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Evidence for a Surface Evolution Trend in Jupiter-Family Comets

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Abstract

We studied the rotation-rate changes and surface properties of comets 14P/Wolf, 143P/Kowal-Mrkos, and 162P/Siding Spring. We derived upper limits for the spin changes which occurred during their latest perihelion passages, and confirmed that large comet nuclei experience small rotation rate changes. This finding adds to a growing list of evidence suggesting that large comets are expected to survive more perihelion passages than smaller ones. We added 143P to the small group of Jupiter-family comets (JFCs) for which both the albedo and the phase-function slope have been measured. These comets indicate a possible correlation between the albedo and the phase-function slope [1]. In the light of recent findings from the Rosetta mission, we propose a hypothesis which interprets this trend as a result of the sublimation-driven erosion of JFC nuclei.

1. Introduction

Ground photometric observations of bare Jupiter-family comet nuclei can be used to study their rotations and surface characteristics. We have developed a method for absolute photometric calibration using the Pan-STARRS catalogue. This has allowed us to derive precise lightcurves and phase functions of comets using sparsely-sampled observations from various ground-based telescopes. Combining our observations with quasi-simultaneous thermal infrared observations from the SEPPCoN program [2] enables us to derive the albedos of the comet nuclei.

2. Enhanced survivability of large JFC nuclei

We collected photometric data for 3 comets. The data enabled us to derive the current rotation periods and to compare them with the known rotation rates of the comets from previous orbits. None of the three comets had detectable period changes, and we set conservative upper limits of 4.2 (14P), 6.6 (143P) and 25 (162P) minutes per orbit.

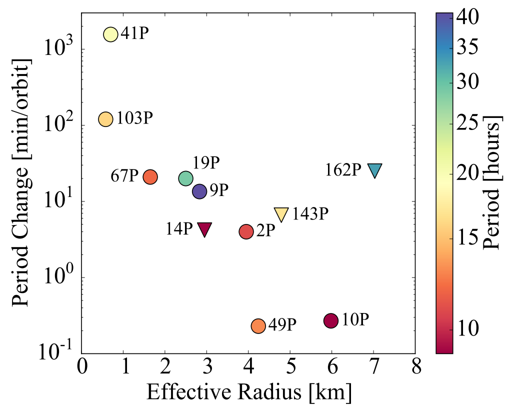

Figure 1: Properties of the JFC nuclei with measured rotation changes. The circles correspond to comets from the literature. The triangles indicate the upper limits of the spin changes measured for the comets from this work. The symbol colours correspond to the rotation rates of the comets. The largest period changes were measured for the smallest comets, 41P and 103P, while the smallest period changes were detected for the biggest nuclei.

We compared the upper limits from this study to all previously measured period changes of JFCs (Fig. 1). It is evident that, in agreement with theoretical predictions [3], the smallest comets experience the largest period changes, while the large nuclei change their periods the least. Large comets are therefore less likely to experience significant spin-up over their lifetimes. This conclusion agrees with the observation from [1] that no large comets lie close to the rotational-instability limit. The small period changes of large

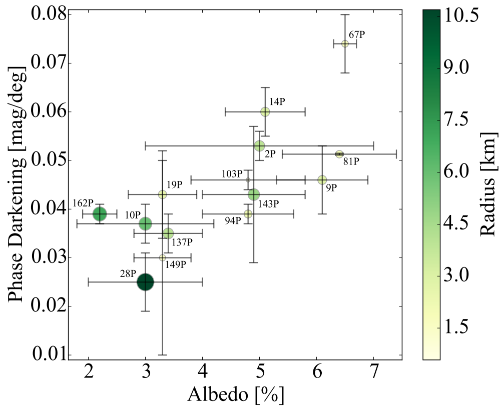

Figure 2: Linear phase-function slope β versus geometric albedo in R-band for JFCs. The colours and the sizes of the points correspond to the effective radii of the nuclei. The distribution of the points on the plot suggests a trend for increasing albedos wih increasing β. The largest and least active nuclei are at the lower left corner of the plot, with small albedos and β values.

comet nuclei can be added to the factors which contribute to the excess of large objects in the cumulative size distributions of JFCs [2] and asteroids on cometary orbits [4, 5].

3. Surface evolution of JFC nuclei

In [1] we identified a possible correlation between the phase-function slope and the albedos of JFC nuclei. Interestingly, the largest and least active comets are observed to have low albedos and shallow phase functions. In this work we added comet 143P to this sample and attempted to understand the physical parameters behind the correlation (Fig. 2). Based on the conclusions from recent detailed studies of the surfaces of JFCs visited by spacecraft [6, 7], we hypothesise that the albedo-phase function correlation corresponds to the evolutionary path of comet surfaces. According to this scenario, dynamically young JFCs have relatively high albedos and steeper phase functions. As their sublimation-driven erosion progresses, their surfaces become smoother and their phase-function slopes decrease. As the the dust layers gradually cover larger portions of the surfaces, the comets transition to dormancy, their surfaces lose the remaining volatiles, and therefore their albedos decrease even further.

4. Conclusions

We found evidence that the sublimation-driven evolution of the surfaces of JFCs might be observable through a correlation between their phase-function slopes and albedos. This hypothesis needs to be validated with further observations. If confirmed, it provides an exciting prospect to characterise the surfaces of an extended number of comets with telescope observations. The details of this work can be found in [8].

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