PYU33A03 Galactic Structure Assignment 1

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Objective: The aim of this assignment is to familiarise yourself with two of the components of the Milky Way galaxy — you will examine the electron and neutral hydrogen density distributions.

Marking: The assignment is worth 5% of the PYU33A03 module.

Submission and deadline: Your submission should be uploaded to Blackboard by the deadline of 23.59 on Monday 25 September 2023.

Format: Your submission should be a single PDF document and include your name and student number at the top of the first page. Your upload should include the answers to the questions (handwritten or typed+scanned) as well as your workings, e.g. computer code, plots and any other handwritten/typed workings.

Plagiarism reminder: You are welcome to discuss the assignment but you must complete the questions and coding yourself.

Background: The electron density distribution, i.e. $n_{\text{e}}(x, y, z)$, gives the number of electrons per unit volume, typically quoted in units of cm^{-3}. This distribution is modelled using empirical evidence derived from a wide array of observational studies. The two most well-used electron density models are called NE2001 and YMW16. From these models one can interchange between dispersion measure $\text{DM} = \int_0^d n_{\text{e}} dl$ and distance d, if one has only a measurement of one or the other. The neutral hydrogen density distribution is related to the electron distribution by the ionisation fraction of the interstellar medium.

Question:

1. Choose one of these electron density models and get it running. You can either get the source code and install it as they come using 'make'; alternatively there are also many python wrappers and even web interfaces if you get stuck. For me running: `> python3 -m pip install pyne2001` 'just worked'; ditto for installing it from GitHub. But do whichever you prefer and works for you. Make it clear which model you are using.

2. Consider your own unique line of sight through the Galaxy. Use the last 3 digits of your student ID number for the longitude. If this is > 360 deg add a decimal place, e.g. if the last 3 digits are '361' take $\ell = 36.1$ deg. For the latitude take the day of the month your birthday is on multiplied by 2.5, e.g. if your birthday is on the 7$^{\text{th}}$ of the month use $b = 17.5$ deg.

3. What is the maximum dispersion measure that the Milky Way alone can contribute along your line of sight? Also answer this same question for a Galactic

latitude that is a further 10 deg from the Galactic plane. Give your answer in units of pc cm^{-3}.

4. Plot the dispersion as a function of distance for these 2 lines of sight through the Galaxy up to a distance of 50 kpc. What do you notice? Make sure to appropriately label and annotate your plot.

5. The interstellar medium is found to be $10^{+4}_{-3}\%$ ionised, i.e. there is one free electron per every 10 Hydrogen atoms. What is the neutral hydrogen column density to the edge of the Galaxy along the above 2 lines of sight? Give your answer in units of cm^{-2}.

6. From your plot determine the derivative of the dispersion measure with respect to distance at $d = 1$ kpc.

7. Neutral hydrogen and extinction in the optical are related empirially by the relation: $N_{\mathrm{H}}(\mathrm{cm}^{-2}) = 2.21 \times 10^{21} A_{\mathrm{V}}(\mathrm{mag})$. Estimate the extinction along the above 2 lines of sight.

Tip: You're free to use any package you like to make plots.