(G01) **Uncovering Galactic dark matter using a radio telescope** **[150 marks]**

(G01.1) We estimate the resolution of our radio telescope and compare it with the angular accuracy of its pointing devices.

(G01.1a) Measure the aperture dimensions of the radio telescope (longer length a, shorter length b) and express in metres. From this, estimate the resolution corresponding to each of the dimensions separately ($\theta_{\rm res}^{\rm a}$ and $\theta_{\rm res}^{\rm b}$, respectively) in degrees. Tick (✓) the dimension which gives you the higher resolution. **7**

(G01.1b) In order to compare with the above resolution, write down the least count (smallest measurable unit) of the protractor ($\theta_{\rm min}^{\rm az}$) and the digital inclinometer ($\theta_{\rm min}^{\rm alt}$). **2**

(G01.2) Open the telescope operating software and verify using Tab 1 that the system is working. For each longitude, **25**

- Use Tab 2 to enter a Galactic coordinate (longitude ℓ, latitude $b = 0$) and note the time, corresponding altitude, azimuth and v_{corr} in the Table in Summary Answersheet.
- Point to this altitude and azimuth and use Tab 3 to record the data 'ℓ.csv' (e.g. a file named '30.csv' could contain data corresponding to longitude 30°).

Repeat this procedure for all the different longitudes from the table.

(G01.3) Use Tab 3 to record the calibration data 'sky.csv' and 'ground.csv' by pointing the telescope towards a region of the sky away from the Galactic plane, and then towards the ground, respectively. Add the altitude and azimuth you pointed to and the time when you carried out each of these measurements in the Summary Answersheet. **14**

(G01.4) Perform the gain and temperature calibration using the procedure corresponding to Tab 4. **7**

(G01.5) Now for each observation 'ℓ.csv', use Tab 5 to obtain the temperature spectrum at the 5 different longitudes ℓ.

(G01.5a) Determine the most redshifted frequency $f_{\rm obs}$ of the HI line (which has a temperature of 5 K above the baseline) corresponding to a given Galactic longitude (ℓ), and tabulate in the Summary Answersheet. **19**

(G01.5b) Calculate $v_{\rm Earth}^{\rm obs}(\ell)$ and $v_{\rm LSR}^{\rm max}(\ell)$ and tabulate in the Summary Answersheet. **10**

(G01.5c) Using values of $v_{\rm LSR}^{\rm max}$ at each of the observed Galactic longitudes, calculate the rotation velocity $v_{\rm rot}(R)$ and the Galactic radius for the maximum redshifted emission for each of the 5 Galactic longitudes. Tabulate all these values in the Summary answersheet. **10**

(G01.6) Plot the rotation velocity versus Galacto-centric radius on the graph-sheet provided as a part of Summary Answersheet and draw a smooth curve going through these points. **6**

(G01.6a) Assuming a spherically symmetric mass distribution, estimate the enclosed mass within the corresponding radius of your observations using the formula: **10**

$$M_{\rm encl}(R) = \frac{v_{\rm rot}^2 R}{G},$$

where R is galacto-centric radius, $v_{\rm rot}$ is the rotation velocity, and G is the gravitational constant. Express your answer in units of solar mass.

(G01.6b) The mass in ordinary baryonic matter enclosed at different Galacto-centric radii, R, of the Milky Way is shown with ⊙ symbols in the graph given in the answersheet. Plot $M_{\rm encl}(R)$ from your measurements in the same graph-sheet, and draw two smooth physically correct curves, one for each set of measurements. **12**

(G01.6c) Calculate the value of enclosed dark matter mass, $M_{\rm dm}(R)$, and record it in the Table in the Summary answersheet. **10**

(G01.7) Estimate the sensitivity of your observation per spectral bin in units of temperature in K given that the spectrum has a total of 512 bins spanning a total frequency range of 2.048 MHz. **9**

(G01.8) Which of the following parameter(s) will improve if observations were made with a horn antenna of larger aperture dimensions. Tick against the correct option(s) in the Summary answersheet. **9**

A. Sensitivity σ_T for $T_{\text{ant}} = 5\,\text{K}$

B. Angular resolution

C. Estimation of v_{rot}

D. Resolution in frequency