1. Imagine that you are the Edwin Hubble of a planet in an alternate universe many billions of years from now. You discover Hubble's Law, but you find that all galaxies have blueshifts, not redshifts.
    a. (3 pts.) How is it possible that galaxies all have blueshifts?
    b. (2 pts.) In this alternate universe, what is a possible value for the density parameter?
2. Consider supernovae A and B in Figure 1. We will plot them in Figure 2.
    a. (3 pts.) What determines the horizontal position of the supernovae in Figure 2?
    b. (3 pts.) What determines the vertical position of the supernovae in Figure 2?
    c. (2 pts.) Draw supernova A in Figure 2. Give reasons for its location in the vertical direction.
    d. (2 pts.) Draw supernova B in Figure 2. Give reasons for its location in the vertical direction.
    e. (4 pts.) Using (a)–(d), explain how supernovae are used to weigh the universe.

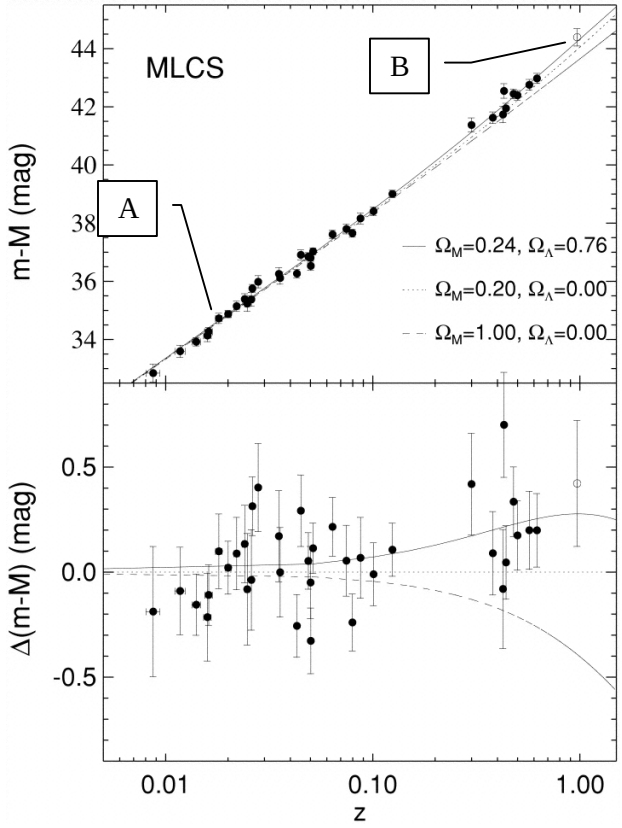

Figure 1 Redshift & magnitude of supernovae (top panel) and magnitude relative to that of a universe with Ω=0.2 (bottom panel), from Reiss et al., 1998. Ω_Λ is the density parameter in cosmological constant, and Ω_m is the density parameter in matter.

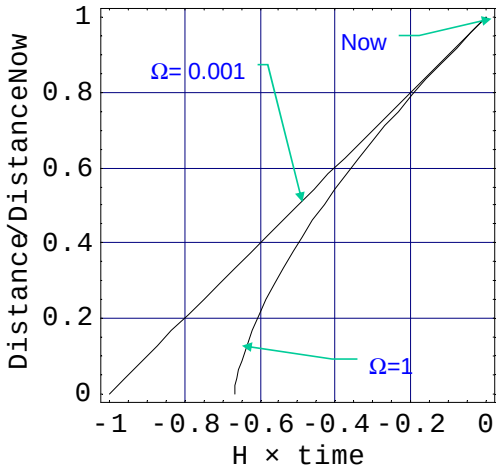

Figure 2 Expansion parameter vs H×time for two models, Ω=1 and Ω=0.001. H is Hubble's constant. There is no cosmological constant in these models.