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Natural Calligraphy

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Abstract

The term 'natural calligraphy' is introduced to describe a class of dynamic lines found in nature. These lines are well-defined although sometimes short-lived. They occur in different natural processes and on different scales. A selection is presented in this paper so as to better understand the class. They possess, for instance, cusps in density, involved topology and sweeping curves. Their occurrence is sometimes surprising because diffusive processes lead to smoothening of densities, the weakening of strong gradients, and the erasure of edges and sharp boundaries. As they change over time, forms of the line - 'characters' - emerge that seem particularly striking but these can disappear as quickly as they appear. As these characters evolve from and to less remarkable forms, we have a better chance of understanding the characteristics that make them appear compelling or beautiful. The lines exist in higher-dimensional spaces and we present two-dimensional projections of these spaces (photographs and images from simulations) as illustrations in this paper. Features that we describe as striking are often a result of this projection so that the natural form and the viewer both play a part in creating a 'work of art'. We distinguish two types of experiment that we can conduct simultaneously in natural calligraphy. First, there is the scientific study of the natural processes creating the line. These processes possess both predictable and random (chaotic) elements. They are therefore not strictly repeatable although some features of the process are robust. Second, there is our placement in, and subjective selection from, the process as artists. We discuss these two types of experiment in more detail in relation to our examples.

The exciting possibility suggested by these natural processes is a dynamic evolving calligraphy with a continuum of forms and symbols. Modern developments in the concept of trajectory in science have enriched the simple idea of a line and the extremal principles at the heart of these developments underlie the aesthetic of natural calligraphy. This paper aims to give an introduction to these ideas that might be of interest to both to scientists and practitioners in the arts.

Calligraphy can be a synthesizing activity to bring into dynamic equilibrium the forces of the intellect and the pleasures of the senses

Lee Hall (adapted by Sheila Waters and forming the frontispiece to Child (1985))

How are lines drawn in the world? What shapes the paths taken by light and by matter? And what do the answers to these questions have to do with calligraphy concerned as it is with the shape and quality of a line?

Let's start simply, ignore the quality of line and just think about its progress - of getting from A to B. One of the ways of transferring a drawing to a support for painting is pouncing. A series of holes is made along the lines of the drawn design. The drawing is laid on the canvas or panel, and fine charcoal or chalk dust in a small muslin bag pounced or rubbed over the holes leaving a faint network of dots on the support. Now completing the transfer of the design is not the simple exercise of pair-wise joining the dots because the intent is to use the dots as a guide to recreate the curves of the original drawing. If the dots are close together, simple line elements are reasonable, if inelegant, approximations to the curve. But where the dots are sparse, the copyist must make judgements: in getting from A to B, the path is a curve, weighted by the knowledge of points that precede A and those we will join beyond B. The points constrain the curve but without further prescription its path is not unique. One such prescription might be to minimise extremes of curvature, or more specifically (some function of) the curvature averaged along the path. A convenient way to compute this path is to use a mechanical spline - a thin piece of flexible wood pressing against pins placed at the pounced points. The anchored spline relaxes to follow the curve in which it has the smallest possible elastic bending energy given the constraint of the pins. The local bending energy within the spline is related to its local curvature; so the relaxed state, minimizing the sum of all these local energies, also minimizes (the square of) the local curvature summed along the spline. The resulting smooth curve manifests a natural law and indeed, more generally a natural principle – that equilibria (relaxed stationary states) are associated with constrained configurations of least energy. This does raise an interesting question – are these relaxed states aesthetically appealing because we recognise them as equilibria – stationary and therefore unthreatening?

A bent wooden strip generates pleasing interpolated curves – can we learn more from other naturally created paths? You are walking along a beach and see a swimmer in difficulties. The line between the two of you is oblique to the shoreline [Fig. 1]. You want to reach the swimmer as quickly as you can. But you can run faster than you can swim and so you realise that it may be better to follow a path that allows you to exploit this, not simply the straight line path from A to B. The bent path is longer (and its initial direction quite alarming to the swimmer who might think you are racing to someone else). However, the total time can be made shorter than the simple straight line path as you have less distance to travel in the water where your speed is lower. The exact offset in your bearing (and the bending of the line) depends on the ratio of your running and swimming speeds. The path from A to B now consists of two line elements: but if we imagine the sand getting wetter as we approach the water (making running more difficult) and swimming getting easier as we head further from the shore, the trajectory will become a curve, still with the property of being the path from A to B that takes the shortest time. If we replace the rescuer by a light ray and sand and water by air and glass (or any material in which light travels slower than air), we have refraction of light at the interface.

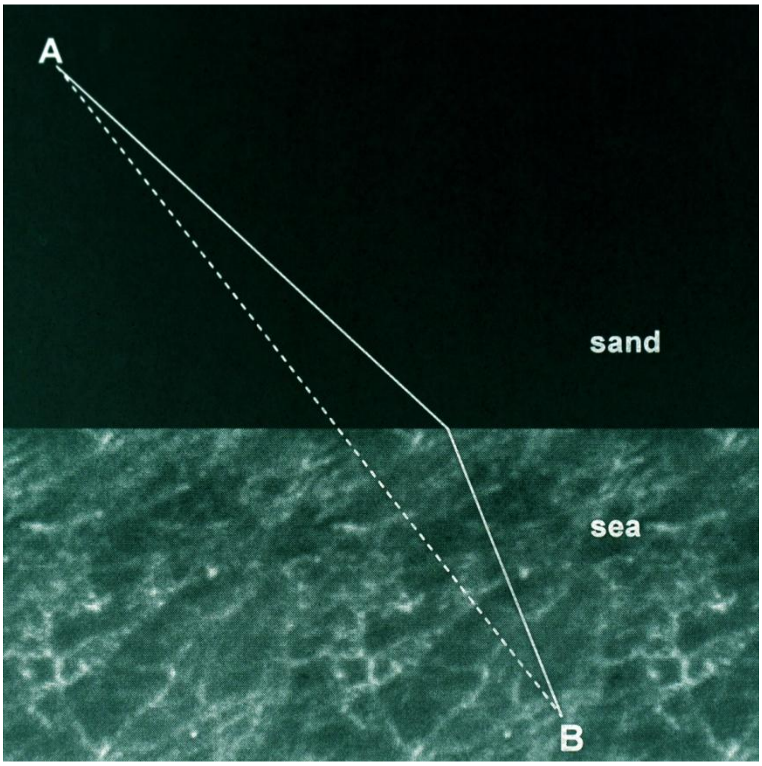

Fig. 1: The minimal time path between A and B is not the simple straight line trajectory (dotted line) but the refracted path that involves less distance in the sea where the rescuer’s speed is lower. Diagram © the author.

Another natural path is therefore described by an extremal principle – in this case Fermat’s principle of minimal time. It turns out that this is actually a special case of a more general principle that can be used to describe not just light but objects as diverse in size as atoms and stars – the principle of least action. So dynamic processes in nature and the calligraphic properties they possess are, just like the spline, described by an extremal quantity. The principle of least action underlies an approach to the study of quantum paths pioneered by Richard Feynman (Feynman 1942). In quantum mechanics we cannot identify one true trajectory that a particle will follow. But to each possible path we can attach a weight and this weight is determined by the action evaluated along that path. It would seem like quite a task to enumerate all possible paths (and indeed it is) but fortunately cancellation of contributions from neighbouring paths occurs so that the focus of attention remains, in typical cases, close to the classical trajectory. Nevertheless this is now diffuse: the consideration of non-classical paths close to the unique classical trajectory is now required in determining where our particle might be found. There is something of an analogy here with exploratory drawings, for instance Leonardo's *Rearing Horse* in the Royal Collection at Windsor Castle (Zöllner and Nathan 2011, 317). In this pen and ink and red chalk study, we see the limbs and head of the horse depicted in several overlapping dynamic states with the fixed curves of the torso qualified by stronger lines.

But we should not think of these microscopic paths as determinate and visible like Leonardo's construction lines or aircraft contrails, they are potential paths useful in calculation but forever inaccessible as visible histories. When quantum mechanics was developed, real paths visible in the laboratory, such as the contrails of α-ray tracks in a Wilson cloud chamber, seemed at odds with the weakened idea of the classical trajectory. But even these paths really only consist of many pinned points - locations where atoms have been ionised and condensation has occurred; we complete the full path in our minds. The cloud chamber does raise another interesting question: how to reconcile the spherical wave that theory predicts to accompany the α-particle's emergence from a radioactive nucleus, with the linear trail we observe, without abandoning the wave description of the particle. As Neville Mott nicely put it, the difficulty of imagining how: "a spherical wave can produce a straight track arises from our tendency to picture the wave as existing in ordinary three-dimensional space, whereas we are really dealing with wave functions in the multispace formed by the coordinates both of the α-particle and of every other atom in the Wilson chamber" (Mott 1929, 79). This mutual dependence is also a feature of intermediate pinning points along Feynman's ghostly trajectories. A higher dimensionality underlying a path will be a recurrent theme in this paper.

Quantum mechanics has led us then to weaken the line strength of classical paths and dispense with the idea that they have no thickness. We can think of the quality or breadth of each path varying along its length, dependent on the degree to which nearby trajectories contribute at each point. A character in traditional calligraphy has a line changing in definition and breadth along its length. There is a simplistic analogy here. The tip of the drawing instrument (be it pen or brush) has a width; so that different parts of the tip describe different paths. The breadth of the character is changed by varying the angle between the tip and the line of the figure, with the narrowest line created by having the two parallel. More interestingly perhaps, some calligraphic characters can be imagined as three-dimensional ribbons, twisted and viewed in two-dimensional projection. What we perceive as the energy of these characters may unconsciously be related to the dynamic of this twist.

Varying line strength is also familiar in the evolving calligraphy of the caustics formed at the base of a swimming pool by intersecting light rays refracted to different degrees by the gentle disturbance of its surface. A static example created by reflections rather than refraction is depicted in Figure 2. The caustics in this figure nicely introduce the idea of line strength in natural calligraphy but there is a feature of the quantum paths that eludes them. In the caustics, line strength is related to reinforcement – intensities from many overlapping rays, arriving from slightly different directions, are purely additive and cannot lead to cancellation. The sources of light are incoherent and so there are no interference effects in determining the strength of line. But it is just these phase effects that lead to the addition and subtraction of neighbouring paths in quantum mechanics and the resulting 'smeared' classical trajectory.

We can make one more observation here. The light rays from the bottle lids in Figure 2 are streaming through a three-dimensional space. But they are made visible to us when they strike a two-dimensional shelf (and are captured in a two-dimensional image). The pattern of scattered light will change if we change the position of the scattering surface. We can select from the continuum of positions of the surface, those that give rise to illuminated 'characters' with a special appeal to us. Experimentation suggests that the most interesting 'characters' have localised well-defined intense arcs and cusps embedded in a veil of ghostlier curves – a high dynamic range of brightness and of spatial frequency. Small movements of the surface or of the light sources change these two distributions and with it the 'character'. We can, to some extent, quantify the appeal of a particular figure in the numbers that represent these distributions, in the same way that we can investigate how we respond to computer-generated landscapes by varying their fractal dimensions. Talk of numbers and beauty is fraught with danger and cultural references and tradition will colour any aesthetic of the characters. However traditional strokes across cultures are all limited by the articulation of the hand and there is a universal appreciation of fluidity and instinctive mark-making. Their very simplicity does make it meaningful to ask about the sensual impact of varying geometrical qualities such as curvature and balance.

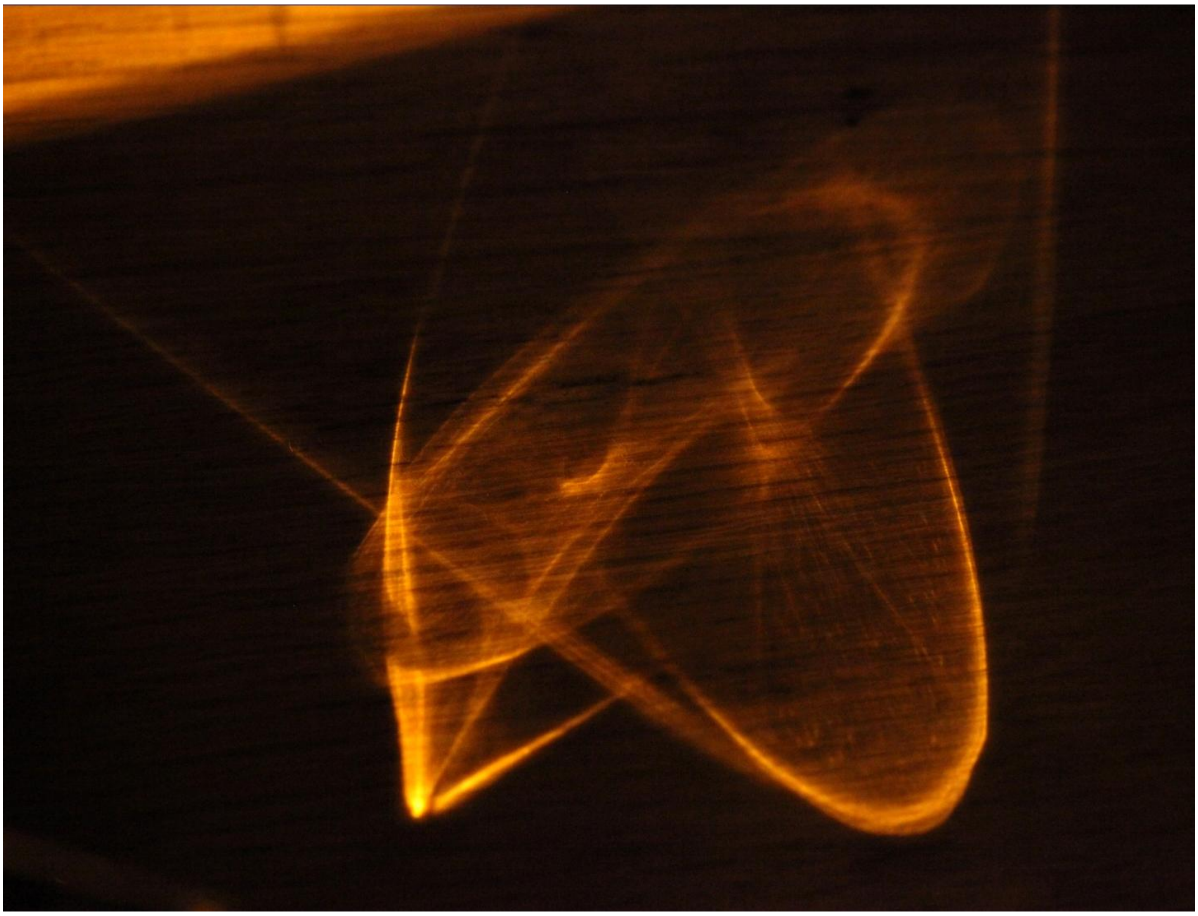

Fig. 2: The sweeping curves and varying strength of caustics formed on a wooden bathroom shelf by light reflected from two extravagantly curved plastic bottle lids. (Photo © the author)

In the case of the light caustics we have just described, the two-dimensional surface can, in principle, be moved so as to meet the envelope of light rays in differing ways and give rise to different characters. There is another example of natural calligraphy, where the two-dimensional surface is now fixed but the characters still evolve, and that is the vertical soap film [Figs. 3, 4, 5]. In fact the soap film is truly three-dimensional because, although its thickness is tiny, it is variations in this dimension that give rise to the different colours in the film. These are interference colours so, unlike the case of overlaid intensities in the caustics, we are seeing phase effects and cancellation of waves. These are effects of just the type we described earlier that give a breadth and varying quality of line to the classical path of a particle

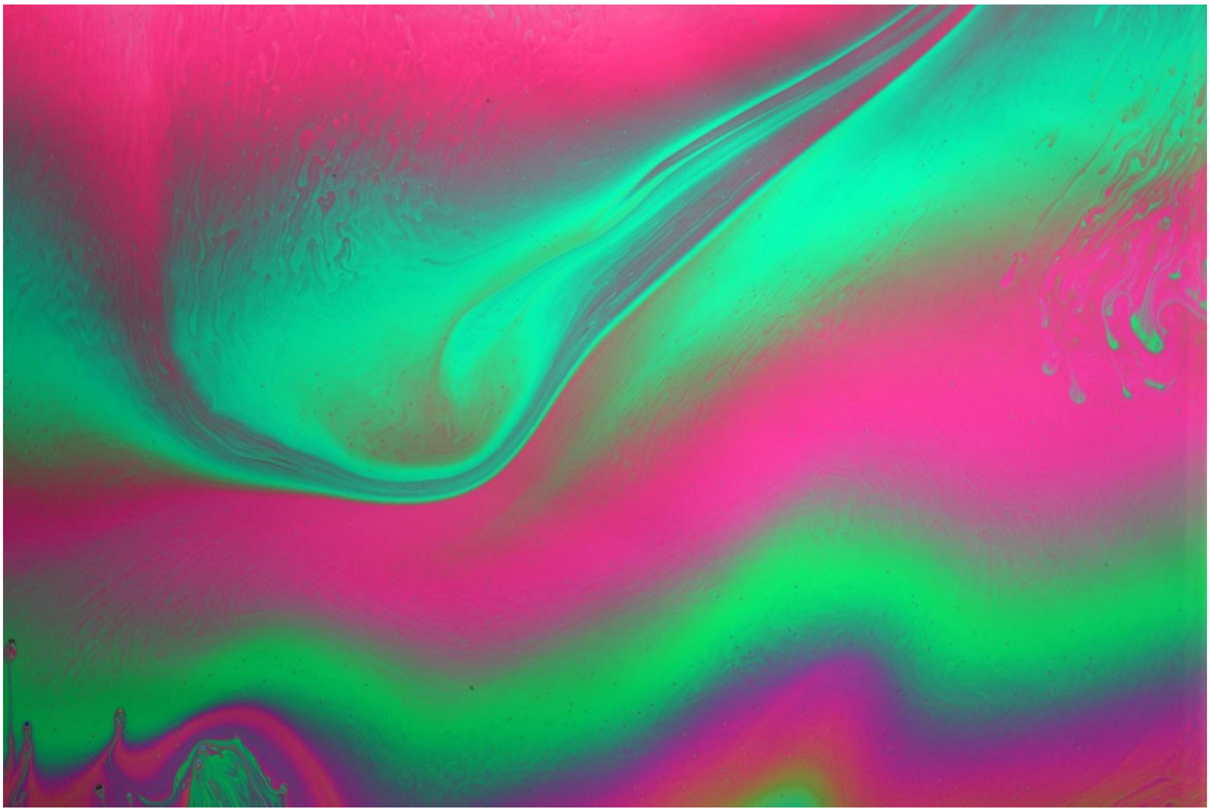

Fig. 3: Interference colours in the early evolution of a draining soap film. Note the varying crispness of line in different parts of the film and the broad range of intensity. (Photo © the author)

The colour in a particular region of Figures 3 to 5 indicates that the thickness of film there can accommodate a whole number of that colour's waves (reinforcement through interference); so the picture can be thought of as a natural contour map, albeit of a very shallow topography. The colours are ephemeral, changing as the film thins under drainage or evaporation. When the soap film is drained vertically, there is initially horizontal striping reflecting the gradually increasing thickness toward the base of the film; but instabilities set in at the edges of the supported film [Fig. 4], and can be further stimulated to create a turbulent structure that resolves itself into relatively stable islands.

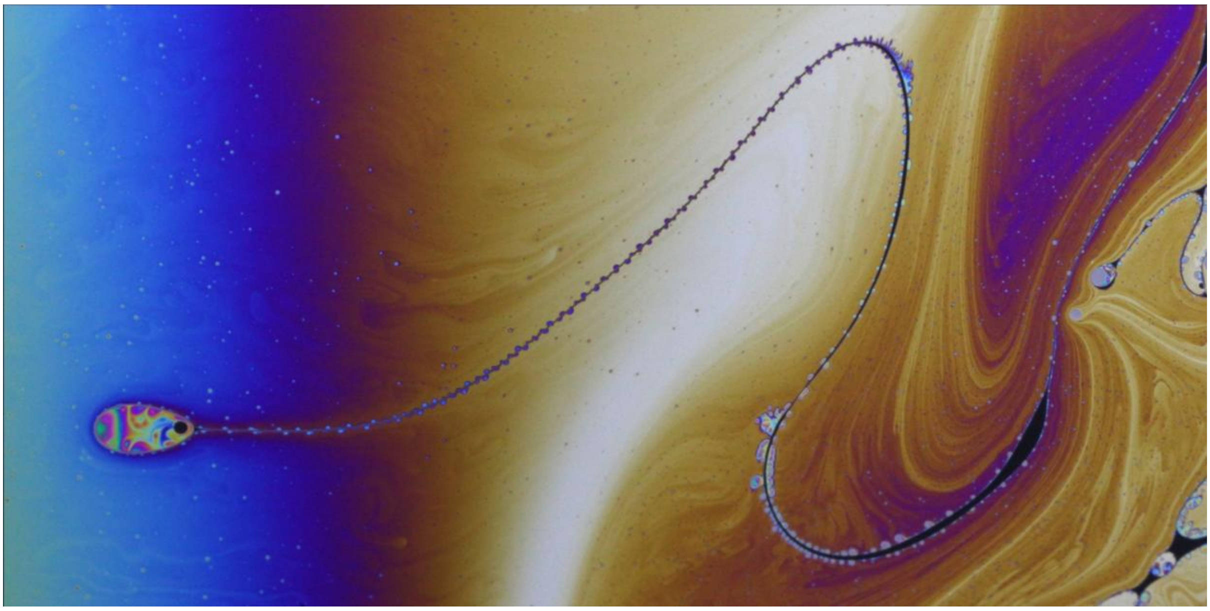

Fig. 4: The sinuous trail of a heavy droplet falling within the film. Note the interlacing on the tail and the broad banding present before the film becomes strongly turbulent. (Photo © the author)

This late stage in the evolution of the film [Fig. 5] leads to a calligraphic ornamentation that has strong resonance with the intricate abstract whorls in early illuminated books such as *The Book of Kells*. A nice example is provided by the historiated initials on *Folio 34r*, the *Chi-Rho* page, in which spiral mandalas float like islands within island lakes in a geometric archipelago (Meehan 1994, 27).

Let's examine our idea of the two experiments – the scientific and the artistic - in the context of the soap films. The scientific study focuses on the instabilities that occur; when thicker portions of the film are displaced from their equilibrium positions (for example by gently blowing on the film) or when fast-flowing streams develop close to the edge of the film. But not every flow in the film leads to a calligraphic character that works artistically. The success of Figure 3 again seems to be related to the co-existence of intense well-defined curves in a smoother background, enhanced in this case by a striking juxtaposition of colours. What do we understand by meaning in an abstract image like Figure 3? Calligraphic characters can carry literal meaning when they represent words; but they can, simultaneously or independently, convey meaning through their shape (for instance, Klee, 1961). Nicolette Gray (1970, 28) gives some specific examples from branches of early Western calligraphy: 'dynamic energy in a Gothic flourish, insecurity in a cramped Merovingian irregularity, balanced self-sufficiency in the *litterae caelestiae*'. The well-defined intense regions of Figure 3 are first to draw our attention when we try to read the image. But we pick them out because they sit in a background which has gentler coloration and smoother transitions. On the other hand, a world too dense with potential meaning becomes overwhelming. So whilst we admire the order on many different scales and in differing colours that seems to underlie Figure 5, we don't progress much beyond that. We are perhaps not trying to understand this world when we look at it, but the richness of the pattern suggests its exploration may go very deep. The selection process in our artistic experiment seems then to be directed toward those images in which we can visually select features within them strong enough to bear distinct meanings; and selection implies that there are also features within the same image that that don't immediately have this property.

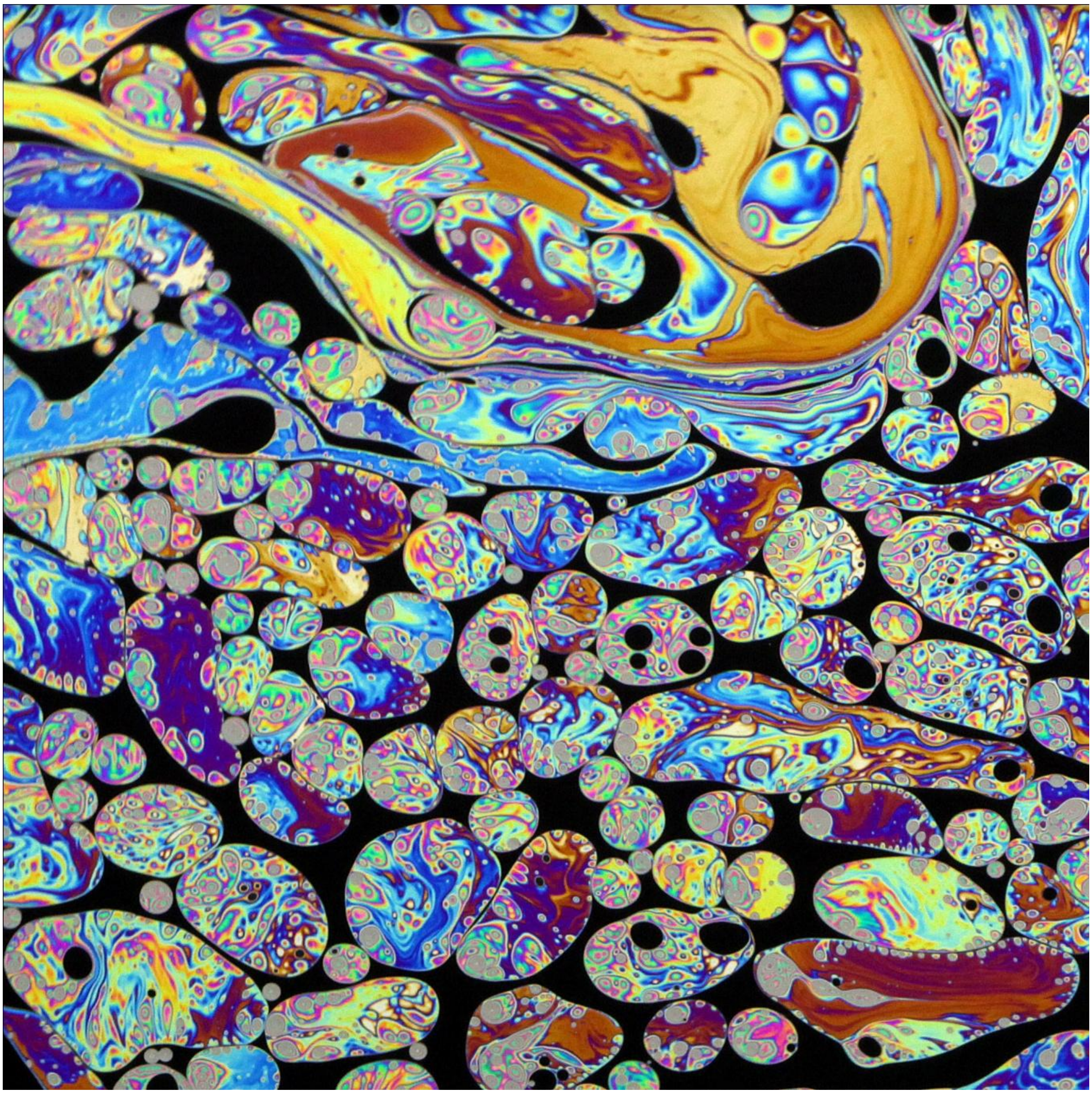

Fig. 5: Interference colours in the late evolution of a thin vertical soap film. The dark regions ('the page') are the thinnest regions of the film. (Photo © the author)

We now turn our attention to the components of natural calligraphy to see if we can draw useful comparisons with the physical elements of traditional calligraphy. Ching Hao separated brush and ink in the six essentials of painting described in his *Pi Fa Chi* (*Notes on Brushwork*) and repeated in the compendium, *The Spirit of the Brush*, compiled and translated by Sakanishi (1939). A Chinese calligraphic character has a life in the movement of the brush and the laying down of the ink, modulated by the resistance and absorbency of the paper to that viscous fluid. A natural calligraphy with a similar angular elegance and dependence on process and material is that of the spark. The character so created, in the photographic documentation of the event, is partly the result of chance (the shape and size of the incandescent fragment of steel) but is also strongly dependent on the carbon content of the steel - indeed spark testing exploits the character of the spark to deduce the carbon content. The hot carbon is rapidly oxidised to carbon dioxide and the expanding hot gas blows the fragile steel scrap apart - individual fragments are smeared into jets of light even in a brief exposure [Fig. 6]. The balance of the character is preserved naturally by the requirement that momentum be conserved – a small fast moving offshoot from the main line causes that line to veer in the opposite direction. Balance is achieved in the pictogram of the spark by a conservation law of nature. This conservation law is known to arise from a particular symmetry of the equations describing the motion (Arnold, 1978, for example) – an invariance to spatial translation. Since the momentum is a product of mass and velocity, a small particle of low mass ejected in one direction may need only a small compensating velocity shift in the more massive parent fragment. When we judge the balance of a calligraphic character, we will naturally weight the thickness of the line in much the same way, so that the centre of mass of the character remains stably and, from our perspective, comfortably positioned deep within the character. This is a well known characteristic of standard Chinese characters and geometrical guidelines ('hua ko') are often used in the preparation of texts for printing (Gaur 1994, 111). The Feynman diagrams that are widely used in quantum mechanics, designed to simplify involved calculations and manifest momentum conservation, look not dissimilar to the spark. Clearly the character we have created here is very dependent on the exposure time within our camera. But the balance will exist in any image by virtue of the physical law, at least as long as the brightness of a fragment is proportional to its mass (something however that is far from guaranteed). The artistic experiment in the case of the spark involves the selection of a spark image with sufficient detail (the varied strengths and angular dispersal of lines) to hold the attention without losing its luminous simplicity.

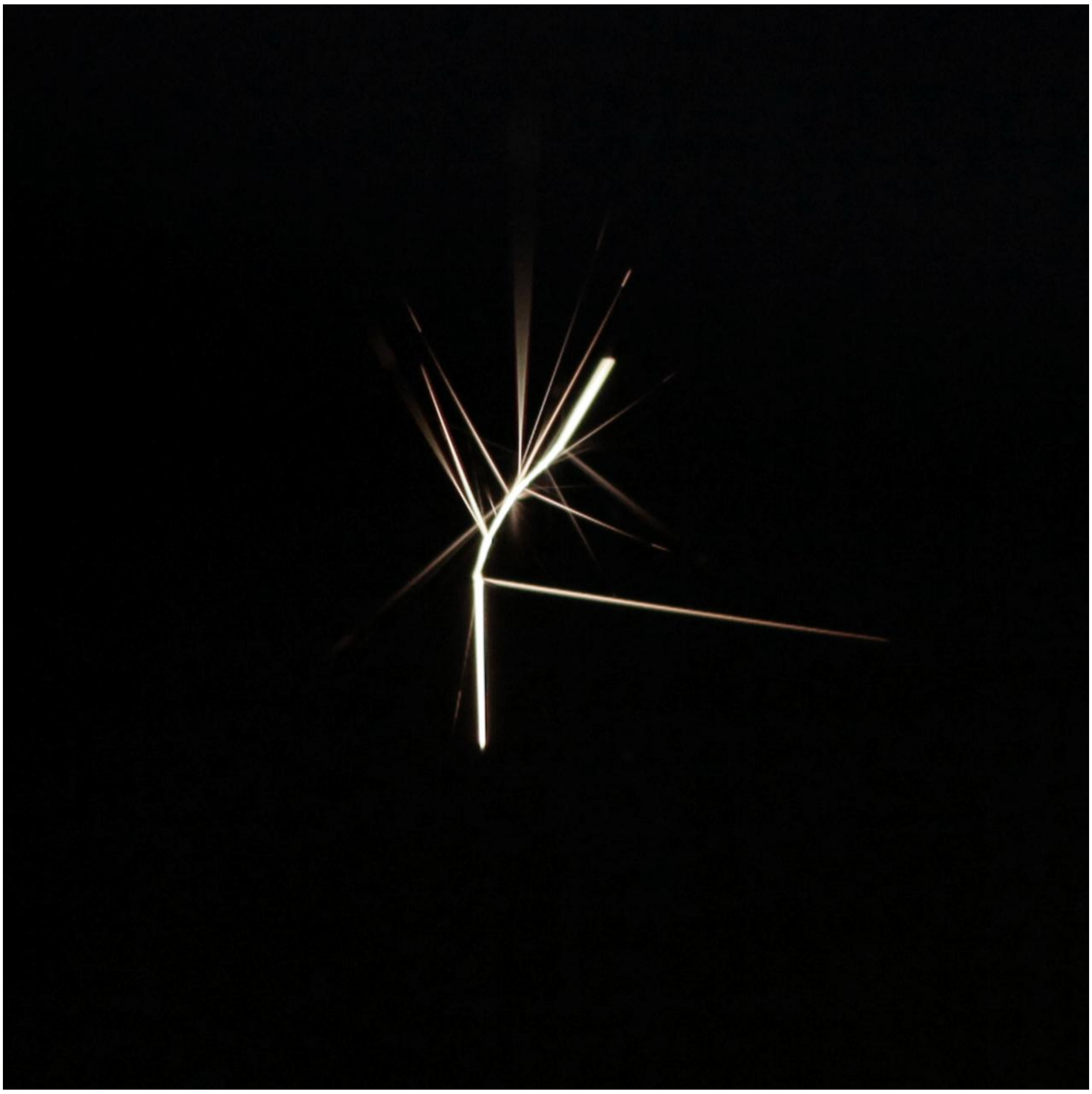

Fig. 6: This image of a single spark shows the sequential break-up of the main fragment (the strongest line). Note the branching of the smaller ejected parts and the compensatory movement of the fragment to balance momentum. (Photo © the author)

If sparks can be compared to a cursive Chinese script, the fluid and rolling line of semi-cursive script requires a different natural hand. We might also have in mind here, styles of cursive writing within Islamic calligraphy, in particular Thuluth or the closely-related Tawqi (Safadi 1978). These share long gently curved horizontal wave-like strokes that are punctuated by loops or cusps. Episodes of slow change in the line's journey begin and end in sudden but graceful changes in curvature. So where can we look to find a similar intermittence in nature?

A nice example is provided by a thin stream of glycerol released into water [Fig. 7]. The interface between two distinct fluids in relative motion is a fertile source of instability though we can exert some control over the evolution of the character by modulating the supply rate of glycerol. There is again an important lesson to take from this example – the stream with its sinuous line is three-dimensional and viewed from different angles offers distinct projections and hence quite distinct characters. Meaning could, quite literally, be changed by our perspective. The head of one stream [Fig. 8] provides a beautiful natural counterpart to knotted decorated animal letters represented in *The Book of Kells*.

There are reminders too of an intriguing scientific sculpture in the Whipple Museum in Cambridge, an interesting example of how real models can help in the visualization of natural phenomena. Three tangled wire loops represent the motion of an earth particle during the earthquake of January 15, 1887 constructed by Professor S. Sekiya of the Imperial University Japan. The motion in the model is magnified by a factor of 50 in all three space dimensions, doubtless for clarity but also constrained by the use of relatively thick gauge wire. A sequence of numbered tags along the wires represents second markers, so that in all 72 seconds of motion are represented in the wire loops. This is truly a line that resides, and is fully appreciated, in three-dimensions. However, the passage along the line can be seen in different terms in our two experiments. In the scientific one, we follow the pace of the time markers, but in the artistic one, we follow the natural pace of the curve – a curve that, like the spline described earlier, is an interpolation (and therefore an invention) from sparse data.

Calligraphic characters are of course often carriers of meaning and this requires a lack of ambiguity in deciphering them, although this may be overcome statistically by context (the principle behind some methods of code breaking). However in this last example, we have seen that a calligraphic reading may be changed by altering our viewing position. Whilst geometric properties of characters are not invariant under plastic deformation (or an altered viewpoint), topological properties are. So knots - already the seeds of a rich symbolism that exploits their strength (Eliade 1952) – are also robust carriers of potential meaning.

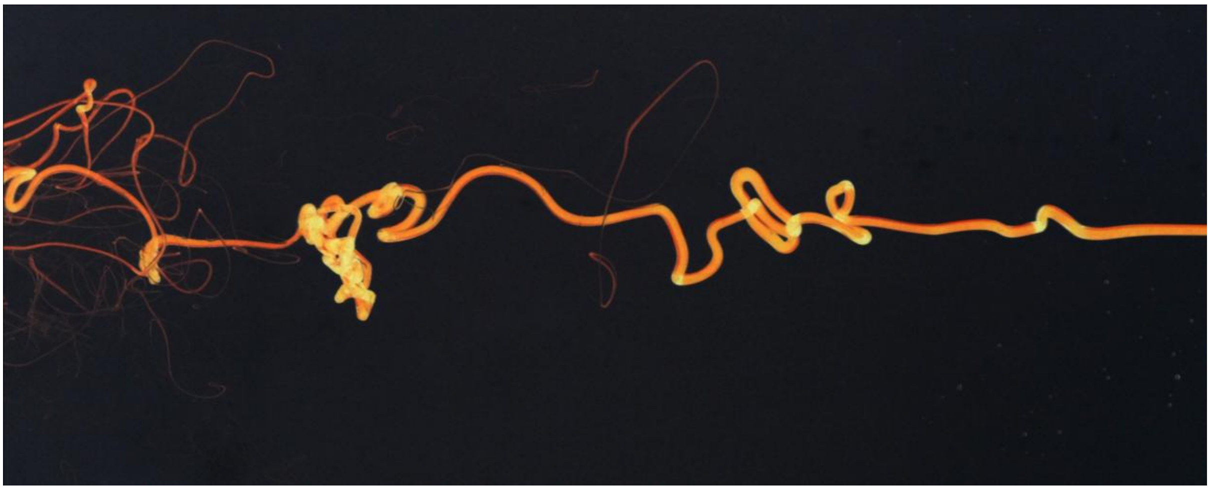

Fig. 7: A jet of glycerol released into water. Some idea of the three-dimensionality of the line can be got from the 'hotspots' along the stream which indicate that a significant component of the movement of the glycerol tube is along the line of sight. (Photo © the author)

One of the themes developed here is that natural calligraphy often involves the projection of a structure from a higher-dimensional space. Up to this point, however, the examples selected can be interpreted as projections from three to two-dimensional space. The majuscules of natural calligraphy are drawn on cosmic scales and they also require us to think in terms of higher dimensional spaces to appreciate how they form. Galaxies are sometimes surrounded by sweeping streams and veils of stars [Fig. 9]. The delicacy of these structures belies the destruction to which they owe their origin. A small galaxy orbiting in close proximity to a massive host galaxy will be tidally stressed - the parts of the small companion closer to the host experience a greater gravitational pull than those parts further away. If this differential pull is large enough, it can overcome the binding of the small galaxy and tear it apart.

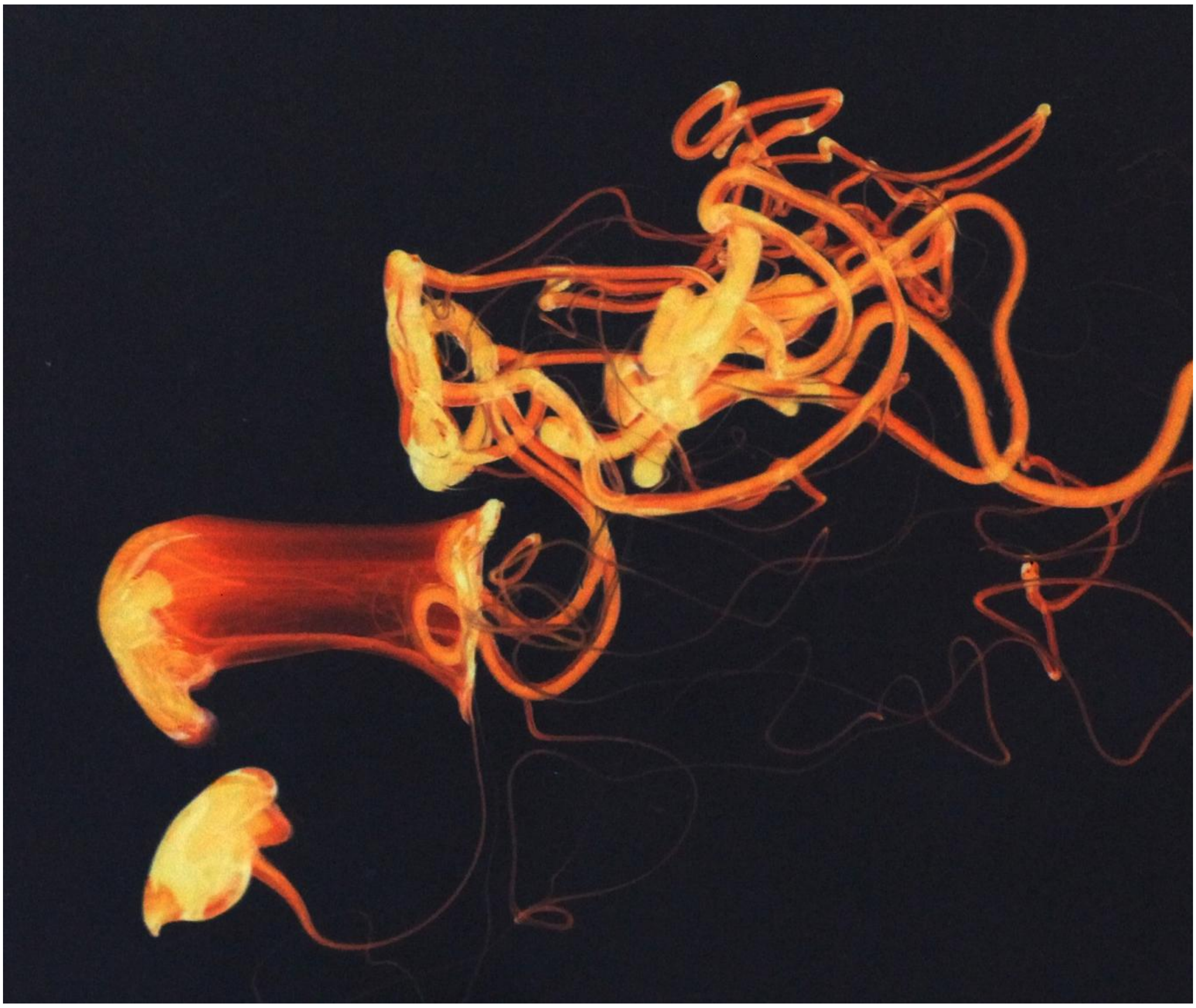

Fig. 8: The intricate topology of the head of a glycerol stream. The classification of knots can be based on a study of properties of their projected intersections, properties that are invariant under moves that leave the topology of the knot unchanged. As a result, knots as symbols can be robust carriers of meaning. (Photo © the author)

Stars leak out of the small galaxy and their differing speeds around the larger galaxy translate over time into a difference in position. A nice analogy is the slowly increasing length of a field of marathon runners. However, unlike a marathon field, the dispersal results from the combined effect of the runners (stars) starting with different speeds and the fact these speeds lead them to locations within the galaxy (orbits) where they are carried at different speeds. It is as if the marathon was run along a series of neighbouring moving walkways, driven at slightly different rates. There is another complication – the image of the stream we see is a two-dimensional projection of a three-dimensional structure (like the glycerol stream) and can show density enhancements that are simply the result of projection effects.

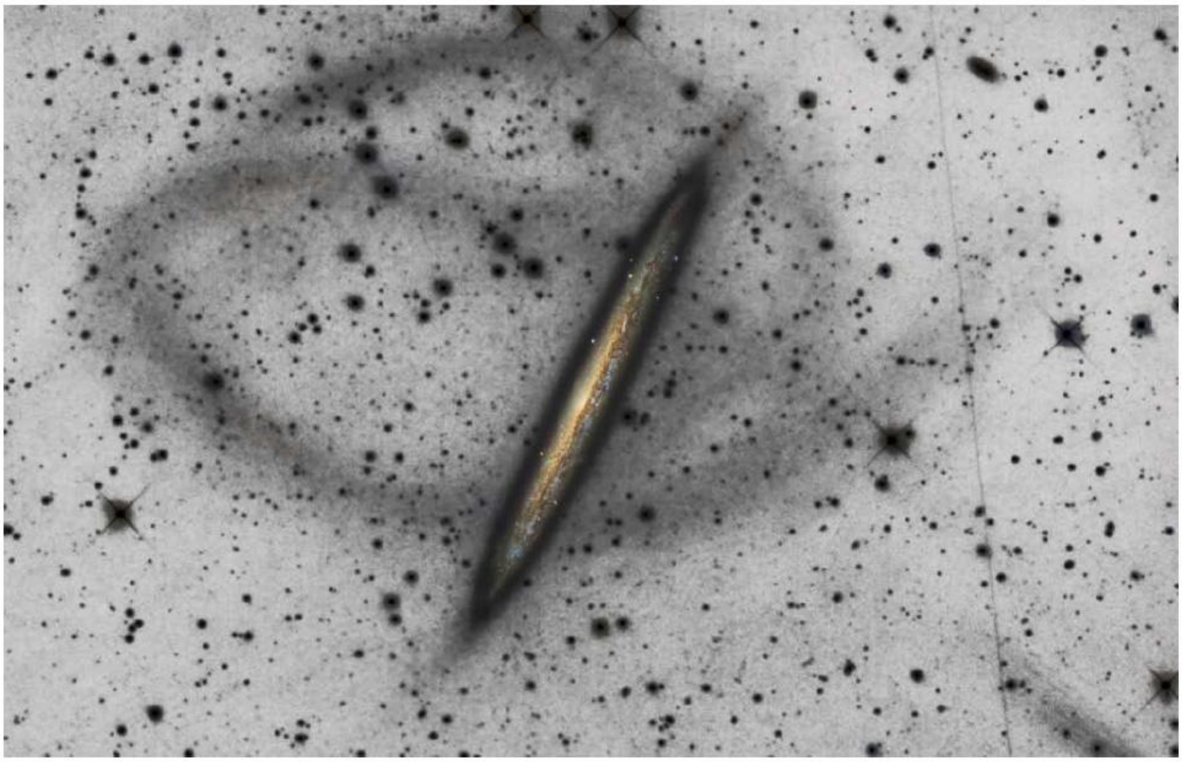

Fig. 9: The spiral galaxy NGC 5907 and its associated ghostly stream of stars - the unresolved grey band in the negative image external to the main galaxy. The main galaxy is represented in the central oval positive image. The main galaxy disc is seen edge-on so that the stream lies well outside the plane of the disc. The calligraphic character of the stream depends on many factors including the internal strength of the progenitor dwarf galaxy and its associated survival time. Whilst the dwarf survives, frictional forces from the diffuse star cloud through which it moves can modify the orbit and accordingly divert the arc of dispersed stars. (Image ©: R. Jay Gabany (Black Bird Observatory) taken from Martinez-Delgado et al. (2008, 463) and reproduced with kind permission of the authors and the Astronomical Society of the Pacific)

The stream can display caustics and self-intersections which evolve over time in a truly dynamic calligraphy. What dictates the sharpness of the characters created? The crucial quantity is the distribution of the stars in something called phase space – the six-dimensional space of position and velocity components. If the dispersion of the stars in phase space is small - the system is described as being cold - then the calligraphic character can be well-defined and caustics appear, reminiscent of perspectives through Naum Gabo's wire and Perspex sculptures (Nash and Merkert 1985, 122). A hot system on the other hand has a broad dispersion (like a diffuse ink spot), so that the character lacks sharp edges and caustics are weak. Figure 10 shows a simple simulation of the dispersion of stars in the gravitational (tidal) field of a massive galaxy. The character evolves over time with a shape dependent on the shear in trajectories caused by the galaxy's force field (the process), the initial dispersion of released stars, both in position and velocity, and the ease with which they unbind (the material). In this example, the force field was assumed not to change with time. It is clear that this assumption is only true where the stream is so dilute that it has little self-interaction and feels only the effect of the massive galaxy. Strictly, the massive galaxy will react to the unwinding stream but with the gentle reflex of a dancer casting off a thin veil. There are cases however where the galaxies are closer in size and this reflex leads to a significant evolution of the massive galaxy and its force field. There is something of an analogue in contemporary practice: Zhang Qiang, the creator of 'traceology', has the surface on which he is writing moved by an assistant in an unrehearsed and unpredictable way (Barrass 2002).

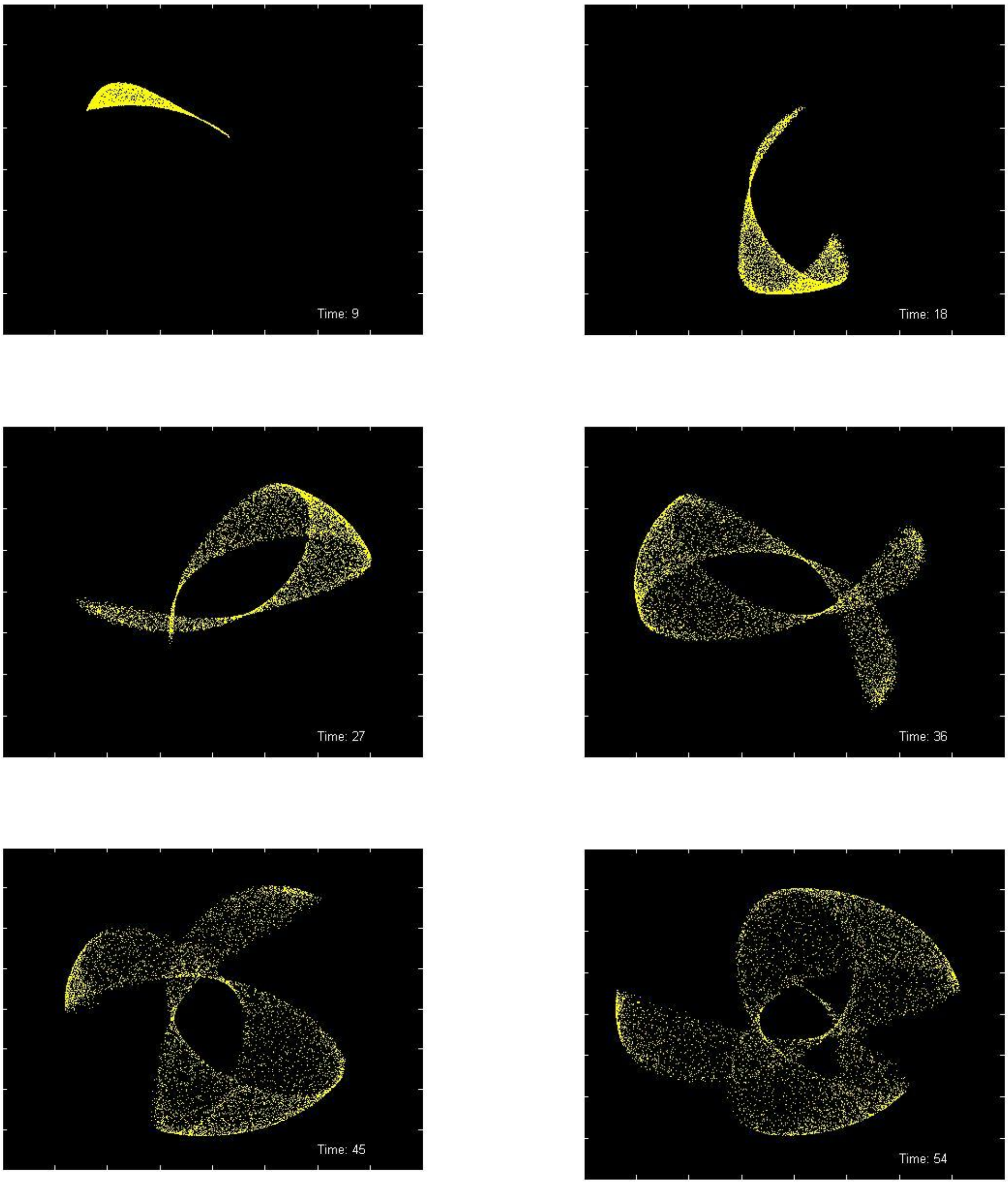

Fig. 10: A time sequence showing the calligraphy of an evolving stream of stars. The stars move under the gravitational force exerted by a massive galaxy. The cusps in density near the outer envelope of the stream are caused by the slowing-down of the stars as they reach this outermost limit, like a pendulum bob at the extremity of its swing. (Photos © the author)

We can now summarize what we mean by natural calligraphy. Our common expectation is that natural processes lead to a universal softening of lines through diffusion, the gradual disappearance of linkages, and the merging and blending of colours. Natural calligraphy however describes the means by which nature creates beautiful well-defined lines, intricate knots and sharply delineated areas of colour. We see that traditional calligraphy shares these physical characteristics although its forms depend on the interplay of technical virtuosity and cultural reference. Our concern in this paper is not with the latter, or with the interesting question (which we will address elsewhere) of the aesthetic properties of particular curves and knots. We have however attempted to show that the principles that underlie the shaping and evolution of natural trajectories – extremal curves and conservation laws derived from symmetries – are reflected in the natural (and satisfying) way the hand can form a curve and stroke, and in the resulting balance of a character. The compelling beauty of some calligraphy is interesting and it is useful to understand why this is the case and how this aesthetic evolves within a tradition and a culture. This is too large a question for this paper but it is relevant to our theme.

Modern theoretical physics represents a way of understanding the world that is often practised without an acknowledgement of the tradition in which it is nestled. Current theory development in microphysics is based on aesthetic prejudices, not suggested by experience or experiment, a recipe in the past for generations of misdirection. We are vulnerable to aesthetic archetypes and we need to be aware of how and why we involuntarily succumb to some symbols and schemes. In the case of knots for instance, they can carry information (or meaning) in a robust way – we see them as persistent and having strength, but they also have an attractive plasticity (and corresponding independence from particular coordinate systems). Those areas of physics that we have drawn on in this paper lie within the realm of experimental and observational testing. Quantum mechanics was introduced to the argument to show how the path of an object really comes about from the interplay of many potential paths and we noted that an extremal principle (and symmetry) underpins this picture. The dynamics of a small galaxy was used to illustrate a high-dimensional space from which calligraphic characters emerged through projection. These projections might be images such as Figure 9 that we can photograph in the sky. However, we could also project into a two-dimensional space with components of position and velocity. We cannot observe this space but we can create the projection in a computer and evolve characters within this space. This was a recurrent theme of our discussion; that natural calligraphy is a process, but a process in which, as observers, we have to play a part.

Natural calligraphy suggests new departures for something we could call, in the broadest sense, artistic letter-forming. Contemporary calligraphic art is rapidly evolving and we will summarise how it may draw on lessons from nature as presented in this paper. First, a recurring theme of our natural examples was that the stroke-making processes were occurring in higher dimensional spaces and the characters were projections of the strokes in lower-dimensional spaces. We find two-dimensional characters which have broad and narrow elements attractive (for example, half-uncial script). It would be interesting to investigate if one reason for this is an unconscious reading of them as dynamic twisted ribbons viewed in projection. We can embrace this further - calligraphy could be made more sculptural. A work could be made in which we would have to assimilate different physical viewpoints to uncover the piece's sense, and in the case of calligraphy, we can imagine viewpoints carrying very particular meanings as 'letterforms' appear and disappear as we move around their higher-dimensional sculptural parent. This picture envisages a static parent, so that our movement alone creates change. But we have also given examples where there is instead time-dependence in the parent itself (like the disturbed galaxy), so that even a stationary observer will see an evolution of curve and hence, in principle, meaning. We can imagine a (probably hypnotic) calligraphic 'space' in which multiple letterforms evolve over time giving rise, from time to time, to tiny islands of ephemeral meaning [Fig. 11]. We also made the point that there are properties of the parent, such as its knottedness, that do persist under different projections and in many cases under dynamic evolution. These are robust characteristics that could carry a persistent set of references for the parent, such as a vocabulary or grammar. There can be a random character to this process that runs a little counter to the discipline that calligraphy is traditionally associated with, but mutation can be simultaneously encouraged and monitored. Most of the natural processes described here, although deterministic, were unpredictable. They manifested laws of nature but in an irreproducible way – no two sparks are likely to show the same pattern of tendrils of light, but they all show the balance that momentum conservation forces on them.

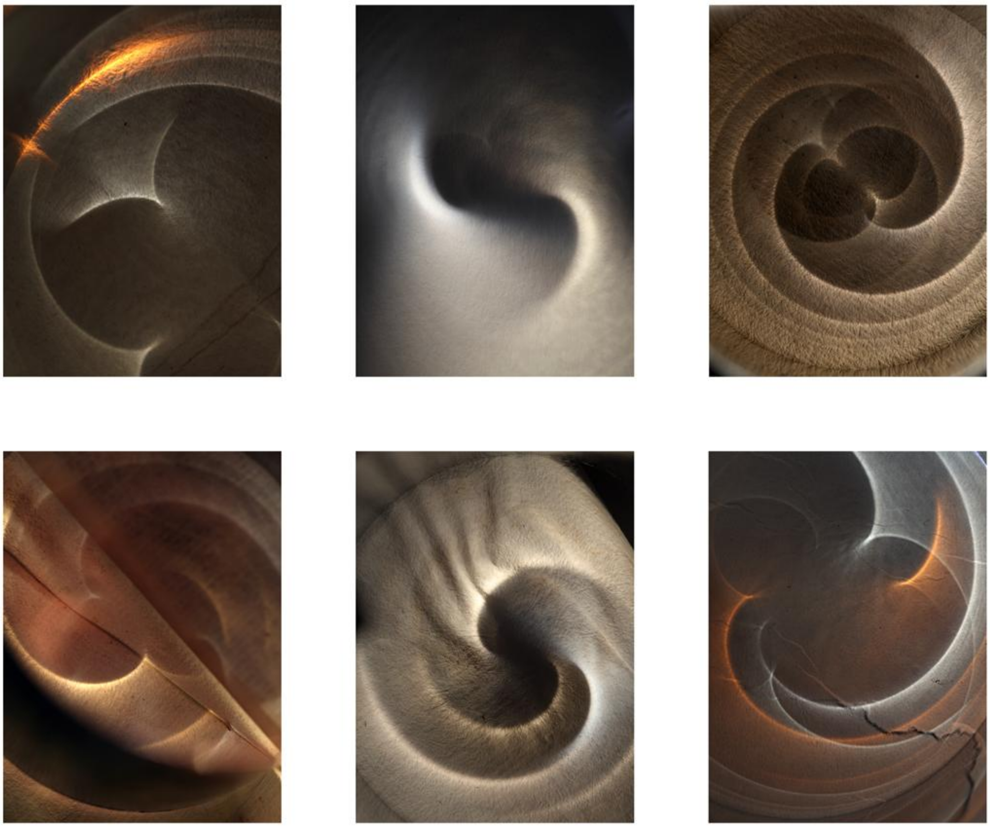

Fig. 11: *Six Letters from a Utopian Alphabet*, 2011. These letterforms made from light are made one from the other by small changes in the position of the light sources and small displacements of the scattering surface. (Photos © the author)

Another beautiful lesson of natural calligraphy is the pleasure to be had in seeing the process. A calligraphic mark often reflects the verve or grace with which it was formed but we see it at one time and as a finished object. But we lose something, like watching a ballet in fast forward or frame-by-frame; the meaning that is carried in the pacing. Clearly a technician is limited by transference of ink to paper, by articulation of the hand, and by the need to breathe and pause. But a glycerol train could run virtually endlessly and be modulated mechanically by a pre-written programme like a player-piano, allowing the artist (or indeed artists) to orchestrate multiple parallel lines of composition – a new calligraphy sharing many of the possibilities of music performance. The modulation controls the rate of supply of glycerol to the stream; it might thicken, thin or even stop. We control the presence and position of changes in the stream but we cannot make the changes with wholly predictable outcomes. We are removed further from the art work than we are in other practices that have a random element such as drip painting. But the randomness leads to something graceful and striking, even as it is unexpected - qualities we surely welcome in making a work of art.

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