

Astronomy 150: Killer Skies

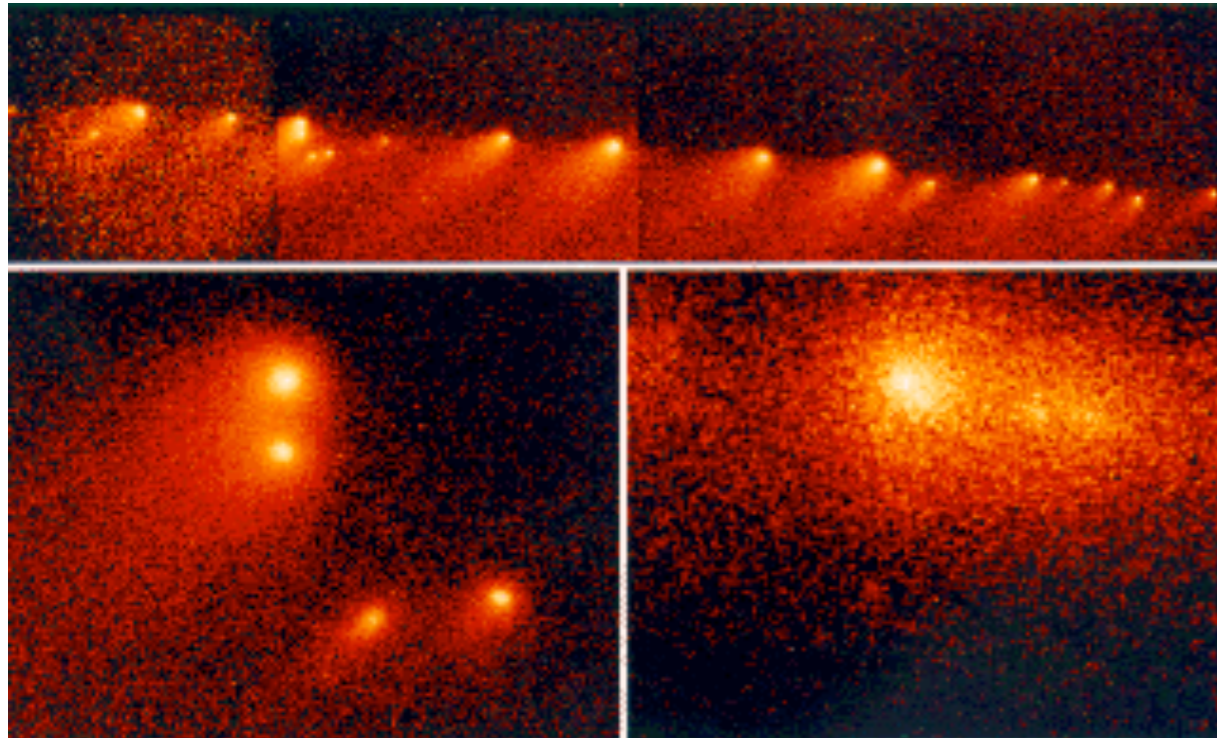
Lecture 11, February 10

Assignments:

- ▶ **HW 3 due now**
good news: no homework next Friday
- ▶ **Bad news: Hour Exam 1 next Friday Feb 17, in class**
information on [course website](#)
- ▶ **Planetarium: report due Feb 24**
extra show added next Thursday Feb 16
can go to public shows on “Black Holes” or “Prairie Skies”

Last time: T. Rex and the Crater of Doom!

Today: **A Warning from Jupiter, and Hunting for Impactors**



iClicker Poll:

Hour Exam 1 Question Count

The exam will be multiple choice.

You will have the usual **50min** of classtime:
no more, no less.

How many questions would you like?

few Qs = each counts more, but more time per question

many Qs = each counts less, but less time per question

- A. 20
- B. 25
- C. 30
- D. 35
- E. 40





If something like Tunguska happens every ~100 years, how come we haven't heard about it? Why haven't more people been killed by asteroid impacts in the past?



If something like Tunguska happens every ~100 years, how come we haven't heard about it? Why haven't more people been killed by asteroid impacts in the past?

- Before the 20th Century, human population was much lower, so likelihood of someone being affected is lower.**
- If someone did see a Tunguska, less likelihood of word getting around -- news didn't disperse as easily back then.**

Witness to Disaster?

Impact cratering is an important process in the history of Earth and other planets

Have we ever seen a large impact?



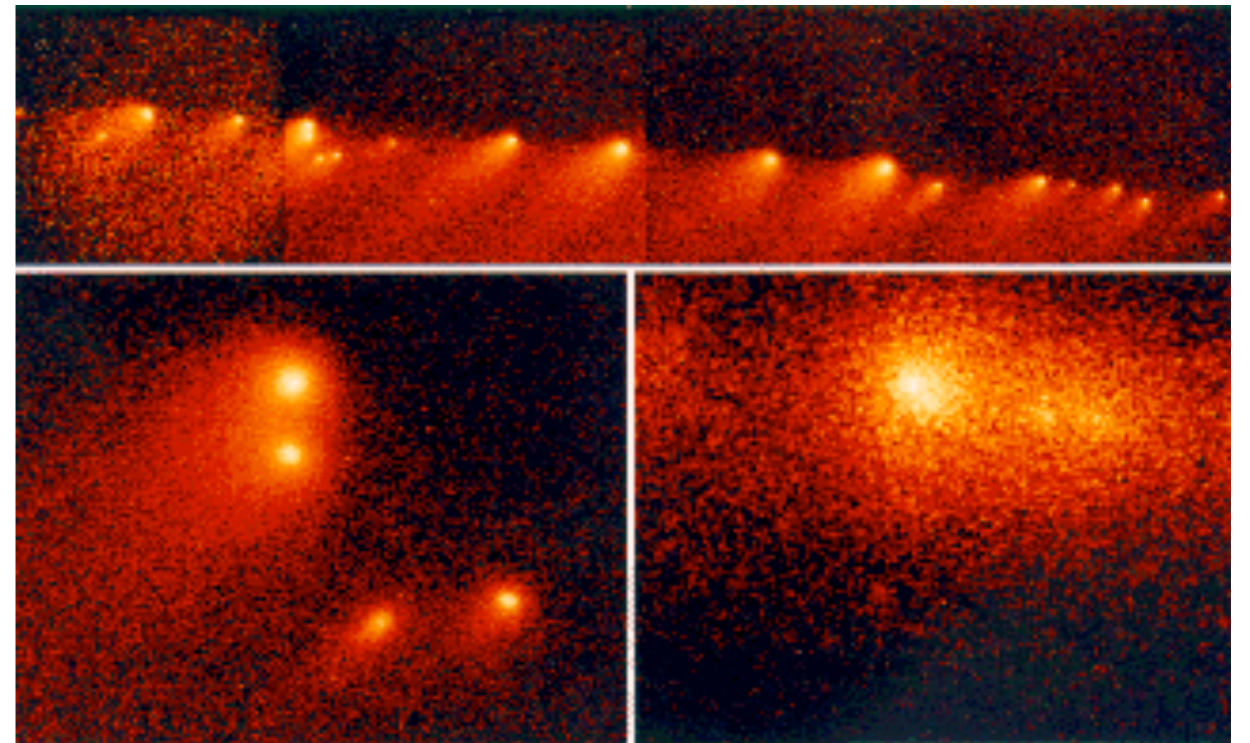
YES, we have seen a major impact....on Jupiter:

In 1994, Comet Shoemaker-Levy 9 (5km!) -- already broken up into fragments -- collided with Jupiter.

Each fragment impacted, reminding us that catastrophic collisions can and do happen

The sequence of events

The collision of the comet with Jupiter occurred over several days, 16-22 July 1994
It was the first collision of two solar system bodies ever observed



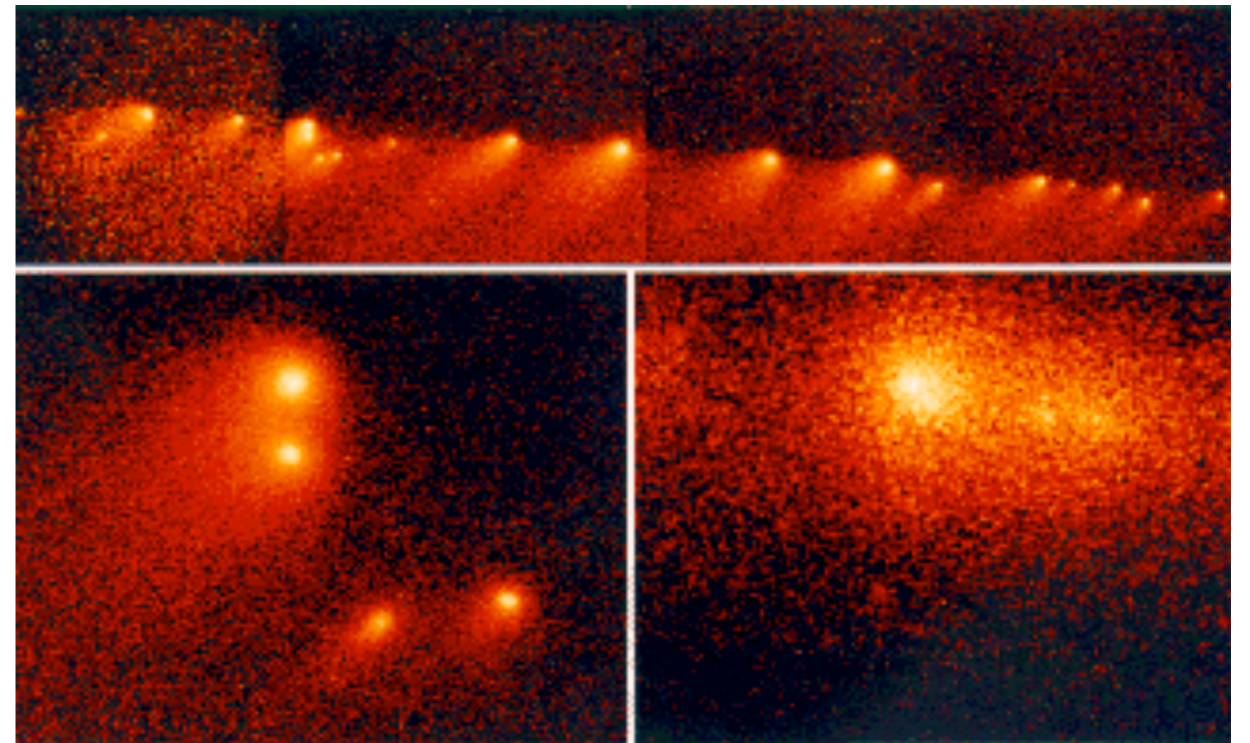
<http://www2.jpl.nasa.gov/sl9/background.html>

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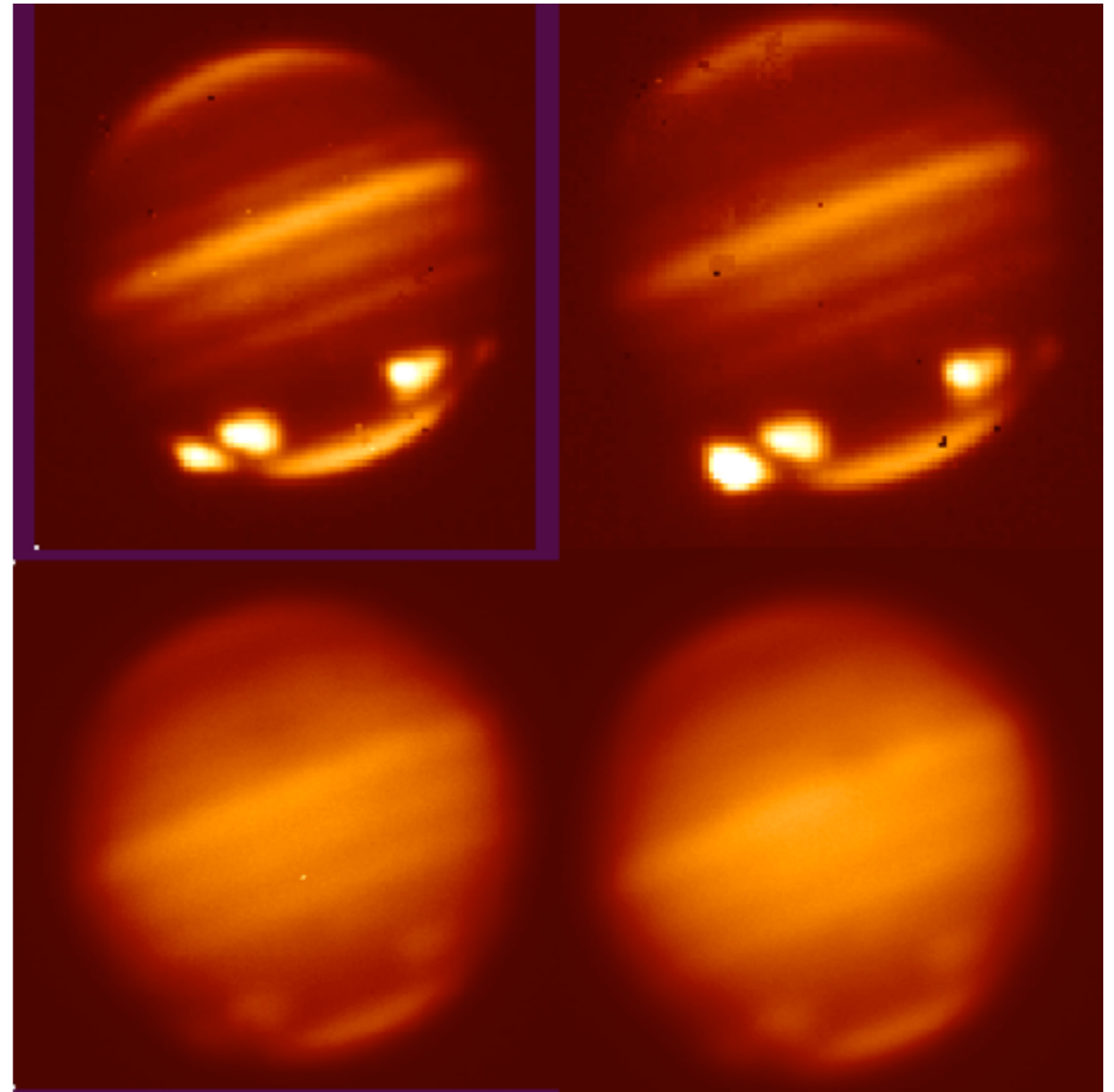
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- ▶ **At least 20 fragments hit Jupiter**
- ▶ **at speeds of 60 km/second = 130,000 mph**



<http://www2.jpl.nasa.gov/sl9/background.html>

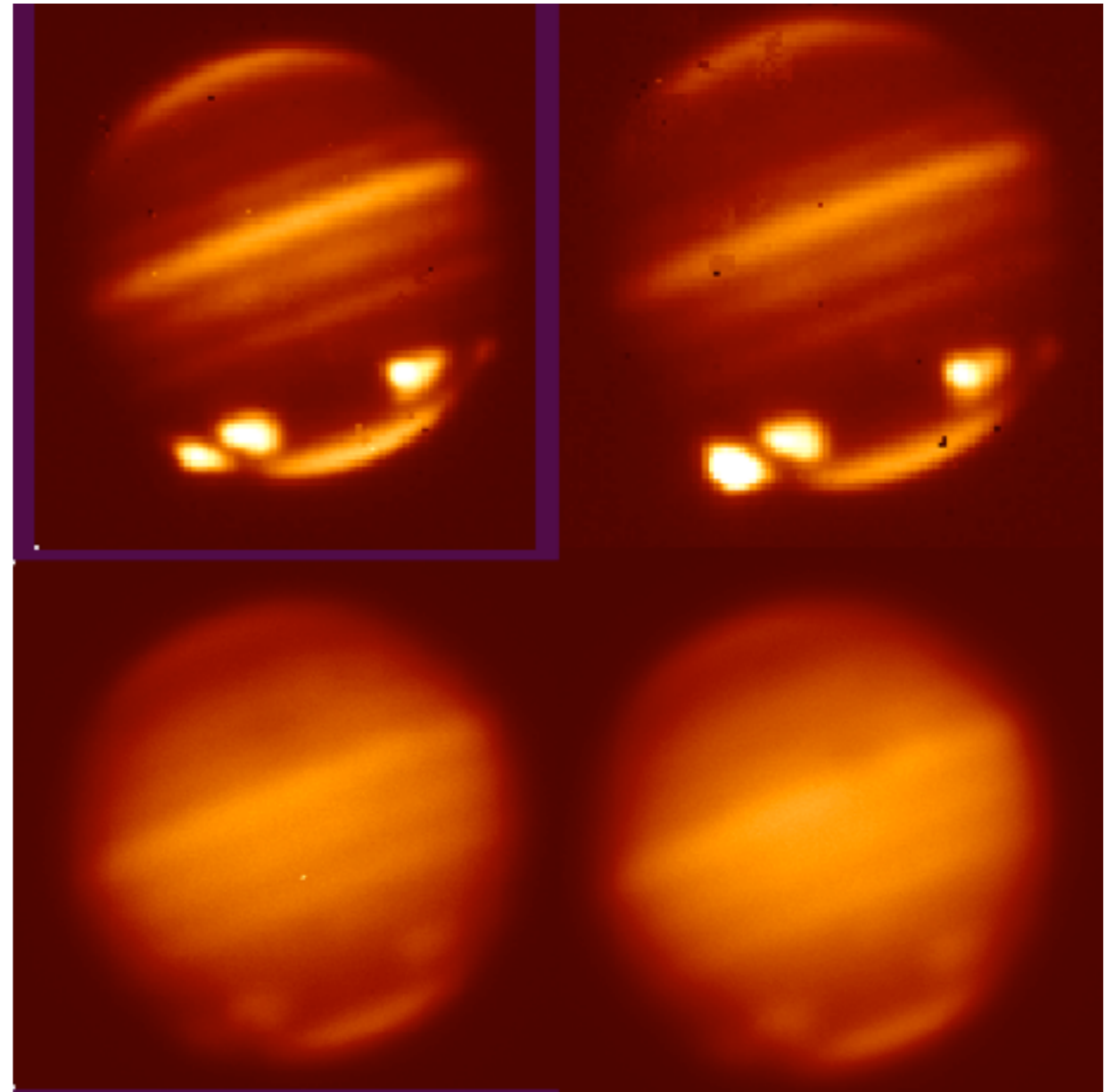
Sizes of fragments



<http://www.as.utexas.edu/mcdonald/comet/jul21.gif>

Sizes of fragments

The largest fragments were about 2 km in diameter

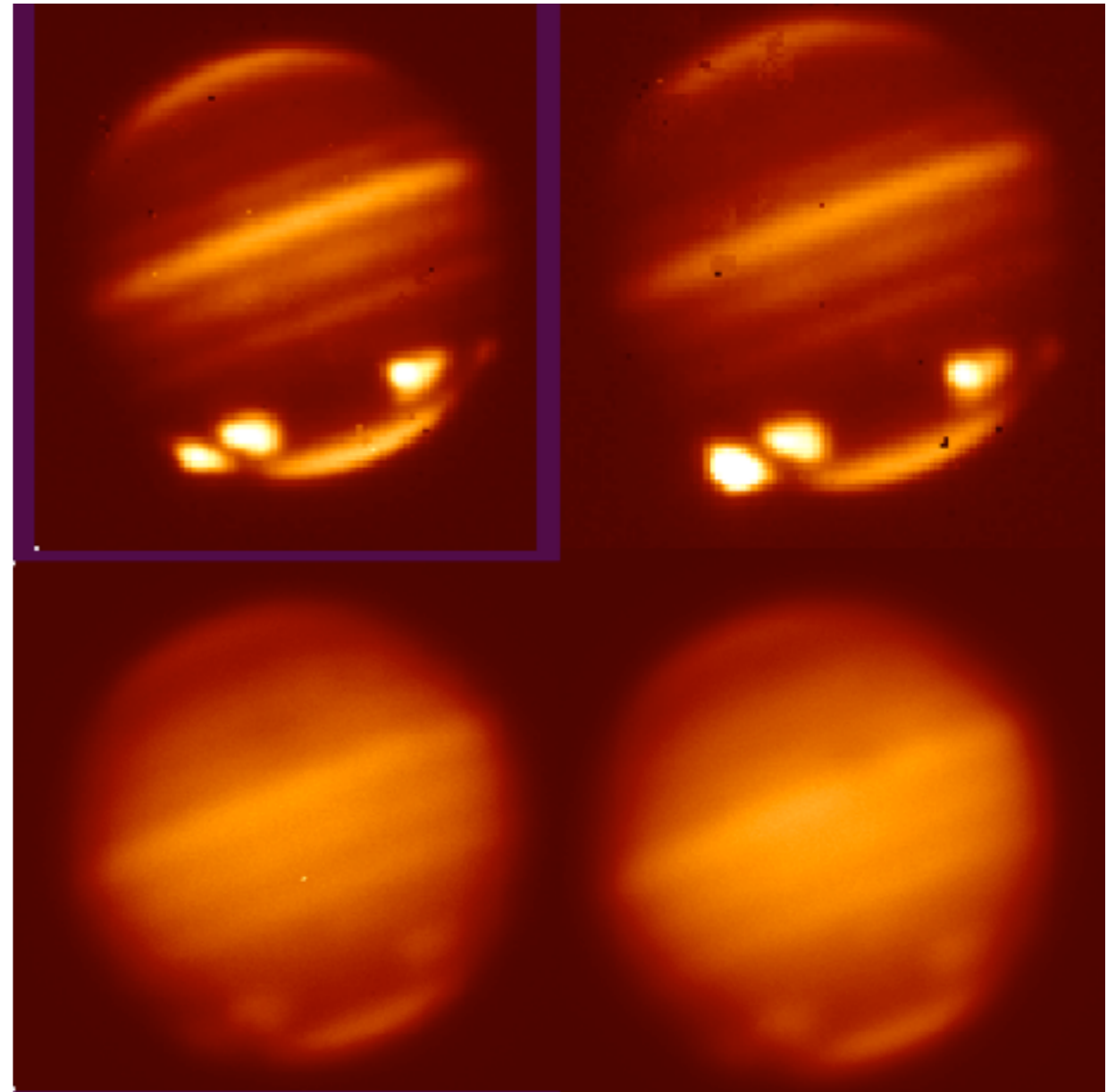


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Sizes of fragments

The largest fragments were about 2 km in diameter

Huge plumes thousands of km high were generated



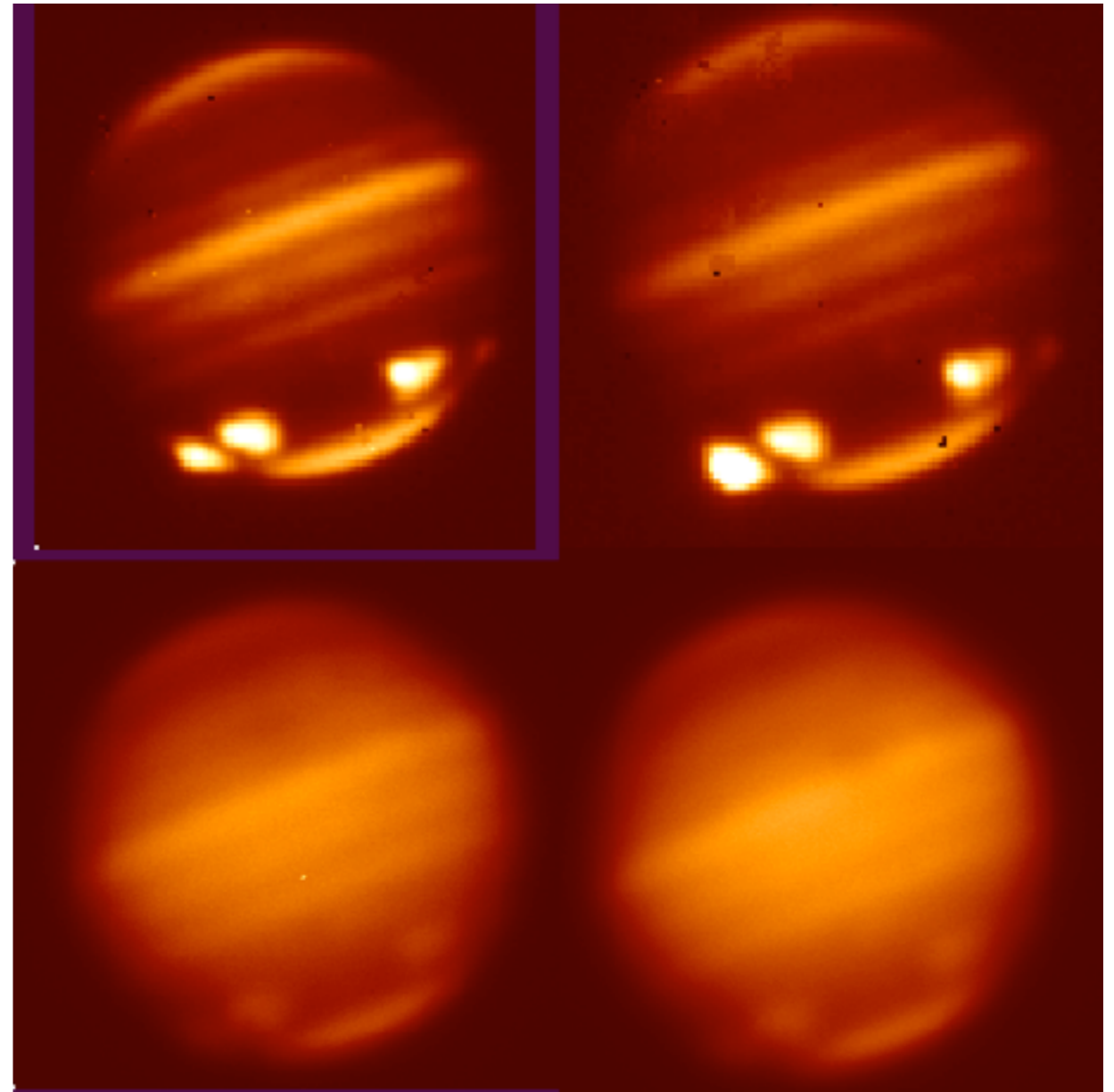
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Comparisons can be made with the Cretaceous-Tertiary (KT) extinction event—Dino Killer

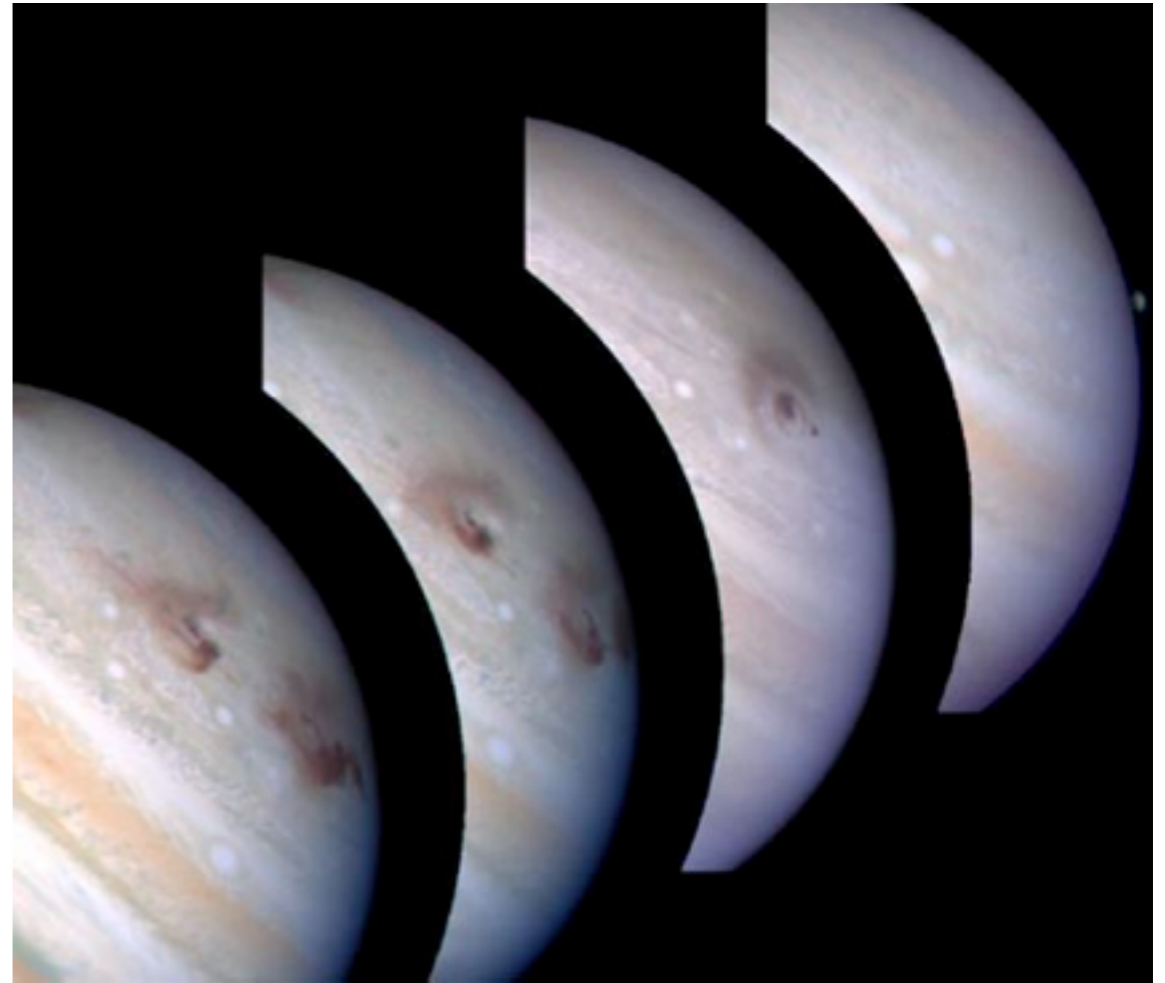


<http://www.as.utexas.edu/mcdonald/comet/jul21.gif>

Stop Giggling?

<http://www.youtube.com/watch?v=l6AIt36-whc>

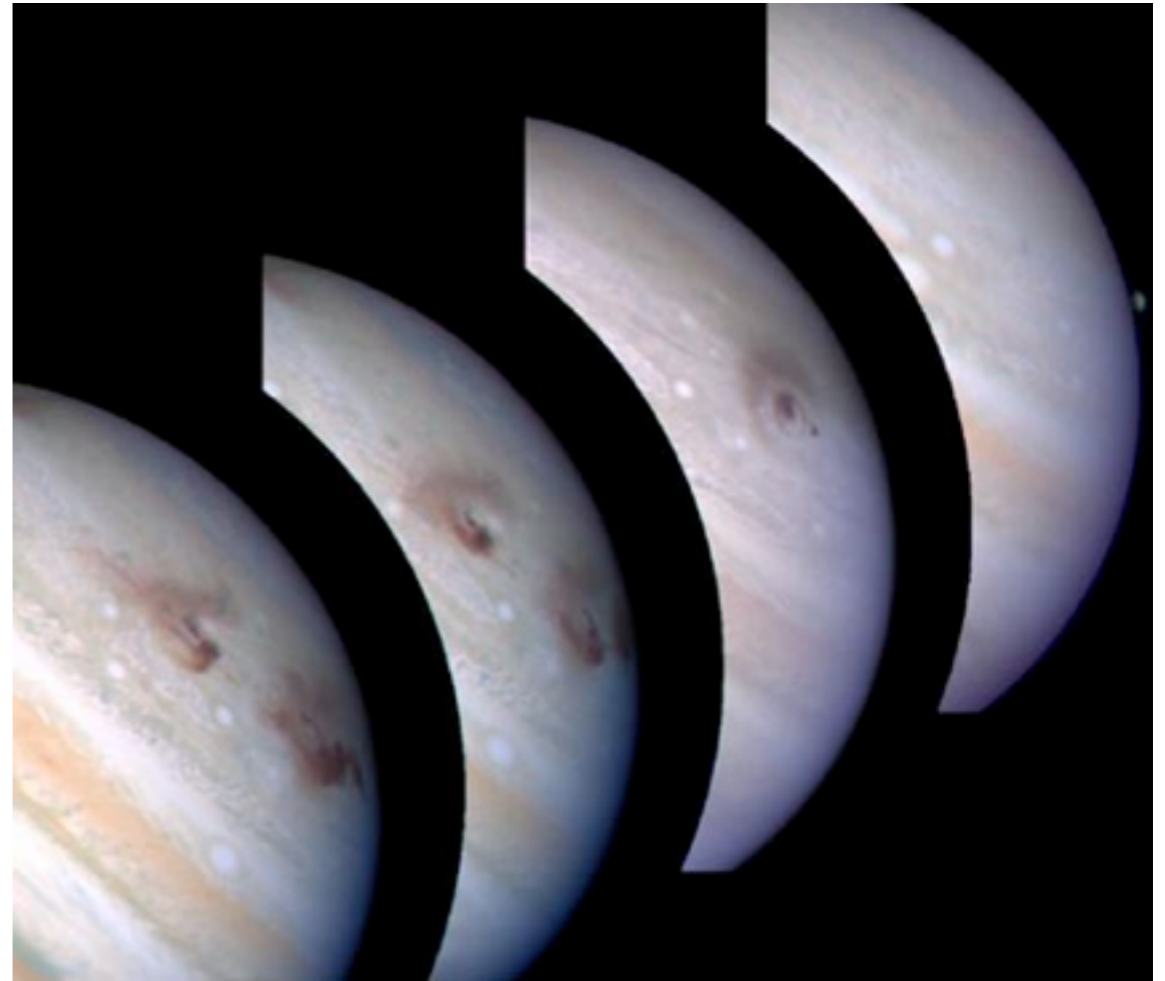
Energies



http://www.sai.msu.su/apod/image/9808/sl9gevol_hst.jpg

Energies

Fragment A struck with energy equivalent to 225,000 megatons of TNT, the plume rising to 1000 km

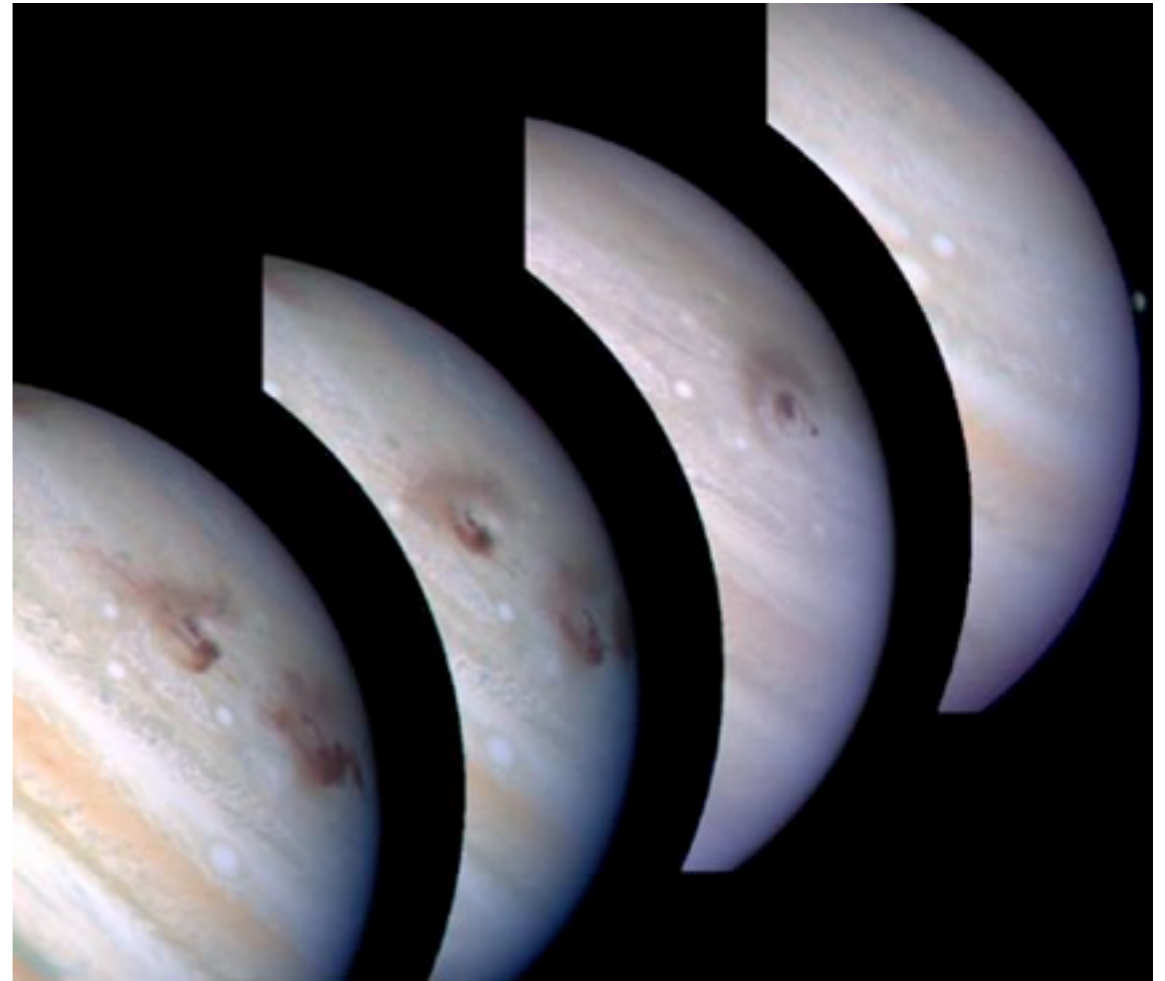


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Fragment G was the biggie, with 6,000,000 megatons TNT energy and a plume rising to 3,000 km



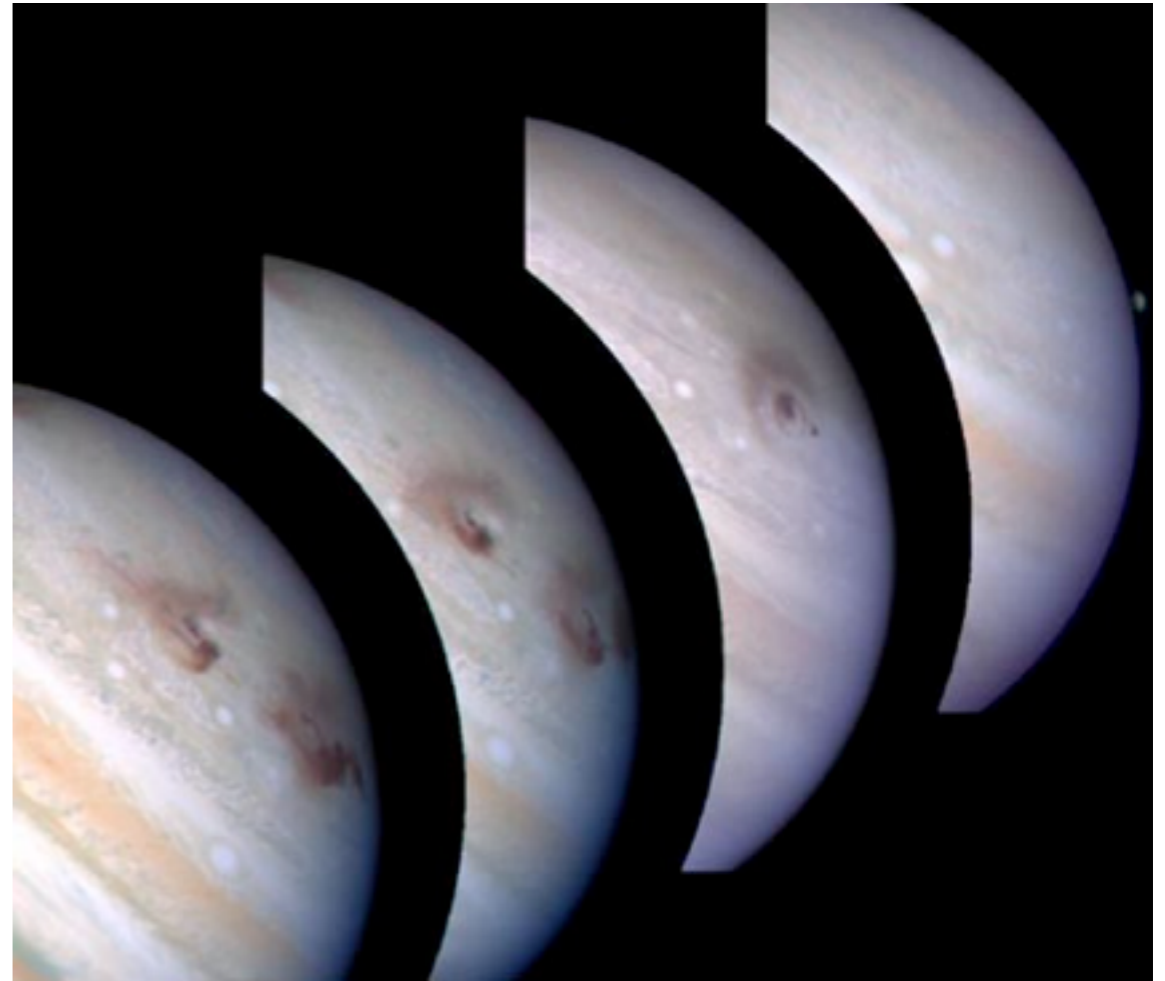
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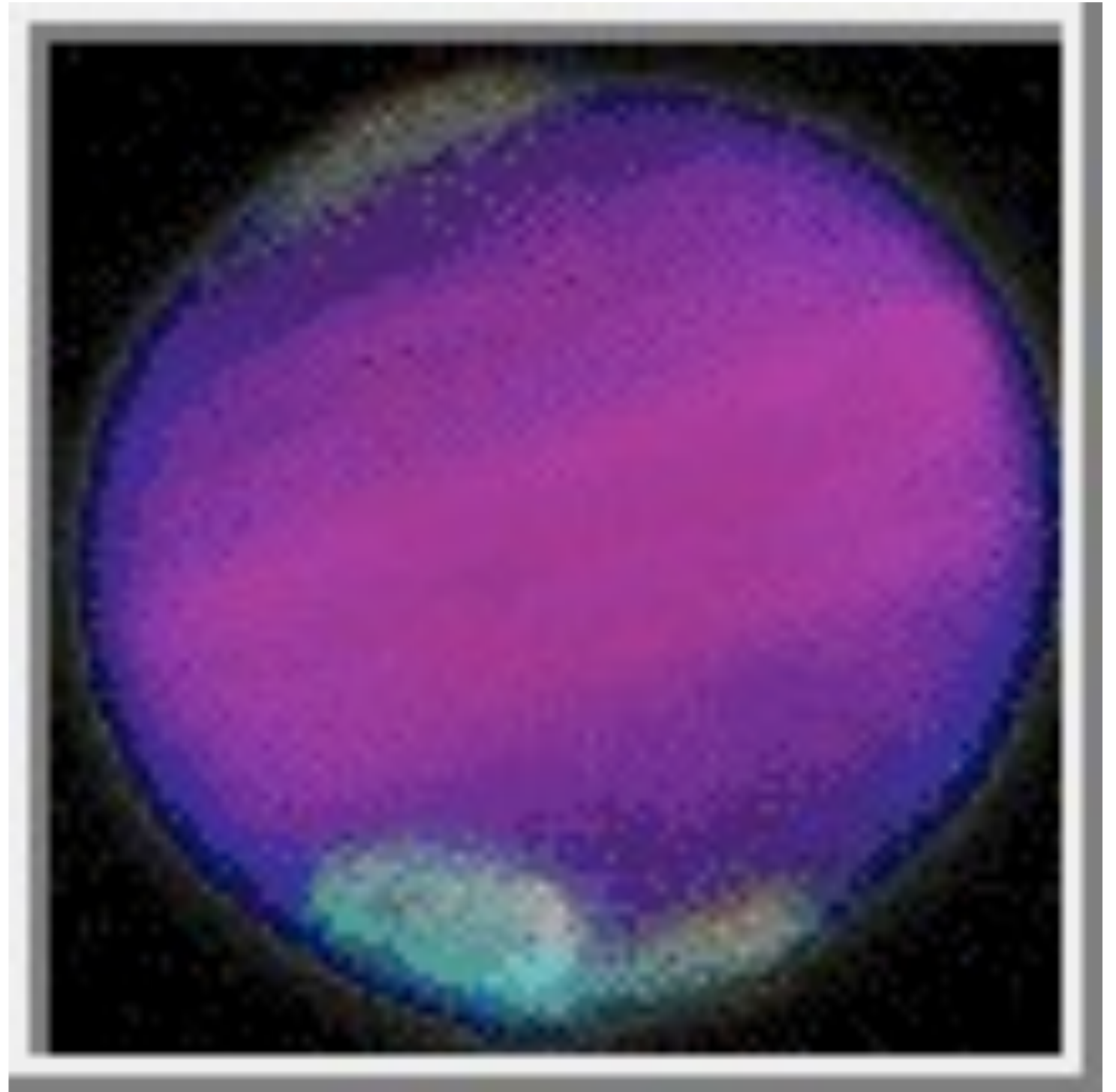
Fragment G (and K, L) created dark impact sites whose diameters were at least that of Earth's radius

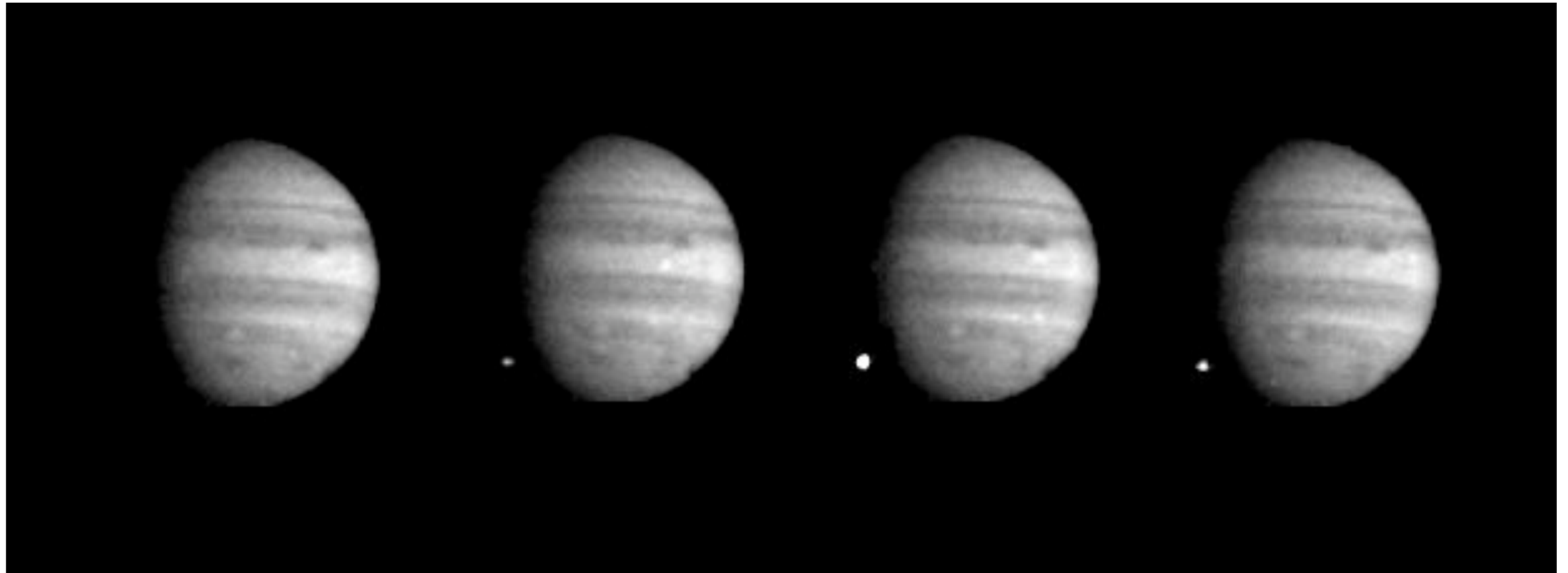


http://www.sai.msu.su/apod/image/9808/sl9gevol_hst.jpg

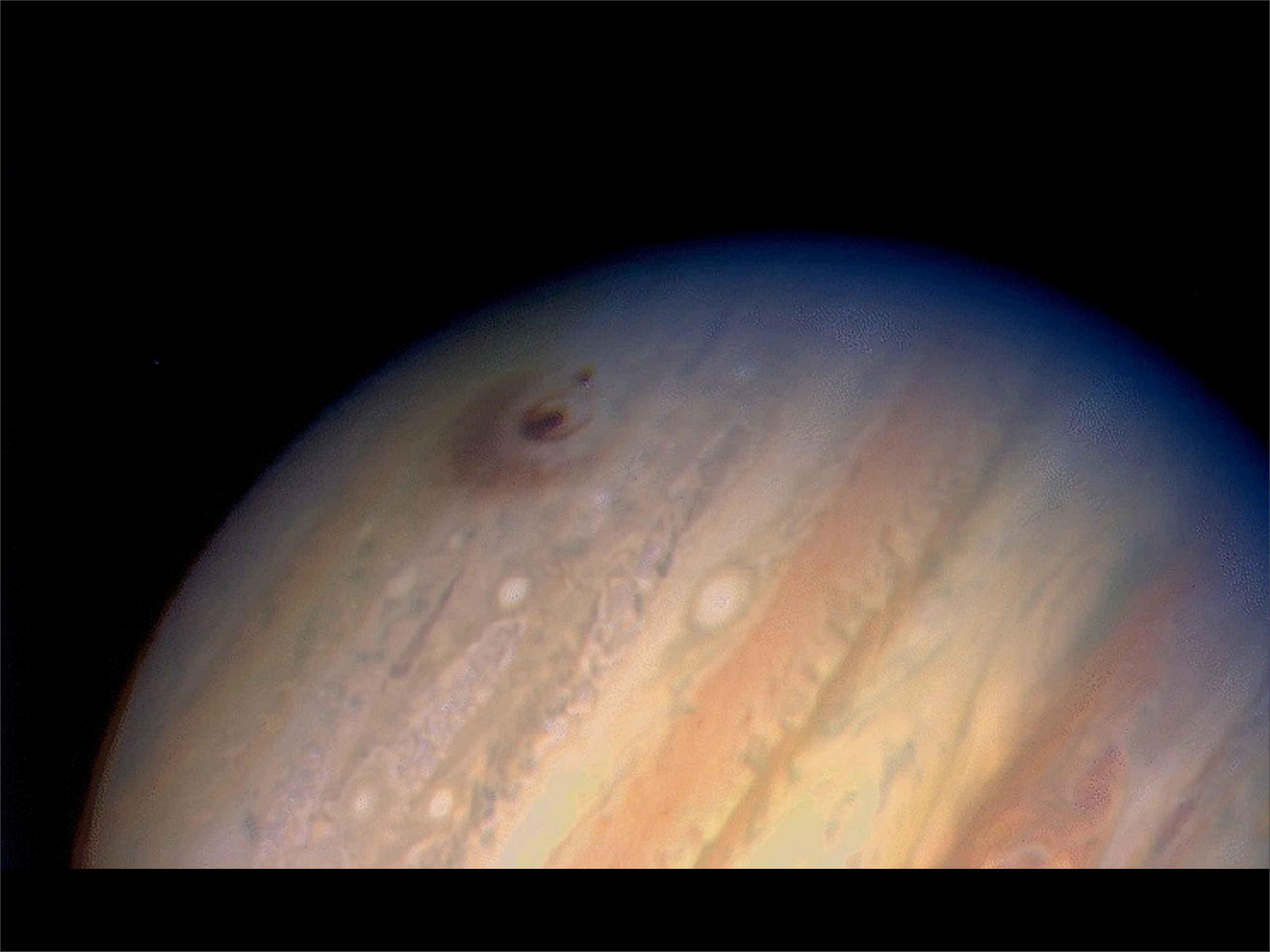
Fragment G

This image shows a ring of hot gas about 33,000 km in diameter and expanding at 4 km/second from the impact of fragment G

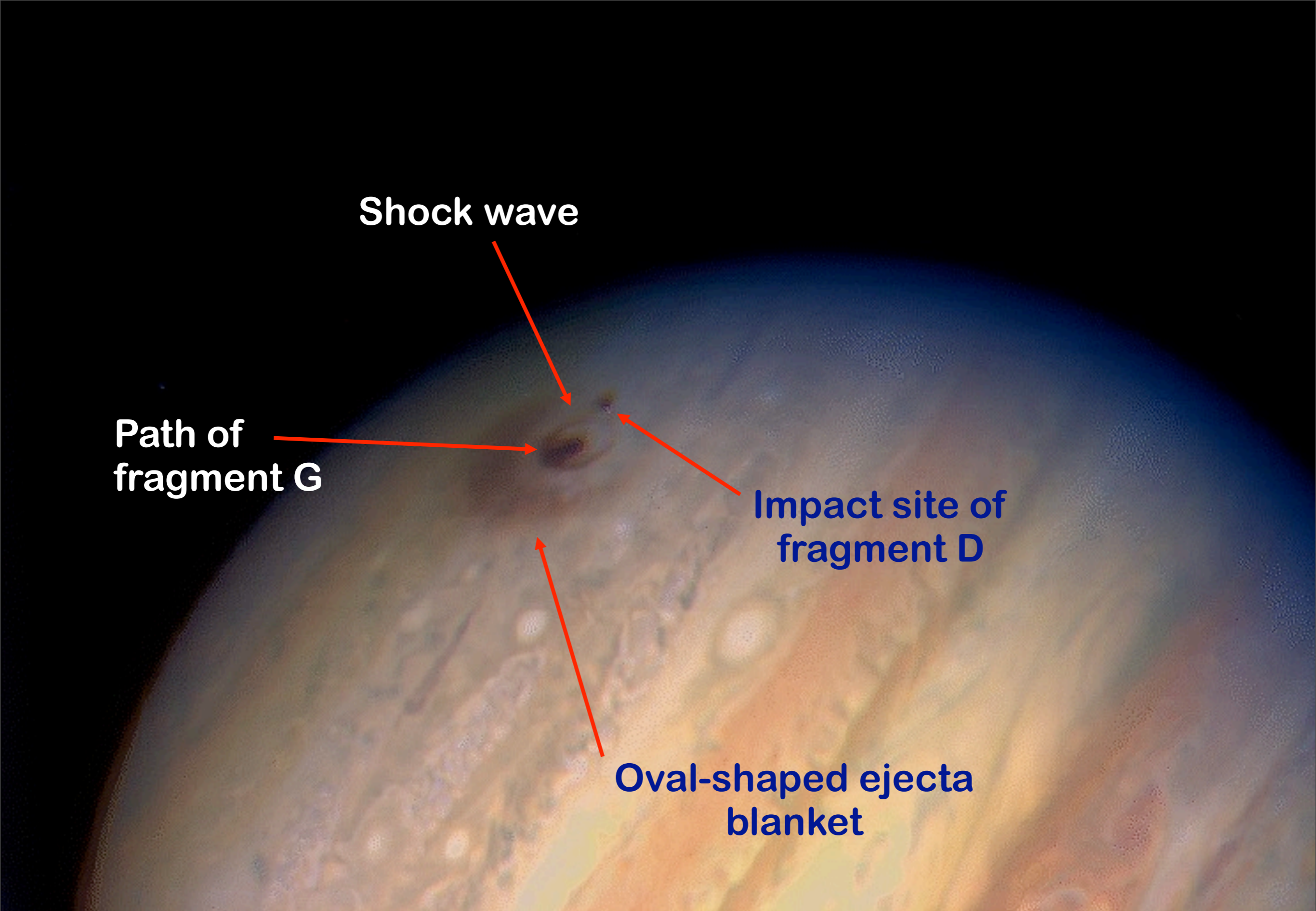




Images of Jupiter catch the fireball of fragment G. Amazing!



Friday, February 10, 2012

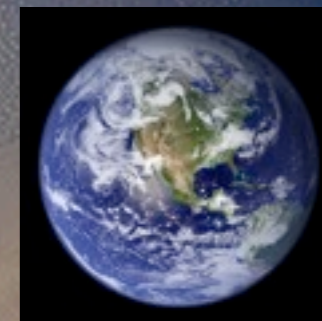


Shock wave

**Path of
fragment G**

**Impact site of
fragment D**

**Oval-shaped ejecta
blanket**

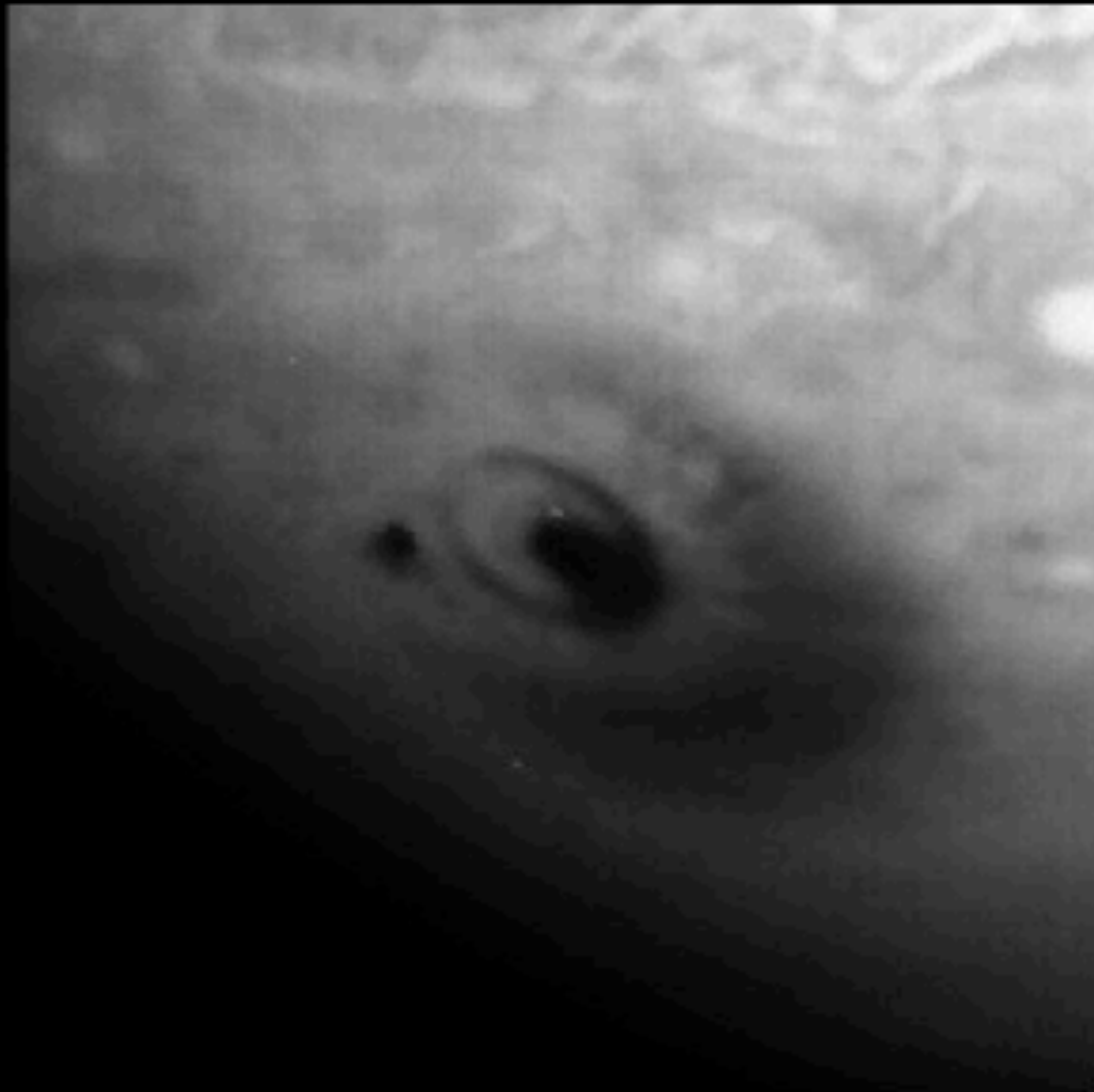


Dusty debris at an impact site -- it's as big as Earth!

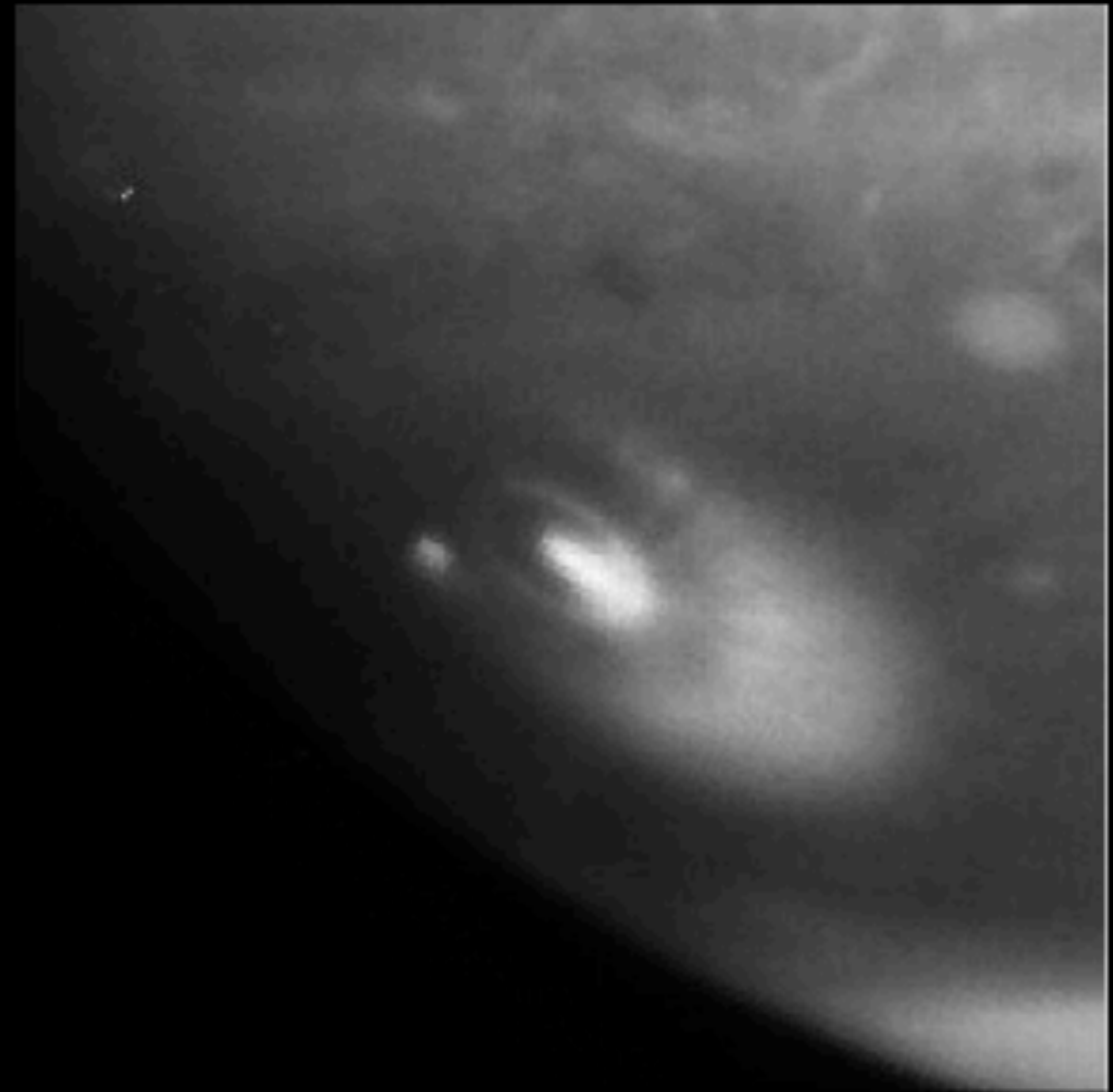
Though note that this is debris on the top of Jupiter's atmosphere.
The comet exploded in the atmosphere & didn't hit ground.

G Impact Site

Green

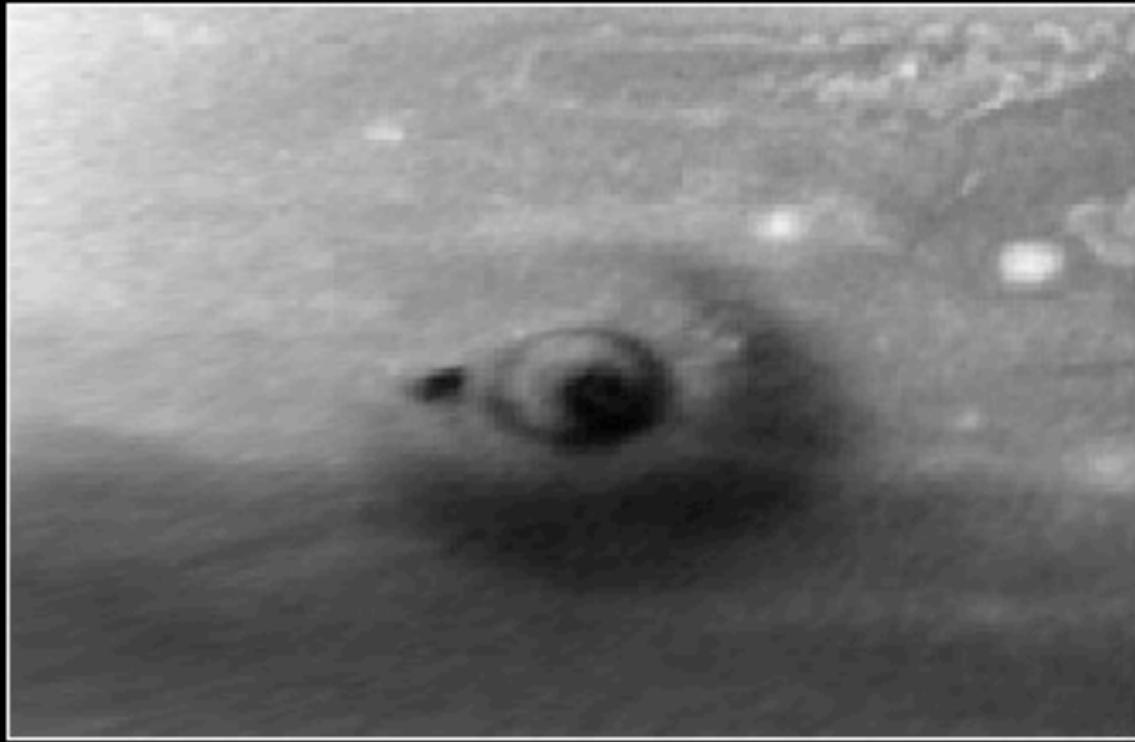


Methane

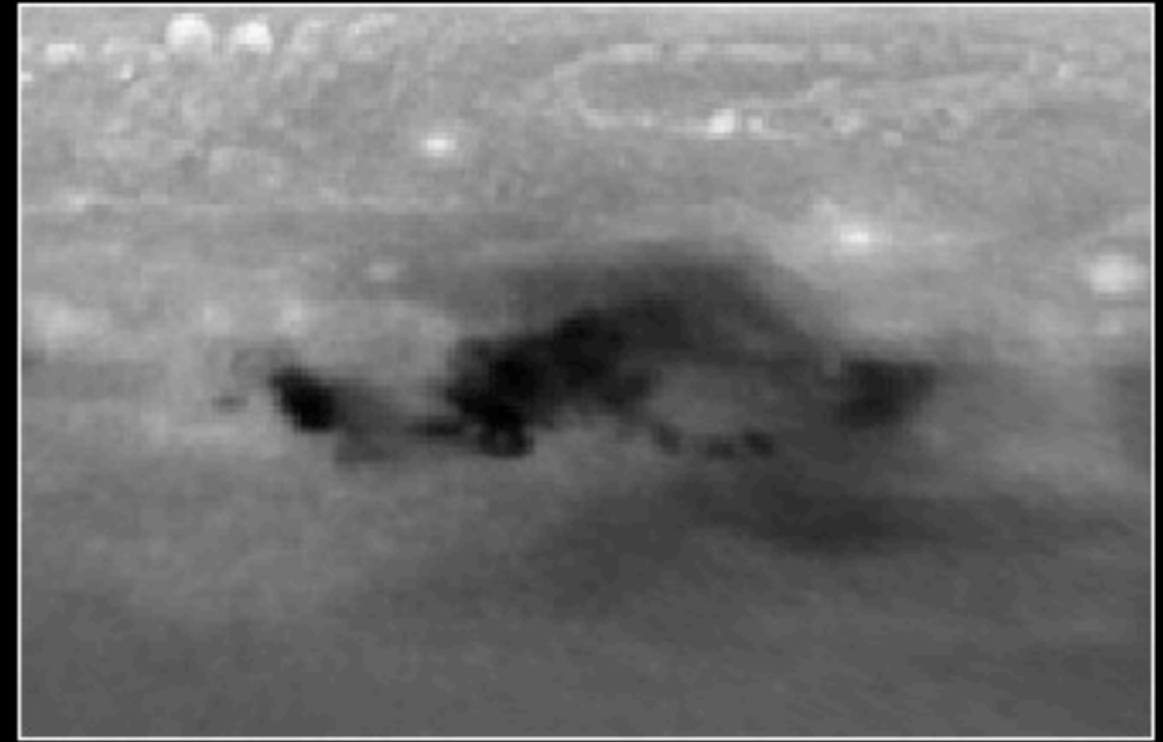


18 July 1994

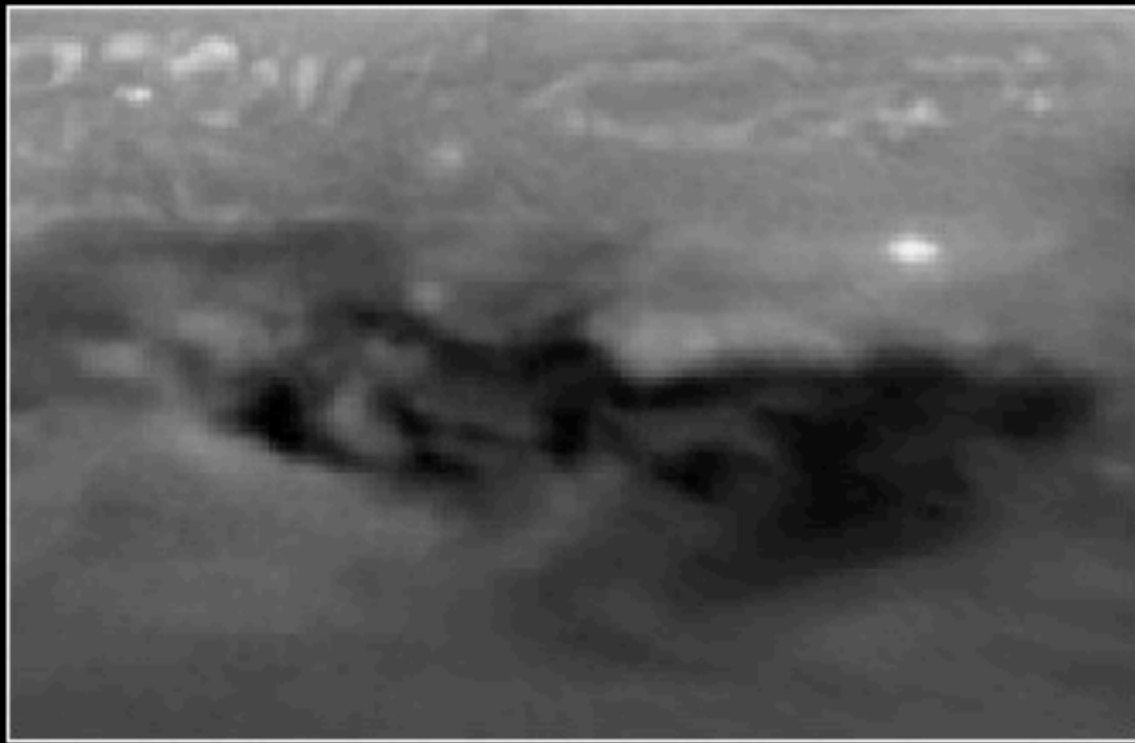
Evolution of D/G Comet Impact Sites on Jupiter



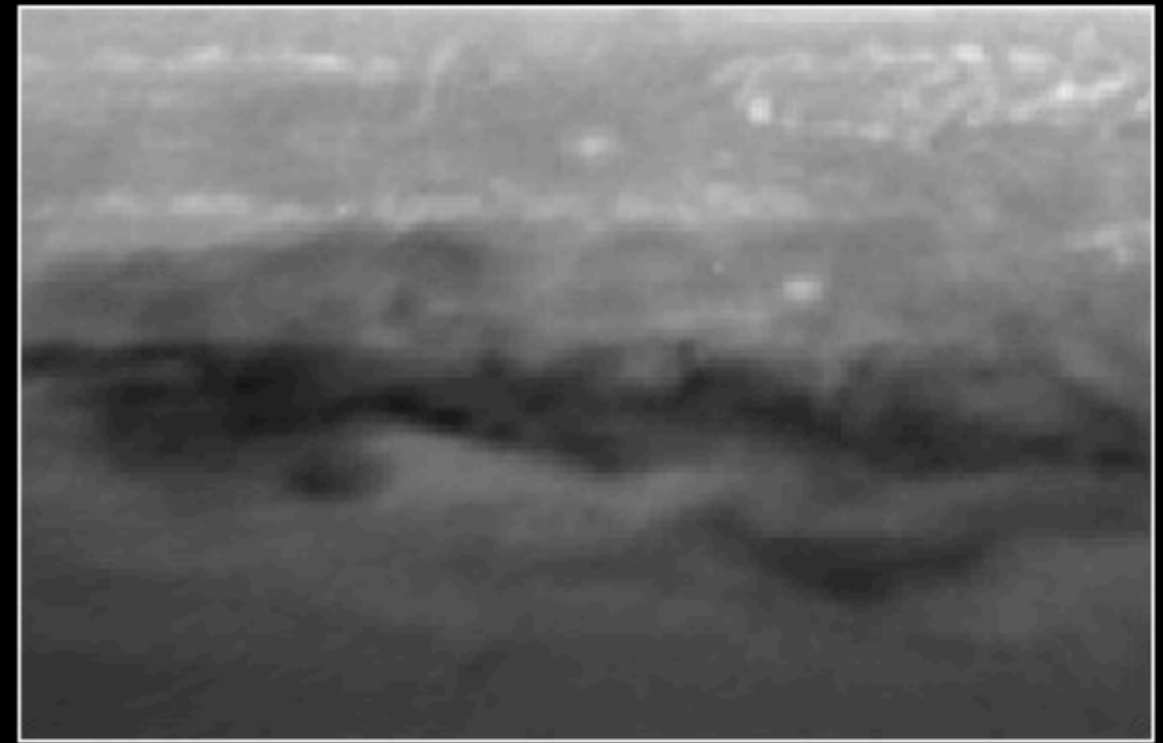
July 18, 1994



July 23, 1994

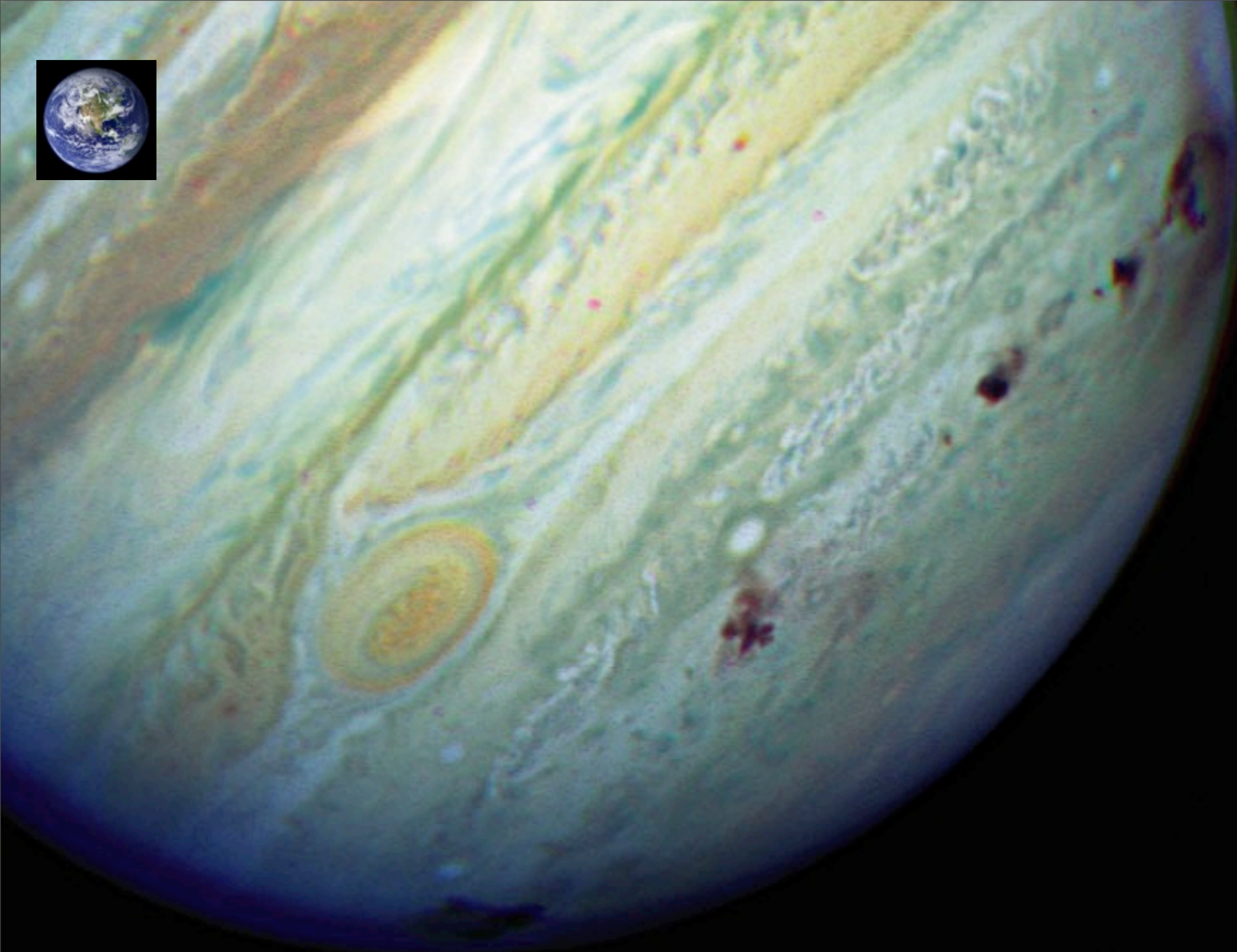


July 30, 1994



August 24, 1994

Hubble Space Telescope • Wide Field Planetary Camera 2



Several impact sites

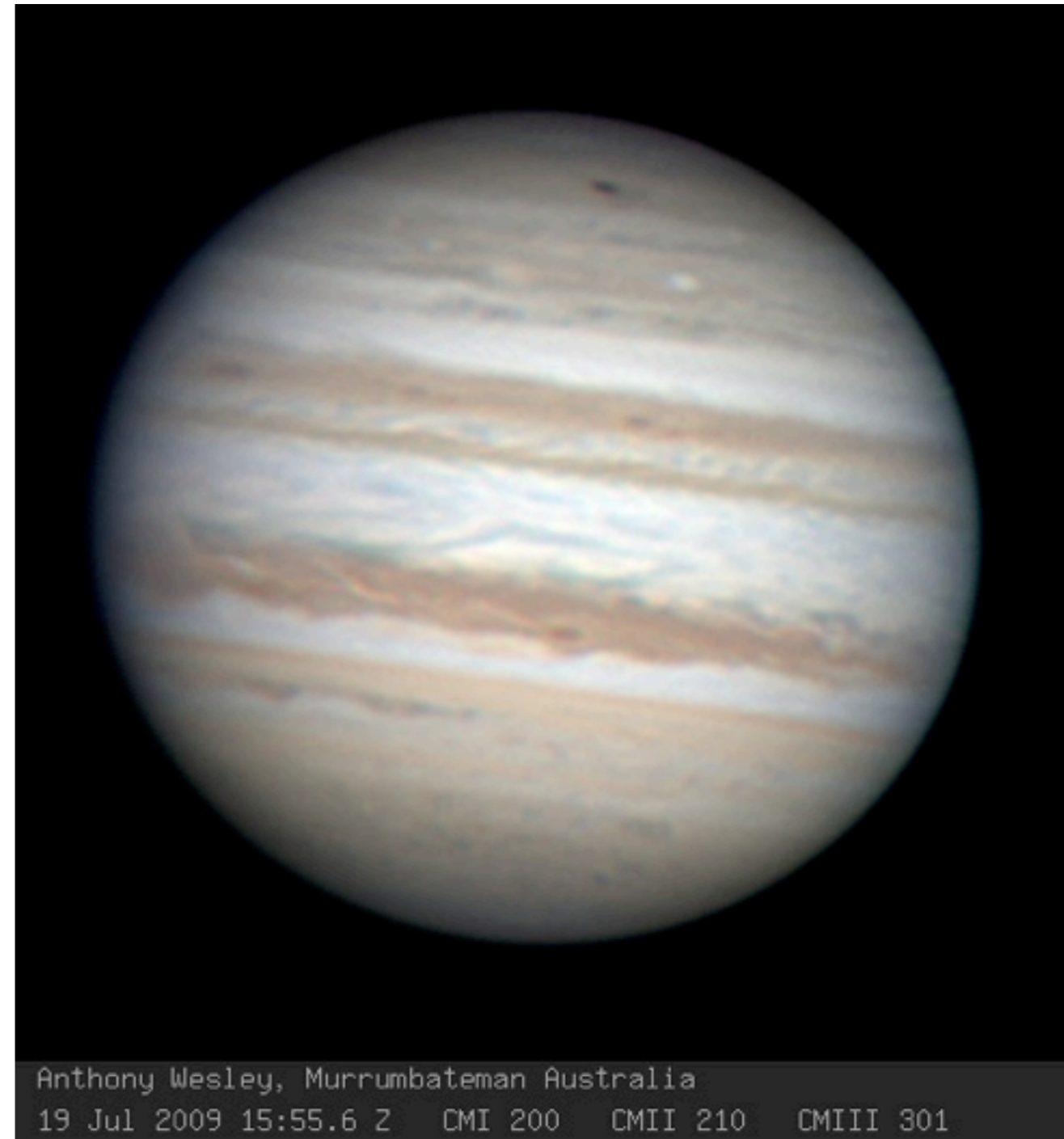
Even More Recently: July 19, 2009

Anthony Wesley, a 44-year-old computer programmer from Australia, made the discovery using his 14.5 inch telescope.

Earth-sized impact scar on Jupiter, but:

- ▶ we didn't see the impactor!
- ▶ we didn't see the collision!

Probably a comet impact, but we don't know.



Anthony Wesley, Murrumbateman Australia
19 Jul 2009 15:55.6 2 CMI 200 CMII 210 CMIII 301

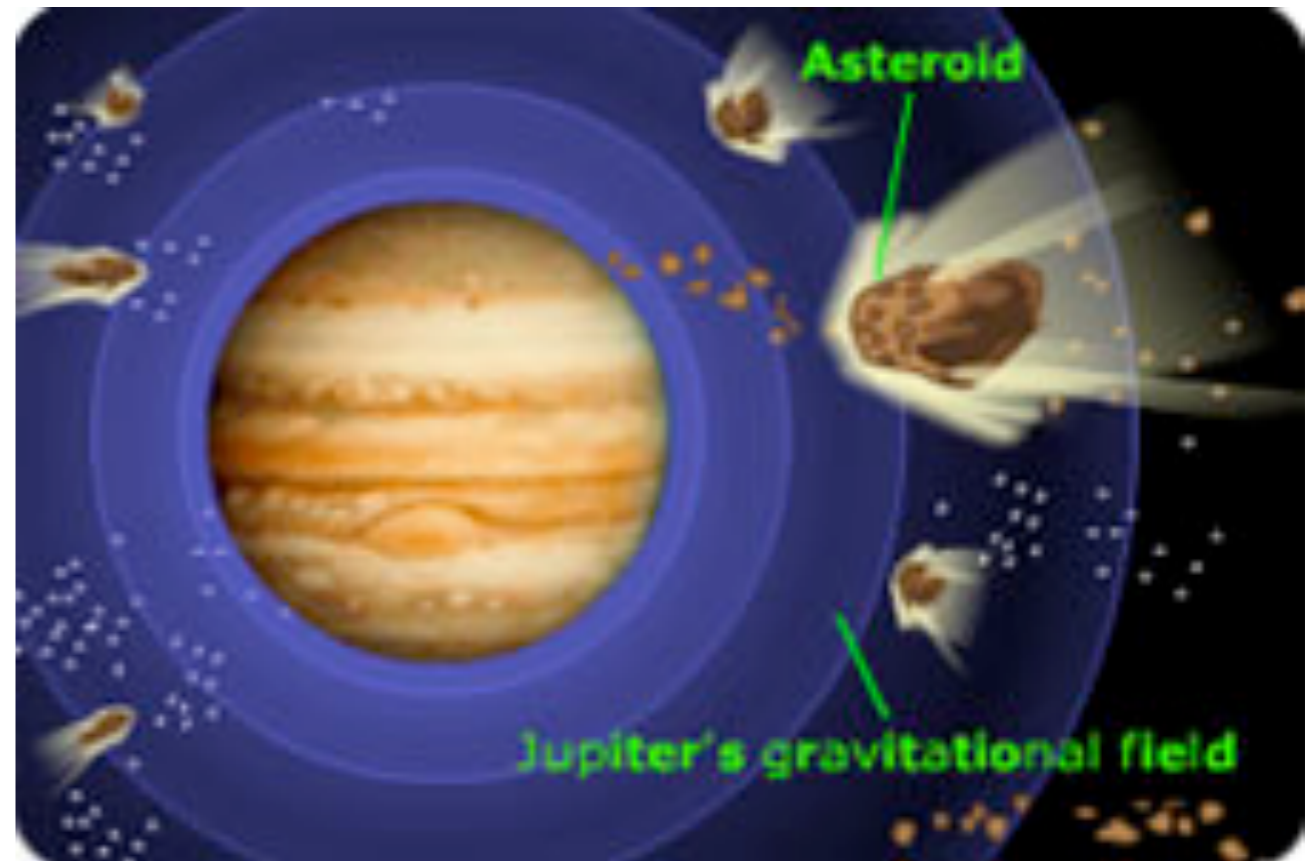
<http://jupiter.samba.org/>

Jupiter: The Vacuum Cleaner

Strong gravitational influence, so many small comets and asteroid impacts.

Estimate that rate of impacts is 2000 to 8000 higher than the rate on Earth!

Without Jupiter, the probability of asteroid impacts with the Solar System's inner planets would be greater.



Global Defense: What's the Plan?

Group Discussion:

Based on your outstanding performance in ASTR 150, you are placed in charge of **assessing** and **defending** against the global impact threat

Set your priorities:

- ▶ What do we need to know?
- ▶ What do we do if a threat is found?
- ▶ How do we prepare ahead of time?

Click A when you have good answers



GLOBAL DEFENSE I: FINDING THE THREAT



How do we find asteroids?

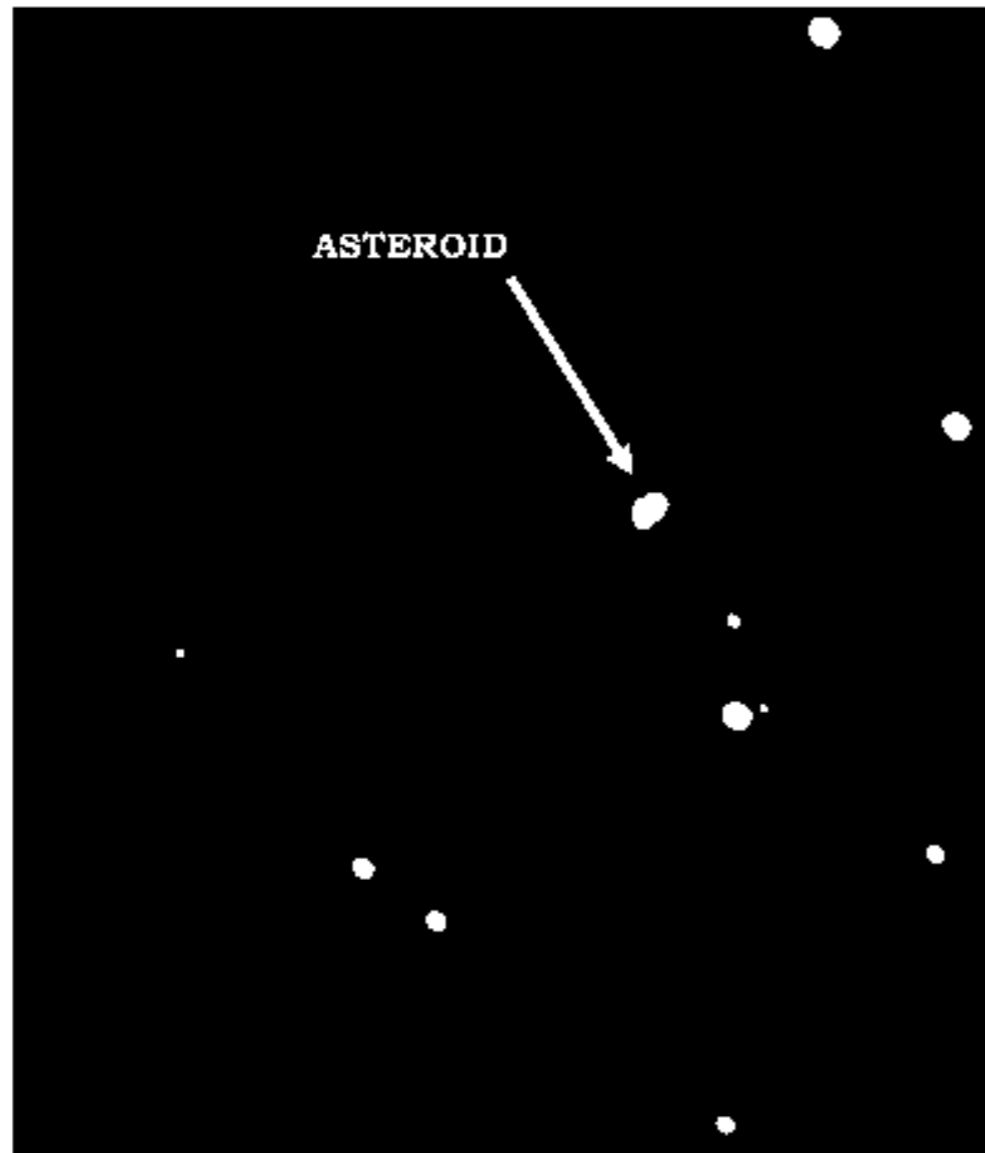
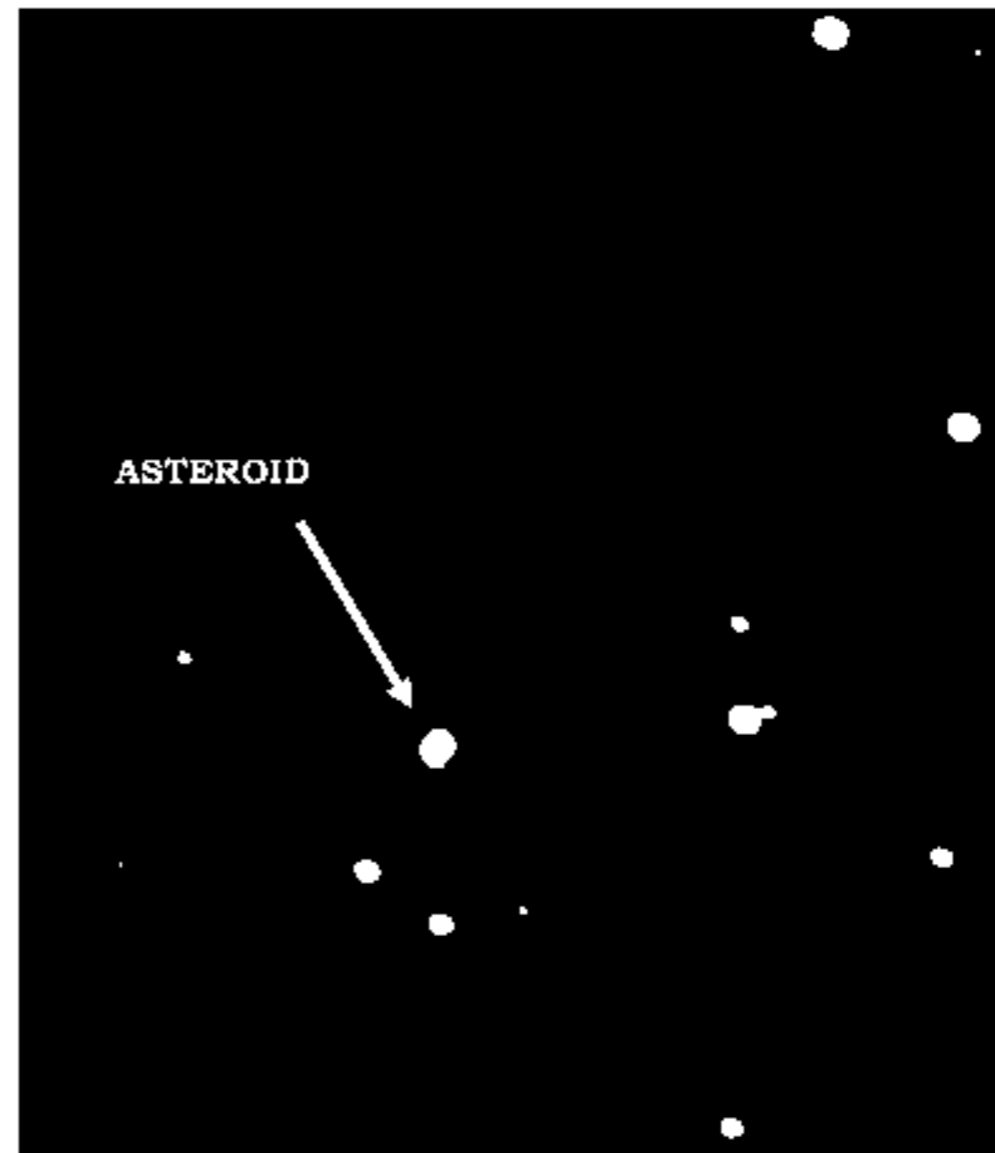


IMAGE NUMBER 1



**IMAGE NUMBER 2
(25 minutes later)**

In two pictures of the sky a few minutes apart, the stars will not move with respect to one another, but an asteroid will

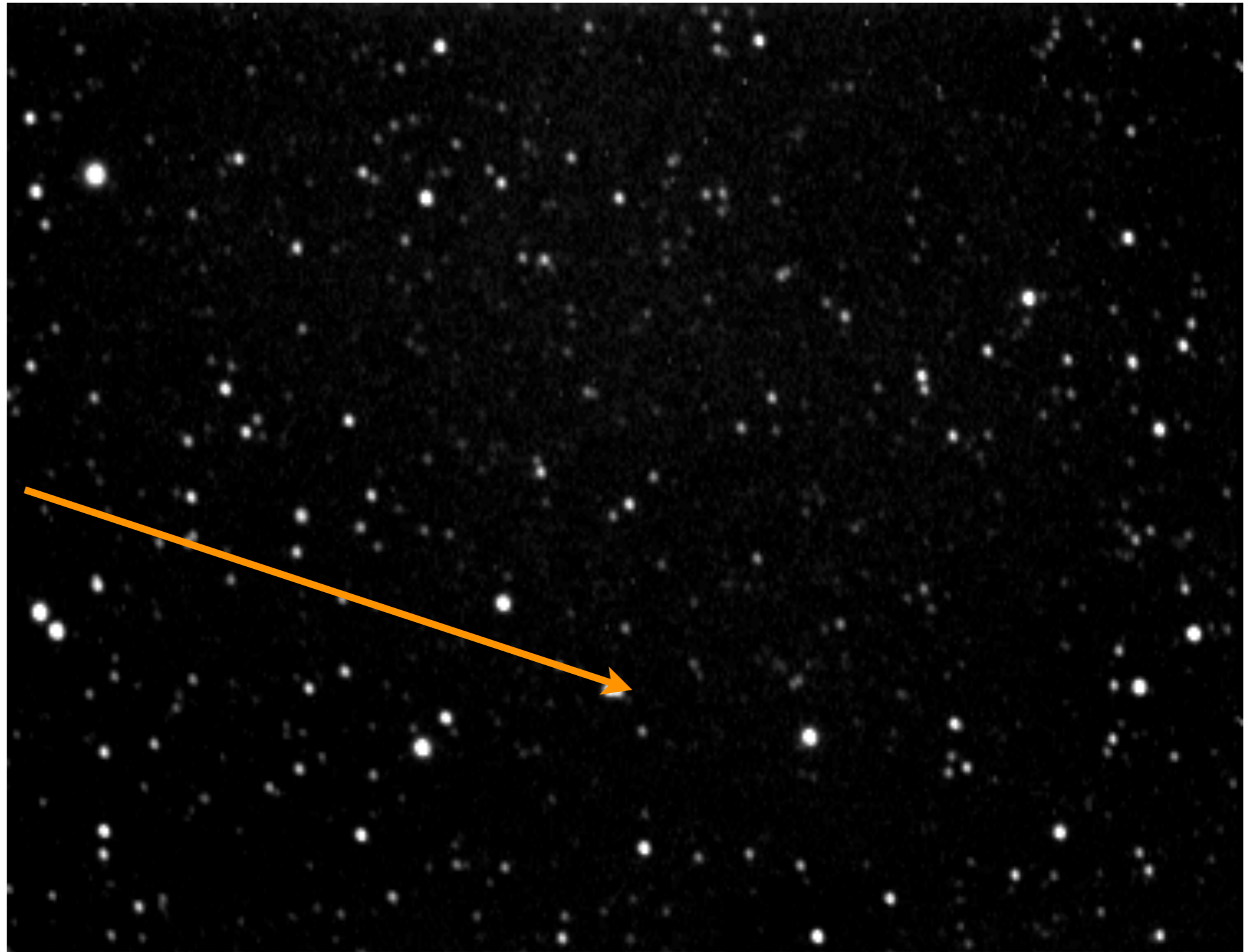
- ▶ In the blink technique, quickly switch between two images of the same part of the sky
- ▶ Any asteroids in the image will appear to “jump”

**Can you spot
the asteroid?**

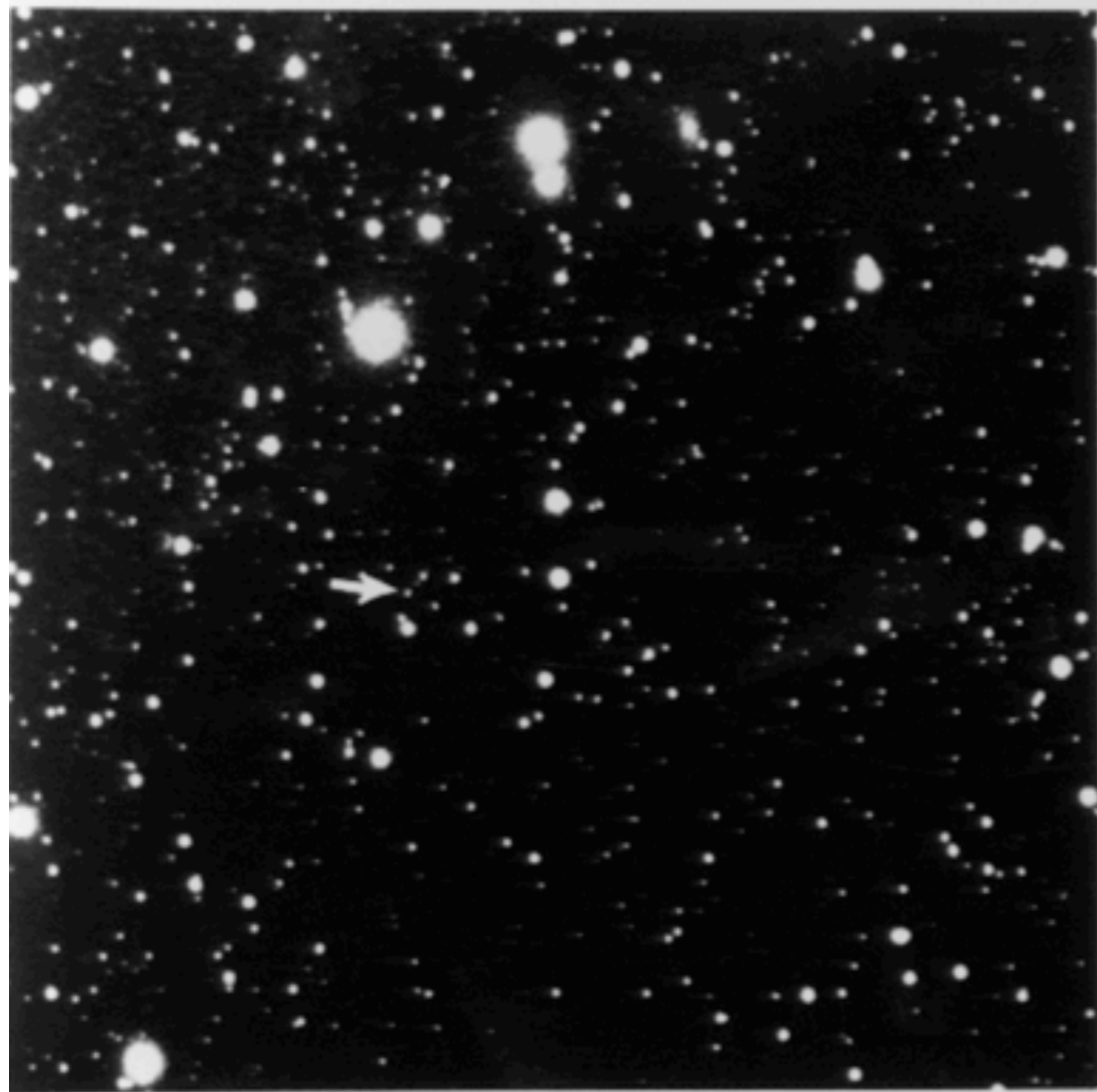


- ▶ In the blink technique, quickly switch between two images of the same part of the sky
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Can you spot the asteroid?



DISCOVERY OF THE PLANET PLUTO



January 23, 1930



January 29, 1930

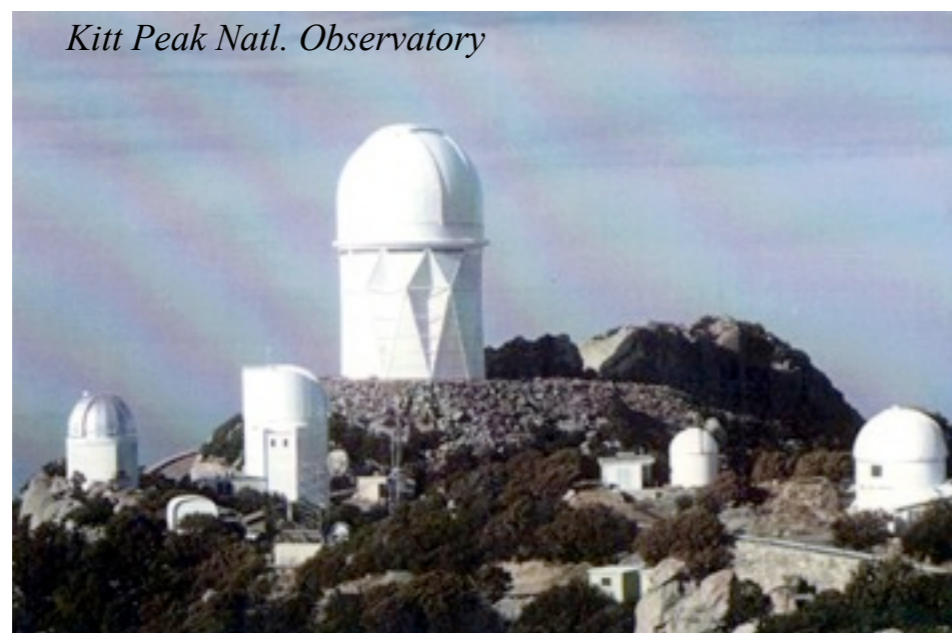
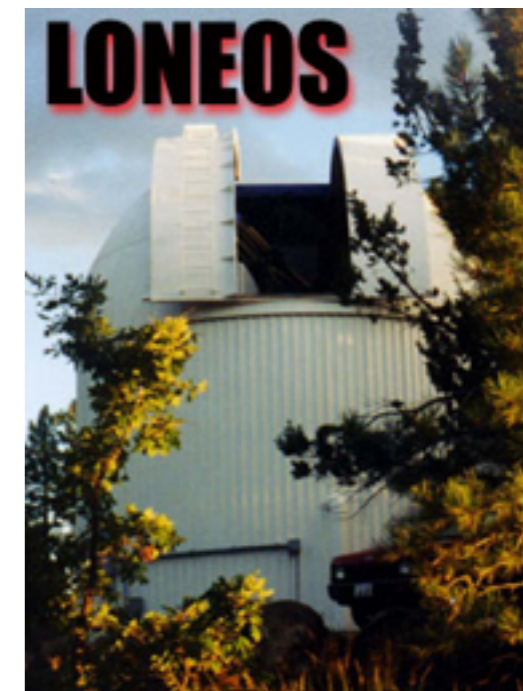
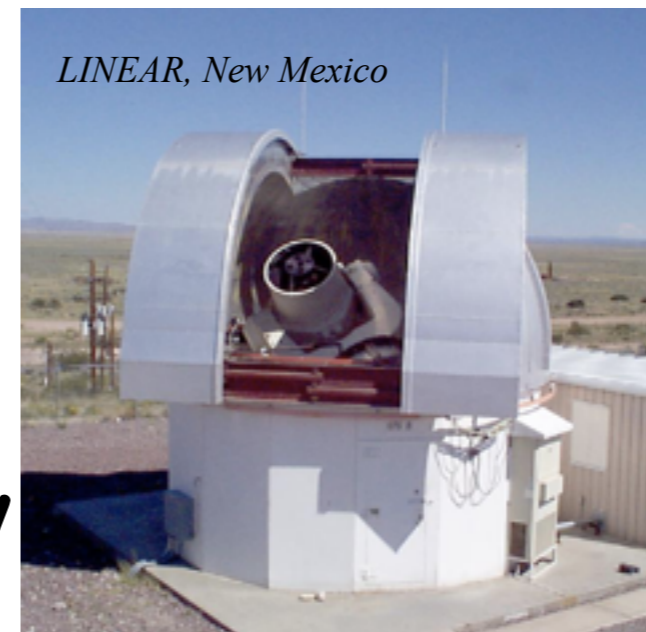
The blink technique was used to discover the planet Pluto!

Near Earth Object Program

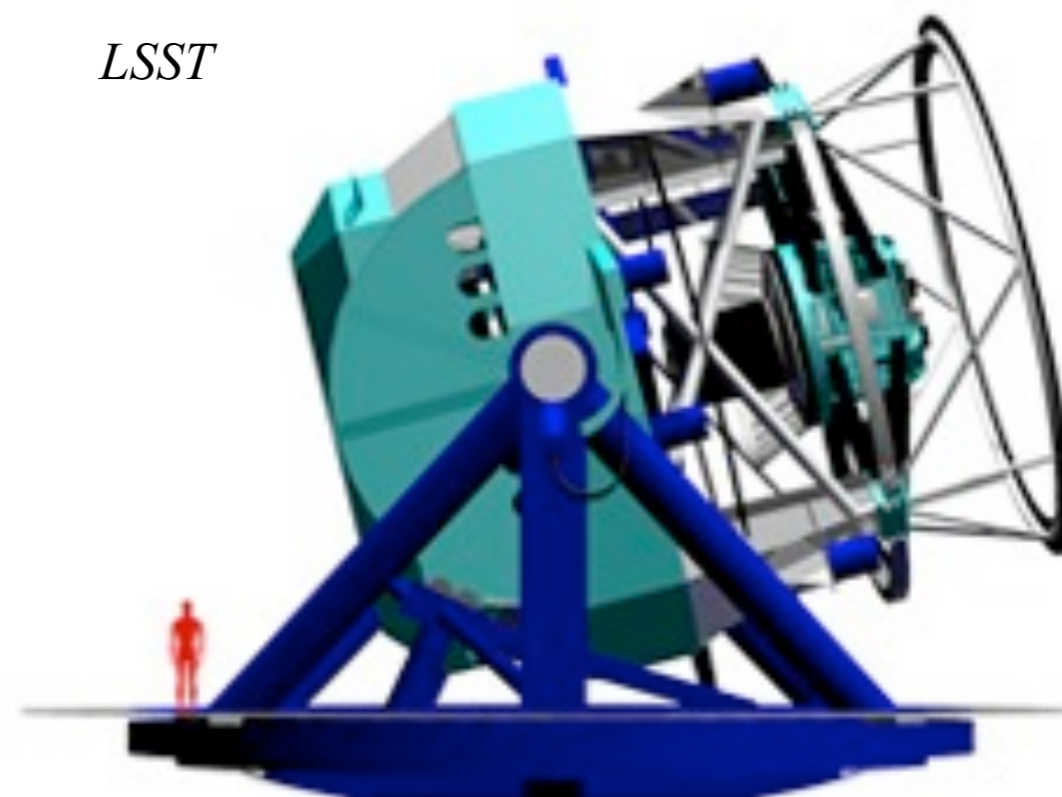
<http://neo.jpl.nasa.gov/>

Survey: 1998 to 2009, found
>90% of NEOs >1 km
diameter (Near Earth
Objects)

Congress ordered NASA to
find 90% of NEOs >140 m by
2020



LSST

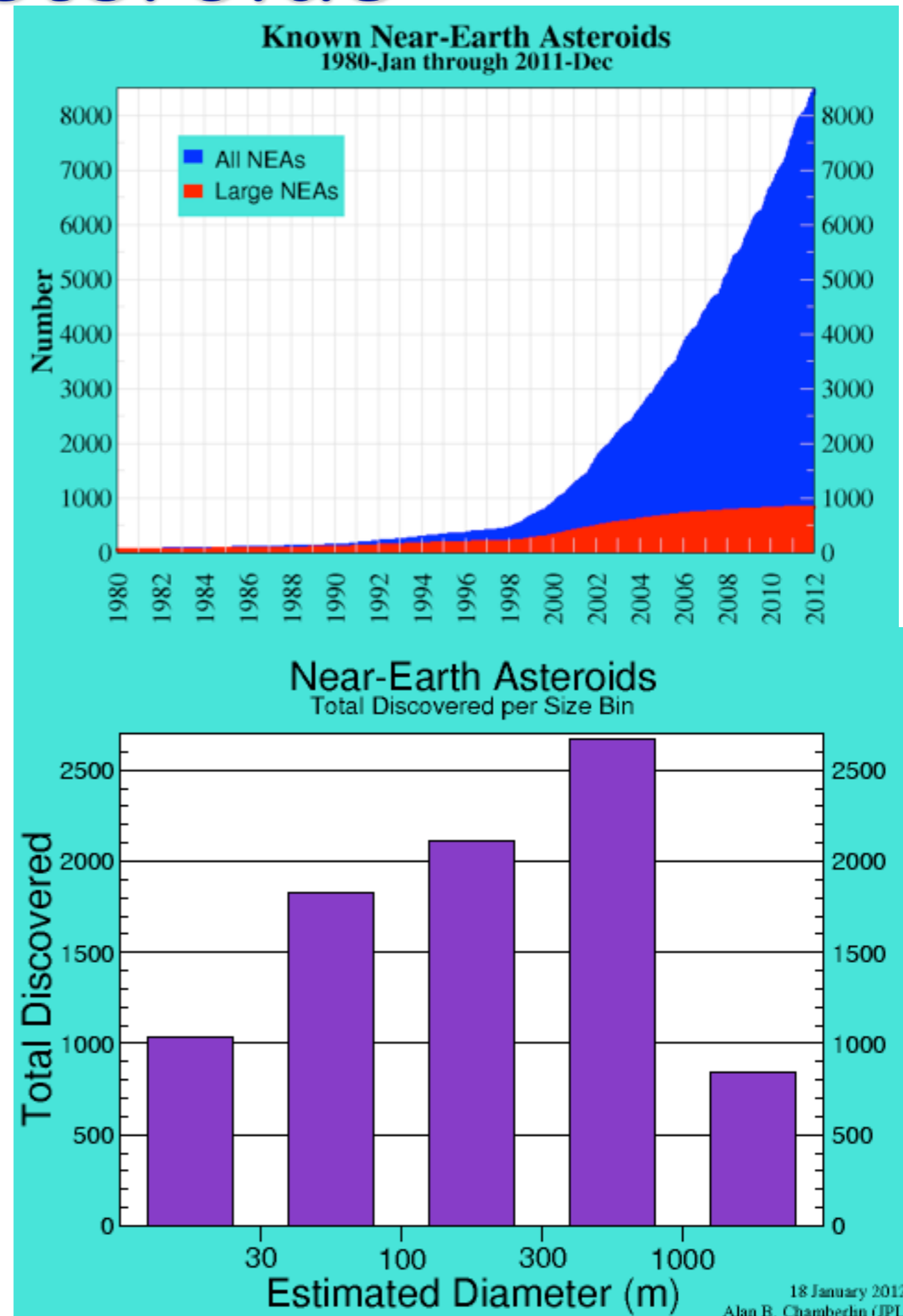


Killer Asteroids

As of Jan 2012,
8582 Near-Earth Asteroids (NEAs)
are known
840 of these are
> 1km

1288 of these are
classified as
**PHAs: Potentially
Hazardous
Asteroids**

<http://neo.jpl.nasa.gov/faq/>
<http://neo.jpl.nasa.gov/stats/>



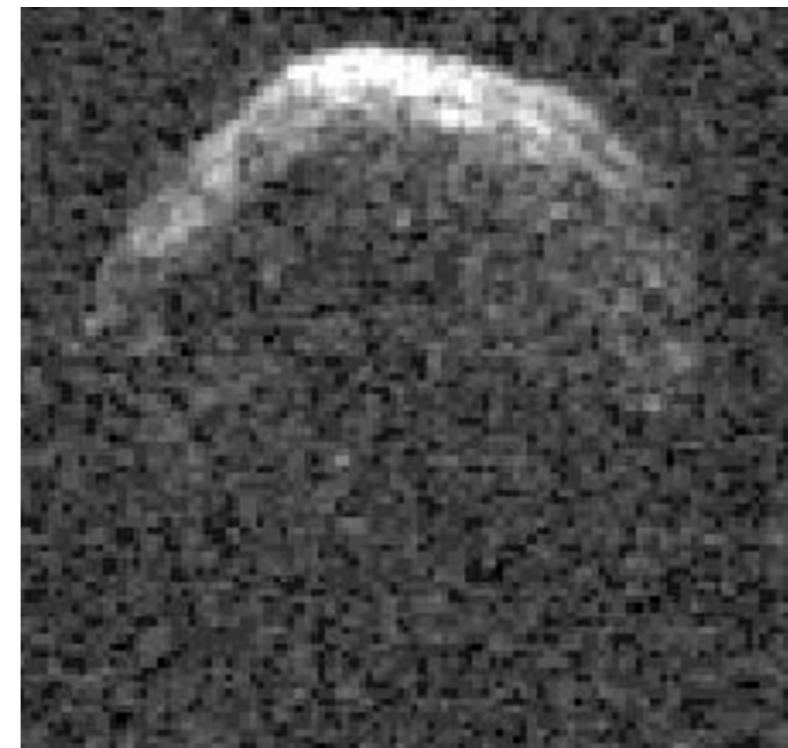
Killer Asteroids

The most dangerous currently known is 1950 DA (~1.2km), 0.33% chance of collision in March 2880

Would be a 100,000 MT impact event

But... can't reliably predict asteroid orbits more than ~20 years in advance

Asteroid may crash into Earth — in 2880



Radar image of asteroid 1950DA

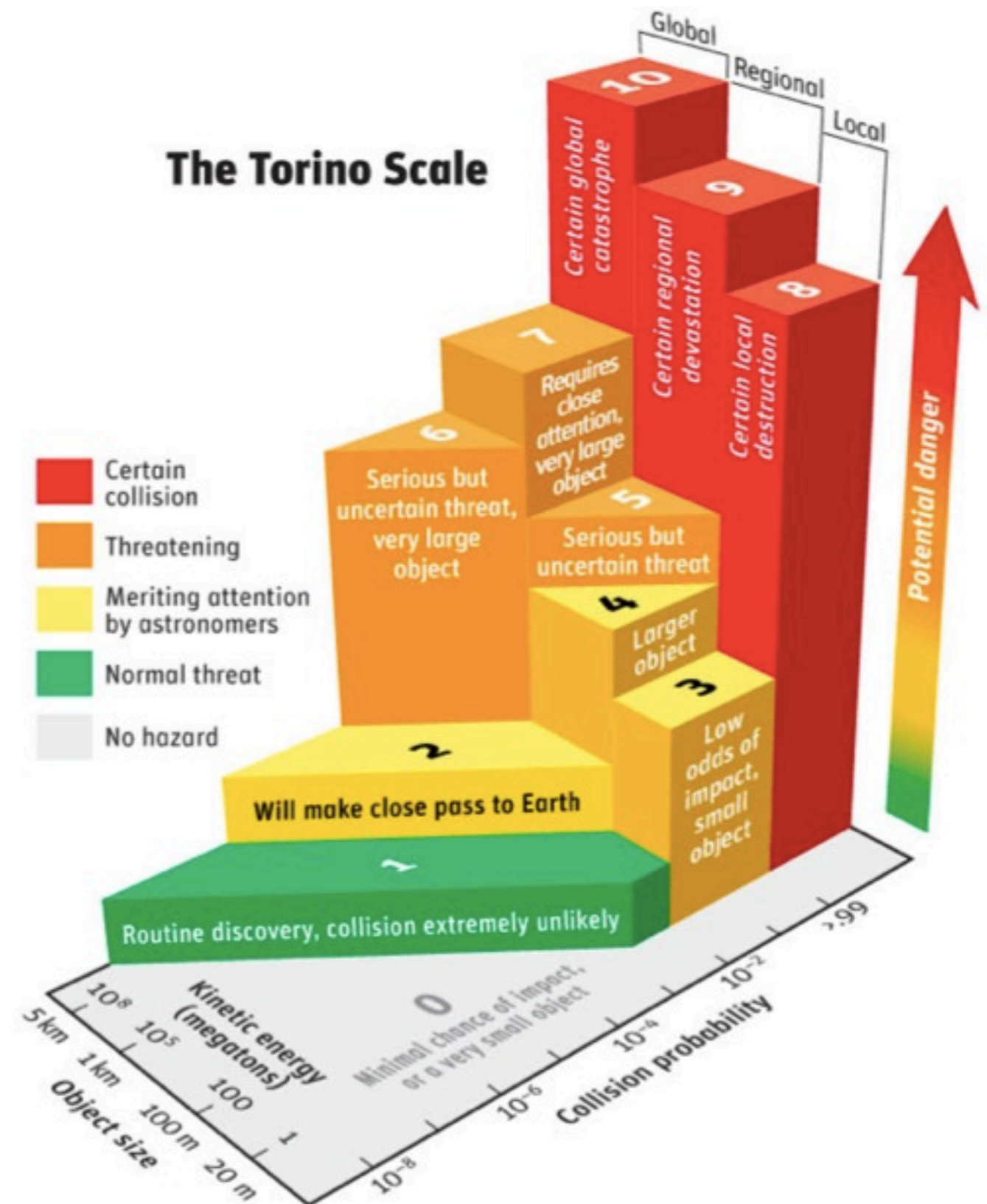
Scale It! - The Torino Scale

Based on

- ▶ Probability of impact
- ▶ Potential for damage

Scale from 0 to 10

- ▶ 0: minimal chance of impact OR too small to cause damage
- ▶ 10: certain impact, global devastation



Also color coded!

White - no hazard

Green - normal threat (routine discovery)

Yellow - Meriting attention by astronomers

Orange - Threatening

Red - Certain Collision

THE TORINO SCALE

0	ZERO OR VIRTUALLY ZERO CHANCE OF IMPACT
1	IMPACT EXTREMELY UNLIKELY, MERITS MONITORING
2	IMPACT VERY UNLIKELY
3	CLOSE ENCOUNTER WITH AT LEAST 1% CHANCE OF LOCAL DESTRUCTION
4	CLOSE ENCOUNTER WITH AT LEAST 1% CHANCE OF REGIONAL DESTRUCTION
5	CLOSE ENCOUNTER WITH SIGNIFICANT THREAT OF REGIONAL DESTRUCTION
6	CLOSE ENCOUNTER WITH SIGNIFICANT THREAT OF GLOBAL CATASTROPHE
7	CLOSE ENCOUNTER WITH EXTREMELY SIGNIFICANT THREAT OF GLOBAL CATASTROPHE
8	CERTAIN COLLISION WITH LOCAL DESTRUCTION
9	CERTAIN COLLISION WITH REGIONAL DEVASTATION
10	CERTAIN COLLISION CAUSING GLOBAL CLIMATIC CATASTROPHE

iClicker Poll: Guess the Threat

We have found >90% of asteroids >1km in size.

Vote your conscience!

For known large asteroids, what is the biggest score on the Torino Scale?

▶ where 0 = no problem, 10 = we're doomed

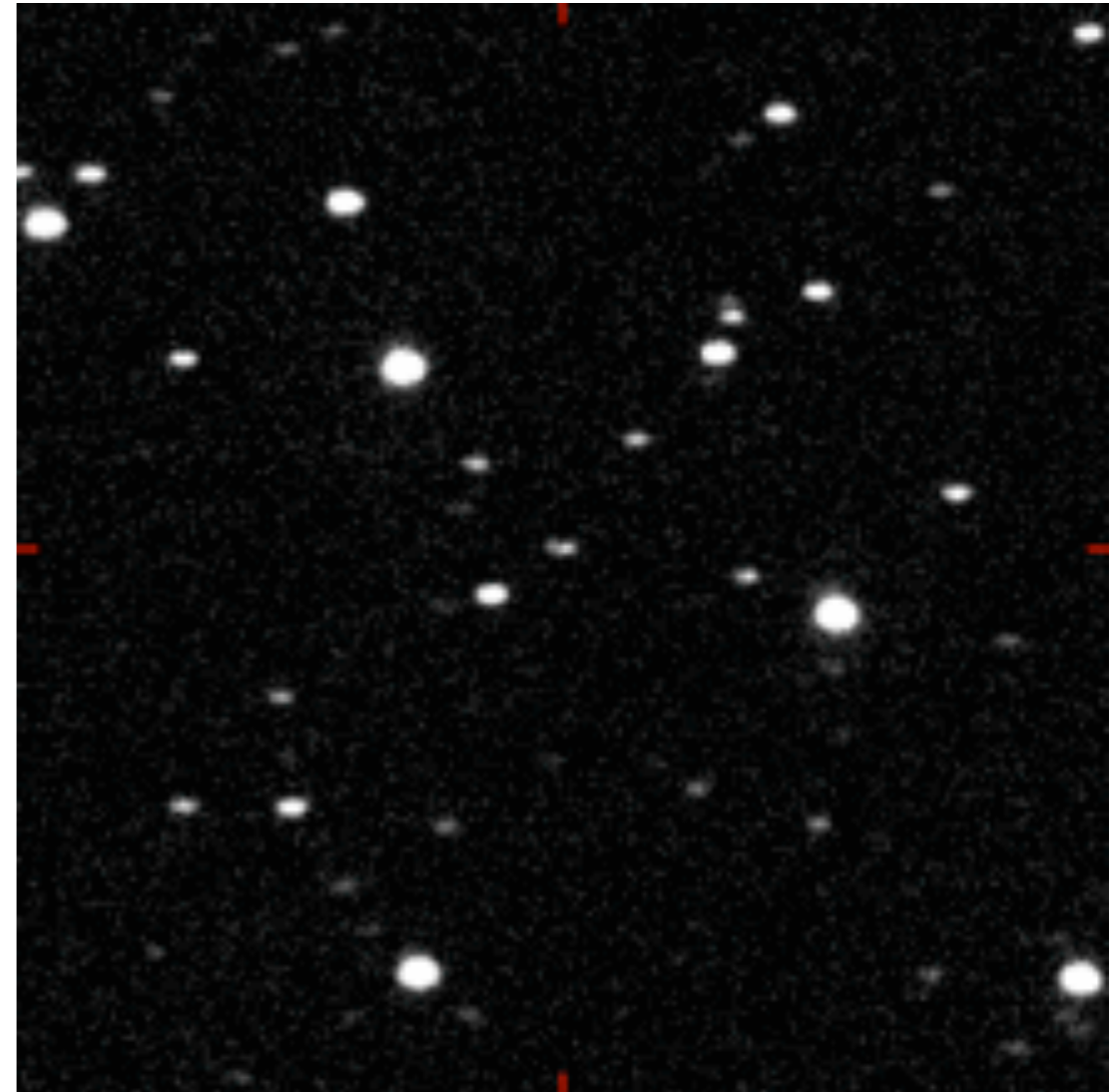
- A. 0
- B. 2
- C. 5
- D. 8
- E. 10

The Asteroid with Our Name on It: The Deadly Impactor

We haven't seen it yet.

But we want to find all the potentially hazardous asteroids, to be sure nothing's coming soon....

Though statistics are on our side.



**2004 FH (30 meter)
passing 10% the Earth-
Moon distance**

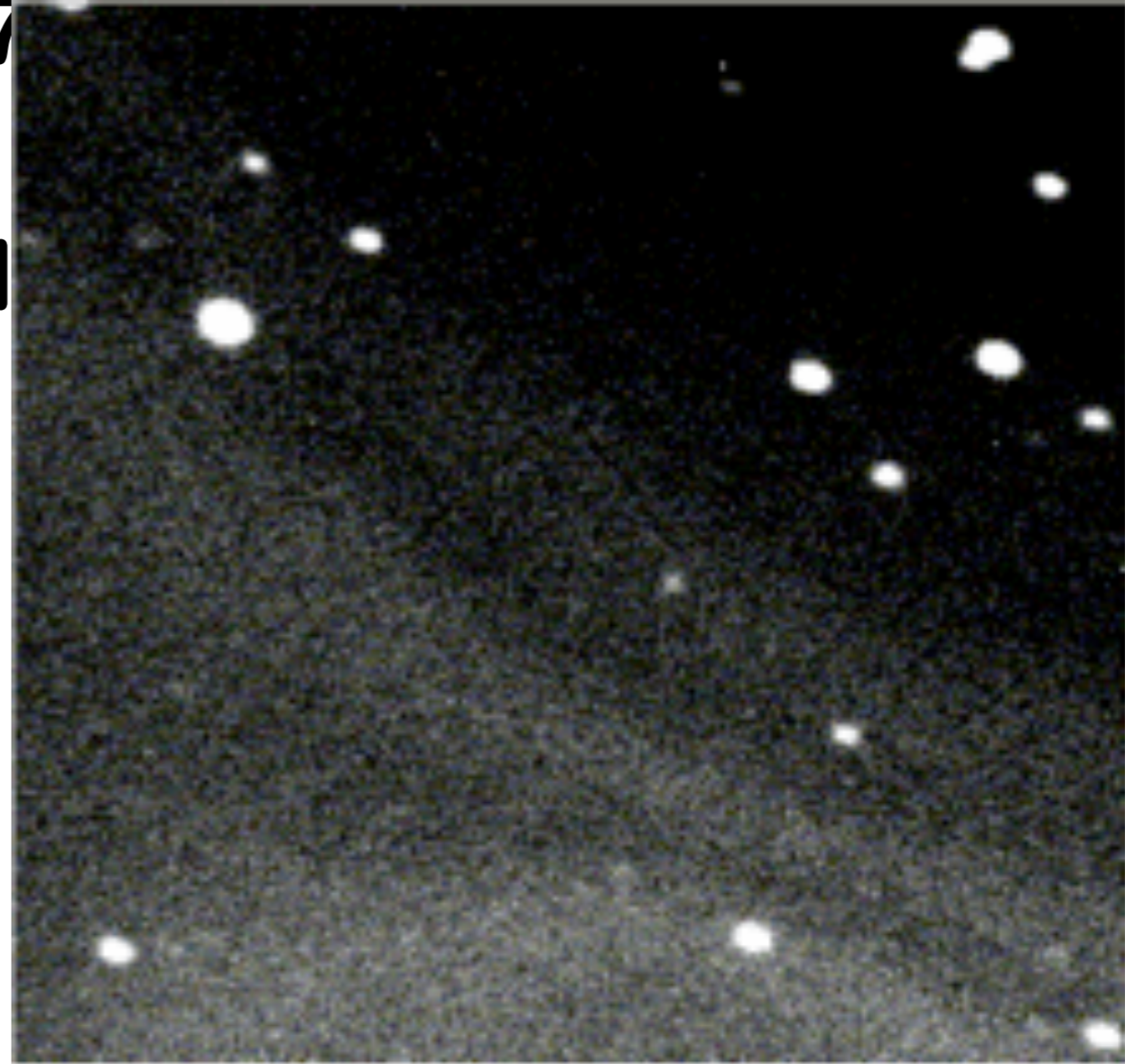
<http://antwrp.gsfc.nasa.gov/apod/ap040322.html>

Most famous “close call”: Asteroid Apophis

At one time, the chance of a hit was estimated at 1 in 37 for 2029, now 0%

In 2036, chance is currently 1 in 250,000

Highest Ever Ranked NEA on the Torino Scale (for a time)



Asteroid Apophis

99942 Apophis

Discovered June 19, 2004

- ▶ Initial designation 2004 MN₄
- ▶ Permanent name 99942 Apophis

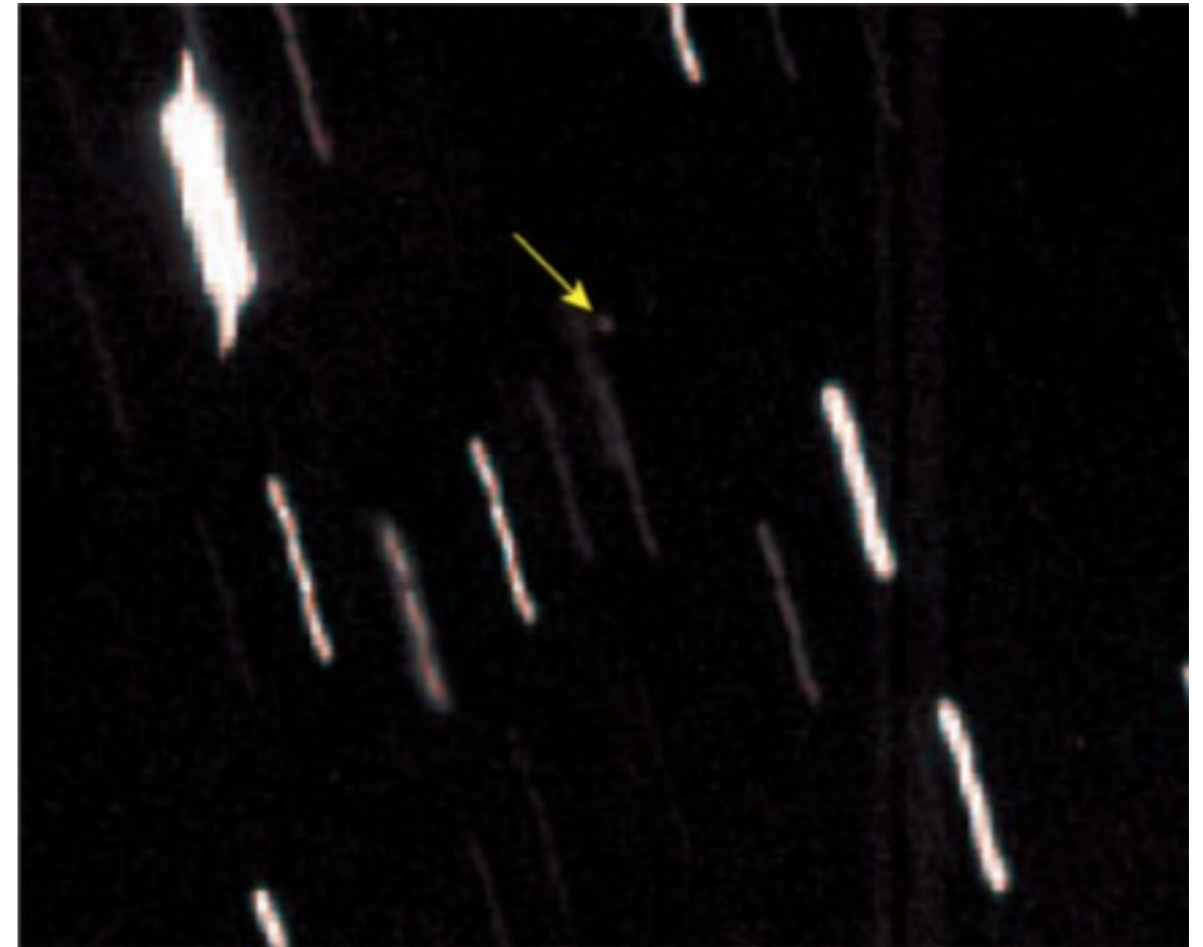
Near-Earth Asteroid

- ▶ ~270m in diameter
- ▶ ~30 million metric tons

What would happen?

Neil de Grasse Tyson:

http://www.youtube.com/watch?v=xaW40I3_M1o



The discovery image of
asteroid Apophis

Apophis Impact Scare

12/23/04: NASA announces 1 in 200 chance Apophis will hit Earth on 04/13/29

12/25-12/27: chance goes up to 1 in 37!

Potential Impact (at the time):

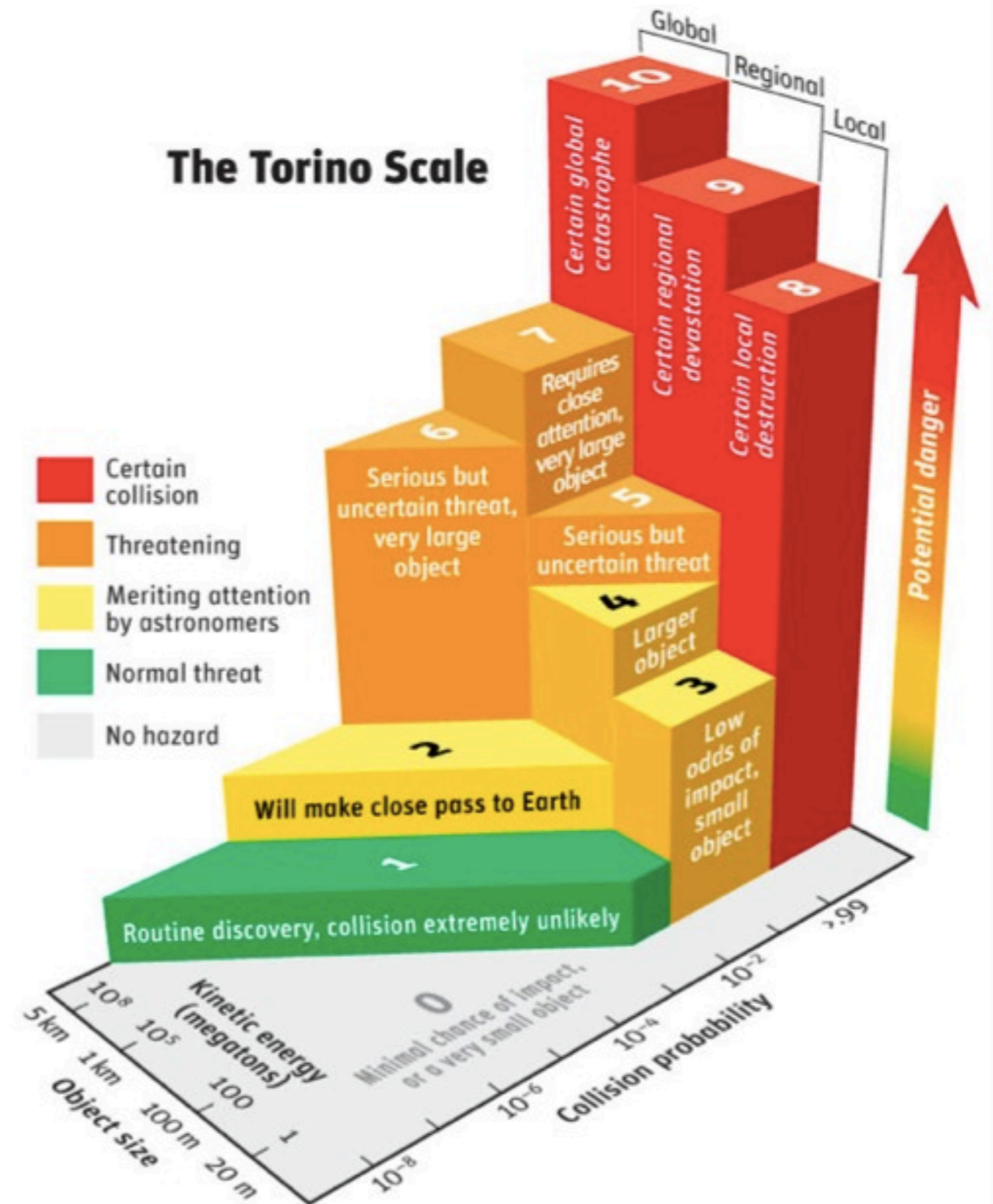
- ▶ 1200 MT of energy
- ▶ 7.7 magnitude quake
- ▶ 3.4 km crater
- ▶ Torino Scale: 4!



Observations predicted a 2.7% chance Apophis would hit Earth in 2029

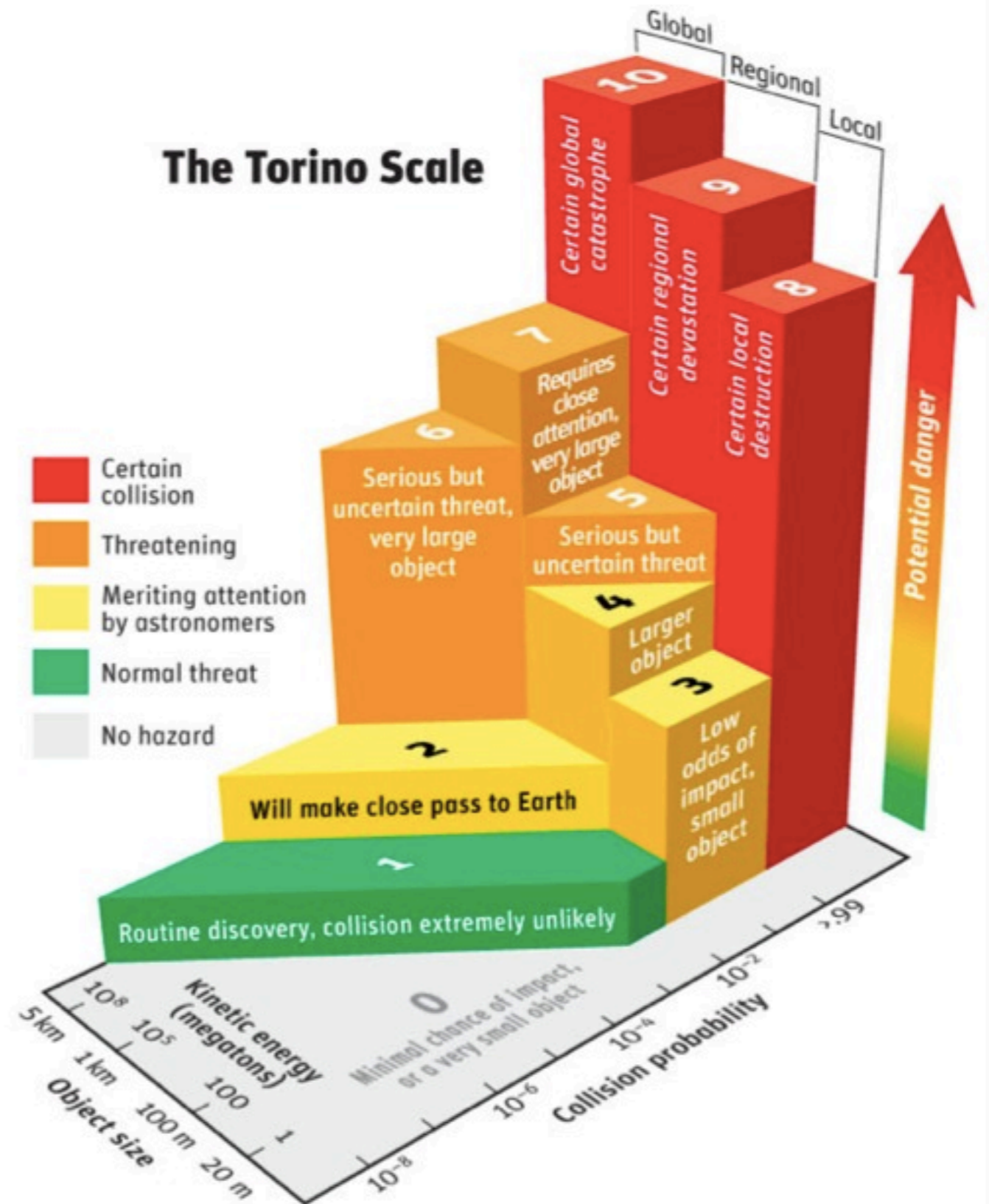
Apophis on the Torino Scale

Initially ranked a 2



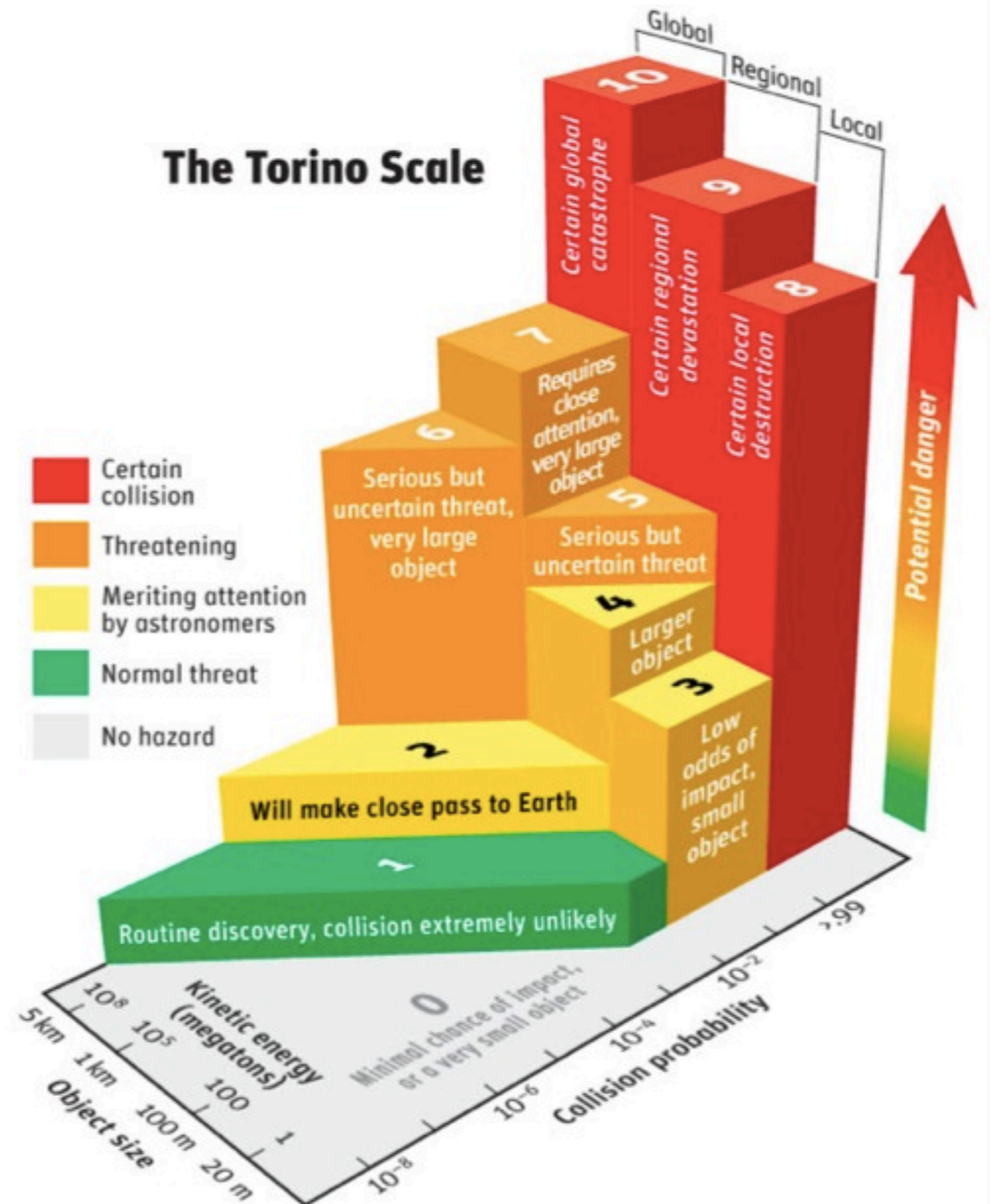
Apophis on the Torino Scale

Initially ranked a **2**
1 in 37 chance of collision increased ranking to a **4**!
▶ Highest rank ever!



Apophis on the Torino Scale

Initially ranked a **2**
1 in 37 chance of collision increased ranking to a **4**!
▶ Highest rank ever!
As a better fit of its orbit was found, it dropped to a **1**



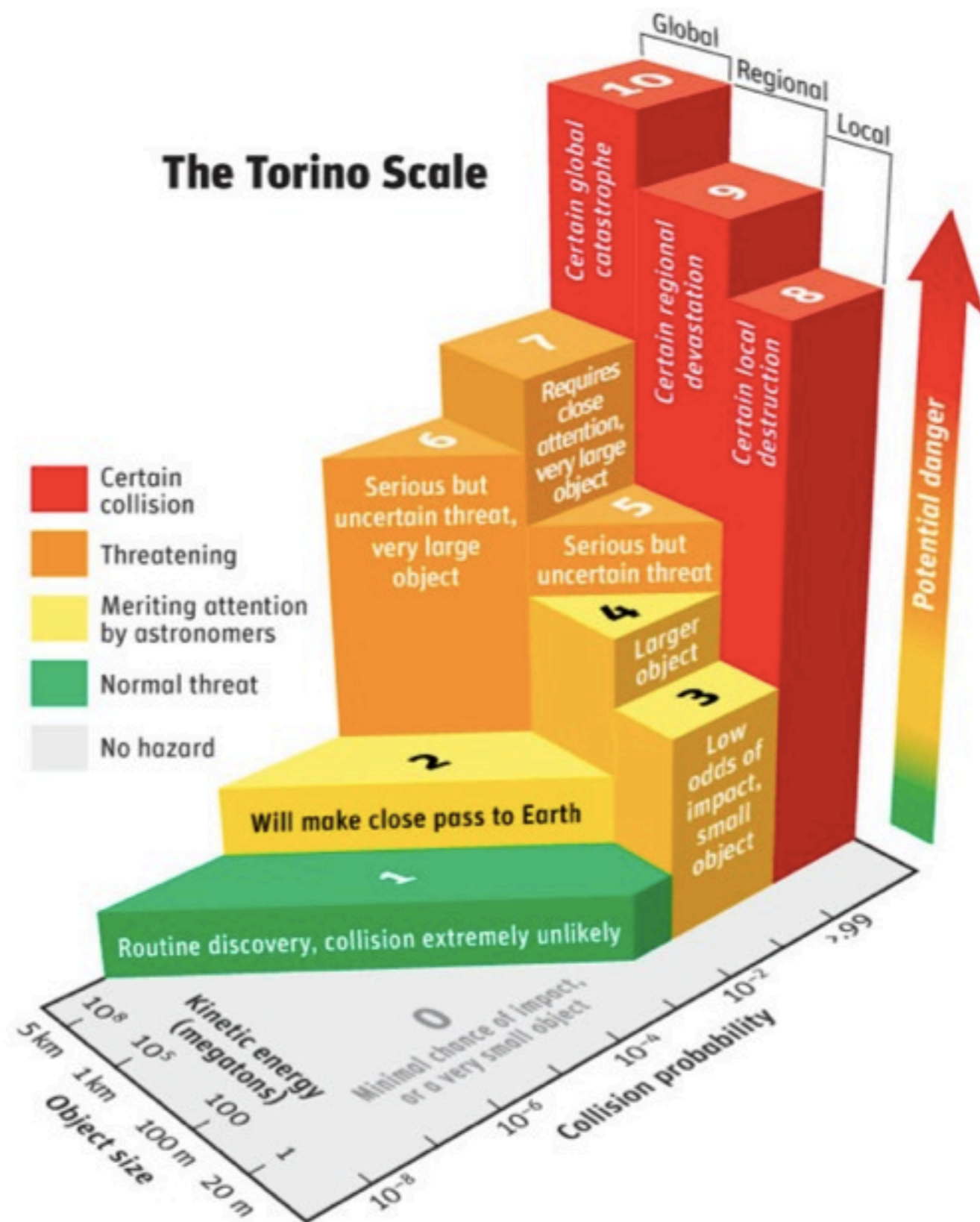
Apophis on the Torino Scale

Initially ranked a **2**
1 in 37 chance of collision increased ranking to a **4**!

▶ Highest rank ever!

As a better fit of its orbit was found, it dropped to a **1**

Now a **0**



Initial Prediction:

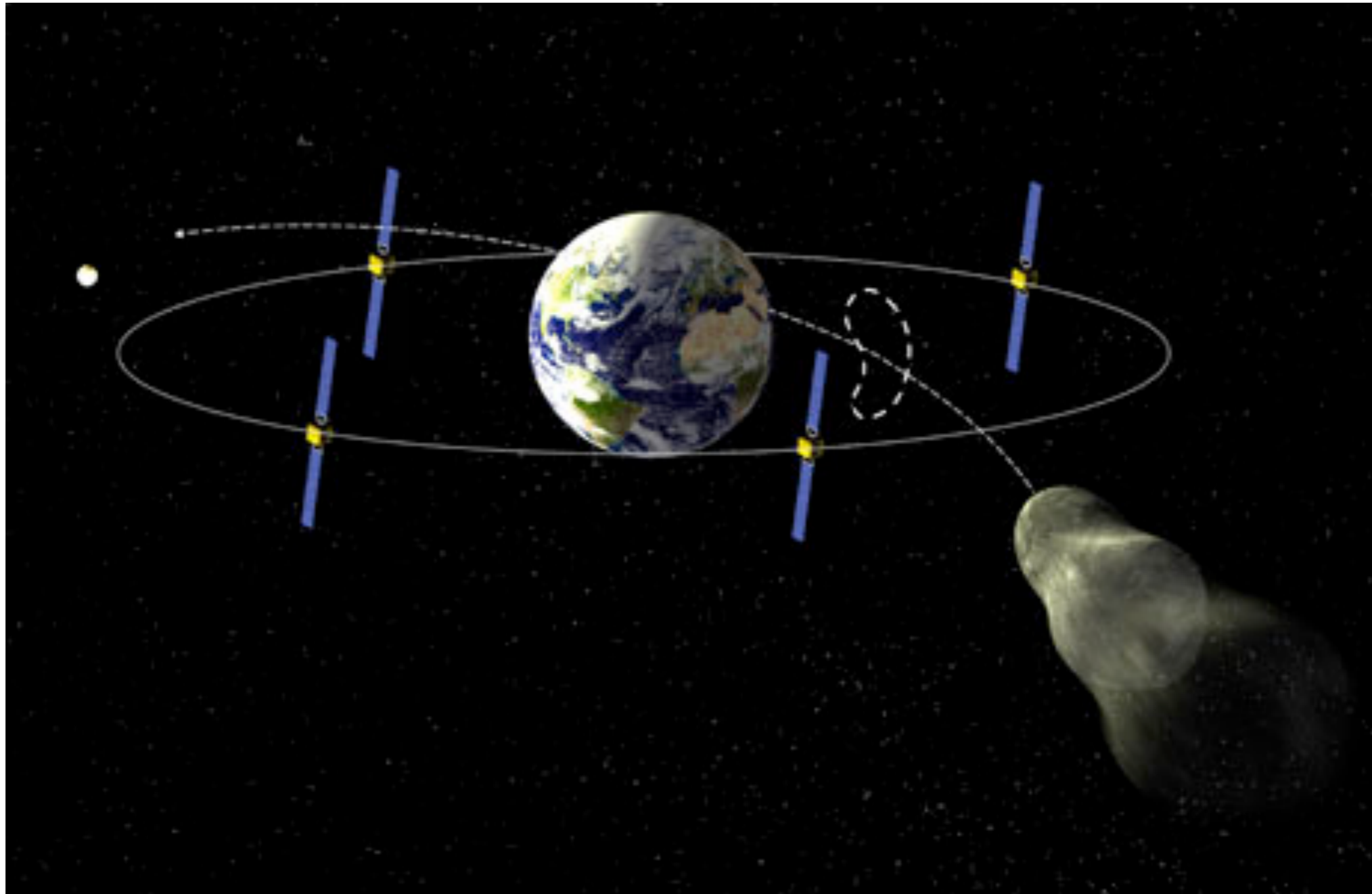


Later (Refined) Prediction:



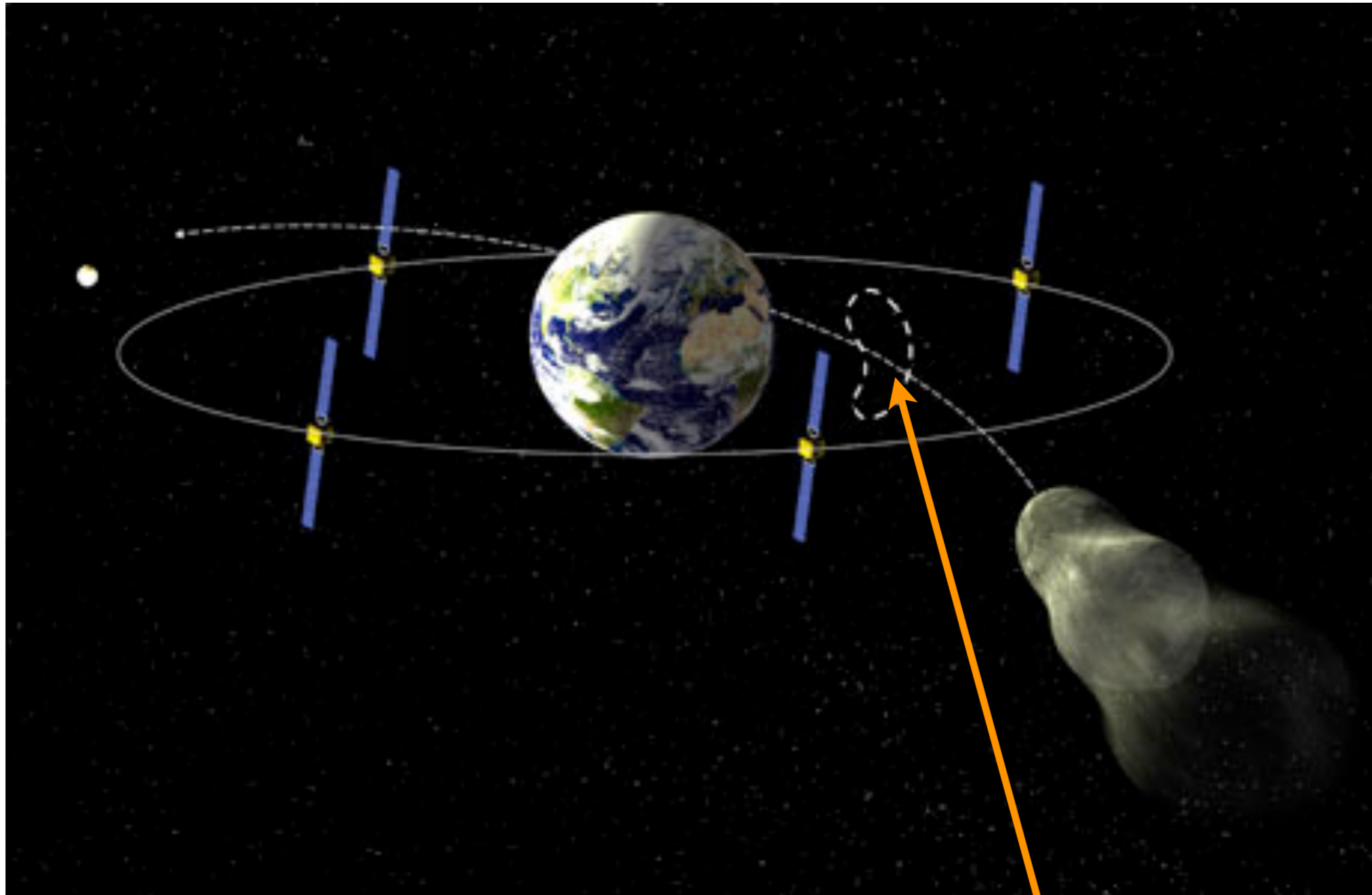
Additional observations refine impact probabilities - similar to refining predictions of where the golf ball will land as we observe its trajectory

No impact in 2029, but...



- ▶ Apophis will miss Earth by just 5 Earth radii!
- ▶ Under the orbits of communications satellites!

No impact in 2029, but...



Apophis may pass through a “keyhole” in 2029

Apophis's View of the Error Ellipse and Keyhole

0.527 Earth radius (3,357 kilometers)



- ▶ 2036 keyhole only ~600 meters wide
- ▶ Apophis' error ellipse = **uncertainty** in trajectory prediction ~**3000 km** in diameter
- ▶ Chance of Apophis hitting keyhole:
1 in 250,000

i>clicker poll

Right now, the US Government is spending money on finding PHAs. How much money should we be spending on this issue?

- A. \$0 per year -- we've got bigger problems to worry about.**
- B. Few million \$ per year -- get some people working on it, and this cost is a drop in the bucket compared to e.g. DoD.**
- C. Few billion \$ per year -- given the consequences, this requires lots of resources.**
- D. Few trillion \$ per year -- Holy Crap, this should be our top priority!**