Announcements

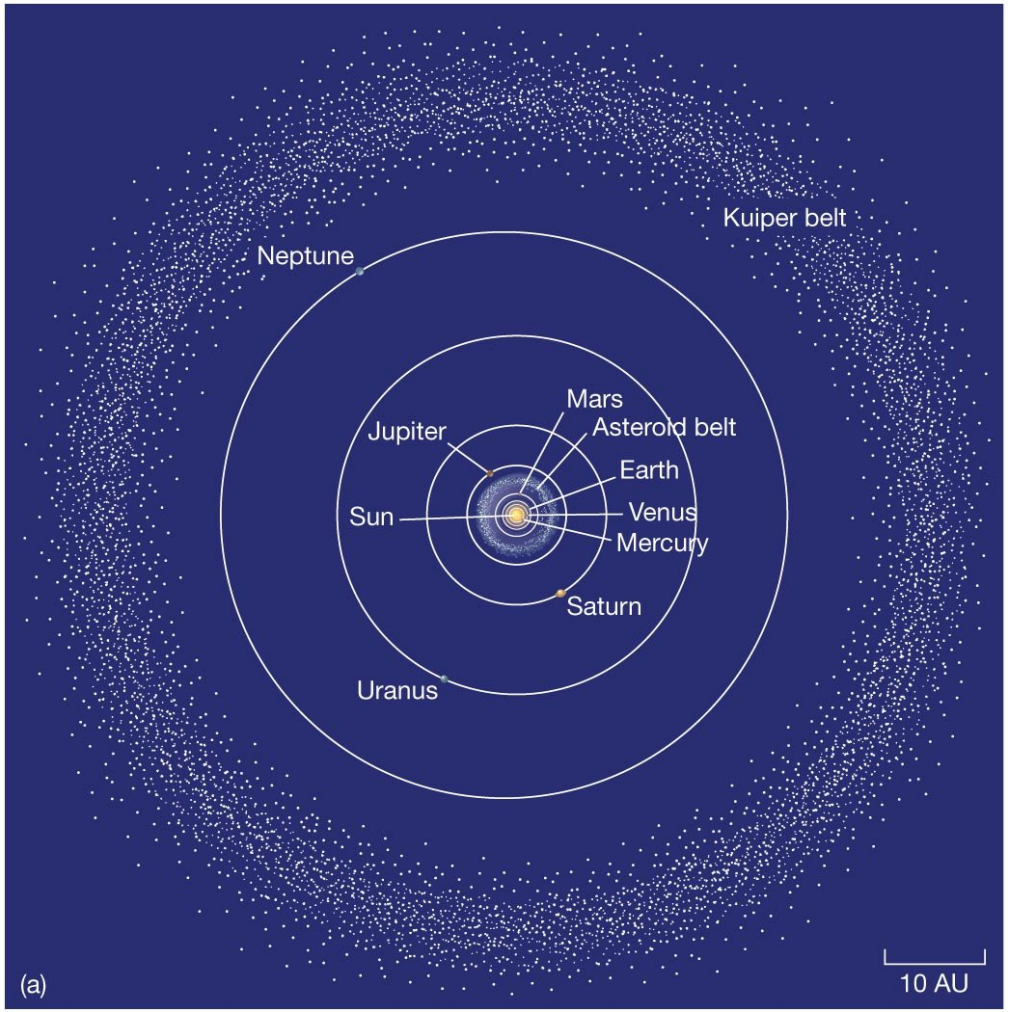
- Today: Chapter 4, 6, 7: Solar System, Planets
- Midterm #2: October 29
  - covers Chapters 3 (Telescopes) and 9-12 (Sun, Stars, Interstellar Medium, Stellar Evolution)
  - Same rules as mid-term #1 (no books, notes, calculators)
  - formulas and relevant constants given
  - Review coming Monday, October 27
- After midterm: Extrasolar Planets and planetary highlights, Galaxies and Cosmology
- Don't forget to hand in your extra credit news summary!

An Inventory of the Solar System

Early astronomers knew Moon, stars, Mercury, Venus, Mars, Jupiter, Saturn, comets, and meteors.

Now:

- 1 star
- 8 planets (add Uranus & Neptune)
- 166 moons
- >660,000 asteroids
- comets, meteoroids
- ~50 dwarf planets,
- Kuiper Belt objects



History of the Solar System

We want to understand the history of the solar system

However, large bodies like planets evolve

Volcanism, erosion, plate tectonics…

So it is important to look at things that hold a better record of the past: small bodies that don't change much

The small bodies that have the best clues are **asteroids, comets, meteoroids** (coming from asteroids and comets) and **plutoids**

The age and chemical composition of these things can tell us about the early solar system

Asteroids

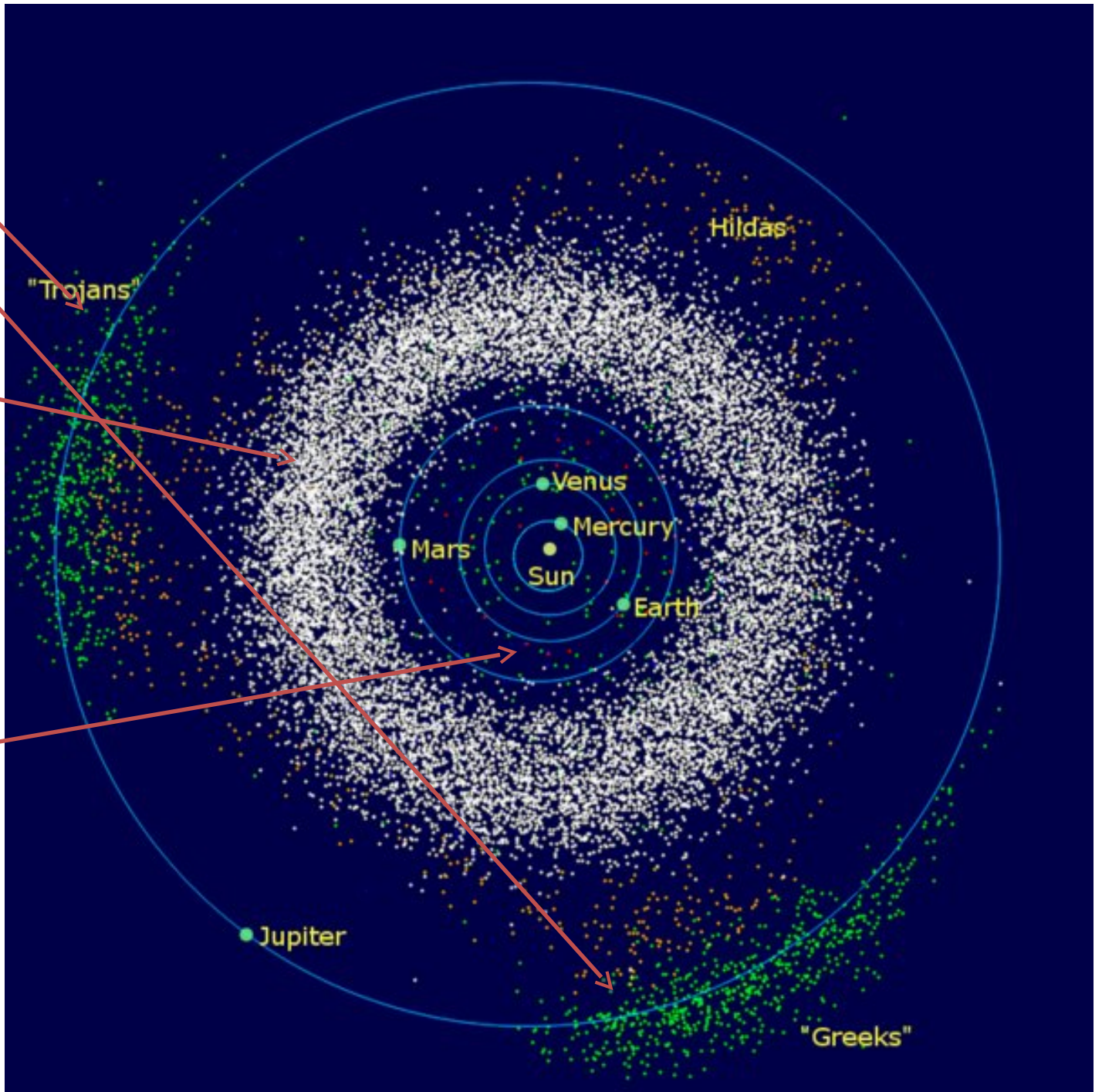
- Rocky bodies that are held together by gravity and internal forces
- Most live in a belt between Mars and Jupiter at 2.8 A.U. called the asteroid belt
- about 100,000 rocky objects bigger than 1 km exist
- Ceres is the largest asteroid with a diameter of ~1000 km
- A few thousand have orbits that cross Earth's orbit – called near-Earth asteroids (NEAs)
- Some are near Jupiter (60 degrees ahead and behind) and are called Trojans

Asteroids

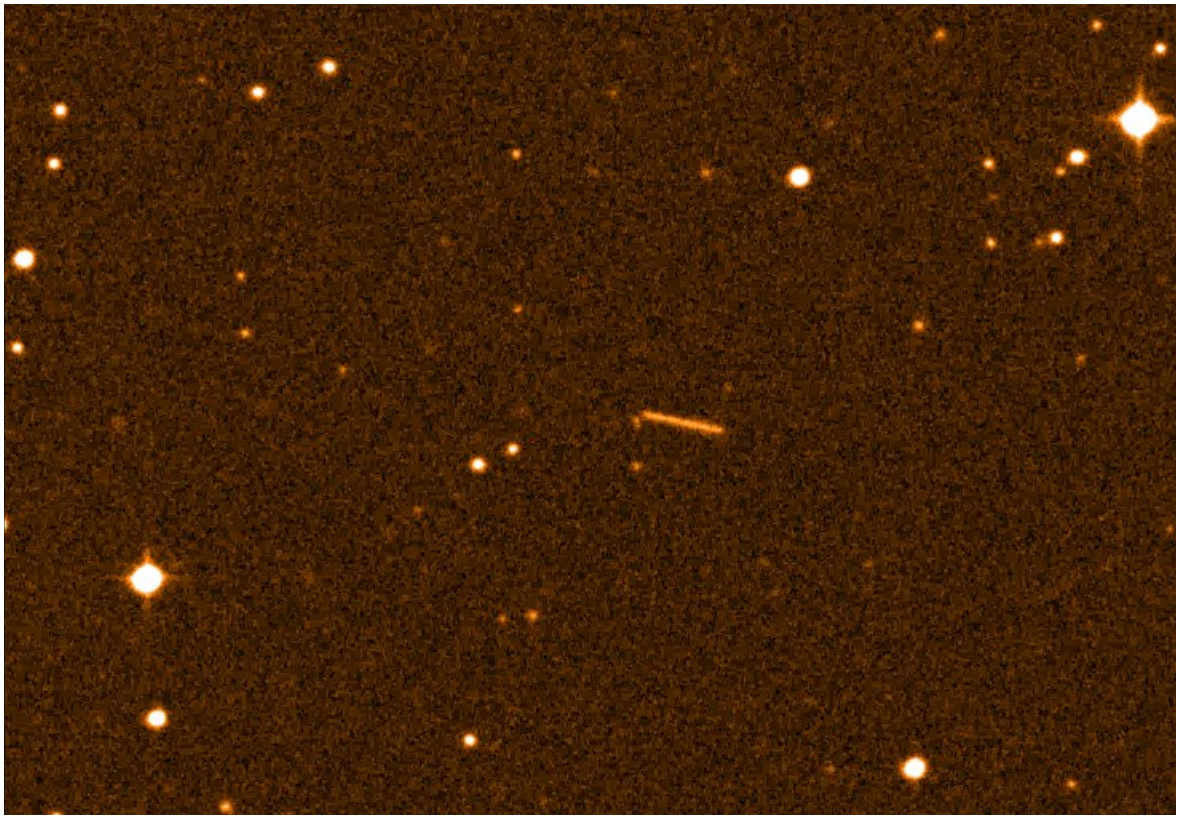
Trojans

Asteroid Belt

Near Earth Asteroids



Asteroids are faint because they shine only in reflected light and they are small. But they can be differentiated from stars because they move.



Over a long exposure, they appear as streaks.

Searching for asteroids at UW

Small team at WIYN Observatory and UW-Madison and follow up near-earth objects to refine orbits

Detect new asteroids in same data

Asteroids

- Their composition is not well known, but it is believed that some of them have iron cores and rocky or icy exteriors, or are rocky all the way through.
- Some are dark and have lots of water ices and organic material on the surface – known as carbonaceous asteroids
- Others are more reflective and are mainly bare rock – known as silicate asteroids
- Total amount of mass in asteroids is about the mass of the Moon

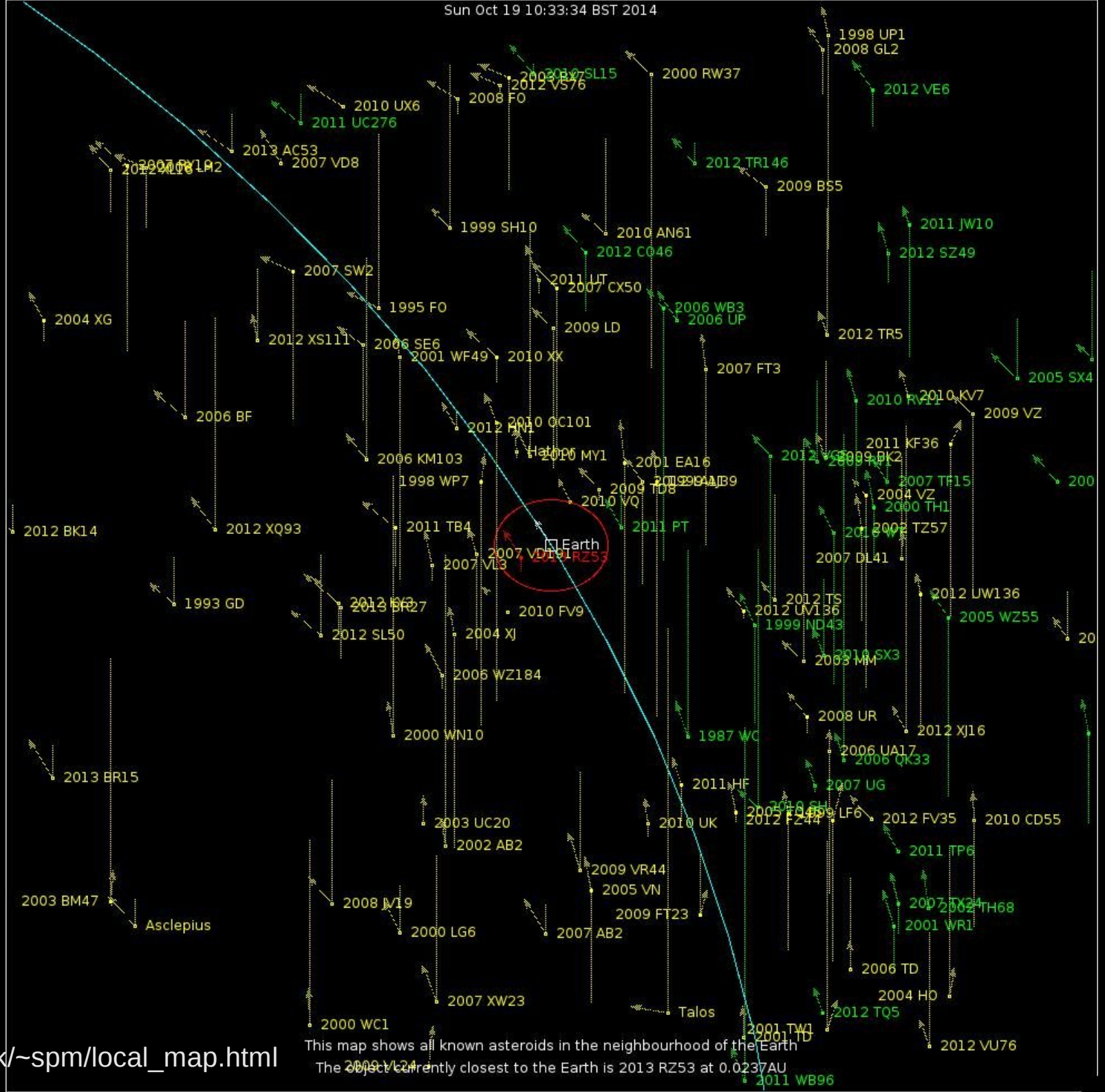
Asteroids – Why do we care?

- Asteroids are left-over material from formation of the solar system
  → ideal laboratory to study formation of earth and other planets
- Potential source of water on earth

Asteroids – Why do we care?

- Derive orbits to predict close encounters to earth and prevent armageddon.

Source: http://www.kotaku.com.au/2013/05/japan-has-an-insane-number-of-armageddon-flicks/



Source:
http://szyzyg.arm.ac.uk/~spm/local_map.html

Asteroids in the Inner Solar System

Green dots represent objects which do not approach the Earth at present e.g. Main Belt asteroids

Yellow dots represent objects which approach the Earth but do not cross its orbit e.g. Amor asteroids

Red dots represent objects which cross the Earth's orbit e.g. Aten and Apollo asteroids

Source: http://www.arm.ac.uk/neos/anim.html


Barringer Crater, Arizona: 1 km across, from a 50 m
iron meteor landing about 50,000 years ago

The Manicouagan reservoir in Quebec

Giant Impact: Tunguska

Tunguska explosion 1908: result of a 30 m meteor which exploded above the ground.

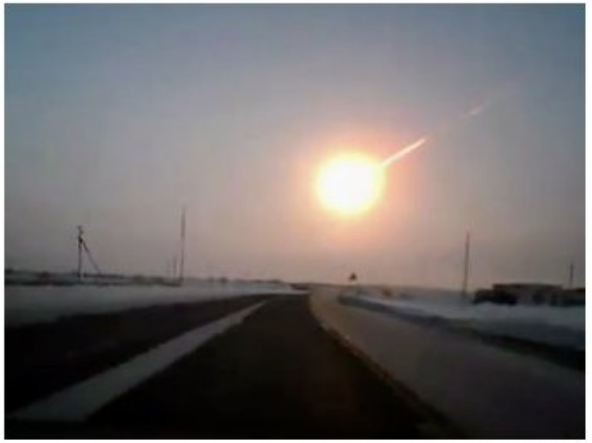
Exploded with the power of a 10 megaton nuclear bomb.

Fortunately hit in Siberia.

Russian meteor of February 15, 2013

The New York Times

Friday, February 15, 2013 Last Update: 9:42 AM ET



www.ng.kz, via Associated Press

Pieces of Possible Meteorite Hit Siberia

By ELLEN BARRY and ANDREW E. KRAMER 8:48 AM ET

Hundreds of injuries were reported after bright objects streaked through the sky in Chelyabinsk, above, accompanied by a loud boom that damaged buildings.

· The Lede: Video of Object Believed to Be Meteorite 6:13 AM ET

LIVE VIDEO, 10 AM ET

Richard P. Binzel, a Massachusetts Institute of Technology professor, discusses the event in western Siberia.

theguardian

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Breaking news: Flights canceled as strikes hit 2 Gerr

Meteor explodes dramatically over Russian Urals, injuring 950 – live updates

LIVE Reports conflict over whether it was a single meteor or a meteor shower that struck over Chelyabinsk region, breaking windows

231 comments

Hundreds hurt in meteor explosion over Chelyabinsk

The Washington Post

41° Washington, DC February 15, 2013 Edition: U.S. | Regional Make us y

ival Triumph Eye implant Chuck Hagel Oscar Pistorius

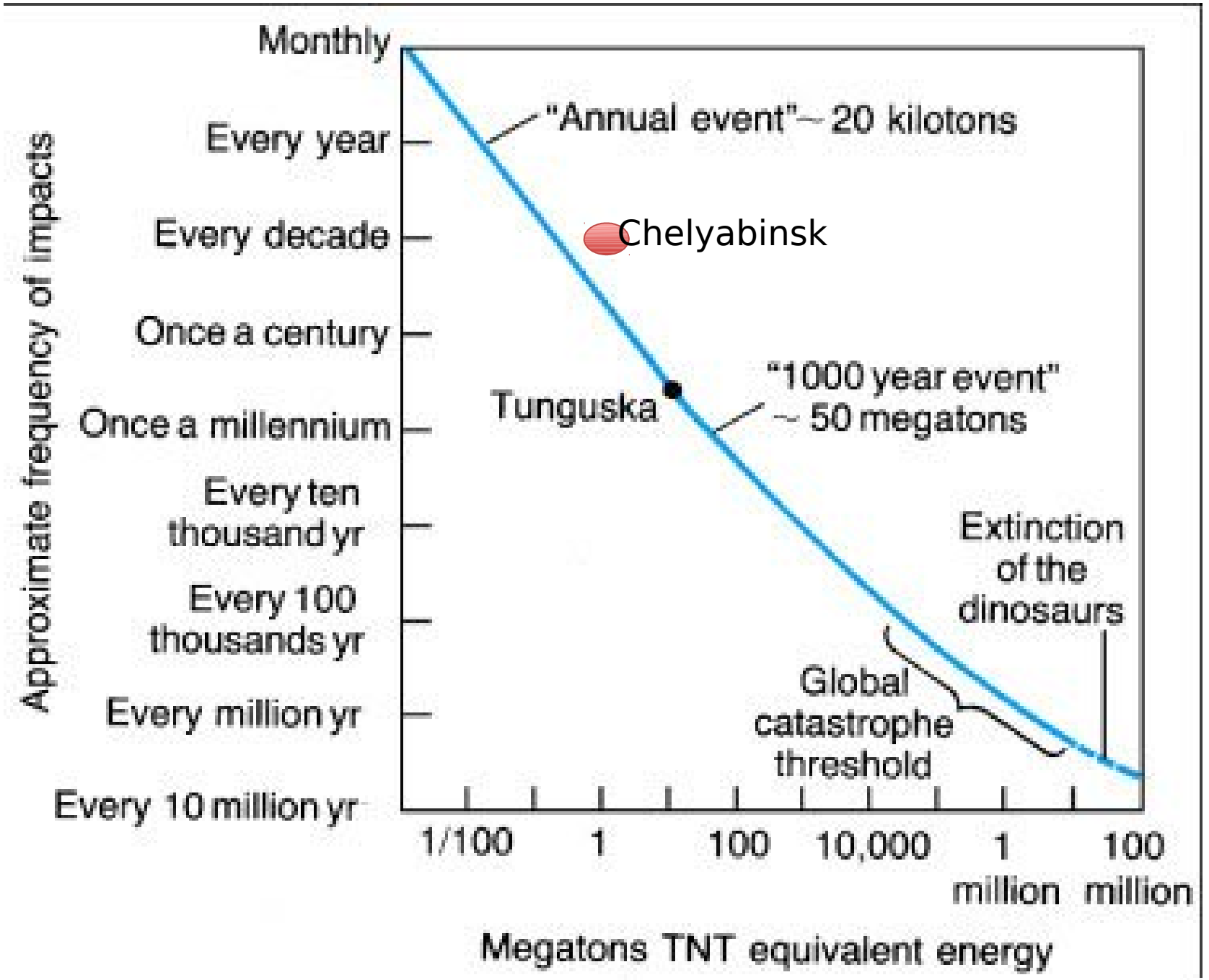
Sonic blast injures more than 900

Will Englund 8:13 AM ET

Windows shattered and roofs collapsed as an apparent 10-ton meteor streaked across the sky at up to 12 miles per second.

· 'We saw a big burst of light'

Giant Impacts and Mass Extinctions

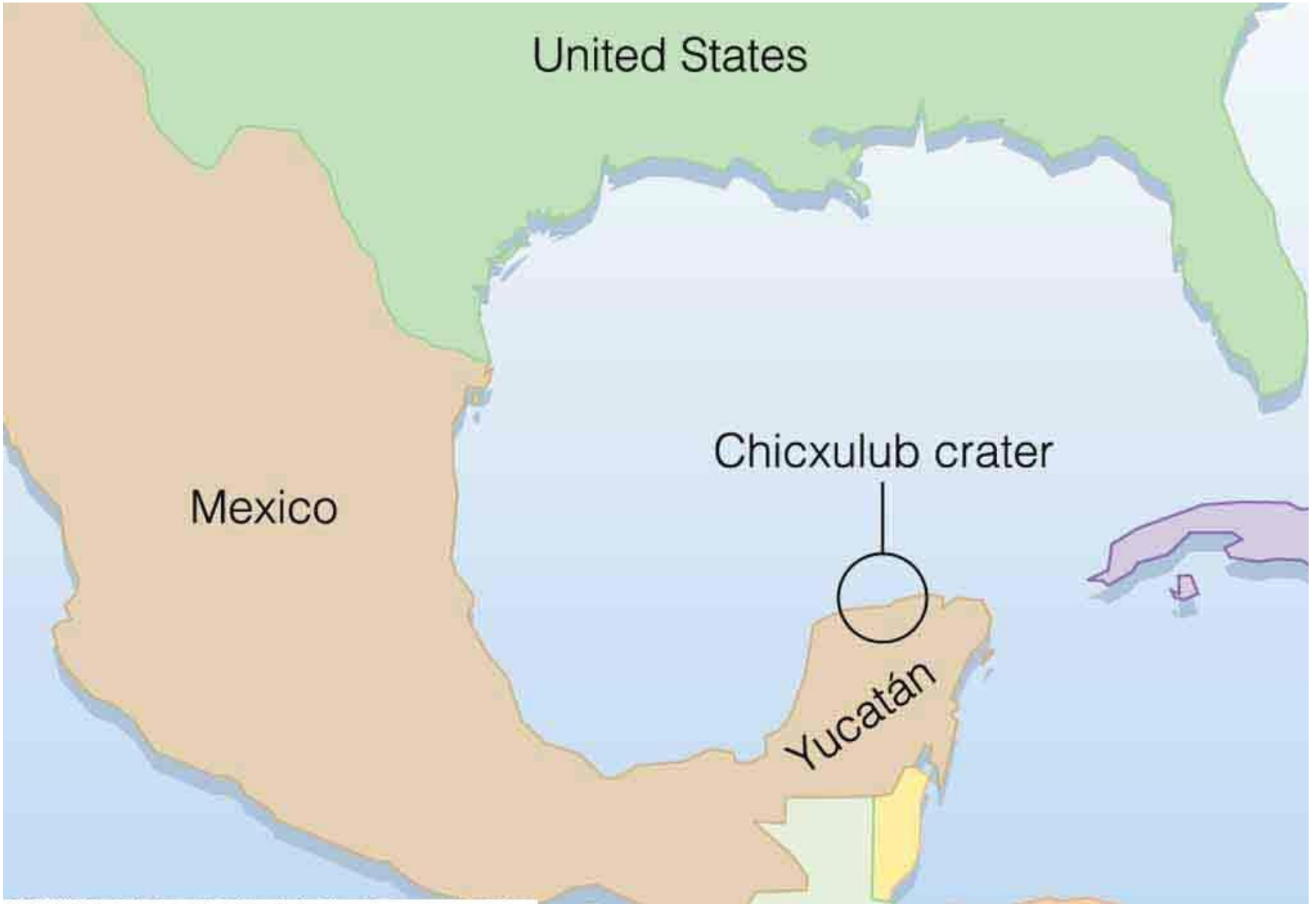


Giant Impacts and mass extinctions

A widely accepted hypothesis is that an impact of a 10 km asteroid hit the Earth 65 million years ago and killed off the dinosaurs.

A layer of iridium is found in 65 million year old rock sediments worldwide – iridium is rare on Earth because it sank to the center, but found in meteorites

A crater of the right age and size has been found in the Yucatan peninsula in Mexico: the **Chicxulub crater**.



Giant Impacts and mass extinctions

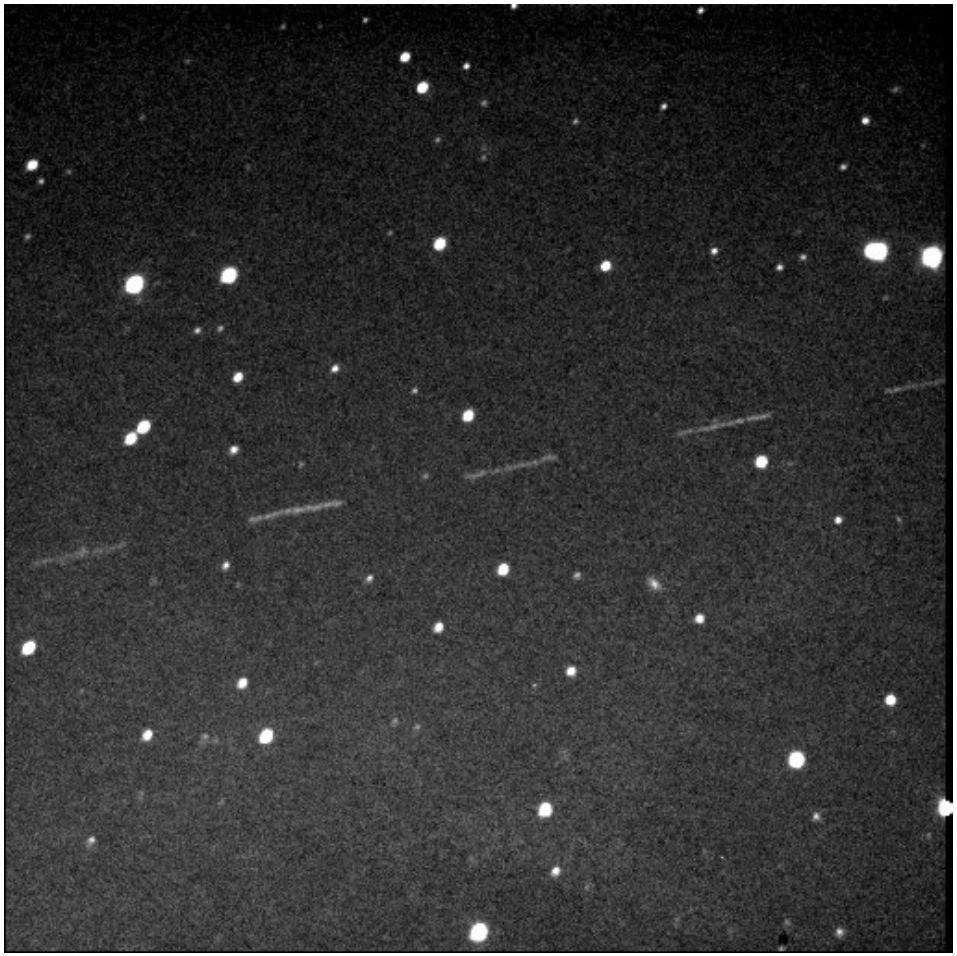
- Such an impact would have generated mega-tsunamis kilometers high – seen in fractured rocks that are piled in regions around the impact site
- Material thrown up from the impact would re-enter the Earth's atmosphere around the world and heat the surface up to a temperature of 400+ degrees – triggers world-wide forest fires
- Production of dust and sulfate would block out the sun for years and bathe the Earth in acid rain – death of many plant species, and bad news for the food chain

Giant Impacts

- To help understand the threat of Earth-crossing objects, we need to find all of them.
- One such effort is the Catalina sky survey being run in Arizona
- Uses a bunch of (relatively) small telescopes to look for near-Earth asteroids.

Giant Impacts

- First detection of an rock that actually hit the earth (2008 TC3)
- Detected it on Oct 6 2008 – 20 hours before impact.



Giant Impacts

- Hit the earth on Oct 7, 2008 in Northern Sudan
- Exploded with a force of 2.1 kilotons (1/5 of the Hiroshima bomb)
- The fragments were collected by geologists who flew into the area

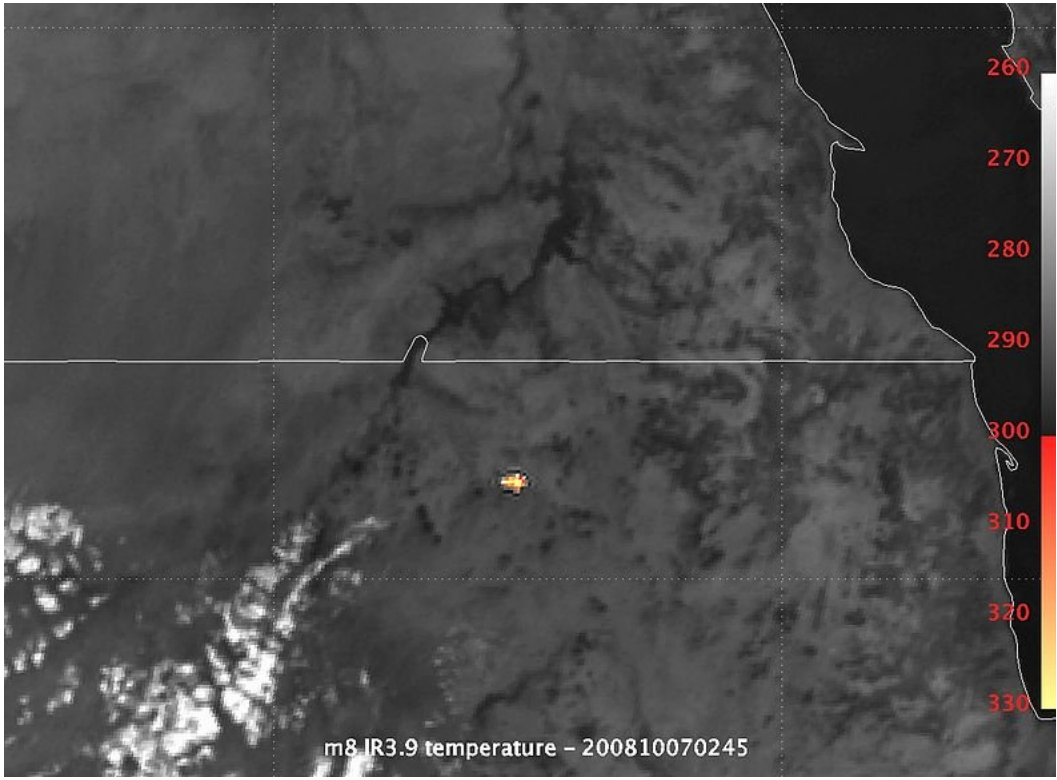
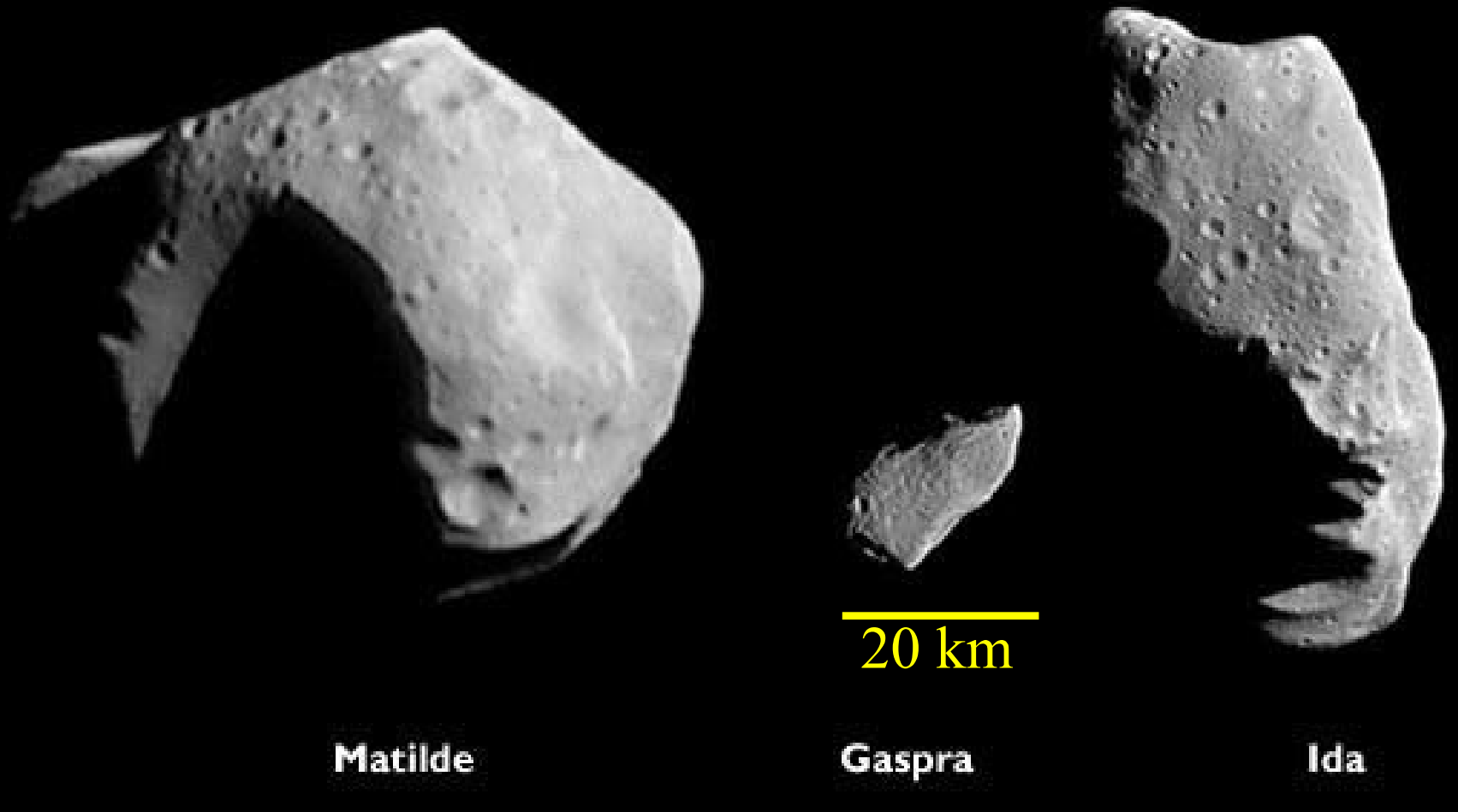


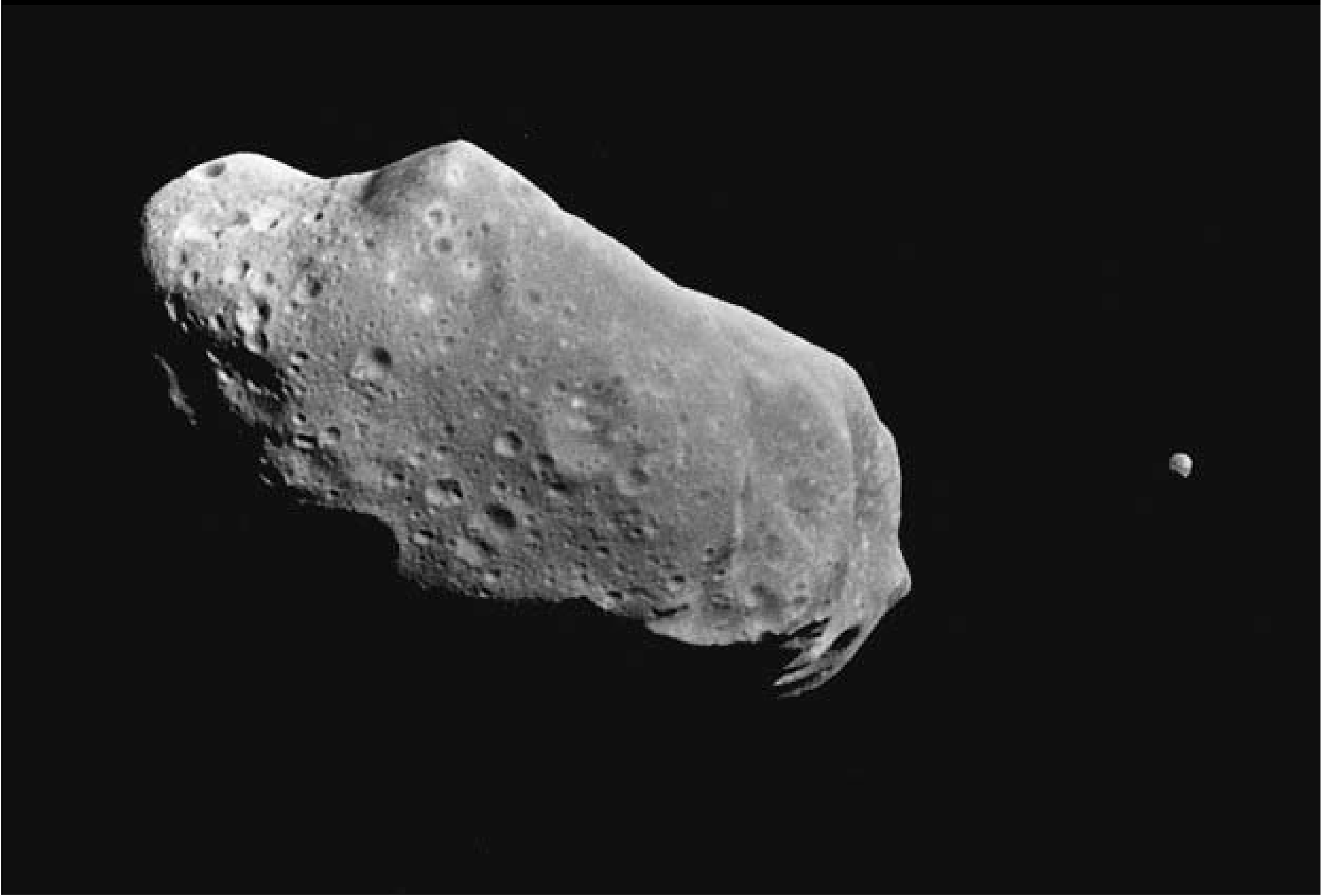
Image Source: Wikipedia

The first close-up photos of asteroids

(photos taken by Galileo in ‘91, NEAR in ‘97)



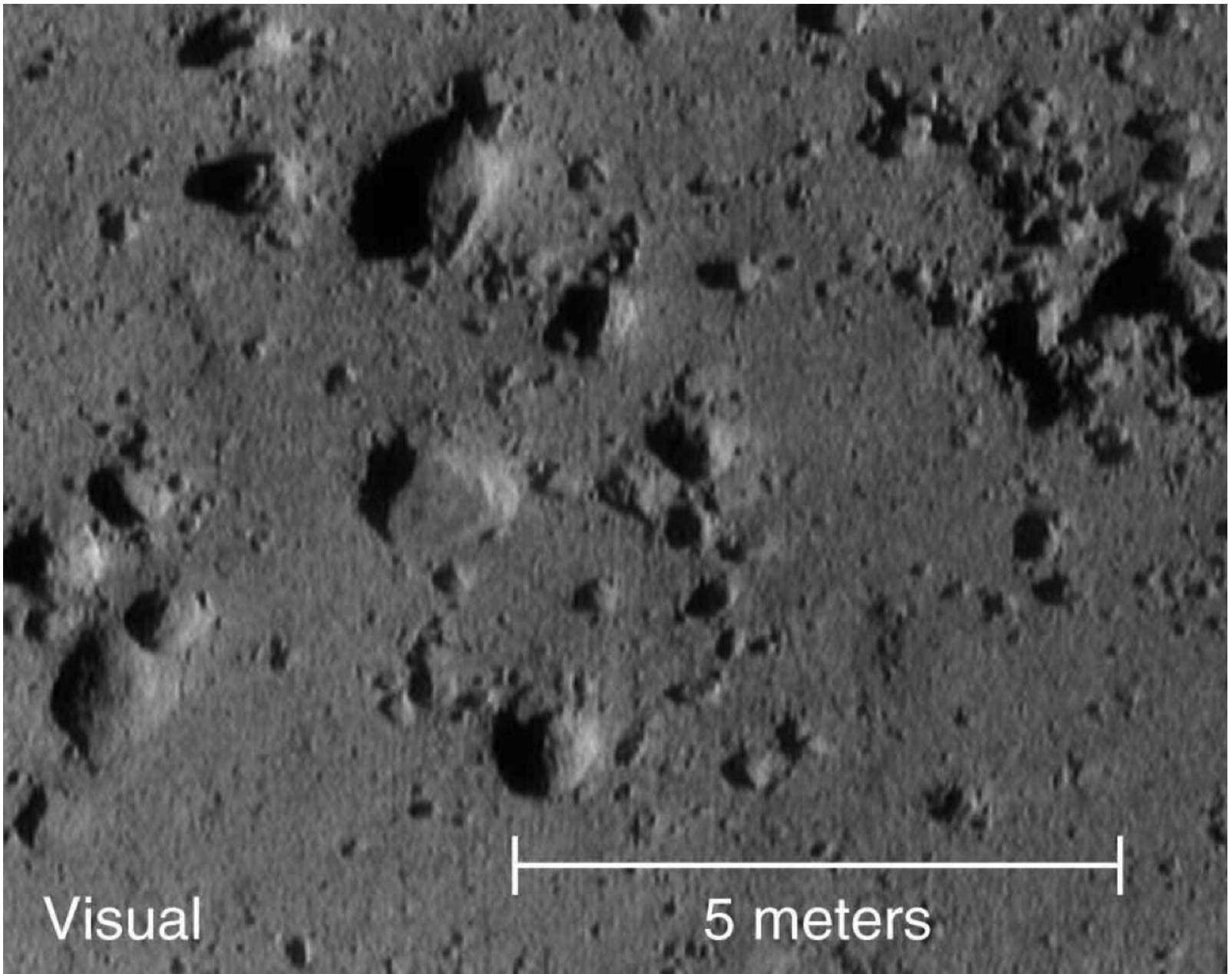
Ida and its moon Dactyl (Dactyl is about 1 km across)



More Asteroid Properties

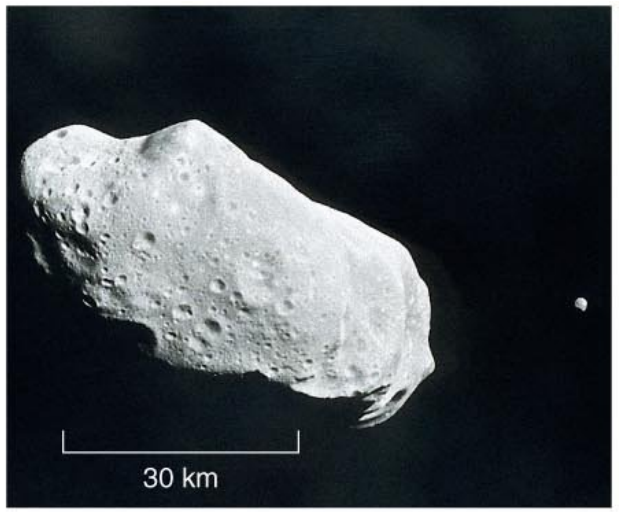
- Measurements of their density from Galileo (the space probe) and NEAR (Near Earth Asteroid Rendezvous) gives asteroid densities from 1000 – 3000 kg/m^3
- Remember that the terrestrial planets have densities of about 5000 kg/m^3
- This means that while these object are rocky, they are probably very porous – sometimes referred to as “rubble piles”
- Might be important to know if you want to stop a killer asteroid

Picture from NEAR/Shoemaker spacecraft right before landing/crashing on an asteroid



Asteroids and Meteoroids

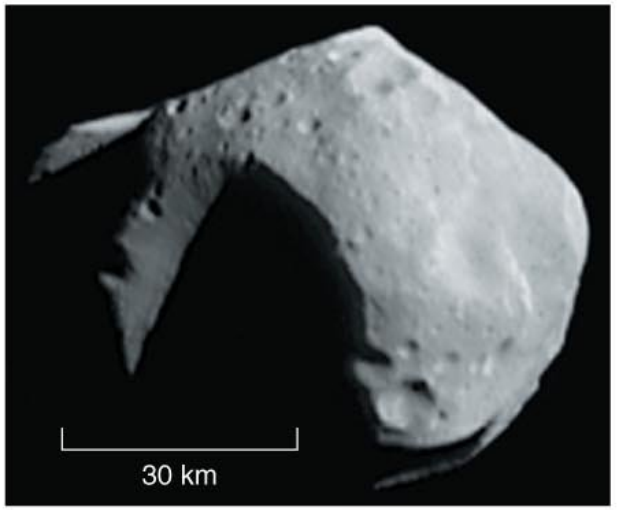
Asteroids and meteoroids have rocky composition; asteroids are bigger.



(b)

Asteroid Ida with its moon, Dactyl

Asteroid Mathilde



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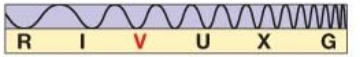
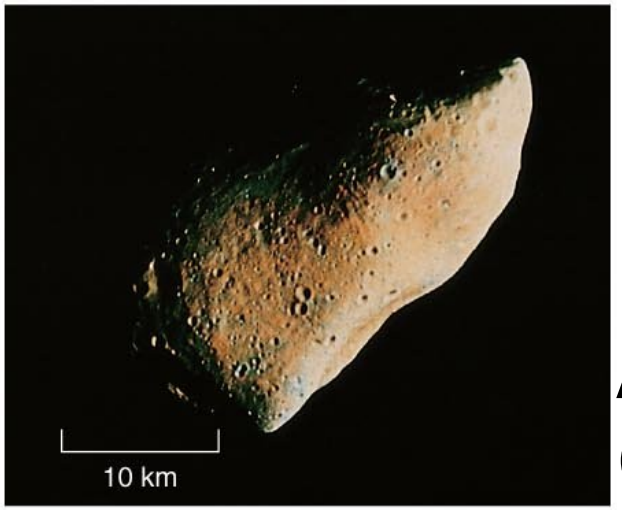




(a)

Asteroid Gaspra

Comets

- Icy bodies – called “dirty snowballs” – made of rocks, water ice, frozen methane, frozen ammonia, and frozen carbon dioxide
- ~1 – 10 km in size.
- When they pass close to the sun, the ices sublimate: solid → gas. Blows out a halo of gas and rocks (pebbles), which is called a **coma**
- Sunlight and the solar wind push on the gas and dust blowing the tail away from the sun
- Comet tails point away from the sun, NOT opposite of direction of motion

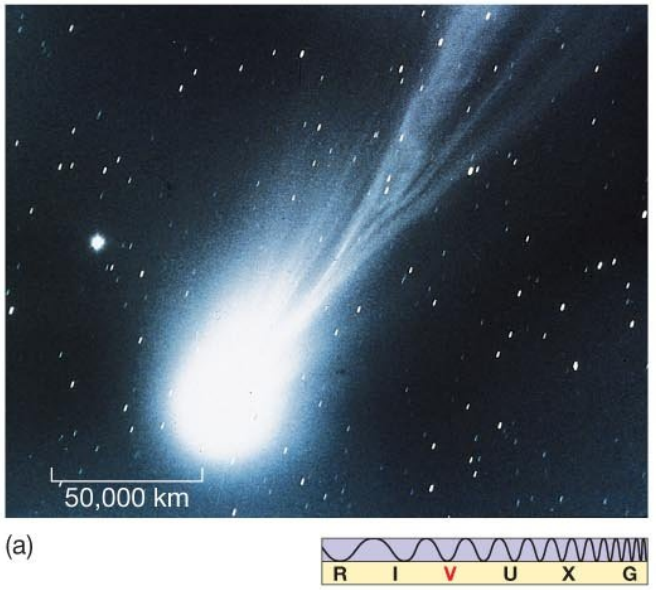
Comets

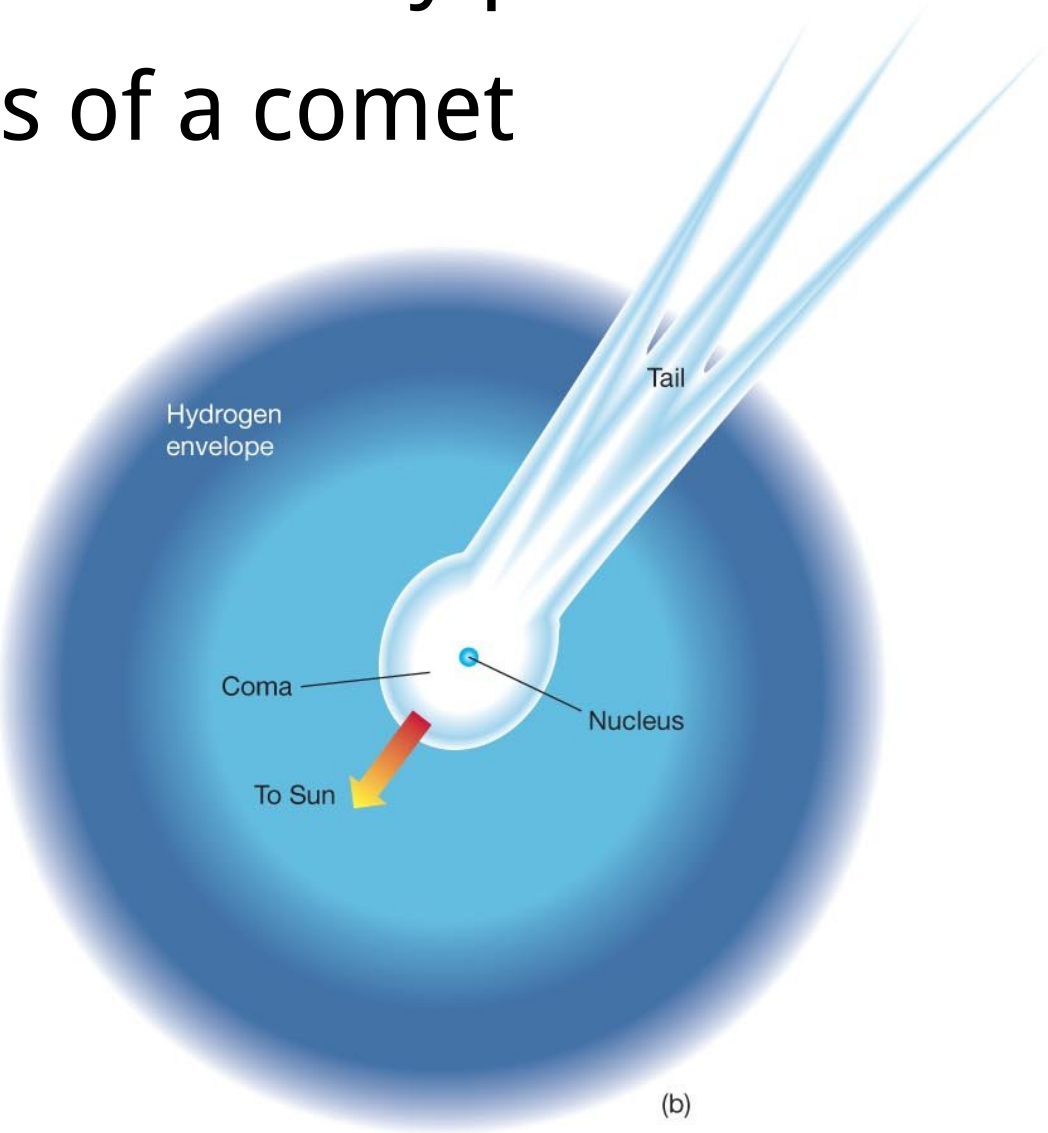
- Consist of the **nucleus** – main solid body of the comet
- And the **coma** – diffuse halo of gas and dust around it
- Very low density ~ 100 kg/m^3 << water ice (1000 kg/m^3), so they are loosely packed snowballs
- Orbits are typically 1000s of years and originate far beyond the orbit of Pluto in the **Oort cloud**.
- Short period comets (<200 years) originate in the region near Pluto known as the **Kuiper belt**

Comets

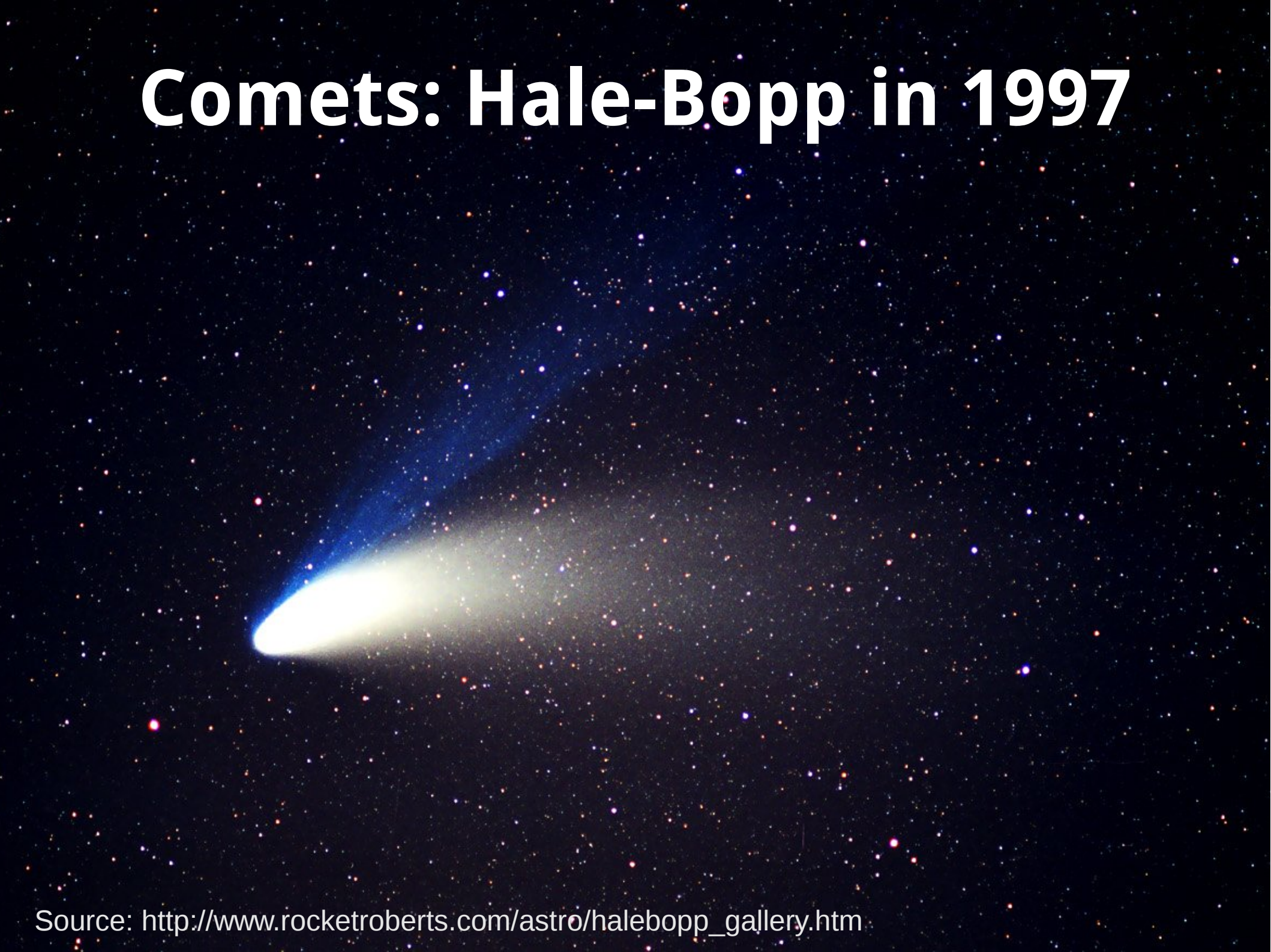
Comets are icy, with some rocky parts.

The basic components of a comet





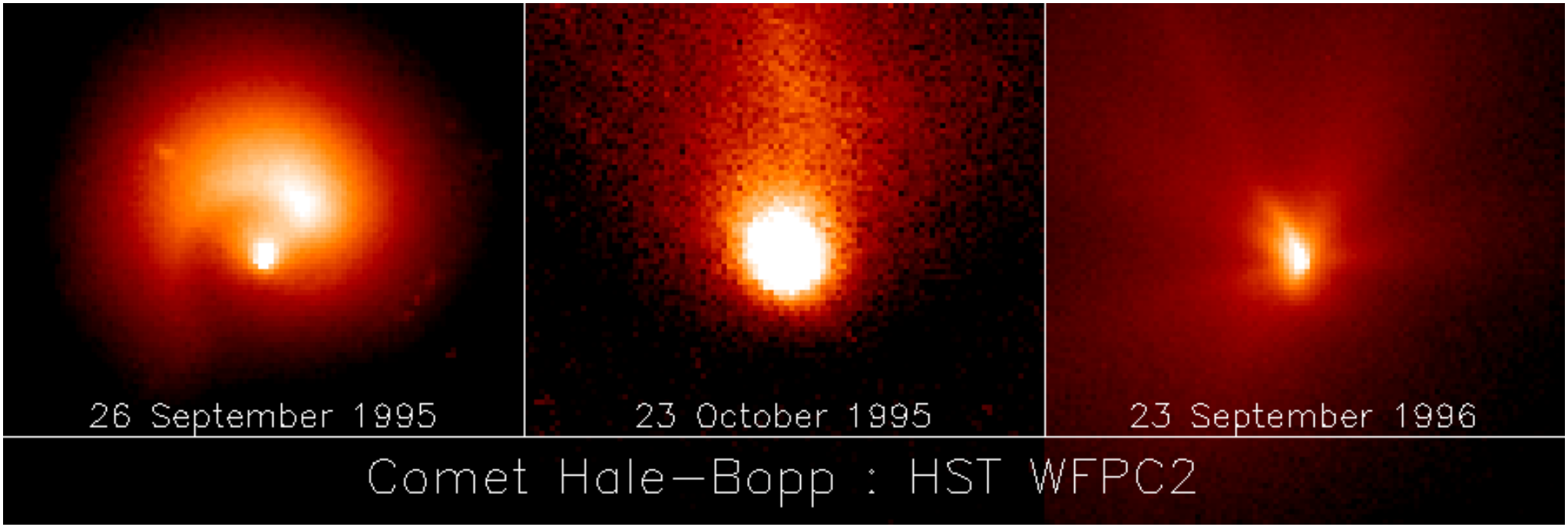
Comets: Hale-Bopp in 1997



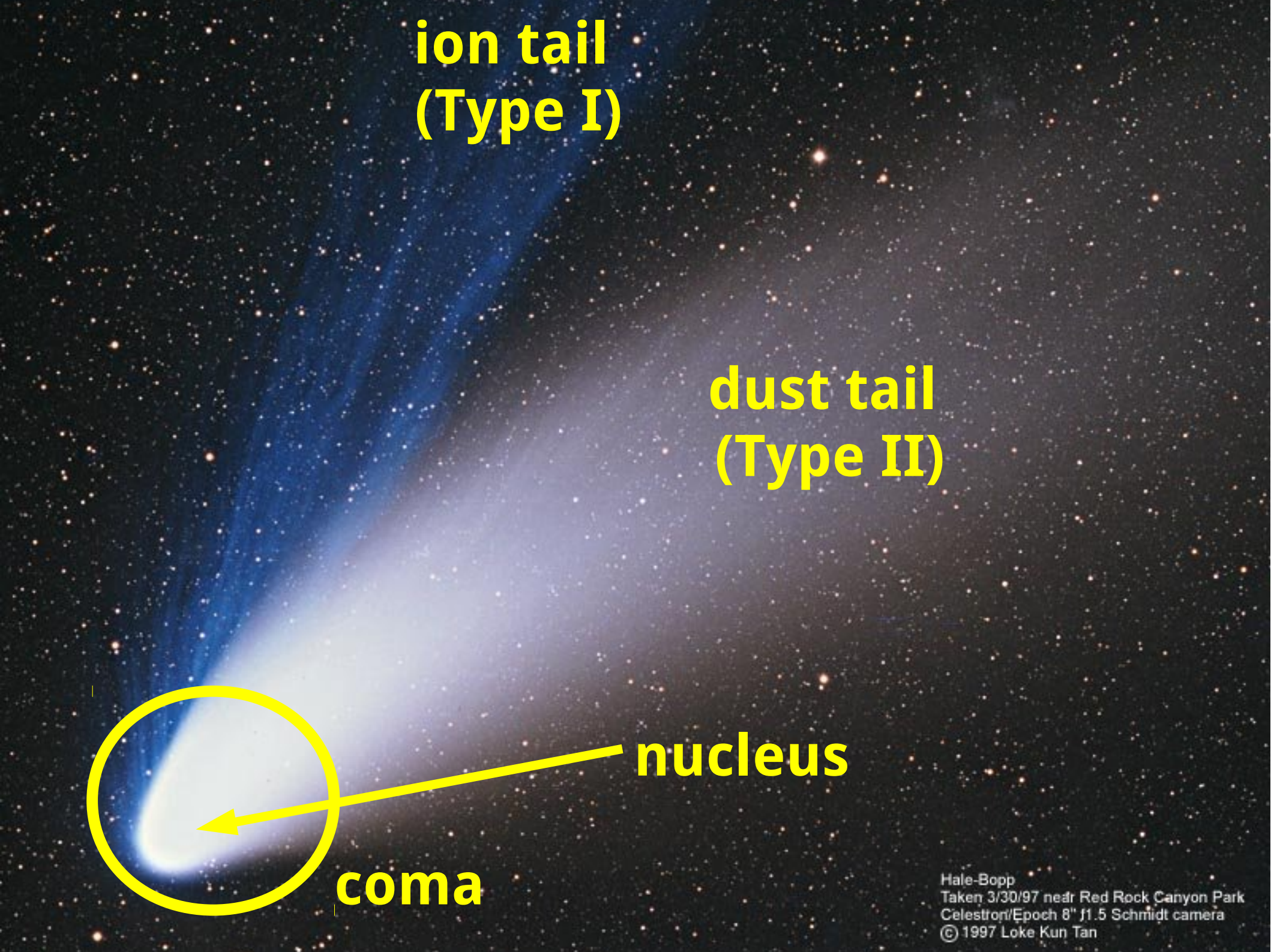
Source: http://www.rocketroberts.com/astro/halebopp_gallery.htm

Comet ISON – November 2013

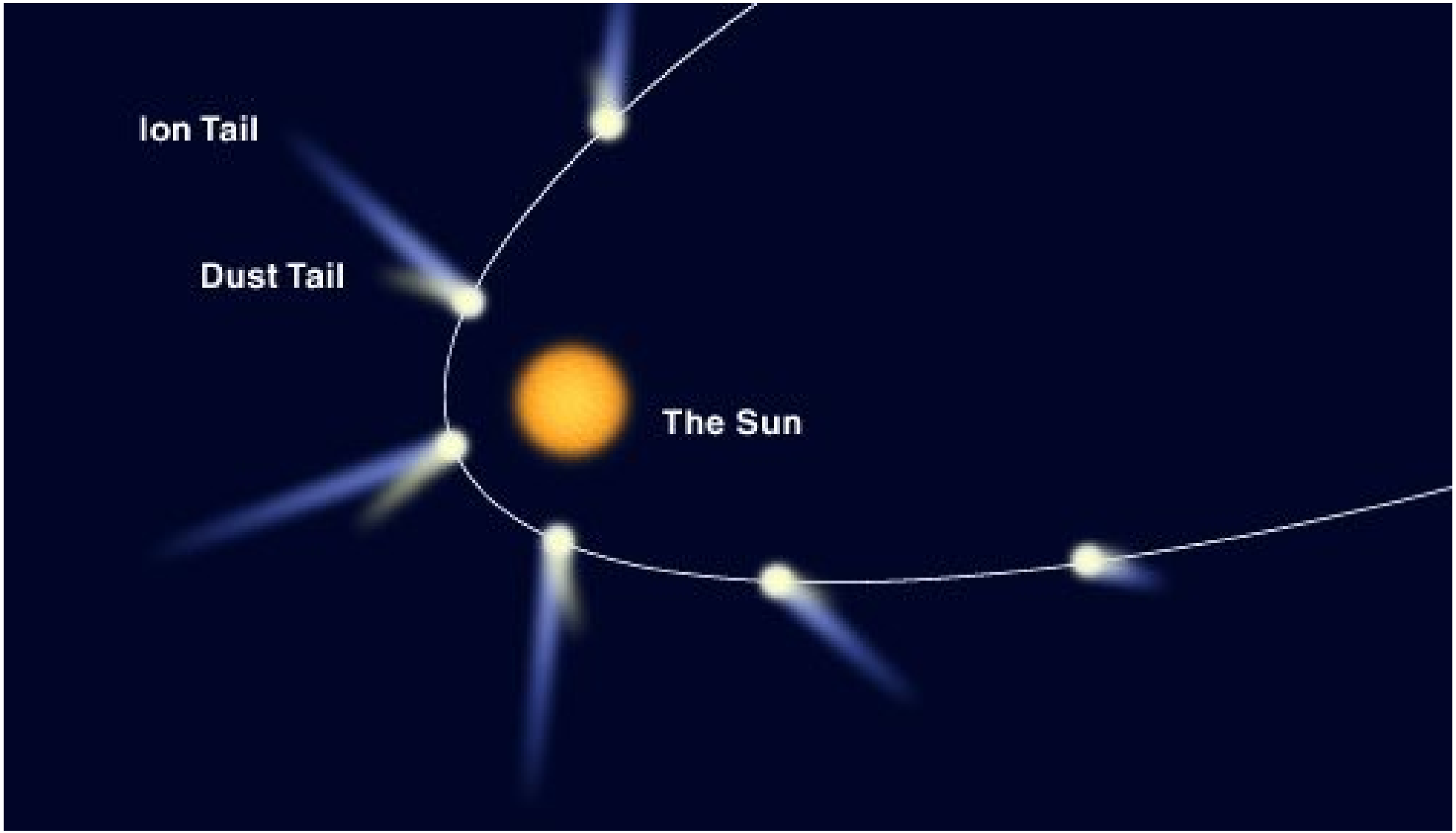
Comets: Coma & Tail



Source: http://apod.nasa.gov/apod/ap961219.html


ion tail
(Type I)
dust tail
(Type II)
nucleus
coma
Hale-Bopp
Taken 3/30/97 near Red Rock Canyon Park
Celestron/Epoch 8" f1.5 Schmidt camera
© 1997 Loke Kun Tan

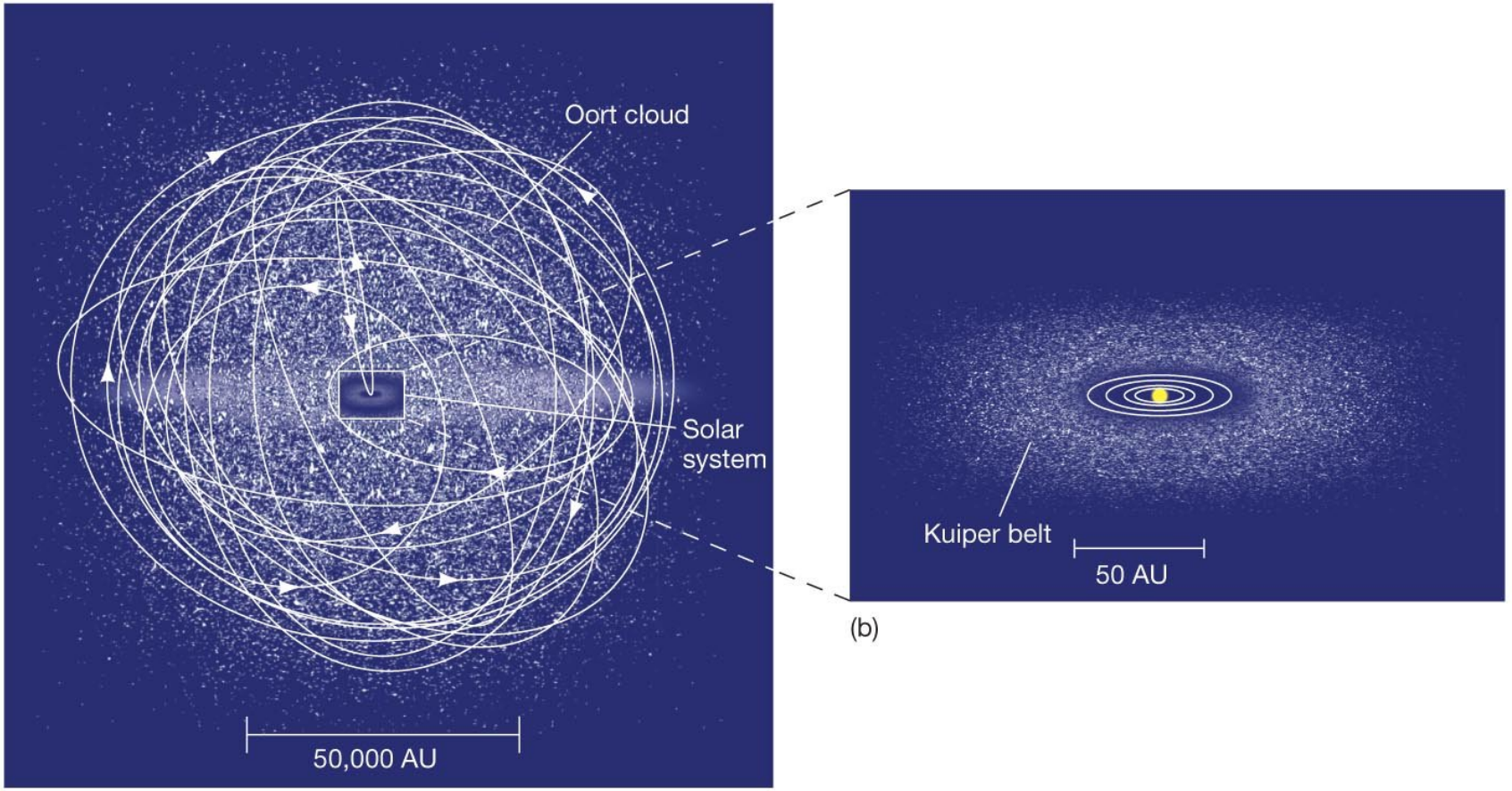
Comet's tail



Comet tails point away from the sun due to the solar wind and the light from the Sun.

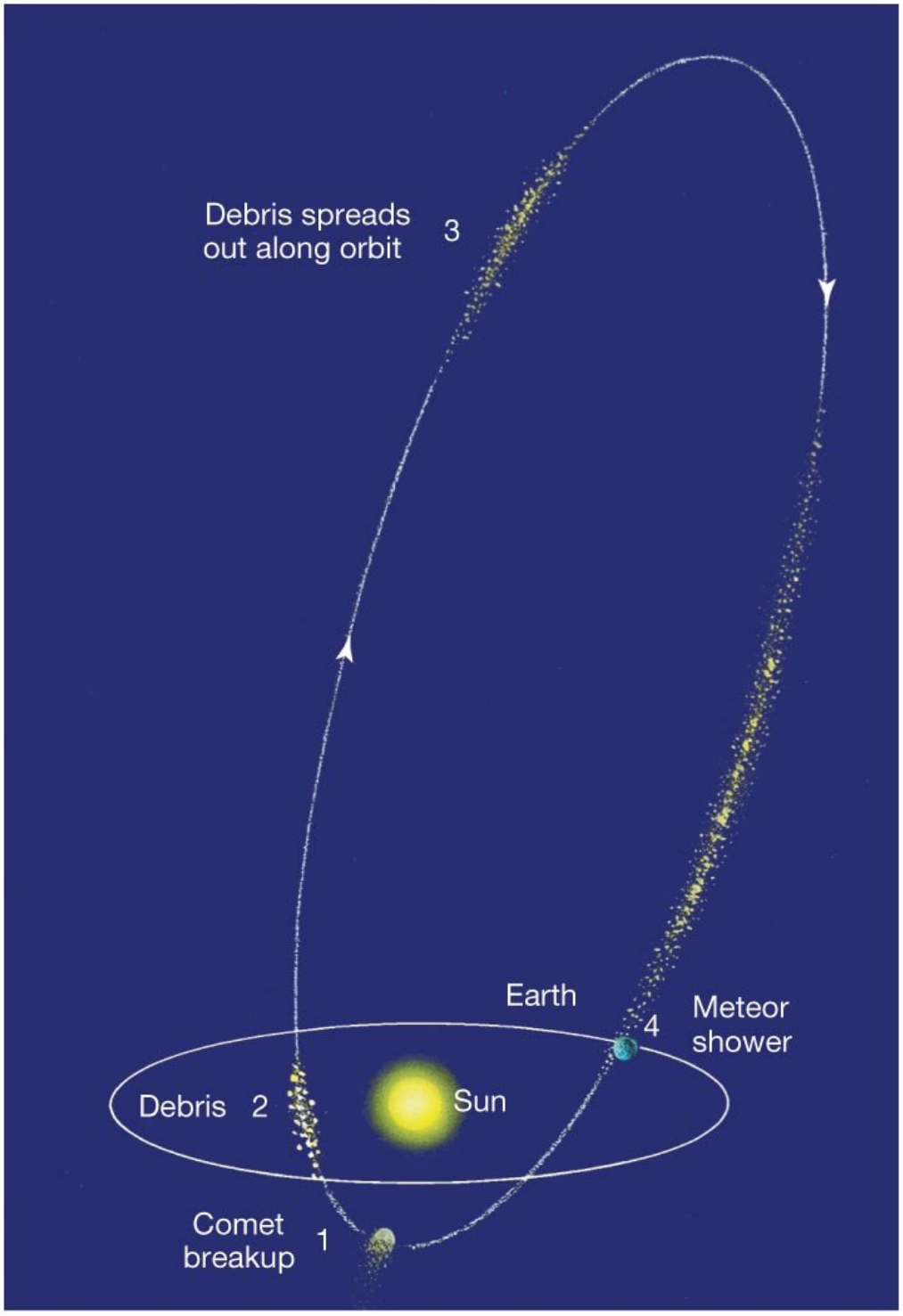
Orbits of Comets

The size, shape, and orientation of cometary orbits depend on their location. Oort cloud comets rarely enter the inner solar system.



Comets and Meteor Showers

Meteor showers are associated with comets – they are the debris left over when a comet breaks up.



Solar System: Planets

- Not all planets discussed in detail now
- More info and pictures on Mars, Jupiter and Saturn during Planetary Highlight Class after the midterm

Earth

- Radius ~ 6400 km
- **Density** ~ 5000 kg/m^3 – five times density of water
- Has a thick atmosphere of mostly nitrogen and oxygen
- Has active volcanoes
- Has a magnetic field
- Has known life

Mercury

Radius ~ 2400 km

mass ~ 5% of Earth

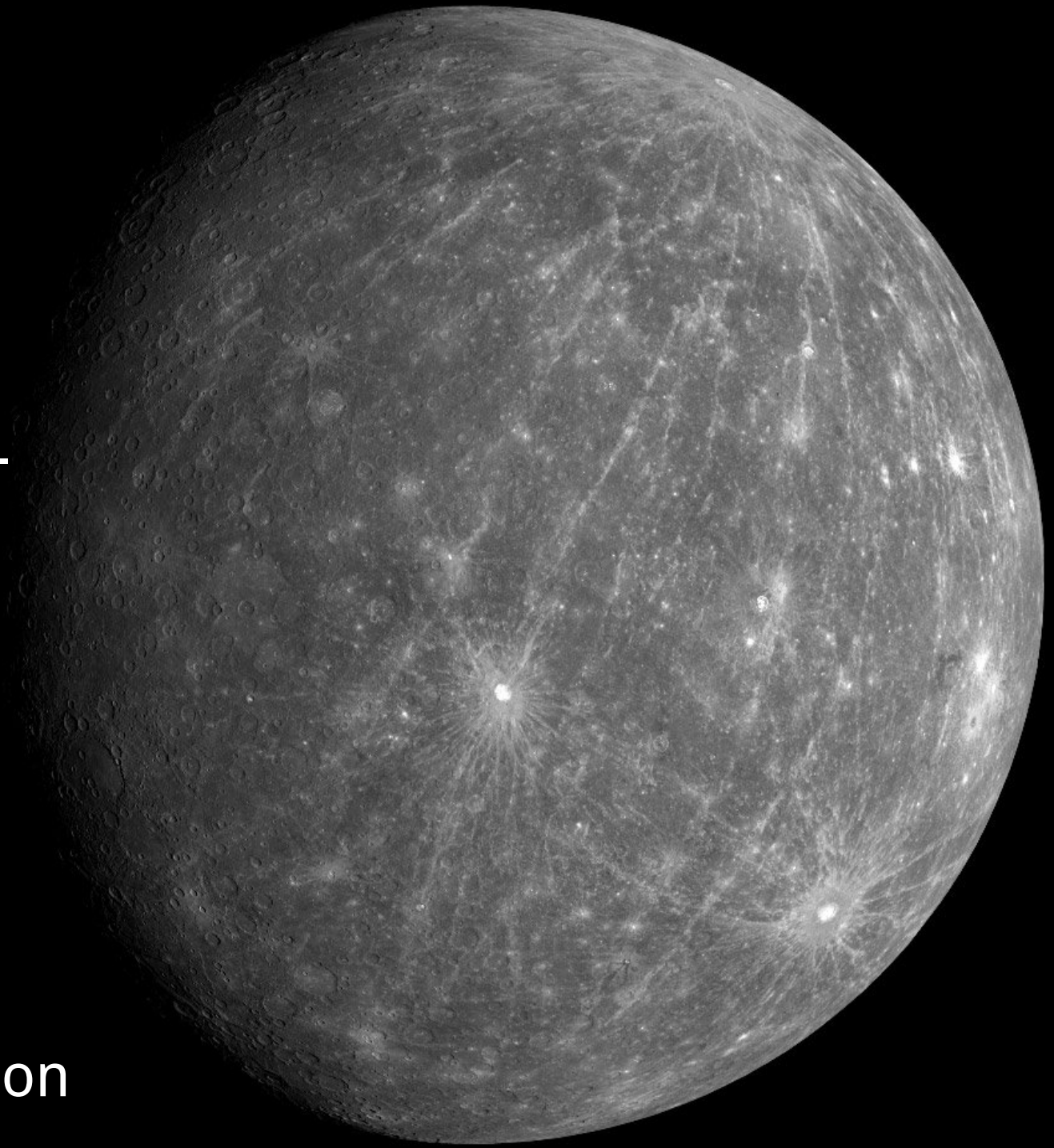
Density 5400 kg/m^3 – about the same as Earth

No atmosphere

No volcanoes

Has a magnetic field

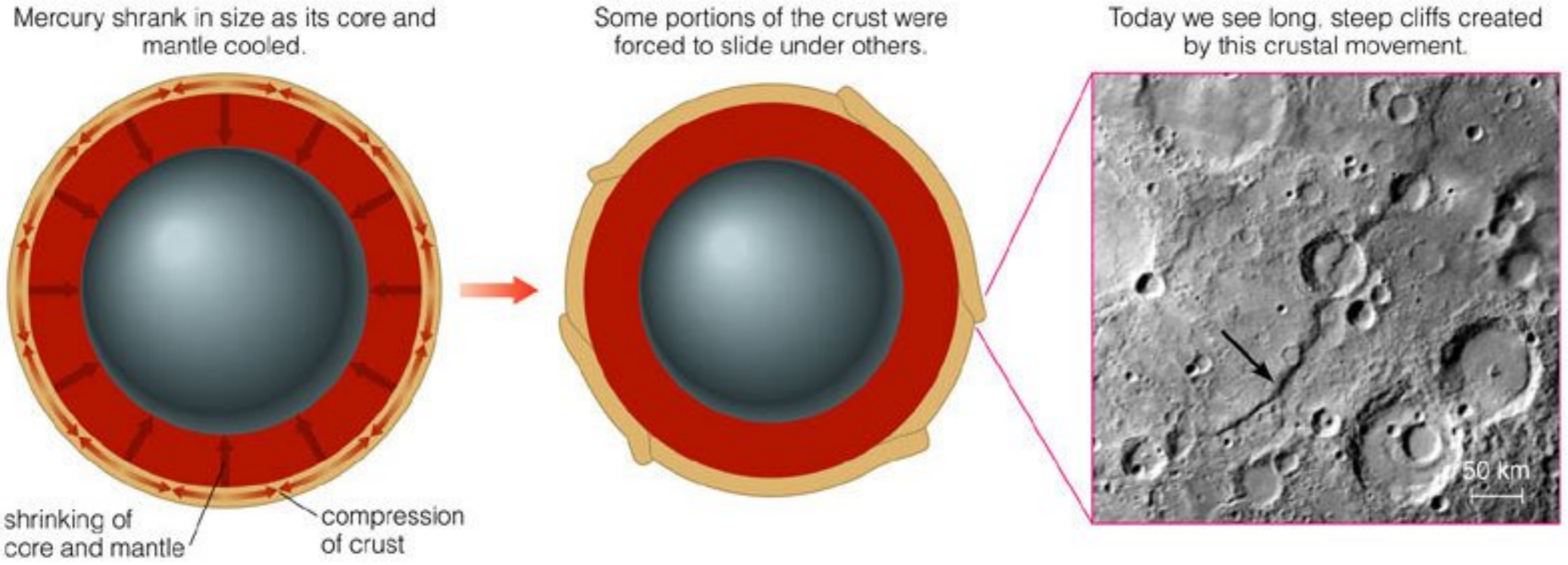
Covered in craters similar to Earth's moon



Mercury

- Temperature on Mercury varies drastically! On the day side it is hot, 700K, but on the night side it is cold, 100 K (-200 F)
- Wide variation in temperature because there is no atmosphere to trap heat and moderate temperatures
- Because Mercury has no atmosphere and no water, there is no erosion, so the surface is heavily cratered like the Moon


Mercury close-up from Messenger

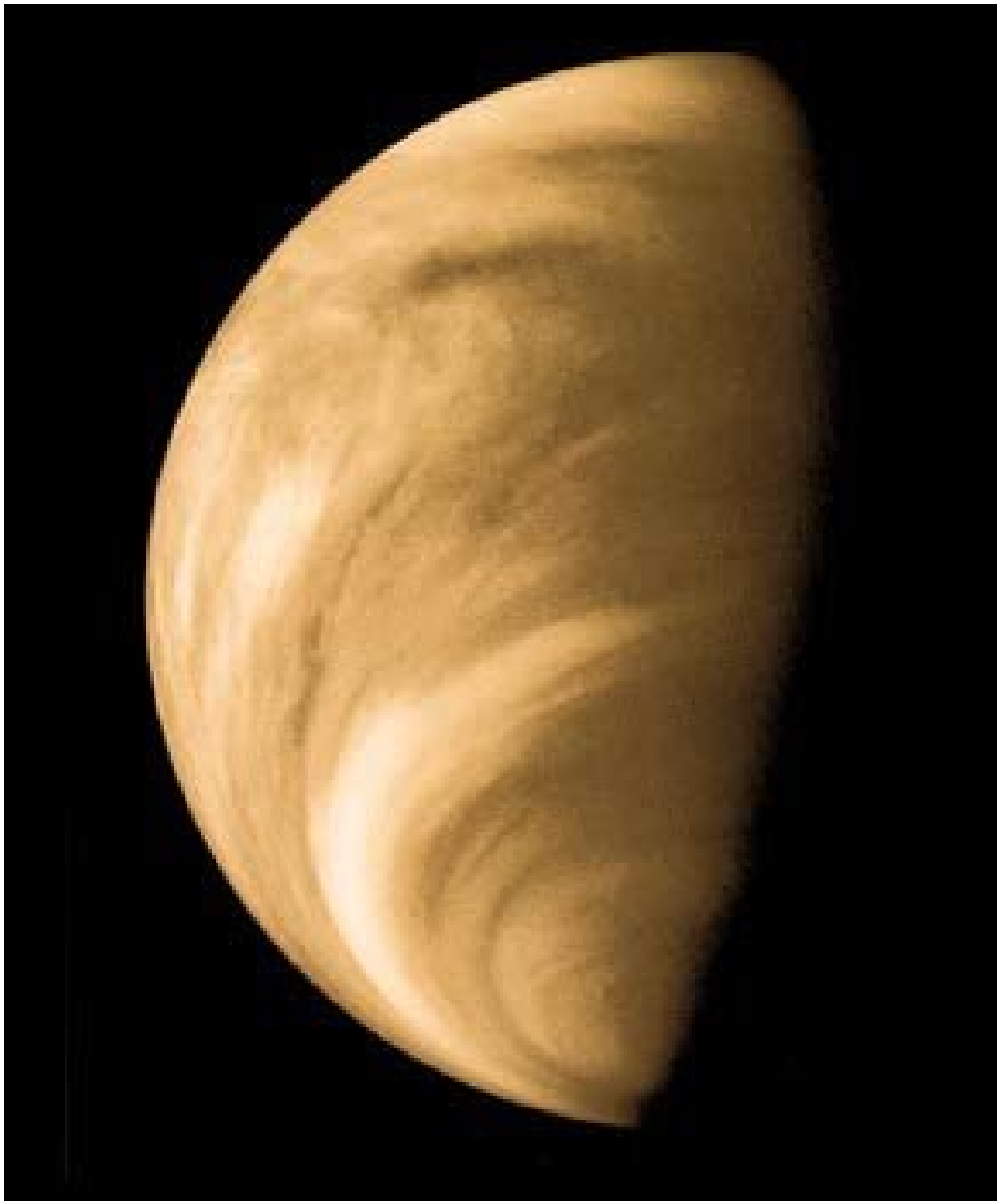


Mercury has one feature unique to it and not found on the Moon. It has scarps or cliffs.

These scarps result from the cooling (and shrinking) of Mercury, which resulted in compression and cracking of the surface.

Venus

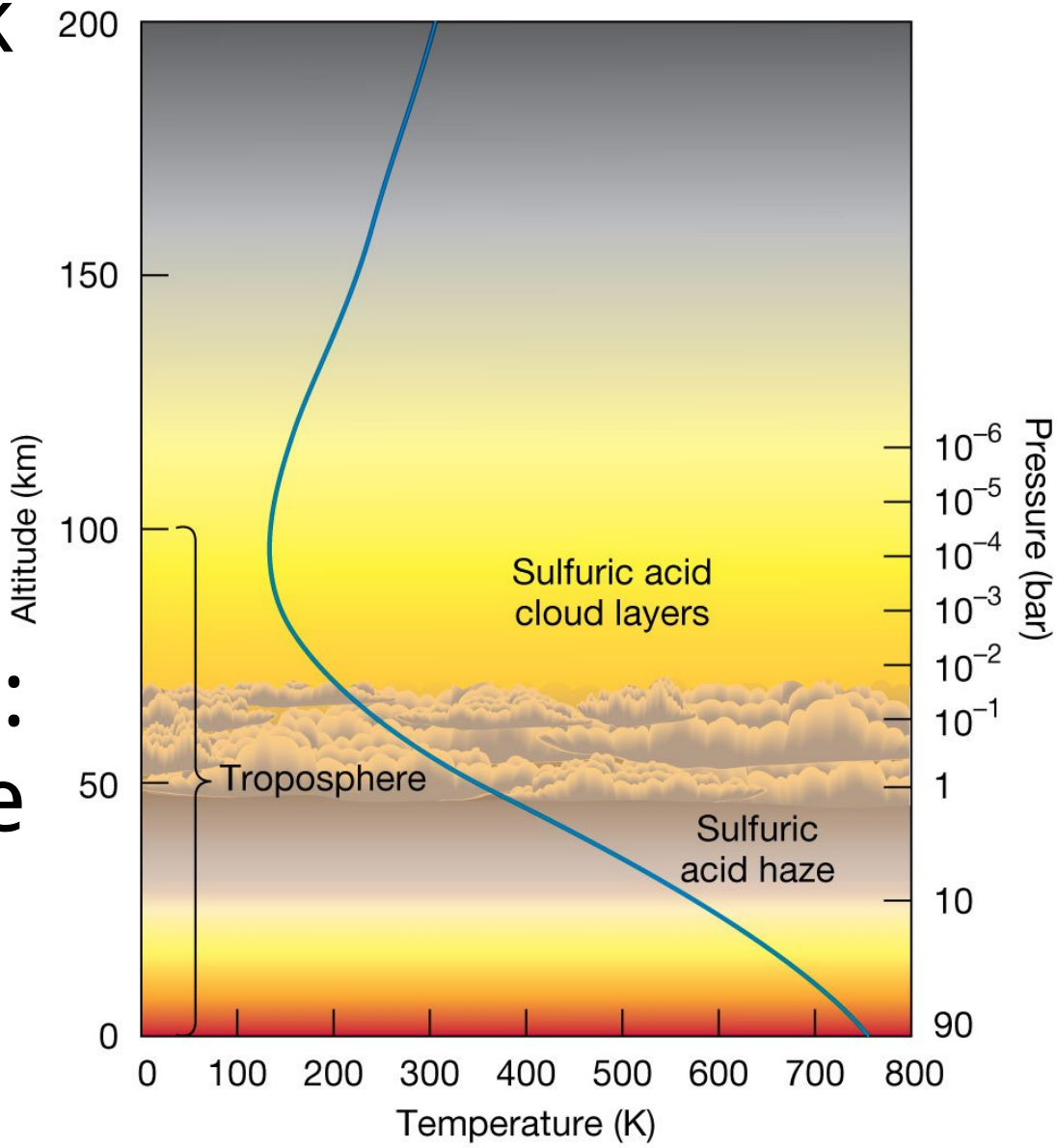
- Radius ~ 6100 km
- Mass ~ 82% of Earth
- Density ~ 5300 kg/m^3 – about the same as Earth
- Very thick atmosphere
- Many volcanic features, indirect evidence of current volcanic activity
- No magnetic field



Venus

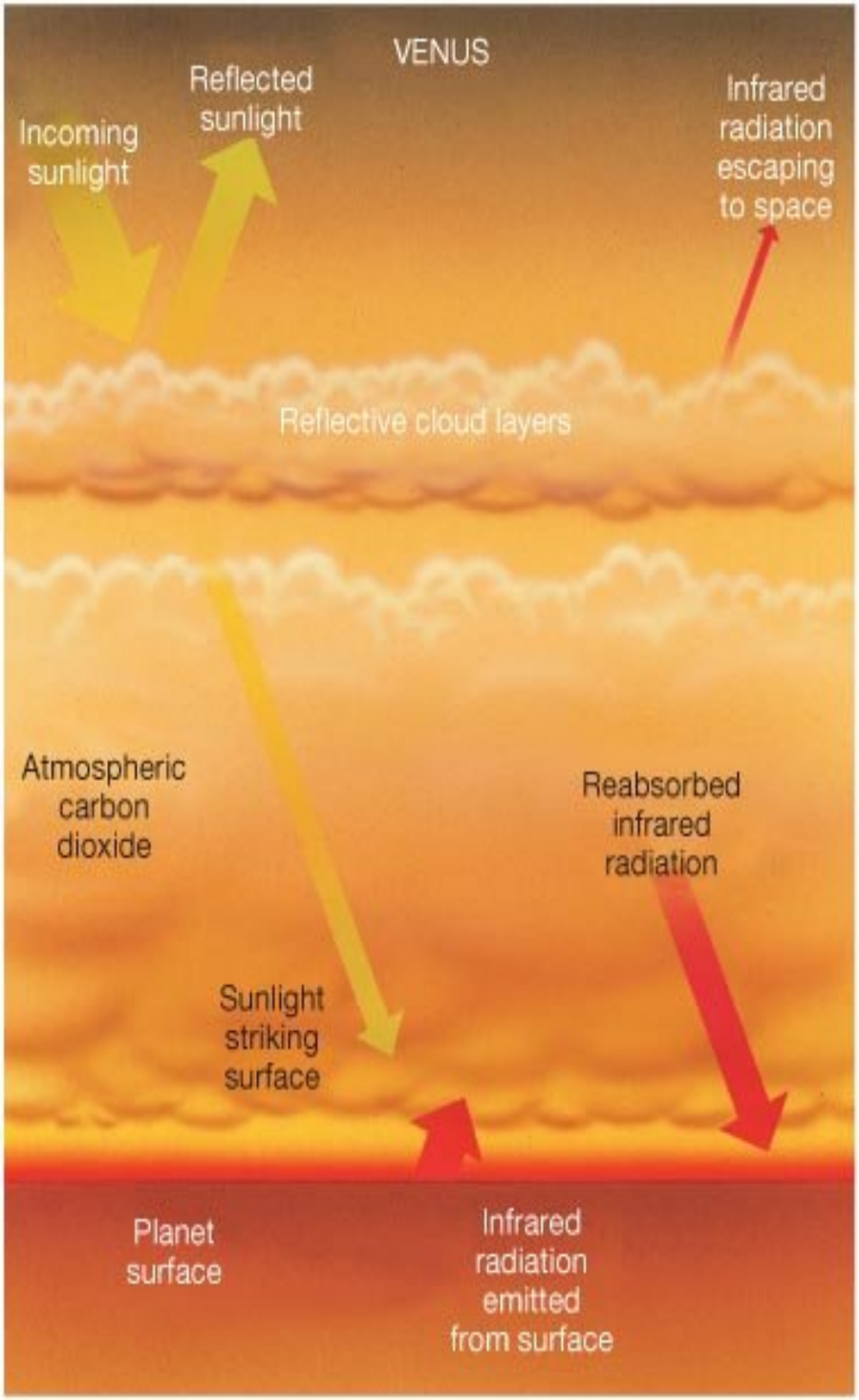
Venus has a large, thick atmosphere which covers the entire surface with clouds of sulfuric acid.

Its atmosphere is 90x thicker than the Earth's: pressure on the surface is 90 times higher than on Earth



Venus

- Venus is HOT! Its average temperature is 730 K – hotter than Mercury and hot enough to melt lead.
- This is because the atmosphere traps heat via the greenhouse effect
- Sunlight strikes surface and is converted to heat, which is absorbed and re-radiated by carbon dioxide in the atmosphere instead of radiating out into space
- Also operates on Earth

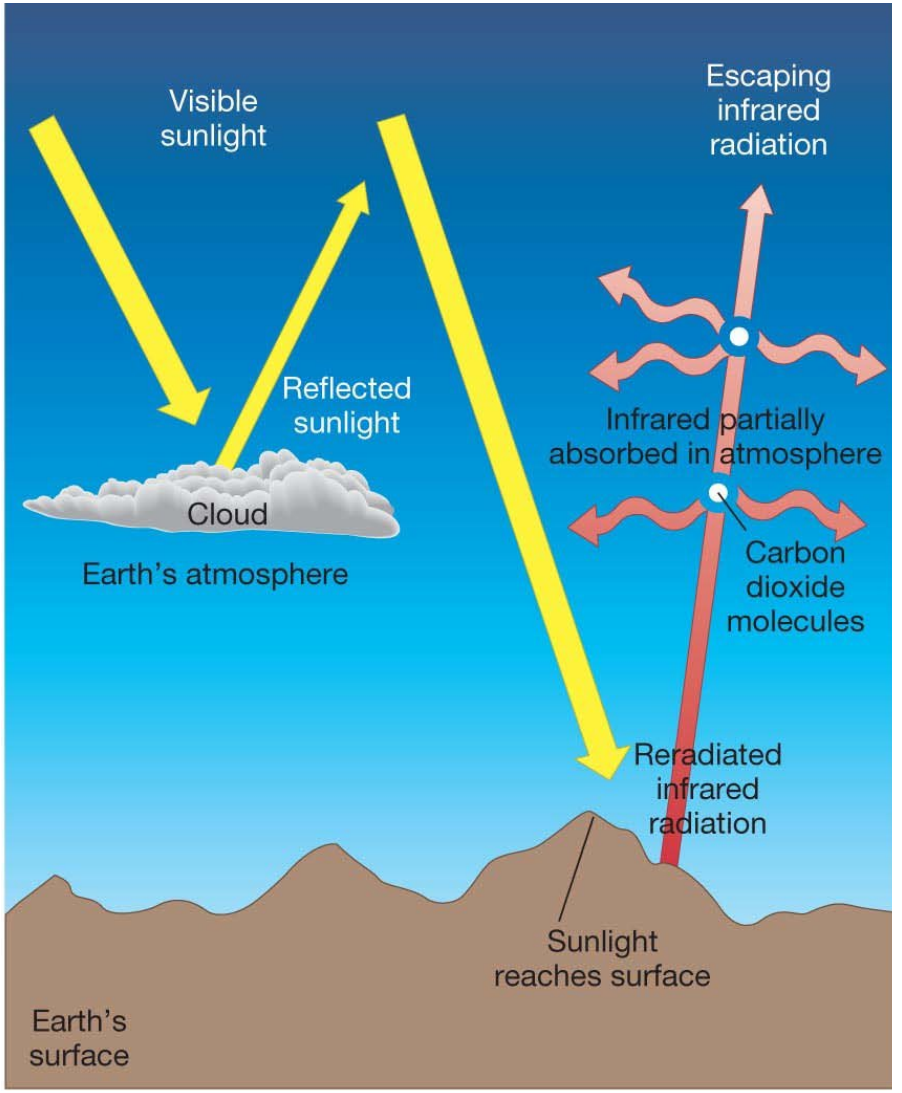


The greenhouse effect on Earth

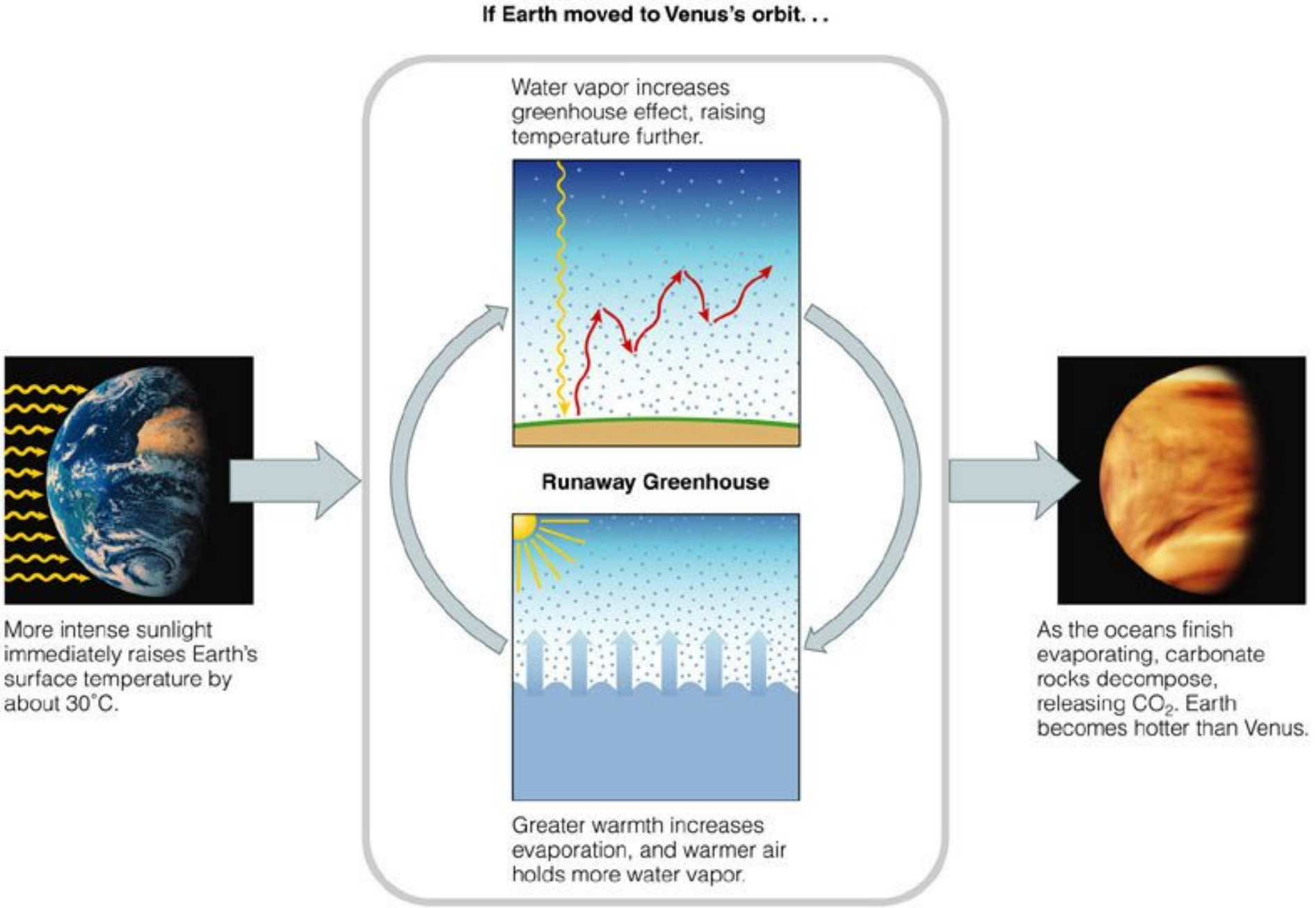
Greenhouses gases (carbon dioxide, water vapor, methane) in the atmosphere trap heat

Sunlight strikes surface and is converted to heat, which is absorbed and re-radiated in the atmosphere instead of radiating out into space

An increase in the amount of greenhouse gases in the atmosphere increases the heat trapped

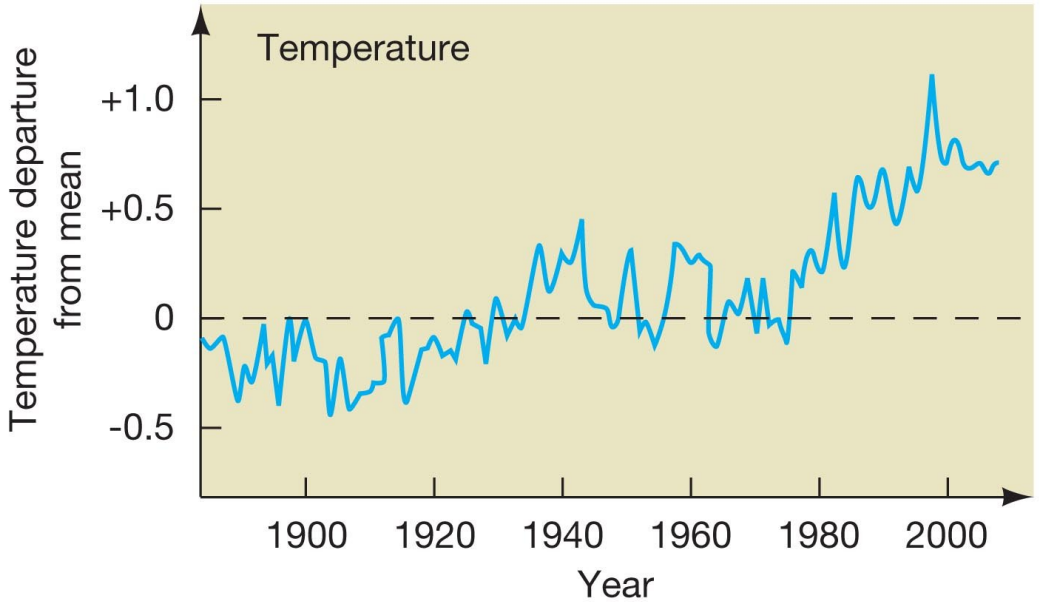


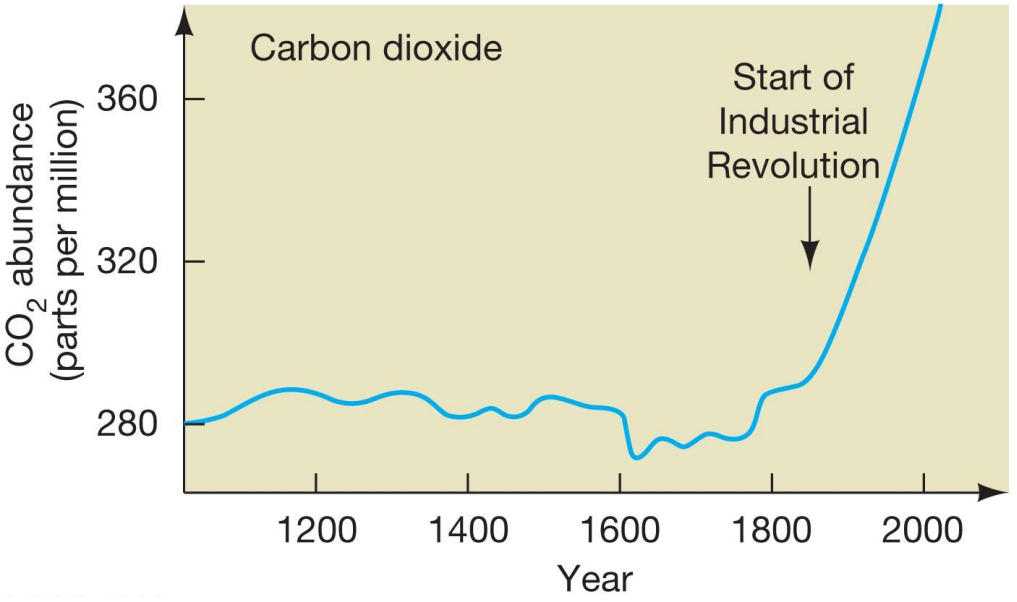
Runaway Greenhouse Effect



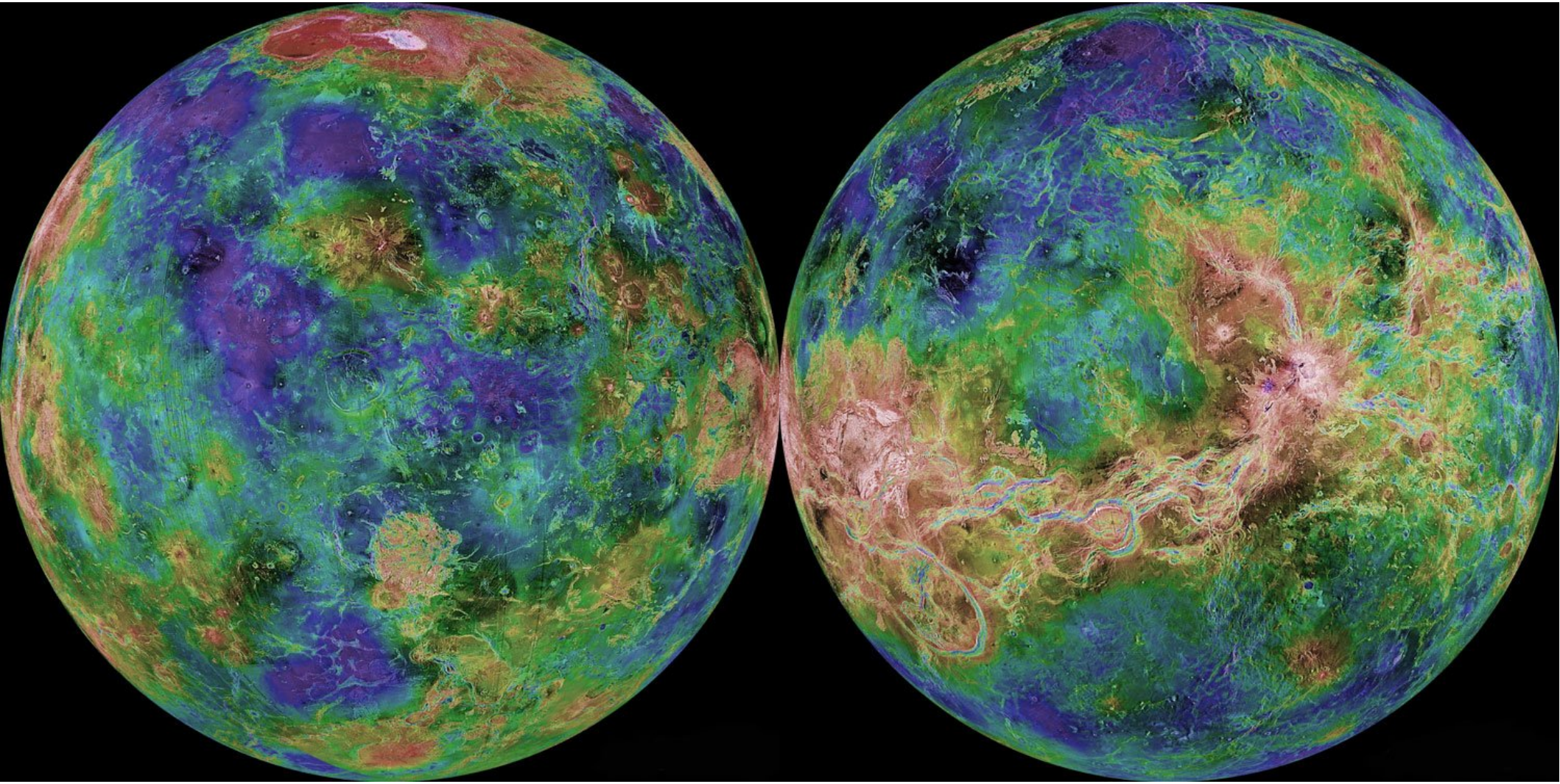
The Greenhouse Effect and Global Warming

There is extremely strong evidence that Earth is getting warmer, and that this warming is related to the increase in atmospheric carbon dioxide.

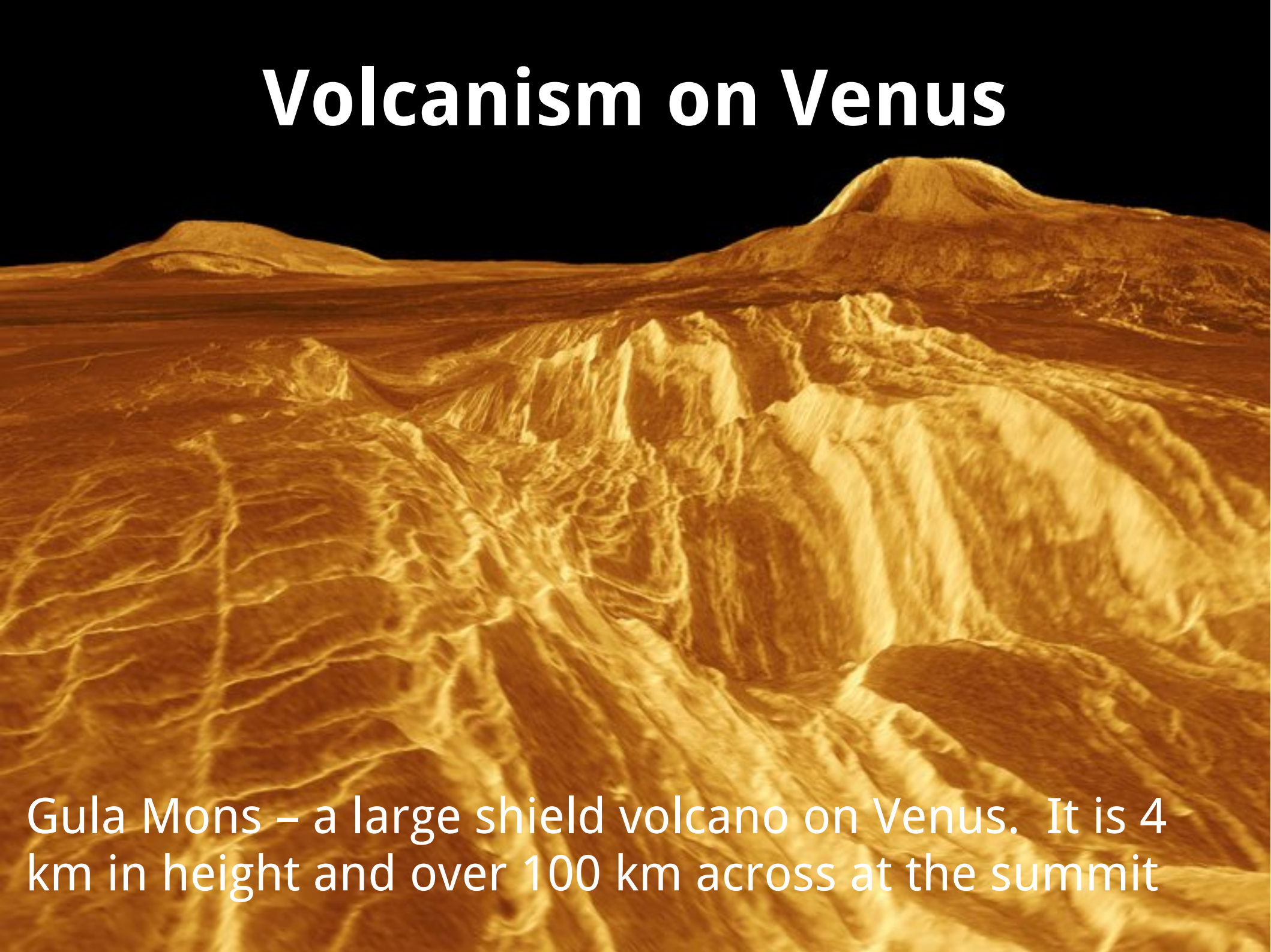




Venus topography



Volcanism on Venus



Gula Mons – a large shield volcano on Venus. It is 4 km in height and over 100 km across at the summit

Which gas is responsible for the greenhouse effect on Venus?

A nitrogen

B hydrogen

C carbon dioxide

D sulfuric acid

Which gas is responsible for the greenhouse effect on Venus?

A nitrogen

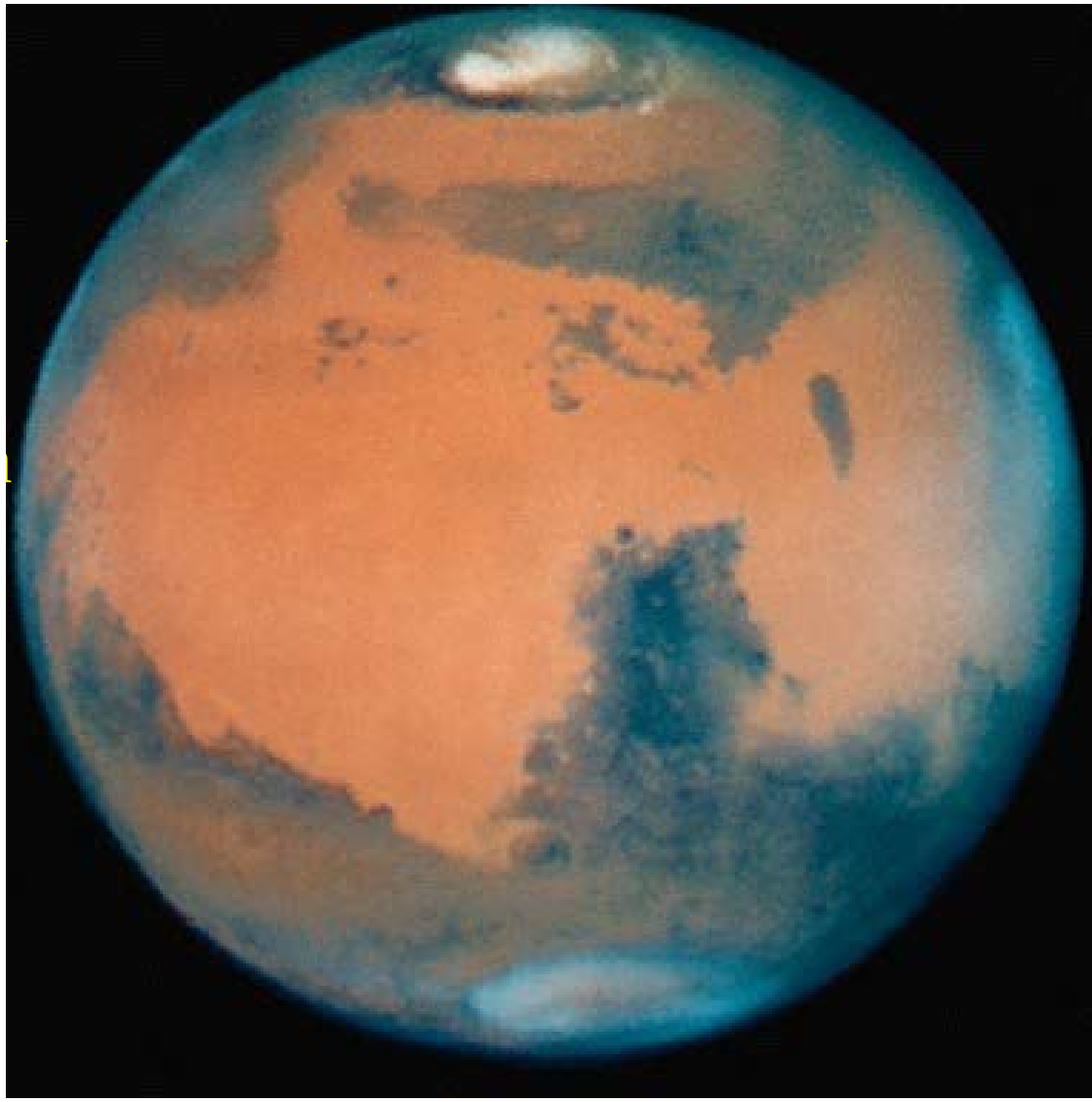
B hydrogen

C carbon dioxide

D sulfuric acid

Mars

- Radius ~ 3400 km – ½ radius of earth
- Mass ~ 10% of Earth
- Density ~ 3900 kg/m^3 – smaller than Earth – density of rock.
- Thin atmosphere
- Extinct volcanoes
- No magnetic field

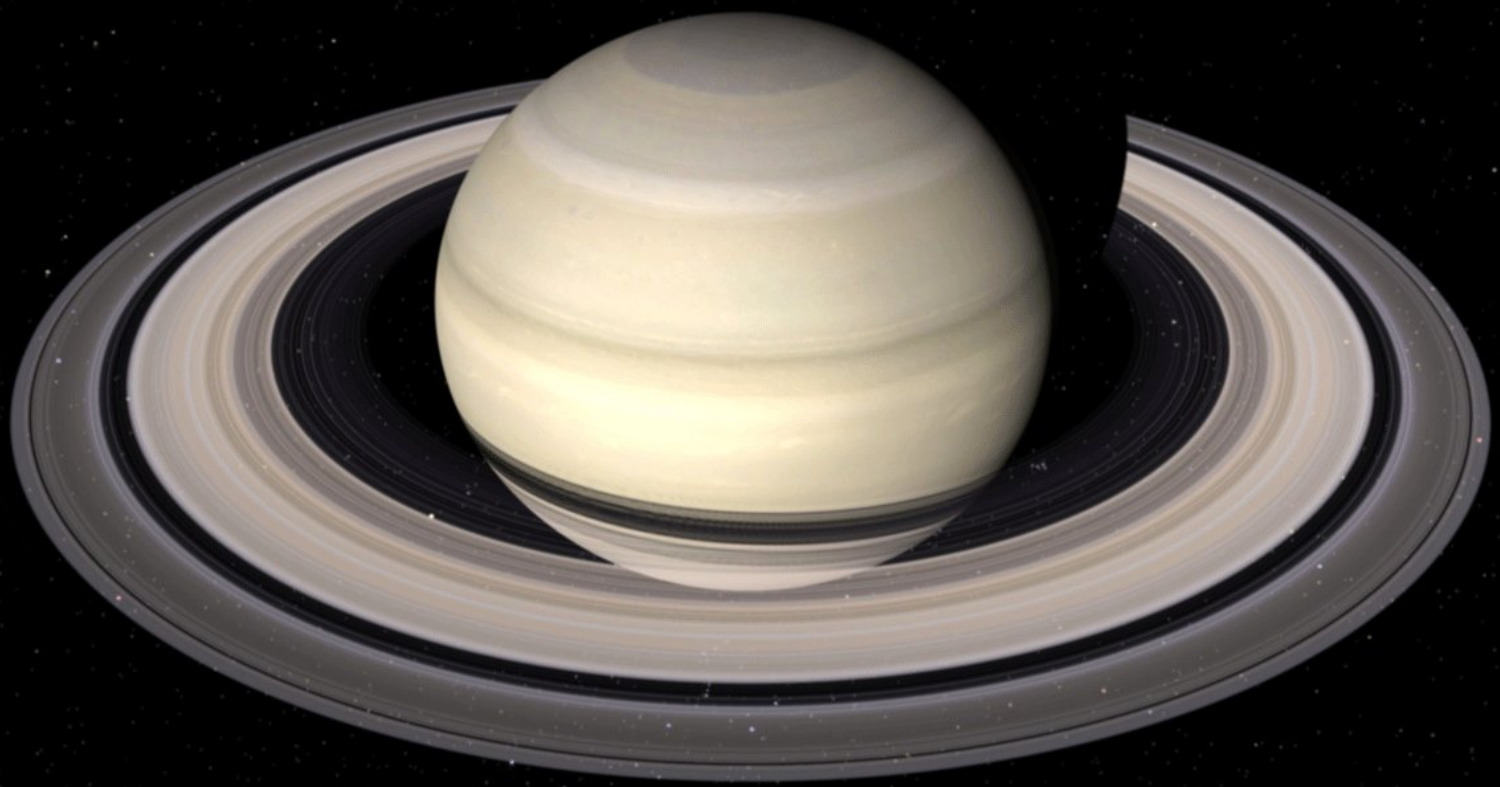


Jupiter

- Radius ~ 10 x Earth's
- Mass ~ 300 x Earth's
- Density ~ 1300 kg/m^3 – about same as water
- Composed of mainly hydrogen and helium
- No surface
- Strong magnetic field
- Rapid rotation ~ 10 hrs

Saturn

- Radius ~ 10 times Earth, mass ~ 100 times Earth
- Density ~ 700 kg/m^3 – less than water, Saturn would float!
- Composed of mainly hydrogen and helium
- No surface - Strong magnetic field



Uranus

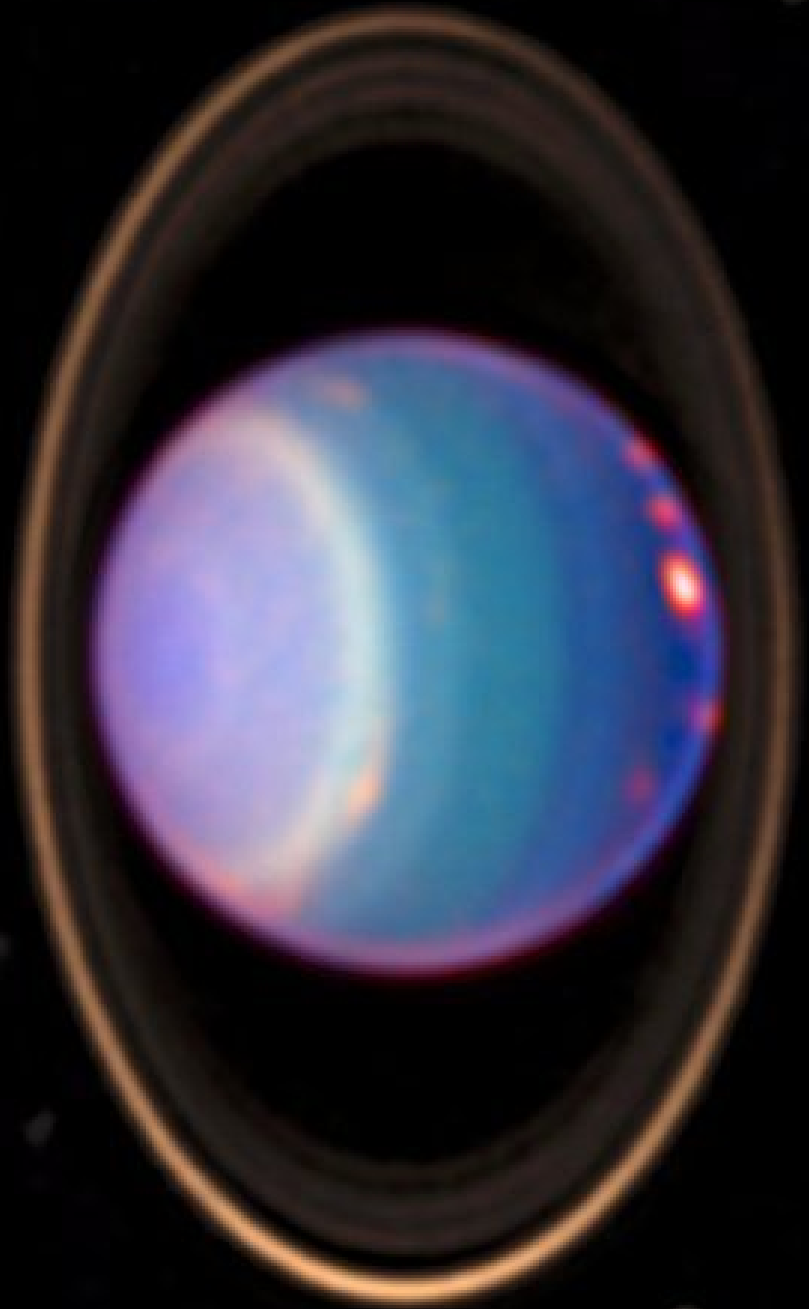
Radius ~ 4 times Earth

Mass ~ 15 times Earth

Nearly featureless – image at right is a false color image.

Rotation axis is tilted 98 degrees!

The tilt may be result of a giant impact (?)



Neptune

Radius ~ 4x bigger than Earth.

Mass ~ 17x Earth

Has bands of clouds unlike Uranus

Has a large storm on it called the Great Dark Spot.