Asteroid Retrieval Mission Study

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Terminology

- "Near Earth Objects (NEOs)"- any small body (comet or asteroid) passing within 1.3 Astronomical Unit (AU) of the Sun
  - 1 AU is the distance from Earth to Sun = ~ 150 million kilometers (km)
  - NEOs are predicted to pass within ~ 45 million km of Earth's orbit
  - Population of near-Earth asteroids & comets (100:1)

- "Potentially Hazardous Objects (PHOs)" – small body that has potential risk of impacting the Earth at some point in the future
  - NEOs passing within 0.05 AU of Earth's orbit
  - Appears to be about 20% of all NEOs discovered
- Human mission accessible NEOs are a subset of PHOs

NASA's NEO Search Program

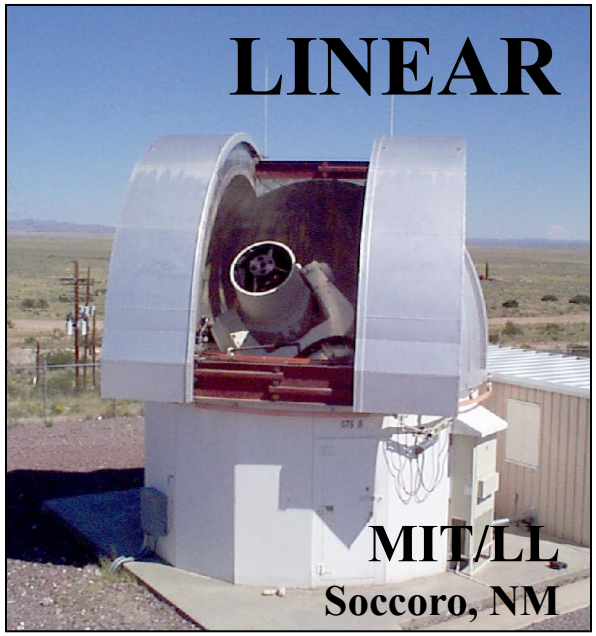
(Current Systems)

Minor Planet Center (MPC)
- IAU sanctioned
- Int'l observation database
- Initial orbit determination

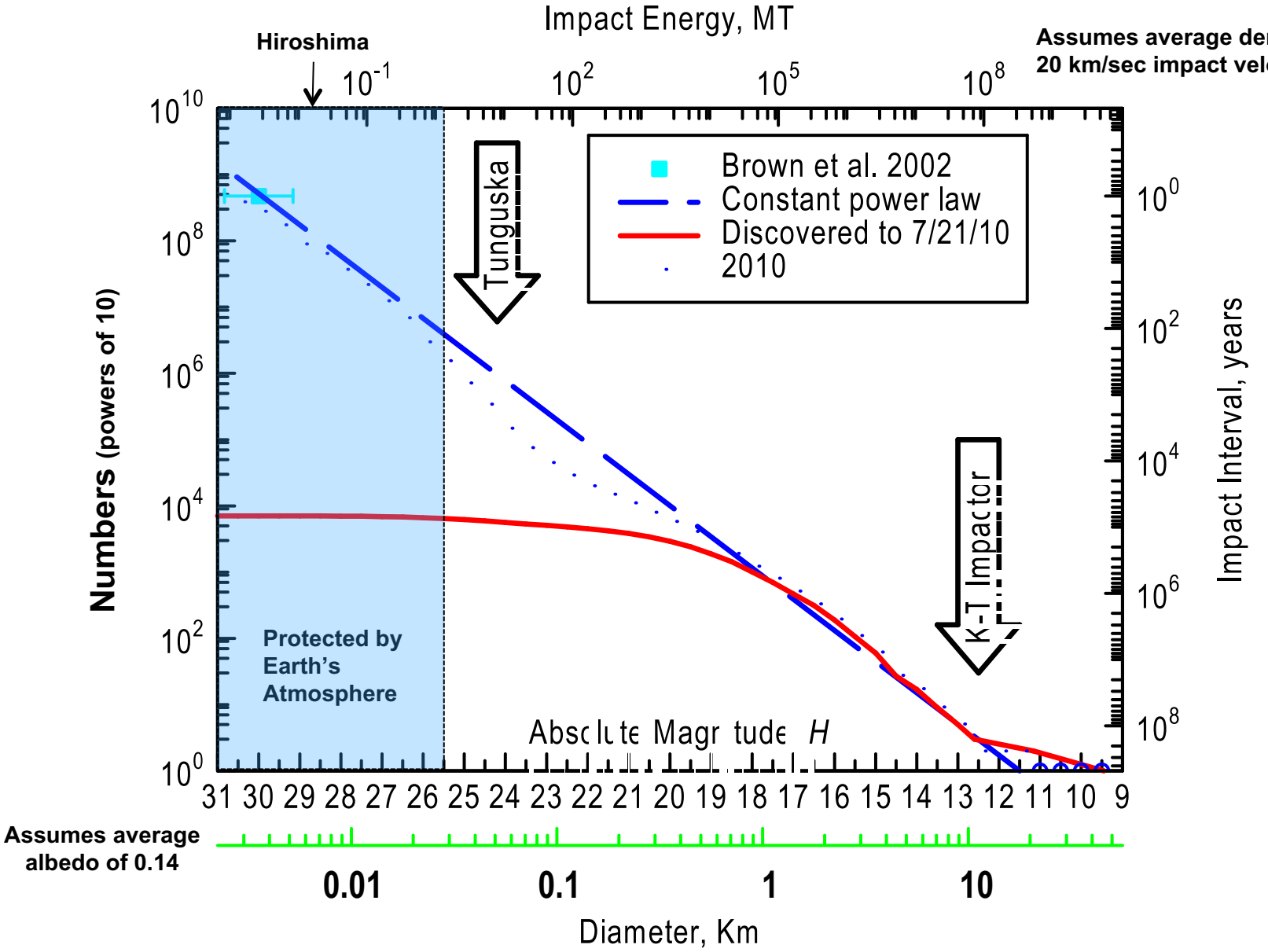
www.cfa.harvard.edu/iau/mpc.html

NEO Program Office @ JPL
- Program coordination
- Precision orbit determination
- Automated SENTRY

www.neo.jpl.nasa.gov



Population of NEAs by Size, Brightness, Impact Energy & Frequency (Harris 2006)



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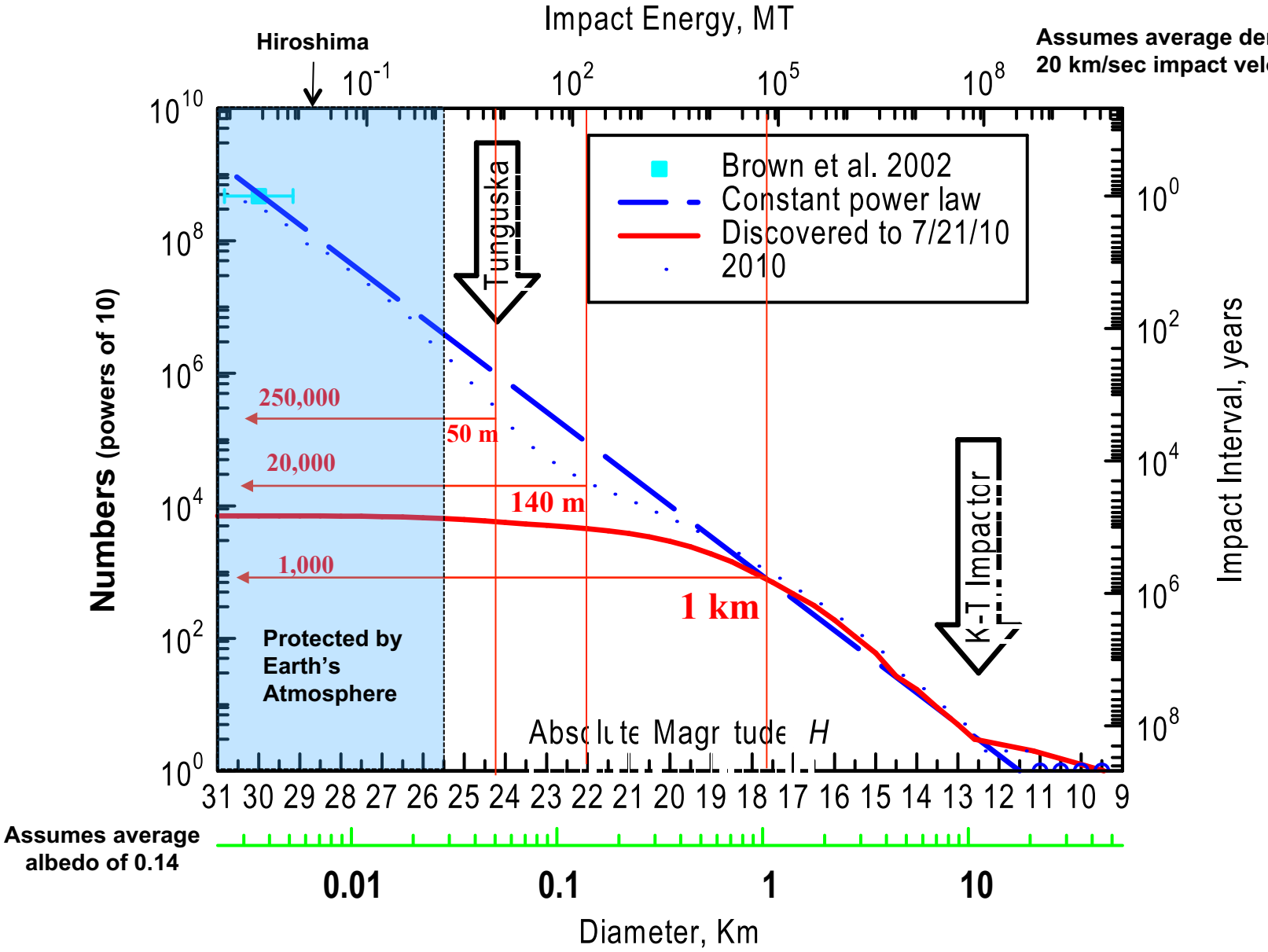
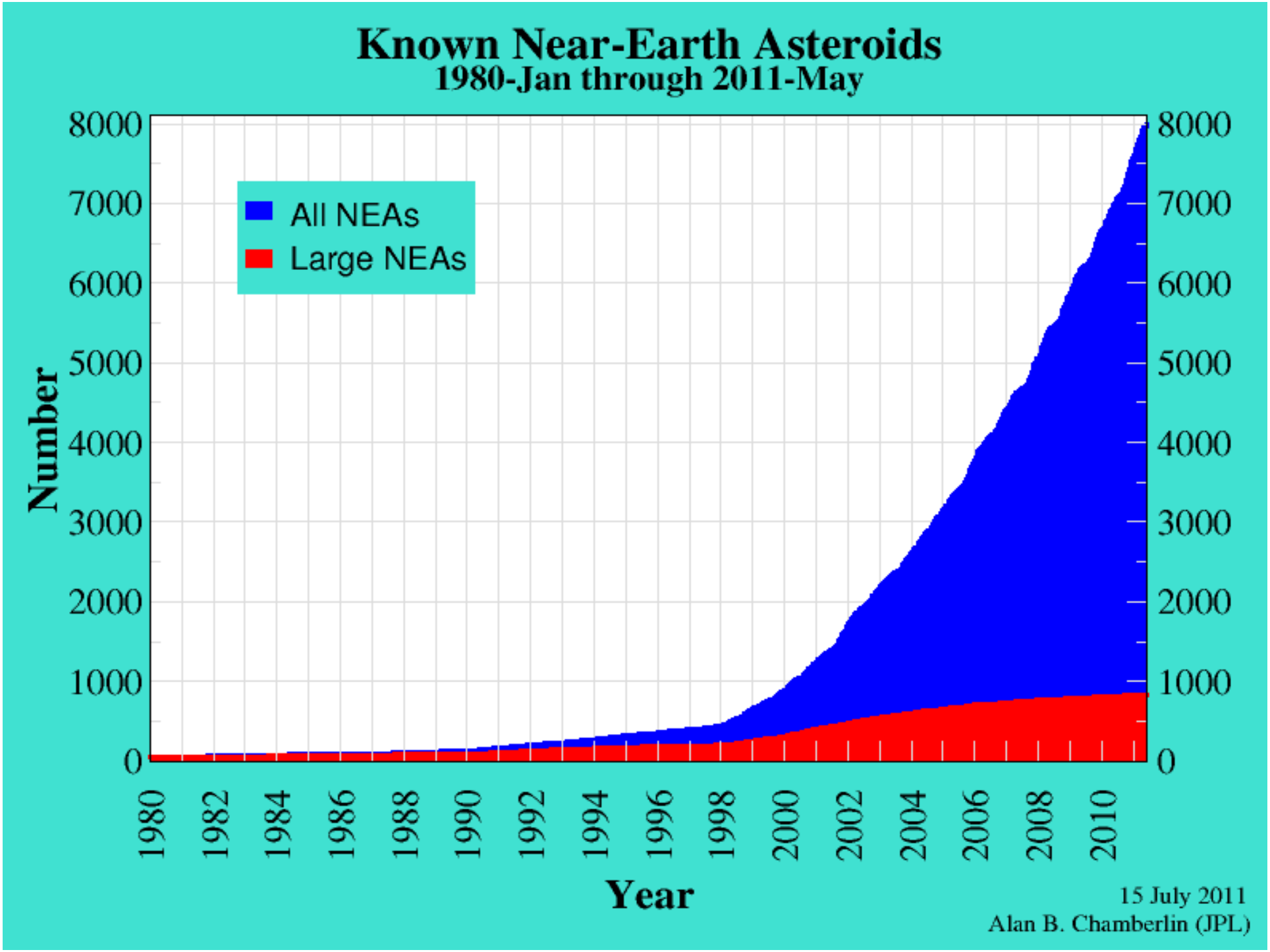
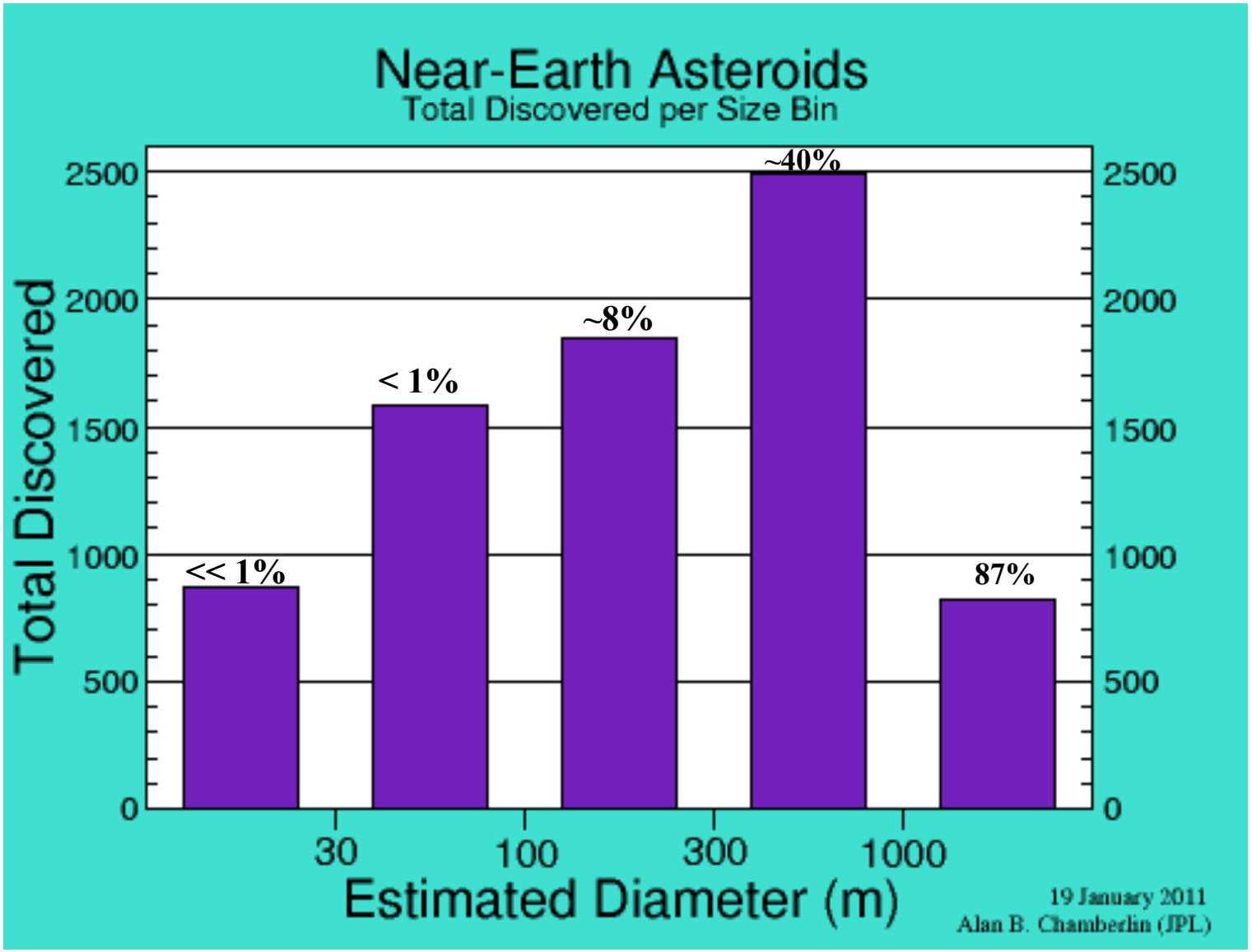



Known Near-Earth Asteroids
1980-Jan through 2011-May
All NEAs
Large NEAs
Number
Year
0
1000
2000
3000
4000
5000
6000
7000
8000
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
15 July 2011
Alan B. Chamberlin (JPL)

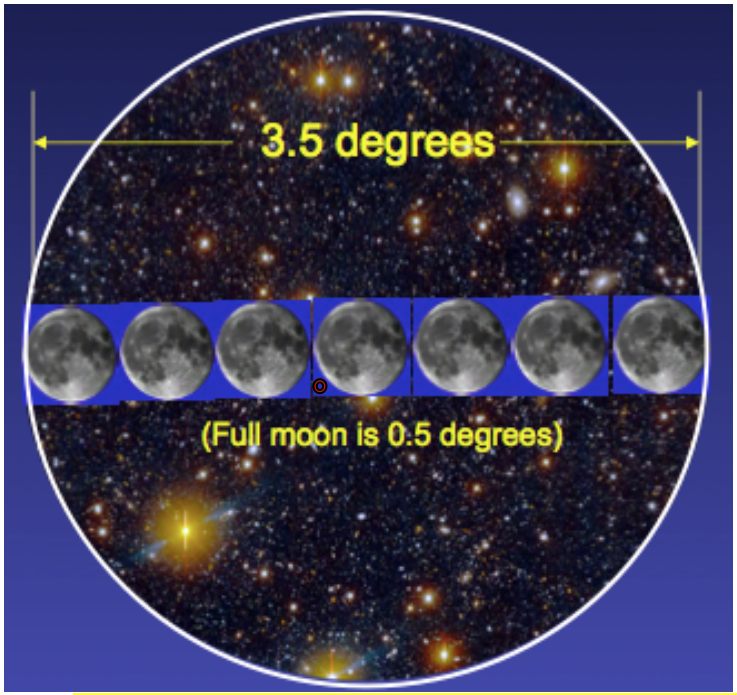
Known Near Earth Asteroid Population

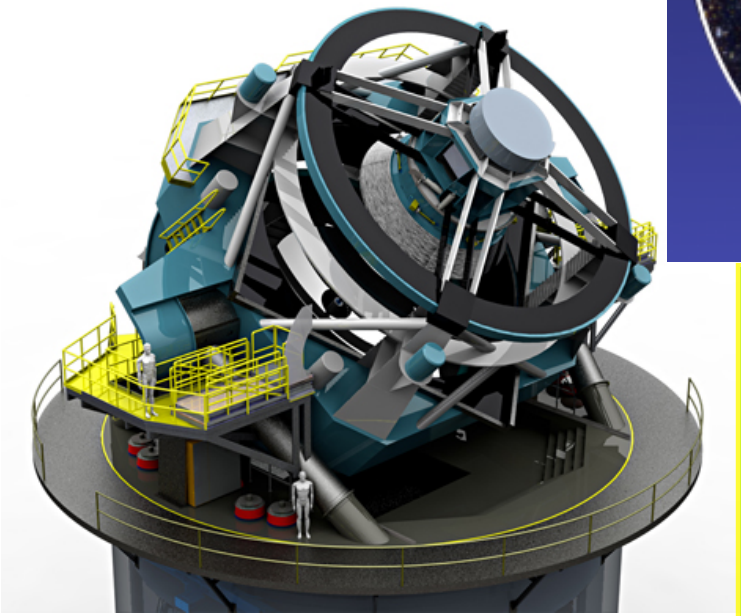


Candidates for NextGen Survey

- Ground-based Survey Telescopes
  - Pan-STARRS 2 to 4 ?
    - Air Force Research Labs “sponsored”
    - Operated with Science Consortium $$ (includes NASA NEOO)
    - PS-2 in construction
    - Build of future apertures uncertain
  - Large Synoptic Survey Telescope (LSST)
    - Start-up on private funding for mirrors
    - Large format camera being developed by DOE
    - Construction by NSF – Operations $$??
    - Four mission drivers
      - Dark Energy/Matter
      - Transient Optical Sky
      - Milky Way
      - Solar System Science (including NEOs)
  - Space Surveillance Telescope (SST)
    - DARPA developed for improved Space Situational Awareness (SSA)
    - To be operated by AF Space Command
- Space-based Survey Telescopes
  - Optical
  - Infra-Red

Large Synoptic Survey Telescope





- 6.4-m effective diameter
- 10 sq deg field of view
- ugrizy optical filters
- 18,000 square degrees ++
- 2x15s exposures + 2 more within 60 minutes
- Survey entire visible sky every 3-4 days in 2 filters for 10 years

LSST Survey for NEOs

NASA/NSF Discussions regarding LSST

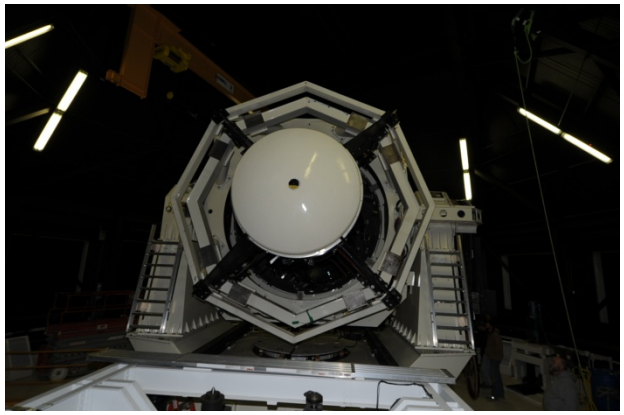
- LSST will be a valuable additional asset regardless of state of survey
  - Orbit follow-up & maintenance continuing task
- Projected involvement of NASA NEO Program with LSST
  - Modification of our previously developed MOPS detection software
  - Funding of additional operations time needed for NEO survey
  - Total cost estimated to be $120M by LSST Project

Issues with LSST

- Start of survey operations comes “late to the fight” - late 2019
- Proposed survey cadence may not work for effective NEO detection
  - LSST proposes only 2 Observations/night to minimize impact
  - Current surveys use 4 – 5 Obs/night to reduce “false detections”

Space Surveillance Telescope

- **DARPA funded project**
- **Designed and built by MIT/LL**
  - **Same division as LINEAR**
- **Located Atom Peak, WSMR, NM**
- **3.6 meter primary mirror**
- **First Light was Feb 2011**
- **Started 1 year of checkout**
- **Eventual operations by AFSPC**
- **First of 3 to 4 worldwide sites**
- **Serendipitous detection of NEOs in background mode to space surveillance**



SST Project for NEOs

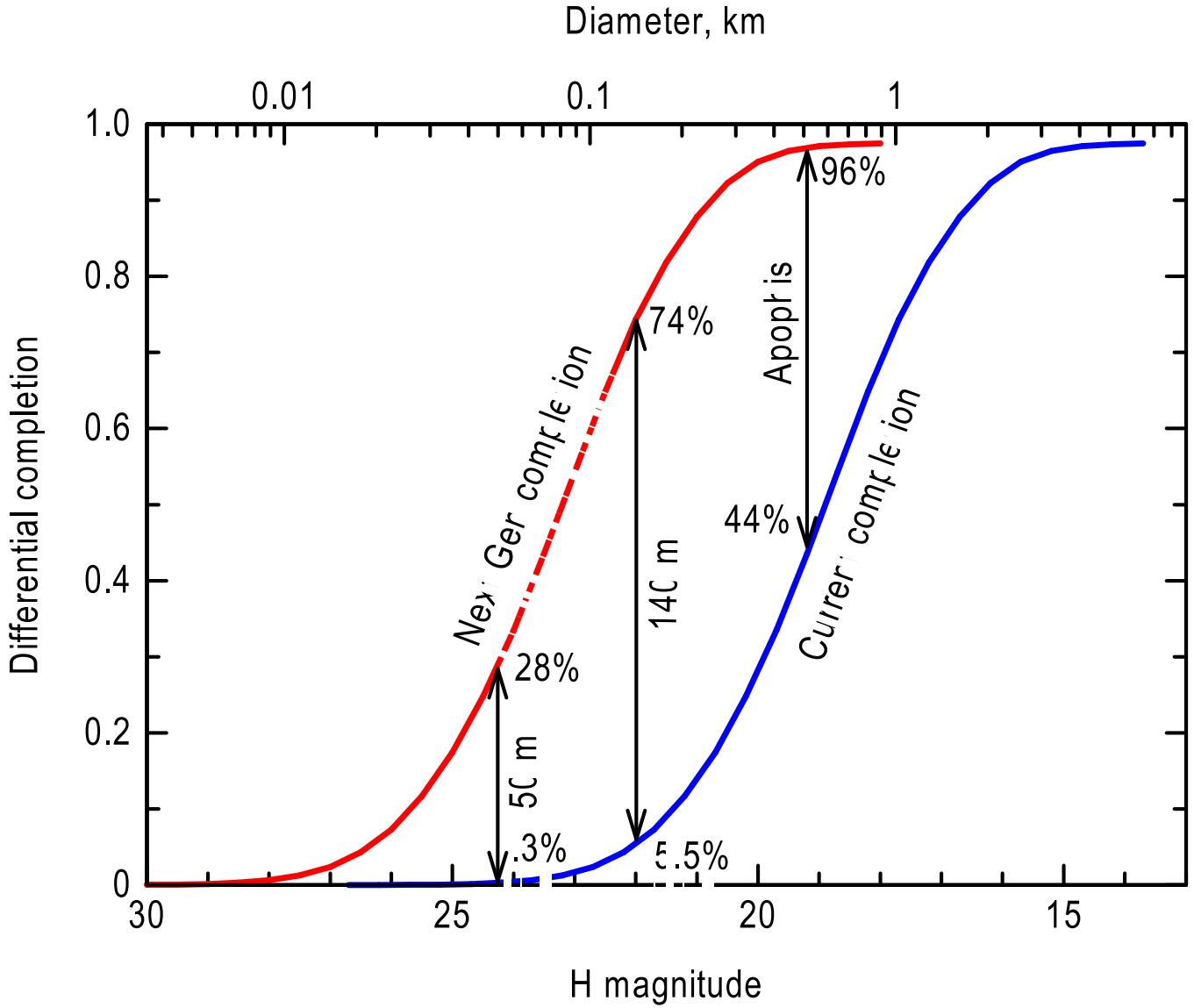
NASA / MIT-LL / DARPA Discussions regarding SST

- SST can provide near term enhancement to NEO survey capability (2012-13)
- Involvement of NASA NEO Program with SST
  - Funded study by MIT/LL of SST's NEO survey potential
    - NEO survey can be conducted in background with image data tap
    - Minimal impact to AF space surveillance operations
    - Discovers 25% of 140 m NEO within 5 years (+ 15 – 20% next 5 years)

Issues with SST

- SST operates at classified levels. Must protect SSA system performance/data
- Data extraction for NEO detection requires security gateway
- Process and procedures require vetting/approval by DARPA and Air Force

Differential completion of Survey



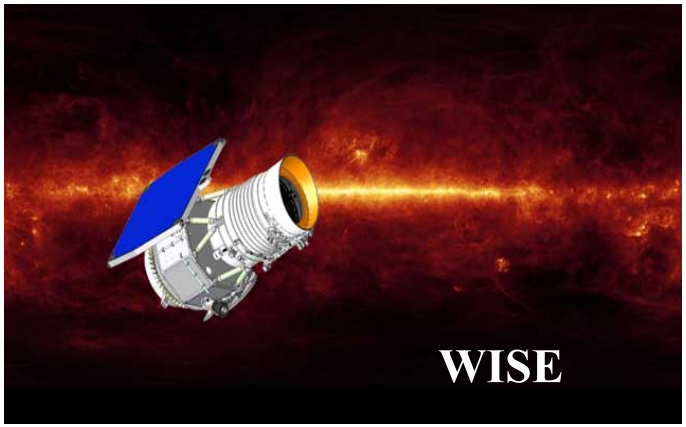
In the course of the next generation survey, we can expect to discover:

2x as many Apophis sized objects

13x as many ~140 m diameter objects

100x as many Tunguska sized objects

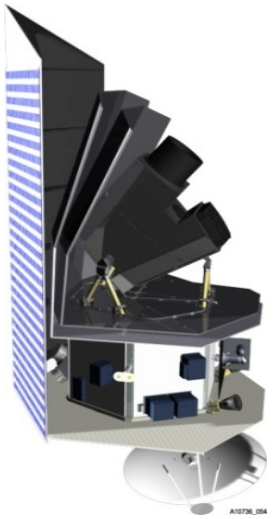
Space-based *"NEOStar"* Concept



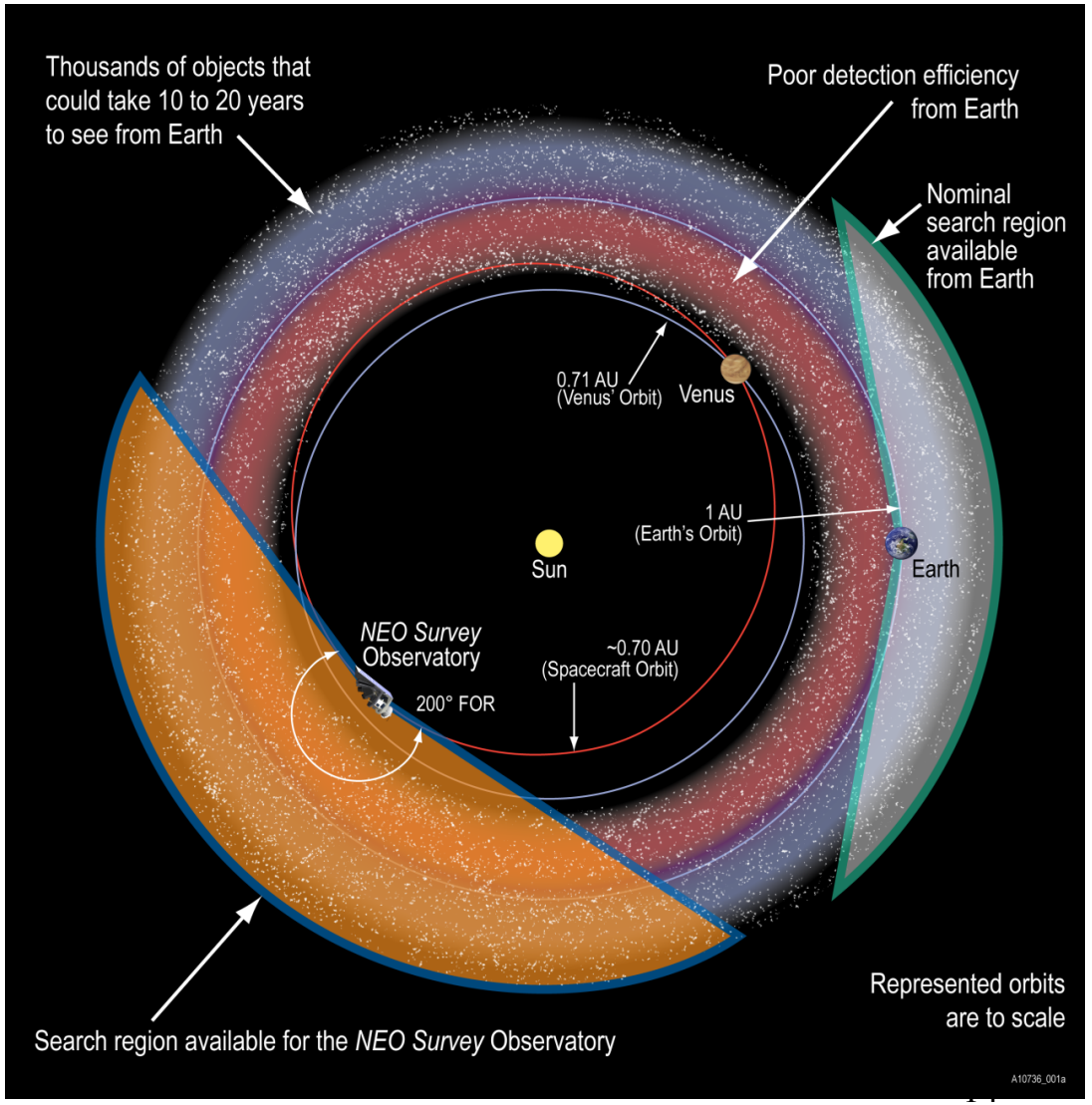
X

Kepler

≈



"NEOStar"



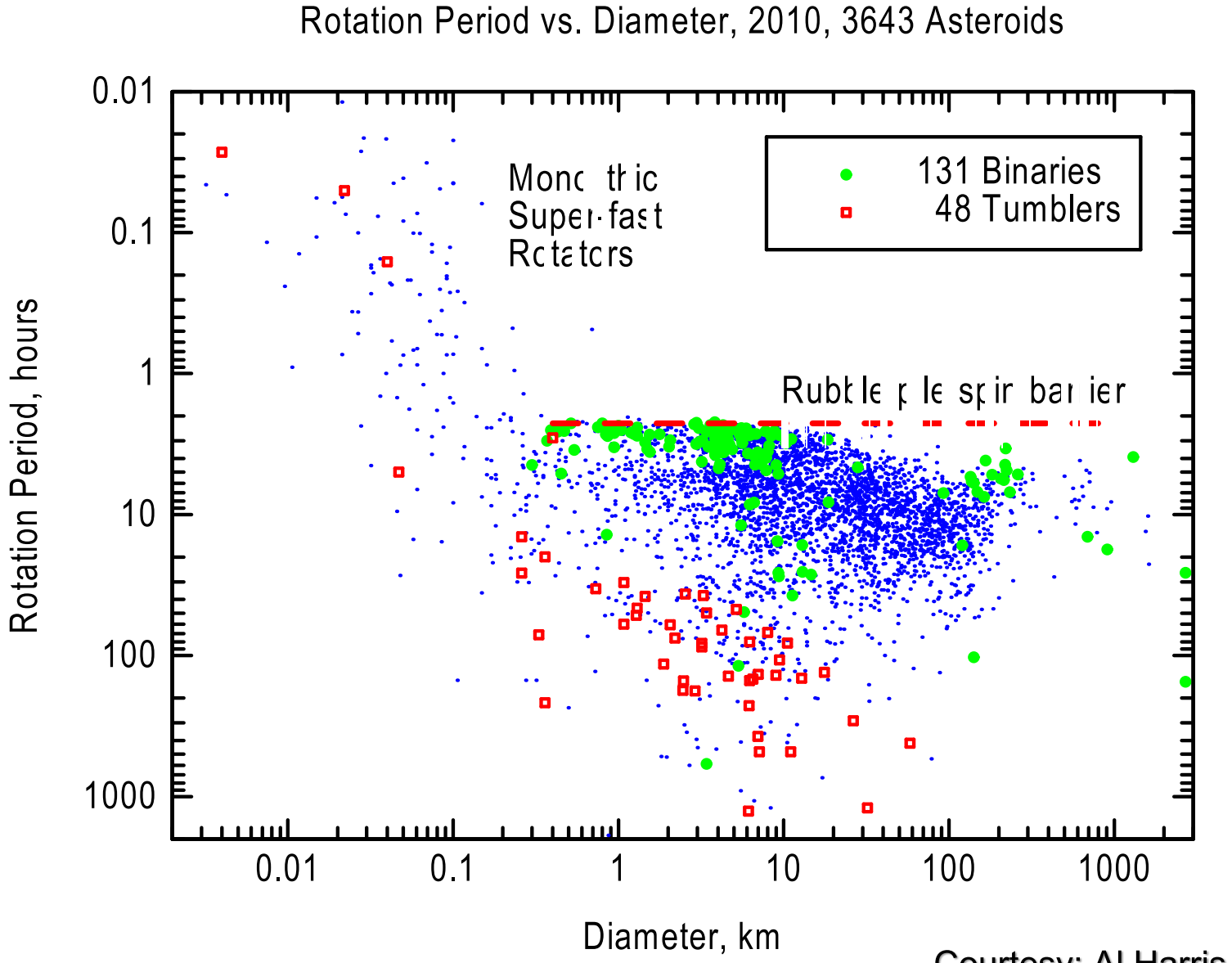
Asteroid Target Bodies

Their diameters are uncertain

H	D1(A=.04)	D2(A=.14)	D3 (A=.25)
31	4 m	2.2 m	1.7 m
30	7	4	3
29	11	6	4
28	17	9	7
27	27	14	11

- A = 0.04 Typical C-type albedo
- A = 0.14 Average NEO albedo
- A = 0.25 Typical S-type albedo

Asteroid Spin Periods vs. Diameter



Courtesy: Al Harris

Future Target Bodies

- There are now 4 NEAs with H > 31.0 (D ≤ 2 m)
- All were discovered within 0.005 AU of Earth
- All are lost and must be rediscovered during future close Earth approaches
- Catalina Sky Survey is currently the most efficient survey. E = Aperture x FOV ~ 2
- LSST: E ~ 321 (~150 x more efficient)
- Number of 2 meter targets in 2025 may be ~ 600
- Will need to secure orbits during discovery return
- Determining spectral class requires m < 18

Example Target List

Asteroid	H	OCC	Obs. Opportunity	Radar Opportunity Date, Δ (AU), SNR
1991 VG	28.4	2	2017-Jul	
2003 WT153	28.0	5	2030-Nov survey	
2003 YS70	28.8	5	2022-Nov survey	
2006 RH120	29.6	1	2028-Jul	
2008 CM74	28.0	6	2025-Jun survey	6/2025 .014 8G
2008 EL68	28.0	9	2011-Dec survey	
2008 GM2	28.4	5	2035-Apr survey	
2008 HU4	28.2	4	2016-Feb	
2008 UA202	29.4	6	2029-Oct survey	
2009 BD	28.3	1	2011-Jun	

Example Target List

Asteroid	H	OCC	Obs. Opportunity	Radar Opportunity
----------	----	---	-------	Date, Δ (AU), SNR
2009 WR52	28.3	6	2028-May survey	
2009 YR	28.0	5	2030-Sep survey	
2010 TE55	28.0	3	2022-Jul	
2010 UE51	28.3	2	2011-Mar	
2010 UY7	28.5	6	2027-Dec survey	
2011 BQ50	28.3	6	2035-Dec survey	5/2028 0.006 2200A

Representative Asteroid Masses

Asteroid Diameter	Asteroid Mass (kg)		
	1.5 g/cc	2.5 g/cc	3.5 g/cc
1.0	785	1,309	1,833
2.0	6,283	10,472	14,661
3.0	21,206	35,343	49,480
4.0	50,265	83,776	117,286
5.0	98,175	163,625	229,074
6.0	169,646	282,743	395,841
7.0	269,392	448,986	628,580
8.0	402,124	670,206	938,289
9.0	572,555	954,259	1,335,962
10.0	785,398	1,308,997	1,832,596
11.0	1,045,365	1,742,275	2,439,185
12.0	1,357,168	2,261,947	3,166,725
13.0	1,725,520	2,875,866	4,026,213
14.0	2,155,133	3,591,888	5,028,643
15.0	2,650,719	4,417,865	6,185,011

Conclusions

- Optical photometry & IR spectroscopy needed for determining rotation rates, diameters, spectral class and whether or not object has hydrated minerals
  - In general, small sizes => coherent structures & fast rotation rates
  - A few % of small NEAs could be binaries or tumblers
  - IR data can provide diam. to ~10% & albedos to ~20%
    - w/o IR, albedo range could be 0.04 – 0.6; diameters could differ by factor of 4; masses by factor of 64
    - Mass uncertain by factor of ≥ 2 for best observed objects
    - Ground based IR data ($m < 18$) requires VERY close Earth approach of ~0.002 AU for a 2 meter sized object – or an IR space telescope (but probably not JWST)…..

Conclusions

- There are no suitable targets currently
- Next generation discovery surveys should help
- Potential target bodies in ~2025
  - All types: < 600
  - C/D types: < 150, perhaps ~75 with hydrated minerals
  - Still fewer targets with IR observing opportunities
- Will need to secure target orbits and characterize:
  - During discovery (optical + radar + IR)
  - Observe during post discovery close Earth approaches
  - Invest in space-based IR telescope survey

The Importance of Near-Earth Objects

- Exploration
- Science
- Future Space Resources
- Planetary Defense