

The Search for Extraterrestrial Intelligence (SETI)

and having fun with the Drake Equation

By Leigh Edwards

Overview

Speculations on other worlds and advanced intelligence

First SETI attempts

The Drake Equation set out

Background on habitability

The Drake Equation factors and their values

Fun with the numbers

Drake equation criticisms and variants

The scale of things and numerical probabilities

SETI – searching and sending

The Fermi Paradox

What if we find them?

Where does that leave us?

Existence of Other Worlds & Intelligence

First Era - philosophical discussions

Anaximander 600 BC, a Greek Philosopher - Cosmic Pluralism – speculated on the plurality of worlds

Lucretius 1st century BC, a Roman poet and philosopher spoke of other parts of the universe with races of different men and animals

What happened on Earth must have also have happened elsewhere

All based on no data at all

Second Era - Copernican revolution starting in 1543

From Earth stationary at the centre of the universe – the Ptolemaic view

To the heliocentric model with the Sun at the centre of the Solar System & Earth in orbit with all the other planets

Based on the first planetary observations lead to philosophical discussions about other worlds and life in the Cosmos

Such views could be deadly - Giordano Bruno 1600

Third Era – 1959/60

Calculations on the probability and first measurements for signs of life elsewhere

Fourth Era is now with thorough quantitative searches

First SETI Proposal

September 1959

Physicists Giuseppe Cocconi & Philip Morrison published in Nature

With the provocative title

"Searching for Interstellar Communications"

On the basis that Radio Telescopes were becoming sensitive enough -
from around 10 light years out

First Systematic SETI Search

Seven months later, in 1960, Frank Drake made the first search for extra-terrestrial signals at some personal risk

Using the 25 meter dish of the National Radio Astronomy Observatory in Green Bank, West Virginia

Monitored two nearby Sun-like stars:

Epsilon Eridani (10.5 lya) &

Tau Ceti (12 lya)

lya = light years away, 1 ly \approx 6 trillion km

Project Ozma slowly scanned frequencies (1420 MHz) close to the 21 cm wavelength, one channel at a time for six hours a day from April to July in 1960 – 200 hours

Although well designed, inexpensive & simple, by today's standards, it was unsuccessful



The Drake Equation Origin

To estimate the number of detectable advanced intelligent alien civilisations in our Milky Way Galaxy

Devised in 1961 by Frank Drake

Basis of an agenda for the first ever meeting on SETI

With only ten attendees at Green Bank , West Virginia, USA



The Drake Equation

$$N = R^* \times f_p \times n_e \times f_l \times f_i \times f_c \times L \text{ - where:}$$

N = The number of civilizations in our Galaxy whose electromagnetic emissions are detectable

R^* = rate of star formation per year in our Milky Way galaxy

f_p = fraction of those stars with planets

n_e = average number of planets that can potentially support life per star that has planets

f_l = fraction of those planets with life

f_i = fraction of those with intelligent life

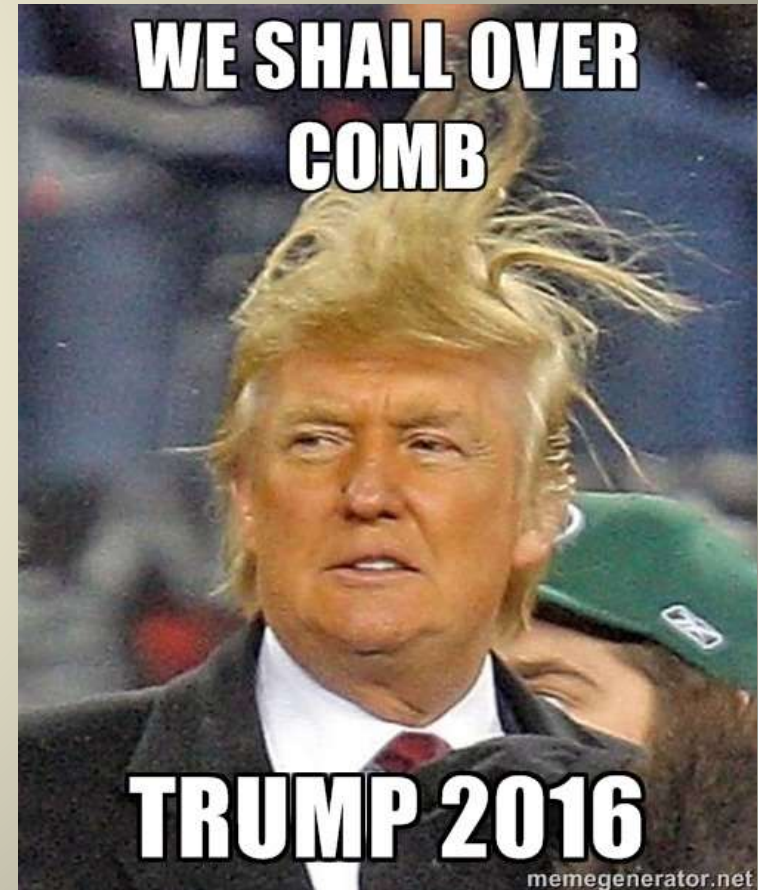
f_c = fraction that communicate outside of their planet either accidentally or deliberately

L = Longevity of the detectable phase

Do We Qualify as Advanced?

You do have to wonder sometimes!

Do we have advanced technology?



Do We Qualify as Advanced?

We've had radio communications for only around 100 years Marconi 1897

High power radio, television and radar transmissions for around 60 or so years

A sphere of artificial electromagnetic radiation has been expanding outwards from the Earth at the speed of light

Now our power output and hence visibility is dropping due to satellites and digital signals

An extraterrestrial intelligence could deduce the existence of Intelligent life in our Solar System up to 60 light years away (assuming they have very sensitive radio telescopes)

Limited (short-duration) manned spaceflight for around 50 years

Robotic spacecraft to the edge of the Solar System only in the past few decades



The Milky Way Galaxy

Milky Way Galaxy sphere forming 11 Bya from stars coming together due to gravity,
thin disc forming 9 Bya

Grew by more stars forming from hydrogen gas & through mergers with other galaxies

Now at least 300 billion stars in the flat disc of our Milky Way Galaxy stretching over
100,000 light-years across

Gaia ESA Satellite Dec 2013 3D map of Milky Way, 100,000 stars per hour for 5 years,
whole sky 70 times

1 billion pixel cameras, map each stars position, motion, distance & brightness

Bya = Billions of years ago

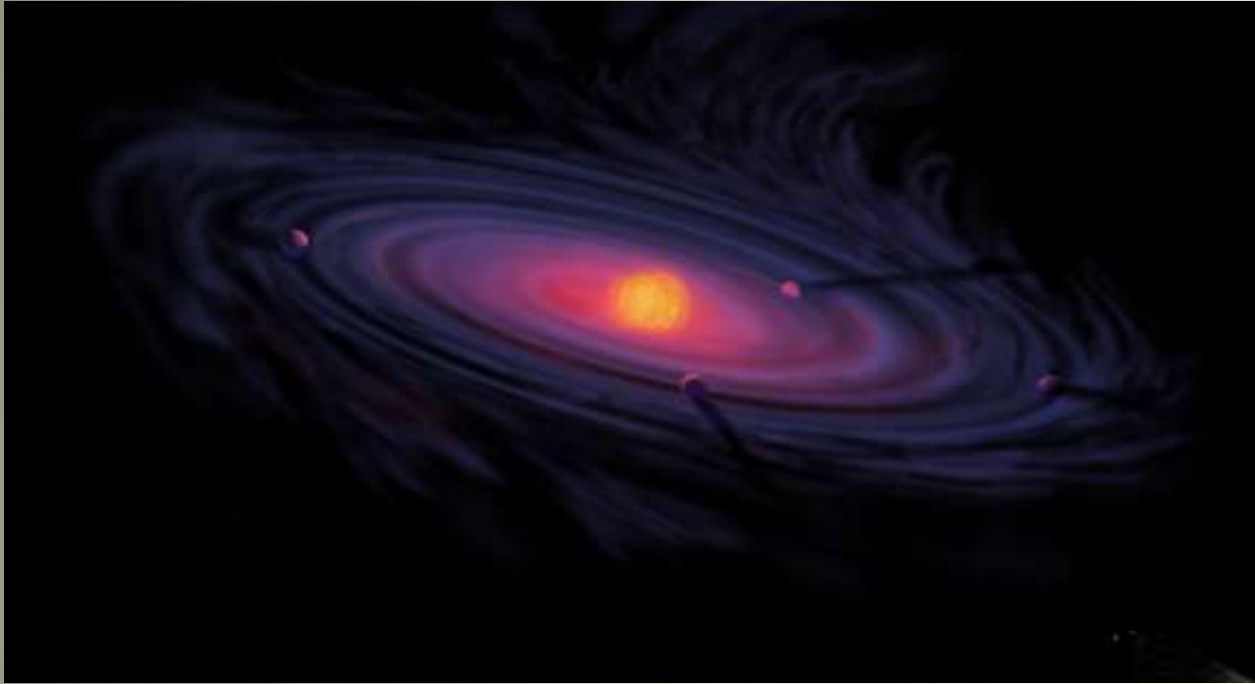


Milky Way started spherical



Later it formed into a thin disc

Solar System and Earth's Formation



Sun and Solar system forming around 4.57 Bya

From a proto-planetary disc where the Sun is 99.86% of the total mass

Earth and all of the planets are the dust left over and are less than 0.3% by mass

Earth formed around 4.54 Bya by accretion of material from the Solar Nebula

Earth is approximately one-third of the age of the Universe

Bya = Billions of years ago

The Goldilocks Zone

The range of orbits around a star within which a planetary surface can support liquid water given sufficient atmospheric pressure

Technically called the: Circumstellar Habitable Zone (CHZ)

The bounds of the CHZ are based on Earth's position in the Solar System and the amount of radiant energy it receives from the Sun

For different types of star the habitable zone could be larger or smaller than that for the Earth e.g. Red Dwarf stars

Goldilocks zone has recently been dramatically increased e.g. Trappist 1 system 7 rocky exoplanets and 3 or 4 in Goldilocks Zone e.g. volcanic hydrogen



“Goldilocks tweeted me that my porridge was just right.”

From Dead Chemistry to Live Biology

The complex processes that transformed chemistry into biology on Earth took millions of years

It then took billions of years of evolution to go from simple single cellular life to complex cellular life then to multi-cellular life

Then hundreds of millions of years to get to complex animal life based on specialised organs such hearts, livers, kidneys, and then to high intelligence & supremely complex structures like the human brain

Then for an intelligent species to develop technology & to start investigating its own origins & place in the universe



Chemistry in deep sea thermal vents



To biology via self replicating molecules - ultimately in the form of RNA & DNA

Nearest Star to the Sun

Proxima Centauri is the closest star to the Sun and is part of a group of three stars

Much too dim to be seen without a telescope – seen here in Infrared
It is only about 12% of the mass of our Sun

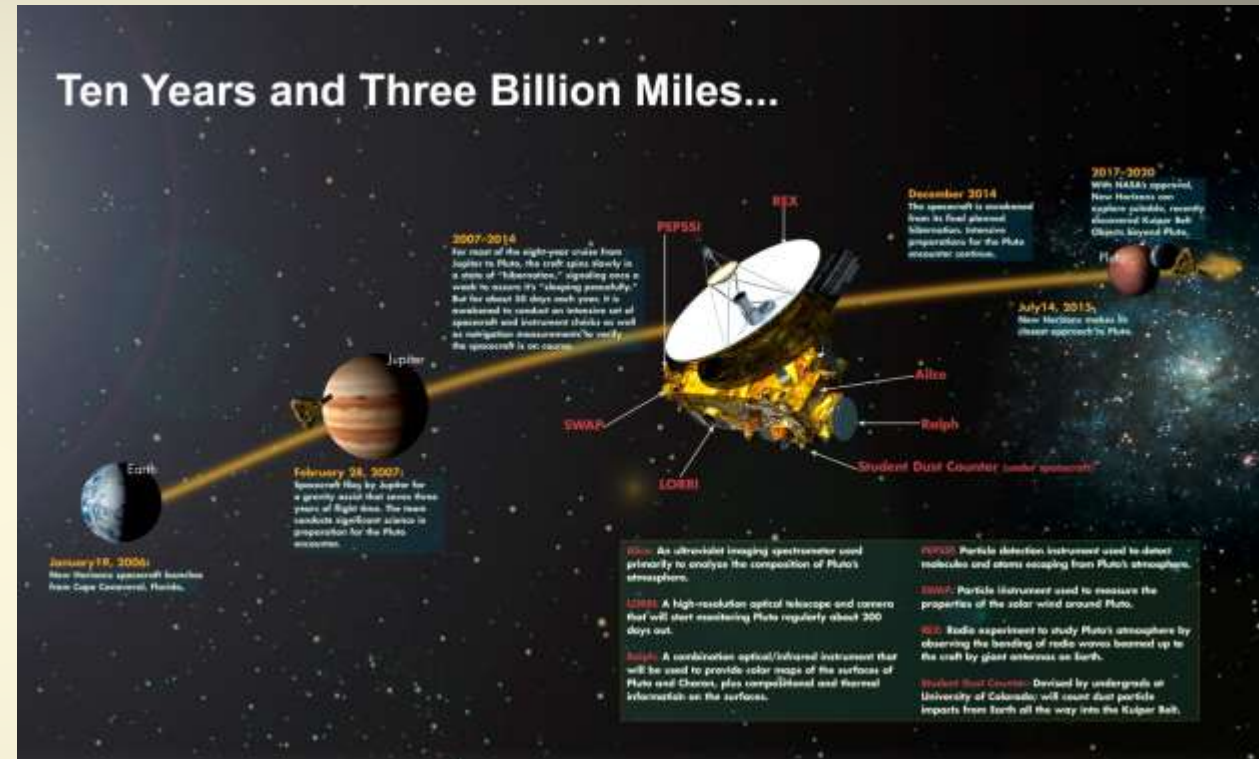
A rocky extra solar (exoplanet) planet with a mass similar to Earth's was recently (Oct 2016) detected around Proxima Centauri (Proxima b) in the Goldilocks Zone – now Proxima c found

Mystery signal apparently from Proxima Centauri system – Dec 2020 – more later

The light from Proxima Centauri takes 4.24 years to reach Earth
4.24 light years – new measure of distance

One light year = 9.461 trillion km or 5.86 trillion miles
So around 25 trillion miles away

New Horizons probe to Pluto took nearly ten years
Using similar spacecraft technology at 58,500 kmph (36,400mph) it would take nearly 77,000 years to reach Proxima Centauri



The Drake Equation – The Factors

$$N = R^* \times f_p \times n_e \times f_l \times f_i \times f_c \times L \text{ - where:}$$

N = The number of civilizations in Galaxy whose electromagnetic emissions are detectable – either accidentally or deliberately

The Drake Equation – The Factors

$$N = R^* \times f_p \times n_e \times f_l \times f_i \times f_c \times L \text{ - where:}$$

R^* = rate of suitable star formation per year in our galaxy the Milky Way

Many stars are not considered suitable e.g. very massive stars, variables etc.

The star must produce the right amount of energy to power the planet without too much heat and radiation

A star that has a reasonably long life (approx 10 billion years)

Long enough for life to arise and for evolution to do its work

Stars like the sun tend to either form solo stars with planets or a binaries with few if any planets

Recent calculations indicate that the current star formation rate in MW is about 4 solar masses per year

Using initial mass function (IMF) for stars, where the average new star mass is about $0.5 M_{\odot}$

This gives a star formation rate of about 7 – 8 stars per year

Sun sized stars is on the order of 3 per year

The Drake Equation – The Factors

$$N = R^* \times f_p \times n_e \times f_l \times f_i \times f_c \times L - \text{where:}$$

f_p = fraction of suitable stars with planets

Stars with planets are thought to be the rule not the exception

Now shown theoretically that binary or multiple star systems can have planets (and with stable orbits)

f_p now thought to be around 1.6

If you include moons then it is much higher

Kepler Space Based Telescope

1995 until the first confirmed exoplanet was found named 51 Pegasi b

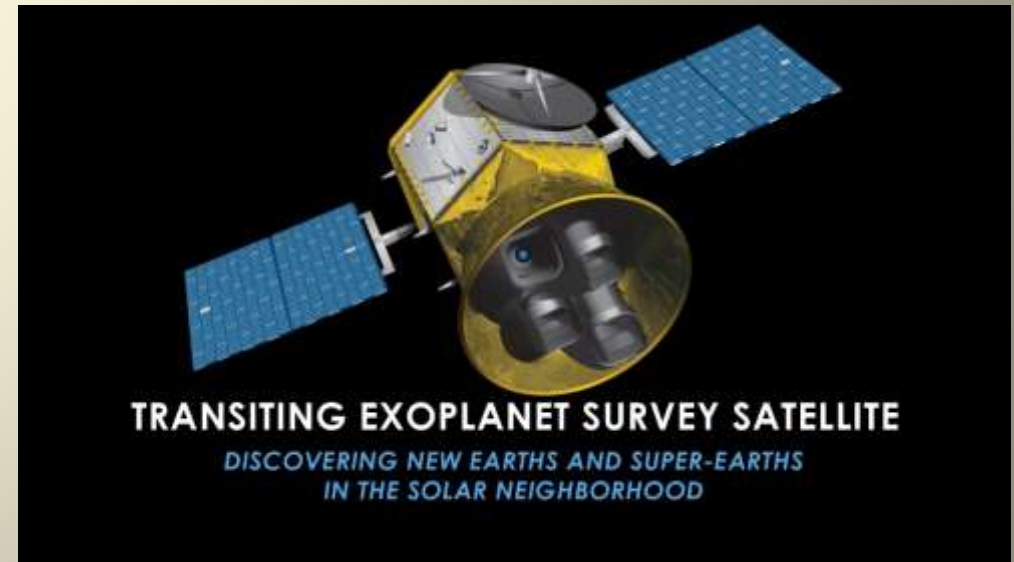
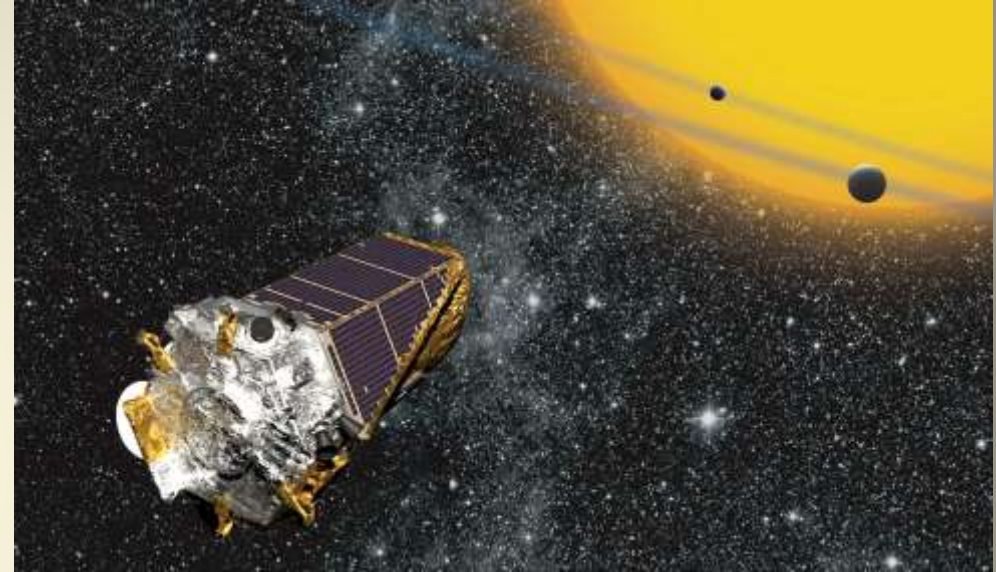
A statistical study suggests that in the Milky Way, each star has an average of 1.6 planets in orbit

Kepler for exoplanets – right – retired as of May 4 2017, the extrasolar planets listed >4300 confirmed exoplanets out of >5600 candidates

One in ten stars in MW could have an Earth-like planet around them

Estimated as many as 40 billion Earth-like planets in our Milky Way Galaxy
Around 11 billion of them are orbiting Sun-like stars, the rest mainly around Red Dwarves

New Transiting Exo-planet Survey Satellite TESS – launched March 2018



The Drake Equation – The Factors

$$N = R^* \times f_p \times n_e \times f_l \times f_i \times f_c \times L \text{ - where:}$$

n_e = the average number of those planets that can potentially support life (per star that has planets)

In the Goldilocks Zone – depends upon the type and size of star

The Drake Equation – The Factors

$N = R^* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$ - where:

f_l = fraction of those planets where life emerges

Need liquid water, organic compounds and a source of energy

Clues from Earth's history – a sample size of only one:

First life arose \approx 3.8 Bya (May 2017 4.28 Bya)

Multi-cellular life \approx 1.2 Bya

Cambrian explosion \approx 545 Mya

Land colonization \approx 475 Mya

Abiogenesis on Earth – once only?

Evidence for independent abiogenesis past or present in the Solar System e.g. Mars?

Unless you believe in Panspermia – accidental or directed

James Webb Space Telescope - Hubble On Steroids

Hubble telescope has provided so much new information, but it will eventually fail

James Webb Space Telescope – launch due in Oct 2021 – visible light plus far Infrared

Examination of exoplanets in much more detail – atmospheric composition etc. – biosignatures or even technosignatures



The Drake Equation – The Factors

$N = R^* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$ - where:

f_i = fraction of those with intelligent life, is even harder to guess

Homo Sapiens emerged $\approx 200,000$ years ago (June 2017 > 300,000 ya Morocco)

Took millions of years for life to emerge, but ≈ 40 times longer for an intelligent species to appear out of billions of species that have ever existed on earth

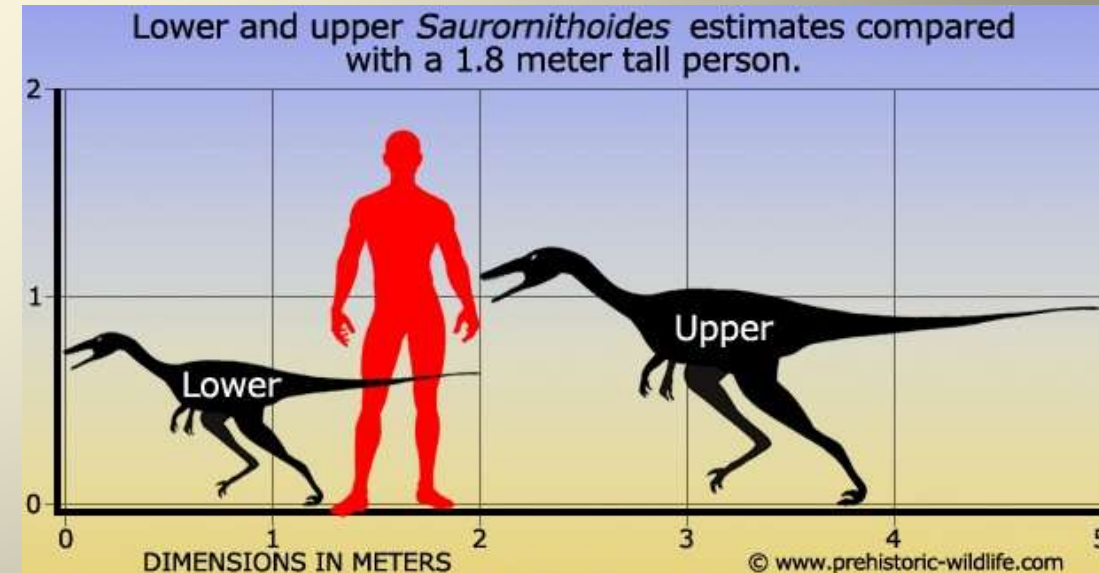
Saurornithoides a Dinosaur that possessed a very large brain case (100g) which was much bigger than any other known dinosaur
Stood on its hind limbs, had large eyes with binocular vision and had the equivalent of opposable thumbs.

Is intelligence too costly (evolutionary pov) for the advantages it confers?

Niche exploitation – sharks, birds - range, primates

Is Earth a very special place, stable, in a safe region, large moon stabilisation?

Wild Guess: f_i 0.1 (is it rarer than that, or maybe it just takes longer?)



The Drake Equation – The Factors

$N = R^* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$ - where:

f_c = fraction that communicate outside of their planet – either accidentally or deliberately via radio waves, visible light or Infrared, X-ray, gamma or even FRB's

Close enough to be detectable

1000 light years for directed signals e.g. Radar, light?

30 - 50 light years for stray signals?

Ocean only worlds – intelligence but no technology!

Effects of colonisation on this factor – more signals

The Drake Equation – The Factors

$N = R^* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$ - where:

L = Longevity of the detectable phase

Fall of civilisations – self inflicted or accidental – is this common?

Average duration on Earth is 336 years

Reappearance factor – but technology only very recent

Does contact increase the chances of survival?

Overcome the threats to achieve effective immortality?

Effects of colonisation on this factor – signals for longer time

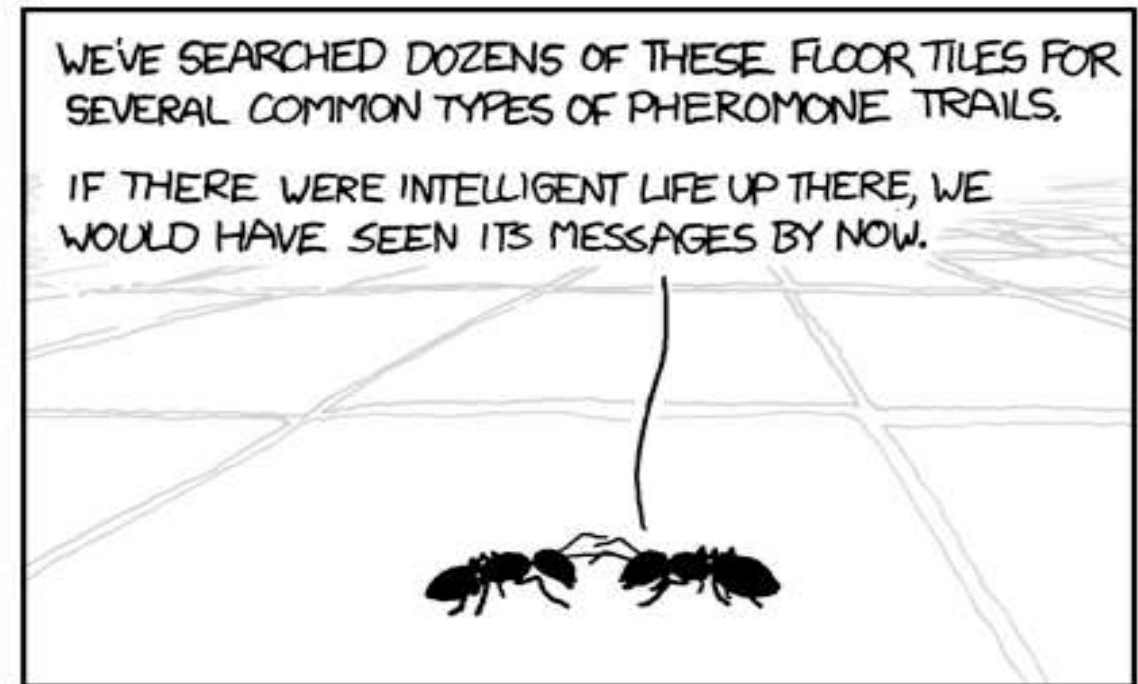
Extreme longevity – a few percent very long makes $N \approx L$

Most stars in our region of space are a billion years older than our Sun

So on average they will be billions (2) of years ahead of us

And would probably have little interest in us

Would we even recognise them if we tripped over them?



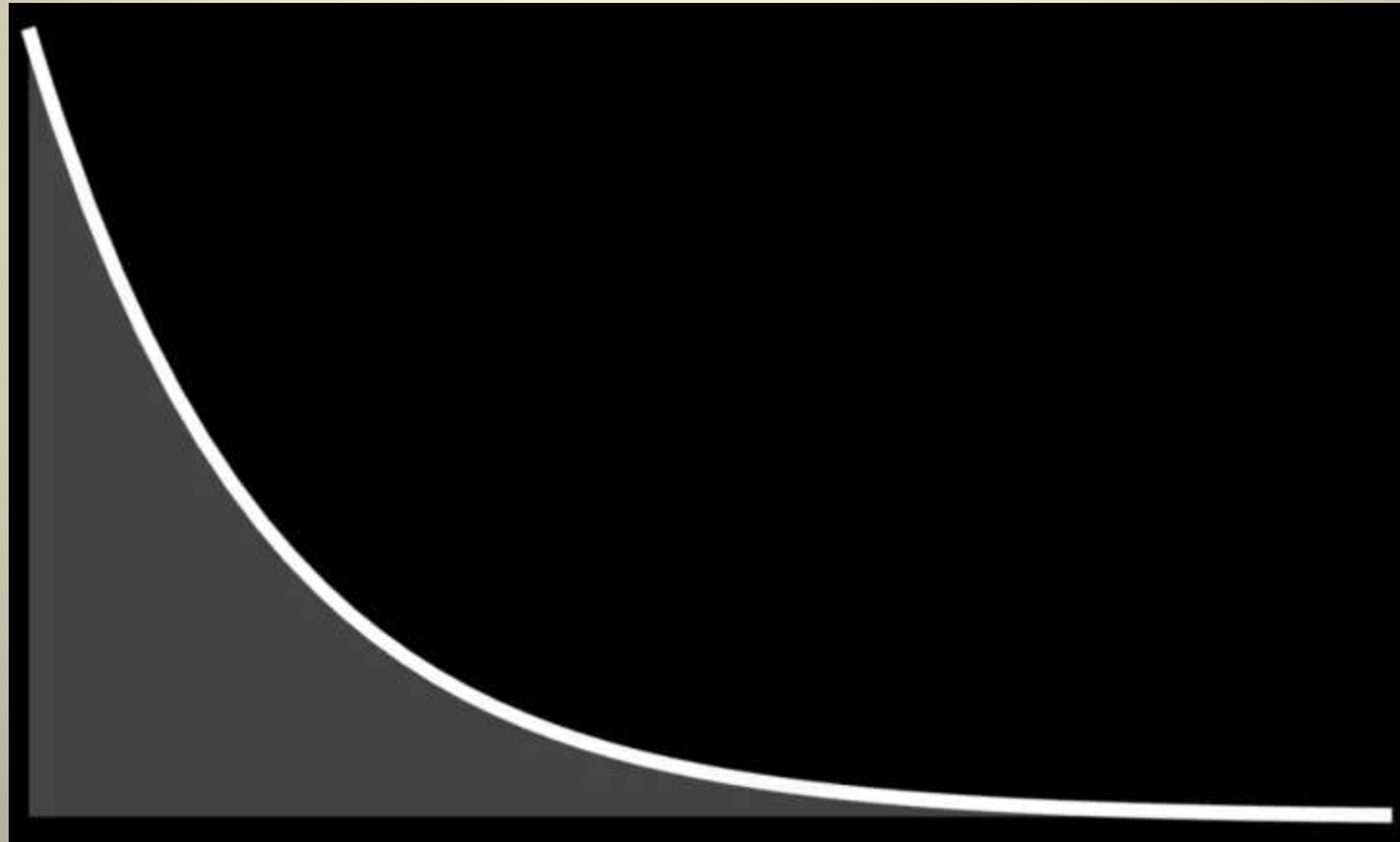
THE WORLD'S FIRST ANT COLONY TO ACHIEVE SENTIENCE CALLS OFF THE SEARCH FOR US.

The Drake Equation

$$N = R^* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

L = 25% younger & 75% older – so 3 out of 4 would be older

Number of
Civilisations



Time - >

The Drake Equation

$$N = R^* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

Let's have a bit of fun with the numbers

The Drake Equation - Lower Limits		
Term	Value	Description
R	0.00	Average rate of suitable star formation (stars/year)
f_p	0.00	Fraction of stars that form planets
n_e	0.00	Average number of habitable planets per star
f_l	0.00	Fraction of n _e where life emerges
f_i	0.00	Fraction of f _l where intelligent evolves
f_c	0.00	Fraction of f _i capable of interstellar communication
L	0	Years a civilization remains detectable
N_{mw}	0.0	The number of detectable civilizations in MW Galaxy
N_U	0	The number of possible civilizations in the Universe

The Drake Equation - Upper Limits		
Term	Value	Description
R	0.00	Average rate of suitable star formation (stars/year)
f_p	0.00	Fraction of stars that form planets
n_e	0.00	Average number of habitable planets per star
f_l	0.00	Fraction of n _e where life emerges
f_i	0.00	Fraction of f _l where intelligent evolves
f_c	0.00	Fraction of f _i capable of interstellar communication
L	0	Years a civilization remains detectable
N_{mw}	0.0	The number of detectable civilizations in MW Galaxy
N_U	0	The number of possible civilizations in the Universe

The Drake Equation – Criticisms

$$N = R^* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

Too many factors are very uncertain

No statistical estimates are possible for some parameters, where only one example is known

Coincidence factor – between communicating civilisations

Doesn't account for population dynamics if interstellar colonization is considered

We are gaining new knowledge all the time

e.g. Star formation and exoplanets data are getting more certain

Only intended as a way to stimulate dialogue

Then the focus becomes how to proceed experimentally

What parameters are most significant or uncertain

In terms of SETI design – what to look for, where to look, how to look

The Drake Equation – Variants

$$N = R^* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

Many attempt to account for, or quantify, the uncertainty inherent in many of the terms

Stochastic techniques – simulations seeking distribution type or patterns

Simulation and heuristics – non optimal practical problem solving

Some add in new ‘missing’ factors e.g.

To account for colonisation, reappearance, deliberate communication, biogenic atmospheric gases etc.

The odds that a habitable planet ever develops intelligent life i.e. that Earth is the only one

In our MW galaxy - less than 1.7×10^{-11} (about 1 in 60 billion)

In the whole universe - less than 2.5×10^{-24} (about 1 in 600 thousand billion billion)

Fastest Things

Light travels at 300,000 kilometres or 186,000 miles per second

Seems fast but on the scale of the universe it is extremely slow

The reflected light from the moon takes just over 1 second to reach us on earth

Sunlight takes 8 minutes and 19 seconds to reach us

Light from the most distant objects takes many years to reach us so when we look at them we see them as they were many years ago

Many billions of years ago in some cases!



Nearest Neighbouring Galaxy

Our nearest neighbouring Galaxy is Andromeda part of the local (galactic) group

Furthest object visible to the naked eye in the night sky

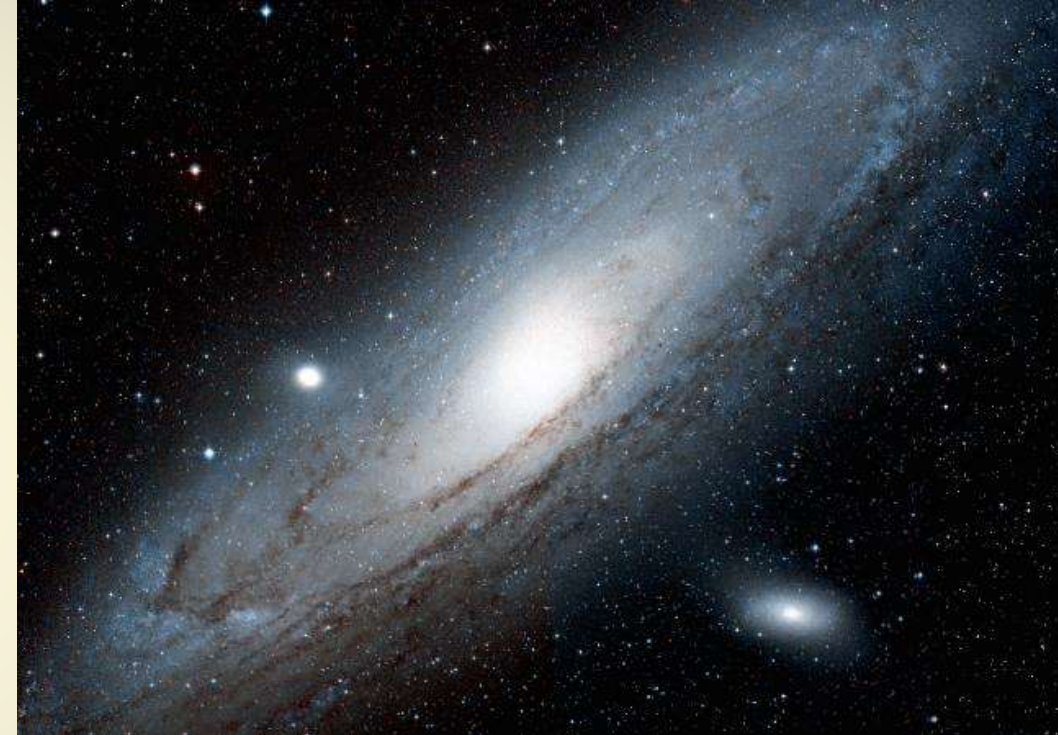
Over 220,000 light years across

Around a trillion or 1,000,000,000,000 stars

Its moving towards us at around 110 km (69 miles) per second

But it is 2.54 million light years away (one light year = 9.461 trillion km or 5.86 trillion miles)

So it will be 4.5 billion years before it collides with the Milky Way galaxy

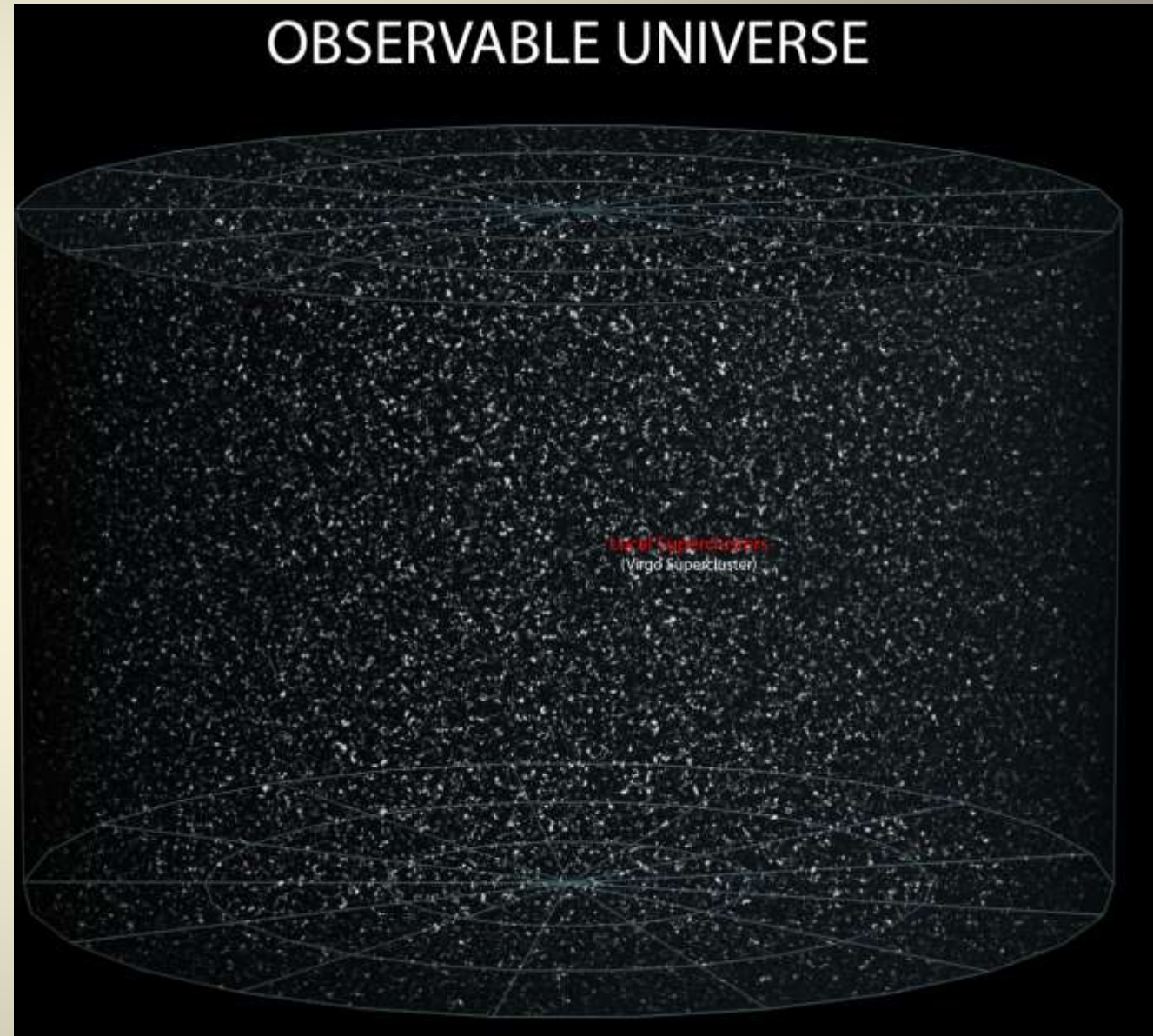


The Observable Universe

93 billion light years wide

Around 10 million galaxy super clusters in the observable Universe

There are between 400 billion to 2 trillion other galaxies



Sheer Numerical Probability

One reason we think intelligent life must have arisen elsewhere is the sheer number of stars and now exoplanets

In Milky Way 300 – 400 billion stars containing an estimated sixty billion potentially habitable planets

From 400 million to 2 trillion galaxies in the visible Universe

Say on average of 100 billion stars per galaxy

Total of $2 \times 10^{23} = 200$ billion trillion (or 200 Sextillion) stars

More stars in the universe than grains of sand on every beach on the Earth 7.5×10^{18}

Even a chance of 1 in 10^{12} (a trillion) would yield around 200 billion possible sites for life

But – we don't know how easily life arises or how often intelligence occurs – Bayesian statistics

Two key factors with four possibilities

The Fermi Paradox

If the galaxy and the universe are so big and so old (now with billions of exoplanets) then where is everyone else?

At lunch with other scientists one day in 1950, physicist Enrico Fermi posed a question he had been thinking about: 'Where are they all?'

A book published in 2015 (S. Webb) elaborated on 75 different explanations and the answers break down in a few groups

Intelligence is extremely rare, or Earth is a very rare type of planet, in a fortunate place or sparsely populated part of the Milky Way galaxy

In a universe teeming with simple life seems almost inevitable, but the odds do seem stacked heavily against intelligent, technological based, life arising

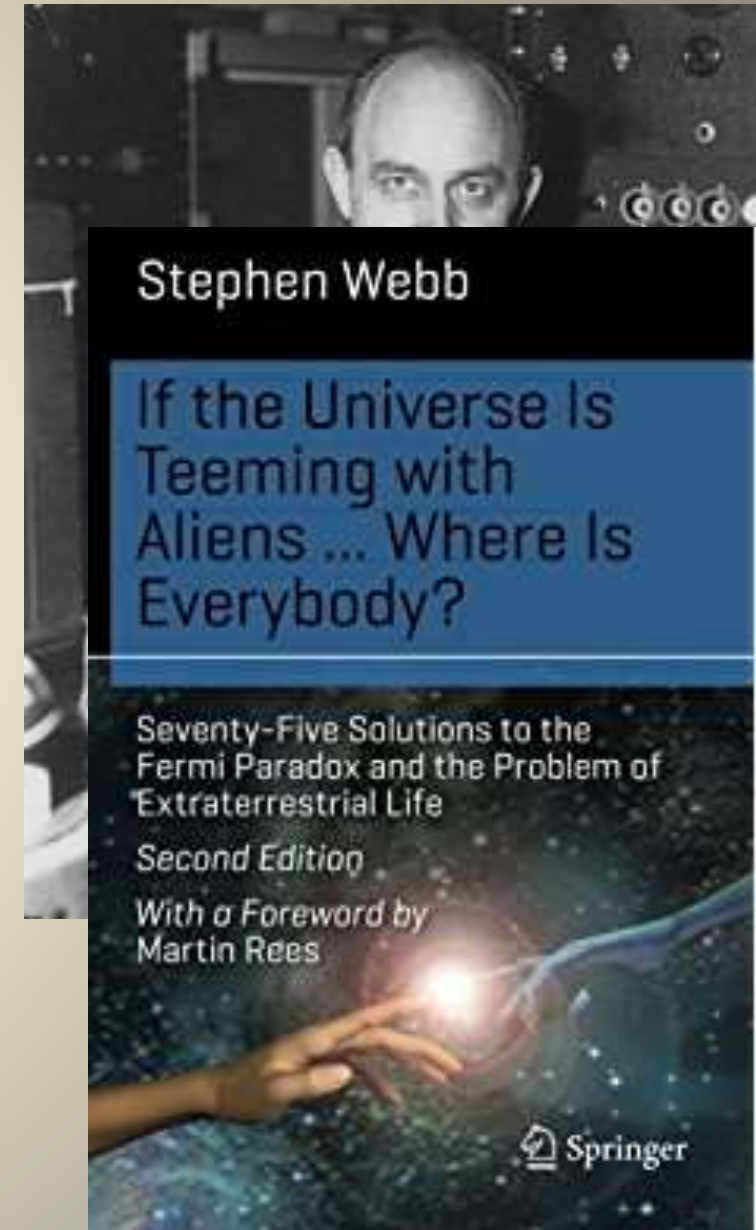
Intelligence is out there but:

Too expensive to spread throughout the galaxy – the energy required - millions of times less energy to colonise your home solar system, on planets, moons or in orbit

Colonisation is too dangerous – catastrophic impacts, radiation, time taken kills the colonists

Civilizations broadcast signals for only a brief period of time, it is dangerous to communicate, or their technology is not detectable by us – not AM or FM but digital

They are extremely old and advanced so they have no interest in us – non biological?



The Fermi Paradox

Life time of the detectable phase is very short and the coincidence is low

There many great filters to get in the way of progress

It took over 4 billion years on earth to go from first life to intelligence

Complex multi-cellular life may be very rare – we have only one example

Our technological civilisation relied on huge amounts of energy from fossil fuels

Maybe we were extremely lucky to have this available?

Annihilation is possible in so many ways e.g.

Self inflicted via genetically engineered organisms causing a pandemic, nuclear war, nano technology, development of rogue AGI, disease, pollution, climate change or some other mechanism

Through natural disasters e.g. a large asteroid or comet impact, a supernova or gamma ray burster too close by

There have been at least 5 natural mass extinctions and a 6th is going on right now

No civilization exists for long enough to be detected or to colonize the galaxy?

Mankind may be the first and only advanced life form in the Galaxy, explaining why there is, as yet, no evidence of any others

Unfortunately for SETI projects this appears to be the most probable solution, indicating that we are truly alone in the Galaxy

Sending Messages - METI

Nicola Tesla in 1899

using a 75 ft high coil of wire broadcasting to Aliens from Colorado Springs

Accidental transmissions of TV, Radio and Radar

e.g. I Love Lucy and the Super Bowl action for 60 years or more

Arecibo message 1974

1000 ft diameter , at 1000 kW for 3 minutes

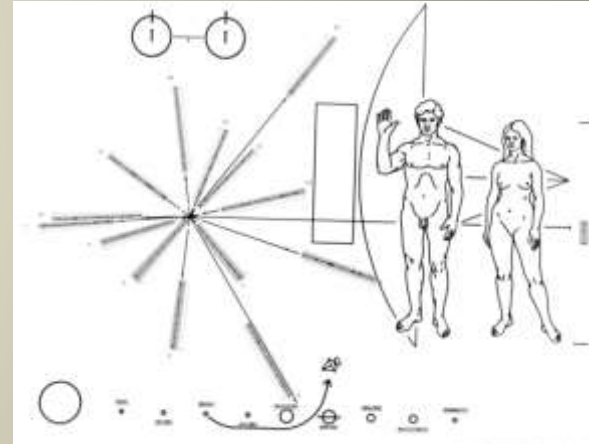
Aimed at M13 globular star cluster

Will take $\approx 25,000$ years to get there – but not corrected for proper motion so will miss!

Pioneer plaques with pictorial information 1972

Voyager analogue recordings plus pictures 1977

Should we advertise our presence or not?



SETI – Future

Some 50 years of SETI (on and off) have failed to find anything, even though:

Radio telescopes, receiver techniques, and computational abilities all have improved enormously since the early 1960s (millions /billions of channels with SETI at home)

A few false alarms – the WOW signal (Aug 1977 Ohio State Univ Big Ear) etc.

Funding has been patchy due to Politicians who believe it a waste of taxpayer dollars (often through total ignorance)

Even though SETI is overwhelmingly popular with the US population

Has got a lot better – Allen Telescope Array, \$100M

Breakthrough Listening Project – Yuri & Julia Milner etc.

Optical SETI – e.g. Automated Planet Finder of Lick Observatory

Square Kilometre Array and China's FAST radio telescope



Nearest Star to the Sun

Proxima Centauri is the closest star to the Sun and is part of a group of three stars

Mystery signal apparently from Proxima Centauri system – Dec 2020 – more later

Breakthrough Listen – found a signal from Proxima Centauri in April & May 2019

Hit the news Dec 2020 due to a leak

Australian Parkes Radio Telescope at 982.002 MHz

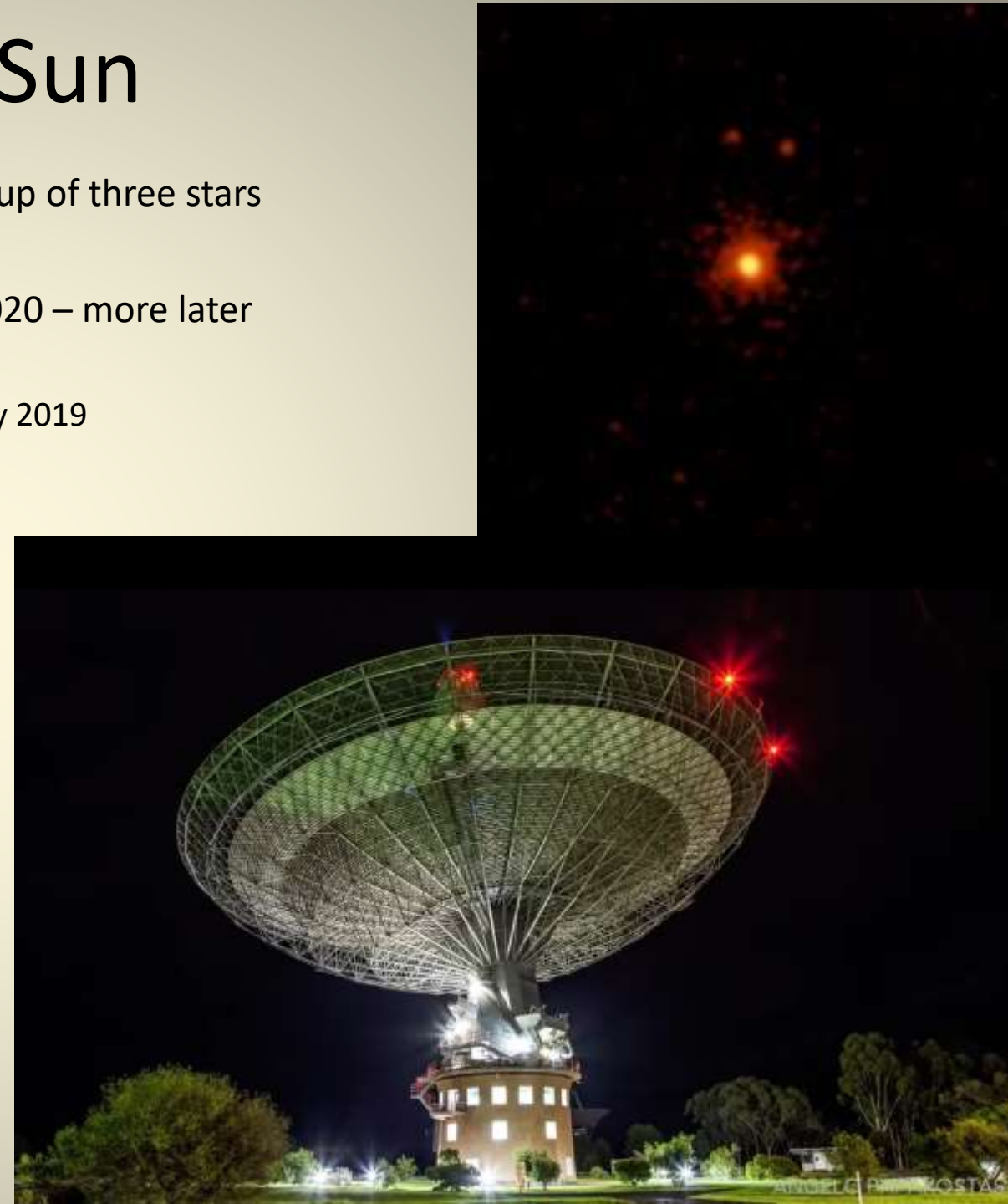
A transient signal called BLC-1

And it is blue shifted as though by the movement of Proxima b

Passed all the initial tests for stray terrestrial signals – nod test and more

Now waiting for scientific papers to hopefully explain it

Almost certainly from an Earth based source



SETI – Future

It is a huge job and we have barely scratched the surface

There are only 52 stars within 15 light years of Earth

Of the 20 nearest only three are bright, most are too dim to be seen with the naked eye

Most that we can see and are recognisable without a telescope are very far away

The same is true of bright radio sources

Need to look at regions of the sky that have most stars to increase the chances of detection

If there are 10,000 civilisations out there in the MW and there are 300 billion stars then on average we would need to carefully search 30 million stars before we would find the first

One glass out of all the Oceans? – Jill Tarter

SETI – Is It Worth It?

SETI projects should still continue because:

Are we alone? - There are few questions more fundamental

The absence of evidence (for extraterrestrial civilizations) is not the same as evidence of absence

No amount of theoretical reasoning will give us a definitive answer

No amount of failure in SETI searches would constitute proof that we are truly alone

The only way to prove the existence or otherwise of intelligent aliens is to search

SETI – What If We Find Them?

Check, double check and check again before any announcement but then tell everyone

SETI Post Detection Task Force

Protocols in place e.g.

“Concerning Activities Following the Detection of Extraterrestrial Intelligence. We, the institutions and individuals participating in the search for extraterrestrial intelligence ...”

“To inform the Secretary General of the United Nations as well as the public and the international scientific community...” etc.

International Academy of Astronautics SETI Permanent Committee

Rio Scale

SETI – What If We Find Them?

The effects of contact or proof would be transformational to human society

Reactions – everything from very happy to abject terror and some will over react and some just won't care

People's views of the important things in life would shift

Gives hope that it's possible for an advanced civilisation to prosper & avoid a global catastrophe

But over time interest will subside somewhat

SETI – What If We Find Them?

If accidental signals detected then decoding them maybe impossible

Have analysed complex dolphin and whale sounds and failed to derive any meaning

Ancient Easter Island script has still not been deciphered

If deliberate signals then decoding should be easier – crib in with messages

We would have many questions

But probably no dialogue due to the extreme time lags

Probably only lengthy mutual monologues

Exchanging information about science, technology, where they come from, do they have religion, how did life arise on their planet, how did they avoid self destruction, how do they enjoy themselves, do they have art and music?



SETI – What If We Find Them?

SETI scientists call this the archaeology of the future because the aliens answers to these questions will be strongly indicative of the future direction of the human race

May contain advanced knowledge leading to of leaps forward in our civilisation

May even containing warnings of potential threats to existence and mistakes to avoid

Where Does That Leave Us?

My own view is that simple life is indeed common in the galaxy and universe

But intelligent technological life is rare because:

- It doesn't evolve very often, and it took billions of years on Earth

 - Some aquatic planets/species it may be precluded

- It doesn't last very long once it does

- Age of the universe is enormous so the coincidence between us & them is very unlikely

- It's probably very thinly spread in space & the cosmos is so huge, so very hard to detect

We are probably very young and very uninteresting – Zoo hypothesis?

- Advanced civilisations have a 75% chance of being older and therefore more advanced

Arthur C Clarke

“Any sufficiently advanced technology is indistinguishable from magic”

“Sometimes I think we are alone, sometimes I think we're not, but either way the implications are staggering”

“If ET's not out there, then Earth is more than merely special - it's some sort of miracle.” Seth Shostak – SETI

Thank You

For attending and

for your attention

Any questions?

