Cosmology Review II

1. People
    a. Vesto Slipher
    b. Henrietta Leavitt
    c. Vera Rubin
    d. Kent Ford
    e. Roberts and Whitehurst
    f. E. Hubble
    g. Fritz Zwicky
    h. Sir Arthur Eddington
    i. Erwin Freundlich
    j. Allan Sandage
    k. Hipparchus
    l. Henri Poincaré
2. Objects
    a. Cepheids
    b. LMC, SMC
    c. Coma Cluster
    d. Virgo Cluster
    e. M31
    f. Supernovae
    g. White-brown-red dwarfs, neutron stars, black holes, MACHOs, WIMPs
    h. Dark halo
    i. Clusters
3. Terms
    a. Hubble time, Hubble length
    b. Horizon
    c. Planck scales
    d. Chandrasekhar limit
    e. Baryonic
    f. Deceleration parameter
    g. Standard candle
    h. Lookback time
    i. Bolometer
    j. Luminosity, flux
    k. Big Crunch, Big Freeze, Big Bounce
    l. Loitering universe
    m. Benchmark Model
    n. Density is destiny
    o. Mass to light ratio
    p. B-band filter
4. Hubble Law $v = H_0 r,\ z \approx \frac{v}{c}$, Hubble parameter $H(t) = \frac{\dot{a}(t)}{a(t)}$
5. Hubble time H_0^{-1}, Hubble length $\frac{c}{H_0}$

Cosmology Review II

6. Steady State Model – H_0, ρ_0 constant => $\frac{dr}{dt} = H_0 r$
7. Horizon distance $d_p(t) = c\int_0^{t_0} \frac{dt}{a(t)}$
8. Red shift $1+z = \frac{1}{a(t_e)}, a(t_0) = 1.$
9. Friedmann Equation
   a. $\left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi G}{3c^2}\varepsilon - \frac{\kappa c^2}{R_0^2 a^2}$
   b. $H_0^2 = \frac{8\pi G}{3c^2}\varepsilon_0 - \frac{\kappa c^2}{R_0^2},$
10. Energy density
    a. $\varepsilon_w = \varepsilon_{w,0} a^{-3(1+w)} \Rightarrow \varepsilon_m, \varepsilon_r$
    b. $\dot{a}^2 = \frac{8\pi G}{3c^2}\sum_w \varepsilon_{w,0} a^{-1-3w} - \frac{\kappa c^2}{R_0^2}$
11. Density parameters
    a. $\Omega_{CMB} = 5.0\times 10^{-5}$, $\Omega_\nu = 0.681\Omega_{CMB}$, $\Omega_r = 8.4\times 10^{-5}$
    b. $\Omega_m = 0.3, \Omega_\Lambda = 0.7$ (Benchmark)
12. Models
    a. Curvature Only (Zero, positive negative curvature – what happens? $a = ?, t_0 = ?, t_e = ?$)
    b. Solve for $d_p(t_0) = c\int_{t_e}^{t_0} \frac{dt}{a(t)}$, $d_p(t_e) = \frac{d_p(t_0)}{1+z}$
    c. Spatially Flat Universes
       i. $a(t) = \left(\frac{t}{t_e}\right)^{2/(3+3w)}$, $t_0 = \frac{2}{3(1+w)}H_0^{-1}$, $\varepsilon(t) = \frac{3c^2}{8\pi G}H_0^2\left(\frac{t}{t_0}\right)^{-2}$
       ii. Lambda Only
           1. $\dot{a}^2 = \frac{8\pi G\varepsilon_\Lambda}{3c^2}a^2 \Rightarrow \dot{a} = H_0 a \Rightarrow a(t) = e^{H_0(t-t_0)}$
    d. Multiple-Component Universes
       i. $\frac{\kappa}{R_0^2} = \frac{H_0^2}{c^2}\left(1-\Omega_0\right),$
       ii. $\frac{H^2}{H_0^2} = \frac{\Omega_{r,0}}{a^4} + \frac{\Omega_{m,0}}{a^3} + \Omega_{\Lambda,0} + \frac{1-\Omega_0}{a^2}$
       iii. $H_0 t = \int_0^a \frac{da}{\sqrt{\frac{\Omega_{r,0}}{a^2} + \frac{\Omega_{m,0}}{a} + \Omega_{\Lambda,0}a^2 + 1 - \Omega_0}}$
       iv. Determining eras of dominant components (Epochs), $a_{rm}, a_{m\Lambda}$, t_{crunch}, etc.

Cosmology Review II

13. Cosmological Parameters
    a. $a(t) \approx 1 + H_0(t-t_0) - \frac{1}{2} q_0 H_0^2 (t-t_0)^2$
    b. $q_0 = \Omega_{r,0} + \frac{1}{2}\Omega_{m,0} - \Omega_{\Lambda,0}$
    c. Look back time $t_0 - t_e \approx H_0^{-1}\left[z - \left(1 + \frac{q_0}{2}\right) z^2 \right]$
14. Luminosity
    a. flux $f = \frac{L}{4\pi S_\kappa^2(r)(1+z)^2}$
    b. Luminosity distance $d_L = S_\kappa^2(r)(1+z), d_L = d(t_0)(1+z), [\kappa = 0]$
    c. Parallax - $d_{pc} = \frac{1}{\theta_{arc\sec}}$
    d. Angular diameter distance $d_A = \frac{\ell}{\delta\theta}, d_L = \frac{d_L}{(1+z)^2} = \frac{d_p(t_0)}{(1+z)}, [\kappa = 0]$
        i. Standard Candles – Cepheids, Supernovae Type Ia - $L = 4 \times 10^9 L_{sun}$
    e. $d_L \propto \overline{f}$
    f. Apparent magnitude $m = -2.5 \log_{10} \frac{f}{f_x}$
    g. Absolute magnitude $M = -2.5 \log_{10} \frac{L}{L_x} = m - 5 \log_{10} \frac{d_L}{1Mpc} - 25$
15. Dark Matter
    a. What is it?
    b. Density parameters for stars (0.004), baryonic matter (0.04 ± 0.01), galaxies (0.04-0.16), clusters (0.2))
    c. Orbital speeds in spiral galaxies $v = \sqrt{\frac{GM}{R}}$
    d. Surface brightness $I(R) = I(0)e^{-R/R_s}$ (R_s – 4 kpc Earth, 6 kpc M31)
    e. Axis ratio $\frac{b}{a} = \cos i$
    f. Half-mass radius
16. Gravitational lensing
    a. Deflection angle $\alpha = \frac{4GM}{c^2 b}$, Sun – 1.7 arcsec
    b. Einstein radius $\theta_E = \left(\frac{4GM}{c^2 d} \frac{1-x}{x} \right)^{1/2}$
    c. Lensing event - $\Delta t = \frac{d\theta_E}{2v}$