Solar-phase-angle effects on the taxonomic classification of asteroids

J. Carvano[1] and J. Davallos[1]

[1]Observatorio Nacional – Rio de Janeiro, Brazil

Asteroid taxonomy is the effort of grouping asteroids into classes based on similarities of a number of their observational properties. The most used properties include measurements of their spectral reflectance (by means of low-resolution spectra, spectro-photometry, or colors), and geometric albedo. The usefulness of asteroid taxonomic classes derived in this way relies on the assumption that the classes bear some correspondence to the mineralogy of the asteroids, and on the fact that such classification can be made using types of observations that presently are available to a large number of asteroids. Therefore, asteroid taxonomy can be used to infer trends in the distribution of compositions in the main belt and other populations, as an additional parameter in defining asteroid families, and as a selection tool to identify candidates for more detailed observations. However, the fact that the correspondence between taxonomic class and composition is far from perfect is still sometimes overlooked in the literature. Indeed, although a taxonomic classification narrows down the possible mineralogies of a given asteroid, it will seldom point univocally to one particular mineralogy. This happens for a number of reasons, some linked to the intrinsic difficulty involved in the remote characterization of the mineralogy of an asteroid, since it depends on the presence of absorption bands in its reflectance spectrum which may be absent or not completely sampled by the observations used to derive taxonomy. Other problem here is the exposure of the material on the surface of the asteroid to space-weathering effects, such as solar wind implantation and micro-meteorite bombardment, which can change the optical properties of the material. Finally, the overall shape of the reflectance spectrum of an asteroid is also affected by the geometry of the observation, as well as by its shape. In this work, we analyze how the classification of asteroids observed by the Sloan Digital Sky Survey is affected by the solar phase angle of the observation. It is found that the number of observations assigned to several taxonomic classes has a clear dependency on the solar phase angle of the asteroid at the moment of the observation. In order to understand how variations of phase angles affect the reflectance spectra of the individual asteroids listed in the SDSS with multiple observations, we use the reflectance spectra derived from the SDSS colors to define two parameters, which measure the spectral slope in the visible and the depth of the 1-micron band, if present. It is found that most asteroids in the sample tend to be redder at higher phase angles, and that, for the classes showing a 1-µm band, most show increasing band depth with increasing phase angle. This predominance of positive correlations for both band depth and spectral slope might suffice to explain the offsets in the distribution of classes. However, for both parameters there is a significant fraction in each sample for which there seem to be no correlation at all, and a comparable number seem to display anti-correlation between the parameters and the phase angle.

Therefore, although phase-reddening effects, as currently understood in the literature, can account for the offsets in the distribution of taxonomic classes with phase angle, it cannot explain all variability seen in the SDSS data. There is also a dependency on composition and also shape effects involved, which can be reproduced using Hapke reflectance models.