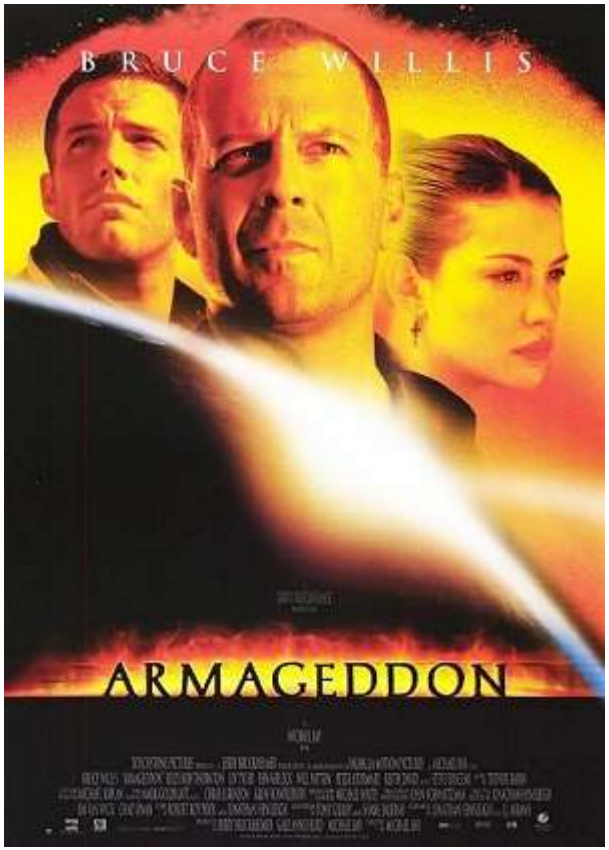
Worlds In Collision

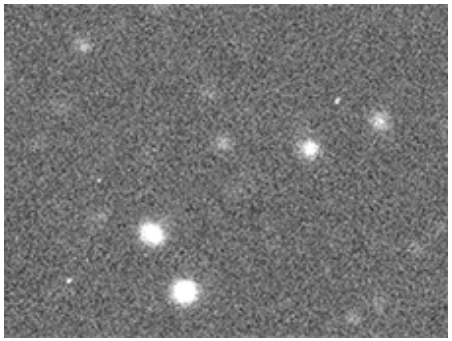
Chelyabinsk, 2012/DA14, and Near-Earth Objects

S. Kent Feb, 2013



February 15, 2013 - A Busy Day

- **Meteor impacts Russia near Chelyabinsk**
- **Asteroid 2012 DA14 passes inside geocentric orbit**
- **Post-Valentine's Day sales begin**



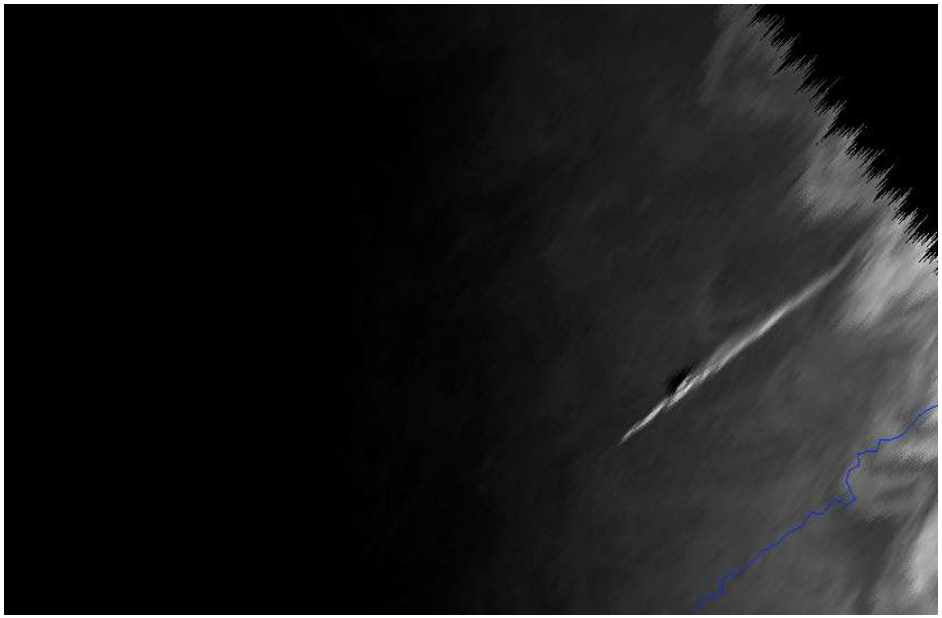
Chelyabinsk (Tankograd)

Location: 1500 km East of Moscow
Impact time: Feb 15, 2013, 9:20 am (local time)
Advanced warning: None
Duration: 30 seconds
Injuries: ~ 1200
Buildings damaged: ~ 4000
First reports in West:
http://www.russianmachineneverbreaks.com/

[Play video]

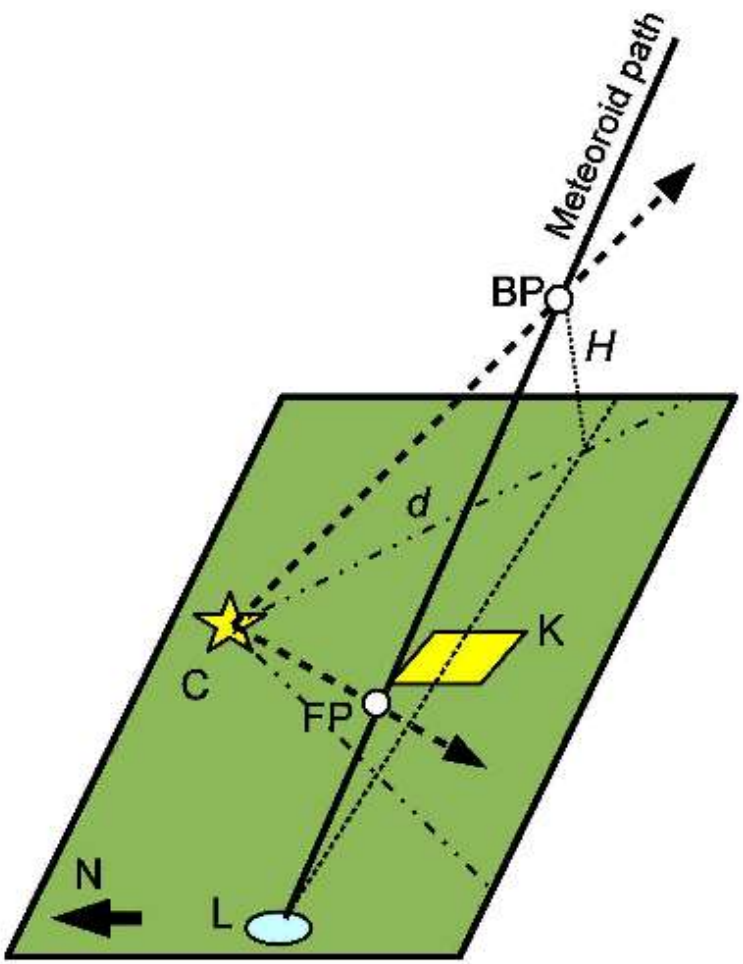
Tracking the Meteor

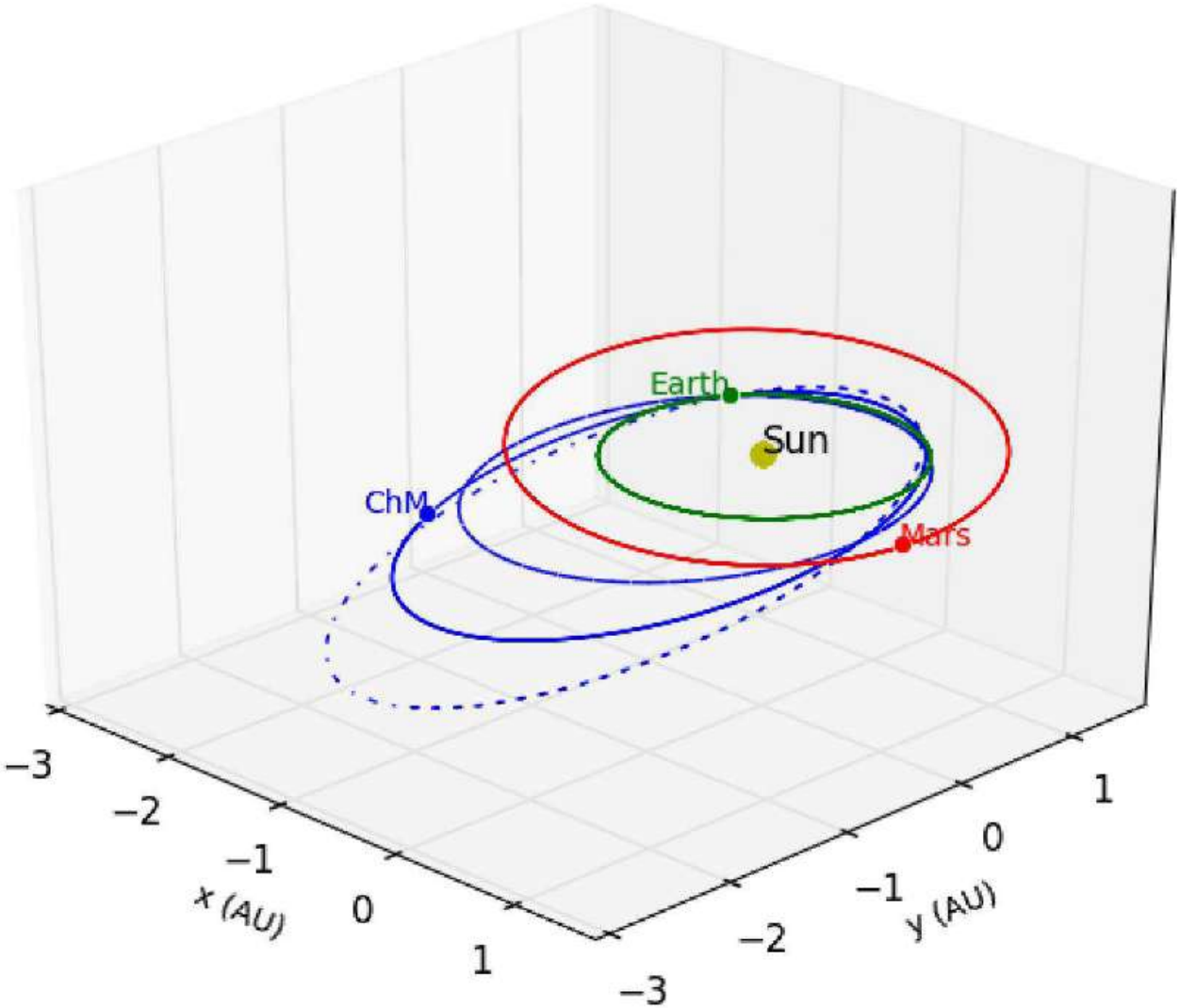
Trajectory: W by SW
Inclination to ground: 20 deg.
Altitude visible: 20-50 km



Meteosat IX
(European Weather Satellite)

Orbit





Zuluaga & Ferrin (2013)
2.3 year period **[Play video]**

Comprehensive Nuclear Test-Ban Treaty Organization (CTBTO) Infrasound Results

Infrasound Stations (60 worldwide)

Detected by 11 stations
- **Energy 300-500 Ktons**
- **Mass 7000-10,000 tons**
- **Size 15-17 m**

17 m diameter: No Significant Ground Damage

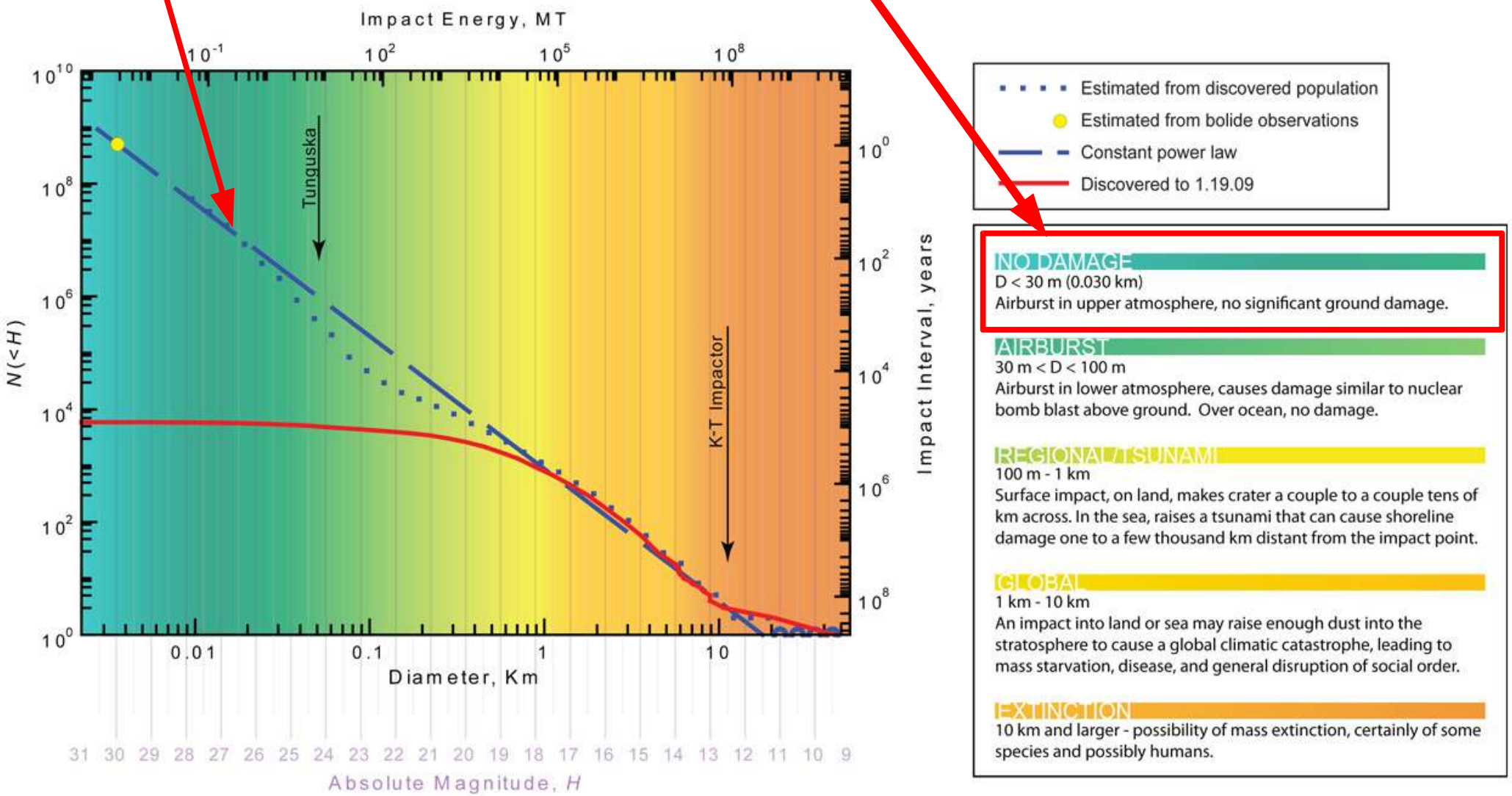


Image Credit: A. W. Harris, SSI/LSST

Damage from Sonic Boom

- **Most damage, injuries from broken window glass**
- **~ 4000 buildings damaged**

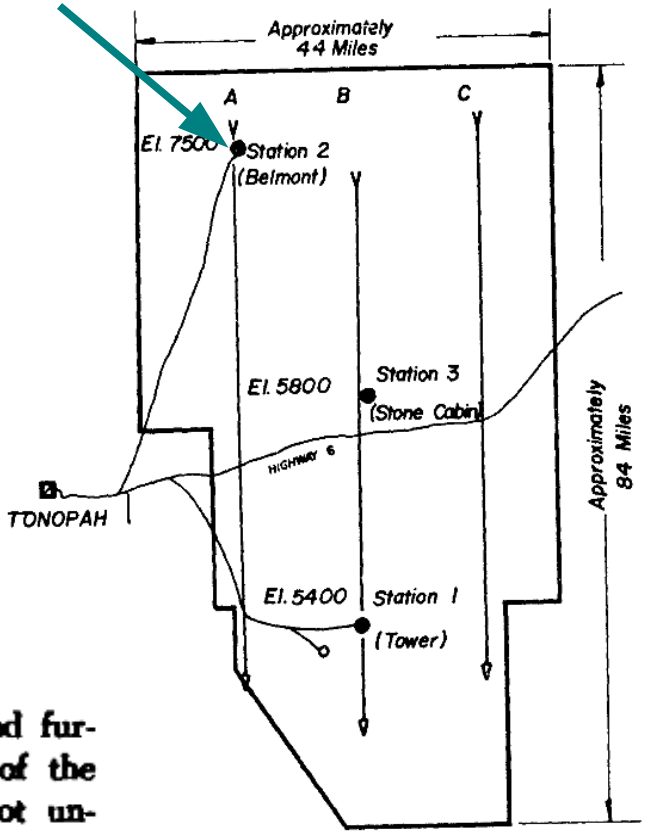
[Play video]

– **Sonic "boom" similar to that produced by Supersonic jets. E.G.**
  - **1968 Air Force study**
  - **2009 Discovery Channel study**
  - **2012 Brazil incident**

Air Force Study 1968

McDonnell Douglas F4-C Phantom II
Mach 1.1 - 1.3

"Nearly abandoned" town



Damage to structures was principally confined to glass breakage, plaster cracking and furnishings falling from shelves. In almost all cases glass breakage occurred at the side of the building facing the approaching aircraft. The extent and nature of the damage was not unexpected for the magnitude of the sonic boom exposures experienced. There was no damage in the trailers.

Sandia Test Range,
Tonopah, NV

Discovery Channel Study 2009

Adam is passenger in F/A-18 Hornet fighter jet conducting supersonic flight tests

Myth: A supersonic jet can break any kind of glass by the sonic boom it generates.

Result: Jamie set up a test area filled with various glass items and products while Adam performed a flyby in an F/A-18 going supersonic. However, at flybys of 8,000, 2,000, and 500 feet (2,400, 610, and 150 m), the jet failed to break any of the glass. They then performed a series of low altitude flybys at 200 feet (61 m), but *only managed to break a single window.* Since the majority of the glass was still intact, the MythBusters declared the myth BUSTED.

July 1, 2012 Brazil Incident

July 1, 2012 Brasilia, Brazil

National Flag exchange ceremony Praça dos Três Poderes, at the Esplanada dos Ministerios.

Two Mirage 2000 jets perform flyover

[Play Video]

July 2, 2012 Newspaper Headline

Supersonic Fighters Shatter Every Window in Brazil's Supreme Court Building

Brazil Mirage 2000 sonic boom supersonic

by Max Eddy | 2:15 pm, July 2nd, 2012

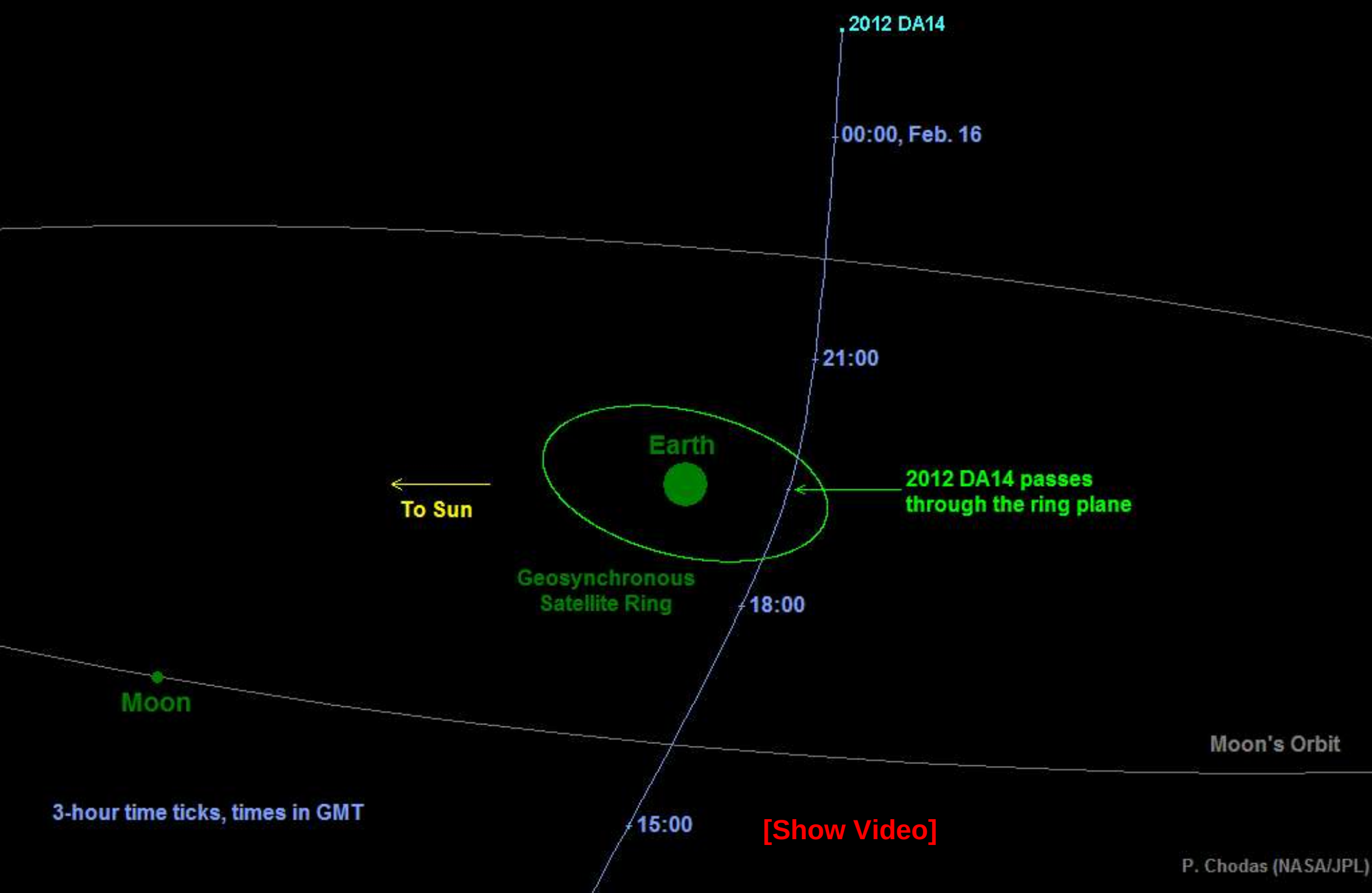
Comparison of Hazardous Objects

Parameter	Phantom II F4-C	Chelyabinsk Meteor	Asteroid 2012/DA14
Diameter/Length	19 m	17 m	45 m
Weight/Mass	20-30 tons	10,000 tons	185,000 tons
Velocity	0.4 km/s	15 km/s	20 km/s
Energy (TNT equivalent)	0.15 ton	500 Kilotons	9 Megatons
Discovery or First Flight	May 27, 1958 Lambert Field St Louis, MO	Feb 15, 2013 Chelyabinsk commuters	Feb 2012 La Sagra Sky Survey (Spain)

Asteroid 2012 DA14

- **Discovered Feb 23, 2012 Oservatorio Astronomico de la Sagra, Granada, Spain**
- **Orbital period (post-encounter) 317 days (reduced from 368 days)**
- **Aphelion 0.9917 AU**
- **Inclination: 11.6 degrees**
- **Absolute Mag: H=24**

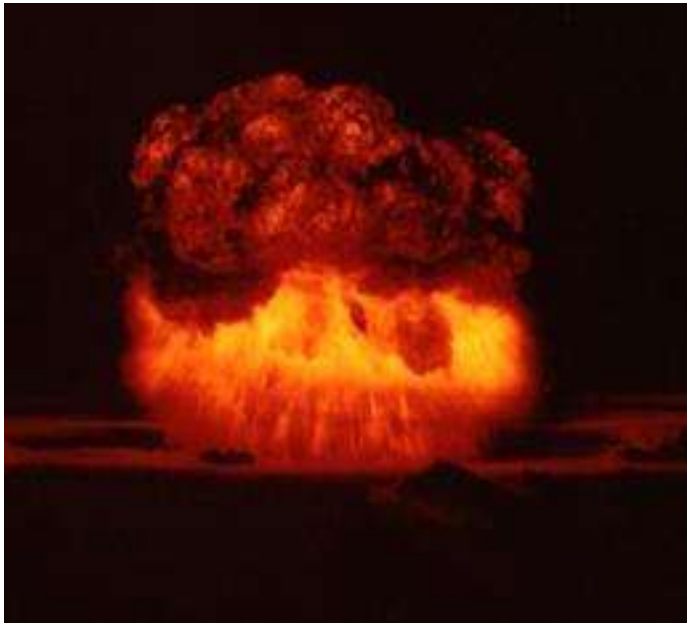
Asteroid 2012 DA14: Close Approach to Earth, Feb. 15, 2013



Examples of
2012 DA14 NEO-type event

Meteor Crater
Arizona
50,000 B.C.

Mount
St. Helens
1980



Bravo
Nuclear
Test
1954

Tunguska Anomaly

- **1908 Impact near Tunguska River, Siberia**
- **Impact energy 5-20 Megatons**
- **100 years ago - why so recent?**
  - **MTBI for 5 Megatons is 4000 years**
  - **Why two in a row?**

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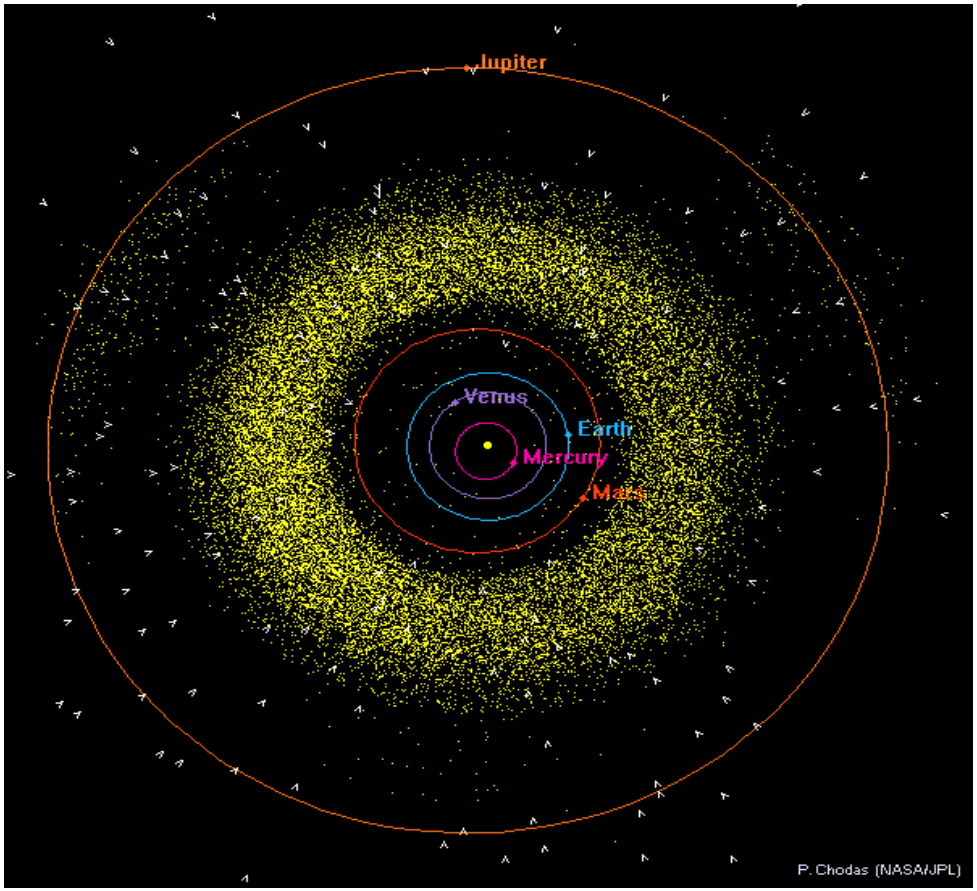
I. NEO Basic Information

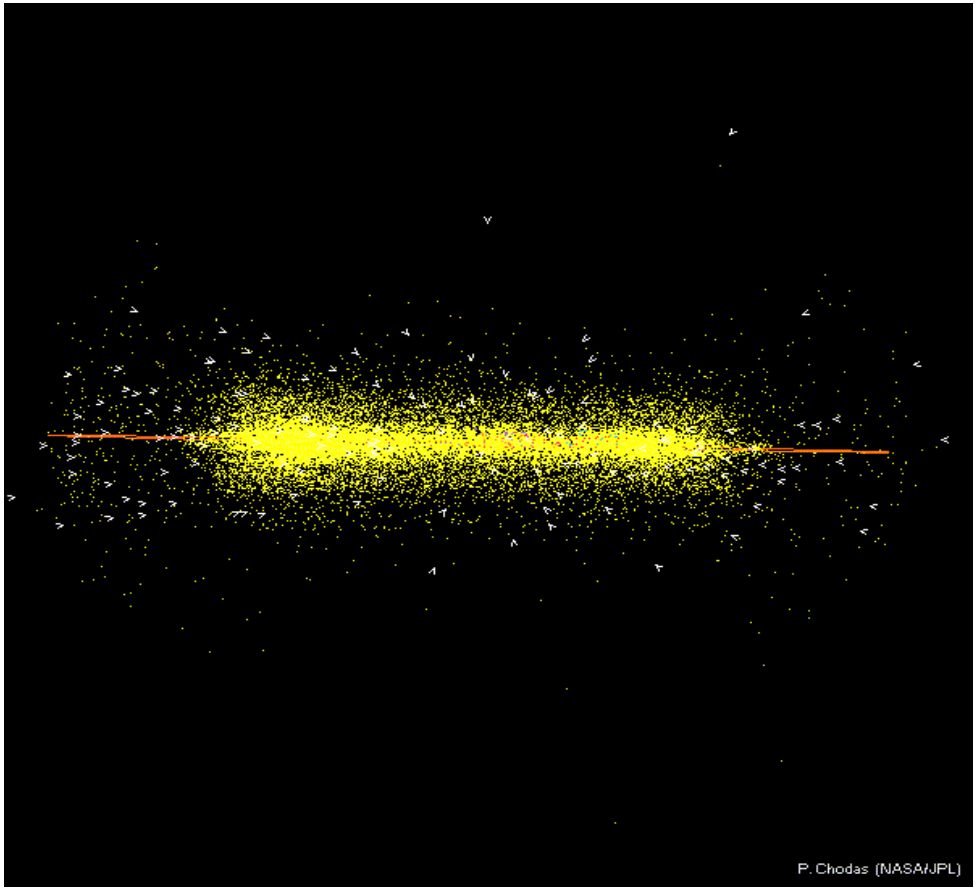
1. Definition: NEO = Near Earth Object
   (asteroid or comet). Perihelion q < 1.3 AU.
   ~7000 known.

2. PHA = Potentially Hazardous Asteroid (big
   & might hit the earth).
   997 Known
   H=13 10 km diam - Dinosaur extinction
   H=18 1 km diam - Goal for completeness

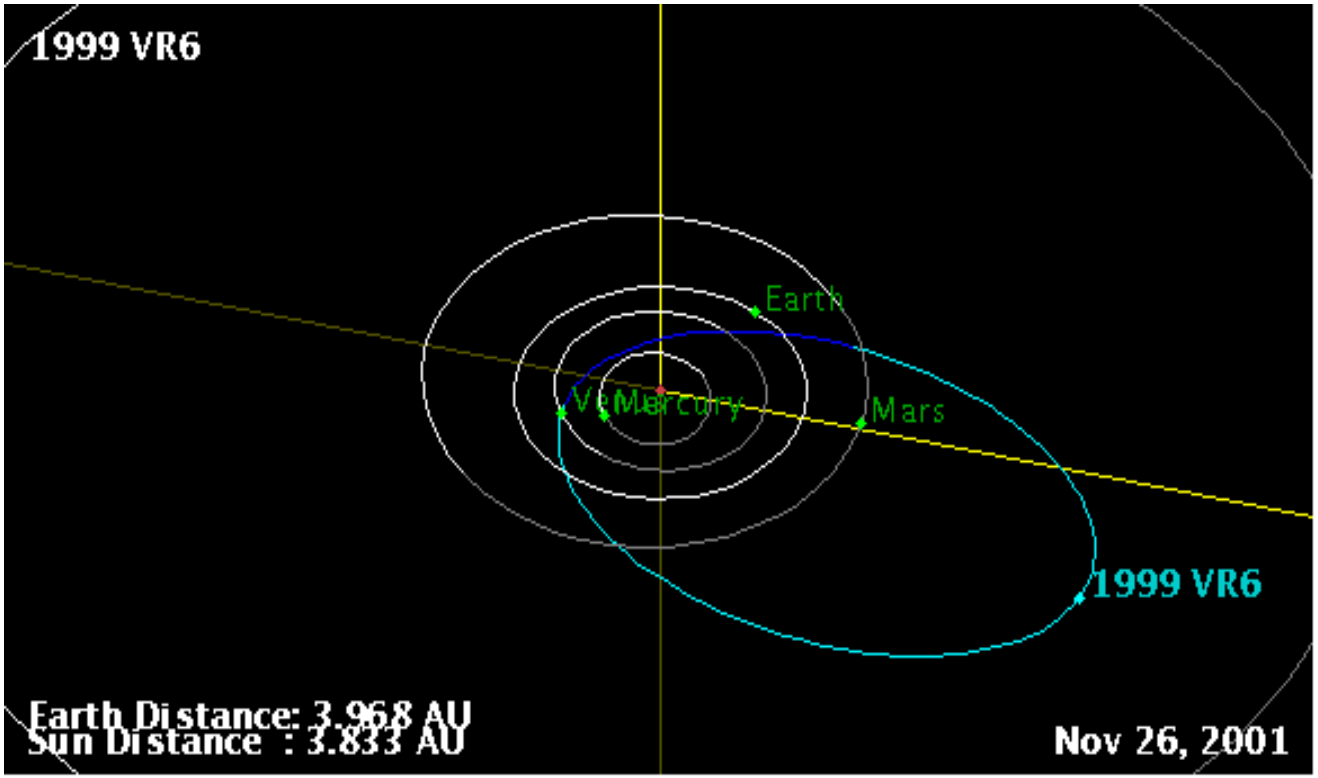
(H is apparent mag of asteroid viewed face-on
from sun at a distance of 1 AU)

Distribution of Main Belt Asteroids





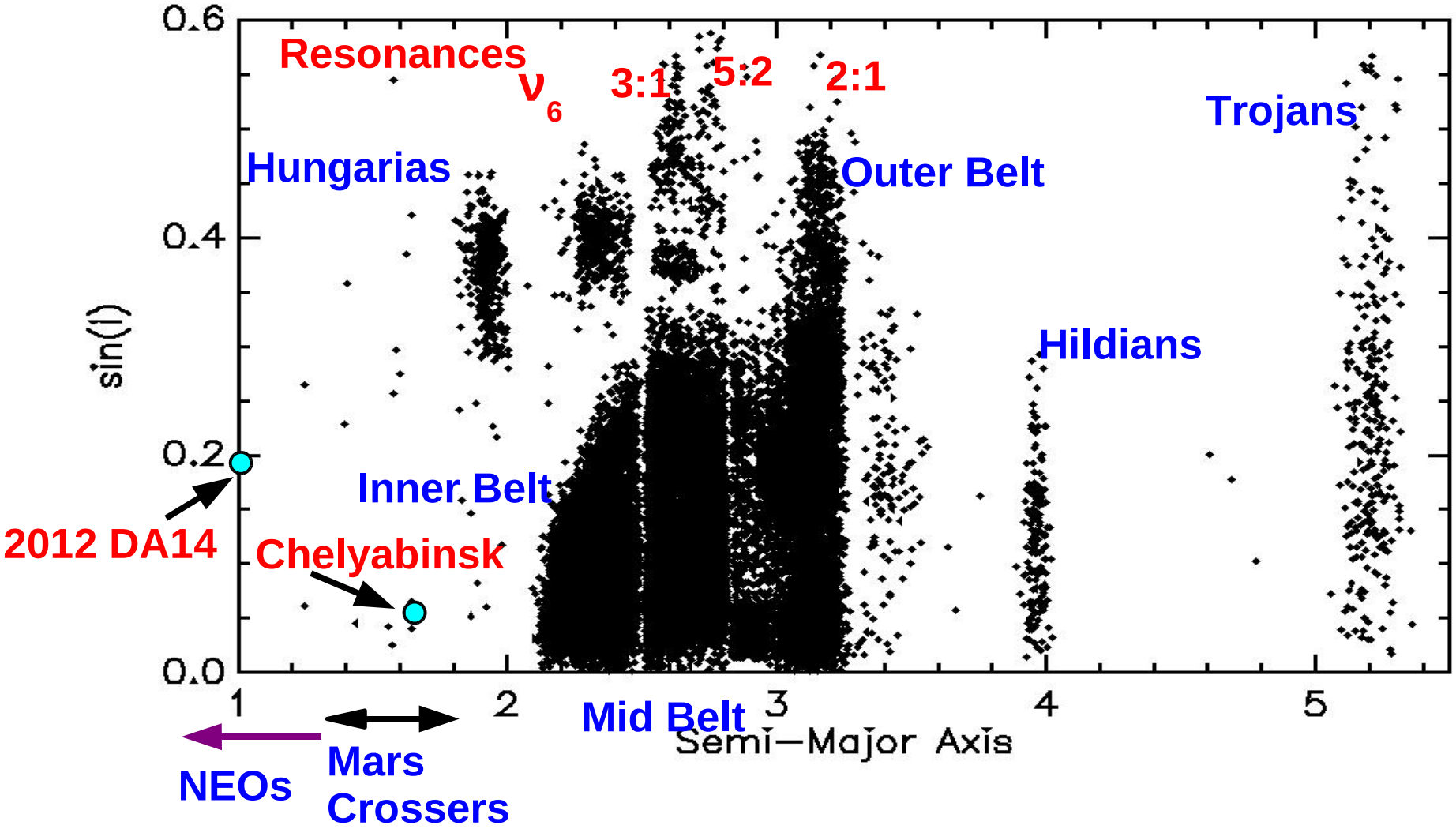
Orbits of NEO's



Typical NEA Orbit

IV. Origin of NEOs

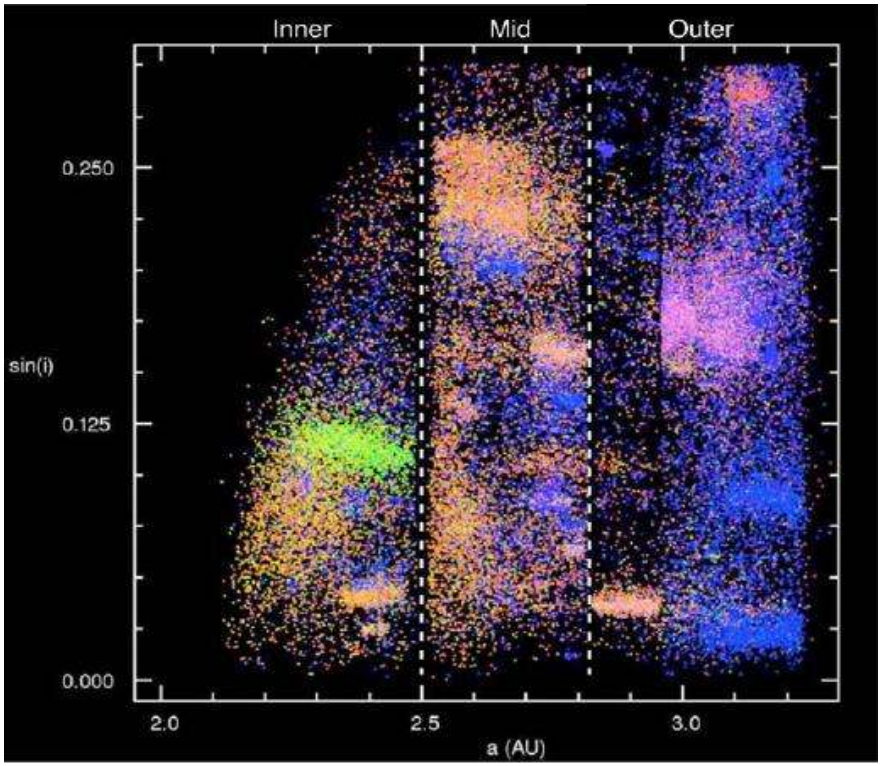
SDSS-Detected



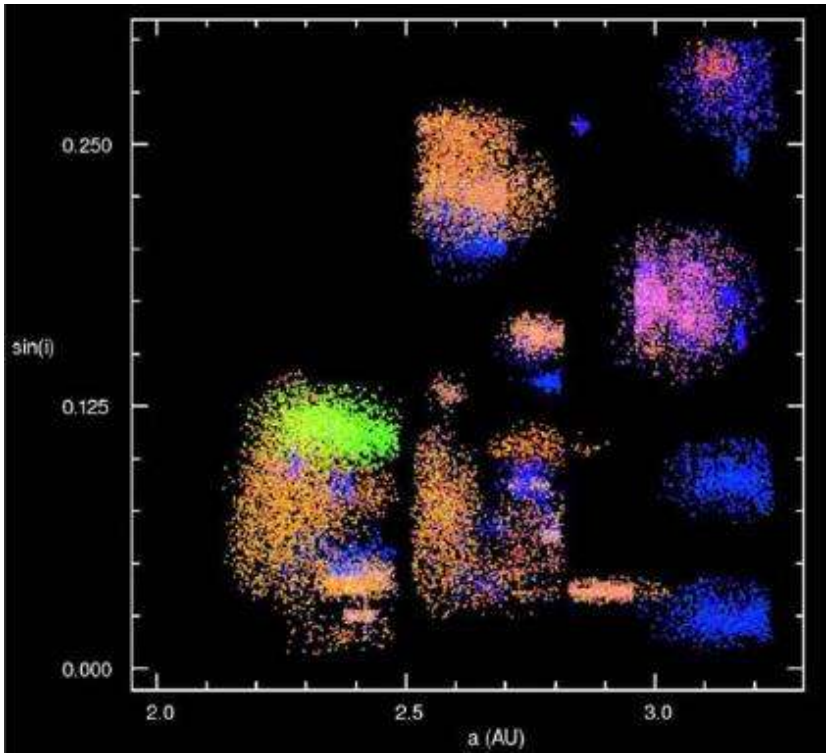
Collisional **fragmentation** followed by migration in semi-major axis via **Yarkovsky effect.** Chaotic orbits in resonances - few million year migration timescale.

Asteroid Families (main belt)

All



Families Only



Inclination

Semi-Major Axis

(Parker et al. 2008)

Programs to find NEOs

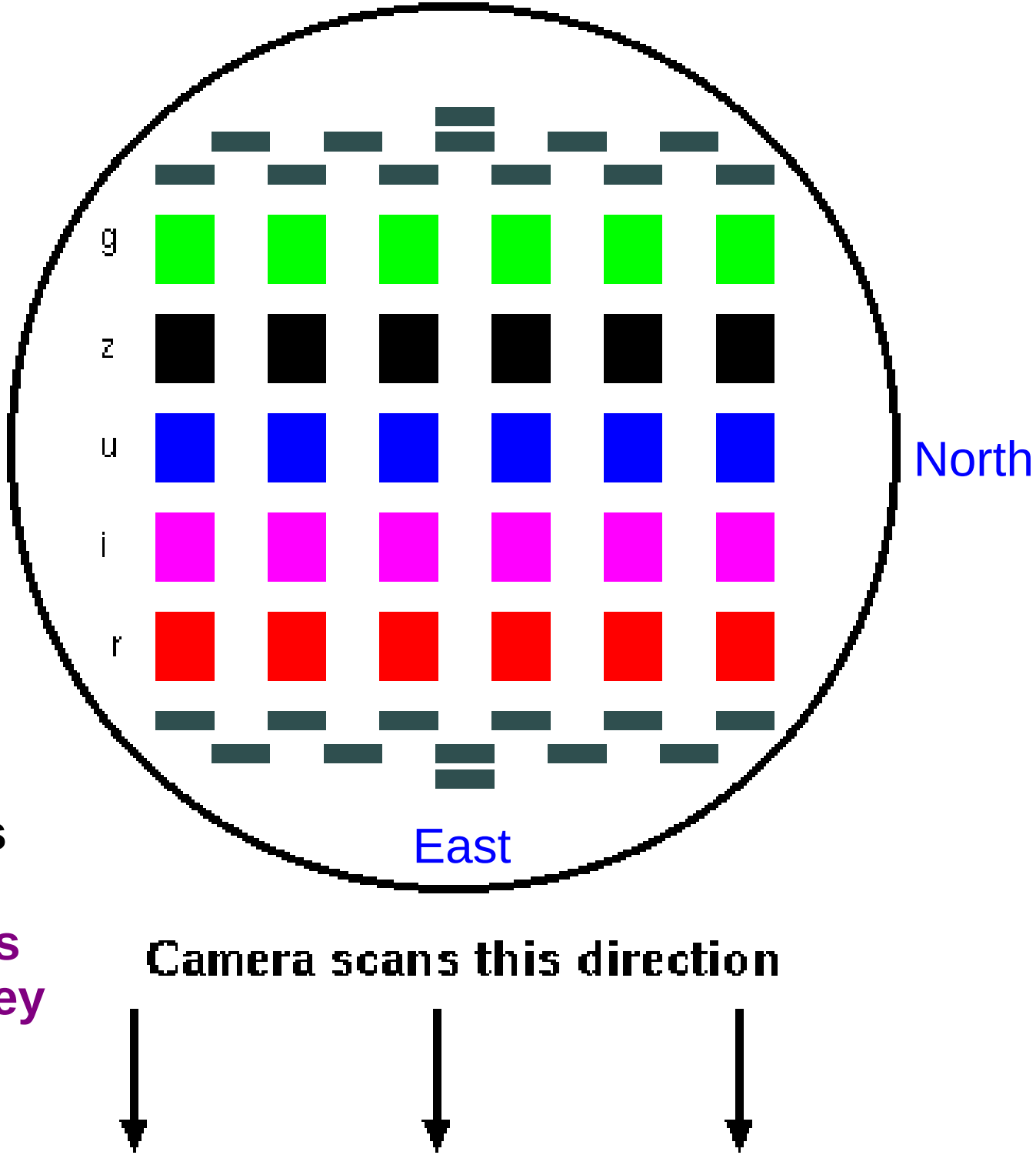
1. **LINEAR** (MIT) Socorro NM
2. **NEAT (Near Earth Asteroid Tracking)** JPL
3. **LONEOS** (Lowell Observatory) Lowell, AZ
4. **Spacewatch** (Steward Observatory) Kitt Peak
5. **Catalina Sky Survey**

   Steward Observatory; ANU

   3 telescopes (Catalina Mtns; Siding Springs)
6. **La Sagra Sky Survey** (Mallorca) Southern Spain

Many other telescopes and surveys can find NEOs but do not specifically target them for followup

SDSS IMAGING SURVEY as an NEO detector



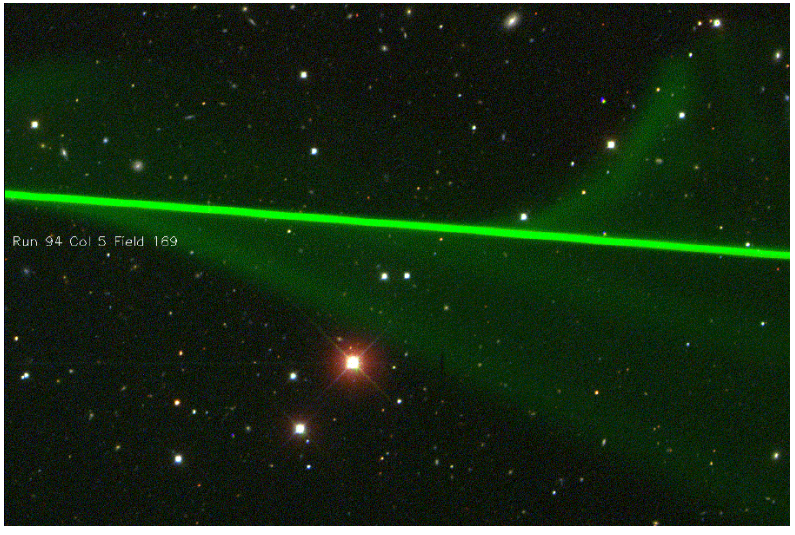
54 sec per filter

5.4 min per 5 filters

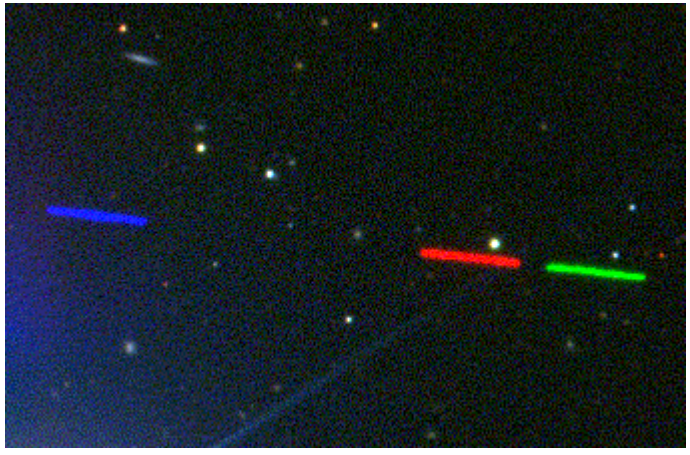
Identified 114 NEOs in a complete survey

Transient Objects in SDSS

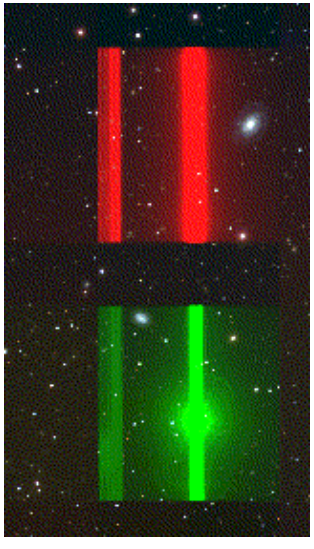
Comet Dalcanton



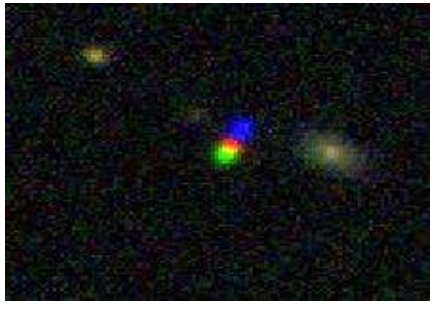
Meteor



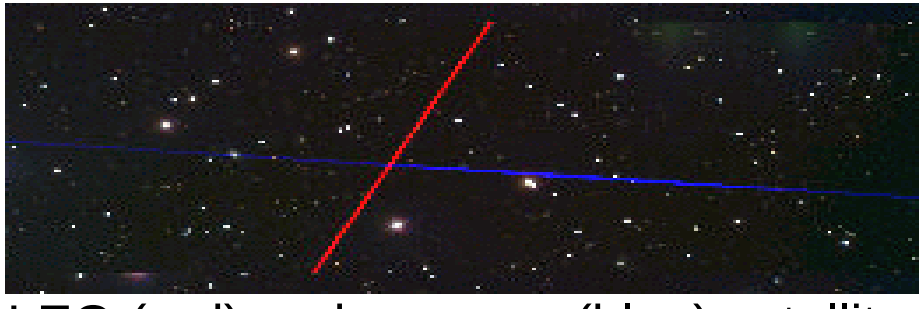
High earth orbit satellite (ASTRON)



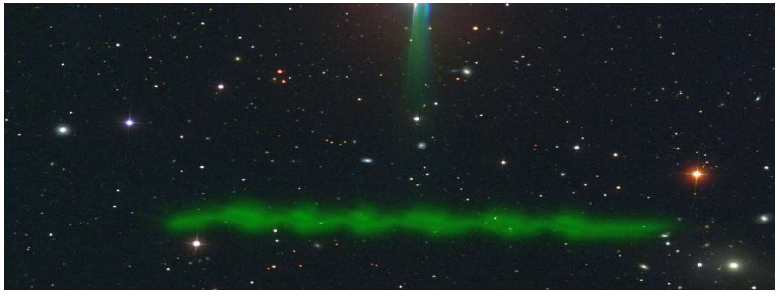
Aircraft



Main-belt asteroid



LEO (red) and geosync (blue) satellites



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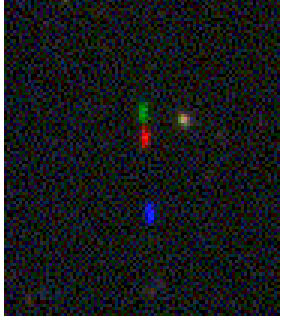
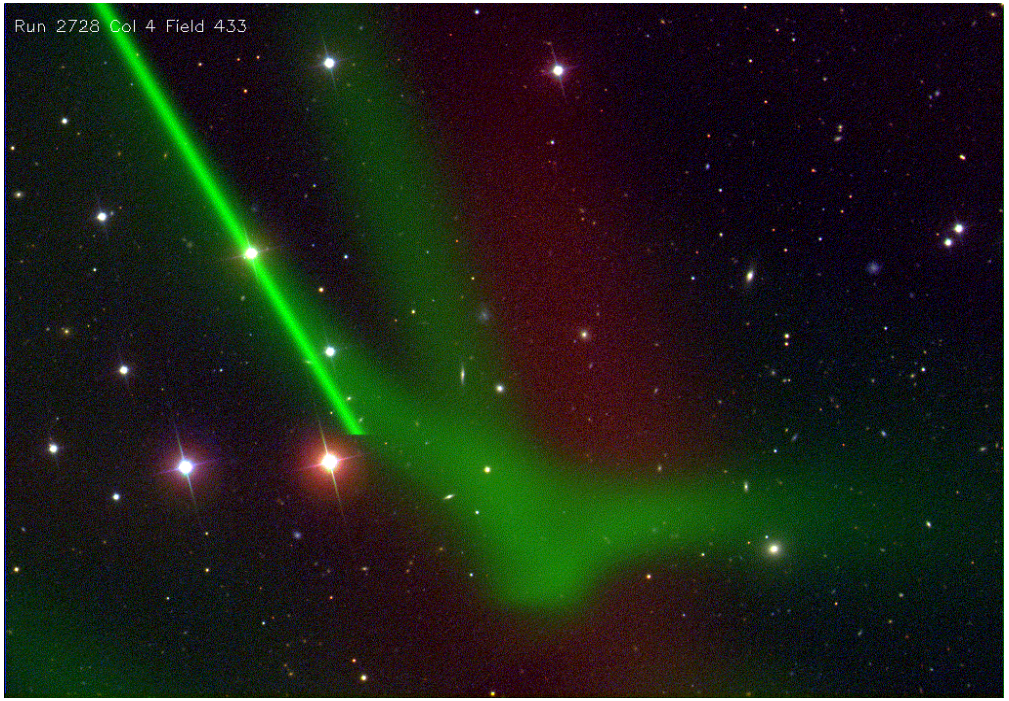
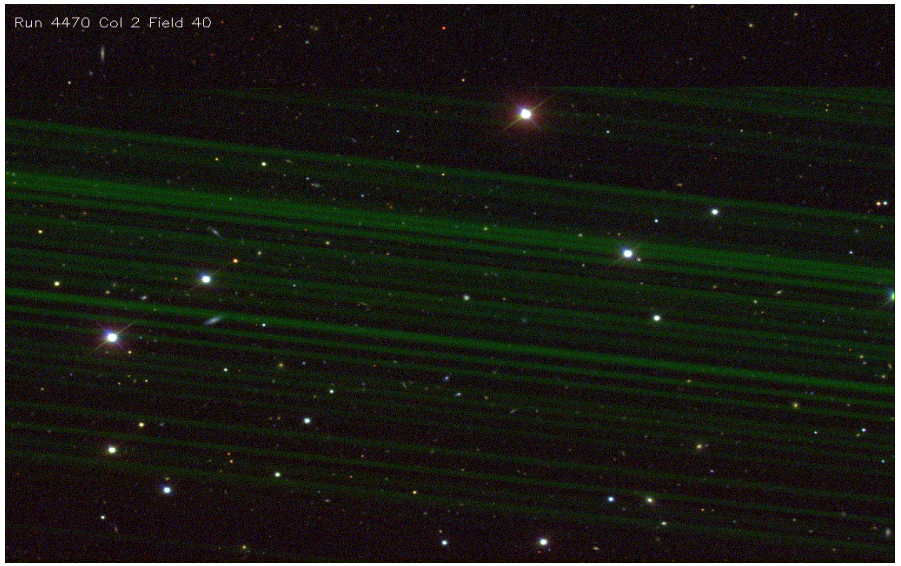
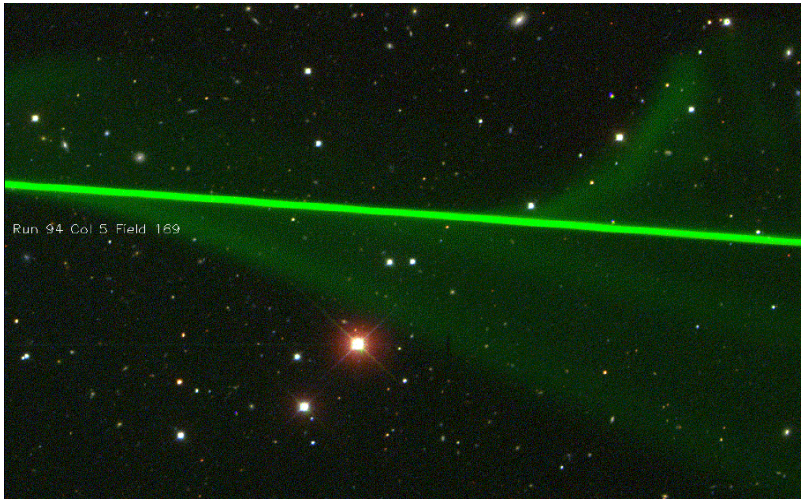


Near-earth object

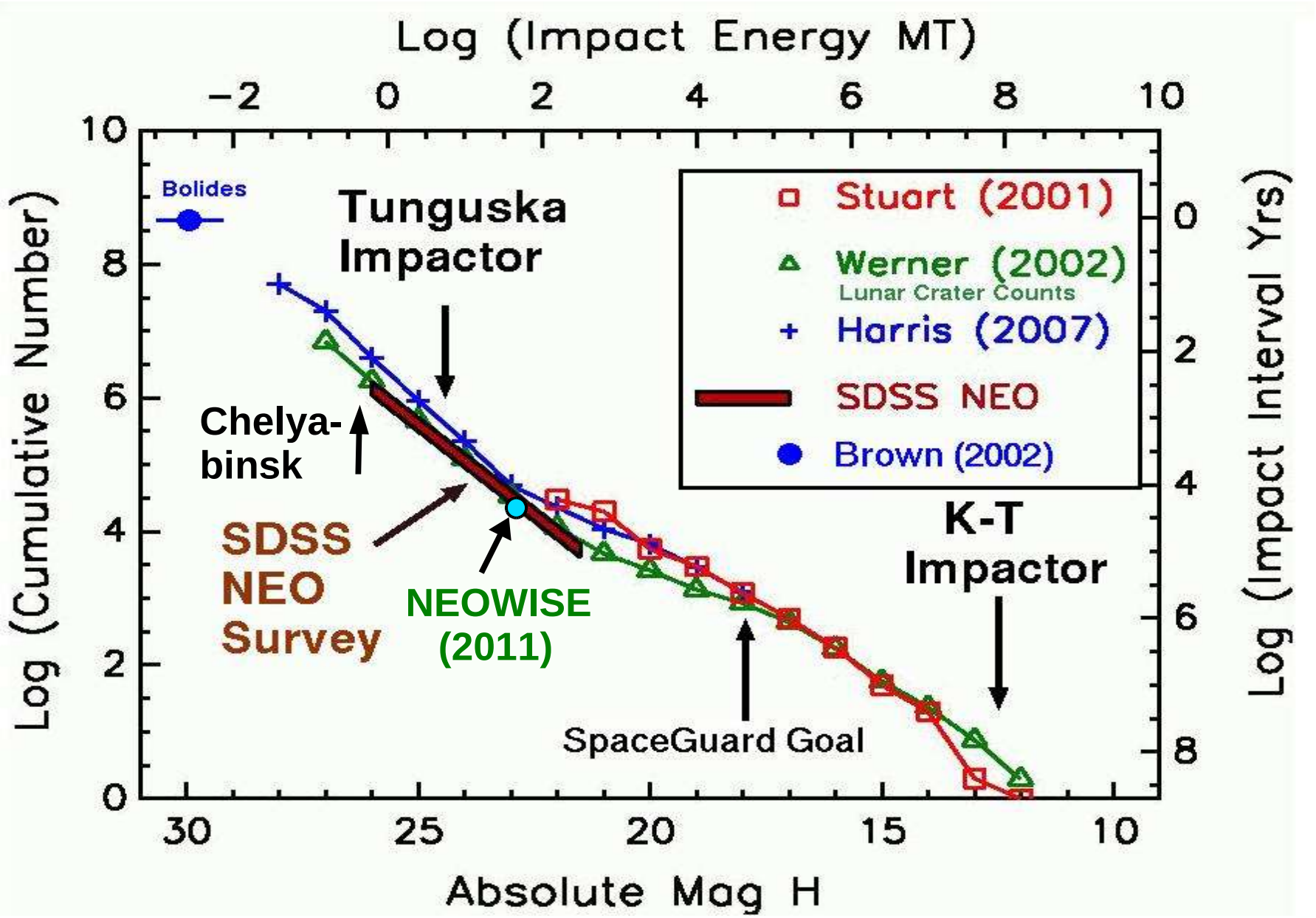
Meteor Sample







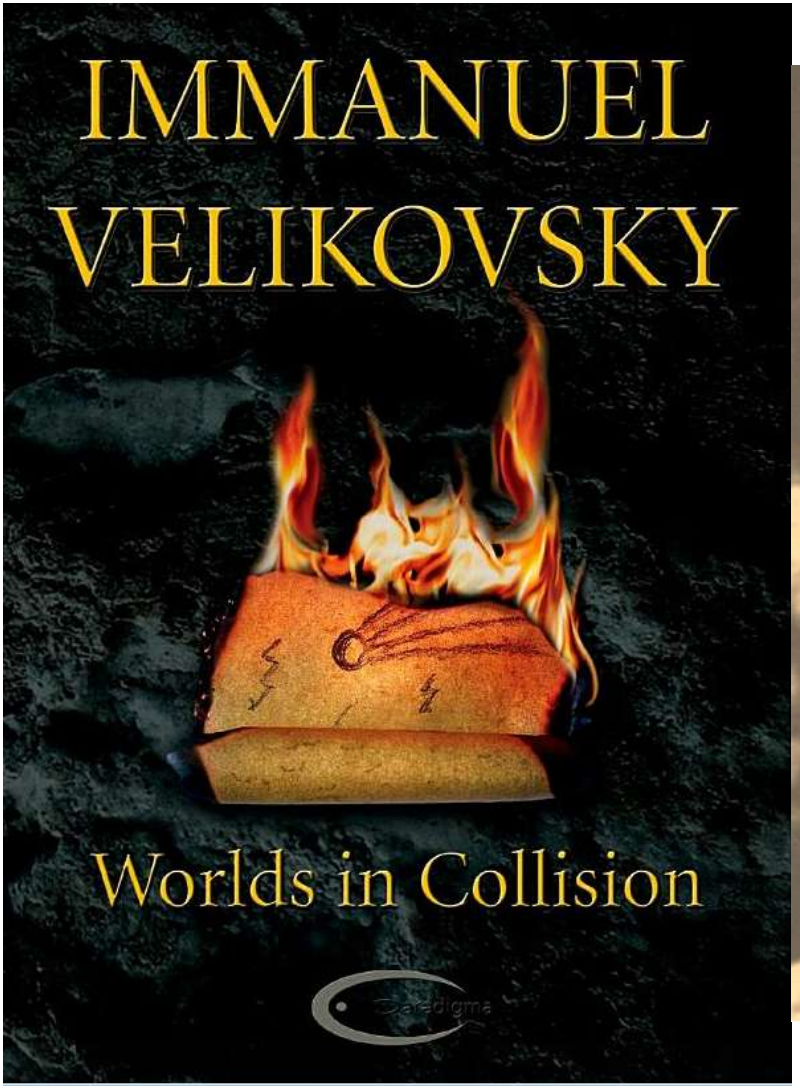
Earth Collision Rate

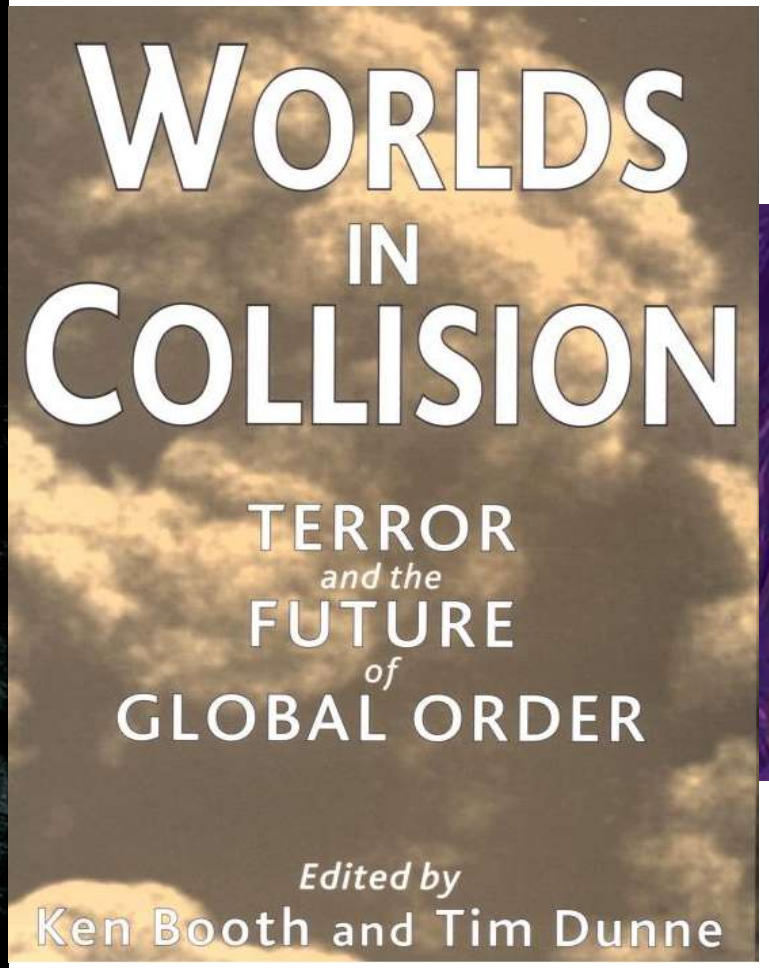


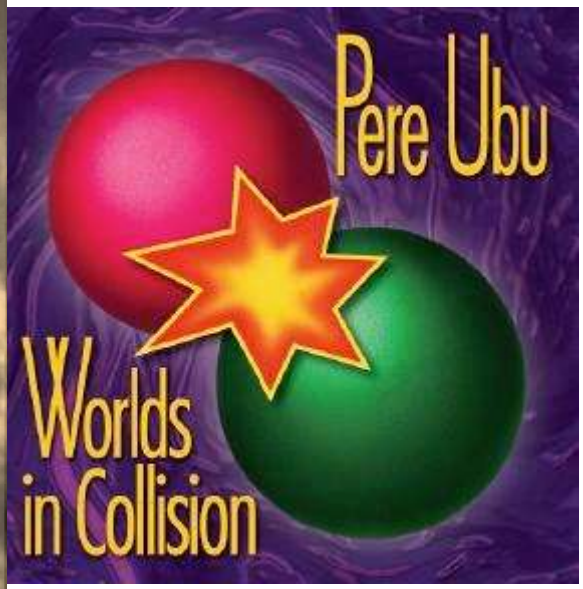
Summary and Future

- **Earth collision rate @ 500 Kilotons (Chelyabinsk) 63-200 years**
- **Earth collision rate @ 9 Megatons (2012 DA14) 1,600 to 5000 years**
- **Dark Energy Survey will detect hundreds of NEOs (no plans to follow up)**
  - ***DECam NEO Pilot Program (Allen et al.) approved***
- **LSST - NEO search is an integral part of the operations plan**
- **Reliable detection of Chelyabinsk-sized objects requires 24x7 monitoring from multiple sites - still well into future.**

Thank You!


IMMANUEL
VELIKOVSKY
Worlds in Collision


WORLDS
IN
COLLISION
TERROR
and the
FUTURE
of
GLOBAL ORDER
Edited by
Ken Booth and Tim Dunne


Pere Ubu
Worlds
in Collision