OBSERVATIONS OF NEAR-EARTH SPACE OBJECTS AT THE SAYAN OBSERVATORY. OPPORTUNITIES AND PERSPECTIVES.

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Abstract. Optical telescopes of the Sayan Observatory of the Institute of Solar-Terrestrial Physics are multi-purpose tools, allowing us to carry out various observations of near-Earth space objects. Our priority problems are: tracking and measurement of the parameters of movement of high-elliptical and geostationary space objects with brightness up to 22 magnitudes and their multi-color photometry. We also pay attention to observations and search for space debris on other types of orbits, and to images of low-orbit satellites, when geophysical experiments with their participation are carried out in space. Some results of observations are cited, and the necessity of the application of wide-field systems with a high limit of detection, for maintenance of small-sized objects dynamic catalogue, is estimated in this paper. The basic characteristics of the experimental model of the wide-field telescope (diameter = 1.6 meters, field of view = 3 degrees), the current state, and planned date of putting into operation are given.

1. Introduction

Nowadays, the presence of the large number of space objects deduced from active operation mode and their fragments are a threat to space security. The information about high-elliptical space objects (with the height of apogee of more than 10000 km) is basically provided by optical sensors and methods. Multi-color photometrical measurements give the information for revealing the physical characteristics of the objects, such as form, size, material, and proper rotation. Regular trajectory measurements allow us to specify parameters of orbital movement, which are very unstable for objects with a high area-to-mass ratio (AMR).

2. Observations of faint objects in GEO

Regular observations of objects in GEO and HEO are provided due to the modernized telescope AZT14A and AZT33IR. Special attention is given to small-sized space debris and objects with high area-to-mass ratio. The trajectory information on 250 catalogued objects less than 15 mag has been obtained this year. Brightness and AMR distributions of the small-sized objects observed are shown on **Fig.1** (above), and distribution of their orbital parameters is shown below. A considerable number (53) of tracks (up to 18 mag), not operated by space surveillance systems (red color), has been registered. 19 new small-sized objects (having presumably the sizes of an order of 1 meter), basically with high area-to-mass ratio, are catalogued with the assistance of the "Mondy" observation point this year.

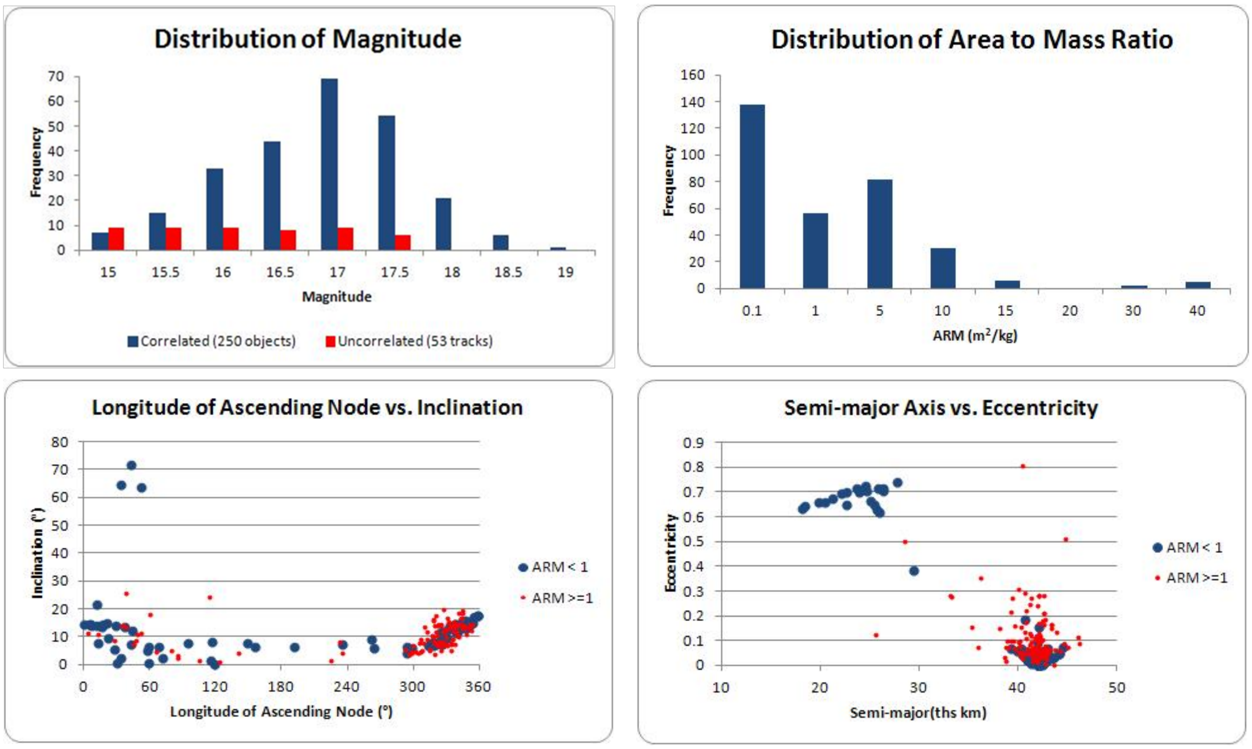


Fig. 1 Brightness and AMR distributions (above) and distribution of their orbital parameters (below)

Photometrical characteristics of objects with a high area-to-mass ratio show a large variety, and have no specific features distinguishing them from objects with small AMR. Both bright and very weak objects meet, and it was not possible to establish any dependence of the brightness of the object from the AMR in the sample of observations available.

The brightness of the most objects observed varies with time. Brightness variations may reach 2.5 mag. At the same time, some objects with AMR from ~3 to ~30 sq. m./kg., whose brightness remained constant throughout the session of observation, have been revealed (**Fig. 2**).

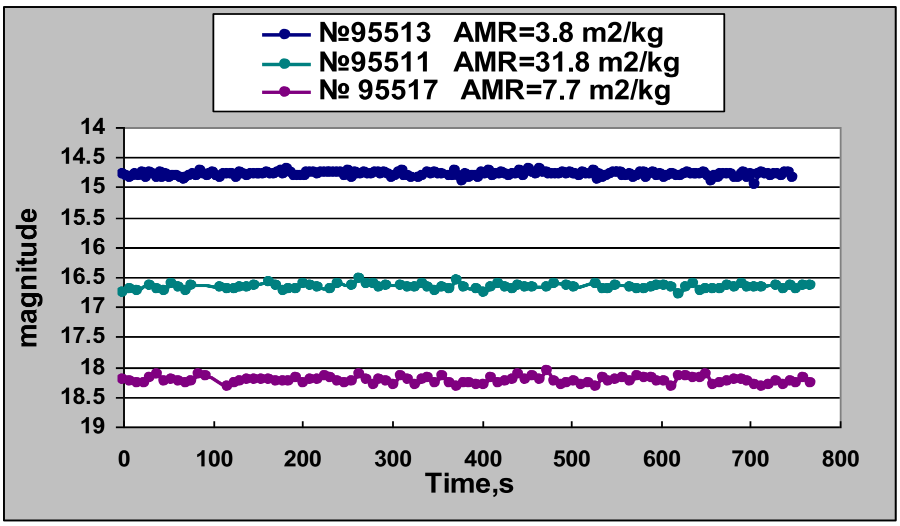


Fig. 2 Some objects showing constant brightness over the observation session

Color indexes of objects also vary largely, which is evidence of the various nature (material) of the objects with a high area-to-mass ratio.

We took a short series with consistently long exposures in each filter (of the order of the prospective period of brightness variations) for color index definition, to avoid fast brightness variations. Then the average object brightness was determined in each filter, and a color index was calculated for the given series. The color indexes averaged over all the available observation series are presented in **table 1**. Measurements are presented in the form of phase curves for each filter for clearness (**Fig. 3**).

No.	AMR m^2/kg	B-V	V-R
43213	1.4	1.5	0.76
43155	1.4	0.7	0.64
43096	1.8	1.6	0.77
90119	2.2	0.75	0.65
90103	3	1	0.6
90162	3.1	0.86	0.64
95397	3.5	0.6	0.42
90096	3.5	0.85	0.40
95300	21	0.65	0.43
90121	21.7	0.63	0.35

Tab.1 Averaged color indexes B-V

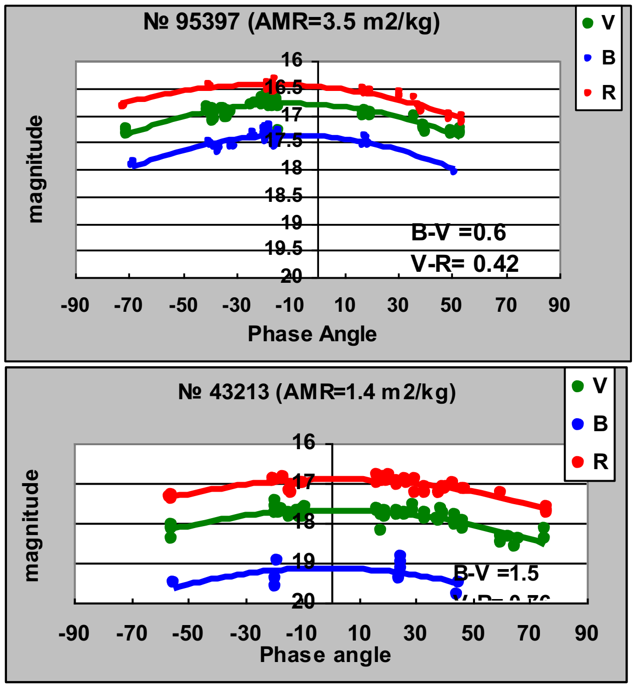
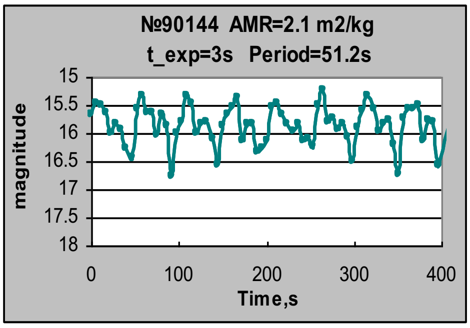
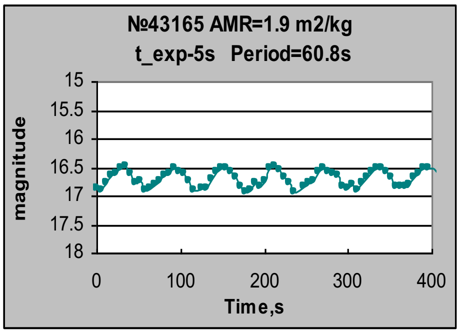


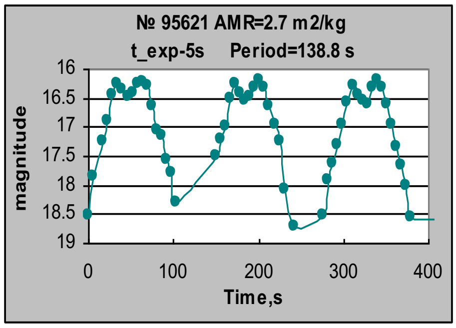
Fig.3 Phase curves in filters B, V, R

Various types of object light curves with high AMR with average brightness from 13.5 to 18.5 mag. are presented in **Fig. 4**. The top line represents the light curves of slowly rotating objects with periods of an order of minute and more. Such periods are easily defined both for bright and faint objects. The bottom line represents quickly rotating objects with periods ~ 10 seconds and probably shorter. Detection of such periods demands short exposures. Observation of faint objects requires a long exposure time, which can exceed the value of the brightness variation period. Therefore, detection of short periods of such objects is problematic [1].

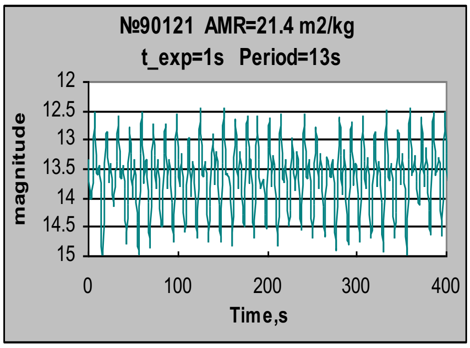
Objects with large period of brightness variations

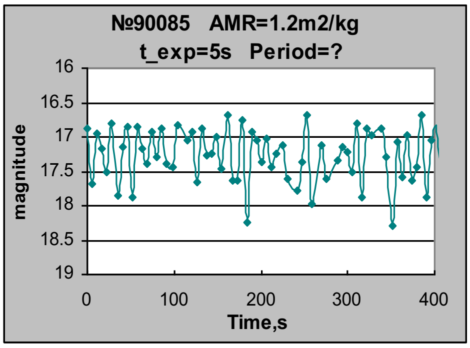






Objects with small period of brightness variations





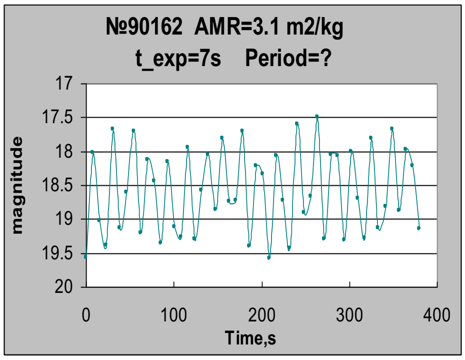
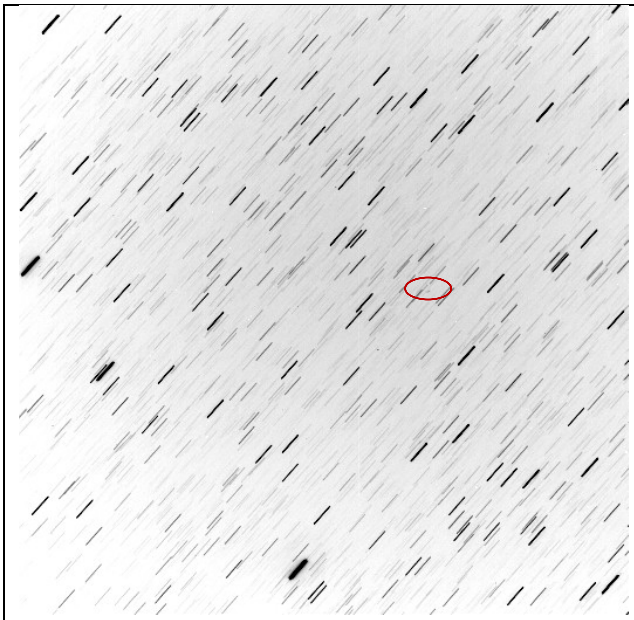


Fig .4 Light curves of the small-size objects with high area-to-mass ratio

2. First attempts to detect space debris in MEO

Nowadays, the navigational orbits of the satellite types of GLONASS and GPS are interesting from the viewpoint of the presence of space debris and the reliability of the operating satellites. In [2], the requirements for the methods and optical facilities for detecting non-cataloged objects on these orbits are described in detail.

To establish the presence (absence) of a non-cataloged space object, it is necessary to scan areas of the sky that are visited by active satellites, fragments of launches, and out-of-operation satellites. From the point of view of detection probability, the most preferable areas were the areas where the orbital planes crossed. Survey observations of space objects are carried out at the Sayan observatory on the AZT-14 telescope with the corrector in the prime focus, and are aimed at developing the method for detecting and measuring small-size space objects in MEO (of the GLONASS type). 10-16 non-cataloged objects were detected in each session with a duration of 3-4 hours. An object with 15 magnitudes, missing in catalogs, was detected. Measurements were made for that object on a long time arc (of the order of 40 min), and orbital parameters were calculated (see **Figure 5**). The orbit obtained may be referred to the region of MEO.



MJD =55869.000000 (2011 11 4)

T=0.530605

a=29560504.998354 m

e=0.000462

i=54.658956°

Ω=129.374908°

ω=49.778720°

n=1.708185 day-1

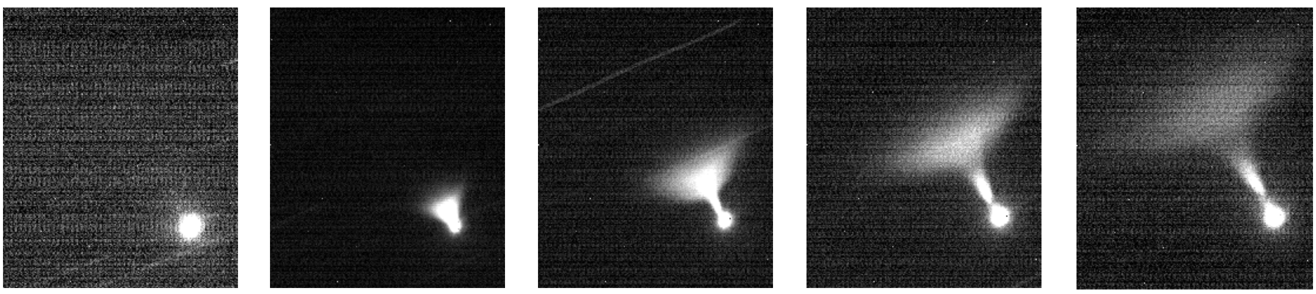
Fig. 5 Unknown object in MEO

3. Imaging LEO satellites in geophysical experiments

Optical observations of a cargo transport vehicle (CTV) «Progress-M» were performed during its onboard propulsion system operations (September 2010 and April 2011, as a part of «Radar-Progress» active space experiments). A typical CTV engine operation time was 7.5-8 seconds, whereas distances from the observatory were 350 – 420 km (at the moments of engine start).

The following phenomena were registered:

- A faint small «cloud» near the CTV at the moments of engine starts.
- A «jet» (rapidly changing in shape and brightness) which is the fuel particles emitted into space during a purging process after engine shutdown. A shock occurs when fuel particles collide with the environment material **(Fig.6)**



6.7 7.3 8.0 8.6 9.3

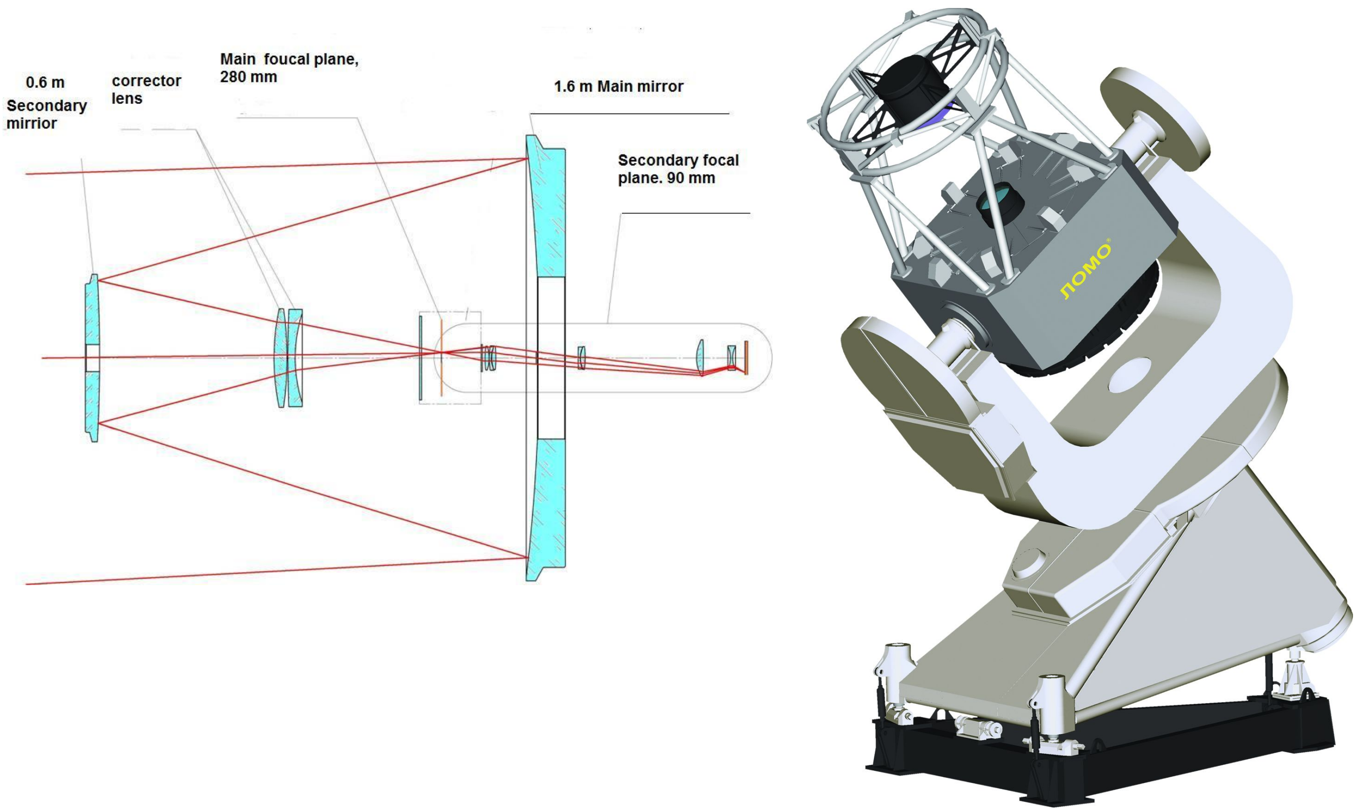
Fig. 6 Engine purging process between 6.7 and 9.3 seconds after the engine start

4. Wide-field telescope AZT33VM

Taking in consideration the number of objects observed and their distribution on the sky, it is easy to determine that the overview speed of the sky must be of the order of several hundred square degrees per night. As this takes place, the depth of the overview must exceed 21-22 magnitude.

Although the telescopes used for detecting small-sized fragments in GEO have a sufficient detection limit, their field-of-view does not exceed 0.3 square degrees. An overview of the GEO region with an area of 6000 square degrees takes about a half of the year, with this field of view and a measurement time of each area of 1.5 minutes. Taking into consideration the duration of dark time and the weather conditions, we cannot expect to solve the task of searching and cataloging of small-sized fragments. We need wide-field telescopes with a high detection limit, permitting us to overview the given area of the sky (of the order of 6000 square degrees) during one night.

A wide-field telescope with a diameter of 1.6 meters and 3° field of view is developed at ISTP SB RAS (Irkutsk) and LOMO (St. Petersburg) [3]. Its manufacturing will be completed in 2.0 - 2.5 years [3]. **Fig. 7** presents: optical scheme, telescope appearance, basic optical characteristics, and a prospective kind of photodetector.



Spectral range	400-1100 nm
f’	5600 mm
F/D	1:3,5
2ω	2,8°
2y’	277 mm

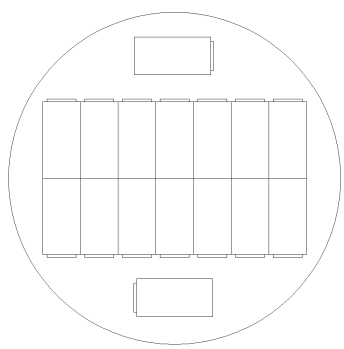


Fig.7 Wide-field telescope AZT33VM

Conclusion

Equipment of Sayan Observatory is successfully applied for measuring near-Earth space objects in different types of orbits. High-precision trajectory and multi-color photometrical measurements performed at Sayan Observatory cover a wide range of problems, such as: determination of the orbital parameters and photometrical characteristics of high-apogee objects and obtaining images of LEO objects. Observations performed at SO make a considerable contribution to maintaining the Russian catalog of high-apogee space objects.

Observations confirmed the existence of a constantly growing fraction of small-sized space debris and the possibility of its presence in MEO. Solving the current and prospective problems of assured detection of dangerous space objects is ensured by the manufacturing of wide-field optical telescopes with a high detection limit. Scientific and technical groundwork, available at SO, allows ISTP to complete the building of a wide-field telescope, AZT33VM, on a national experimental base by 2015.

Authors of the report express their gratitude and respect to their scientific head P.G. Papushev, who passed away January 31 2012.

References

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3. Denisenko S. et al. Optical Journal (2009) High–speed, wide field telescope AZT 33VM Optical Journal of Russia, 76, 10, 2009.