

Lecture 25

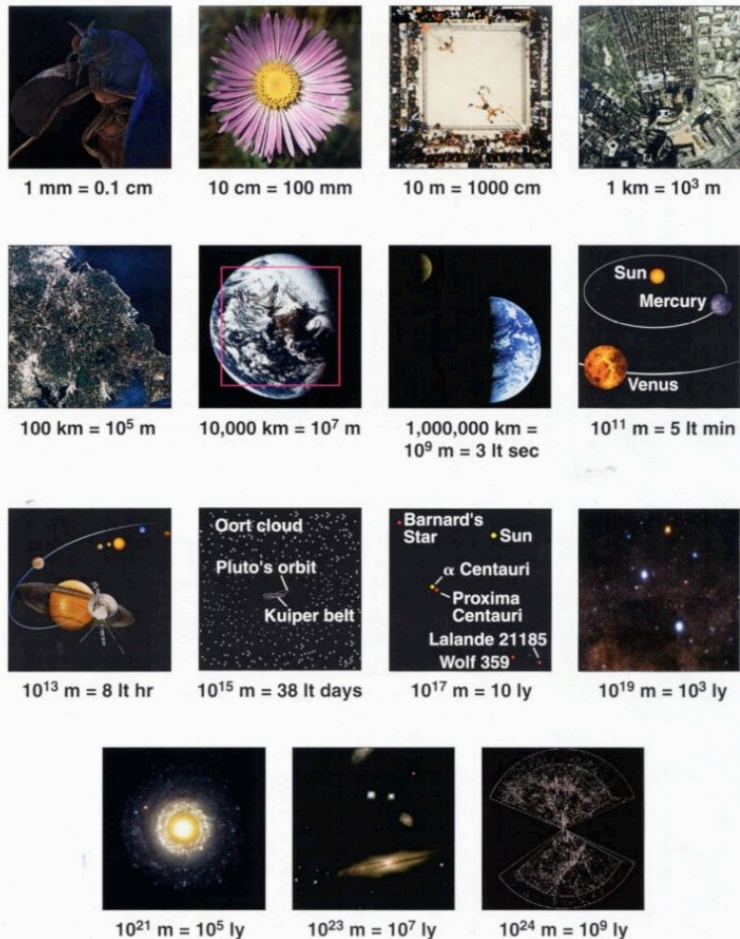
Back to the Solar System

Outline of Lecture 25

- Planets, satellites, and rings.
 - Jovian
 - Terrestrial
- Small bodies in the solar system:
 - Icy comets
 - Rocky asteroids
 - Interplanetary dust & meteoroids (debris left from disintegrating comets & smashed asteroids)
- Age dating
 - Radioactive dating of rock samples gives accurate age of solar system as 4.56 billion years
 - Crater counts gives approximate age of most recent lava flows in rocky bodies

Cosmic Landscape, Cosmic Calendar

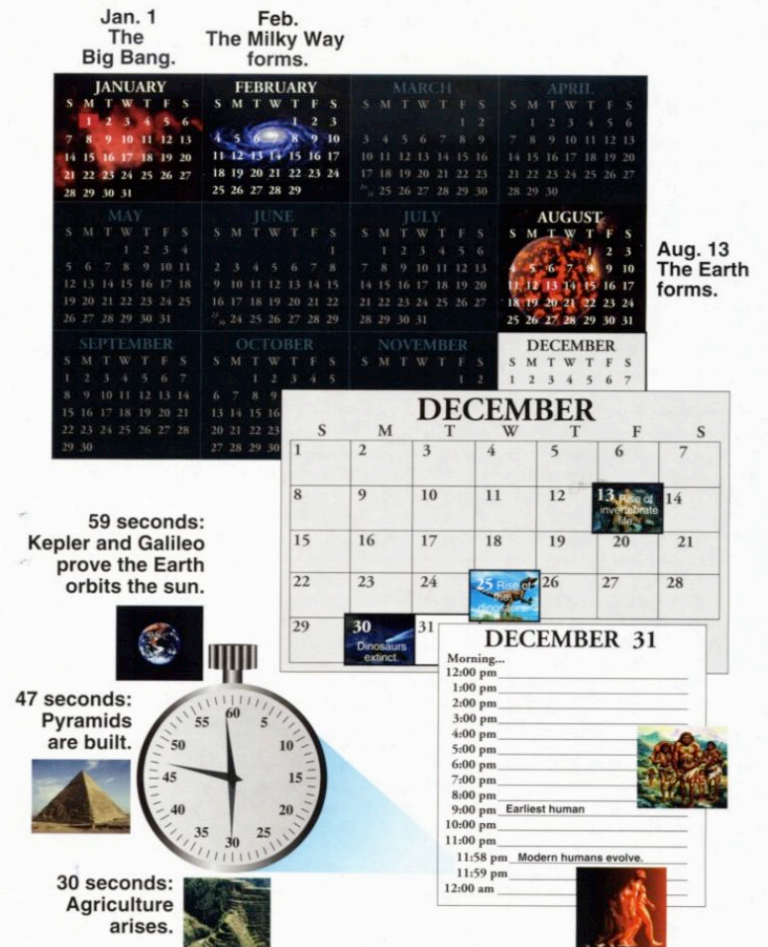
Pasachoff, The Cosmos: Astronomy in the New Millennium
Page 6, 7, 8



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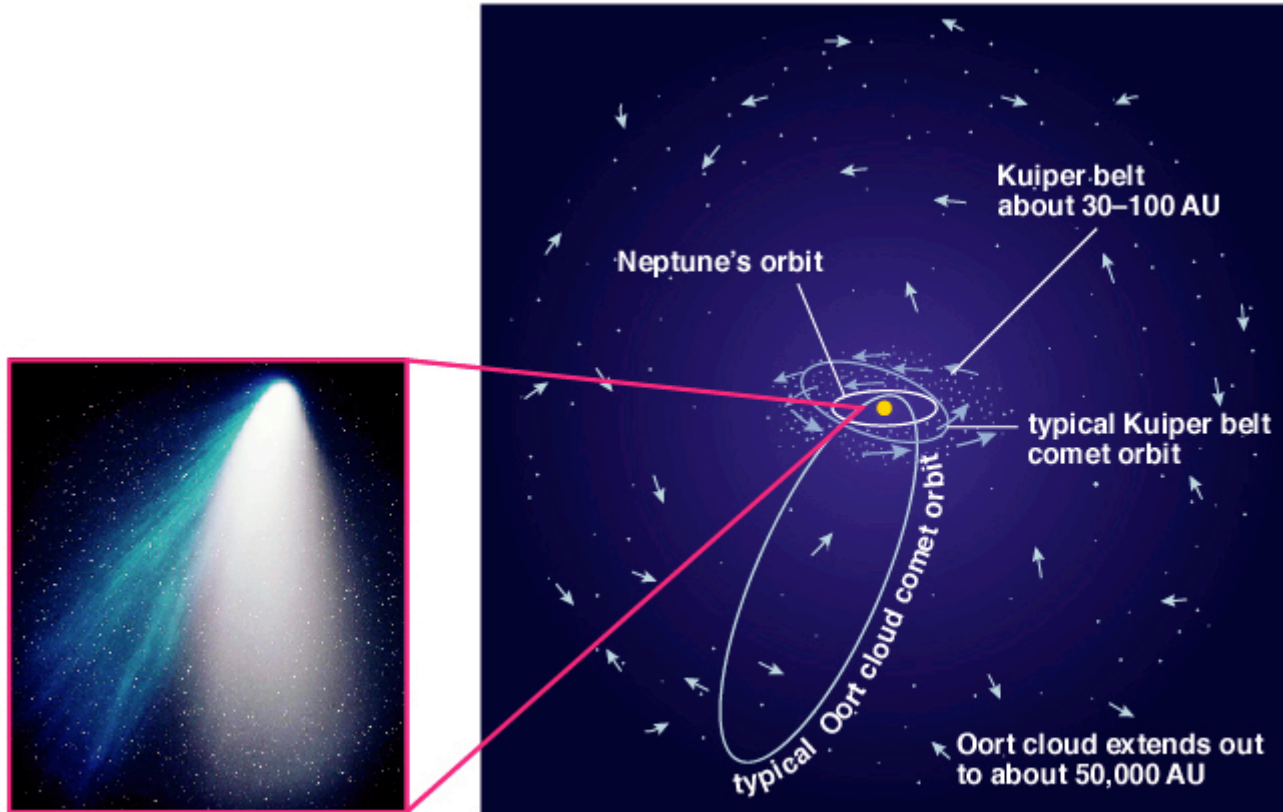
Fig. 1.9 Cosmic calendar, compressing history of universe to 1 year.

2



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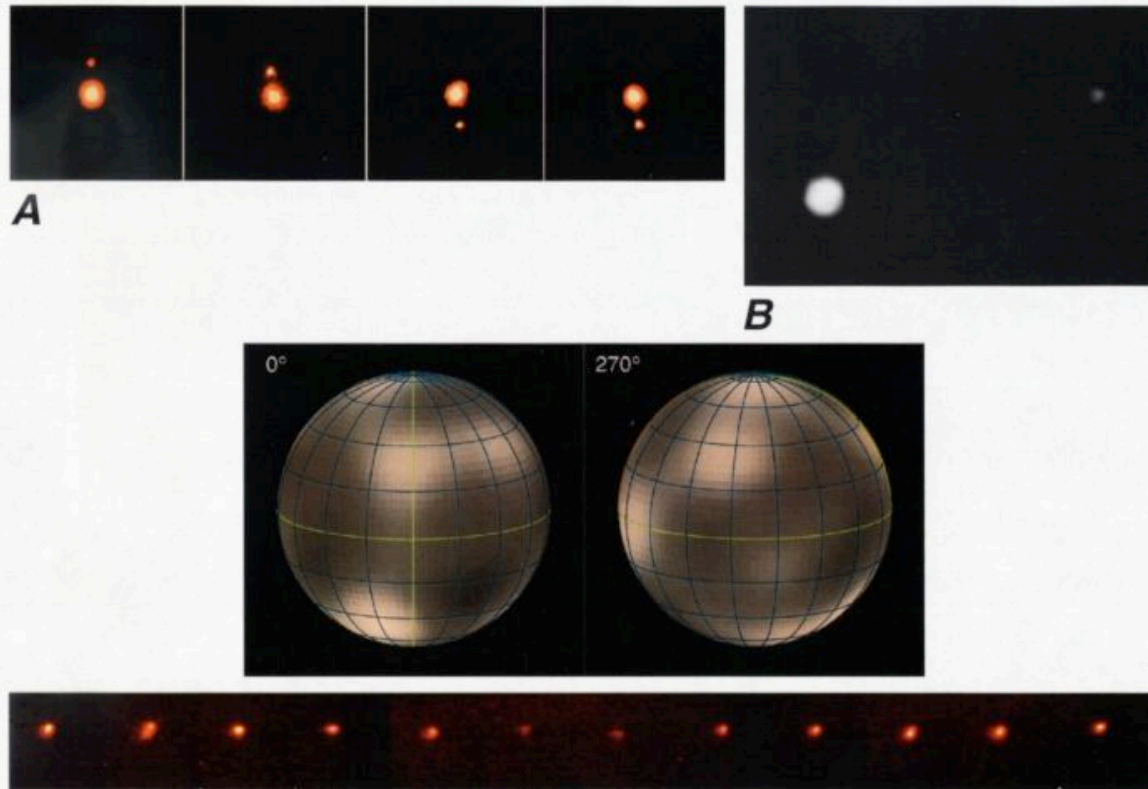
Comets Usually Reside Beyond the Orbit of Neptune; They Develop Long Tails When They Come Near to the Sun



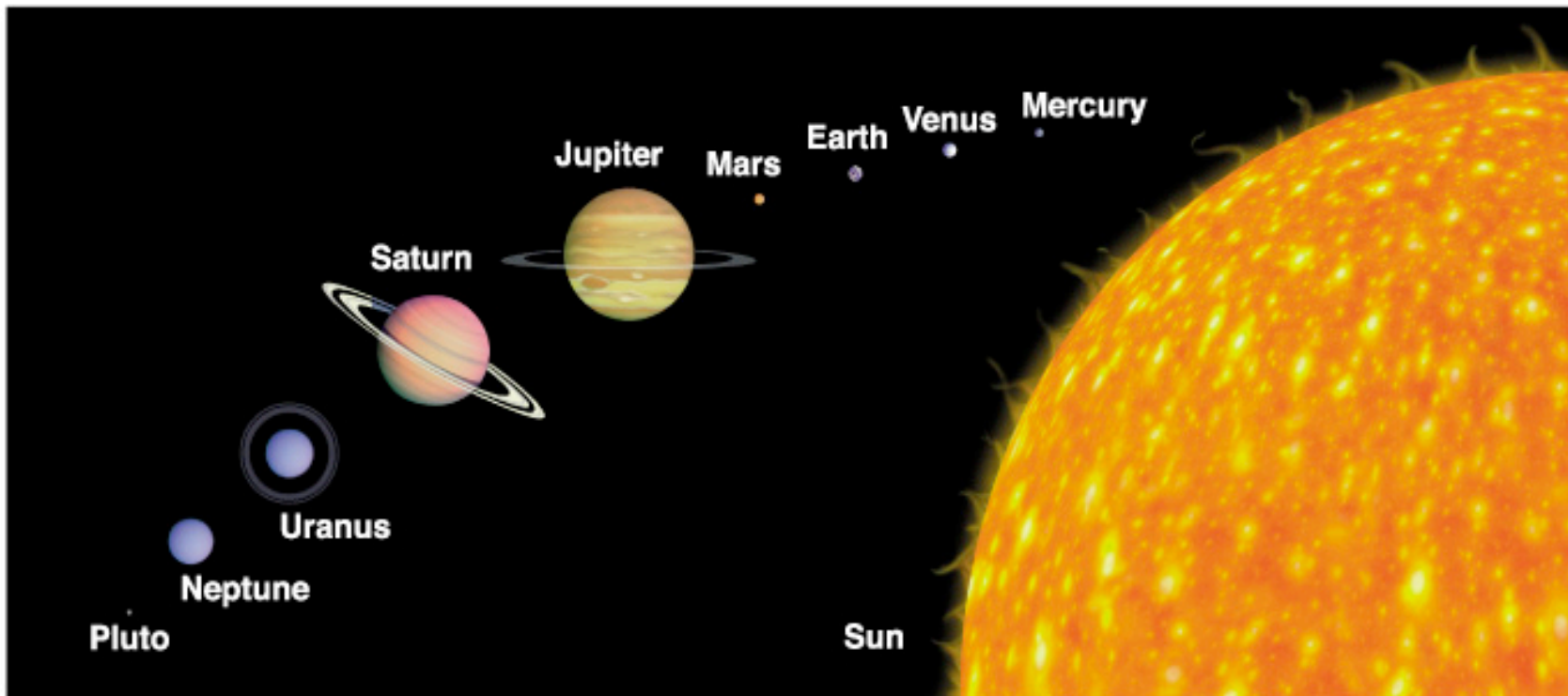
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Pluto is the Largest Cometary Body & Has a Large Icy Satellite, Charon

Pasachoff, The Cosmos: Astronomy in the New Millennium
Figure 8.5, 8.6, 8.7

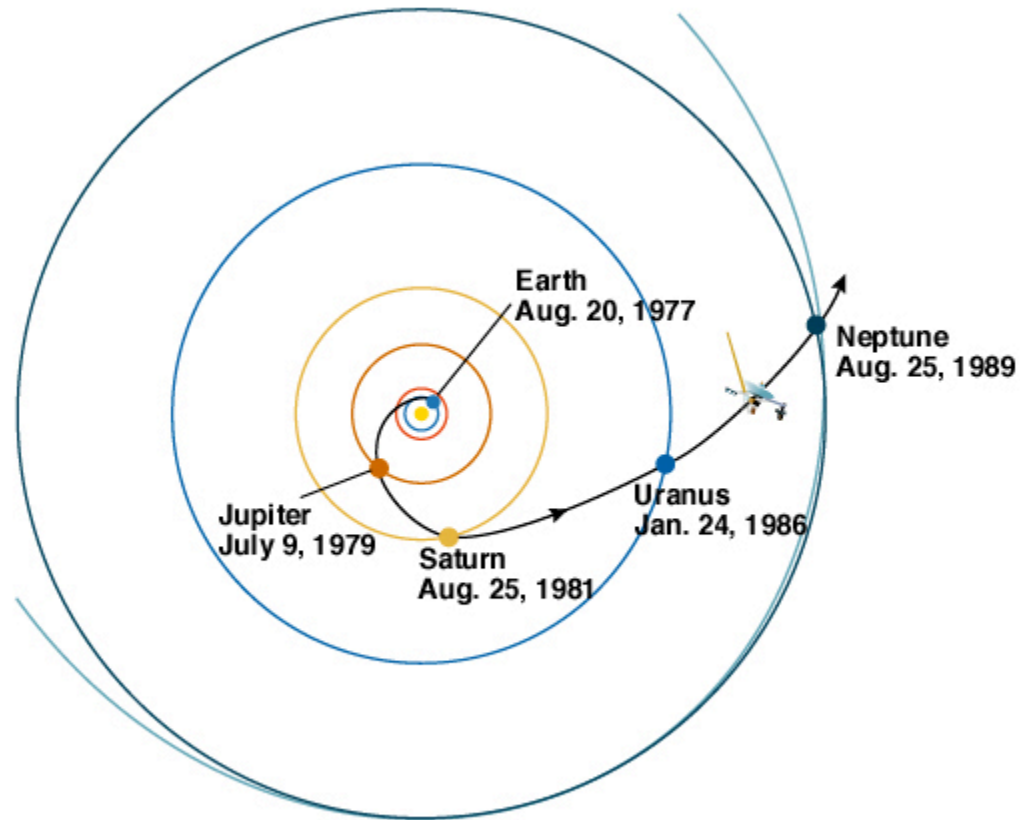


Not Counting Pluto, the Solar System Has Eight Major Planets



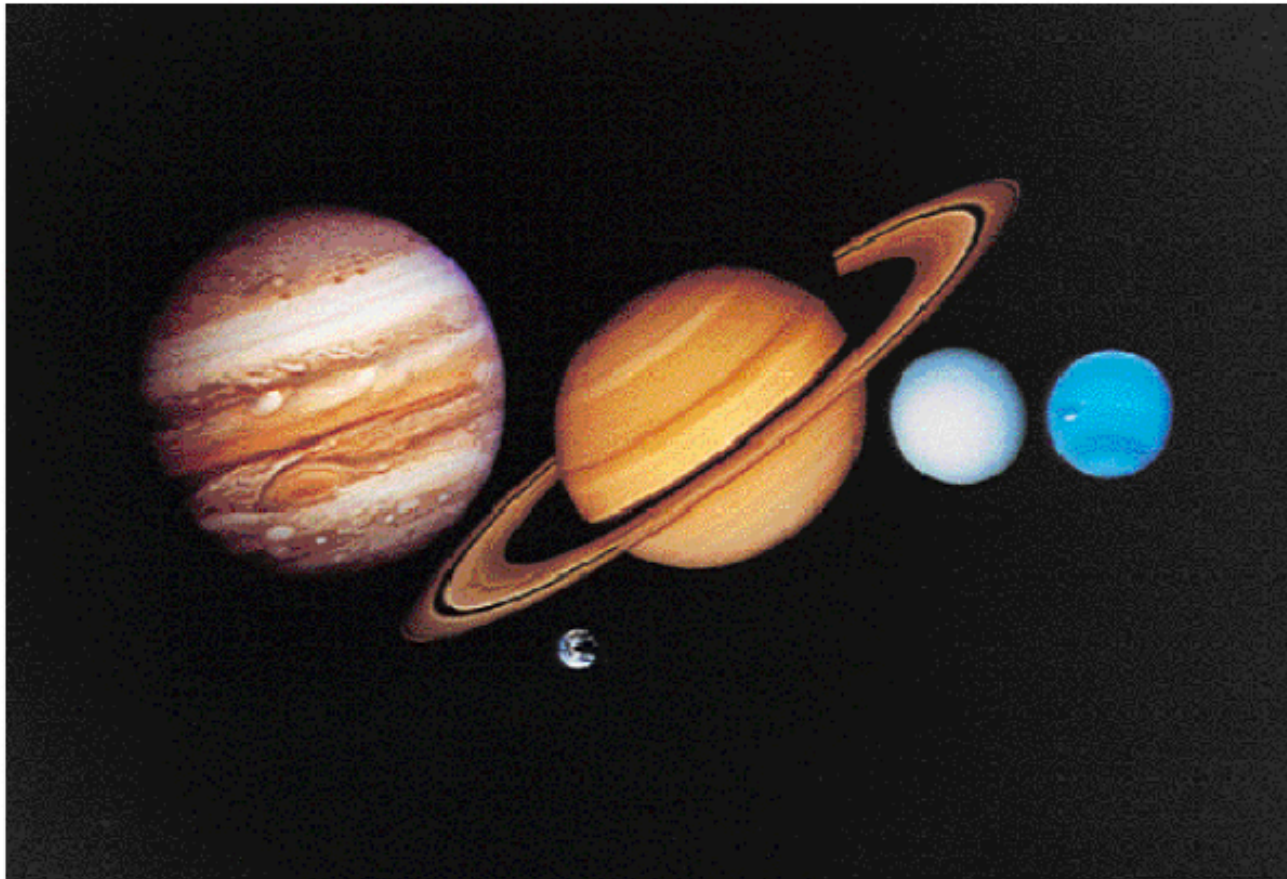
4 Giant or Jovian Planets: Jupiter, Saturn, Uranus, Neptune
4 Rocky or Terrestrial Planets: Mercury, Venus, Earth, Mars

Voyager 2 Did a Grand Tour of All Four Giant Planets



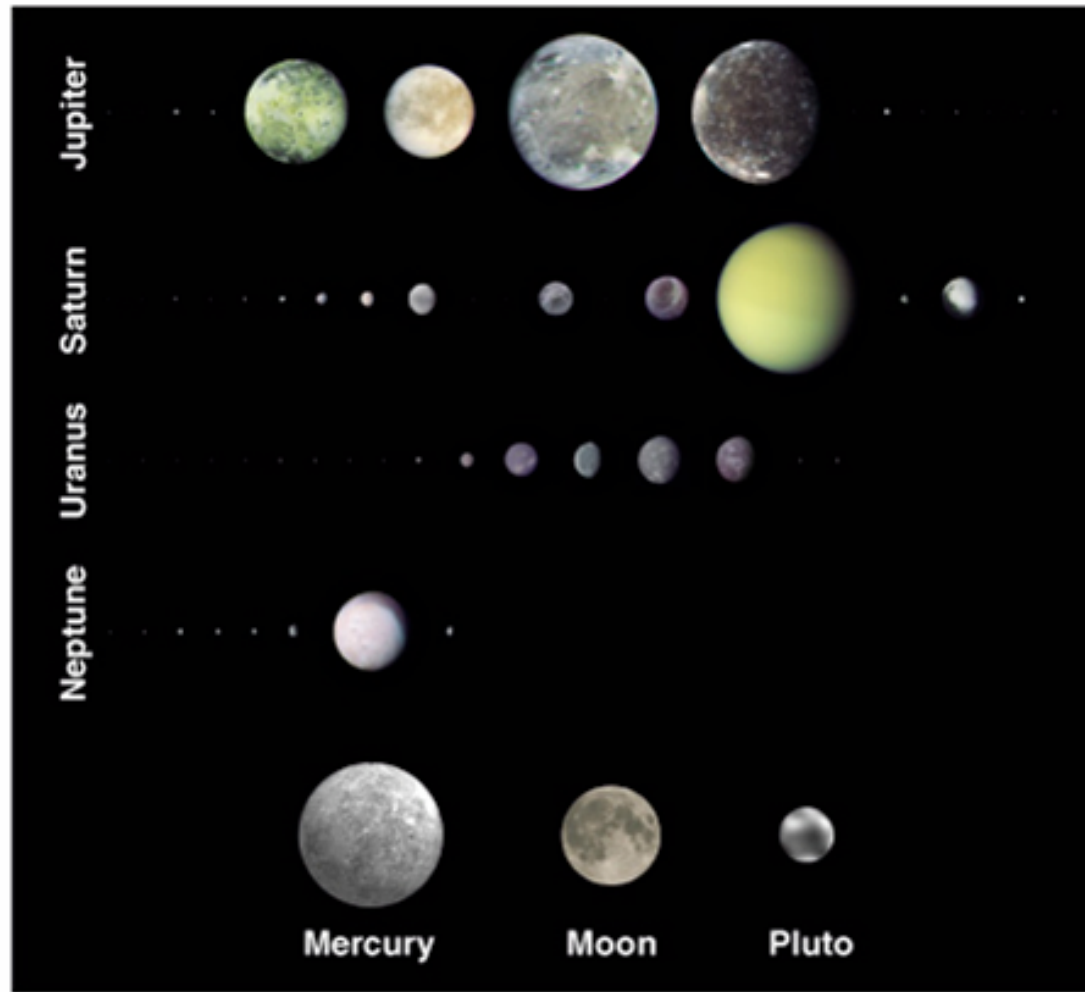
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The Giant or Jovian Planets



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The Giant Planets Have Many Large Icy Moons

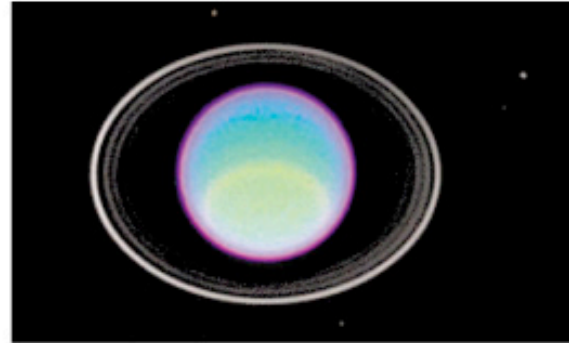


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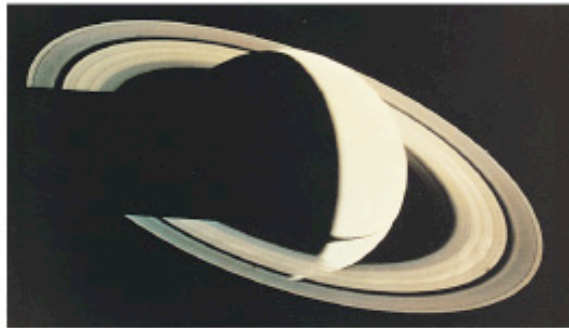
The Giant Planets All Have Rings



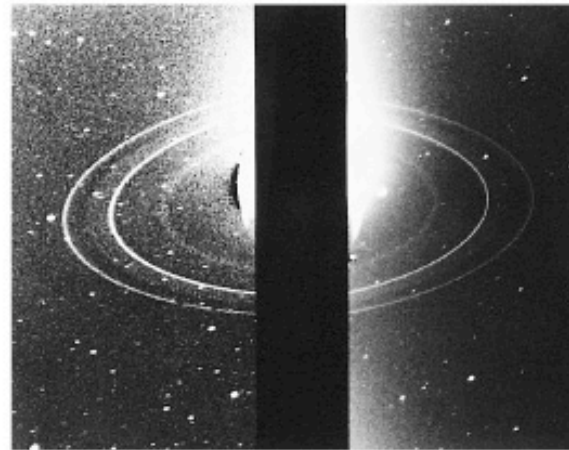
Jupiter



Uranus

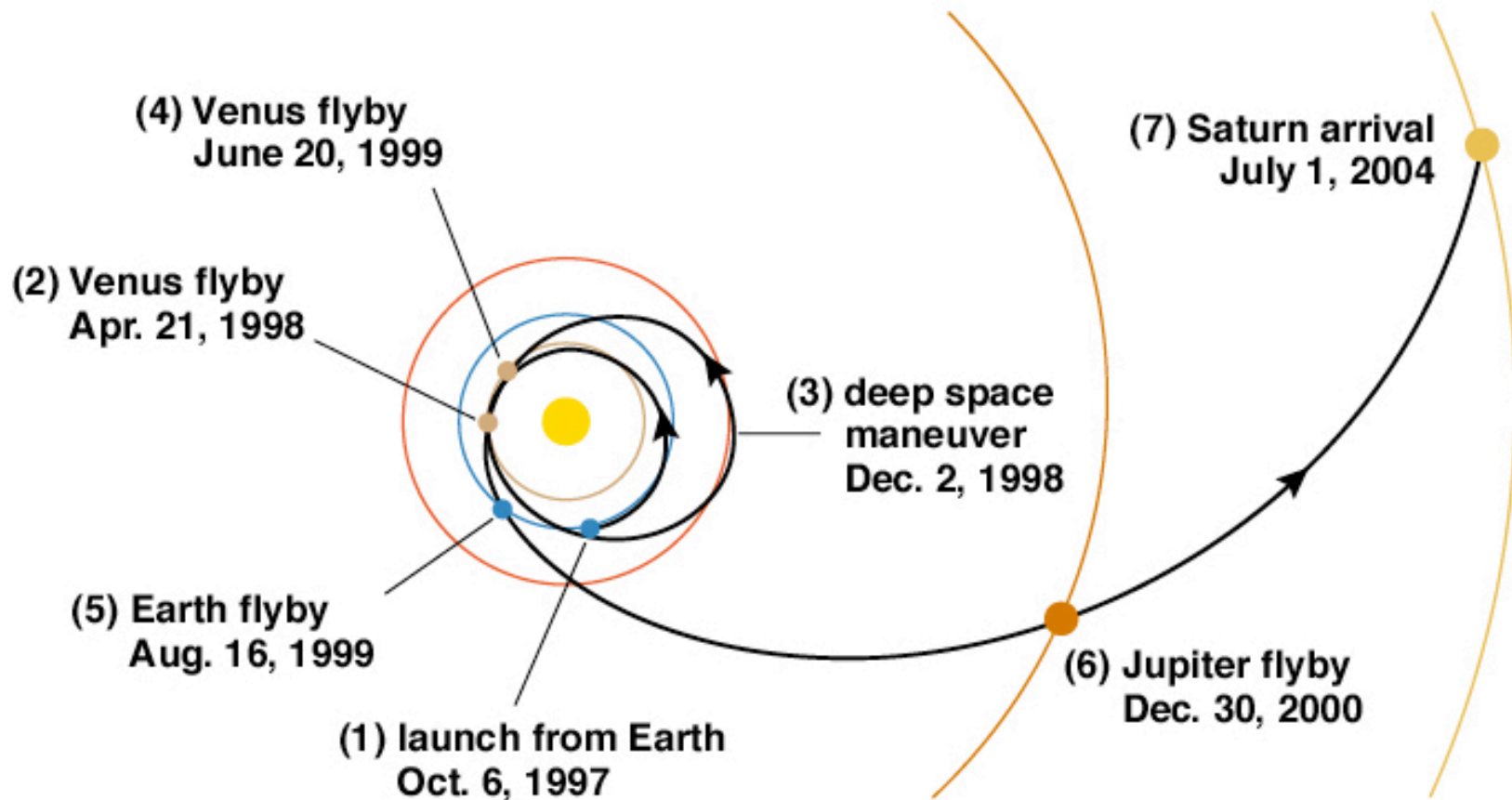


Saturn

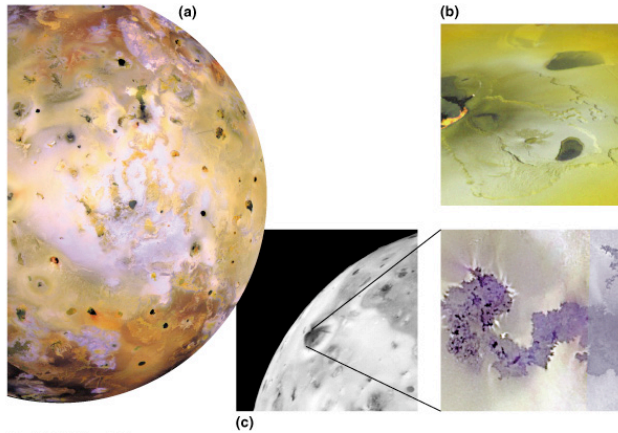


Neptune

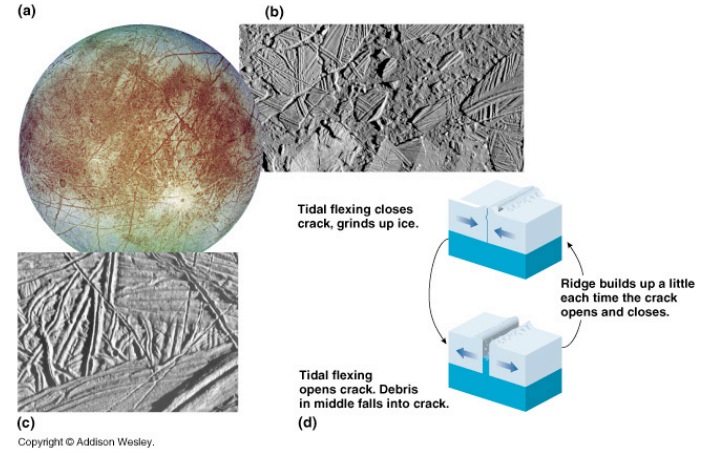
Cassini Mission Returned to Study Saturn System in Great Detail



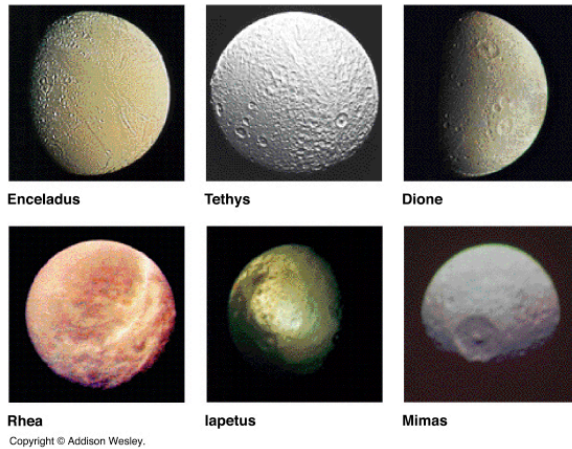
Some Close-Ups of the Icy Moons of Jupiter, Saturn, & Neptune



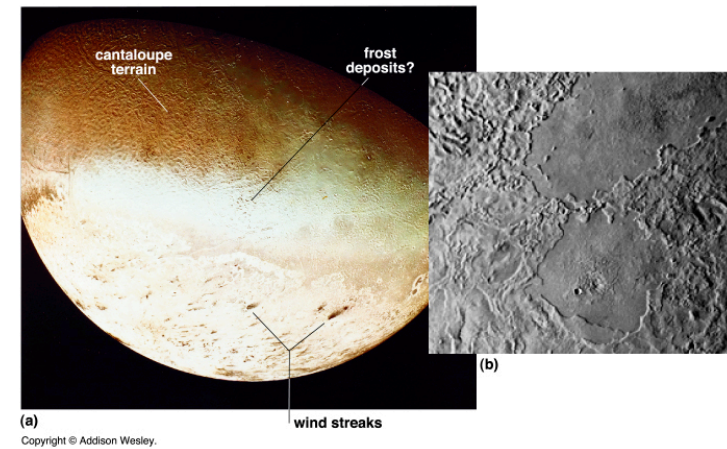
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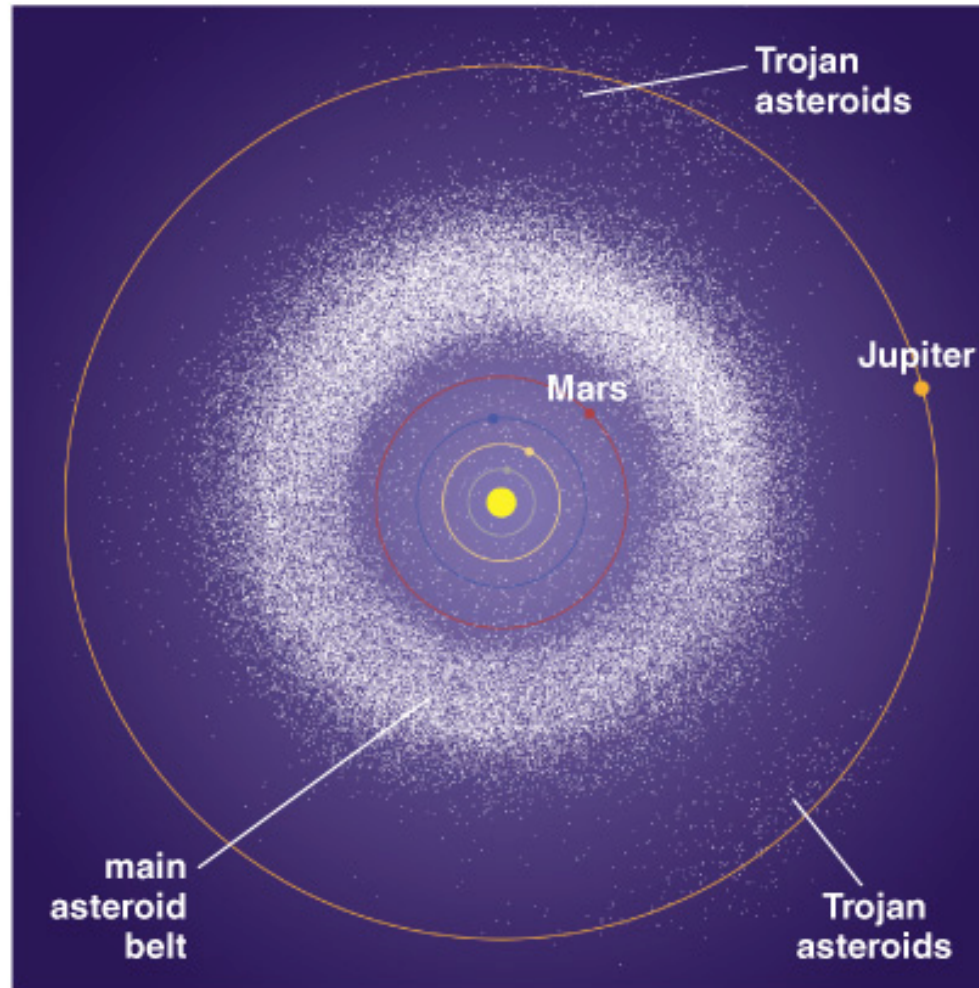


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A Comparison of Bulk Properties of the Giant Planets

Planet	Average Distance from Sun (AU)	Mass (Earth masses)	Radius (Earth radii)	Average Density (g/cm ³)	Bulk Composition
Jupiter 	5.20	317	11.2	1.33	Mostly H, He
Saturn 	9.53	90	9.4	0.70	Mostly H, He
Uranus 	19.2	14	4.11	1.32	Hydrogen compounds and rocks, H and He
Neptune 	30.1	17	3.92	1.64	Hydrogen compounds and rocks, H and He

An Asteroid Belt, Leftovers from the Process of Planet Formation, Lies Between Jupiter & Mars

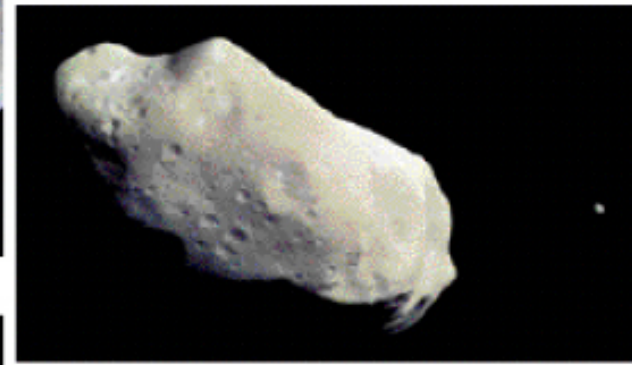


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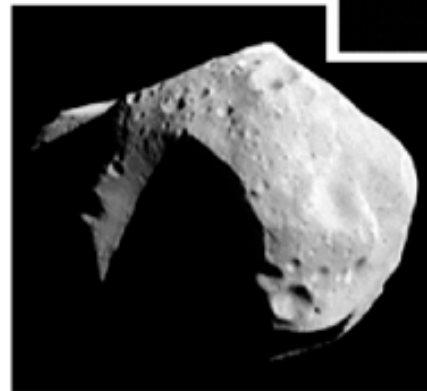
Asteroids Are Rocky Bodies with Irregular Shapes if Size < 100 km



(a)



(b)



(c)

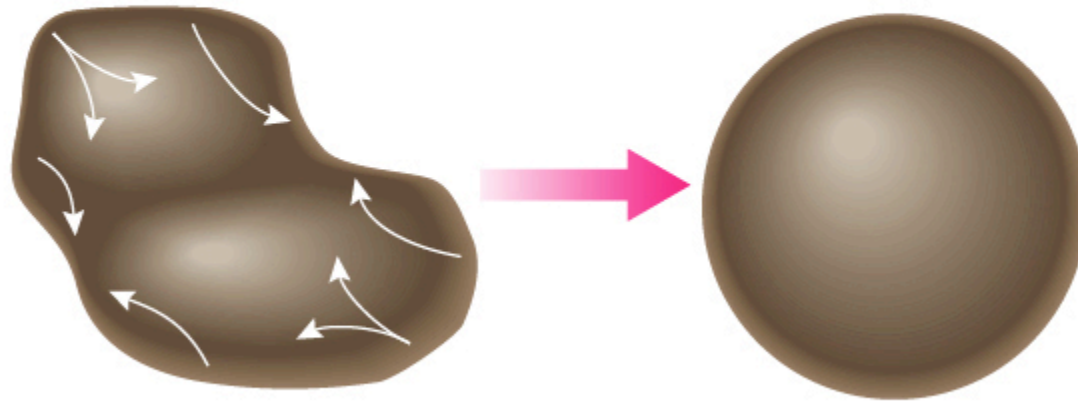


(d)

Why Rocky Objects > 100 km in Size Become Round

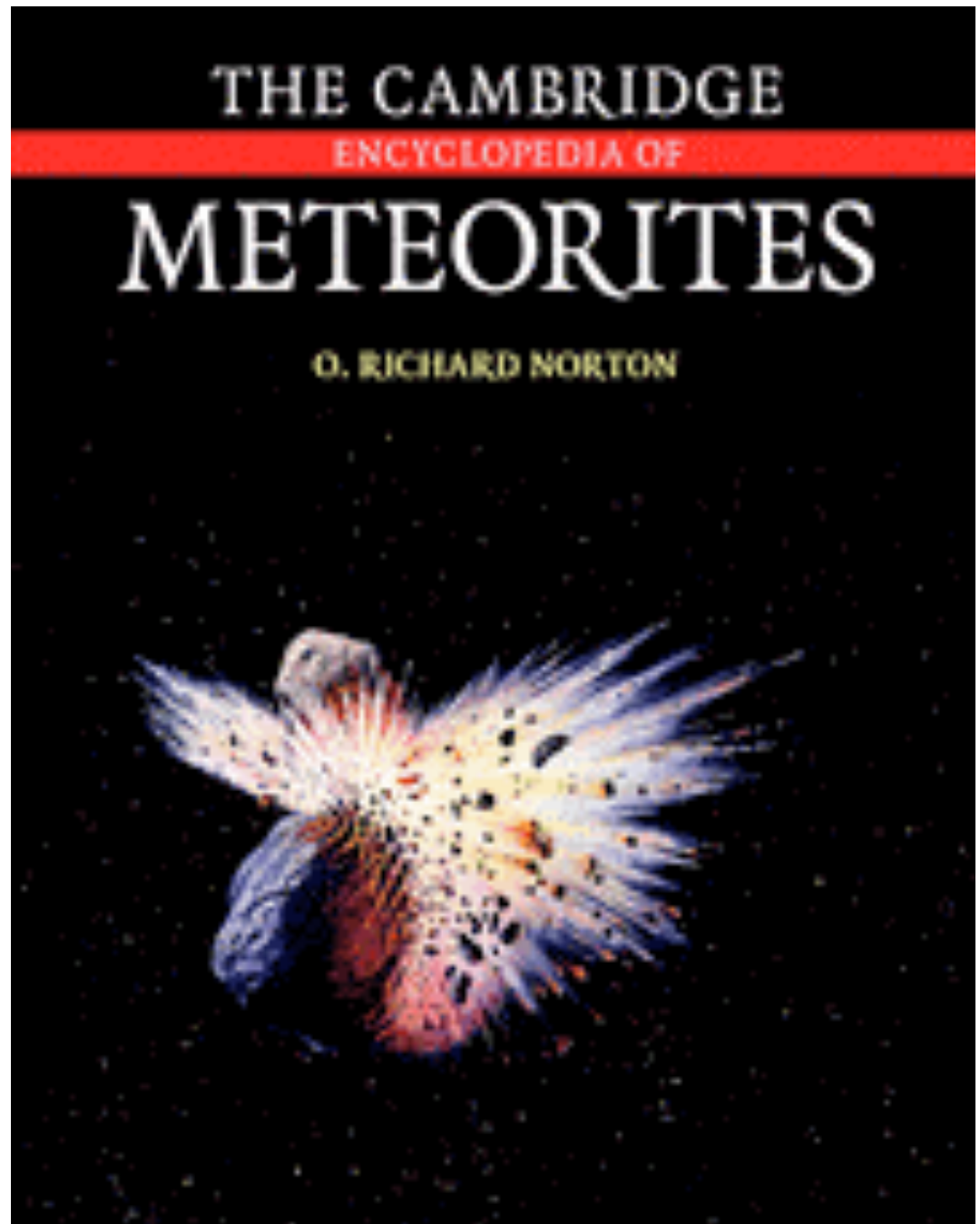


Weak gravity is unable to deform small objects.



Stronger gravity makes larger objects spherical.

Asteroids whose eccentricities have been resonantly pumped up by Jupiter may shatter rather than agglomerate into larger bodies when they collide, yielding fragments that may become meteorites if they are thrown into Earth-crossing orbits.

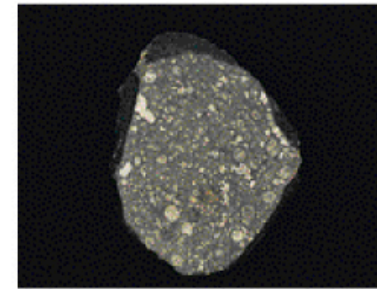
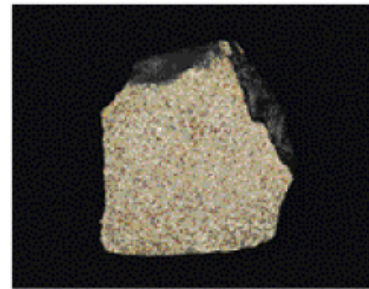


Cosmic Rock Samples Delivered for Free, Meteorites, Are Not Like Earth Rocks

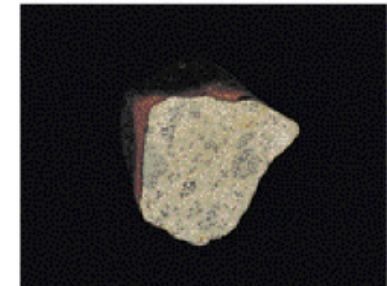
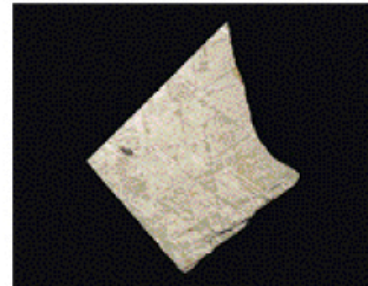


(a)

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(a)



(b)

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CAIs, Chondrules, & Matrix in Carbonaceous Chondrites Are a Strange Mixture of Hot and Cold

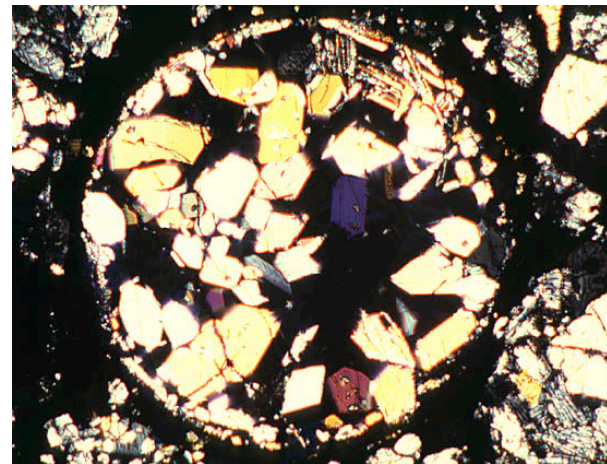


Murchison meteorite

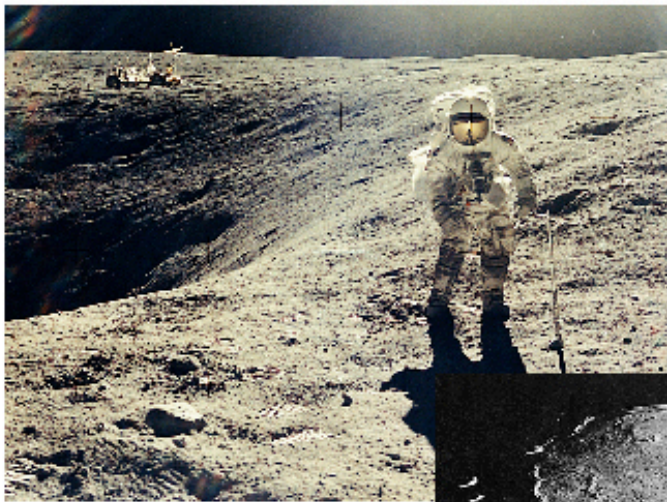
- CAIs and chondrules have been heated to temperatures high enough (2000 K or more) to melt or vaporize rocks before cooling to their present state. They are isotopically homogeneous, with mean compositions similar to the Earth, Moon, and Mars.
- The black matrix contains a mixture of thermally processed and fairly pristine material. The latter contains aqueous and organic compounds that show they never experienced temperatures in excess of about 600 K.
- Pre-solar dust grains can also be found in the matrix that have wildly individualistic isotopic and elemental compositions, indicative of material ejected from perhaps 200 disparate evolved stars that pre-date the formation of the solar system.

Chondrules Have Been Flash Heated to Melting Temperature of Rock

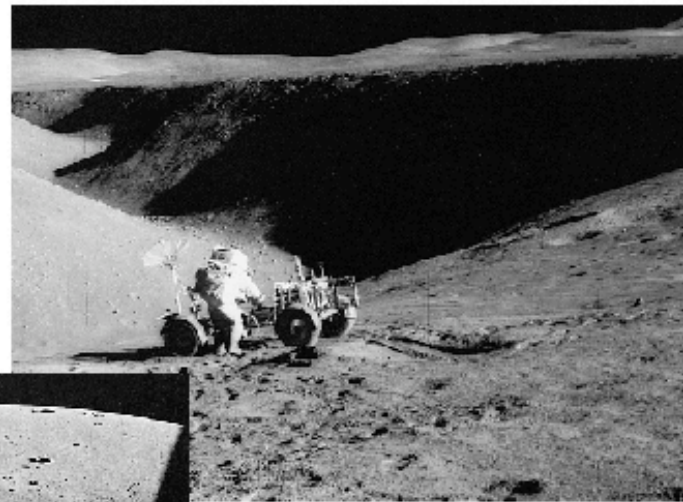
- Spherical shape (top) and crystalline nature of thin sections (bottom) indicate mm-sized chondrules have been heated to greater than 2000 K for only about an hour.
- Such temperatures and time scales are not naturally associated with regions of free space 2-3 AU from the Sun.
- Were chondrules (up to 80% of the mass of primitive meteorites and perhaps also of comets) originally made much closer to the Sun and sprayed somehow to much larger distances?
(Shades of Anaxagoras!)



Manned Missions to the Moon Brought Back Rocks that Could Be Radioactively Dated for Their Ages



(a)

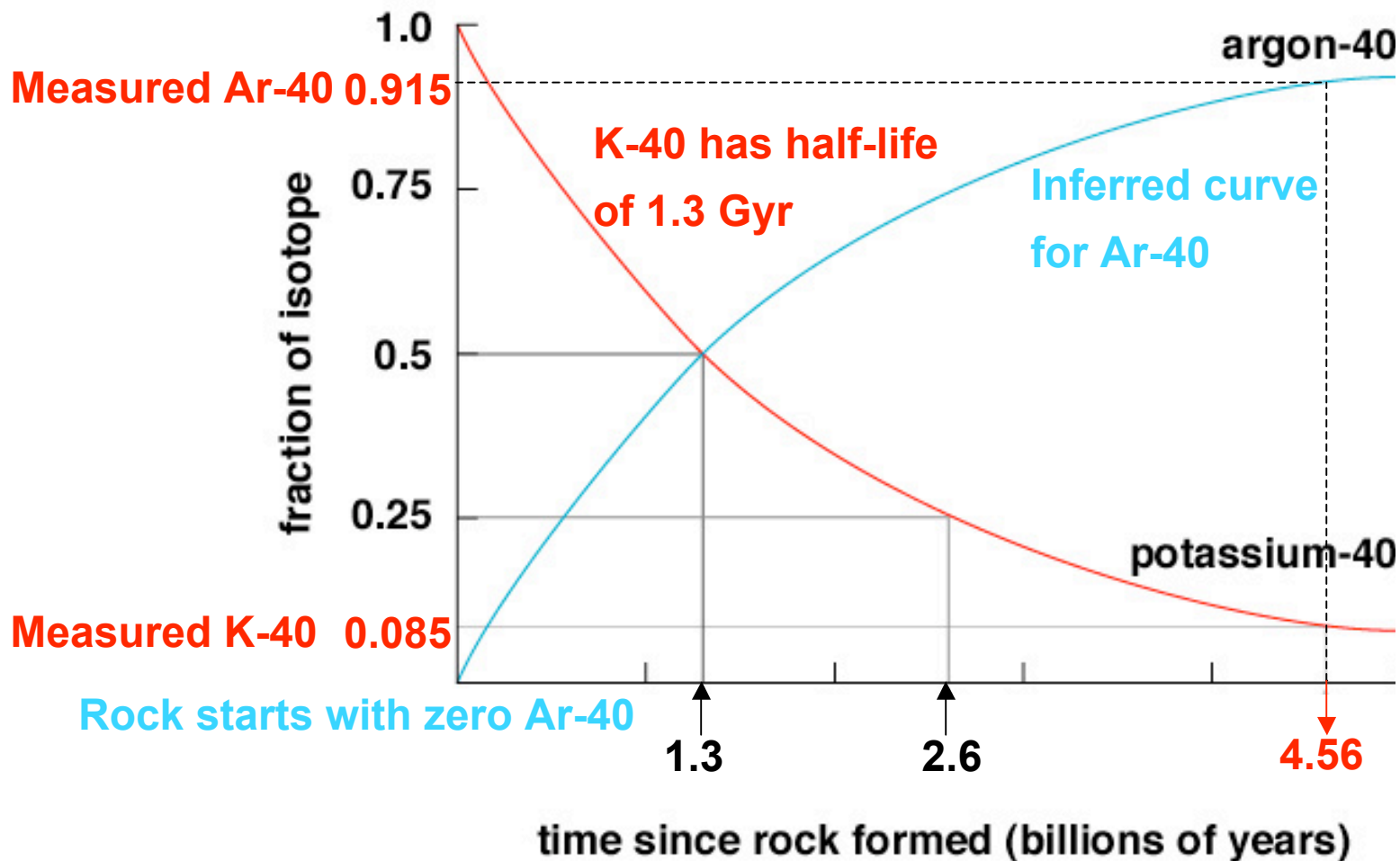


(b)



(c)

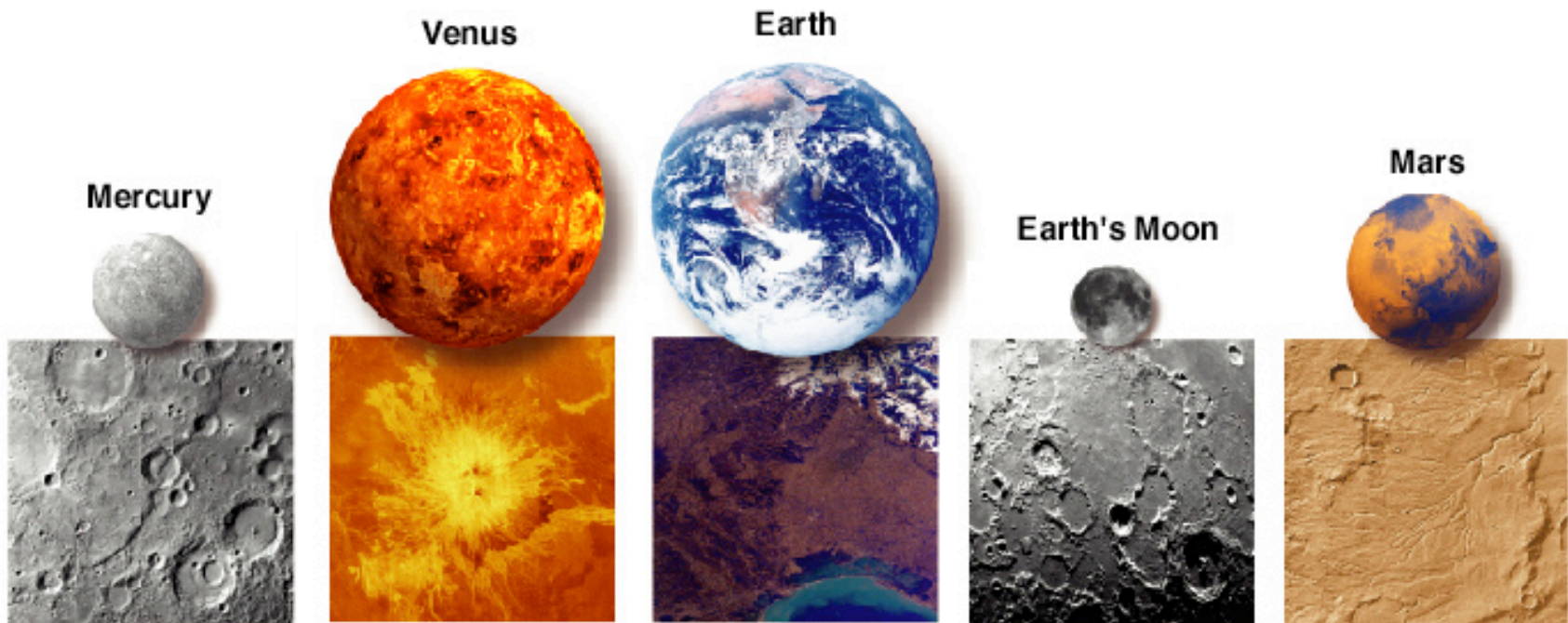
Radioactive Dating of When Rocks Solidified, Trapping Daughter Products of Radioactive Decay



Oldest ages of rocks on Earth and Moon date 3.8 and 4.4 GYr.

In contrast, CAIs in all chondritic meteorites have a single age 4.56 Gyr. Last is taken to be age of Sun and solar system.

Terrestrial Planets Are Rocky and Round



Of the Planets, Only the Earth Has Oceans and is Known to Harbor Life



Photo Credit: NASA/JPL/USGS Flagstaff

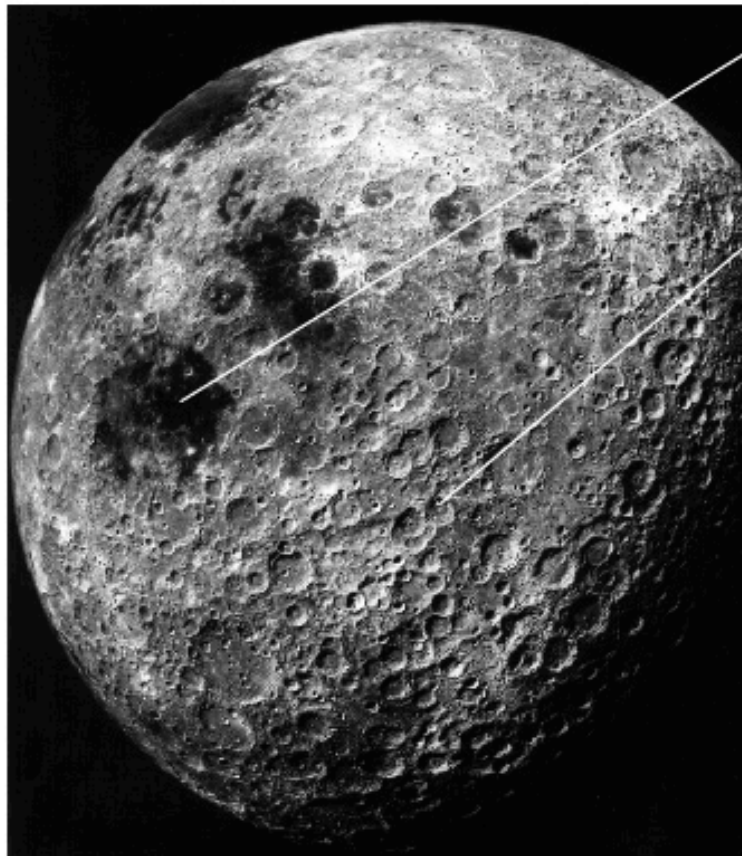
Among Terrestrial Planets, Only the Earth Has Active Plate Tectonics



(a)

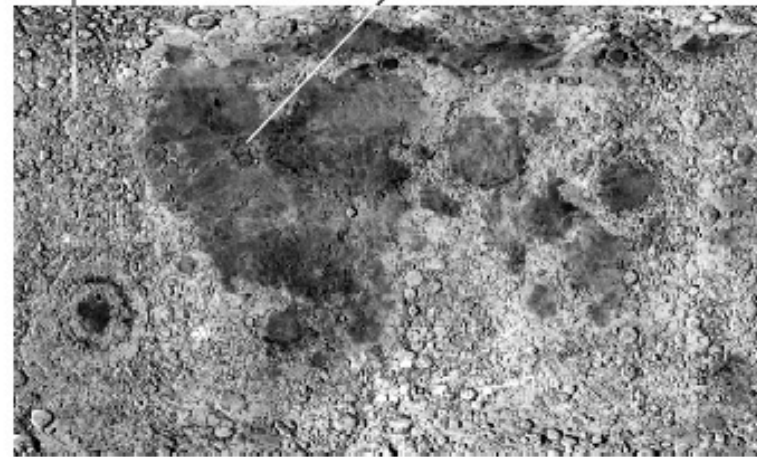
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Among Terrestrial Planets, Earth also Uniquely Has a Large Moon



Lunar Maria are huge impact basins that were flooded by lava. Only a few small craters appear on the maria.

Lunar highlands are ancient and heavily cratered.



(a)

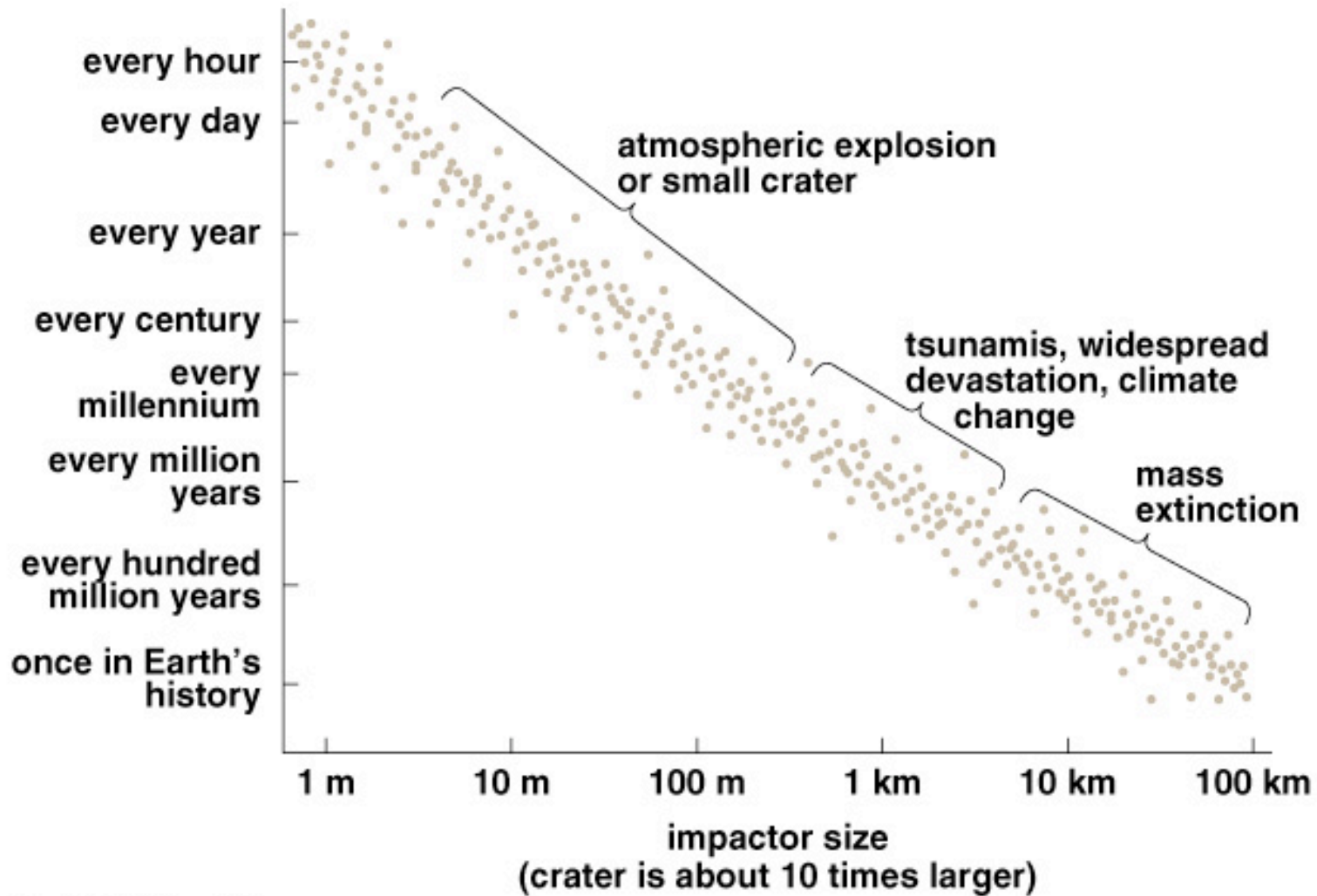
The Earth Has Fewer Visible Craters Because of Weathering and Erosion



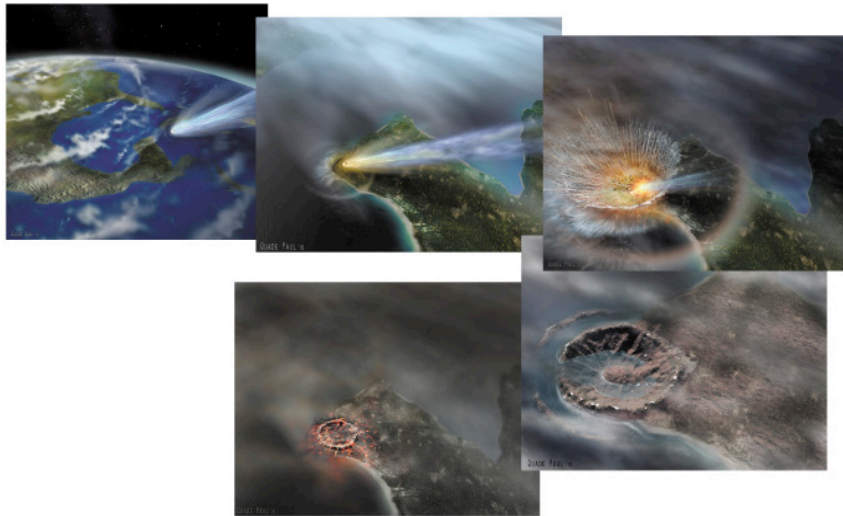
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Meteor Crater in Arizona

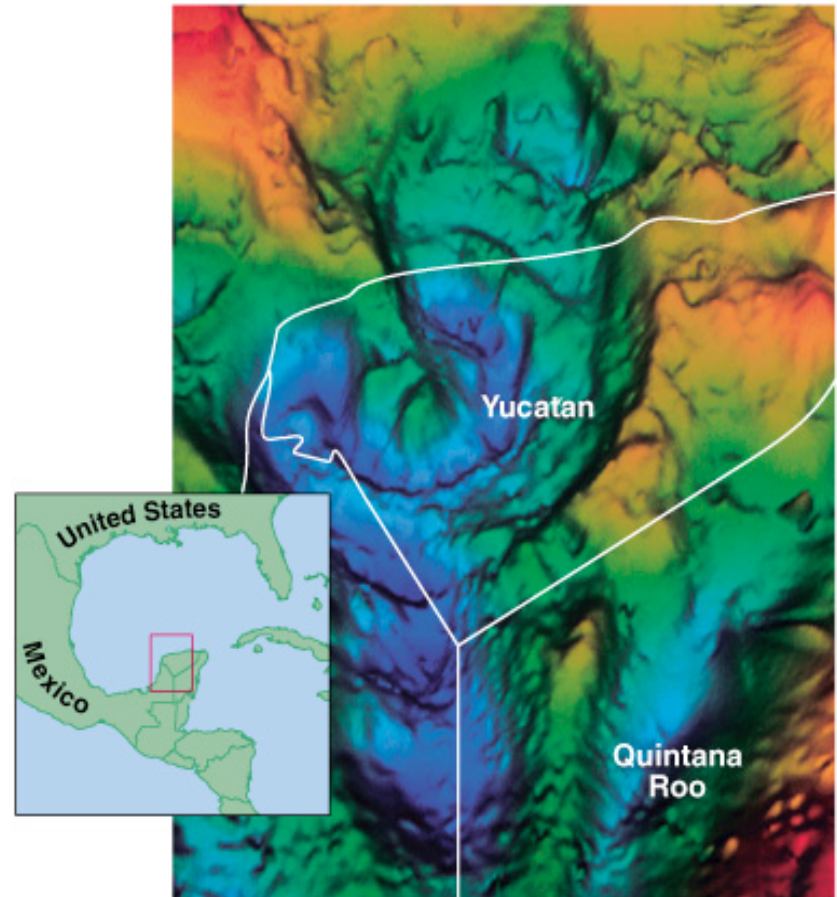
Crater Coverage and Age Dating of Lunar Rocks Calibrates Frequency of Meteor Impacts on Earth



On Earth 65 Million Years Ago, A Giant Impact Killed the Dinosaurs



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Extinction of the Dinosaurs



Iridium Layer Laid Down 65 Million Years Ago



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Iridium, common in meteorites, is uncommon on surface of Earth (all carried into iron core).

Zodiacal Dust and False Dawn Associated (mostly) with Gradual Accumulation of Comet Trails



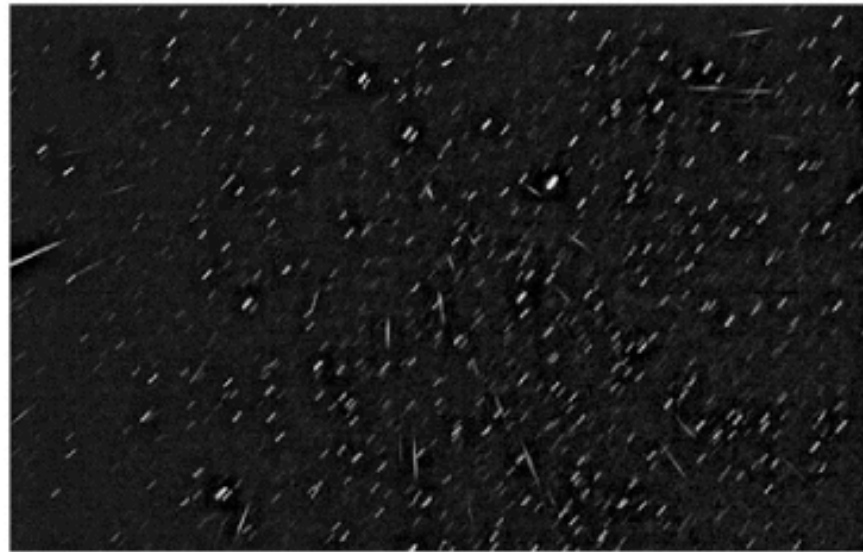
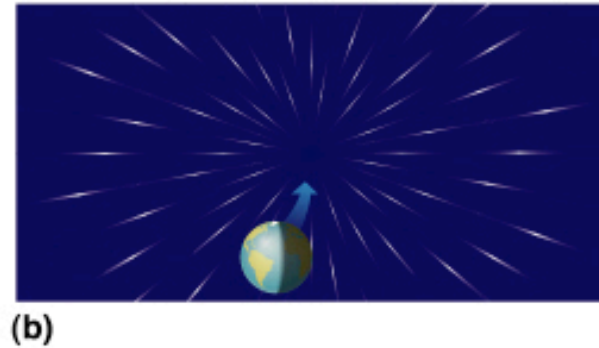
Photo Credit: P. Kalas

Meteor Showers from Space Debris Left by Comets and Asteroids

Table 12.1 Major Annual Meteor Showers

Shower Name	Approximate Date
Quadrantids	January 3
Lyrids	April 22
Eta Aquarids	May 5
Delta Aquarids	July 28
Perseids	August 12
Orionids	October 22
Taurids	November 3
Leonids	November 17
Geminids	December 14
Ursids	December 23

A Meteor Shower



Geminid Shower, Dark Site, Before Moon Rises on Evening of Dec 13

