On the parameters of NEO encounters with the Earth

R.V. Zolotarev, B.M. Shustov

Institute of Astronomy of the Russian Academy of Sciences

119017, Pyatnitskaya str., 48, Moscow, rzolotarev@inasan.ru, bshustov@inasan.ru

Introduction

Currently, an active development of systems for the detection and monitoring of dangerous celestial bodies of natural origin is underway. One of the most important tasks is an optimization of search (detection) of near-Earth asteroids (NEAs), in particular potentially hazardous asteroids (PHAs – asteroids with MOID<0.05 au). The modern interpretation of PHA detection problem includes the requirement for mass detection of asteroids larger than 10 m. Although decameter-class object do not pose a threat of a global catastrophe, its collision can lead to significant local consequences. An example is Chelyabinsk event in February 2013. To build more efficient systems, it is necessary to know the distribution properties of such bodies, in particular – distribution on the sky, distributions of apparent magnitude and angular velocity. Unfortunately, sufficient completeness (>90%) has only been achieved for NEAs larger than ~0.7 km. Therefore, it is necessary to use a NEA population models that includes decameter size NEAs .

Population of objects experiencing close encounters to the Earth (entering near-Earth space (NES) – a sphere with radius of 0.01 au around the Earth) are the subject of special attention. In this work we named such a subgroup of PHAs as very potentially hazardous asteroids (VPHA).

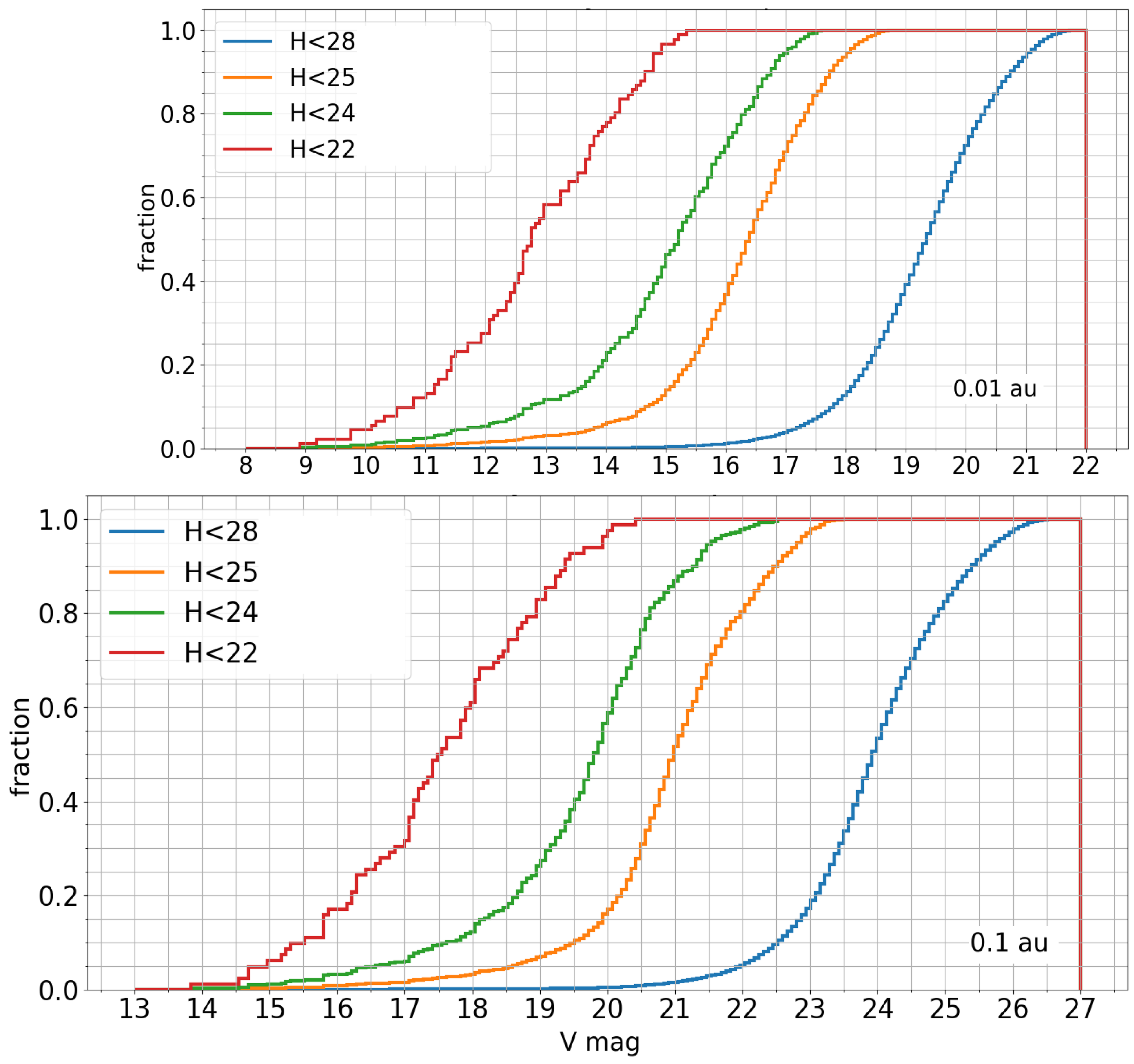
The goal is to consider conditions for optical observations of the NEAs (PHAs and VPHAs) with ground-based telescopes, i.e. observations in the night sky. More detailed description of concepts of day-time sky and night sky are given in [1].

Modeling method

To construct a NEO population model we use NEOMOD software package [2]. This model predicts that the total number of asteroids larger than 10 m (15<*H*<28) is about 11.5 million.

After the initial distribution of the NEOs in size and motion parameters are set using NEOMOD, their positions in space, *V* magnitudes and the geocentric angular velocities can be calculated for any time moment. We integrated asteroid motion using the REBOUND open source software package [3]. To obtain VPHA population model, main model has been integrated for 100 years with tracking close encounters with the Earth.

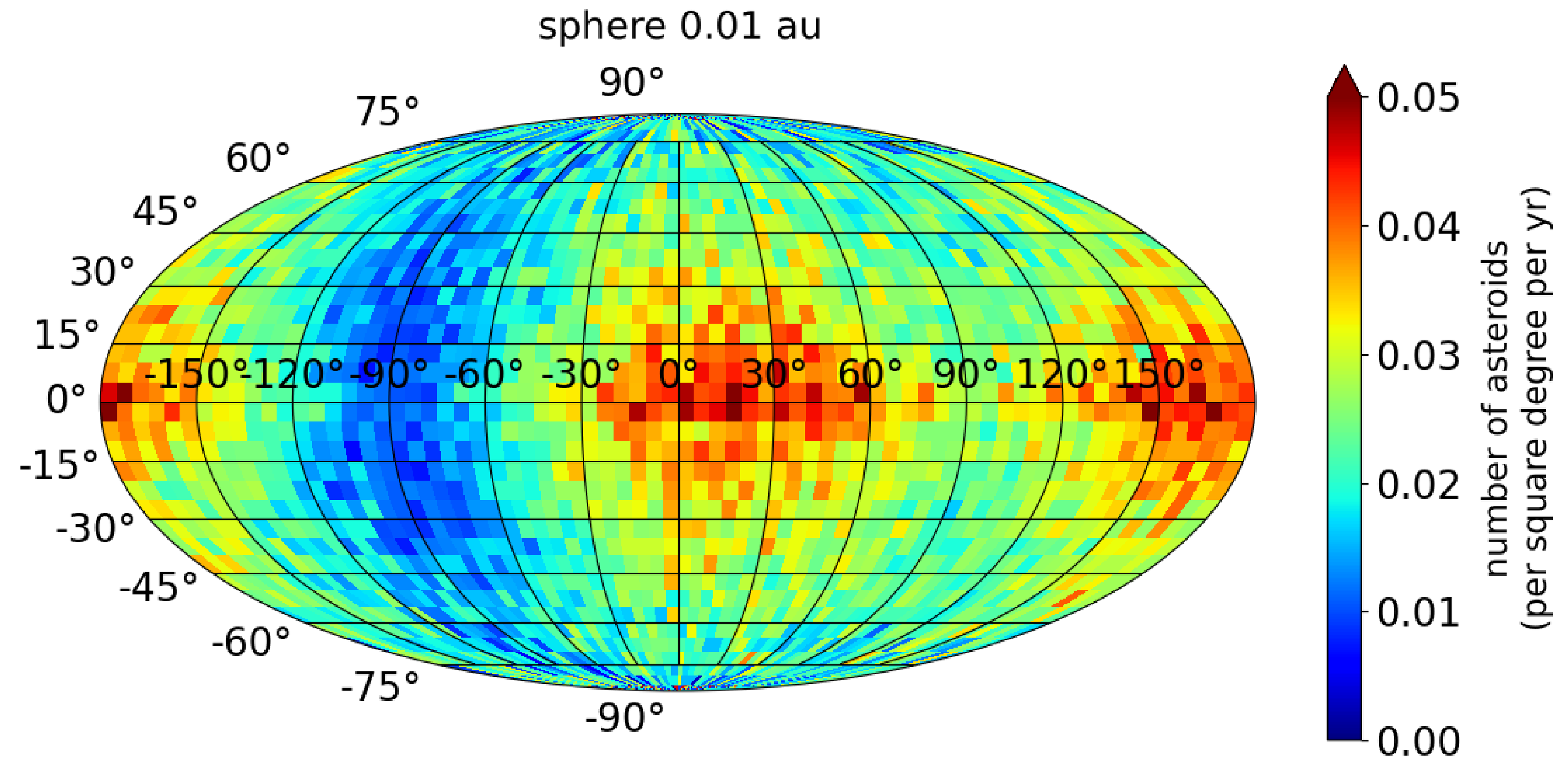
Apparent magnitudes



The figures show the fraction of the number of asteroids with apparent magnitudes *V* less than the specified value at the specified distances for the NEOMOD model population at the night sky.

As it follows from the figure an instrument with a limiting magnitude of ~21^m is required for observations of 90% of NEAs larger than 10 m at a distance of 1.5 million km. The 140 m-sized NEAs can be confidently (> 95%) observed at a distance of 0.1 au with a telescope with a limiting magnitude of 20^m. However, for larger distances mass detection of such objects becomes a difficult (almost impossible) task for visible-range telescopes [4].

Distribution of NEOs Entering the NES by Directions

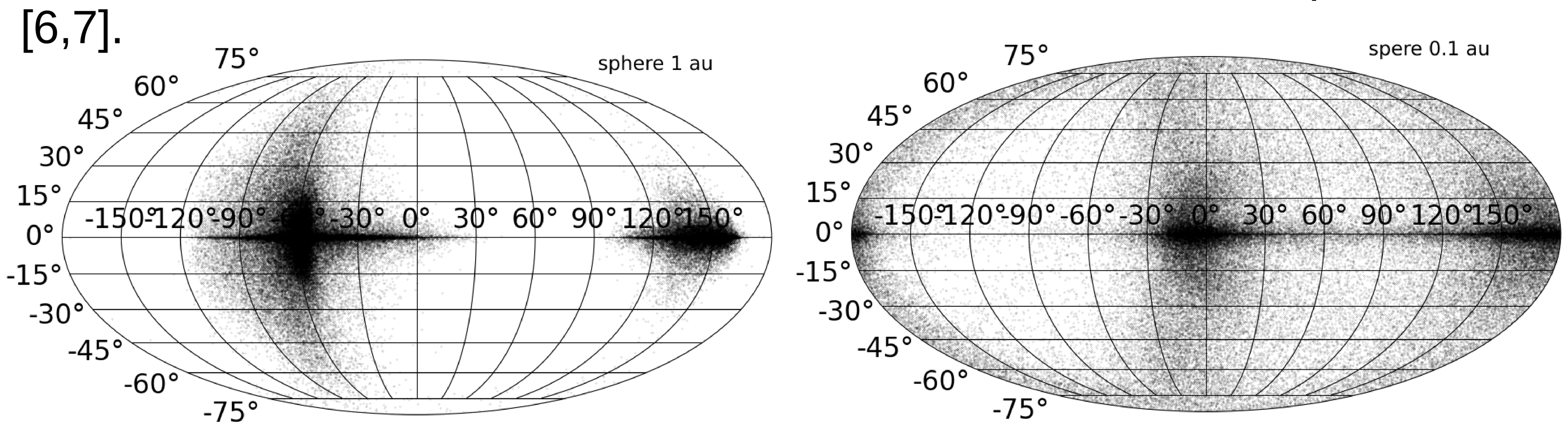


The figure illustrates the flux density of NEAs entering NES by directions in sun-centered ecliptic coordinate system. The -90° mark at longitude axis corresponds to the direction of the Earth's velocity vector. There are significantly more asteroids "catching up" with the Earth than with the asteroids that the Earth "catches up" with. See for more details [5].

According to the calculation results, the average number of model asteroid entries into the NES is 1050 per year.

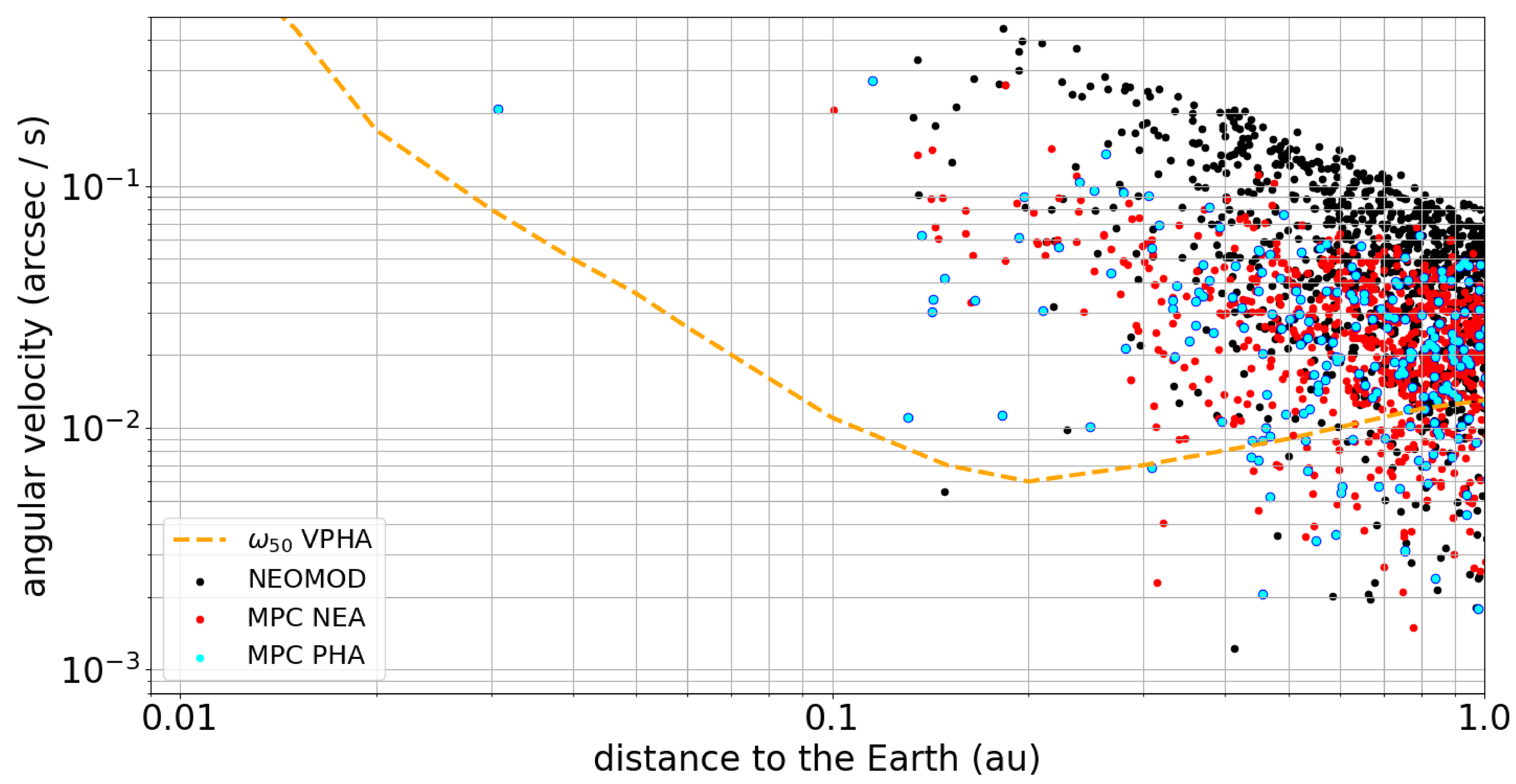
Pre- close encounter configuration

The figures illustrate distribution over the sky of VPHAs population at the distances 0.1 and 1.0 au to the Earth. A similar models were presented in [6,7].



Angular velocities

The angular velocity ω of the object is an important parameter. It allows to estimate the qualification time, i.e. the minimum time interval required for the preliminary classification of the body's orbit and evaluate the blurring of the image of a moving object in star tracking mode. It is clear that the main factor influencing the angular velocity of an object is distance, since distance can vary by orders of magnitude, and spatial velocities only by several times. Dependence ω on distance for asteroids with *H*<22 for May 5, 2025 is illustrated below. Black dots correspond to NEOMOD model, other points correspond to NEAs (red) and PHAs (cyan) calculated with IAU MPC data, ω_{50} is the median angular velocity for VPHA model population.



References

1) B.Shustov, et al., Sol. Syst. Research, 47 (4), 288 (2013)/
2) D. Nesvorný, et al., Icarus, 411, article id. 115922 (2024).
3) H. Rein & S. F. Liu, A&A, 537, id. A128 (2012).
4) B. Shustov, et al., submitted to Astronomy Reports
5) R.Zolotarev, et al., Astrophysical Bulletin, 79 (4), 683 (2024).
6) P. Vereš, et al., Icarus, 203 (2), 472 (2009).
7) D. Farnocchia et al., Icarus, 219 (1), 41 (2012).