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Cascade disruptions in asteroid clusters

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Abstract

We studied the membership and ages of asteroid clusters formed by rotational fission. We performed backward orbital clone integrations of 25 asteroid clusters. We found that the members of some clusters separated from their primary at two (or more) distinct times. The identified multiple-fission clusters are: 1. (14627) Emilkowalski cluster showing two groups with 2 and 4 secondaries that formed about 330 kyr and $1-3$ Myr ago, respectively. 2. (63440) 2001 MD30 cluster with one secondary separated about 70 kyr and another one about 820 kyr ago. 3. (157123) 2004 NW5 cluster with separation times about 150 kyr and $1.3-2.5$ Myr ago for its two members. And 4. (11842) Kap'bos cluster showing separation times about 40, about 600, and > 1500 kyr ago, respectively, for 1, 1, and 2 of its secondaries. These findings suggest that some clusters underwent a cascade primary or secondary fission process.

1. Introduction

The existence of genetically related pairs of asteroids on highly similar heliocentric orbits is known for over a decade now [1]. The common origin of members of asteroid pairs is indicated by backwards orbital integrations [2], taxonomy similarity [2], [3] and estimation of probability of random orbital coincidence of asteroids from background population [4].

Asteroid clusters are young groups of three or more asteroids on highly similar heliocentric orbits. Most asteroid pairs and clusters were formed by rotational fission after being spun up to critical spin rate by the YORP[1] effect [5], [6]. A relative velocity of the members of an asteroid pair after their separation is comparable to the surface escape velocity of the primary (largest) member of the system.

[1]Yarkovsky–O'Keefe–Radzievskii–Paddack effect [7]

2. Backward orbital clone integrations

To confirm the membership of an asteroid to a cluster, we integrated a set of geometric clones (1000 clones for each asteroid) with the Yarkovsky effect acting on each clone differently. The Yarkovsky effect was represented using a fake transverse acceleration acting on the clone with a magnitude providing secular change in semimajor axis $\dot{a}_{\rm Yark}$ [7]. It was randomly chosen from the range $\langle -\dot{a}_{\rm max}, \dot{a}_{\rm max} \rangle$, where $\dot{a}_{\rm max}$ was estimated from the asteroid size.

The goal of our backward orbital integrations was to find low relative velocity close encounters between the clones of the members of a tested cluster. Because of the initial orbit parameter uncertainties, an unknown strength of the Yarkovsky effect and the fact that we used a finite number of clones, we set the limits for a slow and close encounter to $2\times$ or $4\times$ the primary surface escape velocity and $10\times$ or $15\times$ the Hill radius of the primary member of the cluster. The more relaxed limits were used for higher ages or more chaotic orbits.

For our integrations we used WHFast integrator [8] from the REBOUND package [9].

3. Multiple fission clusters

For most of the studied clusters, we found that all the secondaries of a given cluster separated from the primary at about the same time. However, we found four asteroid clusters where the backward orbital integrations indicate two (or more) secondary separation events.

The most representative example is the cluster of (14627) Emilkowalski. In Figure 1, there are shown the distributions of times of slow and close encounters between clones of the primary asteroid (14627) and clones of the six secondaries of this cluster. It appears that the Emilkowalski cluster underwent at least two, possibly three separation events.

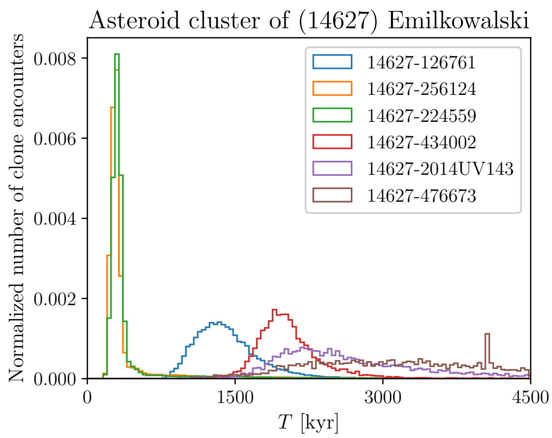

Figure 1: Distributions of the normalized number of clone encounters between the primary asteroid Emilkowalski and each of the six secondaries of its cluster. The separation time of asteroids (256124) and (224559) from asteroid (14627) occurred about 330 kyr ago, while the other four secondaries separated much earlier.

4. Conclusions

A specific formation process of asteroid clusters with multiple separation events is unknown. One hypothesis is that after the first fission event the primary asteroid was spun up to the critical spin rate by the YORP effect again and underwent another fission event. However, further studies will be needed to prove this proposed mechanism. We could also speculate about possible fission event of a temporarily bound secondary (temporary satellite) of the primary that was formed during an earlier fission event from the primary and underwent a secondary fission at much later time, but a theory for such possible cascade fission process is missing. More work, both observational and theoretical is needed to obtain understanding of how asteroid clusters with cascade disruptions formed.

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References

[1] Vokrouhlický, D. and Nesvorný, D.: Pairs of asteroids probably of a common origin. Astron. J., Vol. 136, pp. 280-290, 2008.

[2] Pravec, P., et al.: Asteroid pairs: a complex picture. Icarus, submitted, 2019.

[3] Wolters, S., et al.: Spectral similarity of unbound asteroid pairs. Monthly Notices of the Royal Astronomical Society, Vol. 439, Issue 3, p.3085-3093, 2014.

[4] Pravec, P. and Vokrouhlický, D.: Significance analysis of asteroid pairs. Icarus, Vol. 204, Issue 2, p. 580-588, 2009.

[5] Pravec, P., et al.: Formation of asteroid pairs by rotational fission. Nature, Vol. 466, Issue 7310, pp. 1085-1088, 2010.

[6] Pravec, P., et al.: Asteroid clusters similar to asteroid pairs. Icarus, Volume 304, p. 110-126, 2018.

[7] Bottke, W. F., Jr., et al.: The Yarkovsky and Yorp Effects: Implications for Asteroid Dynamics. Annual Review of Earth and Planetary Sciences, Vol. 34, p.157-191, 2006.

[8] Rein, H. and Tamayo, D.: WHFAST: a fast and unbiased implementation of a symplectic Wisdom-Holman integrator for long-term gravitational simulations, Monthly Notices of the Royal Astronomical Society, Vol. 452, Issue 1, p.376-388, 2015.

[9] Rein, H. and Liu, S.-F.: REBOUND: an open-source multi-purpose N-body code for collisional dynamics. Astronomy & Astrophysics, Vol. 537, id.A128, 10 pp., 2012.