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METEORITE MINERALS AND GRANULAR PHYSICS: UNIQUE EARLY SOLAR SYSTEM CONDITIONS, FIRST PRINCIPLES CONDENSED MATTER PHYSICS AND TECHNOLOGICAL APPLICATIONS

Abstract

The unique conditions in the early Solar System led to the creation of dozens minerals not found on Earth and known only from meteorites. These "meteorite minerals" can help us: (1) understand those special conditions; (2) guide first principles theories to find new stable states in a vast computational landscape; (3) discover minerals with unprecedented properties of potential technological application. Moreover, rubble pile asteroids provide natural experiments in the new field of granular physics.

The physics of granular materials has been well-studied in Earth's gravity, but lacks a general theory. Because of the compacting effects of gravity, some experiments desired for testing these theories remain impossible on Earth. Studying the behavior of a micro-gravity rubble pile – such as many asteroids are believed to be – could provide a new route towards exploring general principles of granular physics. These same studies would also prove valuable for planning missions to sample these same bodies, as techniques for anchoring and deep sampling are difficult to plan in the absence of such knowledge.

In materials physics, first-principles total-energy calculations for compounds of a given stoichiometry have identified metastable, or even stable, structures distinct from known structures obtained by synthesis under laboratory conditions. The conditions in the proto-planetary nebula, in the slowly cooling cores of planetesimals, and in the high speed collisions of planetesimals and their derivatives, are all conditions that cannot be achieved in the laboratory. Large samples from comets and asteroids offer the chance to find crystals with these as-yet unobserved structures as well as more exotic materials. Some of these could have unusual properties important for materials science.

Exploration of small bodies in the Solar System should be designed to include studies of granular physics and searches for "meteorite minerals", not all of which may survive in meteorites themselves due to atmospheric heating and subsequent weathering on Earth.