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Space born small aperture wide field telescope with full aperture slewing mirror to detect decameter size NEOs for the SODA mission

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The System of Observation of Day-time Asteroids (SODA) is a concept for a future space mission, aimed to observe asteroids approaching the Earth from daytime sky. The system (in optimal configuration) consists of two Spacecraft (SC) placed into orbits in the vicinity of the Lagrange point L1 of the Sun-Earth system. The mission is aimed to detect all bodies larger than ~10 m coming towards the Earth from the Sun's hemisphere.

Some years ago, we presented pre-Phase A study (feasibility and definition) of SODA. The baseline design of the SODA's payload included up to 3 identical optical 30 cm aperture telescopes.

Recently substantial improvements of optical features of the SODA project were made. These include a new optical design of the telescope, pre-aperture slewing mirror and new detector. Here we describe the improved design of the SODA project and take special attention to the optical issues.

SODA telescopes should provide two modes of operation:

- complete discovery of new asteroids coming from the solar celestial hemisphere using the barrier technique of detection;
- target mode to accurately define the orbit of a dangerous asteroid.

In order to optimize the design of the SC, both modes should be implemented by a set of identical telescopes.

The technological progress in manufacturing a smaller pixel size CMOS (about 5 um) gives us the opportunity to design a more compact optical system without impacting the field of view, sensitivity and astrometric accuracy.

We have analyzed various optical schemes of the telescope and have chosen the axial F:1.5 prime focus lens corrector design. The optical scheme of the telescope is based on the Sonnefeld camera and consists of a two-lens aperture corrector, the inner element of which operates in a double beam path, a Mangen mirror and a two-lens corrector near the focal plane. All surfaces of optical elements are spherical. This scheme helps us to minimize the size of the slewing mirror (480×340 mm) and to provide a good image quality (up to 4 um RMS) across a 3.75 deg field of view. The slewing mirror provides a 50×120 deg area of observation with a single telescope.

The telescope tube provides basic suppression of the light scattering from the Earth and stars. The slewing mirror will be shielded from the direct light of the bright disk of the Earth by a light-shielding mask mounted on the rod at a distance of about 2 m from the telescope. The angular diameter of this mask will be about 10 deg, so observations of asteroids at an angular distance of less than 5 deg from the Earth will be impossible.

The suitable parameters of a visual-NIR CMOS detector for the SODA telescope are quite realistic: 30×30 mm photosensitive area size, 6×6 k format and 5 um pixel size. Both rolling and global shutters are acceptable. One of the recent examples to mention is the modern CMOS GSPRINT4521 with a photosensitive area of 23×18.4 mm, pixel size of 4.5 um with capacity of 30000 e- and readout noise of 3 e- RMS.

To solve the problem of mass detection of asteroids flying from the Sun using the optical barrier technique, at least two telescopes, each capable to monitor a 50×120 deg observable area, are needed. The combined field of view of the two telescopes provides a full angle of 100...120 deg at the apex of the cone of the optical barrier which is enough for the SODA project. However, in the 2 telescope option, there is no redundancy. This option can only be recommended in case of a very severe weight limit or cost limit of the project.

In the 3 telescope option about 50% of the total monitored sky area can be simultaneously observed by two telescopes. This will increase the reliability of the system, if one telescope fails, only 17% of the observable area will be lost. The other benefit of 3 telescope option is a possibility to observe potentially hazardous bodies in the tracking mode synchronously with two telescopes from one SC, which will increase the astrometric accuracy.

The 4 telescope option will provide a fully redundant system, all objects can be observed with two telescopes simultaneously.

Depends on the budget, 3 and 4 telescope options can be recommended for the SODA project.

The characteristics of the SODA system can be improved by using a modern off-axis TMA optical design or by freeform optics which provides more parameters for optimization. Because of the absence of vignetting and in combination with a small pixel size CMOS detector with an enhanced NIR sensitivity, this approach potentially allows us to decrease the telescope aperture down to 20-25 cm without impacting the system efficiency. A smaller aperture implies a reduction of the overall mass of the payload as well as the total cost of the project.