13.2 **Measuring the Universe** Name SA

Past Paper Questions

- Describe and explain evidence for a 'hot big bang' origin of the universe from cosmological red-shifts (Hubble's law); cosmological microwave background.
- Make calculations and estimates of distances and ages of astronomical objects.

Jan 2001 2863

10 This question is about evidence of a 'hot big bang' origin of the Universe.

(a) Fig. 10.1 shows how the speed of recession of galaxies, *v*, is related to distance, *d*, from the Earth.

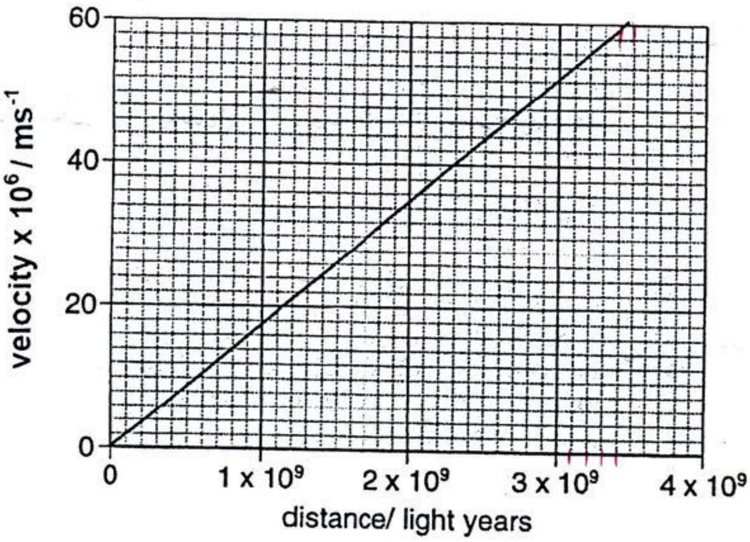

Fig 10.1

Use the graph to determine a value for the Hubble constant, H_0, where $v = H_0 d$

1 *light year* = 9.5×10^{15} m

$$H_0 = \text{gradient} = \frac{\Delta v}{\Delta s} = \frac{60\times10^6\ ms^{-1}}{3.45\times10^9\ ly \times 9.5\times10^{15}\ m}$$

$$= 1.83\times10^{-18}\ s^{-1}$$

Ho= 1.8×10^{-18} units= s^{-1}

[3]

The recession of the galaxies was first observed by the astronomer Edwin Hubble in 1925. Since that time the strongest evidence for a hot big bang has come from observations of cosmological red shift and the cosmological microwave background.

(b) (i) Describe how the cosmological red shift is observed and explain how it supports the big bang model.

Cosmological red shift is observed as in increase in the wavelength of lines in the spectrum of distant galaxies. The increase in wavelength is due to the expansion of the Universe which stretches the waves as they travel to us. An expanding Universe must* have begun in an initial small state called the Big Bang. (*or a 'steady state' that was ruled out by the observation of CMBR.)

(ii) The cosmological microwave background has been described as 'the biggest red-shift known'. It is detectable in all directions. Explain why the microwave background gives evidence of events further back in time than any other red shift observations.

When the Universe had expanded and cooled enough to become transparent the first and hence oldest light began its journey through the Universe. If we look far enough in any direction we can observe this oldest light which as been cosmologically red shifted the most because it has been travelling the longest.

[7]

2863 June 2002

12 This question is about the expansion of the Universe.

(a) The speed of light is 3.0×10^8 m s^{-1}. Show that the distance light will travel through space in one year is about 10^{16} m.
(assume one year = 3.2×10^7 s)

$s = vt = 3 \times 10^8 \times 3.2 \times 10^7 = 9.6 \times 10^{15}$ m $\approx 10^{16}$ m

[1]

(b) (i) During the past century it has been possible to observe galaxies which are receding from Earth.
One such galaxy is observed in the area of the sky known as Virgo. The distance to this galaxy is 10 000 million light years.
Explain why the galaxy is observed as it was 10 000 million years ago.

It takes light 10,000 million years to reach us so the light we see today started its journey 10,000 million years ago.

(ii) Show that the galaxy is about 1.0×10^{26} m from Earth.

$s = vt = 3 \times 10^8 \times 10{,}000 \times 10^6 \times 3.2 \times 10^7 = 9.6 \times 10^{25}$ m

$\approx 10^{26}$ m [2]

(c) The light from the galaxy shows 'red-shift'. This is thought to be due to the expansion of space and is called 'cosmological red-shift'.

(i) Explain what is meant by 'red-shift'.

The lengthening of the wavelength of spectral lines moving them towards the red end of the visible spectrum.

(ii) Explain how the expansion of space causes a cosmological red-shift.

As the radiation travels through expanding space the wavelength is stretched as the space expands.

(iii) The cosmological red-shift is greater for galaxies further away from the Earth. Describe how the model of an expanding universe explains this observation.

The further away a galaxy the longer the radiation travels so the more the space expands stretching the wavelength more.

[6]

2863 June 2003 Q11

(d) Distant galaxies are observed to be receding (moving away) from the Earth at high velocities. The velocity of a galaxy in deep space is calculated from its redshift. The distance d to the object can be determined from its velocity of recession v using the relationship

$$v = H_0 d$$

where H_0 is the Hubble constant.

(i) Galaxy Y is observed to be receding at a velocity of $1.0 \times 10^6 \, m \, s^{-1}$.

Show that the distance from the Earth to galaxy Y is about 4.5×10^{23} m.

In the year 2001, $H_0 = 2.2 \times 10^{-18} \, s^{-1}$.

$$d = v/H_0 = \frac{1.0 \times 10^6 \, ms^{-1}}{2.2 \times 10^{-18} \, s^{-1}} = \underline{4.55 \times 10^{23} \, m}$$

[1]

(ii) Observations of distant galaxies show how the galaxies appeared millions of years ago.

Use your answer to **(d)(i)** to explain why this is so.

1 year = 3.2×10^7 s

We see the galaxy as it was when the light started its long journey to us. Even at $3 \times 10^8 \, ms^{-1}$ this takes a long time.

$$t = s/v = \frac{4.55 \times 10^{23} \, m}{3 \times 10^8 \, ms^{-1}} \Big/ 3.2 \times 10^7 = \underline{47 \text{ million years.}}$$

[2]

(e) The value of H_0 given in **(d)(i)** as $H_0 = 2.2 \times 10^{-18} \, s^{-1}$ is often given in the alternative form $H_0 = 70 \, km \, s^{-1} \, Mpc^{-1}$.

One megaparsec (Mpc) is an astronomical unit of distance equal to 3.1×10^{22} m.

Show that the value $70 \, km \, s^{-1} \, Mpc^{-1}$ is approximately equivalent to $2.2 \times 10^{-18} \, s^{-1}$.

$$70 \, Kms^{-1} \, Mpc^{-1} = \frac{70 \times 10^3}{3.1 \times 10^{22}} = \underline{2.26 \times 10^{-18} \, s^{-1}}$$

[2]

2863 Jan 2004

4 Read the short passage and answer the questions below.

Most physicists accept the Hot Big Bang model of the origin of the Universe. Two pieces of evidence for this model are (i) the expansion of space and (ii) the microwave background radiation that is observed to be of almost equal intensity in all directions.

(a) State an observation that leads physicists to suggest that space is expanding.

Cosmological red shift of distant galaxies

OR Hubble's law $v = H_0 d$

[1]

(b) Explain why the second piece of evidence suggests that all the early Universe was at approximately the same temperature.

The wavelength* of the cosmic microwave background is almost the same in all directions indicating that the early Universe was almost the same in all directions.

(* Black body spectrum)

[2]

2863 Jan 2005

7 The image in Fig. 7.1 comes from the COBE satellite. It shows the differences in the mean wavelength of microwave background radiation in different parts of the sky. The differences are very small.

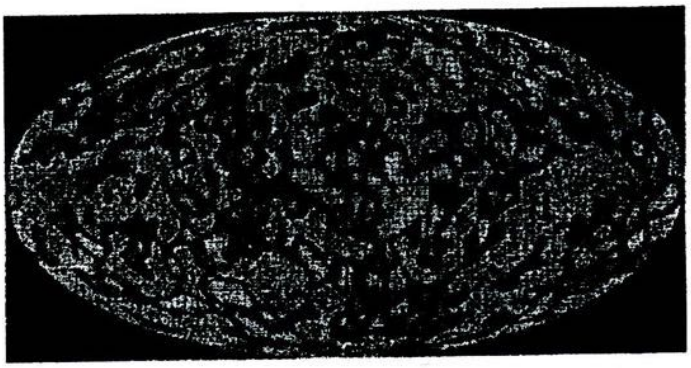

Fig. 7.1

(a) When the radiation was first emitted 300 000 years after the Big Bang during the so-called **era of recombination**, it was in the visible region of the spectrum. Explain why the visible radiation emitted during the era of recombination is now observed in the microwave region.

During the time that the radiation has travelled the Universe has expanded stretching out the wavelength into the microwave region of the spectrum. [2]

(b) State and explain what the COBE data tell scientists about the temperature variation of the early Universe.

The wavelength has only very small differences indicating that the temperature of the Universe was almost the same everywhere. [2]

2863 June 2005

3 About three hundred thousand years after the Big Bang, the Universe was at a temperature of roughly 3000 K.

The photons emitted at that time are now observed to be at a temperature of around 3 K.

(a) Calculate the ratio $\dfrac{\text{energy of photons at 3 K}}{\text{energy of photons at 3000 K}}$

$E = kT \quad \therefore \quad 3/3000$

ratio = 0.001 [1]

(b) Calculate the ratio $\dfrac{\text{wavelength of photons at 3 K}}{\text{wavelength of photons at 3000 K}}$

$E = \dfrac{hc}{\lambda} \quad \therefore \quad \lambda = \dfrac{hc}{E} \quad \lambda \propto 1/E$

$\therefore \quad 3000/3$

ratio = 1000 [1]

(c) Suggest why the answer to **(b)** gives a measure of how the radius of the Universe has changed since the photons were emitted.

The wavelength is stretched by the expanding universe, cosmological red shift.

[1]

2 Which of these ages is estimated correctly?

A The Earth is about 4 billion years old. ✓ (4.5 billion)

B The Sun is about 14 billion years old. × ~ same as the Earth.

C The Milky Way Galaxy is about 20 billion years old. ×

D The Universe is about 20 billion years old. ×

The Universe is only ~ 14 billion years old.

Your answer A

[1]

2863 June 2006

5 Hubble's Law states that the velocity of recession of a galaxy is proportional to the distance to the galaxy as measured from Earth. The further away a galaxy is, the faster it recedes from us.

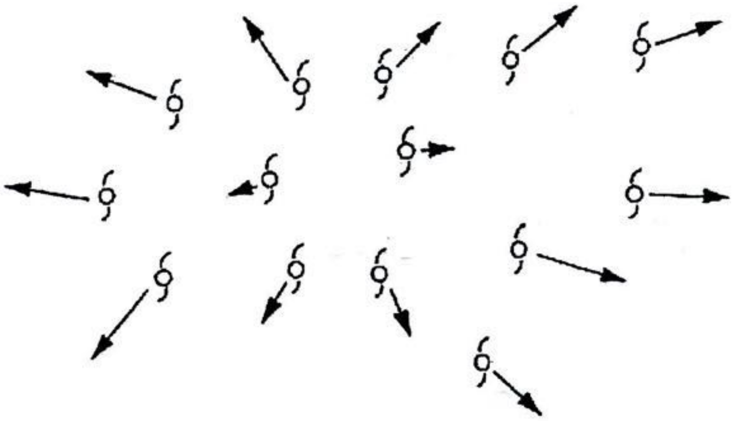

Fig. 5.1

Hubble's Law can be written as

$$v = H_0 d$$

where v is the velocity of recession
d is the distance from Earth
H_0 is the Hubble constant = $2.2 \times 10^{-18}\ s^{-1}$.

(a) State the observational evidence that supports Hubble's Law.

Red shift of distant galaxies

[1]

(b) The value of $1/H_0$ gives an estimate of the time passed since all the galaxies were close together. This gives an estimate of the age of the Universe.

Use the value of H_0 to estimate for the age of the Universe in years.
1 year = 3.2×10^7 s

$$\text{Age} = 1/H_0 = 1/2.2 \times 10^{-18} = 4.55 \times 10^{17}\ s$$

$$4.55 \times 10^{17} / 3.2 \times 10^{7} = \underline{1.4 \times 10^{10}\ \text{years}}$$ [2]

(c) Suggest one reason why the age of the Universe may be larger than this value.

The Universe had been around for some time before the first galaxies formed. [1]

OR The rate of expansion may have been slower in the past.

2863 Jan 2007

11 This question is about observations which suggest that space is expanding.

In 1929 Edwin Hubble (Fig. 11.1) suggested that distant galaxies were moving away (receding) from our own galaxy with velocities that are directly proportional to the distance to the galaxy. This is known as Hubble's law.

↓

$v = H_0 d$

$H_0 = v/d$

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Fig. 11.1

Some data collected by Hubble are given in the table below.

galaxy	distance to galaxy / light years	velocity of recession / m s^{-1}
NGC 221	9.0×10^5	2.0×10^5
NGC 379	2.3×10^7	2.2×10^6
Gemini cluster	1.4×10^8	2.3×10^7

(a) Propose and carry out an arithmetical test to decide if velocity of recession is directly proportional to distance.

test proposed:

If directly proportional then v/d = constant.

working:

	v/d / ms^{-1} light-year^{-1}
NGC 221	0.22
NGC 379	0.096
Gemini Cluster	0.16

conclusion: The largest v/d value is 2.3 × the smallest v/d value. The data here is not enough to demonstrate proportionality.

[4]

Hubble's Law can be written in the form

velocity of recession = H_0 × *distance from galaxy*

where H_0 is the Hubble constant.

The accepted value of H_0 in 2005 was $2.2 \times 10^{-18}\,s^{-1}$. This is considerably lower than Hubble's early results suggested.

(b) Use the data on the Gemini cluster given in the table to calculate a value for H_0. Show that this value is about eight times the modern value.

One light year is the distance light travels in one year.

1 year = 3.2×10^7 s
velocity of light = $3.0 \times 10^8\,m\,s^{-1}$

$$H_0 = \frac{v}{d} = \frac{2.3 \times 10^7}{1.4 \times 10^8 \times 3.2 \times 10^7 \times 3.0 \times 10^8} = 1.71 \times 10^{-17}\,s^{-1}$$

$$\frac{1.71 \times 10^{-17}}{2.2 \times 10^{-18}} = 7.8 \text{ times greater.}$$

[3]

The speed of recession of the galaxies is found from observations of *redshift.* It is thought that distant galaxies show *cosmological redshift* which gives evidence that the speed of recession is due to the expansion of the Universe.

(c) **(i)** State what is meant by the term *redshift.*

An increase in the wavelength of radiation

[1]

(ii) Explain why the expansion of space will cause light from more distant galaxies to show greater redshift.

The light from a more distant galaxy will have travelled for longer so space will have expanded more during its journey.

[2]

2863 Jan 2008

2 Distant galaxies are observed to be receding from Earth at velocities approximately proportional to the distance from Earth. This relationship is shown in Fig. 2.1. Each point represents a galaxy.

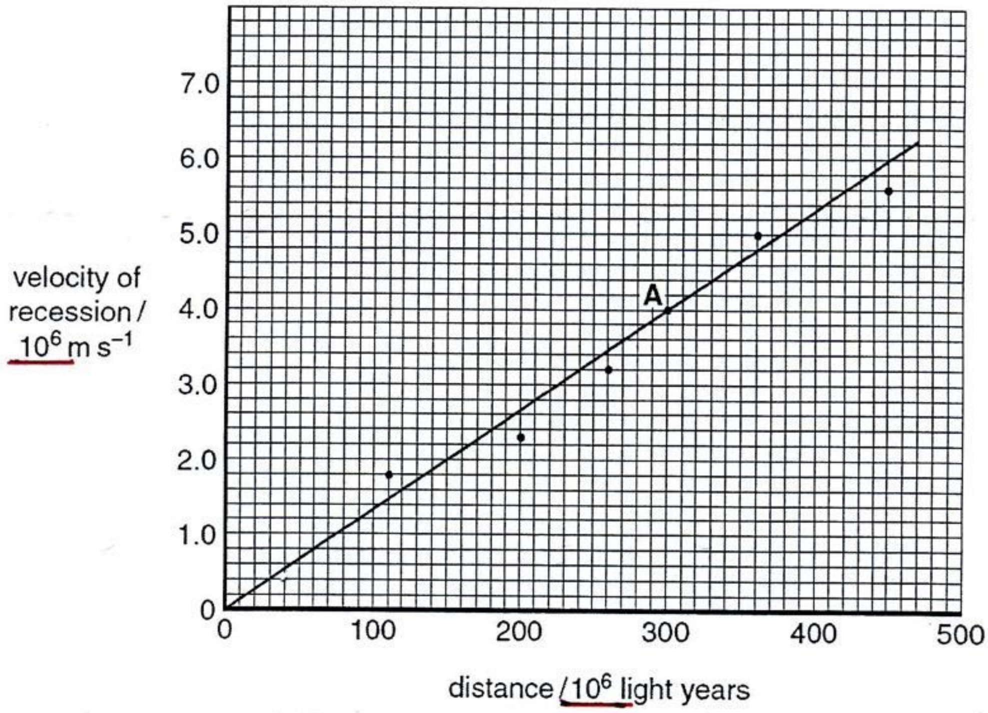


Fig. 2.1

(a) State the observational evidence that allows the velocities of distant galaxies to be calculated.

red shift

[1]

(b) Show that the galaxy represented by point **A** is about 3×10^{24} m from Earth.

1 light year = 9.6×10^{15} m

A is at a distance of 300×10^6 Ly

$= 300 \times 10^6 \times 9.6 \times 10^{15}$ $= \underline{2.88 \times 10^{24} \text{ m}}$

[1]

2863 June 2008

11 This question is about the expansion of the Universe and measurements of its age.

Distant galaxies are observed to show redshifts. The further away a galaxy is the greater the redshift that is observed.

(a) **(i)** State what is meant by the term 'redshift'.

An increase in the wavelength of radiation

(ii) Use the concept of the expansion of space to explain
- the redshift of light from distant galaxies
- why light from more distant galaxies shows greater redshift.

Cosmological red shift is due to the expanding space stretching the wavelength of radiation as it travels through the Universe. The more distant a galaxy the longer the journey takes so the greater the expansion of space and hence the lengthening of the wavelength.

[3]

2863 June 2008

(b) The Hubble Law states:

$v = H_0 d$ $\therefore$ $H_0 = v/d$

where v is the velocity of recession, d is the distance to the galaxy and H_0 is the Hubble constant.

Fig. 11.1 shows data for four galaxies.

distance/ m	velocity of recession / km s^{-1}	H_0 / s^{-1}
2.2×10^{24}	4000	1.8×10^{-18}
3.4×10^{24}	7500	2.21×10^{-18}
1.2×10^{24}	2600	2.17×10^{-18}
1.0×10^{24}	2200	2.20×10^{-18}

Fig. 11.1

Use the data to estimate a value for the Hubble constant H_0. Explain how you reached your value.

Mean value =

estimated value for H_0 = 2.1×10^{-18} s^{-1}

Reasoning: ↑

[3]

(c) $1/H_0$ gives an estimate of the time since all the galaxies were close together. This gives a lower limit on the age of the Universe.

(i) Use the value $H_0 = 2.2 \times 10^{-18}$ s^{-1} to estimate the time in years since the galaxies were close together.
1 year = 3.2×10^7 s.

$t = 1/H_0 = \frac{1}{2.2 \times 10^{-18}} / 3.2 \times 10^7 =$

time since galaxies were close together = 1.4×10^{10} years [2]

(ii) Suggest why this gives a **lower** limit for the age of the Universe.

Galaxies were not formed at the beginning of the Universe.

[1]

OR. The rate of expansion was lower in the past.

2863 June 2002

6 Distant galaxies are observed to be moving away (receding) from the Earth at high velocities.

(a) State the observation that indicates that distant galaxies are receding from the Earth.

red shift

[1]

(b) If the velocity of recession v of a distant galaxy is known, its distance from Earth can be determined using the relationship

$$v = H_0 d$$

where H_0 is the Hubble constant.

A galaxy, X, is at a distance of 4.5 x 10^{20} km and is observed to be receding at a velocity of about 1000 km s^{-1}.

Another galaxy, Y, is observed to recede at a velocity of about 800 km s^{-1}.

Calculate the distance to galaxy Y.

X $H_0 = v/d = \frac{1000 \text{ kms}^{-1}}{4.5 \times 10^{20} \text{ km}} = 2.22 \times 10^{-18} \text{ s}^{-1}$

Y $d = v/H_0 = 800 \text{ kms}^{-1} / 2.22 \times 10^{-18} \text{ s}^{-1} =$

distance to galaxy Y = 3.6×10^{20} km **[2]**

2863 Jan 2010 (also used in 2002)

3 Here is a list of astronomical phenomena:

A red shift of light from distant galaxies
B microwave background radiation
C stellar parallax
D black holes

From the list, choose the phenomenon that gives the clearest evidence that the Universe is expanding.

answer A **[1]**

2863 June 2010 (also used in 2003)

(d) Distant galaxies are observed to be receding (moving away) from the Earth at high velocities. The velocity of recession of a galaxy in deep space is calculated from its red-shift.

Explain the meaning of the term *red-shift*.

The increase in wavelength of radiation (toward the red end of the visible spectrum)

[1]

(e) The distance d to a galaxy can be determined from its velocity of recession v using the relationship

$$v = H_0 d$$

where H_0 is the Hubble constant.

A galaxy is observed to be receding at a velocity of $9.0 \times 10^5\, m\, s^{-1}$.

Calculate the distance to this galaxy.

$H_0 = 2.2 \times 10^{-18} s^{-1}$

$$d = \frac{v}{H_0} = \frac{9.0 \times 10^5}{2.2 \times 10^{-18}} =$$

distance = 4.1×10^{23} m **[2]**

(f) The value of H_0 given above is often given in the alternative form $H_0 = 70\, km\, s^{-1}\, Mpc^{-1}$.

One megaparsec (Mpc) is an astronomical unit of distance equal to 3.1×10^{22}m.

Show that the value $70\, km\, s^{-1}\, Mpc^{-1}$ is approximately equivalent to $2.2 \times 10^{-18}\, s^{-1}$.

$$70\, km\, s^{-1} Mpc^{-1} = \frac{70 \times 10^3}{3.1 \times 10^{22}} = 2.26 \times 10^{-18}\, s^{-1}$$

[2]

G494 Jan 2010

8 The Universe is believed to be expanding, starting from an original 'hot big bang'.

Put ticks in the boxes next to the **two** statements which provide support for this picture of the Universe.

Distant and close galaxies are very similar in shape and structure. ✗	☐
Microwave radiation from the Universe can be detected in all directions. ✓	☑
Massive stars explode as supernovae at a certain point in their lifecycle. ✗	☐
Much of the mass of the Universe does not appear to emit electromagnetic radiation. ✗	☐
The red-shift of lines in a galaxy's spectrum is proportional to its distance from our galaxy. ✓	☑

[2]

G494 Jan 2011

5 The Universe is believed to be expanding, starting from an original 'big bang'.

One piece of evidence for this is provided by the cosmological red-shift of galaxies.

(a) State what property of light is measured to determine the red-shift of a galaxy.

wavelength (of spectral lines)

[1]

(b) Explain how cosmological red-shift provides evidence for an original 'big bang'.

Cosmological red shift tells us the Universe is expanding according to Hubble's law. Going back in time the Universe gets smaller ultimatly being a single point* at the big bang.

[2]

* Well the observable universe would be shrunk down to a tiny scale.

A bit of revision of 13.1 Measuring the Solar System.

G494 June 2011

8 A satellite in orbit around Mars uses pulses of light to map the surface of the planet.

(a) The satellite emits a brief pulse of light towards the surface.
The satellite detects a reflected pulse after a time delay of 840 μs.

Calculate the distance *d* of the planet surface below the satellite.

$c = 3.0 \times 10^8 \, \text{m s}^{-1}$

$$d = \frac{vt}{2} = \frac{3 \times 10^8 \times 840 \times 10^{-6}}{2} =$$

d = 126,000 m **[1]**

(b) State an assumption you have made in your calculation in **(a)**.

The speed of light is the same in both directions. OR (It is not affected by Mars's atmosphere)

[1]

(c) Suggest how the satellite could use the pulses of light to check whether the altitude of its orbit was decreasing gradually.

Repeat the pulse measurement and see if the time gets shorter.

[1]

OR Look for doppler shift in returning pulse wavelength or frequency.

G494 Jan 2012

7 The rate of rotation of a distant spiral galaxy, like that shown in Fig. 7.1, can be found by comparing the light from the left and right hand side of the galaxy.

Fig. 7.1

(a) Explain why there will be a difference in the redshift of the light from the left and right hand sides of the galaxy.

The rotation of the galaxy means that one side is moving away faster than the other side. The red shift is larger for the side moving away faster.

[2]

(b) State what effect, if any, the motion of a distant galaxy relative to Earth has on the speed of light from it measured by observers on the Earth.

There will be no effect. (The speed of light is constant for all observers)

[1]

G494 June 2012

10 This question is about the Hubble law and the age of the Universe.

(a) The Hubble law can be expressed by the equation

$$v = H_0 r$$

where H_0 is the Hubble constant.

(i) What are the meanings of the terms v and r in the expression for the Hubble law?

v is the velocity of a distant galaxy

r is the distance to the distant galaxy **[2]**

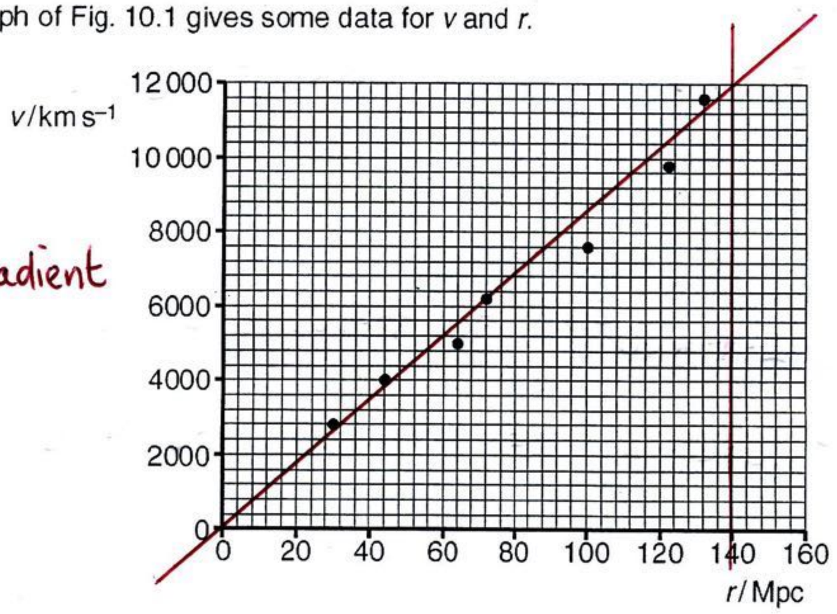
(ii) Show that the unit of the Hubble constant is s^{-1}.

$$H_0 = \frac{v}{r} = \frac{ms^{-1}}{m} = s^{-1}$$

[1]

(b) The graph of Fig. 10.1 gives some data for v and r.

$H_0 = \frac{v}{r}$ = gradient



Δv = 12000 kms^{-1}

Fig. 10.1

Δr = 140 Mpc

Use the graph to determine a value for the Hubble constant H_0.

1 MPc = 3.1×10^{22} m

$$H_0 = \frac{\Delta v}{\Delta r} = \frac{12000 \times 10^3\ ms^{-1}}{140 \times 3.1 \times 10^{22}\ m} =$$

H_0 = 2.8×10^{-18} s^{-1} **[4]**

(c) (i) Explain how the Hubble law $v = H_0 r$ supports the idea that the Universe started with a Big Bang.

Hubble's law suggests galaxies are moving apart in an expanding Universe. An expanding universe must have started will everything in the same place.

[2]

(ii) If the value of v for a particular galaxy has remained constant, explain why the value of $\frac{1}{H_0}$ gives an estimate of the age of the Universe.

If a galaxy has moved a distance r at a speed of v then the time taken is r/v since $v = r/t$. $H_0 = v/r$ so $1/H_0 = r/v$ = time taken = age of Universe [1]

(iii) Recent data from the Hubble telescope allows the value of H_0 to be determined as $2.40 \times 10^{-18}\,s^{-1}$. Use this value of H_0 to estimate the age of the Universe in years.

1 yr = 3.2×10^7 s

age = $1/2.4 \times 10^{-18}$ = 4.167×10^{17} s

$4.167 \times 10^{17} / 3.2 \times 10^7$ = age = 1.3×10^{10} yr [1]

G494 Jan 2013

2 Here are some observations about the Universe.

Put ticks (✓) in the boxes next to the **two** observations which provide evidence for a big bang at the start of the Universe.

Observation	
Some nearby galaxies emit blue-shifted light. ✗	☐
Microwave radiation is detected from all directions in space. ✓	☑
X-rays from galaxies imply the presence of black holes at their core. ✗	☐
The red-shift of light from most galaxies increases with increasing distance. ✓	☑
Most of the visible matter in the Universe appears to be clumped in galaxies. ✗	☐

[2]

G494 June 2014

8 The recessional velocity of a distant galaxy is measured to be $3.5 \times 10^3\,\text{km}\,\text{s}^{-1}$.

Use the age of the Universe (14×10^9 years) to estimate the distance from Earth to this galaxy. State the assumption you have to make.

1 year = 3.2×10^7 s

Age of universe = $14 \times 10^9 \times 3.2 \times 10^7 = 4.48 \times 10^{17}$ s

Assuming the recessional velocity is constant then

distance = velocity × time = $3.5 \times 10^3 \times 4.48 \times 10^{17}$

= 1.6×10^{21} km

distance = 1.6×10^{24} m **[3]**

OR Use age to calculate $H_0 = 1/\text{age} = 1/4.48 \times 10^{17}$

$= 2.23 \times 10^{-18}\ \text{s}^{-1}$

Then $d = v/H_0 = \dfrac{3.5 \times 10^6}{2.23 \times 10^{-18}} = 1.6 \times 10^{24}$ m

G494 June 2015

2 The Big Bang theory states that the Universe has been expanding ever since it first appeared.

State and explain **one** piece of evidence for this theory.

The cosmological red shift in the light from distant galaxies. due to expansion of space.

OR The cosmic microwave background radiation comming from all directions.

[2]

G494 June 2016

7 The idea that the Universe started with a big bang almost 14 billion years ago is now a widely accepted theory.
Explain how the red shift of distant galaxies provides evidence for this theory.

Cosmological red shift of radiation from distant galaxies tells us that the universe is expanding carrying galaxies further and further away from us. So in the past the galaxies must have been all at the same point.

[2]

G494 June 2017

4 Hydrogen atoms can emit ultraviolet light of wavelength 122 nm. A spectrum from a distant astronomical source shows that this light has been stretched to a wavelength of 420 nm.

(a) Calculate the factor by which the Universe has expanded since the light was emitted by the source.

factor $= \frac{420}{122} =$

factor = 3.44 **[1]**

(b) Explain why the cosmological redshift observed in light received from a source increases with the distance of the source from Earth.

The greater the distance the light has travelled the longer its journey takes. The longer the journey takes the more space will have expanded stretching the wavelength more. **[2]**

Specimen 557/01

35 Theory suggests that about 14×10^9 years ago the Universe was much smaller than it is now and that the temperature of the Universe was about 3000 K. Since that time, the Universe has expanded and cooled to a background temperature of about 2.8 K.

(a) State the observation that suggests that the Universe is continuing to expand.

Red shift of light from distant galaxies.

[1]

(b) The energy of photons released in the very early Universe has reduced by a factor of about 1000. Calculate the factor by which the wavelength of the photons has changed during this time.

$E = \frac{hc}{\lambda}$ $\therefore$ $\lambda = \frac{hc}{E}$ & $E \propto kT$

E and T has decreased by $3000/2.8 = 1070$ times

$\therefore$ λ has increased by 1070 times. **[2]**

36 This question considers some of the evidence for a Hot Big Bang start to our expanding universe.

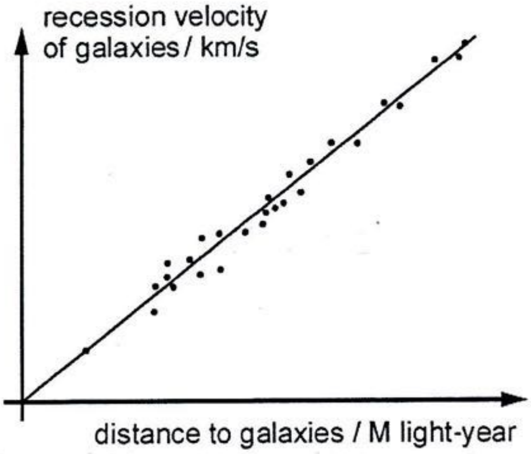


Fig. 36.1

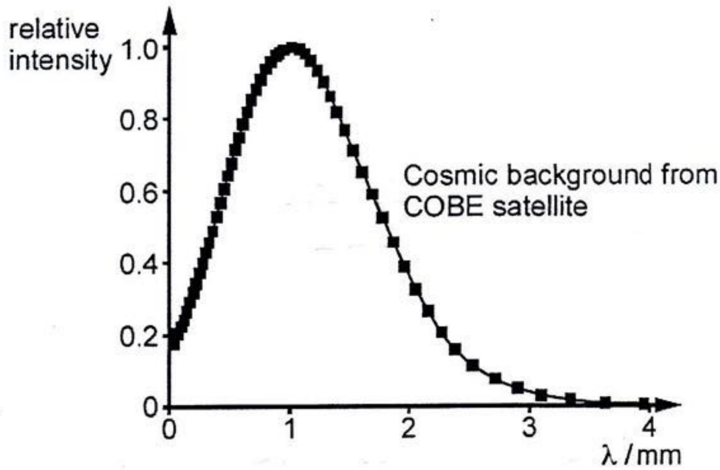


Fig. 36.2

(a) Explain how the graph(s) show evidence that the universe started from:

(i) a big bang expansion

Fig 36·1 shows recessional velocity is proportional to distance to a galaxy - Hubble's Law which implys an expanding Universe that started all in same place **[2]**

(ii) a hot state.

The cosmic microwave background has a wavelength of around 1 mm which has been cosmologically red shifted by an expanding and cooling universe. In the past the **[2]**
shorter wavelength indicates a much higher temperature.