The Handbook of Mathematics, Physics and Astronomy Data is provided

KEELE UNIVERSITY

EXAMINATIONS, 2010/11

Level III

Wednesday 27th April 2011, 16.00-18.00

PHYSICS/ASTROPHYSICS

PHY-30025

LIFE IN THE UNIVERSE

Candidates should attempt to answer THREE questions.

NOT TO BE REMOVED FROM THE EXAMINATION HALL

1. (a) Give three reasons why it is not surprising that the elem carbon forms the basis for life on Earth. [15]

(b) Give three different functions of carbon-based molecules in our bodies. [15]

(c) State the physical origin of the carbon atoms in our bodies.[10]

(d) Describe the mechanisms through which carbon atoms made it from their place of formation into our bodies. [40]

(e) Give two different essential roles that liquid water plays in the functioning of life on Earth. [20]

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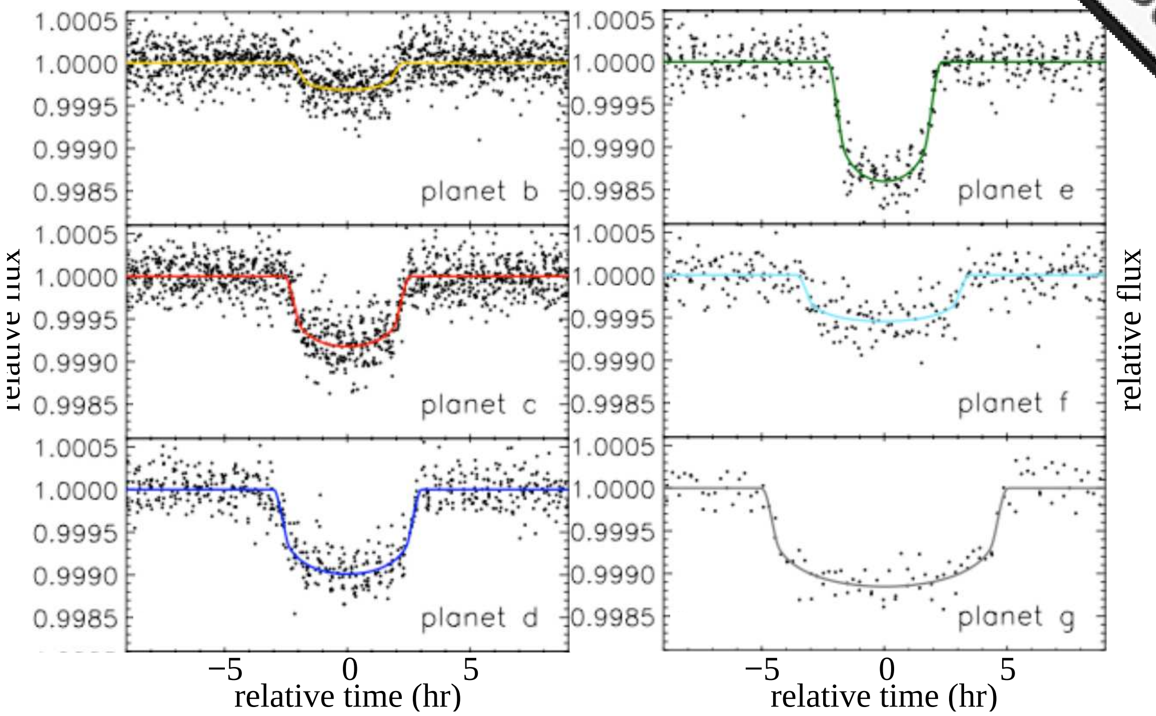

Figure 1: Brightness measurements of Kepler 11, for use in question 2.

2. Star Kepler 11 has a radius $R_\star = 1.1\ \mathrm{R}_\odot$ and a mass $M_\star = 0.95\ \mathrm{M}_\odot$.

   (a) Use Fig. 1 to place the six planets in a schematic diagram of size versus distance to Kepler 11. [20]

   (b) Use Fig. 1 to determine the size of planet g in Earth radii. [30]

   (c) Show that the relation between the transit duration, Δt, and distance between planet and star, d, can be approximated by

   $$\frac{\Delta t}{P} = \frac{R_\star}{\pi d},$$

   where P is the orbital period, provided that $d \gg R_\star$. [20]

   (d) Using Fig. 1, the relation in question 2c and Kepler's Third Law,

   $$\frac{P}{2\pi} = \sqrt{\frac{d^3}{GM_\star}},$$

   determine the distance of planet g to the star and compare this with the distance between Earth and the Sun. [30]

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3. (a) Explain what is meant by the term "Habitable Zone" aroun star, and give a practical definition for its limits. [20]

(b) Derive the formula for the temperature T of a planet with Bond albedo a, orbiting a star with luminosity $L_\star$ at a distance d:

$$T \;=\; \left(\frac{(1-a)L_\star}{16\pi\sigma\, d^2}\right)^{\frac{1}{4}} . \qquad [30]$$

(c) Consider a planet with mass $M = 6 \times 10^{24}$ kg, radius $R = 6.4 \times 10^6$ m and Bond albedo $a = 0.3$, which orbits a star with luminosity $L_\star = 3.8 \times 10^{26}$ W at a distance $d = 1.5 \times 10^{11}$ m.

(i) Calculate the temperature of this planet and comment on its location with respect to the Habitable Zone around this star. [10]

(ii) Comment on the likelihood that this planet sustains a dense atmosphere, and support this with a simple calculation.[20]

(iii) For the case that this planet *does* have a dense atmosphere, comment on the likelihood that the surface conditions on this planet are suitable to life. [10]

(iv) For the case that this planet does *not* have any atmosphere, comment on the likelihood that the sub-surface conditions on this planet are suitable to life. [10]

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4. (a) Describe an experiment, and explain the methods underlying that uses Earthshine to determine Earth's albedo as a function of wavelength. [20]

(b) Describe two different experimental ways in which the spectrum of a planet may be obtained, and describe also under which conditions each is most likely to succeed. [40]

(c) Explain two different ways in which the measurement of the spectrum of a planet may provide supporting evidence for the possible presence of a biosphere on that planet. [20]

(d) Discuss under which conditions the detection of ozone in a planet's atmosphere may provide supporting evidence for the presence of a biosphere on that planet, and also comment on the possibility of a biosphere in the *absence* of ozone. [20]

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5. (a) Explain the fundamental physical principle behind propuls of a rocket. [10]

(b) Describe two different ways in which the design of a rocket or choice of its fuel increases the final velocity of the rocket. [20]

(c) Explain two different ways in which the timing and direction of the launch of a rocket from Earth may enhance the velocity with which it leaves the Solar System. [20]

(d) Consider a rocket launched from Earth around sunset, quickly reaching a velocity of $v \sim 40$ km s^{-1}. The engine is then switched off. Not much later, it starts falling towards the Sun, narrowly missing it at a shortest proximity of $d_0 = 10^6$ km to the centre of the Sun.

(i) Neglecting its initial potential and kinetic energy at the time the engine was switched off, calculate the velocity of the rocket at the closest proximity to the Sun. [20]

(ii) The rocket subsequently moves way from the Sun.

Calculate the velocity of the rocket at a distance $d \gg d_0$.[10]

(iii) Now consider the case in which, at the time of closest proximity to the Sun, the rocket expels half its mass in a direction opposite to its flight path at a relative velocity of $\Delta v = 1$ km s^{-1}.

Calculate the velocity of the rocket at a distance $d \gg d_0$, and comment on the difference with respect to the case in which no additional boost was applied at the time of closest proximity to the Sun. [20]