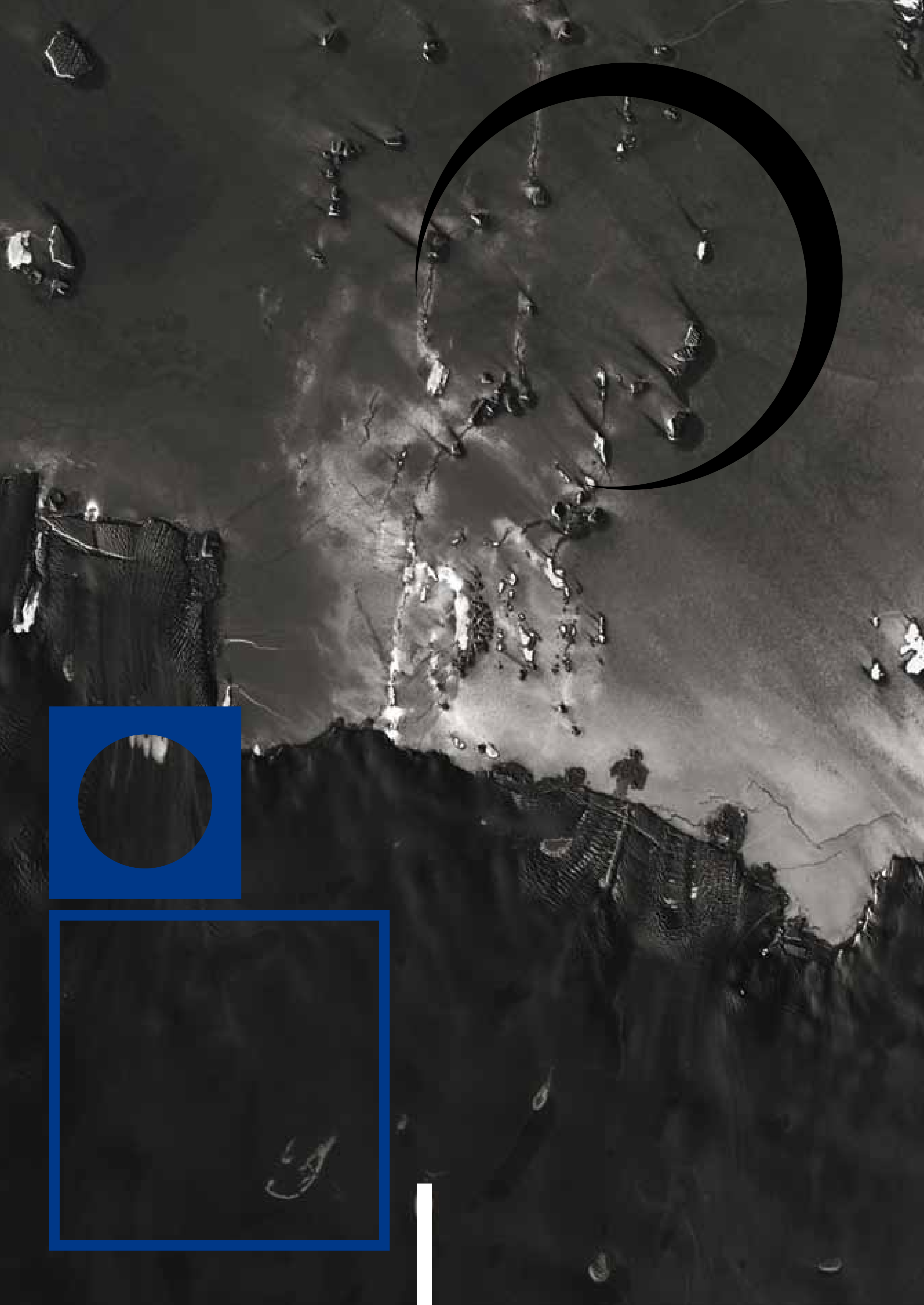
A Ray of Darkness

Kontraste Cahier N° 2

Sonic Acts Press
ISBN 978-90-810470-5-0



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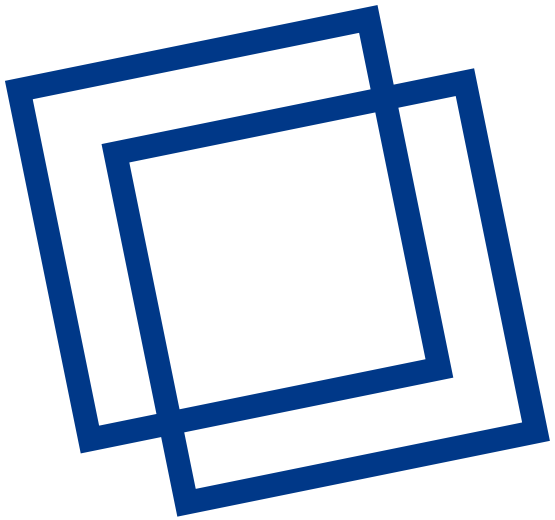
A Prelude to Dark Matter

A short overview of ideas that inspired the 2012 Kontraste festival

Arie Altena



I

Human beings are among the most visually spoiled species on Earth. Our eyes have evolved to see colour, and we have acquired hawk-like visual acuity.[1] Yet our eyes only respond to wavelengths ranging from roughly 390 to 750 nanometers. We can only see 'visible light'. Similarly, our ears are equipped with membranes that enable us to hear sound waves between—in the most extreme cases—20Hz and 20,000Hz.

We are naturally blind and deaf to a large part of the electromagnetic spectrum. We cannot directly see infrared or ultraviolet light, nor can we hear ultrasonic and infrasonic frequencies. We are used to this. Led by curiosity and the desire to explore the nature of reality we have become aware of the existence of a wider spectrum of radiation and waves. We have invented all kinds of instruments to detect and translate these, and have discovered that the electromagnetic spectrum ranges from gamma rays to radio waves. These instruments have amplified our senses, enabling us to investigate the phenomena and acquire knowledge of a greater part of electromagnetic reality.

The instruments we use to investigate the nature of reality are now immensely advanced. On 4 July 2012, CERN, the European Centre for Nuclear Research, officially announced that they had—most probably—detected the Higgs boson in the Large Hadron Collider (the largest particle accelerator ever built with a circumference of 27 kilometres, located underground near Geneva). The existence of the Higgs boson was predicted by the Standard Model of particle physics, but had never actually been 'seen'. At the same time the Planck Space Observatory of the European Space Agency orbits the Earth examining the Cosmic Microwave Background radiation at a high resolution, looking back and listening to the birth of the Universe, 13.7 billion years ago.

There have been enormous advances in the area of cosmology. Not so long ago cosmology was mostly a speculative endeavour; now the empirical evidence is accumulating to underpin cosmological theories about the birth and the nature of the universe. It suggests that we are blind to a stunning 96% of all matter and energy. Never mind that we can only see visible light, even with all our advanced instruments, 96% of the Universe is dark.

We know about the composition of the universe through a combination of observation and calculation. Astronomical data of the rotation of galaxies can only be explained by postulating the existence of dark matter, which gravitationally pulls on the galaxies. Dark matter is hidden from our view. It does not interact with the electromagnetic spectrum, it does not reflect light. The astronomer Vera Rubin mentioned the possible existence of 'dark matter' when she published her findings on the rotation of galaxies in 1970. (The term 'dunkle Materie' was first used in 1933 by the astronomer Fritz Zwicky to explain similar observations, but his suggestion was never taken seriously.) Since then scientists have attempted to theorise what dark matter might consist of, and have tried to detect it in caves and mines hundreds of metres underground, shielded from cosmic radiation. Unfortunately, without much success.

In the late 1990s, the study of the universe's expansion by analysing the light from type Ia supernovae (a type of exploding star), by teams led by Saul Perlmutter and by Adam Riess, led to another stunning hypothesis. Their data and calculations indicated that the universe was expanding much faster than previously thought. This fact can be explained by assuming the existence of dark energy. Data about the shape of the universe collected by the WMAP-satellite (The Wilkinson Microwave Anisotropy Probe, a NASA Explorer mission launched in 2001) gave credence to this hypothesis.

The analysis of all these data leads to a cosmological standard model of the composition of the universe in which only 4% of it consists of normal baryonic matter —the protons, neutron, electrons which make up the elements of the periodic table. The 'rest' is dark matter, more or less 23%, and a whopping 73% should be dark energy.

1. See Simon Ings, *The Eye: A Natural History*. London: Bloomsbury, 2007.

Not that all scientists unanimously agree on this, however. Some defend an alternative explanation: Modified Newtonian Dynamics (MOND). This theory posits that gravitational force—one of the fundamental laws of nature—functions differently on large scales than on smaller scales. Until now most evidence favours the dark matter and dark energy theory, and the adherents of MOND are a minority in the scientific world.

We live in a weird reality. We do not know what dark matter is, we know nothing of its properties, and it has not been detected in particle accelerators. Dark energy is even stranger; its presence is also predicted in every theory relating to elementary particles and quantum fields, but the calculations involved produce numbers that are way too large. Alternatively, we have to believe that we have completely misunderstood the fundamental laws of nature. We still have to build instruments that can detect and sense dark matter and dark energy. We are only beginning to explore a universe that consists of stuff other than that detected by human senses and scientific instruments.

II

Dark matter and dark energy, fascinating in themselves, are a powerful cultural imaginary for the arts, comparable to how relativity theory and quantum mechanics and their radical redefinitions of space-time, very broadly speaking, inspired twentieth-century avant-garde artists to new visions and formal innovations.

Artists are on a similar quest to scientists when they explore the unknown aspects of our world. For instance, they build installations or invent their own instruments that enable visitors to experience phenomena beyond the visible and audible spectrums. Metaphorically speaking one could say that their works present shadows of such phenomena so as to render the unimaginable. The shadows are perceived by our senses and processed by our brain in unexpected ways. There are artists who work with radio waves, laser light or infrasonics, and manipulate the signals to amplify our senses, investigate the dark, and perhaps provide a glimpse of cosmological unknowns. Or at least we can imagine it so.

I do not want to imply that all the works presented at the 2012 Kontraste Festival are inspired by cosmology or current astrophysical research, nor that all these works are part of the same quest that science is involved in. Not even all the invited artists work with radiation beyond the range of human perception—but some do. Rather, it is the idea of works of art as instruments that might help us sense the full spectrum of reality, and cosmology with its theories of dark matter and dark energy, which gives a context to Kontraste 2012.

Several works make us see things ‘in the brain’ through a poetic manipulation of light. What we see in these works cannot be reduced to a projected image. Matthew Biederman’s *Event Horizon* achieves this with red, blue and green colour fields, interspersed with black. Matthijs Munnik’s *Lightscape* explores the borders of our sensory hardware, using flickering coloured light. While the eye tries to make sense of this sensory overload, detailed patterns and colour combinations form in the retina and are fed to the brain. Ivana Franke seats her audience in front of LEDs that flicker at different speeds to induce a quasi-hallucinatory visual experience of flowing images behind closed eyes. Otolab’s performance *Bleeding* is based on the phenomena of retinal persistence coupled with an overload of stimuli, resulting in a perceptual ambiguity that cannot be reduced to visual signals. In the audiovisual performance *COVEX*, Yamila Ríos and Joris Strijbos investigate the relations between electroacoustic sound and diffracted light patterns, Strijbos shoots laser beams through transparent objects to create ‘speckle patterns’ and abstract landscapes of evolving shapes.

There is also a shadow history of experimenters from the eighteenth to the twentieth century who were attempting to understand electromagnetic energy and put it to functional use. Their work resulted in the technology we use today, and also spawned ideas about, for example, animal magnetism, electrotherapy, earth energy, and

neuroscience. Some of these notions were totally crackpot, others evolved into new scientific approaches. Justin Bennett’s new work *Spectral Analysis* explores this history.

There are also other ways to seduce, bewitch or augment our senses. The idea behind Makino Takashi’s film *The Intimate Stars* was to visualise the images of light that are left on the retina when we shut our eyes. In *Aberration of Light: Dark Chamber Disclosure* Sandra Gibson and Luis Recoder use film loops, crystals and manual gestures to bend, reflect and refract the light beam from a film projector to create a hypnotic light sculpture. In his site-specific installation *Fray* Raviv Ganchrow meticulously investigates the acoustics of a roadway tunnel in Durnstein, Austria, unveiling a subtlety of spatial sound that usually escapes us. *~~Kulunka~~* by Yolanda Uriz Elizalde evokes visual and tactile ways to perceive vibrations. She uses inaudible frequencies to generate audible overtones, visible wave patterns and vibrations that can be felt. The Synchronatorchestra manipulates analogue audio and video signals to create noise; in fact there is a freedom to play with the signals, tap into unexpected channels, or stumble into the unknown—one just has to remember that 5 to 10% of the snow of an un-tuned analogue television channel is actually cosmic background radiation.

All these works amplify our senses to hint at the reality beyond human perception. They tap into the ‘life’ of electrical signals, and explore the unknown. Let’s say they are a leap into the void—metaphorically searching for the dark matter and dark energy that eludes our eyes and ears.

Field Notes on Dark Matter

A collection of quotes from different sources

Selected and arranged
by Arie Altena

1/35

'Today, as we have done for centuries, we gaze into the night sky from our planetary platform and wonder where we are in this cavernous cosmos. Flecks of light provide some clues about great objects in space. And what we do discern about their motions and apparent shadows tells us that there is much more that we cannot yet see.'

2/35

'What do we know … of the world and the universe about us? Our means of receiving impressions are absurdly few, and our notions of surrounding objects infinitely narrow. We see things only as we are constructed to see them, and can gain no idea of their absolute nature. With five feeble senses we pretend to comprehend the boundlessly complex cosmos, yet other beings with wider, stronger, or different range of senses might not only see very differently the things we see, but might see and study whole worlds of matter, energy, and life which lie close at hand yet can never be detected with the senses we have.'

3/35

'In 1609 Galileo had discovered that looking farther into space than what he could see with the naked eye led to seeing *more* of the universe. Since the middle of the twentieth century, astronomers had discovered that looking farther along the electromagnetic spectrum than what they could see with an optical telescope led to seeing even more of the universe—including the echo of its origins. And now (…) you could ask (…) How could you possibly see farther than the electromagnetic spectrum—farther than seeing itself?'

4/35

'Understanding something you cannot see is difficult—but not impossible.'

1. Vera Rubin, 'Dark Matter in the Universe', in *Scientific American Presents (special quarterly issue: Magnificent Cosmos)* 9, no. 1, 1998, pp. 106–10.

2. H.P. Lovecraft, 'From Beyond', in *The Fantasy Fan* , 1934 (written in 1920). en.wikisource.org/wiki/From_Beyond

3. Richard Panek, *The 4% Universe. Dark Matter, Dark Energy, and the Race to Discover the Rest of Reality.* Boston, New York: Mariner Books 2011, p. 54.

4. Vera Rubin, 'Dark Matter in the Universe', in *Scientific American Presents (special quarterly issue: Magnificent Cosmos)* 9, no. 1, 1998, pp. 106–10.

5/35

'This is the enigma which we must confront: *mathematics' ability to discourse about the great outdoors; to discourse about a past where both humanity and life are absent.*'

6/35

'The search for the Standard Model Higgs boson at the LHC is reaching a critical stage as the possible mass range for the particle has become extremely narrow and some signal at a mass of about 125 GeV is starting to emerge. We study the implications of these LHC Higgs searches for Higgs portal models of dark matter in a rather model independent way. Their impact on the cosmological relic density and on the direct detection rates are studied in the context of generic scalar, vector and fermionic thermal dark matter particles. Assuming a sufficiently small invisible Higgs decay branching ratio, we find that current data, in particular from the XENON experiment, essentially exclude fermionic dark matter as well as light, i.e., with masses below 50 GeV, scalar and vector dark matter particles. Possible observation of these particles at the planned upgrade of the XENON experiment as well in collider searches is discussed.'

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5. Quentin Meillassoux, *After Finitude: An Essay on the Necessity of Contingency.* London: Continuum 2008, p. 26.

6. Abdelhak Djouadi, Oleg Lebedev, Yann Mambrini, Jeremie Quevillon, 'Implications of LHC searches for Higgs – portal dark matter', December 2011. <arXiv:1112.3299v3>

7/35

'There was a time, not so long ago, when science seemed to understand how the universe worked. Everything —us, the Earth, the stars and even exotic-sounding supernovae—was made of atoms which were all created at time-zero: the Big Bang. In between the atoms was nothing, a void: quite literally, "space". But recently things have started to unravel. There is, it seems, a lot more to the universe than meets the eye. According to the best estimates, we only really know what about 4% of it is made of. But if only 4% is made of atoms, what about the rest? The rest is made of mysterious entities about which very little is understood, with equally mysterious names: dark matter and dark energy.'

8/35

'I have to admit that I find neither discovery (of dark matter and dark energy) all that mysterious. To me, the word *mystery* conveys something that completely eludes rational explanation. The discoveries of dark matter and energy were surprises but not mysteries.'

9/35

'Based on 50 years of accumulated observations of the motions of galaxies and the expansion of the universe, most astronomers believe that as much as 90 percent of the stuff constituting the universe may be objects or particles that cannot be seen. In other words, most of the universe's matter does not radiate—it provides no glow that we can detect in the electromagnetic spectrum. First posited some 60 years ago by astronomer Fritz Zwicky, this so-called missing matter was believed to reside within clusters of galaxies. Nowadays we prefer to call the missing mass "dark matter", for it is the light, not the matter, that is missing.'

10/35

'(O)ur ignorance about dark matter's properties has become inextricably tangled up with other outstanding issues in cosmology—such as how much mass the universe contains, how galaxies formed and whether or not the universe will expand forever.'

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7. Text for the BBC Horizon documentary *Most of Our Universe is Missing*, 2006. www.bbc.co.uk/sn/tvradio/programmes/horizon/missing.shtml

8. Leonard Susskind, *The Cosmic Landscape. String Theory and the Illusion of Intelligent Design.* New York: Little, Brown and Company 2006, p. x.

9 & 10 Vera Rubin, 'Dark Matter in the Universe', in *Scientific American Presents* (*special quarterly issue: Magnificent Cosmos*) 9, no. 1, 1998, pp. 106–10.

11/35

‘So here is what we know with good confidence. First the ordinary mass in the universe, stars, gas, clouds, and dust, is not sufficient to make the universe flat. (…) Without other hidden sources of matter, the universe would be open and negatively curved. But there is more matter in the universe, about ten times more, that we know about by its gravitational effects. It may be made up of new elementary particles that hardly interact with the usual kind. These dark-matter particles, if that’s what they are, would fill the galaxy, passing right through the sun, the earth, and even us. But they are still not enough to make the universe flat or closed. If the universe is flat, another kind of mass or energy must be pervading space.’

12/35

‘When we observe the orbits of stars and clouds of gas as they circle the centers of spiral galaxies, we find that they move too quickly. These unexpectedly high velocities signal the gravitational tug exerted by something more than that galaxy’s visible matter. From detailed velocity measurements, we conclude that large amounts of invisible matter exert the gravitational force that is holding these stars and gas clouds in high-speed orbits. We deduce that dark matter is spread out around the galaxy, reaching beyond the visible galactic edge and bulging above and below the otherwise flattened, luminous galactic disk.’

13/35

‘The galaxies are all heavier than the astronomers had thought. Roughly speaking, every galaxy is about ten times more massive than all the visible stars and interstellar gas that it contains. The remaining nine-tenths of the mass is a mystery. It is almost certainly not made of the things that comprise ordinary matter: protons, neutrons, and electrons. Cosmologists call it dark matter: dark because it gives off no light. Nor does this ghostly matter scatter light or allow itself to be visible in any form, except through its gravity. So strange is modern science.’

11. Leonard Susskind, *The Cosmic Landscape. String Theory and the Illusion of Intelligent Design*. New York: Little, Brown and Company 2006, pp. 160–1.

12. Vera Rubin, ‘Dark Matter in the Universe’, in *Scientific American Presents* (*special quarterly issue: Magnificent Cosmos*) 9, no. 1, 1998, pp. 106–10.

13. Leonard Susskind, *The Cosmic Landscape. String Theory and the Illusion of Intelligent Design*. New York: Little, Brown and Company 2006, p. 147.

14/35

‘Dark matter is the dominant form of matter, apparently observed to be present in the initial stages of our own aeon. It comprises some 70% of ordinary matter (where ‘ordinary’ just means not counting the contribution of the cosmological constant Lambda—commonly referred to as ‘dark energy’), but dark matter does not seem to fit at all comfortably into the standard model of particle physics, its interaction with other kinds of matter being solely through its gravitational effect.’

15/35

‘Subtler ways to detect invisible matter have recently emerged. One clever method involves spotting rings or arcs around clusters of galaxies. These “Einstein rings” arise from an effect known as gravitational lensing, which occurs when gravity from a massive object bends light passing by.’

16/35

‘There is now compelling evidence for the Lambda-CDM or the “Standard Model” of cosmology according to which the energy of the universe is about 74% dark energy, 22% Dark Matter, and 4% baryonic matter. There have been independent confirmations of the dark energy component of the universe from observations of high redshift Type Ia supernovae. The evidence for Dark Matter is even more compelling from the study of galactic rotation curves, acoustic oscillations in the cosmic microwave background, large scale structure formation, and gravitational lensing.’

14. Roger Penrose, *Cycles of Time. An Extraordinary New View of the Universe*. London: The Bodley Head 2010. p. 161.

15. Vera Rubin, ‘Dark Matter in the Universe’, in *Scientific American Presents* (*special quarterly issue: Magnificent Cosmos*) 9, no. 1, 1998, pp. 106–10.

16. S.M. Carroll, S. Mantry, and M.J. Ramsey-Musolf, ‘Implications of a Scalar Dark Force for Terrestrial Experiments’, in *Physical Review* D 81, 2010. <arxiv:0902.4461>

17/35

'The existence of dark matter is abundantly clear to astronomers, who can see its gravitational effect on galaxies and clusters of galaxies through their telescopes. But its nature is a mystery: the stuff is utterly transparent, and passes through stars and planets as if they weren't there. A prevailing theory holds that it is a haze of weakly interacting massive particles (WIMPs) that formed during the Big Bang, and have permeated the Universe ever since. The trick is to catch and study WIMPs in a laboratory detector—a task that, once again, requires ultra-low background radiation.'

18/35

'The tradition of postulating new, hard-to-detect particles began when Wolfgang Pauli correctly guessed that radioactivity involved an almost invisible particle called the neutrino. Dark matter is not made of neutrinos, but by now physicists have postulated plenty of particles that could easily form the invisible stuff. There is no mystery there—only the difficulties of identifying and detecting those particles.'

19/35

'When dark matter collides with the nucleus of a xenon atom, a tiny light flash will be seen. This light flash is generated by the recoil that the xenon atom has experienced. Dark matter will not be made visible in this research; it remains an indirect process in which the researchers will prove the presence of dark matter by its reaction with a particle known to us. The detector can distinguish between the WIMP and possible leftover background radiation. The researchers hope that on the basis of the measurements they are able to prove it is indeed a new subatomic particle, and determine what the mass of the particle is and what its likelihood of interaction with ordinary matter is exactly.'

17. Nicola Nosengo, 'Gran Sasso: Chamber of Physics', in *Nature*, 23 May 2012. www.nature.com/news/gran-sasso-chamber-of-physics-1.10696

18. Leonard Susskind, *The Cosmic Landscape. String Theory and the Illusion of Intelligent Design*. New York: Little, Brown and Company 2006. p. x.

19. Text on the Nikhef website about dark matter research. www.nikhef.nl/en/science-technology/astroparticle-physics/donkere-materie/xenon-1t/#c1251

20/35

'The early universe was a liquid-like plasma of protons and electrons in which light was trapped, with dark matter also part of the mix. "Baryons" (ordinary matter) moved in "acoustic oscillations" (sound waves) through the plasma. When the Universe cooled enough for the protons and electrons to combine into hydrogen atoms, the photons were freed and the Universe became transparent. The dark matter stayed invisible, but variations in density left their mark in the CMB (Cosmic Microwave Background radiation) and were the seeds of large-scale structure in today's universe, such as clusters of galaxies.'

21/35

'In the 1990s, scientists studying exploding stars called supernovae in far-flung galaxies discovered that the Universe's expansion is accelerating, not slowing as theorists predicted. This discovery led them to the conclusion that some unknown process was causing the Universe to speed up, and they named it dark energy.'

22/35

'(I)t seems likely that the standard model is missing some fundamental physics. Perhaps we need some new kind of accelerating energy—a "dark energy" that, unlike Lambda, is not constant.'

20. Paul Preuss, 'The Evolving Search for the Nature of Dark Energy, Part 2, Baryon Acoustic Oscillation: A Very Large Standard Ruler', Berkeley Lab Newscenter. 2009. newscenter.lbl.gov/feature-stories/2009/10/27/evolving-search-2

21. Text for the BBC Horizon documentary *Most of Our Universe is Missing*, 2006. www.bbc.co.uk/sn/tvradio/programmes/horizon/missing.shtml

22. Saul Perlmutter, 'Supernovae, Dark Energy, and the Accelerating Universe', in *Physics Today* 53, April 2003. supernova.lbl.gov/PhysicsTodayArticle.pdf

23/35

'Independent evidence from measurements of the cosmic microwave background and other estimates of the matter density of the Universe provided early support for the radical idea of dark energy. Newer and quite different techniques, including weak lensing and baryon acoustic oscillations, are now poised to offer unique insights into what Nobel Prize-winner Frank Wilczek has called "the most fundamentally mysterious thing in basic science".'

24/35

'The cosmological constant is equivalent to another term that may be easier to picture: vacuum energy (…) The vacuum is empty space. By definition it is empty, so how can it have energy? The answer lies in the weirdness brought to the world by quantum mechanics, the weird uncertainty, the weird granularity, and the weird incessant jitteriness. Even empty space has the "quantum jitters". Theoretical physicists are used to thinking of the vacuum as being full of particles flickering in and out of existence so quickly that we cannot detect them under normal circumstances.'

25/35

'But vacuum energy is very different. It's a property of empty space. When empty space expands it's still just empty space, and the energy density is exactly what it was originally. No matter how many times you double the size of the universe, the vacuum energy density stays the same, and its repulsive effect never diminishes!'

23. Paul Preuss, 'The Evolving Search for the Nature of Dark Energy, Part 1, Supernovae as Standard Candles', Berkeley Lab Newscenter. 2009. newscenter.lbl.gov/feature-stories/2009/10/27/evolving-dark-energy

24. & 25. Leonard Susskind, *The Cosmic Landscape. String Theory and the Illusion of Intelligent Design*. New York: Little, Brown and Company 2006, p. 72. & p. 264.

26/35

'Three-quarters of the Universe is dark energy, but nobody knows what it is. An unknown form of energy that fills space? Some kind of "antigravity" matter? Is it caused by extra dimensions of the cosmos, or is it just a flaw in Einstein's theory of gravity?'

27/35

'Like dark-matter astronomers, dark-energy astronomers had to confront a paradoxical question: How do you see something you can't see? And like dark-matter astronomers, they had to expand their understanding of "seeing" until it could encompass some manner of "coming into contact with".'

28/35

'The dark energy evinced by the accelerating cosmic expansion grants us almost no clues to its identity. Its tiny density and its feeble interactions presumably preclude identification in the laboratory. By construction, of course, it does affect the expansion rate of the universe, and different dark-energy models imply different expansion rates in different epochs. So we must hunt for the fingerprints of dark energy in the fine details of the history of cosmic expansion.'

29/35

'In spite of such strong evidence for the existence of dark energy and Dark Matter, almost nothing is known about their properties. The simplest explanation of dark energy is a small but non-zero cosmological constant. The Dark Matter properties such as its mass, quantum numbers, and interactions with the Standard Model remain unknown. Furthermore, it remains to be seen if there is only one type of Dark Matter particle responsible for all of the observational evidence, or if there exists a rich spectrum of Dark Matter particles analogous to the complexity seen in the visible sector.'

26. Paul Preuss, 'The Evolving Search for the Nature of Dark Energy, Part 1, Supernovae as Standard Candles', Berkeley Lab Newscenter. 2009. newscenter.lbl.gov/feature-stories/2009/10/27/evolving-dark-energy

27. Richard Panek, *The 4% Universe. Dark Matter, Dark Energy, and the Race to Discover the Rest of Reality.* Boston, New York: Mariner Books 2011, pp. 207–8.

28. Saul Perlmutter, 'Supernovae, Dark Energy, and the Accelerating Universe', in *Physics Today* 53, April 2003. supernova.lbl.gov/PhysicsTodayArticle.pdf

29. S.M. Carroll, S. Mantry, and M.J. Ramsey-Musolf, 'Implications of a Scalar Dark Force for Terrestrial Experiments', in *Physical Review* 81, 2010. <arxiv:0902.4461>

30/35

‘We live in an unusual time, perhaps the first golden age of empirical cosmology. With advancing technology, we have begun to make philosophically significant measurements. These measurements have already brought surprises. Not only is the universe accelerating, but it apparently consists primarily of mysterious substances. We’ve already had to revise our simplest cosmological models. Dark energy has now been added to the already perplexing question of dark matter. One is tempted to speculate that these ingredients are add-ons, like the Ptolemaic epicycles, to preserve an incomplete theory. With the next decade’s new experiments, exploiting not only distant supernovae, but also the cosmic microwave background, gravitational lensing of galaxies, and other cosmological observations, we have the prospect of taking the next step toward that “Aha!” moment when a new theory makes sense of the current puzzles.’

31/35

‘As I see it, science is slowly and painstakingly excavating the deep structure of a reality whose fundamental features may turn out to bear little resemblance to the kinds of entities and processes with which we are currently familiar.’

32/35

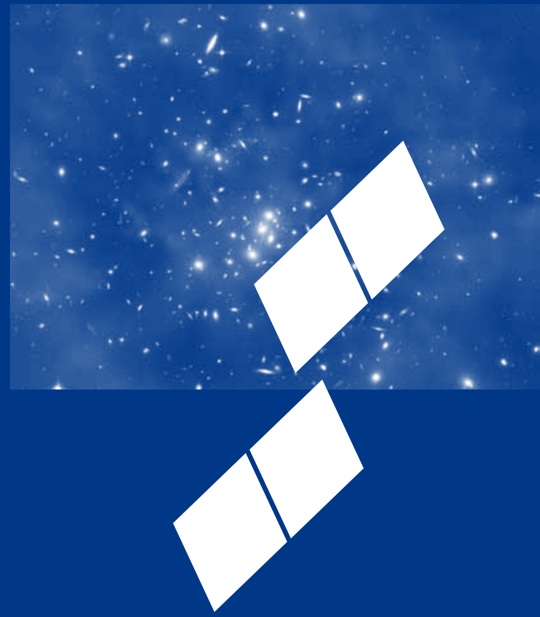
‘My conviction is that the sources and structures of human experience can and will be understood scientifically, but this integration of experience into the scientific worldview will entail a profound transformation in our understanding of what it means to be human—one as difficult for us to comprehend from within the purview of our current experience as the latter would have been for our hominid ancestors.’

30. Saul Perlmutter, ‘Supernovae, Dark Energy, and the Accelerating Universe’, in *Physics Today* 53, April 2003. supernova.lbl.gov/PhysicsTodayArticle.pdf

31. & 32. ‘Against an aesthetics of noise’, Ray Brassier interviewed by Bram Ieven, *nY*, 2009. www.ny-web.be/transitzone/against-aesthetics-noise.html

33/35

‘It seems to me that the astronomer confronted with the mysteries of dark matter and dark energy and the artist trying to make sensible the very real but incommensurable phenomena of quantum mechanics find themselves in a connected search for a Sublime, for those moments of an inkling of a perhaps larger context that we only glimpse partially. For the scientist the potential horror in the Sublime would be the incomprehensibility, unpresentability, of the world; perhaps for the artist the reverse?’



34/35

‘There is a reality that transcends the bounds of possible human experience set out by Kant, but we are learning that it is populated by “things” about which it is proving increasingly difficult to say “what” they are, using the resources of sense currently available to us. We will have to forge new vocabularies to be able to say what these things are. Admittedly, this still has a “speculative” ring, but I would like to insist that metaphysical speculation be constrained by scientific knowledge.’

35/35

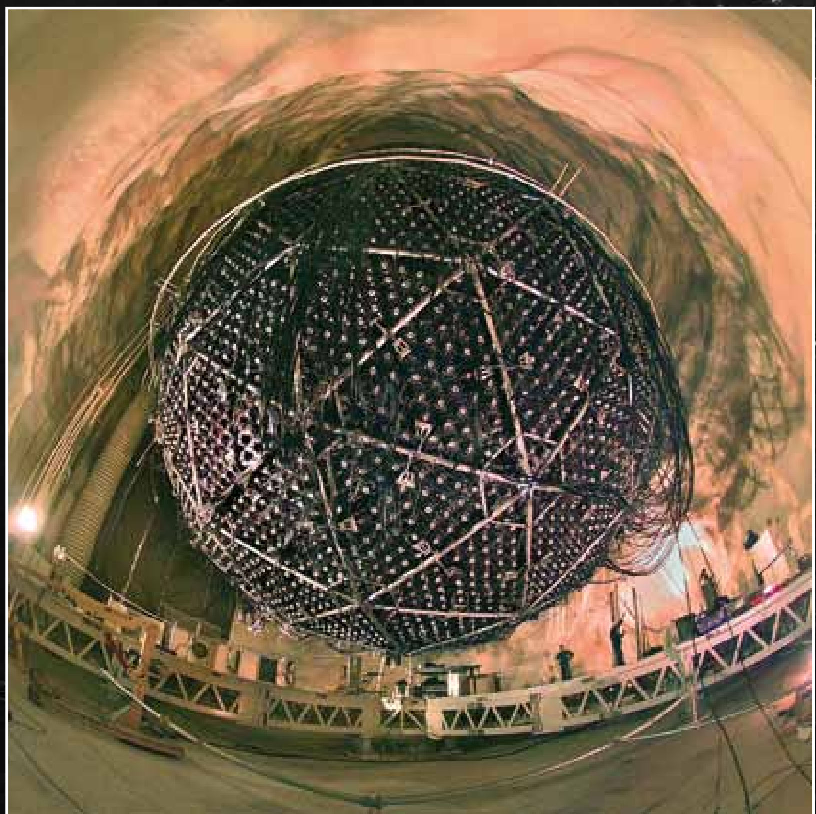
‘The time has come when the normal revolt against time, space, and matter must assume a form not overtly incompatible with what is known of reality—when it must be gratified by images forming supplements rather than contradictions of the visible and measurable universe.’

33. Roger Malina, ‘Is there a Role for the Sublime in Artscience Today?’. May 2012. malina.diatrope.com/2012/05/28/is-there-role-for-the-sublime-in-artscience-today

34. ‘Against an aesthetics of noise’, Ray Brassier interviewed by Bram Ieven, *nY*, 2009. www.ny-web.be/transitzone/against-aesthetics-noise.html

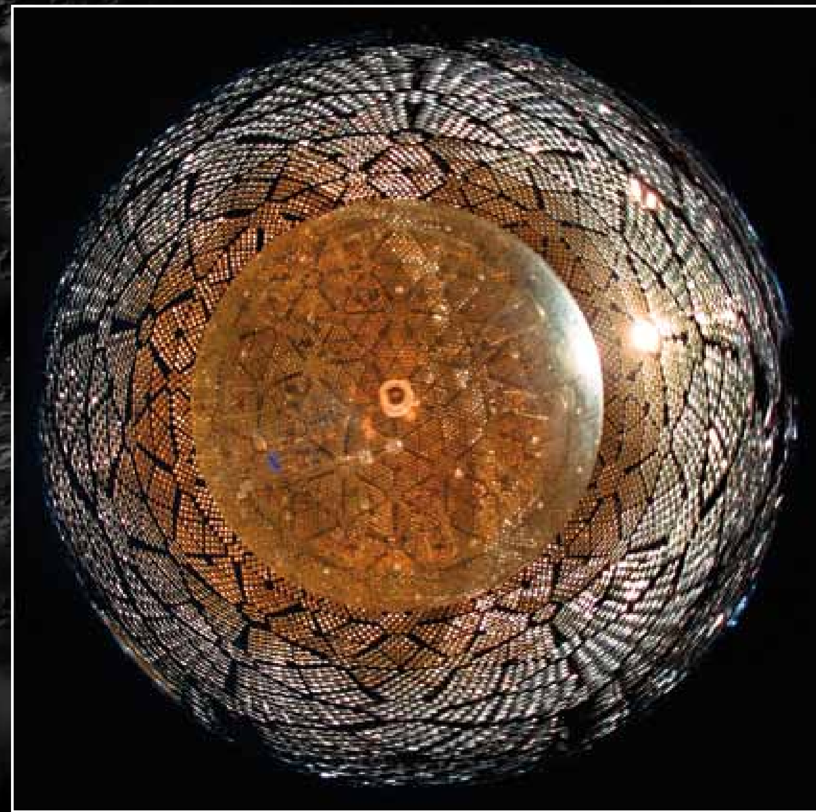
35. H.P. Lovecraft, *Selected Letters III*, 1929–1931, edited by August Derleth and Donald Wandreil. Sauk City, Wis: Arkham House 1965. p. 293.

Ray Davis inspects the neutrino detector under construction at the Homestake Gold Mine in Lead, South Dakota (US) (1965). This detector was used it to demonstrate the existence of solar neutrinos. The mine, 1475 metres underground, and shielded from cosmic rays, now houses the Large Underground Xenon detector (LUX), which aims to directly detect galactic dark matter.



The Sudbury Neutrino Observatory is a neutrino observatory located about two kilometres underground in Vale Inco's Creighton Mine in Sudbury, Ontario, Canada. It was designed to detect solar neutrinos through their interactions with a large tank of heavy water. Located in the deepest part of the mine, the overburden of rock shielded the detector from cosmic rays. The detector was switched on in May 1999, and was turned off on 28 November 2006. The existing facilities constructed for the Sudbury Neutrino Observatory have been expanded into the SNOLAB, an underground science laboratory specialising in neutrino and dark matter physics.

View of the Sudbury Neutrino Observatory, an 18-metre diameter stainless steel geodesic sphere containing an acrylic vessel filled with 1000 tons of heavy water. Attached to the sphere are 9522 ultra-sensitive light-sensors called photomultiplier tubes.



View from the bottom of the Sudbury Neutrino Observatory acrylic vessel and the array of photomultiplier tubes with a fish-eye lens.

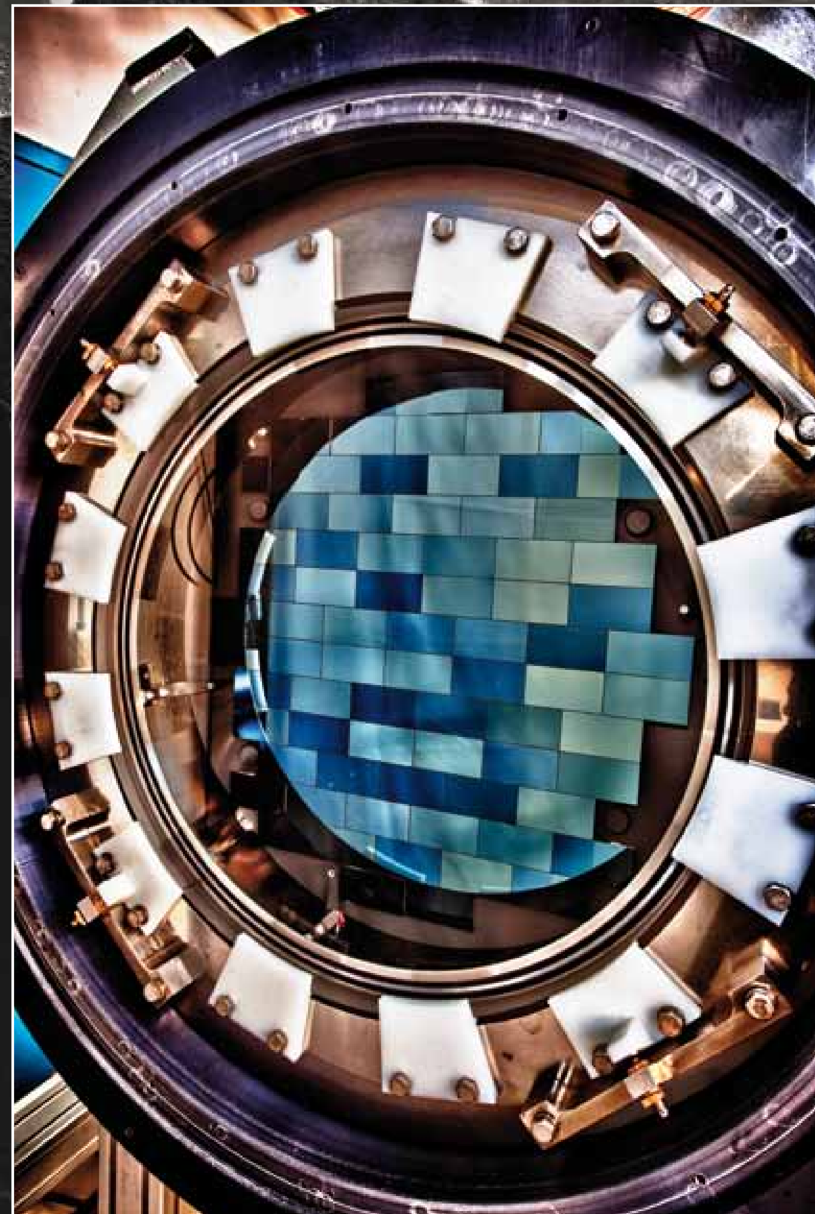
9522 ultra-sensitive photomultiplier tubes attached to the geodesic sphere of the Sudbury Neutrino Observatory.

Photos courtesy of Lawrence Berkeley National Laboratory. Photographer: Roy Kaltschmidt.

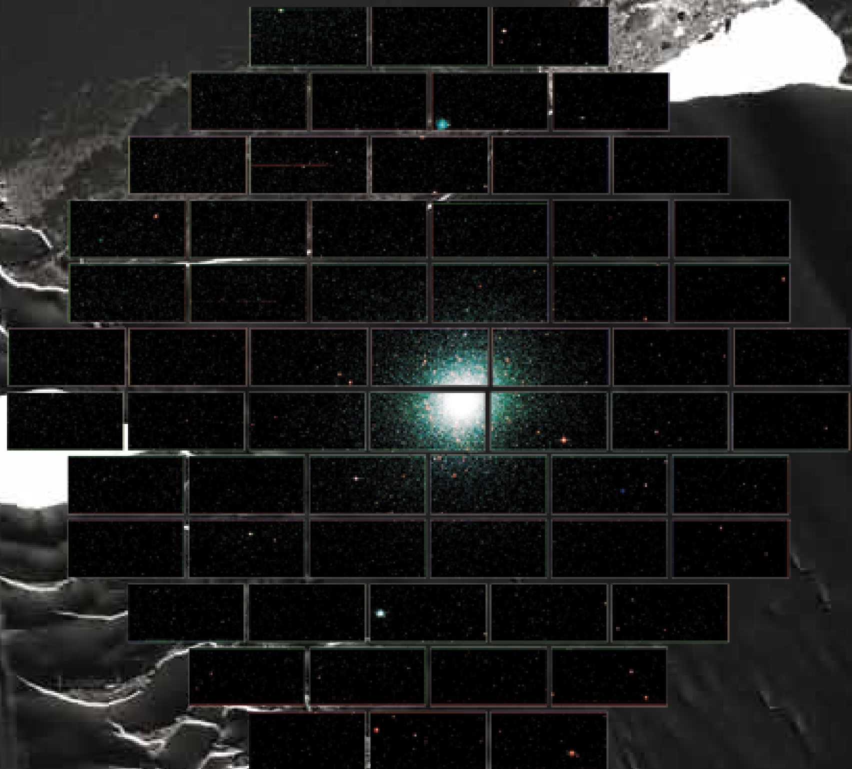
The Dark Energy Camera, designed for the Dark Energy Survey, probes the origin of the accelerating universe and helps uncover the nature of dark energy by measuring the 14-billion-year history of cosmic expansion with high precision. The 570-Megapixel digital camera, with an array of 62 charged-coupled devices, is able to see light from over 100,000 galaxies up to eight billion light years away in each snapshot. The first pictures were taken in 12 September 2012.

The Blanco telescope in Chile, where the Dark Energy Camera is mounted, as seen from the air. Photo courtesy of NOAO/AURA/NSF.

The Dark Energy Camera, mounted on the Blanco telescope in Chile. Photo courtesy of Dark Energy Survey Collaboration.



The Dark Energy Camera features 62 charged-coupled devices (CCDs), which record a total of 570 megapixels per snapshot. Photo courtesy of Fermilab.



Full Dark Energy Camera composite image of the globular star cluster 47 Tucanae, which is about 17,000 light years from Earth.

Image courtesy of Dark Energy Survey Collaboration.

This three-dimensional map, created in 2007, shows the large-scale distribution of dark matter in the universe. The map provides evidence that normal matter, largely in the form of galaxies, accumulates along the densest concentrations of dark matter. It reveals a loose network of dark matter filaments, gradually collapsing under the relentless pull of gravity, and growing clumpier over time. The three axes of the box correspond to sky position (in right ascension and declination), and distance from the Earth, increasing from left to right (as measured by cosmological red-shift). The clumping of the dark matter becomes more pronounced, moving from right to left across the volume map, from the early universe to the more recent universe. The map was created using the largest survey of the universe by the Hubble Space Telescope, the Cosmic Evolution Survey (COSMOS), which probes the growth of large-scale structure in the universe over cosmic time.

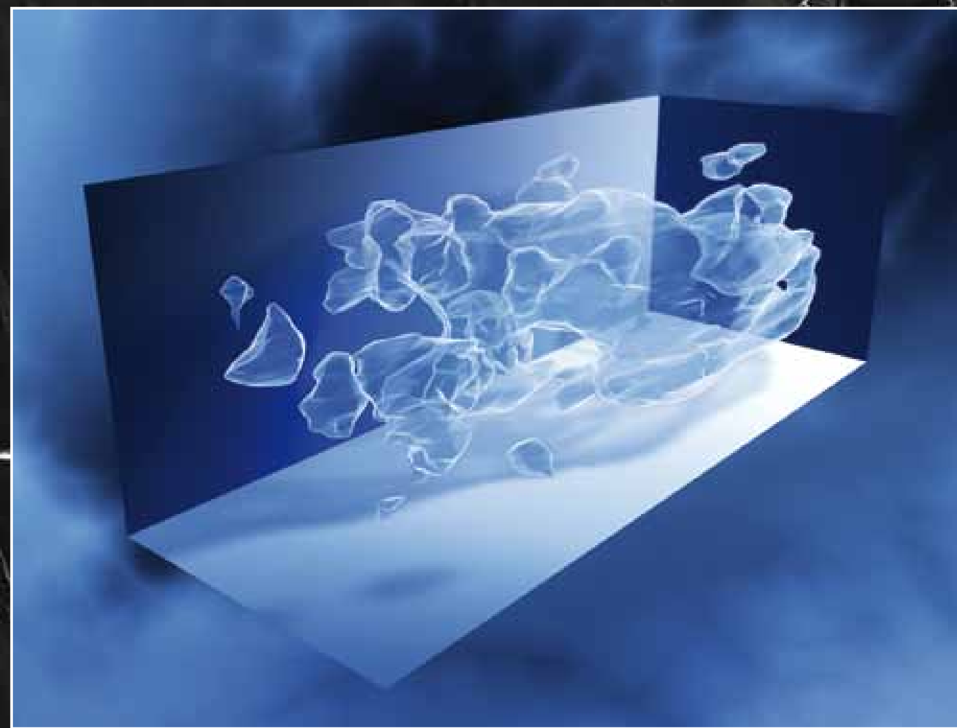
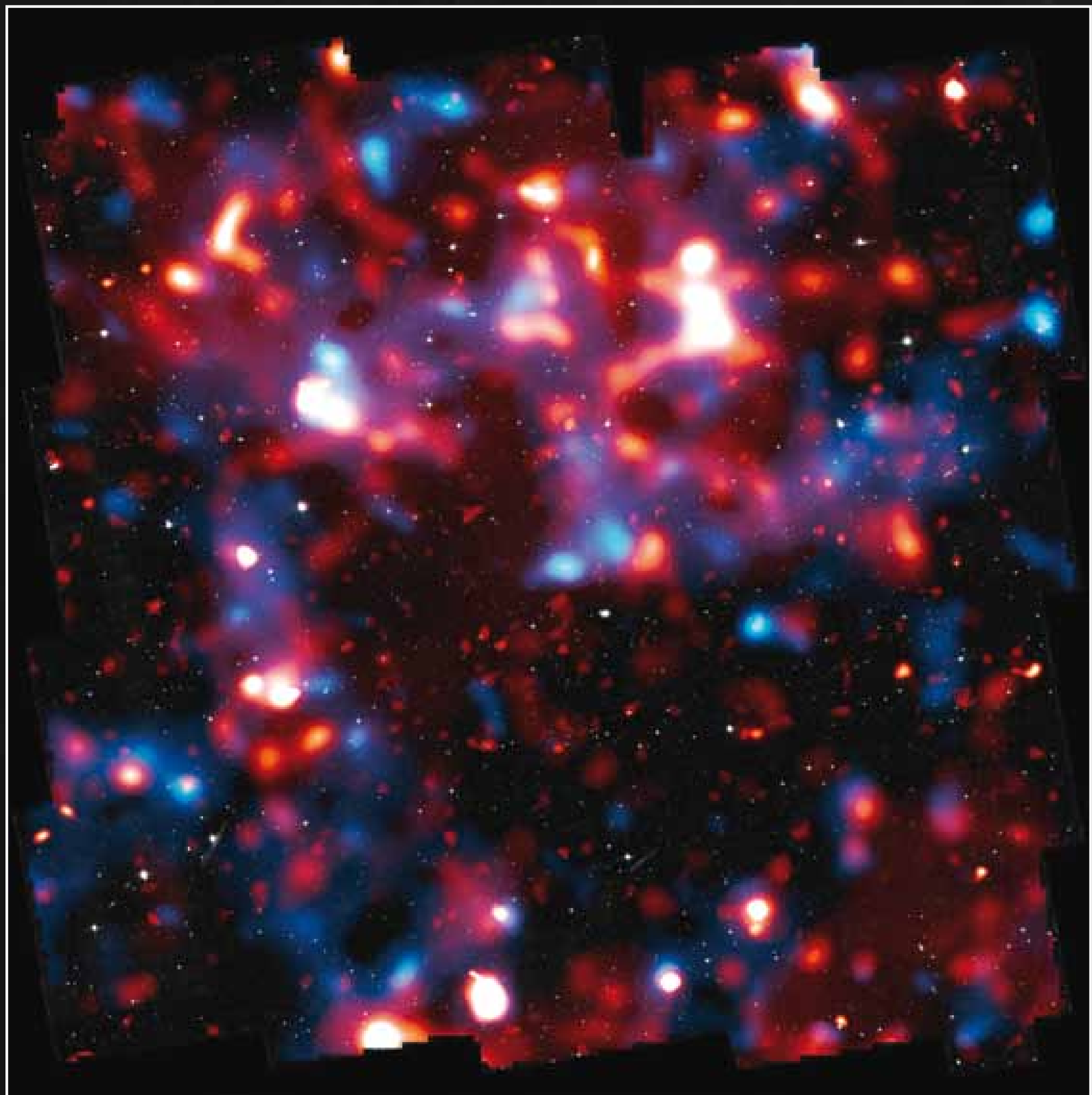
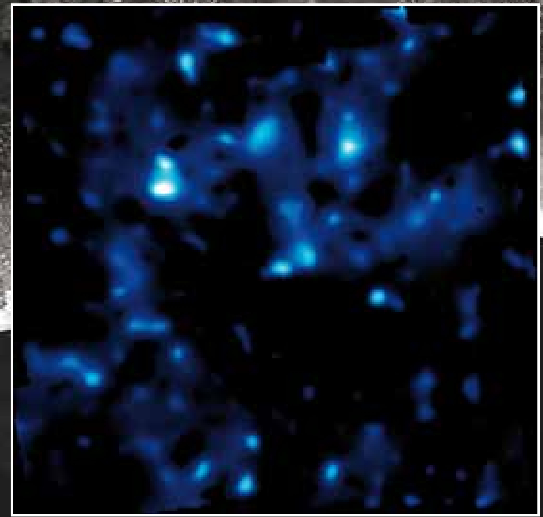


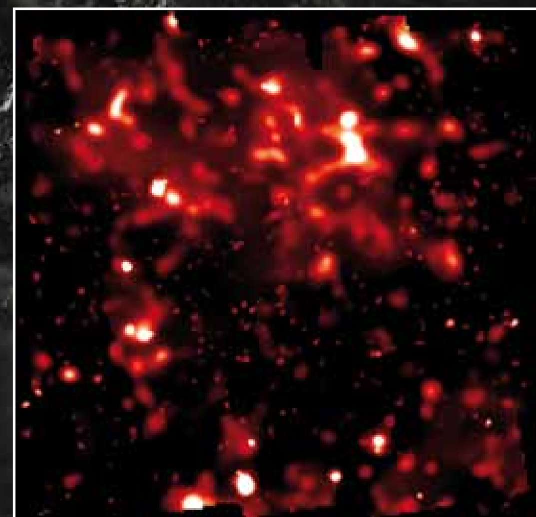
Illustration courtesy of NASA, ESA, and R. Massey (California Institute of Technology).



Normal matter, dark matter, stars and galaxies.

Composite image showing three different components of the Hubble Cosmic Evolution Survey (COSMOS): the normal matter (in red) captured mainly by the European Space Agency's XMM/Newton telescope, the dark matter (in blue) and the stars and galaxies (in grey) observed in visible light with Hubble.

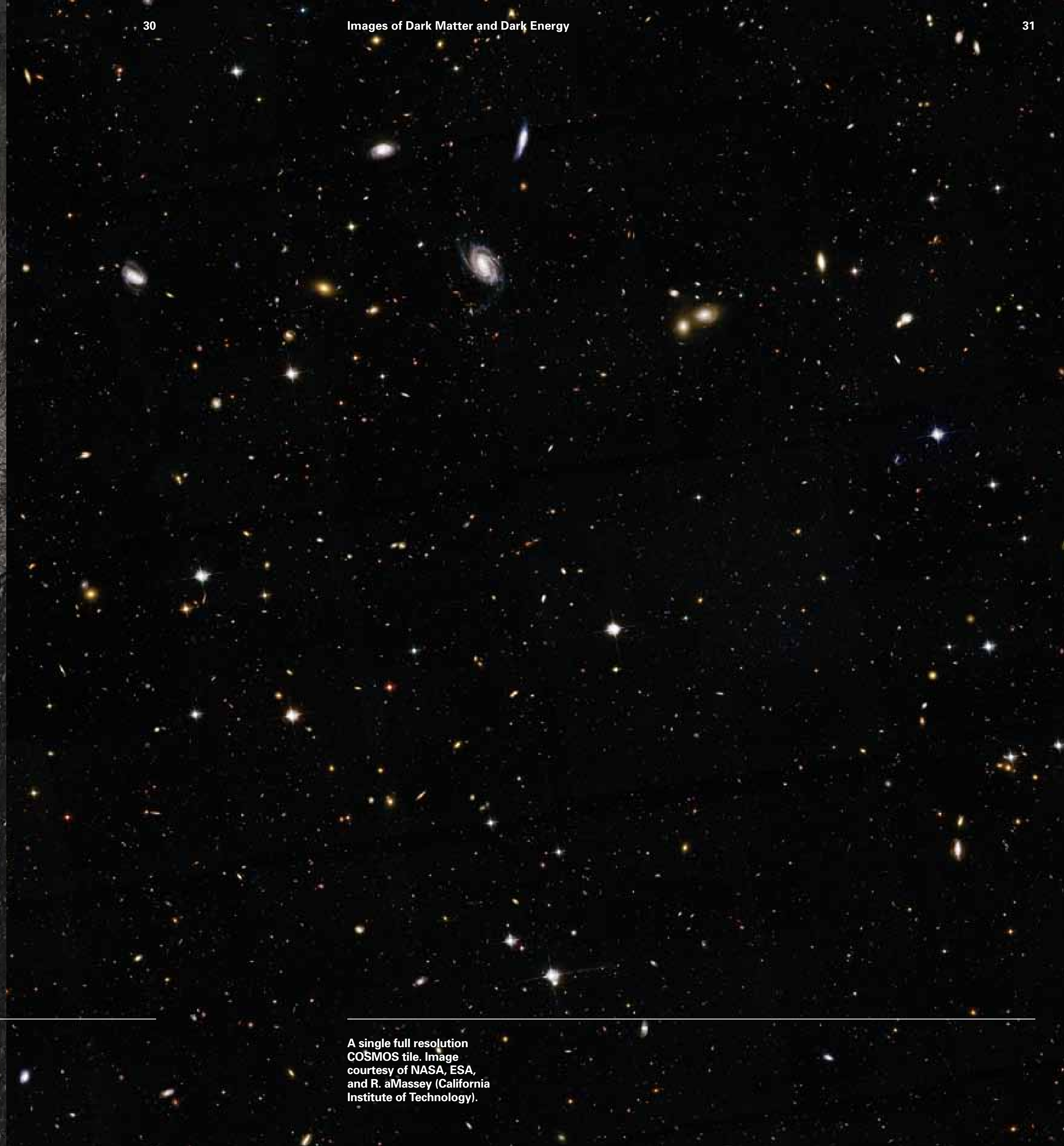




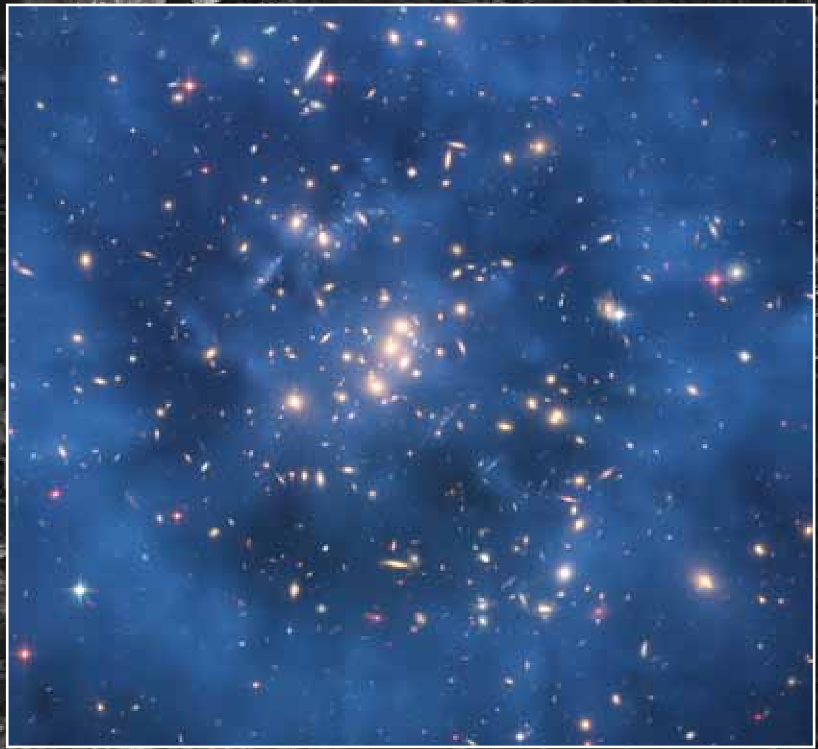
These two false-colour images compare the distribution of normal matter (red) with dark matter (blue) in the universe. The brightness of the clumps corresponds to the density of mass.

Images courtesy of NASA, ESA, and R. Massey (California Institute of Technology).

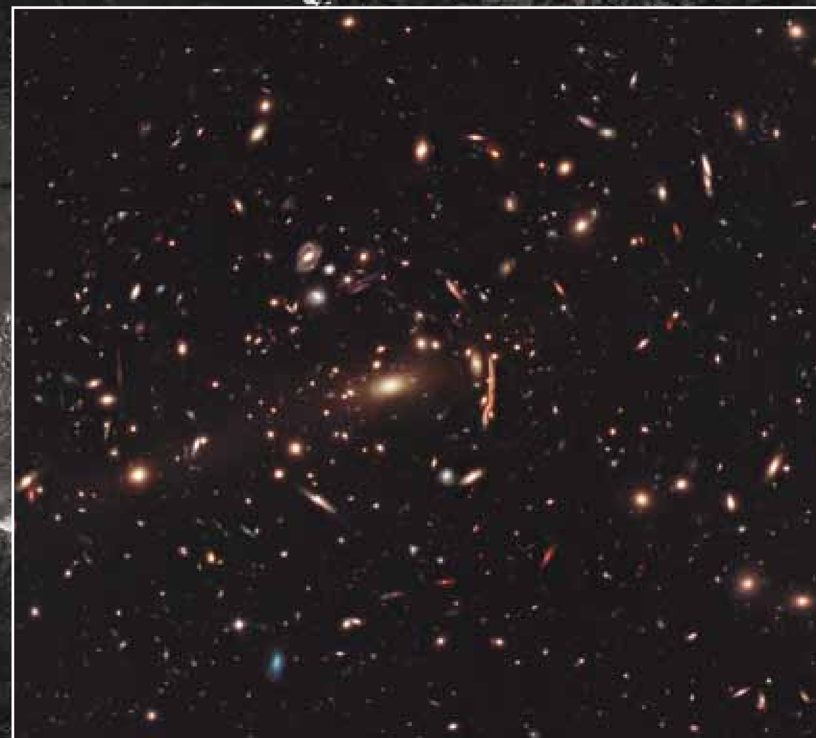
An excerpt of the COSMOS survey in full resolution. Image courtesy of NASA, ESA and A. Koekemoer (STScI).



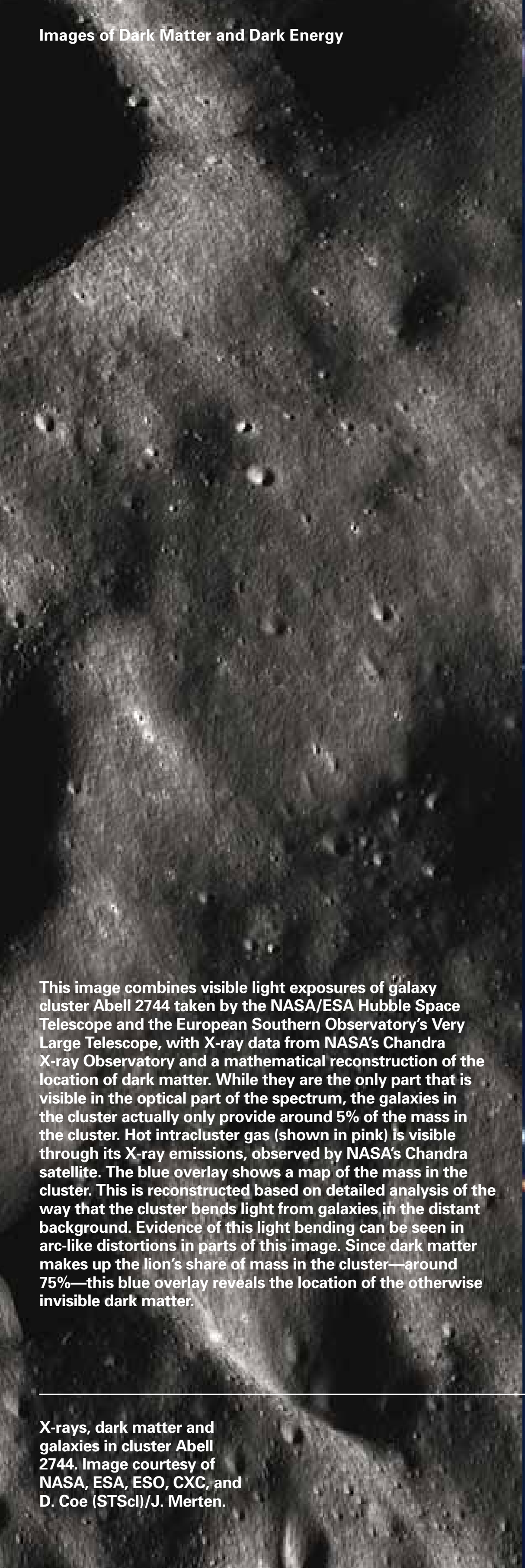
A single full resolution COSMOS tile. Image courtesy of NASA, ESA, and R. aMassey (California Institute of Technology).



Another Hubble Space Telescope composite image showing the ghostly ring of dark matter in the galaxy cluster Cl 0024+17. Image courtesy of NASA, ESA, M.J. Jee and H. Ford (Johns Hopkins University).

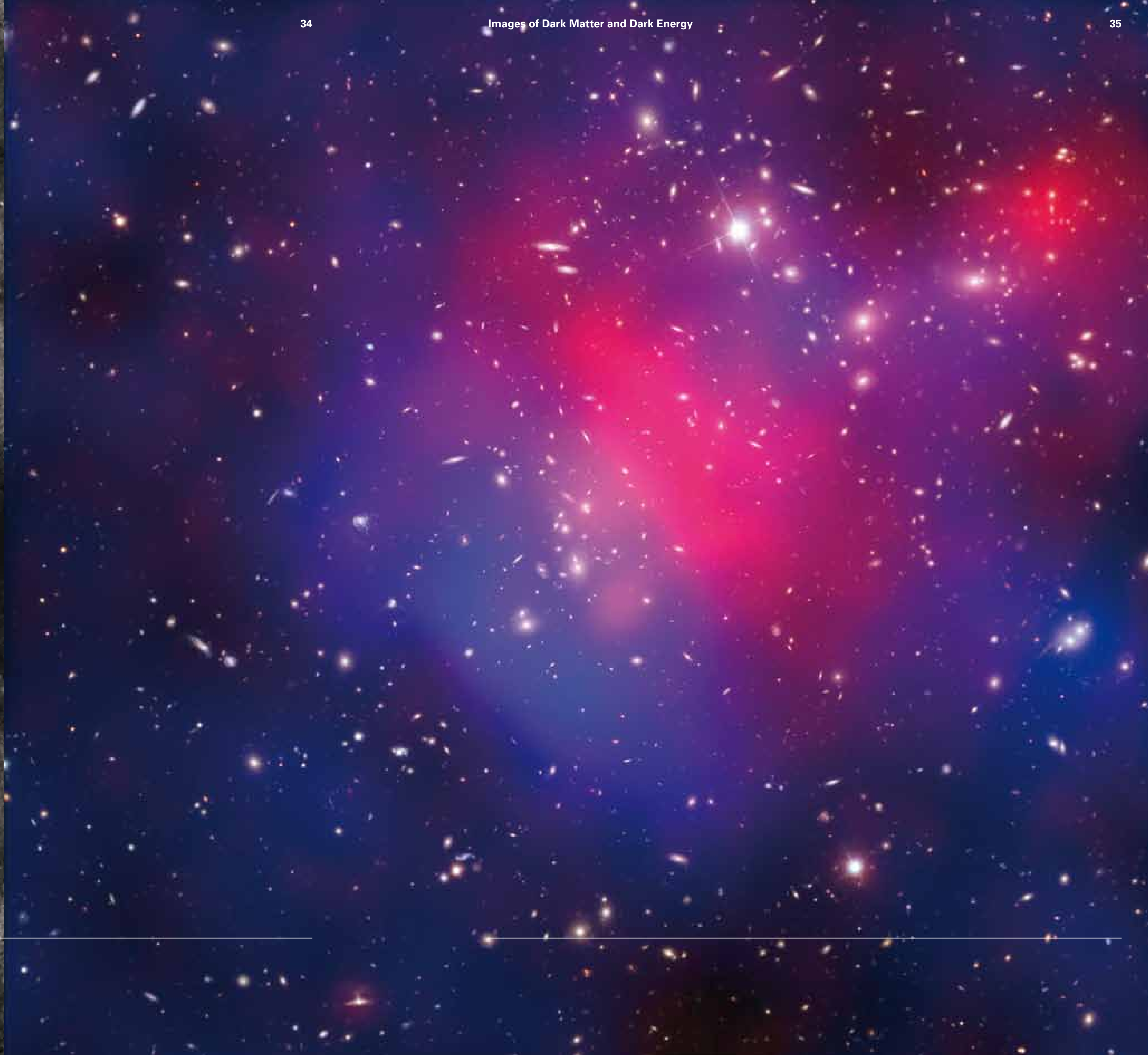


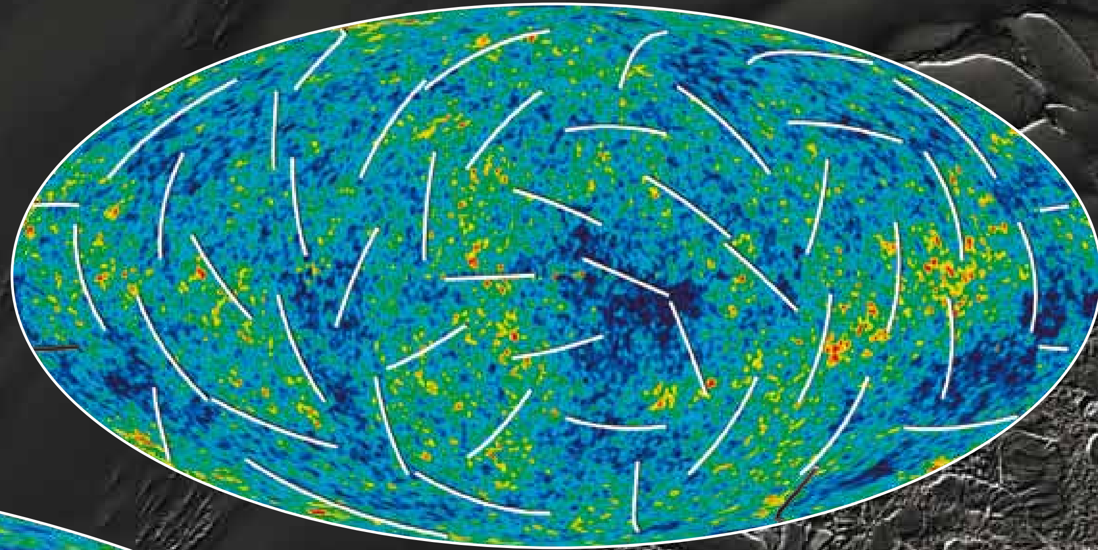
The galaxy cluster MACS 1206 as seen by the Hubble Space Telescope (2011). Galaxy clusters like these have enormous mass, and their gravity is powerful enough to visibly bend the path of light. Image courtesy of NASA, ESA, M. Postman (STScI), the CLASH team and the Hubble Heritage Team (STScI/AURA).

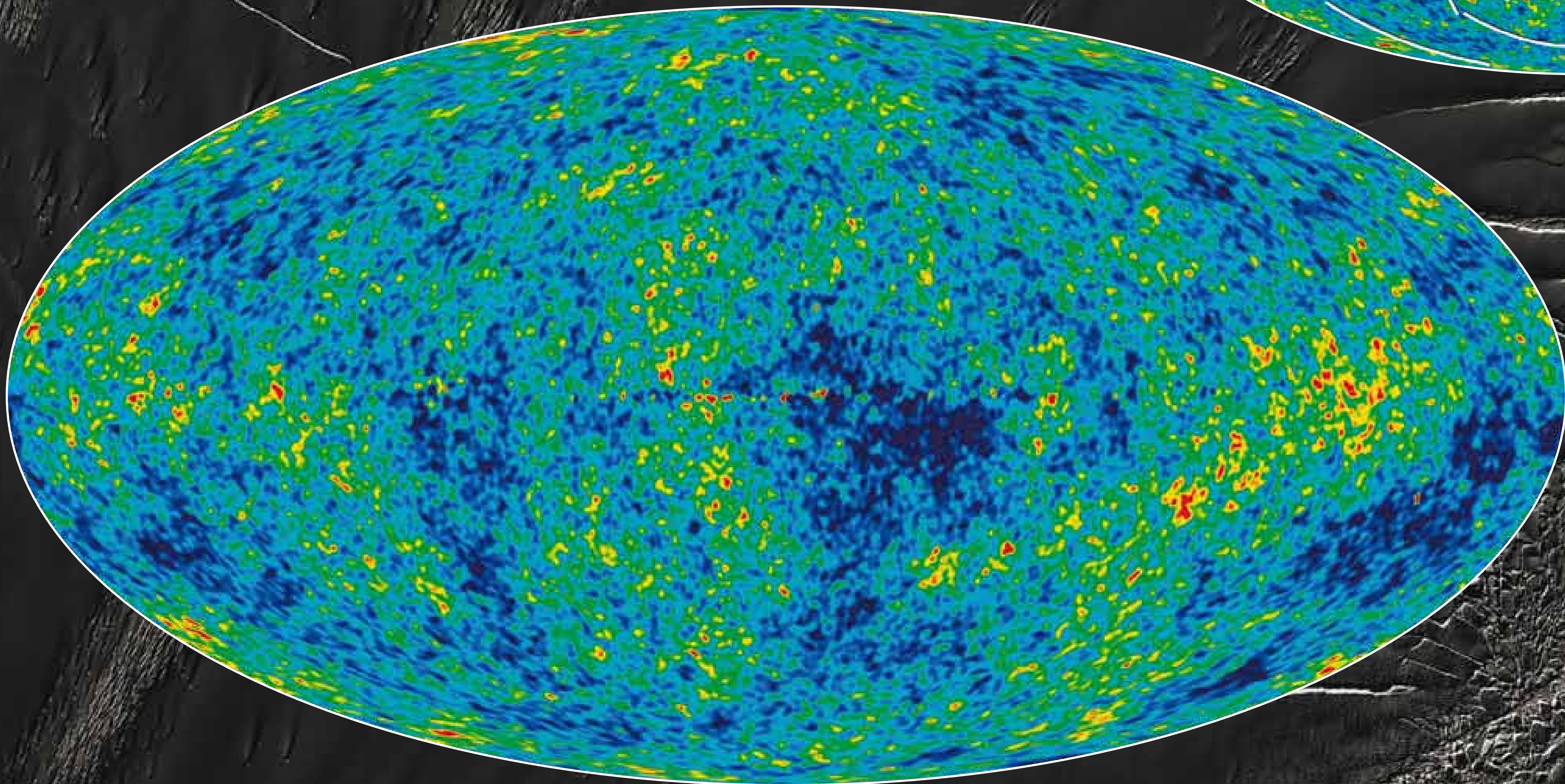


This image combines visible light exposures of galaxy cluster Abell 2744 taken by the NASA/ESA Hubble Space Telescope and the European Southern Observatory's Very Large Telescope, with X-ray data from NASA's Chandra X-ray Observatory and a mathematical reconstruction of the location of dark matter. While they are the only part that is visible in the optical part of the spectrum, the galaxies in the cluster actually only provide around 5% of the mass in the cluster. Hot intracluster gas (shown in pink) is visible through its X-ray emissions, observed by NASA's Chandra satellite. The blue overlay shows a map of the mass in the cluster. This is reconstructed based on detailed analysis of the way that the cluster bends light from galaxies in the distant background. Evidence of this light bending can be seen in arc-like distortions in parts of this image. Since dark matter makes up the lion's share of mass in the cluster—around 75%—this blue overlay reveals the location of the otherwise invisible dark matter.

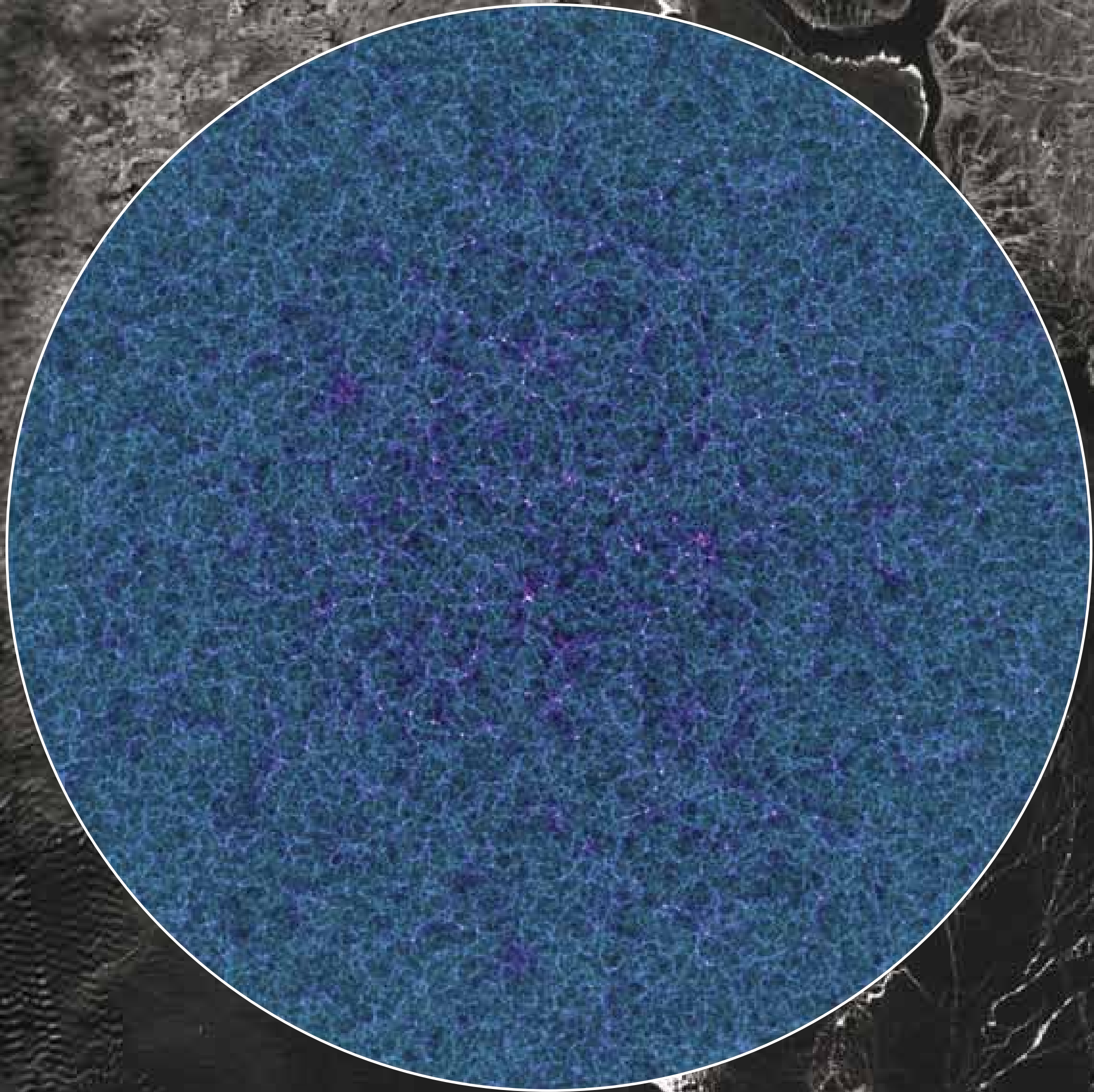
X-rays, dark matter and galaxies in cluster Abell 2744. Image courtesy of NASA, ESA, ESO, CXC, and D. Coe (STScI)/J. Merten.





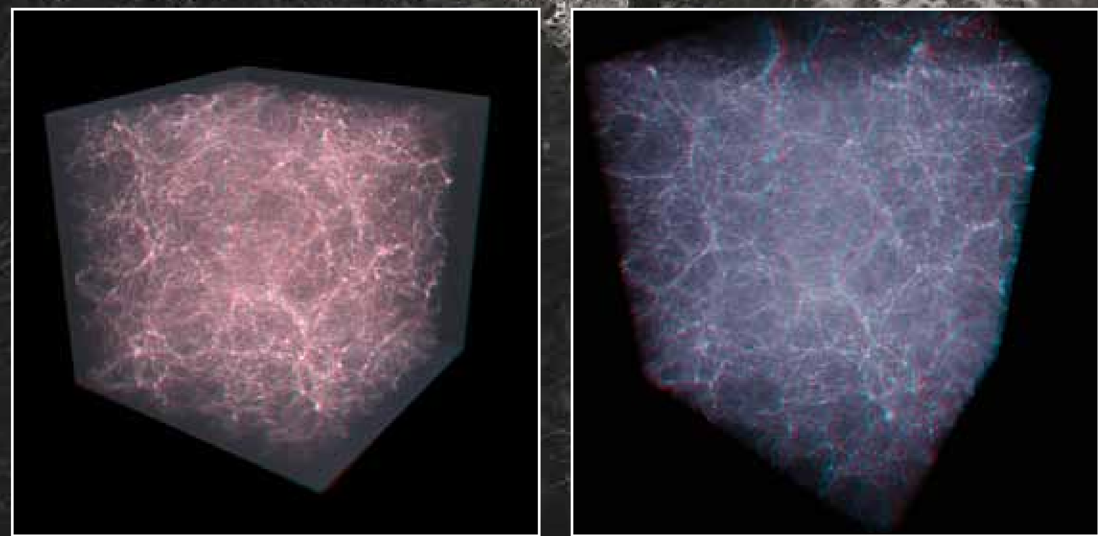


Two detailed all-sky pictures of the infant universe created from WMAP data. The Wilkinson Microwave Anisotropy Probe (WMAP) measures differences in the temperature of the Cosmic Microwave Background radiation across the full sky. The image reveals 13.7 billion-year-old temperature fluctuations (shown as colour differences) that correspond to the seeds that grew to become the galaxies. The image on the right is created in 2005 from three years of data. The white bars show the polarisation direction of the oldest light. The image in the centre is created in 2010 from seven years of data. Images courtesy of: NASA/WMAP Science Team.



The goal of the DEUS project (Dark Energy Universe Simulation) is to investigate the imprints of dark energy on cosmic structure formation through high-performance numerical simulations. The entire history of the observable universe, all 13.7 billion years of it, has been modelled in 2012 on the CURIE supercomputer at the Très Grand Centre de Calcul in Bruyères-le-Châtel, France. The simulation created and tracked 550 billion particles, each with the mass of our own Milky Way galaxy or greater, that were thought to be created in the Big Bang, to the present day. As for dark matter, the first DEUS full universe run discovered that fluctuations and distribution in dark matter throughout the known universe are the same as those of the cosmic microwave background radiation observed by satellites.

Slices of full sky light cones using different simulation sizes. Luminosity/colour = dark matter density. Images © DEUS consortium.

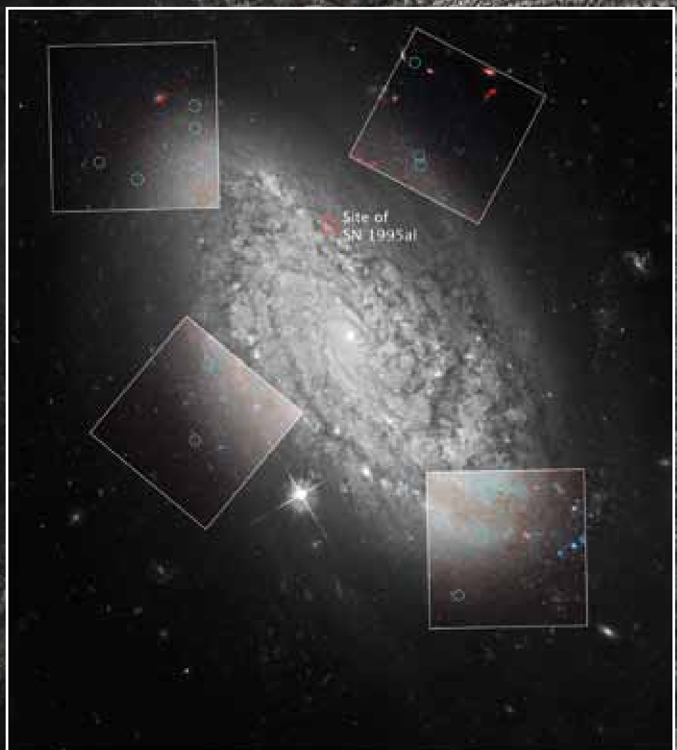


Stereoscopic images of the dark matter simulation of the entire cosmos by the DEUS consortium, 2012. Images © DEUS consortium.

39 Distant Supernovae. Image courtesy of NASA and A. Riess (STScI).

Full Dark Energy Camera image of the Fornax cluster of galaxies, which is about 60 million light years from Earth. The centre of the cluster is the clump of galaxies in the upper portion of the image. The prominent galaxy in the lower right of the image is the barred spiral galaxy NGC 1365.

Full Dark Energy Camera composite image of the Small Magellanic Cloud (a band of greenish stars running from lower left to upper right), a dwarf galaxy that is about 200,000 light years from Earth, and is a satellite of our Milky Way galaxy. Images courtesy of Dark Energy Survey Collaboration.



Cepheid variable stars in spiral galaxy NGC 3021. A Hubble Space Telescope photo of the spiral galaxy NGC 3021. This was one of the type Ia supernovae observed by astronomers to refine the measure of the universe's rate of expansion, called the Hubble Constant. Image courtesy of NASA, ESA and A. Riess (STScI/JHU).

A Hubble Space Telescope photo of the spiral galaxy NGC 3021. Image courtesy of NASA, ESA and A. Riess (STScI/JHU).

Dark Energy, Dark Matter, Big Data, Intimate Data

Roger F. Malina

Astronomy, with the agricultural and health sciences, is no doubt one of the oldest human sciences. The regularity of events in the sky, the daily and annual cycles, provided a predictable framework in a world that was often chaotic for early hominids. Humans lived at the mercy of climactic variations and disasters, threats from predators and unpredictable diseases and events. Astronomy on the other hand provided a metronome for human existence. And unusual events in the sky took on symbolic and religions importance. For most of human history astronomy has been a 'regalian' science associated with the ruling classes. Its role in navigation, even to the present, and with the contributions by the space sciences to GPS systems, provided a continuous link between science and economic benefit. Today China and India use the space sciences not only to demonstrate their technological prowess, but because we need the space sciences to help 'manage' our impact and activities on the planet.

Cosmology

Within astronomy, cosmology has had a particularly important role as it has contextualised our relationship to the larger universe. The Galilean revolution was at its root cultural. It is no accident that the theories of gravity have played such an important role in the development of modern science. The Universe provides one of our richest laboratories, testing and extending our knowledge of the world around us. Our understanding of the expansion of the universe from a hot dense phase, the Big Bang, has provided an overall 'calendar' within which stars, planets, and then life has emerged. The theory of evolution is joined at the hip with the theory of the Big Bang; astronomers played an important role in establishing the time scales of geological history; the cultural impact of astronomy is still felt in the debates with fundamentalist religions. Cosmology today is one of the most active areas of astronomy. New generations of space- and ground-based telescopes are producing a data flood of the nature and distribution of matter on all scales and distances going back to the first formation of stars in the universe after the Big Bang.

The Dark Universe

It is therefore ironic that astronomy is undergoing such a crisis of epistemology today. The oldest science finds itself among the youngest sciences, with established understandings unsettled by new data. A recent issue of *Science Magazine* detailed ten fundamental areas of ignorance in modern astronomy that include:[1]

> What is Dark Energy: 95% of the content of the universe is of an unknown nature except that it is causing the expansion of the universe to expand.
>
> What is Dark Matter: 83% of the physical matter in the universe is of an unknown nature except that it holds together galaxies and other large structures in the universe.
>
> Where is the Missing Matter: Of the matter that we can see or detect, 50% is still unaccounted for.

The article goes on to detail other major areas of ignorance such as the source of the most energetic cosmic rays in the universe, or how stars explode.

In 2011 Saul Perlmutter, Adam Riess and Brian Schmidt were awarded a Nobel Prize in Physics for the discovery of dark energy. This Nobel Prize is perhaps ironic because it was awarded for discovering our ignorance of the nature of 95% of the universe. The story of this discovery is almost an exemplar of how good science is done, with small groups of scientists taking data, discovering step by step that the current understanding was very flawed and slowly convincing their colleagues who initially dismissed their work. As their work proceeded, it motivated the invention of new instruments and new telescopes that could capture the data needed to confirm or refute their ideas. New generations of space telescopes now on the drawing boards will collect vast amounts of data and perhaps elucidate the nature of dark energy.

1. 'Mysteries of Astronomy', in *Science Magazine*, June 2012. www.sciencemag.org/site/special/astro2012/index.xhtml

Big Data

The era of big data started early in astronomy. When I started my career in 1979 we were still using photographic plates. Then astronomers digitised their photographic plates. Then diode arrays and eventually Charge Coupled Devices (as used in cellphone cameras) started generating ever-larger volumes of data. Then it was discovered that these flows of data could not be combined; each field in astronomy used different data formats, different software systems, different archiving mechanisms. The astronomical community, supported by funding agencies, mobilised to develop data and software standards. With today's online virtual observatory databases scientists, or citizen scientists, can access large data sets from multiple telescopes. In a very real sense most of the telescopes are now networked into a large collective observing machine. New professions of data analysts have emerged and indeed many astronomers today have never used a telescope or recorded their own data; they use the data archives to make new discoveries. This evolution to the big data era spread rapidly to other fields of science, such as genomics, and now to business, government and the social media industries.

As many have pointed out, big data is not just more data. Science historian Daniel Boorstin called this an 'epistemological inversion'. What he meant was that the way that science could be done was changing. When Charles Darwin travelled to the Galápagos he was in search of new data. Data were rare; indeed all of Charles Darwin's data that transformed our understanding of human nature is contained in a series of notebooks on a bookshelf in his study. When data becomes plentiful, it changes the way most scientists do their work. They can study archives instead of studying the world. The way that governments fund science encourages the building of new instruments to record new data. The result is that the direction of science, which questions are investigated, and the methodology of science itself changes. There is often little funding to actually analyse and draw conclusions from the data. Daniel Boorstin joked at a World Space Congress that maybe space agencies should stop taking data for a while since they didn't have time to analyse all of it.

Citizen Science and Data Rights

In the information economy, 'data is power'. The opening of astronomical databases to the public has led to a large growth of citizen science with private citizens able to make scientific discoveries. This citizen science movement goes beyond the concept of the 'amateur'. In many fields citizen scientists are not only analysing online data; they are also generating new data. The social and political ramifications are important, as is being shown by the community mapping and community 'remote sensing' movements. With kites and balloons and remotely controlled drones, and of course cellphones, private citizens can collect and use data to contest the claims of governments or companies. Last year the Buckminster Fuller Prize was awarded to several such groups, including a Congo citizen science-mapping project that successfully contested illegal logging of old growth tropical forests. The issue here is not big data but the right data and the right to data.

Several years ago I wrote an Open Observatory Manifesto asserting two new simple rights.[2] I first asserted that all citizens had a right to access data compiled with taxpayers' money. In astronomy this is actually implemented in most government grants; the astronomers are required to make their data public after a certain period. It is hotly contested in many other areas where governments refuse to make data, paid for by taxpayers, available to the public. The second assertion I made was that citizens had a duty to capture data and contribute it to the data commons. In fact, this is rapidly happening as social media systems archive all kinds of data uploaded by private citizens. We are rapidly becoming a data-taking culture. The biomedical sciences are being transformed as the cellphone becomes the generic data-taking interface. Data privacy has become a major ethical and societal issue.

Data Visualisation and Sonification

When you have very little data you can look at all of it. Astronomers used to study each galaxy in an image. When you start having millions or billions of objects in your database it is humanly impossible to do this. You start by automating the process but inevitably this means you build in blind spots. Every data-processing algorithm filters, sorts, selects and often throws away most of the data.

In astronomy one of the popular stories is how astronomers made surprising astronomical discoveries in data collected by the US military. The military satellites were watching for nuclear bomb tests during the Cold War era. The data analysis system rejected any signals that seemed to come from above the satellites, because they were looking for tests carried out underground or in the earth's atmosphere. The astronomers discovered that the signals coming from above the satellite were real and were a previously unknown phenomenon now known to be emitted by gamma ray stars and galaxies.

As data volumes grow, traditional scientific illustration techniques become inadequate and this has led to the growth of new professions and techniques in data visualisation. Data can be displayed in three-dimensional immersive environments, in ways that are interactive and malleable. Techniques in complex network science allow the structure of the data to be analysed, drawing conclusions about the content of the data. Infoviz, bioviz and dataviz conferences are proliferating.

More recently scientists have started sonifiying their data as well as visualising it. Human perception functions differently in visual and aural domains, different kinds of patterns can be detected and time evolutions noted. Sonification goes beyond alarms and alerts to systems of complex data representation exploiting the 3D and time-based nature of sound. Composers and sound artists, such as Scot Gresham Lancaster, have been on the forefront of developing these techniques.

No Data or the Wrong Data

What if there is no data or if we are collecting the wrong data? Dark energy astronomers are collecting vast amounts of data but since we don't have good theoretical models, other astronomers have pointed out that the data might be useless. Without good hypotheses to test it, how do we know which data is relevant? The observational astronomers reply that dark energy was discovered without a guiding theory, and that many discoveries are not driven by the process of confirming or falsifying hypotheses. Science indeed advances by both approaches.

2. Roger F. Malina, 'An Open Observatory Manifesto', in *Leonardo Electronic Almanac,* January 2010. www.leoalmanac.org/an-open-observatory-manifesto-by-roger-malina

During the birth of the big data transformation some argued that it was 'the end of theory'. Just collect data, look for correlations and do extrapolations. In many cases this may work very well, but in others understanding causal networks is necessary to interpret correlations and extrapolations. There is a very real danger that the data flood will blind us to the fact that we don't have the most relevant data. And it's easier now to get funding to analyse big data than to fund research where you don't yet know which data you need.

Quantitative Data and Qualitative Data

One of the ancient battlegrounds between the sciences and humanities has been whether scientific understanding can only come from quantitative data. The social sciences and the cognitive sciences find themselves straddling the digital divide. Within the arts, the digital and new media arts are still fighting fundamental battles with art forms that don't rely on manipulating digitally encoded, quantified data. In recent years the birth of the Digital Humanities has re-awakened these disputes as the new generation of humanities scholars, born digital, develop new research strategies that are more easily funded today than pre-digital scholarship. Big Data is re-orienting the humanities, driving curiosity towards questions that could not been tackled before, but also putting in the shade fundamental questions that have no data or rely on unquantifiable qualitative analyses.

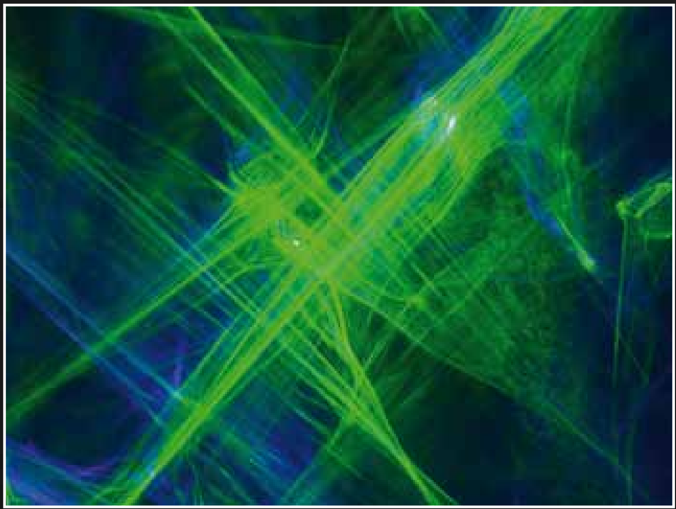
Intimate Data

For artists perhaps the question is elsewhere; the human experience with an artwork relies on qualia of human cognition. That experience is in a sense neutral to the technology used to develop the artwork. Artists have often been early adopters of new technologies, and in many cases have made inventions for their art making that have been widely used. Metallurgy and chemistry have long straddled the fine and applied arts. We now know that the human senses are very efficient filters, and that almost all of the world around us cannot be directly perceived by human senses. Most of the universe is dark. That artists use data obtained by scientific instruments seems to be a desirable process of cultural appropriation of phenomena

to bring them into the intimacy of personal perception and cognition. In his books like *The New Landscape in Art and Science* (1956), Györgi Kepes asserted the right of artists to use scientific data as a raw material like any other. In a sense the citizen science movement has its equivalent in 'citizen' art, with artists also generating new data using scientific instruments for their own purposes, I believe this should be encouraged. There is a growing movement to find new ways to cross-link Science and Engineering to the Arts and Humanities. The Dark Universe and Big Data are common ground vto be explored.

Electric Shadows

Artworks Kontraste 2012

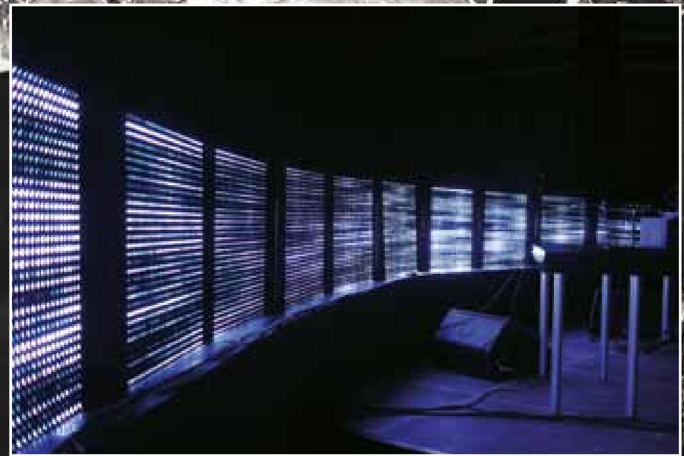


In *COVEX*, Yamila Ríos and Joris Strijbos investigate the relations between electro-acoustic sound and diffracted light patterns. A live performance on an extended cello creates a mass of sound, which morphs from a complex noisy environment of fast fragmented textures to a serene, harmonic drone. An intricate visual constellation is formed by shooting laser beams through transparent objects. Thus, an effect known as the 'speckle pattern' occurs, resulting in abstract landscapes of detailed colour patterns and dynamically evolving shapes.

In *Seeing with Eyes Closed* visitors are invited to sit on the floor in front of LED lights and close their eyes. They are exposed to flashing light, which produces a quasi-hallucinatory visual experience of flowing images behind closed eyes. Each person's experience of it differs from that of others. Some see black and white or coloured geometric patterns that swirl, jump or flow; others see aerial images of the earth, cities, eyes, or human figures.

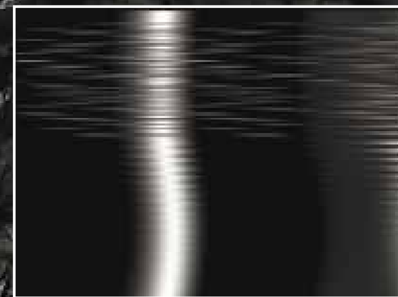
Yamila Ríos & Joris Strijbos, *COVEX*, audiovisual performance, 2012.

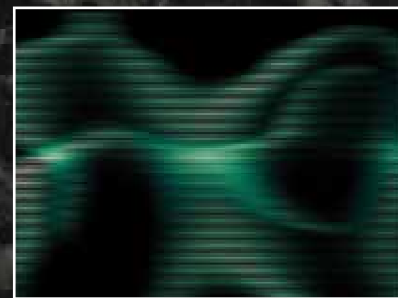
Ivana Franke, *Seeing with Eyes Closed*, installation with LED-lights, 2011. Photo © Ivana Franke.



An arc of very bright, flickering LED screens serves as a dynamic set-design for the expressive voice and electronic explorations of composer and performer Maja Solveig Kjelstrup Ratkje.

The Synchronator, developed by Bas van Koolwijk and Gert-Jan Prins, translates three channels of audio input into the primary colour channels of an analogue video signal. Performing live with the device they create a spectacle of synchronised audio and video noise.





HC Gilje, set-design, 2012. Photo: HC Gilje.

Bas van Koolwijk, Synchronator images.

Detail of Gert-Jan Prins' performance set-up. Photo © Gert-Jan Prins.

~~Kulunka~~ is an immersive installation by Yolanda Uriz that evokes visual and tactile ways of perceiving vibrations. Low frequencies beyond our range of hearing are transmitted to water in a glass container, creating patterns of waves. The morphing geometries are illuminated by strobing, high-powered LEDs and projected on the surrounding space. Tactile transducers beneath the platform allow visitors who lie down to 'hear' with their bodies, evoking a peculiar sensation of gravity and – at times – the loss of it. Visitors are submerged in a tactile sonic experience, enveloped by the rhythms of the composition, and enter a universe of sound and light, in which the boundaries between imagination and reality blur in an amalgamation of the senses.

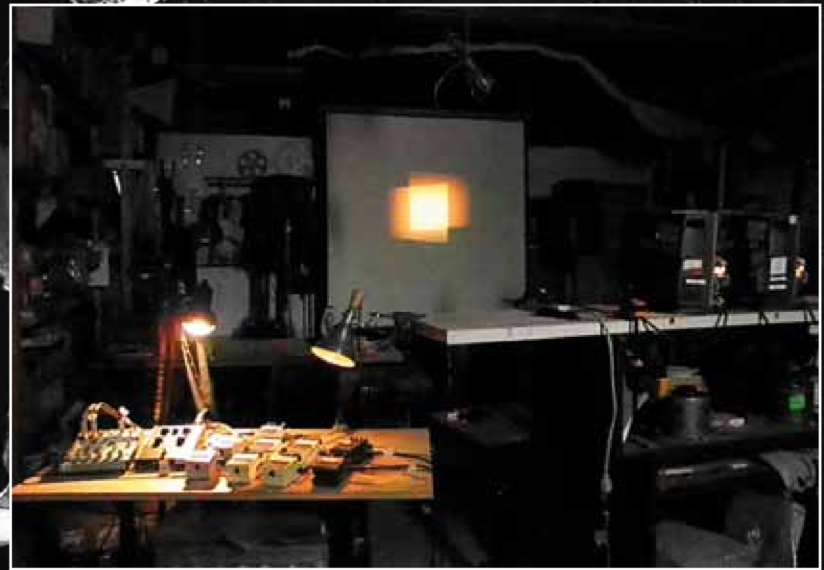
In his work Justin Bennett painstakingly examines the sounds of our everyday urban environments. The theme of his sound walk for Kontraste 2012 is the shadow history of electromagnetic invention and discovery from the eighteenth till the twentieth century, when experimenters at the forefront of scientific development were attempting to understand and harness energy, especially electromagnetic and acoustic energy. This inquiry led to the audio and video technology we use today, but also spawned ideas about animal magnetism, electrotherapy, earth energy, orgone energy, spiritualism, revolutionary politics, experimental psychiatry and neuroscience. The sound walk translates some of these experiments into the 21st century.

Fray is a site-specific sound intervention that reworks the immediate, everyday acoustic environment. *Fray* seeks the unnoticed seams in audible coherence, conducive to notions of the everyday environment, with particular attention to locations where the stitching noticeably loosens. By reorienting temporal patterning of in-situ acoustic waves and enhancing their potentials for fray, the intervention reworks the immediate auditory tapestry in a manner that reveals its threads, and the inherent situatedness of everyday hearing.

Yolanda Uriz, *~~Kulunka~~*, immersive installation, 2012.

Justin Bennett recording. Photo © Matthea Harvey.

Location for Raviv Ganchrow's sound piece *Fray*, 2012. Photo © Raviv Ganchrow.



Bruce McClure uses the film projector as his primary tool to organise light and sound into what he calls projector performances. By definition his performances are detached from any necessity for recording and exploit the 16mm projector as both a picture and sound device freed from subservience to film playback or fidelity.

In the live collaborative expanded cinema work *Aberration of Light: Dark Chamber Disclosure* two projectionists (Gibson and Recoder, using two 35mm projectors) and a sound artist (Block) unmask the cinematic apparatus in a play of sights and sounds. Using film loops, crystals and manual gestures to bend, reflect and refract the projector's beam, Gibson and Recoder forge a hypnotic, sculptural work of light. Block mixes and improvises sounds in a spontaneous dialogue with the images.

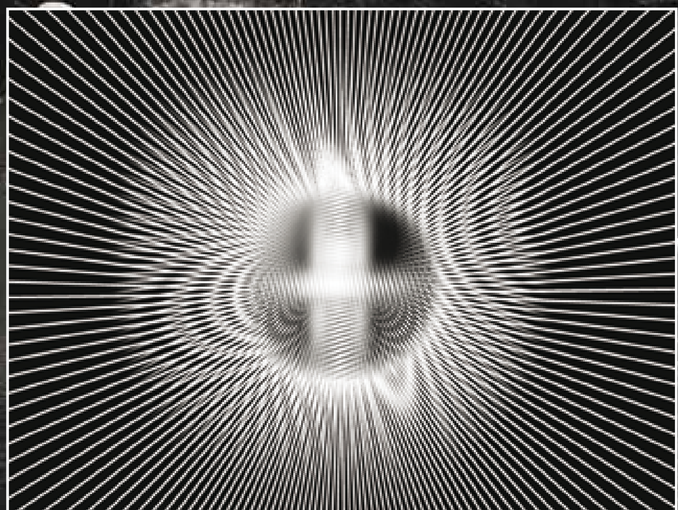
Performance set-up of Bruce McClure.

Sandra Gibson, Luis Recoder and Olivia Block, *Aberration of Light: Dark Chamber Disclosure*, projector performance, 2011.

Makino Takashi's *2012* is a solo cinematic project which he screens as a single channel work. He plays music himself, close to the screen.

The set-up of Optical Machines contains an obscure variety of modified record players, pattern models, lamps, lenses, cameras and analogue synthesisers. In *(SHIFT)*, Optical Machines uses this equipment to create an abstract play of light, interference patterns and abstract animation. The soundtrack is created in an interactive play with the shifts in the intensity of light.

Bleeding is a synaesthetic and synchronic live performance based on the phenomena of retinal persistence. Bleeding uses two screens, one of which is painted with phosphorescent pigments. Projecting on both simultaneously results in a perceptual ambiguity between the real and the retinal permanence of vision.

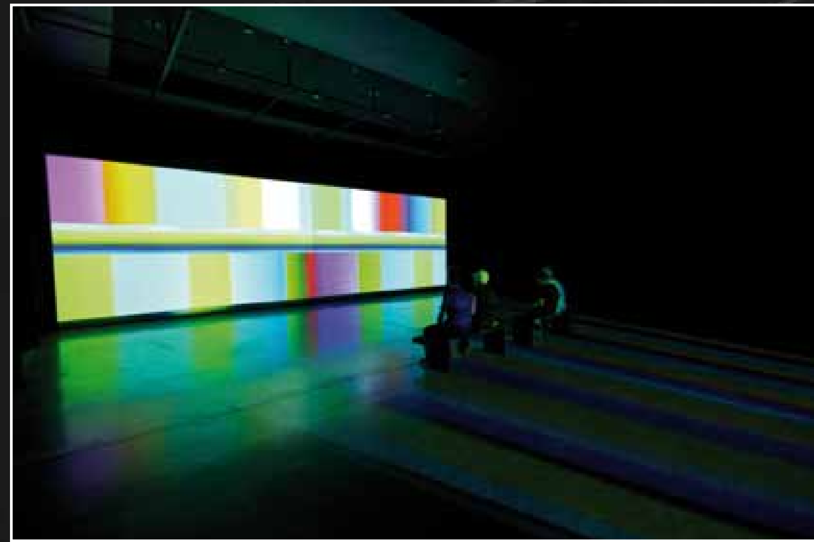


Optical Machines, screenshot of *(SHIFT)*, audiovisual performance, 2012.

Part of the set-up of Optical Machines.

Makino Takashi, still from *2012*, audiovisual performance, 2012.

Otolab, *Bleeding*, live audiovisual performance, 2012.



Event Horizon by Matthew Biederman metaphorically explores the phenomenon of the 'event horizon'. The term refers to the space-time beyond which events cannot affect an observer. This occurs naturally at the edges of a black hole, where light cannot escape beyond the event horizon and thus cannot be observed. In *Event Horizon* software iterates through a basic generative system that uses pure fields of Red, Blue, and Green, modulated, layered and interspersed with black. This creates the 'event horizon' state where a third image is created that only exists in the viewer's mind.

In *Lightscape* Matthijs Munnik researches the qualities of flickering light. As a window to a virtual world, *Lightscape* visualises an abstract universe composed only of light and sound, exploring the borders of our sensory hardware. While the eye tries to make sense of the sensory overload, a dazzling display of highly detailed patterns and colour combinations is formed in the retina and fed to the brain. The phenomena you see are created by the eye itself, induced by the flickering lights.

Matthew Biederman, *Event Horizon*, multichannel video installation, 2012. Photo © Matthew Biederman

Matthijs Munnik, *Citadels, Lightscape*, installation, 2012.

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A Ray of Darkness is the second Kontraste Cahier. It is published on the occasion of the 2012 Kontraste Festival, *Electric Shadows*, 12–14 October in Krems, Austria. The Kontraste Cahiers is a series edited by Sonic Acts for Kontraste. These publications contain intriguing thoughts and materials connected to the Kontraste festival themes.

The Kontraste Cahier series is made possible thanks to Klangraum Krems Minoritenkirche and NÖ Festival-Ges.m.b.H., Austria.

Published by
Sonic Acts Press
Weteringschans 6–8
1017 SG Amsterdam
The Netherlands
info@sonicacts.com
www.sonicacts.com

ISBN: 978-90-810470-5–0
NUR: 640

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Special thanks to Pierre Ballings and Albrecht Großberger.

The 2012 Kontraste Festival, *Electric Shadows*, is curated by Sonic Acts and produced by Kontraste.

‘We now know that the human senses are very efficient filters, and that almost all of the world around us cannot be directly perceived by human senses. Most of the universe is dark.’
— *Roger F. Malina*

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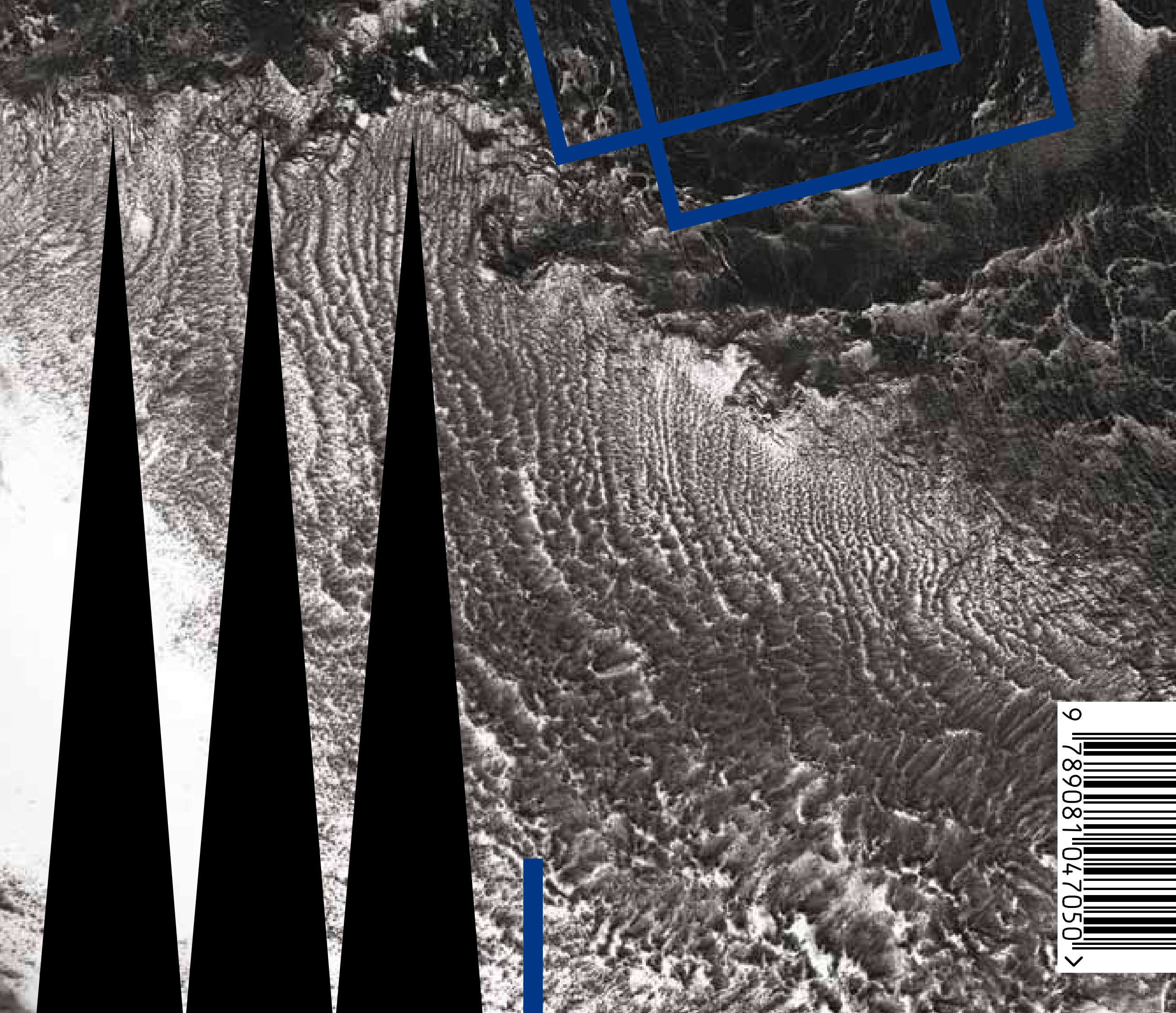

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