بسمه تعالی

Midterm Exam of Modern Cosmology Name: Date: 2010/12/06

1) Suppose at 100 seconds after big-bang, the equation of state of filled gas is $U = 3PV$. Also according to energy transfer formula: $U = \sigma V T^4$,
A) Calculate entropy as a function of temperature and volume.
B) Based on adiabatic expansion of the universe (explain why adiabatic), determine the evolution of temperature as a function of scale factor.
C) How does the entropy density evolve for radiation and non-relativistic particles? What about dark matter and dark energy?

2) Determine the evolution of temperature versus scale factor for non-relativistic and non interacting particles.

3) Write the energy and number density of one generation of neutrino as a function of energy and number density of photons, separately.

4) Define the following quantities:
A) Causal horizon
B) Hubble horizon
C) Event Horizon
D) Determine above quantities for flat, open and closed universe.

5) Imagine that we divide the interval of redshift, $z \in [0.0, 2]$ in to M parts. Also N numbers of supernovas have been observed in this interval. If the rate of generation of supernova to be constant, How many supernovas belong to each interval? write your answer according to the behavior of relevant quantities in the dark matter as well as dark energy dominant epochs. Explore this question for closed and open universe.

6) Gold survey with systematic error, $\sigma_{sys} = 0.05$, observed distance modulus for some supernovas which is reported in the below table,
A) Calculate deceleration parameter at present time and corresponding error.
B) Rely on $\Omega_{total}(t = t_0) = 1.01 \pm 0.05$, calculate state parameter of dark energy, w, and its errors.

Redshift	μ	$\Delta\mu$
0.023	35.24	0.16
0.025	35.24	0.22
0.027	35.52	0.13
0.030	35.90	0.21
0.032	36.08	0.21

7) Explain the solution of inflationary scenario for two most important problems of cosmological standard model. Compute the sufficient value of e-folding to solve those problems.

8) For a typical inflationary potential, $V(\phi)=\frac{1}{2}m^2\phi^2$, one can find the evolution equation according to: $\ddot{\phi}+\sqrt{\frac{2}{3}}\frac{1}{M_p}\left(\dot{\phi}^2+m^2\phi^2\right)^{1/2}+m^2\phi=0$

Describe the graceful exit and find the scale factor as a function of time.

9) According to the reaction as $e^- + P \rightleftharpoons H + \gamma$ and by using Boltzmann equation for annihilation, find the recombination and decoupling epochs. Use proper estimations to calculate final results.

موفق باشید

موحد