XVI Международная астрономическая олимпиада

XVI International Astronomy Olympiad

Казахстан, Алма-Ата 22 – 30. IX. 2011 Almaty, Kazakhstan

Theoretical round. Problems to solve

General note. Maybe not all problems have correct questions. Some questions (maybe the main question of the problem, maybe one of the subquestions) may make no real sense. In this case you have to write in your answer (in English or Russian): «**impossible situation – ситуация невозможна**». Of course, this answer has to be explained numerically or logically.

Data from the tables (Planetary data, stars, constants, etc.) may be used for solving every problem.

The answers «Да-Yes» or «Нет-No» has to be written in English or Russian.

1. **Observation of a star.** Observations were done by the naked eye on June 16, 2008, Universal time was used. An observer has registered that a star passed zenith at 0^h18^m, and at 8^h17^m its height above the horizon was 87°12'. Find the latitude of the observations.

2. **Planetarium.** Classical devices "planetaria" are arranged so that each group of stars is projected on a dome by a small optical system. Foils with hole-stars of the corresponding sizes are often used as these "slides" of constellations which are projected on the dome, so that most of the light is blocked by the foil (the black sky appears), and only light through the holes are transmitted (so stars appear). For example, images of 0^m stars on the foil have the size $l_0 = 0.1$ mm, and stars up to 6^m are demonstrated, the focal length of the projecting system is f = 25 cm, and the device has 16 separate projecting systems for every hemisphere. The dome of the planetarium of the observatory "Bobek" has a diameter of 2R = 10 m.

   Let's suppose that all slides have been removed for replacement by more perfect ones, and the whole light began to be projected on the dome. What would the total stellar magnitude of the illuminated dome be (the artificial gray sky)? Would it be possible to read a newspaper in such an illuminance?

   The answer has to include a list of the necessary parameters with formulae and numerical values.

3. **Sunrise on Mars.** The Polar Bear (whom was already met in the texts of many International Astronomy Olympiads) was tired to make astronomical observations on Earth. He made a fascinating journey to the North Pole of Mars, and decided to observe a sunrise there. Calculate how long this sunrise lasts. The solution has to include a picture with an image of the Bear on the North Pole of Mars. Necessary sizes or angular sizes should be in the picture. Assume that Mars is spherical and its orbit may be considered circular. Recollect for yourself the necessary information about the Polar Bear.

4. **Photo of Jupiter.** In the photo of Jupiter that was taken on October 19, 2009, one of the Galilean moons and its shadow on the disc of the planet can be seen. Jupiter was near the middle of Capricornus constellation when the photo was taken.

   Find the orbital distance from the moon to the surface of the planet. Determine the name of the moon. The solution should be illustrated by drawings. The name of the moon in the solution and in the drawings should be written (or duplicated) in English.

5. **Jupiter disappeared.** Let us suppose that Jupiter suddenly disappeared. The moons of Jupiter became independent bodies.

   5.1. Which former Galileo moon(s) and in what case may leave the Solar system?

   5.2. Which former Galileo moon(s) and in what case may fall into the Sun?

   The answers "which moon" and "in what case" (configurations at the moment of Jupiter disappearance) have to be given in the form of drawings, and calculations should be the base for the answers. The names of the moons in the solution and in the drawings should be written in English. Consider the orbit of Jupiter (before its disappearance) to be circular.

Theoretical round. Problems to solve

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1. **Solar radiation.** Find, with how many percents the mass of the Sun is diminishing per year due to its radiation.

2. **Planetarium.** Classical devices "planetaria" are arranged so that each group of stars is projected on a dome by a small optical system. Consider the planetarium of observatory "Bobek" which diameter of the hall (dome) is 2R = 10 m. On slides of the constellations projected on the dome images of 0^m stars have the size $l_0 = 0.1$ mm (foils with hole-stars of the mentioned size are often used as these "slides").

   2.1. Estimate what the parameters should be (decide yourself, which parameters are important here) of the objective of this optical system, so that the visitors sitting in the centre of the hall of the planetarium would perceive the "stars" as points (not as circles or nebulae).

   2.2. Let's suppose that all slides have been removed for replacement by more perfect ones, and all the light began to be projected on the dome. What would the total stellar magnitude of the illuminated dome be (the artificial gray sky)? Would it be possible to read a newspaper in such an illuminance?

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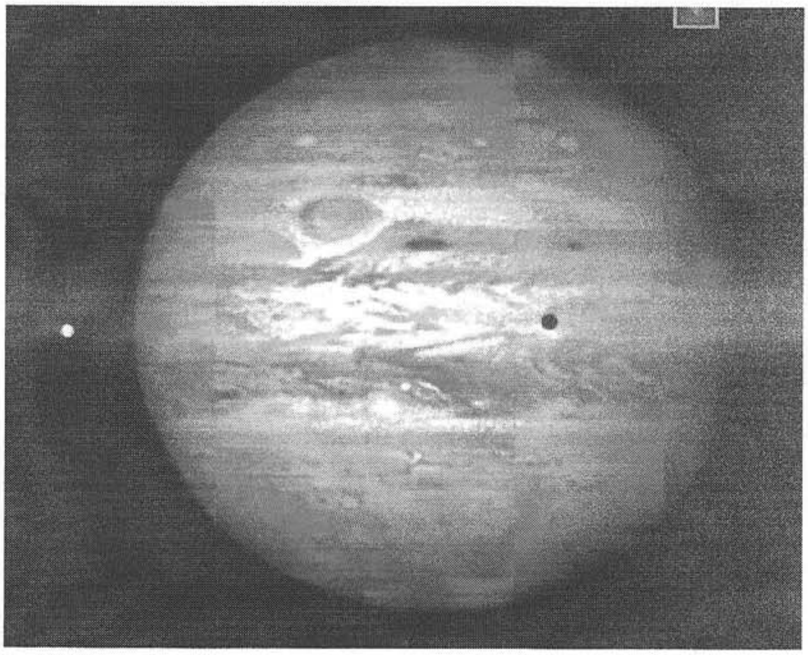
Задачи теоретического тура. Рисунок

Theoretical round. Problems to solve. Picture

4. **Снимок Юпитера.**
4. **Photo of Jupiter.**



Элементы орбит. Физические характеристики Солнца, некоторых планет, Луны и Галилеевых спутников Юпитера

Parameters of orbits. Physical characteristics of Sun, some planets, Moon and Galilean moons of Jupiter

Небесное тело, планета	Среднее расстояние от центрального тела		Сидерический (или аналогичный) период обращения		Экс-центри-ситет,	Экватори-альн. диаметр	Масса	Сред-няя плот-ность	Ускор. своб. пад. у пов.	На-клон оси	Аль-бедо
	в *астр. ед.*	в *млн. км*	в тропич. годах	в средних сутках	*e*	*км*	10^{24} *кг*	*г/см*^{3}	*м/с*^{2}		
Body, planet	Average distance to central body		Sidereal (or analogous) period		Ec-centri-city	Equat. diameter	Mass	Av. den-sity	Grav. acceler. at surf.	Axial tilt	Al-bedo
	in ***astr. units***	in ***mln. km***	in troph. years	in days	*e*	***km***	10^{24} ***kg***	***g/cm***^{3}	***m/s***^{2}		
Солнце Sun	$1{,}6\cdot10^9$	$2{,}5\cdot10^{11}$	$2{,}2\cdot10^8$	$8\cdot10^{10}$		1392000	1989000	1,409			
Меркурий Mercury	0,387	57,9	0,241	87,97	0,206	4 879	0,3302	5,43	3,70	0,01°	0,06
Венера Venus	0,723	108,2	0,615	224,70	0,007	12 104	4,8690	5,24	8,87	177,36	0,78
Земля Earth	1,000	149,6	1,000	365,26	0,017	12 756	5,9742	5,515	9,81	23,44	0,36
Луна Moon	0,00257	0,38440	0,0748	27,3217	0,055	3 475	0,0735	3,34	1,62	6,7	0,07
Марс Mars	1,524	227,9	1,880	686,98	0,093	6 794	0,6419	3,94	3,71	25,19	0,15
Юпитер Jupiter	5,204	778,6	11,862	4 332,59	0,048	142 984	1899,8	1,33	24,86	3,13	0,66
Сатурн Saturn	9,584	1433,7	29,458	10 759,20	0,054	120 536	568,50	0,70	10,41	26,73	0,68

Спутник	Среднее расстояние от центра планеты		Сидерич. период обращения	Накло-нение орбиты	Экс-центри-ситет,	Диаметр	Масса	Сред-няя плот-ность	Ускор. своб. пад. у пов.	Макс. блеск, вид. с Земли *)	Геом Аль-бедо
	в *астр. ед.*	в *тыс. км*	в средних сутках	*(°)*	*e*	*км*	10^{21} *кг*	*г/см*^{3}	*м/с*^{2}		
Moon	Average distance to planet center		Sidereal period	Orbit inclination	Ec-centri-city	Diameter	Mass	Av. den-sity	Grav. acceler. at surf.	Max. magn. From Earth *)	Geom Al-bedo
	in ***astr. units***	in ***thous. km***	in days	*(°)*	*e*	***km***	10^{21} ***kg***	***g/cm***^{3}	***m/s***^{2}		
Ио Io	0,00282	421,70	1,769137	0,050°	0,0041	3 643	89,31	3,53	1,80	$5{,}02^m$	0,63
Европа Europa	0,00449	671,03	3,551181	0,471°	0,0094	3 122	48,00	3,01	1,32	$5{,}29^m$	0,67
Ганимед Ganymede	0,00716	1070,41	7,154553	0,204°	0,0011	5 262	148,19	1,94	1,43	$4{,}61^m$	0,43
Каллисто Callisto	0,01259	1882,71	16,689018	0,205°	0,0074	4 821	107,59	1,83	1,23	$5{,}65^m$	0,20

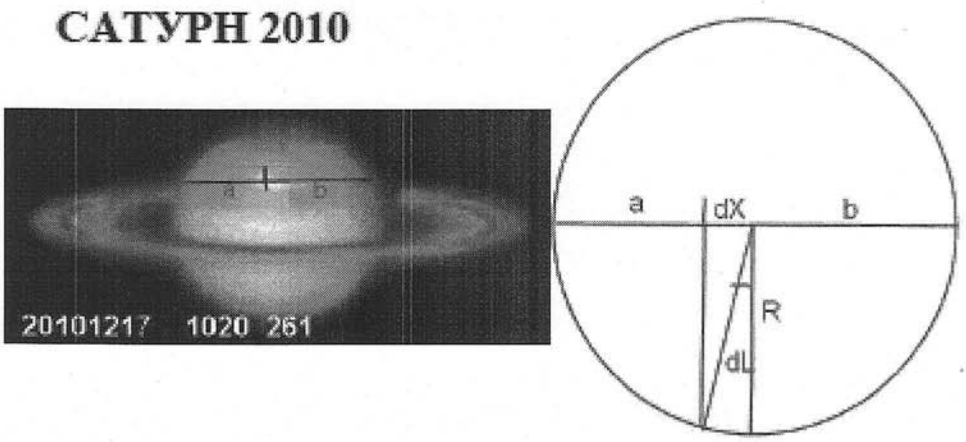
*) В среднем противостоянии. *) In mean opposition.

Некоторые константы и формулы
Some constants and formulae

Скорость света в вакууме, c (м/с)	299 792 458	Speed of light in vacuum, c (m/s)
Гравитационная постоянная, G (Н·м²/кг²)	$6.674 \cdot 10^{-11}$	Constant of gravitation, G (N·m²/kg²)
Солнечная постоянная, A (Вт/м²)	1367	Solar constant, A (W/m²)
Параметр Хаббла, H_0 (км/с/МПк) — среднее значение / диапазон значений	71 / 50-100	mean value / diapason of values — Hubble parameter, H_0 (km/s/Mpc)
Постоянная Планка, h (Дж·с)	$6.626 \cdot 10^{-34}$	Plank constant, h (J·s)
Заряд электрона, e (Кл)	$1.602 \cdot 10^{-19}$	Charge of electron, e (C)
Масса электрона, m_e (кг)	$9.109 \cdot 10^{-31}$	Mass of electron, m_e (kg)
Соотношение масс протона и электрона	1836.15	Proton-to-electron ratio
Постоянная Фарадея, F (Кл/моль)	96 485	Faraday constant, F (C/mol)
Магнитная постоянная, μ_0 (Гн/м)	$1.257 \cdot 10^{-6}$	Magnetic constant, μ_0 (H/m)
Универсальная газовая постоянная, R (Дж/моль/К)	8.314	Universal gas constant, R (J/mol/K)
Постоянная Больцмана, k (Дж/К)	$1.381 \cdot 10^{-23}$	Boltzmann constant, k (J/K)
Стандартная атмосфера (Па)	101 325	Standard atmosphere (Pa)
Постоянная Стефана-Больцмана, σ (Вт/м²/К⁴)	$5.670 \cdot 10^{-8}$	Stefan-Boltzmann constant, σ (W/m²/K⁴)
Константа смещения Вина, b (м·К)	0.002897	Wien's displacement constant, b (m·K)
Лабораторная длина волны H**α** (Å)	6562.81	Laboratory wavelength of H**α** (Å)
Длина тропического года, T (сут)	365.242199	Tropical year length, T (days)
Показатель преломления воды при 20°C, n	1.334	Refractive index of water for 20°C, n
Момент инерции шара	$I = {}^2/_5 MR^2$	Moment of inertia of a solid ball
Площадь сферы	$S = 4\pi R^2$	Area of sphere
π	3.14159265	π
e	2.71828183	e
Золотое сечение, φ	1.61803399	Golden ratio, φ

Practical round. Problems to solve

6. Saturn 2010.



You are provided with a series of Saturn images. Find the rotational period for Saturn, and the velocity and the direction of the movement of unique formation in the atmosphere of Saturn – Great Northern Disturbance (GND), which appeared on December 8, 2010.

6.1. Use measurements of two images on Saturn on 13 December 2010 to determine the rotational period T for Saturn from the angular change of the GND position during the time interval between two images.
6.2. Plot from all measurements of the GND core a graph showing how the core longitude L depends on time t. The time should be expressed in hours and parts of hours. Set the time of the first image as zero time (0.0^h). The inclination of the graph must show the direction and the angular velocity of GND.
6.3. Determine the value of radius R=(a+b)/2 at the GND latitude in kilometers and determine the linear velocity of the GMD core latitude in kilometers using the graph that shows L vs t.

You may neglect the tilt of the equator to the line of sight (the direction Earth-Saturn). In the images north is up. Saturn's equatorial radius R_0 = 60266 km. The planet is rotating counterclockwise if you look from the north pole, or from left to right in the images. The longitude of the central meridian of the planet increases following the planet's rotation. It means that L increases from right to left in the images.

Data on the images: date (2010, December, day), time UT (h, m), and LCM, the longitude of the central meridian (in degrees) in system of coordinates of planet.

On the above drawing you can see the scheme (a view from the North), R is the radius on the GND latitude. Evidently $R < R_0$.

Practical round. Problems to solve

6. Planetary nebula.

The table provides the results of the measurements of the wavelength of the spectral line of hydrogen with λ_0 = 6562,81Å (Hα) of the planetary nebula NGC 5643 (points shown in the picture on separate sheet). Draw a graph that shows the dependence of the radial velocity of the points on the declination δ. Draw a diagram showing the direction in which each point is moving. Assuming that the extreme points in the table correspond to the boundary of the nebula, calculate the motion velocity (the velocity at which the nebula as a whole approaches or recedes) and the velocity of the nebula expansion.

δ	+66° 34′	+66° 35′	+66° 36′	+66° 37′	+66° 38′	+66° 39′	+66° 40′
λ, Å	6563,17	6562,80	6562,68	6562,40	6562,65	6562,77	6563,16

Practical round. Problems to solve

7. Exoplanet.

Recently astronomers discovered an exoplanet that practically reflects no light and belongs to the class of hot Jupiters. Its mass corresponds to 12 Jupiter's masses, the average orbit radius is 0.036 AU and the period is 2.47 days. The given data about the exoplanet has been obtained with the help of the data from the "Kepler" telescope which continuously monitors the sky region between the constellations Cygnus and Lyra. The device was launched in March 2009 and is capable of seeing not only gas giants, but also planets with the size of Earth. Recently scientists have discovered that exoplanets are capable of causing huge tidal waves in the stars that have a significant influence on the spectral parameters of the emitted light from the star. In fact, with the help of this effect scientists have been able to prove that the planet moves around a star in a circular orbit.

In the graph (see separate sheet) the flux of radiation from the system vs. the phase (phase ϕ given in radians) can be seen, normalized to the radiation flux from the star.

7.1. During the transit there are four "contacts" when the contour of the smaller object touches the contour of the larger object at one point. The contacts take place in the following order:

- First contact: The smaller body is completely outside of the larger and moving inside.
- Second contact: The smaller body is completely inside of the larger and continues to move inwards.
- Third contact: The smaller body is completely inside of the larger and moves outwards.
- Fourth contact: The smaller body is completely outside of the larger and starts to move away.

In the given graph mark the points of the first, second, third and the fourth contacts. Write in the copybook the value of the phase for each contact.

7.2. Determine the duration of the transit (duration of the passage of the disk of planet over the disk of the star).

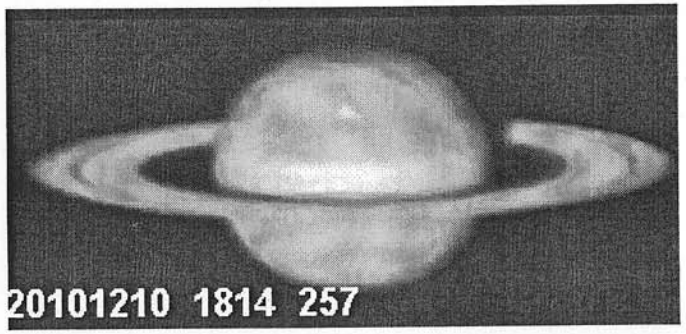
7.3. Determine the inclination of the orbit (for exoplanets and binary stars the reference plane is assumed to be the "image plane" – the plane that is perpendicular to the line of sight).

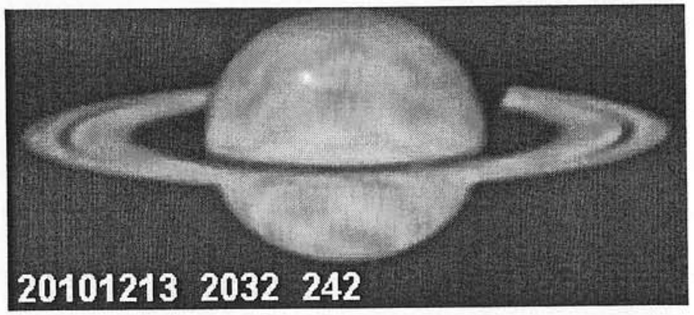
7.4. Calculate the radius of the star.

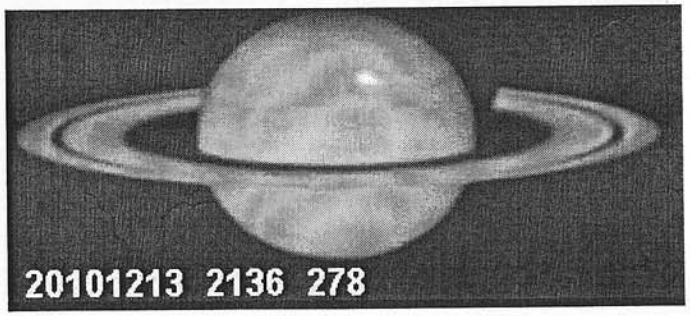
7.5. Calculate the radius of the planet.

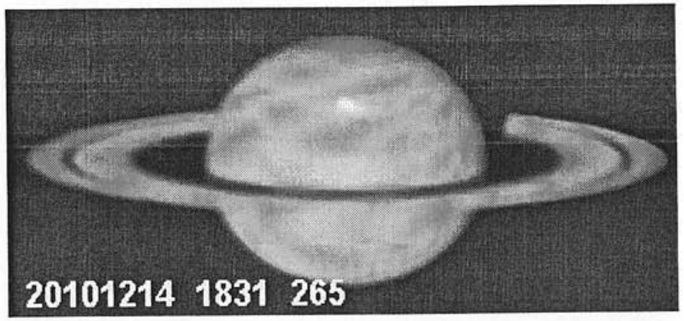
6. Сатурн 2010.

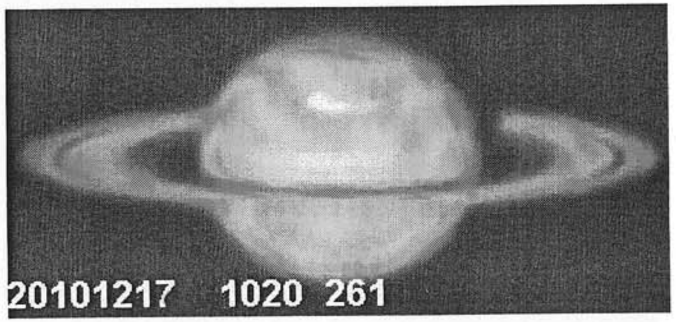
6. Saturn 2010.

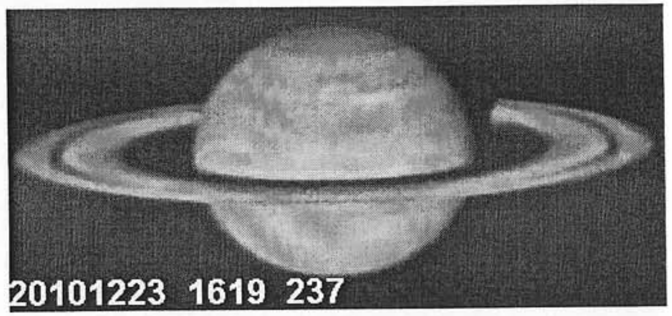


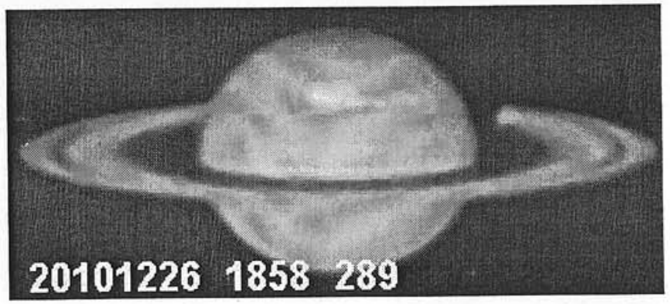






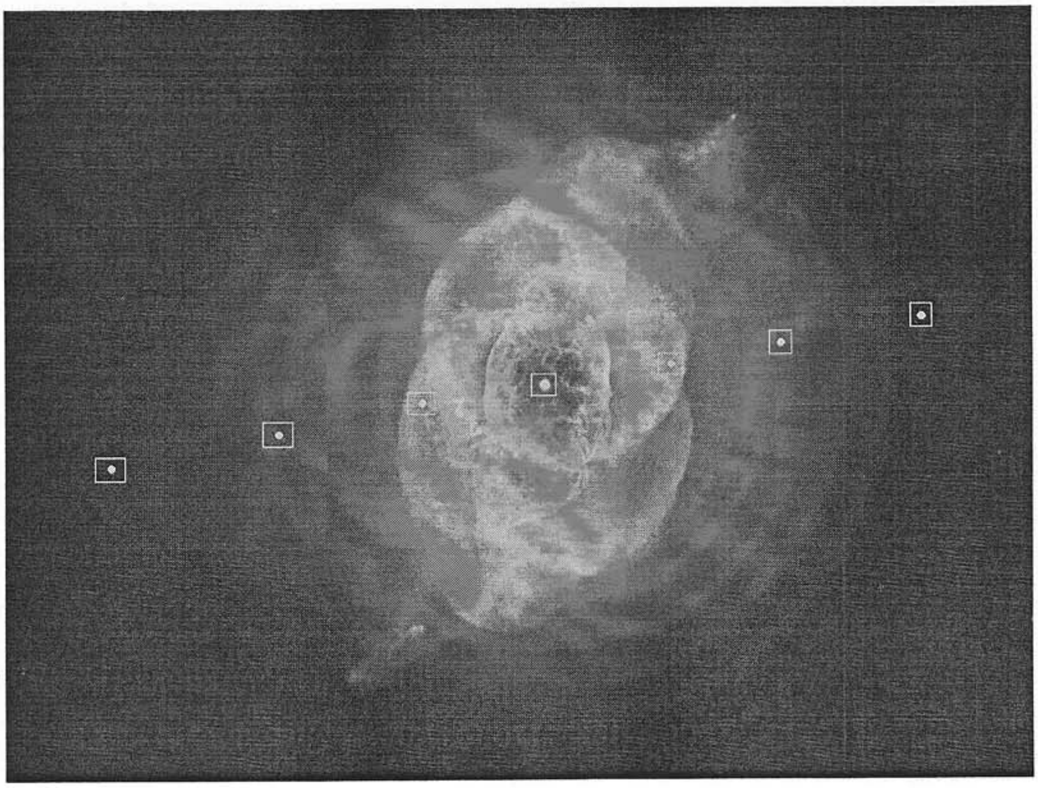






6. Планетарная туманность.

6. Planetary nebula.



XVI Международная астрономическая олимпиада
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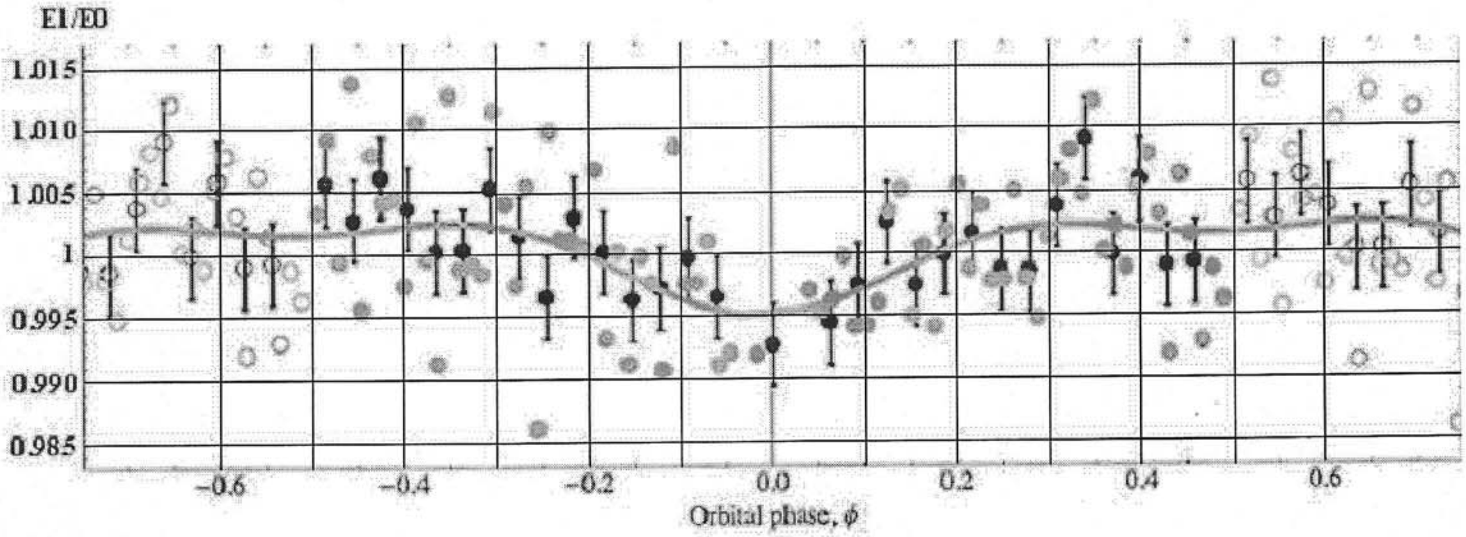
7. Экзопланета.

7. Exoplanet.



Вопросы наблюдательного тура — Observational round. Questions

Русский	*English*
В Вашем распоряжении **фонарик** и **часы**.	You are provided by **light** and a **watch**
1. Установите Юпитер в центр поля зрения телескопа. Покажите результат экзаменатору. Зарисуйте расположение спутников Юпитера на момент наблюдения.	**1.** Bring Jupiter to the center of field of view of the telescope. Demonstrate the result to examiner. Draw a picture with the positions of the moons of Jupiter at the moment of observation.
2. Определите и напишите на листке часовой угол и горизонтальные координаты **α** Peg.	**2.** Calculate and write down on the paper the hour angle and horizontal coordinates of **α** Peg.
3. Зарисуйте и пронумеруйте в порядке убывания яркости (1, 2, ...) восемь основных звезд созвездия "Cygnus".	**3.** Draw and enumerate in descending order by brightness (1, 2, …) the eight main stars of the "Cygnus" constellation.
4. Определите поле зрения телескопа, стоящего перед Вами. Фокусное расстояние окуляра F = 10 мм.	**4.** Calculate the field of view of the telescope in front of you. The focal length of the eyepiece is F = 10 mm.
Максимальное время выполнения задания – **20 минут**.	The maximum total time for all tasks is **20 minutes**.