Astronomy 311: *Midterm Solutions*

Multiple Choice

1. b 2. c 3. c 4. a 5. d 6. a 7. a 8. c 9. b 10. d

True or False

1. T 2. F 3. T 4. F 5. F

Short Answer

1. f, a, c, e
2. CMB is the last 'scattering' of radiation (photons) or energy from recombination (where neutral atoms first became stable), stretched from visible light to microwaves as moved through expanding spacetime; found accidentally but it had been exactly predicted by the BBT
3. No; doesn't apply to galaxy clusters or nearby galaxies (strong local gravity) & 'old' SN
4. understanding of earliest moments and the Big Bang itself requires physics that describes both massive AND small (a joining of QM and GR); theory & experiment indicate unification of (at least 3) forces at high temperatures
5. shape depends on overall matter & energy content of the universe; closed, flat, open
6. dark matter was necessary to account for additional gravity required to keep stars in stable orbits near the visible edge of galaxies; together DM & DE make up 95% of the universe, but we don't know what either is!
7. - Cosmic Microwave Background at 3 K matches prediction of echo of Big Bang energy
   - Helium content of universe exactly matches prediction of Big Bang
   - Night sky is dark (Olber's Paradox) resolved by a finite, changing Universe
   - redshift of all galaxies (expansion!)
   - appearance of old galaxies (an evolving, finitely old universe)
8. a frame of reference is your 'point of view' or reference point for a measurement or observation; Einstein said there were no preferred frames of reference, or that all frames of reference were equivalent. This is much like our modern view of the (observable) universe in that the universe looks the same in all directions, with NO obvious edge or center or 'preferred' location within it

Essay Questions

(1) - Steady State Model ruled cosmology prior to Hubble's observations
- Hubble determined distances to galaxies containing pulsating Cepheid variable stars
- pulsation rate gave true brightness, which if compared to measured brightness yields distance
- he also observed doppler shift in measured EM spectra of galaxies
- noted that almost all galaxies were 'red shifted', or moving away from us (except nearby/clusters)
- amount of redshift determined the speed of the galaxies
- plotted distance vs. recession speed - resulted in an (unexpected) linear relationship
- Hubble's Law, $v = H_o \times d$, resulted ; slope is the Hubble constant, H_o (yields age)
- since distant galaxies move faster, it is the space BETWEEN galaxies expanding (distant galaxies have more space between them and us, so more expansion)
- strong local gravity keeps objects and clusters from expanding
- all galaxies are expanding away from each other, not just us; evidence from distribution of galaxies, i.e. Cosmological Principle: no preferred vantage point
- if galaxies now moving apart, in past they must have been closer - a beginning, ie. BB

(2) - universe is at least 4D (perhaps higher), so 'shape' is by analogy to 3D
- shapes are: Closed ('sphere'), Flat ('critical'), Open ('saddle') - behaviour of 2 light beams
- overall matter & energy content of the universe determine shape; shape determines fate
- Closed leads to Big Crunch (gravity overcomes expansion, universe recollapses)
- Flat: slowing expansion, eventually stops (infinite time), leads to Big Chill/Heat Death
- Open: continuous expansion leads to Big Chill/Heat Death
- universe appears to be flat based on observation (CMB, WMAP, Planck, etc.)
- critical energy density ρ_c is that required to exactly halt observed expansion
- compare the observed matter/energy density ρ to the critical density to determine fate
- ρ from regular luminous matter, energy is only $\sim 5\%$ of ρ_c
- galaxy rotation curves require adding Dark Matter to above; still only $\sim 30\%$ ρ_c
- $\rho << \rho_c$, too low to account for observed flat universe, so add Dark Energy so $\rho \approx \rho_c$
- Dark Energy may be repulsive & accelerate the expansion
- distant (old) supernovae deviate from Hubble's Law (dimmer than expected) - a Big Rip!