EPSC Abstracts
Vol. 6, EPSC-DPS2011-1633, 2011
EPSC-DPS Joint Meeting 2011

Constraints on Space Weathering from the Albedos of WISE-detected Asteroids

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Abstract

Numerous experimental and observational studies have shown that space weathering causes planetary surfaces to darken over time. However, details of this process remain poorly understood. The derivation of albedos for the ∼150,000 asteroids observed by NASA's Wide-Field Infrared Survey Explorer (WISE) mission provides an excellent means for investigating in a statistically significant manner the relevant mechanisms and timescales associated with space weathering. We will present an analysis of the preliminary release of WISE data with a focus on the relationship between the surface ages of asteroids and their calculated albedos.

1. Space Weathering Effects

Planetary surfaces are modified over time due to a complex interplay of irradiation by high-energy particles, incident solar UV flux, micrometeorite bombardment, and impact blanketing [1]. This modification has been directly observed in lunar samples, e.g. [2], and studied in the laboratory with simulated weathering experiments, e.g. [3]. In-situ observations of asteroids from orbiting or passing spacecraft have provided clues about space weathering on airless bodies, e.g. [4]. Ground-based photometric and spectroscopic observations have also identified signatures of space weathering amongst main belt and near-Earth asteroids, e.g. [5, 6, 7].

In general, this ensemble of observational evidence suggests that the consequences of space weathering include a lowering of albedo, changes in the depths of absorption bands, and changes in the slopes of reflectance spectra. Each of these changes are compositionally dependent, such that the magnitude and even the direction of change may vary from one body to the next [8].

Figure 1 shows the outcome of irradiation experiments for three different meteorite types. In each of these examples the reflectance or albedo decreases as the irradiation level is increased. These effects can be large (∼10% albedo change) and thus may be detectable with the available precision of albedo estimates from thermal infrared observations like those from the WISE satellite [11, 12].

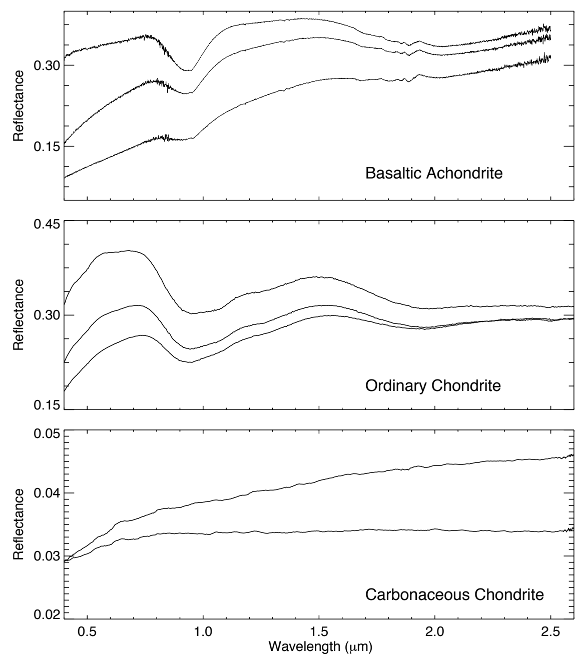

Figure 1: Effects of irradiation on three different meteorite types. In each panel the top spectrum corresponds to the un-irradiated, fresh sample and the bottom is the most irradiated. These samples clearly become darker with increased irradiation. The basaltic achondrite is the eucrite Bereba, data from [9]. The ordinary chondrite (L6 Chateau Renard) and carbonaceous chondrite (Tagish Lake) are both from the RELAB database [10].

2. Albedos of WISE Asteroids

Over its one year lifetime the WISE satellite surveyed the entire sky with four infrared filters, W1, W2, W3 and W4 (centered at 3.4, 4.6, 12 and 22 μm respectively). Included in this survey were observations of over 157,000 minor planets [13]. The first public data release covers about 50% of the WISE survey and includes detections of over 60,000 minor planets. The WISE bands span the thermal emission peaks of most minor planets in the inner Solar System and thus provide an opportunity to constrain the diameters and albedos for this large sample of objects.

As an illustrative example, Figure 2 shows WISE observations of asteroid 38707. The albedo and diameter of this object are constrained through application of the Modified Standard Thermal Model (STM) [14]. We have run the STM for all $\sim$60,000 asteroids in the first data release. This provides a statistically significant sample for addressing questions related to the relevant timescales and specific processes associated with space weathering.

We will focus this study on the physical processes and properties that can act to reduce the effective surface age (i.e. degree of weathering) of an asteroid and thus result in a detectable albedo signature. Such processes include collisions and the formation of dynamical families, rotational evolution due to non-gravitational forces, and gravitational perturbations to surface regoliths via planetary encounters.

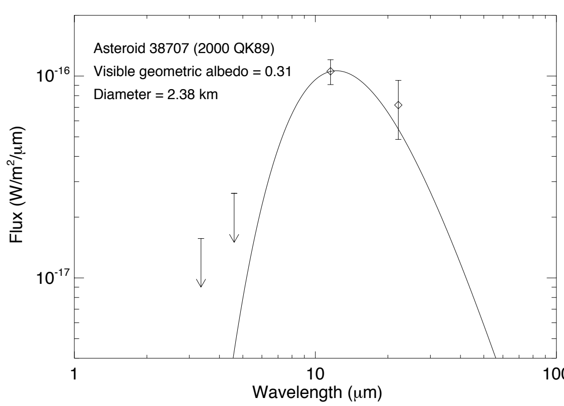

Figure 2: WISE observations of asteroid 38707 from April 8, 2010. An STM fit to the observations (solid curve) provides a constraint on the albedo (p_V=0.31) and diameter of this asteroid (2.38 km). Upper limits are plotted for the W1 and W2 bands, which are not used in the STM fit.

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