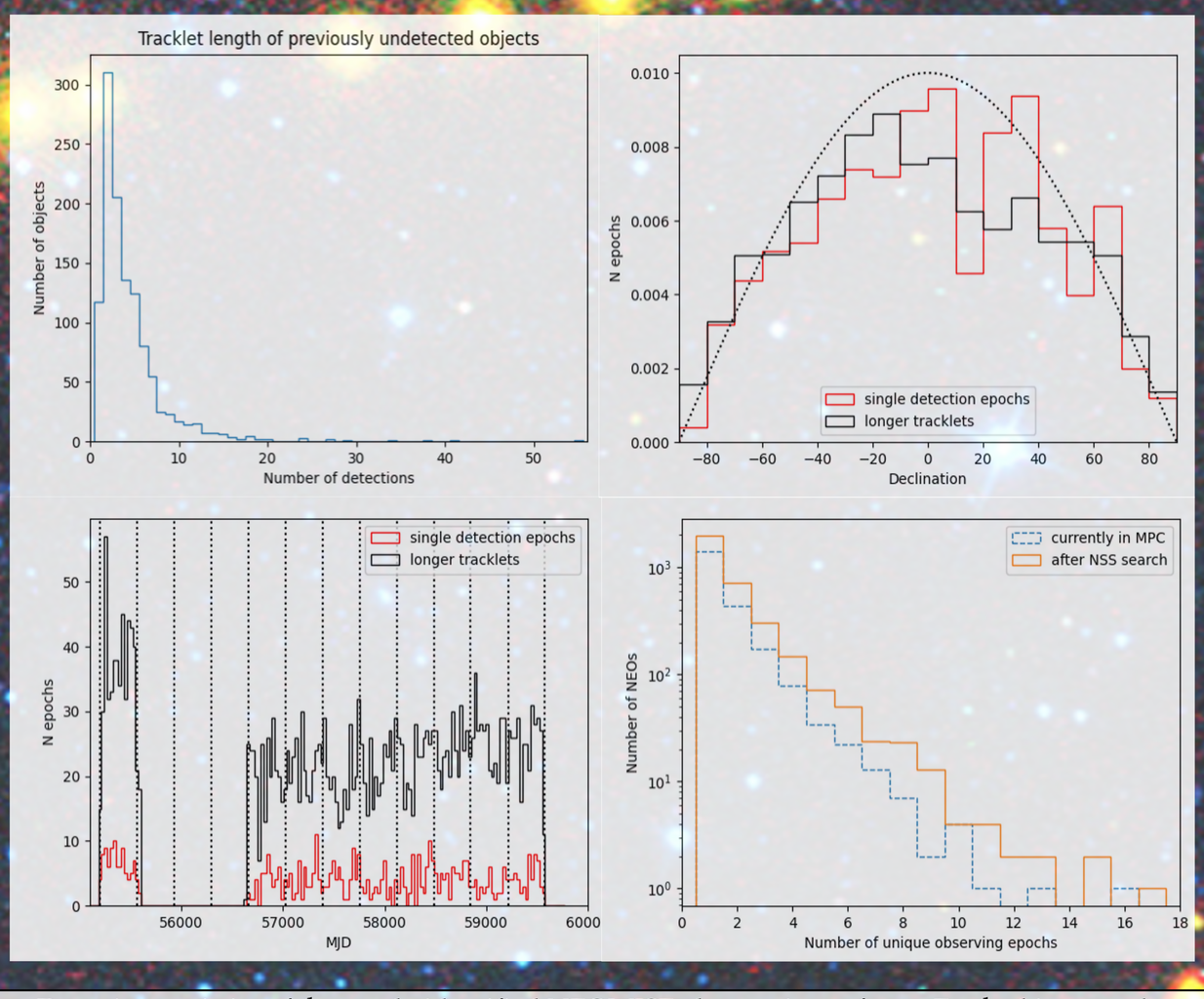
Validation of the Survey Simulator Tool for the NEO Surveyor mission using NEOWISE data

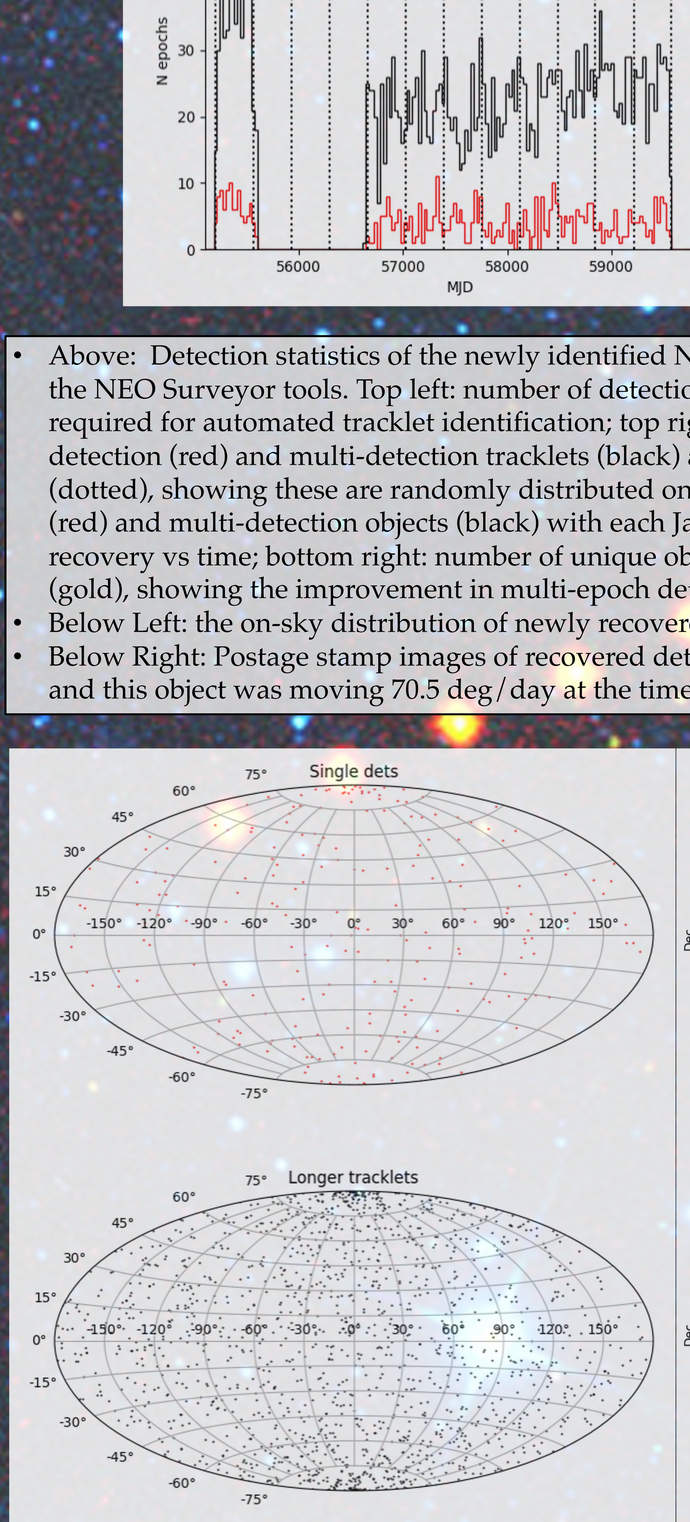
Authors: Joseph Masiero (Caltech/IPAC), Dar Dahlen (Caltech/IPAC), Amy Mainzer (U. Arizona) and the NEO Surveyor Team

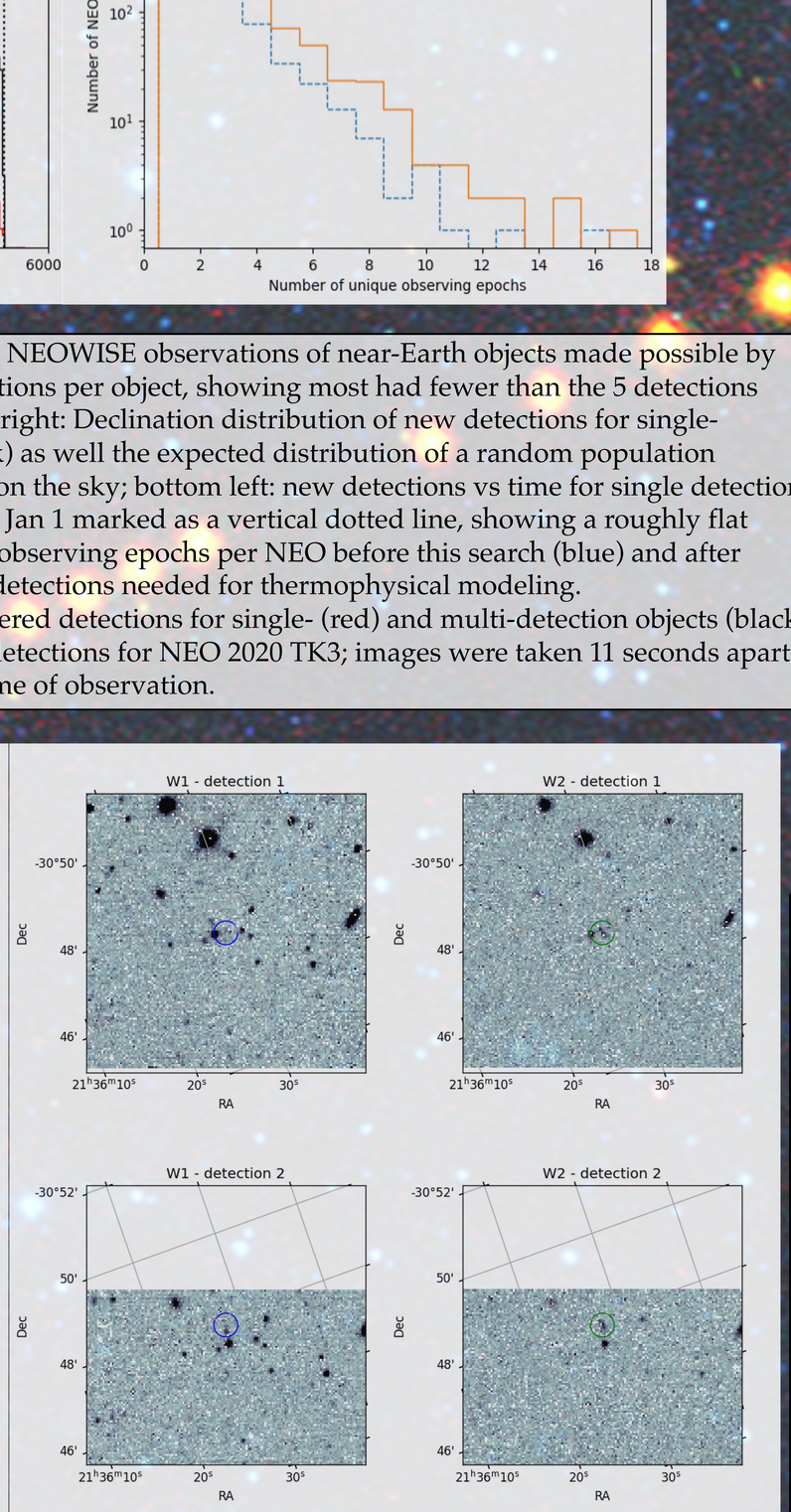
Introduction: The Near-Earth Object Surveyor mission [see talk by **Mainzer et al Tues 17:30**] has a requirement to find two-thirds of the potentially hazardous asteroids larger than 140 meters in size. To determine the mission's expected progress toward this goal during design and testing, as well as the actual progress during the survey, a simulation tool has been developed to act as a consistent and quantifiable yardstick (**Mainzer et al. 2023**, PSJ, in review). This simulator will be run on a regular basis during design, testing, and operations, and will provide performance metrics that can be used to evaluate the mission design and determine the effects of trade studies being investigated.

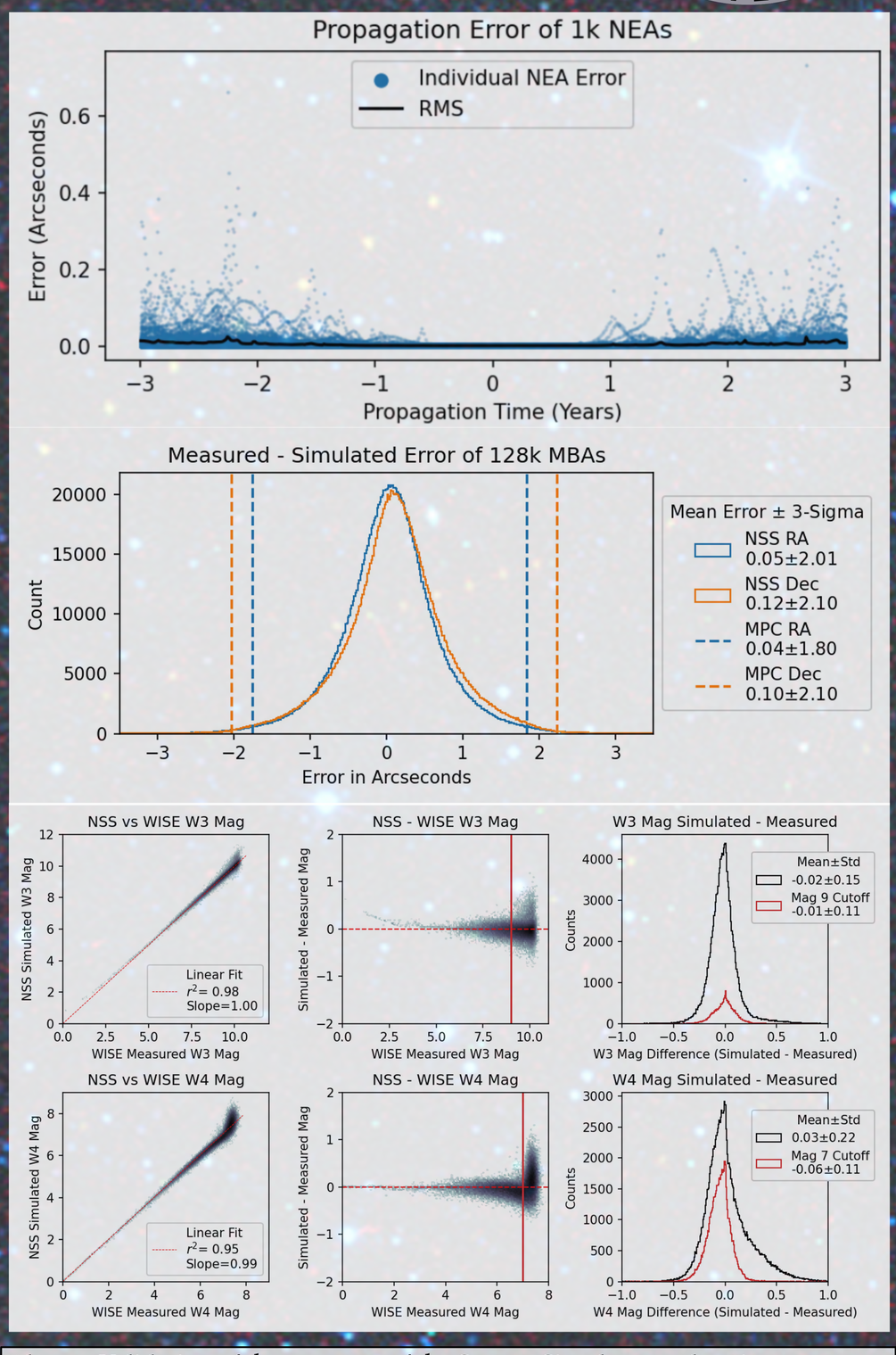
Methods: We validate that the survey simulation software is correctly predicting on-sky positions and thermal infrared fluxes by simulating the observations that were obtained during the NEOWISE cryogenic survey from Jan 2010 to Aug 2010, and comparing predictions made by the Survey Simulator code to measurements reported by NEOWISE (right). As a further test, we use these tools to predict the positions and estimated fluxes of all known NEOs over the course of the NEOWISE survey and search for detections in the source catalog that have not yet been reported to the MPC (below). We find 21,661 additional NEO detections, including first-time NEOWISE observations of 1,166 NEOs.



- Above: Detection statistics of the newly identified NEOWISE observations of near-Earth objects made possible by the NEO Surveyor tools. Top left: number of detections per object, showing most had fewer than the 5 detections required for automated tracklet identification; top right: Declination distribution of new detections for single-detection (red) and multi-detection tracklets (black) as well the expected distribution of a random population (dotted), showing these are randomly distributed on the sky; bottom left: new detections vs time for single detection (red) and multi-detection objects (black) with each Jan 1 marked as a vertical dotted line, showing a roughly flat recovery vs time; bottom right: number of unique observing epochs per NEO before this search (blue) and after (gold), showing the improvement in multi-epoch detections needed for thermophysical modeling.
- Below Left: the on-sky distribution of newly recovered detections for single- (red) and multi-detection objects (black)
- Below Right: Postage stamp images of recovered detections for NEO 2020 TK3; images were taken 11 seconds apart and this object was moving 70.5 deg/day at the time of observation.







Above: Validation of the accuracy of the Survey Simulator tools using NEOWISE data as 'ground truth'.

- Top: the difference between the predicted on-sky position of 1000 synthetic NEOs over 3 years in each direction compared to the Horizons-calculated positions. Individual object offsets grow when having a close pass with the telescope, but are always sub-arcsec, and the RMS for the population is <0.1 arcsec at all times.
- Middle: Predicted position of 128,000 MBAs compared to the positions measured and reported by NEOWISE for the cryogenic mission phase. The systematic offset and 3-sigma uncertainty match the MPC-computed offsets and uncertainty
- Bottom: The predicted W3 and W4 magnitudes for all MBAs observed during the cryogenic mission compared to the measured values reported in the public catalog. The vertical red line shows when background noise beings to bias the comparison on the low side, while the brightest magnitudes begin to diverge when the detectors approached saturation. Predicted magnitudes were produced by using the physical properties reported in the Planetary Data System.

Conclusions:

- Our comparisons demonstrate that the accuracy of the Survey Simulator's astrometric positions and infrared photometry is sufficient to meet the requirements of the NEO Surveyor mission.
- The additional NEO detections found through our search help expand our knowledge of the physical properties of the near-Earth population by increasing the number of NEOs with measured thermal infrared fluxes and the number of multi-epoch objects that can undergo thermophysical modeling [see **talk by Satpathy et al. Wed at 11:10**]
- Our search shows the significant benefits of archived, publicly accessible source catalogs and images for precovery searches
- This work is discussed in detail in **Masiero et al. 2023** (PSJ, in review)