Physics 262 Early Universe Cosmology
**Homework 3**
*Assigned Wed April 14*
*Due Wed April **28** 11pm (uploaded to Canvas)*

*I've posted a .mat file for this homework. When you download it into a directory where you are using Matlab you can type "load RiessGold" and you will then have the structure RiessGold. This structure contains a supernova data set. You will use this below (NB more modern data sets in more modern formats exist, but they are less transparent to use for the purposes of this HW.)* ***For student using other languages, I've also posted the data in a .xls file***

*For the data file and important Matlab Hints please look here:* [HW3: Extra files]

**3.1)** Write a program that evaluates the distance modulus $\mu$ at each of the redshift values ReissGold.z. To do this you will need to do an integral to get the luminosity distance. I would prefer you do this integral numerically because that will keep your options open for using this work on future problem sets. *Hint: Be careful about the difference between "z" and "a"*

3.2) Evaluate $\chi^2 \equiv \sum_1^N \frac{\left(\mu_i^D - \mu_i^T\right)^2}{\sigma_i^2}$ for the canonical model (with $\omega_k = 0$) you have from homework 2. Here $\mu_i^D$ is the distance modulus for the i$^{th}$ data point given by RiessGold.mu and $\mu_i^T$ are the theoretical values calculated at each value $z_i = RiessGold.z(i)$ in problem 3.1. (For the definition of $\mu$ see eqn 5.23 of the FRW notes.)

3.3) Write a function that finds the value of $\mu_{off}$ that minimizes value of $\chi^2_{Off} \equiv \sum_1^N \frac{\left(\mu_i^D - \mu_i^T + \mu_{Off}\right)^2}{\sigma_i^2}$. For reasons discussed in class these values of the distance modulus data are only trusted up to an overall arbitrary constant offset, so the minimized value of $\chi^2$ is the one you would use to evaluate the probability for that model.

3.4) Evaluate $\chi^2$ in the manner of problem 3.3 on a 20x20 grid of theoretical models given by $0.01 \le \omega_m \le .35$ and $0.25 \le \omega_\Lambda \le 0.50$ (corresponding to values today). Keep $H_0 = 65 km/\sec/Mpc$ which will allow you to determine $\omega_k$ for each case. Plot this grid of $\chi^2$ values using the Matlab "surf" command. (Hint: You may want to modify some of these parameters slightly to get a prettier plot).

3.5) The probability is given by $P\left(\omega_m, \omega_\Lambda\right) = \exp\left(-\chi^2\left(\omega_m, \omega_\Lambda\right)/2\right)$. Plot the probability for the same grid you produced in problem 3.4). *Hint: This is an un-normalized probability (so it just gives relative probabilities). I'm not asking you to normalize* *it but you may need to multiply it by some arbitrary factor so the "surf" command does not choke on it.*

*What you turn in: Please turn in a copy of your code and the plots, as well as the numerical answer to problem 3.2*