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Practical work on asteroid-comet hazard based on open data as a component of astronomical education

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Abstract. Astronomical education is the basis for the worldview of modern man. However, not all universities and technical colleges in Russia teach astronomy courses. The proposed practical work based on open scientific data can be used in the system of astronomical education for both schoolchildren and students of natural sciences.

Keywords: Moon; minor planets, asteroids: general; comets: general; astronomical databases: miscellaneous

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1 Introduction

It all started in 1699, when by decree of Tsar Peter I, the School of Mathematical and Navigational Sciences appeared in Moscow. It was the first educational institution in Russia where astronomy was taught. The Sukharev Tower was built specifically for it in 1692-1695, where an observatory was equipped. "1/2 of the school's graduates, in addition to sailors, included engineers, artillerymen, teachers at other schools, surveyors, architects, civil officials, clerks, and artisans" (Veselago 1852). From that moment on, the science of celestial bodies became a compulsory discipline in technical schools: In 1715 the School was transferred to the New Capital, where the Maritime Academy was created on its basis.

In the 19th century in the Russian Empire, astronomy ("cosmography") was taught at the highest level. The fact that astronomy has been studied in secondary schools for 100 years is a unique fact in world pedagogy. In the Russian Empire, there were observatories in the following cities: Vilnius (1752), Kharkov (1808), Dorpat, now Tartu (1810), Moscow (1831), Kazan (1838), St. Petersburg, Pulkovo (1839), Kiev (1845) , Odessa (1871), Tashkent (1874), Simeiz (1908), and astronomy was taught at the following universities: St. Petersburg, University of Imperator's Acasemy of Sciences (1724), Moscow ($\sim$1764), Derpt (1802), Vilnus (1803), Kazan (1810), St. Petersburg (1819), Kyiv (1833), Odessa (1865).

In the first years of the USSR, the teaching of astronomy deteriorated significantly. But already from 1932 astronomy became an independent subject at school (35 hours). Its main purpose is the fight against religious views. A real astronomical boom occurred in the USSR with the beginning of the Space Age.

The second "failure" of astronomy occurred in 1993, when "the school was excommunicated from astronomy". Astronomical olympiads and scientists involved in the popularization of astronomy helped to survive it. Since 2017, astronomy has returned to the School Curriculum. However, only 4 universities teach a classical course in astronomy: in Moscow, St. Petersburg, Kazan and the Urals.

2 New type of practical works

We think there is a gap in astronomy teaching that can be filled with interesting, practical works based on open-access scientific data. We have developed one such work, which estimates the frequency of asteroid impacts on Earth based on crater count on the Moon and Mercury. This work has methodological advantages over traditional ones: 1) it touches on a topic that is relevant and interesting to students; 2) forms an objective idea of the diverse connections of the studied objects in nature; 3) is multidisciplinary, containing a large set of reference data from various fields;

4) the work is visual; 5) allows you to vary the material used; 6) does not require expensive equipment; 7) allows distance learning; 8) can be used in teaching various specialties (but not professional astronomers).

Conducting laboratory work involves:

– introduction to the concept of asteroid-comet hazard;
– study of possible mechanisms for the formation of craters and calculation of their sizes on the Earth, on the Moon and on Mercury depending on the parameters;
– training in the basics of research activities;
– estimating the frequency of asteroid impacts on Earth from photographs of the Moon and Mercury.

The data for the work — photographs of the Moon, reference data on geology and physics — was taken from open sources.

The proposed laboratory work allows the student to independently conduct a small but complete scientific research on a current topic and compare his results with the results of modern scientists. In laboratory work, the student gets acquainted with and operates with data from several sciences: physics, astronomy, geology. This approach encourages the student to become more familiar with scientific activities earlier and more deeply.

Even without changing its plan and content of laboratory work, the large volume of the archive of source data makes it possible to provide a large number of students with independent source materials. At the same time, you can easily modify the work in several ways. For example, assume that the image scale is not constant within the frame. The change in scale may be due to the tilt of the spacecraft camera towards the lunar surface. In this case, the student will be required to construct a scale model within the fragment to count craters.

Another possibility is to calculate the density of craters on the more cratered continents of the Moon and on the seas less rich in craters. This difference is explained by the fact that in the first billion years of the Moon's existence, the seas were filled with lava, which hid the previously formed craters. The goal of such work might be to compare asteroid impact rates during the "late heavy asteroid bombardment" of the Solar System with impact rates in later periods (including the present). For this option, the reference book must include the ages of the lunar seas.

Another option is to determine and compare the frequencies of asteroid impacts on the Moon and Mercury (as an option: on the Moon and Mars). The end result of this option will be to compare the frequency of asteroid impacts in different parts of the Solar System (at different distances from the Sun).

The practical work consists of four parts: *review*, containing a brief overview of the problem of asteroid-comet hazard, *theoretical*, *practical* and *methodological*. The theoretical part suggests solving assessment problems. Such problems, containing rather rough estimates, are useful as methodological point of view: they use simple and understandable physical models, to solve them it is necessary to involve various data from independent sources, and the estimates made are comparable with measurements presented in the relevant scientific sources.

In the practical part, it is proposed to measure the sizes of craters and count their number on a section of the lunar surface from its photograph, and then estimate the frequency of events associated with impact cratering. The frames were taken from the open archive of photographs[1] of the Lunar-Orbiter spacecraft. In this archive, several of the largest craters are circled on each frame, the diameters of which are known (but not indicated in the figure). This data allows us to determine the scale for measuring the remaining craters and the surface area of the Moon included in the frame. As a result of the calculations, the average frequency of objects falling on the Moon and Earth during the existence of the Solar System (4.6 billion years) is estimated.

Unlike the Moon, on Earth you can find either the youngest craters that have not yet been destroyed by erosion, or the largest. Today, about 200 craters with proven impact origin are known on Earth (AKO 2010). Of these, only 40 are suitable for statistical analysis, i.e. they have a diameter of more than 3 km and an age of less than 250 million years, and have been dated with an accuracy better than 10 million years. The average age of these craters is approximately 50 million years (Napier 2006), which is approximately 50–100 times less than on the Moon. Analysis of impact craters on Earth says that the fall of bodies creating craters with a diameter of $D > 1$ km occurs approximately once every 1000 years (Medvedev et al. 1996). This is about 8 times rarer than estimates for craters on the Moon.

The methodological part contains an approximate description of the sequence of work, methodological recommendations and the results of the time management we carried out when testing the methodology.

3 Conclusions

Astronomy is a discipline that shapes the worldview of modern man. We propose to strengthen its position both in universities and in schools by offering practical work in the form of a small research project, which contains all the necessary information and a description of the methodology for its implementation based on open scientific sources. The proposed practical work is the first such work. The advantage of this is that a student can independently do a small but comprehensive scientific research

[1] http://www.lpi.usra.edu/resources/lunarorbiter/

on a current topic and compare his results with the results of modern scientific research. It is also good that the student gets acquainted with and operates with data from several sciences: physics, astronomy, geology. This stimulates earlier and deeper familiarization with scientific activities. The work can be carried out at any university and can also be included in distance learning courses. It should also be noted that there is great potential variability in these work. Even without changing plan and content of it, the large volume of the source data archive makes it possible to provide a large number of students with independent source materials. At the same time, you can easily modify the work in several ways.

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References

2010, Asteroid-comet danger. Yesterday, today, tomorrow, Moscow: Fizmatlit

Medvedev Yu.D., Sveshnikov M.L., Sokol'skii A.G., et al., 1996, Asteroid-comet hazard, St. Petersburg: ITA RAS

Napier W.M., 2006, Monthly Notices of the Royal Astronomical Society, 366, p. 977

Veselago F.F., 1852, Essay on the history of the naval cadet corps, St. Petersburg