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EXCITED OXYGEN – LIFE EXISTS HERE

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Figure 1. Aurora beams viewed from Taieri (Taiari) Mouth, August 2014. Photograph: Ian Griffin.

For this Art+Science project (whose theme was air), we look to auroras where excited atmospheric gases light up the night sky. In Ōtepoti Dunedin we often see the top of distant aurora australis over the horizon, through the near-vertical auroral beams (Figure 1). When we see these we are looking at Earth's magnetic field (Figure 2).

Auroras require three components: stellar wind (or plasma), a planetary magnetic field and atmospheric gases.[1] Solar plasma (itself an interplanetary magnetic field) hits the magnetosphere enveloping and protecting Earth's atmosphere; charged particles then spiral down magnetic field lines and penetrate Earth's atmosphere, exciting atmospheric gases. As the excited gases relax back to their lower energy state, they emit light.

Following the introductory Art+Air meeting, scientists and artists visit each other's spaces. On visiting weaver Christine Keller's Dunedin's LoomRoom, paleomagnetist Faye Nelson was struck by how the warp threads on the floor looms looked like magnetic field lines. Paleomagnetists study Earth's changing magnetic field as recorded by rocks and sediments. Ferrimagnetic minerals such as magnetite (Fe_3O_4) – an iron oxide – act as tiny compasses, locking the magnetic field vector (strength and direction) into the geologic record.

Christine had glow-in-the-dark thread from Germany in her inventory, which called for an aurora-related weaving project. Glow-in-the-dark thread is treated with a phosphorescent substance that absorbs light and then releases it over time after the light source has been removed. In a way, phosphorescence is like remanent magnetism, the fundamental process behind paleomagnetism, in that magnetisation is retained even after the magnetic field is removed.

Christine visited the Otago Paleomagnetic Research Facility at the University of Otago, where she immediately felt at home reading the three-dimensional vector diagrams portraying the Earth's past magnetic field. Recalling the description of charged particles spiralling down magnetic field lines, Christine thought of the weave structures of the twill family, with visible diagonals in the way that the two-thread system's warp and weft cross each other.

EARTH'S MAGNETISM

Both geomagnetic storms and magnetic polarity transitions push auroras to lower latitudes. Earth's magnetic field is generated by a geodynamo – the fluid motion of Earth's liquid iron outer core. According to the geocentric axial dipole (GAD) model, Earth's 'bar magnet,' when averaged over tens of thousands of years, is aligned to Earth's spin axis. Thus, inclination (the dip angle) can be derived from latitude (l) using the formula tan I = 2 tan l.

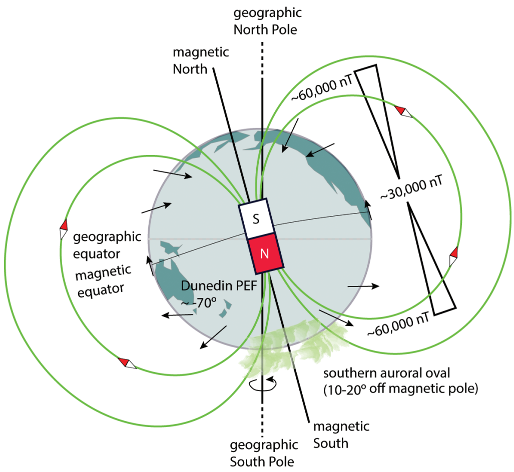

Figure 2. Earth's inclined geomagnetic field.[2]

Ōtepoti Dunedin's GAD inclination is -64 degrees (the negative sign indicates that the field is pointing outward, the current, normal polarity in the Southern Hemisphere). However, Earth's magnetic poles are constantly wandering, and Earth's geomagnetic field is not aligned with Earth's spin axis (Figure 2). According to the International Geomagnetic Reference Field (IGRF-13) model, the field at Ōtepoti Dunedin in 2022 is inclined to -70 degrees.[3] If a strong solar flare hits Earth, we may see that 70-degree angle reflected in the auroral beams over Dunedin. Earth's dipole field (Figure 2) has weakened, and the magnetic poles have travelled to the opposite polar region at various times throughout geological history. Recent full transitions have taken as long as twelve thousand years.[4] At some point in the future a geomagnetic pole may move over Ōtepoti Dunedin, and steep auroral beams will light up our night sky.

EXCITED OXYGEN

The source of the auroral green at 557.7 nm on the visible light spectrum was not known until 1925, when physicists Gordon Shrum and John McLennan reproduced the spectral green line in the cryogenic laboratory at the University of Toronto, when they discovered it to be oxygen.[5] Green auroras predominate due to free oxygen – produced via photosynthesis – in Earth's atmosphere at 100–150 km altitude. Auroras' sub-polar lights are like neon crowns signalling "life exists here" on this planet.[6]

ARTIST'S RESPONSE
Christine Keller

After initial discussions with Faye, my challenge was to create a wall hanging that depicted our aurora as it appears in the local night sky. Weaving is the crossing of thread systems, warp and wefts. I responded to the verticals and relevant angles of -70 and -64 degrees in the aurora and, using phosphorescent materials in combination with opaque ones, created weave structures which were emphasised in the diagonal. This was done on an AVL 24-shaft Compu-Dobby loom. I used locally grown and spun wool from Milton and twine produced in the now defunct Donaghy's Rope and Twine factory to keep to the local story.

Figure 3. Christine Keller, concept image for Art+Air Project. Photograph: Ian Griffin.

The work *Excited Oxygen* was viewed in a dark space to accentuate the effect of the 'glow-in-the-dark' yarn, as if encountering an aurora in the Dunedin night sky – as many are encouraged to do by Otago Museum's director and aurora-hunter Ian Griffin.

A smaller version of the piece was shown in the entrance so that people could appreciate the fabric structure in the light, as only the phosphorescent effects would be visible in the dark space.

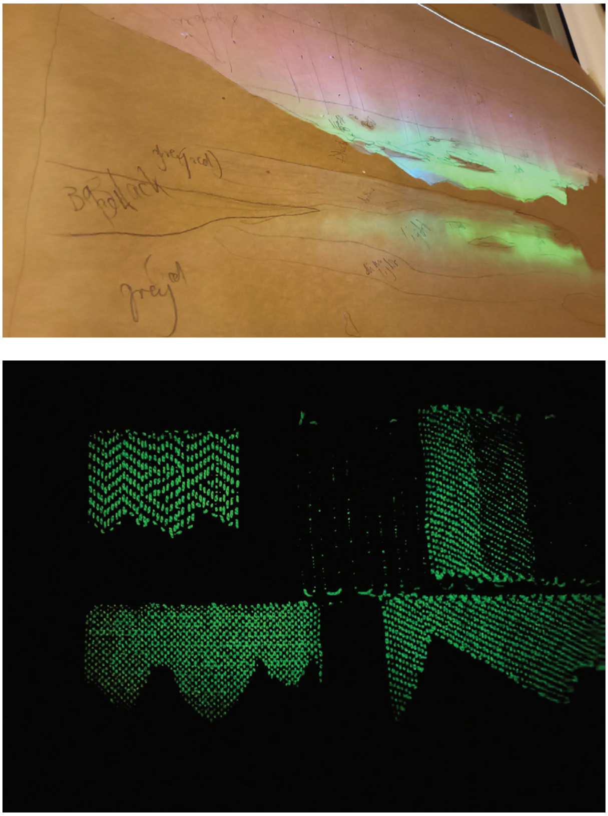

Figure 4 & 5. Christine Keller, Exploratory work in progress.

German-born, New Zealand-based artist **Christine Keller** holds an MFA from Concordia University (2004) in Montreal, Canada, and a Masters equivalent from Gesamthochschule Uni Kassel (1994), Germany. Christine has exhibited her award-winning work nationally and internationally since 1987. She was the academic leader of the Textile Section of Dunedin School of Art at Otago Polytechnic from 2005 to 2010. In late 2012 she founded the Dunedin-based weaving studio Weaving on Hillingdon, and in 2015 the community space known as Dunedin's LoomRoom.

Faye Nelson (https://orcid.org/0000-0001-6241-0628) is a geologist and technician at the Otago Paleomagnetism Research Facility (Department of Geology, University of Otago). This is Faye's second Art+Science project.

1 M Windridge, *Aurora: In search of the Northern Lights* (London: William Collins, 2016).

2 Diagram redrawn from MW McElhinny, *Palaeomagnetism and Plate Tectonics* (Cambridge: Cambridge University Press, 1973). World Data Center for Geomagnetism, Kyoto, "Model field at a point by IGRF (IGRF-13)," https://wdc.kugi.kyoto-u.ac.jp/igrf/point/index.html (accessed 1 May 2022).

3 World Data Center for Geomagnetism, Kyoto, "Model field at a point by IGRF (IGRF-13)," https://wdc.kugi.kyoto-u.ac.jp/igrf/point/index.html (accessed 1 May 2022).

4 F E Nelson, GS Wilson and H I Neil, "Sediment Flux Variability during the Last 1.8 Ma, Hokitika Canyon, New Zealand," manuscript in preparation.

5 H Kragh, "The Green Line: A Chapter in the History of Auroral Physics," *Astronomy & Geophysics*, 50:5 (2009), 5.25–5.28.

6 S-I Akasofu, *Exploring the Secrets of the Aurora*, 2nd ed. (New York: Springer, 2007).