UCF Physics: AST 6165 Planetary Atmospheres

Spring 2020 Homework 6 and 7
HW6: Problems 1 – 6, DUE Thursday, 20 February 2020
HW7: Problems 7 – 9, DUE Thursday, 26 March 2020

Reading for this assignment: Andrews, sections 3-3.4.
Problems:

Calculate a spectrum. Consider light $L_{\nu 0}$ entering a horizontal tube of gas. The gas is like Earth's, with molar mass = 29 g/mol, density $\rho = 1.2$ kg/m^3, and temperature $T = 288$ K. We'll make it somewhat like looking down an isothermal atmosphere by making the tube one Earth scale height long (so it has the same columnar mass as that atmosphere), but the pressure is constant in the tube. The entering light has a blackbody spectrum with $T = 300$ K. In the range $\lambda = 2.0001 - 2.0002$ µm, the gas has several spectral lines, tabulated in the online file hw6-linelist.txt (the minimum and maximum wavelengths in the file are these limits). There is no scattering at these wavelengths. In the problems below, make all plots on linear-linear axes, with proper titles and axis labels, including units. If a problem asks for several plots with modest differences (a quantity at multiple locations along the tube or at different temperatures), **make a single plot** with multiple traces, and label the traces. Use sufficient **precision** in your constants that your horizontal axis frequencies are accurate compared to the interval being plotted. (How much precision do you need?)

There are many plots to make, mostly repeats at different locations along the tube, so it will be best to use something like Python, IDL, or Matlab. Hand in both the plots and the code (or the spreadsheet if you're going that route) in a single upload, per the syllabus. Submit questions 1 – 8 on the second due date. Problems 1 – 3 are worth half their original credit in that assignment.

If you use separate files for the plots, name them as follows:
`hw6-<username>-prob<probnumber>-plot<plotnumber>.<ext>`, for example, `hw6-jh-prob6-plot4.png`.

For each of the descriptions, give at most a few sentences, but do answer the question, "Why?", don't just describe the plots. Bulleted lists, fragments, etc., are fine. Include these in your attachment. They may be in a separate file from the plots, or on separate pages from the plots if you have just one file.

1. (10 points)
   (a) Read the file and set up any constants.
   (b) Convert the wavelengths to frequencies. Watch units! Make a set of 300 frequencies ν spanning the dataset at uniform intervals.
   (c) Plot $L_\nu(0)$ (the light entering the end of the tube) at your tabuated ν (all plots are at your tabulated ν). Describe in words why you see what you see. Do you see any curvature? Why or why not?
2. (10 points) Plot $k(\nu)$, considering only Doppler broadening. Describe in words why you see what you see. About how wide are the isolated lines? About what fraction of their frequency is that? NOTE: If your lines seem impossibly narrow, check units in the Doppler width expression in detail.
3. (10 points) Plot J_ν. Describe in words why and how it is different from your first plot.
4. (10 points) Plot $\tau_\nu(s)$ at six evenly-spaced locations along the tube, including both ends. What is happening in the series of plots? How are they different from each other?
5. (10 points) Plot $L_\nu(s)$ at those locations, but neglect the source term. In other words, plot the effect of absorption on the incoming light, $L_\nu(0)$. What is happening in the series of plots? How are they different from each other? Why do the weak line and strong line seem to have almost the same effect in the final plot? How are they still different?
6. (10 points) Plot the effect of emission only, as seen looking back up the tube from each of your six locations. In other words, set $L_\nu(0) = 0$ for this part only. What is happening in the series of plots? How are they different from each other?

7. (10 points) Plot $L_\nu(s)$ at each of your six locations. What is happening in the series of plots? How are they different from each other?

8. (10 points) Repeat the last plot for incoming temperatures of 200 K, 288 K, and 350 K. What happens in each case and why?

9. (20 points, source: Holton) Derive a formula for the dependence of depth on radius for an incompressible fluid in solid-body rotation in a cylindrical tank with a flat bottom and a free surface at the upper boundary. The origin is where the tank's (eventual) rotation axis intersects the fluid when the tank is not rotating. Let H be the depth of the fluid when the tank is not rotating, Ω be the angular velocity of rotation of the tank, and a be the radius of the tank. You should end up with an equation for depth *vs.* radius with no unknowns. Plot it. What atmospheric circulation type is this equivalent to? **Do not look the solution up online!**