

Abstract

This contribution tries to pioneer an objective understanding of flowing time. It takes the form of a sketchy, pre-scientific sort of story but is intended to be broadly congruent with established scientific knowledge. The true nature of flowing time remains almost uncharted territory, so the aim is tentative exploration - to provide a hypothetical picture which is sufficiently intelligible that it could serve heuristically. It might have the potential to help future efforts to make scientific headway in this notoriously paradoxical domain.

To formulate this story it's been necessary to adopt one of the radical views of space that modern physics offers. Some physicists see space in purely relational terms, not as an independent entity. But in sharp contrast to this view, and in accordance with the perspective inherent in quantum field theory (QFT), this story about time is based on the premise that space is the primary reality of the universe. What we normally think of as bits of matter are seen by QFT as secondary, as spatial field disturbances. The quantum fields of space are considered to be substantive, structurally complex and ubiquitously energetic.

What moves the story a step beyond current science is that it also takes on board the ancient aphorism that "everything flows". Accordingly, the heart of space everywhere is imagined to be in an incessant state of turbulence and flow. The unfolding tale suggests how this hypothesis, were it true, might help explain the fleeting passage of time within an enduring, law-bound material world, much as we perceive and have begun to know it.

Panta rhei - towards an objective understanding of flowing time

By Tim Moon

Introduction

Although he was writing in Ancient Greek, 500 years before Christ was born, it's still possible Heraclitus was right in asserting *ta panta rhei*. Maybe our whole universe truly is a place where "everything flows". If so, then we would need to consider new ways of describing how the world really works. The old language of a Newtonian world where solid objects move in an orderly procession through immutable time, suspended in the eternal void of space, will no longer do. Even more modern talk of particles of matter moving in a relativistic way through their more 'ethereal' fields might not entirely suffice.

It seems Heraclitus saw 'fire' as the basic substance of his flowing world. However, the scrappy and obscure nature of what little remains of his ideas - to say nothing of their sheer antiquity - suggests it's time to take a fresh look at what it is that could possibly flow so ubiquitously.

So, if for the moment we go along with Heraclitus's basic vision and assume that the universe really is a great unified flow, then this must involve something - something everywhere - being in a permanent state of flux. This something must be capable of having parts of itself in relative motion. This something must also be holistic in nature, yet capable of being extremely fluid too. It must be able to flow very differentially and with great rapidity - be able to vibrate, wave and swirl in such a way as to form a wide variety of discrete, quasi-independent, quasi-permanent units, somewhat like eddies spinning away in a pool. Maybe like smoke rings blowing in a cloud of smoke, or individual wave crests tumbling in the sea. The flow must be unceasing: the something must be impelled powerfully from within, into a state of constant turbulence. Finally, the something must allow movement within itself to occur at all scales and in three dimensions. Or in four, to include the flow of time.

Looking at all these these specifications for a unified something that's been presumed to flow, and considering the physical universe as we recognise it today, there seems to be only one candidate that could possibly begin to meet them. It lies all about us: it is energetic space itself. But not a Newtonian sort of space - never just a passive and empty void. The modern view of space may be far from settled, but it's certainly very different indeed from Newton's. For a start, ever since Einstein, space has been modelled as amalgamated with time. So it's now referred to generally as an aspect of spacetime. Space is no longer seen as a background container. Instead, spacetime is now often called the very fabric of our universe. While it's true that space is still commonly thought (not necessarily correctly) to be totally invisible, the idea that it's simply nothing seems today very far indeed from the truth. A totally empty and inert vacuum no longer exists in modern physics. Quantum field theory says there's always a variety of energy-carrying fields superposed throughout all space - and that all 'particles' are better seen as field disturbances, rather than as entirely independent material entities. The 'vacuum', even in deepest space, is theorised to be full of energetic action, with its fields vibrating and seething in a state sometimes referred to as quantum foam. And to top it all, if spacetime is to warp and bend as general relativity suggests, then some would say it's clearly a something - and it's already recognised as having the potential for flexibility. Also, by all accounts space is distinctly holistic, insinuating itself into and connecting with every domain, from the very smallest to the very largest (as far as we know). It even runs right through the heart of what used to be thought of as separate, solid matter. All this is a far cry indeed from Newton's picture of space as a faceless and inert void, forming just a background, with independent, material objects featuring as the primary reality suspended within it.

Developing a modernised tale of flow

In order to explore Heraclitus's ancient idea further, what follows is a modernised tale of flow. It's based firmly on the modern scientific premise that our universe is indeed made only of energetic space. But in addition, following Heraclitus, the story also relies on a separate and largely untested hypothesis. It takes on board the assumption that the foundations of space everywhere are driven by its energy into a perpetually turbulent and flowing state. The account thus derived results in an unusual view of the nature and origins of our law-bound material universe. Although this view amounts only to a rudimentary and essentially pre-scientific sort of picture, the firm intent is that it should remain congruent with established scientific knowledge.

Contemplating a potential universe of perpetually super-fluent space, one soon confronts its integral flow-mates, time and of course, energy. The story focuses mainly on the temporal aspect of spatial flow. This entails an objective interpretation of the passing moment we call 'now'. With good reason then, we must turn first to Einstein.

Is a universal 'now' even possible?

Seeking to extend 'now' to the universe at large, one finds the way blocked by a foundation stone of Einstein's theory. It's the relativity of simultaneity - and unfortunately it specifically outlaws such a universal time. Special relativity predicts in principle that if two observers are seeing the same event, but are each spatially distant and moving very rapidly in different reference frames, then they won't see it happening anywhere near simultaneously. For one observer the event is way in the other's past, while for the other it's happening right now. Within the workings of general relativity too, although space across the universe is essentially uniform in scale, time isn't. Sadly then, a universal 'now' seems to be a non-starter.

We can't simply disregard Einstein's crucial prohibition. The problem isn't really his reputation as a unique genius, nor the authority of his name throughout the world of physics. It's more the weight of empirical corroboration his theory has accumulated. It's supremely well tested. The recent well-publicised detection of gravitational waves thought to emanate from a collision of black holes bears yet more testimony to the far-reaching power of Einstein's theorising. (Incidentally, if one remains sceptical about granting a substantive and fluid status to all space, including the notion that matter is integral to it, then the LIGO 'chirps', minute though they were, take some explaining away.)

Remarkably, there's a way forward through this apparent impasse. For a while now an increasing number of theoretical physicists have pointed out that *bona fide* reformulations of relativity are mathematically possible - including in such a way that the flexibility of time is traded for the flexibility of space. Time becomes uniform at the expense of spatial scales, which will then differ. In consequence, it becomes at least theoretically possible for time to be universal. A general 'now' is no longer right out the question. And the grand thing is, we're told such reformulation doesn't require standard relativity physics to be ditched. Apparently all its empirical successes can still stand without contradiction. But of course the possibility of regarding time as fixed and space as more changeable is profound. I would refer you to an open-minded paper recently co-authored by physicist Carlo Rovelli (Maroun and Rovelli, 2015). It looks at one approach to reformulation.

Introducing philosophical presentism

If there is indeed a universal time, and if the world really is a unified but immensely complex, incessant flow of space (two very big if's!), then the theory of time known as presentism comes right to the fore. As this philosophical term suggests, it says things only exist right now, in the present moment.

To start unfolding the story, the specific conjecture afoot is this. If space everywhere is so ubiquitously dynamic, its turbulent or flowing pattern is constantly changing. The current configuration of space as a whole - how it's organised, in detail, right now - is forever shifting. So how it just was has now gone. It no longer exists. The next dynamic configuration, although it may be heralded in the details of the current one, has yet to form. It too doesn't exist. Only the present configuration ever actually exists.

This objective picture seems to be reflected in the reality of our subjective lives. We all recognise that our perceptions work on the basis of a constantly fleeting present moment. However, an immediate word of caution is needed. Through both modern physics and psychology, we've learnt not always to expect anything like an exact correspondence between our conscious experience of reality - direct though it may seem - and more objective knowledge of the same situation. This has proved especially true as a result of establishing knowledge at very different scales compared to those we are all born into. Even so, while acknowledging the essential dichotomy of the two avenues to knowledge - subjective and objective - we can still adopt a realist compromise and say it's very likely there's at least some sort of link between them. This approach suggests that when there are unexplained perceptions we all without exception share - such as those of a fleeting 'now' - we shouldn't be too quick to dismiss them as totally illusory or as beyond the realm of science, simply on the grounds that they are a misfit within the currently dominant paradigms of physics.

Perhaps reflecting a subjective/objective relationship, attempting to delineate 'now' from either perspective leads to a remarkably similar looking difficulty. Let's consider this situation, first from the subjective point of view.

The smearing of the specious moment

Analysing the present instant introspectively, William James famously tussled with pinning down this slippery experience. It was dubbed 'the specious moment' - specious because it isn't truly an instant. While this moment is clearly fleeting, it isn't literally instantaneous. This would require us to experience change happening abruptly, in no time at all - which clearly isn't how we perceive the passing moment. Somehow, our experience of 'right now' is that it's an indivisible but 'smeared' period - an elusive, moving moment which elides between the steadily incoming future and the outgoing past. No matter how hard one struggles to describe it, one thing seems clear. Its distinctly ineffable quality is surely due to the un-stopping, flowing nature of our perceptions.

Less obviously, when taking an objective view of 'here, right now', a similar situation arises. Except in purely abstract or imaginary terms, we can never freeze the incessant flow of the world to

pinpoint an instantaneous 'now'. Once again, a literally instantaneous, static moment is specious - it's a total fiction. It would be no time at all. It couldn't partake of a real world of unceasing flow. It's no good trying to capture 'now', even with an atomic stopwatch!

Having said that, an ordinary snapshot seems beguiling evidence to the contrary. A photo looks like clear testimony that the flow of the world actually *can* be frozen, one click capturing a moment of reality in a sharp, static image. But the greater truth lies in what happens when you keep zooming in on the photo. No matter how fast the shutter speed nor how high the resolution, the image will sooner or later start to blur. It will become too indeterminate to identify what you wish to see.

Zooming instead deeply into reality itself, we come similarly unstuck. Attempting to focus right down to make measurements that require a precise instant or the exact spot to be pinpointed, for anything that's constantly flowing we find we can't do better than identify a 'smeared', indivisible moment of location in time and space. There is a built-in indeterminacy when trying to establish a precise location in any flow, and this includes a location in passing time, as space flows. The smear is equally one of space and time, both indivisibly combined as properties of the flowing moment. Such a unique, indeterminate moment of spacetime, conjoined fully into a flowing series of such moments, is the world we inhabit. As we live, our personal configurations too are conjoined into that smeared, ever-dynamic arena of unified spacetime flow.

How long is 'now'?

What happens if we persist in asking how long is 'now'? In psychological terms the answer must be much more complex than introspection might suggest. Firstly, there's the time required to sense and then reconstruct incoming information. Our mental mechanisms have to form a pragmatic, flowing representation in consciousness. (These mechanisms will have evolved to serve us safely and therefore veridically in terms of the practical business of managing our bodies within the flowing environment of spacetime.) Implicated too is what psychologists call working memory, which acts to stretch the conscious moment. For instance, when reading it allows us the 'mental space' to construct the holistic meaning of sentences as they unfold from start to finish. Expectation is also known to play a major role in the construction of perceptions. It seems likely that the psychological 'now' is much more artificially spread out than the physical 'now' that it tracks. In effect, the subjective version represents the mental distillation of the passage of an extremely long series of objective, immensely briefer present moments.

Looking at 'now' as a physical event, all we can say with precision is that it can't literally be instantaneous. But then we're left with a 'fluent spacetime moment' that's indivisible and smeared. It's inherently indefinite - an indeterminate moment of passage that's built into the whole spacetime dynamics of the world. And, given that this world accommodates flows at the speed of light, the re-configuration of space must happen very rapidly indeed. (Maybe the universal limit on light speed suggests that space, while superfluid, may nonetheless have some sort of deformation limit). The smear of the flowing moment of spacetime must be past and gone, not infinitely quickly, but certainly in a trice! The snapshot we considered would have been a record of events occurring over a whole block of physical time - over a very large blur of conjoined moments, as the world of space flows forward.

How do things persist and endure?

All this raises an obvious question. How come things, including us, exist? I don't mean "Whence all existence?" - that's way too big a question! Rather, I'm asking how come things continue in much the same form through passing time? How come they persist from moment to moment, maybe for quite a long time - or even endure right down through the ages? If at heart our whole universe is just an incessant flow, where a universal and dynamic moment of spatial re-configuration comes and goes in a blurred flash, then how come anything at all lasts beyond this extremely fleeting moment? This seems a tough nut to crack.

First of all, we should recognise the difference between chaotic, random turbulence and highly organised, 'law-abiding' flowing, where specific re-configurations of space keep on repeating and recycling themselves in tight, well-determined and interactive patterns. Spinning and spiralling patterns of spacetime, so to speak, formed in a way which is anything but random. It's this sort of notion which provides an understanding of what any 'stuff' in the universe really is - the stuff we sense and identify as independent conglomerations of matter. Similarly, repetitive oscillations of space may themselves be repeated in the form of a spacetime flow of radiation. Such patterns of flowing space can become integrated or disintegrated from moment to moment, although it can be specifically conjectured that space itself, like its energy, is never really created or destroyed. As Heraclitus saw, the universe is all about incessant transformation. While there's no such thing as true stasis within spacetime (according to the story), objects regularly *seem* quite static in both time and space. This is because at human scale their deeper nature isn't perceived. Beneath their bland surface appearance, at deeper scales their form is always spatially complex and highly dynamic. Objects are an ever-replicating, ever-spinning organisation of extremely rapid spatial flow. As such patterns bind together and establish themselves from moment to moment in a repeating fashion, they can grow and grow in terms of their interactive shape and organised form. Eventually their synthesis can exhibit emergent, distinctive properties and, despite the incessant flow, take on a very stable and objective identity over time. Perhaps in this way the world of chemistry is born.

Thus the most elementary 'particles' may take their apparent form from flickeringly brief, single vortices of space - possibly contributing only the most transient of identities and properties to the spatial milieu in which they appear. At the other end of the scale we have enormous macro-objects with the most rigid, outwardly unchanging spatial forms, existing over eons of time. Once again, belying their surface appearance at human scale, they must be composed of huge multitudes of strongly bound, spin-based units of spatial flow. They must also be able to keep replicating this fabulously intricate form very faithfully over immense periods of time. (The synchronous stability of replicating flows in their environment, both locally and then increasingly distally, will no doubt contribute significantly to their longevity. This applies to anything: the survival of our personal identity depends on the stability of form of our brain cells, which depends on the stability of our body, which depends on the stable nature of our planet, and it's climate, both of which depend on our solar system, which depends on the Milky Way... and so on.)

A hidden assumption

The sort of deeply complex model just sketched is necessary if the presentist view of spacetime is to hold. But before pursuing things further, first I'd like to reprise the story a little. The purpose is to underline how this approach successfully confronts a truly fundamental philosophical issue. It's an issue obscured by an unquestioning assumption - one so basic and common-place, it grips us all.

The fact is, we're all apt to take the persistence of objects - be they particles, rocks, planets or galaxies - totally for granted. Such things just 'naturally' persist. It's their inevitable base-state, once formed. It's their birthright, you might say. Take for example the formation many millions of years ago of a dinosaur's fossilised footprint. Having roughly understood a story as to how it got there in the first place, we then automatically accept that it's simply stayed there, unchanging, ever since. Perhaps it lies buried, awaiting some point far into the future when soil erosion finally exposes it to view. All this sounds trivially correct. Bar some destructive event, we're sure the footprint is simply bound to be there, all the time.

But, while appreciating the apparent certainty of this view, the presentist takes issue. There's actually no clear warrant for such a blind act of faith on behalf of a fossil.

Despite the 'obvious' state of continual existence for the dinosaur's footprint, when viewed from the presentist position such a simple expectation seems unduly dogmatic. After all, why not assume things are just naturally inclined to cease, rather than continue? The fact that things *do* regularly seem to persist then demands a rational explanation. We should ask how it happens. And remember, adopting presentism means the pattern that just existed in the onward flow is now no

longer there - it's all gone, forever. Nor is there a pre-constructed future world already sitting out there somewhere, just waiting to be realised as future 'nows' arrive. Reality is determined only in the interactive configuration of space, and this has its source entirely in the present moment.

As Heraclitus surely envisioned all those years ago, the only model which works in this situation is one which extracts a precarious permanency from perpetual change. The model already outlined aims to achieve this. As we saw, it posits a deeply complex process of ongoing replication, moment by moment - a creative process that can carry the essential identity and emerging properties of an object forward, making its future. As spacetime flows, everything that exists and happens is rooted in the blurred arena of the rapidly shifting present moment. The essential form of the dinosaur's footprint is recreated at every changing, swirling moment. Only thus may it survive.

So, taking the universe as a whole, the form in which any part of space continues to exist owes that fact to the continual re-creation of its future, now. For any one object of space, to the degree that its particular replicating process changes or fails completely, so does its existence change or come to an end. But all the while space in general, plus a number of objects which are part of it, all keep on re-configuring and replicating together, then the whole unified lot can continue in co-existence, all in the same time flow. In consequence the collection of objects, despite being part of unified space, can all move or establish a position relative to one another, interacting with each other and with the rest of space in general.

In this way we've arrived at a more familiar view of the spacetime dynamics of our universe. Except we can no longer dismiss the passage of the present moment as just some elusive side-effect or as a psychological illusion. 'Now' has become the central powerhouse of all existence.

Classical and quantum reality

On this basis, the so-called classical world is the realm of replicating, time-extended macro-objects. At our everyday scale, we experience their surface appearance synchronously, via our replicating, 'specious moment' of constructed consciousness. It's a world of straightforward measurement. The smearing effect of the limited speed of macro-object movements is negligible. But, if we leave our everyday scales behind and probe into space as its structure replicates more freely at the speed of light, or, as already touched on, if we zoom deeply into the confines of matter, descending far into its swiftly spinning structure, then eventually the quantum realm emerges.

Approaching either micro-domain, the indivisible smearing within the lightning-paced structures involved is no longer negligible. It starts to enter significantly into all attempts at precision spacetime detection and measurement. The closer one gets to focusing on the heart of our replicating world, on its 'here, right now' as it flashes onwards, the more the inherent indeterminacy of location in the moment of spacetime flow becomes completely dominant. Its shifting, turbulence-based character may be what makes the use of a continuous, probabilistic wave function so very effective in this domain. The apparent collapse of this function might simply be the consequence of imposing a precise measurement on what is in reality always an unstopping flow.

Life and death in the spacetime flow

We can hardly avoid seeing all this in life and death terms. Our energetic world of interactive, material activity depends on a sort of co-survival across time, based on unbroken reproduction. But as the configuration of space transforms with the flow, some parts of that co-existing universe can die, while others can be born, emerging afresh from the passage of present moments, and live on. Of course that will be equally true for the tiniest sub-atomic particle and for something much more composite and large, say a star. It depends on the scale of your viewing perspective.

Stand back far enough and one could with good reason wonder if the highly determined, law-like structuring of our universe is actually the outcome of a selective process. A natural effect that's been operating for an immensely long time, at every moment - a very simple form of evolutionary.

process, acting as a harbinger to the biological mechanism Darwin famously recognised. A process based on incessant, free turbulence, where the already existing constraints of form in the passing present serve to mould the nascent structures of the future. A selective situation arises, where survival depends on aspects of the turbulence by chance conjoining with existing structures, becoming both part of and the means of their replicating form.

Thus the apparently law-bound regularities of the universe which seem destined to govern its future may have a history of crystallisation and growth via chance-based survival. Their turbulent origins have succeeded in acting repeatedly to extend the current pattern of cosmic flow by fortuitously harmonising with it. As a result of such coherence of re-configuration during successive passing moments, they've become regularly encoded as part of the world. On the other hand, where the turbulence is so chaotic it's completely improbable - entirely out of kilter with the currently replicating flow pattern - then it gets left behind.

This whole story (and of course that's all it is) suggests that the moment by moment evolution of deterministic, causal effects and their consolidation over time as lawful structures with regular, emergent properties may thus reflect the same naturally creative process.

Energy and inertia

An obvious feature of space is its energy - or in ancient terms, its fire. Space certainly harbours plenty of potentially dangerous 'oomph'. It's what empowers all its incessant transformations. It was suggested earlier that along with time, energy is an ever-present companion to space. You might say we live as part of a space-time-energy flow. Even so, it seems easiest to see three-dimensional space as the primary, unified stuff of our world - which then through incessant turbulence and flow makes both its energy and time manifest.

Wherever there is a heavy concentration of recycling, spinning space, resulting in motion persisting in a pooled, organised way across time - the situation that underpins the survival of all so-called material objects - then this means the confinement of a significant store of energy. Presumably, this localised corralling of spatial motion and its associated energy is what can be measured as the object's inertia, momentum, or mass. In other words, the density of potential oomph it carries, reflecting the object's degree of internal and external motion. The relationship between the movements of such localised, high-energy, compacted spatial conglomerations and the dynamics within much more free, less energetically dense, stretched-out space is perhaps what characterises our universe.

A final reality check

The ancient vision of Heraclitus has, it seems, been made to live on. By donning his mantle while possessing the advantage of modern scientific knowledge, it's been possible to venture the beginnings of a worldview that accounts for our experience of flowing time. However, at this point a quick reality check is in order. This worldview, much like his, is a rather outlandish and very abbreviated blend of knowledge and conjecture - all constructed into a sweeping and no doubt naive tale. If the ideas have any scientific value, it can only lie in how some of them might be picked up and developed a great deal further, even perhaps to the point of being testable.

I shall though finish on an upbeat note, with a question. To find the moment when a universe is being created, is it always necessary to probe way back to its remote, primordial past? Isn't a wonder of universal creation also happening right under our noses - here, right now, all the time?

Reference

Maroun, S. and Rovelli, C. (2015). "Universal time and spacetime 'metabolism' ", <http://smc-quantum-physics.com/pdf/version3English.pdf>