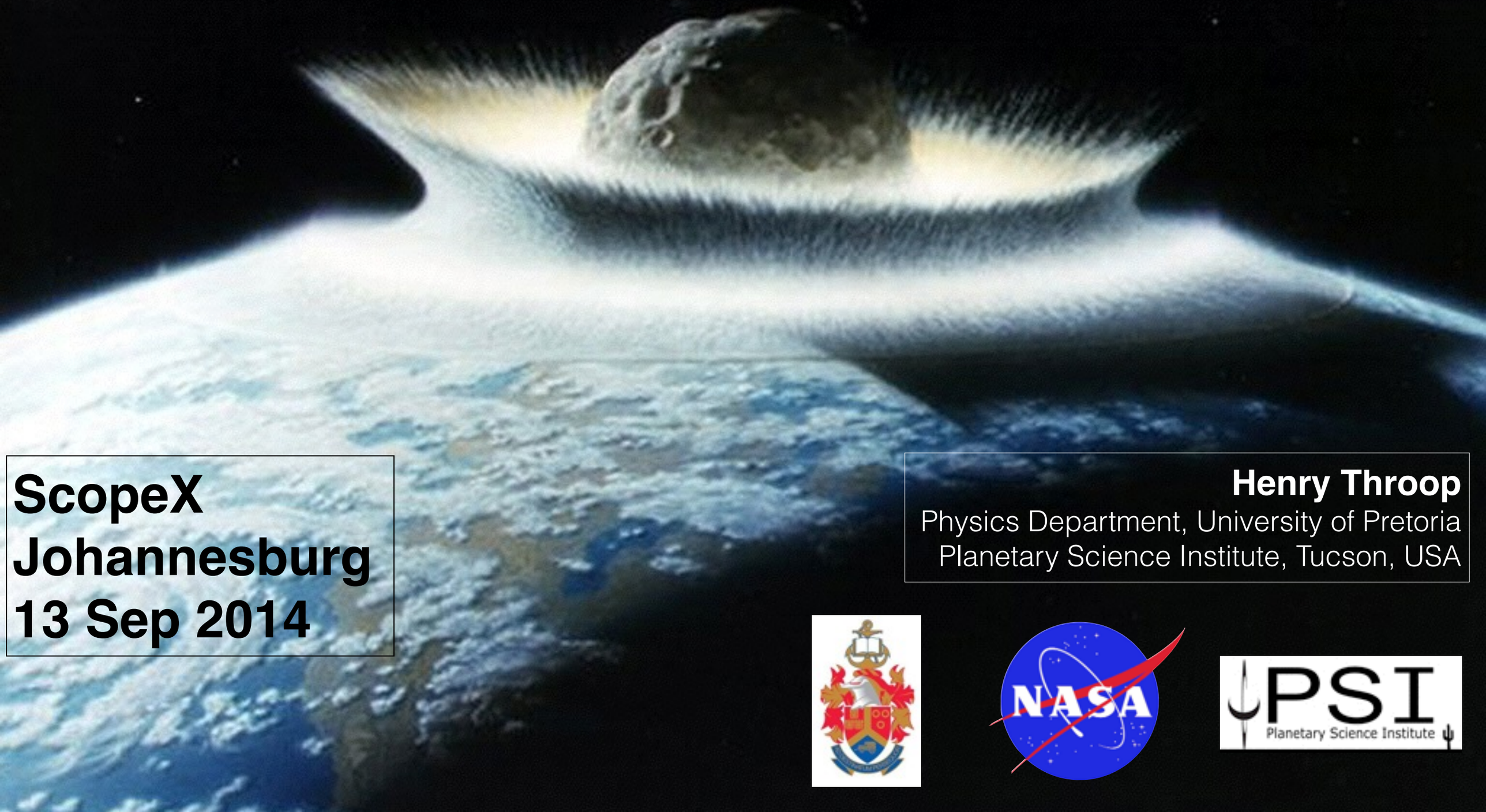
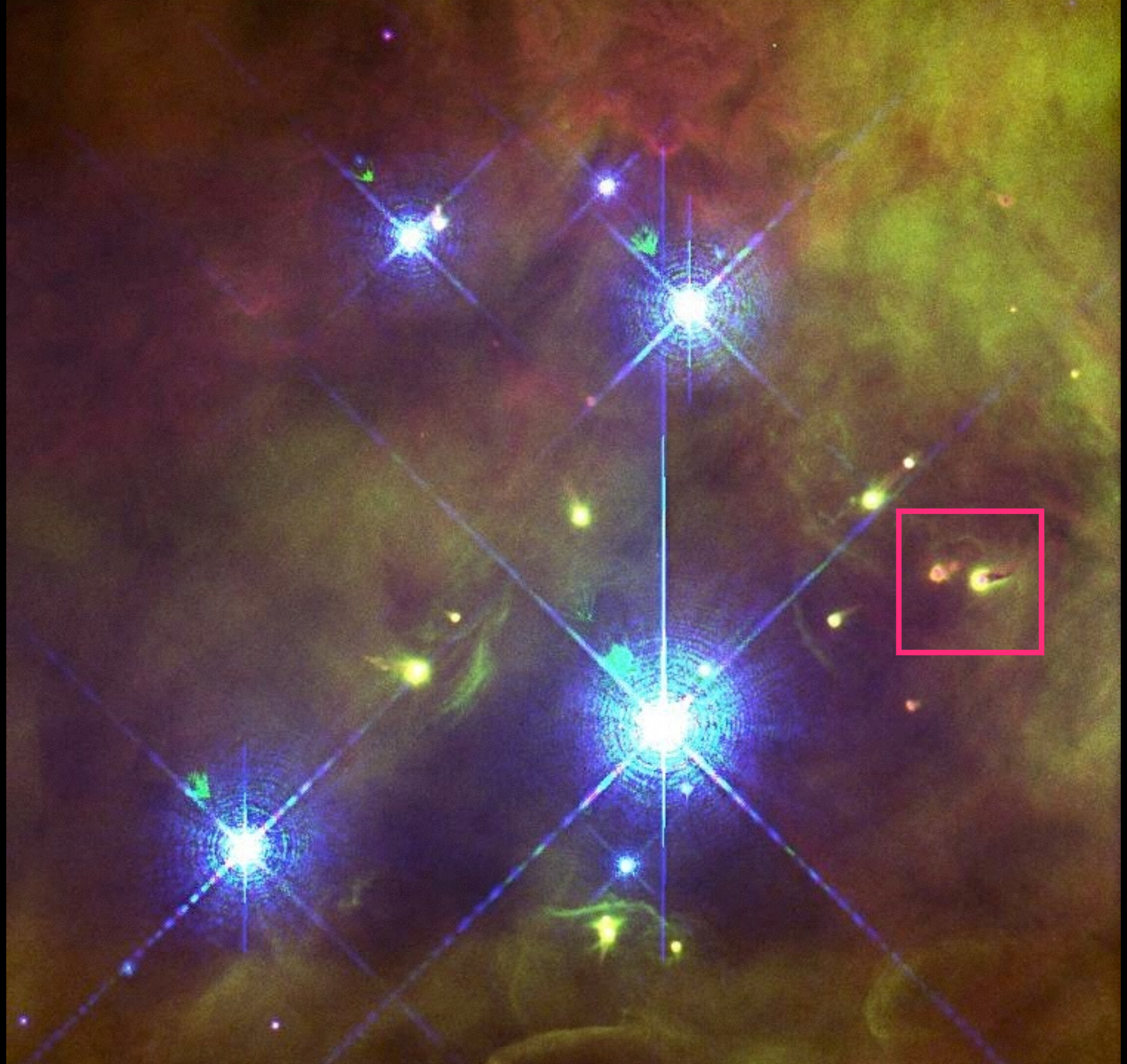
Observations of Near-Earth Asteroids and the Impact Hazard to Earth



ScopeX
Johannesburg
13 Sep 2014

Henry Throop
Physics Department, University of Pretoria
Planetary Science Institute, Tucson, USA

Orion Constellation (visible light)



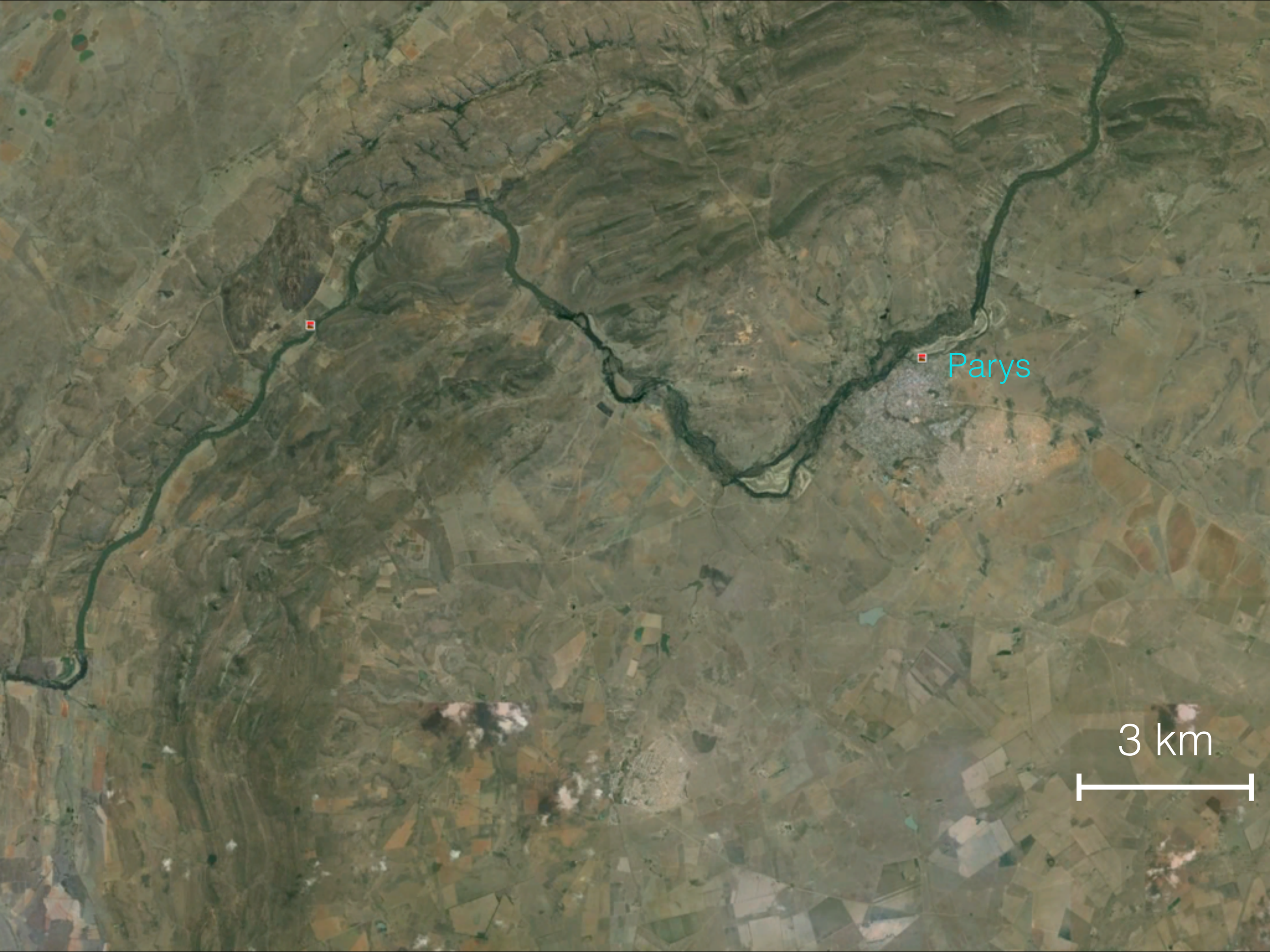

200 AU

The Solar System was built with collisions

Craters on Moon were thought to be volcanic until 1960s

We now know that almost all are impact craters.
Typical crater diameter ~ 50x impactor diameter.

Vredefort Impact Crater
Parys, NW / Free State
2.2 billion years ago, 300 km original diameter
Largest and oldest visible impact crater on Earth


Parys
3 km

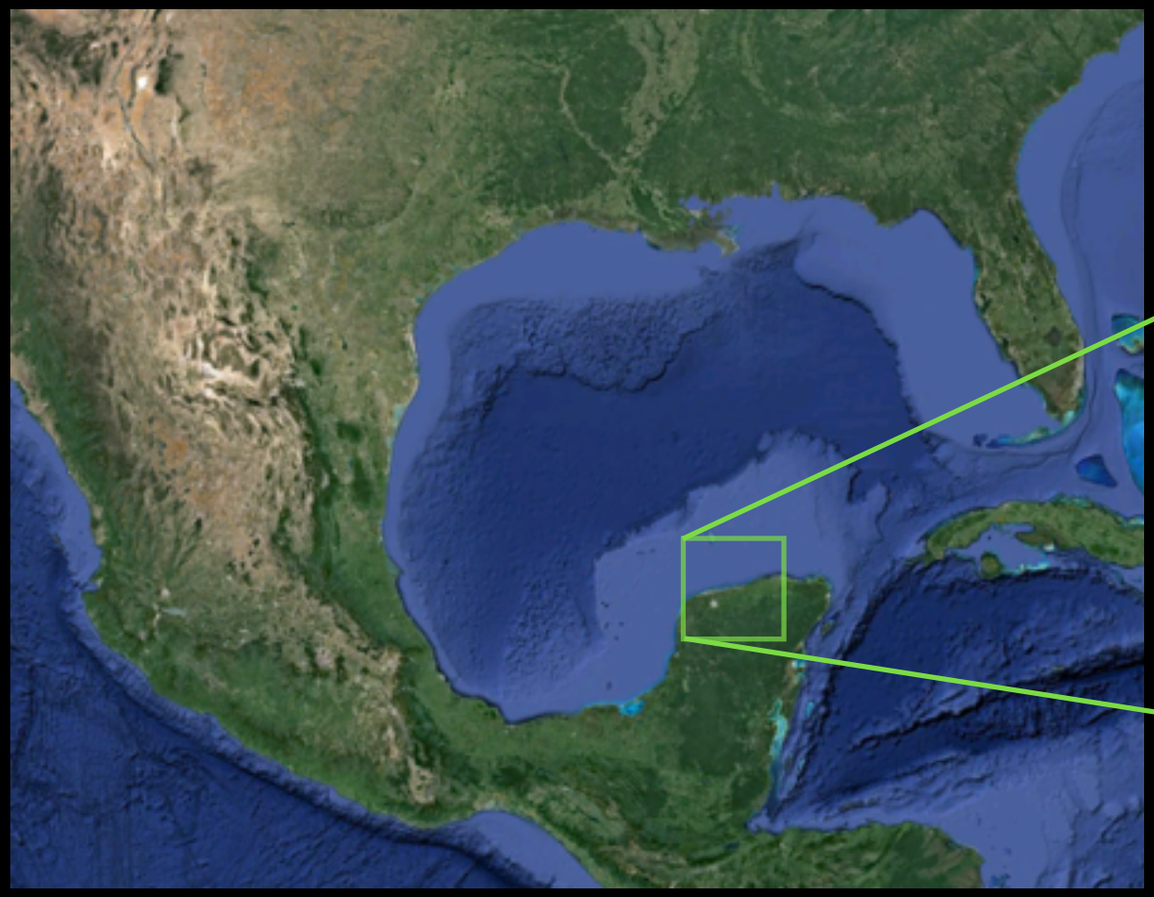
Vredefort Impact Crater
Looking from outer rim toward inner rim

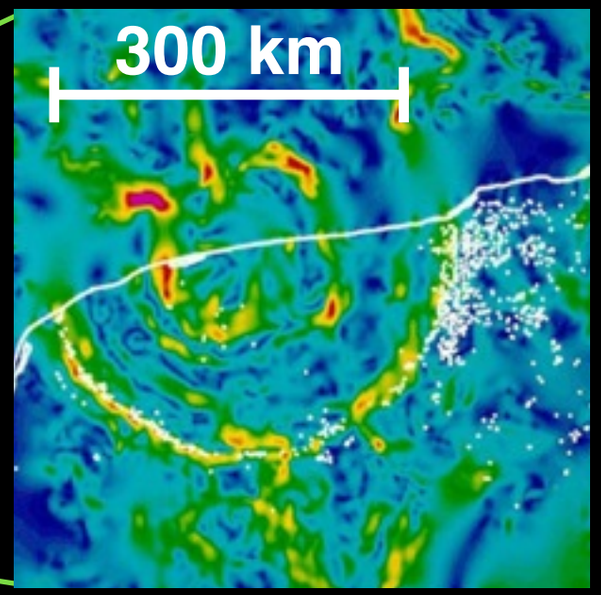
Vredefort Impact Site, t+2.2 Gyr

Meteor Crater, Arizona
1.3 km diameter
55,000 years old

Tswaing Crater, Gauteng
1 km diameter
220,000 years old

Chicxulub Impact Crater





Gravity map

- Gulf of Mexico, 65 million years ago
- Global fallout believed to cause KT extinction, killed dinosaurs
- Crater is eroded but visible in gravity field data
- Impactor of similar size to Vredefort impactor
  - 10 km impactor; 300 km crater

time = 0.11 hour

time = 0.86 hour

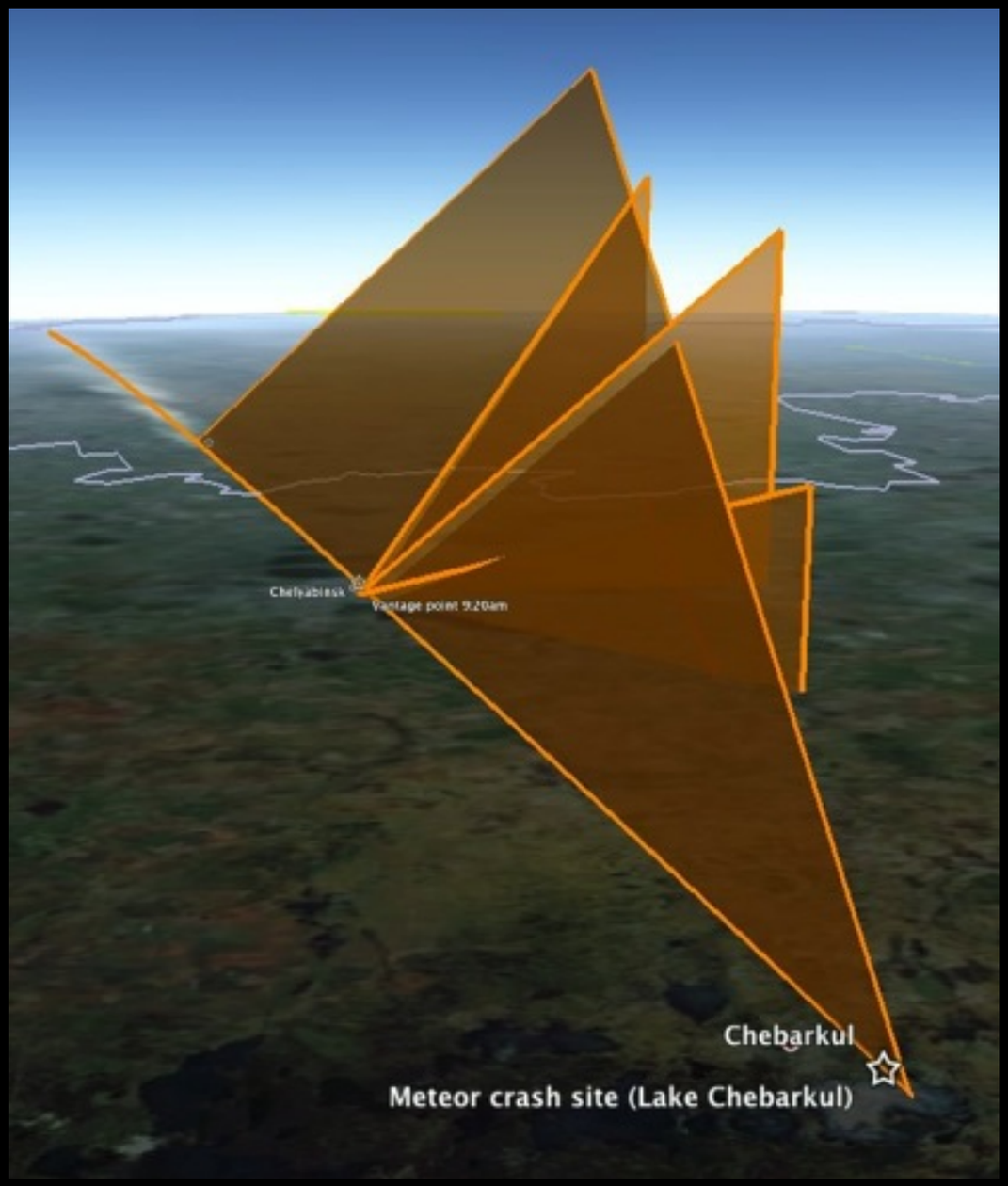
time = 2.16 hours

time = 5.93 hours

Moon-forming impact
4.5 billion years ago

Chelyabinsk, Russia 15 Feb 2013, 9h20

Where did Chelyabinsk meteor come from?



Path can be traced precisely using security videos and cell phone images!

What Do We Know About the Chelyabinsk Impactor?

- Origin: One of several million Near Earth Asteroids (NEAs)
  - a = 1.6 AU; e = 0.5; i = 4°
  - Derived orbit is similar to NEA (1999 NC43); may have come from same parent body
  - Slightly too small to be detected in current NEA surveys
- 13,000 metric tons of rock, 30 meter diameter, 60,000 km/hr, 3 g/cm^3
- Impactor exploded in air, 30 km above ground
- 1500 people sent to hospital, most with glass cuts from broken windows
- 7200 damaged buildings, many $M in damages
- Largest object to enter Earth's atmosphere in last 100 years
- Best-observed meteor ever: cell phones and security cameras!
- Thousands of pieces recovered, including 1200 kg chunk from frozen lake

Tunguska Impactor, Russia 1908

Largest human-recorded meteor impact on Earth

50-100 meters, several times larger than Chelyabinsk

tunguska.ru

Tunguska Event

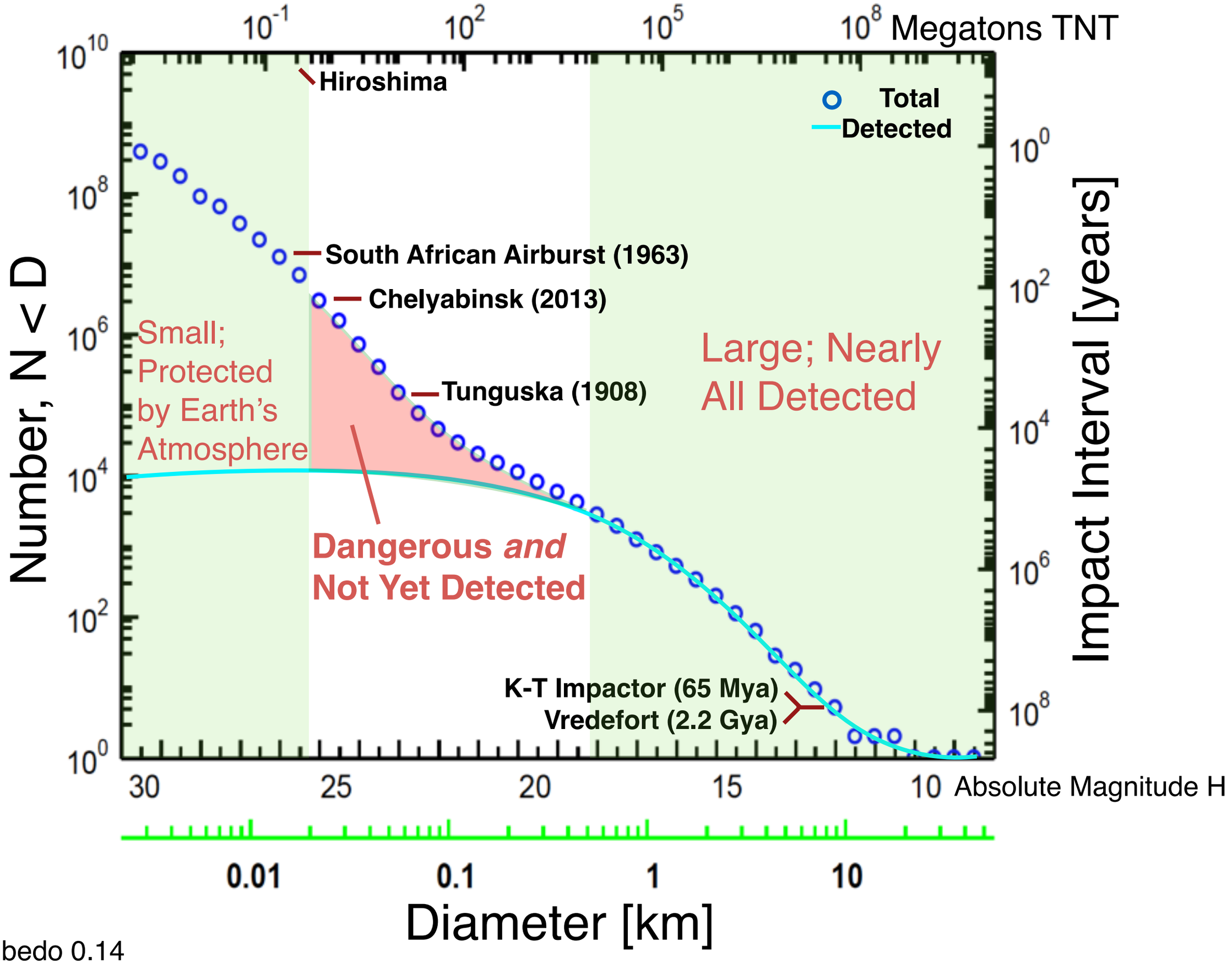
30.06.1908


Tunguska
Chelyabinsk

Impactors on Earth Today

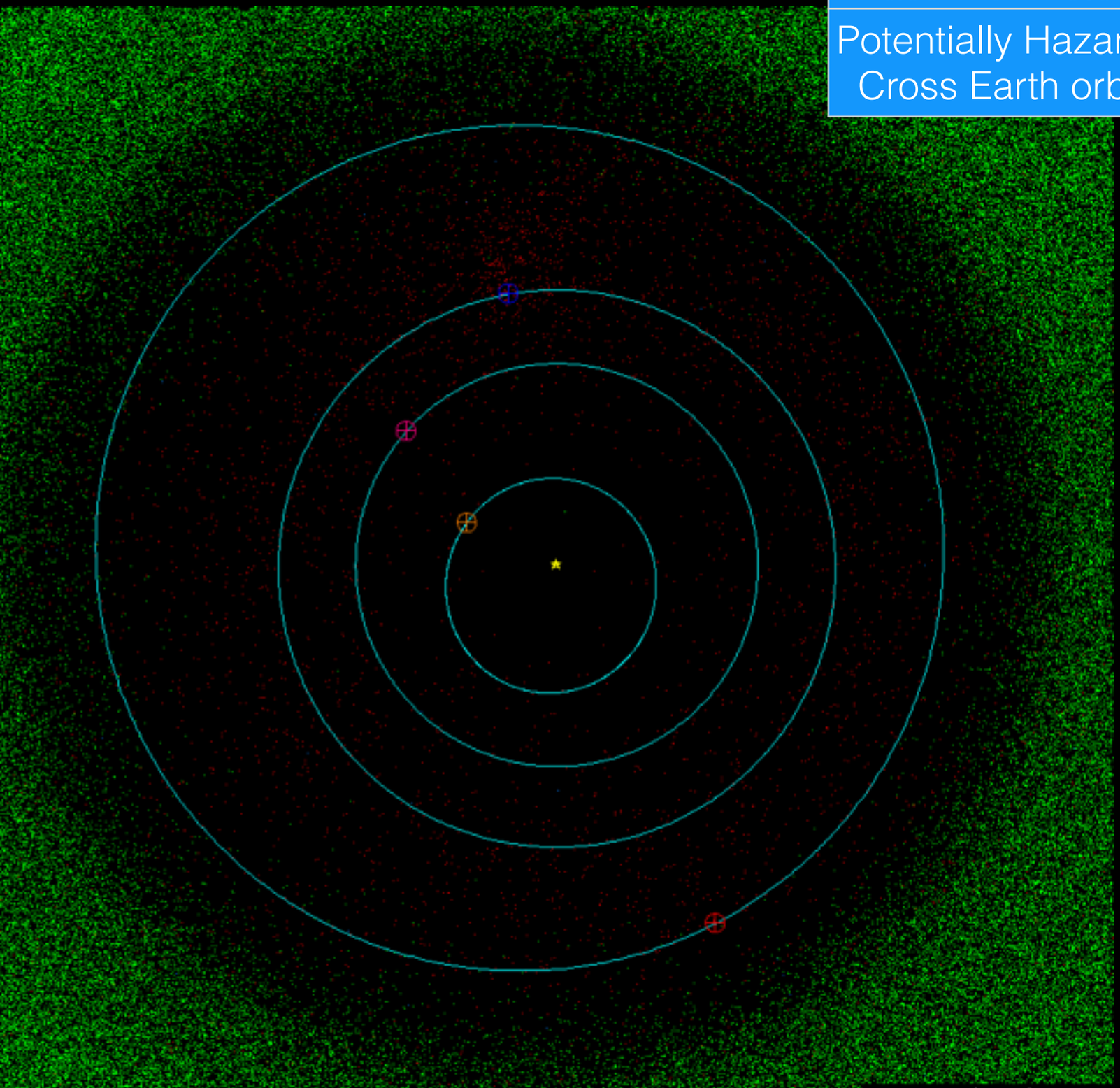
- The earth is hit by 40 tons of material a day.
- Most of this is leftover material from the creation of the solar system.
- Most of it is dust grains 1 mm or smaller, making ‘shooting stars.’
- But it is a power-law distribution, and large impacts will go on…
  - Impact 65 million years ago killed dinosaurs, and these will continue

Inventory of Earth Impactors



Assumes albedo 0.14

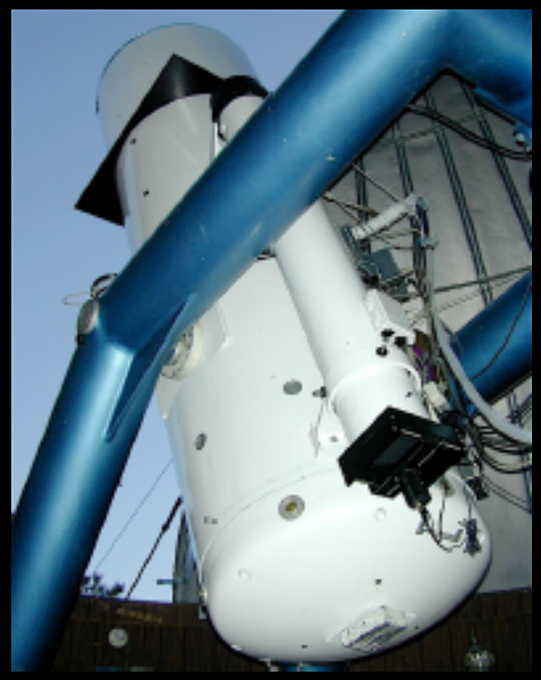
Asteroid Type	# Known
Main-Belt Asteroids	500,000
Near-Earth Asteroids (NEAs) Pass within 0.3 AU of Earth	11,000
Potentially Hazardous Asteroids (PHAs) Cross Earth orbit *and* diameter > 30 -140 m	1400 > 140 m



Size	Survey Completeness
NEAs > 1000 m	95%
NEAs > 140 m	39%
NEAs > 30 m	2%

How to Detect Asteroids

MIT LINEAR
New Mexico



Catalina Sky Survey
Arizona & Australia

Pan-STARRS
Hawaii

- Since 1998, NASA's Near Earth Object Observation (NEOO) Program has led the global effort to find potentially hazardous asteroids
- These robotic telescopes are searching for new NEAs continually, every clear night.
- Within the last 15 years this effort has successfully found 95% of the NEAs larger than 1 km.
- Work now focuses on extending the surveys to much smaller objects, down to 100 m.

How many people are killed annually by asteroids?

Historic value

$$N = 0$$

$$0 \text{ yr}^{-1}$$

Expected value

$$N = \frac{\#}{\Delta t} \sim \frac{7 \times 10^9}{70 \text{ Myr}}$$

$$100 \text{ yr}^{-1}$$

Asteroid impact is a low-probability but high-consequence event!

Cause of Death	Deaths yr
Malaria 	600,000
Commercial Airplanes 	100
Sharks 	4

We spend many $B per year protecting against a huge variety of preventable deaths.

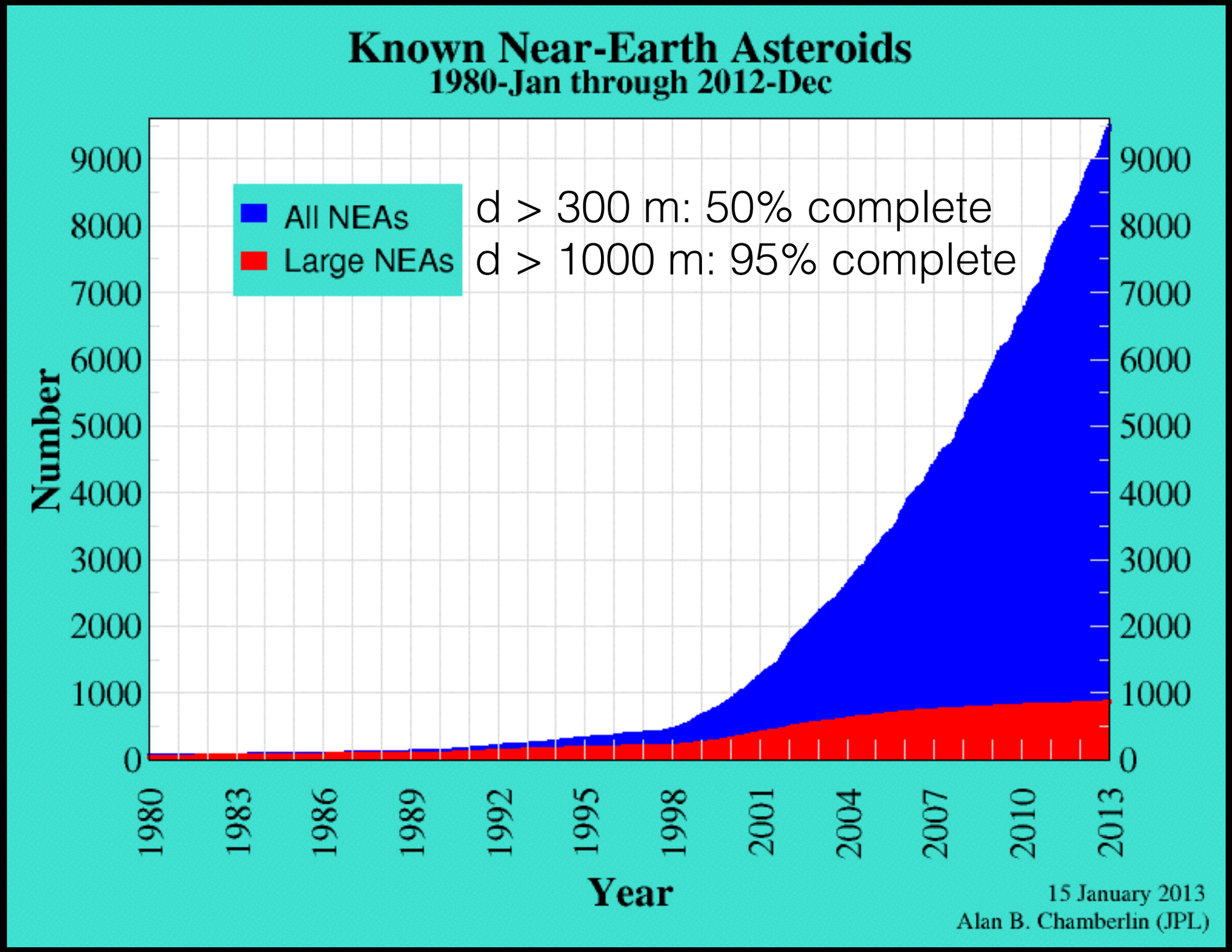
How to Handle the Asteroid Risk?

Asteroid Grand Challenge

NASA must "**find all asteroid threats to human populations and know what to do about them.**"

- Detect all NEAs > 100 m
- Characterize them
- Determine a way to mitigate them

US Congress, July 2013



NEA surveys only 2% complete at 30 m.
Much of Grand Challenge will involve deeper surveys, to get to N ~ 50,000

How Southern Africa can play a role in the Asteroid Grand Challenge and NEA studies

	Discovering new NEAs	Requires wide-angle robotic telescopes
	Immediate followup post-discovery; orbital measurements	Geographic advantage of SA fills major hole

There is a huge gap in global observational coverage of asteroids…
and it is centered on South Africa, which has a lot of telescopes!

How South Africa can play a role in the Asteroid Grand Challenge and NEA studies

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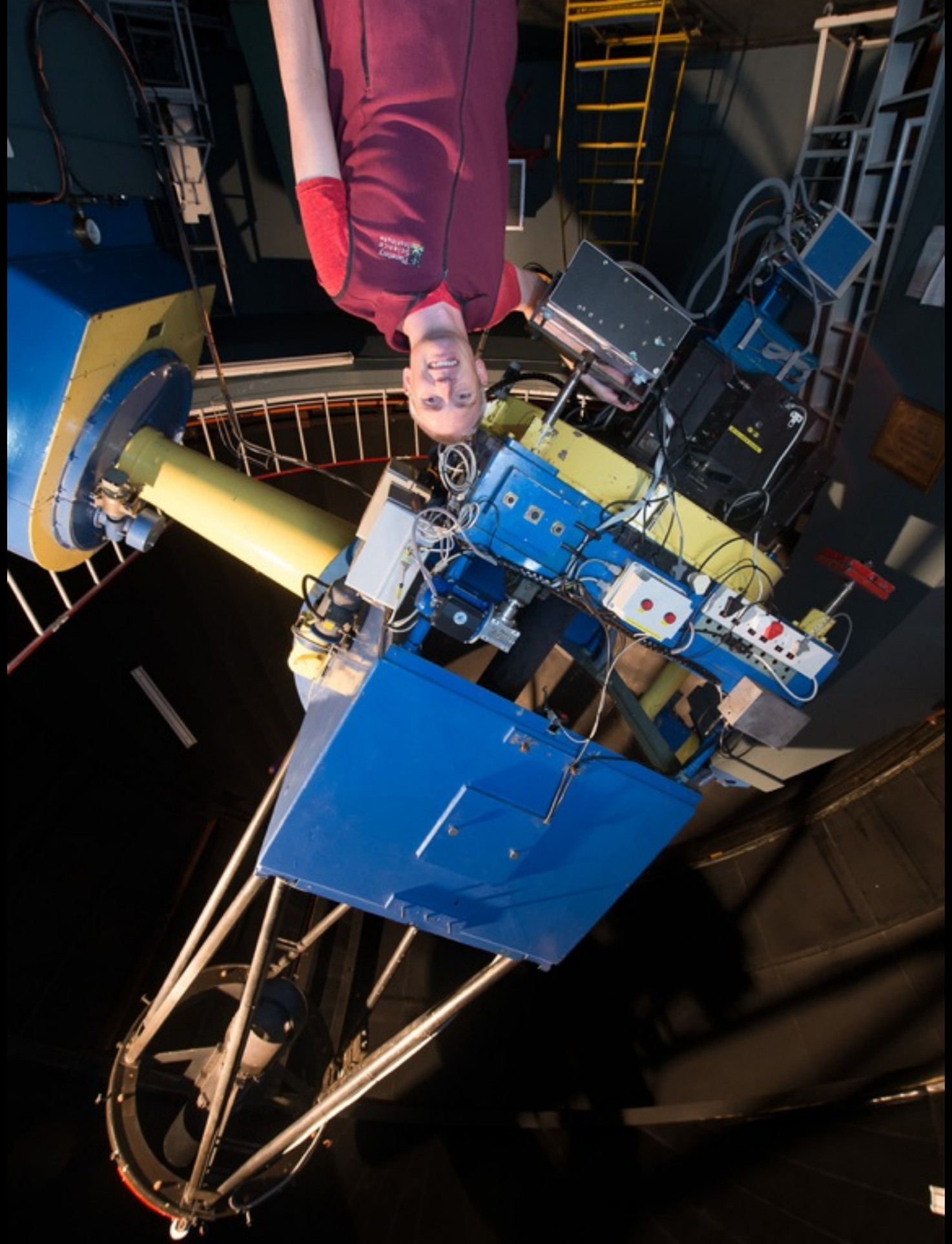
	Characterization: Shape, spin rate, composition	Ready access to moderate telescopes (~1 m); amateurs



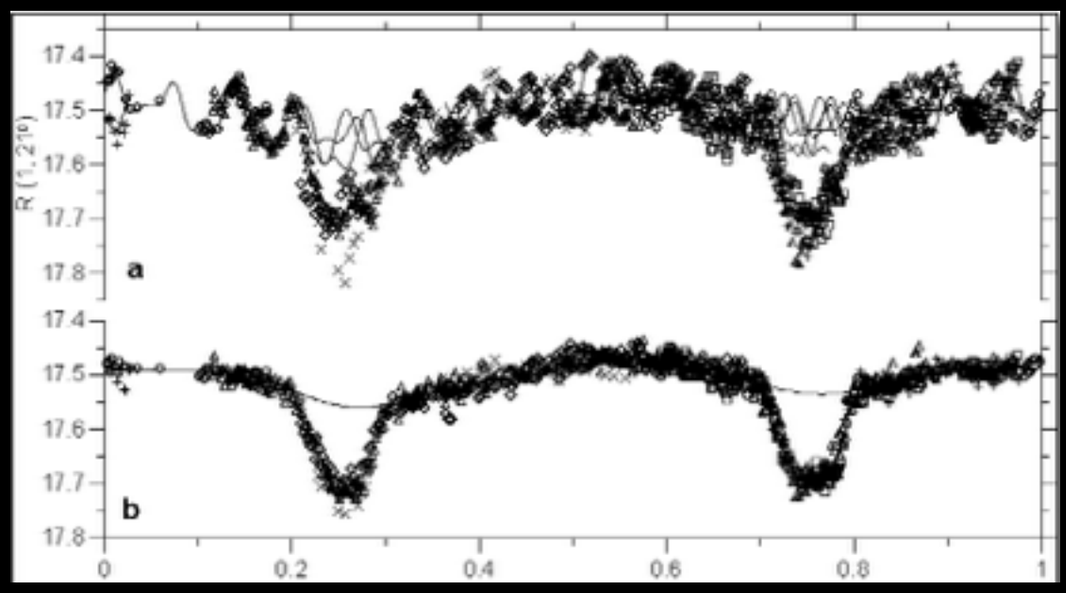
Asteroid 3288 Selucus

NEA, perihelion 1.1 AU, e = 0.45, H=15.3, v = 17, discovered 1982

June 2014, SAAO 1m STE4
Throop / Reddy / Morris

We measure light curve to determine rotation rate, shape, binarity of asteroid.

Vast majority of NEAs have never been studied post-discovery.



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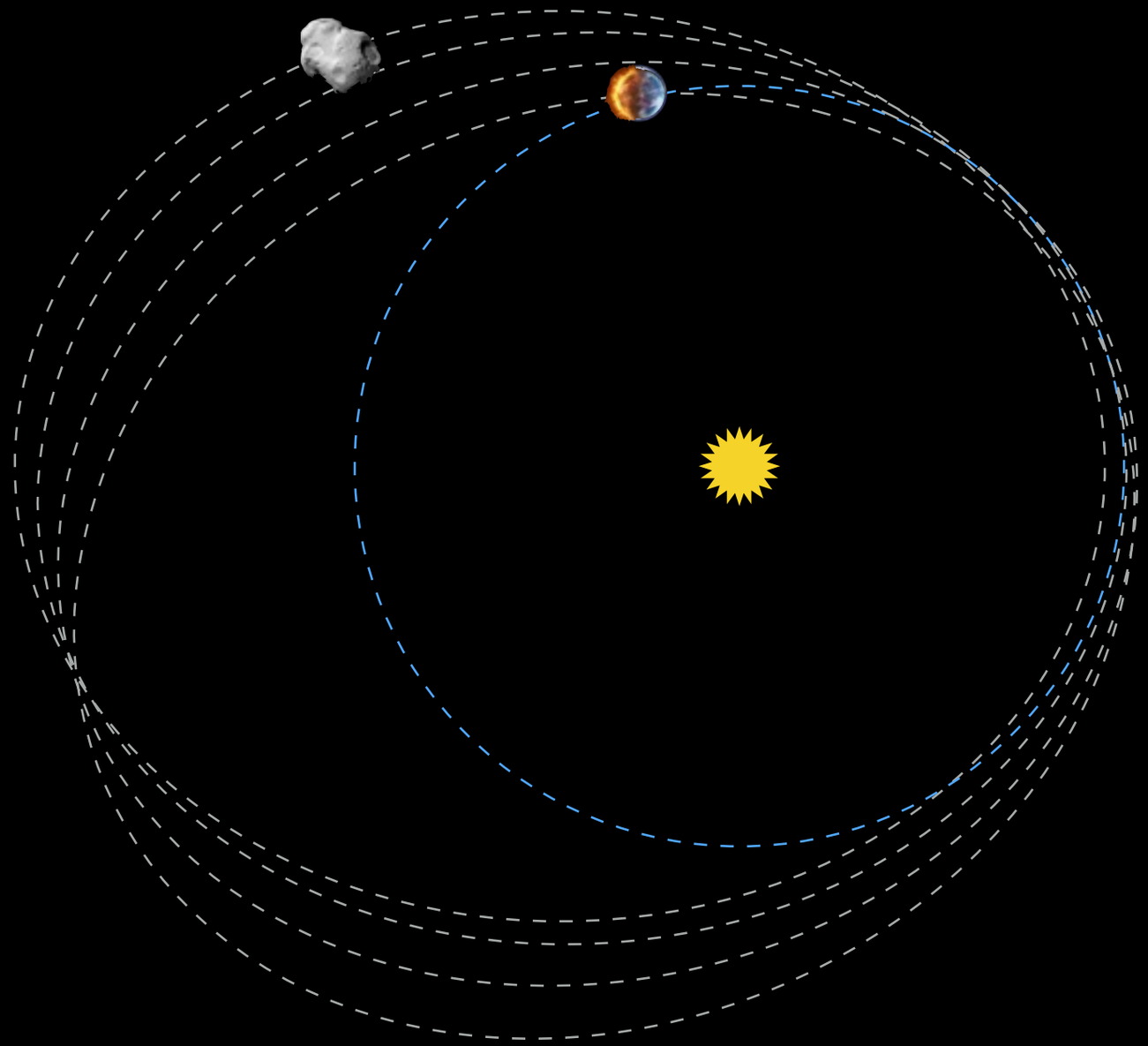
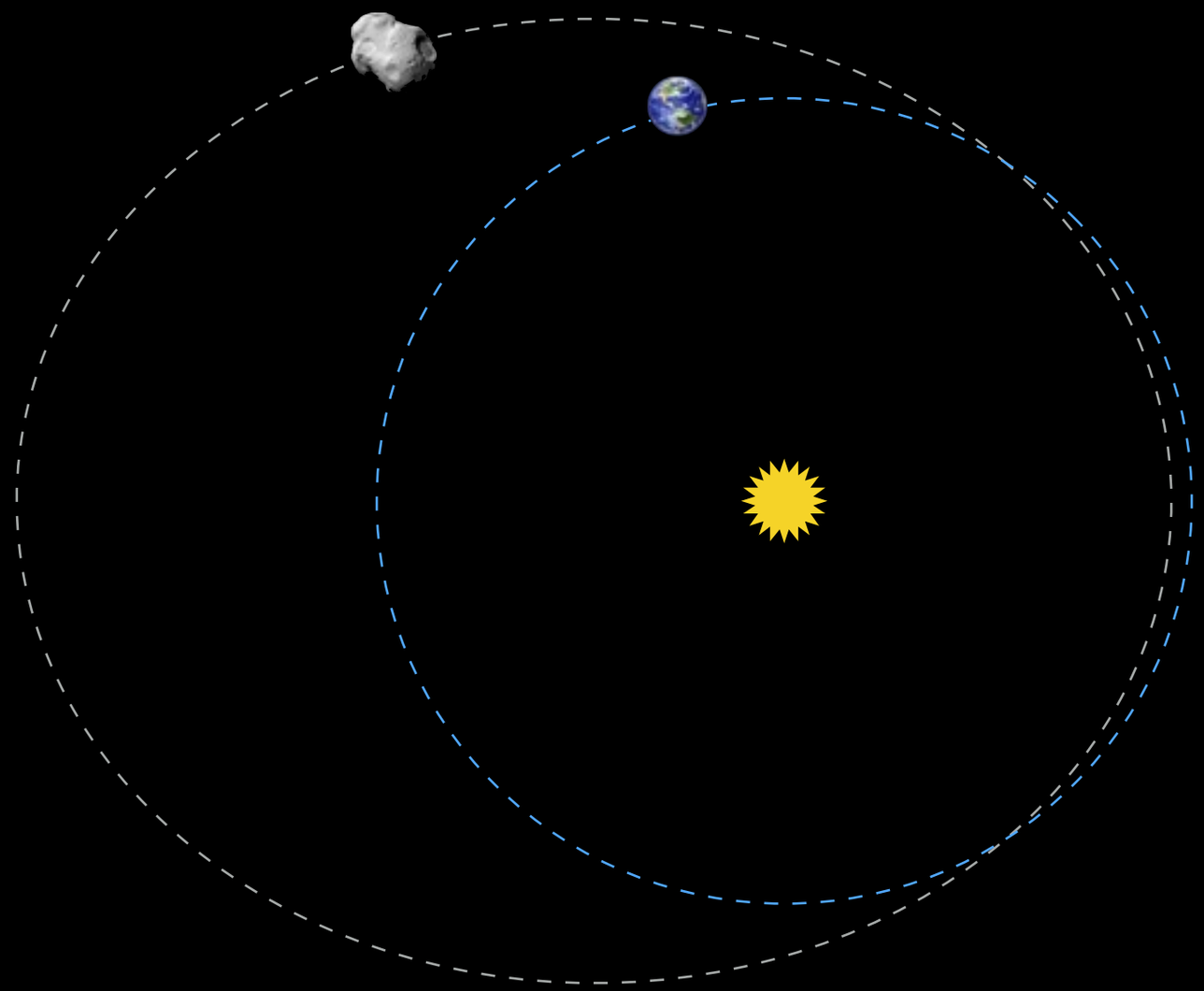
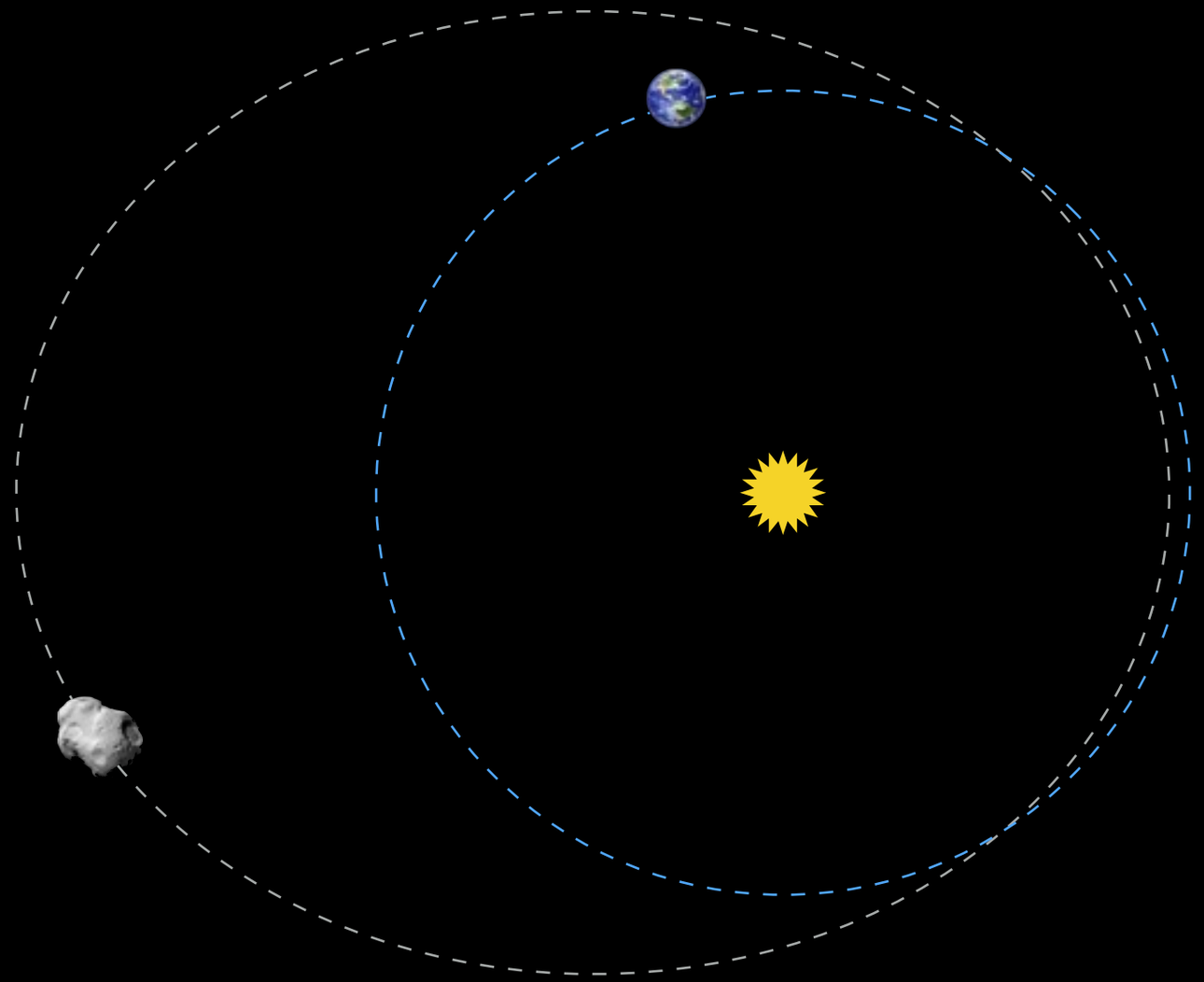
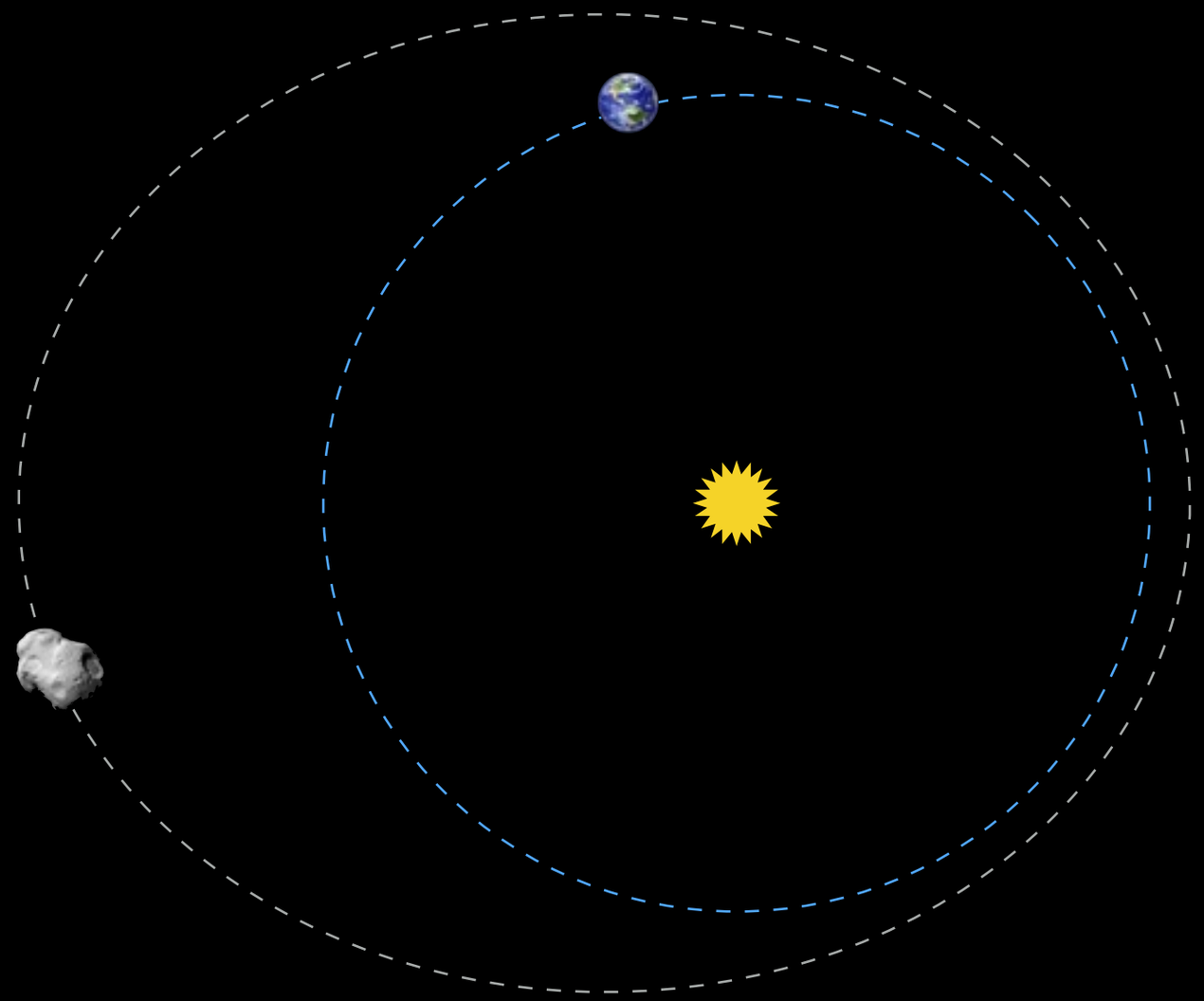
How to Move an Asteroid



In general, we have many years of advance warning before an NEA collides with Earth







Three ways to change asteroid's orbit:

Traditional chemical thrusters

Low-thrust ion drive

Strategic use of solar radiation pressure

One way *not* to move an asteroid…

Asteroid Retrieval Mission

Proposed future NASA *Asteroid Grand Challenge* mission to capture a very small asteroid (8 meters), change its orbit, and study it.

Concept only; potential launch in 2020's.

Closing Thoughts

Asteroid threat is a non-negligible threat to humanity.

The majority of potentially hazardous asteroids (PHAs) have not yet been discovered… and of those known, the majority have never been studied.

South Africa has a unique advantages to help with this search, in collaboration with NASA and amateur astronomers.

throop@psi.edu

The End