## Return Visit Optimization for Planet Finding Missions

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Long Range Return Visit Simulation
A sample of 1 million orbits was created with planets placed on them at points where they would be detected. The planets were then propagated forward on their orbits, with checks to see whether they were detectable at every $1 / 10$ th of a year. The target star was taken to be a twin of the sun, located 10 pc from Earth. Detection limits on the instrument were set to $\Delta \mathrm{mag}<25$ and $s$ between 0.57 and 2.205 AU (the lower this system) The initial population of orbits was drawn from uniform distributions of $a$ in $[0.4,30]$ and $e$ in $[0,0.8]$ (the range of these parameters for all known solar and extra-solar planets). [4] Figure 4. Return visit detection rates for Sun-twin at 70 Figure 4. Return visit detection rates for Sun-twin at
$\mathbf{1 0} \mathbf{~ p c .}$ Blue curves represent results for all of the 10 pc . Blue curves represent results for all of the planets simulated, while red curves describe only Earth-like planets ( $a$ in $[0.7,1.5], e$ in $[0,0.35])$. The solid curves show the percentage of the initially detected planets that are found a second time as a function of re-visit time. The dashed lines are the percentage of planets found a second time when the
return time is calculated as $1 / 2$ of the estimated orbital return time is calculated as $1 / 2$ of the estimated orbital period (these lines represent one specific return time per planet and are not functions of time).

The overall best strategy from this simulation appears to be to return as quickly as possible after initial detection. Unfortunately, this will often be impossible in a real mission, separated points on the orbit. The second strategy is to return at a later time which maximizes detection. In this case, that would be 1.5 years for Earth-like planets and 2.2 years for all planets. However, this corresponds to the mean orbital periods of the populations in question, and is problematic for the same reasons
as the first strategy. Using the orbital period approximation as the first strategy. Using the orbital period approximation yeuld hearly the same detection rates as this approach, and

Return Visit Simulation Using Real Stars
In order to test these return timing strategies, a candidate pool was constructed consisting of 245 stars within 30 pc of Earth. All of hese are main sequence stars, with no close, bright companions, no indications of intrinsic variability of low metallicity, and whose luminosities and distances would allow for detection of Earth-like planets. [6] For each star, 100,000 initially found planets were created and detection rates of a 1 AU orbit scaled by the square root of the star's luminosity and using the star's mass estimate).


Figure 5. Return visit detection rates for $\mathbf{2 4 5}$ stars within $\mathbf{3 0}$ pc of Earth using multiple re-visit timing strategies. Each data point represents the percent of initially detected planets found during the re-visit. The results are plotted as a function of the star's visual magnitude.


Figure 6. Comparison of the most successful re-visit timing strategies from Figure 5.

## Conclusions and Future Work

We can draw several important conclusions from the last simulation
There is no single optimal return strategy: a combination of these (and other) strategies must be employed, along with all available information about the candidate stars, to produce an optimal revisit schedule.
than another. For example, at $V=$ region, describable by apparent magnitude, where the various strategies cross and one is clearly better period.
period.
While in some cases returning a fixed time after initial detection produces better results than basing the re-visit time on the approximated orbital period, the latter produces much more consistent results (the variance between results for stars of similar $V$ is much smaller). The best performance in the absolute time cases occurs on the largest orbits, where the planets would not have moved very far in the given time (and the resulting orbital characterization would be much worse).
On average, using the orbital period approximation provides more information from two visits than the fixed time strategy. If the planet is detected in the re-visit, the second measurement of apparent separation significantly improves the semi-major axis estimate. In cases where the planet is not found again, the period estimate can be updated, providing tighter bounds on the times when the planet is likely to be detected. The fixed time strategy provides little or no additional information in cases of a failed second detection.

Future work in this area will include the incorporation of other known data about the candidate pool of stars to improve the fidelity of our estimates, as well as the application of the basic simulation framework to other questions, including return timing when no initial detection has occurred, and overall mission planning.

## References

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