Read once more before you start your work

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.

Do not forget that in clean copy you should write solutions **only on even (left) pages. The odd (right) pages** will be used by your team leader to translate solutions into English and also to emphasize your thoughts in solutions.

EVEN PAGE	ODD PAGE
Текст решения. *Text of solution.* *Текст решения.* *Text of solution.* *Текст решения.* *Text of solution.*	
ЧЁТНАЯ СТРАНИЦА	НЕЧЁТНАЯ СТРАНИЦА

Ещё раз прочитайте перед началом работы

Общее замечание. Не исключено, что не во всех задачах вопросы поставлены корректно. Некоторые вопросы (возможно, главный вопрос задачи, возможно – подвопрос) могут не иметь смысла. В этом случае следует написать в ответе (по-русски или по-английски): «**ситуация невозможна – impossible situation**». Естественно, ответ должен быть подкреплён вычислениями или логическими рассуждениями.

Данные из таблиц (Солнечная система, звёзды, константы) могут быть использованы в любой задаче.

Ответы «**Да-Yes**» или «**Нет-No**» должны быть написаны по-русски или по-английски.

Не забудьте, что в чистовике вы должны писать решения только на чётных (левых) страницах. Нечётные (пра́вые) страницы предназначены для того, чтобы руководитель вашей команды перевёл решения на английский язык и подчеркнул основные мысли решения.

EVEN PAGE	ODD PAGE
Текст решения. *Text of solution.* *Текст решения.* *Text of solution.* *Текст решения.* *Text of solution.*	
ЧЁТНАЯ СТРАНИЦА	НЕЧЁТНАЯ СТРАНИЦА

Theoretical round. Problems to solve

α-1. Double star. A double star consists of components by all physical characteristics equal to α Centauri **A** and α Centauri **B**, which are rotating around the common center of gravity by circular orbits. As observed from the Earth the angular distance between the components varies from 0.17" till 2.2" with a period of τ = 39.6 years. Find the distance to the double star.

β-1. Double star. A double star consists of components by all physical characteristics equal to α Centauri **A** and α Centauri **B**, which are rotating around the common center of gravity by circular orbits. As observed from the Earth the angular distance between the components varies from 0.17" till 2.2" with a period of τ = 39.6 years. Find the apparent magnitude of every component and also their combined magnitude.

α-2. Extraterrestrial summit. Extraterrestrial Bear and Extraterrestrial Penguin living in different planetary systems of our Galaxy, came to a summit organized at the Intercivilizational Space Station (ISS) somewhere in the depths of space, where no one star is visible brighter than 1^m. However, it appeared that both stars, from which planetary systems the Bear and the Penguin came, are visible with the naked eye at the summit (assume the sensitivity of the retina of these extraterrestrial animals to be the same as of humans), and the angular distance between them is equal to **β** = 30°.

2.1. Find the possible minimum and maximum linear distance between the native stars of the Bear and the Penguin. Consider the planetary systems are possible near the stars of spectral classes from **A** to **M** of main sequence.

2.2. Include an artistic picture with an image of the Extraterrestrial Bear and Extraterrestrial Penguin (and possibly other extraterrestrial animals) on the ISS.

β-2. Extraterrestrial summit. Extraterrestrial Bear and Extraterrestrial Penguin living in different planetary systems of our Galaxy, came to a summit organized on the Intercivilizational Space Station (ISS) somewhere in the depths of space, where no one star is visible brighter than 1^m. However, it appeared that both stars, of which planetary systems came the Bear and the Penguin, are visible with the naked eye at the summit (assume the sensitivity of the retina of these extraterrestrial animals the same as of humans), and the angular distance between them is equal to **β** (30° < **β** < 90°).

2.1. Find the possible minimum and maximum linear distance between the native stars of the Bear and the Penguin? Give the answers in numerical form, and if it is not possible, as a function of the angle **β**. Consider the planetary systems are possible near the stars of spectral classes from **A** to **M** of main sequence.

2.2. Include an artistic picture with an image of the Extraterrestrial Bear and Extraterrestrial Penguin (and possibly other extraterrestrial animals) on the ISS.

αβ-3. Mirror and plate. There is a system, consisting of a plane mirror (100% reflection) and a plane glass plate that transmits K% of the light and reflects the other (100-K)% (this characteristics is the same for the light coming from both the directions). The mirror and plate are parallel and infinite on their right side. An observer is placed at the point O (marked by *) and sees a star with a magnitude 2^m within a cone around direction «A». What magnitude(s) star(s) (if any) would the observer see in a cone near direction «B» that is symmetrical to «A»? Calculate numerical value for K = 50% and K = 5% for each such a star (if any visible) or explain why no stars are visible.

```
                     B
                    /
                   /
        ---------------------------------------- Mirror
                 /
Observer O * ----------------------------------- Plate
              \
               \
                \
                 A
```

α-4. Eclipse in USA. A little more than two months ago, on August 21, 2017 from West to East of the USA territory a total solar eclipse was observed. The middle line of the track of the eclipse is shown schematically on the map. Below are four pictures taken by the Bulgarian-Russian group of observers who were in state of Oregon, through which the Moon's shadow ran as it shown in Fig.α4. (see separate sheet). The local time (UT –07) of the shots is indicated below each image. By using the data and making calculations, estimate:

4.1. altitude of the Sun in Oregon at the moment of totality;

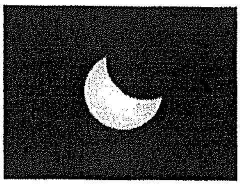
4.2. time **t** (in seconds) between the positions 1 and 2 of the shadow as marked at Fig.α4.

β-4. Eclipse in USA. A little more than two months ago, on August 21, 2017 from West to East of the USA territory a total solar eclipse was observed. The middle line of the track of the eclipse is shown schematically on the map. Below are four pictures taken by the Bulgarian-Russian group of observers who were near the West coast, in the state Oregon, through which the Moon's shadow ran almost along the latitude $\varphi = 45°$. The local time (UT –07) of the shots is indicated below each image. At the moment of totality the Sun was in the South-Eastern part of the sky, in $\chi = 59{,}5°$ from the South in azimuth, at an altitude of $h = 41.9°$ above the horizon. By using the data and making calculations, estimate:

4.1. the speed of the Moon's shadow in the state Oregon;

4.2. the width of the path of the total eclipse (in km) on its territory.

21.08.2017.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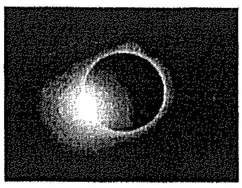
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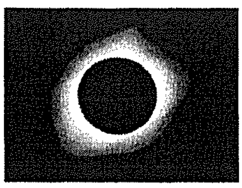
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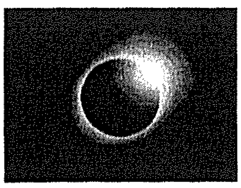

10:22:14

α-5. Whirlpool galaxy. An imaging observation of Messier object M51, consisted of galaxy NGC 5194 ($\alpha = 13^h29^m56^s$, $\delta = +47°13'50''$) and its companion NGC 5195, was made by the 1-m telescope of Weihai Observatory (WHO), on December 25, 2014. The V-band image is shown in Fig.α5. (see separate sheet), the bounding box marks the field of view of the image taken by the telescope (with focal length of 8 meters) and the PI CCD (2048 × 2048, pixel size 13.5 μm × 13.5 μm).

5.1. Find the Beijing time (UTC+08, write the answer in 24h format: hh:mm) of the upper culmination of NGC 5194 in Weihai Observatory on the observing date, in form of «T_c = ...».

5.2. Estimate the angular size (diameter) of NGC 5194 (in units of arc minutes, write the answer in form of «β = ...»).

5.3. If the physical size of NGC 5194 is known as about half the size of the Milky Way Galaxy, estimate the distance to M51 (in units of Mpc, write the answer in form of «L = ...»).

5.4. Which is the morphological type of NGC 5194 ("elliptical", "spiral", "barred spiral", "irregular")? Write the answer in English in form of «Type = ...».

β-5. Seyfert galaxy. The low-resolution spectrum of a galaxy: NGC 7479 ($\alpha = 23^h04^m57^s$, $\delta = +12°19'22''$) was observed by the 2.16 m telescope of Xinglong Station near Beijing, National Astronomical Observatories of China, on September 14, 2009. The red part of this spectrum is shown in Fig.β5 (see separate sheet). The emission lines in the part of the spectrum are (from left to right): [NII]a, Hα, [NII]b.

5.1. Find the Beijing time (UTC+8, write the answer in 24h format: hh:mm) of the upper culmination of this galaxy in Xinglong Observatory on the observing date, in form of «T_c = ...».

5.2. Estimate the redshift z of this galaxy (write the answer in form of «z = ...»).

5.3. Find the distance to NGC 7479 (in units of Mpc, write the answer in form of «D = ...»).

5.4. Estimate the full width at half maximum (FWHM) of the Hα line (in units of km/s, write the answer in form of «FWHM(Hα) = ...»).

5.5. If the galaxy is known as a Seyfert galaxy, based on the line width of Hα, which type it should be ("Seyfert-I" or "Seyfert-II")? Write the answer in English in form of «Type = ...». (Assume that the instrumental broadening can be neglected.)

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·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, H_0 (км/с/МПк), среднее значение	68	mean value, Hubble parameter, H_0 (km/s/Mpc)
диапазон значений	50-100	diapason of values
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/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)
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)
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
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

XXII Международная астрономическая олимпиада
XXII International Astronomy Olympiad

Диаграмма Герцшпрунга-Рассела Hertzsprung-Russell diagram

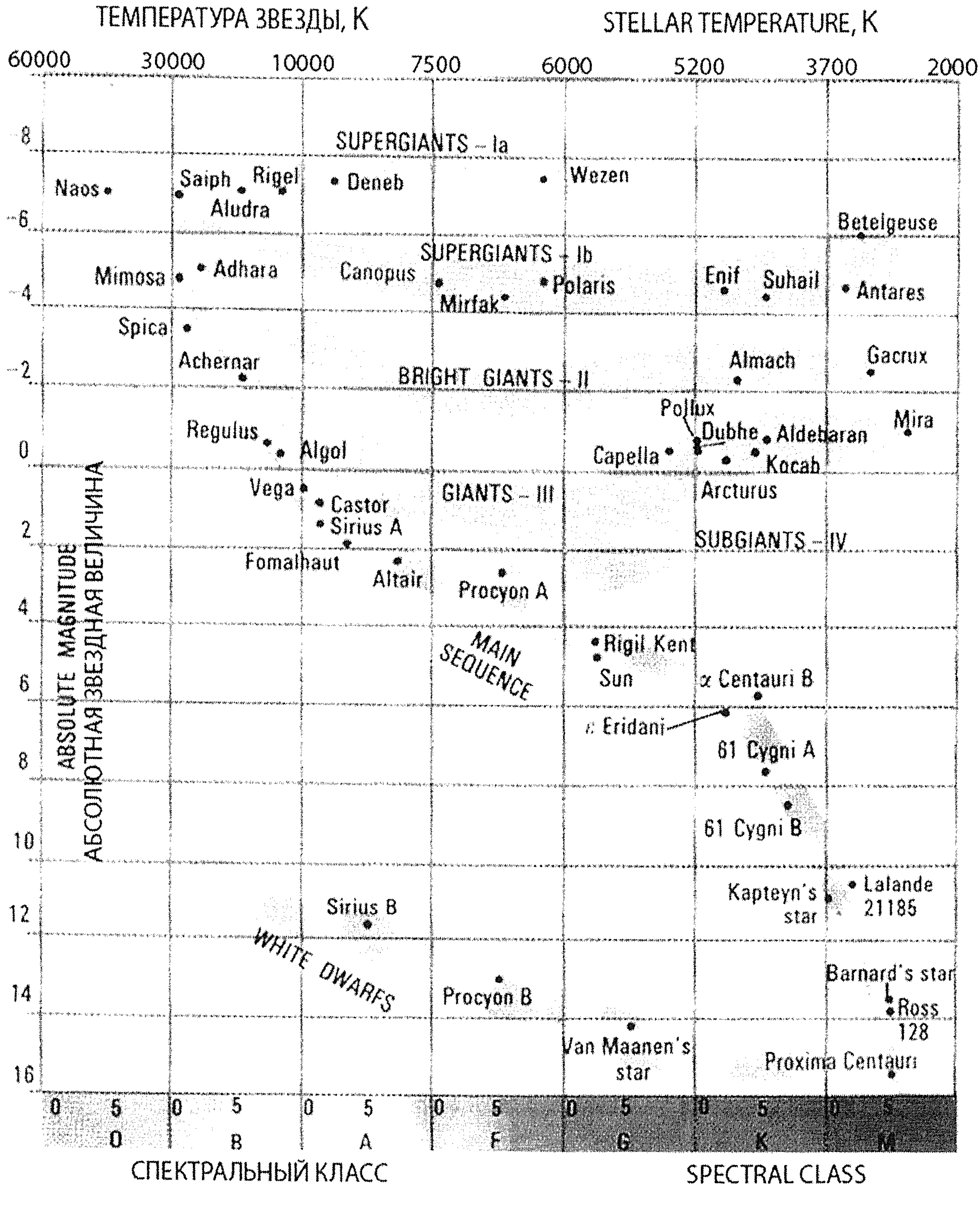
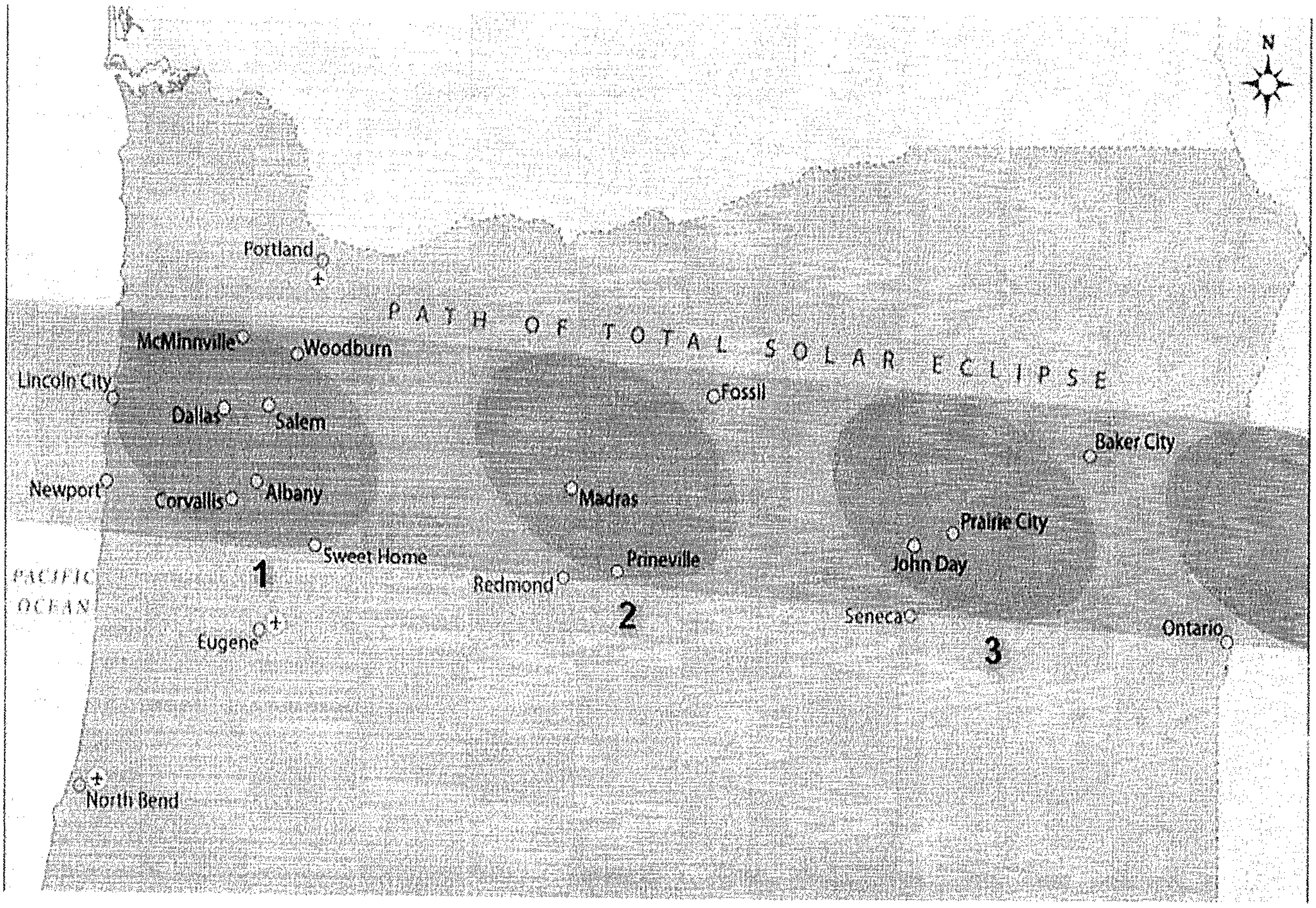
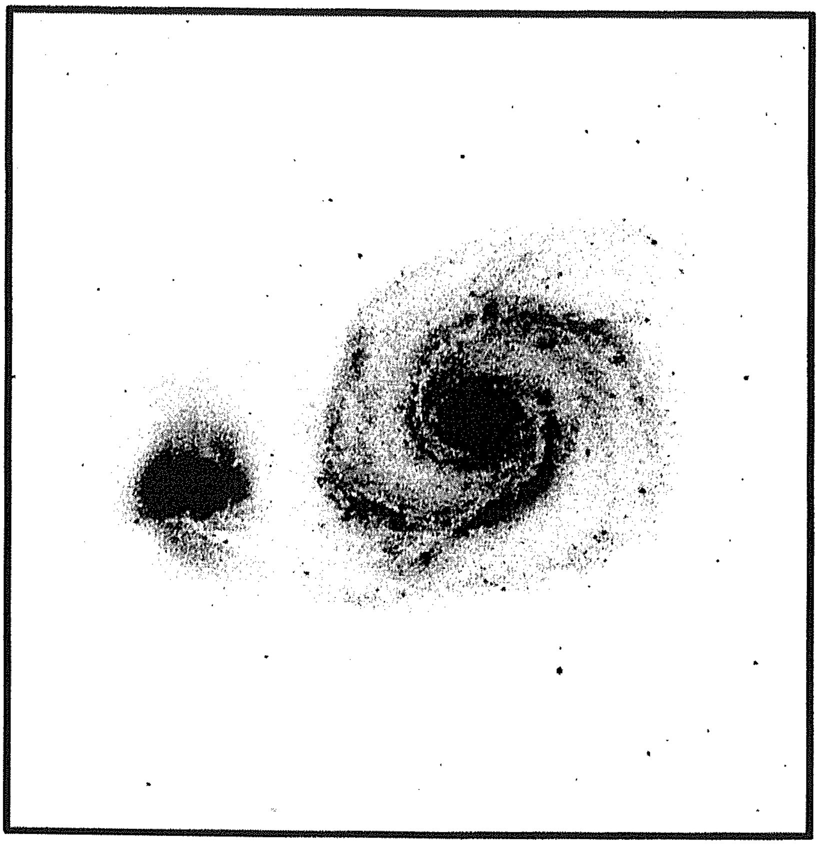


Рис. к задаче 4. **Fig. for problem 4.**



α4

Рис. к задаче 5. Fig. for problem 5.

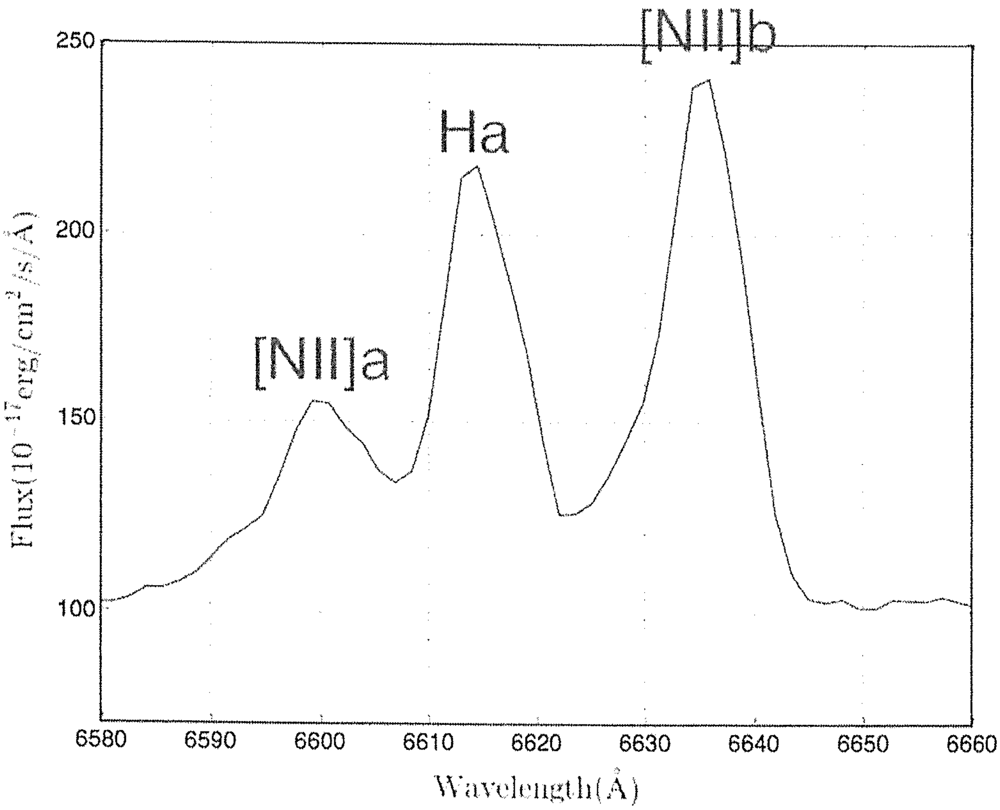


Данные о некоторых звёздах Data of some stars

			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 M☉
Бетельгейзе	Betelgeuse	α Ori	$05^h\ 55^m\ 10^s$	07° 24' 25"	0".005	$0^m.5$	3590 K	11.6 M☉
Вега	Vega	α Lyr	$18^h\ 36^m\ 56^s$	38° 47' 01"	0".130	$0^m.03$	9600 K	2.14 M☉
Наос	Naos	ζ Pup	$08^h\ 03^m\ 35^s$	-40° 00' 12"	0".003	$2^m.21$	42000 K	40 M☉
Толиман	Toliman (Rigel Kent)	α Cen A / B	$14^h\ 39^m\ 36^s$	-60° 50' 07"	0".747	$-0^m.01$ / $1^m.33$	5810 K / 5260 K	1.11 M☉ / 0.93 M☉
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 M☉

Координаты Coordinates	WHO Observatory	Xinglong Observatory
φ (N / с.ш.)	**37° 32′**	**40° 24′**
λ (E / в.д.)	**122° 03′**	**117° 35′**
Часовой пояс Timezone	**UT+08**	**UT+08**

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



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 M⊙
Бетельгейзе	Betelgeuse	α Ori	$05^h\ 55^m\ 10^s$	07° 24' 25"	0".005	$0^m.5$	3590 K	11.6 M⊙
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Наос	Naos	ζ Pup	$08^h\ 03^m\ 35^s$	-40° 00' 12"	0".003	$2^m.21$	42000 K	40 M⊙
Толиман	Toliman (Rigel Kent)	α Cen A B	$14^h\ 39^m\ 36^s$	-60° 50' 07"	0".747	$-0^m.01$ $1^m.33$	5810 K 5260 K	1.11 M⊙ 0.93 M⊙
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 M⊙

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Часовой пояс Timezone	**UT+08**	**UT+08**