UCSD Physics 162 *Cosmology* Assignment 4

Prof. B. Keating Assigned: May 5, 2009 Due: May 19, 2009 In Class

THIS IS A HARD ASSIGNMENT, SO IT IS DUE IN *TWO* WEEKS NOT ONE.

1 Supernova Type Ia and Ω_Λ, Ω_m This problem concerns fitting recent Type Ia supernova data to cosmological data. The data for this problem can be found in the paper by Knop et el. http://arxiv.org/abs/astro-ph/0309368

(a) Read the abstract AND, If desired, read the entire article.

(b) If you didn't read the whole article, read section 2.2 and 2.4 on the modelling and fitting of the high-z supernova data to cosmological models. Don't worry about understanding the details of the method (i.e., 'K-corrections, V-band magnitude, etc').

(c) Visit the Physics 162 Website and download the data table that I have posted there under Handouts. The data lists the names of the supernovae used for this HW, their redshifts, their observed, corrected peak magnitudes, and the uncertainty, σ, in the peak magnitude. Plot the data. Use a log-z axis [20pts].

(d) Fit the data to various cosmological models, by varying q_0, keeping $\Omega_m = 0.25$ and $\Omega_{rad} = 0$, i.e., vary Ω_Λ. Minimize χ^2 when fitting to the following model of apparent magnitude (m_B) to luminosity distance (d_L) as a function of cosmological parameters (Ω_m and Ω_Λ). The model you should fit to is:

$$m_B - M_B = 25 + 5\log_{10}\frac{d_L(\Omega_m, \Omega_\Lambda)}{1Mpc}.$$

This is Ryden's Equation 7.50. We can test the fit (agreement) of the data to a model of how they *should* behave using χ^2 minimization. Refresh your understanding of how χ^2 fitting works. Here $\chi^2 = \sum_{i=1}^{N}(y_i - y_i^{model})^2/\sigma_i^2$, where y_i is the i-th data point value of $m_B - M_B$ and y_i^{model} is the i-th value the data *would* have *if* the model is correct. You can assume $H_0 = 70km/s/Mpc$. To be more accurate we would need to let H_0 vary as a function of Ω_m and Ω_Λ as well.

You don't need to know M_B; you can estimate it since it is the same for all SNIa by assumption (hint: see Ryden figure 7.5). This is what it means to be a 'nuisance parameter'. You should calculate χ^2 for a 10×10 "grid"of values of Ω_m and Ω_Λ ranging from ($\Omega_m = 0, \Omega_\Lambda = 0$) to ($\Omega_m = 1, \Omega_\Lambda = 1$) in steps of $\Delta\Omega = 0.1$. You should use a spreadsheet program like the free one available at Google Documents to calculate the grid of χ^2 values. 50 pts.

(e) Estimate M_B for type Ia supernova and then convert to metric units (In other words, "Watt is it?") [5pts].

(f) What is the best-fit value of Ω_Λ assuming $\Omega_m = 0.25$ and using Ryden Eq. 7.11 [5pts]?

(g) Dust in the SN1a's host galaxy or elsewhere between the SN and observer is a serious source of *systematic error* that could lead us to incorrectly estimate Ω_Λ. We can model dust as a slab of material which attenuates the optical power, P, from the SNIa as $P_{obs} = P_{emitted}\exp(-\tau r_{Host})$ where $\tau = \rho\sigma$ is the optical depth of the dust, ρ is the column density of the dust and $\sigma = \pi r_{dust}^2 = (1\mu m)^2$ is the cross-section of a single dust grain. Assume that the dust is uniformly distributed in the host galaxy of the supernova. What density, ρ, of dust is required for the data to be consistent with $\Omega_m = 0.25$ and $\Omega_\Lambda = 0$ at $z = 0.5$? You can assume the host galaxy is a spheroid with radius $r_{Host} = 30Kpc$ and all SNIa erupt at the center of their host galaxies [20pts]