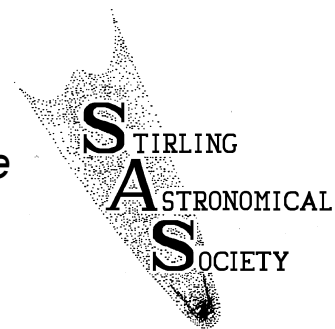


Newsletter of the



Vol. 16 No. 3 July 2001

---

### **EDITORIAL**

First, please note that the volume number has mysteriously changed from Vol.15 No.2 for the last Issue to Vol.16 No. 3 for this Issue. The two previous Issues should also have been Vol. 16, instead of duplicating last year's Vol. 15 - many apologies!

Now for a more serious bit. Mercury is intended to be *for* Members of the Society, written *by* members of the Society. As well as containing items of general astronomical interest, its function is also to report on, and record, the various news and activities of the Society and its Members. For this Issue, items have only been forthcoming from a very small number of contributors, so let's have many more please, from many more Members. I'm sure most of us could have something to say which is of interest. What we need urgently are Members willing to review and report on Society activities, as we have had nothing in Mercury for several Issues now about what the Society is actually *doing*. We need reports on Society Lectures held at the Smith, Members' Evenings at Mayfield, SAG Meetings, and Meetings of other Societies attended. So *please* can we have some volunteers for this?

Please send your contributions to (or first discuss them with) :

*either:-*

Dr Derek Allen,  
Road, Stirling FK8 2HK  
Tel: 01786 472771

1 Ogilvie

E-mail:derek.allen@btinternet.com

*or:-*

Dr Harry Stout,                   17 Anderson Street, Dunblane FK15 9AJ  
Tel: 01786 824034

Copy can be in clear handwriting, typescript, e-mail, or on floppy disk (preferably in *.rtf* format), in that ascending order of preference for the work involved in editing. Please have material ready by about the end of August for the next issue of *Mercury* due the beginning of October.

Most Members know that our President, Harry Stout, had a hip replacement operation in June. He is now at home making a good recovery, and we all wish him well and look

---

---

## THE NIGHT SKY for July, August, and September 2001

### SUN

	July		August		September	
	8	22	5	19	9	23
(approx) Rises	04.25	04.46	05.11	05.39	06.20	06.47
(approx) Sets	21.44	21.26	20.59	20.27	19.34	18.56

### MOON

	July				August				September			
Phase	FM	LQ	NM	FQ	FM	LQ	NM	FQ	FM	LQ	NM	FQ
Date	5	13	20	27					4		12	
	19		25	2			10	17			24	
Rises	21.57	00.42	03.48	13.57	21.36	23.35	05.32	14.24	20.19	22.30	06.04	
15.46												
Sets	04.00	13.01	21.39	00.10	04.51	14.34	21.08	22.53	05.03	14.57	19.47	22.34

### PLANETS

#### Magnitude

<b>MERCURY</b>	July	Unsuitable for observation	
		August	Unsuitable for observation
		September	Unsuitable for observation.
<b>VENUS</b>	July	Morning object eastern sky, 3° North of Aldebaran on 15th	-4.1
		August	Morning object eastern sky, South of Castor &
Pollux	-4.0		
		September	Morning object eastern sky, within 1° of Regulus
on 20th		-4.0	
<b>MARS</b>	July	Southern sky most of night, now fading	-2.2 to -1.5
		August	Low SW sky in evening, in Ophiuchus but
still fading	-1.5 to -0.9		
	September	Low SW sky in evening, not visible after 22nd	-0.6
<b>JUPITER</b>	July	Unsuitable for observation until 12th, then early morning low ENE	-1.9
		August	Morning object low ENE sky, close to Venus

## CONJUNCTIONS (with the moon unless stated otherwise)

July			August		
Date	Time		Date	Time	
3	12.00	Mars 6°S	5	23.00	Mercury in superior conjunction
4	15.00	Earth at aphelion, 152 million miles	5	23.00	Jupiter 1°N of Venus
12	23.00	Jupiter 2°N of Mercury	14	04.00	Saturn 0.2°N
15	09.00	Saturn 0.7°N of Venus	15	16.00	Uranus at opposition
17	14.00	Saturn 0.6°N	15	21.00	Jupiter 0.4°S
17	19.00	Venus 0.3°S	16	14.00	Venus 2°S
19	01.00	Jupiter 0.2°N	20	03.00	Mercury 3°S
19	14.00	Mercury 1°S	23	17.00	Pluto at stationary point
20	00.00	Mars at stationary point	27	14.00	Mars 5°S
30	13.00	Neptune at opposition			
30	16.00	Mars 6°S			

### September

Date	Time	
10	14.00	Saturn 0.2°S
12	14.00	Jupiter 1°S
15	10.00	Venus 3°S
18	00.00	Mercury at greatest elongation
19	09.00	Mercury 7°S
25	01.00	Mars 2°S
27	01.00	Saturn at stationary point

## METEORS

**August** Perseid meteors occur on the 12th August, but there is viewing interference from the Moon, which rises around midnight in last quarter.

## ZODIACAL LIGHT

**September** Morning cone may be seen reaching up from eastern horizon along ecliptic before the beginning of the morning twilight, from 17th to end of the month.

*Hamish MacPhee*

---

**BLUE "TALKING" PLANTS ON MARS?** A team of American scientists has created genetically engineered mustard plants capable of communicating information about their environment. The intention is to send them to Mars in 2007 where they will be planted in Martian soil and grown inside a mini-greenhouse on the landing vehicle, to communicate information about conditions there. The mustard plants have genes from jellyfish spliced into their cells to produce an iridescent blue protein which makes the plants fluoresce when stressed. Different plants will fluoresce when stressed in different ways, including being subjected to water deprivation, heat intolerance and exposure to heavy metals. This fluorescence will be detected and the information sent back to Earth. The long term goal is to accumulate data to assist in establishing a human colony on Mars. To maintain a human environment, vegetation will be needed to reduce its carbon dioxide and increase its oxygen contents. The mustard plant forerunners will identify possible problems in doing this.

DA

---

---

## DELAYING BEING FRIZZLED

Since the Sun started shining about 4.6 billion years ago, it has steadily grown in size and it has also become brighter. It is now 30-40 percent brighter than when it first entered the main sequence, its period of stability. This trend will continue, so that in another billion years it will be a further ten percent brighter than it is now. The Earth will then be a lot hotter than it is at present and if our descendants are still around, life for them will have become extremely difficult, if not impossible.

It's reassuring therefore to know that someone is already thinking about this and planning ahead for our descendants' benefit! A recent paper in *Astrophysics and Space Science* suggests a way in which the frizzle-up could possibly be delayed for another six billion years. The proposal is to increase the diameter of the Earth's orbit around the Sun as the Sun's radiation increases, so that the intensity of its radiation reaching Earth remains the same. "But how can this be done?" you may well ask. This is the clever bit. The idea is to use the gravitational slingshot technique that has already been used to assist spacecraft on their way. As a spacecraft nears Jupiter, for example, the planet's gravity accelerates it and it shoots away with increased energy and speed on its way to Neptune or Pluto. However, energy and momentum are always conserved, so Jupiter's orbital energy and momentum are very slightly decreased as a result.

To increase its orbit significantly, the Earth has to gain energy from something pretty massive - something with a mass of about ten thousand million million ( $10^{16}$ ) tonnes. Looking around the Solar System, an asteroid about 100 km across would do nicely. If such an asteroid, with an orbit bringing it near the Earth, can be made to fly in front of the Earth as the Earth moves in its orbit, the asteroid would transfer some of its orbital energy to the Earth, so shifting the Earth to a slightly larger orbit, i.e. away from the Sun. This would have to be repeated several times, but the same asteroid could be used over again. By arranging that after its fly-by of the Earth the asteroid heads towards Jupiter or Saturn, a reverse of this process could be engineered so that it picks up energy from the planet on its fly-by to replace the energy it lost to the Earth. When the asteroid reaches its farthest point from the Sun a small course correction to its orbit would be needed, to send it once more back towards Earth. How could the asteroid's course be corrected? In a billion years our descendants should have the technology to be able to fire suitably powerful engines on the asteroid using fuel made from materials mined on the asteroid itself.

Calculations show that for the Earth to continue to receive the same intensity of sunlight as it does now, it would have to be nudged outward in this way about once every 6,000 years for the entire remaining main sequence life of the Sun. In six million years or so the Earth would then be just beyond the present orbit of Mars. While postponing the frizzle-up, this procedure would have its risks. Any error or malfunction could result in the asteroid hitting the Earth instead of flying by it, so ending life here long before the frizzle-up occurs. The change in the Earth's orbit could also disturb the orbits of other planets in the Solar System in unknown ways with unknown consequences. And what would happen to the Moon? It could be lost as an Earth satellite unless a way could be found to move it in step with the Earth. Without the Moon the Earth's axial tilt could be destabilised and, together with the absence of tides, the effect on our climate could be catastrophic.

While it may be possible to postpone the end of life on Earth in this way for a long time, the only way ultimately to survive would be for our descendants to move to another, younger, suitable star system. When the Sun eventually becomes a cool, dim, white dwarf the insuperable problem would not be too much radiation reaching Earth, but too little to sustain life here.

*Derek Allen*

---

---

## CRATERS - LARGE AND SMALL

Xenon is one of the rare gases, and was discovered by Sir William Ramsey in 1898. He must have thought that its value lay in its rarity, and that it would be unlikely to find any useful purpose. How wrong he was!

In the last issue of Mercury I discussed the use of xenon as a fuel in a NASA thruster to propel a spacecraft to remote parts of the Universe. Another use is as beams of xenon ions bombarding gold film to imitate the impact of meteorites on a planet or moon. A meteorite forms a crater with a circular rim, and with a much greater volume excavated than the size of the meteorite itself. The extra volume excavated depends on the kinetic energy of the meteorite, all of which is dissipated on impact.

Two physicists at the Argonne National Laboratory in the USA, together with a colleague nearer here at Salford University, have now discovered that beams of xenon ions fired at a gold film can produce similar circular rimmed craters. They accelerated the beams to an energy of about 400 keV for these experiments. This is about two and a half times the energy which Cockcroft and Walton used to "split the atom (or rather its nucleus)" in 1932. However, their bombarding beam was sharply focused, whereas these xenon ion beams were wider.

Further information can be found in *Physics World*, March 2001.

*Harry Stout*

---

## METEORITES - LARGE AND SMALL

Recently, in York, someone heard a whizz and a bang, and saw a smoking hole in the ground. It was reported to the police, who thought it might be a meteorite, and they called a curator from York Museum to investigate. In fact it turned out to be merely the explosion of a shorting underground cable.

Although a lot of extra-terrestrial material reaches the Earth (estimated at 40,000 tonnes per year), not much of it reaches the surface as actual lumps. The chance of a piece of extra-terrestrial rock reaching the ground intact depends very much on its size. The "shooting stars" we see flashing across the sky arrive as particles ranging in size from a sand grain to a pea. Hitting the atmosphere at a typical speed of 30 km per second, they are heated and evaporated by friction in the upper atmosphere. Their material then condenses to fine dust which is eventually washed down to the surface by the weather.

Contrary to what you might expect, particles much smaller than a sand grain (less than a tenth of a millimetre across) are decelerated by the atmosphere without being evaporated or even fused. This is because their ratio of surface area to mass is much greater than for larger grains, and this enables them to radiate away the heat generated quickly enough to avoid the temperature rising above their fusing point. These grains, called micrometeorites, slow to a halt and then gradually fall through many kilometres of atmosphere to the Earth's surface. This can take a long time - years for the smallest grains. NASA scientists, flying in the stratosphere, have collected samples of them for analysis using sticky plates projecting from the aircraft's wings. Another method of collecting samples is by melting and sieving large volumes of snow and ice which has accumulated over thousands of years in Greenland and Antarctica, onto which the grains have fallen and remained.

Micrometeorites are all around us in fact. In typical house dust, one in a thousand particles is probably a micrometeorite! Roof gutters are likely to contain a much higher proportion of metallic

micrometeorites, because they are washed down in rain and then preferentially deposited in the gutter sludge because of their high density.

Meteorites much larger than a pea, say between an orange and a football, produce extremely bright fireballs which change night into day for a second or two as they heat up and evaporate. It is possible under certain conditions, in a small fraction of cases, for some of the original solid meteorite to reach the ground intact. For this to happen it must be strongly coherent, i.e. made of metal or solid rock and not be a loose agglomeration of ice or smaller lumps. The chances are increased by the meteorite having a low approach speed. The minimum possible is about eleven km per second, i.e. the speed it would reach in free fall from space under the Earth's gravity. Also, if the meteorite arrives at a fairly oblique angle to the Earth's atmosphere, it is decelerated more slowly as it takes longer to reach the denser layers of air and does not heat up as much (a returning space Shuttle does this).

Meteorites, or parts of them, which actually reach the ground are fairly rare. Because of their fiery arrival, it is usually assumed that they are very hot when they hit the ground. In fact, this is not the case. Arriving on a suitable trajectory, they are slowed down in 10-20 seconds. During this time their outer layers are intensely heated and fuse, and some evaporate away. The fused surface of a recovered meteorite is obvious. However, during its passage through the atmosphere there simply is not time for the heat generated on its surface to be conducted through to the interior of the meteorite. As a result, when a meteorite reaches the ground, its interior is still at the temperature it had in space at the Earth's distance from the Sun, around -30°C. A similar effect occurs when a frozen chicken is placed in a hot oven - the outside can appear to be cooked, while the inside is still frozen. Just fallen meteorites then are cold, not hot. Observers reaching the site soon after a meteorite impact have reported it be covered in ice or frost, condensing on the cold body.

Meteorites this sort of size do not make craters. If they survive entry into the atmosphere, they are completely decelerated while they are still about 30 km from the ground. From then on they fall freely in the atmosphere and reach a terminal velocity of about 300 km per hour, the same speed as something of the same size and density dropped from a high flying aircraft. If it lands on soft ground, it might bury itself a bit, but it will not make a crater, and on hard ground it will remain on the surface.

So, if you hear a bang and see a smoking hole in the ground, whatever it is, it won't be a meteorite!

*Derek Allen*

---

**SPACE ROCK or SPACE ROCKET?** An item in the last *Mercury*, "We're Helping to Stop the End of the World", was about the possibility of an asteroid hitting us. There is a one-in-a-thousand chance that a smallish object, named SG344, could hit us on 16 September 2071. However, from more recent scrutiny of its orbit in relation to the Earth's, it has now been suggested that SG344 may not be an interesting lump of rock from space, but merely the more mundane remains of an Apollo-era booster rocket originally launched from Earth! As such, it doesn't pose any threat - what a relief! *DA*

---

### **FACTS and FIGURES - JUPITER**

Jupiter is both the largest planet in the solar system and the most massive. Its equatorial diameter is 143,884 km, which is 11.209 times the diameter of Earth, and 0.103 times the diameter of the Sun. Jupiter is not spherical because it spins rapidly and is made of gas and liquid. Its polar diameter is 133,708 km. The volume of Jupiter is equivalent to 1,319 Earths. Jupiter's mass is 318 times Earth's mass, and is 2.5 times greater than total mass of all the other planets. It would take 1,047 Jupiters to make up the mass of the Sun. The equatorial diameter of the next largest planet, Saturn, is 0.84 that of Jupiter and its mass is 0.30 Jupiter's. Both Jupiter and Saturn grew into relatively large planets because they formed at a place and time in the early development of the solar system that enabled them to collect vast quantities of gas from the solar nebula.

---

---

## A STORM IN SPACE

On the morning of 14 July last year (Bastille Day) the Space Environment Center in Boulder, Colorado, detected a warning sign from the GOES-8 satellite, which not only monitors weather conditions on Earth but also detects X-rays from the Sun. At 10.03 Universal Time a sharp jump occurred in the intensity of X-rays emanating from a region of the Sun's surface which had been active for several days. The data indicated the onset of a solar flare, a brief but powerful burst of radiation.

The flare reached its maximum intensity 21 minutes later and was also sighted by the Solar and Heliospheric Observatory (SOHO), which is a spacecraft stationed between the Earth and the Sun about 1.5 million km from Earth. Half an hour later as the flare was waning, SOHO detected a bright, expanding cloud surrounding the Sun like a halo. It was a coronal mass ejection (CME), which is an eruption in the Sun's outer atmosphere (the corona), throwing billions of tonnes of electrically charged particles into interplanetary space. The visual halo effect meant that the particles, mainly protons, were heading directly towards the Earth, and their speed was estimated to be 1,700 km per second.

Streams of ionised gas flow continuously away from the Sun at a much lower speed, and are known as the solar wind. As the CME ploughed into the solar wind it created a shock wave that accelerated some charged particles to even higher speeds. In less than an hour a deluge of high energy protons struck SOHO, temporarily putting its instruments out of action and damaging its solar panel arrays. In fact it caused a year's normal degradation in only 24 hours.

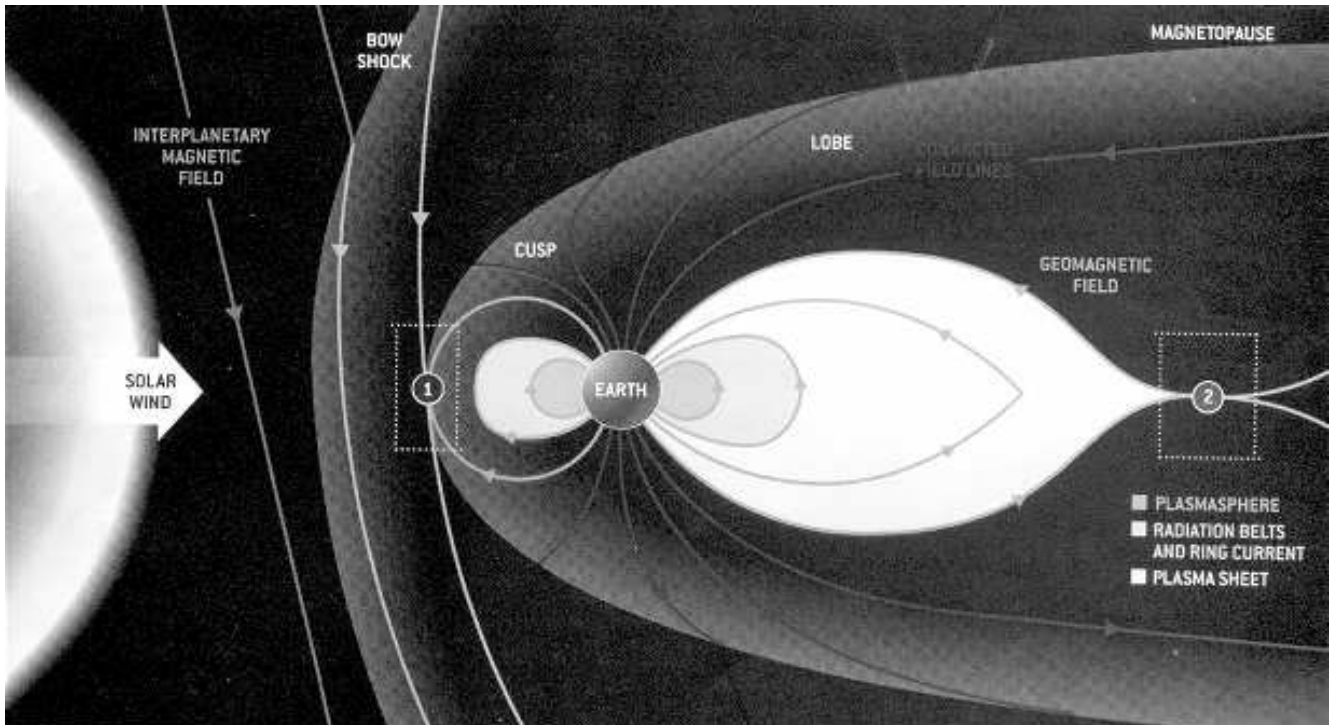
The shock wave travelled on in front of the CME, and reached the Earth's magnetic field the next day at 14.37 UT. It started a severe geomagnetic storm which increased even further in magnitude a few hours later when the CME itself arrived. According to measurements made by the Space Environment Center, this was the largest such storm in nearly a decade.

Most people on the ground were completely unaware of what was going on, but scientists followed it very closely, collecting data about it from instruments on the Earth and in space. One satellite tracking the storm was the Imager for Magnetopause-to-Aura Global Exploration (IMAGE for short) which NASA had launched just four months earlier.

During this space storm, code named Bastille, IMAGE began recording its effects less than two minutes after the CME-driven shock wave hit the Earth's magnetic field. IMAGE's wide band imaging camera sent back excellent pictures of the aurora borealis triggered by the resulting compression of the magnetic field. A movie created from the pictures shows a sudden and dramatic brightening of a ring above the Arctic region, with brilliant emissions racing towards the North Pole. The aurora quietened down less than an hour after the storm began, but flared up again when a second shock wave hit at about 17.00 UT. Powerful substorms followed, as stored energy was explosively released into the upper atmosphere and more substorms and auroral displays continued until the following morning.

During Bastille's main phase, which began about four hours after it started, the Earth's magnetic field strength down at the surface fell dramatically. This phenomenon, an important characteristic of such storms, results from a rapid growth in the so-called ring current around the Equator. IMAGE's instruments showed that this flow of ions and electrons reached a peak on 16 July and then subsided as the loss of charged particles from the ring exceeded the arrival of new ones. The Earth's magnetic field then also began to recover, although more slowly.

During space storms, charged particles swirl around the Earth and bombard the upper atmosphere, particularly at higher latitudes, and this can have many adverse effects. As electrons cascade down-

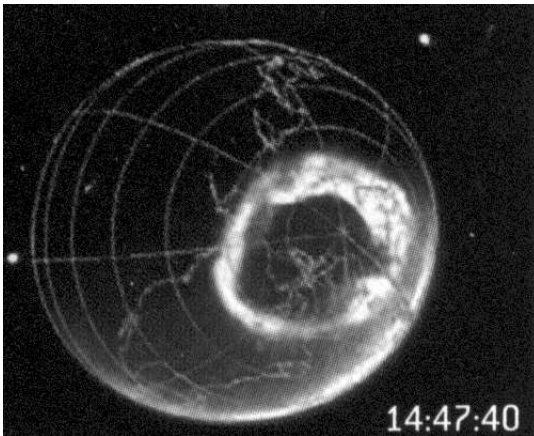


*The complex interactions caused by a space storm*  
*Disturbances occur in the Earth's magnetosphere when the interplanetary magnetic field (IMF) carried by the solar wind and the CME coming from the Sun are turned towards the Earth's south pole. The field lines of the IMF connect with the Earth's geomagnetic field lines at the day side of the magnetopause boundary nearest the Sun region (1). Energy and particles rush into the magnetosphere, enlarging its northern and southern lobes and narrowing the ionised plasma sheet of the space storm. Then behind the Earth, on the dark side, the geomagnetic field lines reconnect, region (2). This releases energy and accelerates ions and electrons towards the Earth, causing aurora around the north pole.*

wards, they create a strong electric current in the upper atmosphere, known as the auroral electrojet. This causes fluctuations in the geomagnetic field which in turn can induce electrical surges in power lines on the ground. This occurred, for example, during a severe space storm in 1989 when such a surge knocked out the Hydro-Quebec power grid and plunged large parts of Canada into darkness.

Satellites can be affected as well because, when they are struck by charged particles, their surfaces become electrically charged. In severe cases this can cause sparks which short-circuit the satellite's electronics. In fact Bastille wrecked the operation of the Advanced Satellite for Cosmology and Astrophysics, which was an X-ray observatory launched in 1993 by the Japanese space research agency. A further hazard is that space storms heat the Earth's atmosphere, so causing it to expand. For a satellite in fairly close orbit to the Earth, this will increase friction which drags it downwards into a lower orbit, increasing the atmospheric friction even more. It was this process which led to the premature fall of Skylab in 1979.

Astronauts are also at risk. A severe space storm can expose the International Space Station to high speed protons which could penetrate a spacesuit, or even the space station's walls. To protect astronauts at the space station, NASA monitors space weather forecasts. If an incoming space storm is thought to pose a risk, any planned space walks are postponed or cancelled, and astronauts shelter in a specially shielded part of the space station for the storm's duration.



*Aurora recorded by IMAGE's wideband imaging camera during the Bastille space storm.*

Just like weather on Earth, space weather is extremely variable. Conditions can turn from quiet to stormy in a matter of minutes, and storms can last for only hours or go on for days. As Earth weather alters with the terrestrial seasons, space weather follows cycles depending on the Sun. Solar magnetic activity, which causes solar flares and CMEs, rises and falls in eleven year cycles and space storms follow this pattern as well. The Bastille storm occurred during the most active part of the solar cycle. Space weather also varies to a lesser extent with the Sun's 27 day rotation period, which affects the speed of the solar wind sweeping past the Earth.

IMAGE is the first satellite dedicated to imaging the magnetosphere, the region of space influenced by the

Earth's magnetic field. By providing overall pictures of activity in the magnetosphere, IMAGE is attempting to do for this region of space what weather satellites do for the Earth's ordinary atmosphere. It investigates how CMEs and the solar wind interact with the magnetosphere and, more practically, improves space weather forecasting and so helps to mitigate the adverse effects of space storms.

*Derek Allen*

---

## **THE MARS ODYSSEY**

This latest mission to Mars blasted off successfully in April and started on its seven month voyage. The Mars Odyssey, as it is called, is named after Arthur C Clarke's science fiction classic. It is designed to orbit Mars to look for signs of water, and to send back data to prepare for another mission in 2003 to land robotic vehicles on Mars' surface. Its cost is \$300 million.

It is the first spacecraft to be sent on a mission to Mars since the very embarrassing 1999 failure. Then, the Mars Polar Lander crashed onto the surface of Mars instead of making a soft landing to send back images to Earth. NASA found that in designing the Lander there had been confusion between numbers in metric units and imperial units. As a result, the on-board computer still believed it was way above the surface at impact. A salutary lesson in the disadvantages of continuing to use two systems of measurement! [*Smug comment: In Britain, engineers and scientists have all standardised on metric units for nearly fifty years now, so it couldn't happen here!*]

When the Mars Odyssey orbiter starts work in January next year it will map the chemical make-up of Mar's surface. It carries a gamma-ray spectroscope to look for the presence of a range of elements, including hydrogen, a key to the presence of water. It will also measure the intensity of radiation of various wavelengths to assess what protection future astronauts on Mars may need. After this work is complete, the orbiter will remain above Mars to act as a communications satellite for future missions.

Will this latest Mars mission be successful? Experience shows that Mars missions are very chancey ventures. So far, just 60% of US missions, and only 40% of all missions to Mars have succeeded. A wide range of risks has been carefully considered in a detailed hazard analysis, and many changes have been made as a result. All 220,000 measurements involved in the mission have been double checked. However, instead of standardising on metric units throughout, design and operational documents duplicate these numbers in both metric and imperial units - a curious way of trying to avoid any confusion which the simpler use of one single system of measurement would completely eliminate!

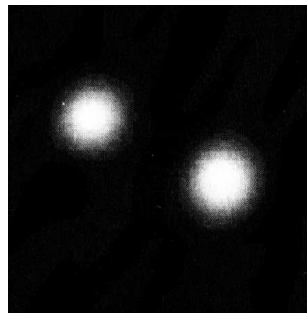
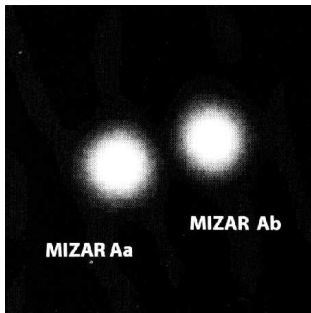
*Derek Allen*

---

---

## A HUNDRED TIMES BETTER THAN HUBBLE

Mizar, the fourth brightest star in Ursa Major, forms an optical pair with Alcor. This is just a line-of-sight binary and not a true binary system. Mizar, however, is also a true binary star and was the first one ever to be resolved into its two components by a conventional telescope. Mizar *A* and Mizar *B*, as they are called, are less than 0.004 degrees apart in the sky and were each shown spectroscopically to be a binary star as well. These are known as Mizar *Aa*, Mizar *Ab*, Mizar *Ba* and Mizar *Bb*. In 1996 the American NPOI (Navy Prototype Optical Interferometer) succeeded in optically resolving Mizar *A* into Mizar *Aa* and Mizar *Ab*. At the time this was the highest resolution image ever produced in optical astronomy.



*Images of the two binary components of Mizar A, which is itself a component of the binary star Mizar, taken by optical spatial interferometry at different points in their orbit around one another.*

Interferometry as an astronomical technique was first proposed in 1868 by Fizeau, a French physicist. He suggested measuring the size of stars by placing a two-hole mask over a telescope and observing the resulting interference patterns. Stephan tried it out with an 80 cm telescope in 1876 but the 65 cm separation he used between the holes was insufficient to measure the stars' sizes. When he looked through his eyepiece at a star, he saw an image of it from each aperture in the mask. These images were large and overlapped. The overlap was crossed by dark stripes - interference fringes, caused by light waves following the two different paths of slightly different length interfering with each other, and alternately cancelling and enhancing one another. To measure a star's diameter, the separation between the apertures is increased until the fringes disappear; the larger the separation required, the smaller the star. Unfortunately, Stephan's telescope was not large enough to enable the two apertures to be separated sufficiently to make the fringes disappear. He concluded that the stars he looked at must all be smaller than 0.16 arcseconds across. One arcsecond is about the size of the largest moons of Jupiter as seen from Earth. Betelgeuse, the star with the largest disc as seen from Earth after the Sun, is one about fifteenth of this - 0.06 arcseconds, or 60 milliarcseconds. Most stars visible to the naked eye are at the most only a few milliarcseconds or less across.

Michelson was the first to achieve some success with the technique. He was able to measure the Galilean moons of Jupiter because of their size, 1-2 arcseconds. Later, in 1920, he was also the first to measure the size of stars. He did this for Betelgeuse and five other supergiants by fixing a six metre metal beam with mirrors at each end across the aperture of the 100-inch (2.5 metre) Hooker telescope at Mount Wilson, then the largest in the world. The size of the stars he measured was 20-50 milliarcseconds. If the human eye had this power of resolution, we would be able to see individual atoms in our hand held at arm's length!

The resolving power of a telescope and its ability to discriminate between small objects is proportional to the size of the telescope's aperture. If a 15 cm telescope can resolve a one arcsecond disc, then a 2.5 metre one could resolve Betelgeuse, and a 10 metre Keck telescope in Hawaii might resolve other bright stars. The problem in practice, however, is that beyond a 15 cm aperture any improvement is counteracted by the turbulence in the Earth's atmosphere. This can be dealt with by adaptive optics (see *Mercury* Vol.16/15 No. 1, Un-Twinkling a Star), but not to the extent of being

able to discern the size of very many stars. Under perfect conditions a 10 metre telescope could only resolve down to 10 milliarcseconds. To measure all the stars visible to the naked eye, a 500 metre telescope would be needed - far beyond present technology.

Advances in astronomical interferometry came in the 1950s and 60s in radio astronomy. Radio interferometry is easier than optical interferometry because the wavelengths are several thousand times longer. This reduces the atmosphere's effects and less engineering precision is needed to achieve the required interference. It also has the advantage that the signals can be easily amplified. The technique of using two telescopes on a measured baseline, instead of a single one, was also developed using radio telescopes.

The essence of modern spacial interferometry, as it is called, is to combine two nearly identical signals from a source to produce interference, and from this obtain information that is not available from either signal on its own. Overlapping the light from two separate telescopes produces interference pattern of dark and light bands. The spacing of these bands and how they vary as the telescopes are moved provide information about the light source at a much finer resolution than that of the individual telescope images alone.

The pioneers of doing this for optical astronomy were Brown and Twiss in the 1960s and early 70s, with the Intensity Interferometer near Narrabi, Australia. They used two 6.5 metre optical telescopes which could be separated by up to 188 metres - still the largest separation ever used. They were also the first to use electronic detection and data recording instead of the human eye. Their approach involved detecting individual photons at the separate telescopes and correlating their arrival times. Thus the light beams never actually needed to be brought together, but the technique has a very low sensitivity. A 100 hours of observation were needed to measure a star in Orion's Belt.

In 1974, Labeyrie used a 12 metre baseline and the older technique of combining the two beams before detection to observe the star Vega. Since then several more spacial interferometers have been, or are still being built, all based on Labeyrie's approach. Measurements are now taken from many different baselines, merely by waiting for the Earth to rotate. The data from a single baseline is of very high resolution, but is incomplete. Collecting data from more baselines compensates for this so that a complete image is eventually obtained.

Current optical spacial interferometers can achieve resolutions 100 times greater than the Hubble Space Telescope. Stars have been measured with sizes down to 0.4 milliarcseconds. There are now proposals for space-borne interferometers, e.g. the Space Interferometer Mission, which will overcome the remaining limitations of terrestrial instruments. These new instruments are intended to push measurements into the microarcsecond range (i.e. millionth) and they may be able to detect optically planets orbiting other stars.

*Note:* Readers may like to refer to Harry Stout's article in *Mercury*, Vol.10 No.2 Sept 1995," The Resolving Power of Telescopes", in which he discusses some of the optical principles involved.

*Derek Allen*

---

FLOATING MOONDUST At the time of the Moon landings, a tenuous, barely visible layer of dust was seen floating a metre or so above the moon's surface. A full explanation of this is has now been published. The Sun's ultra-violet light knocks electrons off particles of moon dust lying on the surface and off the moon rock itself, so giving them both a positive charge. Because positive charges repel each other, the dust is pushed away upwards from the rock to the point where this repulsive force just balances the Moon's feeble gravity. The phenomenon has been simulated by experiments with mineral grains in a vacuum chamber bathed in ultraviolet light.

---

---

## FROM THE PYRAMIDS TO THE STARS

Cambridge archeologists have suggested that the Egyptian pyramids may have been built as launch pads for the pharaohs' journeys to the afterlife among the stars. The pyramids were all precisely oriented towards northern stars which rotate about the Pole Star and never set below the horizon. They were thus regarded as undying stars by the ancient Egyptians and ideal destinations for the souls of dead pharaohs. There are also supporting clues from the names given to pyramids, for example "The Pyramid that is a Star" and "Gleaming". One pharaoh founded an estate to finance his pyramid and called it "Horus Rises as a Star".

The first pyramid, the step pyramid at Saqqar built in the third dynasty (2685-2615 BC) had its altar to the north and its ramp down into the underground burial chamber started from the north face. Viewed from the burial chamber, the ramp rose to the northern sky and was, according to this suggestion, the launch pad for the pharaoh's spirit, to eject him to a northern star where he would spend his afterlife. Fourth dynasty (2615-2496 BC) pyramids, including the Great Pyramid and others nearby, were similarly oriented towards the stars.

There is also speculation that the shape of the pyramids was based on the shape of an unusual meteorite which fell on ancient Egypt. A stone, long since lost, was revered at the Temple of Heliopolis in the fourth dynasty. It was known as the Benben Stone and was represented in inscriptions as conical or pyramid shaped. The Egyptian word for the top capstone of a pyramid was "benbenet" or "little benben". The high priest at Heliopolis was called "Greatest of Observers", an astronomical title. The Benben Stone could well have been an unusually shaped meteorite which fell on ancient Egypt and which they deduced came from the Heavens - maybe even a star. It was therefore worshipped as a sign specially sent from the Heavens, and used as a model for the pyramids.

*Derek Allen*

---

**GANYMEDE'S OCEAN** The surface of Ganymede, Jupiter's largest moon, appears to have a lot of bright bands of smooth frozen water. Stereo images compiled from the Voyager and Galileo spacecraft fly-bys of the moon reveal that the bright bands lie in troughs up to a kilometre lower in altitude than the darker, more cratered regions of the surface. This seems to indicate that the bands originated from volcanic eruptions of water or slush which flowed into the depressions and then froze into the smooth strips that now cover much of the moon's surface. A recent analysis of Ganymede's magnetic field suggests that the moon contains a layer of salty water, several miles thick, below about 200 km of icy crust, and this also tends to support this theory. When the volcanic eruptions were occurring, about a billion years ago and before the moon cooled as much, this liquid ocean would probably have extended upwards to much nearer the icy surface. *DA*

---

### Stirling Astronomical Society

#### OFFICERS AND COMMITTEE FOR 2001

President	Dr Harry Stout
Chairman	Douglas Cooper
Secretary	Hamish MacPhee
Treasurer	Dr Iain Smith
Director of Observations	Dr Ken Mackay
Membership Secretary	Albert MacKenzie
Librarian	Maurice Dixon
Committee Members	Terry Aitchison Dr Alan Cayless