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Life on Mars?
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If, on a clear night in the next week or so, you looked up into the southern sky you should see a bright 'salmon pink star'. It is, in fact, the planet Mars and you could well be looking at somewhere that life could have existed in the distant past and could even be present today. 2010 is likely to be a significant year in our search for life on Mars as new techniques are being employed to investigate evidence of fossilized life forms in Martian rocks, with some scientists becoming convinced of their existence. We are now sure that in the past the conditions on Mars were suitable for life to arise, but it has taken just over a century for astronomers and scientists to have come to these conclusions - an exciting story of discovery that is well worth telling.

Mars is a rocky planet having about half the diameter of the Earth but only one tenth its mass. The reddish tint is due to oxides of iron on the surface known as hematite or rust which forms a dust with the consistency of talcum powder. Its atmosphere is very thin, about one hundredth that of Earth's, and is largely composed of carbon dioxide along with nitrogen, argon and traces of water vapour and oxygen, and as a result the surface faces extremes of temperature - not a suitable abode for life at the present!

As the Earth and Mars have similar axial tilts, it has comparable seasons whose lengths are about twice those of Earth's as the Martian year is approximately two Earth years in length. Martian surface temperatures range from approximately -140 C during winter up to 20 C in summer. Mars also suffers from dust storms which can occasionally cover the entire planet's surface. It has two polar ice caps which are primarily composed of water ice but covered by a layer of solid carbon dioxide (dry ice). At the southpole the carbon dioxide layer is ~8 m deep overlying ~3km of water ice within a diameter of ~350 km. The north polar cap has a diameter of ~1000 km and is about 2 km thick. During the winter, dry ice builds up a ~1 m layer above the water ice and this caused a reduction of carbon dioxide in the atmosphere, so reducing the atmospheric pressure.

Observing Mars

An interesting consequence of the eccentricity of the orbits of Mars and, to a lesser extent, the Earth is that when Mars comes closest to us (every 2 years and two months) its distance from us can vary greatly. As a result, its angular size at closest approach will vary significantly and so determine the amount of surface detail that we can see from Earth. Mars is closest to us within a few days of opposition - that is, when it is on the opposite side of the sky to the Sun - and will thus be seen approximately south at midnight. At opposition, Mars will be seen with the smallest angular size when Mars is furthest from the Sun (at aphelion) and the Earth is closest from the Sun (at perihelion) as shown in diagram (a) below. Diagram (b) shows the inverse situation when Mars will be seen with the largest angular diameter during opposition.

The Earth is at aphelion, furthest from the Sun, on July 4th each year, so the very closest approaches of Mars will occur in the summer months. The closest approach for nearly 60,000 years occurred on August 27th2003 when Mars was 55,758,006 km from Earth and had an angular diameter of just over 25 arc seconds. In contrast, if Mars is at aphelion and the Earth at perihelion at the time of closest approach as shown in Figure 3.1(b) then the angular size is just less than 14 arc seconds - a very significant difference! The angular sizes observed at opposition are currently reducing and reach a minimum of 13.89 arc seconds on March 3rd 2012. (That in January 2010 was only a little greater at 14.1 arc seconds.) They will then increase again until, on July 27th 2018, it will have an angular diameter of 24.31 arc seconds - only just less than the absolute maximum.

Mars at closest approach in August 2003 - Hubble Space telescope

Canals and advanced civilizations on Mars?

Mars was first seen through a telescope by Galileo in 1609, but his small telescope showed no surface details. When Mars was at its closet to Earth in 1877 an Italian astronomer, Giovanni Schiaparelli, used a 22cm telescope to chart its surface and produce the first detailed maps. They contained linear features which Schiaparelli called 'canali', the Italian for channel. However, this was translated into English as 'canal' - which implies a man made water course - and the feeling arose that Mars might be inhabited by an intelligent race. It should be pointed that a waterway*could not* be detected from Earth, but it was thought that these would be used for irrigation and so would have field of crops growing adjacent to them which *could* be seen from Earth.

Influenced by Schiaparelli's observations, Percival Lowell founded an observatory at Flagstaff in Arizona, USA, (later famous for the discovery of Pluto) where he made detailed observations of Mars which showed an intricate grid of canals. However as telescopes improved, fewer canali were seen though the surface did show distinct features.

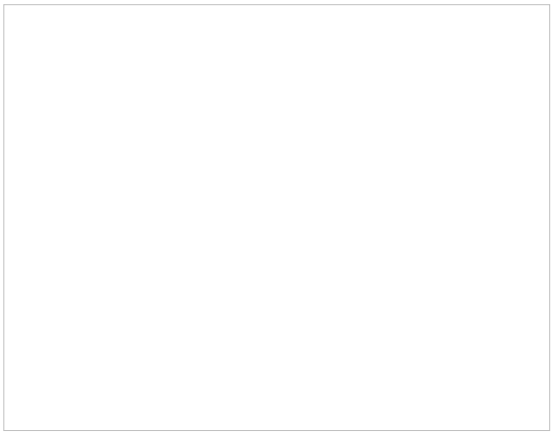
Percival Lowell's drawing of Mars showing many 'canal like' features.

Canali appear to have been an optical illusion, but the myth of advanced life on Mars was not finally dispelled until NASA's Mariner spacecraft reached Mars in the 1960's. This was perhaps why Orson Well's 1938 radio program 'War of the Worlds', broadcast in the form of a breaking news story rather than a play, caused such panic in the United States. (An intriguing image of a huge rock formation, called the 'Face on Mars', was obtained by the Viking 1 space craft in 1961 leading some to suspect that this was a giant representation of a past civilisation. However, a detailed photograph taken by Mars Global Surveyor in 2001 showed it to be a 'mesa' - a broad flat topped rock outcrop with steep sides.)

The detailed images taken by the Mariner spacecraft showed vast canyons and giant volcanoes. One of these, Olympus Mons, is the largest known volcano in the Solar System with a caldera of 85 km in width surmounting the volcanic cone whose base is 550km in diameter. The caldera is nearly 27 km above the Martian surface, three times higher than Everest! It was realised that when these giant volcanoes were active, some three thousand million yeas ago, they would have given Mars a far thicker atmosphere than now and the effects of greenhouse gasses in the atmosphere would have allowed the surface temperature to be sufficiently high for water to exist on the surface. Other visible surface features gave ample evidence of water flow over the surface leading to speculation that simple life forms might then have existed on Mars.

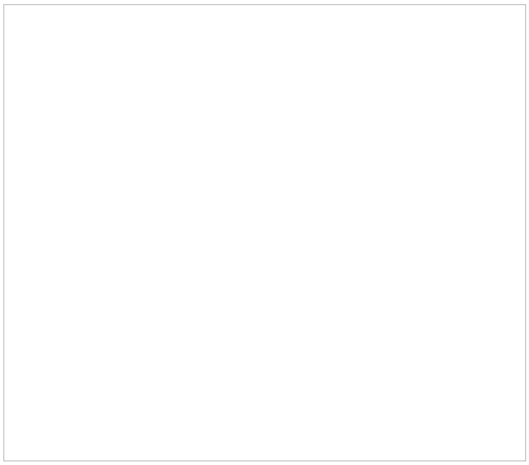
In 1965, Mariner 4 took the first close up pictures of Mars revealing numerous impact craters and a generally barren landscape devoid of any semblance of canals. Photographs taken later by Mariner 9 provided considerable evidence that water had flowed across the surface of the Red Planet. It was also observed that the polar ice caps were growing and shrinking with the seasons and clouds were seen drifting in the Martian atmosphere. In 2004 Europe's Mars orbiter also found water ice on the Red

Planet's surface. The discovery was based on analysis of vapors of water molecules detected by the infrared camera aboard the Mars Express spacecraft which was circling the Red Planet's south pole.



Frozen lake of water discovered by The European Space Agency Mars Orbiter

An intriguing thought is that Mars, being smaller, would have cooled more quickly than Earth and so could have allowed life to form there before it could have done so on Earth. If so, that life could have been brought to Earth on a meteorite (as will be discussed below) and, finding suitable conditions here, could have continued evolving. We could all be Martians!



Vallis Marineris in the lower right with giant volcanoes to its left

The Viking Missions to Mars and a heroic failure, Beagle II.

With the possibility of life being, or having been, present on Mars, in 1976 two Viking probes landed on its surface to search for possible evidence. They each carried four experiments to test for any signs of life or organic compounds in the Martian surface. Of the four experiments, two were negative but two, gave somewhat enigmatic results, initially giving a positive results but not in the way that would be expected had life been present. The consensual opinion is that this was not the result of any life forms being present but the result of a chemical reaction due to the fact that the Martian soil is more chemically active than that on Earth. This view has been supported by the discovery of perchlorate in the soil by the recent Phoenix lander, but Gil Levin who designed the Labeled Release experiment that gave a 'positive' result still maintains that it had detected life. As Mars has a very thin atmosphere (and no ozone layer), far more ultraviolet light reaches the surface than on Earth. This would prevent the existence of life above ground and so, if life had once arisen on Mars, one could now only expect to find evidence for it beneath the surface.

View from one of the Viking Landers

It was nearly 30 years before the next probe to specifically search for evidence of life was sent to Mars. This was the, UK designed and built, Beagle II that was due to land on Christmas day 2003. It had left its mother ship, Mars Express, on a perfect trajectory a few weeks before, but appeared to have crash landed on its arrival at the surface - a sad moment for the author who had been charged with receiving its first signals from the surface using the Lovell Telescope at Jodrell Bank.

Orbiters, Rovers and the Phoenix lander

Following a period when many Mars probes seemed doomed to failure, successes in the last decade have greatly increased our understanding of its surface, either when viewed with high resolution cameras orbiting the planet such as those on Mars Reconnaissance Orbiter which began surveying Mars in November 2006, or with the rovers 'spirit' and 'Opportunity' which landed in 2004 and are, amazingly, still operational and the 'Phoenix' lander which landed in May 2008.

Spirit and Opportunity

The rovers primary scientific mission was to investigate a wide range of rocks and soils that might hold clues to past water activity on Mars. They were targeted to sites on opposite sides of Mars that appear to have been affected by liquid water in the past: Gusev Crater was a possible former lake in a giant impact crater, and Meridiani Planum, where mineral deposits suggested that Mars had a wet past. They have been highly successful, having together traversed over 20 kilometres on the surface of Mars. In 2004, scientists showed pictures revealing a stratified pattern and cross bedding in the rocks inside a crater in Meridiani Planum suggesting that water once flowed there, whilst an irregular distribution of chlorine and bromine suggested that it was once the shoreline of a, now evaporated, salty sea. To confirm the 'wet past' hypothesis, Opportunity has found hematite, in the form of small spheres nicknamed 'blueberries' which could only have been formed inside rock deposits soaked with groundwater.

Gusev Crater

Also in 2004, NASA announced that Spirit had found hints of evidence of past water in a rock dubbed "Humphrey"' which appeared to contain crystallized minerals lodged in small crevices. These minerals been most likely dissolved in water and carried inside the rock before crystallization. When, in December 2007, one of Spirit's wheels was not turning properly, it scraped off the upper layer of the Martian soil and uncovered a patch of ground similar to areas on Earth where water or steam from hot springs had come into contact with volcanic rocks. Here, such locations are often teeming with bacteria as hot water provides an environment in which microbial life can thrive. Though still operational, since May last year Sprit has been stuck in sand and, as it can no longer orientate its solar panels towards the Sun, may only remain alive for a few more months.

The rovers had never been expected to survive so long as it was thought that dust would soon cover their solar panels to such as extent that they could no longer survive. But scientists had not realized that dust devils - mini tornadoes that can sweep across the Martian surface - could act like a Dyson vacuum cleaner and sweep the panels clean. By March 2005, Spirit's panels had dropped to 60% of their full capacity, but suddenly this increased to 93%! The following day Spirit was able to film a dust devil as it sped across the Martian surface. Sometimes major dust storms can fill the Martian atmosphere and, when the orbiter Mariner 9 reached Mars in November 1971, the surface was totally shrouded by dust. As the storm gradually subsided, the first feature to be seen was the caldera of Nix Olympia rising high above the surface. Towards the end of June 2007, a series of dust storms blocked 99% of the direct sunlight to the rovers and they were facing the real possibility of system failure due to lack of power. They were both placed into hibernation to wait out the storms and happily survived to face another Martian year.

Further evidence of water locked up beneath the surface in a permafrost came when the Phoenix lander used its scoop to dig out a trough in the soil. This exposed sub-surface ice which, as would be expected due to the thin atmosphere, began to vapourise over the following days. This confirms the observations made by the Mars Odyssey and Mars Reconnaissance Orbiter

that there is ice beneath the surface of nearly all the northern half of Mars. But until one can drill down into the surface we will not know the depth, and hence amount, of water ice lying beneath the surface.

Methane in the Atmosphere

The discovery of methane in the Martian atmosphere, first detected by the European Spacecraft 'Mars Express' and recently confirmed by a United States orbiter, raises an intriguing thought. Methane cannot last for long in an atmosphere, so its presence implies a current source. It is produced by biological processes - so could life be present now? It could also be a result of decayed life forms (c.f., marsh gas) so indicating that life did, at one time, exist. On the other hand, it could be the result of some chemical processes or indicate that some volcanic activity is present - though we see no obvious evidence for this. But if the latter were the case, then some areas beneath the surface could be sufficiently warm so that, if life did once evolve, it could still survive. A future probe hosting a mass spectrometer will be able to distinguish between a biological or chemical origin for the methane as the isotopic proportions of carbon-12 to carbon-14 in the atmospheric methane would differ.

Rocks from Mars

Every year a group of scientists visit the Allan Hills region of Antarctica prospecting for meteorites. These will have fallen on the Antarctic shelf at some time in the past and compacted into the snow which, as ice, moves down towards the sea. In the Allan Hills region, wind strips off the ice revealing the meteorites which are easily seen against their white background. One of the more interesting meteorites found in 1984 weighed nearly 2 kg and was catalogued as ALH84001. It was initially misidentified and it was not until October 1993 that it was realized that it had originated from Mars. (One other meteorite of its very rare type contains gas inclusions that match the Martian atmosphere as analysed by the Viking landers in 1976.) Dating techniques indicate that it originated from the time when water was present on the surface of Mars and was ejected by an impact about 4 billion years ago to finally land on Anarctica about 13,000 year ago.

ALH84001 with micro-fossil and Carbonate Globules (right)

The rock became the subject of Intense scrutiny by NASA scientists who, in August 1996, announced that they had found evidence of decayed life forms in the form of polycyclic aromatic hydrocarbons. In addition, scanning electron microscopes revealed what may be the fossilized remains of bacteria - though smaller than any then known on Earth. If so, this would be the first real evidence of the existence of extraterrestrial life. However many other scientists refuted these findings: they felt that the organic compounds could be the result of contamination on Earth and that the structures seen in the rock would be too small to contain Ribonucleic Acid (RNA) necessary for a life form to replicate.

However, since then, ALH84001 and two other meteorites (one, the Nakhla meteorite, having fell in Egypt in 1911) have undergone more detailed examination using new techniques. These include an Ion Microprobe that can fire streams of ions onto micro-fossil samples producing a plasma that can then undergo detailed analysis. In 2006, London's Natural History Museum, which holds several fragments of the Nakhla meteorite, agreed that NASA researchers could break one open to provide samples that should be uncontaminated from its period on Earth. The surfaces show small pits containing carbon-rich material similar to that produced by bacteria on Earth hinting at the remains of living matter. In a recent interview given to 'spaceflight Now', David McKay, chief of astrobiology at the NASA Johnson Space Center in Houston, stated that the NASA team is "very, very close to proving there is or has been life on Mars," and that proof may well come this year.

Micro-fossils in the 1.3 billion year oldNakhla meteorite?

Manned Missions to Mars

In January 2004, President George W. Bush outlined an ambitious plan for NASA's future exploration of the solar system which included human missions; first to the Moon and then to Mars. Due to the current budgetary restraints the timescales for these missions have been extended, but at the end of last year, NASA indicated that the Orion Mars Mission in its Constellation program had the intent of landing humans on Mars by the late 2030s. The European Space Agency (ESA) also had long term plans for a manned mission to Mars within its 'Aurora' programme but it now seems likely (and sensible) that NASA and ESA will combine their efforts towards this goal.

However in February 2010, President Obama cancelled the Constellation project stating the project was too costly, "behind schedule, and lacking in innovation". Thought the primary aim was to take man back to the Moon, this was almost certainly a precursor to sending man to Mars.

A White House spokesman stated that: "This isn't a step backwards. I think the step backwards was trying to recreate the Moon landings of 40 years ago using largely yesterday's technology, instead of game-changing new technology that can take us further, faster and more affordably into space." The budget will, however, provide funding for further probes to the Moon, Mars and the Sun.

From April to July last year, four Russians, a German and a Frenchman, spent 105 days isolated in a simulated spacecraft to learn about the psychological problems that might arise on such long missions and a 520 day experiment is scheduled to start this year. Aside from such "human nature" aspects, one of the greatest challenges facing any future Mars mission has been how to protect the astronauts and their space ships from solar flares - clouds of particles that can damage DNA and destroy electronic instruments. The Apollo missions were only around eight days in length and, happily, avoided any such storms but on an eighteen month or more mission astronauts would almost certainly encounter one. This is regarded as the greatest single obstacle to a manned mission to Mars. Here, we are protected by the Earth's magnetic field and British researchers scientists based at the Rutherford Appleton Laboratory and Universities of York and Strathclyde believe that a spacecraft could be protected in just the same way by surrounding it with a magnetic field that deflects the particles. They hope to have a full size working prototype within a few years that might well be a solution to this major problem.

Sadly, or otherwise, it does not now look as though man will reach Mars within most of our lifetimes.

An interesting future.

It is, perhaps, a little surprising that, as the Sun moves towards the end of its life (still 5,000 million years to go) it is getting hotter. This means that, even without climate change, the Earth will get hotter and sometime around 1,000 million years in the future its surface will become uninhabitable. But, at the same time, the surface of Mars will become warmer and carbon dioxide and water will be released into the atmosphere. These are "greenhouse" gasses so the far thicker atmosphere will retain more heat and the surface will, once again, be able to hold liquid water. This could happen as soon as 500 million years into the future and stable conditions could then last for several thousand million years. Any life that might still exist beneath the surface could emerge and evolve and, even if not, there is ample time

for new life to emerge. Mars could even become a "lifeboat" for our human race should we still be in existence when the Earth finds it difficult to support life. There, perhaps, Homo Sapiens could perhaps find sanctuary until the Sun finally runs out of fuel around 6,000 million years into the future!