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# Dust Particle Tracking at Comet 67P/Churyumov–Gerasimenko

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## Abstract

We present first results from developing a particle tracking algorithm to measure the trajectories of individual large boulders (dm- to m-sized) near comet 67P/Churyumov-Gerasimenko. For this process images of the Rosetta/OSIRIS cameras were used. Preliminary tests show a good agreement of the automatic detection with manual track identification results. We expect that the data obtained using this code will help to better understand fundamental processes leading to the ejection of large boulders from the cometary surface.

## 1. Introduction

Between July 2014 and September 2016, the Rosetta spacecraft investigated comet 67P/Churyumov-Gerasimenko from close proximity. During this time period, the comet was undergoing its most active phase, orbiting the Sun near perihelion. In the last stage of the mission, Rosetta's Optical, Spectroscopic, and Infrared Remote Imaging System (OSIRIS) took several image sequences of active regions on the comet's surface. The images show boulders and smaller particles being ejected from confined locations on the surface. [1] have analyzed one of the image sequences and demonstrated it is possible to track many of these objects by hand providing information about their dynamics and potential places of origin (see Fig. 1).

This work is the first stage of a three-year PhD project and aims at automating the tracking procedure by utilizing a computer algorithm currently in development. Early results can be seen in Figure 2. Later stages will focus on the application of the tracking algorithm to a larger set of image sequences and ultimately on the interpretation of the data regarding the debris' dynamics and places of origins.

## 2. Methods

The image sequences consist of image (from here on called frames) pairs taken at different time intervals. For the first ~13 minutes, the time interval of a frame pair was around 6 s, while the duration between consecutive pairs was around 40 s. In the subsequent two hours, frame pairs were taken every 10 minutes at an interval of roughly 12 s.

Even though the overall time resolution of an image sequence is quite small, the fact that the frames were taken in pairs only seconds apart allows us to come up with reasonable constraints and rules for the tracking algorithm to identify a track. This is possible, because the apparent particle velocities are relatively slow, i.e. usually no more than a few pixels per time interval.

The algorithm is divided into two parts. In a first step, the SExtractor software [2] is used identify point sources in each frame of a stack. In the second step, each point source in the first frame of a pair is treated as a potential starting point of a track. In the second frame of the pair, the point source that is closest to the starting point is assumed to be second detection of the track. From this, the initial velocity and direction of the candidate track can be determined. This information is used to estimate the position of the third detection in either the immediately following, or subsequent frame(s). If a matching third detection can be found, a second order polynomial is used to estimate the positions of the next detections in the remaining frames.

## 3. Proof of Concept

An early version of this algorithm has already been shown to work. Figures 1 and 2 show the (color-inverted) stacked first 20 frames of the same image sequence overlaid with the particle trajectories tracked by hand [1] and by the algorithm, respectively.

It is interesting to note that, while there are still

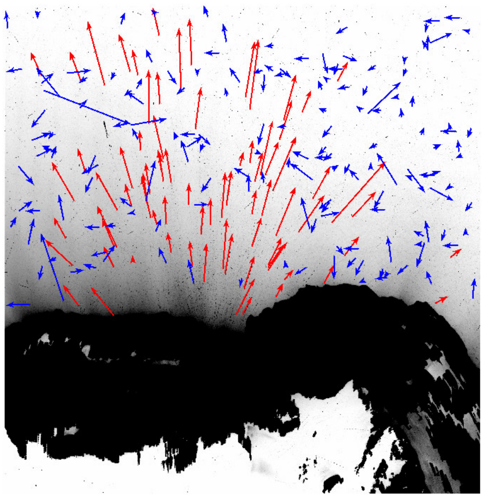

Figure 1: Cometary dust particles tracked by hand, similar to Fig. 5 in [1]. The blue arrows indicate randomly oriented tracks, while the red tracks seem to originate from a specific surface region on the comet.

many tracks in Figure 2 that can be easily identified by eye, but have not been detected by the algorithm, there are also a few particularly longer tracks that have been identified by the algorithm, but would have been hard to detect by eye. The inspection of individual tracks confirmed that only a small number of the identified tracks are false positives.

## 4. Outlook

It is the current goal for the algorithm to be able to identify as many as 90% of the tracks that can be identified by eye, while at the same time achieving a rate of less than 5% false positives.

This data can then be used to estimate the particles potential areas of origin, as well as their fall back ratio. The meter-sized boulders likely carry a significant fraction of the mass emitted by the comet to interplanetary space. This work might therefore provide important information needed to understand the processes responsible for lifting and accelerating such objects. One aim in particular is to investigate whether the motion of the boulders is influenced by recoil forces from asymmetric outgassing.

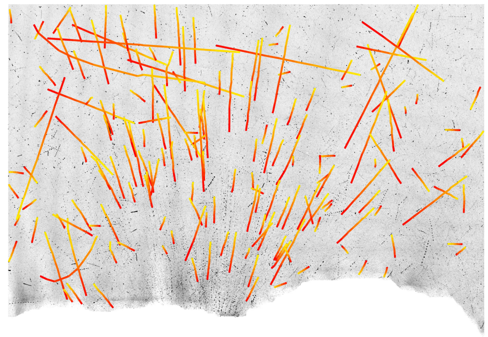

Figure 2: Preliminary results of the tracking algorithm. The color gradients of the tracks indicate the particles' direction of travel from red to yellow.

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