Dynamical evolution of small family members: 288P cluster case study

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Abstract. Here we examine the dynamical evolution of small members of the 288P cluster as a case study of the dynamical behavior of asteroids below 50 meters in size. We especially focus on transport to the NEO (Near Earth Object) region.

1 Motivation

Studies on the dynamical evolution of large asteroids may not apply to smaller objects, as non-gravitational effects such as the Yarkovsky and YORP or solar radiation pressure (SRP) may have a more significant impact on the orbits of smaller asteroids.
Here we present a case study of the evolution of small main belt asteroids. The study was performed on the members of the 288P cluster, selected due to its young age and relatively small parent body [1].

2 Simulations and results

Numerical simulations Based on the available data, we reconstructed the size-frequency distribution of cluster members between 2 and 50 meters. We found that there could be over 600 million members in this size range, but in simulations, we worked with 12,600, introducing a scaling factor of 50,000.
The numerical simulations are made using the Mercury package [7] and are completed with four different dynamical models. We used the physical and thermal properties compatible for C-type asteroids [2, 3] to model non-gravitational effects.
Transportation to the NEO region During their dynamical evolution, many objects enter and exit the NEO region. In our most representative simulation that includes gravitational and all considered non-gravitational effects, we found that 1499 objects in total spent some time in the NEO region. Fig. 1 shows variations in the number of family members in the NEO region. In the simulations, we obtained about 40 objects at any instance of time in the NEO region. This number translates into 2 million real objects which move in the vicinity of Earth at any time.

Link to the Orgueil meteorite An interesting byproduct of our study is establishing a possible link between the 288P cluster and the Orgueil meteorite.

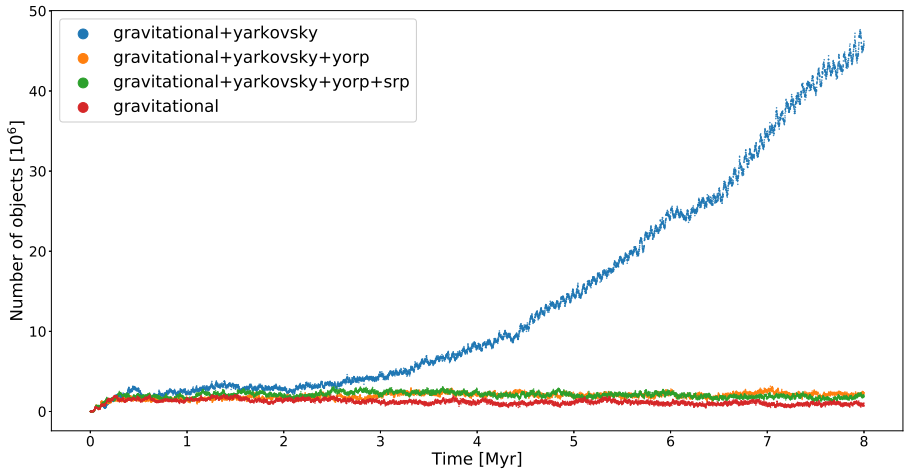

Fig. 1. The expected number of real objects inside the near-Earth region at any instance of time. Different colors correspond to different dynamical models, as indicated in the plot.

The cosmic ray exposure (CRE) age of the Orgueil meteorite was determined to be between 2-16 Myr [4, 5], with the actual age being the most likely in the 4-8 Myr range. This matches very well the age of the 288P cluster, estimated at 7.5 $\pm$ 0.3 Myr [1]. Our results, on the other hand, show dynamical pathways from the cluster to the Earth. Furthermore, orbit reconstruction by [6] suggests that it is compatible with the meteorite origin in the outer main belt. If we recall that there is also a reasonably good spectral match between the meteorite and the cluster members, we hypothesize that the Orgueil meteorite might originate in the 288P cluster.

References

1. Novaković, B., Hsieh, H. H., & Cellino, A. 2012, MNRAS, 424, 1432
2. Watanabe, S., Hirabayashi, M., Hirata, N., et al. 2019, Science, 364, 268
3. Rozitis, B., Ryan, A. J., Emery, J. P., et al. 2020, Science Advances, 6, eabc3699
4. King, A. J., Bates, H. C., Krietsch, D., et al. 2019, Chemie der Erde / Geochemistry, 79, 125531
5. Mazor, E., Heymann, D., & Anders, E. 1970, Geochim. Cosmochim. Acta, 34, 781
6. Gounelle, M., Spurný, P., & Bland, P. A. 2006, , 41, 135
7. Fenucci, M. & Novaković, B. 2022, Serbian Astronomical Journal, 204, 51