MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Physics Department

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PROBLEM SET 5 ADDENDUM
COMMENT ON THE RIESS *ET AL.* SUPERNOVA DATA

This comment will be needed only if you choose to do the extra credit Problem 6 on Problem Set 5, and if you choose to use the recent data of Riess et al., instead of the older data of Perlmutter et al. Both of these data sets are posted on the server.

Unlike the Perlmutter et al. data, the Riess et al. data is expressed in terms of the distance modulus, which is a direct measure of the luminosity distance. The distance modulus is defined both in the Riess et al. paper and in Ryden's book (p. 120) as

$$\mu = 5 \log_{10} \left(\frac{d_L}{1\ \text{Mpc}} \right) + 25\ ,$$

where Ryden uses the notation $m - M$ for the distance modulus, and d_L is the luminosity distance. The luminosity distance, in turn, is really a measure of the observed brightness of the object. It is defined as the distance of that the object would have to be located to result in the observed brightness, if we were living in a static Euclidean universe. More explicitly, if we lived in static Euclidean universe and an object radiated power P in a spherically symmetric pattern, then the energy flux J at a distance d would be

$$J = \frac{P}{4\pi d^2}\ .$$

That is, the power would be distributed uniformly over the surface of a sphere at radius d. The luminosity distance is therefore defined as

$$d_L = \sqrt{\frac{P}{4\pi J}}\ .$$

Thus, a specified value of the distance modulus μ implies a definite value of the ratio J/P.

When you plot theoretical curves to compare to this data, I would recommend replacing choice (iii), as given on the Problem Set, by the nearly identical choice $\Omega_{m,0} = 0.29$, $\Omega_{\text{vac},0} = 0.71$, which corresponds to the theoretical curve plotted in Figure 4 of the Riess et al. paper. In plotting this theoretical curve you will also need to choose a value for H_0. Riess et al. do not specify what value they used, but I found that their curve is most closely reproduced if I choose $H_0 = 66$ km-sec^{-1}-Mpc^{-1}. This seems a little on the low side, since the value is usually estimated as 70–72 km-sec^{-1}-Mpc^{-1}, but Riess et al. emphasize that they were not concerned with this value. They were concerned with the relative values of the distance moduli, and hence the shape of the graph of the distance modulus vs. z. In their own words, from Appendix A, "The zeropoint, distance scale, absolute magnitude of the fiducial SN Ia or Hubble constant derived from Table 5 are all closely related (or even equivalent) quantities which were arbitrarily set for the sample presented here. Their correct value is not relevant for the analyses presented which only make use of differences between SN Ia magnitudes. Thus the analysis are independent of the aforementioned normalization parameters."