Cosmology Questions

The Smooth Universe

1. **What are the major components of the Universe?**
2. **What is the one quantity that determines the fate of the Universe?**
3. **How is Ω defined?**
4. **What is the order of magnitude of the critical density? How many hydrogen atoms does this correspond to?**
5. **What contributes to ρ?**
6. **How does ρ change with time? Sketch a log-log plot of the various components of ρ against time. Explain the crossing points on the plot; roughly at what redshifts do they occur?**
7. **How do you characterize these three components? (ans: equation of state)**
8. **What are SNe teams measuring? Draw a plot of their data and discuss: What can be found from these observations and how?.**
9. **What is the key evidence for Λ?**
10. **What is the connection between CMB measurements and the SNe results?**
11. **Briefly describe how μ–z plots behave with and without Λ. (sketch the plot)**
12. **What can contribute to curvature other than Λ?**
13. **What are the main assumptions of the R-W Friedmann model?**
14. **What evidence is there for the isotropy of the Universe?**
15. **What observations indicate an accelerating Universe?**
16. **Write down the Friedmann equation. Write down the "second" Friedmann equation.**

17. **What is the general equation of state (EOS)? What is the EOS for the different components of the Universe? What components cause deceleration? Acceleration?**
18. **How does the Hubble constant depend on density?**
19. **What is Ω currently believed to be? What are its various components believed to be?**
20. **Sketch Ω versus time.**

The Bright Side: Thermal History, BBN

21. **What is the most abundant particle in the Universe?** (Photons or hydrogen?)
22. **Estimate the number density of photons. Where are they?**
23. **How can you estimate the number density from the CMB?**
24. **How does the number density depend on temperature?**
25. **Are neutrinos more related to matter or radiation?**
26. **How does the number density of neutrinos compare to photons? Does it depend only on T?**
27. **When did neutrinos decouple?**
28. **Why are the photon and neutrino temperature different?**
29. **How does the number density scale with scale factor?**
30. **What about the energy density?**
31. **What is the current best constraint on neutrino families? How does BBN constrain it?**
32. **What determines how a evolves? Write the equation.**
33. **What happens to a if there are more neutrinos? How does this effect BBN?**
34. **On what three factors does the helium abundance depend?**
35. **How do we determine if neutrinos are relativistic?**

36. **What is the temperature of radiation today? In electron volts?**

37. **What is mc^2 for electrons? How does this compare to the temperature of radiation (kT_γ)?**

38. **If $m_\nu c^2$ is similar to kT_γ today, were neutrinos relativistic earlier?**

39. **How does photon behavior differ from neutrino behavior? (ans: bosons vs. fermions)**

40. **Does this difference in statistics affect the scaling with a?**

41. **Why is ρ_Λ the "ugliest number" in physics?**

42. **What is the Planck scale?**

43. **How do the de Broglie wavelength and Schwarzschild radius cale with mass?**

44. **What does BBN tell us about Ω_b?**

45. **How do different values of Ω_b affect BBN abundance ratios?**

46. **How are electrons and photons coupled?**

47. **What is the difference between Thomson and Compton scattering? Why is Thomson applicable?**

48. **Estimate the temperature of photons at recombination.**

49. **Why is n_n/n_p important for nucleosynthesis?**

The Dark Side

50. **What are the dark matter problems (baryonic and non-baryonic)?**

51. **Before modern measurements, what was the evidence for non-baryonic DM? How does the growth of structure depend on DM?**

52. **Is CDM an ideal gas?**

53. **What are the observations that indicate DM?**

The Lumpy Universe: Structure Formation History

54. **Draw a typical CDM fluctuation spectrum. These are fluctuations of what?**

55. **Why is there a special scale in $P(k)$?**

56. **What size scales grow first?**

57. **What is the primary mechanism for structure formation?**

58. **What is the Jeans wavelength? Derive it, roughly, without constants.**

59. **What does the sound speed mean?**

60. **Compare the free-fall and sound crossing timescales. What happens if $\lambda < \lambda_J$?**

61. **What happens if $\lambda < \lambda_J$ in an expanding Universe?**

62. **Sketch the CMB power specturm.**

63. **What does l mean? How is l related to the angular scale? Why is $l = 200$ important? What scale is that?**

64. **Why the peaks and troughs? Why no peaks in CMB at $l < 200$?**

65. **What is the sound speed in fluid before and after decoupling? Why do you get these values?**

66. **What mass scale is associated with the sound speed after decoupling?**

67. **How does ρ scale with time in a static Universe? In an expanding one?**

68. **How does a perturbation (in the matter-dominated era) change with the scale factor a?**

69. **Is non-baryonic DM important during acoustic oscillations?**

70. **What is the fundamental force in acoustic oscillations? What leads to oscillations?**

71. **If the Universe had no non-baryonic DM, how would the growth of structure be different?**

72. **Does the collapse of baryons after recombination depend on CDM? If there were no CDM, how would the growth of baryons change?**

73. **How fast do fluctuations grow with z?**

74. **What is the amount of growth since last scattering?**

75. **If there were no CDM, what would the fluctuations in baryons be now (quantitatively?) (Hint: What were they at last scattering? So, if there were no CDM, what would $\delta\rho/\rho$ be now? Would the baryons have grown enough?)**

Very Early Universe

76. **What is the significance of the Planck mass? What is its value?**

77. **Peaks of the CMB? How does the position of the first peak move, and what does this tell us?**

78. **What are the problems with the Big Bang model?**

79. **How far could photons have traveled at the time of the CMB?**