

## Jupiter – Friend or Foe?

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# 1. Introduction

Chelyabinsk, population 1.1 million people.  
15<sup>th</sup> February 2013, local time 9:20am.



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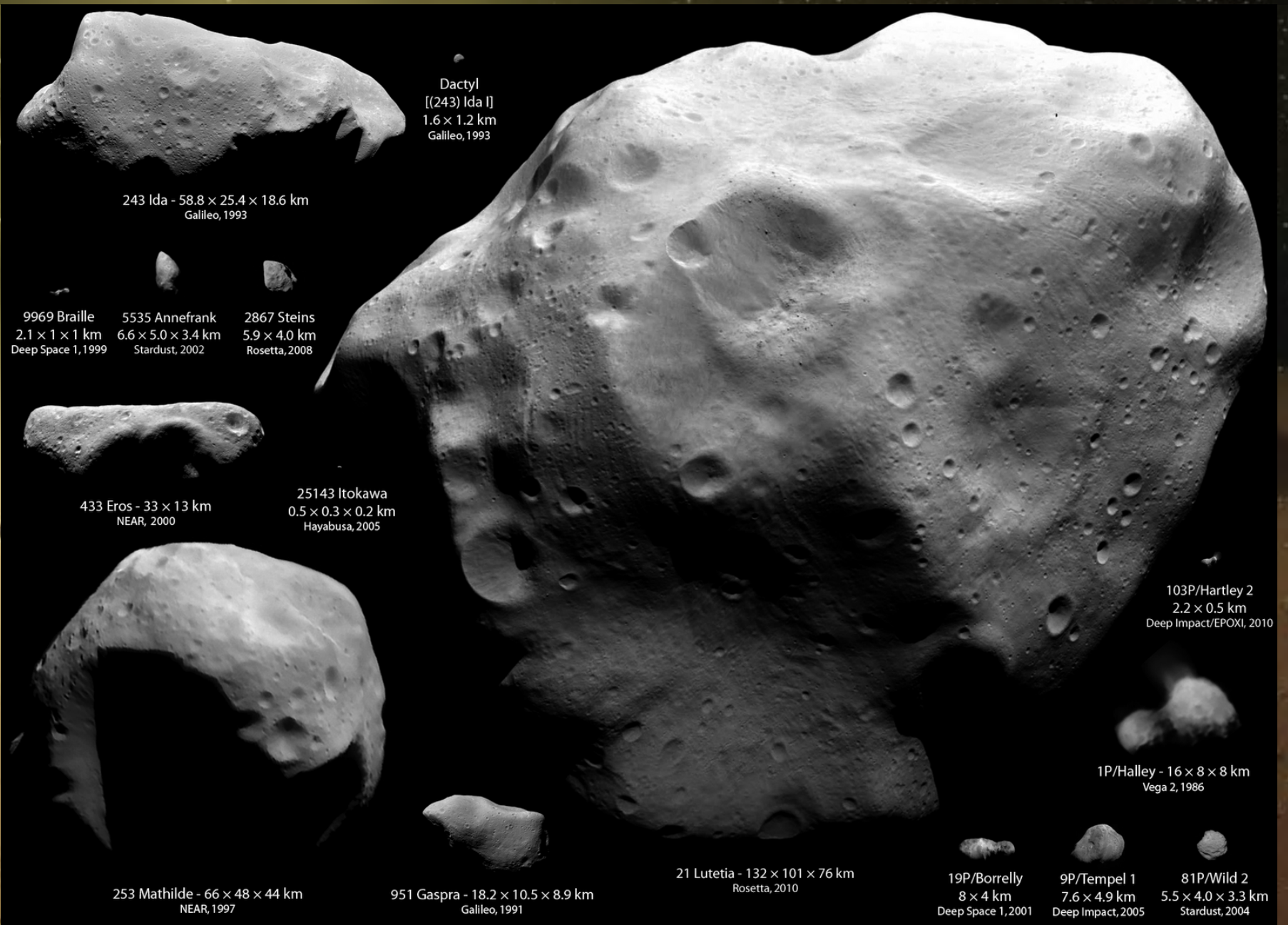


## 2. Left-overs from Planet Formation

So – where do these objects come from?



# 2. Left-overs from Planet Formation



Dactyl  
 [(243) Ida I]  
 1.6 × 1.2 km  
 Galileo, 1993

243 Ida - 58.8 × 25.4 × 18.6 km  
 Galileo, 1993

9969 Braille  
 2.1 × 1 × 1 km  
 Deep Space 1, 1999

5535 Annefrank  
 6.6 × 5.0 × 3.4 km  
 Stardust, 2002

2867 Steins  
 5.9 × 4.0 km  
 Rosetta, 2008

433 Eros - 33 × 13 km  
 NEAR, 2000

25143 Itokawa  
 0.5 × 0.3 × 0.2 km  
 Hayabusa, 2005

103P/Hartley 2  
 2.2 × 0.5 km  
 Deep Impact/EPOXI, 2010

253 Mathilde - 66 × 48 × 44 km  
 NEAR, 1997

951 Gaspra - 18.2 × 10.5 × 8.9 km  
 Galileo, 1991

21 Lutetia - 132 × 101 × 76 km  
 Rosetta, 2010

19P/Borrelly  
 8 × 4 km  
 Deep Space 1, 2001

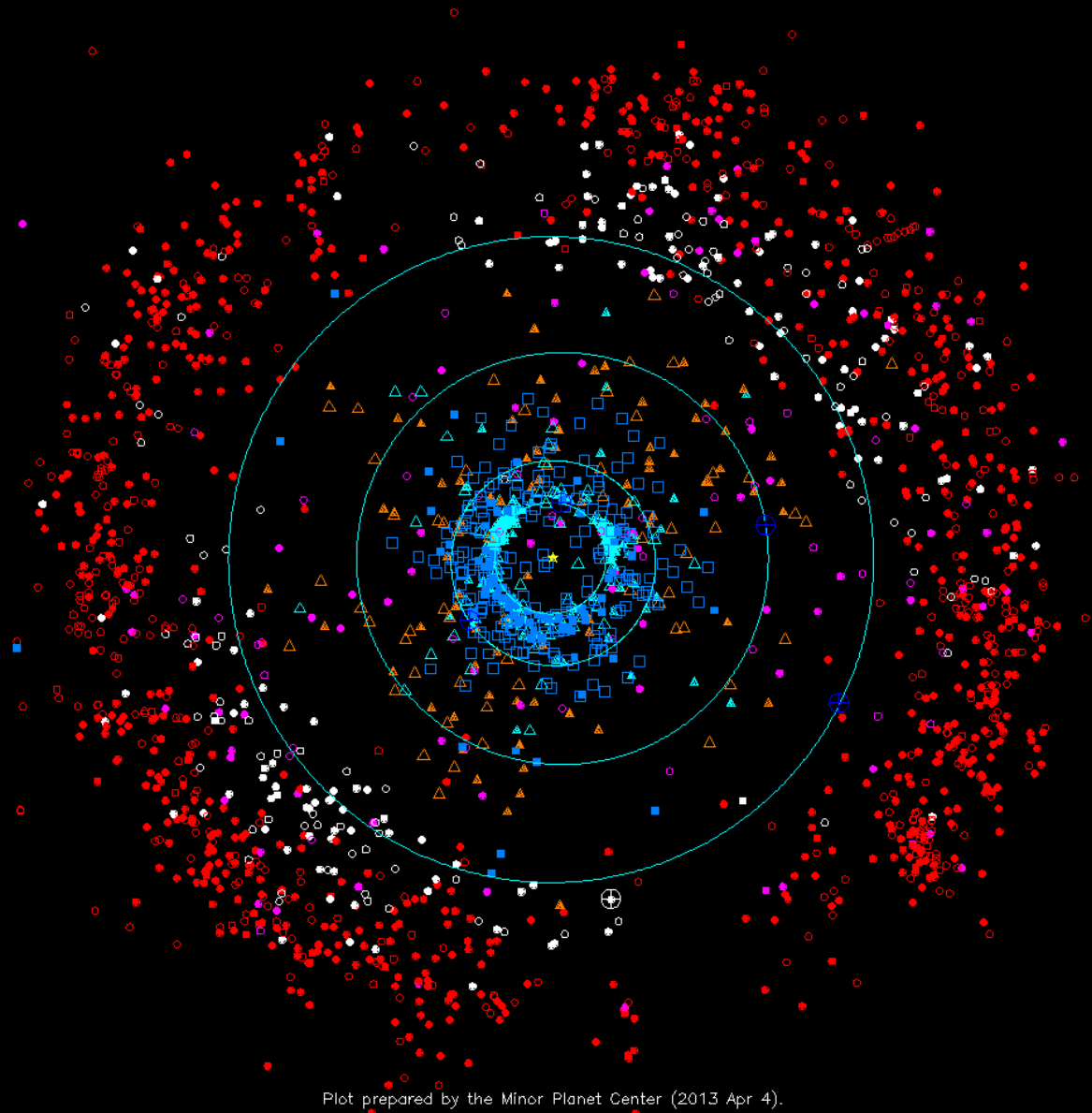
9P/Tempel 1  
 7.6 × 4.9 km  
 Deep Impact, 2005

81P/Wild 2  
 5.5 × 4.0 × 3.3 km  
 Stardust, 2004

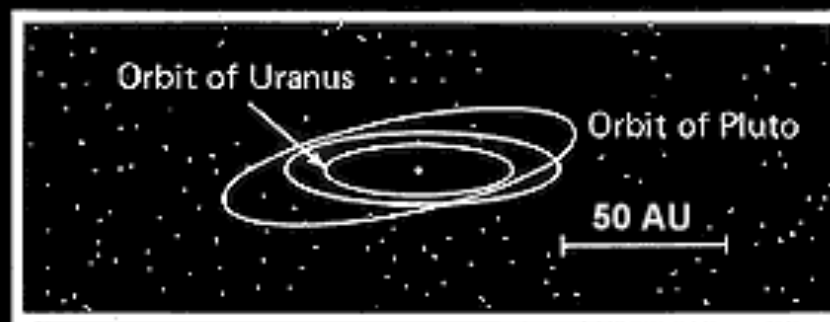
Montage by Emily Lakdawalla of The Planetary Society. Ida: Dactyl, Braille, Annefrank, Gaspra, Borrelly: NASA / JPL / Ted Stryk; Steins: ESA / OSIRIS team; Eros: NASA / JHUAPL; Itokawa: ISAS / JAXA / Emily Lakdawalla; Mathilde: NASA / JHUAPL / Ted Stryk; Lutetia: ESA / OSIRIS team / Emily Lakdawalla; Halley: Russian Academy of Sciences / Ted Stryk; Tempel 1 & Hartley 2: NASA / JPL / UMD; Wild 2: NASA / JPL. Revised 2010-11-16.

## 2. Left-overs from Planet Formation

## 2. Trans-Neptunian objects

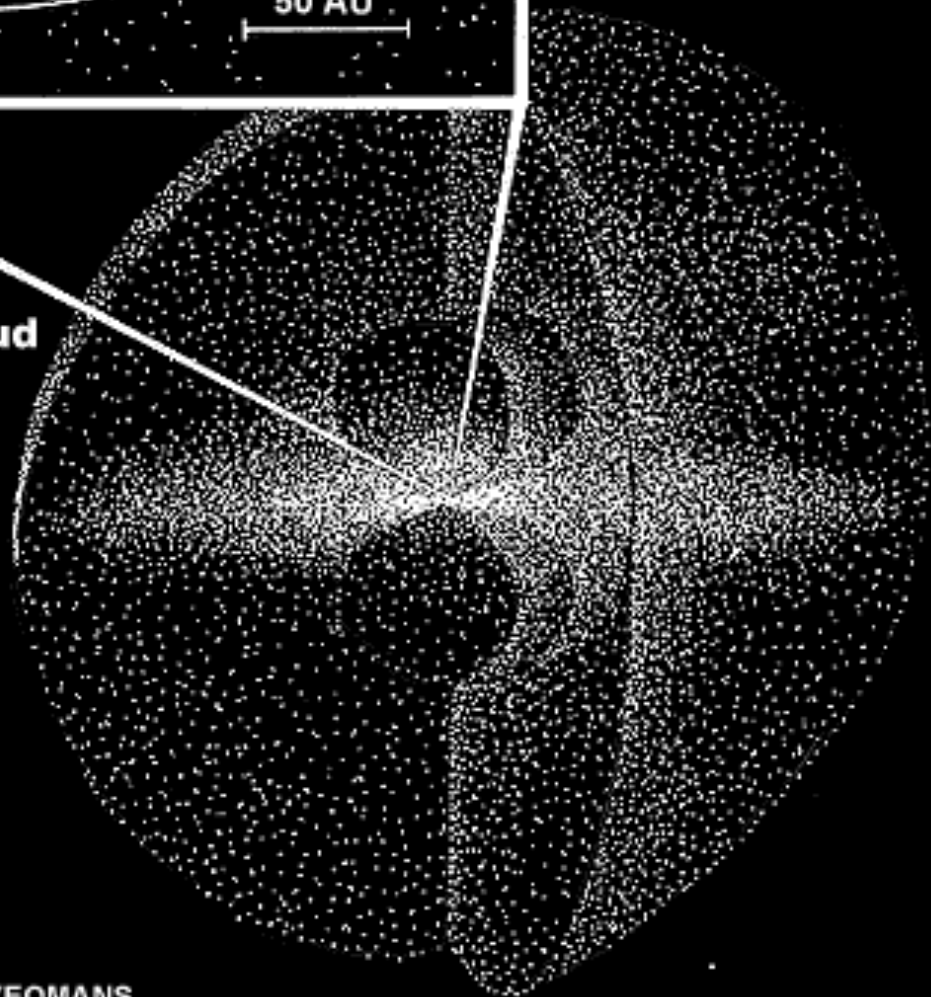


## 2. Left-overs from Planet Formation



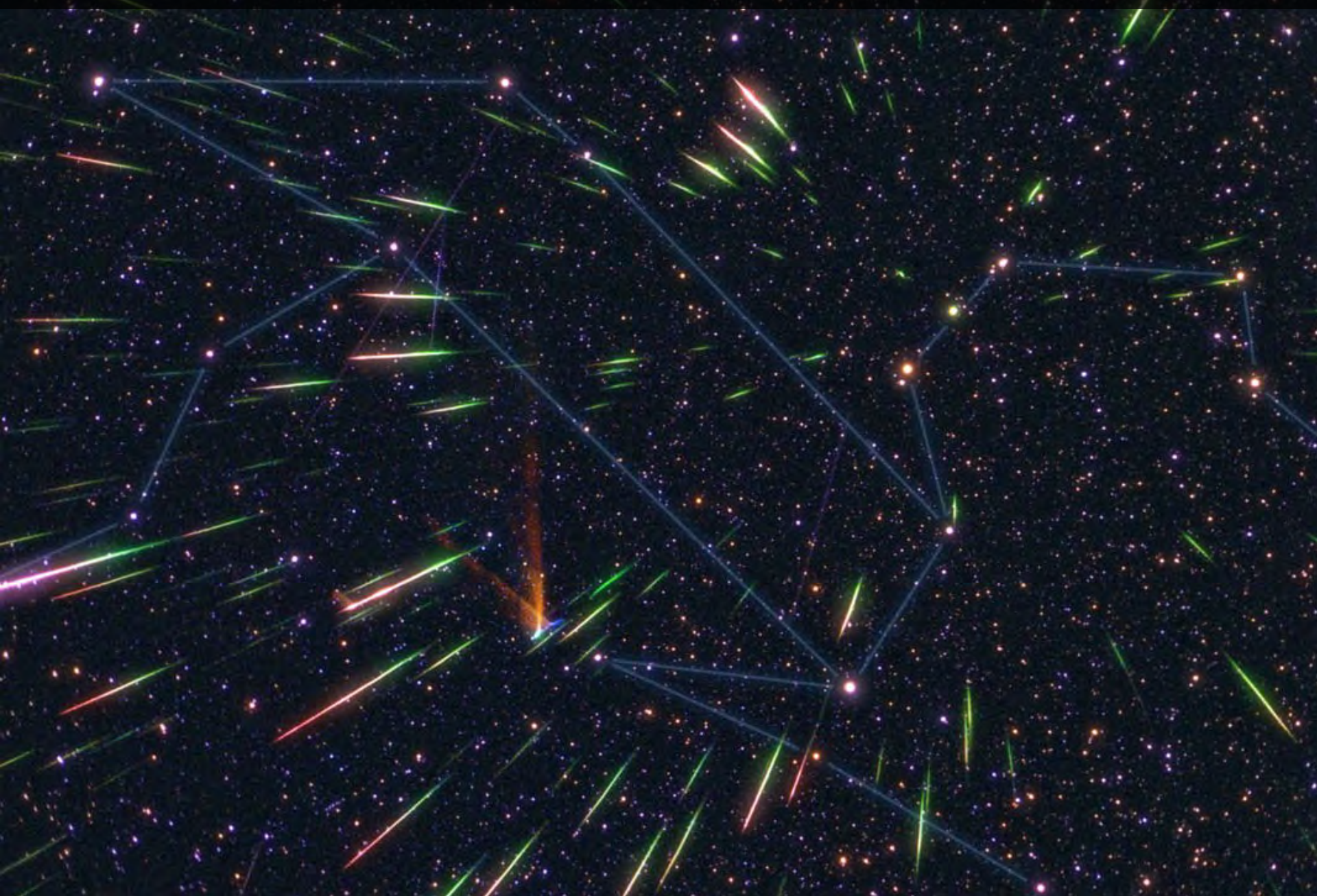
### The Oort Cloud

The orbits of the planets are tiny compared to the size of the Oort cloud.



SOURCE: NASA/JPL/YEOMANS

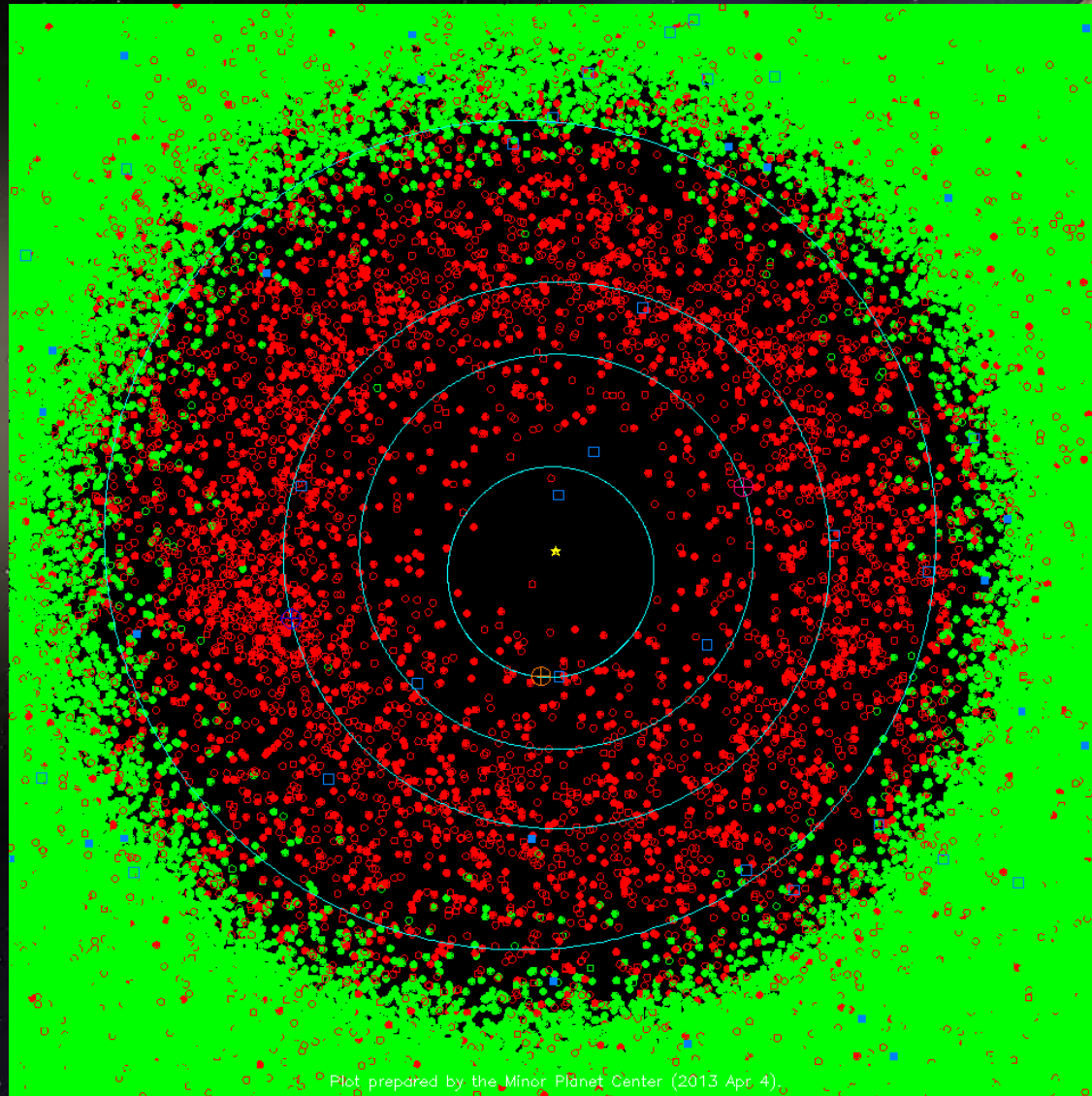
## 2. Left-overs from Planet Formation





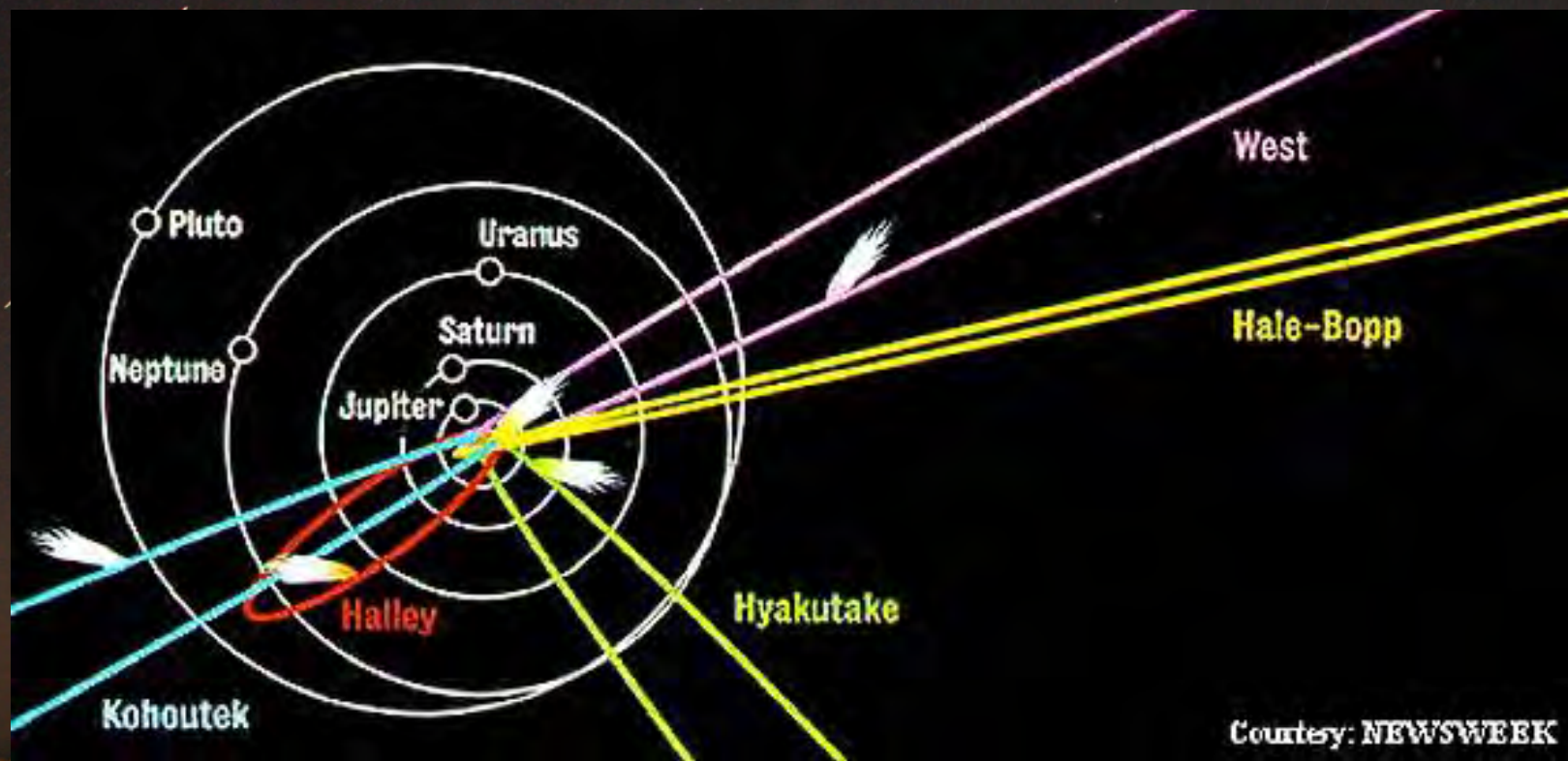
## 2. Left-overs from Planet Formation

### Near-Earth asteroids



## 2. Left-overs from Planet Formation

# Long Period Comets



## 2. Left-overs from Planet Formation

### Short Period Comets

A deep-sky photograph of a starry night sky. The background is filled with numerous small, distant stars. In the upper center, there is a reddish, nebulous structure. In the lower center, there is a bright, white, circular object that appears to be a comet or a planet, with a soft, glowing aura around it. The overall scene is dark and rich with celestial detail.

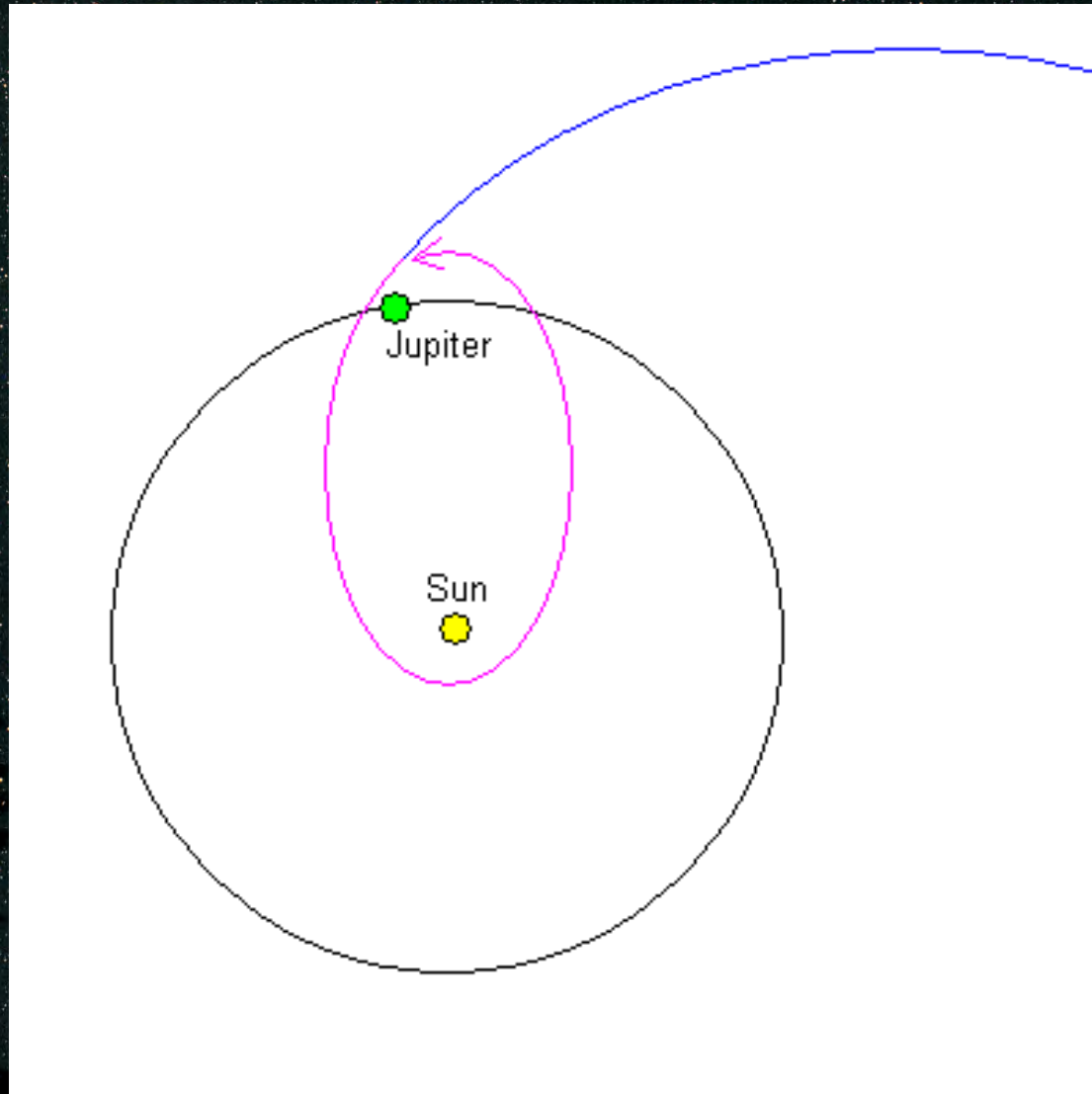
### 3. Jupiter – Friend or Foe?

A WIDELY HELD BELIEF



### 3. Jupiter – Friend or Foe?

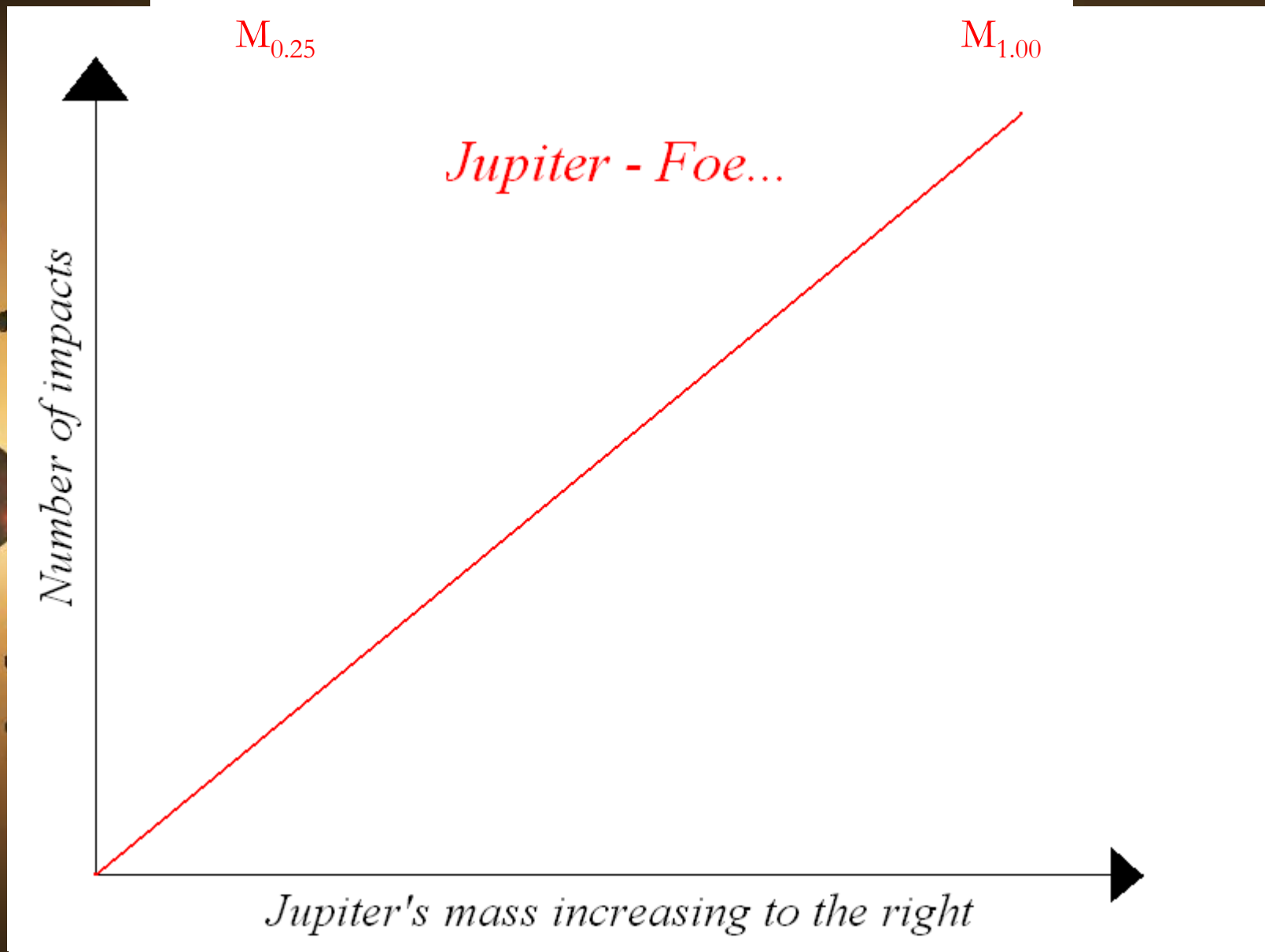
## Comet Lexell – Jupiter as Friend and Foe...



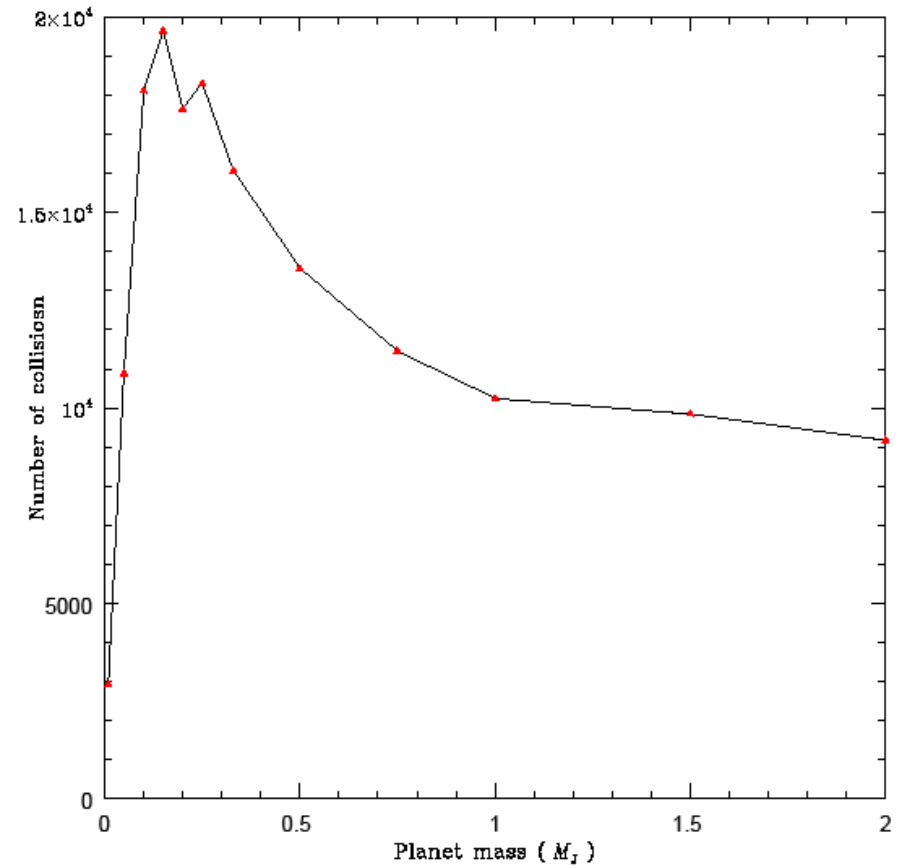
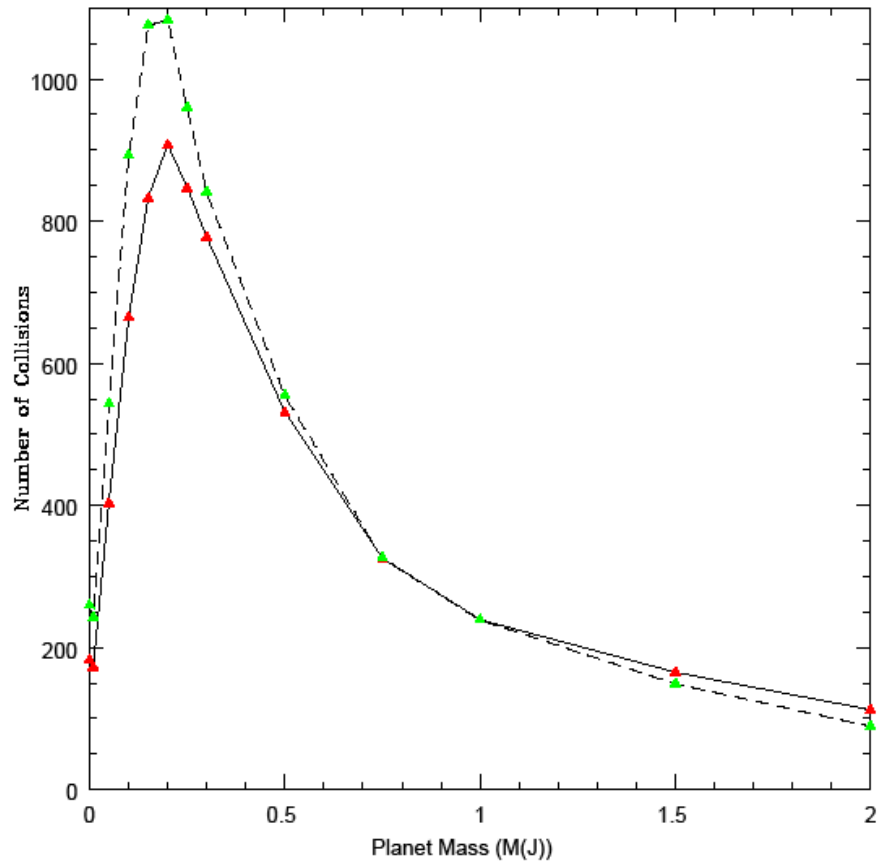
**Simulating the Asteroids**

Simulating the Asteroids

### 3. Jupiter – Friend or Foe?



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### 3. Jupiter – Friend or Foe?

## Simulating the Long Period Comets



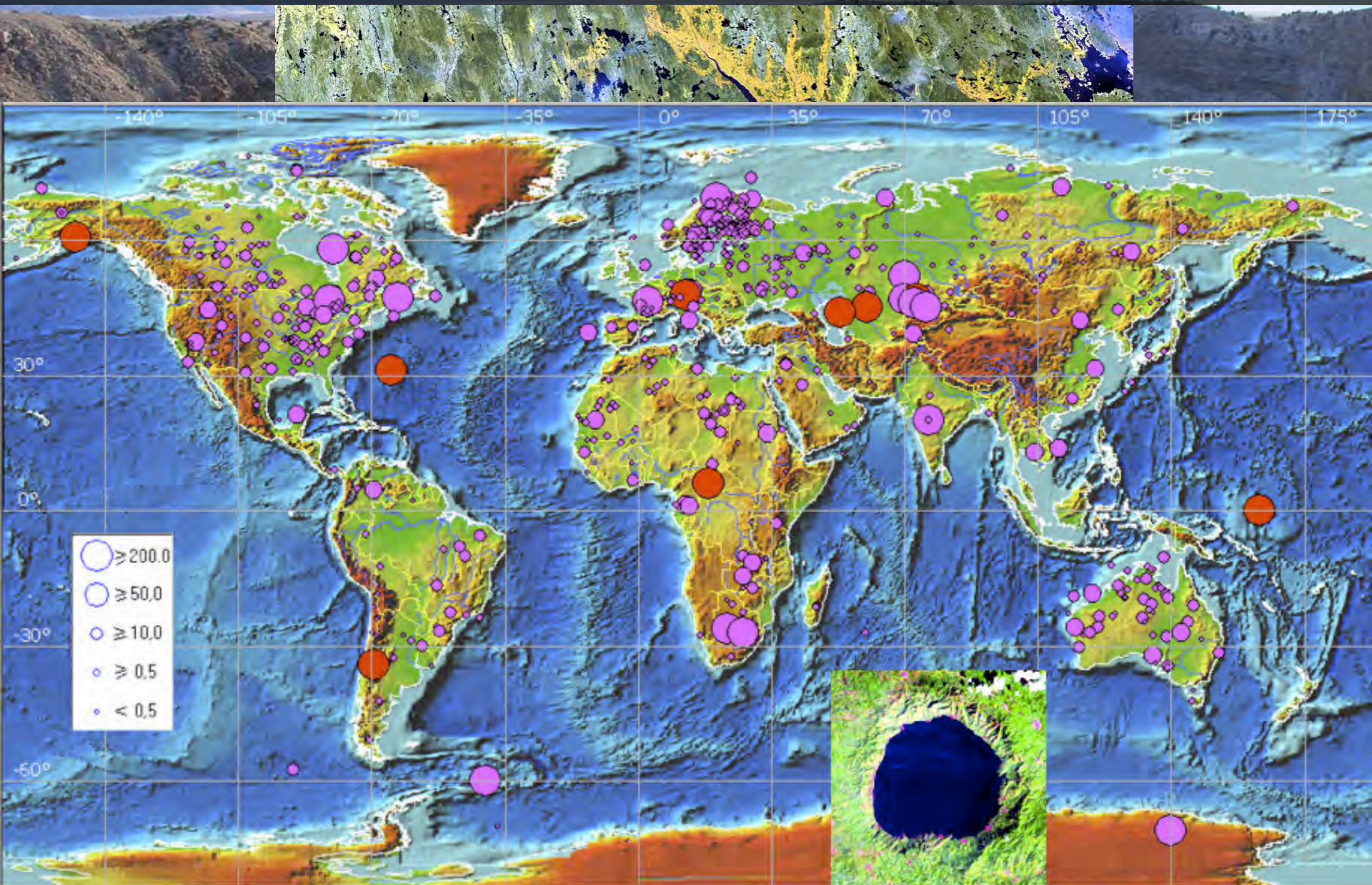
**For the Long Period Comets, Jupiter is a FRIEND!**

## 4. Historical Impacts – on Earth and Beyond

Everywhere we look, we see evidence of impacts...



# 4. Historical Impacts – on Earth and Beyond



## 4. Historical Impacts – on Earth and Beyond

### Impacts and extinctions...



## 5. Impacts in the Modern Solar System

### Meteor Crater, Arizona, c. 50,000 BC

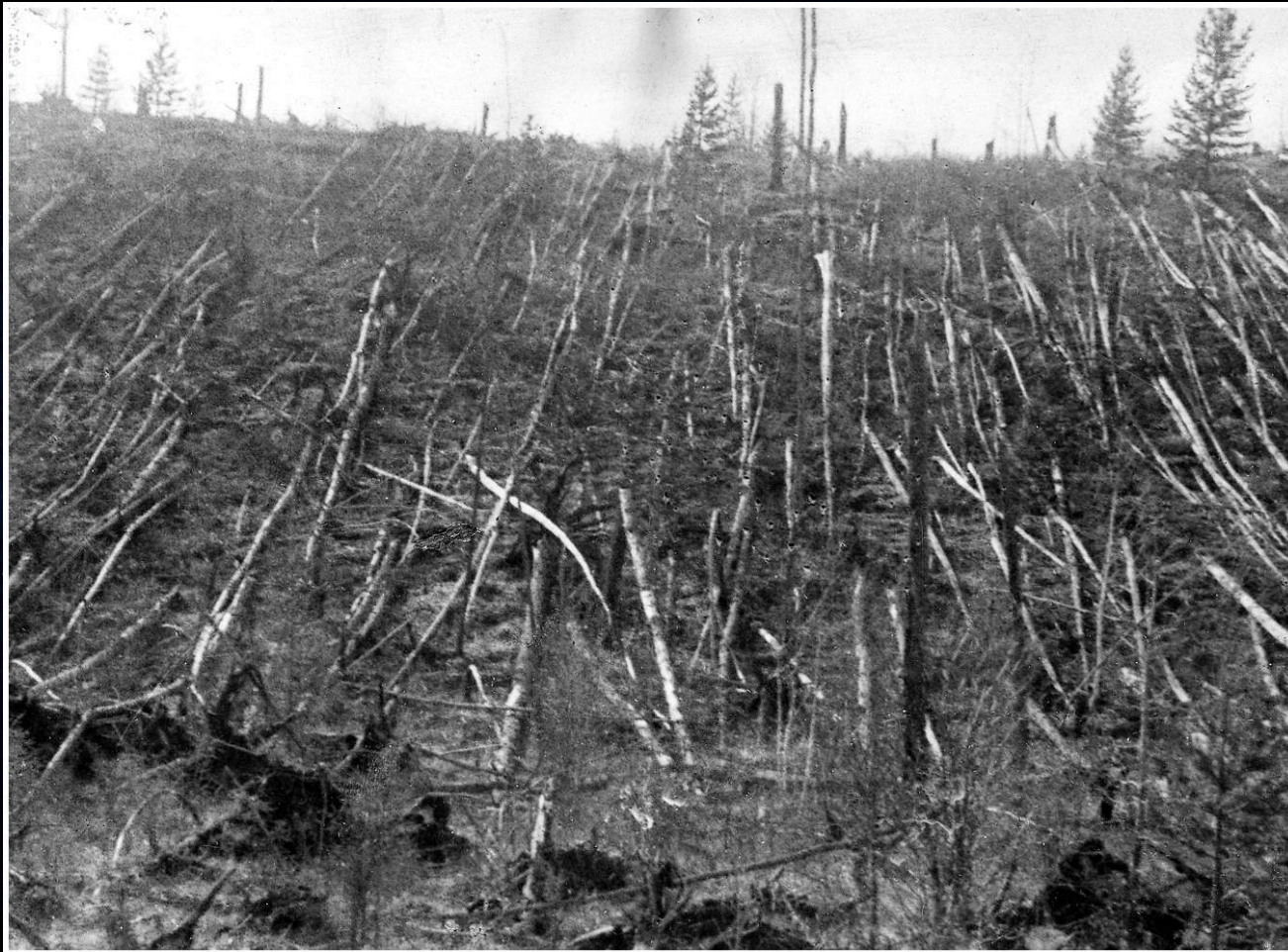


1,200 metres across, 200 metres deep, a 50 metre high crater rim.

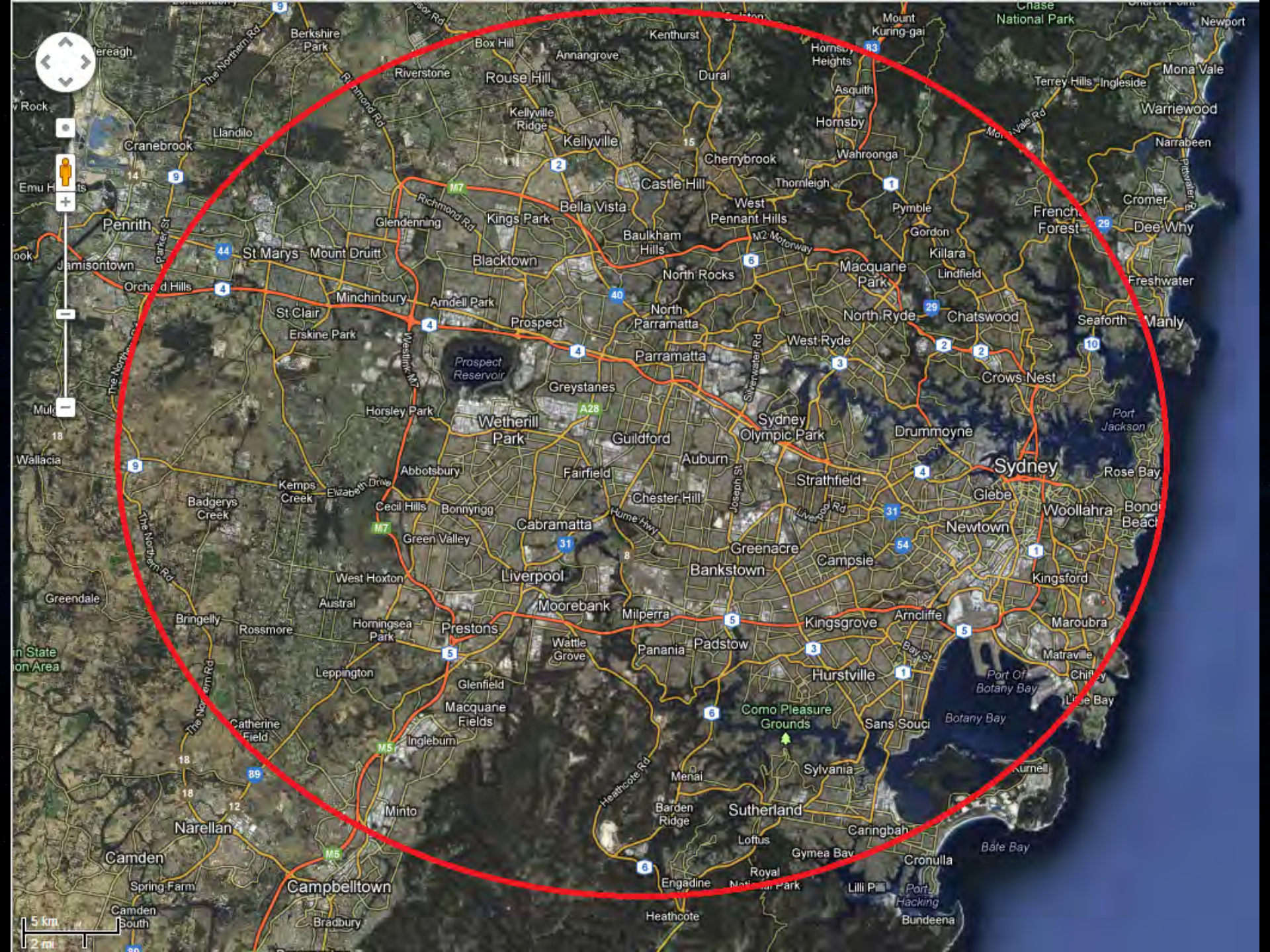
Remnant of the impact of a 50 metre diameter nickel-iron meteorite.

## 5. Impacts in the Modern Solar System

### The Tunguska Event



30<sup>th</sup> June, 1908 – the largest impact on Earth in recorded history.



## The 1972 Great Daylight Fireball



Alberta, Canada, 10<sup>th</sup> August 1972.  
An Earthgrazer, between 3 and 14m in diameter.  
Sonic boom heard in Montana.  
Closest approach was 57km above the ground.



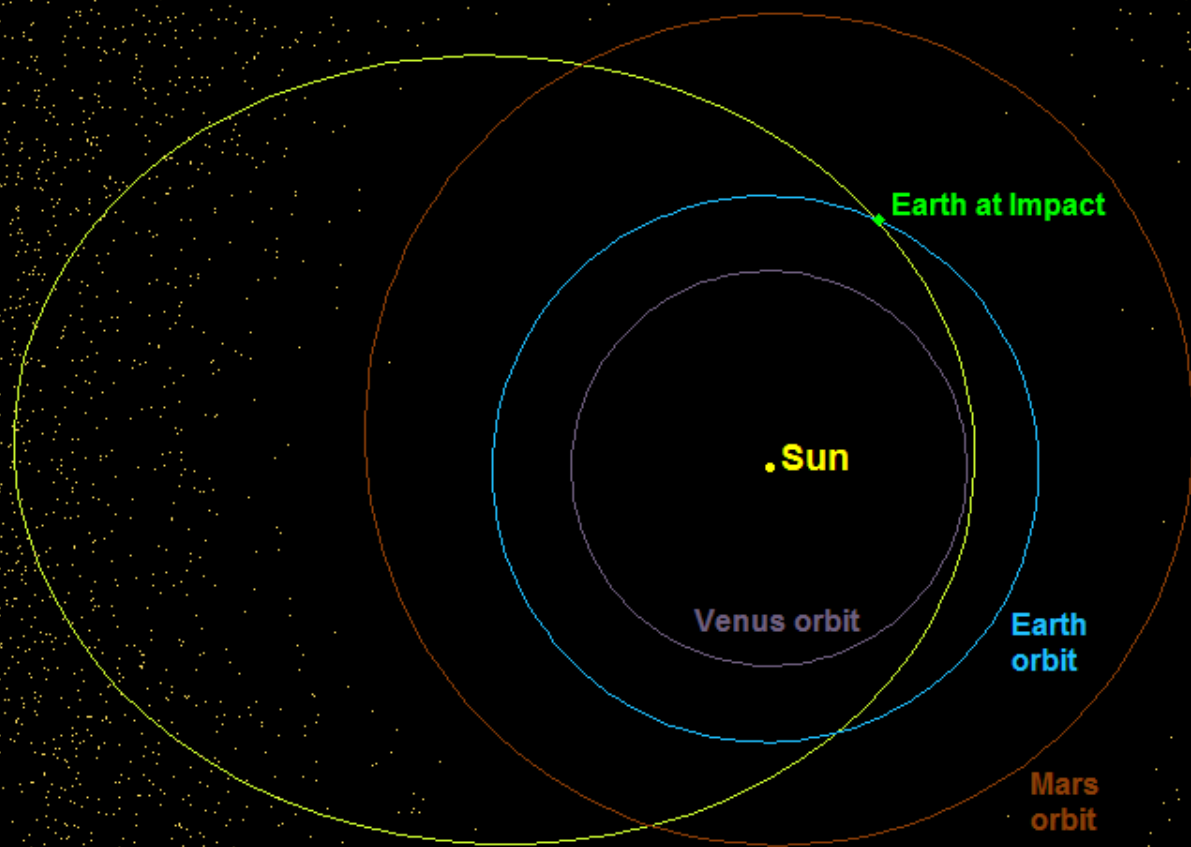
## 5. Impacts in the Modern Solar System

2008 – the impact of 2008 TC<sub>3</sub>



**The first time we have discovered an asteroid before it hit.  
Airburst equivalent to just 2 kilotons of TNT.**

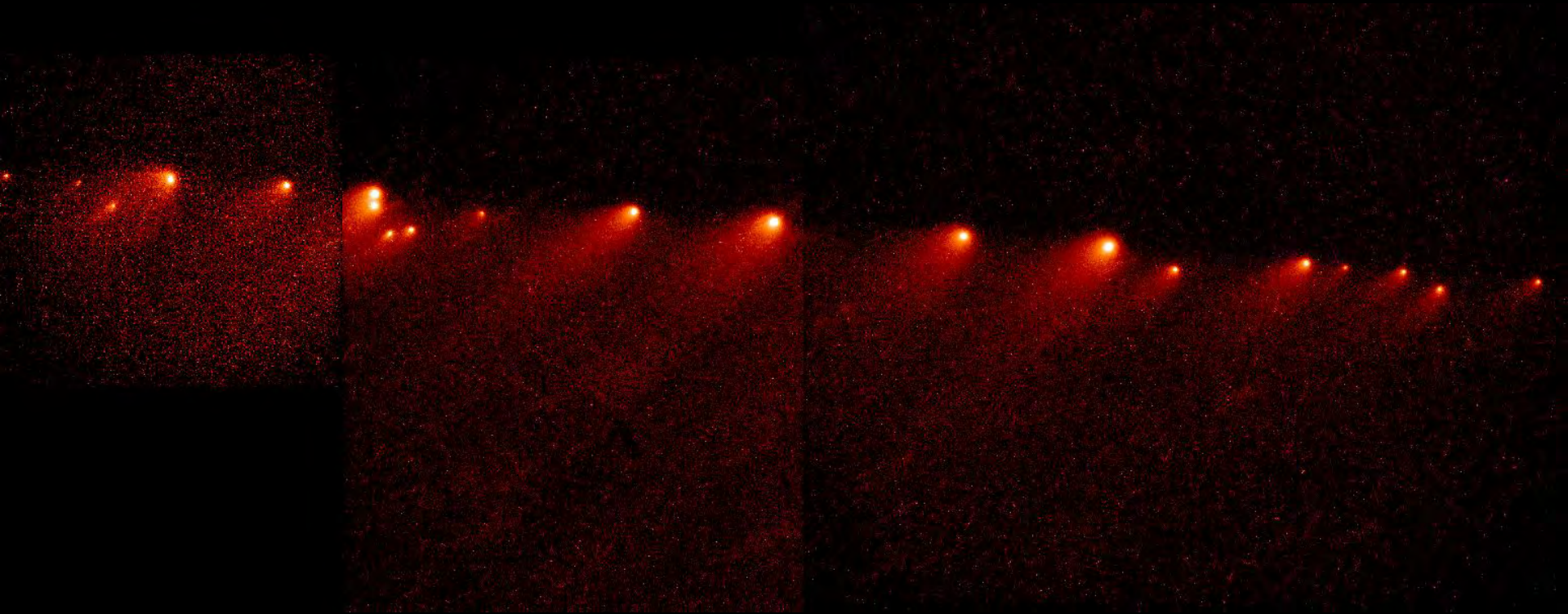
# Pre-Impact Orbit About the Sun of the Chelyabinsk Impactor



**Asteroid Belt**

## 5. Impacts in the Modern Solar System

But the Earth isn't the only planet being pummelled...



This is comet Shoemaker-Levy 9, torn to pieces by Jupiter in 1992.

# Impact on Jupiter, 2012 Sep.10: before & after

Approx. impact site arrowed,  
near N edge of orange EB.

(Images copyright to the observers.  
Compilation by John Rogers) North up.



Sep.8: best pre-impact images  
(part of a multispectral set by T. Akutsu)

2012/09/08 21:22:07(UT) T.AKUTSU  
I=317.4 II=213.4 III=250. Cebu Philippines

Sep.11: Impact site on second rotation,  
11 hours after fireball, with transit of Ganymede  
(Also images by others inc. Mike Phillips & Brian Combs)

Sep.11: Impact site  
on third rotation



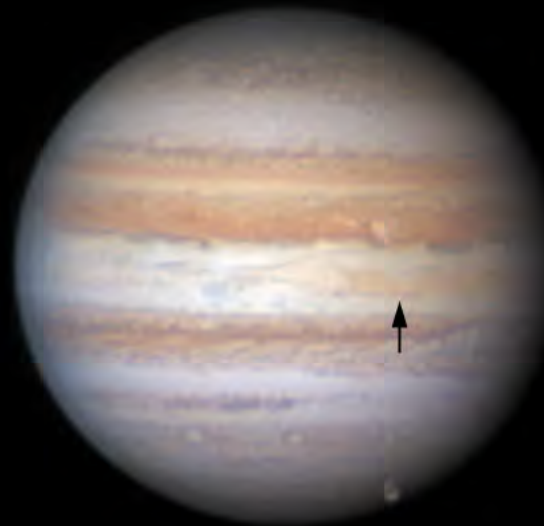
11 Sep 2012, 19h01m24s UT,  
CM1:345.8, CM2:219.6, CM3:257.8  
I. Miyazaki, Japan



2012 Sep. 11 09-14.6 UT  
CM1=348.0 CM2=225.0 CM3=263.0  
Gary Walker Macon, GA (USA)



2012 Sep.11\_09-23-12\_UT  
Mike Hood (GA) USA



2012 Sep.11, 9:51.5ut  
CMI=10.5° CMII=247.3° CMIII=284.9°  
W. Jaeschke ./ West Chester, PA (USA)

## 6. The Future...



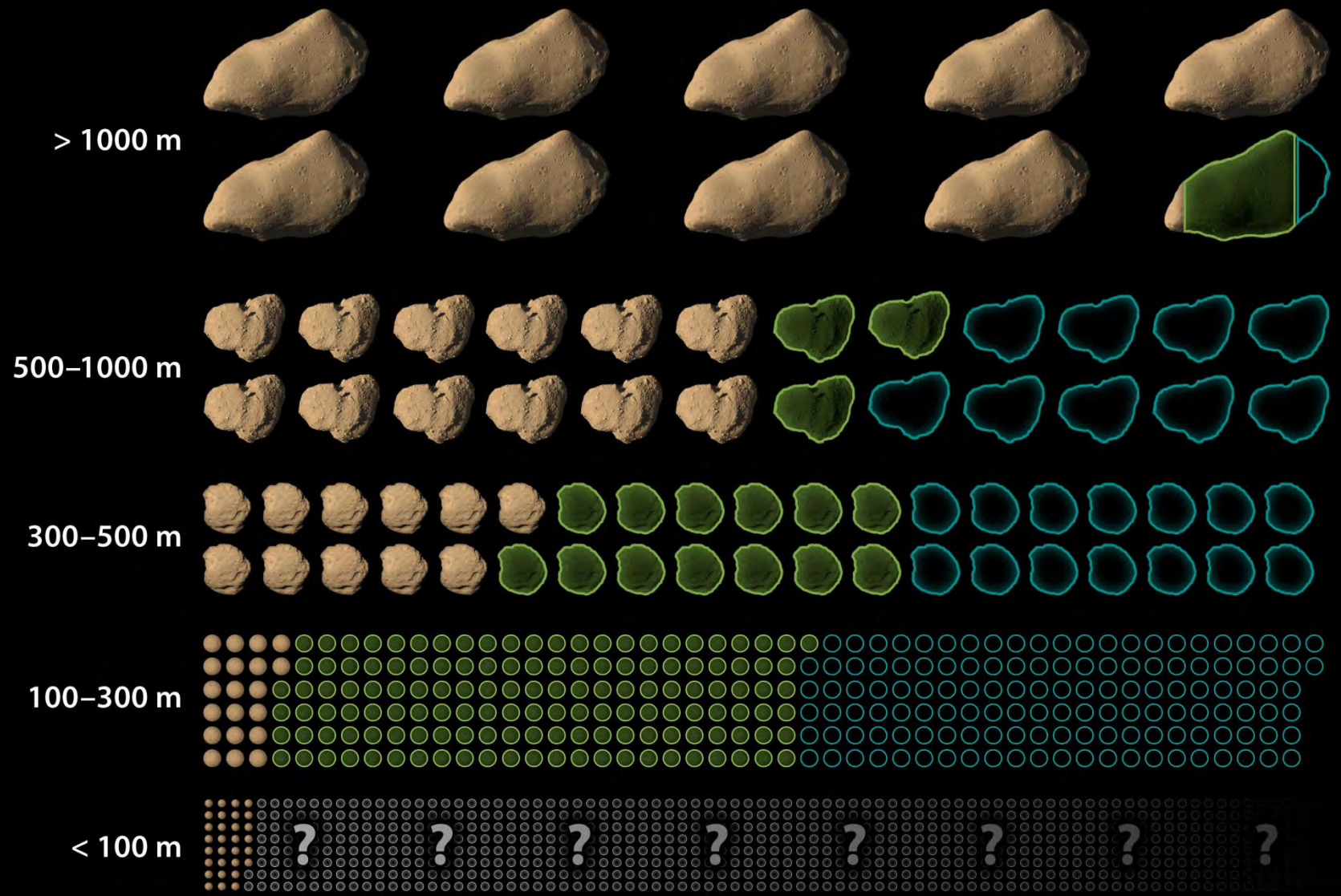
The Earth **will** be hit again –what can we do about it?

# 6. The Future...

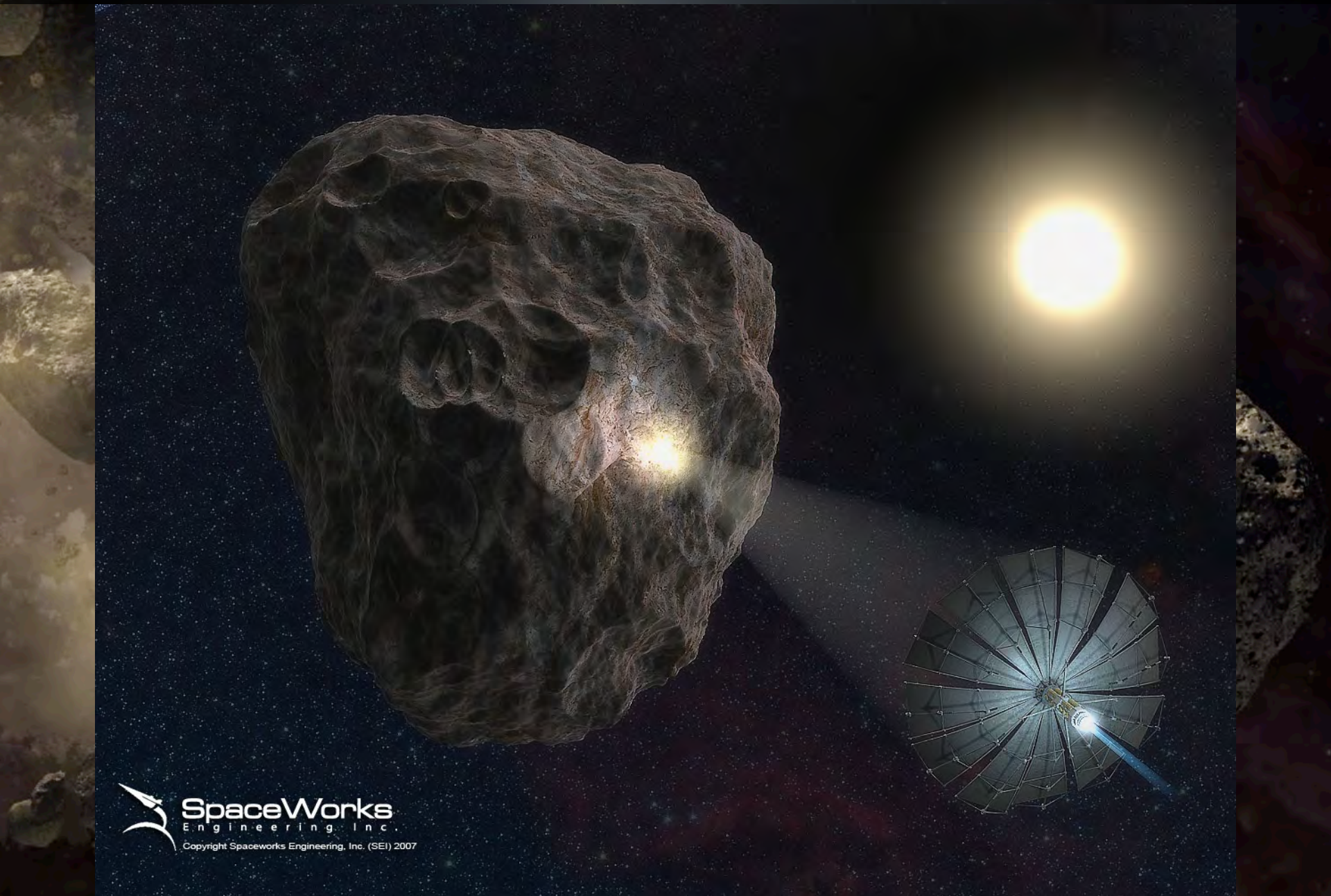
## A Near-Earth Asteroid Census

Each image represents 100 objects

Known Asteroids ●  
New Predicted Total (WISE) ○  
Old Predicted Total (pre-WISE) ○



## 6. The Future...



 **SpaceWorks**  
Engineering, Inc.  
Copyright Spaceworks Engineering, Inc. (SEI) 2007

## 6. The Future...

### Deep Impact, 4<sup>th</sup> July 2005

A 370 kg impactor fired into comet 9P/Tempel at a speed of 10.3 km/s, while the companion spacecraft flew by and watched.

Comet Tempel is 7.6 x 4.9 km in size, with a mass of just over  $7 \times 10^{13}$  kg, which is ....

200,000,000,000 times the mass of the impactor...





Don Quijote...



Our next step in learning how to deflect **FRIEND OR FOE EXTRA.....**