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Small perihelion effects on near-Earth objects

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Abstract

Many comets and asteroids end their lifetimes with small perihelion distances, or low-q, through dynamical interactions with Jupiter [1, 6]. While low-q objects are a common end state for small bodies, there are fewer such asteroids observed than are predicted by dynamical models [7, 13]. The lack of observed low-q asteroids is thought to be due to destruction by thermal processes. Asteroids of similar size with lower albedos are hypothesized to disrupt further from the Sun [7], meaning such objects have different physical properties that make them more vulnerable to thermal disruption.

The thermal processes that occur near the Sun can potentially alter the surface properties of a low-q object throughout its lifetime, possibly affecting the object's survivability. A number of mechanisms for such processes have been suggested. When objects come close to the Sun, torques such as asymmetric reradiation (e.g., YORP) or from outgassing can become very strong, potentially leading to rapid spin-up [12]. If the rotation period approaches critical values, the object can lose material and change shape as the material moves toward the rotational equator to escape [9]. Near-Sun objects can experience thermal fracturing due to differing thermal expansion throughout the body between either a temperature gradient or component materials [9]. If the asteroid contains hydrated minerals, heating near the Sun can cause the loss of bound water from those materials (desiccation) [8, 4]. We may already be seeing evidence for these mechanisms in low-q comets 322P/SOHO 1 [11] and 96P/Machholz 1 [5], each of whom rotates faster than the critical spin limit for strengthless bodies of typical comet density and exhibit unusual colors for comet nuclei.

Observations of more low-q objects are needed to assess whether such properties are widespread and extant in both the comet and asteroid populations. Many of these asteroids are faint and therefore, difficult to observe. In these cases, observations can be most easily made using optical colors, which can be obtained for fainter objects than spectra or albedo. Color observations could reveal dessication of hydrated materials, which could alter the spectral reflectance properties of an object [4]. For objects bright enough to allow the measurement of lightcurves, rotation period and axial ratio serve as additional characteristics to use for finding trends in low-q objects. Further observations may also yield insights into the nature of some near-Sun objects seen by solar observatories whose faintness and large orbital uncertainties prevent traditional observations. Such objects are classified as "comets" but are unrelated to any known objects and may simply be active when at extremely small heliocentric distance due to thermal processes [2].

There are 39 known asteroids that reach perihelion at $q < 0.15$ au, only seven of which have been included in previous studies of low-q asteroids [3, 10]. Since 2017, we have undertaken a campaign to measure optical colors of these objects primarily using Lowell Observatory's 4.3-m Discovery Channel Telescope and the 4.1-m SOAR telescope, supplemented by data from INT, NTT, ZTF, and Lowell Observatory's 42-in and 31-in telescopes. To date, we have obtained optical colors for 18 low-q asteroids. Seven more objects were predicted to be within our fields of view and above our detection limit but were not recovered, most likely due to the very large uncertainty in their orbits. We have also acquired lightcurves for two objects to be added to the lightcurves of six previously published low-q asteroids. Based on Tisserand parameters, the full sample of low-q objects is roughly split between cometary and asteroidal orbits, allowing us to investigate the differences between these populations. Additional observations are planned for the 2019A and 2019B semesters, and we will report on our progress.

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