Homework for Week #12

1. Below is a picture of a supernova explosion, dubbed SN 1999em, that occurred in the “nearby” spiral galaxy NGC 1637. Using the Hubble Space Telescope to discover and analyze Cepheid variable stars in the “host” galaxy, your humble professor determined that NGC 1637 is located approximately 12 million parsecs (Mpc) away from us.

With this information, please answer the following two questions:

(a) How long ago did the supernova actually occur? That is, for approximately how many years has the light from SN 1999em been traveling through space before finally reaching us in 1999? (Hint: Recall that 1 pc = 3.26 LY.)

Solution: For this, we just have to convert the stated distance, 12 Mpc, into light years. Since a light year is the distance traveled by light in one year, this will then tell us how far back in time we are looking when we are observing SN 1999em. So, we have:

\[
12 \text{ Mpc} \times \frac{3.26 \text{ MLY}}{1 \text{ Mpc}} = 39 \text{ MLY}
\]

Thus:

The supernova actually exploded about 39 million years ago.

(b) Assuming a Hubble’s constant of \(H_0 = 100 \text{ km s}^{-1} \text{ Mpc}^{-1}\), with what velocity would you expect NGC 1637 to be receding from us? Please give your answer in km/s.

Solution: From Hubble’s law we know that \(v = H_0 d\). Thus, we have:

\[
v = H_0 d = 100 \text{ km s}^{-1} \text{ Mpc}^{-1} \times 12 \text{ Mpc}
\]

\[
v = 1,200 \text{ km/s}
\]

Thus:

We would expect NGC 1637 to be receding from us at about 1,200 km s\(^{-1}\).

Homework for Week #13

1. Lauren takes a spectrum of galaxy and determines it to have a redshift of \(z = 2\). Assuming that the present age of the universe is 14 BY, how long ago was the light that Lauren observed actually emitted from the galaxy? →Hint: Read section 20.2.4 of the text!

(a) If we live in a “critical” universe (i.e., one where the mass density exactly equals the critical density needed to ultimately halt the expansion) with no dark energy.

Solution: Let’s start by taking the hint! In §20.2.4, we find Table 20.3, which tells us the percentage of the current age of the Universe that has elapsed for light that is emitted for a variety of redshifts for a critically dense Universe and also one with \(\Omega_M = 0.3, \Omega_\Lambda = 0.7\). The first situation applies to this part of the problem. For a redshift of \(z = 2\), the table tells us that the Universe was just 19% of its current age when the light was emitted. If the Universe is 14 BY old, that means that it was emitted when it was just 14 BY × 0.19 = 2.66 BY old. In other words, that light was emitted 14 BY − 2.66 BY = 11.34 BY ago. Thus:

The light was emitted 11.34 billion years ago.
(b) In a universe where the mass density equals 30% of the critical density and the dark energy content equals 70% of the critical density.

Solution: Following the technique used in part (a), we see that the Universe in which $\Omega_M = 0.3$ and $\Omega_\Lambda = 0.7$ was just 25% of its current age when the light was emitted. If the Universe is 14 BY old, that means that it was emitted when it was just $14 \text{ BY} \times 0.25 = 3.5 \text{ BY}$ old. In other words, that light was emitted $14 \text{ BY} - 3.5 \text{ BY} = 10.5 \text{ BY}$ ago. Thus:

The light was emitted 10.5 billion years ago.

Homework for Week #14

Please carefully answer the following question in your own words and with as much detail as you feel is necessary to thoroughly explain your answer.

1. Why is the actual age of a universe whose expansion rate has always been decelerating less than a Hubble time (i.e., the inverse of the current value of Hubble’s constant: $t_0 = 1/H_0$)?

Solution: Please see the sample student response(s) on reserve at the book reserve desk at the library (should be available by Tuesday, May 9).

Homework for Week #15

Please carefully answer the following question in your own words and with as much detail as you feel is necessary to thoroughly explain your answer. This assignment will be collected on May 4, when the 4th and final homework collection will take place.

1. Cosmologists often say that when we observe photons from the cosmic microwave background (CMB), “we are looking back to a redshift of $z = 1000$”. Explain as best you can the meaning of this statement.

Hint: Think carefully about the true meaning of cosmological redshift that we discussed earlier in the course. Scrutinizing §20.4.2 of the text and the first few pages of Ch. 7 in Kirshner’s book may help as well.

Solution: Please see the sample student response(s) on reserve at the book reserve desk at the library (should be available by Tuesday, May 9).