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Gas production of comet 67P/Churyumov-Gerasimenko reconstructed from DFMS/COPS data

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Abstract

We reconstruct the temporal evolution of surface emissions for the four major gas species H_2O, CO_2, CO, and O_2 emitted during the 2015 apparition of comet 67P/Churyumov-Gerasimenko (67P/C-G). Measurements from the Double Focusing Mass Spectrometer (DFMS) of the Rosetta Orbiter Spectrometer for Ion and Neutral Analysis (ROSINA) and the COmet Pressure Sensor (COPS) are used to determine the gas sources on the surface with an inverse gas model for the entire coma. For all species, peak production rates and integrated production rates per orbit are evaluated separately for the northern and the southern hemisphere. Complemented with the total mass production, this allows us to estimate the dust-to-gas ratio of the emitted material.

1. Introduction

The ROSINA instrument, a part of the Rosetta mission, has studied the gas environment of the comet 67P/C-G with mass spectrometers and pressure sensors. With an inverse gas model we analyze the species resolved evolution of the coma of 67P/C-G for ±350 days around perihelion, August 13th 2015, which corresponds to heliocentric distances in the range $3.5 - 1.24$ au.

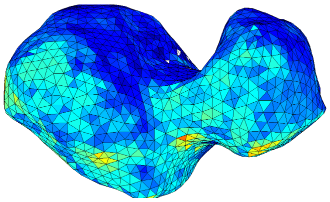

Figure 1: Surface shape approximation of comet 67P/C-G with triangular elements. The colors describe H_2O emission rates around perihelion, see [3].

2. Analysis of DFMS/COPS

For the global reconstruction of the three-dimensional gas atmosphere around comet 67P/C-G we run a numerically efficient gas model based on equations neglecting collisions in the tenuous atmosphere, see [2]. Each of the 3996 triangular elements approximating the surface shape, see Fig 1, possesses an emitting gas source with normal and lateral velocity components, see [5]. Applying an inverse model approach, the emission rates are determined as the best fit to the actually measured DFMS/COPS data at the spacecraft position.

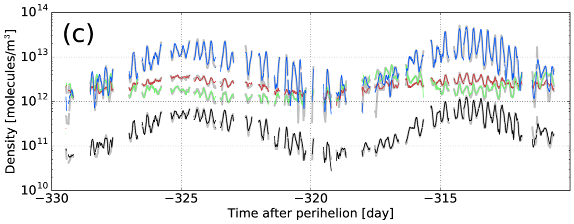

Figure 2: Modeled gas densities at the spacecraft position, 330 days to 310 days before perihelion. H_2O – blue, CO_2 – green, CO – red, and O_2 – black. DFMS/COPS data – gray lines.

Density measurements are available for the four major gas species H_2O, CO_2, CO, and O_2 from DFMS/COPS at the spacecraft location. The mission time is divided into subintervals with an average length of 14 Earth days. Each subinterval is chosen such that the spacecraft trajectory provides a good coverage of the comet surface. A typical, species-resolved density reconstruction between 330 days and 310 days before perihelion is shown in Fig. 2. A detailed analysis of gas source localization is given in [3].

3. Gas production

The integration of spatially and temporally resolved emission rates leads to integrated production rates for each of the gas species, see Fig. 3.

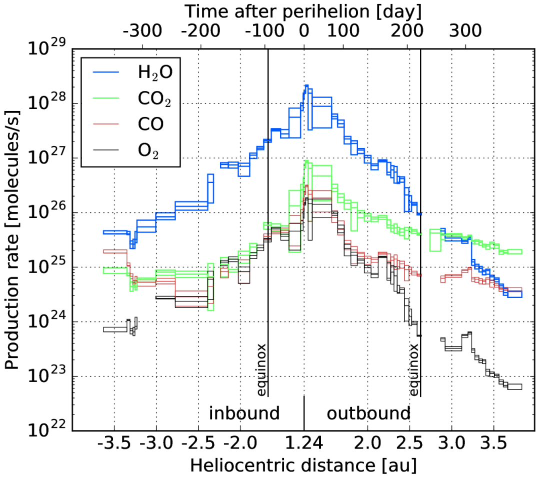

Figure 3: Gas production rates over time and heliocentric distance, The boxes denote error estimates due to varying spacecraft surface coverage.

H_2O production dominates the gas production up to the outbound equinox. A crossover from a water dominated to a carbon dioxide dominated coma happens at 2.75 au. The peak production is reached three weeks after perihelion and is dominated by H_2O. CO_2 adds only one tenth, the CO and O_2 contributions are below 5%. With respect to H_2O, our results are lower than the gas productions in [1], but higher than the analysis of [4] and [6].

The orbital losses allow us to constrain the dust-to-gas ratio of the emitted material from 67P/C-G. With the total gas loss including contributions from the four gas species investigated here and further 5% volatiles, we obtain a dust-to-gas ratio of below than 1.5.

Exponents appearing in power law fits ($\sim r_h^\alpha$ with the heliocentric distance r_h) of the production rates are characteristic for cometary activity. We provide exponents α for all species ranging from -7 to -4.5.

We analyze the gas production separated to the regional origin, from the northern and southern comet hemispheres. Caused by the stronger illumination of the southern latitudes during perihelion (summer solstice is 23 days after perihelion), all species are released in higher quantities from the southern hemisphere. For CO_2 we observe southwards shifted production rates for almost the whole mission time.

4. Summary and Conclusions

Based on the inverse gas model in [2] and DFMS/COPS measurements in the coma, gas emissions rates are reconstructed for the major gas species H_2O, CO_2, CO, and O_2 spatially resolved on the surface of comet 67P/C-G and temporally resolved during the mission time, see [3]. Derived from that, we present the temporal evolution of cometary gas production rates, the peak production and the total production over one orbit. We indicate the dust-to-gas ratio for the emitted material. The power laws (functions of heliocentric distance) for the gas production is analyzed and different gas activities from northern and southern hemispheres can be reported.

Acknowledgements

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References

[1] Hansen, K.C., et al.: Evolution of water production of 67P/Churyumov-Gerasimenko: An empirical model and a multi-instrument study, MNRAS, 15, S491, 2016.

[2] Kramer, T., Läuter, M., Rubin, M., and Altwegg, K.: Seasonal changes of the volatile density in the coma and on the surface of comet 67P/Churyumov-Gerasimenko, MNRAS, 469, S20–S28, 2017.

[3] Läuter, M., Kramer, T., Rubin, M., and Altwegg, K.: Surface localization of gas sources on comet 67P/Churyumov-Gerasimenko based on DFMS/COPS data, arXiv:1804.06696, 2018.

[4] Marshall, D.W., et al.: Spatially resolved evolution of the local H2O production rates of comet 67P/Churyumov-Gerasimenko from the MIRO instrument on Rosetta, A&A, 603, A87, 2017.

[5] Narasimha, R.: Collisionless expansion of gases into vacuum, Journal of Fluid Mechanics, 12, 294, 1962.

[6] Shinnaka, Y., et al., Imaging observations of the hydrogen coma of comet 67P/Churyumnov–Gerasimenko in 2015 September by the Procyon/Laica, The Astronomical Journal, 153, 76, 2017.