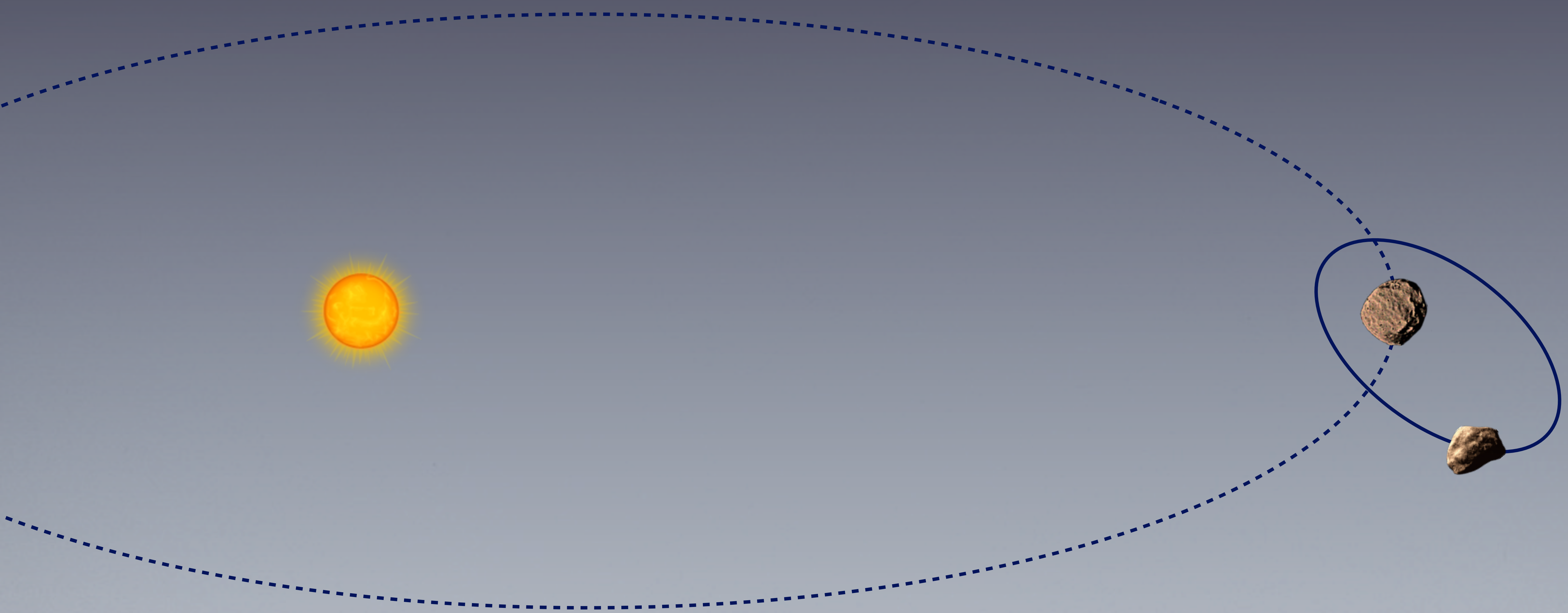


Discovery and Characterization *of* Trans-Neptunian Binaries *in* Large-Scale Surveys

Alex Harrison Parker - *New Horizons Outer Solar System Science Fellow - CfA*

October 10 2011 - Orbital Couples: "Pas De Deux" In The Solar System And The Milky Way

Ultra-Wide Trans-Neptunian Binaries

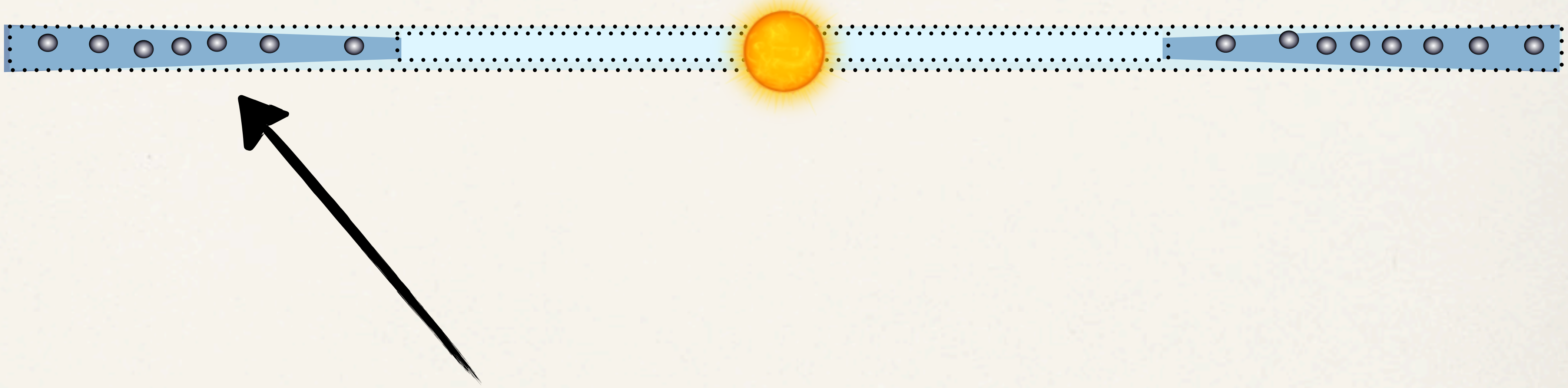
- Tail of the separation distribution
    - ~0.5″ - 5″ mean separation as observed from Earth
    - Several to several tens of percent of Hill radius
- Found exclusively in Cold Classical Kuiper Belt (or can be traced there)
- Lower limit on extant population: ~1.5% of all Cold Classical Kuiper Belt Objects are ultra-wide binaries

Ultra-Wide Trans-Neptunian Binaries

- Valuable dynamical tracers
  - Delicate, sensitive to disruption by collisions or flybys
- Mutual orbits constrain:
  - Migration history of the giant planets
  - Extent of collisional grinding in the Kuiper Belt
  - Environment and processes in the primordial disk

“Cold” disk

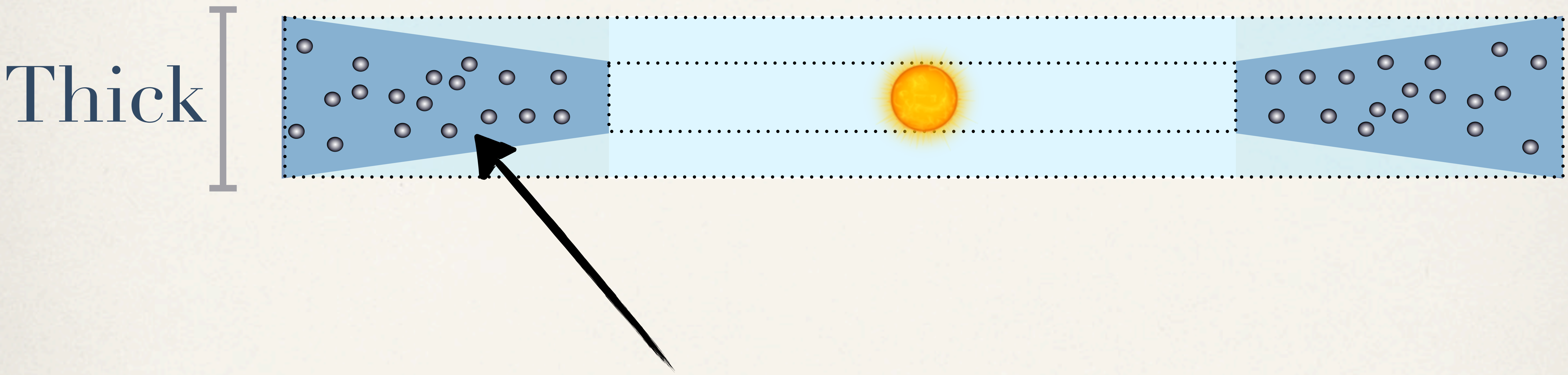
Thin I



Very little random motion

- Makes binaries efficiently (many-body processes)
- Wide binaries can survive
- Only low mutual inclinations
- Only retrograde orientations

“Hot” disk



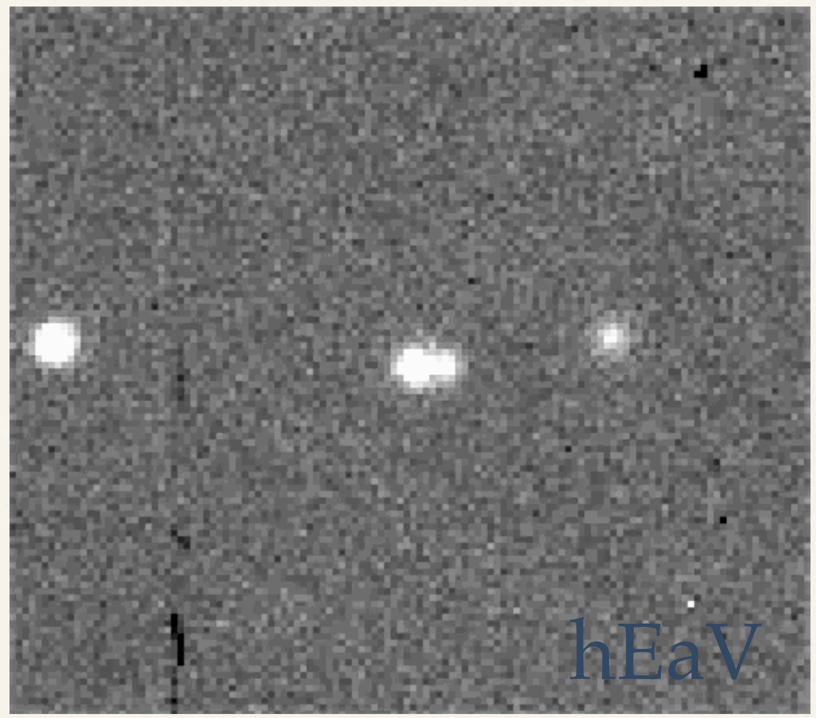
Lots of random motion

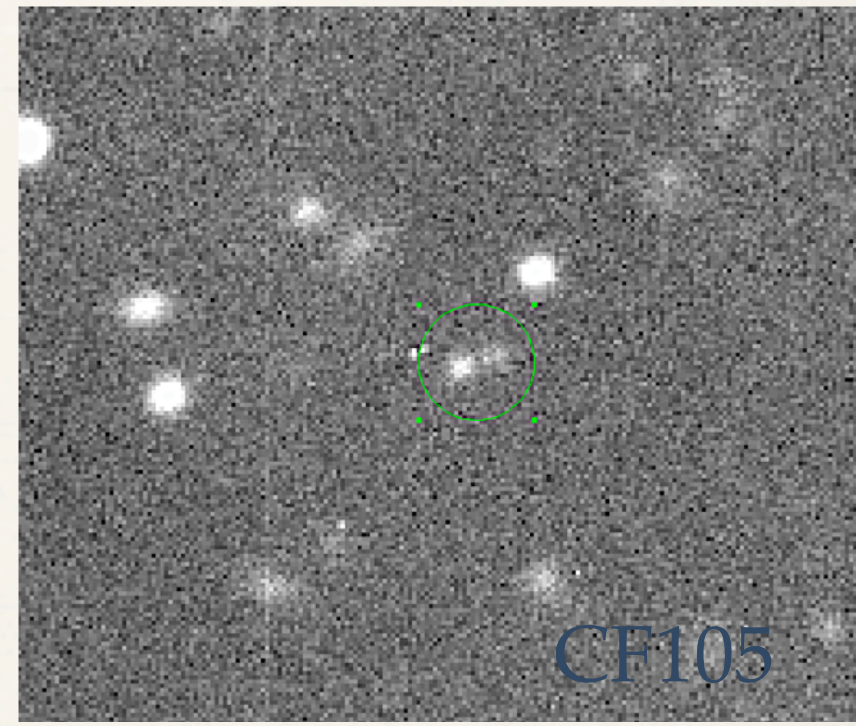
- Makes fewer binaries (three-body processes)
- Only tightly-bound binaries survive
- Random mutual inclinations
- Random orientations

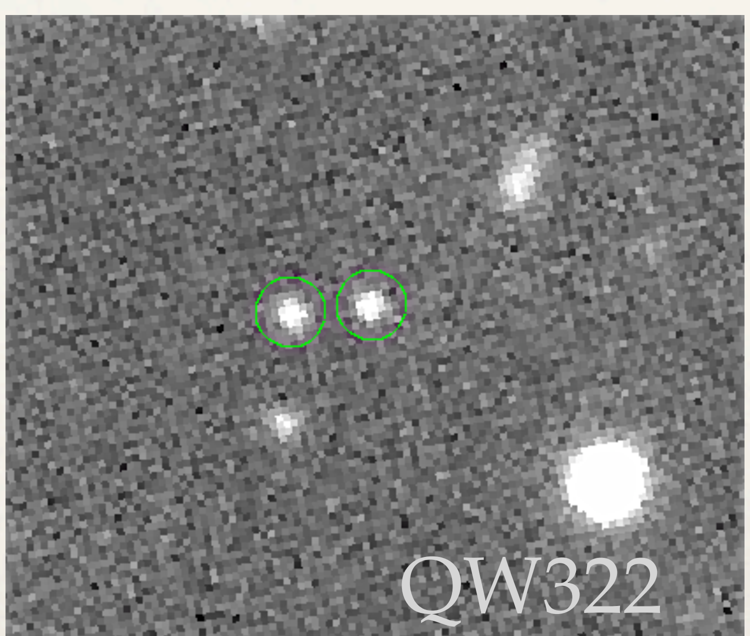
Current sample

- Parker et al. 2011:
  - Up to 10 years of observations for 7 systems with $a/R_H > 0.07$
  - Accurate and precise mutual orbits, mirror degeneracy broken at $> 95\%$ confidence
- Sheppard et al. (in prep):
  - One additional ultra-wide binary with comparable orbit

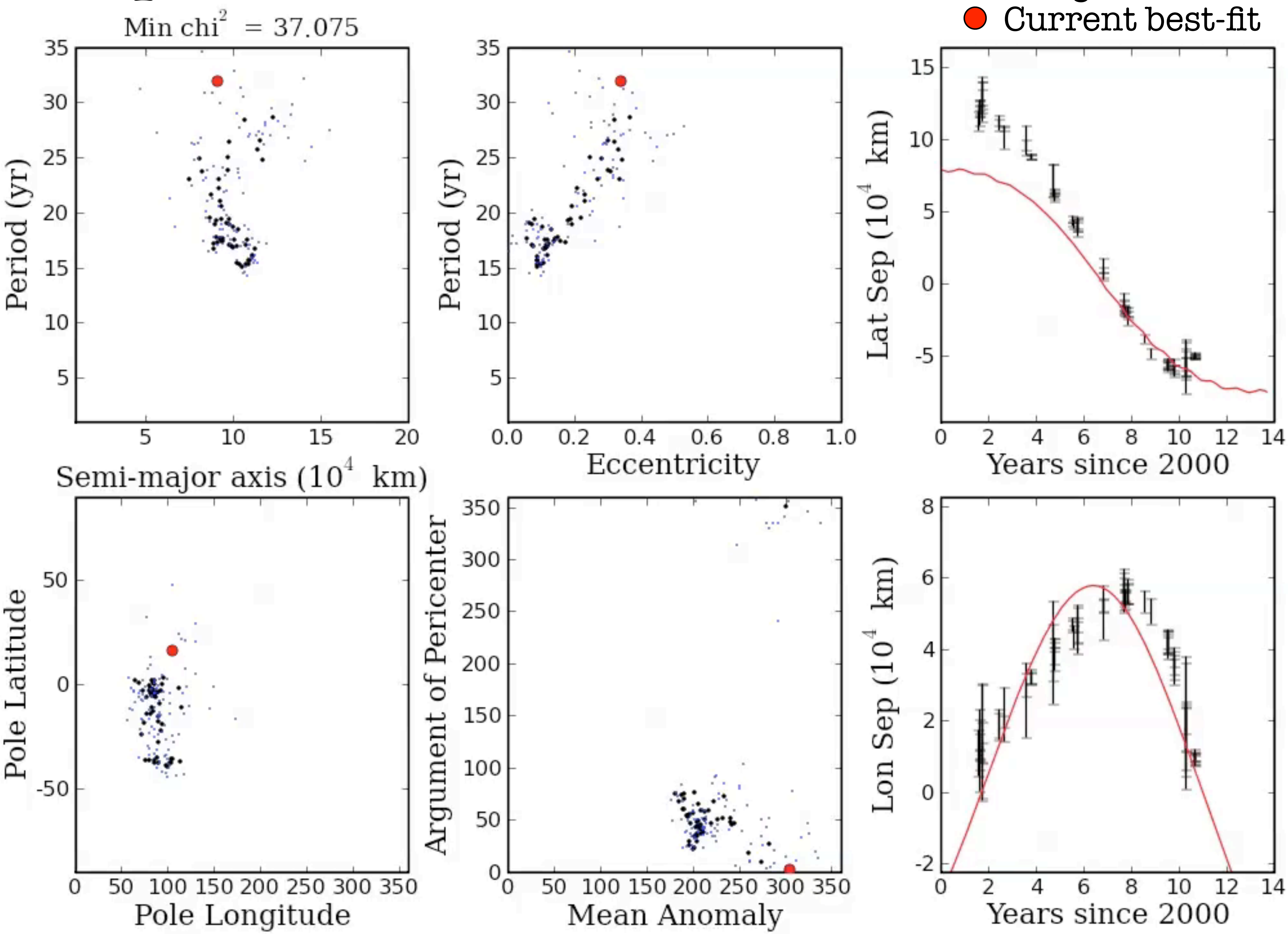
Example observations



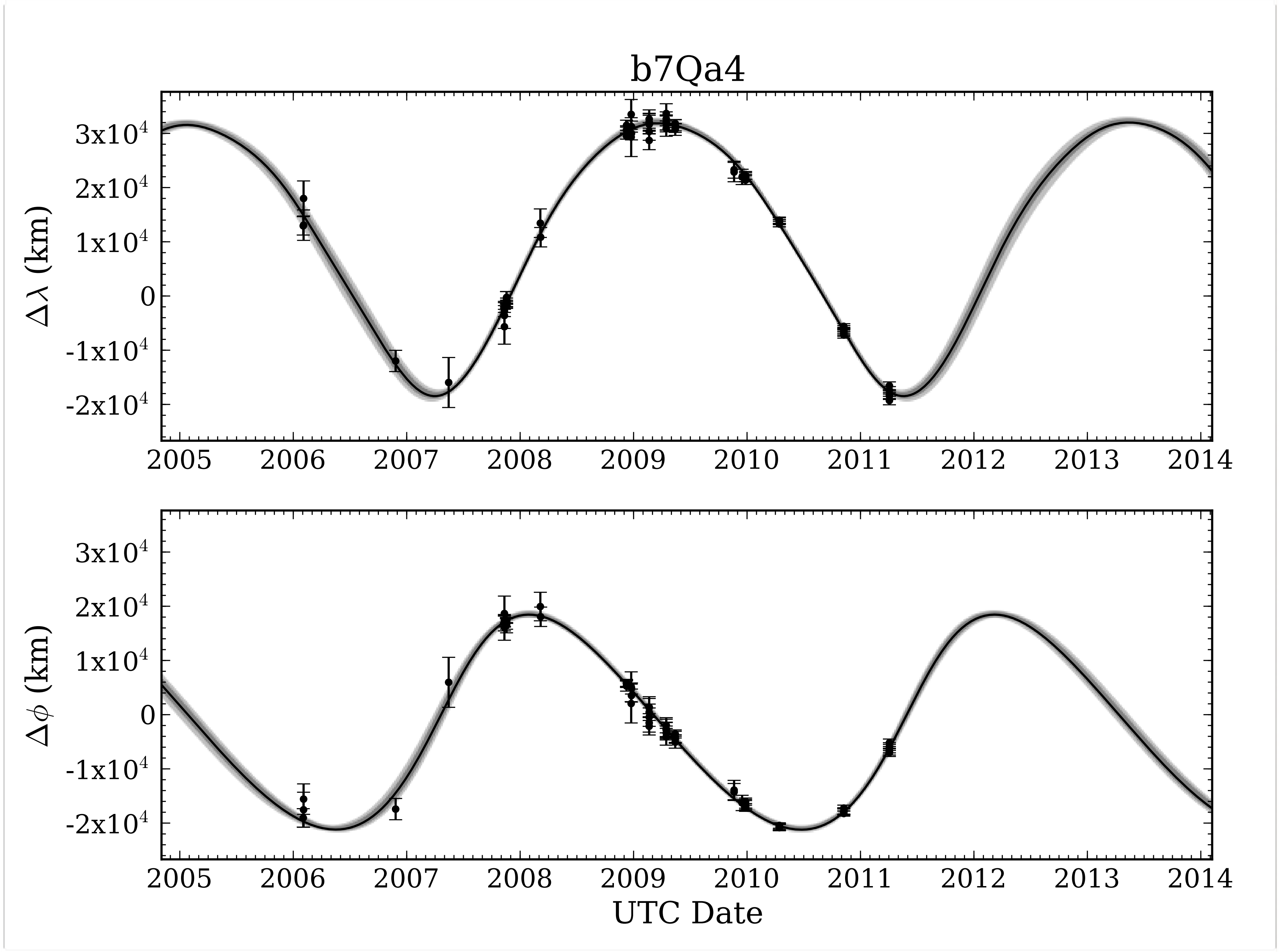




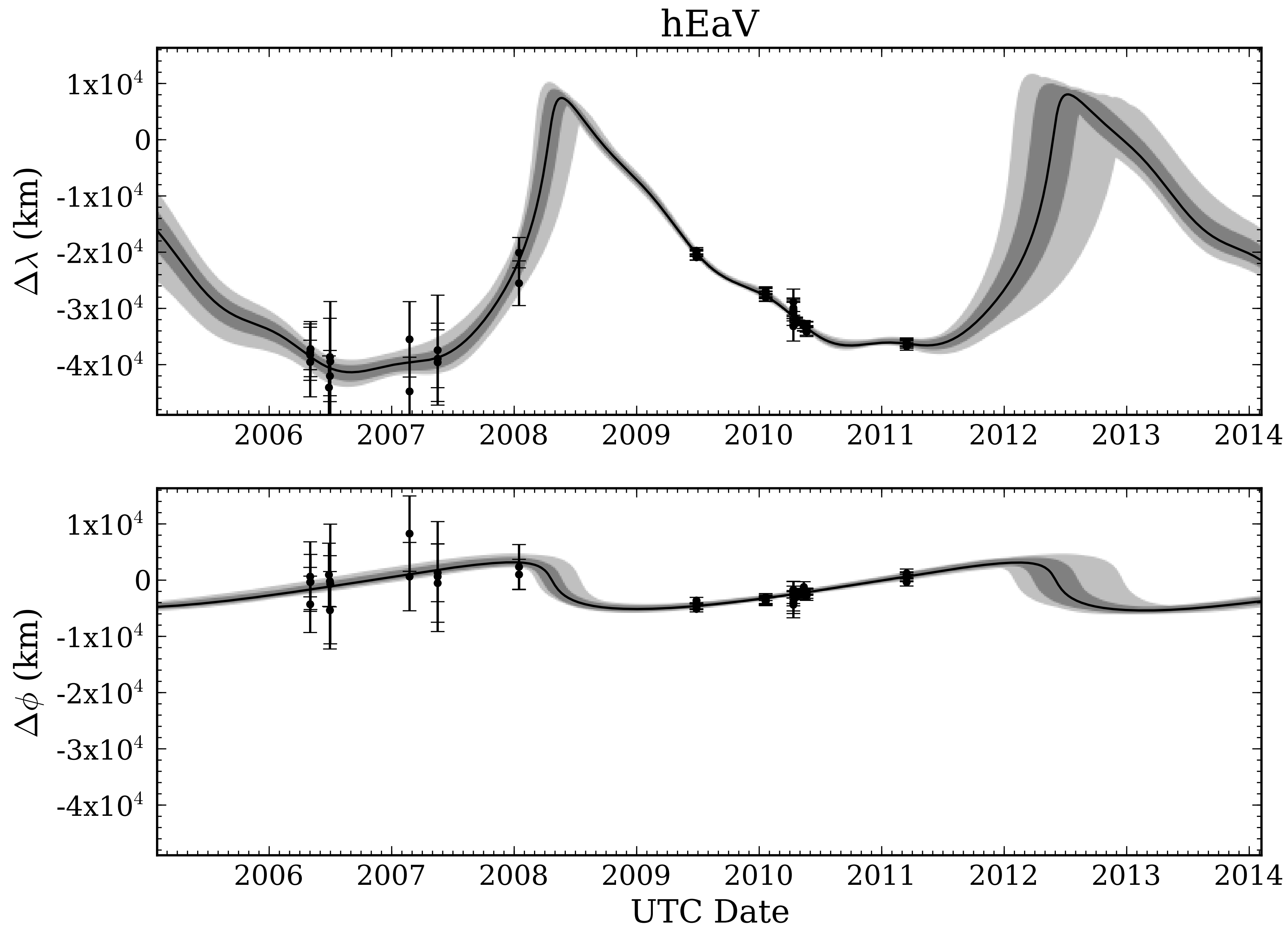
Metropolis Algorithm
7-parameter orbit fit to 2001 QW_{322}



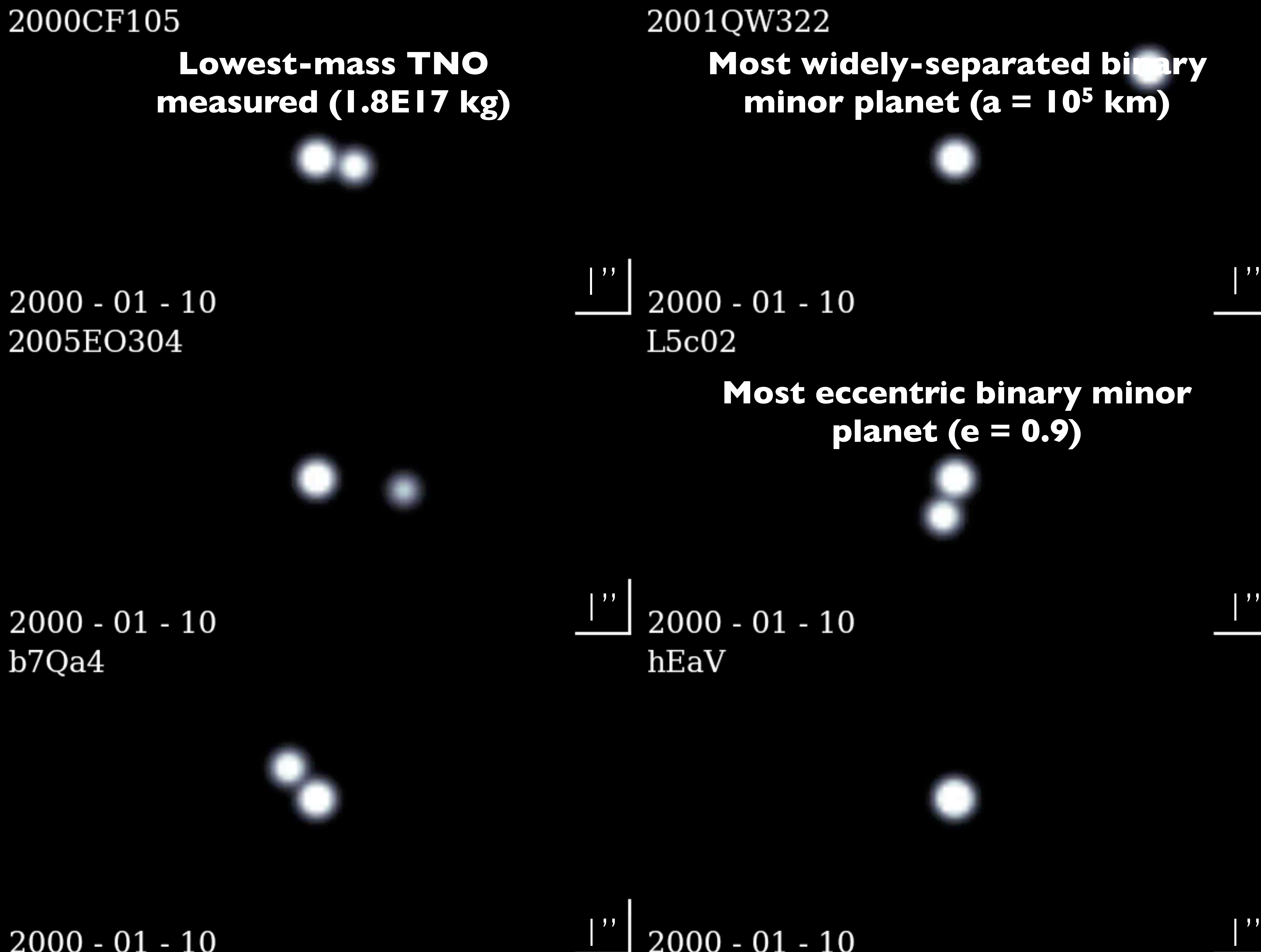
Example orbit fits



Example orbit fits



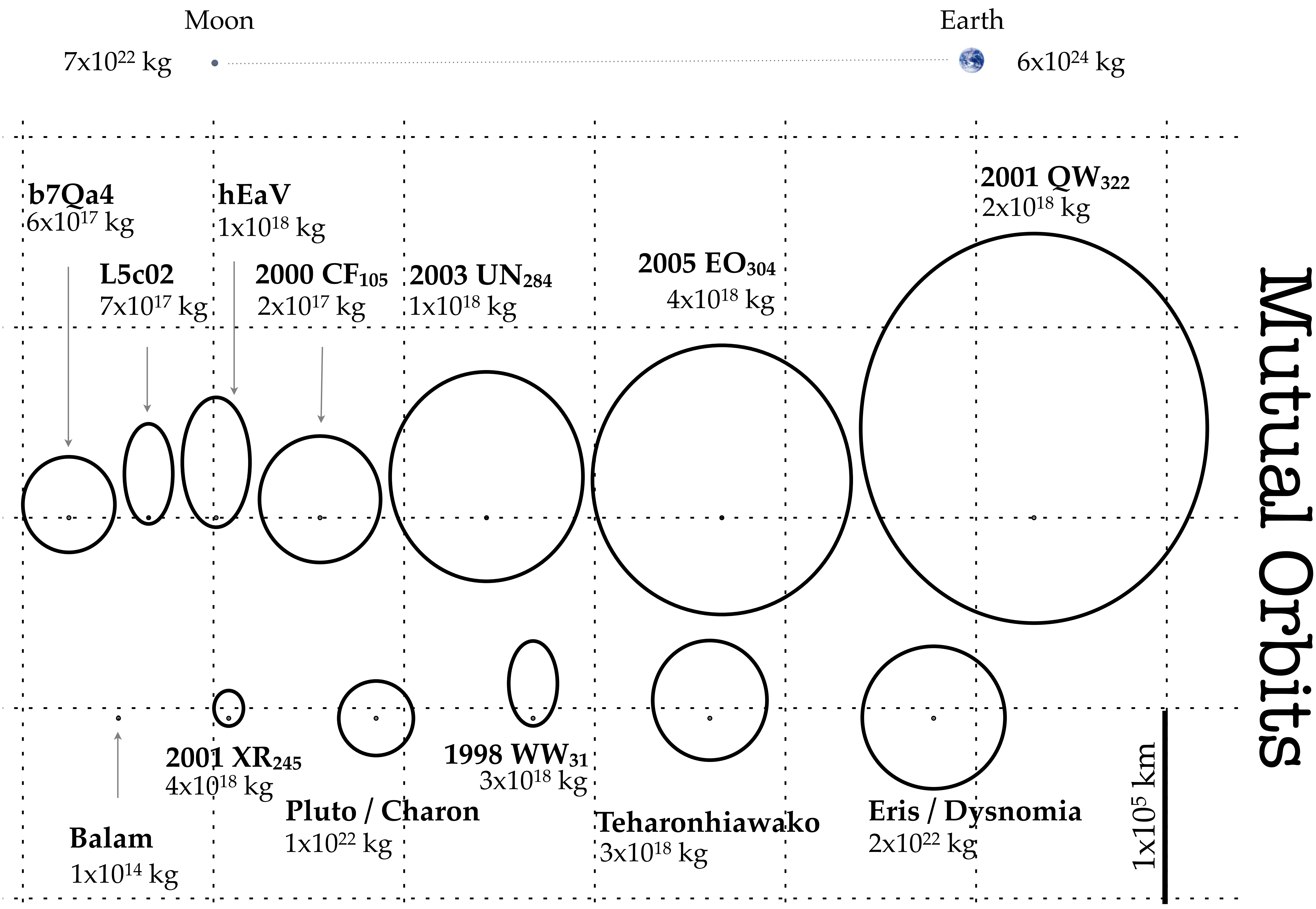
Best-Fit Binary Mutual Orbits, 2000-2013



Simulated 0.35'' seeing

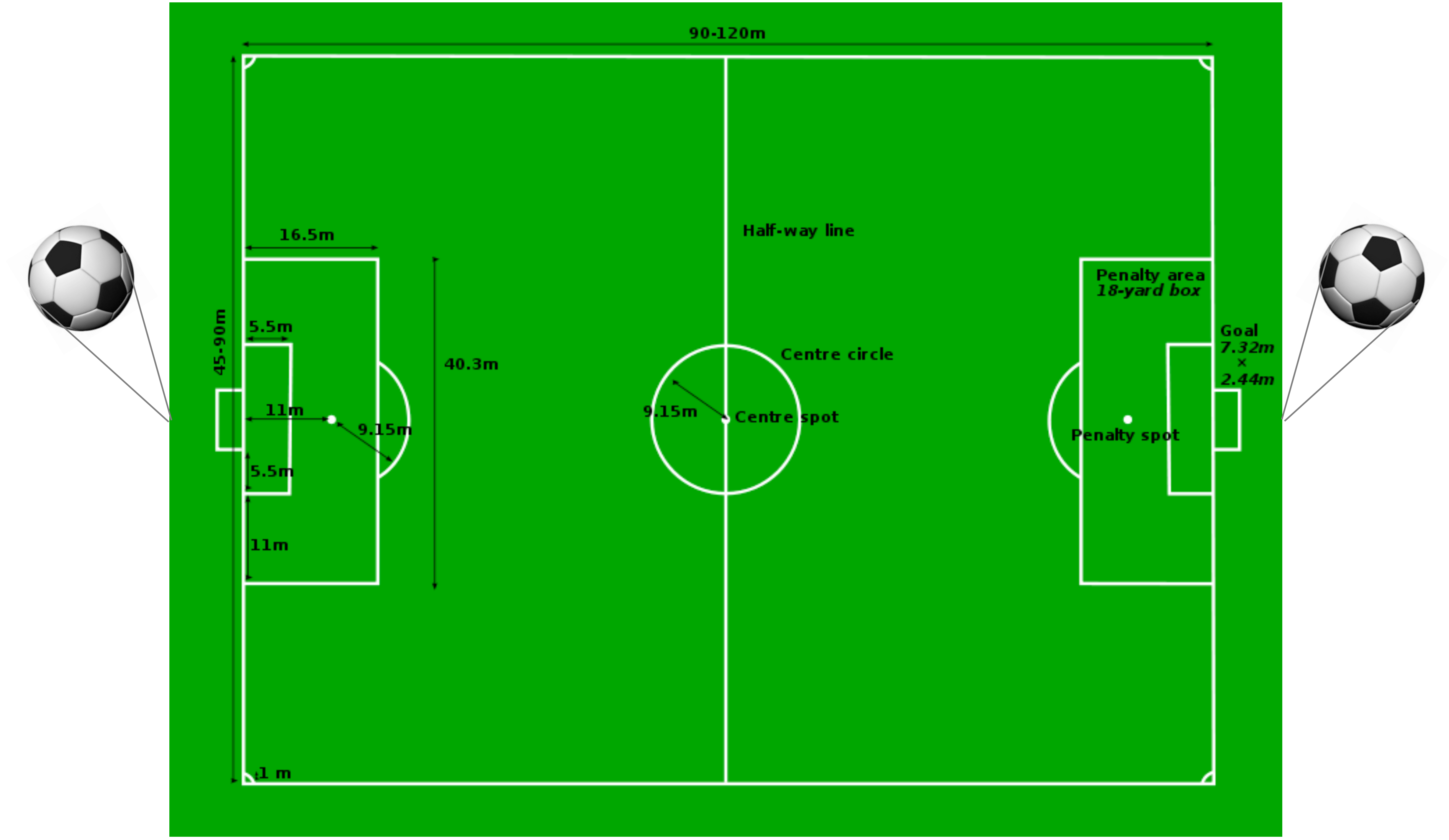
1'' ~ 3×10^4 km

The Moon L5c02 b

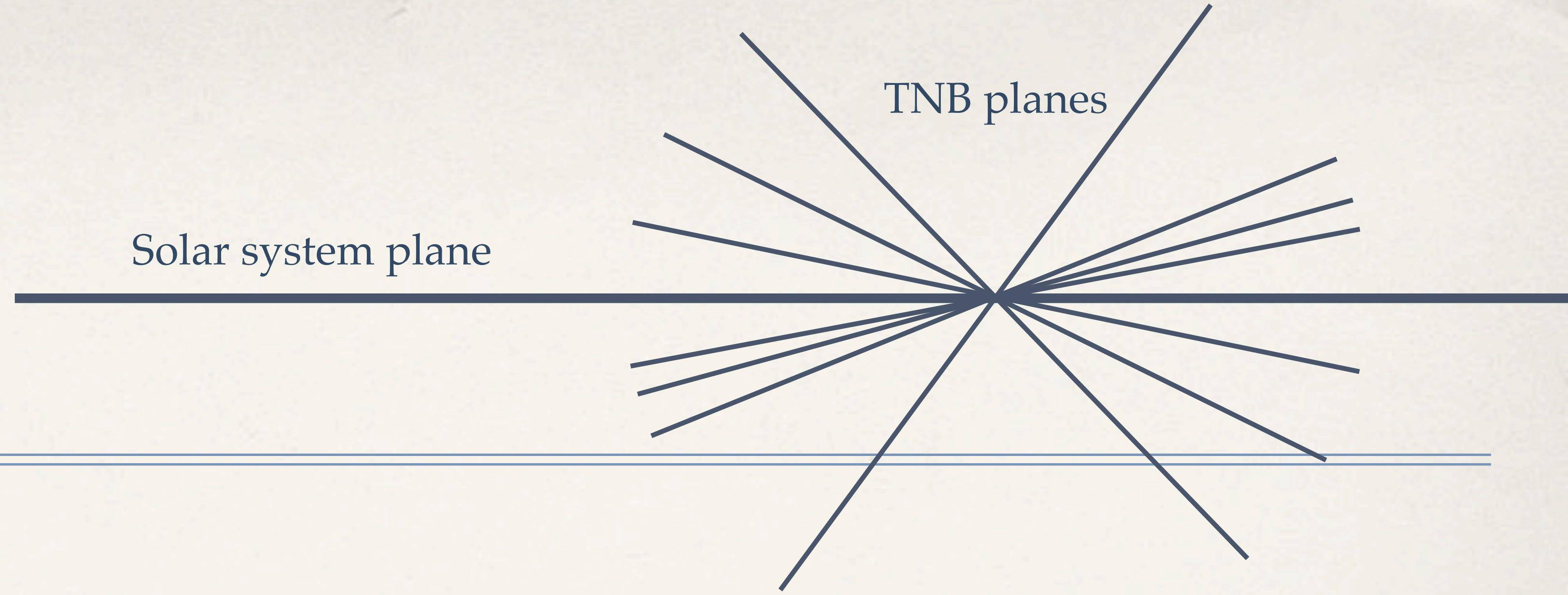


Moon
7x10^22 kg
Earth
6x10^24 kg
Mutual Orbits
b7Qa4
6x10^17 kg
hEaV
1x10^18 kg
L5c02
7x10^17 kg
2000 CF105
2x10^17 kg
2003 UN284
1x10^18 kg
2005 EO304
4x10^18 kg
2001 QW322
2x10^18 kg
2001 XR245
4x10^18 kg
1998 WW31
3x10^18 kg
Balam
1x10^14 kg
Pluto / Charon
1x10^22 kg
Teharonhiawako
3x10^18 kg
Eris / Dysnomia
2x10^22 kg
1x10^5 km

Separation comparison:
2001 QW322 - football pitch separating two footballs



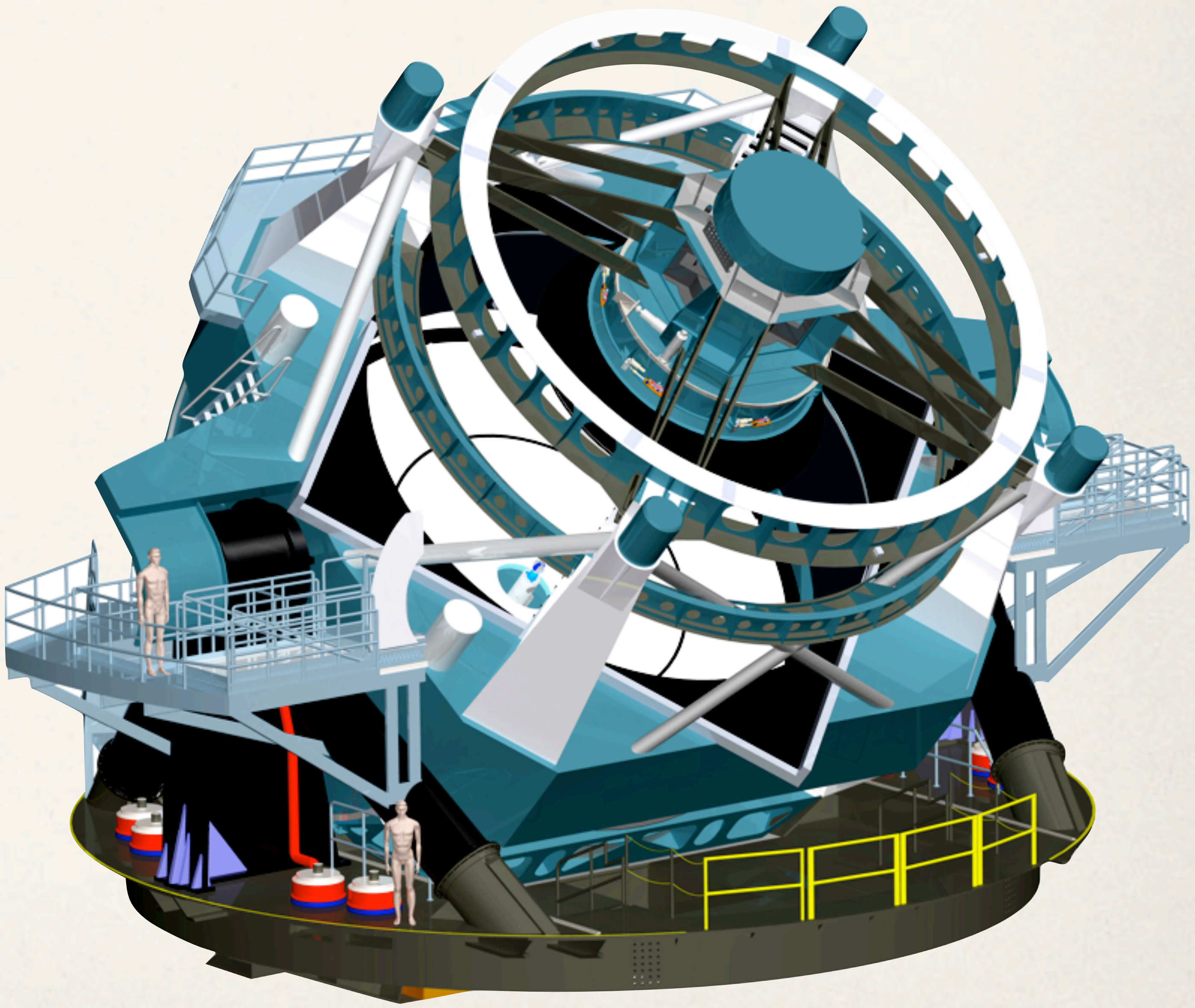
Current sample



- Prefer low mutual inclinations (orbits prefer plane of Solar System), unlike tighter binaries
- Roughly equal numbers prograde and retrograde
- Range of eccentricities: 0.2 - 0.9
- Collisional lifetimes limit ~1 km impactor population in KB
- Wide separations sensitive to disruption by close encounters with Neptune - CCKB was not emplaced by scattering

Discovery simulations: LSST

- Compare predicted seeing for LSST to on-sky separation distribution for known binaries
- How many resolved visits would we expect per binary?



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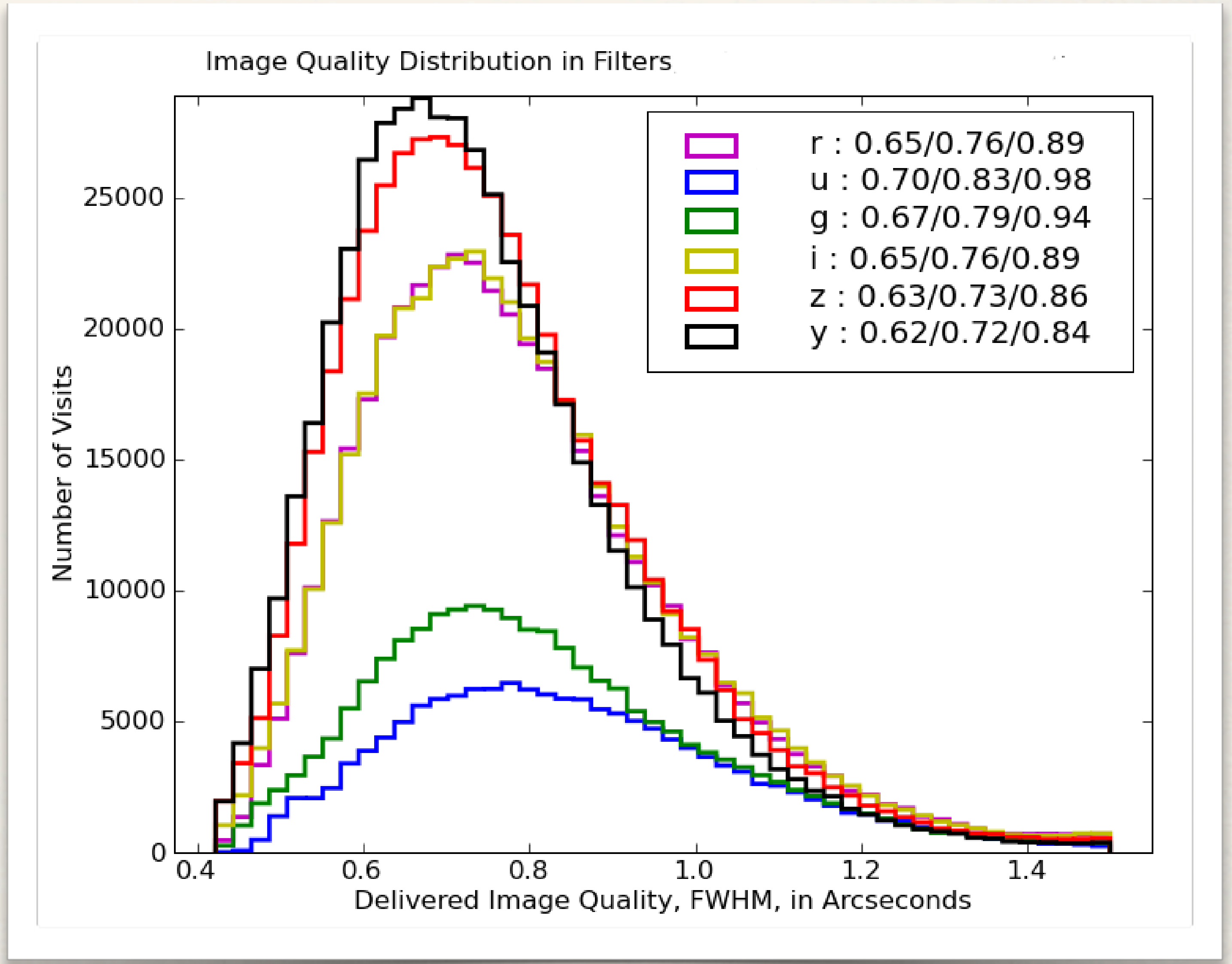
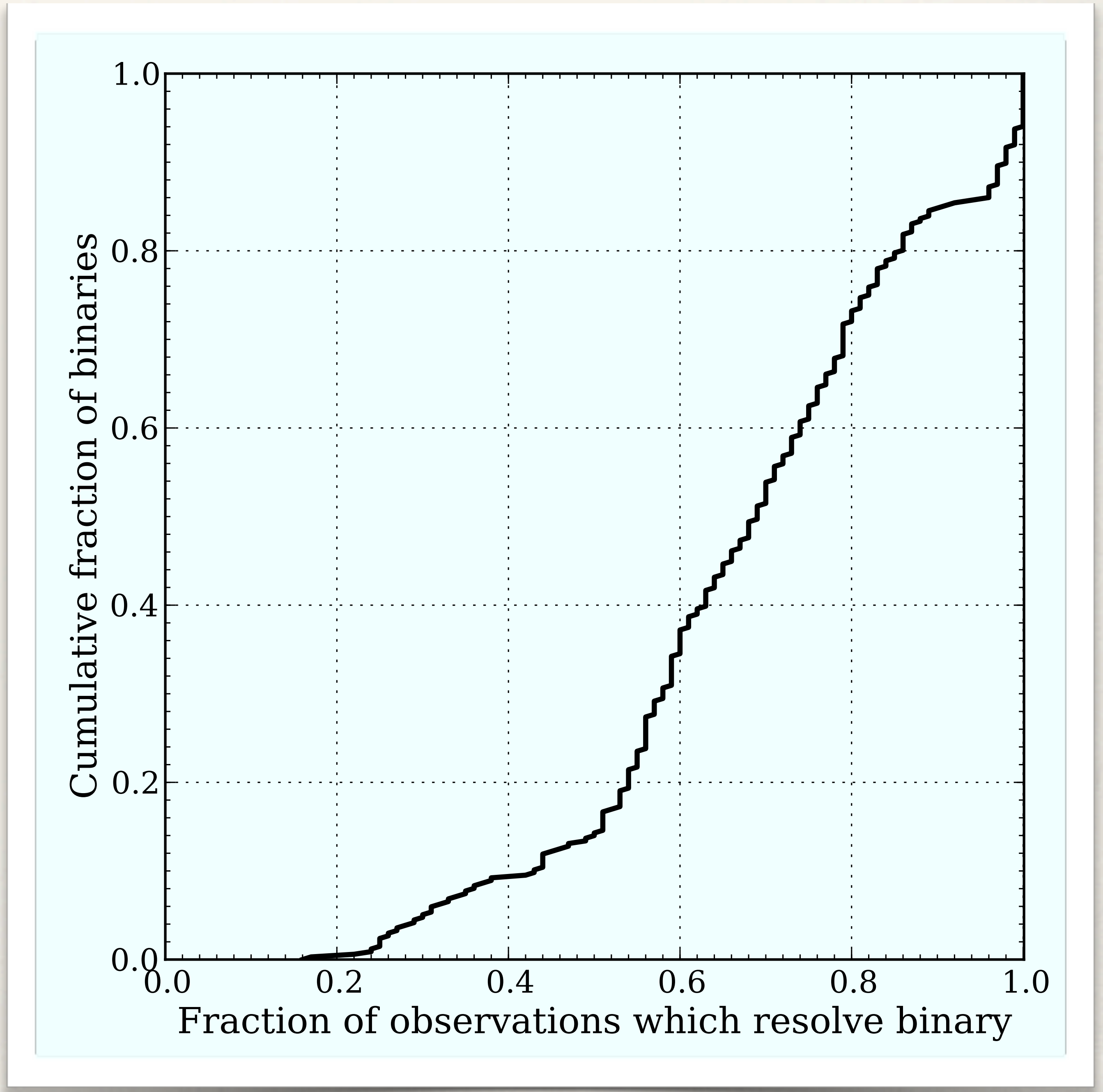


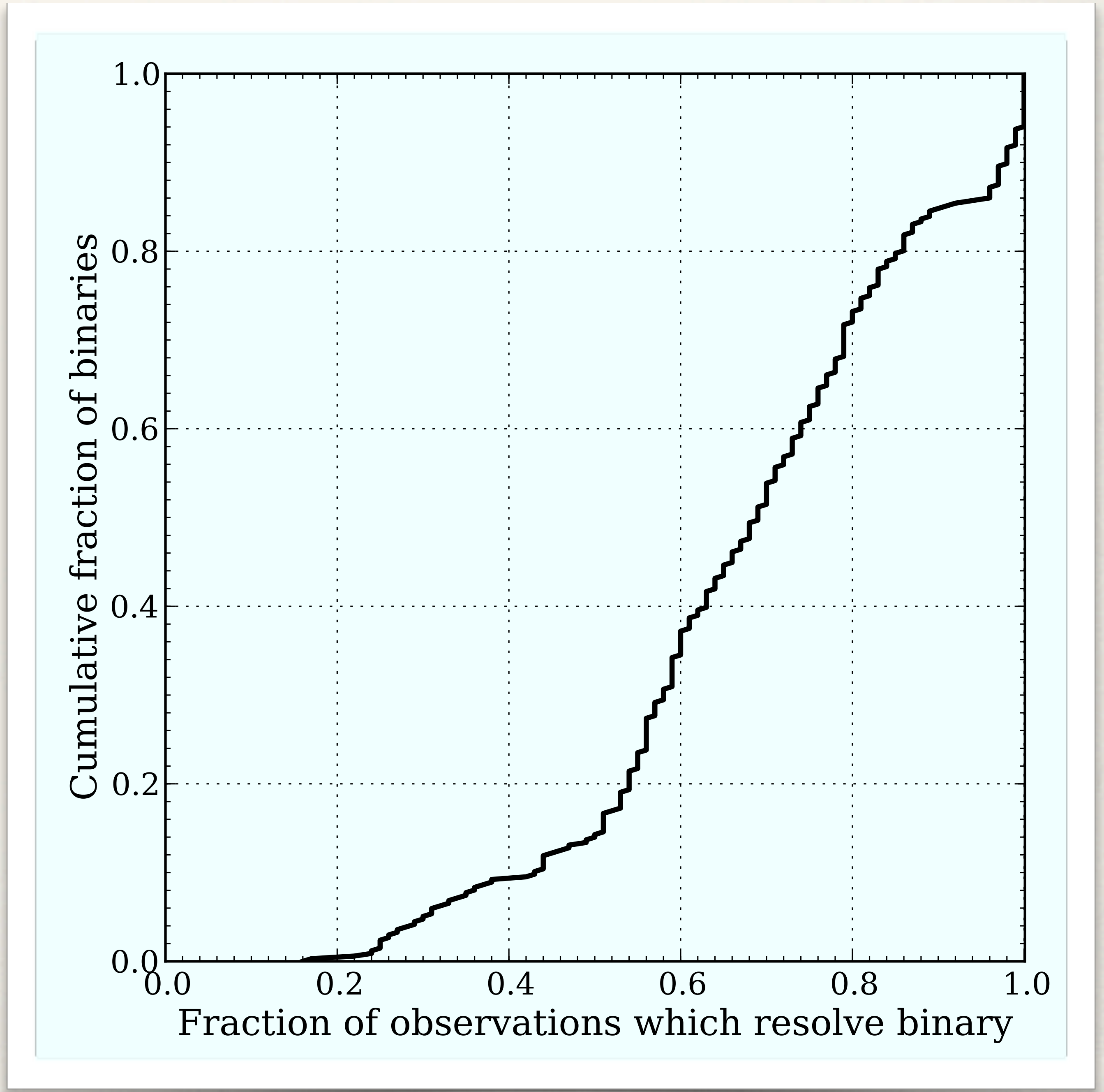
Discovery simulations: LSST

- All binaries from Parker et al. 2011 would be resolved in at least 18% of LSST visits over 10 years of operation
- With planned baseline of ~230 r-band visits per field, minimum number of resolved epochs is ~40.
- Compare to Parker et al. maximum sampling of 35 epochs (2001 QW322)



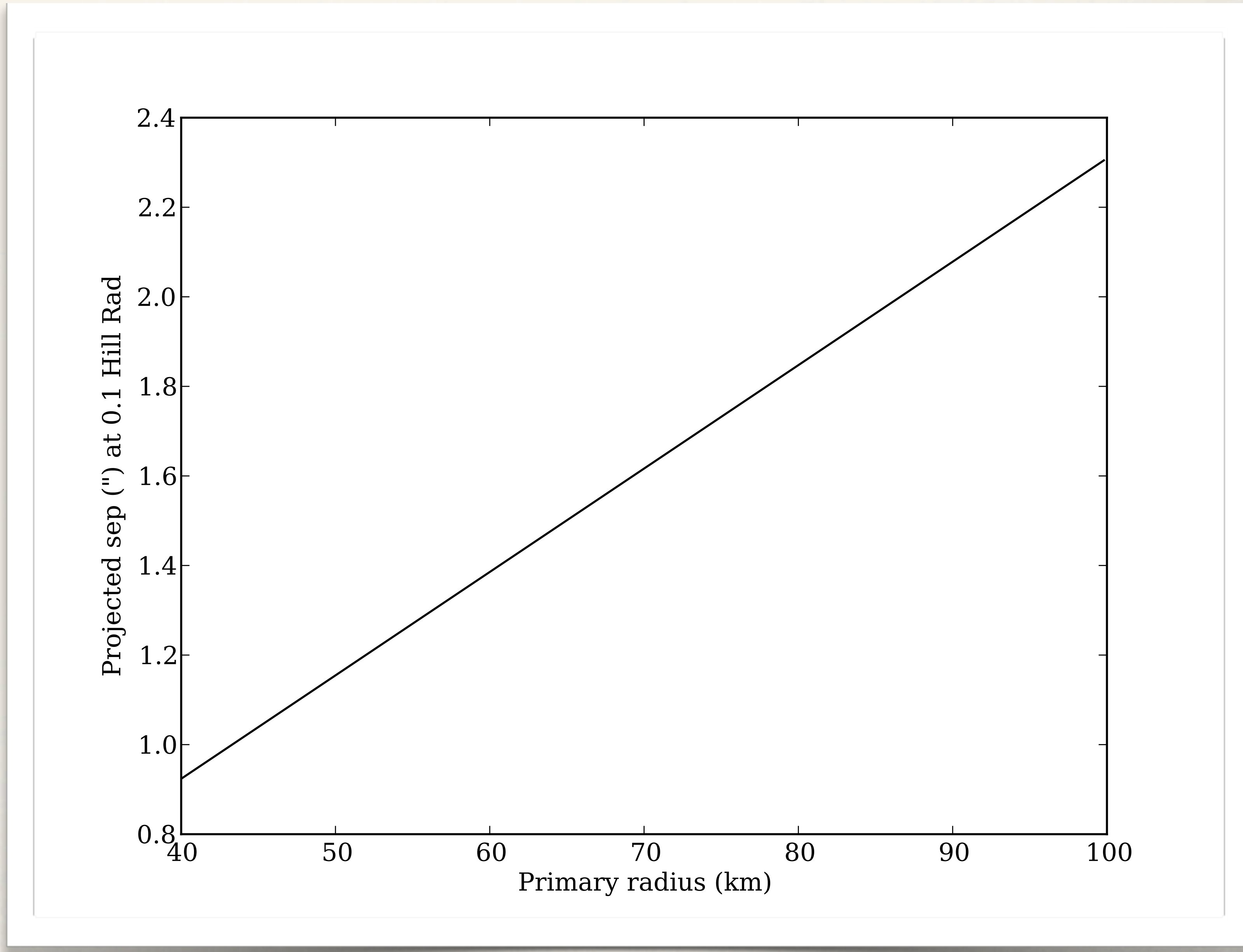
How many UW-TNBs?

- Lin et al. (2010): UW-TNBs at least 1.5% of Cold Classical Kuiper Belt (95% lower limit)
- Assume no binary fraction variation with radius
- CFEPS estimates ~17,000 objects in CCKB at magnitude limit of LSST
    - ~250 ultra-wide binaries



How many UW-TNBs?

- Biases to take care of:
    - Albedo vs. luminosity function
    - Separation
    - Orientation

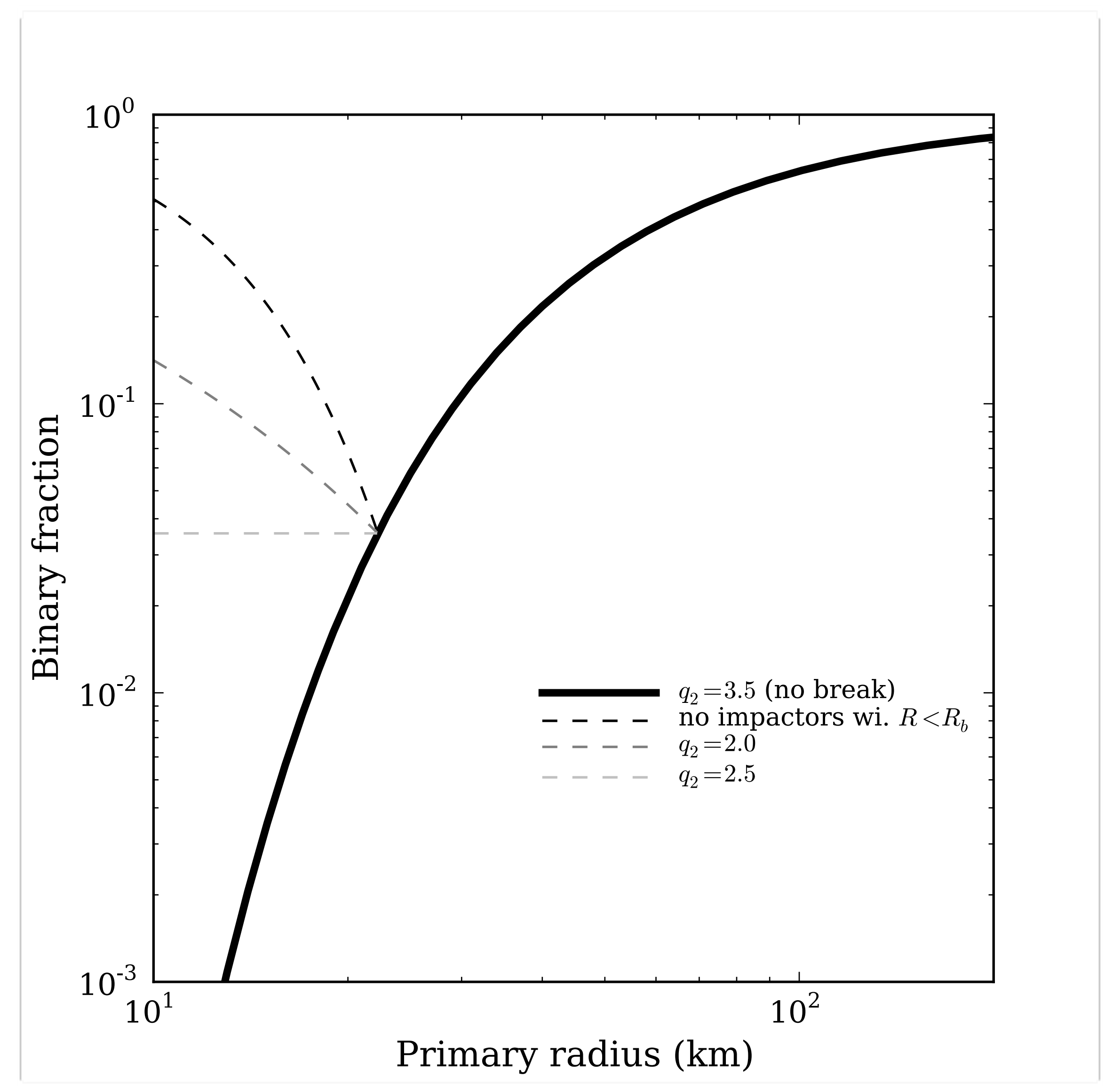


What can we do with 250 binaries?

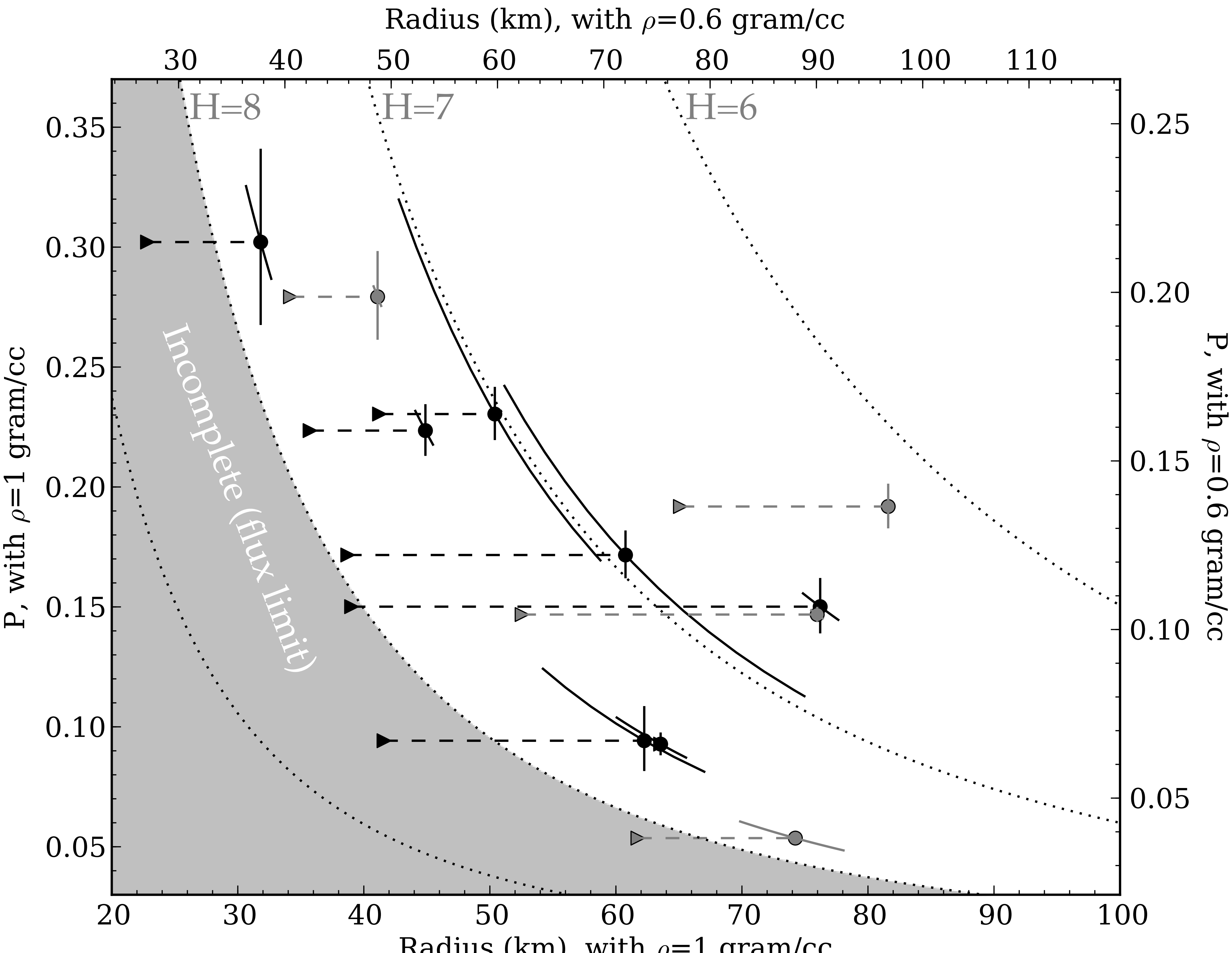
- Extremely detailed mutual orbit distributions
    - eg., is inclination distribution different for prograde / retrograde systems?
- Color / orbit trends
- Detailed host population information
    - eg., does the “Kernel” component host wide binaries?

What can we do with 250 binaries?

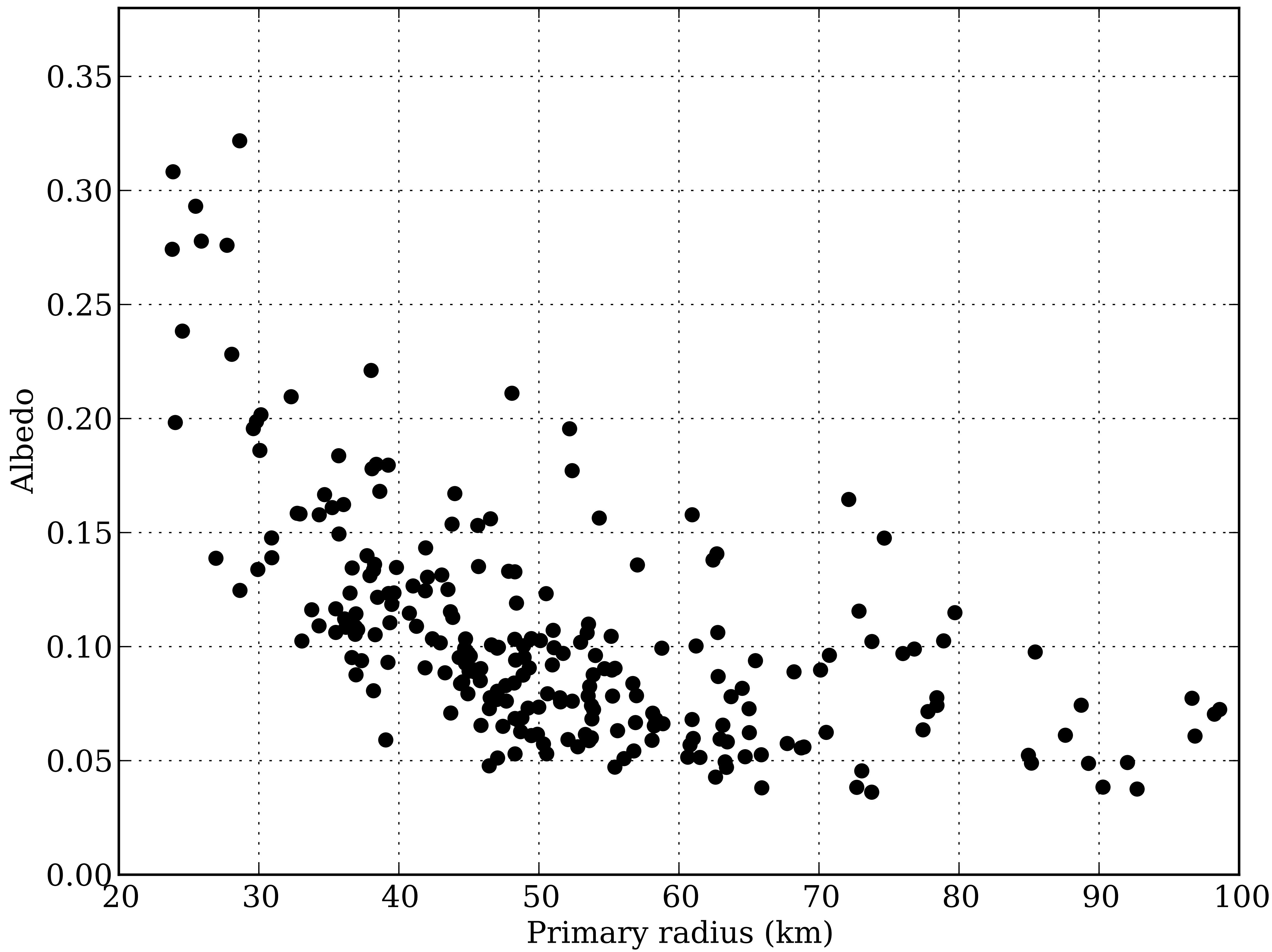
- Albedo distribution vs. binary fraction variations
    - Collisional evolution with certain impactor distributions will cause a strong trend in binary fraction with radius
    - Can be used to measure total extent of collisional grinding



Albedos and Radii

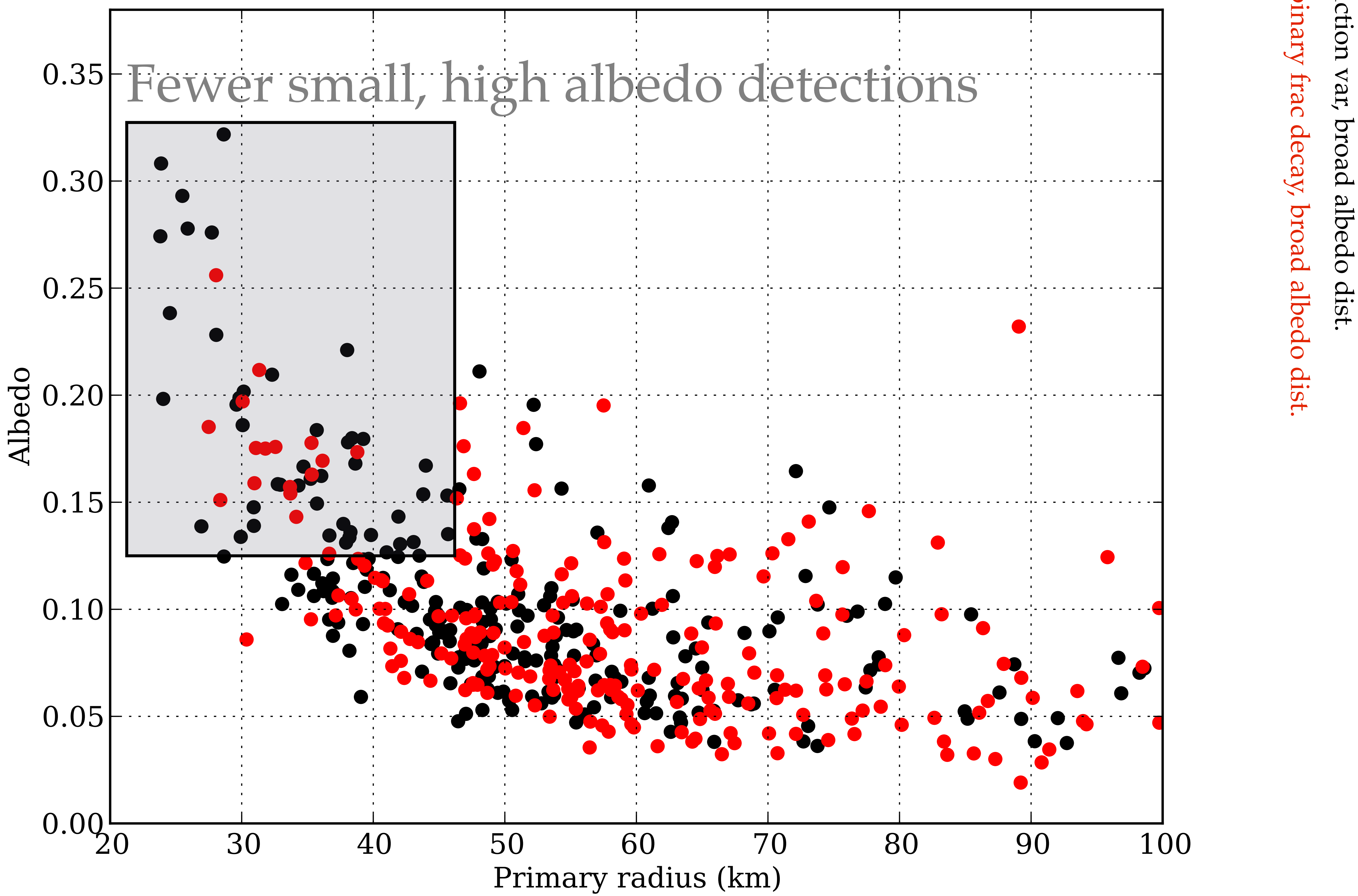


Albedos and Radii

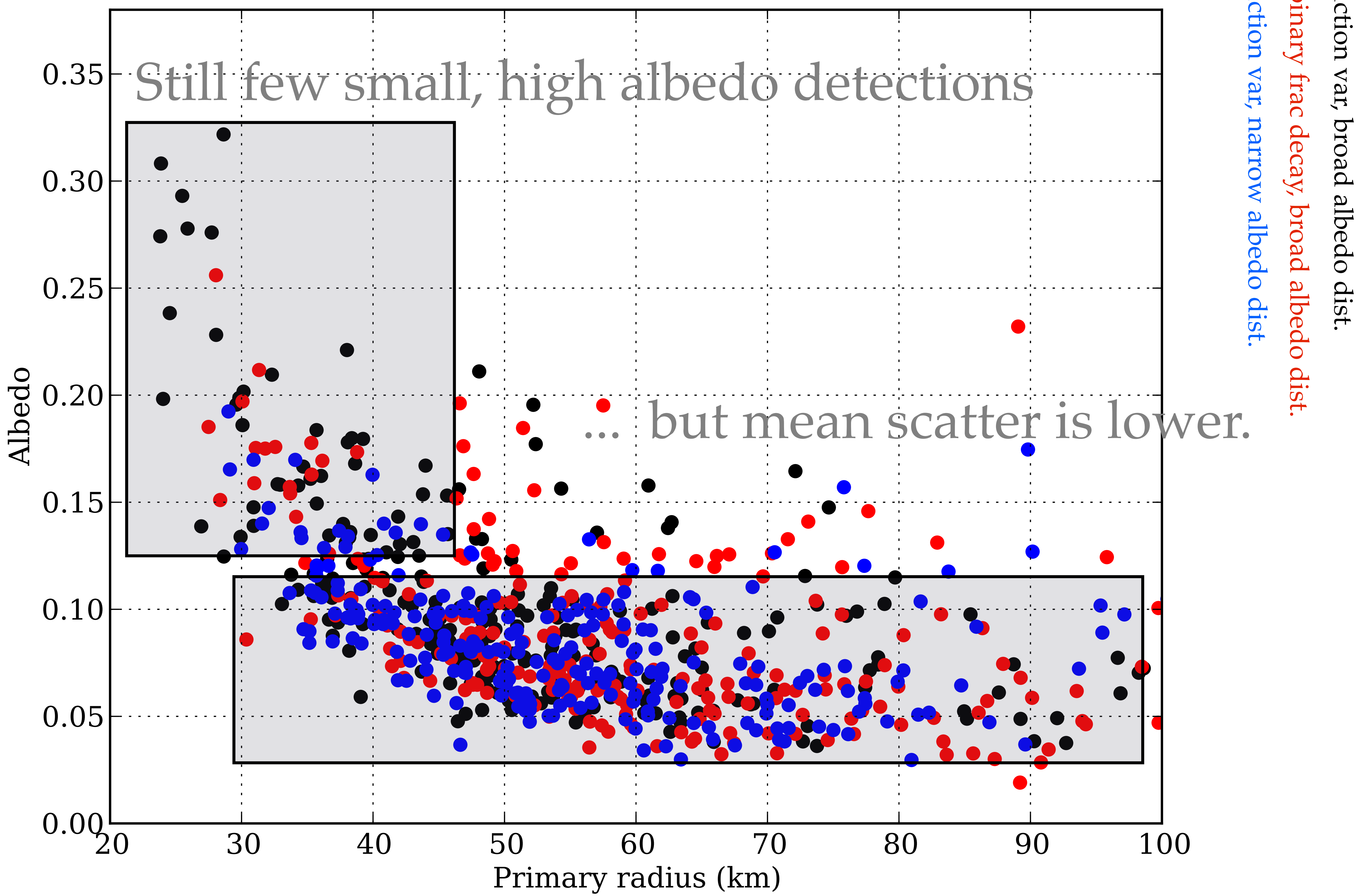


No binary fraction var, broad albedo dist.

Albedos and Radii



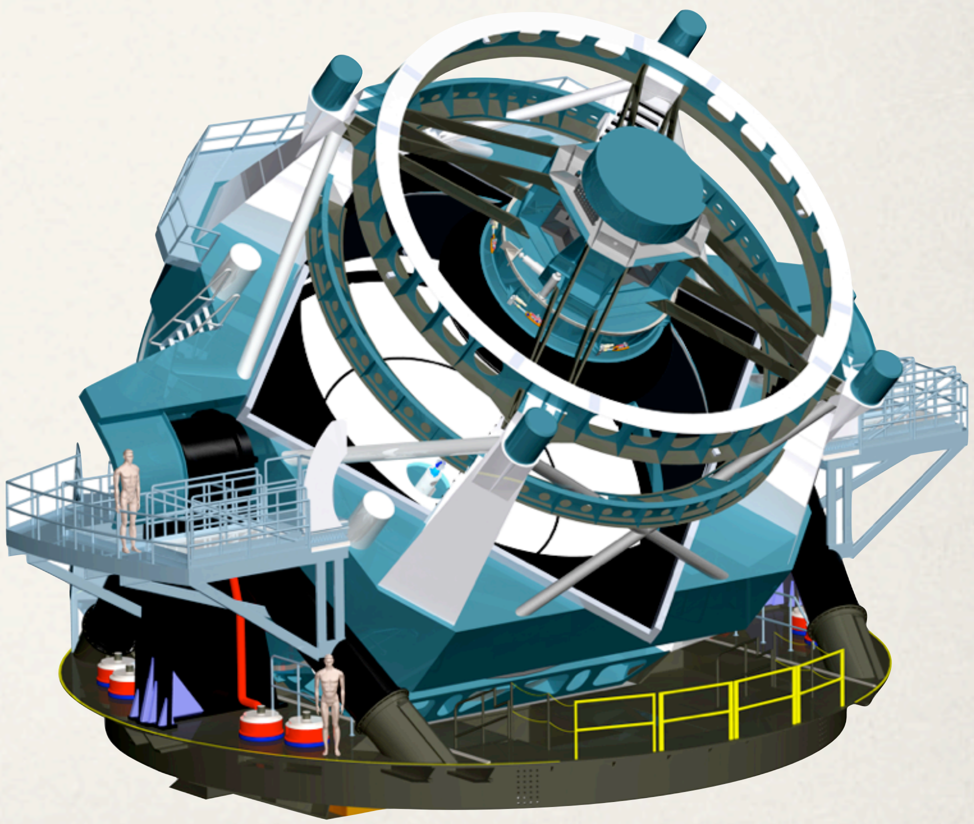
Albedos and Radii



Conclusions

- Ultra-Wide Trans-Neptunian Binaries are valuable tracers of the dynamical history of the outer Solar System

- Wide-area surveys like LSST will discover and characterize the orbits of hundreds of UW-TNBs



- Careful debiasing will allow disentanglement of albedo distribution and binary fraction trends, further constraining collisional grinding in the Kuiper Belt