Tutorial Two

Exercise 1:

Look for antiferromagnetism in the half-filled Hubbard model. Use $n = 4$ (a 4x4 lattice), $t = 1, U = 4, \mu = 0$, and $\Delta\tau = 0.125$. Run with $l = 4, 8, 16, 32, 48, 64$ so that so that $\beta = l\Delta\tau = 0.5, 1, 2, 4, 6, 8$. Use nwarm=500 and npass=5000. Look at the values for
  zz Spin correlation function
  xx Spin correlation function
The integers in the first two columns are the x and y separations between the two spins in the correlation function.
Questions:
[1] Why are only six values listed? Aren't there 16 possible separations?
[2] Is the pattern of signs in your low T data consistent with antiferromagnetism?
[3] Why is the $(0, 0)$ correlation function enhanced over its $T = \infty$ value of 0.500 even at the highest temperatures, $T = 2$ $(\beta = 0.5)$ while the other separations only start to build up at much lower T?
[4] It looks like the correlation functions for (0,2) and (1,1) separations are the same to within error bars. Yet these are not the same separation in space. Or are they?!

Exercise 2:

If the computers are fast enough, try to redo Exercise 1 with $n = 6$ (a 6x6 lattice).
[1] If you compare spin correlations at the same separation and same temperature for different lattice sizes, what happens? Why?

Exercise 3:

Look for the Mott plateau and encounter the sign problem! Use $n = 4$ (a 4x4 lattice), $t = 1, U = 4$, and $\Delta\tau = 0.125$. Run with $l = 32, 48, 64$ so that so that $\beta = l\Delta\tau = 4, 6, 8$. Sweep chemical potential $\mu = 0.0, -0.2, -0.4, -0.6, -0.8, -1.0, -1.2, -1.4$ for each l. Use nwarm=500 and npass=5000.
[1] Why don't you need to get data at $\mu > 0$? Did you really need to run $\mu = 0$?
[2] Make a plot of density versus μ for each β. Do you see a Mott plateau?
[3] Make a plot of the error bars in the density as a function of the density. Also make a plot of the average sign versus density. Do these help you understand my claim that $\beta \approx 6$ is the temperature limit in these simulations?
[4] It looks like some sort of plateau might also be developing around $\rho = 0.6$. Do you have any idea where that might come from?