Comet 9P/Tempel 1: Application of the Comet Standard Model to Observations of Its Dust

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Short-period comets are originally composed of ices and dust that were present in the cold comet-formation region of the primordial solar nebula. When the comets leave the trans-Neptunian region and approach the Sun, volatile components of its nucleus begin to sublime. Expanding volatile gases drag light dust having a large surface-to-volume ratio and leave preferentially heavy dust of a small surface-to-volume ratio on the surface of a comet to form a dust mantle. Indeed, optical and infrared observations of cometary comae suggest that large compact aggregates of tens of micrometers or larger lie in a dust mantle with depleted volatile materials, while large fluffy aggregates are embedded with volatile materials below the dust mantle. Dust mantle formation results in chemical differentiation of ices over tens or hundreds of meters below the dust mantle as well as crystallization of pristine amorphous water ices just below the dust mantle. In addition, impact cratering by interplanetary bodies affects the surface evolution of the nucleus. Therefore, primordial materials in comet nuclei remain only in the deepest region far below the dust mantle (we call this scenario the standard model).

Observations of comet 9P/Tempel 1 by NASA's Deep Impact (DI) mission gave us a good opportunity of examining the standard model for comet nuclei, because DI excavated the nucleus up to ~10-20 m depth. In this study, we demonstrate how well the standard model can explain the available DI observational data by calculating the optical properties of aggregate dust particles in the framework of the standard model: (1) A dust mantle with a thickness of ~1-2 m builds up on the surface, where compact aggregates with sizes > tens of micrometers dominate; (2) Large fluffy aggregates are embedded in chemically differentiated layers as well as in the deepest part of the nucleus with primordial materials. We conclude that the DI results support the standard model and do not need any peculiar view of a comet nucleus suggested by recent several researchers.