



**ASTEROID
INSTITUTE**
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LSST & Impactors

**How Much Warning Time for Asteroid Impacts Will We
Have in the Vera Rubin Era?**

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https://github.com/B612-Asteroid-Institute/adam_impacts_study

Vera C. Rubin Observatory Collects Data This Year

The Rubin Legacy Survey of Space and Time will start collecting data in November this year.

It is predicted to discover ~130 NEOS per night in its first year and over 60% of NEOs with a diameter of 140 meters or larger over 10 years.

Impactors represent only a small fraction of total NEOs and pose unique issues in simulations.

We want to know how well LSST will do with impactors.

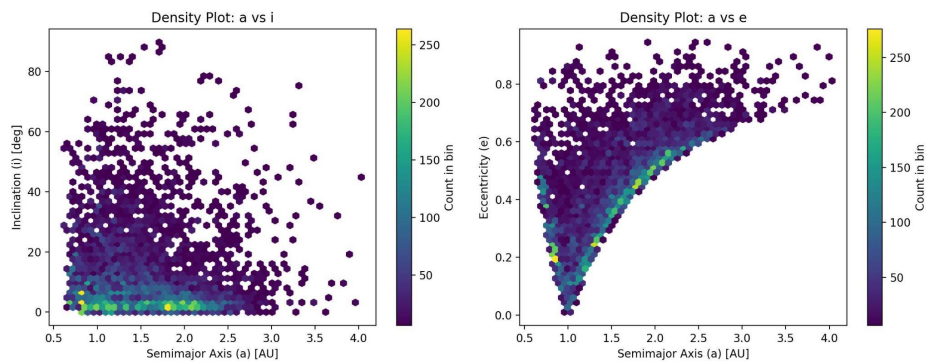


Generated Synthetic Impactor Population w/ Granvik Model

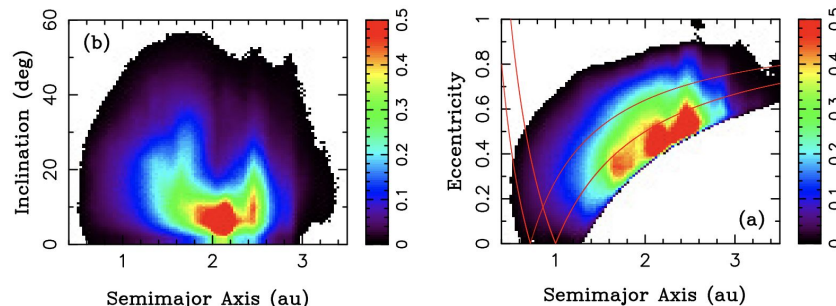
Used Granvik¹ model to generate a realistic population of virtual impactors following the method laid out in Chesley et al (2024)².

Generated 500 unique orbits impacting each decade from 2025 to 2125, across six size bins (40m, 80m, 140m, 250m, 500m, 1km) with albedos drawn from a bimodal rayleigh distribution.

Total impactor population of 30,000.



NEOMOD population



Granvik, M. et al. (2018). Debiased orbit and absolute-magnitude distributions for near-Earth objects. *Icarus*, 301, 1-13

Chesley, S. R., Valsecchi, G. B., Egl, S., Granvik, M., Farnocchia, D., & Jedicke, R. (2019). Development of a realistic set of synthetic Earth impactor orbits. *IEEE Aerospace Conference*, 1-14

Nesvorný, D. et al. (2024). NEOMOD 3: The debiased size distribution of Near-Earth Objects. *Icarus*, 417, 116110

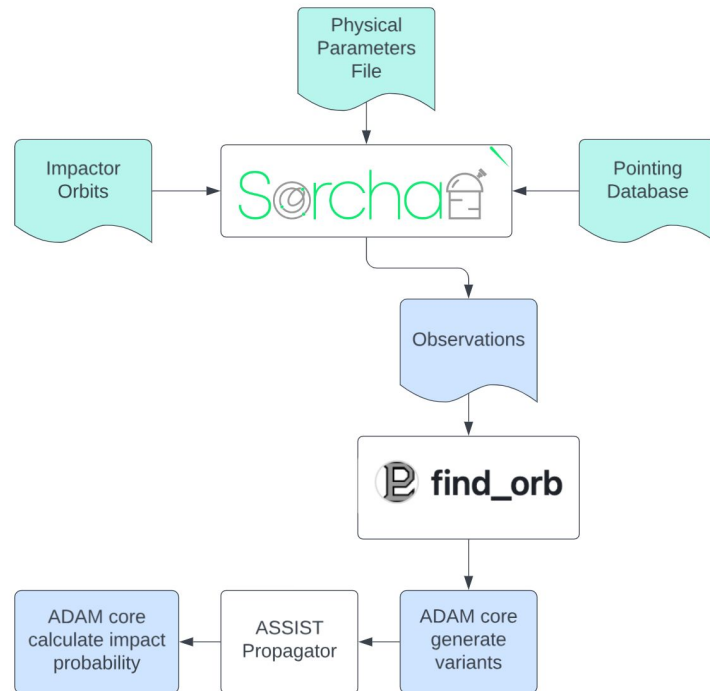
Calculated Time Series of Impact Probabilities from Simulated Observations

Sorcha¹ (Rubin's survey simulator) + impactor population to generate observations

find_orb² to calculate an orbit for each cumulative night of observations

adam_core³ to generate 10,000 monte carlo variants and propagate to detect impacts using ASSIST⁴

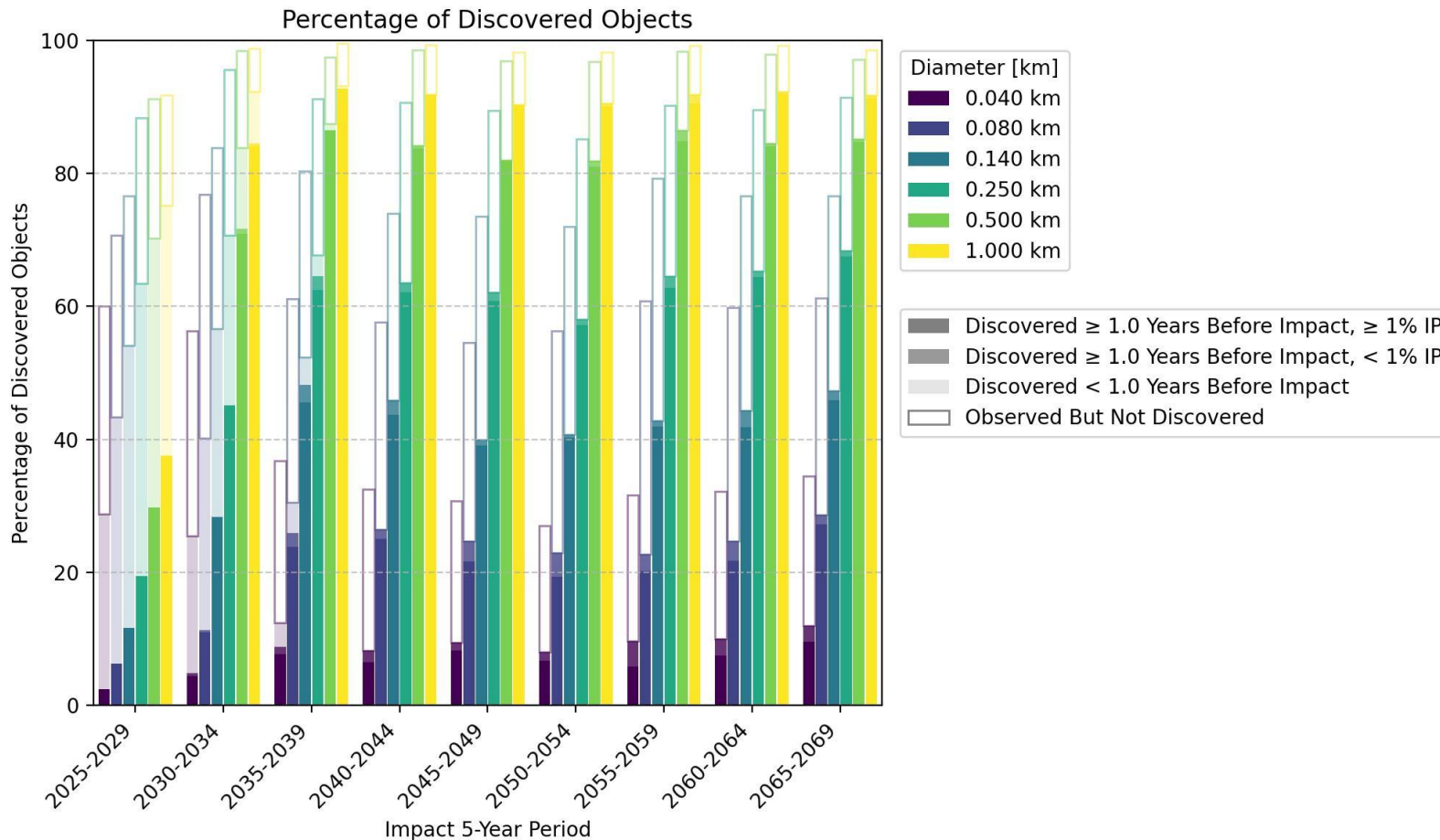
Calculate impact probability for each new night of observations



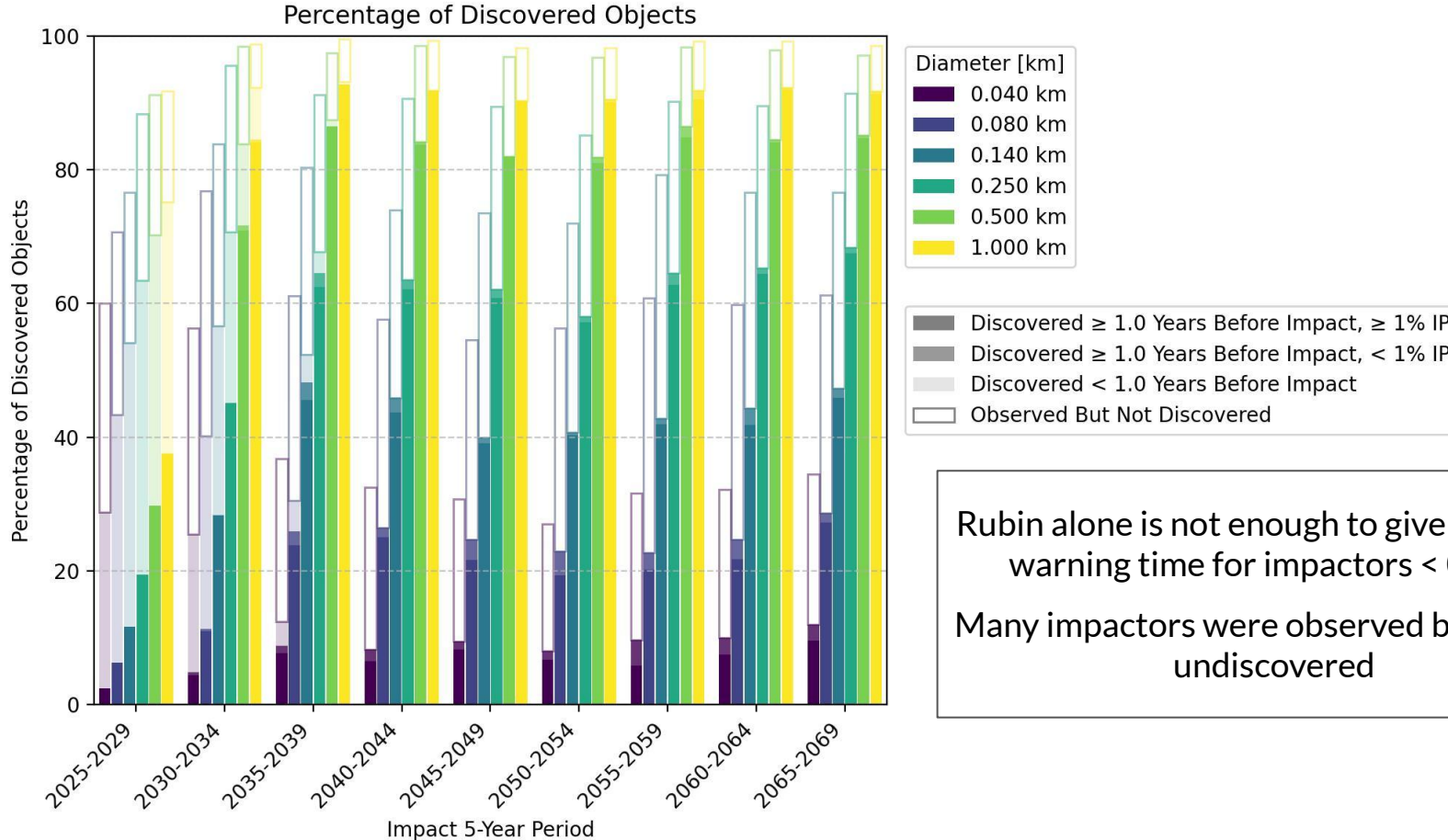
Only observations from Rubin's initial 10 year survey are considered

1. <https://github.com/dirac-institute/sorcha>
2. https://www.projectpluto.com/find_orb.htm
3. https://github.com/B612-Asteroid-Institute/adam_core
4. <https://github.com/matthewholman/assist>

What proportion of impactors will Rubin discover?



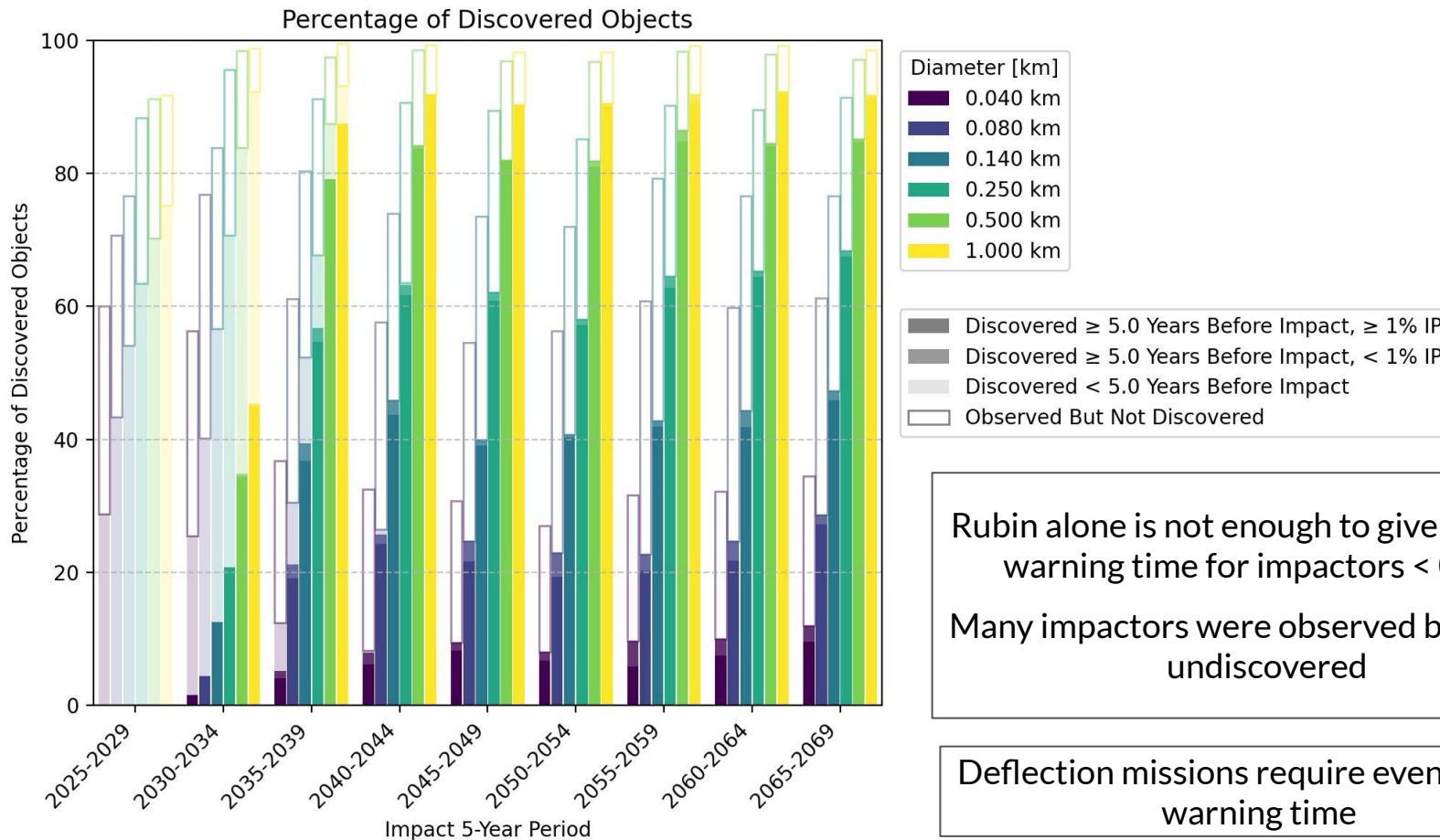
Many impactors are observed but not discovered



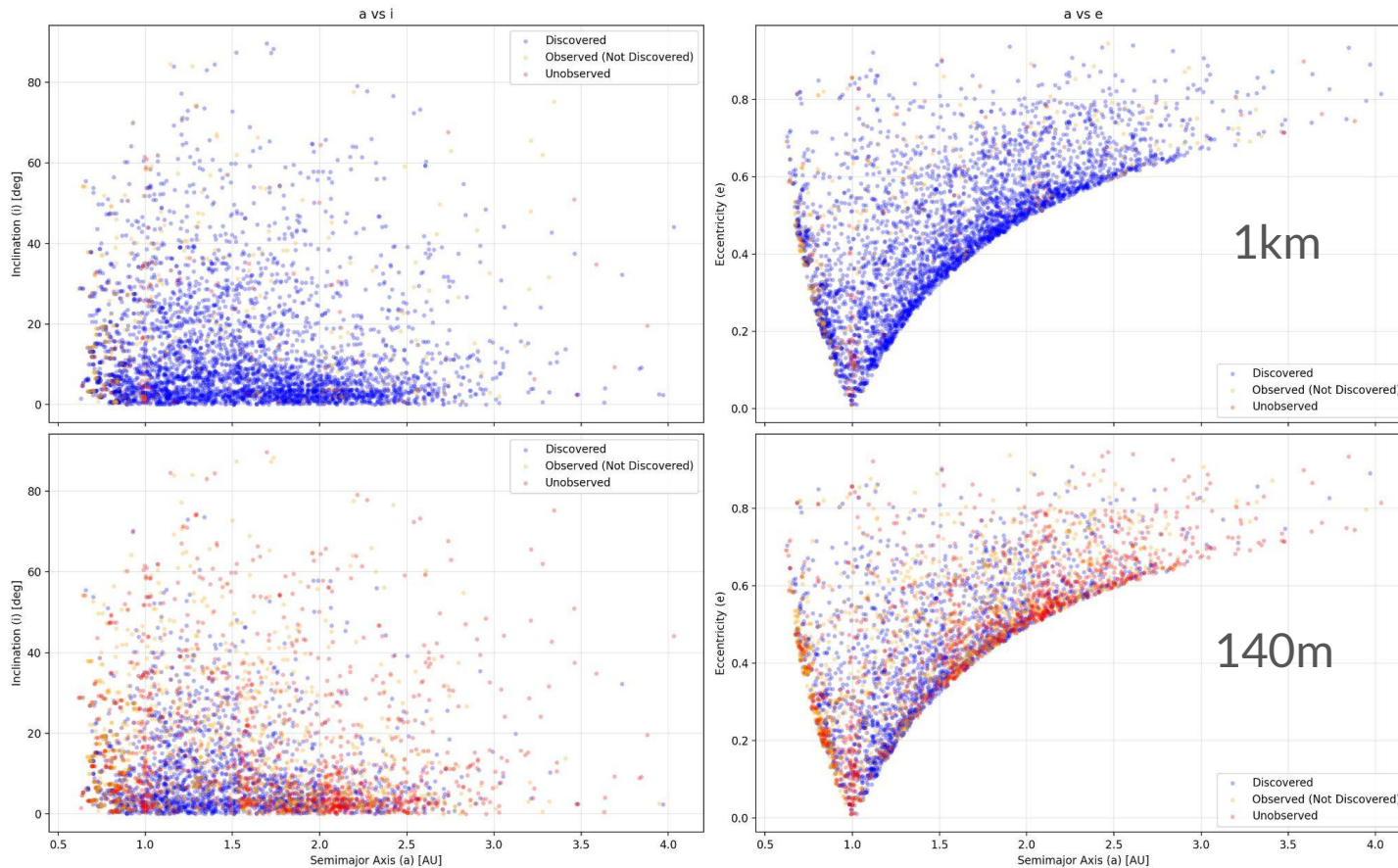
Rubin alone is not enough to give sufficient warning time for impactors $< 0.5\text{km}$

Many impactors were observed but remain undiscovered

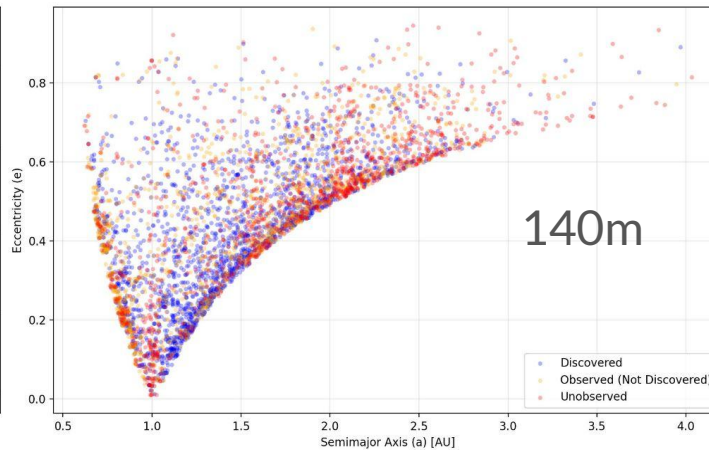
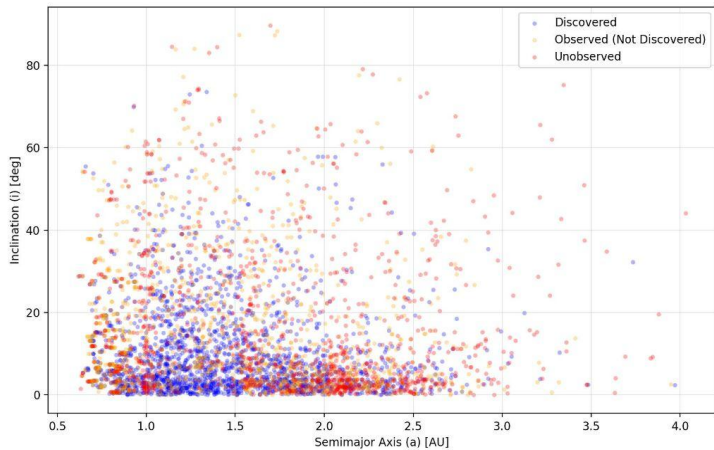
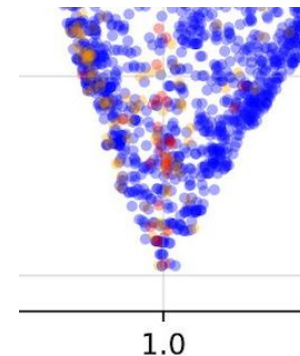
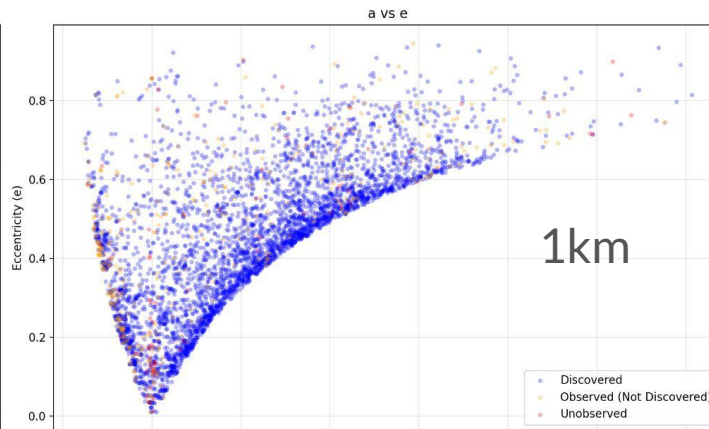
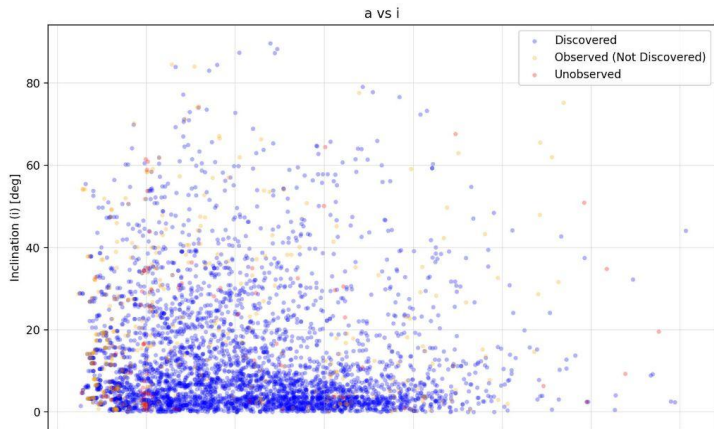
Rubin alone gives insufficient warning for deflection



Does the survey have any systematic blind spots?



Survey Struggles With Twilight and High Synodic Period Objects

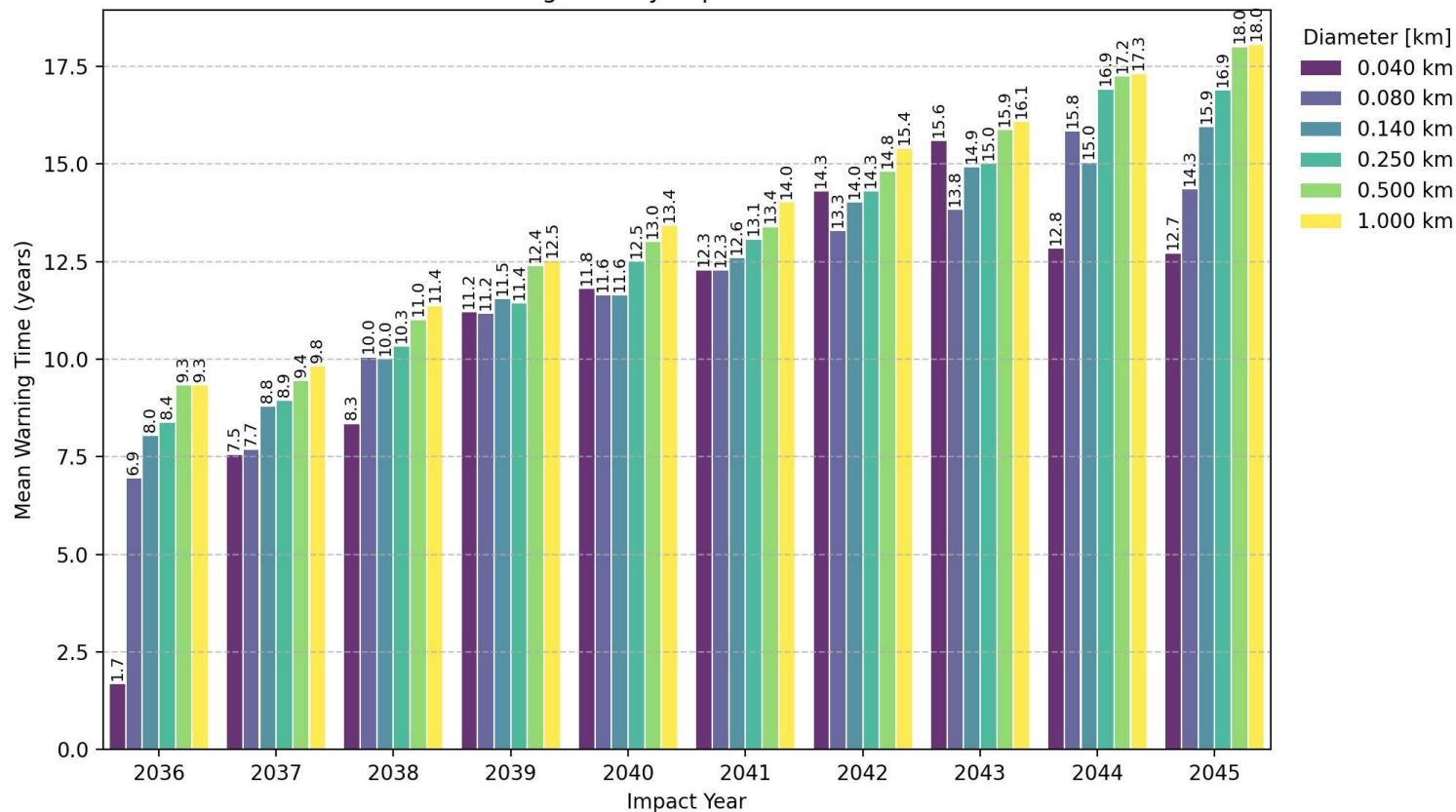


$a \approx 1.0$ AU domain
(high synodic period)
may have 1 or 0 close
approaches during
survey

Observing geometry
for orbits interior to
Earth is challenging

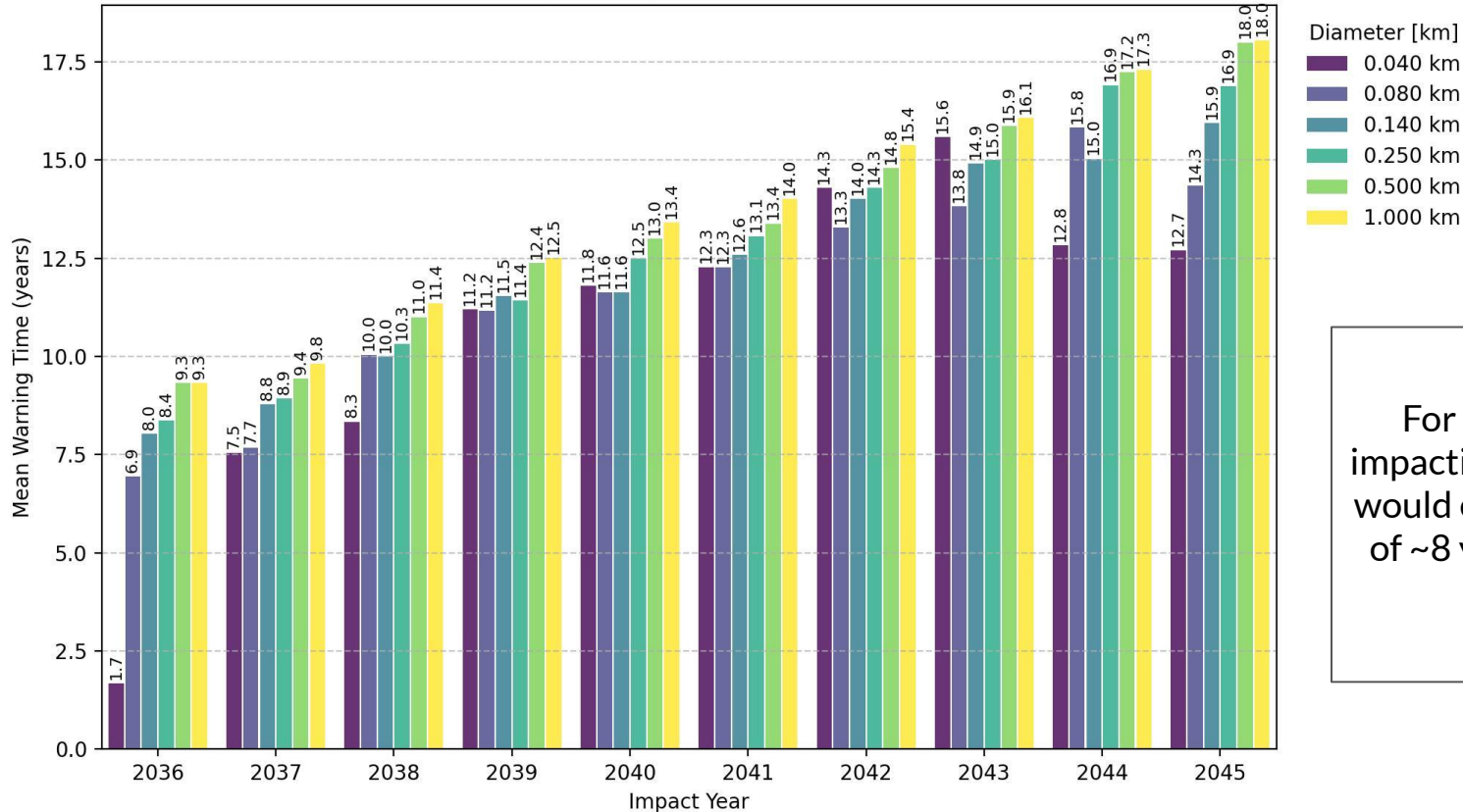
How much warning time will we have?

Mean Warning Time by Impact Year and Diameter



How much warning time will we have?

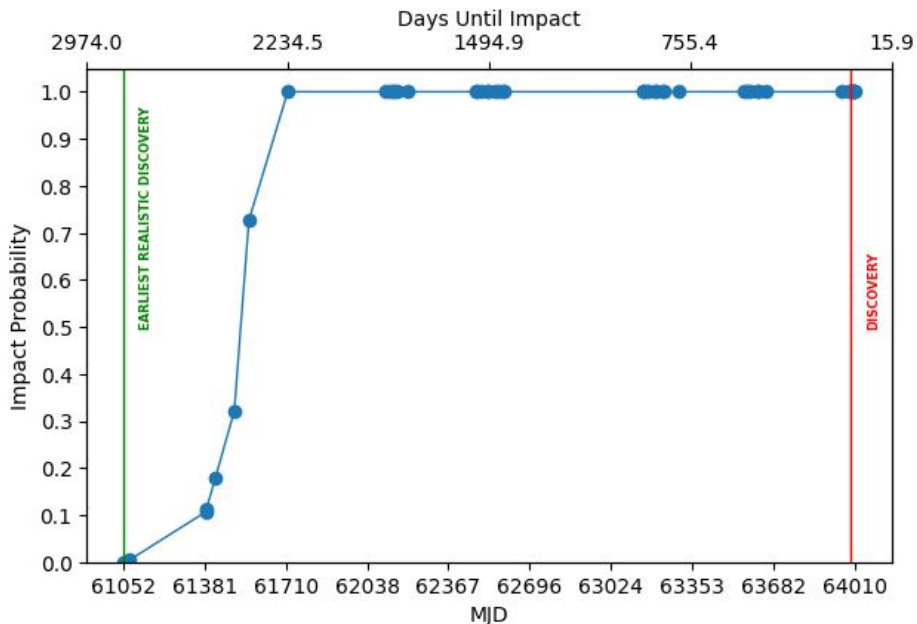
Mean Warning Time by Impact Year and Diameter



For a 140m object impacting in 10 years we would expect an average of ~8 years of warning time.

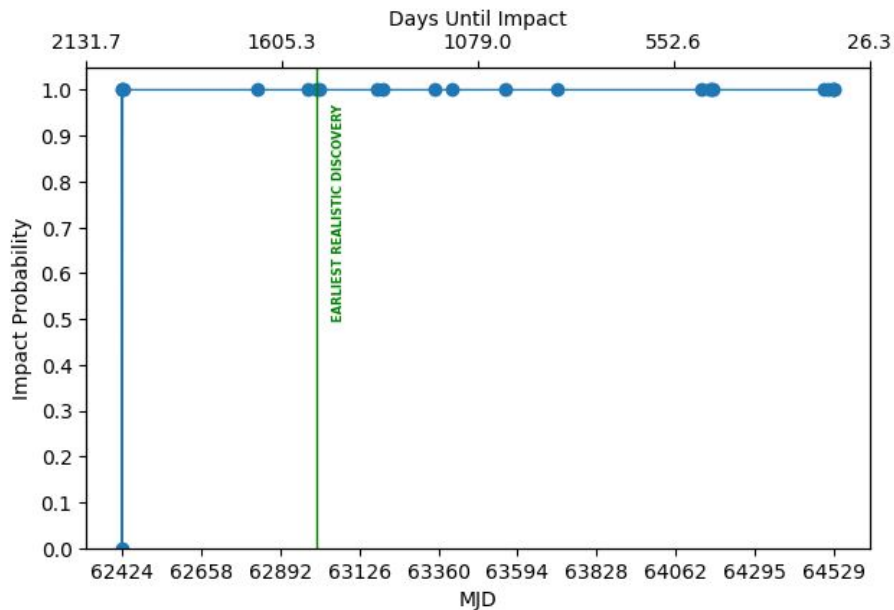
Linking Algorithms Can Improve Discovery Rates and Warning Time

I00285_b011_v000000_2025-2035



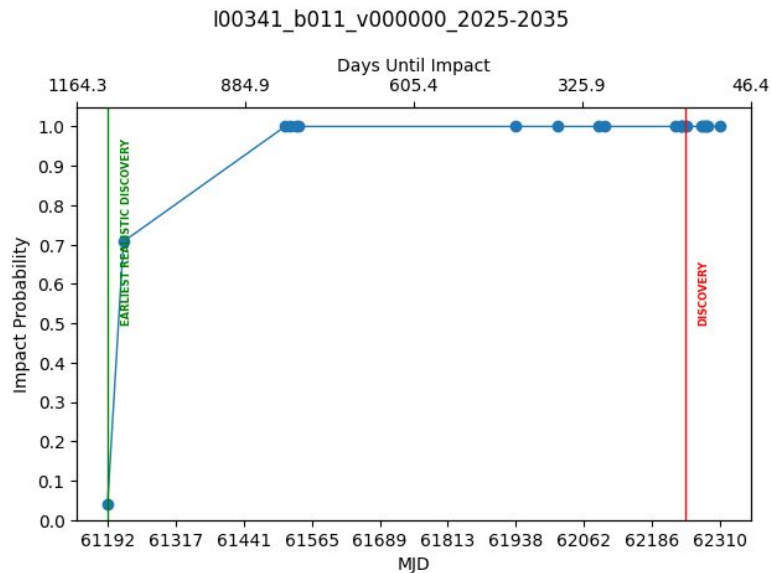
38.5% of undiscovered objects are discoverable with a more generous criteria

I00466_b011_v000000_2025-2035

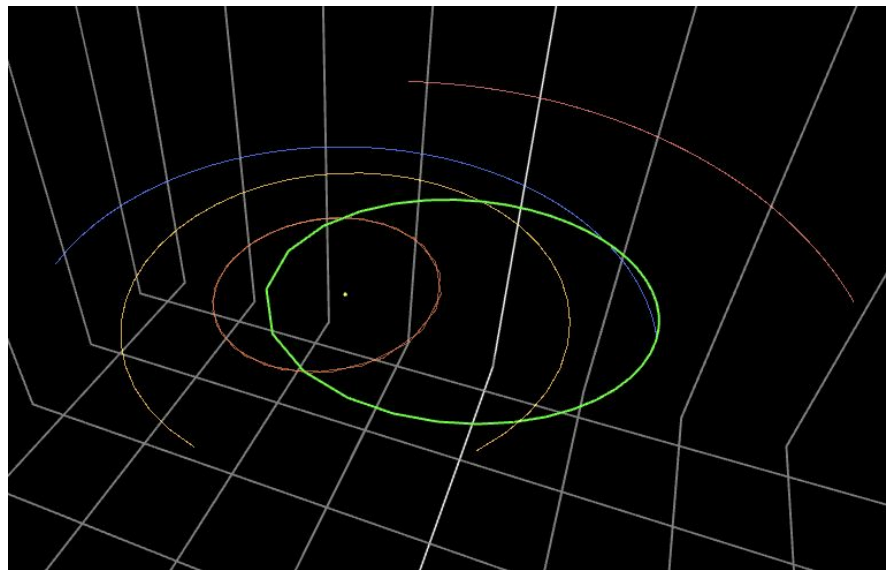
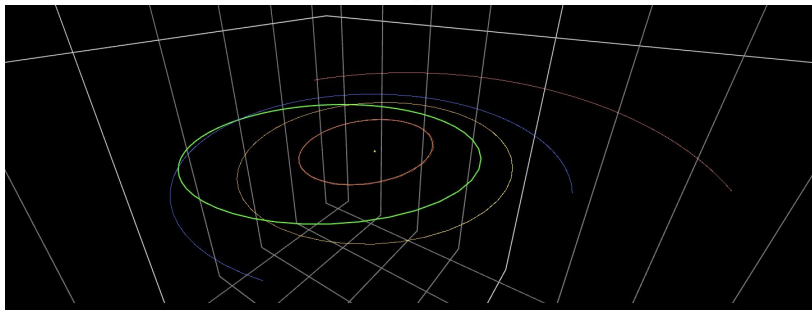


Additionally, mean warning time could increase by as much as 240 days

Twilight Asteroids Are Difficult to Discover

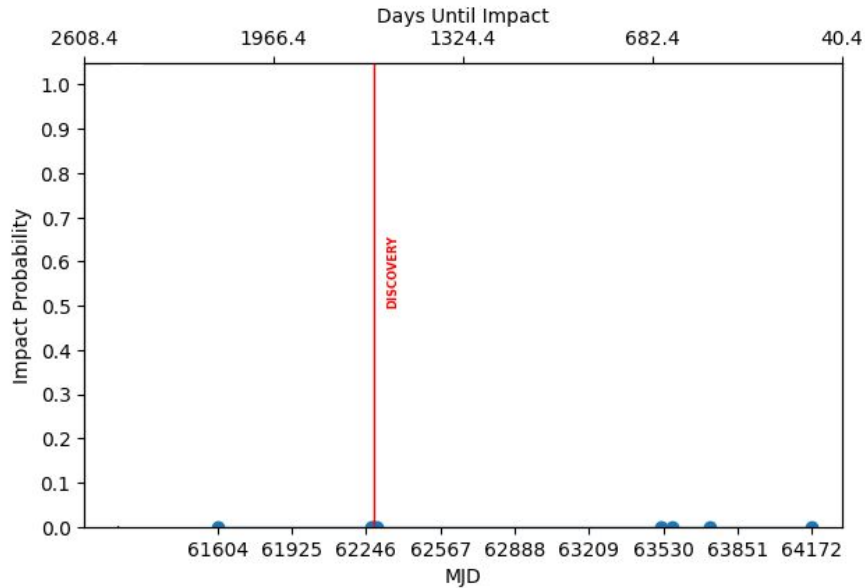


This object was never observed

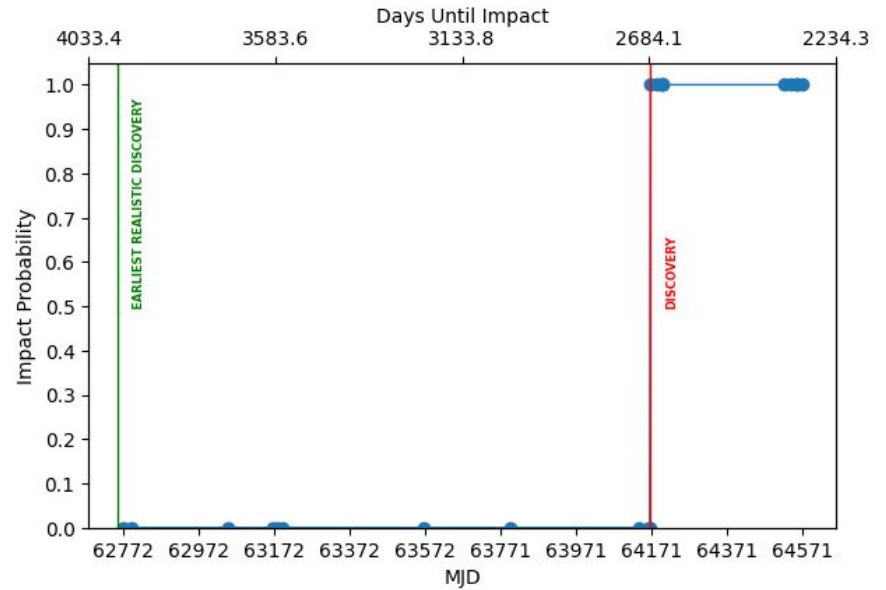


Some Objects Will Have Low Impact Probability For a Long Time

I00225_b011_v000000_2025-2035



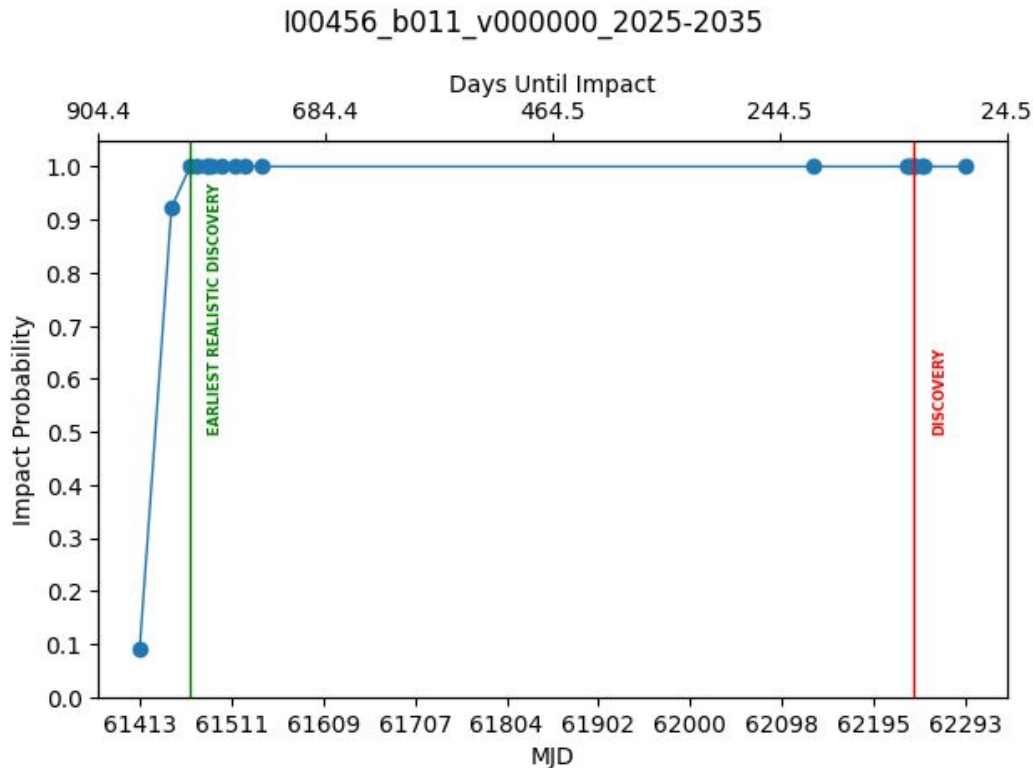
I00084_b011_v000000_2035-2045



Precovery Is Important

We assume perfect precovery, which is not guaranteed.

In cases like this, if an object is not discovered early on, it may never be linked to prior observations



Rubin Does Well But Needs Some Help

Averaged over realistic population, our simulation shows LSST discovering 70.4% of impactors at or above ~140m, in line with expectations of NEO discoveries¹.

Smaller objects (140m and below) had a less than 50% chance of being discovered.

Objects around 1AU in semi-major axis or with orbits interior to the Earth have a higher chance of not being discovered. Twilight surveys or NEOSurveyor could help.

Many objects within the impacting population will have a low impact probability for a significant period of time, highlighting the importance of follow up of risk list objects.

Novel linking algorithms can help to close the gap on discoveries.

Reliable Open Source tools capable of handling impactors are vital for studies like this.

1. Jones et al., 2018, <https://doi.org/10.1016/j.icarus.2017.11.033>



**For additional questions,
please reach out to:**

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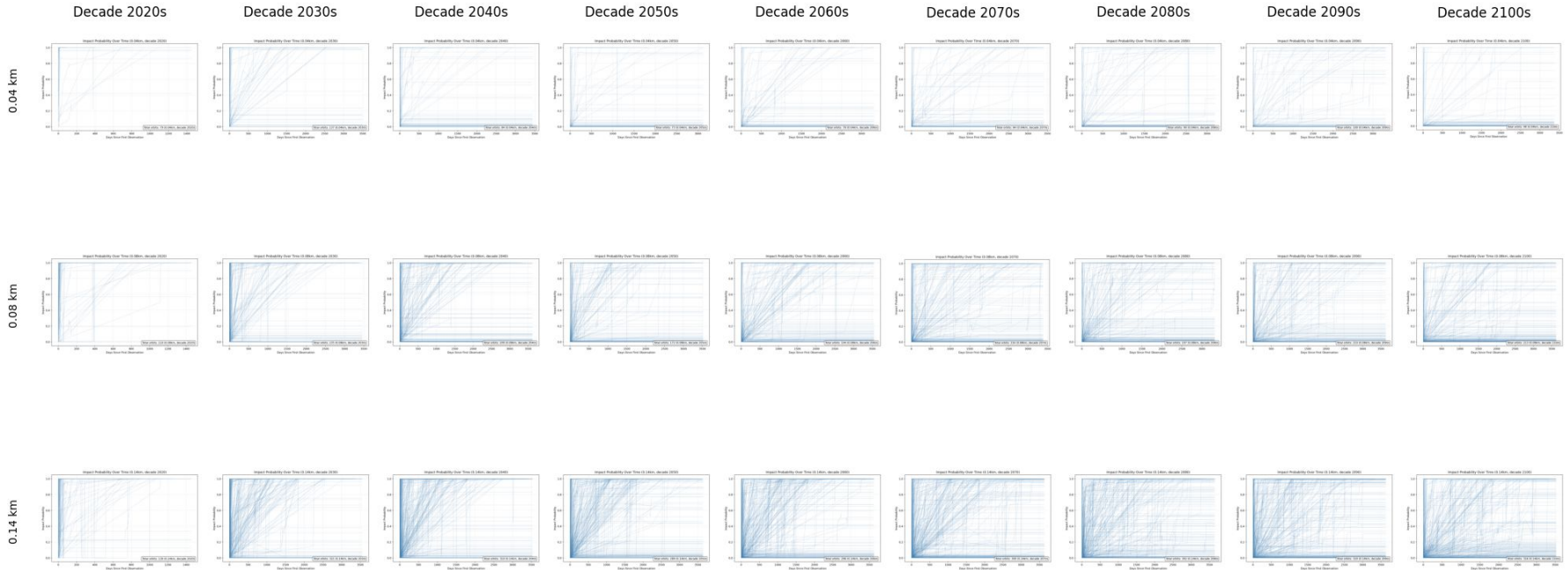
Joachim Moeyens: moeyensj@uw.edu

Code: https://github.com/B612-Asteroid-Institute/adam_impacts_study

Nate Tellis: nate@b612foundation.org

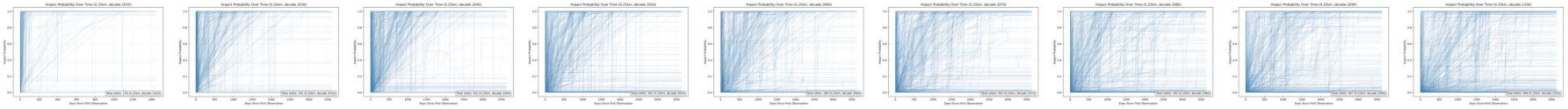
Additional Slides

Impact Probability Over Time for 40m, 80m, 140m

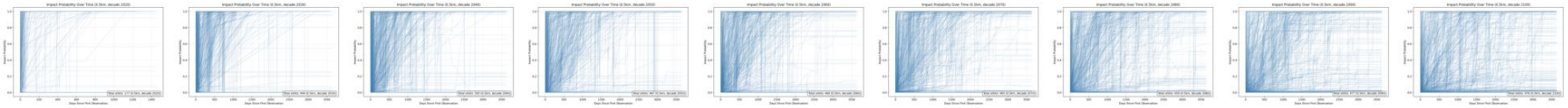


Impact Probability Over Time for 250m, 500m, 1km

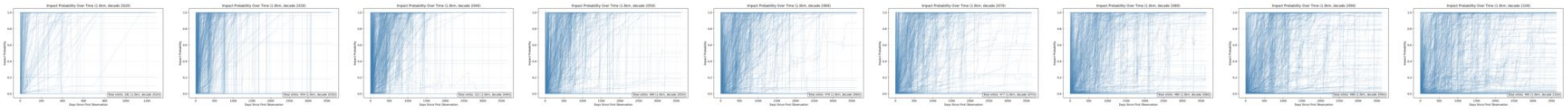
0.25 km



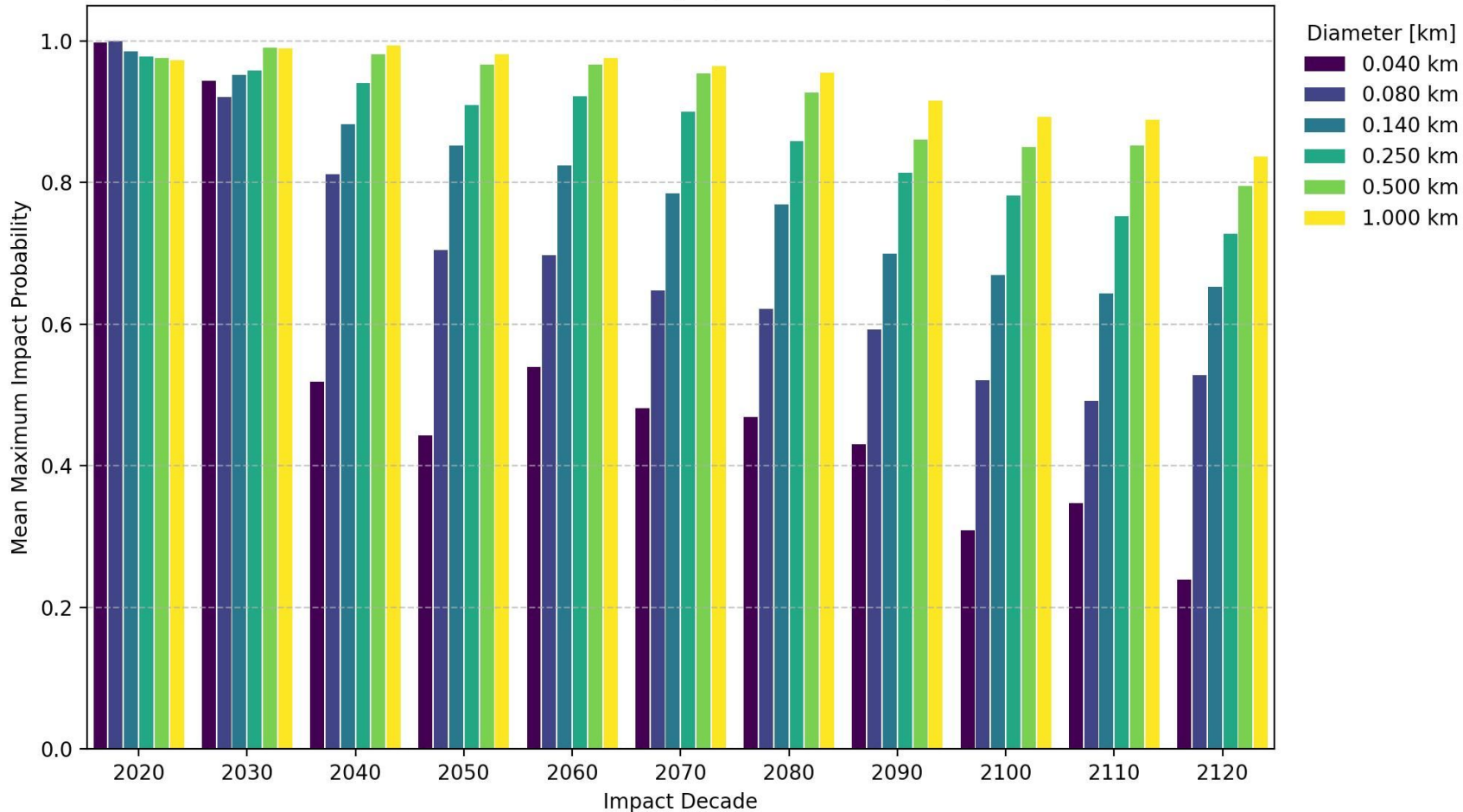
0.50 km



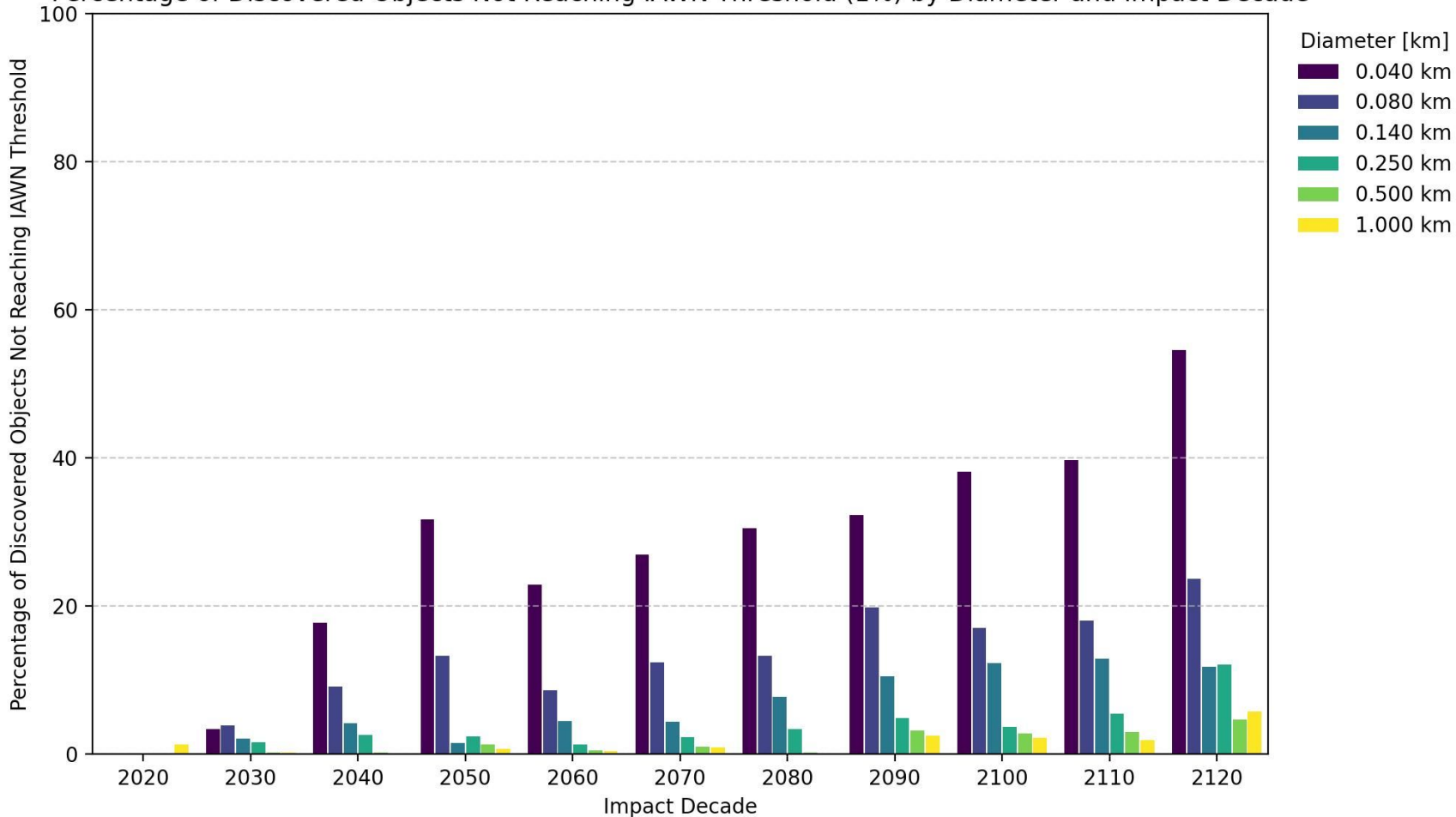
1.00 km



Mean Maximum Impact Probability by Diameter and Impact Decade



Percentage of Discovered Objects Not Reaching IAWN Threshold (1%) by Diameter and Impact Decade



Percentage of Discovered Objects Not Reaching 0.01% Impact Probability by Diameter and Impact Decade

