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Spectro-photometry of Dynamically Associated Asteroid Pairs

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Abstract

Pairs of dynamically associated asteroids have recently been identified in the Main Belt. We will present the results of a spectro-photometric study of these objects that includes observations of 29 primaries and 24 secondaries, with a total 14 pairs in which both the primary and secondary have been observed. With these data we will address the formation of these unusual objects.

1. Introduction

Analysis of the osculating orbital elements of Main Belt asteroids has recently revealed over 80 pairs of asteroids that reside in nearly identical heliocentric orbits [1, 2]. These objects are different from binary asteroids as they are not bound in orbit around their common centers of mass. However, backwards integration of their orbits suggests that they may have separated recently into their unbound state, in some cases less than 20 kyr ago [3, 4].

One formation scenario for these pairs, which is supported by studies of their rotational properties [4], suggests that their parent asteroids were spun up to a critical frequency by the YORP effect, i.e. a change in angular momentum due to anisotropic emission of thermal photons. At this critical frequency the parent fissioned into a proto-binary system, which would eventually disrupt under its own internal dynamics, thus forming an unbound asteroid pair. Over time these pairs can drift sufficiently far apart in orbital element space such that their prior association can no longer be inferred. The components of these pairs are typically a few km in size.

There remain several unaddressed questions regarding the formation and evolution of these asteroid pairs. For instance, the relationship between asteroids pairs and bound multi-component systems is unclear. In addition, little is known about the compositions/taxonomic types of these pairs. If they formed by rotational fission then the components of a given pair should be compositionally similar. On the other hand, collisional formation might result in compositionally distinct components. Formation by rotational fissioning should also be largely independent of composition, resulting in a population of pairs that is representative of all Main Belt asteroids.

2. Observations

During several observing runs in 2010 we performed photometric observations of asteroid pairs with the SITe2K CCD at the DuPont 2.5m telescope and with the IMACS instrument at the Magellan Baade 6.5m telescope, both located at Las Campanas Observatory in Chile. BVRI filters were used at both facilities. Visible (0.5-0.9 μm) spectra with IMACS operating in its low resolution grism mode were also obtained for 5 targets that were brighter than V=19.0. When available we have also included Sloan Digital Sky Survey *ugriz* photometry in our analysis (Fig. 1).

For all pair observations, a best-fit SMASS taxonomic type has been determined by translating the mean of each SMASS taxonomic type [6] into the BVRI photometric system. Chi-squared differences between the observed photometry and each of the synthesized BVRI taxonomic types were calculated. The type with the minimum chi-squared value was considered the best fit. In general, we find that this technique works reasonably well at assigning objects to the correct complex (S-, C- or V-), but the coarse resolution and narrower wavelength coverage with the BVRI filter set precludes detailed taxonomic classification. Nevertheless, this technique is sufficient to determine the compositional relationship between pairs.

Figure 2 shows spectro-photometry from the DuPont telescope for a primary and a secondary from two different pairs (the primary and secondary are respectively defined as the largest and smallest components in a given pair). In the top panel, asteroid 3579 is found to have BVRI photometry consistent with a Cgh-type asteroid. Along with our observations of other pairs, these data suggest that pairs are found within each of the major taxonomic classes, S-, C-, V- and X-.

The bottom panel in Figure 2 shows that asteroid 54041 is most closely associated with a Q-type taxonomy. Q-types, though common in the near-Earth population, have been difficult to confirm in the Main Belt [7, 8]. As putative intermediates in a weathering sequence that ranges from from ordinary chondrites (fresh) to S-type asteroids (weathered) [10], Q-types are likely to have recently exposed surface material. Scheduled near-infrared spectroscopic observations (June 2011) will unambiguously determine whether 54041 is a Q-type asteroid with an ordinary chondrite-like composition. This will provide insight into the effects on asteroid surfaces from the pair formation process.

In general this study will present the first comprehensive taxonomic/compositional analysis of asteroid pairs in the Main Belt. Observations of both components will also help to confirm or refute as statistical flukes the genetic relationship between members.

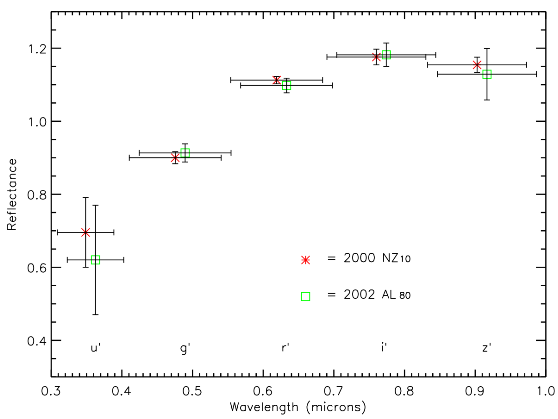

Figure 1: SDSS *ugriz* photometry of each component in an asteroid pair. The data have been normalized such that a straight line between the *g* and *r* points passes through unity at 0.55 μm. A small horizontal offset has been applied to each data point for clarity. These objects have colors consistent with one another and an Sl- or L-type taxonomy. Figure from [5].

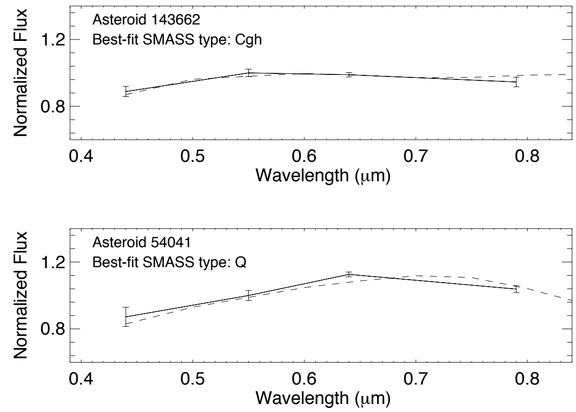

Figure 2: BVRI photometry of an asteroid pair secondary (top) and a primary (bottom). These objects are not part of the same pair. The data have been normalized to unity at the center of the V-band. In each case the best-fit to an SMASS spectral class is indicated. The dashed lines represent the mean values of the respective best-fit SMASS classes [6].

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