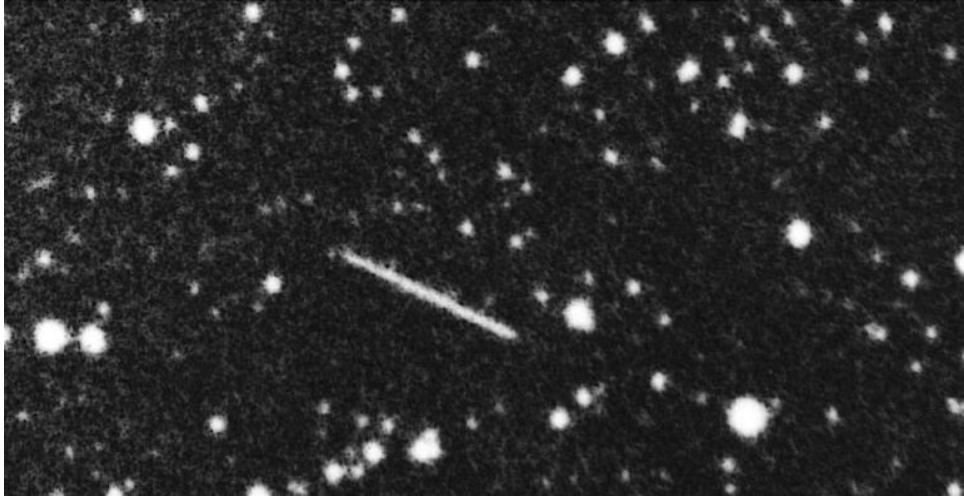
Chapter 9
Remnants of Rock and Ice
Asteroids, Comets, and Pluto

9.1 Asteroids and Meteorites

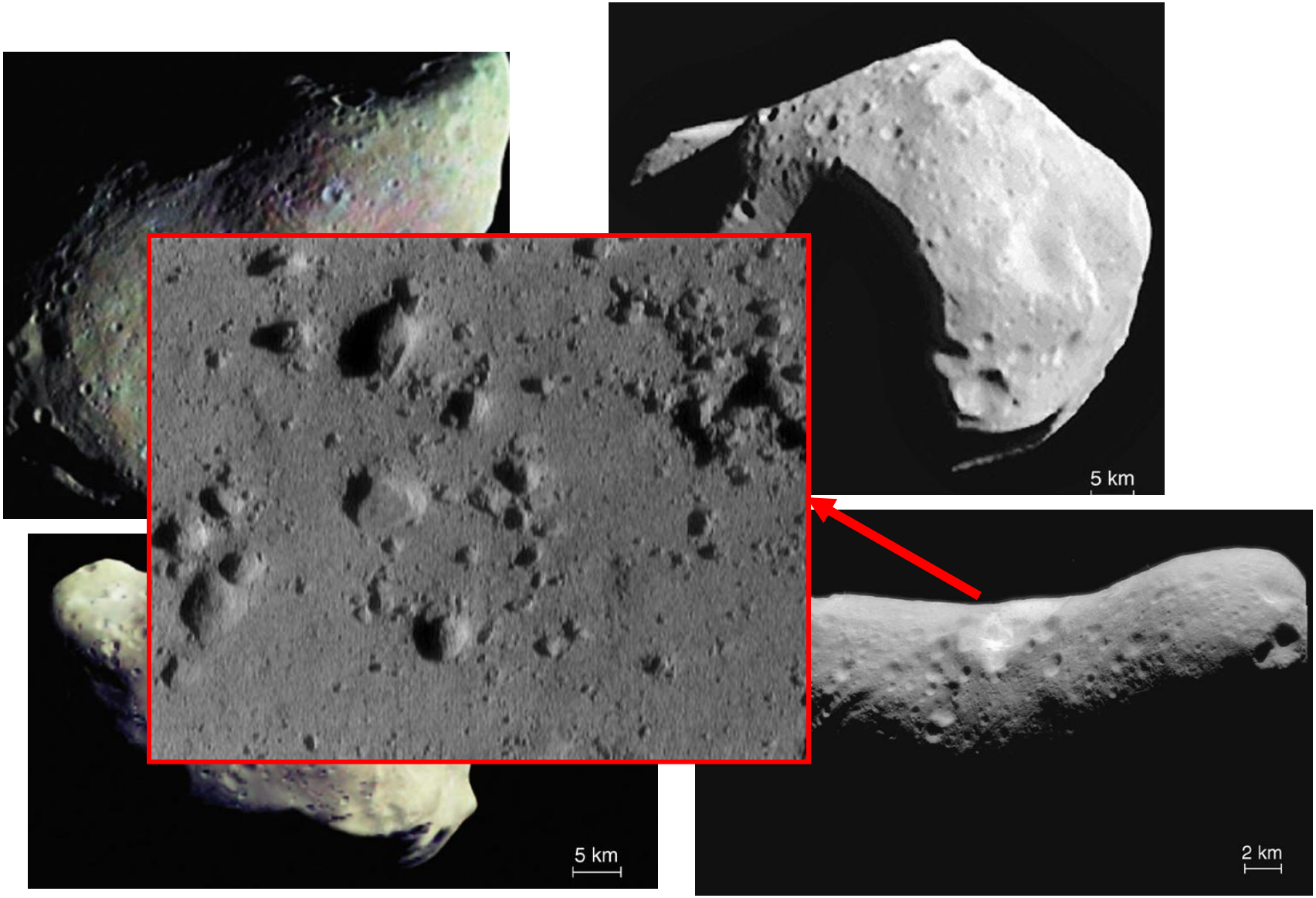
Our Goals for Learning

- **Why is there an asteroid belt?**
- **How are meteorites related to asteroids?**

Asteroid Facts



- Asteroids are rocky leftovers of planet formation.
- Largest is Ceres, diameter ~1,000 km
- 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.

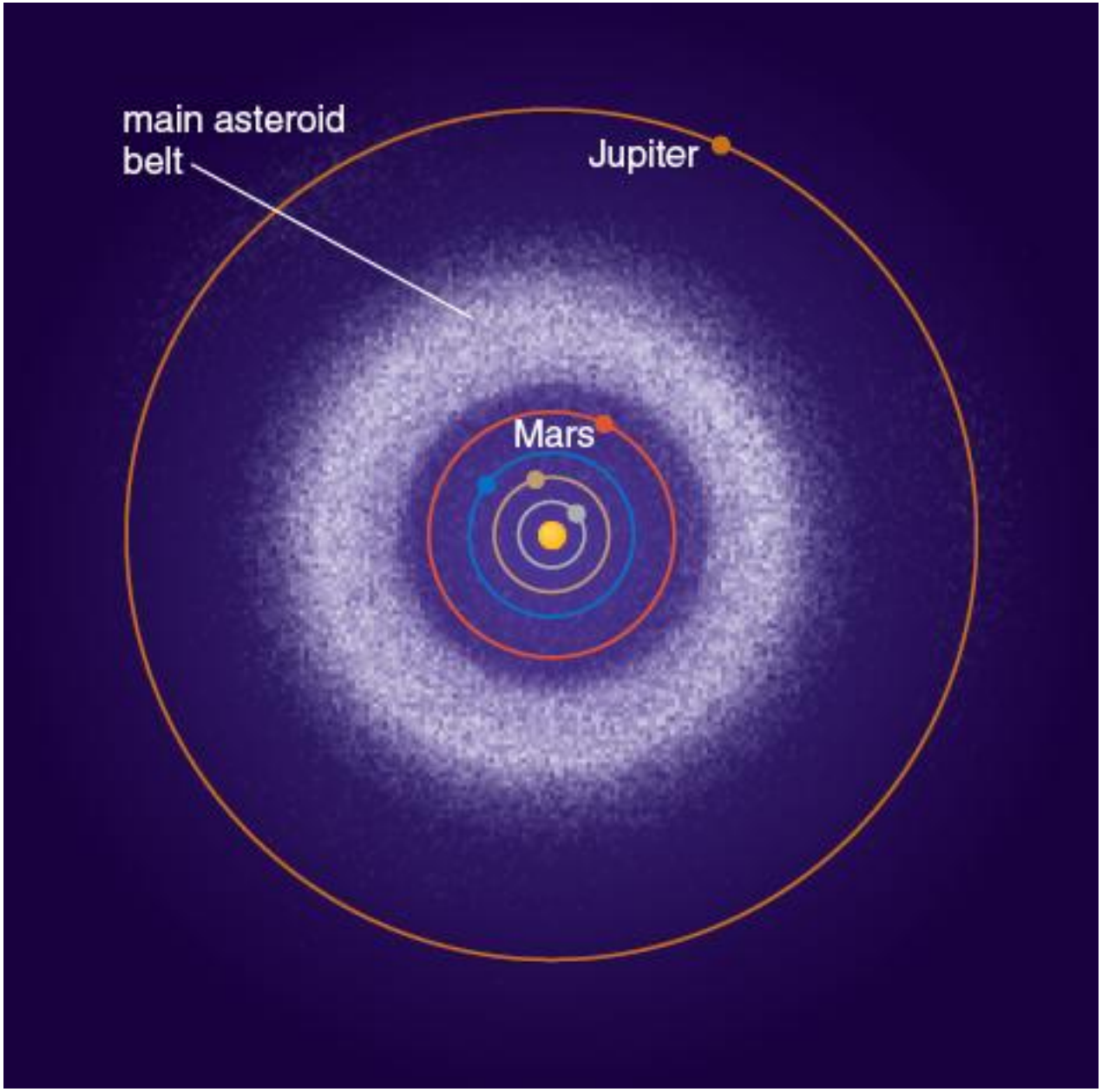


Asteroids are cratered and not round

Why is there an asteroid belt?

More than 150,000 asteroids at their predicted locations for Jan 1 2004

On this scale, asteroids are much smaller than the dots used to represent them



Which explanation seems to be the most plausible?

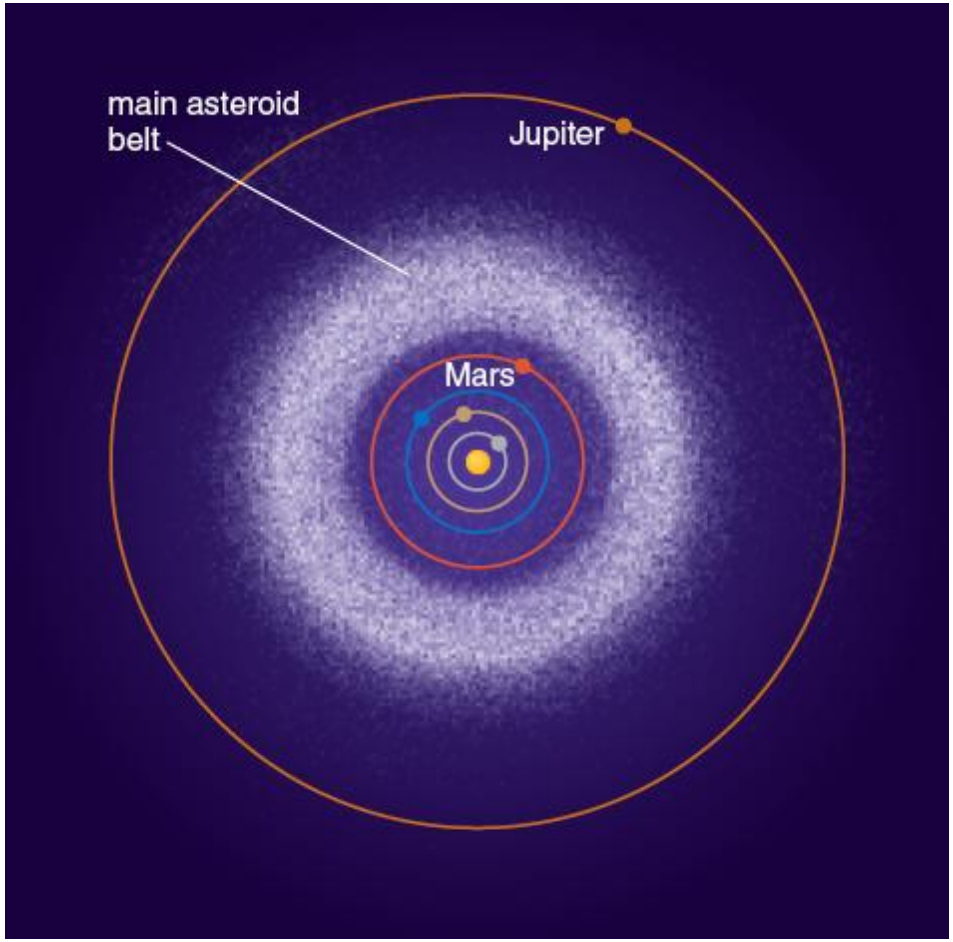
A. The belt is where all the asteroids happened to form.
B. The belt is the remnant of a large terrestrial planet that used to be between Mars and Jupiter.
C. The belt is where all the asteroids happened to survive.

Which explanation seems to be the most plausible?

A. The belt is where all the asteroids happened to form.
B. The belt is the remnant of a large terrestrial planet that used to be between Mars and Jupiter.
C. **The belt is where all the asteroids happened to survive.**

But WHY didn't they form a little planet?

Rocky planetesimals survived in the asteroid belt between Mars and Jupiter because they did not accrete into a planet.



<u>Jupiter's gravity, stirs up the asteroid orbits and prevents their planet formation.</u>

How are meteorites related to asteroids?

How are meteorites related to asteroids?

Meteorites are pieces of asteroids - or sometimes planets or the Moon.

Meteor: The bright tail of hot debris from the rock

Meteorite: A rock from space that reaches Earth's surface

Peekskill, NY:

October 9, 1992

Pieces of Asteroids:Meteorite Types

1) <u>Primitive: Unchanged in composition since they first formed 4.6 billion years ago.</u>

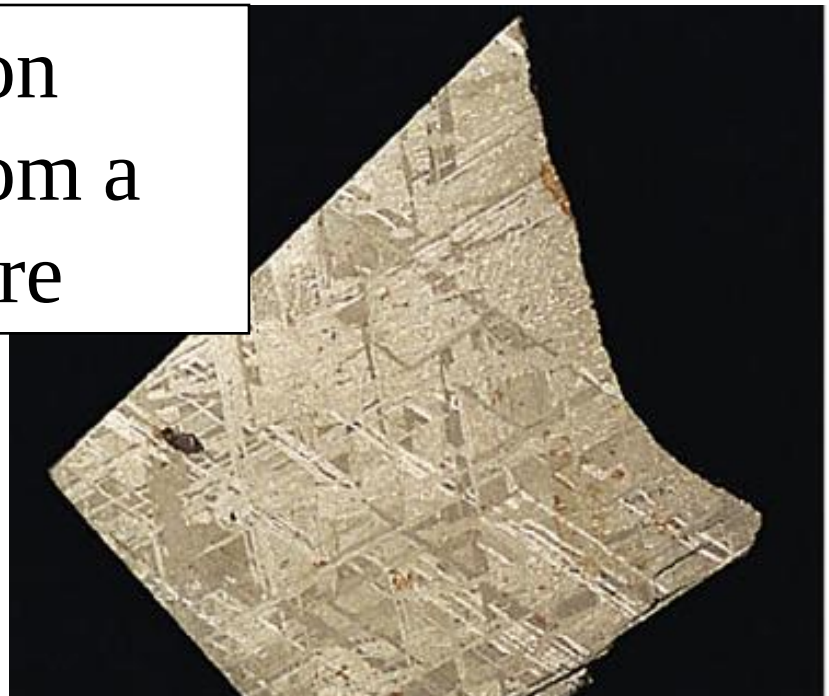
2) <u>Processed: Younger, have experienced processes like volcanism or differentiation.</u>

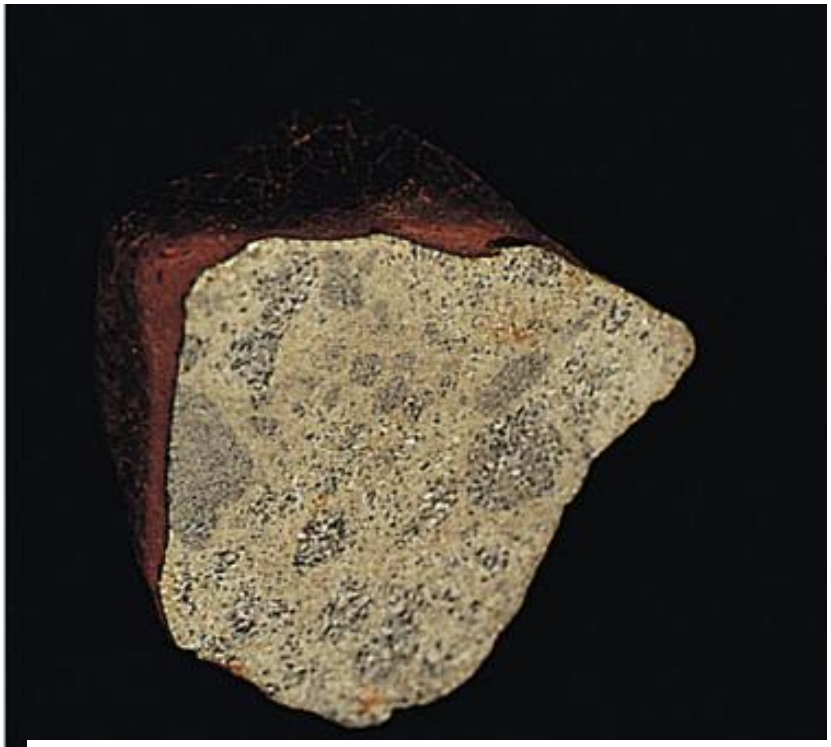
Primitive Meteorites: simple, all ingredients mixed together

Processed Meteorites:

shattered fragments of larger objects

Iron from a core





Volcanic rock from a crus
or mantle

What do we learn from meteorites?

- primitive meteorites tell us when solar system formation began.
- Processed meteorites tell us what asteroids are like on the inside.
- Processed meteorites provide direct proof that differentiation and volcanism happened on asteroids.

Meteorites from Moon and Mars

- A few meteorites arrive from the Moon and Mars
- Composition differs from the asteroid fragments.
- A cheap (but slow) way to acquire moon rocks and Mars rocks.
- One Mars meteorite generated a stir when scientists claimed evidence for microscopic life in it.

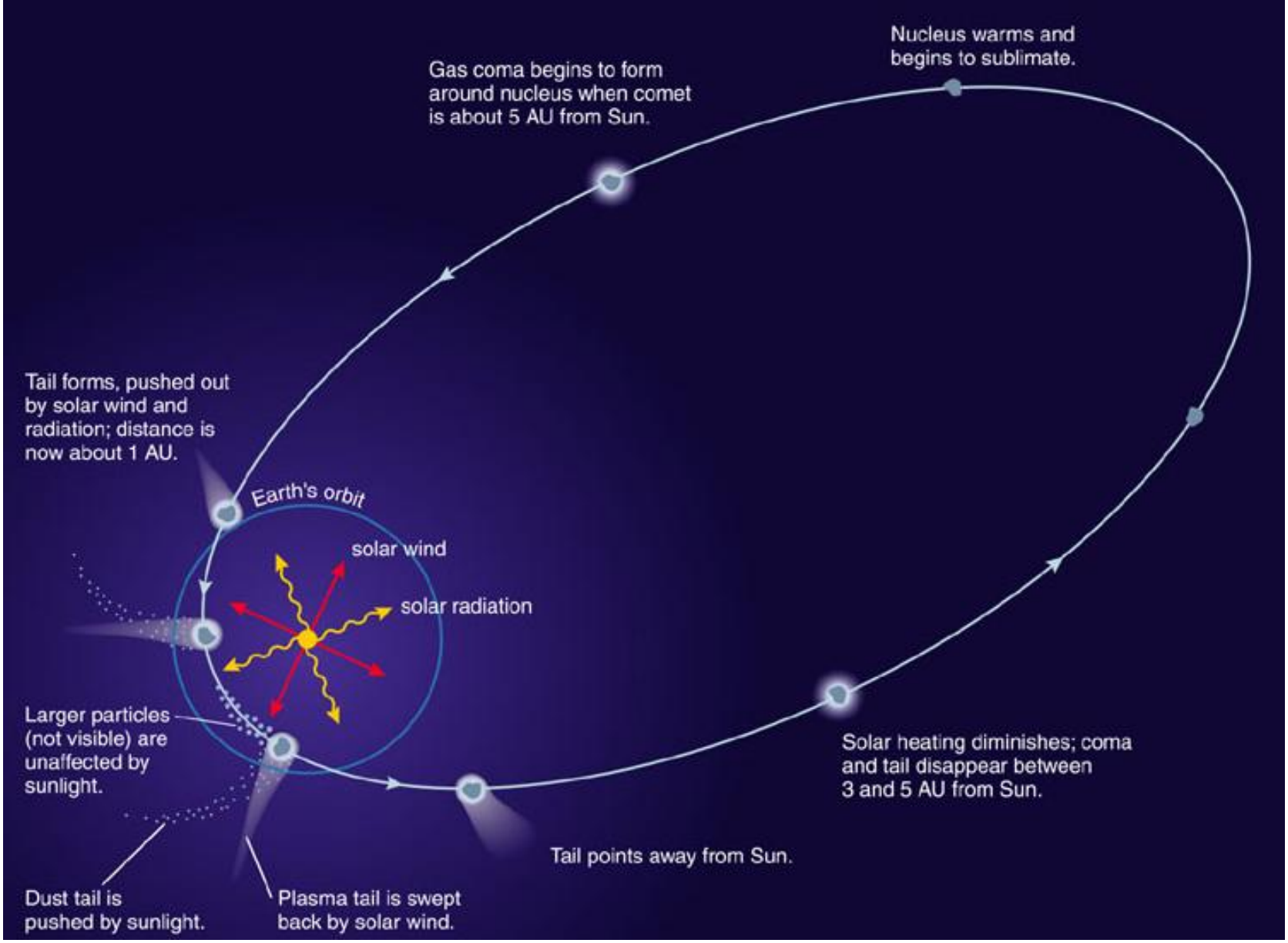
9.2 Comets

- Our Goals for Learning
- **How do comets get their tails?**
- **Where do comets come from?**

How do comets get their tails?

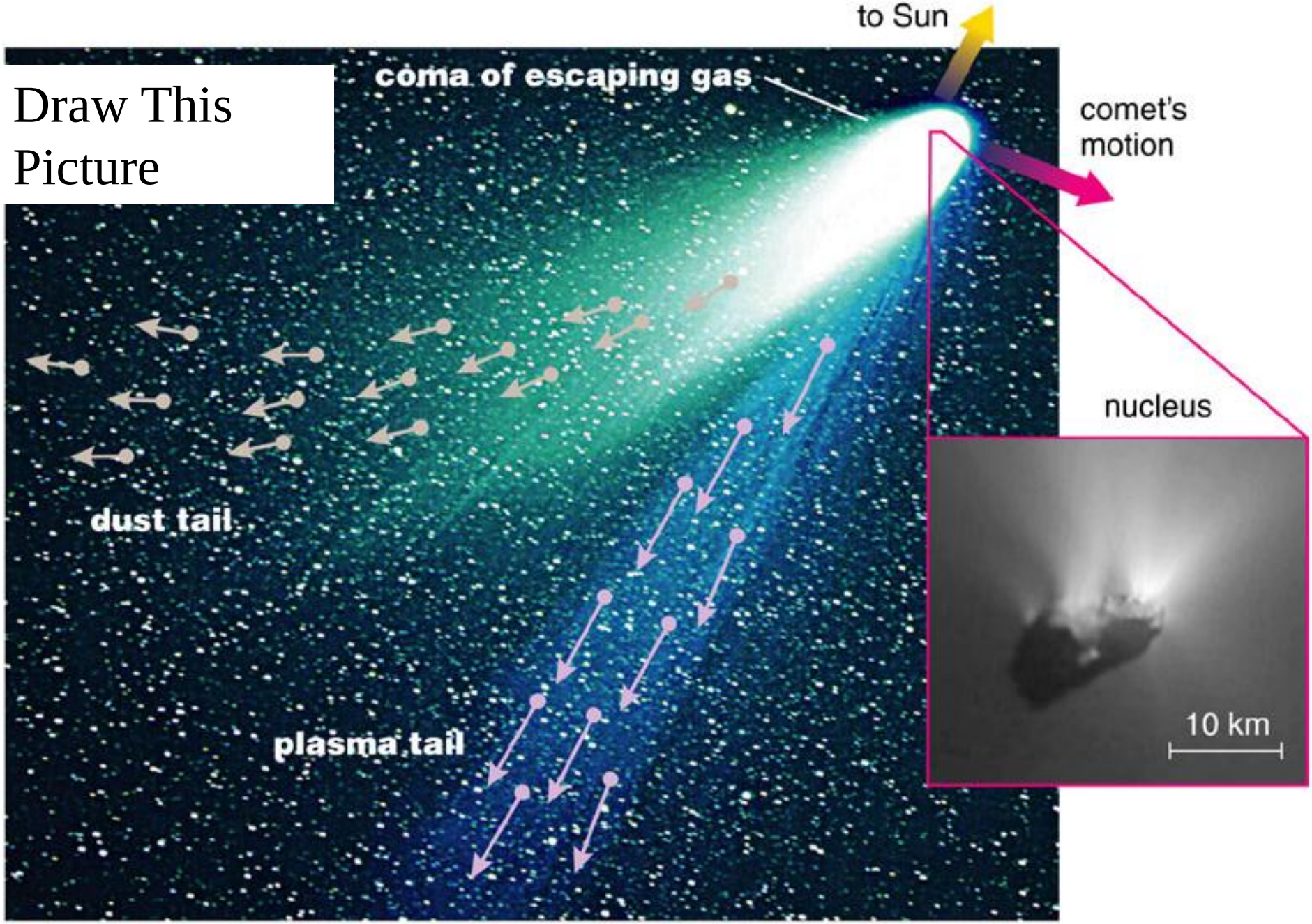
Comet Facts

- Formed beyond the frostline, comets are icy counterparts to asteroids.
- "Dirty snowballs" = the nucleus
- Most comets do not have tails.
- Most comets remain perpetually frozen in the outer solar system. Only a few enter the inner solar system, where they can grow tails.



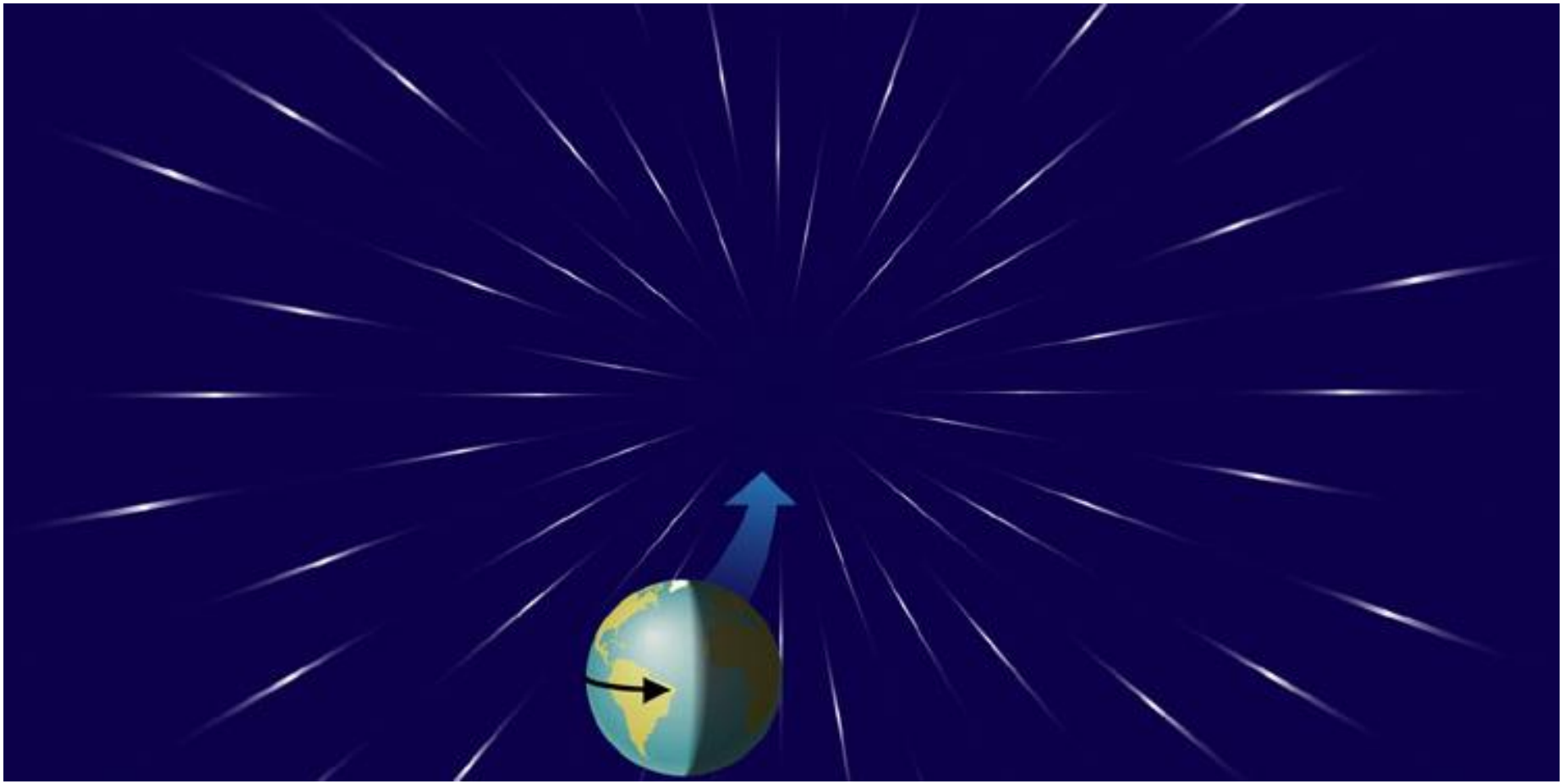
When a comet nears the Sun, its ices can sublimate into gas and carry off dust, creating a coma and long tails.

Draw This Picture



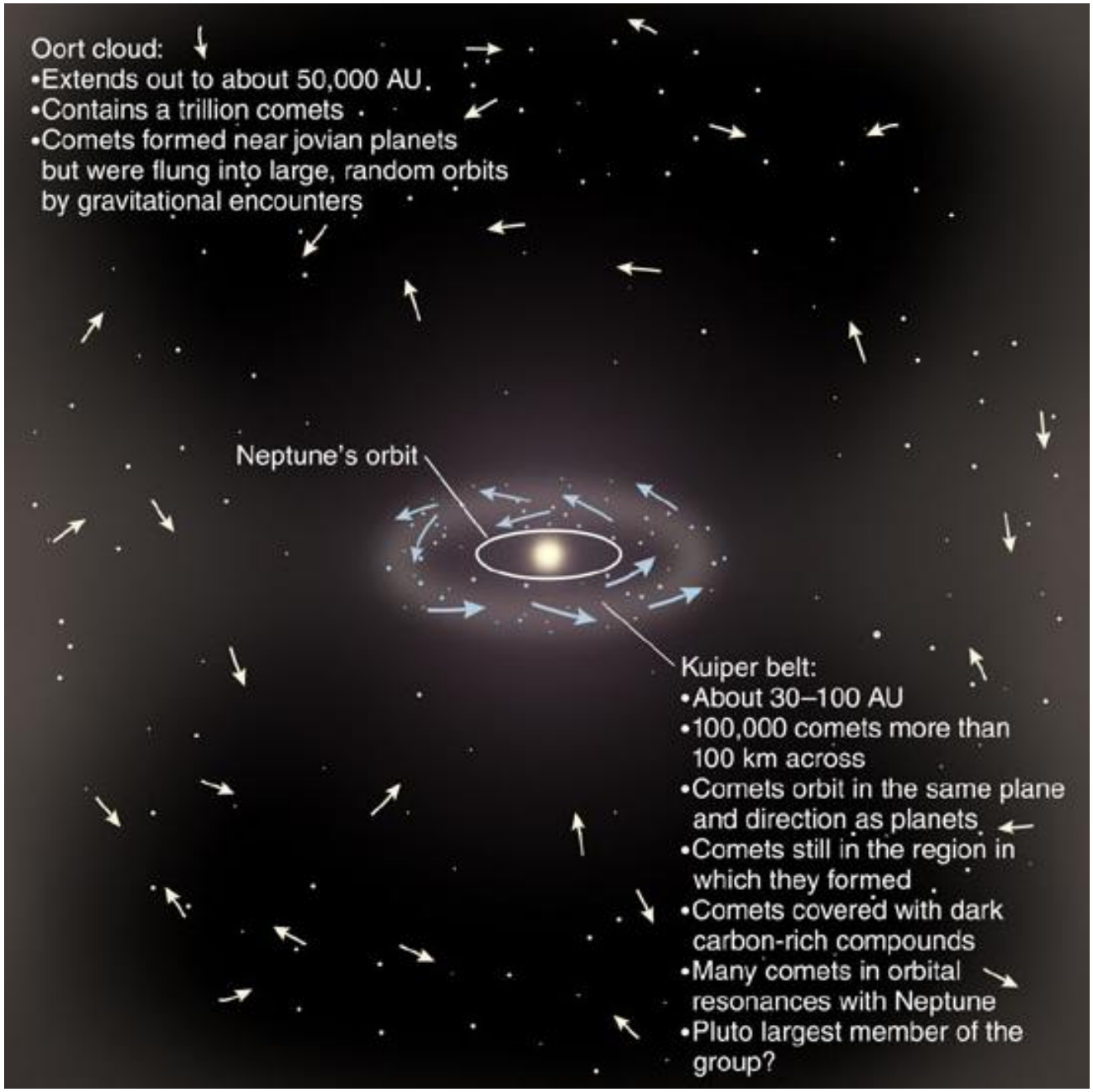
Comets eject small particles that follow the comet around in its orbit

<u>This can cause meteor showers when Earth crosses the comet’s orbit.</u>



Meteors in a shower appear to emanate from the same area of sky because of Earth’s motion through space

Where do comets come from?



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 30-100 AU in disk of solar system

How did they get there?

- Kuiper belt comets align with the plane of planet orbits
- Oort Cloud Comets were kicked out of the solar system by the gravity from jovian planets: **random orbits**

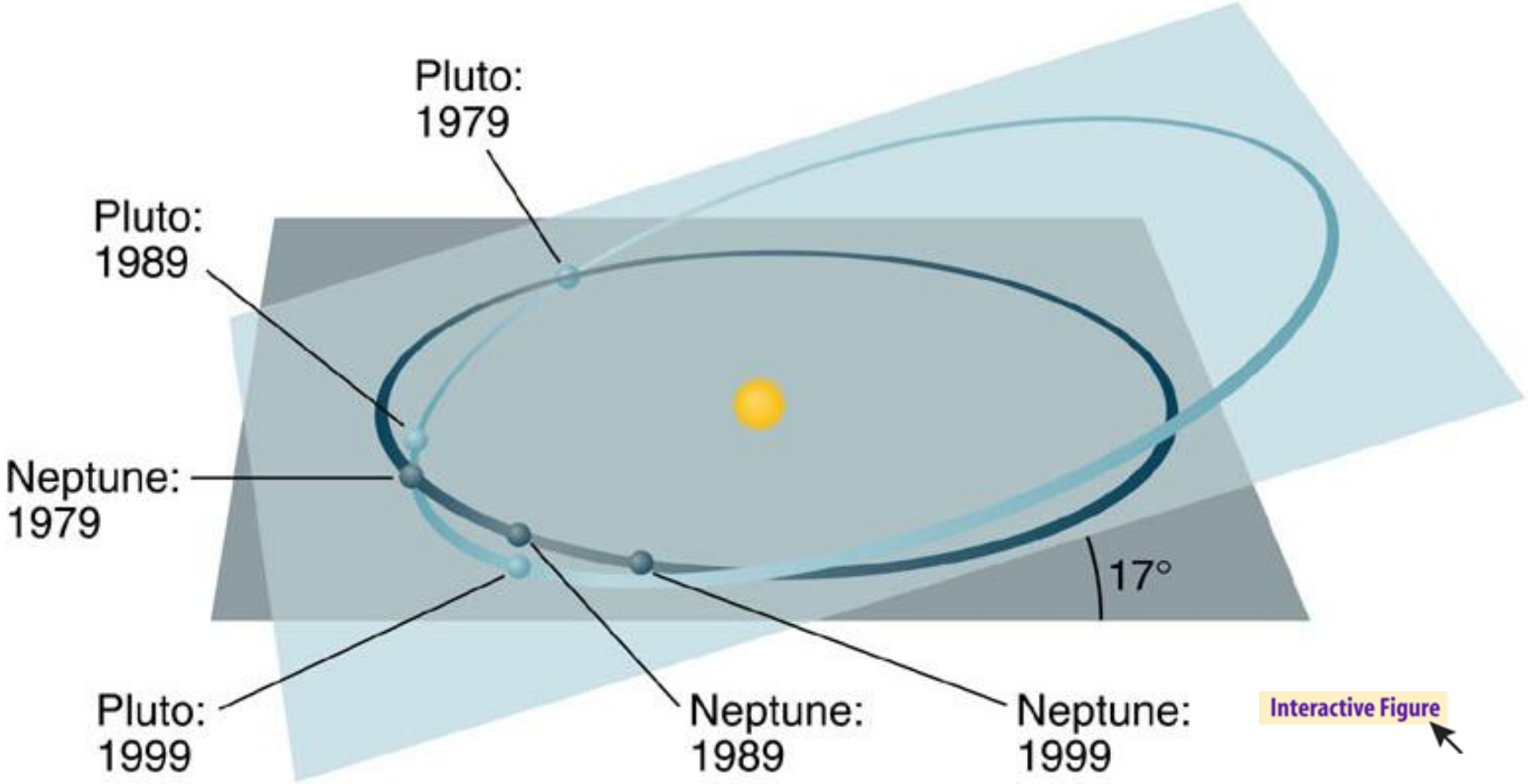
9.3 Pluto: Lone Dog or Part of a Pack?

- Our Goals for Learning
- **What is Pluto like?**
- **Is Pluto a planet or a Kuiper belt comet?**

Pluto: the exception

- Not a gas giant like the other outer planets.
- Has a very elliptical, inclined orbit.
- By far the smallest planet, and smaller than several moons.
- Has a surprisingly large moon Charon, probably formed by a huge comet collision with Pluto.

Pluto will never collide with Neptune because of a 3:2 orbital resonance.

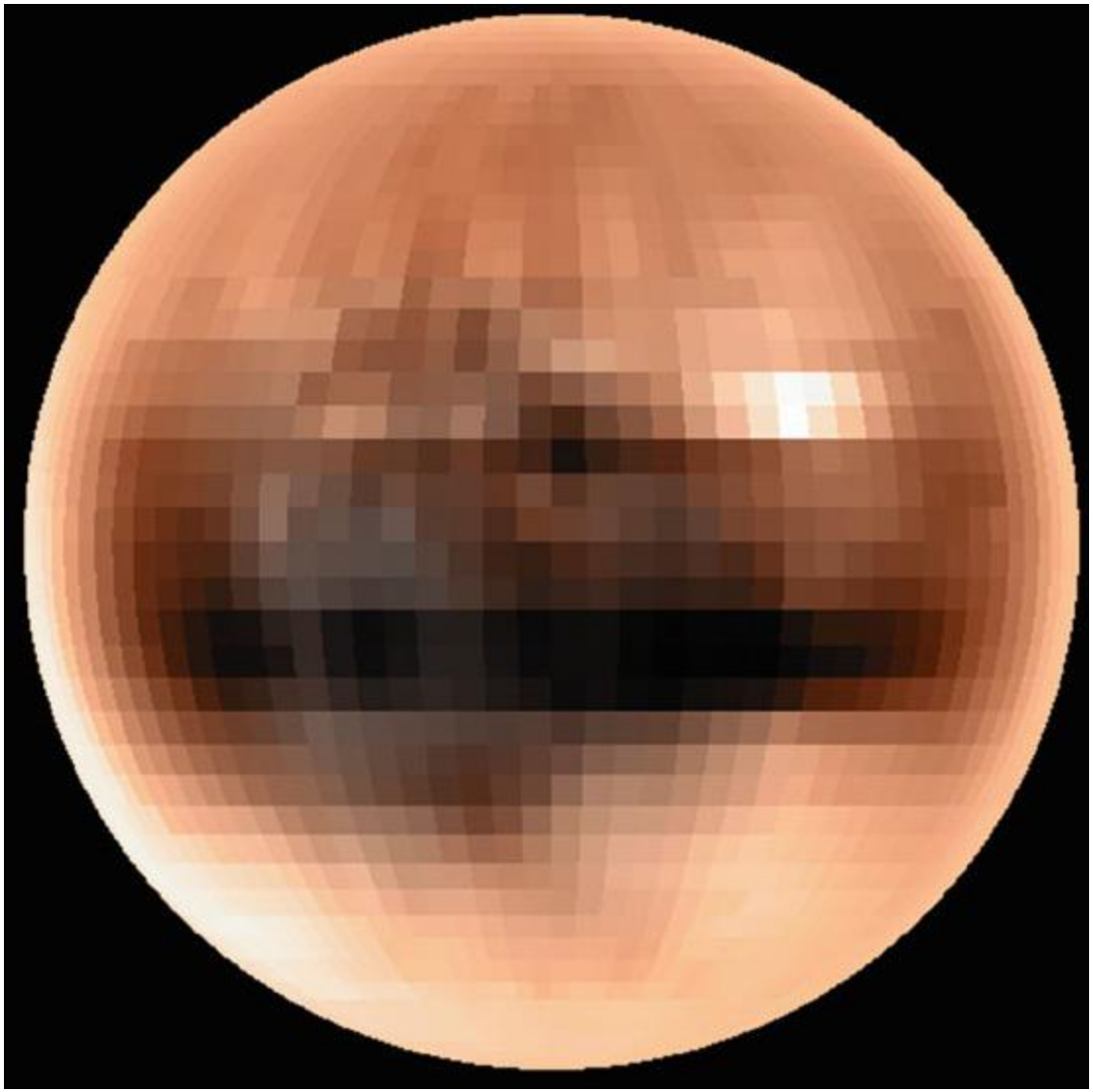


What is Pluto like?

- 1978 discovery of Pluto's moon Charon: Pluto's mass from Newton's orbital law.
- It has a thin nitrogen atmosphere that will refreeze onto the surface as Pluto's orbit takes it farther from the Sun.
- Pluto is the largest Solar System object that has not been visited by spacecraft.

HST's view of Pluto & Charon

Brightness variations during eclipsing orbits showed dirty ice - like comets.



Is Pluto a planet or a Kuiper Belt comet?

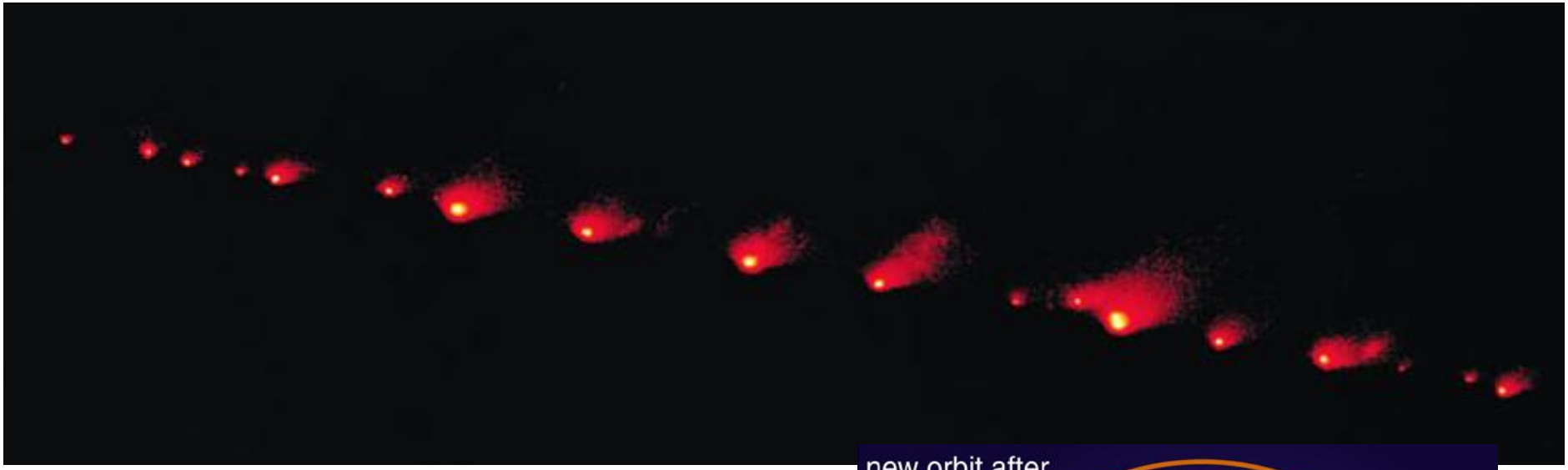
Is Pluto a planet or a Kuiper Belt comet?

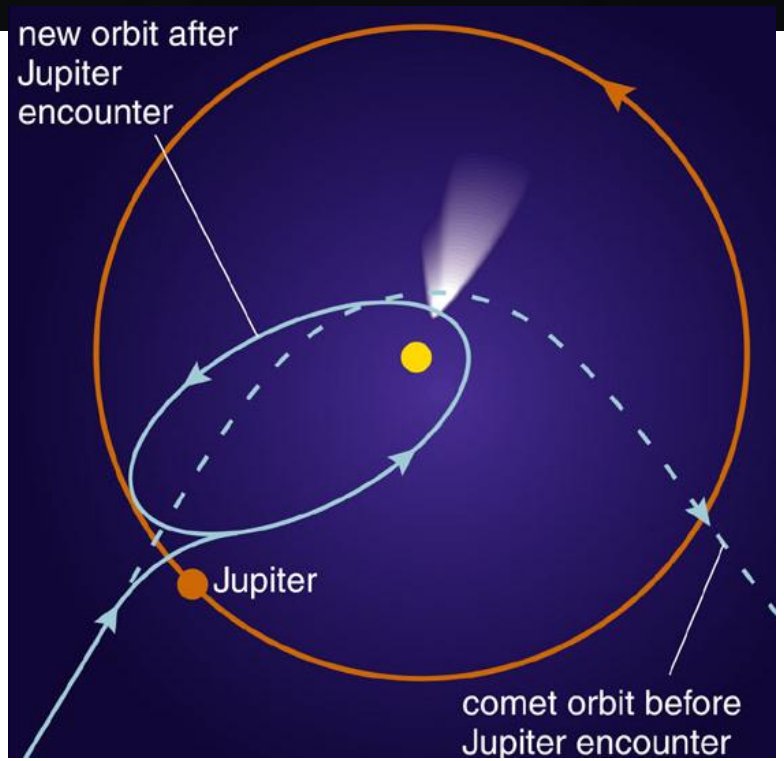
- Pluto is well beyond Neptune, in the Kuiper Belt.
- Inclined orbit is typical of Kuiper Belt comets.
- Composition is typical of Kuiper Belt comets, but not any of the other planets.

Is Pluto a planet or a Kuiper Belt comet?

- Kuiper Belt objects have been found that approach Pluto’s size.
- Kuiper Belt comets have similar orbital resonances with Neptune.
- Kuiper Belt comets can have moons.
- Triton (a captured moon) is even larger than Pluto.

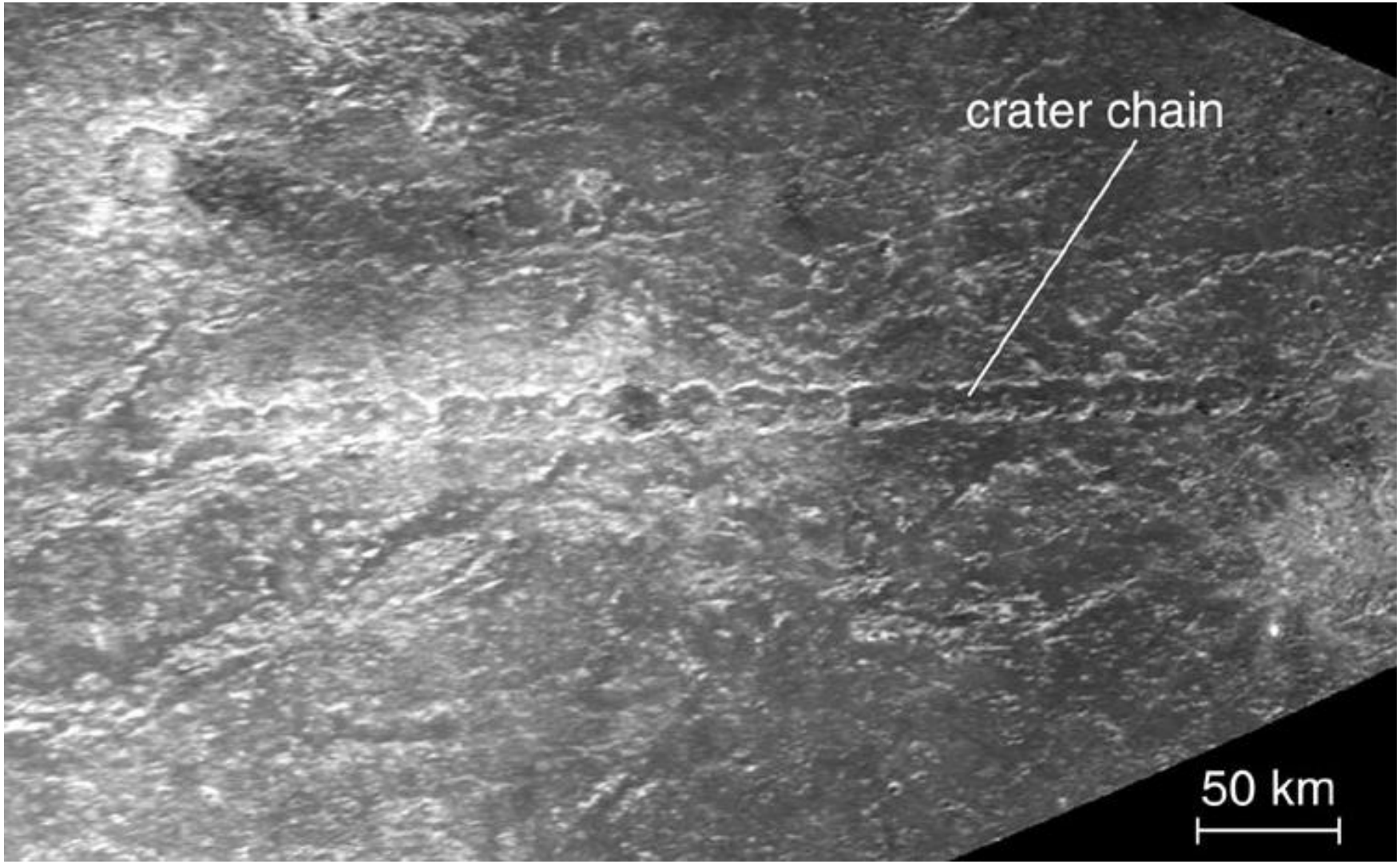
Have we ever witnessed a major impact?

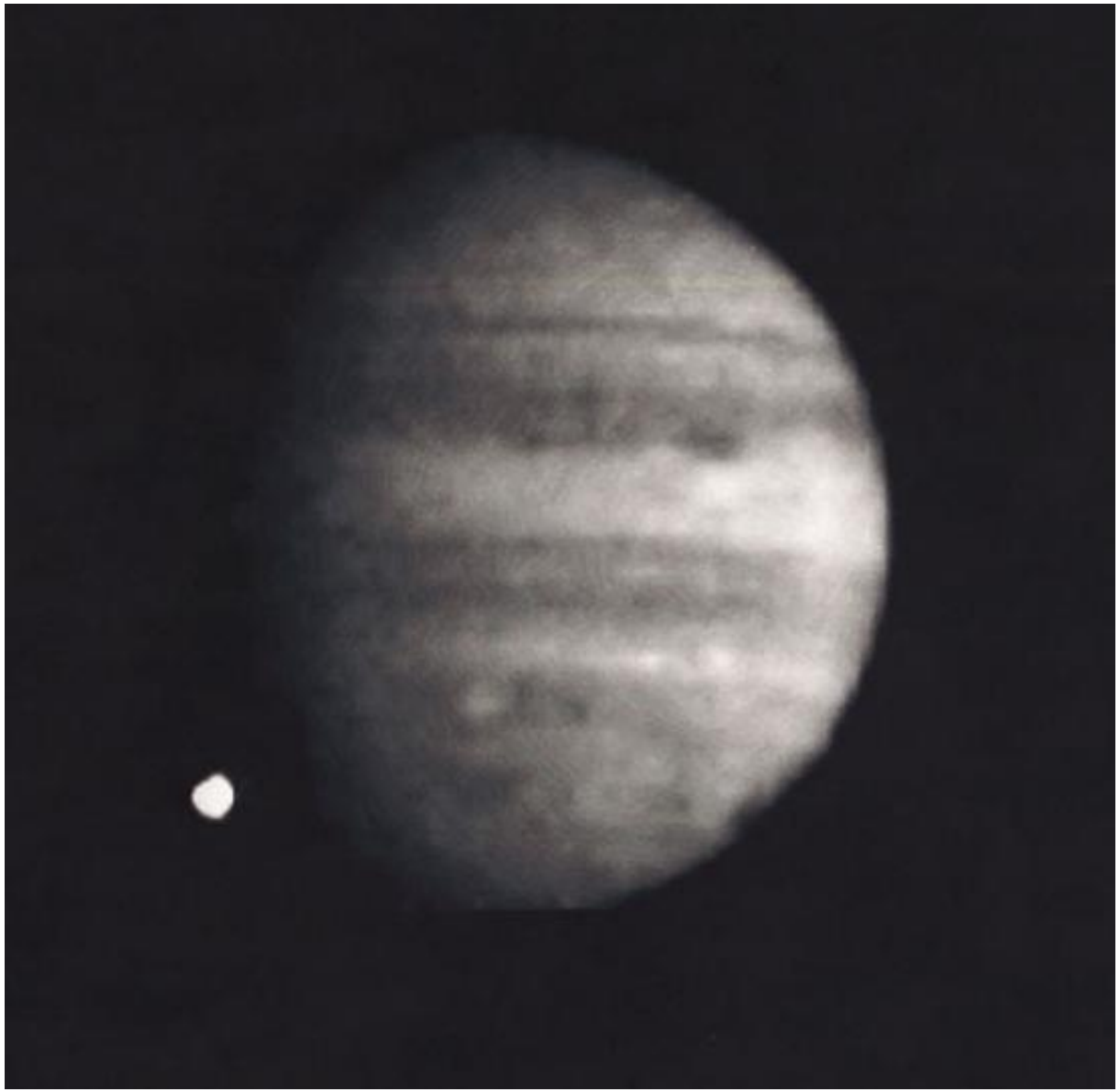


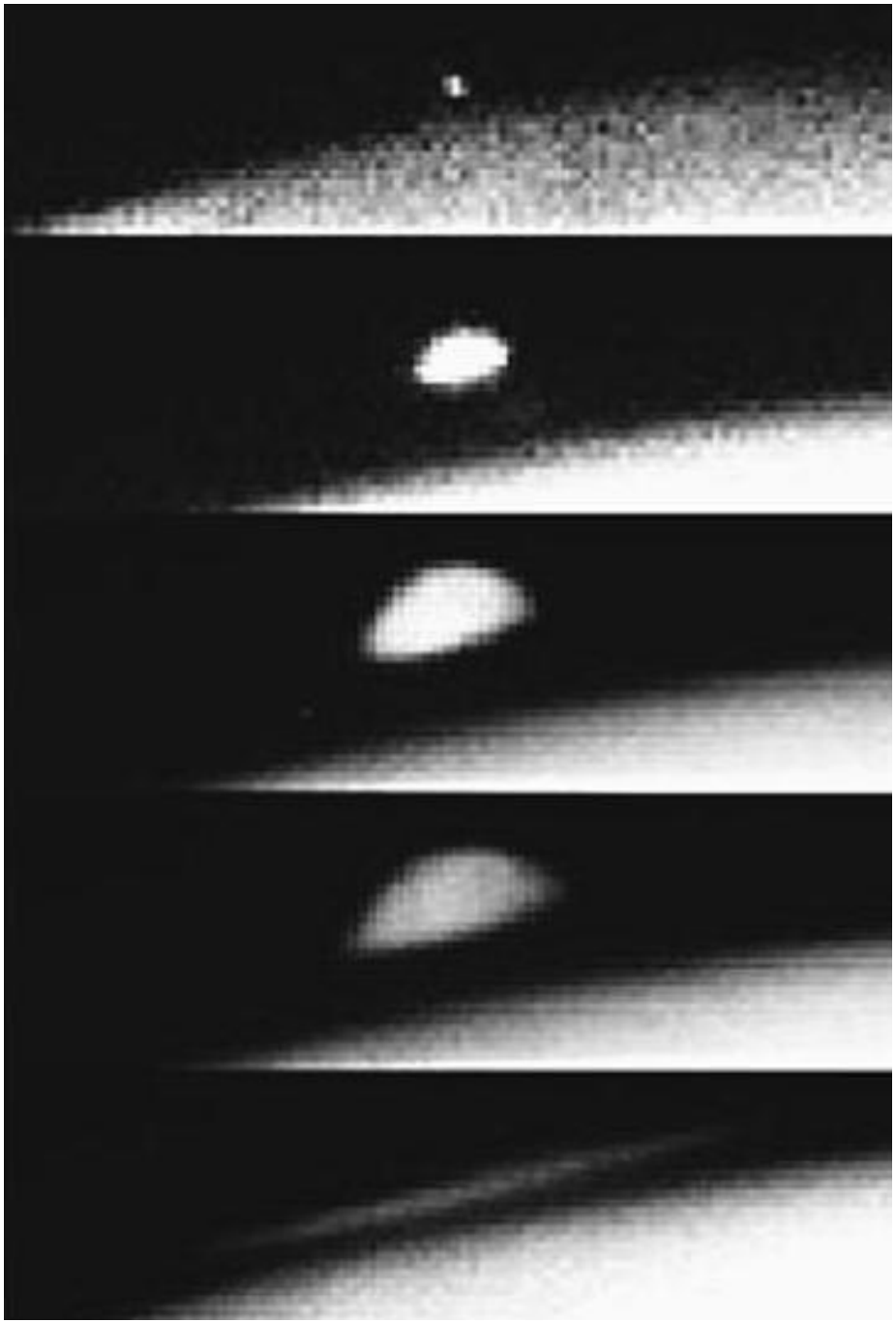


Comet SL9 caused a string of violent impacts on Jupiter in 1994, reminding us that catastrophic collisions still happen.

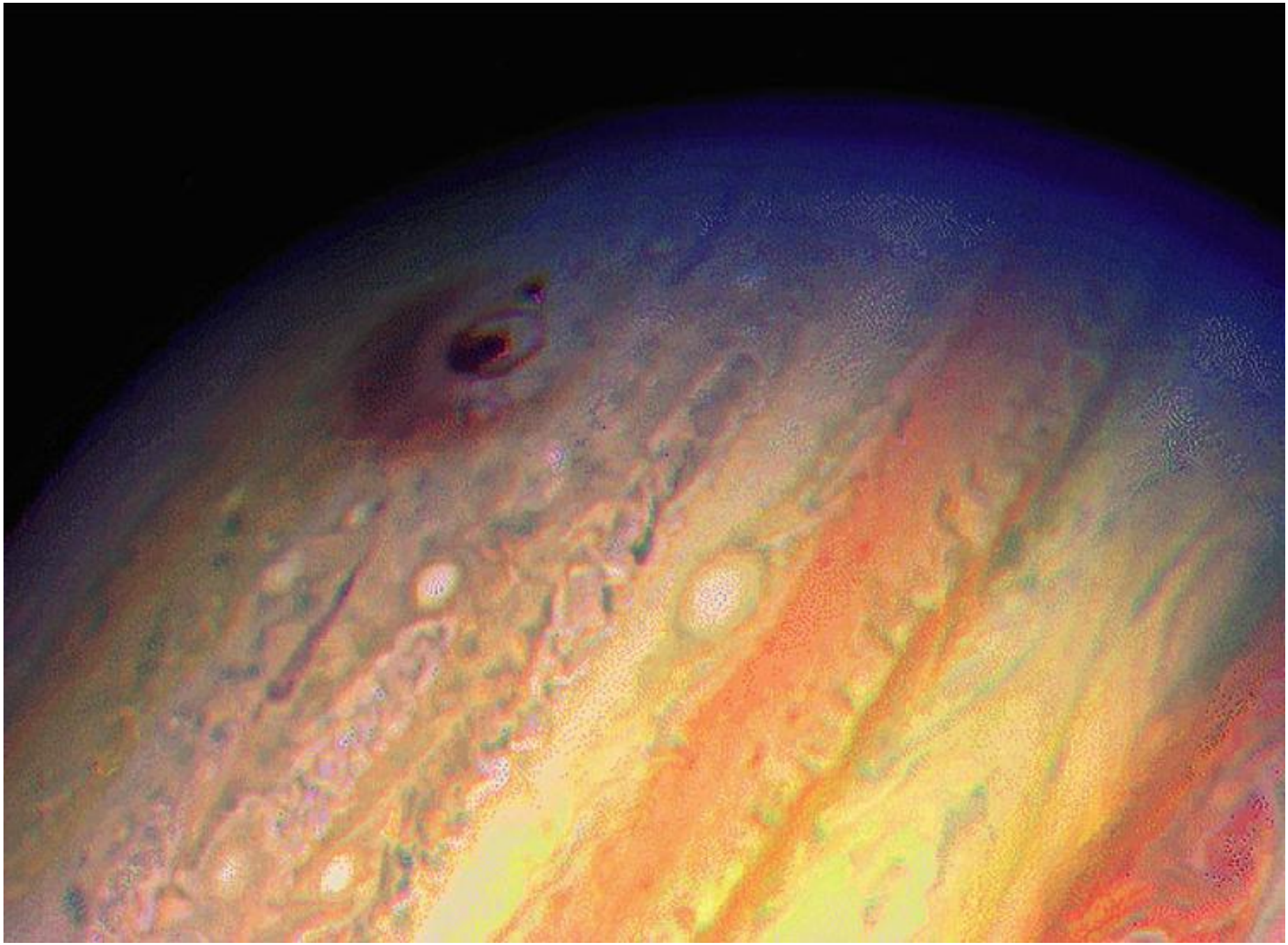
Tidal forces tore it apart during previous encounter with Jupiter

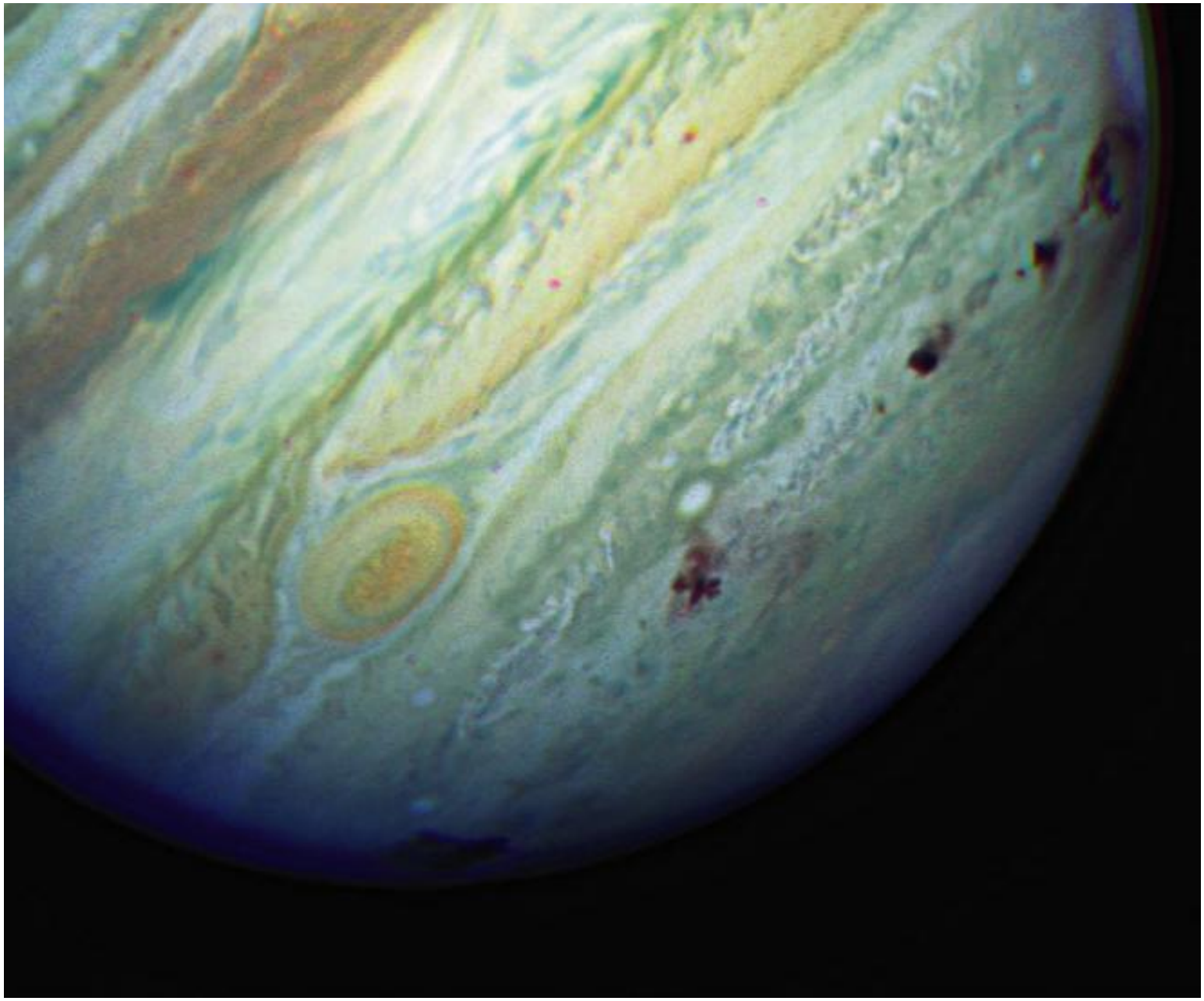

crater chain
50 km





Impact plume rises high above Jupiter’s surface





Did an impact kill the dinosaurs?

Mass Extinctions

- Large dips in total species diversity in the fossil record.
- The most recent was 65 million years ago, ending the reign of the dinosaurs.

Was it caused by an impact?

How would it have happened?

No dinosaur fossils in these rock layers

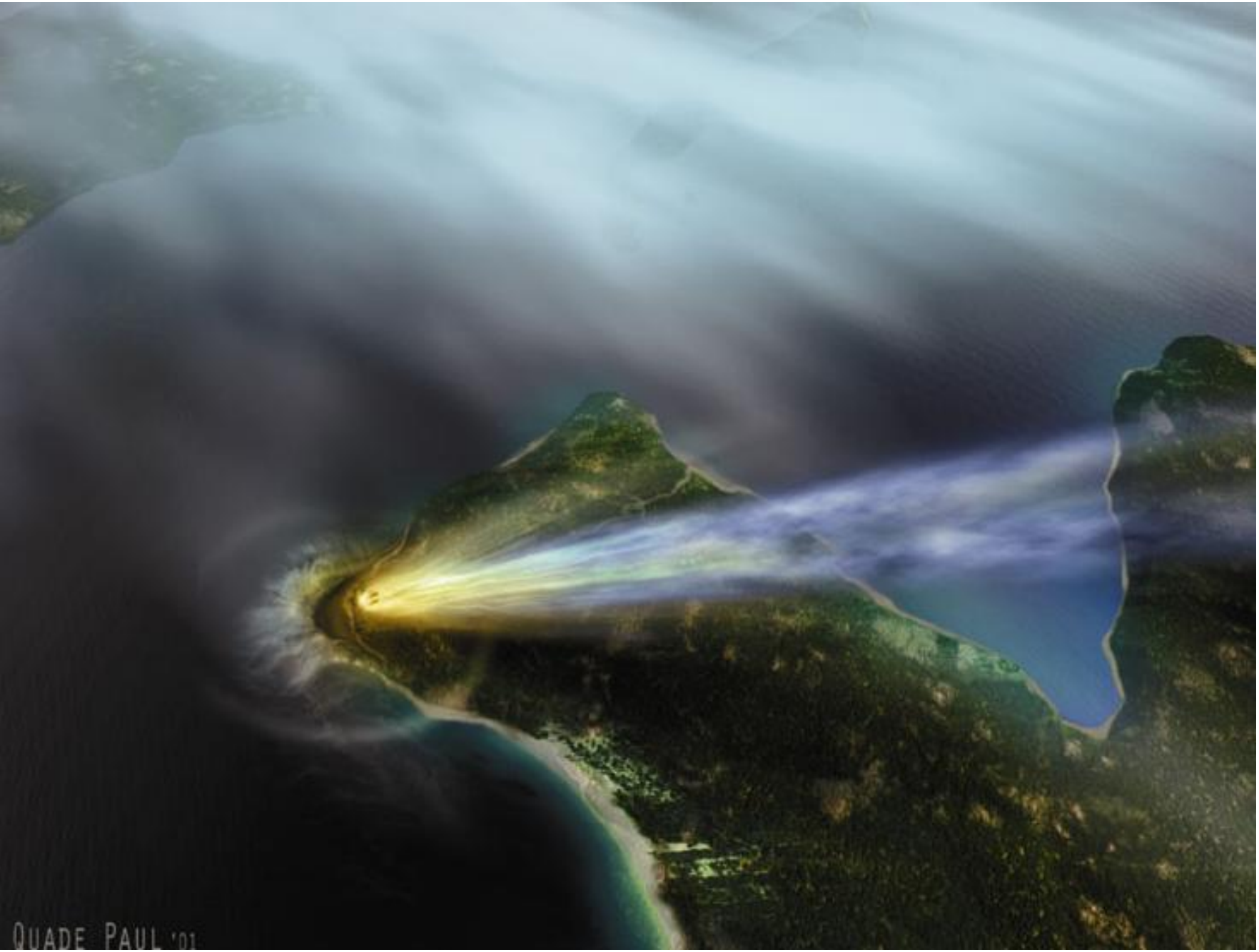
Thin layer containing iridium from impactor

Dinosaur fossils in lower rock layers

Iridium - evidence of an impact

- Iridium is very rare in Earth surface rocks but often found in meteorites.
- Luis and Walter Alvarez found a worldwide layer containing iridium, laid down 65 million years ago.

Comet or asteroid about 10km in diameter approaches Earth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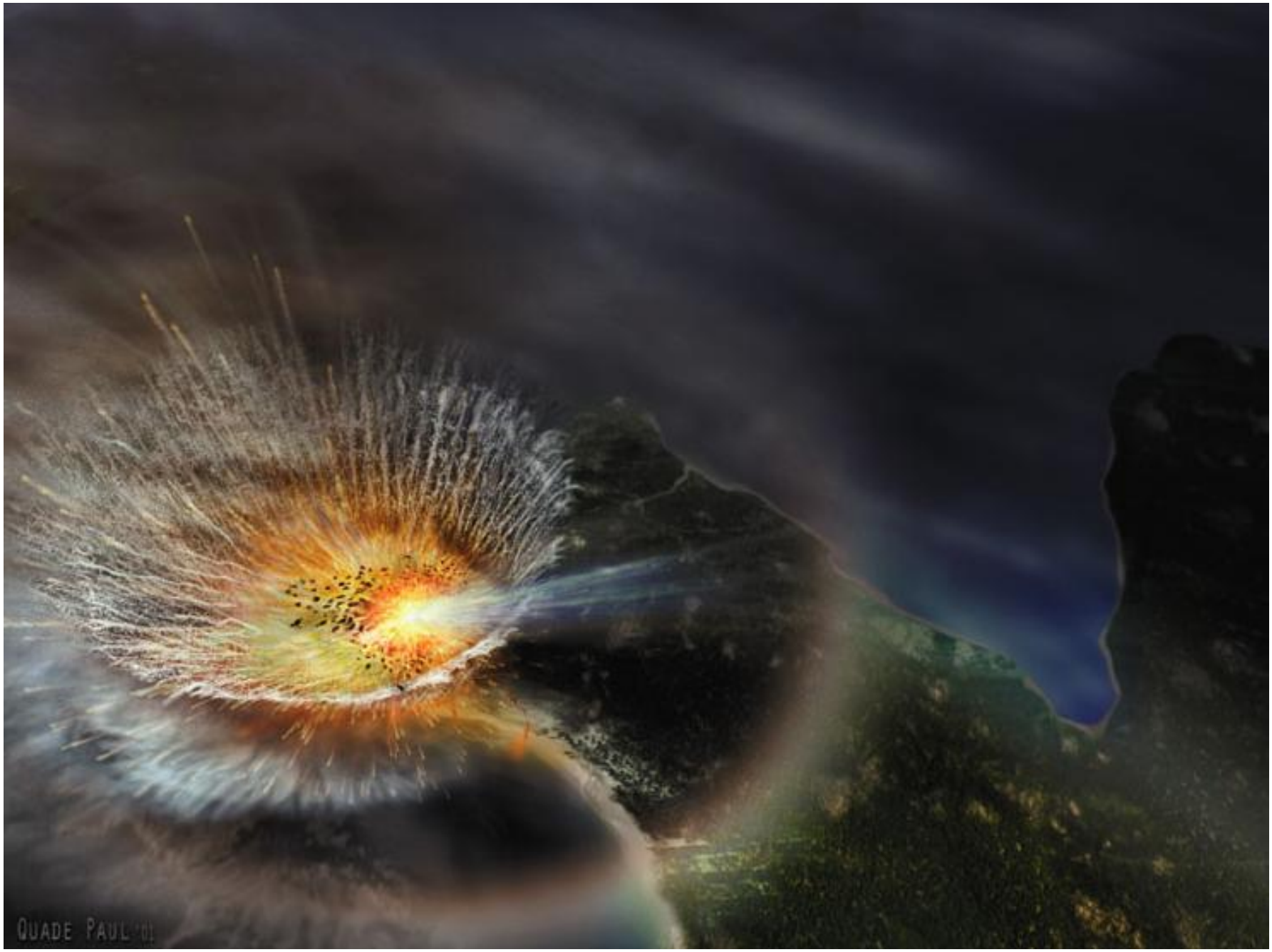
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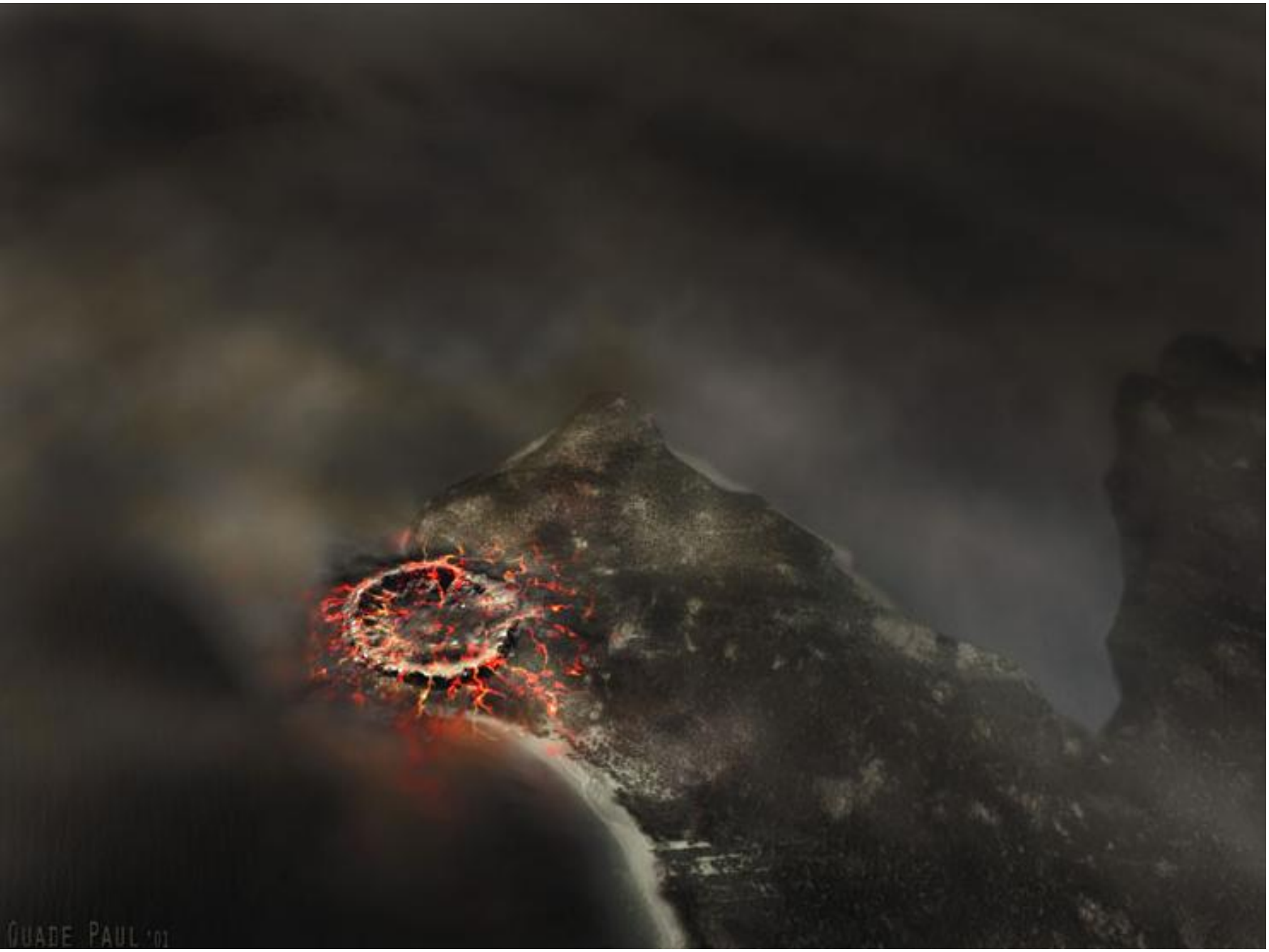
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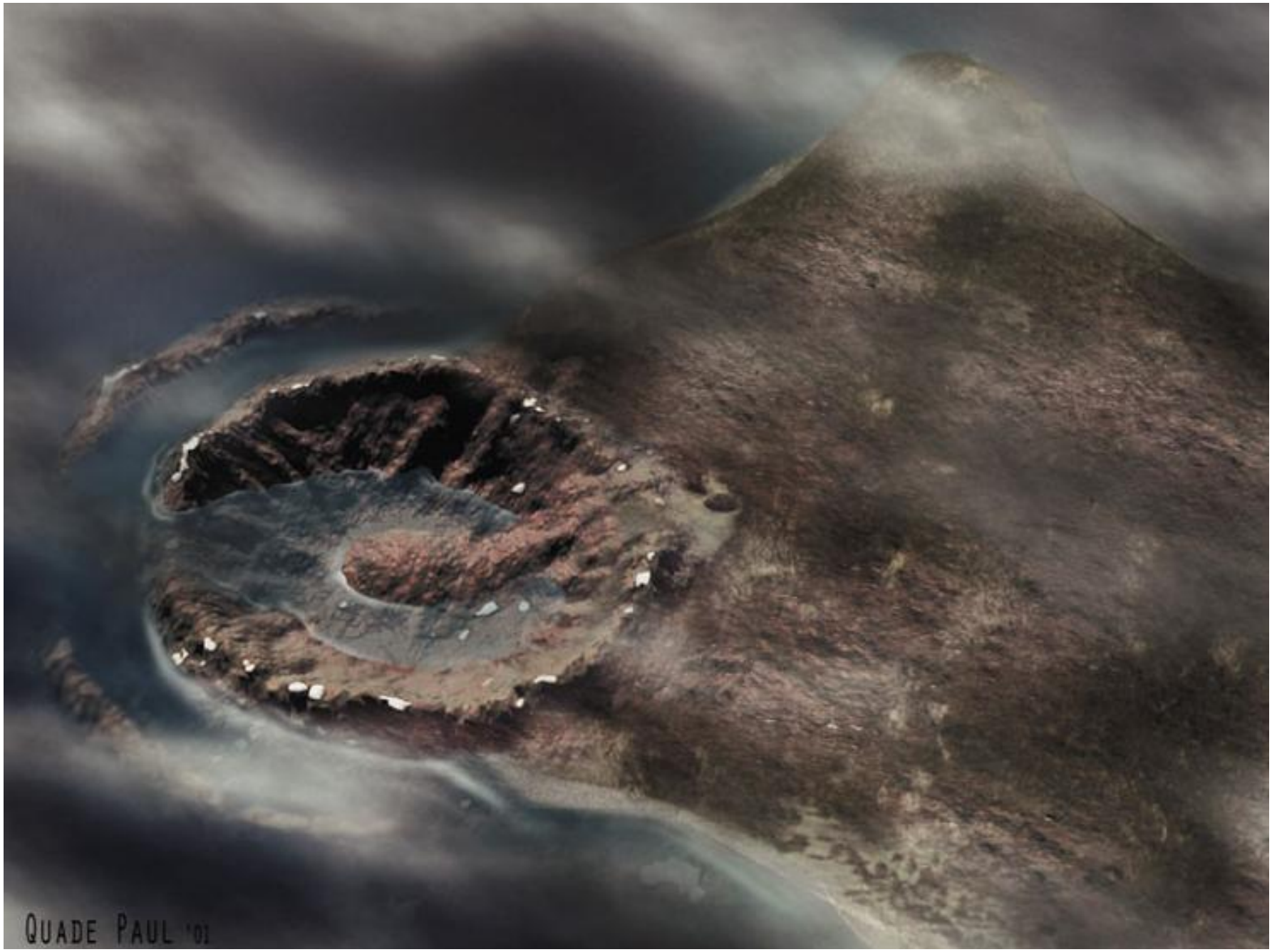
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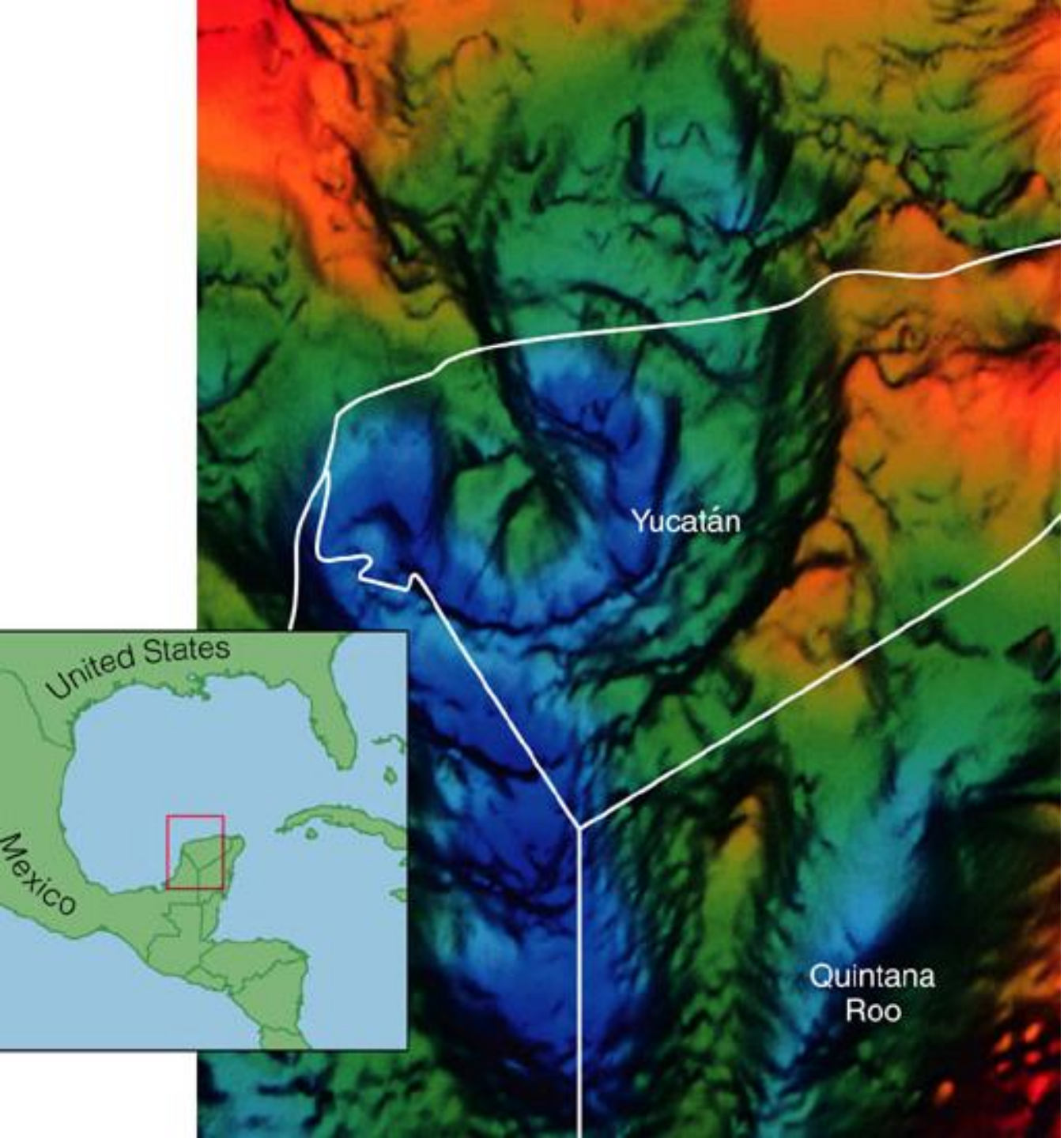


<u>An iridium-rich sediment layer and an impact crater on the Mexican coast 65 million years ago.</u>
shows that a large impact occurred at the time the dinosaurs died out,

The Impact Threat: Real danger or media hype?

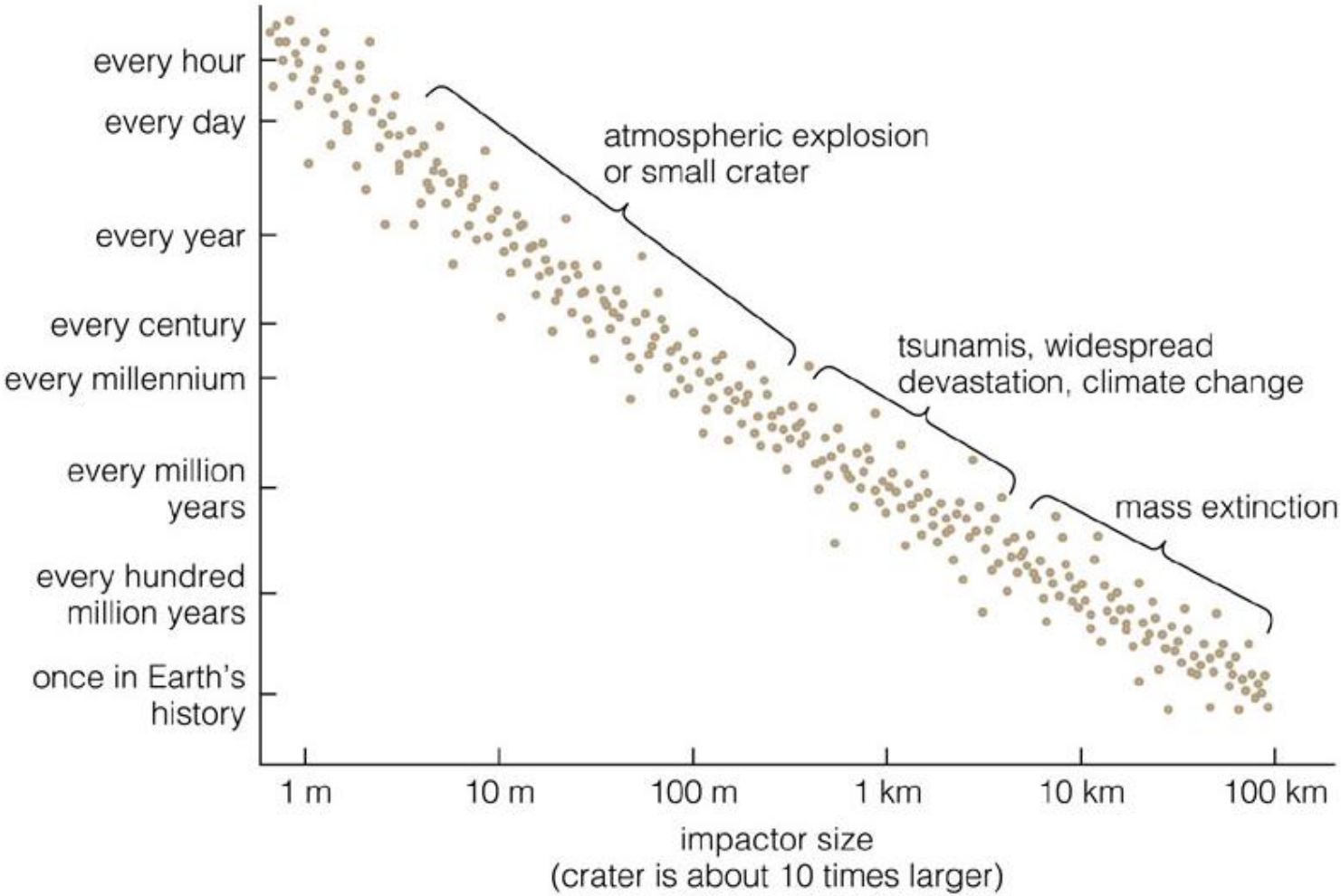
Facts

- Asteroids and comets have hit the Earth.
- A major impact is only a matter of time: not IF but WHEN.
- Major impact are very rare.
- Extinction level events ~ millions of years.
- Major damage ~ tens-hundreds of years.

Tunguska, Siberia: June 30, 1908

The ~40 meter object disintegrated and exploded in the atmosphere

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



Impacts will certainly occur in the future, and while the chance of a major impact in our lifetimes is small, the effects could be devastating.

The asteroid with our name on it

We haven’t seen it yet.

Deflection is more probable with years of advance warning.

Control is critical: breaking a big asteroid into a bunch of little asteroids is unlikely to help.

We get less advance warning of a killer comet…