They are all ears

Ae.aegypti,the mosquito that carries dengue and zika viruses

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The mosquito is not just a menace because of its bite, it could be listening in to what we speak

It was long known that the whine of the female mosquito beating her wings was the signal for the male mosquito that romance was at hand. But it was believed the sound had to be really close at hand, as the mosquito could not hear from more than a few centimetres.

In a paper in the journal, *Current Biology*, Gil Menda, Eyal I Nitzany, Paul S Shamble, Amelia Wells, Laura C Harrington, Ronald N Miles and Ronald R Hoy, from the universities of Cornell, Chicago, Harvard, New York (at Binghamton) and Northwestern University, report that the male mosquito, in fact, can hear his lady in flight from over 10 metres! This has implications, both in understanding the anatomy of the mosquito as well as in design of microphones and audio receptors.

The mosquito, like most small insects, does not have a compound ear, with a tympanum, or eardrum, and resonating cavities to amplify sound. These are the devices that make for the great sensitivity and range of the ears of mammals. The human ear, for instance, can hear sounds where the variations of air pressure are less than one billionth of the atmospheric pressure. And there are animals that better this by far, both in the sensitivity to faint sounds and the range of frequencies of sound.

The paper says that the mating behaviour of the species of mosquito that was studied takes place mid-air, and accompanied by two-way exchange of sound signals, with matching of the pitch of the tones, at short range, of millimetres to centimetres. As this exchange took place at short distances, it has been assumed, the paper says, that the range of the arrangement of hairs, or antennae, with which the mosquito receives sound information, must be sensitive only in the short range.

The male mosquito has antennae whose ends are furry, and divided into hairs. As early as 1855, it has been proposed that these hairs were the structure that enabled the mosquito to sense sound.

In a 1999 paper in the journal, *Experimental Biology*, MC Gopfert, H Briegel and D Robert reported that this structure, in both the male and the female mosquito, was tuned to maximum sensitivity at specific pitch of sound. In the case of the male, this was at nearly the frequency of the wing movement of the female, which in turn, is in the same range as human speech. The hair structures were also coupled with the antenna shaft and thence with the organs of hearing. This was seen to enhance sensitivity to feeble sounds and the male mosquito was not just more sensitive than the female but better than all other insect-like creatures that have bony outer ear structures.

Another paper in 2000, in the journal of the Royal Society, by Gopfert and Robert, identified the sensory organs at the base of the antenna, that led to extraordinary sensitivity, in both male and female mosquitoes. Even the less sensitive female organ responded to deflections of antennae by just 0.0005 degrees, induced by displacements of air particles in the sound field by just 11 millionths of a millimetre.

These investigations, which were carried out using lasers and the Doppler effect, where the frequency of light rises or falls when a reflecting surface moves, gave rise to the possibility that mosquitoes may use sound for long range communication, the current paper says. In the case of mammals and larger animals, the auditory function has an important role and the dimensions of the animals have permitted the evolution of sensitive hearing organs. Insects and smaller creatures, on the other hand, rely mainly on scents or chemical signals, and this sense has evolved to great sophistication. That the mosquito could be sensitive to feeble sounds from a distance would i fodf come as a surprise.

The current team, accordingly, undertook to see from what distance the male mosquito could detect the flight sound of a female. There was an older study, of 1948, where it had been found that the male mosquito quickly took flight and moved towards a tuning fork that was sounded, from a distance of one to ten centimetres, at a tone of 400 cycles per second. The methods used were adapted to the current study and controlled experiments carried out, using both recorded sounds of same species, female mosquitoes as well as generated pure tones. "The acoustically triggered flight behaviours demonstrate that male *Ae. aegypti* (the mosquito species) respond briskly and instantaneously to supra-threshold flight tones (at about 400 cps) of conspecific females, even at distances of three metres," the paper says.

To confirm whether this behaviour was in fact a result of sound reception, the stimulation of the physical organ at the base of the mosquito antennae was monitored at the time the sounds were played. The stimulation was recorded using a tungsten micro-electrode that was introduced into the relevant nerve of the mosquito. The nerve responses were recorded while the sounds were played, at different loudness and pitch and random intervals, and the timing of responses was matched. The paper reports that the nerve response followed the pattern of behaviour response, to suggest that it was the sound that triggered the flight response of the male mosquitoes.

While these experiments had been made with sounds from a distance of three metres, because of the confines of the sound-proof experimental chamber, they were repeated with arrangements for greater distance. Now, again, it was found that the nerve activity was seen even when the sound source was 10 metres away.

There has been a concept that the "near field", where sounds can be effective, is about one-third of the wavelength of the sound. In the case of a 400 cps tone, the wavelength is about 90 cms. The near-field range would thus be some 30 cms. But a distance of three metres is 10 times as much and a distance of 10 metres is 33 times as much. It is hence time, the paper says, to let go of the notion that it is tympanal (eardrum based) hearing that works for the far-field and hair-based hearing is for the near-field.

The result throws open new behaviour analyses of insects and possibly new methods of mosquito control. The sensitivity to sound at frequency that matches human speech suggests that sound may be a device, in addition to smell and sensing warmth, which draws mosquitoes to humans. Better understanding of the anatomy of the mosquito may also clarify its place and role in the environment. And apart from this, there is the technological consequence, of using hair-based devices for detection of feeble sounds, where conventional diaphragm-based methods are not feasible.

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Living in a bubble

Dark matter may not actually exist — and our alternative theory can be put to the test

JURI SMIRNOV

Scientists have been searching for "dark matter" — an unknown and invisible substance thought to make up the vast majority of matter in the universe — for nearly a century. The reason for this persistence is that dark matter is needed to account for the fact that galaxies don't seem to obey the fundamental laws of physics. However, dark matter searches have remained unsuccessful.

But there are other approaches to make sense of why galaxies behave so strangely. Our new study, published in *the Journal of Cosmology* and *Astroparticle Physics*, shows that, by tweaking the laws of gravity on the enormous scales of galaxies, we may not actually need dark matter after all.

The Swiss astronomer Fritz Zwicky discovered in the 1930s that velocities in galaxy clusters were too high to account for how much matter we could see. A similar phenomenon was described by several groups of astronomers, such as Vera Rubin and Kent Ford, when they studied the motion of stars at the far edges of the Andromeda Galaxy.

The velocities of the stars far from its centre were expected to decrease, as they experience less gravitational force. That's because, according to Newton's second law of motion, the gravitational pull on orbiting matter can be equated to a product of its mass and acceleration (which is related to velocity).

However, the measurements showed that there was no such decrease in velocities with distance. That led scientists to believe there must be some invisible matter there to create a stronger gravitational pull and faster stellar motion. In the past decades, countless other probes of gravitating systems at very large length scales indicated the same problem.

Beyond dark matter

The mystery of what dark matter actually is remains the ultimate challenge of modern fundamental physics. The core question is whether it is indeed a missing mass source, such as a new type of matter, or whether the gravitational law is simply different at gigantic length scales.

While the first option seems very tempting, we haven't actually found any dark matter yet. Also, while gravity laws are well tested within the solar system, one has to be careful extrapolating this to scales, which are at least one billion times larger.

One well known attempt to get rid of the need for dark matter is Modified Newtonian Dynamics, which suggests that Newton's law of gravity becomes irregular when the gravitational pull is very weak — as is the case in the outer regions of the galaxy. But this theory, although successful in many respects, hasn't passed the same stringent tests as our standard model of cosmology, which includes dark matter.

The main problem is that Mond cannot explain the missing mass problem in galaxies and galaxy clusters at the same time. Another very strong argument against Mond is based on the observation of colliding galaxy clusters, where the stars of each galaxy pass through each other, but the gas clouds stick together and stay behind. A famous example is the Bullet Cluster, which consists of two such colliding clusters. Observations suggest that dark matter follows the stars in these events, which have a lower total mass than the gas cloud. Mond cannot explain why that is.

Space bubbles

We set out to tweak the laws of gravity in a different way. Our approach assumed that a phenomenon known as Vainshtein screening is at work. This suggests that each sufficiently dense, compact object in space generates an invisible sphere around it which determines how the laws of physics behave with growing distance. This sphere is a theoretical concept to help us understand the difference between small and big scales, rather than an actual physical membrane.


Gravitational lens mirage around a galaxy

According to our theory, within this bubble the laws of ordinary Newtonian gravity that we see in our solar system hold for objects interacting with the massive body at the centre. Outside the bubble, the theory suggests that the gravitational pull by the central object can be significantly enhanced — even though there is not more mass present.

The bubble size would be proportional to the mass of the central object. If, for example, in a galaxy this sphere has a radius of a few thousand light years — a typical distance at which signs of dark matter are observed —the corresponding sphere of our sun would have a radius of 50.000 astronomical units (one such unit is the distance between the sun and the Earth). However, the edge of the solar system is only 50 astronomical units away. In other words, there are no objects we could observe that far from the Sun to test whether the sun has a different gravitational pull on them than it has on Earth. Only the observation of entire systems very far away allows us to do that.

The surprising effect is that the size of the Newtonian bubble grows with the enclosed mass in a particular way. This means that the law of gravity changes at different length scales in galaxies and clusters of galaxies respectively and therefore it can explain the apparent dark matter in both systems simultaneously. That's not possible with Mond. Furthermore, it is consistent with the observation of the Bullet Cluster. That's because the gas clouds left behind in the collision are not compact enough to generate a sphere around them — meaning that the apparent dark matter is only notable around the more compact stars. Mond doesn't distinguish between stars and gas clouds.

To our big surprise, our theory allowed us to explain the stellar velocities in galaxies a lot better than with Einstein's general relativity, which allows for dark matter to exist. So there may actually be less mysterious dark matter out there than we think — and maybe even none at all.

We plan to further investigate this interesting phenomenon. It could also be responsible for the high variability of galactic motion, for which we gather more and more evidence.

Any massive body warps the space and time around it, according to general relativity. As a result, light rays take an apparent turn around the object rather than travelling in a straight line — an effect dubbed gravitational lensing. An extremely interesting test of our finding would be the observation of precise gravitational light deflection by individual galaxies, which is albeit a difficult measurement. Our theory predicts a stronger light deflection for very compact galaxies so, excitingly, it could one day be falsified or confirmed by such a measurement.

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PLUS POINTS

Delaying use

The search for new antibiotics to tackle increasingly-resistant infections is a priority for health professionals and governments around the world. But a study by researchers has suggested there could be a benefit in withholding widespread use of some new antibiotics until the outbreak of a major pandemic.

The study's authors cite the 1918 Spanish Flu pandemic, which is estimated to have killed 50 to 100 million people worldwide, where bacterial infection was shown to be a complicating factor in 95 per cent of post-mortem samples. Many of those deaths, they claim, might have been prevented had antibiotics been available.

Today countries have put in place measures to tackle future pandemics, such as infection control procedures, vaccines and stockpiles of antibiotics and anti-virals. However, researchers at the University of Strathclyde in the UK, say growing resistance to antibiotics may render such stockpiles useless. They highlight that just two new classes of antibiotic have been introduced since the 1970s.

Lead author Itamar Megiddo, of the department of management science at the University of Strathclyde, said, "Our study investigated the value of delaying the introduction of a hypothetical novel antibiotic so we do not incentivise narrowing investment in antibiotics to ones that provide immediate value. If we presuppose a strategy of immediate widespread use of newly-discovered antibiotics we leave the population unprepared for outbreaks caused by resistant pathogens."

The study used "real options theory" to assess the trade-offs to estimate the value of investing in, developing and conserving a hypothetical antibiotic to mitigate the burden of bacterial infections during a pandemic influenza caused by a strain of S aureus resistant to all oral options except for the hypothetical drug.

The authors say that, while their study was a simplification of potential scenarios, further analysis on a case-by-case basis could guide investment in novel antibiotics as well as strategies on how to use them. Megiddo said, "The results we present in our worked example suggest that considering the option value of delaying introducing antibiotics is important for making decisions to invest in antibiotics. Secondary infections caused by a significant influenza pandemic today could be catastrophic."

The study has been published in the journal, Health Economics.

Taking too long

Hundreds of animal species are at risk of extinction because wildlife trade restrictions are taking too long to come into effect, a major new study warns.

Over a quarter of animals on the International Union for the Conservation of Nature (IUCN) red list -- the world's most critically endangered -- are not protected by Cites (the Convention on International Trade in Endangered Species of Wild Fauna and Flora).

The research also revealed the long wait species have to endure to gain recognition by Cites. Even among IUCN's red-list species, 62 per cent of those protected by Cites had waited as long as 19 years for recognition or are still waiting to be listed up to 24 years after being first considered. "It's absolutely critical that policymakers allow science to inform a speedy protection process," said Eyal Frank, co-author of the study and an assistant professor at the University of Chicago. The researchers said the pattern of slow recognition by the convention was the same even for the most threatened species.

The team collected data on 958 threatened species particularly targeted by the international wildlife trade, and looked at how they were classified by the IUCN and treated by Cites. They found 28.2 per cent of species on the IUCN red list were not listed by Cites, a discovery the researchers said was "striking".

The release of the research comes ahead of the Cites conference, which will be held in Colombo in May and where international wildlife authorities will gather to vote on animal trade restrictions.

The research is published in Science.

The independent