A-Level Physics

Cosmology

Mark Scheme

Time available: 67 minutes
Marks available: 38 marks

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MP2 – allow black hole no longer feeding; Black hole no longer active.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

2. (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.

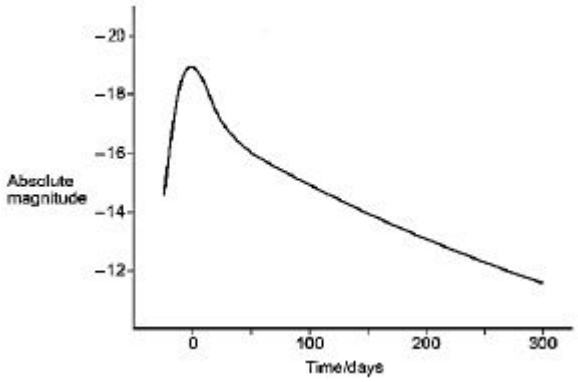
1

(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]

3. (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]

4. 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]

5. (a) Apparent magnitude of star is measured over a long period of time ✓

When planet passes in front of star (as seen from Earth), some of the light from star is absorbed and therefore the amount of light reaching Earth reduced ✓

This produces a light curve showing constant value with a dip periodically as the planet passes in front of the star ✓

3

(b) Dip in light curve can be caused by other effects ✓

Except for planets very close to star, periods likely to be very long and may take many years of observation using transit method alone ✓

2

[5]

6. (a) Star much brighter than reflected light from planet ✓

Or

Planet very small and distant – subtends very small angle compared to resolution of telescopes

1

(b) Planet and star orbit around common centre of mass that means the star moves towards/away from Earth as planet orbits ✓

1

Causes shift in wavelength of light received from star ✓

1

(c) Light curve showing constant value with dip ✓

1

When planet passes in front of star (as seen from Earth), some of the light from star is absorbed and therefore the amount of light reaching Earth reduced ✓

1

Apparent magnitude is a measure of the amount of light reaching Earth from the star ✓

1

[6]