Infrared Photometry of GEO Spacecraft with WISE

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ABSTRACT

NASA launched the Wide-field Infrared Survey Explorer (WISE) into orbit on December 2009 with a mission to scan the entire sky in the infrared in four wavelength bands of 3.4, 4.6, 12, and 22 microns. WISE acquired data in the four bands for 10 months until the solid hydrogen cryogen was depleted and then proceeded to operate in the two shorter wavelength bands for an additional four months in a Post-Cryo phase. In its trove of data, WISE captured many streaks that were artificial satellites in orbit around Earth. We have examined a subset of equatorial WISE images with |declination| < 15.0 degrees to find geosynchronous Earth orbit (GEO) station-keeping satellites. Furthermore, we require |galactic latitude| > 30 degrees in order to minimize contamination of the satellite streaks by stars in the galactic plane. At least one streak of the length appropriate for a GEO station-keeping satellite appears in over 10% of these images. In bands 1 through 3 (for images 1016x1016 in size), the streaks are approximately 100 pixels in length, and in band 4 (for images 508x508 in size), the streaks are approximately 50 pixels in length. Most, but not all, of these spacecraft appear in all 4 wavelength bands. Since WISE is in a Sun-synchronous orbit pointed approximately radially away from the Earth at all times, all observations of GEO objects were obtained at a solar phase angle of approximately 90 degrees. We report on the color distributions of these detections and interpret the colors and compare the spacecraft colors with colors of other astronomical objects such as stars, galaxies, and asteroids that have appeared in previously published works on WISE data.

1. INTRODUCTION

Simultaneous, multi-wavelength observations of orbiting objects can yield important information on the objects' albedo and sizes ([1,2]). The NASA WISE mission observed the entire sky in 4 infrared bands simultaneously for 10 months in 2010 ([3]), which included a long wavelength band (22 microns) that is not observable from the ground due to atmospheric absorption. Thus, the WISE archive could be an important dataset on studying the characteristics of Earth-orbiting objects. Previous work with WISE data on GEO objects has been reported, which analyzed WISE data for uncontrolled objects (debris) at GEO to derive a size distribution and an estimate of collision rates at GEO ([4]).

In this paper, we present our studies of a sample of controlled objects at GEO that appear in the 4-band WISE data.

2. WISE MISSION DESCRIPTION

WISE was initially launched to scan the entire infrared sky. To avoid directly looking at the Sun in order to prevent its optics from overheating and avoid scattered light from the Sun, WISE adopted a strategy that scanned the sky in great circles that traversed the ecliptic poles with a constant solar phase angle of ~90 degrees. Furthermore, WISE's pointing was aimed perpendicularly to the terminator with an additional scanning strategy that avoided the Moon in order to avoid its stray diffraction spikes. In this survey strategy, images that fell within the GEO regime serendipitously caught GEO satellites in approximately 10% of those images. Additionally, with this survey strategy, the phase angle is always close to 90 degrees, and thus, GEO satellites are never in eclipse by the Earth's shadow.

3. GEO OBJECTS IN THE WISE DATASET

For this initial project, we selected a subset of the WISE data of high quality in order to optimize the chances of finding controlled objects at GEO. Our selection criteria were:

- Right Ascension of the field center between 0 and 1 hour.
- Declination of field center between -15 and 15 degrees.
- | Galactic latitude | greater than 30 degrees to minimize streak contamination from stars.
- Moon separation greater than 10 degrees to avoid stray Moon diffraction spikes.
- South Atlantic Anomaly separation greater than 10 degrees.
- Additional data quality parameters selected to ensure high quality images.

Approximately 10% of the images examined had streaks consistent with controlled objects at GEO.

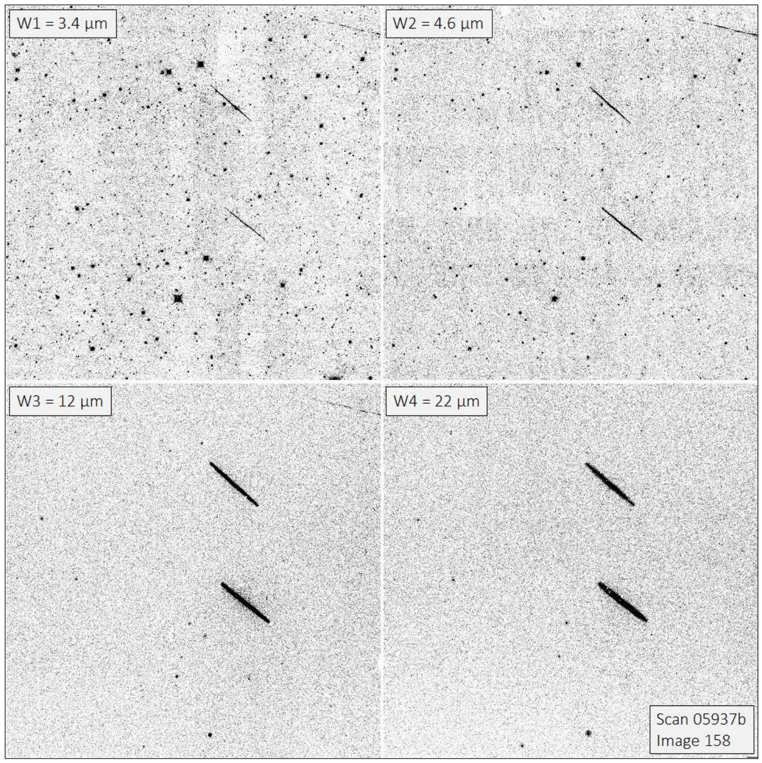

Figure 1. An example 4-band WISE image with two active GEO satellites and one uncontrolled object (at the top right of each band). Note the flaring and difference in the position angle of the uncontrolled object compared to the controlled satellites.

4. GEO SATELLITE COLORS

In our subset of data, a total of 63 streaks were detected that have streak lengths and position angles consistent with controlled objects at GEO. We plot GEO satellites in IR color-color space and observe their distribution in relation to other works on WISE data.

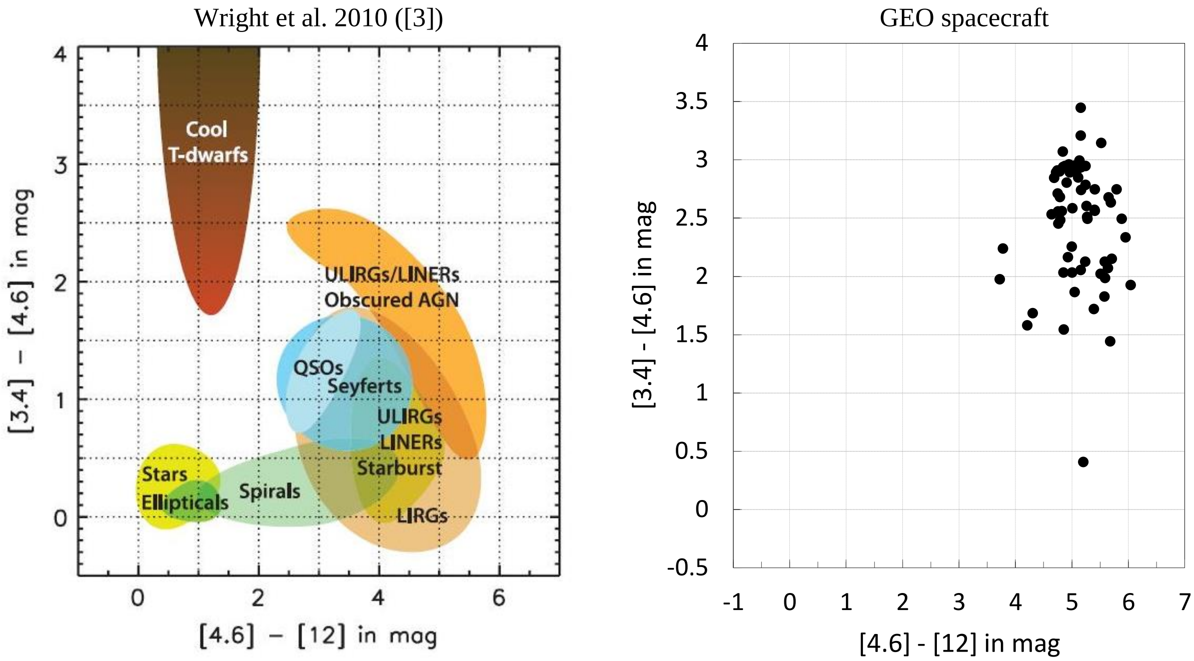

Figure 2. (Left) Color-color plot for stars and galaxies in the WISE system;
(Right) Color-color plot with same scales for GEO satellite measurements.

Comparing the colors plots from [3] and our GEO satellite measurements, we observe that the spacecraft occupy their own subspace in the plot, evidently not appearing to be similar in color to stars and galaxies, which can be explained by the fact that the processes that produce the observed fluxes between the astronomical objects and artificial satellites are significantly different.

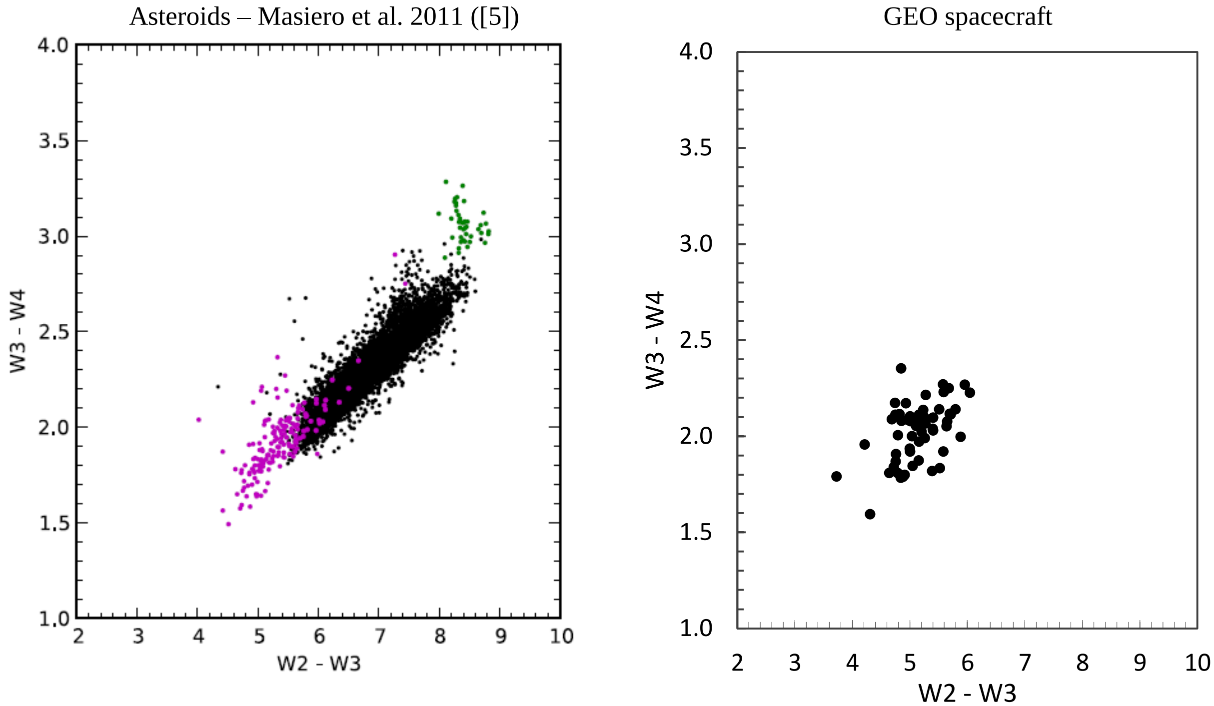

Figure 3. (Left) Color-color plot for Main Belt Asteroids (MBAs) (black), Trojans (green), and Near Earth Objects (NEOs) (magenta);
(Right) Color-color plot with same scales for GEO satellite measurements.

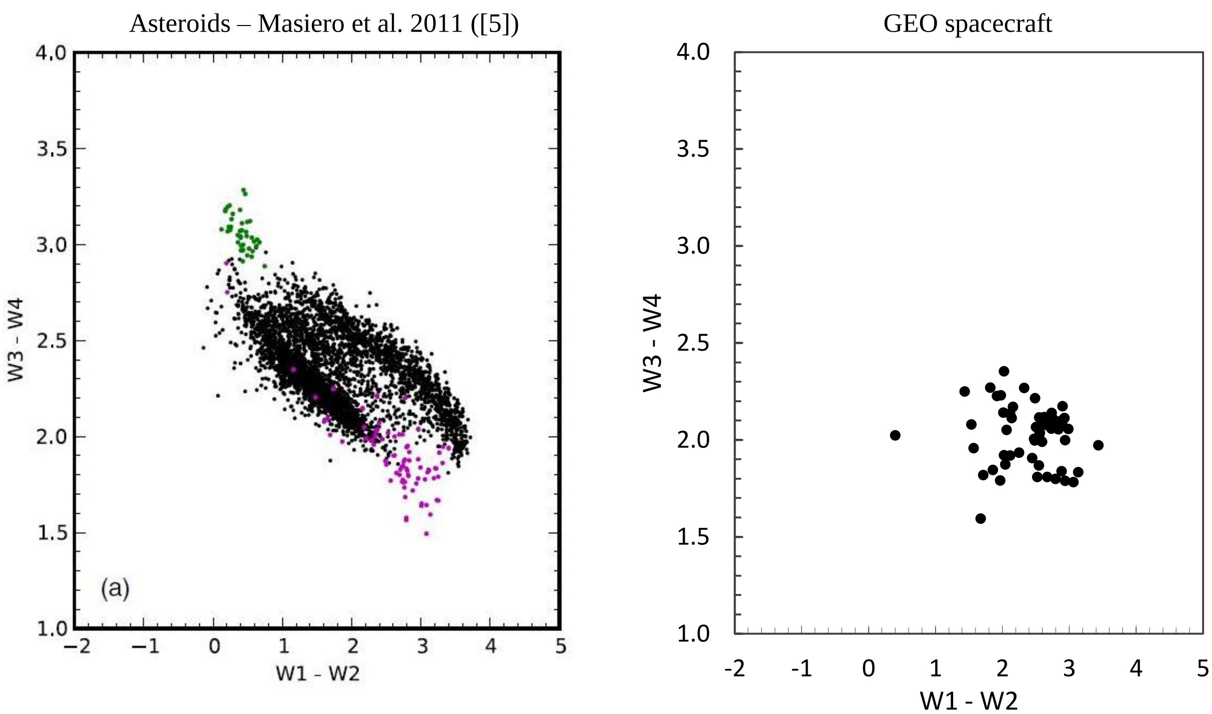

Figure 4. Similar plots as Fig. 3 but now with the x-axis color determined from the two bluest wavelengths.

In order to understand the albedos, colors, and diameters of asteroids, [4] plotted Main Belt Asteroids (MBAs), Trojan asteroids, and Near Earth Objects (NEOs) using WISE data. We observe that GEO satellites occupy the subspace that contains the overlap between MBAs and NEOs as shown in Figs. 3 and 4.

The similarities in colors begin to make sense if one considers the heliocentric distance of the various objects (Fig. 3 in [5]). Earth and GEO satellites are 1 AU from the Sun like NEOs. Given that bands W1 and W2 are dominated by reflected sunlight and W3 and W4 are dominated by thermal emission ([4]), this suggests that GEO satellites (and perhaps other satellites as well) share similar blackbody emissivity and albedos as NEOs that are similar in distance to the Sun, despite having different surface characteristics and composition. An alternative explanation is that the WISE colors are not very sensitive to changes in albedo, thermal emission from different materials, or a mixture of both.

5. FUTURE WORK

Currently, our data subset only includes observations taken in June and July, close to the summer solstice, where solar declination is around its maximum. We will work through the entire equatorial dataset to study possible changes in GEO satellite colors with season, or solar declination. Furthermore, we will identify the satellites in the public catalog.

We have generated an artificial streak simulation program that allows us to create and insert streaks of known brightness and length into astronomical data. Despite specifying our galactic latitude parameter, our images still have a considerable number of astronomical sources, particularly in W1 and W2, as exemplified in Fig 1. Given streaks of known brightness, we can measure the artificial streaks in WISE data and determine our systematic and random measurement errors.

Our ultimate goal is to determine the infrared characteristics of GEO spacecraft to make inferences concerning the structure of the spacecraft, and possibly the albedo. Potential difficulties in albedo determination include, but are not limited to, additional thermal emissivity due to power sources on board the spacecraft, and self-shadowing of the spacecraft, which may conceal sections of the satellite in a range of different ways.

6. REFERENCES

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