A Space-Based Occultation Survey

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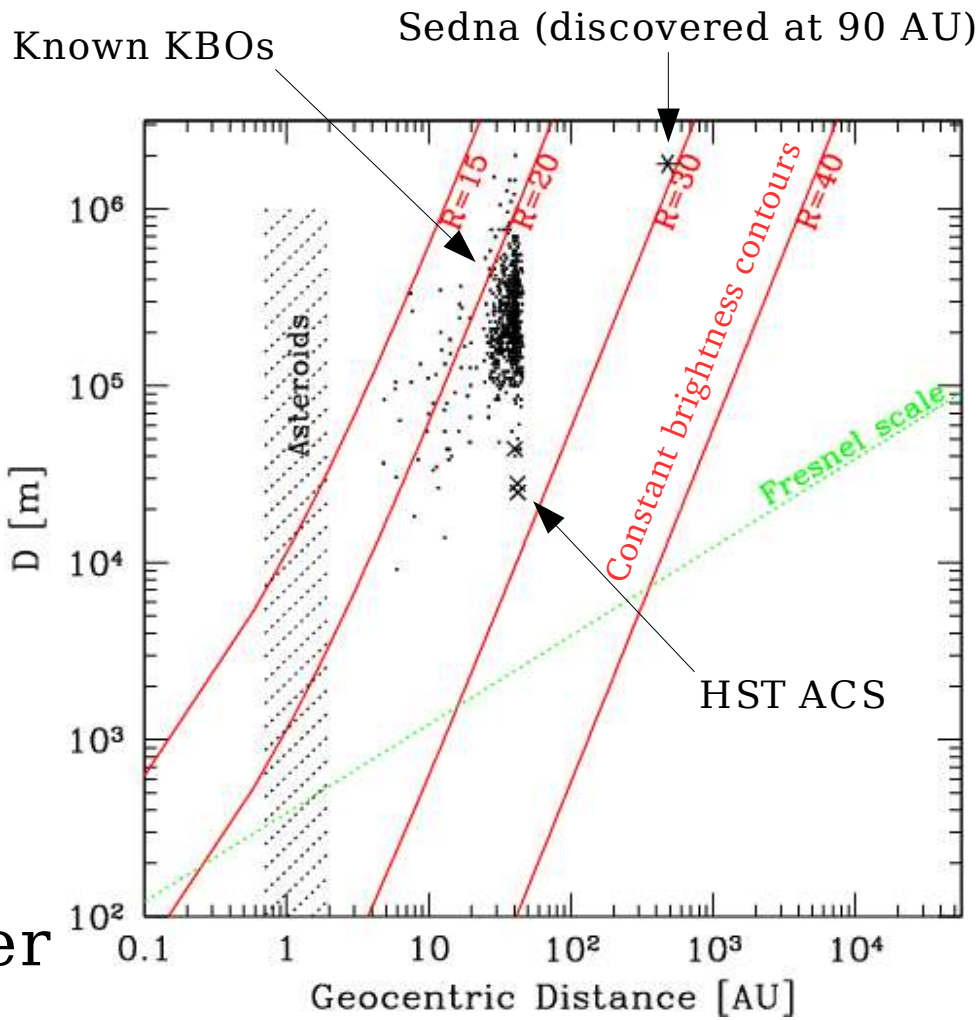
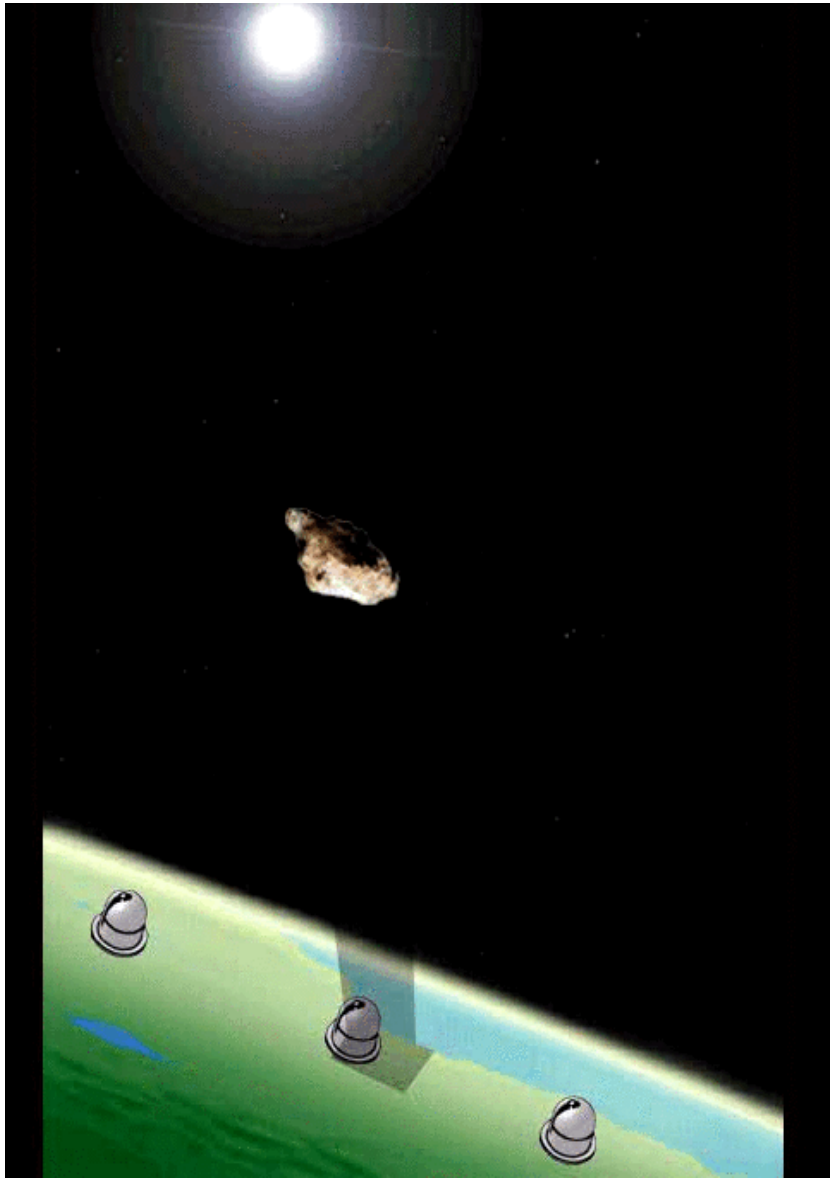
Ball Aerospace

Motivation: Detection of small, distant objects at outer edge of Solar System

- Brightness in reflected sunlight falls off $\propto r^{-4}$
- Limiting magnitude of HST ACS Survey ~28.5
- Discovery of Sedna: many objects between 100 and 1000 AU???
- Oort Cloud: 30,000 AU
- An occultation survey can expand observable parameter space



The Taiwanese-American Occultation Survey (TAOS): A ground-based survey

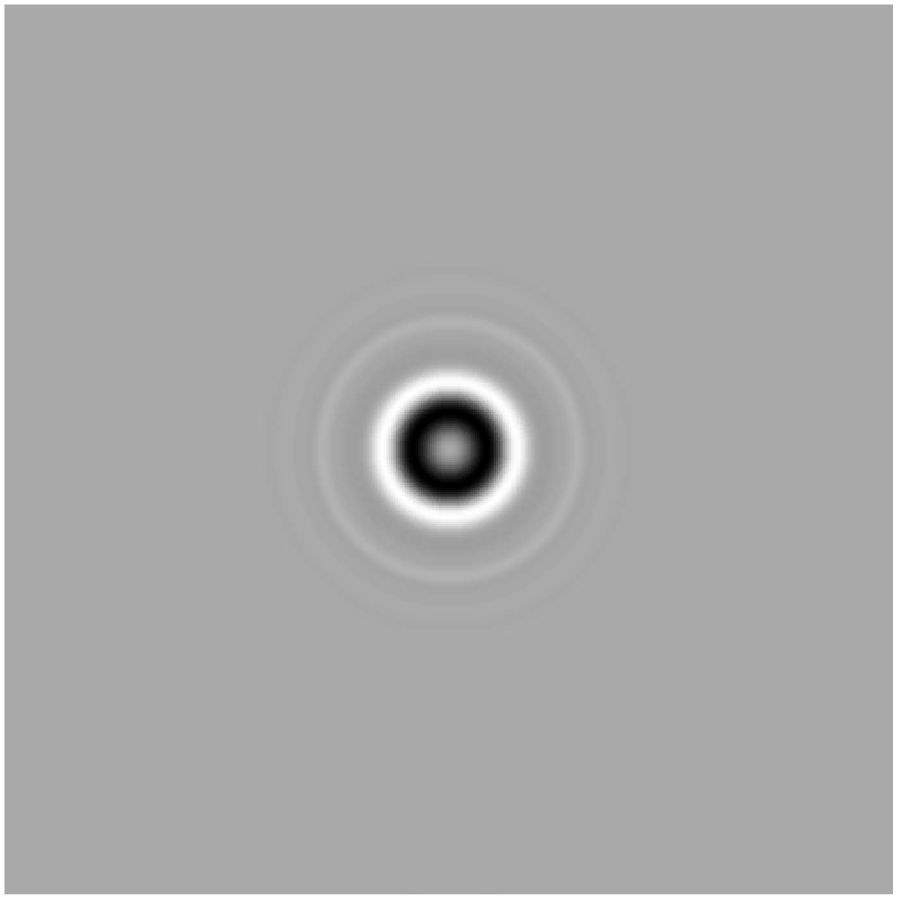


- Samples ~3000 stars at 5 Hz
- Sensitivity:
  ~1km objects at 45 AU
  ~100 km objects at 30,000 AU
- Degeneracy between size, distance, impact parameter
- Expect 10 to 100 events per year when operational (Fall, 2004)

Object sizes and distances near Fresnel scale:
Occultation “shadows” produce diffraction patterns

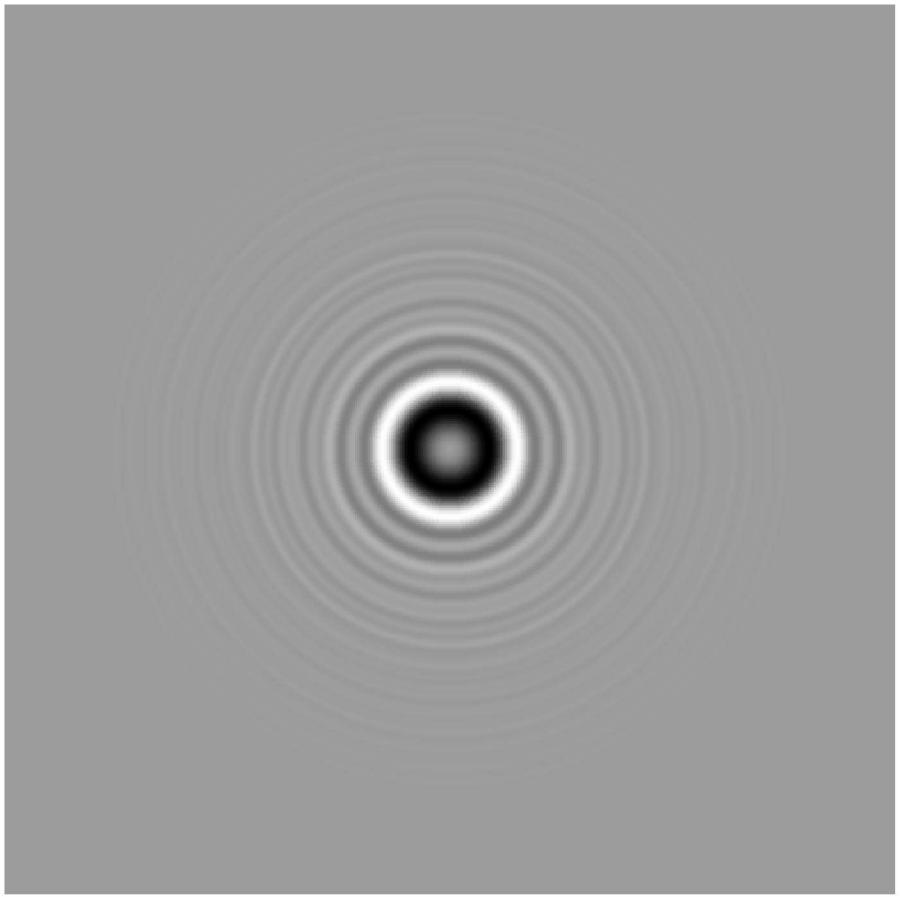
Typical shadows from occultation events projected onto surface of Earth:

1 km object at 45 AU



30 km

3 km object at 45 AU

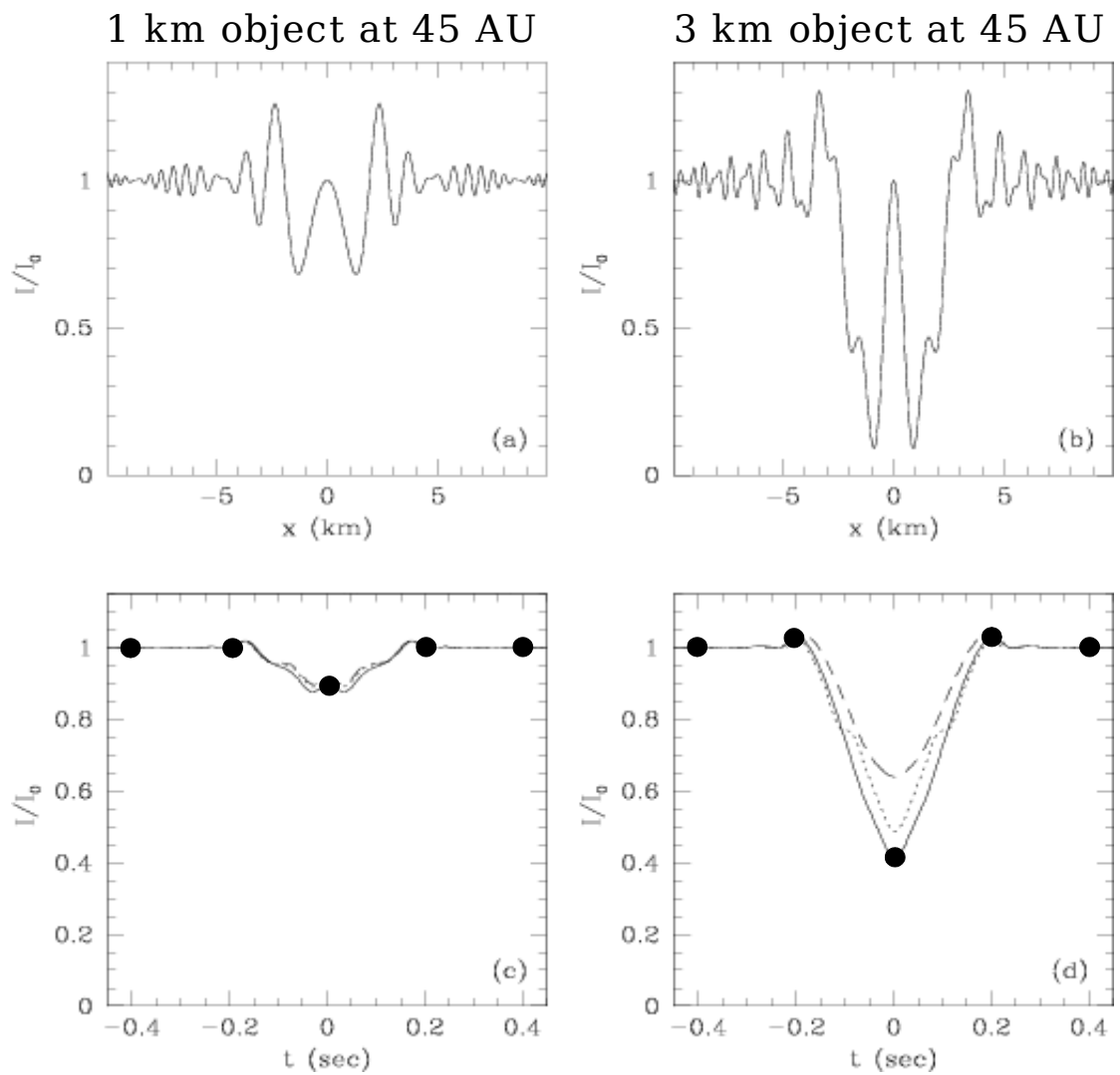


Objects in relative motion w.r.t Earth: shadows move over telescopes, need rapid photometric sampling

Slice through center of occultation shadow, for single wavelength (λ=600 nm).

Lightcurves for broadband A0 star, 5 Hz sampling, impact parameters of 0, .5D, .75D. Large dots indicate times of measurements.

Need very accurate photometry to detect 1km object.



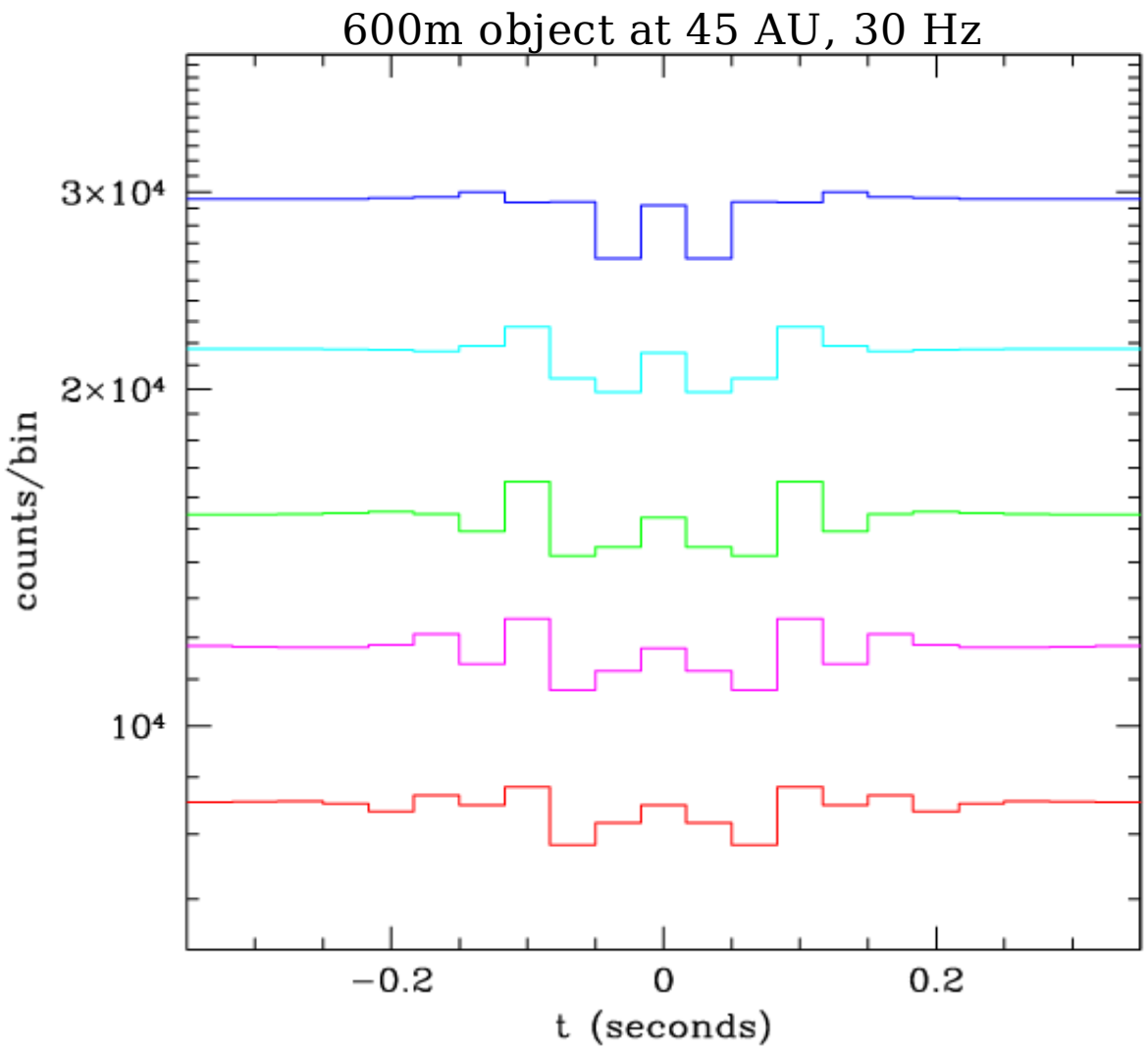
Next-Generation Survey: TAOS in Space

- Wide field of view: Sample 100,000 stars simultaneously
- > 30 Hz sampling
- < 1% photometry
- Modest spectral dispersion: simultaneous measurements in five passbands

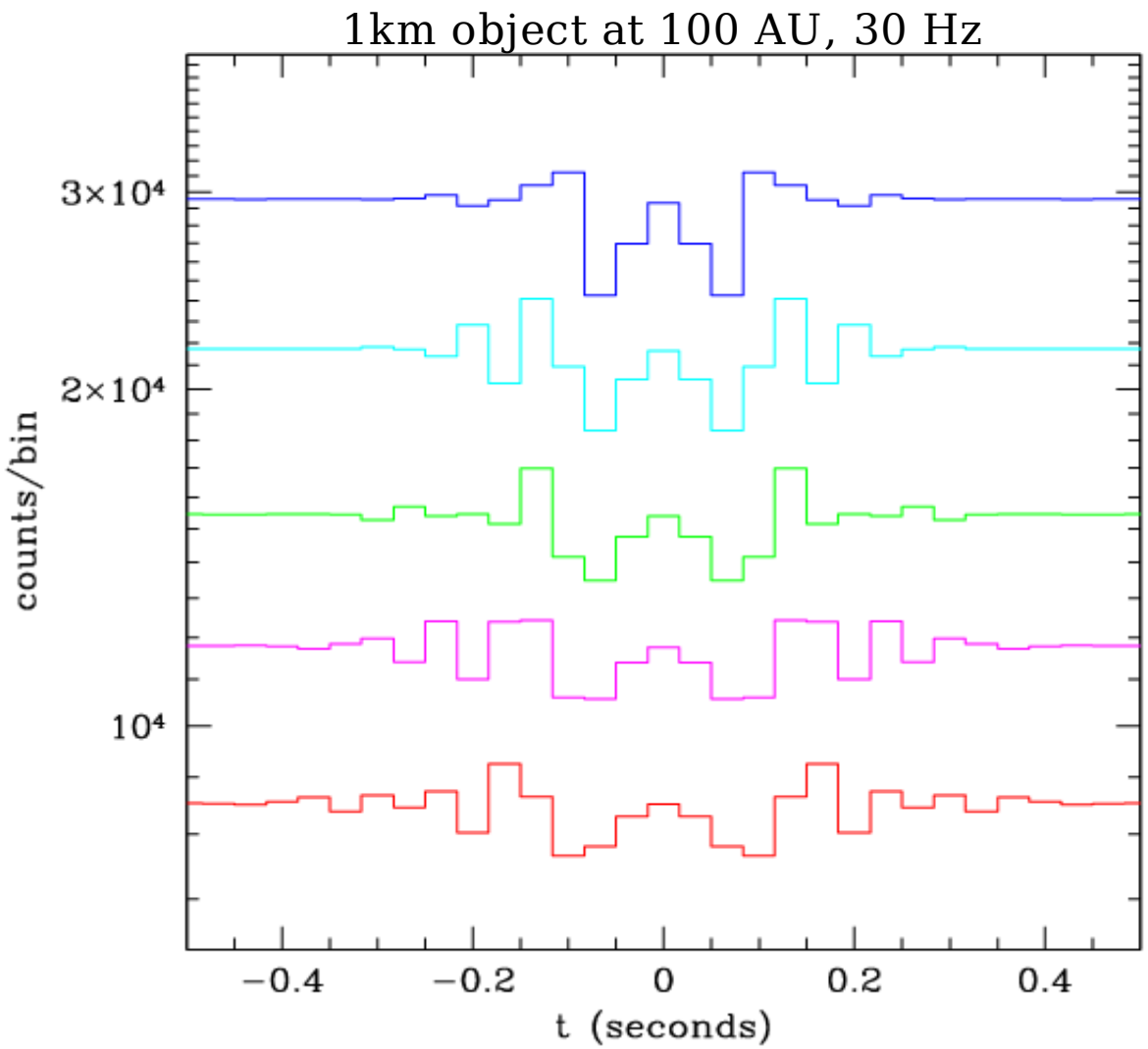
→ Sensitivity to 600m objects at 45 AU, 10km objects at 30,000 AU

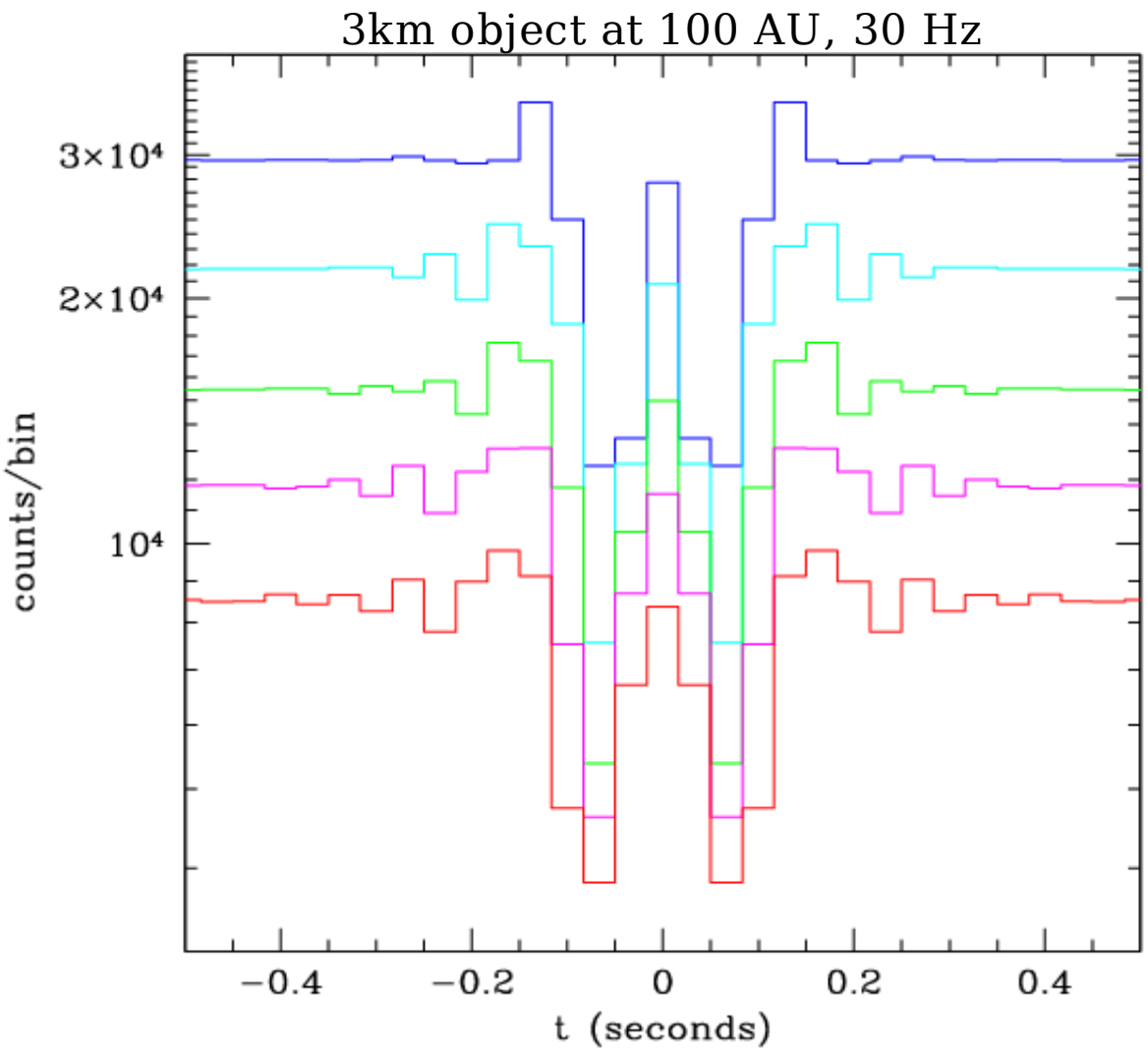
→ High sampling rate, multiple pass bands break degeneracy, ***get size and distance information!***

1% photometry, fast readout: can resolve very small KBOs

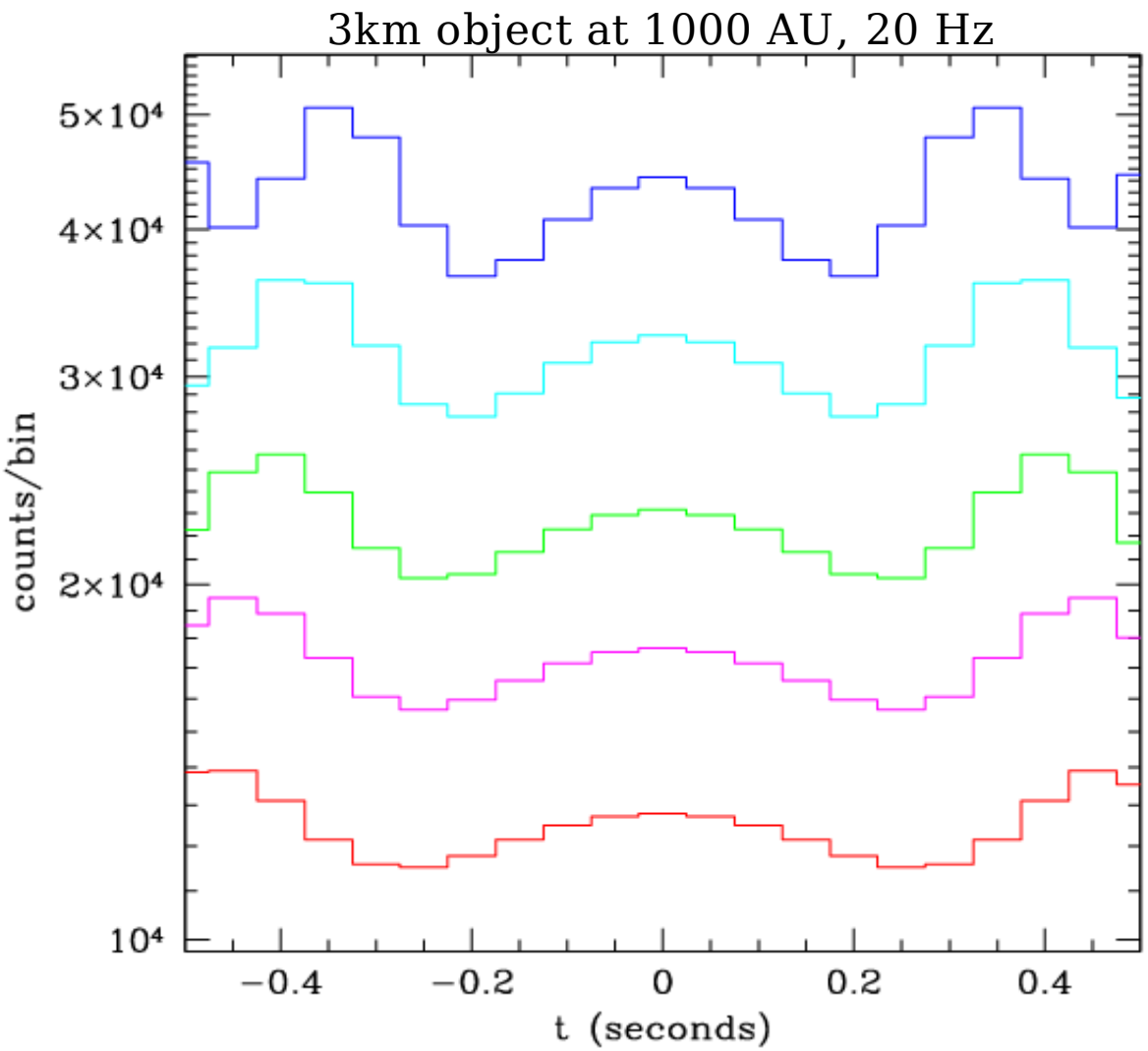


Multi-band, resolution of diffraction peaks: break degeneracy between size, distance

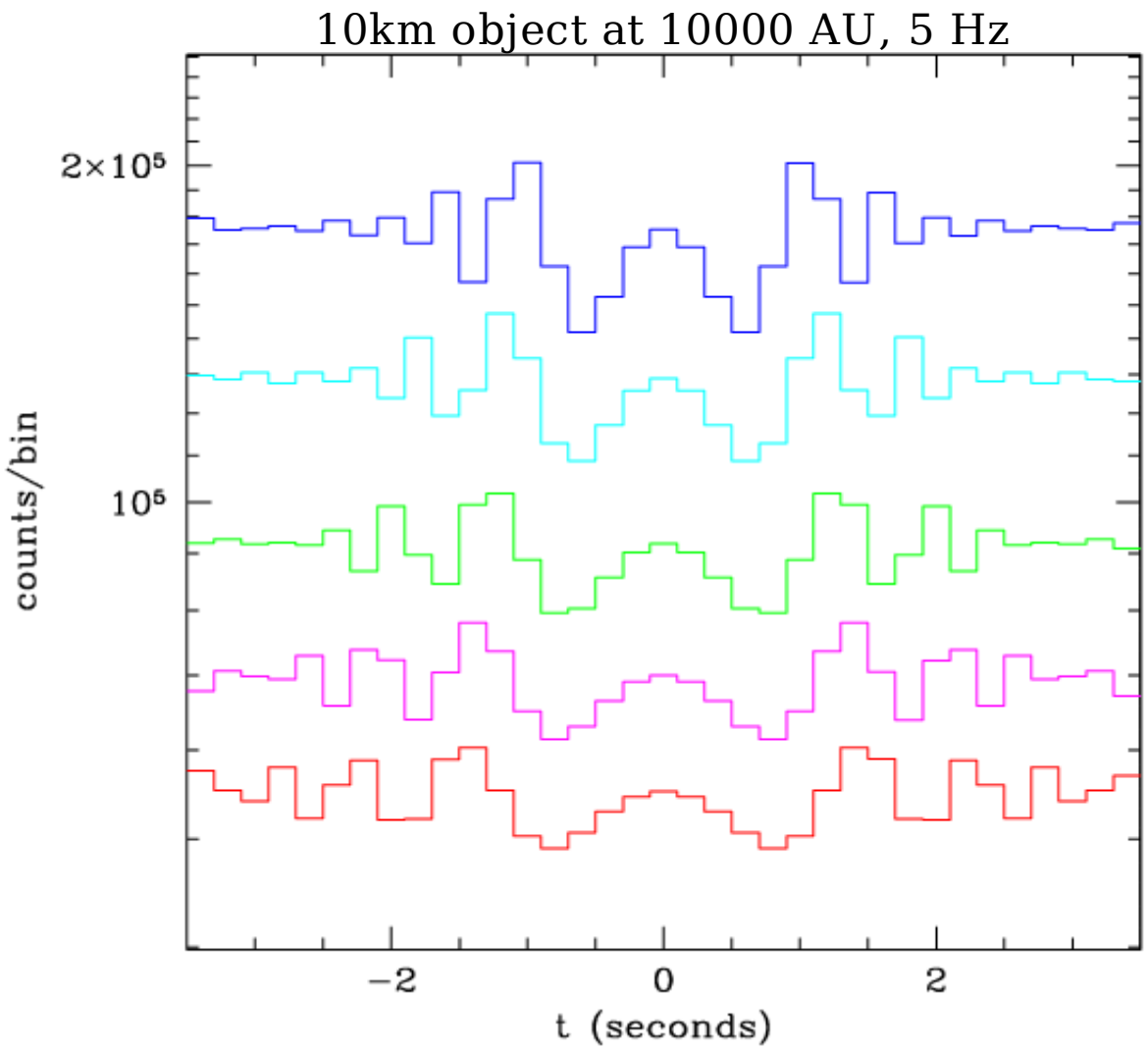



3km object at 100 AU, 30 Hz
3×10⁴
2×10⁴
10⁴
counts/bin
−0.4
−0.2
0
0.2
0.4
t (seconds)

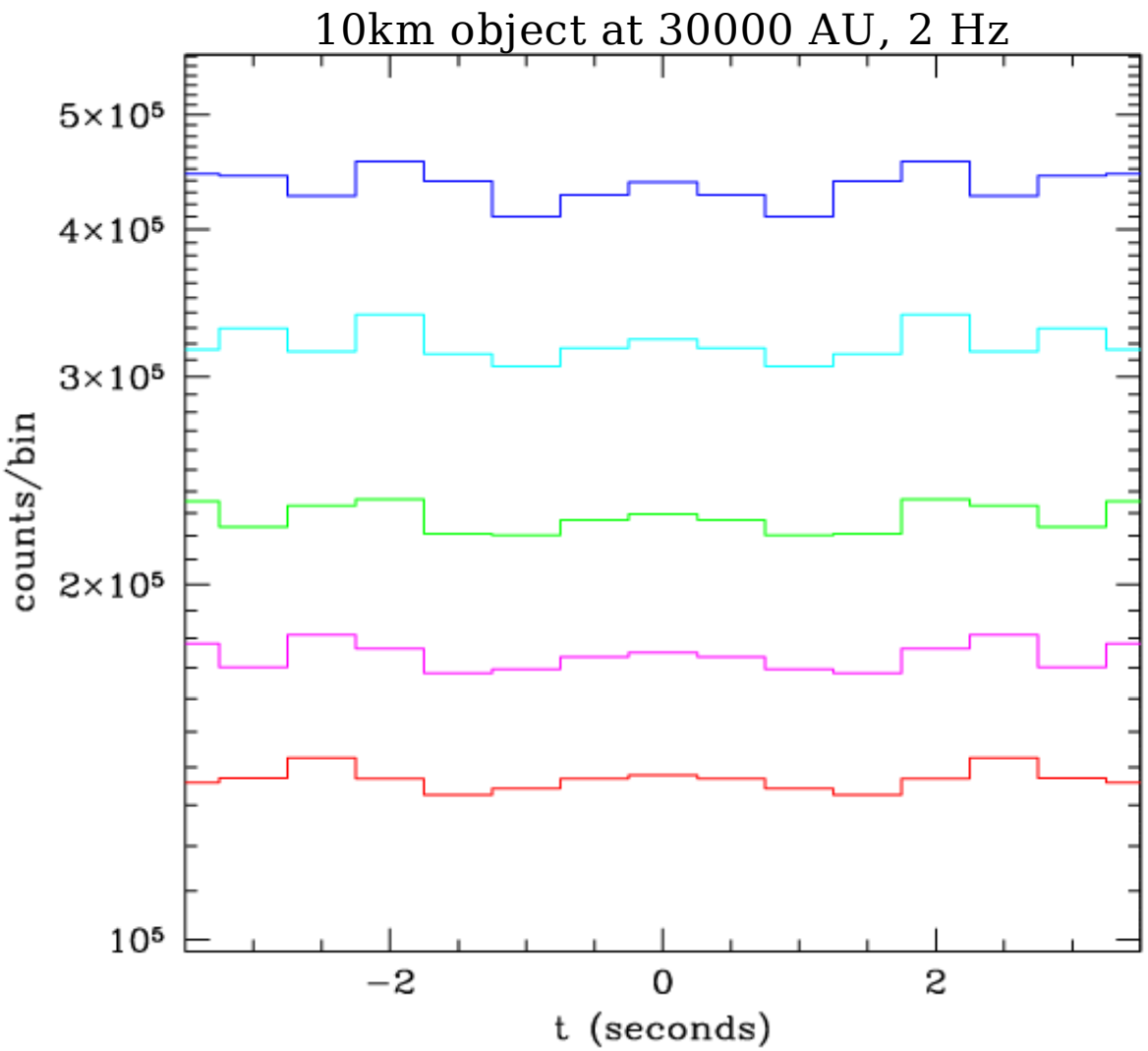
Sensitivity to small objects in Sedna-like orbits



Inner Oort Cloud object



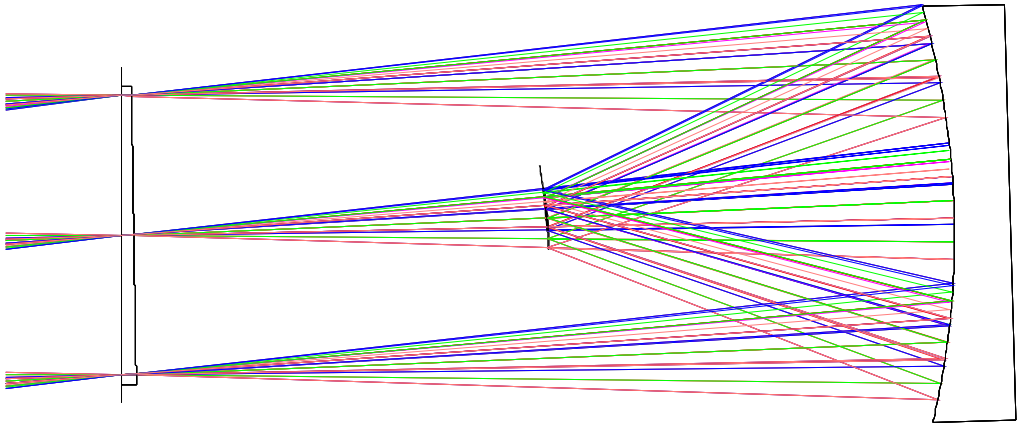
Outer Oort Cloud object

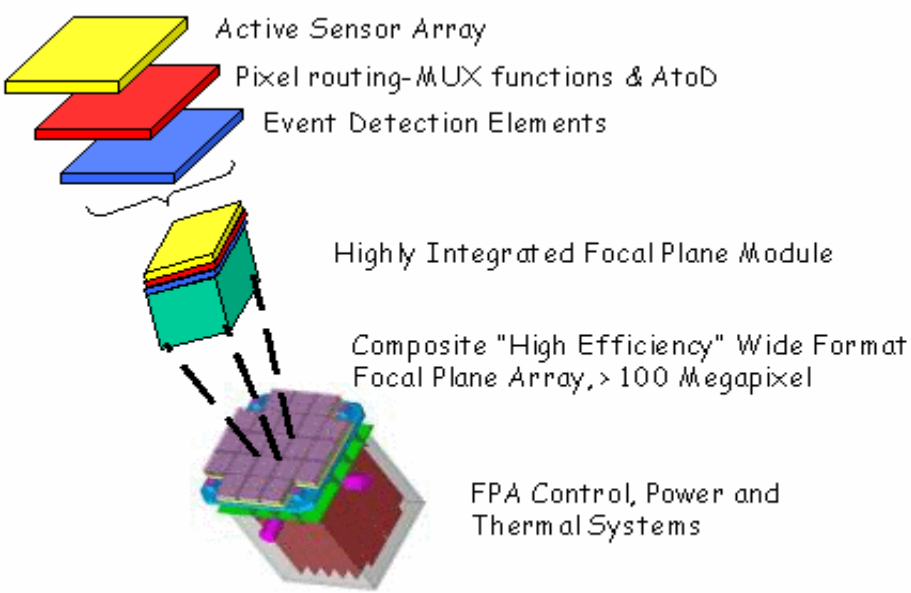


Straw Man Design

- Based on Kepler Schmidt telescope design
- ~100□° FOV
- Small angle prism on corrector for spectral dispersion over ~5 pixels

  (5 pass bands)
- Image 100,000 stars





Focal Plane

- Close-packed geometry (maximize focal plane coverage)
- 100 megapixels
- Fast readout (30 Hz or higher)
- Multiple sub-aperture readout
- Need significant amount of on-board processing

Data Volume estimates are daunting! Need physical reduction techniques for viable space mission

- 100,000 star objects
- Each star has 10x10 window of pixels for noise processing
- Digitization 12 to 16 bits (14)
- Sampling-integration rate 10 ms with limited read-time
- ~100 Event Processors
- Event Processing data rate = 140 Mbps
- Number of events 100's to 1000's (TBD) per year
- 10,000's seconds of data per year vs 31 Msecs per year
- Kbps or higher telecom links would be acceptable with on board buffering

Expect 1000's of detections per year.