The ROSINA Neutral Gas Mass Spectrometer on Rosetta

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Introduction: The Rosetta Orbiter Spectrometer for Ion and Neutral Analysis (ROSINA) is an instrument of the orbiter payload onboard the ROSETTA spacecraft that was successfully launched 2 March 2004 by the European Space Agency. The ROSINA instrument package is designed to determine the elemental, isotopic, and molecular composition of the atmosphere of comet 67P/Churyumov-Gerasimenko.

ROSINA Characteristics: The ROSINA instrument package consists of two mass spectrometers and one pressure sensor. The mass spectrometers are the Double Focussing Mass Spectrometer (DFMS) and the Reflectron Time-Of-Flight mass spectrometer (RTOF) that are both designed to analyze cometary neutral gases and cometary ions. The third sensor, the COmetary Pressure Sensor (COPS), consists of a pressure gauge assembly. These three sensors will measure the neutral gas and the ion composition in the cometary environment as a function of the heliocentric distance to the comet [1, 2]. The Data Processing Unit (DPU) controls all three sensors and is fully redundant. The characteristic features of the three sensors are described in more detail below.

DFMS. The DFMS sensor is a very compact state of the art high-resolution double-focussing mass spectrometer [3] realized in the Nier-Johnson configuration [4]. The sensor weights 16 kg and the power consumption averages 22 W. The DFMS is a high-resolution mass spectrometer with a large dynamic range and good sensitivity. It covers a mass range of 12–140 amu/e and has a mass resolution of $m/\Delta m > 3000$ at the 1% peak height which corresponds to $m/\Delta m > 7000$ at the 50% level. This allows separation of isobaric interferences, for example ^{13}C and ^{12}CH. Several examples of resolved of mass doublets and triplets recorded in space are given in Figure 1. With an integration time of typically one second the recording of a whole mass spectrum measured with the Channel Electron Multiplier (CEM) detector from 12 to 140 amu/e takes approximately two hours. The mass resolution of the DFMS is high enough to measure scientifically important isotope ratios. For example, the measurement of the two nitrogen isotopes, $^{14}N^+$ and $^{15}N^+$ are of great importance to determine and explain the anomalous nitrogen isotopic ratios in comets.

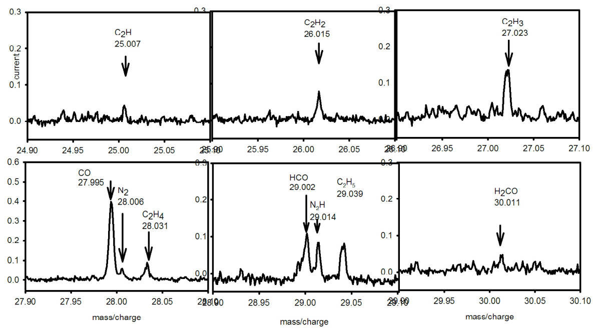

Figure 1: High-resolution mass spectra at several mass lines recorded with the DFMS sensor during flight on 6 July 2005. For each mass line a recoding time of 20 s was used.

RTOF. The Reflectron Time-of-Flight (RTOF) mass spectrometer is characterized by a large mass range from 1 up to > 300 amu/e to identify organic material, e.g. polyaromatic hydrocarbons [5]. The RTOF sensor weights 15 kg and consumes up to 30 W depending on mode [6, 7]. The high sensitivity of the RTOF sensor, between 10^{-4} to 10^{-2} A/mbar depending on mode, is essential with respect to the pressure range that is expected when Churyumov-Gerasimenko is at 3 AU where measurements are activated. The expected water production rates at perihelion, during peak activity, and at 3 AU at comet Churyumov-Gerasimenko are given in Table 1. Figure 2 shows a residual gas mass spectrum recorded with RTOF during 60 s demonstrating the high sensitivity of the sensor.

Table 1: Expected water production rate and the corresponding pressure at 2 km from the nucleus for comet Churyumov-Gerasimenko [8].

Heliocentric distance	$Q(H_2O)$ $[s^{-1}]$	H_2O density $[cm^{-3}]$ @ 2 km	Pressure [mbar]
Perihelion (1.3 AU)	4.1×10^{27}	2.0×10^{11}	6.0×10^{-6}
Peak activity	1.0×10^{28}	8.0×10^{11}	2.5×10^{-5}
3 AU	1.0×10^{23}	1.0×10^{7}	1.0×10^{-10}

An advantage of the RTOF sensor is that a full mass spectrum of the entire mass range (1 to > 300 amu/e) is recorded within 100 μs with its range limited only by the size of the signal accumulation me-

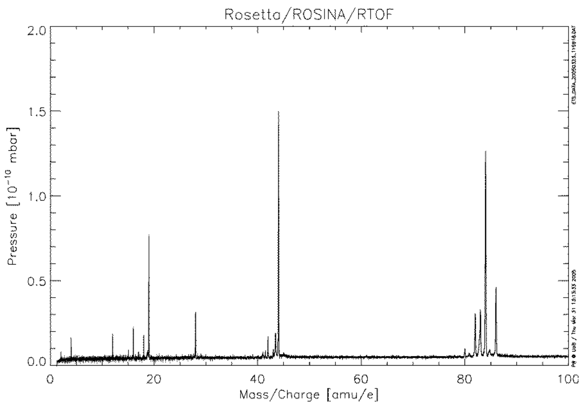

Figure 2: RTOF gas mass spectrum recorded on 23 March 2005 in space using the gas calibration unit (GCU) with a recording time of 200 s. Mass peaks around m/q = *84 are due to Kr, at* m/q = *44 amu are due to CO_2, and at* m/q = *4 amu are due to He from the GCU gas mixture. In addition, there are doubly-charged Kr ions around* m/q = *42 amu, and the fragments CO, O, and C from CO_2, The remaining peaks are residual gas in the vicinity of the spacecraft at a total pressure of $5 \cdot 10^{-11}$ mbar measured with COPS. The GCU gas introduced into the storage ion source represents a pressure of about $1.1 \cdot 10^{-9}$ mbar.*

mory. The mass resolution in the triple reflection mode is m/Δm > 4500 at the 50% peak height [6, 7]. The DFMS and RTOF sensors complement one another

COPS. The COPS weights 1.7 kg and consumes 7 W. It consists of two ionization gauges to determine the gas dynamics of the comet. One gauge is a nude hot filament extractor type Bayard Alpert ionisation gauge [9]. It measures the total particle density with a nitrogen sensitivity of about 20 mbar^{-1} at 100 µA. The other gauge, a closed ionisation gauge, with its opening facing towards the comet, measures the molecular flow from the comet. Combining the results from both gauges and the known spacecraft orientation relative to the nucleus of the comet, the velocity and the density of the cometary gas can be calculated. In addition, this sensor serves as a safety instrument for Rosetta in case of pressure increases.

Anticipated Analyses at Mars Flyby: On 25 February 2007 Rosetta spacecraft will perform a flyby at Mars with a closest approach (CA) of about 264 km. Coming from interplanetary space to CA the spacecraft trajectory allows to cover the full extent of the exosphere (the exobase is at 220 km). Of course, it is planned that all three ROSINA sensors will be operating and exospheric profiles for at least the elements H, C, and O will be recorded with high temporal resolution.

Anticipated Analyses at the Comet: During the increasing activity of the comet from aphelion to perihelion more and more cometary material like dust particles as well as ice will evaporate. The evaporation products can easily be measured by the

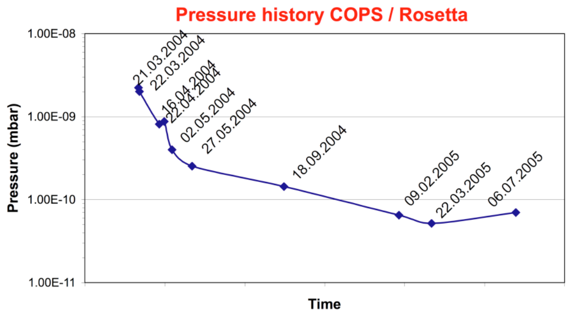

Figure 3: Pressure history of the Rosetta spacecraft measured with the COPS sensor of the ROSINA instrument on Rosetta.

ROSINA mass spectrometers. Together with other instruments onboard Rosetta that are specialized on dust measurements it will be possible to determine the dust composition due to the capability of ROSINA to measure in an extended mass range (> 300 amu/e) with a high sensitivity and a large dynamic range. Therefore, the two ROSINA mass spectrometers support the dust analyses performed by the dust specialized instruments.

Conclusions: The ROSINA instrument package was designed to measure relevant elemental, isotopic, and molecular abundances from the onset of activity through perihelion. It will easily cope with the activity of Churyumov-Gerasimenko at 4 AU as well as at perihelion. Finally, it will analyze the composition of the volatile material over a large mass range with a large dynamic range, and it will significantly contribute to our understanding of the dynamics of this comet.

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