For translation only. **Theoretical round. Problems to solve**

Note for translators: in texts for Group β by the red color marked the text identical to that used for Group α.

αβ-1. Culmination of the Moon. To prepare for observing the annular solar eclipse, which will take place on December 26, 2019 (early in the morning Romanian time), the Polar Bear-astronomer decided to observe the culmination of the Moon and came to Piatra Neamt for this.

1.1. At what day of October 2019 will the Moon culminate at the highest position?

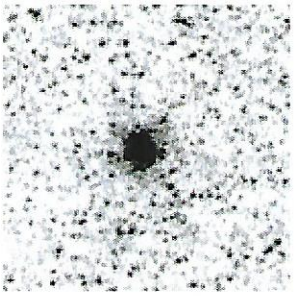
1.2. At what time (with the accuracy of an hour) will this happen?

1.3. Estimate at what ~~heigh~~ height this culmination will take place?

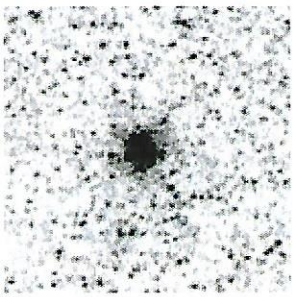
1.4. Include an artistic picture with an image of the Bear-astronomer observing the culmination of the Moon.

The inclination angle of the lunar orbit 5°09′ should not be taken into account.

α-2. NGC of the Year. NGC 2019 is a globular cluster in the constellation Mensa, observed against the background of the Large Magellanic Cloud. The cluster has a visible magnitude $m = 10.9^m$, and is located at a distance of approximately L = 50 kpc from us. To the right, you can see a 4×4 arcmin negative picture of NGC 2019. Assume that the cluster consists of stars similar to the Sun, more or less evenly distributed in the space of the central "sphere" region, the image of which is clearly visible in the center of the image against the background of the LMC. Estimate, at what distance from the center of the cluster an observer need to be located in order to distinguish separately the stars visible in the projection on the center of the cluster with the naked eye.



β-2. NGC of the Year. NGC 2019 is a globular cluster in the constellation Mensa, observed against the background of the Large Magellanic Cloud. The cluster has a visible magnitude $m = 10.9^m$, colour index $B–V = 0{,}04^m$, and is located at a distance of approximately L = 50 kpc from us. To the right you can see a 4×4 arcmin negative picture of NGC 2019. Assume that the cluster consists for the most part of approximately the same stars located on the main sequence, as well as a small percentage of white dwarfs, and that all these stars are more or less evenly distributed in the space of the central "sphere" region, the image of which is clearly visible in the center of the image against the background of the LMC. Estimate, at what distance from the center of the cluster an observer need to be located in order to distinguish separately the white dwarfs visible in the projection on the center of the cluster with the naked eye.



α-3. Sunset in Chukotka. The brown Bear-astronomer Chukchi, sitting on the shore of the Bering Strait on the easternmost point of the Eurasian continent (Cape Dezhnev, Chukotka) observes the sunset (the last ray of the Sun). At the same time his distant relative, the Bear-astronomer Eskimo, sitting on the other side of the Bering Strait exactly at the same latitude (the west coast of Alaska) sees the sunrise (the first ray).

3.1. Find the approximate date of the event (± 2 days).

3.2. Calculate, whether this moment occurs on the same date or on different dates for Chukchi Bear and Eskimo Bear in the time of the local time zone for each of them.

3.3. Accompany the solution with art drawings of Chukchi Bear and Eskimo Bear observing these astronomical events.

β-3. UY Scuti. Supergiant UY Scuti is the largest (its volume is estimated as 5 billion volumes of the Sun) and one of the fastest burning stars currently known. Herewith, the mass loss per unit time due to radiation is only 0.04% of the total mass loss over the same time, and only 0.5% of the light pass through its shell (that is, go to the observers).

3.1. Estimate the values of the necessary parameters and plot the position of UY Scuti on the Hertzsprung-Russell diagram.

3.2. Estimate the remaining life time of UY Scuti.

αβ-4. Comet particles. Particles of characteristic cometary matter of various sizes come off a comet. Estimate, the characteristic sizes D of the particles which are not ejected outside the Solar System due to the solar radiation pressure.

Note: You will get more points for the solution if you first derive the algebraic formula of the answer D = f (a,b,c,d,e...) and only then get the numerical answer by inserting the numerical data a, b, c, d, e... into this formula.

*For Group **α** only. Note: In the middle of the time of the round you will be provided with one additional formula.*

α-5. Interstellar comet. 2I/Borisov is the first observed interstellar comet. It was discovered on August 30 this year by the Crimean astronomer G. V. Borisov with a 65-cm telescope of his own development. The point on celestial sphere from where the comet moved before entering the Solar System is located near the star Ruchbah in the constellation Cassiopeia. On December 7, the comet will pass the perihelion of its orbit at a speed of 43 km/s relative to the Sun, being 2.01 au from it.

5.1. Will it be possible to observe the star Ruchbah from Piatra Neamt tonight?

5.2. Estimate how long ago the comet 2I/Borisov passed near the star Ruchbah.

5.3. Calculate whether our Sun is visible with the naked eye from the vicinity of the Ruchbah star (write the answer in English, "Yes" or "No").

By the way. The comet was discovered at the observational round place of the IV and VI IAO (1999, 2001), and G. V. Borisov was a member of the Organizing Committee of these IAOs.

β-5. Two satellites. Two artificial satellites move around an unknown planet in circular orbits. The satellite S_1 moves in an equatorial orbit with the angular velocity ω_1, and the satellite S_2 moves in a polar orbit with the angular velocity ω_2, as shown in Fig.5. The planet rotates around its axis with the angular velocity ω_0. At the initial time, the satellites are in zenith for observer O.

5.1. It is known that for observer O, the duration of the visibility (from the zenith to setting) of satellite S_2 is t_2. Find the similar visibility duration t_1 of satellite S_1.

5.2. Find the azimuth ζ of the satellite S_2 setting point (the point of its "disappearance" for the observer). Consider the South direction as the zero azimuth point (0°).

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АСТРОНОМИЧЕСКОЕ ОБЩЕСТВО

EURO-ASIAN ASTRONOMICAL SOCIETY

Round **Theo**

Group **α** **β**

XXIV Международная астрономическая олимпиада
XXIV International Astronomy Olympiad

Румыния, Пьятра-Нямц 19-27. X. 2019 Piatra Neamt, Romania

Язык / language	**Русский**
Язык / language	**English**

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 ($Н \cdot м^2/кг^2$)	$6.674 \cdot 10^{-11}$	Constant of gravitation, G ($N \cdot m^2/kg^2$)
Солнечная постоянная, A ($Вт/м^2$)	1367	Solar constant, A (W/m^2)
Параметр Хаббла, H_0 (км/с/МПк) — среднее значение	68	mean value — Hubble parameter,
Параметр Хаббла, H_0 (км/с/МПк) — диапазон значений	50-100	range 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 mass 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 Hα (Å)	6563	Laboratory wavelength of Hα (Å)
Лабораторная длина волны Hβ (Å)	4861	Laboratory wavelength of Hβ (Å)
Длина тропического года, T (сут)	365.242199	Tropical year length, T (days)
Длина сидерического года, T (сут)	365.25636	Sidereal year length, T (days)
Длина аномалистического года, T (сут)	365.259636	Anomalistic year length, T (days)
Период обращения узлов лунной орбиты (лет)	−18.6	Nodal period of lunar orbit (years)
Зависимость атмосферного давления от высоты	$P = P_0 e^{-\mu g h / RT}$	Dependence of atmospheric pressure on height
Стандартная атмосфера, P_0 (Па)	101 325	Standard atmosphere, P_0 (Pa)
Высота однородной атмосферы (м)	7991	Height of homogeneous atmosphere (m)
Ослабление видимого света слоем 1 атмосферы (минимально)	19%, 0.23^m	Visible light extinction by the terrestrial atmosphere in zenith (minimum)
Показатель преломления воздуха (1 атм., 0°C), n	1.0002926	Refractive index of air (1 atm., 0°C), n
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
Момент инерции сферы	$I = {}^2/_3 MR^2$	Moment of inertia of sphere
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

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Элементы орбит и физические характеристики Солнца, планет, некоторых карликовых планет и Луны

Parameters of orbits and physical characteristics of Sun, planets, some dwarf 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	Equat. diameter	Mass	Av. density	Grav. acceler. at surf.	Max. magn. from Earth **)	Albedo
	in *astr. units*	in *mln. km*	in *tropical years*	in *days*	*e*	*km*	10^{24} *kg*	*g/cm*^{3}	*m/s*^{2}		
Солнце Sun	$1{,}65\cdot10^9$	$2{,}5\cdot10^{11}$	$2{,}3\cdot10^8$	$8{,}4\cdot10^{10}$		1392000	1989000	1,409		-26,8^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
Церера Ceres	2,77	414	4,60	1 681	0,077	963	0,0009	2,16	0,27	6,7^m	0,09
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
Плутон Pluto	39,482	5906,4	248,09	90 613	0,249	2 374	0,0130	1,86	0,61	15,1^m	0,6

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

Coordinates Координаты	Piatra Neamt Пьятра-Нямц	Cape Dezhnev Мыс Дежнёва	Opposite point in Alaska Противоположная точка Аляски
λ (E / в.д.)	+26° 22′	–169° 39′	–166° 40′
φ (N / с.ш.)	+46° 56′	+66° 05′	+66° 05′
Altitude above sea level Высота над уровнем моря	345 м	0 м	0 м
Local timezone Местный часовой пояс	UT+03	UT+12	UT–09
	Romania	Russia	USA

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Code of participant / Код участника

Диаграмма Герцшпрунга-Рассела
Hertzsprung-Russell diagram

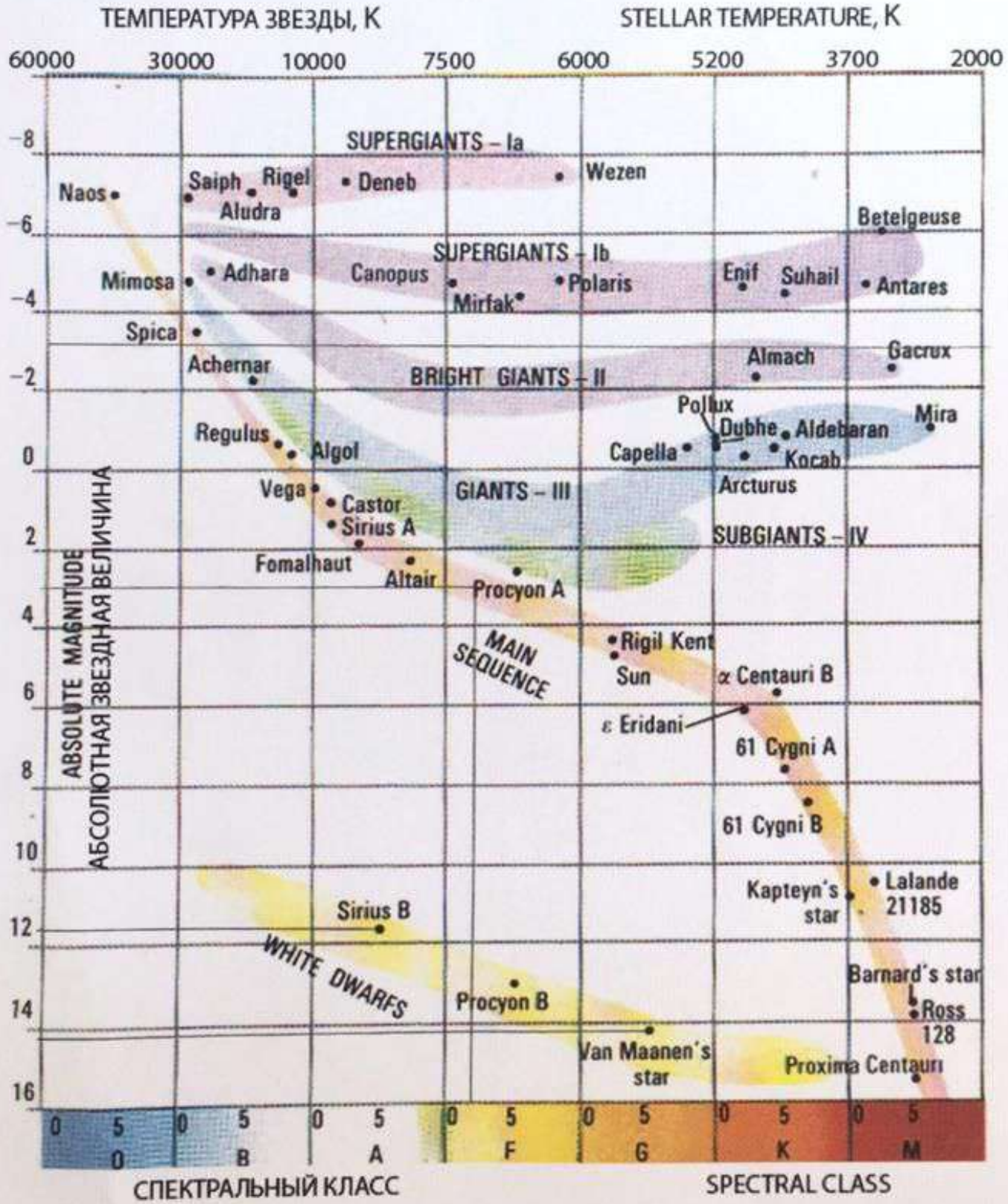
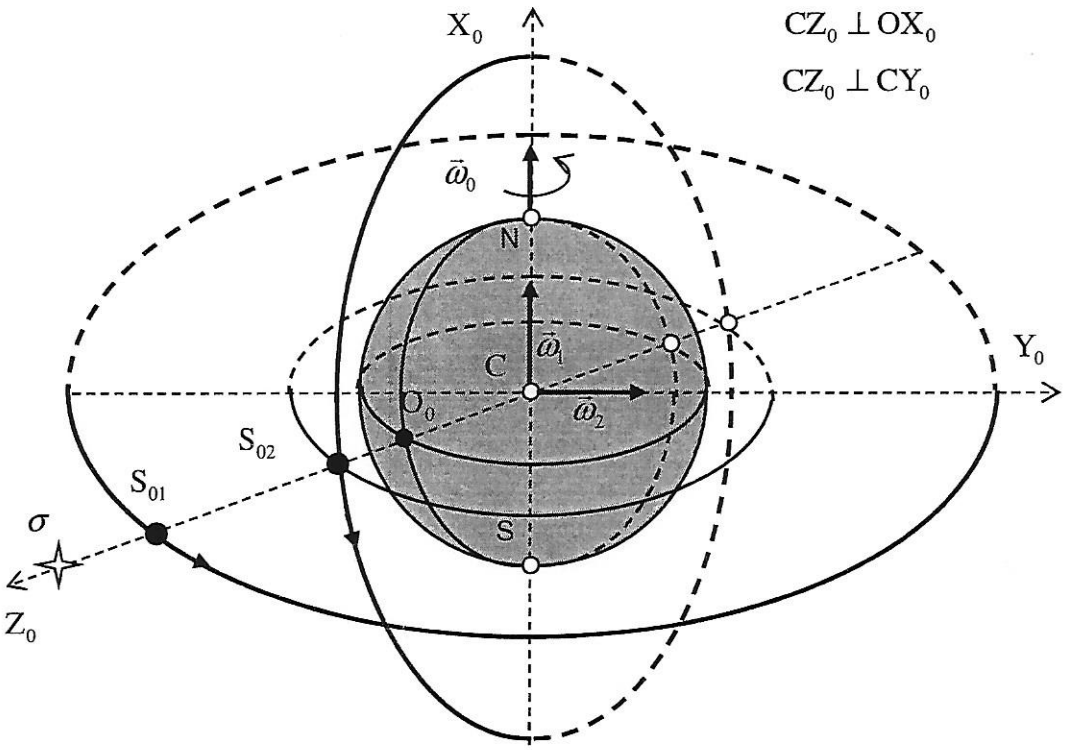


Рис. к задаче 5. **Fig. for problem 5.**



16 самых ярких звёзд неба и некоторые другие звёзды

16 brightest stars in the sky and some other stars

			R.A.	DEC	p	Лучевая скорость Radial velocity	Зв.вел. Mag.	Масса Mass
Солнце	Sun	⊙	$0^h - 24^h$	-23°26' – +23°26'	8".794	0	$-26^m.74$	1 Mo
Сириус	Sirius	α CMa	$06^h\ 45^m\ 09^s$	-16° 42' 58"	0".379	–5,5 km/s	$-1^m.46$	3.1 Mo
Толиман	Toliman (Rigel Kent)	α Cen A	$14^h\ 39^m\ 36^s$	-60° 50' 07"	0".747	–21,6 km/s	$-0^m.01$	1.11 Mo
		α Cen B					$1^m.33$	0.93 Mo
Канопус	Canopus	α Car	$06^h\ 23^m\ 57^s$	-52° 41' 45"	0".011	+20,7 km/s	$-0^m.74$	10 Mo
Арктур	Arcturus	α Boo	$14^h\ 15^m\ 40^s$	19° 10' 56"	0".089	–5,2 km/s	$-0^m.05^v$	1.1 Mo
Вега	Vega	α Lyr	$18^h\ 36^m\ 56^s$	38° 47' 01"	0".130	–20,6 km/s	$0^m.03^v$	2.14 Mo
Капелла	Capella	α Aur	$05^h\ 16^m\ 41^s$	45° 59' 53"	0".076	+30,1 km/s	$0^m.08$	6.1 Mo
Ригель	Rigel	β Ori	$05^h\ 14^m\ 32^s$	08° 12' 06"	0".004	+20,7 km/s	$0^m.12^v$	21 Mo
Процион	Procyon	α CMi A	$07^h\ 39^m\ 18^s$	05° 13' 30"	0".286	–4,1 km/s	$0^m.37$	1.50 Mo
		α CMi B					$10^m.75$	0.60 Mo
Ахернар	Achernar	α Eri	$01^h\ 37^m\ 43^s$	-57° 14' 12"	0".023	+16,0 km/s	$0^m.45$	6.7 Mo
Бетельгейзе	Betelgeuse	α Ori	$05^h\ 55^m\ 10^s$	07° 24' 25"	0".005	+22,0 km/s	$0^m.5^v$	11.6 Mo
Хадар	Hadar	β Cen	$14^h\ 03^m\ 49^s$	-60° 22' 23"	0".008	+5,9 km/s	$0^m.61^v$	26.6 Mo
Альтаир	Altair	α Aql	$19^h\ 50^m\ 47^s$	08° 52' 06"	0".195	–26,1 km/s	$0^m.77$	1.7 Mo
Акрукс	Acrux	α Cru	$12^h\ 26^m\ 36^s$	-63° 05' 57"	0".010	+11,9 km/s	$0^m.77$	39 Mo
Альдебаран	Aldebaran	α Tau	$04^h\ 35^m\ 55^s$	16° 30' 33"	0".050	+56,3 km/s	$0^m.85^v$	2.5 Mo
Антарес	Antares	α Sco	$16^h\ 29^m\ 24^s$	-26° 25' 55"	0".024	–3,4 km/s	$0^m.96^v$	12.4 Mo
Спика	Spica	α Vir	$19^h\ 50^m\ 47^s$	08° 52' 06"	0".013	+1,0 km/s	$0^m.98^v$	18.6 Mo
Полярная	Polaris	α UMi	$02^h\ 31^m\ 49^s$	89° 15' 51"	0".007	–17 km/s	$1^m.97^v$	6.4 Mo
Хамаль	Hamal	α Ari	$02^h\ 07^m\ 10^s$	23° 27' 45"	0".050	–14,2 km/s	$2^m.00^v$	1.8 Mo
Кохаб	Kochab	β UMi	$14^h\ 50^m\ 42^s$	74° 09' 20"	0".025	+17,0 km/s	$2^m.08$	2.2 Mo
Наос	Naos	ζ Pup	$08^h\ 03^m\ 35^s$	-40° 00' 12"	0".003	–24 km/s	$2^m.21$	40 Mo
Рукбах	Ruchbah	δ Cas	$01^h\ 25^m\ 49^s$	60° 14' 07"	0".0328	–6,7 km/s	$2^m.68$	2.49 Mo
UY Щита	UY Scuti	UY Sct	$18^h\ 27^m\ 37^s$	-12° 27' 59"	0".00034	+18,3 km/s	$9^m.1$	8 Mo
Проксима Центавра	Proxima Centauri	V645 Cen, α Cen C	$14^h\ 29^m\ 43^s$	-62° 40' 46"	0".769	–21,7 km/s	$11^m.06$	0.123 Mo