Halogen-containing species at Comet 67P/Churyumov-Gerasimenko: Full mission results

Frederik Dhooghe\textsuperscript{1}, Johan De Keyser\textsuperscript{1}, Kathrin Altwegg\textsuperscript{2}, Nora Hänni\textsuperscript{2}, Martin Rubin\textsuperscript{2}, Jean-Jacques Berthelier\textsuperscript{3}, Gaël Cessateur\textsuperscript{1}, Michael Combi\textsuperscript{4}, Stephen Fuselier\textsuperscript{5,6}, Romain Maggiolo\textsuperscript{1}, and Peter Wurz\textsuperscript{2}

\textsuperscript{1}Royal Belgian Institute for Space Aeronomy, Brussels, Belgium (frederik.dhooghe@aeronomie.be)
\textsuperscript{2}Physikalisches Institut, University of Bern, Bern, Switzerland
\textsuperscript{3}LATMOS/IPSL, Université Versailles Saint-Quentin, France
\textsuperscript{4}Department of Climate and Space Sciences and Engineering, University of Michigan, Ann Arbor, Michigan, USA
\textsuperscript{5}Southwest Research Institute, San Antonio, Texas, USA
\textsuperscript{6}University of Texas at San Antonio, San Antonio, Texas, USA

Dhooghe et al. (2017) studied halogen-bearing compounds in the coma of 67P/C-G with the Double Focusing Mass Spectrometer (DFMS) of Rosetta's ROSINA instrument during a few time periods from first encounter up to perihelion (August 2014-August 2015). The main halogen-bearing compounds identified in the comet atmosphere were the hydrogen halides HF (hydrogen fluoride), HCl (hydrogen chloride) and HBr (hydrogen bromide). The halogen to oxygen ratios were found to vary between $\sim 10^{-4}$ (Cl/O and F/O) to $\sim 10^{-6}$ (Br/O), which shows these compounds have a very low abundance. In a follow-up article, De Keyser et al. (2017) observed an increase in the halogen-to-oxygen ratio as a function of distance, which suggests a distributed source for HF and HCl, probably through progressive release of these compounds from grains. Fayolle et al. 2017 and recent work by Altwegg et al. 2020 show that also CH\textsubscript{3}Cl and NH\textsubscript{4}Cl, respectively are present in the coma.

To further our knowledge on halogen containing species, we have applied recent improvements in DFMS data analysis techniques (De Keyser et al. 2019) to obtain a high quality time series for the complete mission duration. These data analysis techniques improve the retrieval of the abundances for overlapping mass peaks ($^{18}$OH$^+$ for F$^+$, H\textsubscript{2}^{18}O$^+$ for HF$^+$, H\textsubscript{34}S$^+$ for $^{35}$Cl$^+$, and H\textsubscript{2}^{34}S$^+$ for H$^{35}$Cl$^+$). The contribution of CS\textsubscript{2}\textsuperscript{++} to the signal of H$^{35}$Cl$^+$ has been determined from data for CS\textsubscript{2}\textsuperscript{+}.

Based on the full mission data, and focusing on chlorine, we determine the $^{37}$Cl/$^{35}$Cl isotopic ratio. An interesting finding is that the $^{35}$Cl$^+$/H$^{35}$Cl$^+$ and $^{37}$Cl$^+$/H$^{37}$Cl$^+$ ratios in the DFMS mass spectrometer do not match the NIST ones for the H$^{35}$Cl and H$^{37}$Cl parents. This indicates that at least one
additional chlorine source must be present. The variability of halogen-containing species as a function of time is discussed, as well as the possible role of distributed sources.


Fayolle et al. (2017): Protostellar and cometary detections of organohalogenes. Nature Astronomy 1, 703, doi.org/10.1038/s41550-017-0237-7