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Color Uniformity of Comets in the Sloan Digital Sky Survey

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Abstract

We present the ensemble properties of 31 comets (27 resolved and 4 unresolved) observed by the Sloan Digital Sky Survey (SDSS). This sample of comets represents about 1 comet per 10 million SDSS photometric objects. Five-band (u, g, r, i, z) photometry is used to determine the comets' colors, sizes, surface brightness profiles, and rates of dust production (A$f\rho$). The resolved comets show an extremely narrow distribution of colors (0.57 ± 0.05 in $g - r$ for example), which are statistically indistinguishable from that of the Jupiter Trojans. Further, there is no evidence of correlation between color and physical, dynamical, or observational parameters for the observed comets.

1. Introduction

The physical properties of small planetary bodies offer insight into the formation and evolution of the Solar System. However, observational studies of the remote regions of the Solar System are limited to the largest bodies in the Kuiper Belt, and are still not generally possible in the case of the Oort Cloud. Nevertheless, through delivery of scattered members of their populations, such as comets, these regions may be probed observationally. Comets may be distinguished from other populations of small bodies due to their activity: the production of a gas and dust comae, typically when the comet is at small heliocentric distances, due to the sublimation of volatiles. The comet populations that are thought to directly sample these two remote regions are the Jupiter Family Comets (JFC), from the Kuiper Belt, characterized by generally low-inclination prograde orbits, and Long Period Comets (LPC) thought to originate in the Oort Cloud, with a large range of orbital inclinations, directions, and whose aphelia lie far beyond the orbits of the planets [3].

2. Methods

In order to successfully acquire comet observations from the Sloan Digital Sky Survey (SDSS) [1] database we employed two methods. The first involved making selection cuts based on SDSS measured photometry and data processing quality flags [5]. The resulting candidate objects were then visually inspected). The advantage of this technique is that it is blind to the known comet sample. It does not matter whether the candidates are known comets, thought to be asteroids, or being observed (discovered) for the first time. The weakness of this approach is that it requires visual identification of each candidate object, and is subject to SDSS pipeline issues (e.g. deblending errors, multiple epochs represented by a single image) [5]. Since this technique was specifically designed for "cometary" (resolved) objects it will not select comets that are inactive, or have sufficiently low activity to appear as point sources at the resolution of the SDSS.

A second technique to select comets from the SDSS employs the method used to identify known asteroids in the SDSS Moving Object Catalogue (SDSS MOC) [2] . We propagated the orbits of known comets through the SDSS observational cadence. Much as in the case of the SDSS MOC, this code generates all possible SDSS positions that a known comet could have been observed by the telescope over the course of the survey [4]. Due to strong non-gravitational effects on comets the results of this method must also be visually inspected, and will only generate positions for bound orbits, excluding the LPCs.

With these methods 35 observations of 31 comets have been identified in the SDSS dataset. The u, g, r, i, z observations were then used to construct surface brightness profiles and A$f\rho$ parameters in all five bands. The $r-$band photometry was used to place upper limits on the size of the cometary nuclei, and derive the cumulative luminosity function for the JFCs.

3. Results and Discussion

Despite the variety of cometary parameters, the distributions of photometric colors seen in Fig. 1 occupy a very narrow distribution, exhibiting the median colors of $u-g: 1.57 \pm 0.21$, $g-r: 0.57 \pm 0.05$, $r-i: 0.22 \pm 0.07$, and $i-z: 0.09 \pm 0.07$. These colors are statistically indistinguishable from those of Jupiter Trojans [7]. The comets exhibit ***no*** correlation between color and any physical, dynamical, or observational parameter. Additionally the surface brightness profile for each individul comet is found to be invariant with wavelength in the optical.

The uniform, red color of the comets suggests that the light from the dust in the coma is much more complex than could be explained by sub-micron particle Rayleigh scattering, or simple Mie scattering. The visible light observed here is light scattered by the larger particles in the coma, either conglomerates of small grains, or larger, macroscopic rocks. The similarity in reflectance to solid surfaces (both cometary nuclei, and Jupiter Trojans) may indicate that the material responsible for the dark, reddish appearance of these solid objects is also present in the coma and dictates its optical properties.

Using the SDSS measured PSF-magnitude [6] to place upper limits on the nuclear radii, we find that the cumulative luminosity function for the JFCs can be fit by a power law of the form $N(<H) \propto 10^{(0.49 \pm 0.05)H}$, with evidence of a broken power law with a exponent of 0.73 ± 0.08, transitioning to 0.19 ± 0.03 at $H \sim 14.5$. These results are consistent with distributions of small bodies, both of JFCs, and other Solar System populations.

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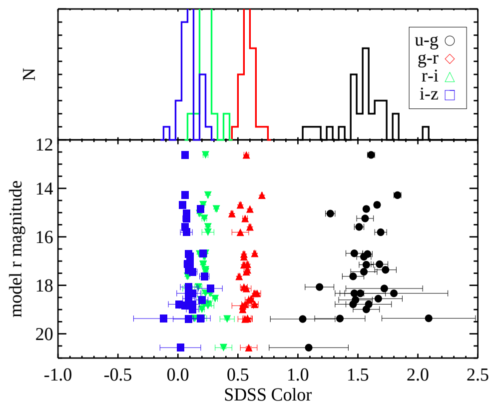

Figure 1: Color-magnitude distribution of the resolved comets with 2-σ error bars. The plotted symbols are: $\bigcirc$ $u-g$ (black), $\triangle$ $g-r$ (red), $\triangledown$ $r-i$ (green), and $\square$ $i-z$ (blue). Plotted above is the histogram of the color distribution.

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