NEW SPECIAL COURSE " MAPPING OF PLANETS AND THEIR MOONS OF SOLAR SYSTEM" FOR STUDENTS.

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A new special course "The mapping of the solar system planets and their moons" has been produced for the students of the Moscow University Geographical faculty. The students prepare their course and diploma works on planets and moons successfully. The aim of this course is to acquaint the students with the new data about physical features of the Solar system planets and their moons, mapping of these bodies and using the cartographic method of investigation for obtaining a relief morphometrical characteristics, revealing spatial regularities as well as analysis of the distribution of typical topographic forms in comparative planetology. The lectures with the show of beautiful slides interchange with the practical works on analysis of the space images, maps and schemes. This is promote to better understanding of the material. This course renews every year because the new data acts from the space probes uninterrupted.

The main questions discussed in the course are following:

- The space era of the planetary investigation. The main features of the inner and outer planets. Peculiarities of planetary mapping.
- The main features of the Earth's moon. The history of the lunar mapping. Terrestrial and space surveys of the lunar surface. The main relief forms and methods of their representation on maps. Thematic mapping of the Moon. The perspective for creation of a lunar base and demands on large-scale maps.
- The history of mapping of Mercury, Venus and Mars. The methods of obtaining the surface images and photo maintenance. Catalogues of control points. The accuracy of cartographic gridding of photographs. The mathematical basis of the maps. Nomenclature of relief objects. Mapping of the Martian moons.
- Thematic mapping of the terrestrial planets.
- The giant planets and their moons.
- The representation of space achievements in the cartographic production.
- The role of cartographic methods of investigation in comparative planetology.

Students work with contour maps, writing the names of the main maria and mountains, and sites of space probes during the practical lessons. They examine the relief features which can be seen during full moon lighting: rays systems, boundaries of low albedo by the analyses of images obtained with the different conditions of lighting of the lunar surface.

Maps of Mercury are used for the examination of multi-ringed basins and inter-crater plains. Radar images of Venus are compared with the relief maps and geomorphological maps. Martian maps are used for calculating the density distribution of craters and determining the referenced age of regions. The Atlas of the terrestrial planets and their moons is used for discussion of thematic mapping. The morphological features of craters are studied using images of the Moon, Mercury, Venus and Mars, and also images of the moons of giant-planets.

An example of the lecture-review devoted the mapping of the Moon is given below.

Introduction

The Moon is the natural satellite of the Earth and the brightest object in the night sky. There is no atmosphere on the Moon as we are accustomed to, no rivers and lakes, no vegetation or living organisms. The mean lunar radius is 1737.5 km, and it is located at a mean distance of 384 400 km. The distance increase in apogee till 405 500 km and decrease in perigee till 363 300 km. The gravity on the lunar surface is 6 times less than on the Earth. Day and night with a temperature range of about 300° each last for two Earth weeks. In spite of this the Moon attracts us more and more with the possibility to use its exceptional conditions and resources.

Fig.1 The changes of the sizes of the near side of the Moon in the apogee and the perigee

Humanity will enter a very difficult period in future in the opinion of scientists. There will be no resources on the Earth, so it is already necessary to plan the mastering of resources of other planets and their moons. The Moon will become the first object for extraterrestrial industrial production. The creation of a lunar base and then a network of bases is planned in the next ten years. It is possible to extract oxygen, hydrogen, iron, aluminum, titanium, silicon and other elements. Lunar soil is the best raw material for obtaining various

construction materials and also for mining the isotope helium-3, which may provide a safe and clean nuclear fuel for the Earth's power stations. The Moon will be also used for exceptional scientific investigations. Studying the lunar surface scientists will be able to look into a very ancient period of our planet, because the features of the Moon's evolution retain their relief over billions years. Besides, the Moon will serve as an experimental base for the development of space technology and then it will be used as the main center of inter-space flights.

The Moon has been well investigated using terrestrial telescopes and more than 50 space probes. Twelve American astronauts visited the Moon during 6 missions of the "Apollo" programme.

A short review of the mapping of the Moon

It is surprising but everybody can make a drawing of the Moon even without a telescope. Look at the Moon in its full phase and draw the borders of the dark regions and you will have a 'map' of the lunar maria. If you have a field-glass or small telescope you can see large craters, mountains, valleys and other features of the lunar surface. So the Moon is an exceptional celestial body.

Drawings of the Moon were perhaps made in ancient Greece or China but we have no information about such drawings. So it is an interesting task for scientists to find ancient drawings of the Moon. Philip J. Stooke has published an information about Neolitic Lunar maps at Knowth and Baltinglass, Ireland in the journal for the History of astronomy in 1994 y. It is known that Leonardo da Vinci made drawings of the lunar maria in about 1505 y. English physicist William Hilbert (1544-1603) made pre-telescopic drawing of the Moon in 1603 year. It was published in Amsterdam later.

The first telescopic drawings of the Moon were made in 1609-1610 by Italian astronomer Galileo Galilei, German astronomer Simon Marius (1573-1624) and English astronomer Thomas Harriot (1560-1621). The more perfect the telescopes became the better were the drawings. Some of astronomers (for example De Rheita, 1645) drew the Moon in astronomical orientation where the north is at bottom, i.e. as one sees in a telescope. At the same time other astronomers (for example Van Langrenus) made their drawings in astronautical orientation where the north is at the top, i.e. as we see the Moon without a telescope. However, these drawings were not maps, because they have no coordinate grid.

As the result of prolonged observations with telescopes the main features of the motion of the Moon were discovered, for example librations - visual oscillations of the lunar sphere relative to its mean position caused by unequal movement of the Moon in its orbit for even rotation around its axis and also the incline of the axis and orbit to the ecliptic. Polish astronomer Janis Hevelius made some attempts to depict lunar librations on his maps in 1645.

The quality of drawings of the Moon became better with the time (for example, the draw by Cassini in 1680). But it was still not a map. The first map of the Moon was made by German astronomer Tobias Maier (1723-1762) in 1750. He used a control grid of 24 points determined by him and constructed a selenographical system of coordinates. There was a control net of selenodesical points, a net of coordinates in an orthographical projection , and a scale on his map. Maps of separate regions of the Moon on larger scales on several sheets appeared in the 19th century. For example the lunar map made by German amateur astronomer Beer and astronomer Madler who measured 105 control points with a high accuracy was issued on 25 sheets (40x40 cm each) in 1837.

In the middle of the 20th century the Moon became the first object of astrophotography and until the end of the century lunar pictures had a good quality but visual observations gave more details. About 120 drawings and maps for the near side were compiled before space flights.

There were no lunar maps in Russia as we know before the middle of the 20th century. However the first map of the far side of the Moon was compiled in Russia (USSR) on the basis of the first pictures obtained by space probe "Luna 3" in 1959. The first details of relief of the far side ever seen by humans were shown by the conventional signs , their coordinates were determined in the unified system of selenographical coordinates and 18 relief features were named after Tsiolkovsky, Giordano Bruno, Mendeleev, Tsu Chung Chi and others. Mare Moscovience (of Moscow) and Mare Ingenii (of dreams) and Montes Sovietici were also new names adopted by the International Astronomical Union. Usually Latin names are used on lunar maps. The first space pictures obtained on Earth had many distortions but the methods of processing suggested in the Sternberg State Astronomical Institute by Lipskiy Yu. N. allowed us to decipher many details. It is interesting that Mare Ingenii is shown in the place were there is now the famous South Pole - Aitken basin of diameter 2 500 km.

The first "Complete map of the Moon" on which were shown the near side (on the basis of terrestrial telescopic pictures) and the far side (on the basis of soviet space probes "Luna 3" and "Zond 3") was issued in the USSR in 1967 at a scale 1:5 000 000. Later this map was enhanced with the data of "Lunar Orbiter", "Zond 6,7,8" and "Apollo" and issued in 1969 and 1979.

During the 40 years from the beginning 1960 as many lunar maps and atlases were issued in the world as during the 350 years of terrestrial telescopic observations. These were maps of different scales and functions. In the USSR were issued : Atlas of the far side of the Moon, parts 1-3, "Photomap of the near side" 1:5 000 000, "A map of the Moon" 1:5M in astronomical orientation for amateur astronomers, " Map of the equatorial part of the Moon" 1:1M on 7 sheets and for part of the far side 1:2M, " Photometrical Map of the Moon",

"Albedo map of the Moon", "Map of Colour of the Moon" 1:5M, " Geological Map" for the near side, globes of the Moon at a scale 1:10M and others.

In the USA mapping of the Moon began from the compilation of the Photographical Atlas of the Moon edited by G. Kuiper who chouse the better pictures from different world observatories. The pictures resolutions in the center of the Moon is 0.7 km and in the edge is about 2 km. For compiling "Lunar aeronautical chart" at a scale of 1:1M a television camera was used at the Medi-Pyrenii observatory to follow the changes of shadow from different forms of relief to determine the heights of mountains and the depth of craters.

The maps of the Moon of different appointment were issued in USA at a scale 1:10M, 1:5M, 1:2.75M, 1:500 000, 1:250 000 and more large scale maps for the individual regions of the surface. The map "The Earth Moon" at scale 1:11 620 000 is of very high quality. It has been prepared by the Cartographic Department of the National Geographical Society of the USA and contains together with the images of hemispheres the schemes of the Moons' motion, views of the Moons' phases and many references. Some contemporary maps were compiled in Czechoslovakia by j. Klepeshta and A. Rukl, in Germany, in England and other countries.

There are 14 types of relief forms on the Moon which are the system of lunar nomenclature. Table 1 represents the main types of relief forms on the Moon.

Table 1. The main types of relief forms on the Moon.

The types of relief forms (Latin/Engl)	**Definition**
Catena/ Chain	Chain of craters
Crater / Crater	Ringed depression rounded by walls
Dorsum / Ridge	Linear elevation of irregular form
Lacus / Lake	Dark lower elevation region of small area
Mare / Sea	Dark lower elevation region
Mons / Mountains	Large elevation
Oceanus / Ocean	Extensive dark lower region
Palus / Marsh	Lower region less dark than sea
Planitia / Plain	Flat lower region
Promontorium / Cape	Part of highland projecting into a sea
Rima / Rille	Narrow shallow linear depression
Rupes / Scarp	Precipice
Sinus / Bay	Part of sea projecting into highlands
Vallis / Valley	Wide elongate depression

There are a description of the features of the reflecting of lunar relief forms

on maps in the author's paper " Lunar maps and globes compiled in the Sternberg astronomical institute" and the used literature in these volume.