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ACTIVITIES IN RUSSIA ON NEO: PROGRESS IN INSTRUMENTATION, STUDY OF CONSEQUENCES AND COORDINATION

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Russia continues to develop studies on NEO problem in various directions. We present here the recent progress in three issues of practical interest: coordination, instrumentation and collision consequences.

COORDINATION:

In [1] it we argued that establishing of national (federal) NEO program seems to be the most practical way to the real international cooperation. Good examples of (inter)national programs were provided by NASA's NEO program and European SSA program. We believe that for the effective participation of Russia in the international cooperation on the NEO problem we have to develop a comprehensive national (federal) program. The arguments pro national (federal) program are simple:

1. The NEO problem is a multi-problem. Various organizations are to be involved (coordinated);
2. The capabilities of research centers are not sufficient for implementation and support modern service of detection and monitoring of NEO, in particular those requiring space facilities;
3. The expensive technologies of preventing collisions and mitigation can be proposed but not be realized under the responsibility of research institutions;
4. Cooperation of countries on the NEO problem implies the involvement of Russia Government (or authorized body);

5. Regular funding. This is absolutely necessary for the realization a real program.

The major elements of a concept of the long-term federal NEO program, that was prepared by the Expert Working Group on NEO by the Space Council of the RAS, were described in [2].

In the last few years new insights in the NEO problem have appeared in governmental bodies of Russia. The NEO problem seems to be recognized as a problem which attention on the federal level should be paid for. The issue of construction of special NEO detection instruments and techniques has been included into the Federal Space Program (FSP) for the period of 2016-2025. To remind, the FSP is a major planning document of space activities in Russia. The main goal of this special program named Dozor (Patrol) is to construct an efficient system for detection of dangerous bodies.

The system is considered to be incorporated in the system of international cooperation on the problem. Priority of the international cooperation is becoming more distinct for Roscosmos. Russian astronomical research institutions begin to join international projects for detection and monitoring NEOs (IAWN Project). Roscosmos plans to activate it’s participation in the SMPAG Project, though till now these plan remain just plan. Since 2016 Russian institutions also participate in the relevant PR Projects (e.g. Asteroid Day).

INSTRUMENTATION:

Recent progress in ground based instruments both working ones and those under construction as well as space born facilities are briefly described.

In 2016 a new 1.6 m wide field (see major parameters in Table 1) telescope AZT-33VM has got the first light. The instrument is installed at the Mondy observatory of the Institute of Solar-Terrestrial Physics of the Siberian Branch of Russian Academy of Sciences. It is to be used for search of NEOs in a long distance mode. First test frames that were made with single detector mode (FOV 0.5 degrees) and general view of the telescope are presented at Fig.1.

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

Table 1. Parametrs of AZT -33VM.

First observations of asteroids of asteroids were sent to MPC. To be efficient for NEO detection AZT-33VM will be equipped with a camera with set of 16 detectors.


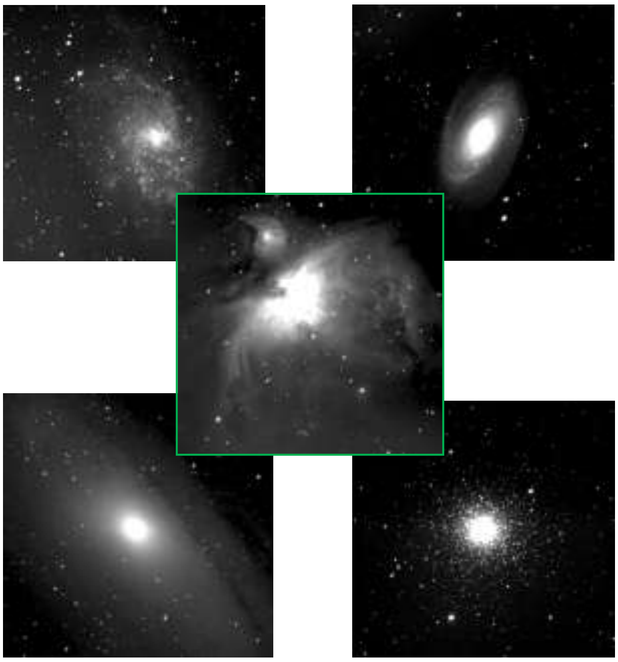

Fig.1. General view of the telescope AZT-33VM and the first optical test frames (single detector mode with FOV 0.5 degrees).

Small aperture ground based instruments that are evoted to detection and monitoring NEOs in the near Earth space are working on NEO in networks ISON and MASTER. A number of new robotic small aperture telescopes is under construction. Here we describe only one example.

After the Chelyabisk event it became evident that not only large asteroids but also ~10 m size bodies can be dangerous. Although the number of detected NEOs rapidly grows due to efficiency of special surveys there remain large uncertainties in population numbers, physical properties and dynamical characteristics of small asteroids. Current program of survey typically focused on 100 m class objects. The cataloguing decameter size NEOs is a task for very remote future. The only way to protect Earth against such bodies and/or to mitigate is to detect NEOs and to warn about possible collision. A team from Institute of astronomy RAS proposes to build INF (INASAN NEO Finder) – a dedicated network of robotic telescopes to detect 10 m class NEOs entering into the near Earth space. Several hours of warning time provided by INF project seems to be sufficient to decrease risks. Larger warning time implies dramatically larger cost.

INF multi-aperture telescope consists of 8 telescopes VT-78d mounted at ASA DDM160 mount (Fig.2, left). VT-78d telescope is a new generation wide field telescope designed by V. Terebizh (INASAN patent №162010 (RU)). The telescope provides a unique combination of aperture, field of view and image quality: (250 mm aperture, 10 degrees FoV, 4 arcsec quality). Very important feature of the VT-78d is simplicity and manufacturability of its optics. In VT-78d simple optical elements are used. All optical surfaces are spherical, all optical elements are made of ordinary glass (see Fig.2, right). More information on INF and its technical constituents one can find in [3].

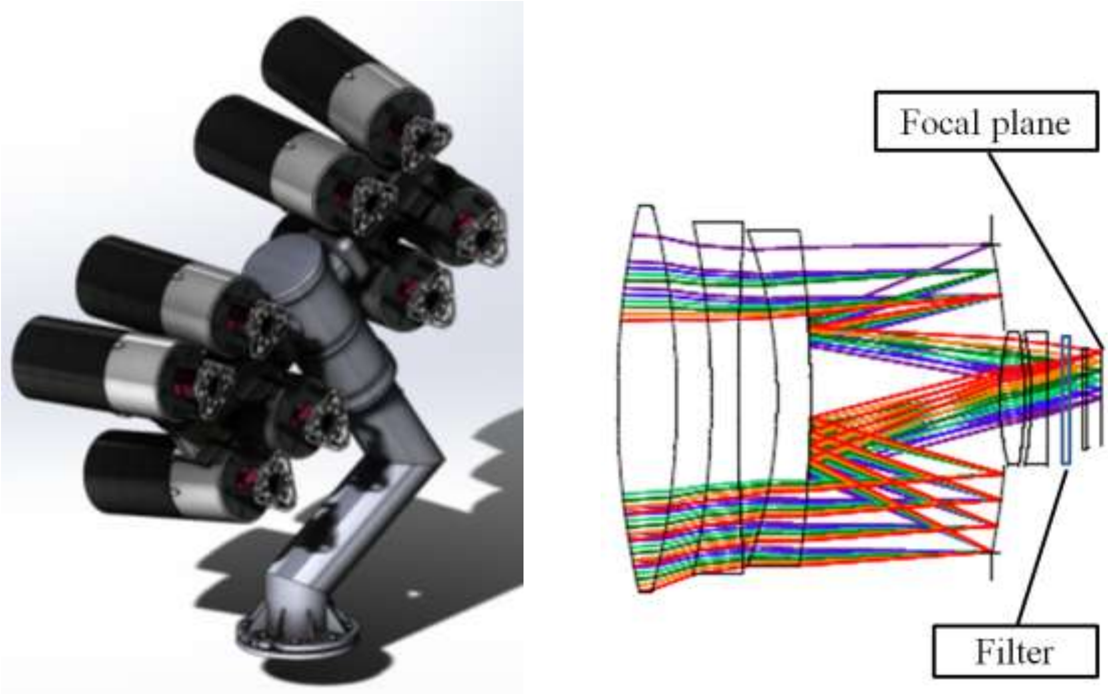

Fig.2. Left - general view of the INF multi-aperture telescope: 8 x VT-78d at ASA DDM160 mount. Right - VT-78d optical layout.

The Moscow University satellite ”Lomonosov” (launch in 2016) equipped with cameras for detecting bodies in the near space has brought first results. First images from Russian cameras with ultra-wide FOV, named SHOK, were recieved on May, 14, 2016 (see Fig.3). Two 8 cm aperture mini-telescopes with FOV of about 1000 square degrees each are designed for simultaneous optical observations of the most powerful explosions in the universe GRBs, which are the result of a collision of neutron stars and black holes (short gamma-ray bursts). See for the details http://lomonosov.sinp.msu.ru/scientific-equipment-2/shok .

These cameras are considered as prototypes of future space born instruments designed for NEO and space debris detection and monitoring. In Fig.3 many artificial objects that are flying near the ”Lomonosov” satellite are seen. These are mostly satellites and space debris. Close passages of satellites and space debris appear as bright stripes.

Projects of larger space instruments (NEBOSVOD-2 and SODA) are under design.
In [4, 5] the project of space system SODA (System of Observation of Day-time Asteroids) for exhaustive detection of decameter (larger than 10 m) bodies coming from the Sun direction to the near Earth space (Chelyabinsk type meteoroids) is described. The set of medium-size (30 cm) wide field telescopes will be put into vicinity of L_1 (Earth-Sun) point. Observations will be performed in barrier mode. General idea of the project is illustrated in Fig.4. The entire project could be implemented with off-shelf components.

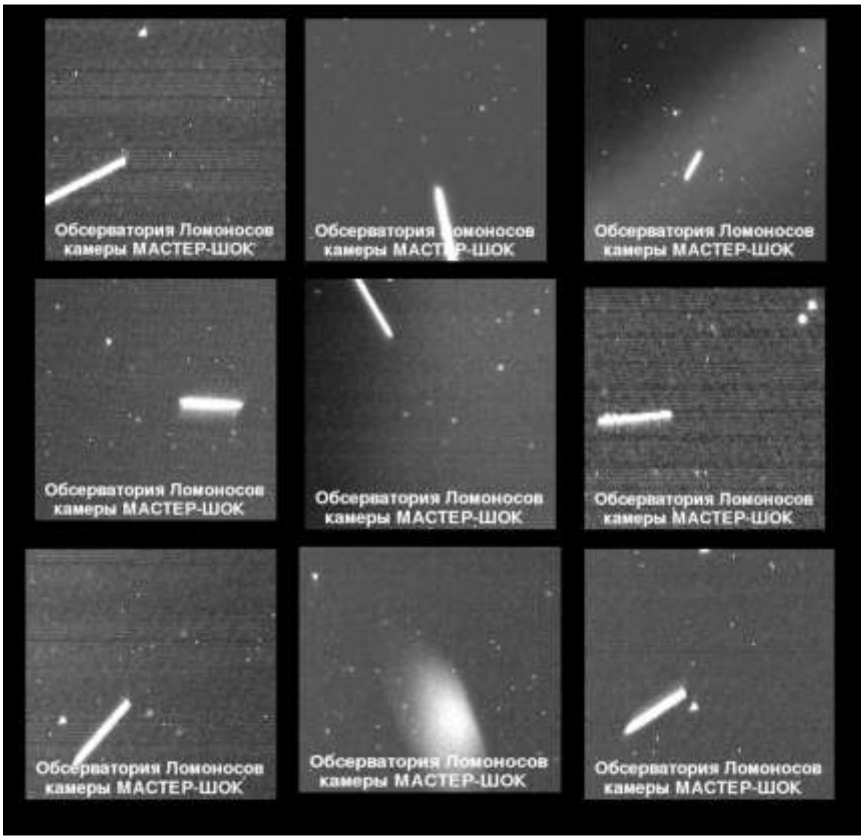

Fig.3. The first snap shots made with SHOK: wide field mini –telescopes.

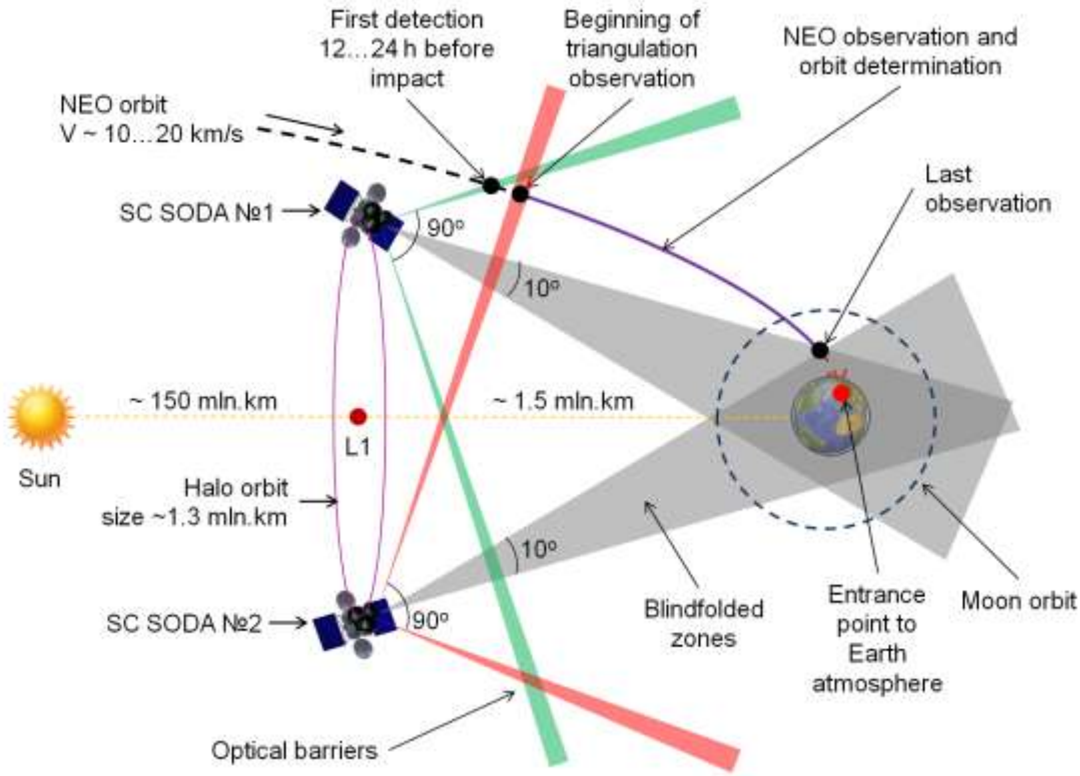

Fig. 4. Scheme of observation with SODA project . View from ecliptic pole.

COLLISION CONSEQUENCES:

Special attention is paid to study of the collision consequences and mitigation methods.

Experts of the three institute of the RAS: Institute of Dynamics of Geospheres, Institute of Oceanology and Institute of Astronomy proposed to construct world data-bank of impact consequences. The initiative was launched at the UN NEO group AT-14 meeting in Vienna in February 2012 and introduced in more details in [1]. The data bank is considered to be similar to those elaborated and/or under creation for tsunami and climatic hazards in some developed countries.

The idea is simple. It is known that the consequences of a collision are very dependent on many details: the characteristics of the colliding body, parameters of atmospheric entry, the relief details, the density of populations, industrial environment etc. One requires a lot of CPU time at the most powerful supercomputers to calculate consequences with a sufficient accuracy. The suggestion is to pre-calculate the consequences for all the most “sensitive” regions on the Earth (see e.g. [6]) during “quiet age” (before the next serious collision). This will speed up and facilitate decision-making process. It is clear that for some countries it will be problematic to construct an own part of the relevant data bank. A dedicated international program would be helpful.

Shuvalov et al. (see [7]) have began development of methods for calculating the consequences with a “classical” case of asteroid 99942 Apophis. They have conducted numerical simulations of an atmospheric passage and an impact on the Earth's surface of a stony cosmic body with a diameter of 300 m and kinetic energy of about 1000 Mt, which roughly corresponds to the parameters of the asteroid Apophis, at atmospheric entry angles of 90° (vertical stroke), 45°, and 30°. The simulation is performed by solving three-dimensional equations of hydrodynamics and radiative transfer equations in the approximations of radiative heat conduction and volume emission. The following hazards are considered: an air shock wave, ejecta from the crater, thermal radiation, and ionospheric disturbances. The calculations of the overpressure and wind speed on the Earth's surface show that the zone of destruction of the weakest structures can be as large as 700-1000 km in diameter; a decrease in the atmospheric entry angle leads to a marked increase in the area affected by the shock wave. In fig. 5 the distribution of the maximum overpressure for four different entry angles is shown.

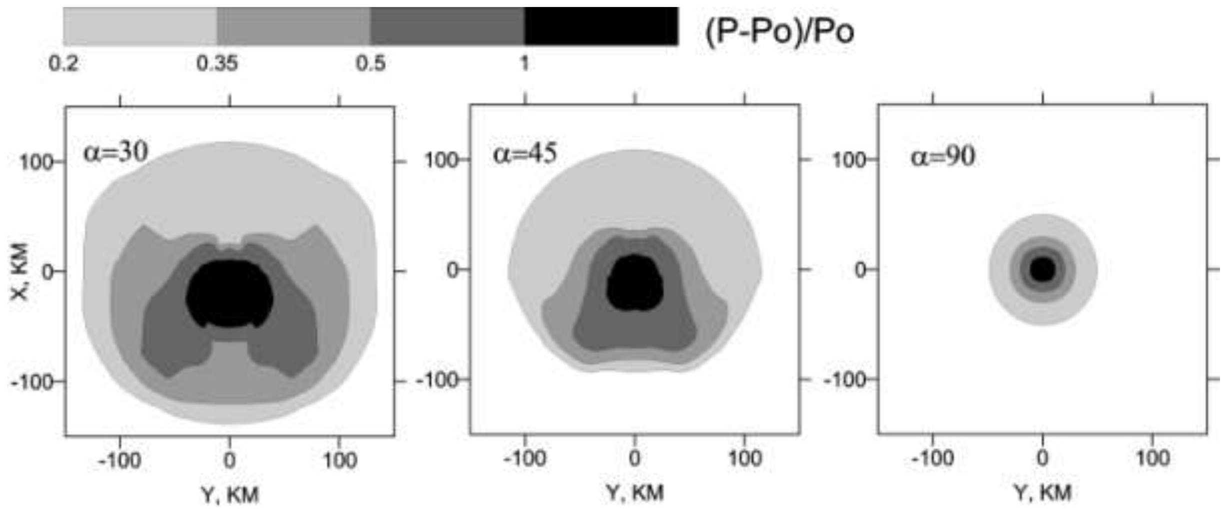

Fig.5. The distribution of the maximum overpressure induced by collision with a 300-m asteroid for different entry angles α (indicated on the panels). For two left-side panels projection of asteroid trajectiory is directed to the bottom side of the panel.

The consequences of collision are rather complex. The ionospheric disturbances are global in nature and continue for hours: at distances of several thousand kilometers at altitudes of more than 100 km, air density disturbances are tens of percent and the vertical and horizontal velocity components reach hundreds of meters per second. The impact of radiation on objects on the Earth's surface is estimated by solving the equation of radiative transfer along rays passing through a luminous area. In clear weather, the size of the zone where thermal heating may ignite wood can be as large as 200 km, and the zone of individual fire outbreaks associated with the ignition of flammable materials can be twice as large. In the 100-km central area, which is characterized by very strong thermal damage, there is ignition of structures, roofs, clothes, etc. The human hazardous area increases with the decrease in the trajectory angle, and people may experience thermal effects at distances of up to 250-400 km from the crater.

The construction of world data bank of consequences require internationally approved approach and technologies. At the moment several tens of the physically important parameters of colliding body (size, mass, velocity, trajectory angle, structure, composition are the most obvious ones), a lot of data on geological, social industrial etc. characteristics of a given area and mathematical (numerical) restrictions are considered as input data. We hope this initiative will be supported by scientific community and governing bodies.

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