comets?
- Reason you care: you should know the names of the planets for the exam. You don't need to know all the dwarf planets.

Other Kuiper Belt Objects

- Most have been discovered very recently so little is known about them.
- NASA's *New Horizons* mission will study Pluto and a few other Kuiper Belt objects in a planned flyby.

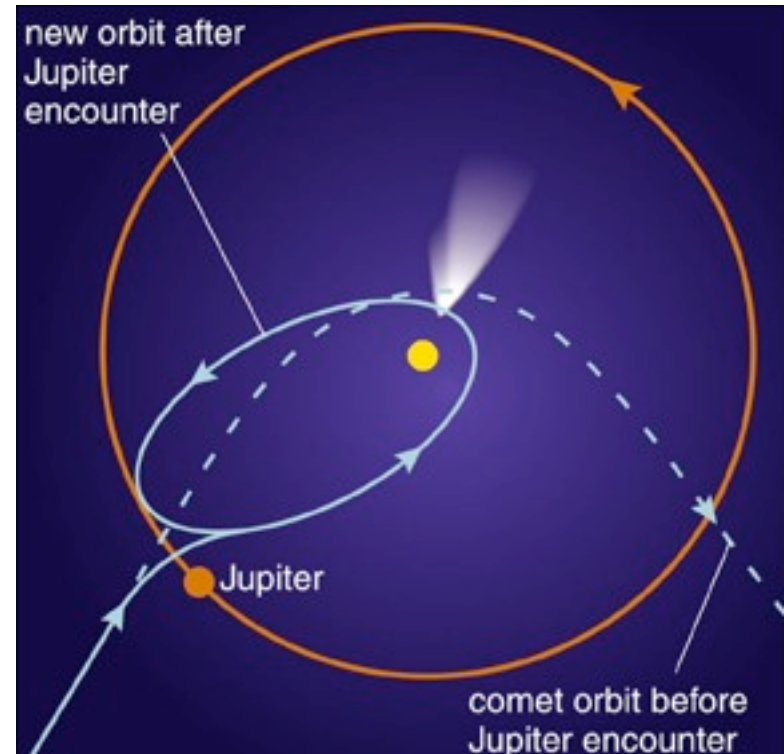
When planets collide

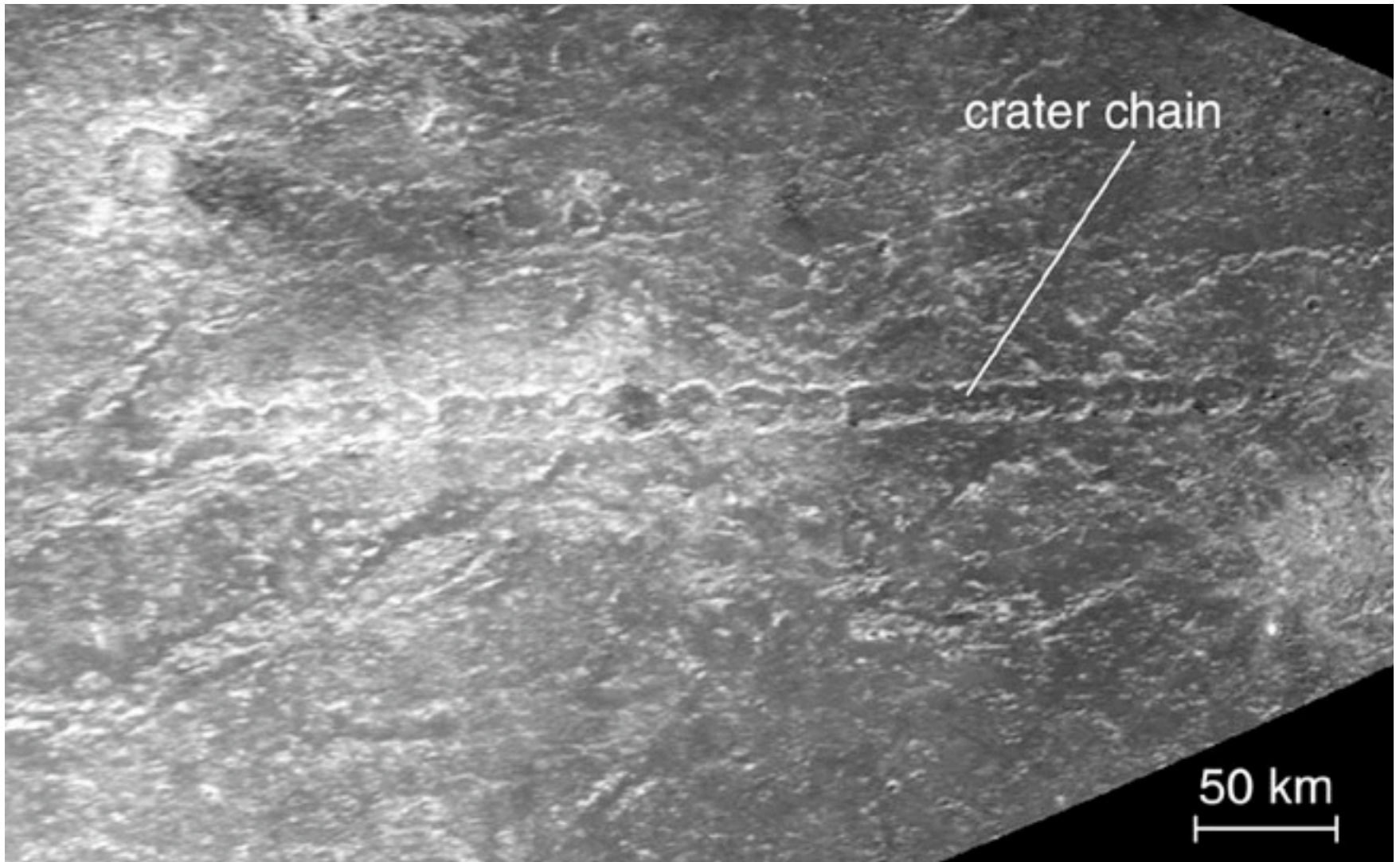




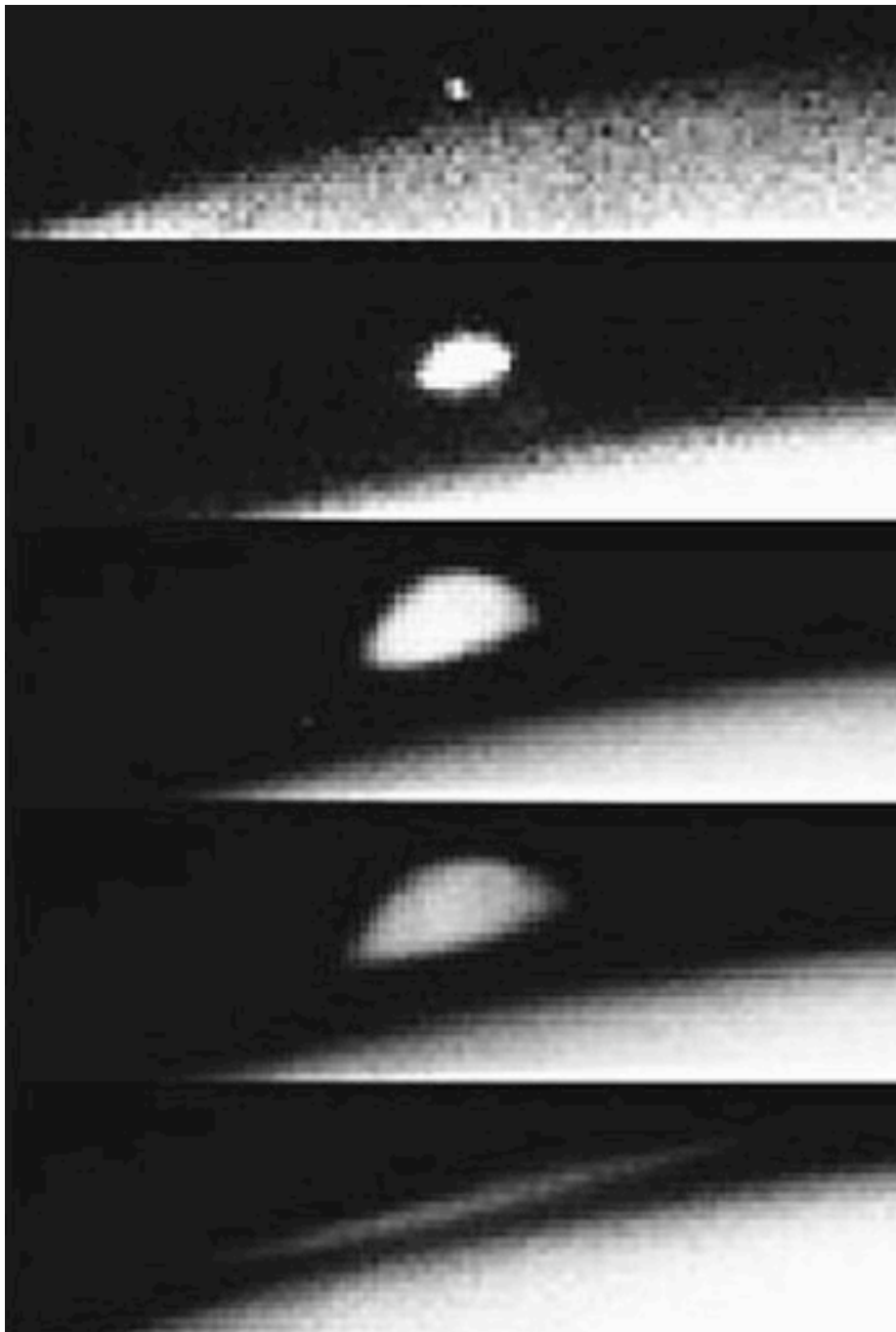
Comet SL9 caused a string of violent impacts on Jupiter in 1994, reminding us that catastrophic collisions still happen.

Tidal forces tore it apart during a previous encounter with Jupiter.





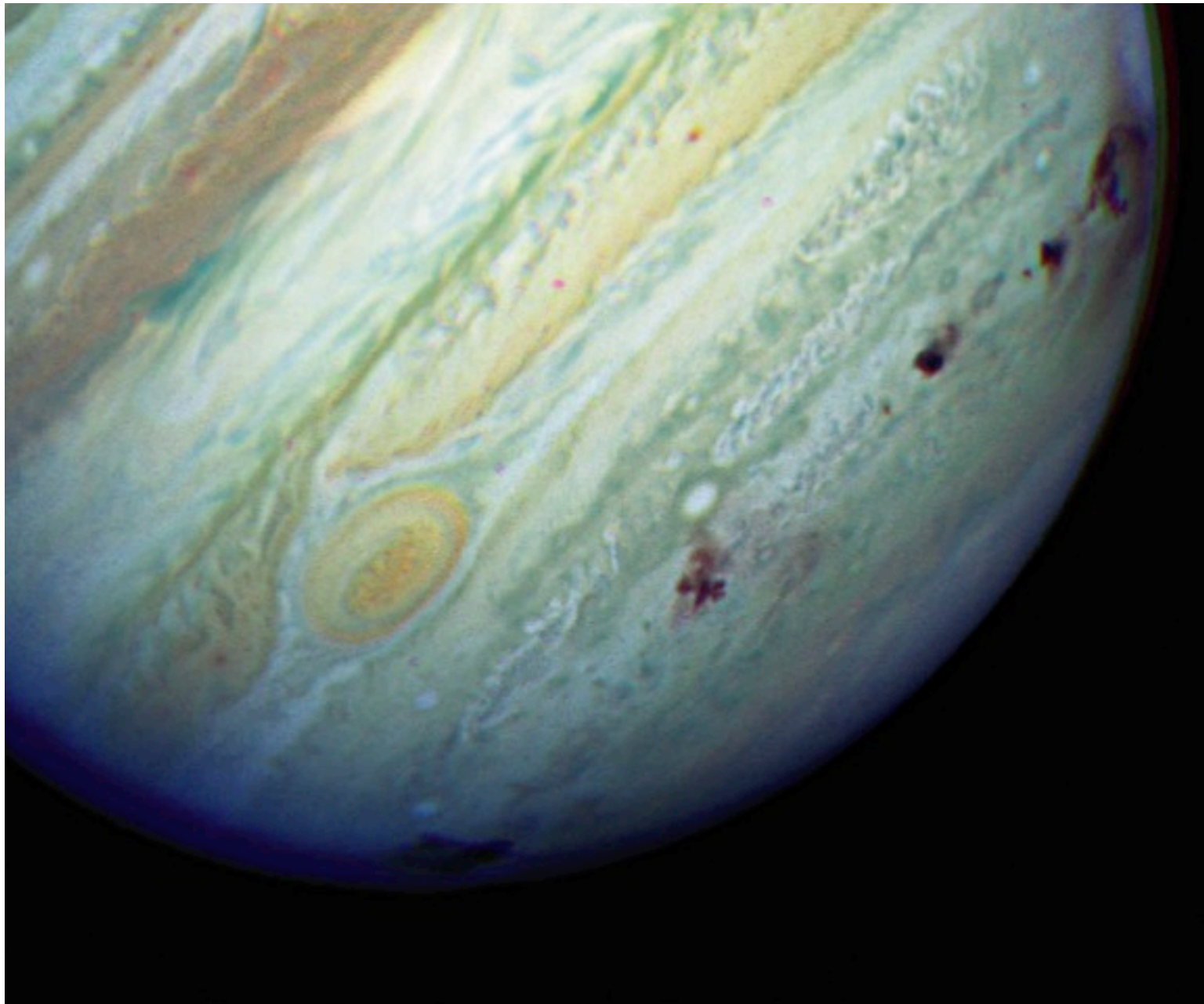
This crater chain on Callisto probably came from another comet that tidal forces tore to pieces.



Impact plume
from a fragment
of comet SL9
rises high above
Jupiter's surface



Impact sites in infrared light



Several impact sites

Facts About Impacts on Earth

- Asteroids and comets have hit the Earth.
- A major impact is only a matter of time: not IF but WHEN.
- Major impacts are very rare.
 - A major impact is thought to have contributed to the extinction of the dinosaurs 65 Myr ago.
- Something large enough to harm a city might occur every century or so.



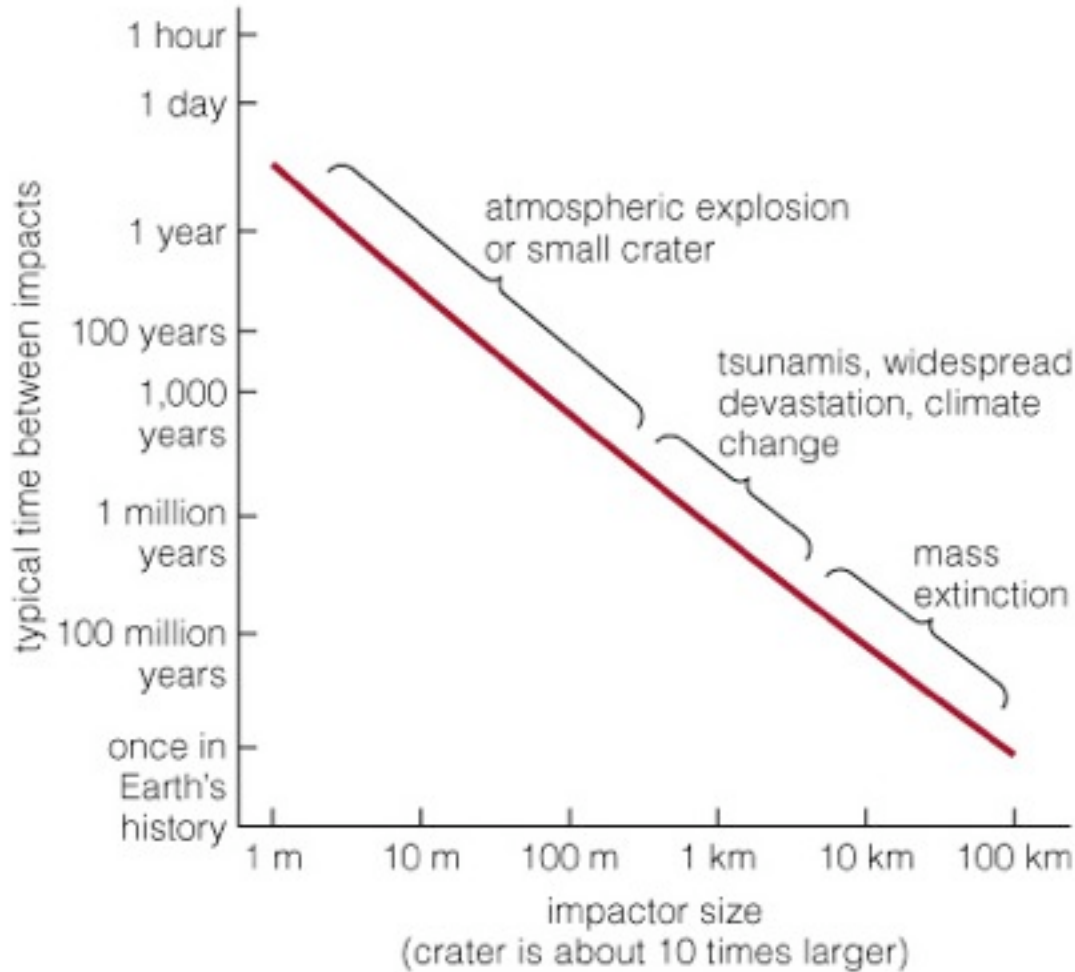
Tunguska, Siberia: June 30, 1908

A ~40 meter object disintegrated and exploded in the atmosphere



Meteor Crater, Arizona: 50,000 years ago (50 meter object)

Frequency of Impacts



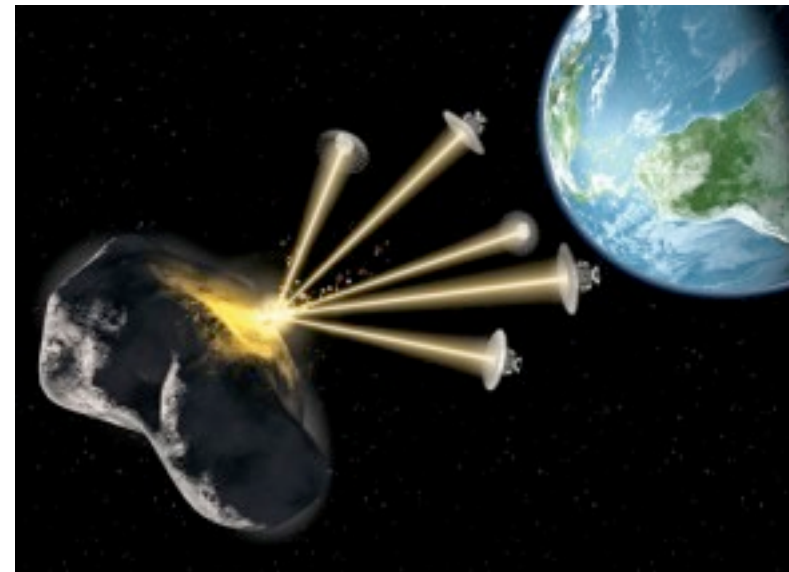
- Small impacts happen almost daily. – meteors!
- Impacts large enough to cause mass extinctions are many millions of years apart.

Asteroid Deflection

- Deflection is challenging; the more advance warning the better.
- Breaking a big asteroid into a bunch of little asteroids does not really help.
- Best chance is to nudge the orbit a bit.



gravity
tug



solar sublimation