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# Investigating the extended $H_2O$ and $CO_2$ gas coma of comet 67P/Churyumov-Gerasimenko by Rosetta VIRTIS-H

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## Abstract

With the great success of the Rosetta rendezvous mission to the comet 67P/CG, it makes us possible to investigate this primitive object in detail. The Visible and Infrared Thermal Imaging Spectrometer (VIRTIS) onboard the Rosetta orbiter provides an excellent opportunity to in situ studying the infrared fluorescence emission from some volatile and organic chemical species such like $H_2O$, $CO_2$, $OCS$, and $CH_4$ (Bockelée-Morvan et al., 2016). From different instrument pointing and geometric conditions of the Rosetta spacecraft, we can resolve 3-dimensional chemical abundances of the $H_2O$ and $CO_2$ molecules. In this study, we present the column density measurements in the extended coma of comet 67P/CG.

## 1. Observation

To study the extended gas environment of the coma of comet 67P/CG, we reviewed all the VIRTIS-H observing data acquired when the comet was near the perihelion passage for minimum line-of-sight (LOS) distance greater than 100 km. We found that six of the VIRTIS-H datacubes have significantly $H_2O$ and/or $CO_2$ fluorescence emission which minimum LOS distance to the comet center between 171 and 444 km. The detail observing and geometric conditions are shown in Table 1. Two of these observations are pointing opposite to the comet ($T1$_00397814956 and $T1$_00399410937) which measurements can be referred to the local $H_2O$/$CO_2$ density around the Rosetta spacecraft. The solar elongation angle shows that the first two observations in Table 1 are taken around the day-night boundary of the comet with only $H_2O$ detection.

## 2. Methodology

The opacity effect is an important issue when measuring the gas fluorescence emission in the inner coma of a comet. Fortunately, at cometocentric distance exceeding 100 km, we can assume that $H_2O$ and $CO_2$ emission bands are optically thin. Under this condition, we have estimated the rotational temperature by fitting the observed data with a synthetic spectrum based on Crovisier (2009) which assume a Boltzmann distribution for the population of ro-vibrational energy level. The ortho-to-para ratio (OPR) of water was taken equal to 3. By integrating the total band intensity of best-fitted synthetic spectra in a wavelength range between 2.60 and 2.75 micron ($H_2O$), 4.225 and 4.30 micron ($CO_2$), the band intensities were then computeing into column densities using g-factors under the derived rotational temperature.

## 3. Results

We found that the column density of $CO_2$ is highly related to the LOS projection on the cometary surface. For the datacubes with positive $CO_2$ detection, the LOS are all above the southern hemisphere of the comet. This result is consistent with the previous finding (Fougere et al., 2016; Hoang et al., 2017; Lauter et al., 2018) that the southern hemisphere is the main $CO_2$ source region because it was directly illuminated by the Sun during the perihelion passage. In contrast, we can not detect $CO_2$ emission even when the minimum LOS distance is 171km under a 3.5 hours' integration in the non-illuminated northern hemisphere. For the $H_2O$ emission, the column density has no direct connection to the LOS projection. $T1$_00399410937 is the only observation without $H_2O$ detection which can be explained by the short integration time and relative large LOS distance.

Table 1: Observing and geometric conditions

| obsID | start time | duration | $R_h$ | elong.[a] | $D^b_{sc}$ | $D^c_{min}$ | sslat[d] |
|---|---|---|---|---|---|---|---|
| T1_00397317711 | 2015-08-04T13:55:17 | 3:30:21 | -1.25 | 102 | 240.6 | 170.7 | -4.31 |
| T1_00397814956 | 2015-08-10T08:02:38 | 2:58:01 | -1.24 | 87 | 316.2 | 316.2 | 30.28 |
| T1_00399410937 | 2015-08-28T19:15:21 | 1:46:42 | 1.26 | 54 | 418.4 | 411.9 | -54.75 |
| T1_00400693542 | 2015-09-12T15:39:09 | 2:41:46 | 1.30 | 19 | 323.6 | 209.8 | 49.07 |
| T1_00401827524 | 2015-09-25T18:38:48 | 4:54:42 | 1.35 | 43 | 700.9 | 345.6 | -45.17 |
| T1_00402322010 | 2015-10-01T12:00:15 | 3:54:42 | 1.38 | 65 | 1310.3 | 443.9 | -58.29 |

[a]Minimum solar elongation to the LOS

[b]Mean distance from comet center to the Rosetta orbiter [km]

[c]Minimum distance from comet center to the LOS [km]

[d]Sub-solar latitude

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