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# PHYSICAL PROPERTIES OF "HOT POPULATION" OBJECTS IN THE KUIPER BELT

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ABSTRACT. Most planetesimals formed at distances of 15 - 30 a.u. were gravitationally ejected from the Solar system as a result of the migration of the giant planets, but a small part remained, captured by Jupiter and the Kuiper belt. As a result, we can now observe such a variety, in terms of physical and dynamic characteristics, in the Trojan asteroids of Jupiter and in the Kuiper belt. Planetesimals captured by the Kuiper Belt are a "hot population" now. The term "hot" does not refer to the temperature of bodies, but characterizes the orbit of objects. ~120,000 objects larger than 100 km. in diameter are known in the "hot population". This population is characterized by an orbital inclination greater than 5 degrees and a large eccentricity. The main task of the work, based on physical and dynamic characteristics, is to search for the same properties Trojan asteroids of Jupiter and objects from the "hot population" of the Kuiper belt, which supposedly migrated earlier from the region of the original orbit of Neptune. The data from ground-based observations and space missions is used in the work.

**Keywords:** minor planets, TNO, asteroids.

АНОТАЦІЯ. Більшість планетезималей, що утворилися на відстанях 15-30 а.о., були гравітаційно викинуті з Сонячної системи в результаті міграції планет-гігантів, але невелика частина залишилася, захоплена Юпітером і поясом Койпера. У результаті ми зараз можемо спостерігати таку різноманітність, з точки зору фізичних і динамічних характеристик, у троянських астероїдів Юпітера і в поясі Койпера. Планетезималії, що захоплені поясом Койпера, зараз є «гарячою популяцією». Термін «гарячі» не стосується температури тіл, а характеризує орбіту об'єктів. Приблизно 120 000 об'єктів розміром понад 100 км в діаметрі відомі в «гарячому населенні». Ця популяція характеризується нахилом орбіти понад 5 градусів і великим ексцентриситетом. Основним завданням роботи, заснованої на фізико-динамічних характеристиках, є пошук однакових властивостей троянських астероїдів Юпітера та об'єктів із «гарячого населення» поясу Койпера, які, ймовірно, мігрували раніше з області первісної орбіти Нептуна. У роботі використані дані наземних спостережень і космічних місій.

**Ключові слова:** малі планети, ТНО, астероїди.

## 1. Introduction

During the evolution of the Solar system, planetesimals, originally located in the accretion disk, are dispersed due to gravitational interaction with the giant planets. Most of them are ejected from the Solar system, one small part is captured by Jupiter at the Lagrange points, and the other is scattered into the Kuiper belt and forms a "hot population" (Levison et al., 2021). The "hot population" is characterized by an inclination of more than 4 degrees and is located in the region of 39.4 - 55.8 au (Delsanti & Jewitt, 2006; Levison et al., 2008). Hot population objects are interesting in that most of them may be ancient or primary objects that have changed slightly since their formation.

## 2. Target selection

From 2000 known objects, we chose numbered objects that had a well-known orbit. These objects are shown in Fig.1, which demonstrates the dependence of the eccentricity on the semi-major axis and inclination on the semi-major axis. The dashed lines mark the resonances of Neptune with objects (3:2, 5:3, 7:4, 2:1, 5:2).

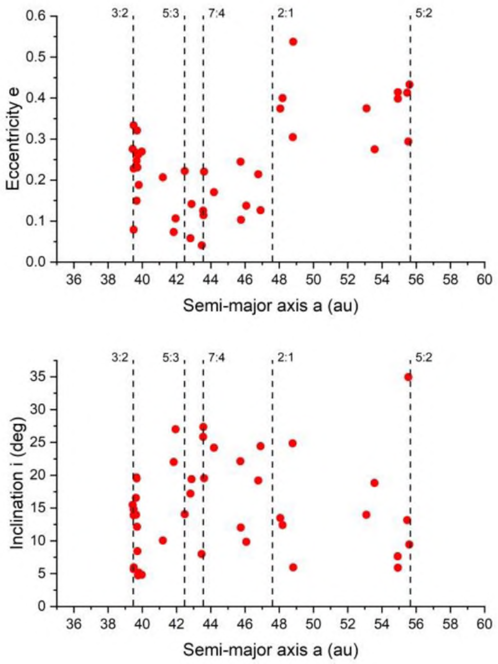


Figure 1: Orbital distribution of asteroids considered in this work.

### 3. Physical properties

Known periods of small bodies of the Solar system are presented in the diagram Fig. 2. On it, we marked in red the objects of the "hot population" with a known period. They fall into the region of trans-Neptunian objects (TNO), which are marked in yellow. The dotted line in the diagram marks the restriction on the rotation period, i.e. the spin barrier and the objects we have chosen do not exceed it.

$$H = -5lg\frac{D\sqrt{p}}{1329} \qquad (1)$$

were $H$ - absolute magnitude, $D$ - diameter, $p$- geometric albedo.

Using the formula (1), we recalculated the values of diameter and absolute magnitude for objects 1993 SC, 1996 TO66, 1999 KR16, 2002 TX300 and obtained distribution Fig 3.

We also obtained the albedo and absolute magnitude values for the objects 1999 KR16, Quaoar, and Varuna. For the Quaoar object, we recalculated the values based on new diameter data (Morgado et al., 2022). As a result, we got the distribution in Fig. 4.

For the objects of the "hot population", we calculated the average albedo value $p = 0.104 \pm 0.054$.

From the database "IAU Minor Planet Center" we took the values of the phase function, which were obtained by ground-based observations and from the joint results of "Herschel and Spitzer observations" (Lellouch et al., 2013), and obtained a distribution on the absolute magnitude (Fig. 5).

We have averaged the phase function G = 0.137 ± 0.048 from ground-based observations and from Herschel and Spitzer observations.

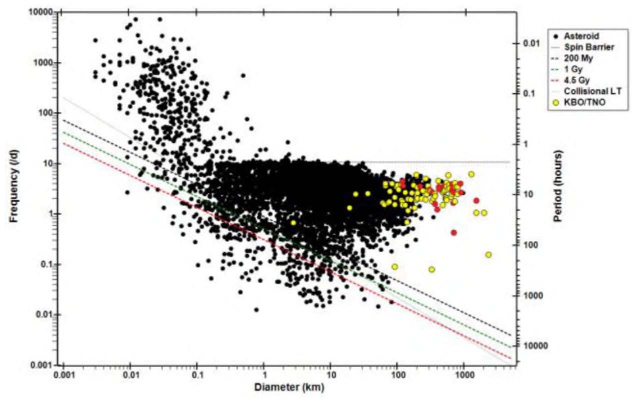


Figure 2: The distribution of asteroids based on rotation rate (frequency) versus diameter (Warner et al., 2009). Objects of the "hot population" from our list are marked in red.

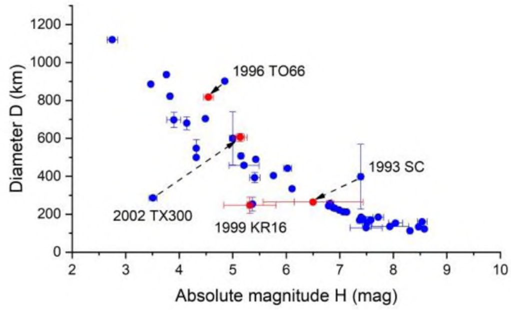


Figure 3: The distribution of asteroids based on diameter versus absolute magnitude. In the red marked recalculated values for 1993 SC, 1996 TO66, 1999 KR16, 2002 TX300.

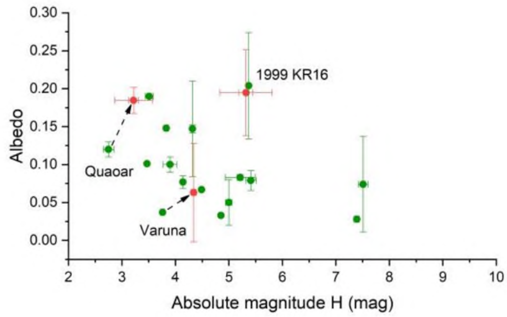


Figure 4: The distribution of asteroids based on albedo versus absolute magnitude. In the red marked recalculated values for 1999 KR16, Quaoar, Varuna.

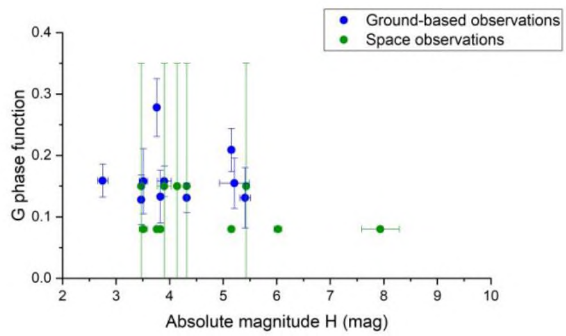


Figure 5: The distribution of asteroids based on phase function versus absolute magnitude.

## 4. Conclusion

As a result, we obtained the average albedo value for the objects of the "hot population" $p = 0.104 \pm 0.054$. It can be concluded that the objects are rather dark.

We also obtained the average value for the phase function based on ground-based observations and the results of the Herschel and Spitzer space missions ($G = 0.137 \pm 0.048$). Based on the obtained value, we can confirm the taxonomy of the object, using only photometric observations (Shevchenko et al., 2016; Oszkiewicz et al., 2021).

For asteroids 1993 SC, 1996 TO66, 1999 KR16, 2002 TX300, Varuna, Quaoar, we have received new values of diameter, absolute magnitude and albedo. The obtained refined physical parameters of our objects will be used in further work. Numerical simulation (Troianskyi & Bazyey, 2018; Oszkiewicz et al., 2019; Troianskyi et al., 2022) of orbits on – 4 Gy to must confirm the theory of "hot population" migration from the region of Neptune (Levison et al., 2021).

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