Exercises for Radiative Transfer in Astrophysics (SS2013)

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Exercise sheet 7

Spherical circumstellar dusty envelope model (part III)

We continue with the model of an optically thick spherically symmetric dusty cloud around a star of exercise sheet 5 and 6. Now we are going to make it a 2-D axisymmetric model, and we will include a polar cavity created by an outflow.

1. **The 2-D envelope model with conical polar cavity**

   (a) Download the new `problem_setup.f90` code. Compare it to the previous one, and try to understand the differences. Explain in words how this new model is a modified version of the previous one.

   (b) Also download the new `dustkappa_silicate.inp` opacity. What is the difference with the previous one?

   (c) Run the `problem_setup.f90` program (using the new opacity) and calculate the dust temperatures with RADMC-3D in the usual way.

   (d) Compute the SED for face-on inclination ($i = 0$), for edge-on inclination ($i = 89$[2]) and for an inclination in between ($i = 35$). Plot all three SEDs in a single plot and explain the differences.

   (e) Use RADMC-3D to make an image at $\lambda = 1\,\mu$m at $i = 30$, using the following command: `radmc3d image lambda 1.0 incl 30`. This will produce a file called `image.out`. The RADMC-3D manual can tell you the format of this file. However, this file is not yet directly viewable.

   (f) Now let us make a directly viewable image: a `.bmp` file. Download the program `image_to_bmp.f90` from the lecture website/moodle which will allow you to convert `image.out` into `image.bmp` which is a standard (Microsoft) image format. This program asks you questions such as the minimum and maximum intensity, and whether you wish to use a linear or log scale, and whether you wish to use a greyscale or color table (if you wish to use the color table, then please also download the `ct.inp` file). Play a bit until you are satisfied with the image.

[2] RADMC-3D still doesn't like exact edge-on images and spectra; bug to be fixed.

2. **A parabolic cavity (voluntary exercise)**
There are several observational pieces of evidence that outflow cavities are not perfectly conical in shape. Let us try to make a somewhat more realistic model.

   (a) Let us assume that, at any given z above the equatorial plane, the cylindrical radius r_{cc} that defines the cavity walls is given by

   $$r_{cc} = r_0 \sqrt{z/r_0} \tag{6}$$

   for some r_0 to be set by you. Build this model cavity into the model (replacing the conical cavity).

   (b) Make SEDs and images to get a feeling for the result.

   (c) Show that the angle-dependency of the SED is less sharp than before.