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WISE Thermal IR Observations of IDCSP Satellites

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Abstract

The Initial Defense Communications Satellite Program (IDCSP) comprised a series of 27 communications satellites launched into sub-geosynchronous orbit between 1966 and 1968. They are some of the oldest satellites in the geosynchronous (GEO) regime. These were 0.86-m diameter 26-sided polygon spin-stabilized satellites covered with solar panels. There were no batteries or attitude control systems. The population was largely but not entirely identical. We report on observations of these satellites with the Wide-field Infrared Survey Explorer (WISE) satellite which conducted a four-band infra-red survey of the entire sky between January and October 2010. In the WISE images are observations of every one of these satellites. They are marginally or not detected in the two shorter wavelength WISE bands (3.4 and 4.6 microns) where the flux is dominated by reflected sunlight. This result is not surprising, since these are some of the faintest objects at visible wavelengths in the public catalog, and the WISE observations were obtained at a phase angle of close to 90 degrees. The IDCSPs are better detected in the two longer wavelength WISE bands (12 and 22 microns) where the flux is dominated by thermal emission from the satellite. At 12 microns the magnitude distribution is very sharply peaked near 6.3. We report on the thermal IR magnitudes and colors of these inactive satellites and compare them with thermal IR magnitudes and colors of other objects in the GEO regime.
Keywords: (geosynchronous, space debris, infrared, satellites)

1. Introduction

Objects in the GEO regime are unresolved with small telescopes. Optical and infrared measurements can in principle learn some of the characteristics of the unresolved object by measuring brightness, colors, and how these change with time.

In this paper we report on measurements in the thermal IR at 12 and 22 microns of the sub-GEO satellites in the IDCSP constellation. We will compare this with previous studies of GEO objects [1][2][3].

2. The IDCSP Constellation

In the 1960s were the first steps taken in populating the geosynchronous regime. One of the first constellations was that of the IDCSP satellites launched between 1966 and 1968. There were 4 launches, of which one failed. 27 satellites were placed into circular orbits some 2000 km below the GEO belt[4]. They drifted some 30 degrees per day as they did not station-keep.

These satellites were totally passive, covered in solar panels, with no batteries or attitude control systems (Fig. 1.). They were 26 sided polygons, 86 cm in diameter, and a mass of 45 kg [4].

The population was largely identical [4]. Thus, they provide a unique sample to investigate in both the optical and infrared.

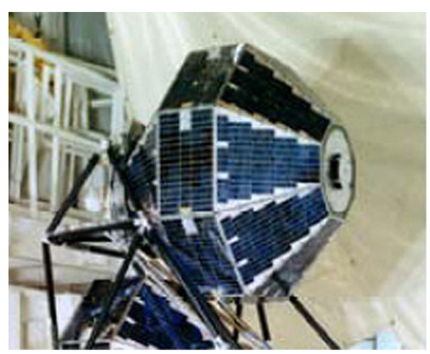

Fig. 1. IDCSP satellite [4].

Since these objects are some of the oldest satellites near GEO, their orbital evolution is of interest. Fig. 2 shows the change in orbital inclination with time since 1990. This is due to the precession of the orbital plane due to gravitational forces. At GEO, the period of this precession is 54 years, but at the lower altitude of the

IDCSPs the observed period is 47 years. The satellites have completed one period and are starting their second.

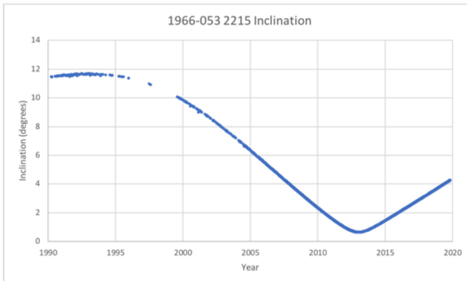

Fig. 2. Change in orbital inclination with time for an IDCSP launched in 1966.

3. The WISE Mission

The WISE spacecraft has a 0.4-m telescope and was launched into a Sun-synchronous orbit with an altitude of 525 km [5]. During the 10 months in 2010 that the cryogens lasted, the system was sensitive to the 4 bands shown in Fig. 3 [5].

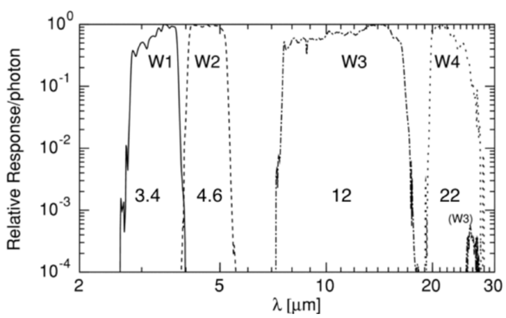

Fig. 3. The four passbands of the full WISE mission. From [5].

The bluest passband W1 was most sensitive to reflected sunlight, while the two reddest passbands W3 and W4 were most sensitive to thermal emission from the source. W2 is sensitive to both reflected and thermal emission depending on the temperature of the source.

Because WISE observed perpendicular to the Earth-Sun line, the phase angle was always close to 90 degrees. The distance from the telescope to objects in the GEO regime was always the same. Therefore, observations of GEO objects are a very uniform sample. No corrections were made for phase angle nor distance.

GEO objects are observed at either 6 or 18 hours after eclipse.

Fig. 4 shows an example of what the WISE images look like. The WISE observing scan resulted in stars being point sources, and satellites being streaks.

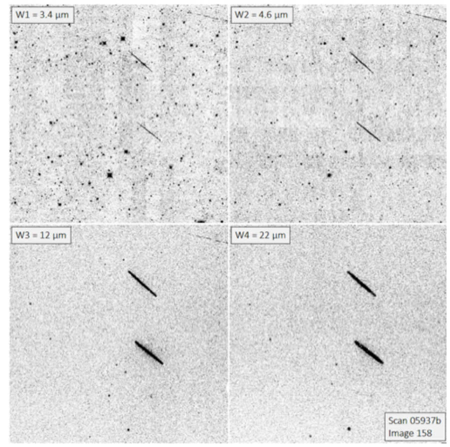

Fig. 4. Example of one WISE observation of a field with two geosynchronous satellites in it. On top are 3.4 and 4.6 micron images. On the bottom are the 12 and 24 micron images.

4. Previous Studies of GEO Objects with WISE

Previous WISE studies of satellites have concentrated on active GEO satellites [1][2] and Titan rocket bodies and debris [3]. Fig. 5 shows the color-color plot for a sample of active GEO satellites

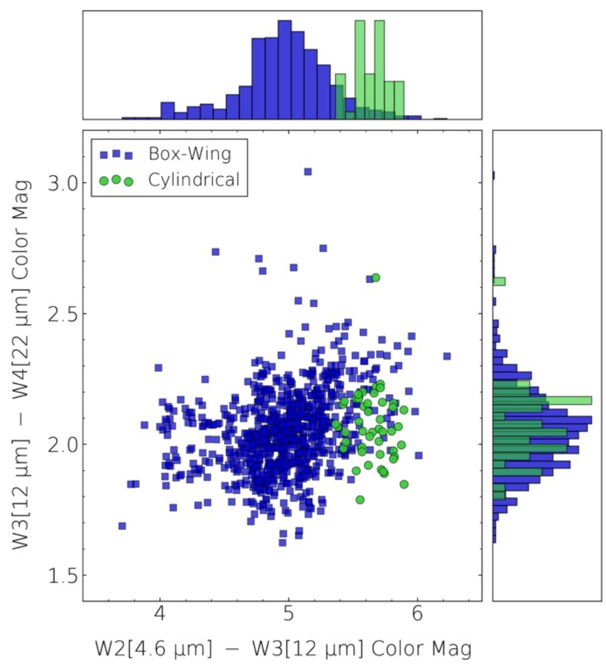

Fig. 5. Color-color plot of active satellites distinguished between box-wing (blue squares) and cylindrical satellites (green circles).

Active box-wing and cylindrical satellites occupy different places in the W2-W3 color space. The distributions overlap enough that it would not be possible to unambiguously distinguish between box-wing and cylindrical satellites in some regions of the W2-W3 color space. In the thermal color W3-W4 both classes of satellites overlap. This is not surprising if both have the same effective temperature.

For inactive satellites, Fig. 6 shows the same color-color plot as active satellites. The distribution of the thermal color W3-W4 is now shifted to the blue from active satellites.

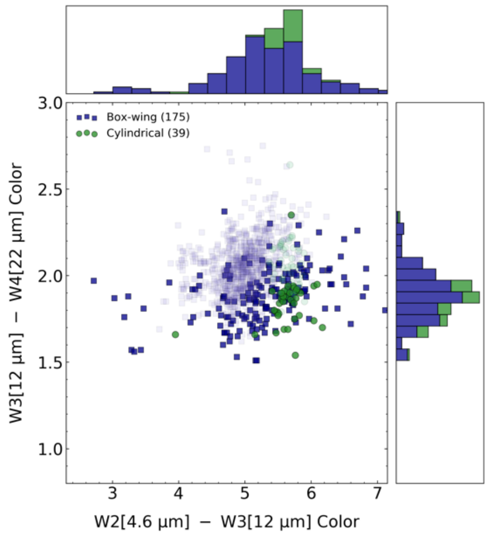

Fig. 6. Color-color plot of inactive box-wing and cylindrical satellites overlaid on active satellites.

5. WISE Observations of IDCSP Satellites

The IDCSP satellites are some of the fainter objects in the public catalog. Coupled with the fact that they are significantly fainter in the WISE images because they are observed at a phase angle of 90 degrees, they are largely not detected in the two bluest passbands W1 and W2. Measurable detections were found only in the two reddest passbands W3 and W4, which are dominated by thermal emission. Fig. 7 shows the histogram of the W3-W4 colors for all 115 measurements. The median color is around -1.8, which is not significantly different from that for inactive satellites. If all objects from both samples have reached thermal equilibrium in sunlight, then this result is to be expected.

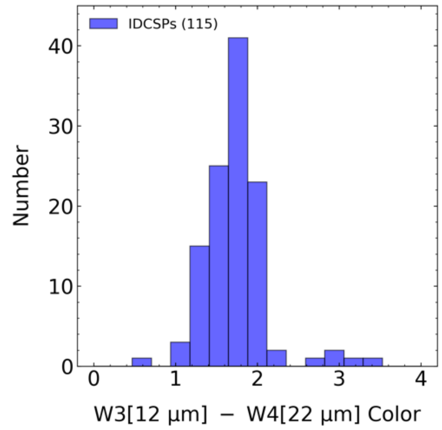

Fig. 7. Thermal IR color histogram of all measurements of IDCSPs in the WISE images.

Of interest is the brightness comparison between GEO satellites and IDCSPs. The IDCSPs have a tightly peaked W3 observed magnitude near 6.3, with both active and inactive satellites almost 4 magnitudes brighter.

If these objects were observed at LEO near 800 km, then the objects would be among the brightest objects in the 10 micron N band as observed from the ground! Fig 8 shows the scaled magnitudes. This assumes that the thermal behaviour with time is the same as at GEO, which is not correct since at LEO they would be in 90 minute orbits and have much more frequent thermal cycling.

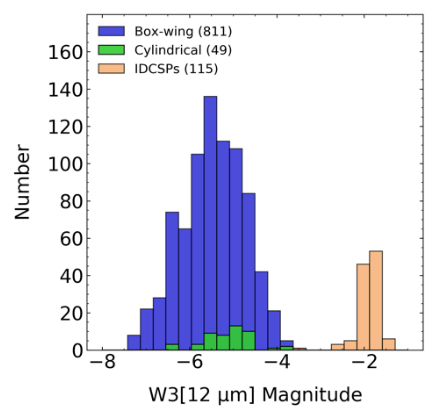

Fig. 8. W3 magnitude of GEO objects scaled to LEO orbit.

6. Conclusions

The IDCSPs are some of the oldest and faintest GEO objects in the public catalog. They have completed one complete precession cycle of their orbital plane, and are now starting the second with a period of 47 years.

In the WISE images they are detected only in the two reddest passbands W3 (12 microns) and W4 (22 microns). These passbands are dominated by thermal emission, and not by reflected sunlight. The thermal IR color W3-W4 peaks near 1.6, which is very close to that of inactive GEO satellites.

As expected, if thermal emission scales with size, the W3 magnitude is on the order of 4 magnitudes fainter than inactive satellites at GEO.

References

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