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Abstract

For two years, the time-of-flight secondary ion mass spectrometer COSIMA (COmetary Secondary Ion Mass Analyzer), on board the Rosetta orbiter, performed *in situ* analyses of the dust particles ejected from the comet 67P/Churyumov-Gerasimenko (hereafter 67P) [6, 7]. Exploiting different analyses of organic analogs that have been analyzed via the COSIMA reference model, we are now able to estimate the H/C elemental ratio of the 67P cometary particles.

Introduction

The Rosetta mission was dedicated to the study of the comet 67P. Between September 2014 and June 2016, more than 35,000 particles and particle fragments were collected [9] and, among them, around 250 were analyzed by the COSIMA mass spectrometer in positive and negative secondary ion registration modes. Here we are interested in the chemical composition of ejected cometary particles originating from the nucleus. Cometary organic matter, including solid organic matter in the particles, was poorly characterized by *in situ* observations before the arrival of Rosetta at the vicinity of the 67P nucleus. Using mass spectra obtained by the COSIMA instrument, we have shown that this solid cometary organic matter was different from all the well characterized organic compounds analyzed during the calibration phase on ground (such as carboxylic acids, amino acid, nucleobases, hydrocarbons and PAHs) [5, 8]. On the other hand, similarities with Insoluble Organic Matter (IOM) extracted from carbonaceous chondrites are notable [5]. Thus, the 67P cometary particles contain a high molecular weight organic matter. Moreover, we have shown that the cometary particles are among the most carbon-rich objects in the Solar System, containing about 50% by mass of organic matter [4]. Through analyses of different complex carbonaceous samples (including sedimentary rocks and IOMs) with the ground reference model of COSIMA, we attempted to establish correlations between ionic ratios and H/C elemental ratios in order to estimate the H/C elemental ratios in the 67P cometary particles.

Method

Numerous carbonaceous samples, with H/C elemental ratios ranging from 0 to 2.1 [1, 2, 3, 10], have been recently analyzed with the reference model of COSIMA. They are used to construct calibration curves involving measured ionic ratios and H/C elemental ratio. The hydrogen of 67P particles is thought to be mainly contained in the organic phase since COSIMA mass spectra do not show signatures from hydrated minerals [4]. Thus, the estimated cometary H/C is related to the organic component. Several ionic ratios, such as C_2H^-/C_2^- and H^+/C^+, were tested in the search for calibration lines (e.g., Figure 1). Then, the H/C elemental ratio have been estimated for two sets of about 20 particles, based on the measured ionic ratios and calibration curves.

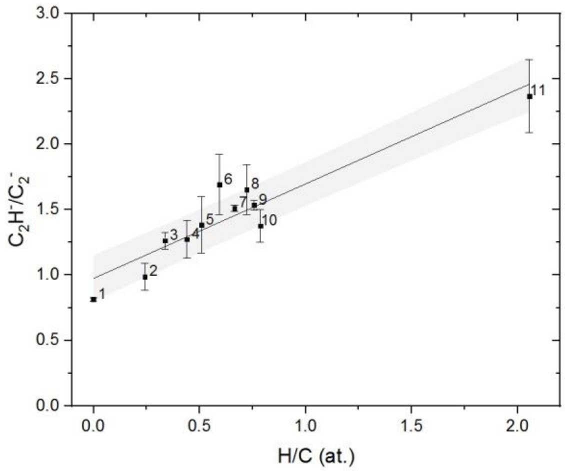

Figure 1: Example of H/C calibration curve, using the C_2H^-/C_2^- ionic ratio measured from negative ion mass spectra. The black squares are the different calibration samples: (1) Graphite, (2) IOM PCA, (3) IOM Tagish Lake original, (4) IOM Tagish Lake 11v, (5) IOM Tagish Lake 11i, (6) IOM Tagish Lake 11h, (7) IOM GRO 95566, (8) IOM Tagish Lake 5b, (9) IOM EET 92042, (10) IOM GRO 95577, (11) Hexatriacontane. The individual error bars are the uncertainties on the ionic ratio. The grey area represents the 1σ uncertainty.

Results and conclusions

The analyses of the carbonaceous samples show that the H/C elemental ratio correlates with several ionic ratios (especially C_2H^-/C_2^- and H^+/C^+). Using these calibration lines, H/C elemental ratio can be estimated for numerous cometary particles. The cometary H/C elemental ratio suggests values equal or higher than the one measured in the IOMs (the highest H/C in IOM being 0.8 [1]). Considering that the cometary hydrogen is mainly present in the organic phase and mostly linked to carbon [4], these results imply that the refractory macromolecular organic matter detected in 67P dust particles might be less unsaturated than the one in meteorites.

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References

[1] Alexander C. et al. (2007) Geochimica et Cosmochimica Acta 71, 4380–4403

[2] Alexander C. et al. (2010) Geochimica et Cosmochimica Acta 74, 4417–4437

[3] Alexander C. et al. (2014) Meteoritics & Planetary Science49, Nr 4, 503–525

[4] Bardyn A. et al. (2017) Mon. Not. Roy. Astron. Soc., 469, 712-722

[5] Fray N. et al. (2016) Nature, 538, 72-74

[6] Hilchenbach M. et al. (2016) The Astrophysical Journal Letters, 816, L32

[7] Kissel J. et al. (2007) Space Science Reviews, 128, 823–867

[8] Le Roy et al. (2015) Planetary and Space Science, 105, 1–25

[9] Merouane S. et al. (2017) Mon. Not. Roy. Astron. Soc., 469, 459-474

[10] Quirico E. et al. (2016) Icarus Volume 272, 32-47