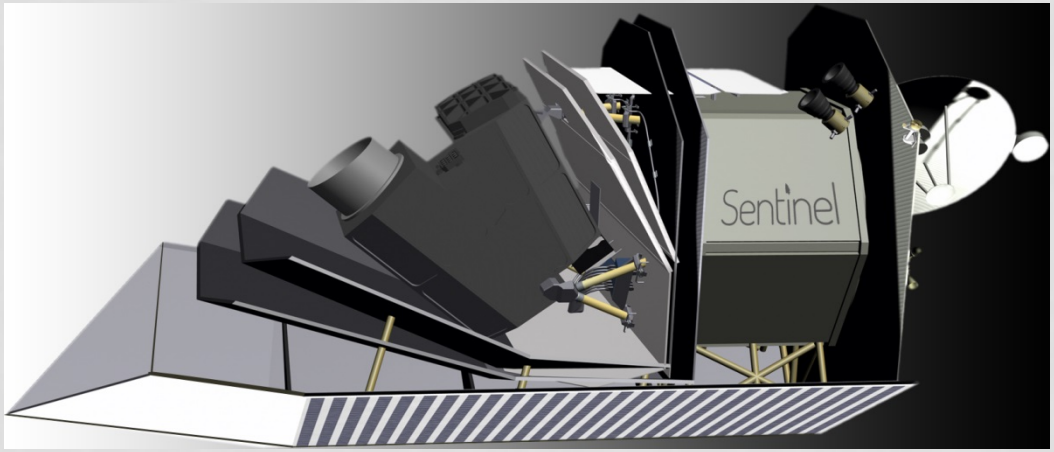


B612 FOUNDATION SENTINEL

MARC BUIE – MISSION SCIENTIST

Project Status

MISSION GOALS

- 90% of NEOs with D>140m
- Build a more complete catalog of PHAs
- For those discovered, provide multi-decade warning for PHAs
- Add to catalog for smaller objects
  - Better determination of size-frequency distribution
  - Identify potentially interesting mission targets

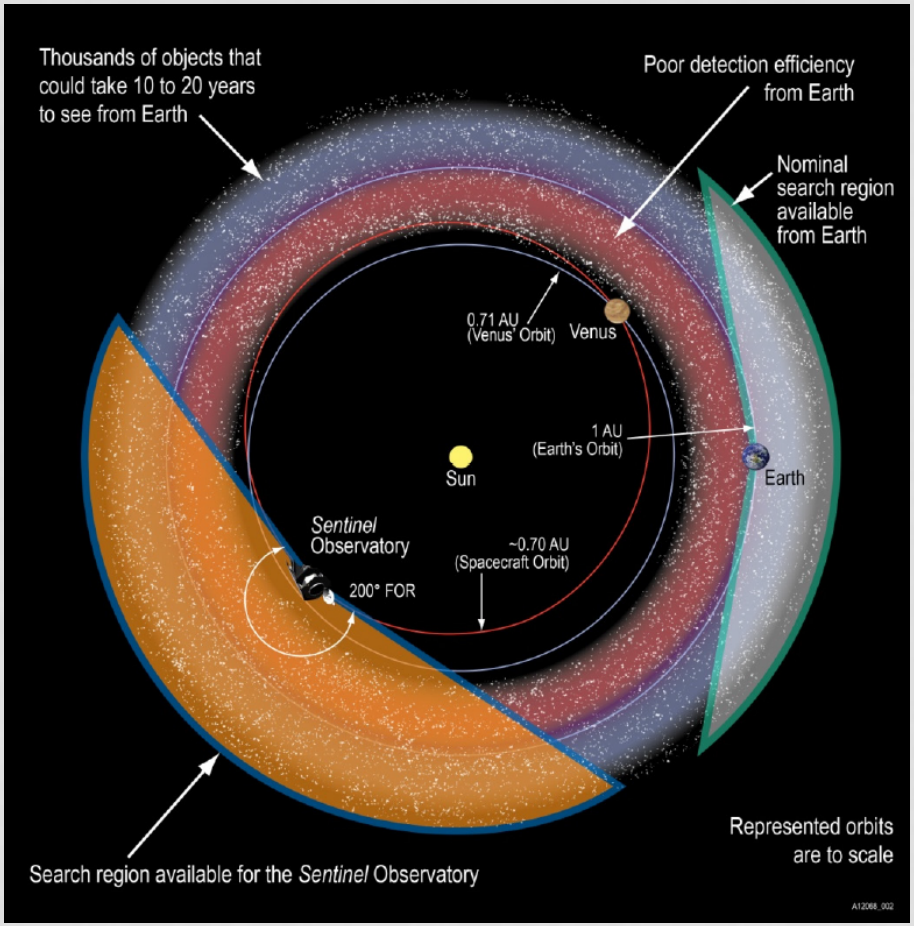
BASELINE MISSION CONCEPT

- Infrared 0.5m space telescope
  - Passive cooling on telescope structure
  - Active cooling on detector
  - Expendables: thruster fuel for desaturating gyros
- Orbit interior to Earth
  - a=0.66 AU, i=0.27°, e=0.091
  - Gravity assist from Venus to lower aphelion
  - Short synodic period between Sentinel and PHOs

BASELINE MISSION CONCEPT

- 1.9° x 5.2° field-of-view imager
  - 2.15 arcsec/pixel scale = 1.6*FWHM
  - 5 – 10 micron sensitivity
  - Six 30-s exposures for cosmic ray strike removal
  - Filling factor is 96.3% (1.1mm gaps between detectors)
- Field of regard covers the sky > 80° from the Sun
  - 28 days to cover the field of regard four times
  - [0,1,48,49] hour timing on field samples
- Low data rate to DSN
  - Full images not usually transmitted
  - Region of interest around transients returned to ground

VIEWING GEOMETRY



ANALYSIS OF SYSTEM PERFORMANCE

- Orbit quality
- Sensitivity
- Completion rate
  - Differential
  - Cumulative
- System design trades
- Main-belt asteroid impact on survey
- Limiting factors

ORBIT QUALITY

- Initial detection and first orbit estimate comes from 4 measurements spanning 49 hours
  - Linkable tracklet
- First recovery provides a 28-day arc (or better)
  - Goal for object to be considered discovered
- Second recovery provides a 56-day arc (or better)
  - Orbit good enough for recovery with reasonable effort for at least 100 years

BASELINE CADENCE

0	1	2	3	4	5	6	7	8	9	10	11
0d 0h	0d 1h	2d 0h	2d 1h	26d 0h	26d 1h	28d 0h	28d 1h	n*26d 0h	n*26d 1h	n*28d 0h	n*28d 1h

Object not observable if solar elongation is ≤ 80°

Observations are in groups of 4 (observing cycle)

Sampling rate between observing cycles set by time needed to cover the field-of-regard (FOR)

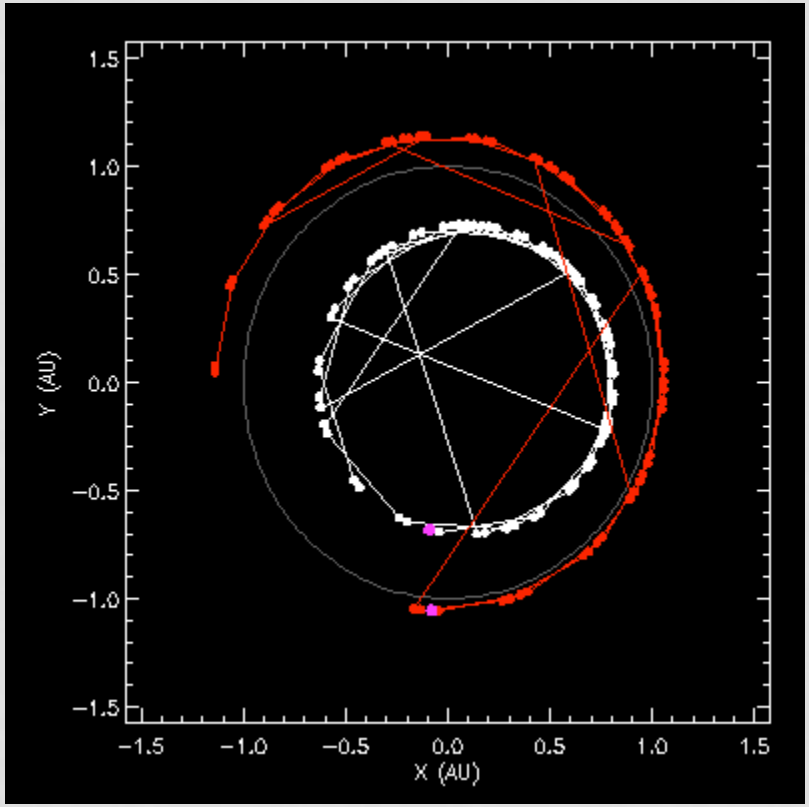
SNR ≥ 5, sources are all transients

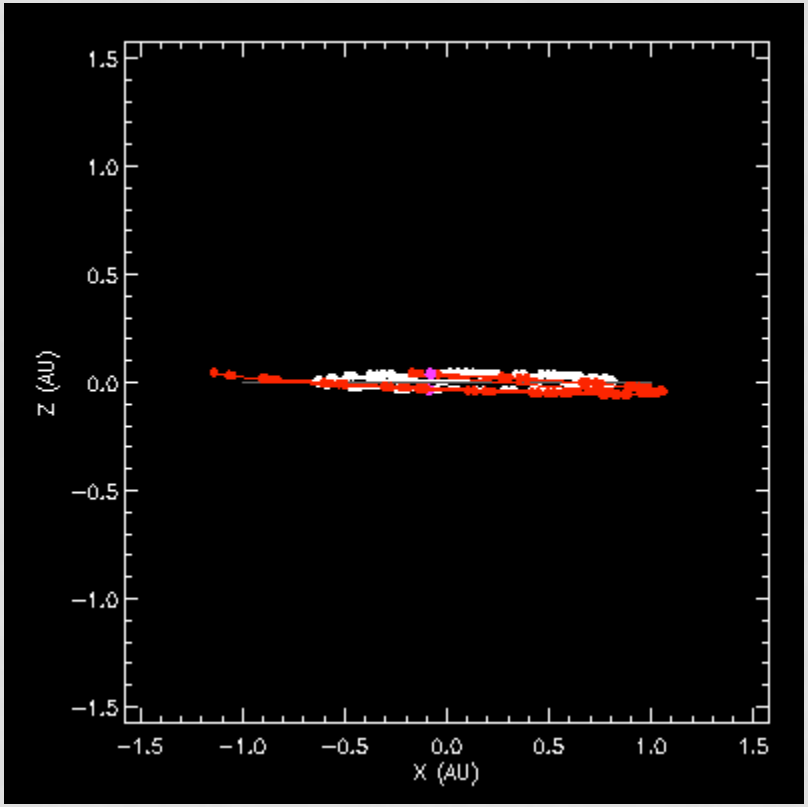
TEST OBJECT LIST

	#1	#2	#3
a	1.1	1.13	2.13
e	0.05	0.15	0.55
i	3	3	3
Ω	127.2	127.2	127.2
ω	185.1	185.1	185.1
M	285	285	285

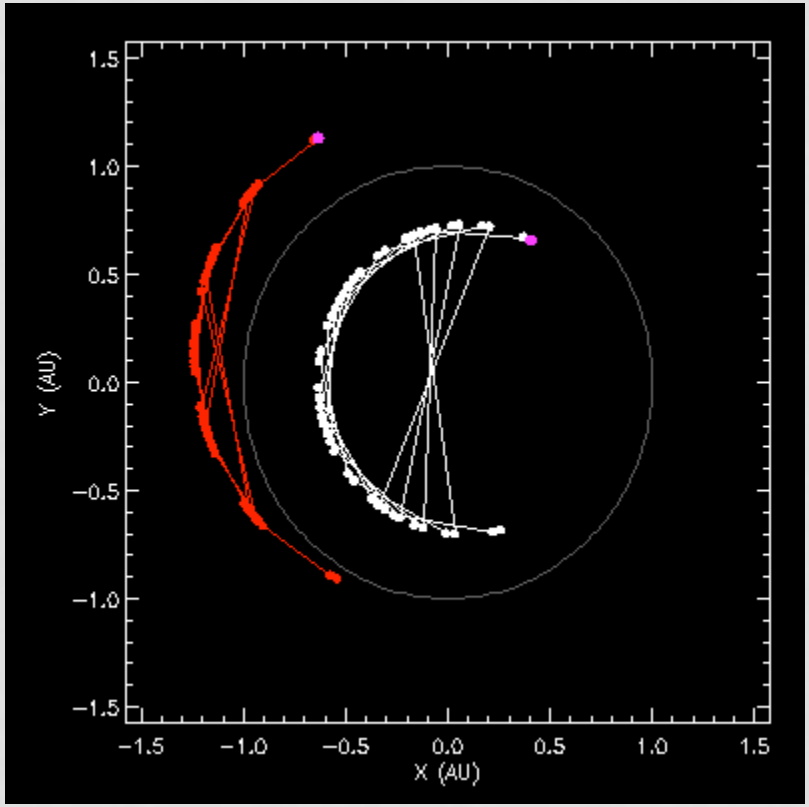
#1 – orbit close to Earth's orbit
#2 – intermediate orbit
#3 – high eccentricity orbit

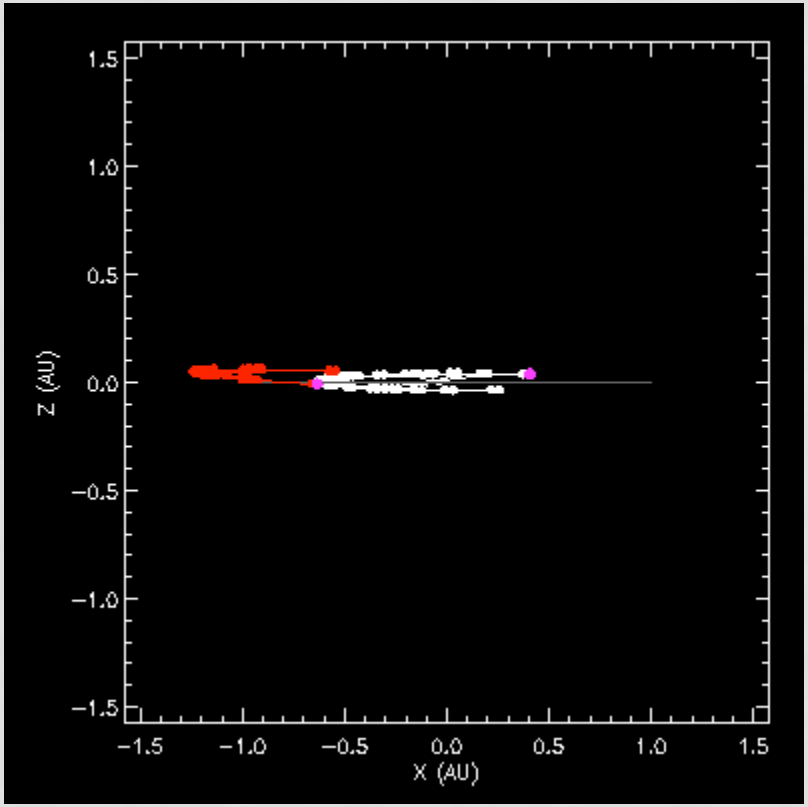
OBJECT #1
MISSION COVERAGE



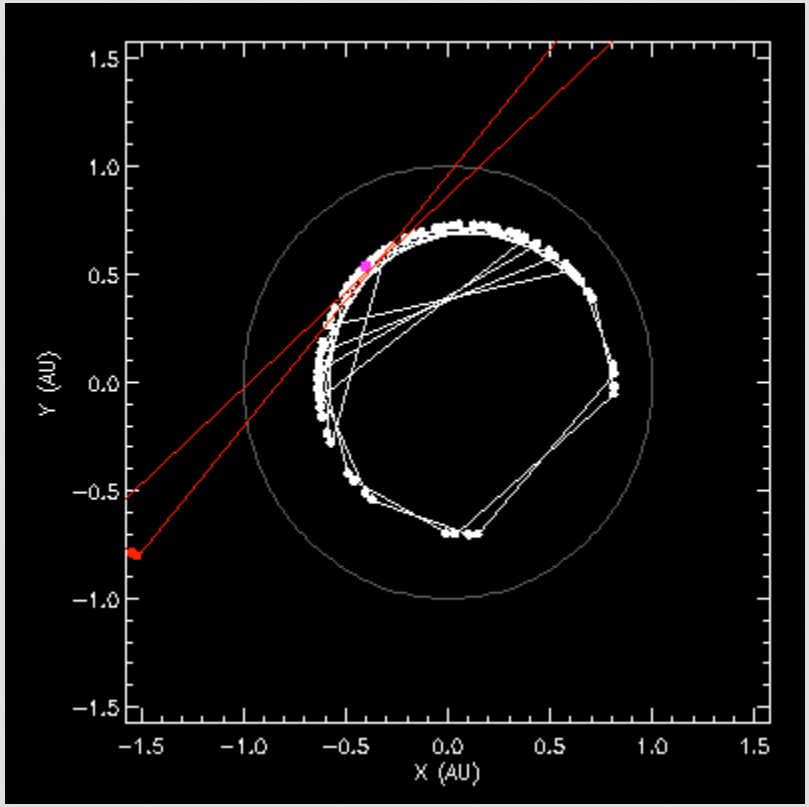


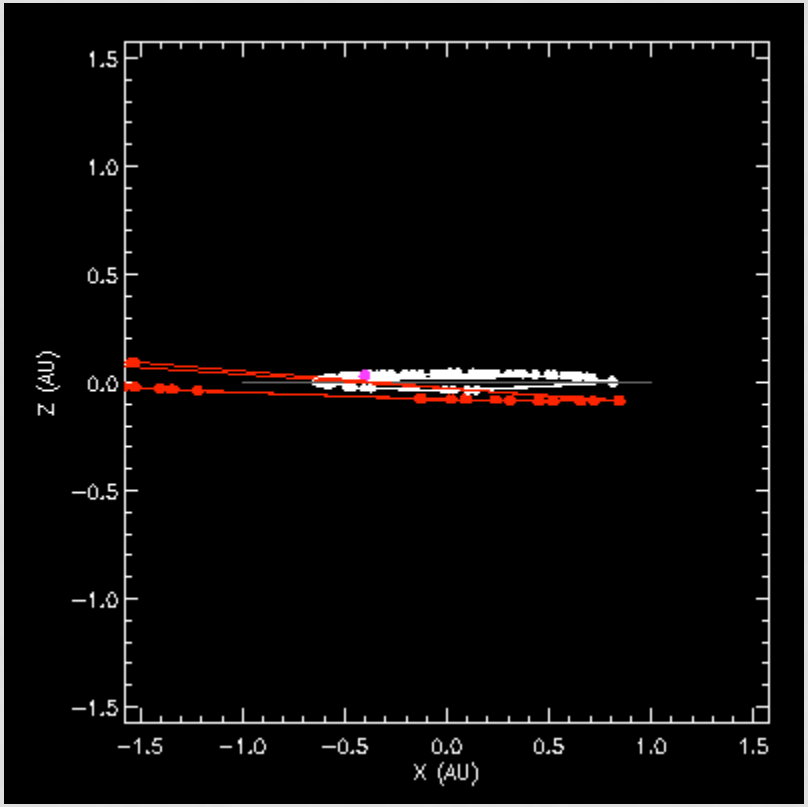
OBJECT #2
MISSION COVERAGE



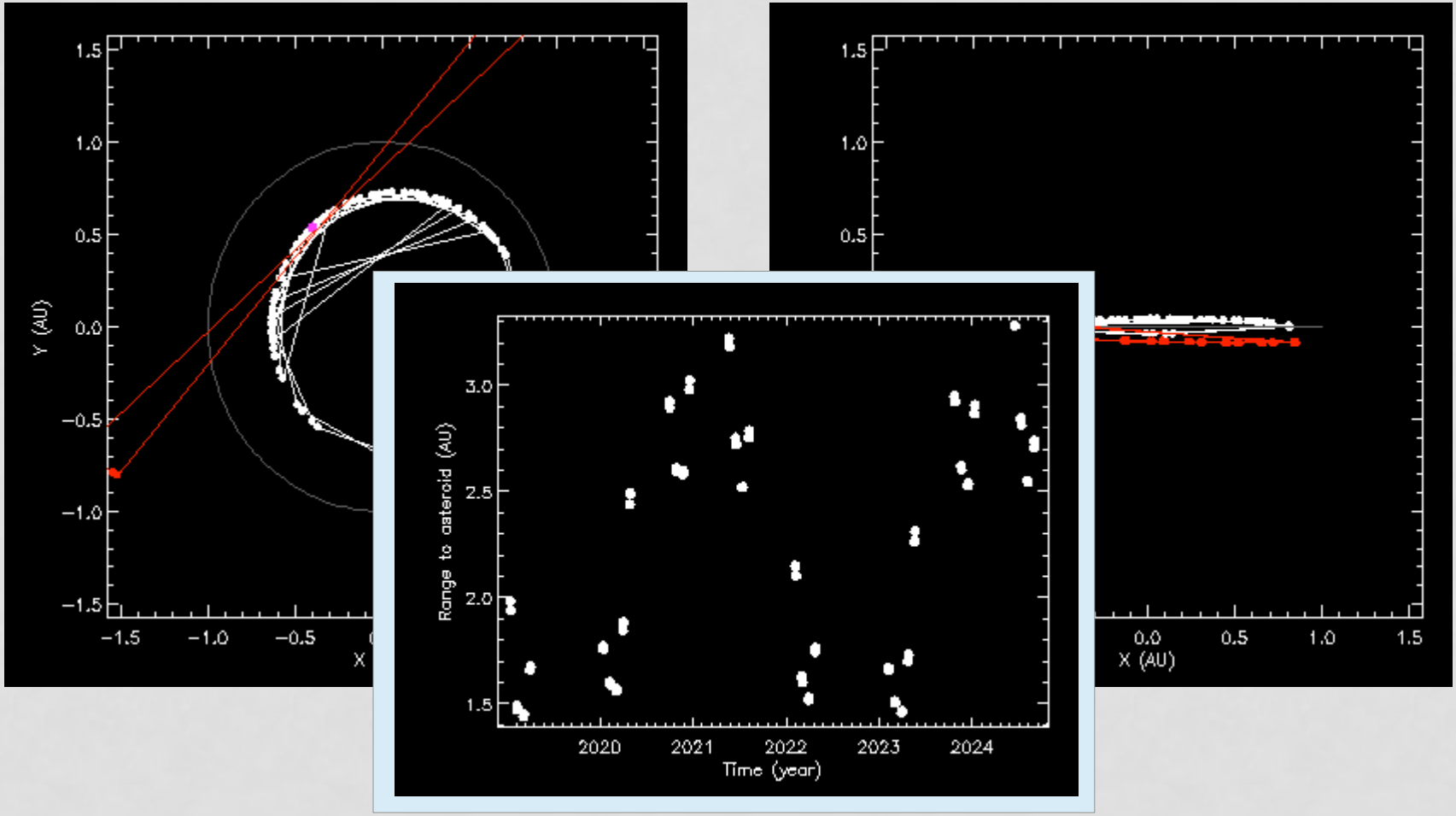


OBJECT #3
MISSION COVERAGE

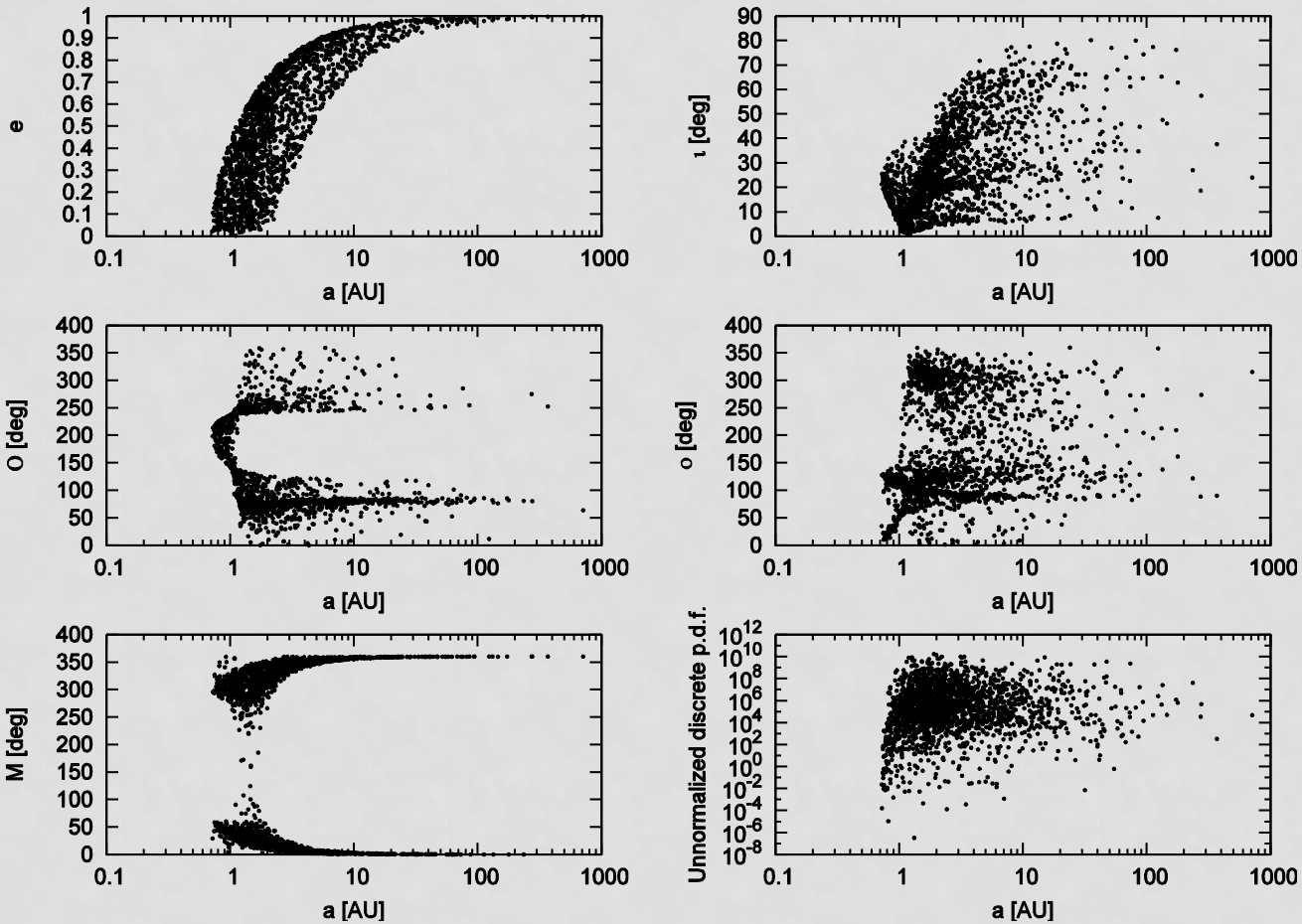




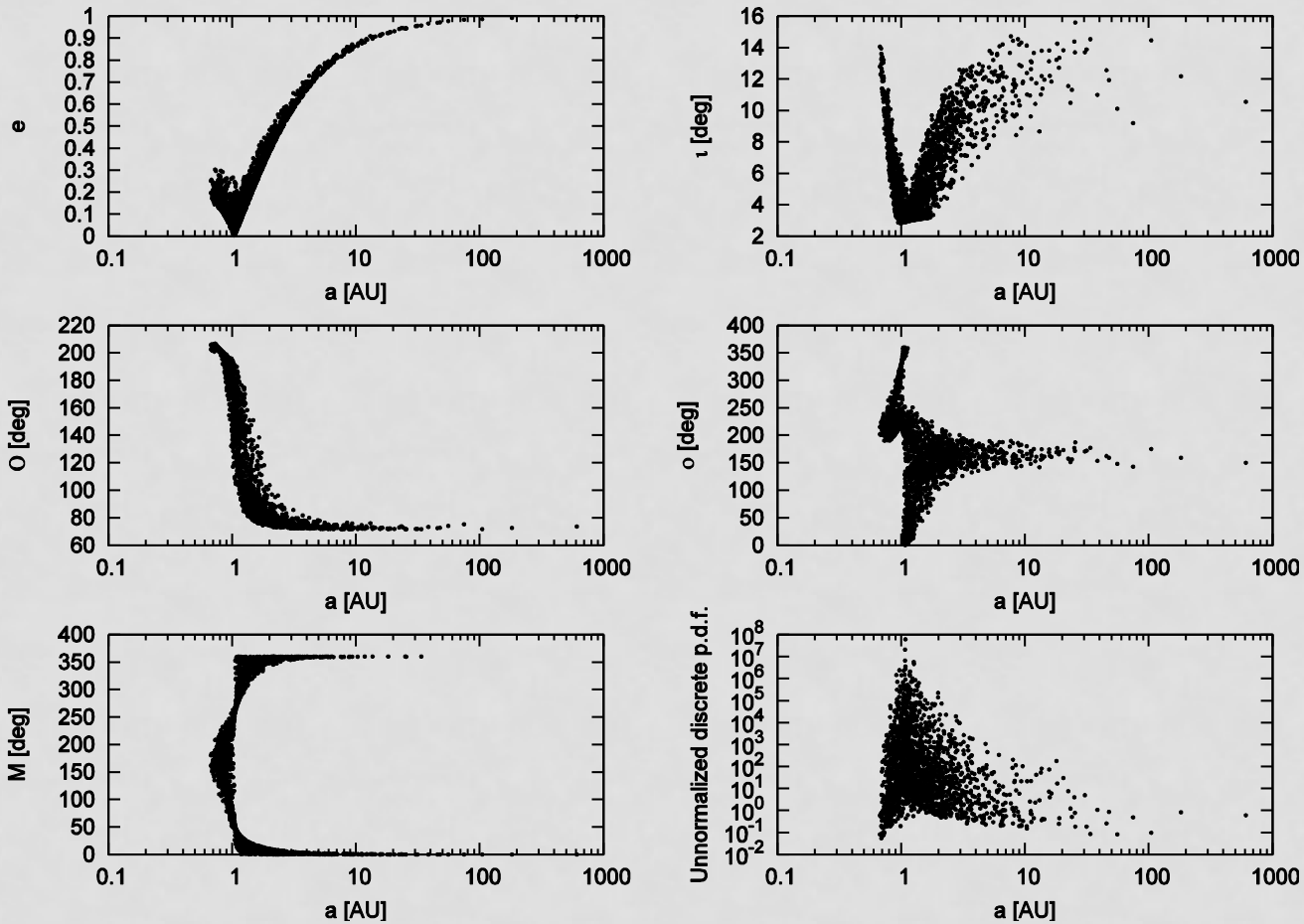
OBJECT #3
MISSION COVERAGE



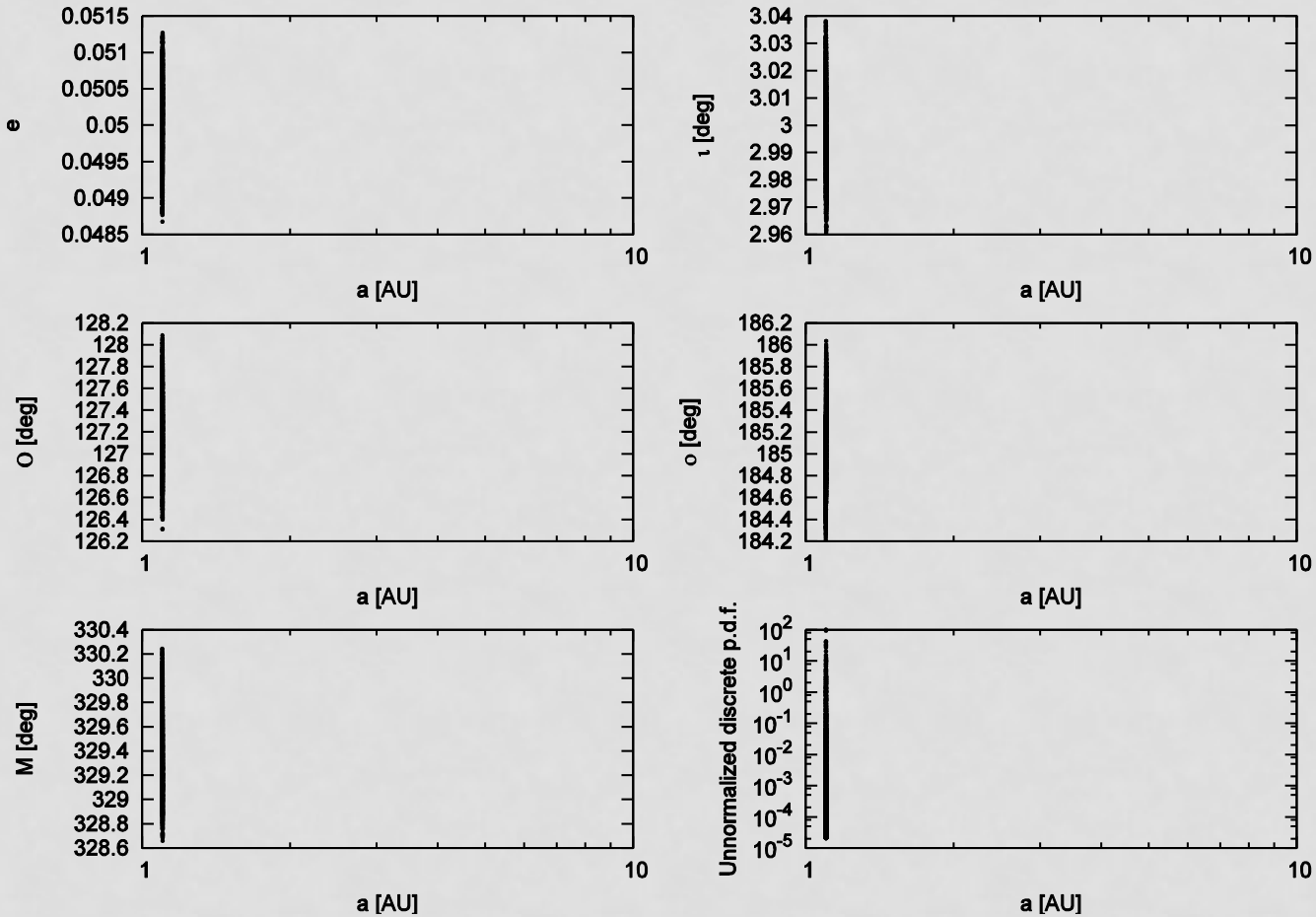
OBJECT #1, 1H ARC (2 OBS)



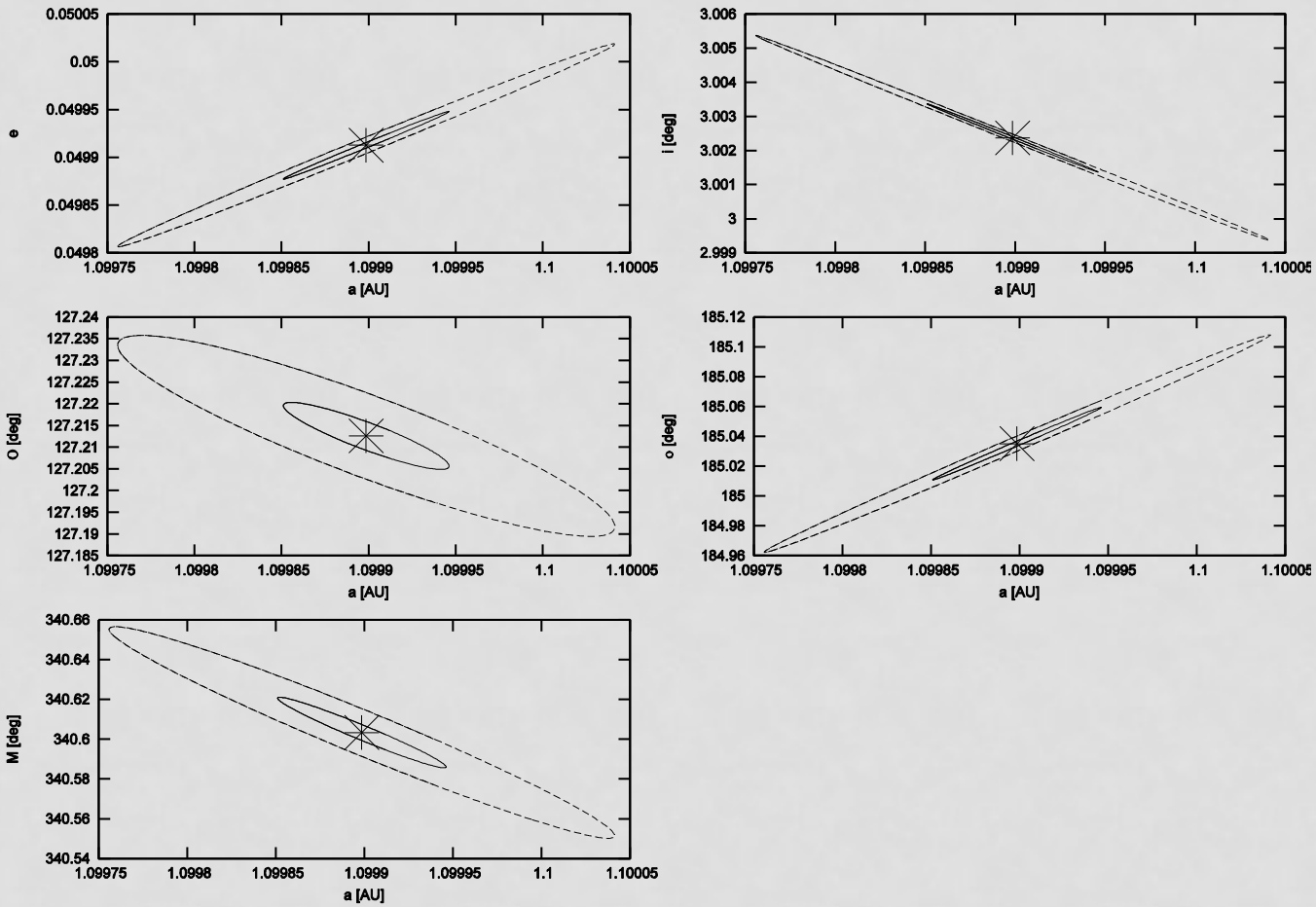
OBJECT #1, 2D ARC (4 OBS)



OBJECT #1, 28D ARC (8 OBS)



OBJECT #1, 56D ARC (12 OBS)



OBJECT #1, 53D ARC

- 24d predict Positional error σ_{α}=1.1" σ_{δ}=2.3"
- 0.5y predict Positional error σ_{α}=16" σ_{δ}=1"
- 10y predict Positional error σ_{α}=18" σ_{δ}=2.3"

- Three linked observing cycles achieves a very good orbit for long-term future followup observations.
- This example is for consecutive observing cycles. Furture predictions are more accurate if these cycles are not consecutive.

BASELINE CADENCE SUMMARY

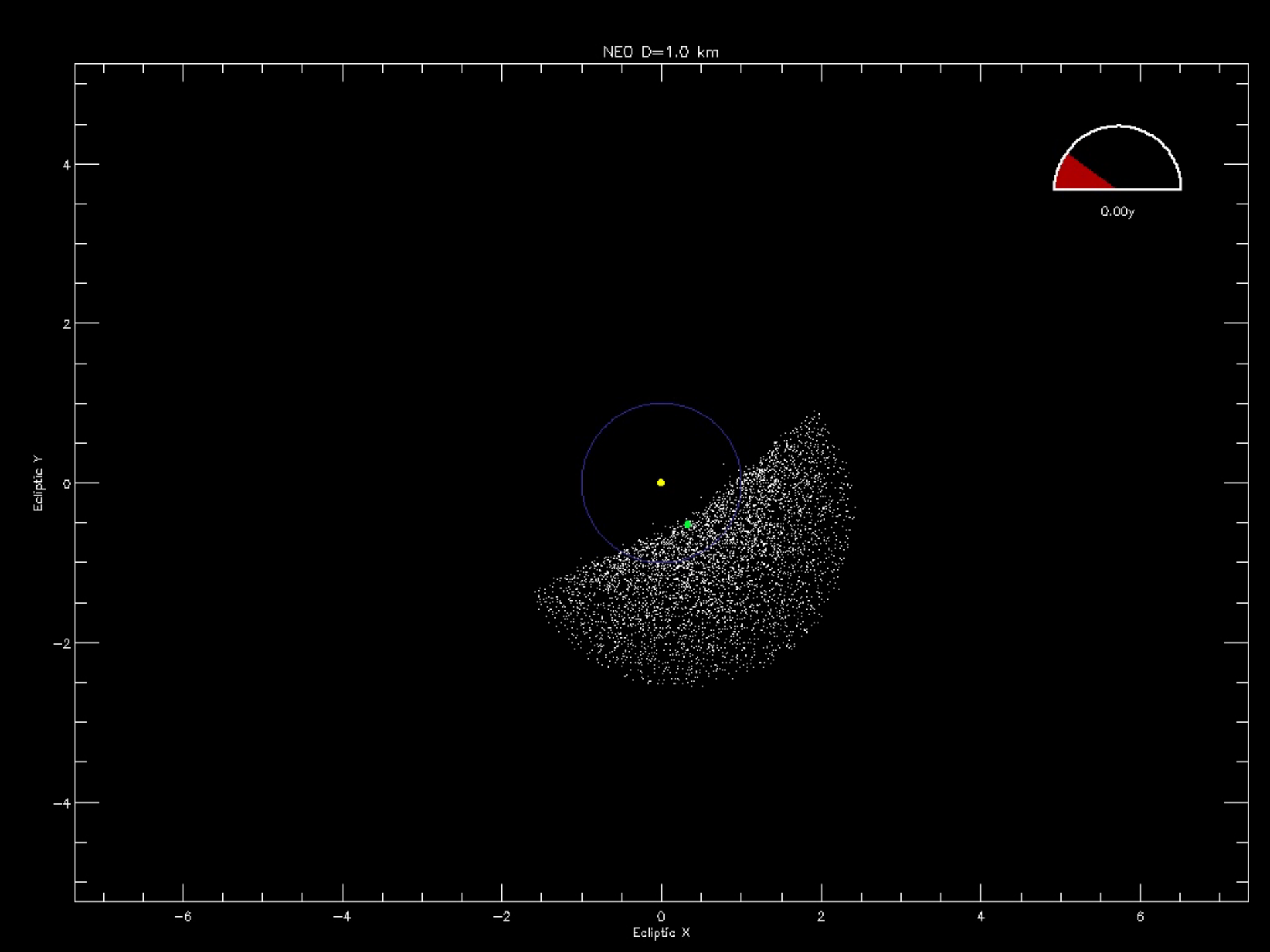
Nobs	Ncycles	Arc-length	Predict-arc	σ_{α}	σ_{δ}
2	½	1 hour	2 days	229"	251"
4	1	2 days	26 days	2.4°	3.2°
8	2	28 days	28 days	30"	69"
12	3	56 days	28 days	2"	3.7"
12	3	56 days	10 years	37"	12"

SENSITIVITY

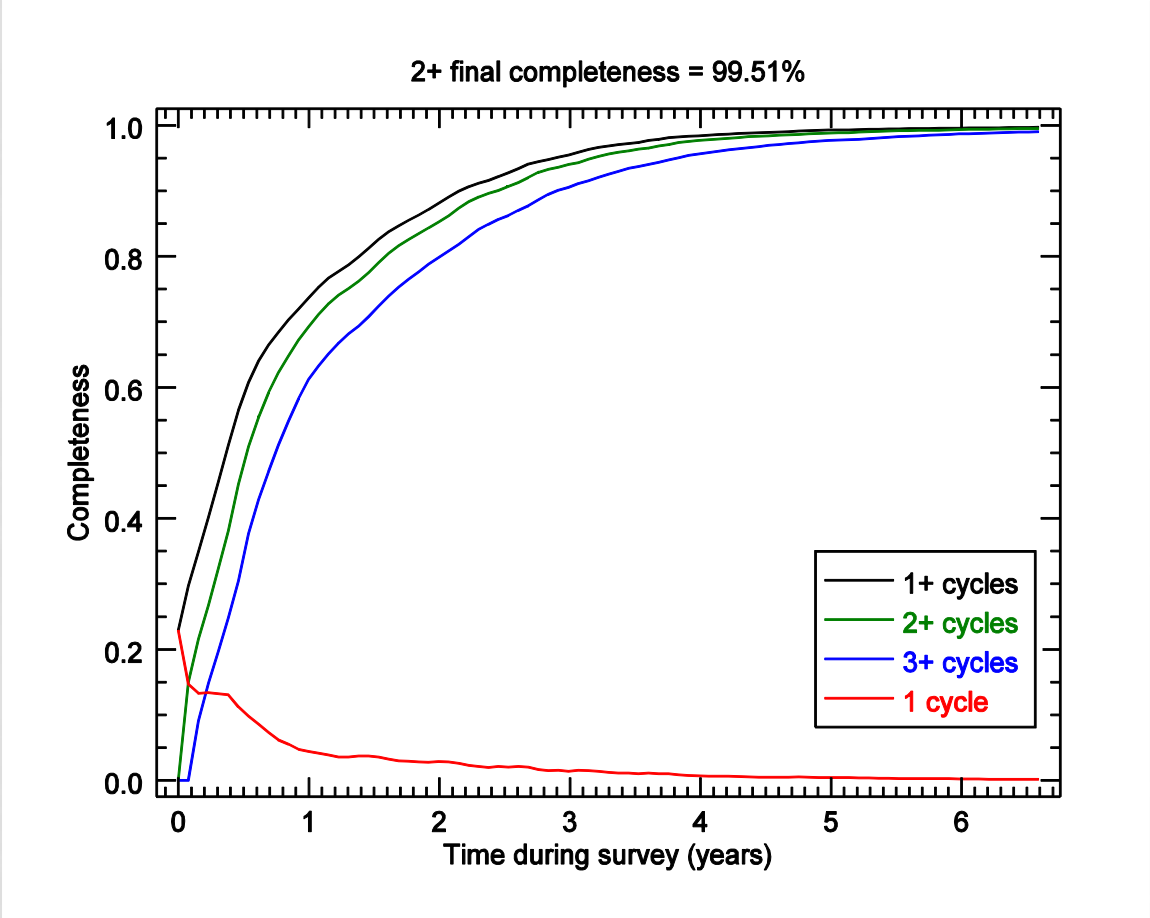
- Thermal emission from object
  - Rapid rotator
  - Average aspect
- Detector read-noise ignored
- Background flux from zodiacal light
  - Dominant noise source
- Rate of motion
  - Objects moving slower than 0.03°/day are not recognized as "moving" and never transmitted to the ground
  - No sensitivity loss for rates between 0.03°/day and 0.57°/day
  - Sensitivity degrades linearly with rates faster than 0.57°/day

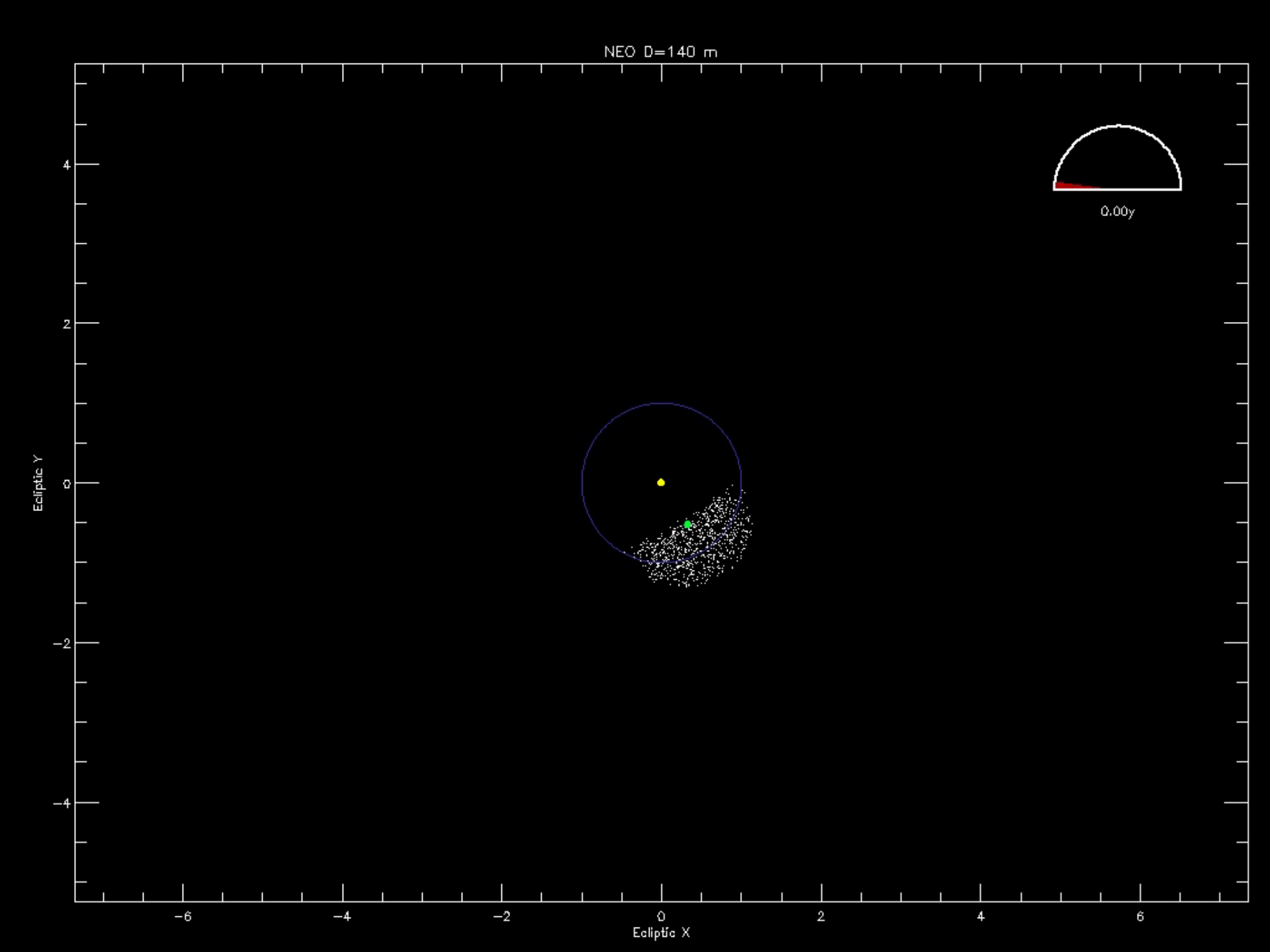
COMPLETION RATE

- Size distribution from Harris (2010)
- Orbit distribution from Bottke et al. (2002)
- Monte Carlo simulation with single size for differential completion rate
  - 20,000 random orbits from distribution
- Integrate differential results to get cumulative completion rate
- Simulation tool based on orbital calculations by OpenOrb

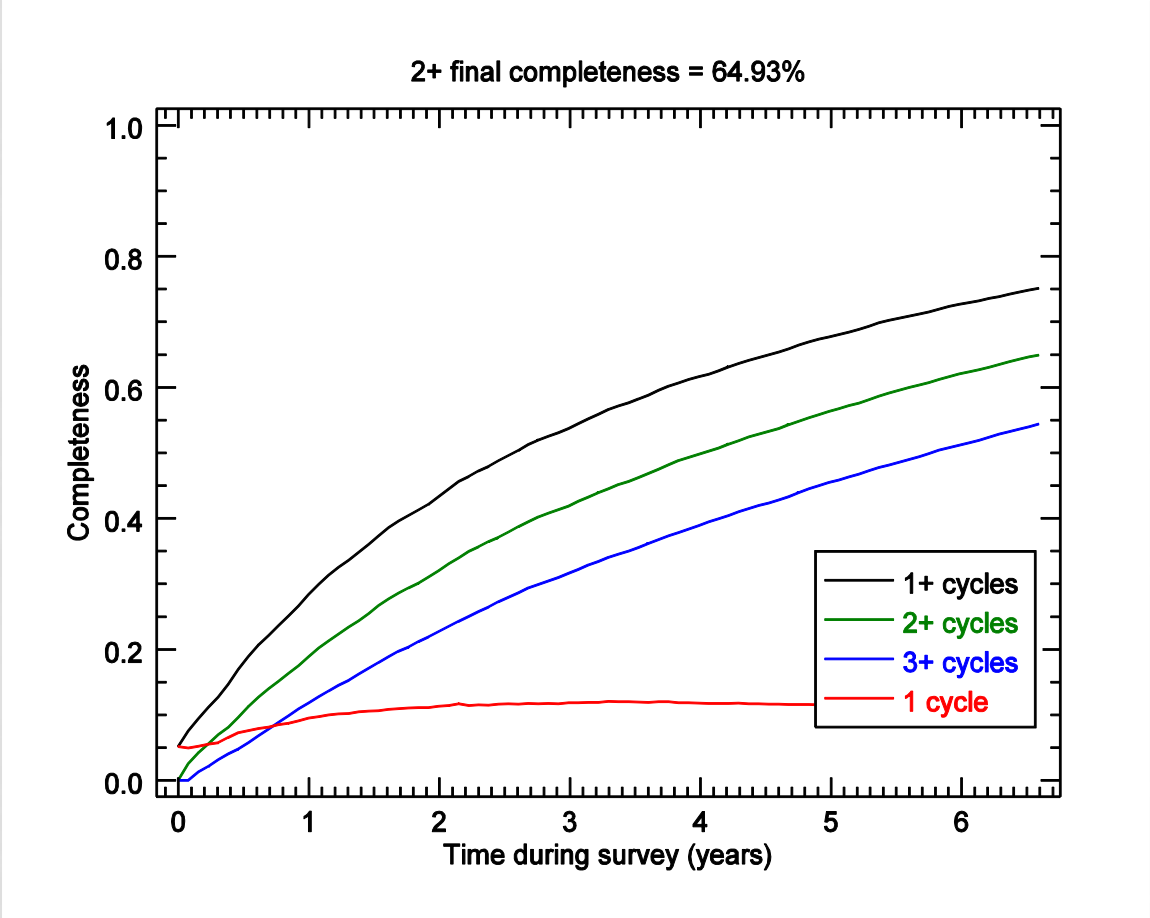

NEO D=1.0 km
0.00y
Ecliptic Y
Ecliptic X
4
2
0
−2
−4
−6
−4
−2
0
2
4
6

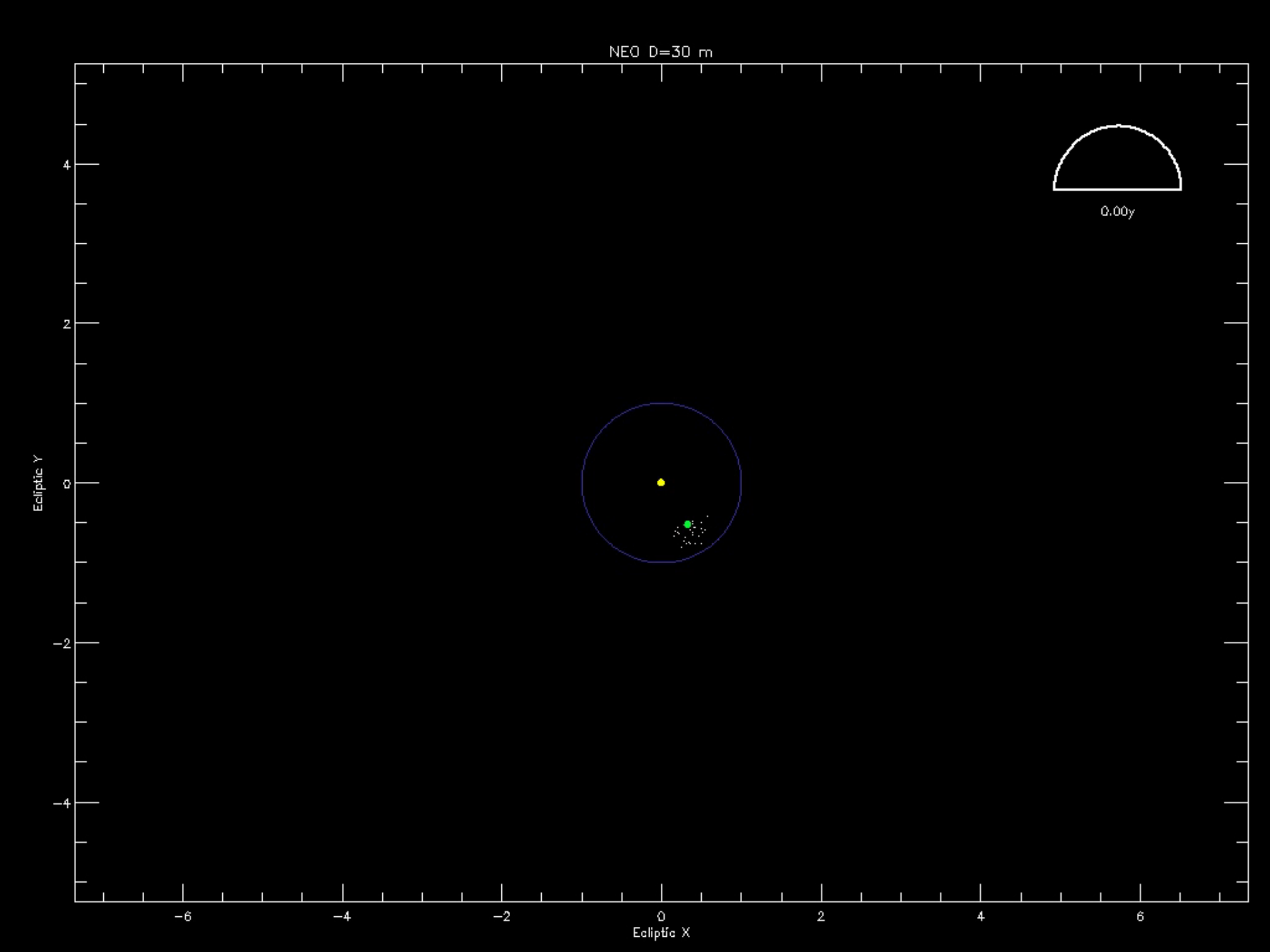
D=1 KM COMPLETION

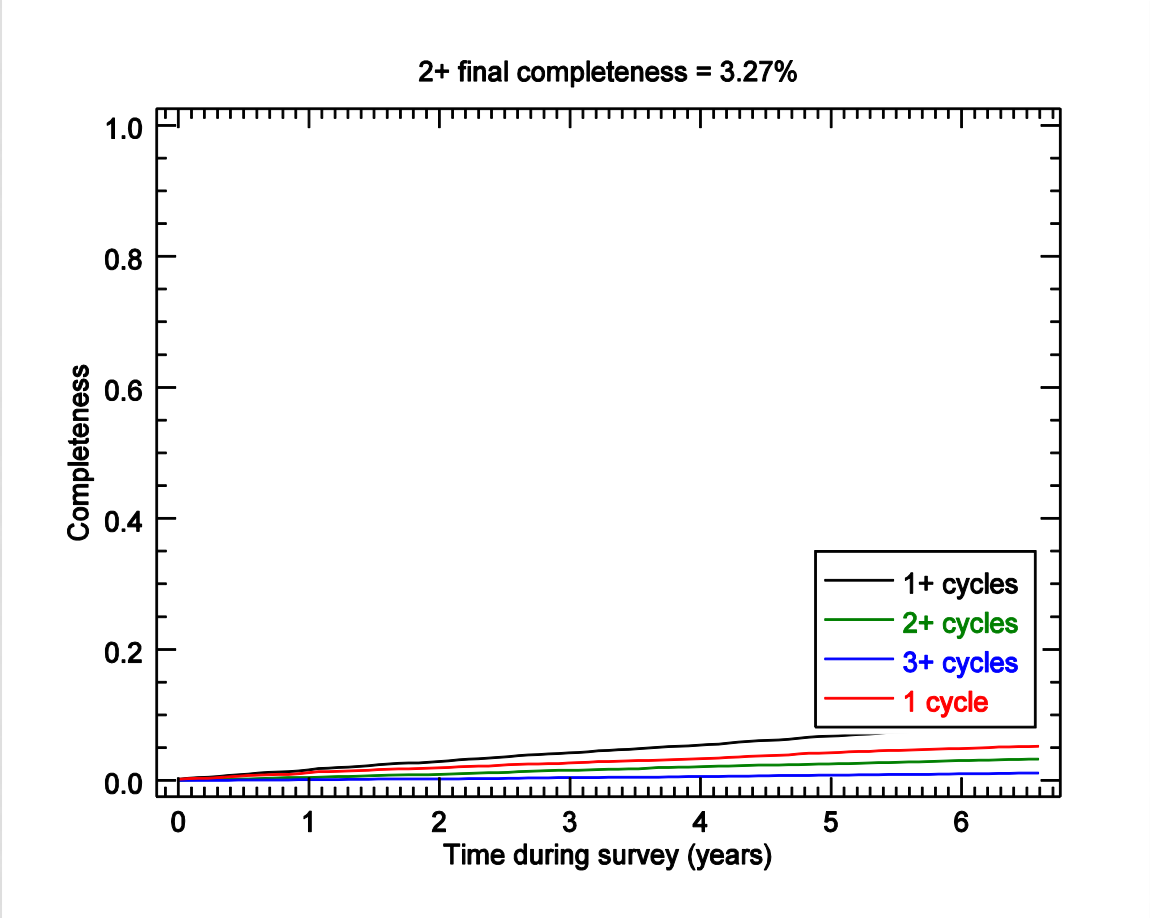



NEO D=140 m
0.00y
Ecliptic Y
Ecliptic X
4
2
0
−2
−4
−6
−4
−2
0
2
4
6

D=140M COMPLETION




NEO D=30 m
0.00y
Ecliptic Y
Ecliptic X
4
2
0
−2
−4
−6
−4
−2
0
2
4
6


2+ final completeness = 3.27%
Completeness
1.0
0.8
0.6
0.4
0.2
0.0
0
1
2
3
4
5
6
Time during survey (years)
1+ cycles
2+ cycles
3+ cycles
1 cycle

CUMULATIVE COMPLETION

Scenario	D>140m	D>30m
Baseline/NEO	74%	7%
Baseline/PHA	77%	9%

For the baseline case, there are 31,000 objects found with D>140m and 270,000 objects with D>30m.

INVESTIGATIONS USING SURVEY TOOL

- Modifications to field-of-regard
- Fill factor optimizations
- Implication of triples/quads/sextuples
- Detection location vs. cos(ecliptic latitude)
- Importance of the Zodiacal background model
- Observation visit timing vs. changes in approach
- Alternative spacecraft orbits
- Variations with NEO distribution models
- Orbit distribution of detected objects vs. size
- Main-belt asteroid influence on survey

SOME CONCLUSIONS

- Two linked cycles will put an object into the ***found*** category
- Three linked cycles (or more) will result in a very good orbit estimate
- Ecliptic longitude coverage is not usually complete
- Orbit periods close to an (integer) x (Sentinel orbit period) will have some blind spots
- While these last two issues are real, they will likely not be an issue with regard to mission success

SOME CONCLUSIONS

- Baseline mission design is a very effective survey tool
  - Zodiacal background is the dominant noise source
  - Time scale for completion set by range of orbit eccentricities in target population
- Main-belt asteroids will generate a large number of detections
  - Largest consequence is in data load but there are credible mitigation options
- Most of the objects detected will be smaller than the survey "goal" size (D=140m) and will provide excellent constraints on the size distribution down to 30m.