NEOWISE Observations of the Asteroid (99942) Apophis

Akash Satpathy[1], Amy Mainzer[1], Joe Masiero[2], Jana Chesley[3], Roc Cutri[2], Tommy Grav[1], Emily Kramer[3], Tyler Linder[4], Vishnu Reddy[1], Edward L. Wright[5]

[1]Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ, USA | Contact: satpathyakash@email.arizona.edu
[2]Caltech-IPAC, Pasadena, CA, USA
[3]Jet Propulsion Laboratory/Caltech, Pasadena, CA, USA
[4]Astronomical Research Institute, Ashmore, IL, USA
[5]UCLA Astronomy, Los Angeles, CA, USA

THE UNIVERSITY OF ARIZONA

About NEOWISE

The Near-Earth Object Wide-field Infrared Survey Explorer (NEOWISE; Mainzer et al. 2014, Wright et al. 2010) is a two-band all-sky thermal infrared survey that is well suited to investigating the physical properties of asteroids and comets. Since its reactivation in 2013, NEOWISE has detected tens of thousands of minor planets in the solar system in addition to the initial detections from the original prime WISE mission.

Asteroid (99942) Apophis

- Apophis is a potentially hazardous near-Earth asteroid that was discovered on the 19th of June, 2004 by R. A. Tucker, D. J. Tholen, and F. Bernardi at Kitt Peak.
- It made headlines post-discovery when the initial collision probability for the year 2029 was estimated to be as high as 2.7%. Follow-up studies ruled out the chance of impact during the two close approaches - 2029 and 2036.
- Nevertheless, it remains a potentially hazardous asteroid of interest since it will pass beneath the altitude of Earth's geostationary satellites during its 2029 approach (based on close-approach data from the JPL Small Body Database).
- Currently, Apophis is the subject of an ongoing international exercise where it is being treated as a newly discovered object. NEOWISE reported the initial "discovery" observations of the object, and these "discovery" images were used to determine its physical characteristics, allowing for an improved assessment of its threat level and showcasing the speed and accuracy of the NEOWISE data pipeline.
- The results allowed exercise participants to immediately conclude that if the object were to impact Earth, then it would merely cause a regional disaster and not a global one.

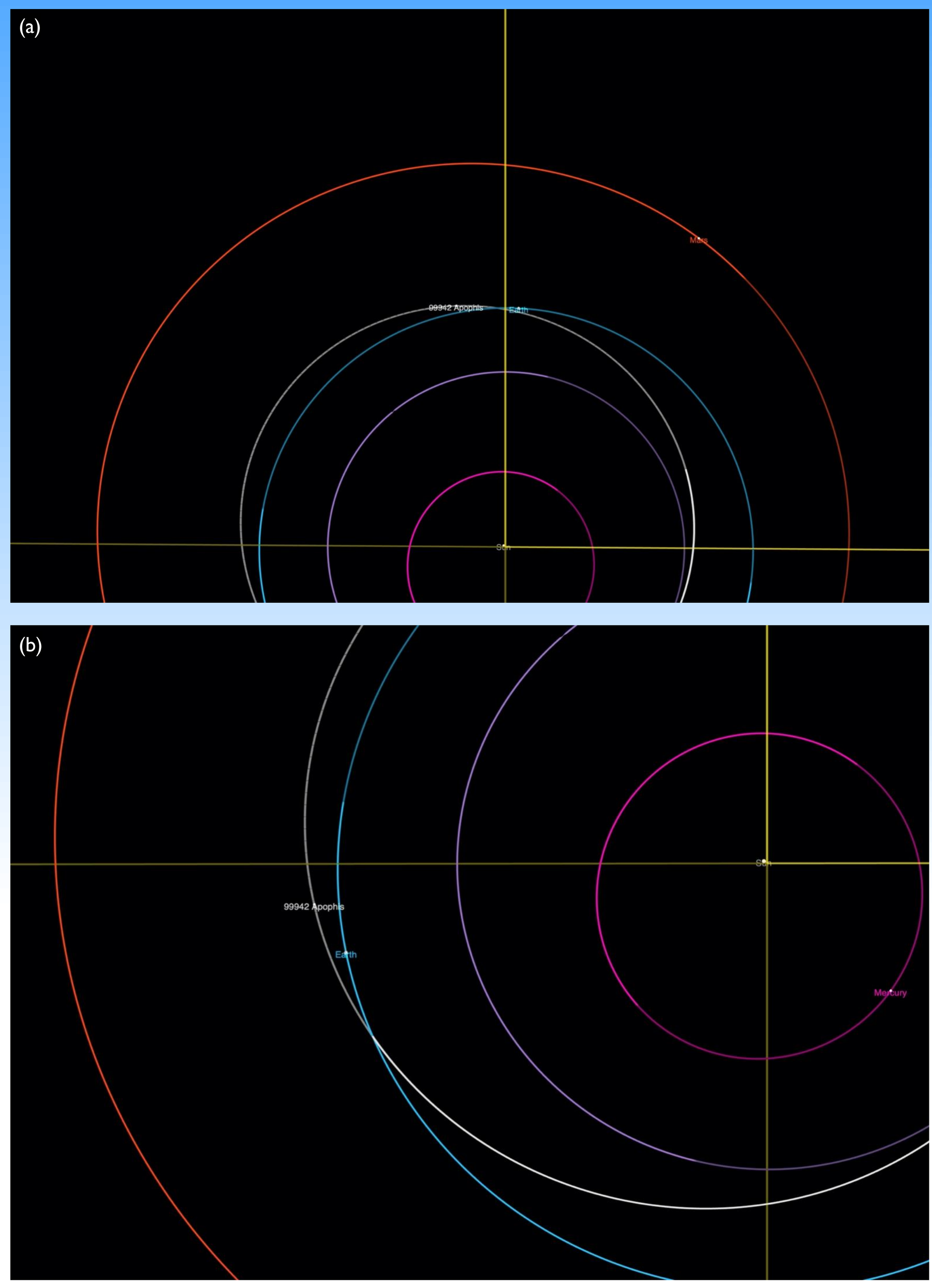


Figure 1: (a) Observing geometry during the second epoch on the 2nd of April, 2021; (b) Observing geometry during the first epoch on the 19th of December, 2020 (both obtained from the JPL Small Body Database).

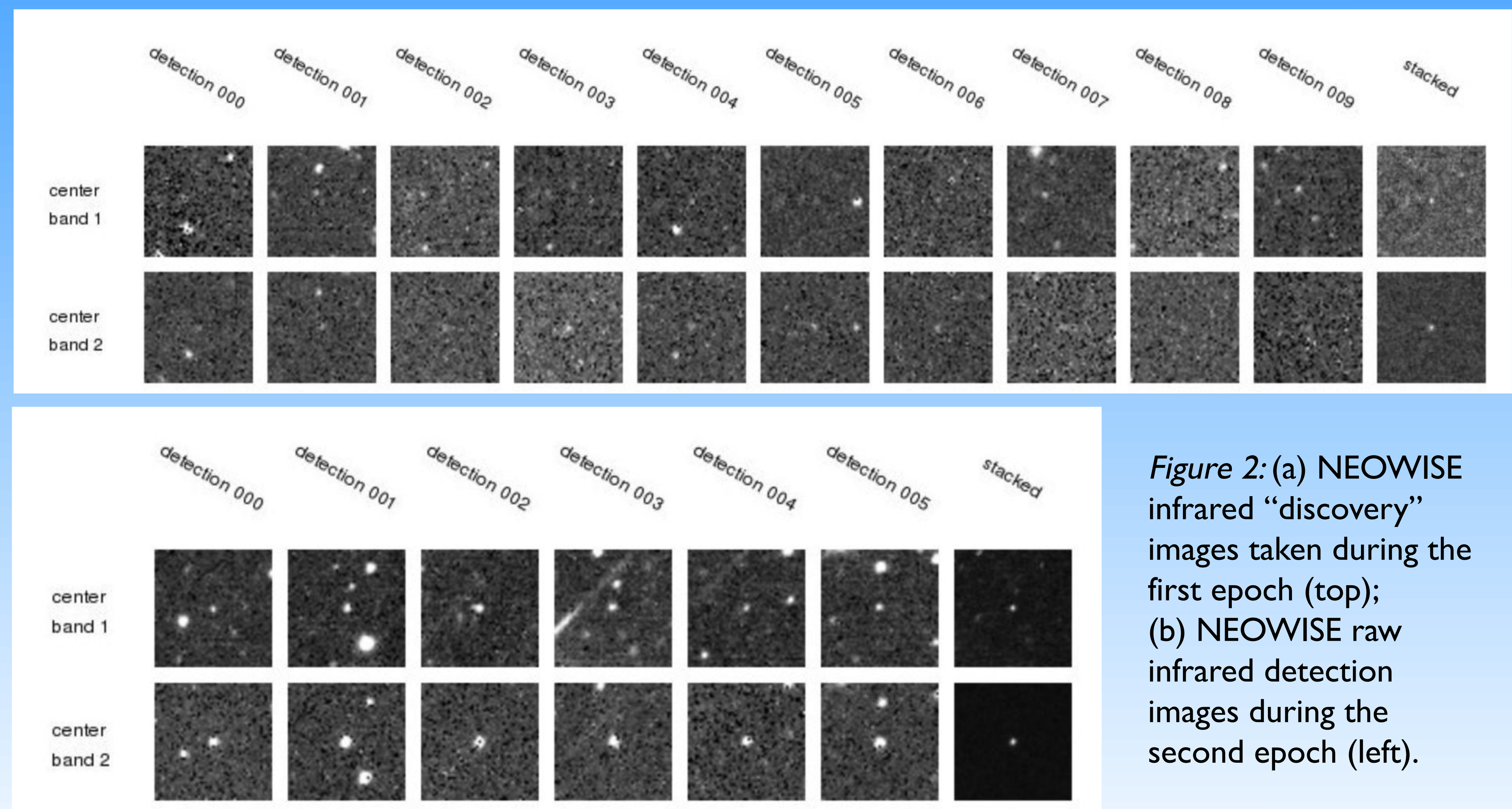
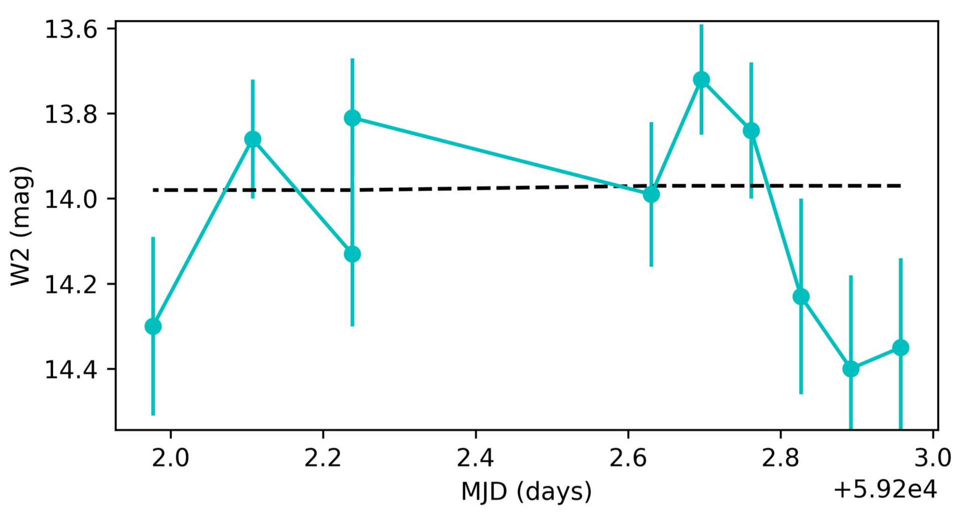


Figure 2: (a) NEOWISE infrared "discovery" images taken during the first epoch (top); (b) NEOWISE raw infrared detection images during the second epoch (left).

The Observations

- NEOWISE observed Apophis during two different epochs: first, on the 18th of December 2020, and the second, on the 2nd of April 2021 (Figure 1 & Figure 2).
- Having two epochs is significant as it allow us to observe the object from different viewing angles which in turn improves diameter, albedo, and thermal inertia estimations using thermophysical models (Figure 3 & Figure 4).
- Near-simultaneous visible photometry obtained using the SMARTS 1.0 meter telescope from the Cerro Tololo Inter-American Observatory (CTIO) was also used to provide an improved constraint on the absolute visual magnitude (H) of 19.04 +/- 0.20 mag.



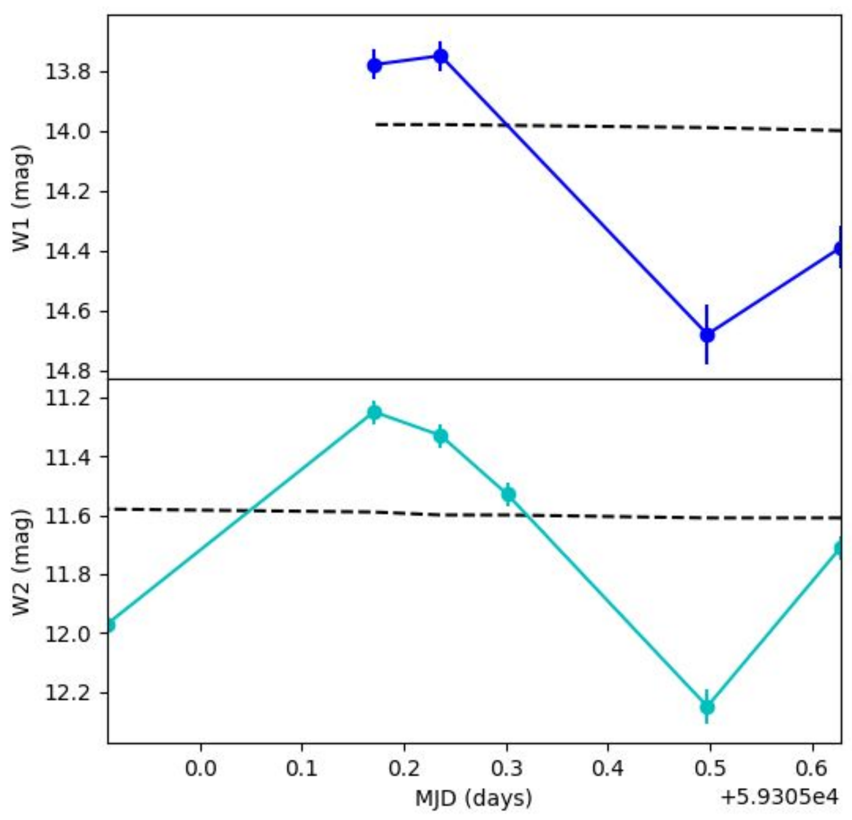
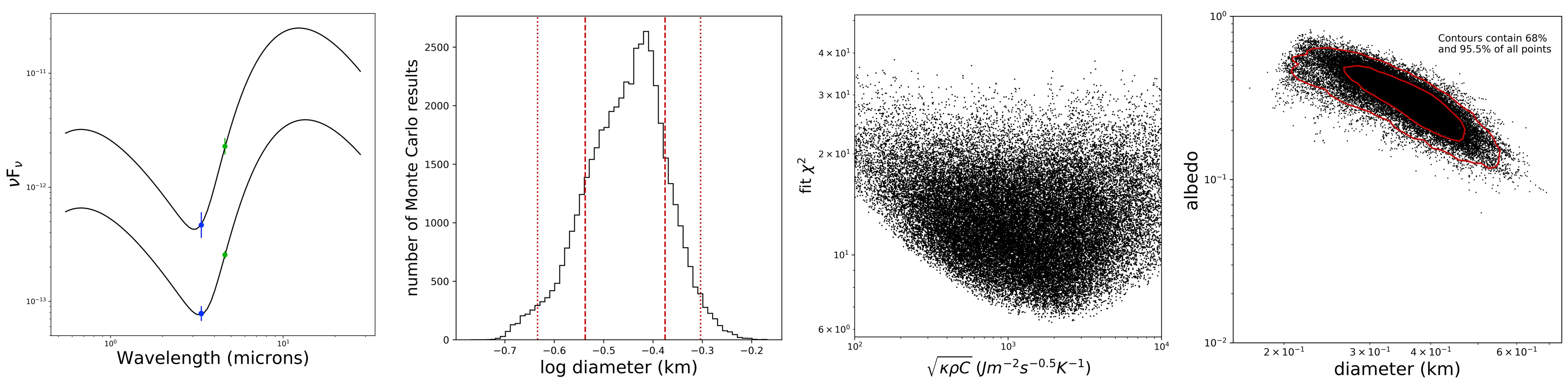


Figure 3: Plots produced post-NEATM analysis (a) lightcurve from the first epoch with a topocentric distance of 0.263 AU (top); (b) lightcurve from the second epoch with a topocentric distance of 0.135 AU (right).

Results from the Near-Earth Asteroid Thermal Model (NEATM)

- The Near-Earth Asteroid Thermal Model (Harris 1998) is a modified version of the Standard Thermal Model (STM) by Lebofsky et al. (1986) that takes into account irregular shapes, high phase angles of observations, rotational features, smaller size, and unique thermal properties of asteroids to produce improved fits.
- Applying NEATM on the first epoch data gives a diameter of 300 ± 60 m and an albedo of 0.47 ± 0.26 (systematic uncertainties for diameter albedo are ~20% and ~50%, respectively for diameters derived from 3.4 and 4.6 micron data; see Mainzer et al. 2014). NEATM analysis on the second epoch data gives a diameter of 410 ± 80 m and an albedo of 0.34 ± 0.15 (difference arises due to varying observing geometry).
- Average effective spherical diameter: 355 ± 70 m
  Average effective albedo: 0.41 ± 0.20
- Apophis appears to be significantly elongated due to the large lightcurve amplitude (Figure 3).
- Calculated diameter and albedo results are consistent with previous studies by Delbo et al. (2007), Muller et al. (2014), and Brozovic et al. (2018).

Figure 4 - Plots produced using the TPM analysis (left to right): (a) Flux during the two epochs; (b) Effective spherical diameter of the object; (c) log-log plot of the χ^2 values vs thermal inertia; (d) distribution of diameter vs. albedo in the 1σ and 2σ range.



Preliminary Results from Thermophysical Model (TPM)

- The Thermophysical Model employs (Wright et al. 2007 and Koren et al. 2015) Markov Chain Monte Carlo fits to compute the effective diameter, albedo, rotational pole position, and the thermal inertia of asteroids. Unlike NEATM where surface roughness is approximated by the beaming parameter, TPM calculations are done by assuming that the asteroid is a a rotating cratered sphere, where the steepness and fraction of the craters covering the surface can be varied.
- Effective diameter: 370 ± 60 m
  Effective albedo: 0.33 ± 0.09
  Thermal inertia: 500 - 3000 J m^{-2} $s^{-0.5}$ K^{-1}
  (Thermal inertia is important as it helps better constrain diameter and albedo estimations. A high thermal inertia indicates that the asteroid surface will be rockier, and that the asteroid will have a high Yarkovsky coefficient.)
- A previous study by Mueller et al. (2014) used thermal data from *Herschel* and found a thermal inertia in the range of 250 - 800 J m^{-2} $s^{-0.5}$ K^{-1}. Further, Licandro et al. (2015) combined GTC data with *Herschel's* thermal data and found a thermal inertia in the range of 50 - 500 J m^{-2} $s^{-0.5}$ K^{-1}.

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