MISSION CONCEPTS OF SAMPLE RETURN FROM SMALL BODIES— ADDRESSING KEY QUESTIONS OF THE 1ST 10 MA YEAR EVOLUTION OF THE SOLAR SYSTEM

Y. T. Lin. The Key Laboratory of Earth and Planetary Physics, Institute of Geology and Geophysics, Chinese Academy of Sciences (Beijing 100029, China, LinYT@mail.iggcas.ac.cn).

Introduction: Small bodies, including asteroids and comets, are the relict “building blocks” of the solar system, providing probes to explore the origin, initial status and condensation of the solar nebula, and accretion of planetesimals. These processes took place within the first 10 Ma years of the solar system, and largely determined the compositions of the Earth and other planets. Exploration missions of small bodies, mostly via remote sensing and in situ measurements, have brought us with numerous discoveries. However, sample analysis especially of trace elements and isotopes with the state-of-art instruments is critical to reveal the history of the solar system. Our knowledge of the solar nebular condensation has mainly been contributed by asteroid meteorites, with up to 38 chemical groups classified (MetSoc Bulletin Database). The genetic linkage between meteorites and asteroids was connected by their reflect spectra, but only that between LL5/6 chondrites and the S-type asteroid Itokawa has been confirmed [1]. Furthermore, many spectroscopic types of asteroids are absent in the collection of meteorites, and there is no rock samples from comets. In addition, most meteorite samples have been suffered various degrees of terrestrial weathering, and terrestrial organic contamination is hardly to avoid even for witnessed falls. Hence, sample return missions from small bodies are expected to clarify how a primordial nebula evolved into the highly heterogeneous solar system.

Key Questions of the Formation of the Solar System: The first 10 Ma years of the solar system formation can be divided into three episodes, i.e. initial status of the presolar nebula, condensation of solar nebula, and accretion of planetesimals. Each episode has key questions that can be addressed only by returning samples from asteroids and/or comets. The presolar nebula, before igniting of nuclear fusion of the Sun, was cold and consisted of dust particles and gas. It is unknown if the presolar dust particles distributed homogeneously in the primitive nebula? Why the abundance of presolar grains in the matrix of primordial chondrites is very low, even in the stardust samples from comet wild 2 [2]? Ca-, Al-rich inclusions are the first solid assemblages of the solar nebula, probably formed in a same region. How were they transported to different locations in the nebular disk, even found in comet wild 2 [3]? How the nebula evolved into the heterogeneous system, as indicated by variation in oxygen fugacity and abundance of water, organic matter and other volatile components among meteorites and also planets and asteroids? High precision isotope analysis of O, Cr and Ti reveal a clear dichotomy among available planetary materials, which can be referred to as carbonaceous and non-carbonaceous [4]. What caused the differences between the inner and outer solar system? And what role Jupiter played? In addition, how planetesimal accreted? Did their materials originate from distinct reservoirs?

Mission Concepts of Sample Return from Small Bodies: In order to address the key questions of the solar nebular processes, it is required to return samples from the most primitive asteroids and comets. Carbonaceous asteroids are usually preferred targets for sample return. However, some of them could have been suffered severe aqueous alteration, largely destroying presolar silicates and erasing most records of the nebular processes. Also important is to return samples from various types of small bodies accreted at different distances from the Sun. In our roadmap, three types of small bodies are chosen as the candidate targets of sample return, including enstatite chondrite-like asteroids for the most inner solar system, L- or C-type asteroids for the middle region, and D-type asteroids or comets represent the most outer solar system. It was reported that L-type asteroids may contain high abundance of CAI up to 30% [5], and there is no analogical samples of L-asteroids in the meteorite collection. Finally, in order to reveal possible heterogeneity of the targets, multi-site sampling capability is required.

Outlines of the First Sample Return Mission: To reveal the initial status and condensation of the inner solar region and possible relationship with the out solar region, E-type near Earth asteroids are selected as the candidate targets of sample return. The spacecraft is designed to sample three times at three sites. It will have three major play loads, including topographic cameras, visible and near-IR spectrometer (0.4-3 μm) integrated with thermal emission spectroscope (5-12μm), and electro-magnetic field detectors. The target asteroid will be first mapped to achieve the global DEM and compositional distribution. Based on the global exploration, three sampling sites will be selected.

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