Mark schemes

1.

(a) Quasars are produced by (supermassive) black holes. ✓

These black holes are at the centre of (active) galaxies (active galactic nuclei.) ✓

2

(b) Using v = cz gives

$v = 3 \times 10^8 \times 0.0415$ ✓ $= 1.25 \times 10^7 = 1.25 \times 10^4$ kms^{-1}

Using 1pc = 3.26 lyr

$d = 5.81 \times 10^8$ lyr $= 5.81 \times 10^8/3.26$ ✓ $= 1.78 \times 10^8$ pc

$= 1.78 \times 10^2$ Mpc ($= 5.5 \times 10^{24}$ m)

Using v = Hd

($H = v/d = 1.25 \times 10^4/1.78 \times 10^2 = 70$ kms^{-1} Mpc^{-1})

Age of Universe = 1/H = d/v ✓

$= 5.81 \times 10^8 \times 9.47 \times 10^{15}/1.25 \times 10^7 = 4.42 \times 10^{17}$ s ✓

The first mark is for use of zc.

The second mark is for a calculation of d.

The third mark is for using the idea that the age of the Universe is 1/H.

The fourth mark is for the answer.

Allow own H for 3rd and 4th marks.

4

(c) Both quasar and galaxy should have same brightness (and therefore similar received power) ✓

Use of Inverse square law eg

Power of quasar/(distance to quasar)^2 = power of galaxy / (distance to galaxy)^2 ✓

Or $1000/d^2 = 1/1$

So distance to quasar = $(1000)^{½}$ = about 30 times greater than distance to galaxy ✓

The first mark is for relating the similar "brightness". Accept intensity. Accept in form of equation linking quasar and galaxy.

The second mark is for applying the inverse square law. Simply quoting it does not get this mark.

The final mark is for coming to a valid conclusion related to the distance to the quasar compared to the distance to the galaxy.

Do not accept answers involving square roots.

These are standalone marks.

1
2

[9]

2. The mark scheme gives some guidance as to what statements are expected to be seen in 1 or 2 mark (L1), or 3 or 4 mark (L2) and 5 or 6 mark (L3) answer. Guidance provided in section 3.10 of the 'Mark Scheme Instructions' document should be used to assist in marking this question.

Mark	Criteria	QoWC
6	All three methods described. All three methods applied to Earth-like planets. Judgement reached.	The student presents relevant information coherently, employing structure, style and spg to render meaning clear. The text is legible.
5	Only two methods described and all three applied, Or All three described and only two applied.	
4	Two methods described and applied, Or three described and only one applied.	The student presents relevant information and in a way which assists the communication of meaning. The text is legible. SPG are sufficiently accurate not to obscure meaning.
3	Three methods described, Or Two methods described and one applied.	
2	Only one method described and applied Or two methods described with application.	The student presents some relevant information in a simple form. The text is usually legible. SPG allows meaning to be derived although errors are sometimes obstructive.
1	Only one method described.	
0	No relevant information.	The student's presentation, SPG seriously obstruct understanding.

Higher Level (5 or 6 marks)

All three methods of measurement are described (transit, radial and direct observation)

Problems associated with each one are discussed, with particular reference to detecting an object an Earth-like planet.

Intermediate Level (3 or 4 marks)

Only two of the three methods are described and little effort is made to link the methods to the detection of an Earth-like planet.

Low level (1 or 2 marks)

Only one method is described, or two methods poorly.

Little or no reference is made to the detection of an Earth-like planet.

(a more detailed mark scheme will be produced with levelled statements)

Transit *– dips in brightness as planet crosses in front of star from our point of view.*

Alignment must be correct for planets to eclipse, so many possible candidates not observed. Earth-like planet could be observed provided not too far away.

Radial velocity *(Doppler) – periodic shift in spectra of star due to star's movement around common centre of mass with planet.*

Earth-like planet mass much less than mass of Sun-like star so effect slight. Earth-like planet could be detected with highly sensitive spectrometers.

Direct observation *– very unlikely as Earth-like planet to small and too near star and too cool to be detected against the brightness of the Sun-like star. Unlikely to be detected.*

[6]

3. (a) Hipparcos scale: (brightest 1) down to 6 dimmest (visible in good conditions) ✓

Gamma A and HD 66141 much dimmer than two brightest stars / not much brighter than magnitude 6 ✓

Only two stars (Gomeisa and Procyon) likely to be seen (unless conditions are good) ✓

6 dimmest may be inferred.

Accept reverse argument.

1
2

(b) Gomeisa (is a B class star) ✓

(B class stars are hot enough) to have electrons/hydrogen in n=2 state ✓

Condone "The B class star" for first mark

1
1

(c) Same spectral class so similar temperature ✓

Absolute magnitude of Gamma A (and therefore power output) brighter (greater) than HD 66141 ✓

Due to Stefan's Law, Gamma A has larger area, and therefore larger diameter ✓

Accept same temperature

Confusion with apparent magnitude, max 1

Accept power, but Not brightness, of Gamma A is greater without direct reference to Abs Mag

P prop to A at constant T equivalent to is enough for Stefans Law

3

(d) Periodic Doppler shift in light received (from star) ✓

Due to star and planet orbiting common centre of mass ✓

Statement or implication that light is from planet loses this mark.

Red and Blue shift is equivalent.

Red shift could increase and decrease.

Periodicity could be implied

Ignore 'wobble' unless clearly explained.

2

(e) Use of $m - M = 5 \log (d/10)$

To give

$0.34 - 2.65 = 5 \log (d/10)$ ✓

$\log (d/10) = -2.31/5$

$d = 3.45$ ✓ pc ✓

Reversing magnitudes (giving 29pc) is a physics error. Can score unit mark only.

Beware of $\log_e$ in expression – PE max 1 for unit

Condone parsec, PC or Pc but Not ps OR pC.

Unit mark cannot be awarded without an attempt at calculation.

Allow correct converted unit.

(e.g. 11.2 or 11.3 ✓ ly ✓; 7.1×10^5 AU; 1.1×10^{17} m)

Other units can only be awarded if clear intention of conversion. (e.g. AE in calculating parsecs correctly converted to metres)

3

[13]

4. (a) It is the radiation coming from all parts of the Universe ✓

When the Universe cooled sufficiently for matter and radiation to 'decouple', with the combination of protons and electrons to form neutral atoms ✓

This radiation has been red-shifted into the microwave region as the Universe has expanded ✓

OR

This is (em) radiation from all parts of the Universe, ✓

the spectrum has a peak in the microwave region / corresponds to a temperature of 2.7 K ✓

It can be interpreted as the radiation left over from the Big Bang / the photons having been stretched to longer wavelengths and lower energies ✓

One mark is for stating that CMBR comes from all parts of Universe.

Accept Isotropic.

Condone homogeneous.

Condone same at all points in universe.

Another is for referencing the idea that the radiation has a peak in the microwave region.

The third is for linking it to the Big Bang theory.

Condone "left over heat from Big Bang".

3

(b) (The Big Bang theory suggests that a very brief period of) fusion occurred (when the Universe was very young), resulting in the production of helium from fusing hydrogen. ✓

Fusion stopped as the Universe then expanded and cooled ✓

Resulting in a relative abundance of hydrogen and helium in the ratio of 3:1/ cooled too rapidly for the creation of larger nuclei,

Or suitable relevant observation ✓

One mark is for linking helium production to fusion in the early Universe. This mark can also be awarded for description of proton and neutron creation/ 7:1 ratio

3

[6]

5. (a) Correct use of Doppler equation for both Galaxies ✓

Correct use of Hubbles law for both Galaxies ✓

Justified comparison leading to conclusion ✓

Award full credit for calculation:-

1. Hubble's constant for two galaxies and then related to Hubble's constant value in data booklet or to each other:

NGC 936 is consistent (H=69 km s^{-1} Mpc^{-1})

NGC 3379 is not consistent (H=92 km s^{-1} Mpc^{-1})

2.Using Hubble constant from data booklet to deduce if z or d in table are in agreement with calculated values for both galaxies.

3.Calculate ratio z/d for both galaxies and compare.

z/d = 4.8/6.8 = 0.7 and z/d = 3/3.2 = 0.9

Condone POT errors when compared in a ratio.

ECF for comparison if at least one calculation correct. (max2/3)

Candidate who calculates values for only one galaxy can only score 1 mark.

Credit discussion suggesting that other factors also affect galaxy velocity or distance measurements and difference not large so Hubble's Law is OK.

3

(b) Distant quasars are very faint; or Type 1a supernova (or standard candle) in associated galaxy would be very faint ✓

Reference to inverse square law ✓

or

Due to dark energy/accelerating universe, ✓

use of Hubble's Law/inverse square law not reliable over large distances. ✓

Condone 'barely detectable OWTTE' for faint.

Condone

Some quasars are situated behind intervening galaxies/gas clouds

Affecting data/light received from quasar

2

[5]

6. (a) It has a known absolute magnitude. ✓

Other wordings are possible. It must be clear that the candidate knows that it is the intrinsic power/brightness that must be known.

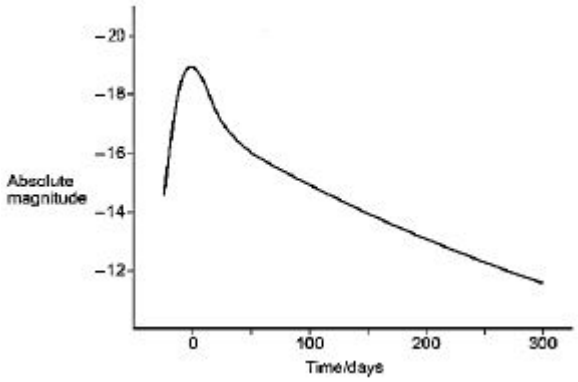
1

(b) Peak between −18 and −20 AND axis correct direction ✓
Time scale 40 to 500 days ✓
Lhs steeper than rhs (by eye) ✓

−ve sign essential

Allow magnitude and/or time axes starting at 0

Accept any unit for time which fits with the 40-500 days range. Ideal graph:



3

(c) The mark scheme gives some guidance as to what statements are expected to be seen in a 1 or 2 mark (L1), 3 or 4 mark (L2) and 5 or 6 mark (L3) answer. Guidance provided in section 3.10 of the 'Mark Scheme Instructions' document should be used to assist in marking this question

Mark	Criteria
6	All 3 areas covered with at least two aspects covered in some detail. 6 marks can be awarded even if there is an error and/or parts of one aspect missing.
5	A fair attempt to analyse all 3 areas. If there are several errors or missing parts then 5 marks should be awarded.
4	Two areas successfully discussed, or one discussed and two others covered partially. Whilst there will be gaps, there should only be an occasional error.
3	One area discussed and one discussed partially, or all three covered partially. There are likely to be several errors and omissions in the discussion.
2	Only one area discussed or makes a partial attempt at two areas.
1	None of the three areas covered without significant error.
0	No relevant analysis.

Examples of points which might be made in a good answer.

Data

- Also need z (or red shift).
- Use z value to find velocity ($v = zc$).
- Measure wavelength of spectral lines

2

Graph

- Plot graph of velocity on y-axis vs distance on x-axis.
- v in km/s, distance in Mpc.
- H is gradient of graph.

2

Limitations

- Value of apparent magnitude may be affected by what the light passes through.
- Much variation in the data (there must be specific reasons given e.g. variations between galaxies or random errors in measurement).
- At large distances accelerating universe will affect graph.
- Need data from lots of supernovae

2

[10]

7. (a) Quasars are formed around black holes ✓$_1$

Black hole (at the centre of IC2497) no longer has matter falling into it ✓$_2$

MP2 – allow black hole no longer feeding; Black hole no longer active.

If no mention of black holes no marks can be awarded.

2

(b) use of $z = v/c$ to give $v = zc = 0.0516 \times 3.00 \times 10^8$ ✓$_1$

Accept 2sf in final answer.

3

$= 1.55 \times 10^7$ m s^{-1} $= 1.55 \times 10^4$ km s^{-1}

use of $v = Hd$

to give $d = \frac{v}{H}$ ✓ $= \frac{1.55 \times 10^4}{65}$

= 238 ✓$_3$ Mpc✓$_4$

*Condone Megaparsec, MPC or MPc but **not** Mps OR MpC.*

Unit mark cannot be awarded without an attempt at calculation.

Allow correct converted unit.

(eg 782 ✓Mly ✓; 4.93 × 10^{10} AU; 7.40 × 10^{21} m)

Units other than Mpc can only be awarded if there is a correct conversion – but allow ecf.

(eg AE in calculating Mpc correctly converted to m)

1

[6]