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# NewScientist

11 August 2007

## STRANGE SOUNDS FROM SPACE

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WHEN NASA's Spirit rover touched down on the vast floor of a Martian crater in January 2004, the space agency really did have something to celebrate. For the first time in history, a robot was viewing an alien world in the same exquisite detail that a person would enjoy. Since then, the panoramic cameras on Spirit and its twin, Opportunity, have gazed around the Red Planet like human eyes with 20/20 vision.

So it might sound churlish to point out that the rovers are both as deaf as a post. Like the vast majority of spacecraft sent to other worlds, neither carries a microphone. They are oblivious to the soundscape of Mars. They can't hear the buzz of grit whirling around in dust devils, the rumbles of Martian thunder, or even the noise of their own wheels crunching across the dusty plains.

In fact, the sounds of the entire solar system are woefully unexplored. "I compare it to the stage that space imaging was at 30 or 40 years ago – people didn't think they needed to fly cameras," says Greg Delory, a physicist at the University of California, Berkeley. "The concept for early space probes was that we needed detailed physics measurements of things like temperature and pressure. What's the use of a picture?"

Compared with cameras, acoustic sensors are usually smaller, lighter, cheaper and less power-hungry. However, their simplicity may have had the adverse effect of underselling them as instruments able to deliver subtle and rich scientific information, says Tim Leighton, a physicist at the University of Southampton in the UK.

"We can do an awful lot more with acoustics than simply hear a rumble, shrug our shoulders and say 'that sounds like thunder'," Leighton says. "A rumble might tell you the thickness of an ice sheet, or the

temperature across an entire ocean. Sound travels through these things over vast distances towards you and carries a lot of extraordinary information."

Acoustics is not the glamorous side of science, certainly not for space scientists, Leighton admits, but he adds that "since NASA has set its sights on sending people to the moon and Mars, acoustics could be a very powerful tool. Think of the information and cues a deaf person on Earth loses. It's not just in speech and communication, but in diagnosing whether a drill is working properly or whether the gravel beneath our shoes is slipping."

The European Space Agency's Huygens probe, which landed on Saturn's giant moon Titan in 2005, carried acoustic instruments that worked amazingly well, according to John Zarnecki of the Open University in Milton Keynes, UK, principal investigator for the probe's surface-science instruments. "We've shown that it's feasible. These are elegant, simple, low-resource instruments which really can do a great job," he says.

Science apart, the sounds of other planets and moons could give us all a fantastic connection with these worlds – an awesome sensory feast. "We shouldn't underestimate its value for bringing the public into the experience," says Delory. "They're the taxpayers, they're the people that we're doing this for."

Imagine listening to babbling brooks of methane on Titan, or hearing deep thunder booming through Venus's dense, noxious atmosphere. Or what about the creaking and groaning of ice on Jupiter's satellite Europa, which could reveal whether the moon's frigid exterior hides a warm ocean, hospitable to life? The solar system's surround-sound has many delights in store, so listen up.

# Noisy neighbours

Space isn't nearly as quiet as it's cracked up to be. Hazel Muir tours the solar system's astonishing soundscapes



## Mars

Five NASA landers – the twin Vikings, Mars Pathfinder, Spirit and Opportunity – have beamed back spectacular images of the Martian landscape. None of them has recorded any sound, says Delory, but that's not to say other missions haven't tried.

Delory was part of a team funded by the California-based Planetary Society that sent a microphone to Mars aboard the Mars Polar Lander in 1999. Alas, NASA lost contact with the lander – it probably crashed when the engines that slowed its descent switched off too early – but had the mission worked, the Mars Microphone team hoped to hear a whole gamut of sounds, such as wind and soil whirling around in dust devils. “You can watch pseudo-movies of the dust devils on Mars, but imagine having a soundtrack to that. It would be so exciting,” says Delory.

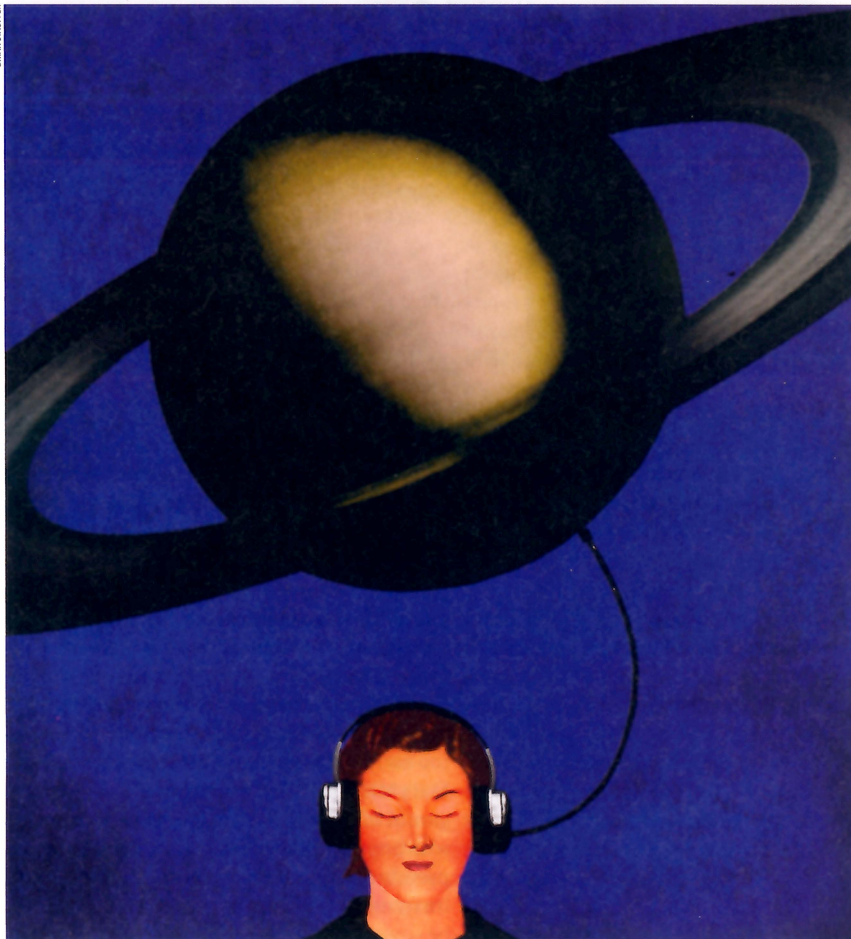
The microphone would also have recorded noises from the lander itself, such as the scratching and scraping of its robotic arm digging into the ground. It might also have heard the snaps, crackles and pops of electrical discharge created by the swirling dust devils. “It could be that there are tiny electrical discharges happening everywhere in a dust column, but it's also possible that you get big-scale events like the lightning we have on Earth – we just don't know,” says Delory.

NASA's Phoenix lander, which was due to launch last week, will carry a microphone to Mars. But it will only record noise during the parachute descent, a bit like a black-box recorder. “It provides a measure of the vibrational environment experienced by the entry, descent and landing system, which cannot be collected in any other way,” says Mike Malin of Malin Space Science Systems in San Diego, California, a NASA contractor for the Phoenix lander. “The microphone has significant public appeal.”

Delory hopes the Mars Microphone will fly on a future mission, and says the project has already spawned many attempts to understand how well sound travels on Mars. Last year Amanda Hanford from Pennsylvania State University and her colleagues showed in computer simulations that because Mars's



BRIAN STAUFFER



atmosphere is much thinner than the Earth's – the average distance between molecules is about 120 times greater – sound waves attenuate very quickly.

While a typical scream on Earth might still be audible a kilometre away, it would only travel about 16 metres on Mars, Hanford says. The speed of sound in Mars's predominantly carbon dioxide atmosphere is also slower, so if you could stand on Mars and talk, it would have the opposite effect to inhaling helium and sounding like Donald Duck: while helium gas has a higher speed of sound than air, which makes your voice sound high, Mars's low sound speed would lower the pitch of your voice.

## Venus

In the glory days of the space race, the favourite destination for the Soviet Union was Venus, often called Earth's evil twin. Sulphuric acid rains down through a CO<sub>2</sub> atmosphere with a crushing surface pressure 90 times greater than Earth's.

In 1982, two Soviet Venera landers carried microphones and recorded the sound of the breeze on Venus. Comparisons with wind

tunnels suggested there were gentle winds of about 2 kilometres per hour. The landers also heard deep rumbles that might have been thunder, but could have been turbulent airflow.

The question of whether lightning occurs on Venus is unresolved. Soviet probes spotted faint flashes, possibly lightning, on the planet's night side, while a telescope in Arizona also saw flashes in 1993. However, none of these sightings has been confirmed.

Sending a microphone to Venus could resolve this once and for all, by matching any flashes to rumbles of thunder. "If you get those two together, you're in business," says Delory. He hopes a microphone might one day fly through the clouds of Venus on a balloon mission; tests with a hot sulphuric acid mist showed that even in Venus's hellish sky, the microphone could work for several hours.

So how would the thunder sound on Venus? Not necessarily like thunder on Earth, says Andi Petculescu from the University of Louisiana in Lafayette, who has modelled sound propagation on the planet with Richard Lueptow from Northwestern University in Evanston, Illinois. Only low-frequency sounds carry well in the crushing CO<sub>2</sub> atmosphere, Petculescu told a June meeting of the Acoustical Society of America in Salt Lake City, Utah.

"The high frequencies are muffled considerably on Venus," says Petculescu, who has created an acoustic filter that can morph a given noise into how it would sound after travelling a kilometre through the Venusian atmosphere. They used it to record a Venus remix of the guitar intro from Deep Purple's *Smoke on the Water*, giving it a much deeper, thumping bass.

Fun and games apart, knowing how the Venusian atmosphere distorts noise will be crucial to interpreting sound recordings from future probes. A distant rumble of thunder, say, might be distorted beyond obvious recognition. That's a problem Petculescu has yet to get around to. "Perhaps a better choice would have been thunder rather than *Smoke on the Water*," he says, "but I couldn't resist."

## The moon

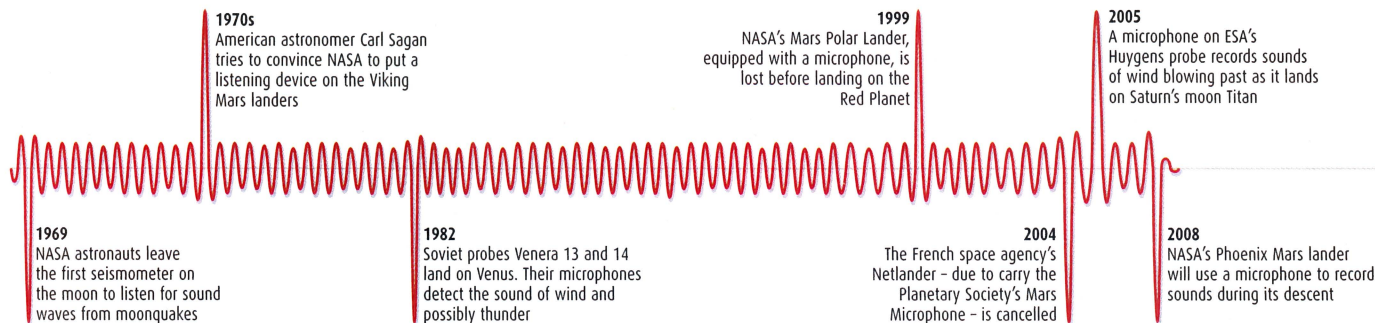
There is only one place in the solar system where we have made a concerted effort to listen in. Between 1969 and 1972, astronauts on four Apollo missions left seismometers on the moon to record sound waves rattling through the lunar crust. This network of sensors beamed back data on moonquakes until 1977, when it was switched off to save money.

Analysis of the measurements has continued for decades, revealing different kinds of shakes and shudders. Some originate more than 700 kilometres down and occur monthly, signalling the stresses and strains on the moon due to the tidal forces of Earth's gravity. The network also picked up meteorite impacts, as well as quakes triggered as heat from the sun swelled the moon's crust.

These quakes were fairly mild, but the network also recorded about 28 major quakes just 20 or 30 kilometres below the surface. Seven registered at above 5 on the Richter scale – vibrations that on Earth would be powerful enough to move heavy furniture and crack walls. The dry, rigid structure of moon rock means these strong quakes last for more than 10 minutes. On Earth they would

## LISTENING IN ON THE SOLAR SYSTEM

There have been few attempts to record sound on other worlds



usually fade in under a minute. So what causes them? "We really don't know and, to my mind, that's a problem," says Clive Neal at the University of Notre Dame in Indiana, whose team analysed the lunar data.

NASA intends to establish a manned lunar base on the moon after 2020, and the quakes could spell trouble. A magnitude-5 quake could easily rupture the airtight seal of a moon base and cause a catastrophic loss of pressure. So Neal's team is developing a proposal to deploy a new network of three to six seismometers around the moon. "It would probe the hazards to potential lunar habitats," says Neal, so that lunar base engineers could plan ahead, choosing a safe site and selecting sufficiently tolerant building materials. "It would also give us information about the composition and physical state of the lunar core and lower mantle, of which we really know nothing, except from models." Neal hopes the mission will launch around 2014 and run for six to 10 years.

## Titan

When the European Space Agency's Huygens probe landed on Saturn's moon Titan in January 2005, it marked the first time in more than two decades that we had heard the sound of another world. The probe, which hitched a ride to Saturn with NASA's Cassini probe, carried a basic microphone that recorded the whistle and whoosh of the probe's descent. "It was mostly just the wind blowing through the rigging," says Zarnecki.

Huygens also carried a sonar instrument that emitted high-pitched squeals at a frequency of 14.7 kilohertz and listened for any echoes. It was designed to measure the depth of any lake or ocean in the event that the probe splashed down into one. As it happened, Huygens crunched down onto a plain littered with icy pebbles, but Zarnecki says the instrument returned five or six echoes from Titan's surface during the last 100 metres of the descent. That allowed the

team to clock the probe's landing speed at 4.67 metres per second and accurately reconstruct the probe's entire trajectory.

"You need to know where the instruments took their measurements, and that requires a reconstruction of the whole trajectory from top to bottom," says Zarnecki. "That was very important for the science."

The sonar also revealed the lie of the land over an area of about 1000 square metres around the landing site, confirming that the camera's restricted view was typical. Camera and sonar agreed that the landscape featured gentle undulations of about a metre or so. "It showed the surface was not perfectly flat like a mirror; at the same time it didn't have canyons or cliffs, sharp edges or big boulders," says Zarnecki.

### WORLDS WITH ATMOSPHERE

The atmospheric pressure on a planet or moon affects how far and how fast sound travels



There are also hints that the sonar heard echoes from dense methane rain clouds, although the scientists are still analysing the data. Models have suggested that "raindrops" on Titan might be much larger than on Earth - up to about a centimetre wide - and would fall much more slowly, since the surface gravity is about one-seventh of Earth's.

A third acoustic instrument on Huygens measured the speed of sound during the last 11 kilometres of its descent by emitting high-frequency sound pulses and clocking their arrival at a receiver. These measurements revealed the methane content rising from about 2 per cent at an altitude of 10 kilometres to about 3.5 per cent near the surface, as the speed of sound in a gas is inversely proportional to the mean molecular weight.

"One of the most exciting things about Titan is that its atmosphere is a factory for complex hydrocarbons," says Zarnecki. "There's all this photochemistry going on as methane is broken down by radiation and then chemistry builds more complex hydrocarbons. But to model it all, you need to know what's there in the first place."

Zarnecki says that next time around he would target a lake. A radar instrument on the Cassini orbiter has found good evidence for dark hydrocarbon lakes near the polar regions of Titan, some as large as the Caspian Sea. In case of just such a landing with Huygens, Leighton simulated in advance the bubbly noise that a microphone would hear if the probe splashed down in a methane lake on Titan, or if it landed close to a methane "waterfall", so that scientists would know what they were hearing. "Bubbles are the most potent naturally occurring sound source - they're like little bells and gongs," he says.

When a moving liquid squeezes a bubble, the gas inside exerts a restoring force, making the bubble pulsate like a vibrating bell. This radiates sound. "Each bubble knows its characteristic note just as each piano wire knows its characteristic note," says Leighton. "It's like having a chorus of little bubbles each 'plinking' at its own pitch: low notes for big ▶

bubbles, high notes for smaller ones." The sound of a methane fall or splashdown is the sum of this chorus, with other splashing sounds on top.

On Titan, the chemistry and temperature would make the sound of bubbles different to that on Earth. On one hand, liquid methane is denser than water, which would deepen a bubble's tone. "It's like taking a piano string and wrapping some metal around it, which makes it more massive and deepens its characteristic note," says Leighton. On the other hand, the restoring force of the gas would be higher, effectively tightening the piano string and raising its pitch. The combined effect, says Leighton, is that a methane fall on Titan or the sound of a probe's splashdown would sound more metallic, more "robotic", than a waterfall or splashdown on Earth.

The sound speed at Titan's surface is only about 60 per cent of that on Earth because the temperature is a frigid 90 kelvin (-183 °C). However the atmospheric pressure is 50 per cent higher, so sound carries farther on Titan than on Earth across the whole audio range. To illustrate this, Petculescu has also created a version of the Venus filter to simulate *Smoke on the Water* in the Titan soundscape. Future environmental noise authorities on Titan, be warned – it sounds even louder and more annoying there than on Earth.

## Europa

If there is one world where scientists are most keen to do some eavesdropping, it's probably Europa, Jupiter's third-largest moon. Right now, Europa is the hot favourite site for extraterrestrial life in the solar system, after NASA's Galileo orbiter fuelled speculation that it has a vast, warm sea under its icy surface.

In 2000, instruments on Galileo revealed that Jupiter's magnetic field induces a magnetic field inside Europa, suggesting it must have an electrically conducting layer under the surface – most likely a salty liquid water ocean. Underneath the icy outer shell, which is perhaps 10 to 20 kilometres thick, there may lie an ocean, 100 to 200 kilometres deep, containing more water than all of Earth's oceans put together.

Although no Europa missions are on the cards, NASA has toyed with the idea of sending a lander to the moon to drill through the ice and sample the water. However, Nick Makris, an ocean scientist at the Massachusetts Institute of Technology, argues that it would be far simpler to send one or more acoustic sensors to Europa's surface to sit and listen.

Tidal forces from Jupiter constantly squeeze and stretch the moon during its

# The best of the rest

## One day we might also hear...

- The rumble of volcanoes on Jupiter's moon Io
- Geysers of liquid nitrogen spluttering into life in the sunshine on Neptune's moon Triton
- Liquid methane waves breaking on the shores of Titan's enormous hydrocarbon lakes
- Meteors smacking into a planet or moon with no atmosphere
- Thunderstorms on Jupiter, Saturn and Uranus
- Incoming comets fizzing as they wake in the sun's heat
- Huge watery geysers whooshing from cracks on Saturn's moon Enceladus
- The screaming winds of Jupiter's giant hurricanes
- Icy dwarf planets like Pluto and Eris – they may appear dead and silent, but who knows?

3.5-day orbit, altering its radius by up to 30 metres. Scientists calculate that this should constantly open up cracks in the ice, which would propagate at about 1 metre per second and arc for hundreds of kilometres. Probes haven't seen this in action, but it would explain why the moon is criss-crossed with lines.

Makris and his team estimate that cracks form every 30 seconds or so in the most highly stressed regions. They should typically penetrate about 100 metres and radiate low-frequency sound waves of about 0.1 to 100 hertz. Even with a single sensor, Makris says it should be possible to determine the location of a crack by comparing the arrival times of compressional and shear waves, which travel at different speeds, and to listen for later echoes from subsurface boundaries to figure out the ice and ocean depths.

"Sound propagates very well at low frequencies under water and in the ground," says Makris. "On Earth, you can track vocalising whales over hundreds if not thousands of kilometres using listening stations." Because the speed of sound in an ocean depends on its temperature, scientists might be able to estimate how warm Europa's ocean is, and whether it could host life. Depending on the thickness of the ice, who knows, could we even hear sounds of life?

That's a long-shot, Makris thinks. Even if complex life existed there, the ice itself may drown out any subtle biological sound. "If you listen to sounds recorded from the Arctic on Earth, they sound like creaks, moans and groans. It's a little like a haunted house," he says. "But they're not biological, they're the ice itself."

Until a probe lands on Europa, it remains anyone's guess what's really going on there. With NASA focusing on getting people to the

moon and Mars, a Europa lander mission is unlikely to happen in the next decade or two. NASA cancelled an orbiter and lander mission called the Jupiter Icy Moon Orbiter (JIMO) in 2005. Even so, Makris, who worked on the JIMO plans, is confident that a lander will go there eventually. "Planetary science is a lot like cathedral building – projects pass from one generation to the next," he says. "It's a matter of when, not if."

## ...and beyond

So where else in the solar system would have an interesting soundtrack? Makris backs Jupiter's moon Io, the most volcanically active world known. "If I could just put my ear down on the ground anywhere, I think it would be on Io – it would be really cool just to hear the rumble of the volcanoes."

Then there are Jupiter's moons Callisto and Ganymede, and Saturn's Enceladus, where acoustic sensors might uncover underground water. Microphones on Neptune's moon, Triton, could eavesdrop on geysers spluttering and whooshing into life in the sunlight, raising dusty plumes of liquid nitrogen or methane up to 8 kilometres high.

The sharp-eyed cameras of robots on Mars may still be flavour of the month with NASA but, one day, electronic ears might really steal their thunder. ●

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