Astro 503 Homework #11

Due Thursday, April 13

1. **The Ephemeris:** Continue coding your sections. By Thursday, you should have committed to the CVS repository a successfully compiling version of your code. The last week will be for assembling the driver programs and debugging.

2. **FitStream:** Write a program called `fitstream` which will execute a linear least-squares fit on data read from standard output, and place the resulting best-fit coefficients and their standard deviations on standard output. You should feel free to solve by the normal equations if you like, we won't worry about obtaining high numerical accuracy right now. I encourage you to make use of Mike Jarvis's TMV package for your matrix algebra.

   To be more specific, the program will have two operating modes: Mode 1, where the y_i are all assumed to have equal (but unknown) errors $\sigma_i = \sigma$, and Mode 2 where each input line gives an error σ_i along with the y_i and X_{ij}. The mode selection will occur by some command-line argument that you can specify.

   Input lines that are blank or begin with `#` should be treated as comments and ignored. Each other input line will have the format:

   ```
   y_i    <sigma_i>   X_i1    X_i2     X_i3     X_i4 ... X_iM
   ```

   The second field is present only if you are in Mode 2. If the input lines don't have the same number of fields, then your program should print an error message and quit.

   The output of your program should have the following format, with one line for each parameter:

   ```
   i     a_i      sd_i
   ```

   where `sd_i` is the standard deviation $\sqrt{\mathrm{Var}(a_i)}$. The last line of the output should give the χ^2 and the number of degrees of freedom for the best fit, if you are in Mode 2; for Mode 1, the output should be the value of σ that would produce a reduced χ^2 value of 1.

3. **Dark Energy II:** Using the `Cosmology` class that you wrote for Homework 10, write a program that will determine the best-fit cosmology (and uncertainties) to the "gold" sample of supernova data given by Riess *et al.* (2004). The file `RiessSNe.txt` contains the relevant data, namely the redshift z_i and corrected distance modulus μ_i for each Type Ia supernova event. If the Type Ia supernovae are standard(ized) candles, then their apparent magnitudes (or distance moduli) will satisfy

$$\mu_i = \mu_0 + 5 \log_{10} D_L(z_i). \tag{1}$$

Here the *luminosity distance* is $D_L(z) = (1+z)D(z)$, with $D(z)$ as the comoving radial distance described in HW10. The absolute luminosity of a Type Ia supernova is not known, we only know they're all the same. Hence μ_0 is a free parameter in our model. You can assign a Gaussian uncertainty of $\sigma = 0.15$ mag to each distance-modulus measurement.

To make the fitting process converge well, we will assume a flat model with constant w: you can set $\omega_r = w_a = \omega_k = 0$ in your cosmology. The free parameters are then $\{\omega_m, \omega_X, w_0, \mu_0\}$.

(a) First, determine the best-fit parameters and their covariance matrix, using just the SNe data. There will be a degeneracy in the fit, which you should be able to diagnose, understand on a physical basis (*Hint: it is related to H_0 and μ_o*), and fix.

(b) Repeat the fit, this time using a simplified version of the constraints from WMAP: $D(z = 1088) = 13.7 \pm 0.5$ Gpc, $\omega_m = 0.126 \pm 0.009$.