AC 2018 Post Mortem

Project Round Videos

Most attempted questions

- JNR: 3 attempted Question 9 (What are some of the weirdest stars out there?); wide variety of questions were attempted generally.
  - On <u>average</u>, Q9 was not answered well across Junior and Senior.
  - All but one mentioned HV 2112 : none actually mentioned <u>**observable characteristics**</u> other than its membership to an hypothetical class of objects.
  - Distinguishing teams here had <u>**good content management**</u>: e.g. mentioned key characteristics of Przybylski's Star but deferred further discussion of reasons to the live segment

- SNR: Q17 (Why have we not found life outside of Earth?) which met varying degrees of success.
  - Most did fine, though a few conceptual errors were spotted

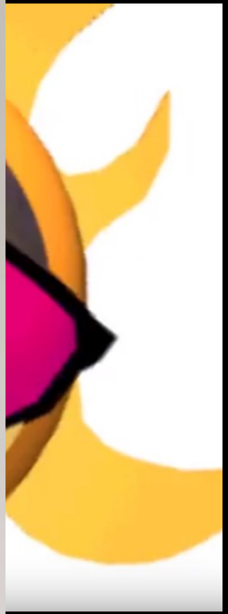
JNR General Comments

- Teams generally did okay but lacked the ‘wow’ factor
  - Some videos were droning; demonstrated little effort for project.
- Please manage your background audio well.
  - Subtitling helps a LOT
- Fast-forwarding of video means BOTH content and delivery suffer.
- Keep content **family friendly**
  - If not handled well, father/mother scenes can be quite disturbing
  - Gory scenes are also not quite palatable to the judges.
- In future, we’ll **limit the maximum upload size**

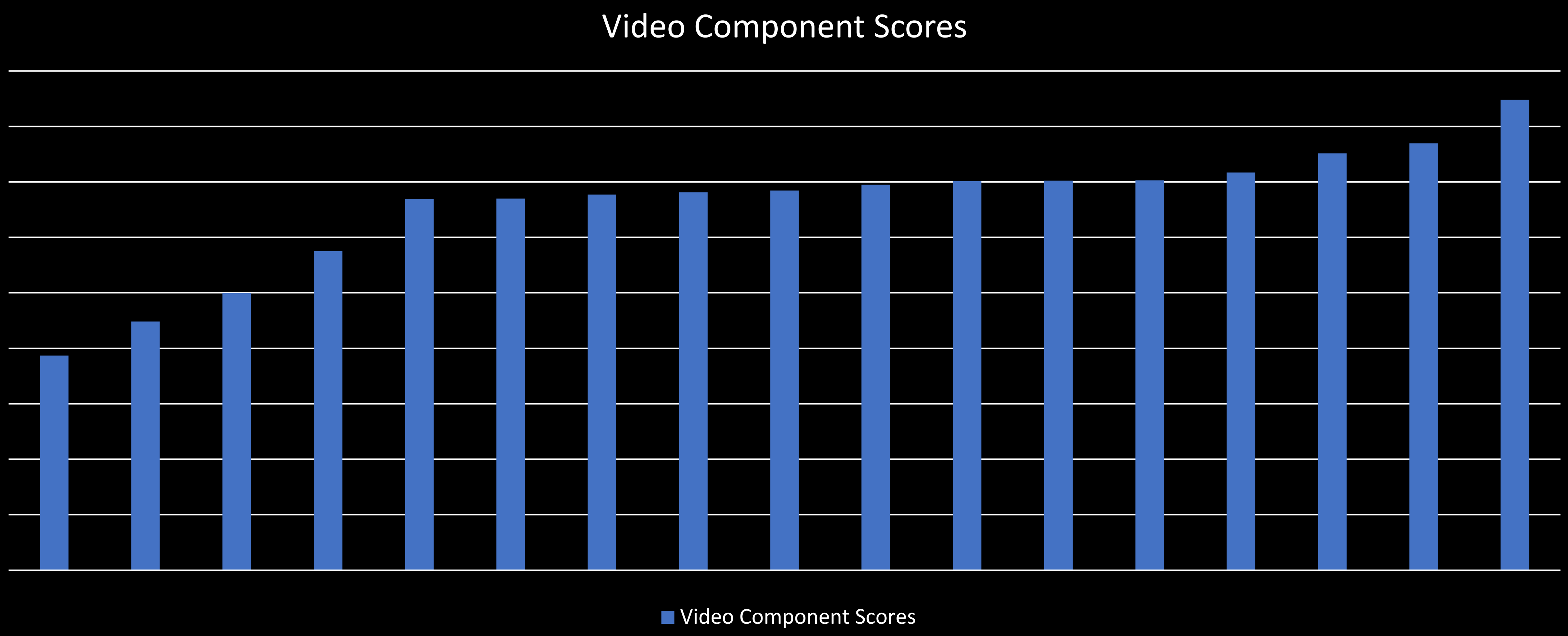
SNR General Comments

- SNRs performed generally better with better scores; more effort was shown in the preparation of the video.
- Some videos really went all out to be ELI5 and greatly impressed the judges with their creativity.
- **Content management** is critical: some had very heavy content which made it rather droning
- Side note: do control usage of memes and inside jokes
  - The video ultimately is targeted at a general audience.

Unfortunate examples of inside jokes

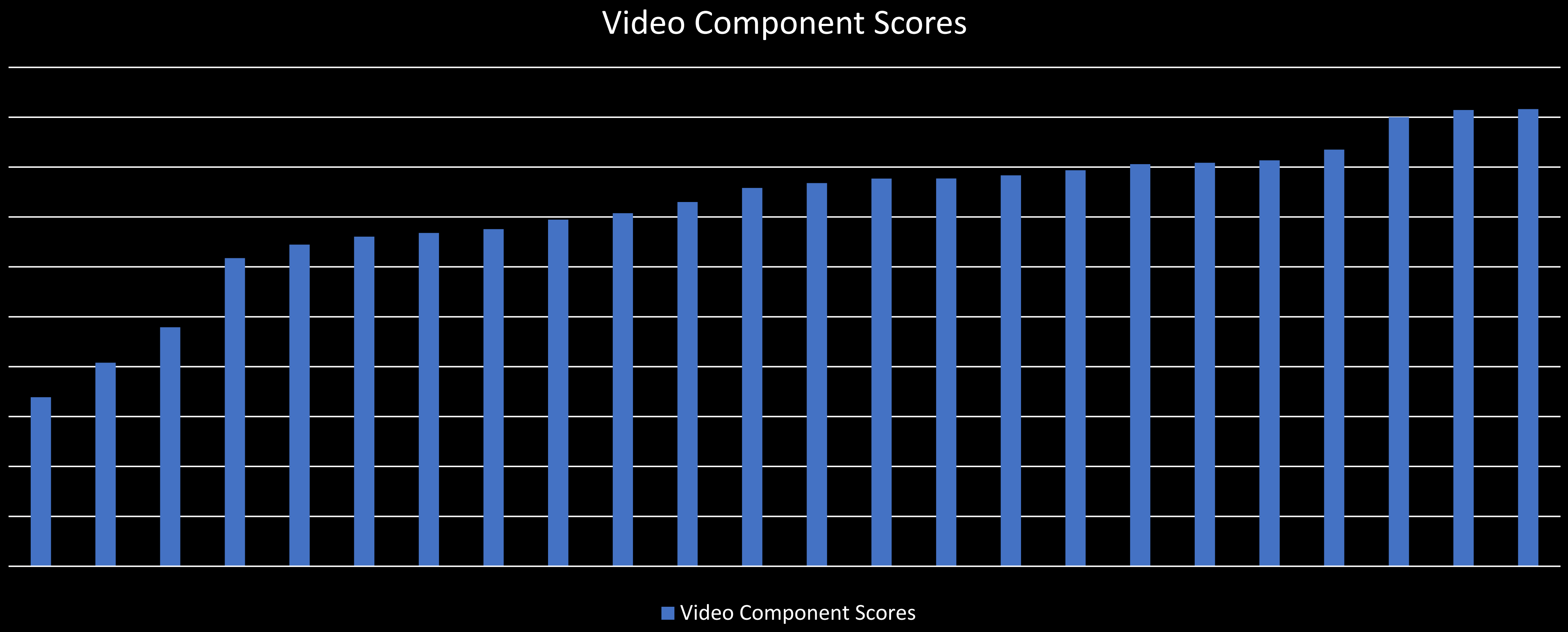


JNR Project Round Video Scores



Mean = 65.76, Standard Deviation = 11.7

SNR Scores



Mean = 71.98, Standard Deviation = 14.62

MCQ

This year’s “100%”

- Q1: Which planet has the most circular orbit?
  - Scan the table and find the lowest value of orbital eccentricity!

- JNR: 77.5%
- SNR: 89.8% (Easiest Question)

JNR MCQ

Easiest Question: **Q22** (87% correct)

- Arrange statements about the life-cycle of stars in chronological order

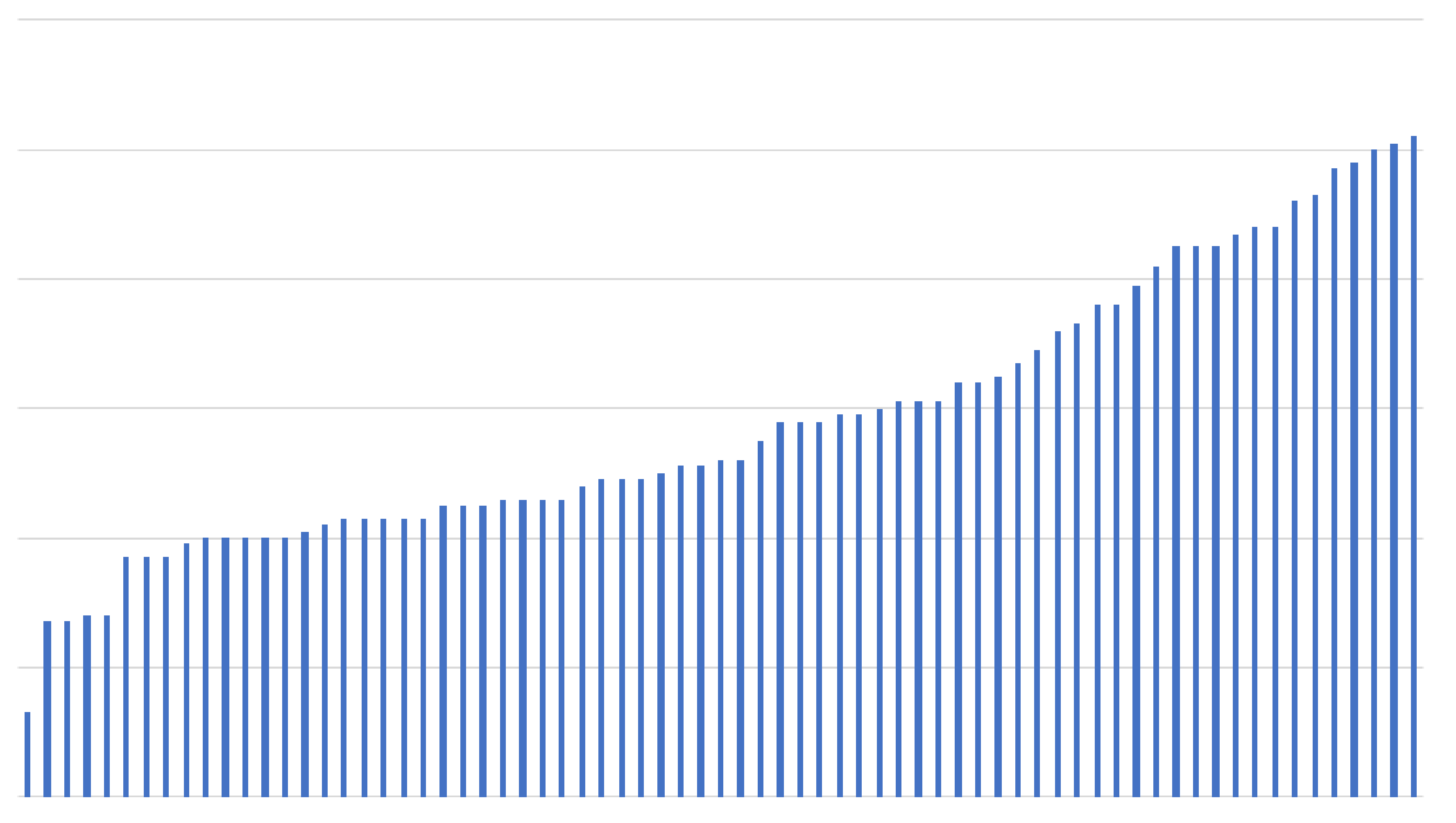
Most incorrect answers: **Q16** (10% correct)

- Consider the following statements about TRAPPIST-1…
- Planets in the HZ do not always have liquid water!

Most blanks: **Q38**

- What is the angle of maximum elongation for Venus from Mars?

JNR MCQ Score Distribution



Mean = 58, Median = 52, Standard Deviation = 20.8

SNR MCQ

Second Easiest Question: <u>**Q45**</u> (87% correct)

- Consider statements regarding the "smell" of the Milky Way

Most incorrect answers: <u>**Q11**</u> (22% correct)

- Consider the following statements about a non-rotating black hole
- Common error is assuming all black holes have a EH density > Earth.
- But $\rho = \frac{M}{V} \rightarrow \rho \propto \frac{M}{r^3}$
- Further, note that $r = \frac{GM}{c^2} \rightarrow r \propto M$
- Combining the two: $\rho \propto \frac{1}{M^2}$ meaning that <u>EH density decreases rapidly as mass increases</u>

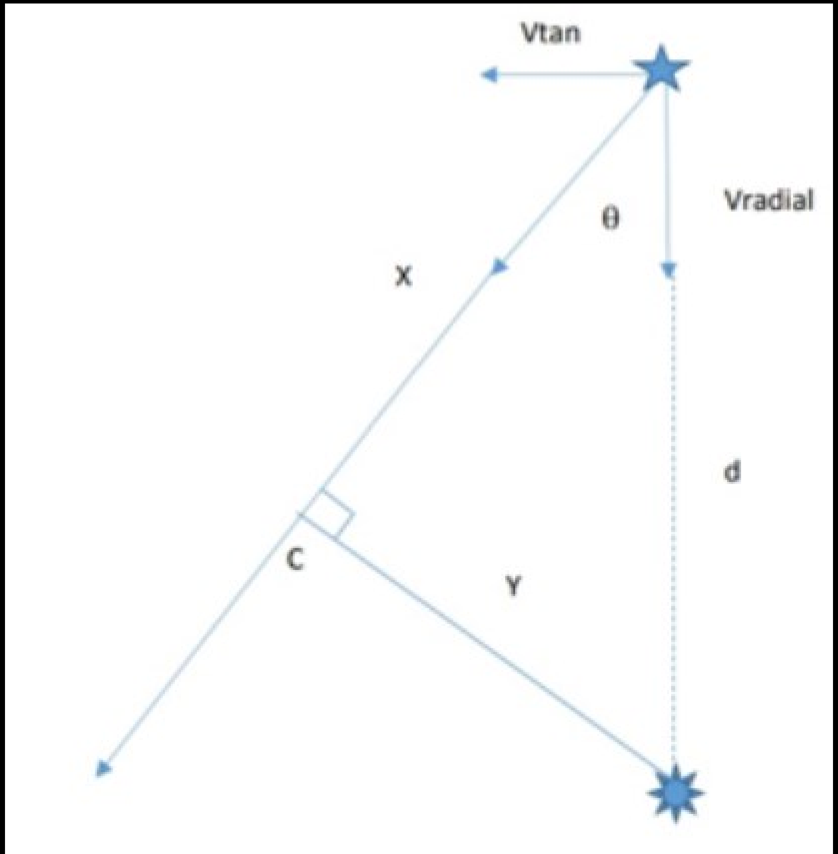
SNR MCQ

Most blanks: **Q12**

- How long will it take for Barnard's star to reach its closest approach to the Sun?

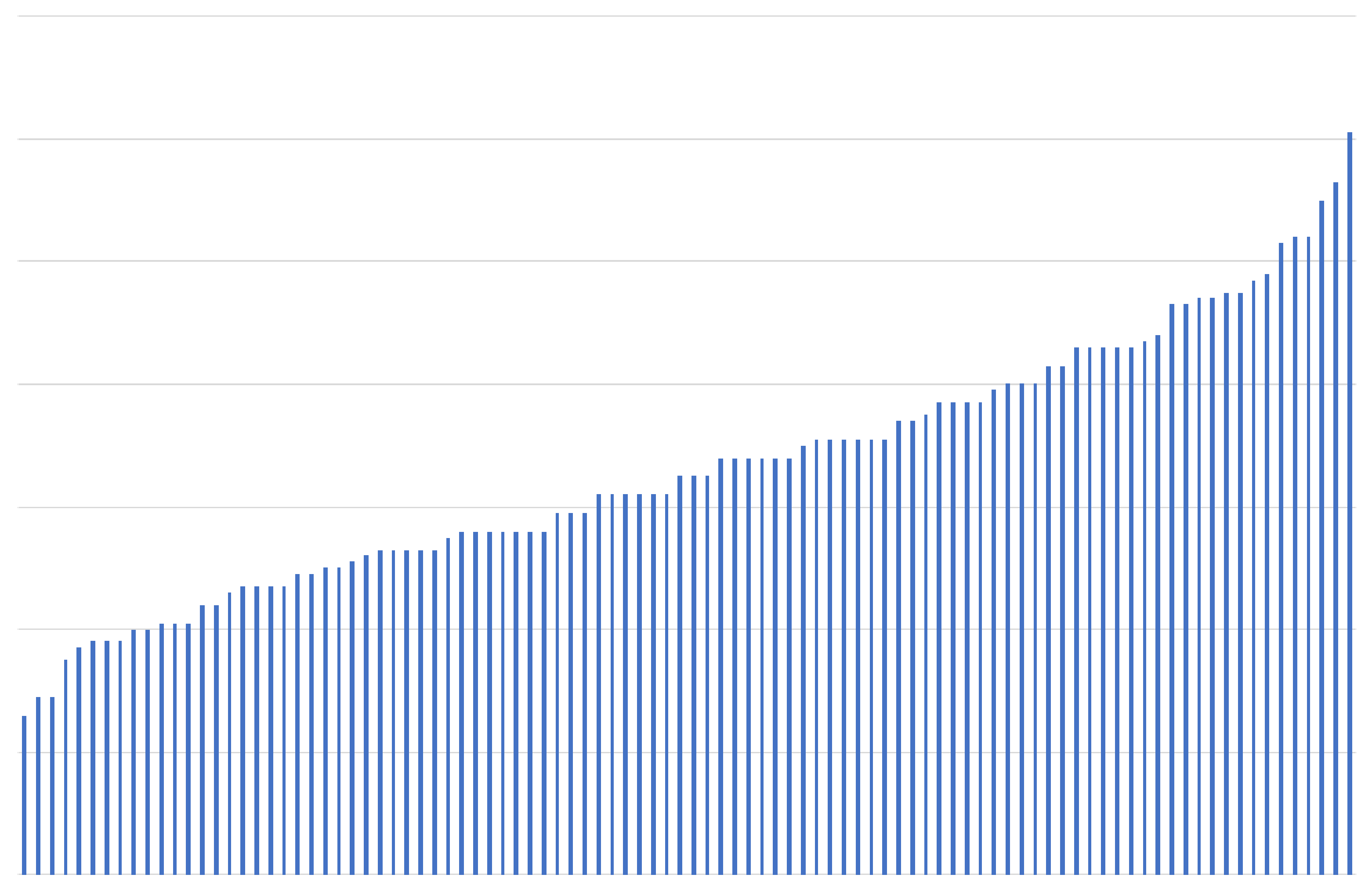
(Hint: Drawing a diagram of the situation will help.)

- Is this question really so scary if we gave you this diagram?



Moral of Story: PLEASE DRAW DIAGRAMS!!!

SNR MCQ Score Distribution



Mean = 66.2, Median = 65, Standard Deviation = 20.5

JNR DRQ

Q2: Planetary Analysis

JNR Q2 – Planetary Analysis

Idea:

- Wants to set an open-ended question worth 6 points at the end.
- Bomb some random relevant concepts
- Expand on the concepts

Expectation vs Reality

JNR Q2 – Planetary Analysis (Part 1)

(i) [1 point] We tend to assume that one primary heat source for a planet a few billion years after the formation of the star system is via radioactive decay. Briefly explain why this assumption is valid.

Common Answers:

- Talked about the origin on radioactive elements (no time comparsion)
- Did not talk about this assumption, i.e, why radioactive decay **<u>is a primary source of heat after a few billion years</u>**

JNR Q2 – Planetary Analysis

(iii) [2 points] Determine the total energy released from the entire chain of radioactive decay of ONE uranium-238 nuclide, and show that it is approximately 7.9×10^{-12} J.

Only a few teams got it right **even though a lot of hints are provided in the Appendix!**

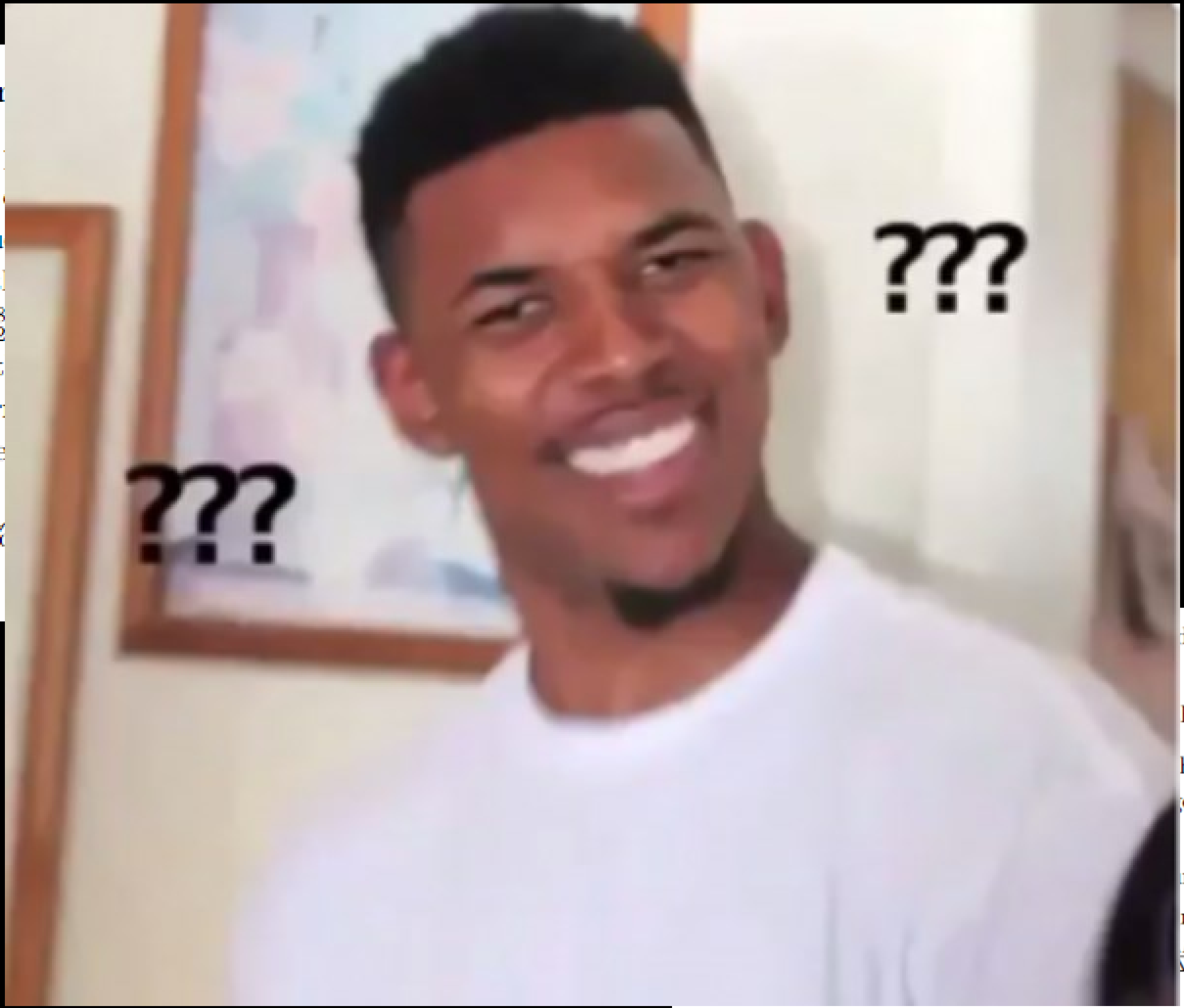
JNR Q2 – Planetary Analysis (Part 2)

Part 2: Planetary Thermody

To analyse the thermodynamics of a
as an example. Beneath the surface
the radioactive decay of unstable nu
by $^{232}_{90}$Th is approximately equal to t
detectors can detect the decay of $^{238}_{92}$

Hence, the power generated by t
It has been determined that the cur
that the prefix T here is Tera and re

The half-life of uranium-238 is
that uranium made up 3.4×10^{-6}%
approximately 4.5 billion years ago.



d by the radioactive decay of $^{238}_{92}$U is approximately

his question into solving multiple mini questions.

he mass of the Earth when it was first fully formed
o. What is the mass of uranium now? Consider

m nuclei, N_0, are there now?
ılate the power generated from radioactive decay?
$\frac{N}{\Delta t}$, and E for the decay of a nuclide all relate to

Points will be awarded for solving the mini-questions!)

Little did you know ....

JNR Q2 – Planetary Analysis (Part 2)

To analyse the thermodynamics of a planet, we will try to illustrate the concepts by using Earth as an example. Beneath the surface of the Earth, radiogenic heat is being generated mainly by the radioactive decay of unstable nuclides such as $^{40}_{20}$K, $^{238}_{92}$U, and $^{232}_{90}$Th. The power generated by $^{232}_{90}$Th is approximately equal to that of $^{238}_{92}$U, and is twice of that of $^{40}_{20}$K today. Geoneutrino detectors can detect the decay of $^{238}_{92}$U and $^{232}_{90}$Th, but are unable to detect the decay of $^{40}_{20}$K.

Hence, the power generated by the decay of $^{40}_{20}$K is being detected by other similar means. It has been determined that the current total heat flux from Earth to space is 44.2 TW. Note that the prefix T here is Tera and represents 10^{12}.

(iv) [3 points] Show that the power generated by the radioactive decay of $^{238}_{92}$U is approximately 10 TW.

(v) [1 point] Hence, show that the total power generated by the radioactive decay of $^{40}_{20}$K, $^{238}_{92}$U, and $^{232}_{90}$Th is approximately 25 TW.

Ans: 10 x 2.5 = **25**

Schools were too demoralised to look for marks that are easy to score!

An exam skill that will be useful for exams in general!!

JNR Q2 – Planetary Analysis (Part 3)

Characteristic of Kepler-90	Value
Spectral type	G0V
Distance from Earth	2545 ly
Apparent magnitude V	+14
Absolute magnitude (M_V)	+4.3
Mass	$1.2 M_{\odot}$
Surface temperature	6080 K
Age	Approx. 2 billion years

(x) [1 point] Show that the luminosity of Kepler-90 is approximately 7.28×10^{26} W.

JNR Q2 – Planetary Analysis (Part 3)

(x) [1 point] Show that the luminosity of Kepler-90 is approximately 7.28×10^{26} W.

Relationship between Luminosity and Absolute Magnitude	$\frac{L_1}{L_2} = 10^{\frac{M_2 - M_1}{2.5}}$

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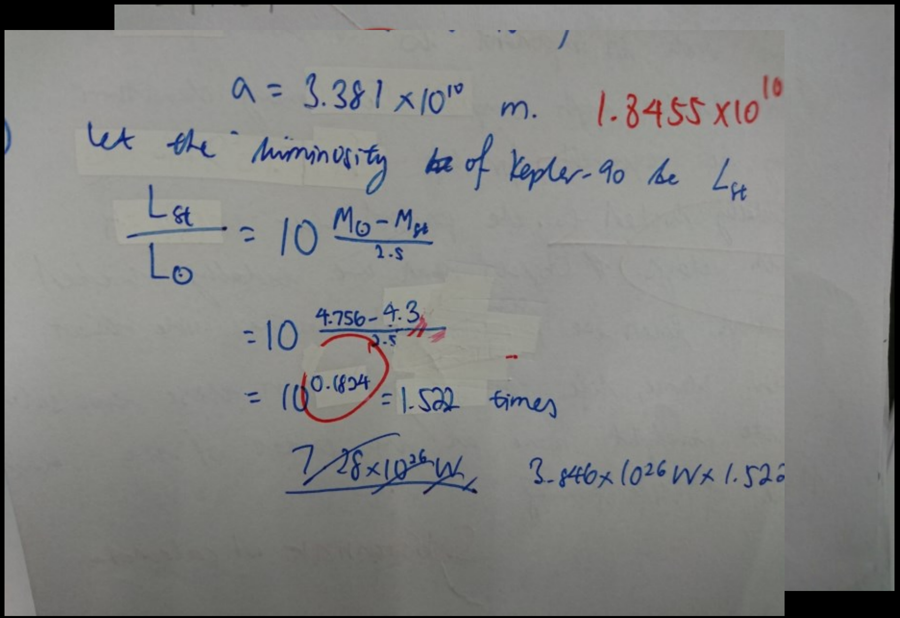

JNR Q2 – Planetary Analysis (Part 3)

(xi) [2 points] Show that the surface temperature of Kepler-90i is ~~768 K.~~

929 K

No one voiced out the error in the surface temperature.
Answer should be 929 K (Only two teams got the exact 929 K, other terms with the correct method will still be given the full 2 points)

JNR Q2 – Planetary Analysis (Part 3)

(xii) [6 points] With reference to any of the concepts mentioned in the previous parts of this question, the characteristic data of Kepler-90, and its orbiting planet Kepler-90i, discuss the probability of life on Kepler-90i.

In your answer, you should support your argument with reference to relevant calculation(s) and/or theory. You should include at least 2-3 points/arguments (with hopes of scoring more than half of the marks allocated for this question).

Max score here: <u>**2**</u> out of 6

- Most that attempted this part of the question got the most obvious point, high surface temperature
- Albedo is accepted
- No one supported other types of answer with calculations.

JNR Q2 – Planetary Analysis (Part 3)

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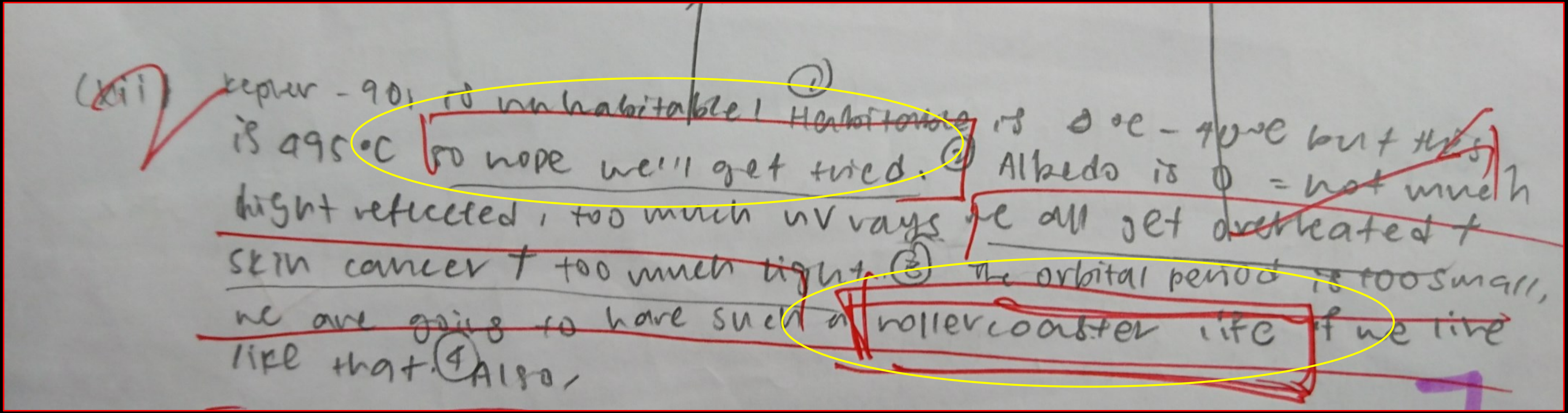

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Solution. Arguments against:

- This temperature is probably too high for water to exist in liquid state at Earth's atmospheric pressure.
  - An improvement of this argument would be that this calculation assumes the lack of atmosphere. With the presence of an atmosphere, a requirement of habitability to shield against the magnetic field from Kepler-90, this will further increase the temperature of the surface of Kepler-90i. These two factors further support the fact that Kepler-90i would not have a chance of life. (Note: This counts as another argument supported by theory.)
  - Another improvement of this argument that is closer to its star than Earth would be from its own star (as seen from its semi-major axis). For an inner planet, the main determinant of temperature is solar irradiation. Hence, a closer planet would mean that the value of surface temperature obtained would be quite accurate, further supporting the fact that Kepler-90i would not have a chance of life with such a temperature.
- The close distance of Kepler-90i from its star Kepler-90 implies strong solar wind from its host star. If the planet Kepler-90i is rotating at a slow rate, this generates a small protective magnetosphere which cannot prevent the strong solar wind from stripping off the atmosphere. Hence, it might be possible that Kepler-90i is left without its atmosphere and exposed to solar radiation, thus it is unsuitable for life to thrive in.
- We can determine the possible atmospheric composition of Kepler-90i.
  The escape velocity of particles is given by $v_e = \sqrt{\frac{2GM}{R}}$. For simplicity, let us use the root-mean-square speed of the particles $v_{\text{rms}} = \sqrt{\frac{3RT}{M_r}}$.
  A rule of thumb is that the particles must have approx. less than 1/6 of the escape velocity of the particles to be retained in the atmosphere over the age of the solar system (4.5 billion years).
  Hence, for the particles to be retained in the atmosphere, $v_{\text{rms}} < \frac{1}{6}v_e$. Solving for the critical molar mass, $\frac{3RT}{M_r} < \frac{2GM}{36r}$, i.e. $M_r > 23.0\,\text{g}\,\text{mol}^{-1}$.
  This is higher than the Mr of carbon atoms. Thus, carbon/oxygen in its element form OR water molecules ($M_r = \text{g}\,\text{mol}^{-1}$) might not be retained. (Note: Other molecules such as methane that is hypothesised to be essential, also fall out of the required M_r range as calculated.)

JNR Q2 – Planetary Analysis (Part 3)

(xii) [6 points] With reference to any of the concepts mentioned in the previous parts of this question, the characteristic data of Kepler-90, and its orbiting planet Kepler-90i, discuss the probability of life on Kepler-90i.

In your answer, you should support your argument with reference to relevant calculation(s) and/or theory. You should include

more than half of the marks alloca

Arguments for:

- Though the conditions are extreme, extremoph
extreme conditions. Hence it is not totally impo
find life on Kepler-90i.

- We can proceed to calculate the density of the planet, and see that

$\frac{\rho_K}{\rho_\oplus} = (\frac{M_K}{M_\oplus})(\frac{R_\oplus}{R_K})^3$ = 1.14. Hence, the density of Kepler-90i is approximately that of the density of Earth, indicating a terrestrial/rocky origin. Coupled with the large mass of the planet and the young age of the star system (larger mass than Earth and younger age than our solar system), it is likely the interior of the planet has more than enough internal heat for tectonic and volcanic activities to occur on its surface. (1 mark - Calculation)

  - ➔ This contributes to the creation of an atmosphere via outgassing to protect life from magnetic fields from Kepler-90/acts as a thermostat by negative feedback via the carbonate-silicate cycle (carbon cycle, or any other similar terminologies). (1 mark - Theory)
  - ➔ The ongoing tectonic activities can create continents, and becoming a crucial driver of evolution and biodiversity for complex life on Kepler-90i (1 mark - Theory)

Q3: Story of a Star Strife Engineer

JNR Q3 – Story of Star Strife Engineer

A DRQ Question on Star Wars (Credit: Jian Ming for the storyline)

- Mixture of random topics

Expectation vs Reality

JNR Q3 – Story of Star Strife Engineer

Expectation:

Higher score obtained in Part 3 than Part 1

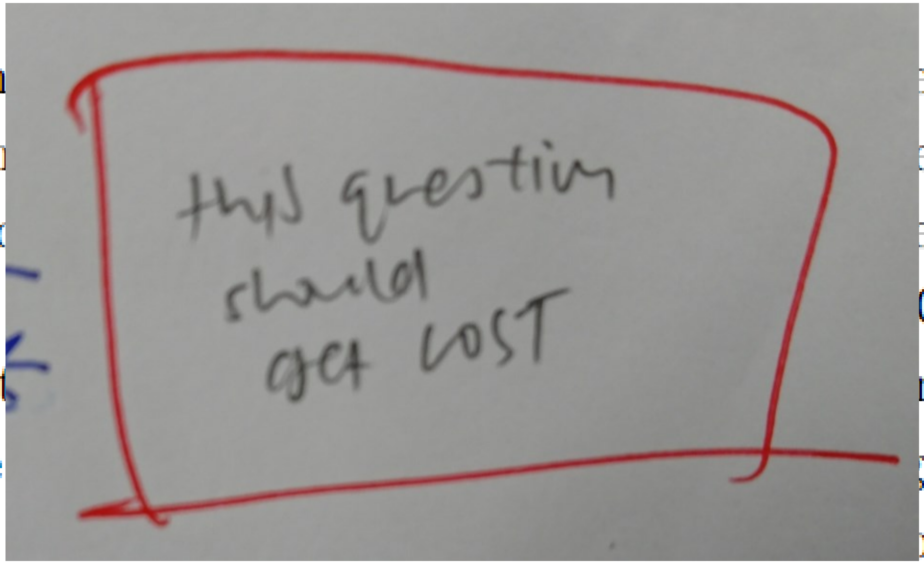
Reality:

Higher score obtained in Part 1 than Part 3

JNR Q3 – Story of Star Strife Engineer

Part 1: Not Just LOST, but Very LOST! **(Sub-total: 7 points)**

You are an engineer of th ... ent of folly, you dropped your spanner down the hole th ... et. Knowing that losing your spanner is punishable by ... ery Low-Orbit Satellite Transport system (Very LOST) ... OST is a mass rapid transport system that uses low-orbit ... rt people across the surface of the planet. This satellite ... htly above the surface of the planet, so slightly that it ... bit is the radius of the planet. Surprisingly, this planet has a uniform density, unlike that of Earth.



JNR Q3 – Story of Star Strife Engineer

(i) [1 point] Show that the time it would take for Very LOST to transport you from one side to the planet to the other side of the planet is given by $\tau = \pi\sqrt{\frac{R^3}{GM}}$.

(Note: This is also the time taken for the spanner to fall from the entrance of the hole to the exit of the hole. Thus the Very LOST is able to save your life!)

Figure 5: Pictorial representation of the journey of the spanner and Very LOST.

- Use Kepler's 3rd Law: $T^2 = \frac{4\pi^2}{GM}a^3, \tau = T/2$, simplify and get ans.

JNR Q3 – Story of Star Strife Engineer

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(Note: This is also the time taken for the spanner to fall from the entrance of the hole to the exit of the hole. Thus the Very LOST is able to save your life!)

Figure 5: Pictorial representation of the journey of the spanner and Very LOST.

- Answers that we get:

=> Proof by verification: Sub in values, prove LHS = RHS .... But τ = ?????

JNR Q3 – Story of Star Strife Engineer

(iii) [3 points] Show that the difference in period of LOST and your space shuttle ΔT is given by

$$\Delta T = \frac{3\pi \Delta r}{v}.$$

(Hint: Try to obtain an expression that contains $\left(1 + \frac{\Delta r}{r}\right)^{\frac{3}{2}}$. Then, since $\Delta r \gg r$, hence $\frac{\Delta r}{r}$ is small. A binomial expansion from the Formula Booklet might help at this point.)

- This was surprisingly well done! (For schools who got the first two points, they are able to get this 3 marks)

JNR Q3 – Story of Star Strife Engineer

On the space shuttle, the fear of not being able to catch the spanner with your Super Advanced Magnet (SAM) strikes you. Your plan is to wait for the spanner (which can be assumed to be at the same orbital radius as LOST), your space shuttle, and the planet to form a straight line to activate your SAM. However, being an engineer yourself, you start to worry and attempt to calculate the time at which such an alignment will next occur, if you by any chance happened to miss the upcoming perfect alignment.

(iv) [1 point] Explain why τ satisfies the equation

$$\frac{v\tau}{r} - \frac{(v - \Delta v)\tau}{r + \Delta r} = 2\pi.$$

- Did not clarify what τ was. (Required time to re-establish the alignment)

JNR Q3 – Story of Star Strife Engineer

(iv) [1 point] Explain why τ satisfies the equation

$$\frac{v\tau}{r} - \frac{(v-\Delta v)\tau}{r+\Delta r} = 2\pi.$$

Solution. The spanner, being faster than your space shuttle, would have to cover an extra 2π rad to re-establish perfect alignment.

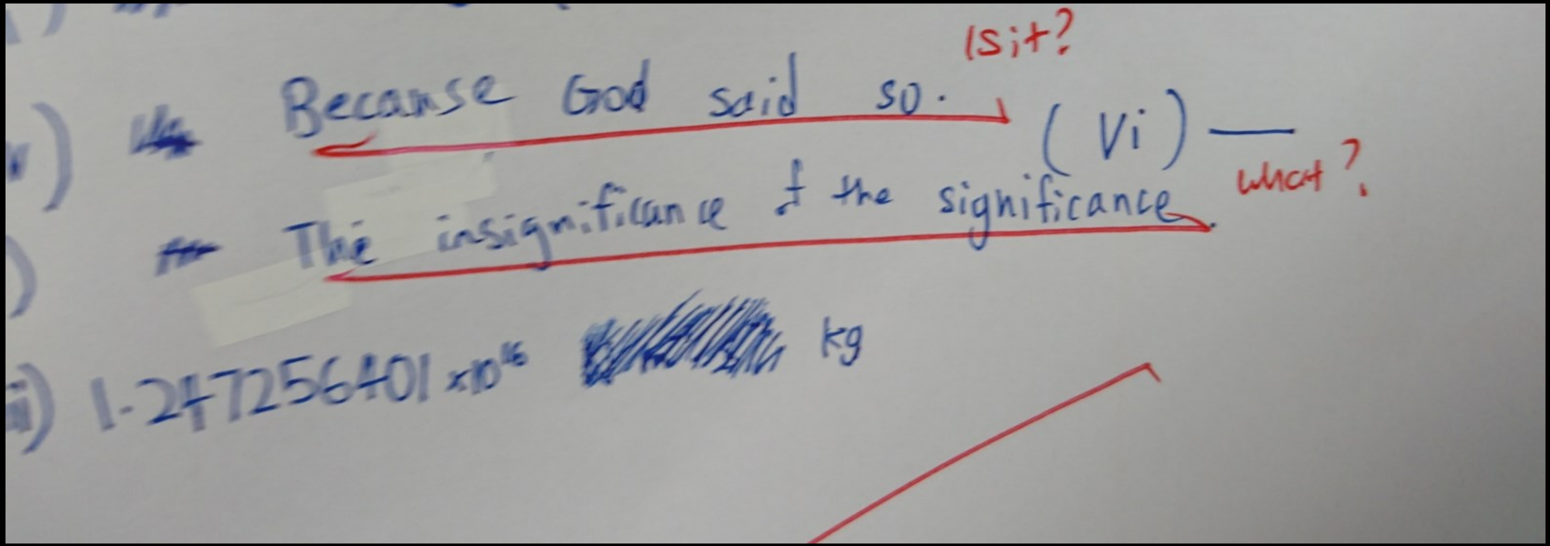
The first term represents an angular distance of $2n\pi + 2\pi$ covered by your spanner, and the second term represents an angular distance of $2n\pi$ covered by your space shuttle, where n is an integer. This therefore gives rise to the equation above.

JNR Q3 – Story of Star Strife Engineer

(v) [1 point] The above expression simplifies to $\tau = \frac{2\pi r}{\Delta v + \frac{v \Delta r}{r}}$. By binomial expansion, this can be further simplified to

$$\tau = \frac{T^2}{\Delta T}.$$

What is the significance of this expression?



JNR Q3 – Story of Star Strife Engineer

(v) [1 point] The above expression simplifies to $\tau = \frac{2\pi r}{\Delta v + \frac{v \Delta r}{r}}$. By binomial expansion, this can be further simplified to

$$\tau = \frac{T^2}{\Delta T}.$$

What is the significance of this expression?

Solution. Since $T^2 \gg \Delta T$, $\frac{T^2}{\Delta T}$ is very large. Therefore, this perfect alignment probably would only re-occur after a very long time.

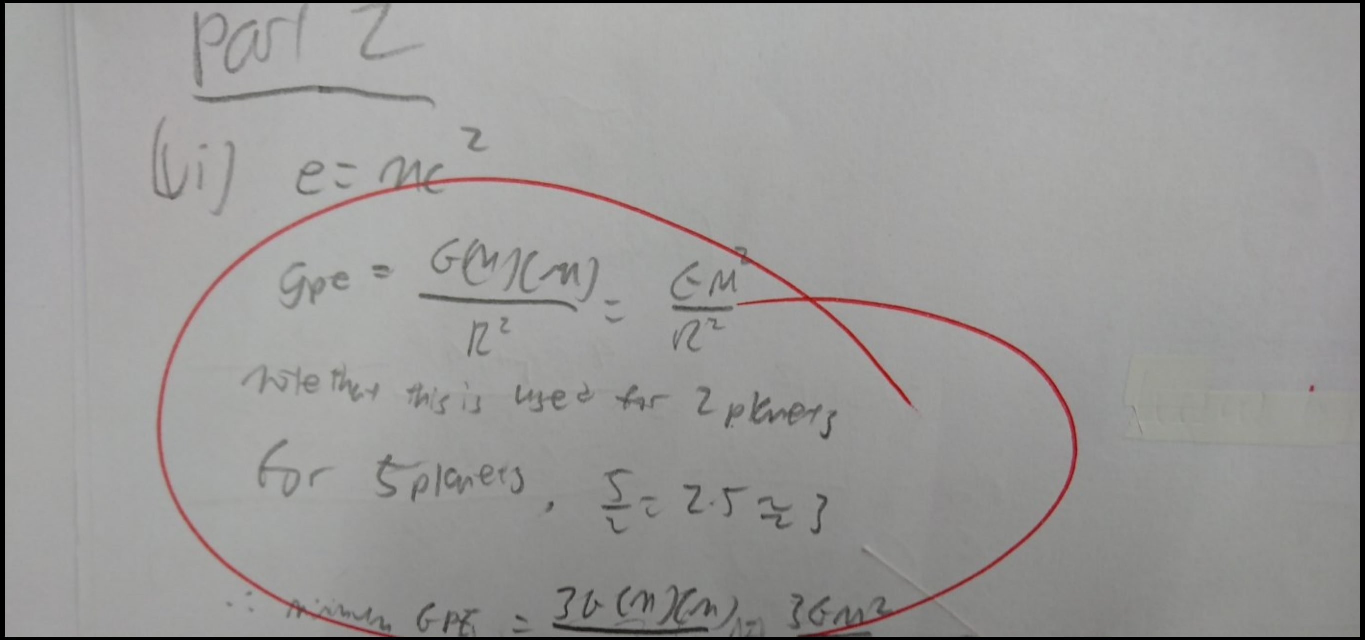
JNR Q3 – Story of Star Strife Engineer

(vi) [1 point] If Starslayer Base consumed a star and destroyed the Hasnian system, show that the minimum mass m of the star is

$$m = \frac{3GM^2}{R^2c^2},$$

where M and R refer to the mass and radius of the Earth respectively.

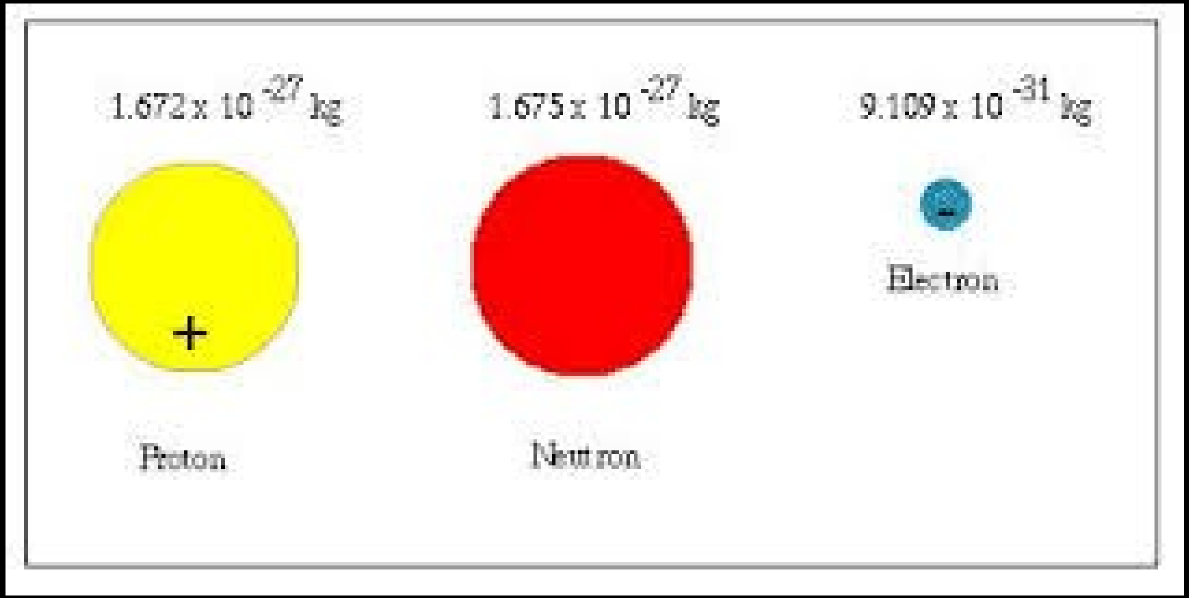
(Hint: Use Einstein's mass-energy equivalence.)

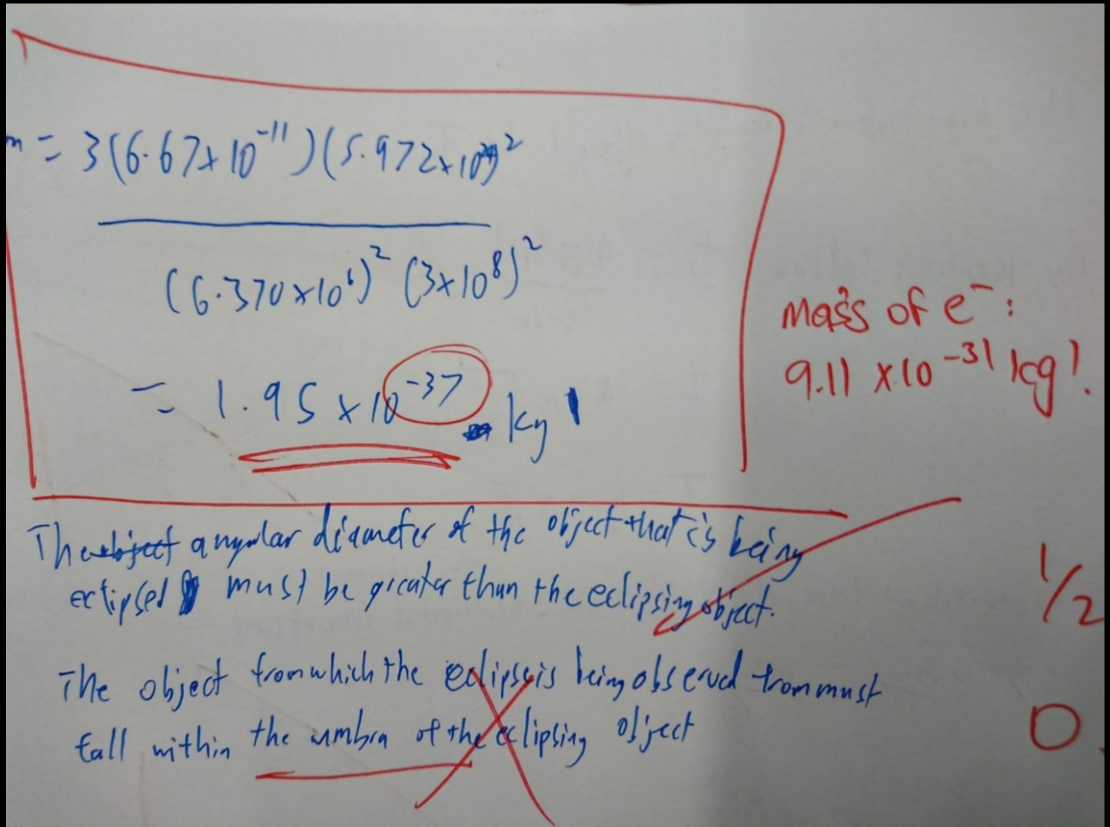


JNR Q3 – Story of Star Strife Engineer

(vii) [1 point] Use the above equation to determine the minimum possible mass of Star-A1.

(Note: If you realise that the mass is too low, do not fret. Star Strife is parked under Science Fiction.)





JNR Q3 – Story of Star Strife Engineer

(vii) [1 point] Use the above equation to determine the minimum possible mass of Star-A1.

(Note: If you realise that the mass is too low, do not fret. Star Strife is parked under Science Fiction.)

vii

$$m_{min} = \frac{3(6.67\times10^{-11})(5.972\times10^{24})}{(6.37\times10^{6})(3\times10^{8})^2}$$

$$= 2.08\times10^{-9}\ \text{kg (3sf)}$$

0.5

JNR Q3 – Story of Star Strife Engineer

A planet was recently discovered to be located at approximately 0.70 AU from Star-A2. However, upon thorough investigations conducted by the military advisers, they realised that this planet is inhabitable.

(x) [1 point] The military advisors claim you have made an error with your calculations. You disagree; the advisors have not looked at the assumptions of the calculation. But you need to convince them! Explain why this planet is inhabitable even though it lies within the Goldilocks zone.

Solution. The calculation above fails to account for the runaway greenhouse effect. An analogous example would be in the Solar System, where the orbital semi-major axis of Venus is 0.723 AU, but it is not habitable due to the runaway greenhouse effect.

JNR Q3 – Story of Star Strife Engineer

(xii) [3 points] Determine the eccentricity value of the orbit of Starslayer Base's moon such that the angular size of the moon is the same as the angular size of Star-B3 during aphelion.

(Hint: To prevent you from failing this task, you secretly bought a 'hint' from Kylo Ben. He gave you the following diagram.

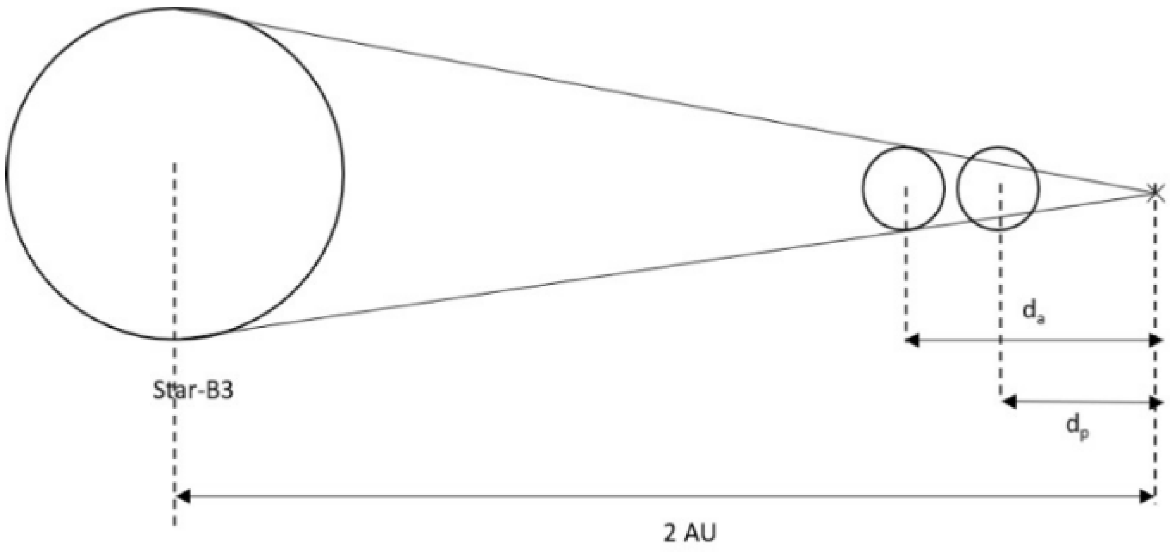


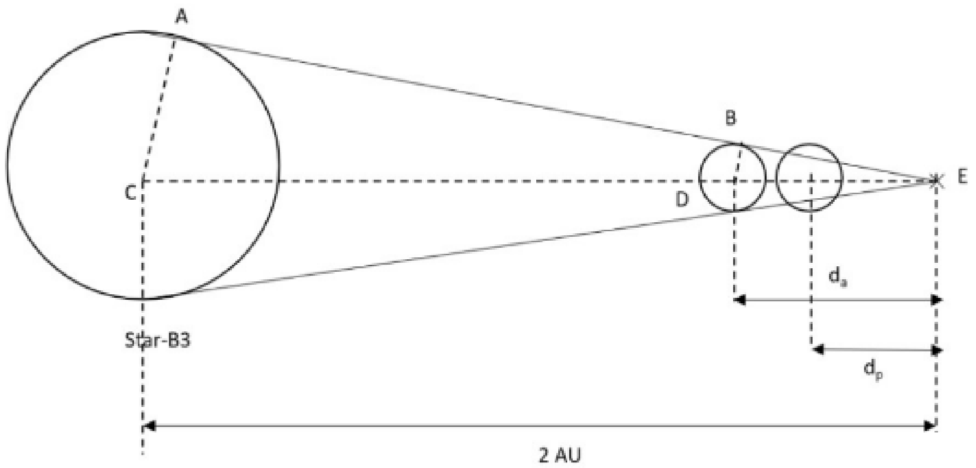
Figure 6: Kylo Ben has good drawing skills.

d_a is the distance of Starslayer Base from its moon at aphelion, and d_p is the distance of Starslayer Base from its moon during perihelion. Use geometric arguments to derive your answer.)

No teams got this portion right :(

JNR Q3 – Story of Star Strife Engineer

Consider the following triangle $ABEDC$.



Note that angles CAE and DBE are right angles. By similar triangles,

$$\frac{CA}{DB} = \frac{CE}{DE}.$$

The corresponding physical interpretation of these lengths are

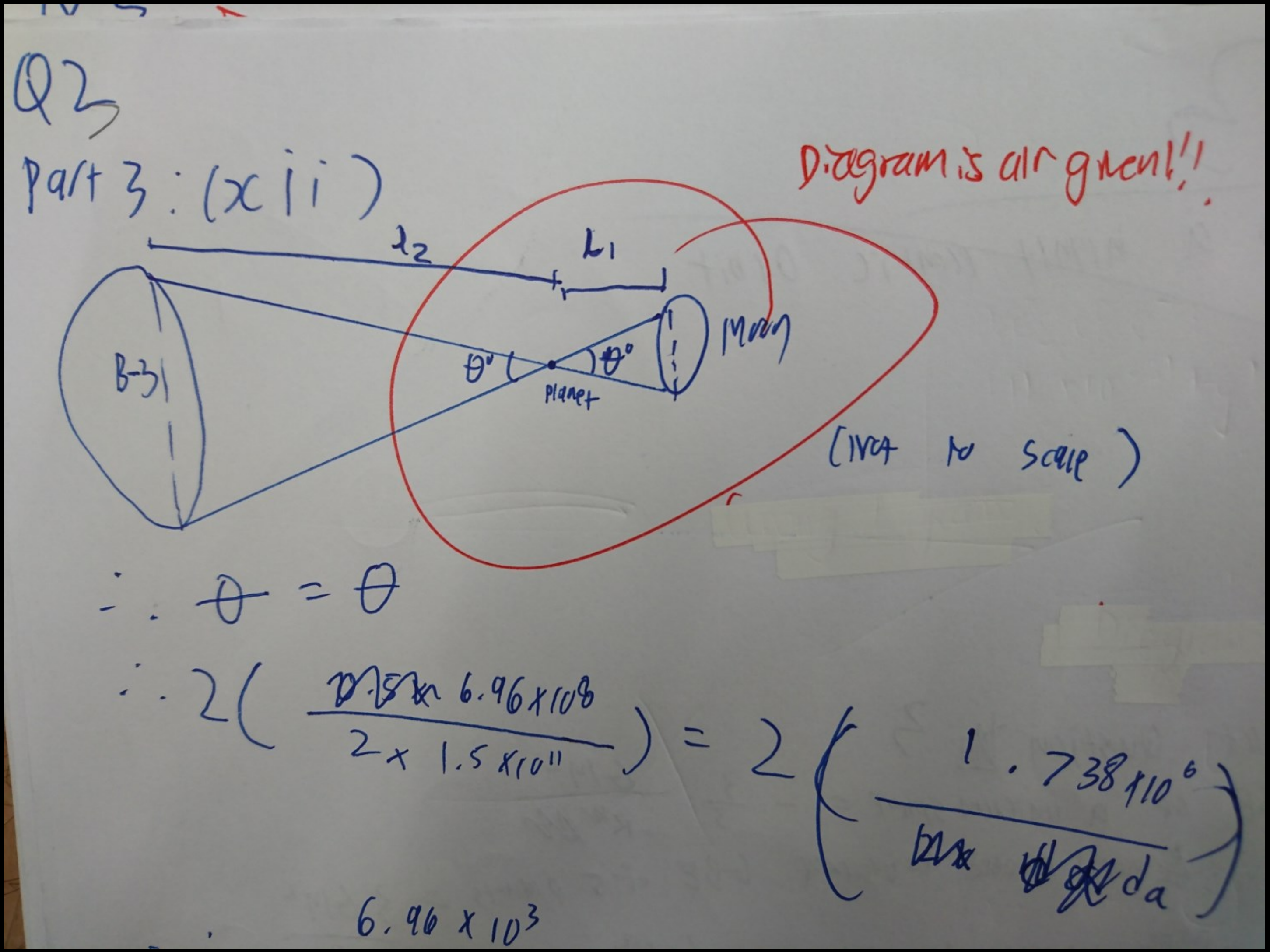
$$\frac{r_{\text{Sun}}}{r_{\text{Moon}}} = \frac{2\,\text{AU}}{d_a}.$$

Solving, $d_a = r_Sun/r_Moon = (2AU)/d_a Solvethisequationtoyielddavalueof2AUxr_Moon/r_Sun =$ $4.992 \times 10^{-3}\,\text{AU} = 7.468 \times 10^{8}\,\text{m}$.

Now, solving for ε using $d_a = 1.4a_{\text{Moon}}(1+\varepsilon)$, we obtain

$$\varepsilon = \frac{d_a}{1.4a_{\text{Moon}}} - 1 = 0.388.$$

JNR Q3 – Story of Star Strife Engineer



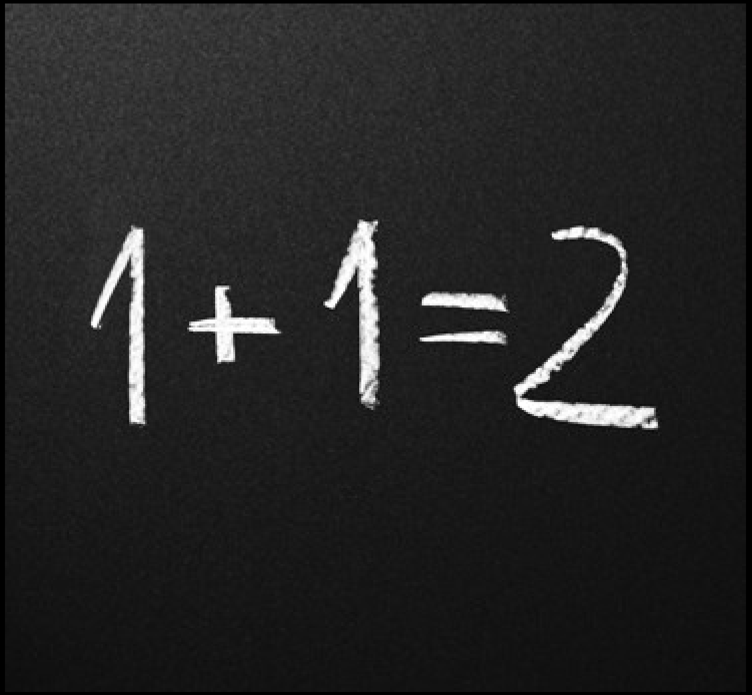
Annular???? (During lunar eclipse?)

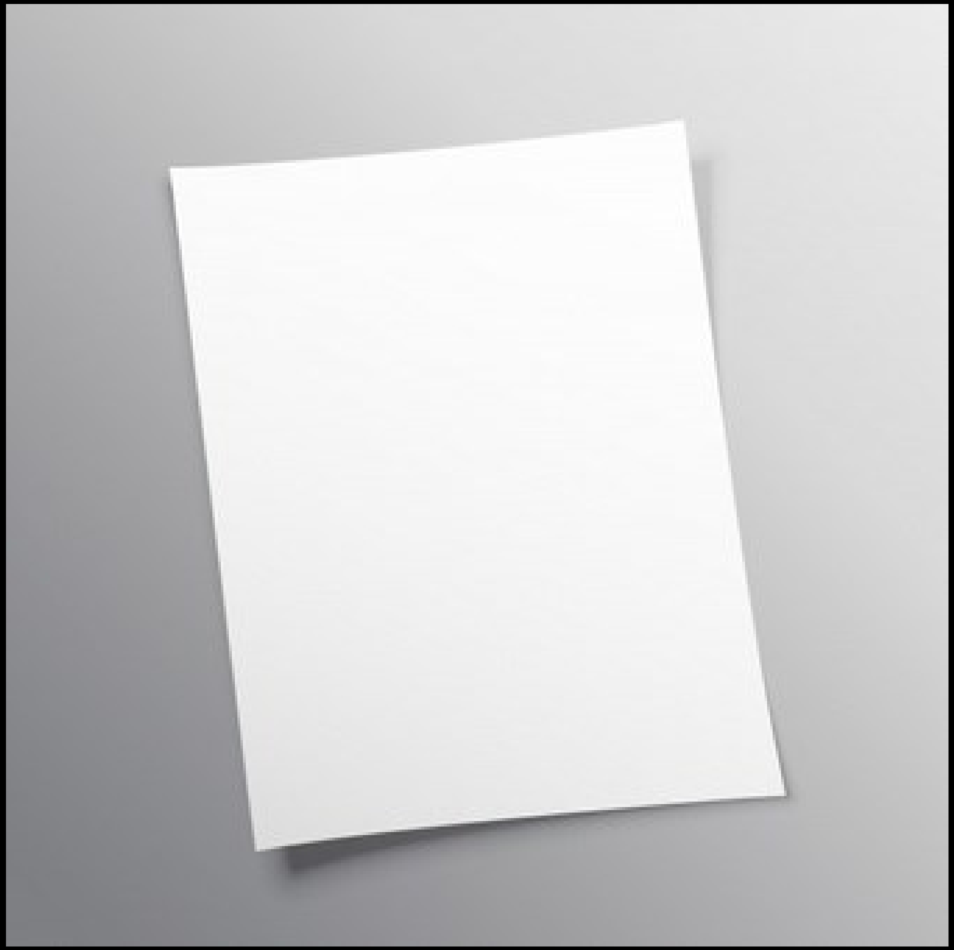
Thinking that the diagram is wrong and did not clarify? (The diagram is correct in the end tho :D)


Junior DRQ Q4

DRQ Jnr Question 4

- Fundamental Questions

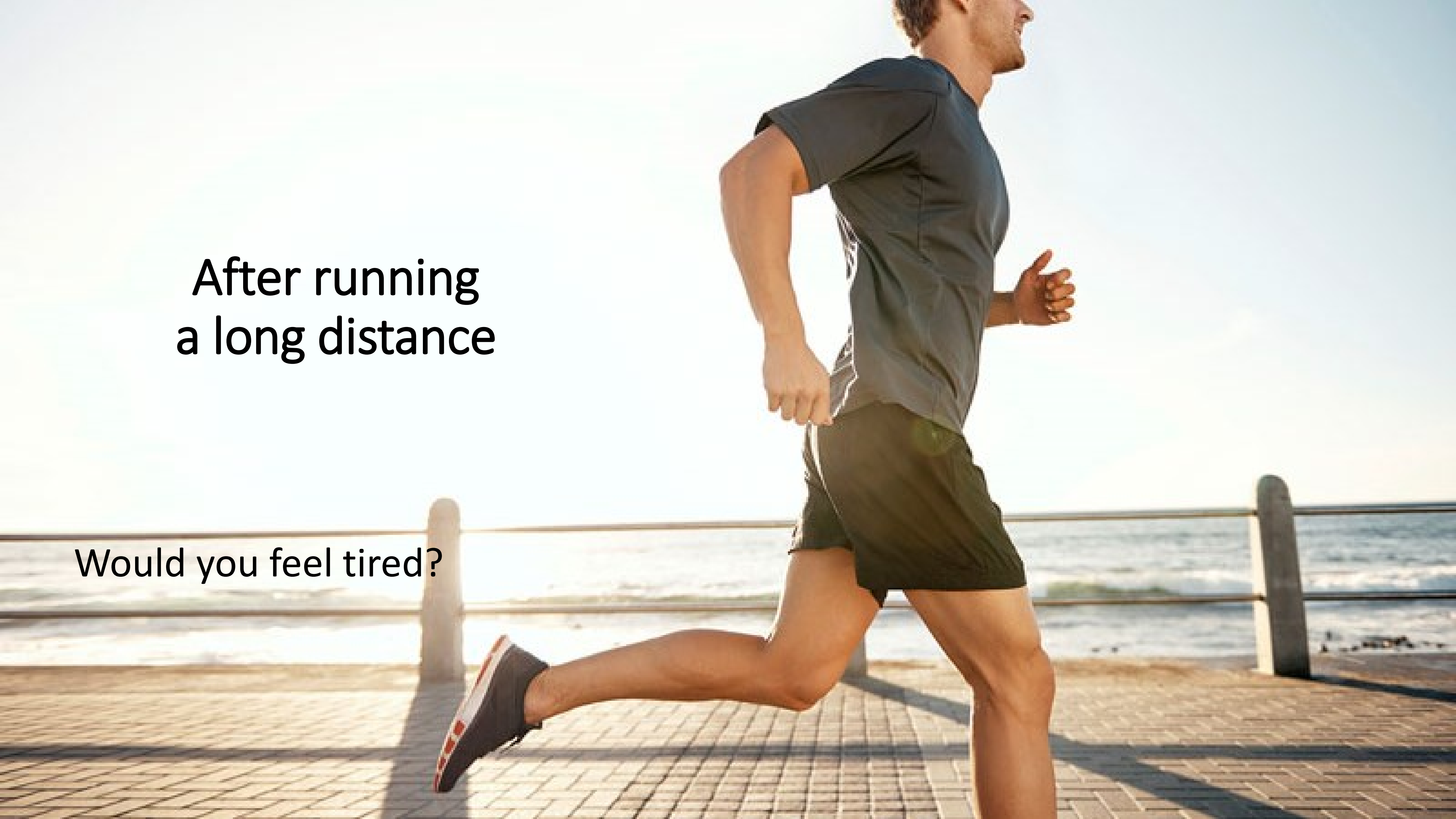




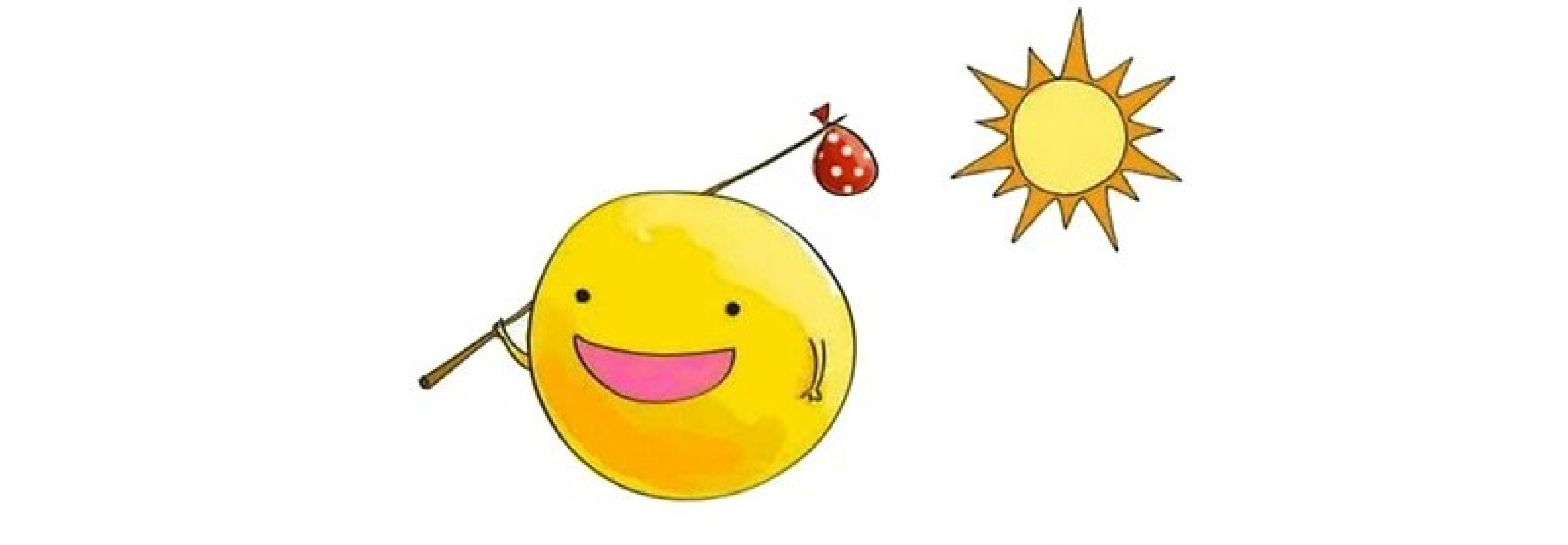

NONSENSE
100%
GUARANTEED

Fundamental questions

- 4i) The Greeks were aware of the phenomenon that objects in the distance appear to be smaller. Why do objects in the distance appear smaller? (1 marks)
- 4ii) The notion that the Earth is round is commonly attributed to Pythagoras of Samos. Give a plausible argument as to how Pythagoras may have known that Earth was round? (1 mark)


After running
a long distance
Would you feel tired?

Oh yes it must apply to photons too



- Objects in the distance travel a longer distance, photons lose energy / wavelength become longer so the object in the distance appears smaller.
- ?????????
- “Tired Light” Hypothesis???

Anti Flat Earth Question

Correctly explaining how objects disappear at the horizon is key to answering this question

Q1: Do You See What I See?

JNR DRQ 1: Goals and Intentions

- Part 1: To think about different types of light astronomy and what makes them work.
- Part 2: To think about how astronomy is carried out through spectral methods.
- Part 3: To investigate a common concept in virtually anything to do with distributions and waves – the Full-Width Half-Maximum.

Find the FWHM.

Refer to Figure 3. Boom, there's the FWHM of $\phi(f)$

Also this should be ϕ. Sorry about that.

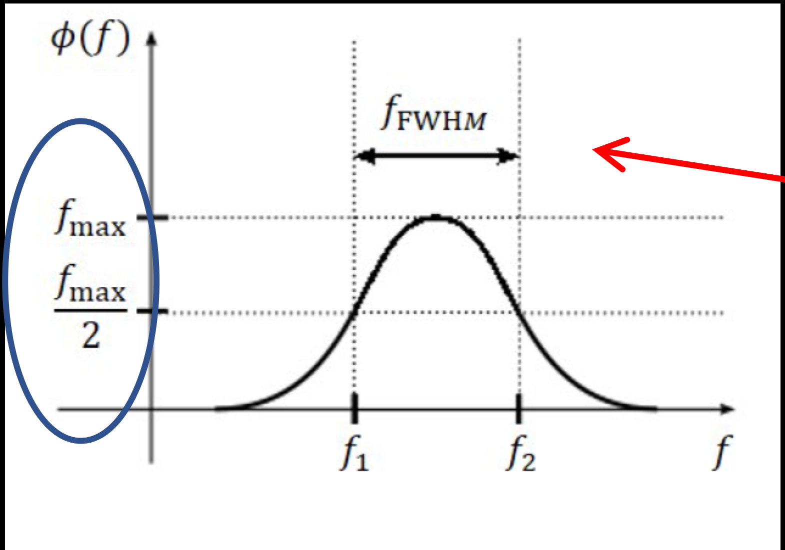
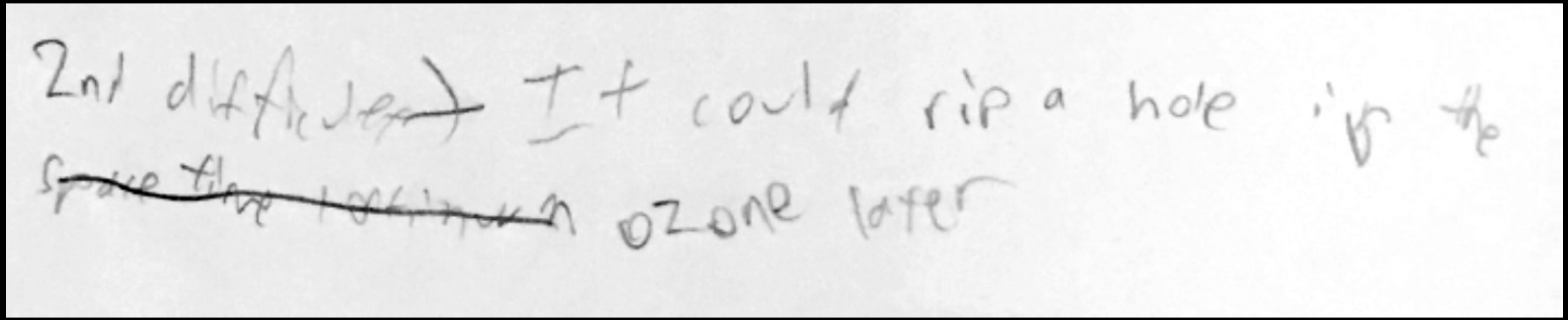
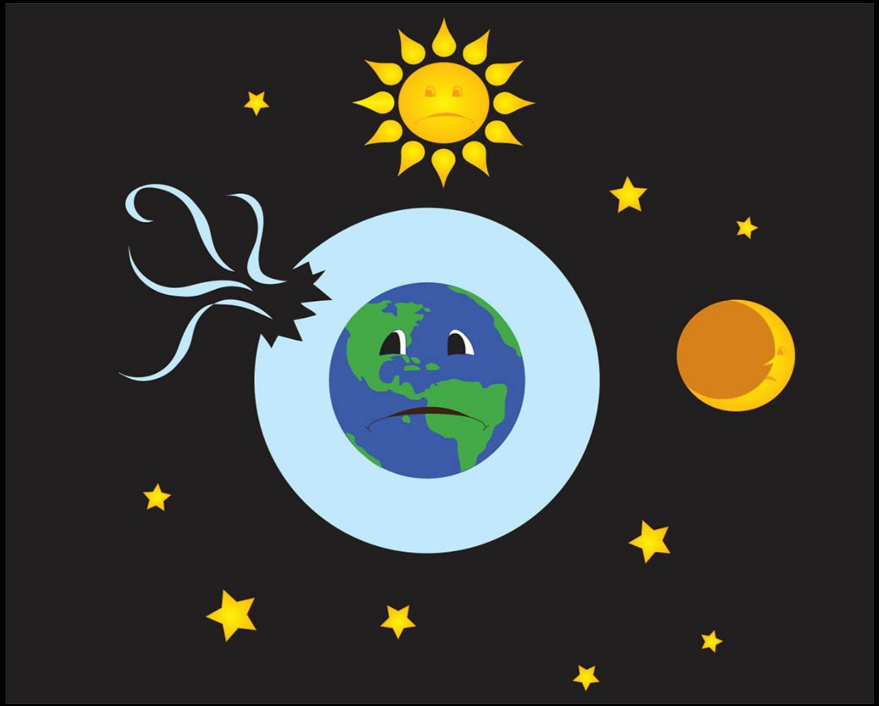


Figure 3: FWHM of $\phi(f)$.

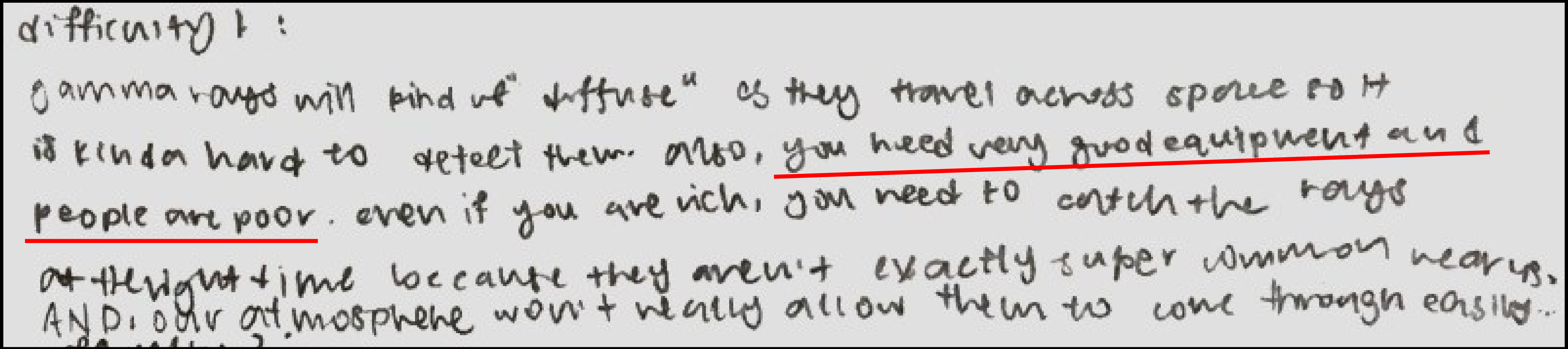
Here it is!

Difficulty of gamma-ray astronomy?


2nd difficulty → It could rip a hole in the ~~space the [illegible]~~ ozone layer



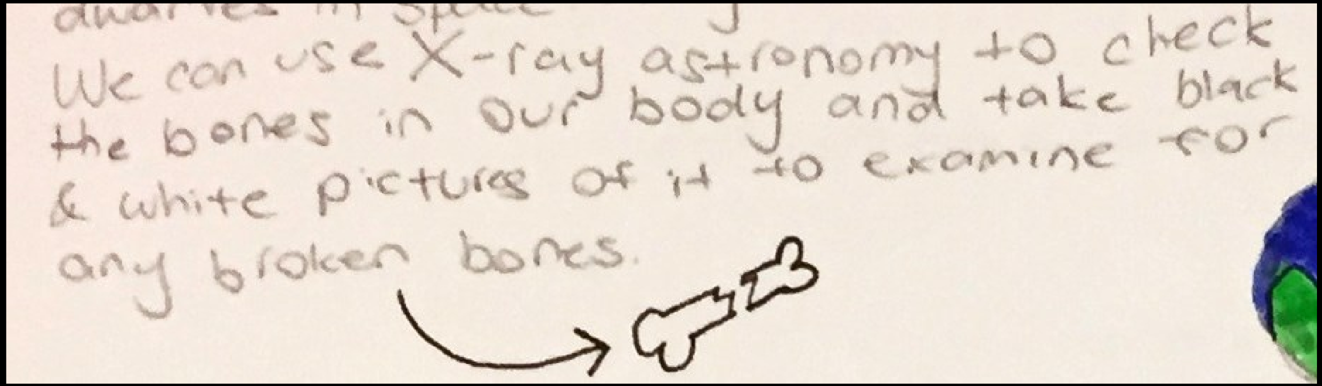
Truly Singaporean


difficulty 1 :

gamma rays will kind of "diffuse" as they travel across space so it is kinda hard to detect them. also, you need very good equipment and people are poor. even if you are rich, you need to catch the rays at the right time because they aren't exactly super common near us. AND, our atmosphere won't really allow them to come through easily..

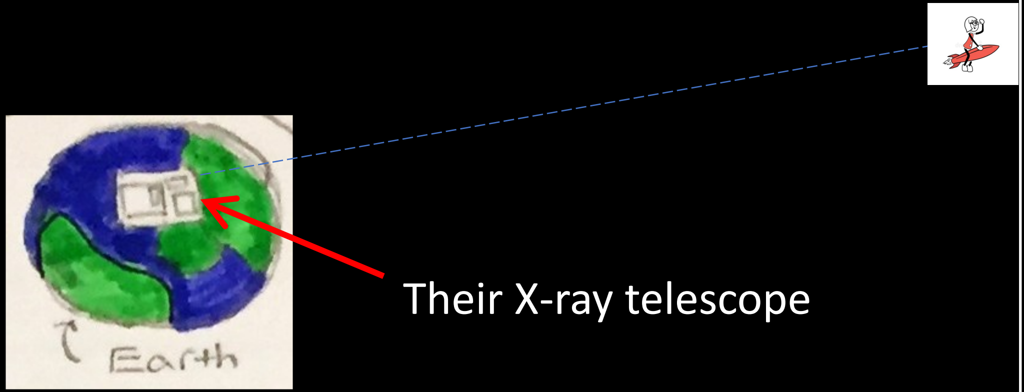
Grader's reply: I'm poor too :(

Five Simple Steps

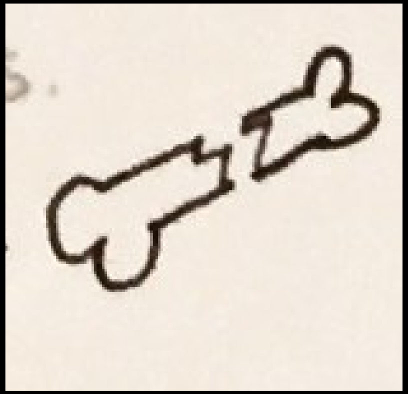


Step 1:

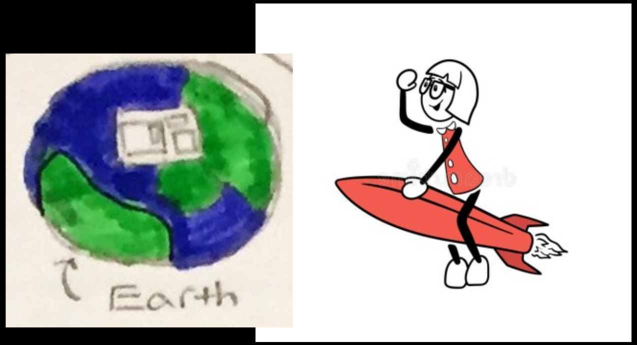
Step 2:



Step 3:

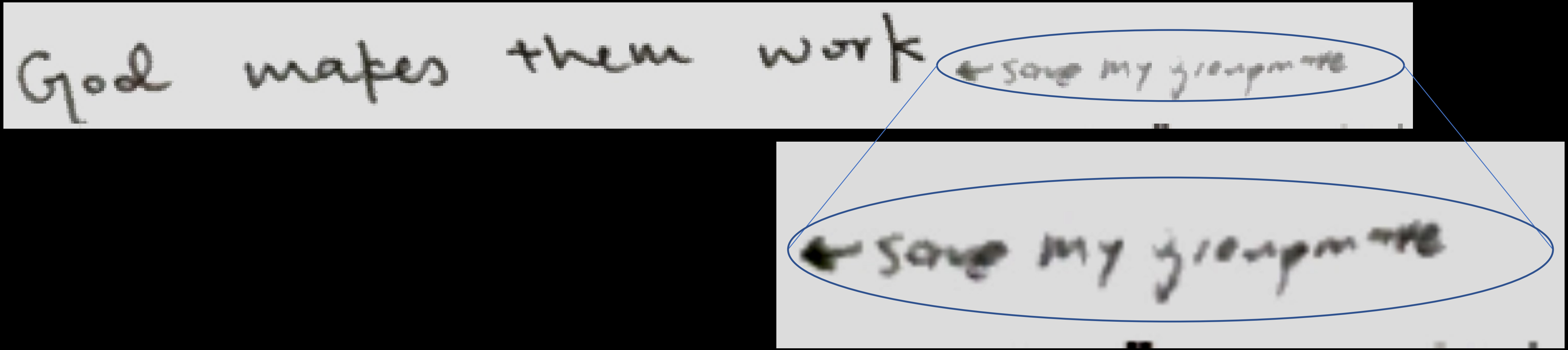


Step 4:



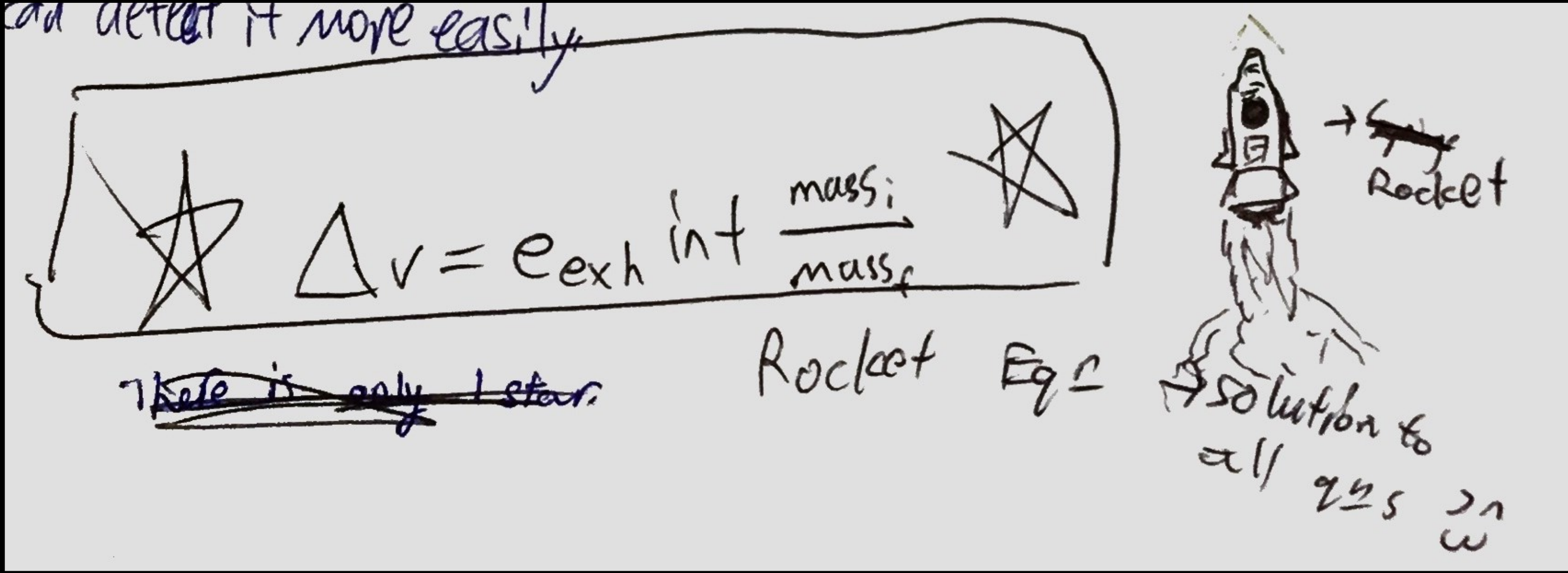
Step 5:

When you give up

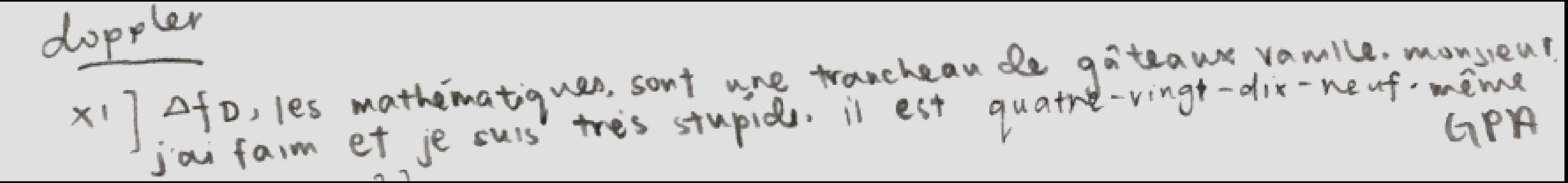


Translation: I have no brain :c

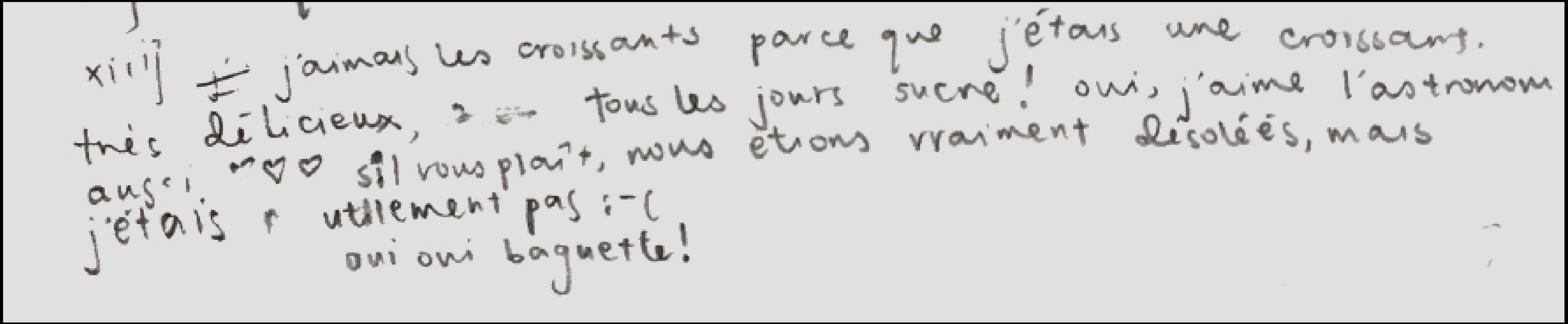
When you give up, pt. 2



When you give up, French edition



Translation: The mathematics is a piece of vanilla cake, mister. I'm hungry and very stupid. It is 99. Same GPA.



Translation: I like croissants because I am a croissant. Very delicious, all the sugar!
Yes, I love astronomy too. ♡♡ Please, we are really sorry, but I am not useful :-(
yes yes baguette!

Grader's reply: Gâteau au chocolat? ♡

General Comments: JNR DRQ 1

- Part 1 (i to vii): The trend of marks is like a smile – starts high, goes down, and goes back up. Good understanding of different astronomy types, except maybe gamma-ray astronomy. Oops?

- Part 2 (viii to x): The trend starts high and drops real fast like the Admiral's jaw at the Starship Enterprise's repair bill. But if you remembered to submit the graph, you *probably* got that part right.

- Part 3 (xi to xiii): You guys hate math. What did math ever do to you? :(

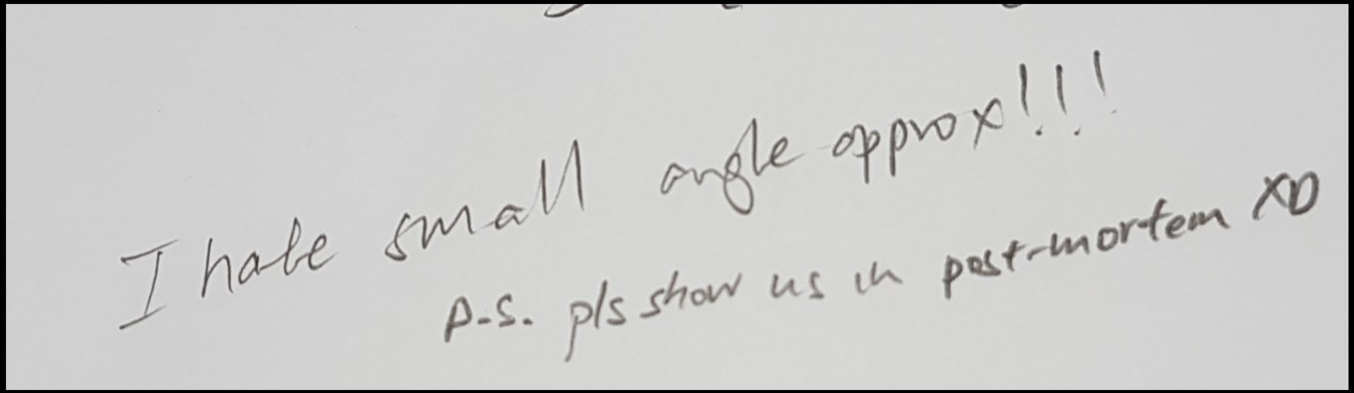
Q5: Practical Astronomy

JNR Q5 – Practical Astronomy

- Did not know the meaning of cardinal points: NSEW
- Recognised North and apply Geography. Clockwise counting N E S W but the positions are flipped and different from normal terrestrial maps.
- Good thing is that many are able to discern the Great Square of Pegasus!

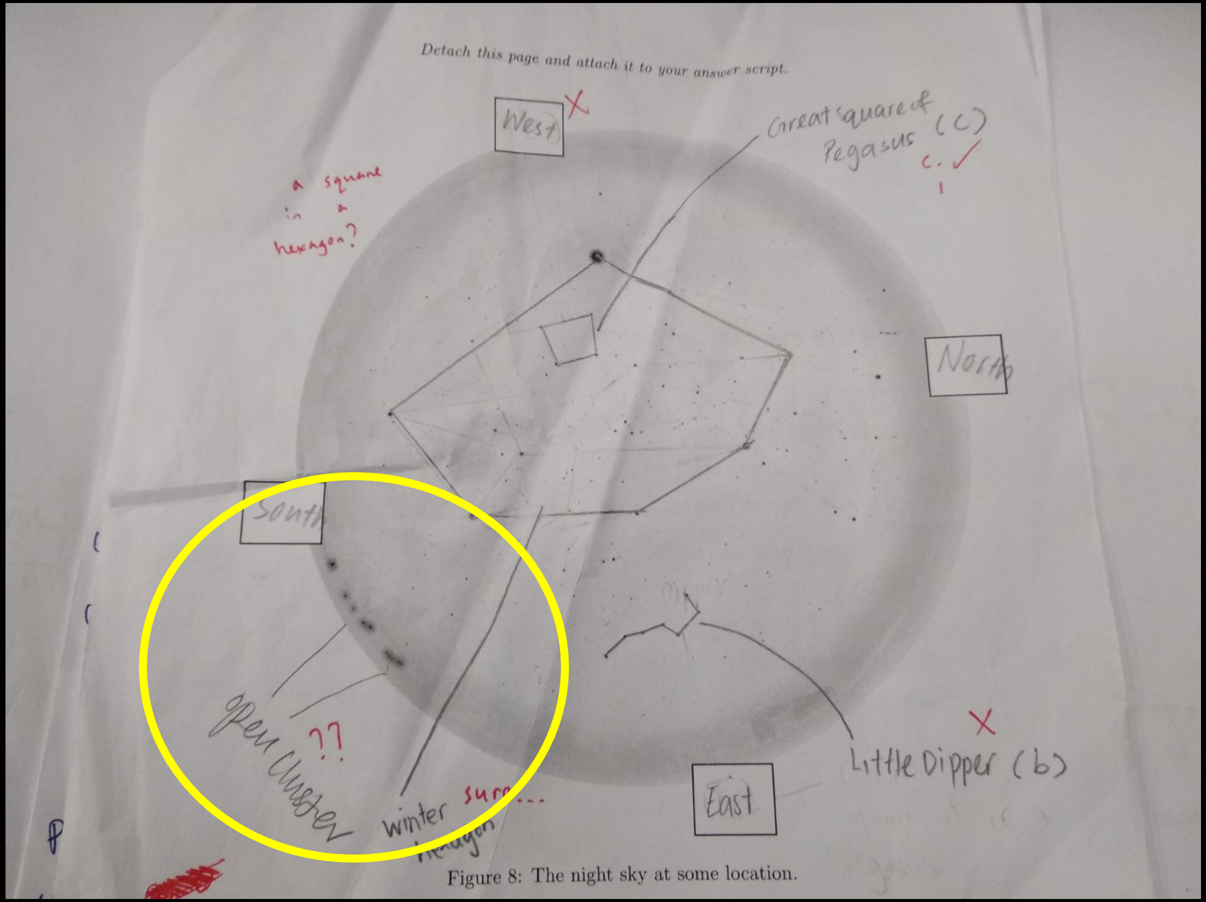
JNR Q5 – Practical Astronomy

- Many mistook the Big Dipper for the Little Dipper
- Latitude question: Some schools indicated without **units** (°? '? ''?) or the **directions** (N or S)?
- Many did not even attempt Part 2!



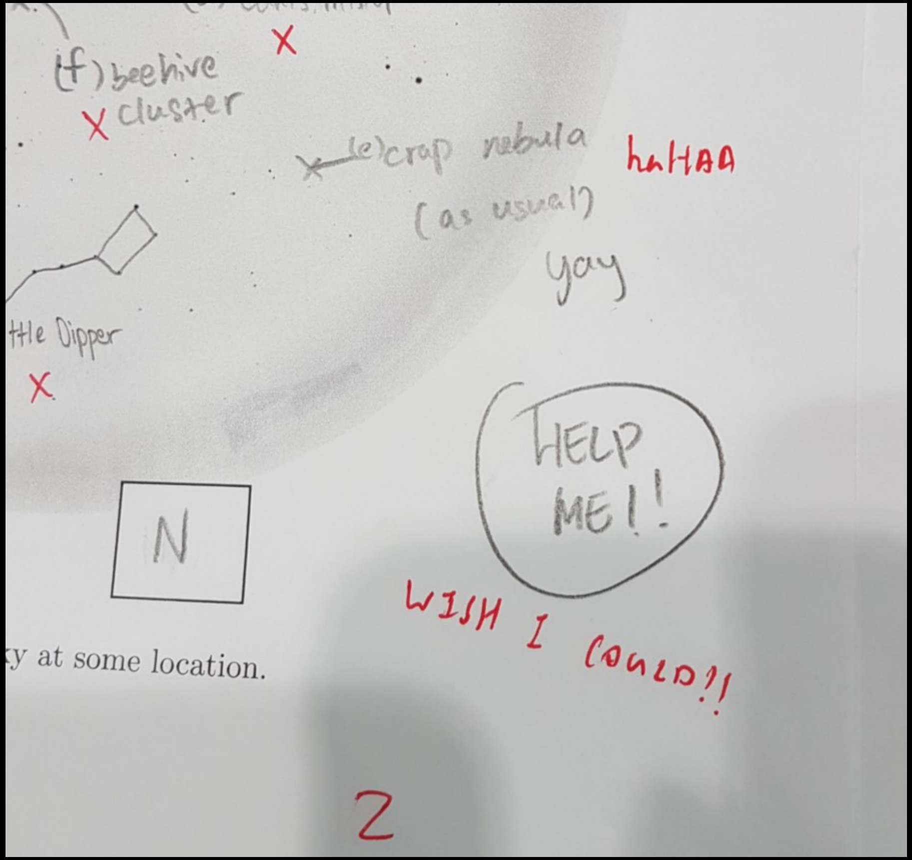
JNR Q5 – Practical Astronomy Hall of Fame

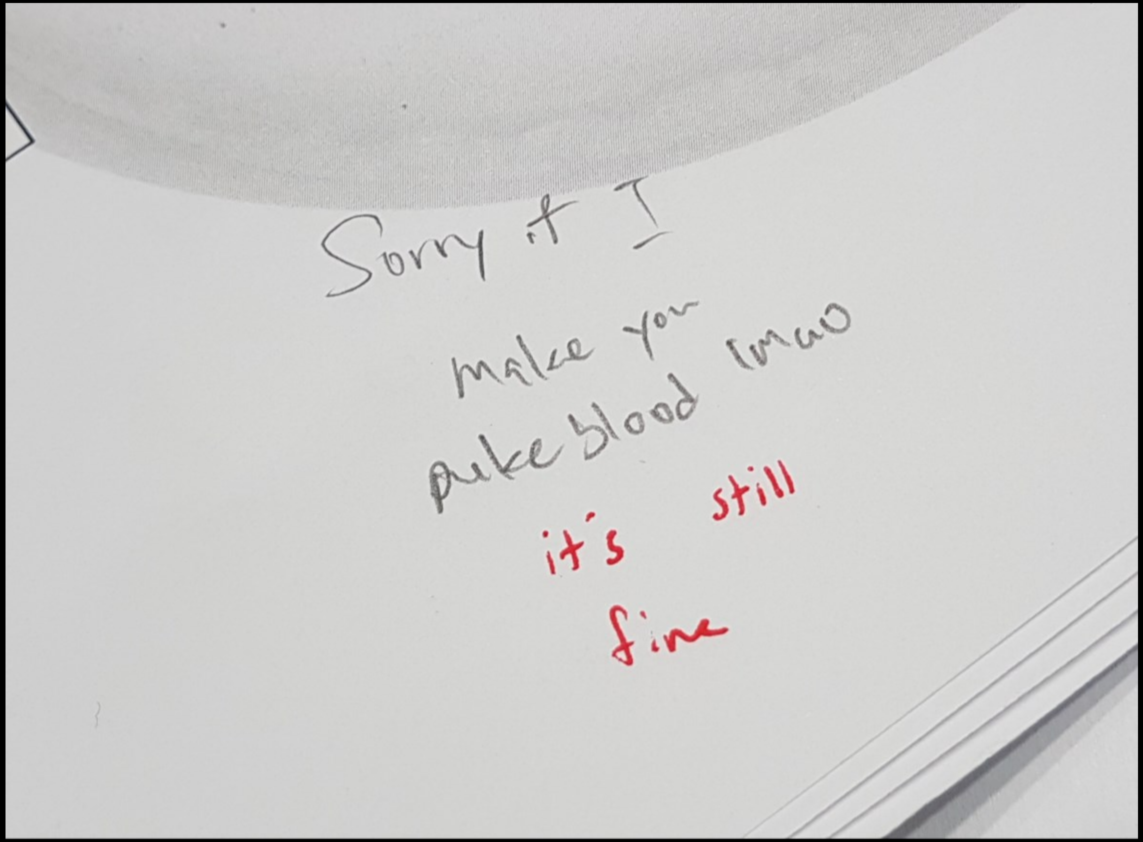
Insufficient experience in Stellarium:



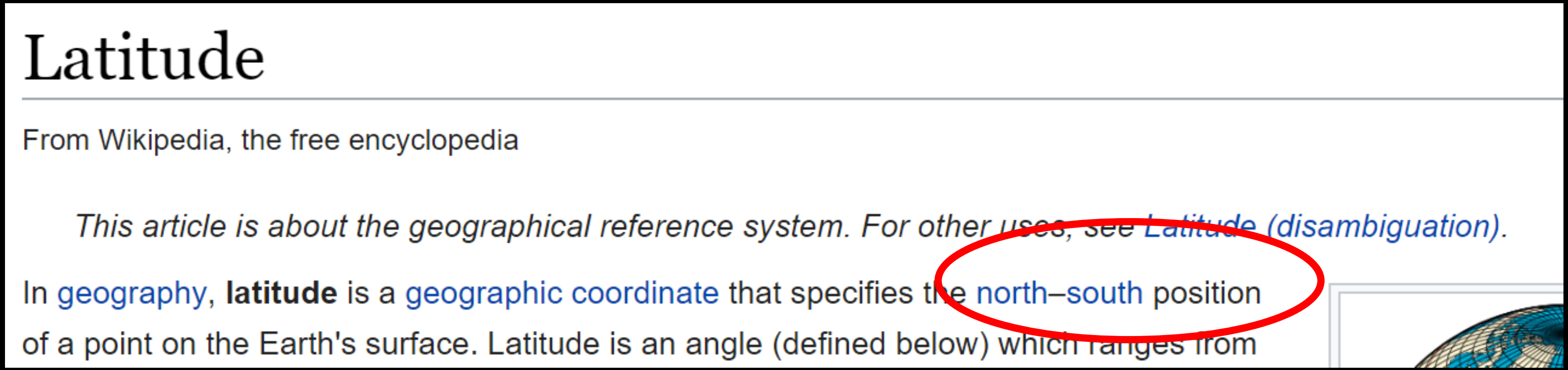
JNR Q5 – Practical Astronomy Hall of Fame

At least you tried…





JNR Q5 – Practical Astronomy Hall of Fame

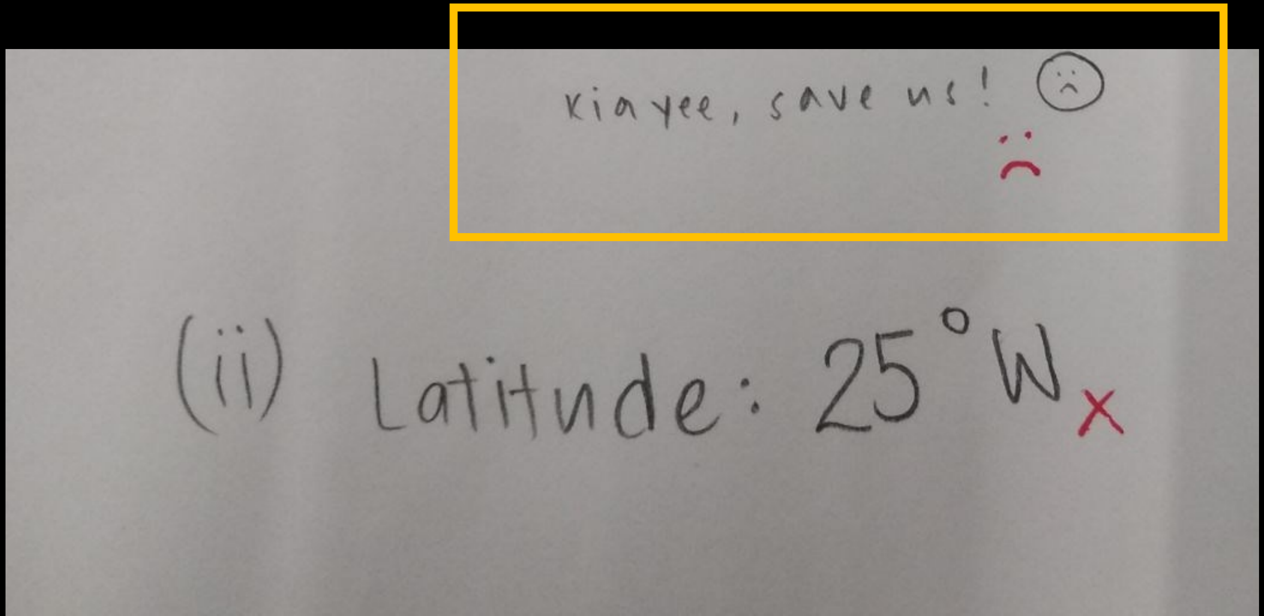


Latitude

From Wikipedia, the free encyclopedia

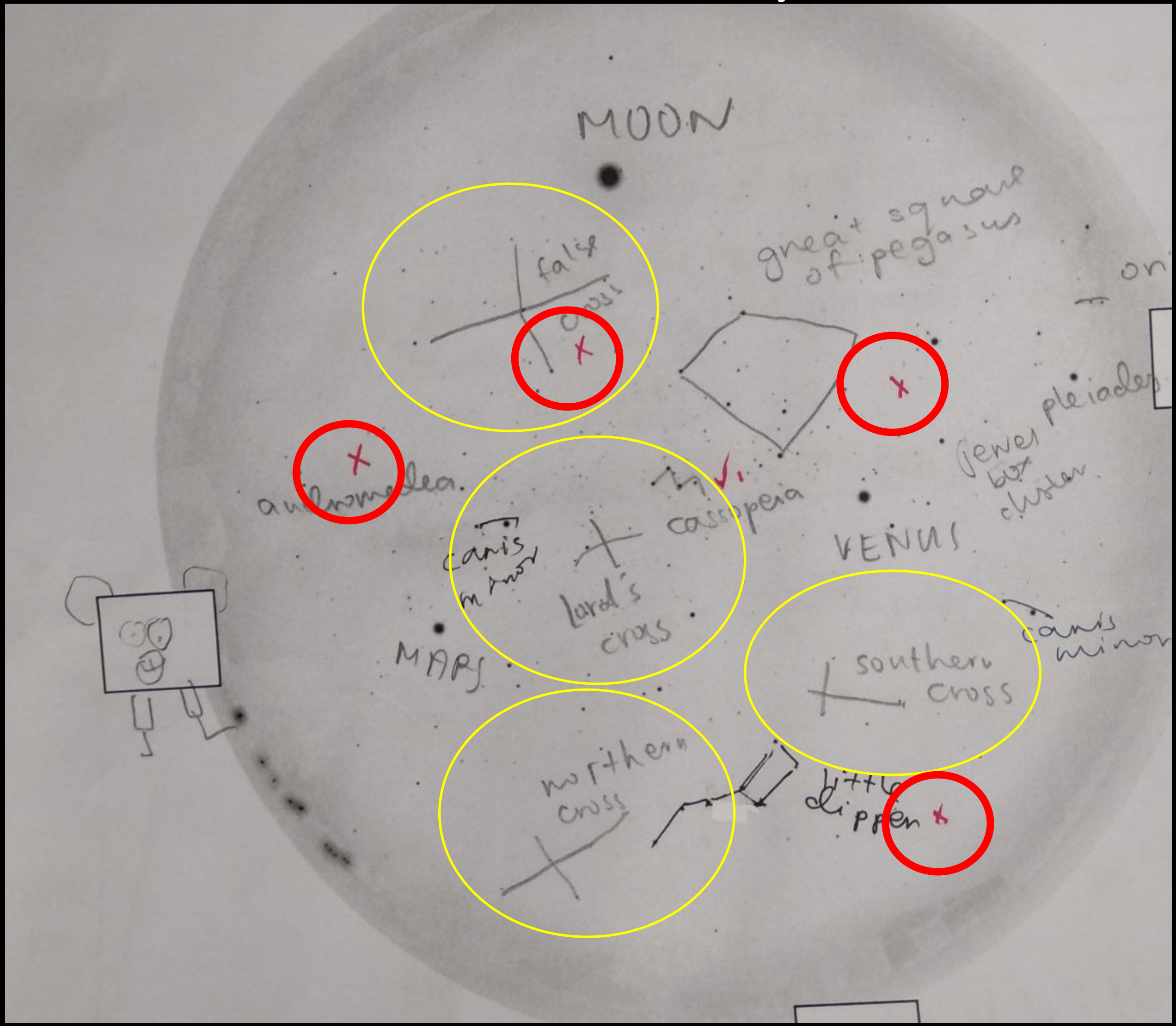
This article is about the geographical reference system. For other uses, see Latitude (disambiguation).

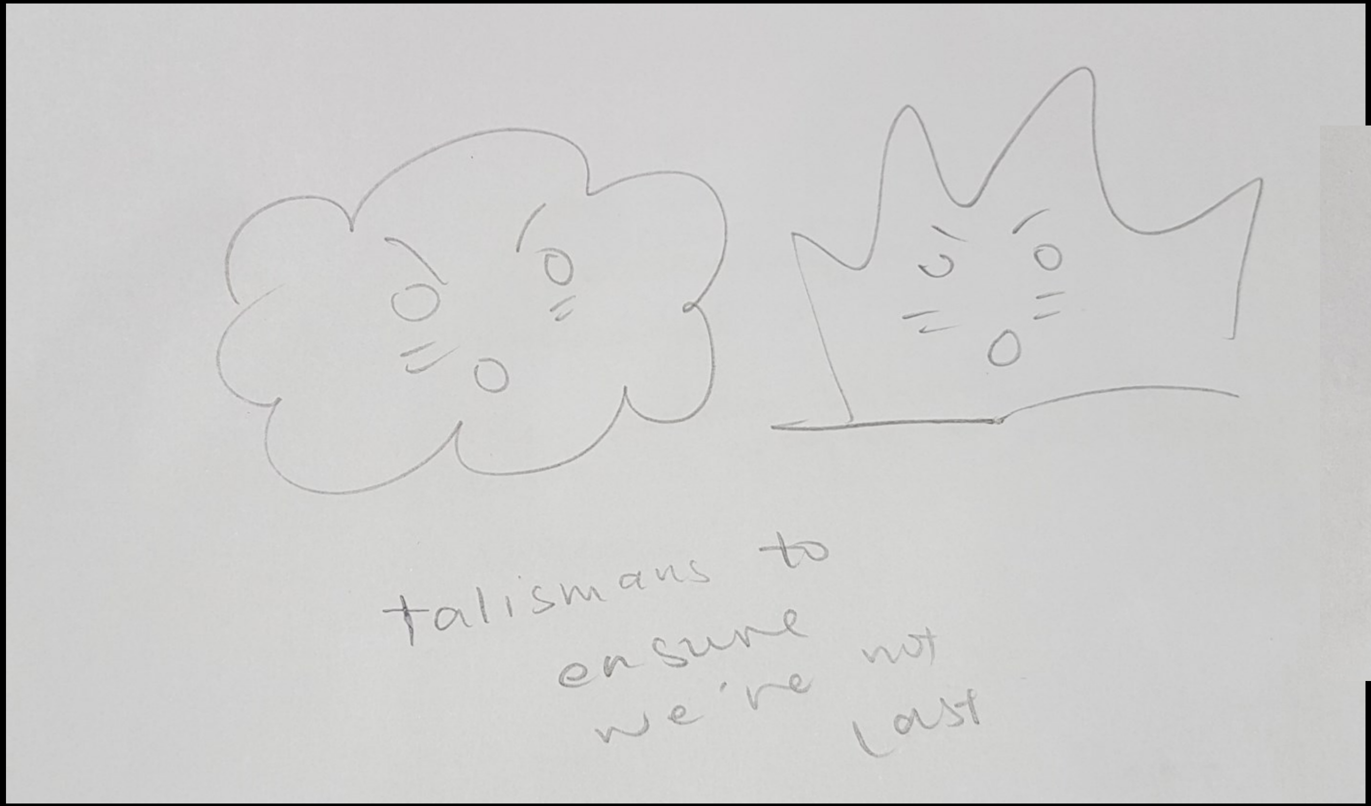
In geography, **latitude** is a geographic coordinate that specifies the north–south position of a point on the Earth's surface. Latitude is an angle (defined below) which ranges from

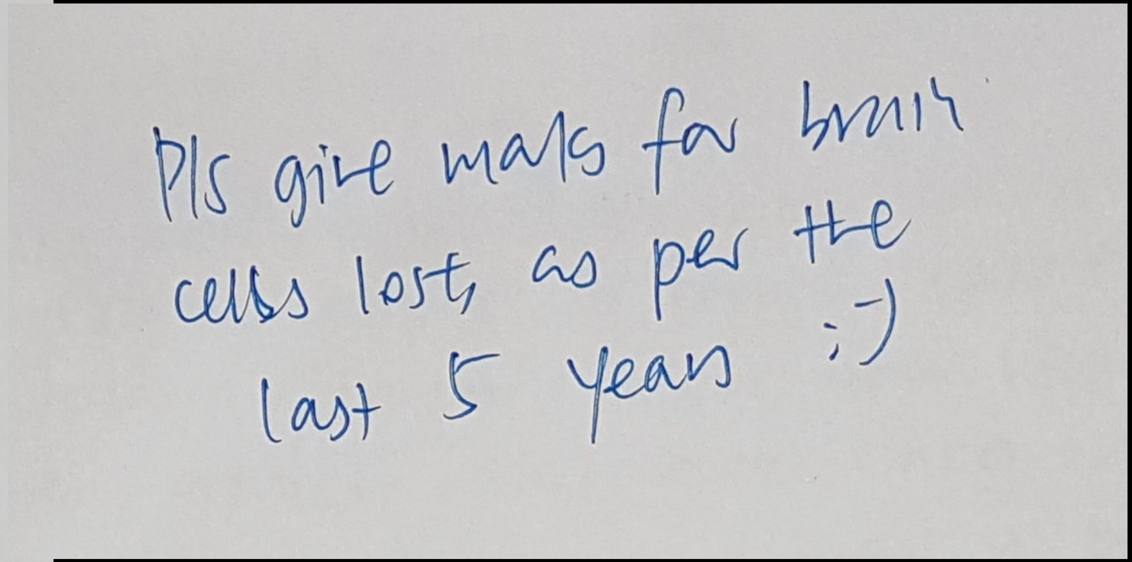


JNR Q5 – Practical Astronomy Hall of Fame

Crosses

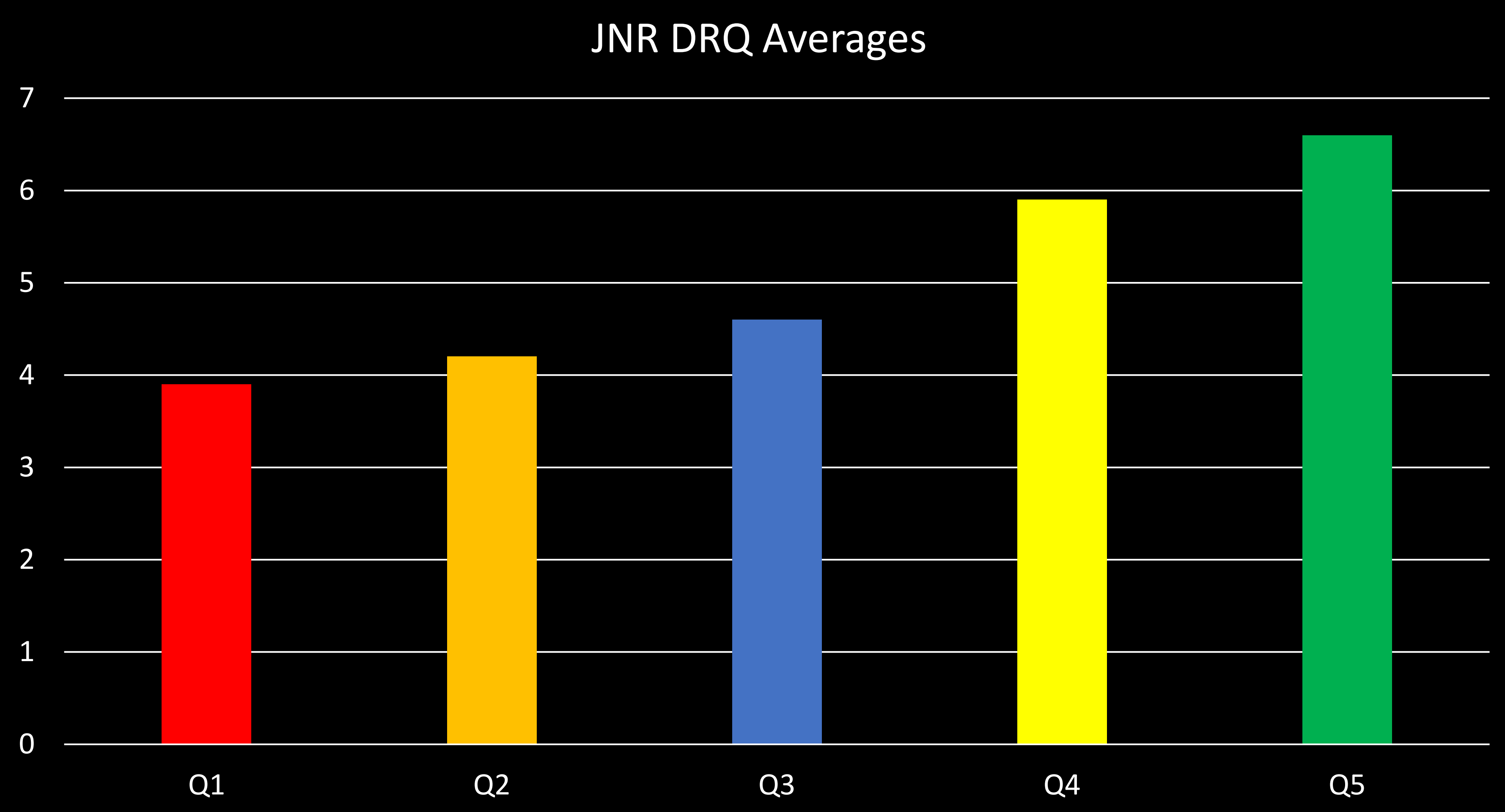




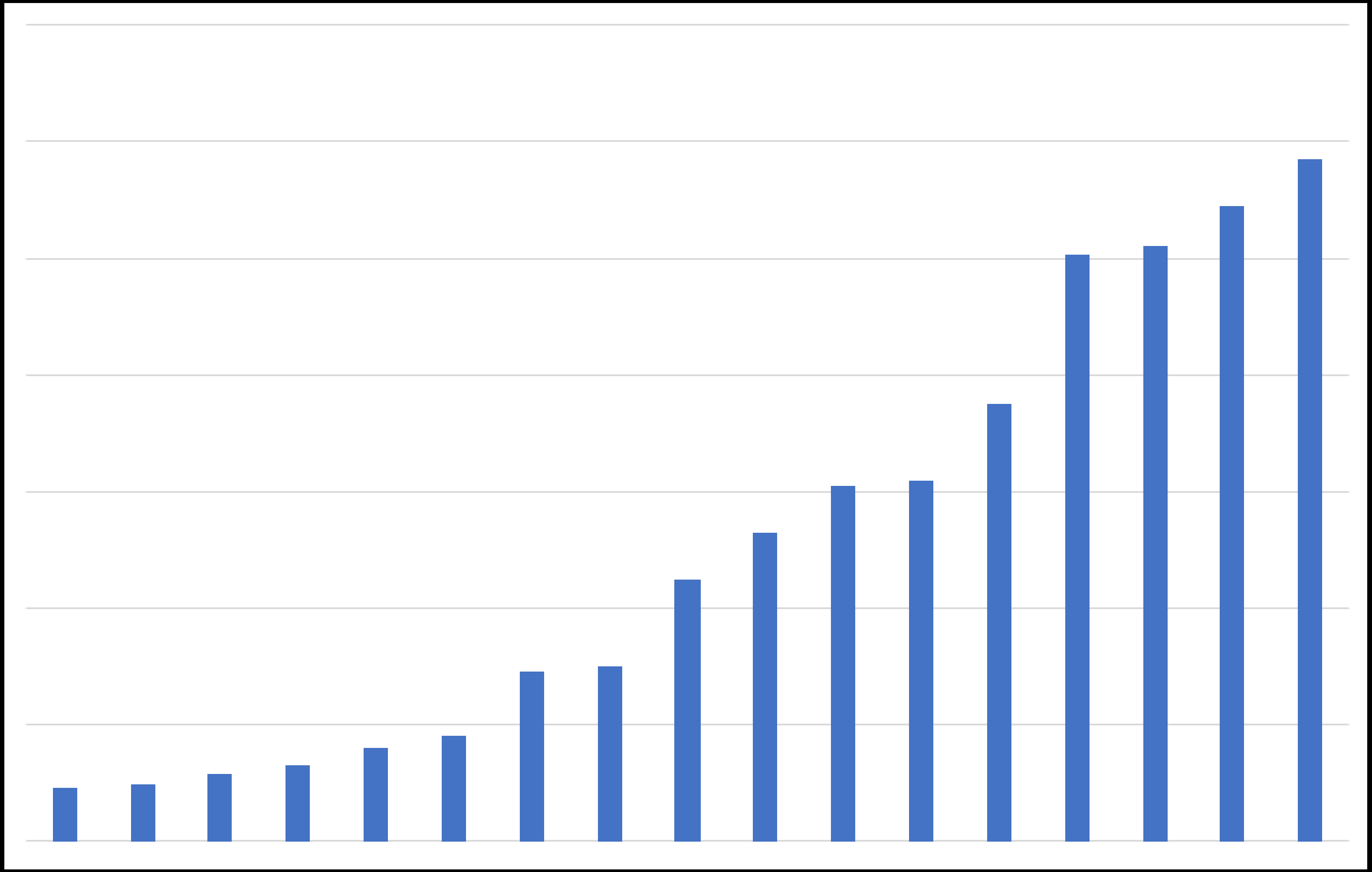


This question ended up being the **most** generous...

JNR DRQ Average Score by Question



JNR DRQ Score Distribution



Mean = 25.3, Median = 22.5, Standard Deviation = 18.5

SNR DRQ

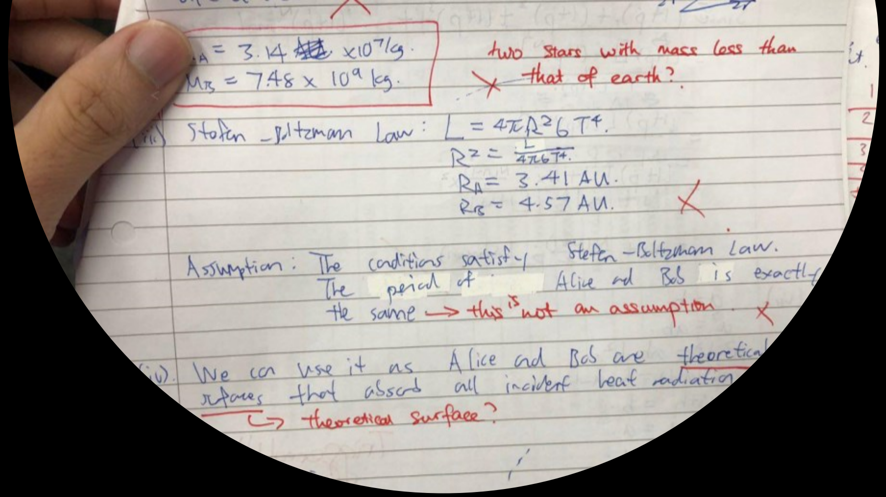
Q5: Alice and Bob Circling in the Sky

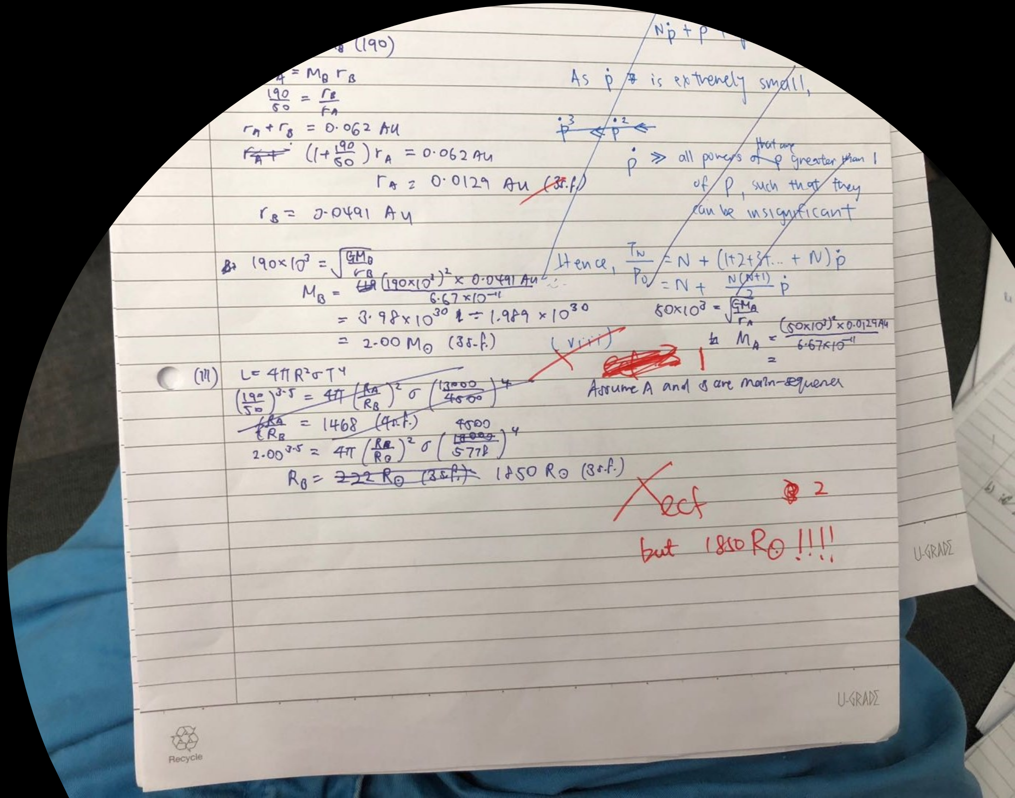
General comments

- Generally not very well done
- Clear separation of teams
- Top teams generally got 10+ points
- Do not try to smoke

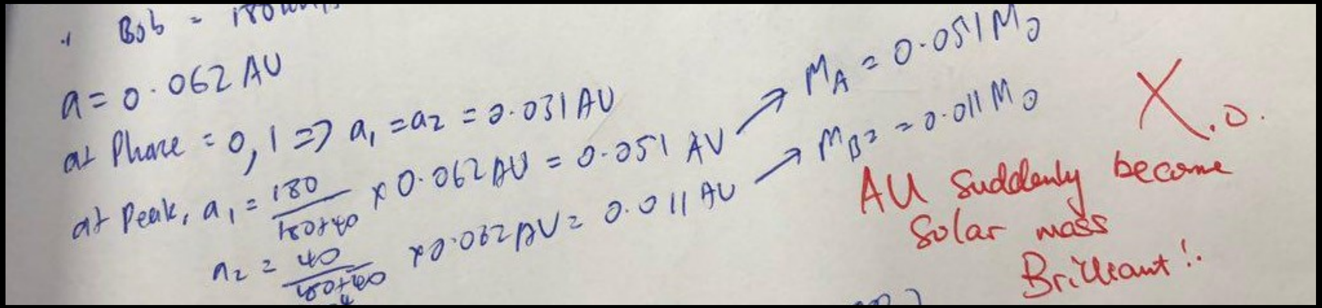
Rationality check

- Check if an answer make sense
- If it doesn't check your working

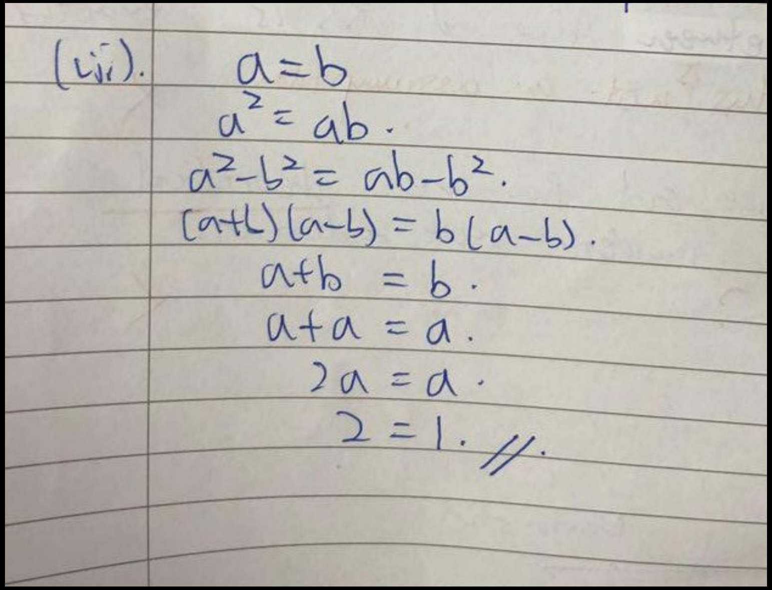


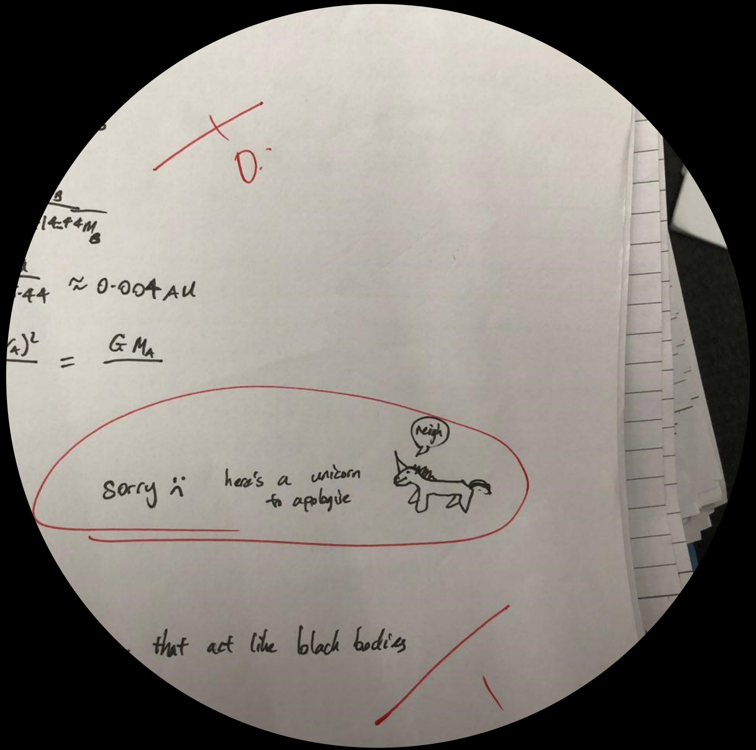


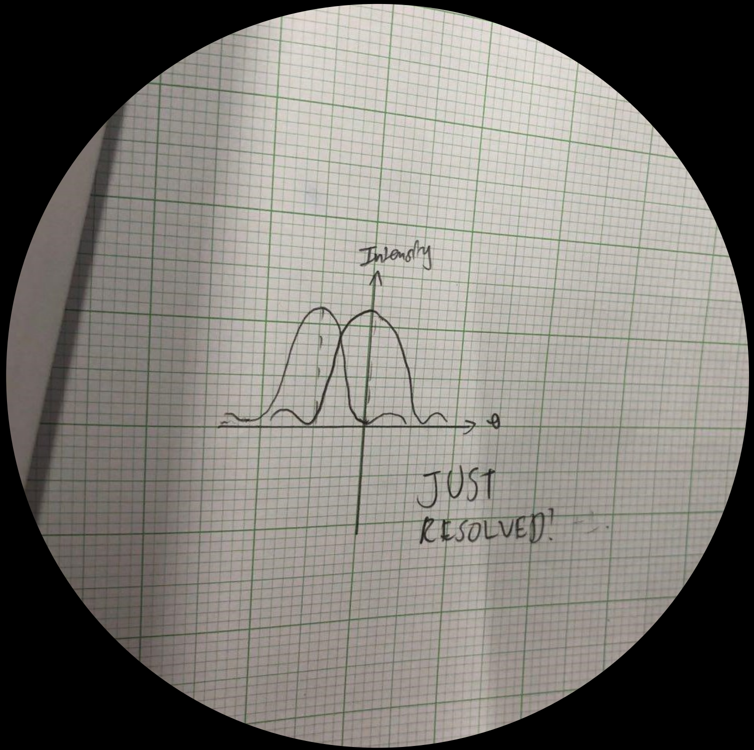
Do Not Smoke

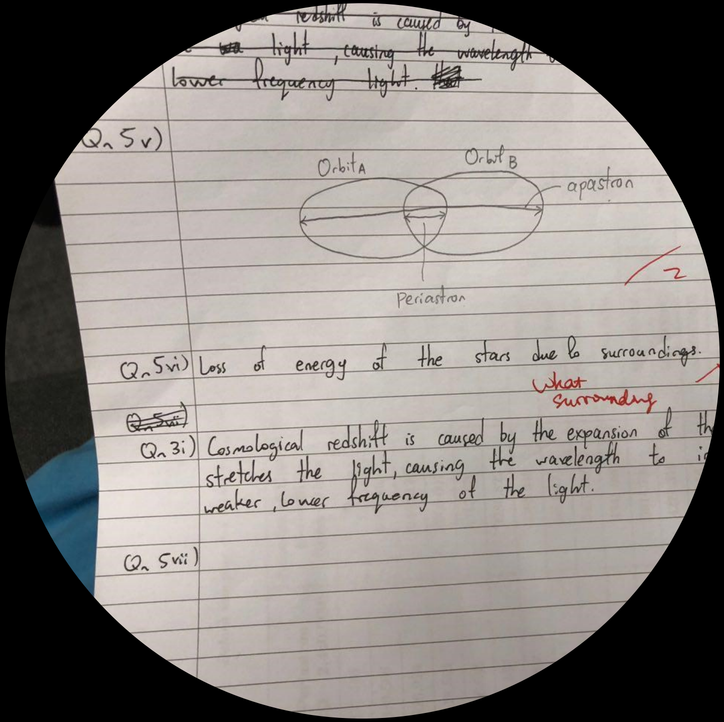


- Its ok to leave blank and move on…
- Do Not Smoke

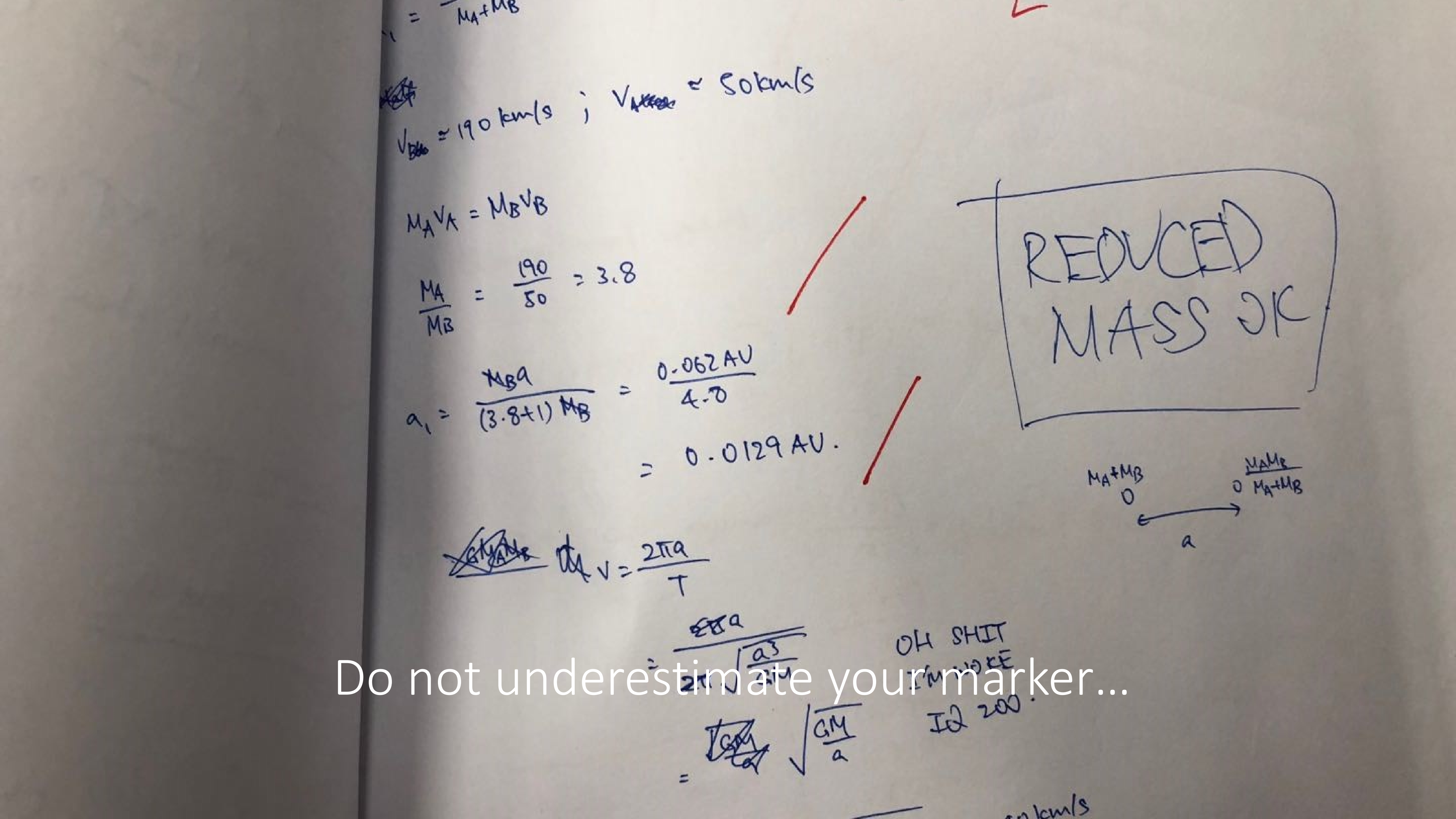



D:
≈ 0.004 AU
Neigh
sorry :(here's a unicorn to apologise
that act like black bodies


Intensity
θ
JUST RESOLVED!


Q. 5v)
Orbit A
Orbit B
apastron
Periastron
Q. 5vi) Loss of energy of the stars due to surroundings.
what surrounding
Q. 3i) Cosmological redshift is caused by the expansion of
stretches the light, causing the wavelength to
weaker, lower frequency of the light.
Q. 5vii)

Do Not Smoke ☹



Do not underestimate your marker...

Q3: The Red Distance

SNR DRQ 3: Goals and Intentions (The Red Distance)

- Part 1: To investigate a bit about redshift and how it correlates to the universe expanding.
- Part 2: To think about the scale factor.
- Part 3: To investigate different notions of distances.

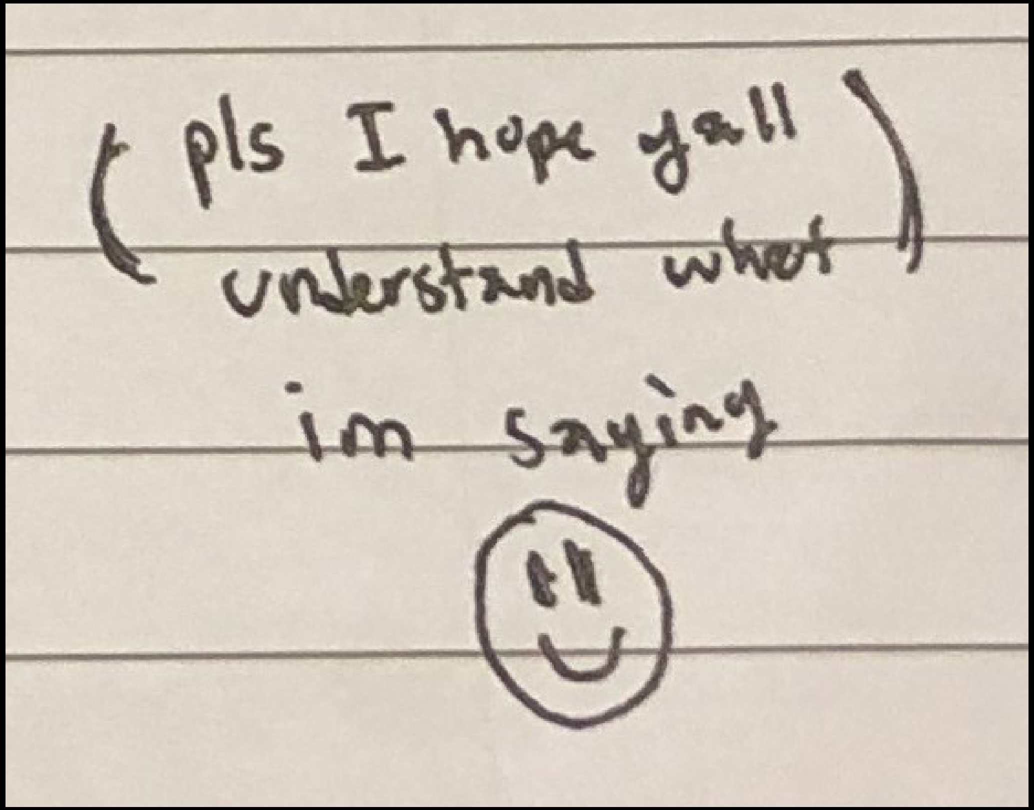
The Hubble length (distance to galaxies receding at speed c)

$$C = \frac{c}{H_0}$$

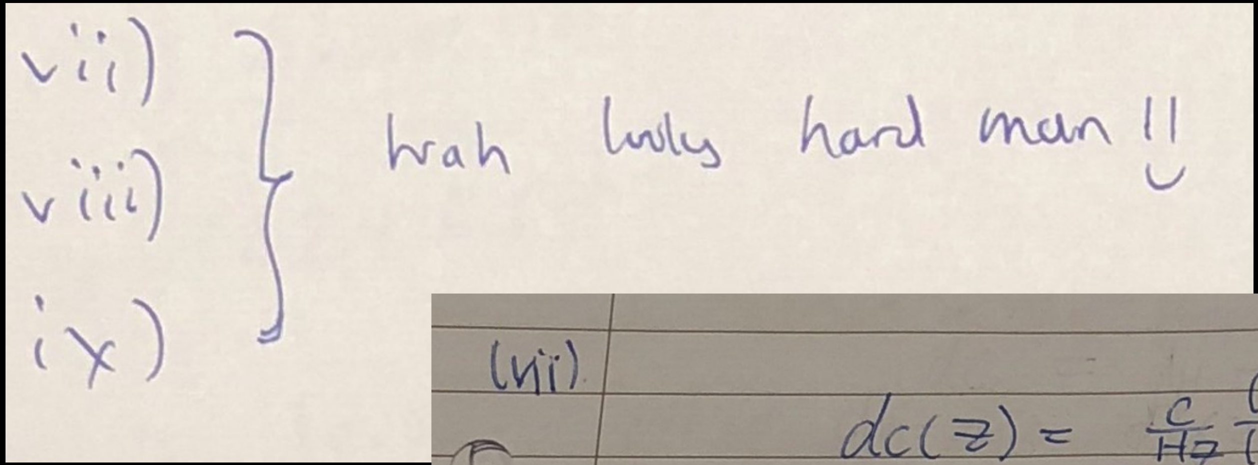
$$= 4.42 \times 10^9 \text{ Mpc}$$

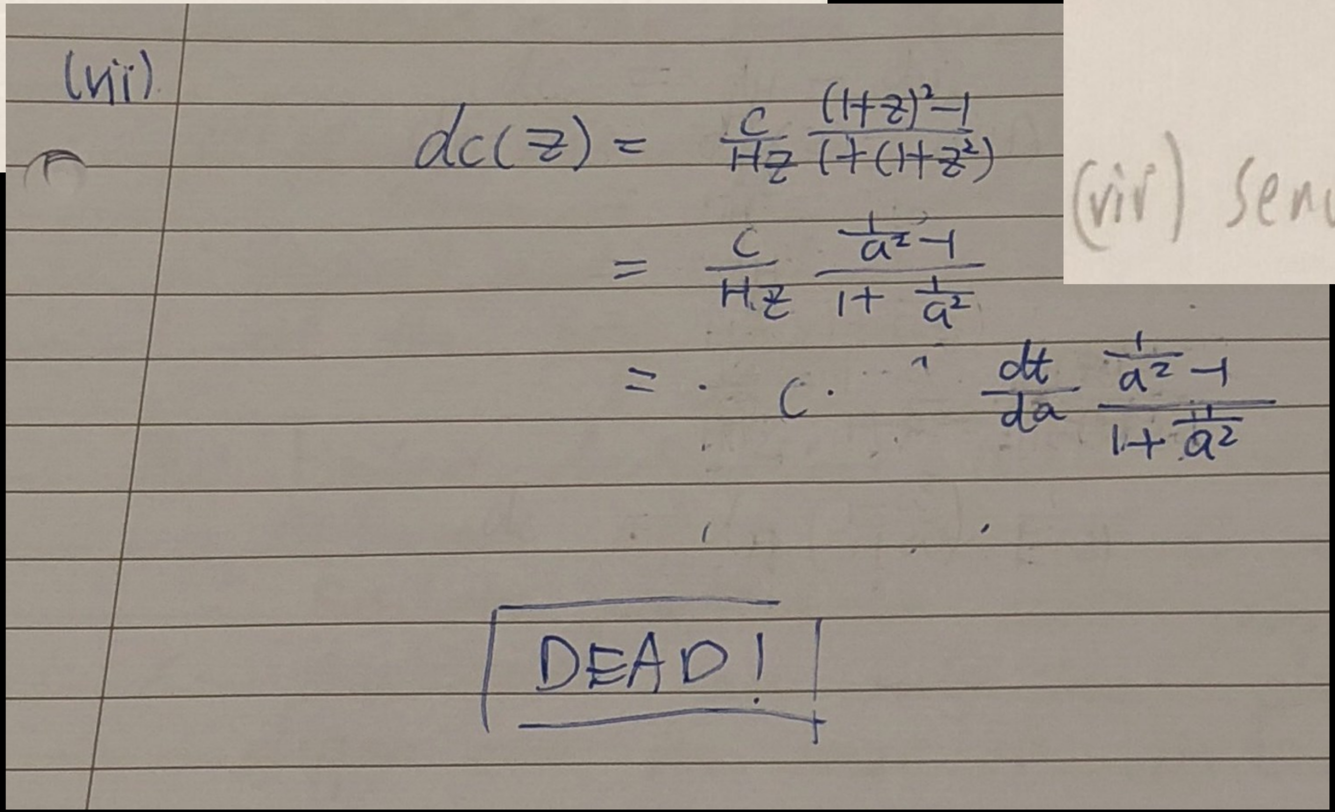
This is approximately 14.4 *quadrillion* light years! Our observable universe must be *very huge indeed*.

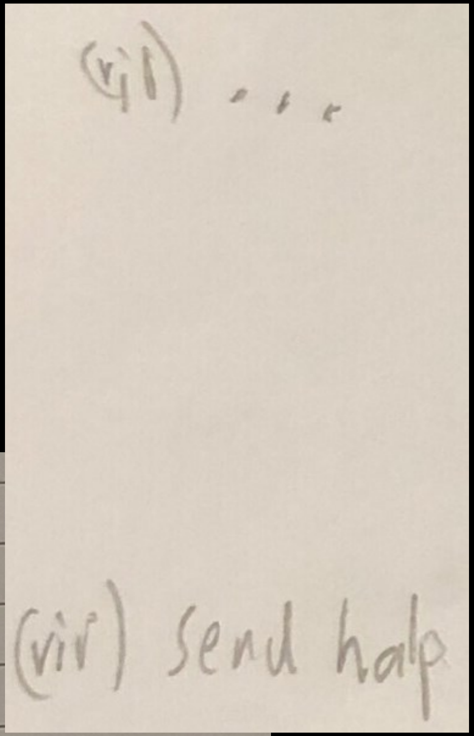
We hope so too…for your sake…

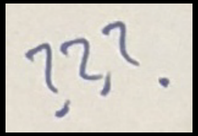


The marks are too far away!









General Comments: SNR DRQ 3

- Part 1 (i to iii): VERY GOOD! Relatively.
- Part 2 (iv to v): Everyone started to hubble along, it seems. All of you hubbled and tripped at the same place :P
  (Hint: Is density of a matter-dominated universe constant?)
- Part 3 (vi to ix):

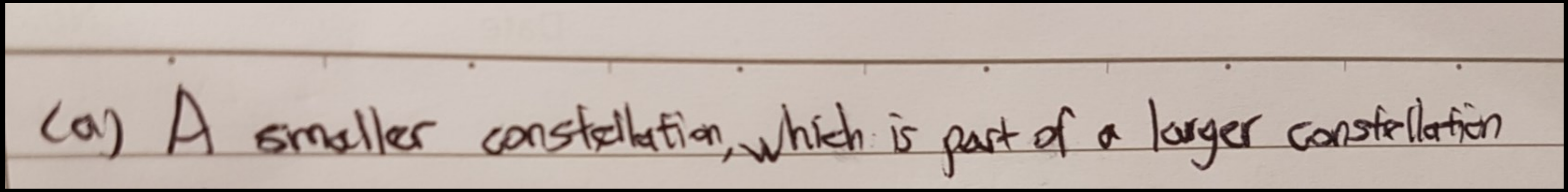
Q4: A Study of the Big Dipper

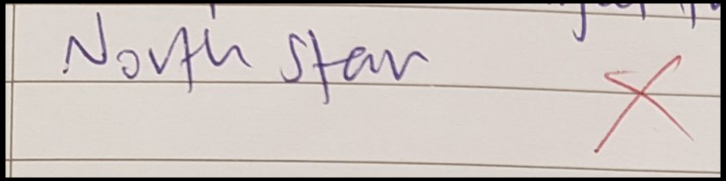
Intention

- ~~To test knowledge of the RA/Dec system~~
- ~~How can we use the night sky to keep track of time?~~
- To give away marks to participants

This was intended to be a giveaway…

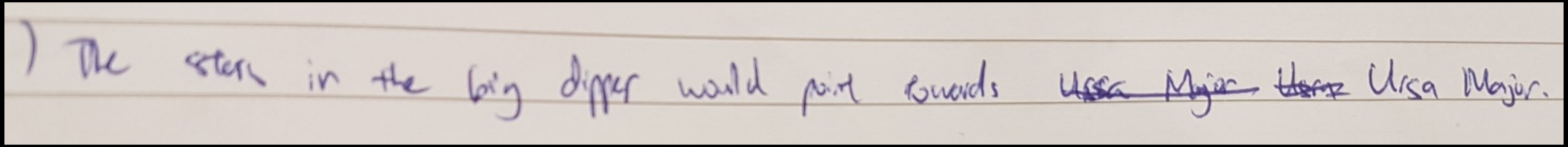
- Surely people know what an asterism is…right?

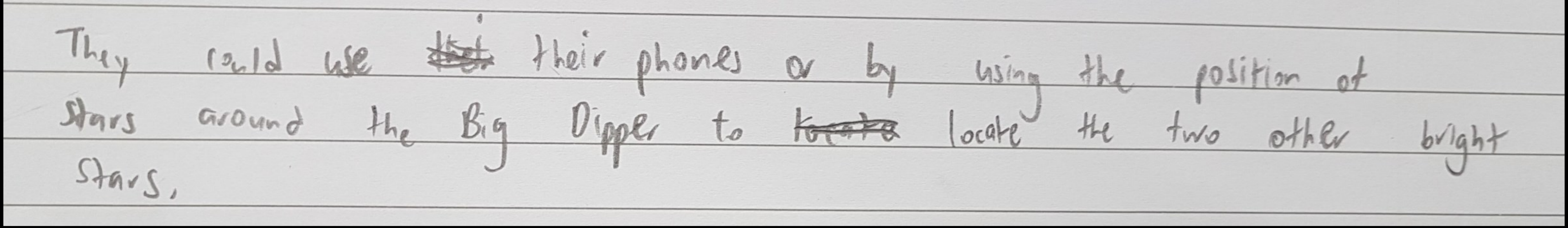




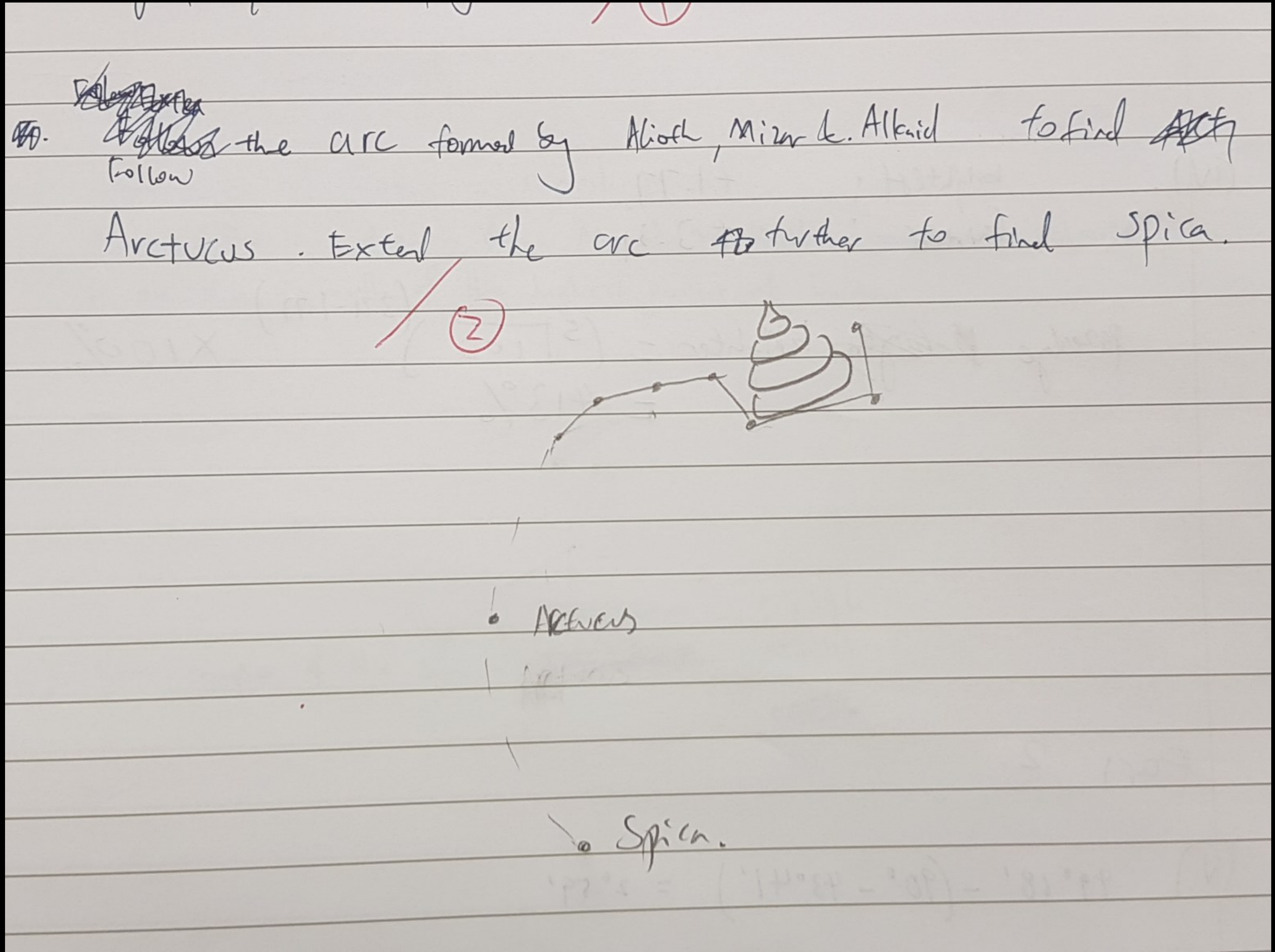
This was intended to be a giveaway…

- Surely people can use the Big Dipper to find 2 bright stars…right?


) The stars in the big dipper would point towards ~~Ursa Major~~ ~~Ursa~~ Ursa Major.


They could use ~~that~~ their phones or by using the position of Stars around the Big Dipper to ~~locate~~ locate the two other bright Stars,

The expected answer (kinda)


Follow the arc formed by Alioth, Mizar & Alkaid to find Arcturus. Extend the arc further to find Spica.

(2)

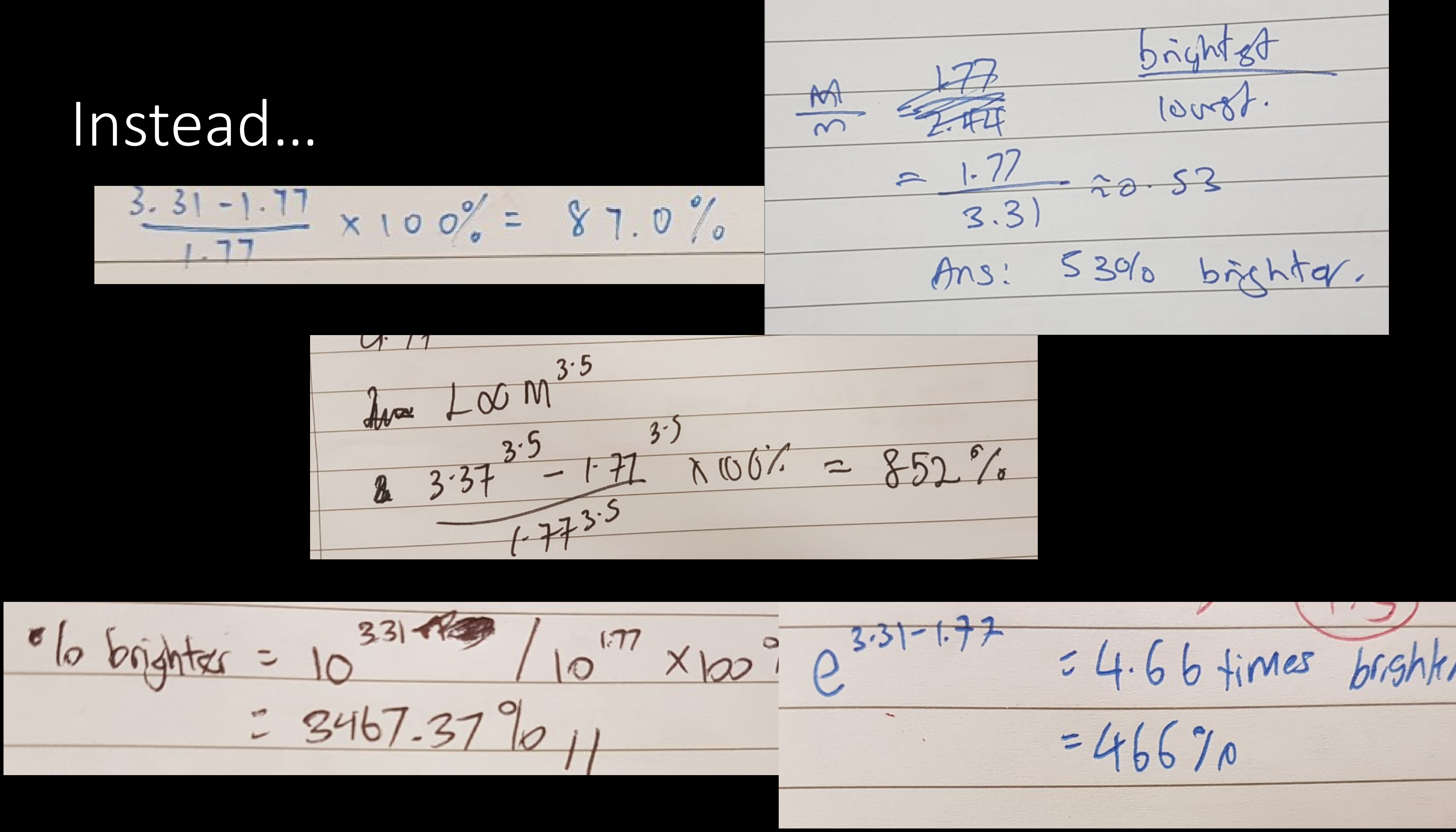
Surely people know how to use the Formula Book… right?

(iv) [1 point] To the naked eye, the stars of the Big Dipper have noticeably different brightnesses. How much brighter is the brightest star of the Big Dipper compared to its faintest star? Express your answer in percentages.

Relationship between Luminosity and Absolute Magnitude	$\frac{L_1}{L_2} = 10^{\frac{M_2 - M_1}{2.5}}$

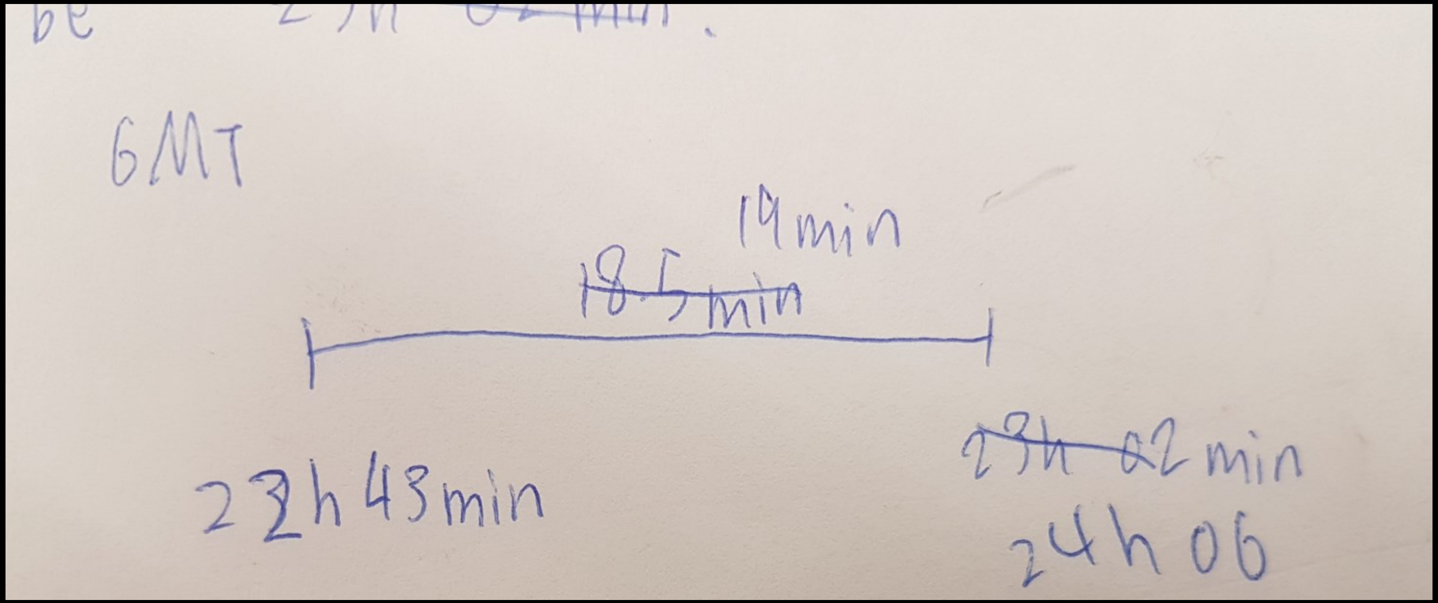
The same relationship exists between brightness and apparent magnitude!

Instead...



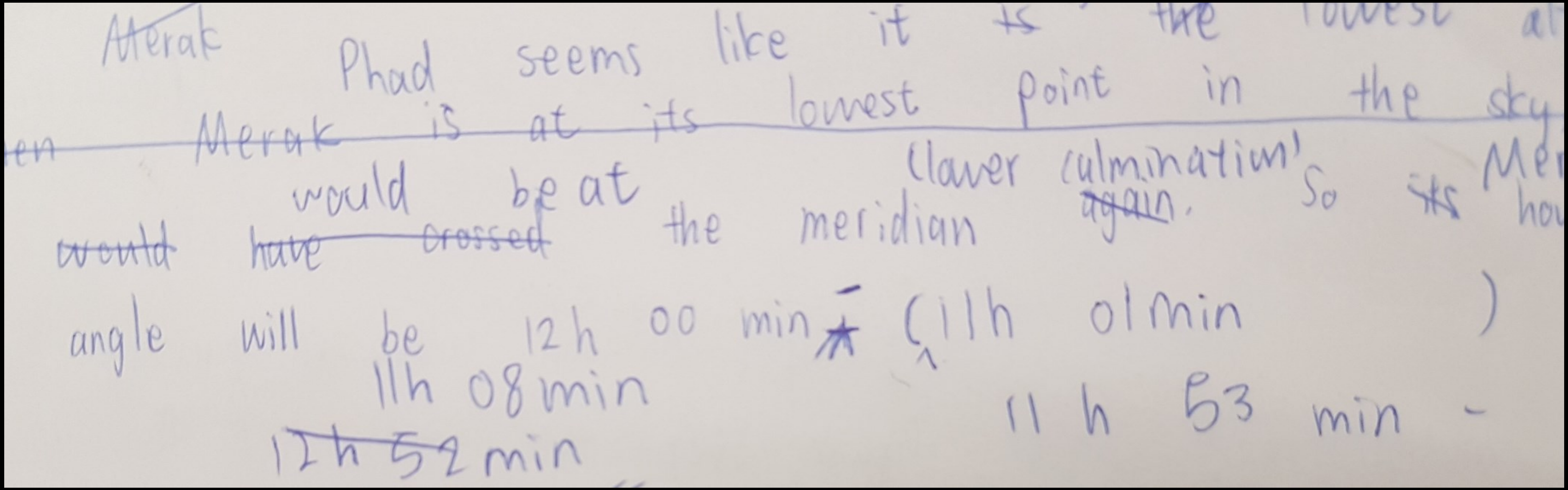
3.31 - 1.77 / 1.77 × 100% = 87.0%
M / m
brightest / lowest
= 1.77 / 3.31 ≈ 0.53
Ans: 53% brighter.
L ∝ M 3.5
3.37 3.5 - 1.77 3.5 / 1.77 3.5 × 100% = 852%
% brighter = 10 3.31 / 10 1.77 × 100
= 3467.37 %
e 3.31-1.77
= 4.66 times
= 466%

Surely people know how to tell time…right?



I need to start including clock faces in the Appendix

MAJOR BUGBEAR: POOR PRESENTATION

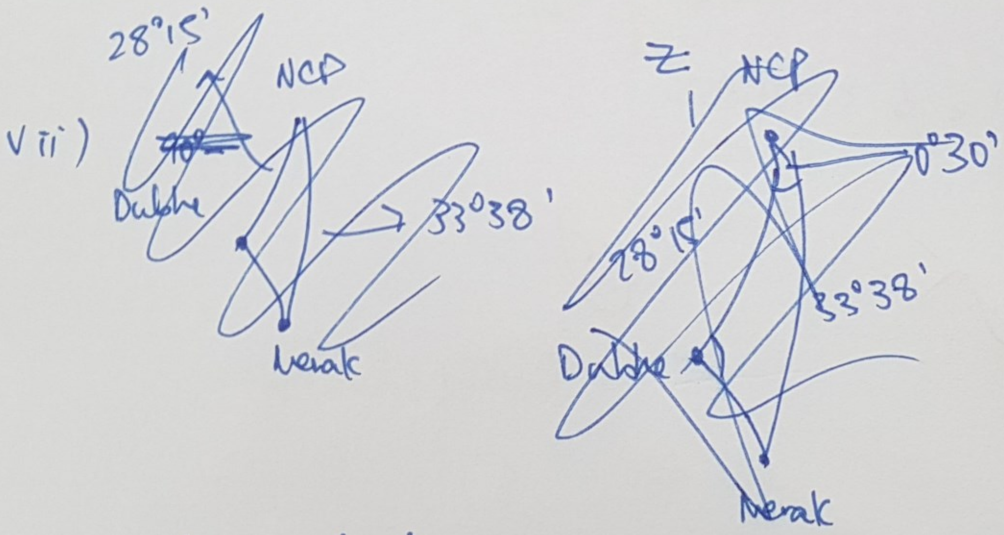


Is this a “buy one get 3 free” sale?

Questionable Assumptions about Merak and Dubhe

A showcase in desperate measures

What I expected

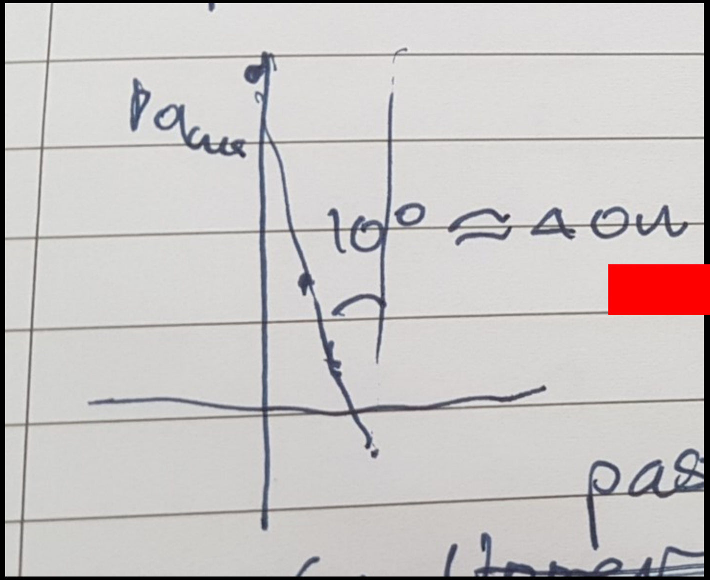


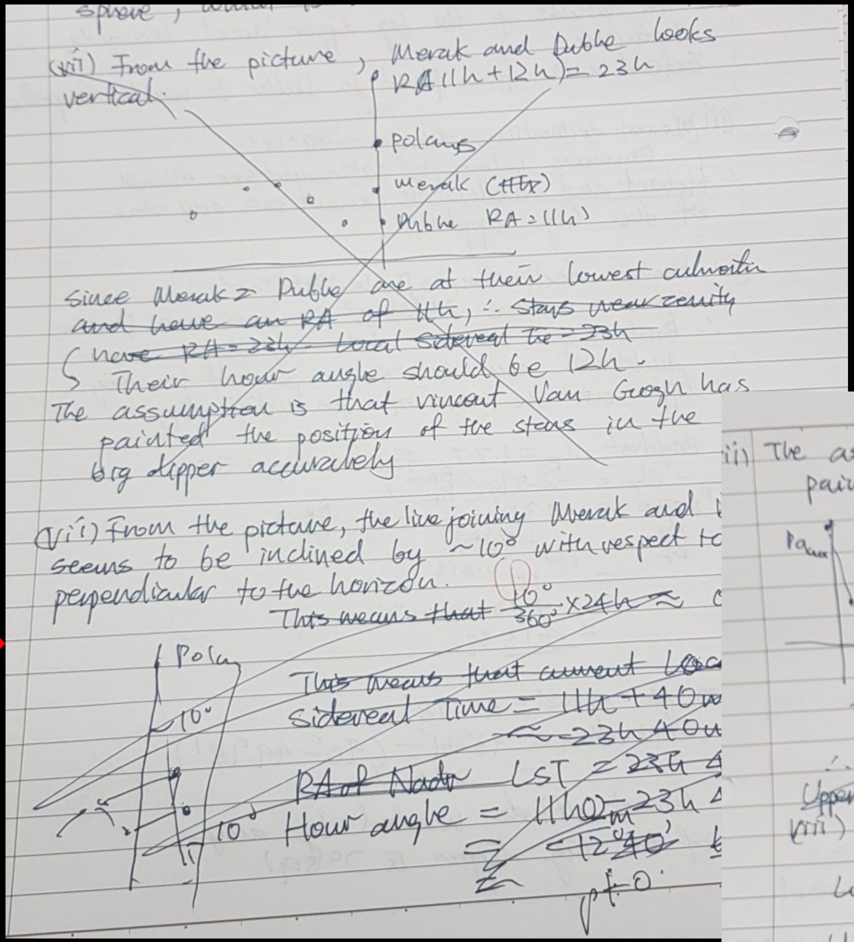
Ok. you know what.

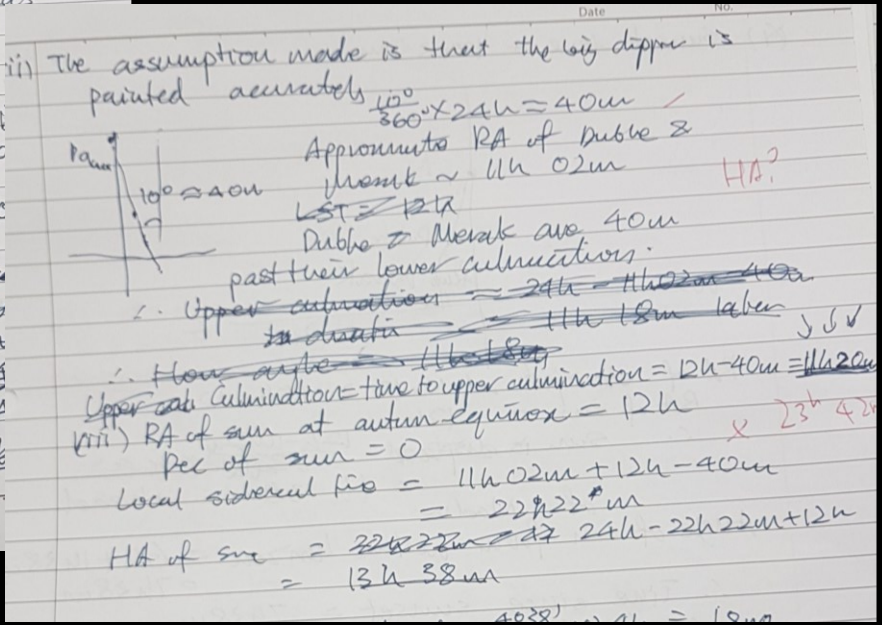
Merak and Dubhe are vertical → Polaris (NCP) is right above the two stars. /①

∴ HA = 12ʰ00ᵐ. /①

Instead

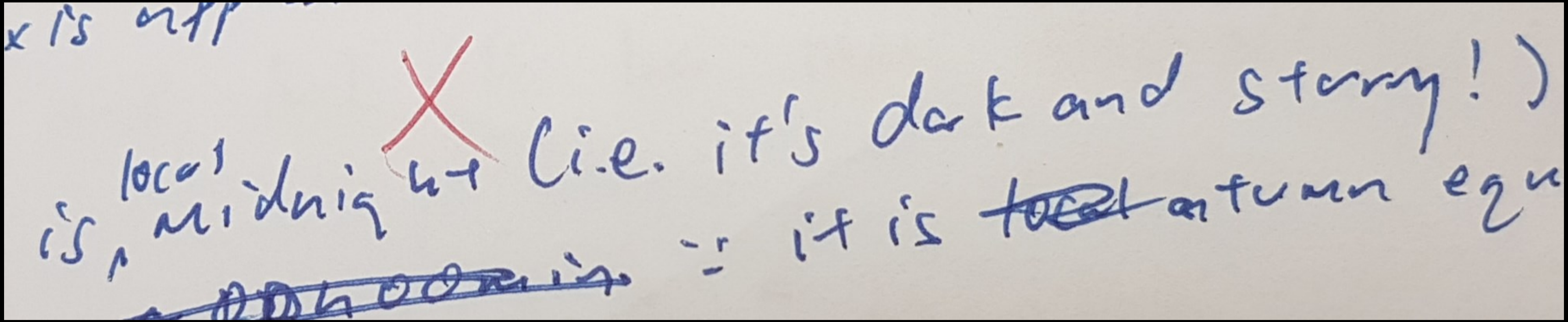




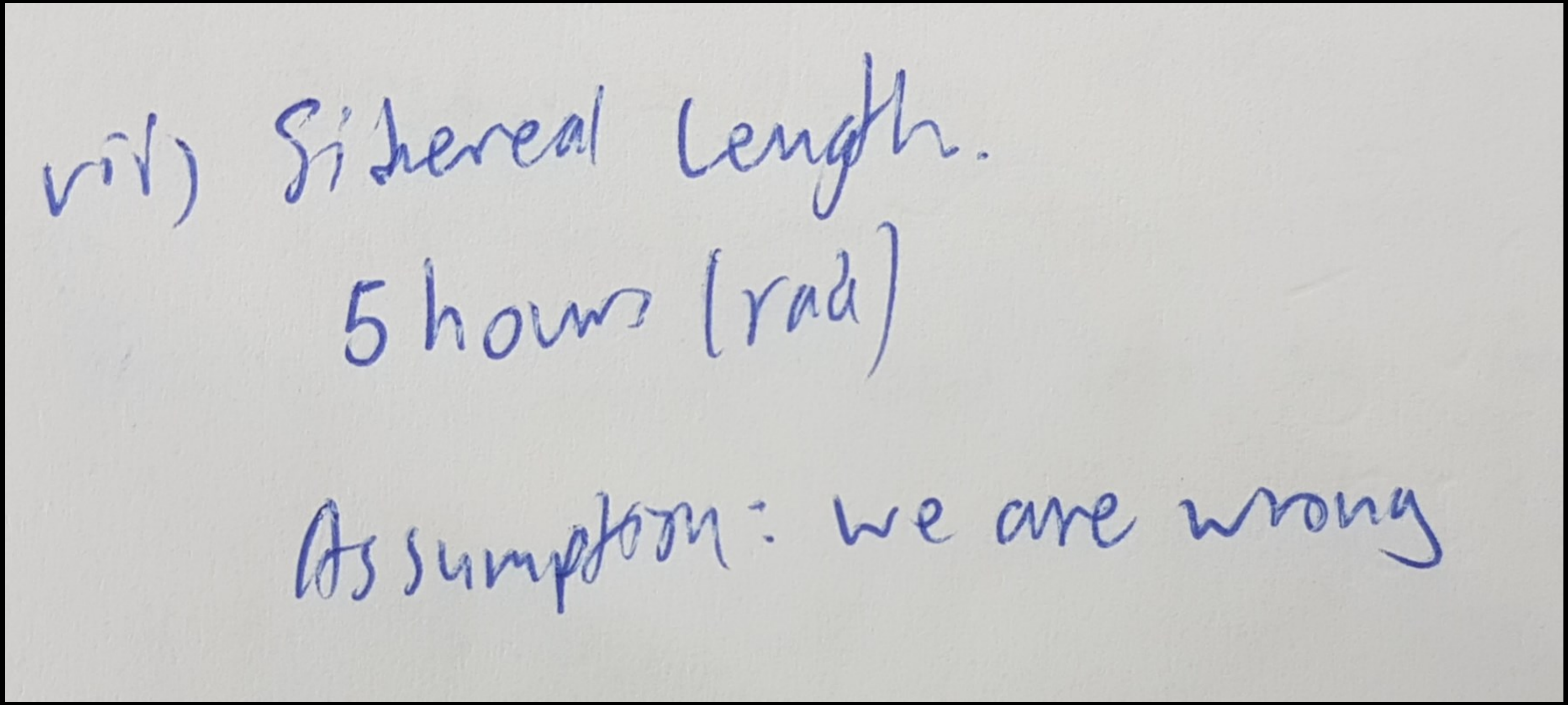


If you want to restart from scratch, have the decency to **write on fresh sheets of paper**…

It was a dark and stormy night?



Yeah this was pretty good actually



So the giveaway question wasn’t a giveaway after all…

Q1: Getting Crabby

Intention

- ~~To explore the evolution of a dynamic system using astrophysics~~

- To be (mostly) kind to participants

I thought I placed a lot of safety barriers in this question...

(i) [1 point] What is the current luminosity of the Crab pulsar solely due to black-body radiation L_B?

According to Stefan-Boltzmann Law,

$L = 4\pi R^2 \sigma T^4$

$= 4\pi (10000)^2 (1.3806488)(10)^{-23} (1.6\times10^6)^4$

$\approx 1.14 \times 10^{11}$ W (3s.f.)

Boltzmann's Constant $k_B = 1.3806488 \times 10^{-23}$ J K^{-1}
Coulomb Constant $k_e = \frac{1}{4\pi\epsilon_0} = 8.98755179 \times 10^9$ N m^2 C^{-2}
Stefan-Boltzmann Constant $\sigma = 5.67 \times 10^{-8}$ W m^{-2} K^{-4}

Major bugbear: INABILITY TO COUNT

(vi) [1 point] Charles Messier first observed the Crab Nebula in 1758. What is the luminosity of the Crab Nebula now compared to then? Express your answer as a percentage.

Too many assumed that just because its 2018, the nebula is **2018** years old

How to bash past safety barriers

Compute number of years between 1758 and 2018 = 260 years

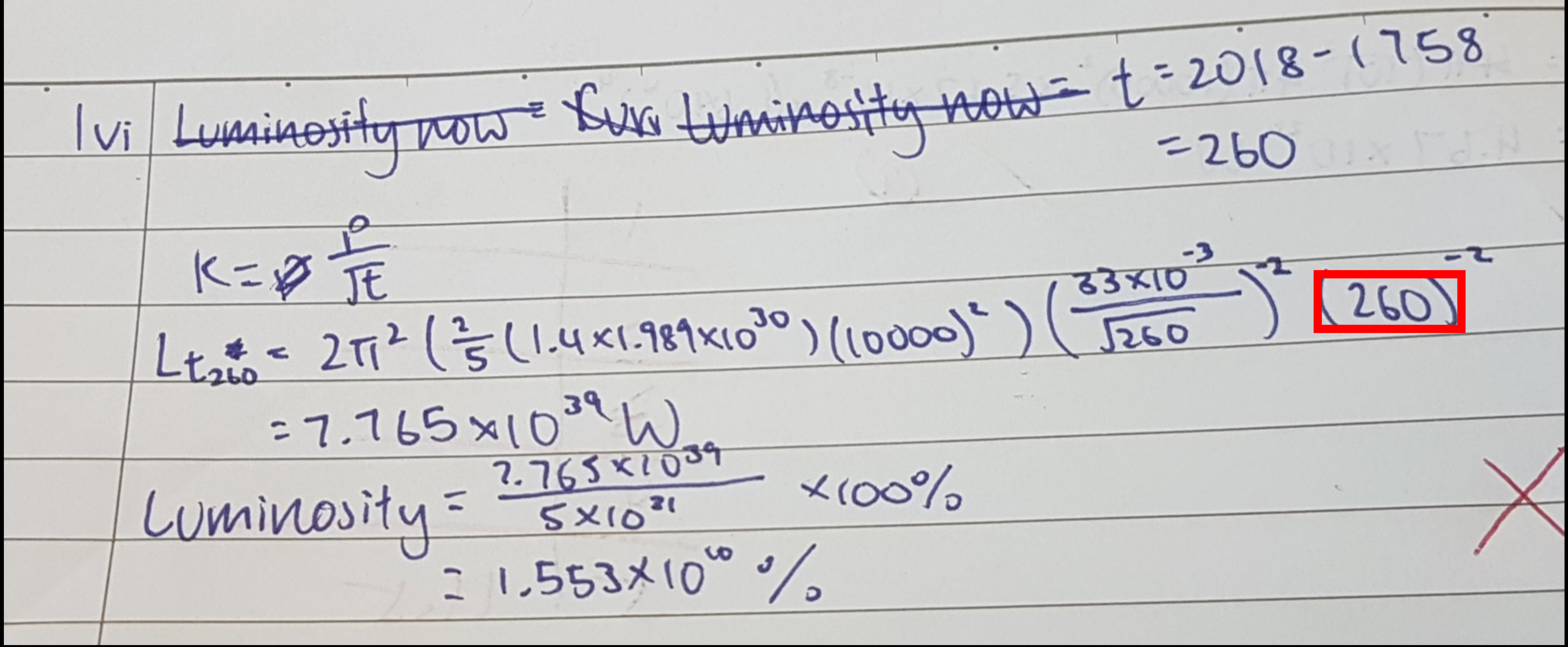
↓

Assume nebula is 260 years old

↓

Decides to drop the years

Behold this work of perfection



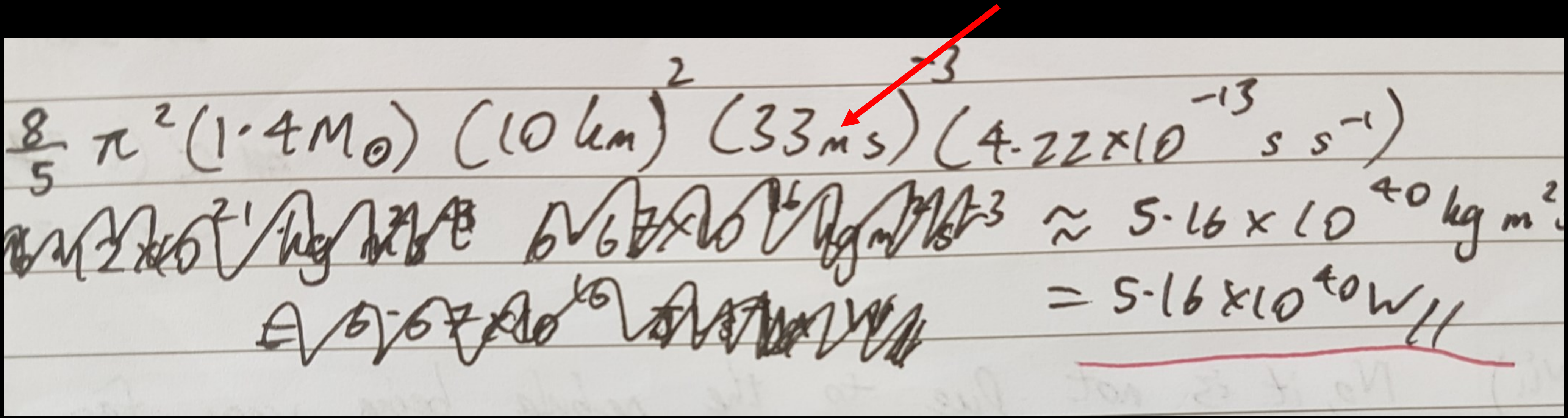
PAY ATTENTION TO UNITS

Major bugbear: UNITS AND SI PREFIXES

Ever wonder why your answer is off by 10^9?

- Milli = 10^{-3}!

Did you think this was micro…?



Quick sanity check on 5×10^{40}W

=

× 10,000

(viii) [1 point] Let the radius of the nebula be R. Consider a test mass expanding with the edge of the nebula (a.k.a. R). Write down the second-order differential equation relating acceleration $\frac{d^2R}{dt^2}$ to M, R, and other constants where appropriate.

(Hint: Analyse the forces involved.)

(xi) [3 points] Find a relationship between the expansion velocity v and R, including any other appropriate constants. Label and explain any constants that you introduce.

(Hint: While it may be tempting to solve the differential equation in Part (viii) to obtain an answer, there is another (and better) way to approach this question.)

The part where everybody died

The 2nd order DE is really just reading comprehension

The Crab Nebula itself currently has a radius of 5.5 light years and is expanding at 1500 km s^{-1}, and we know the expansion rate is being slowed by gravity. We also know that the entire nebula

$$F = F_G \quad \rightarrow \quad a = \frac{d^2R}{dt^2} = -\frac{GM}{R^2}$$

Too many teams took the bait…

(xi) [3 points] Find a relationship between the expansion velocity v and R, including any other appropriate constants. Label and explain any constants that you introduce.

(Hint: While it may be tempting to solve the differential equation in Part (viii) to obtain an answer, there is another (and better) way to approach this question.)

Did you forget about **energy**??

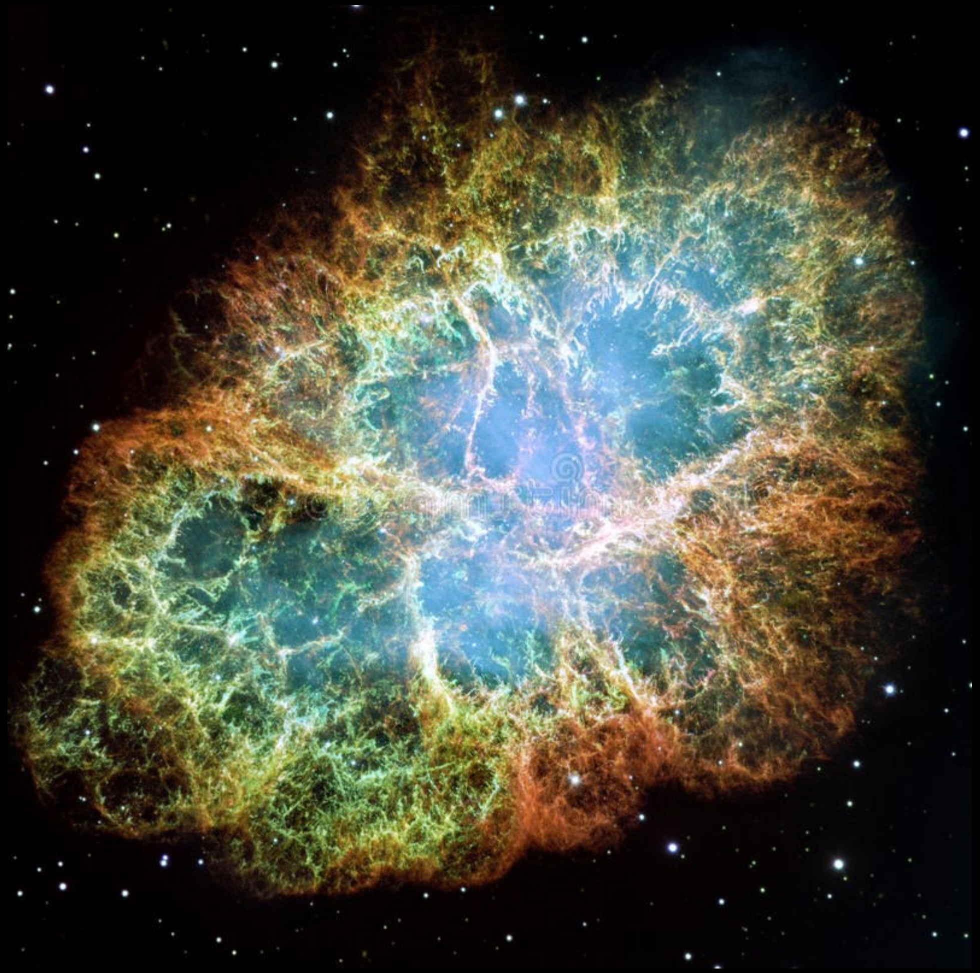
For the few that remembered that…

There's a difference between:

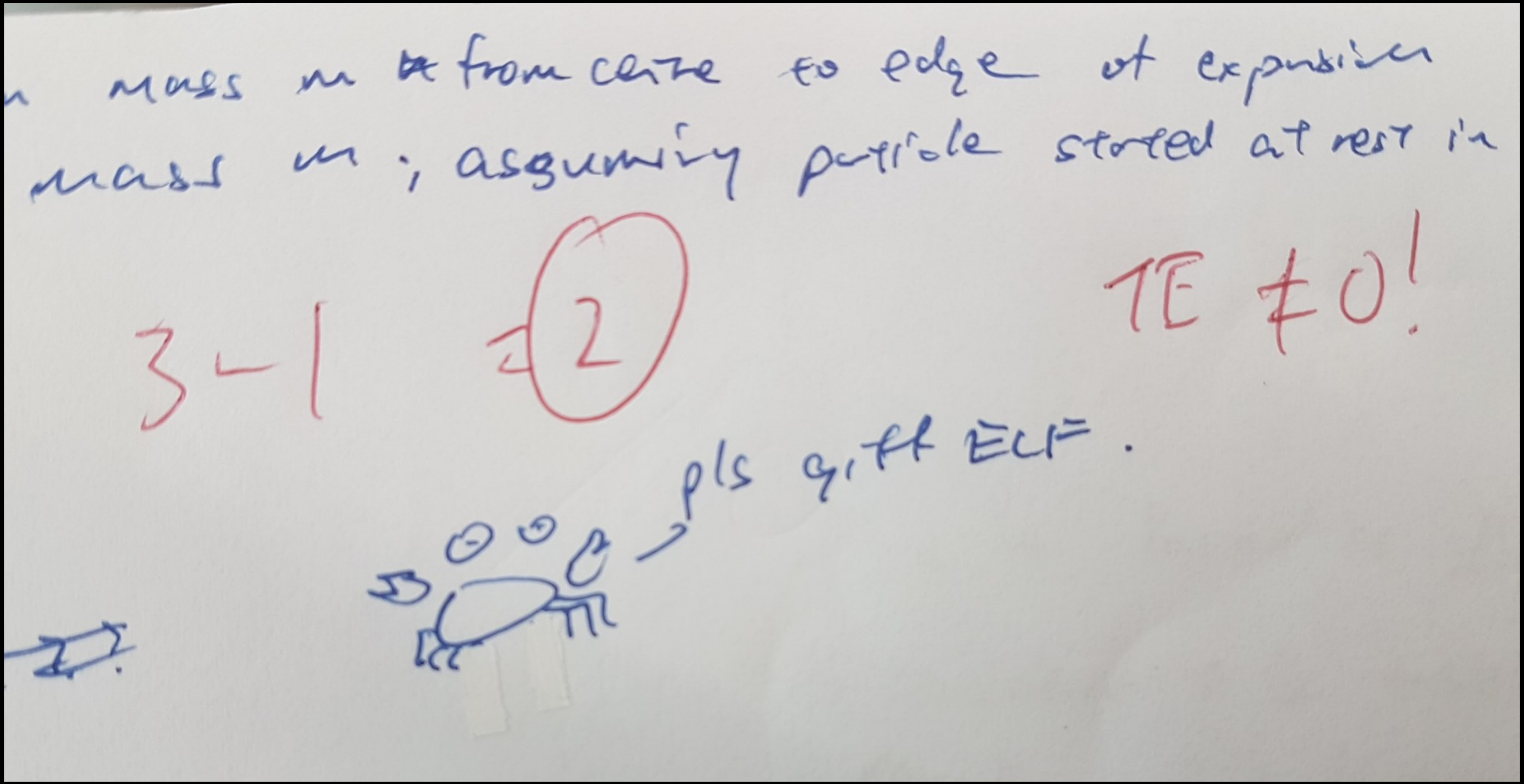
1. Loss in KE = Gain in GPE

2. KE + GPE = 0

TE is not 0 here!

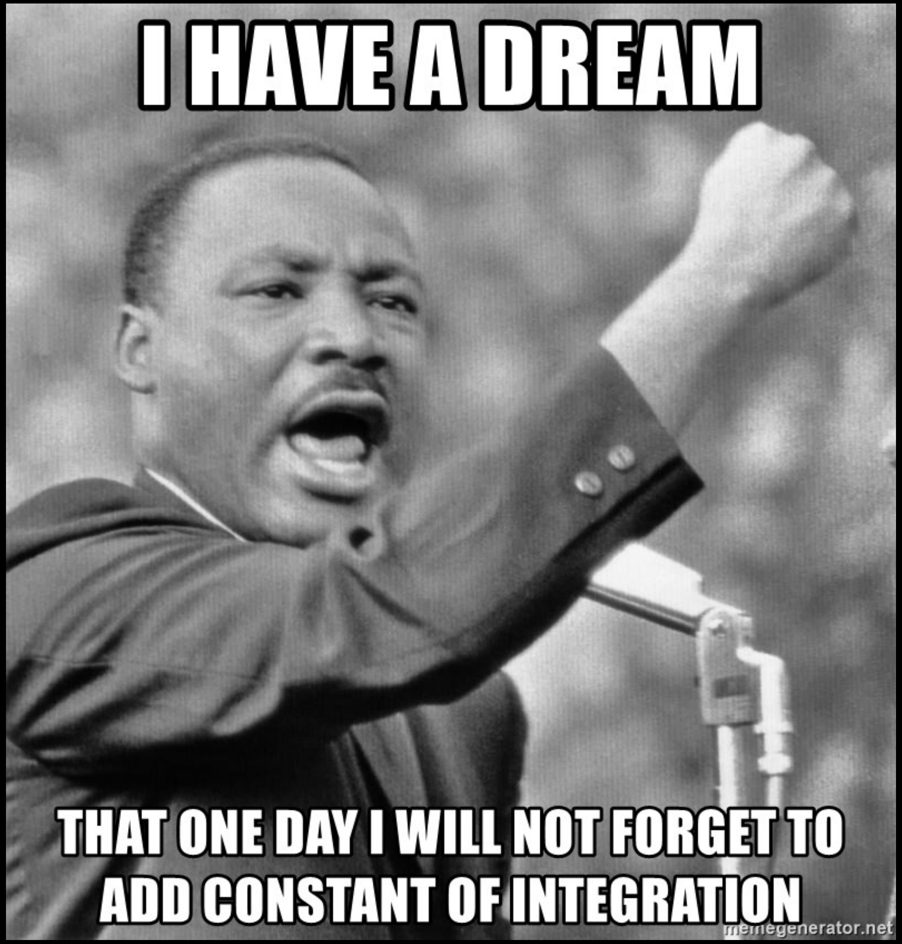


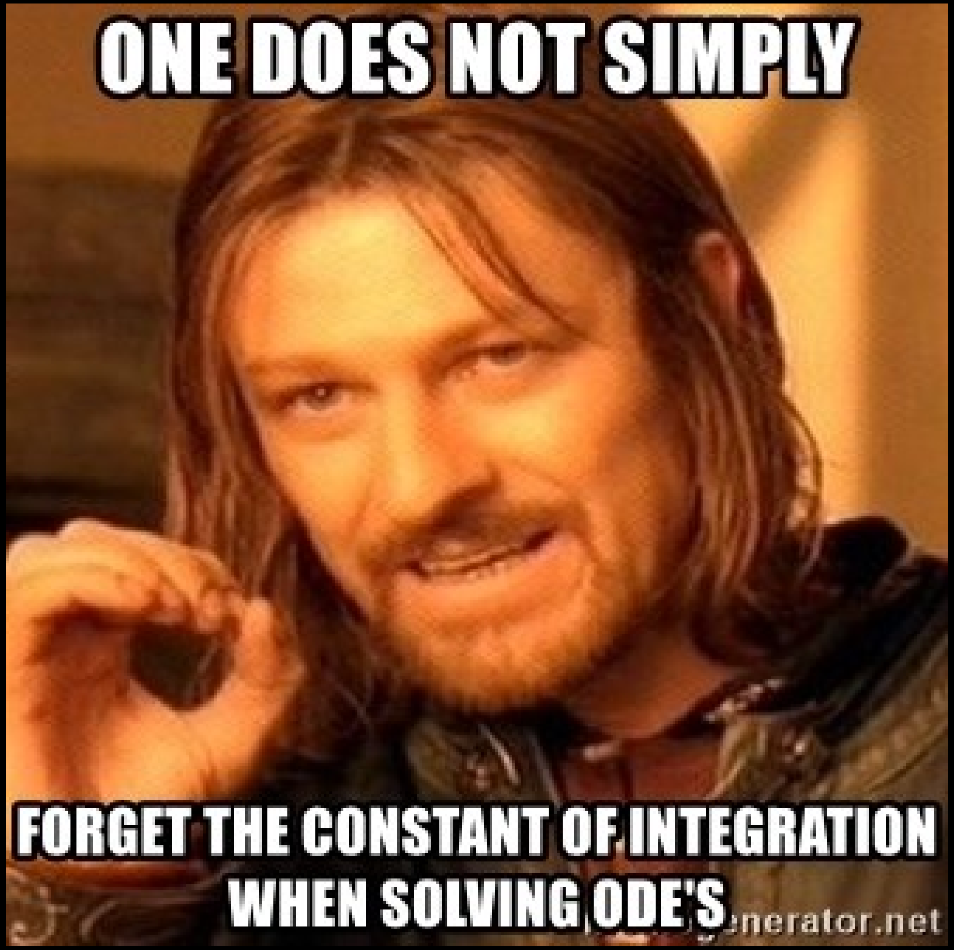
ECF Crab gets ECF



The Gallery of Integration Errors

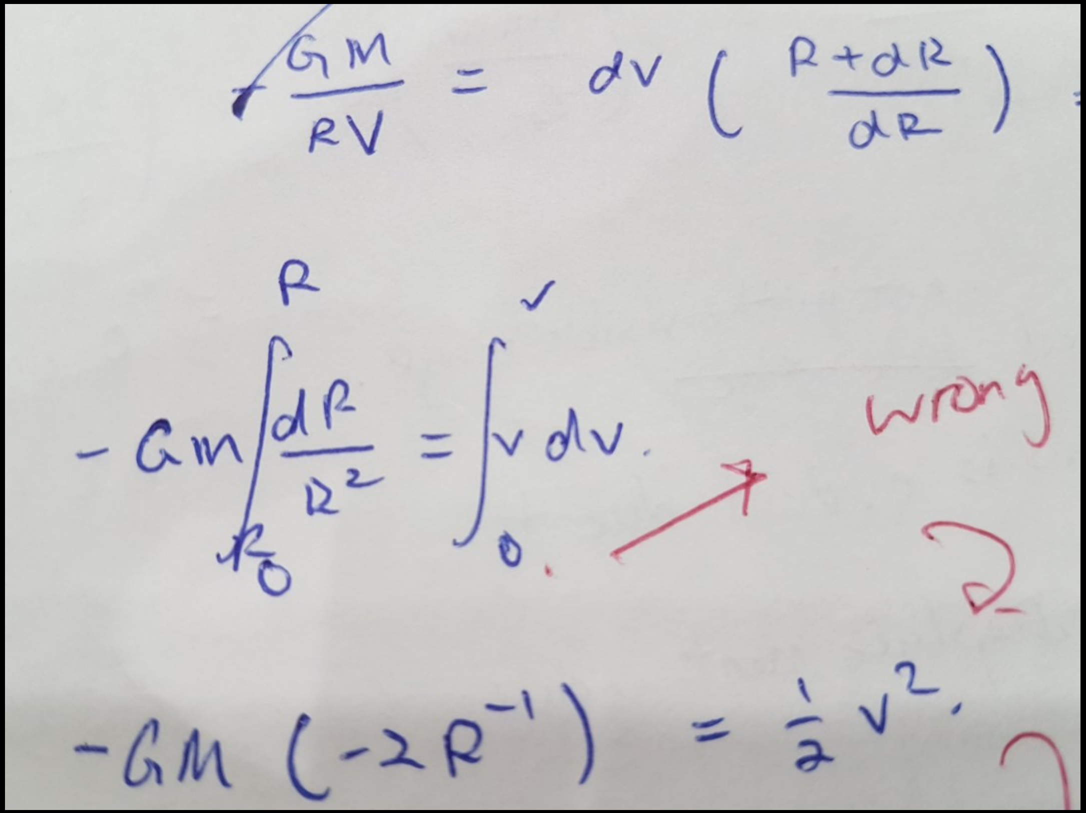
1. Constant of Integration





Other horrific errors

2. Not paying attention to limits of integration



Other horrific errors

3. Not knowing how to solve a separable DE

   - No matter how many times you flip/split/recombine that derivative, its not going to solve itself…

Q2 : Are Black Holes really Black?

Goals of the question

- Guide students to understand the simplest physical model of gravitational lensing
- How to determine the mass of a black hole from its Einstein radius
- Help students in understanding Hawking radiation:

i. black hole as a thermodynamical object

ii. evaporation of black hole

- Estimating the upper bound of energy release during BH merger
- Estimating the evaporation time of BH

Lack of Physical Understanding

$$= \int \frac{8\pi G k_B}{\hbar c} M \, dM$$

$$= \frac{8\pi G k_B}{2\hbar c} M^2 + C$$, where C is an arbitrary constant.

$$= \frac{4\pi G k_B}{\hbar c} M^2 + C$$

$$\therefore k = \frac{4\pi G k_B}{\hbar c}$$ //

$$\frac{d(Mc^2)}{\frac{\hbar c^3}{8\pi G M k_B}} = dS$$

$$\Downarrow$$

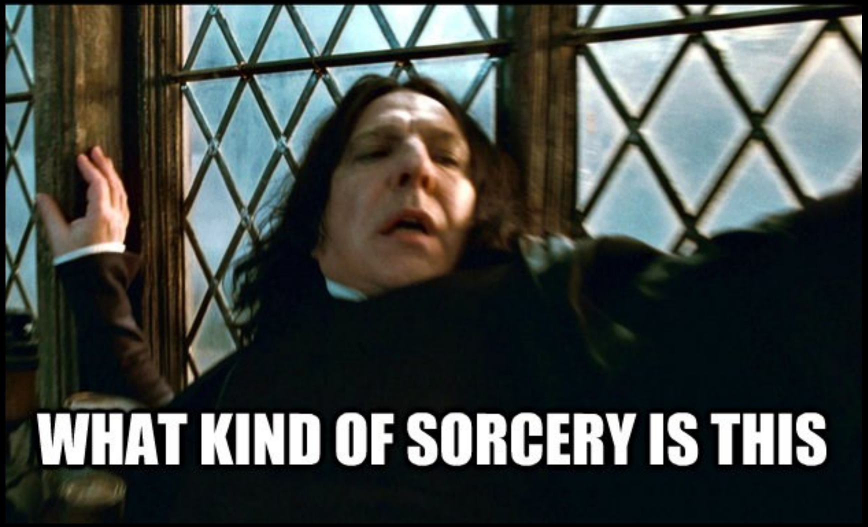
$$\int dS = \int \frac{8\pi G M k_B}{\hbar c^3} c^2 \, dM$$

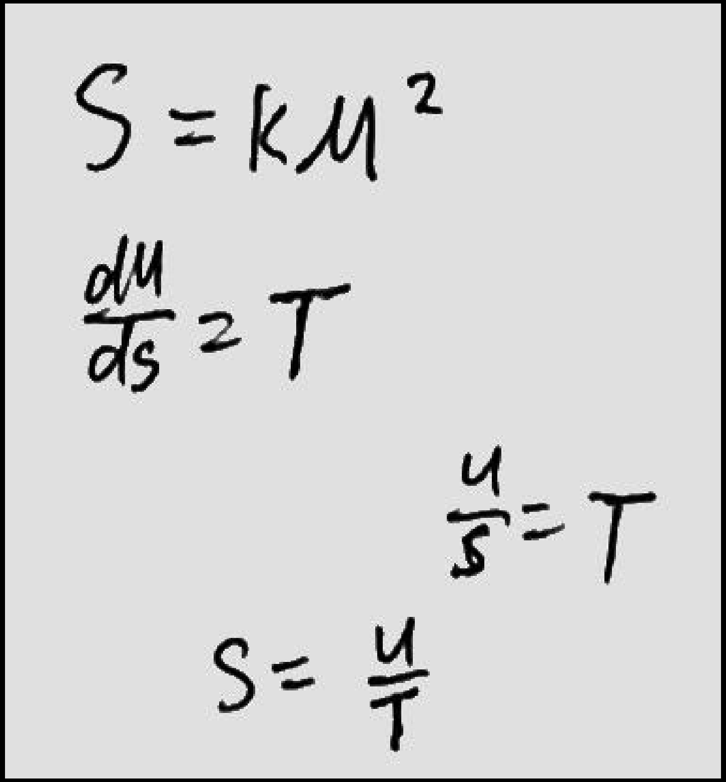
$$\therefore S = \frac{4\pi G k_B}{\hbar c} M^2$$ (shown)

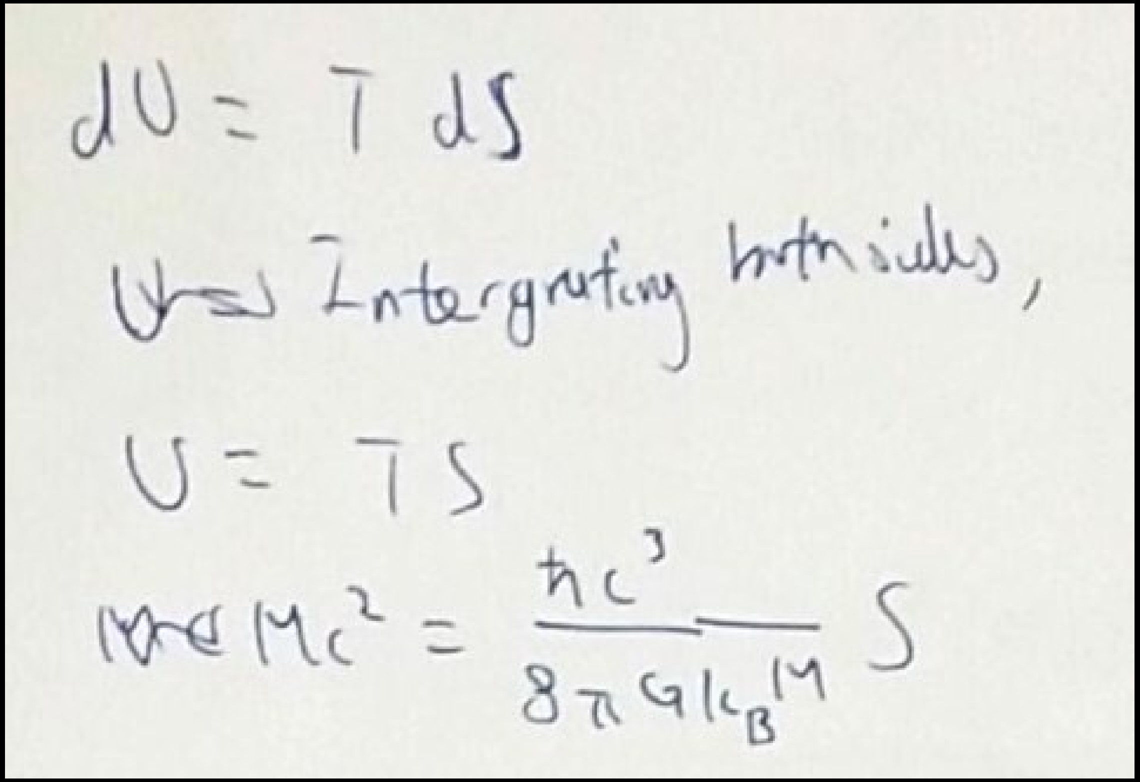
You must justify the constant of integration or the limits of integration, don’t just randomly pick a constant or limits that match the question

Calculus Magic

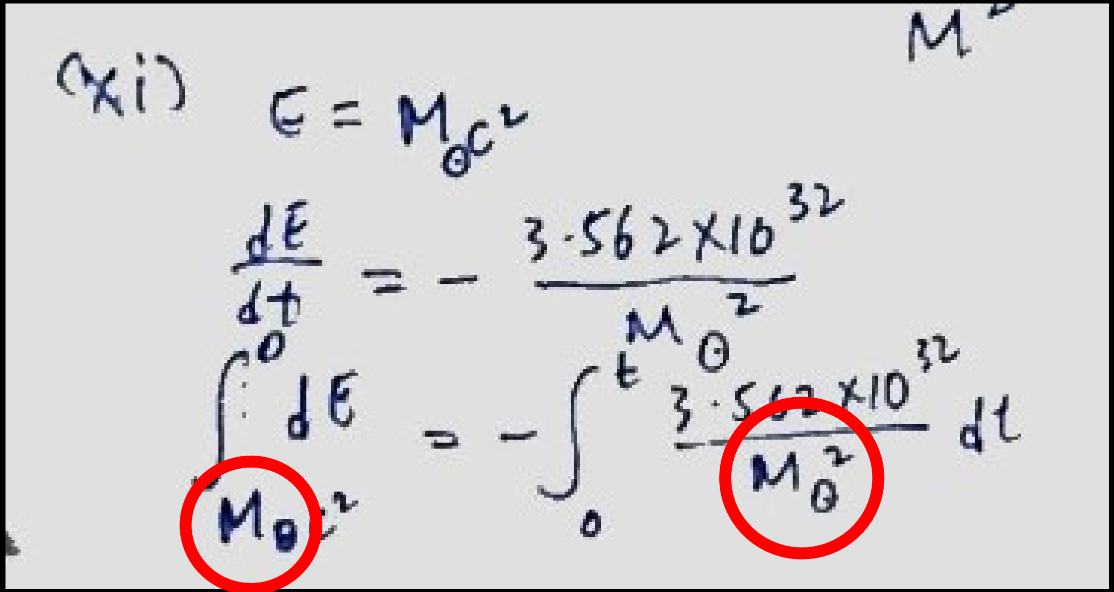
(dU = T dS, hence U = TS)

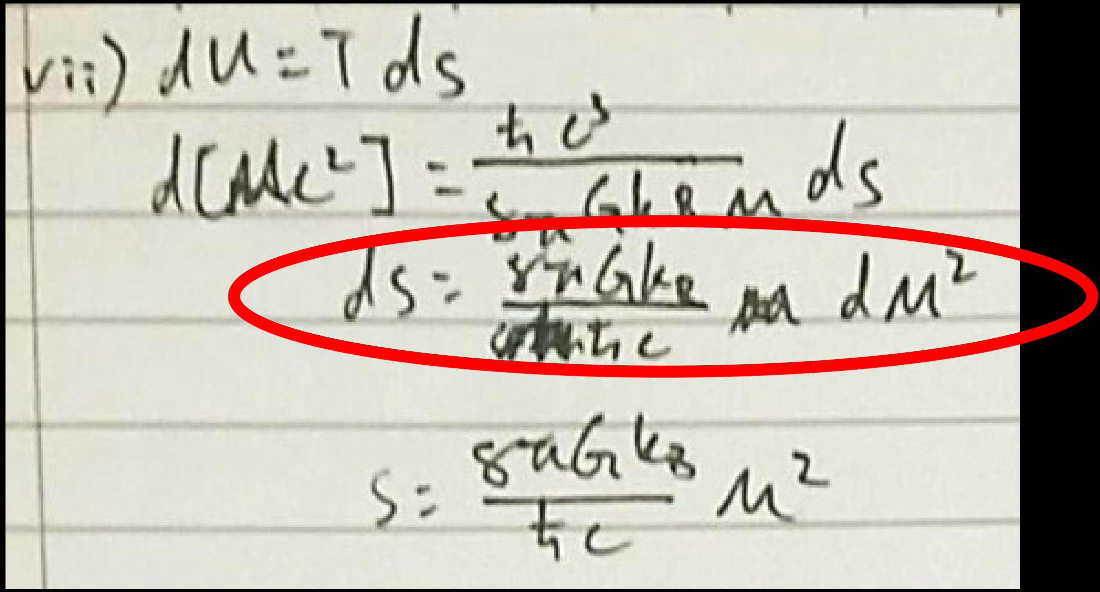






More calculus magic





(i) [2 points] By using Newtonian mechanics and equating the escape velocity at the Schwarzschild radius to the speed of light, derive the expression for the Schwarzschild radius, r_s, as given in the formula book. This derivation is heuristic: the steps are invalid, but it happens to be true. Can you explain why is it invalid?

$$r_s = \frac{2GM}{c^2}$$

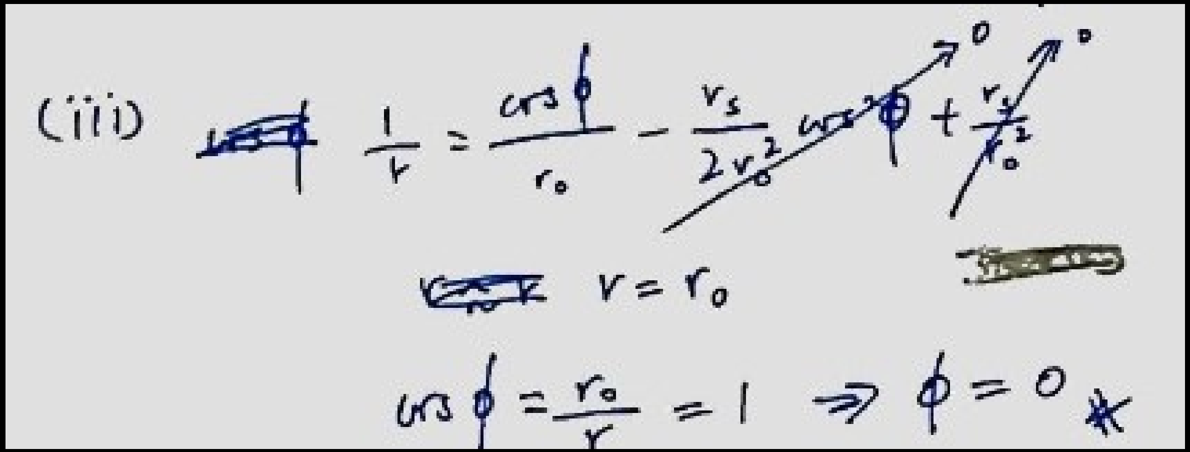
~~The Schwarzschild radius of~~

Newtonian mechanics do not apply well to black holes.

I know!

Stationary photons!!!

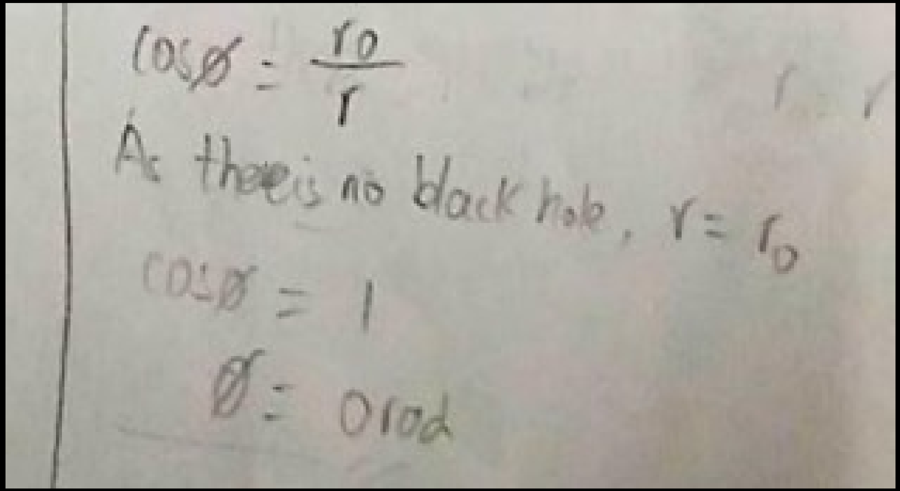
r = constant means that the photon does not move!



(iii) $\frac{1}{r} = \frac{\cos\phi}{r_0} - \frac{r_s}{2r_0^2}\cos^2\phi + \frac{r_s}{r_0^2}$

$r = r_0$

$\cos\phi = \frac{r_0}{r} = 1 \Rightarrow \phi = 0$ *

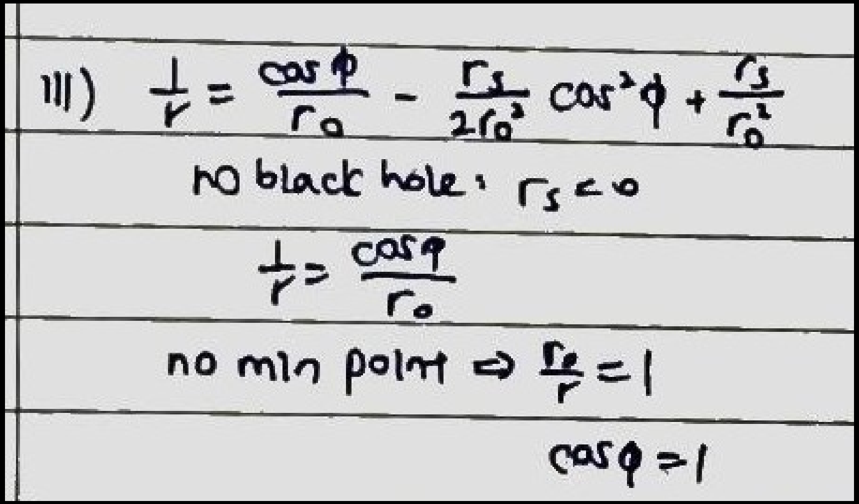


$\cos\phi = \frac{r_0}{r}$

As there is no black hole, $r = r_0$

$\cos\phi = 1$

$\phi = 0$ rad



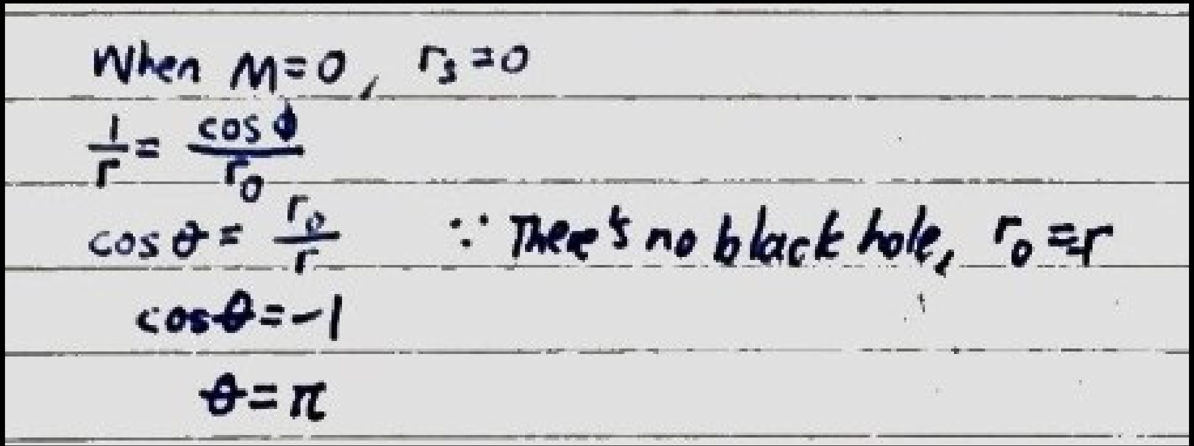
iii) $\frac{1}{r} = \frac{\cos\phi}{r_0} - \frac{r_s}{2r_0^2}\cos^2\phi + \frac{r_s}{r_0^2}$

no black hole: $r_s = 0$

$\frac{1}{r} = \frac{\cos\phi}{r_0}$

no min point $\Rightarrow \frac{r_0}{r} = 1$

$\cos\phi = 1$



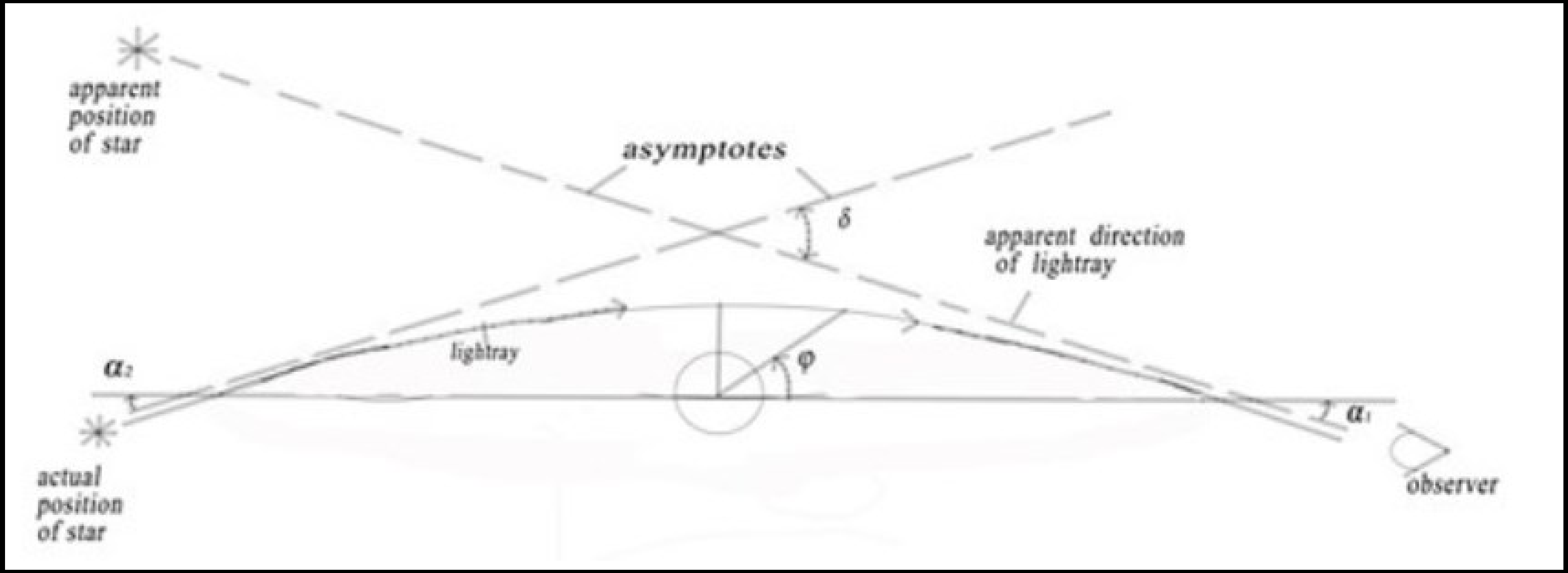
When $M = 0$, $r_s = 0$

$\frac{1}{r} = \frac{\cos\phi}{r_0}$

$\cos\theta = \frac{r_0}{r}$ ∵ There's no black hole, $r_0 = r$

$\cos\theta = -1$

$\theta = \pi$



And then there’s this…

Surefire way to be featured in the Post Mortem

1. Read Question.

(vi) [2 points] Suppose we have an event where a black hole located 7.5×10^{20} m away from Earth passes in front of a star 3.0×10^{21} m away from Earth. It is observed that the angular deflection of the star image observed from the Earth (often called the angular Einstein radius, denoted by α_1 in the figure) is 0.025 arcseconds. Calculate the mass of the black hole in terms of solar masses.

2. Fail to press panic button

[DON'T PANIC]*

Surefire way to be featured in the Post Mortem

3. Cooks up innocuous yet dubious equation

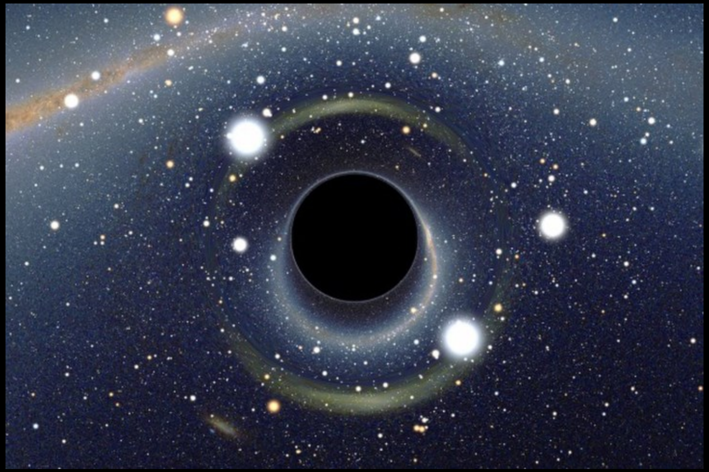
$$2r_0 = 0.025\, r_s$$

R_0 is the closest approach of a ray of light to the black hole

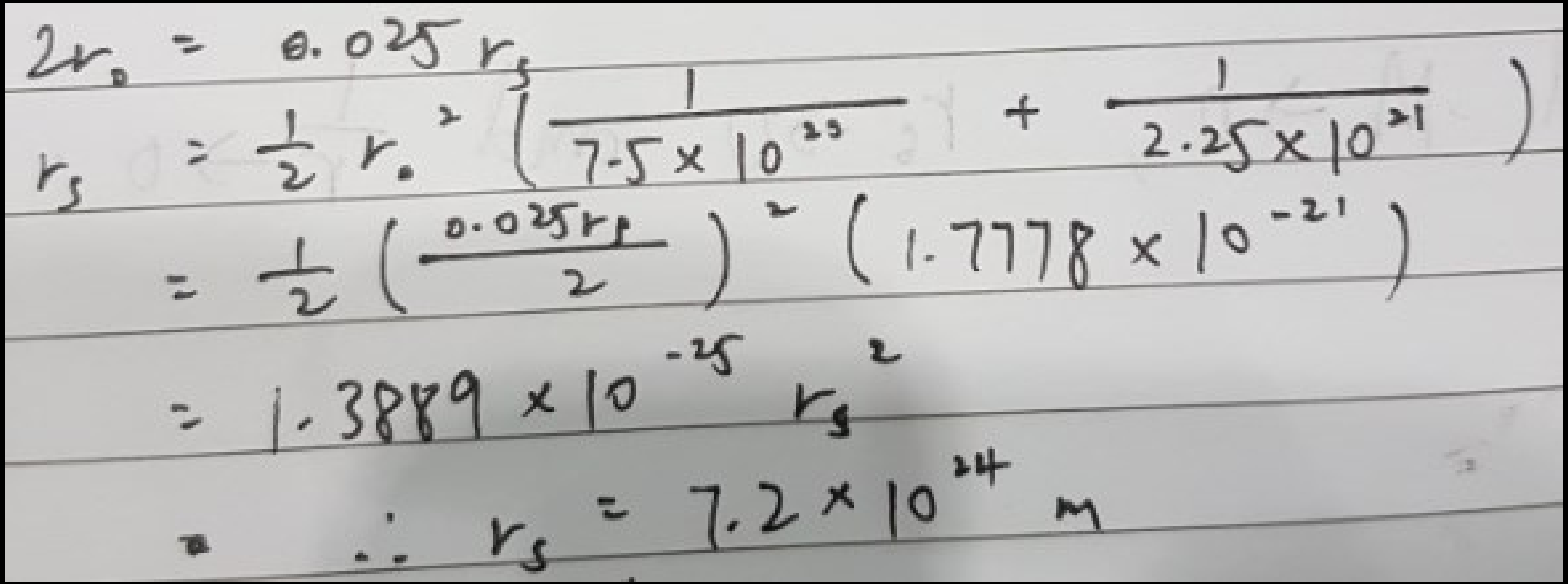
R_s is the Schwarzschild Radius

$R_s > R_0$ means the light ray ENTERS the black hole…

4. Plugs that into the given equations…



The Universe attempts to satisfy your ill-formed desires

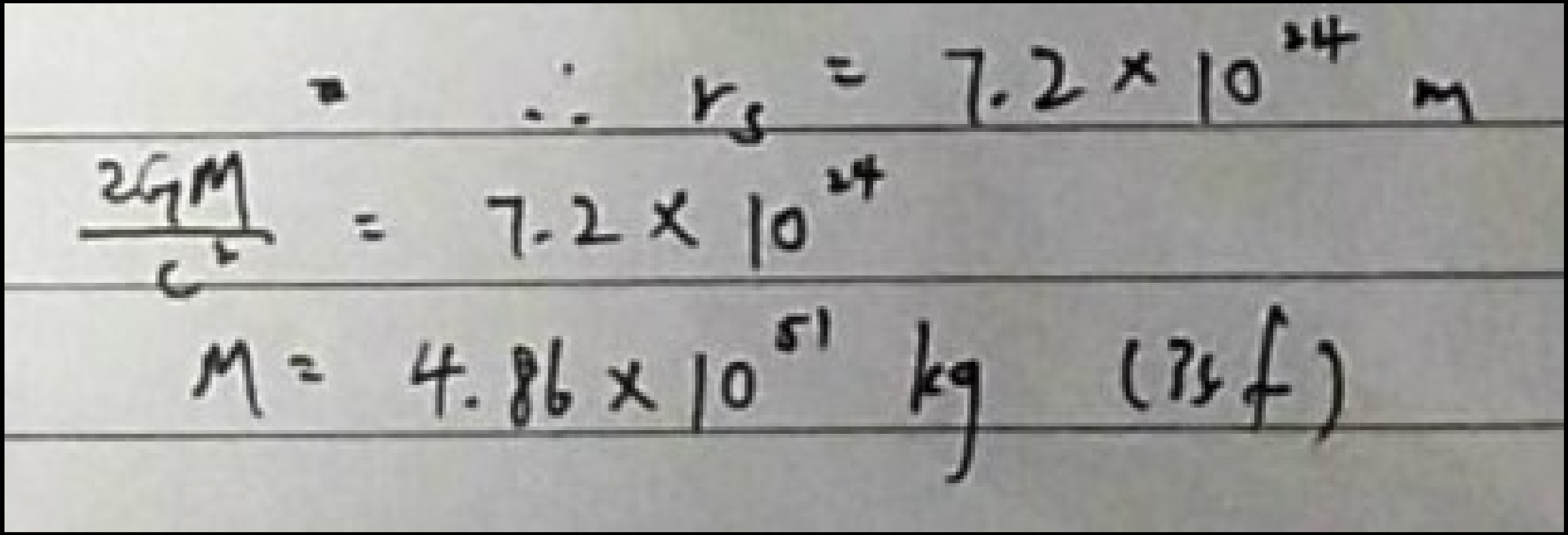


What monster have you created?

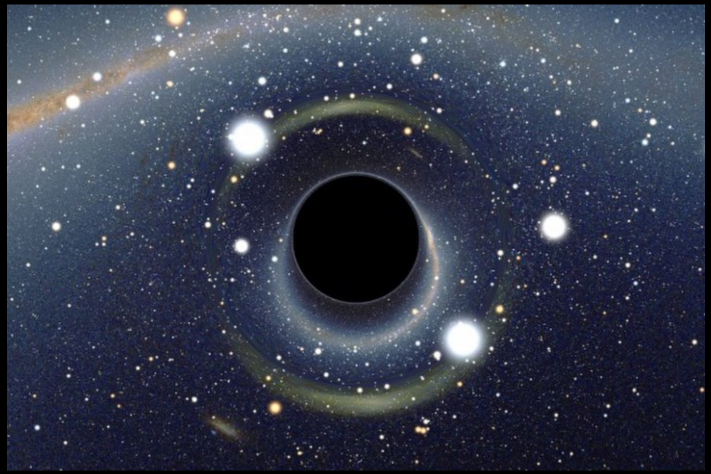
(vi) [2 points] Suppose we have an event where a black hole located 7.5×10^{20} m away from Earth passes in front of a star 3.0×10^{21} m away from Earth. It is observed that the angular deflection of the star image observed from the Earth (often called the angular Einstein radius, denoted by α_1 in the figure) is 0.025 arcseconds. Calculate the mass of the black hole in terms of solar masses.

Did you forget me?

What have we done?!?

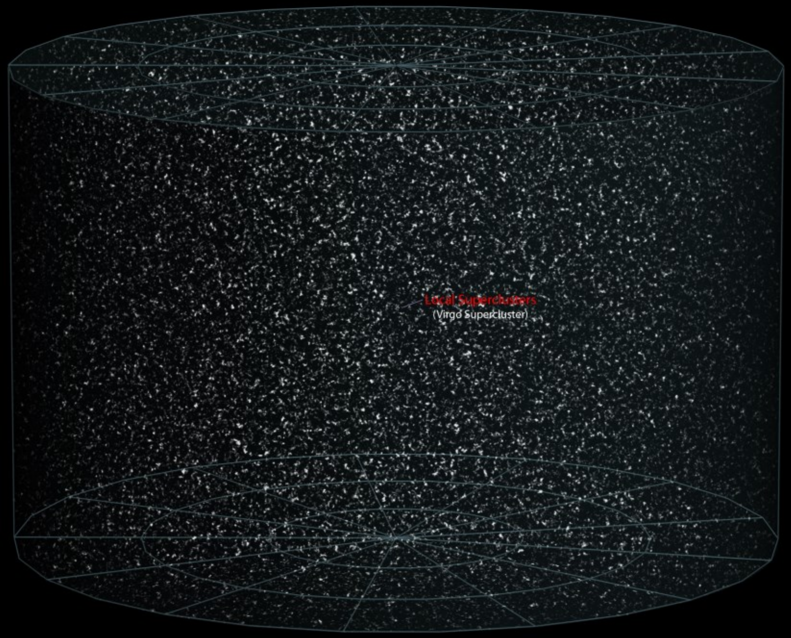


What monster have you created?



= 0.1

OBSERVABLE UNIVERSE



This black hole has swallowed 10% the mass of all ordinary matter in the entire observable universe...

(ix) [1 point] Hence or otherwise, give an upper bound for the energy flux expected to pass through a detector situated on Earth in $\mathrm{mJ\,m^{-2}}$.

Part II: Hawking Radiation

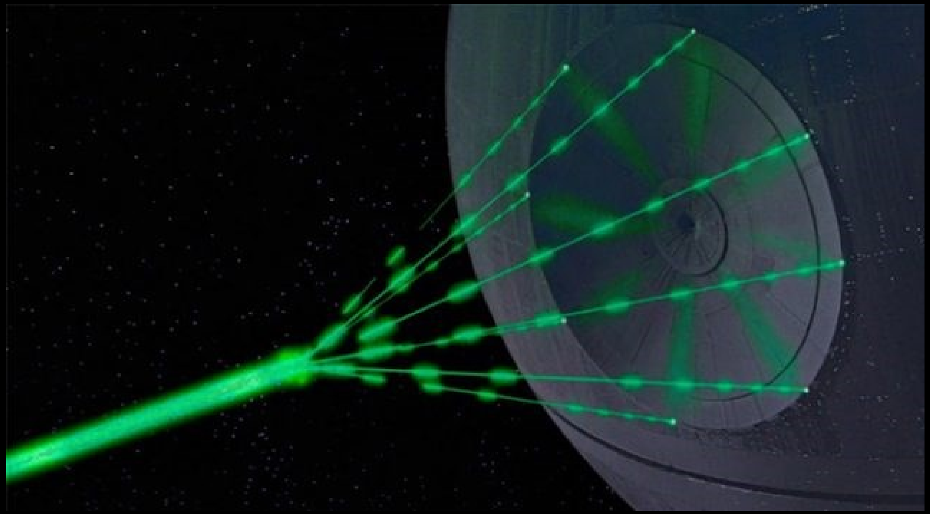
Surefire way to be featured in the Post Mortem (x2)

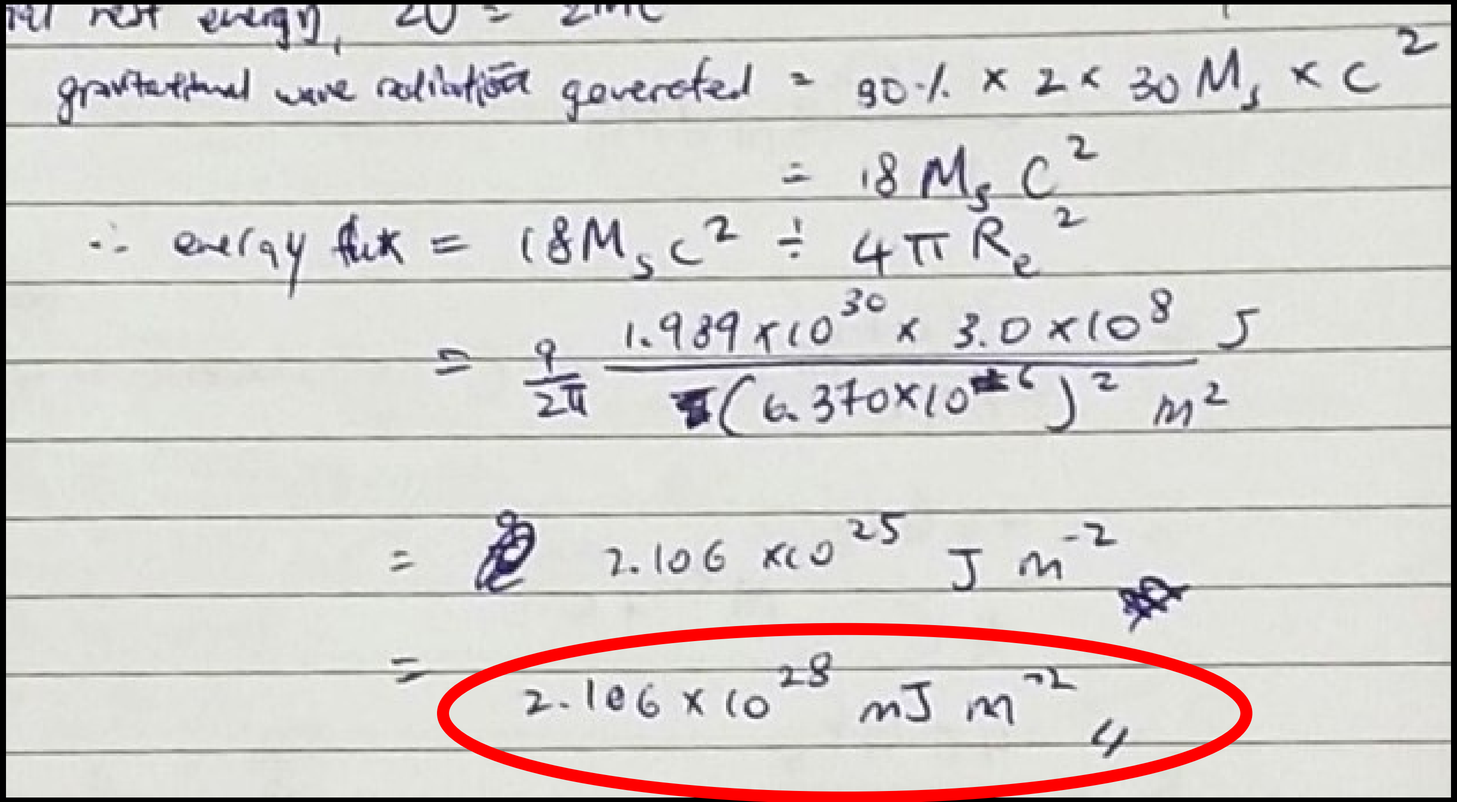
3. Cooks up innocuous yet dubious equation

$$\therefore \text{energy flux} = 18 M_s c^2 \div 4\pi R_e^2$$

Energy released   Earth

4. Plugs that into the given equations…

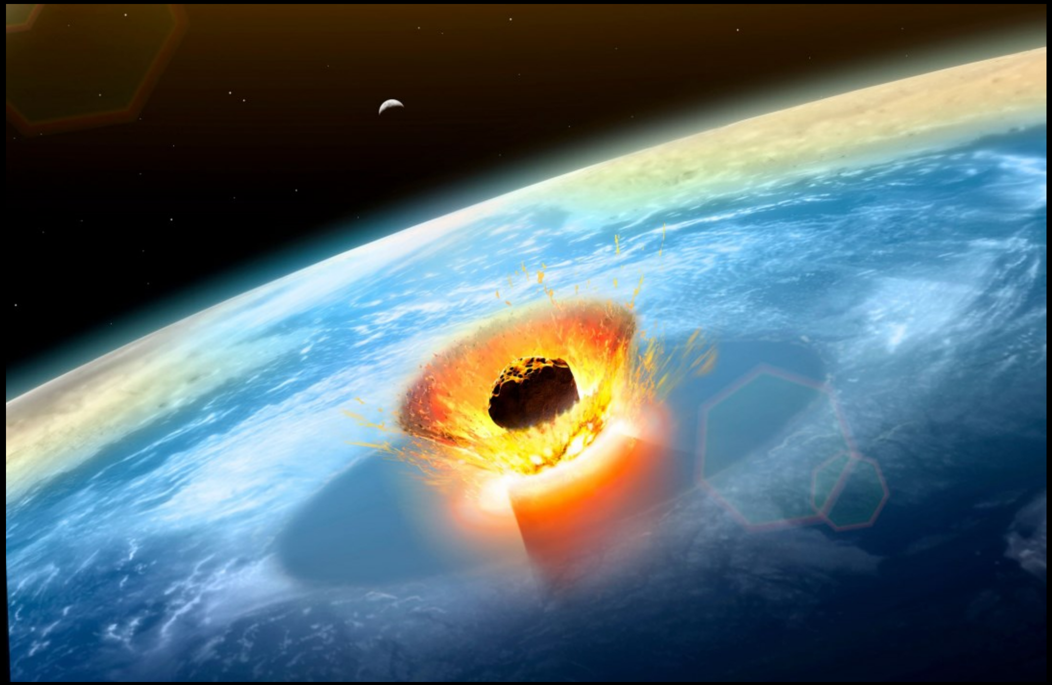




Keep in mind that this is the energy passing through a detector on Earth

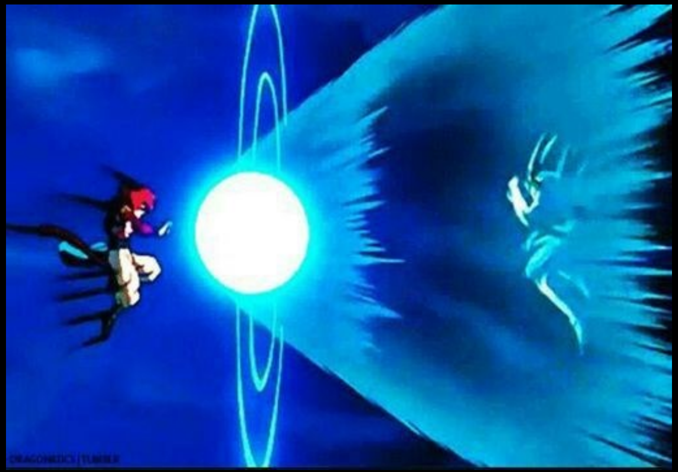
Want to know how much energy is this?

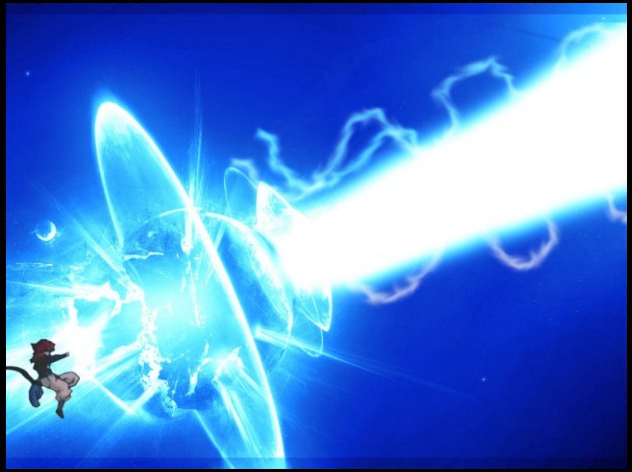
Chicxulub impactor (aka Dino killing asteroid)

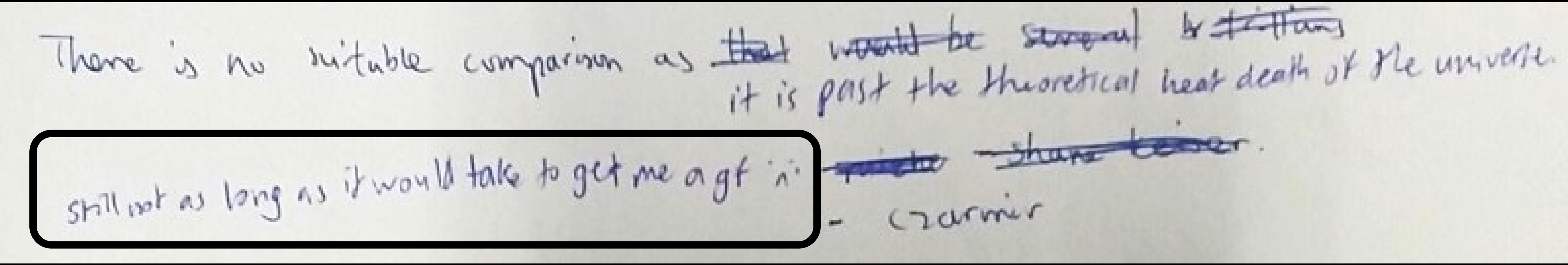


X 210

Put all that energy on a 1 m^2 area





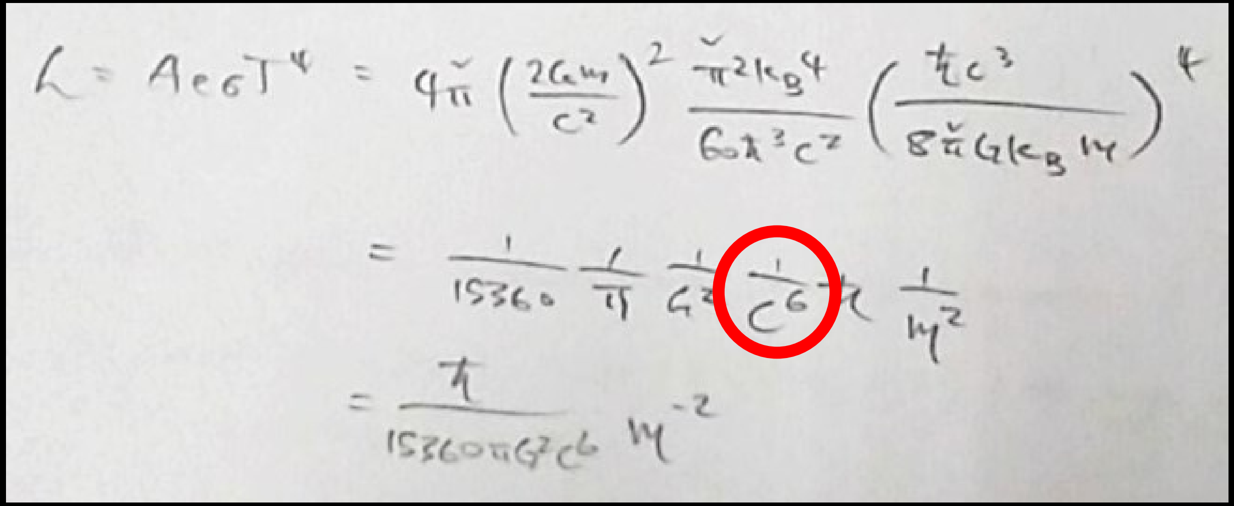

There is no suitable comparison as it is past the theoretical heat death of the universe.
still not as long as it would take to get me a gf :'(
- czarnir


FINDING
GF
TO THE HEAT DEATH AND BEYOND

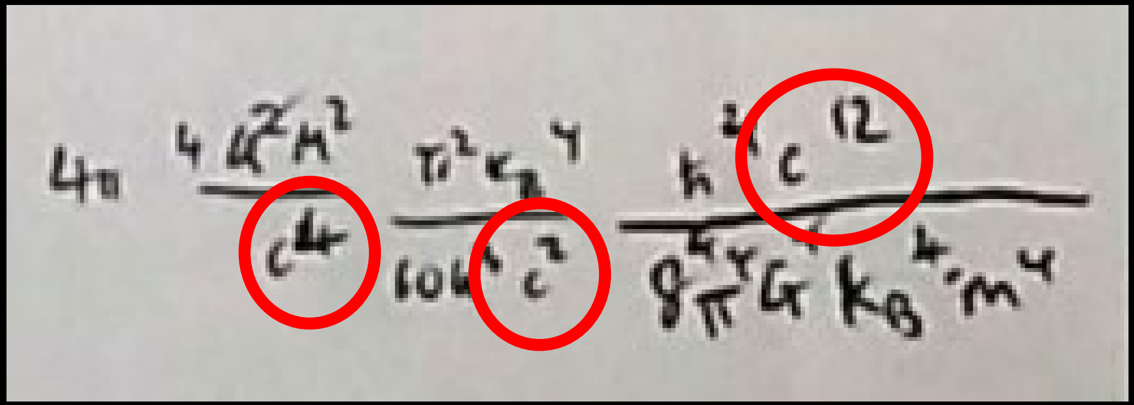
Messy handwriting only harms yourself…

$$\frac{c^{12}}{c^6} = \frac{1}{c^6}$$

Your answer



What is in the scratch

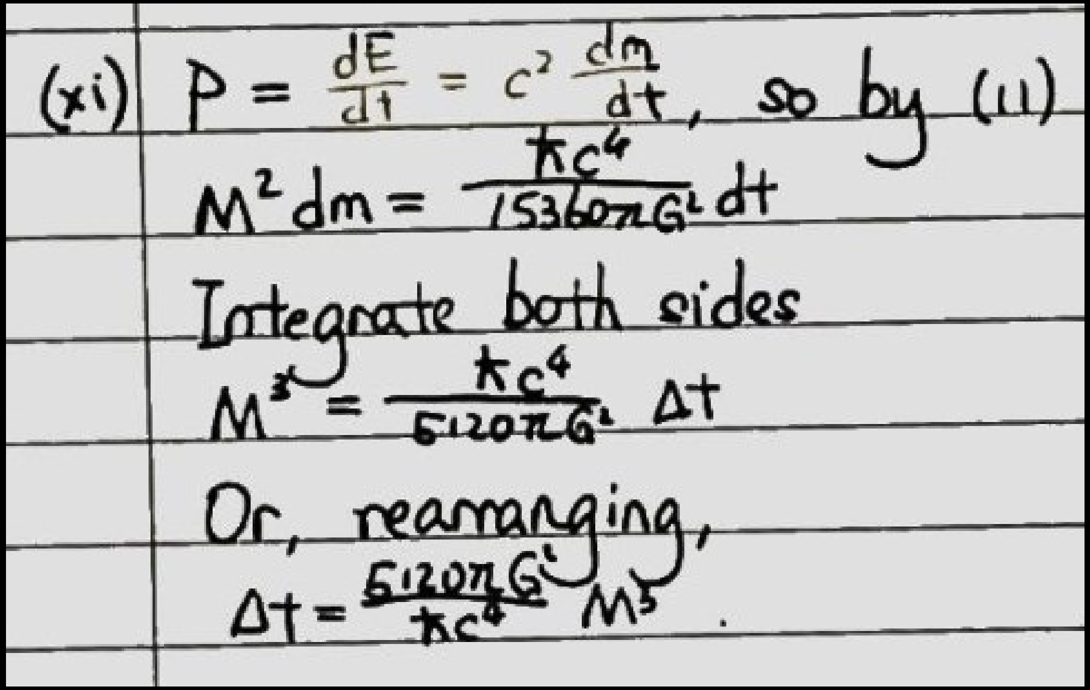


The good news

One team almost got full marks

Too bad they didn't bother to calculate the numerical value of $\Delta\mathrm{T}$ and make a comparison (which would not take much time I believe)

They also didn't specify the limits of integration.. but I can forgive them for this one (as no one did, apparently)



(xi) $P = \frac{dE}{dt} = c^2 \frac{dm}{dt}$, so by (11)

$M^2 dm = \frac{\hbar c^4}{15360\pi G^2} dt$

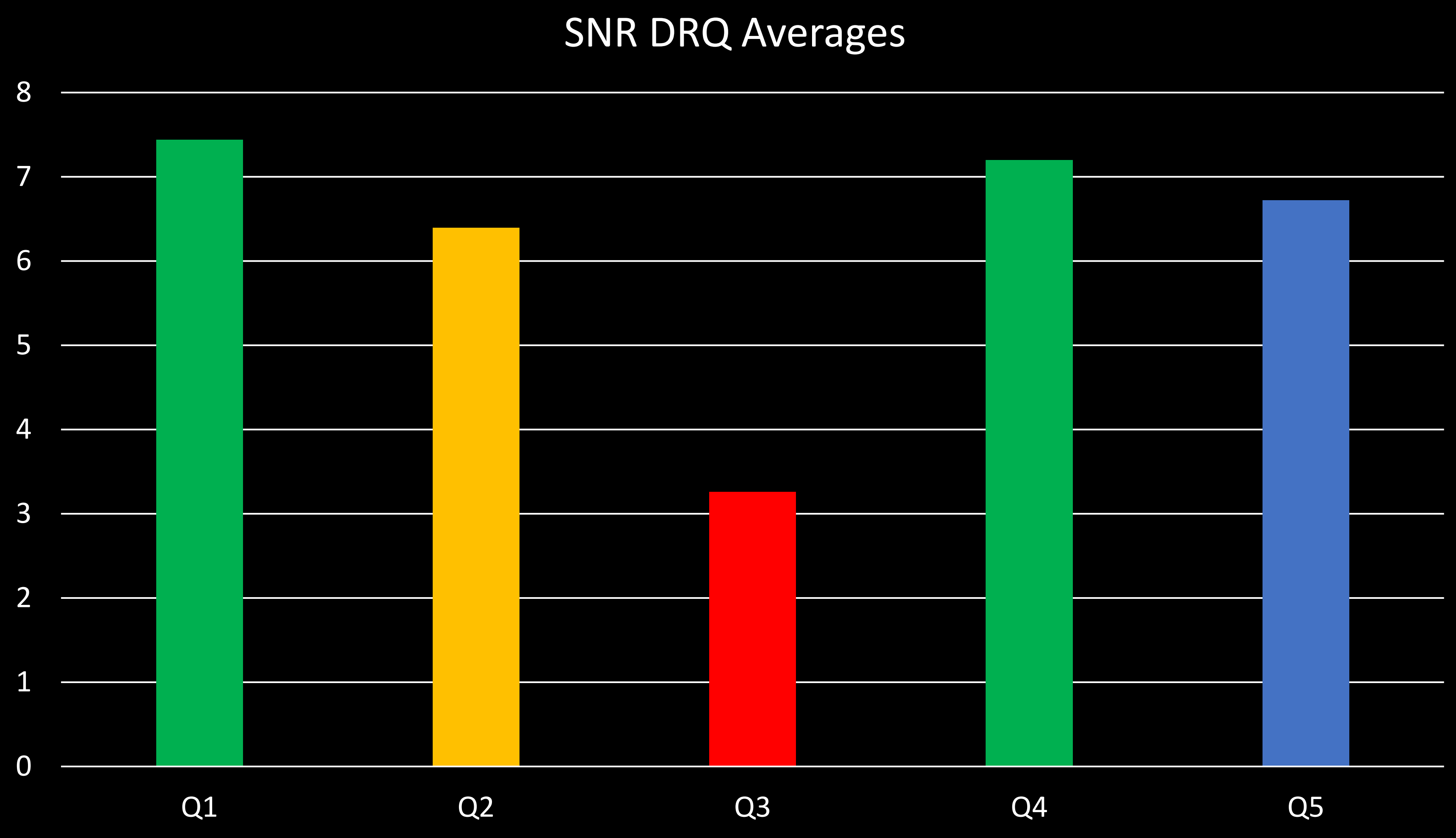
Integrate both sides

$M^3 = \frac{\hbar c^4}{5120\pi G^2} \Delta t$

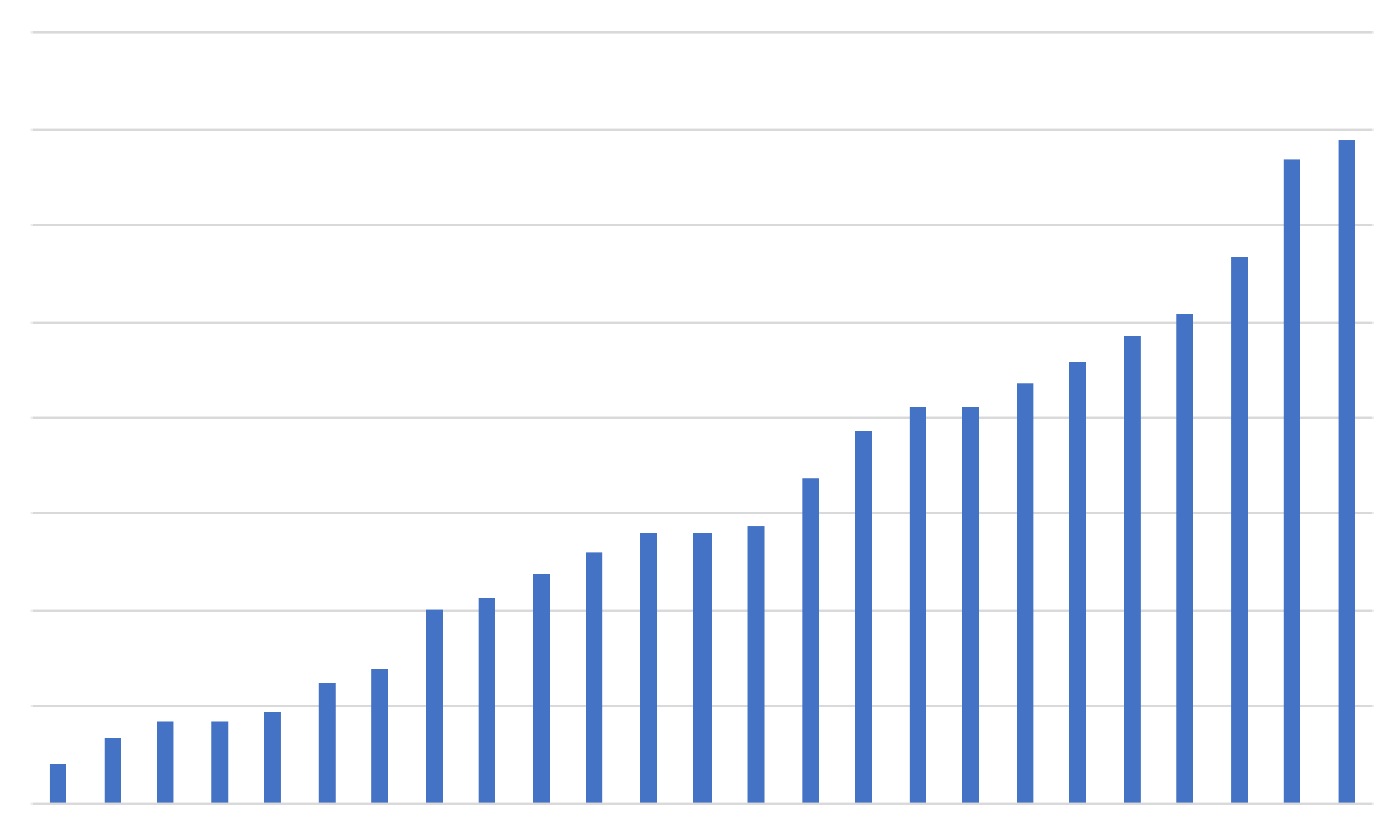
Or, rearranging,

$\Delta t = \frac{5120\pi G^2}{\hbar c^4} M^3$.

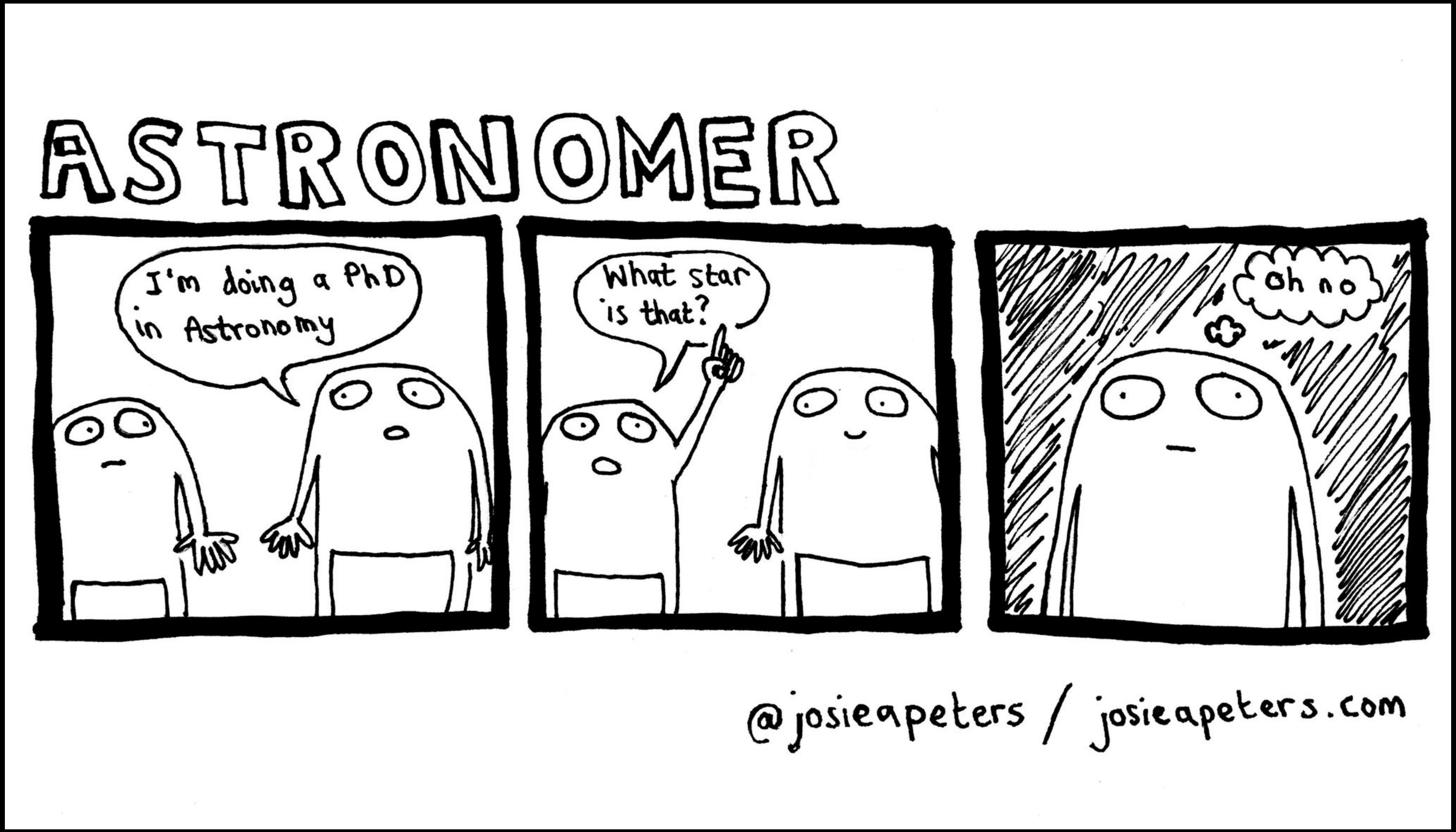
SNR DRQ Average Score by Question



SNR DRQ Score Distribution



Mean = 31 , Median = 28, Standard Deviation = 18.4



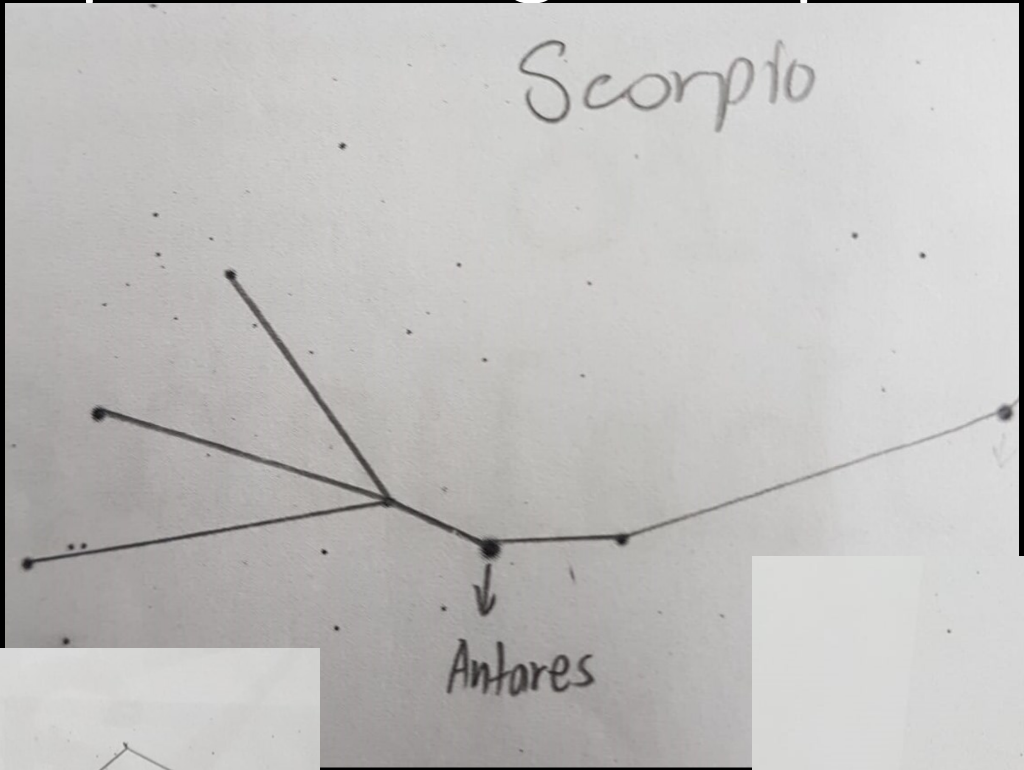
Observation Round

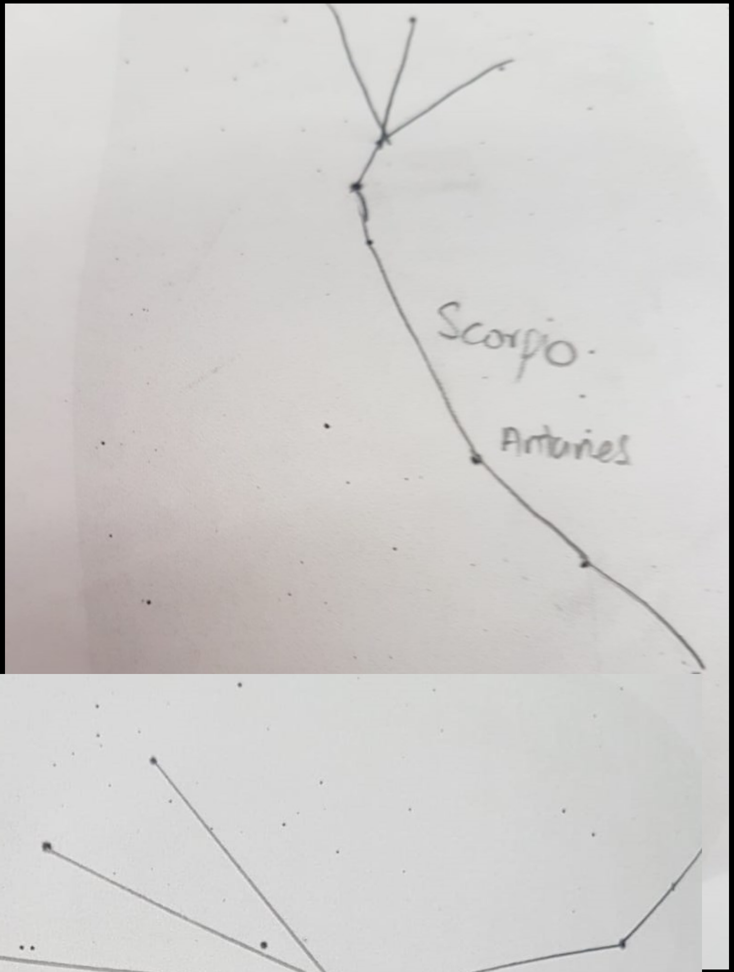
Theory Paper

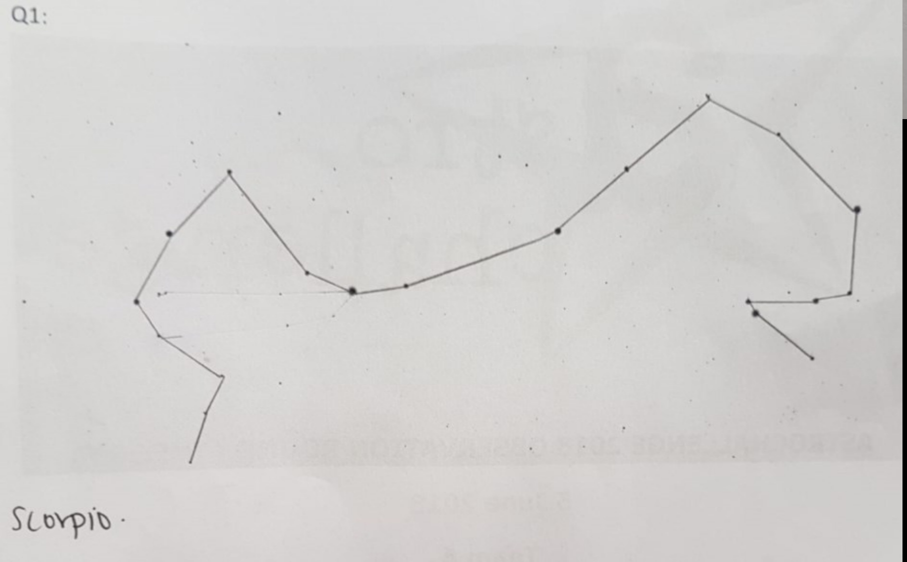
- Constellation Drawing/ Night Sky ID was intended to be pretty kind

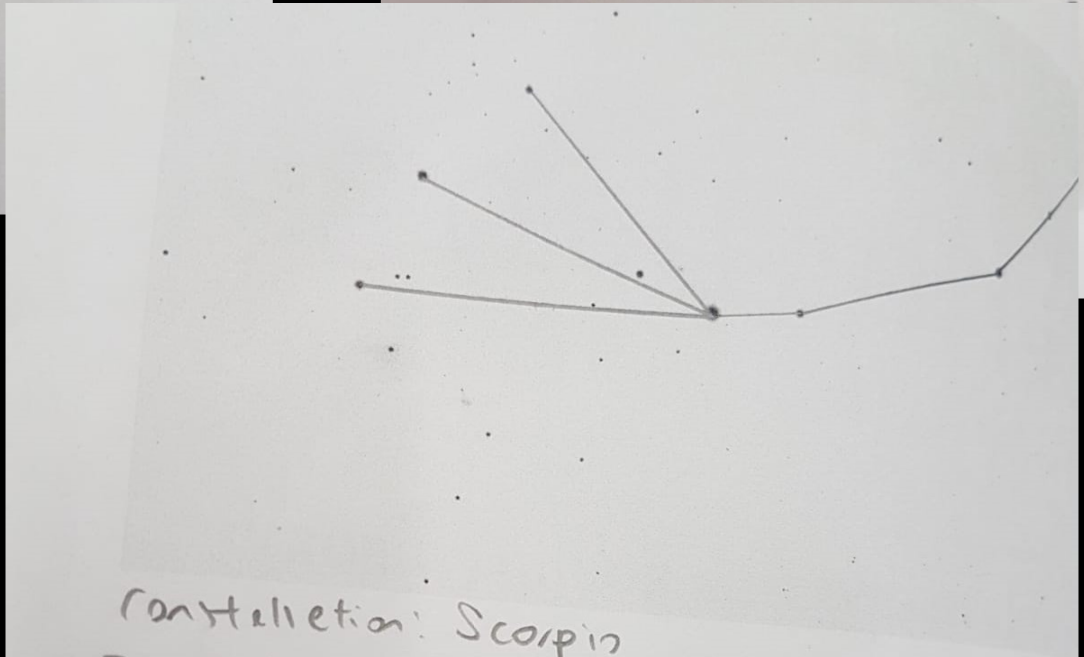
Q1:

Please stop shaming Scorpius

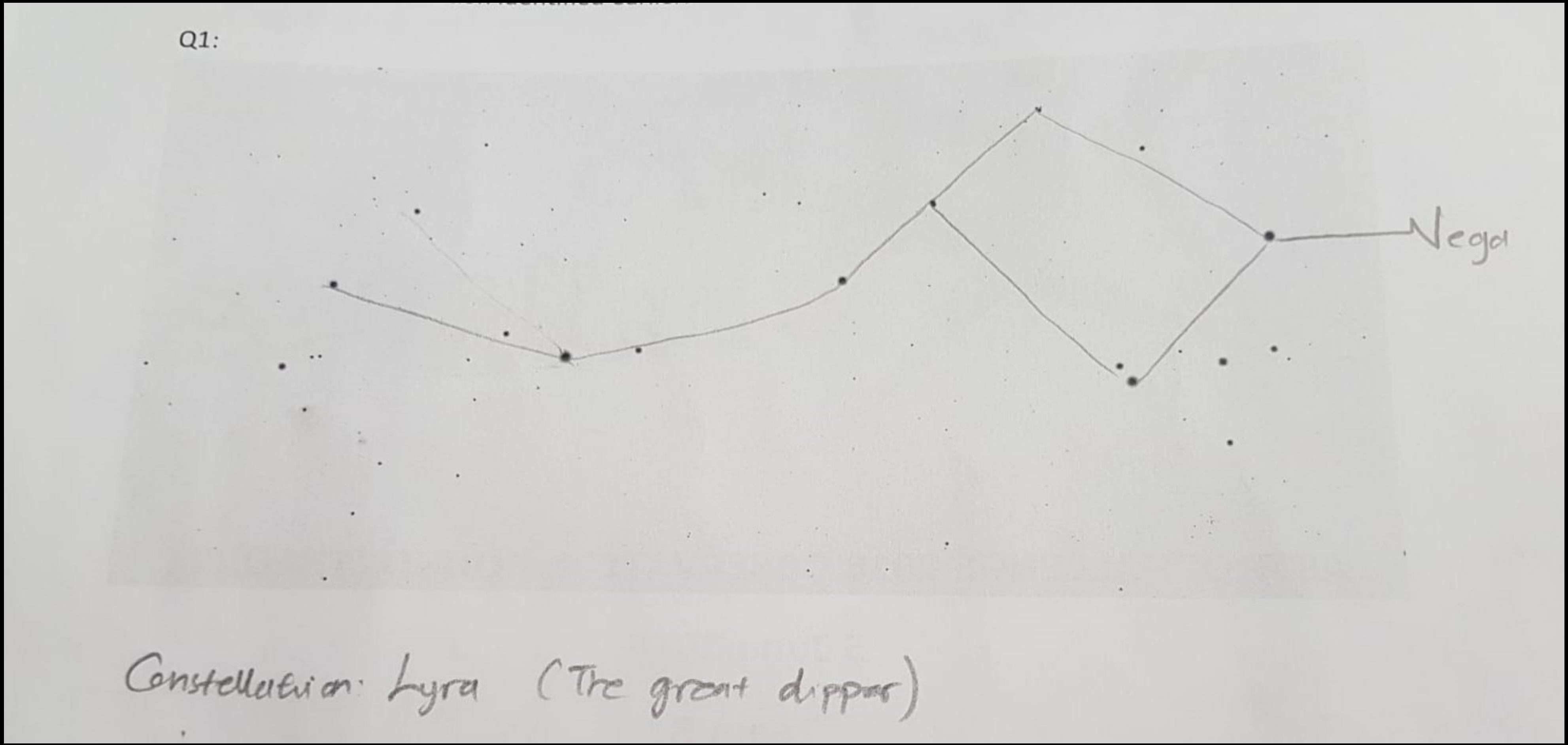








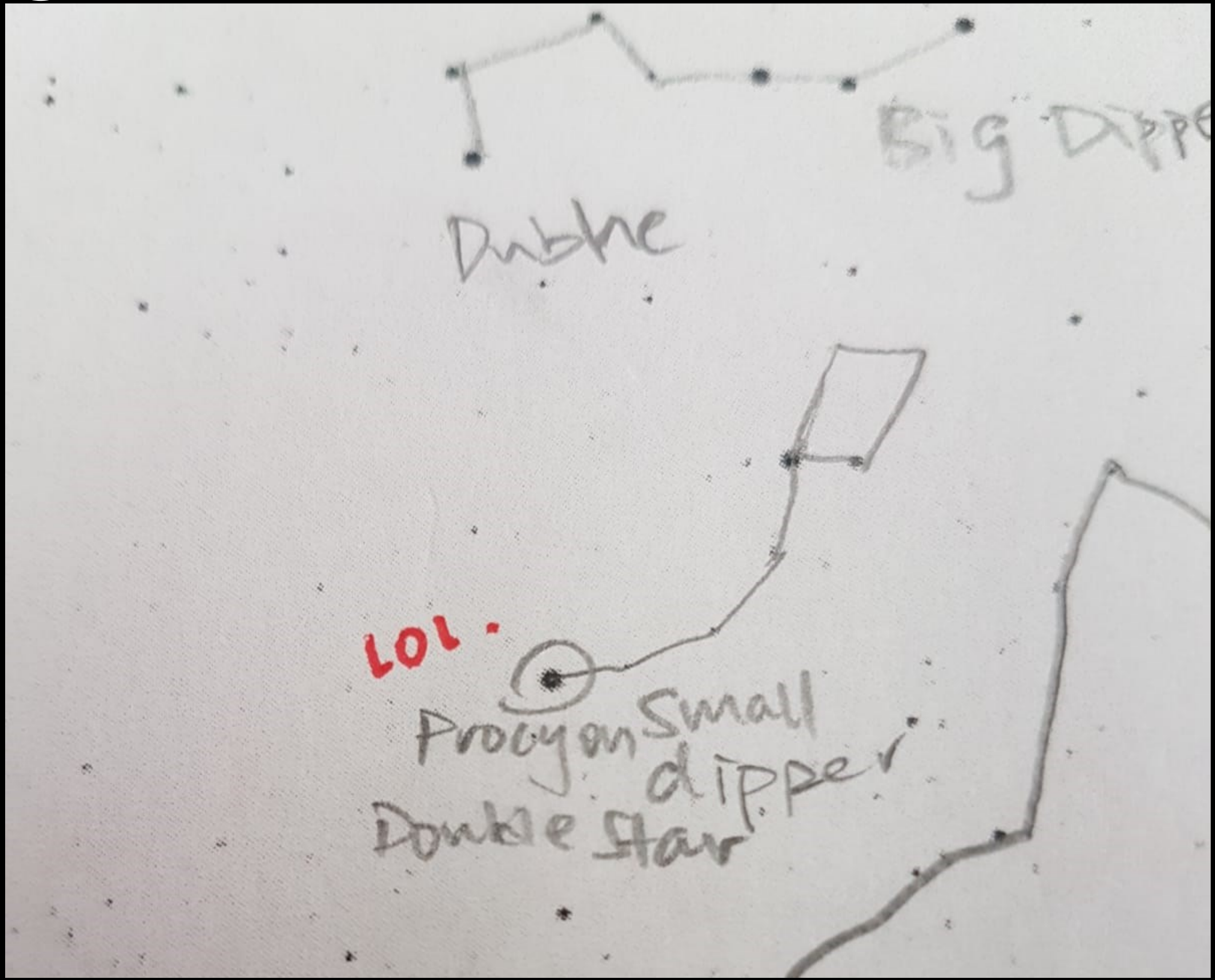
Rejected Gifts



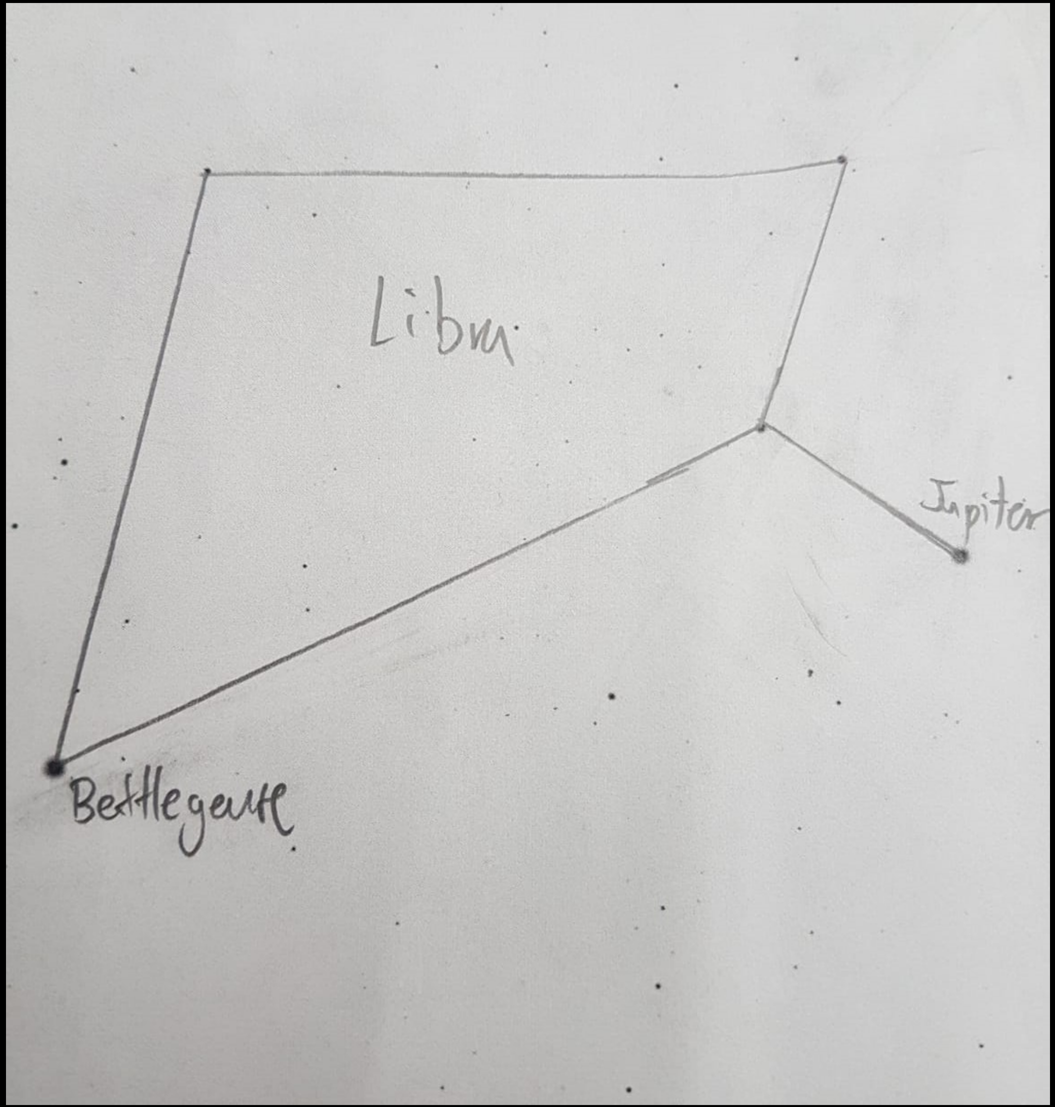
Unfortunate Naming

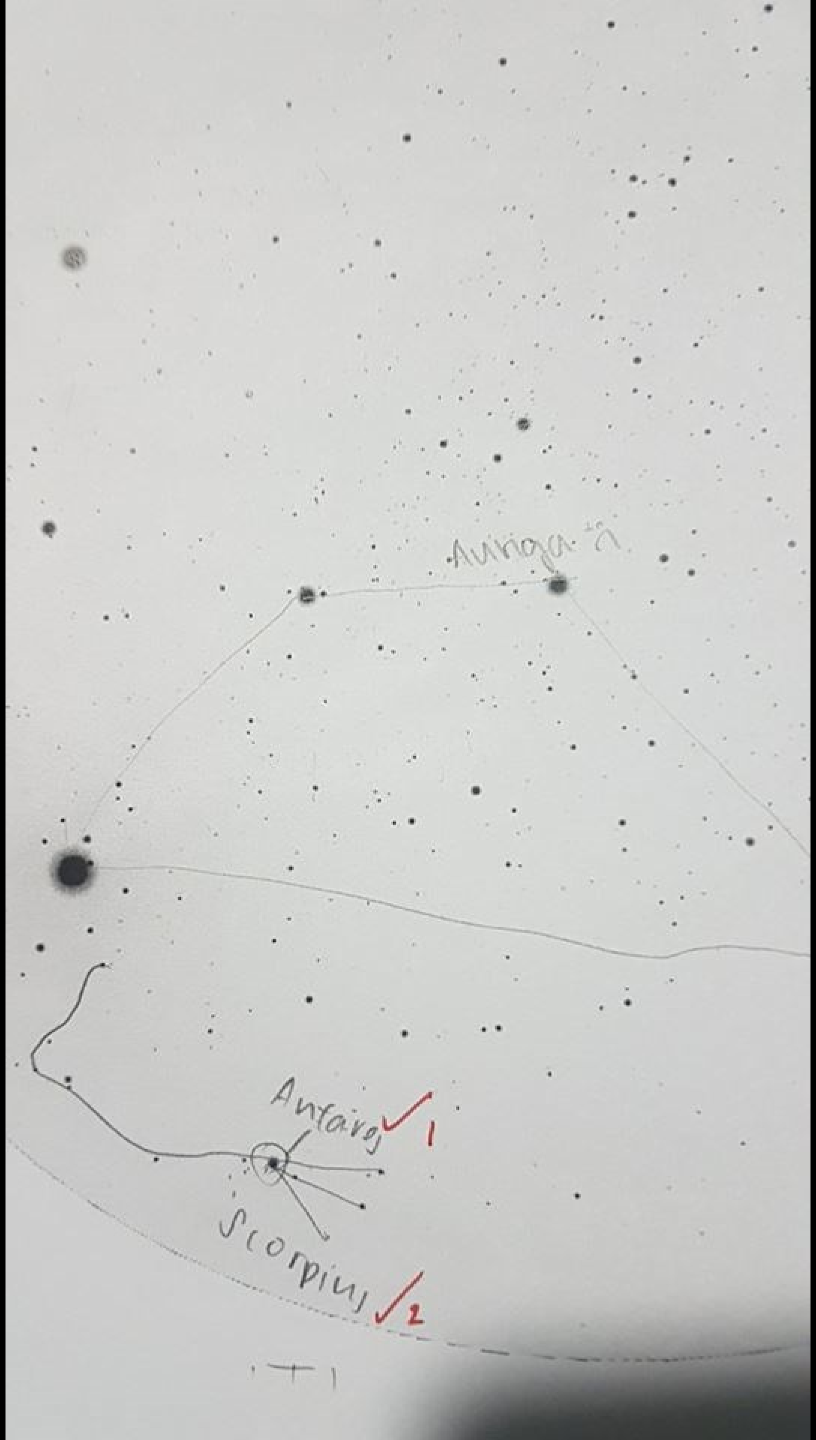
Its Polaris (think POLAR)

NOT Procyon

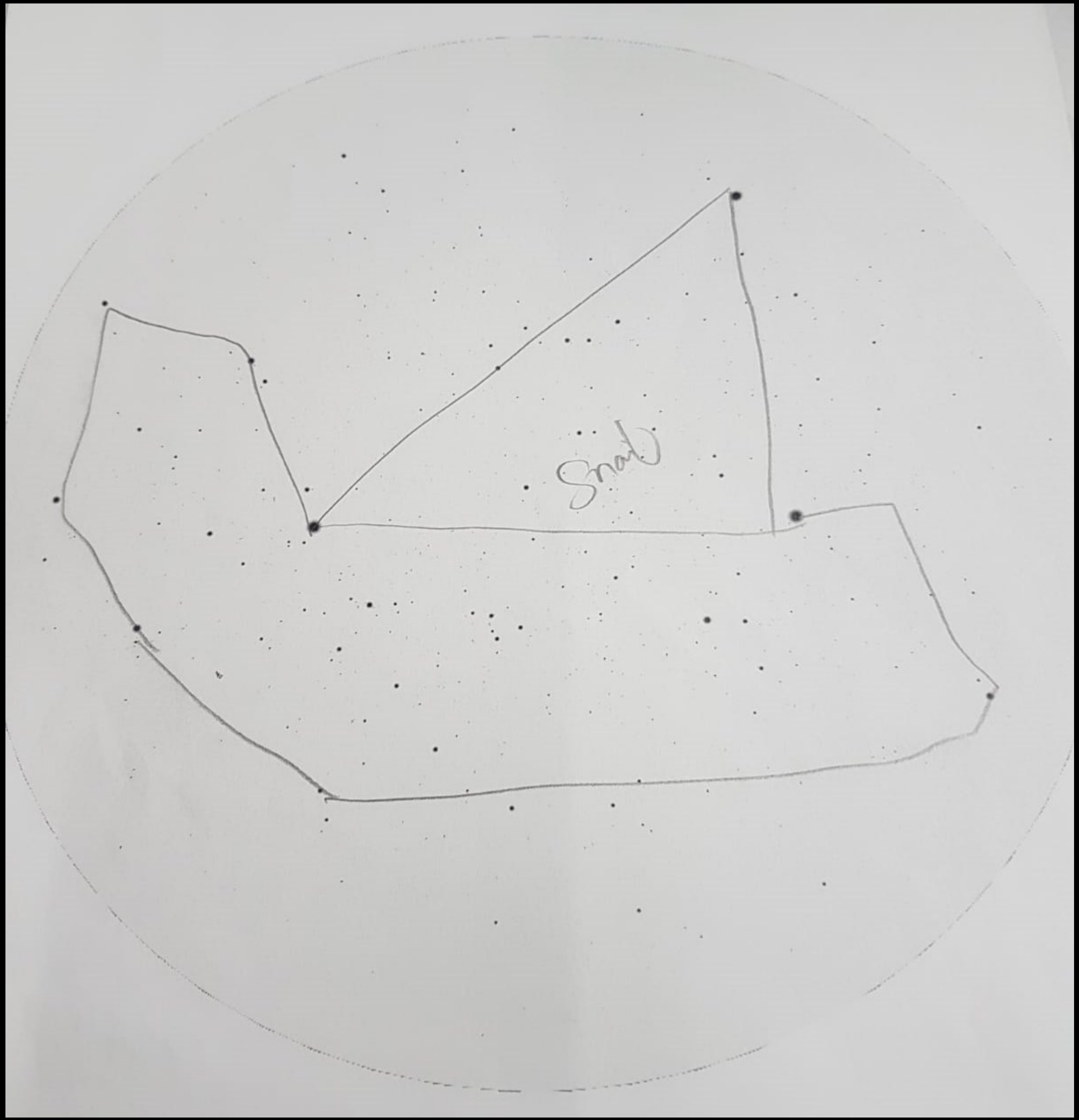


Misplaced Constellations

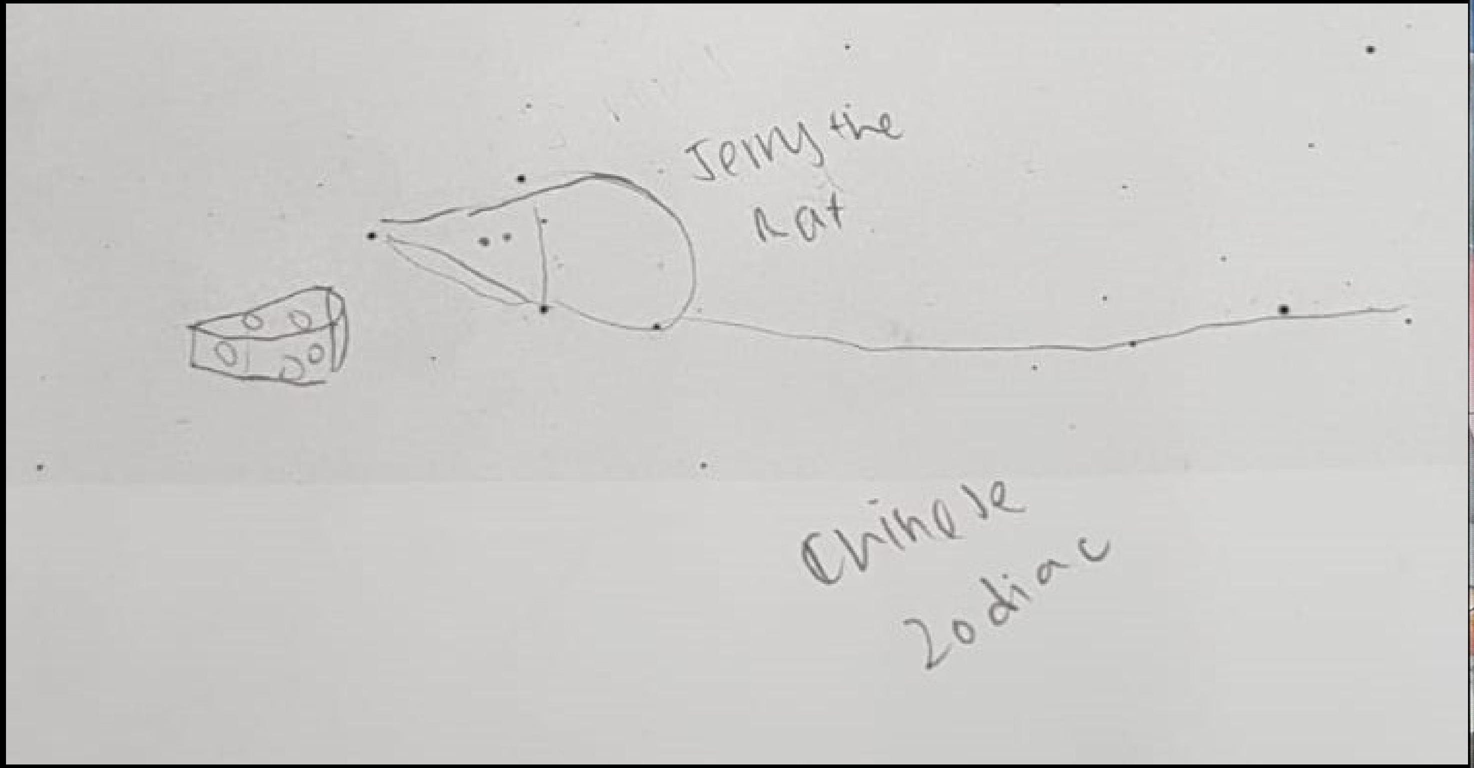




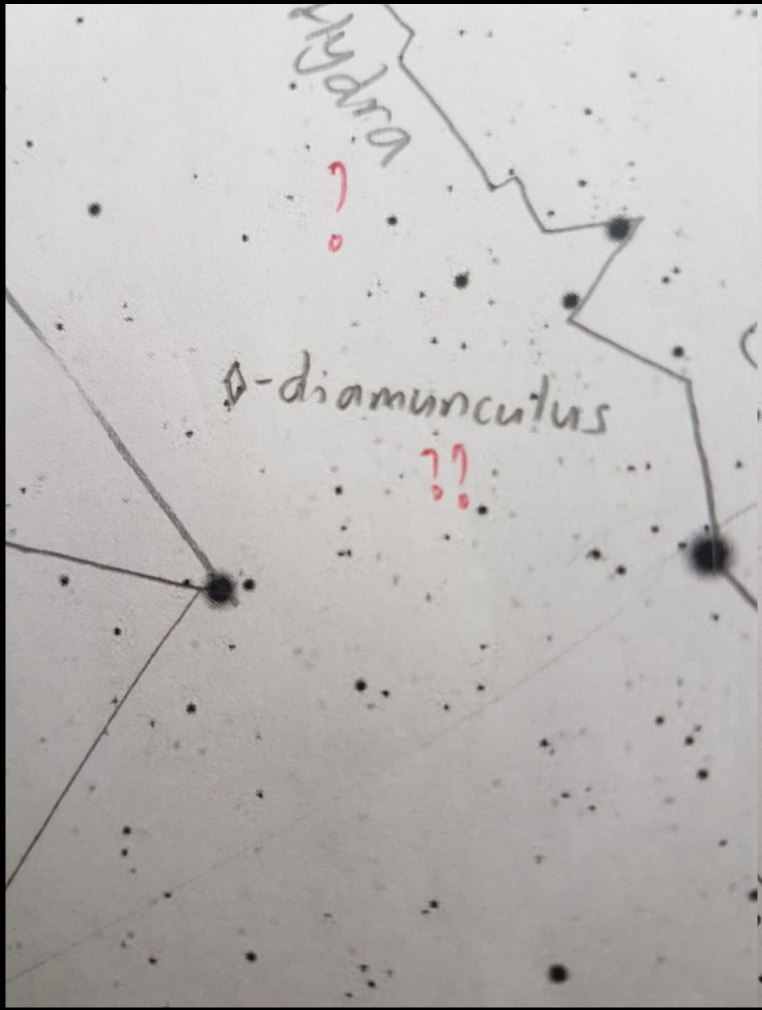
The Great Snail/Sail in the Sky

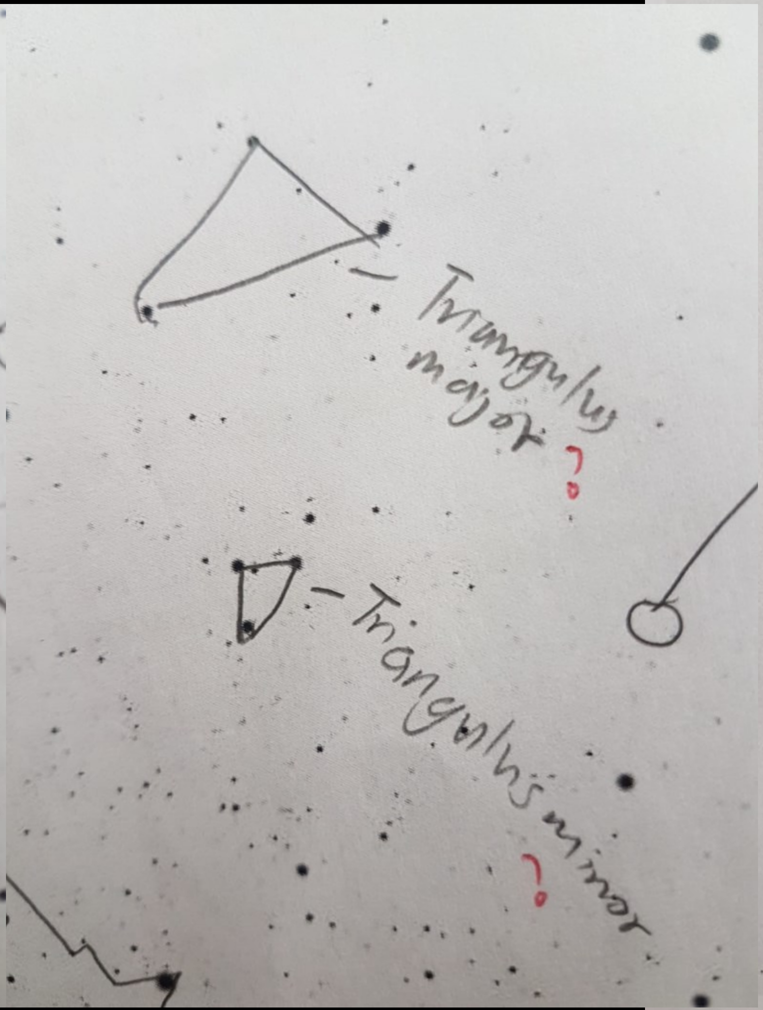


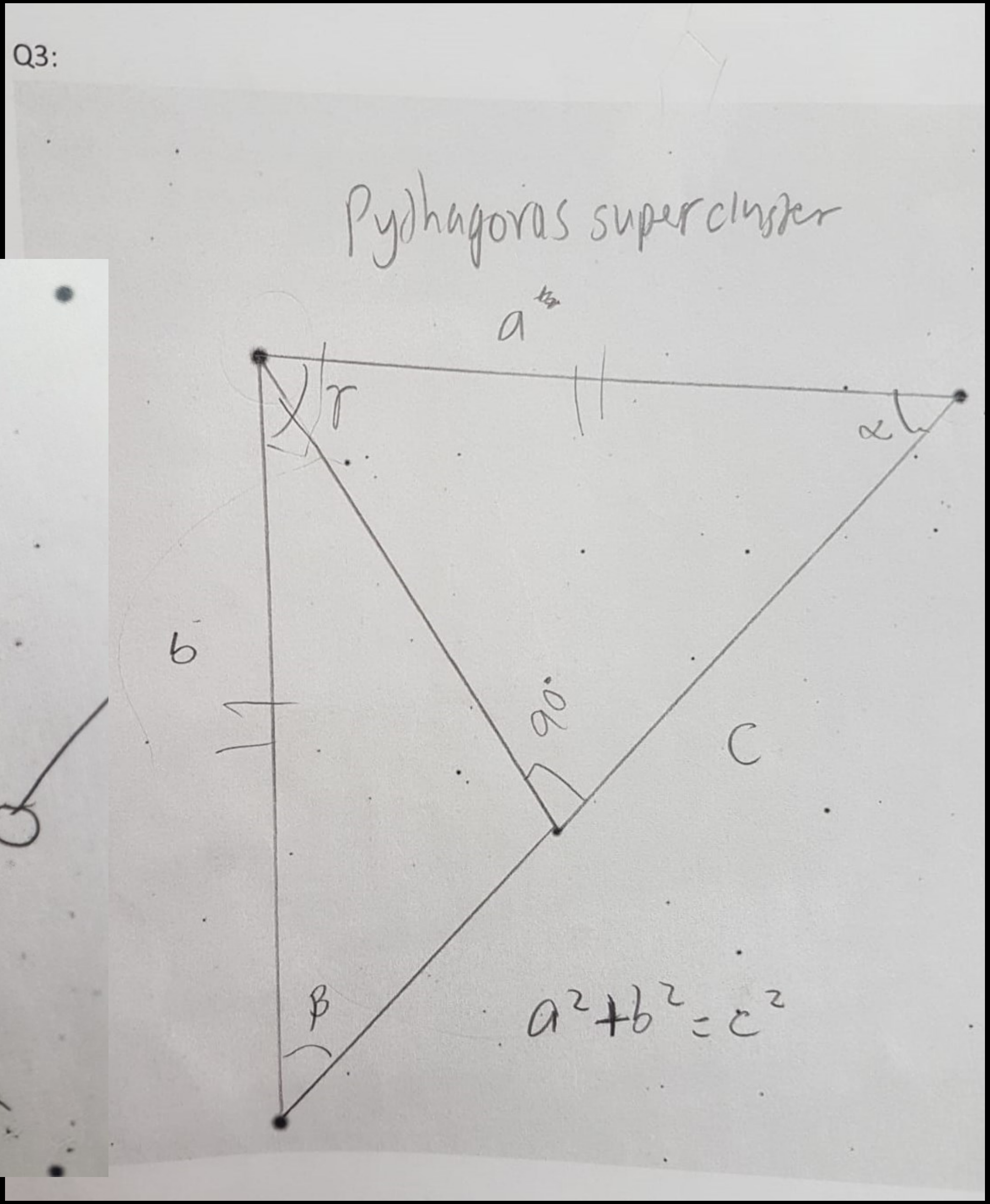
Chinese Zodiacal Constellation



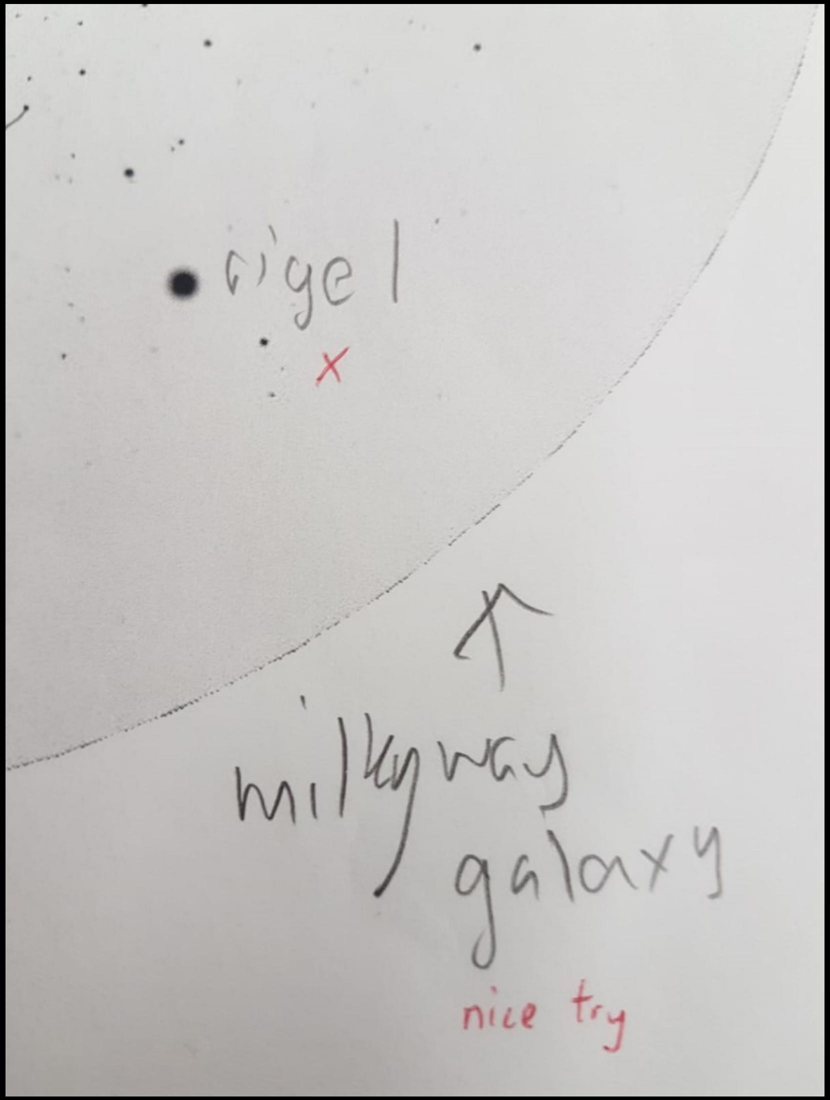
Geometry? Math?

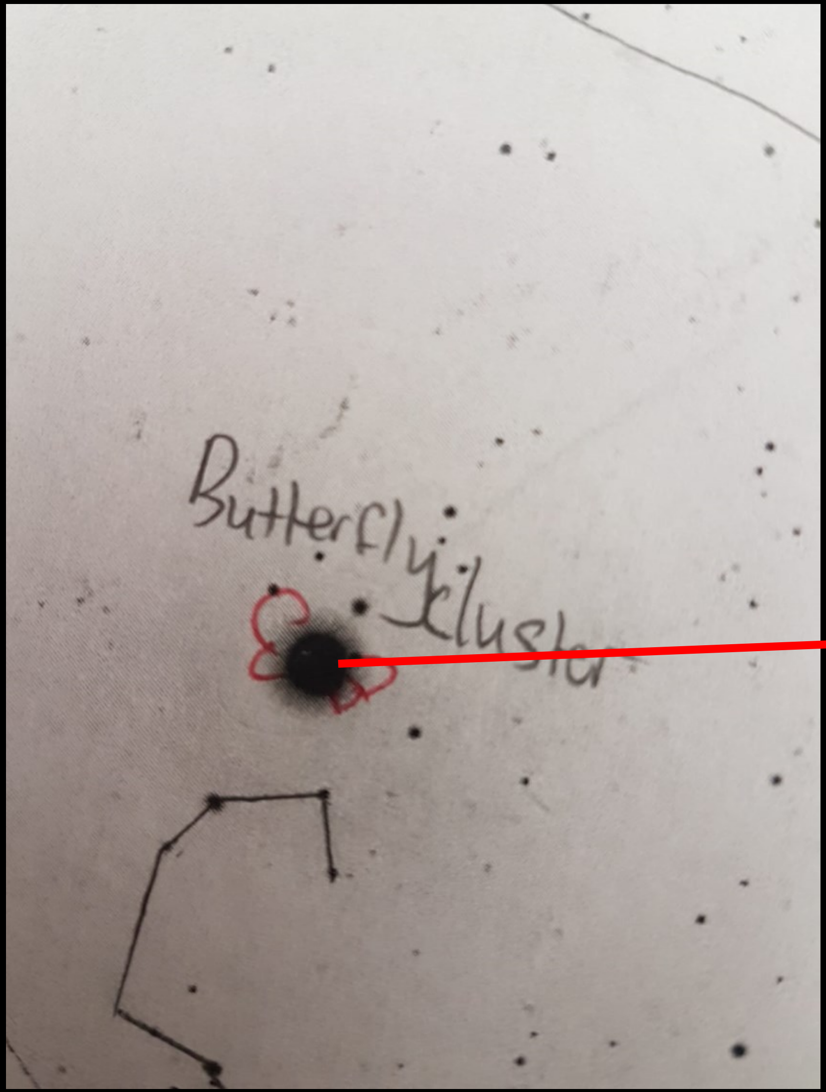






Inspiration or desperation?

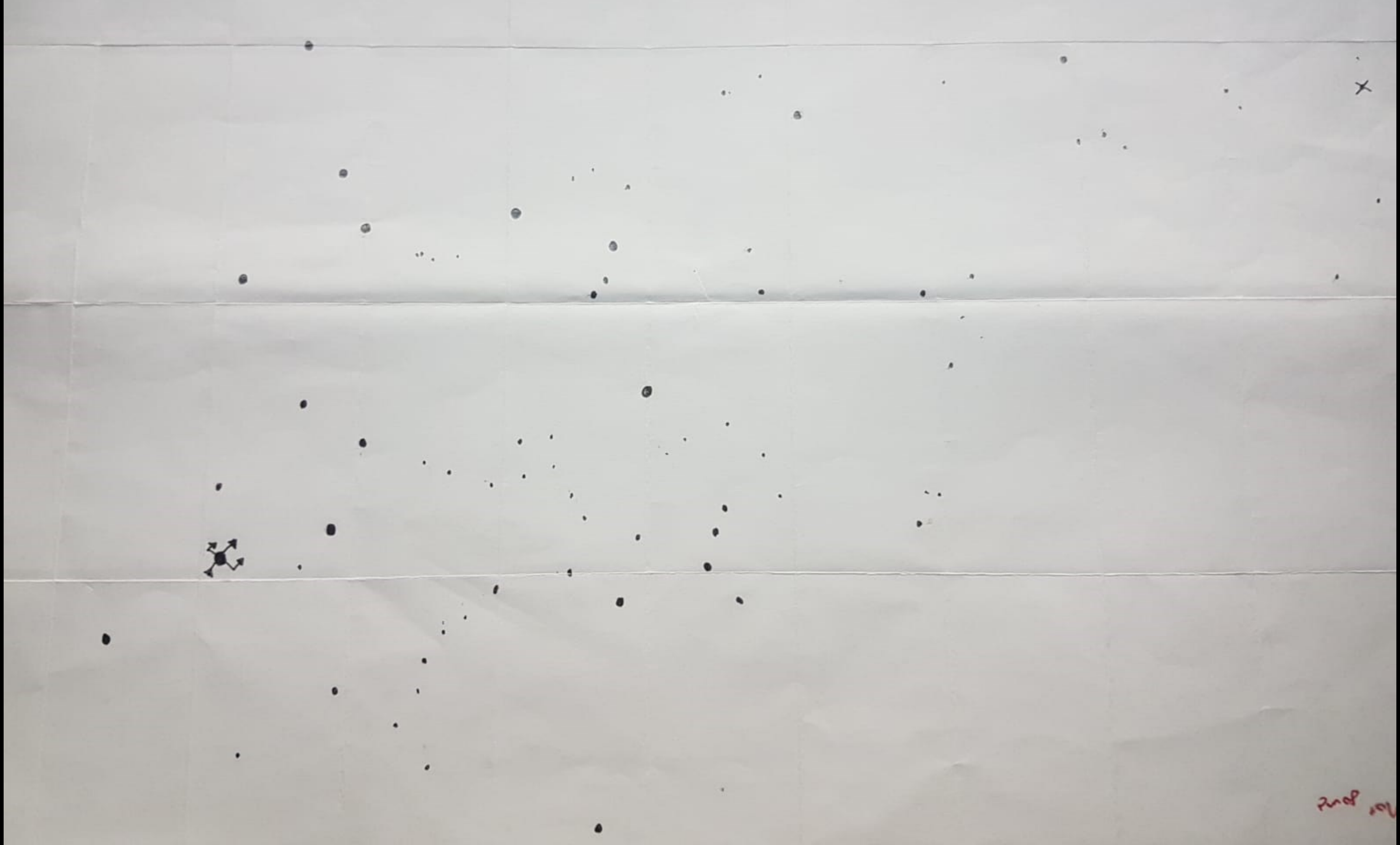




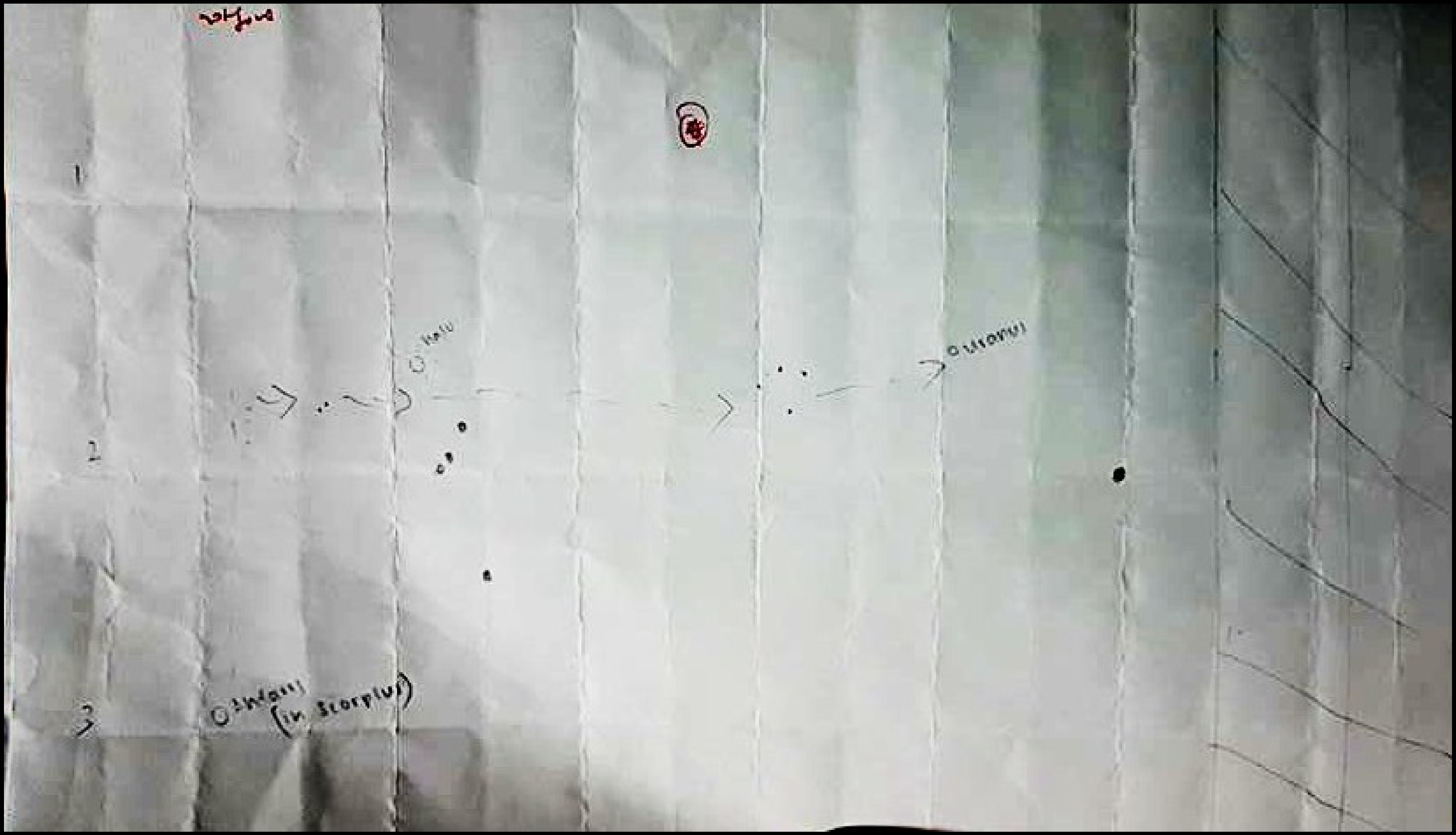
Finding Chart Errors

AKA being a good teammate

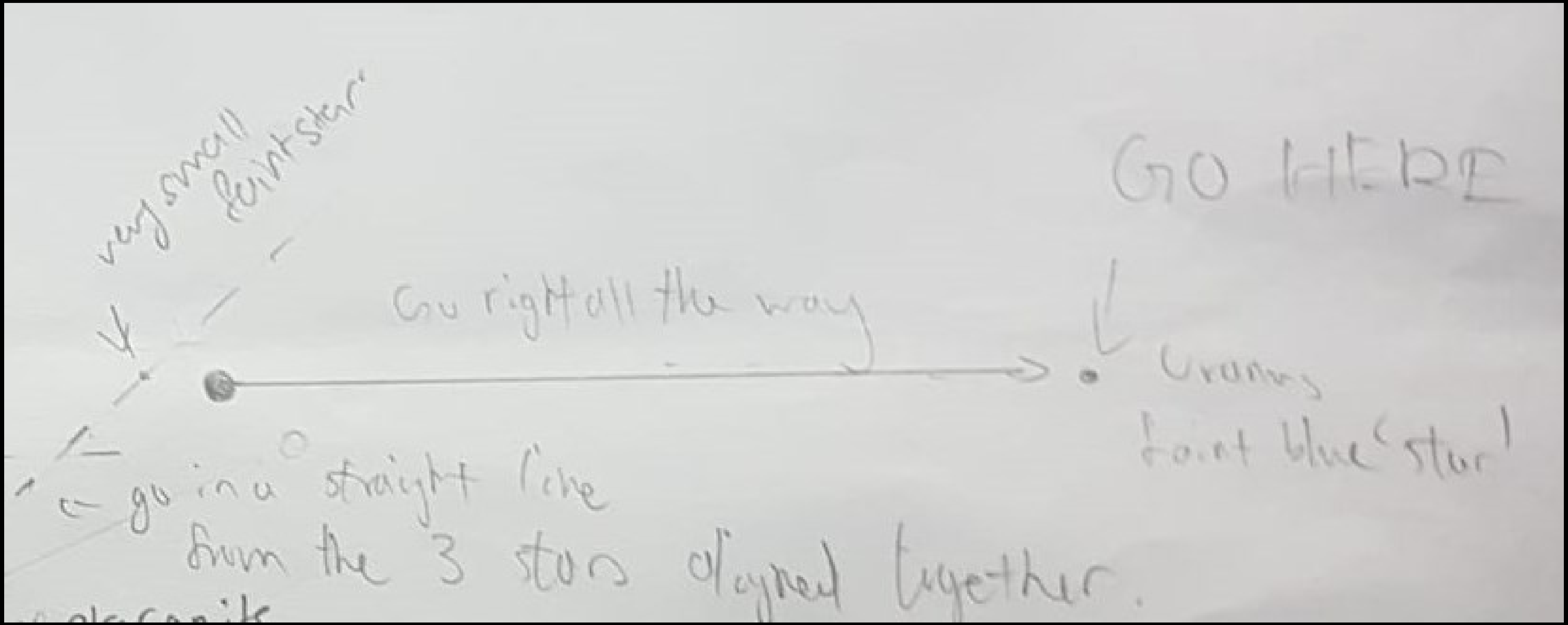
1. At least tell your friends what to find



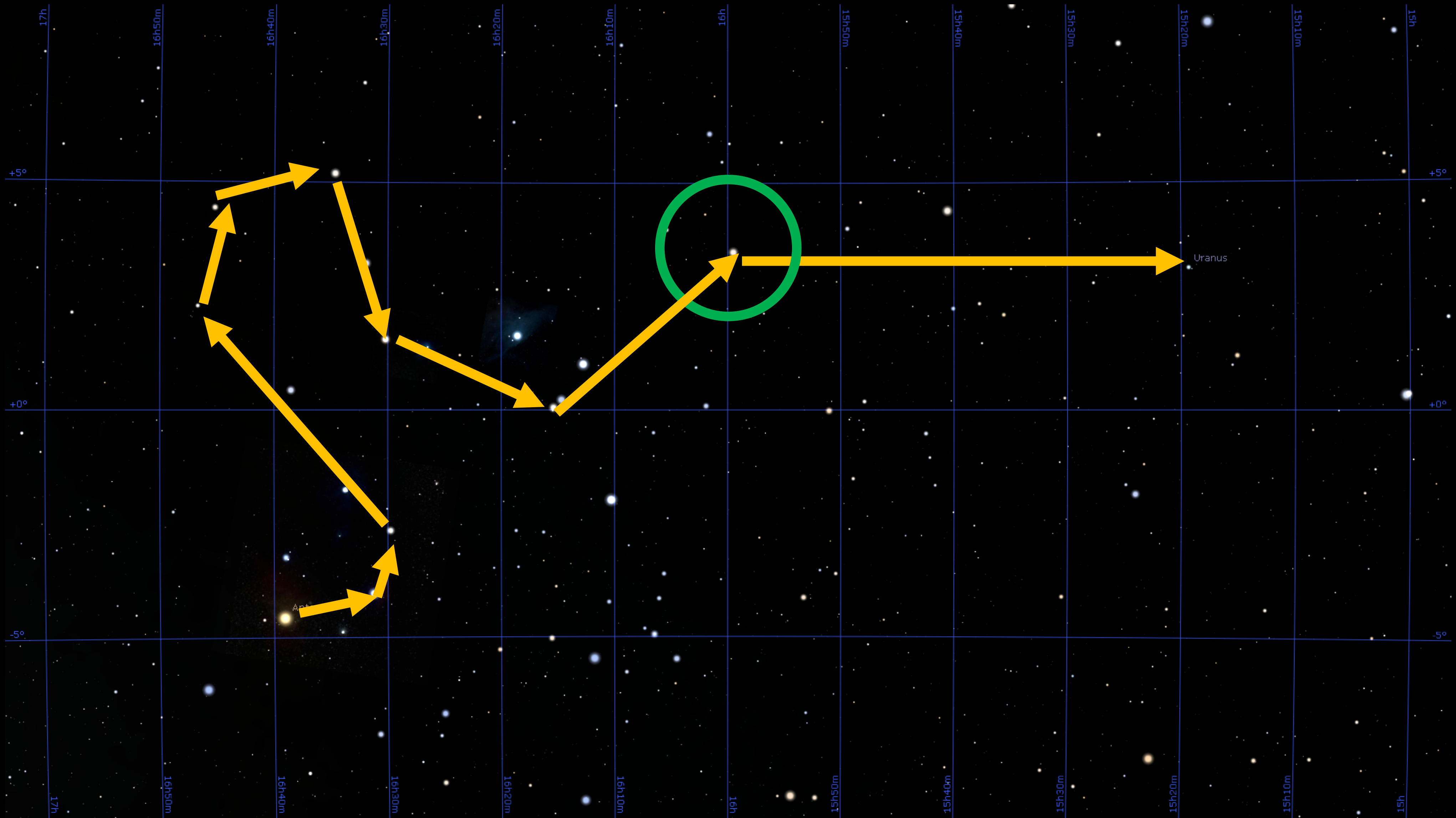
2. Draw CLEARLY and ACCURATELY



3. Don't use UP/DOWN/LEFT/RIGHT

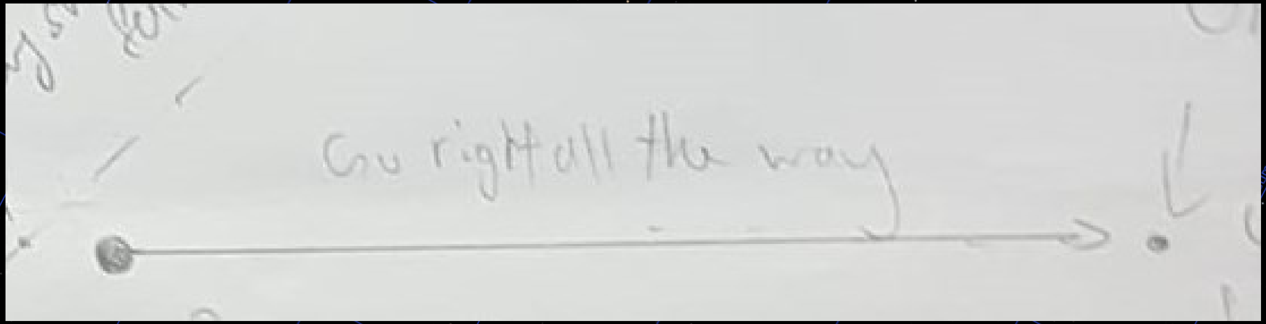


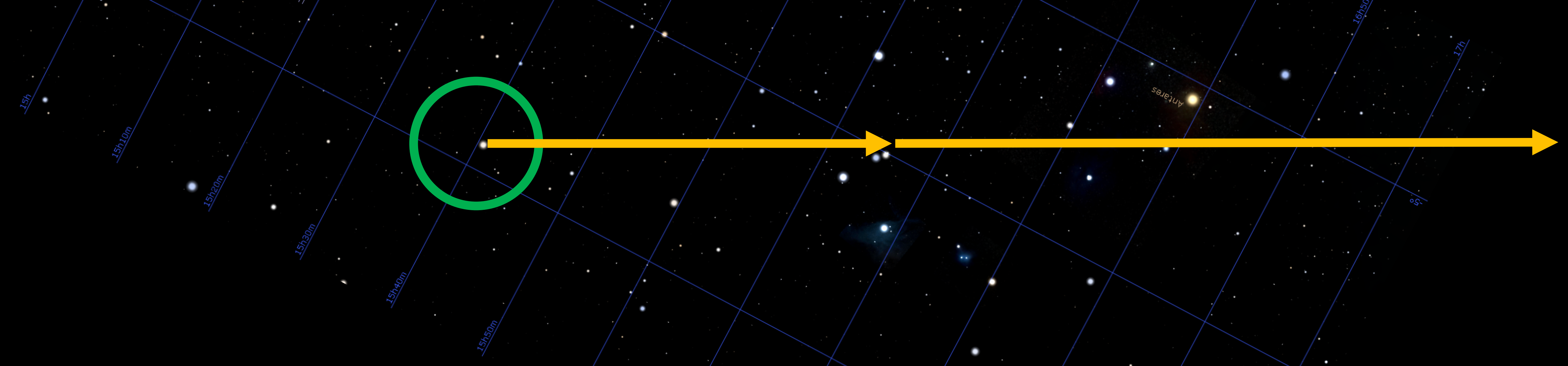
What you saw…



17h
16h50m
16h40m
16h30m
16h20m
16h10m
16h
15h50m
15h40m
15h30m
15h20m
15h10m
15h
+5°
+0°
-5°
Uranus

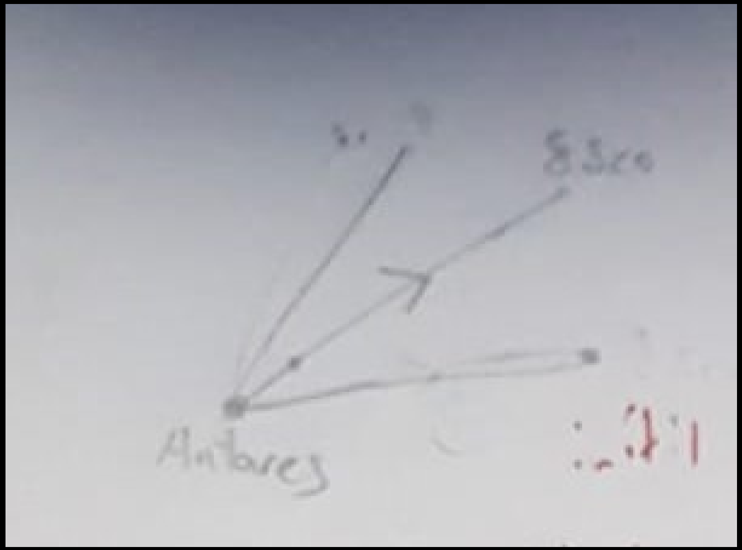
And what they got (without the grid lines)

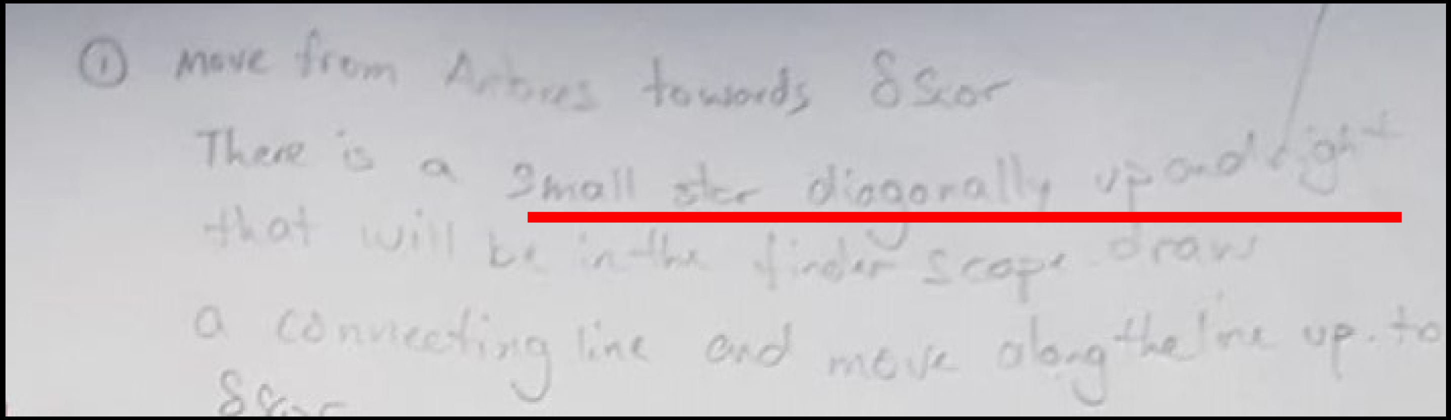




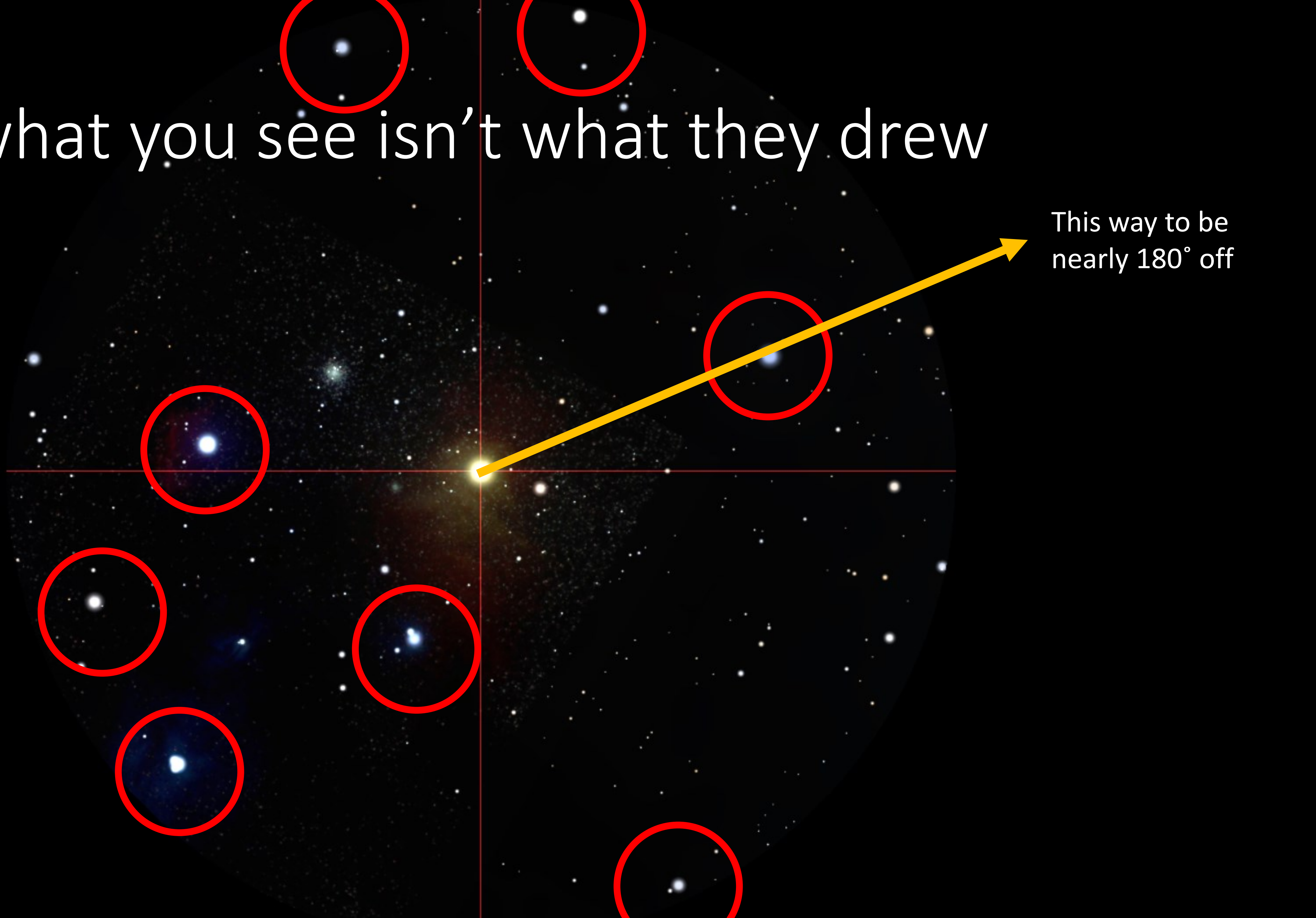
PS: they found it by luck (probably after realising what terrible friends they had)

More instructions from terrible friends

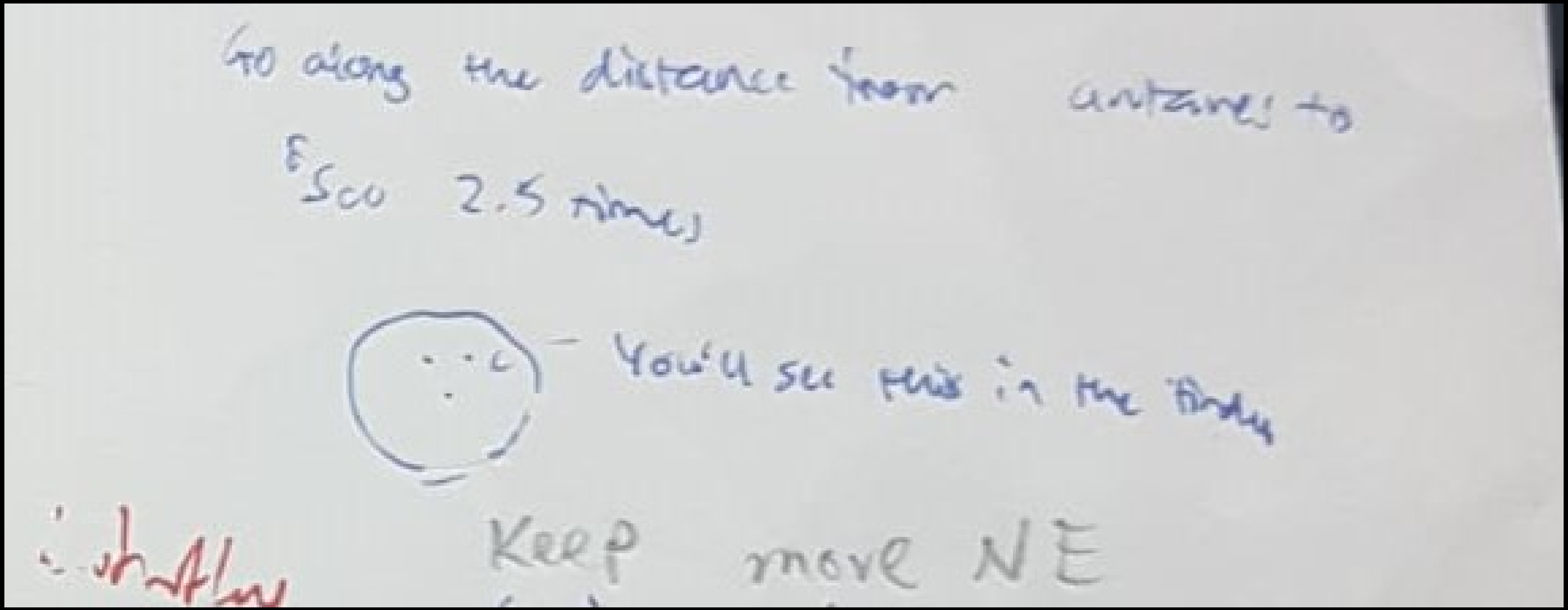




TFW what you see isn't what they drew



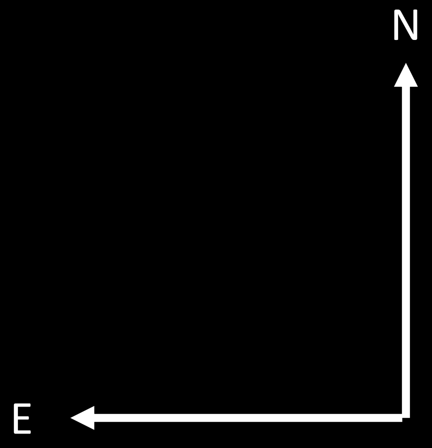
Suppose they miraculously got past δ Sco



Apa ini NE?

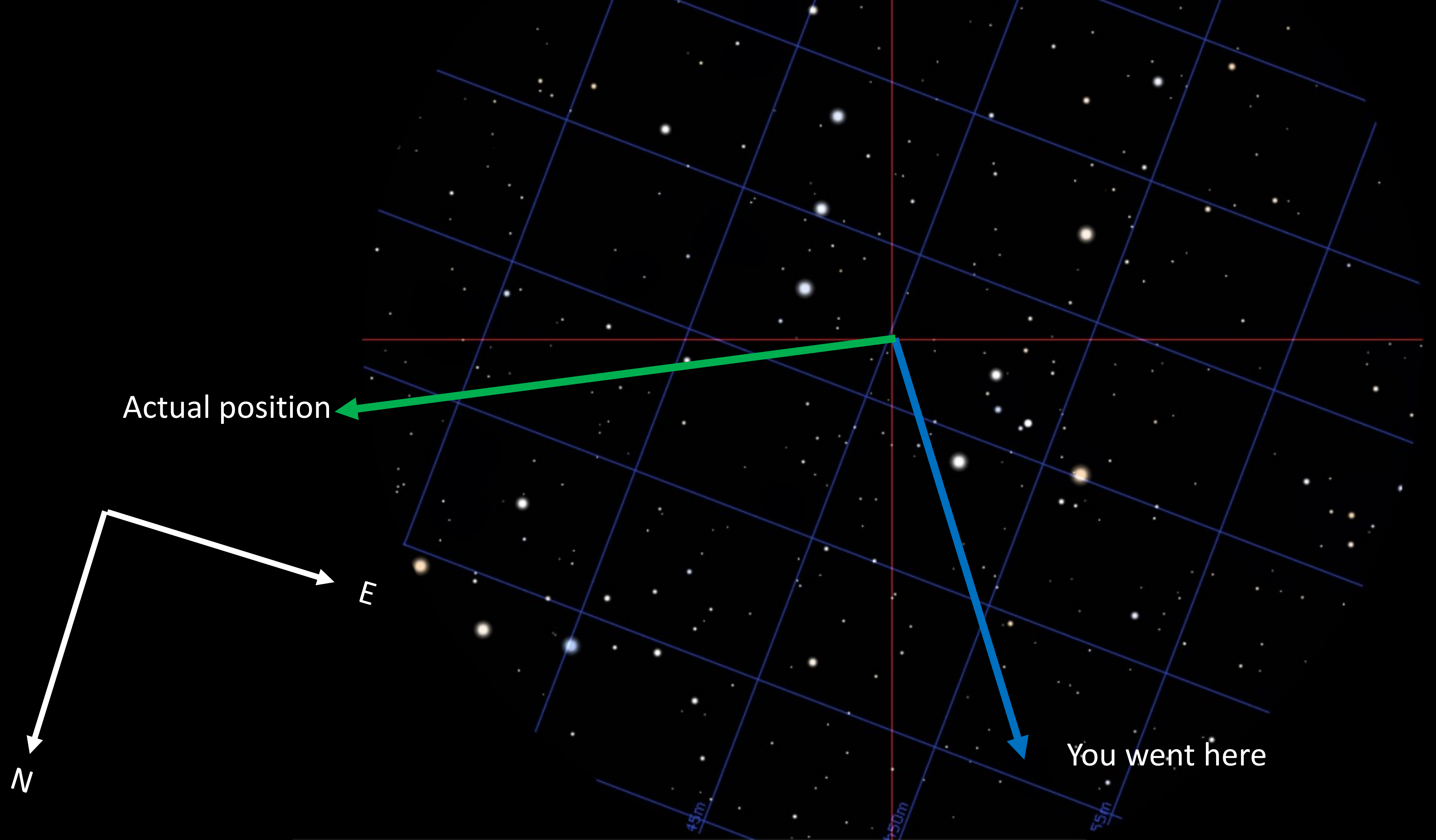
4. DRAW YOUR CARDINAL DIRECTIONS

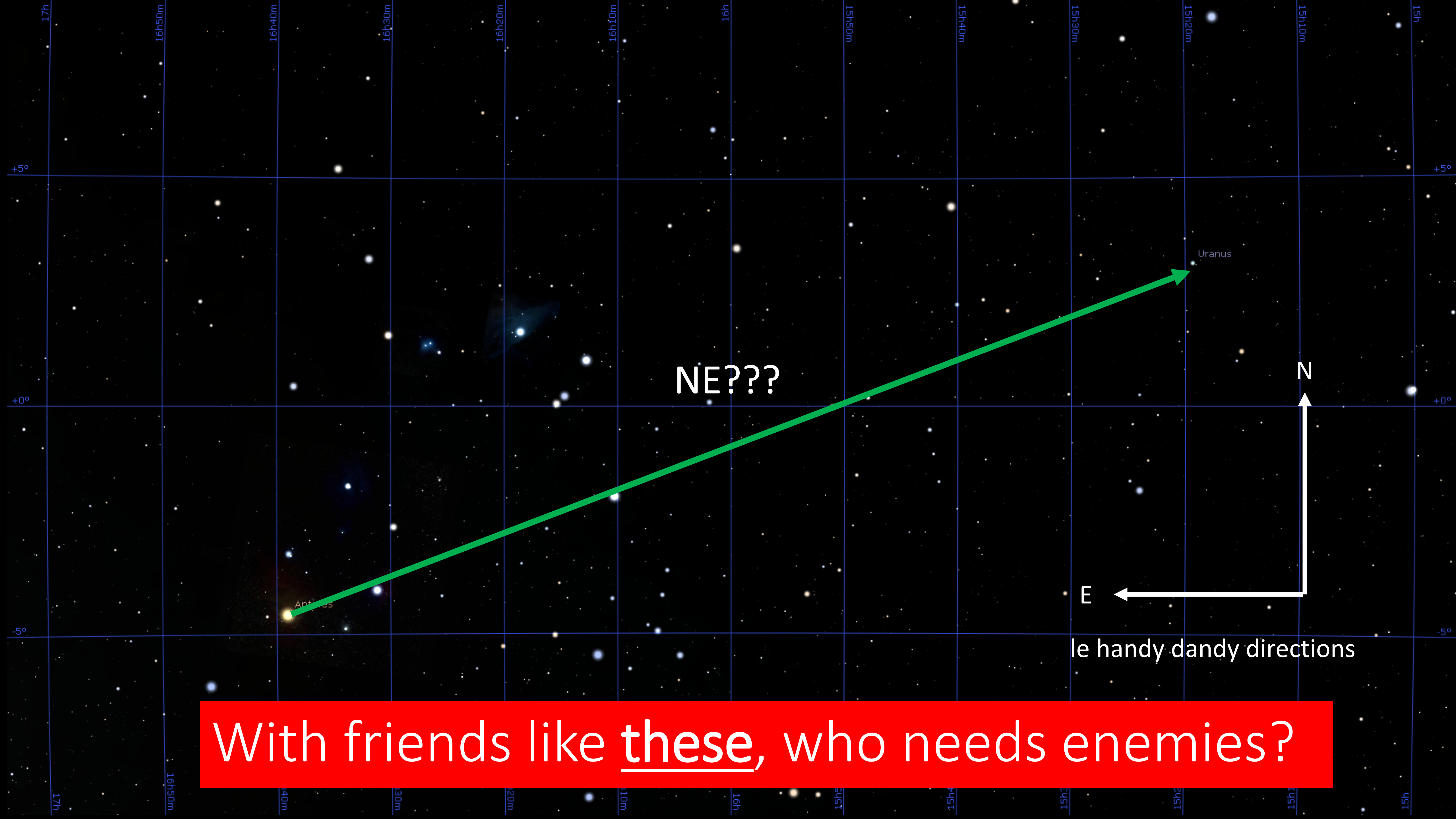
100% accurate finder FOV



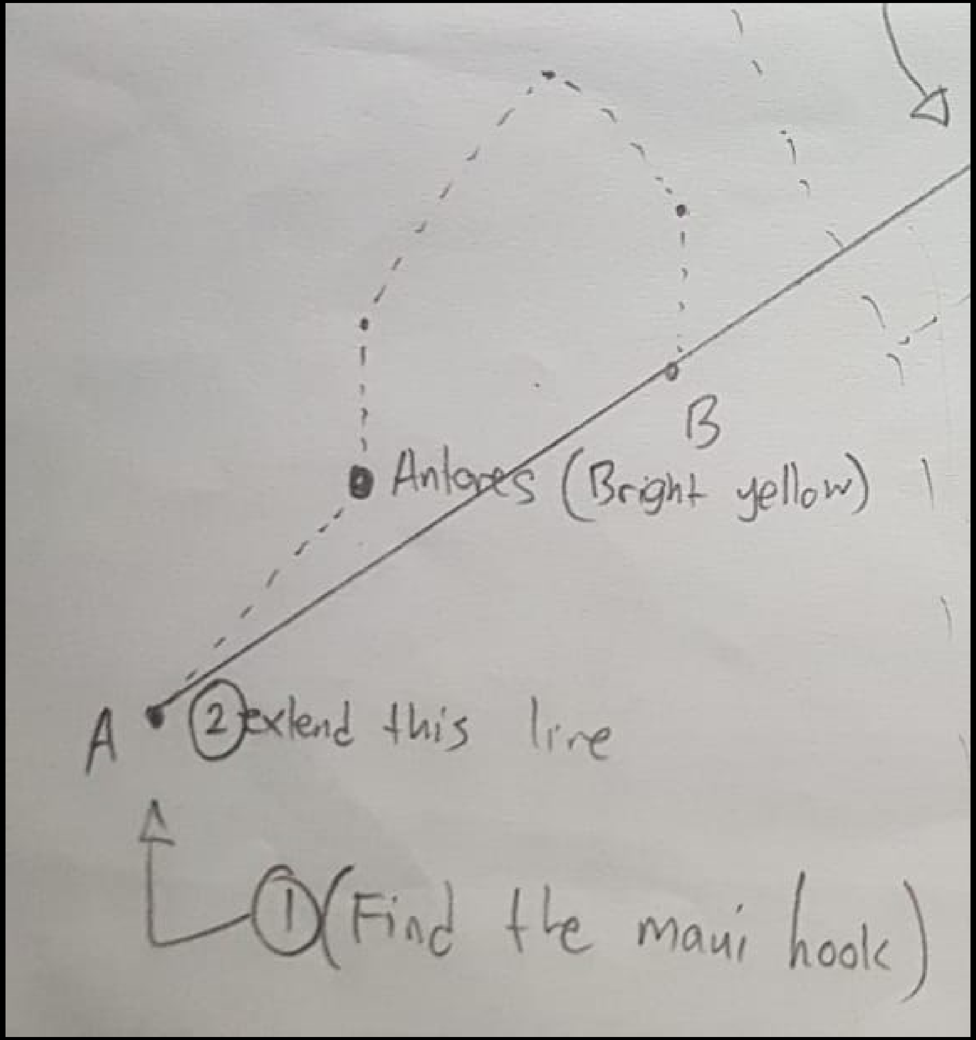
le handy dandy directions

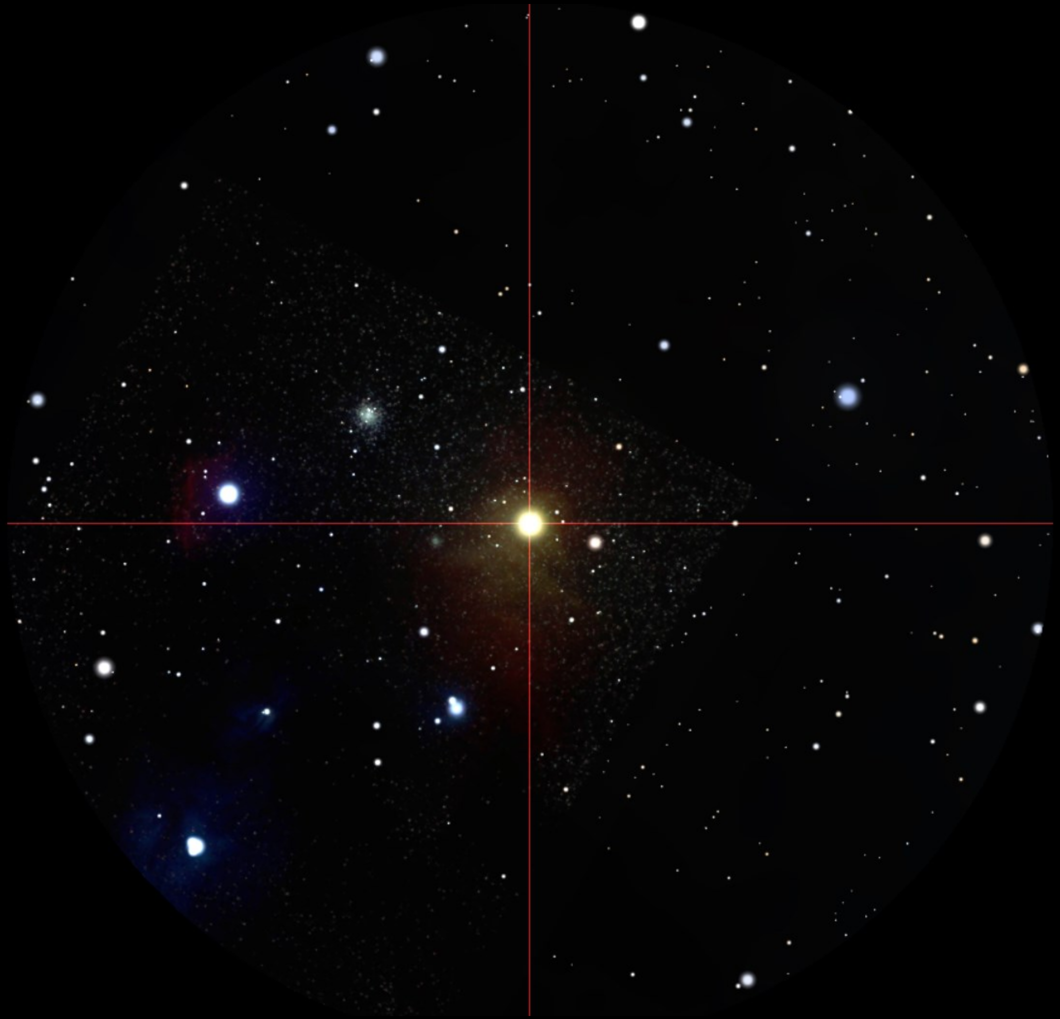
MAGIC CARDINAL DIRECTIONS ON SKY



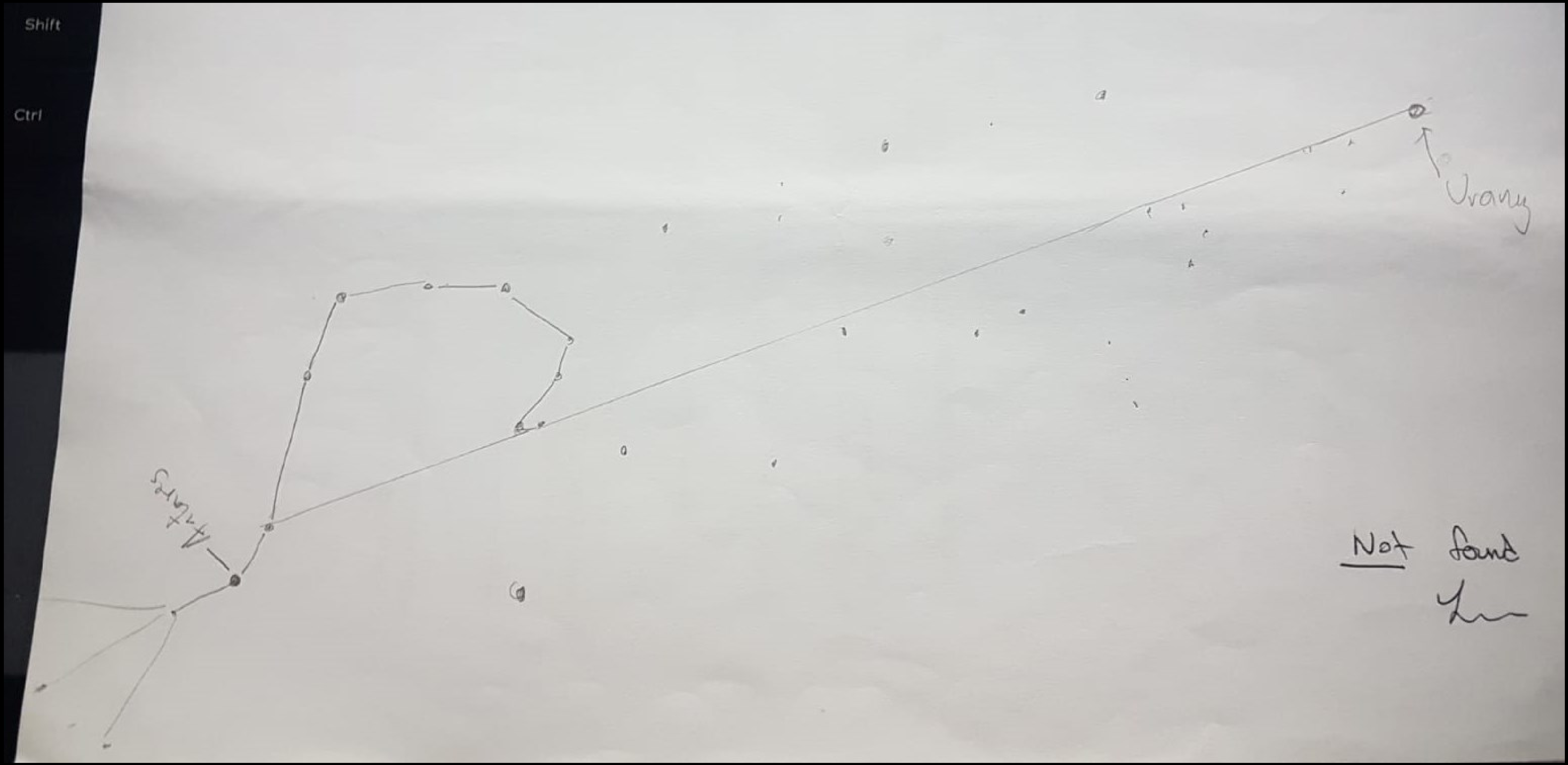

Uranus
NE???
N
E
le handy dandy directions
With friends like **these**, who needs enemies?

6. Bear in mind FOV (Draw it out!)





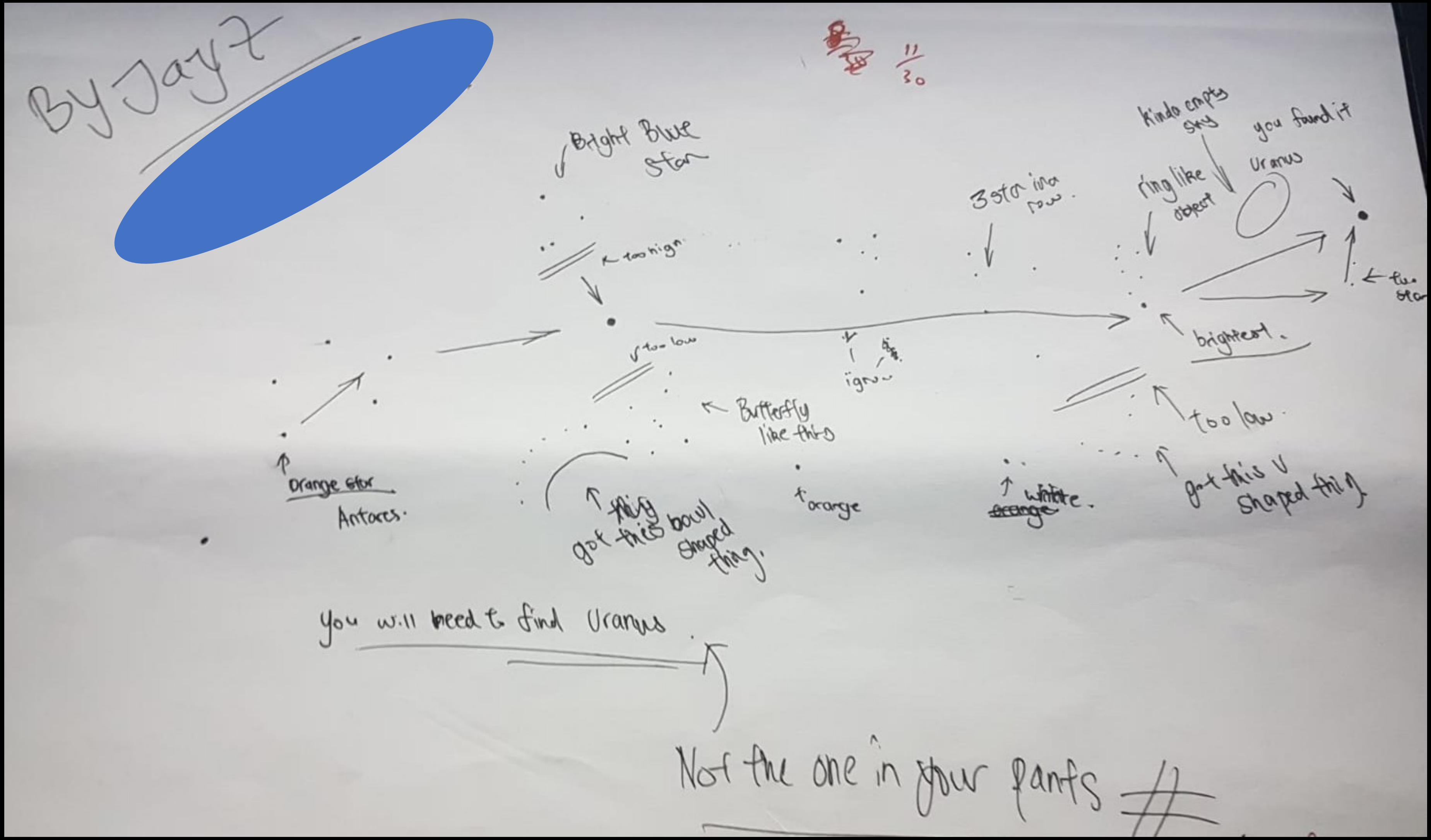
7. Don't give WRONG instructions



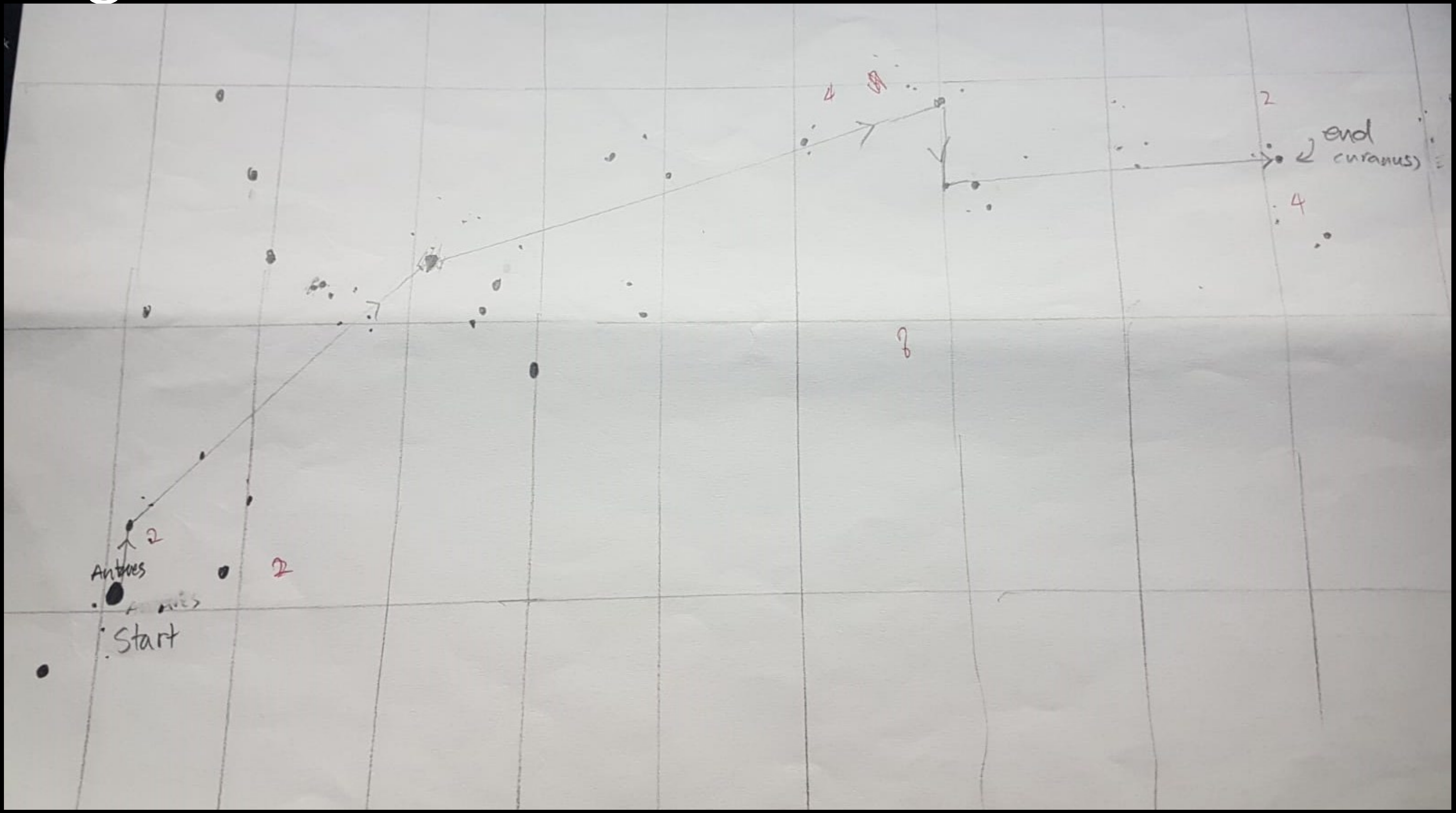
What they thought they had to do

What you REALLY wanted them to do

Be a good friend: handhold them



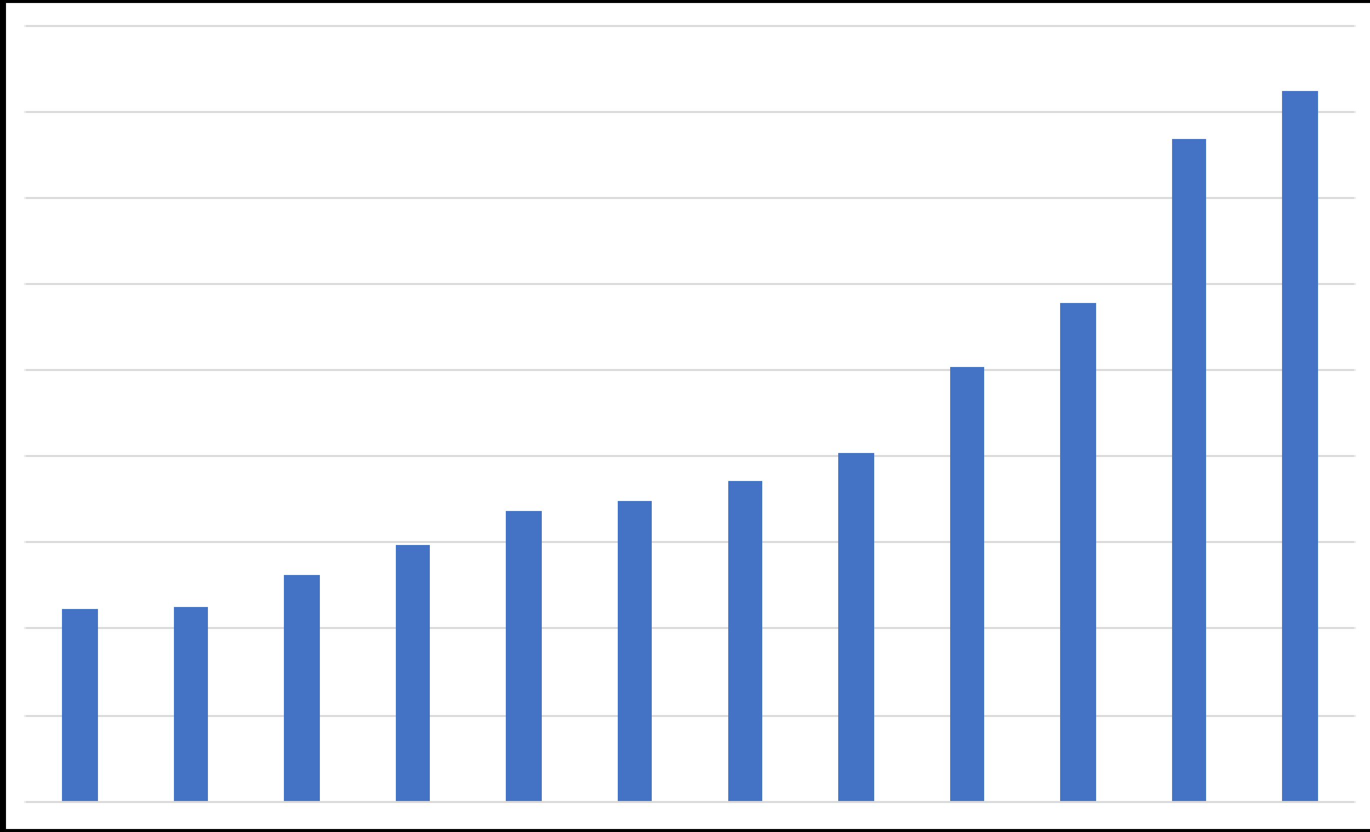
Be a good friend: handhold them



Observation Round (Practical)

- Setup was largely done without mistakes
- Some teams spent way too much time on the individual component
  - Don't neglect the last 35%!
- Most importantly, I hope you had a magical experience under the clear sky :D

Observation Round Score Distribution



Mean = 42.8, Median = 36.0, Standard Deviation = 19.3