MIRA

2019.1
Number 104
Price 60p

The Journal of the
Coventry and Warwickshire Astronomical Society

http://www.covastro.org.uk/
covwarksastro@yahoogroups.co.uk

Mike Frost has been to the "Land of the Mid-Day Dusk" and his story starts on page two of his adventure to see the aurora borealis.

Above, 10:45 AM, sailing off North Cape. It's five days before the Sun rises here.

Above, the MS Trollfjord docked at Kirkenes.

Left, Bright Aurora along the wake of the Trollfjord.

CONTENTS

Land of the Mid-Day Dusk

By Mike Frost

Last January I spent a week on holiday in the far north of Norway in the company of my friends from the Totally Insane Travel Society, the people with whom I enjoyed the Svalbard eclipse in March 2015. Once again our aim was to observe the Northern Lights. The core of the trip was a four day cruise around Norway's North Cape on the MS Trollfjord, a ship in the Hurtigruten fleet.

A lot of people have this particular trip on their bucket list – but not necessarily in January. Usually people want to visit the Arctic Circle during the summer, when the sun never sets. Lapland markets itself as *"The Land of the Midnight Sun"*, but is curiously quiet about how that pans out around the winter solstice.

"The Land of the Mid-Day Dark", perhaps? Well, no, not really. The sun never rose during the week I was in Norway, but nor was it dark at lunchtime. January is a week or two past the solstice, far-north Norway is only just inside the Arctic Circle, and so the Sun, although never rising, is not far below the horizon. The result is a rather pleasing extended dusk, often with a gorgeous pink glow in the sky. The Norwegians claim to love this time of the year.

After a night spent in Heathrow EasyHotel, the most soul-destroying establishment I've ever stayed in - it was made entirely of orange plastic - I caught the early SAS flight to Oslo, joining up with "tour organiser" Steve and his partner Lilia; and from Oslo the regional flight up to Tromsø. This was my third visit to this lovely city, capital of the Arctic; I've never failed to see the aurora borealis when I visit Tromsø, although it's not always a lucky location for me – my first attempt to get there was thwarted when I came down with flu; my second attempt ended with me catching a heavy cold at my destination.

For our first night in Norway, we stayed in the Radisson Blu hotel right by Tromsø harbour. We met up with the remaining two members of our party, Colin and Kevin, who had flown in from Ireland. We went out for a pizza and a beer or two. Unfortunately the weather was cloudy, although both the weather forecast and solar weather forecast were very optimistic for later in the week.

Tuesday was cruise day. MS Trollfjord didn't arrive in Tromsø until 2:15 PM and didn't leave until 6:30 PM, so there was plenty of time to kill before our boat left. Our original plan was to take the Fjellheisen cable car and enjoy the views over Tromsø Island (the city is a little like New York, on a small island sandwiched between the mainland and a larger island, Kvaløya). However, the wind was too strong and the cable car was shut.

Plan B involved first visiting the glass-blowing centre. We watched a demonstration of blowing and Lilia purchased one of their ornaments. Then we walked across the road to the Mack Brewery – the world's most northerly. We had a quick sup of their excellent beers in their pub, the Olhallen, then joined the brewery tour. Mack have been brewing in Tromsø since 1877, as a family business; the majority of the brewing now takes place 70 miles south of Tromsø, and the original building hosts a microbrewery where they try out new recipes.

The brewers, Rune, Eivin and Esben, have an entertaining approach to brewing. They make beer to a rock music soundtrack, and each brew has its own playlist, which can be accessed on Spotify from the Mack website. The brewing vats are named for an eclectic selection of artists: Ringo Starr, Elvis, Patti Smith, Iggy Pop and a Norwegian by the name of Jokke. One of their favourite brews was named Lemmy's Lager until Motorhead objected – so it's now Lenny's Lager. Iggy Pop, on the other hand, visited the brewery to sample the beer brewed in honour of him.

We'd have stayed for another beer or three but we had a boat to catch. We wobbled back to the hotel, picked up our luggage, and hauled the bags round the corner to where the boat was waiting for us.

Hurtigruten run a service which sails all the way along the Norwegian coast from Bergen to Kirkenes, calling three or four times a day at many of the ports along the route. For smaller towns, the visit may only be fifteen minutes; for larger cities such as Tromsø or Hammerfest, the boat docks for several hours. For many years, the Hurtigruten service was the quickest and most convenient way of traveling along the crinkly coastline of northern Norway, and the main way by which freight, such as fishery catches, could be moved around. The ferry service is still used to travel from place-to-place, but demands of modern-day food chains now means that a lot of fish is flown by air, to arrive fresher into restaurants.

At the same time as the decline in cargo, there was a pick-up in the number of tourists who wanted to use the ferry service. The Norwegian coast, after all, is one of the most spectacular sights on Earth, and the midnight Sun a novelty to be experienced. Hurtigruten therefore

decided to upgrade the previously rather basic passenger service to offer an experience more like a cruise ship.

We found this out, memorably, when we joined the 8 PM sitting for dinner. The food was tasty and plentiful. But the menu descriptions were laugh-out-loud pretentious. "The delicate but at the same time modest chicken soup we are serving today derives from our efforts to reduce Hurtigruten's ecological footprint. The same hens we have prepared for this evening's light soup laid the eggs that we are serving on board". We searched high and low for the onboard chicken coop but never found it.

Mid-way through our meal an announcement came on the tannoy – the aurora was visible from the deck. We polished off dessert – Roros yogurt cake, made with syrup derived from dandelions "hand-picked during the Arctic spring by the youngsters of Rolvsøy, giving them a chance to earn some summer holiday money" - put on umpteen layers of clothing, and adjourned to the upper deck. The Trollfjord had nine decks; decks 1 and 2 for the crew, 3 for cars, 4 for passengers (including my little cabin). The restaurant and lecture theatres were on deck 5, posh cabins on 6 and 7, with a promenade deck round the outside of 6. Deck 8 had a bar, café, and scenic lounge, deck 9 the gym, sauna, outside hot pool and a large open space for observing.

Orion and the Pleaides with light pollution. Exposure 10 sec at f3.5, ISO3200 for all aurora pictures.

I had brought a Christmas prezzie with me – a Nikon 5300 DSLR camera. Fortunately I was in the presence of some superb imagers, who were very happy to help me set up the camera for aurora photography. The display on the Tuesday evening was not fantastic, but it did enable me to take a few test shots and prove that I could capture the aurorae on my camera.

Wednesday morning we docked in Honingsveg, the port furthest north on the itinerary. Several excursions were available: Steve and I joined the trip to North Cape. The road to the most northerly point in Europe is bleak and, in winter, you are only allowed to drive it in convoy behind a snow plough; our coach joined two other coaches and a minibus on a single-carriageway road which would have been passable without the plough, but would quickly become blocked as soon as snow fell.

North Cape is not a very hospitable place in January, even when not snowing. There's a giant metal globe and a monument commemorating the visit of King Oscar II. You spend about five minutes bearing the howling gale and then you flee into the visitor centre, where you can see dioramas from the history of North Cape, and a rather good film about the people of the region.

I have problems with North Cape. It's supposed to be the most northerly point in Europe – but, when you stand by the giant sphere, you can see a promontory half a mile to the west which juts out a little further to the north. But it's far too jagged to build a visitor centre there, so everyone has to pretend that the visitor-friendly, flatter cape is the furthest north.

And, while I'm at it . . . North Cape is on Mageroya Island – so it isn't even on the European mainland. I want my money back! And if it's an island … how do the reindeer migrate here for the summer season, as our tour guide assured us they did? I was told the answer to this one – they arrive by reindeer ferry, and in the autumn the seas are warm enough to allow them to swim back to the mainland. But why don't the reindeer just take the tunnel to the mainland? None of this rings true – I suspect a giant conspiracy...

Thursday saw us dock in Kirkenes, the most easterly point on the Hurtigruten route. I joined the excursion to the Russian border. We started with an interesting side trip into recent history when we entered one of the extensive air-raid shelters built underneath the city. In the Second World War, northern Norway was a brutal battlefront. Nazi-occupied Norway fought against Russians. Kirkenes was levelled by daily air-raids. Eventually, Germany ordered the forced evacuation of the civilian population. Half left; half fled into the mountains and mines – neither was a palatable option in the bleak Norwegian winter.

We drove to the village of Elvenes and across the Pasvikelva River. For most of its course, this river is the border between Norway and Russia, but there is an Orthodox church on the Norwegian side a mile to the

"It could be you…" The aurora auditions for the National Lottery.

south, and so the Russians traded territory east of the river for a slice of land to the west, which included the church. Our tour guide told us that the church was occasionally used for baptisms, but the water supply to the church sometimes froze. Not a problem, he added: the congregation would simply head outside, cut a hole into the ice, and baptise the child in the river.

Then he said "only kidding".

The border itself was a bit of a disappointment. The tour guide has promised us a shopping mall, bit this turned out to be a small souvenir hut guarded by a bored looking husky dog. We weren't allowed up to the border itself so there was no chance to poke a foot onto Russian territory.

We were by no mean the only aurora watchers on board the Trollfjord. John Mason was leading a large party (80+) of northern lights observers who were on the boat for the entire 12-day cruise. We joined and enjoyed one of the lectures that John gave – "From the International Space Station to the surface of Mars". The ship crew were delighted with our TITS t-shirts, featuring Dr Mason being launched as a rocket. John was an assiduous aurora spotter – we joked that his cabin was underneath the funnels, as he seemed to spend all his nights on the deck. Thursday night was better still for aurorae and I snapped a few more pics.

On Friday we stopped in Hammerfest, which claims to be the northernmost city in the world, although Honingsveg disputes this. There isn't a huge amount to do in Hammerfest – we had a stroll around town, visiting the rather elegant church and having a coffee in one of the cafes. Final stop was the Royal and Ancient Polar Bear Society, a museum dedicated both to the history of the town, and the natural history of the North Atlantic. It's full of polar bear memorabilia, even though there are no polar bears anywhere near Hammerfest, which is much too far south. This doesn't stop Hammerfest erecting polar bear statues in the town centre.

One place we didn't get to visit (it was the far side of the harbour) was the Struve Geodetic Arc memorial. Hammerfest was the northernmost point on this ambitious attempt to map the shape of the Earth by accurately surveying a meridian line, due north-south, from Hammerfest to the Black Sea. This line passed through the Tartu Observatory in Estonia, whose director Friedrich Struve, was in charge of the project. The arc consisted of 265 separate locations, each of which had its latitude and longitude measured, plus its exact distance from the nearest neighbours. This information enabled the length of a line of longitude to be measured at 70 degrees north (the latitude of Hammerfest) all the way down to 45 degrees north (the Black Sea). If the Earth was a perfect sphere the length would not vary with latitude; Struve's measurements instead confirmed that the Earth is an oblate spheroid – there's a bulge round the middle.

In recent years the economy of Hammerfest has been greatly boosted by the building of a natural gas terminal on Melkøya Island. Kevin, who is a geophysicist, was involved in the survey of the island, and spent several weeks going back-and-forth across the island, taking measurements. One day, his team was joined by a military-looking type with a clipboard, who was not very forthcoming with information. Eventually, he was asked directly what he was doing. "Checking the minefield. . ." was the response. "What minefield?" "Left over from World War Two", he responded; "and don't worry, all the mines are accounted for. Except one. . ."

The last leg of our cruise was from Hammerfest back to Tromsø. Once again, during the evening meal, it was announced that the Northern Lights were visible. And were they visible! For the next three hours, we were treated to the best display I've seen. The aurora stretched from overhead, along the wake of the boat. Activity shimmered along the curtains; coronae erupted above us. I was able to set up shots of aurora running above Orion; either side of the Plough; underneath Leo; appearing to spout from the ship's funnel. By now, I had figured out the remote control, so my images were more stable, however it was very windy. At one stage I had one hand resting on the tripod to grab it if it fell over, the other hand operating the remote control, and my gloves between my knees so that could operate the camera. The wind caught the end of my scarf – and suddenly I no longer had a scarf! The next time you see a documentary on pollution in the Arctic Ocean, watch out for it!

All too soon we pulled into Tromsø and disembarked to end our cruise. We took a midnight taxi south from the dockside to the Sidspissen Hotel, on

the southern point of Tromsø island. Even as we checked in, the auroral display was still active, so we immediately rushed outside to the waterfront to watch the last twists of the display.

It was, not surprisingly, a late start on Saturday morning. We planned a visit to the island to the west of Tromsø, and in particular to the resort of Sommerøy, on some small islands to the west of Kvaløya. We took the road bridge from Tromsø over to Kvaløya, loaded up with provisions and lunch, and then had a leisurely drive across the island on a road which wound around the sea fjords. Lovely scenery.

We ate at the resort and then went outside to see how the aurora was doing. The evening started off promisingly, but frustratingly failed to deliver the storm we had witnessed the previous night. After half an hour or so we decided to return to Kvaløya, stopping en route at observing sites which we had noted on the way out. After trying out a series of locations we eventually returned to Tromsø, arriving around midnight. The others stayed on an extra night after me and were able to get some great pictures Sunday evening from one of the Kvaløya locations we had scouted.

I was dropped off at the airport the next morning and enjoyed a trouble-free flight back to England, where it was pouring with rain. The sun didn't rise for the entire time that I was in northern Norway, but that didn't stop it being an excellent holiday.

A Wooly Solar System

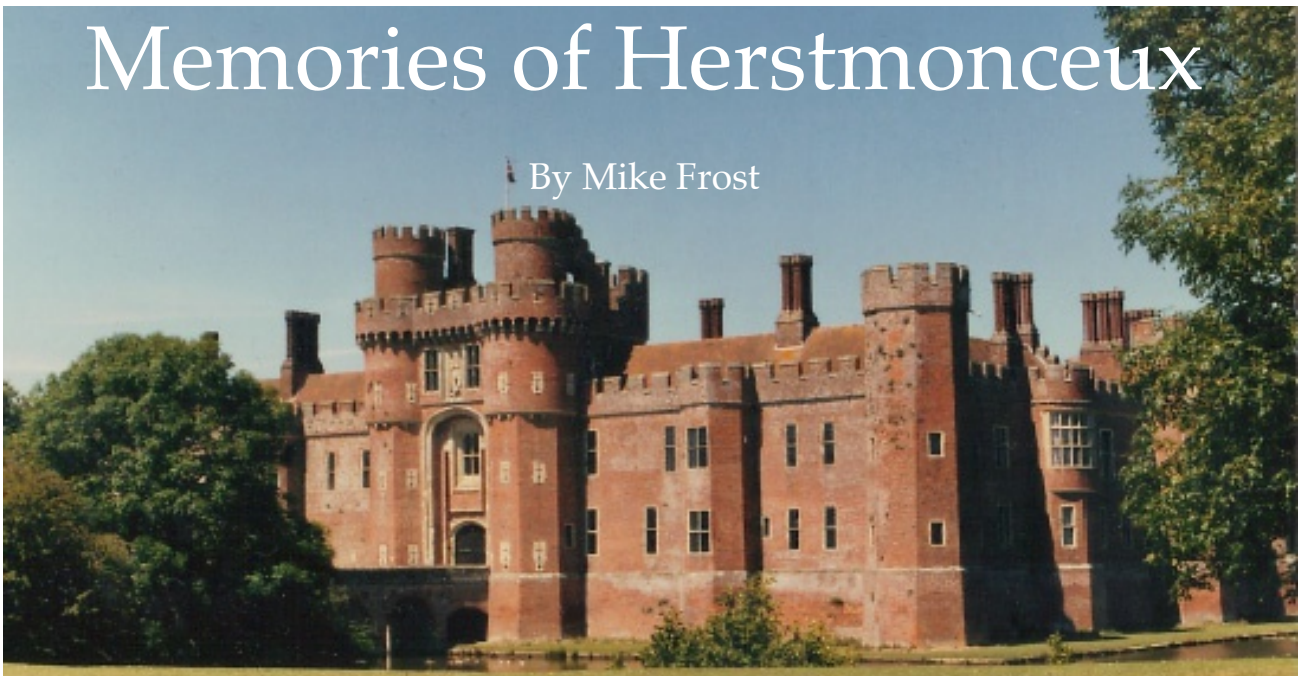
Spotted by Ivor Clarke

Above Mercury, Venus, Earth & Mars with the odd star. Right from the centre post, Jupiter, Saturn, Uranus and Neptune with a Black Hole and a nebula all in wool.

During September my wife and I spent a few days down on the south coast. One of the towns we visited was Battle, which gets its name from a little punch-up nearby in 1066. While walking around the town we came across lots of knitted covers on bollards and railings and down a street at the bottom of the town was a knitted representation of the solar system's planets advertising the local East Sussex Astronomical Society. Each of the planets was a colourful furry ball of wool hanging over a A4 picture of that planet in order from the sun with the planets name and the title of the music section from Holst's *"Planets Suite"*. In the centre was a little notice saying "The Solar System was yarn bombed by. . . " with the names of the knitters. As an advert for the local society, I thought it caught the eye and a board nearby gave a list of forth coming talks and club nights for the coming months.
Any knitters in our society?

Memories of Herstmonceux

By Mike Frost



As you might know, I am the director of the British Astronomical Association's historical section. Twice a year we produce a newsletter, edited by the section's deputy director, Dr. Lee Macdonald. In the autumn 2018 newsletter, there was an article by Gerald North, the distinguished astronomy writer, about his experiences as a guest observer at the Royal Greenwich Observatory, Herstmonceux, during the 1980s. Lee and I were delighted to run the article in the newsletter because we both had connections to the Herstmonceux observatory. Lee has researched the history of the RGO at Herstmonceux, and lectures on the fascinating story of the Isaac Newton telescope, which started life in Sussex before moving to La Palma.

My own connection to Herstmonceux is via the M.Sc. course in astronomy which I studied at Sussex University from 1984 to '85. For that course we had to produce a dissertation. We had a choice of around 30 topics, but most of them seemed to involve only library study. I wanted to do real astronomy! There were only two options that interested me, both of which involved processing astronomical data at Herstmonceux. There were seven students on the M.Sc. course. One other student, Bruce Swinyard, felt the same way as me, so we each picked one of the two options. And for the rest of the academic year, every Wednesday, I caught the train to Polegate, where the RGO's resident driver picked me up and delivered me to Herstmonceux.

I loved the observatory. It was located in a beautiful estate in the Sussex countryside, centred on Herstmonceux Castle, a medieval manor house with an impressive but ornamental moat at the front, and formal gardens to the rear. The remainder of the estate was devoted to astronomical activity. To the east of the castle, on a hill, was the Equatorial group of telescopes, six domes connected to a central block, divided by ornamental pools which were a menace to observers on dark nights! To the south was the great dome of the Isaac Newton telescope, the largest telescope ever used in Britain, which had been moved to La Palma in the Canaries a few years before I arrived. Close to the castle was a laser ranging facility. The final part of the estate, to the south-west, was the administrative block housing the astronomers.

The RGO was an inspiration. My thesis supervisor was Dr. Jasper Wall, who went on to become the final director of the RGO before it was subsumed into the Institute of Astronomy in Cambridge. My job was to process CCD images of the Galactic Centre taken from the La Silla observatory in Chile (Bruce was also processing CCD images, looking for galactic jets). I must have processed dozens of images from the computer tape, and end result was a series of colour vs magnitude plots for stars in the direction of the centre of the Milky Way. My supervisor had published a paper in Nature in which he and his collaborators claimed that two of the stars in the field were actually at the galactic centre, but I was able to show that they were actually foreground stars. I'm still waiting for the retraction in Nature!

In addition to my weekly visits, there was also a two week residential course in instrumental astronomy at the observatory. I remember staying in a tiny attic room in the Castle – great fun! In addition to a whole series of practical lectures, we were able to do some direct observations from one of the telescopes in the six domes up the hill from the castle. Thirty two years on, I can no longer remember which telescope, but Gerald North advises me that it was likely to have been either the 13-inch astrographic refractor or the 26-inch (the Thompson refractor that originally shared its mount with the 30-inch reflector referred to in Gerald's

article). We had a list of recurrent novae and we took a series of exposures, to see if any of our targets were in outburst. When we developed and examined the plates, none of them were. But we were so enthusiastic that we requested a second set of targets to observe the following night.

I hope I'm conveying how much I enjoyed my time at Herstmonceux – a beautiful location, full of interesting and knowledgeable people. A few reminiscences spring to mind – attending a seminar by David Allen, who had observed the Galactic Centre, and pummelling him for information for my thesis; pestering Neill Reid for information on the luminosity function of stars; being described by Stuart Keir, the tech assistant, as "one of Starlink's noisier users"! One month I was the second-greatest user of computer resources at Herstmonceux, beaten only by Carlos Frenk – who was running large-scale simulations of the universe!

However, both Bruce and I noticed one very obvious thing – the number of very talented young astronomers who were seemingly making little progress with their careers, moving from one post-doctoral post to another, with no hope of achieving tenure. To an ambitious young man like me, this didn't seem to be way to achieve a meaningful career. I made enquiries about doing a PhD, both at Sussex and elsewhere. It turned out that my lecturers at Sussex were keen on me doing a PhD, but that didn't come across to me at the time. By contrast, I also applied for jobs in industry, and companies appeared much keener to recruit me. GEC and the CEGB made me job offers, and I chose GEC in Rugby. Bruce Swinyard also took a job in industry.

I'm still in the job I started in 1985 – the company has changed ownership many times, and is currently owned by General Electric. Bruce, on the other hand, decided after a year or two that he had made a mistake, and returned to academia. He had a very successful career designing space probe instrumentation, based at the Rutherford Appleton Laboratory, with a visiting professorship at UCL in London.

There's a sad postscript. Bruce Swinyard passed away with cancer three years ago, in the prime of his life, leaving behind his widow Margaret (who I knew from Sussex) and children. His obituary was in the January 2016 edition of Astronomy and Geophysics.

Which brings me to my conclusion as a historian. It's up to those of us who were there to record our memories of these historic locations, while we still can.

If you're interested to know more about life at Herstmonceux, I'd also recommend George Wilkins' entertaining account which appeared in The Antiquarian Astronomer *("A Personal Review of the History of the Royal Greenwich Observatory at Herstmonceux Castle, 1948-1990", Vol 4, January 2008, pp.69-80)*. George painted an appealing picture of how sociable life at Herstmonceux could be.

Once the Isaac Newton Telescope had been transferred to La Palma, the need for a dedicated observatory in Sussex dwindled. In 1990 the RGO was transferred to Cambridge, and in 1998 it was subsumed into the Institute of Astronomy there. The Equatorial Group of telescopes now houses a science centre, home to a popular science festival every September. The RGO buildings and the Castle are a European Campus for Queens' University in Canada. Herstmonceux Castle and the gardens are open to the public, and hosts weddings, and a medieval festival. But the laser ranging station still exists, and still carries out scientific research as the NERC/BGS Space Geodesy Facility.

Left, Part of Herstmonceux Gardens and below, Bruce with Margaret.

Mars

A brief geological history By Paritosh Maulik

Although the Earth is about 4.5 billion years old, our knowledge of the process of formation of the geological features, as we see on the Earth today, extends to about the past 600 millions of years. These processes involved, migration of land masses across the globe, forming and breaking up of super continents, global flooding, formation and erosion of mountains and repeated ice ages to name a few. The continents are still being reshaped by geological processes such as volcanism, earth quakes, movement of land masses and weathering. What we have learnt from the processes of formation of the Earth, is now being applied to explain the land features we see on other planets and the moons. Here is a brief description of the geological feature of Mars. Evidence is being gathered by the orbiting space probes and probes on the planet carrying out in-situ chemical analysis of the rocks.

One crucial data point is lacking, radiometric analysis to determine the age of the extraterrestrial rocks. Currently we do not have samples of Martian rocks for analysis on Earth. Some information has come from examination of Martian meteorites, about 120 Martian meteors have been found. Bringing back samples of Martian rocks to the Earth for still better examination are being seriously considered.

Some facts about the Red Planet

Diameter: 6794km (about half the diameter of Earth)
Surface area: 145 million sq km (about the same as Earth's land area)
Gravity: 3.711m/s^2 (about one third of Earth's gravity)
Density: 3.93g/cm^3 (Earth: 5.51g/cm^3)
Average distance from the Sun: 227,940,000km (1.52 times that of Earth)
Martian day: (a 'sol'): 24 hours 37 minutes
Martian year: 669 sols or 687 Earth days
Average temperature: –55°C (from –133°C at the winter pole to +27°C during summer)
Atmosphere: 95.32% carbon dioxide, 2.7% nitrogen, 1.6% argon, 0.13% oxygen. There is a trace of methane and the methane level increases from time to time. On Earth the methane is of biological origin. We do not have any confirmatory evidence of the of source of Martian methane, wether it is geological or biological. One possibility may be reaction of radiation between the organic materials, brought by the meteors.
Atmospheric pressure at the surface: 6.35 mbar (less than one hundredth of Earth's atmospheric pressure, 1 bar)
Moons: Phobos: 27x22x18km; ~6,000km above Mars; Deimos: 15x12x11km; ~20,000km above Mars

Geological periods

A Geological period is generally named after place name where the geological evidence was first identified, such as Cambrian period (543–510 million years ago), after the Cambrian mountains in Wales, Devonian (409–301 million years ago) as in Devon. These geological periods are best guesses, based on rock formation and fossil record. These are not the absolute dates. Absolute date is determiner by radiometric dating. On Earth, we can analyse rock samples for chemistry and determine the age by radiometry, but we have limited data of Martian rocks. Our knowledge of Martian geology is based on in-situ analysis by landers and spectroscopy by the orbiting probes. There is no radiometric data of Martian minerals.

Geological time

Pre-Noachian: (4.5–4.1 billion years ago) (named after the Biblical Noah)
Noachian: (4.1–3.7 billion years ago)
Hesperian: (3.7–2.9 billion years ago)
Amazonian: (2.9 billion years ago to present)

The Martian surface is mainly in two halves. The southern highlands of Mars is highly cratered and therefore formed earlier, where as there are fewer craters in in the northern plains and this area is younger and formed after 3.8 billion years after the great bombardment (by asteroids and comets). In the equatorial region there is Valles Marineris canyon system. It is 4000km (2000 miles) long and 704km (4 miles deep). This Martian canyon is large enough to dwarf the Grand Canyon, 800km (500 miles) long and 1.6km (1 mile deep). Valles Marineris has become the iconic image of Mars as the Houses of Parliament is for London.

Pre-Noachian: (4.5–4.1 billion years ago)

The crust formed around 4.5 billion years ago. There were heavy impacts of asteroids and comets. Relatively flatter northern half with relatively fewer craters probably formed in this period. The planet is mainly two halves, northern lowlands and highly mountainous southern highlands. The atmosphere was dense with gasses and dust from impacts and outgassing from the interior. Water vapour condensed to form vast oceans with water at high temperature. The water cooled and life could have emerged 4.4–4.3 billions years ago. Since then most of the atmosphere has escaped the planet and some of it has been absorbed by the surface.

Noachian: 4.1–3.7 billion ears ago

Heavy bombardment by asteroid and comets

created large features like Hellas, Isidis and Argyre basins and smaller craters. There was large scale volcanism, with some of the volcanoes the largest in the solar system. These volcanic activities were associated with fracturing of the crust. It formed rift valleys systems such as Valles Marineris. Dust and gasses released from these volcanos were trapped, forming an atmosphere. The atmosphere was warmed by the solar heat and clouds formed. Precipitation from the cloud gave rise to large lakes in many these basins and craters. Conditions were favourable for the formation of life, albeit in restricted places. Some of these were also present in the northern lowlands as well. Most of the valley system present in Mars today probably formed in this period.

The water reacted with soil and formed clay minerals, as identified by the surface rovers on the planet. The water was non-acidic. The planet is still cooling down, with the interior probably froze; the dynamo ceased to operate and the planet lost its magnetism.

Hesperian: 3.7–2.9 billion years ago

Evidence of this period is named after Hesperia Planum. There has been considerable reduction in impact cratering, but volcanic activities were continuing, geological activities were slowing down. Much of the northern lowlands were shaped by the lava flows. About 30% of the Martian surface as we see it today was formed in this period.

Acidic gasses from the volcanoes acidified the water. This acidic water reacted with minerals to form sulphate mineral deposits. The planet is still cooling. More water is locked up in the soil. Formation of valleys are slowing down. However meteoric impacts released occasional large quantity of water leading to flash floods. The surface formed from such activities are described as chaotic terrain, large areas strewn with rocks.

Amazonian: 2.9 billion to present

The beginning of this period is somewhat uncertain, but represent about half of the life of the planet. Large-scale geological and climatic changes are slowing down. The atmosphere is dry and arid. Erosion and weathering of rock is also considerably low, however there are warmer and wetter condition from time to time. These lasted for shorter periods.

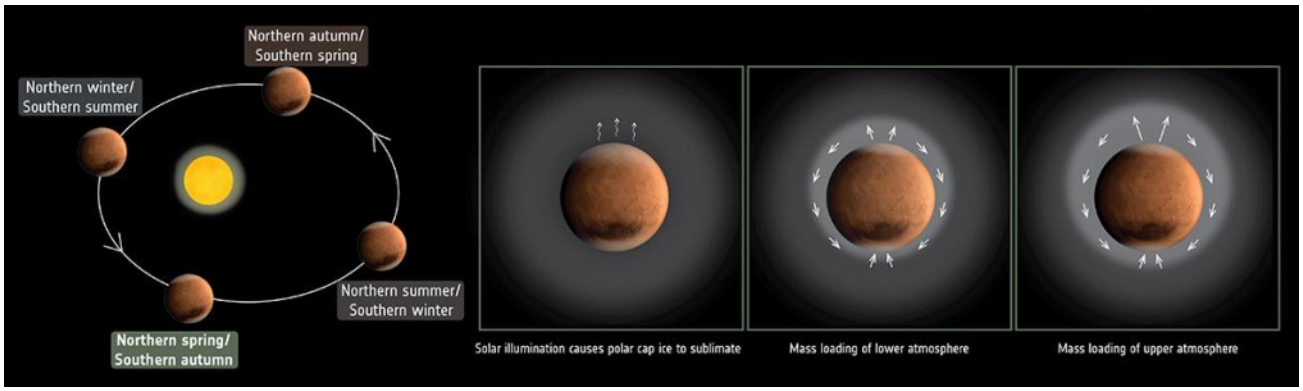
The atmosphere is now too thin and surface pure water evaporates. Depending on the position of the planet and tilt from the Sun, the surface water could have stayed on the surface over millions of years. There is some evidence of the melting of the polar ice caps.

Volcanism has not ceased completely, but continues from time to time reshaping the northern lowlands. There is lava flows from the highest volcano in the solar system, the Olympus Mons and other places. Wind erosion sculpts the older features. Some evidence of glaciation is present in places. Red ferric oxide forms on the surface to give the red colour of the planet, we see it today.

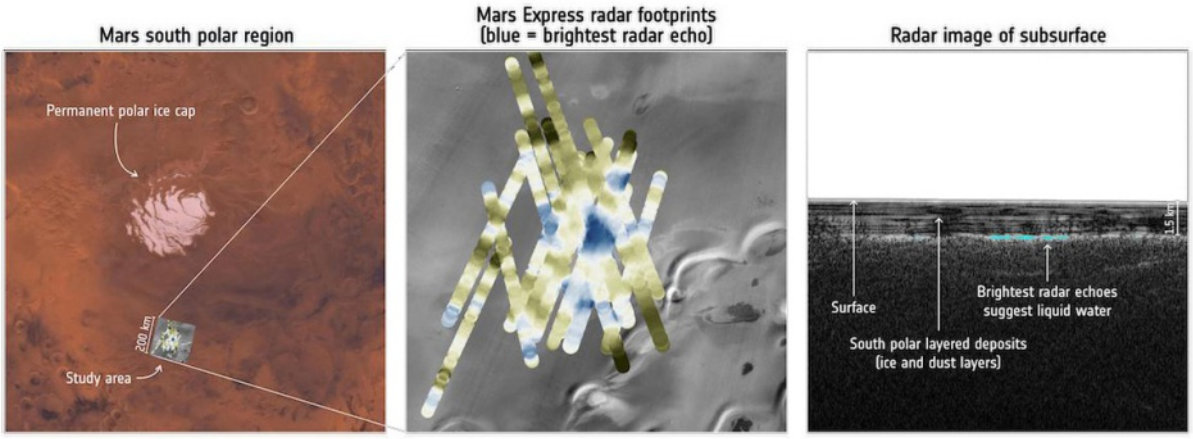
Both of the poles of Mars has ice caps consisting of water and carbon dioxide, where as on Earth, the polar cap is water ice. In the respective polar caps, carbon dioxide evaporate during spring and reform in autumn. In the high altitude areas, there are polygon shaped land features. On Earth similar features are seen in areas where there is periodic freezing and thawing of land. This may be one of the evidences of presence of water on Mars.

Mars Interior

Not much information is currently available on the Martian interior. NASA's Mars Pathfinder mission has measured the moment of inertia of the planet. Moment of inertia gives an idea about the distribution of matter in a rotating body. From such observations, the core of the Mars is about 1,794km (1,115 mile) ±65km (40 mile) in radius. Primary constituents are iron and nickel with about 16–17% sulphur. Metallic sulphides generally have lower melting point. Therefore the core is expected to be fluid. A rotating fluid core is expected to generate a magnetic field. Orbiting satellite suggest that the magnetic field of Mars is localised. The southern half is more magnetic than the northern half. Mars once had a magnetic field, but it is switched off now. However this does not mean that the core is not fluid.



Left inset: Sun warms the polar cap; gases begin to sublimate. Centre: Gasses rise to lower atmosphere, about 30 km altitude and circulate: Gasses rises to to about 200 km and condensates on the other cap.



Left: Permanent ice cap and the area scanned. Middle: Radar footprints. Right: Highest radar reflection suggests liquid water at a depth of 1.5 km. Dust and ice layer above the water level.

The average thickness of the Martian crust is about 50km, but this is not uniform. The crust is thicker in the south than the north. Both Mars and the Earth formed at similar times, Mars being smaller, it cooled faster and hence, the crust of Mars is thicker than that of the Earth.

Volcanoes on the Mars suggest that there is movement of material in a liquid core. On Earth there is the process of to plate-tectonics. Plates move away from each other and when a plate meets another plate, it subducts, eventually gets molten and come out as volcanos, recycling of material. But on Mars perhaps there is no evidence of such plate-tectonics. There has been movement of plates on Mars, but no recycling as occurs on Earth. This may be the reason that the Martian volcanoes are so high. Redistribution of material did not occur.

Some Martian meteors are of volcanic origin, that is, these are from the mantle. The trapped gasses is these meteors have similar composition to those of Mars, therefore these meteors are from Mars. Mantle rock composition of Earth and Mars similar, but the latter has higher iron content.

Atmosphere

Gas circulation on Mars is Global. Mars has polar caps consisting of water and carbon dioxide ice. During spring when one of the one of the polar caps gets warmed by the Sun, the other cap is on its way to freezing. ESA's Mars Express has monitored the circulation of over a period of 10 years. These observations showed that the circulation of gas is on global scale; it rises from one polar cap and condenses on the other. Gases from the sublimation of the polar caps can rise up to about 200km from the surface.

Dust storms occur on Mars. These are often localised and lasts for a few weeks. However storms on a global scale can occur every 3–4 Martian years (6–8 Earth years) and may continue for months. The orbit of Mars is more elliptical than that of the Earth, as a result, the southern hemisphere gets hotter. As the warm air rises, it caries dust with it. Sublimation of carbon dioxide from the polar cap, thickens the atmosphere, and helps to carry more dust. The upper level is still cooler. This temperature difference of the air column creates storms as occurs on Earth. Most of the storms are not large scale, but some of these can occur of global scale. It is not certain why there are gaps between the occurrences of large storms. It may be that the dust sources may have to go through some cycles to build up the level required to start big storms.

Water, water. . .

Ground penetrating radar experiment on board Mars Express claims to have found the most compelling evidence as yet of liquid water near the southern ice cap of Mars. The observations have been interpreted as the presence of a sub-tertian lake of 20km diameter at a depth of 1.5km below the surface. The area scanned is about 200km. The water is not “pure”; it is likely to be saturated with salts. Ice melts under pressure and the pressure from the overlying surface and the salt content would reduce the freezing point of the water. So it is possible that the water can stay as liquid. The results are based on 3 years of pains-taking observation and data analysis, between 2012-2015. Mars Express will be 15 years old on December 25th. This is still an indirect evidence. For direct evidence one has to dig to a depth of 1.5 km for sampling, which brings some technical challenges.

Mars Missions

The InSight Mission, launched in 2018 May and landed on 2018 November 26th, is part of NASA Discovery programme and will carry out a detailed geological study of Mars. The main instrument is seismometer; other probes include heat flow measurement, magnetic studies, weather station and probes to monitor how the interior structure of Mars affects its rotation. It will monitor Mars quakes. Quakes can be set off by the cooling of planets. This mission is capable of estimating the crust thickness to about 5km accuracy. Duration of the mission is 1 Martian year equivalent to about 2 Earth years.

A ESA and Russian Space Agency ExoMars Trace Gas Orbiter and Schiaparelli Landing craft a demonstrator module. Launched 2016, reached Mars 2016 October. Trace Gas orbiter is continuing the orbit; science operation from 2018 March–2019 December. The Schiaparelli lander lost contact 43 second before the touch down. Images from NASA Mars Reconnaissance Orbiter seems to suggest that there was hard landing and the assembly broke up.

ExoMars Rover (ESO) and Stationary Platform (Russian Space Research) to monitor surface environment at the landing site; to be launched 2020 and a NASA 2020 Rover.

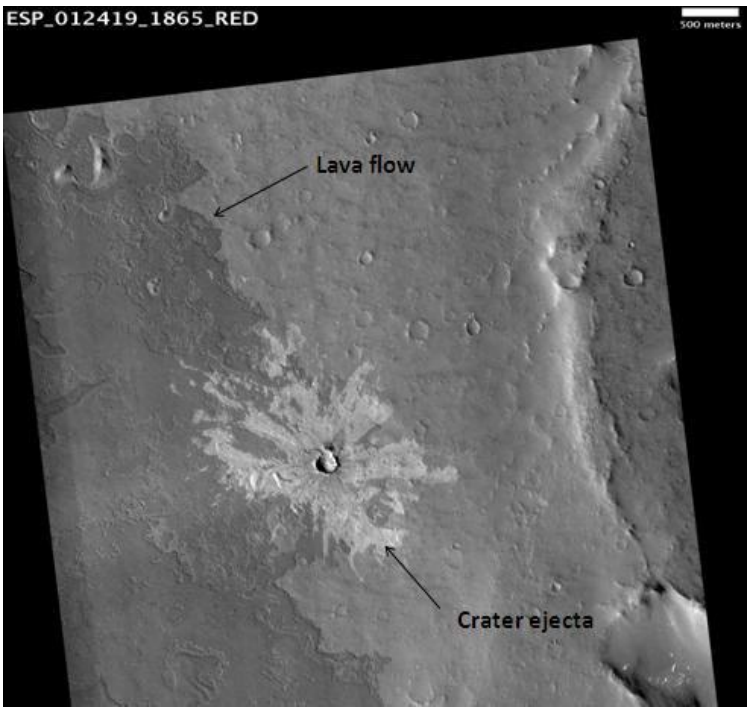


Image illustrating superpositioning, a principle that lets geologists determine the relative ages of surface units. The dark-toned lava flow overlies (is younger than) the light-toned, more heavily cratered terrain (older lava flow?) at right. The ejecta of the crater at centre overlies both units, indicating that the crater is the youngest feature in the image. The lighter area on right is covered with impact crater. This area is older than the darker lava flow the left side of the image. The lava flow has covered the older area. Ejection from the crater covers both areas and therefore a still later occurrence (NASA-JPL image)

Oumuamua: a distant visitor

By Paritosh Maulik

In 2017 October the Pan-STARRS1 telescope at the Hawaii Institute for Astronomy detected an object, provisionally named as A/2017 U1 (A for asteroid), travelling through the solar system. Its trajectory was different from the previously observed asteroids and comets. Further observations indicated that the new object appeared to be travelling from interstellar region and the name was changed to the current name, 1I/2017 U1, I stands for interstellar. It is the first interstellar designation of an astronomical object. The other name in the Hawaii language is Oumuamua meaning *"like a scout or messenger sent from the distant past to reach out to us"*.

Comets and Asteroids, a brief description

Both asteroids and comets are the leftover material from the formation of the solar system.

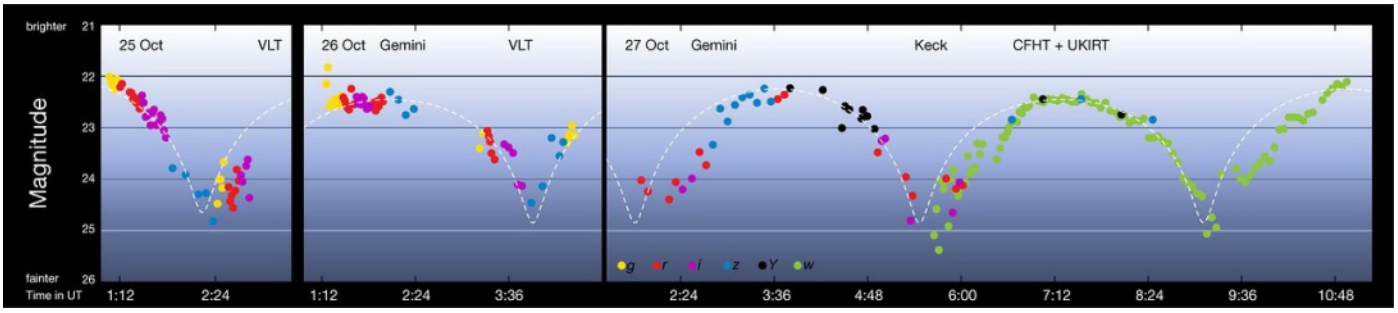
Asteroids formed close to the Sun. Asteroids reside in the asteroid belt in between Mars and Jupiter. These are mainly made from rocks and minerals and are generally free of ice.

Comets are likely to have formed away from the Sun, where the temperature was low. Comets contain volatile materials including water ice, so as the comets come near the Sun the volatile matters sublimate and form ion and dust tails.

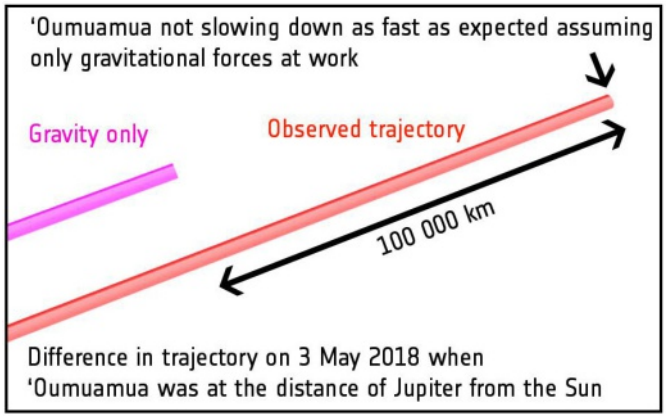
Oumuamua Detection and Trajectory

The first detection was in 2017 October, by PANSTARR 1, 1.8m diameter; 1.4 Gigapixel camera, digital survey telescope at the university of Hawaii. It appeared that the trajectory of this object was unusual and moving vary fast. Different terrestrial and space telescopes were trained on the object. The total observation period was just over a month, before the object disappeared.

Eccentricity, e, is a term used for indication of roundness of orbit. For circular orbit, e=0; for elliptical, e is in between 0 to 1; for parabolic, e=1 and hyperbolic, e is greater than 1. The trajectory of Oumuamua is highly eccentric, 1.2. An object of eccentricity e=1, has a velocity of greater than the escape velocity of the Sun; it will overcome the influence of solar gravity and will escape into interstellar space. The interaction of an object with a planet can put the object into an orbit, with eccentricity just greater than 1, but with the eccentricity of 1.2 of Oumuamua rules out an encounter with any known or unknown planet of the solar system. And even if there was a planet with which Oumuamua had an encounter, which has led to its highly eccentric orbit, this planet must be very far away from the Sun. When detected, the speed of Oumuamua was 83.7km/sec (196,000 mph). Detailed calculation of the trajectory has led to the conclusion that Oumuamua has its origin not in the left over debris of solar system or any nearby star, but somewhere else in the Milky Way. Its orbit is such that even if it had an encounter with a nearby star, the nearby star was farther away from where it is now.



This plot shows how the interstellar asteroid `Oumuamua varied in brightness by a factor of 10 during three days in October 2017. The colored dots represent measurements through different filters, covering the visible and near-infrared part of the spectrum. The dotted line shows the light curve expected if `Oumuamua were a cigar-shaped ellipsoid with a 1:10 aspect ratio. The deviations from this line are probably due to irregularities in the object's shape or surface albedo. ESO / K. Meech et al.



Shape of Oumuamua

Oumuamua was too small and too far to for detailed imaging. Its shape was derived from its light curve. There is high variation in the brightness (magnitude 22 to 25). It spins on its axis at every 7.3 hours, the motion is not rotation, but more like tumbling. It is estimated that Oumuamua is a highly elongated object of 400m length and a length to width ratio of around 10 to 1. Combining all this information, it is thought that Oumuamua might have formed in a binary star system and during its travel, it had an encounter with other star, the gravity of which has elongated it to the current elongated shape.

The ESO, Very Large Telescope, Chile, failed to find any sign of a coma, the nebulous region around a the nucleus of a comet, around Oumuamua. This indicates that the ice on its surface may only be a few square meters and volatiles, if they exists, must be about 0.5m below the surface. The conclusion from this is the object might has spent a long time close to its parent star and lost most of its volatiles.

It is dark reddish in colour. Such a feature is a result of cosmic ray radiation on organic molecules and are seen on far away objects in the solar system. It is a dense object with mineral or metal content. Radio telescopes also failed to find any radio signal.

Predicted trajectory in near future

In 2017 November Oumuamua had travelled above the orbit of Mars, by 2018 May, above the orbit of Jupiter.

By 2019 January, it will be above the orbit of Saturn and 2022, the orbit of Neptune and is expected to leave the solar system in about another year at a speed of about 23km/sec (58,160 mph) close to the approaching speed towards the solar system.

Hot of the press/Update

This was the state of affairs until recently. Then on 2018 June 27th the news came in that Oumuamua is an interstellar comet and perhaps not an interstellar asteroid. This object, like typical of comets, show slowing down of speed as it moves away from the Sun. Monitoring the trajectory by terrestrial and space observations showed the current speed to be 31.6km/sec (114,000 mph). This speed is higher than if only the gravity is responsible for the observed trajectory. In order to solve the discrepancy of the observed and predicted speeds, astronomers took into the account of the following factors in their calculation.

Pressure from the solar radiation
Pressure due to solar wind
Heat from the Sun
Oumuamua is composed of two loosely bound bodies
Collision with another object

None of the above could provide the correct answer. The conclusion was then drawn that, outgassing is the only likely reason of the higher observed speed and hence Oumuamua is a comet. However the fact remains that even Hubble could not see any evidence of outgassing. The possible reasons for the absence of observed outgassing is explained as, during its long travel through the interstellar space, the surface is depleted of fine dust particles or pure gas without much dust and only coarse dust particles remain on the surface. The cloud of coarse particles may obscure any outgassing.

More telescopes are now looking for asteroids. One of the newcomers is Large Synoptic Survey Telescope in Chile with 8.4m diameter mirror and 3200 megapixel camera. It is of special design, 3 mirrors and 3 optical systems. Each image is the size of 40 full Moons. The large light gathering power is expected to find fainter objects. It is due to be operational by 2019.