Occultations and Binaries

Extra science from Gaia

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Occultations – Figure of Merit

- $Q = 2\sigma\Delta/D$
  - Dimensionless characterization of probability of successful observation ($[\sigma]$=radians; $[\Delta, D]$=km)
- $N_T = 3(Q+1)$
  - Number of telescopes needed to get three chords across diameter of object.
  - Q=0, no error, you know where to be

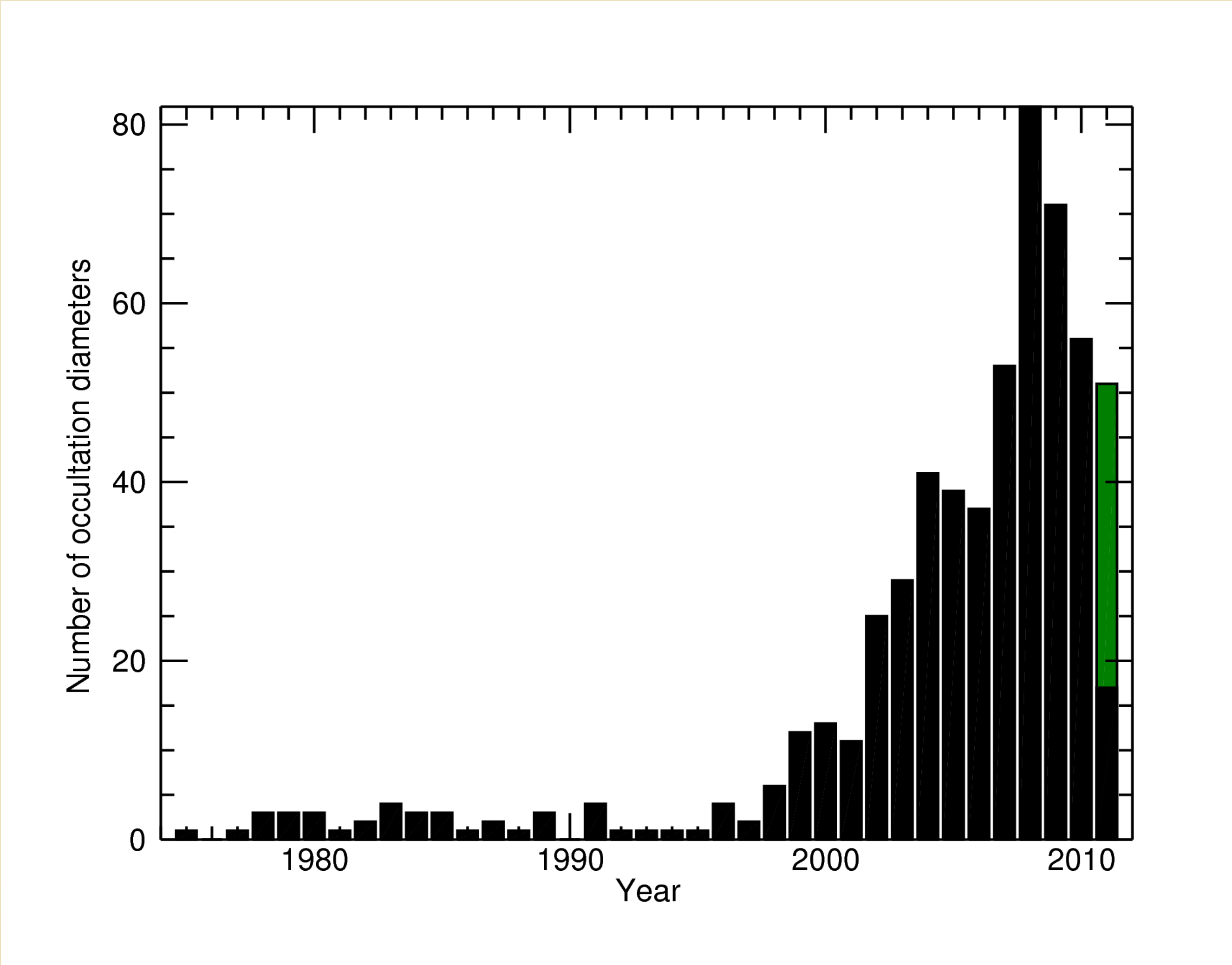
Importance of positional accuracy

- Baseline: σ = 1″, Δ=1 AU, D=100km; Q=14.5
- Main belt: Δ=3 AU, σ = 0.01″; Q=0.4, N_T=4
- Outer: Δ=30 AU, σ = 0.001″ for N_T=4
  - σ = 0.01″; Q=4, N_T=40 (fixed network)
- Distant
  - σ = 0.1 mas → Δ=300 AU
  - σ = 0.01 mas → Δ=3000 AU

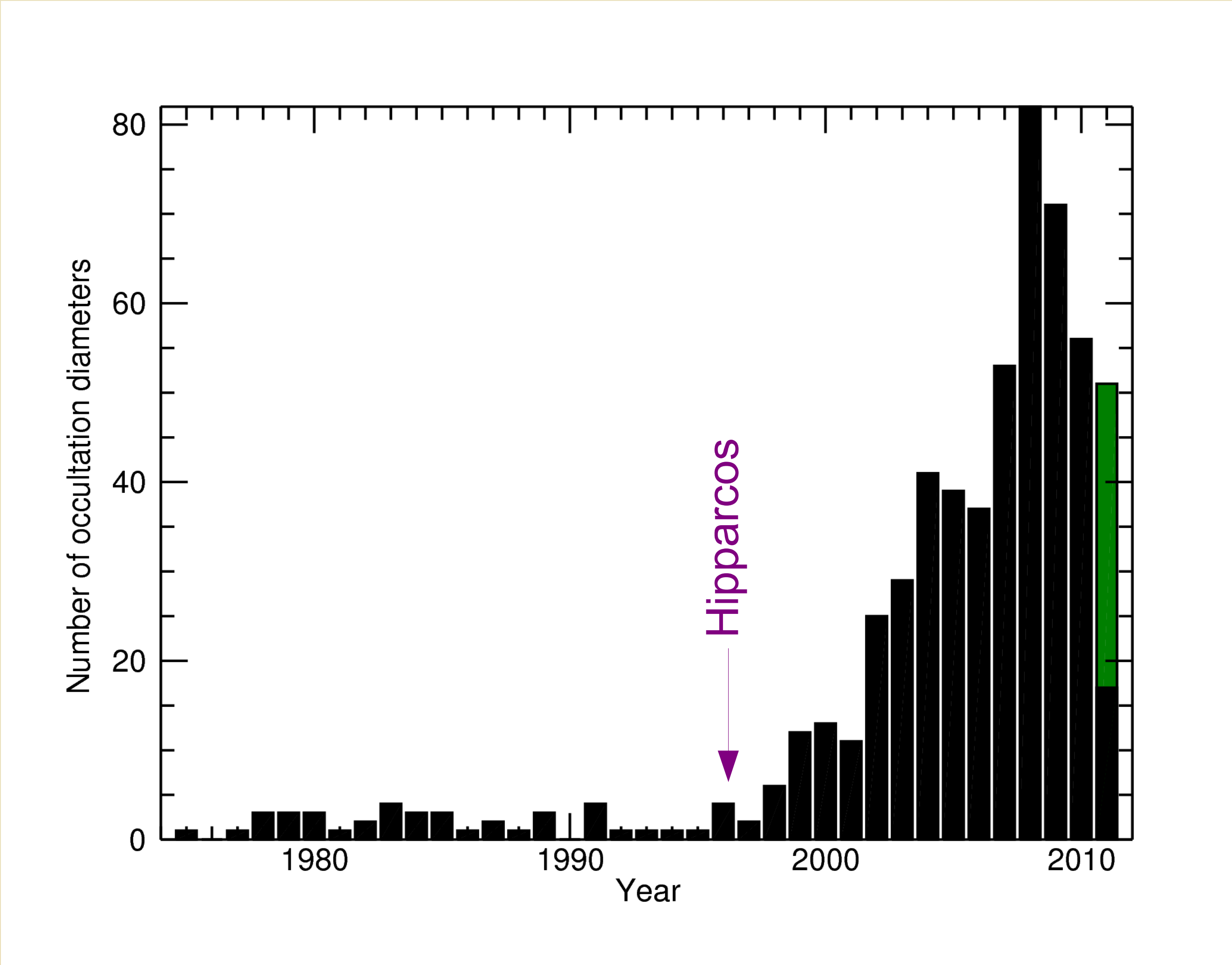
Occultation Observation Type

Type	Fixed	Portable	Network
Low-Q (Jupiter, Titan, some asteroids)	Good for large objects, target of opportunity	Excellent – high density sampling	Useful but can't pick events
Modest-Q (Pluto, Triton, most main-belt asteroids)	Excellent, Rare, easy to do	Good – requires large effort	Excellent – need decent target sample
High-Q (average TNOs, small asteroids, NEOs)	Very low return, rarely worth effort	Poor – effort too large	Good – need large target sample
Q~∞ (small TNOs)	Not useful	Not useful	Possible with very large sample

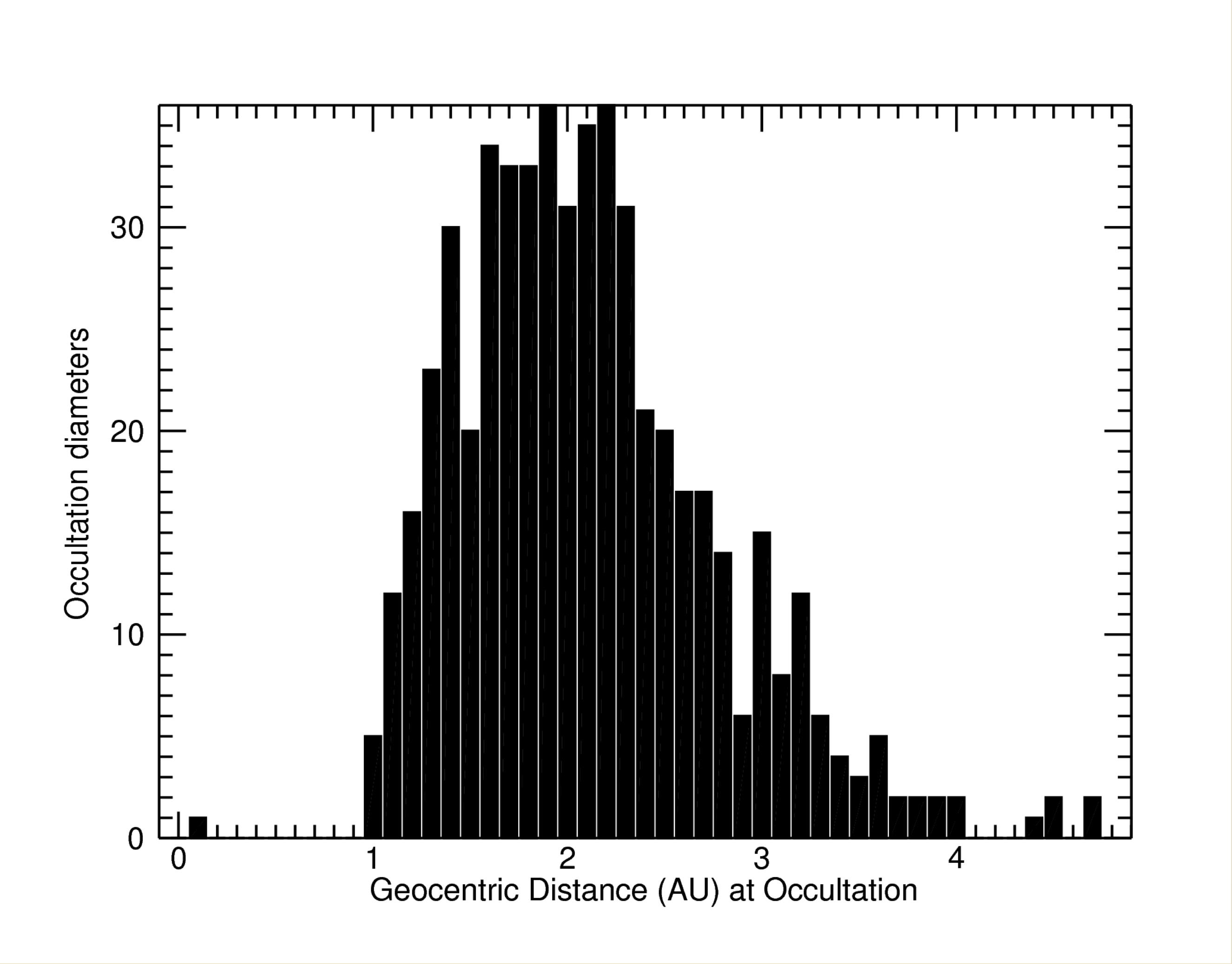
Asteroid occultations vs. time



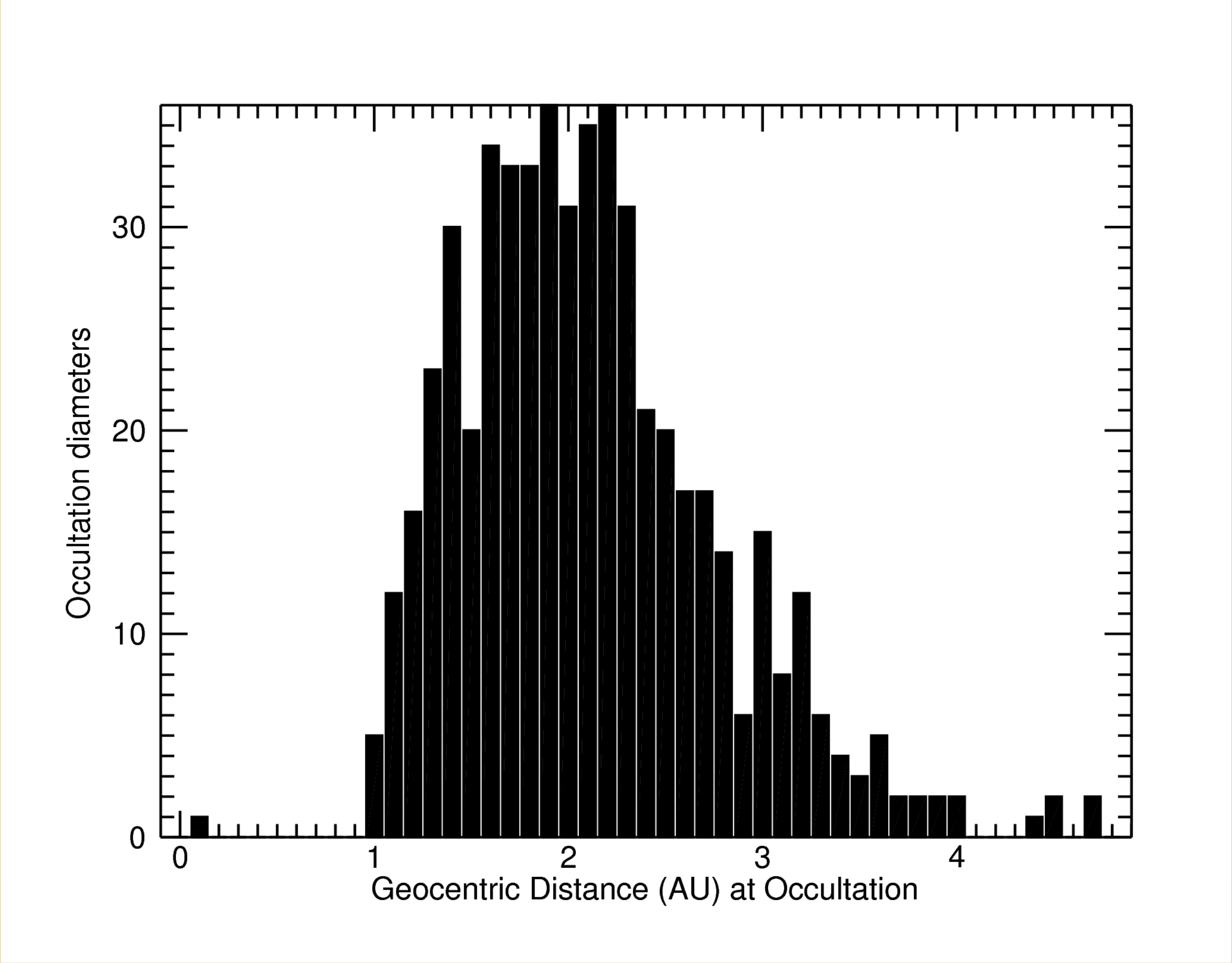
Asteroid occultations vs. time



Asteroid occultations vs. distance

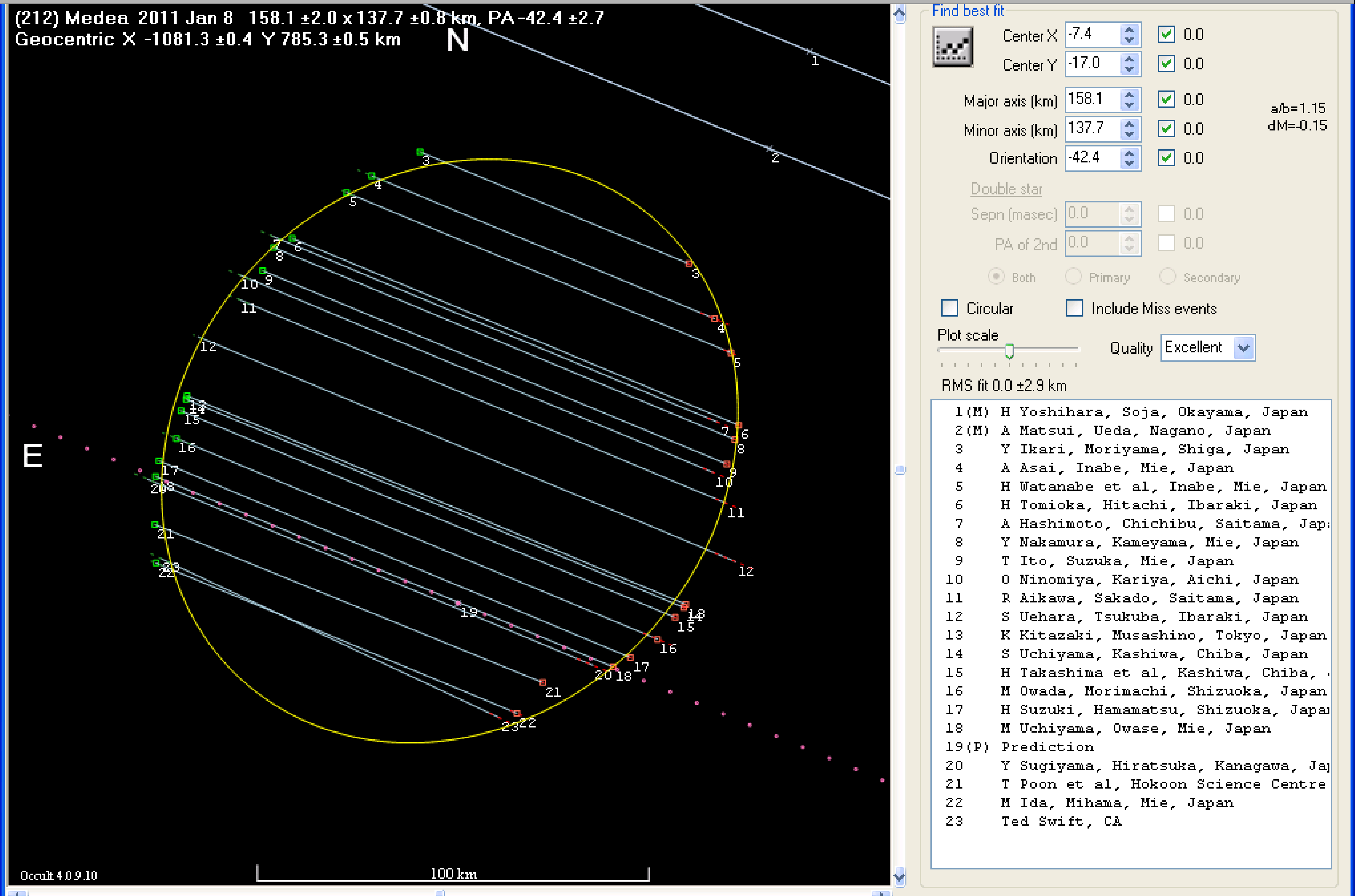


Asteroid occultations vs. distance

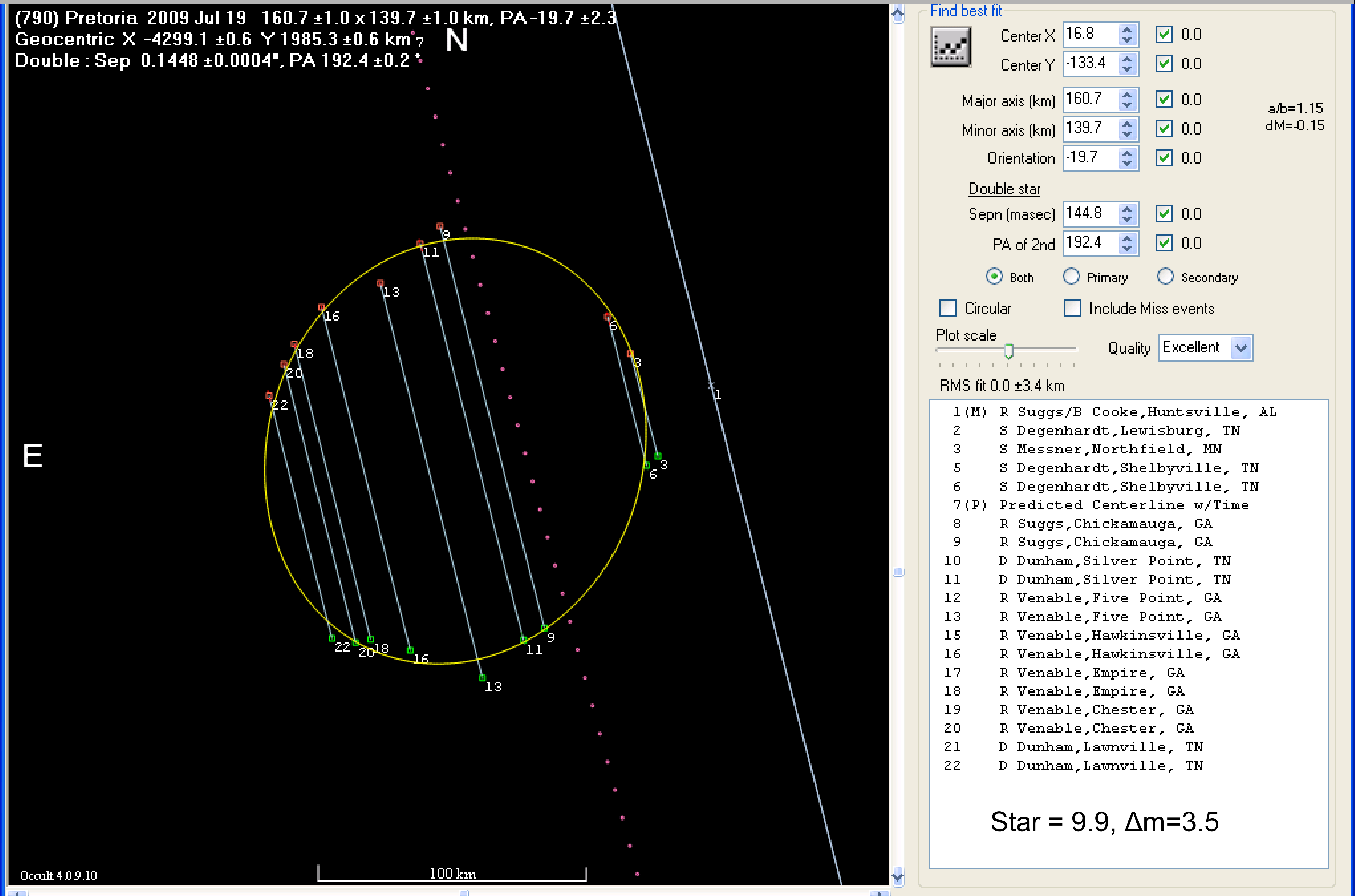


4+ TNOs
Chiron
Pluto
Triton

Example result



Example result



Current challenges

- Small objects
  - Small region of action, difficult if not impossible to get shapes with multiple chords
- Distant objects
  - Large objects can be done with large effort
  - Medium objects require different observing strategy (RECON)
  - Both star and object not well enough known

Classical TNOs

- Low-*e* and low-*i*, *a* ~ 43AU
- "100km" class object
- Most were not-detectable with Spitzer
  - Implies, cold, high-albedo, smaller size
- Highest rate of binaries (≥10%)
- Least disturbed remnant of solar system formation
- Second *New Horizons* destination

RECON

Research and Education Cooperative Occultation Network

- Targeting 100-km class TNOs
- V<13 (at limit gives size good to 10%)
- Fixed network of 28cm telescopes
- simple instrument (no computer)
- $5,300 per system (off-the-shelf hardware), includes telescope
- 40 stations, 1800 km spread, 48 km mean spacing
- Staffing with educators and students, rural communities
- Works for Q up to 12 (can constrain tight binaries on low-Q events)

Additional Considerations

- Small or distant objects will be routine
- Prediction effort is simplified
  - Catalog search for target stars
  - Object astrometry directly tied into catalog
- No proper motion catalog degradation
  - Predictions no longer time dependent
  - Deployment can be planned well in advance
    - No more last-minute border crossings
  - More credibility for large telescope requests

Binaries

- Key to formation and evolution models
- Discovery
  - Rate of duplicity, "size" ratio (statistical result is good)
- Orbits
  - System mass, component masses, aggregate orbital properties (a,e,i)
- Mutual events, albedos, shapes, tidal evolution, densities

Gaia related issues

- Look for co-moving sources
  - Quick release needed to enable followup and more detailed characterization
- Look for departure from normal PSF that repeats within scan
  - Need to eliminate background star confusion
  - This will be a result from entire mission
- Astrometric deviations will indicate unseen companion