Read once more before you start your work

Requirements:

— **Languages of the solutions.** *(For Practical and also for Observational rounds).* No text in any language is permitted to use in solutions. All the solution must be written using only drawing pictures, plotting graph, writing formulae, numerical values and standard international astronomy symbols (like ♂, ♎, α UMa, M31, 5^m). Numerical values must be written using standard symbols but not symbols of National alphabet. Jury of the Practical round will not take into account any text in any language in solution.

For example, the names of constellations, written in English, Russian or any other language will be not taken into account (should be only UMa, Ori, etc.).

Ещё раз прочитайте перед началом работы

Требования:

— **Языки написания решений задач.** *(На практическом и наблюдательном турах).* Тексты в решениях не допускаются (ни на каком языке). Все решения должны содержать только рисунки, графики, формулы, численные значения и стандартные международные астрономические символы (такие как ♂, ♎, α UMa, M31, 5^m). Цифры должны быть написаны стандартными символами (не символами национального алфавита). Жюри практического тура не будет учитывать какие-либо тексты (на любом языке) в решении.

Например, не учитываются названия созвездий, написанные на английском, русском или ином языке (должно быть только UMa, Ori и т.д.).

Practical round. Problems to solve

6. Transiting extra-solar planet.

The transit of an extra-solar planet (TrES-3b) across a star (TrES-3) was observed by the 1-m telescope of Weihai Observatory (WHO) on April 16, 2009, using the broad-band V filter and a PI CCD. The photometric data (selected part from the original one) are given in the Table 6 (see separate sheet), the time is in Julian days, and m_V is the V-band magnitude.

6.1. Plot the transit light curve (magnitude vs time), determine the moment of mid-transit (the deepest transit) and write result (in Julian days) in form of «T_{mid} = ...», estimate the duration of the transit (in days) in form of «T_d = ...», determine the depth of the transit (in magnitudes) in form of «D = ...» .

6.2. Give the formula and calculate the radius of the extra-solar planet TrES-3b R_p (in units of the radius of Jupiter: $R_{Jupiter}$, write the answer in form of «R_p = ...»). The radius of the star (TrES-3) is known to be 0.813 radius of the Sun, $R_s = 0.813\ R_{sun}$.

6.3. Estimate the approximate value of the angle *i*, in unit of degrees (°) between the axis of this planet's orbiting and the line of sight of the observer. Write the answer in form of «$i \approx$ ...».

6.4. The next mid-transit moment after the above transit event was: JD = 2454939.578. The mass of the star (TrES-3) is known to be 0.924 mass of the Sun, $M_s = 0.924\ M_{sun}$. Calculate the orbital period of TrES-3b (in units of days, in form of «P = ...»), and the semi-major axis of the orbit (in units of au, in form of «a = ...»).

Practical round. Problems to solve

7. Extinction in terrestrial atmosphere.

Extinction is a term used in astronomy to describe light attenuation due to its absorption and scattering.

A star ($\alpha = 22^h02^m40^s$, $\delta = +42°14'41''$) was observed at different zenith distances on October 26, 2017 (after its upper culmination at 11:34:20 UT), at the Weihai Observatory (WHO) of Shandong University. Astronomers use parameter F(z), air mass, as an extinction characteristic, $F(z) \approx 1/\cos(z)$ if the zenith distance (z) is smaller than 60°. The atmospheric extinction equation can be written as: $m_V = m_0 + K \cdot F(z)$, where m_0 is the magnitude of the star without atmospheric extinction, K is the atmospheric extinction coefficient. Table 7 (see separate sheet) gives the observing times (UT, in units of hour) and the measured magnitudes (m_V) of the star.

7.1. Draw the table (similar to that you see below) in your answer book. Calculate zenith distances, z, in unit of degrees (°), for given observing times in 1st column, and write the result into the 2nd column. Calculate the air mass (F(z)) for different zenith distances, and write the result into the 3rd column.

UT_obs (hour)	z (°)	F(z)
12.49484		

7.2. Plot the scatter diagram between magnitudes (m_V) vs. air mass (F(z)). Draw a straight dashed line on the plot to indicate the linear relation between m_V vs. F(z).

7.3. Estimate the atmospheric extinction coefficient (K) and the magnitude of this star without atmospheric extinction (m_0) with help of graphical method, and write results in forms of «K = ...», «m_0 = ...».

7.4. Determine the magnitude (m_Z) of this star as it was observed in zenith, and write result in form of «m_Z = ...».

Practical round. Problems to solve

7. Spectral observation on an interacting galaxy.

The low-resolution spectra of 15 different regions in an interacting galaxy **Arp 86** were observed by Multi-Object Spectrograph (MOS) on the 2.16-m telescope of Xinglong Station near Beijing, National Astronomical Observatories of China. The data is analyzed by Zhou et al. (2014, RAA, 14, 1393). The measured fluxes of the [OIII], Hβ, [NII], Hα emission lines are shown in Table β7 (see separate sheet). The fluxes are in units of 10^{-16} erg/s/cm^2.

7.1. Plot the scatter diagram between $\log_{10}$([OIII]/Hβ) vs. $\log_{10}$([NII]/Hα) for regions in the galaxy.

7.2. Draw a dashed curve on the diagram for the diagnostic function:

$$\log_{10}([\mathrm{OIII}]/\mathrm{H}\beta) = 1.3 + 0.61/(\{\log_{10}([\mathrm{NII}]/\mathrm{H}\alpha)-0.05\}),$$

given by Kauffmann et al. (2003, MNRAS, 346, 1055). If the point of a region in the diagram is above this curve, the region can be classified as "AGN" (Active Galactic Nuclei). Determine which regions can be classified as "AGN", write the answer in form of «AGN = "Region ID" …». ("Region ID" are given in the 1st column of Table.β7.)

7.3. In your answer book draw a table in form of the following example. Calculate the angular distance between each region to the center ($\alpha = 23^h47^m04.8^s$, $\delta = +29°29'00.6''$) of the galaxy (in units of arcsec). Calculate the luminosities of Hα (L(Hα)) for each region (in units of erg/s), and then estimate the Star Formation Rate (SFR) for each region based on Hα luminosities, following the formula:

$$\mathrm{SFR}\ (M_\odot/\mathrm{yr}) = 7.9 \times 10^{-42}\ [L(\mathrm{H}\alpha)]\ (\mathrm{erg/s}).$$

Calculate the metallicities (oxygen abundance in units of $\log_{10}$(O/H)) of interstellar medium (ISM) for each region, following the formula:

$$12 + \log_{10}(\mathrm{O/H}) = 8.9 + 0.57 \times \log_{10}([\mathrm{NII}]/\mathrm{H}\alpha).$$

The redshift of **Arp 86** is: 0.016.

Region ID	Angular Distance to the center (arcsec)	L(Hα) (erg/s)	SFR ($M_\odot$/yr)	$\log_{10}$(O/H)
1				
2				

7.4. Plot the radial distribution of the $\log_{10}$(O/H) of this galaxy. The radial distribution should be plotted as a scatter diagram: $\log_{10}$(O/H) vs. β, where β is angular distance to the center in arcsec.

7.5. Draw a straight dashed line on the scatter diagram of oxygen abundance ($\log_{10}$(O/H)) radial distribution to indicate the trend of the profile. If there is a linear relation between $\log_{10}$(O/H) and β, i.e. as $\log_{10}(\mathrm{O/H}) = A + B\times\beta$, estimate B with a help of graphical method, write the answer in form of «B = …».

Таблица к задаче 6. Table for problem 6.

time (JD)	m_V
2454938.220	12.4080
2454938.231	12.4094
2454938.239	12.4074
2454938.244	12.4074
2454938.248	12.4144
2454938.251	12.4217
2454938.257	12.4261
2454938.261	12.4292
2454938.267	12.4353
2454938.274	12.4365
2454938.279	12.4333
2454938.283	12.4267
2454938.287	12.4254
2454938.294	12.4172
2454938.297	12.4146
2454938.304	12.4102
2454938.314	12.4075
2454938.324	12.4086

Элементы орбит и физические характеристики Солнца, Земли, Луны и Юпитера
Parameters of orbits and physical characteristics of Sun, Earth, Moon and Jupiter

Небесное тело, планета / Body, planet	Среднее расстояние от центрального тела / Average distance to central body		Сидерический период обращения / Sidereal (or analogous) period		Эксцентриситет / Eccentricity	Экваториальн. диаметр / Equat. diameter	Масса / Mass	Средняя плотность / Av. density	Ускор. своб. пад. у пов. / Grav. acceler. at surf.	Макс. блеск, вид. с Земли **) / Max. magn. from Earth **)	Альбедо / Albedo
	в астр. ед. / in astr. units	в млн. км / in mln. km	в тропич. годах / in tropical years	в средних сутках / in days	*e*	км / km	10^{24} кг / 10^{24} kg	г/см^3 / g/cm^3	м/с^2 / m/s^2		
Солнце Sun	$1{,}6\cdot10^9$	$2{,}5\cdot10^{11}$	$2{,}2\cdot10^8$	$8\cdot10^{10}$		1392000	1989000	1,409		$-26{,}8^m$	
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
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

**) В среднем противостоянии. **) In mean opposition.

Таблица к задаче 7. Table for problem 7.

UT_{obs} (hour)	m_V
12.49484	16.9040
12.76648	16.9195
13.30982	16.9135
13.58151	16.8938
13.85316	16.9306
14.12483	16.9460
14.39651	16.9420
14.66817	16.9520
14.93982	16.9528
15.21151	17.0046
15.48372	17.0630
16.02750	17.1581

Координаты Coordinates	Обсерватория Вэйхай WHO Observatory	Набл. станция Синлун 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

Таблица к задаче 7.

Table for problem 7.

Region ID	R.A. (J2000.0)	Decl. (J2000.0)	f([OIII]) λ5007	f(Hβ)	f([NII]) λ6583	f(Hα)
1	23:47:05.7	+29:29:37.7	25.4	22.3	44.0	125.0
2	23:47:06.5	+29:29:37.7	18.2	28.0	28.5	82.1
3	23:47:04.4	+29:29:34.8	15.4	24.6	45.6	126.0
9	23:47:07.2	+29:29:22.9	6.45	8.57	12.4	26.8
15	23:47:06.3	+29:29:13.2	119	23.9	140.0	285.0
16	23:47:05.3	+29:29:12.6	7.13	4.70	14.4	25.8
19	23:47:01.1	+29:29:06.9	24.8	11.8	20.4	53.3
23	23:47:04.0	+29:29:02.3	10.3	8.63	12.6	43.9
28	23:47:08.0	+29:28:56.1	103.0	34.7	95.5	276.0
33	23:47:03.2	+29:28:50.7	14.7	16.4	30.0	84.0
34	23:47:01.8	+29:28:48.3	48.2	25.0	65.5	183.0
37	23:47:08.2	+29:28:45.0	107.0	33.2	77.4	214.0
43	23:47:02.3	+29:28:35.5	224.0	143.6	407.0	1180.0
45	23:47:02.8	+29:28:33.2	33.7	60.0	97.4	255.0
47	23:47:06.6	+29:28:29.1	11.5	19.1	33.9	104.0

Координаты Coordinates	Обсерватория Вэйхай WHO Observatory	Набл. станция Синлун 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**