EXTRACURRICULAR ACTIVITIES FOR SCHOOL STUDENTS WITH SPECIAL INTEREST IN ASTRONOMY

Astronomical observatory "Nicolaus Copernicus"
Varna, Bulgaria

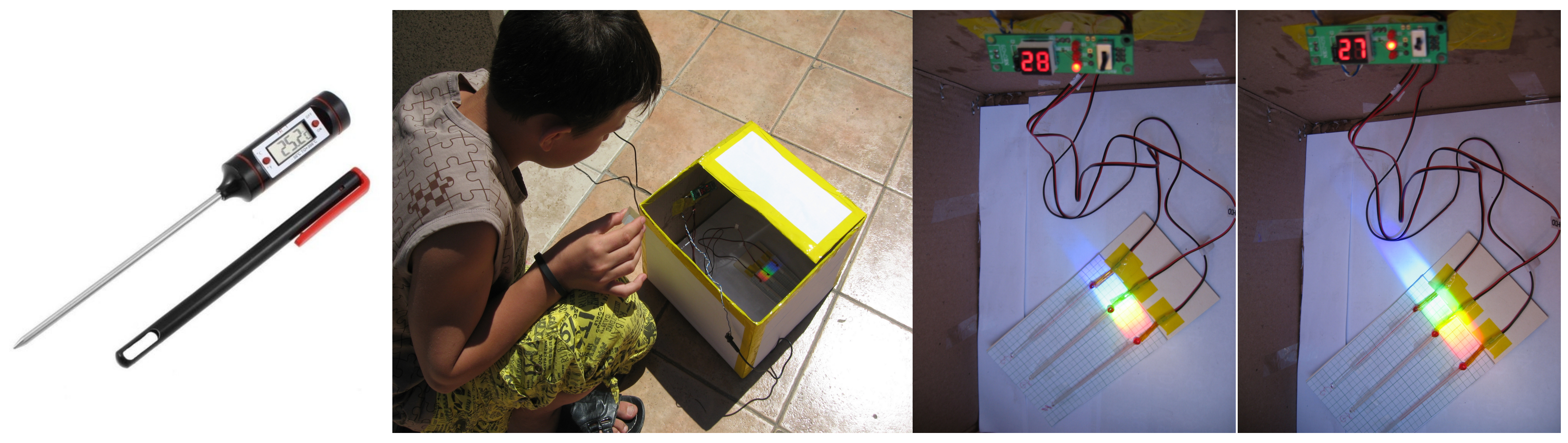
Antoaneta Avramova-Boncheva (1,2)
Eva Bojurova (1)

Abstract: *Due to the significant reduction of the physics and astronomy classes in the school curriculum during the recent decades, important phenomena and laws of nature for most of the students remain a mystery, which has a negative impact on their general knowledge and understanding. Extracurricular activities which take place in the public astronomical observatories of our country are an additional, and sometimes main source of information, especially for motivated students who are interested in science, but not only for them. Our observatory has a history of nearly 60 years (it was founded in 1963) and a very rich experience in this field. We organize free astronomy classes which are attended by students of grades 5-12 on a regular base throughout the whole school year. During the vacations the students participate in observing camps and expeditions. In addition to studying theory, a wide variety of experiments and observations of space objects are made. We present some of our ideas for extracurricular activities during the astronomy classes at the observatory. We have selected four lessons with which the students can point out or understand the concepts related to the main properties of light, determine the scale of various astronomical images and find the parameters of the objects or the size of features within the image. They can investigate the diurnal path of the Sun changing with the seasons. Last but not least we present an idea for observational exercise to determine Jupiter's mass using Kepler's third law.*

Herschel's experiment - discovering the infrared radiation:

This school year is special since the JWST space telescope was launched successfully on its long journey to L2. Our astronomical observatory's teaching staff has decided to spend a week dedicated to the telescope, during which students will learn about the structure of the device and the scientific aims of its mission. The first task was to explain to the students which part of the electromagnetic spectrum this telescope would be operating on and how infrared rays would be detected. The first portion of the experiment (Newton's experiment) related to the dispersion of sunlight from a glass prism. Once the students were convinced that sunlight is made up of the colors of the rainbow, we moved on to the actual experiment.

In 1800, William Herschel decided to investigate the thermal effect of the various colors in the spectrum of the sunlight. He used several thermometers placed in different color bands of the spectrum and found that the temperature rose from violet to red. But his control thermometer, that was in the "darkness" aside from the red band, showed the highest temperature. He concluded that there should be a kind of invisible "light" next to the red color So the infrared radiation was discovered. Our students repeated the experiment, using a glass prism, a box with a white paper sheet placed in the base, and a cooking thermometer with accuracy ±0.1°.

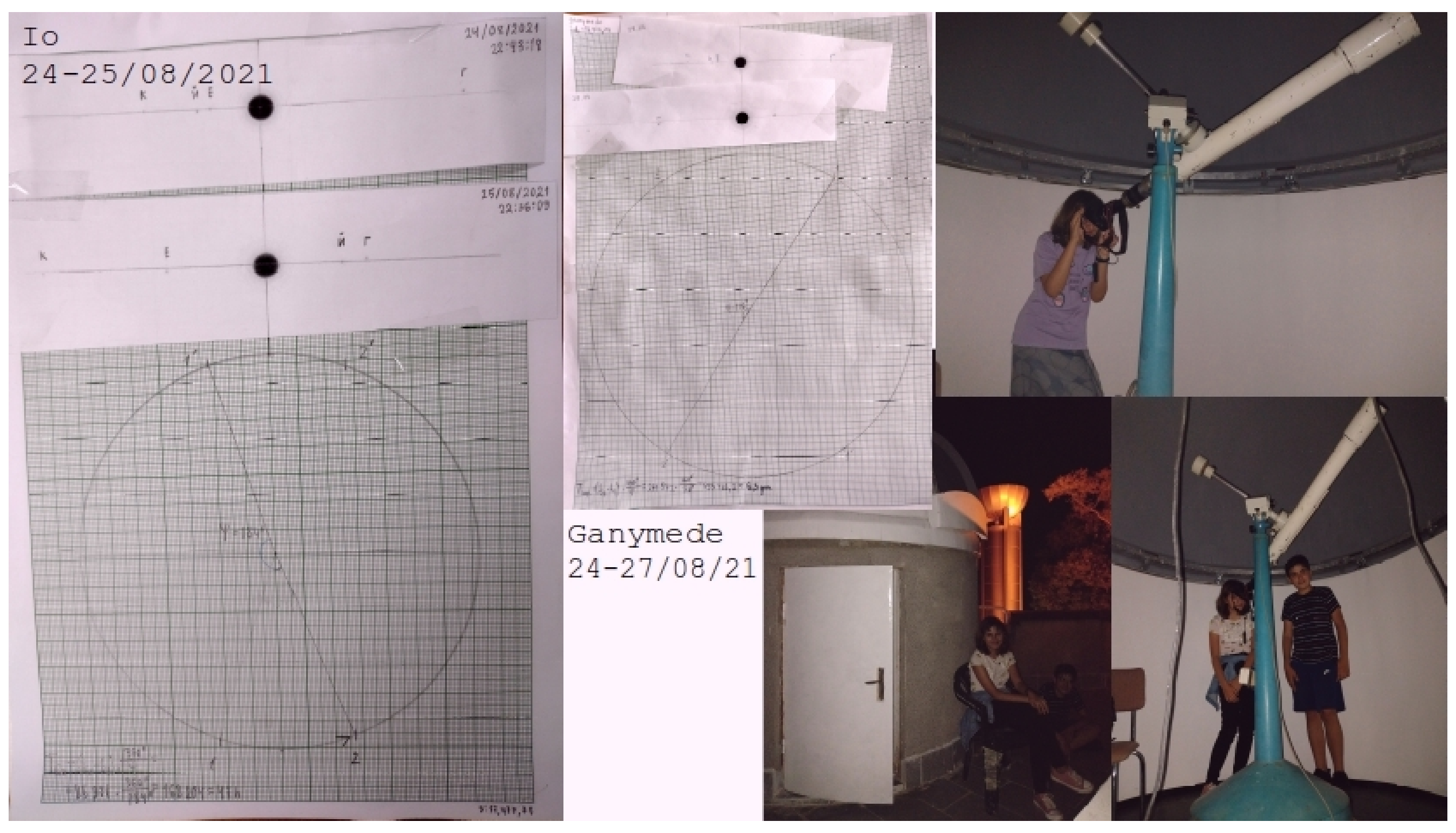


Measuring sidereal periods of Galilean moons and obtaining the Jupiter mass by using Kepler's third law:

An 8 cm refractive telescope with a guiding mechanism and a Canon 80D camera were employed for the task. On August 24, 25, and 27, 2021, photographic observations of Jupiter and its four Galilean satellites were made. The students turn the photos negative and accept the assumption that the satellites' orbits are circular. They use graph paper to draw the orbit of each satellite on a scale, using data from sources for the semi-major axis. By measuring the angle that the given satellite traveled between the two observations they can calculate the period of each satellite using Eq 1.
Using Kepler's third law (eq. 2) and the approximation:

$$M_1 \gg M_2 \Rightarrow M_1 + M_2 \approx M_1$$

the pupils also determined **Jupiter's mass**. Table 1 shows all of the results.



$$T = (t_2 - t_1)\frac{360^\circ}{\psi^\circ}$$

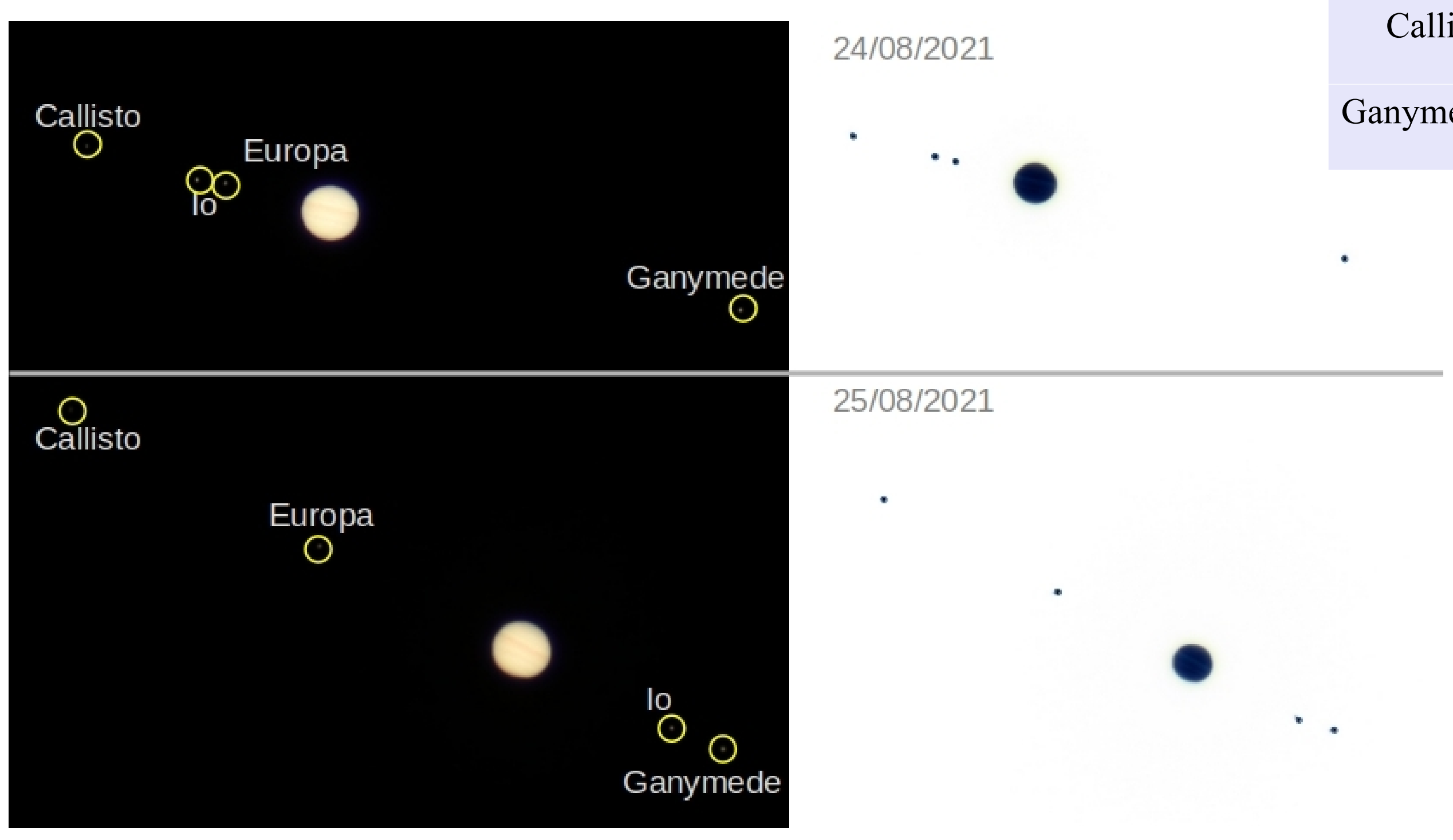
Eq.1

$$T^2 = \frac{4\pi^2}{G(M_1 + M_2)}a^3$$

Eq.2

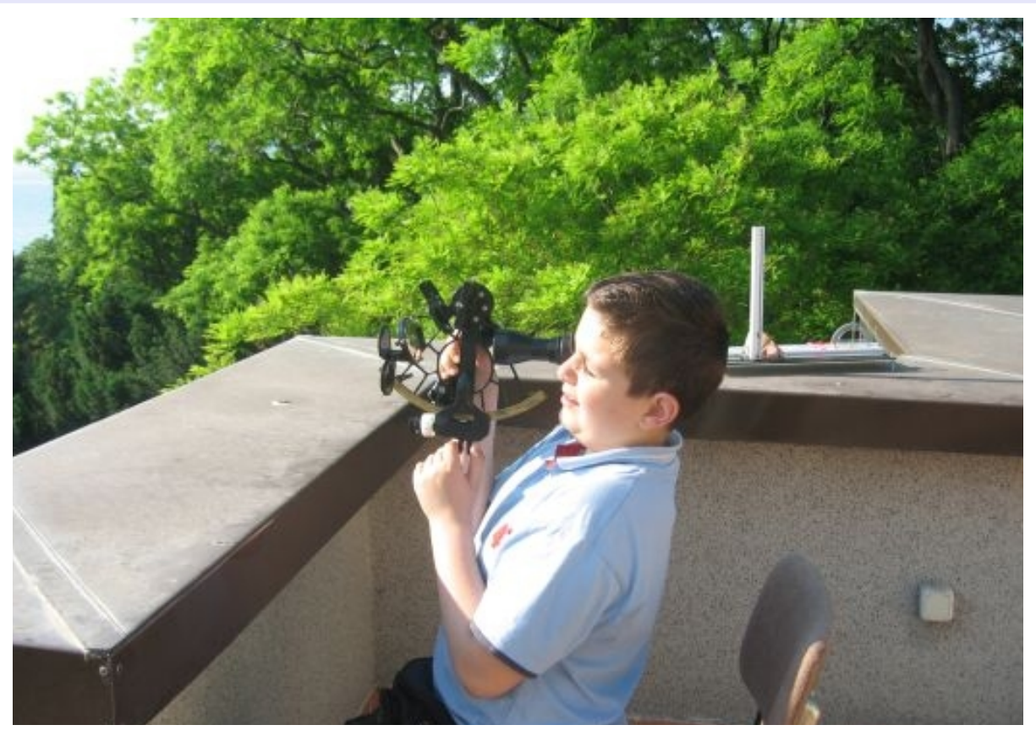
Object	a [km]	T [sec]	M_J [km]
Io	421800	168204	1.56993×10^{27}
Europa	671100	315632	1.79570×10^{27}
Callisto	1882700	1345633	2.18134×10^{27}
Ganymede	1070400	555488	2.35246×10^{27}

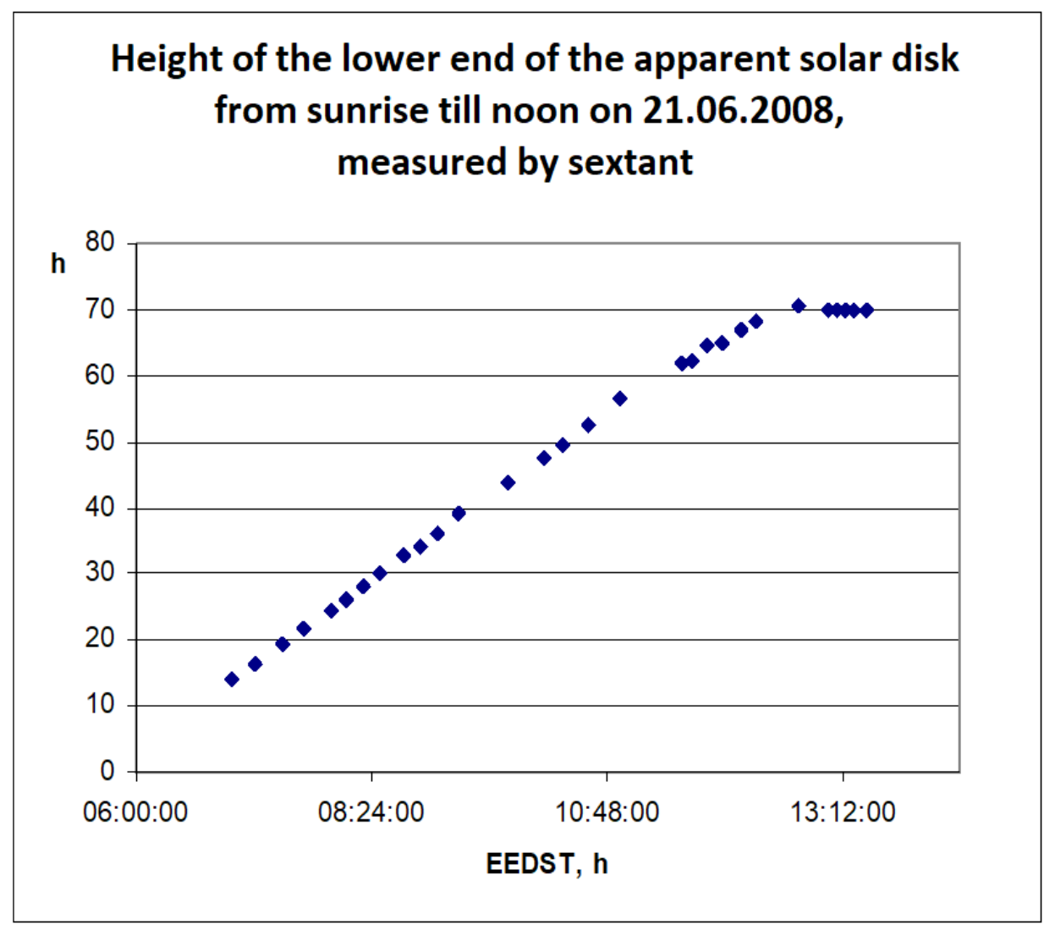
Tab.1

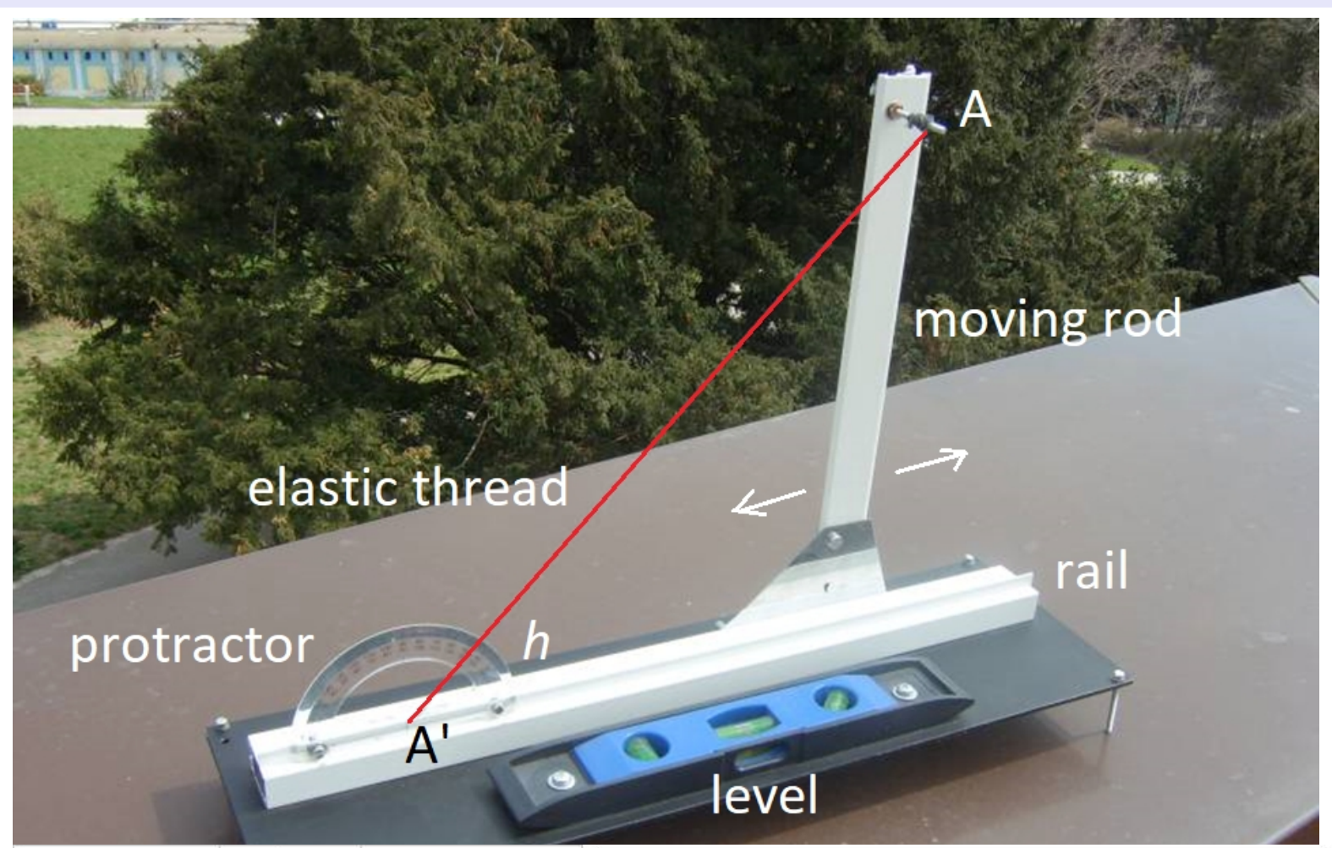


Measuring the height of the Sun above the horizon

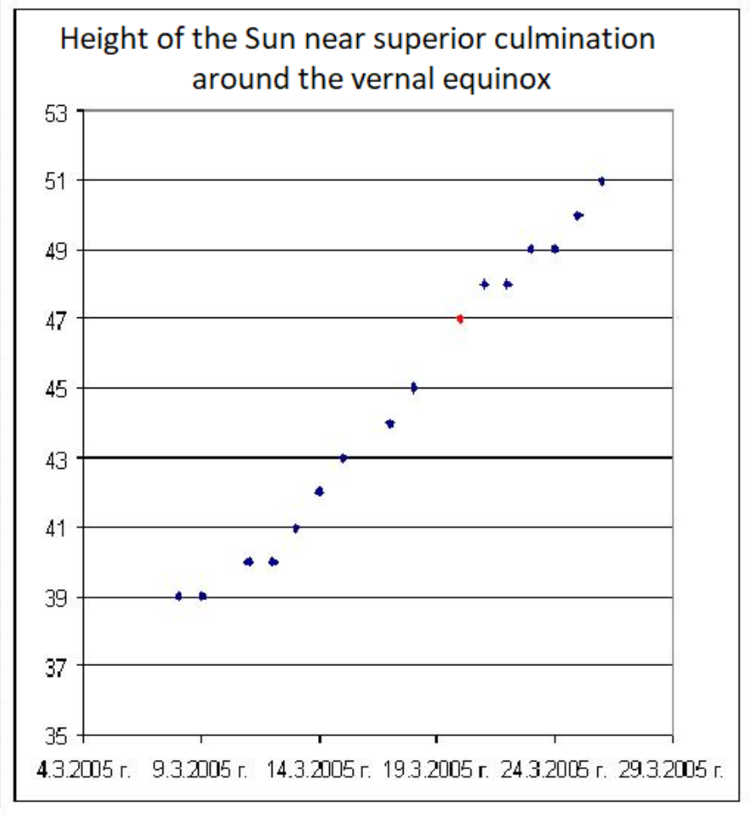
It is interesting to observe how the height of the Sun above the horizon changes during the day and to follow the variations of the maximal height to which the Sun reaches at noon (in superior culmination) during the different seasons.
Due to the location of our observatory near the sea coast our students are able to use a sextant. But working with a sextant is somewhat complicated especially for younger students, also it can only be used if a clear sea horizon is seen, and of course not every educational institution has a sextant. That is why we designed a simple alternative device for measuring the height of the Sun, which can be seen on the following picture. First the device should be turned towards the Sun and it should be leveled. Then the vertical rod should be moved along the rail until the shadow of point A coincides with the center of the protractor A'. The height of the Sun h can be read on the protractor.







Date	Time EEDST	Height of the Sun, deg
08.3.2005	12:30	39
09.3.2005	12:30	39
10.3.2005		
11.3.2005	12:29	40
12.3.2005	12:29	40
13.3.2005	12:29	41
14.3.2005	12:29	42
15.3.2005	12:30	43
16.3.2005		
17.3.2005	12:30	44
18.3.2005	12:30	45
19.3.2005		
20.3.2005	12:24	47
21.3.2005	12:31	48
22.3.2005	12:30	48
23.3.2005	12:30	49
24.3.2005	12:30	49
25.3.2005	12:30	50
26.3.2005	12:29	51
27.3.2005		



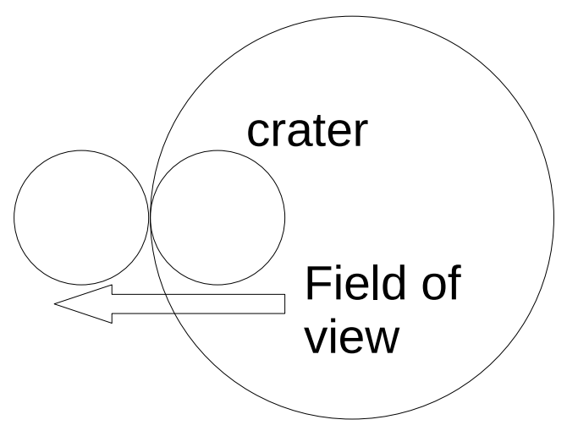
Measuring the sun spots and the Moon craters

The sizes of the lunar craters, the sun spots and other features on the surface of various space objects can be determined by means of measurements on photographic images or through a telescope and simple calculations.

Using a scale. On a photographic image of the whole Sun the size s of a large sun spot and the solar diameter d are measured in millimeters. Then the real diameter D of the Sun is used and the size S of the sun spot in kilometers is calculated:

$$S = s.\frac{D}{d}$$

Using a chronometer. The Moon is observed through a telescope without a guiding system. Measured is the time interval t in which a large crater crosses the boundary of the field of view when leaving it - between the positions 1 and 2.



We use the angular velocity of the Moon's orbital motion (based on the sidereal month) and the angular velocity of the Earth's rotation (based on the sidereal day) to calculate the relative angular velocity of the Moon's apparent diurnal motion on the sky with respect to an observer on Earth:

$$\varpi = \langle \varpi_{Earth} - \varpi_{Moon} \rangle .cos\delta$$

Here we take into account the lunar declination, since it determines the dimension of the celestial parallel on which the Moon is located at the time of our observation. Finally we use the distance to the Moon d in the same moment and the time interval t measured by us, to obtain the diameter D of the crater:

$$D = 2\pi d.\frac{\varpi t}{360^\circ}$$

On 21 August 2021 we used a small 6 cm telescope with a magnification of 80x and were able to determine the diameter of the Copernicus crater with an error of 9%. In this exercise the choice of the crater is important - it has to be large and located not far from the center of the apparent lunar disk, so that the distortions of the crater due to the spherical shape of the Moon to be minimal. To reduce the error it is recommended to carry out multiple measurements of the time t and to use the averaged value. The variability of the Moon's orbital velocity is not taken into account.

Conclusion: The experiments and observations we carry out are invaluable to all students. No video or book can replace the experiment in which students develop their skills and understand the laws of nature first-hand, i.e., prove them. On the other hand, the student's own observations with the telescope are an indispensable part of the astronomy classes, confirming the knowledge of celestial mechanics and their importance.

(1) The Astronomical Observatory "Nicolaus Copernicus" , Varna, Bulgaria;
(2) Institute of Astronomy and National Astronomical Observatory, Bulgarian Academy of Sciences;

References: * Project number: 2017-1-SK01-KA201-035344, Erasmus+ Programme, KA2, Strategic Partnerships in School Education