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Distributed sources for the hydrogen halides in the coma of comet 67P/Churyumov-Gerasimenko

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Abstract

Rosetta has detected the presence of the hydrogen halides HF, HCl, and HBr in the coma of comet 67P/Churyumov-Gerasimenko. Analysis of the abundances of HF and HCl as a function of cometocentric distance suggests that these hydrogen halides are released both from the nucleus surface and off dust grains in the inner coma. We present three lines of evidence. First, the abundances of HF and HCl relative to the overall neutral gas in the coma appear to increase with distance, out to ∼200 km, indicating that a net source must be present; since there is no hint at any possible parent species for HF and HCl with sufficient abundance, dust grains are the likely origin. Second, the amplitude of the daily modulation of the halide density due to the rotation and geometry of 67P's nucleus and the corresponding surface illumination is observed to progressively diminish with distance; this can be understood from the roughly omnidirectional outgassing from grains as well as from the range of grain speeds well below the neutral gas expansion speed, which both tend to smooth the coma density profiles. Third, strong halogen abundance changes detected locally in the coma cannot be easily explained from composition changes at the surface, while they can be understood from differences in local gas production from the grains near the spacecraft.

1. Introduction

Rosetta has provided the in situ detection of halogens in a cometary coma, that of 67P/Churyumov-Gerasimenko. Neutral gas mass spectra collected by the ROSINA/DFMS mass spectrometer on the European Space Agency's Rosetta spacecraft indicate that the main halogen-bearing compounds are HF, HCl and HBr. The bulk elemental abundances relative to oxygen are typical of those of the protosolar nebula. The observations point to an origin of the hydrogen halides in molecular cloud chemistry, with frozen hydrogen halides on dust grains, and a subsequent incorporation into comets as the cloud condensed and the solar system formed.

2. Evidence for distributed sources

A detailed analysis of the abundances of the hydrogen halides detected in the coma has been performed.

These abundances depend on the total gas production rate, the comet-Sun distance, the spacecraft-comet distance, the phase angle, and the latitude and longitude of the spacecraft relative to the nucleus. The effects of all these parameters have been disentangled and lead to three important findings.

A first result is that the halogen abundance relative to the total gas production tends to increase with distance within roughly 200 km from the nucleus. This points to the existence of an additional source of neutral hydrogen halides in the inner coma. Note that photo-dissociation and/or other loss processes can be neglected in this region. Since no other halogen-bearing species have been detected by DFMS in sufficient quantities, the plausible conclusion is that these hydrogen halides are progressively released from grains in the inner coma.

A second observation is that the daily abundance variations seen in the overall neutral gas production are also present for the hydrogen halides in measurements close to the nucleus, but they disappear at larger distances. This suggests that part of the hydrogen halides sublimates from the nucleus, but the major part is released from the grains which are distributed more evenly in the coma.

Finally, we occasionally observe strong local changes in composition, which are hard to explain in terms of inhomogeneities on the nucleus surface since DFMS at any instant observes material originating from all over the illuminated surface of the comet. An explanation in terms of a local source from dust jets, however, seems plausible.

3. Summary and Conclusions

A careful analysis of hydrogen halide abundance measurements by Rosetta/ROSINA provides several lines of evidence that suggest that a distributed source for the hydrogen halides exists in the inner coma.

Thermal desorption of the hydrogen halides apparently occurs at higher temperatures than the bulk of the neutral coma gas (especially H_2O, CO, CO_2). This is in line with the observed depletion of the halogen content in molecular clouds, where they are believed to be frozen out on the grains even when H_2O, CO, CO_2 are still present in the gas phase. The precise nature of the hydrogen halide reservoir on the grains is still unknown at present.

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