A b s t r a c t

Freie Universität Berlin

THE NATURE OF NEAR-EARTH ASTEROIDS
FROM THE STUDY
OF THEIR THERMAL INFRARED EMISSION

The topic of this dissertation is the investigation of physical properties of near-Earth Asteroids (NEAs) to improve our understanding of their nature, origin and their relation to main-belt asteroid (MBAs) and comets. A major aspect of the research is the use and the improvement of models of the thermal infrared emission of asteroids (the so-called thermal models) to facilitate the determination of sizes, albedos and other physical properties of NEAs.

A major development within this study is the discussion of the results from new observing programs with the 10m - Keck 1 telescope, the NASA-Infrared Telescope Facility (IRTF) on Mauna Kea, Hawaii and the 3.6m telescope at the European Southern Observatory (ESO), La Silla, Chile. In the framework of these observing programs, thermal emission continua of thirty-two NEAs have been obtained in the medium infrared (MidIR) (5-20µm).

By fitting thermal models to the observational data, we have derived the sizes and the albedos of a significant sample of the near-Earth asteroid population. This work increments the number of NEAs with measured sizes and albedos by 54%. If we include objects for which the diameter and the albedo have been refined, this increment increases up to almost 70%. The uniqueness of our project was the possibility of studying smaller and fainter objects which are only accessible with the most up-to-date Mid-IR instrumentations and the largest telescopes on the ground. There were very few thermal infrared observations of asteroids in the 1-kilometer size range, and we have more than doubled the number of subkilometer-NEAs with measured size and albedos. The good quality data that we have obtained constitute the largest database of NEAs radiometric diameters and albedos.

An accurate determination of sizes for a significant sample of NEAs, besides providing crucial input for the assessment of the impact hazard these objects pose for our planet, gives important clues about their surface characteristics.

Although we confirm that the spread of NEA albedos is very large ($p_V = 0.02 - 0.55$), consistent with their being supplied from more than one source region, we have found that observed NEAs are on average brighter than MBAs. The average value of radiometrically determined albedo is 0.27, which is much higher than the mean albedo of observed MBAs (~0.11). In several cases the albedos are in the ranges expected for their taxonomic types, although some exceptions are evident. Overall, we find that observed S-type NEAs are on average 20% brighter than S-type MBAs, whereas observed C-type NEAs have on average albedos 57% higher than C-type MBAs. Such dichotomy between the albedo statistics of large and small asteroids implies a fundamental difference in surface properties of small asteroids with respect to the larger ones. We show, moreover, that a variation of surface properties with size exists within the NEA population itself. A trend of increasing albedo with decreasing diameter for S-type NEAs has been identified. We argue that this trend is indicative of recently exposed, relatively unweathered surfaces. Although a selection effect in favor of the discovery of the brightest asteroids would give rise to such trend, this result is also consistent with the trend to ordinary-chondrite-type reflection spectra with decreasing size observed in the NEA population. This last effect is also attributed to a lack of space weathering of relatively young surfaces.

NEAs do not only have higher albedos than larger MBAs, but they differ also in surface thermal properties. Our work confirms the hypothesis that these asteroids have higher thermal inertias than large MBAs. We have derived a best-fit estimate for the thermal inertia of the observed near-Earth asteroids of 550 ± 100 J m^{-2} $s^{-0.5}$ K^{-1}. This value is about eleven times higher that of the Moon and more than 30 times larger that of the largest asteroids 1 Ceres and 2 Pallas. This result has important implications for our understanding of the nature and the origin of these bodies. For instance, the higher thermal inertia is an indication that these asteroids have surfaces covered with a regolith courser than the lunar one and, very likely, different surface fractional rock coverage than large MBAs.

This result was obtained by studying the correlation of the observed distribution of surface color temperatures that NEAs display as a function of the phase angle in the light of a thermophysical model. The thermophysical model that we have developed in this work, takes account of the effects of rotation rate, thermal inertia and surface roughness on the thermal emission of airless bodies. In particular, we have demonstrated that the observed distribution of the color temperature with the phase angle can be used to constrain the thermal inertia (and partially the surface roughness) of the observed asteroids in the hypothesis that their spin vectors were randomly oriented.

By means of our thermophysical model, we have also obtained a quantitative assessment of the uncertainties in the NEAs albedos and diameters derived by using the Standard Thermal Model (STM and the near-Earth asteroids thermal (NEATM) model, which both make assumption about the surface temperature distribution and the thermal inertia of NEAs. We have numerically estimated a correction function for NEAs radiometric diameters and albedos derived by means of the STM and of the NEATM, provided that spin status and thermal parameter of the asteroid are known. When such information is not available, the accuracy of NEATM results can be still estimated on the basis of the derived color temperature of the objects.

Our intriguing new results suggest that, by analyzing thermal infrared observations of NEAs of different sizes and classes by means of thermophysical modeling, it is possible to study the range of thermal properties and surface structure present in the NEA population.

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