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CHARACTERIZATION OF NEAR-EARTH ASTEROIDS FROM NEOWISE SURVEY DATA

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Extended Abstract—

The Near-Earth Object Wide-field Infrared Survey Explorer (NEOWISE) spacecraft has been conducting a survey of the sky in two thermal infrared wavelengths since its reactivation in December of 2013 (Mainzer et al. 2014b). NEOWISE orbits the Earth in a sun-synchronous polar orbit, surveying a ring of sky near quadrature, following the plan of the original WISE mission (Wright et al. 2010). Due to NEOWISE's scan pattern, it obtains repeated images of the same area of the sky, with most asteroids receiving 8-10 observations over the course of approximately 1 day. The WISE Moving Object Processing System (WMOPS, Mainzer et al. 2011a) searches this data stream for moving objects, reporting new and known objects that meet our search criteria to the Minor Planet Center. Periodically, manual searches are used to recover near-Earth objects outside of the WMOPS detection thresholds.

NEOWISE captures images simultaneously at 3.4 microns and 4.6 microns. For objects near the orbit of Earth, the 4.6 micron bandpass is dominated by thermal emission, which allows for thermal modeling to provide a constraint on the size of the object. When ground-based visible light measurements are also available, an albedo can be computed based on the thermal-infrared diameter. Since the beginning of the NEOWISE Reactivation mission, NEOWISE has obtained diameter and albedo characterization data for over 1400 near-Earth objects. We present an overview of the NEO characterization results from NEOWISE and their implications for our understanding of the NEO population. We also discuss the capabilities of the NEOWISE data with respect to the 2021 PDC impact exercise object.

NEO sizes from NEOWISE

Asteroids emit thermal infrared light because they are warmed by absorbing incident sunlight and re-radiate that light as heat. Once the orbit of an asteroid is known, the emitted light is primarily a function of the size of the asteroid, and can be constrained using a thermal model such as the Near-Earth Asteroid Thermal Model (NEATM, Harris 1998). Thermal infrared detections of asteroids therefore allow us to directly constrain the sizes of the observed objects.

As shown in Fig 1, the two bandpasses that are used by the NEOWISE Reactivation mission probe the thermal emission of asteroids that have heliocentric distances near 1 AU. NEOs are brighter in the W2 bandpass, and so the majority of NEOWISE NEO detections are at this wavelength. W2 also will have the smallest component of reflected light of the two bands, improving our ability to constrain the asteroid's size.

Using detections at these wavelengths, NEOWISE has provided characterization data for over 1500 near-Earth objects over all mission phases as part of regular data analysis (Mainzer et al. 2011b, Mainzer et al. 2012, Nugent et al. 2015, Nugent et al 2016, Masiero et al. 2017, Masiero et al. 2020a). This includes 582 NEOs that were observed during the cryogenic, 3-band cryo, and post-cryo missions in 2010-2011. Many of these NEOs have been observed at multiple epochs as well, enabling more detailed thermophysical modeling to be undertaken that can constrain thermal inertia as well as size and albedo (e.g. Koren et al. 2015, Masiero et al. 2019). Dozens of NEOs have more than 4 epochs of detections in NEOWISE data, and this count continues to grow as the mission survey continues.

In addition to the objects detected automatically by the survey, other NEOs pass through the NEOWISE field of view, but are not initially identified usually because their rates of motion are outside the search parameters or curved beyond the system search tolerances. Others of these objects pass quite close to the telescope and therefore are not observed a sufficient number of times to be recorded as a real object by the blind search carried out during data reduction. To augment the automatically detected objects, we periodically carry out a manual search of known NEOs that are likely to be detectable (Mainzer et al. 2014a, Masiero et al. 2018, Masiero et al. 2020b). This has resulted in increasing the number of NEOs with size and albedo characterization data provided by NEOWISE over all mission phases to 1845 objects. This count will continue to rise as the mission continues taking data.

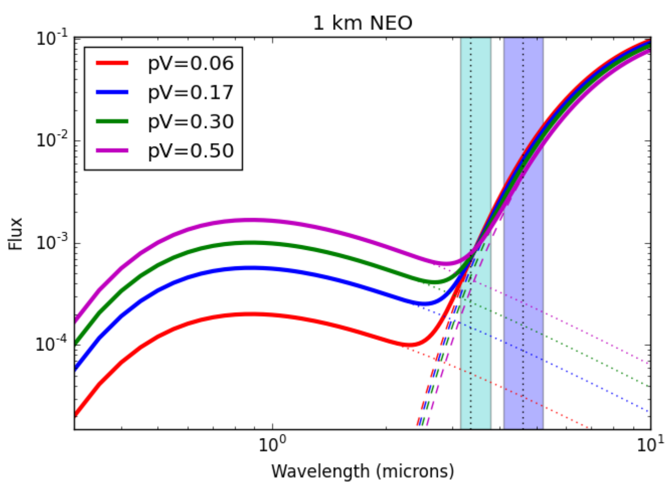

Figure 1 - Spectral energy distributions (solid lines) for 1 km NEOs with four different albedos (pV, as indicated by the line color) at a heliocentric distance of 1.04 AU, a geocentric distance of 0.3 AU, and a phase of 73°. Dotted and dashed components show the reflected and emitted components, respectively. The shaded vertical bars indicate the W1 and W2 bandpasses of NEOWISE, with the central wavelengths marked with vertical dotted lines.

NEOWISE capabilities for exercise object "2021 PDC"

As part of the PDC asteroid impact exercise (which can be found here: https://cneos.jpl.nasa.gov/pd/cs/pdc21/), a simulated object (referred to as "2021 PDC") was created that would be 'discovered' on 19 April 2021 and by the time of the conference have an impact probability of 5% for October 2021. The discovery conditions and orbit of the simulated object are such that it will pass through the field of regard of the nominal NEOWISE survey in early June 2021. Based on the discovery information, thermal modeling indicates that NEOWISE would not detect this object as part of normal survey operations, as the predicted thermal infrared brightness is well below the survey sensitivity.

The scan region of the NEOWISE survey is set by its orbital geometry. Initially after launch in 2009 NEOWISE was following a sun-synchronous orbit over the terminator and the survey scanned at a Solar elongation of 90 degrees. Since then, the spacecraft's orbit has precessed by approximately 25 degrees. On the evening side of the orbit, NEOWISE surveys at zenith to reduce the heat load from the Earth on the telescope, while on the morning side it surveys at 90 degrees elongation to ensure sunlight does not enter the telescope. While NEOWISE has no on-board propulsion to change its orbit, it would be possible to plan the survey to observe at lower elongations on the evening side, down to the 90 degrees elongation limit. The consequence of this would be to increase the heat load on the telescope, warming the detectors and potentially reducing their sensitivity.

Survey scan parameters are loaded to the spacecraft twice per week, and can be regenerated in a day or two, so the ~5 week timeline between the impact probability reaching 5% and the entry of 2021 PDC into NEOWISE's field of regard on 6 June 2021 would be sufficient to enable this change of survey. If we schedule every scan to pass over the object's predicted position, we estimate we could obtain about 300 exposures on the object that could be combined to achieve much greater sensitivity than the individual exposures.

A cursory check of the object's nominal position at this time indicates that the background star field is not overly dense, and its galactic latitude would be >70 degrees for the month of June. While some frames will be impacted by background objects, it should only be a small fraction of the total, and it would be possible to remove these manually before stacking. A more significant concern would be the sensitivity loss due to the increased telescope heat load from the altered survey parameters. We conservatively estimate that the overall sensitivity of the stack would be reduced by 50% due to the increased heating, resulting in a 1 sigma sensitivity of 7e-6 Jy for the stacked data.

If 2021 PDC is approximately 100m in size (which would give it an albedo of pV=0.21), then for the orbital geometry of June 2021, we estimate it would have a flux of 2.24e-5 Jy at the NEOWISE 4.6 micron bandpass. This 3-sigma detection, when run through our thermal fitting software results in a model fit of 160m +/- 80m for diameter. The center of the fit is offset from the 100m size used to generate the flux due to the different thermal models being used for generating and fitting the data. The large diameter uncertainty is driving by a combination of the low signal-to-noise of the detection and the large value of the assumed uncertainty on the beaming parameter used in the fit, following our standard NEO fitting process for the mission. There would likely be additional sources of systematic uncertainty on the detection due to the large number of frames being co-added. Deep stacks of NEOWISE data have been made for the ecliptic poles as part of the cryogenic mission, so these detector-level systematics can be constrained using those data, however systematics from the unknown light curve will add to the overall uncertainty. These results lead to a conclusion that the size of the body is <240m, as a three-sigma upper limit for the exercise object.

NEOWISE down-links data on a daily basis, so analysis could begin immediately even as additional detections are being obtained. Based on the timing of the observations, a size constraint from NEOWISE would likely be available no later than the first few days of July 2021, to feed forward to the mitigation planning. Initial NEOWISE observations will be able to exclude the largest possible sizes for the object, and as more data are obtained during the survey the upper limit will be lowered. Regular updates to the mitigation planning team would be made as new data were obtained.

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