Riometer Exercises

1. Explain in your own words, what is a riometer. Include reference to your favorite scientific article about riometers. Use less than 200 words.

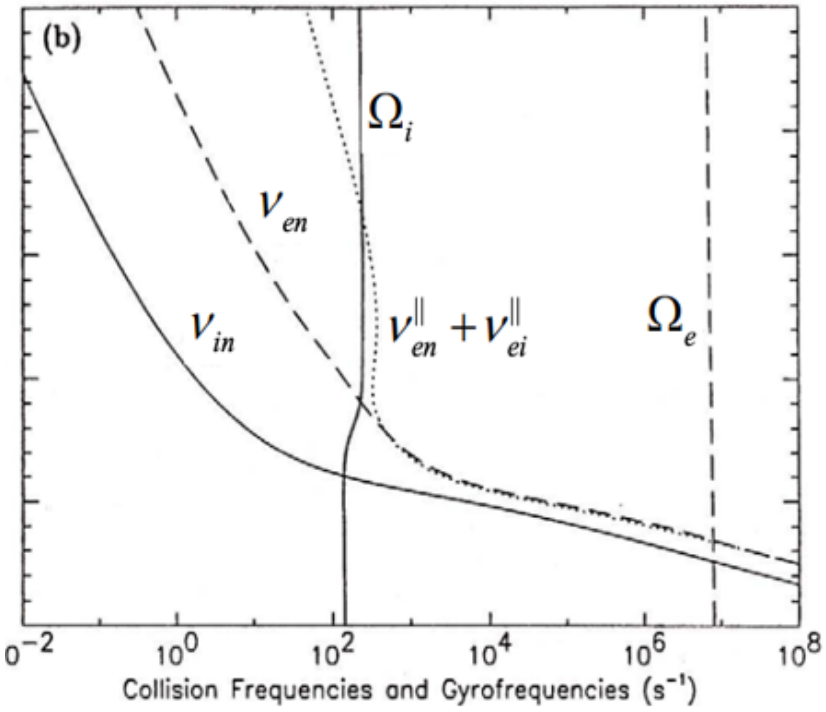
2. Riometers measure power as a function of time. In the absence of any sporadic ionospheric perturbations, measured power repeats with a certain period. What is this period measured in days?

3. How much brighter is the Milky Way at 50 MHz compared to 200 MHz in terms of radio brightness temperature?

4. Several figures in Ocker et.al., 2021[8] show measurements of Langmuir waves by the Voyager 1 space probes plasma wave sensor. Use the formula for plasma-frequency to convert electron plasma-frequency to electron density in units of electrons per cubic meter. What is the approximate value between 2019-2020?

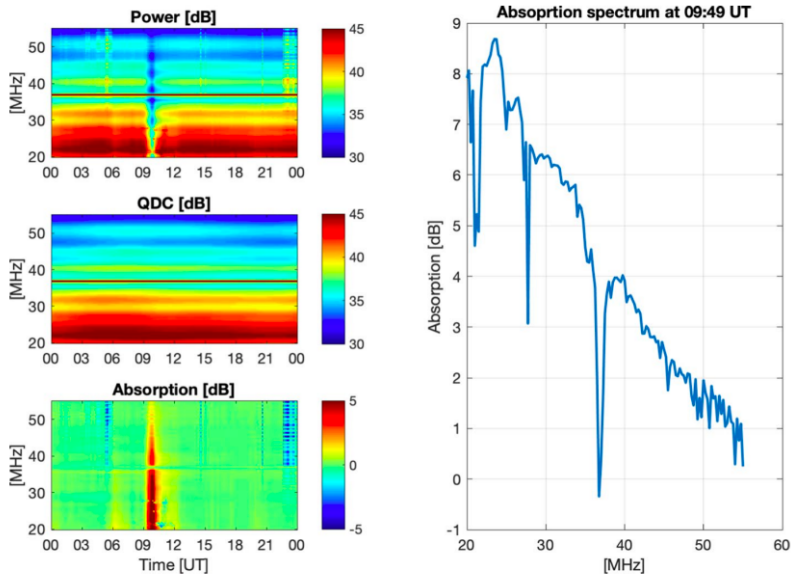
[8] Ocker, S. K., Cordes, J. M., Chatterjee, S., Gurnett, D. A., Kurth, W. S., & Spangler, S. R. (2021), Persistent plasma waves in interstellar space detected by Voyager 1. Nature astronomy, 5(8), 761-765.

5. Many textbooks and scientific papers that show a Figure like the one shown below have a mistake. Can you figure out what is the mistake? Hint: Use the example code `https://github.com/jvierine/fys3002/blob/main/ex00/igrfdemo.py` that uses the IGRF magnetic field model to evaluate the electron gyro-frequency.



6. What advantages are there for using a multi-frequency or wide band riometer. Provide at least two advantages.

7. Identify regions with radio interference in the measured absorption in the following Figure. Explain what in the measurement points to these regions being interference.



8. In which of the following telecommunications applications should you be worried about radio wave absorption due to electron-neutral collisions: a) GNSS positioning, b) GSM cell phone communications, c) HF telecommunications links that rely on ionospheric reflction. Explain why.

9. A riometer measures an absorption of 6 dB at 30 MHz. How much attenuation does the cosmic radio noise experience (in linear units). Can you estimate how much absorption will occur at 60 MHz, assuming that $\omega \gg \nu_{en}$ and $\omega \gg \omega_c$. Here ω is the radio wave angular frequency, ν_{en} is the electron-neutral collision frequency, and $\omega_c = eB/m_e$ is the electron gyro-frequency.

10. There is some code in `https://github.com/jvierine/fys3002/blob/main/ex00/sim_riometer.py` that evaluates an electron density profile based on a solution to the steady-state continuity equation:

$$\frac{dn_e}{dt} = q - \alpha n_e^2 = 0 \tag{1}$$

You are provided with q, and recombination-rate α. The program also uses PyMSIS to obtain a neutral density profile, and evaluates

the electron-neutral collision-frequency based on the N_2 molecular density. Use the formula in e.g., Hargreaves (1969) to calculate the absorption of radio waves that propagate vertically through the ionosphere. Evaluate frequencies of $f = 10, 15, 30, 60, 120$ MHz. Evaluate both extraordinary and ordinary mode absorption. Make a plot of absorption as a function of frequency for both modes. Which mode is absorbed more?