1

Question			Answers	Marks	Guidance
	(a)		The universe is homogeneous. and isotropic (on a large scale).	B1 B1	
	(b)		The intensity of the microwaves is the same in all directions.	B1	**Allow** the microwave (background radiation) is isotropic.
			These microwaves correspond to a temperature of 2.7 K or The temperature of the universe is 2.7 K.	B1	**Allow** 3 K
			The expansion of the universe following the big bang led to cooling and hence we observe microwaves rather than short wavelength e.m. waves / gamma waves.	B1	**Allow** - The short e.m. / gamma waves during the early stages of the universe have been 'stretched out' / 'red-shifted' to microwaves by the expansion.

2)

Question			Answer	Marks	Guidance
	(a)		The night sky should be bright / have uniform brightness (but it is not) The line of sight ends on (the surface of a star) or 'number of stars $\propto r^2$ and intensity $\propto 1/r^2$' Any two assumptions about the Universe: Infinite / uniformly distributed matter or stars throughout / static / infinite age	B1 B1 B1	
	(b)		(recessional) speed of galaxy $\propto$ its distance (from the Earth) The universe is finite / it is expanding / it has a beginning / visible light is red-shifted (because of expansion of space) (AW)	B1 B1	**Allow**: $v = H_0 x$, v = (recessional) speed of galaxy, x = distance and H_0 is Hubble constant / a constant
	(c)	(i)	$v = H_0 x$ $3.4\times10^{7} = H_0 \times 1.4\times10^{25}$ $H_0 = 2.4 \times 10^{-18}$ unit: s^{-1}	 C1 A1 B1	 **Note**: This is an independent mark **Note**: Allow full credit for an Hubble constant of 75 with unit km s^{-1} Mpc^{-1}
		(ii)1	age = $\frac{1}{2.4\times10^{-18}}$ age = 4.17×10^{17} (s) age = 1.3×10^{10} (years)	C1 A1	Possible ecf from **(i)**
		(ii)2	distance = $4.17 \times 10^{17} \times 3.0 \times 10^{8}$ (= 1.25×10^{26} m) distance = $\frac{4.17\times10^{17}\times3.0\times10^{8}}{3.1\times10^{16}}$ distance = 4.0×10^{9} (pc)	C1 A1	 Possible ecf from **(ii)1**
			Total	**12**	

3)

Question			Answer	Marks	Guidance
	(a)		A core / 'star' left behind after a red giant (has shed its outer layers)	B1	**Allow**: It is the core of a red giant **Allow**: It is the remnant of a low-mass star **Allow**: A core / 'star' • supported by Fermi pressure / electron degeneracy (pressure) • with maximum mass of 1.4(4) solar masses / 1.4(4) $M_\odot$ / Chandrasekhar limit **Not**: It is a collapsing red giant
	(b)		(parallax = $1/d$) $d = 0.0059^{-1}$ (pc = 169 .49 .... pc) distance = $0.0059^{-1} \times 3.26$ distance = 550 ly	 C1 A1	 **Allow** other correct methods
	(c)	(i)	power per (unit) area or power/area	B1	**Allow** 'energy per (unit) area per unit time' **Not**: power per m^2
		(ii)	**1** (density = mass/ $\frac{4}{3}\pi r^3 \propto$ mass/r^3) ratio = $\frac{12}{(1.1\times10^5)^3}$ ratio = 9.0×10^{-15} **2** (power = intensity × surface area) power $\propto T^4 r^2$ ratio = $\frac{4300^4 \times (1.1\times10^5)^2}{25000^4}$ ratio = 1.1×10^7	 C1 A1 C1 C1 A1	 **Allow**: 9.0×10^{-15} : 1 **Allow**: 1 sf answer of 9×10^{-15} **Note**: Answer to 3 sf is 1.06×10^7 **Allow**: 1.1×10^7 : 1
			Total	**9**	

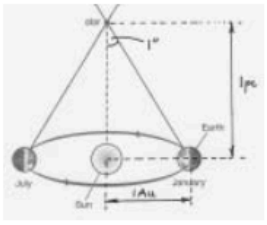
4)

Question			Answer	Marks	Guidance
	(a)		recessional speed / velocity of galaxy is proportional to its distance (from us)	B1	**Allow**: recessional speed of galaxy = Hubble constant × distance
	(b)	(i)	v = 1010 (10^3 m s^{-1}) d in the range 4.47 to 4.54 (10^{23} m)	B1 B1	**Note**: Answer to 4 sf is 1014 (10^3 m s^{-1})
		(ii)	(Straight line drawn through the points gradient = Hubble constant, H_0) gradient = 2.24×10^{-18} (s^{-1}) age = $(2.24 \times 10^{-18})^{-1}$ age = 4.46×10^{17} (s) age = 1.4×10^{10} (y)	 C1 C1 A1	 **Allow**: gradient in the range 2.21 to 2.27 × 10^{-18} **Allow** ecf from incorrect value of the gradient **Allow**: A maximum of 2 marks if values from the table are used instead of the gradient of the line drawn on Fig. 11.2 **Note**: No marks for a bald 14 billion years
	(c)		Big bang: Creation / birth / expansion / evolution of the universe or The universe was very hot / very dense / singularity (at the start) Evidence: Any two from: • Microwave / background radiation / 3 K (or 2.7 K) • Existence of (primordial) helium / lithium / lighter elements • Tiny variation (or ripples) in (background) temperature	B1 B1 × 2	 **Not**: More matter than antimatter / baryonic asymmetry
			Total	**9**	

5)

Question			Answers	Marks	Guidance
	(a)		$V = \frac{4}{3}\pi \times (6\times10^3)^3$ or $V = 9.05 \times 10^{11}$ (m^3) density = $\frac{2.0\times10^{30}}{\frac{4}{3}\pi\times(6\times10^3)^3}$ density = 2.2×10^{18} kg m^{-3}	C1 C1 A1	**Note**: An incorrect equation here for V prevents this and any subsequent marks. The correct unit must also be included to score this A1 mark. **Allow** 2 marks for 2.76.... $\times 10^{17}$ kg m^{-3} – 12 km used instead of 6 km for the radius.
	(b)		$g \propto 1/r^2$ ratio = $\left(\frac{1.4\times10^9}{12\times10^3}\right)^2$ or ratio = $\left(\frac{0.7\times10^9}{6\times10^3}\right)^2$ ratio = 1.4×10^{10}	C1 A1	**Note**: The answer to 3 sf is 1.36×10^{10}. **Allow** 1 mark for 7.3×10^{-11} – inverse of the ratio.
	(c)		($p = 1/d$) $d = \frac{8.6\times9.5\times10^{15}}{3.1\times10^{16}}$ (pc) or $d = 2.64$ (pc) $p = 0.38$ (arc seconds)	C1 A1	**Allow** full credit for alternative methods.
	(d)		$(\frac{\Delta\lambda}{\lambda} = \frac{v}{c})$ fractional change = $\frac{7600}{3.0\times10^8}$ percentage change = 2.5×10^{-3} %	C1 A1	**Allow** 1 mark for 2.5×10^{-5} (factor of 100 missed out).
	(e)		The suggestion is incorrect because Hubble's law applies to (distant receding) galaxies. or The suggestion is incorrect because Hubble's law does not apply to stars in our own galaxy.	B1	Do **not** allow this mark if 'Sirius / star is moving towards us' is also included.
			Total	**10**	

6)

Question			Answer	Marks	Guidance
	(a)		(distance =) $3.0 \times 10^8 \times 3.16 \times 10^7$ distance = 9.48×10^{15} (m) $\approx 9.5 \times 10^{15}$ (m)	B1	**Allow**: (distance =) $3.0 \times 10^8 \times 365(¼) \times 24 \times 3600$ **Allow** 1 mark for bald 9.48×10^{15} (m)
	(b)		Correct labelling of 1 pc, 1 AU and 1" 	B1	**Allow**: 'hypotenuse' labelled as 1 pc
	(c)	(i)	(distance =) $9.5 \times 10^{15} \times 2.1 \times 10^7$ (m) or 2.0×10^{23} (m) (distance in pc =) $2.0 \times 10^{23}/3.1 \times 10^{16}$ distance = 6.4×10^6 (pc)	C1 A1	Possible ecf from **(a)**
		(ii)	(time =) $10^{44}/4 \times 10^{26}$ (s) or 2.5×10^{17} (s) (time =) $2.5 \times 10^{17}/3.16 \times 10^7$ time = 7.9×10^9 years	C1 A1	**Allow**: 1 sf answer of 8×10^9 years
	(d)		Any one from: • Very dense / infinite density / very small / singularity Any one from: • (Very strong gravitational field therefore) light cannot escape from it / curves space / slows down time / emits Hawking radiation	B1 B1	
			Total	**8**	

7)

Question			Answer	Marks	Guidance
	(a)	(i)	H_0 = 1/age H_0 = 1/(13.7 × 10^9 × 3.16 × 10^7) (H_0 =) 2.31 × 10^{-18} (s^{-1}) (H_0 =) $\frac{2.31\times10^{-18}\times3.09\times10^{16}\times10^{6}}{10^{3}}$ Hubble constant = 71.4 (km s^{-1} Mpc^{-1})	C1 C1 A1	**Allow:** 2 sf answer **Special case**: Using H_0 = 1/13.7 × 10^9 = 7.30 × 10^{-11} (y^{-1}) gives an answer of 2.26 × 10^9 (km s^{-1} Mpc^{-1}) – allow 1 mark
		(ii)	$v = H_0$ d (v =) 71.4 × 50 or 3.57 × 10^3 (km s^{-1}) or 3.57 × 10^6 (m s^{-1}) $\frac{\Delta\lambda}{\lambda}=\frac{3.57\times10^{6}}{3.0\times10^{8}}(=1.19\times10^{-2})$ $\Delta\lambda$ = 656 × 1.19 × 10^{-2} or $\Delta\lambda$ = 7.80 (nm) wavelength = 656 + 7.80 wavelength = 664 (nm)	C1 C1 C1 A1	Possible ecf from **(a)** **Allow**: 2sf answer
	(b)		Big bang: Creation of the universe (from which space/time evolved) (AW) Any three from: 1. (At the start) the universe was hot / infinitely dense 2. Expansion of the universe led to cooling 3. The (current) temperature of universe is 2.7 K / 3 K 4. (The universe as a black body) is associated with microwaves at this temperature (AW) or The (wavelength of the) gamma radiation stretched to microwaves (by the expansion). QWC: (Cosmological principle is supported because) MBR is isotropic	B1 B1 × 3 B1	 **Not**: The universe now has microwaves. (The microwaves must be linked with current temperature) **Allow**: Microwaves have the same intensity in all directions

Question			Answer	Marks	Guidance
	(c)		(For an open / flat universe) Further expansion will lead to cooling / temperature lower than 3K / temperature tend to absolute zero (AW) The wavelength (of the EM radiation) gets longer / frequency (of the EM radiation) gets smaller / energy of photons decreases / microwaves become radio waves	 B1 B1	 **Alternative**: Temperature (will eventually) increases if closed universe B1 The wavelength (of EM radiation) get smaller B1
	(d)		Graph starting from origin and having a shape consistent with either open or accelerated universe	B1	**Not** a straight line
			Total	**15**	

8)

Question			Expected Answer	Mark	Additional Guidance
	(a)		Diagram showing (star,) 1 AU, 1 pc and angle of 1 arc second Distance from a base length of 1 AU that subtends an angle of 1 (arc) second or Parsec is a distance that gives a (stellar) parallax of 1 second (of arc) / 1/3600°	B1 B1	 **Allow**: 1 pc is the distance calculated using: 1 AU/tan(1/3600°) **Not**: 1 pc = 3.26 ly **Not**: 1 pc = 3.1 ×10^{16} m
	(b)	(i)	distance (pc) = 1 / 0.275 distance = 3.64 (pc)	 B1	
		(ii)	distance in m = 3.1 × 10^{16} × 3.64 = 1.127 × 10^{17} (m) distance in ly = 1.127 × 10^{17}/9.5 × 10^{15} distance in ly = 11.9	C1 A1	Possible ecf from **(b)(i)** **Alternative**: 1 pc = 3.26 ly C1 distance = 3.26 × 3.64 distance 11.9 (y) A1
			Total	5	

9)

Question			Expected Answer	Mark	Additional Guidance
	(a)		The speed of recession of a galaxy is proportional to its distance (from Earth / observer)	B1	
	(b)	(i)	$v = \frac{\Delta\lambda}{\lambda} \times c$ $v = 0.15 \times 3.0 \times 10^8$ speed = 4.5×10^7 (m s^{-1})	M1 A0	**Allow**: '15% of $3.0 \times 10^8 = 4.5 \times 10^7$ (m s^{-1})' **Not**: '0.15c'
		(ii)	distance = v / H_0 (Any subject) distance = $\frac{4.5\times10^7 \times 3.1\times10^{22}}{65\times10^3}$ distance = 2.15×10^{25} (m)	C1 A1	 Possible ecf from **(b)(i)** **Allow**: 1 mark for 2.15×10^n, $n \neq 25$
		(iii)	$H_0 = \frac{65\times10^3}{3.1\times10^{22}}$ (= 2.10×10^{-18} s^{-1}) age = $1/H_0 = 4.77 \times 10^{17}$ (s) age = 1.49×10^{10} (y)	C1 A1	 **Allow**: 1 mark for 1.49×10^n, $n \neq 10$
	(c)		Any two from: 1. Spectra from galaxies show shift to longer wavelengths (suggests galaxies are moving away from the Earth) 2. The more distant galaxies are moving faster (than the ones closer to our galaxy) 3. Existence of microwave background radiation (which is the same in all directions) / The temperature of universe is 3 K (after cooling due to expansion) / gamma (radiation) became microwaves (as the universe expanded) 4. Existence of primordial helium (produced in the early stages of the universe) 5. Temperature fluctuations (predicted and observed)	B1 × 2	**Not** 'red-shift' for 1. **Allow**: Reference to CMB (radiation) in 3. **Not** bald 'ripples' for 5.
			Total	8	

10)

Question			Expected Answer	Mark	Additional Guidance
	(a)	(i)	Any five from: 1. Gas / dust (cloud) drawn together by gravitational forces 2. Loss in (gravitational) PE / KE increases / PE changes KE / temperature increase 3. Fusion of protons / hydrogen nuclei (produces helium nuclei and energy) 4. A stable star is formed when radiation pressure is equal to gravitational pressure 5. When hydrogen runs out the outer layers of the star expands / core shrinks 6. Red giant formed / eventually (the core becomes) a white dwarf QWC mark for '*correct sequencing of the processes from birth to death*'	B1 × 5 B1	 **Allow**: 'Gravitational collapse of dust cloud'
		(ii)	Supernova followed by neutron star / black hole	B1 B1	
	(b)		$\Delta E = \Delta m c^2$ energy = $2.0\times10^{30} \times 10^{-6} \times (3.0\times10^8)^2$ or $1.8(0) \times 10^{41}$ (J) time = $1.80 \times 10^{41}/3.8 \times 10^{26}$ (= 4.74×10^{14} s) time = $4.74 \times 10^{14}/3.2 \times 10^7$ time = 1.5×10^7 (y)	 C1 C1 A1	**Alternative**: rate = 4.22×10^9 (kg s^{-1}) C1 time = $2.0 \times 10^{24}/4.22 \times 10^9$ (= 4.74×10^{14} s) C1 time = 1.5×10^7 (y) A1

Question			Expected Answer	Mark	Additional Guidance
	(c)	(i)	Any four from: 1. Protons / hydrogen nuclei to produce He nuclei (positrons and neutrinos) 2. There is electrostatic repulsion (between the protons) / The protons repel (each other because of their positive charge) 3. High temperatures / 10^7 K needed (for fusion) 4. (At high temperatures some of the fast moving) protons come close enough to each other for the strong (nuclear) force (to overcome the electrostatic repulsion) 5. High density / pressure (in the core of the Sun) 6. There is a decrease in mass, hence energy is released / products have greater binding energy	B1 × 4	**Not**: 'heat' in place of temperature in 3.
		(ii)	Kinetic (energy) Electromagnetic / photons	B1 B1	**Not**: heat / thermal (energy) **Not**: 'radiation' / 'wave energy'' **Allow**: Gamma
		(iii)	BE = 4 × 7.2 = 28.8 (MeV) BE = 28.8 × 1.6 × 10^{-13} BE = 4.6 × 10^{-12} (J)	C1 A1	Possible ecf if BE value is incorrect
			Total	19	

11)

Question			Answers	Marks	Guidance
	(a)		Any four from: 1. (Sun / star formed from) dust cloud /nebula / (hydrogen) gas 2. Gravitational collapse (AW) 3. Temperature of (dust) cloud increases / KE (of cloud) increases / (cloud) heats up 4. Fusion occurs (when temperature is about 10^7 K) 5. Protons / hydrogen nuclei combine to make helium (nuclei) 6. Stable size star is produced when thermal / radiation pressure is equal to gravitational pressure Steps sequenced correctly – **QWC mark**	B1× 4 B1	**Must use ticks on Scoris to show where the marks are awarded**
	(b)		Any two from: 1. Very dense star 2. Hot star / high surface temperature / low luminosity 3. No fusion reactions take place / leaks away photons (from earlier fusion reactions) 4. Its collapse is prevented by Fermi pressure / mass less than 1.4 solar masses (AW)	B1×2	**Must use ticks on Scoris to show where the marks are awarded** **Not**: small in size, but allow 'smaller than main sequence star / Sun'
	(c)	(i)	Flat or universe will expand towards a (finite) limit or the rate of expansion will become/tend to zero	B1	
		(ii)	Hubble constant = 1/age $H_0 = 1/4.4\times10^{17}$ ($= 2.273\times10^{-18}$ s^{-1}) density = $\frac{3H_0^2}{8\pi G}$ density = $\frac{3H_0^2}{8\pi G} = \frac{3\times(2.273\times10^{-18})^2}{8\pi\times6.67\times10^{-11}}$ density = 9.2 × 10^{-27} (kg m^{-3}) or 9.24 × 10^{-27} (kg m^{-3}) density is about 10^{-26} (kg m^{-3})	C1 C1 A1 A0	**Allow**: 2 marks for a bald 9.24 × 10^{-27} (kg m^{-3}) answer **Note**: This mark can only be scored if working is shown

Question			Answers	Marks	Guidance
		(iii)	number = 9.24 × 10^{-27}/1.7 × 10^{-27} number = 5.4 (Allow 5)	C1 A1	Possible ecf from **(c)(ii)** **Allow**: 2 marks for '10^{-26}/1.7 × 10^{-27} = 5.9 or 6'
	(d)		$\frac{1}{2}mv^2 = \frac{3}{2}kT$ / speed $\propto \sqrt{T}$ ratio = $\sqrt{\frac{10^8}{2.7}}$ ratio = 6.1 × 10^3 or 6.09 × 10^3	C1 A1	
			Total	**15**	

12)

Question			Answer	Marks	Guidance
	(a)		Any four from: 1. (Fusion is the) joining / fusing together of ('lighter') nuclei / protons (to make 'heavier' nuclei) 2. Mass decreases in the reaction and this is transformed into energy OR the products have greater binding energy 3. High temperatures / ~10^7 K needed for fusion 4. High pressure / density (required in the core) 5. The protons / nuclei repel (each other because of their positive charge) 6. The strong (nuclear) force comes into play when the protons / nuclei are close to each other	B1×4	**Not**: Atoms / particles for nuclei /protons.
	(b)		(When hydrogen / helium runs out) the outer layers of the star expands / a (super) red giant is formed The core (of the star) collapses (rapidly) / a supernova is formed (Depending on the initial mass of the star the remnant is either a) neutron star or a black hole	B1 B1 B1	
			Total	**7**	

13)

Question			Answer	Marks	Guidance
	(a)		$F = \frac{GMm}{r^2}$ force = $\frac{6.67\times10^{-11}\times(10^{41})^2}{(4\times10^{22})^2}$ force = 4.2×10^{26} (N)	C1 C1 A1	**Allow**: 4×10^{26} (N) or 10^{26} since this is an estimation **Allow**: 2 marks for 4.2×10^{n}; $n \neq 26$ (POT error)
	(b)		Allow any one from: • The galaxies are receding / moving away from each other (because of the big bang) • Other galaxies may be pulling them in opposite direction • The acceleration is too small to collapse (other than over a very long period of time)	B1	
	(c)		Any six from: 1. (At the start it was) very hot / extremely dense / singularity 2. All forces were unified 3. Expansion led to cooling 4. Quarks / leptons (soup) 5. More matter than antimatter 6. Quarks combine to form hadrons / protons / neutrons 7. Imbalance of neutrons and protons / (primordial) helium produced 8. Atoms formed 9. Idea of gravitational force responsible for formation of stars / galaxies 10. Temperature becomes 2.7 K / 3 K or (the universe is saturated with cosmic) microwave background radiation	B1×6	**Show annotation on Scoris**
	(d)	(i)	Dark lines / bands against a background of continuous spectrum	M1 A1	

14)

Question			Expected Answers	Marks	Additional guidance
	(a)		The critical density is the density for which the universe will expand towards a (finite) limit or rate of expansion **tends** to zero / which will result in a flat universe	B1	**Not:** critical density is given by $\frac{3H_0^2}{8\pi G}$
	(b)		Hubble constant = $\frac{65\times10^3}{10^6\times3.1\times10^{16}}$ Hubble constant = 2.1×10^{-18} s^{-1} critical density = $\frac{3H_0^2}{8\pi G}$ critical density = $\frac{3\times(2.1\times10^{-18})^2}{8\pi\times6.67\times10^{-11}}$ critical density = 7.9×10^{-27} (kg m^{-3})	B1 C1 A1	Possible e.c.f. from value of Hubble constant within this calculation
	(c)	(i)	open: (density of universe < critical density hence) the universe will expand forever closed: (density of universe > critical density hence) the universe will (eventually stop expanding and then) contract / big crunch flat: (density of universe = critical density hence) the universe will expand towards a (finite) limit / rate of expansion **tends** to zero	B1 B1 B1	**Allow:** 'universe continues to expand' **Not:** 'The universe stops expanding' **Special case:** Award 1 mark for correct sketches if no explanation is given for open, closed and flat
		(ii)	Any one from: Existence of dark matter / black holes / neutrinos / dark energy / H_0 is not known accurately	B1	
			Total	**8**	

15)

Question			Expected Answers	Marks	Additional Guidance
	a		static / homogeneous	B1	Uniform (density)
			infinite / infinite number of stars	B1	Do not allow isotropic or fixed
	b	(i)	gradient of graph = H_0	C1	
			value H_0 = 66 ± 4 (km s^{-1} Mpc^{-1})	A1	
		(ii)	age = 1 / H_0 (H_0 = 2.1 x 10^{-18} s^{-1})	C1	ecf from H_0 value
			= (1 / 66 x 3.2 x 10^{-20} x 3.2 x 10^{7})	C1	Or correct age in seconds (4.7 x 10^{17} s)
			= 1.5 x 10^{10} (1.48 x 10^{10}) (year)	A1	Answer will depend on H_0 value in **(b)(i)** Minus one if Mega or kilo omitted
	c	(i)	$\rho_c = 3H_0^2 / 8\pi G$ = [3 x (2.1 x 10^{-18})^2] / (8 x π x 6.67 x 10^{-11})	C1	If units of H_0 not converted or converted incorrectly then maximum one out of two
			= 7.9 x 10^{-27} (kg m^{-3})	A1	ecf from H_0 value in **(b)(i)**
		(ii)	if average density of the Universe is less than critical then it will be too small to stop it expanding / it goes on forever	B1	do not allow answers open, closed and flat
			if the average density of the Universe is greater than the critical value it will cause the contraction (and produce a big crunch)	B1	
			close to critical value and therefore a universe expands that will go towards a limit / expands at an ever decreasing rate asymptotic	B1	
	d		galaxies are moving apart / universe is expanding	(B1)	Allow stars for galaxies
			if galaxies have always been moving apart then at some stage they must have been closer together / or started from a point	(B1)	allow from a singularity
			evidence in red shift either optical / microwave	(B1)	allow statement that red shift is observed or that blue light becomes red or gamma from big bang has become microwave
			further away the galaxy the faster the speed of recession	(B1)	
			the existence of a (2.7 K) microwave background radiation	(B1)	
			there is more helium in the universe than expected	(B1)	
			MAX 4	B4	
			Total	[16]	

16)

Question			Answer	Marks	Guidance
	(a)		Any three from: 1. (Interstellar dust and gas) cloud is drawn together by gravitational force / gravity 2. Loss in (gravitational) PE / KE increases / temperature increases 3. Fusion (of protons / hydrogen nuclei) takes place 4. Energy is released in fusion reactions 5. A stable star is formed when gravitational pressure is equal to internal / gas / radiation pressure QWC: The steps in the process are correctly sequenced	B1 × 3 B1	**Allow**: 'gravitational collapse'
	(b)	(i)	Any two from: • (extremely) dense / (very) hot / low luminosity • no fusion reactions occur • it is a remnant of a low-mass star • correct reference to Fermi pressure / electron degeneracy / Chandrasekhar's limit	B1 × 2	
		(ii)	Red giant identified (It is cooler but has) large surface area (and therefore radiates large amounts of energy)	B1 B1	
			Total	**8**	

17)

Question			Answer	Marks	Guidance
	(a)		The night sky should be bright / have uniform brightness (but it is not) The line of sight ends on (the surface of a star) or 'number of stars $\propto r^2$ and intensity $\propto 1/r^2$' Any two assumptions about the Universe: Infinite / uniformly distributed matter or stars throughout / static / infinite age	B1 B1 B1	
	(b)		(recessional) speed of galaxy $\propto$ its distance (from the Earth) The universe is finite / it is expanding / it has a beginning / visible light is red-shifted (because of expansion of space) (AW)	B1 B1	**Allow**: $v = H_0 x$, v = (recessional) speed of galaxy, x = distance and H_0 is Hubble constant / a constant
	(c)	(i)	$v = H_0 x$ $3.4\times10^{7} = H_0 \times 1.4\times10^{25}$ $H_0 = 2.4 \times 10^{-18}$ unit: s^{-1}	 C1 A1 B1	**Note**: This is an independent mark **Note**: Allow full credit for an Hubble constant of 75 with unit km s^{-1} Mpc^{-1}
		(ii)1	age = $\frac{1}{2.4\times10^{-18}}$ age = 4.17×10^{17} (s) age = 1.3×10^{10} (years)	C1 A1	Possible ecf from **(i)**
		(ii)2	distance = $4.17 \times 10^{17} \times 3.0 \times 10^{8}$ (= 1.25×10^{26} m) distance = $\frac{4.17\times10^{17}\times3.0\times10^{8}}{3.1\times10^{16}}$ distance = 4.0×10^{9} (pc)	C1 A1	Possible ecf from **(ii)1**
			Total	**12**	