EURO–ASIAN ASTRONOMICAL SOCIETY

АСТРОНОМИЧЕСКОЕ ОБЩЕСТВО

XIX International Astronomy Olympiad

XIX Международная астрономическая олимпиада

Bishkek – Cholpon-Ata, Kyrgyzstan 12–21. X. 2014 Киргизия, Бишкек – Чолпон-Ата

Theoretical round

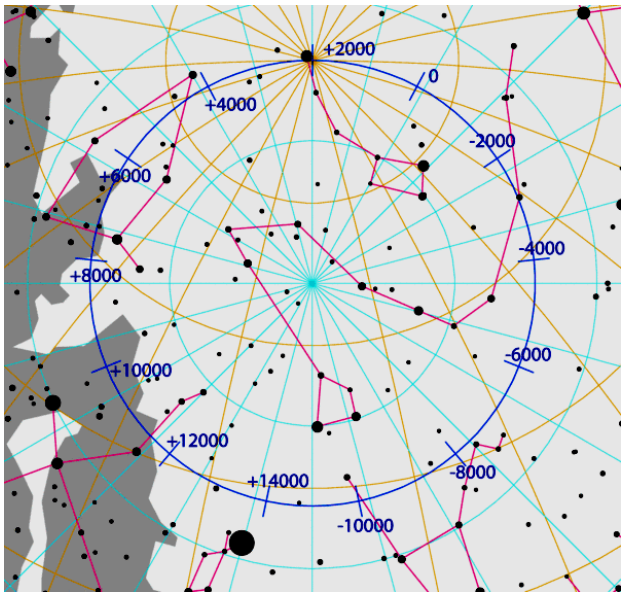
Practical round

Observational round

Элементы орбит. Физические характеристики некоторых планет, Луны, Солнца и Эриды

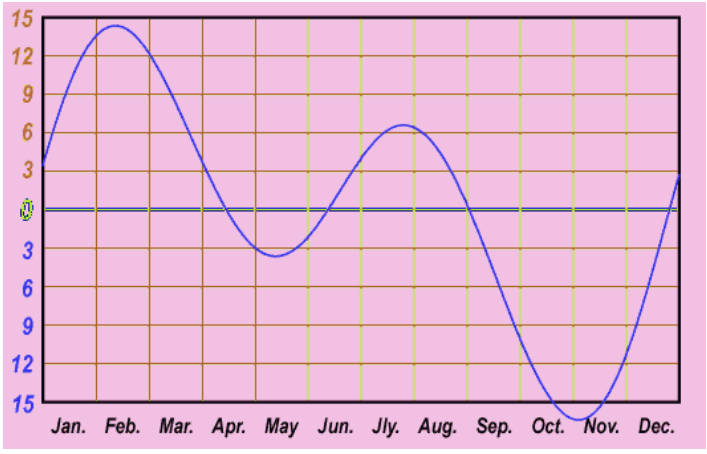
Parameters of orbits. Physical characteristics of some planets, Moon, Sun and Eris

Небесное тело, Планета	Среднее расстояние от центрального тела		Сидерический (или аналогичный) период обращения		Наклон орбиты,	Эксцентриситет,	Экваториальн. диаметр	Масса	Средняя плотность	Ускор. своб. пад. у пов.	Наклон оси	Макс. блеск, вид. с Земли **)	Альбедо
	в *астр. ед.*	в *млн. км*	в тропич. годах	в средних сутках	*i*	*e*	*км*	10^{24} *кг*	*г/см*^{3}	*м/с*^{2}			
Body, Planet	Average distance to central body		Sidereal period (or analogous)		Orbital inclination,	Eccentricity	Equat. diameter	Mass	Av. density	Grav. accelr. at surf.	Axial tilt	Max. magn. From Earth **)	Albedo
	in *astr. units*	in 10^6 *km*	in tropical years	in days	*i*	*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			-26,74^m	
Меркурий Mercury	0,387	57,9	0,241	87,969	7,00°	0,206	4 879	0,3302	5,43	3,70	0,01°		0,06
Венера Venus	0,723	108,2	0,615	224,7007	3,40	0,007	12 104	4,8690	5,24	8,87	177,36		0,78
Земля Earth	1,000	149,6	1,000	365,2564	0,00	0,017	12 756	5,9742	5,515	9,81	23,44		0,36
Луна Moon	0,00257	0,38440	0,0748	27,3217	5,15	0,055	3 475	0,07348	3,34	1,62	6,7	-12,7^m	0,07
Марс Mars	1,524	227,9	1,880	686,98	1,85	0,093	6 794	0,6419	3,94	3,71	25,19	-2,0^m	0,15
Юпитер Jupiter	5,204	778,6	11,862	4 332,59	1,30	0,048	142 984	1899,8	1,33	24,86	3,13	-2,7^m	0,66
Сатурн Saturn	9,584	1433,7	29,458	10 759,20	2,48	0,054	120 536	568,50	0,70	10,41	26,73	0,7^m	0,68
Эрида Eris	68,05			205 029	43,82	0,435	2 326	0,0167	2,52	0,7			0,96



Прецессия * Precession

**) Для внешних планет и Луны – в среднем противостоянии.
**) For outer planets and Moon – in mean opposition.



Уравнение времени Equation of time

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 ($Н·м^2/кг^2$)	$6.674·10^{-11}$	Constant of gravitation, G ($N·m^2/kg^2$)
Солнечная постоянная, A ($Вт/м^2$)	1367	Solar constant, A (W/m^2)
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)	$6.626·10^{-34}$	Plank constant, h (J·s)
Заряд электрона, e (Кл)	$1.602·10^{-19}$	Charge of electron, e (C)
Масса электрона, m_e (кг)	$9.109·10^{-31}$	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)	$1.257·10^{-6}$	Magnetic constant, μ_0 (H/m)
Универсальная газовая постоянная, R (Дж/моль/K)	8.314	Universal gas constant, R (J/mol/K)
Постоянная Больцмана, k (Дж/K)	$1.381·10^{-23}$	Boltzmann constant, k (J/K)
Постоянная Стефана-Больцмана, σ ($Вт/м^2/K^4$)	$5.670·10^{-8}$	Stefan-Boltzmann constant, σ ($W/m^2/K^4$)
Константа смещения Вина, b (м·K)	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)
Стандартная атмосфера (Па)	101 325	Standard atmosphere (Pa)
Ослабление видимого света слоем 1 атмосферы (минимально)	$19\%,\ 0.23^m$	Visible light extinction by the terrestrial atmosphere in zenith (minimum)
Высота однородной атмосферы (м)	7991	Height of homogeneous atmosphere (m)
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
Объём шара	$V = {}^4/_3\ \pi R^3$	Volume of a 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**

Координаты / Coordinates	Бишкек / Bishkek	Чолпон-Ата / Cholpon-Ata
λ (E / в.д.)	**74° 34′**	**77° 05′**
φ (N / с.ш.)	**42° 52′**	**42° 39′**
Часовой пояс / Timezone	**UT+6**	**UT+6**

28 самых ярких звёзд неба — 28 brightest stars in the sky

			RA	DEC	*p*	m	S C
Альтаир	Altair	α Aql	$19^h\ 50^m\ 47^s$	08° 52' 06"	0".195	$0^m.77$	A7
Капелла	Capella	α Aur	$05^h\ 16^m\ 41^s$	45° 59' 53"	0".073	$0^m.08$	G5+G0
Арктур	Arcturus	α Boo	$14^h\ 15^m\ 38^s$	19° 10' 57"	0".089	$-0^m.04^v$	K1
Канопус	Canopus	α Car	$06^h\ 23^m\ 57^s$	-52° 41' 45"	0".028	$-0^m.72$	F0
Бета Киля	Miaplacidus	β Car	$09^h\ 13^m\ 12^s$	-69° 43' 02"	0".029	$1^m.68$	A2
Толиман	Toliman (Rigel Kent)	α Cen	$14^h\ 39^m\ 36^s$	-60° 50' 07"	0".747	$-0^m.01$ $1^m.33$	G2 K1
Хадар	Hadar	β Cen	$14^h\ 03^m\ 49^s$	-60° 22' 23"	0".009	$0^m.61$	B1
Сириус	Sirius	α CMa	$06^h\ 45^m\ 09^s$	-16° 42' 58"	0".375	$-1^m.46$	A1
Адара	Adara	ε CMa	$06^h\ 58^m\ 38^s$	-28° 58' 19"	0".008	$1^m.50$	B2
Процион	Procyon	α CMi	$07^h\ 39^m\ 18^s$	05° 13' 30"	0".288	$0^m.38$	F5
Акрукс	Acrux	α Cru	$12^h\ 26^m\ 36^s$	-63° 05' 57"	0".010	$0^m.77$	B0
Бекрукс	Becrux	β Cru	$12^h\ 47^m\ 43^s$	-59° 41' 20"	0".009	$1^m.30$	B0
Гакрукс	Gacrux	γ Cru	$12^h\ 31^m\ 10^s$	-57° 06' 48"	0".037	$1^m.60$	M4
Денеб	Deneb	α Cyg	$20^h\ 41^m\ 26^s$	45° 16' 49"	0".002	$1^m.25$	A2
Ахернар	Achernar	α Eri	$01^h\ 37^m\ 43^s$	-57° 14' 12"	0".026	$0^m.46$	B3
Кастор	Castor	α Gem	$07^h\ 34^m\ 36^s$	31° 53' 18"	0".065	$1^m.58$	A1+A2
Поллукс	Pollux	β Gem	$07^h\ 45^m\ 19^s$	28° 01' 35"	0".097	$1^m.14$	K0
Регул	Regulus	α Leo	$10^h\ 08^m\ 22^s$	11° 58' 02"	0".041	$1^m.35$	B7
Вега	Vega	α Lyr	$18^h\ 36^m\ 56^s$	38° 47' 01"	0".123	$0^m.03$	A0
Бетельгейзе	Betelgeuse	α Ori	$05^h\ 55^m\ 10^s$	07° 24' 25"	0".005	$0^m.5^v$	M2
Ригель	Rigel	β Ori	$05^h\ 14^m\ 32^s$	-08° 12' 06"	0".013	$0^m.12$	B8
Беллатрикс	Bellatrix	γ Ori	$05^h\ 25^m\ 08^s$	06° 20' 59"	0".013	$1^m.64$	B2
Фомальгаут	Fomalhaut	α PsA	$22^h\ 57^m\ 39^s$	-29° 37' 20"	0".130	$1^m.16$	A3
Антарес	Antares	α Sco	$16^h\ 29^m\ 24^s$	-26° 25' 55"	0".024	$0^m.96$	M1+B4
Шаула	Shaula	λ Sco	$17^h\ 33^m\ 37^s$	-37° 06' 14"	0".005	$1^m.62$	B2
Альдебаран	Aldebaran	α Tau	$04^h\ 35^m\ 55^s$	16° 30' 33"	0".048	$0^m.85^v$	K5
Эль-Нат	Elnath	β Tau	$05^h\ 26^m\ 18^s$	28° 36' 27"	0".025	$1^m.66$	B7
Спика	Spica	α Vir	$13^h\ 25^m\ 12^s$	-11° 09' 41"	0".023	$0^m.98$	B1

Некоторые другие звёзды — Some other stars

Хамаль	Hamal	α Ari	$02^h\ 07^m\ 10^s$	23° 27' 45"	0".050	$2^m.01$	K2
Шератан	Sheratan	β Ari	$01^h\ 54^m\ 39^s$	20° 48' 30"	0".055	$2^m.64$	A5
Тубан	Thuban	α Dra	$14^h\ 04^m\ 23^s$	64° 22' 33"	0".011	$3^m.65$	A0
Растабан	Rastaban	β Dra	$17^h\ 30^m\ 26^s$	52° 18' 05"	0".009	$2^m.79$	G2
Этамин	Etamin	γ Dra	$17^h\ 56^m\ 36^s$	51° 29' 20"	0".021	$2^m.24$	K5
Полярная	Polaris	α UMi	$02^h\ 31^m\ 49^s$	89° 15' 51"	0".007	$1^m.97^v$	F7
Кохаб	Kochab	β UMi	$14^h\ 50^m\ 42^s$	74° 09' 20"	0".025	$2^m.07$	K4
Феркад	Pherkad	γ UMi	$15^h\ 20^m\ 44^s$	71° 50' 02"	0".007	$3^m.06^v$	A3
Йильдун	Yildun	δ UMi	$17^h\ 32^m\ 19^s$	86° 35' 11"	0".019	$4^m.35$	A1
Проксима Центавра	Proxima Centauri	**V645** Cen, α Cen **C**	$14^h\ 29^m\ 43^s$	-62° 40' 46"	0".769	$11^m.05$	M5.5

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**» have to be written in English or Russian.

1. **Dreams of the Polar Bear.** Terrestrial Polar Bear-observer, watching the lunar disk in the phase of the full moon, in his dreams became thousand times closer to it. What did the magnitude of the Moon become? The solution has to include an artistic picture with an image of the Bear-observer on the North Pole.

2. **Great oppositions.** Now great oppositions of Mars happen every 15 or 17 years. To simplify colonization of Mars, to improve environmental conditions on it, and to increase the effect of the great oppositions, our civilization has conceived an ambitious project: to reduce by 6.0% the semi-major axis of this planet's orbit, while keeping the eccentricity of the orbit unchanged. How often will the great oppositions of Mars occur in the case of the new orbit?

3. **Proxima Centauri.** Can the star Proxima Centauri be visible from the vicinity of Alpha Centauri by naked eye? (**«да-yes»** or **«нет-no»**). Justify your solution by calculations of the corresponding apparent magnitude of Proxima Centauri.

4. **Hydroplanet.** Hydroplanet consists of a rocky "core" of radius ***R*** and a thick layer of water surrounding it from all sides. Local humans live at the bottom of this world's ocean (i.e., on the surface of the "core"), and hydrosphere is an analogue of our atmosphere for them. Local scientists observe astronomical objects from the bottom of the ocean. Like on our Earth, the duration of day-night period on Hydroplanet is T = 24 hours.
   4.1. Find the minimum depth ***H*** of the ocean, for which celestial bodies will be visible at the horizon.
   4.2. What will be the duration of the day for inhabitants of the planet's equator? The disk of the central star can be considered as a point source of light.
   4.3. Calculate the value of "atmoshperical" refraction at the horizon on such a planet.
   Points of your solution have to include drawings with all necessary sizes or angular sizes. The outer surface of the ocean is smooth, no waves or ripples.

5. **Argali.** Argali (mountain sheep, in Kyrgyz and Russian - Arkhar), who lives in the foothills near Cholpon-Ata, is interested in the fact that students from different countries came to the Issyk-Kul and are looking at the sky at night, and not just so, but using some tubes. Moreover, Argali found himself in the logo of the event, as well as learned that one of the constellations in the sky was named in his honor. Will Argali see the stars of this constellation in the sky tonight? (**«да-yes»** или **«нет-no»**). At what time (Kyrgyz time) and at what altitude the brightest star of this constellation will culminate during the nearest day or night? The solution has to include an artistic picture with an image of Argali observing "his" constellation in the sky.

6. **Brightest stars.** Which four stars will be the brightest in the night sky of Cholpon-Ata in the CL (150^{th}) century AD? Consider that ~5° of the sky above the horizon are blocked by mountains. Explain your answer and prove it by necessary drawings and calculations. Any names of stars write in Latin.

Theoretical round. Problems to solve

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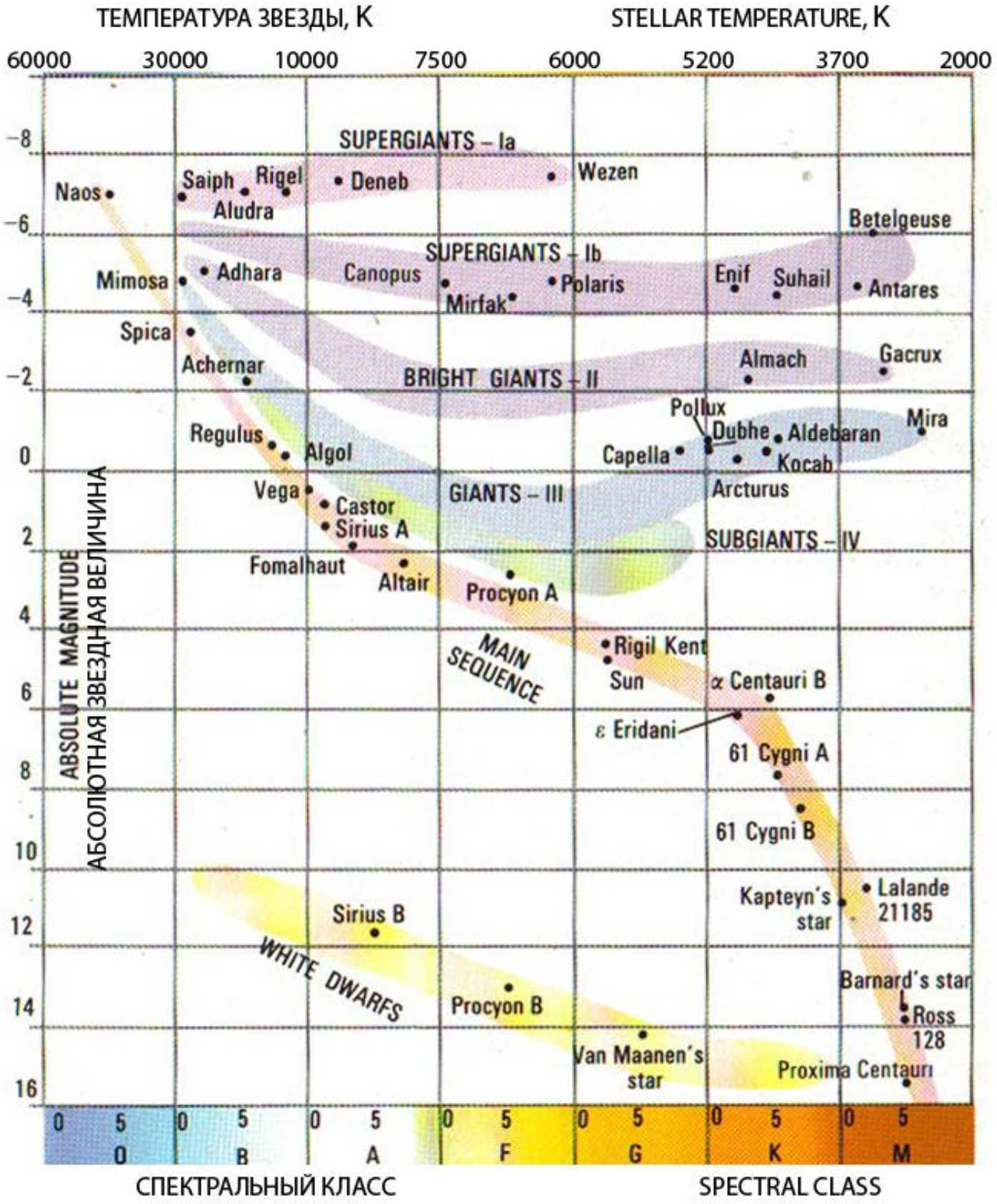
   Points of your solution have to include drawings with all necessary sizes or angular sizes. The outer surface of the ocean is smooth, no waves or ripples.

5. **Climate.** The XXXII (32^{nd}) century AD. Due to unknown reasons, the Sun became cooler, not changing its size, and the inclination of ecliptic to the celestial equator plane decreased to zero. Scientists proved that the problem of preserving the Earth's climate and the annual change of seasons can be solved by a small star, negligible mass, but similar to a main-sequence star, moving in a circular orbit around the Sun. The star will revolve around the Sun as an inner planet, resulting in establishing a temperature regime on the Earth similar to the actual one at Issyk-Kul: the average winter and summer temperatures are -3 and +17 degrees respectively.
   5.1. Estimate the temperature of the cool Sun.
   5.2. Estimate to what spectral class the star which will be placed in the desired orbit will correspond.

6. **Sombrero Galaxy.** The Sombrero Galaxy, M104, is known as a holder of one of supermassive black holes. Images of the galaxy and its center (left side) have angular sizes 10'×7' and 10.8"×7.2" respectively. To the right, three spectra from the Hubble space telescope (in the region containing the emission lines from ionized oxygen and nitrogen) are shown for regions around the center of the galaxy. The bottom spectrum is from a region around the very center, while other two spectra are from flanking region. The values on top of the dotted lines indicate the rest (laboratory) wavelength in Ångströms.
   6.1. Is M104 approaching us or receding from us? (Answer this question by sketch drawing.)
   6.2. Estimate the velocity of M104 towards us or away from us.
   6.3. Roughly estimate the approximate mass of the supermassive black hole in the center of M104 (answer in solar masses $\mathbf{m}_\odot$).

Диаграмма Герцшпрунга-Рассела

Hertzsprung-Russell diagram

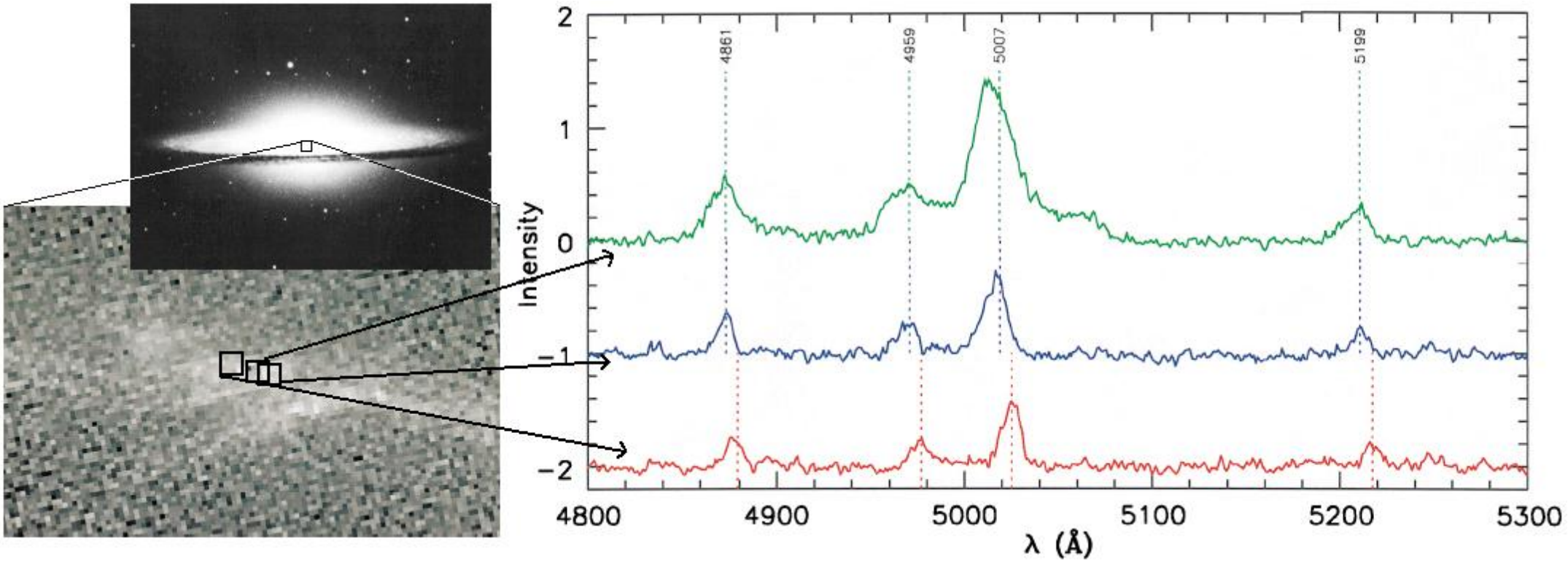


Round **Theo**

Group **β**

язык / language	***Русский***
язык / language	***English***

Теоретический тур. Галактика Сомбреро
Theoretical round. Sombrero Galaxy



Practical round. Problems to solve

7. Jupiter. In 2009, a nucleus of unknown comet or an asteroid crashed into Jupiter's atmosphere. A powerful explosion formed a dark cloud, which gradually stretched parallel to equator due to zonal flow in the atmosphere. Hubble Space Telescope was able to take a few pictures of Jupiter during this period.

Determine the rate at which the dark cloud on the surface of Jupiter increased its length after the impact with the comet or asteroid by measuring the length of image fragments on the set of the 3 top images displayed on the right.

The photos were taken in the same position of the cloud relative to the central meridian. The scale is determined from the image of Jupiter and position of the fragment marked on it. The equatorial diameter of Jupiter is 143842 km.

8. Comet. In the middle of July 2014, an automatic interplanetary spacecraft Rosetta of European Space Agency made the discovery that the comet 67P / Churyumov–Gerasimenko had a bipartite nucleus. On September 5th Rosetta was able to determine that its albedo was about 0.04 and the maximum nucleus length, 4 km.

On a separate sheet are the pictures demonstrating rotation of the comet nucleus, taken with 40 minutes intervals. Each picture has the date when it was taken and the angle of nucleus rotation relative to the first picture indicated on it. Using these images, determine the rotation period of the comet and plot its light curve based on them. Assume the same albedo over the entire surface of the comet.

According to NASA, the estimated distances at that time were as following:

Rosetta to Sun 557 794 935 km,
Rosetta to Earth 407 252 536 km,
Rosetta to the comet 12 294 km.

Practical round. Problems to solve

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8. A new variable star. During late winter – early spring, 2014, a recently discovered variable star GSC 4560-02157, in the constellation of Ursa Minor, was observed at the Tien Shan Observatory of the Kazakhstan Astrophysical Institute, located in the mountains to the south of Almaty city, approximately in 60 km to the north of Cholpon-Ata (Kyrgyzstan). The star features complex physical variability along with regular eclipses. During the night of February 28 – March 1, the star was observed non-stop for almost 9 hours. The table (right) presents the most important data points derived from these observations. The time in the table is the mean solar time for the Almaty time zone.

At times of the primary minimum, the star's properties correspond to the K0 spectral type.

Plot the light curve. At the time axis, mark times of minimal brightness in the primary minima and in the secondary minimum. Knowing that the Julian date 2456949.000 begins at today's (October 18) Greenwich noon, label the times of minimal brightness with their Julian dates, with three digits after the decimal point.

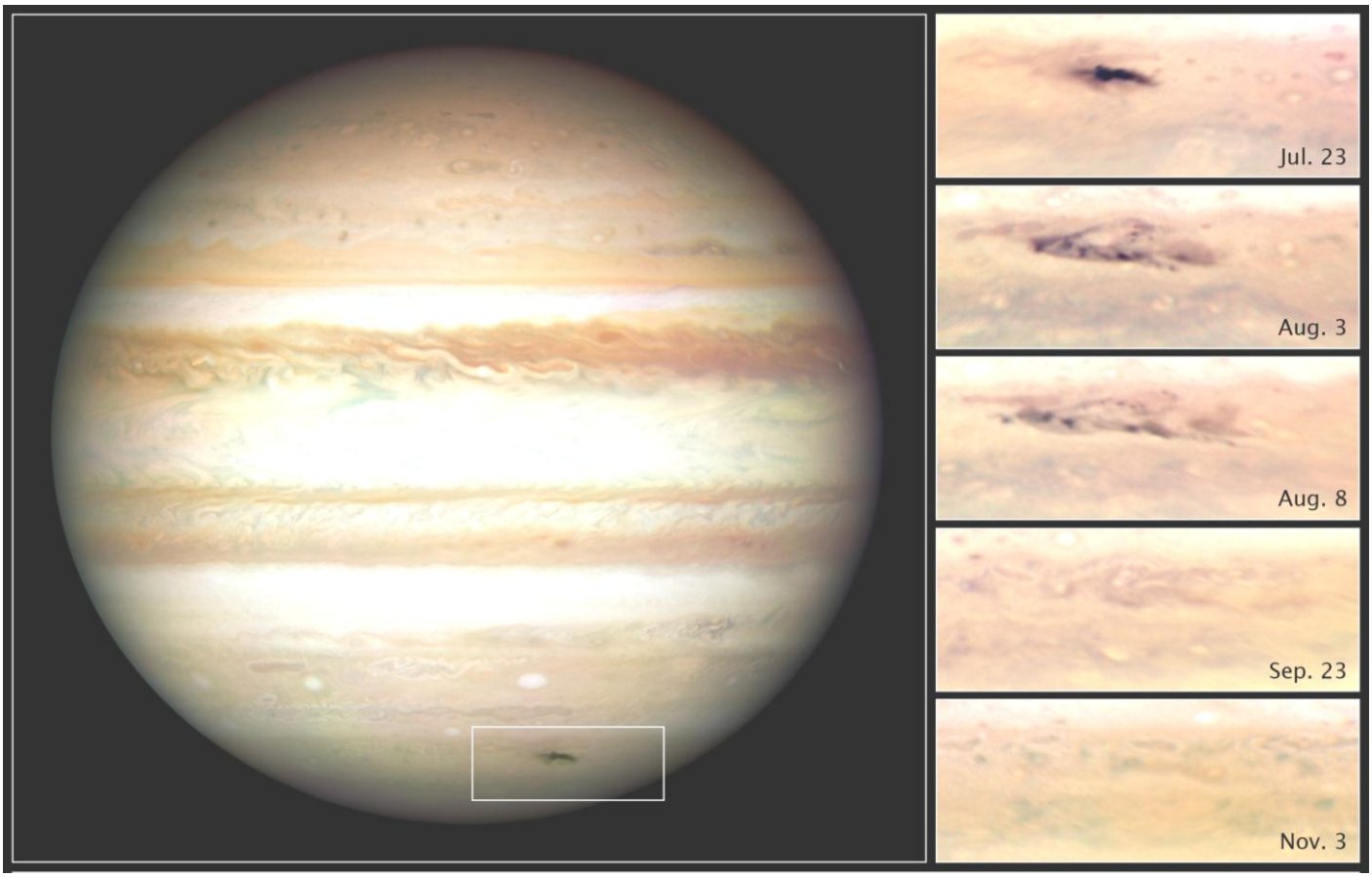
One of simplified models describing the event assumes that the process involves two stars only. From your analysis of the light curve in the frame of such a model, determine the spectral types (for example, that of the Sun is G2) of the larger (1) and smaller (2) components as well as the ratio of the radii of the larger (R_1) and smaller (R_2) components. Illustrate the solution with necessary figures.

Almaty and Cholpon-Ata are in the same time zone.

T	m
22 h 00 m (February 28)	14.92
22 h 12 m	15.08
22 h 24 m	15.41
22 h 36 m	15.44
22 h 48 m	15.37
23 h 00 m	15.12
23 h 12 m	14.92
23 h 30 m	14.89
00 h 00 m (March 1)	14.80
00 h 18 m	14.78
00 h 42 m	14.80
01 h 00 m	14.82
01 h 24 m	14.85
01 h 48 m	14.96
02 h 12 m	14.72
02 h 30 m	14.72
03 h 12 m	14.63
03 h 36 m	14.65
04 h 15 m	14.77
04 h 25 m	14.84
04 h 36 m	15.10
05 h 00 m	15.43
05 h 12 m	15.32
05 h 24 m	15.05
05 h 36 m	14.90
05 h 48 m	14.75
06 h 12 m	14.73
06 h 48 m	14.70

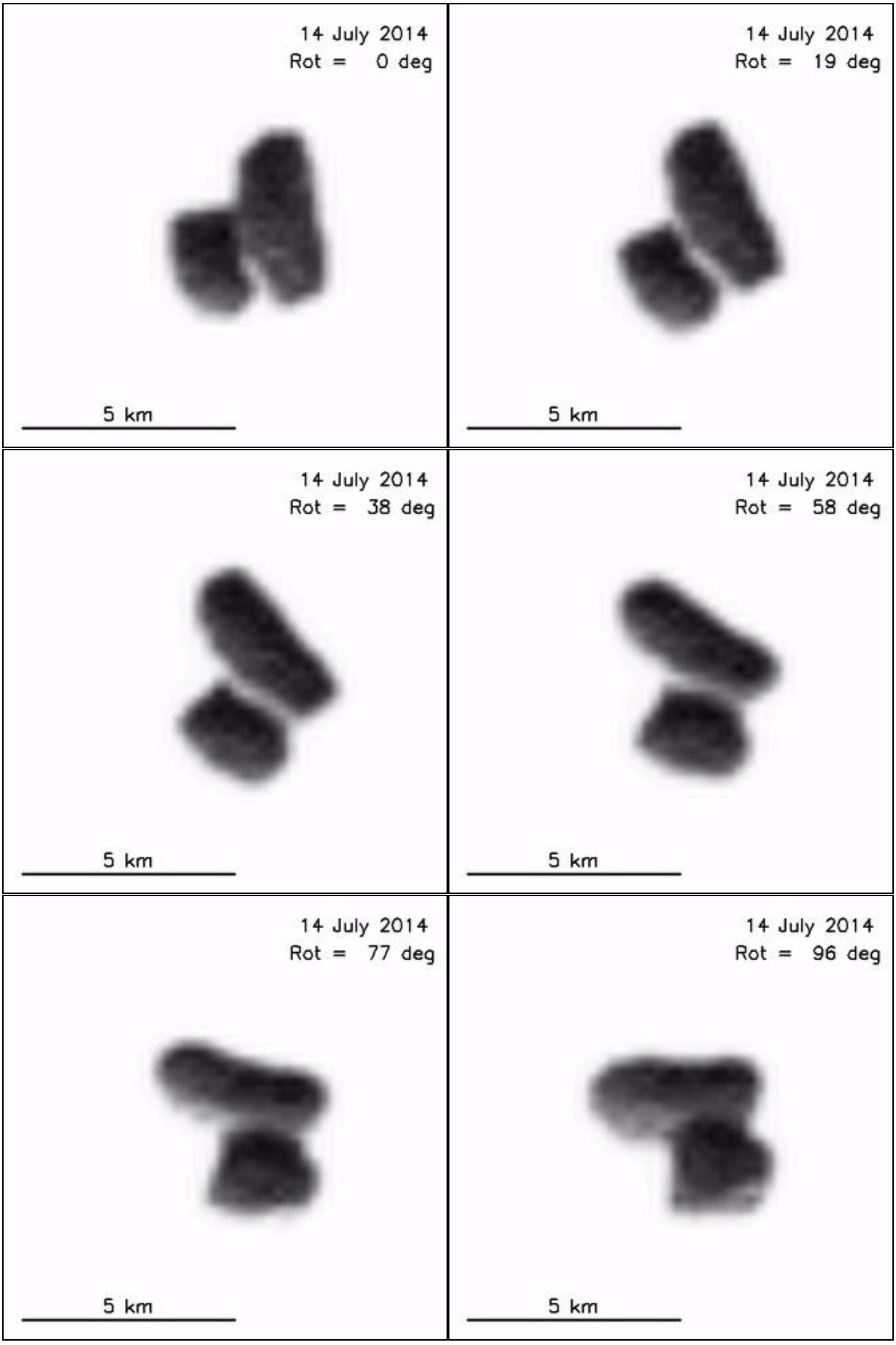
7. Юпитер.

7. Jupiter.



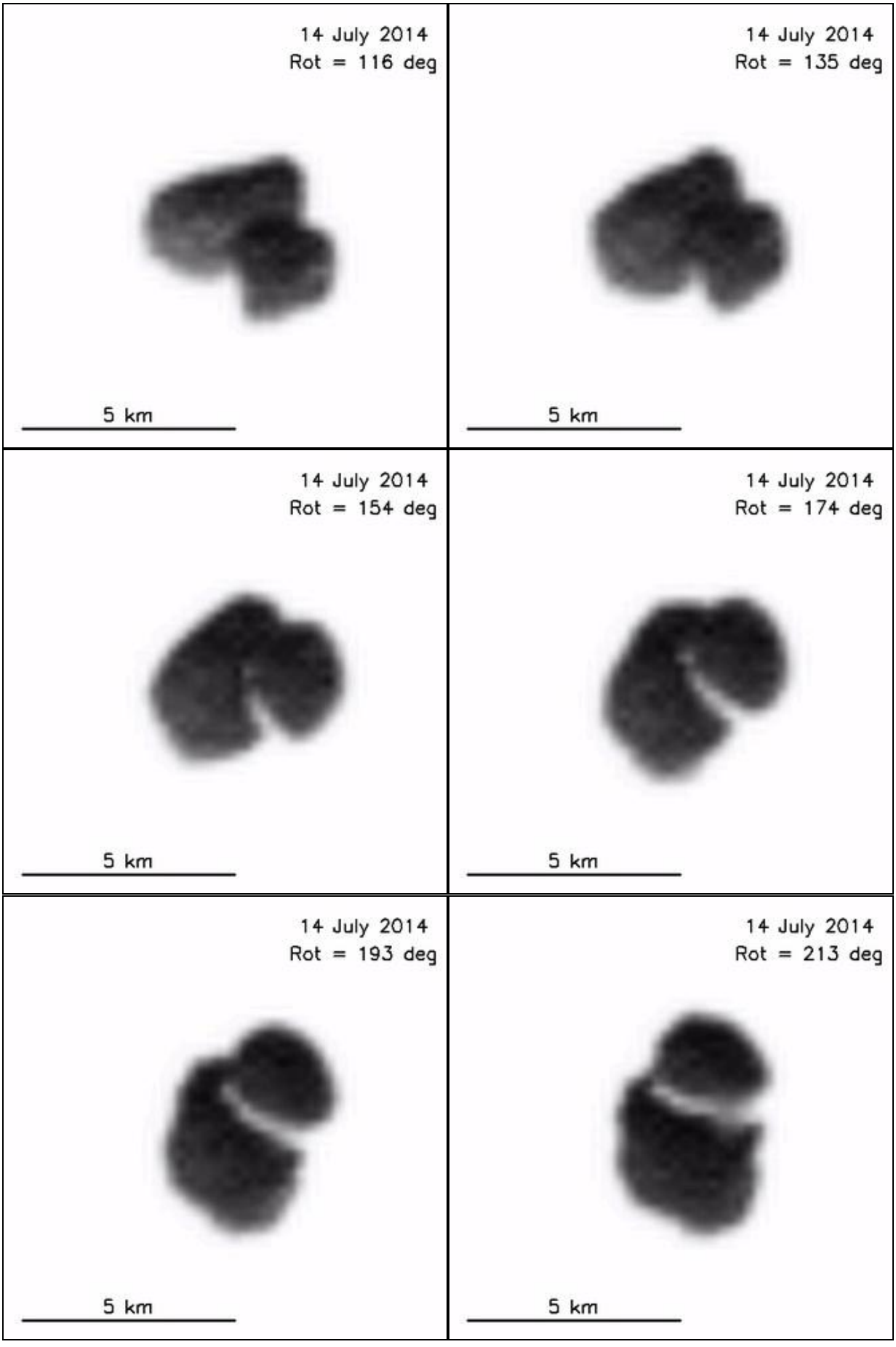
8. Комета. 8. Comet.

1

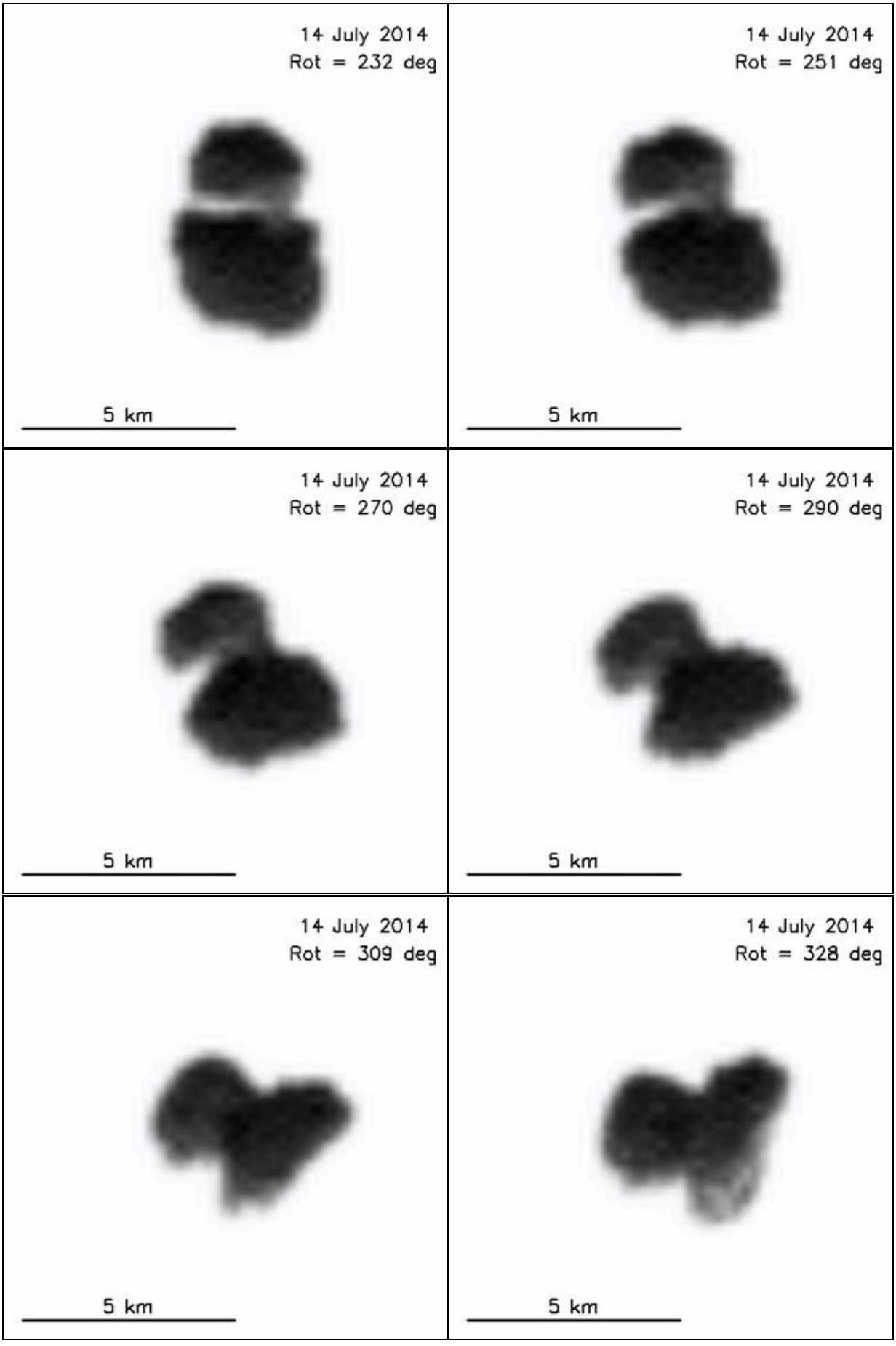


8. Комета. 8. Comet.

2



8. Комета. 8. Comet. 3



Round **Obs**

Group **α** **β**

язык / language	**English**

Observational round. Questions. Clear sky

Code of participant	*код участника*

Observations by the naked eye

9. Assess the color of the stars and mark accordingly it with a "X":

	White	**Blue**	**Yellow**	**Red**
α UMi				
α And				
α Ari				
α Cyg				
α Tau				

10. What is the angular distance between **α Cas** and the north celestial pole?

Answer:

11. Specify direction to the points of intersection of the ecliptic and the equator.

List the names of the constellations (in Latin) in which these points are located.

Answer:

Observations with telescope

12. Point your telescope to the M45. Show to the examiner. Classify the object as one of the following: open cluster (**OC**), a globular cluster (**GC**), an emission nebula (**EN**) and planetary nebula (**PN**).

Answer:

13. Point your telescope to the binary star ***π Pegasus*** using 10 mm eyepiece and ***star map*** as a guide. Estimate the distance between the stars in arc minutes.

Answer:

*The maximum total time for all tasks is **20 minutes**.*

Наблюдательный тур. Чистое небо

Observational round. Clear sky