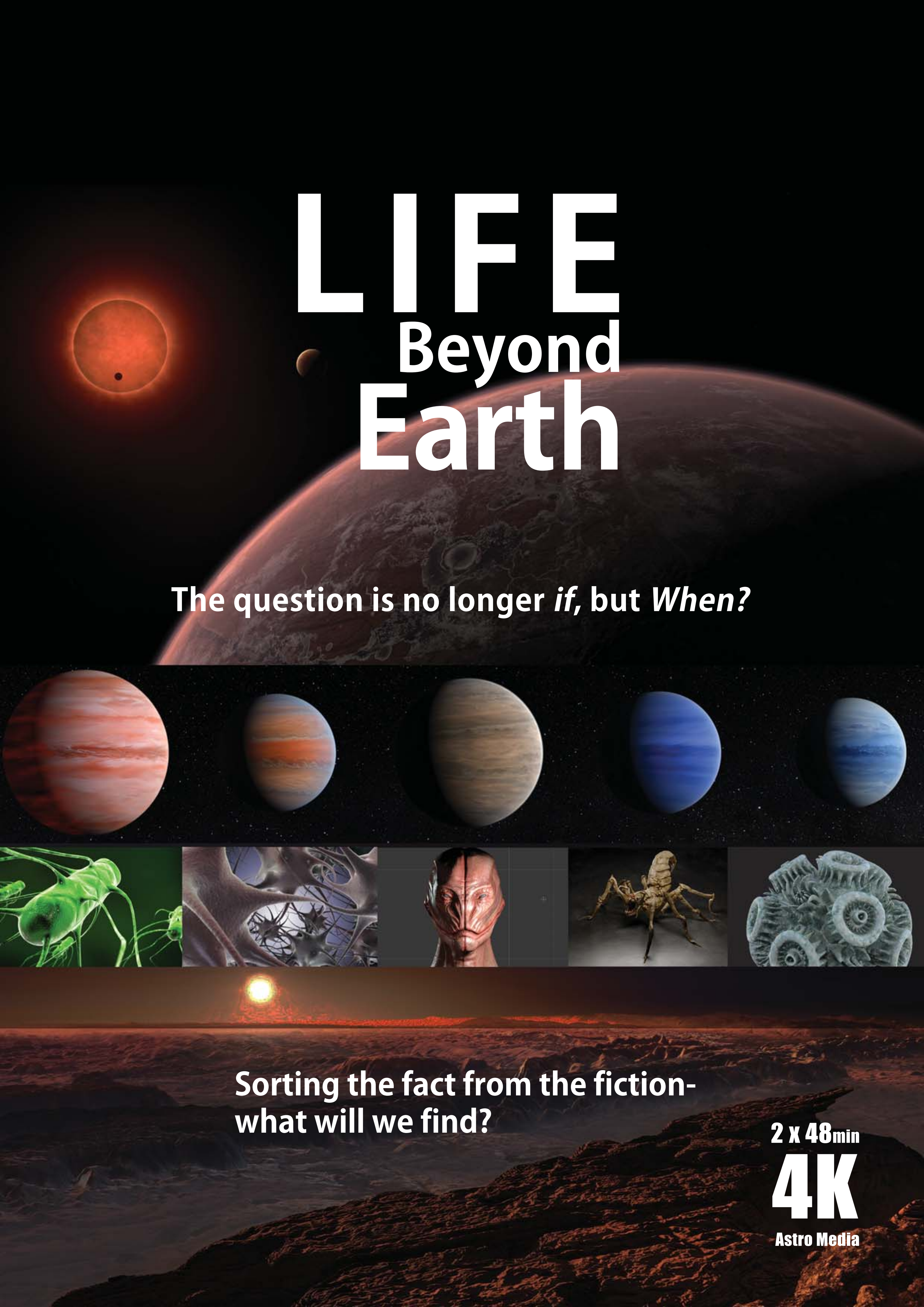

LIFE
Beyond
Earth
The question is no longer *if*, but *When?*
Sorting the fact from the fiction-
what will we find?
2 x 48min
4K
Astro Media

LIFE Beyond Earth

2 x 48 mins.

CONCEPT:

The intent of this program is to explore the reality of life beyond Earth.
No aliens or monsters as popularised in the culture of our times but most likely microbial life; DNA based carbon life forms, multi celled organisms habituating bodies of water, even mosses and lichens spreading over land or even grasses and perhaps insect life.

TREATMENT:

With the recent discovery of new world's orbiting nearby stars bringing the total number discovered so far in the thousands many are believed to be worlds that can host liquid water and the basic ingredients for life.

Life Beyond Earth looks at the possibility of life evolving in the oceans of distant worlds including places within our own solar system, What kind of microbial life could exist? Would this life resemble anything like our own, based on DNA and the known structures of carbon based life.

With interviews from exo biologists and experts in Astrobiology we develop an insight into these fascinating questions, would their evolution mimic our own or something entirely alien? With 3D animation and visualisations we will explore the alien environments, the microbes and viruses that might exist; events that shape evolutionary processes over time to more evolved multi cell creatures and what would be required for the emergence of intelligence?

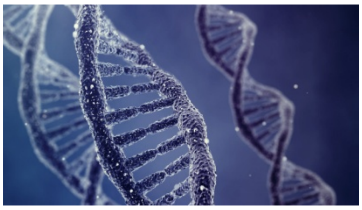
With the number of planets now being observed why hasn't the Search for Extraterrestrial Intelligence located any radio or other signal sources, is mankind truly alone?

All these and other questions will be asked and the answers speculated upon in Life Beyond Earth.

Part One - The Solar System

1. Introduction
H.G.Wells - War of the worlds
Georges Méliès - Trip to the Moon
Sir Winston Churchill and the Aliens
What are we looking for?

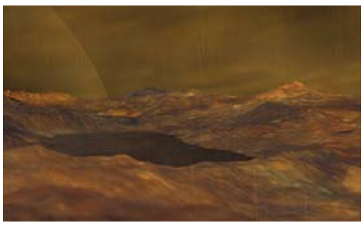
2. Organics in Space
Microbes and early life
Cometary Chemistry
Meteorites from Mars



3. How Does Life Evolve
Discoveries in Greenland
Prebiotic Evolution
A New Theory
Hot Springs on Mars

4. Martians
Methane
Contamination of Mars
Ice Moons & Oceans

5.Alien Oceans
Europa
Enceladus
Ganymede

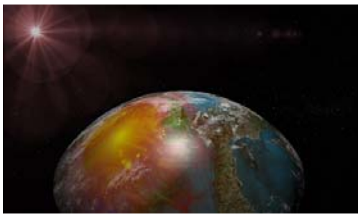


6. Titan
Seas of Titan
Unexpected Pluto
Conclusion

Part Two - Exoplanets

1. Introduction
How to Find Planets
Thousands and Counting
Next Generation of telescopes.

2. Looking For Goldilocks
What sort of Worlds to look for.



3. Extinction Events
Early Evolution of Life and the Biosphere
Snow Balls and bacteria
Asteroids

4. Evolutionary Processes
Microbes to Algae
Complexity

5. The Drake Equation
SETI why has it failed?

6. Knocking on the Door
Proxima Centauri - further study
Sending a Probe 4.1 light years
Conclusion

The Experts

We have conducted interviews with the appropriate scientific experts from renowned Universities and Institutes:

Professor Martin Van Kranendonk
the Australian Centre for Astrobiology

Director of the Centre. He was among the team that found the oldest evidence for life on Earth last year. He is also helping advise NASA on where to land the Mars 2020 rover.

Professor Chris Tinney,
UNSW School of Physics

Planet Hunter. In 2015, found what was then the closest potentially habitable planet outside our solar system.

Dr Sasha Wilson,
Monash Uni School of Atmosphere and Environment.

Sasha is a low-temperature geochemist specialised in environmental mineralogy. She studies biogeochemical and environmental change at planetary surfaces.

Dr Helen Maynard-Casely,
Bragg Institute Lucas Heights NSW

Instrument scientist, WOMBAT high intensity powder defractometer, Helen studies the surfaces of the Ice Moons and Titan in the laboratory.

Dr Chris Greening,
Micro Biologist Monash University

Chris studies evolutionary development in single cell organisms and how bacteria can survive in harsh environments.

Assoc Professor Alistair Evans,
Biologist Monash University

Al studies the morphology of species and how they evolve.

Original Footage

All original footage has been shot on 4K HDR including interviews and location studies.

3D Animation and CGI

Alien Terrains animated by Double Impact Studios Calgary Canada.
(Some materials are available from the NASA 4K and ESO libraries)

Voice Over

Documentary Voice Over will be provided by Prof. Stuart Sykes a long time media specialist and author.

Written by

Prof. Stuart Sykes and Andrew Thomson.

Produced By

Astro Media Pty Ltd, International Television Productions, Melbourne, Australia.
Andrew Thomson Director.

LIFE Beyond Earth

A Documentary
By
Astro Media Pty Ltd © 2017

PART I
THE SOLAR SYSTEM

Written by
Andrew Thomson
Stuart Sykes

Voice Over:
The question is no longer *If*, but *When*?

Looking for life beyond Earth has been a human obsession for centuries, but it was brought into sharp relief not by scientists but by creative spirits more than 100 years ago.

H G Wells became a household name with imaginative works like *The Time Machine* and especially *The War of the Worlds*. French pioneering film-maker Georges Méliès took things a stage further in 1902 with his hugely popular fantasy, *Voyage dans la lune/A Trip to the Moon.*

Wells was by no means the first to suggest alien eyes are upon us. Some of his predecessors were, after all, burned alive for even suggesting the possibility of life on other planets.

But Wells' sustained invention was the game-changer. The radio play based on his work caused widespread panic in the USA when listeners mistook what they heard for an actual alert.

Two-time British Prime Minister Sir Winston Churchill, took a close interest in the possibility of alien life. A Nobel Prize-winning man of words, penned an article in 1939: Are we alone in the Universe?

'I, for one,' wrote Churchill*, 'am not so immensely impressed by the success we are making of our civilisation here that I am prepared to think we are the only spot in this immense universe which contains living, thinking creatures.'*

Film and then television milked the idea of aliens for decades, alas it all amounts to nothing except a billion dollar entertainment industry.

*What if, instead of waiting for aliens to come to us, we went in search of life beyond the world we know? S*cience is overtaking those visions. We keep looking and we're getting better at it science and fiction are about to meet in the middle when if not if we come across life beyond earth.

OPENING TITLES

Voice Over:
We have only one reference point; our planet and the life on it, the complex DNA-based carbon life form that has infiltrated every nook and cranny of the environment on this planet including its most hostile places: volcanic vents on its ocean beds, its highest mountains, and its coldest regions.

Voice Over:
The assumption that organic compounds might be difficult to find in the cold dark vastness of space is quite wrong, space is full of them. As we have discovered in our exploration of our solar system that asteroids, comets and meteorites indeed carry the carbon compounds needed for life.

SOT (English) Sihane Merouane, Co-investigator COSIMA Instrument, ESA
“and we discovered this carbon was actually a very complex material, very complex carbon very different from the simple molecules that we would expect to find there so we don't see any ? or alcohol this kind of molecules which is observed in the gas but we see something much more complex and very rich in carbon and poor in nitrogen or hydrogen compared to these other materials.”

Voice Over:
It appears the fundamental assets to make life are distributed throughout the Solar System; a function of the evolution of planets.

What at first glance appears a simple question; where can life be? Rapidly spirals into a complex conundrum. The complexity of DNA here on Earth and what other environments could facilitate that growth in complexity.

Can biological life even get started in the harsh conditions of the Solar system? Until concrete evidence is available the question *is* polarizing.

SOT (English) Doctor Sasha Wilson, ARC, DECRA Fellow/Senior Research Fellow School of Earth, Atmosphere and Environment, Monash University:
I can't say for sure because we've only got the one example of life on Earth to work with so far but all the ingredients are out there, Solar systems make everything you need for life as far as we know so it could be that matter naturally organises itself into life.

SOT (English) Professor Chris Tinney Head of Exo Planetary Science UNSW
My answer to the question whether there is life out there in the universe is I'm afraid I don't know the great thing about being a scientist and not a politician is I'm not required to have an opinion on anything I'm only required to be able to tell you what the facts tell us and what the evidence is we don't know we don't know how life on Earth got started in detail we don't know how long it took we don't know what the pre conditions were and so life could be incredibly common because there's lots of planets out there or it could be an incredibly rare event that only happens on one in a billion planets in a galaxy.

SOT (English) Doctor Sasha Wilson, ARC, DECRA Fellow/Senior Research Fellow School of Earth, Atmosphere and Environment, Monash University:
You want to have fluids available so water in so far as we know is necessary bio geo chemistry on Earth so you would expect anywhere to have liquid water **or liquid** organics would be good places to look for life.

Voice Over:
Another question for scientists; the environment that hosts life now may not be the originating location for that life. Professor Martin Van Kranendonk is director of the Australian centre for Astrobiology.

SOT (English) Professor Martin Van Kranendonk, Director of ACA UNSW.
Life now occupies almost every imaginable niche you know most rain storms are seeded on bacteria that float around in the water vapour then they start to nucleate water droplets and down they come so you know life is just everywhere and its ion the Antarctic ice caps and in snow patches so it's everywhere at the moment and it can survive for unbelievably long periods under harsh conditions but are they the conditions to make life? Those are kind of two steps we've got to almost detach our minds from in two different kind of views so that whole idea about where do you start life? Because the most primitive organism is already a unbelievably complex piece of machinery you know it's got a membrane that isolates an interior component that's different chemistry from the outside its got a mechanism for mobility it's got this incredibly complex molecule inside so those are almost like different pieces of a puzzle put together into something that works and then can self replicate and such so even before you get to that stage you have this immense series of events that we can't really begin to understand yet were starting to but how do you get to that stage so you almost have to detach yourself from life where can it live now to the building blocks of life.

Voice Over:
Life as we know it is a complex mechanism capable of self replication and great diversity, but what actually is it? How do you get from a puddle of organic chemical broth exposed to some form of energy turn and into this?

BREAK ONE

Voice Over:
To know how life evolves from the fundamental organics to functioning single cell organisms is a key to the riddle of our times. To find answers in space we must first look back at ourselves.

SOT (English) Dr Chris Greening, Evolutionary Biologist, School of Biological Sciences, Monash University.
One of the things that's massively debated is whether the precursors to these molecules such as amino acids and nucleic acids were already available on Earth before life evolved and one really popular hypothesis is that there were and with the help of electricity from lightening fundamental chemicals such as Carbon, Nitrogen and Oxygen were able to react to form the first amino acids which then form precursor proteins and also the first nucleic acids which formed precursors to DNA but my own hypothesis and this is backed up by a number of other evolutionary biologists is that these compounds were probably not that common before life evolved and instead it was life itself that started to create these compounds and instead they basically used pre existing energy sources in the environment Hydrogen probably being the key one here to fix carbon dioxide and then use this to make organic carbon and increasingly you would have had more sophistication develop were you would have formed the initial amino acids which would have then elongated becoming the first proteins and increasingly more complex chemical metallises would have developed.

In terms of life outside Earth it is hotly debated whether this would be dependent on the same exact building blocks but would also depend on organic carbon because carbon is such a flexible molecule also such a stable molecule where it can polymerise and its by having these polymers available that life is able to conduct these complex chemical reactions required to basically convert energy into usable biomass.

And so by focusing on energy as this sort of universal currency for life it then becomes more possible to predict possible environments where life could be found and where life may be able to evolve. For higher life such as ourselves we currently are highly metabolically inflexible so we depend on organic compounds as our energy sources and we depend on oxygen to basically combust these energy sources and generate usable chemical energy from it. However in the case of micro-organisms they are basically capable of almost infinite number of patabations upon these processes so while some micro-organisms can use organic carbon others instead use inorganic energy sources such as hydrogen, or alternatively there might be Sulphur, Methane, petroleum, iron Uranium all of these microbes have been characterised on Earth and we basically have something we say in my lab which is if there is an energy source available you can bet there is a microbe out there able to use it.

Voice Over:
One of the first places to look for the ingredients of life is in the remnants from the early manufacture of the solar system; Meteorites.

SOT (English) Mike Callahan, Research Physical Scientist in the Astrobiology Analytical Laboratory at Goddard Space Flight Centre:
We've discovered a variety of nucleic base analogs in meteorites and so what a nucleic base is a small molecule that are the building blocks of your RNA and DNA and these molecules are essential for all of life.

So this has implication for the origins of life on Earth, we know that meteorites can contain amino acids which are the building blocks of your proteins and now from our research we can show that nuclei bases that are the building block of genetic material like DNA and RNA are also found in meteorites and so these things together could have seeded an early Earth with these really important molecules that could have built up to the larger molecules that you see today that are essential for biology.

SOT (English) Doctor Sasha Wilson, ARC, DECRA Fellow/Senior Research Fellow School of Earth, Atmosphere and Environment, Monash University:
Meteorites do have a potential for astrobiological exploration one thing my group's looking at because they fall to the planets and moons in our solar system and are sterile when they do that they're pretty delicious for micro organisms they have a lot of available phosphorous which is essential for all life as we know it sulphur, carbon organic matter it's not a bad place to live we know a lot about meteorites they're the best studied rocks in the solar system so you can pick one up on any stony meteorite from the early days of the solar system pick it up any planet or moon in our solar system and know basically everything about it so you could tell based on our knowledge of life on earth if anything had been living on it and leaving behind something we called bio marker a sign left behind by life.

Voice Over:
During the violent early lives of the planets, collisions and volcanic eruptions often blasted debris into space, one such rock was cast from Mars 17 million years ago and fell to Earth roughly 13,000 years later. It contained some contentious signs.

SOT (English) Doctor Sasha Wilson, ARC, DECRA Fellow/Senior Research Fellow School of Earth, Atmosphere and Environment, Monash University:
Yes, there is a very controversial meteorite the Alan Hills meteorite and in the mid 90's there were some studies released that put forward the idea that they might have contained nano bacteria from Mars so the Alan Hills meteorite is a Martian meteorite part of the crust and surface rocks on Mars and it would have been ejected from that surface and fallen to earth at some point in the past and there were morphological features that looked like micro fossils.

However the results are still ambiguous it's really difficult to determine whether a textural feature like a micro fossil is true evidence of a biological process of the presence of cells so typically we want to use microfossils textural evidence of the imprint of the cells or life that were in a meteorite or in a rock from another planet or moon as well as chemical evidence so metabolism or energy generation in all organisms on Earth produce very distinct chemical signatures isotope fractionations that we can recognise as a sign of life and those can be present for billions of years and we also look for organic biomarkers so molecules that we know life produces and in very specific patterns of organic molecules we can see preserved in the rock record. So we want to look for fossils and chemical evidence in terms of organics and organic chemistry.

Voice Over:
Scientists need to go back and look at the only sources of evidence for early life: fossils.

SOT (English) Doctor Sasha Wilson, ARC, DECRA Fellow/Senior Research Fellow School of Earth, Atmosphere and Environment, Monash University:
Astrobiologists are mostly concerned with micro fossils so fossilization of single celled microorganisms or communities of them. So you can get various conditions that will preserve micro fossils but general the common theme is that you need to replace them or preserve them with a mineral so in some cases you can get micro organisms that change the chemistry around them so pH what ions are building up around them in a solution and just as a function of the waste products that they produce they can end up precipitating their own minerals crystals will actually grow on them or inside the cells and eventually preserve a record of the micro organism and you can get say sulphide minerals like pyrite or fool's gold can preserve fossils that way and also carbonate minerals are very good at preserving a record of micro organisms as fossils.

BREAK TWO

GREENLAND
Voice Over:
Recent discoveries of fossilized microbes called stromatolites in Greenland is helping pinpoint the earliest evolution of life and the time window is narrowing, allowing for more accurate searches elsewhere in the solar system.

SOT (English) Professor Martin Van Kranendonk, Director of Australian Centre for Astrobiology (ACA) UNSW.
It's an extraordinary discovery in really two different ways one is that these stromatolites are preserved at all in rocks that are 3.7 billion years old were talking incredibly ancient periods of time and the exciting thing is and we put this in the title of a paper were we talk about a 'rapid emergence of life'. So these rocks in Greenland are actually almost the oldest preserved rocks in the world of anything and they're preserved in the immediate aftermath of what's known as the late heavy meteorite bombardment which we know about from studies on the Moon, was an intensive period of large bolides coming in and really impacting the Earth with incredible energy and in fact enough energy that the oceans would have vaporized and had to recondense again up till the period of 3.9, 3.8 billion years ago so the thing that it's starting to point to is that you know if life got started really earlier on Earth and maybe it did may be back to 4.2 billion years ago and we know there were liquid oceans it's hard to imagine that surviving through those incredibly energetic impact events until about 3.9 - 3.8 and then we got evidence of stromatolites at 3.7 so it's all about like how long do you need to make life that chemical soup that energy to generate complexity we always thought it took half a billion or a billion years but these discoveries are just shortening that time frame down to like a hundred million years which sounds like a lot to you and me but actually on geological time scales that very short and so it's really exciting in terms of thinking about what does that mean for generating life in other planets that don't have the long history of geology like Earth does were still an active planet but Mars other planets have died because they're smaller but then the question is could they have formed life? Well this fore shortened period suggest that yeah maybe they could and that expands our envelope for thinking about where to search for life in the solar system in the universe really everywhere.

Voice Over:
However with these recent discoveries a new theory is emerging into the spotlight.

SOT (English) Professor Martin Van Kranendonk, Director of Australian Centre for Astrobiology (ACA) UNSW.
At the moment a developing paradigm shift in the community about where did life get started on the planet so at the moment its known or its been theorised that life started in the deep oceans by these hot vents that extrude mineralised water onto the sea floor, 400 degrees temperature thousands of meters below the ocean surface no sunlight just chemical energy and that's been a really evocative model for a long time but now people are starting see there are problems with that model and it's not about life living at those vents we know that's the case we can see it with our rovers when we go down and see big tube worms and crabs and everything but before you get life you have to make organic molecules become more complex so organic molecules are simple they're everywhere they come in from meteorites and comets and dust falling in and stuff but to make them complicated to make them long

chain you've got to stick those bits together and the funny thing is that sticking those bits together requires not just wetting but drying conditions each of those reactions makes those organic molecules longer requires a water molecule to be kicked out so the community is starting to realise that actually you can't make life in the oceans its actually too wet. So now with a group of us looking at hot springs because hot springs on the surface of the Earth have all the conditions of the deep sea smokers they're not as hot so it's actually better and they have the capacity for wetting and drying cycles on the edge of hot springs pools that have geysers they erupt and they expand then retract so they get these wetting drying cycles that provides the power and the energy for making complex organic molecules and their chemistry is very complicated each hot spring is different ones pH2 ones pH7 ones pH11 they've got different nutrients different chemicals and you mix and match all those things together and all of a sudden you've got complexity that could make life in 10 million years so this is a new model we've just published in Scientific American very exciting and its applicable to Mars because it looks like form the history of the geology of Mars that actually it never had oceans but it had volcanoes and it had hot springs so if our ideas about the origin of life are changing from the deep oceans we're we'd would say why go to Mars? They never had deep oceans so life wouldn't start there to hot springs all of a sudden minds are going ah very exciting.

Voice Over:
The next obvious target for scientists is our age old '*agent provocateur'* Mars, the closest in time and space to our Earth and the best first chance of evidence of non terrestrial life.

SOT (English) Professor Martin Van Kranendonk, Director of Australian Centre for Astrobiology (ACA) UNSW.
Absolutely, were looking exactly at the same window of time as the discoveries from Greenland through to our well known work in Pilbara in Western Australia where there's the most convincing evidence of life the whole community is satisfied about it but that window 3.8 - 3.5 is exactly the time in the history of Mars that we know it had warm and wet conditions or at least wet conditions with abundant flowing water and so that's exactly the window that we're looking at and that's why these areas are so important as analogues because they really are you know a window back on this incredibly deep time period and it's the same time on Mars when things were still going on there still had volcanoes that were providing heat and volcanic activity and chemical complexity in water rock interactions those are all the things the ingredients that we need for life on Earth and we know that we have them on Mars so that's why we're looking at these comparisons and going ahh that's the time and the place to look.

Voice Over:
The next Mars rover mission Rover 2020 is fast approaching, scientists and technicians have one shot at finding ancient signs of life, so their landing site selection is a serious business.

SOT (English) Professor Martin Van Kranendonk, Director of Australian Centre for Astrobiology (ACA) UNSW.
We're literal on the advisory team for one of the landing sites for the Mars 2020 we've gone for the past two years to the landing site workshops where they're whittling down the numbers and at the moment they're top three sites candidates for the Mars 2020 mission and ours is still one of them and that's to go and look at what appears to be from all the evidence we have hot spring deposits the silica rich deposits that's from extruding hot water that's coming out of the ground and flowing over the landscape and were so excited about that because the work that we've done in the Pilbara has shown that at 3.5 billion years ago the same age as the crust on Mars this ancient life on Earth was thriving in active hot springs with geysers depositing opaline silica and they found from one of the previous rover studies on Mars the Spirit Rover found opaline silica deposits and they've got textures I mean this is totally mind blowing they've got textures like these little fingers coming out of these silica things so it's not just boring layered rock these have vertical structures, finger like structures and they found identical structures in hot springs active today in these very high desert areas in Chile the most Mars like conditions you could ask for bang we've got the same structures opaline silica, these finger like structures and on Earth they're made by microbes so were saying you know go to these known hot spring deposits on Mars.

BREAK THREE

Voice Over:
Another area of interest is the detection of Methane gas in the atmosphere more tantalizing clues of possible life processes.

SOT (English) Doctor Sasha Wilson, ARC, DECRA Fellow/Senior Research Fellow School of Earth, Atmosphere and Environment, Monash University:
I reckon that's geological, so there are geological processes that will produce organic molecules including methane including the process of serpentinization which is when you have essentially you heat up magnesium and iron rich rocks and add water into them so you hydrate it what we call a metamorphic reaction and that can generate organic matter or organic chemicals that's well known from studies on Earth.

SOT (English) Doctor Sasha Wilson, ARC, DECRA Fellow/Senior Research Fellow School of Earth, Atmosphere and Environment, Monash University:
I really hope we do find fossilized micro organisms on Mars that would be a triumph for science and for humanity, I'm not holding my breath though it could be a long journey to try and find a record there but it's probably be our best hope in the solar system.

Voice Over:
There is another consideration to be made when looking for alien life, in particular on Mars; contamination. Earthly bacteria can easily ride the rocket through space and land on Mars with the probe, leaving the distinct possibility of contaminating and possibly destroying what we're looking for.

SOT (English) Professor Martin Van Kranendonk, Director of Australian Centre for Astrobiology (ACA) UNSW.
This is a real possibility and there's a group in NASA and I'm sure other agencies have them as well called Planetary Protection Officers who take the most careful steps imaginable to try and protect a planet from seeding with our own sort of bacteria the community that we bring in with us everywhere so that's the main reason why the Mars 2020 mission is not going to look for active like existing life because we know there's water flowing on Mars its coming up from the subsurface but we know that can live on Earth no problem but they're not going there because they're worried that if they put in a sampler they might introduce bacteria that ride on spaceships we know it can survive in space so they're avoiding that all together and going for the ancient life in rocks where there's not the possibility of contaminating an existing water body so yeah there's great care being by at least some groups.

Voice Over:
Beyond Mars, the next out posts in our solar system to be potential habitats for life are the ice moons of Jupiter and Saturn. Doctor Helen Maynard Casely has been studying the planetary conditions of these icy worlds in the laboratory.

SOT (English) Dr Helen Maynard-Casely, Instrument scientist, WOMBAT high intensity powder defractometer, Bragg Institute Lucas Heights NSW
So my expertise is re-creating those surface and interior conditions of the icy moons in order to understand what the materials are doing and how they interact there. But from the various space missions that we've sent out to Europa and Enceladus we know or at least infer quite a lot about about their structures. Europa everybody gets very excited about because we believe it has quite a thick ice crust thin or thick were not entirely sure how much but there is a global ocean underneath that ice and that should boundary straight on to a rock mantle a rock inner core so at that interface you got rock and water quite warm probably more than room temperature so you've got potential for that water to pluck out minerals, nutrients then of course that whole ocean is shielded from the intense radiation of Jupiter so it a rather snug little place to be .

SOT (English) Professor Martin Van Kranendonk, Director of Australian Centre for Astrobiology (ACA) UNSW.
The (scientific) community is fascinated by the fact there's water, known water and liquid water in these very far off moons of Jupiter and Saturn but this gets back to the origin of life so we have life occupying in these chemical hot springs down deep in oceans and they're some of the most primitive of organisms no doubt but it gets back to that question of how do you make something that's as complex as life from very simple building blocks if you can't do it in the oceans then I would say you are wasting your time in going to Europa and Enceladus because those deep oceans would never have the wetting drying cycles so they probably and very likely have the kind of elements we see in the deep ocean on Earth they may have hot smokers they may have mineralized water rock interactions but form our groups perspective if never had an exposed land surface we probably never got life and so without that we really question whether it's worth going.

Voice Over:
Perhaps meteors could have punched through the ice crust to deliver the additional organic chemistry required.

SOT (English) Dr Helen Maynard-Casely, Instrument scientist, WOMBAT high intensity powder defractometer, Bragg Institute Lucas Heights NSW
Potentially yes, I've seen that there's a big change in the craters, so there are craters on the surface of Europa let's talk here, the surface of Europa is very young geologically at most one hundred million years old which is why a lot of people get excited about the potential of activity, craters up to about thirty kilometres are pretty normal they compare normal for an icy satellite they compare quite well with a similar similar sized craters adjusted for gravity on Ganymede and on Callisto now once you get above 30 kilometres they change very dramatically in morphology you don't get the big crater you don't get the crater shape you get a sort of ring like structure now again the modelling of that is not complete but you could imagine that's happened

because something's actually punched all the way through and then water has sort of squadded though and it may form that with but there is a big debate as to how thick or thin the Europa crust is but I believe from the cratering people see points toward it being more in the twenty kilometres range that's good because it would protect anybody down there it's bad because it's very difficult for us to get down there and actually go and find them. So we shall see.

BREAK FOUR

SOT (English) Dr Helen Maynard-Casely, Instrument scientist, WOMBAT high intensity powder defractometer, Bragg Institute Lucas Heights NSW
Enceladus though which is one of the moons of Saturn is I believe quite a surprise because it's absolutely tiny, I don't think I realized how small it was though. Europa is a little bit bigger than our own moon, Enceladus is about the size of the U.K. it's absolutely tiny and so when Cassini got there and saw these massive geysers coming out the first big question is where is all the heat coming from it something potential it's tidal friction or is it radiogenic heating there's still not the definite: it's definitely this but we know there is a lot of heat coming out of Enceladus. And it is very very small and we now know that from Cassini / the way it's passed by Enceladus we know there is an ocean under the south pole so again the other potential is there but whether that ocean is trapped in ice or actually goes all the way down to the rock were not sure yet. We know quite a bit but there's always the potential to find out more and what I'm trying to do is follow up with laboratory experiments that take those materials and find out how it's never just pure water ice there's a dirty component and how that dirty component be it salt, sulphate or even organics interact with water ice is very variable its very weird and does some very interesting things.

Voice Over:
Discovering geysers emanating from the moon, Cassini was re tasked to fly through the plumes and make close up observations.

SOT (English) Dr Helen Maynard-Casely, Instrument scientist, WOMBAT high intensity powder defractometer, Bragg Institute Lucas Heights NSW
"So they used their mass spec instrument which enables them to directly detect a number of gases but that particular instrument really wasn't designed to do that because they didn't really know what they were going to discover when they had it on so they managed to detect I think CO2 and methane for instance but really what they want to look for is the potential of amino acids the building blocks of proteins and that's why there's now a proposal to send another mission there and it's called ELF or Enceladus Life Finder a more sensitive mass spectrometer that would be able to directly detect the potential for amino acids. Now amino acids don't necessarily mean life and I know that the ELF science team have come up with a

sort of cube matrix of observations that build up a probability of life or not so amino acids is just one of those and there's a number of other things, parameters in that cube and they've come to the idea if it's more to one side then we know its life or if it's the other side we could say it's not life but that was a really fascinating study to see all those little markers what could they detect for in order to say that there's actually something in there.

SOT (English) Dr Helen Maynard-Casely, Instrument scientist, WOMBAT high intensity powder defractometer, Bragg Institute Lucas Heights NSW
Certainly the ingredients seem to be there or we infer the ingredients are there if the water the ocean goes all the way down to that rock crust you've got water rock interactions you've got the ingredients there we believe it could potentially be like hot smoker environments that we have right down in the bottom of our own oceans and I thinks' motivating a lot of study into those environments. There is always the potential that if it's too deep the pressure of the water can go so high that you actually solidify the water it becomes solid ice and if you get the solid ice round that rock interior then pretty much wipes out any possibilities or it makes it much harder and much slower this is one of the reasons for a long time Europa is one moon but it has a bigger sister called Ganymede and it was thought Ganymede would have an internal ocean the fact that internal oceans seen as a must have for most icy moons now we've seen them on Pluto potentially on Titan Ganymede and Callisto the reason people are less excited about Ganymede was thought the ocean would be so deep that the water would then freeze and isolate anything from the rock so you couldn't get those interactions, however threes been more work looked at the interactions of the dirty stuff the potential salt in Ganymede's Ocean and actually it could cause layers so you could potentially get a solid, liquid, solid, liquid, solid liquid and a few of the models worked out you could get liquid in contact with the rock so I think there's a lot of justification for doing a lot more study in the potential of taking those ingredients that could be in the bottom of Europa and Ganymede and potentially Callisto if there's a lot of environments we think like that in the solar system and to find out a bit more about how the biology might work down there.

BREAK FIVE

TITAN
Titan the moon of Saturn has always drawn attention to itself, the mysterious satellite with a dense and cloudy atmosphere with liquid oceans and rocky terrain and abundant carbon organics,

SOT (English) Dr Helen Maynard-Casely, Instrument scientist, WOMBAT high intensity powder defractometer, Bragg Institute Lucas Heights NSW
Titan is quite an easy place to constrain but it's got very thick atmosphere much thicker than our own atmosphere, it's made out of the same stuff, its nitrogen based where as our atmosphere on the surface is around one bar, Titans is one and a half bars it's actually a much thicker atmosphere it would be quite oppressive it would be to walk around on Titan would be like being 6 meters under a swimming pool if I remember rightly from my calculations it would like that sluggish and the oppressiveness of the atmosphere because of that it controls the temperature very well on the surface so globally we think the surface temperature of we don't think we have measured the surface temperature of titan to be 92 Kelvin around 190 degrees C. And it hardly varies, hardly varies from that value so if you want to study the surface of Titan from my point of view makes it very interesting or very easy all I have to do is go drive to 90 Kelvin and sit around there so you've got those conditions, you've got very thick nitrogen there's also methane in the atmosphere, now that methane was always a bit of a mystery it was actually first discovered by Gerald Kuiper back in 1944 and it got everybody a bit interested because methane shouldn't really be held on to by Titan it's quite small doesn't have quite the gravitational field methane should have escaped into space and so automatically it was like well where's that methane coming from that starts to get Titan a little bit more interesting but then of course you've got this methane you've got this nitrogen and you've got this atmosphere isn't well protected it doesn't have a magnetic field like we do on Earth and so you've got all this cosmic and solar radiation causes interactions to happen and you see interactions into bigger organics things like benzene acryl nitrite anything with C H and N pretty much there is a pathway it actually could form this bigger stuff starts forming and then starts raining down onto the surface you've got this; whenever you see Titan or see it visually its very orangey hazy and that's what this organic haze is and this is thought to have been going on for a very very long time so much so that any water ice that's on the surface of Titan has been buried completely that there's actually a massive carpet of organic material and that's where we're at at the moment and try to work out what that organic material actually is well we know chemically what it can be and it's components that make up for it but physically what structures have appeared there and so that's what we're trying to do here.

Voice Over:
recently discovered Vinyl cyanide (C_2H_3CN) is an organic molecule which help forms biological membranes in the atmosphere; is it a harsh and unwelcoming world for life?

SOT (English) Dr Aaron La Brun,
So vinyl cyanide is believed to be a precursor for forming the molecules needed for forming a cell membrane these molecules have been recently discovered on Saturn's moon Titan and this is quite an exciting discovery because these molecules are the building blocks of what's needed for forming the cell membrane, the cell membrane is what defines the barrier of a cell and protects the inside components of a cell from its outside environment so the cell can metabolise and grow and divide.

PLUTO
Voice Over:
Next possible habitat is the outer reaches of the solar system, a newly visited world showing a complex environment with a potential to harbour microscopic life.

SOT (English) Elliot Sefton-Nash, Planetary scientist, ESA
"If you go in closer to the surface you can see this type of really diverse terrain. So you have the very bright region, these are flat plains. We're not entirely sure how they formed yet but there's a couple of leading theories. There's a huge range of mountains. There's all kinds of different aged surfaces. Some of them have lots of craters. Some of them have very few, which means they're younger. If you look in a lot of detail at some of the mountainous regions, you can see that actually they're a few kilometres high but they're made of water ice. On Pluto it's so cold that water ice is the hardest thing. It's more like rock and so the stuff that forms the softer material is actually nitrogen ice."

SOT (English) ELLIOT SEFTON-NASH, Planetary scientist, ESA
"One of really fascinating things is some of the surface coloration you can see in these images actually shows that there are these compounds called tholins, which are a combination of elements but they're related to prebiotic molecules, so they're kind of relevant to prebiotic chemistry. And I think the fact that they have able to form on planetary surfaces very far out in the Solar System, at very cold temperatures really has implications for a lot of places. If you can imagine for star systems outside our own, where the star may be dim and the planets are quite far away, it's interesting to know that there are molecules that could be involved in supplying biotic material to processes that may, one day, lead to life, or be involved in life or something like that, that they're actually forming way out in the Solar System where no one really expected."

SOT (English) Dr Chris Greening, Evolutionary Biologist, School of Biological Sciences, Monash University.
We know that microbes can continue to have a very low useful amount of metabolism in extremely cold and extremely dry environments so for instance in these Antarctic soils that we sampled we're observing the microbes they could very easily oxidize molecules such as hydrogen in temperatures as low as minus twenty degrees and these were incredibly dry soils.

SOT (English) Dr Chris Greening, Evolutionary Biologist, School of Biological Sciences, Monash University.
So I'd imagine that in certain planets where they have very low temperatures and if very dry it would be possible if there's an energy source at least a very very low level of metabolism to occur and according to all the basics it comes down to thermo dynamics and with a warmer planet then as long as it's not too warm then metabolism will be more favourable and this will yield a much faster evolutionary processes but in reasonably cold environments down to minus 80 degrees or so you can still have microbes survive and some very very low metabolism to at least tick over maybe not necessarily grow.

SOT (English) Professor Martin Van Kranendonk, Director of Australian Centre for Astrobiology (ACA) UNSW.
Organic molecules are extremely complex so carbon is one of the most common element in the Universe and we know that it's on comets there was that beautiful Rosetta mission that landed and sampled the but they're very very simple molecules and so same with the organic molecules that have been found so far on Mars and the ones that are inferred on Pluto are very very simple now the exciting thing about Pluto is what we didn't know until we got closer up that it s got a complex history we can see different domains and that means that there was activity there like geological activity and organic molecules and a surface then there's interesting stuff going on.

CREDITS