АСТРОНОМИЧЕСКОЕ
ОБЩЕСТВО

EURO–ASIAN
ASTRONOMICAL SOCIETY

Round **Theo**

Group **α**

XIX Международная астрономическая олимпиада
XIX International Astronomy Olympiad

Бишкек – Чолпон-Ата   12–21. X. 2014   Bishkek – Cholpon-Ata
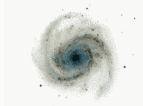
язык
language | ***English***

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 (150th) 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.
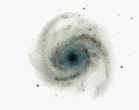
АСТРОНОМИЧЕСКОЕ ОБЩЕСТВО

EURO–ASIAN ASTRONOMICAL SOCIETY

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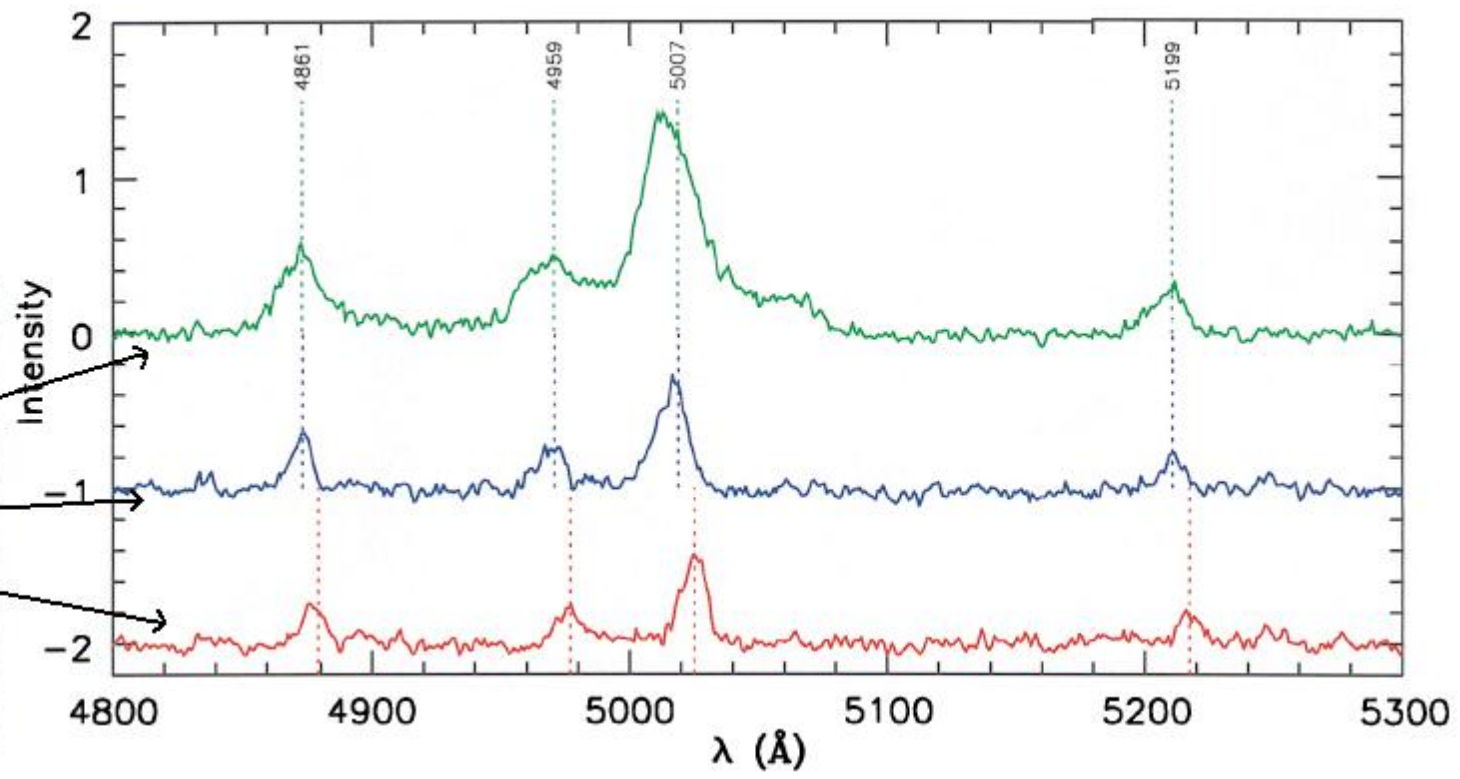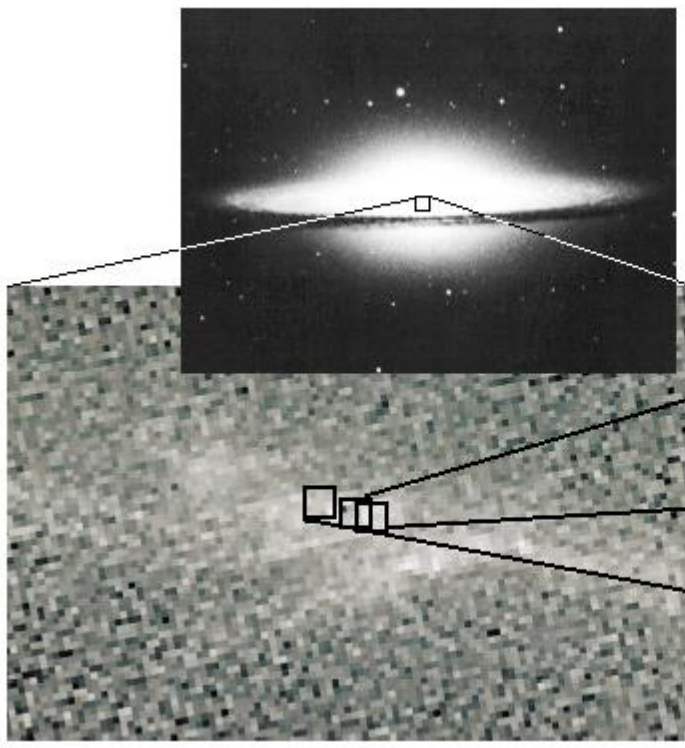
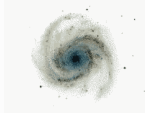The answers «**Да-Yes**» or «**Нет-No**» have to be written <u>in English or Russian</u>.

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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'×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 $m_\odot$).

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| язык / language | ***English*** |

XIX **Международная астрономическая олимпиада**
XIX **International Astronomy Olympiad**

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Теоретический тур. Галактика Сомбреро

Theoretical round. Sombrero Galaxy

XIX Международная астрономическая олимпиада
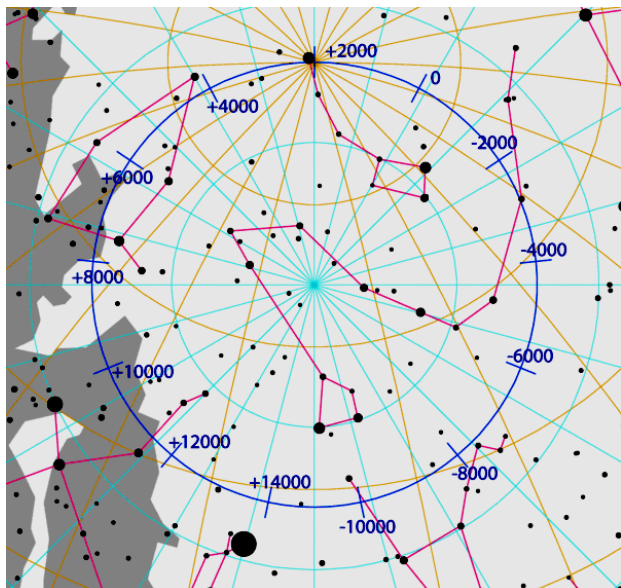# XIX International Astronomy Olympiad

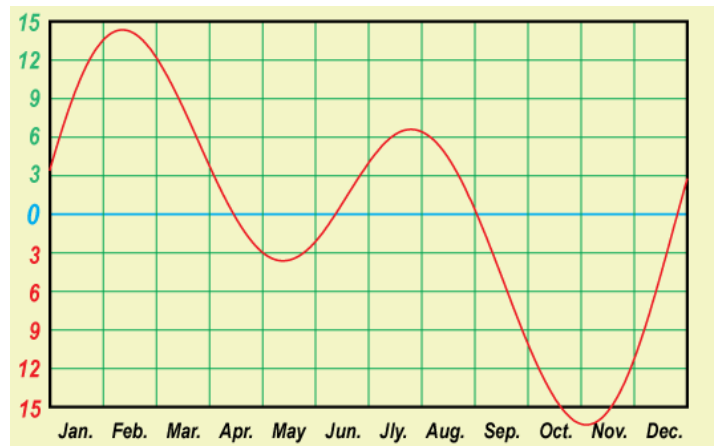Бишкек – Чолпон-Ата   12–21. X. 2014   Bishkek – Cholpon-Ata

Элементы орбит.
Физические характеристики некоторых планет, Луны, Солнца и Эриды
Parameters of orbits.
Physical characteristics of some planets, Moon, Sun and Eris

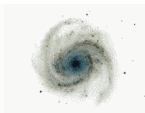| Небесное тело, Планета / Body, Planet	Среднее расстояние от центрального тела — в *астр. ед.* / Average distance to central body — in *astr. units*	— в *млн. км* / in 10^6 km	Сидерический (или аналогичный) период обращения — в тропич. годах / Sidereal period (or analogous) — in tropical years	— в средних сутках / in days	На-клон орби-ты, *i* / Orbital inclin-ation, *i*	Экс-цен-триси-тет, *e* / Eccentri-city *e*	Эквато-риальн. диаметр *км* / Equat. diameter *km*	Масса 10^{24} *кг* / Mass 10^{24} kg	Сред-няя плот-ность *г/см³* / Av. den-sity *g/cm³*	Ускор. своб. пад. у пов. *м/с²* / Grav. accelr. at surf. *m/s²*	На-клон оси / Axial tilt	Макс. блеск, вид. с Земли **) / Max. magn. From Earth **)	Аль-бедо / Al-bedo
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			$-26{,}74^m$	
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

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

Прецессия * Precession

Уравнение времени   Equation of time

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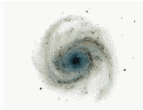
Некоторые константы и формулы
Some constants and formulae

Русский	Значение	English
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, среднее значение H_0 (км/с/МПк) 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)
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 Hα (Å)	6562.81	Laboratory wavelength of Hα (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	p	m	S C
Альтаир	Altair	α Aql	19ʰ 50ᵐ 47ˢ	08° 52' 06"	0".195	0ᵐ.77	A7
Капелла	Capella	α Aur	05ʰ 16ᵐ 41ˢ	45° 59' 53"	0".073	0ᵐ.08	G5+G0
Арктур	Arcturus	α Boo	14ʰ 15ᵐ 38ˢ	19° 10' 57"	0".089	−0ᵐ.04ᵛ	K1
Канопус	Canopus	α Car	06ʰ 23ᵐ 57ˢ	−52° 41' 45"	0".028	−0ᵐ.72	F0
Бета Киля	Miaplacidus	β Car	09ʰ 13ᵐ 12ˢ	−69° 43' 02"	0".029	1ᵐ.68	A2
Толиман	Toliman (Rigel Kent)	α Cen	14ʰ 39ᵐ 36ˢ	−60° 50' 07"	0".747	−0ᵐ.01 / 1ᵐ.33	G2 / K1
Хадар	Hadar	β Cen	14ʰ 03ᵐ 49ˢ	−60° 22' 23"	0".009	0ᵐ.61	B1
Сириус	Sirius	α CMa	06ʰ 45ᵐ 09ˢ	−16° 42' 58"	0".375	−1ᵐ.46	A1
Адара	Adara	ε CMa	06ʰ 58ᵐ 38ˢ	−28° 58' 19"	0".008	1ᵐ.50	B2
Процион	Procyon	α CMi	07ʰ 39ᵐ 18ˢ	05° 13' 30"	0".288	0ᵐ.38	F5
Акрукс	Acrux	α Cru	12ʰ 26ᵐ 36ˢ	−63° 05' 57"	0".010	0ᵐ.77	B0
Бекрукс	Becrux	β Cru	12ʰ 47ᵐ 43ˢ	−59° 41' 20"	0".009	1ᵐ.30	B0
Гакрукс	Gacrux	γ Cru	12ʰ 31ᵐ 10ˢ	−57° 06' 48"	0".037	1ᵐ.60	M4
Денеб	Deneb	α Cyg	20ʰ 41ᵐ 26ˢ	45° 16' 49"	0".002	1ᵐ.25	A2
Ахернар	Achernar	α Eri	01ʰ 37ᵐ 43ˢ	−57° 14' 12"	0".026	0ᵐ.46	B3
Кастор	Castor	α Gem	07ʰ 34ᵐ 36ˢ	31° 53' 18"	0".065	1ᵐ.58	A1+A2
Поллукс	Pollux	β Gem	07ʰ 45ᵐ 19ˢ	28° 01' 35"	0".097	1ᵐ.14	K0
Регул	Regulus	α Leo	10ʰ 08ᵐ 22ˢ	11° 58' 02"	0".041	1ᵐ.35	B7
Вега	Vega	α Lyr	18ʰ 36ᵐ 56ˢ	38° 47' 01"	0".123	0ᵐ.03	A0
Бетельгейзе	Betelgeuse	α Ori	05ʰ 55ᵐ 10ˢ	07° 24' 25"	0".005	0ᵐ.5ᵛ	M2
Ригель	Rigel	β Ori	05ʰ 14ᵐ 32ˢ	−08° 12' 06"	0".013	0ᵐ.12	B8
Беллатрикс	Bellatrix	γ Ori	05ʰ 25ᵐ 08ˢ	06° 20' 59"	0".013	1ᵐ.64	B2
Фомальгаут	Fomalhaut	α PsA	22ʰ 57ᵐ 39ˢ	−29° 37' 20"	0".130	1ᵐ.16	A3
Антарес	Antares	α Sco	16ʰ 29ᵐ 24ˢ	−26° 25' 55"	0".024	0ᵐ.96	M1+B4
Шаула	Shaula	λ Sco	17ʰ 33ᵐ 37ˢ	−37° 06' 14"	0".005	1ᵐ.62	B2
Альдебаран	Aldebaran	α Tau	04ʰ 35ᵐ 55ˢ	16° 30' 33"	0".048	0ᵐ.85ᵛ	K5
Эль-Нат	Elnath	β Tau	05ʰ 26ᵐ 18ˢ	28° 36' 27"	0".025	1ᵐ.66	B7
Спика	Spica	α Vir	13ʰ 25ᵐ 12ˢ	−11° 09' 41"	0".023	0ᵐ.98	B1

Некоторые другие звёзды

Some other stars

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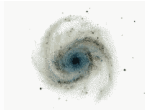
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Диаграмма Герцшпрунга-Рассела   Hertzsprung-Russell diagram