The University Of Sheffield.

Department of Physics And Astronomy.

Autumn Semester 2006-7 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

B1 Briefly explain how you would go about determining

(a) the distance of a nearby star; [1]

(b) the surface temperature of a star; [1]

(c) the surface chemical composition of a star. [2]

Under what circumstances could you determine the star's mass? [1]

B2 The Sun is a class G (yellow) main sequence star. Vega is a class A (white) main sequence star, while Aldebaran is a class K (orange) giant star. Both Vega and Aldebaran are considerably more luminous than the Sun.

(a) Explain carefully how you know that Vega is younger than the Sun. [2]

(b) Explain how you know that Aldebaran is physically larger (i.e. has a greater radius) than the Sun. [1]

(c) Is Aldebaran (i) necessarily older than the Sun, (ii) necessarily younger than the Sun or (iii) either older or younger than the Sun – it is not possible to tell with only this information? Carefully explain your answer. [2]

B3 The table below shows the isotopes of indium, cadmium, silver, palladium and rhenium. Those marked ε decay by converting a proton to a neutron; those marked β decay by converting a neutron to a proton; those marked with a number are stable (the number is the percentage of the natural metal that is made of that isotope). Blank squares indicate nuclei so unstable they have never been seen.

Study this table and answer the questions below.

	number of neutrons														
	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67
$_{49}$In									ε	ε	ε	4.3	β	95.7	β
$_{48}$Cd				ε	ε	1.25	ε	0.89	ε	12.5	12.8	24.1	12.2	28.7	β
$_{47}$Ag				ε	ε	ε	ε	51.8	β	48.2	β	β	β		
$_{46}$Pd	ε	ε	ε	1.0	ε	11.0	22.2	27.3	β	26.7	β	11.8	β	β	
$_{45}$Rh	ε	ε	ε	ε	ε	100	β	β	β						

(a) Explain what is meant by the term *s-process*. Which **stable** isotopes of **palladium** ($_{46}$Pd) are made by the s-process? [Specify the isotopes by their number of neutrons.] [2]

(b) What is meant by the term *r-process*? Write down (i) a stable isotope of **palladium** which *must* be made by the r-process and (ii) a stable isotope of **cadmium** ($_{48}$Cd) which *cannot* be made by the r-process. [2]

(c) Name one stable isotope shown on the table which cannot be made by either the s-process or the r-process, and name the process by which it is made. [Specify the isotope you name by its chemical symbol and the number of neutrons.] [1]

B4 Explain the significance of any TWO of the following observations in the context of modern cosmology:

(a) the fact that the sky is dark at night; [2.5]

(b) the redshifts of galaxy spectra; [2.5]

(c) the properties of the cosmic microwave background; [2.5]

(d) the brightness of distant supernovae. [2.5]

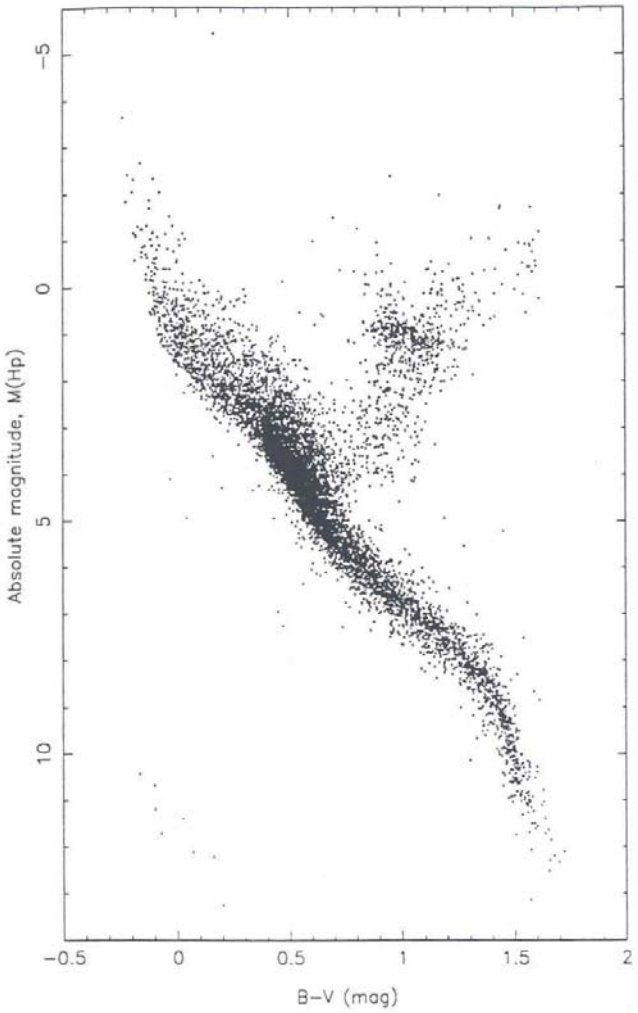
B5 Most of the planets discovered around other stars have been detected using the spectroscopic (Doppler shift) method.

(a) Explain how this method works, and what kind of planetary systems it is most likely to detect. [2.5]

(b) Briefly describe the properties of the detected extrasolar planets. With reference to your answer to part (a), discuss how these properties are likely to be biased by the detection method used. [2.5]

SECTION C
Answer *one* question

C1 The picture below shows the Hertzsprung-Russell diagram for those nearby stars whose parallaxes were accurately measured by the HIPPARCOS satellite.



(Note that the Sun has absolute magnitude 4.8 and colour index $B - V = 0.65$.)

(a) The vast majority of the stars in the diagram are on the main sequence. Explain what defines a main sequence star, in terms of its energy generation mechanism, and why we should expect most stars to be on the main sequence. [2]

(b) Carefully explain what features of the diagram show that the stars included are not all of the same age, and, in particular, that they include stars which are much younger than the Sun. [3]

(c) What are the stars at the bottom left of the diagram, and what can you tell about them purely from their position on the diagram? [2]

(d) Bearing in mind that HIPPARCOS had a relatively small telescope, do you expect this diagram to be a fair sample of the stars in the solar neighbourhood? If not, explain which stars will be undercounted, and why. [2]

(e) Describe the evolution of a star of approximately 2 solar masses, from its arrival on the main sequence to the end of fusion processes, including an account of the remnant left after fusion stops. Include a sketch of its trajectory on the HR diagram, and where possible relate your description to the features of the HIPPARCOS HR diagram shown above. [6]

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C2 (a) Describe, with appropriate diagrams, the Hubble tuning fork system for the classification of galaxies. [6]

(b) The Milky Way is a typical large spiral galaxy. Explain:

(i) how you can deduce simply from observations of the night sky (at a suitably dark site) that the Milky Way is a disc galaxy and that the Sun is located fairly close to the plane of the disc; [3]

(ii) why we think that the mass of the Milky Way is dominated by dark matter, rather than by stars; [3]

(iii) the evidence for the presence of a supermassive black hole at the centre of the Milky Way galaxy. [3]

C3 Write essays on *THREE* of the following:

(a) binary stars [5]

(b) neutrinos in astrophysics [5]

(c) the search for dark matter [5]

(d) prospects for extraterrestrial intelligence [5]