PETRA FERSTERER AND LYNN TAYLOR

Trapping Ultra-cold Atoms in Optical Lattices

There are many perceptions about artists and scientists which imply that our temperaments and work processes are very different. However, pairing a scientist with an artist in collaboration is a practice that is gaining momentum and generating new ways of seeing, experiencing and interpreting the world. In the early 1960s theoretical physicist Richard Feynman, whose diagrams are printed in some of the pendants used in the *Trapping Atoms* installation, exchanged art and science lessons with his artist friend Jirayr "Jerry" Zorthian on alternate Sundays.[1] A more recent example is Marc Quinn's portrait of the DNA of Sir John Sulston, one of the genetic scientists who decoded the human genome.[2]

Over the last three years in Dunedin, Peter Stupples and Ruth Napper have coordinated projects where artists work alongside scientific researchers with a view to creating artwork and presenting public exhibitions. This year the project was themed as "Art and Light," connecting with the 2015 UNESCO global initiative, the Year of Light and Light-based Technologies. The Art and Light collaboration between physicist Petra Fersterer and artist Lynn Taylor centres on the former's research on trapping ultra-cold atoms in optical lattices. This article blends our voices and experiences of the project, beginning with an introduction from Petra.

PETRA FERSTERER

I am a PhD student in the Physics Department, Otago University, under the supervision of Professor Rob Ballagh. In my research I study ultra-cold atoms. By ultra-cold I don't just mean ice-cold, I mean as close as we can get to the coldest temperature possible, absolute zero. That is minus 272 degrees Celsius, which is colder than anywhere else in the universe; it is even colder than outer space! But where does light come in? To hold onto and cool down an atom we use laser light.

In my research, I study a grid of laser light—called an optical lattice—to trap atoms where the beams intersect. This means that instead of a single cloud of atoms, I create a whole grid of atoms. We can think of this light as an egg carton, and the atoms as marbles bouncing around inside. Just as water has three different states—liquid water, steam or ice—the atoms have different states. When the lattice is shallow, the "marbles" move all around in what we call the superfluid state. When it is deep, the marbles go to one site each and stay there, in what we call the Mott insulator state. Knowing what state they are in is the big question!

Answering that question can be tricky, and is further hindered by the fact that simply looking at a quantum system can change and destroy it. This means we can only make one measurement at a time, and then we have to start all over again. What I am trying to do is find a way of looking at the atoms without disturbing the system, so that we can make further measurements. I find this research exciting because when we look at things this small and this cold, matter and light act very differently from how we encounter them in everyday settings. The idea that light could hold onto something is quite outside our everyday experience with light. We also find that rather than being like a tiny marble, as we might intuitively imagine, the atoms act more like a wave.

My research, which is built on strict physical rules, seems very far from the creative work of an artist, but as Valerie Hazan asserts, artists and scientists are "both manipulating reality to understand it."[3] In the Art and Light project I paired with artist Lynn Taylor, who describes below how the *Trapping Atoms* collaboration unfolded over the ten months that we worked together.

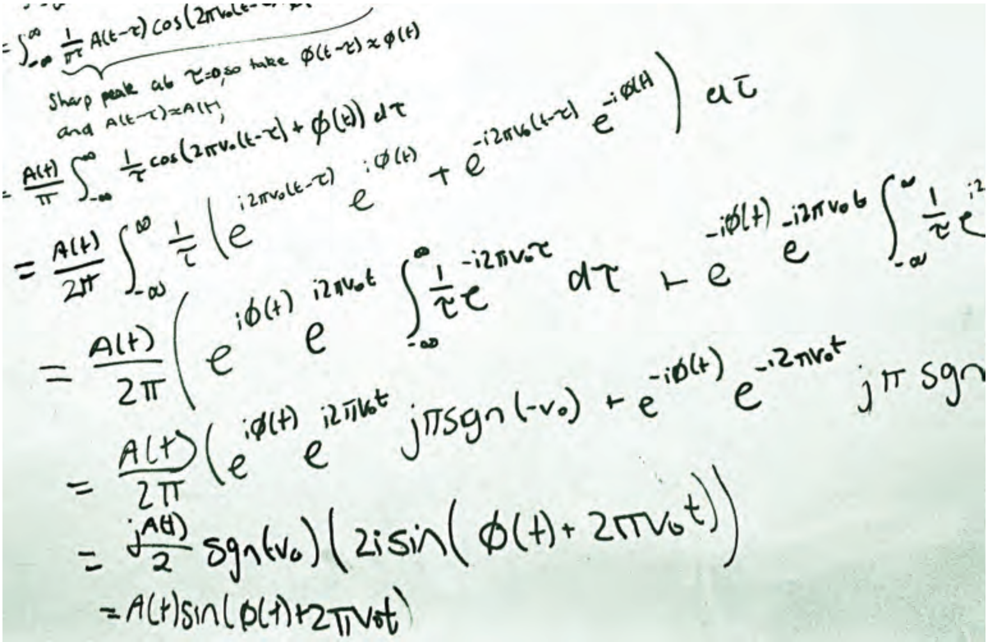

Figure 1. Whiteboard showing equations in Petra's office.

LYNN TAYLOR

How 'we' see the world is subjective. If we consider Maurice Merleau-Ponty's notion of the body as a perceptual tool—"we live in a world of sense-experience and what we can touch and feel, see and hear, is the sum of our reality"[4]—it raises important questions about how and what we perceive. Humans develop an understanding of object permanence, but does what we see exist when it is out of sight?

Answers to these questions are being developed not only in science, but in art. For example, in his book *The Object Stares Back*, art historian James Elkins describes the act of seeing as metamorphosis, affecting both the object seen and the one seeing.[5] However, our ability to observe quantum mechanics shows us a different reality: the objects casting the shadows are not actual, but rather different projections of potential objects. There is an objective world, but it is not an actual world fixed in space and time, or one that strictly follows deterministic laws. The world is not made up of hard matter; it does not exist as a collection of objective entities, independent of observers. Physicist David Bohm, whose central thesis is that we exist in a vast ocean of energy, believes we are beings who inhabit a myriad of parallel "nows." He adds that "we are all part of a seamless whole (the holomovement) that is pulsing with life and intelligence. Our visible, palpable three-dimensional world is derived from the multidimensional reality…everything in our world consists of this teeming, vibrating system of conscious energy, all around, between and through everything."[6]

As an artist, I am interested in identifying both similarities and differences in the way that artists and scientists approach creativity and research in order to see and understand the world. One time, when Petra and I were out walking together, while I was busy admiring the colours of falling autumn leaves, Petra was noticing how the forces of the wind made the leaves twist in tiny hurricanes. Nevertheless, the similarities in our processing methods are extensive: they include problem-solving, decision-making, editing, making connections, learning from failures and mistakes, moments of discovery and direct observation.

Although we both simultaneously love and hate our work, our intrinsic drives differ. While I comprehend the world through processing imagery and finding multiple answers to the questions I ask, Petra's research is driven by the things that don't make sense in the normal world and finding the one right answer. During this investigation I became aware of a flaw in my questions, because they were constructed from my perceptions as a visual thinker. Because pictures like movie stills are constantly flickering through my head, I kept asking Petra, "What do you see when you are working on a code?" This question remained unanswered until I changed those limiting words.

Our partnership on the *Trapping Atoms* project had the added characteristic of being a mother-and-daughter relationship. This made for ease of access to each other during the project. We did not have to set up formal meetings or establish social conventions, and consequently tacit knowledge-sharing flowed efficiently. A quick text or Facebook message offered critique or support. Whenever we met up incidentally, we would usually turn to the project at some point. One day over coffee we each recorded six words that came to mind when thinking about our own work: probe, experiment, trap, layer, scattering, print, register, coherence, reflect, potential, state, code. Which terms belong to whom? Our closeness meant that I could not trick Petra into letting me using an image I had fallen in love with but that was not relevant to the project. (Google 'Bubble Chamber images' and you will understand my distraction.) Our relationship also meant that it was possible for the artwork to become a hybrid work, not just in content but also in practical terms.

Petra spent some time printing solar plates and scratching mirrors, and enjoyed the physicality of working with graphics that she usually only sees on a computer screen. She wrote to me:

> I have found this project interesting as I like seeing what things an artist would be interested in, and it reminds me of the reason I started doing this in the first place. I have also found it valuable explaining my research to a different audience. I did Honours last year and have since started my

PhD, so I am relatively new to the research world. This means I am used to presenting to people from a similar level of physics education to me, up to professors who seem to know everything! Communicating my research to people with no physics background is naturally very different to this, and I have enjoyed thinking how to do it.

Interestingly, a neutral platform where our science and art disciplines could meet was created through writing about *Trapping Atoms*. Although we approached writing with the primary goal of communicating what we were doing to other people, our communications turned inwards and impacted on us personally. Part-way through our project, Petra and I jointly wrote a short presentation for one of the Art and Light meetings which gave us clarity and elicited feedback on what we were actually doing, and in turn provided the springboard for the next development. Writing a floor talk, preparing a catalogue brief and retrospectively putting words together for this article all served to clarify our distinctive thought processes and rewarded us with momentary sensations of two separate minds merging into one.

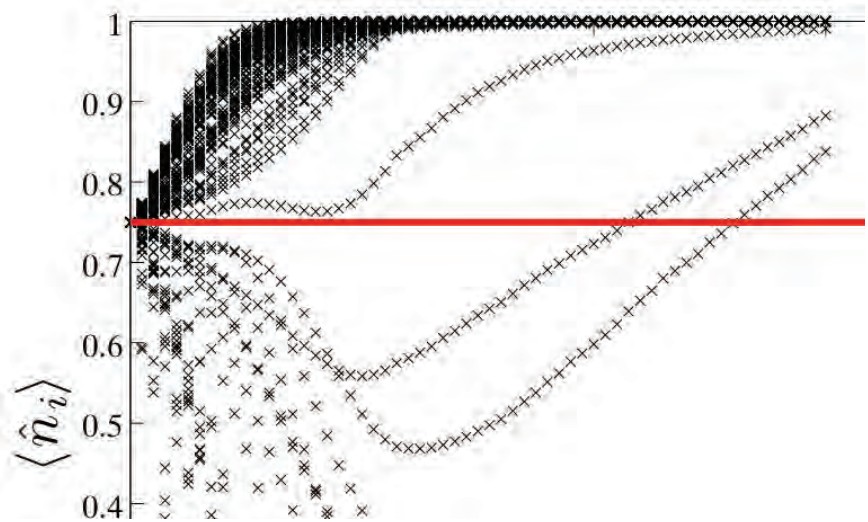

Figure 2. A graph showing changes in the position of atoms when random specks of light are added to an optical lattice.

Despite Petra's increasing ability to describe quantum physics in layman's terms, in the beginning I could not conceive what to make of such complex information and so resorted to the best way for me to start resolving anything, which is to process images. I began with scanning Petra's physics information and *LaTeX*[7] formulas, as well as collecting images off the web, until I had a reasonable folderful of material to choose from. I proceeded to alter these graphics digitally, mostly using Photoshop or CorelDraw, in a way that mimicked Petra's research processes. For example, because numbers in her codes may be either ordered or disordered, I got a packet of laser-cut numbers and scattered them across the scanner bed, then ordered some and left others where they fell and recorded the result. As she uses a cross for a graph marker (Figure 2), I applied a cross "trace" pattern over a digital image of the cover of the 1704 edition of Newton's *Opticks*.[8] This led in turn to the squiggles found in Feynman's diagrams[9] inspiring me to apply a Photoshop filter to distort and abstract some of Petra's text. My image choices were literal: an eye for optics, a red dot for the laser, and a brain for a brain. (Although the installation included an upside-down, back-to-front brain, as sometimes making a cerebral shift physically feels like this!) There came a connecting point in the project where I began drawing imagery that was the equivalent of an optical lattice for me in the art world, like a crochet doily. These drawings and text were then printed out onto transparency film using a laser copier.

I photo-etched these transparencies onto light-sensitive photopolymer plates—fittingly, a medium where graphics become entrapped within an acrylic matrix through a process involving exposure to UV light.[10] These plates are inked and printed onto paper using an etching press. This photo-etching approach to printmaking allows for relatively easy reproduction of certain kinds of images and graphics. Text, for example does not have to be written in reverse, which is why photopolymer plate, commonly referred to as solar plate amongst artists, was developed for the letterpress industry. Because I use a clear plastic-backed solar plate, I can look through the plate and get an indication of how and where the matrix will print, so I don't need to use a mirror or complicated registration beds. However, with computer-generated imagery—especially in this instance where the source material mainly takes the form of maths coding—the solar plate produces an even tonal quality which I find too mechanical and smooth in appearance.

Figure 3. Lynn Taylor, selection of papers printed from light-sensitive photopolymer plates, with 30mm circles punched through them.

I offset this flatness of tone in different ways, mainly by deliberately underexposing the plates so as to leave irregularities that produce a bit of "bite" and some unexpected surprises. I like to leave a trace of the maker's hand by leaving some plate tone when inking up. I build prints up in layers by running several plates through the press until the paper is saturated with ink. Graphic surprise abounds and some prints are layered to the point of visual confusion, echoing my own confusion with understanding the science content in *Trapping Atoms*. From this activity, an unexpected graphic parallel to an atom's ability to exist in a twin state—either wave-like or particle-like—emerged. By a traditional printmaking convention, sheets are printed from a plate to create an edition of prints that all look the same. If a subsequent edition is printed where significant changes have been made, it is signed as a "second state." In *Trapping Atoms*, the plates have been printed over each other on paper multiple times, so every print can be considered to constitute a different "state."

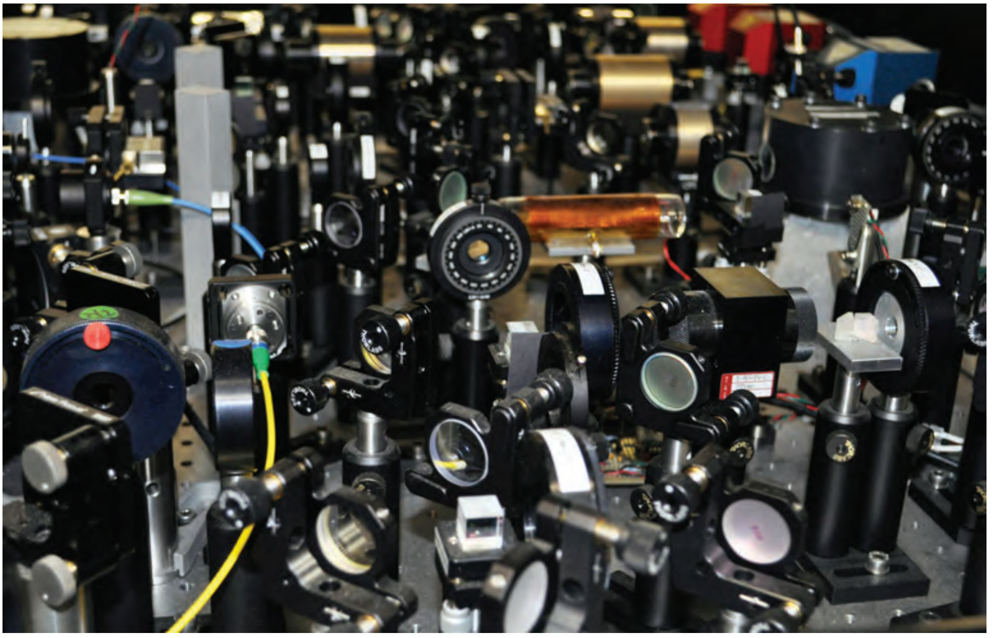

Figure 4. Laser equipment in Niels Kjærgaard's Light and Matter Laboratory at Otago University.

Masters student Kris Roberts, who is undertaking experimental research similar to Petra's, took me on a tour of Niels Kjærgaard's Light and Matter Laboratory at Otago University so that I could "see" the practical application of Petra's theoretical research. Normally I take lots of photos on field trips, which I did on this occasion. My other normal pattern is to record everything in a workbook. Yes, I had purchased a workbook, but the pages remained empty. In a desperate bid to change the way I work and move forward, I mimicked Petra's way of problem-solving whereby she writes everything up on a whiteboard. I got some black builder's paper and white chalk and started brainstorming with a view to identifying what fascinates me about catching atoms with light. In the lab the lenses stood out for me, probably because I could relate them to a camera, a connection which prompted me to deconstruct some old cameras. Lenses, mirrors, dials, prints and chalk words were arrayed around me as I explored the notion that in the quantum world, atoms change when they are observed. How, I wondered, could I make an artwork that changes when you look at it?

The idea evolved of making round pendants, containing graphics and text relating to physics theory, set behind mirrors or lenses. To achieve this, 30mm circles were punched out of the material I had already printed; to supplement these, I made some additional images and prints to specifically fit the uniform bezels on these pendants. I tried printing directly onto the glass mirror discs—but

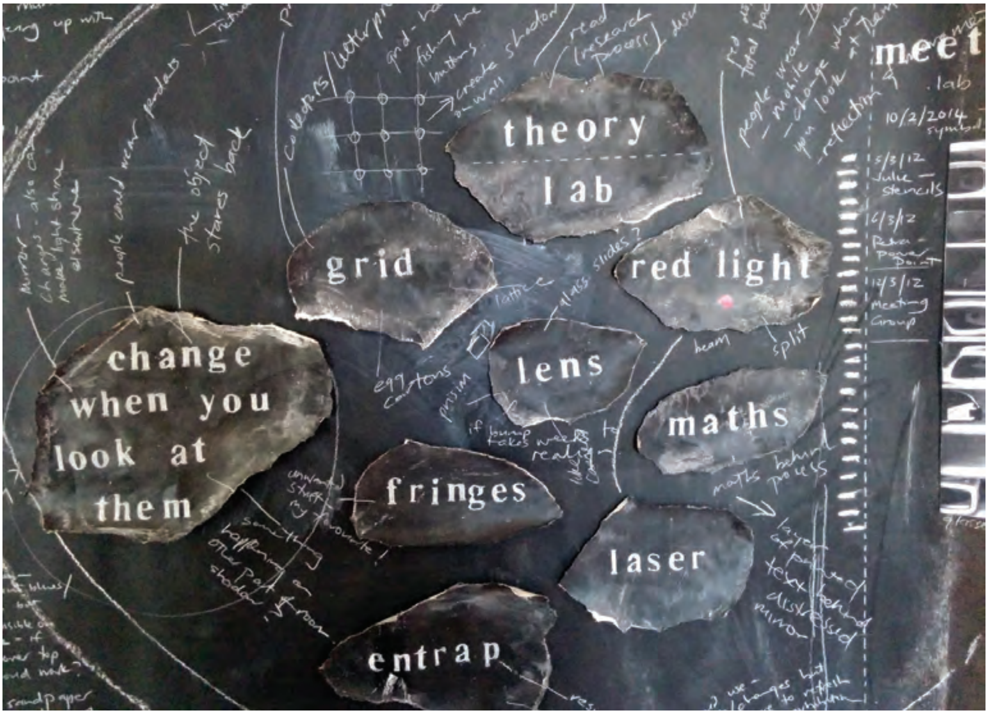

Figure 5. Visualising and imagining – a detail of Lynn Taylor's studio blackboard.

let's just say I clocked up quite a bit of bad luck trying this. A more successful approach involved adding extra layers of "disturbance" through scratching, distressing and glass-etching the mirrors, to suggest information getting lost or being able to be seen in different ways. After trialling multiple combinations, each print and mirror layer was trapped in a pendant bezel using clear resin. My biggest fear at this point in the project was that the Trapping Atoms installation would end up looking like a giant glitter ball.

Together, Petra and I installed *Trapping Atoms* by hanging the pendants off long ball chains from a wire lattice. Craig Scott, head of design at Otago Museum, where the work was shown, lined the wall behind the installation with a mirror in order to echo the smaller mirrors that were part of the work. As a result, when a viewer entered the space their reflection became part of the work, as if they were "wearing" the pendants. Another interesting fact about atoms is that they can be paired, so that if one is affected a linked atom will display a change in behaviour, even if it is on the other side of the world. Likewise, these pendants displayed coherency of a kind by reflecting and shining light on each other. Pendants are usually seen being worn on an individual, and we like the idea that after the exhibition the pendants disperse, they are touched, they are worn and so the art is mobile—rather like the marbles analogy Petra gave to describe the probability of finding an atom in a particular place. Both pendants and atoms could be here, they could be there, they could be anywhere.[11]

Figure 6. Lynn Taylor, one of the trial installations for *Trapping Atoms* (2015), exploring various ways of arranging the pendants used in the work.

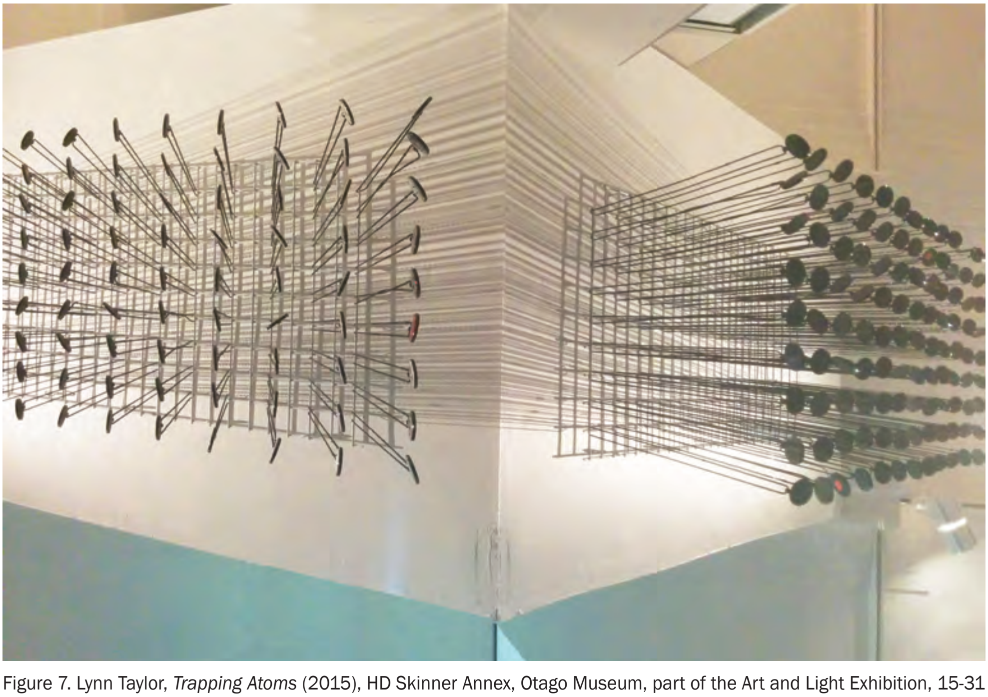

Figure 7. Lynn Taylor, *Trapping Atoms* (2015), HD Skinner Annex, Otago Museum, part of the Art and Light Exhibition, 15-31 August 2015.

Petra Fersterer graduated with a BSc hons from Otago University in 2014. She is currently continuing at Otago University as a PhD student in Theoretical Physics, researching "Light scattering as a probe for ultra cold atom many body states." She has presented at IONS KOALA Conferences in 2014 and 2015. Petra also has an interest in art and is represented by Gallery de Novo, Arrowtown Gallery and local charity auctions.

Lynn Taylor graduating in 1984 with a Bachelor of Education and focused her early career on specialist art teaching. In 1998 she graduated with a Bachelor of Fine Arts, followed by a Master of Fine Arts in 2003. These dual steams operated together when she was a lecturer at the Dunedin School of Art and they continue through her work as a Visual Arts facilitator where her praxis revolves around collaborative projects which encourage audiences and groups from different sectors becoming involved in art experiences and contributing to exhibitions. She has been the recipient of Artist Residencies, and her work is held in numerous collections.
http://lynn-taylor.blogspot.co.nz/

1. Maria Popova, "The Art of Ofey: Richard Feynman's Little-known Sketches & Drawings," http://www.brainpickings.org/2013/01/17/richard-feynman-ofey-sketches-drawings (accessed 9 Aug 2015).
2. Stuart Jeffries, "When Two Tribes Meet: Collaborations between Artists and Scientists," *The Guardian*, 21 August 2011, http://www.theguardian.com/artanddesign/2011/aug/21/collaborations-between-artists-and-scientists (accessed 25 Aug 2015).
3. Ibid.
4. M Merleau-Ponty cited in Elizabeth Grosz, *Volatile Bodies: Toward a Corporeal Feminism* (Bloomington, IN: Indiana University Press, 1994), 100. See also Jeanette Winterson, *Art Objects: Essays on Ecstasy and Effrontery* (London: Vintage, 1995), 135.
5. James Elkins, *The Object Stares Back: On the Nature of Seeing* (New York: Simon and Schuster, 1996).
6. As explained by Belleruth Naparstek, cited in Sandra Weintraub, *The Hidden Intelligence: Innovation through Intuition* (Woburn: Butterworth-Heinemann, 1998), 177.
7. LaTeX is a typesetting system that includes features for technical and scientific documentation.
8. See https://en.wikipedia.org/wiki/Opticks (accessed 21 May 2015).
9. Yu-Ming Bai et al., "Revisiting the Large Extra Dimension Effects on W-pair Production at the LHC in Next-to-leading Order QCD," *Physics Review*, D85 (2012) 016008, http://inspirehep.net/record/1082448/plots (accessed 6 May 6 2015).
10. Photopolymer or solar plate can be developed as either a relief or intaglio plate, and I use both methods of processing. The more complex of these plates to make is the intaglio, where it is necessary to create columns for the ink to sit in and subsequently print tone. This process requires what is referred to as the "double exposure". Making a glass sandwich to create close contact, the plate is first exposed to the light using a random-pattern aquatint screen (stochastic screen) for 90 seconds. This hardens approximately 20% of the plate and helps create enough "tooth" for areas that are blocked by the light in the second exposure. The aquatint screen is then removed and replaced by a transparency containing the graphics. In the second exposure, also of 90 seconds, the clear areas of the transparency get a full blast of light and the acrylic polymer hardens. The blacks of the graphics—the toner from the photocopier—block the light from the partially (20%) hardened polymer underneath, leaving it mainly soft. This process is counterintuitive in that the longer the image is exposed on the plate, the lighter the image becomes. The plate is then washed out in water, and the unhardened areas of plate dissolve away with a gentle rub of a sponge, revealing a column-like structure. Finally, the plate is dried and post-hardened under light for about ten minutes before it is ready to be inked up and printed through a press.
11. One outcome we didn't consider prior to the exhibition was the extent to which the Art and Light project would become represented on social media. This online presence, mainly in the form of digital photographs, reached audiences beyond those who saw the exhibition in the Otago Museum's HD Skinner Annex, Dunedin, 15-31 August 2015. This development, too, echoes the theme of here, there and anywhere.