



International Asteroid Warning Network

Arecibo Radar Observations of Near-Earth Asteroids

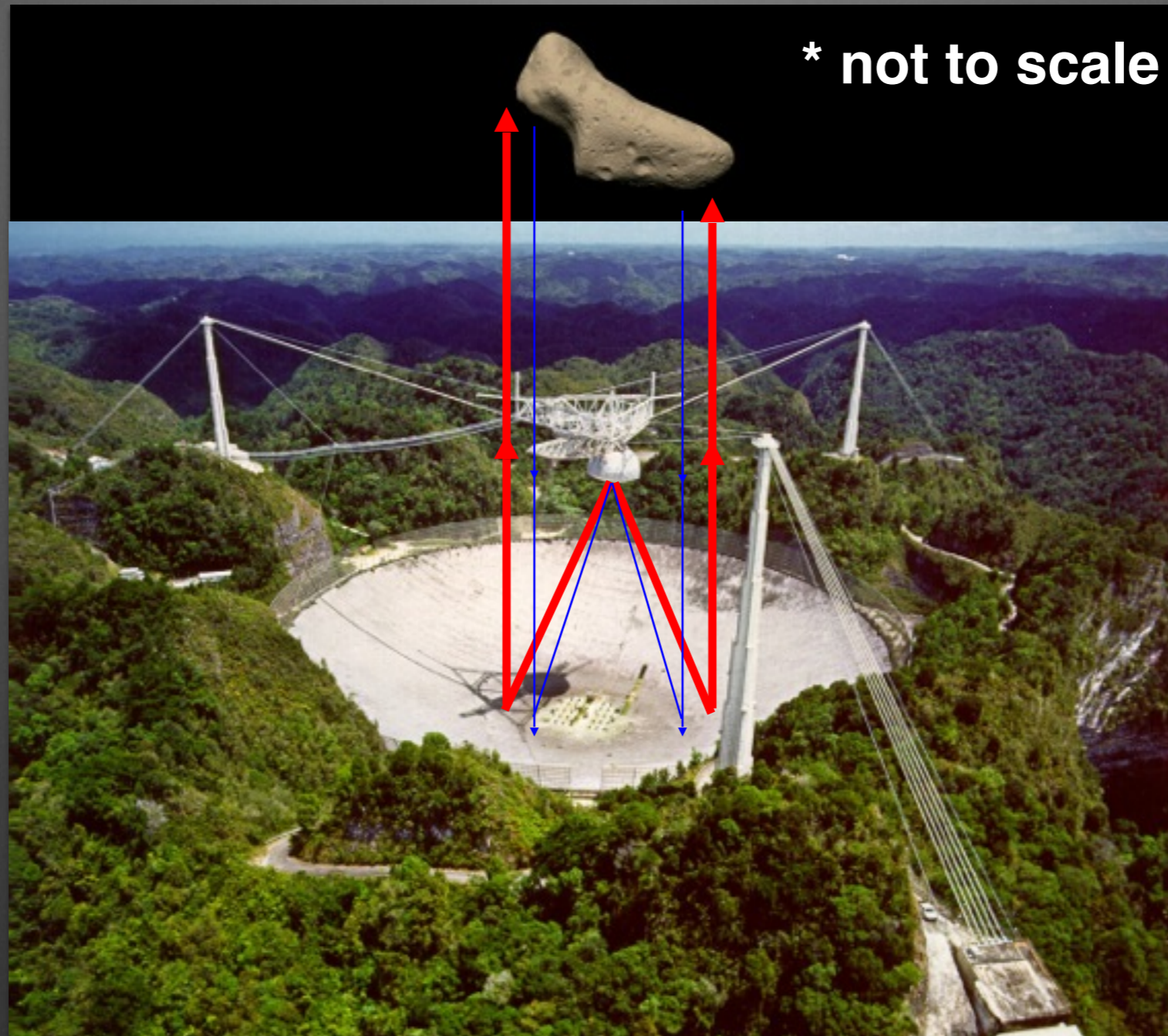


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Arecibo Observatory/USRA



Radar Astronomy



- ← Transmitted wave
- ← Echo from object

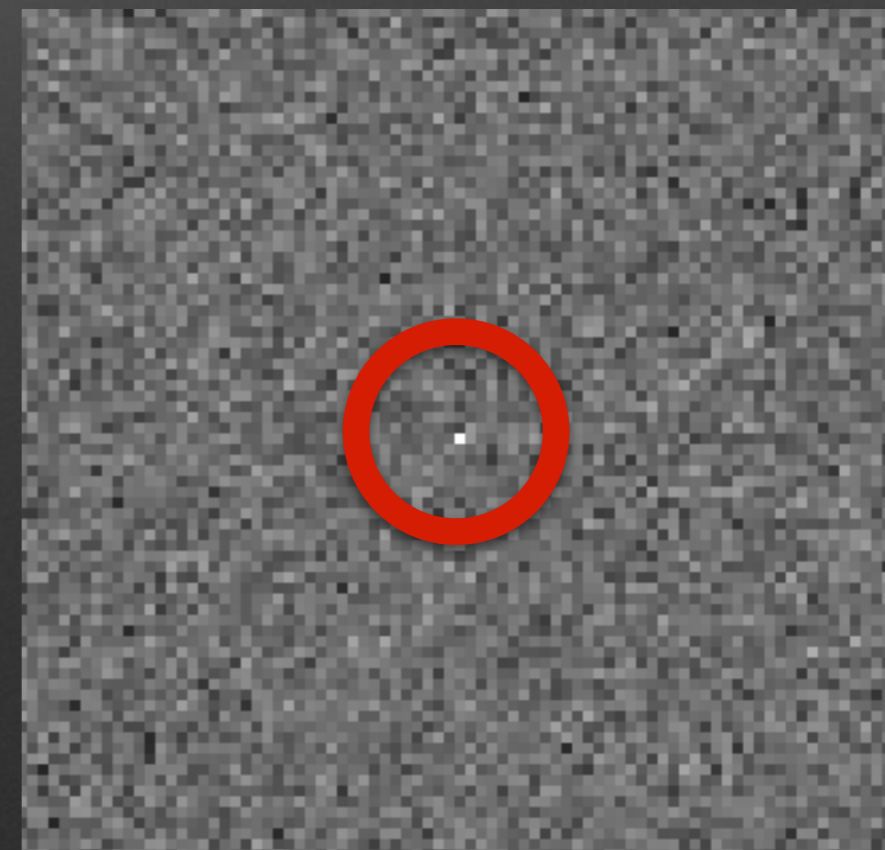
What Do We Measure with Radar?

- Line-of-sight distance and velocity —> Astrometry
- Object depth —> Size and shape
- Velocity dispersion —> Spin state
- Scattering properties —> Surface roughness, composition



Left: 1998 QE2

Right: 2002 GT



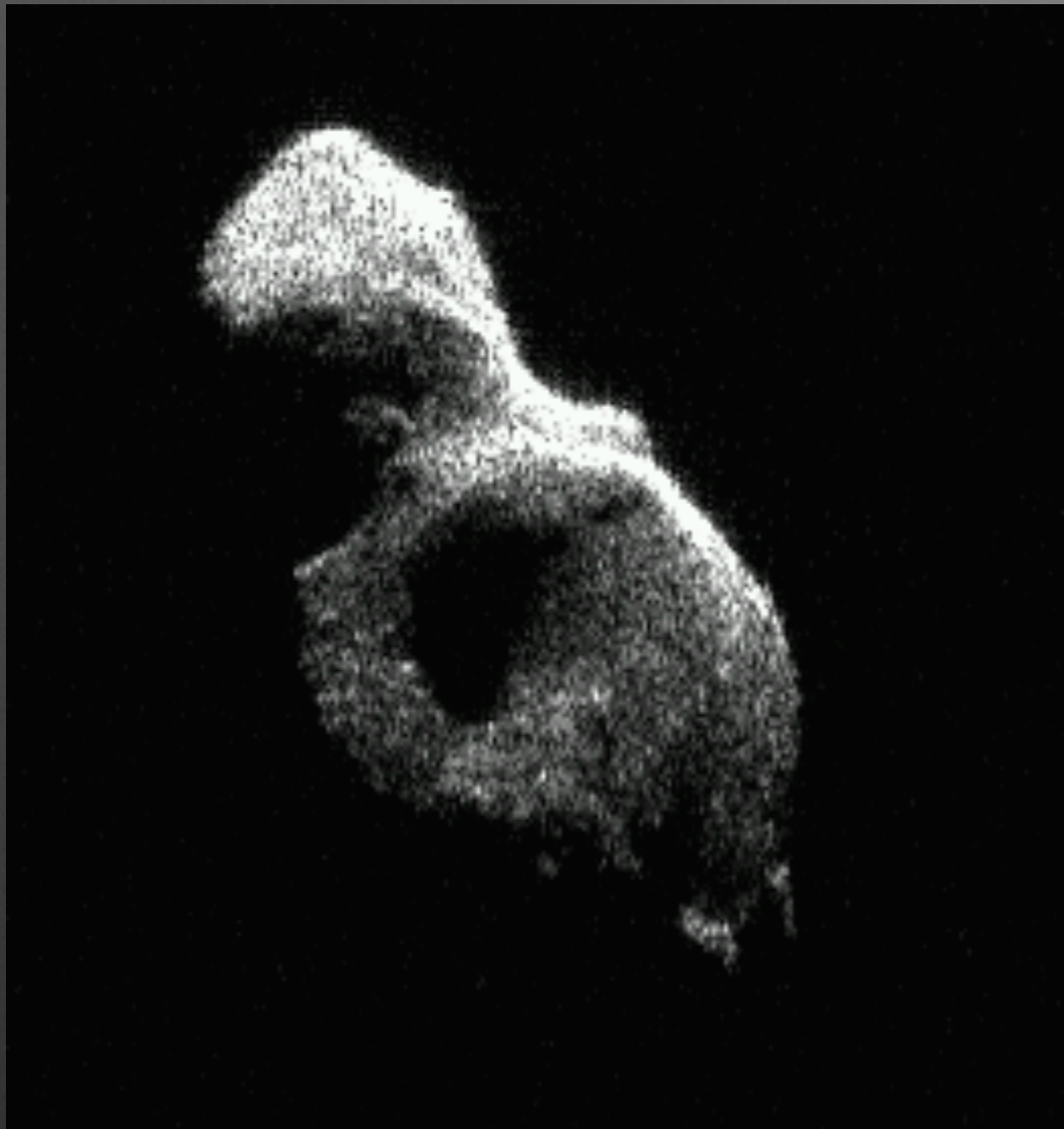
Radar Astrometry

- Radar relies on prior optical astrometry
 - Pointing: Arecibo beam is ~ 1 arcmin
 - Initial estimate of distance and velocity
- Radar-derived line-of-sight distances and velocities are orthogonal to optical plane-of-sky observations
 - Simultaneous radar and optical give the full 6-d state vector
- High fractional precision: 10^{-8} in distance, 10^{-5} in velocity
- Prevent loss of objects with short arcs, often extend Earth-encounter predictability by hundreds of years
- Radar astrometry is collected simultaneously with radar imaging

Modes of Observation

- High priority targets: high-resolution imaging (including shape modeling) or otherwise scientifically interesting
- Medium priority: astrometry and low-resolution imaging
- Whatever is up: one night following new moon, observe anything available (often new discoveries)
- Targets of opportunity: targets overlapping already scheduled objects
- Urgent: new discoveries requiring observations within hours or days (at site director's discretion)

Examples of Radar Observations



DSN-AO: 3.75 m x 0.00625 Hz

- **2014 HQ124**
 - Discovered by WISE
 - PHA, ~370 m long
 - On June 8, passed Earth at ~3 lunar distances
 - First Goldstone-to-Arecibo X-band imaging at 3.75 m

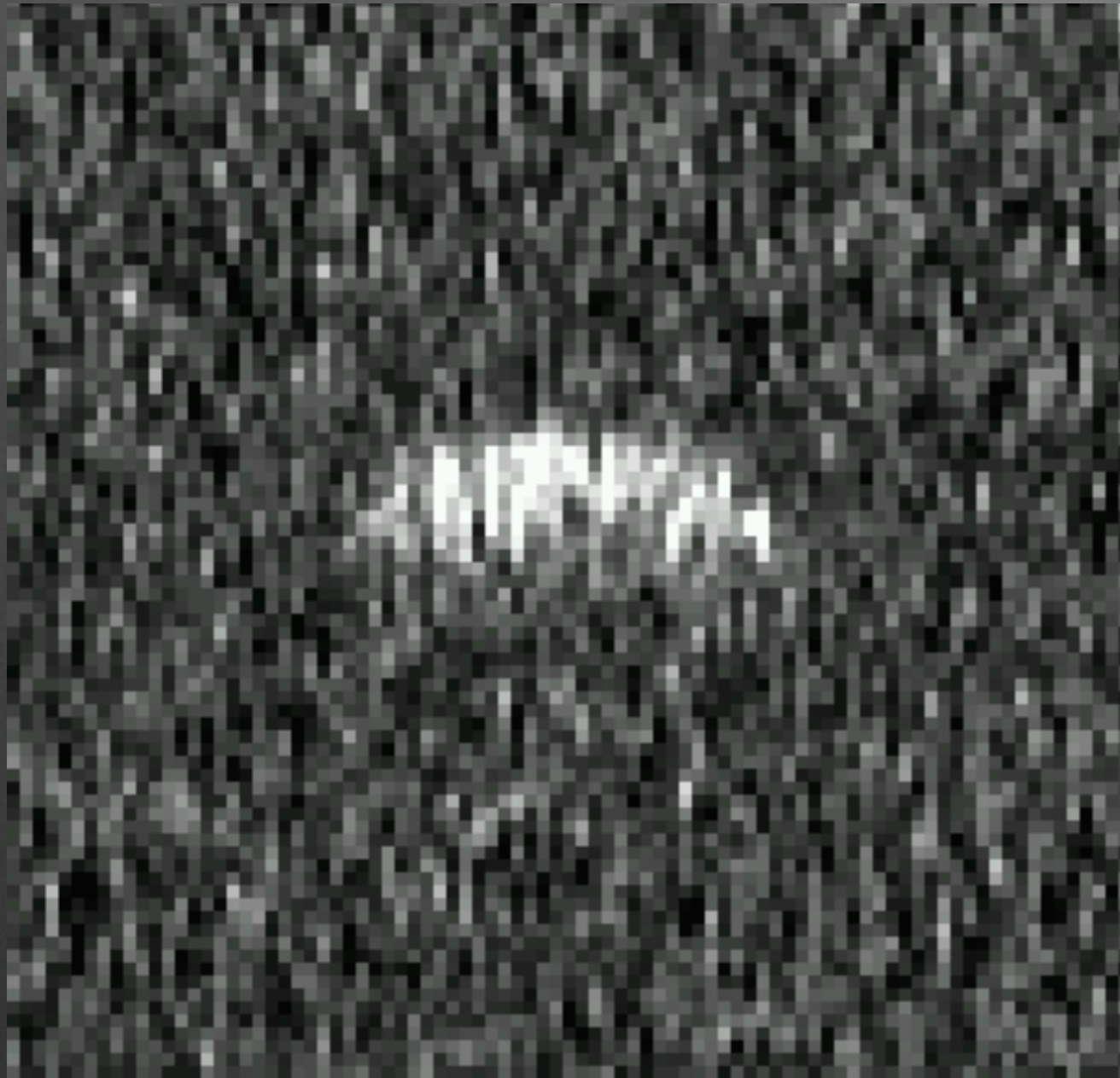
Examples of Radar Observations



Arecibo: 4-us ranging

- **2013 LB2**
 - Range correction of 90% of Earth's diameter
 - Prevented from being lost
 - Extended Earth-encounter predictability from 2013 out to 2508 (~2000% in all)!

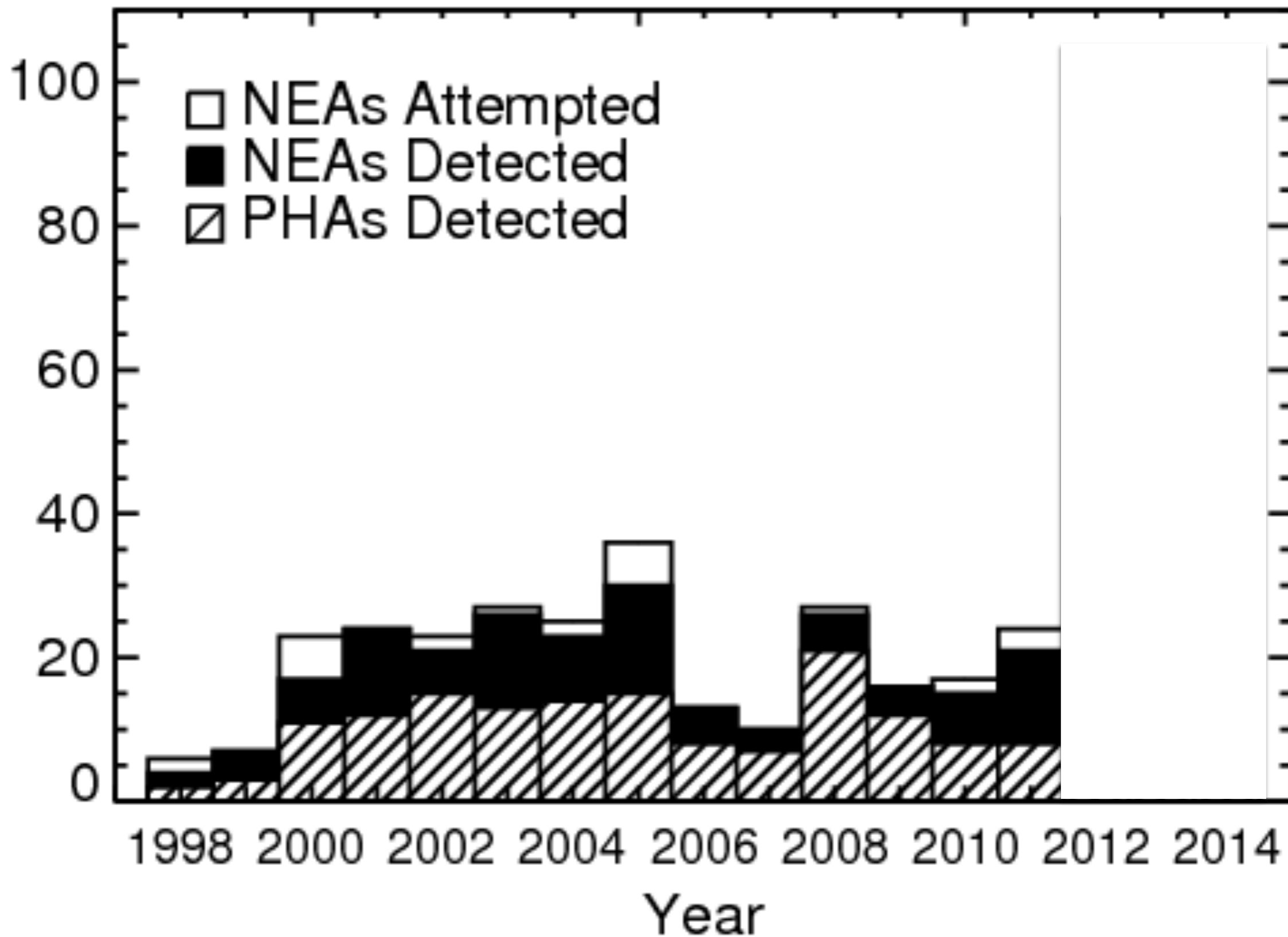
Examples of Radar Observations



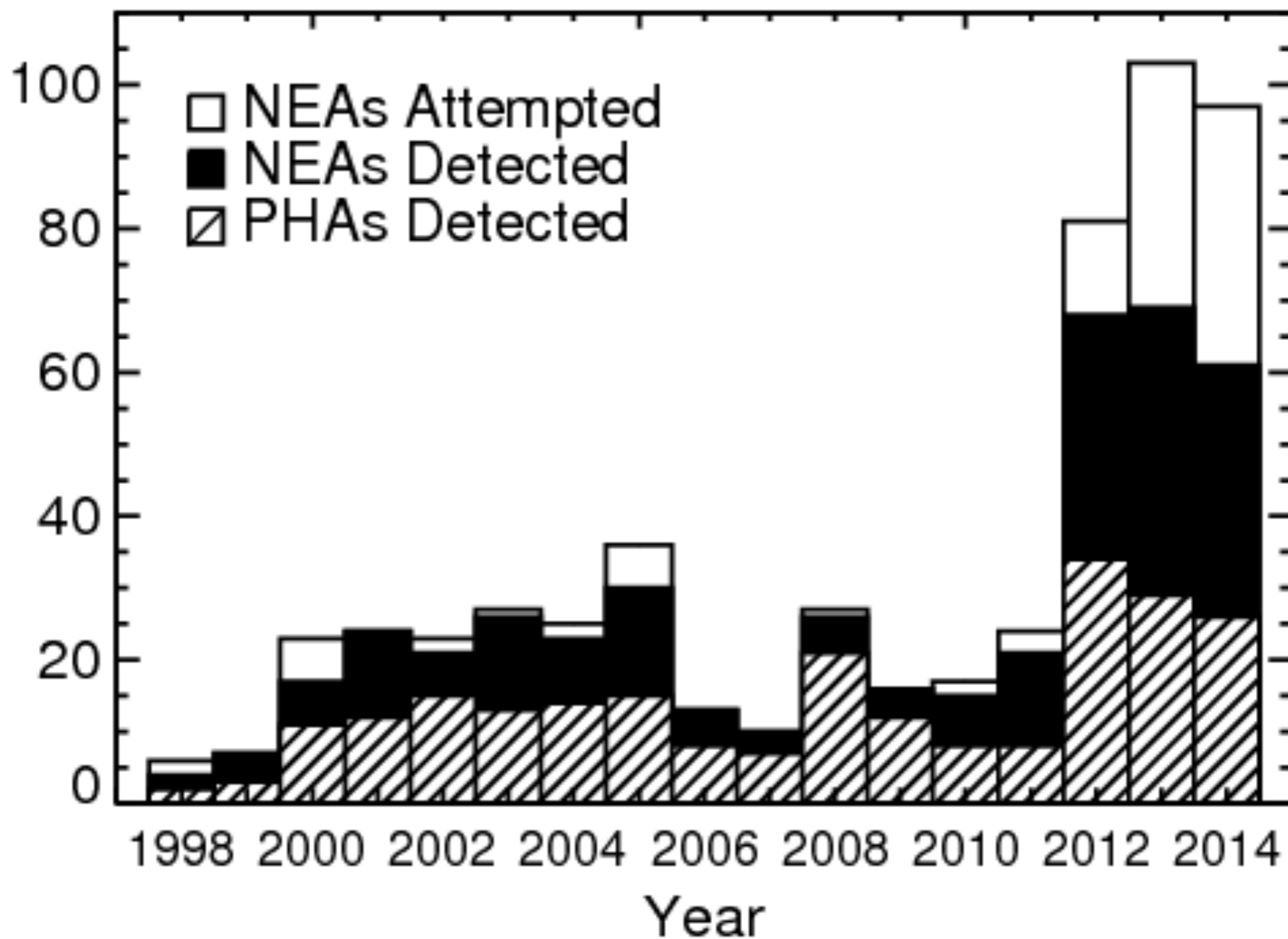
Arecibo: 7.5-m imaging

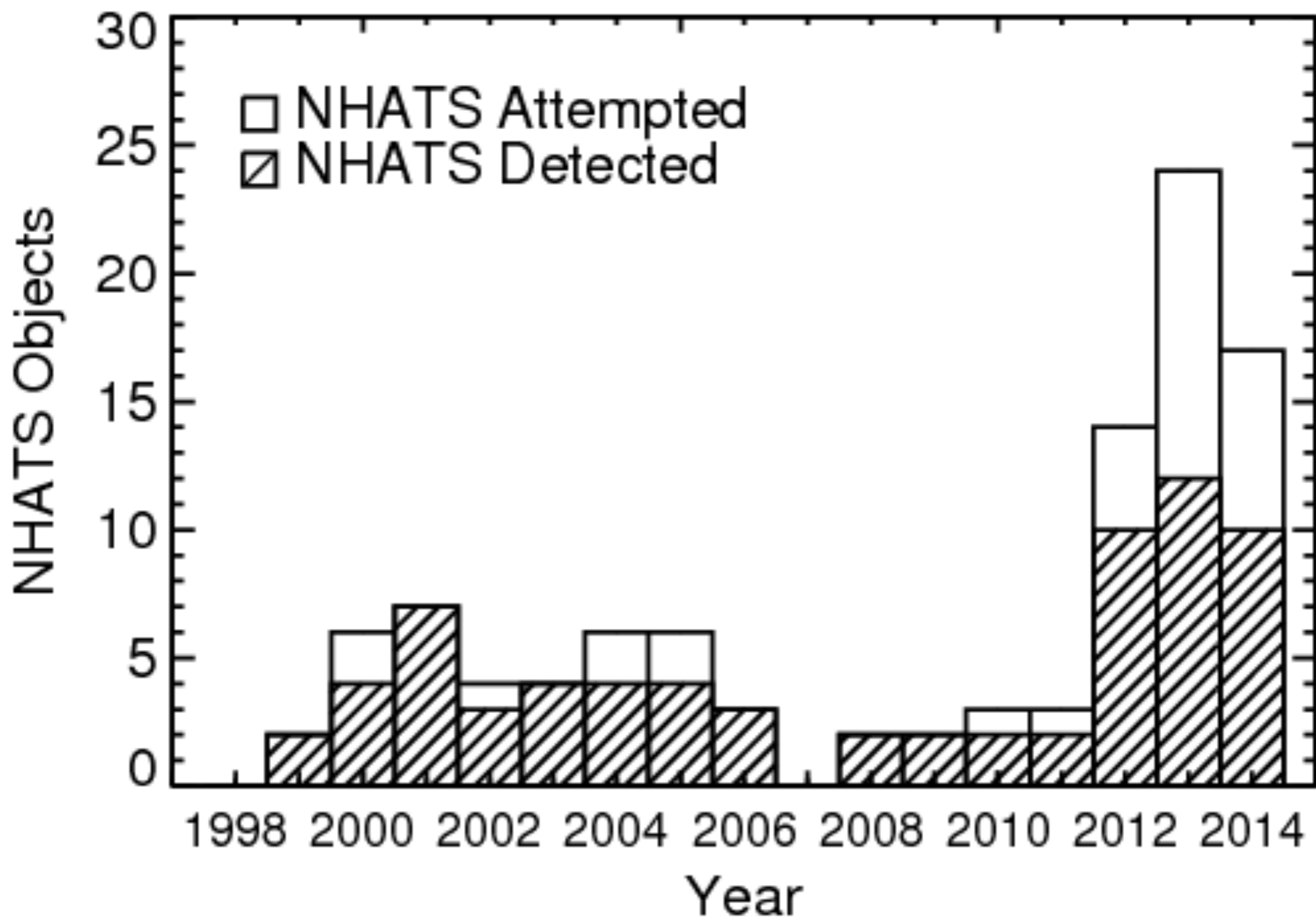
- **(2340) Hathor**
 - 185 optical observations since 1976
 - Pre-radar range uncertainty of ~ 110 us
 - Actually ~ 2500 us off (22-sigma error)
 - Likely due to Yarkovsky orbital drift

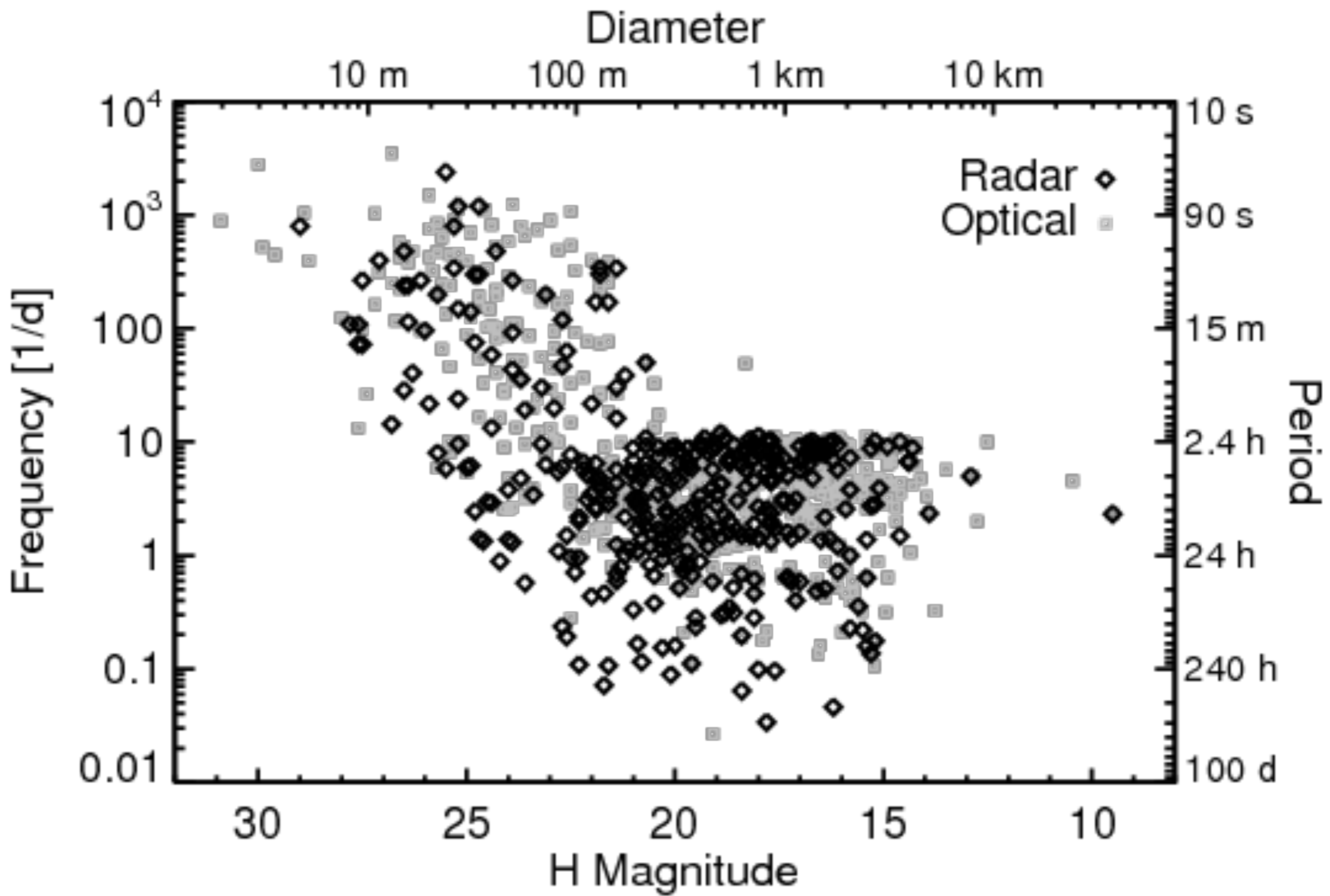
Near-Earth Asteroids

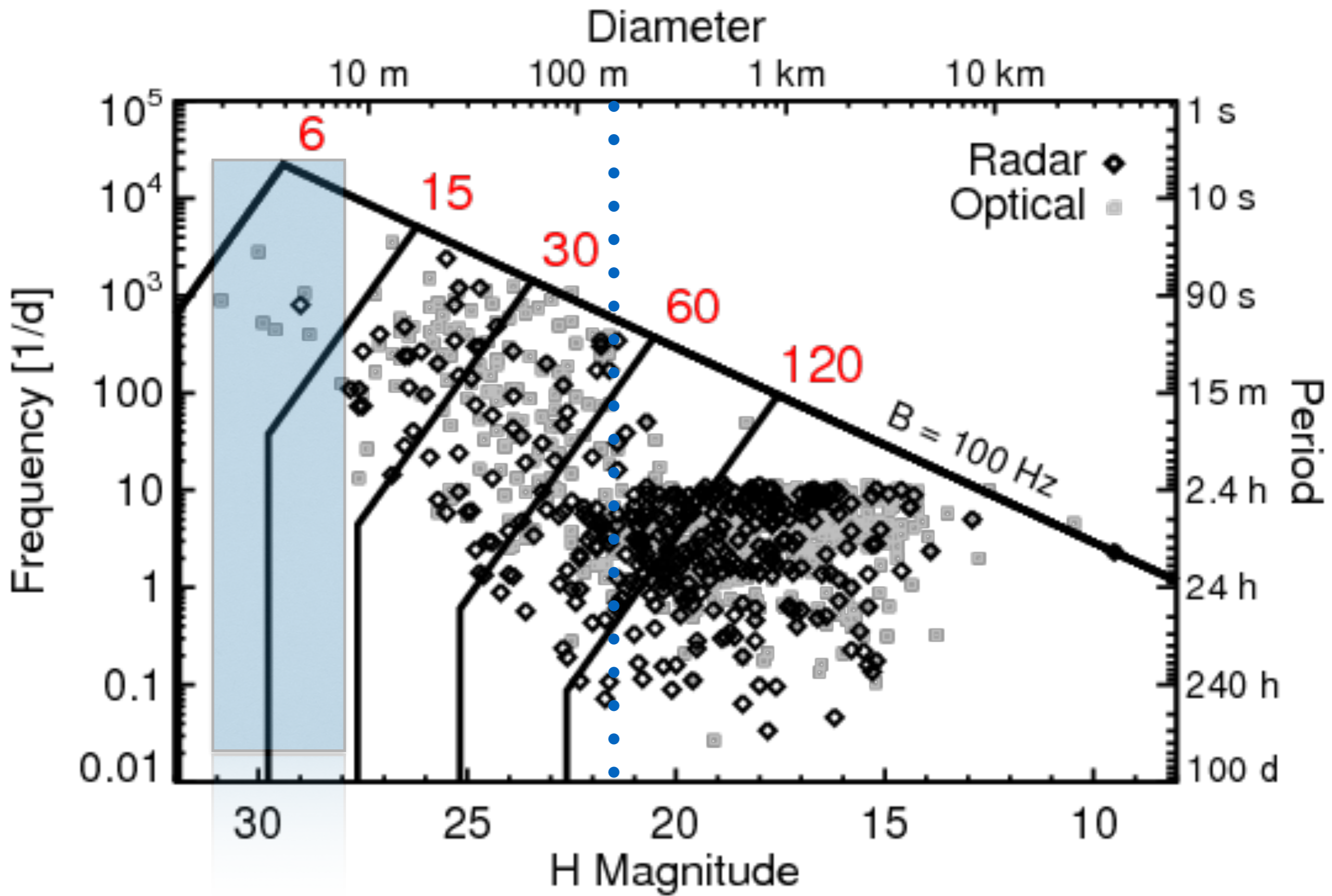


Near-Earth Asteroids









Summary

- The Arecibo radar program is strong and growing, but requires a healthy observatory to continue
- Telescope time and detections are at an all-time high
- All detectable PHAs are attempted as scheduling and transmitter/receiver status allow
- All detections provide astrometry needed for accurate long-term trajectory prediction including impact-hazard determination

2014 QY33 29 Aug 2014

H=27.2 RTT=19s

7 sums of 7 – 2.3 min each

