



Music of the

The Sounds of Space Project harvests found sounds and signals from Earth and way beyond, and gathers them into evocative sonic compositions. Here Nigel P Meredith, Kim Cunio, Diana Scarborough and Amanda D Wynne tell the story of the group's second album: *Celestial Incantations*.

Jezero Crater on Mars, inspiration for a track on "Celestial Incantations"

(ESA/DLR/FU-Berlin/NASA/JPL-Caltech)

It was at an art/science 'speed dating' event in 2016 that a series of like minds got together to explore the possibilities of giving voice to a diverse range of waves and signals, and to extend the boundaries of music beyond the simply sonic. So began the Sounds of Space Project.

An international multi-disciplinary collective, the project comprises British Antarctic Survey (BAS) space weather research scientist Nigel Meredith, Cambridge-based multimedia artist-engineer Diana Scarborough and Australian National University composer-musicologist Kim Cunio.

Since that first date, the team has indulged in experiments with the natural sounds of space, and how they can be communicated and made accessible to larger audiences (Meredith, 2019, *Sounds of Space 2021*). Sound waves cannot travel in the near-perfect vacuum of space, but electromagnetic and gravitational waves can. Converting these waves to sound reveals a vast palette of natural expression.

The first album by the Sounds of Space Project, '*Aurora Musicalis*' (2020) featured space weather recordings from the VLF receiver at BAS Halley VI Research Station in Antarctica, accompanied by piano compositions by Kim Cunio, recorded over a single day.

Second album '*Celestial Incantations*' (bit.ly/30dUZg60) released at the summer solstice in June 2021, saw an expansion of scope, introducing a new spectrum of space sounds and extended orchestral and traditional arrangements.

Wrapping up this package of aural innovation is a suite of conceptual artwork by visual artist Diana Scarborough, whose work seeks to establish a narrative journey through art as an evocation of space and time. Scarborough's approach to '*Celestial Incantations*' uses blended scientific imagery, and frequently pays homage to medieval symbology and cosmological views.

Recording

Collecting and selecting the 'sounds' of Earth and space featured in '*Celestial Incantations*' took several years. They include data from the British Antarctic Survey (BAS), the University of Iowa, NASA, ESA, Jodrell Bank Observatory, the LIGO Scientific Collaboration and the Virgo Collaboration.

Opening track '*Stone Age Ice*' features the sounds of compressed air bubbles escaping from an Antarctic ice core, recorded by BAS, combined with a slow and solemn piano response and the percussion of knitting needles on traditional bowls to symbolize the freedom of the gases. The gases in the air bubbles are around 200000 years old, from ice deep beneath the surface in Antarctica. They provide a pre-industrial time capsule of greenhouse gas concentrations long before detectable anthropogenic changes to the atmosphere. Data from these cores contributes to the Intergovernmental Panel on Climate Change (IPCC) global climate change assessment, and informed discussion at the 2021 United Nations Climate Change Conference (COP26).

Scarborough's blended image artwork for the composition (figure 1) creates an image evoking an ice core, a homage to melting fragments of ice; outwardly coherent but internally complex.

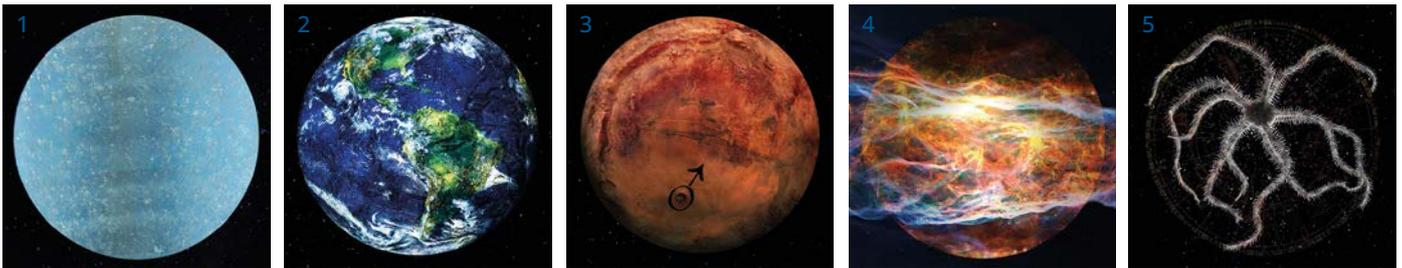
Second track 'The Earth and Heavens Combine' features the natural radio 'sounds' of our planet, recorded both on Earth and in near-Earth space. These emissions occur at the low end of the radio spectrum, in the audio-frequency range, and have been directly converted to sound with no manipulation of frequency or time. We hear distant lightning in the clicks and pops of spherics and the pinging of tweaks. There are also the rising tones of chorus emissions, generated during geomagnetic storms, and the descending tones of whistlers, signals from lightning activity that have leaked into space. The Earth is seen and heard in a new way, something echoed in the piano work that has been reversed to give a disconcertingly unfamiliar effect. The artwork (figure 2) gestures to the idea that this track concerns Earth, yet not Earth: star constellations,

from the Sun first encounter Jupiter's vast magnetic field. The track features no human instrument or voices; instead the jovian wave 'sounds' captured on board NASA's Juno spacecraft as it approached Jupiter for the first time in 2016 are compressed and processed into a 24-second reverb and delay loop. Other Jupiter 'sounds' are processed with pattern enhancers, equalizers and pitch excitors.

'Evocation of Saturn as Souls Return and Demons Depart' makes use of intense radio emissions from the Radio and Plasma Wave Science instrument on board the NASA/ESA Cassini spacecraft recorded at Saturn in 2003. The original 30–80kHz radio emissions are shifted downward by a factor of 44 and compressed, such that 27 minutes of data is played back in 73 seconds, accompanied by a string orchestra and Iranian santour (a hammer dulcimer) that pulse with composed imaginings of the rings of Saturn.

When it came to representing such a culturally familiar planet as Mars in a new and engaging way, Scarborough opted to include the medieval symbol of Mars set over layered contemporary images of the planet itself (figure 3). For Jupiter, overlaying imagery of a simple circle with the Veil Nebula tells a story of power and energy as an abstraction from the traditional visual representations of Jupiter and the Sun (figure 4). Saturn uses an angelic – or possibly demonic – figure, invoked with a manipulated image of a sea spider from BAS archives, enveloped by a circle of stars (figure 5).

spheres



symbols and painted imagery combine with the globe to amplify both the known and the imaginary.

One striking aspect of these and other space sounds on the album, besides the science and engineering that has made it possible to record and process the data into sonic experiences, is how similar they are to how we have imagined them over time. The celebrated BBC Radiophonic Workshop and Bell Labs both explored analogue synthesis to make similar types of sounds. Scores of space-based movies have soundscapes that are not dissimilar to what we hear on this album.

Heading out into space

Three of the album's tracks feature audio sourced from planets. 'Jezero Crater' features the first acoustic recording of Mars's atmosphere by the Mars Perseverance Rover. Responding to the long human journey of experimentation and learning that eventually brought the Mars Perseverance Rover to the Jezero Crater in 2021, we hear the doleful tone of the Armenian duduk, an ancient double reed woodwind instrument made of apricot wood. This most precise and difficult of instruments is played (after years of practice) by Cunio, and is matched with newly composed lines sung by soprano Heather Lee. These lines present a reflection on the present state of Earth's atmosphere even as we celebrate the first terrestrial recording of the martian atmosphere, reminding us that there is no second Earth in the solar system.

'Celestial Forces of Jupiter and Sun Collide' focuses on the jovian bow shock, where particles streaming

Diana Scarborough's artwork for the "Celestial Incantations" album uses blended science imagery to evoke the origin of the music.

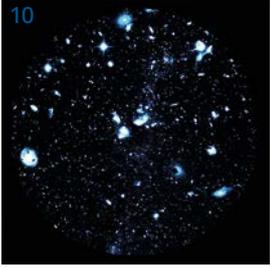
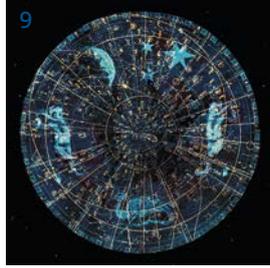
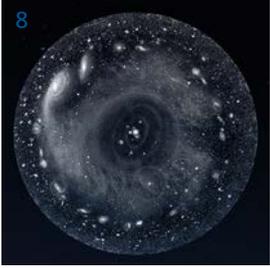
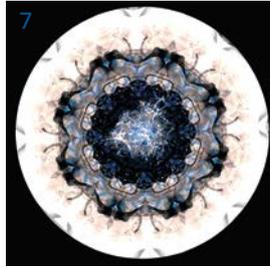
1 Stone Age Ice; **2** The Earth and Heavens Combine; **3** Jezero Crater; **4** Celestial Forces of Jupiter and the Sun Collide; **5** Evocation of Saturn as Soul Return and Demons Depart.

(Diana Scarborough)

Unexpected oscillations and a cataclysmic chirp

Fifth track "Nomadic Messenger of the Realms" presents an interpretation of the sound of comet Churyumov-Gerasimenko, created by composer Manual Senfft based on unexpected magnetic oscillations recorded by the magnetometer experiment onboard the ESA Rosetta spacecraft when it was about 100km from the comet. The comet's sound is combined with a piece played by Chris Pidcock, composed by Cunio, which stretches the possibilities of the cello in pitch, harmonic language and timbre. The drama in the track is created when the cello and comet duel. Scarborough's artwork (figure 6) is inspired by an ESA image of the comet, evoking the spirit of an imagined soul split in two, emphasized with glow and contrast to capture the journey of the lonely comet.

'Cataclysm' is the setting of an ultimate universal event, and one of the most astounding breakthroughs in astrophysics. In this track we hear the 'chirp' from the merger of two black holes that took place 1.3 billion years ago. This seminal recording, captured in 2015 by the LIGO consortium, is the first ever detection of gravitational waves. These ripples in space-time, produced by some of the universe's most violent events, were first predicted by Albert Einstein in 1916. Both artist and musical composer took the almost incomprehensible magnitude and importance of the discovery as an invitation to push creative boundaries to render the phenomenon tangible. Scarborough has digitally painted, blended and distorted unrelated



6 *Nomadic Messenger of the Realms*; 7 *Cataclysm*; 8 *Sky Diamonds*; 9 *Celestial Incantations*; 10 *Interstellar Incursions*. 11 (below) *Album art for "Celestial Incantations"*

[Diana Scarborough]

imagery. Patterns upon patterns converge in a kaleidoscopic abstraction to represent the almost invisible yet infinitely complex (figure 7). Cunio notes the frequency of the gravitational waves in the chirp moves from an approximation of notes A to Eb, an interval with the most forward potential of any two notes, known affectionately as 'the interval of the Devil'. He has composed a piece around the notes of the chirp which most excited him. The result is performed in a virtual piano set up so that a switch triggers a note doubler, meaning that once the doubler is triggered every note will be played twice.

Sonic heritage

On 'Sky Diamonds', a 110kg polished granite stone is bowed by hand while water is poured on it. The sound is a response to whistler emissions recorded high above Earth's atmosphere by the EMFISIS instrument on board NASA's Van Allen Probe A spacecraft in 2015. BAS scientists use EMFISIS measurements in global plasma wave models (Meredith *et al.* 2018, 2020) that are ultimately used to forecast space weather (Horne *et al.* 2013; Glauert *et al.* 2014). The track artwork (figure 8), accentuates the crystalline, using the contrast of dark sky against a cosmic abstraction to create a sense of white heat and energy.

Title track 'Celestial Incantations' features one of the oldest pieces of scored music, a composition by 12th-century Abbess Hildegard of Bingen, performed by Heather Lee. The 900-year-old music is combined with pulses of radiation from pulsar PSR B0329+54, a highly magnetized neutron star 3460 light years from the Sun, recorded by the Lovell Telescope at Jodrell Bank Observatory. Hildegard's collection of music was titled 'The Symphony of the Harmony of Celestial Revelations', which inspired the title of this album. The track artwork (figure 9) recalls medieval influences, altered by a soft blue of ocean or sky, to form an emblematic talisman.

In the track artwork for 'Interstellar Incursions' (figure 10), a circle of light sits in black, a glimpse of the vastness of space through an imagined telescope portal. We are travelling with the Voyager 1 spacecraft into interstellar space. This piece uses a recording from the plasma wave instrument on board the spacecraft, compressed so that three years of oscillations play back in just 18seconds. The sound, with a virtual doppler effect to simulate the feeling of movement, plays alongside the accelerating North Indian tabla. The energy of 15-year old tablist Samarai Cunio symbolizes the hope embodied in this, and in future journeys into space.

The music of 'Celestial Incantations' and previous album 'Aurora Musicalis' is freely available, in the spirit of cooperation that sees the international academic community offer their primary and processed data to all. The team hope that listeners will be inspired to



create and share their own audio and visual responses, increasing the visibility and accessibility of space science. They plan to take the project forward by experimenting with the sonification of multiple space weather data sets with a view to creating new and exciting music, art, performances and events, and enhancing the visibility of this increasingly important area of research. ●

AUTHORS

Dr Nigel P Meredith (nmer@bas.ac.uk) is a space weather research scientist at British Antarctic Survey, Cambridge, UK.



Prof. Kim Cunio (kim.cunio@anu.edu.au) is Head of the School of Music, Australian National University, Canberra, Australia (picture: Peter Damo).



Diana Scarborough (dianasj62@yahoo.co.uk) is a multimedia artist based in Cambridge, UK.



Amanda D Wynne (amwynne@bas.ac.uk) is a digital content manager at British Antarctic Survey, Cambridge.



ACKNOWLEDGEMENTS

We would like to thank the institutions who have provided the audio data used in this project including the British Antarctic Survey, the University of Iowa, NASA, the European Space

Agency, Jodrell Bank Observatory, the LIGO Scientific Collaboration and the Virgo Collaboration. Nigel Meredith would like to acknowledge funding from Natural Environment Research Council Highlight Topic grant NE/P10738X/1 (Rad-Sat), and the NERC grants NE/V00249X/1 (Sat-Risk) and NE/R016038/1.

LINKS

Sounds of Space updates twitter.com/SoundsofSpaceP.
BAS 'Sounds of Space' bit.ly/3n9UzQK

Aurora Musicalis 2020 bit.ly/3De3CWv
Celestial Incantations 2021 bit.ly/30dUZg6

REFERENCES

Glauert SA *et al.* 2014 *J. Geophys. Res.* **119**
Horne RB *et al.* 2013 *Space Weather* **11**
Meredith NP 2019 *Astron. & Geophys.* **60** 2.18
Meredith, N. P. *et al.* 2018 *J. Geophys. Res.* **123**
Meredith, N. P. *et al.* 2020 *Geophys. Res. Lett.* **47**