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How to use Microbial Motility as Biosignature and Separate Cells from Martian Regolith Analogs

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A major indicator for the presence of microbial life is motility, or the ability to move independently using metabolic energy. Motility can be observed and quantified by analyzing the trajectories of individual cells in microscopic videos and by comparing them with the movement of abiotic particles due to Brownian motion or drifts.

Using microscopy for detecting possible extraterrestrial organisms on Mars provides an efficient technique. However, there are major challenges that need to be overcome, such as a) separating potential cells from the regolith particles, b) stimulating potential cells to move, and c) automated in-situ analysis of microscopic images, which is essential for rapid and reliable identification of living cells. Here we will present our latest findings on all three aspects of this issue and derive recommendations for methodologies and instruments for a Mars mission.

Separating the potential microorganisms from the Martian regolith is a key challenge for detecting microbial life on Mars. Certain minerals or other compounds contained in the regolith may interfere with the detection or identification of living cells. Therefore, it is important to develop efficient and reliable separation methods that can extract microbial cells from the regolith without damaging them or compromising their viability. We have tested various separation methods using Martian analog regolith samples. These methods include physical methods, such as filtration, centrifugation, and sonication. We have evaluated their performance in terms of concentration, and viability of the extracted cells. We analyzed the motility with our novel tracking approach and investigated the implications of different separation steps on their motility behavior. Additionally, we examined stimuli (chemotaxis, temperature variation) that can be used to enhance the motility of specific bacteria. The goal is to find an agnostic substance, which works for many bacterial species and does not harm individual organisms. The tracking of small and simple cells like prokaryotes is an engineering challenge, because the objects to be tracked are close to the resolution limit of the microscope. We apply new tracking and identification methods that are based on a combination of image processing techniques, such as motion history images, region growing, background subtraction, adaptive thresholding, blob detection, particle filtering, and machine learning. These methods can handle large datasets of highly motile microorganisms with low signal-to-noise ratios, such as those obtained from natural environments or Martian analog samples.

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