

PDC2025
Stellenbosch, Cape Town, South Africa

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

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Keywords: *detection, impact probability, warning time, orbit determination, simulation*

We simulated the operations of the Vera C. Rubin Observatory in observing 5,000 virtual impacting asteroids over a range of size bins, whose orbits were chosen to impact Earth over a period of 50 years. We used the Sorcha package to simulate the observations of these impactors for the planned 10-year Legacy Survey of Space and Time. We performed running orbit fits for the state vector and covariance to these observations as a function of time, then carried out Monte-Carlo simulations to calculate impact probabilities, which start small and evolve towards 1 as more observations are taken and as the impact date approaches. We tabulate the distribution of impact probabilities as a function of time before impact across all of the simulated impactors.

In particular, although these asteroids were constructed to hit Earth, the impact probability for any one impactor takes some time to rise to a significant level due to the fitted orbit's uncertainty. We quantify the number of observations and time it takes for the impact probability to reach the early warning threshold of 1%, as defined by the Space Mission Planning Advisory Group (SMPAG), if the Rubin observatory were the only telescope contributing observations. We can then characterize the warning time of the asteroid impact as the interval between when the impact probability reaches this threshold and the predicted impact date.

We investigate how this warning time varies with asteroid size and orbital characteristics. These findings are critical for preparedness efforts, as they highlight the importance of early and accurate detection to maximize warning time. Finally, we evaluate the implications of these findings for planetary defense, underscoring the importance of robust survey operations and follow-up observations to ensure that impact probabilities are calculated early enough to allow for required mitigation efforts. By quantifying the timeline of rising probabilities, we provide actionable insights into how long we will have to prepare for potential impacts in the Rubin era.