Practical round. Problems to solve

6. **NGC 1325.** In the theory problem 4 you answered the question about the spiral galaxy NGC 1325. You estimated that the inclination of the galaxy is 70° and its angular diameter is roughly 6'.5, corresponding to roughly 43 kpc in the physical diameter. This galaxy was observed at GMRT, India during the month of May 2001, to study its rotation profile using the 21 cm wavelength of hydrogen gas in the galaxy. The bottom figure shows distribution of ~~radial~~ rotational velocities of the gas as a contour map. The image is superimposed on an optical image of the galaxy (not taken by GMRT).

   The centre of this galaxy is receding from us. As the galaxy is rotating about itself, one side of the galaxy would appear to recede at a slower speed from us as compared to the other side. In the bottom figure the white contour lines denote velocities slower than the mean velocity and dark contour lines show velocities faster than the mean velocity. Contour lines are drawn for every 10 km/s change in the velocity in the plane of the galaxy (i.e. do not worry about inclination effects).

6.1. Draw the rotation curve of the galaxy (i.e. rotational velocity vs. distance from centre in arcsec).

6.2. From the rotation curve drawn, estimate the total mass of the galaxy (in masses of Sun M_S) assuming the circular motion.

7. **Antennae GMRT.** A table with coordinates of the GMRT antennae as relative positions from the central antenna A14 is given below. The latitude and longitude of A14 are $\varphi = 19° 05' 36"$, $\lambda = 74° 03' 01"$.

7.1. Prepare the map of the GMRT antennae system. You need to mark the central square on the map (the 1 km × 1 km area, which you saw during your GMRT visit), mark antenna at the origin and plot all the antennae outside the central square. Write down the antenna number near its location on the graph paper.

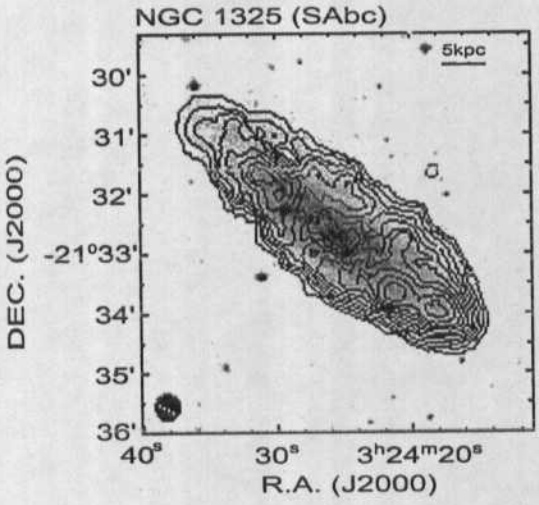
Parallel beams of radio-waves come from distant objects and falls on the GMRT antenna. The signals will reach different antennas at slightly different times depending on the inclination of the source with respect to the Antenna. Let us assume that the four antennas A1, A10, A14, A30 listed below are observing Sun at noon 23rd September.

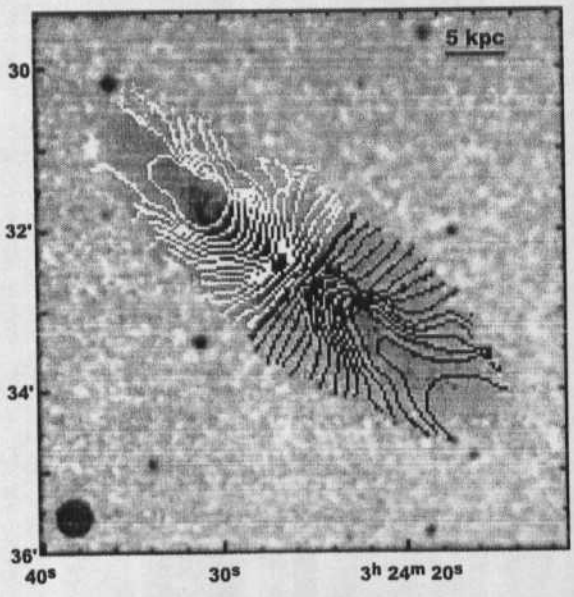
7.2. Calculate the delay in signal arrival between A1 and the Antenna farthest from A1, assuming a flat Earth.

7.3. Assuming now the Earth is not flat, calculate the additional term in time lag due to curvature of the Earth.

Practical round. Pictures. Table
Практический тур. Рисунки. Таблица

6. NGC 1325.





7. Antennae GMRT.
7. Антенны GMRT.

Number of Antenna / Номер антенны	x (to the East) (m) (на восток) (м)	y (to the North) (m) (на север) (м)	z (to zenith) (m) (в зенит) (м)
A01	-11245.6	9405.97	-802.858
A02	-8103.19	8241.44	-711.116
A03	-7039.01	5340.29	-411.950
A04	12073.2	4791.68	-389.911
A05	10199.8	3529.75	-324.311
A06	7780.52	3071.49	-266.059
A07	-5199.93	3054.46	-242.446
A08	4575.99	2047.70	-203.543
A09	-3099.40	1496.91	-90.1932
A10	2814.54	1012.49	-73.9663
A11	-1591.91	625.657	-15.1934
A12	-565.940	132.944	-9.99081
A13	-372.720	142.908	-7.13641
A14	0.00000	0.00000	0.00000
A15	67.8200	-257.968	22.0312
A16	-31.4400	-230.489	24.4676
A17	326.430	-39.7862	32.7314
A18	687.870	-18.0767	37.1877
A19	280.670	-419.343	38.2252
A20	41.9400	-156.320	40.3858
A21	-164.860	-615.653	51.1638
A22	174.850	-666.922	53.1313
A23	-603.940	-333.732	56.0502
A24	-474.670	-658.490	70.3163
A25	-639.500	-1171.08	119.326
A26	633.920	-2948.73	258.251
A27	-367.080	-4503.71	371.735
A28	333.120	-6742.06	581.014
A29	947.470	-9458.39	782.898
A30	-369.050	-14097.4	1202.39

Practical round. Problems to solve

6. **Monitoring of a star.** There was a monitoring of a bright star in Mumbai over a whole night. It has been done with a 14" telescope in three wavelength bands (B, V and R bands). Assume that the observed wavelengths can be approximated by effective wavelengths of 450 nm, 550 nm and 700 nm for the observed star. As the night progresses, the star is seen at different zenith angles and hence the starlight passes through different thickness of the Earth's atmosphere. Consequently, the extinction due to the Earth's atmosphere changes; it is minimum when the star is closest to the zenith and maximum when the star is rising or setting. Sample data are given in the table. The air-mass in the second column gives effective air-mass of the atmosphere normalized with the air mass at zero zenith angle taken as one. Magnitudes are correct to 0.05^{m}.

6.1. Plot the appropriate graph and find the apparent magnitude of the star in the three wavelengths, in the absence of Earth's atmosphere.

6.2. The Hipparcos satellite gave a parallax of 0.0076 arcseconds for this star. Mark the location of the star in the H-R Diagram given separately.

6.3. The colour index can be calibrated in terms of the stellar temperature. An empirical fit (for the region of H-R diagram to which this star belongs) is given by:
$B-V = -3.68 \log(T) + 14.55$ (where T is the absolute temperature).
Estimate the temperature of the star.

6.4. If the particular star was in the constellation Orion, which is the most likely candidate out of the four brightest stars in the constellation? Write the Latin name of the star (you have to write in roman script, spelling mistakes will be tolerated as long as the name of the star is understandable).

6.5. In Mumbai, let us assume the extinction varies as $\lambda^{-\alpha}$ (where λ is the wavelength). From the given data, find parameter α.

7. **A Binary Radio Pulsar.** A radio pulsar is a rapidly spinning neutron star emitting beams of radio waves from its magnetic poles. These are observed on Earth as a series of pulses separated by the apparent pulse period P_t. When the pulsar is a member of a binary system, this differs from the true pulse period (P_0) of the pulsar. The pulsar 0514-40 was studied with the GMRT, India in the year 2004. The true pulse period of this pulsar is $P_0 = 4.990575$ ms.
Table gives data of P_t as a function of time in units of orbital period, t/T (T = 18.35 days). Assume the observer is located in the orbital plane of the pulsar.

7.1. Make a graph of this data set (scale the graph properly).

7.2. If the orbit had been circular, shape of the data curve would not be the same as the graph you have just drawn. Sketch the shape of the data curve for a circular orbit.

A graph of the elliptical orbit of the pulsar with eccentricity 0.866 is provided to you (for the pulsar 0514-40, the eccentricity of orbit is very close to this value). The arrow on the curve indicates that the pulsar is moving anticlockwise in its orbit around the focus O. AP and BD are perpendicular to each other; AP is the major axis of the ellipse.

Practical round. Problems to solve

7.3. Taking u_A at A as unit speed, calculate the transverse speeds at positions B, P and D (transverse speed u_G of the pulsar at any point G is the magnitude of the component perpendicular to OG).

7.4. On the graph of orbit provided to you, a tangent to the curve at point B is shown on the graph. Using the graph of the orbit or otherwise, determine the total speed at B, P and D (v_B, v_P and v_D respectively) in the same unit of speed.

7.5. From the shape of the P_t versus t/T data, infer whether the observer is located close to the major axis, or minor axis of the orbit and on which side.

7.6. Assume that the velocity component parallel to the major axis is maximum at the points B and D. Mark the points A, B, P and D on the graph of the data drawn by you.

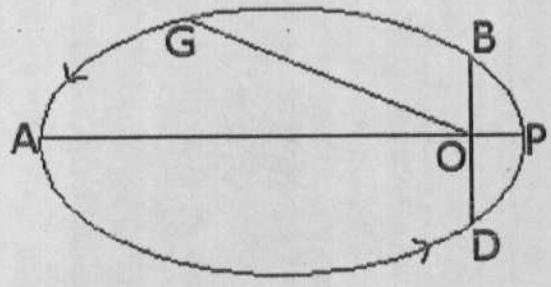
7.7. Sketch roughly, on the same graph paper, the P_t vs. t/T curve if the observer was on the axis perpendicular to that in 7.5.

7.8. From the orbital graph, estimate the fraction of the total orbital period taken to travel the arc DPB? Estimate the same from the graph of the data you have drawn.

7.9. Draw a line $P_t = P_0$ on your graph of the data. Measure the areas under the curve you have drawn on the upper and lower sides of this line and use it to give an estimate of the major axis in light seconds.

Table of data

(t / T)	P_t (ms)
0.136661	4.990905
0.211722	4.991053
0.268267	4.991236
0.343782	4.991742
0.373530	4.992284
0.376936	4.992207
0.384599	4.990415
0.386994	4.989791
0.406418	4.989308
0.410888	4.989361
0.415199	4.989412
0.452397	4.989698
0.465116	4.989770
0.503379	4.989925
0.671385	4.990276
0.774999	4.990418
0.986004	4.990680



Note: Use the figure of the elliptical orbit drawn on the graph paper. Here it is drawn only schematically.

Practical round. Pictures. Table
Практический тур. Рисунки. Таблицы

6. Monitoring of a star.
6. Наблюдения звезды.

Zenith Angle (deg)	Air-mass	B magnitude	V magnitude	R magnitude
Зенитное расстояние (°)	Воздушная масса	Зв. величина B	Зв. величина V	Зв. величина R
15	1.035	2.80	0.85	-1.00
30	1.154	2.85	0.85	-1.00
45	1.412	3.00	0.95	-0.90
60	1.991	3.20	1.10	-0.85
69	2.762	3.50	1.30	-0.75
75	3.785	3.90	1.55	-0.55
81	6.053	4.90	2.15	-0.25