CASCADE DISRUPTIONS IN ASTEROID CLUSTERS. Petr Fatka[1,2], Petr Pravec[1] and David Vokrouhlický[2]. [1]Astronomical Institute AS CR, Ondřejov, Czech Republic. [2]Astronomical Institute MFF, Charles University, Prague, Czech Republic.

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 references herein) and low 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 effect [5], [6], [7]. A relative velocity of the members of an asteroid pair or cluster after their separation is comparable to the surface escape velocity of the primary (largest) member of the system.

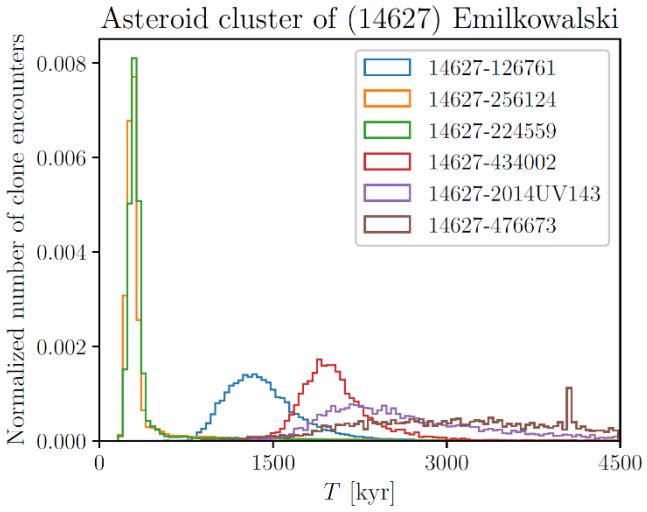

Figure 1. Distributions of the clone encounter past times between the primary asteroid Emilkowalski and each of the six secondaries of its cluster. The separation time of asteroids (256124) and (224559) from asteroid (14627) occurred about 330 kyr ago, while the other four secondaries separated much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

Results: 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.

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.

Acknowledgements: This work was supported by the Charles University, project GA UK No.842218, and by the Grant Agency of the Czech Republic, Grant 17-00774S. Computational resources were provided by the CESNET LM2015042 and the CERIT Scientific Cloud LM2015085, provided under the programme "Projects of Large Research, Development, and Innovations Infrastructures".

References: [1] Vokrouhlický, D., et al. (2008). *Astron. J.* **136**, 280-290.
[2] Pravec, P., et al. (2019): *Icarus*, in press.
[3] Wolters, S., et al. (2014) *Monthly Notices RAC*, **439**, 3085-3093.
[4] Pravec, P., et al. (2009). *Icarus*, **204** 580-588.
[5] Scheeres, D., et al. (2007). *Icarus*, **189** 370-385.
[6] Pravec, P., et al. (2010) *Nature*, **466,** 1085-1088.
[7] Pravec, P., et al. (2018) *Icarus*, **304**, 110-126.