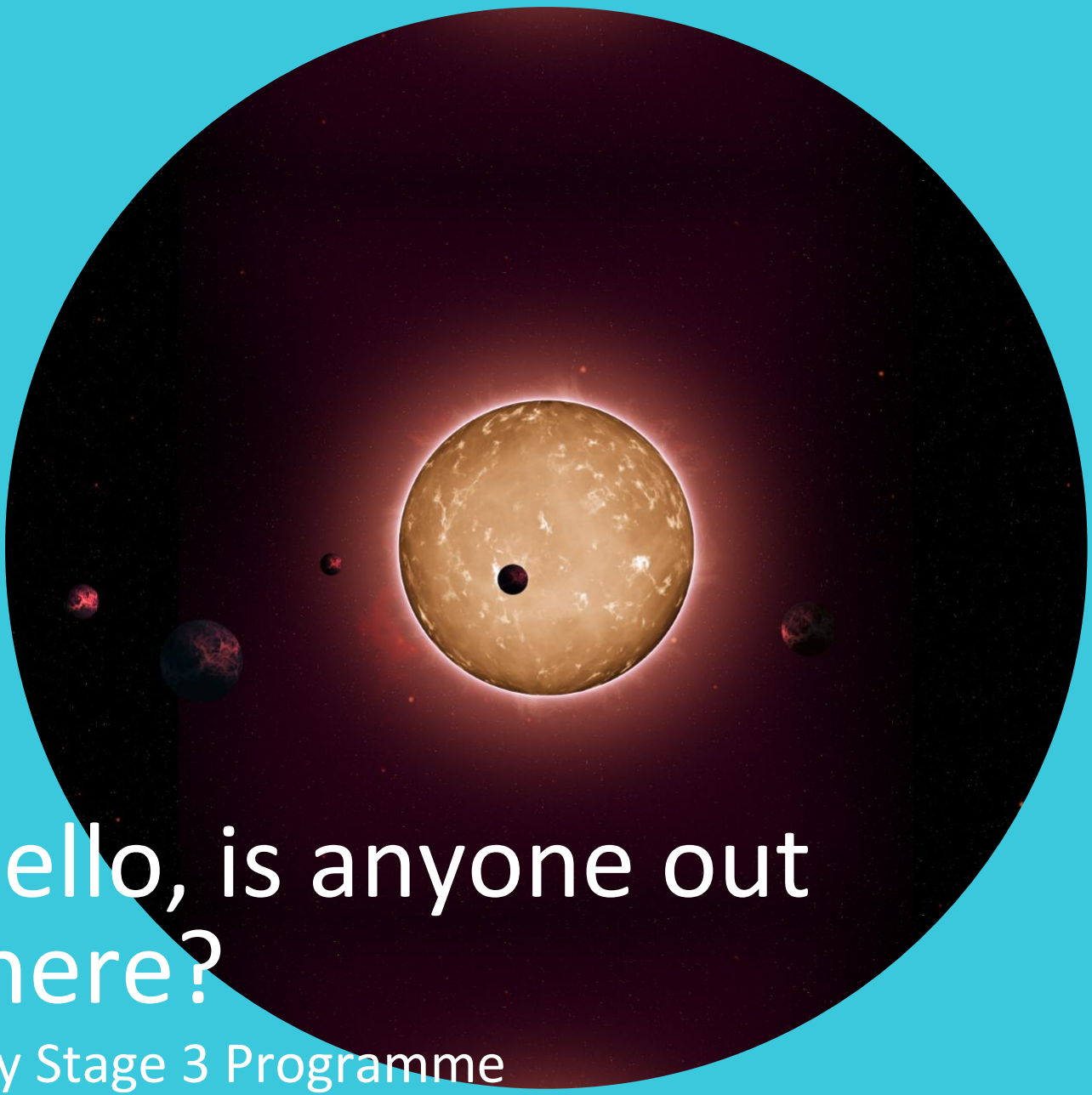

Hello, is anyone out there?

Key Stage 3 Programme

Pupil Name	
Handbook Designed by	Dr Thomas North

Timetable and Assignment Submission

Timetable – Tutorials

Tutorial	Date	Time	Location
1			
2			
3			
4			
5			
6 (Feedback)			
7 (Feedback)			

Timetable – Homework Assignments

Homework Assignment	Description	Due Date
Tutorial 1	Baseline Assignment: Life and death of stars	Tutorial 2
Tutorial 2	Orbits and Equation rearranging	Tutorial 3
Tutorial 3	Transits and detecting planets	Tutorial 4
Tutorial 4	Habitable worlds and temperatures	Tutorial 5
Tutorial 5	Final Assignment Draft	Tutorial 6

Assignment Submission – Lateness and Plagiarism

Lateness	
Submission after midnight on 1st March	10 marks deducted
Plagiarism	
Some plagiarism	10 marks deducted
Moderate plagiarism	20 marks deducted
Extreme plagiarism	Automatic fail

Uni Pathways – Pupil Feedback Report

Grade	Marks	What this means
1st	70+	Performing to an excellent standard at A-level
2:1	60-69	Performing to a good standard at A-level
2:2	50-59	Performing to an excellent standard at GCSE
3rd	40-49	Performing to a good standard at GCSE
Working towards a pass	0-39	Performing below a good standard at GCSE
Did not submit	DNS	No assignment received by The Brilliant Club

Lateness	
Any lateness	10 marks deducted
Plagiarism	
Some plagiarism	10 marks deducted
Moderate plagiarism	20 marks deducted
Extreme plagiarism	Automatic fail

Name of RIS teacher	Dr Thomas North		
Title of Assignment	Are we alone-a new look at the Drake Equation		
Name of Pupil			
Name of School	Cromer Academy		
ORIGINAL MARK / 100		FINAL MARK / 100	
DEDUCTED MARKS		FINAL GRADE	

If marks have been deducted (e.g. late submission, plagiarism) the PhD tutor should give an explanation in this section:

Knowledge and Understanding
Critical Evaluation/Problem Solving
Structure and Presentation
Resilience Comment

Contents

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Course Rationale

The night sky, and the vast emptiness of space has enthralled humanity for all known history. What is the universe made of? Why do the stars shine? Why do some of them seem to wander across the sky whilst other appear fixed on the celestial sphere? Perhaps most fundamentally, what is our place in the universe and are we alone? It is only with the invention of the telescope that humanity began to unlock the heavens, with the true nature of the universe being far more fascinating than anyone could have imagined.

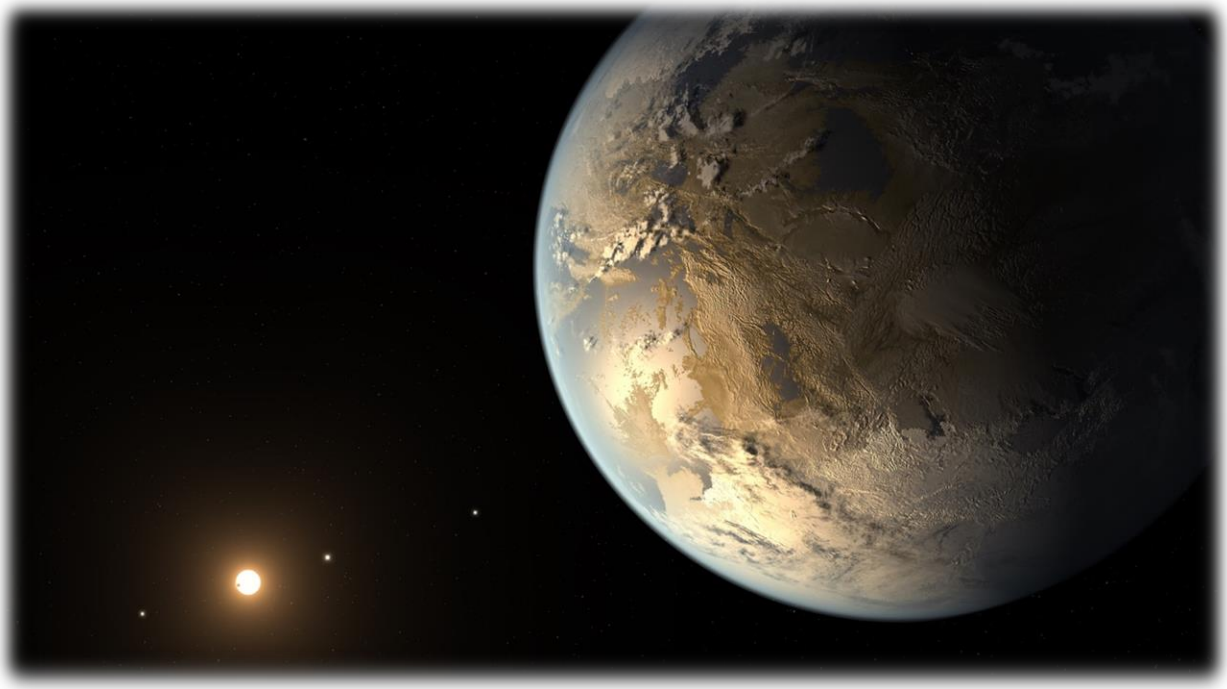
In this course we will explore how stars and planets form and the different types of planets and stars. We will consider what types of stars are the best to look for to try and detect planets around. After this, we'll consider how astronomers on Earth detect these planets over interstellar distances. We will look in depth at the transit and radial velocity methods of detecting planets around other stars - 'exoplanets'- and how we use the measurements from these methods to calculate the size and mass of a planet. To do this, we will be using cutting edge data collected in space using the NASA Kepler and TESS telescopes, amongst others.

With the planets weighed and measured, we move on to consider if life could begin and evolve on these planets. To do this we need to consider how to classify if a planet is habitable or not, and what are the key features we should look for to suggest that a planet may already host life.

Finally, we will look at life on Earth, and consider the different challenges life has faced before humanity, from ice ages to volcanoes and comet impact. With the evolution of intelligent life on Earth, and humanity specifically, the threat of climate change, and global war also present threats to life on this planet.

Our final goal will be to use all the information from throughout the course to estimate the number of contactable alien civilisations in our local galaxy, the Milky Way. To do this we will need to consider how well we know all of the facts and look at the idea of estimation in science.

Most the material in the course will require GCSE mathematics, and some A level material.



Mark Scheme
STEM Mark Scheme

Skills	1st (70-100)	2:1 (60-69)	2:2 (50-59)
Knowledge and Understanding	All content included is relevant to the general topic and to the specific question/title Good understanding of all the relevant topics. Scientific terms are defined and used accurately throughout Clear justification on how the content included is related to the specific issues that are the focus of the assignment	Most of the content included is relevant to the general topic and to the specific question/title Good understanding of most the relevant topics Scientific terms are used accurately but not always clearly defined. Adequate justification on how the content included is related to the specific issues that are the focus of the assignment	Some of the content included is relevant to the general topic and to the specific question/title Good understanding on some of the relevant topics but occasional confusion on others. Scientific terms are used mostly accurately with occasional confusion and often not defined. Some justification on how the content included is related to the specific issues that are the focus of the assignment
Critical Evaluation/ Problem solving	Moved beyond description to an assessment of the value or significance of what is described Evaluative points are consistently explicit/systematic/reasoned/justified Effective critiques on the reliability of sources provided Consistently demonstrate clear, analytical and logical steps to solving problems	Mostly description but some assessment of the value or significance of what is described Evaluative points are mostly explicit/systematic/reasoned/justified Some evidence of critiques on the reliability of sources provided Some examples of solving problems but not consistently clear, analytical and logical	Only description with minimal assessment of the value or significance of what is described Evaluative points are at times explicit/systematic/reasoned/justified Limited evidence of critiques on the reliability of sources provided Demonstrate clear steps to solving problems but not consistently analytical or logical

Structure and Presentation	Ideas are presented in paragraphs and arranged in a logical structure that is appropriate for the assignment The introduction clearly outlines how the essay/report will deal with the issues The conclusion summarises all the main points clearly and concisely All calculations, formulas and methods are clearly structured, clear to follow and correct Tables and graphs are effectively constructed including appropriate headings, units and scales. All sources are referenced correctly in an agreed format	Ideas are presented in paragraphs and arranged in a structure that is mostly appropriate for the assignment The introduction adequately describes how the essay/report will deal with the issues The conclusion summarises most of the main points clearly Calculations, formulas and methods are mostly structured, clear to follow and correct Most tables and graphs are well constructed Most sources are referenced correctly in an agreed format	Ideas are presented in paragraphs and arranged in a structure The introduction mentions how the essay/report will deal with the issues The conclusion summarises some of the main points clearly Calculations, formulas and methods are not always structured, clear to follow and correct. Some tables and graphs are well constructed but contains some errors Some sources are referenced correctly in the agreed format with occasional errors

Knowledge Organiser

Key Equations

Equation	Definition
Gravity between two objects	$F = \frac{Gm_1m_2}{r^2}$
Centripetal (central force)	$F = \frac{mv^2}{r}$
Kepler's third law	$P^2 = \frac{4\pi^2a^3}{GM}$
Transit depth	$\delta = \left(\frac{R_p}{R_s}\right)^2$
Transit duration	$T_{\text{dur}} = \frac{R_sP}{\pi a}$
Equilibrium temperature	$T_{\text{eq}} = T_{\text{eff}}\left(\frac{(1-A)}{\epsilon}\right)^{\frac{1}{4}}\sqrt{\frac{R_s}{2a}}$
Stellar luminosity	$L = 4\,\pi R_s^2\sigma T_{\text{eff}}^4$
Scientific equations	Always use metres, kilograms and seconds when doing calculations unless otherwise specified
Scientific notation	$1.5\text{x}10^{11}$m=150 million km $5\text{x}10^{9}$years=5 billion years $1\text{x}10^{-3}$=0.001 ppm=parts per million

Knowledge of a planet's radius **does not** give direct information on the mass of a planet and vice-versa

Science is not always exact, estimation and educated guesswork are key concepts

Drake Equation

$$N = R_\star \cdot f_p \cdot n_e \cdot f_l \cdot f_i \cdot f_c \cdot L$$

N = the number of civilizations in our galaxy with which communication might be possible
R_* = the average rate of star formation in our galaxy
f_p = the fraction of those stars that have planets
n_e = the average number of planets that can potentially support life per star that has planets
f_l = the fraction of planets that could support life that actually develop life at some point
f_i = the fraction of planets with life that actually go on to develop intelligent life (civilizations)
f_c = the fraction of civilizations that develop a technology that releases detectable signs of their existence into space
L = the length of time for which such civilizations release detectable signals into space

Many aspects of astronomy follow inverse-square laws. The strength of gravity, or light intensity from a star fall off as the square of the distance from the source

E.g.

Position 1
Distance=1000km
Gravity = 400N
Light intensity=100W/m^2

Position 2
Distance=2000km
Gravity = 100N
Light intensity=10W/m^2

Stars generate energy through nuclear fusion in their cores.
Planets do not generate energy, they absorb it from their parent star, and some have retained heat from formation

Big planets are easy to find. This is a form of observation bias
Planets near to their star are also easy and fast to find.
Hot Jupiters are therefore the easiest planets to find

The search for life is 'human-centric' in that we define if a planet is habitable considering if humans could potentially live there.

Subject Vocabulary

Word	Definition	Example
Star	A sphere of hot gas and plasma. Powered by nuclear fusion. Releases light and heat.	The Sun is the nearest star. Other known stars are Alpha Centauri, Sirius, or Bellatrix.
Planet	Spherical body, composed of metal, rock and gas. Planets orbit stars, and do not generate energy.	There are 8 major planets in our Solar System; Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus and Neptune.
Orbit		
Lightyear		
Extra-solar planet		
Civilisation		
Interstellar		

Tutorial 1 – The Life and Death of stars and civilisations

Are We Alone? Maybe. The Better Question Is, Can We Survive?

'Earth 2.0' found in Nasa Kepler telescope haul

Is NASA about to announce discovery of ALIEN LIFE in just over an hour?

What is the Purpose of Tutorial 1?

- To understand the differences between stars and planets
- To understand the key point in the lifetime of a star and planet
- To discuss the needs of a civilisation, and what requirements a planet would need to support a civilisation of technologically advanced intelligent lifeforms
- To understand what the Drake Equation is, the features of it, and some of the pitfalls

Activity (10mins)

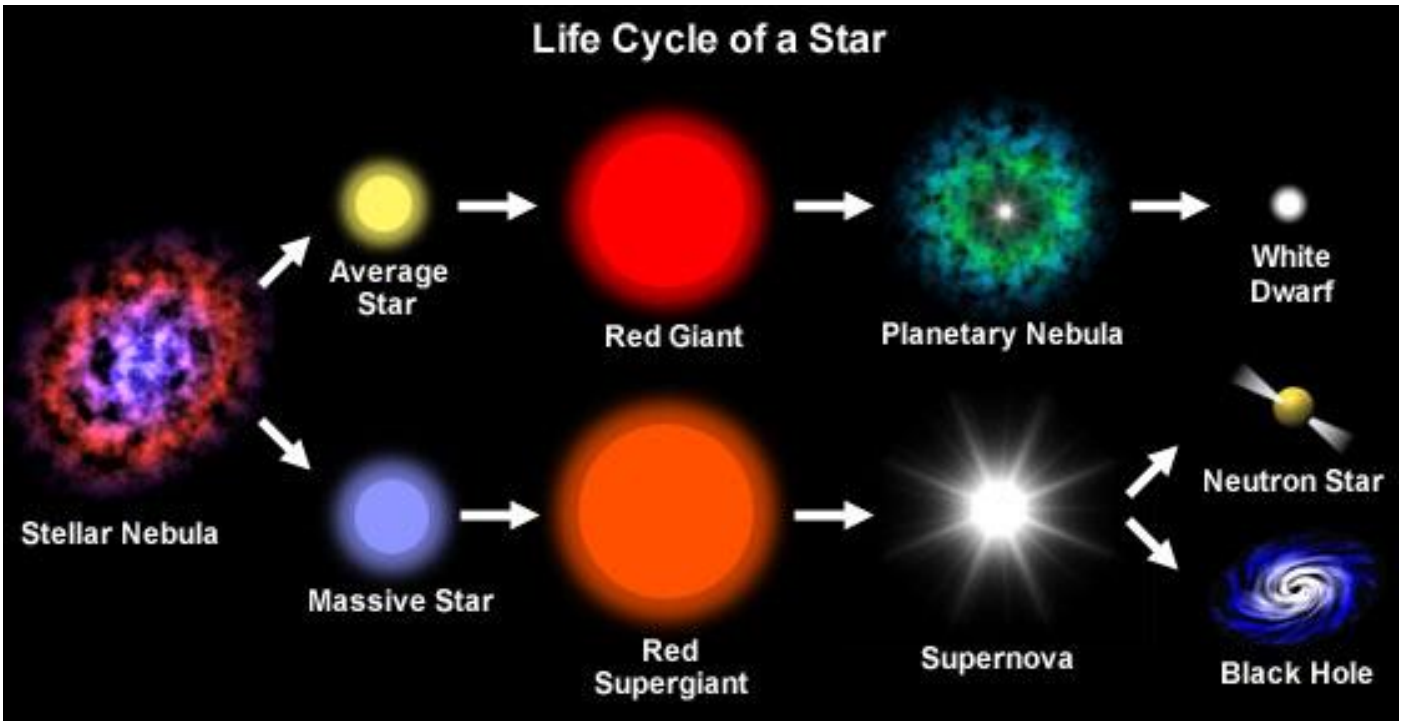
Do you believe in aliens? Jot down any ideas here as why you do or don’t believe in aliens:

Activity

Fill in definitions in Vocabulary Glossary and give an example of each one

Life cycle of a star and planets Pt I

Like humans, stars have lifecycles. They are born (with siblings), they live, and they die. Alongside them planets are also born and will ultimately die. What route a star takes depends entirely on the mass when it first forms



Stars are composed of

……..

Other elements are called …… in astronomy.

A typical star has a mass of?

……..

The Sun has an age of?

……..

Stars are powered by?

……..

The Galaxy contains

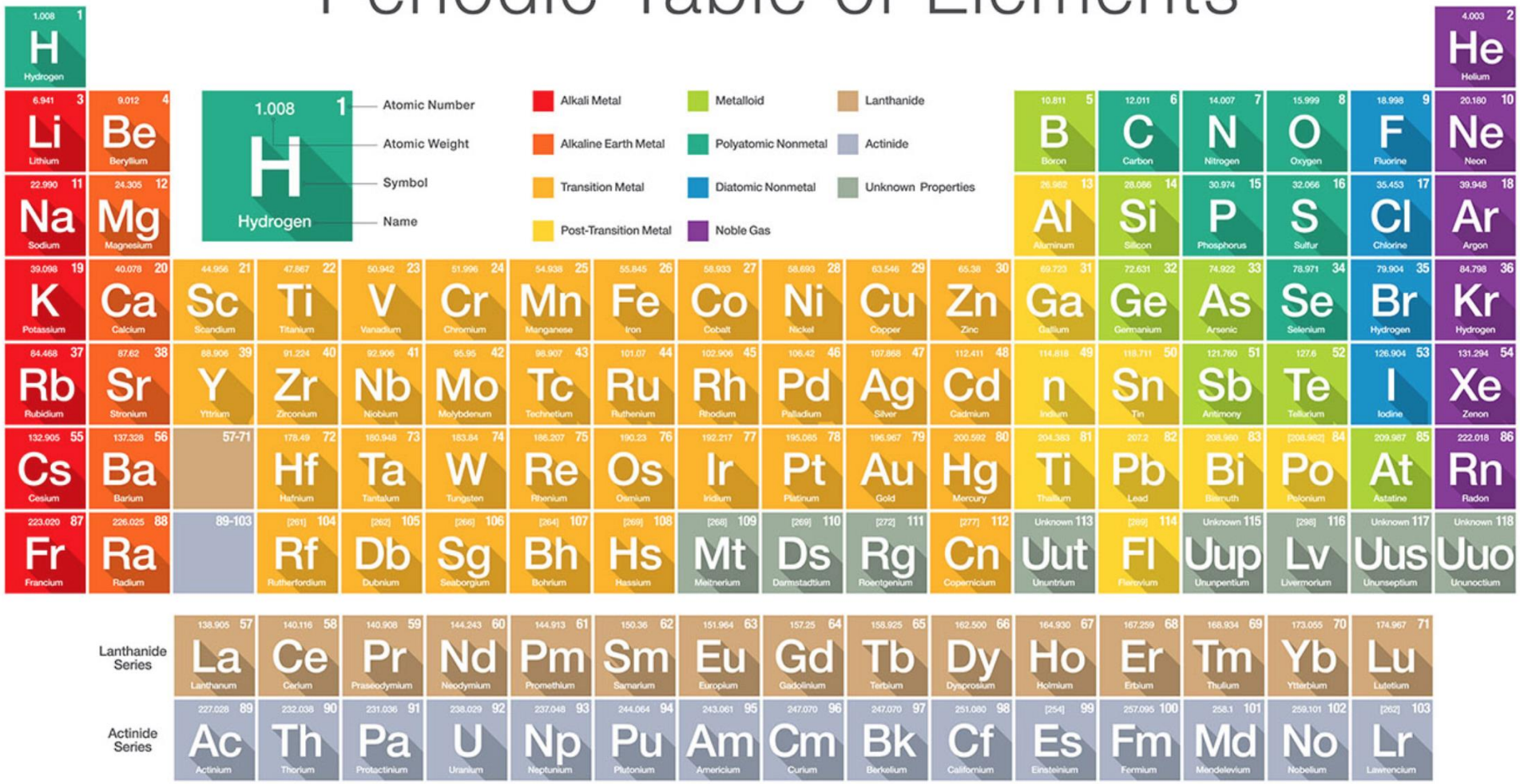
…… stars and forms approximately …… new stars per year

After star like the Sun runs out of fuel in the core, it will expand become a red giant.

Stars greater than …….. times the mass of the Sun end their life by exploding as ……., scattering their remains, and heavy elements back into space to form new stars.

We are made of star dust

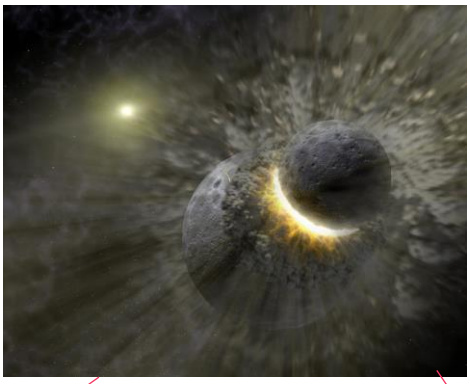
Periodic Table of Elements

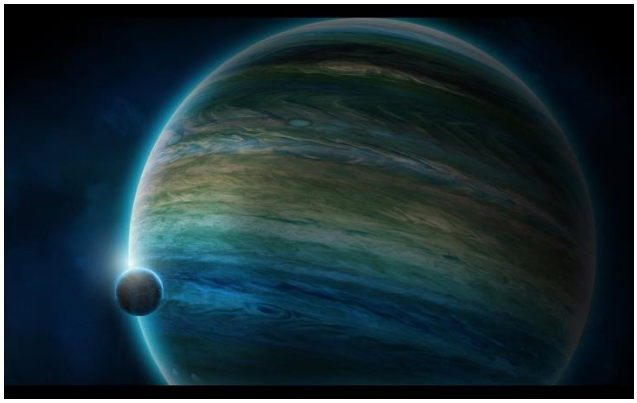


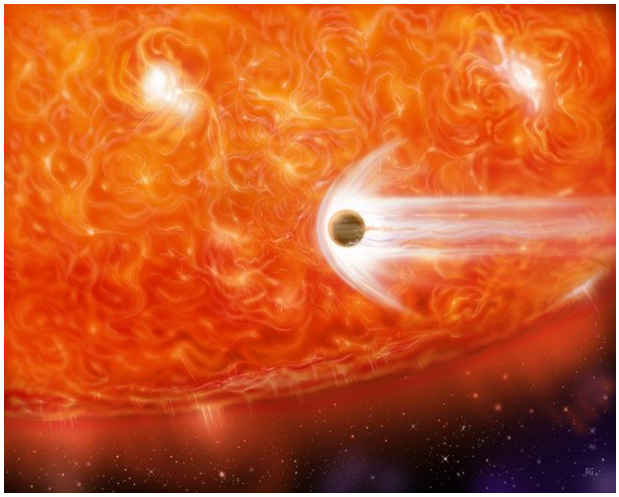
Periodic Table of the Elements
for Astronomers
H
nearly everything in the universe
He
every-thing else
Metals
Metals
Star Killer!
Fe
Metals
Supernova poop
Heidi Wessman Kneale

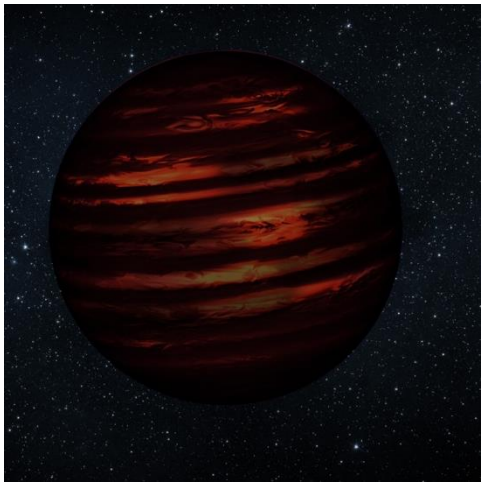
Notes

Life cycle of a star and planets Pt II









Notes

Activity: Life as we know it. Discuss as a group or in pairs what you think are the key conditions on Earth that led to the appearance and continuation of life?

What does life on Earth need to survive?

Where are we going?

$$N = R_\star \cdot f_p \cdot n_e \cdot f_l \cdot f_i \cdot f_c \cdot L$$

Notes

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They’re made of out meat- (Terry Bison, OMNI, April 1991).

"They're made out of meat."

"Meat?"

"Meat. They're made out of meat."

"Meat?"

"There's no doubt about it. We picked up several from different parts of the planet, took them aboard our recon vessels, and probed them all the way through. They're completely meat."

"That's impossible. What about the radio signals? The messages to the stars?"

"They use the radio waves to talk, but the signals don't come from them. The signals come from machines."

"So who made the machines? That's who we want to contact."

"They made the machines. That's what I'm trying to tell you. Meat made the machines."

"That's ridiculous. How can meat make a machine? You're asking me to believe in sentient meat."

"I'm not asking you, I'm telling you. These creatures are the only sentient race in that sector and they're made out of meat."

"Maybe they're like the orfolei. You know, a carbon-based intelligence that goes through a meat stage."

"Nope. They're born meat and they die meat. We studied them for several of their life spans, which didn't take long. Do you have any idea what's the life span of meat?"

"Spare me. Okay, maybe they're only part meat. You know, like the weddilei. A meat head with an electron plasma brain inside."

"Nope. We thought of that, since they do have meat heads, like the weddilei. But I told you, we probed them. They're meat all the way through."

"No brain?"

"Oh, there's a brain all right. It's just that the brain is made out of meat! That's what I've been trying to tell you."

"So ... what does the thinking?"

"You're not understanding, are you? You're refusing to deal with what I'm telling you. The brain does the thinking. The meat."

"Thinking meat! You're asking me to believe in thinking meat!"

"Yes, thinking meat! Conscious meat! Loving meat. Dreaming meat. The meat is the whole deal! Are you beginning to get the picture or do I have to start all over?"

"Omigod. You're serious then. They're made out of meat."

"Thank you. Finally. Yes. They are indeed made out of meat. And they've been trying to get in touch with us for almost a hundred of their years."

"Omigod. So what does this meat have in mind?"

"First it wants to talk to us. Then I imagine it wants to explore the Universe, contact other sentiences, swap ideas and information. The usual."

"We're supposed to talk to meat."

"That's the idea. That's the message they're sending out by radio. 'Hello. Anyone out there. Anybody home.' That sort of thing."

"They actually do talk, then. They use words, ideas, concepts?"
"Oh, yes. Except they do it with meat."

"I thought you just told me they used radio."

"They do, but what do you think is on the radio? Meat sounds. You know how when you slap or flap meat, it makes a noise? They talk by flapping their meat at each other. They can even sing by squirting air through their meat."

"Omigod. Singing meat. This is altogether too much. So what do you advise?"

"Officially or unofficially?"

"Both."

"Officially, we are required to contact, welcome and log in any and all sentient races or multibeings in this quadrant of the Universe, without prejudice, fear or favor. Unofficially, I advise that we erase the records and forget the whole thing."

"I was hoping you would say that."

"It seems harsh, but there is a limit. Do we really want to make contact with meat?"

"I agree one hundred percent. What's there to say? 'Hello, meat. How's it going?' But will this work? How many planets are we dealing with here?"

"Just one. They can travel to other planets in special meat containers, but they can't live on them. And being meat, they can only travel through C space. Which limits them to the speed of light and makes the possibility of their ever making contact pretty slim. Infinitesimal, in fact."

"So we just pretend there's no one home in the Universe."

"That's it."

"Cruel. But you said it yourself, who wants to meet meat? And the ones who have been aboard our vessels, the ones you probed? You're sure they won't remember?"

"They'll be considered crackpots if they do. We went into their heads and smoothed out their meat so that we're just a dream to them."

"A dream to meat! How strangely appropriate, that we should be meat's dream."

"And we marked the entire sector unoccupied."

"Good. Agreed, officially and unofficially. Case closed. Any others? Anyone interesting on that side of the galaxy?"

"Yes, a rather shy but sweet hydrogen core cluster intelligence in a class nine star in G445 zone. Was in contact two galactic rotations ago, wants to be friendly again."

"They always come around."

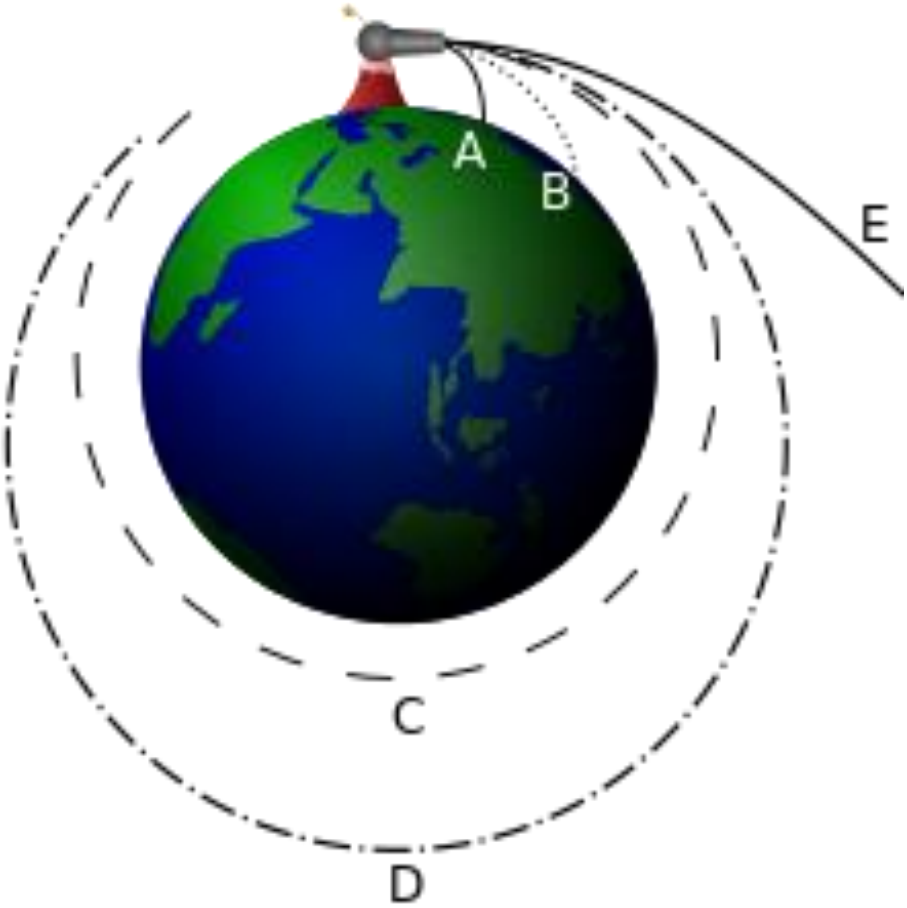
"And why not? Imagine how unbearably, how unutterably cold the Universe would be if one were all alone ..."

Homework 1-Baseline:

1) Summarise (700 words or less), the lifecycle of the Sun, and the ultimate fate of the inner planets and life on Earth. Word process and submit a printed copy. 700 words is approximately 1½ pages of text. Feel free to include any figures you find relevant, making you tell me the source.
Things to include:

- Key timescales such as lifetime of the Sun and how quickly it will evolve after it runs out of fuel
- Impact of evolution of the Sun on the planets, will they be destroyed, or thrown out of the Solar System etc
- How long life on Earth might have been detectable
- How long humans might survive on Earth
- Make sure to check spelling and punctuation
- This homework will probably take around an hour or two, and maybe an hour of wider reading
- Anything you are unsure of, research using the Internet, and justify any statements you make
- Justifying a statement is a key exercise at university and requires accurate referencing of how you found information. On Word you can add either footnotes or endnotes for references. Try to not use Wikipedia as a direct reference. Follow the link on Wikipedia to where it can be found elsewhere on the internet. If you can, also use books and other sources.

Tutorial 2 – Gravity and orbits



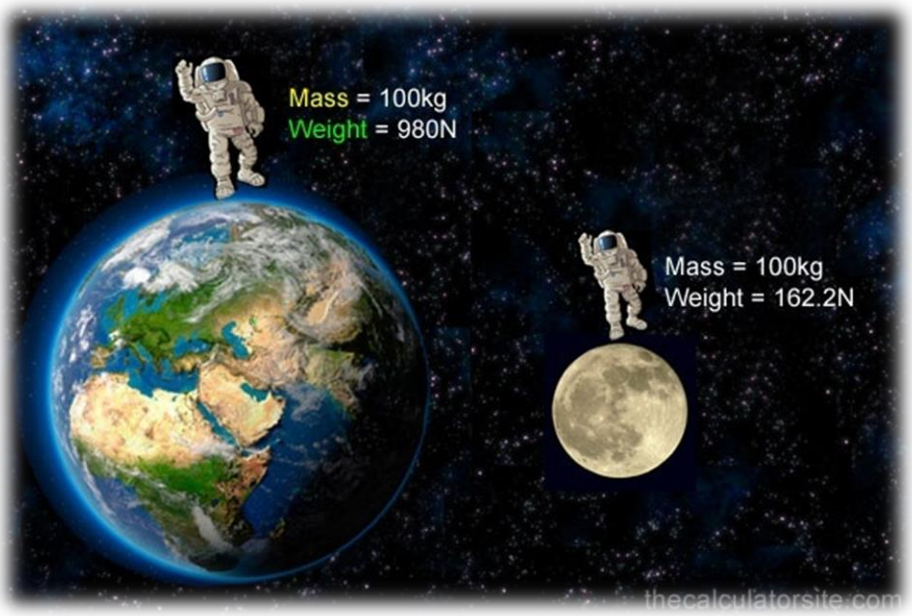
What is the Purpose of Tutorial 2?

- Understand the key equations underpinning orbits and Kepler's laws
- Be able to rearrange equations relating to orbits and substitutions into equations.

Activity: What is g? Consider what you know about gravity on the Earth and the Moon (as a group)

$$W = mg$$

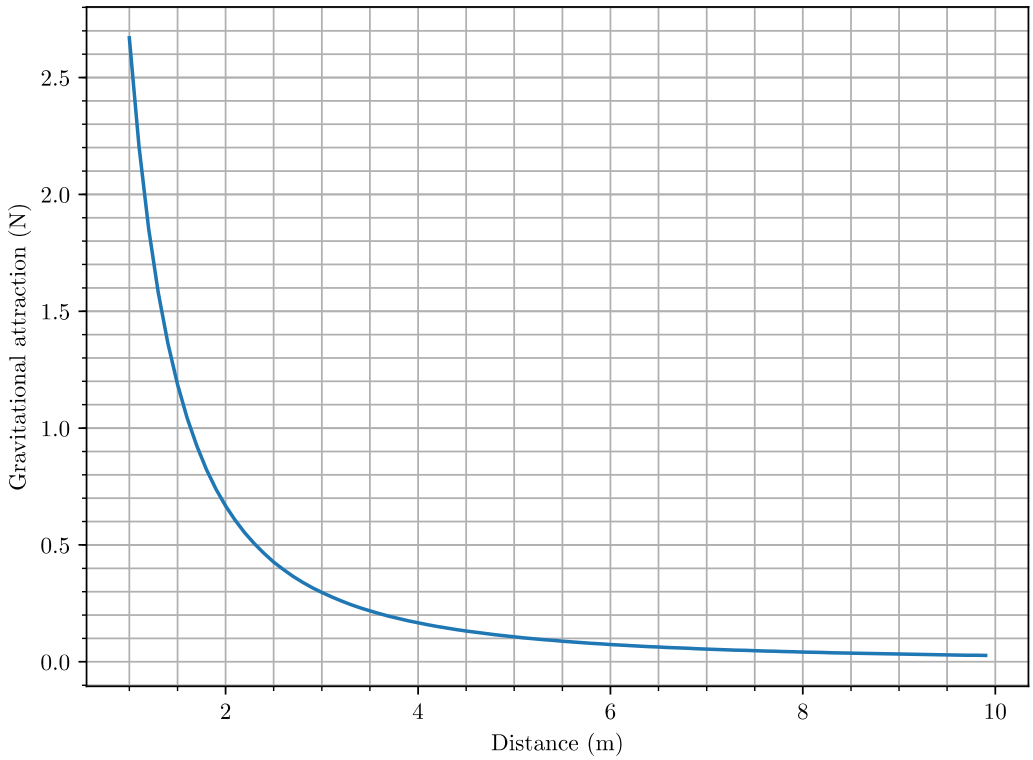
$$Weight\ (\mathrm{N}) = mass\ (\mathrm{kg})\ \times gravitational\ acceleration\ (\mathrm{m/s^2})$$

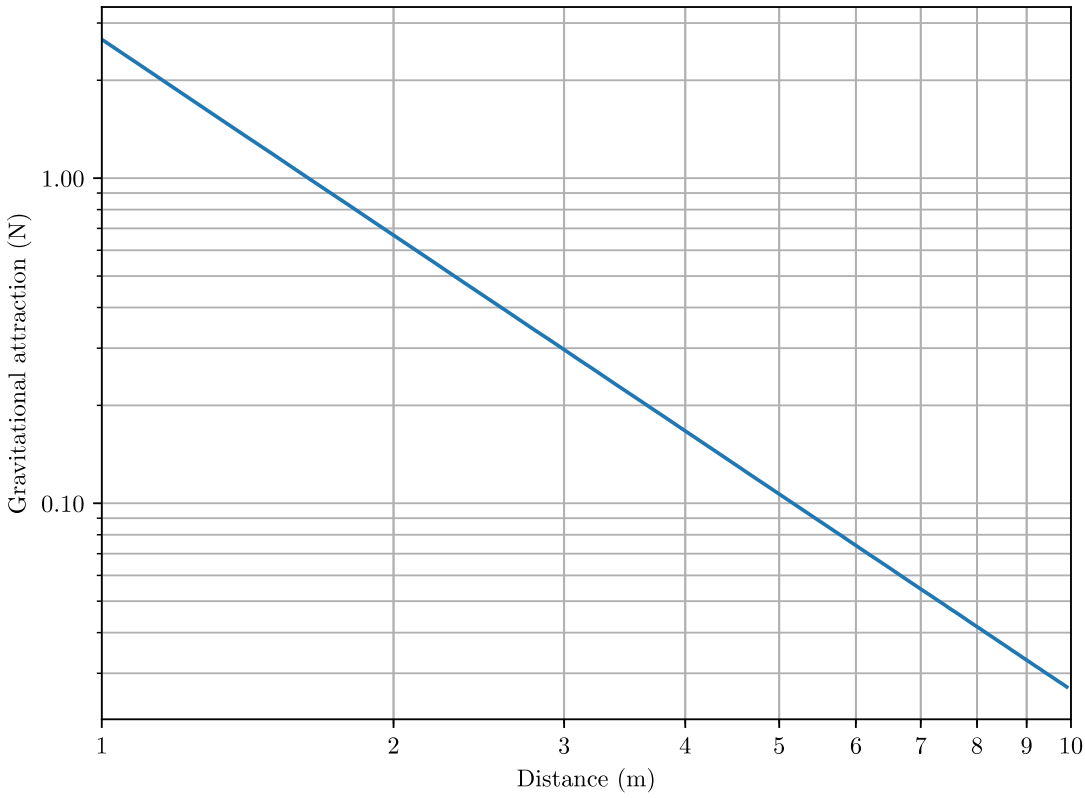


What does g depend on?

Newton's law of gravitation-Pt I

Gravity is an 'inverse square law' which means if we travel twice as far away, then the force of gravity is only a quarter of the original strength. The figure below shows the gravitational attraction between two blue whales (m=2x10^5 kg) as a function of distance between them. The lower graph is on a logarithmic scale.





$$g = \frac{Gm_E}{r_E^2} \qquad F = \frac{Gm_1m_2}{r^2}$$

An 'inverse square law' which means if we travel twice as far away, then the force of gravity is only a quarter of the original strength

Constants	Value

Q: Prove $W = mg$ is the same as $F = \frac{Gm_1m_2}{r^2}$ using the values given for the mass and radius of the Earth. For m and m_2 assume 60kg

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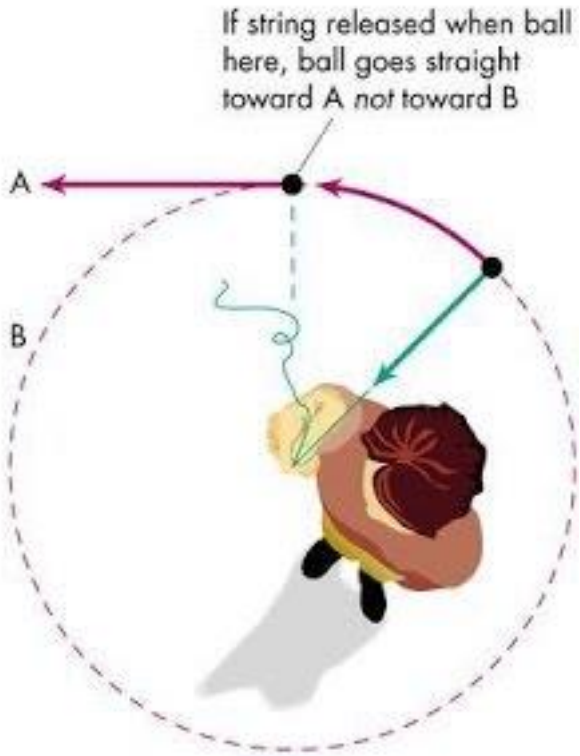
Newton's law of gravitation-Pt II

For objects travelling on circular paths, the force that stops them flying off is known as the centripetal force (cars around corners, planets on orbits)

Side view



Top view

For things going around stars and planets, we already know that force as gravity! This means we have two equations that **must** give the same result. This means we can equate them

$$F = \frac{mv^2}{r}$$

Newton's law of gravitation- Pt III

Notes

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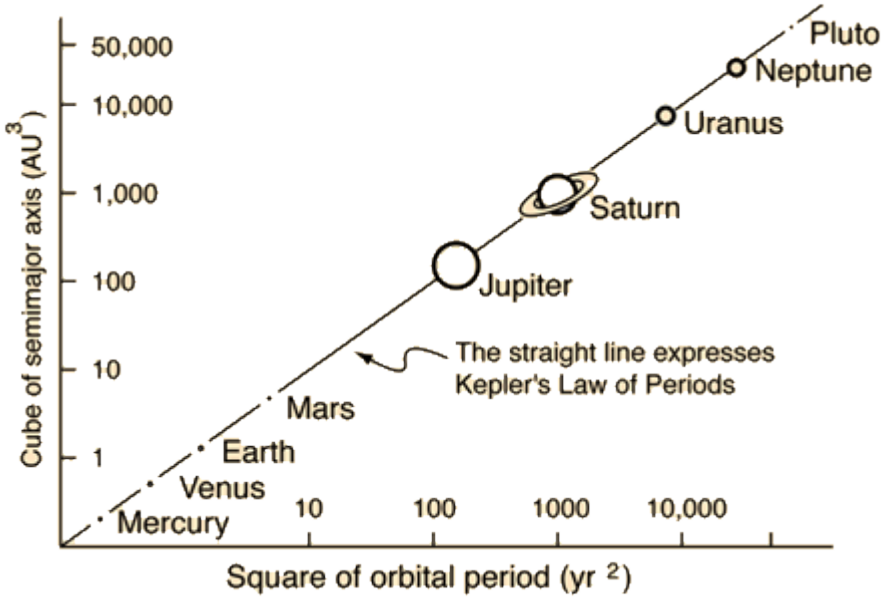
Sketching space: draw a circle and write down the key equation that relates speed, distance and time.

From this, and the equation for gravity we are going to derive an equation that relates orbital period, distance and mass. The equation is known as Kepler's third law

Kepler's third law



$$\frac{T^2}{a^3} = \frac{4\pi^2}{GM}$$

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Homework 2: Orbits

Using the equations given here complete the following questions. You will need to research some information on the internet to complete some of these questions or refer to the table of constants from the tutorial.

Remember in physics we use kilograms, metres and seconds when doing calculations! Equation D gives the mass of a sphere of uniform density. The ρ in equation D is density and has units kg/m^3.

A) $$g = \frac{Gm_E}{r_E^2}$$

B) $$F = \frac{Gm_1m_2}{r^2}$$

C) $$T^2 = \frac{4\pi^2 a^3}{GM}$$

D) $$M = \frac{4}{3}\rho\pi r^3$$

E) $$F = \frac{mv^2}{r}$$

Homework 2: Orbits

1) The roundabout is a common sight in many parks. A common game is to spin the roundabout as fast as possible and try and hold on. If you fell off, you would often injure yourself. What is the name of the force (in this case provided by your arms) holding you on the roundabout:

   …….

2) The maximum force a human child's arm can withstand (without coming apart) is 5kN. Assuming the child has a mass of 50kg, and the roundabout has a radius of 1m, how fast can the roundabout spin and the child be able to hold on. (Clue: rearrange Equation E)

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3) Look up the mass and radius of the Moon, use these values and Equation A to calculate *g* on the Moon. Compare this to value for *g* on the Earth

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   ……

4) Using equations B and E to calculate the v needed to escape the Earth's surface

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5) A typical red giant I have studied during my PhD has a mass of 1.4x the mass of the Sun, and a radius of 5x the radius of the Sun. A planet I discovered orbits at a distance of 4x the stellar radius from the star. What was the orbital period of the planet in days. Comment on your answer compared to planets in our Solar System. You will need Eq C and to look up the mass and radius of the Sun

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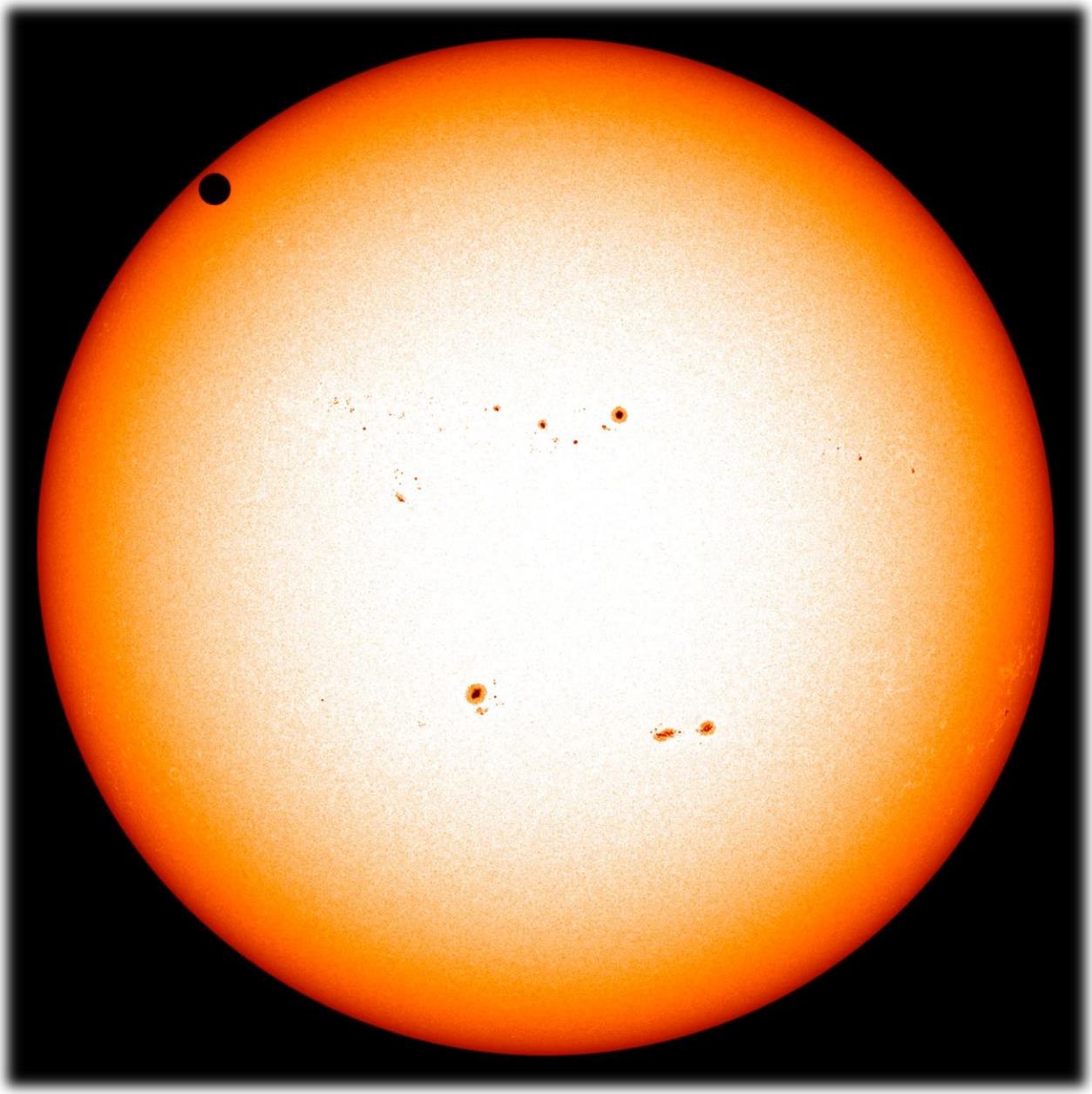
Tutorial 3 – Detecting planets

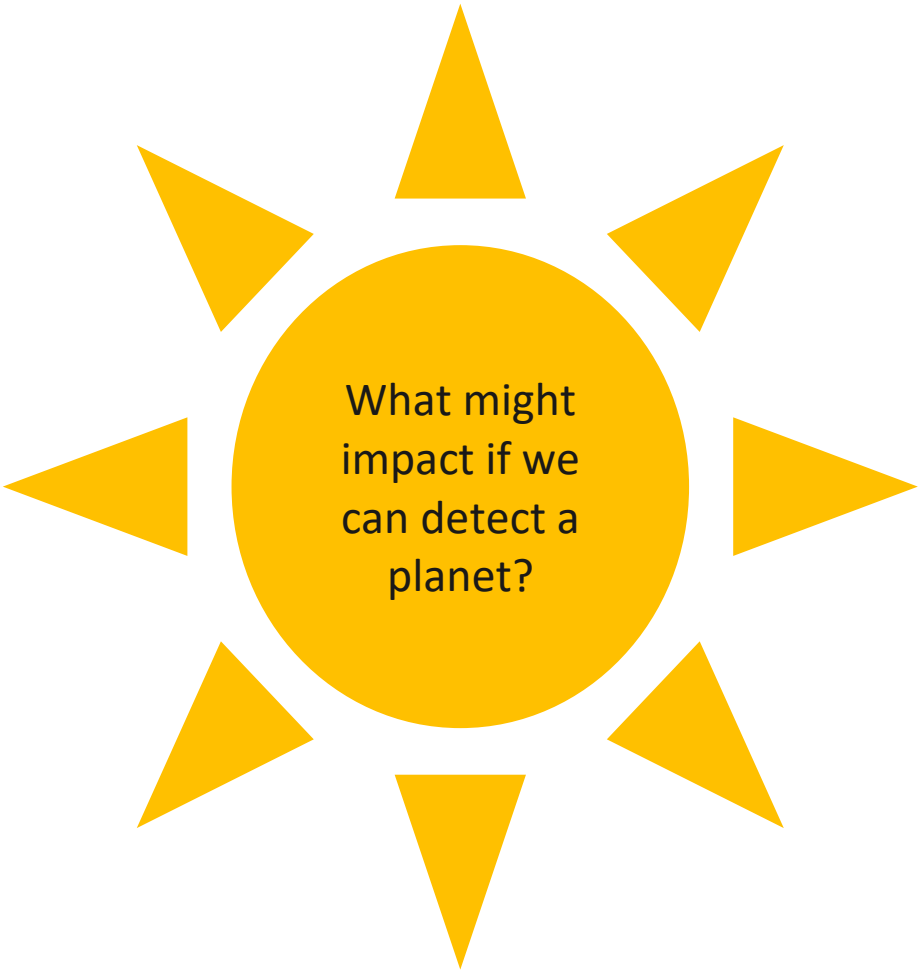


What is the Purpose of Tutorial 3?

- To understand the transit method of detecting exoplanets
- To understand the key benefits and difficulties of the transit method
- To be able to find the radius of a planet detected via the transit method
- (If time) to understand the radial velocity 'Doppler Wobble' method of detecting exoplanets, the benefits and difficulties of that method, and to be able to give the mass of a planet detected via the Doppler Wobble method

Detecting planets

Activity-In Pairs



Transits

$$N = R_\star \cdot f_p \cdot n_e \cdot f_l \cdot f_i \cdot f_c \cdot L$$

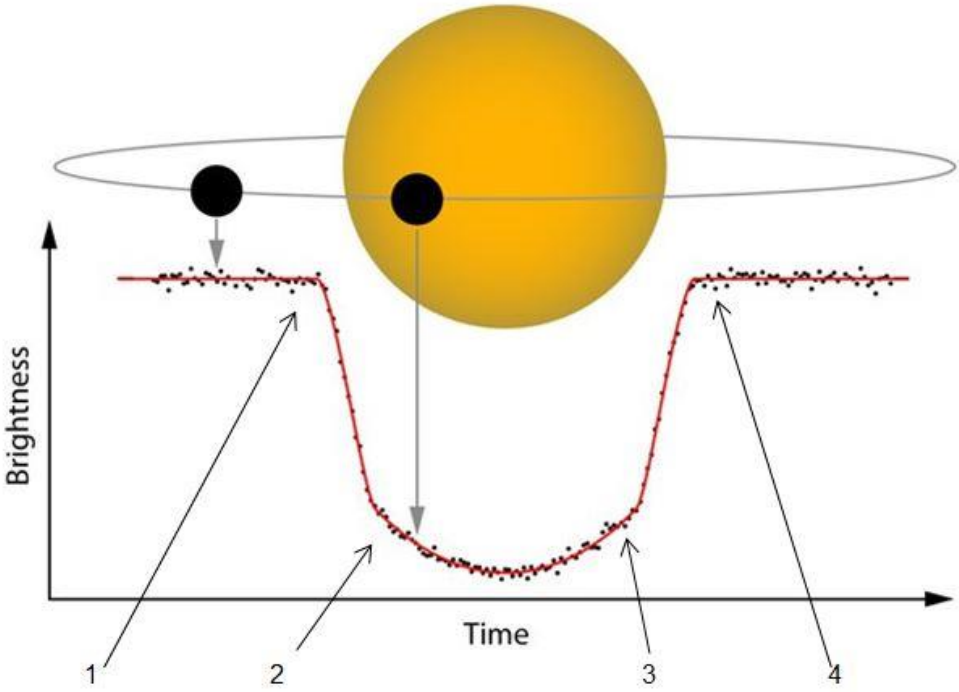
The NASA *Kepler* mission has detected thousands of planets around other stars by carefully monitoring the same stars continuously for nearly 4 years. If a planet passes in front of the star as seen from Earth, it produces a tiny dip in the total light from the star (known as photometry). *Kepler* observed around 100,000 stars, of which 40,000 were very similar to the Sun.

Activity: Transit Equation

Sketching space: draw two circles, with one circle much smaller and inside the first circle. Shade the smaller circle. Write down an expression for the total area of the unshaded region.

Derivation

We normally state transit depths in parts per million (ppm)



Questions

1) Calculate the depth of a transit of a 1.8x Earth radius planet around a 0.8x Sun radius star

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2) Calculate the depth of a transit of a 0.8x Jupiter radius planet around a 1.6x Sun radius star

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3) Comment on these values

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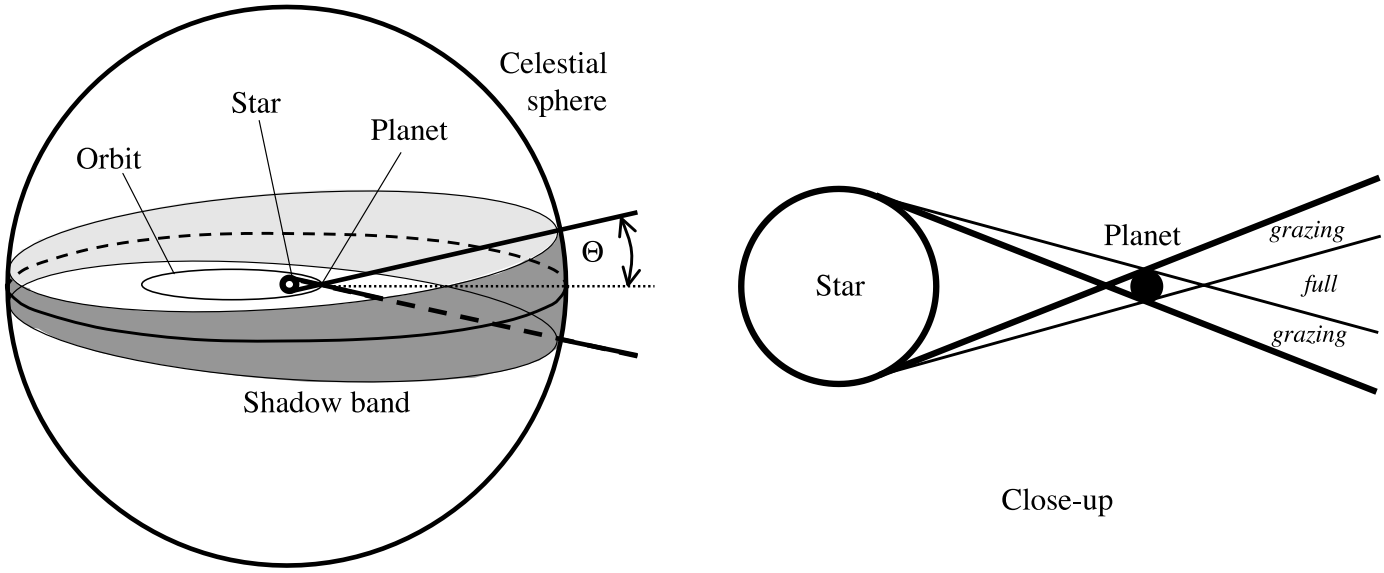
Transit Probability

To find a transit, the planet must pass in front of the star as viewed from Earth. Since different solar systems are not aligned, this means for many stars, the planets do no pass in front of the star, so many stars must be monitored to find the few that **do** transit

$$P = \frac{R_S}{a}$$



Derivation

Occurrence Rates of planets

Activity- Discuss in pairs

Q: A survey of 10000 similar stars find 100 stars the mass of the Sun with transiting planets on 10 day orbits. How many of the stars actually have planets? (for a star the mass of the Sun a 10 day orbit has an *a* of 1.36×10^{10}m). Think about what the transit probability is!

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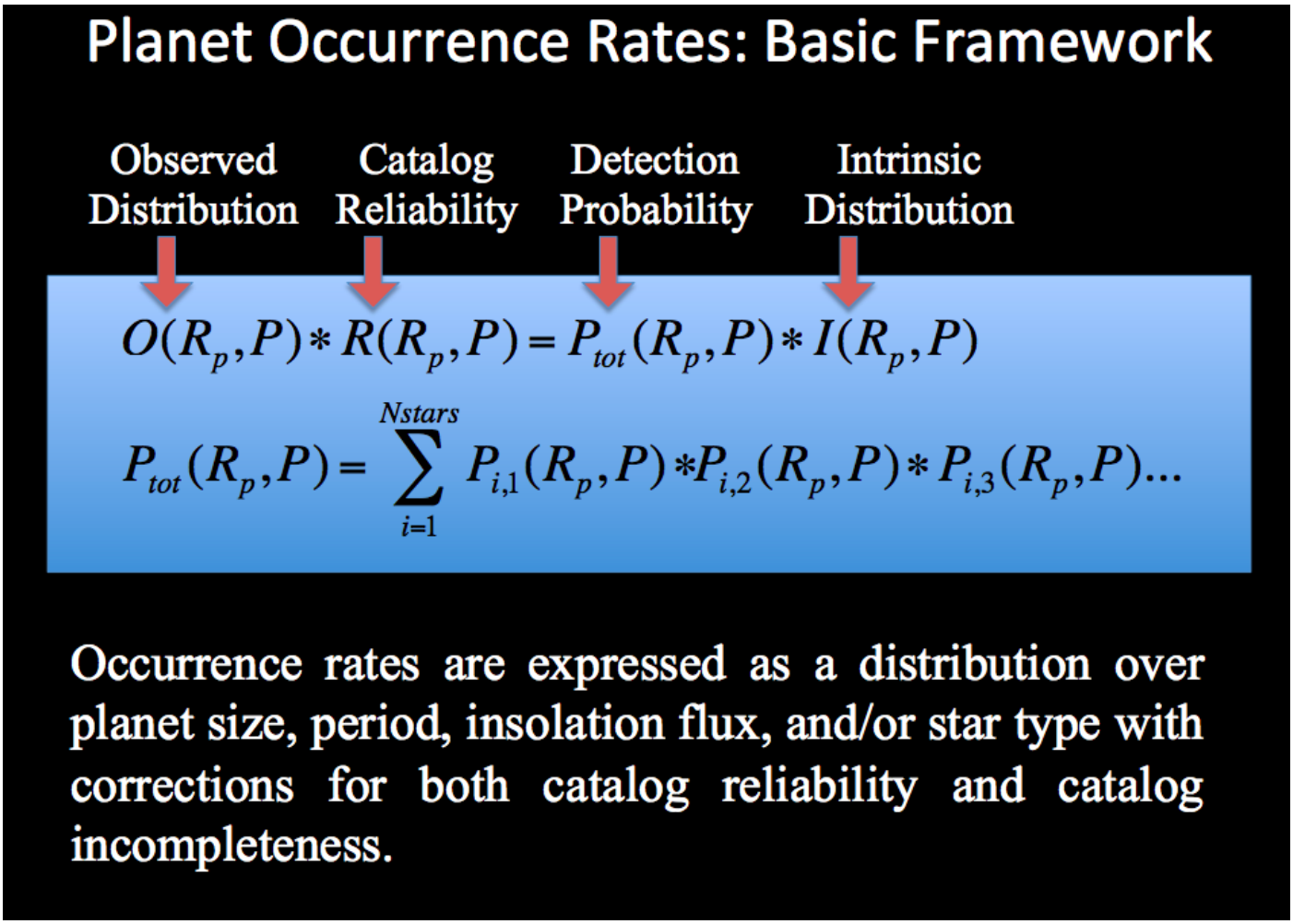

$$\text{Occurence rate} = \frac{\text{Detection rate}}{\text{Transit Probability}}$$

E.g

The Kepler mission has detected around 10 Earth like planets on orbits similar to the Earth around stars like the Sun. Using this information, we can approximately infer the true occurrence rate of planets like the Earth around stars like the Sun on similar orbits.

$$D_{rate} = \frac{10}{40{,}000} = 0.025\%$$

$$P_{tran} = \frac{R_{Star}}{a} = \frac{6.96 \times 10^8}{1.50 \times 10^{11}} = 0.47\%$$

$$O_{rate} = \frac{D_{rate}}{P_{tran}} = \frac{0.025\%}{0.47\%} = 5.32\%$$

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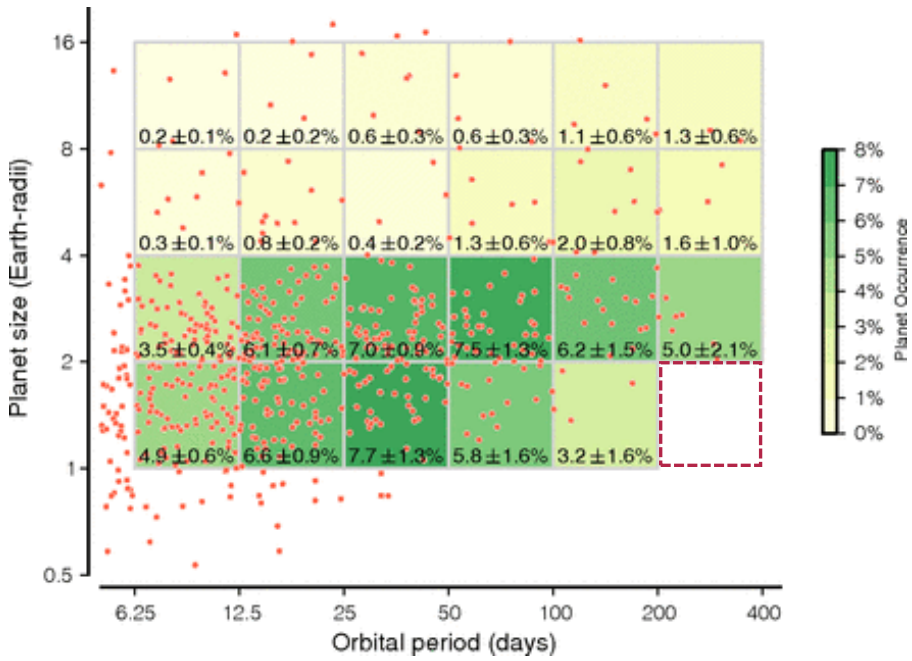
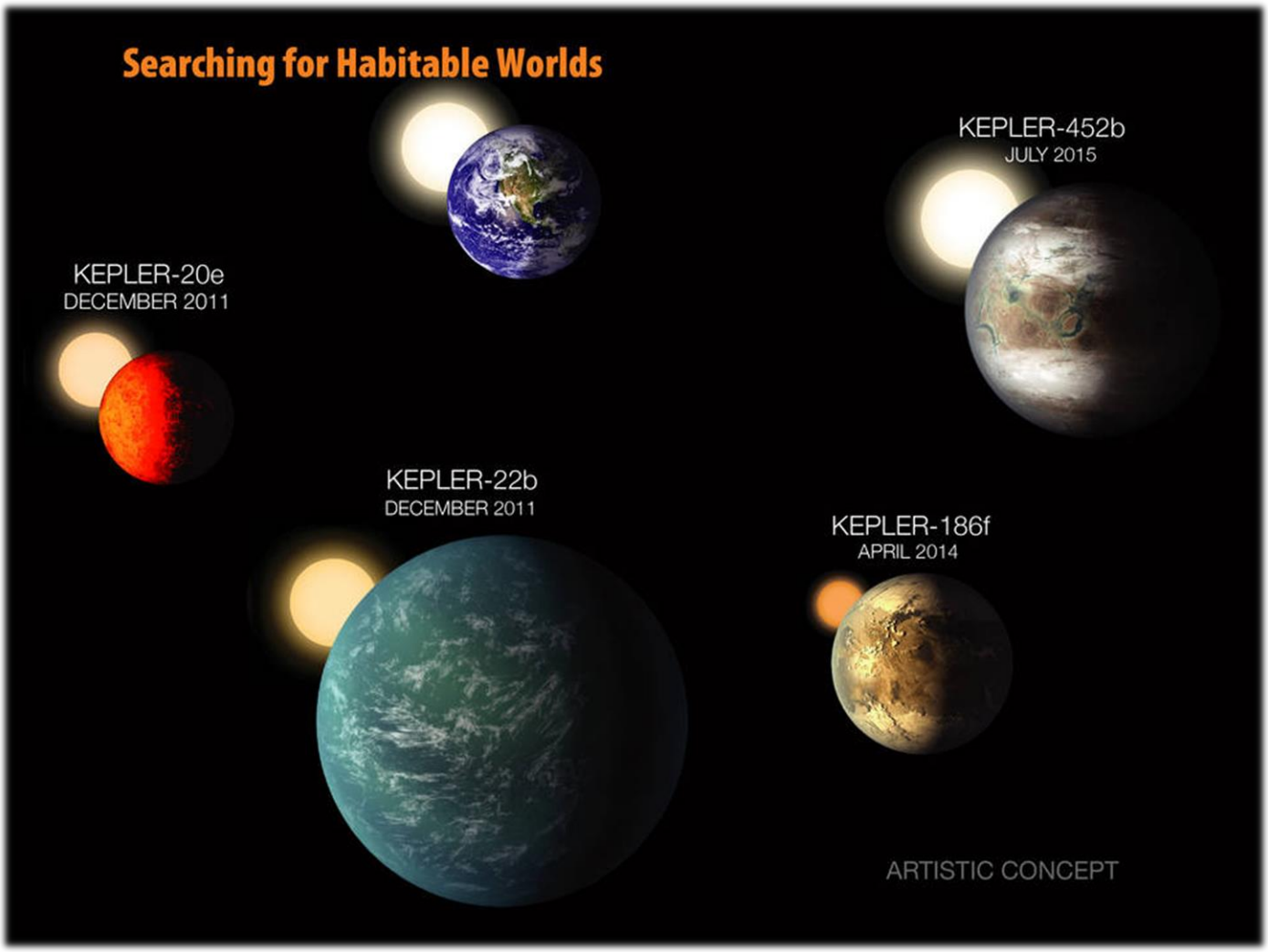
Around 5% of stars very similar to Sun should be expected to have planets or the same as the Earth in orbits much like the Earth's. This value is sometimes called 'eta-Earth' or $\eta_{e.}$ There are some **caveats** to this value though!



Notes



The sweep of NASA Kepler mission's search for small, habitable planets in the last six years. The first planet smaller than Earth, Kepler-20e, was discovered in December 2011 orbiting a Sun-like star slightly cooler and smaller than our sun every six days. But it is scorching hot and unable to maintain an atmosphere or a liquid water ocean. Kepler-22b was announced in the same month, as the first planet in the habitable zone of a sun-like star, but is more than twice the size of Earth and therefore unlikely to have a solid surface. Kepler-186f was discovered in April 2014 and is the first Earth-size planet found in the habitable zone of a small, cool M dwarf about half the size and mass of our sun. Kepler-452b is the first near-Earth-Size planet in the habitable zone of a star very similar to the sun.
Credits: NASA Ames/W. Stenzel

Homework: Transits

1) Calculate the transit depth and probability for the Earth and Jupiter

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2) For the Earth and Jupiter calculate the minimum number of stars needed to detect one such planet if every star hosted had such planets

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3) Around Sun-like stars, Earth-like planets on Earth-like orbits (habitable planets) have a calculated occurrence rate of ~5%. Considering this, and the transit probability previously calculated, how many stars should you observe to hope to find another Earth (Earth 2.0)

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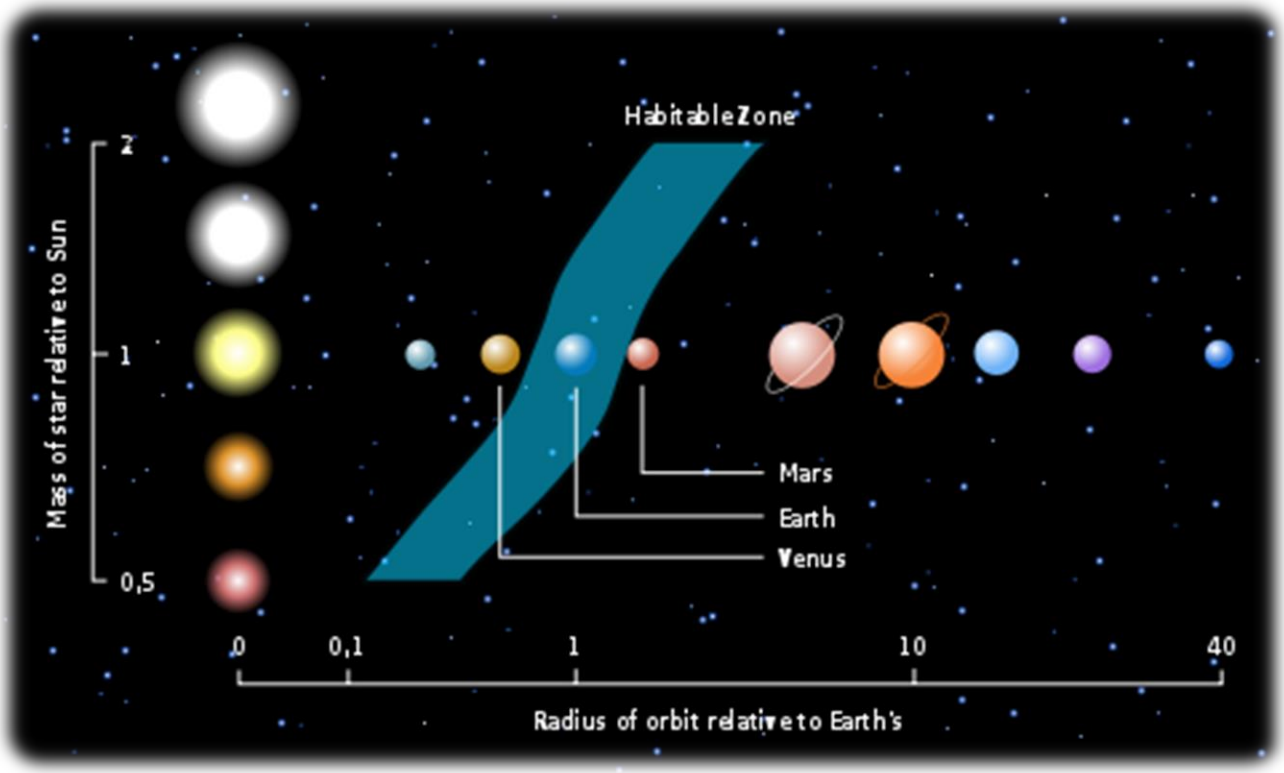
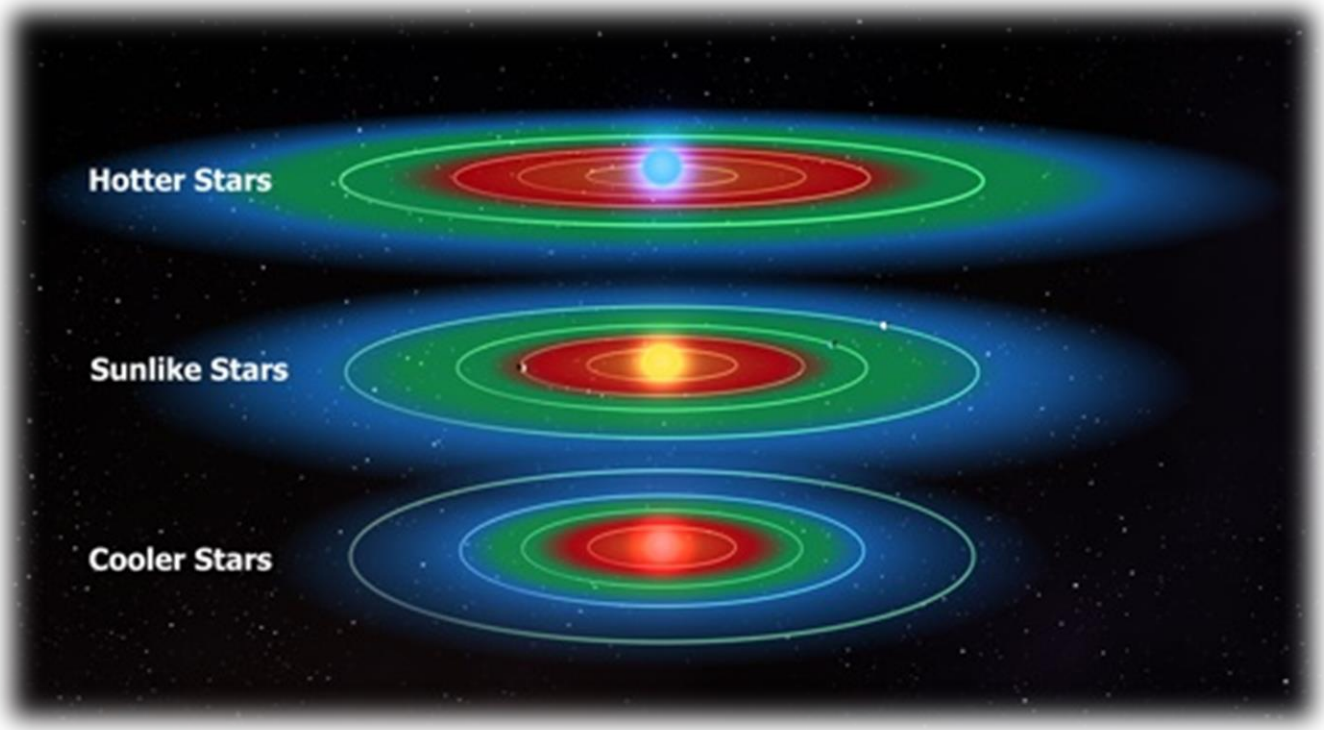
Tutorial 4 – Life and habitability





What is the Purpose of Tutorial 4?

- To define the habitable zone of a star, and understand the underlying assumptions and possible flaws in the definition
- (If feeling brave) Produce equation to describe the equilibrium temperature of a planet based upon the luminosity of the star and the distance to the planet

Activity: What makes a planet habitable

Consider the pictures below and list the order of importance on the following page. Comment on what each of these processes needs to get started and be maintained

$$N = R_\star \cdot f_p \cdot n_e \cdot f_l \cdot f_i \cdot f_c \cdot L$$

Notes

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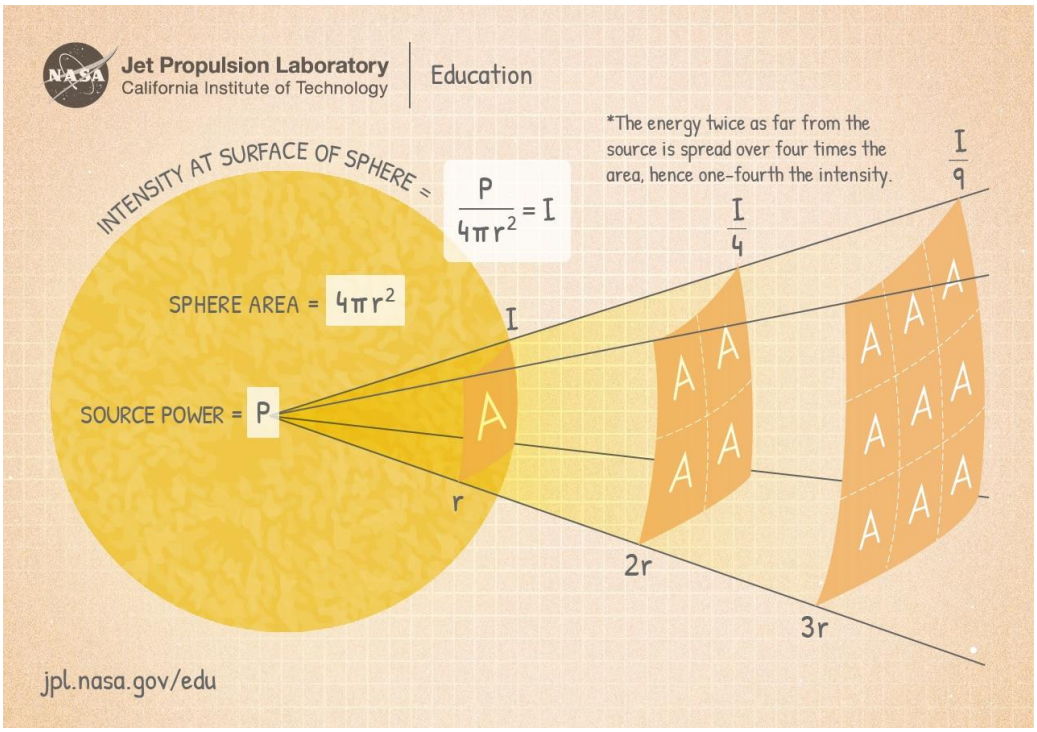
Habitable Zone Pt I

The habitable zone of a star can be defined as the region of orbits in which liquid water can exist on the surface of a planet. This is just one definition of the habitable zone.

More Constants	Value



Light intensity from a star also falls off as an **inverse square law**

Habitable Zone Pt II
Equilibrium temperature derivation

The surface temperature of planet is dominated by the energy it receives from the star it orbits, for planets near the star.

In our Solar System the giant planets radiate more than they receive but we aren't going to worry about that!

This calculation also ignores tidal heating, which for moons of giant planets, can be very strong, and keep the moon warm over astronomical timescales.

The impact of if the planet is rotating or is tidally locked to the star like the Moon is to the Earth (we only ever see one side of the Moon from Earth because it rotates in exactly the same time it takes to orbit the Earth) is ignored in the basic calculation.

Luminosity is form of power, measured in watts (like lightbulbs). Intensity (or flux) is measured in power per unit area (W/m^2)

The amount of light reflected by a planet is known as the albedo *A*

Key equations and conditions

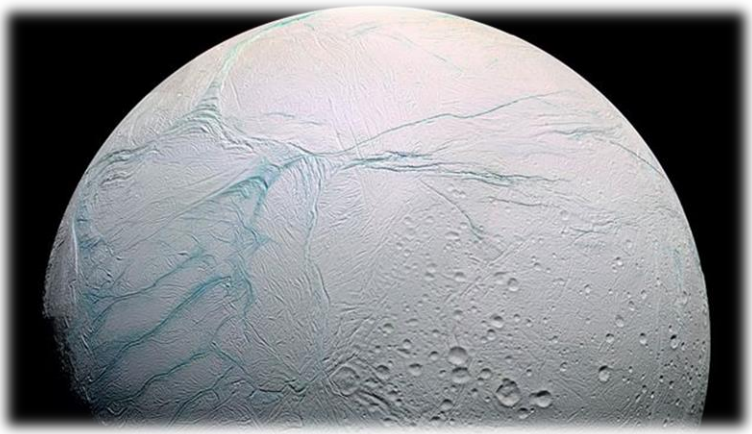
$$L = 4\pi R^2 \sigma T_{eff}^4$$

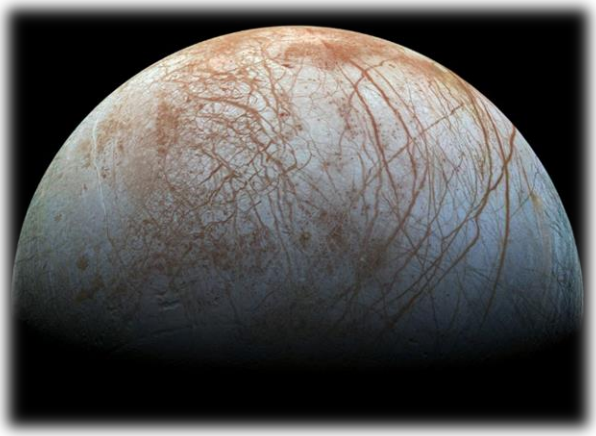
$$Power\ in \equiv Power\ out$$

$$F = \frac{L}{4\pi a^2}$$

Notes

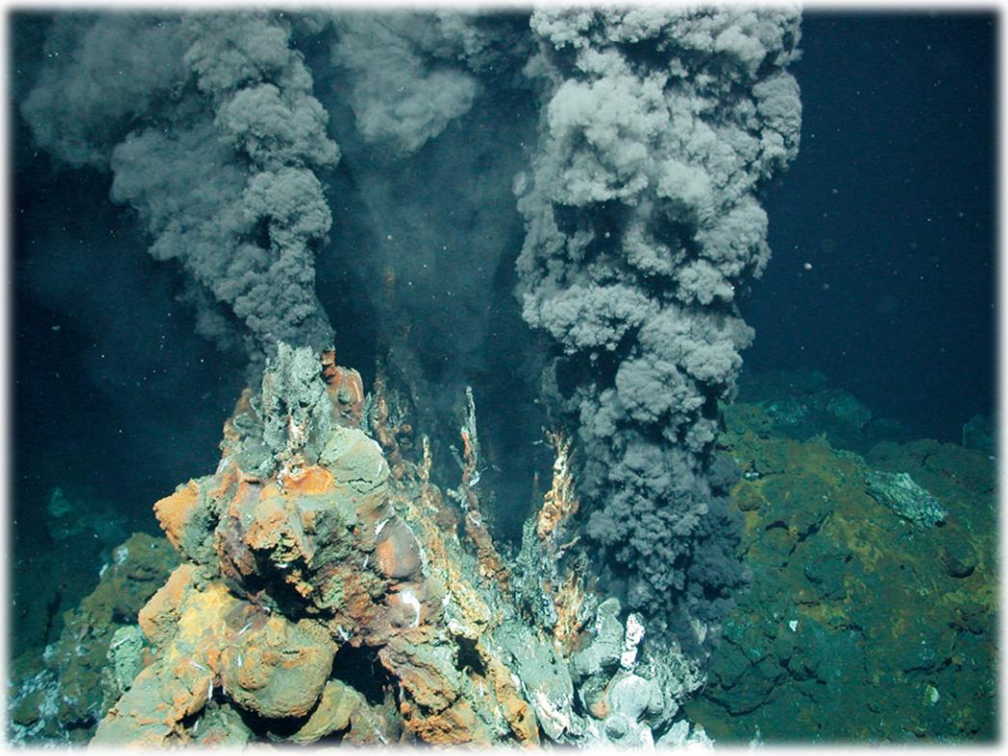
Where else *could* life exist?



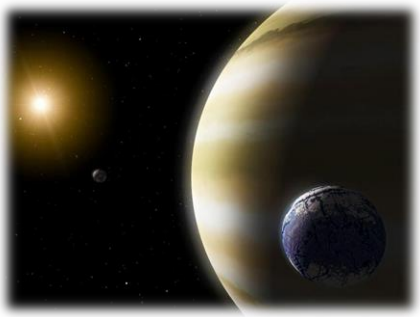


Moons of giant planets could harbour life! Kept warm by tidal forces, both Saturn's moon Enceladus (left) and Jupiter's moon Europa are believed to have liquid water oceans under an insulating layer of ice.

There are even places on Earth that operate with limited input from the Sun as the bottom of the ocean in hydrothermal vents, known as 'black smokers'



Activity: What do you think this means for the probability that life has evolved elsewhere in the universe? Class discussion-jot down any ideas here:



Notes

Notes

Questions/Homework

You will need to look up some information on the distances of the planets to the Sun

1) What is the equilibrium temperature of Venus, Earth and Mars? For albedo assume the following, Venus 0.7, Earth 0.3, Mars 0.4.

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2) What atmospheric effect is the equilibrium temperature ignoring?

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3) What is the equilibrium temperature of Europa (assume same distance as Jupiter, with albedo of 0.8)?

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4) What is the energy source for Europa?

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5) What implications does this have for the evolution of life in systems with gas giants?

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6) What impact might the evolution of the Sun have on the habitable zone of our Solar System?

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7) In ~6 billion years, the Sun will have expanded to be a red giant, with a temperature of 4000K and a radius of ~0.8AU, what will the equilibrium temperature be on Earth then?

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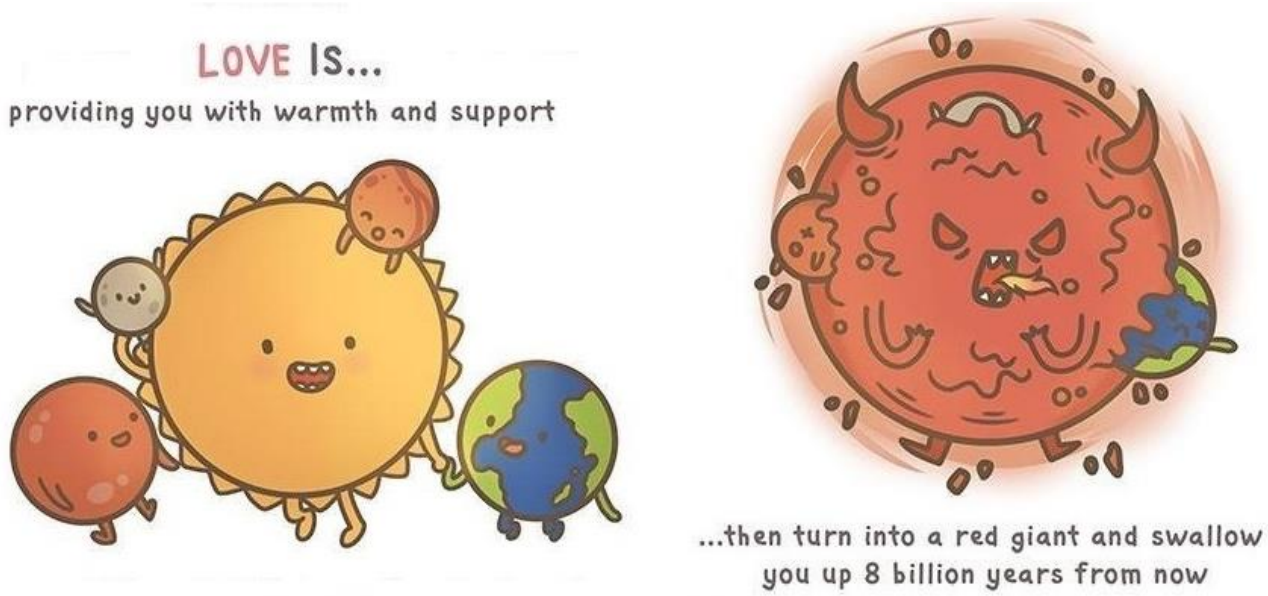


Tutorial 5 – Rise and Fall

What is the Purpose of Tutorial 5?

- Consider the dangers posed to life in the Universe, Galaxy, and on Earth
- Discuss the end of the world!
- Ask **any** science related questions you like
- Ask **any** university related questions you like

"It suddenly struck me that that tiny pea, pretty and blue, was the Earth. I put up my thumb and shut one eye, and my thumb blotted out the planet Earth. I didn't feel like a giant. I felt very, very small"

From this distant vantage point, the Earth might not seem of any particular interest. But for us, it's different. Consider again that dot. That's here. That's home. That's us. On it everyone you love, everyone you know, everyone you ever heard of, every human being who ever was, lived out their lives. The aggregate of our joy and suffering, thousands of confident religions, ideologies, and economic doctrines, every hunter and forager, every hero and coward, every creator and destroyer of civilization, every king and peasant, every young couple in love, every mother and father, hopeful child, inventor and explorer, every teacher of morals, every corrupt politician, every "superstar," every "supreme leader," every saint and sinner in the history of our species lived there – on a mote of dust suspended in a sunbeam.

The Earth is a very small stage in a vast cosmic arena. Think of the rivers of blood spilled by all those generals and emperors so that in glory and triumph they could become the momentary masters of a fraction of a dot. Think of the endless cruelties visited by the inhabitants of one corner of this pixel on the scarcely distinguishable inhabitants of some other corner. How frequent their misunderstandings, how eager they are to kill one another, how fervent their hatreds. Our posturings, our imagined self-importance, the delusion that we have some privileged position in the universe, are challenged by this point of pale light. Our planet is a lonely speck in the great enveloping cosmic dark. In our obscurity – in all this vastness – there is no hint that help will come from elsewhere to save us from ourselves.

The Earth is the only world known, so far, to harbor life. There is nowhere else, at least in the near future, to which our species could migrate. Visit, yes. Settle, not yet. Like it or not, for the moment, the Earth is where we make our stand. It has been said that astronomy is a humbling and character-building experience. There is perhaps no better demonstration of the folly of human conceits than this distant image of our tiny world. To me, it underscores our responsibility to deal more kindly with one another and to preserve and cherish the pale blue dot, the only home we've ever known.

•

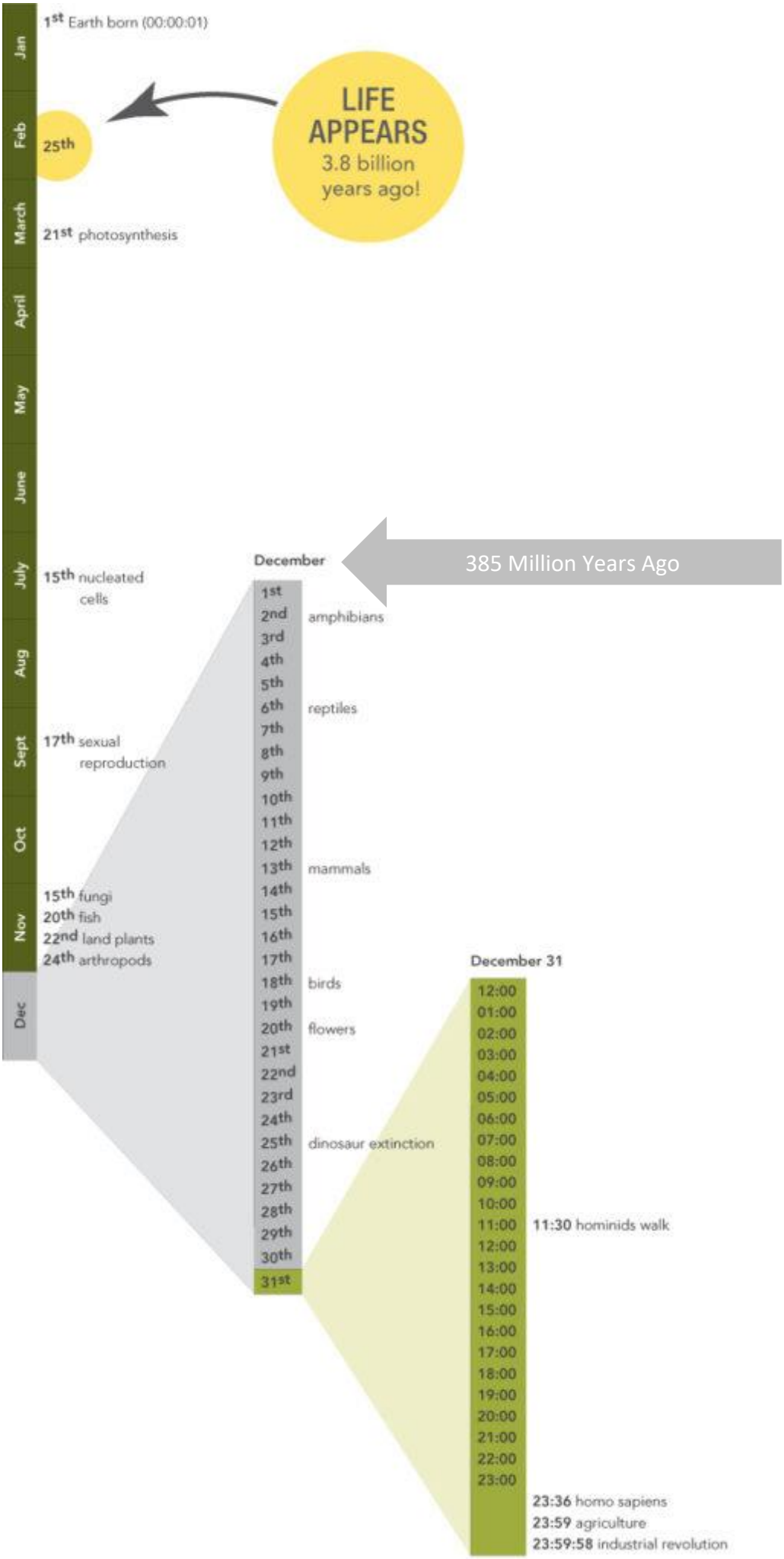
Carl Sagan

Pale Blue Dot

Activity: How to destroy life on Earth

$$N = R_\star \cdot f_p \cdot n_e \cdot f_l \cdot f_i \cdot f_c \cdot L$$

Threats to life on Earth


Jan
Feb
March
April
May
June
July
Aug
Sept
Oct
Nov
Dec
1st Earth born (00:00:01)
25th
LIFE APPEARS
3.8 billion years ago!
21st photosynthesis
15th nucleated cells
17th sexual reproduction
15th fungi
20th fish
22nd land plants
24th arthropods
December
385 Million Years Ago
1st
2nd amphibians
3rd
4th
5th
6th reptiles
7th
8th
9th
10th
11th
12th
13th mammals
14th
15th
16th
17th
18th birds
19th
20th flowers
21st
22nd
23rd
24th
25th dinosaur extinction
26th
27th
28th
29th
30th
31st
December 31
12:00
01:00
02:00
03:00
04:00
05:00
06:00
07:00
08:00
09:00
10:00
11:00
11:30 hominids walk
12:00
13:00
14:00
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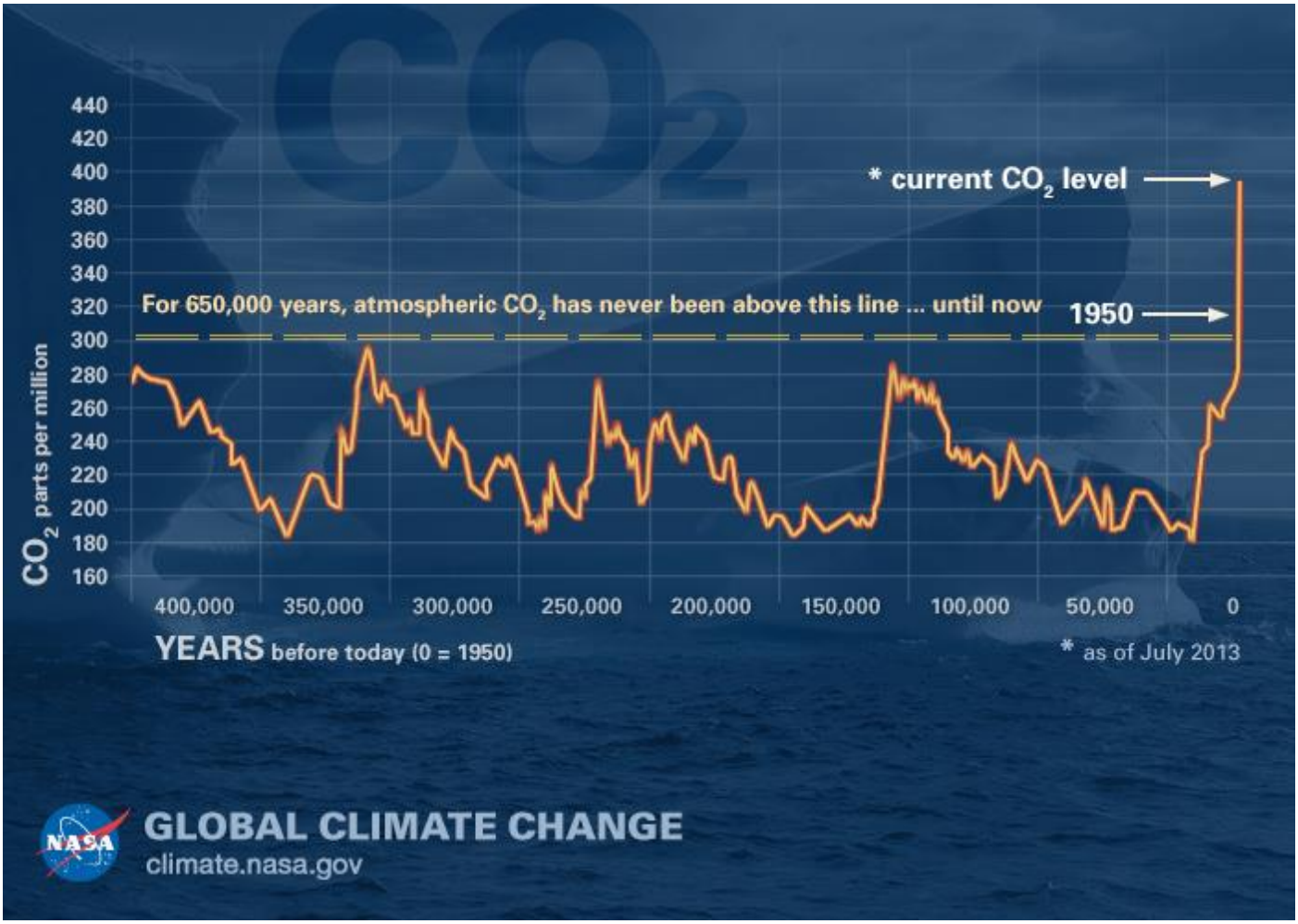
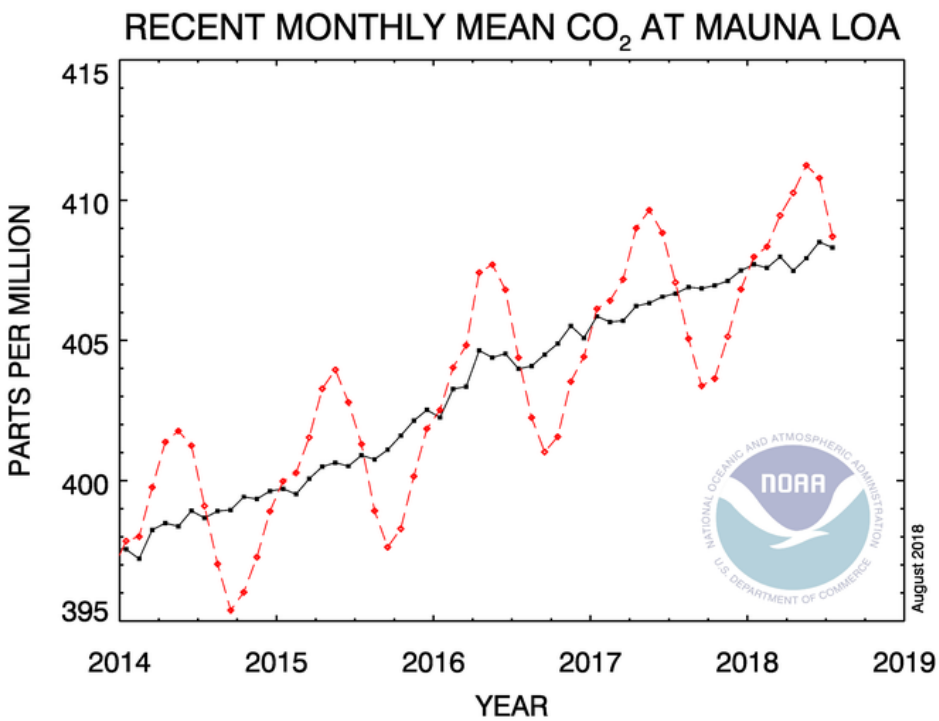
18:00
19:00
20:00
21:00
22:00
23:00
23:36 homo sapiens
23:59 agriculture
23:59:58 industrial revolution

Intelligent and contactable life

Humans are the greatest threat to life on Earth at the present time due to man-made climate change. This is the first time in the history of the planet that a single species has had such a pivotal role in the future evolution of the entire planet.

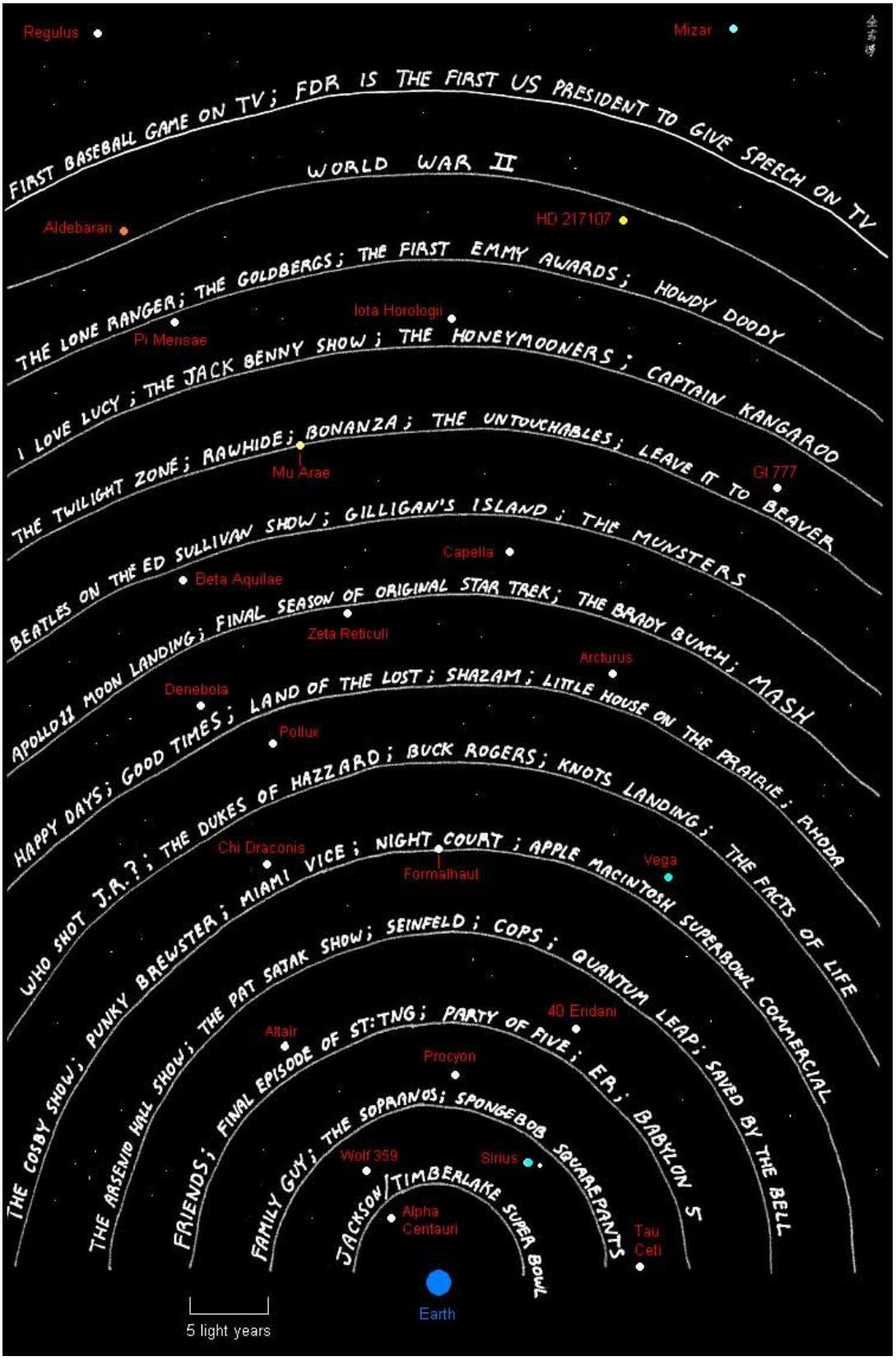




In ~200 years since the Industrial Revolution we as a species have had a considerable impact on the levels of CO_2 in the Earth's atmosphere.

Humans have only been contactable for ~50 years by extra-terrestrials as we have only been transmitting strong radio signals around the globe and into space for that long. While we have had radio for ~100 years, the signals would have been too weak to be detectable.

Remember a light-year is a measure of distance, and nothing can travel faster than light (or other electromagnetic waves like radio)



Q) If advanced aliens 400 light-years away turned their telescopes on Earth what would they see? Would they be able to contact us?

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Q) If advanced aliens 65 light-years away turned their telescopes on Earth what would they see? Would they consider such a world worth contacting?

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Q) For what percentage of time that life on Earth has existed has life been contactable?

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Q) For what percentage of time that life on Earth has existed has life been contactable?

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Extinction events

Life on Earth has suffered many setbacks before modern humans evolved. Best known is the extinction of the dinosaurs ~65Mya. This is also known as the K-T boundary, as it is the boundary of two geological eras, the Cretaceous (dinosaurs) and the Tertiary (post-dinosaurs).

Most scientists believe the Chicxulub crater, in Mexico is impact site of an asteroid, or comet, that wiped out the dinosaurs, along with 75% of life on Earth. The crater is around 100 miles across, and over 10 miles deep, most of the way through the crust of the planet.

Some scientists believe that dinosaurs could have continued to evolve to human-level intelligence if they had survived the K-T event. Modern birds, the descendants of dinosaurs are some of the most intelligent non-mammal species on the planet.

Over 99% of all species that have ever existed have now gone extinct.

Notes

Notes

Activity -in pairs

Q) What might have prevented the dinosaurs from developing the same technology (cars, planes, motors, generators, rockets) that have driven human industry the past 100 years?

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Activity-working alone

Do you believe we are alone in the universe? Jot down any ideas here as why you do or don’t believe in aliens:

Activity-Class discussion

Do you believe we will ever be able to contact/be contacted by an alien civilization?

Activity- Class discussion

Any questions about space, science, or university life?

Final Assignment

$$N = R_\star \cdot f_p \cdot n_e \cdot f_l \cdot f_i \cdot f_c \cdot L$$

Using the Drake Equation, given above, along with the information covered in the tutorials, and relevant online research, calculate a value for *N*. I suggest working through each parameter methodically as we have in this workbook.

The format for the assignment is a word-processed report (max 2500 words, min 2000 words) that should be fully referenced, with relevant tables, diagrams and figures where needed. If used, these should be in the relevant area of the text and should have a caption that fully explains the figure/table. Captions to do not count towards the word count.

Without figures 2000-2500 is 4 to 5 pages writing

The title for the assignment is **"Are we alone-a new look at the Drake Equation"**

To assist you with this I have given you a copy of one of my scientific papers I wrote during my PhD- also available at https://arxiv.org/abs/1708.00716
You do not need to understand the content, but be sure to look at the structure that goes as so:

- *A clear introduction, making clear what the question is and the justification*
- *A clear line of argument. In your case it might be a good idea to present your results in an abstract at the start ('I find a value of 2000 civilisations in the galaxy'), then go on in the text to develop your argument*
- *References to support your argument*
- *Recognising there may be alternate points of view*
- *Considering the validity of any assumption you make, and the potential impact on your final conclusions if the assumption is wrong*
- *A good figure can say 1000 words (not literally). A good figure can add strong impact to an argument*

- *One thing I want to make clear is that there are no wrong answers here, if you want to discuss this assignment outside of these tutorials remember that! I just want to see how you develop your argument. This is a key concept in science, backing your viewpoint with a strong and well justified argument, even if others have different answers*

- *Any plagiarism detected will incur a loss of marks. Be sure to reference properly and write in your own words, don't just copy and paste off the Internet*

To do this in a scientific manner you will need to do the following:

- Justify all assumptions
- Give clear reasoning and discussion for whatever value you find for each parameter
- Clear introduction and conclusion to the report
- Justification for the work
- Correct usage of scientific terminology-your vocabulary table may be useful there

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Tutorial 6 – Feedback tutorial on draft assignment

What is the Purpose of Tutorial 6?

- To receive feedback on final assignments **drafts**.
- To share examples of best practice with the other pupils in your group.
- To write targets for improvement in school lessons.
- To reflect on the programme including what was enjoyed and what was challenging.

Final assignment feedback

What I did well…	What I could improve on…
•	•
•	•
•	•

My target for final draft is…

Tutorial 7 – Feedback tutorial

What is the Purpose of Tutorial 7?

- To receive feedback on final assignments.
- To share examples of best practice with the other pupils in your group.
- To write targets for improvement in school lessons.
- To reflect on the programme including what was enjoyed and what was challenging.

Final assignment feedback

What I did well…	What I could have improved on…
•	•
•	•
•	•

My target for future work is…

Reflecting on Uni Pathways

What did you most enjoy about Uni Pathways?
•   •   •

What did you find challenging about the programme?	How did you overcome these challenges?
• • •	• • •

Uni Pathways next year-looking ahead

Next year, you will receive another set of tutorials tailored around one specific aspect of the GCSE Physics curriculum that I identify students struggling with.

Questions/Notes

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Appendix 1 – Referencing correctly

When you get to university, you will need to include references in the assignments that you write, so we would like you to start getting into the habit of referencing in your Brilliant Club assignment. This is really important, because it will help you to avoid plagiarism. Plagiarism is when you take someone else's work or ideas and pass them off as your own. Whether plagiarism is deliberate or accidental, the consequences can be severe. In order to avoid losing marks in your final assignment, or even failing, you must be careful to reference your sources correctly.

What is a reference?

A reference is just a note in your assignment which says if you have referred to or been influenced by another source such as book, website or article. For example, if you use the internet to research a particular subject, and you want to include a specific piece of information from this website, you will need to reference it.

Why should I reference?

Referencing is important in your work for the following reasons:

It gives credit to the authors of any sources you have referred to or been influenced by.
It supports the arguments you make in your assignments.
It demonstrates the variety of sources you have used.
It helps to prevent you losing marks, or failing, due to plagiarism.

When should I use a reference?

You should use a reference when you:

Quote directly from another source.
Summarise or rephrase another piece of work.
Include a specific statistic or fact from a source.

How do I reference?

There are a number of different ways of referencing, and these often vary depending on what subject you are studying. The most important to thing is to be consistent. This means that you need to stick to the same system throughout your whole assignment. Here is a basic system of referencing that you can use, which consists of the following two parts:

1. A marker in your assignment: After you have used a reference in your assignment (you have read something and included it in your work as a quote, or re-written it your own words) you should mark this is in your text with a number, e.g. [1]. The next time you use a reference you should use the next number, e.g. [2].
2. Bibliography: This is just a list of the references you have used in your assignment. In the bibliography, you list your references by the numbers you have used, and include as much information as you have about the reference. The list below gives what should be included for different sources.

    a. Websites – Author (if possible), title of the web page, website address, [date you accessed it, in square brackets].

    E.g. Dan Snow, 'How did so many soldiers survive the trenches?', http://www.bbc.co.uk/guides/z3kgjxs#zg2dtfr [11 July 2014].

    b. Books – Author, date published, title of book (in italics), pages where the information came from.

    E.g. S. Dubner and S. Levitt, (2006) Freakonomics, 7-9.

    c. Articles – Author, 'title of the article' (with quotation marks), where the article comes from (newspaper, journal etc.), date of the article.

    E.g. Maev Kennedy, 'The lights to go out across the UK to mark First World War's centenary', Guardian, 10 July 2014.

Notes

Hello, is anyone out there?

Key Stage 3 Programme

researchersinschools.org