MERCURY

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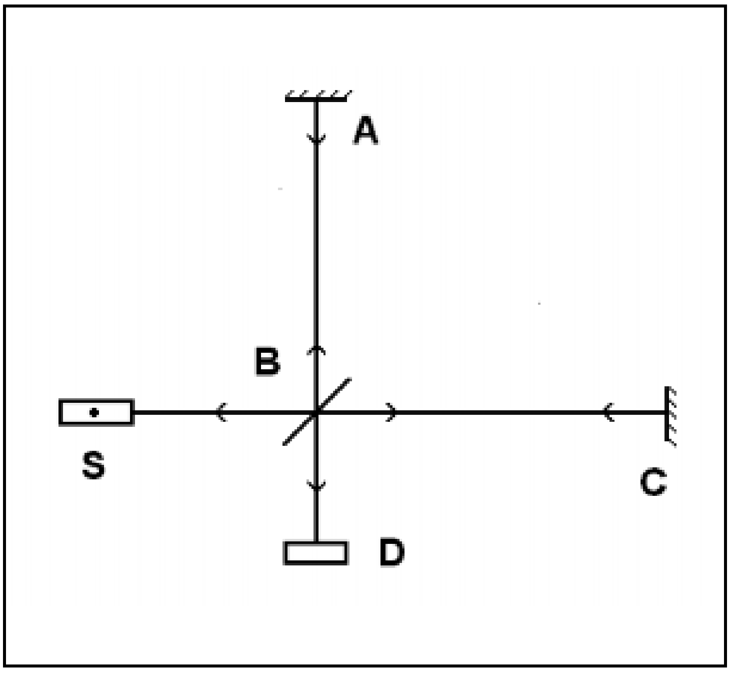
DETECTION OF GRAVITATIONAL WAVES BY INTERFEROMETRY

In the last issue of *Mercury* (Vol 17 No 1), the detection of gravitational waves by Weber cylindrical bars was discussed. But as well as these resonant-mass detectors (as they are technically called) a great deal of effort is being put into the design of interferometer detectors. In an interferometer, a beam of coherent light is divided by a beam-splitter into two smaller beams which are sent along two perpendicular arms which each carry a mirror at its extremity. These mirrors reflect the beams back to the beam-splitter, where they are first superimposed on each other and then again split into two perpendicular beams. One of these beams then takes a path to a photodetector which measures the intensity of the superimposed beams. Coherent light is monochromatic, i.e. it has only a single wavelength, and can be produced by a suitable laser.

In the diagram, the laser source is at *S*, *B* is the beam-splitter, *A* and *C* are the mirrors at the ends of the two arms, and *D* is the photodetector. If *BA* is exactly equal to *BC*, the superimposed beams are in phase with each other and the intensity recorded at the photodetector is a maximum. But should the optical paths of *BA* and *BC* differ by half a wavelength of the light, the superimposed beams are 90^o out of phase and the intensity recorded is a minimum. Maximum intensity is also recorded if the optical path difference is an even number of wavelengths, and minimum intensity if the optical path is an odd number of wavelengths. An intermediate intensity indicates that the phase difference is a fraction of a wavelength, and as there can be 20,000 or more wavelengths per cm, an interferometer can in principle detect minute changes in the relative lengths of the two arms by measuring changes in intensity at the photodetector.

If a gravitational wave travels perpendicular to the plane of the interferometer, one of its arms will be stretched and the other one compressed, and the quadrupole cycle of alternate lengthening and shortening will produce a time-dependent cycle of intensity at the photodetector. Although small, this should be observable, and thus provide a measure of the strength of the gravitational wave. A single such detector can only ascertain the direction from which a gravitational wave originates. It cannot pinpoint the actual origin of the wave. This requires a second interferometer situated elsewhere; detectors are being built in Europe, USA and Japan to help pinpoint the origin of gravitational waves.



The technical developments needed in interferometer detectors are not readily available. Long arms are essential; a combined British-German interferometer with 600 m arms has been under construction near Hanover for several years and physicists at Glasgow University have contributed to this project. The USA has a pair of interferometers - one at Hertford, Washington, and the other in Livingston County, Louisiana.

These go under the name of the Laser Interferometer Gravitational Wave Observatory (LIGO). A French-Italian detector (VIRGO) near Pisa has arms 2 km in length. It is said that any of these instruments should be capable of detecting amplitudes of 10^{-20} across bandwidths of several Hertz, when fully developed.

For the future, the European Space Agency has a plan for a Laser Interferometer Space Antenna (LISA), consisting of three spacecraft communicating by lasers over distances of several million km. Each interferometer would have three arms to provide two independent gravitational signals. Just when this will come to fruition is anybody's guess, but it could be by 2040.

Historical Note

The interferometer was originally invented by Prof Albert Michelson who had the distinction of being the first American physicist to receive a Nobel Prize. This was in 1907 with a citation "for Spectroscope and Metrological Investigations". The first use of such an instrument was in collaboration with Prof Edward Morley in 1887, when one of the most famous experiments in Physics, known as the Michelson-Morley experiment, was performed at the Case School of Applied Science in Cleveland.

To appreciate fully the consequences of this experiment, some familiarity with the background is necessary. In 1676 the Danish astronomer Romer made the first measurement of the velocity of light. By observing the eclipses of Jupiter's moons he showed that variations in their times of occurrence could be explained by light having a finite velocity of propagation. Many other experimenters then used a variety of different methods of measurement, and between 1676 and 1880 ten results were reported for the velocity of light, averaging 299,860 km/sec.

But how is light propagated? At the time it was thought that space could not be empty but must be filled with a medium, the aether (or ether), within which light could travel without difficulty. However, if the aether is at rest and the Earth is moving through it, and a flash of light travelling with velocity v is discharged from the Earth in the direction in which the Earth is moving with velocity u, to an Earth-bound observer the velocity of the light would appear to be $(v-u)$. If the Earth is moving in the opposite direction to the light, to the observer the velocity of the light would then appear to be $(v+u)$. If the Earth is travelling at right angles to the direction of the light, to the observer it would still not appear to have the true velocity v, but the vector sum velocity $(v^2+u^2)^{1/2.}$

It was considerations of this kind which led Clerk Maxwell to write to Michelson in 1880, saying that the motion of the Earth through the aether might alter the velocity of light relative to different parts of optical apparatus, to produce effects which he thought were too small to measure experimentally. The effects Maxwell was concerned about depend on $(u/v)^2$. However, Michelson thought these could be detected with a suitably designed instrument, and he began work on his interferometer.

The final result of the Michelson Morley experiment was unexpected and fundamental. Comparison of the velocity of light in the direction of the Earth's motion and at right angles to it showed that they were identical. It was left to Einstein to resolve this dilemma with his special theory of relativity.

Harry Stout

Editor's Note

A recent discovery by physicists in Germany gets around what was thought to be a fundamental limitation of interferometry, which currently uses bright and dark fringes produced by two laser beams to measure distances as small as half the wavelength of the light. They have shown that a single laser beam sent down a narrow channel between two mirrors propagates as several modes, like the harmonics of a plucked guitar string, and that these modes interfere with one another. The result is that the fringes in the emerging beam are much finer that any ever seen before. Using this technique they have measured distances down to one ninth of the wavelength of the laser light used. Theoretically, however, it may now be possible to measure distances to a precision equivalent to the radius of a hydrogen atom.

DA

GRAVITATIONAL LENSING

The study of gravitational lensing is a relatively new branch of astronomy. Ten years ago only a few examples of such lenses were known. Since then, new manifestations of gravitational lensing continue to be discovered and their possibilities for astronomy indicate that gravitational lensing is rapidly become a major astronomical tool.

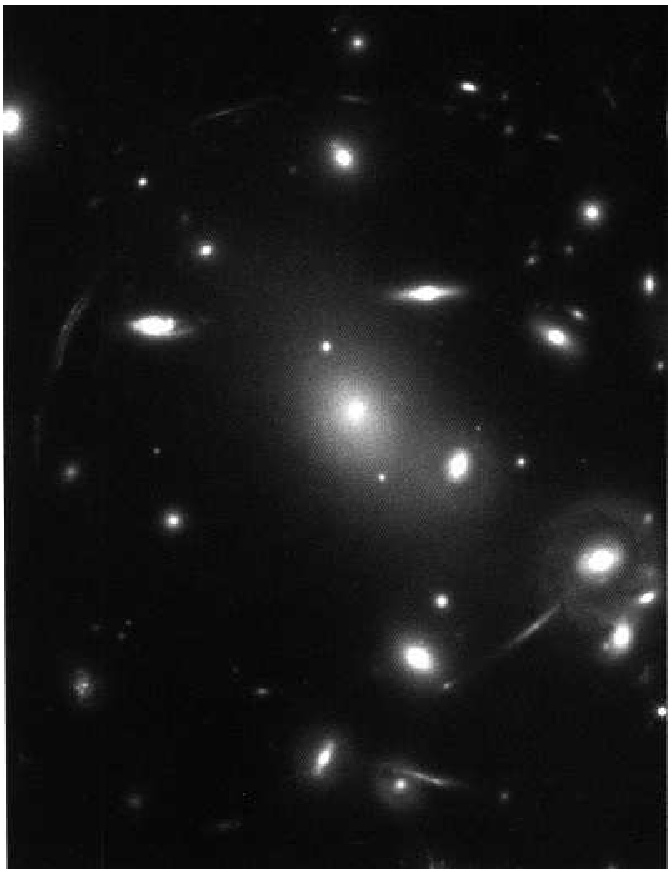
The first person to predict what is now called gravitational lensing was Johann Georg von Soldner in 1801, when he argued that the attractive force of the Sun should bend light rays from distant stars. According to Newtonian physics, the position of a star seen near the edge of the Sun shifts by 0.84 arcseconds relative to its position measured half a year later, when the Sun is elsewhere in the sky. When Einstein developed his theory of general relativity, however, he predicted that the shift should actually be twice this value: half the shift resulting from the Newtonian attraction of the Sun, and half from the curvature of space caused by the Sun. During a solar eclipse in 1919 Eddington and Dyson measured the effect and confirmed Einstein's prediction. Later, Einstein also predicted that a foreground star could magnify the image of a background star, and astrophysicist Fritz Zwicky predicted the lensing effects of galaxies and galaxy clusters. But it was not until 1979 that the first real evidence of gravitational lensing was seen when astronomers at Jodrell Bank detected the double quasar Q0957+561, which in reality was only a single one.

A gravitational lens system needs a light source, such as a star, galaxy or quasar, and an intervening mass between the source and the observer, anything from a black hole down to a planet. Light always follows the shortest path between two points, but Einstein showed that this may be curved, just as the shortest distance between two points on the Earth's surface is part of a great circle. As a ray of light approaches the curved space near a massive body it is deflected; the angle of deflection is directly proportional to the mass and inversely proportional to the closest distance of the ray from the body.

In many ways gravitational lenses act like ordinary glass lenses. A major difference, however, is that a glass lens has a well-defined focal point, whereas a gravitational lens produces a focal line or surface. The convex shape of a glass lens ensures that the deflection angle is directly proportional to the distance from the optical axis, i.e. from the line connecting the lens and the observer, so that all incoming parallel rays meet at the same point behind the lens - at its focal point. A typical gravitational lens, however, causes light rays to undergo *smaller* deflections the farther they are from the optical axis, and not *larger* ones as for a glass lens. Parallel rays deflected by gravity thus meet at different locations behind the lens, depending on how far from the optical axis they are at the lens. Another difference between gravitational and glass lenses is that the former, unlike the latter, are *achromatic*. For glass lenses the degree of deflection depends on the wavelength of the light. This is not the case with gravitational lensing - all wavelengths are affected equally, even down to X-rays, which cannot be focused by glass optics. If the source, gravitational lens and observer are exactly aligned and the lens is a point or a sphere, the rays converge along the optical axis beyond the lens and the resulting image is a ring. If the alignment is not exact or if the lens has an irregular shape, the ring is broken into discrete images of various shapes, as the lens magnifies different parts of the source by different amounts.

Evidence of gravitational lensing is now widespread. Sixty four double, triple and multiple quasars separated by only a few arcseconds are known. To be the result of gravitational lensing, the images must obviously all lie at the same distance as measured by their redshift; their spectra must also match, as must also any fluctuations in brightness, and there must be a lensing galaxy between us and the quasar. If the lensing galaxy is spherically symmetrical, the quasar image appears as a ring of light, the diameter of which is proportional to the square root of the lensing mass. This provides a way of determining the mass of the lensing galaxy. They are called Einstein rings, and about a dozen of them are now known. If just a star passes in front of a quasar, the lensed images are too close to be resolved but the observed effect is that the quasar brightens and dims in a particular way. This so-called microlensing has been seen in five multiple-quasar images. The way a quasar brightens and dims depends on its size, and can be used to measure its size. If the lens is a whole cluster of galaxies the image can be a pattern of strongly distorted arcs and arclets. Almost a hundred such galaxy cluster lenses have been discovered, including Abell 2218, the effect of which as illustrated on the next page. These images can be used to identify the mass distribution within the lensing cluster.

The microlensing of stars provides a way of detecting dark bodies that cannot be otherwise detected because they do not emit radiation, such as black holes, dead stars or planets. If one of these passes in front of a visible star, this star will appear to brighten temporarily in a way which can be distinguished from other causes of star brightening. The duration of the brightening is proportional to the square root of the lensing dark mass. Although the chances of observing the lensing of any particular star are very small, monitoring of millions of stars at a time produces results. This has been done for stars in the Large Magellanic Cloud where over twenty microlensing events were detected over seven years. The dark objects causing these events were estimated at around half the mass of the Sun. The monitoring of stars toward the centre of the Milky Way has detected over 500 microlensing events. Most appeared to be caused by normal dead stars with low mass; a few by double dead stars, and one or two by stellar-mass black holes. Stellar microlensing can even detect a planet orbiting a dead star, by a short brightening blip on the longer brightening caused by the star itself. Two of these events have been recorded.



Galaxy Cluster Abell 2218 distorts images of more distant galaxies

Other applications of gravitational lensing include estimating the Hubble constant by observing the lensed double images of a quasar and measuring the delay between a change in brightness of one image compared with the other. from a knowledge of the mass and shape of the lensing galaxy the delay can be estimated as a fraction of the total light travel time from the quasar, and hence its distance. The technique was first applied to the first double quasar to be detected, Q0957+561, Flickers in brightness appeared 417 days apart, which implies that it is about 14 billion light-years away. Together with the measured red-shift of the quasar, this enables the Hubble constant to be calculated.

Derek Allen

AN EVEN BIGGER ROCK

So Ceres, the first asteroid ever to be discovered two hundred years ago, is not the largest one after all. Astronomers at the European Southern Observatory have estimated that an asteroid which rejoices in the name of 2001 KX76 is 1200 km across, compared with the 950 km Ceres. It it much further away, however, in an orbit just beyond that of Pluto, and it is larger than Pluto's moon Charon.

A new "virtual" telescope called Astrovirtel, which is actually computer software, was used to scan old photographs for images of the asteroid. This information was used in conjunction with recent images from a conventional telescope to calculate its orbit around the Sun. Combining this data with the amount of sunlight reflected from the asteroid's surface yielded the estimate of its size.
DA

TAKING A LIFT UP TO SPACE?

Feasibility studies have started on a space elevator which would give a smooth vertical ride along a 100,000 km long cable. Payloads going up the Earth-to-space cable would avoid the stresses of a rocket launch as they climb slowly from the atmosphere into vacuum. *See the next issue of* ***Mercury****!!*

VOLCANOES ON OTHER PLANETS

Volcanism on the Moon

The Earth's Moon has no large volcanoes, but vast plains of basaltic lavas cover much of the lunar surface. As the earliest astronomers thought that these plains were seas of lunar water, they were called *mare* ('sea' in Latin). Other volcanic features such as sinuous rilles, dark mantling deposits and small volcanic domes and cones occur within the lunar mare, most of which are fairly small and form only a tiny fraction of the lunar volcanic record.

Volcanism on the Moon differs in several respects from that on Earth. Volcanism on the Earth is an ongoing process and many of Earth's volcanoes are geologically young, often less than a few hundred thousand years old. Most volcanism on the Moon, however, appears to have occurred between 3,000 and 4,000 million years ago. Typical mare samples are about 3,500 million years old. Even the youngest mare flows have estimated ages of nearly 1,000 million years but these rocks have not been sampled or directly dated, so this figure is unsubstantiated. For comparison, the oldest dated rock on the Earth is about 3,900 million years old, and the oldest sea floor basalts are about 200 million years old.

Additionally, Earth's volcanoes occur mainly as long linear mountain chains. The Andes, for example, mark the edge of a lithospheric plate, whereas mountain chains like the Hawaiian Islands mark past plate movements over a mantle hotspot. In contrast, lunar mountain chains form the edges of very large, very old impact craters, most of which are nearly circular and which tend to surround the lunar mare. There is no evidence that any system of plate tectonics ever developed on the Moon. The lunar mare are primarily found covering nearly one third of the lunar nearside but less than 2% of the lunar farside. The surface on the lunar farside is much higher, and the crust is typically much thicker, there also. The primary factors controlling volcanism on the Moon appear therefore to be surface elevation and crustal thickness.

There are also some major physical differences between volcanism on the Earth and on the Moon. Firstly, lunar gravity is about one sixth of Earth's, meaning that the forces driving lunar lava flow are weaker. The very flat and smooth mare surfaces imply that mare lavas were very fluid, flowing easily and spreading out over large areas. The low gravity also means that explosive eruptions can throw debris further on the Moon than on Earth, spreading lavas out into a broad flat layer and not into the cone-shaped features seen on Earth. This provides one reason why large volcanoes are not seen on the Moon. Secondly, the Moon has essentially no dissolved water (that we know of) and lunar mare are bone dry, whereas water vapour is one of the most common gases in Earth lavas, with water playing a major role in driving violent eruptions. Lack of lunar water should strongly affect lunar volcanism, with violent explosive eruptions much less likely.

Volcanism on Mars

Mars has the largest shield volcanoes in the solar system, as well as a wide range of other volcanic characteristics. These include large volcanic cones, unusual patera structures, mare-like volcanic plains, and a number of other smaller features. However, there are less than 20 named volcanoes on Mars, only 5 of which are giant shields, and volcanism occurs mostly within three regions where the mare-like plains cluster. The main assemblage of volcanoes and lavas is in Tharsis, with a much smaller cluster of three volcanoes in Elysium and a few paterae near the Hellas impact basin. However, volcanoes in the northern Tharsis region are so enormous that they deform the planet's sphericity. The gigantic equatorial rift valley, the Valles Marineris, is a canyon system that stretches a distance equivalent to that from New York to Los Angeles; the Grand Canyon in Arizona could easily fit into one of its side canyons.

Like the Moon, volcanism on Mars is very old. The mare-like plains are the same age as the lunar mare, approximately 3,000 to 3,500 million years old. Volcanism on Mars, however, lasted much longer than on the Moon and it appears to have changed over time. Volcanism in the Martian highland paterae and mare-like plains ended 3,000 million years ago, but some of the smaller shields and cones were erupting 2,000 million years ago. The giant shield volcanoes are even younger, having formed between 1,000 and 2,000 million years ago. The youngest lava flows on Olympus Mons are only 20 to 200 million years old, but are very small, and probably represent the last gasp of Martian volcanism. The odds of finding an active volcano on Mars today are thus very low. (Olympus Mons is the largest known *extinct* volcano in the solar system. It rises about 27 km above the Martian surface, is 600 km from edge to edge at the base and the central crater is 64 km wide from rim to rim.)

Mars, like the Moon, shows no sign of plate tectonics and has no long mountain chains, with no clear global pattern to its volcanism. Over half of Mars is as heavily cratered as the lunar farside, but unlike the Moon, most Martian volcanism lies outside large impact basins, with the mare-like plains chiefly near the largest volcanoes. These plains are not restricted to the lowest elevations, however, and some are much higher than the cratered uplands. Although some Martian lava plains lie at lower elevations, thick layers of dust and sediment cover both the Northern Lowlands and the large basin floors and echo a long history of wind erosion, glaciation and flooding, veiling any volcanism that may have occurred. The concentration and duration of volcanism into the two regions are attributed to the evolution of a long-lived mantle hotspot.

Volcanism on Venus

Venus has more volcanoes than any other planet in the solar system. Over 1600 major volcanoes or volcanic features are known, and numerous smaller volcanoes occur (there may be over a million). Venusian volcanoes come in a variety of forms, many complex and unusual, and with some large flow features, but most are either large or smaller shields. No volcano is known to be active at present, but data is inconclusive on this score.

Venus is superficially Earth-like in many ways, being of similar size and with a comparable bulk composition. It orbits the sun close to Earth and has both clouds and a thick atmosphere, and even has a reasonably young surface age (about 500 million years). However, Venus differs greatly from the Earth in close-up in three major ways.

Since the atmosphere is mostly carbon dioxide (CO_2), Venus has an extreme Greenhouse Effect, with a surface temperature of about 470 degrees C and a surface air pressure of about 90 times that at sea level on Earth, or roughly equivalent to the water pressure on Earth one kilometre beneath the ocean’s surface. These surface conditions have two effects. Firstly, there is no water on the Venusian surface (there is almost no water in the air) and the clouds are mostly of sulphuric acid, existing at much greater altitudes than most clouds on Earth. Secondly, as a result of high atmospheric pressure, winds on Venus are relatively slow. This means that neither wind nor rain can really affect the planet’s surface and volcanic features will look freshly formed for a long time.

Venus shows no evidence of plate tectonics, with no long, linear volcano chains and no clear subduction zones. Rifts are common, but none look like the mid-ocean ridges on Earth. Continent-like regions are rare, and show none of the ‘jigsaw’ fitting patterns found on Earth. Volcanism on Earth tends to marks plate boundaries and plate movements, but on Venus it is a great deal more regional and much less organised.

Volcanism on Venus shows fewer eruptive styles than on the Earth, with most apparently involving fluid lava flows. There is no sign of explosive, ash-forming eruptions, and little evidence for the eruption of sludgy, viscous lavas. There may be several reasons for this. High air pressure means that Venusian lavas must contain much higher gas concentrations than Terran lavas to erupt explosively. Additionally, the main gas driving lava explosions on Earth is water vapour, a commodity in very short supply on Venus. Also, many viscous lavas and explosive eruptions on Earth occur near plate subduction zones and the lack of these on Venus may reduce the probability of such eruptions.

Volcanism on Io

Generally, bodies must be larger than Mars to have enough heat to drive volcanism but exceptions include moons that are subject to tidal forces as a result of the gravity of their parent planets. On Io, the Galilean moon closest to Jupiter, there are as many as eight or nine volcanoes erupting at any given time. Volcanism on Io results from the flexing of the solid material of the moon itself. Io is very close to Jupiter and moves in a slightly elliptical orbit, so Jupiter's powerful gravitational field pulls with varying strength. When Io is closest to Jupiter, it is stretched equatorially. When it is farther away, the stress relaxes. This constant flexing produces heat, sufficient to melt rock.

Io is the innermost large Jovian moon and is about the same size and density as Earth's Moon. It is the most volcanically active body known in the Solar System. Eruptions are so common and so large that the entire surface can be buried under 100 meters of material every 1 million years (it takes submarine volcanoes about 80 million years to resurface about two-thirds of the Earth). The frequent volcanic eruptions on Io bury the impact craters that are common on so many other planets and satellites in our solar system. Volcanic plumes rise 300 kilometres above the surface, with material spewing out at nearly half the required escape velocity. Some areas on Io are red and are closely associated with very recent explosive eruptions and volcanic plumes. The most prominent red oval surrounds the volcano Pele.

Volcanism on Europa

Europa also moves in a slightly elliptical orbit and calculations show that it may be sufficiently stressed to generate the heat necessary to melt rock and fuel volcanoes. The gravitational fields of the outer Galilean moons, Ganymede and Callisto, also contribute to the flexing. We know that the surface of Europa is covered with water ice, with a surface temperature in the neighbourhood of -142 degrees C. The late Eugene Shoemaker indicated that the Europan surface is very young, an assertion based on the rarity of craters. He catalogued all the known comets that have been captured by Jupiter's gravitational field. Some of those eventually crash into Jupiter while others hit its satellites, and Shoemaker calculated the current cratering rate on Europa. The surface should be liberally sprinkled with craters, but is not. Therefore the surface must be renewing itself. Some parts of its surface show so few craters that Shoemaker estimated they are less than ten million years old. The surface is laced with cracks and fissures, some of which look as though they have been pushed apart after forming, as if water, or slush, were pushing up from below. This activity would account for the obliteration of old craters, with enough heat moving up to melt ice from below. An ocean of liquid water may hide beneath the ice, under which submarine volcanoes may be spewing out the minerals, including sulphides, from which life could arise. Bacteria that can live on sulphur and do not need to photosynthesise exist around hydrothermal vents, and these would seem to be promising as a source of life on Earth. The idea that the same thing could have happened on Europa was first proposed back in 1983.

Sandie Cayless

A TWISTING STAR

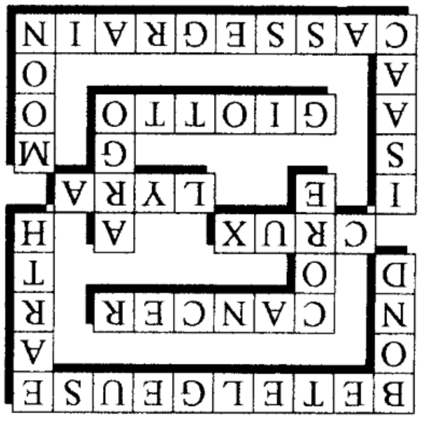
We are all familiar with sunspots. Ever since Galileo, astronomers have observed these dark blemishes moving across the surface of the Sun, and which are caused by magnetic fields within the Sun creating areas of relative coolness on its surface. Tracking the movement of sunspots provides information on the rotation of the Sun, including the fact that the Sun, which of course is not solid, spins faster at its equator that at its poles.

Recently astronomers from St Andrews and Toulouse, using the 3.9 m Anglo-Australian telescope in New South Wales, have made some startling discoveries about the rotation of another star, AB Doradus in the southern constellation of the Swordfish, fifty light years away. Unlike the Sun, which takes about a month to complete one rotation on its axis, AB Doradus takes only 12.3 hours to do this, so it is spinning more than fifty times faster than the Sun! On top of this, it has been observed over a period of several years that its "starspots" exhibit very complex patterns during its rapid rotations. Like the Sun, its equator spins faster than its poles, but the difference is not constant. The star goes through a cycle during which the spin rates of its equator and poles change. First the equatorial spin slows down as the polar spins speed up and then the equatorial spin speeds up as the polar spins slow down, and the cycle repeats. AB Doradus is doing a stately twist!

These interesting observations are being further investigated to learn more about the way the magnetic field generated by a star affects its shape and the circulation of gas within it. They may also throw more light on how the magnetic field of a star can affect nearby objects, and help to explain the erratic behaviour of some close binary stars, as well as providing new insights into the workings of our Sun.

Derek Allen

Solution to Astropuzzle No. 3



THE BIGGEST TELESCOPES IN THE WORLD

NO.	DIA(m)	NAME	DATE	LOCATION
1	10.4	Gran Telescopio Canarias (GTC)	2003	La Palma, Canaries
2	9.8x2	Keck 1 & 2	1993, 1996	Mauna Kea, Hawaii
3	9.2	Hobby-Eberly (HET)	1997	Mt.Fowikes, Texas
4	9.2	South African LargeTelescope (SALT)	2003	Sutherland, South Africa
5	8.4x2	Large Binocular telescope (LBT)	2003	Mt Graham, Arizona
6	8.2x4	Very Large Telescope (VLT)	1998-2001	Cerro Paranal, Chile
7	8.2	Subaru	1999	Mauna Kea, Hawaii
8	8.1	Gemini North	1999	Mauna Kea, Hawaii
9	8.1	Gemini South	2001	Cerro Pachon ,Chile
10	6.5	MMT (ex-Multi-Mirror Telescope)	2000	Mt Hopkins ,Arizona
11	6.5x2	Magellan I & 2	2000, 2001	Cerro Manqui, Chile
12	6	Bolshoi Teleskop Anyi (BTA)	1975	Zelentchouk, Russia
13	6	Large Zenith Telescope (LZT)	2001	Maple Ridge, Canada
14	5	George Ellery Hale Telescope	1948	Mt Palomar, California
15	4.2	William Herschel Telescope (WHT)	1987	La Palma, Canaries
16	4.2	Southern Observatory for Astroph.Res. (SOAR)	2002	Cerro Pachon, Chile
17	4	Victor Blanco Telescope (CTIO)	1976	Cerro Tololo, Chile
18	3.9	Anglo-Australian Telescope	1974	Siding Spring, Australia
19	3.8	Nicholas Mayall Reflector	1973	Kitt Peak, Arizona
20	3.8	UK Infra-Red Telescope (UKIRT)	1978	Mauna Kea, Hawaii
21	3.7	Advanced Electro-Optical System Telescope	2000	Maui, Hawaii
22	3.6	ESO '360'	1977	La Silla, Chile
23	3.6	Canada-France-Hawaii Telescope (CFHT)	1979	Mauna Kea, Hawaii
24	3.6	Telescopio Nazionale Galileo	1998	La Palma, Canaries

ABBREVIATIONS:

Type:	C	Cassegrain	*Mounting:*	Alt	Altazimuth
	G	Gregorian		A	Azimuthal
	P	Paraboloid		E	Equatorial
	S	Spherical		Z	Zenithal
	R-C	Ritchey-Chretien			

Ken Mackay

A PLANET BY ANY OTHER NAME . . . . .

In 1781, when William Herchel became the first person since the ancients to discover a new planet, he wanted to break with their tradition of giving planets mythological names, and proposed to call it Georgium Sidus, or George's Star, after his patron King George III. Astronomers across Europe objected, not least because it isn't a star. The alternative names proposed included Astrea, Cybele, Hypercronius, Minerva, Oceanus and Neptune. It eventually ended up with three names. Here in Britain we deferred to Herchel and called it Georgium Sidus; the French, honouring Herchel, named it after him, and the Germans gave it the mythological name Uranus, which of course eventually stuck and by which we all now know it.

We still have this problem today, but even more so! Since 1995 astronomers have discovered more than sixty planets orbiting other stars, and new ones are being found at a rate of more than one a month. The-

NO.	ALT(m)	TYPE	MOUNTING	OPERATED BY
1	2400	R-C	Alt	Spain (Astrophysics Institute)
2	4150	R-C	Alt	University of California, Caltech & NASA
3	2000	S	A	5 US & German Universities
4	1800	S	A	South African Astronomical Observatory
5	3170	C	Alt	Italian, US & German consortium
6	2640	R-C	Alt	European Southern Observatory (ESO)
7	4140	R-C	Alt	National Astronomical Observatory of Japan
8	4210	R-C	Alt	} US, UK, Canada, Chile, Brazil,
9	2720	R-C	Alt	} Australia, Argentina.
10	2600	C	Alt	Smithsonian Institute, University of Arizona
11	2280	G & C	Alt	Carnegie Institute & 4 US Universities.
12	2070	C	Alt	Russian Academy of Sciences
13	390	P	Z	IAP & 2 Canadian Universities
14	1700	C	E	Caltech
15	2340	C	Alt	Isaac Newton Group
16	2700	R-C	Alt	Southern Observatory for Astrophysical Research.
17	2210	R-C	E	Cerro Tololo Int-Am Observatory (CTIO)
18	1130	R-C	E	Anglo-Australian Observatory
19	2120	R-C	E	Kitt Peak National Observatory
20	4200	C	E	Joint Astronomy Centre
21	3060	C	Alt	US Air Force
22	2390	R-C	E	ESO
23	4200	C	E	Canada, France and Hawaii
24	2360	R-C	Alt	Italy

first extrasolar planet to be discovered, orbiting the star 51 Pegasi, was labelled 51 Pegasi b. This is an extension of the system of naming binary and multiple stars in which the letter 'a' is assigned to the star itself. It also, like Herchel, gives planets names as if they were stars! Multiple planets of a star such as Upsilon Andromedae are called b, c, d, etc. in order of their distance from the star. But what if later another planet is discovered in between two of these? They can't be renamed, as previously published information on them would become ambiguous.

Other naming schemes are now being proposed. One is to use roman numerals in order of their discovery, as has been done with Jupiter's moons. Another is to label the planets numerically (to distinguish them from binary or multiple stars) by their distances from the parent star, or by the times taken to orbit it. A problem with this is that this information is initially not always known accurately enough, so the names might have to change later. So why not just give the planets proper names? The Swiss astronomers who discovered 51 Pegasi b have suggested calling it Epicurus, after the Greek philosopher who first suggested that there might be a 'plurality of worlds'. But another astronomer, whose team have discovered more planets than any one else, has countered with the mythological name Bellerophon, after the Greek hero who tamed Pegasus the flying horse. At least this approach now seems to be ruled out, as new space missions are expected to find thousands, if not millions of extrasolar planets, and we would simply run out of suitable names.

Last year an International Astronomical Union meeting in Manchester failed to agree on a naming system for extrasolar planets and will try again at its next meeting in Sydney in 2003. Meanwhile, most astronomers in this field are too busy and excited actually making new discoveries to spare much time for the much more mundane task of sitting in committees to decide what to call their discoveries.

Derek Allen

A SIDEWAYS LOOK AT GRAVITY AND INERTIA

In the last Mercury (1) it was postulated that subatomic matter consists entirely of fields in the space time continuum, and that the property of "solidity" results from repulsive forces between these subatomic fields. This makes fields the fundamental constituents of matter rather than particles. Electromagnetic and gravitational fields then become natural extensions of subatomic fields, and the problem of trying to get particles to explain electromagnetic and gravitational fields just goes away.

There might be another clarification a field theory could make. Conventional physics baldly states that the gravitational field of a body is proportional to its inertial mass. The field theory could explain why this is so.

The gravitational field of a subatomic entity is vanishingly small, and virtually undetectable in subatomic physics experiments, so it is therefore to all intents and purposes ignored. What if despite its weakness the subatomic gravitational field is quite difficult to relocate in the space time continuum?

Imagine an undisturbed proton. Assume it has a gravitational field component which is spherically symmetrical and tapers off from the proton's centre. Now imagine the proton gets a nudge from say a positive electric field. Assume the dislocation of the gravitational field centre propagates out at the speed of light so that the spherical gravitational field re-establishes its symmetry. Just before it does this the field will be distorted. If even a weak gravitational field has a strong resistance to distortion this might be what causes the phenomenon of "inertia" in matter.

So a field theory of matter would turn round the conventionally stated relation between inertial mass and gravity, to say the inertial mass of matter is proportional to matter's gravitational field component.

There is also a tantalising hint that relativistic effects might be explained by the increasing significance of the field restoration lag when matter is moving at speeds close to that of the restoration front i.e. the speed of light.

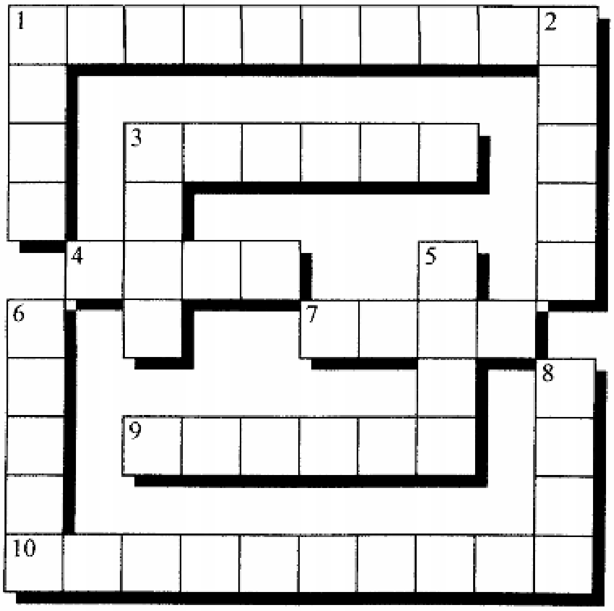
Chris Davis

(1) Mercury Vol 17 No1 Jan 2002 p8 under "Forces to be reckoned with."

Comments or discussion on this will be very welcome!

Astropuzzle No. 3

Terry Aitchison



(SOLUTION on page 7)

ACROSS

1. "Beetle juice" (10)
3. Constellation shaped like a crab (6)
4. Constellation: the southern cross (4)
7. Constellation: the lyre (4)
9. European space probe which visited Halley's comet (6)
10. Reflecting telescope viewed through a gap in the primary mirror (10)

DOWN

1. American astronomer who discovered Saturn's moon Hyperion in 1848 (4)
2. Third planet from the sun (5)
3. Innermost layer of the Earth or planet (4)
5. The constellation in which Canopus is located (4)
6. British scientist . . . Newton (5)
8. Earth's nearest neighbour (4)

THE NIGHT SKY : April, May, June 2002

SUN	April				May				June			
	7	14	21	28	5	12	19	26	9	16	23	30
(approx) Rises	06.16	05.58	05.40	05.24	05.08	04.53	04.40	04.30	04.15	04.13	04.14	04.17
(approx) Sets	19.50	20.04	20.19	20.33	20.47	21.01	21.14	21.25	21.43	21.49	21.51	21.49

MOON	April				May				June			
	LQ	NM	FQ	FM	LQ	NM	FQ	FM	LQ	NM	FQ	FM
Date	4	12	20	27	4	12	19	26	3	10	18	24
Rises	03.39	06.23	10.31	20.11	03.35	05.16	11.04	21.41	02.31	03.58	13.17	21.55
Sets	10.06	18.21	03.41	04.58	11.12	21.07	02.49	04.38	12.38	21.26	01.47	03.35

PLANETS

			Magnitude
MERCURY	*April*	Visible briefly after sunset low WNW sky from 17 onwards	-1.5 to 0.0
	May	Visible 1st week only at end of evening twilight, low WNW	0.0 to +1.0
	June	Unsuitable for observation	
VENUS	*April*	Visible short time evenings, low western sky	-3.9
	May	Visible 2hrs after sunset, western sky	-3.9
	June	Bright object western sky but observation decreasing through month	-4.0
MARS	*April*	Visible briefly evenings low western sky, moving from Aries to Taurus	+1.6
	May	Visible evening low WNW sky but lost to view end of month	
	June	Unsuitable for observation.	
JUPITER	*April*	Evening object SW sky until midnight	-2.1
	May	Evening object SW sky for 2hrs after sunset	-1.9
	June	Only visible first half of month low western sky after sunset	-1.9
SATURN	*April*	Evening object western sky	+0.1
	May	Difficult to detect low western sky, lost to view after middle of month	
	June	Unsuitable for observation	

CONSTELLATIONS (near meridian at 22.00hrs)

1st April	Cepheus & Cassiopeia (below pole), Ursa Major, Leo Minor, Leo, Sextans, Hydra and Crater
1st May	Cepheus & Cassiopeia (below pole), Ursa Major, Ursa Minor, Canes Venatici, Coma Berenices, Bootes, Leo, Virgo, Crater, Corvus, Hydra
1st June	Cassiopeia (below pole), Ursa Minor, Draco, Ursa Major, Bootes, Corona, Borealis, Serpens Caput, Libra

COMETS

Comet Ikeya-Zhang

Whilst Ikeya-Zhang will not rival the last two great comets, Hale-Bopp and Hayakutake, it is nevertheless a naked eye object with a long active tail, visible for a couple of hours after sunset in the western sky moving between Andromeda and Cepheus. It is thought to have an orbital period of 341 years as it is believed that it is the same comet that was seen in 1661.

CONJUNCTIONS (with the Moon unless otherwise stated)

April

Date	*Time*	
7	10.00	Mercury in superior conjunction
13	11.00	Mercury 4°N
14	20.00	Venus 3°N
16	01.00	Mars 2°N
16	21.00	Saturn 0.8°S
18	24.00	Jupiter 2°S

May

Date	*Time*	
4	07.00	Saturn 2°S of Mars
7	13.00	Saturn 2°S of Venus
10	21.00	Mars 0.3°S of Venus
13	13.00	Neptune at stationary point
13	23.00	Mercury 2°N
14	09.00	Saturn 1°S
14	20.00	Mars 0.6°N
14	24.00	Venus 0.8°N
15	20.00	Mercury at stationary point
16	13.00	Jupiter 2°S

June

Date	*Time*	
3	01.00	Uranus at stationary point
3	24.00	Jupiter 2°S of Venus
8	16.00	Mercury at stationary point
9	12.00	Saturn in conjunction with Sun
9	14.00	Mercury 3°S
10	22.00	Saturn 1°S
12	13.00	Mars 0.9°S
13	05.00	Jupiter 2°S
13	23.00	Venus 1°S

Hamish MacPhee

Stirling Astronomical Society

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Copy can be in clear handwriting, typescript, e-mail, or on floppy disk, preferably in rich text (*.rtf)* format, in that ascending order of preference for the work involved in editing. Contributions should usually be not more than about 750 words in length, or 1000 at the most. Please have material ready by the end of May for the next issue of *Mercury* due out the beginning of July 2002.