Developing skills through observational activities

GCSE (9-1) Astronomy

Pearson Edexcel Level 1/Level 2 GCSE (9-1) in Astronomy (1AS0)

GCSE (9-1) Astronomy 2017

Contents

Introduction

This Additional Guidance is designed to support both teaching staff and students involved in the completion of Observational Tasks for GCSE (9-1) Astronomy.

As well as giving some general guidance on how to produce high-quality observations, it also provides some specific guidance on each of the task titles suggested in the GCSE (9-1) Astronomy specification.

Examples of successfully completed Observational Tasks are included.

Observational skills requirements

Throughout their study of this qualification, students should develop their observational skills.

Students must undertake at least **one unaided and one aided** observation, from the selection listed in this section. Students will need to use their knowledge and understanding of observational techniques and procedures in the written assessments.

Students need to record the work that they have undertaken for these observations. The observation record must include the knowledge, skills and understanding they have derived from the observational activities.

Centres must confirm that each student has completed at least one unaided and one aided observation by completing and submitting an Observation Statement (see page 19). This must be submitted to Pearson by 15th May in the year that the students will sit their examinations. Any failure by centres to provide this Observation Statement will be treated as malpractice and/or maladministration.

It is important to realise that these mandatory observations are the minimum number of observations that should be taken during the course.

Safety is an overriding requirement for all observational work. Centres are responsible for ensuring appropriate safety procedures are followed whenever their students complete observational activities.

Pearson may review and amend these observational activities if necessary. Centres will be told as soon as possible about any changes to them.

Skills in astronomical observations

Astronomical observation is an iterative cycle of design, observation, analysis and evaluation.

Through the evolution of each set of observations, students suggest improvements that form the foundation of the design of the next set of observations.

Astronomical observations require students to:

1 Design observations

2 Make observations

3 Analyse observations

4 Evaluate observations.

1. Design observations

There are many uncontrollable variables in astronomical observations and reliability is improved by iteratively refining the observation programme. All astronomical observations require the informed selection of target object, observing site, time and date along with their choice of observing equipment. Students should, therefore, be involved in selecting these features of their observing programme, as well as refining them.

Students should:

- produce a list of feasible target objects, location, date, time and observing instrument, as appropriate to their chosen task
- use astronomical data to select the most appropriate target object, location, date, time or observing instrument
- generate an initial observing programme that will allow them to solve the problem posed by the title of their chosen task, including health and safety considerations
- make refinements or improvements to their observing programme, following the results of initial trials.

2. Make observations

There are many variables affecting astronomical observations that are outside the control of the observer. Students will need to undertake a series of observations to generate sufficient data to support valid conclusions. This is the observational programme. Students should gain experience of undertaking an observational programme in both unaided ('naked eye') and aided situations, as follows:

- conduct unaided observations, using techniques such as averted vision, dark adaptation
- conduct aided observations, using equipment such as binoculars, telescopes and cameras
- ensure that all observations are accompanied by the necessary observational details, including:
    - date
    - time
    - location
    - seeing conditions
    - optical instruments used

- ensure that sufficient observations are taken to produce accurate data for the specific task.

3. Analyse observations

Students will need to analyse their observations to produce reliable and valid conclusions for the specific observation. This will involve a wide range of skills, depending on the nature of the original observations, as follows:

- identify patterns or trends from a series of drawings or photographs
- present numerical data in the form of graphs or charts
- perform calculations
- perform basic digital image processing, including the adjustment of image brightness, dynamic range and the use of false colour.

4. Evaluate observations

Students will need to compare the results of their observations with those obtained by professional astronomers or with accepted values. This will enable them to evaluate the reliability and accuracy of their resulting conclusions and suggest improvements for further observations. This should include the following:

- compare the results of their observations with professional images or accepted values to assess their accuracy
- where possible, calculate a quantitative assessment of their accuracy
- identify the effects of light pollution on naked-eye observations
- identify the effects of light pollution, exposure time and filtering on photographic observations
- recognise some of the major artefacts that can affect astronomical images, such as scattered light, diffraction spikes, cosmic rays and trails from satellites, aircraft or meteors
- identify the major causes of error in the conclusions
- suggest and implement improvements to the observing programme.

Observational Tasks

Each of the following Observational Tasks sets out a problem, which can be solved by a programme of observations. Completion of these tasks will give students an understanding of the cycle of astronomical observation and help them to develop the key observational skills.

Centres must ensure that each student completes at least one unaided and one aided observation task from the following list.

Students may not select both of their Observational Tasks (unaided and aided) from the same row on the Observational Task table. For example, not A1 and B1.

Unaided tasks	Aided tasks
A1 Demonstrate the changing appearance of lunar features Use a series of naked-eye drawings of individual lunar features to demonstrate their changing appearance during the lunar phase cycle	**B1 Demonstrate the changing appearance of lunar features** Use a series of telescopic drawings or photographs of individual lunar features to demonstrate their changing appearance during the lunar phase cycle
A2 Finding the radiant point of a meteor shower Use naked-eye drawings of the paths of meteors to determine the radiant point of a meteor shower	**B2 Finding the radiant point of a meteor shower** Use photographs of the paths of meteors to determine the radiant point of a meteor shower
A3 Assess the accuracy of stellar magnitude estimates Using reference stars, estimate the magnitude of a range of stars from naked-eye observations and thus assess the accuracy of this technique	**B3 Assess the accuracy of stellar magnitude measurements** Using reference stars, estimate the magnitude of a range of stars from photographs and thus assess the accuracy of this technique
A4 Estimate a celestial property using drawings of a suitable event Use naked-eye drawings or measurements of a celestial event such as a comet or eclipse to determine a celestial property such as the relative size of the Earth and Moon	**B4 Measure a celestial property using telescopic drawings or photographs of a suitable event** Use telescopic drawings, measurements or photographs of a celestial event such as a comet, transit, eclipse or occultation to determine a celestial property such as the Earth-Sun distance or the orbital period of a Jovian satellite
A5 Estimating levels of light pollution Use estimates of the magnitude of the faintest stars visible with the naked eye to conduct a survey of the astronomical effects of light pollution in an area	**B5 Measuring levels of light pollution** Use estimates of the magnitude of the faintest stars visible on photographs to conduct a survey of the astronomical effects of light pollution in an area

A6 Estimate the solar rotation period using drawings of sunspots Use a series of drawings from pinhole projections of sunspots to estimate the length of the Sun's average rotation period	**B6 Determine the solar rotation period using photographs of sunspots** Use a series of photographs or drawings from telescopic projections of sunspots to estimate the length of the Sun's average rotation period
A7 Estimating the period of a variable star Use estimates of stellar magnitude from naked-eye observations to produce a light curve for a variable star and thus estimate its period	**B7 Measuring the period of a variable star** Use estimates of stellar magnitude from telescopic observations or photographs to produce a light curve for a variable star and thus estimate its period
A8 Comparing stellar density estimates Use naked-eye estimates of stellar density taken in and outside the plane of the Milky Way to estimate their relative sizes	**B8 Comparing stellar density measurements** Use telescopic measurements of stellar density taken in and outside the plane of the Milky Way to estimate their relative sizes
A9 Finding longitude using a shadow stick Use measurements of shadow length around local noon to estimate the observer's longitude	
A10 Assess the accuracy of a sundial Use a log of sundial and clock times to assess the accuracy of a sundial	
	B11 Demonstrate the range of objects in the Messier Catalogue Use detailed drawings or photographs of objects from the Messier Catalogue to demonstrate the range of different objects it contains
	B12 Calculation of the length of the sidereal day Use long-exposure photographs of the area around the celestial pole to produce an accurate measurement of the length of the Earth's sidereal period

Additional information on Observational Tasks

The following additional guidance provides centres and students with more detailed information on the particular requirements of each Observational Task.

A1/B1 Lunar features

This task requires students to produce a series of drawings of several lunar features, each pictured at a different lunar phase. Using a series of drawings, students can then form conclusions about the effect of the angle of illumination on the appearance of the lunar feature in question. To produce high-quality observations, students should attempt to draw each feature at four or more different points in the lunar phase cycle. It should be noted that this task does not require any drawings of the entire lunar disc.

Lunar photography

Recent advances in affordable telescopes and digital cameras have produced a substantial improvement in the standard of images that students can obtain. Some excellent images can be recorded simply by placing a digital camera at the eyepiece of a telescope or by replacing the eyepiece with a camera.

A2/B2 Meteor shower

As the most prolific meteor shower (the Perseids) is during August, this can make an excellent introductory activity for school and college students to complete during their summer holidays. With a suitable wide-angle lens, this project can be completed very effectively using a camera pointing towards the radiant of the shower.

A3/B3 Stellar magnitude estimates

Although a relatively straightforward task, estimating stellar magnitudes is not an entirely straightforward skill. Students would thus benefit from spending some time practising this skill before taking their final measurements. In the days before photography this would have been an essential skill for an astronomer and students should be encouraged to make this a key part of their project.

A4/B4 Celestial event

This task is designed to allow students to observe unpredictable or infrequent events as part of their Observational Tasks work. Successful examples have included transits of Venus, the retrograde motion of Mars, the appearance of a bright comet, the motion of Jupiter's major satellites and solar or lunar eclipses.

A5/B5 Estimating levels of light pollution

An effective measure of the level of light pollution can be the magnitude of the faintest star which is visible, either by the naked eye (A5) or photograph (B5). Making reliable observations of this will generally involve taking repeated readings in each location. When comparing results from different locations, care needs to be taken to ensure that they have been obtained fairly, that is by using identical exposures for photographs or identical lengths of time for dark adjustment of the eye.

A6/B6 Sunspots

Centres must ensure that they make all their students aware of the essential safety precautions which must be followed when attempting this task. Students' attention is drawn to the requirement that they observe the same group of sunspots on several occasions over a sufficiently long time period to enable an estimate of the solar rotation period for the appropriate latitude to be made.

SAFETY: Throughout these tasks, students must never view the Sun directly. They should project the solar image or use correctly filtered optical instruments.

A7/B7 **Estimating the period of a variable star**

Students attempting this task will need to select a variable star with a sufficiently large variation in magnitude to suit their optical equipment, whether naked eye (A7) or telescope/camera (B7). They will also need to ensure that the star's period is sufficiently short to allow a suitable section of the light curve to be obtained within the time available for the completion of the Observational Tasks.

A8/B8 **Stellar density**

To produce the clearest results, students are advised to compare stellar density measurements from areas of the sky in the plane of the Milky Way galaxy with those at 90° to it. It is also essential for the student to ensure that the same counting method is applied to each area, to ensure a fair test and thus genuinely comparable data.

A9 **Finding longitude with a shadow stick**

This activity can make a very effective introduction to the topic of the Earth's motion relative the Sun, which has obvious links to the early historical development of astronomy.

As with any scientific measurement, students should be encouraged to take sufficient shadow measurements on each occasion to enable an accurate determination of local noon. Students can also use their data to determine the direction of the north celestial pole. They can then use a compass and an Ordnance Survey map to compare this with magnetic north.

A10 **Estimating the accuracy of a sundial**

To obtain a high-quality assessment of the accuracy of a sundial, students will need to return to the sundial on a number of occasions and to take time of day readings over a suitably lengthy period. This will allow them to calculate more reliable average figures in the analysis of their results.

B11 **Messier objects**

The 'range' of astronomical objects included in the Messier Catalogue may be interpreted in several ways. For example, a student may decide to obtain images of Messier objects which show the various stages of stellar evolution. They would therefore need to obtain images of objects such as emission, planetary and supernova remnant nebulae.

Alternatively, a student may choose to use their Messier object images to illustrate the various types of galaxy within the Hubble classification. Images could include elliptical, spiral, barred spiral and irregular galaxies from the range of objects available in the Messier Catalogue.

B12 **Measuring the sidereal day**

Star trails should be recorded for at least half an hour to ensure that they are of sufficient length to enable accurate estimation of the Earth's rotation period. Students also need to measure the angle covered by several star trails so that a reliable average angle for the photograph can be produced. It is therefore important that a reasonably wide angle of sky around Polaris is recorded.

Students should also be aware of the potentially harmful effects of leaving cameras, particularly those with electronic circuitry, outside for extended periods at night.

Guidance on completing Observational Tasks

Observations

The purpose of the Observational Tasks is to give students the opportunity to make some astronomical observations for themselves. The list of suggested task titles is designed to ensure that all students are catered for, irrespective of the optical instruments and other equipment to which they may have access.

It is an important principle of the Observational Tasks that students use their observations to solve a problem, rather than simply documenting them. Each task requires students to take observations which will allow them to illustrate an astronomical principle or obtain an estimate for an astronomical quantity. For example, they may use their drawings to illustrate the changing appearance of lunar features during the Moon's phase cycle, use their photographs to determine the length of the sidereal day or use their measurements to assess the accuracy of a sundial.

Candidates should therefore be encouraged to approach their observational work as an iterative problem-solving process, involving Design, Observation, Analysis and Evaluation.

Safe practice

Attention is drawn to the need for safe practice when students carry out observation tasks. Relevant advice can be obtained from CLEAPPS.

Risk assessments must be carried out for all observing tasks. It is the responsibility of the centre to carry out all risk assessments, to ensure that they are appropriate for their students, equipment and conditions.

Of particular concern is any observation of the Sun and the Moon. The Sun must not be viewed directly, either with or without optical aids. If the Moon is observed directly using a telescope at high magnification then a student's ability to make further observations directly afterwards is impaired.

Health and safety is a particular concern throughout all of the observation tasks, but particularly in A6, B6, A9 and A10, which are concerned with observing phenomena related to the Sun.

Common errors

- Students often produce incomplete Observational Tasks by forgetting to include all the necessary observational details with every one of their observations. Each astronomical observation must be accompanied by:
    - date
    - time
    - location
    - seeing conditions
    - full details of optical instruments (if used).
- Students sometimes make their drawings too small so that all necessary detail cannot be shown clearly, making analysis and evaluation difficult to complete.
- Students' Observational Tasks should show evidence of having been carried out throughout the course. Lower quality work often results when observations are rushed in the final weeks before the submission deadline. This results in either observations taken when the seeing is poor or no observations able to be taken at all.

High-quality tips

- The essential element in successfully completing Observational Tasks is the quality of the drawings or photographs which are produced. Interestingly, some of the best observational work is often produced by students working with the naked eye. Although more sophisticated equipment allows access to more astronomical objects, producing the best-quality results using such specialised equipment often takes considerable skill and practice.
- High-quality observational work often involves returning to the same celestial object on several occasions, resulting in several sketches of the same object.
- Clear explanation of calculations or deductions from observations is important in all tasks. For example, in the *Finding Longitude* (A9) or *Determining Sidereal Day Length* (B12) tasks, ensuring that the calculations performed on the observational data are completed accurately, showing clearly how the final values for longitude, sidereal day, etc., are obtained, is essential for successful completion.

Guidance on the use of robotic telescopes

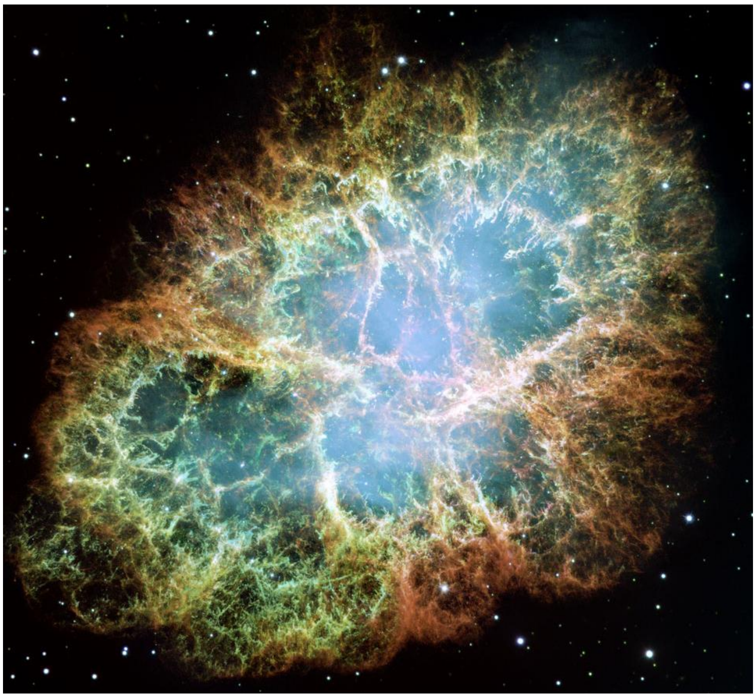
Several of the Observational Tasks listed in the Aided (List B) section of the GCSE (9-1) Astronomy Specification are suitable for completion using one of the robotic telescopes available to students via the internet. Access to these large telescopes clearly extends the range of objects available to GCSE Astronomers as well as the detail with which familiar objects can be observed.

For the GCSE Astronomy Observational Tasks to be secure, the basic requirement is for centres to ensure that all students design, take, process and evaluate their own observations, whatever instrument or equipment is used.

Centres should take steps to ensure that each student is obtaining and processing their own individual images. Each student should therefore work with their own password-protected username, either for their centre's internal network or for the particular robotic telescope website.

Use of published material

It is sometime useful for the candidate to include images or other material obtained from an external source, particularly in the Evaluation section of the Observational Tasks. In this case it must be made completely clear which material has been taken from another source, with full references included at all times. For example, when completing the task *Messier Objects* (B11), a candidate may wish to compare their images of the Crab Nebula with those obtained by a professional telescope such as the Hubble Space Telescope. The example on the next page shows how this image should be clearly credited.



Hubble Space Telescope image © NASA/ESA

Features of successful Observational Tasks

This section lists some of the essential features of successfully completed Observational Tasks in GCSE Astronomy.

Design

The Design section of a successfully completed Observational Task should show clear evidence of:

- A range of alternatives considered for several of the key elements within an observing programme: date, time, location, target object or optical instruments appropriate to the Observational Task.
- Sound astronomical reasons given for the final choices made for the above features of the observing programme.

Observations

The Observations section of a successfully completed Observational Task should show clear evidence of:

- Sufficient observations to enable firm conclusions to be drawn regarding the problem posed by the title of the Observational Task.
- Full observation details for each observation including date, time, location, seeing conditions and instrument used.

Analysis

The Analysis section of a successfully completed Observational Task should show clear evidence of:

- Evidence of further processing of the observations obtained.
- Sound conclusions drawn from the observations obtained.

Evaluation

The Evaluation section of a successfully completed Observational Task should show clear evidence of:

- Wherever possible, an objective assessment of the accuracy of the observations obtained, either by quantitative assessments such as percentage error or by comparison with professional observations.
- Specific suggestions for the extension or improvement of the observational work undertaken.

Examples of completed Observational Tasks

This section contains three examples of successfully completed Observational Tasks, along with a detailed commentary explaining how each demonstrates the Observational Skills.

Example 1

Design

I planned to draw three different constellations on the 7th April, those being Ursa Minor, Ursa Major and Cassiopeia. I will make my observations from 9:45pm to 10:30pm from Ilkley Moor in West Yorkshire at latitude 53.92 and a longitude of -1.75. I will take my observations from here because light pollution will not affect my view of the sky and I will be higher up.

I checked the weather forecast for the might and it was forecasted to be clear skies.

Important terms

Constellations are groups of stars forming patterns which are named after mythical creatures or animals that look like it. Modern astronomers use constellations to split the sky into separate areas.

Apparent magnitude is a measure of the brightness of a permanent natural object in the sky, in this case a star measured from the Earth.

Circumpolar stars are always above the horizon for the full 360 degree rotation of the Earth.

History of my constellations

Ursa Minor: One of the original 48 constellations listed by Ptolemy. It is best seen in the month of June.

Ursa Major: One of the original 48 constellations listed by Ptolemy. It is best seen in the month of April.

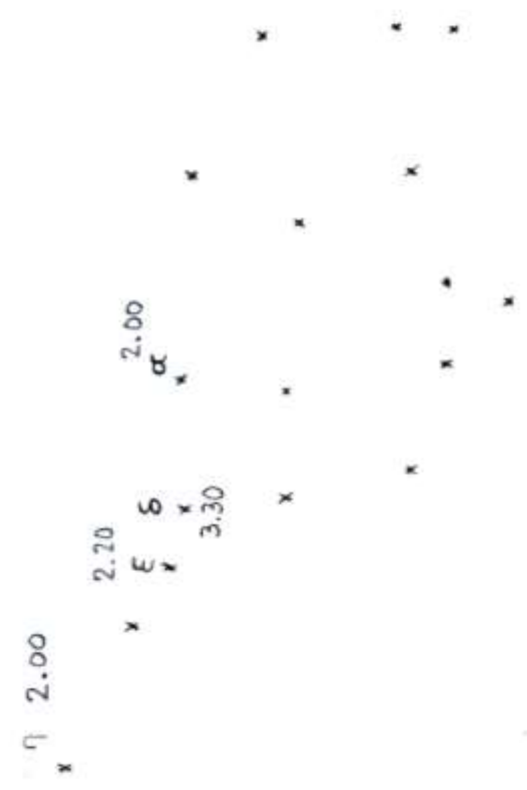
Cassiopeia: One of the original 48 constellations listed by Ptolemy. It is best seen in the month of November.

Ptolemy was an Egyptian astronomer who lived around 150AD.

I chose these three constellations as they are all circumpolar so I could see them at anytime when the sky was clear.

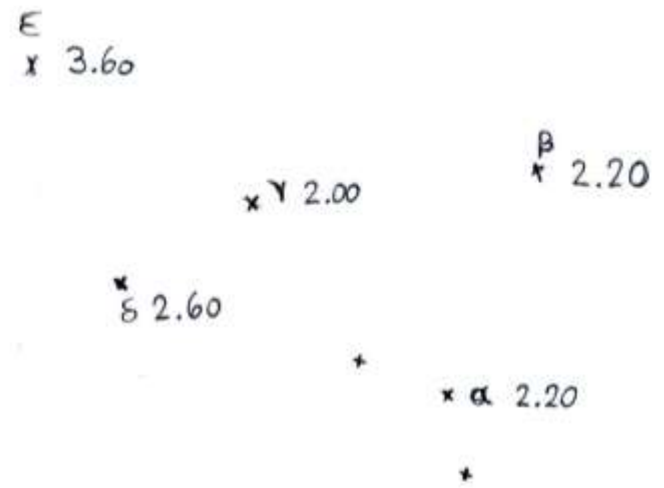
Observations:

NAME OF CONSTELLATION	Ursa Major
DATE - 7/4/11	
TIME - 23:30	
SEEING - II	
WEATHER CONDITIONS - cloud cover on the South horizon otherwise clear	



NAME OF CONSTELLATION	Ursa Minor
DATE - 7/4/11	
TIME - 23:10	
SEEING - II	
WEATHER CONDITIONS - Cloud cover on the South horizon otherwise Clear	

NAME OF CONSTELLATION	Cassiopeia
DATE - 7/4/11	
TIME - 22:50	
SEEING - II	
WEATHER CONDITIONS - Cloud cover on the South horizon otherwise Clear	



Analysis

Here are my results for the magnitudes of the constellations:

	Constellation:	**Ursa Major**			
Beyer letter	Star	My mag	Actual	Diff	% Diff
Eta	Alkaid	2.00	1.90	0.1	5.26%
Alpha	Dubhe	2.00	1.80	0.2	11.11%
Epsilon	Alioth	2.20	1.80	0.4	22.22%
Delta	Megrez	3.30	3.30	0.0	0.00%
	Polaris	***Ref Star***	***2.02***	-	-
			Total:	0.7	
			Avg Diff	0.175	
			Avg Diff%		**9.65%**

	Constellation:	**Ursa minor**			
Beyer letter	Star	My mag	Actual	Diff	% Diff
Delta	Yildun	4.00	4.40	0.40	9.09%
Eta	Anwar al F.	5.00	4.95	0.05	1.01%
Beta	Kichab	2.10	2.07	0.03	1.45%
Nu	Pherkad	3.00	3.00	0.00	0.00%
Alpha	Polaris	2.02	2.02	0.00	0.00%
	Megrez	***Ref Star***	***3.30***	-	-
			Total:	0.48	
			Avg Diff	0.096	
			Avg Diff%		**2.31%**

	Constellation:	**Cassiopeia**			
Beyer letter	Star	My mag	Actual	Diff	% Diff
Beta	Caph	2.20	2.28	0.08	3.51%
Alpha	Shedir	2.20	2.24	0.04	1.79%
Nu	Cin	2.00	2.15	0.15	6.98%
Delta	Ruchbar	2.60	2.68	0.08	2.99%
Epsilon	Segin	3.60	3.34	0.26	7.78%
	Polaris	***Ref Star***	***2.02***	-	-
			Total:	061	
			Avg Diff	0.122	
			Avg Diff%		**4.61%**

Evaluation:

Reviewing my drawings I was happy with two out of three of my drawings. I was not so happy however, with my ursa minor drawing as I was unsure whether it was correct or not, as the stars in ursa minor are a lot dimmer on average than those in ursa major or Cassiopeia.

After evaluating my estimated magnitudes I felt that within 0.20 magnitudes was okay. I was quite disappointed after following this guide to accuracy to find that I was outside my 'Zone' on three occasions. I was bang on the magnitudes on three occasions but I had used one of those stars for the reference for my three constellations so I did know the correct apparent magnitude. The other magnitude I got right was a well rounded number.

My estimates were too high 42.9% of the time, they were too low 35.7% of the time and I got my magnitudes correct 21.4% of the time.

On average I was 5.50% out on the magnitudes.

- **Cassiopeia** I was on average 4.61% out
- **Ursa Major** I was on average 9.65% out
- **Ursa Minor** I was on average 2.31% out

I thought that on average my estimates were good because I was within 10% of the apparent magnitude average. The overall average could have been lower – it was let down by my Ursa Major estimates. It appears that I have only really been let down by my Alioth estimate.

The brightest stars that I saw on that night were 1.80 magnitudes and they were Dubhe and Alioth. The dimmest star was Anwar al Farkadan and that had a magnitude of 4.95 which for on top of a moor above three towns isn't that bad.

To improve the observations:

1. I could have measured the distances between the stars better as I thought they were slightly inaccurate.
2. I could have used different sized stars on my drawings to show different magnitudes.

Commentary

Design Observations

Strengths:

- The candidate has explained clearly where and when the observations took place and which constellations were observed and has provided some justification for their choice of location in terms of its view of the night sky.

Areas for improvement:

- With the possible exception of the location, the candidate has not explained why they chose any other aspects of their observational programme such as their choice of constellations, time of observation, etc. This has meant that they have missed several opportunities to use the astronomical terms which are central to this project such as rising and setting, culmination, declination, etc. If this had been done, there would be no need for a section defining some of these terms.
- Greater detail on the observing process would also have improved this section and allowed the candidate to talk about further astronomical ideas such as dark adjustment of the eye and averted vision.
- Although not directly detrimental, no credit can be given for the 'History of my constellations' section at the end.

The candidate has apparently chosen an appropriate site, time and equipment but has not fully justified their choice. Their actual use of astronomical terminology as part of the design process is very limited and this area needs to be addressed for the requirements of Design Observations section to be fully met.

Make Observations

Strengths:

- The design of a standard template page for all observations is a good one, particularly as it includes boxes for all the key observational details which must accompany each and every observation. A small improvement might be to include a box to indicate Time Zone or GMT/BST in the UK. The A5 size of page is appropriate for drawing constellations and the drawings themselves are of a reasonable quality.

Areas for improvement:

- Given the time taken to draw a constellation accurately, it would be more appropriate to include a range of times over which the drawing was completed, rather than what is presumably the start time for the observation.

The observations could be judged as just adequate for the task as set out in the Specification, with all key observational details included.

Analyse Observations

Strengths:

- The results tables for this section are quite well designed and provide something of a narrative for the analysis which has taken place. The data presented appear to be accurate with all calculations correct.

Areas for improvement:

- The section would be improved by some text explaining the analysis being carried out along with some conclusions at the end. The estimation process would have been improved by the use of two reference stars, whose magnitudes spanned those of the other stars, rather than having only one point of reference in each constellation.

- It is also not appropriate to quote estimated magnitudes to two decimal places, even if they are judged to have the same magnitude as a reference star whose magnitude is known to this accuracy.

The candidate has broadly carried out the correct analysis of their observations, with their conclusions made more explicit in the following Evaluate Observations section.

<u>Evaluate Observations</u>

Strengths:

- The candidate is clearly aware of the aim of the task and assesses their observations and conclusions against it. They have made their assessment quantitative by calculating percentage errors wherever possible. They have also attempted some simple suggestions for improving the work in the future.

Areas for improvement:

- The figure of 0.2 of a magnitude to define 'okay' levels of accuracy seems very arbitrary, particularly as it is not explained in the report. The need for repeats is not mentioned, nor is the absence of colours which could have been discussed in terms of levels of light pollution, etc.

Although the candidate has really made only some very general suggestions for improvement, they have broadly met the requirements of this section.

Example 2

Design

The Earth rotates once every 24 hours. Therefore the Sun appears to rise in the East and set in the West. As noon approaches the Sun gets higher in the sky and so the shadows get shorter. The time when the shadows are shortest is known as local noon. Local noon differs as longitude increases, as the Sun reaches the Zenith (highest point in the sky) at increasingly later times.

However, due to two astronomical factors, both the fact that the ecliptic is tilted at 23½^{o} and that the elliptical shape of the Earth's orbit around the Sun, local noon is not exactly when the shadows are shortest, it can be as much as 16 minutes fast or 14 minutes slow. This is called the Equation of Time.

To find the true local noon, one must find the equation of time for that day and add it on to the local noon found for that day from a sundial or shadow stick. For example if I found that local noon was 12:15pm, and the equation of time for that day was -7, the time of local noon would be 12:08pm.

The aim of the shadow stick observation is to find both the local noon and the longitude of the observer. I chose a weekend to do my observation (Saturday 26th and Sunday 27th March) and I went out into my garden at 11:40am on both days. I measured the length of the shadow projected from a pen in a plant pot onto A3 paper every five minutes until 12:15pm. I used the Antoniadi Scale to measure the seeing conditions.

Observations

For my observations I used the Antoniadi Scaled to represent the viewing conditions.

Observation 1 – 26th March

Antoniadi II   Lat.: 54^{o}N Long.: 2^{o}W

Time	Length of shadow
11:40	202
11:45	198
11:50	197
11:55	194
12:00	192
12:05	192
12:10	194
12:15	194

Observation 2 – 27th March

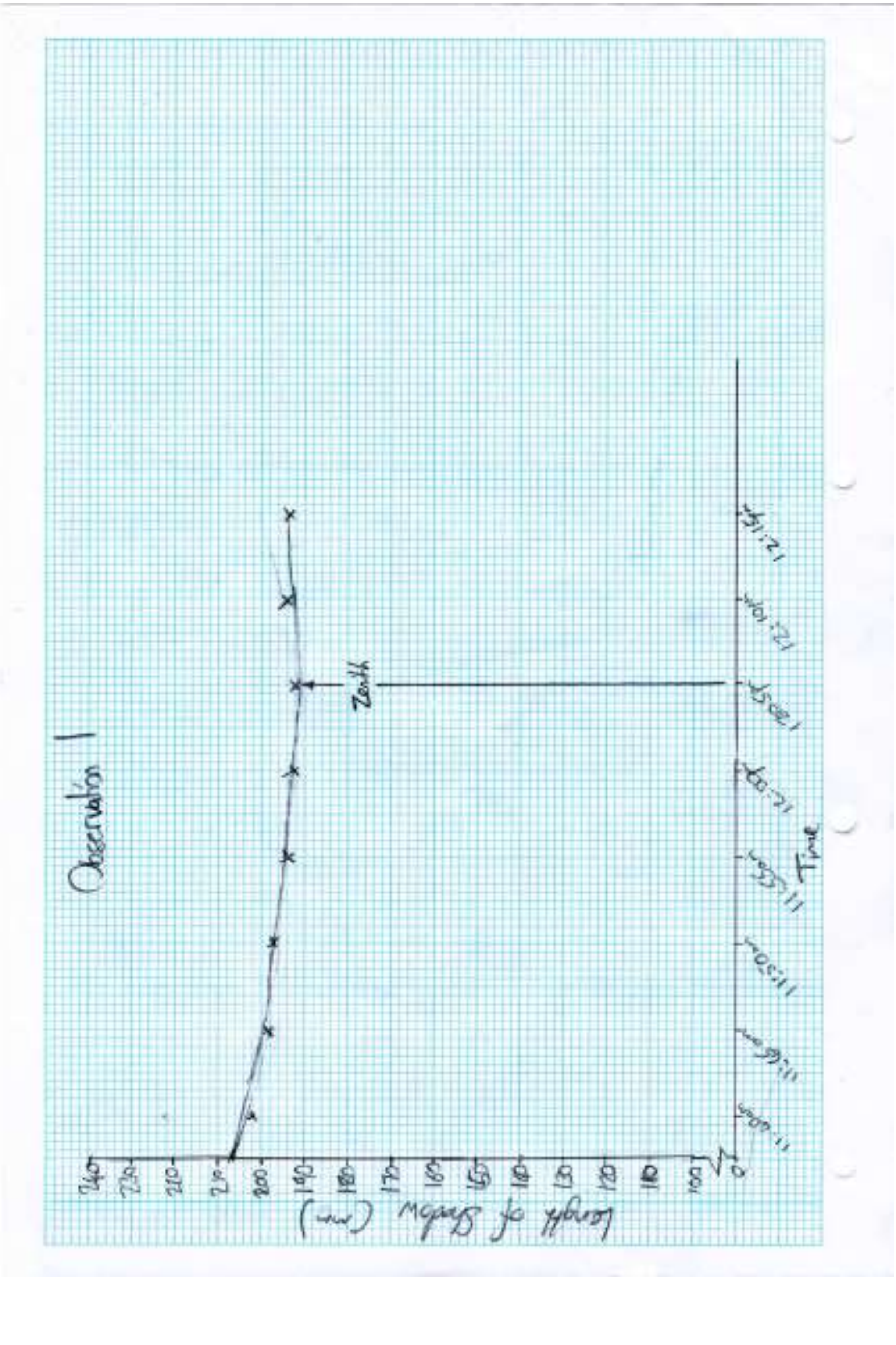
Antoniadi III   Lat.: 54^{o}N Long.: 2^{o}W

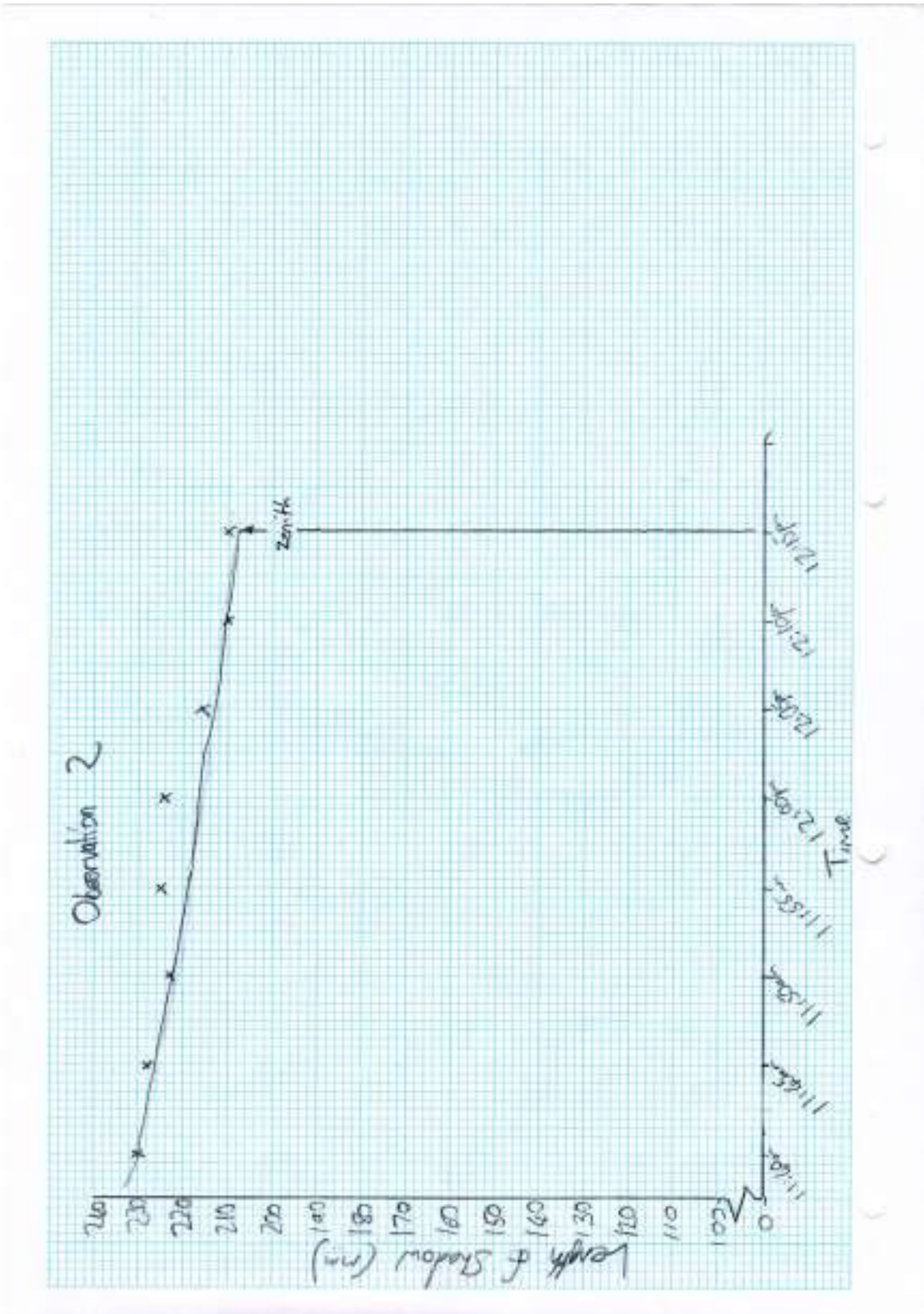
Time	Length of shadow
11:40	180
11:45	176
11:50	175
11:55	175
12:00	174
12:05	172
12:10	174
12:15	174

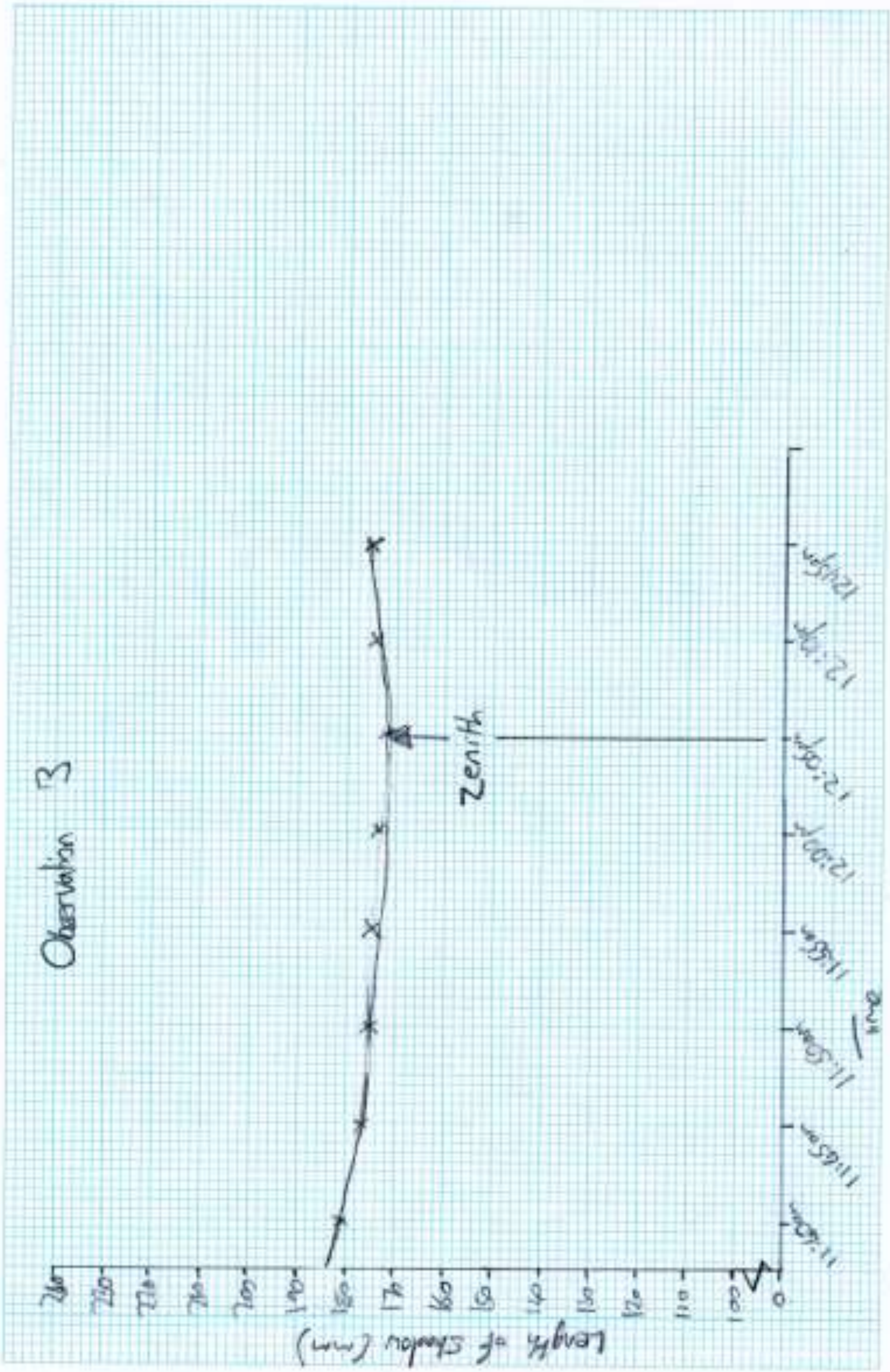
Observation 3 – 30th April

Antoniadi I   Lat.: 54^{O}N Long.: 2^{O}W

Time	Length of shadow
11:40	230
11:45	228
11:50	223
11:55	225
12:00	224
12:05	215
12:10	210
12:15	210


Observation 1
Zenith
Time
Length of Shadow (mm)


Observation 2
Zenith
Time
Length of Shadow (mm)


Observation 3
Zenith
Length of shadow (mm)
time

Analysis

Using my graphs I then calculated my longitude:

Observation 1 (26th March):

Zenith	12:05pm
Add Equation of Time	-5
Local Noon	12:00pm
Difference between Local Noon	0
Longitude	0

Observation 2 (27th March):

Zenith	12:15pm
Add Equation of Time	-5
Local Noon	12:10pm
Difference between Local Noon	10 mins
Longitude	2^{0} 30'W

Observation 3 (27th March):

Zenith	12:05pm
Add Equation of Time	+2
Local Noon	12:07pm
Difference between Local Noon	7
Longitude	1^{0} 45'W

Summary:

	Obs. 1	Obs. 2	Obs. 3	Average:
Longitude	0^{0}	2^{0}	1^{0}	**2^{0} 7'W**

Ignoring the anomalous result in Observation 1, I found that the my longitude was **2^{0} 7'W**.

Evaluation

Overall I think my observation went well. However there were a few problems I encountered along the way. I think my observation could have been improved by doing the shadow sticks on sunnier days, as the shadows were not very clear, and so my results may not be as accurate as I would have liked them to be.

I can show that my results were not perfect because the longitude I determined was 2^{o} 7'W whereas my actual longitude was 2^{o} 3'W. This is a 17% error as the longitude I found was 17% above the true longitude.

I also did not manage to do many observations as I did not have much time. This meant my averages may not have been as accurate as they would have been if I had done four or five observations

Commentary

Design Observations

Strengths:

- At the start of the section, the candidate explains some of the astronomical concepts which are relevant to this task. This is generally a good starting point for producing a clear Design Observations section.
- The candidate also attempts a short explanation of why they chose their particular times for observation.

Areas for improvement:

- Unfortunately, the candidate makes a couple of errors in explanation of astronomical terms at the start of the section. When the Sun reaches its highest point in the sky it is not necessarily at the observer's zenith or overhead point, especially in the UK where the Sun never actually reaches an overhead point, even at the summer solstice.
- In addition, reference to the ecliptic being 'tilted at 23½°' is incomplete as this should be 'tilted at 23½° to the plane of the Earth's equator'. In space, orbits and their planes can only ever be tilted relative to one another as there is no absolute 'level' to provide a reference, as on the Earth.
- As the candidate is attempting to explain ideas such as the apparent daily motion of the Sun and the tilt of the Earth relative to the plane of the Solar System, some diagrams would definitely have improved this section and may have alerted the candidate to the two errors before the work was finally submitted.
- Although the candidate has explained their choice of times for observation, they have not explained the Design of the observing programme in terms of choosing equipment or location. This is a serious omission.

Although the candidate has not mentioned it explicitly in this section of their report, one can infer some aspects of the design of their observational programme from the observations which were submitted. It is clear that they have devised and completed a broadly 'appropriate' number of observations at a suitable time of day. However, there are no details of the selection of site or equipment. In addition they have used only a limited range of astronomical terms and made some errors with their use.

Make Observations

Strengths:

- The candidate has taken a set of shadow length readings on three occasions, which must be regarded as something of a minimum for this task. They have also recorded a full set of observational details for this naked eye task, viz. date, time, location and seeing conditions and it is pleasing to see the use of the Antoniadi Scale rather than just general comments about the weather.

Areas for improvement:

- Graphs of solar altitude against time generally have a fairly flat minimum around local noon, making accurate assessment of the time of local noon difficult. Hence, many candidates record shadow lengths every minute for the 15 minutes or so before and after local noon, giving more densely spaced points and making the line of best fit and the position of the minimum easier to assess.
- Although three sets of results are adequate for the requirements of this task, a more accurate average value for longitude can be obtained with five or more sets of data. In particular, if one of the sets of readings proves to be

anomalous, being left with two reliable longitude estimates for the averaging process is clearly less than ideal.

The candidate has clearly collected observations giving adequate data for the task at hand and accompanied them with clear and accurate observational details.

Analyse Observations

Strengths:

- The candidate has clearly used the time of local noon, as assessed from the graphs, to calculate longitude on three occasions and then averaged three values, as presented in a clear summary table at the end of the section. The analysis which has been completed is therefore clearly shown.

Areas for improvement:

- As mentioned in the previous section, only having three sets of readings leaves the candidate in a rather precarious position should one of these sets be declared anomalous. In addition, there are several mistakes in this section.
- The term 'zenith' is once again used incorrectly in all three tables. The fourth row of each table is titled 'Difference from Local' which is not clear and the average of 2° and 1° is not 2° 7', as presented in the summary table which contains rounded-off data.

The candidate does present calculations and conclusions which address the task of measuring longitude. However, their use of astronomical knowledge and understanding is unclear and incorrect in several places.

Evaluate Observations

Strengths:

- The candidate has addressed one aspect of the Evaluate Observations section by quantitatively assessing the difference between their estimate of longitude and the actual value and presenting this as a percentage.

Areas for improvement:

- The candidate mentions observational difficulties to do with the exact assessment of the position of the tip of the shadow, particularly on days with light cloud but does not give any further details or explain what was done to address these problems. There is also no assessment of their likely impact on the final longitude figures.
- In addition, the candidate has not really addressed the area of suggesting improvements to the method employed. Apart from the very general suggestion of taking more readings, there are no specific, detailed suggestions. A practical strategy for helping to make the tip of the shadow easier to see would be an example which would have improved the candidate's work here.

The candidate has a supported statement about the accuracy of their data but no feasible suggestions for improvements or extensions to the work.

Example 3

Messier objects

Design

In 1771, French astronomer Charles Messier composed a list of astronomical bodies. He did so because he was a comet hunter, and was frustrated by things that resembled, but were not, comets. Originally there were only 45 objects in the list, but by the time Messier published the list, , it contained 103 objects. After the death of Messier and his assistant Mechain, others continued to add to the list.

Choice of Target Object:

The Messier Catalogue contains a wide variety of astronomical objects. The purpose of this observation is to obtain images of each of the several types o0f objects in the Messier such a galaxy, nebula etc,.. The objects I chose are:

		Example of:	Apparent Mag:
M42	The Great Orion Nebula	Emission Nebula	+4
M51	The Whirlpool Galaxy	Galaxy	+8.4
M1	The Crab Nebula	Supernova Nebula	+8.4
M43	De Mairan's Nebula	H-II Region	+9
M40	URsa Major double star	Double Star	+9.7

I checked on the robotic telescope's website to see when my chosen objects would be in the sky. I found that M42 and M43 were circumpolar from its location and the rest, M51 and M1, were in the sky most of the time, occasionally setting.

Choice of Observing Instrument:

Since most of my target objects have apparent magnitudes well below that visible to the naked eye, I will need to use some form of telescope to image them. With such faint objects, I will need toe nsure that my telescope has a suffiecntly large aperture. The connection between telescope aperture and the faintest magnitude which can be image is shown below:

Aperture (mm)	Faintest Magnitude Visible
6	7.5
8	8.2
51	12.2
70	13.1
102	14.2
127	14.6
152	15.2

203	15.7
254	15.9
279	16.1

As we can see from the above table, if I am going to image event eh faintest objects in my list of Target objects, I will need to use a telescope with an aperture of at least 51cm.

Choice of Location:

Although I have access to a telescope of 6” aperture, a major factor in the quality of my observations will be the seeing conditions. Where I live in Anytown, UK has an average of 175 clear nights per year. The Bradford Robotic Telescope is sited in the Canary Islands where they can expect over 300 clear nights per year

I then logged on to the robotic telescope site and submitted several jobs for each object, with a different exposure time for each one, so that I would most likely get a good image back for each one.

Observations

Observation #1: The Whirlpool Galaxy (M51)

Seeing Conditions: Antoniadi I

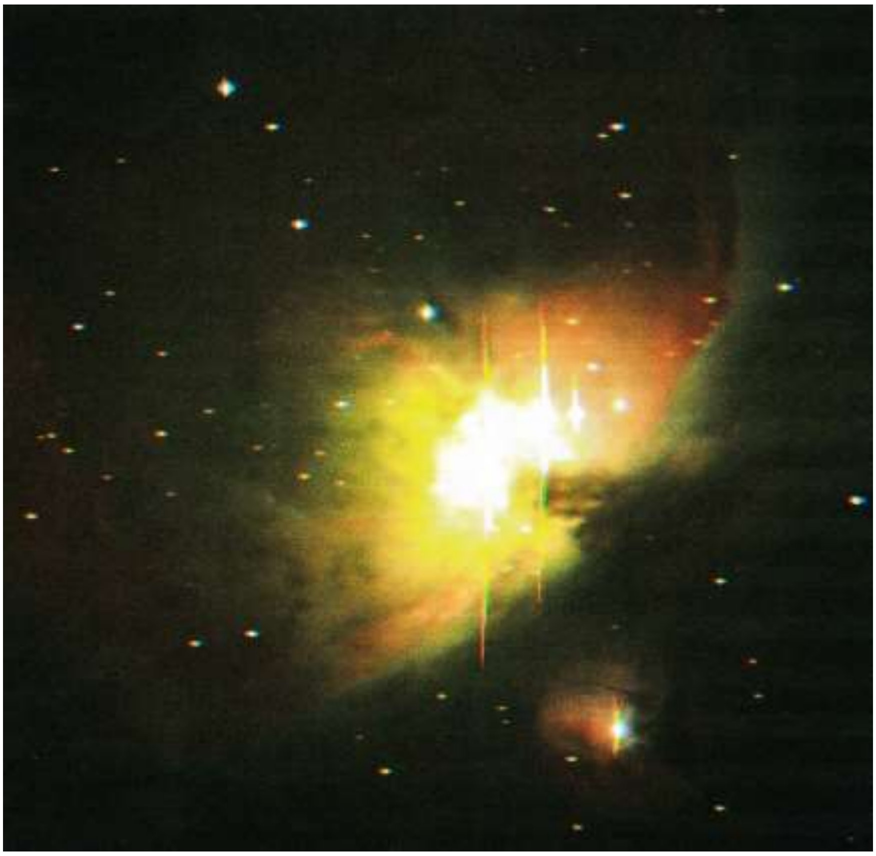
Time: 01:36 am on 6th April 2011

Observation #2: The Crab Nebula (M1)

Seeing Conditions: Antoniadi I

Time: 23:56 am on 29th March 2011

Observation #3: The Great Orion Nebula (M42)



Seeing Conditions: Antoniadi I

Time: 22:27 am on 12th April 2011

Observation #4: De Mairan's Nebula (M43)

Seeing Conditions: Antoniadi I

Time: 22:40 am on 12th April 2011

Analysis

In the Analysis section I am going to compare the images from the robotic telescope with some images taken by the Hubble Space Telescope.

Observation #2: The Crab Nebula (M1)


Hubble Space Telescope image © NASA

The HST image is better than my robotic telescope image due to a number of factors. Firstly, the aperture on the HST is 2400mm whereas it is only 400mm. This allows for more detail nit he image as the wider lens can take in more light. Secondly, the magnification on the HST is much greater than from my robotic telescope, so a more in-depth view of the subject can be taken.

Thirdly, the HST is in space whereas my robotic telescope is ground-based. This means that the HST does not get interference from the atmosphere (eg clouds etc). Finally the HST is maintained by NASA so more funding can be put into technology, hardware and personnel etc.

Observation #3: The Great Orion Nebula (M42)


Hubble Space Telescope image © NASA

The HST image is, again, better than the robotic telescope image. This is most importantly down to the fact that the aperture of the HST is 2400mm, as mentioned before, whereas the robotic telescope aperture is only 400mm. Also, the HST's magnification is bigger than that of my robotic telescope, allowing more detail to be seen 'close up'.

In addition, my robotic telescope image was accidentally over-exposed when photographing M42, unlike the HST image. As mentioned before, the HST is a satellite and isn't affected by the atmosphere, unlike my robotic telescope.

Evaluation

Overall I think my observations went quite well. However, as I was using a robotic telescope, controlled over the internet, there were certain problems encountered.

Firstly, the robotic telescope had some technical problems one weekend and was unable to take my images. Secondly, it was slow to take some of my photographs (possible because they were not visible straight away).

I also over-exposed a couple of my pictures M42 and M43) and you can see some 'light-bleeding. I could have improved the observations by decreasing the exposure time on these two shots. I could also have ordered my pictures sooner so that I had time to get more images.

If I did this project again I could have looked in more detail at the types of objects within the Messier catalogue and tried to find an example of each one. For instance, there are several types of galaxy (Spiral, Elliptical, Barred Spiral and Irregular). I could also have covered each kind of nebula by including a planetary nebula.

It would also have been good to produce images of a particular member of the Messier catalogue with different powers of telescopes from a small refractor up to the BRT.

Commentary

Design Observations

Strengths:

- The candidate has clearly arrived at an effective system for using the robotic telescope to obtain images of their selected Messier objects, as explained in this section. They have also used several astronomical terms correctly in this section.
- Instead of simply describing how the observations were taken, the candidate has attempted to provide a justification for their choice of target object, observing instrument and location. They have made a significant attempt at using detailed astronomical concepts such as aperture, magnitude and the various types of astronomical objects in the Messier Catalogue.

Areas for improvement:

- The introductory paragraph about the origin and history of the Messier Catalogue is interesting and provides an effective introduction to the report. As it stands, it does not contribute significantly to the marks awarded for the section but it does provide a (missed) opportunity for the candidate to use a number of astronomical terms.
- It is not clear from where the figures relating aperture and magnitude are derived. This section would also be improved by consideration of a range of optical instruments, each listed with the faintest magnitude that they can image.
- A summary paragraph to the Design section would also help here, selecting the robotic telescope as a result of several factors, including aperture and location.

The candidate has used an effective process for obtaining images. They have attempted to consider some alternatives in terms of target object, observing instrument and location. They have made use of some detailed astronomical knowledge in deciding between these alternatives.

Make Observations

Strengths:

- The candidate has produced some reasonable images of their target objects, with some showing some useful detail. They have clearly mastered the software and facilities of their chosen robotic telescope and made sound use of its capabilities. The candidate has included some of the important observational details which accompany their images.

Areas for improvement:

- This section would also have been improved by the adoption of some kind of 'theme' to the observations, such as attempting to get an image of each of the major types of object in the Messier Catalogue (galaxy, nebula, cluster, etc....) or trying to image objects with a range of magnitudes, etc. The adoption of such a 'theme' would make it much easier to structure the Design, Analyse and Evaluate Observations sections of the images.
- A significant and unnecessary omission is any details of the location or instruments (telescope and camera) used to produce each image. It is essential that candidates (for all tasks) include the date, time, location, seeing and weather conditions and instrument details with every one of their observations.
- Some of the images contain evidence of overexposure towards the centre of their target objects and some 'bleeding' from the brightest pixels.

The candidate has produced some reasonable images but has not provided the full set of observational details with their observations.

Analyse Observations

- Unfortunately, almost all of the material presented under the 'Analysis' section is, in fact, Evaluation.
- In fairness to the candidate, the Analysis section of this task is not straightforward as the observations generally generate no numerical data for analysis. In this section the candidate should be describing the process by which they processed their raw image files to arrive at the final images printed in their report or commenting in detail on the features within each Messier object that can be seen in their images.

The lack of any sustained analytical commentary leaves this work inadequate in this section.

Evaluate Observations

Strengths:

- The candidate has provided some useful comparison images against which to evaluate their observations. The origin of these comparison images is acknowledged. The candidate has clearly understood the effect of the Hubble Space Telescope's larger aperture and unique position above the atmosphere in terms of producing its superior images. The candidate has also attempted to provide some strategies for obtaining an improved set of images.
- The candidate has correctly identified the need for repeats and a longer observing period with this task.
- At the end of the Evaluation section the candidate has made some effective and specific suggestions for extending and improving the work.

Areas for improvement:

- Firstly, the candidate has printed their images and the Hubble Space Telescope images at very different sizes. For example, taking the first pair of images, the candidate's image shows the nebula only about 1 cm across, whereas the Crab Nebula in the HST image is around 5 cm across. If the two objects were shown at the same size on the paper (i.e. enlarging and cropping the candidate's image), then this would show much more clearly the large difference in central detail of the Hubble image. Printed to the same size as the Hubble image, the candidate's image would be little more than an outline of the nebula.

By comparison with NASA images, the candidate has provided some useful (although not quantitative) evaluation of their observations, invoking some astronomical terms in the process. They have offered some specific suggestions for improvement and extension.

Observation Statement

As explained in the Specification, an Observation Statement must be completed and signed for each candidate, confirming their successful completion of their Observational Tasks.

Pearson

Appendix 5: Observation Statement

Pearson Edexcel Level 1/Level 2 GCSE (9–1) in Astronomy	1AS0
Centre name:	Centre number:
All candidates must carry out one unaided and one aided observation throughout the course of this qualification.	
Observation work	**Number of students**
Unaided Observation	
Aided Observation	

Teacher declaration

I declare that:

i. all candidates have completed one unaided and one aided observation, and

ii. the work submitted for assessment has been carried out without assistance other than that which is acceptable according to the rules of the specification.

Teacher name:			
Teacher signed:		**Date:**	

Head teacher declaration

I declare that the observation work recorded above has been carried out in accordance with the Pearson Edexcel Level 1/Level 2 GCSE in Astronomy (9–1) observation work requirements.

Each candidate has made a contemporaneous record of:

i. the work that they have undertaken during these observations, and

ii. the knowledge, skills and understanding which that candidate has derived from those observations.

Head teacher name:			
Head teacher signature:		**Date:**