Possibility of the Near Earth Objects Distance Measurement with Laser Ranging Device

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Abstract

The orbit perihelion of a some of minor planets is nearer from the Sun than the Earth's orbit. Observations are possible only in a small part of the orbit. Orbital elements of them cannot be determined accurately because we have only angular coordinates. The use of a laser ranging device for distance measurements will greatly improve the precision of determining orbital elements.

Keywords: *minor planets, laser ranging*

Introduction

We know a number of minor planets whose orbital perihelion is nearer from the Sun than the Earth's orbit.[1] Accurate forecasting of their motion is not possible, because they can be observed only in the vicinity of aphelion when their lighted sides are turned toward the Earth, and the Sun is located on the opposite side. Observations are possible only for a small part of the orbit because the planets are small in size and it is not possible to observe them from the Earth even with powerful telescopes. In order to determine orbits more accurately, we assess the possibility to measure the distance to these orbits with a laser ranging device. [2, 3, 4]

Possible measurements of minor planets with laser ranging device

A possible scheme of the experiment is shown in Fig. 1. The laser device LAS, which is situated on the Earth, radiates impulses of light in the direction of the minor planet MP. The distance is L and the diameter of the laser beam is d_{la}:

$$d_{la} = 2 \cdot L \cdot \mathrm{tg}\, r_d \tag{1}$$

where r_d is the diffraction, the angle radius $r_d = 1.2197\ \lambda/d_t$ that depends on the radiation optics' diameter d_t and the wavelength λ [5].

As the energy l_i diffraction image is irregular, the energy radiated in the direction of the minor planet E_{ep} can be calculated using formula

$$E_{ep} = E_{las} \cdot c_{at} \cdot c_{op} \frac{\int_0^{d/2} l_i(r) \cdot r \cdot dr}{\int_0^{r_d} l_i(r) \cdot r \cdot dr} \tag{2}$$

where E_{las} – laser emanated energy;

c_{at} – light transmissivity of the atmosphere;

c_{op} – light transmissivity of the optical system;

d – diameter of the minor planet.

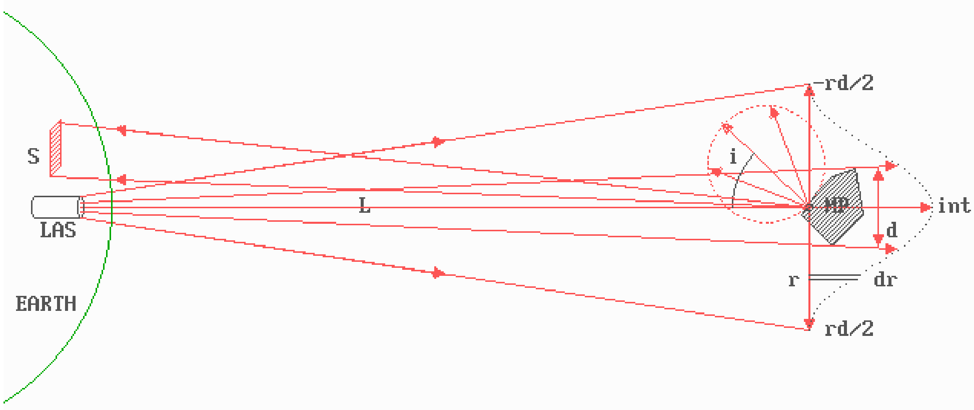

Fig. 1. Measurments of minor planets with laser ranging device

The surface of the minor planet is matted and its each element reflects the light in accordance with the Lambert Law. Area S on the Earth receives radiated energy E_e:

$$E_e = E_p \cdot c_{at} \cdot a \cdot \cos i \cdot \frac{S}{\pi L} \qquad (3)$$

where i – mean surface normal angle turned in the direction of the Earth;

a – reflection coefficient (albedo).

As E_e is very weak, the reflected energy can be described with the number of photons per unit of area $n_f = E_e/E_{fot}$, where E_{fot} – photon energy:

$$E_{fot} = h \cdot \nu \qquad (4)$$

where h – Planck's constant ($h = 6.622 \cdot 10^{-34}$ J·s);

ν – frequency of light wavelength.

The calculation results are showed in Table 1:

Laser energ. = 10 J

Laser wave length = 0.694 mkm

Laser beem divergence = 0.5819907" (2 r difr)

Atmospher transmitance = 0.8

Telescope transmitance = 0.9

Planets albedo = 10 % (black)

	Planets diameter, m				
	50	100	200	400	800
Range, km	Reflected photons on 1 km^2				
50000	1.953181E+7	6.593346E+7	1.413264E+8	1.583503E+8	1.631335E+8
100000	1275306	4882952	1.648337E+7	3.53316E+7	3.598758E+7
200000	80588	318826	1220738	4120841	8832901
400000	5052	20147	79706	305184	1030210
800000	316	1263	5036	19926	76296
1600000	19	79	315	1259	4981
3200000	1	4	19	78	314
6400000	0	0	1	4	19
1.28E+7	0	0	0	0	1
2.56E+7	0	0	0	0	0

***Table 1**. Reflected photons from minor planet.*

The minor planet is irradiated by the Sun. Energy received by the minor planet per second is:

$$E_{sp} = W_s \cdot \pi \cdot \frac{d^2}{4} , \quad (5)$$

where W_s – constant of the Sun (near the Earth W_s = 1360 W/m^2).

Of late, CCD devices with very high sensitivity in red waveband 0.694 μm wavelength laser have been used. In this waveband, the Sun's radiation is less intense than in the visible range. If wavelength is dλ, energy in the zone is

$$\varepsilon_\lambda = \frac{2\pi hc^2 \cdot d\lambda}{\lambda^5 \cdot e^{\frac{hc}{\lambda kT}} - 1} . \quad (6)$$

Energy of the reflected light is

$$E_{st} = E_{sp} \cdot \frac{\varepsilon_\lambda}{\varepsilon} \cdot c_{at} \cdot a \cdot \cos i \cdot \frac{S_{tr}}{\pi L} , \quad (7)$$

where S_{tr} is the area of the reflected light:

$$S_{tr} = \pi \cdot \frac{D_{dt}^2}{4} . \quad (8)$$

And the frequency f_n is

$$f_n = \frac{E_{st} \cdot q}{E_{fot}} , \quad (9)$$

where q – receiver quantum efficiency.

The probability that at least one photon enters the telescope aperture is small. If a telescope with 1.6 m diameter is used, about 50 reflected pulses may be detected in one hour, the noise from the solar background is 249 pulses per second on the average. If a larger receiving telescope is used, a minor planet’s trajectory can be spotted better, the measurements can be done at a larger distance and the reflected pulses received with a higher frequency (Fig. 2).

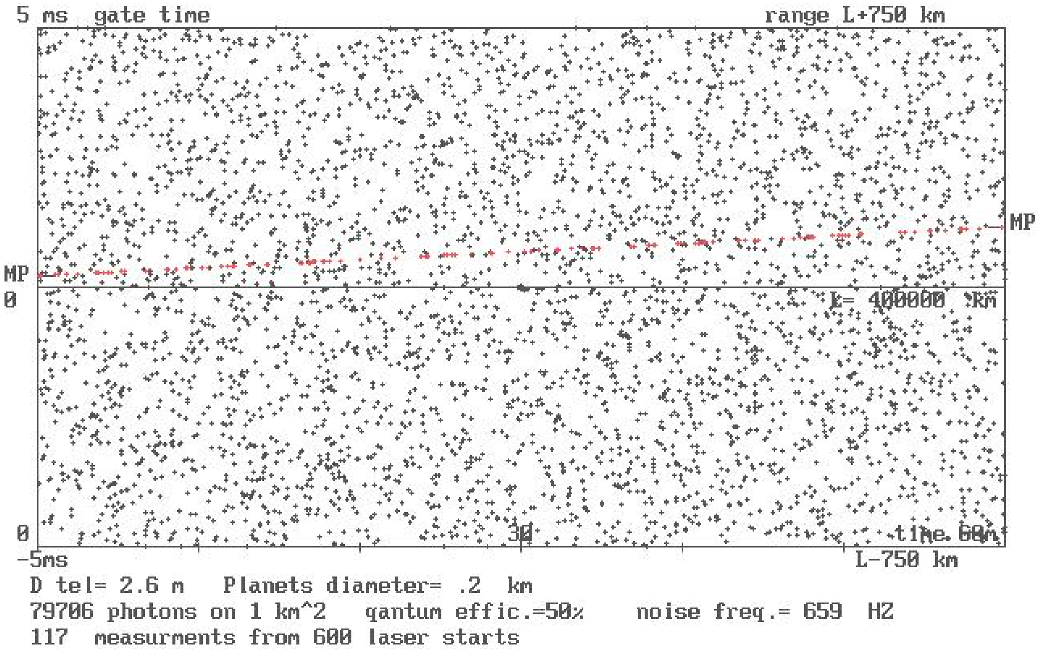

Fig.2. Reflected laser pulses and noise from minor planet

Experiment realization possibility

Described experiment is in planning stage. In order to ensure irradiation of the minor

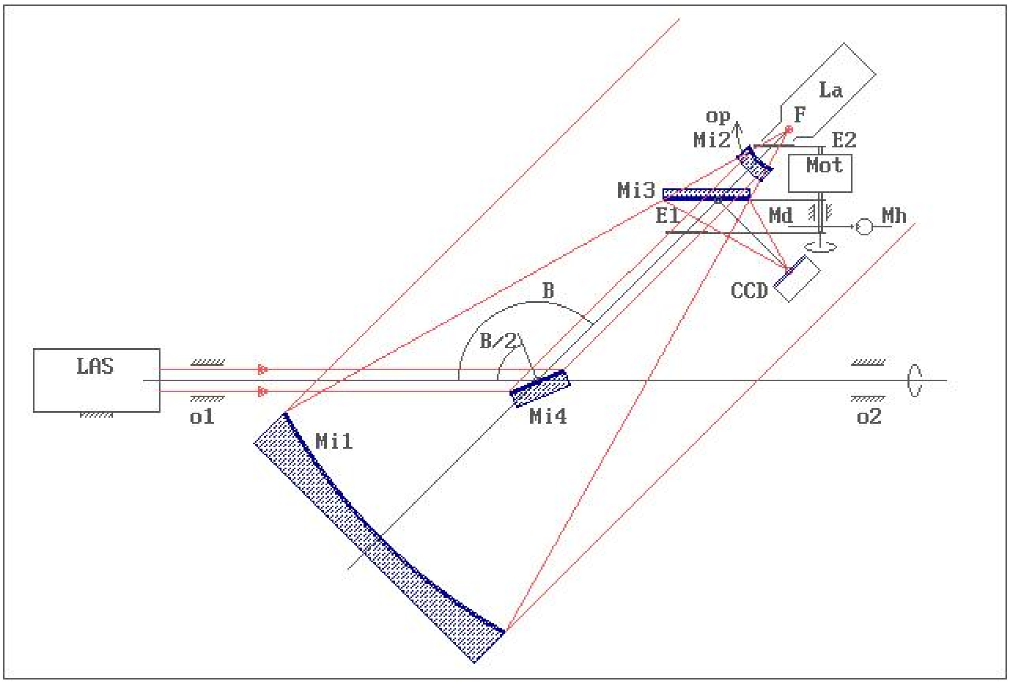

Fig.3. The laser arangement relative to the telescope

planet with a laser beam, a telescope for lighting up cosmic objects from the Earth is being devised at the Institute of Astronomy of the University of Latvia [Fig. 3, 4].

Its main optical element is the paraboloid mirror, 600 mm in diameter, that is put in a special mounting with a horizontal first axis of mounting. It allows for the laser beam to be directed to the irradiation object by a single additional mirror. [6] A laser device with the power level of 10 J can be manufactured in Lithuania by EKSPLA Company.

The receiver telescope of the reflected signal can be placed in a large distance from the transmitting source. Any astrophysical telescope with a mirror of over 1 meter in diameter could be used, and the 1.6 m telescope of the Moletai Observatory (Lithuania) could be a good option. In order to minimize the signals reflected from the Sun, for background impulses the exit of the telescope needs to be equipped with the narrow-band light filter.

Fig.4. *The telescope model.*

Taking into account that the transmitting and receiving devices are situated in a large distance each from the other, it is difficult to harmonize their frequency ranges. The frequencies of transmitted and reflected energy may also differ due to the Doppler Effect. Therefore, it is convenient to make use of a spectrograph with its exit equipped with a charge coupled device (CCD) camera. The scheme of the measurement device is showed in Figure 5.

The spectrum of the minor planet is projected on the outer column of the charge matrix CCD. At the time moment when the re-transmitted impulse from the planet can be expected, a frequency from the silica generator GEN, which moves the accumulated information along j axis, is supplied by the help of an electronic switch whose operation has been synchronized with the GPS time scale. When all matrix cells are filled consistently with the ordinary algorithm with the help of the synchronization scheme SINH through a digital amplitude modifying device, the matrix content is fed to the computer DAT. The available information covers ~ 1000 spectrum zones. One of them can capture the retransmitted impulses from the surface of the minor planet. Any needed zone can afterwards be found from within the absorption zones of the Sun. If a frequency that shifts information from one matrix column to another is 15 MHZ, the distance measurement discreet is 10 m. This allows realization of the showed algorithm of measure.

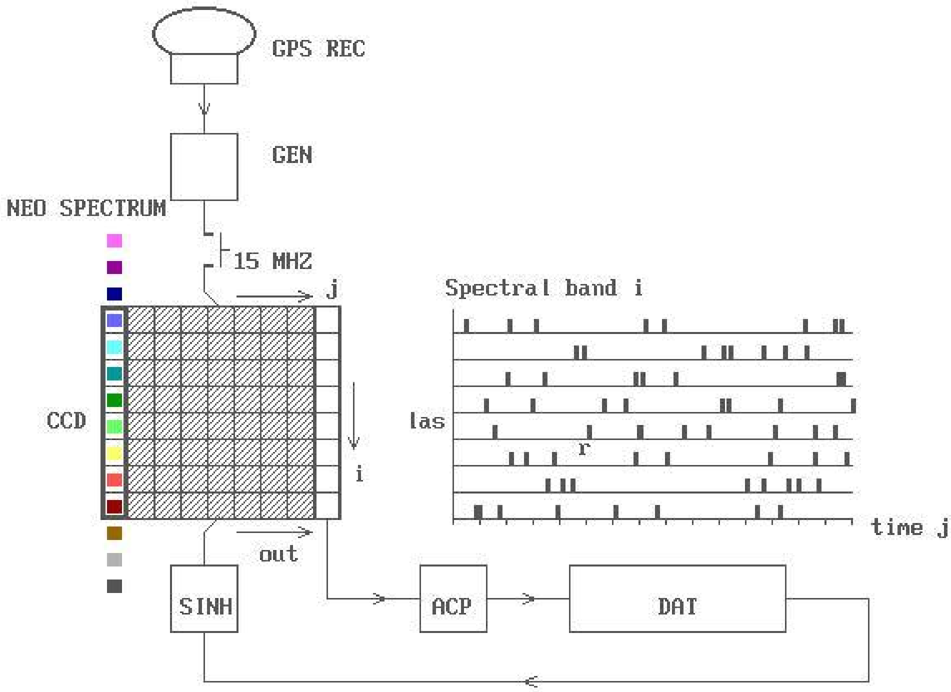

Fig. 5. Spectrograph for reflected pulses measurment

Conclusions

This project can be carried out in co-operation with other astronomers of the Baltic States. Its implementation would enable scientists to improve significantly the orbital elements of the minor planets that present danger to the Earth and to forecast their motion in the future.

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