ASTRONOMY 191 - Fall 2024
Homework Assignment #2
DUE by Friday, October 18, 2024
270 points

1. Problem 1 [40 points]

A stationary (in position) electric field varies with time as $E(t) = E_1(t/t_1)$ from time $t = 0$ to time $t = t_1$ and is zero otherwise. (1) Obtain an expression for the spectrum $\hat{E}(\omega)$ that corresponds to $E(t)$; express it in terms of sines and cosines, separating the real and imaginary parts. (2) Draw a graph of the real part of $\hat{E}(\omega)$ vs ω.

2. Problem 2 [50 points]

A polarimeter measures the total flux density F_ν, as well as Stokes parameters Q and U (in units of flux density rather than intensity) for a cosmic source; assume linear polarization (V=0). Calculate the degree of polarization Π (measured in percent) and position angle γ (relative to north-south and measured in degrees from $-90°$ to $+90°$) for the following measurements (5 points each):

(a) Q=$0.1F_\nu$, U=0
(b) Q=0, U=$0.1F_\nu$
(c) Q=$-0.1F_\nu$, U=0
(d) Q=0, U=$-0.1F_\nu$
(e) Q=$0.1F_\nu$, U=$0.1F_\nu$
(f) Q=$-0.1F_\nu$, U=$-0.1F_\nu$
(g) Q=$0.05F_\nu$, U=$0.15F_\nu$
(h) Q=$0.15F_\nu$, U=$0.05F_\nu$
(i) Q=$-0.05F_\nu$, U=$-0.15F_\nu$
(j) Q=$-0.15F_\nu$, U=$-0.05F_\nu$

3. Problem 3 [50 points]

Non-thermal emission from a flare in a star is observed to have a flux density of 2.00 Jy in the optical V band (5.44×10^{14} Hz). A number of measurements with a polarimeter oriented at different position angles define a sine curve with a maximum flux density of 1.05 Jy along the east-west direction (position angle 90°) and a minimum flux density of 0.95 Jy along the north-south direction (position angle 0°). A separate quarter-wave-plate detector measures the Stokes V parameter to have a value of 0.04 Jy.

(a) Determine the degree of circular polarization; (b) determine the degree of linear polarization; (c) determine the position angle of linear polarization; and (d) calculate the values of Stokes parameters Q and U.

4. Problem 4 [130 points]

A source consists of four separate regions, each with distinct linear polarization. A VLBI image of the radio emission resolves the regions, numbered 1-4 below. From the I, Q, and U images, the following values of the Stokes parameters (in flux density units instead of intensity) are measured for the different regions: I_1=0.5 Jy, Q_1=0.05 Jy, U_1=0.03 Jy for region 1; I_2=0.4 Jy, Q_2=-0.03 Jy, U_2=-0.01 Jy for region 2; I_3=0.3 Jy, Q_3=0.02 Jy, U_3=0.06 Jy for region 3; and I_4=0.2 Jy, Q_4=-0.02 Jy, U_4=-0.02 Jy for region 4.

(a) Calculate the degree of polarization Π (measured in percent) and position angle γ (relative to north-south and measured in degrees from -90° to +90°) for each of the four regions.

(b) Calculate the degree of polarization Π and position angle γ for the entire radio source.

(c) At the same time, an optical telescope measures I_{opt}=0.01 Jy, Q_{opt}=0.001 Jy, U_{opt}=0.0025 Jy. Calculate the degree of polarization Π and position angle γ for the optical; these are the values integrated over the entire source.

(d) Compare the optical and radio polarization and position angle for the entire source. Based on this comparison, state whether you think that the optical emission might be related to the radio emission. What further observations would you propose to determine whether or not there is such a relationship?

TIPS:

⋆ For Problem 1, you will need to write a code to produce the requested figure. You can use whatever language you want for the coding, but I would strongly recommend Python. Save the plot figures as PDF or PNG and submit them with the rest of the homework assignment.

⋆ Do not hesitate to reach out to me for any questions you may have!