The Jeety Starn

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Welcome to Issue 13 of *The Jeety Starn*, the Stirling Astronomical Society's quarterly newsletter. In this issue, as we celebrate 40 years of the Society, we include items on the six successful robotic rovers that have landed on Mars, wonderful images of the Lovell Telescope at Jodrell Bank, an article on Wolf-Rayet stars, our regular quota of quotes, and our Happy Observing section, with details of what to look out for in the sky over the next three months, including the Geminid meteor shower (active 4-17 December), which this year promises to produce a peak of up to 110 meteors per hour.

Stirling Astronomical Society Celebrates 40th Anniversary

By Alan Cayless FRS

On the 18th February 2006, 18 members of Stirling Astronomical Society gathered for a dinner at the Stirling Highland Hotel to celebrate the 20th anniversary of the Society. The guests included Dr. Ken Mackay (1931-2014), president and founder member of the Society, who instigated the restoration of the High School Telescope in the 1980s, along with several other original members of the Society.

On the 23rd October this year, the Society celebrated its 40th anniversary with a dinner and musical evening attended by 20 current members, including three who were at the first anniversary dinner, together with several of our younger members.

With the telescope tower and dome currently undergoing maintenance and repairs, the occasion was reminiscent of the situation in 1986 following the initial restoration of the Observatory. The works currently taking place on the dome and shutter mechanism will ensure that the Observatory will be maintained in full working order for many more years. Alongside all of the advances in modern astronomy it is reassuring that the Peck telescope from 1889 will be preserved for future generations.

We are pleased that the Society continues to be healthy, with many enthusiastic and capable members, and we look forward to the next 20 years, hopefully with another anniversary dinner in 2046!



The Society's telescope is a 12.5 inch Newtonian reflector with an oak tube, built in 1889 by William Peck of Edinburgh. This historic instrument is located in the dedicated observatory, on the roof of the former Stirling High School, which is now the Stirling Highland Hotel. The observatory has a rotating domed roof sheathed in copper; its green surface is a familiar landmark above the tower entrance to the Hotel in Spittal Street, Stirling.

Wolf-Rayet Stars

By Alan Cayless FRS

In December 1867, a report by French astronomers Charles Wolf (1827–1918) and Georges Rayet (1839–1906) was published in the Comptes Rendus of the French Académie des Sciences in Paris. Using the 40-centimetre Foucault–Secretain telescope at the Paris Observatory they had observed unusual features in the spectra of three eighth-magnitude stars in Cygnus (Wolf and Rayet 1867; Tobin 2016). These three stars were originally listed in Argelander's Bonner Durchmusterung (BD) catalogue, which gave details of their magnitude and position, but this was the first time that their spectra had been studied in detail.

Ce sont les étoiles suivantes du Catalogue de Bonn (1850):

Argelander.	Zone + 35°	8,5	$\mathcal{A} = 20^h.4^m.49^s,3$	$\mathcal{D} = +35°.45',1$
	Zone + 35	8,0	$\mathcal{A} = 20.6.27,3$	$\mathcal{D} = +35.46,1$
	Zone + 36	8,0	$\mathcal{A} = 20.9.6,7$	$\mathcal{D} = +36.13,3$

Magnitudes and coordinates of the three stars studied by Wolf and Rayet
(From their 1867 report to the Académie des Sciences)

Originally developed by Fraunhofer in 1814 and refined by Kirchhoff and Bunsen in the 1850s, the science of spectroscopy was still in its infancy. Wolf and Rayet used a prism attached to the eyepiece of the 40-centimetre telescope to view the spectra of stars and were surprised to find three stars with similar unusual spectra within a small patch of sky near Sadr, the central star of Cygnus. The spectra contained none of the usual dark Fraunhofer lines of Hydrogen and other elements typically seen in the Sun and other stars. Instead, there were a number of broad emission lines, whose wavelengths did not appear to correspond to any known element. The colours of the stars were also unusual. Wolf and Rayet described the first as being yellow, the second as yellow-orange, and the third a greenish yellow.

It was only in the following year, 1868, that a solar eclipse permitted spectroscopic analysis of the Sun's outer atmosphere for the first time. On 18 August, the path of totality crossed India, Malaysia and Indonesia. The eclipse was observed by French astronomer Pierre Janssen (1824–1907), who wrote to the French Académie des Sciences in September of that year describing his observations of bright spectral lines in the solar prominences visible during the eclipse (Janssen 1868). In the same issue of the *Comptes Rendus*, British astronomer Norman Lockyer (1836–1920) reported his own observations of spectra from solar prominences, using a technique he had developed for observing solar spectra at any time, without the need to wait for an eclipse (Lockyer 1868). In the months following the eclipse, Lockyer realised that the bright yellow spectral line that both he and Janssen had observed in the solar spectrum must be from a hitherto unknown element. Lockyer named this new element *Helium* after the Greek god of the Sun.

Although the discovery of Helium is generally attributed to Janssen and Lockyer, the eclipse of 1868 was also observed by Georges Rayet himself. Observing from Malacca on the Malay peninsula, Rayet noted nine bright emission lines in the spectra of one of the solar prominences. Several of these lines corresponded to known Fraunhofer absorption lines in the solar spectrum, but the spectrum also included an unknown line, labelled F by Rayet (Rayet 1868). This was the same yellow line, with a wavelength of 587.6 nm, that had been observed by Janssen and Lockyer and which had also appeared, in broadened form, in the spectra of the three unusual stars studied by Wolf and Rayet the previous year.

The presence of this broadened Helium line, together with the absence of Hydrogen lines, indicated that Wolf-Rayet stars were of a very different composition to normal stars, being rich in the new element Helium. Most stars are made predominantly of Hydrogen, with only a small amount of Helium. During the main sequence lifetime of a star nuclear fusion converts Hydrogen into Helium in the core but there is very little mixing, so the outer layers remain rich in Hydrogen. The spectra of main sequence stars typically consist of a bright continuum from the photosphere, with dark absorption lines formed from light passing through tenuous layers of gas above the photosphere.

In Wolf-Rayet stars the presence of emission, rather than absorption, lines suggest outer layers of extremely hot, energised Helium gas of sufficient density to outshine the continuous spectrum from the layers below. The broadening of the Helium emission lines is caused by the Doppler effect. Beals

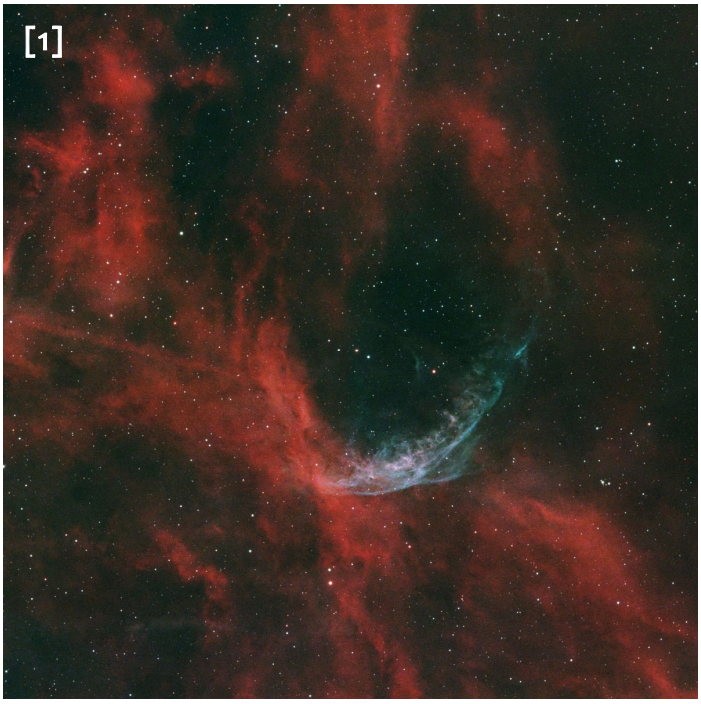
(1929) interpreted this broadening as evidence of rapid radial expansion, with shells of gas thrown off at high velocities propelled by strong stellar winds.

Wolf-Rayet stars are now known to be massive stars that have reached the ends of their lives, throwing off their outer layers to reveal the Helium-rich material underneath. Towards the end of a star's lifetime, with Hydrogen in the core used up, Helium begins to fuse into heavier elements. This requires extremely high temperatures and pressures in the core and the star becomes unstable, throwing off shells of highly energetic Helium gas and often expanding to become a red giant. Some of these stars may eventually become supernovae.

For a while, the Wolf-Rayet stars were added to the Harvard spectral classification of stars. The Harvard scheme organises stars into lettered groups according to their temperature and brightness. This alphabetical classification system was originally developed at the Harvard College Observatory in Cambridge, Massachusetts by Williamina Fleming (1857–1911) and later developed by Antonia Maury (1866–1952) and Annie Jump Cannon (1863–1941) into the familiar sequence OBAFGKM (Cayless 2026). The temperature of a star is also linked to its colour, with the brightest (and hottest) O and B stars being a bluish white, and the dimmest (and coolest) stars (K and M) being reddish orange. Our own Sun lies somewhere near the middle of this sequence, with its modest energy output and yellowish colour giving it a spectral classification of G2.

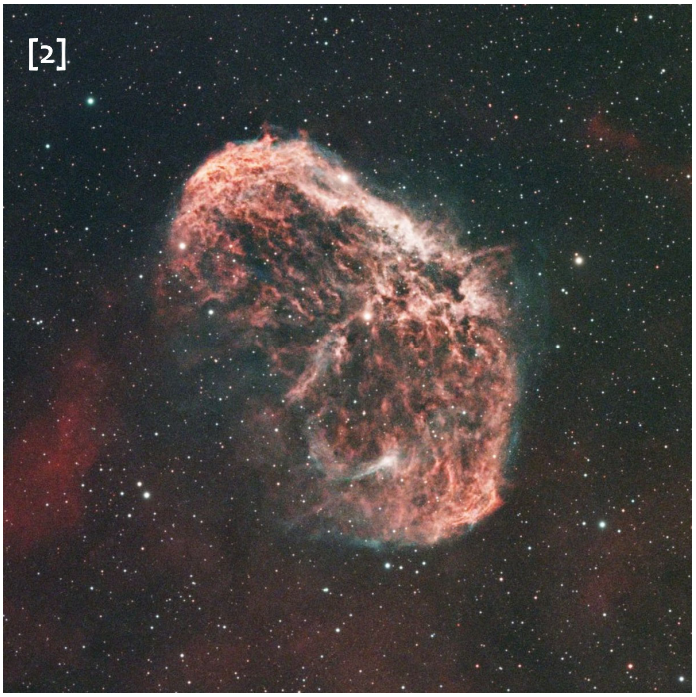
With surface temperatures of up to 200,000 K, Wolf-Rayet stars are hotter than even the brightest O and B stars, and were therefore originally added at the start of the Harvard sequence. For a while the sequence became (W)OBAFGKM, with the (W) in brackets to indicate that Wolf-Rayet stars are not truly stable on the main sequence, but as more subtypes of Wolf-Rayet stars became known they developed a classification scheme of their own (Hiltner and Schild 1966) and the Harvard sequence reverted to the traditional OBAFGKM.

In star catalogues, Wolf-Rayet stars are denoted by the initials WR. Having thrown off their outer layers, many WR stars are at the centres of planetary nebulae and other interesting structures. The three stars originally reported by Wolf and Rayet are now designated WR 134, WR 135 and WR 137. All three of these are in Cygnus and can be imaged today [1].



WR 134 in Cygnus, one of the three stars originally reported by Wolf and Rayet. Surrounded by an expanding shell of glowing blue gas, WR 134 is the bright orange star near the centre of the image. WR 135 is the bright star within the vertical red filament at the top of the image (Alan Cayless).

Many more WR stars have since been discovered, including several more in Cygnus. One of the most prominent of these is the Crescent Nebula (NGC 6888), which has the Wolf-Rayet star WR 136 at its heart [2].



NGC 6888, the Crescent Nebula in Cygnus. The bright star at the centre of the nebula is Wolf-Rayet star WR 136 (Alan Cayless).

There are now over seven hundred known Wolf-Rayet stars in our own galaxy, with examples in both the northern and southern hemispheres. Because of their strong emission lines WR stars can even be detected in nearby galaxies, but those in the Cygnus region remain among the most interesting and visually appealing.

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Wolf-Rayet Star

By Arryll Idrennis

Through gulf of night, a muted light cuts dark,
The rare-bright radiance of a distant mark,
Whose light in ultraviolet wavelengths beam,
Denying blue-bright fire and cosmic gleam.

With wide emission bars on spectrum's breadth
The gas shears off to fill the stellar depth,
Erupting as a shroud of nebulous haze
Round massive stars that fluorescent, blaze.

Helium, carbon, oxygen and more –
Forged hot around the blazing stellar core,
To shed as streaming banners into space,
As fierce Wolf–Rayet wind lends lightning pace.

A white-hot ember sparking in the depth –
With nebula that cloaks the dying breath…
As sudden supernova ends the fight,
And crowns the dying sun with radiant light.

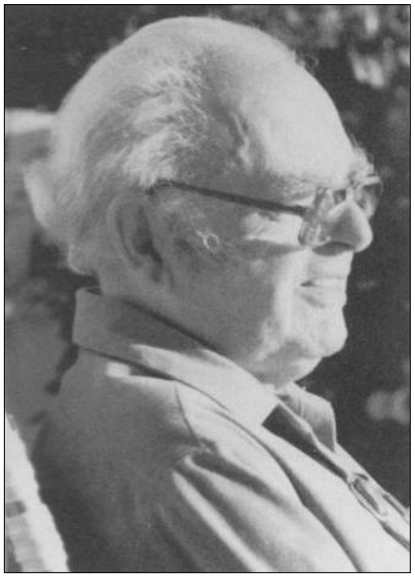


Dutch Astronomers: Bart Bok

By Sandi Cayless

Bartholomeus (Bart) Jan Bok (1906–1983) was a Dutch-American astronomer, teacher and lecturer. He is best known for his work on the structure and evolution of the Milky Way galaxy, and for the discovery of Bok globules.

Bart Jan Bok (1906–1983)



Bartholomeus Jan Bok was born on 28 April 1906 in Hoorn, a medieval town north of Amsterdam, the son of Sgt Major Jan Bok of the Dutch army and his wife Gesina (Graham *et al*. 1994; Millman 1984; Lada 1987; Van Woerden 1985).

After his primary schooling in Haarlem, he attended high school in The Hague, where the family moved in 1918 (Graham *et al*. 1994). Here, he was an active astronomer, learning the night sky while on camping trips with the Scouts, and writing astronomy articles for a Hague newspaper. He also came to admire Harlow Shapley, who would later become a prime influencer in his life. After graduating with high marks in 1924, he set out to study astronomy at the Sterrewacht, the Observatory and Astronomical institute of the Faculty of Mathematics and Natural Sciences of Leiden University (the Sterrewacht is the oldest still-working university observatory in the world). He joined alongside two other young Dutchmen who would become notable in astronomy: Gerard Kuiper and Pieter Oosterhoff. His tutors included de Sitter, Hertzsprung, Oort, Woltjer, Ehrenfest and de Haast, and Schrödinger, Heisenberg, Dirac and Madame Curie were among visitors to the Sterrewacht. He moved from there in 1927 to Groningen University, to take up a PhD under Piet van Rijn.

The following year, 1928, Bart attended the Third General Assembly of the International Astronomical Union (IAU), held in Leiden; two events there would change his life. First of all, he met his hero Harlow Shapley, who was so taken by the keen young man that he invited him to come to Harvard the following year (Graham *et al*. 1994). Secondly, Bart was appointed to the reception committee of an American associate professor, Priscilla Fairfield. He immediately fell in love with her though she was ten years his senior, and had proposed by the end of the Assembly (Levy 1993). Priscilla was less sure and refused, but Bart avidly corresponded with her over the next year, and eventually changed her mind. Two days after his arrival in the USA from the Netherlands, on 9 September 1929, Bart and Priscilla were married in Troy, New York. This marriage was the most significant event in his life, the alliance between the two an outstanding example of cooperation in both their private and professional astronomical lives (Graham *et al*. 1994). They went on to have two children, Joyce and John.

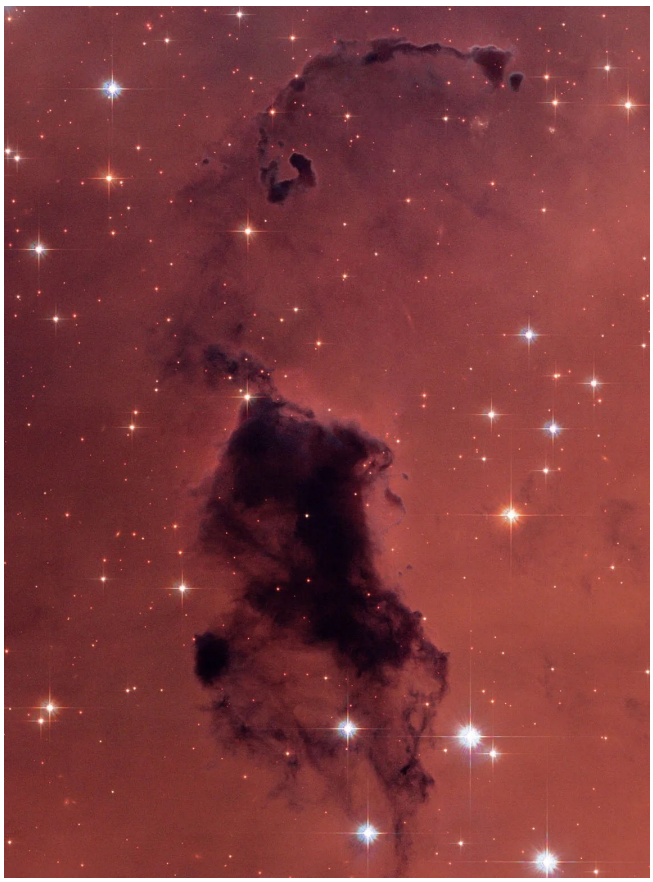
Bart had meanwhile to finish his PhD. With the Milky Way as his main sphere of interest, he joined Harvard College Observatory in Cambridge, Massachusetts under Shapley, where Priscilla also worked and where the two would remain until 1957 (Levy 1963). Bart completed his PhD, *A Study of the Eta Carinae Region*, in 1932 (Bok 1932), taught astronomy, and carried out research. He was made assistant professor in 1933, associate professor in 1939, associate director of the Observatory in 1946, and as full professor, he took up the Robert Wheeler Wilson Chair in Astronomy. He became a US citizen in 1938. Priscilla was also engaged in her own (unpaid) writing and research during this time, bringing up the two children, and supporting her husband's research and public outreach.

Bart Bok was intensely interested in the formation of star clusters and galaxies, and his seminal paper on the apparent clustering of external galaxies (Bok 1934) showed that the observable uneven distribution of galaxies (giving rise to galactic clusters) was not down to the density of absorbing materials in or outside the Milky Way.

Bart's first book in 1937, ground-breaking in its time, was *The Distribution of the Stars in Space* (Bok 1937), which dealt with the clarification of the extent of light absorption by dark nebulae and interstellar matter; this would eventually allow intra-galactic distances to be measured accurately. It described the intrinsic snags of the star-counting method, anticipating the advances that would result (Heeschen 1983). After this, his mentor Shapley embarked on a series of books on astronomy supported by Harvard, and asked Bart and Priscilla

to author one on the Milky Way (Bok & Bok 1941). The popular book, begun in 1937, would go into five editions over four decades. This work was part of the close scientific alliance of the Boks that continued for the next forty years; it was so close that the Royal Astronomical Society held that it was difficult and futile to differentiate their scientific and literary achievements (Lada 1987). As well as the structure of the Milky Way, their subjects included stellar magnitudes and open star clusters.

Bart first detected the small, dark clouds of dense dust and gas in the Milky Way that would come to be called Bok globules in the 1940s, in work with a PhD student, Marguerite Risley (Heeschen 1983). In a paper published in 1947, Bok and Edith Reilly theorised that the clouds or 'globules' were collapsing under gravity into new stars and star clusters (Bok & Reilly 1947), but could not prove the theory, as the dense clouds prevented visible light emission and made observation impossible. However, observations made after Bart's death using the IRAS (Infrared Astronomical Satellite) verified that stars were indeed being born inside Bok globules (Yun & Clemens 1990).



Bok globules, NGC 281 (IC 11 /Sh2-184). Credit: NASA, ESA, Hubble Heritage Team (STScI/ AURA); Ack. P. McCullough (STScI)

As well as research and writing, the Boks travelled widely, helping set up the Tonantzintla Observatory in Mexico in 1941, and setting up the Schmidt Telescope in South Africa in 1951, at Harvard's Boyden Station, moved from Arequipa, Peru to near Bloemfontein in 1927, in the hopes that it would prove less cloudy (it was). At Boyden, Bart and Priscilla studied the southern stars, including *Eta Carinae* (Lada 1987; Graham *et al*. 1994; Millman 1984). This launching of new observational facilities was to become a habitual facet of their work.

Bart had been passed over for the directorship of the Harvard Observatory on Shapley's retirement as a result of political difficulties in 1952, for the less than tactful Shapley had upset Senator Joseph McCarthy and the Committee on Un-American Activities (Ashworth 2023; Bhathal *et al*. 2013). He was to stay another four years, however, and in 1952 he obtained the funding for, and directed the building of Harvard's large radio telescope facility at Oak Ridge Observatory. Combined with optical astronomy, he felt that the joint approach would be key in advancing the analysis of interstellar space, and understanding the internal mechanism of Bok globules (Heeschen 1983). This had been given impetus by the discovery by Ewen and Purcell, and independently by Van Hulst and Oort, of the 21 cm hydrogen emission line (see Cayless 2026). He and a group of young students designed and built a 7.3 m radio telescope at Harvard's Agassiz Station in 1952. One of these young students was Frank Drake, later to become the first astronomer to use a radio telescope to look for intelligent life beyond Earth and to found SETI, the Search for Intelligent Life Institute. Meanwhile, Bart moved on to the building of an 18 m radio telescope at Harvard that opened in 1956, before leaving the Observatory.

Bart left Harvard, having been offered and accepted the position of director of the Mount Stromlo Observatory, sited west of Canberra and part of the Australian National University (ANU), in March 1956 (Bhathal *et al*. 2013). The Boks moved to Australia in 1957, Bart developing into a familiar national figure in public education in astronomy over the next ten years, by making a television series that reached a wide audience and helped support Australian astronomy (Ashworth 2023; Bessell 2011; Levy 1993), lecturing to groups and schools, opening the Mount Stromlo Observatory to visitors for viewing nights and writing popular articles for *Sky and Telescope*, *Scientific American* and *Science Monthly*.

Bart Bok was also the only astronomer ever to have been invited to address a meeting of both Houses of the Australian Parliament (Bhathal *et al*. 2013). This was a result of the shockwaves sent through the scientific community by the launch of the Russian Sputnik in 1957, after the Observatory announced that it had captured the first photograph of the artificial satellite as it passed over Mount Stromlo (taken by K. Gottlieb using Stromlo's Uppsala Schmidt telescope).

During his time in Australia, Bart set up a successful international graduate and post-graduate programme in astronomy at Stromlo, as well as a summer vacation hands-on course; and as Canberra's increasing urban light pollution was making astronomy tough, he initiated a search for a new field observatory site (Bok 1960). This led to the establishment of the world-class Siding Spring Observatory, or SSO (Bhathal *et al*. 2013), where he, with Priscilla, carried out part of their seminal research into the structure of the Milky Way and Magellanic Clouds using the new ANU 40 inch Boller & Chivens Telescope, the first constructed at SSO, and created for photography/photoelectric work (ANU 2026).



Large Magellanic Cloud Image Credit: ESA/NASA/Hubble

Bart also led the way in using computers in astronomical observation, having the first one fitted in the observatory (and a first for the ANU) in 1960. In 1963, Bart organised a symposium on the Milky Way at Stromlo as part of the International Astronomical Union (IAU) and International Scientific Radio Union symposium on *The Galaxy and the Magellanic Clouds* (Bhathal *et al*. 2013). One of his crowning successes was his determined initiation of the project to build the huge 3.8 m reflecting Anglo-Australian Telescope, eventually opened in 1974.

Despite his pressing administrative duties and an ongoing series of improvements to Observatory telescopes and the introduction of a range of new instruments such as a faint star photometer and an underground Coudé spectrograph, Bart continued his own research and, with Priscilla, carried out a series of observations of Southern Hemisphere stars, continuing with a study of two small fields of blue giants in the Large Magellanic Cloud (Bok & Bok 1960; Bok & Bok 1962; Bok *et al*. 1962; Bok 1964). The couple left Australia in 1966.

The Boks were set for Arizona, where Bart took on the headship of the Department of Astronomy at the University of Arizona, and became the director of the Steward Observatory. He continued in the posts until 1970. During his tenure, he was deeply involved in constructing the 90 in (2.3 m) telescope at Kitt Peak National Observatory, massively increasing the number of staff, growing the graduate student programme to reach 5th highest in the USA, and earning Steward a name for first-class astronomical research (Bessell 2011; Lada 1987).

After his retirement in 1970, Bart remained an emeritus professor of the University of Arizona, and continued to raise the public profile of astronomy (Ashworth 2023), serving as vice-president of the International Astronomical Union's (IAU) executive committee (being appointed to a second term) and president of the American Astronomical Society (AAS). However, Priscilla had had a stroke in 1972, and as her health failed, Bart resigned his IAU and AAS posts in 1974 to care for her. She died of a heart attack in 1975 (Graham *et al*. 1994).

In 1975, Bart was the lead author of *Objections to Astrology*, a statement backed by 186 professional scientists, including nineteen Nobel laureates (Bok *et al*. 1975). It was published by *The Humanist*, with copies sent to key US newspapers. It kick-started the founding of the Committee for the Scientific Investigation of Claims of the Paranormal (CSICOP), now the Committee for Skeptical Inquiry (Frazier 1996, Anon. 2026). He was also busy elsewhere, travelling, lecturing to many groups, publishing widely and taking part in and often leading observing trips. His own research gravitated towards the study of low mass star formation in the globules that would later bear his name, especially means of detecting the molecular gas and dust in these regions (Graham *et al*. 1994). He passed away suddenly in 1993, at his home in Tucson, Arizona.

Bart Bok's long and exceptional life led him to be awarded numerous honours, and various astronomical features are named for him. These are listed below.

Bart Bok: Honours

ADION medal (1971), Association pour le Développement International de l'Observatoire de Nice (ADION 2004).
Jansky Prize (1972), National Radio Astronomy Observatory (NRAO 2026).
Catherine de Wolfe Bruce Medal (1977) of the Astronomical Society of the Pacific (ASP 2026a)
Knight in the Order of Oranje-Nassau (Nationaal Archief 2026).
Henry Norris Russell Lectureship (1982) American Astronomy Astronomical Society (AAS 2026).
Klumpke-Roberts Award (1982) Astronomical Society of the Pacific (ASP 2026b).

Bart Bok: Named for him

Bok globules: isolated, small dark nebulae of dense cosmic dust and gas from which stars may form.
Bok Telescope: the 90-in (2.3 m) telescope at Steward Observatory, named for him in 1996 (University of Arizona 2026).
Comet C/1949 N1 (Bappu-Bok-Newkirk): an unclassified comet that Bok co-discovered (JPL 2026; Kapoor 2013).
Lunar crater Bok: named jointly for him and Priscilla, a 43-km diameter impact crater on the far side of the Moon (USGS 2026).
Minor Planet 1983 Bok: named jointly for him and Priscilla, discovered at Catalina Station by Elizabeth Roemer in 1975; the first minor planet discovered with the 2.3 m Steward Observatory Bok telescope to be numbered (IAU 2026).

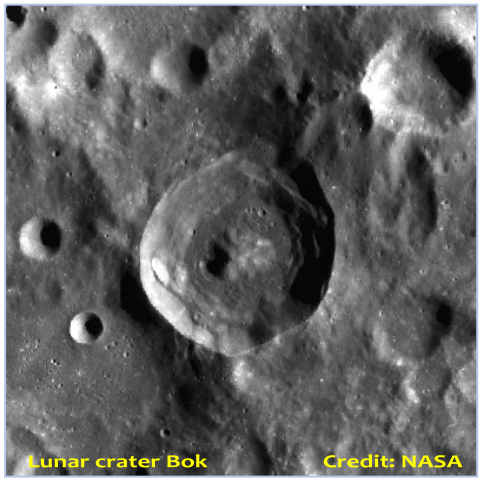
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Bart Bok in his last year (1983), University of Arizona, https://james.as.arizona.edu/~psmith/90inch/bok.html.
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Lunar impact crater Bok: NASA, 16 February 2013.



A Quote or Two...

Terry Pratchett (1948-2015)
In the beginning there was nothing, which exploded.

Light thinks it travels faster than anything but it is wrong. No matter how fast light travels, it finds the darkness has always got there first, and is waiting for it.

A good bookshop is just a genteel Black Hole that knows how to read.

The sun rose slowly, as if it wasn't sure it was worth all the effort.

He was determined to discover the underlying logic behind the universe. Which was going to be hard, because there wasn't one.

So much universe, and so little time.

Gravity is a habit that is hard to shake off.

The world is a globe – the farther you sail, the closer to home you are.

… the awesome splendour of the universe is much easier to deal with if you think of it as a series of small chunks.

Of all the forces in the universe, the hardest to overcome is the force of habit.

The Universe is a lot more complicated than it looks from the outside.

Bill Bryson (1951-)
The upshot of all this is that we live in a universe whose age we can't quite compute, surrounded by stars whose distances we don't altogether know, filled with matter we can't identify, operating in conformance with physical laws whose properties we don't truly understand.

Stanley Kubrick (1928-1999)
The most terrifying fact about the universe is not that it is hostile but that it is indifferent, but if we can come to terms with this indifference, then our existence as a species can have genuine meaning. However vast the darkness, we must supply our own light.

Seth Shostak (1943-)
It will be the mother of all telescopes, and you can bet it will do for astronomy what genome sequencing is doing for biology. The clumsy, if utilitarian, name of this mirrored monster is Large Synoptic Survey Telescope, or LSST. You can't use it yet, but a peak in the Chilean Andes has been decapitated to provide a level spot for placement.

Certainly the history of astronomy shows that every time we thought we were special, we were wrong.

Sandra Faber (1944-)
One lesson astronomy tells us is that we're a tiny mote in a hostile void, and help is too far away.

Like many astronomers who use the great telescopes on Mauna Kea, I have participated personally and joyfully in ceremonies to celebrate the profound cosmic understanding that comes from joining ancient Hawaiian navigator traditions with the techniques of modern astronomy.

John Glenn (1921-2016)
As I hurtled through space, one thought kept crossing my mind: every part of this rocket was supplied by the lowest bidder.

Captain James T. Kirk (*USS Enterprise*)
They used to say if man could fly, he'd have wings. But he did fly – he discovered he had to.

Risk. Risk is our business. That's what this starship is all about. That's why we're aboard her.

Edwin P. Hubble (1889-1953)
The history of astronomy is a history of receding horizons.

Lawrence M. Krauss (1954-)
Every atom in your body came from a star that exploded. And, the atoms in your left hand probably came from a different star than your right hand.



A Visit to Jodrell Bank

By Josh Heesom

Last month (September 2026), I visited Jodrell Bank Observatory, where seeing the enormous Lovell Telescope up close was an incredible experience. In the evening, I attended a fascinating talk by Professor Jeff Forshaw and was lucky enough to meet him afterwards.

Seeing such an iconic telescope during the day and meeting a leading physicist that evening made the trip one I'll always remember.







NOTE:
Jodrell Bank Observatory is a world-leading deep-space radio observatory near Macclesfield, in England, a part of the University of Manchester, and a UNESCO World Heritage Site. Set up in 1945 by radio astronomer Sir Bernard Lovell, University of Manchester, the observatory initially carried out cosmic ray research, the rays detected by radar echoes.

As well as the Control Building and the Lovell Telescope, Jodrell Bank has several other radio telescopes and outbuildings. Nowadays, the observatory's important research work ranges from studies of the moon, meteors, quasars, quantum optics, pulsars, masers and gravitational lensing, to tracking space probes and other spacecraft.

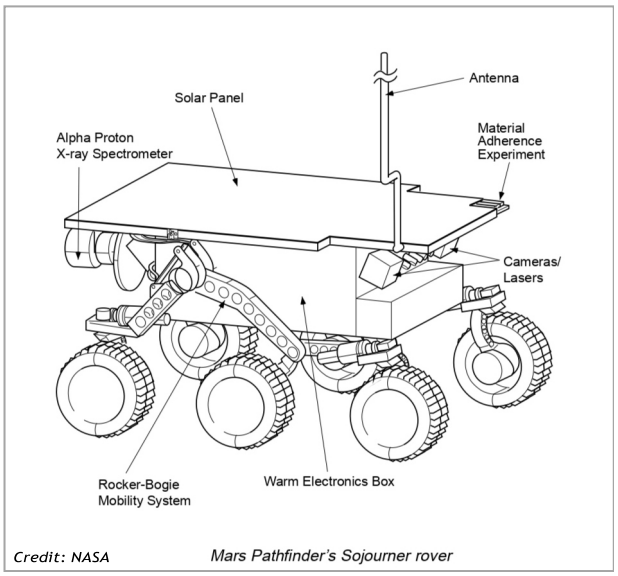
Roving on Mars

By Sandi Cayless

Six rovers on the surface of Mars have thus far made successful forays across the Red Planet's rather forbidding terrain, and in doing so have greatly expanded our knowledge of our near neighbour: Sojourner, Spirit, Opportunity, Curiosity, Perseverance and Zhurong.

Sojourner

The first rover to drive on Mars, the six-wheeled Sojourner (named for American civil rights advocate Sojourner Truth), was a microwave-size, 10.6 kg (+ 5 kg equipment) vehicle aboard the NASA spacecraft Pathfinder (NASA 1997; NASA 2026a, b; NASA/JPL 2005; Siddiqi 2018). Launched on 4 December 1996 from Cape Canaveral one month after the Mars Global Surveyor, the spacecraft landed a base station (later renamed Carl Sagan Memorial Station) with the robotic rover on Mars on 4 July 1997. Touchdown (at 19°7'48" N, 33°13'12" W) was in the outflow channel Ares Vallis, which runs northwest from Margaritifer Terra, via the Xanthe Terra highlands to the Chryse Planitia region (ESA 2005; Siddiqi 2018).



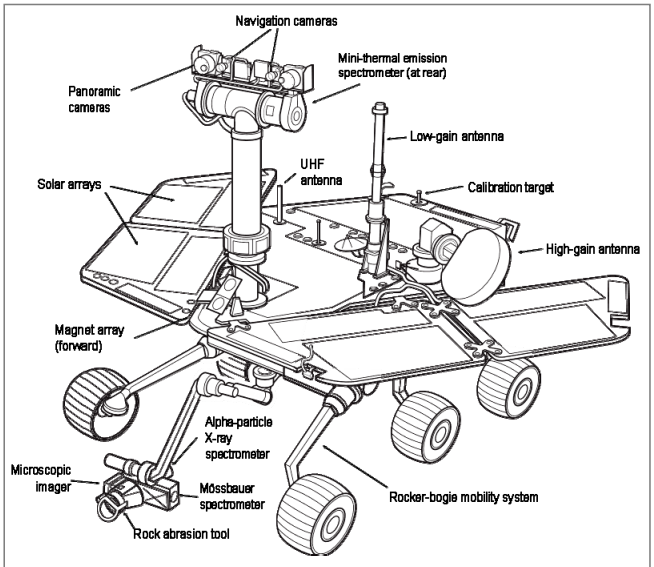
Credit: NASA *Mars Pathfinder's Sojourner rover*

The base station's job was to support the rover by capturing operations and communicating rover data to Earth. Sojourner had front and rear cameras, and equipment made to carry out scientific experiments. On July 5, late in the second Martian sol, Sojourner extended to her full height of 30 cm and rolled down the tilted (20° to surface) rear ramp of the lander (NASA 2026a).

Sojourner had covered 0.1 km (JPL 2026) and had taken 550 images and carried out over 15 chemical analyses of rocks and soil, when communication was lost. Later, the findings from Sojourner's mission, together with investigations performed by the lander's instruments, indicated that Mars had been warm and wet at some past period (NASA 2026a). Sojourner's last transmission via Pathfinder was on 27 September, Sol 83 of the mission, and the rover entered contingency mode on Sol 92 (NASA 1997).

Spirit and Opportunity

The next two successful rovers to reach the Martian surface were NASA's six-wheeled, 174 kg twin explorers, Mars Exploration Rover (MER) Spirit (MER A), and Opportunity (MER B), both carrying the same analytical instruments (NASA 2026c). Designed as robotic geologists, Spirit and Opportunity landed on Mars on 3 and 24 January 2004 respectively. They had been launched separately in 2003, Spirit on 10 June, Opportunity on 7 July. Both were sent up on Boeing Delta II 7925-9.5 rockets from neighbouring pads at Cape Canaveral, Opportunity on the heavy version of the launch rocket, as extra energy was needed for Trans-Mars injection (the heliocentric orbit needed for her propulsion gear to send her on the correct trajectory to make Mars transfer orbit. The rovers were tasked with finding out about the history of water on Mars.



Credit: NASA *Mars Exploration Rover*

Spirit and Opportunity were aimed for landing sites on the opposite sides of Mars, as both areas seemed to have been modified by past liquid water action (NASA 2013; NASA 2026c). Spirit's target was the giant impact crater Gusev (14.5°S, 175.4°E), thought once to have been a lake (Ruff *et al*. 2014). Opportunity landed on the plain Meridiani Planum: the Thermal Emission Spectrometer (TES) on NASA's orbital Mars Global Surveyor had shown that part of

the plain's surface, composed of sandstones formed by wind and water actions on sand, held up to 20% grey crystalline haematite, a variety of iron-oxide which on Earth generally forms in association with liquid water (Squyres *et al*. 2006; NASA 2024a).

The scheduled missions of the rovers were 90 sols, which both greatly surpassed. Spirit was active until 22 March 2010 (mission sol 2210) and Opportunity until 10 June 2018 (mission sol 5111).

Spirit

Spirit landed on 3 January 2004 about 13.4 km off the planned target, and inside Gusev, a 166 km-wide crater believed to have once held a lake fed by Ma'adim Vallis, one of the largest outflow channels on Mars. The landing site (14.57°S, 175.48°E) was named Columbia Memorial Station, in honour of the seven astronauts killed aboard space shuttle Columbia on 1 February 2003 (NASA 2024b). Spirit transmitted data to Earth on landing via Mars Global Surveyor, but on deployment of her solar panels, data was relayed via 2001 Mars Odyssey; these included stunning images. Among the features imaged by Spirit were the Apollo Hills, three distinctly separate hills in the Gusev crater, and named Grissom, White and Chaffee, in memory of the three lost Apollo 1 astronauts, at 7.5 km, 11.2 km and 14.3 km respectively from the landing site. One of Spirit's first tasks was to use her rock abrasion tool (RAT) to grind the surface a rock called Adirondack.

On her travels, Spirit visited Bonneville Crater, ~370 m from the landing site, continuing over the rough terrain to Columbia Hills (also named for the seven Columbia astronauts), a journey of 3 km across the plains (Orbital Radar 2026) where she spent an extended period of time making forays, deploying her instruments and relating data home. The rover's data from here showed that the area had a complex geological history, as it held altered rocks with minerals that could only have formed in the presence of water: goethite, hematite and sulphate salts (NASA 2024b).

By 2005, Spirit began her gradual way up a slope to the apex of Husband Hill (named for Rick Husband, Columbia's commander), over rocky and sandy ground, stopping frequently to investigate and use the RAT (NASA 2024b). By a strange quirk in March 2005, passing dust devils swept the dust from the surfaces of Spirit's solar panels, thus increasing the solar power to the rover from about 60% to 93% and appreciably extending the mission lifetime. The rover captured several dust devil movies.



Martian Dust Devil Credit: NASA/JPL-Caltech/Univ. of Arizona

Spirit gained the flat summit of Husband Hill on 29 September 2005, and took 360° panoramic true-colour shots of Gusev Crater. Early in 2006, she was put on track for the north face of McCool Hill (named for Columbia astronaut Wm. C. McCool), where it was assumed that enough sunlight would be available to continue system operations through the imminent Martian winter, but the journey was cancelled, due in part to a front wheel breakdown. In another quirk, the immobile wheel scraped off the upper soil layer as the rover moved, to uncover bright silica-rich dust: this implied contact between soil and water (NASA 2024b). The silica patch, named *Gertrude Weise*, offered strong evidence that Mars had a much wetter past, because the silica was probably created around hot springs or steam vents.

In 2006, Spirit examined churned up light soil at a site named Tyrone and found sulphur and trace water, possibly a volcanic deposit created round ancient gas vents, or the result of precipitation, when underground water containing the dissolved minerals came to the surface and evaporated. Also in 2006, Spirit took images of rough, rounded grains over finer material while visiting Home Plate, a bright, low plateau. This implied an ancient explosion, where accrued material falls to the ground after a volcanic or impactive event.

New software uploaded to Spirit *and* Opportunity in early 2007 let the rovers carry out various actions autonomously, but as the year progressed, huge dust storms reduced their effective operation by decreasing solar panel energy generation. A late winter storm in 2008 further reduced Spirit's solar panel output to ~89 watt-hours per sol (*cf*. a typical 700 watt-hours per sol), forcing the rover to use her own batteries.

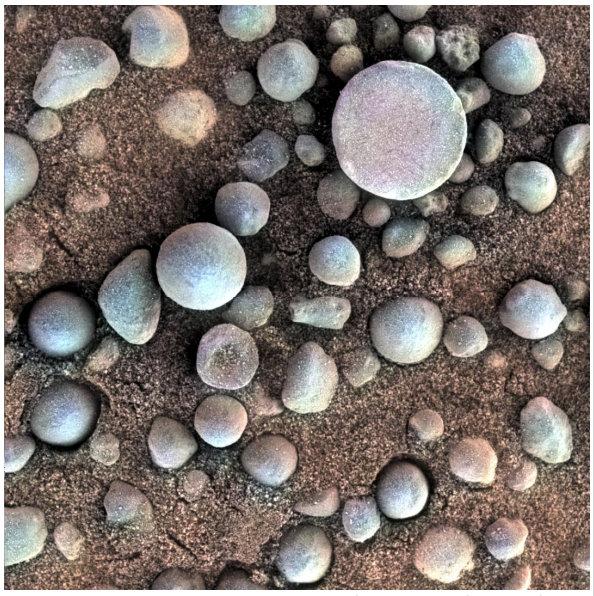
Dust storm damage was reversed in early 2009 by several events that included wind blowing the dust off the solar panels, and Spirit's power slowly increased, reaching ~372 watt-hours per sol by April 2009. Unluckily, as Spirit was driving south along the edge of the low plateau Home Plate on 1 May 1, 2009, she stuck in soft soil. The wheels could not get grip against the soft ground and the rover was immovable, no measure being able to correct it. On 28November, her right rear wheel stopped working, and by late January 2010, after the failure of numerous attempts to move the rover, Spirit was declared a stationary science platform.

The mission controllers at NASA JPL (Jet Propulsion Laboratory) could not contact Spirit after 22 March 2010, and in spite of over 1,300 commands, recovery efforts were ended on 25 May 2011. The loss of contact was probably due to extreme cold that inactivated the rover's survival heaters. By the time she stopped, Spirit had covered 7.73 km, operated for 6 years, 2 months and 19 days (> 25 times her intended lifetime), returned over 124,000 images, ground surfaces off 15 rocks and brush-scoured 92 targets to prepare them for analyses. Spirit is now embedded at a location called Troy (NASA 2010).

Opportunity

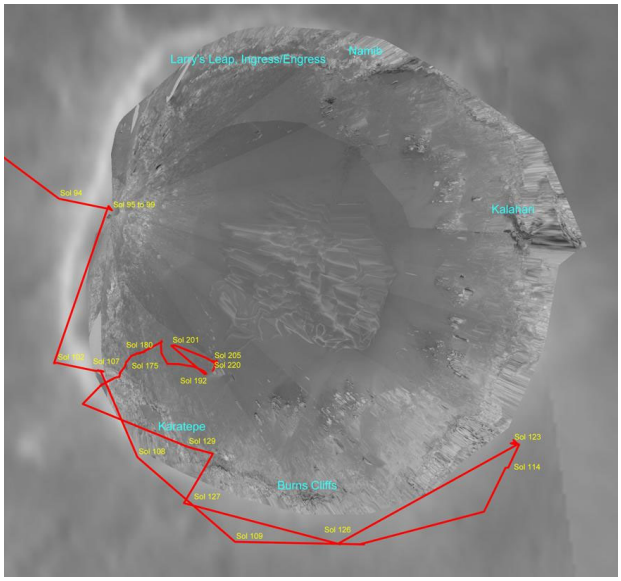
Opportunity landed on Meridiani Planum on 24 January 2004, at 1.9462°S, 354.4734°E, in Eagle, an impact crater, three weeks after Spirit had touched down. Her lander, named Challenger Memorial Station, had been selected because of orbital detection of the grey haematite that forms in water (Orbital Radar 2026b), and within weeks of probing regolith and rock samples, the rover had found evidence that Mars had once had liquid water (NASA 2024a). Opportunity (named 'Oppy' by her engineers), on the way from Eagle to Endurance crater, found teeny iron-rich spherules in the bedrock near Fram crater in April 2004 (NASA 2015a). Dubbed 'blueberries', these haematite concretions develop in water-saturated rock; this was the first evidence that liquid water once existed on the surface of Mars.

Oppy went on to explore Endurance crater by rather a circuitous route from June to December 2004 (JPL 2004), whereupon she studied the impact site of her own heat shield; here she found an intact iron meteorite, named Heat Shield Rock, on the surface, the first meteorite identified on another planet (JPL 2005). Meteorite identification was confirmed using Oppy's Mossbauer and alpha particle X-ray spectrometers.



Martian 'Blueberries' Credit: NASA/JPL-Caltech/Cornell/USGS

Oppy was then directed south to the large, shallow impact crater Erebus, via craters including Argo, Alvin, Jason, Vostok, James Caird, Viking and Voyager, on her way towards Victoria crater, between October 2005 and March 2006. After problems with her robotic arm, Oppy reached Victoria in late September 2006, circumnavigating its rim to regain her original arrival point (Duck Bay) in June 2007. In September 2007, the rover drove into the crater to start a full analysis that would take a year. In August 2008, having climbed out, Oppy left Victoria to make the long (21 km) trip to the huge (22 km diam.) Endeavour crater, reaching a spot named Spirit Point (after Oppy's twin, Spirit) on the crater rim on 9 August 2011 (Vega & Webster 2011).



Opportunity's Trek around Endurance Crater from sol 94 to sol 205
Credit: NASA/JPL/Cornell/OSU/MSSS

At Cape York on Endeavour's western rim, Oppy examined the rocks for phyllosilicates, as the Mars

Reconnaissance Orbiter had detected these (Wray *et al*. 2009), analysing in detail until summer 2013. The rover's findings of veins of gypsum and clay minerals formed in neutral-pH water provided strong signs of Mars' watery past (NASA 2026c). Still driving south around the crater's rim, Oppy passed a marathon distance on 24 March 2015, mission sol 3,968, and continued to Marathon Valley in July 2015, roving around for over a year, until 4 September 2016, when she headed east and downhill into Endeavour Crater itself (Rayl 2016a).

By 2017 Oppy had made Perseverance Valley, but a jammed right front steering wheel slowed progress (the wheel steering actuator had locked 12½ years before and the rover had driven with the awry wheel ever since). But on 4 June, the left front wheel activator stalled and stopped, twisting that wheel. Oppy, helped by engineers at home, managed to straighten things out, but it was considered risky to use the two front wheels, and she was left with rear steerage (Rayl 2017a). Using the new driving tactic, Oppy made Perseverance Valley in July to work through solar conjunction (Mars behind the Sun, Earth on the opposite side and out of contact) on auto-pilot (Rayl 2017b).

Oppy remained active in Perseverance Valley until 10 June 2018, when a planetary-scale Martian dust storm cut communication and ended her travels of an amazing 45.16 km over 15 years of operation (Agle 2019; Strickland 2019). After over a thousand commands to restore contact, a final transmission from NASA's Goldstone Deep Space Complex in California ended the eight-month recovery strategy on 12 February 2019.

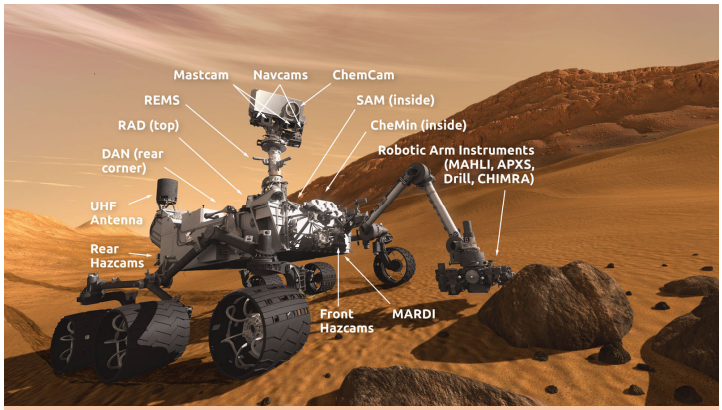
Curiosity, the other active Mars rover now on surface, tweeted a farewell to her feisty companion at 20:54, 13 Feb 2019: "It seems to me you lived your life like a rover in the wind/ never fading with the sunset when the dust set in/ Your tracks will always fall here/ among Mars' reddest hills/ your candle's burned out long before/ your science ever will. #ThanksOppy. I owe you so much."

Oppy's extra-terrestrial distance record stood until NASA's Perseverance exceeded it on 11 October 2026. In 2019, JPL, with Industrial Light and Magic, began a documentary about Oppy and her twin, and their amazing missions. With other contributors, *Good Night Oppy* was acquired by Amazon Studios in 2021 and released in 2022 (Morfoot, 2022).

Curiosity

Part of NASA's Mars Science Laboratory (MSL) mission, Curiosity launched from Cape Canaveral on 26 November 2011, to land on Mars inside the 154 km wide Gale impact crater on Aeolis Palus on 6 August 2012, at 4.5895°S 137.4417°E (NASA 2015d; NASA 2026d). Named Bradbury Landing (Brown *et al*. 2012), the site was under 2.4 km from the projected target after a trip of 560 million km, and is by the foot of Aeolis Mons (Mount Sharp), the 5 km tall centre point of Gale crater. Curiosity's task was to find out if Mars ever had an environment that could or did support microbial life.

Curiosity carries a huge 75 kg payload of ten advanced scientific packages (see NASA 2012, 2025 for full lists and descriptions) that include a full chemistry laboratory, a rock-vaporising laser and 17 cameras (Orbital Radar 2026c). The size of a small car, the six-wheeled 899 kg rover is 3 m long (with a 2.1 m arm), 2.8 m wide and 2.1 m high, and has a 2 m tall mast that carries three of her camera systems. Three radio antennae communicate data back to Earth. Curiosity also, unlike Spirit and Oppy and their solar panels, is powered by a Multi-Mission Radioisotope Thermoelectric Generator (MMRTG). This converts heat from plutonium-238 decay into electricity, providing ~110 watts continuous power despite dust, season, or light. Curiosity can thus operate through winters and dust storms, and the MMRTG should supply sufficient output to last well beyond 2026 (Orbital Radar 2026c).

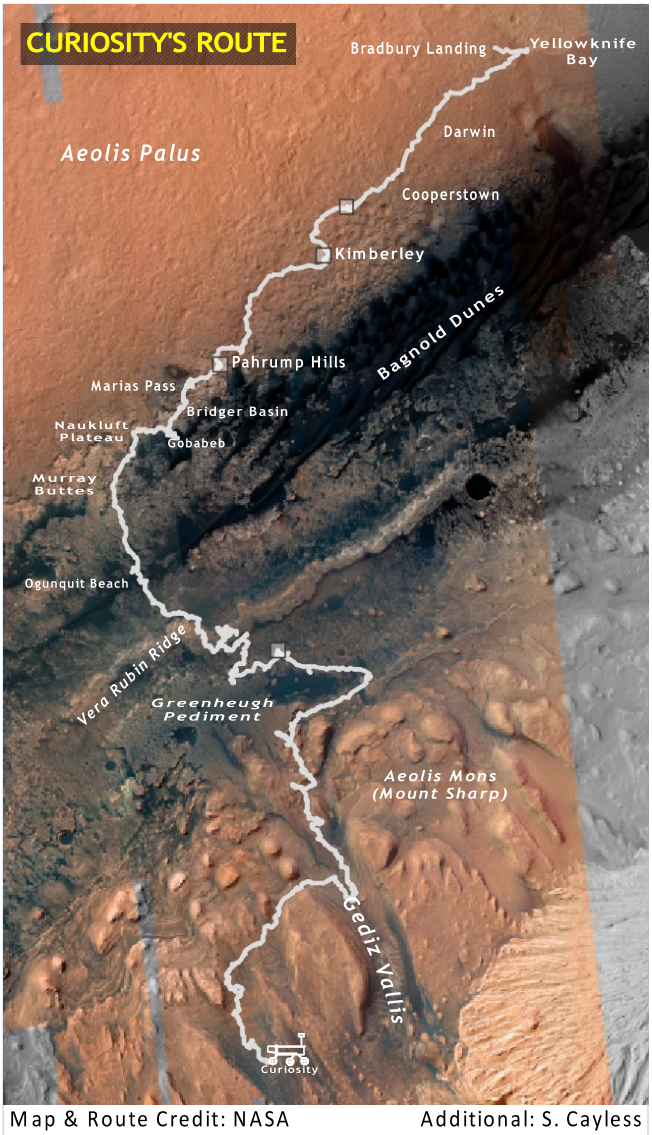


Curiosity's scientific instruments. Credit: NASA / JPL-Caltech

In a first, Curiosity steered herself during descent through the Martian atmosphere, using a series of S-curve moves similar to those used by space shuttle pilots (NASA 2012, NASA 2015d). In the three minutes before landing, Curiosity used a parachute and then retros fixed round her upper stage rim to slow descent. In the last seconds, the upper stage operated as a sky crane, lowering the rover on a tether to land upright on her six wheels. Within

hours, she had begun to beam in-depth data on systems, status, entry, descent and landing experience (Webster *et al*. 2012).

Since her landing in 2012 and up until now, the longest-operating Mars rover has explored Gale Crater and climbed Mount Sharp. Curiosity began her drive from Bradbury Landing on 22 August 2012 with a series of forward, turn and reverse segments and use of systems to check their functionality (Brown *et al*. 2012). Gale had been initially chosen as it was posited to have been filled in by water- and wind-deposited sediments, then subject to wind erosion that scoured out the deposits to leave the central mountain, with its exposed deposits. The landing site, near an alluvial fan possibly laid down by ground water flow, was thus potentially the repository of two billion years of Martian sedimentary history.



Map & Route Credit: NASA Additional: S. Cayless

The longest-running rover on Mars, Curiosity is still in Gale crater and still operational. She reached a peak (thus far) of her 14-year mission on 26 August 2026, with an elevation gain of 1 km up the slope of Mount Sharp (NASA 2026e).

Curiosity's location on Sol 5045, 22 October 2026, having driven 36.18 km, and the route she took to get there, is shown in the image here (NASA 2026f). With hundreds of images, experiments, drilling and laser operations, the amazing list of the rover's achievements is too long to detail here, but her significant discoveries include proof that Gale Crater once held a freshwater lake system that may have carried microbial life, the first evidence for a habitable environment outside Earth (Grotzinger *et al*. 2014). She found complex organic molecules in 3-billion-year-old mudstone, as well as seasonal atmospheric methane variations (Webster *et al*. 2014), and she detected manganese oxide minerals, implying that oxygen-rich conditions did exist at the surface in the past (Lanza *et al*. 2016).

As her ascent of Mount Sharp progressed, the rover recorded a shift from clay- rich lake sediments to layers that were sulphate-rich, a chemical indication that Mars *has* gradually dried out over hundreds of millennia (Clark *et al*. 2024). On 30 May 2024, whilst in Gediz Vallis, Curiosity drove over a rock, cracking it open to reveal yellow elemental sulphur crystals (JPL 2024a). After more travelling, on 23 September 2026 (sol 5023) Curiosity carried out a 48th successful rock-drilling at a site target, Basque Lakes, to capture a powdered rock sample for analysis by the rover's CheMin (Chemistry and Mineralogy) X-ray diffraction gear (Lavender 2026). Curiosity goes on, still travelling, still carrying out experiments, and still astounding the folks back home.

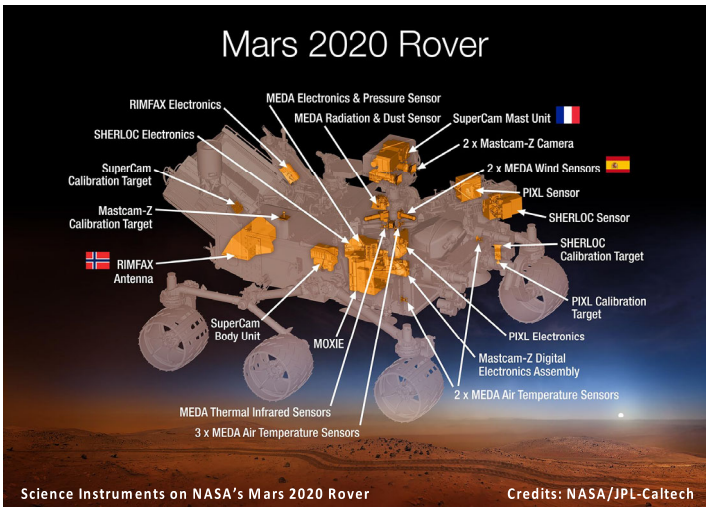
Perseverance

Curiosity's sister rover, Perseverance, was built on the same chassis, but with upgrades that meant she weighed in at 1,025 kg, and is the most advanced robotic explorer sent to Mars (NASA 2026g).

Perseverance, as part of the Mars 2020 mission, was launched from Cape Canaveral on 30July, 2020, and landed on Mars on 18 February 2021 as Curiosity did, steering herself in S-curves, and using a parachute and retros, the upper stage lowering her to surface. Her target was Jezero (18.447°N, 77.402°E), a 45 km diameter impact crater on the edge of the Isidis basin in the Syrtis Major quadrangle that has a clay-rich fan-delta deposit, and once held an ancient lake active at the time of valley network forming on early Mars (Goudge *et al*. 2017). On 5 March 2021, NASA

named the rover's landing site after the science fiction author Octavia E. Butler (NASA 2021a).

Perseverance' mission was to look for signs of past microbial life, to increase knowledge of the past habitability of Mars, and to collect, seal and drop core samples of Martian rock and regolith that could be picked up by future missions and brought back to Earth for detailed analyses (NASA 2026g). The rover was also to test upgraded and new technology.



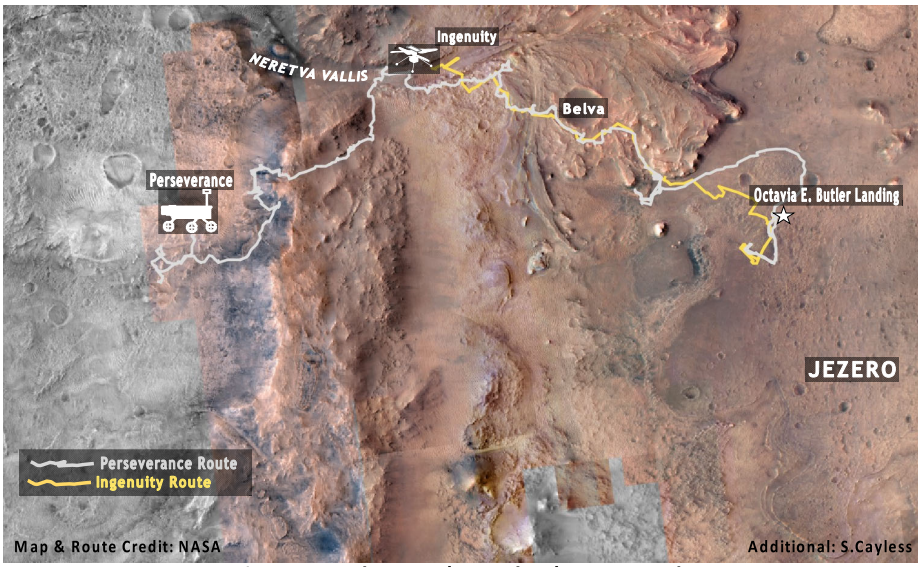
Perseverance' first task after arrival was to test and validate her systems and gear, which she did successfully, using her science instruments, generating oxygen with MOXIE, capturing sounds from Mars (NASA 2021b, c, 2026g) – and deploying her passenger, the Ingenuity helicopter, which carried out the first of 72 historic powered flights on Mars on 19 April 2021, and the final on 18 January 2024 (NASA 2024c).

The rover's first science operation was the Cratered Floor Campaign, from June 2021 to April 2022. Here, she explored a unit of crater floor (Crater Floor Fractured Rough) while avoiding the Séítah sand dunes, collecting samples en route. Perseverance then returned to base to begin her second campaign (Delta Front Campaign, Apr 2022-Jan 2023) of analyses and sample-collection, with Ingenuity travelling alongside (NASA 2022). The rover has since carried out other Campaigns: the Upper Fan (aka the Delta Top), Jan-Sept 2023; the Margin, Sept 2023-Aug 2024; and the Northern rim, Aug 2024 – present.

During Margin, Ingenuity made new records, such as a max altitude of 24 m and max groundspeed of 10 m/s, but due to a failure on flight 72, Ingenuity's rotor blades were damaged, ending her flight career on 18 Jan 2024 (JPL 2024b). She now rests at Valinor Hills, named for Valinor, the Undying Lands of Tolkien's Middle-earth, but NASA is already improving blade technology for the 3-helicopter Skyfall mission of 2028 (Sarvestani 2026).

Over her five years on Mars, Perseverance has made numerous important scientific discoveries and technical advances (NASA 2026g). For example, she has gathered over 25 geologically varied rock samples, one of which, from an ancient dry riverbed, contains possible biosignatures (Hurowitz *et al.* 2025), she has probed Jezero crater's geology and its water and habitable environment history (Mangold *et al.* 2021), and she has confirmed the promise of off-world helicopter flights and onsite oxygen production, feats that pave the way for human exploration in the future.

One of Perseverance' greatest feats thus far is that she has the record for driving further than any rover ever has on another world. On 11 October 2026, her odometer reached 45.22 km, surpassing the previous record of 45.16 km set by Opportunity. Perseverance reached the mark on sol 2,006 of her mission. The milestone came as she was heading for the area Idubi, just off the western rim of Jezero Crater in a region dubbed Lac de Charmes, where she is exploring terrain that could be some of the oldest ever studied in our solar system. She had covered a distance in five and a half years that took Opportunity almost 15 (JPL 2026). Like her smaller sister rover, Curiosity, she is still operating and carrying out her main mission of astrobiology – searching for evidence of life on Mars.



Perseverance Location on Sol 2009 (45.2 km), 26 October 2026

Zhurong

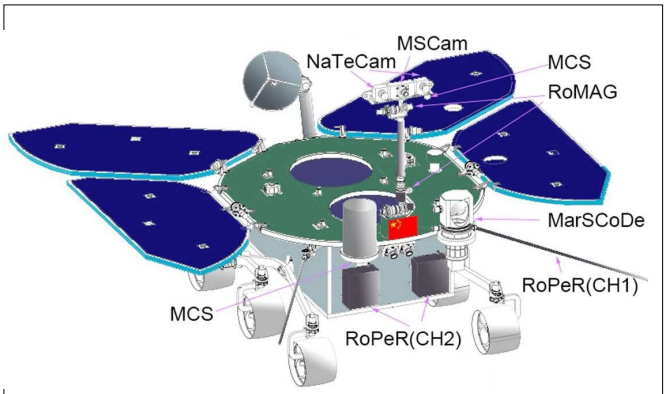
The latest rover thus far to land on the Martian surface, the Chinese Zhurong, was China's first on the Red Planet, after having landed two rovers on the Moon. Zhurong is part of the Tianwen-1 mission directed by the China National Space Administration (CNSA). The mission was launched on 23 July 2020 from the Wenchang Spacecraft Launch Site on the South Chinese island of Hainan. The 5-ton vehicle comprised three separate spacecraft: an orbiter, a lander and the rover (Corbett 2021), a combination never used before for a Martian mission (Orbital Radar 2026d). Tianwen-1 inserted into Martian orbit on 10 February 2021. The orbiter then surveyed the landing site for the next three months.

For the landing of 14 May 2021, the Tianwen-1 orbiter was temporarily de-orbited to place it on a line to intersect with the Martian atmosphere, in order to release the lander/rover capsule (Corbett 2021). After separation, the unit hit the atmosphere at around 4.8 km/s. The capsule was protected by a heatshield to keep it safe from entry heating, and at 4 km of the surface, it deployed a parachute to begin slowdown. The heatshield was subsequently jettisoned at 1.5 km. At about 0.1 km above ground, the lander ignited engines and slowed to a hover for final descent, to make successful touchdown on southern Utopia Planitia, at 25.102°N, 109.914°E, and on 6 June 2021 the HiRISE camera aboard NASA's Mars Reconnaissance Orbiter imaged the rover a short way south of the lander, its parachute, backshell and heat shield (McEwen 2021).

Utopia Planitia is the largest known impact basin in the solar system (3,300 km diam.) and the landing site was chosen due to physical constraints such as latitude and altitude, slope and surface conditions, local wind speeds and visibility, and to serve the needs of the rover's scientific and analytical objectives, the determination of (Li *et al*. 2021):

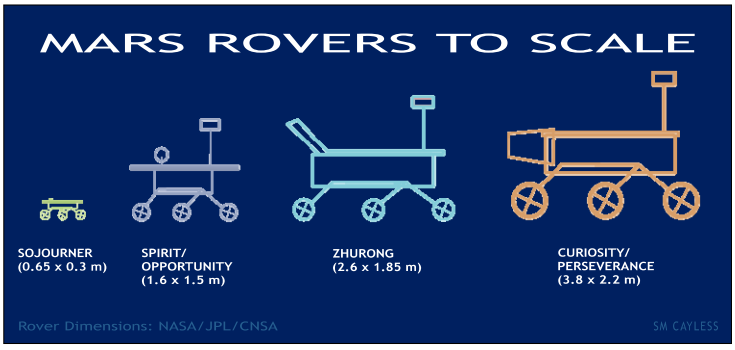
(1) topography and geological structure;
(2) soil structure and possible water ice deposition;
(3) chemical composition, minerals and rock typography;
(4) physical atmospheric and surface characteristics.

The flattish volcanic terrain was suitable for the solar-powered rover, and as orbital data had indicated shallow subsurface water ice, Zhurong's ground-penetrating RoPeR, or Rover Penetrating Radar, was designed for such investigation (Orbital Radar 2026d).



Instruments on Zhurong rover Credit: Li et al. (2021)

Zhurong has a mass of 240 kg, 7 cameras and 6 scientific instruments. As well as the RoPeR, her other instruments are: a magnetometer (RoMAG) to measure Mars' magnetic field; a Mars Climate Station (MCS) for meteorological and sound measurements; a Mars Surface Compound Detector (MarSCoDe); a Multispectral Camera (MSCam), which with the MarSCoDe and MSCam analyses mineral elements to determine the association between surface water conditions and secondary mineral types, and search for past environmental conditions for indications of liquid water; and, Navigation and Topography Cameras (NaTeCam), used to build topography maps, isolating factors such as slope, ripple and unevenness, and to explore geological structures, and conduct analyses on surface geology (Li *et al*. 2021; Jones 2021a).



Zhurong is larger than NASA's early rovers, though a good deal smaller than Curiosity and Perseverance (Jones 2021a), with an intended operative lifetime of 90 sols (Li *et al*. 2021). Once good communication with the rover had been set, the China National Space Administration (CNSA) published the first images of the Martian surface on 19 May 2021 (Amos 2021). On 22 May, Zhurong left the lander for the surface to start exploring, and the CNSA announced that by 11 July 2021, the rover had driven more than 410 m on the Martian surface (Zhang 2021). On July 12, she returned to visit her parachute and backshell, dropped at landing on 14 May (Jones 2021b).

By 18 Aug 2021, Zhurong had moved about 900 m, having outlived her 3-month life expectancy and completed all her pre-set tasks (CNSA 2021). The mission was thus expanded to take in an ancient Martian coastal area (Kooser 2021). Zhurong exceeded the 1 km distance mark on 23 August, on mission sol 97 (China Daily 2021). Zhurong took a planned break from mid-September to late October during solar conjunction, having travelled 1.182 km; communication was successfully re-established and the mission continued after 20 October 2021 (Jones 2021c), the rover setting off southward.

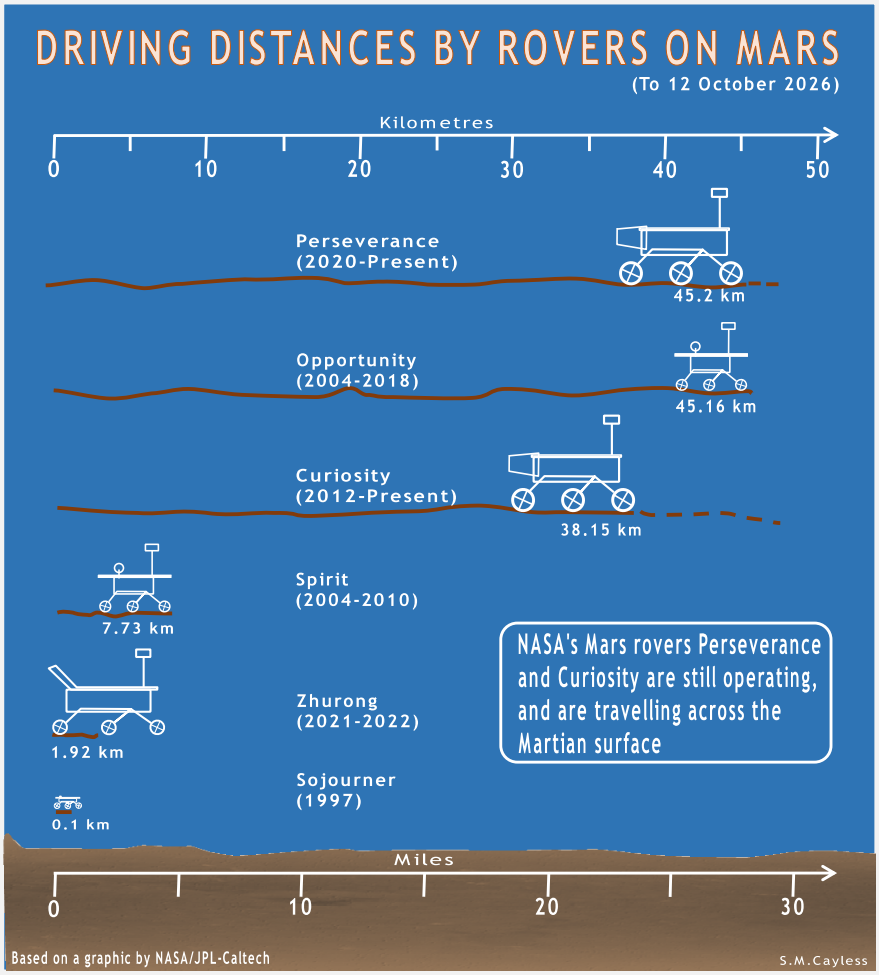
On the approach of Martian winter and a huge sandstorm, solar-powered Zhurong was switched to hibernation mode in May 2022, having travelled 1.921 km and sent back 1,480 gigabytes of raw data, some pointing to the existence of an ancient ocean on Utopia Planitia (Waldek 2022). The CNSA expected the rover to wake in spring, December 2022, but communications could not be resumed (Xin & Zheng 2023). Orbital images taken by the HiRISE on NASA's Mars Reconnaissance Orbiter showed that Zhurong had not moved since the start of hibernation (McEwen 2023), possibly as a result of major dust accumulation on the rover's solar panels (Cheung 2023).

However, even though Zhurong's operational lifetime was fairly short, the scientific data produced was remarkable. The rover found evidence for two major flooding events in Utopia Planitia that took place about 3.4 billion and 1.6 billion years ago (*much* more recent than hitherto believed), she found hydrated minerals that pointed to past water-rock interactions, and the atmospheric measurements taken added new data on surface-atmosphere interactions and Martian dust storms (Orbital Radar 2026d). The results of a recent study released in 2025 by an international research team, using data from Zhurong's ground-penetrating radar, provided evidence of beaches buried beneath Utopia Planitia, supporting the existence of an ancient Martian ocean and offering clues into the evolution of Mars' ancient environment (Li *et al.* 2025).

Zhurong explored the Martian surface for 347 sols, travelling 1.921 km and far exceeding her original mission time span. Although reawakening is a possibility, it is also possible that the rover will never recover (Hart 2023; Al Jazeera 2023).

Six Pioneers

The six pioneering Mars rovers, Sojourner, Spirit, Opportunity, Curiosity, Perseverance and Zhurong, have between them set records, delivered exceptional data, and provided major insights into our most hospitable neighbouring planet. With Curiosity and Perseverance still traversing the Martian surface, we hope for even more insights that will one day, allow humans to set up home on the Red Planet.



The image here shows the distances driven by the six successful rovers now on Mars. Of the vehicles shown, the NASA Mars rovers Perseverance and Curiosity are still operational and moving across the surface; the figures shown for the two are the distances driven as of 12 October 2026. The data here (apart from Zhurong) is based on a graphic by NASA/JPL-Caltech (JPL 2026).

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Mars Pathfinder's Sojourner Rover: Sojourner rover scheme, 1 July 1997, from Mars Pathfinder Landing: NASA's Mars Exploration Program Press Kit, NASA.
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Instruments on Zhurong rover: Credit: Li *et al*. (2021).
Mars Rovers to Scale: SM Cayless; rover dimensions from NASA/JPL/Chinese National Space Agency.
Driving Distances by Rovers on Mars: S. Cayless, based partially on an infographic by NASA/JPL-Caltech (JPL 2026), with additional data from Azmth (2026).

Happy Observing!

December 1st brings us the Moon at last quarter; it rises in the middle of the night and will be well-placed in the sky before dawn. On 5 December, there is a conjunction of the Moon and Venus in Virgo. The 26-day old Moon will pass 7°09' to the south of Venus. Look in the dawn sky to see the pair rising just after 04:00 (BST), to reach an altitude of 22° above the horizon, and fade at about 08:00. The December φ-Cassiopeid meteor shower (active 1-8 Dec) peaks on 6 December, close to New Moon. The shower's radiant is in Andromeda, and the best displays will be around 21:00 (GMT). Its parent body is not known, but it may be a Jupiter family comet.

The peak of the December Monocerotids (active 5-20 Dec, radiant in Monoceros) is on the 9th of the month. This meteor shower is best viewed around 02:00 (GMT), and 1-2 meteors/hr may be expected. The parent body of the shower is comet C/1917 F1 (Mellish). The sigma (σ)-Hydrid meteor shower (active 3-15 Dec, radiant in Hydra) is at its peak on the 12th and visible from after 21:00. Its parent body is not known and the rate low, at about 1 meteor/hr. However, two days later brings the peak of the 2026 Geminid meteor shower (active 4-17 Dec). For the best displays, look out at around 02:00 GMT on Dec 14, when the shower's radiant (in Gemini) is at its highest. From Stirling, there may be up to 110 meteors per hour to be seen. With the Moon (in Capricornus) near first quarter, interference should be minimal. The parent body of the Geminid shower is asteroid 3200 Phaethon.



For our astrophotographers, the Running Man (NGC 1977/Sh2-279), a reflection nebula along Orion's sword, will be well placed over several weeks. It reaches its highest point on 15 December. Around this time the Orion Nebula (M42) is well-placed. The Comae Berenicid meteor shower (active 12-23 Dec, radiant in Leo) peaks on 16 December, with 2-3 meteors/hr expected. The Moon will be at first quarter at peak, but sets at 23:46. The shower has no known parent body. The 9-day old Moon and Saturn are in conjunction on 18 December, the Moon passing 6°54' to the north of Saturn. The next night brings the peak of the December Leonis Minorid meteor shower (active 5 Dec - 4 Feb, radiant in Leo Minor). There may be up to 4 meteors/hr at the peak, but the Moon (in Aries) will be 3 days from full and will pose major interference. The parent body of the shower is unknown.

The December solstice on the 21st brings a close approach of the Moon and M45 (the Pleiades). The following evening, the Ursid meteor shower (active 17-26 Dec, radiant in Ursa Minor) reaches its peak of 9-10 meteors/hr, seen from Stirling. Unfortunately, the Moon (in Taurus) will be one day from full and will significantly interfere with viewing. The Ursids have no known parent body.

December's Full Moon, on the 26th, is a **Supermoon**, and will be visible most of the night. This Moon has several names (in the northern hemisphere), including Cold Moon, Bitter Moon, Snow Moon, Long Night Moon, and more poetically, Sun Has Travelled Home to Rest Moon, and, When Deer Shed Their Antlers Moon (Cayless 2024), all reflecting the chill of winter and seasonal events.



The Moon and M44 (Beehive Cluster) will make a close approach on 26 December, and on the 27th, the Moon and Jupiter (both in Leo) will be in conjunction. December 28 brings the Moon (in Sextans) into conjunction with Mars (in Leo), and to round of the month, the open star cluster NGC 2232 in Monoceros and the Rosette Nebula (C49), also in Monoceros, are both well-placed for astrophotography.

On January 3, the Earth will be at perihelion, its closest point to the Sun (at 0.9833 AU). This means that the Sun appears larger than at any other time in the year, and its radiation is at maximum; however, with only 3% variance in distance from the Sun, the change is virtually undetectable. This date also brings a conjunction of the Moon and Venus in Libra. The pair are best seen just before daybreak. January 4 is the peak of the Quadrantid meteor shower (active 12 Dec-12 Jan, radiant in Boötes). From Stirling, we may see around 120 meteors per hour, and as the peak is close to a new moon, interference will be slight. The parent body of the Quadrantids is asteroid 2003 EH1. On 7 January, dwarf planet 1 Ceres is at opposition and visible (by telescope) in Gemini for most of the night, rising in the east.

A conjunction of the Moon and Saturn occurs on 14 January, with the Moon in Pisces and Saturn in Cetus. The closest approach is at 19:28 GMT. Around this time, the spiral galaxy NGC 2403 (Caldwell 7) in Camelopardalis makes a good target for astrophotographers, reaching its highest point at about midnight on 15 January. It is a misty, steel blue dappled with pink glowing clouds, and was discovered by William Herschel in 1788. At 12 million light-years away and with an apparent magnitude of 8.9, a telescope will be needed. The galaxy became famous in 2004 when one of the brightest supernovae ever listed occurred there; supernova 2004dj at its peak brightness reached magnitude 11.2 (NASA 2026a). The Pleiades (M45) and the 11-day old Moon make a close approach in Taurus on 18 January; the following night brings the peak of the 2027 Gamma (γ)-Ursae Minorid meteor shower (active 15-25 Jan; radiant in Ursa Minor). The shower has no known parent body, and observers in Stirling may see 2-3 meteors/hour.



The Full Moon of 22 January will be the first of the two **Supermoons** of **2027**. This Wolf Moon was so named because the cries of hungry Grey Wolves when their food was scarce was heard. Other northern hemisphere descriptive terms include Bear Moon, Bear Hunting Moon, Moon of the Strong Cold, and Sun Has Not Strength to Thaw Moon (Cayless 2024). This Moon will also make a close approach to M44 (Beehive Cluster) in Cancer at this time, close enough to fit within a telescope's field of view (conditions permitting!), as they pass within 6.5 arcminutes of each other.

January 24 includes a conjunction of the Moon and Jupiter in Leo, and following night, a conjunction of the Moon (in Sextans) and Mars (in Leo) occurs. To round off the month, the Beehive open star cluster (M44, NGC 2632) is well placed to view and photograph on 31 January, reaching its highest point about midnight in Stirling.

February opens on the 2nd with a conjunction of the Moon and Venus in Sagittarius. The two may be visible at dawn, as they rise at 05:33 (BST) but will be low, reaching only 10° above the SE horizon. Mercury reaches its highest altitude in evening sky on 5 Feb, but may be difficult to observe from Stirling as it reaches a peak altitude of only 13° above the horizon. Alas, the **annular solar eclipse** of 6 February 2027 will not be visible from the UK, but will be visible from southern Chile and Argentina.

Asteroid 27 Euterpe, in Leo, is at opposition on 9 February and will be visible (by telescope), reaching its highest point about midnight. The Moon in Pisces, and Saturn in Cetus, are in conjunction on 11 February, and on the 14th, the Moon makes a close approach to M45 (Pleiades) in Taurus. For asteroid spotters, Asteroid 6 Hebe, in Leo, is at opposition on 17 February, reaching its highest point close to midnight. The Moon and M44 (Beehive) again approach close to each other in Cancer on 19 February. Mars reaches opposition on this date, and will be visible in Leo most of the night, and Bode's Galaxy (M81, NGC 3031) in Ursa Major reaches its highest point around midnight.

February 20-21 will be a busy night, if viewing conditions are clear. The 14-day old Moon and Jupiter make a close approach, within 1°05' of each other in Leo. Mars also makes a close approach to the Moon, within 5°19' of each other.

We also have the second and last **Supermoon** of **2027** at this time. Various names for this Full Moon include Snow Moon, Frost Sparkling in the Sun Moon, Hunger Moon, Moon of Big Famine, When the Bear Cubs Are Born Moon, and Storm Moon (Cayless 2024). The Moon also passes through the Earth's shadow, to generate a **penumbral lunar eclipse**. This starts at 21:13 GMT on 20 Feb and ends at 01:14 GMT on 21 Feb. Maximum eclipse occurs at 23:14 (Stirling time). The Moon passes last quarter on 28 February; at this phase it appears almost exactly half-illuminated and makes a good subject for lunar photography. It will be visible in Stirling from its rising at 03:17, until just before setting at 09:02.



The Moon's orbit around Earth is not exactly a perfect circle. As a result, the Moon sometimes comes slightly closer to Earth (perigee) and appears a tad larger than normal; at other times it is farther off (apogee) and appears rather smaller. A **Supermoon** occurs when a Full Moon occurs at perigee. In every 27-day orbit around the Earth, the Moon makes perigee at ~ 363,300 km from Earth, and apogee at ~405,500 km from Earth. As the Moon's orbit wobbles and varies, depending on where the Sun and Earth are in *their* orbits, the exact distances of perigee and apogee vary, so some Supermoons are nearer or further than others. Supermoons occur 2-4 times a year and are always consecutive (NASA 2026b).

Happy observing all!

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Many thanks to all our contributors to this quarter's issue of *The Jeety Starn*. Members, please hand submissions to the editor, or any contributions can be sent via the Society's contact email address. Illustrations and snippets also welcome!



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Celebrating 40 years of Stirling Astronomical Society

With thanks to all our members, past and present, who have made the Society the success it is.

Original illustration of our Society's telescope, by the person who designed and built it: William Peck (1862-1925), City Astronomer of Edinburgh and prolific writer and inventor. Taken from his 1890 book: *A Popular Handbook and Atlas of Astronomy* (Designed as a Complete Guide to a Knowledge of the Heavenly Bodies; and as an Aid to those Possessing Telescopes). Published by: Gall and Inglis, 25 Paternoster Square, E.C., London; and Edinburgh.

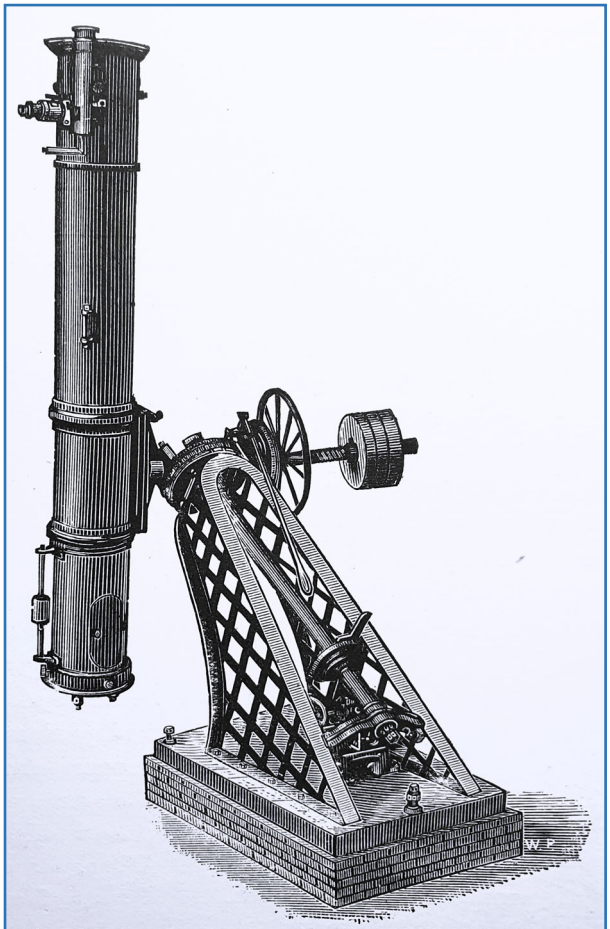


FIG. 36. A MODERN REFLECTOR EQUATORIALLY MOUNTED, CONSTRUCTED BY THE AUTHOR.