AY640 Computational Experiment 1: Monochromatic Radiative Transfer in a Uniform Medium Plots due in class Friday Feb. 4

In this experiment, you will use some python code to numerically integrate the radiative transfer equation (RL 1.23) at a single frequency via the method of finite differences through a uniform medium with constant absorption and/or emission.

1. Make sure you have access to a system that has Python installed, including numpy, scipy, and astropy. The anaconda platform (https://www.anaconda.com/products/individual) has all the necessary libraries and runs on MacOS, Linux and Windows.

2. Download the incomplete code from the Blackboard class site. This consists of two files: `sirtipy.py`, which contains the core radiative transfer code, and `experiment1.py`, which contains the assignment code that you will modify and run.

3. Read through `experiment1.py` and try to understand what each line does. Note that for now, Parts B and on are commented out using '#'. If you want, also read through `sirtipy.py` (don't worry if you don't understand all of it, but it may give you a feeling for what the different pieces of the code are).

4. Part A: Emission only.

   This section computes the radiative transfer through a uniform medium of length 10^{10} cm that is emitting at a rate of $j_\nu = 0.1$ erg/s/cm^2/Hz/ster.

   Run the code as-is ("`python experiment1.py`"). This will generate a `1a.png` file, which plots intensity I_ν versus position s along the ray. Look at it! Compare it to the analytic solution (RL equation 1.24, with j_ν constant). Does it look like you'd expect? By what fraction has the intensity increased?

5. Part B: Absorption only.

   In this part, the medium will instead absorb at a rate of $\alpha_\nu = 4 \times 10^{-11}$ cm^{-1}.

   You will now begin to change various parts of the code. Everything that you will want to change is marked with "FIXME", so search for that. The changes you will need to make to Part B are:

   (a) Uncomment the entire "PART B" section of the code.

   (b) Finish the definition of the `alpha_constant()` function.

   (c) Add the absorption function using `add_absorption_func()`.

   (d) Use the `radiative_transfer()` function to calculate the radiative transfer.

   Then run the code. This will generate a `1b.png` file of I_ν vs. s. Look at it! Compare it to the analytic solution (RL equation 1.25, with α_ν constant). Does it look like you'd expect?

6. Part C: Different absorption coefficients.

   Let's see how the value of the absorption coefficient changes the result. We will use the results of Part B, along with similar calculations with different values of α_ν and put them on the same graph.

   (a) Uncomment the "PART C" section of the code.

   (b) Define `alpha_b2` appropriately and apply it to `medium_b2`.

   Then run the code. Look at `1c-I_vs_s.png`. How do the three cases differ? Which case absorbs the most light? Is that what you would expect?

   The code also computes the optical depth τ, defined as in RL equation 1.26. Look at `1c-I_vs_tau.png`, which plots I_ν vs. τ for the same three cases. What do you see? Why is τ so useful?

7. Part D: The effect of the step size.

   Uncomment the “PART D” section of the code. This redoes the `medium_b2` calculation fromt Part C, but with a different value of the step size Δs used in the finite difference calculation.

   The default value in all previous calculations is $\Delta s = 1 \times 10^8$ cm. In this section, Δs is modified to a value that you specify using the variable `dsbig`. Run the code as currently written, with $\Delta s = 2 \times 10^8$ cm. Look at the `1d.png` file. Is it substantially different? Increase the value of `dsbig` and decide at what point you think the answer is wrong (note that you might want to save each test you do to a different output file by modifying the `plt.savefig()` line). Why does too large a value of Δs give the wrong answer? Would you expect this to change for different absorption or emission properties?

8. Part E: Emission and absorption.

   Now let’s look at a case with both emission and absorption. Uncomment “PART E” and run it. How does it compare to the absorption-only case? What is the asymptotic value of I_ν? Consider the analytic solution from RL equation 1.30 how can you predict this asymptotic value from the values of α_ν and j_ν?

   Now modify the values of the `alpha_d` and `j_d` variables to change the shape of the radiative transfer curve (again, you will probably want to save each case to a different file by modifying the `plt.savefig()` line). Try cases where the net intensity increases as well as decreases. Show how you can choose different sets of values where the intensity reaches the same asymptotic brightness at different distances.

9. Part F: Play.

   Try doing something else of your choice. For example, you could see how your answers to Part D depend on the value of the absorption coefficient, or you see how things change with a different input intensity, or (if you are ambitious) try to implement a non-uniform medium (i.e. write an absorption and/or emission function that depends on location).