



**DEPARTMENT OF PHYSICS AND ASTRONOMY**

**Autumn Semester 2010-11**

**2 hours**

**OUR EVOLVING UNIVERSE  
SECTIONS B AND C**

*Answer ALL questions in Section A (in separate booklet), THREE questions in Section B and ONE question in Section C. You should aim to spend about 45–50 minutes on Section A and 35 minutes on each of Sections B and C.*

*Questions in Section B are marked out of 5, and those in Section C out of 15. The breakdown on the right-hand side of the paper is meant as a guide to the marks that can be obtained from each part.*

**SECTION B**

**Answer THREE questions.**

**You should aim to spend about 35 minutes on this section.**

**B1** You observe a number of bright stars through a spectrometer. You find that:

- the star Naos has an absorption spectrum dominated by lines due to helium;
- the strongest lines in the spectrum of the Sun come from ionised calcium;
- the star Aldebaran has dark bands due to molecules of TiO.

**(i)** Can you conclude that Naos is made mostly of helium, whereas the Sun and Aldebaran are made mostly of heavy elements? If not, explain why. [2]

**(ii)** After correcting for their different distances, you find that both Naos and Aldebaran are much more luminous than the Sun. You conclude that Aldebaran cannot possibly be a main-sequence star, but you are not sure about Naos. Carefully explain the reasoning that leads to this conclusion. [3]

- B2** Popular books on astronomy often say that “the Sun is an average star.”
- (i)** Give two reasons why you might say that this statement is **true**. In each case, explain why you think the Sun is “average” with respect to this particular property. [2]
  - (ii)** Give two reasons why you might say that this statement is **false**. In each case, explain why you think that the Sun is *not* “average”. [2]
  - (iii)** When considering whether this statement is true or false, is it fair to compare the Sun to the stars you see (without a telescope) in the night sky? Briefly justify your answer. [1]
- B3** The main stellar components of the Milky Way Galaxy are the bulge, the disc, the spiral arms and the halo. Briefly describe the properties of the stars in each component. You should mention the age, the heavy element content and the motion of the stars. [4]
- What is the main evidence for the presence of a supermassive black hole in the centre of the Milky Way Galaxy? [1]
- B4** Our current picture of cosmology has been built up based on many different observations. For any *TWO* of the following, explain how they have contributed to our understanding of cosmology.
- (i)** the redshifts of galaxy spectra; [2½]
  - (ii)** the spectrum of the cosmic microwave background; [2½]
  - (iii)** the properties of Type Ia supernovae; [2½]
  - (iv)** the abundance of deuterium (hydrogen-2) and helium. [2½]
- B5** What do cosmologists mean by *inflation*? [1]
- Briefly explain *two* pieces of observational evidence that support the idea that inflation happened, indicating in each case why inflation is useful in explaining the observations. [4]

## SECTION C

Answer ONE question.

You should aim to spend about 35 minutes on this section.

**C1** The diagram on the right is the Hertzsprung-Russell diagram for nearby stars, as measured by the Hipparcos satellite.

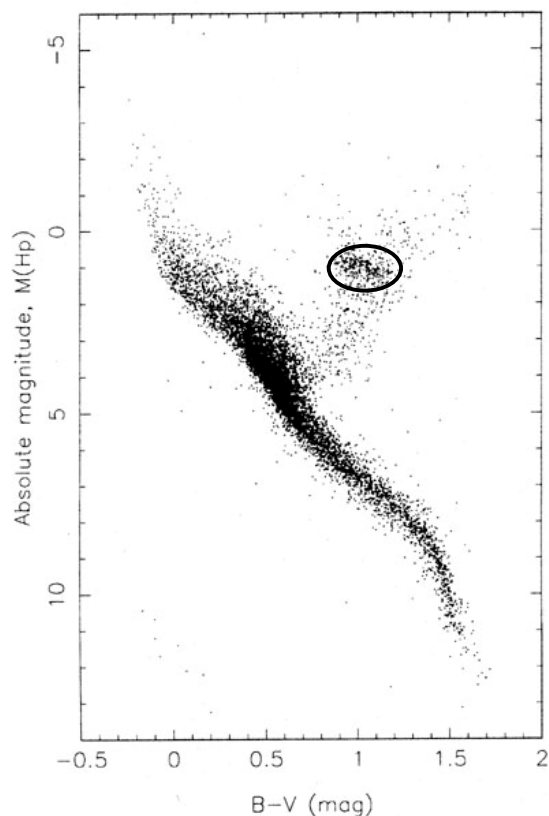
**(a)** Explain how Hipparcos measured the distances of the stars, illustrating your answer with an appropriate diagram. [2]

**(b)** Explain carefully how we know from looking at this diagram that the stars near the Sun are not all the same age. [4]

**(c)** The stars circled on the diagram are horizontal-branch stars. What do these stars tell us about the heavy element content of the stars near the Sun? Briefly explain your reasoning. [2]

**(d)** Do the stars shown in the diagram comprise a fair and representative sample of the stars in the neighbourhood of the Sun? Justify your answer. [2]

**(e)** Describe how a star of approximately the Sun's mass and heavy element content will evolve from the Sun's present age (halfway through its time on the main sequence) to the end of its life. Relate the stages in the star's evolution to its location on the Hertzsprung-Russell diagram. [5]



- C2(a)** Describe *three* methods by which astronomers can detect planets orbiting around other stars. For each method, indicate the types of planets it is most likely to detect. [6]
- (b)** Describe the properties of the extrasolar planets found so far. With reference to your answer to (a), briefly explain why these planets might *not* be typical extrasolar planets. [4]
- (c)** The Drake Equation is a method of estimating the number of technological civilisations currently existing in the Galaxy. It is given by

$$N = f_{\text{star}} f_{\text{planets}} n_{\text{Earth}} f_{\text{life}} f_{\text{int}} f_{\text{tech}} L,$$

where  $f_{\text{star}}$  is the rate of formation of suitable stars,  $f_{\text{planets}}$  is the fraction of such stars with planets,  $n_{\text{Earth}}$  is the number of Earth-like planets per system, and so on.

- (i)** Explain what the other four symbols,  $f_{\text{life}}$ ,  $f_{\text{int}}$ ,  $f_{\text{tech}}$ , and  $L$ , stand for. [2]
- (ii)** For any *three* of the seven factors on the right-hand side of the equation, briefly discuss how good an estimate we can make, and what the prospects are for improving the estimates over the next 20 years. [3]

**C3** Write essays on *THREE* of the following:

- (a)** the hunt for gravitational waves; [5]
- (b)** the lives of binary stars; [5]
- (c)** black holes; [5]
- (d)** the search for dark matter; [5]
- (e)** prospects for intelligent life on other planets. [5]

**END OF QUESTION PAPER**