Examining the Effects of On-Orbit Aging of SL-12 Rocket Bodies using Visible Band Spectra with the MMT Telescope

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ABSTRACT

We present a spectroscopic study of orbital debris aimed at characterizing changes over time in object properties, using ground-based spectroscopy of several similar rocket bodies in geosynchronous orbit, launched at different times.

The characterization of deep space debris has posed a significant challenge in the study of space objects. To be most effective, characterization must be performed quickly and under non-ideal operational conditions, generally using non-resolved techniques. Multi-color photometry and the resultant color indices offer the potential to rapidly discriminate between debris and intact space objects such as rocket bodies and satellites. However, these studies are not well informed by high resolution spectra of these same objects, due to the lack of prior measurements with large astronomical telescopes. High and moderate resolution spectroscopy is not routinely collected by SSA resources. Nonetheless, several researchers have collected satellite spectra for research purposes. Several researchers have also noted the progressive reddening of spacecraft surfaces. Jorgensen measured reflectance spectra over a range of years on orbit (YOO) of 10-13 years of foreign discarded rocket bodies and noted significant increase in relative reflectance above 750 nm. Similarly, aging has been noted on GPS payloads using BVRI photometry by Fliegel.

In this study, we have collected high resolution spectra of a group of five Russian SL-12 rocket bodies in geosynchronous orbit. The spectra were collected with the Blue Channel Spectrograph on the 6.5 m MMT telescope at Mt. Hopkins. The measurements were taken using the 300-line grating, which is blazed for the red, and can cover a 5200 A range at dispersion 1.96 A/pixel. The large collecting aperture of the MMT allowed the rapid collection of multiple high signal-to-noise spectra with only 2 minutes per exposure. This short exposure allowed us to have confidence the solar phase angle was near constant during each collection, but that the spectra were averaged over the rotation of the rocket body. These spectra allow analysis of both the variation in albedo over a large wavelength range, and searches for discrete absorption features. The SL-12 (also called the "Proton K") was a mainstay Russian four-stage to GEO launch vehicle that was used from 1974 to 2012 (Gunter 2017). The SL-12 fourth stage rocket bodies (henceforth referred to as "SL-12 RB") offer a convenient ensemble of objects for which photometric techniques can be developed and tested. For this study, spectra of five SL-12s with a range of years-on-orbit (YOO) ranging from 23-35 years were collected, allowing a comparative study of the evolution of the spectra over a 12-year difference in age. Additionally, all these objects have been previously observed in the near-IR with the UKIRT WFCAM. The spectra are analyzed for evidence of the effects of on-orbit reddening and other changes over time.