ASTROCHALLENGE 2019

PROUDLY ORGANISED BY :

NUS Astronomical Society

NTU Astronomical Society

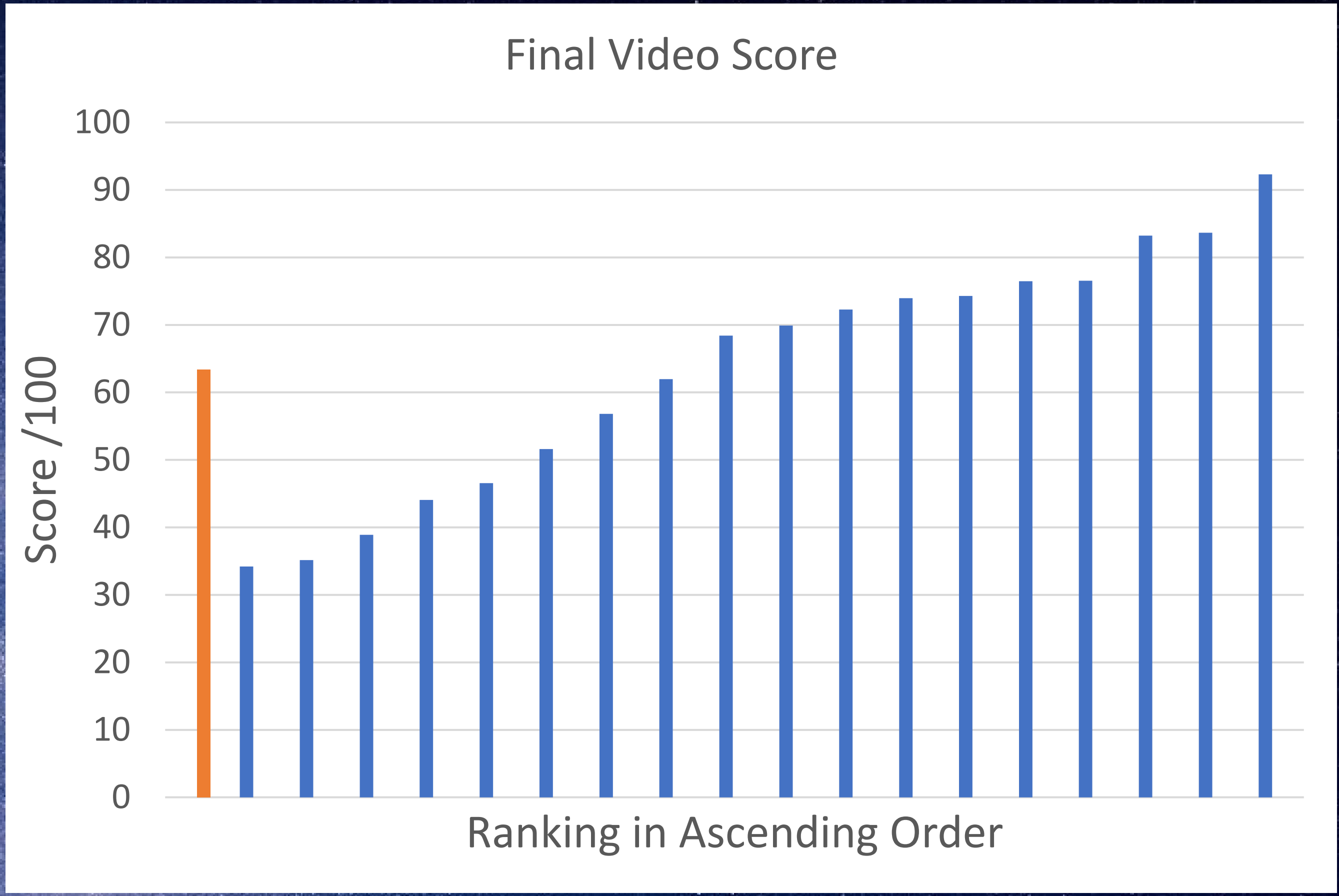
Senior Post Mortem

8 June 2019

Project Round Videos

Summary

- Teams generally did okay (63/100), though there is higher variability. Had a couple of decent videos and one that overwhelmingly exceeded expectations
- Fared better than juniors overall, though a few groups fared worse



Summary

Most popular question : Question 18

- What are planetary nebulae and why are they so colourful?

Videos here were average in general

- Content was OK – though a few mistakes were spotted
- Presentation was the key weakness
  - Irrelevant/unhelpful graphics
  - Choppy audio with interjections

Summary

Best answered question: Question 26

- What lines of evidence prove flat-Earthers are wrong?

- Excellent content, coupled with lots of effort in presentation
  - Cinematography : Synced video + steady camera
  - Engaging video without spamming memes. Plus tasteful jokes

AstroChallenge news: Flat-Earthers Society DESTROYED by FACTS and LOGIC

Pitfalls and how to avoid them

- Problem: Watermarks, poor quality video editing softwares
- Solution: Use this list of free video editing software!!!
- **Bold: Recommended**

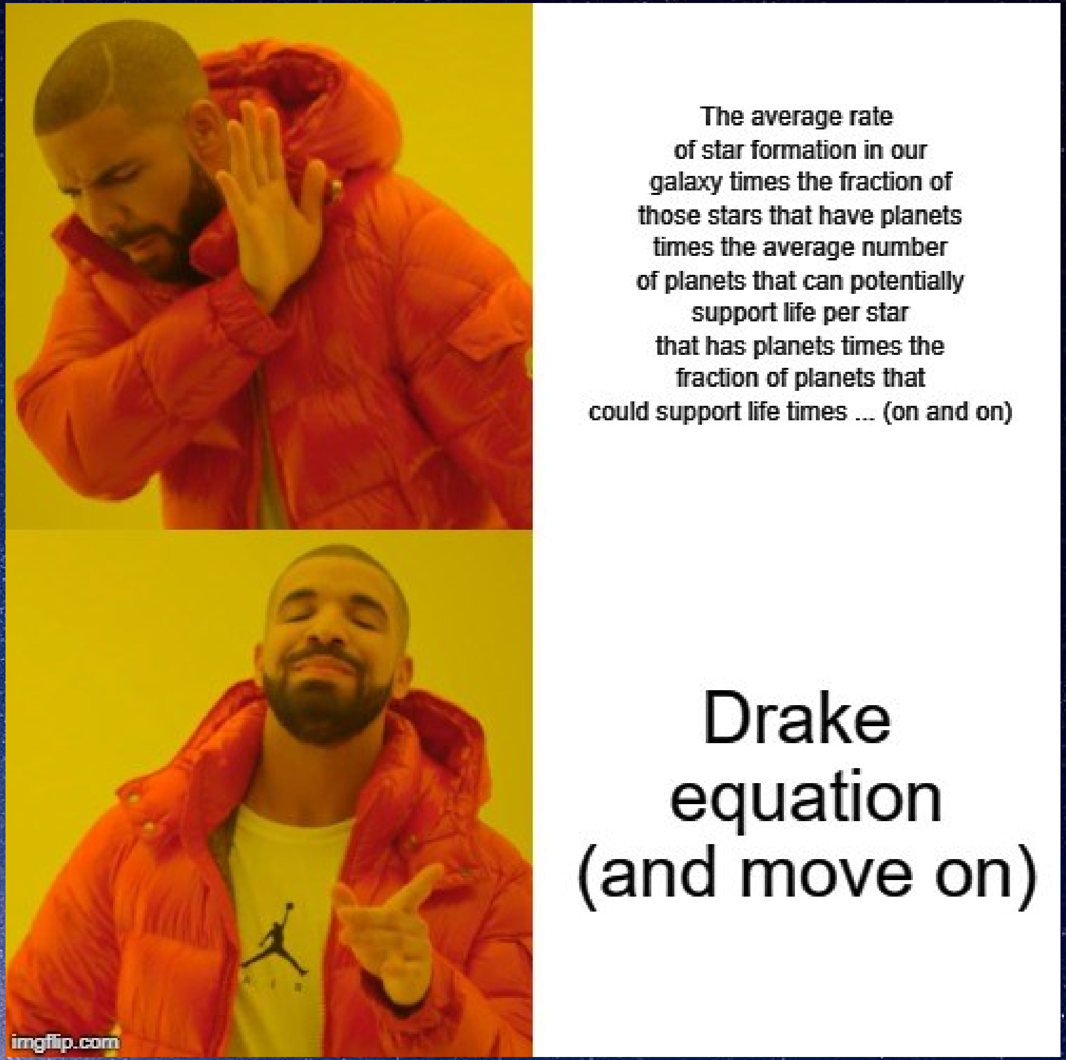
- Problem: Chipmunk voices, speeding up the video, distracting music
- Solution: Make sure your audio is clear and audible; **SUBTITLES**

Windows	***Mac OS***	***Linux***
DaVinci Resolve	**DaVinci Resolve**	**DaVinci Resolve**
Windows Movie Maker	**iMovie**	Kdenlive
ShotCut	LightWorks	avidemux
OpenShot	OpenShot	OpenShot
Kdenlive	ShotCut	ShotCut
avidemux	Blender	Blender
Blender	avidemux	ffmpeg
ffmpeg (command-line)	ffmpeg (command-line)	

Pitfalls and how to avoid them

- Problem: Long and boring, sleep inducing videos
- Solution: Answer the question to the point; NEVER pad runtime by reading out terms of tangentially related equations; research widely and have your own opinion

- Problem: Last minute work
- Solution: All of the above + DO NOT DO LAST MINUTE WORK



Plagiarism

- Asset use warning
  - Create your own assets/ drawings/ material when possible;
  - Credit or reference the original creators, authors and/or artist where applicable; <u>provide links and sources in transcripts & video credits</u>
  - <u>When in doubt, be generous in your credits</u>
- Major incident: Wholesale lifting of content
  - Use at least three different sources of information for research
  - Always include your own opinions after compilation

Plagiarism

Important reminder/ clarification:

- **TIME SPENT ON CREDITS DOES NOT COUNT TOWARDS YOUR TOTAL VIDEO TIME**

- Use this to provide credits for all resources used if possible, in addition to credits for teamwork

Individual Round

This year's "100%"

Q17

- Which of the five pairs cannot possibly be correct?

Object	Deity
Sun	Surya
Mercury	Budha
Mars	Mangala
Saturn	Shani
Neptune	Rahu

- JNR: 27% correct
- SNR: 16% correct

This year’s “100%” x 2

Q38

- With respect to a hypothetical observer on the Sun, the phases of the Moon as seen by the observer repeat once and only once approximately every ....? (Exclude eclipses/occultations from consideration)

- JNR: 18% correct
- SNR: 29% correct

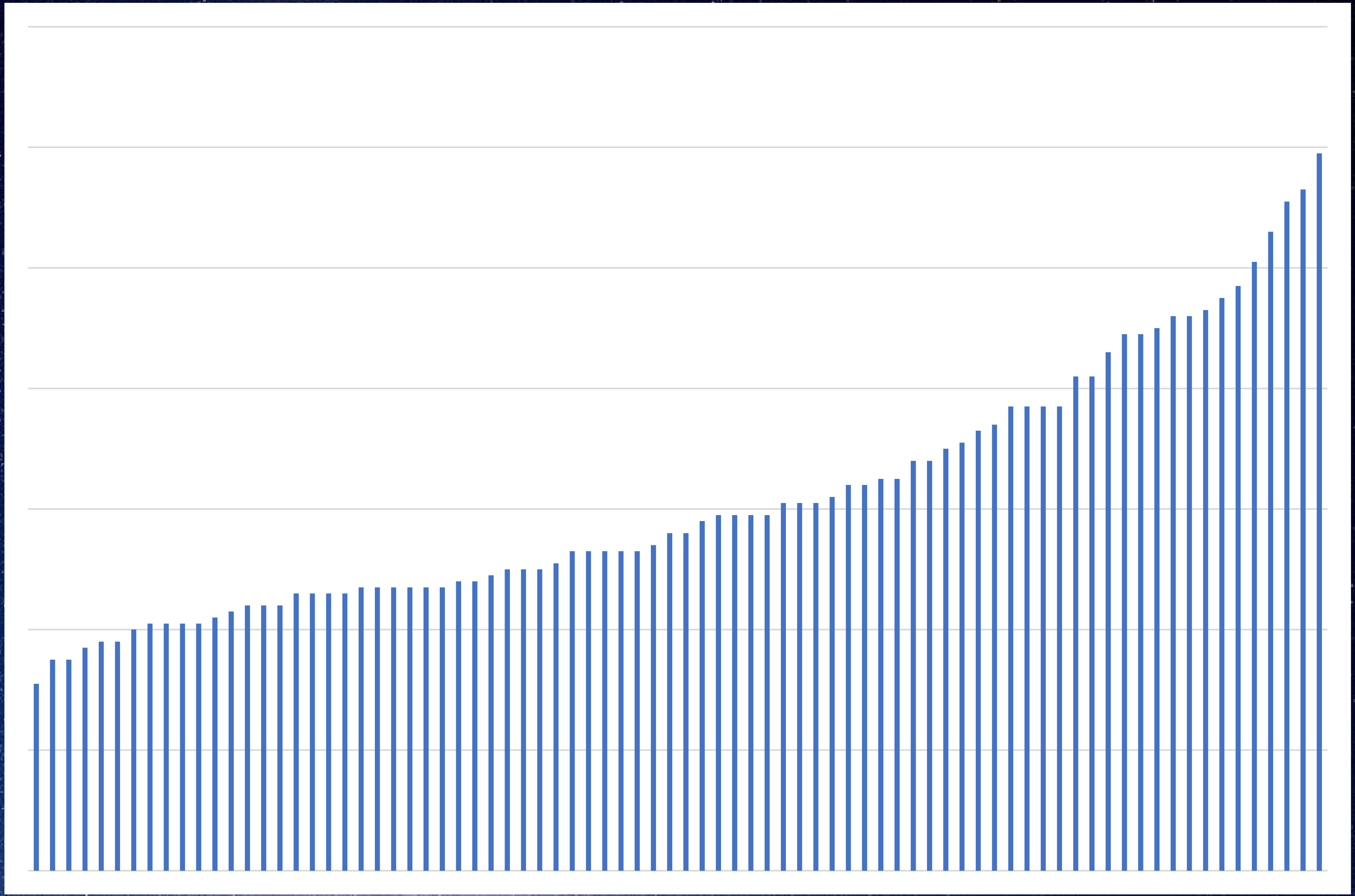
SNR Individual Round

- Easiest Question : Q2 (93% correct)
  - A rule of thumb is that it is best to stargaze during a new moon, rather than during a full moon. Why?
- Most Incorrect : Q24 (9% correct)
  - Which statements about the analemma are true?
- Most Blanks : Q28
  - Keven wants to determine the speed of a star that is moving away from Earth, with respect to himself…

SNR Individual Round Score Distribution

Mean = 61.8

Std. Deviation = 20.6



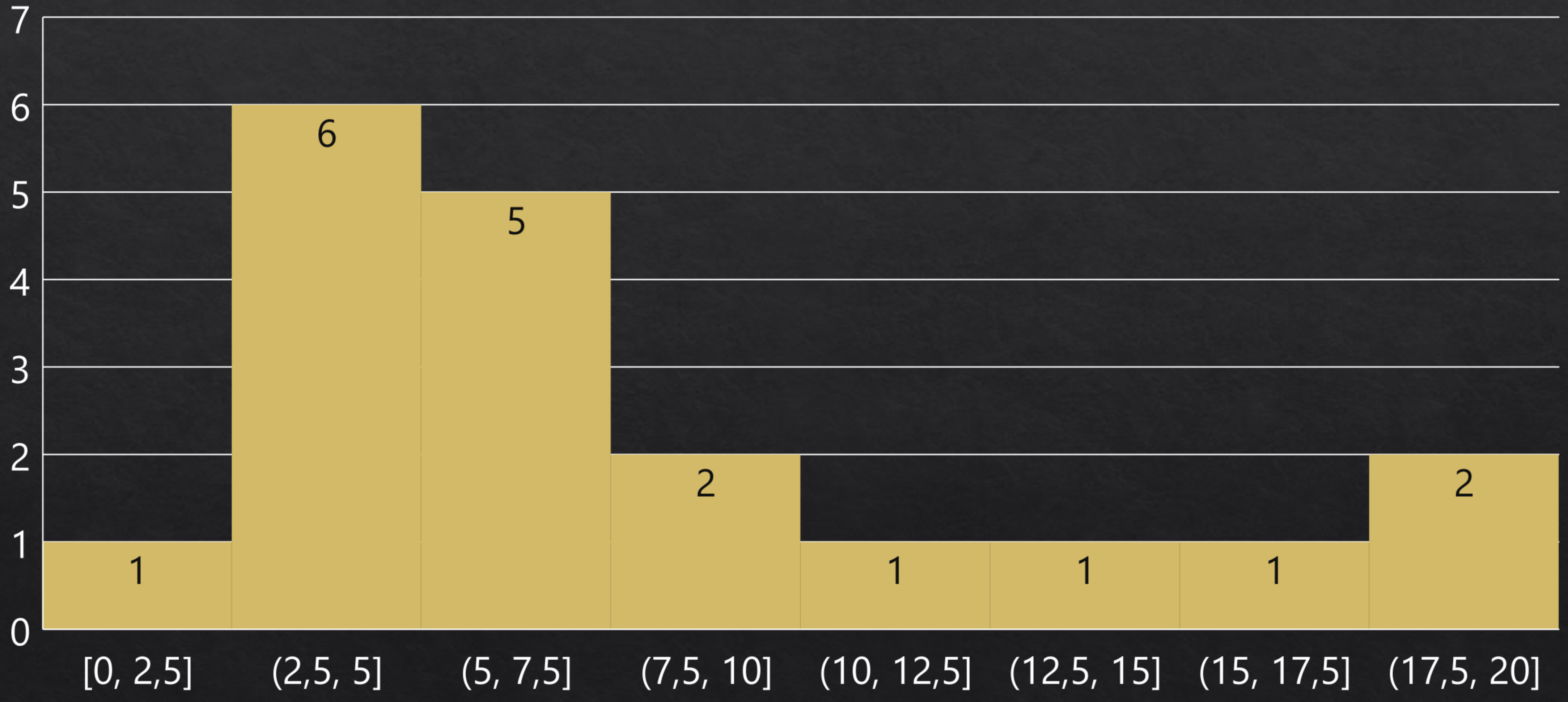
Team Round

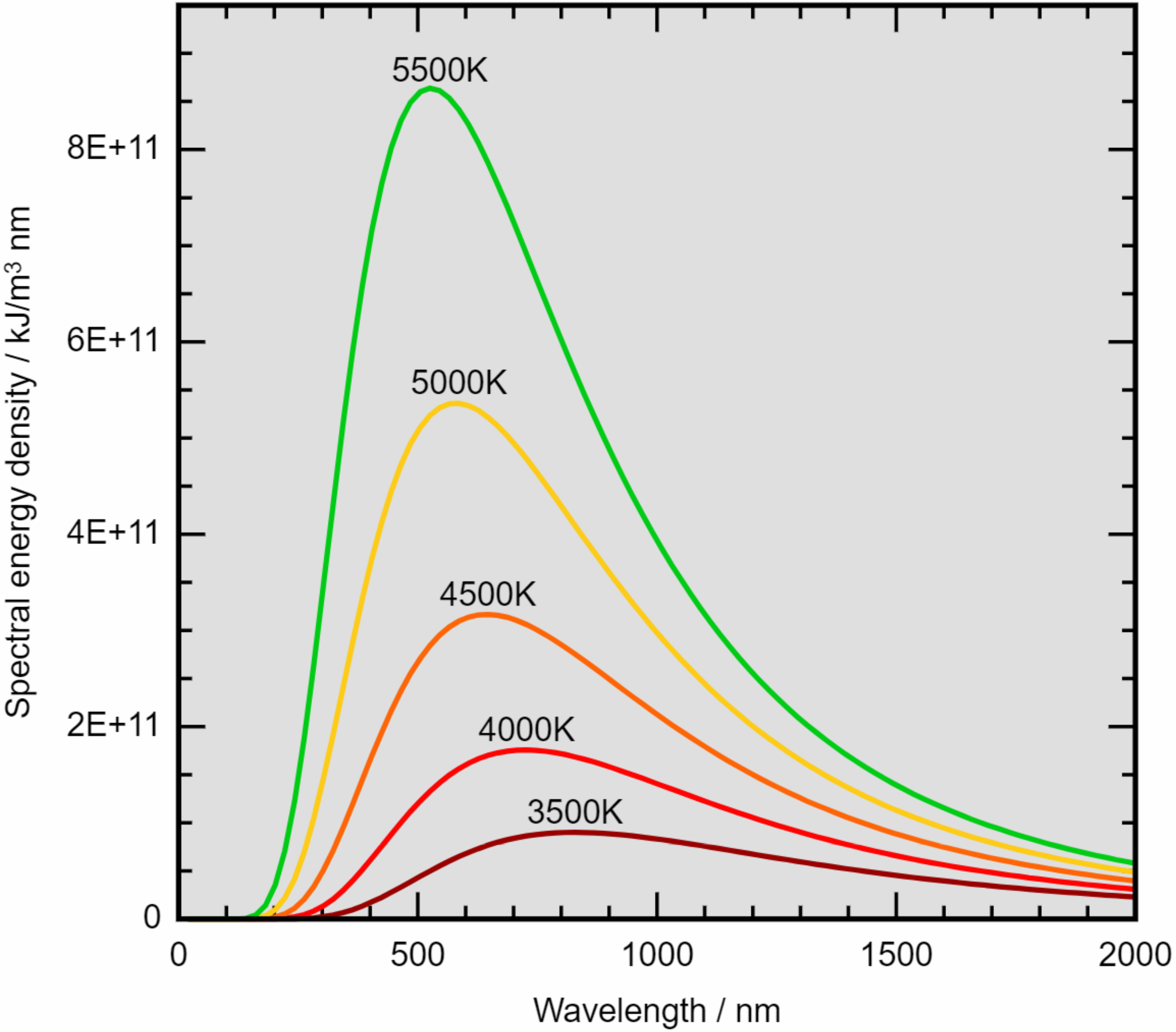
AstroChallenge 2019 Senior Team Round Q1

Post-Mortem

Setter: Lim Kia Yee
Marker: Sharadh Rajaraman

Score Distribution (Bins of 2.5 marks)





5500K
5000K
4500K
4000K
3500K
8E+11
6E+11
4E+11
2E+11
0
0
500
1000
1500
2000
Spectral energy density / kJ/m3 nm
Wavelength / nm

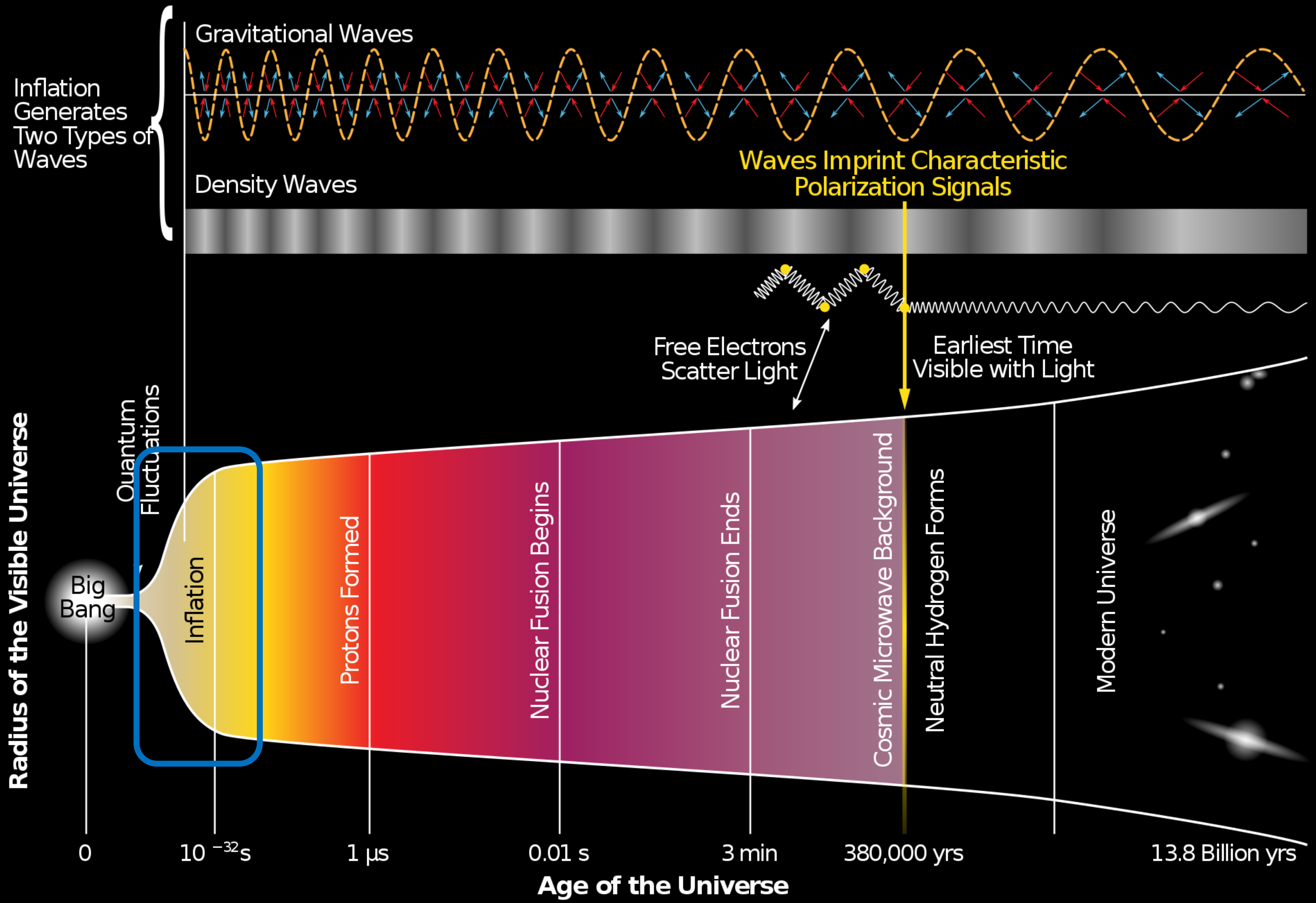
More Stats

Mean	8.18
Median	6
Mode	4.5

Q1(a): In astronomy, what does the term 'cosmological inflation' refer to? [1]

- Common answers:
  - 'Expansion of the Universe'
  - 'Acceleration of the expansion of the Universe'
  - 'Expansion of space-time'
- Correct, complete answer:
  - Cosmological expansion is the **exponential increase** in size of the extremely early Universe, which lasted from 10^{-36} seconds after the Big Bang, to about 10^{-32} seconds after the Big Bang.

History of the Universe



Exemplars

It is a theory of exponential expansion of space in the early universe.

cosmological inflation refers to the process at which the early universe expanded at an enormous rate - inflating from the singularity to about the size of the earth

cosmological inflation refers to the very bried period in ~~a~~ time immediately after the ~~bing~~ Big Bang where the universe expanded at a rate faster than the speed of light.

a. It refers to an incredibly ~~f~~ rapid expansion of the universe after the Big Bang

Q1(b): Cosmological inflation was hypothesised in order to explain certain observations that could not otherwise be easily explained. **Name and describe an example of such a problem.** [2]

- Common answers:
  - ‘Movement of distant galaxies away from us’
  - ‘Galaxies are receding from our POV’
  - ‘Expansion of space-time’
  - ‘Redshift of light emitted from distant objects’
  - ‘More distant objects experience greater redshift than objects less distant’
  - ‘Olber’s Paradox: why the night sky is dark’
  - etc.

Exemplars

(b) The issue was known as the ~~flatness~~ horizon problem, which was that the ~~cosmic microwave background~~ universe was very smooth and homogenous throughout. The horizon problem points out there is no way that the opposite ends of the universe could have interacted ~~and smooth out the temperature in the universe.~~

2

(b) One of these problems is the extreme uniformity observed in the Cosmic Microwave Background Radiation ((MBR). On a very large scale the energy density in all parts of the universe is extremely uniform. ~~Inflation solved this problem~~

b) The Horizon Problem. The observable universe appeared to be much more than 27.6 billion light years across despite the fact that the Universe is only 13.8 billion years old and thus light could only have travelled 13.8 billion light years in either direction.

Q1(c): Explain how cosmological inflation solves the problem you have stated in (b). [2]

- Common answers:
  - 'It explains why distant galaxies appear to be receding from the Local Group'
  - 'The Universe is expanding, hence EM radiation emitted from distant galaxies and objects are redshifted because space-time itself is expanding'
  - 'The Universe is expanding; hence, this means light from all stars in the Universe has not had time to reach the Earth'
  - Etc.

Exemplars

showing ~~a~~ very little variation.

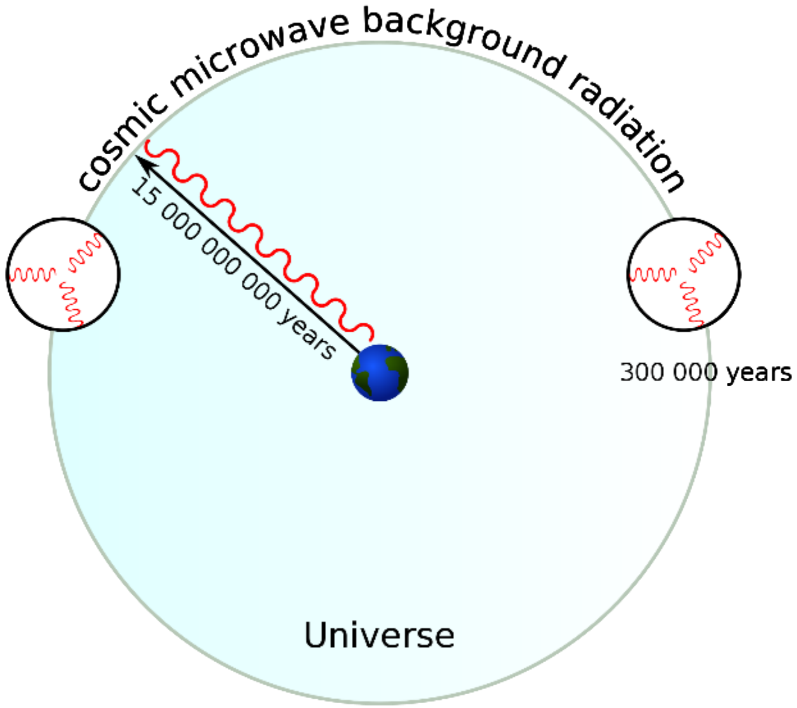
(c) Via cosmological inflation, the universe itself expanded into an extremely big area compared to the time before the inflation. This allowed the matter and energy present in the space to be spread very uniformly throughout. As such, the energy density in all places in the universe is very similar, which would not have happened if inflation had not occurred. (it ~~would be very~~ ~~bundled~~ look as if there were bundles of energy here and there across the universe).

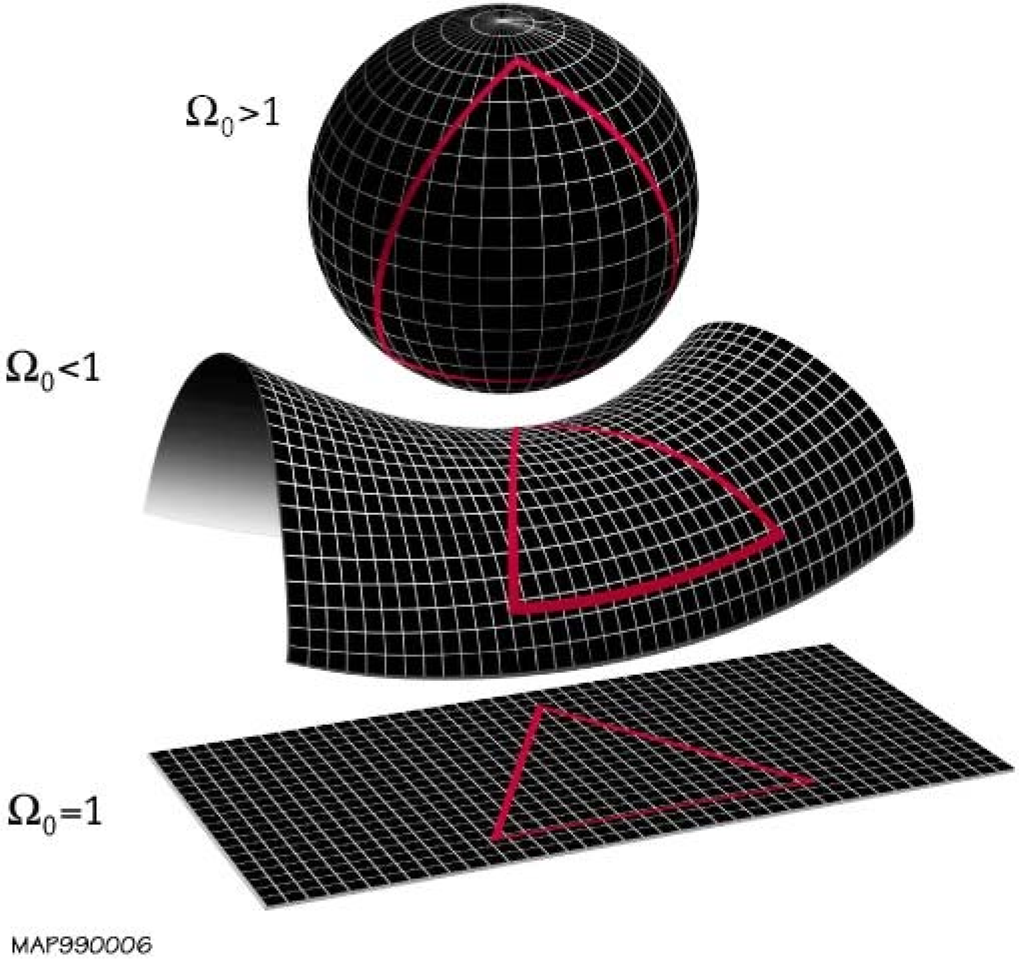
(c) It provides an explanation that the universe started with a point at thermal equilibrium and expanded, so the ends of the universe are in thermal equilibrium.

(c) ~~Post-cosmological Inflation, the expansion rate of the universe was relatively slow allowing for light enough time~~

Inflation forces the Ω-factor to be close to 1. Thus it solves the flatness problem. It then solves the horizon problem, as the universe was much smaller in its early stages for its ends to have interacted with each other.

2

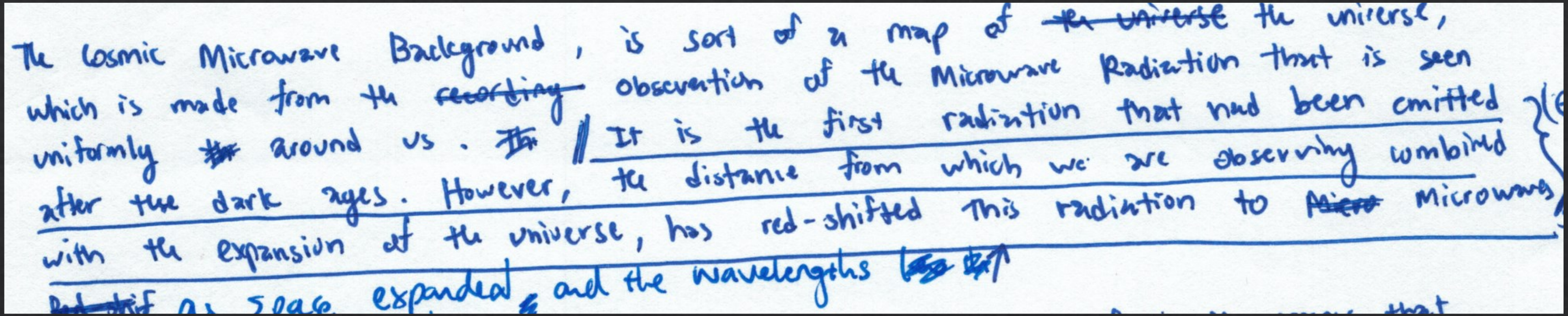

cosmic microwave background radiation
15 000 000 000 years
300 000 years
Universe

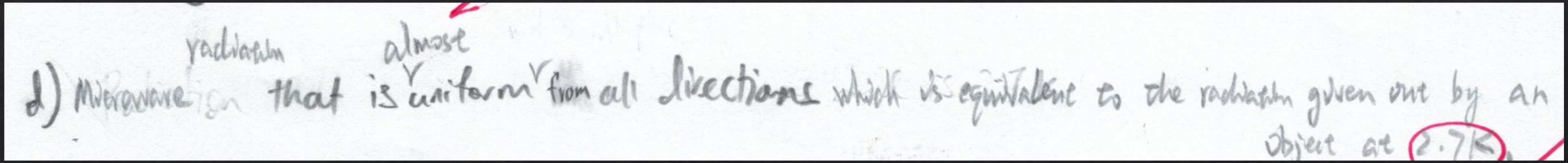

$\Omega_0>1$
$\Omega_0<1$
$\Omega_0=1$
MAP990006

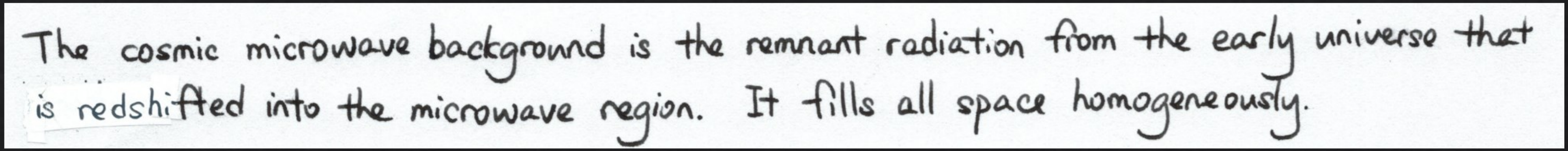
Q1(d): What is the Cosmic Microwave Background? [1]

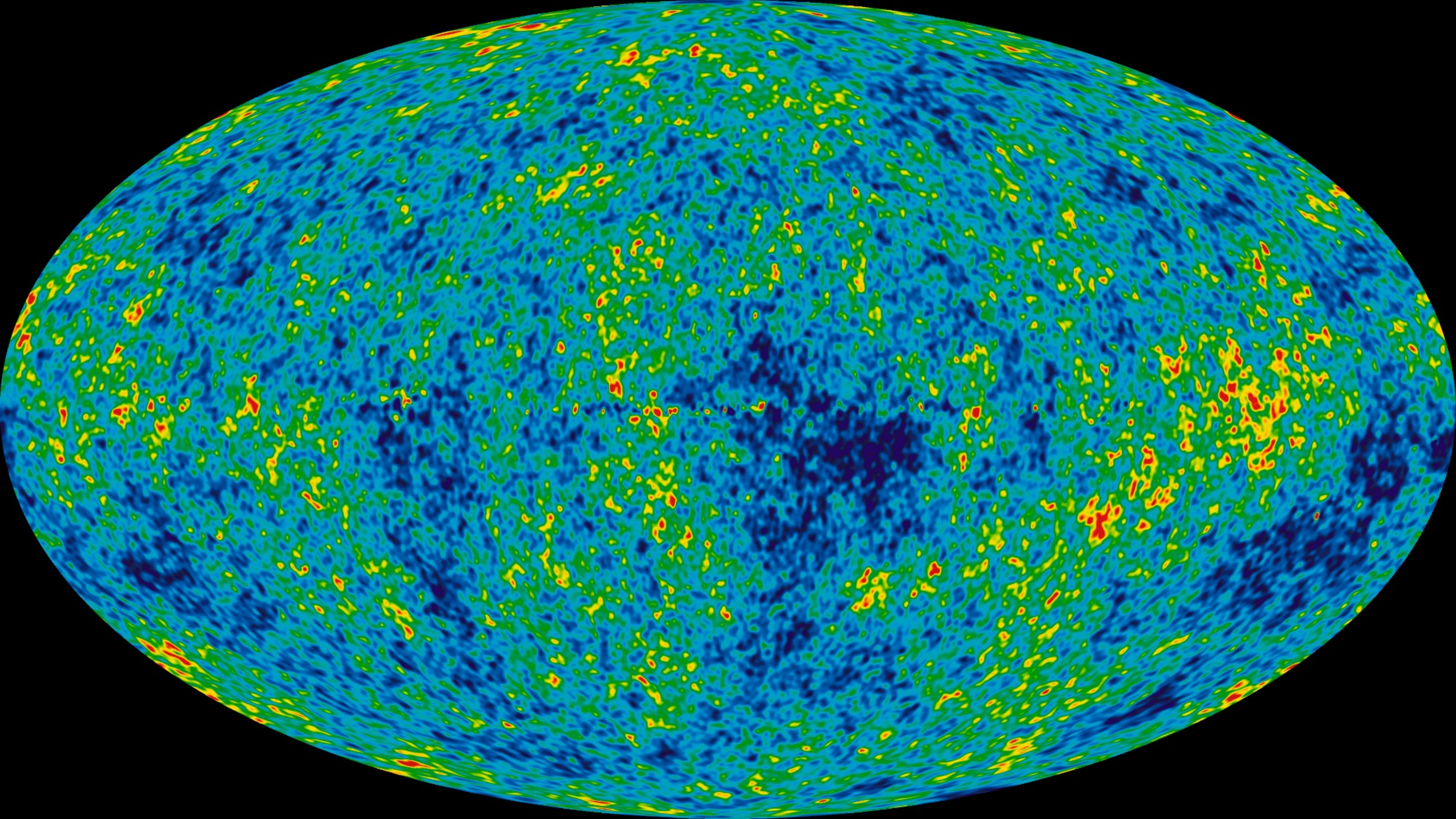
- Common answers:
  - ‘The microwaves that exist in space’
  - ‘The ambient *temperature* of the Universe resulting from the remnant heat of the Big Bang’
  - ‘Remnant light of the first light of the Universe, redshifted into the microwave spectrum
  - ‘It is EM radiation increasing in wavelength’ ???????
  - ‘It is the EM radiation emitted by microwave ovens in the household’ ?????????????????

Exemplars


The cosmic Microwave Background, is sort of a map of the universe the universe,
which is made from the recording observation of the Microwave Radiation that is seen
uniformly around us. It is the first radiation that had been emitted
after the dark ages. However, the distance from which we are observing combined
with the expansion of the universe, has red-shifted this radiation to Microwaves
with the expansion of the universe, has
as space expanded, and the wavelengths


d) Microwave radiation that is almost uniform from all directions which is equivalent to the radiation given out by an object at 2.7K


The cosmic microwave background is the remnant radiation from the early universe that
is redshifted into the microwave region. It fills all space homogeneously.



Q1(e): Name and describe the process that initially created the Cosmic Microwave Background. [2]

- Common answers:
  - ‘Redshift’
  - ‘The Big Bang, which caused the separation between matter and antimatter’
  - ‘The heat and energy of the Big Bang’
  - ‘Inflation’

Exemplars

e) Radiation emitted during recombination that was redshifted as the universe expanded

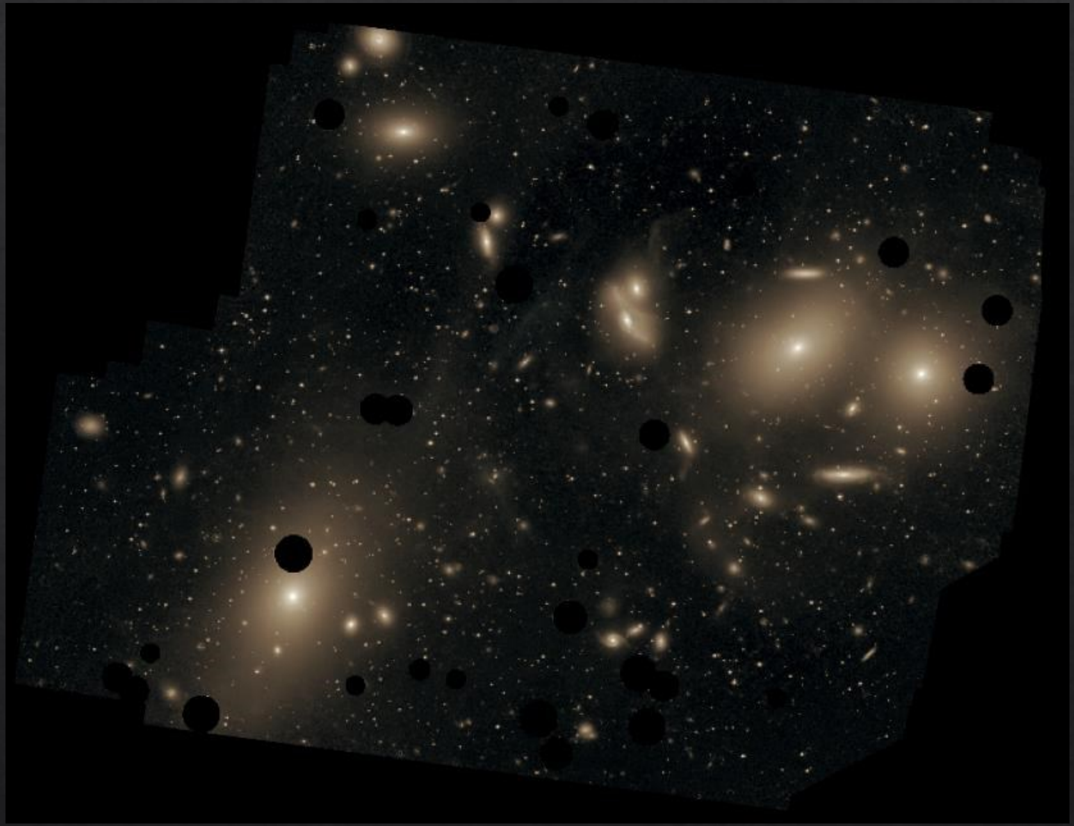
The event was Recombination, when the universe has cooled down enough for protons and electrons to combine into neutral hydrogen atoms. Neutral hydrogen atoms cannot absorb light of all frequencies, and the heat radiation from early universe decouples with matter and now roam freely in the universe. These photons are later redshifted into the CMB.

afterglow.

(e) The process is called recombination. Up until that point, about 380 000 years, the universe was "opaque" due to the abundance of free electrons, and light always get scattered by these free electron. At the recombination epoch, the universe had cooled enough and expanded enough such that mean path of the light is such that it can travel without being scattered. Over the course of the universe's expansion, the light got redshifted into microwave radiation which is the faint after glow that we can observe now.

Q1 (f): **<u>Galaxies</u>** tend to group in **<u>clusters</u>**, rather than exist in complete isolation. Account for this trend. [2]

- Common answers:
  - ‘gravity causes them to cluster together’
  - ‘galaxies exert gravitational pull on each other, causing them to cluster together’
  - ‘gravitational *energy* pulls galaxies together’
  - ‘clusters of galaxies form from a single *patch of mass*’ [sic] ???
  - ‘galaxies form around agglomerations of dark matter’
  - ‘protostars attract matter towards them, triggering the formation of more stars’



Exemplars

Galaxies form where there is gas, and the gas are gravitationally attracted to huge strands of dark metter. The gas then collapse into the many galaxies and form clusters. In other words, distribution of dark metter dictates the formation of galaxy clusters.

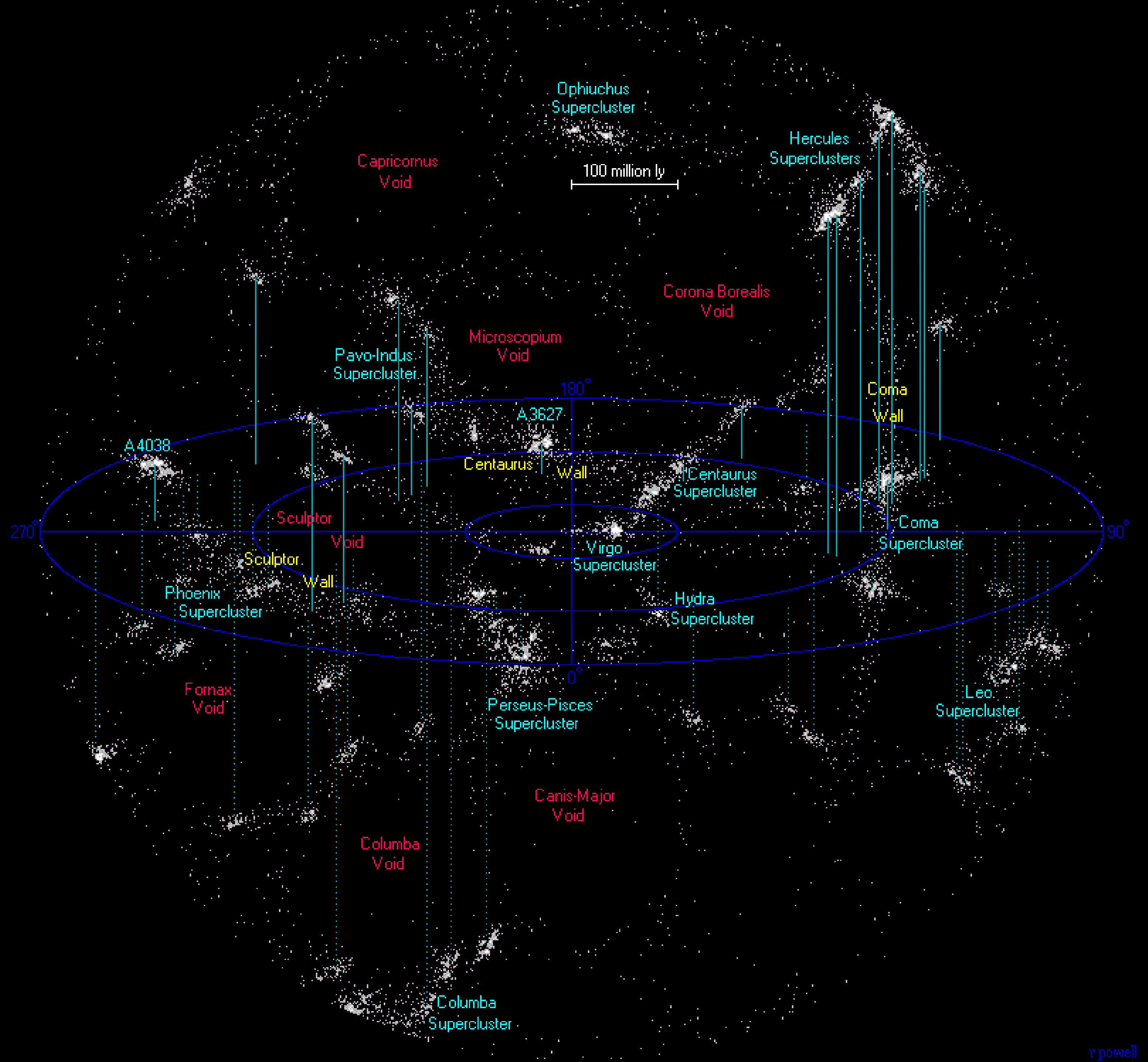
...n observe now.

This is due to the existance of large scale structures which ...

Fluctuations in the early stages of the Universe led to uneven distributions of matter in the Universe, leading to clusters of matter, which we see as the galaxy clusters today.

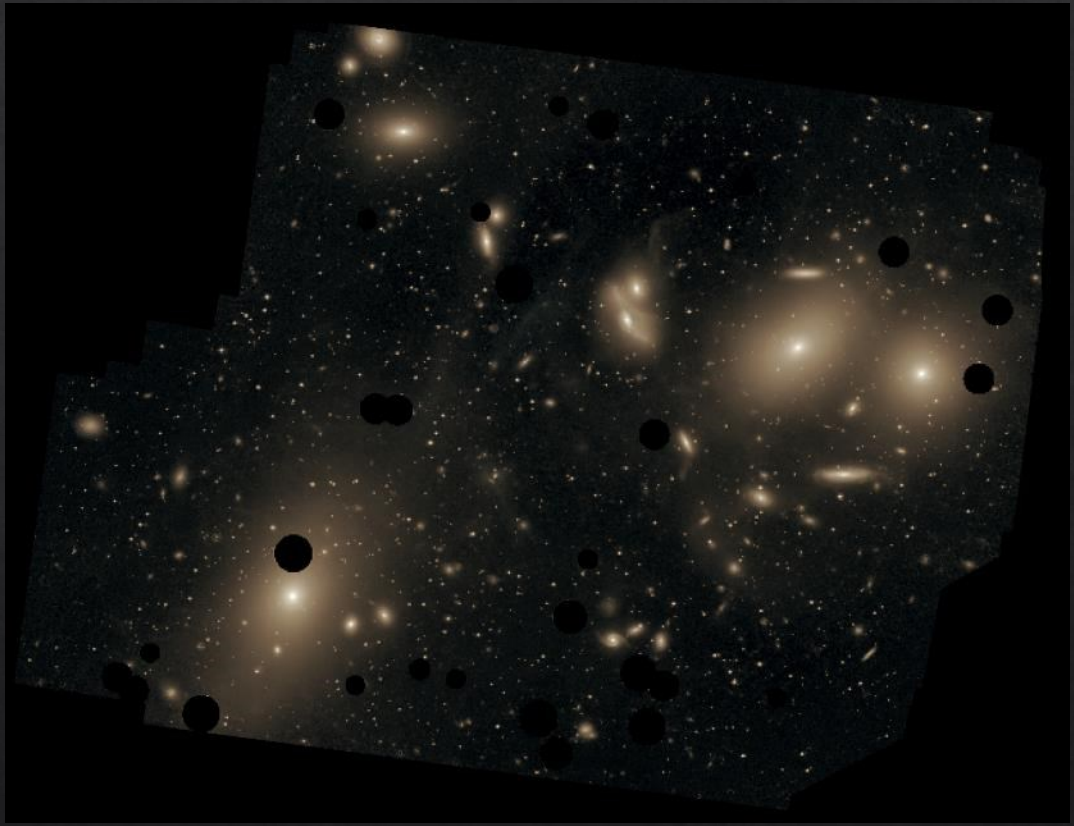
clusters.

At the very beginning of the universe, quantum fluctuations led to a slightly non-homogeneous distribution of matter. Over time, these irregularities with slightly more matter would have a tendency to accrete more matter as a result of gravity. ~~As a res These~~ Due to the presence of cold dark matter, these huge clumps of matter would then coalesce to form galaxy clusters, and so often when there is enough matter present to form one galaxy there is enough matter to form multiple galaxies.


Ophiuchus Supercluster
Hercules Superclusters
Capricornus Void
100 million ly
Corona Borealis Void
Microscopium Void
Pavo-Indus Supercluster
180°
Coma Wall
A3627
A4038
Centaurus Wall
Centaurus Supercluster
270°
Sculptor Void
90°
Coma Supercluster
Virgo Supercluster
Sculptor Wall
Phoenix Supercluster
Hydra Supercluster
0°
Fornax Void
Perseus-Pisces Supercluster
Leo Supercluster
Canis-Major Void
Columba Void
Columba Supercluster
rpowell

Q1 (g): It is clear from the image that spiral galaxies are rare within the core of the Virgo Cluster. Furthermore, the few that *do* exist are highly distorted. Account for this observation. [2]

- Common answers:
  - ‘gravity causes the distortion’
  - ‘galaxies interact and form ellipticals’



Exemplars

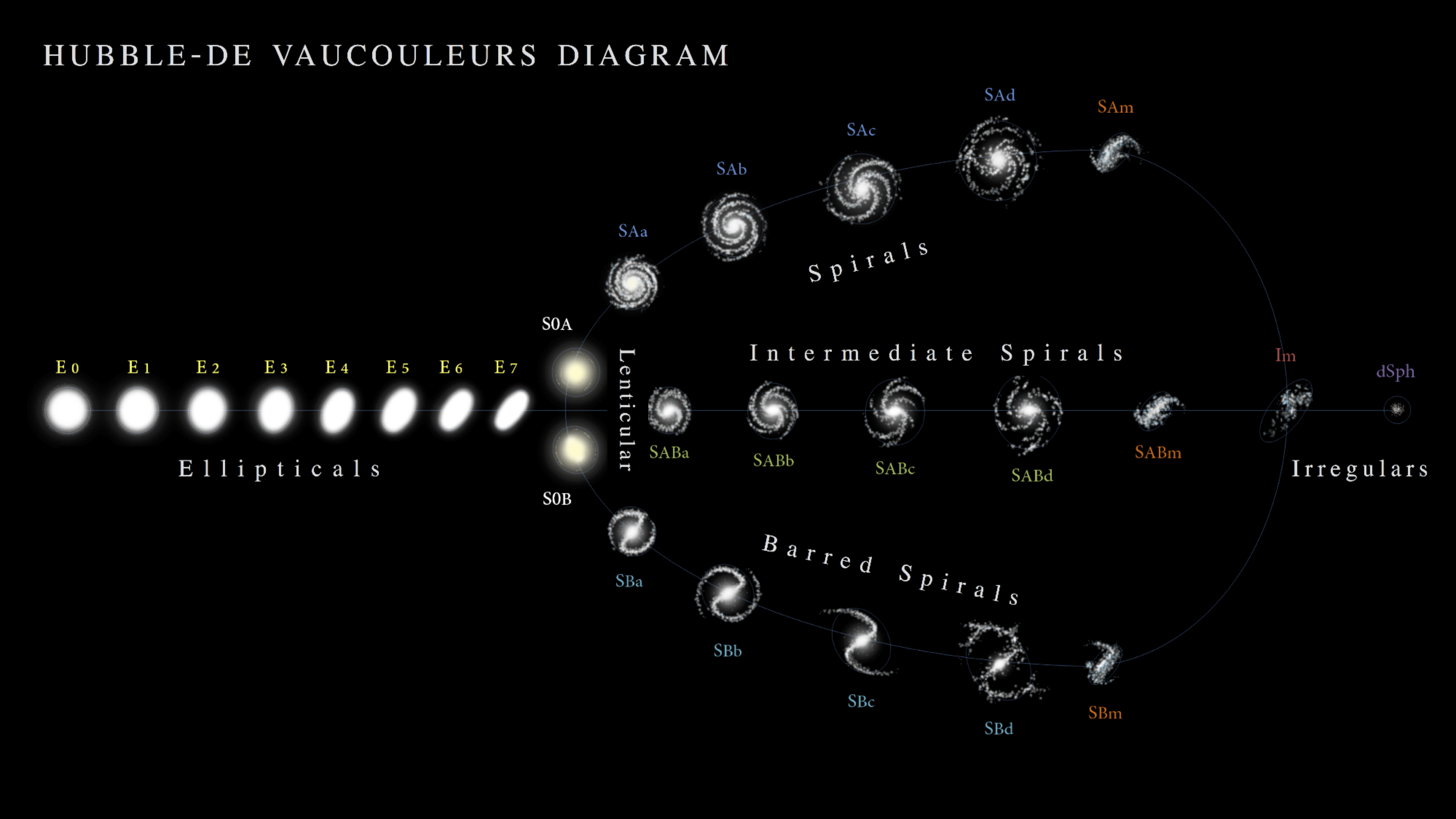
Since ~~g~~ galaxies exist in clusters, collisions between galaxies are imminent and frequent. As such, these collisions will result in the lack of spiral galaxies and favour the creation of elliptical or ~~t~~ irregular galaxies. Moreover, the gravitational attraction ~~betwe~~ between matter from the galaxies ~~inf~~ interfere with ~~the~~ ~~how~~ ~~the~~ the formation processes ~~involved~~ involved in the creation of spiral galaxies.

The small number of spiral galaxies could be attributed to the fact that the spiral galaxies merge to form elliptical galaxies. The distortion is perhaps explained by gravitational tug (tidal forces) from nearby galaxies and gravitational lensing.

g) On the whole, ~~spiral galaxies tend to~~ it is ~~no~~ difficult for spiral galaxies to survive intact in the core of the Virgo Cluster, as the gravitational influences of surrounding galaxies have a tendency to distort and destroy their spiral arms. This ties into both observations as most spiral galaxies ~~have already been~~ ~~affected as~~ have already been affected by the gravitational forces of surrounding galaxies, and the few which remain have been heavily distorted by similar

RI team Senior

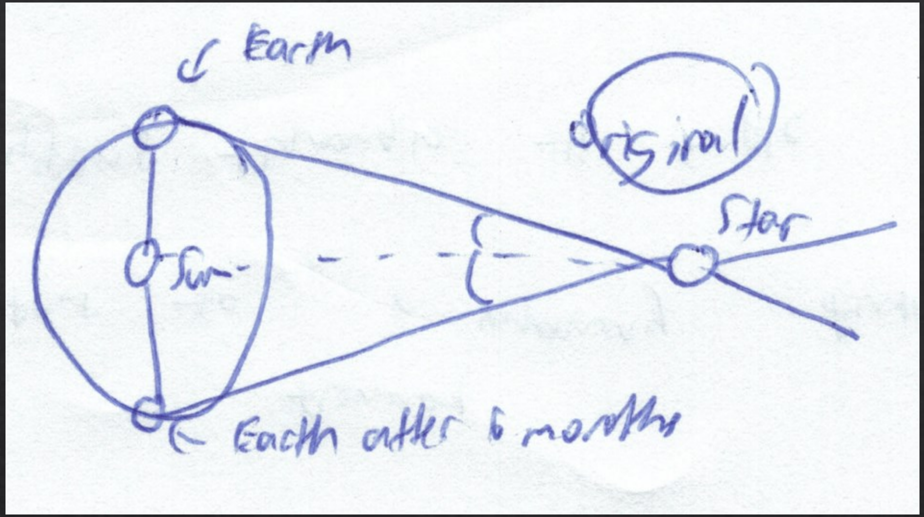
Collisions between spiral galaxies produce elliptical galaxies as the spiral arms of the galaxies are destroyed in the collision. As the density of galaxies in the Virgo cluster is high, it is highly likely that these galaxies have collided in the past.

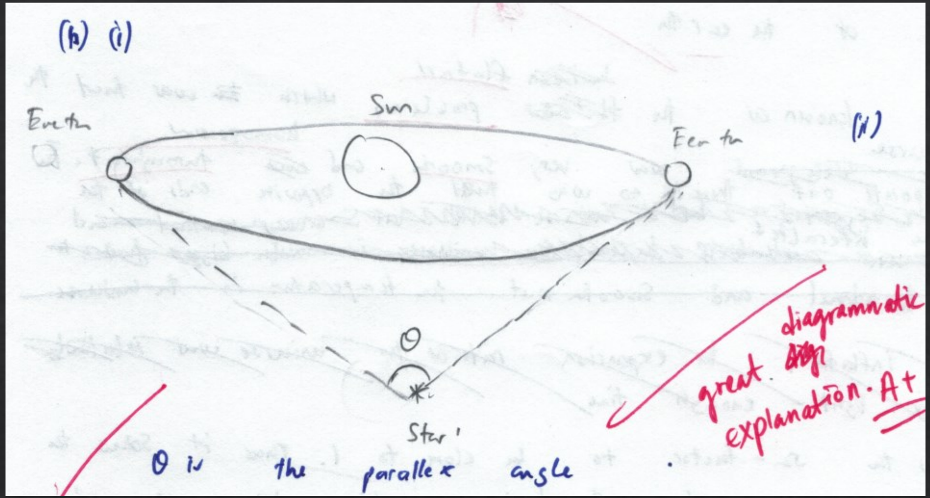

HUBBLE-DE VAUCOULEURS DIAGRAM
E0
E1
E2
E3
E4
E5
E6
E7
Ellipticals
S0A
S0B
Lenticular
SAa
SAb
SAc
SAd
SAm
Spirals
Intermediate Spirals
SABa
SABb
SABc
SABd
SABm
Barred Spirals
SBa
SBb
SBc
SBd
SBm
Im
dSph
Irregulars

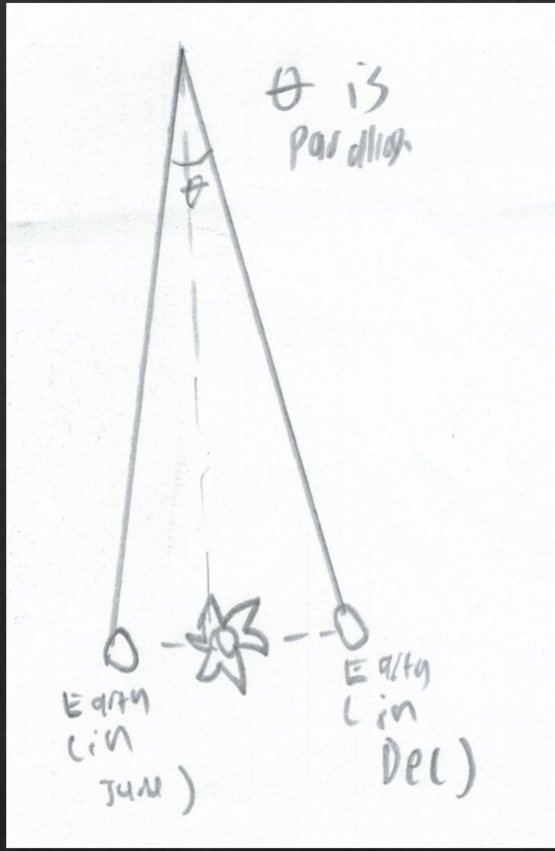
Q1(h)(i): What is parallax? [1]

- Common answers:
  - ‘Angle subtended between the Earth and a star’
  - ‘Angle between viewing an object from 2 different locations’
  - ‘*parallex* error’ [sic]
  - ‘Angle subtended by a star w.r.t. the Earth’
  - ‘estimation of distance to celestial objects’

Exemplars



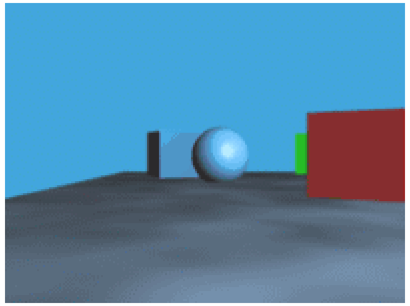


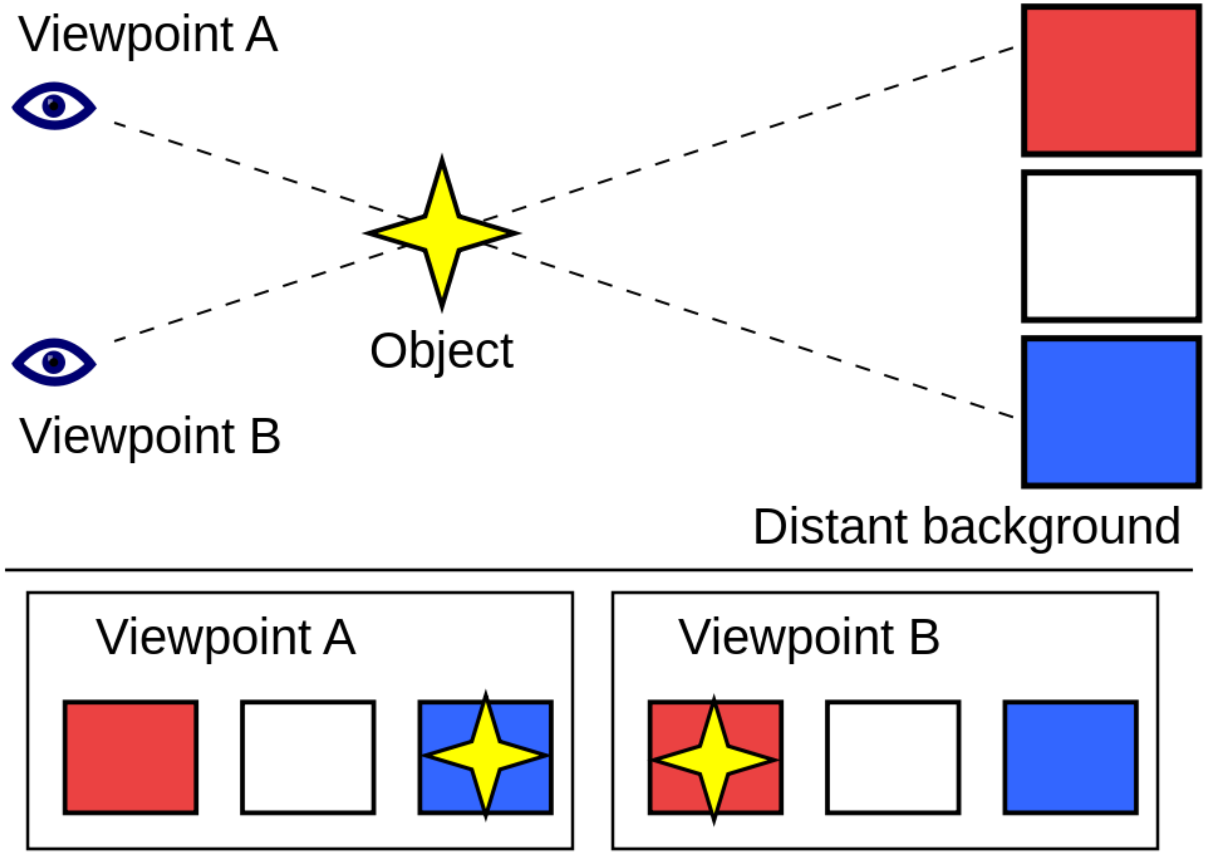


A difference in apparent position caused by a change in the line of sight

1 arcsecond corresponds to 1 parsec (3.27ly). tan θ = 1AU

0.5





Viewpoint A
Object
Viewpoint B
Distant background
Viewpoint A
Viewpoint B

1(h)(ii): How might one use parallax to determine the distance to a star? [1]

[1]

- Common answers:
  - Distance of star, $d = \frac{1}{p}$
- Units?

ANSWER IS IN THE FORMULA BOOK!

astro challenge

ASTROCHALLENGE FORMULA BOOK

Determining distance d in parsecs using an observed parallax p in arc seconds	$d \approx \frac{1}{p}$

Suppose one wishes to find the distance to a certain open star cluster within the Milky Way. The star cluster **is too far away for accurate parallax measurements.**

Name **two** alternative methods to determine the distance to this star cluster, and briefly explain how each method works.

Your answer should explicitly specify what **data** needs to be collected for each method to work. [7]

- 3 marks each for:
  - RR Lyrae variables
  - Cepheid variables
  - Main-sequence fitting

  And relevant explanations and **data** for each.
- 0.5 marks for:
  - Type 1a supernovae

- Common answers:
  - Type 1a supernovae
  - Radiation from supernovae
  - Redshift
  - Use parallax [????]

READ THE QUESTION!

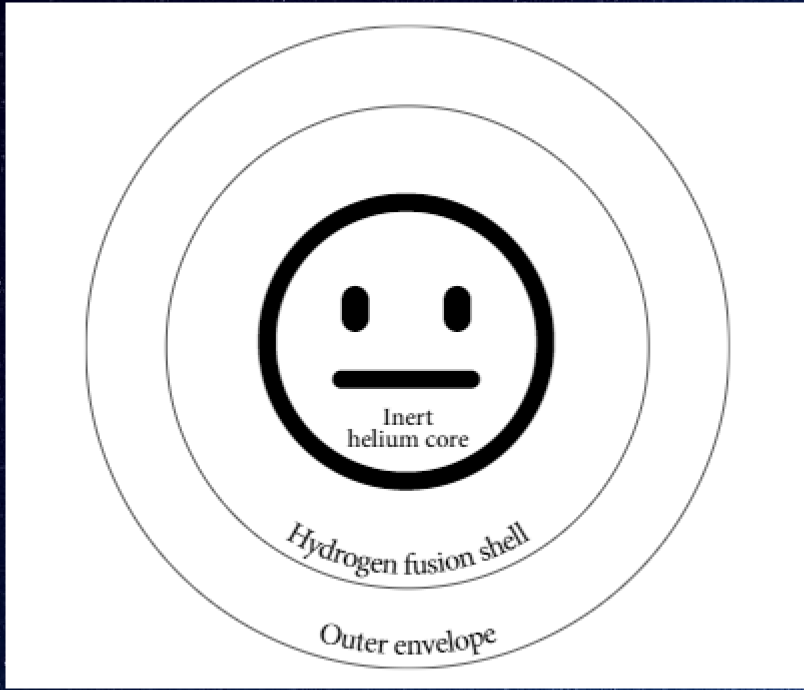
- Star cluster ***within*** the Milky Way; galactic orbits and relative motion of the Sun and the cluster will render redshift ineffective

- Star clusters rarely have Type 1a supernovae; it is impractical to wait for one

- We are basically asking:

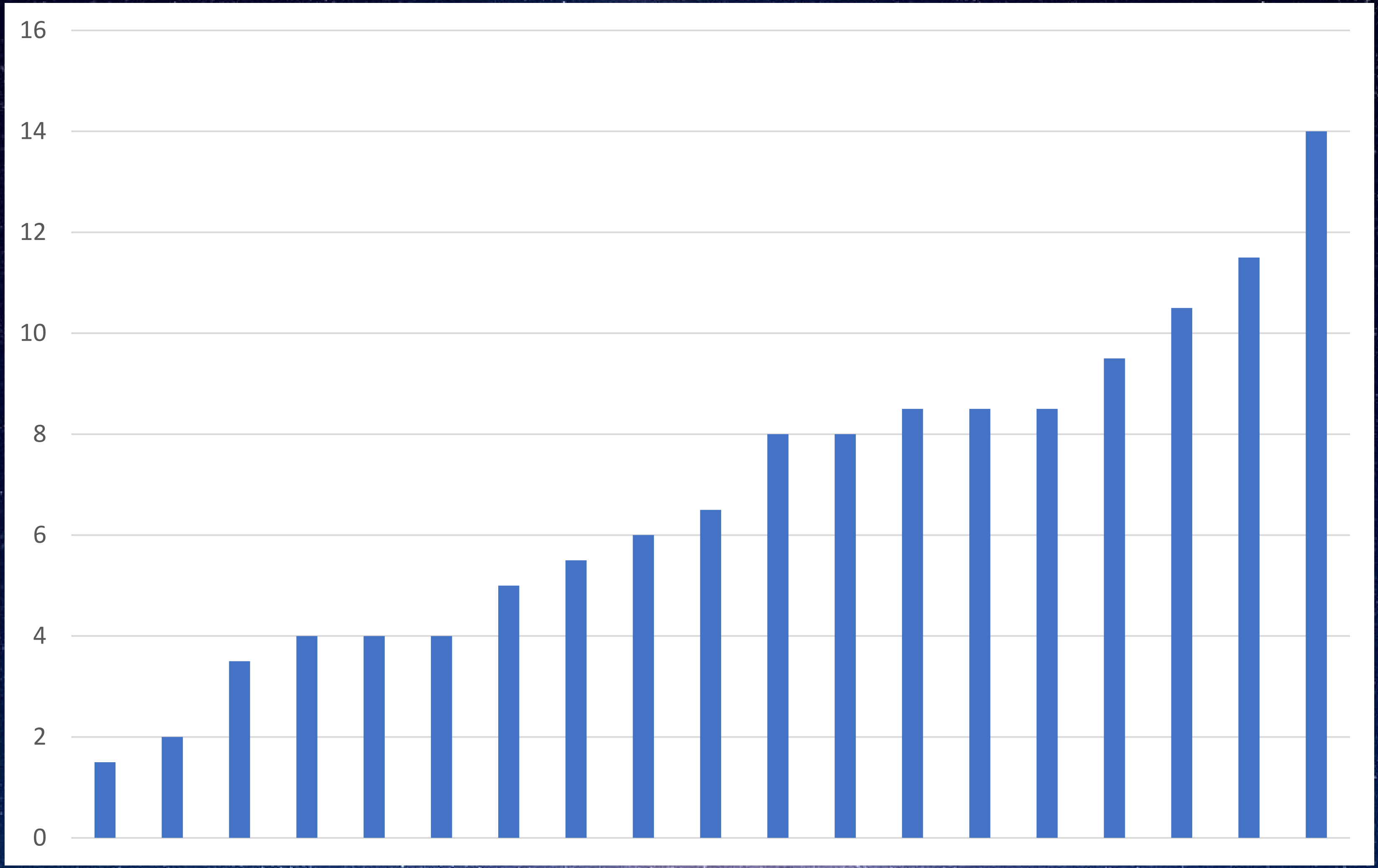
  'What are standard candles to measure distance to star clusters, and what data does each standard candle need?'

- Examples of **data**:
  - ID of suitable Cepheid/RR Lyrae variables
  - Light curve (gives periods and magnitudes for said variables above)
  - Colour-magnitude diagram (CMD) of stars in the cluster, + CMD for a known star cluster



Q2
The Last of the Main Sequence

Obligatory Score Distribution by Team



Summary

Why does a red giant become less luminous when it begins helium fusion?

If you:

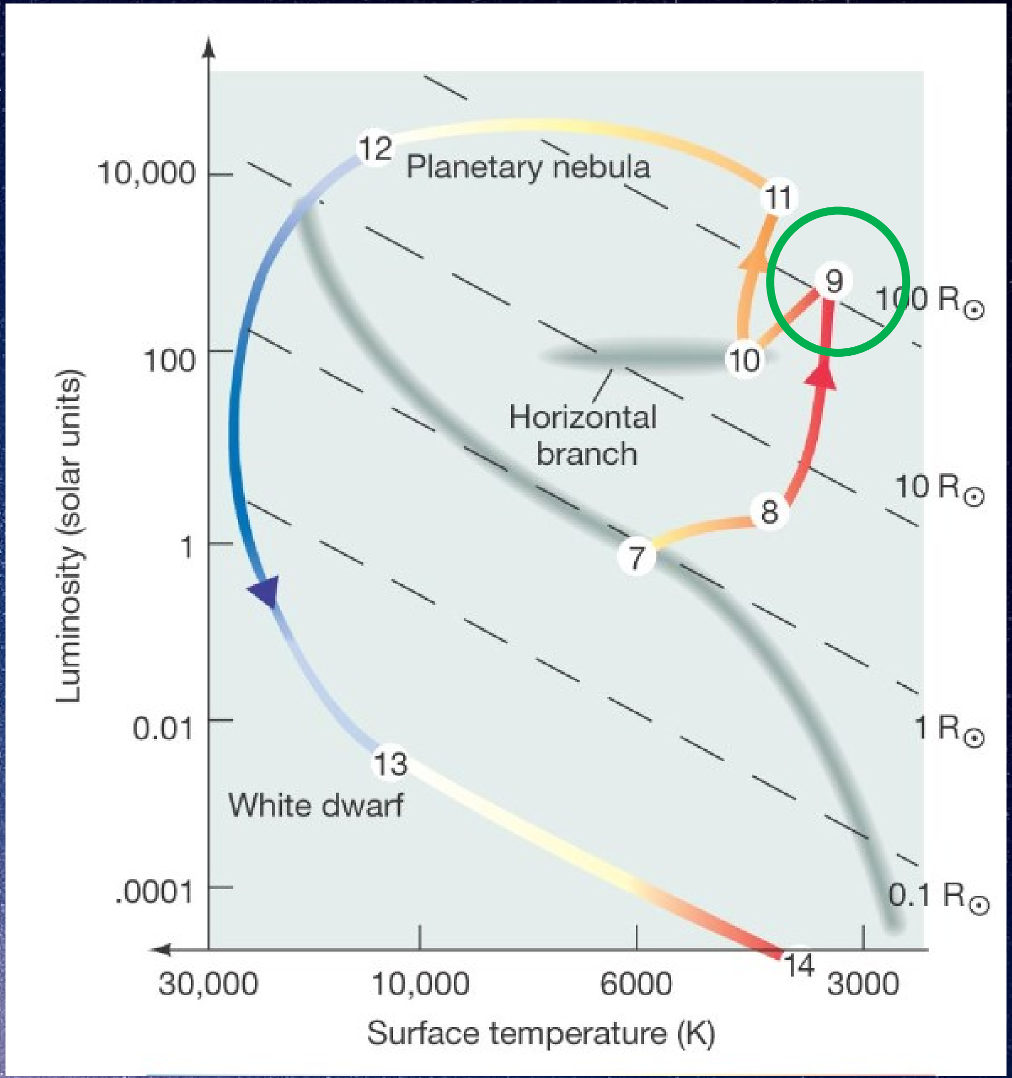
- Know what is a helium flash
- Know how to do the Second Derivative test

You did above average

What is a helium flash? (2b)

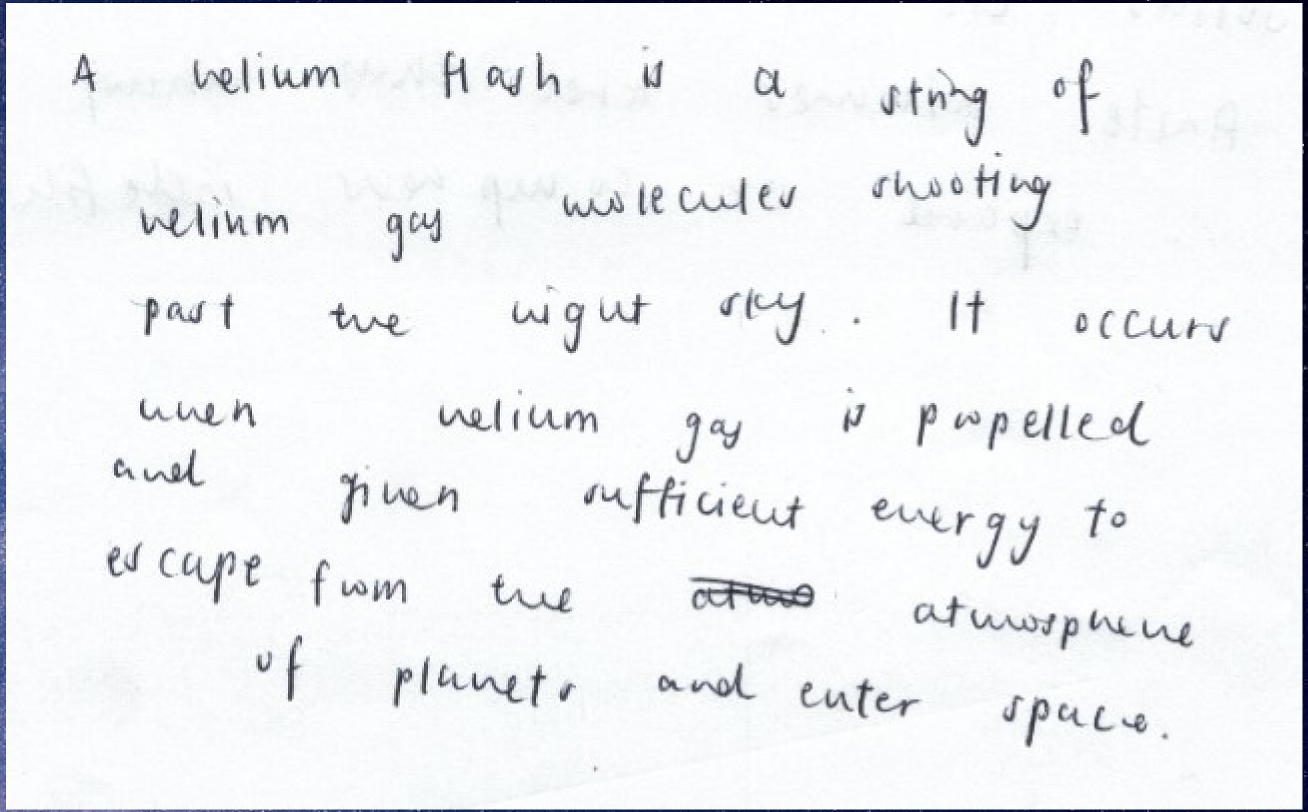
- Turns out a majority actually don't know what is going on here!

- Recall Q26 of the MCQ:
  - What is the dominant source of energy at event 9?
  - 45% correct



What is a helium flash? (2b)

- “string of helium gas molecules shooting past the night sky…”
  - Are you describing a rocket launch?
- Poor handwriting: helium <u>“flush”</u>


A helium flash is a string of helium gas molecules shooting past the night sky. It occurs when helium gas is propelled and given sufficient energy to escape from the ~~atmo~~ atmosphere of planets and enter space.

So what is a helium flash?

1. The core becomes so dense that degeneracy pressure becomes important

2. Helium ash constantly rains onto the core, and so it contracts and heats up

3. Eventually helium fusion begins, but the core doesn’t adjust due to degeneracy
    1. Climbing core temperatures -> accelerating helium fusion rate -> the “flash”

The Second Derivative Test

1. Find the first derivative

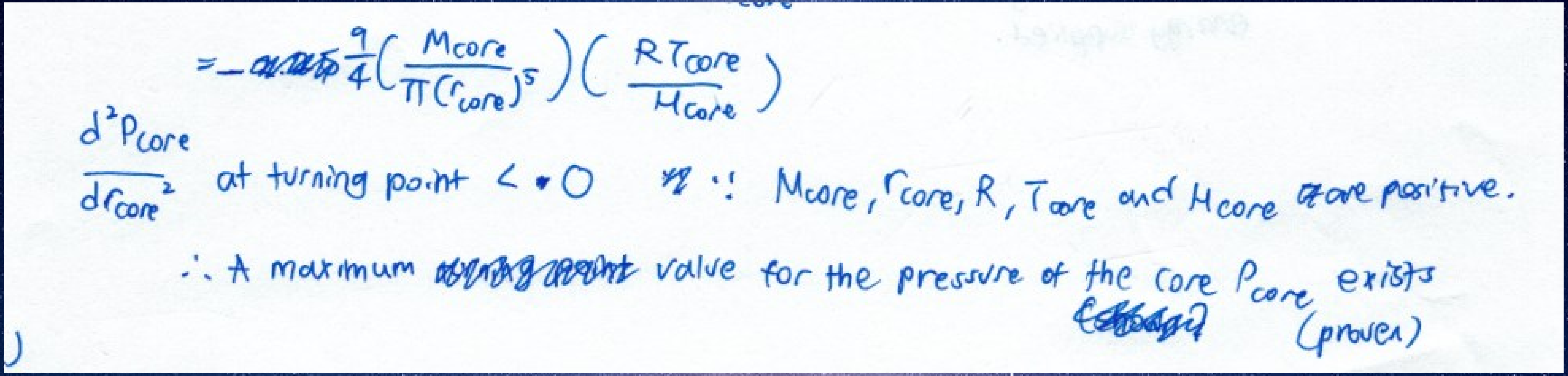
2. Set first derivative to 0
    1. Critical point(s) found!

3. Find the second derivative

4. Evaluate the second derivative AT the critical point
    1. If negative -> maximum

The Second Derivative Test in Practice (2g)

- Many teams (thankfully) tried to make use of the hint
  - Substitutions are important for finding Maclaurin series!
- Only the SIGN of the second derivative matters AT the critical point
  - I'm not interested in its value!
  - Nor do you have to show its negative everywhere!



$$= -\frac{9}{4}\left(\frac{M_{core}}{\pi (r_{core})^5}\right)\left(\frac{RT_{core}}{H_{core}}\right)$$

$\frac{d^2P_{core}}{dr_{core}^2}$ at turning point < 0 ∵ $M_{core}, r_{core}, R, T_{core}$ and H_{core} are positive.

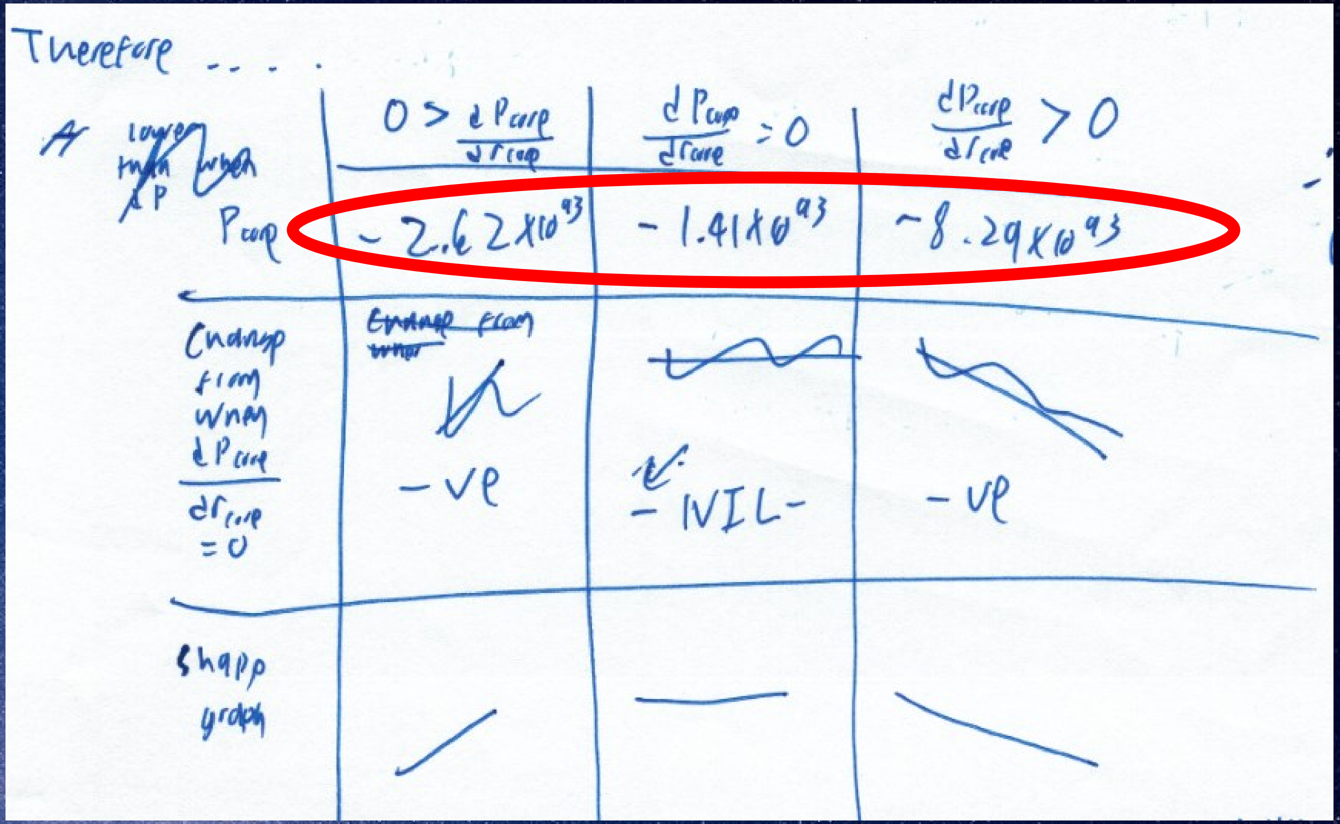
∴ A maximum value for the pressure of the core P_{core} exists (proven)

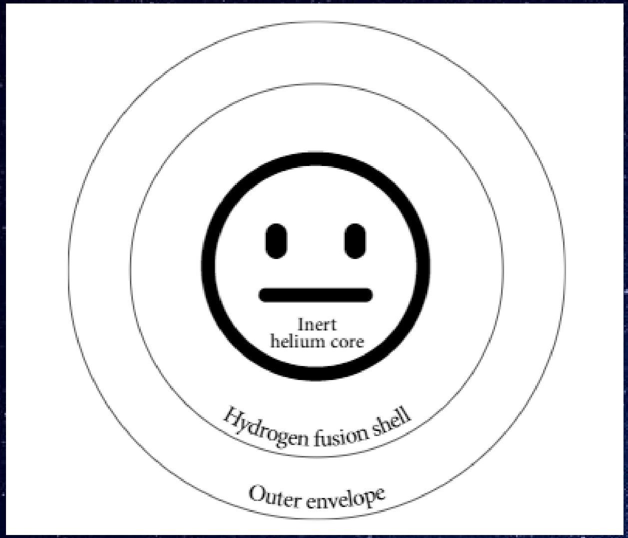
Notable mention

A team rediscovered the First Derivative Test after <u>3 pages</u> of working through the 0^{th} Derivative Test

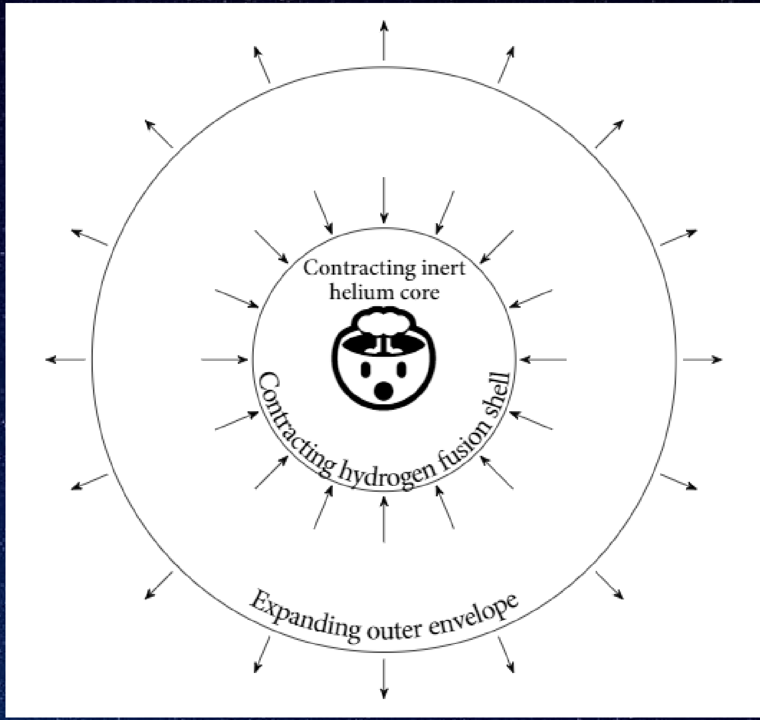
- I ended up accepting that, but had to deduct 1 mark for the <u>**unphysical values**</u> used

- Would STRONGLY recommend learning about the Second Derivative Test in future.





As more scripts rain down...

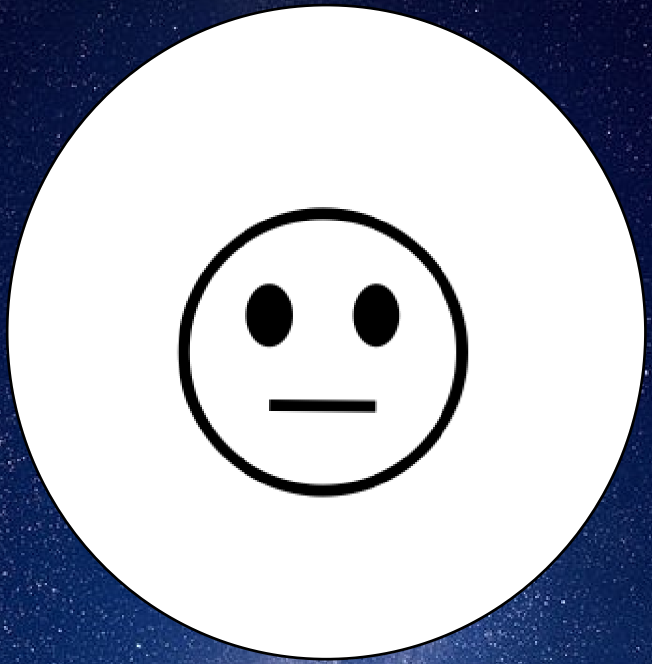


The question graphics ended up describing my marking experience

Story Time!

Don’t worry, minimal math

Initially



Key point: the helium core is doing absolutely nothing.

It sits like a rock

2c: Why does the core have the same temperature as the surroundings?

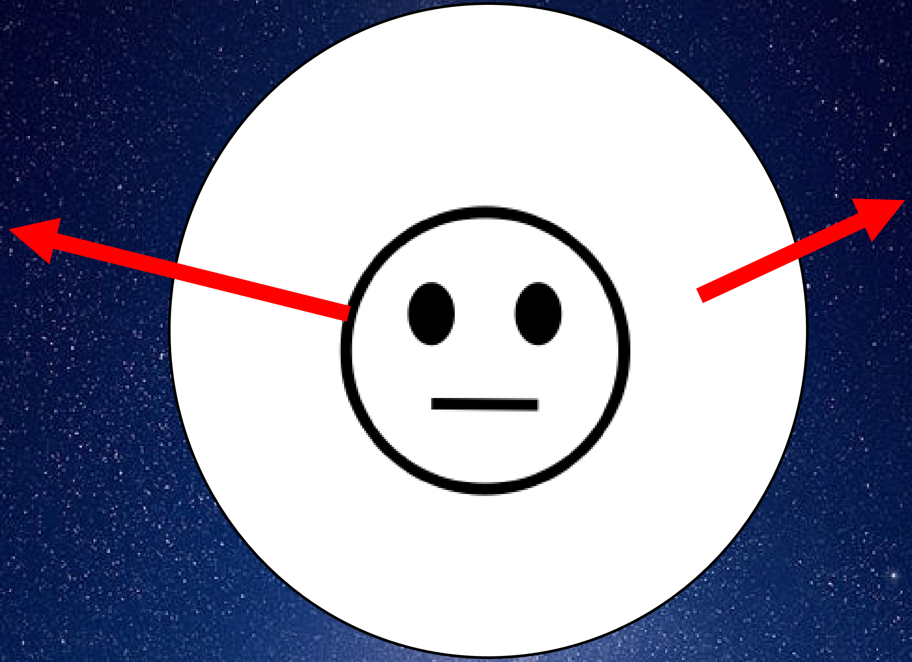
Formally doable via the Table, but what the math is really saying is…

The core is not undergoing fusion and does not produce ~~heat~~ energy and thus temperature does not change within the core.

Intuition: the core is just sitting there until it reaches the same temperature as the surroundings

- No work is being done!

2d: Why can't core/shell temperature change?



<u>Fusion is highly sensitive to temperature!</u>

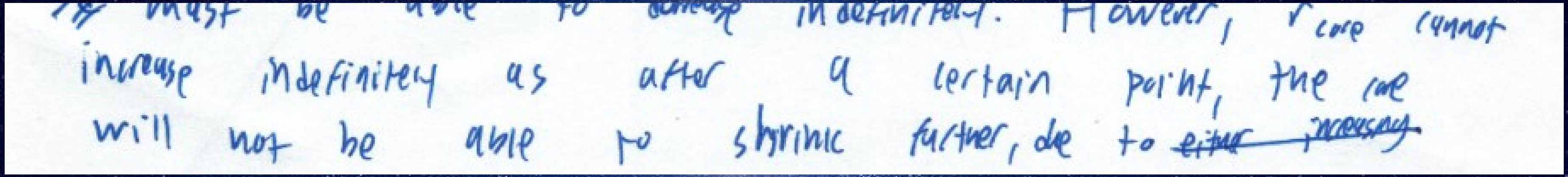
- If its too hot, too much energy is released and the whole star goes haywire

2e: Can the core support infinite pressure?

- Many of you tried to go way too far: your arguments would prove black holes cannot exist
  - e.g. intermolecular forces of repulsion/degeneracy pressure would always be strong enough
  - Even IF true, doesn't that mean the core CAN support infinite pressure?
- The answer: when the pressure becomes too much and the core shrinks beyond a critical point, <u>gravity becomes important</u>.

Why you should read your work

- Core radius cannot increase indefinitely cause the core cannot shrink further?!?


must be able to increase indefinitely. However, r core cannot
increase indefinitely as after a certain point, the core
will not be able to shrink further, due to ~~either~~ increasing

Dimensional Analysis gone wrong

(e) Given a Mcore and Tcore, the mass and temperature of the core remains constant. Hence, since the pressure at the surface of the core is equals to the energy of the inert core minus the gravitational force exerted by the mass at the core due to its temperature. Should the mass and temperature remain constant, the pressure at the surface will reach a maximum constant.

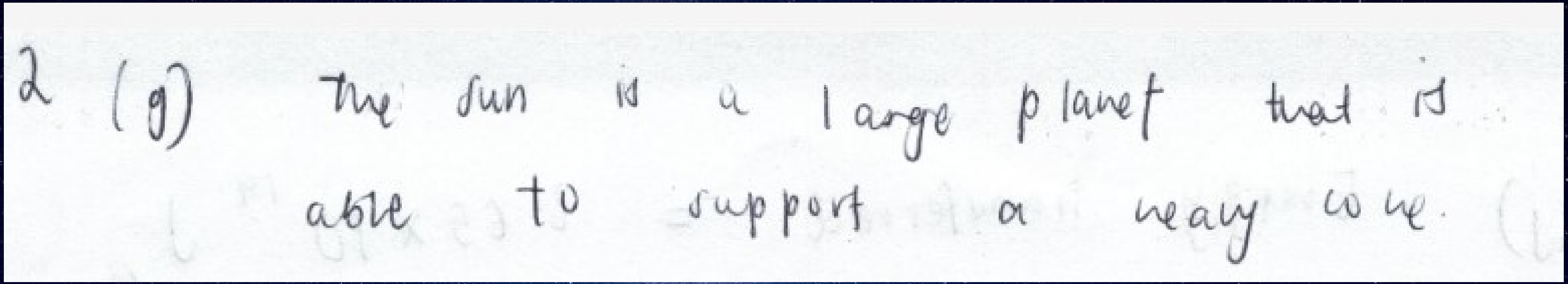
Pressure equals to energy minus gravitational force?!?

2g) Why can the Sun have a HUGE core?

- Recall Presumptuous Assumptions
  - Section assumes an isothermal ideal gas
  - Question tells you the sun will have an isothermal core (note the omission!)

- The sun is a low mass star – it will have a degenerate core and end up going through the helium flash
  - The degeneracy helps to support the core, allowing it to grow beyond the limit.

Best answer


2 (g) The sun is a large planet that is able to support a heavy core.

When people want 9 planets in the solar system, they probably don't mean this!

2h/j) Energy Release from Core Contraction

- Only 1/3 made it to this point
- Of the few survivors, many didn't use the provided formula for gravitational binding energy
  - If you did, you probably ended up near the top for this question
  - Most instead used some variation of the gravitational potential energy formula…

End results

$= 1.9053 \times 10^{...}$ J

$$\text{rate of energy transfer} = \frac{1.9053 \times 10^{41}}{800000 \times 365 \times 24 \times 60^2}$$

$= 0.0201$ W (to 3 s.f.)

$$\text{Rate of energy transfer} = \frac{3.24 \times 10^{8}}{300\,000 \times 365 \times 24 \times 60 \times 60} \div (3.846 \times 10^{26})$$

$= 8.9044 \times 10^{-32}$

$\approx 8.90 \times 10^{-32}\ L_{\odot}$

100,000x less than a typical nightlight???

AKA 3×10^{-5} W

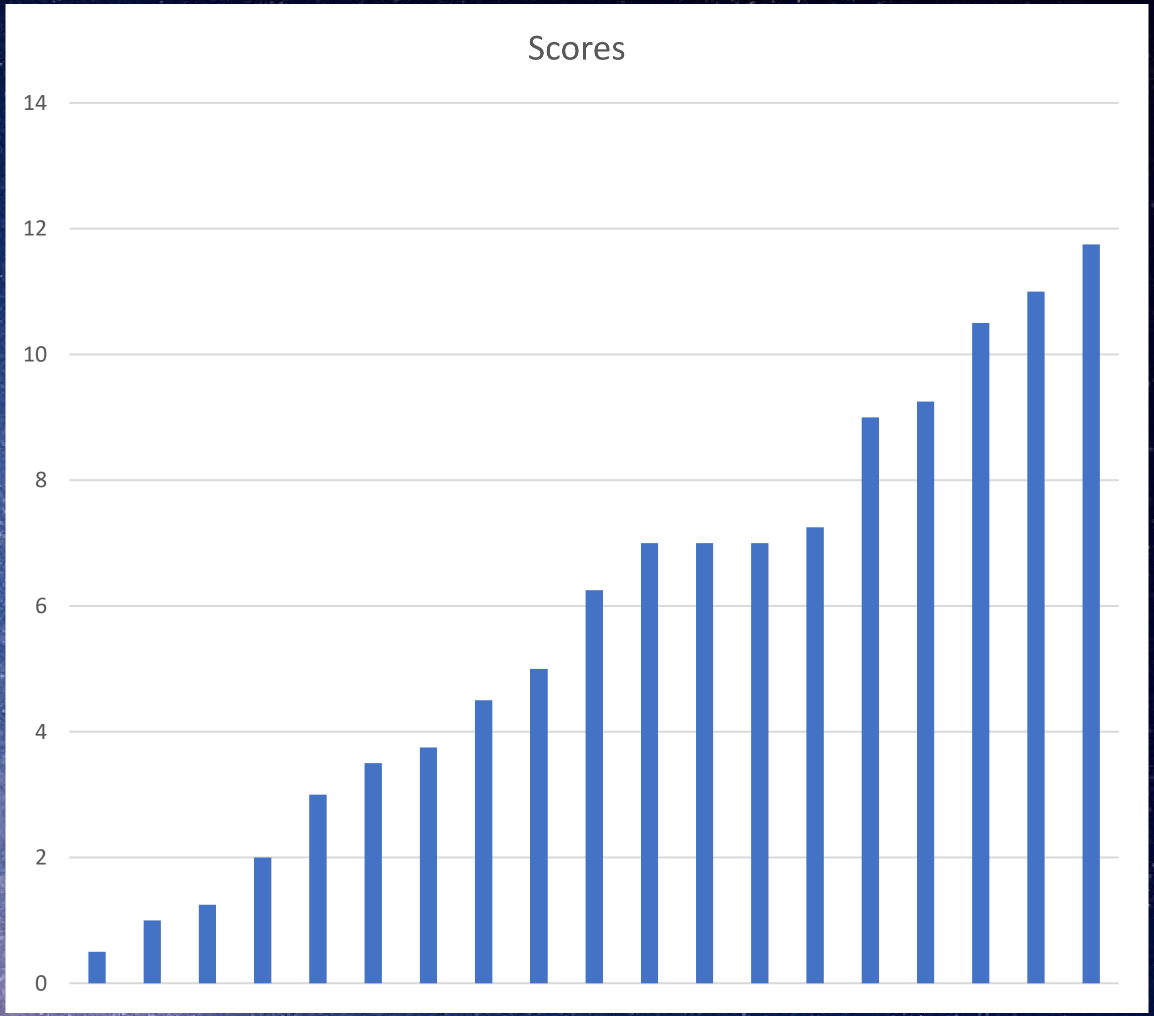
Anything worth doing is worth doing poorly

ECF means that you can attain marks so long as you demonstrate the correct method!

Q3: Flat and *Somewhat* Round

Q3: Flat and *Somewhat* Round

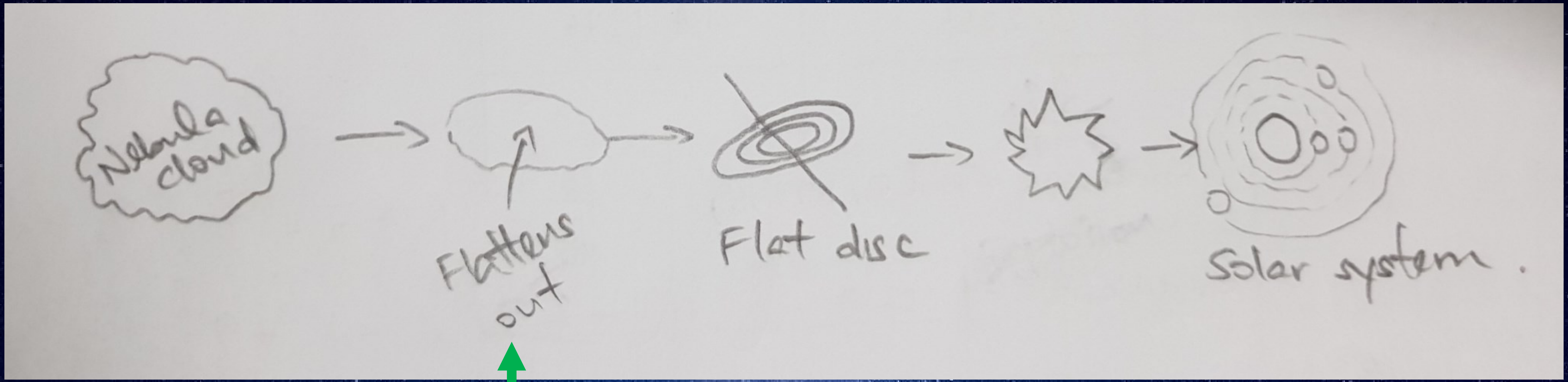
- Idea behind the question:
  - Investigate discs in the Universe.
  - Why are there so many discs?
- Fun fact
  - Question idea + Titles 'A Universal Slimming Regime' and 'Expanding Horizontally' came out of dad jokes.
- Mean: 5.816
- SD: 3.397



Part 1: A Universal Slimming Regime

- Investigate the process from cloud collapse to the disc.
- Generally not well-explained!
- What you did right:
  - Identified the role of gravity and internal gas pressure in cloud collapse.
  - Identified an ‘averaging’ of velocities w.r.t. net angular momenta.
- What you did wrong:
  - Couldn’t explain well details of the above.
  - Didn’t identify the role of centripetal forces in disc formation.

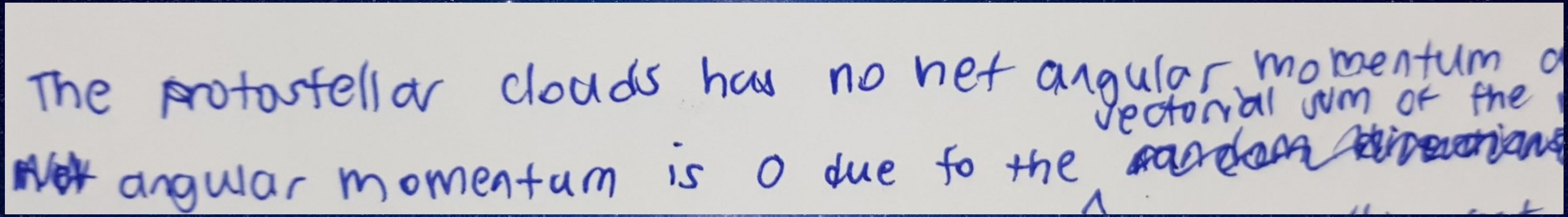
The Main Question



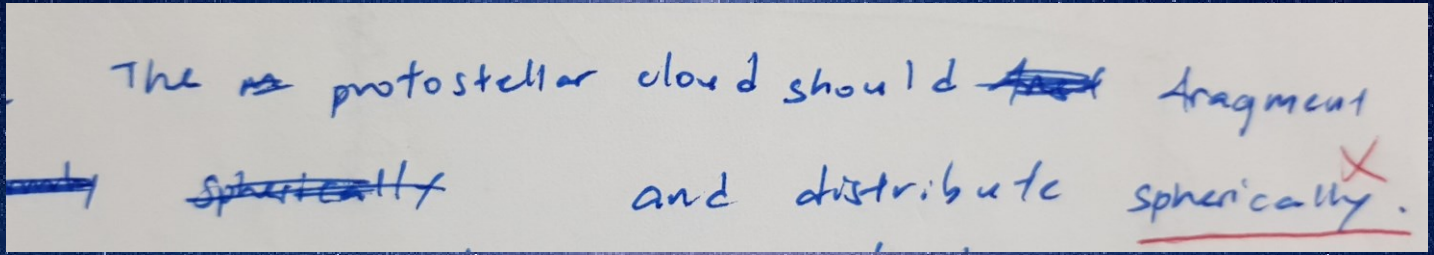
Explain this part!

Fragmentation

- 3bi: Given to you that there are many factors affecting fragmentation.
- 3bii: And you answered…



The protostellar clouds has no net angular momentum as vectorial sum of the
~~Net~~ angular momentum is 0 due to the ~~random directions~~



The ~~a~~ protostellar cloud should ~~fast~~ fragment
~~Spherically~~ and distribute spherically.

Changes in velocity

- The intended answer:
  - On the *direction* of motion averaging out to the direction of net angular momentum.
- You gave:
  - Answers on increased velocity.
- Direction would have made explaining collapse to a disc easier.

A Brief Summary of the Process

- Gravitational attraction overcomes gas pressure → fragmentation.
- Fragmentation is non-uniform → non-zero net angular momenta
- Collapse → more collisions → motion averages out in direction of net angular momentum
- Centripetal force → resists collapse in a plane, no such resistance in the normal direction → disc!

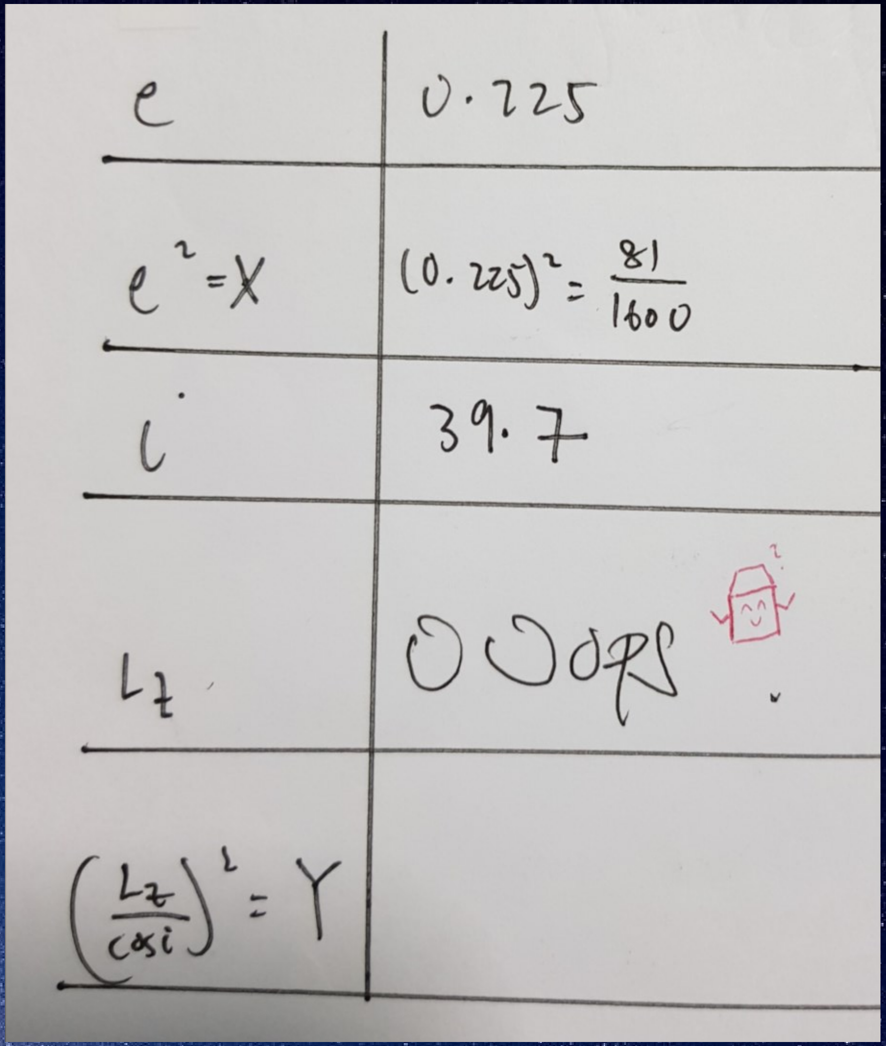
Part 2: Expanding Horizontally

- Data response + Investigate the Kozai mechanism.
- What you did right:
  - Graphing. You guys love graphing.
  - Graph question was meant to test if you could correct for minor uncertainties/deviations in data. Most managed this!
- What you did wrong:
  - Very few attempts at the last question!
  - In fact, most of it can be deduced from the data/information.
  - Did not read carefully!

The Graph

- Most of your marks came from this.

- Common mistakes:
  - Scale
  - Giving a: b instead of a and b
  - Giving non-integer answers
  - Trying to numerically calculate (!!!) without a graph



Linearisation of Equation

- Given equation: $L_z = \sqrt{a - be^2}\cos i$.

- Expected linear form:
  - $\frac{1}{\cos^2 i} = -\frac{b}{L_z^2}e^2 + \frac{a}{L_z^2}$

- What a few of you did:
  - $e^2 = -\frac{L_z^2}{b}\frac{1}{\cos^2 i} + \frac{a}{b}$
  - $e^2 \cos^2 i = \frac{a}{b}\cos^2 i - \frac{L_z^2}{b}$

Kozai Mechanism and Planet Nine

- Argue from data and own knowledge whether the Kozai mechanism could be used as justification for Planet Nine’s existence.

- A hard question, with two-thirds leaving blanks, two teams scoring 1 mark, and one team scoring the full 4 marks.

Kozai Mechanism and Planet Nine

- The essentials:
  - Kozai mechanism can explain high eccentricities and inclinations.
  - Kozai mechanism can explain clustering of argument of periapsis *about certain values.*

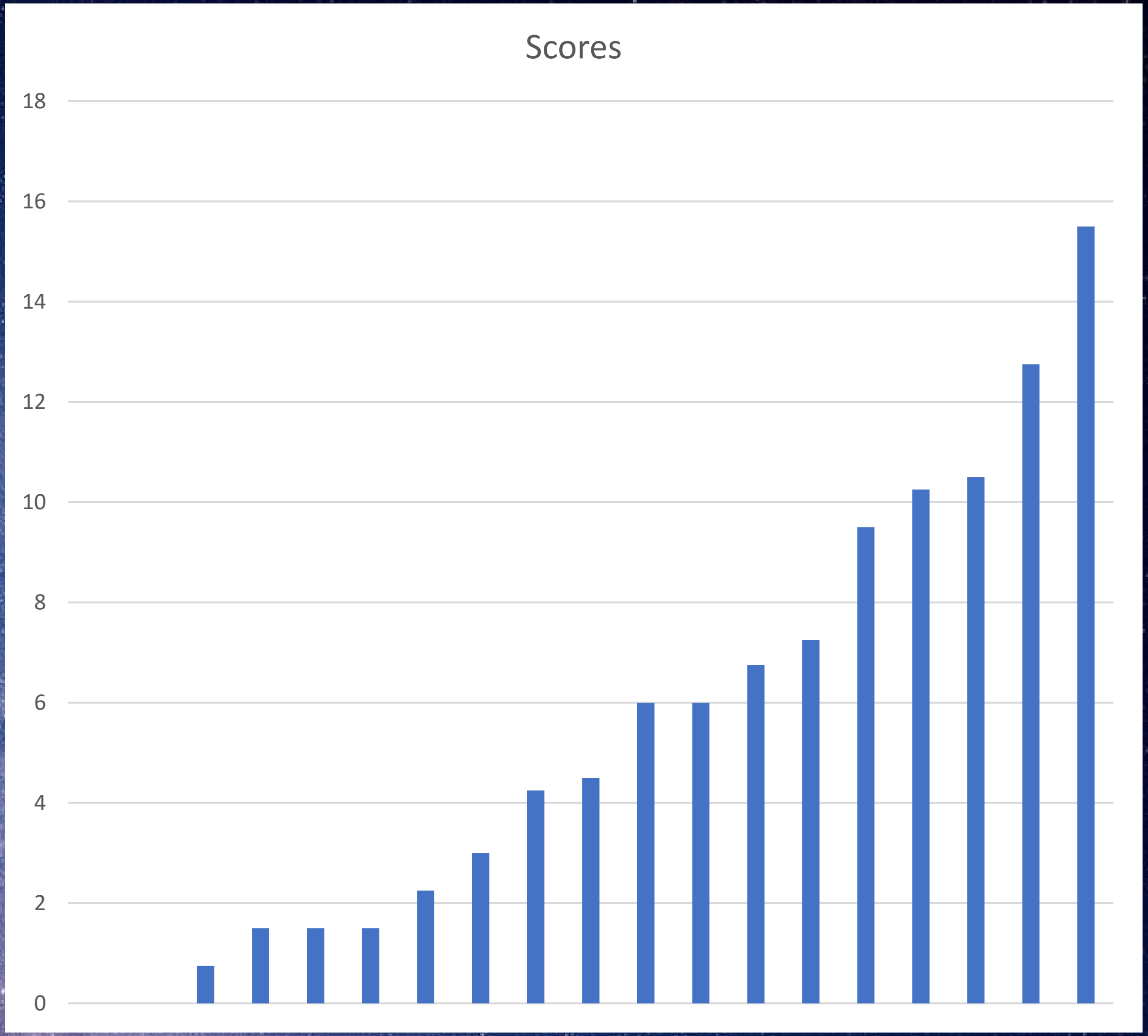
- All the above (and more) can be used as justification!

- Some arguments against:
  - Mean-motion resonances
  - Clustering of argument of periapsis *about certain values.*

Q4: Presumptuous Assumptions

Q4: Presumptuous Assumptions

- Idea behind the question:
  - Investigate the use of assumptions in Astronomy.
  - Diverse question set, but they all deal with assumptions in some way.
- Fun fact
  - I'm a mathematician.
  - Born out of the joke 'assume spherical human…'.
- Mean: 5.461
- SD: 4.423

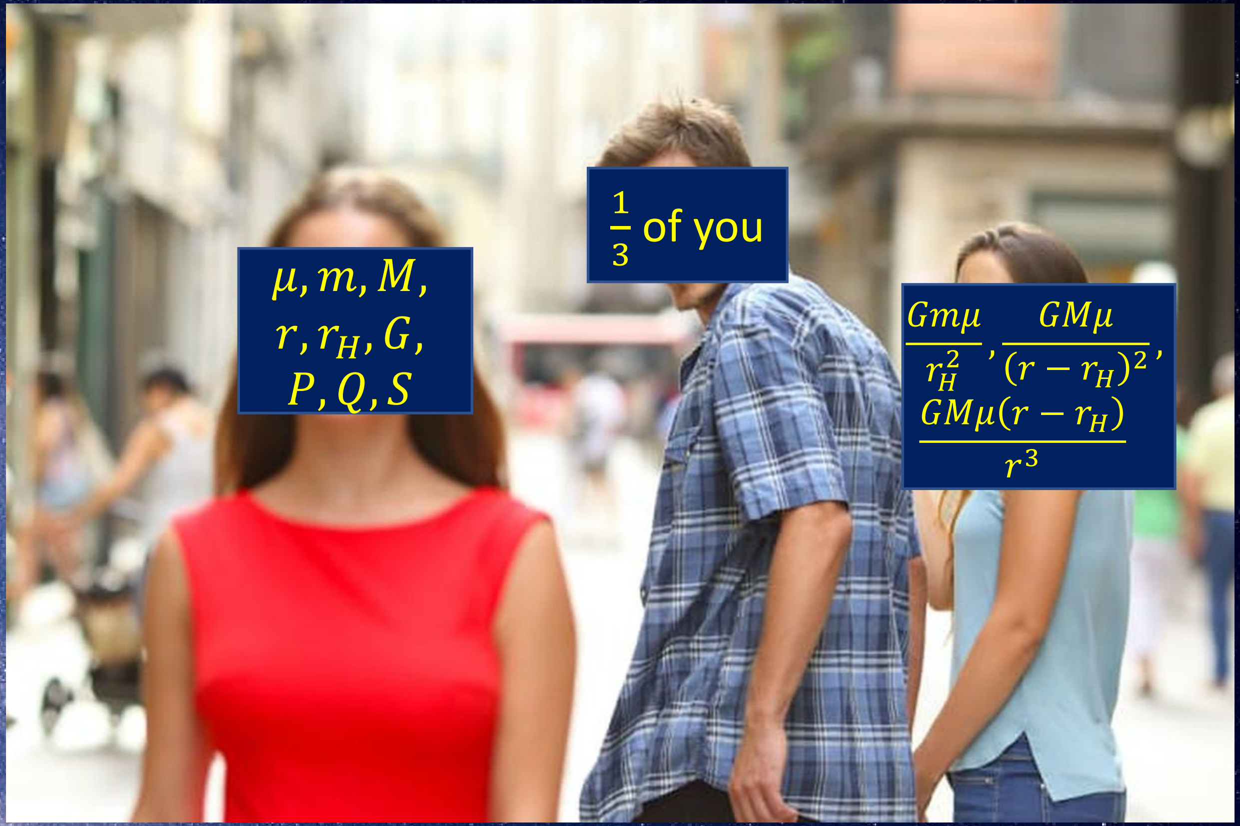


Part 1: How Big is the Hill?

- Investigate assumptions and validity of a naïve theory: The Hill radius.
- What you did right:
  - The majority did okay with identifying components and assumptions.
  - About half could perform the Hill radius calculation.
- What you did wrong:
  - About half bombed the Hill radius calculation.
  - Most didn’t know how to judge validity from data/assumptions.

Components

- You are given an equation with three components:
  - $\frac{Gm\mu}{r_H^2} + \frac{GM\mu(r-r_H)}{r^3} = \frac{GM\mu}{(r-r_H)^2}$
- Question: Identify these three components!
- **If I wanted a copy-paste from the text, it wouldn't be worth marks!**



Binomial approximations

You were given a hint to use binomial approximations. What did you do?

$$mr^3(r-r_H)^2 + Mr_H^2(r-r_H)^3 - Mr_H^2r^3 = 0$$

$$mr^3(r^2-2r_Hr+r_H^2) + Mr_H^2(r^3-3r^2r_H+3rr_H^2-r_H^3) - Mr_H^2r^3 = 0$$

$$mr^5 - 2mr_Hr^4 + mr_H^2r^3 + Mr_H^2r^3 - 3Mr_H^3r^2 + 3Mr_H^4r - Mr_H^5 - Mr_H^2r^3 = 0$$

$$\vdots$$

$$r_H \approx r\sqrt[3]{\frac{m}{3M}}$$

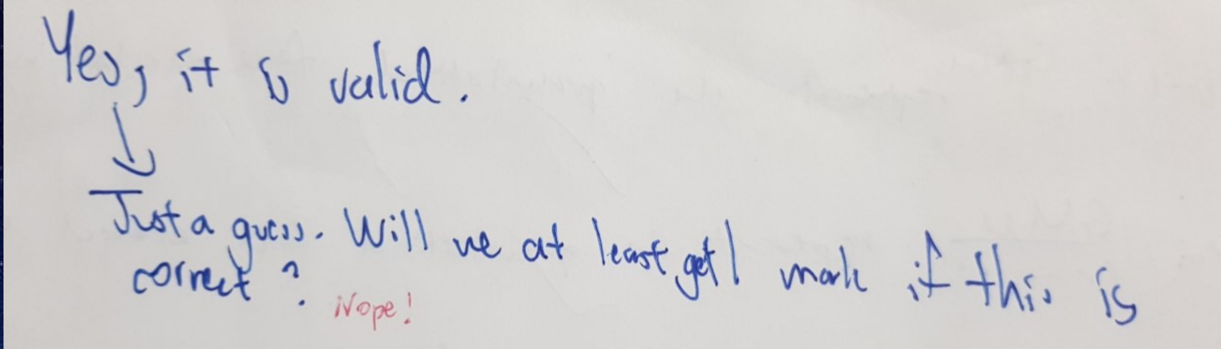
$$\frac{Gmp}{(r_H)^2} + \frac{GMp(r-r_H)}{r^3} = \frac{GMp}{(r-r_H)^2}$$

$$\frac{1}{(r_H)^2} + \frac{(r-r_H)}{r^3} = \frac{1}{(r-r_H)^2}$$

$$r_H \approx r\sqrt[3]{\frac{m}{M}} \quad \therefore \text{ Hence proven}$$

How do you solve a *quintic* polynomial???

How to infer validity?



- Check: You are given the orbital radii of the **furthest moons**. Are they approximately near the Hill radii?
- Check: Is Sun - Jupiter/Saturn - Moon an **isolated system**?
- If no, something's wrong!

Part 2: Working in the Age of Assumptions

- Generic questions.
- What you did right:
  - Fuzzy idea of what station-keeping is.
- What you did wrong:
  - Lots of blanks for the Lagrangian point question.

Station of Station-keeping Solutions

Station-keepin ... point an
it as a st

Part 3: Tremulous Theories

- The obligatory cosmology part.
- Investigate an accepted theory where an assumption *must* be made.
- What you did right:
  - Some idea of what homogeneity/isotropy are.
  - Some idea of which can be assessed and why.
- What you did wrong:
  - …*Some* idea.

...*Some* idea.

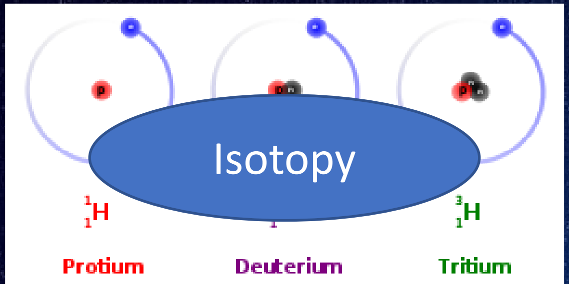
Isotropy on the other hand refers to atoms of the same element but ~~differenuy~~ different number of neutrons. these elements may come in many ~~fo~~ forms as well.

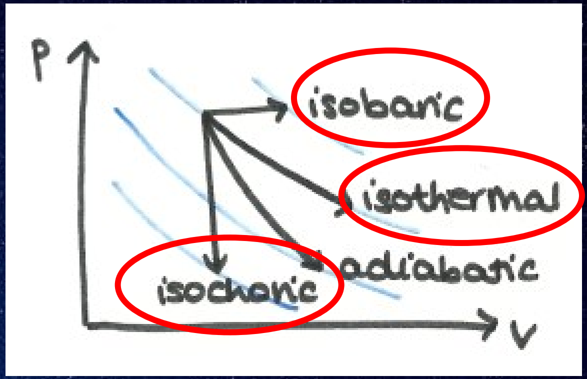
Isotropy is an isotropic quality of an isotrope.
Homogenity is when ~~wh~~ something is homogenous.

homogeneity — properties of matter are the same

isotropy - same temperature and pressure

4 pics 1 prefix

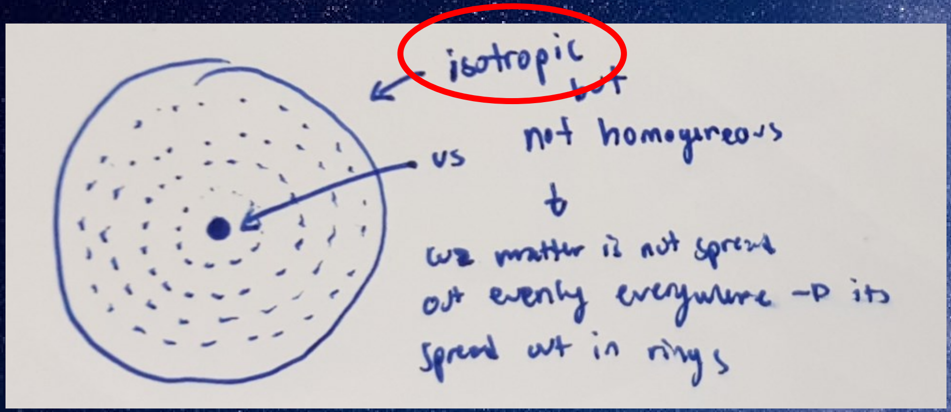




Same pressure

Same temperature

Same volume



You in class

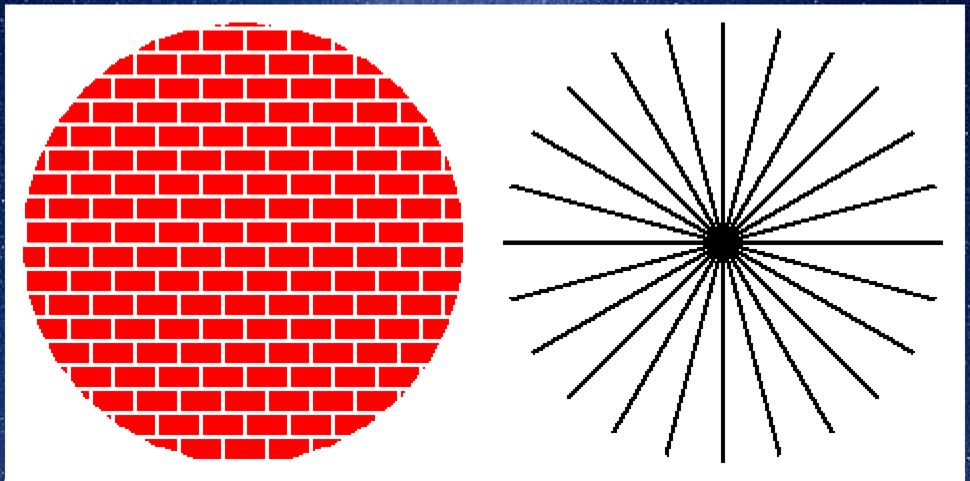
I S O

Isotropy and Homogeneity

- Isotropy: Observations are the same in all directions. (Verifiable)
- Homogeneity: Observations (i.e. energy density) are the same in all locations.

- Why the decoupling of the two?

Homogeneous, not isotropic

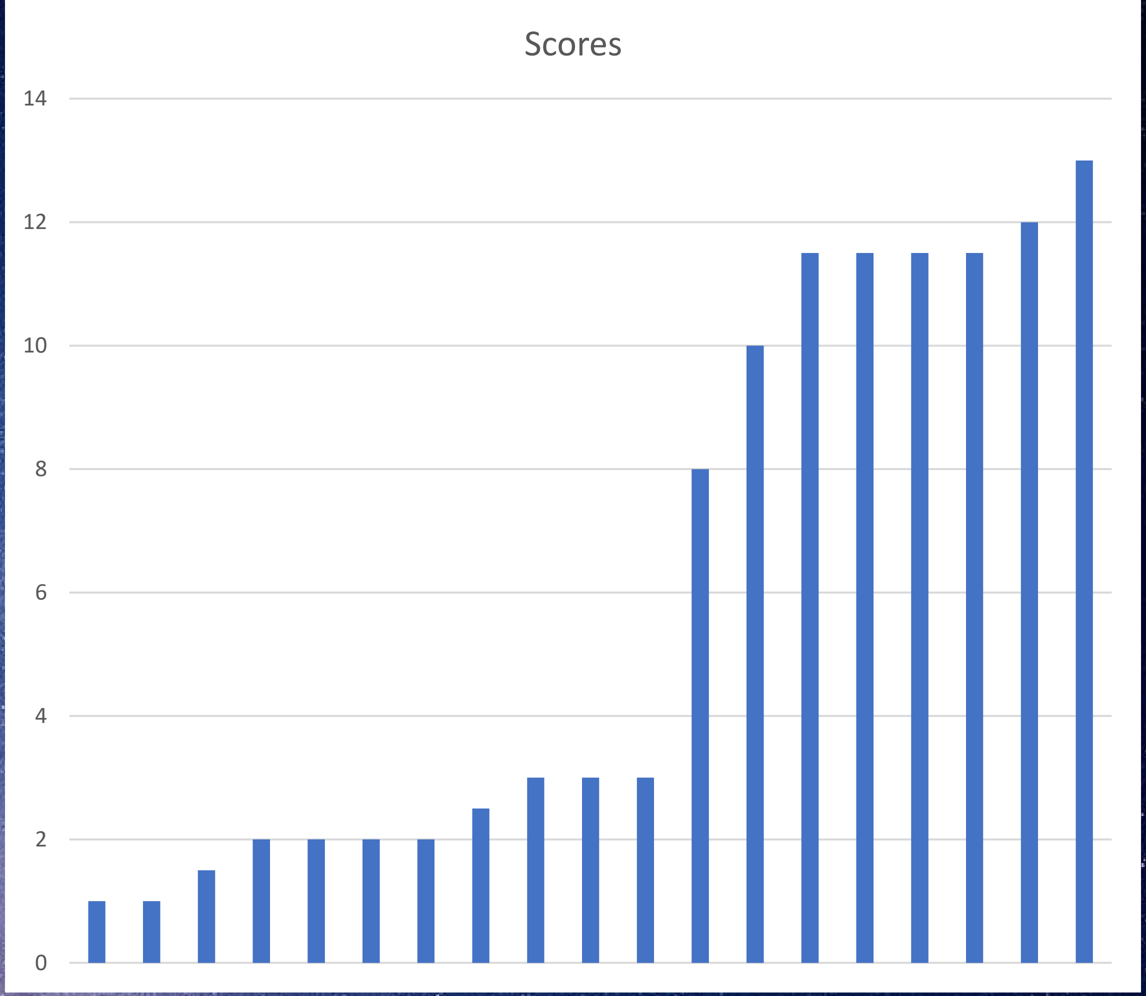


Isotropic, not homogeneous

Q5: Questions of Galactic Proportions

Q5: Questions of Galactic Proportions

- Idea behind the question:
  - Investigate various things about galaxies.
  - Jack-of-all-trades question.
- Fun fact
  - Born out of (finally!) watching Guardians of the Galaxy vol 2.
  - I just wanted a question of epic proportions.
- Mean: 5.895
- SD: 4.584



Part I: The Hypes and Types of Galaxies

- Basic questions about galaxies.
- What you did right:
  - Can compare stellar formation rates + galaxy colour.
  - Good appreciation of galaxy interactions in clusters.
- What you did wrong:
  - Surprisingly, most couldn’t resolve the paradox!

Paradoxical

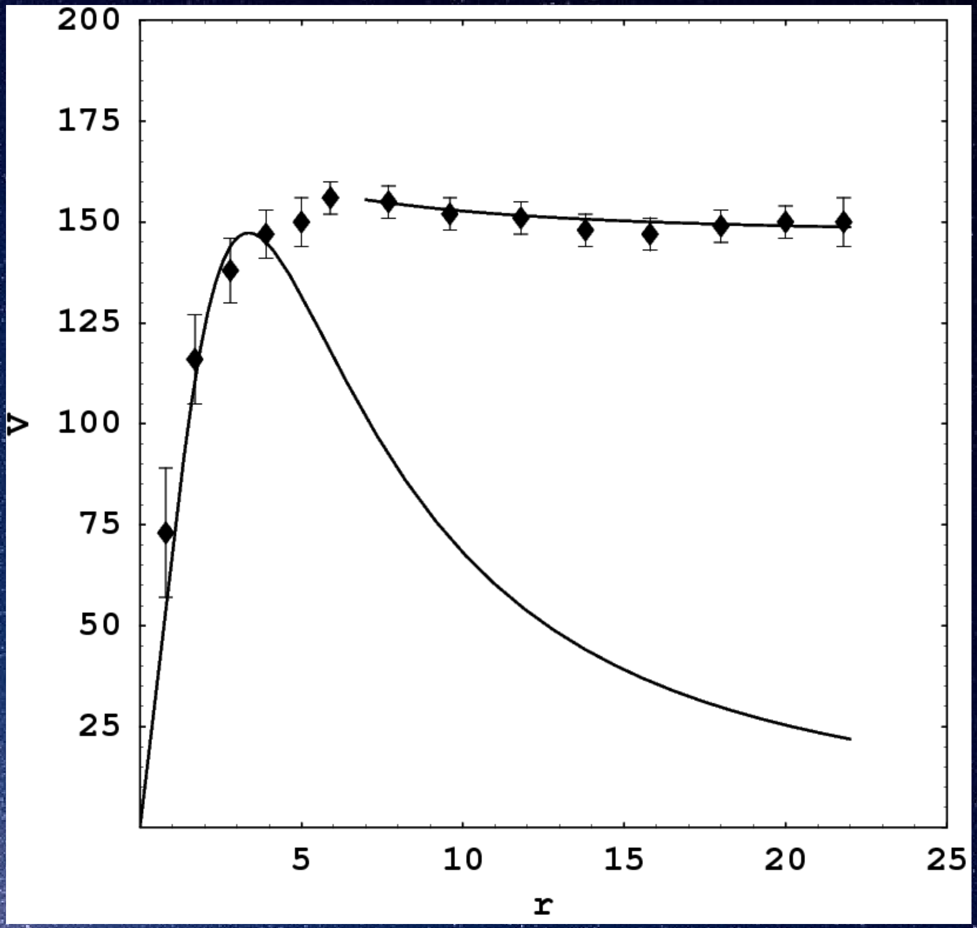
- Most observed galaxies are spiral, but deep sky surveys show more ellipticals.
- A problem about observational bias!
- Ellipticals are more common, but…
- Spirals are brighter → more easily observed.

Part II: Round and Round and Round We Go

- I should have called it ‘Welcome to the Dark Side.’
- Rotation curve + Dark matter.
- What you did right:
  - About half could do the math/integral correctly.
- What you did wrong:
  - Lots of blanks for the 21cm line question!
  - Plenty could not explain the rotation curve correctly.
  - Common mistake in finding $M(R)$: assume density is constant. It’s not!
  - No one (except one team) could progress towards deducing Problem X.

Rotation Curve

- Many know that the eventual drop-off is Keplerian and can explain.
  - Mathematically, $v \propto r^{-\frac{1}{2}}$.
- The initial rise was less obvious.
  - Closer to the centre, it behaves closer to rigid body (non-differential) rotation.
- Difference in behaviour is due to interstellar distance.

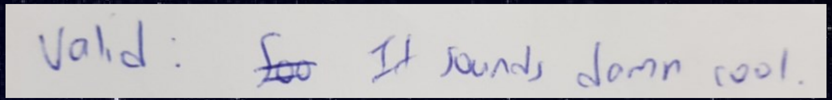


Problem X: The Cuspy Halo Problem

- Flat dark matter density profile ≠ flat galaxy!
- It means that dark matter density is approximately constant!
- Key observation: NFW profile predicts dark matter density to rise sharply at low radial distances → contradicts observation.

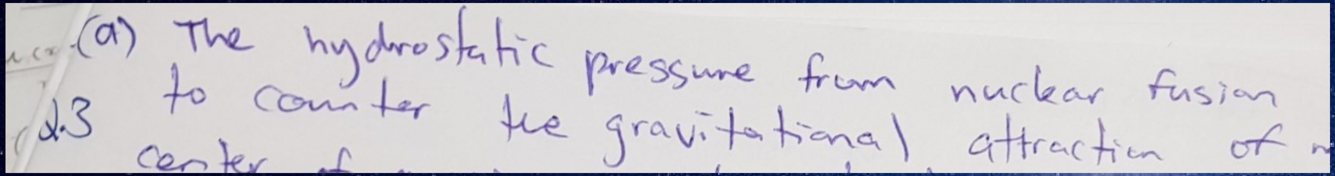
Cat with a flat positional profile.
Not a flat cat.

Mathematical Mishaps
(and other gaffes)

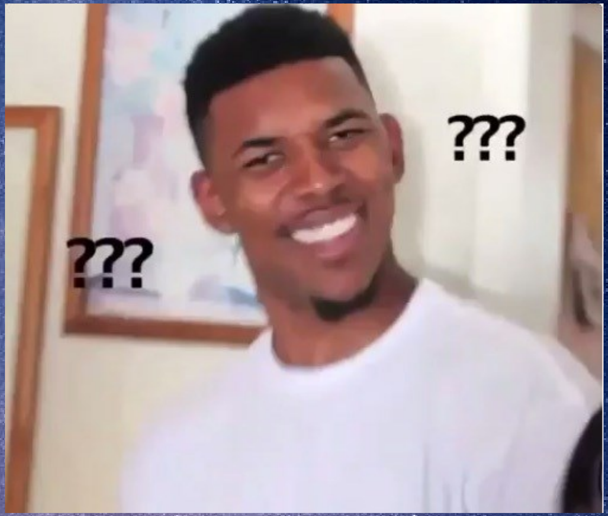

Valid: ~~Too~~ It sounds damn cool.

Cool Compendium of Cool Clunkers

- Q3a: What goes on in a gas cloud


Q3 (a) The hydrostatic pressure from nuclear fusion to counter the gravitational attraction of m
center of

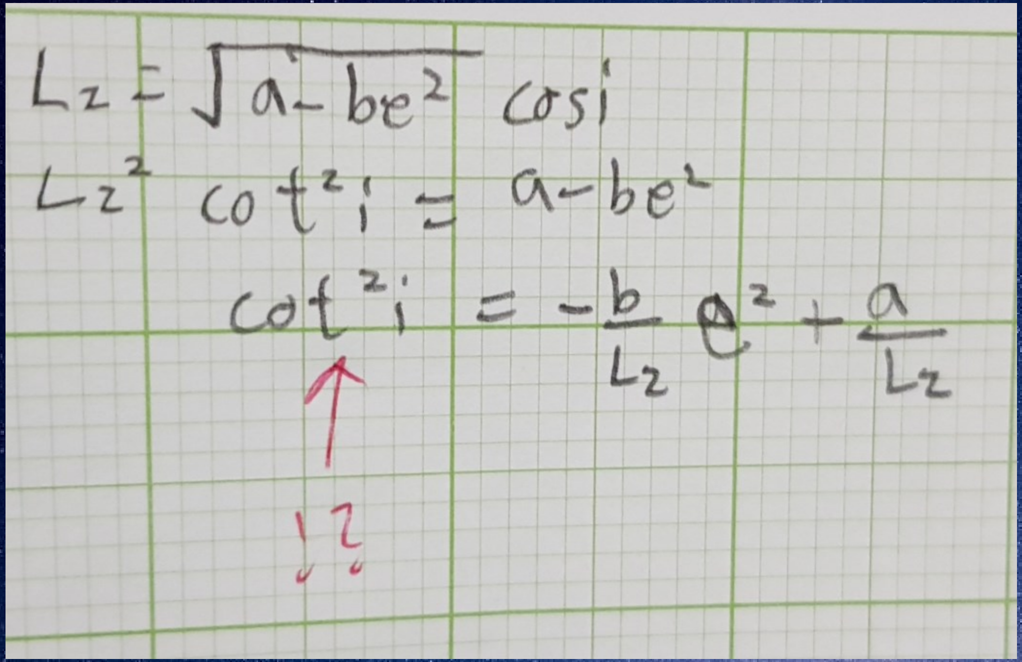
Nuclear fusion. In a cloud of gas. Before protostar stage.



Valid: ~~Coo~~ It sounds damn cool.

Cool Compendium of Cool Clunkers

- Q3d: Trigonometric Trouble

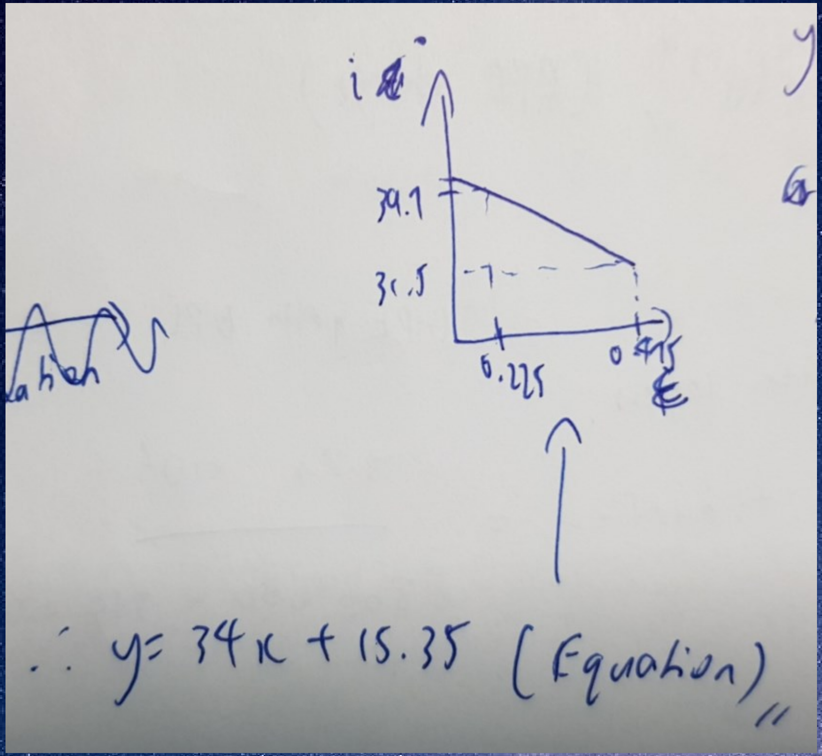


If your graph isn't linear, check your working!!

Valid: ~~Too~~ It sounds damn cool.

Cool Compendium of Cool Clunkers

- Q3d: The graph I didn't know I needed



Not what I meant when I said "draw a graph"...

I mean, it's *a* graph, but...

Valid: ~~Too~~ It sounds damn cool.

Cool Compendium of Cool Clunkers

- Q4d: On the Hill radius

4d)

$$r_{HJ} = r_J \sqrt[3]{\frac{m_J}{3M_\odot}} = 4.87\times10^{6}\,m = 3.25\times10^{-5}\,AU$$

$$r_{HS} = r_S \sqrt[3]{\frac{m_S}{3M_\odot}} = 2.75\times10^{6}\,m = 1.83\times10^{-5}\,AU$$

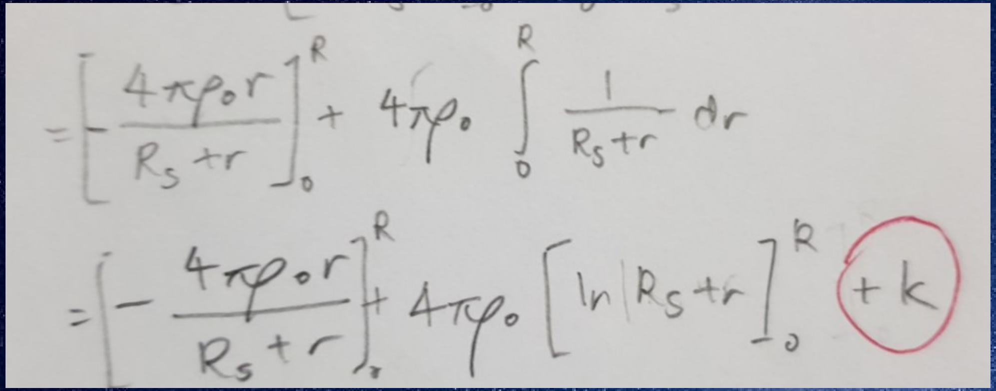
That's 4870km and 2750km! Smaller than the Earth!

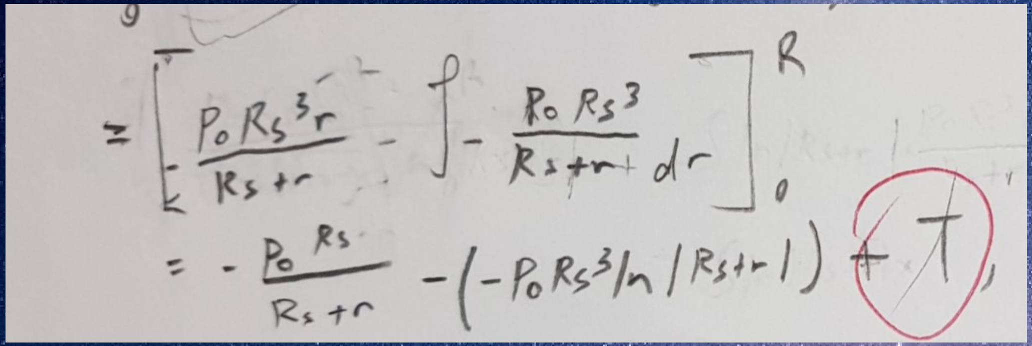
Are you very sure?

Valid: ~~Coo~~ It sounds damn cool.

Cool Compendium of Cool Clunkers

- Q5g: Random arbitrary constants





It’s a finite integral.

You can’t have arbitrary constants in a finite integral.

Valid: ~~Too~~ It sounds damn cool.

Cool Compendium of Cool Clunkers

- Q5c: Spiral galaxies

Spiral galaxies are very spiral rich

...Indeed.

When you give up
(round 2)

When you give up: Brainfart Edition

Isotropy cannot be ~~the~~ assessed as the isotropy ~~assessing~~ assessing machine has not been invented yet.

YEETUS FETUS

(c). The field has grass while galaxy has stars.

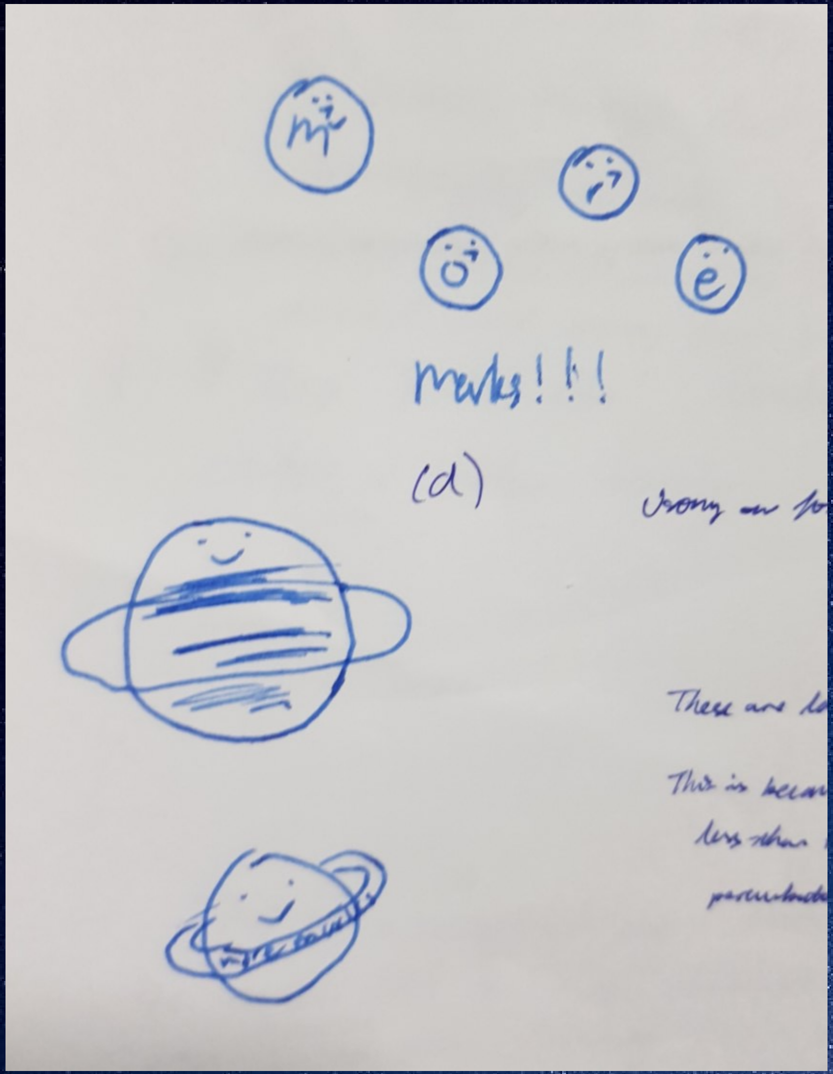
for initial rise,

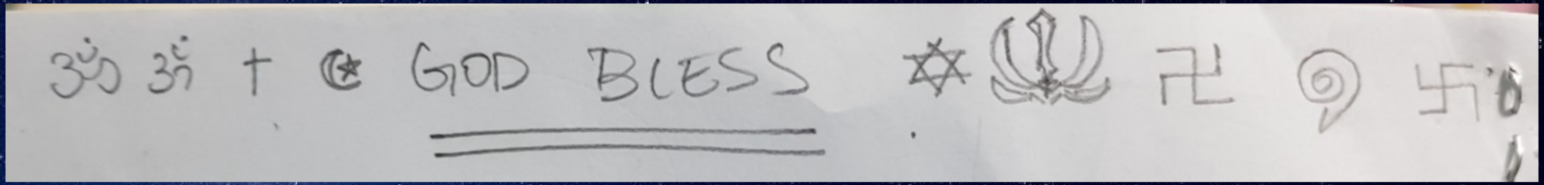
r = Hod

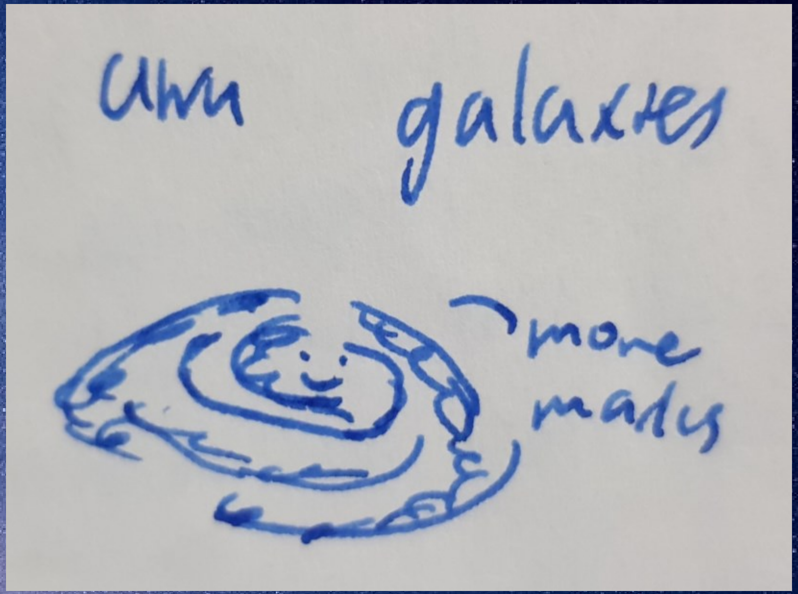
rad ☺

rar

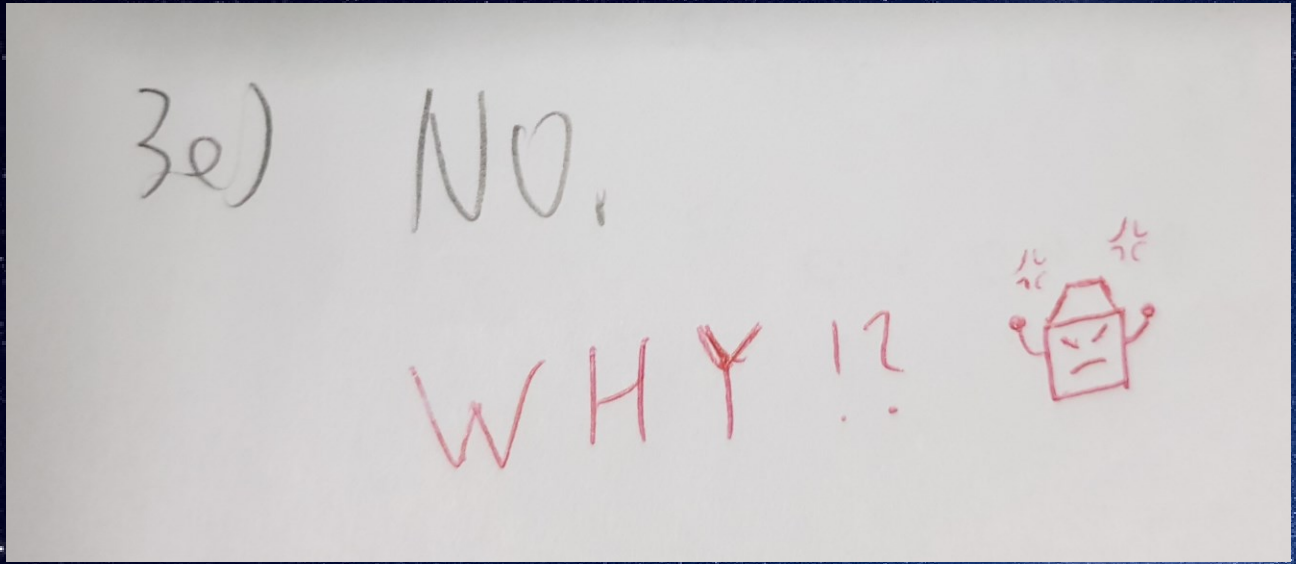
When you give up: Divine Help Needed Edition

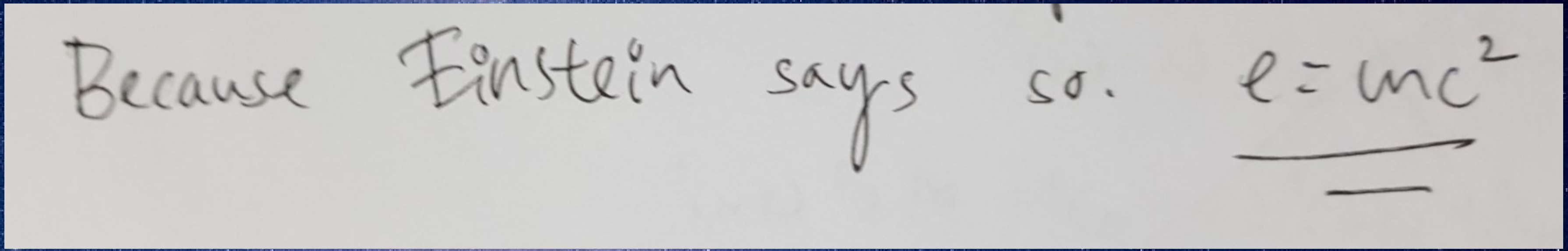




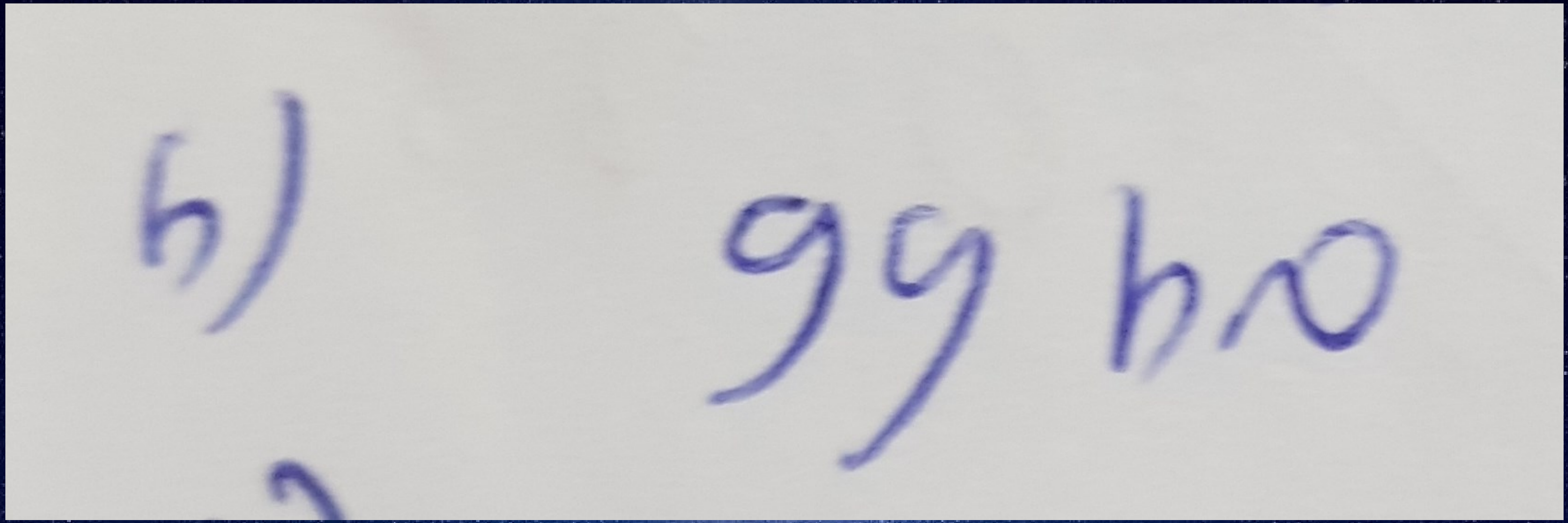


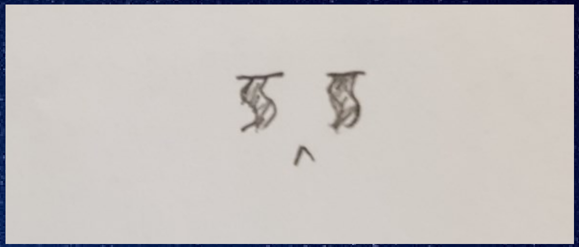
When you give up: A N G E R Y Edition



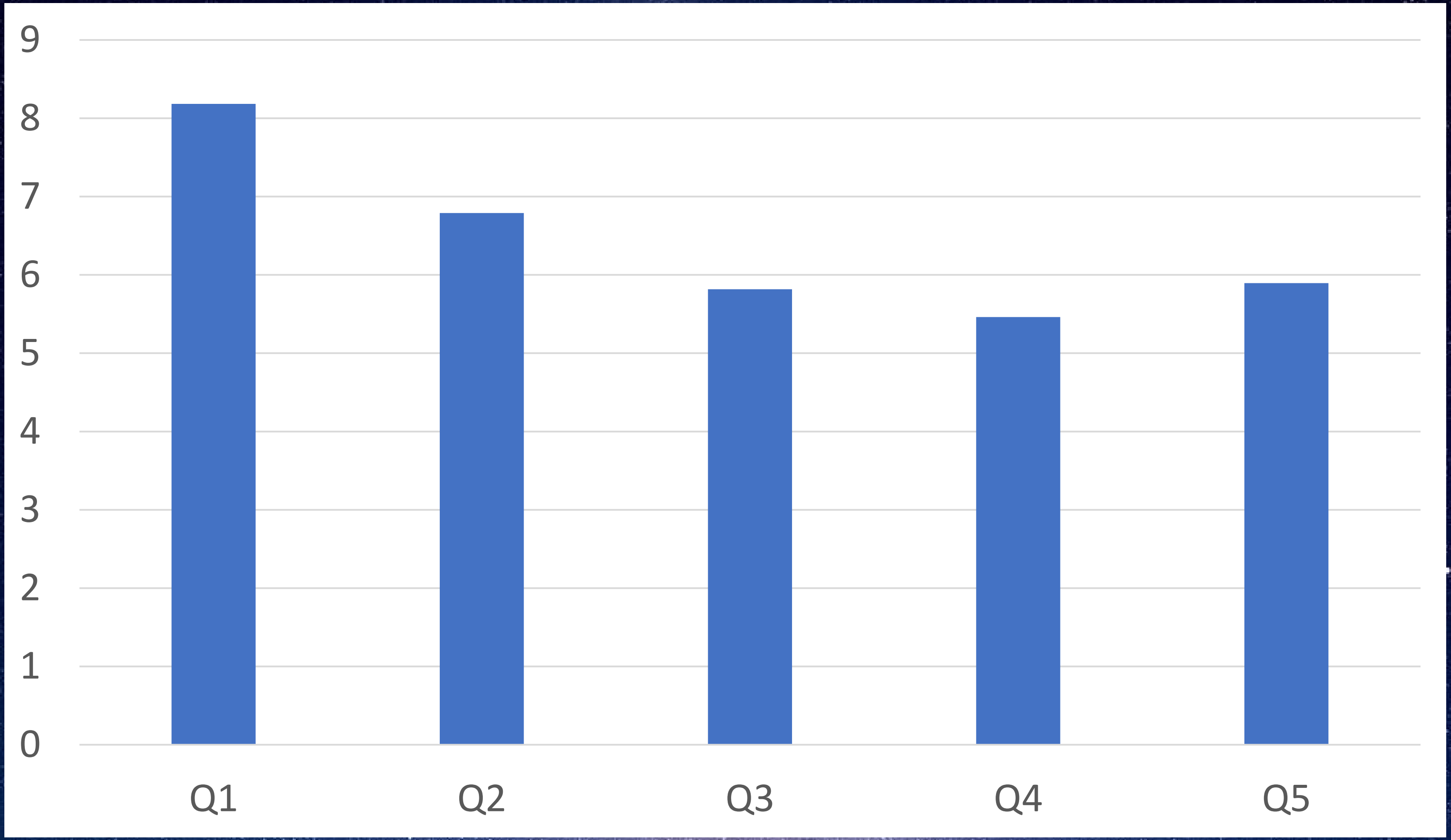


When you give up: GG Edition





SNR Team Round Average Score, by Question

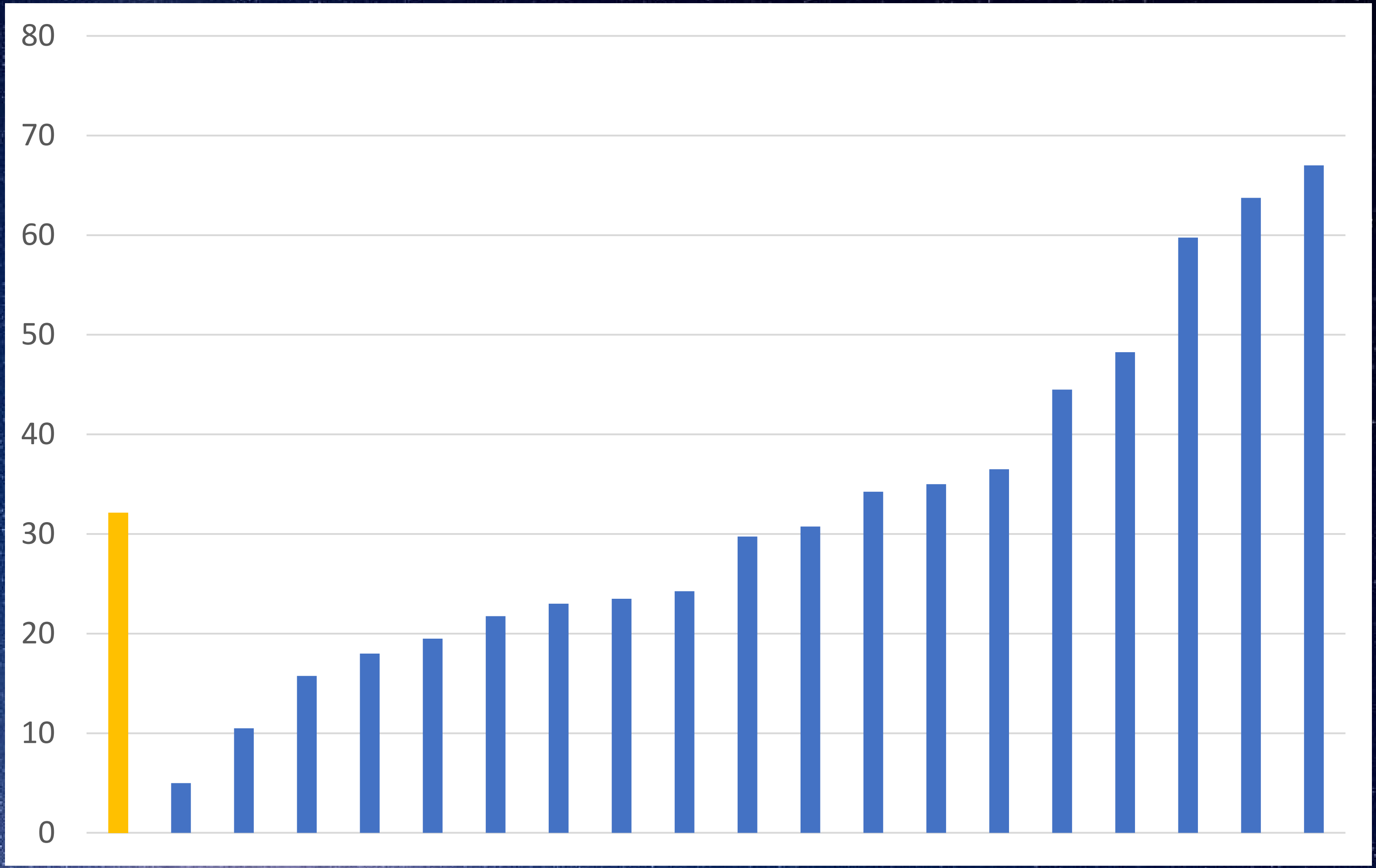


Long story short…

SNR Team Round Score Distribution

Mean = 32.1

Standard Deviation = 17.6



NOTE: TEAM ROUND SCRIPTS

- We will allow you to take a look at your scripts after the Finals
- Note that SNR Q1/Q2 + JNR Q3 were scanned, and so no annotations were made on your script
- You may take photos of your scripts, but for recordkeeping purposes we cannot let you take the scripts home.
- Feel free to clarify with the QMs about where you went wrong, but scores awarded are **FINAL**

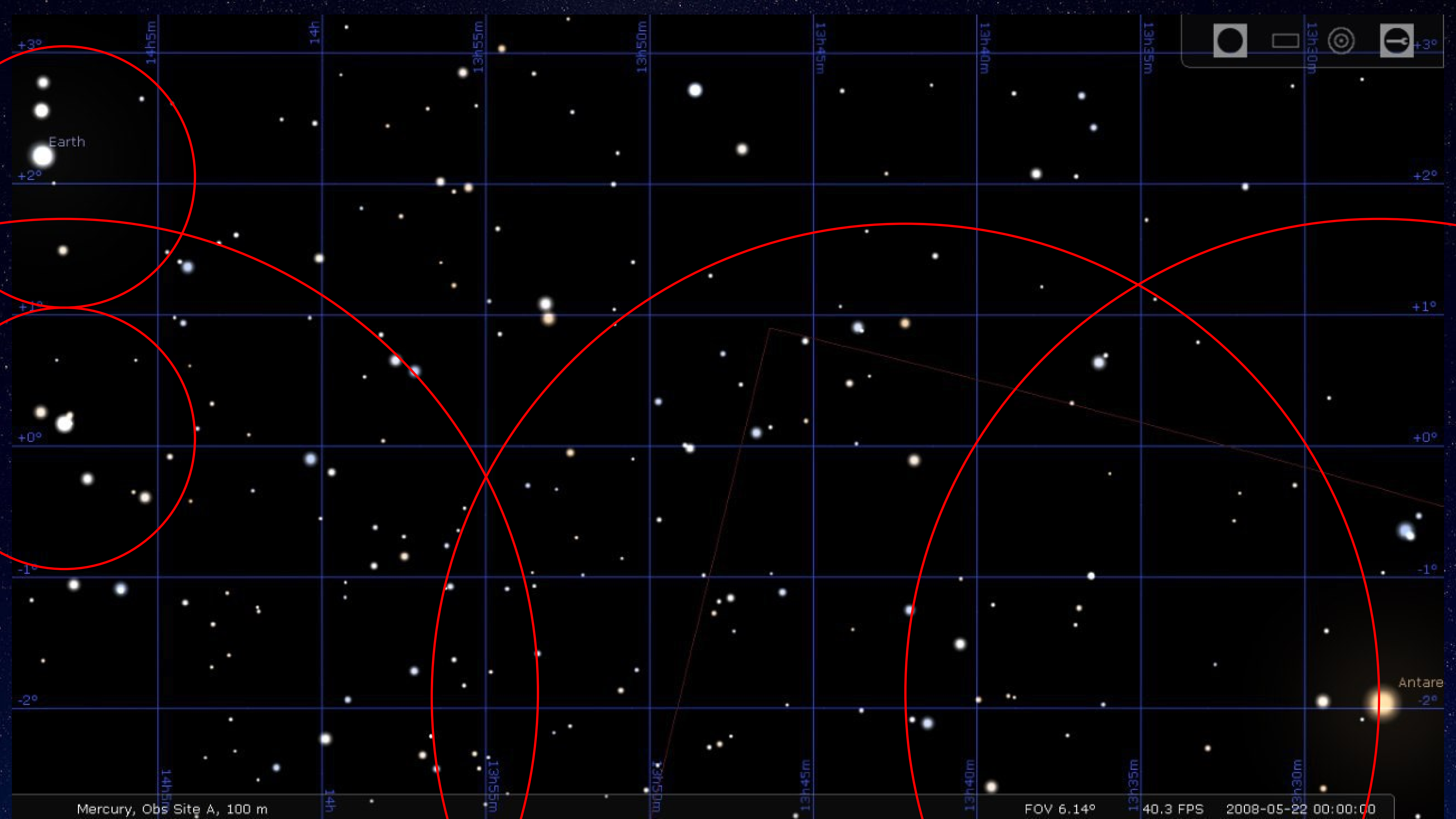
Observation Round

Observation Round (Theory)

- Cloze Passage
  - Generally, mostly well done
- Observation Plan
  - Galaxies (capped at 9)
    - For every extra galaxy that you state, regardless it's correct or incorrect, we deduct 7.5 points and ignore that line.
- Finding Chart
  - Disappointing
  - No use of finder
  - Only one school actually gave slewing instructions
- Constellation Identification
  - Need more work for some schools
  - Generally, mostly well done too

Finding Chart Grading

Component	Percentage (%)
Using of Finder	20
FOV Calculation	20
Accuracy of Drawing	20
Indication of Start and End Points	10
Instructions on Slew	30

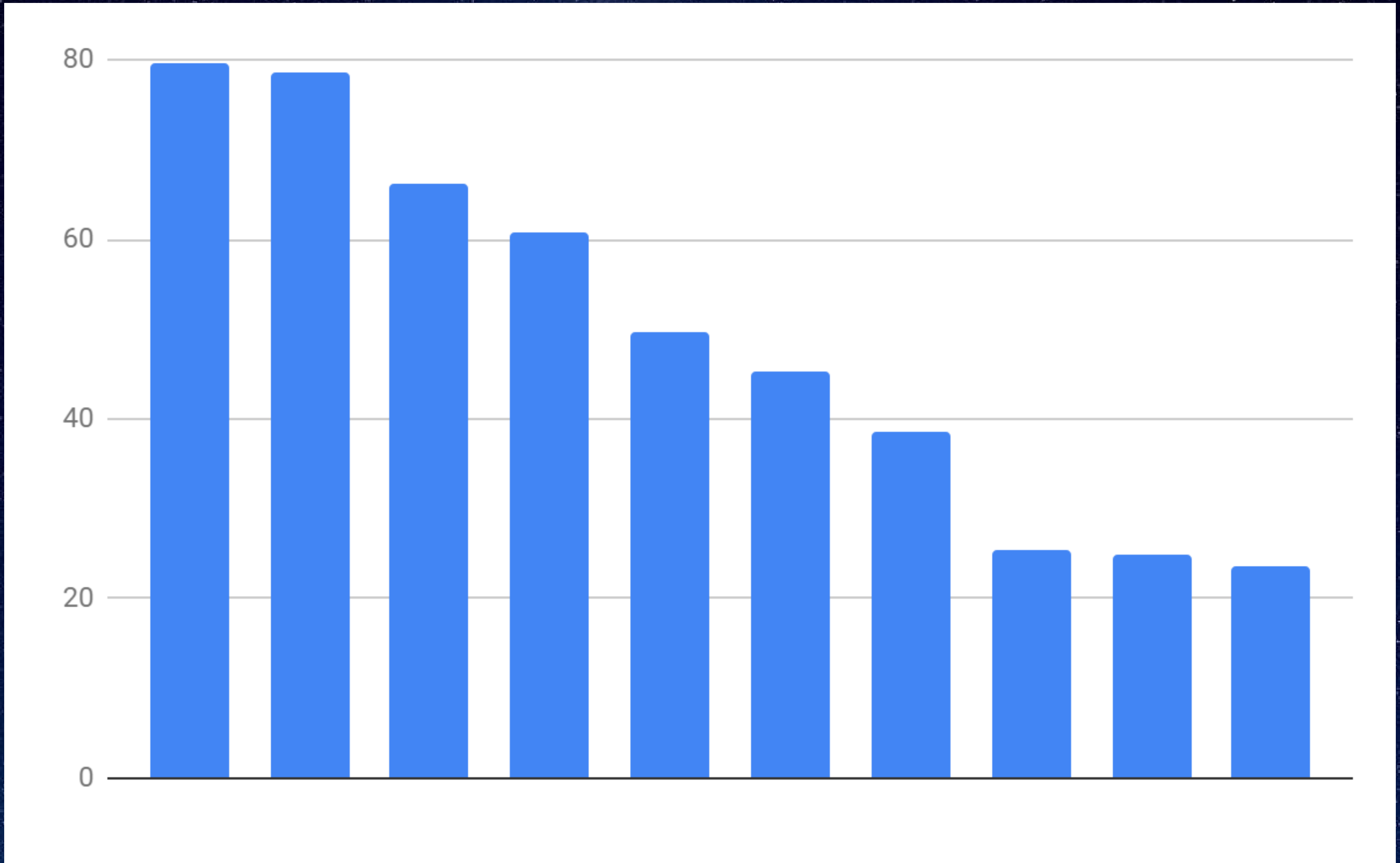


Earth
Antare
+3°
+2°
+1°
+0°
-1°
-2°
14h5m
14h
13h55m
13h50m
13h45m
13h40m
13h35m
13h30m
Mercury, Obs Site A, 100 m
FOV 6.14°
40.3 FPS
2008-05-22 00:00:00

Observation Round (Practical)

- General observation
  - Took too long to set-up
  - Required prompts
- Boresight is an essential skill!

Observation Round Total Score



End of SNR Post Mortem