

*1 Parallax measurements are used to determine the distance to nearby stars, but this method is unsuitable for more distant objects.

Outline how parallax measurements are used to determine the distance to nearby stars and explain how the use of a standard candle enables the distance to more distant objects to be determined.

(6)

(Total for Question = 6 marks)

2 In 1965, two American scientists, Penzias and Wilson, were testing a very sensitive microwave detector. They discovered that the detector was picking up microwave “noise” at a frequency of 160 GHz that appeared to come from all directions equally. Upon investigation they found that the “noise” was the same day and night, throughout the year.

Suggest how this microwave “noise” may show evidence for an expanding universe.

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(Total for Question 3 marks)

3 (a) Astronomers determine the distance to a nearby star using trigonometric parallax.

Describe the measurements that must be taken to determine this distance.

You may use a diagram to aid your description.

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*(b) Radiation received at the Earth from a distant galaxy is redshifted. The distance to the galaxy can be determined from this redshift.

State what is meant by redshift, and explain how it allows the distance to the galaxy to be determined.

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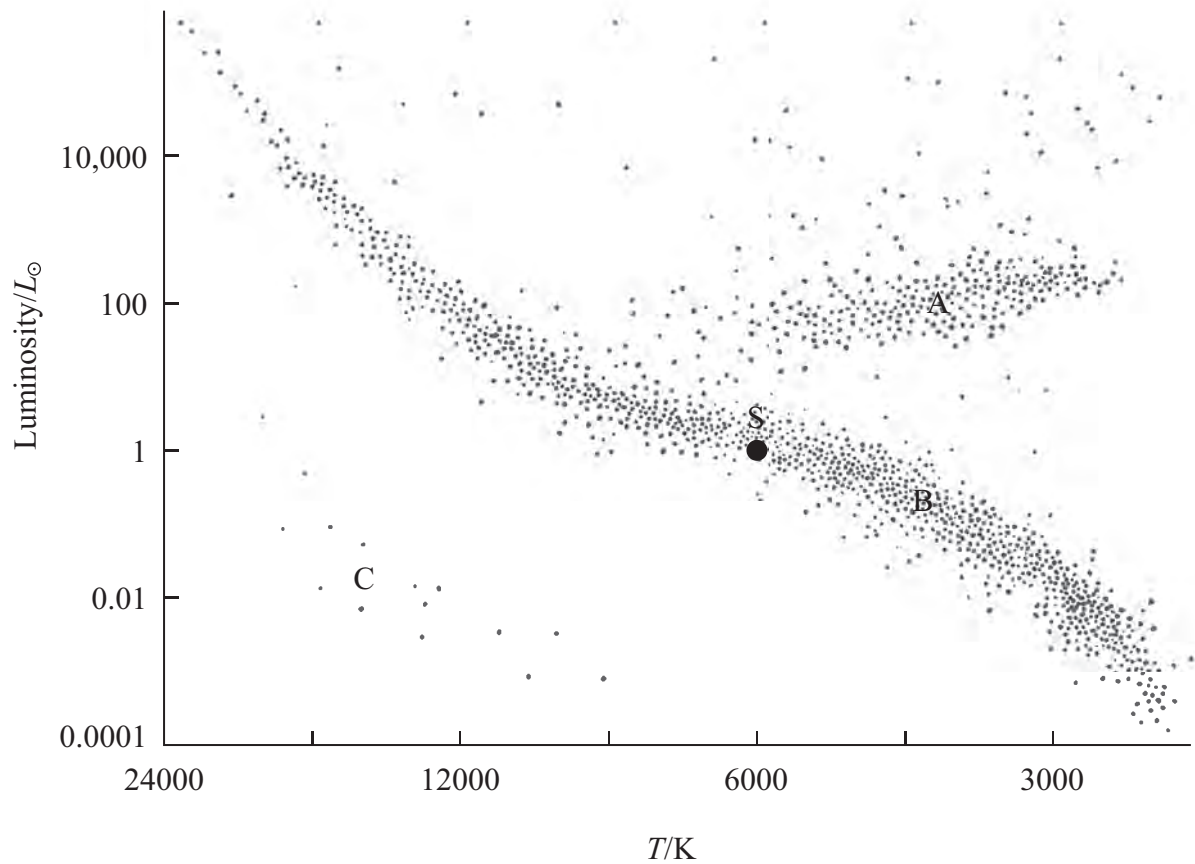
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4 (a) The position of our Sun, S is shown on the Hertzsprung-Russell (H-R) diagram below.



(i) Identify the three main regions of the H-R diagram. (3)

Region A

Region B

Region C

(ii) Add lines to the diagram to show the evolutionary path of our Sun from the time when it comes to the end of its hydrogen-burning phase. (2)

(b) Most stars are too far away from the Earth for astronomers to observe them as anything more than a point source of radiation.

Explain how astronomers calculate the sizes of these stars using information from the H-R diagram.

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(Total for Question 8 marks)

5 (a) State what astronomers mean by a standard candle.

(1)

(b) The luminosity of Sirius is 8.94×10^{27} W and its distance from the Earth is 8.08×10^{16} m.

Calculate the radiant energy flux of Sirius at the Earth.

(2)

Radiant energy flux =

(Total for Question = 3 marks)

- 6 Current theory predicts that there is a massive black hole at the centre of every galaxy. It is suggested that if galaxies approach, then their central black holes begin to orbit each other until the galaxies merge.

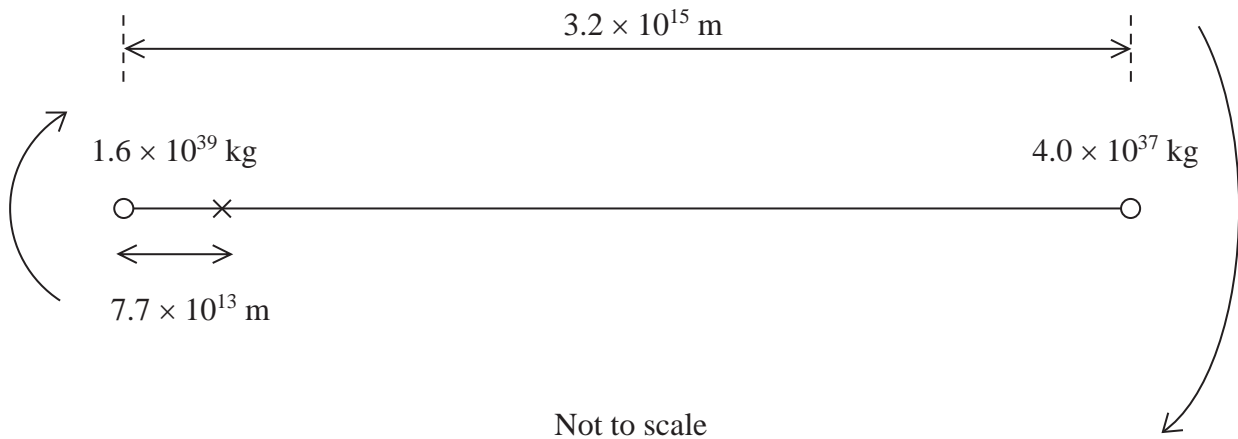


In 2009, astronomers found convincing evidence of two such black holes orbiting as a binary system. From data collected, they estimated that the separation of the black holes was 3.2×10^{15} m and that their masses were 1.6×10^{39} kg and 4.0×10^{37} kg.

(a) (i) State the origin of the force that maintains the black holes in an orbit. (1)

(ii) Show that the magnitude of this force is about 4×10^{35} N. (2)

- (iii) The black holes orbit about a point 7.7×10^{13} m from the larger mass black hole.



Show that the orbital time of the binary system is about 100 years.

(3)

- (b) As the black holes swallow up matter, radiation is emitted. To observers on Earth this radiation appears to be red shifted.

- * (i) State what red shift means and discuss the conclusions that can be drawn from the observation that radiation from all distant galaxies is red shifted.

(3)

- (ii) Suggest why the light from both black holes is red shifted, even though the black holes are orbiting each other and hence moving in opposite directions. (2)

- (iii) The observed red shift for the two black holes was 0.38.

Calculate the distance of the merging galaxies from the Earth.

$$H_0 = 1.6 \times 10^{-18} \text{ s}^{-1}$$

(3)

Distance from the Earth =

(Total for Question = 14 marks)

7 When nearby stars are observed over a period of a year, their positions are seen to move in tiny ellipses relative to the background of more distant stars.

(a) Explain why relative movement of these nearby stars is observed.

(3)

(b) By means of a labelled diagram, outline the steps necessary for this effect to be used to find the distance to nearby stars.

(3)

(c) The effect is too small for the distances to more distant stars to be determined. Outline a method which can be used for more distant stars.

(1)

(Total for Question = 7 marks)

*8 The Hubble Space Telescope (HST) was launched in 1990 into an orbit of radius 6940 km. The satellite makes 15 complete orbits of the Earth every 24 hours and its position high above the Earth's atmosphere has allowed high quality images of extremely distant objects to be produced.

(a) (i) Show that the HST has a centripetal acceleration of about 8 m s^{-2} .

(4)

(ii) The HST is kept in orbit by the gravitational pull of the Earth. Use your answer to (a)(i) to calculate a value for the mass of the Earth.

(3)

Mass =

(b) The telescope was named in honour of Edwin Hubble who measured the red shift of light from a number of galaxies and related it to their distance from the Earth.

Explain what is meant by the term *red shift* in this context and state the inference that Hubble made from his measurements.

(2)

(c) The song “Nine Million Bicycles” by Katie Melua includes the lines, “We are 12 billion light years from the edge, that’s a guess, no one can ever say it’s true”.

(i) Explain how the line “12 billion light years from the edge” implies an age of 12 billion years for the universe.

(2)

(ii) Calculate the value of the Hubble constant consistent with an age of 12 billion years for the universe.

$$1 \text{ billion years} = 3.15 \times 10^{16} \text{ s}$$

(2)

Hubble constant =

(iii) These lyrics were famously contested by Dr Simon Singh in the Guardian newspaper. He argued that the correct age was 13.7 billion years, and disputed that scientists had guessed the age of the universe. As a result Katie performed the song with revised lyrics.

Discuss the suggestion in the song that values for the age of the universe are only guesses.

(3)

(Total for Question = 16 marks)