Sizzling skies

Meteors and auroras shine high up in the atmosphere. So how come you can hear them whispering in your ear, asks Harriet Williams

NINETY MINUTES before sunrise on 7 April 1978, an extraterrestrial guest arrived over Eastern Australia. For about 20 seconds it streaked across the sky leaving a bright trail that turned night into day, before finally exploding into glowing fragments that vanished into the sea. This meteor was just one of thousands that enter our atmosphere every year, yet dozens of witnesses in Newcastle and Sydney reported something particularly strange about this visitor. Just before it blew apart, it produced an unearthly soundtrack of hisses, crackles and pops.

Reports of noisy meteors appear in the Bible, yet the cause of their bizarre sounds has always been a mystery. One person might hear the popping and whooshing clearly while another, standing just a few metres away, hears nothing. Explaining this oddity is especially tricky since there is almost no hard scientific data to go on: even if you spent two hours every night looking for them, you might have to wait fifty years to hear one.

Yet researchers believe they are finally closing in on the origins of these strange sounds. All they need now are some meteors on which to test their theories. But rather than waiting around for one to show up, they're hoping that artificial meteors--redundant satellites brought down from orbit to burn up in the atmosphere--will give them the vital data they need to settle it once and for all. At the same time, there's a good chance that they will solve another age-old mystery--the ghostly, rustling songs sometimes heard by observers of the northern and southern lights.

One of the pioneers of these studies is Colin Keay, a physicist at the University of Newcastle in Australia. The day after the New South Wales fireball fell to Earth, Keay was phoned by a colleague at the Australia Museum in Sydney who asked him if he would search for any fragments of the meteorite that might have landed on dry ground. During this hunt, he discovered something about the fireball that would change the course of his work forever.

The meteorite, Keay calculated, had streaked across the sky at almost 20 kilometres per second, 30 kilometres up, yet he met dozens of reliable witnesses who claimed to have heard it produce strange noises as it flew overhead--anything from "a low moaning" to "an express train travelling at high speed". If these sounds had come directly from the meteorite, people on the ground below shouldn't have heard them until almost a minute after it exploded. It would be like seeing a distant flash of lightning and hearing the thunderclap at the same instant.

What finally clinched it for Keay was meeting two witnesses who claimed the sounds first alerted them to the meteorite trail. "When two people reported hearing the sounds before seeing the light of the fireball, I knew it couldn't be psychological," says Keay. "There had to be something to it." Intrigued, he set to work to uncover the mechanism behind these noises. He spent months creating and discarding one physical model after another. Finally, he settled on one that he suspected was the only way to explain how an observer could hear a meteor's fiery entry at the same time as seeing it. It all comes down to electromagnetic radiation.

Keay suspected that the light given off by a meteor's trail must be accompanied by invisible electromagnetic radiation in the form of very low frequency (VLF) radio waves at frequencies from 10 hertz to 30 kilohertz. Travelling at exactly the same speed as visible light, these waves would reach the observer as soon as the meteorite itself came into view. The problem is that you can't hear radio waves. The only way you might hear them is with the help of a suitable "transducer"--an object that acts rather like a loudspeaker, converting electromagnetic signals into audible vibrations.

After some experiments in a soundproof chamber, Keay found that all kinds of things can act as transducers. Aluminium foil, thin wires, pine needles or dry, frizzy hair all respond to a VLF field. The radio waves induce small charges in such objects, and these charges force the object to vibrate in time with the oscillating waves, effectively making them act like the diaphragm in a loudspeaker. Even a pair of glasses, he discovered, will vibrate slightly. And since they rest against the bones of the skull, glasses could increase an observer's chances of hearing VLF waves.

Pine speakers

The transducer effect would explain why some people heard noises from the Australian meteor while others close by heard nothing. Those who heard sounds were simply nearer to the "speakers"--transducers such as pine trees, for example. It would even explain why attempts to record these sounds have always failed. Scientists go out of their way to place their microphones well away from any possible sources of interference such as trees or electric cables. But without any transducers nearby, the meteors would appear silent.

So the transducer effect seems a plausible source of the strange noises, but how do meteors generate VLF waves? "I was getting nowhere until I got the idea to look at turbulence," Keay says. He remembered a theory put forward by physicist Fred Hoyle which used turbulent plasmas to explain sunspots. Perhaps, thought Keay, interactions between the Earth's magnetic field and the plasma in a meteor's trail could somehow create VLF waves.

When a meteor crashes into the Earth's dense atmosphere, it ionises the air around it, leaving a blazing trail of plasma. For a few metres behind the meteor, this trail flows smoothly, but a little further back it becomes turbulent. Since a plasma is a mixture of ions and electrons, it can trap and hold the Earth's magnetic field. "The plasma is swirling so fast that the magnetic field is trapped and scrambled up like magnetic spaghetti," explains Keay. But as the meteor races across the sky, the plasma left behind cools, and the electrons and ions in it recombine almost immediately. Without the electrical charges to keep the magnetic field lines tangled, they suddenly pop free and vibrate like a plucked violin string. It is these vibrations, Keay believes, that broadcast VLF electromagnetic waves over a range of several hundred kilometres (see Diagram, below).

Sound and fury: a large meteor hitting

Sound and fury: a large meteor hitting the atmosphere creates a plasma which tangles up the Earth's magnetic field (large image). The release of the field lines generates a burst of VLF radiation, which is heard on the ground via transducers. Smaller meteors may also generate VLF when charges separate, creating an electric field (inset)

Keay has named the sounds generated by these radio waves "electrophonic" noise. He even believes that VLF waves are responsible for another eerie effect: the rustling and sighing sounds of the northern and southern lights.

For centuries strange noises have been said to accompany the exquisite curtains of colour seen in the sky near the Earth's magnetic poles. These sounds are heard often enough to be known as the "whisper of souls of the dead" in Eskimo folklore. Yet just as with the burps and whistles of meteors, some people hear the swish of the aurora while others nearby are left in silence--one reason the sounds were often written off as a psychological illusion.

Auroras are created as the Earth's magnetic field captures charged particles from the solar wind. These particles stream along the field lines and down towards the magnetic poles. Here they strike the upper atmosphere and ionise nitrogen and oxygen molecules to produce the characteristic red and green glow of the auroras. During these electrical "storms", scientists have recorded abnormally high electric fields and many believe these fields are responsible for the noises auroras emit. They suggest that they cause "brush discharge", which occurs when electric fields induce an electric potential gradient in objects on the ground. If these objects have points or spikes--such as those on leaves or pine needles, for instance--there can be an electric discharge at their tips that creates an audible crackling.

But Keay believes that the electric fields are rarely strong enough to create brush discharge. The whispering of the auroras must have another cause, he says. He believes that just as with meteor noises, auroral sounds are generated by VLF waves acting on transducers such as hair. These waves seem to be produced by ions and electrons from the solar wind that are reflected back and forth in the Earth's magnetic field.

Keay's model might explain sounds from large meteors and auroras, but it doesn't seem to explain the noises that very small meteors make. In November 1998, astronomers from all over the world flocked to Mongolia for the biggest Leonid meteor display in decades. Over two nights, they witnessed more meteors than they could hope to see in four years of normal observations. There were even seven reports of electrophonic sounds--including the first brief meteor "pop" ever captured on tape, recorded by the Croatian-based group, International Leonid Watch.

Previous recordings of meteors had produced a time delay between the visual observation and the sound, allowing the possibility of interference or even the odd sonic boom to slip in. But the Croatian researchers showed that the VLF signal picked up by radio receivers coincided with the sounds picked up by microphones and an image recorded on video to within one-hundredth of a second: enough to convince all but the most sceptical that this wasn't a statistical freak.

Yet according to Keay's theory, there shouldn't have been any noise at all. Leonids are small objects made of porous, fragile material. Weighing no more than a dried pea, the average Leonid burns up long before it reaches the lower atmosphere, where turbulence in its plasma tail can generate VLF waves. According to Keay's model, only a giant Leonid, upwards of one metre across would stand any chance of producing electrophonics. "When you calculate how bright a meteor of that size would be, the number becomes enormous and would violate the observations," says Dejan Vinkovic, an astrophysicist from the University of Kentucky who attended the Mongolian display. Also, the sounds from Leonids are short pops or clicks, quite different from the prolonged hisses accounted for by Keay's theory.

Martin Beech, an astronomer at the University of Regina, Canada, believes he can resolve the problem. He has studied noisy Leonids on and off for the past decade and has just written a paper that expands his theory to explain these strange pops. "We produced the name 'burster' to distinguish them from the longer-duration sounds that Keay researched," says Beech.

In a model developed with colleague Luigi Foschini, the electromagnetic signal is formed suddenly when a fast, light meteor breaks up. When this happens, says Beech, a shock wave explodes out into the plasma trail just behind it. Since the electrons and ions in the plasma have different masses, the lighter electrons tend to ride the front of the shock and are separated out from the slower-moving ions. "That sets up something called the space charge," says Beech, "where you've got a separation of the negative charge of the electrons from the positively charged ions." This separation is unstable and the charges recombine almost immediately, but not before the short-lived electric field generates a sudden pulse of VLF waves. When this burst reaches the ground it creates audible sound in the same way as the radio waves from larger meteors (see Diagram, opposite).

Violent explosion

Keay likens these electrophonic pops to the audible "click" that occurs at the moment a nuclear bomb detonates. "A nuclear bomb is a violently exploding plasma that causes such a shock to the Earth's magnetic field that it generates a pulse of electromagnetic radiation," says Keay. Beech agrees that the physics may be similar. "But to do that you need something that is literally like a nuclear explosion, and in the case of bursters they just don't have that kind of energy," he says. Despite the progress, it seems that there is still no single theory that can explain all the effects ("Small, medium and large", p 15).

The real problem is that Beech and Keay simply don't have enough data to go on. "With bursters, it is not entirely clear yet what sort of signal you'd expect to see, and it's hard to look for something when you don't know what it looks like," says Beech. To collect more information, he has set up an all-sky video camera and microphone at the University of Regina. "Progress in the future is going to depend upon getting reliable data," he says.

Vinkovic is also busy hunting for noisy meteors. Last year he set up the Global Electrophonic Fireball Survey to gather reports of meteor noises. So far it has 20 separate incidents on its database, and Vinkovic plans to collect further electrophonic information by persuading other international meteor surveys to start listening for sounds.

He is also looking to artificial meteors for help. "Even when you observe electrophonic sounds from a meteor, you don't know what properties that body had when it entered the atmosphere. You don't know the physical parameters," he says. The answer, he has realised, is to listen to satellites as they burn up in the atmosphere. They will behave just like natural meteors, but you know their size and exactly what material they're made from. If you can find out when and where they're coming down, he says, you should be able to get a good idea of what's going on.

Recently, when Motorola drew up plans to dispose of its 66 Iridium satellites, Vinkovic thought that he had hit the electrophonic jackpot. Now a rescue package means the Iridium network looks set to stay up there for the time being, but Vinkovic is not too despondent. Other artificial meteors, such as failed communications satellites, are regularly brought burning down to Earth. The Russian space station Mir is coming down in February. And there are even unconfirmed reports that the space shuttle returns to Earth with an electrophonic crackle. Vinkovic has a busy time ahead, but he knows that only hard evidence will silence the sceptics.

Colin Keay, on the other hand, feels that electrophonics and the theory he has pioneered are on a firm enough footing to put the ball back into the cynics' court. "I believe that I've solved the problem and started a new science," he says. "It is healthy for people to doubt, but the onus is on them to prove their doubts." The challenge to physicists is clear--you may not subscribe to these theories, but do you have any better ideas?

Small, medium and large

THE researchers admit that their efforts to account for electrophonic sound do not provide anything like the whole picture. Colin Keay's plasma-turbulence theory works well for long-duration sounds from large fireballs, and Martin Beech's burster model may work for lightweight meteors, but there are still a number of reports that neither can explain on its own. The real answer may lie in a mixture of both. If a Leonid disintegrates gradually on entry rather than its more typical catastrophic break up, for instance, a repeated burster effect could resemble the longer-duration sound modelled by Keay. There may well be other mechanisms at work that scientists just haven't considered yet. "Personally, I don't think there is one single theory that can explain everything going on out there," says Dejan Vinkovic of the Global Electrophonic Fireball Survey. He thinks that meteors must be able to distort the Earth's magnetic field, even at heights where the air is too thin to create turbulence. In preliminary calculations, Vinkovic has found that this distortion could start at the edge of the ionosphere, some 100 kilometres above the ground. But the question remains, how?

Harriet Williams is a science writer based in London

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