Cosmological Parameters

- Recall the cosmological equations
  - $H^2 = (8\pi G/3)\rho + C/L^2 + \Lambda/3$ **: Friedmann-Lemaitre eq.**
  - $a = -(4\pi G/3)\rho L + \Lambda L/3$ **: Acceleration eq.**
  - $L=Rl$ **: Expansion of length**
- These equations can be re-written as
  - $H^2 = (8\pi G/3)\rho - k/R^2 + \Lambda/3$
  - $-a/R = (4\pi G/3)\rho - \Lambda/3$
- Dividing both sides by H^2, we get
  - $1 = (8\pi G/3H^2)\rho - k/(R^2H^2) + \Lambda/(3H^2)$
  - $q = -a/(RH^2) = (4\pi G/3)(\rho H^2) - \Lambda/(3H^2)$
- "Cosmological Parameters" are related by
  - $1 = \Omega_m + \Omega_k + \Omega_\Lambda$
  - $q = \Omega_m/2 - \Omega_\Lambda$

Many Universes (Fig 18.13 on pp.367)

- Friedmann universes (No dark energy)
  - $\Omega_\Lambda = 0$
  - $1 = \Omega_m + \Omega_k$
    - $\Omega_k > 0$: "Open" universe
    - $\Omega_k = 0$: "Flat" universe (a.k.a. Einstein-de Sitter universe: $\Omega_m=1$)
    - $\Omega_k < 0$: "Closed" universe
  - $q = \Omega_m/2$
    - $q > 0$: Expansion always decelerates in Friedmann universes
    - $q=1/2$ for the Einstein-de Sitter universe
- Friedmann-Lemaitre universes
  - $\Omega_\Lambda > 0$
  - $1 = \Omega_m + \Omega_k + \Omega_\Lambda$
    - Fate of the universe depends on Ω_Λ as well as Ω_k
  - $q = \Omega_m/2 - \Omega_\Lambda$
    - q can be negative: acceleration is possible

Expansion History

- Cosmological parameters evolve with time.
  - Different terms are dominant at different times.
  - $H^2 = (8\pi G/3)\rho - k/R^2 + \Lambda/3$
    - Matter density, ρ, decreases as $1/R^3$
    - k/R^2 decreases as $1/R^2$
    - Λ is constant
  - Therefore, all universes look like the Einstein-de Sitter universe in the past.
    - But, the present and future behavior can be very different depending on cosmological parameters.
    - Values of the present-day cosmological parameters:
      - $\Omega_m = 0.3$
      - $\Omega_\Lambda = 0.7$
      - $\Omega_k = 0$