The History of the Universe

Practice Mini-Exam

ASTRONOMY 143: The History of the Universe

Potentially useful numbers:
1 astronomical unit (AU) = 150,000,000 kilometers = 1.5 × 1011 meters
1 parsec (pc) = 206,000 AU = 3.1 × 1013 kilometers = 3.1 × 1016 meters
1 megaparsec (Mpc) = 1,000,000 parsecs
1 year = 32,000,000 seconds
Diameter of Earth = 12,800 kilometers
Mass of Earth = 6 × 1024 kilograms
Diameter of Sun = 109 × diameter of Earth = 1,400,000 kilometers
Mass of Sun = 330,000 × mass of Earth = 2 × 1030 kilograms
Speed of light = 300,000 km/sec
Hubble constant = H0 = 71 km/sec/Mpc
Hubble time = 1/H0 = 1.4 × 1010 years H
ubble distance = c/H0 = 4300 Mpc
Critical density = 10−26 kg/m3

Short-Answer Problems

1) Which has the greater energy: a photon of infrared light or a photon of ultraviolet light?

2) Which is longer: a sidereal day or a solar day?

3) Arrange the following objects in order of increasing mass: brown dwarf, Jupiter, Sun, Earth.

4) Two stars have the same luminosity. One star has a parallax of 0.1 arcseconds. The other has a parallax of 0.5 arcseconds. Which star has the greater flux?

5) If the density of the universe were greater than the critical density, would the universe be negatively curved, positively curved, or flat?

6) A newly formed zircon crystal contains 1000 uranium-238 atoms. How many uranium-238 atoms will be left after two half-lives?

7) Which contributes most to the average density of the universe: dark energy, dark matter, or ordinary matter?

8) How long after the Big Bang did the first galaxies form?

Mathematical Problems

9) The star named “Gliese 710” is at a distance d = 15 parsecs from the Sun.

a) What is the distance from the Sun to Gliese 710, measured in kilometers?

b) From the Doppler shift of Gliese 710, it is known to be coming closer to the Sun, with a radial velocity v = −24 km/sec. If Gliese 710 is moving straight toward the Sun, how many years will it be until they collide?

Mathematical Problems

10) Ordinary matter provides 4% of the critical density of the universe.

a) What is the average density of ordinary matter in the universe, given in units of kilograms per cubic meter?

b) Suppose that the ordinary matter consisted entirely of regulation bowling balls, each with a mass Mbb = 7 kg. How many bowling balls, on average, would there be in one cubic astronomical unit (AU) of space?

PRACTICE MINI-EXAM SOLUTIONS

1) Which has the greater energy: a photon of infrared light or a photon of ultraviolet light?

- ULTRAVIOLET light has the greater energy per photon.

2) Which is longer: a sidereal day or a solar day?

- The SOLAR day is 4 minutes longer than the sidereal day.

3) Arrange the following objects in order of increasing mass: brown dwarf, Jupiter, Sun, Earth.

- The EARTH is lowest in mass, followed by JUPITER, a BROWN DWARF, and the SUN.

4) Two stars have the same luminosity. One star has a parallax of 0.1 arcseconds. The other has a parallax of 0.5 arcseconds. Which star has the greater flux?

- The star with the LARGER PARALLAX (0.5 arcseconds) is closer, and thus has a greater flux.

PRACTICE MINI-EXAM SOLUTIONS

5) If the density of the universe were greater than the critical density, would the universe be negatively curved, positively curved, or flat?

- The universe would be POSITIVELY CURVED.

6) A newly formed zircon crystal contains 1000 uranium-238 atoms. How many uranium-238 atoms will be left after two half-lives?

- There will be 250 atoms left.

7) Which contributes most to the average density of the universe: dark energy, dark matter, or ordinary matter?

- DARK ENERGY contributes the most.

8) How long after the Big Bang did the first galaxies form?

- The first galaxies formed about 750 MILLION YEARS after the Big Bang.

Mathematical Problems Solutions

9) The star named “Gliese 710” is at a distance d = 15 parsecs from the Sun.

a) What is the distance from the Sun to Gliese 710, measured in kilometers?

The distance in kilometers is

$$d = 15\,\mathrm{pc} \times \frac{3.1 \times 10^{13}\,\mathrm{km}}{1\,\mathrm{pc}} = 4.65 \times 10^{14}\,\mathrm{km}\ .$$

b) From the Doppler shift of Gliese 710, it is known to be coming closer to the Sun, with a radial velocity v = −24 km/sec. If Gliese 710 is moving straight toward the Sun, how many years will it be until they collide?

The time in seconds will be

$$t = \frac{d}{v} = \frac{4.65 \times 10^{14}\,\mathrm{km}}{24\,\mathrm{km/sec}} = 1.9375 \times 10^{13}\,\mathrm{sec}\ .$$

Converted to years, this time is

$$t = 1.9375 \times 10^{13}\,\mathrm{sec} \times \frac{1\,\mathrm{year}}{32{,}000{,}000\,\mathrm{sec}} = 605{,}000\,\mathrm{years}\ .$$

Mathematical Problems Solutions

10) Ordinary matter provides 4% of the critical density of the universe.

a) What is the average density of ordinary matter in the universe, given in units of kilograms per cubic meter?

Since the critical density is $\rho_{\text{crit}} = 10^{-26}\,\text{kg/m}^3$, the density of ordinary matter is

$$\rho_{\text{ord}} = 0.04\rho_{\text{crit}} = 0.04 \times 10^{-26}\,\text{kg/m}^3 = 4 \times 10^{-28}\,\text{kg/m}^3 \ .$$

Mathematical Problems Solutions

b) Suppose that the ordinary matter consisted entirely of regulation bowling balls, each with a mass Mbb = 7 kg.

How many bowling balls, on average, would there be in one cubic astronomical unit (AU) of space?

The number of bowling balls per cubic meter would be

$$n_{\rm bb} = \frac{\rho_{\rm ord}}{M_{\rm bb}} = \frac{4 \times 10^{-28}\,{\rm kg/m^3}}{7\,{\rm kg}} = 5.714 \times 10^{-29}/{\rm m^3}\ .$$

Since $1\,{\rm AU} = 1.5 \times 10^{11}\,{\rm m}$, the volume of a cube 1 AU on a side will be

$$V = 1\,{\rm AU}^3 \times \left(\frac{1.5 \times 10^{11}\,{\rm m}}{1\,{\rm AU}}\right)^3 = 3.375 \times 10^{33}\,{\rm m}^3\ .$$

Thus, the number of bowling balls in a cube 1 AU on a side would be

$$N = n_{\rm bb}V = (5.714 \times 10^{-29}/{\rm m}^3) \times (3.375 \times 10^{33}\,{\rm m}^3) = 193{,}000\ .$$

That's not a lot of bowling balls to be drifting around in such a big cube.