Spectroscopy for space debris objects characterization and age estimation

Dissertation thesis

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Abstract

Spectroscopy is widely used technique in astronomy and this dissertation thesis investigates its application into the space debris domain. Artificial human-made objects on Earth orbits reflect sunlight either diffusely or specularly and bright radiation can be detected by ground observers. Specular reflections or glints can be detected by spectral cameras such as the ones assembled in All-sky Meteor Orbit System (AMOS) network. Bright diffuse reflections can be observed with a spectrograph attached to a small-diameter telescope, such as the Shelyak LISA slit-based spectrograph mounted on 80-cm telescope ZimMain. Fainter, diffuse reflections from more distant objects can be observed with a large-diameter telescope, such as the 10.4-m Grantecan telescope in La Palma. By processing recorded spectra from highly reflective surface elements of satellites or space debris, information about the radiating material can be extracted. Preliminary spectral classes were identified from AMOS recordings of silver aluminum glints, solar panel glares or golden glints from materials such as Kapton Multi-Layer Insulation (MLI) foils. Considering specular glints are usually reflected from a sole type of material, spectral identification and characterization is straight forward. However, when analyzing diffuse spectra from multi-material components a thorough analysis must be implored. To follow up on spectroscopic observations and to study how different materials reflect sunlight, various laboratory experiments were performed with three different spectrographs – AMOS-Spec-HR, LISA slit-based spectrograph and OceanOptics spectrometer. Spectra of wide variety of materials supplied by satellite manufacturer Needronix commonly used in spacecraft design were measured in laboratory. Altogether, thousands of spectra were collected from both observational and laboratory campaigns. Database of laboratory measured spectra was extended by spectra published in literature to create an extended database of common spacecraft materials. This database was used to determine a spectral classification based on absorption features of various types of materials. This classification proposes a simple way of distinguishing between artificial materials used in space missions and was applied on the analysis on high-signal spectra measured with the Grantecan telescope. Types of reflecting materials were identified and investigation into the influence of space weathering and ageing of the materials was conducted. Finally, conclusions can be drawn as to how efficient can the characterization of artificial space objects be using spectroscopy and if material ageing can be studied.