COSMIC LATTE

Katie Paterson

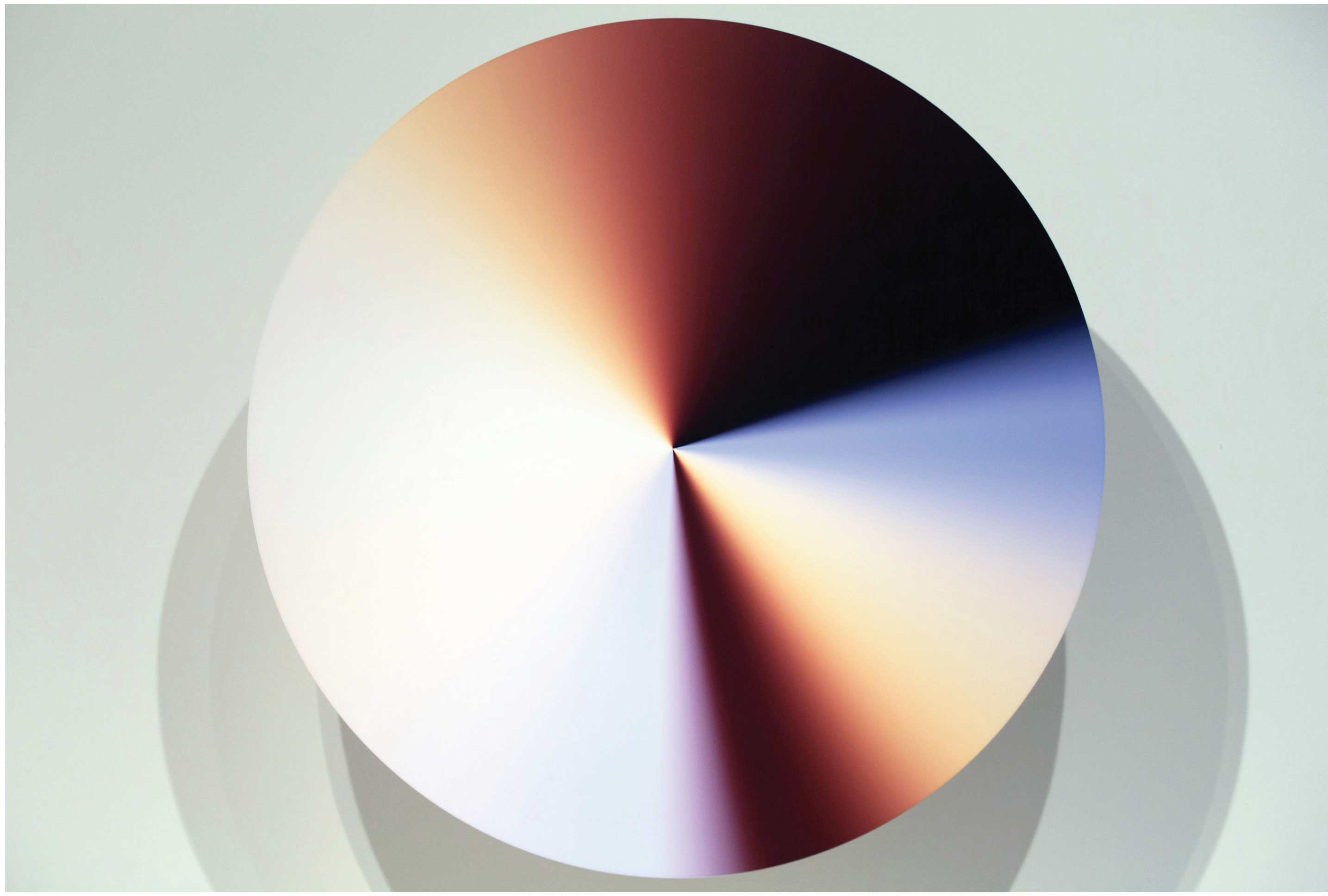
Katie Paterson is an artist whose work collapses the distance between the viewer and the most distant edges of time and the cosmos. She holds a BA from Edinburgh College of Art, an MFA from the Slade School of Fine Art, and is an Honorary Fellow of the University of Edinburgh.

Steve Fossey

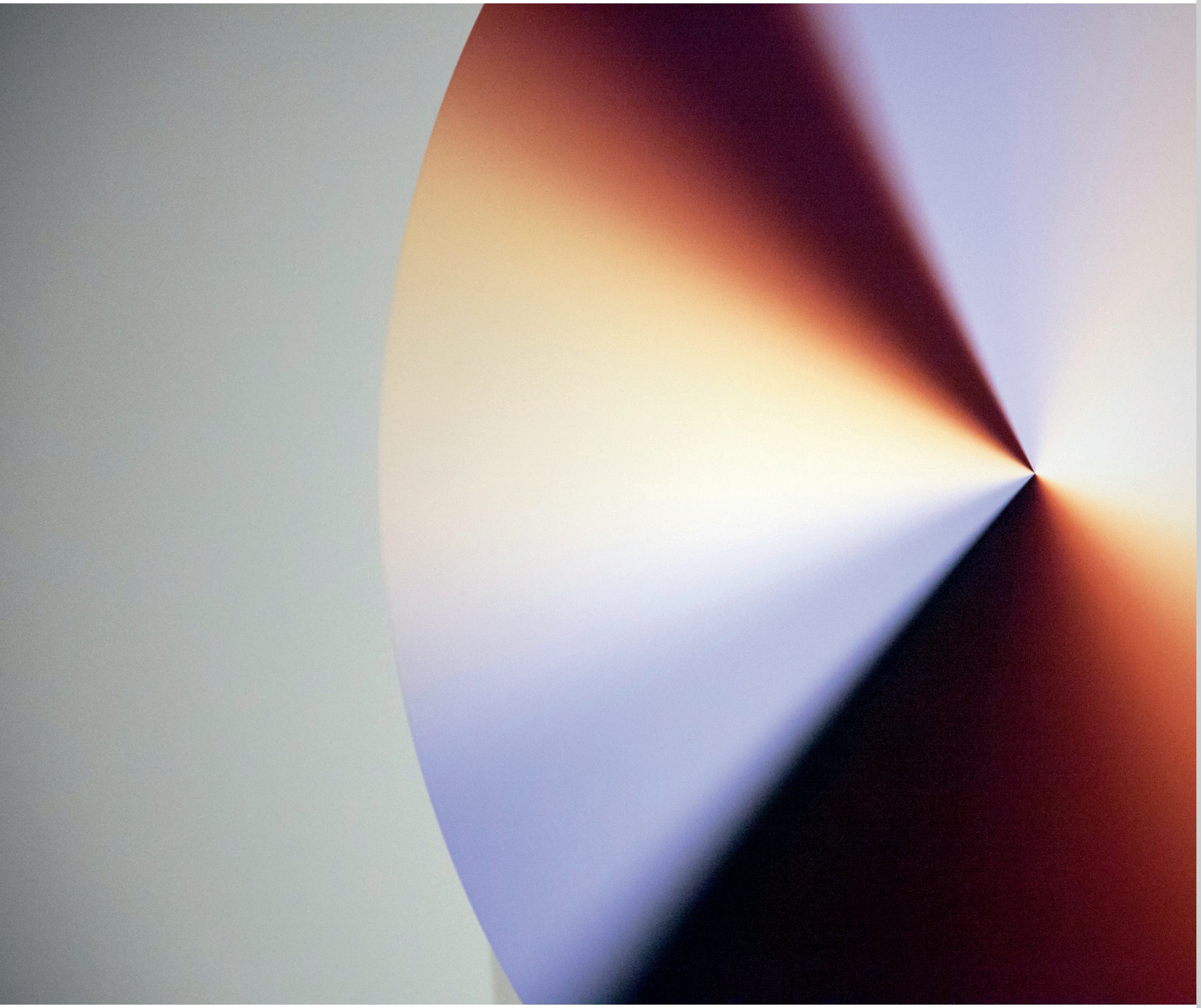
Dr Fossey is currently Senior Teaching Fellow in the Department of Physics and Astronomy, University College London. He is also a long time collaborator on several of Paterson's works.

Approximately half of Katie Paterson's art is inspired by outer space, and it's obvious that she brings a considerable rigour to the work. For Katie, it's not enough to imagine how things might be; she really cares about being as exact as possible. 'When I come up with my ideas in the first place,' says Katie, 'I realise there will be complexity, but I don't know what it will be.' This thorough approach means that she needs to collaborate with astrophysicists, and she has worked frequently with Dr Steve Fossey (Senior Teaching Fellow in the Department of Physics & Astronomy at University College London). I talked to Katie and Steve about the interface of astrophysics and art. We concentrated on four projects, covering the history of the universe in light, interplanetary time, the scents of outer space, and nearly every known Solar Eclipse.

While we've chosen to focus on these pieces, we might equally have considered Katie's work on sending a meteorite back into space (2012-14), recreating moonlight (2008), the brightest-ever explosions (2011), or commemorating the death of stars (2011-present). For *Campo del Cielo, Field of the Sky* (2012–14), a meteorite was cast, melted, re-cast into a new form, and then returned to space by the European Space Agency (Paterson, 2012-14) *Light bulb to Simulate Moonlight* (2008) applied the spectral measurements of moonlight to the creation of a light bulb, whereas for *100 Billion Suns* (2011) the 3,126 known gamma-ray bursts in the Universe (which can burn 100 billion times brighter than our sun) were reduced to 3,216 pieces of appropriately coloured paper to be fired from a confetti cannon (citn). *The Dying Star Letters* (2011- ongoing) sees Katie writing letters to inform scientists upon hearing the news that a star has died, as some do each week (Cervera, 2017). Indeed, Katie has so many ideas that she has taken to making Sterling Silver wall texts of what could be – practicalities aside - possible works. For example, 'objects coated in gold extracted from shooting stars,' 'a place that exists only in moonlight,' and 'the universe rewound and played back in real time' (from Ideas (2015-ongoing).



The Cosmic Spectrum, 2019. Exhibition view Turner Contemporary, 2019 Supported by the Arts Council England. Photo © Manu Palomeque.



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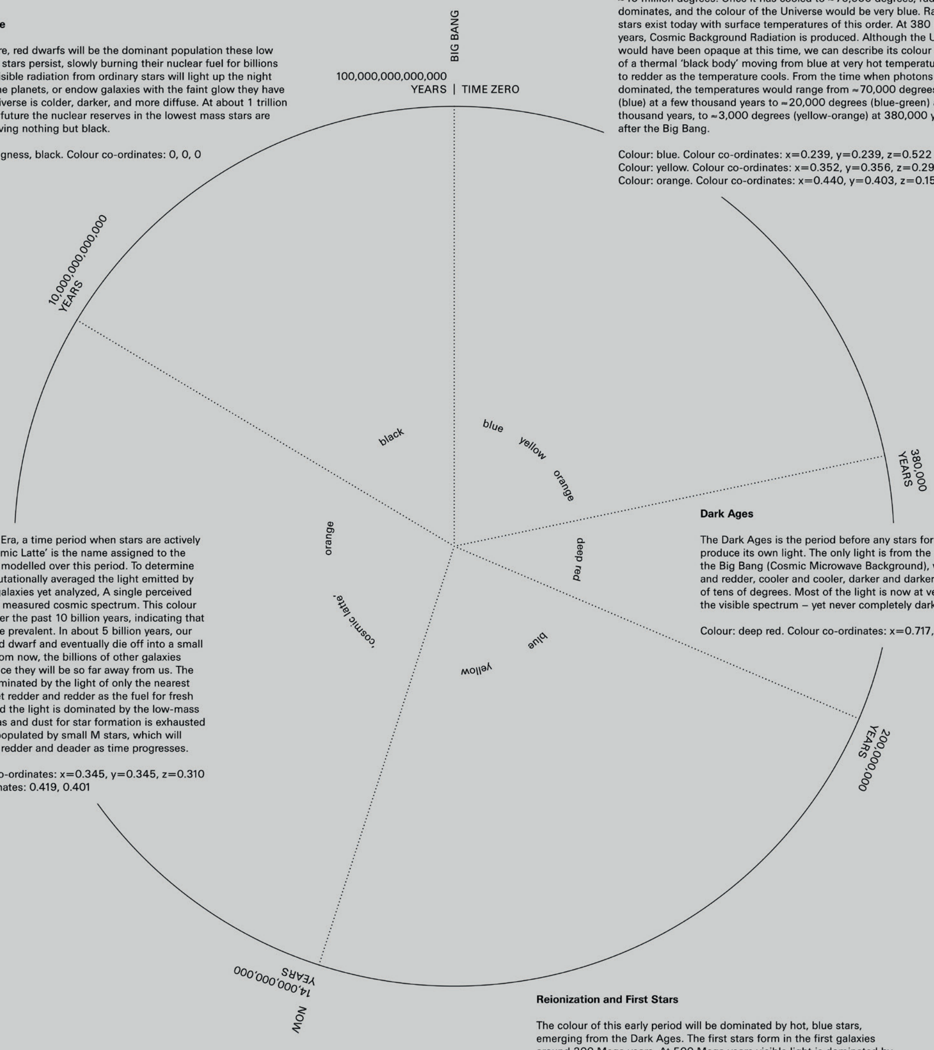

The Primordial Era

From Time Zero to seconds or minutes later, the energy/matter content of the Universe is dominated by interactions between subatomic particles and antiparticles, and very high energy photons of light are generated by matter-antimatter collisions. No astrophysical objects, like stars or galaxies, have been able to form. The Universe would be enormously hot at this time. From around one month, the temperature of the Universe is ≈10 million degrees. Once it has cooled to ≈70,000 degrees, radiation dominates, and the colour of the Universe would be very blue. Rare hot stars exist today with surface temperatures of this order. At 380 Kilo years, Cosmic Background Radiation is produced. Although the Universe would have been opaque at this time, we can describe its colour in terms of a thermal 'black body' moving from blue at very hot temperatures to redder as the temperature cools. From the time when photons dominated, the temperatures would range from ≈70,000 degrees (blue) at a few thousand years to ≈20,000 degrees (blue-green) at ten thousand years, to ≈3,000 degrees (yellow-orange) at 380,000 years after the Big Bang.

Colour: blue. Colour co-ordinates: x=0.239, y=0.239, z=0.522
Colour: yellow. Colour co-ordinates: x=0.352, y=0.356, z=0.292
Colour: orange. Colour co-ordinates: x=0.440, y=0.403, z=0.157

Dark Ages

The Dark Ages is the period before any stars form. The Universe does not produce its own light. The only light is from the slowly cooling echo of the Big Bang (Cosmic Microwave Background), which becomes redder and redder, cooler and cooler, darker and darker, to a colour temperature of tens of degrees. Most of the light is now at very low energy, beyond the visible spectrum – yet never completely dark.

Colour: deep red. Colour co-ordinates: x=0.717, y=0.283, z=0.000

Reionization and First Stars

The colour of this early period will be dominated by hot, blue stars, emerging from the Dark Ages. The first stars form in the first galaxies around 200 Mega years. At 500 Mega years visible light is dominated by young galaxies. The light cannot be described by a unique temperature because it is a combination of many stars. The first stars to form are enormously massive, perhaps 150 times the mass of our Sun, and extremely hot, with surface temperatures of tens of thousands of degrees, and short-lived - a million years, perhaps. They will end their lives as violent supernovae, which will then trigger more waves of massive star formation. The first light may also arise from Active Galactic Nuclei, quasars, and massive black holes at the centres of galaxies; matter that heats up as it falls into black holes producing very energetic radiation (blue). At the midway point of 7 Giga years, half-way through cosmic star-formation history, there is a mixture of young and old stars contributing to the light.

Colour: blue. Colour co-ordinates: x=0.270, y=0.279, z=0.451
Colour: yellow. Colour co-ordinates: x=0.330, y=0.332, z=0.338

The Stelliferous Era

We now live in the Stelliferous Era, a time period when stars are actively forming, living, and dying. 'Cosmic Latte' is the name assigned to the average colour of the Universe modelled over this period. To determine this colour, astronomers computationally averaged the light emitted by one of the largest samples of galaxies yet analyzed, A single perceived colour was calculated from the measured cosmic spectrum. This colour has become much less blue over the past 10 billion years, indicating that redder stars are becoming more prevalent. In about 5 billion years, our own Sun will swell up into a red dwarf and eventually die off into a small white dwarf. 30 billion years from now, the billions of other galaxies we now see will have faded since they will be so far away from us. The observable Universe will be dominated by the light of only the nearest galaxies. These galaxies will get redder and redder as the fuel for fresh star formation is exhausted, and the light is dominated by the low-mass red dwarf stars. Once all the gas and dust for star formation is exhausted only elliptical galaxies remain populated by small M stars, which will gradually become dimmer and redder and deader as time progresses.

Colour: 'cosmic latte'. Colour co-ordinates: x=0.345, y=0.345, z=0.310
Colour: orange. Colour co-ordinates: 0.419, 0.401

The Far Future

In the far future, red dwarfs will be the dominant population these low mass small M stars persist, slowly burning their nuclear fuel for billions of years. No visible radiation from ordinary stars will light up the night skies, warm the planets, or endow galaxies with the faint glow they have today. The Universe is colder, darker, and more diffuse. At about 1 trillion years into the future the nuclear reserves in the lowest mass stars are exhausted leaving nothing but black.

Colour: nothingness, black. Colour co-ordinates: 0, 0, 0

Colour Wheel Diagram, 2018 © Katie Paterson. Larger text available on pp 376-379

‘So, what happens when the lights go out?’

Katie says that *The Cosmic Spectrum* (2019) is her three-year-old son’s favourite piece. The large disc of spinning colours does indeed have an immediate appeal for all ages, but that’s not what took two years to develop. It started from Katie reading Professor Ivan Baldry’s paper introducing the term ‘cosmic latte’ for how the universe is, on average, beige (Baldry *et al.*, 2002; Glazebrook and Baldry, 2002). This amazed Katie, ‘as it is the last colour that would come to mind when you think about all the darkness and stars.’ Scientists had come to that conclusion, she says, ‘by analysing starlight and finding the average colour. What I found interesting to wonder was: if you can determine the colour now, then – given we know so much about how stars formed and how they are likely to develop – can we track the colour across the whole history of the universe?’ She contacted Steve Fossey (of UCL’s Department of Physics & Astronomy) along with Professors Richard Ellis (also of UCL’s Department of Physics & Astronomy) and Ivan Baldry (of Liverpool John Moores University), and eventually, between them, they managed to split the universe into its eras and find out the colour co-ordinates. *The Cosmic Spectrum* (2019) depicts the colour of the universe throughout its existence, spinning in one continuous cycle. It charts a history of starlight; from the primordial era, through the Dark Ages and the appearance of the first stars, to the current ‘Stelliferous Era’ (see: Adams and Laughlin, 1999) and into the Far Future. To allow for this future extrapolation, the piece uses the 2dF Galaxy Redshift Survey (which measures the light from more than 200,000 galaxies (Colless *et al.*, 2001)) and speculative, but informed, data from those leading scientists to establish the average colour of each era, including today’s ‘cosmic latte’ (Glazebrook and Baldry, 2002).

Steve explains that the task was made more complex by the need to take account of not just stars in galaxies but gas, dust, and black holes. The Big Bang itself is ‘relatively simple to encode,’ he says. ‘The initial fireball can be characterised by a temperature which changes over time, making the first 380,000 years easy. Then it gets hard. Go back to the very first stars, and they are massive and hot. To forecast the far future of starlight, we used a research paper by Greg Laughlin called ‘The End of the Main Sequence’ (Laughlin *et al.*, 1997), which describes the evolution of the lowest-mass stars. The Sun is steady; it fuses hydrogen into helium, by and large, for most of its lifetime. Massive stars evolve rapidly, and blow themselves up. The very coolest stars – low-mass red dwarfs – are very slow feeders: they have a supply of hydrogen fuel they convert to helium, and that lasts a long time. And those low-mass stars dominate, as it’s easier to make smaller stars than bigger ones.’ When an astrophysicist says ‘a long time,’ it’s probably beyond our familiar scales. Just how long does Steve mean? ‘They will last 100,000 billion years. That’s some 10,000 times longer than the Sun will last, and getting on for 10,000 times longer than the universe has been in existence so far.’ Our own Sun, by the way, is middle-aged. The universe is about 14 billion years old: the Sun was born at around about the 9 billion year mark with a life expectancy of 10 billion years, and so it will last another 5 billion years or so (Bonanno *et al.*, 2002.).

The team stopped at that 100,000 billion-year point when, as Katie puts it, 'the last lights will go out.' Accordingly, what we see is both a history of starlight, and the evolution of the universe over the scale of cosmic time – an awe-inspiring concept to assign to a disc of spinning colours. So what happens when the lights go out? 'Other objects such as black holes will last beyond that,' says Steve, 'and the cores of the stars will continue to cool and fade.' Katie was struck to discover when she first showed *The Cosmic Spectrum* (2019) alongside paintings by Turner (see: Alfrey, 2019), how closely the piece echoes the colours in his late abstracted-tending sunsets – logically enough, though, as the spinning disc shows the ultimate setting of suns.

There were, however, two particular problems to be solved before arriving at that presentation. The first was what temporal scale would be appropriate to use. On an unadjusted scale, the data translated to rapid initial changes, up the emergence of the first stars after 200 million years, followed by long periods of darkness with just the odd streak of colour. The answer, says Katie, was 'to use a logarithmic timescale so it was concertinaed out in a way we could relate to.' As Steve explains, 'that goes up in powers of ten, so if you take a segment, then the next segment along represents ten times as long.' Thus the relative reduction in visual interest over time was countered by changing the speed at which the time is shown. The second problem they encountered was how the colours modelled on screen could be accurately turned into the colours to be shown in the work? The answer, says Katie, ended up being taking colour co-ordinates to graphic designers and a specialist printer, allowing them to maximise the accuracy of the colour-matching process.

Timepieces (Solar System), 2014. Exhibitoin view Frac Franche-Comté. Photo © Blaise Adilon, 2015

Timepieces (Solar System), 2014. Photo © John McKenzie. Courtesy of the artist and Ingleby Gallery, Edinburgh.

Diagram of *Candle (from Earth into a Black Hole)*, 2015.

'I want to be precise,' explains Katie. 'We went over every era quite rigorously, but I accept that if we reach a certain limit, well, that's the way of all knowledge.'

A series of nine clocks hang on a wall, representing the eight planets of the Solar System (and the Earth's Moon) in order of their distance from the Sun. Each clockface depicts the length of solar days on that planet (or moon), with the density of the hour marks indicating the relative number of hours in the day. Accordingly, while the 'Earth' clock has a familiar 12 hours, at 30-degree increments, the clock for Mercury, which has a solar day of over four thousand hours, is covered with a high density of hour marks, with tiny increments. 'Everyone gets it straight away,' says Katie, 'when they see the density of the strokes marking the twelve earth hours on Mercury compared with the Earth. That's how people visualise it. So, on the Moon it's quarter past 700 o'clock etc'

The data behind the piece aren't quite as simple as one might first assume. 'I got fussy about the rates,' explains Steve, 'because when you look up published rotation periods for the planets, what you get is how they rotate with respect to the stars – the fixed points in the sky against which the rotation is measured. When you do this for the Earth you get what is known as the 'sidereal day,' which is 23 hours 56 minutes. But as the Earth also orbits the Sun, you need a little extra, as the Sun appears to move relative to the background stars because you're going round it. After every 23 hrs and 56 minutes, there's an extra four minutes of rotation to catch up with the sun – from a human point of view, because the Sun is what we're interested in. And that happens for every planet, so rotation periods are all quoted as sidereal, whereas the clocks in Katie's project all relate to the Sun, and so to such concrete human

Candle (from Earth into a Black Hole), 2015. Exhibition view Gwangju Biennale, 2016 concerns as 'when is it lunchtime?' If you were to imagine Solar System civilisations, they would need to know where the Sun is in the sky on their planet, so the calculation must allow for that, leading to a different calculation – the solar rotation period, not the sidereal one.' Once that's all factored in, those days lengths are as follows: Mercury 4,223 hours; Venus 2,802 hours; Earth 24 hours; Moon 708 hours; Mars 24 hours 40 minutes; Jupiter 9 hours 56 minutes; Saturn 10 hours 39 minutes; Uranus 17 hours 14 minutes; Neptune 16 hours 6 minutes.

Steve explains that these timings can change. For example, the Moon greatly influences the Earth's rotation. The satellite is thought to have originated when 'a glancing blow occurred from the collision of two proto-planets, and some material solidified into the Moon, which has slowly retreated from the Earth. The length of the day has increased because of that – 'billions of years ago, a day on Earth was about eight hours long.' Both Venus (which rotates at just 6 km/hr) and Mercury (which rotates at 10 km/hr), may also have been affected by the Moon's gravitational tug. The gas giants, however, are remote and less dense. Their fast spin probably reflects the way they first formed; Jupiter rotates at 45,580 km/hr and Saturn at 36,840 km/hr. Earth has the middling speed of 1,670 km/hr. 'All that,' says Steve, 'is there in the clocks.'

Where *The Cosmic Spectrum* (2019) and *Timepieces* (2014) present scientific data in a poetic way, *Candle (from Earth into a Black Hole)* (2015), combines the scientific and the poetic in its very formulation. 'A scented white candle that burns down over 12 hours,' the work is designed to create a 23-layer 'journey through space via scent' (Paterson, 2015). The candle is formed of multiple strata, 'each containing a unique perfume corresponding to a planet or place in the universe' (ibid.). Here, Katie says she 'had a clear idea of what I wanted to do, but little idea how to do it. We would leave Earth and smell the forest, and then move through

Image on facing page: *100 Billion Suns*, Installation view Venice, 2011. Photo © MJC Courtesy of the Artist

'I have no desire to leave the Earth'

– Katie Paterson

Lightbulb to Simulate Moonlight, 2008. Photo © MJC

the various atmospheres out to the Moon, and on through space, finally reaching a black hole, which is odourless.' The smell of space, however, hasn't been the subject of much scientific investigation. So 'research only took us so far. Some scents relate to the known chemical composition of planets. Moon dust was analysed from astronauts' spacesuits. NASA have a 'recipe' for the atmosphere of Saturn's largest moon, Titan, as 'sweet and bitter almond, cherry, with slight benzene' (NASA, 2014). But for some zones – the sun, for example – we have only fictional descriptions. So we used a mixture of fact and fiction.' Katie worked with a scent maker who makes scents used by high-end chefs in experiential cooking, and a specialist candle-maker, as making so many layers is difficult (they are all hand-dipped at the end of the process, yielding a plain white candle which conceals the complexity beneath). The smells can be tracked in an accompanying diagram (Paterson, 2015). Katie mentions that she likes the earth's atmosphere being like a freshly-opened can of soda. But she says 'Dying Star' – hot metal, diesel fumes, and barbecues – smells as horrid as it sounds.

Does Katie fancy making the journey into space? Perhaps surprisingly, no. 'I have no desire to leave the Earth. I love our viewpoint, though I like to imagine the setting Sun on other planets, and it's good for us to keep in the mind the possibility of a completely different viewpoint.' It seems that she won't be the first artist in residence on the moon. But that doesn't diminish her interest in how 'we're one planet among billions, all ticking away at different rates. Our internal clock has come about in relation to our Earth, so as soon as you go anywhere else, any other life form there is will relate to their day and night.' Does that mean, I wonder, that even if everything else could be held improbably constant, humans would have evolved differently if they had a different length of day? Steve thinks so: 'Yes, that would have made a huge difference, as all evolution is synchronised to the timescale.' Katie mentions being struck to hear that 'every creature sleeps' – and has slept, even going back in time to our origins. Every animal is tied in to its clock.

For *Totality* (2016), 'nearly every solar eclipse documented humankind has been brought together in a mirror ball' (Paterson, 2016). The images, of which there are over 10,000 'span drawings dating from hundreds of years ago through nineteenth-century photography, and up to the most advanced telescopic technologies' (ibid.). The images are arranged – sequenced both horizontally and vertically – around a disco-style mirror ball, and light beams the spinning images onto the walls of the room to theatrical and mesmerising effect. According to Katie, it was exceptionally time-consuming to arrange and affix the images to the ball – the more so as it is an edition of four – but that was nothing compared with the problems in getting the lighting right the first time *Totality* was shown. Many lighting designers and engineers were involved, until the man who lit the Olympics found a precise set-up which worked.

Steve wasn't involved in this project, but explains that the Moon sliding across the Sun is made possible by the remarkable coincidence that they happen to appear about the same size in the sky. Not only is that a rare combination – you'd have to visit thousands of planets to find such a well-matched line-up between satellite and star – it is not permanent. The slow departure of the Moon from the Earth is such that billions of years ago it would have been too close for the eclipse to operate as spectacularly as it does now, and about a billion years hence it will be too far away: by then 'it will become smaller than the Sun and we won't get any more total eclipses.' Steve is also struck by how the flashes of light coming off the spinning globe resemble the Sun's activity as captured in photographs using different light frequencies to reveal the hot gases coming off the corona. Then 'you realise what a dynamic place the Sun is – as energy gets released, magnetic fields fold and buckle and throw material off. The totality of eclipses turns out to be evocative of the dynamic nature of the Sun in its own rotation.'

Katie Paterson, then, has found many ways to summon the poetry that lies behind astrophysical data in order to relativise our place within a universal set of timescales and distances. The rigorous models and assistance from scientists which feed into that work don't just facilitate its making: they ensure an integrity and believability which reinforces our engagement.

PAUL CAREY-KENT

Paul Carey-Kent writes widely on art, including for *Art Monthly, Frieze, World of Interiors* and *Border Crossings*, and has a weekly column online at *FAD Magazine*. He curates shows regularly, most recently 'A Fine Day for Seeing' at Southwark Park Galleries. You can find him on Instagram @ paulcareykent and read a wider range of writing, including photo-poems, at Paul's Art World.

Totality, 2016. Photo © Ben Blackall, 2016 Courtesy of the Lowry