Mapping the Invisible — An Artist's Engagement with Subatomic Particles at the South Pole

Donald Fortescue

Curiosity has fueled our insatiable urge for exploration and discovery. The last continent on Earth to experience this drive was Antarctica. Antarctica is the driest, coldest, and least habitable continent on the planet. It's the terrestrial environment most inimical to life. The physical environment is a near equivalent to that of other planets, and it has been used as a stand-in for the frozen, dry surface of Mars. Humans have only continually occupied it for the last 60 years, and only at great energy and material cost. It consistently rebuffs our efforts to engage with and comprehend it. But strangely enough, the Antarctic is currently at the epicentre of our understanding of life on our planet and the origins and structure of the universe around us.

Both the Arctic and the Antarctic have been compared to blank pages. Author Jack London described the Arctic as a 'large sheet of foolscap'.[1] Stephen J. Pyne, in his poetic analysis of Antarctica, postulated:

> *Antarctica is the earth's great sink, not only for water and heat but for information . . . The extraordinary isolation of Antarctica is not merely geophysical but metaphysical. Cultural understanding and assimilation demand more than the power to overcome the energy gradient that surrounds The Ice: they demand the capacity and desire to overcome the information gradient.*[2]

Here, Pyne describes two separate gradients that run in parallel. As the pole is approached, the physical landscape becomes increasingly isotropic and featureless (the information gradient approaches zero), so the scope increases for the human imagination to write its own meanings onto the landscape. The lack of physical reference for gaining our bearings unmoors us from the real world, and we float into the worlds of metaphor and imagination. It is an attractive place for artists!

Contemporary artists are drawn to the isolation, inhospitality, and otherworldliness of the Antarctic to better comprehend our planet, the cosmos, and our inner worlds.

The tendency for energy and information to approach zero at the South Pole is also what attracts scientists. The primary science they conduct there is atmospheric analysis, glaciology, and astrophysics. All rely on the pristine conditions, clean air, and relative absence of humans and their technology. In the case of astrophysics, the 3,000-metre altitude, the dryness of the air, the six-month-long nighttime, access to the southern skies, and the lack of polluting light, heat, and other electromagnetic interference are unmatched on earth.

My research took me to Antarctica in the austral summer of 2016-17 on a U.S. National Science Foundation Artists and Writers Fellowship. I was hosted by the IceCube Neutrino Observatory, located at the South Pole, which is working at the cutting edge of our ability to perceive subtle energies. IceCube looks for neutrinos. Created in the sun and in distant high energy cosmic events, neutrinos are the most common subatomic particle in the universe. However, they are incredibly difficult to detect as they hardly interact with other matter — they must essentially collide with another subatomic particle to have any effect on it. They have been called 'ghost particles' because of their elusive nature. The only way they can be identified is with an immense detector, large enough to capture and record a useful number of these exceedingly rare interactions. This is where the south polar ice cap comes in.

Figure 1. *Instrument (90°S)* deployed at the South Pole

The IceCube Neutrino array occupies a cubic kilometre of ice and is buried 1 ½ km deep under the South Pole. This huge volume of ice (1 million cubic metres) captures several hundred neutrino interactions every day. The array consists of more than 5,000 basketball-sized photo-sensitive Digital Optical Modules (DOMs) arrayed on 86 vertical 'strings' that have been drilled into the ice. Each DOM can detect a single photon of light. A neutrino hitting a hydrogen or oxygen nucleus generates a tiny blue flash of Cherenkov radiation which then is picked up by the DOMs. The genius of IceCube is that its DOMs actually face down, not up. It relies on the fact that if any particle manages to get through the earth it must be a neutrino — anything else would have been absorbed along the way. The observatory is a gigantic neutrino telescope that uses a cubic kilometre of ice as its lens and our entire planet as a filter to detect something that is almost imperceptible. My goal was to deploy my own sculptural instruments at the Pole. I wanted to work directly with the IceCube scientists to develop a deeper understanding of the flux of energies flowing through the South Pole and get a clearer view of the varying approaches of science and art in comprehending and defining nature.

My *Instrument (90°S)* (Fig. 1) was positioned on the ice surface above the heart of IceCube far underground. It is a hybrid object: a polar marker, an artefact of my expedition, an instrument (both musical and scientific) and, ultimately, a sculptural work. It was specifically designed and constructed for the challenging conditions of the South Pole. It can be tuned, and it responds in different ways to differing levels of input. The instrument transduces the flow between air-pressure differentials (wind) through harmonic vibration. This creates a sound that can be experienced directly and recorded for future use.

Using my instrument on the surface inspired me to use sound to experience the neutrino interactions deep within the ice. In the IceCube Neutrino Observatory, the DOMS are arrayed in 86 2 ½ km long 'strings' frozen into the polar ice. The number of strings in the array and the fact that scientists call the long cables and attached instrumentation 'strings' led me to think of IceCube as an enormous stringed instrument. This conceptualization led directly to the idea of mapping the 86 strings of the array onto the 88 keys of a grand piano and envisioning the photon 'hits' on individual DOMs as strikes on the strings of a gigantic ice-imbedded piano.

IceCube scientists create colourful 2D visual simulations from their data to get an overview of the passage of neutrinos and muons through the ice. In creating the audio work *86 Strings #1 (December 31, 2016)* (Fig. 2), IceCube collaborator Dr. Gwenhaël de Wasseige and I transduced digital signals derived from the detection of photons deep in the ice into sounds we can hear.

There are innumerable ways the IceCube data could be transduced into sound. In each one, the data values of event rate, photon energy, photon flux, and location must be allocated to map the sound values of frequency, volume, duration, and timing. Some mappings are readily suggested by the shared characteristics of sound and light waves, such as frequency, intensity, and duration. Others, such as which events are sampled, the sampling rate, and playback speed, need to be selected to both reflect the underlying physics and to satisfy aesthetic considerations so the resulting work will be engaging. In the case of *86 Strings #1 (December 31, 2016)*, we assigned the values of the timing, intensity, and duration of the DOM signals to timing, volume, and sustain on each struck note. The choice to assign a particular note to a particular IceCube string highlights the physical movement of muons through the ice. Neutrino interactions which result in horizontal muon paths cause distinctive glissandos. Vertical neutrino paths result in repetitive strikes of the same or closely tuned notes.

86 Strings #1 is an audio timelapse of a day's worth of solar muon data from deep in the ice. In the work *Axis Mundi,*[3] it is combined with a video timelapse of the same 24-hour time period's worth of visual data from the ice surface – marked by the presence of my sculptural work *Instrument (90°S)*. Both timelapses last 4 minutes and 48 seconds and are precisely synchronized. *Axis Mundi* captures the transient motions of our atmosphere and the passage of subatomic particles through our planet and provides a means for us to physically engage with these subtle energies.

Artists and scientists working in Antarctica have scaled Pyne's 'information gradient' in their efforts to engage with and map the subtleties of the physical world and our human experience of it. By approaching the energetic and informational sink of the pole, scientists can discern the subtlest of cosmic signals and artists can look both inwards and outwards to connect human experience to the larger cosmos.

Portions of this essay first appeared in 'Synergy between Art and Science: Collaboration at the South Pole', Proceedings of the 36th International Cosmic Ray Conference, July 24-Aug. 1, 2019, in Madison, Wis. and in 'At the Edge of the Natural: Scientific and Artistic Research at the South Pole' in the Unnaturalism issue of Art+Australia*, May, 2018.*

Acknowledgements

Fortescue's research was undertaken with support from the Australian National University and the California College of the Arts in San Francisco. Fortescue's research in Antarctica in the austral summer of 2016-17 was supported by the U.S. National Science Foundation through an Antarctic Artists and Writers Fellowship. Particular thanks go to the scientists and staff of the IceCube Neutrino Observatory for their advice and assistance and for hosting Fortescue and de Wasseige at the South Pole. The data used in this research was generously provided by and used with the permission of the IceCube Collaboration.

Endnotes

1. — Jack London, 'An Odyssey of the North', *The Atlantic*, January 1900, https://www.theatlantic.com/magazine/archive/1900/01/odyssey-north/309202/, 87.
2. — Stephen J. Pyne, *The Ice: A Journey to Antarctica* (London: Arlington Books, 1987), 6.
3. — *Axis mundi* can be viewed at https://vimeo.com/314347886

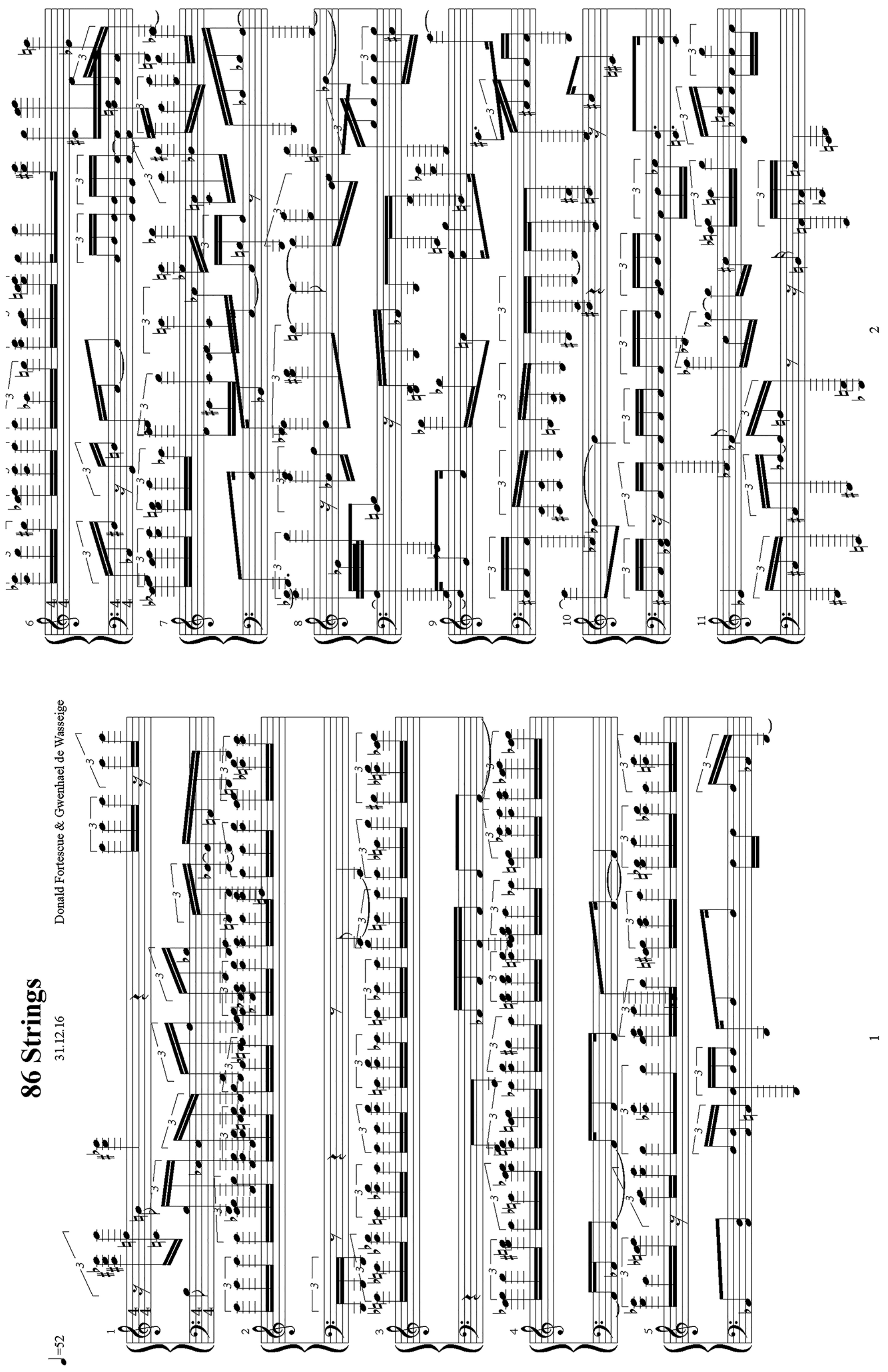

Figure 2. Two pages from the manuscript of *86 Strings #1 (December 31, 2016)* by Fortescue and de Wasseige