

## Widespread water among primitive asteroid families: new insights from the main belt comets

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### Abstract

We present new results regarding the association of main belt comets to asteroid families. We find three new firm links, and three potential associations. These results further strengthen the link between the main belt comets and compositionally primitive asteroid families.

### 1. Introduction

Main belt comets (MBCs) are a subgroup of active asteroids, which exhibit visible mass loss activity yet are dynamically asteroidal, for which it is believed that observed activity is driven by the sublimation of volatile ices [1, 2]. Our recent work has demonstrated that all MBCs associated to collisional families belong to families with primitive taxonomic classifications [3].

Since this work several active asteroids with potentially sublimation driven activity have been discovered. This opens an opportunity to extend our study, and to further test the link between the MBCs and collisional asteroid families.

### 2. A search for family associations

Methodology used here to search for asteroid families associated to active asteroids is basically the same one used in our previous works by Hsieh et al. [3] and Novaković [4]. The main steps of this methodology are:

- Computation of proper orbital elements of active asteroids
- Application of the Hierarchical Clustering Method (HCM, [5])
- Test how robust are the results from the HCM, using orbital clones of active asteroids

The obtained results are summarized in Table 1. For the first time we found active asteroids associated to the Pallas and Luthera families, namely P/2017 S8 and P/2019 A7, respectively.

Table 1: A list of asteroid family associations of newly discovered main belt comet candidates.

MBC candidate	Family
P/2016 P1 (PANSTARRS)	Euphrosyne?
P/2017 S8 (PANSTARRS)	Pallas
P/2017 S5 (PANSTARRS)	Theobalda
P/2017 S9 (PANSTARRS)	Theobalda?
P/2019 A3 (PANSTARRS)	Theobalda?
P/2019 A4 (PANSTARRS)	None?
P/2019 A7 (PANSTARRS)	Luthera
P/2019 A8 (PANSTARRS)	None?

In the cases of three MBC candidates (P/2017 S8, P/2017 S5 and P/2019 A7) we found a firm link between the comet and its associated family. In three other cases (P/2016 P1, P/2017 S9 and P/2019 A3), we found that these objects may also be associated to families, but these links are still inconclusive due to the large orbital uncertainties. Finally, for two objects (P/2019 A4 and P/2019 A8) we did not find an associated family. This may change in the future when better orbit solutions become available.

#### 2.1. The first MBC belonging to the Pallas asteroid family

One of the most interesting newly discovered links is certainly the one between active asteroid and MBC candidate P/2017 S8 and the Pallas family. The Pallas family is a group of B-type asteroids at very high inclinations in the mid asteroid belt [6]. The B-type asteroids are a peculiar spectral sub-class of the C-complex [7]. It was found however that there is the difference between the albedos of B-type asteroids belonging to

the Pallas family and those outside the family, suggesting possible compositional differences [8]. In this respect discovery of an icy object among the members of this family is very interesting.

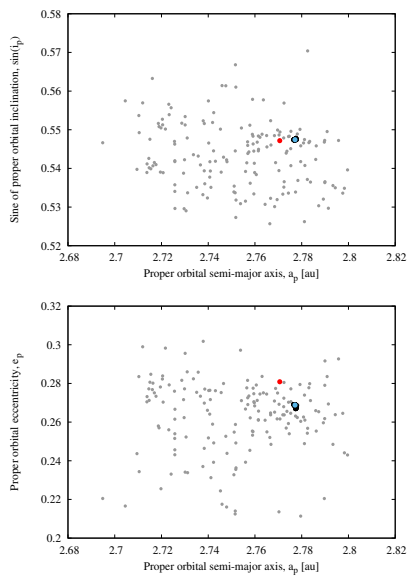


Figure 1: Members of the Pallas asteroid family (gray dots) shown in semi-major axis vs eccentricity (bottom) and semi-major axis vs sine of inclination plane (top). Positions of P/2017 S8 and its clones are shown by blue and black points respectively, while the asteroid (2) Pallas is labeled with red points.

### 3. Discussions and Conclusions

The activity driver is in most of the analyzed active asteroids still uncertain, but based on their locations within the asteroid belt, and dynamical association to the compositionally primitive asteroid families, we believe the activity could be due to the sublimation of water ices.

We now have several, likely water-bearing, asteroid families containing at least one MBC. Most of these families are located in the outer asteroid belt, but mid-belt Pallas family becomes also a repository of the main belt comets. As evidence grows, it seems that link between MBCs and primitive families is getting stronger. Interestingly, MBCs are found among families of different ages, contrary to the previous expectations that they should be primarily found among young

asteroid families.

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