The connection between asteroids and meteorites

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Meteorites and asteroids provide two complementary windows into the processes that shaped the earliest stages of planet building in the internal part of the solar system. The study of meteorites has the advantage that samples can be examined in great detail in the laboratory. Their mineralogy and textures can be described down to extremely small length-scales, while their elemental and isotopic compositions can be quantified with ever increasing accuracy. All of this information provides valuable constraints on the physical and chemical processes that were at work in the early solar system and the time-scales of those processes. However, the stochastic nature of the process that delivers meteorites to Earth has the consequence that the meteorite record is potentially an incomplete or biased sample of inner solar system material that escaped accretion into the terrestrial planets. Furthermore, in light of their small size, meteorites cannot offer a direct view of geological context, hampering insight into the large-scale geophysical evolution of their parent bodies.

The study of main-belt asteroids has the potential to remedy several of these issues. For example, the spectral diversity of such asteroids provides a relatively complete picture of different types of small bodies of the inner solar system and their spatial distribution between Mars and Jupiter, even if the compositional constraints are rudimentary compared to those provided by meteorites. At the very different length-scale of individual parent-bodies, asteroids also offer the opportunity to constrain geological history and internal evolution through mapping of their surface material. While Earth-based and space-based telescopes can provide first order constraints, exploiting this potential requires dedicated study at the smallest length scales possible, calling for dedicated space-based missions.

After several successful flyby missions (e.g. NEAR and Galileo missions), orbiting spacecraft are revolutionizing insight into the mineralogy and chemistry of asteroids. Such missions have the advantage that they can observe the complete surface of a given asteroid, can accumulate data over many months, and can even obtain samples that return to Earth. In this way, the gap between meteorites and asteroids is being bridged. For example, the Hayabusa mission to the small asteroid Itokawa found material similar to L-type ordinary chondrites, while the Dawn mission to the large asteroid Vesta has confirmed the link between this asteroid and the Howardite-Eucrite-Diogenite family of differentiated meteorites. Currently the Dawn mission is wrapping up its observation of the largest asteroid of the main-belt, Ceres, providing constraints on the internal structure and workings of ice-rich, poorly differentiated bodies with similarities to carbonaceous chondrites.

In this review we will showcase these more recent data, highlighting the similarities between asteroids and meteorites, but also pointing out why Ceres is probably not the parent body of any known class of carbonaceous chondrite. We will also mention the exciting missions to a range of new bodies including small carbonaceous and metallic asteroids that are launched or planned for the coming years.

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