For a photon there is only the present

Sally Weber
Resonance Studio,
1406-D Smith Road, Austin, TX 78721 USA
Website: www.sallyweber.com
E-mail: snw@sallyweber.com

Abstract. Two works using holography to explore the unexpected that is always present. One project is an experiment in complexity and the other in light's shadow.

1. Introduction: Wonder exists where the experience does not reflect expectation
My explorations often are nourished by the works of earlier cultures or techniques. The extraordinary 30,000 year old images from Chauvet Cave in France (figure 1) and the Archimedes Palimpsest, a nearly illegible manuscript which revealed lost treatises of Archimedes (figure 2), both show profound insight and technical skill. Looking at these works offers the opportunity to compress the time span between our present and theirs and appreciate the human connection between us and the person who drew these exquisite images on a cave wall or the geometric theorems in Hellenistic Syracuse on Sicily. Displaced in time, but exhibiting a pinnacle of the technologies of their times, these ancient works are a thread of the human continuum of thought and creativity and yet, they are also the ones most susceptible to the inevitable destruction of the very materials that carry these thoughts to us.

Figure 1: (left) Detail from the horse panel at Chauvet Cave, France.
Figure 2: (right) Archimedes Palimpsest detail of an unrestored page (left) and a pseudocolor page (right) revealing the 10th century Greek translation of Archimedes text in red orthogonal to the 13th century black text of the prayer book.
Intuitive and analytic thinking might inspire insights and innovations differently, but similar human queries re-surface through the ages. The human mind has an affinity for patterns and forms and these re-emerge in different guises. Tiny perturbations in the earliest moments of the universe are thought to be the seeds responsible for the distribution of the stars and galaxies we see now. The COBE image (figure 3) of the cosmic microwave background radiation (CMB) is the remnant, the most ancient of memories, "blown up to astrophysical size by the rapid expansion and (it) becomes the seed for all the structures we see today. The pattern seen on the CMB sky is a giant image of the subatomic world."1

Figure 3: COBE satellite image of the cosmic microwave background (CMB) fluctuations are extremely faint, only one part in 100,000 compared to the 2.73 degree Kelvin average temperature of the radiation field.

The signature left by the creation of the universe still inhabits it. Nothing is lost, just recycled to appear again, potentially to be recognized or uncovered. "According to traditional thermodynamics, there is no such thing as a truly clean slate; every system always retains a memory of its past in the configuration of its atoms."2

The experience of looking at the stars compresses our sense of time. When seeing photons from hundreds of millions of light years away, 'now' is neither the origin of the star's light, nor our presence seeing it. It is both simultaneously. Einstein's theory of relativity states and quantum physics confirms that from the point of view of a photon there is no time. At the speed of light time slows down to zero. Since a photon moves at the speed of light, it sees the whole universe at once. A photon is in the perpetual present, everywhere at once. Time and space collapse into 'now'.

"Mathematics would not work at all were there no universal features to be discovered."3

2. Infinity in the Complex
Several years ago I produced a pulsed laser hologram at the Center for Holographic Art, New York to explore an idea illustrated by the ancient Hindu story of Indra's Net. The highly specular model created a secondary set of images surrounding the reconstruction source. Upon close examination, the elements of the objects formed a complex Gabor hologram centered in an array of multi-referenced images. (figures 4a & 4b) The inter-related network of images suggests the infinite reflections of the Indra's Net story and parallels both ancient and contemporary concepts of complexity. (For a detailed discussion of this project, please see the 8th ISDH Proceedings 2009, Shenzhen, China.)4

fig. 3: COBE satellite image of the cosmic microwave background (CMB) fluctuations are extremely faint, only one part in 100,000 compared to the 2.73 degree Kelvin average temperature of the radiation field.
In the ancient story, Indra, the Vedic Lord of the Gods, had an infinite net decorating his palace. At each juncture of the net there was a faceted jewel that reflected every other jewel in the net. In looking at just one gem one saw the reflection of all of the others in the infinite array. One gem was both a single entity and simultaneously intimately connected to all of the others. As a result affecting or removing one altered them all in some significant way. Francis H. Cook in commenting upon Indra's Net and its implications in Chinese Buddhism of the Tang period, states that:

"...each individual is at once the cause of the whole and is caused by the whole, and what is called existence is a vast body made up of an infinity of individuals all sustaining each other and defining each other. The cosmos is, in short, a self-creating, self-maintaining, and self-defining organism."

Unintentionally, the complex reflections of light between elements in the holographic model created an image array paralleling an idea of infinite inter-connections intuited by people in 3rd century India. The complexity structure of light in the hologram resulted from the placement of mirrors and other elements in the model which in combination with a very low reference angle of the pulsed laser established the correct configuration to create the internal Gabor hologram. Intention, intuition and recognition played roles. Time compressed for me in appreciation of people who intuited and observed light's inherent principals centuries ago and created an image in a story of vast networks of inter-connections and inter-relationships close to our conception of the complexity structures that underpin fields of study now as well as the network of galaxies. (figure 5)

fig.5: The Infrared Local Universe: this all-sky map shows galaxies in the 2MASS survey color coded by their distance from us with blue showing the nearest sources, through green to the most distant sources shown in red.
3. Speed of Shadows

Margaret Wertheim, the Director of the Institute of Figuring in Los Angeles, wrote in The Shadow Goes that though light is limited to 186,000 miles a second, a shadow is not. In theory, a shadow can travel faster than the speed of light. Since a shadow has neither mass nor energy it is not constrained by the laws of relativity. The photons emitted by a sweeping source of light, like a rotating hose spewing water, continue straight from the source. However, the rotation of a smaller circle blocking the center of the light source and creating a shadow, (she suggests a giant klieg light in space with the Batman symbol centered on it), can outpace the light as it revolves in a great circle.(figure 6)

"Just as the rim of bicycle wheel moves faster and faster than its hub, so too, away from the source our bat shadow will fly faster and faster, a consequence of the geometry that guarantees the rim of a really big wheel moves faster that a co-rotating small wheel."16

This unexpected speed of a shadow, like a disruption of the natural order, or speculation yet to be quantified, suggests that the limit of a theory might sleep within it.

Figure 6: the bat shadow

In Speed of Shadows, the installation, the shadow partially obscures a vivid orange array of light and motion beyond. Light, shadow, form, solidity, illusions and reflections juxtapose each other. The holographic real image of a blue cube surrounds the spherical black shadow. A thin, black cable hangs from the ceiling through the holographic shadow while the cable's own shadow bisects the entire holographic image. Below, a solid, black jet sphere hanging from the cable hovers over a spherical mirror. It creates a black mirror when seen from above reflecting off the jet surface. Air turbulence moves the jet sphere slowly altering its shadows and reflection in the mirror and on the sphere itself. These reflections are the active counterpoint to the illusive image above. Jet, a highly compressed wood, was the symbol in Classical lore of the darkest black. Black mirrors or black bowl with water were used for divination in Medieval Europe and for star gazing by the Maya. Lightweight and warm to the touch, jet can burn, drawing together both the shadow and the fiery holographic ring above. (figure 7, figure 8a & 8b)
Figure 7 (left) Speed of Shadows (2012)
Figure 8a & 8b (right top and bottom): details of the jet sphere and mirror

Speed of Shadows was not consciously inspired by a solar eclipse, but having seen some it certainly crept in. Experiencing the totality of a solar eclipse is a powerful experience and the lore associated with eclipses seems relevant to the challenges that arose in realizing this work. Throughout the ancient world people feared eclipses. They symbolized death of the sun, the world out of order, illness or the break down of social taboos. Some saw the shadow as either an evil spell or a wild animal attacking and eating the sun. (figure 9) Claude Levi Strauss noted that the orchestrated noise of a 'pandemonium' could scare the creature away or remove the curse.

"In the case of eclipses, it is the disruption of an order causing, by a regular chain of events, the alternation of the sun and the moon, day and night, light and darkness."  

Certainly ancient astronomers recognized the recurrent order over time and prediction of an eclipse became a powerful tool of both divination and political strategy. Einstein's 1911 prediction that a star's light would be bent by the Sun's gravity, based on his theory of relativity, was validated by measurements taken during the 1919 solar eclipse.

Figure 9: progression of partial solar eclipses and totality
"On the tiny difference, less than one second of arc, rested the choice between two theories of one of the basic forces of nature - gravity." Einstein became instantly world famous reaching "superstar status".

4. Project Production

*Speed of Shadows*’ origin was far more humble. The project began in my studio/lab in Austin, TX in 2007 with a two-part model intended for a holographic master and transfer. (figure 10a & b) Inherent optical effects from glass spheres behind the black sphere in the model burned into the silver halide and obliterated the work’s intent in the transfer. Experiments with other means to create a volumetric cube and alternate lighting and optical effects proved unsatisfactory. I set the project aside, but it was always in the background persistently nudging.

![Figure 10a: Initial model for Speed of Shadows](image1.png)  
![Figure 10b: laser illuminated model](image2.png)

In 2009 I began working with Chris Portales, a Master's candidate from Texas A&M. We developed a 3D computer model based on my physical model and specifically worked to capture the speckle of the cube and the optical qualities behind the shadow. (figure 11) The computer generated imagery looked promising but unfortunately, changes in the rendering parameters for Zebra Imaging holograms at that time could no longer accommodate the raytrace of optical qualities we hoped to accomplish. With the semester over and Chris' thesis pending, we curtailed this attempt as well.

![Figure 11: computer model for Speed of Shadows](image3.png)

Two years later while visiting The Light Foundry in Santa Fe, NM the artist and holographer, August Muth, invited me to come and try it again as a dichromate gelatin hologram. I had never worked with dichromates, but was optimistic as our initial test showed that a dichromate hologram was much more forgiving about hot spots and did not burn in as silver halide had. We anticipated two, one beam shots exposures superimposed to create the box and optical effects behind a shadow sphere that I had always visualized.
In April of 2012, I went to Santa Fe to work at The Light Foundry. We experimented with my original models but it was soon apparent that they would need to be rebuilt optimized for the dichromate holography setups. A new cube was made of glass, predistorted for a one-beam setup. (figure 12) The optical and shadow spheres model was also rebuilt using a segment of a decorative glass sphere and optic with the black sphere in front. (figure 13) The new model removed the hotspots but decreased the brightness substantially. The lowered the light level necessitated 23 minute exposures for the master. This coupled with Santa Fe's unsettled spring weather conditions, the idiosyncrasies of dichromates, lasers and holography in general converged on the very fickle eclipse-like image and shadow.

There were other unexpected convergences as well. During the holographic production shoots in Santa Fe the shadows of two different planets crossed the sun. The annual solar eclipse of May 20, 2012, (figure 14) passed directly over Santa Fe. Sixteen days later on June 5, 2012 Venus (figure 15) crossed the Sun in its last transit until 2117. We both observed these natural phenomena from Santa Fe, NM and Austin, TX respectively. However, we should have recognized them as signs and with proper foresight organized a pandemonium ourselves. It might have improved our odds.

On June 15, 2012 the hologram for *Speed of Shadows* was finally complete through the tenacity of August Muth's almost alchemistic understanding of dichromate holography. My collaboration with the Light Foundry proved a dance of light, time and space. The paradox of *Speed of Shadows* was its very
resistance to be realized. The work defined itself in some ways for only after many attempts was a balance of light, shadow, color and forms achieved. "A shadow is not a thing and has no mass. It is the absence of light, weightless and without energy." But light and shadow, like mass and gravity are tied to and reveal each other.

5. Conclusion
Over time the same questions seek new expressions. These seeds like the structure in the COBE image sleep quietly until they resurface as a thought, an expression, an image, a measurement or an equation. The itch to know is deep. The story of Indra's Net was an attempt to suggest infinity and the interconnectedness of life through imagery and metaphor. The passage of an eclipse is a natural, awe-inspiring occurrence once feared for disrupting the natural order by bringing darkness during the day, but also enabled a measurement that changed the 20th century. For a photon it is all simultaneous, but what does that mean in our experience? Both my projects, the complexity experiment, Indra, and the installation, Speed of Shadows, developed not by a direct path but by a meander and search through experimenting with optics, materials and means to explore something ephemeral; a simultaneous tug across time that could be realized only in holography.

6. Acknowledgement
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7. Illustrations
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fig: 5 Jarrett, T., The Scale Structure in the Local Universe: The 2 Mass Galaxy Catalog, 2004, PASA, 21, 396  (Opened source image:2MassRedShiftSurvey https://www.cfa.harvard.edu/~dfabricant/huchra/2mass/)
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