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ACTIVITIES IN RUSSIA ON NEO DETECTION: ASTRONOMICAL REQUIREMENTS, INSTRUMENTS AND PROGRAMS

B. M. Shustov[(1)], S. A. Naroenkov[(2)], V. V. Emel'yanenko[(3)]
[(1)] *Institute of Astronomy, Russian Academy of Sciences, 48 Pyatnitskaia, Moscow, 119017, Russia, tel. +7 495 9515461*
[(2)] *ibid*
[(3)] *ibid*

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INTRODUCTION

NEW DEFINITIONS OF DANGEROUS CELESTIAL BODIES

In the last few years new insights in the NEO problem have appeared. The Chelyabinsk event has brought us to the understanding that meteoroids of decameter sizes are considerably dangerous and they should be included in the coming programs of massive detection of potentially hazardous objects (PHO). This implies that class of PHO (in its classical definition as bodies larger than 140 m with perihelion distance q < 1/3 a.u.) should be considerably expanded.

We propose (see [1]) to determine the PHO definition by changing the lower boundary of body size from 140 m to 10 m. In addition to updating the lower size boundary we introduce additional definitions of the dynamic (orbital) hazardous body classes. We suggest that PHOs (and, consequently, their orbits) be called *threatening* if, on the one hand, the estimate the closest distance d from their orbit to the Earth's center and the accuracy of the orbit characterized by dispersion σ_d in the target fit the following requirements:

$$d < L_D \quad \text{and} \quad D - 3\sigma_d < R_E \qquad (1)$$

and *collisional* if they meeting the conditions

$$d < R_E \quad \text{and} \quad 3\sigma d < R_E\ . \qquad (2)$$

The latter definition does not correspond strictly to collision inevitability, since collision probability for such a body (orbit) is slightly less than 50%. However, all measures to counteract such a collision should be the same as in a case where collision probability reaches

100%. Figure 1 illustrates these conditions for determining a threatening and a collisional body.

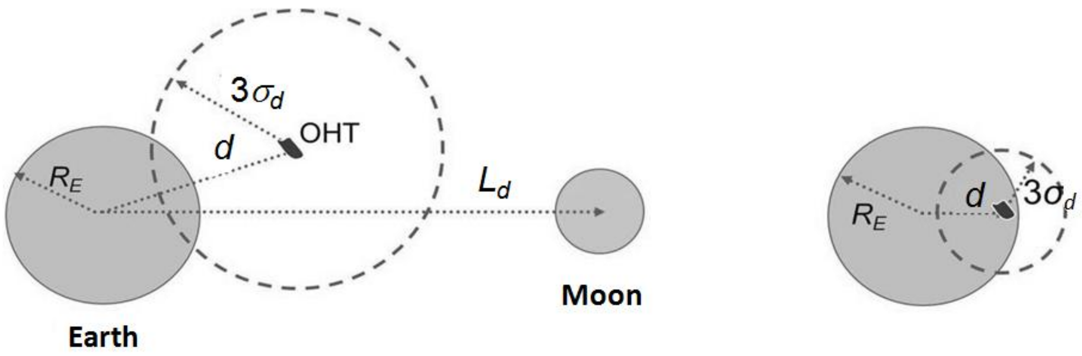

Fig. 1. To definitions of threatening body (right picture) and collisional body (left).

ASTRONOMICAL REQUIREMENTS:

The task of massive detection of PHOs is to be considered as two tasks:

1. long range detection of relatively large bodies (> 50 m) which ensures warning time not less than some weeks (this makes possible organization of counteraction);
2. detection of decameter bodies in the near Earth space (this makes possible warning only).

Construction of national and international system(s) of detection of potentially hazardous objects (PHO) is considered as a practical task in many countries including Russia. This implies that all the requirements should be quite distinct. Basic input requirements are essentially astronomical ones by nature. Spatial distribution of PHOs is important to know if one intends to efficiently organize a survey for detection. The warning time and approach velocity of hazardous bodies limit the required distance at which first detection must be done. From the other side the minimal size and albedo of the PHO are major limiting factors for detection hazardous body with given instrument at this distance. Orbital characteristics of the PHOs, number and distribution of observed positions of the objects (i.e. planning of astronomical observations) as well as an accuracy of astrometric observations strongly influence on the minimal length of orbital arc (and consequently on the time of quasi-continuous observation) required for the reliable classification of orbit the PHO. We reconsider here in a systemic way these and some other astronomical issues in order to understand requirements (practically important ones) for construction of the observational instruments and methods. These are different for tasks 1 and 2.

To study the characteristics of PHO distributions observed across the celestial sphere, we used a sample frame of 1073 PHO (data extracted from Minor Planet Center archivesa at Nov. 2012). We considered the projections of NEA spatial distributions, more precisely, the pictures of NEA distribution positions in the coordinates of the geocentric ecliptic latitude and longitude depending on the volume of the observable space. This volume was set by size (radius) *R* of the observed sphere with its center in the Earth's center. This work considered two extreme cases of *R* [0; 0.05], i.e., a near zone, in which PHOs can appear, and a large volume *R* [0; 1], where the intervals of *R* values are given in astronomical units. For a more explicit representation of NEA distributions, we assumed that the objects are distributed evenly over the mean anomaly and their discovery occurs at random times. Therefore, 360 varied orbits (clones), which differed only in their mean anomaly values with an increment of one degree, were created for each object observed. If an object fell into the set interval *R*, its geocentric ecliptic coordinates (latitude and longitude) were calculated. This method of asteroid spatial distribution was used in [2]. Figure 2 shows distributions of (virtual) NEA across the celestial sphere in the Aitoff projection both for *R* [0; 0.05] and *R* [0; 1].

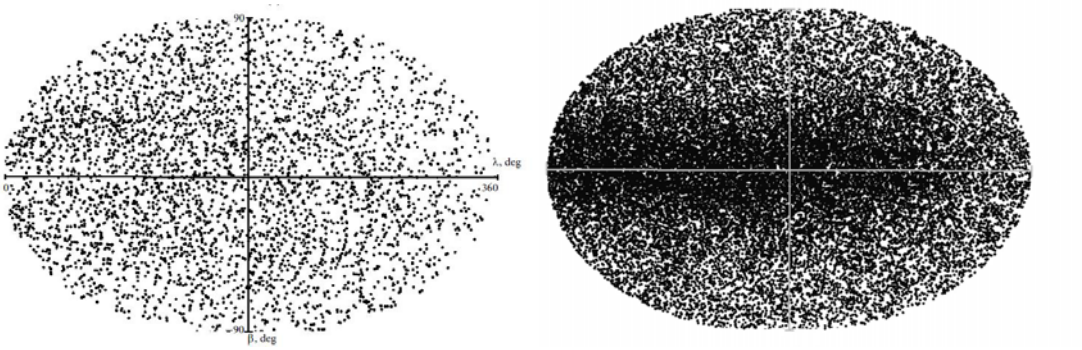

Fig. 2. NEA distributions across the celestial sphere of radius 0.05 a.u. (left) and 1 a.u. (right). See text.

Major conclusion is clear. Close PHO are distributed evenly across celestial sphere More distant PHO concentrate to ecliptic plane. The detection algorithm should take this into account.

In Fig.3 distribution of velocities of PHOs at distance of 0.05 a.u. from the Earth is shown (see details in [3]).

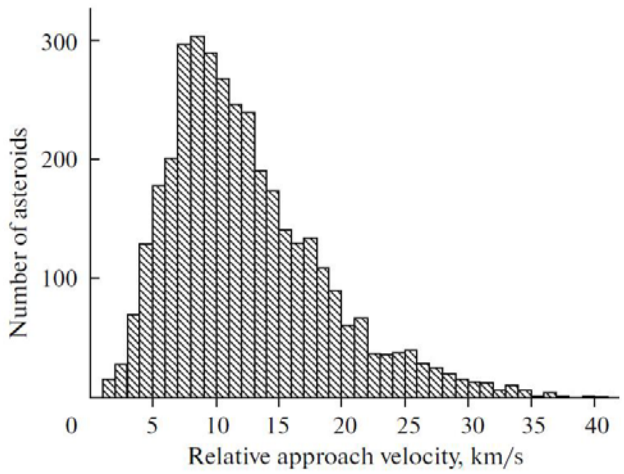

Fig.3. Distribution of PHA approach velocities at 0.05 a.u.(from [3]).

Again the major conclusion is quite clear: the estimated limiting distance for the detection of hazardous body is 40 км/с $\times t_w$ where t_w - warning time. For warning time of 35 days the limiting distance is 0.8 a.u.

General conclusions can be formulated as list of requirements for the construction of the efficient telescope.

For long range detection of PHO:

- Time interval between detection and rendez-vous must be not less than warning time (t_w). $t_w \sim 30$ days.
- V at approach < 40 km/s.
- For the object (at 1 A.U. from the Earth) an observational time interval of 7 days is sufficient for classification as PHO or TO.
- Limiting magnitude $V < 23 – 24$ (for relatively large bodies (> 50 m)).

This mode requires for some ~2 m class wide field ground based telescopes and/or few ~1 m class wide field space telescopes.

For detection in the near Earth space

- Time interval between detection and rendez-vous must be not less than warning time (t_w). $t_w \sim 5^h$.
- V typically 20 km/s .
- Limiting magnitude $V < 18$-19 ((for bodies larger than 10 m)).
- A properly located system of ~ 0.5 m aperture wide field telescopes is required (in visual domain).

The mode requires for system of reasonable number of ~0.5 m class wide field telescopes. Including of space telescopes is obligatory to meet requirement of surveying the "whole sky".

RUSSIA OBSERVATIONAL GROUND BASED NETWORKS AND INSTRUMENTS

Russia continues to develop studies on NEO problem in various directions (see [4]). Ground based instruments both working and under construction are briefly described.

The largest Russia detection telescope AZT-33VM 9 ([5]) is to be completed in 2016. This is a wide field 1.6 m aerture telescope at the Institute of Solar-Terrestrial Physics, Siberian Branch of the RAS (see Fig. 4. and table 1)

Table 1. Parametrs of AZT -33VM.

Spectral range	400-1100 nm
F	5600 mm
focal ratio	1:3,5
2ω	2,80
2y'	277 mm

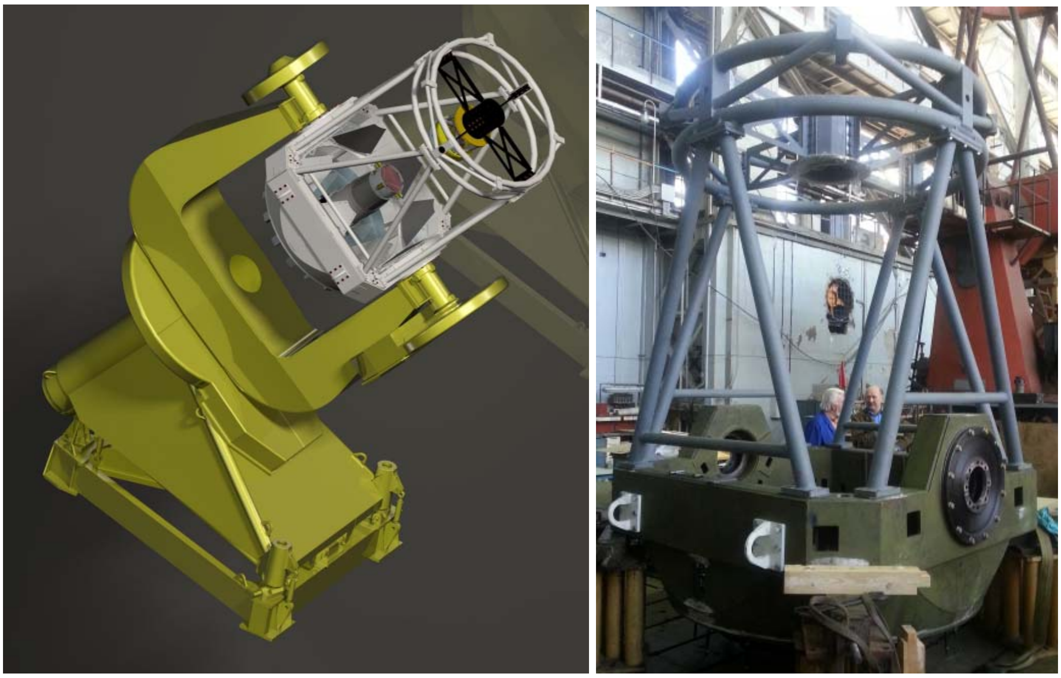

Fig.4. AZT-33VM. Mock up (left) and construction in LOMO Co. (right).

The moderate and small telescopes are efficient for detection of PHO in near space and monitoring. The most efficient networks are the ISON network of 40-65 cm telescopes is (see [6] and Fig.5) and MASTER (see [7] and Fig.6) network of 40 cm robotic telescopes that was originally designed for GRB alert optical observations but nowadays is used for asteroid and comet observations.

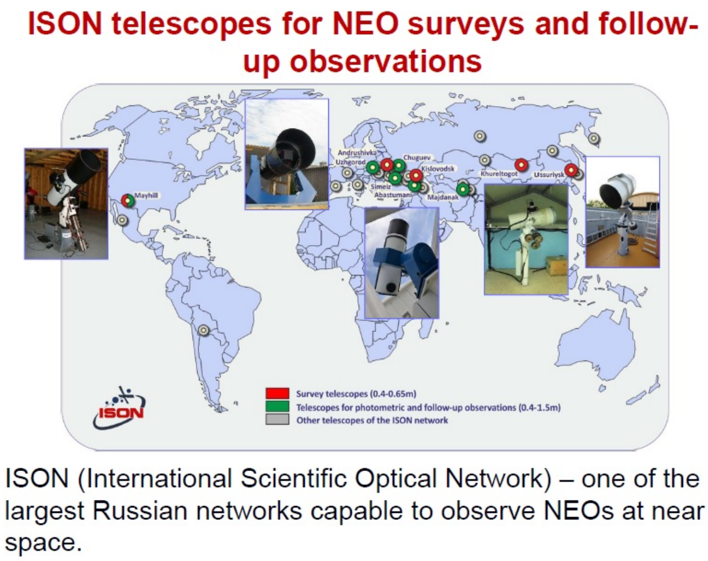

Fig.5. The ISON network. Major partners are Russian Academy of Sciences and Roscosmos.

Fig.6. The MASTER network by Moscow University.

Since recent the Roscosmos network is under construction (Fig.7).

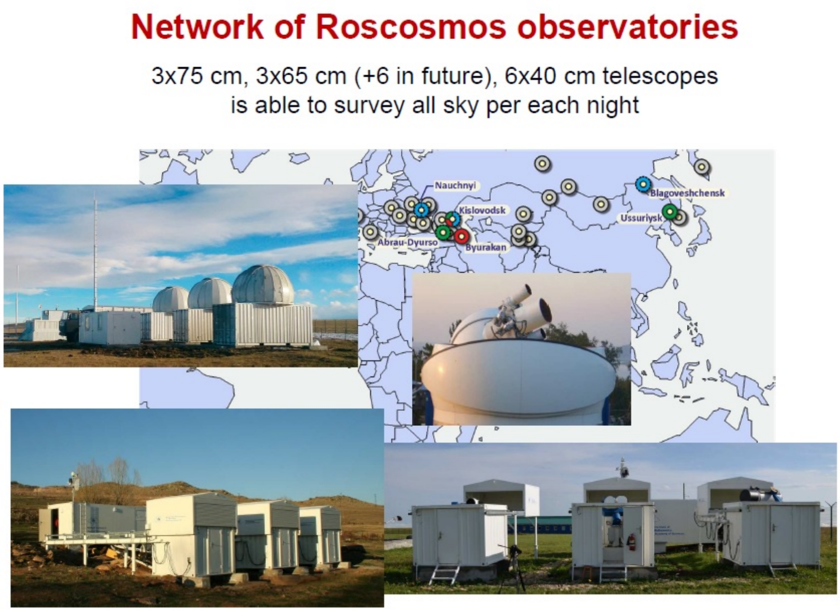

Fig.7. The MASTER network by Roscomos.

Though these ground based instruments devoted to detection and monitoring NEOs (moderate class dedicated telescopes of networks ISON and MASTER as well as larger telescope AZT-33VM) are rather numerous they are still not well integrated in the national network.

SPACE BORN PROJECTS FOR NEO DETECTION

Projects of space instruments are under design. These are projects with completed pre-Phase A study: NEBOSVOD (1.5 m optical telescope at GEO), EKOZONT (0.75 cm optical telescope ([8], an economical variant of NEBOSVOD). The most original project SODA is designed for detection of day time asteroids in near space. The idea of this project SODA (System of Observation Day-time Asteroids) is illustrated at Fig.8.

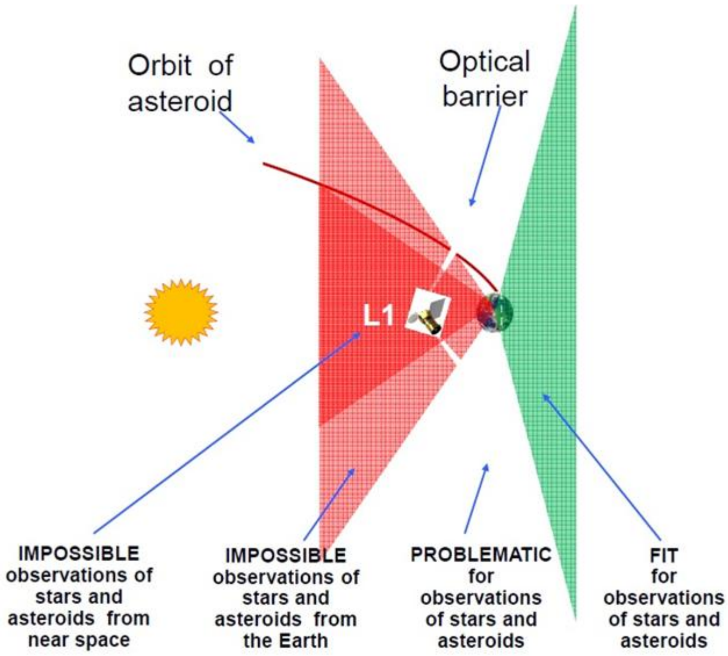

Fig.8. The idea of this project SODA (System of Observation Day-time Asteroids).

Small aperture telescope (50 cm) located in vicinity of L1 Lagrangian point seems to be sufficiently efficient to detect 10 m bodies that travel to the Earth from Sun (i.e. day-time asteroids and comets).

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