In-Situ Mass Spectrometry for Interstellar Dust in Space Missions: A Novel Approach to Study the Physical and Chemical Properties of the Local Interstellar Cloud

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Remote-sensing high-resolution spectroscopic observations of interstellar absorption lines towards nearby stars provide us the opportunity of inferring the chemical elements in the solid phase of the Local Interstellar Cloud (LIC) from the depletion of the elements in the gas phase. In contrast, in-situ mass spectrometry for dust particles streaming into the inner Solar System from the LIC is a promising technique to directly measure the elemental abundances of dust in the LIC. Therefore, in-situ mass spectrometric measurements of the elements in the solid phase and remote-sensing spectroscopic observations of the elements in the gas phase are complementary to each other with regard to the determination of elemental abundances. We show that the chemical composition of interstellar dust measured in situ acts as a powerful tool to constrain the gas-phase abundances and ionization states of the elements undetectable by spectroscopic observations. The isotopic composition of iron in the LIC dust, particularly the magnitude of ^{60}Fe excess, is of great importance for estimating the age of the dust, while laboratory analyses of radioactive isotopes originating from the LIC and collected on the Earth could compensate for a low mass resolution of spectra if measured at Earth's orbit. The elemental abundance of sulfur in the solid phase is the key to determining the ionization fraction of hydrogen in the LIC, although a significant reduction in the baseline noise of in-situ mass spectrometers, compared to previous space missions, is a requisite for the detection of sulfur. Identification of the smallest LIC dust inside the heliosphere gives insights into not only the strength of interstellar magnetic fields, but also the thickness of the heliospheric layer. To probe the coagulation growth of dust in the interstellar medium, the dynamics of dust in the heliosphere could be better simulated with the chemical composition of LIC dust derived from in-situ mass spectrometric measurements. In the light of forthcoming space missions with a state-of-the-art time-of-flight mass spectrometer, we will demonstrate how in-situ mass spectrometry for interstellar dust in space missions is a novel approach to study the physical and chemical properties of the LIC.