Cosmology Quiz Questions

Week 1: The expanding universe

1) Which of the following statements about the cosmological principle is **true**?

A. A homogeneous Universe is always isotropic
B. An isotropic Universe is always homogeneous
C. The cosmological principle says that the properties of the Universe are the same at all times
D. The existence of galaxies contradicts the cosmological principle, because it means that the properties of the Universe change with location

2) Which of the following concepts related to the Big Bang is **not** part of the “balloon analogy”?

A. Every observer in the Universe perceives the same expansion
B. The speed of recession is proportional to distance
C. The Universe has no “edge”
D. The observable Universe is finite, even though the entire Universe may be infinite

3) Which of the following ideas is a **misconception** about the Big Bang?

A. The Universe isn’t expanding into anything
B. The apparent recession velocity deduced from a redshift can exceed the speed of light
C. The Big Bang happens at a special point in space
D. The Big Bang happens at a special point in time

4) As the Universe expands, which property of a distant galaxy remains the same?

A. Comoving distance
B. Physical distance
C. Redshift
D. Age of the galaxy as measured by the light we are receiving

5) Which one piece of information can uniquely determine the redshift of a cosmological object, without knowing any other information?

A. The cosmic scale factor when the light was emitted by the object
B. The physical distance to the object
C. The radial comoving coordinate of the object
D. The time it took for light to travel to us from the object

6) A model universe has a cosmic scale factor of the form $a(t) = \sqrt{\frac{t}{t_0}}$, where t_0 is the current age of the Universe. How long ago (measured backwards from today) was light emitted which today has redshift $z = 1$? *[Hint: what is the relation between z and a?]*

A. $t_0/4$
B. $t_0/2$
C. $3t_0/4$
D. t_0

7) A galaxy has a recession velocity of 0.022 times the speed of light and is known to be located at a distance of 3.5×10^{24} m. Based on this one observation, what is the approximate value of the Hubble parameter H_0 in units of km s^{-1} Mpc^{-1}?

A. 50
B. 60
C. 70
D. 80

8) A model universe has cosmic scale factor of the form $a(t) = \sqrt{\frac{t}{t_0}}$, where t_0 is the current age of the Universe. What is the value of the Hubble parameter today? *[Hint: what is the relation between H and $a(t)$?]*

A. $1/t_0$
B. $1/(2t_0)$
C. $1/(4t_0)$
D. $1/(2{t_0}^{3/2})$

9) Which of the following factors does **not** help to explain why the sky is dark at night?

A. Stars and galaxies are distant, so their received flux is very small
B. The Universe has a finite age
C. The Universe has a finite observable size
D. Light travelling through the Universe is redshifted

10) How do we know the temperature of the radiation field at the time the CMB was produced?

A. We can measure it directly
B. We can infer it from the CMB temperature today
C. We can infer it from the time after the Big Bang the CMB was produced
D. We can infer it from the temperature needed for atoms to combine in the early Universe

Week 2: Measuring the universe

1) How many of the following surfaces are intrinsically curved: cylinder, cone, paraboloid, sphere? *[Hint: can you make these surfaces from a flat sheet of paper without crumpling it?]*

A. 1
B. 2
C. 3
D. 4

2) Which of the following properties is characteristic of a Universe with a **closed** geometry?

A. Parallel lines diverge
B. The circumference of a circle is more than 2π multiplied by the radius
C. The angles of a triangle add up to more than 180°
D. This Universe will always contract to a "Big Crunch"

3) The "time" term in the space-time interval for the FRW metric, $-c^2dt^2$, is the same as in special relativity. What does this signify?

A. The curvature of the Universe must be zero
B. The recession velocities of galaxies cannot exceed the speed of light
C. The metric does not depend on time
D. Time runs at the same rate for all comoving observers (there is no gravitational time dilation)

4) Which one of the following statements is **not** implied by the cosmological principle?

A. The Universe started in a hot Big Bang
B. The Universe is homogeneous and isotropic
C. The Universe has an absolute cosmic time
D. The Universe is described by the FRW metric

5) How does the radial comoving coordinate of a light ray propagating outward into a Universe with zero curvature change with time?

A. $\frac{dr}{dt} = c$
B. $\frac{dr}{dt} = \frac{c}{a(t)}$
C. $\frac{dr}{dt} = 0$
D. $\frac{dr}{dt} = a(t) \times c$

6) What is the formula for the physical (or proper) distance between two points A and B on the same line-of-sight with radial comoving coordinates r_A and r_B in the FRW metric?

A. $r_B - r_A$
B. $\int_A^B a(t)\, dr$

C. $\int_A^B \frac{dr}{\sqrt{1-Kr^2}}$
D. $\int_A^B \frac{a(t)\, dr}{\sqrt{1-Kr^2}}$

7) What is the minimal but complete set of variable(s) needed in order to determine the apparent angular size of a distant object knowing its physical width?

A. The comoving coordinate
B. The comoving coordinate and the redshift
C. The comoving coordinate, the redshift and the curvature
D. The physical distance to the object

8) Which one of the following factors does **not** help to explain the observation that distant galaxies look fainter as their distance increases?

A. Photons decrease in energy as they journey across the Universe
B. Successive photons arrive with longer time intervals
C. Light from the galaxy is spreading out across a larger "area" as distance increases
D. The Universe was younger when the photons were emitted

9) Which of the following combination of variables is an estimate of the characteristic age of the Universe?

A. H_0
B. $1/H_0$
C. c/H_0
D. $c \times H_0$

10) Which of the following combination of variables is an estimate of the characteristic size of the observable Universe?

A. H_0
B. $1/H_0$
C. c/H_0
D. $c \times H_0$

Week 3: Contents of the universe

1) Einstein originally introduced the cosmological constant into the equations of general relativity because:

A. He wanted to create a static Universe
B. He wanted to create an expanding Universe
C. He wanted to create a Universe with accelerating expansion
D. He wanted to include the quantum vacuum energy in general relativity

2) Why does dark energy have no effect on the early Universe?

A. The dark energy density drops to lower values at early times
B. Dark energy is only present in the late Universe
C. The cosmic expansion is only accelerating in the late Universe
D. The matter and radiation densities increase at early times

3) What is the correct comparison between the energy density due to matter (ρ_m) and the energy density due to the cosmological constant (ρ_Λ), between today (scale factor $a = 1$) and the time when $a = 0.5$?

A. Both ρ_m and ρ_Λ are smaller by a factor of 2 when $a = 0.5$
B. ρ_m is smaller by a factor of 2 when $a = 0.5$, and ρ_Λ is the same
C. ρ_Λ is larger by a factor of 2 when $a = 0.5$, and ρ_m is the same
D. ρ_m is larger by a factor of 8 when $a = 0.5$, and ρ_Λ is the same

4) Suppose that the matter density in the Universe, ρ_m, is currently half the critical density. What can we conclude?

A. The Universe has a curved geometry
B. The Universe will expand forever, and never contract
C. The Universe is never matter-dominated across its lifetime
D. The matter density will always be half the critical density

5) In general, Hubble's "constant" is not a constant because it slowly varies with time. In what type of Universe would it actually remain constant?

A. Radiation-dominated
B. Matter-dominated
C. Curvature-dominated (that is, empty)
D. Dark energy-dominated

6) Two galaxies form soon after the Big Bang. One galaxy is observed to have redshift $z = 2$ and age 4 Gyr. The other galaxy has redshift $z = 1$ and age 6 Gyr. Which component of the Universe must have dominated the expansion between these times?

A. Radiation
B. Matter
C. Curvature
D. Dark energy

7) An experiment measures the rate of change of the scale factor, $\frac{da}{dt}$, at a range of different redshifts z, and concludes that $\frac{da}{dt} \propto 1 + z$. In this phase of expansion, the Universe must be:

A. Radiation-dominated
B. Matter-dominated
C. Curvature-dominated (that is, empty)
D. Dark energy-dominated

8) An empty Universe contains (almost) no matter ($\Omega_m = 0$) and zero cosmological constant ($\Omega_\Lambda = 0$). Which one statement is correct about this Universe?

A. It has non-zero curvature
B. It cannot theoretically exist
C. Its Hubble parameter is constant with time
D. Light cannot propagate in this Universe

9) The Universe became matter-dominated approximately how long after the Big Bang?

A. 1 year
B. 30,000 years
C. 300,000 years
D. 10 billion years

10) A component of energy in the Universe has equation of state w_X and current density parameter Ω_X. What conditions are needed such that this component creates an accelerating expansion?

A. $\Omega_X > 0$
B. $w_X < -\frac{1}{3}$
C. $w_X = -1$
D. $w_X < 0$

Week 4: Big Bang physics

1) Which of the following observations would disprove the Big Bang model?

A. The Universe is contracting, not expanding
B. The Cosmic Microwave Background currently has a temperature of 30 K, not 3 K
C. A primordial cloud of gas contains no deuterium
D. The Universe has a closed geometry

2) If the current cosmic expansion should stop in the future and reverse, what would happen about 30,000 years before the Big Crunch?

A. The radiation density would become larger than the matter density
B. The Universe would become opaque to radiation
C. Galaxies would start to collide and merge
D. Nuclei would disassemble into their constituents

3) Why are negligible amounts of elements heavier than helium produced during the first few minutes of the Big Bang?

A. The Universe was so hot and dense that helium nuclei couldn’t hold together
B. The Universe cooled and expanded so rapidly that heavier elements didn’t have chance to form

C. The density of the Universe was too low to allow helium nuclei to fuse into heavier elements
D. Nucleosynthesis was disrupted by radiation pressure

4) Why is there no primordial beryllium leftover from the early Universe?

A. The Universe cools too quickly to allow the formation of beryllium
B. Beryllium fuses into heavier elements
C. There are no nuclear reactions that can produce beryllium
D. Beryllium is an unstable nucleus so cannot survive

5) In Big Bang Nucleosynthesis (BBN), stable deuterium can form when the temperature has cooled to $k_B T \approx 0.06$ MeV. What would happen if the formation temperature was lower, $k_B T \approx 0.03$ MeV?

A. The abundance of helium formed in BBN would be unaffected
B. The abundance of helium formed in BBN would increase
C. The abundance of helium formed in BBN would decrease
D. No helium could form in BBN

6) What is the main reason that we cannot observe light from 1000 years after the Big Bang?

A. The Universe contains a high density of free electrons
B. There are no atoms in the Universe at this time
C. This light has been redshifted out of the visible window
D. The Universe does not contain electromagnetic radiation at this time

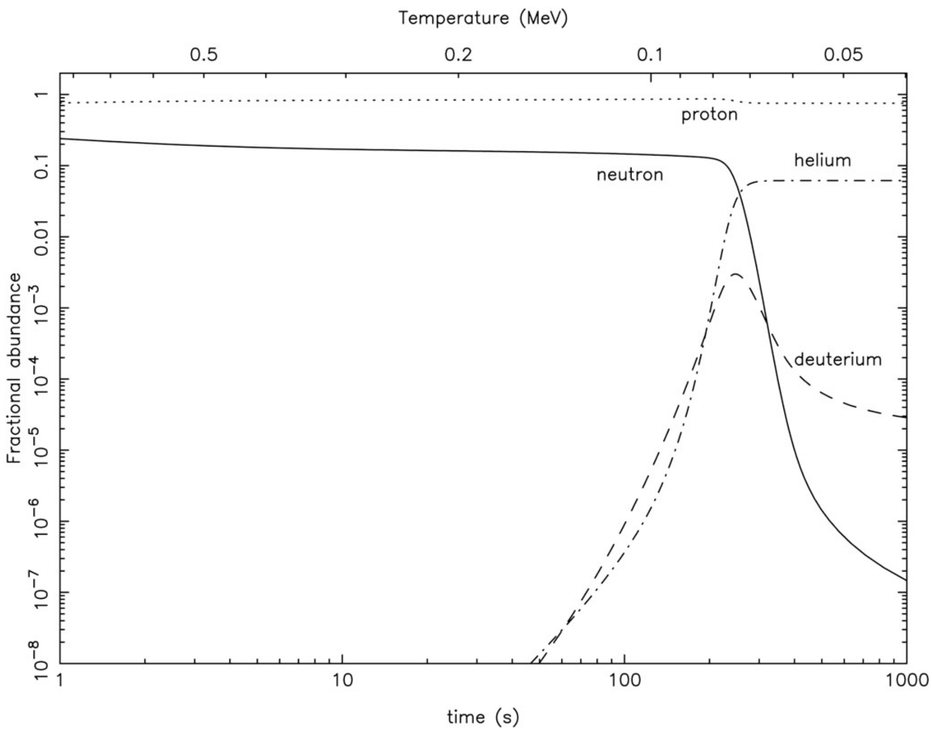
7) What is the dominant source of radiation in today's Universe?

A. Stars
B. Cosmic Microwave Background
C. Supernovae
D. Warm dust

8) What's the best estimate of the CMB temperature when the Universe was about 10% of its current age?

A. 3 K
B. 14 K
C. 30 K
D. 3000 K

9) The following graph shows the relative abundance of several types of particles in the early Universe:



The neutron abundance exhibits a sudden drop at $t \approx 200$ s. What's the main reason for this effect?

A. Neutrons transforming into protons via beta decay
B. Neutrons combining with protons to form helium
C. Neutrons combining with protons to form deuterium
D. Neutrons diluting owing to the expansion of the Universe

10) The fraction of primordial deuterium relative to hydrogen can be used to measure the baryon density in the Universe. Why is this?

A. The baryon density affects deuterium formation by changing the flux of protons and neutrons
B. The baryon density affects deuterium formation by controlling the temperature of the Universe
C. Deuterium constitutes a known fraction of baryons, so the overall number of baryons can be inferred
D. The baryon density affects the expansion of the Universe, and hence the time available for deuterium to form

Week 5: Cosmic structure

1) Which of these factors is **not** a motivation for the theory of inflation in the early Universe?

A. The Cosmic Microwave Background is in thermal equilibrium
B. The spatial curvature of the Universe is close to zero
C. The primordial Universe contains small fluctuations

D. The Universe contains slightly more baryons than anti-baryons

2) In what way does inflation provide a solution for the "horizon problem"?

A. Inflation provides extra expansion, increasing the physical size of the particle horizon
B. Inflation provides more time before recombination, increasing the physical size of the particle horizon
C. Inflation changes the size of observable Universe, bringing it in accord with the particle horizon
D. Inflation changes the curvature of the Universe, affecting the particle horizon

3) If the density parameter Ω_m were measured by observers at different redshifts, over a phase when the expansion was matter-dominated, how would it scale with redshift?

A. $\Omega_m(z) = \text{constant}$
B. $\Omega_m(z) \propto (1+z)^3$
C. $\Omega_m(z) \propto (1+z)^{-1}$
D. $\Omega_m(z) \propto (1+z)$

4) Why is the particle horizon distance $D_H(t) \neq ct$?

A. The Universe is expanding
B. Light is redshifted by the expansion
C. The time interval between successive photons is changing
D. The Universe has curvature

5) A matter-dominated Universe with $\Omega_m > 1$ enters a phase of contraction between times t_1 and t_2. What can be said about the particle horizon D_H between these times?

A. $D_H > c(t_2 - t_1)$
B. $D_H < c(t_2 - t_1)$
C. $D_H = c(t_2 - t_1)$
D. D_H can be greater or less than $c(t_2 - t_1)$, depending on the curvature

6) Which effect is **not** partially responsible for determining the pattern of temperature fluctuations in the Cosmic Microwave Background radiation?

A. Adiabatic compression
B. Doppler effect
C. Gravitational redshift
D. Jeans mass

7) What is the main effect which prevents an overdense clump of matter collapsing under gravity in the early Universe?

A. Thermal pressure
B. Expansion of the Universe
C. Inflation

D. Dark energy

8) The Jeans mass scales with the temperature T and matter density ρ_m of the Universe as $M_J \propto T^{3/2} \rho_m{}^{-1/2}$. If the expansion of the Universe were matter-dominated, how would the Jeans mass scale with cosmic time t?

A. M_J is independent of t
B. $M_J \propto t^{1/2}$
C. $M_J \propto t$
D. $M_J \propto t^{3/2}$

9) Why do we find fewer massive objects in the early Universe than later Universe?

A. The gravitational collapse time of massive objects is long
B. The early Universe is radiation-dominated, whereas the late Universe is matter-dominated
C. The Jeans mass is smaller in the early Universe
D. The average mass density is higher in the early Universe

10) Which of these effects is **not** an observational probe of cosmic structure?

A. Redshift-space distortions
B. Gravitational lensing of light
C. Cosmic Microwave Background
D. Hubble diagram of Type Ia supernovae

Week 6: Cosmological observations

1) Which object is **not** a type of "standard candle" widely used in astronomy?

A. Supernova
B. Variable star
C. Planetary nebula
D. Quasar

2) Why doesn't the dimming of light by dust prevent the use of Type Ia supernovae as a standard candle?

A. Supernovae typically occur in the outskirts of galaxies, where there isn't any dust
B. The dust extinction can be corrected using a known reddening law
C. Type Ia supernovae are very luminous, so can be detected regardless of the presence of dust
D. Dust extinction dims all supernova magnitudes equally, so is unimportant

3) What is plotted in a supernova "Hubble diagram"?

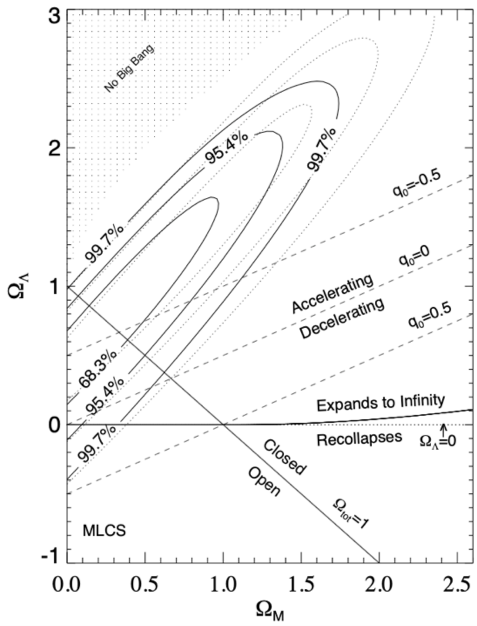
A. Recession velocity versus Distance

B. Distance versus Redshift
C. Magnitude versus Redshift
D. The Hubble parameter versus Redshift

4) What is the best way to determine the absolute luminosity of a Type Ia supernovae?

A. The luminosity can be theoretically calculated, since the formation process is known
B. The luminosity cannot be known
C. The luminosity can be determined from the fall-off in brightness with distance
D. The luminosity can be determined if the distance to the galaxy is known by another method

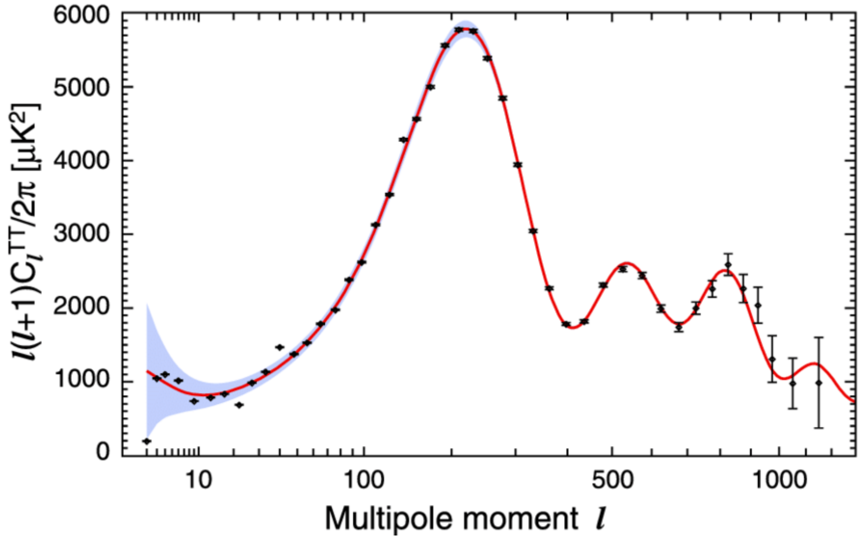
5) The following figure is taken from one of the most important early papers using Type Ia supernovae to test the cosmological model (Riess et al. 1998, AJ, 116, 1009, which has over 14,000 citations):



What is the most significant finding from this figure?

A. The curvature of the Universe is zero
B. The dark energy density is greater than zero
C. The Big Bang must have occurred
D. The dark energy density depends on the matter density

6) The following graph shows a measurement of the angular power spectrum of the CMB temperature fluctuations:



What effect in the early Universe produces these oscillations in power?

A. Sound waves
B. Density fluctuations
C. Reombination of electrons and nuclei
D. Gravitational redshift

7) Which of the following parameters which describe the Universe is known most accurately?

A. The current CMB temperature, $T_{CMB} \approx 2.73$ K
B. The matter density parameter, $\Omega_m \approx 0.3$
C. The Hubble parameter, $H_0 \approx 70$ km s^{-1} Mpc^{-1}
D. The deuterium abundance, $D/H \approx 10^{-4.6}$

8) A standard ruler in the Universe of known **comoving** size W is oriented tangentially to the line-of-sight and has apparent angular size $\Delta\theta$ measured in units of **degrees**. How would we combine these variables to deduce the comoving distance to the object?

A. $W/\Delta\theta$
B. $(W/\Delta\theta) \times (180/\pi)$
C. $(W/\Delta\theta) \times (\pi/180)$
D. $W \times \Delta\theta$

9) A standard ruler in the Universe of known **comoving** size W is oriented radially along the line-of-sight and its ends have redshifts separated by Δz. If the Universe has zero curvature, how would we combine these variables to deduce the Hubble parameter at the object?

A. $c\,\Delta z/W$
B. $W\,\Delta z/c$
C. $c/(W\,\Delta z)$
D. $c\,W\,\Delta z$

10) In the standard model of cosmology, how many separate periods of accelerating expansion has the Universe experienced?

A. 0
B. 1
C. 2
D. 3