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Lorre cluster: an outcome of recent asteroid collision

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Abstract

Here we show an example of a young asteroid cluster located in a dynamically stable region, which was produced by partial disruption of a primitive body about 30 km in size. According to our estimation it is only 1.9 ± 0.3 Myr old, thus its post-impact evolution is very limited. The parent body had a large orbital inclination, and was subject to collisions with typical impact speeds higher by a factor of 2 than in the most common situations encountered in the main belt. For the first time we have at disposal the observable outcome of a very recent event to study high-speed collisions involving primitive asteroids.

1. Introduction

A little altered recently born asteroid families provide more direct information about the physics of break-up events. Evidence of recent collisions in the asteroid belt have been reported in the last decade and our knowledge about young asteroid families has been increased significantly [4, 5, 6]. Most of these groups are formed by asteroids belonging to the S taxonomic class. There are, however, several important differences among the S and C-type asteroids. The objects belonging to former class are thought to have experienced some thermal evolution since the time of their formation, and it is, for example, known that space weathering processes are different for these two classes of objects [1]. Also, numerical simulations show that the outcomes of collisional events are dependent on internal structure of the parent body [2]. Hence, it is necessary to identify also young C-class families in dynamically stable regions, because a few such groups are already known, but none of these is well suited to extract reliable enough information. Two C-type families, namely Veritas and Theobalda, about 8.3 and 6.7 Myr old respectively, are both located in dynamically unstable region [4, 8]. Thus, despite their young ages, these families evolved significantly since post-impact situation. Most of the asteroids belonging to Beagle family [7], which is probably less than 10 Myr old, are located in dynamically relatively stable region. However, this group is embedded in the large Themis family making distinction between the real members and background objects difficult. Finally, the youngest known group that might be formed by C-type asteroids is Emilkowalski cluster, which is only 220 ± 30 kyr old [6]. However, it seems to be rather an X- than C-type group because albedos of its members are much higher than expected for C-type objects.

For these reasons, it is very important to identify young families, that belong to the most primitive C class, that do not suffer from the above mentioned problems. We have found the first example of this kind to be (5438) Lorre cluster, recently discovered by [9]. This makes it a very promising candidate for different possible studies. Two crucial prerequisites for these studies are an accurate identification of its members, and a reliable estimation of its age. These are the questions we address here.

2. Members of the Lorre cluster

A dynamical criterion for family membership is based on distances among the objects in the space of proper orbital elements. Usually, for this purpose, the hierarchical clustering method (HCM) and metric proposed by [11] are used.

Following the method described in [3] we calculated synthetic proper elements for 148 asteroids located in a region somewhat wider than that occupied by the cluster. Then, we applied the HCM to this set of proper elements, and we analyzed the number of dynamically linked objects identified at different mutual distances. The obtained results are shown in Fig. 1.

From these results we can draw three basic conclusions: (i) the cluster is extremely compact and very well separated from the background population; (ii) the nominal membership of the cluster is best charac-

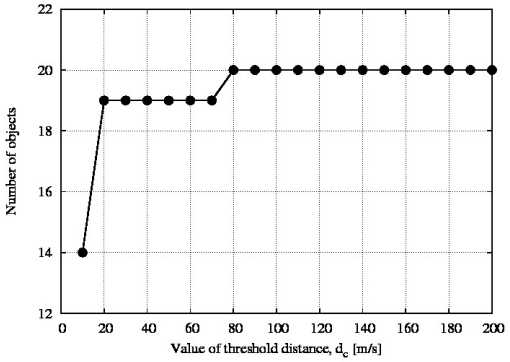

Figure 1: Number of asteroids associated with Lorre cluster as a function of cut-off distance d_c.

terized at $d_c = 20$ m/s; (iii) the asteroid connected with the group at 80 m/s is likely a close background object. Thus, the Lorre cluster has 19 currently known members.

3. Age of the cluster

An accurate method to estimate the age of a young asteroid family is to integrate the orbits of its members backwards in time and to identify the epoch of their convergence [4]. However, as the orbits of the Lorre cluster members are not perfectly stable an application of this method to these asteroids is not reliable enough. Thus, instead of orbits of nominal members we used a number of cloned, statistically equivalent, orbits, to characterize the age of the Lorre cluster in a statistical sense [10].

The orbits of all clones were numerically integrated backward in time for 10 Myr using the *Orbit9* software. The age of the cluster was estimated by randomly selecting one clone for each member and determining the age for that particular combination of clones as the minimum of the function [10]:

$$\Delta V = na\sqrt{(sin(i)\Delta\Omega)^2 + 0.5(e\Delta\varpi)^2} \qquad (1)$$

where $na \approx 18$ km/s is the mean orbital speed of the asteroids in the cluster, and $\Delta\Omega$ and $\Delta\varpi$ are the dispersions of the longitude of node and the longitude of perihelion, respectively.

The obtained result (Fig. 2) suggests that the Lorre cluster was formed only 1.9 ± 0.3 Myr ago. Therefore, its post-impact evolution should have been very limited.

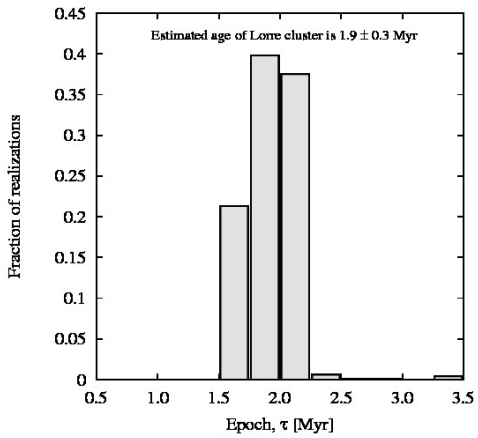

Figure 2: The histogram of possible ages of Lorre cluster constructed from 10^6 different combinations of clones.

Acknowledgements

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