АСТРОНОМИЧЕСКОЕ ОБЩЕСТВО
EURO–ASIAN ASTRONOMICAL SOCIETY
Round Theo
Group α γ
Международная дистанционная астрономическая олимпиада
International Remote Astronomy Olympiad
Италия, Милан 5-13. XI. 2021 Milan, Italy
язык language English

Theoretical round. Problems to solve

Reminding. All the problems are compiled in such a way that the use of any language would not be required from the student when writing solutions. So writing texts is not allowed in solutions of the problems (neither in the native language, nor in one of the official languages of the IAO). Pay more attention to formulas, drawings and graphs. It is permitted to write a few keywords in English (for example, "Yes", "No", "Assume", "Answer", "Average", "Minimum", "Maximum", "Impossible situation", etc.), as well as terms contained in the accompanying tables and names of objects.

1(αγ). Parallax measurements. The annual trigonometric parallax of Sirius, measured from Earth, is $\pi_1 = 0.379''$. And it is exactly $\pi_2 = 1.379''$ if measured from some asteroid orbiting the Sun in an elliptical orbit with an eccentricity of e = 0.59. Find out what the orbital period T of this asteroid can be. Explore all possible cases.

2(αγ). Spacecraft. A spacecraft orbits in an elliptical orbit around some planet of our Solar System. When passing the pericenter of its orbit, the angular diameter of the planet, visible from the spacecraft, was $\alpha_P = 4.6°$, and after half a revolution, after a time of $\tau = 9.64$ days, when passing the apocenter it was $\alpha_A = 1.9°$. Identify which planet the spacecraft is orbiting.

3(αγ). NGC of the Year. NGC 2021 is an open cluster in the constellation of Dorado, observed against the background of the Large Magellanic Cloud, has coordinates $\alpha = 05^H\ 33^M\ 31^S$, $\delta = -67°27'11''$ and apparent magnitude $m = 12.1^m$. To illustrate, at the sheet of images you can see a 4×4 arcmin negative picture of the area with NGC 2021 in the center.

Which animals-astronomers will be able to observe this cluster at the time of the annular eclipse from problem #4 using the objective lens of the Bear-astronomer from problem #4:

a) Polar Bear-astronomer living at the North Pole.
b) Brown Bear-astronomer living in Canada on the Arctic Polar Circle.
c) The Green Woodpecker-astronomer living in Romania at the northern latitude 45°.
d) Two-Humped Camel-astronomer living in Egypt on the Northern Tropic.
e) Masai Mottled Giraffe-astronomer living in Kenya on the Equator.
f) Wild Steppe Cat-astronomer living in Brazil on the Southern Tropic.
g) Gray Fox-astronomer living in Argentina at the southern latitude 45°.
h) Emperor Penguin-astronomer living in the Southern Polar Circle on the Antarctic Peninsula (opposite South America).

Consider the weather clear in all the places, and assume the sensitivity of the retina of eyes of these animals to be the same as of humans.

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I-5(αβγ). Eclipse at the North Pole. For the first time in many years in the center of the Arctic an annular solar eclipse was observed on June 10, 2021. The maximum duration of the annular phase of the eclipse was observed in Greenland, $3^{M}51^{S}$. The Polar Bear-astronomer, who was at the North Pole, photographed the eclipse using a camera (matrix size – 22.3×14.9 mm, the number of pixels of the matrix is 6000×4000), equipped with an objective lens (diameter D = 45 mm, focal length F = 250 mm).

A separate sheet shows a map of the eclipse belt, a more detailed part of such a map in the area of the North Pole, as well as only as illustrations: a photo taken in the town of Chokurdakh (Yakutia) during the eclipse, and a photo of the Bear-astronomer preparing equipment for observations.

The geocentric angular diameters of the visible Sun and Visible eclipsing Moon during the eclipse hours were $d_{\odot}$ = 30′55″ and $d_{☽}$ = 28′58″ respectively.

4.1. Give all the calculations (dimensions, angles) necessary for the correct completion of the next point (4.2.).

4.2. Draw a real image (with basic details) that was obtained at the time of observation of the maximum phase of the eclipse, if the photo is printed with a standard resolution of 300 pixels per inch (1 inch = 25.4 mm). The "top" direction in your drawing should coincide with the "top" direction in the sky.

4.3. Estimate, what was the duration of the annular phase of the eclipse at the North Pole?

5.1. Include an artistic picture of the Bear-astronomer with the photographic equipment shooting the solar ring during the annular eclipse phase.

5.2. Calculate the solar power capacity W falling during the maximum phase of the eclipse on the unit of the horizontal surface near the Bear. Solar limb darkening should not be taken into account.

6(αβγ). Closer to the stars. Let us observe the stars at the zenith. Then we climb a small mountain. The stars become brighter. It can be assumed that this effect is since they become closer to the observer. At what height is the "crystal dome of heaven" located, on which the stars are located in such a model?

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7(βγ). Variable star. A variable star with a period of about 2.7 days has been detected, located in our sky at the tip of the nose of the Ursa Major (i.e. near o UMa). Measurements carried out by British scientists last week showed the result of P_{OBS} = 246 357 s. However, this star is moving away from the Sun at a speed of v = 9 km/s. Calculate with the most reasonable accuracy, what is the real period P_0 of the change in the luminosity of this variable?

8(βγ). Alpha Centauri. They say Alpha Centauri A is very similar to our Sun. The same spectral class G2V. Estimate the density of component A of the star Alpha Centauri.

9(βγ). Dark matter. A double object has been detected in the sky, the components of which, according to the observed spectrometric characteristics, resemble the components of the double star 61 Cygni A+B, the angular distance between the analogues of components A and B is α = 9", and the total apparent magnitude is $m_{AB} = 11.8^m$. It turned out that we see two distant galaxies connected gravitationally and orbiting each other in circular orbits. Assuming that both galaxies consist only of dark matter and stars like the Sun, estimate what the minimum percentage of the mass of dark matter in galaxies can be, and, accordingly, the maximum percentage of visible matter. When solving, the formulas and drawings related to the corresponding objects, mark with labels "Sun", "61 Cyg A", "61 Cyg B", "stars", etc.

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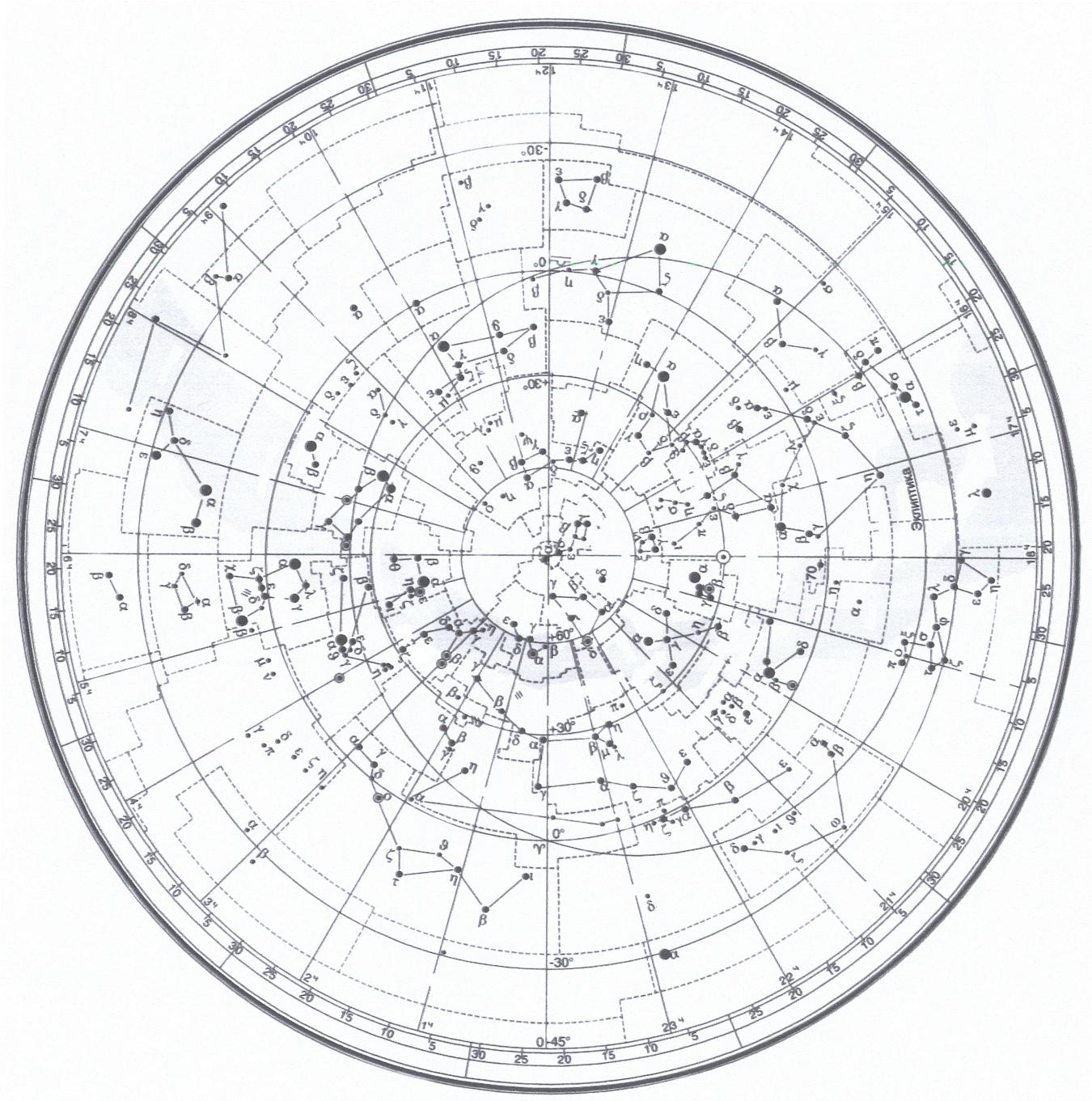

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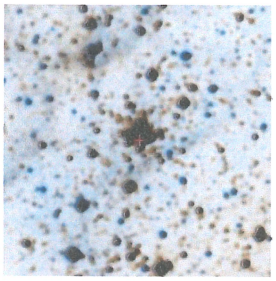
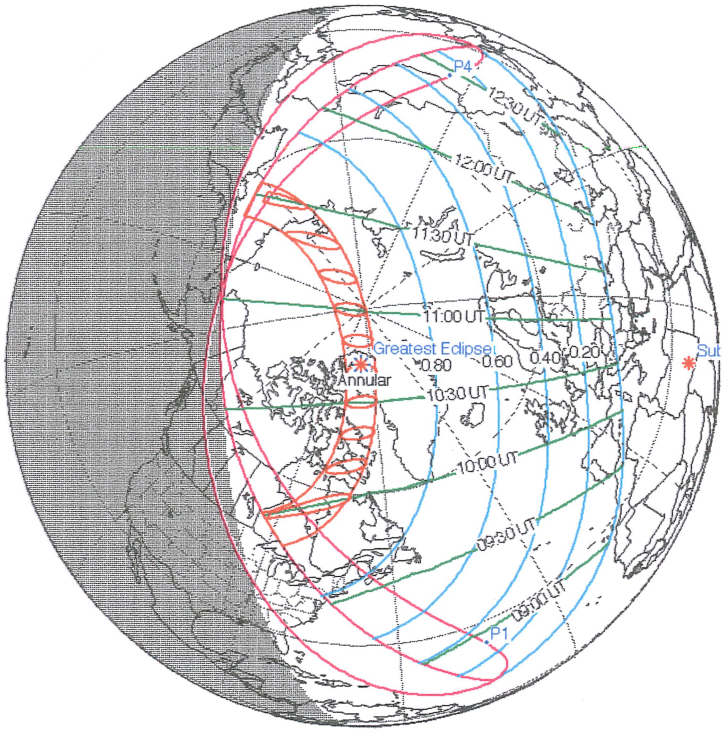
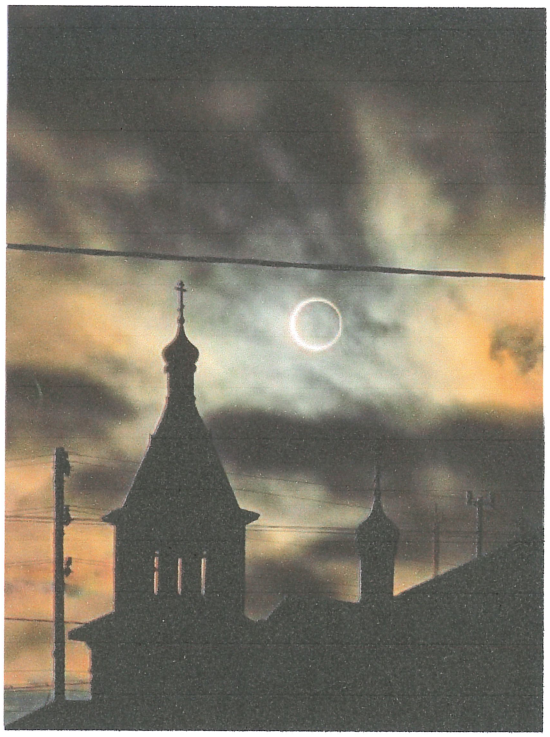
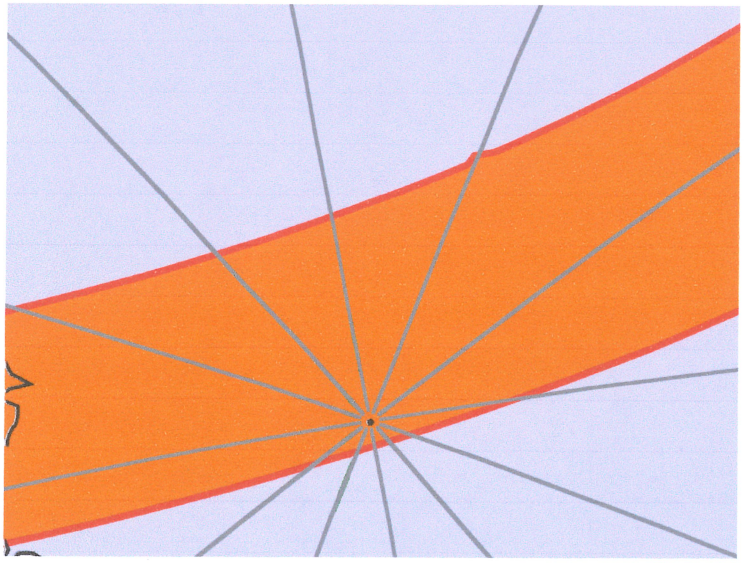
Theoretical round. Images for Problems 3-4-5.

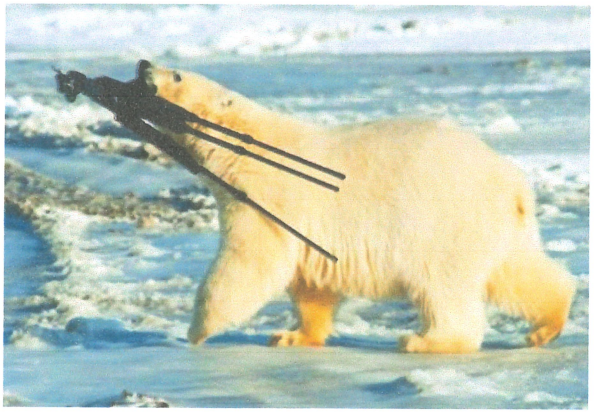


NGC 2021









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Элементы орбит и физические характеристики Солнца, планет и Луны

Parameters of orbits and physical characteristics of Sun, planets and Moon

Небесное тело, планета	Среднее расстояние от центрального тела		Сидерический период обращения		Эксцентриситет, *e*	Экваториальн. диаметр *км*	Масса 10^{24} *кг*	Средняя плотность $г/см^3$	Ускор. своб. пад. у пов. $м/с^2$	Макс. блеск, вид. с Земли **)	Альбедо
	в *астр. ед.*	в *млн. км*	в *тропич. годах*	в *средних сутках*							
Body, planet	Average distance to central body		Sidereal (or analogous) period		Eccentricity *e*	Equat. diameter *km*	Mass 10^{24} *kg*	Av. density g/cm^3	Grav. acceler. at surf. m/s^2	Max. magn. from Earth **)	Albedo
	in *astr. units*	in *mln. km*	in *tropical years*	in *days*							
Солнце Sun	$1{,}65 \cdot 10^9$	$2{,}5 \cdot 10^{11}$	$2{,}3 \cdot 10^8$	$8{,}4 \cdot 10^{10}$		1392000	1989000	1,409		$-26{,}74^m$	
Меркурий Mercury	0,387	57,9	0,241	87,969	0 ,206	4 879	0,3302	5,43	3,70	$-2{,}2^m$	0,06
Венера Venus	0,723	108,2	0,615	224,701	0,007	12 104	4,8690	5,24	8,87	$-4{,}7^m$	0,78
Земля Earth	1,000	149,6	1,000	365,256	0,017	12 756	5,9742	5,515	9,81		0,36
Луна Moon	0,00257	0,38440	0,0748	27,3217	0,055	3 475	0,0735	3,34	1,62	$-12{,}7^m$	0,07
Марс Mars	1,524	227,9	1,880	686,980	0,093	6 794	0,6419	3,94	3,71	$-2{,}0^m$	0,15
Юпитер Jupiter	5,204	778,6	11,862	4 332,59	0,048	142 984	1899,8	1,33	24,86	$-2{,}7^m$	0,66
Сатурн Saturn	9,584	1433,7	29,458	10 759,20	0,054	120 536	568,50	0,70	10,41	$0{,}7^m$	0,68
Уран Uranus	19,191	2871,0	84,015	30 685,93	0,046	51 118	86,625	1,30	8,44	$5{,}5^m$	0,74
Нептун Neptune	30,071	4498,6	164,778	60 187,64	0,008	49 532	102,78	1,76	11,20	$7{,}8^m$	0,58

**) Для внешних планет и Луны – в среднем противостоянии.

**) For outer planets and Moon – in mean opposition.

Данные о некоторых звёздах

Data of some stars

				R.A.	DEC	*p*	Зв.вел. Mag.	Температура Temperature	Масса Mass
Солнце	Sun	☉		$0^h – 24^h$	-23°26' – +23°26'	8".794	$-26^m.74$	5777 K	1 Mʘ
Сириус	Sirius	α CMa	A	$06^h\ 45^m\ 09^s$	-16° 42' 58"	0".379	$-1^m.47$	9940 K	2.06 Mʘ
			B				$8^m.44$	25200 K	1.02 Mʘ
Толиман	Toliman (Rigel Kent)	α Cen	A	$14^h\ 39^m\ 36^s$	-60° 50' 07"	0".747	$-0^m.01$	5810 K	1.11 Mʘ
			B				$1^m.33$	5260 K	0.93 Mʘ
Вега	Vega	α Lyr		$18^h\ 36^m\ 56^s$	38° 47' 01"	0".130	$0^m.03$	9600 K	2.14 Mʘ
Процион	Procyon	α CMi	A	$07^h\ 39^m\ 18^s$	05° 13' 30"	0".286	$0^m.37$	6600 K	1.50 Mʘ
			B				$10^m.75$	9700 K	0.60 Mʘ
Бетельгейзе	Betelgeuse	α Ori		$05^h\ 55^m\ 10^s$	07° 24' 25"	0".005	$0^m.5$	3590 K	11.6 Mʘ
Альтаир	Altair	α Aql		$19^h\ 50^m\ 47^s$	08° 52' 06"	0".195	$0^m.77$	8000 K	1.7 Mʘ
Наос	Naos	ζ Pup		$08^h\ 03^m\ 35^s$	-40° 00' 12"	0".003	$2^m.21$	42000 K	40 Mʘ
Рукбах	Ruchbah	δ Cas		$01^h\ 25^m\ 49^s$	60° 14' 07"	0".033	$2^m.68$	7980 K	2.49 Mʘ
61 Лебедя	61 Cygli	61 Cyg	A	$21^h\ 06^m\ 54^s$	38° 44' 58"	0".287	$5^m.21$	4520 K	0.70 Mʘ
			B	$21^h\ 06^m\ 55^s$	38° 44' 31"		$6^m.03$	4440 K	0.63 Mʘ
UY Щита	UY Scuti	UY Sct		$18^h\ 27^m\ 37^s$	-12° 27' 59"	0".00034	$9^m.1$	3365 K	8 Mʘ
Проксима Центавра	Proxima Centauri	V645 Cen, α Cen C		$14^h\ 29^m\ 43^s$	-62° 40' 46"	0".769	$11^m.06$	3040 K	0.123 Mʘ