TWO-DIMENSIONAL GAS CHROMATOGRAPHY ANALYSIS OF RYUGU SAMPLES. J. C. Aponte[1,2,3,*], J. P. Dworkin[1], D. P. Glavin[1], J. E. Elsila[1], H. Naraoka[4], Y. Takano[5], The Hayabusa2-initial-analysis SOM team, The Hayabusa2-initial-analysis core. [1]NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA, [2]Catholic University of America, Washington DC 20064, USA, [3]Center for Research and Exploration in Space Science and Technology, NASA/GSFC, Greenbelt, MD 20771, USA, [4]Kyushu University, Nishi-ku, Fukuoka, 819-0395, Japan, [5]Japan Agency for Marine-Earth Science and Technology (JAMSTEC); 2-15 Natsushima, Yokosuka, Kanagawa, 237-0061, Japan. *Email: jose.c.aponte@nasa.gov

Introduction: Solvent-soluble organic compounds found in carbonaceous chondrites provide us with a record of the chemical inventory of the early solar system and of the processes that occurred through parent body alteration including aqueous alteration from melted ices and thermal metamorphism from heat sources such as a radiation and impacts. These primitive organics contain the isotopic, enantiomeric, and molecular distributions indicative of the early solar system processes which formed them [1].

The parent bodies of such meteorites, primitive carbonaceous asteroids, contain these compounds without the terrestrial and biological processes which inevitably contaminate these meteorites. To avoid this and provide context for the materials under study, samples from the surface and sub-surface of the near-Earth Cb-Type asteroid (162173) Ryugu [2] were collected by JAXA's Hayabusa2 spacecraft [3,4]. On December 6th, 2020 the sample capsule containing these exceptional samples landed at the Woomera Test Range in Australia containing about 5 g of regolith, hydrated minerals, and carbonaceous materials from Ryugu. After curation at JAXA's Extraterrestrial Sample Curation Center, a portion of these samples were subjected to sequential solvent extraction at Kyushu University as part of JAXA's planned soluble organic material (SOM) analysis campaign [5]. A portion of each solvent extract was sent to NASA Goddard Space Flight Center (GSFC) where samples and procedural blanks were analyzed using two-dimensional gas chromatography with a LECO GC-HRT+ 4D system (High Resolution Time of Flight with GC×GC Mass Spectrometry system (GC×GC-HRMS) (Fig 1).

GC×GC-HRMS operates similarly to standard GC-MS, in that analytes are volatilized and separated on a capillary column by chemical properties depending on the nature of the column. However, a GC×GC-HRMS has a second GC column which addresses the poor chromatographic separation common in complex samples such as carbonaceous meteorites or Ryugu samples. The eluate from the first column is cryo-focused and then sent to a second GC column with different chemical properties. The eluate of this second column is then analyzed by an electron impact time-of-flight high resolution mass spectrometer to determine the molecular formula of the analyte and its fragments.

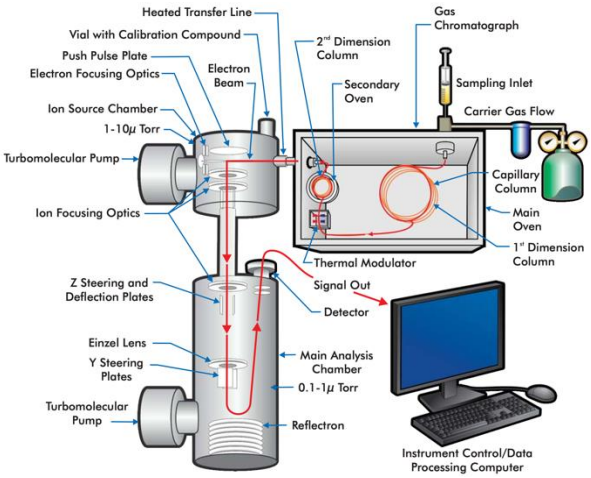

Fig. 1. Diagram of the GC×GC-HRMS used in this study. (Figure taken from LECO form No. 209-252).

GC×GC-HRMS has the advantage of making untargeted study of the soluble organic contents in these samples possible, supporting the first opportunity to evaluate the primordial organic chemical inventory of an asteroid and to look for evidence of the nature of the organic molecules delivered to the early Earth. Additionally, by comparison with previously studied meteorites we may be able to trace parent-daughter relationships between samples collected on the Earth and C-type asteroids.

The analysis of Ryugu's organics will aid in unraveling the complicated history and evolution of organics and their precursor molecules dating from the molecular cloud, the protosolar nebulae, to the planetesimal formation and parent body processing. In this investigation, we focus on the GC×GC-HRMS results from solvent extracts of Ryugu which show a variety of organic species. We will also discuss the untargeted analysis of solvent-soluble organics found in the surface and sub-surface samples of Ryugu using GC×GC-HRMS and comparisons with those found in carbonaceous chondrites [6].

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