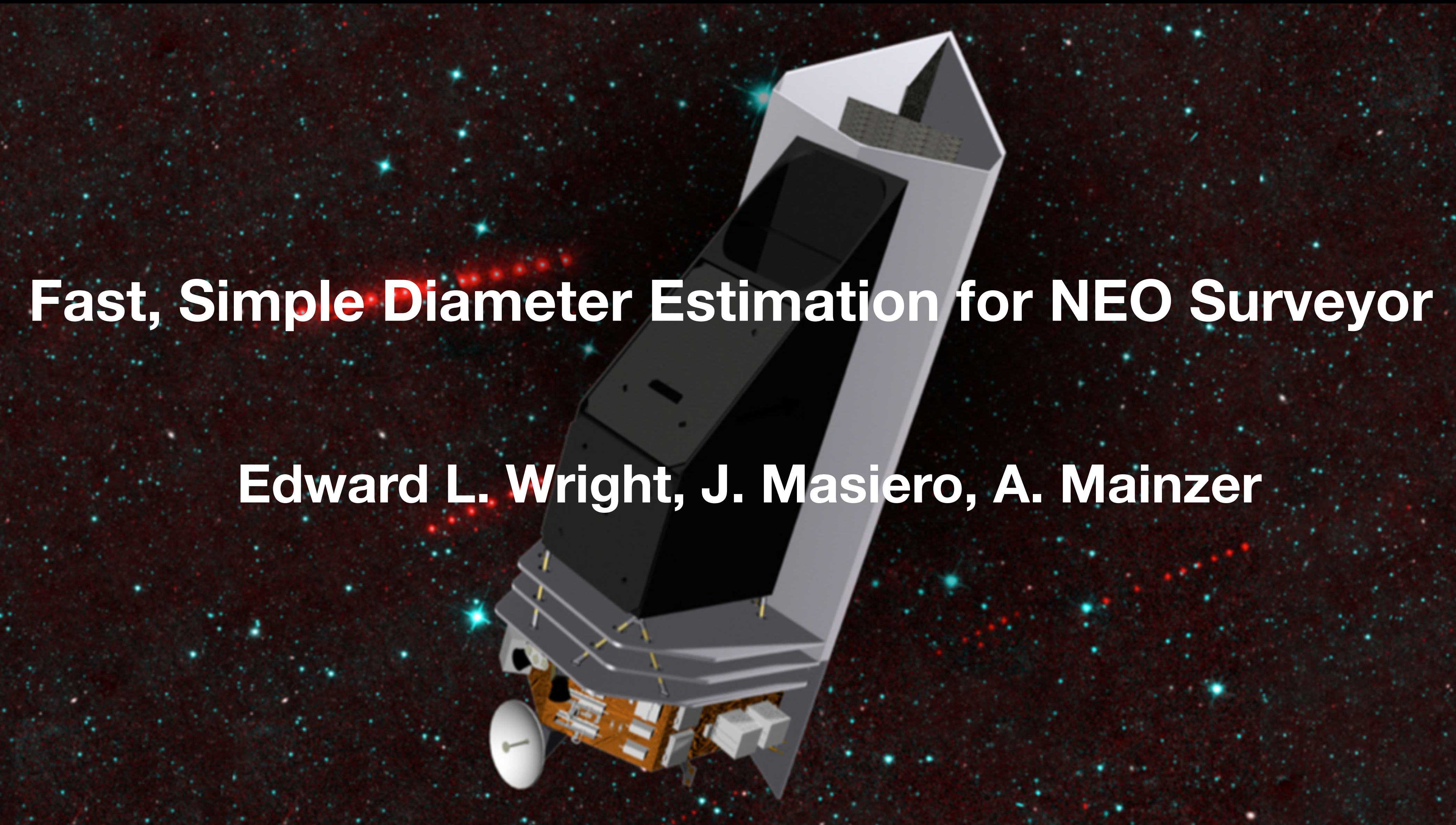


Fast, Simple Diameter Estimation for NEO Surveyor

Edward L. Wright, J. Masiero, A. Mainzer

Total power from the asteroid

=

Solar power to the asteroid

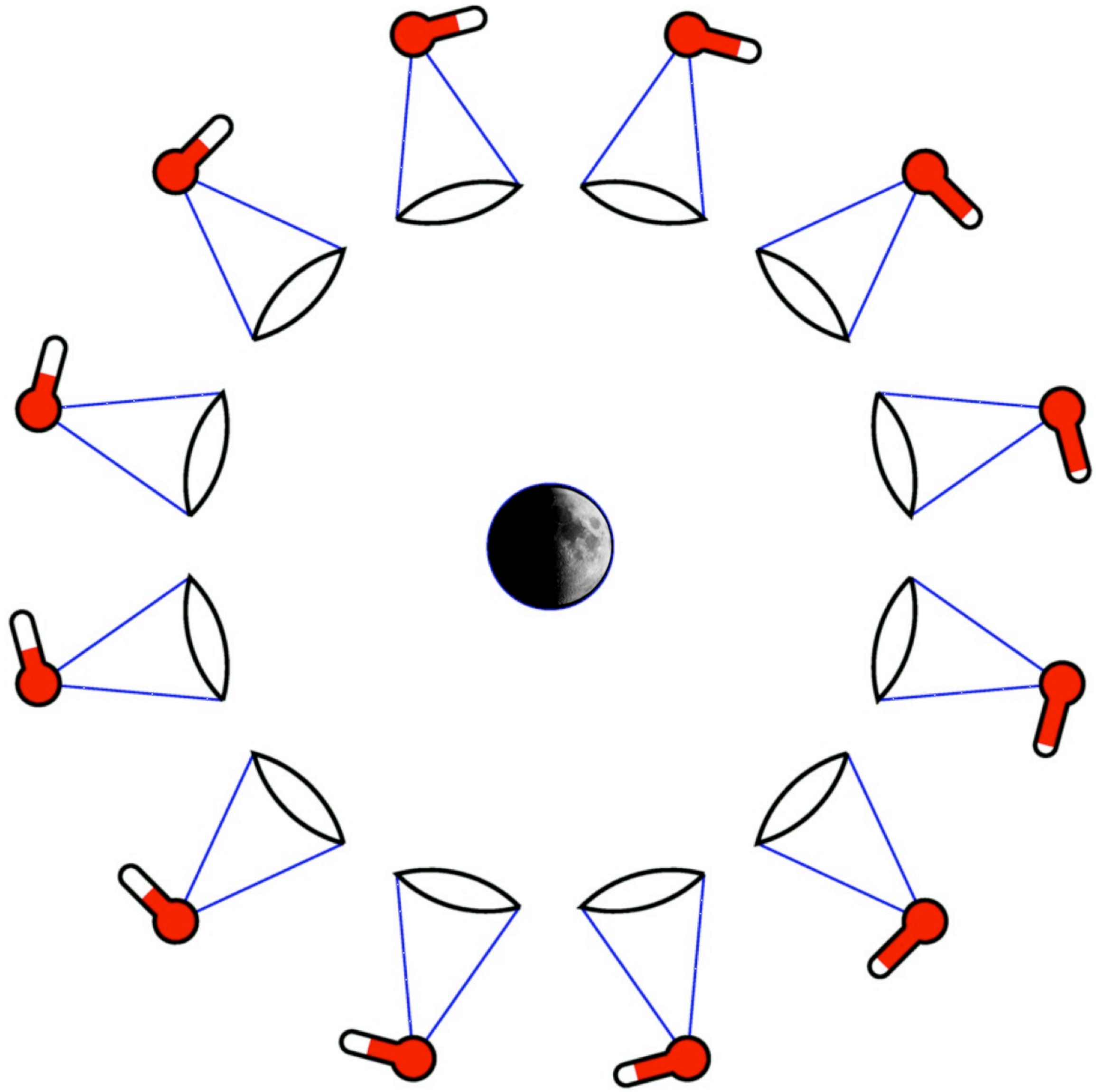
~

Diameter^2

$$L_{ast} = \frac{(\pi/4) D^2 L_{\odot}}{4\pi r^2} = 4\pi\Delta^2 < F_{bol} >$$

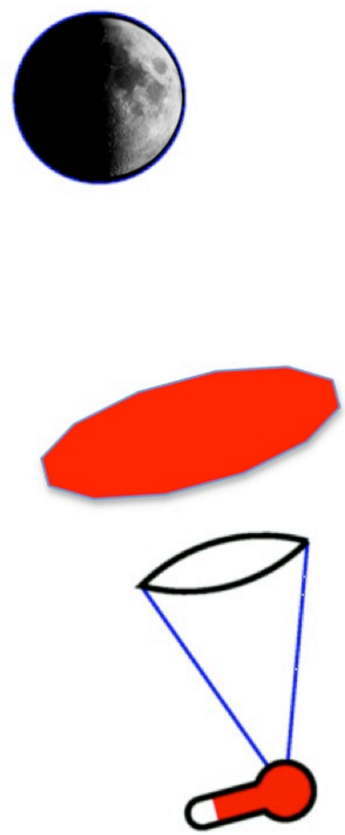
where $<F_{bol}>$ is the angle averaged bolometric flux

$$D = 8\sqrt{\pi} r \Delta \sqrt{< F_{bol} > / L_{\odot}}$$



We want the bolometric flux averaged over all viewing angles to get the total power from the asteroid.

We typically have the flux in the NC2 channel at 8 microns from one viewing geometry. The NC1 channel has lower SNR for asteroids so computing color temperatures (or fitting the NEATM) is a noisy process.



The integral we want

$$4\pi < F_{bol} > = \int \int \nu F_\nu(\hat{n}) d \ \ln \nu \ d\Omega$$

The correction factor we need

$$\mathrm{Fraction} = \frac{\nu F_\nu(\hat{n})}{< F_{bol} >}$$

How well can we approximate the integral over all angles and frequencies using data in one band from one angle?

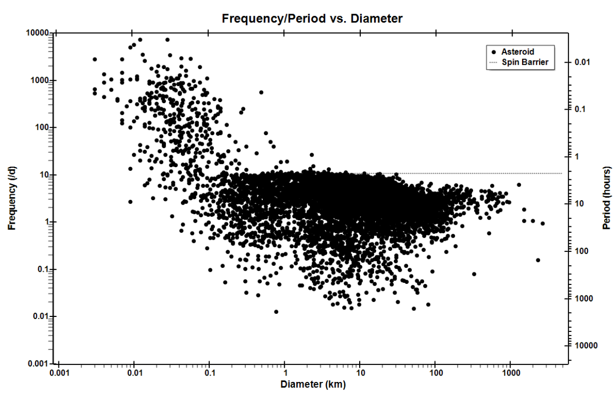
The approximation can be pretty good, and better when the observation is near the peak of the spectrum and the angle is near the peak of the phase curve.

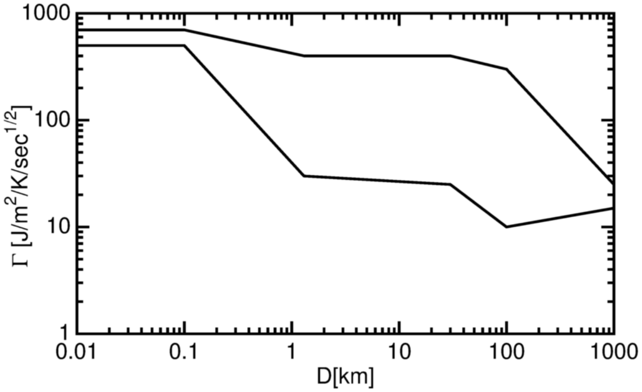
Primary uncertainty is from thermal inertia and direction of rotation.

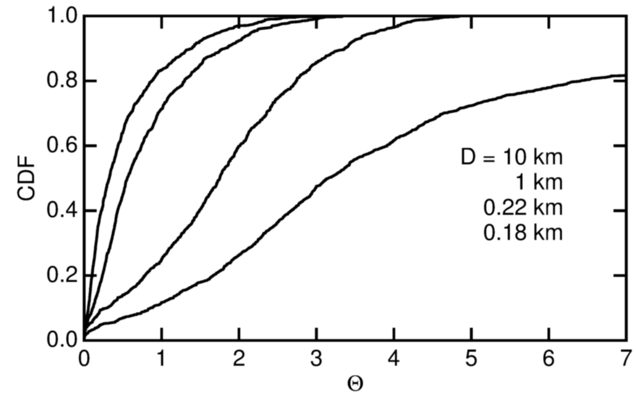
Big Unknowns to Average Over

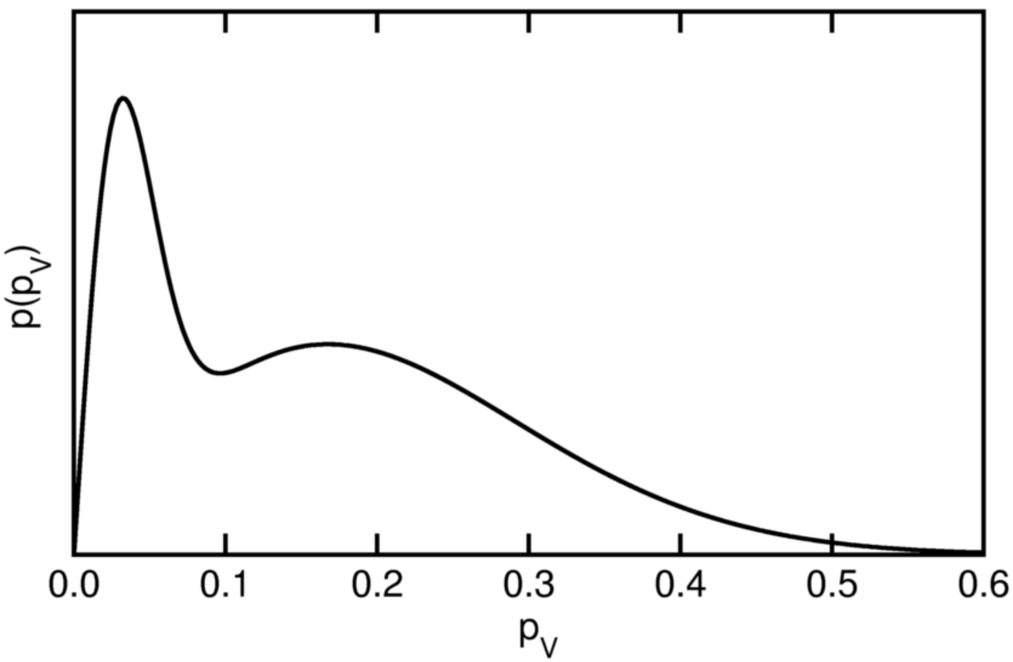
- Thermal Inertia - larger for smaller bodies
- Rotation Period - smaller for smaller bodies
- Direction of rotation [pole position]

Rotating cratered thermophysical model to compute Fraction using these priors:



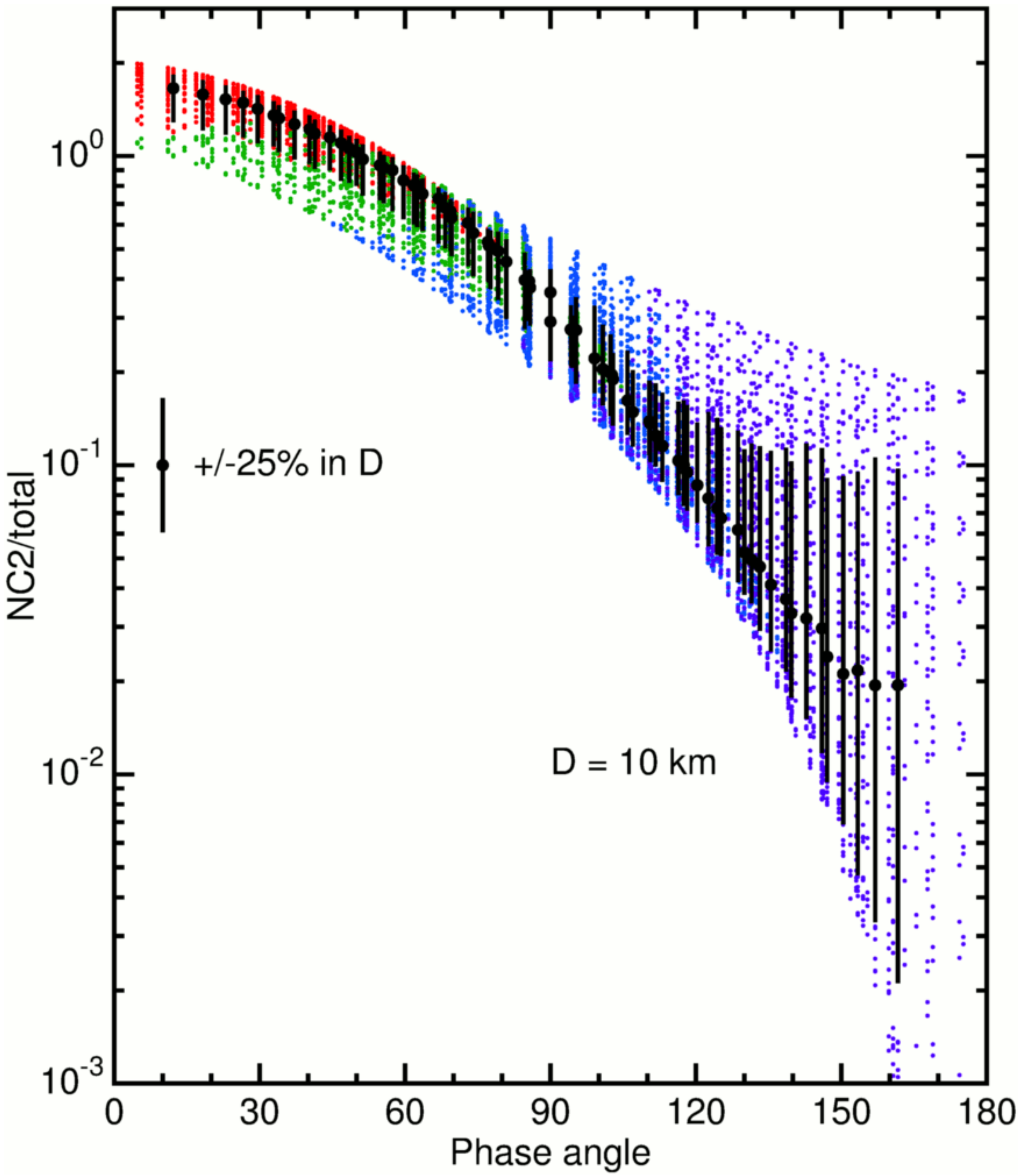






- **Parameter Priors**
  - **Gamma/Period gives Theta²**
  - **Albedo included but not very important**
  - **Pole either isotropic or perpendicular to the orbit**

Big Objects act like NEATM

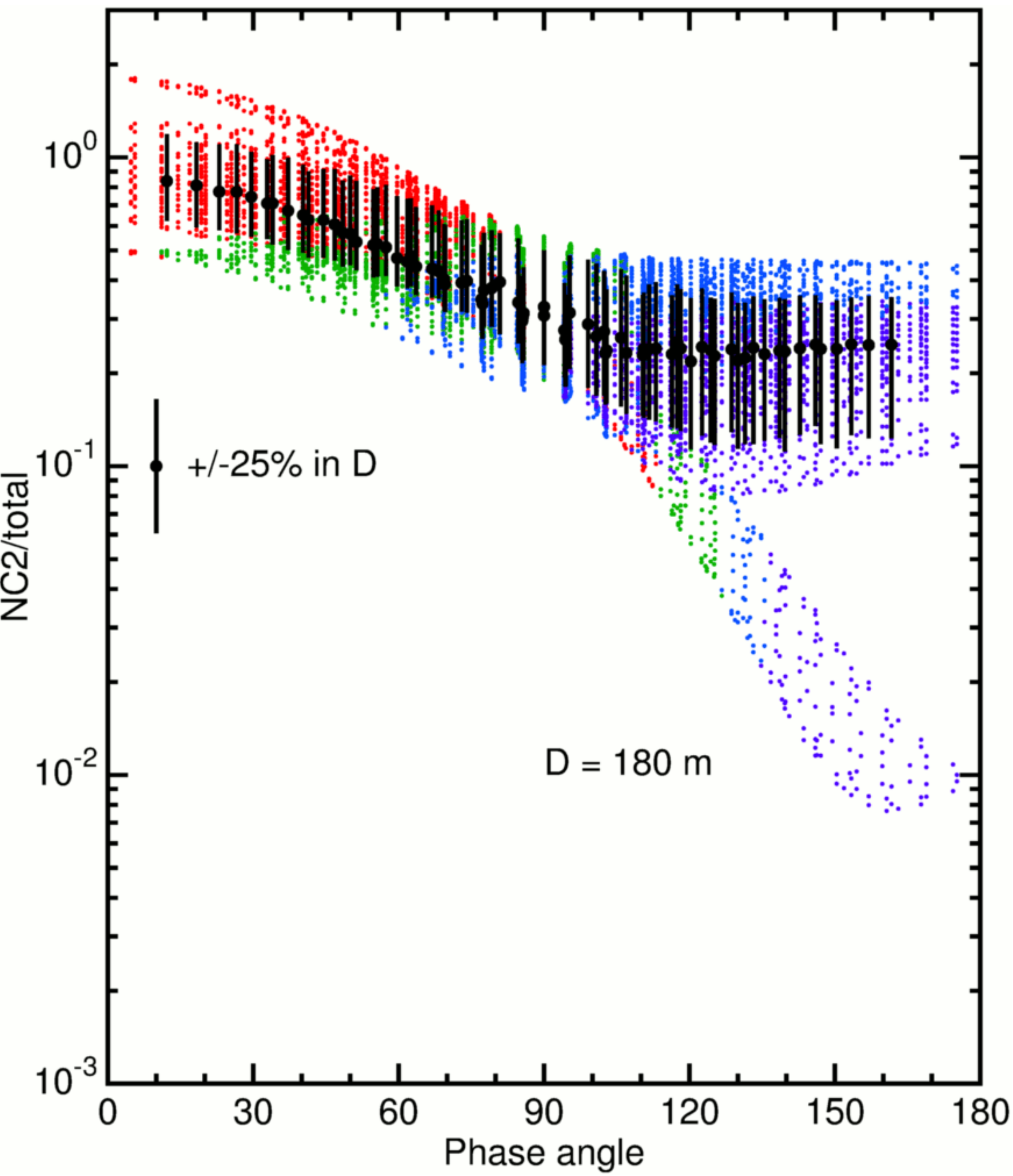


1 AU from Sun

Dot color shows the NC1/NC2 color temperature.

Color temperature is well correlated with the Fraction at small phase angles so the NEATM works well.

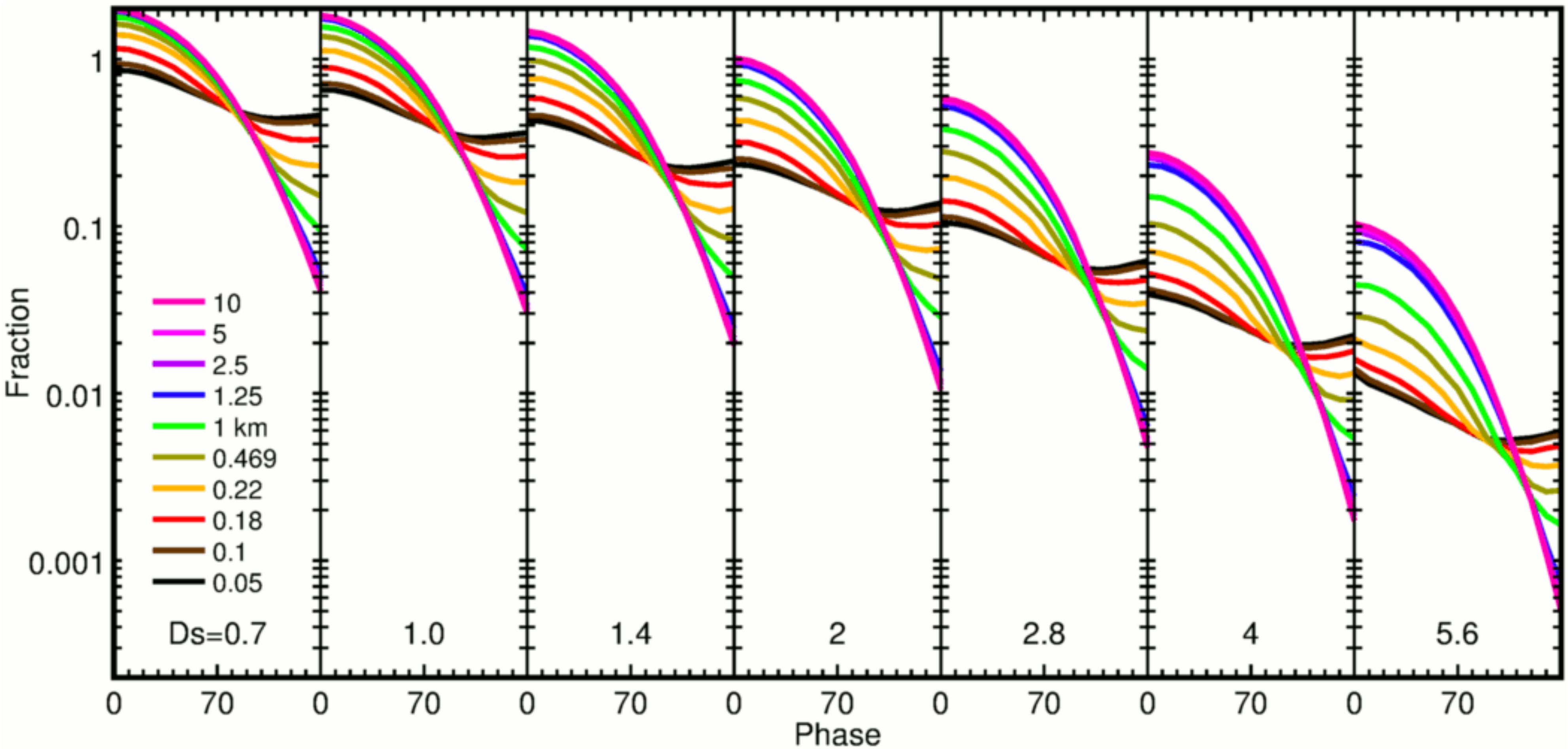
Small Objects act like FRM



1 AU from the Sun

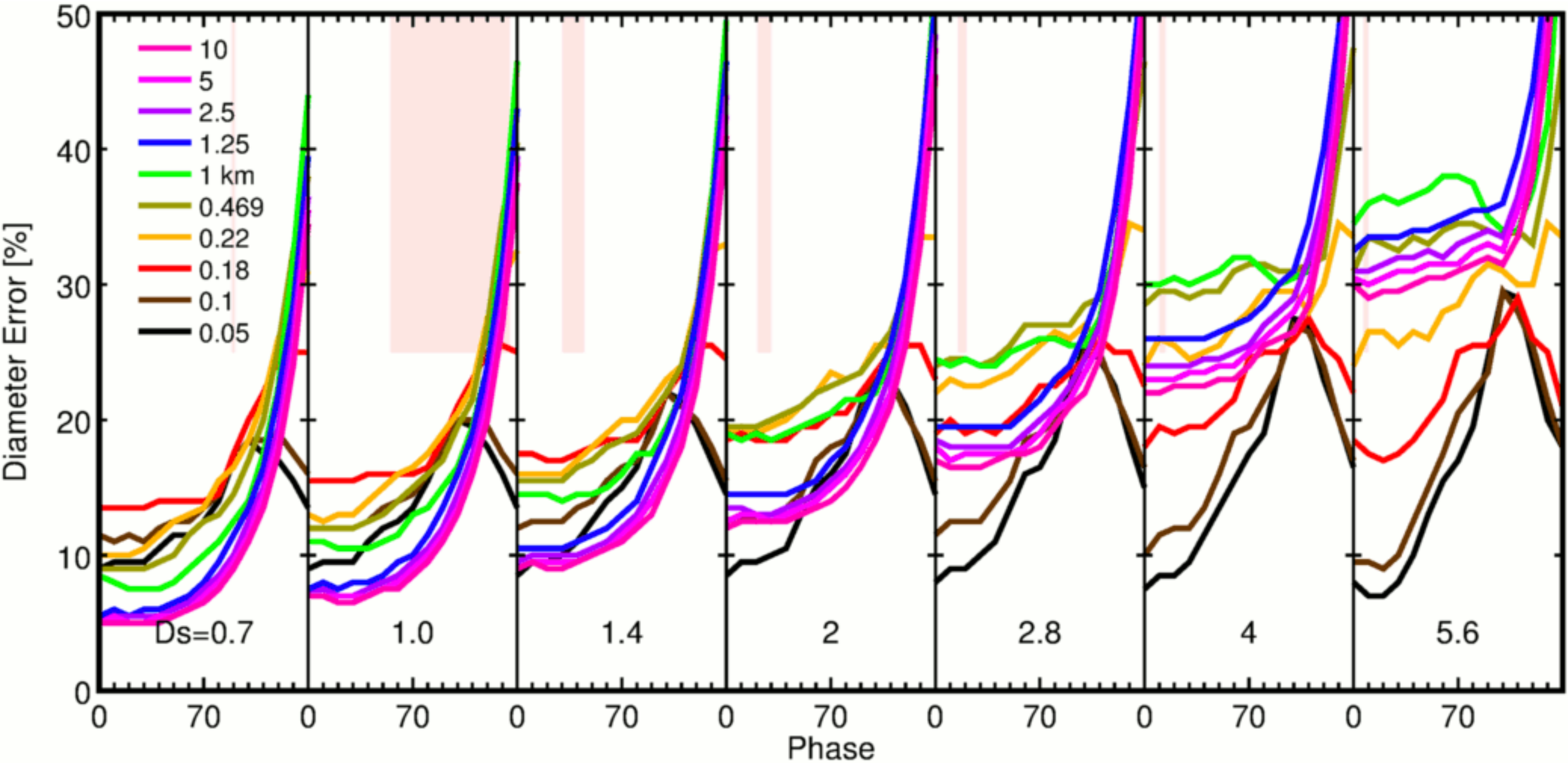
At large phase angles the models are much brighter than the NEATM and the color temperature is poorly correlated with the Fraction.

The FRM works better because both the thermal inertia and the rotation rate are larger for small diameters.



Use median Fraction from these scatter plots for the diameter estimate

Resulting Diameter Errors



Use the scatter from the scatter plots to get the diameter uncertainty. Better than 25% (1 sigma) accuracy for asteroids at r < 4 AU in the NEO Surveyor field of regard (pink shading) and big enough to detect.

Implementation & Future Work

- Better priors on thermal inertias for small sub-km bodies can be incorporated as new data are analyzed.

- The median fraction, the mean color, the fraction vs color correlation, and the scatter are tabulated vs r, phase & D. Predicted fluxes found by interpolation. Table size 22 kB

- Diameters are found by iteration.

- When the rotation pole is perpendicular to the orbit, we also know the sub-observer latitude and the hour angle to within a sign but this information is not currently utilized. A 4-D table will be larger but still practical.

Caveats: Lightcurves

- Clearly one needs to average the bolometric flux over the light curve as well as angles. The diameter of a circle with the average projected area toward the sun will be found.
- In general, the flux variation due to rotation is moderate: even a 2:1 flux range is only a 100 ln(2) = 70% pk-pk variation, or 25% RMS, and NEO Surveyor will get ~8 fluxes at "random" phases so the error on the average flux will be about 9%.
- The Thousand Asteroid Light Curve Survey (Masiero etal, 2009) found $p(b/a)d(b/a) \sim (b/a)^2$ which gives a median b/a=0.8

Caveats: Eccentricity

- Elliptical orbits introduce the possibility of storing heat during perihelion passage and radiating it at aphelion. McLennan & Granvik (2020) found ~5% RMS bolometric flux changes for $e = 0.5$.

- This effect is enhanced for comets which can store a large amount of energy as latent heat of vaporization of volatiles. So diameters of comet nuclei should be treated with caution even if the separation of the nuclear flux from the coma is completely accurate.

Conclusions

- Diameter estimates work better for fluxes measured near the peak of the spectrum in the thermal infrared, and for small phase angles.
- NEO Surveyor will have to contend with large phase angles for some small bodies inside the Earth's orbit that are not detectable across an AU.
- Our current prior knowledge of thermal inertias and rotation periods causes sub-km objects to behave like the Fast Rotating Model which gives larger and less variable fluxes at large phase angles.
- NEO Surveyor should give diameter estimate with uncertainties less than 25% for almost all of the millions of objects it will detect.