

Search for L5 Earth Trojans with DECam

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Abstract

We present the results from a search for Earth Trojans (ETs) using the DECam instrument on the Blanco Telescope at CTIO. This search found no additional Trojans in spite of greater coverage compared to previous surveys of the L5 point. For standard assumptions, we calculate upper limits to a 90% confidence limit on the L5 population of $N_{ET} < 1$ for magnitude $H < 15.5$, $N_{ET} = 60 - 85$ for $H < 19.7$, and $N_{ET} = 98$ for $H = 20.4$. This latter magnitude limit corresponds to ETs ~ 500 m in size for albedo 0.15. At $H=19.7$, these upper limits are consistent with L4 ET constraints and improve on previous L5 constraints by about an order of magnitude.

1. Introduction

Most of the major planets in the Solar System support populations of co-orbiting bodies, known as Trojans, at their L4 and L5 Lagrange points. In contrast, Earth has only one known co-orbiting companion, 2010 TK7. There have been several dedicated searches, such as [1] and [2], but no additional ETs have been found. Upper limits from these surveys suggest there could still be hundreds of undiscovered ETs. Characterization of this population can give a unique insight into our Solar System and its dynamical history. Numerical simulations suggest that these objects could have stable orbits and be undisturbed remnants from the primordial Solar System. They may also be the population of "missing" asteroids responsible for asymmetric cratering on the Moon's surface [3].

2. DECam Survey

Our survey utilized the VR filter on the Dark Energy Camera (DECam) located on the 4-meter Blanco telescope at the Cerro Tololo Inter-American Observatory. The sky coverage for this survey is shown in Fig. 1. We observed shortly after sunset on the night of June

16, 2018. Our survey consisted of 8 fields, covering an area of 24 sq. deg. towards Earth's L5 point.

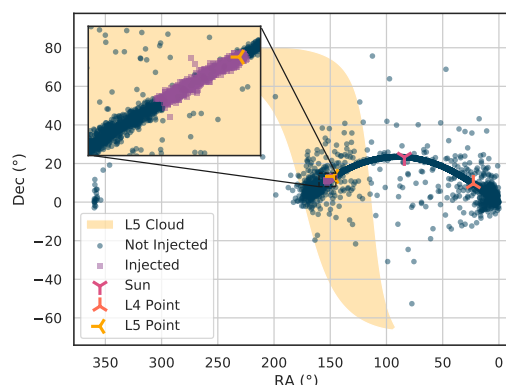


Figure 1: Survey coverage of synthetic ET population. The Lagrange points and the Sun are plotted as "Ys" for reference. The yellow shaded area represents the L5 cloud. Synthetic ETs that were injected into our images are plotted as purple squares, while those that were not are blue circles. These injected points essentially depict the area covered by our survey. These objects make up 24% of the ETs in the L5 cloud.

We found 27 new objects. None were ET candidates (in this survey defined to be objects which moved ~ 1 degree / day).

3. Upper Limits

To place an upper limit on the ET population, we generated a population of simulated ETs, injected them into our data set, and ran these images through our detection pipeline to measure our recovery rate. We then used this rate and our constraint of a non-detection to calculate upper limits as a function of H (Fig. 2). If we assume the ET population follows a power law with $\alpha = 0.46$, we can also extrapolate from our faintest upper limit (dotted line in Figs. 2 and 3) to place more

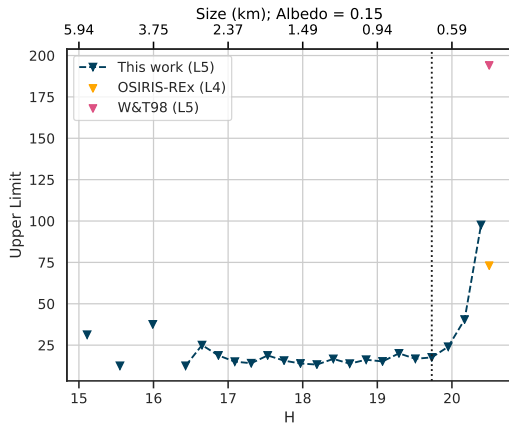


Figure 2: Calculated upper limits on the ET population. The yellow triangle depicts the upper limit calculated for L4 ETs by [1], while the pink triangle is the upper limit extrapolated from the [2] results by [1]. For the faintest bin, $H=20.4$, we calculate an upper limit of 98 ETs. Our recovery rates are flat at the bright end because all of these bins had nearly 100% recovery rates leading to a constant upper limit (~ 15) for those magnitudes. The most stringent upper limit is 18 ETs with $H = 19.7$ (dotted line).

stringent limits on the bright end of the distribution (Fig. 3). Under these assumptions, our survey gives the strictest limits on this population, $N_{ET} = 18$ for $H = 19.7$ (compared to 32 and 128).

4. Summary and Conclusions

In this survey, no ET candidates were found. Using this non-detection, we place upper limits (see Figs. 2, 3) on the ET population of $\sim 60-85$ ETs with $H < 19.7$ and 98 ETs with $H = 20.4$. These results are an order of magnitude more stringent than the previous L5 survey [2] and slightly more stringent to consistent with the previous L4 survey [1]. Broader and deeper searches are needed to further constrain the ET population.

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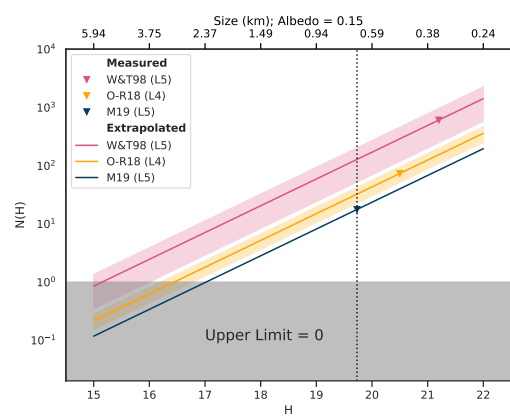


Figure 3: Extrapolated upper limits (lines) based on the measured upper limit (triangles). The results for this work are in blue, [1] in yellow, and the upper limit calculated by [1] based on the results in [2] are in pink. The dotted line represents the point used for extrapolation for the results in this work, $H=19.7$. The grey region depicts where $N(H) < 1$. The slope of the power law assumed for all of the extrapolations was $\alpha=0.46$, which gave the most conservative upper limits. Under these assumptions, the results from this work give the most stringent upper limit on the ET population.

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