The Rubin observatory will unleash a flood of NEO detections, say researchers

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The Vera Rubin Observatory is poised to begin observations next year. It could detect 130 Near Earth Objects each night. Credit: Rubin Observatory/NSF/AURA/B. Quint

After about 10 years of construction, the Vera Rubin Observatory (VRO) is scheduled to see its first light in January 2025. Once it's up and running, it will begin its Legacy Survey of Space and Time (LSST), a decade-long effort to photograph the entire visible sky every few nights.

It'll study dark energy and dark matter, map the Milky Way, and detect transient astronomical events and small solar system objects like Near Earth Objects (NEOs).

New research shows the LSST will detect about 130 NEOs per night in the first year of observations.

NEOs are small solar system bodies, usually asteroids, that orbit the sun and come within 1.3 astronomical units of the sun. When a NEO crosses Earth's orbit at some point, it's considered a potentially hazardous object (PHO). NASA is currently cataloging NEOs, and while they've made progress, there are many more left to find.

According to new research, the upcoming LSST will detect about 130 NEOs per night. The research is "Expected Impact of Rubin Observatory LSST on NEO Follow-up," and it's still in peer-review but is available on the *arXiv* preprint server. The lead author is Tom Wagg, a Ph.D. student at the DiRAC Institute and the Department of Astronomy at the University of Washington in Seattle.

"We simulate and analyze the contribution of the Rubin Observatory Legacy Survey of Space and Time (LSST) to the rate of discovery of Near Earth Object (NEO) candidates," the authors write. They also analyzed submission rates for the NEO Confirmation Page (NEOCP) and how that will affect the worldwide follow-up observation system for NEOs.

The problem with NEOs is that they don't necessarily remain NEOs. A subset of them—about one-fifth—pass so close to Earth that even a small perturbation can send them on an intersecting path with Earth's orbit. These are sources of potentially catastrophic collisions. A further subset of these are called Potentially Hazardous Asteroids (PHAs), and they're massive enough to make it through Earth's atmosphere and strike the planet's surface. To be considered a PHA, an object has to be about 140 meters in diameter.

The Minor Planet Center maintains a database of NEOs, and more are being added constantly. New detections are recorded on the NEO confirmation page (NEOCP), but at first, they're only candidates. Follow-up observations require resources to accurately determine a candidate's orbit and size.

If the LSST contributes 130 more NEO detections each day, which is eight times the current detection rate, the survey will create an enormous amount of follow-up work. According to a standard computer algorithm named digest2 that evaluates them, NEOs are only considered candidates if they meet certain criteria, and that can only be determined by follow-up observations with other telescopes.

Illustration of a near earth object. Credit: NASA/JPL-Caltech

But with so many more detections on the horizon, there could be problems.

"The aim of this paper is to quantify the impact of Rubin on the NEO follow-up community and consider possible strategies to mitigate this impact," the authors write.

Most of the NEOs the LSST finds will be found using a method called "tracklet linking." Tracklet linking is "a computational technique where at least three pairs of observations ('tracklets') observed over a 15-night period are identified as belonging to the same object," the authors explain.

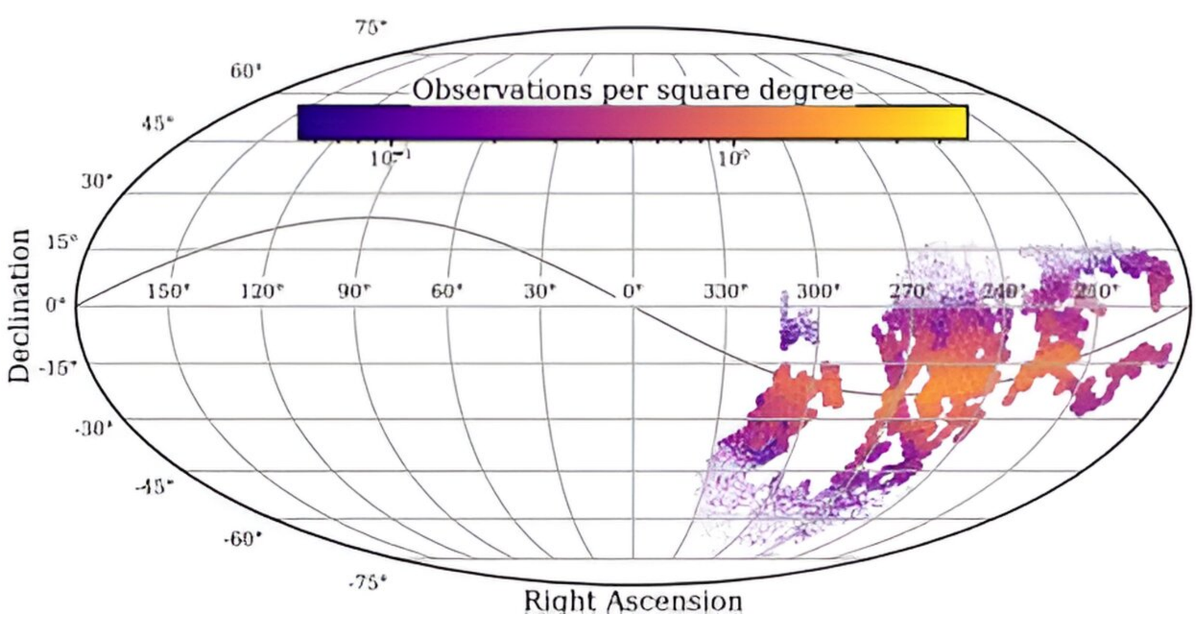
The problem is that the tracklet linking can take time and comes at a cost. "… the object is not identified as interesting until the third tracklet is imaged—at best, two nights after the first observation or, at worst, nearly two weeks later," the authors write. This means that the system may miss interesting or hazardous objects until it's too late to observe them for confirmation.

With other telescopes, there's a way around this. They can capture several back-to-back images of tracklets to create more robust detections that can be immediately followed up on. However, the VRO can't do that because the LSST is an automated survey.

What it can do is serendipitously capture three or more tracklets in smaller sections of the sky where its observing fields will overlap. "Such tracklets could be immediately identified and, assuming they meet the digest2 score criteria, submitted to the Minor Planet Center and included on the NEOCP," the authors write. Because of the scale, the authors say this process could be automated and would require no human vetting.

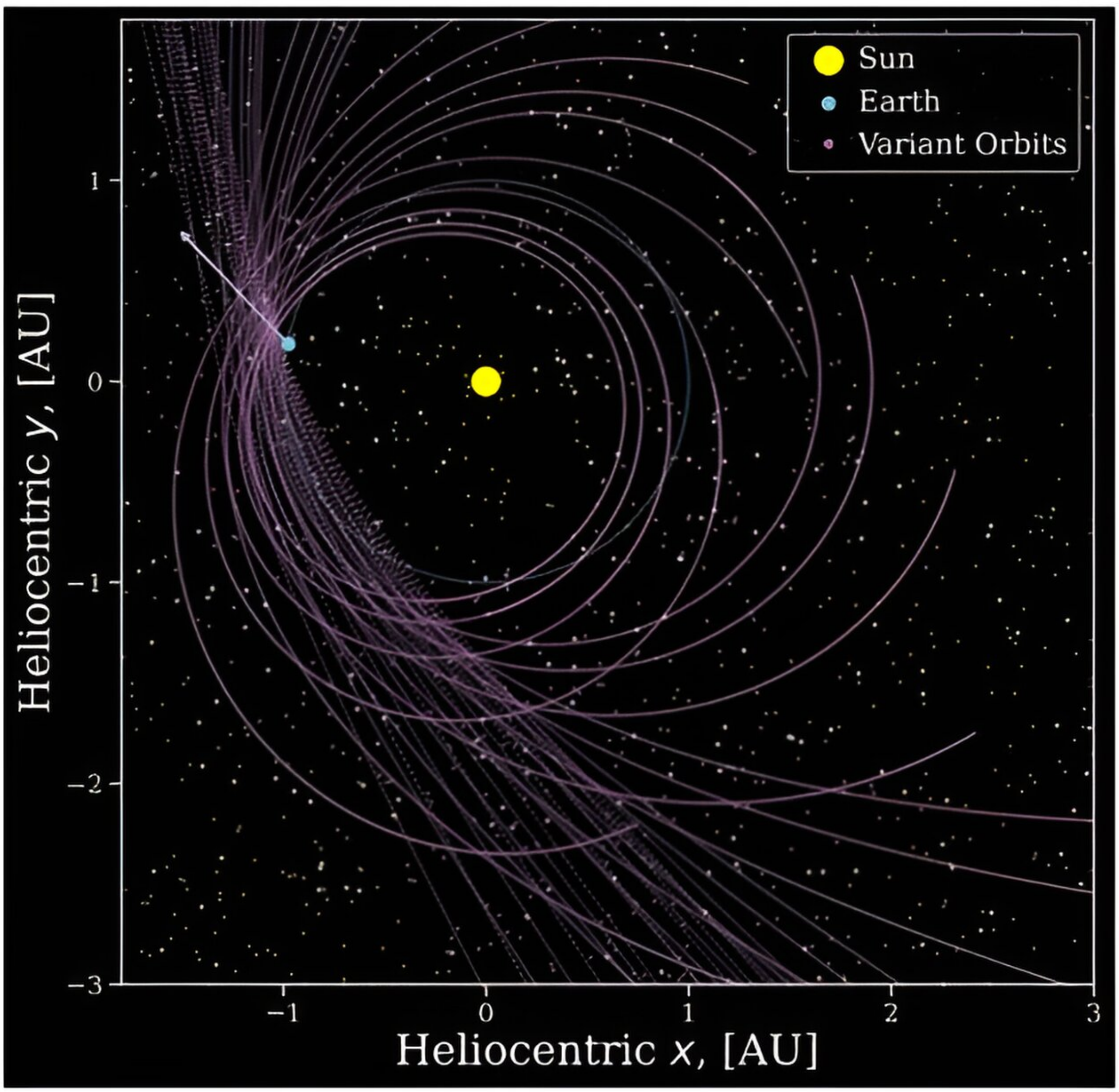
The researchers simulated LSST detections to test their idea and see if it could reduce the follow-up observation workload. "We present an algorithm for predicting whether LSST will later re-detect an object given a single night of observations (therefore making community follow-up unnecessary)," they explain. They wanted to determine how effective it would be in reducing the number of objects that require follow-up observations.

They started by simulating almost 3,600 days of the LSST, consisting of almost 1 billion observations.



This figure from the study shows the number of asteroids detected in one night of LSST simulations. About 350,000 asteroids were observed, including about 1,000 NEOs. The grey curved line represents the ecliptic. Credit: Wagg et al. 2024

From their data, they selected observations that corresponded to tracklets. Single tracklets don't determine an orbit, but they can constrain potential orbits when compared to known solar system orbits. The digest2 algorithm works by comparing observed tracklets to a simulated catalog of solar system objects to estimate the probability that an object is a NEO. It takes all the data and estimates the possible orbits of the objects.



This figure from the research shows the variant orbits computed for one simulated NEO tracklet. The white arrow indicates the initial sight line for the observation. The blue dotted line indicates the orbit of the Earth. The background stars are included for illustrative purposes only. Credit: Wagg et al. 2024

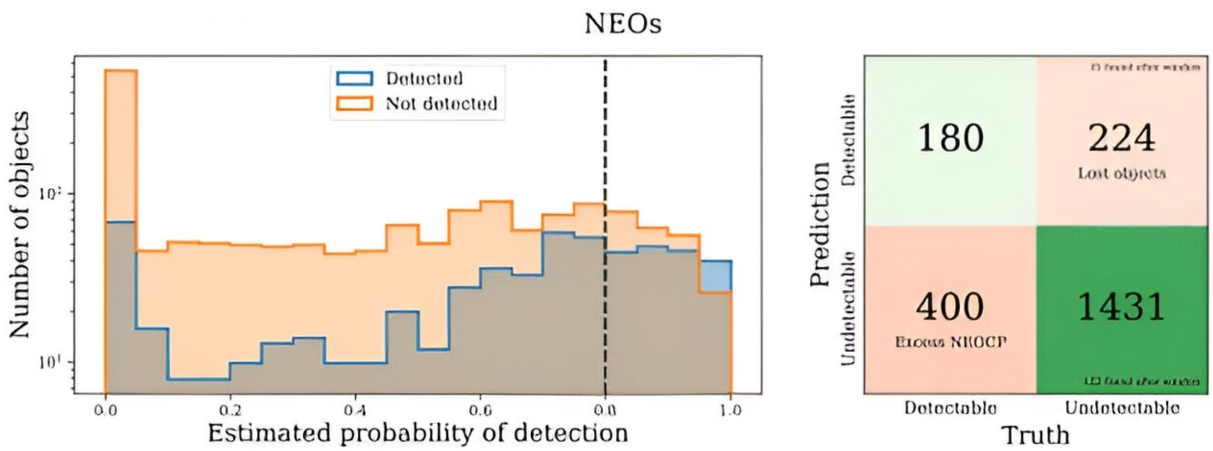
At this point, the number of candidate NEOs is still overwhelming. The candidate population is not a high-purity sample and still contains non-NEOs like main-belt asteroids.

Most of the impurity is caused by main-belt asteroids, and as these were recognized, the purity would rise. The simulations show that purity would continually rise, and after about five months, it would level off. A similar thing happens with submission rates. After about 150 nights, the submission rate reaches a steady state of about 95 per night.

The LSST repeatedly images the sky in overlapping fields. The researchers thought that if they could determine which tracklets were going to be re-observed by the LSST as it goes about its business, they could reduce the follow-up observation burden.

"If we could predict which objects will be followed up by LSST itself, this would reduce the load on the follow-up system and allow the community to focus on the ones that truly require external follow-up to be designated," the authors explain. The researchers developed an algorithm for computing the ensemble of ranges and radial velocities of a single observed tracklet.

"We now examine the effect of applying the LSST detection probability algorithm to reduce the load on the NEOCP," the authors write. The following image illustrates this.



This figure from the research shows the estimated probability of detection by the algorithm and the number of objects, with the dotted black line being the threshold for confirmation. On the right is a contingency matrix with two Truth columns and two Prediction rows. All in all, it shows that the algorithm detected 180 NEOs, with 400 being sent for confirmation needlessly, as the LSST will have confirmed them. Lost objects are objects that have been de-prioritized for follow-up observations but won't receive adequate follow-ups by the Rubin itself. Credit: Wagg et al. 2024

Overall, the algorithm predicted the correct outcome 68% of the time. Also, about 64 of the objects submitted to the NEOCP per night would require external follow-up, but only around 8.3%, or about five, of those objects would be NEOs. The algorithm would only improve accuracy minimally, but it would reduce the follow-up workload by a factor of two.

The researchers say that other tweaks to the algorithm can improve it and make LSST NEO detections more robust without the need for so many demanding follow-up observations.

In their conclusion, the authors write, "LSST contributions will increase the nightly NEOCP submission rate by a factor of about eight over the first year to an average of 129 objects per night." However, the fraction that will be confirmed is low at about 8.3%, but will rise over time.

The LSST is expected to generate 200 petabytes of uncompressed data during its ten-year run, which is about 200 million gigabytes. This study shows that managing the amount of data that the LSST will generate requires new methods.

It may seem like a far-away concern, but understanding the threat to Earth posed by NEOs is critical. While efforts are being made to understand how we can protect the planet from them, cataloging them all is important.

More information: Tom Wagg et al, Expected Impact of Rubin Observatory LSST on NEO Follow-up, *arXiv* (2024). DOI: 10.48550/arxiv.2408.12517

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