

Theoretical round. Problems to solve

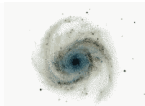
General note. Maybe not all problems have correct questions. Some questions (maybe the main question of the problem, maybe one of the subquestions) may make no real sense. In this case you have to write in your answer (in English or Russian): «impossible situation – ситуация невозможна». Of course, this 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 “atmosphpherical” 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 (150th) century AD? Consider that $\sim 5^\circ$ 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.



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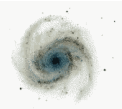
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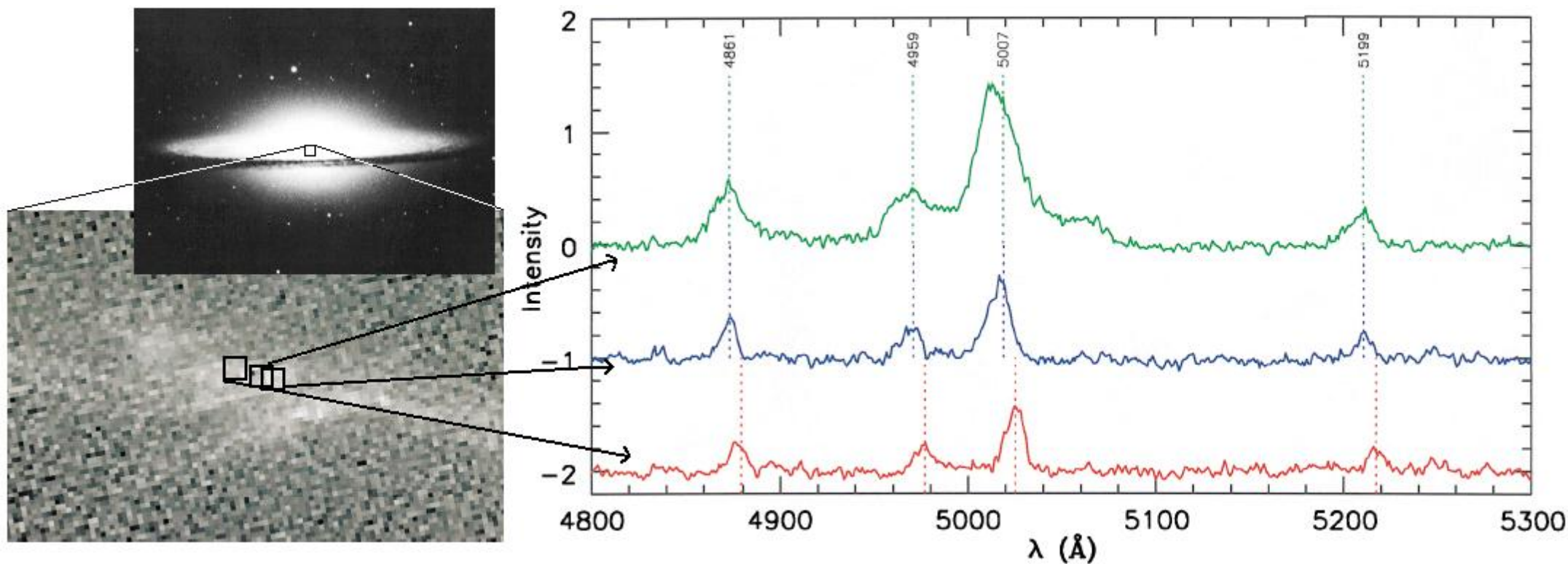
- 1. Dreams of the Polar Bear.** Terrestrial Polar Bear-observer, watching the lunar disk in the phase of the full moon, in his dreams became thousand times closer to it. What did the magnitude of the Moon become? The solution has to include an artistic picture with an image of the Bear-observer on the North Pole.
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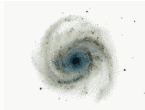
Points of your solution have to include drawings with all necessary sizes or angular sizes. The outer surface of the ocean is smooth, no waves or ripples.
- 5. Climate.** The XXXII (32nd) century AD. Due to unknown reasons, the Sun became cooler, not changing its size, and the inclination of ecliptic 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 $10' \times 7'$ and $10.8'' \times 7.2''$ 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 $m_{\odot}$).



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Теоретический тур. Галактика Сомбреро
Theoretical round. Sombrero Galaxy





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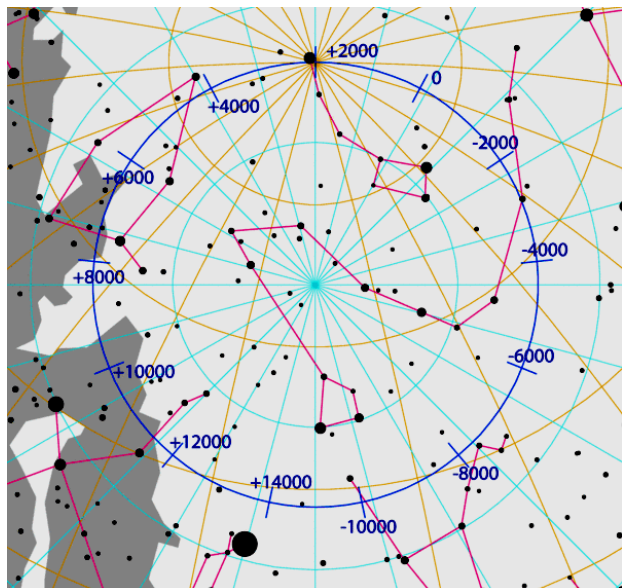
Элементы орбит.

Физические характеристики некоторых планет, Луны, Солнца и Эриды

Parameters of orbits.

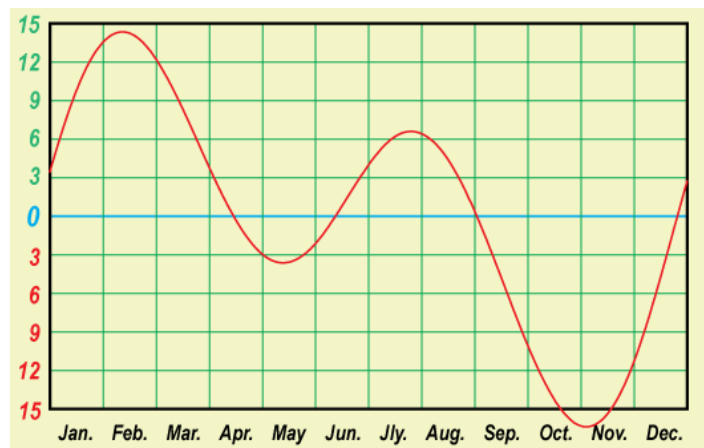
Physical characteristics of some planets, Moon, Sun and Eris

Небесное тело, Планета	Среднее расстояние от центрального тела		Сидерический (или аналогичный) период обращения		На- клон орби- ты, <i>i</i>	Экс- цен- три- ситет, <i>e</i>	Эквато- риальн. диаметр <i>км</i>	Масса 10^{24} кг	Сред- няя плот- ность г/см^3	Ускор. своб. пад. у пов. м/с^2	На- клон оси	Макс. блеск, вид. с Земли (**)	Аль- бедо
	в <i>астр.</i> <i>ед.</i>	в <i>млн.</i> <i>км</i>	в тропич. годах	в средних сутках									
Body, Planet	Average distance to central body		Sidereal period (or analogous)		Orbital inclination, <i>i</i>	Ec- centricity <i>e</i>	Equat. diameter <i>km</i>	Mass 10^{24} kg	Av. den- sity g/cm^3	Grav. accelr. at surf. m/s^2	Axial tilt	Max. magn. From Earth (**)	Al- bedo
	in <i>astr.</i> <i>units</i>	in 10^6 km	in tropical years	in days									
Солнце Sun	$1,6 \cdot 10^9$	$2,5 \cdot 10^{11}$	$2,2 \cdot 10^8$	$8 \cdot 10^{10}$			1392000	1989000	1,409			$-26,74^{\text{m}}$	
Меркурий Mercury	0,387	57,9	0,241	87,969	$7,00^\circ$	0,206	4 879	0,3302	5,43	3,70	$0,01^\circ$		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	$-12,7^{\text{m}}$	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	$-2,0^{\text{m}}$	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	$-2,7^{\text{m}}$	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	$0,7^{\text{m}}$	0,68
Эрида Eris	68,05			205 029	43,82	0,435	2 326	0,0167	2,52	0,7			0,96

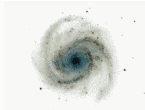


Прецессия * Precession

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



Уравнение времени Equation of time



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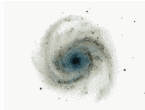
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Некоторые константы и формулы

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)	$6.674 \cdot 10^{-11}$	Constant of gravitation, G (N·m ² /kg ²)
Солнечная постоянная, A (Вт/м ²)	1367	Solar constant, A (W/m ²)
Параметр Хаббла, среднее значение H_0 (км/с/Мпк) диапазон значений	71 50-100	mean value Hubble parameter, diapason of values 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)
Постоянная Стефана-Больцмана, σ (Вт/м ² /К ⁴)	$5.670 \cdot 10^{-8}$	Stefan-Boltzmann constant, σ (W/m ² /K ⁴)
Константа смещения Вина, b (м·К)	0.002897	Wien's displacement constant, b (m·K)
Лабораторная длина волны $H\alpha$ (Å)	6562.81	Laboratory wavelength of $H\alpha$ (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	$I = \frac{2}{5} MR^2$	Moment of inertia of a solid ball
Объём шара	$V = \frac{4}{3} \pi R^3$	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



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28 самых ярких звёзд неба

28 brightest stars in the sky

			RA	DEC	<i>p</i>	<i>m</i>	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



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Диаграмма Герцшпрунга-Рассела

Hertzsprung-Russell diagram

