

Don't blame it on the gods



Once phenomena that inspired fear and foreboding, lunar and solar eclipses can now be predicted down to the second, forecast centuries into the future, and "hindcast" centuries into the past. The person who started us down the path from superstition to understanding has been called the "Einstein of the 5th century BC", and was known to his contemporaries as "The Mind". He went on trial for his impious notions, was banished from his adopted home, but nevertheless influenced generations of later scholars. He was Anaxagoras, a native of Ionia in what is now Turkey, and the first great philosopher to live in Athens. Now this little-known scholar is being seen by some as the earliest known practitioner of the scientific method.

NICIAS was in a quandary. It was the summer of 413 BC, the 19th year of the Peloponnesian war, and the Athenian army he commanded was many stadia from home, camped in a marsh near the Sicilian city of Syracuse. His campaign of shock and awe – forced on him by demagogues in the Athenian government – had turned into a protracted siege. And now the siege was failing as reinforcements from all over the Hellenic world arrived to help the beleaguered city. With hope of victory rapidly vanishing, Nicias cut his losses and decided to sail for home.

On the night of 27 August, the historian Thucydides wrote, "All was at last ready, and they were on the point of sailing away when an eclipse of the moon, which was then at the full, took place... Nicias, who was somewhat over-addicted to divination and practices of this kind, refused even to take the question of departure into consideration, until they had waited the thrice nine days prescribed by the soothsayers."

The delay proved disastrous. Syracuse, under the command of the Spartan general Gylippus, seized the opportunity to block the harbour entrance, trapping the Athenian fleet. Nicias was forced to surrender. According to Thucydides, the defeat was "the most calamitous" in Greek history.

Had Nicias and his fellow citizens cast their minds a little wider, it needn't have turned out that way. The Athenians had been given a perfectly good explanation of eclipses 65 years earlier. Anaxagoras of Clazomenae – who lived in Athens – had tried to persuade them that an eclipse was a purely physical phenomenon and had nothing to do with the gods.

No document survives to tell us how Anaxagoras arrived at his revolutionary insight. But philosopher Daniel Graham of Brigham Young University in Utah argues that Anaxagoras witnessed a solar eclipse that was visible from Athens in 478 BC and put this together with a then-novel theory that the moon was opaque to conclude that the moon could cast a shadow on Earth.

People had seen and recorded eclipses for centuries before Anaxagoras, of course. What made his observations different, Graham says, was that he actively collected data to test his notions about what caused eclipses, adopting what today we would call the scientific method. Clues lie scattered in Anaxagoras's own writing and in computer simulations of the eclipse by

Graham's colleague, physicist Eric Hintz.

In 478 BC, Anaxagoras was 22 years old, and recently arrived in Athens. He had clearly read the work of Parmenides, a Greek philosopher who flourished in Italy around 490 BC. Parmenides wrote that the moon is illuminated by "borrowed light": in other words, the light of the sun. It follows that if the borrowed light goes out – if, for instance, Earth blocks the sunlight – the moon will be extinguished. This would account for lunar eclipses. Parmenides's idea also implied that the moon was opaque, because we do not see the sun shining through it at new moon. It took only a small leap of imagination to realise that the opaque moon could also cause the sun's light to fail – and so create a solar eclipse.

There is no evidence that Parmenides made these deductions, but apparently Anaxagoras did. Although his writings are now lost, they were available to scholars in the Hellenic world for several centuries. Most agree that Anaxagoras explained the cause of eclipses. But none says how.

Before 478 BC, the idea of a solid, opaque moon casting a shadow on Earth could only be considered a hypothesis. The essence of the

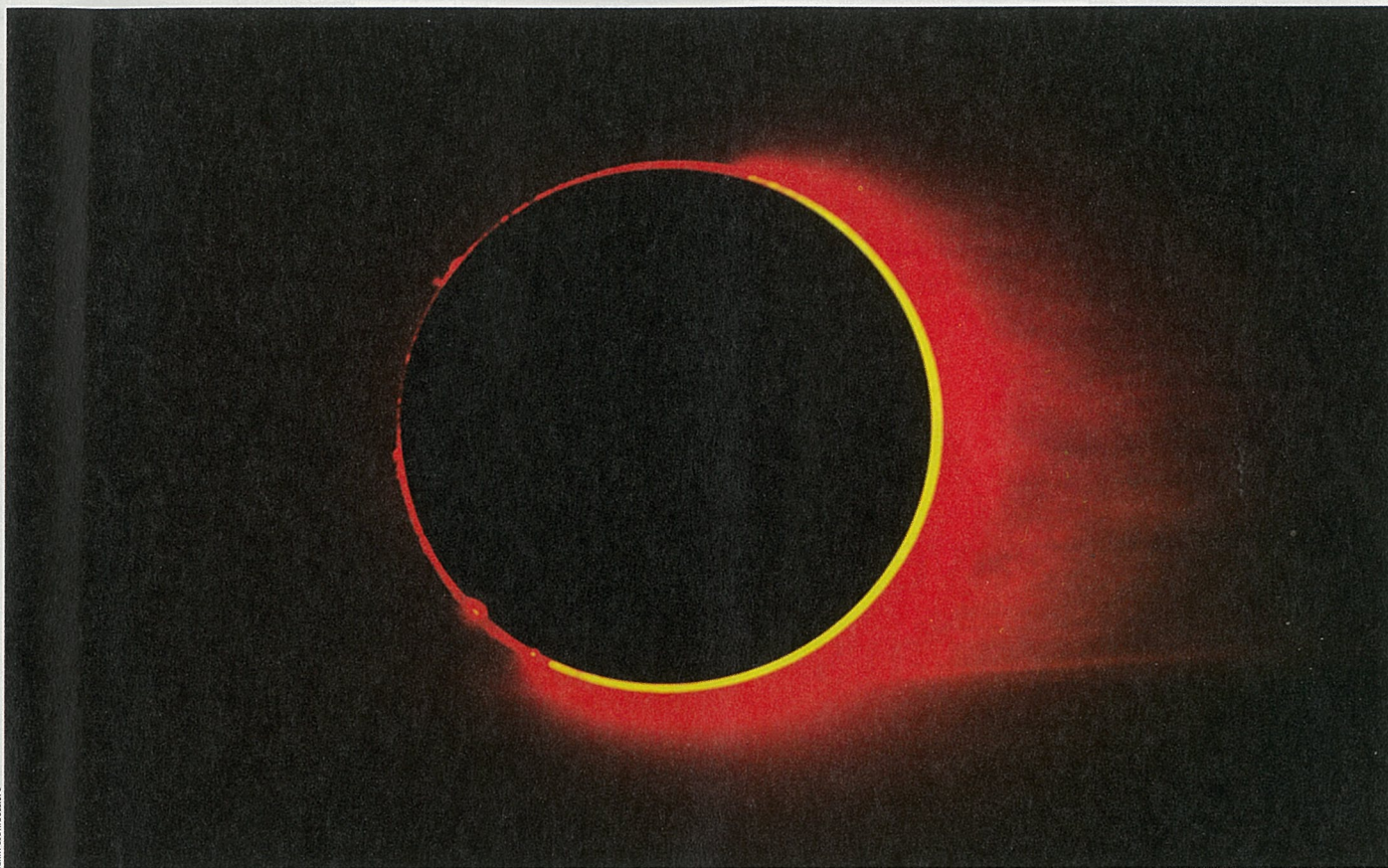
"All he had to do was ask some sailors what they saw last week"

modern scientific method is to test a hypothesis against observations. And to a degree unique among Greek philosophers, that was also Anaxagoras's method. The few quotes of his that have been preserved attest to this. "Phenomena are a view of that which is unseen," he said, in his cryptic fashion. In other words, to understand things you can't see, observe carefully the things you can. Forget gods and superstitions.

The eclipse of 478 BC gave Anaxagoras the chance to put his theory to the test. If the moon casts a shadow on Earth, then that shadow should have a finite size. The idea that some people would see the eclipse and some wouldn't was completely novel. "All the earlier Greek theories would have predicted that everyone would see the eclipse," Graham says.

The clue that Anaxagoras deliberately set out to find the size of the moon's shadow lies in another fragment of his teaching, which

For more on eclipses visit NASA's site at <http://eclipse.gsfc.nasa.gov/eclipse.html>



on the face of it has nothing to do with eclipses. Four ancient writers mention that Anaxagoras compared the moon and Sun to the Peloponnesian peninsula. The moon was "as large as the Peloponnese", Anaxagoras said, and the sun was "greater than the Peloponnese". But why the Peloponnese?

The comparison makes perfect sense when you plot the track of the annular eclipse of 478 BC, as Hintz and Graham did (*APEIRON*, vol 40, p 319). The antumbra, the darkest part of the moon's shadow during the eclipse, passed exactly over the Peloponnese. People in this region would have seen an entire black disc in front of the sun, blocking out 95 per cent of the sun's light – an unforgettable sight. People outside the antumbra would have seen only a dimming of the sun. "All Anaxagoras had to do was go down to the port of Piraeus and ask some sailors what they saw last week or last month," says Graham. Because the moon's shadow roughly covered the Peloponnese, it makes sense that Anaxagoras thought the moon was the same size as the peninsula.

In order to ask those questions, though, Anaxagoras first had to have the right hypothesis. "Only someone who already had

the idea of a limited area [of visibility] would go out and ask where the eclipse was visible," says Graham. "To me, that's real research."

The idea that Anaxagoras witnessed an actual eclipse has been proposed before. In 1973, David Sider of New York University argued that Anaxagoras must have seen the total eclipse of 463 BC. But that eclipse passed over north-west Greece, so Anaxagoras would have had no reason to compare its shadow with the Peloponnese. Sider is now convinced that Graham is right. The most important implication, he says, is not the date but the fact that "Anaxagoras treated the whole phenomenon the way a scientist would".

Nevertheless, the date adds some detail to our picture of Anaxagoras. It makes him a 22-year-old wunderkind when he proposed his theory, not a well-established 37-year-old sage. "He was kind of the Einstein of the 5th century BC," says Graham. Anaxagoras later became the personal teacher of Pericles, the leader who took Athens to the height of its power.

Unfortunately, Anaxagoras's free-thinking ideas eventually led to his downfall. At an unknown date, he was brought to trial on a charge of impiety, for teaching that the moon

During the annular eclipse of 478 BC, the moon's shadow roughly covered the Peloponnese

and sun were physical objects and not gods. According to one account, Anaxagoras was fined 5 talents and exiled from Athens. Another said he had already left Athens and was sentenced to death in absentia, for sympathy with Athens's enemy, the Persians. Two say that Pericles rescued him, bringing him to court so "tottering and emaciated with disease" that he was freed out of pity. Whatever the circumstances of his departure from Athens, Anaxagoras's name became synonymous in Athens with scandalous and forbidden thoughts. In his Ionian homeland, however, he was a national hero.

We know now that many of Anaxagoras's ideas were wrong: the moon is bigger than the Peloponnese, for instance. Nevertheless, his theory of eclipses has stood the test of time as a model of scientific reasoning. If only the Athenians had listened, Nicias and his army might have made it home. ●

Dana Mackenzie is the author of *The Big Splat, or How Our Moon Came to Be* (John Wiley, 2003)