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# On causes of deviations from free-radial outflow in the inner dust coma of comet 67P/Churyumov-Gerasimenko using OSIRIS data

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## 1 Introduction

In this work, we study the light scattered by dust particles, which provides a means of studying processes in the inner coma of comet 67P/Churyumov-Gerasimenko (hereafter 67P). The scattered light was observed by the Optical, Spectroscopic, and Infrared Remote Imaging System (OSIRIS) [1] on board of ESA's Rosetta. Dust emitted from the surface is accelerated by gas drag [2] and follows, albeit in a complex way, the flow of gas from the nucleus. There has been an increasing effort to model the flow of gas and dust in 3D and these kinds of models are now becoming increasingly common ([3]; [4]).

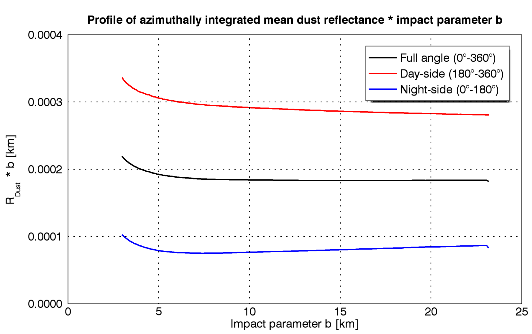


Figure 1: $R_{Dust} \cdot b$ for the full, day-, and night-side integration as a function of the impact parameter, $b$

In the point source, force-free radial outflow approximation, the product of the radiance from the dust $I_{Dust}$ and the impact parameter, $b$, is a constant (often referred to as a "1/r law"). However, deviations from this behaviour can arise from a) non-point source geometry [5], b) particle acceleration effects, c) optical depth effects, d) particle fragmentation (into either optically active or inactive daughters), e) sublimation of particles (reducing the effective scattering area), f) condensation effects (increasing the scattering area), and g) gravitationally-bound particles. Distinguishing between these phenomena is extremely challenging. The most comprehensive way to study the outflow properties of the dust is to integrate azimuthally the dust brightness, $R_{Dust} = \int_0^{2\pi} I_{Dust} d\phi$, at different impact parameters. [6] used this approach in which conservation of radiance (as a proxy for dust column density) on concentric surfaces is used to assess whether specific processes from the list above are dominant. They found $R_{Dust} \cdot b$ increasing with $b$ out to 50 km from the nucleus of Halley's coma.

## 2 Analysis of OSIRIS data

As we are interested in the behaviour of $R_{Dust} \cdot b$ we have filtered the full OSIRIS database to study only images which (1) make use of the full detector and thus are comprised of 2048x2048 pixels for the highest possible resolution, and (2) cover a field of view between 7 km and 50 km from the centre of the comet to each edge of the image. Of the $\sim 70'000$ images $\sim 5'500$ satisfied these criteria and have thus been studied. For images with phase angles of close to $90°$, we have also performed partial integrations for the projected day and night side of the comet. Fig. 1 shows as an example the result of this analysis for one image. At about an impact parameter of 6 km the curve becomes flat indicating the point at which the dust flow becomes radial, force-free and with no further process influencing the dust scattering cross-section. The day side shows a slightly decreasing slope matched by a rising slope on the night side which we interpret as the effects of non-radial dust transport. The decrease with $b$ to a constant value close to the nucleus is opposite to that seen at Halley and suggests that different processes are dominant at 67P.

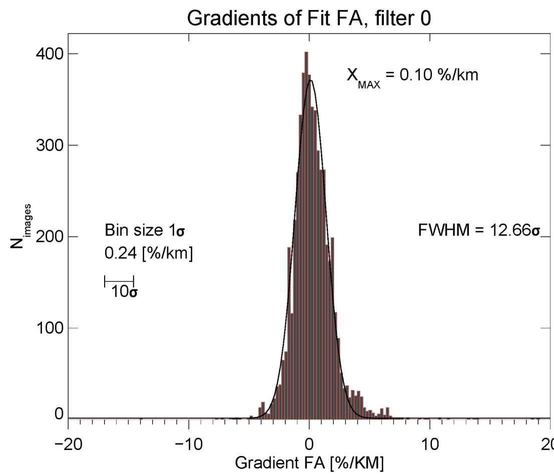


Figure 2: Histogram of the slopes for the full azimuthal integrated $R_{Dust} \cdot b$ and Gaussian fit.

For all considered images we have calculated the slope of $R_{Dust} \cdot b$ at maximum $b$ as well as the point at which the curve becomes flat. We have found that $R_{Dust} \cdot b$ converges to a constant value - representing the beginning of the free radial outflow regime - between 6 and 20 km. This is illustrated in Fig. 2 which shows the distribution function of the slope of $R_{Dust} \cdot b$ once a constant slope is reached. It is normally distributed about zero indicating that $R_{Dust} \cdot b$ is a constant beyond a measurable, definable, distance. The statistical result gives a gradient of $0.10\%$ change in $R_{Dust} \cdot b$ per kilometre with the error in the gradient determined being $0.24\%/\text{km}$ $(1\sigma)$. Deviations of $> 3\sigma$ from the mean are being investigated.

# 3 Dust dynamics simulations

To fully understand the deviations from free radial outflow we have performed first simulations (Fig. 3) using the model of [4] for a spherical nuclei and the shape of comet 67P varying the gas production, emission distribution, and dust size. Deviations from $R_{Dust} \cdot b$ = constant are clearly apparent for non-point source geometries in the absence of any fragmentation, condensation, or optical depth effects. The trends in the model are similar to those seen in the data. We have also assessed analytically and through numerical simulation, the effects of gravitational-bound particles on $R_{Dust} \cdot b$ which will allow us to place constraints on the total scattered light from bound particles. Further analyses will help interpret the results gained in the analysis of the OSIRIS data and constrain dust properties.

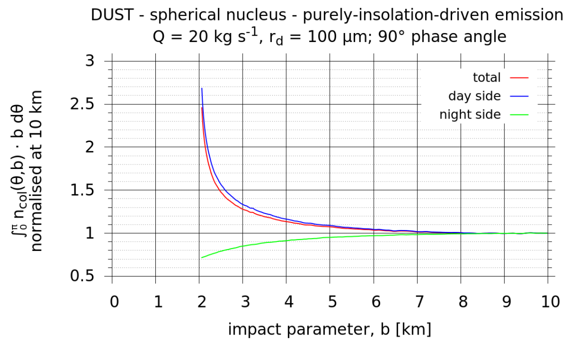


Figure 3: Modelled $n_{col} \cdot b$ ($\sim R_{Dust} \cdot b$) as a function $b$ for dust particles with a radius of 100 $\mu$m


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