The Economist

Shadowlands

A thousand years ago, a total eclipse of the sun was a terrifying religious experience. Next week it will be a splendid occasion for a package holiday. Whatever happened to the mystery?

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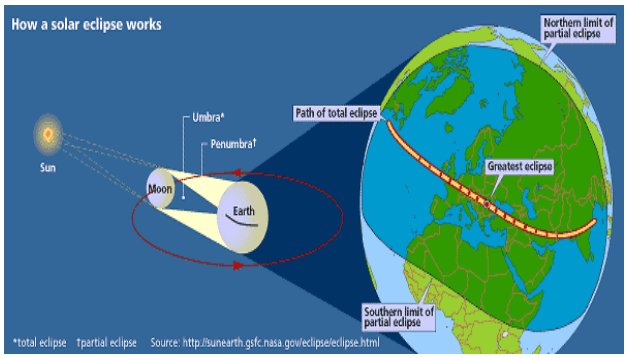


ANY extra-terrestrials are spying on the sunlit side of the earth at 09.31, Greenwich Mean Time on Wednesday August 11th, they will see something peculiar. A black spot will appear suddenly near the coast of Nova Scotia and migrate across the Atlantic. It will nick the south-western tip of Britain, pass through France and Central Europe, and then move across Turkey, Iraq, Iran, Pakistan and India before vanishing somewhere in the Bay of Bengal.

With a really powerful telescope, however, they will see some things that are even more peculiar. Two Concorde jets will screech over the Atlantic, trying to keep up with the spot. Human watchers will have concentrated themselves a hundredfold all along the spot's path throughout Europe. Huge festivals will be waiting for it when it first makes landfall at Land's End, in Cornwall. Hideous hotels in Bucharest will be teeming with visitors wearing silvery spectacles. Cruise ships will ply the Black Sea to position themselves beneath it.

For the few minutes the dark spot envelops them, these supposedly intelligent creatures may seem to go berserk. In a west-to-east wave of weirdness, they will dance, shriek, light fireworks, click camera shutters, clink champagne glasses, shoot bullets in the air. It all demands an explanation.

Black holes in the sky

The dark spot itself is easy to explain. It is the shadow of the moon streaking across the earth. This happens every year or two, each time along a different and seemingly random piece of the globe. Next week, the streak will cross unusually densely populated terrain and, as a consequence, may well be the most observed in history. But this eclipse of the sun is otherwise unremarkable, astronomically speaking.

The reaction is less easily explained. Humans have always overreacted to total solar eclipses—a tradition documented in the oldest historical records, such as an ancient Chinese text expressing concern when "the sun and moon did not meet harmoniously." This was probably a reference to an eclipse on October 22nd 2134 BC. The Chinese were so disturbed by such events that they included in their pantheon a god, named Hsi-Hso, whose job it was to prevent eclipses.

The source of all the hysteria is, ultimately, a freak coincidence. The sun is 400 times larger than the moon, and it is also nearly 400 times as far away from the earth. That means that it appears to be almost exactly the same size as the moon in the sky—which gives the moon the occasional chance to blot the sun out perfectly, rim to rim.

No other planet in the solar system enjoys the same coincidence between any of its moons and the sun, except Saturn and its tiny moon, Prometheus—and there would be nowhere to stand on Saturn's gaseous surface to enjoy an eclipse. This gives earthly eclipses three elements of extra pizzazz that an extra-terrestrial may not have expected. First, they are beautiful. A deep blue curtain falls abruptly over the daytime sky, allowing bright stars and planets to wink on. The sun becomes a black void surrounded by the gossamer glow of its outer atmosphere, the corona. Were the moon a bit larger, it would block the corona and turn the sky black, making eclipses like ordinary night-time rather than surreal twilight. Smaller, and the moon would not completely cover the sun, ruining the dramatic effect.

For the same reason, total eclipses possess a second, equally compelling beauty in the eyes of scientists. They offer a unique opportunity to study the corona and other dim things that are normally lost in the sun's glare. This has both solved and raised scientific mysteries.

Third, and most pertinent for explaining the human overreaction, they are rare. Even though they occur somewhere on earth every year or two, if you sit in your garden-chair and wait, it will take 375 years (on average) for one to come to you. A larger moon would make eclipses a monthly bore; a smaller one would make them impossible. As things are, each event is terribly exciting—or, in an earlier age, just terrible.

Consider, for example, what may have been the last time Turkey experienced such a fuss over a

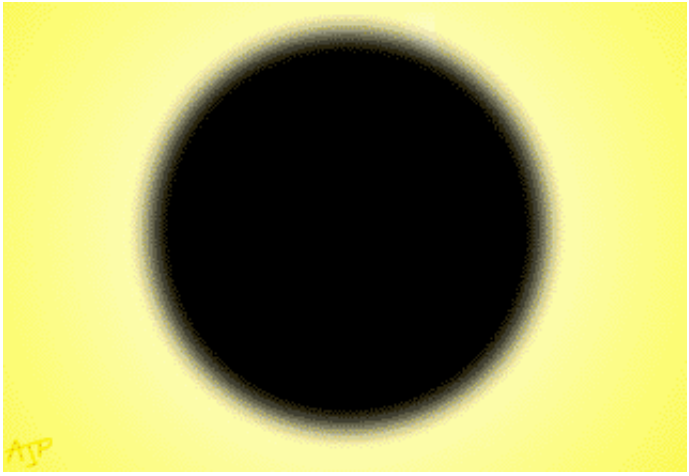
total solar eclipse. It was 2,583 years ago, in the afternoon of what is now called May 28th. The armies of Lydia and Medea were busy bloodying each other for the umpteenth time in the course of a six-year war. Suddenly the sun vanished from above the battlefield, leaving a black puncture-wound in the heavens. As Herodotus told it, this wretched omen caused both sides to drop their arms and seek peace.

Wednesday's eclipse over Turkey is, however, unlikely to persuade the Kurds and Turks to become friendly neighbours. Instead, ancient terror has evolved into irrational exuberance, complete with eclipse cruises, concerts, package tours and T-shirts.

Clockwork moon

The first step in this evolution came with predicting eclipses. An 18-year pattern in their recurrence had been noted by Babylonian priests, but accurate prediction required more mathematics than ancient empires could deliver. Edmond Halley, one of England's Astronomers Royal, who knew his maths well enough to predict the return of the comet that bears his name, was also the first to make a detailed eclipse prediction. He correctly drew the path that the moon's shadow would follow across England in 1715.

This brought eclipses firmly into the scientific domain. It also made possible the first practical application of eclipses—namely, scaring hell out of people who had not yet entered the Age of Reason. One of the pioneers of this technique was Tecumseh, a native American warrior of the Shawnee tribe. In 1795, he reasoned that only a confederation of tribes would be able to repel white Americans' incursions into the Ohio valley.



He and his brother Tenskwatawa (a preacher who called himself a prophet) began a campaign to organise such a confederation, but had all the usual difficulties in persuading disparate peoples to unite. By chance, Tecumseh learnt of an expected eclipse in Ohio from members of a scientific expedition. It was a perfect opportunity for Tenskwatawa to prove his credentials.

Tenskwatawa alerted the tribes that the Great Spirit would hide the sun on June 16th 1806. When this actually happened, and when Tenskwatawa talked the Spirit into releasing the sun a few minutes later, the assembled

tribesmen were impressed, and Tecumseh's confederation won many supporters as a result. (Two years later, alas, it was undone when Tenskwatawa promised his soldiers immortality and was proved very wrong.)

There are many similar tales. For example, the Mahdi, an Islamic revolutionary (and would-be prophet) whose forces besieged Khartoum in 1884, used prior knowledge of an eclipse to demoralise the city's defenders.

Meanwhile, scientists devised non-military uses for eclipses. Astronomers packed up their telescopes and travelled the world to stand beneath the moon's shadow and ponder the sun's corona. Crucially, some carried along prisms. It is possible to deduce the chemical composition of a heavenly body by dissecting its light through a prism. A pattern of dark or bright lines in an otherwise smooth spectrum of colours reveals the chemical elements that the body contains.

When Jules Janssen and Norman Lockyer tried this out on the sun's atmosphere during the eclipse of 1868, they were surprised to see a bright yellow line. It was so bright that they were inspired to search for it even when the sun was not eclipsed—and, when they succeeded, they found that it bespoke an element never seen before.

They named it helium, after Helios, the Greek god of the sun. This was a major find, since helium turned out to be the most common element in the universe after hydrogen. (Its potential for the toy-balloon industry could be realised only after 1895, when it was discovered on earth as well, as a by-product of the radioactive decay of certain rocks.)

An American named Charles Young thought he, too, had bagged a new element during the eclipse of 1869. He discovered a green line in the spectrum of the corona. It did not match any known element, so he attributed it to a new substance called coronium. This puzzling element remained on the books until 1939, when a Swedish physicist realised that coronium was actually iron, made unrecognisable by being extraordinarily hot—so hot that thirteen of its electrons have boiled off. This meant that the corona, to everyone's surprise, must have a temperature of more than 1mC—far hotter than the Sun's yellow surface, which glows at a cool 5,500C. Why the corona is so hot is an unsolved mystery.

A circle in a spiral

Solar eclipses have, however, solved at least as many mysteries as they have raised. The greatest triumph involved the misbehaviour of Mercury, the closest planet to the sun. According to Newton's law of gravity, planets should trace out perfect ellipses in their orbits. Well, almost

perfect ellipses. Because of the gravitational tugs each planet exerts on the others, none of the planets retraces exactly the same ellipse each time it goes around. Instead, the direction of the ellipse rotates a little with every orbit. Once this subtlety was taken into account, however, astronomers could proudly understand the meanderings of all the planets in the sky.

Except Mercury's. Mercury's ellipse rotates faster than it should. The excess is tiny (it would take 3m years to amount to an entire extra revolution). But it is definitely there. That bothered the greatest brains in astronomy for the second half of the 19th century.

Most of them believed that an undiscovered planet was perturbing Mercury's orbit. After all, Neptune had been found in 1846 by looking for the source of Uranus's similar misbehaviour. But the only way such a planet close to Mercury could have been overlooked was if it were lost in the sun's glare. The search for this planet, which was called Vulcan because of the hellish heat it would endure, could take place only during a total solar eclipse.

At the height of the hunt, during the eclipse of 1878, an American astronomer named James Watson, who had trekked all the way from Michigan to Wyoming with his telescope, thought he had spotted Vulcan lurking next to the blackened sun. The discovery was front-page news. But it was later retracted, when nobody else confirmed the sighting.

After many other failures, it was time for new ideas—the sort of ideas that could occur only to Albert Einstein. In 1911 he proposed that, rather than being wrong about the number of planets, astronomers were actually wrong about gravity. His theory of relativity disagreed with Newton's law in just the right way to explain Mercury's peculiar orbit. But it also introduced unpalatable ideas about space and time, such as the notion that time slows down for a body in motion. This made the theory controversial.

Einstein realised that a definitive test of relativity would be possible during (what else?) a total solar eclipse. Another of his theory's predictions was that light rays from stars should be bent by the sun's gravity. The deflection would be tiny, and noticeable only for starlight grazing the sun's surface. It would cause stars to appear in slightly different positions when the sun was near them —but only when the sun is blocked by the moon can these stars be seen at all.

To test this idea, a team of German astronomers mounted an expedition to watch an eclipse in the Crimea. But, the year being 1914, the Germans were detained by Russian police and missed it. Five years later a British team sent observers to less politically hostile climes: the islands of Principe, in the Gulf of Guinea, and Sobral, off the coast of Brazil. Their photographs vindicated Einstein's theory, elevating him to near-legendary status.

Scientific eclipse expeditions still take place, mainly to try to solve the mystery of the too-hot

corona. (It seems to have something to do with the heating effect of solar magnetism.) But scientific expeditions are now vastly outnumbered by tourist ones.

Been there, done that, got the T-shirt

This latest transition really got going in the early 1970s. In 1973 scientists proved they had mastered the eclipse chase. Using a prototype Concorde jet, a team of eclipse-boffins followed the moon's shadow at 2,100kph (1,300mph), from Mauritania to Chad. Those aboard enjoyed a 73-minute eclipse, much longer than the 7 1/2 minutes that is the maximum that can be experienced by the poor slobs stuck on the ground.

Meanwhile, helped by cheap international travel, tourists proved willing to pay good money to bask beneath the moon's shadow for even those few minutes. Eclipses moved from the Age of Reason into the Age of Disposable Income. Commercial cruises and aircraft flights to see an eclipse began in 1972, two years after a total eclipse over the eastern United States had whetted the appetite of the travelling public for more. Carly Simon planted the 1972 eclipse into pop culture with her song, “You're So Vain”:

You flew your Learjet up to Nova Scotia
To see the total eclipse of the sun.

Nowadays, vain vacationers can dish out £1,550 (about $2,500) for a seat on a Concorde flight that will chase the black dot across the Atlantic. Or they can travel with a tour group to the archaeological sites of Turkey, as a way of passing time and positioning themselves for Wednesday's main event. Or they can gather to hear Luciano Pavarotti serenade the return of the sun in Bucharest.

Why have eclipses grown so popular? “Because they are other-worldly,” says Evan Zucker, a software designer from California who has seen seven since 1970, in locations scattered from Mexico to Mongolia. Despite understanding eclipses completely as a scientific phenomenon, many eclipse chasers are overcome by emotion when the moment arrives. When the sun, fundamental to life, goes away, perhaps something primitive in the subconscious—the “lizard-brain”, suggests Mr Zucker—takes over.

Eclipse junkies, once hooked, gather in diverse parts of the world and compare scores—by which they mean cumulative minutes under the moon's shadow. They use eclipse bulletins published by NASA, America's space agency, as travel brochures. They trade stories of the mild discomforts they had to endure, the trains missed, the jungles crossed, the illnesses suffered, in order to

reach the right place at the right time. For them, eclipses have the power to imbue an ordinary foreign holiday with the feeling of a quest.

Wednesday's eclipse, when the black dot crosses over some very hospitable and easy-to-navigate parts of Europe, is almost too easy a catch. Nevertheless, catch it while you can. There will be no total solar eclipse, anywhere, in 2000. For a repeat performance, Europeans will have to wait until 2015 (Iceland will be receiving guests). North America must wait until 2017.

Even worse, one day eclipses may stop happening, as Guillermo Gonzalez, an astronomer at the University of Washington, in Seattle, has recently predicted. The moon is spiralling away from the earth by about four centimetres a year, and the sun is swelling by up to six centimetres a year as it ages. Together, these effects will eventually prevent the moon from covering the sun. Humanity has only 250m years left to cringe in terror, peer through telescopes—or buy the T-shirt.

From the print edition: Science and technology