The origin of time

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Abstract

If in a universe which creates itself out of nothing, particles, their properties must be as much the cause as the effect of their interaction, of forces between them, then their communication –and the transmission of light– must be instantaneous: not over any space distance but over any spacetime distance, which is something else entirely. If there would exist only a single electrically charged particle in the entire universe so it cannot express its charge in interactions, then it cannot be charged itself. Charge, any property then must be something which lives within particle interactions, something a particle cannot privately own. Similarly, if by definition there is nothing outside the universe, then it cannot have any particular property nor be in any particular state as a whole as 'seen' from the outside (no matter that there is no outside to the universe) as well as seen from within. If, as in big bang cosmology, it at any moment in cosmic time would have particular properties and be in some particular state as a whole, then it would have the same properties and be in the same state as 'seen' from without.

Though big bang cosmology aims to describe the universe from within, it fails to achieve this, a failure which has disastrous consequences for cosmology in general and for our notion of time in particular. For in speaking about its age, for example, big bang cosmology in fact states that time is defined, that time passes even outside of it –which of course makes no sense and if true would mean that the origin and nature of time cannot be understood even in principle. While a big bang universe lives in a time continuum not of its own making; as a self-creating universe only exists as seen from within, it contains, produces all time inside of it. As a result, time in this universe cannot be observed to pass at the same pace at all distances, so past, present and future are relative, observer-dependent notions –as opposed to big bang cosmology where we can delude ourselves that we can determine what in an absolute sense precedes what, what is cause of what.

This paper is an exploratory study into the origin and nature of time.

Contents

We have tried for centuries to look deeper and deeper into finding causes and explanations, and suddenly, when we go to the very depths, to the behavior of individual particles of individual quanta, we find that this search for causes comes to an end. There is no cause. In my eyes, the fundamental indeterminateness of the universe has not really been integrated into our worldview yet. –Professor Quantinger, alter ego of Anton Zeilinger.[1]

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Premise

We assume that the way we look at, think about the universe is essentially correct, that modern physics is so sophisticated and evidence-based that conceptual fallacies like the belief that the Earth is flat, that the Earth –no, the Sun– is the center of the universe definitely belong to the past, that it is inconceivable that we might be wrong.

The premise of this study is that if we define what a universe is by saying that there is nothing outside of it, not even space nor time, then, like a particle cannot have any property, exist itself if there exists no other particle, the universe cannot have any particular property nor be in any single, particular state as a whole as seen from within nor as 'seen' from without, no matter that it cannot actually be observed from without but only exists –and only can be understood– as seen from within, from the point of view of the particles doing the creating.

As a big bang universe (BBU) at any moment in cosmic time has certain properties and is in some particular state as a whole as seen from within, it has the same properties and is in the same state as 'seen' from the outside so has an external if, for practical reasons (like the absence of space and time outside of it for an observer to find herself and look at it), unobservable reality, so here we may imagine to look at it and describe it from the outside, as if it is an ordinary object. However, if we only can speak about the age, properties and state of the universe if there is something outside of it relative to which it can be said to exist, something it interacts with, relative to which its age, properties and state can be quantified but by definition there is nothing outside of it, then big bang cosmology (BBC) cannot be a valid description of the universe –in which case there must be something wrong with the assumptions the interpretation of the observational evidence are based upon.

Though the observational evidence for a big bang seems to be overwhelming, some observations are hard to reconcile with a big bang, like the isotropy of 1 part in 100,000 of the cosmic microwave background, not to mention that the nature of 96% of the contents of the universe seems[2] to consist of is unknown. As inflation theory, devised to explain this isotropy cannot be inferred from first principle,[3] it cannot be understood and only works if parameters like the rate of inflation and

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[1] *Dance of the photons* (2010) Anton Zeilinger p. 105

[2] *Cosmology and convention* (2016) David Merrit https://arxiv.org/ftp/arxiv/papers/1703/1703.02389.pdf

[3] *The diffuse light of the universe*. (2016) Jean-Marc Bonnet-Bidaud https://arxiv.org/ftp/arxiv/papers/1701/1701.01017.pdf

the times to start and stop inflating have the right values –which proves to be at least as unlikely as a universe without inflation producing the observed isotropy.[1] As the theory doesn't explain why the universe should inflate, how all points of space know when to start and stop inflating at what rate, it is just an *ad hoc* theory devised to save the big bang tale. Another problem is that the second law of thermodynamics according to which the entropy or disorder in a closed system only can increase in time contradicts the supposition that the initial state of the universe at the big bang was a state of low entropy, of high order, a contradiction which is hard to stomach to many physicists[2] as it seems to imply that the universe has been created by some outside intervention –not to mention that the creation of energy at the big bang violates the 1st law of thermodynamics which states that energy cannot be created nor destroyed –and the universe either cannot be created, exist, or has always has existed and always will exist.

Another objection to BBC is that the universe only can have a beginning, a definite age if it is the same time, if time passes at the same pace everywhere (in empty space, far from masses), if it at any moment in cosmic time is in some particular state as a whole as this contradicts general relativity theory according to which there is no universal 'now.'
The problem is that if we ascribe the universe a definite age –that it is in a single, particular state– as a whole as seen from within, it has that same age, is in the same state as 'seen' from the outside, no matter that (even in BBC) there is no outside to the universe. In speaking about its age, about the pace of time inside of it (which we anyhow cannot quantify as there is nothing to compare it with) we in fact state that time exists, is defined even outside of it and passes at the same pace outside of it: that the universe lives in a time realm not of its own making.
If this makes no sense, then it also cannot make sense to speak about the age of the universe and the pace of time as seen from within. If when a self-creating universe is self-contained, if it only exists as seen from within so doesn't live in a time continuum not of its own making but 'contains,' creates all time inside of it, then time must be something relative, its observed pace be different at different distances and, as will be discussed, even when at rest relative to the observer.

This study investigates how a universe might create itself, a cursory exploration about how if when particles, particle properties are as much the cause as the effect of their interactions, they might acquire properties, evolve to elementary particles, and whether the non-causal, but nevertheless rational approach a selfcreating universe (SCU) forces us to take might open a new perspective on old, as yet unsolved problems.
One question is whether if when the universe can create itself, it always could, it can have a beginning as a beginning implies a decision when to start its creation, an intent to create it: that it has been created by some outside intervention -a

[1] *A Critical Look at Inflationary Cosmology* (1999) Earman J. & Mosterin J. in *Philosophy of Science*, vol. 66, no. 1, 1999, *JSTOR*, www.jstor.org/stable/188736; https://en.wikipedia.org/wiki/Big_Bounce (15-11-21); *The road to reality* (2004) Roger Penrose p. 752-759; *A critique from one of the architects of inflation* (2011) Paul J Steinhardt http://www.physics.princeton.edu/~steinh/0411036.pdf

[2] See, for example, *From eternity to here* (2010), Sean Carroll; *The Janus point* (2020), Julian Barbour; *Fashion, Faith, and Fantasy in the New Physics of the Universe* (2017) Roger Penrose.

question we only can ask in a universe which has a beginning, which lives in a time realm not of its own making and we may imagine looking at it from the outside.
Though time is said to only have started at the big bang so there was no time in which the universe didn't exist; as a beginning presupposes a previous state, a time in which it didn't yet exist, it only can have a beginning if time already passes, before there is a universe and even outside of it, for if it has a definite age as seen from within, then it has the same age as 'seen' from without.
If the supposition that time –the time in the equations which are supposed to describe the expansion of the universe– always passes at the same particular, unperturbable pace, of itself everywhere –if the observed pace of clocks only is affected by the gravitational field at the clock and the observer and their relative motion– is untenable, then these equations describe a fictitious universe.

As their properties in a SCU are cause and effect of their interactions, particles have to keep interacting, exchange energy, information to keep existing, to each other and not, as in a BBU, also to an imaginary observer outside the universe. In a BBU particles, once created at the big bang, stay created without this taking any effort on the part of the particles so they have an autonomous existence –meaning that their properties are privately owned quantities, only the cause and not also the effect of their interactions so would keep existing even if we could prevent them to interact. In BBC particles also exist to a hypothetic observer outside the universe as otherwise it wouldn't make any sense to speak about its age, state and properties, for if it has a certain age, if it has particular properties and is in some particular state as a whole as seen from within, then it has the same age, the same properties and is in the same state as 'seen' from the outside and vice versa.

BBC only might make sense if particles would have an autonomous existence, if they, their properties would only be the cause and not, also, *simultaneously*, the effect of their interactions: only then can the universe have particular properties and at any time be in some single particular state as a whole: if it would have been created, caused into existence by some outside intervention.
As a SCU only exists as seen from within so 'contains,' creates all time inside of it so time cannot be observed to pass at the same pace at all distances, there is no such thing as cosmic time. Unlike in a BBU which, as it lives in a time realm not of its own making, grows older at the same pace everywhere[1] so we may imagine to look from the outside in (which in this text is called the *global view*) where we can see, without the time delay due to the speed of light, the entire universe as is at some particular moment in cosmic time; as a SCU only exists as seen from within and there is no universal 'now,' we are not allowed to imagine to look from the outside in. As a result, we cannot, as in BBC, uphold the illusion that by 'looking' from the outside in, determine what in an absolute sense precedes what, what is cause of what, like whether the emission of a photon at one place precedes its absorption elsewhere. Indeed, if when particles, particle properties are as much the cause, the source as the effect, the product of their interactions, then we cannot escape the conclusion that their communication –and hence the trans-

[1] Ignoring gravitational- and velocity time dilation .

mission of light– must be instant: not over any space distance, but over any spacetime distance, which is something else entirely and will take some time to explain, agreeing with the point of view of the photon according to which its transmission takes no time at all, so the constant of nature denoted by *c* and called the speed of light in a SCU isn't so much a velocity but rather a property of spacetime.

As particles in a BBU, once created at the big bang, don't have to interact to keep existing, their communication, the expression of their properties is thought to be incidental, to proceed by the random exchange –the emission and absorption– of force-carrying particles like photons and gravitons to transmit the electromagnetic and gravitational force between them –as opposed to a SCU where there is a continuous, instant exchange of energy, of information between particles to express and at the same time preserve their, each other's properties, their energy, their existence: as they only exist to each other if, to the extent and for as long as they interact, exchange energy, a SCU only exists as seen from within.
As it has no external reality, it doesn't live in a time realm not of its own making, as it only exists as seen from within but cannot have particular properties, be in any particular state *as a whole*, time cannot be observed to pass at the same pace at all distances, meaning that past, present and future are relative, local notions.

Although the universe cannot have a beginning unless it has been created by some outside intervention; a universe which has no beginning, which always has existed and always will exist is just as unimaginable. It perhaps is because the universe traditionally was believed to have been created by God why we find it so hard to abstain from imagining to look at it from the outside, over Her shoulders at Her creation, so to say; because our own existence is so real to us that its transcends the universe, making it almost impossible not to think of it as an ordinary object and imagine to see ourselves inside of it and because we're used to examine the subject of our study from the outside with the naked eye, a microscope or telescope, as if it is an ordinary object which has particular properties: because we assume that there is a single, absolute, objective, universal reality at the origin of our observations, causally preceding its observation. In the words of Einstein

> We all, more or less in the same way, say that a rose is red, smells like perfume, and feels like velvet. In other words, there is an objective reality which is conceived by the senses, and behind this objective reality are natural laws which are the privilege of the scientist to discover. Nature doesn't know chance, it operates on mathematical principles. As I have said so many times, God doesn't play dice with the world.[1]

If reason insists that what comes out of nothing must add to nothing –let's call this the Nix law, the mother of all conservation laws– so the universe cannot have any particular property nor be in any particular state *as a whole* as 'seen' from the outside, then it also cannot have such properties and be in a single state as seen from within, then there also cannot be a single, objective reality as seen from within –which is the assumption classical mechanics (which comprises general relativity theory and big bang cosmology) is based upon.

[1] Einstein in *Einstein and the Poet: In Search of the Cosmic Man* (1983), William Hermanns, p. 58

Only if the universe would have a beginning, a definite age, an external reality, if it would live in a time realm not of its own making –if all objects and observers only would be real, live (as in attending a concert instead of watching a video of it) within an infinitely narrow time interval at some particular moment in cosmic time would there be a universal 'now' and with it a single, absolute, objective universal reality which causally precedes its observation.

If when a SCU 'contains', creates all time inside of it, time cannot be observed to pass at the same pace at all distances so there is no universal 'now' –or, what's the same, if it cannot have particular properties and be in any particular state as a whole– then there obviously is no single, objective, universal reality which is the same to all observers everywhere (even if they account for the effect of their distance and motion relative to the observed on their observations) and do we have to specify the observer or observing particle[1] when describing –not *the* universe as there is no such thing– but the universe they observe –which then can be different to different observers or observing particles.
Though Einstein stated that "God doesn't play dice with the world" as he insisted that nature obeys causality as he couldn't accept the indeterminacy inherent to quantum mechanics (QM); such indeterminacy is self-evident if particles, particle properties are as much the cause as the effect of their interactions. Only if their properties would be the cause and not also the effect of their interactions would there exist a single, objective reality and only then would it be justified to conceive of the universe as an ordinary object which has certain properties and at any moment in cosmic time is in some particular state as a whole and only then would it be legitimate to imagine looking from the outside in and only then big bang cosmology might make sense. While the world at macroscopic level, the word we see with the naked eye seems to obey causality; this obviously is not so at the most fundamental –quantum– level if particle properties are as much the cause as the effect of their interactions.

Though the distinction between cause and effect has been instrumental to the development of science, of classical mechanics (CM); the flaw of causality is that if we understand an event only if we can identify it as the effect of a previous event and can comprehend this event only if we can trace it back to another, preceding event which caused it and going back in time this chain of cause and effect goes on *ad infinitum,* then we never can understand or prove anything definitely, whereas if this chain ends somewhere, if it starts with a primal cause which, as it

[1] As an interaction between particles is an exchange of information, particles in this study also appear as observers, as sources, carriers and receivers of information, so in this text 'observer' can refer to a person as well as a particle. Unless specified otherwise, the protagonists in this text are an unspecified kind of particles though they may, for the sake of argument, adopt any property of any particle species. Depending on the context, 'particle' can mean an elementary particle or a particle which is in the process of evolving to an elementary particle. Though observation doesn't imply consciousness, a capability to reflect on the received information unless we call the process whereby particles adjust their behavior to changes in their environment 'consciousness.' That is, if when their properties are cause and effect of their interactions, all particles participate in the interactions all other particles within their interaction horizon (IH) are involved in so are entangled, then they are informed, in real time, 'aware,' so to say, of each other's location and motion, though it remains to be seen whether they can distinguish between their motion, distance and properties.

cannot be explained as the result of a previous event, cannot be understood even in principle, then causality ultimately cannot explain anything.

Whereas a meteorologist can explain rain causally –sun heats air (and water) so absorbs more water as gas and expands as it heats, and, as its specific weight decreases as it expands, it starts to lift and cools on the way up until it becomes oversaturated with water which then condenses, forms droplets which grow and eventually start to fall as rain; a physicist has to explain why raindrops fall, why there is gravity, what the origin is of mass, of gravity. However material causality has been to the development of physics, of classical aka causal mechanics; as any causal reasoning only can start from a primal cause which cannot be understood by definition, the assumption that the universe has a beginning presupposes just such primal cause so the creation of a BBU cannot be understood even in principle, so BBC in fact has abandoned the hope of ever comprehending how the universe can exist, create itself. Only if we take things for granted –like the existence of gravity and the fact that air expands as it heats– do causality and reason seem to coincide. If when particle properties are cause and effect of their interactions, then the universe at particle level only can be understood rationally, not causally, so at particle –quantum– level we shouldn't confuse causality with reason.

While the creation of the BBU is supposed to have been a one-off event whereby all energy in some mysterious manner was created from one moment to the next at the big bang, violating the law of energy conservation, where all particles popped up ready-made, with all their properties measured off to the last of an infinite series of decimals, properties which like some kind of DNA predetermine the properties of the stars and galaxies they eventually are to contract to; in a universe where their properties are cause and effect of their interactions, you'd expect the different particle species and properties to be the result of a more or less gradual evolution –which doesn't mean that the universe then has a beginning *as a whole*. If time in a SCU cannot be observed to pass at the same pace at all distances, in empty space, far from masses, so the universe of any observer always contains objects in different phases of their evolution, then we don't, as in BBC, see them as they were, of themselves, in *the* past, at an earlier moment in cosmic time as they are more distant, but see them as they are, to us as we look at them, at what only to us is the present.

If everything in nature is about energy, if a particle only can be said to exist if it can express its existence, its properties in interactions if it has energy and the universe is to create itself (as far as it makes sense to say that it has a beginning), then energy, whatever kind of stuff it may turn out to be must be something which tends to increase, to keep creating itself, a propensity we know as gravity, which drives the processes, the changes we experience as the passing of time.

If reason insist that what comes out of nothing must add to nothing so the universe has no external reality so cannot have any particular property, be in any particular state as a whole, then the net energy or electric charge of the universe, say, cannot be nonzero. If it nevertheless contains energy and electric charge, then that must mean that energy –and electric charge– must be something which can be positive and negative, if its creation is like a zero which keeps splitting itself into positive and negative numbers the sum of which always remains nil.

If a photon is its own antiparticle, if the sign of its energy in one phase is as positive as it is negative in the next –if its energy is proportional to the frequency its sign alternates at– then the energy of the massive particle it is emitted or absorbed by likewise must be a dynamic, wavelike quantity. If the energy of a particle in one phase is as positive as it negative in the next, then it is conceivable that particles express and at the same time preserve their, each other's properties by alternately borrowing and lending each other the energy to exist to each other by exchanging energy. If one particle can pop up with a positive energy together with an identical particle with an equal, negative energy, then no conservation law is violated as they create one another. As they only exist to each other if, to the extent and for as long as they interact, their energy proportional to the frequency they exchange energy, at which their energy sign alternates –and not, as in BBC, to an imaginary observer outside the universe– then the net energy of the universe cannot but remain nil –which is why a SCU has no external reality but only exists as seen from within.

Only if their properties would be privately owned and hence static quantities, only the cause and not also, simultaneously, the effect of their interactions would it be justified to think of the universe as an ordinary object which lives in a time realm not of its own making, to imagine looking from the outside in and speak about its age, properties and state.

The supposition that the energy of particles isn't a static but a dynamic, wavelike quantity follows from the uncertainty principle (UP) which says that the strength, the energy of a field cannot be *and* remain constant –and with it the energy of its quanta. The higher the energy of a particle is, the shorter it can have, borrow or lend that energy, the higher its rate of change is in space and time, i.e., the higher the frequency its energy sign alternates at, at which it exchanges energy with the particles to which it owes its energy and to the energy of which it contributes.

If any kind of charge contributes to, is an expression of the energy of particles then any kind of charge should likewise be a dynamic, wavelike quantity, in one phase as positive as it is negative in the next so it is unclear why the electric charge of a particle is (or only seems to be?) either positive or negative, always, for you'd say that its charge only can be static if it is a privately owned quantity, only the cause and not also the effect of its interactions.

It isn't just that there must be a continuous communication between what classically is thought of as the source of the field, an electron, say, a particle which in quantum mechanics (QM) can as well be seen as the product of the field and the points of its electric and magnetic field to update what values they are to adopt due to changes in the environment and to inform the particle of the location and motion of other charged particles, a two-way communication where a change in the field strength results from a change of the frequency the particle oscillates at or vice versa. If the interference patterns in the double-slit experiment show that massive particles are wave phenomena, then any kind of charge contributing to their energy similarly must be a quantity the sign of which alternates.

We can then think of the selfcreation of particles as an event whereby particle *A* pops up with a positive energy it borrows from particle *B* –which then appears in counterphase, with an equal, negative energy so their total energy remains nil and their mutual selfcreation doesn't violate any conservation law. However, if when *A* borrows all its energy from *B*, then *A* and *B* would only exist to each other, not to the particles in the midst of which they pop up, in which case there would be no force between *A* and *B* –so they wouldn't even have energy, exist to each other in the absence of other particles as according to Newton's 3rd law a force between *A* and *B* only can be as strong as the force they feel from (particles in the) opposite directions. Only if they also borrow and lend part of their energy from and to the particles in the midst of which they pop up, particles which similarly are in *statu nascendi*, can they all start to exist to, interact with each other and acquire energy, evolve to real, elementary particles. As (UP) their lifetime is inversely proportional to their energy, they'd vanish as their time is up unless they manage to set up a continuous energy exchange by means of which they force each other to reappear time and time again after every disappearance at about the same location and moving in about the same fashion. The higher the frequency they exchange energy at, at which they alternately pop up, vanish and reappear, at which their energy sign alternates, the higher the energy they observe each other to have.

If according to the UP the energy of particles increases as the uncertainty in their position decreases, which it does as their distance decreases, as they contract to clusters –or, equivalently, if according to Einstein, the inertia of a given body is greater as there are more ponderable masses in proximity to it[1]– and the inertia of a body equals its mass, then particles can create themselves, each other only if they contract to clusters (and clusters of clusters) everywhere in concert: if their communication is instant over any spacetime distance.

That is, if, for reasons to be discussed, clocks in a SCU must be observed to run at a slower pace at larger distances and we were to conclude from this that we see a galaxy as it was at an earlier time as it is more distant, then this would mean that light moves at a finite, constant velocity. However, if in a universe which doesn't live in a time realm not of its own making, we cannot speak about its age, if the observed pace of time somewhere is a relative, observer dependent quantity and we cannot escape the conclusion that in a universe where particle properties are as much the cause as the effect of their interactions, their communication must be instantaneous –so it doesn't even make sense to ask what precedes what in an absolute sense– then what we observe to happen in some distant galaxy happens when we look at it, in what only to us is the present.
So it isn't so that events which in a BBU happen at different distances at the same moment in cosmic time in a SCU are observed to happen at the same time: in a SCU we see some event happen at a slower pace, at what in a BBU would be in a more distant past as it happens at a larger distance –discussion to be continued.

[1] A. Einstein, *Geometry and Experience*. Lecture before the Prussian Academy of Sciences, Jan. 27, 1921

If the energy of particles only exists, manifests itself as it is in the process of being exchanged, if it is a dynamic, wavelike quantity so its magnitude, its rate of change in space and time varies within every cycle of their oscillation, of their energy exchange, then so does the uncertainty, the indefiniteness or indeterminateness in their position.[1]
The shorter, the less indefinite their distance is, the higher the energy E they observe each other to have, the higher, according to the Planck relation $E = hv$, the frequency v is they exchange energy at, at which they alternately borrow and lend each other the energy to exist, at which their energy sign alternates, so the Planck relation is just another formulation of the uncertainty principle.

If the energy of a particle is higher as it is confined to a smaller space, as its position is less indefinite and its energy varies within every cycle of its oscillation, then so does the indefiniteness in its position, so it acts more like a (point-) particle in the phase in which its energy, its rate of change in space and time is greater, as its position is less indefinite and more as a wave phenomenon in the phase its energy, its rate of change in space and time is lower, as the position its energy acts from is less definite, as its energy is distributed more uniformly over a larger region, as it acts more simultaneously (and hence weaker) from all points in a larger region.
If the frequency it oscillates at is the frequency its wave function Ψ vibrates at and the indefiniteness in its position varies within every cycle of its oscillation, then it can be seen that its wave function describes the extent to which it is present at different places: the square of the wave function (Ψ^2), gives the probability to find it as a particle at different places at different times, a function the evolution in time of which is given by the Schrödinger equation, a function the rate of change of which is proportional to its energy. If the square of the wave function gives the probability to find the particle at some place and time, then that suggests that Ψ^2 refers to the energy density in the region where it can be localized, the extent to which it is present at different places at different times.
If all of the mass of an electron, say, would be electromagnetic (which it isn't) and its energy density somewhere is proportional to the square of its electric and magnetic field in that region, then Ψ would describe the electromagnetic field of the electron –the strength of which at large distances, like a radio signal, decreases linearly with distance.

As the exchange of energy, of information between particles only serves to preserve the *status quo*, the world we see, it isn't observable so doesn't seem to occur at all: it only would become observable if we could cut off their communication – in which case they, the universe would cease to exist and vanish without trace. As particles in the classical view only are the source, the cause of forces so would keep existing even when isolated from interactions, their communication is supposed to proceed via the exchange, the random emission and absorption of force-carrying particles between them, like (virtual) photons and gravitons to express their electric charge and mass, of messenger particles which mediate the

[1] As 'uncertainty' leaves open the possibility that we for some reason cannot know the exact position and momentum of a particle at the same time, but nature always knows where exactly it is and how it moves –which she doesn't– in this text the term 'indefiniteness' is preferred above 'uncertainty.'

electromagnetic and gravitational force between them, particles which if massless move at the speed of light –as opposed to a SCU where particles express and at the same time preserve their, each other's properties by exchanging energy.

If the emission (absorption) of such messenger particles decreases (increases) the energy of the emitting (absorbing) particle and their exchange is random, then the energy, the mass and charge of an electron, say, would vary randomly so it could cease to exist if it keeps losing more energy by emitting messenger particles than it absorbs –if not for the UP according to which the variation in its energy may last for a shorter time as it is higher. It is a mystery, however, how the particles in its vicinity can know when to replete a deficit in its energy, when they are to send photons and gravitons with the right energy at the right times in the right direction for if they move at a finite (light) velocity, then the emitting particles would have to be clairvoyant to predict the position, motion and energy of the electron at any future time to ensure the timely arrival of the messenger particles they send to the electron to replenish its energy. How can the electron know what charge and mass it ought to have, preserve its properties if the emission and absorption of these messenger particles is random –which is to say, if particle properties only are the cause and not also the effect of their interactions– and photons and gravitons move at a finite velocity? There obviously is no such problem in a universe where particles express and at the same time preserve their, each other's properties by exchanging energy and the exchange is instantaneous.

As particles only can exchange energy at equilibrium when in counterphase –at distances equal to 1/2, 3/2 … times the wavelength they exchange energy in– their distance is quantified and with it the energy they emit or absorb as they jump between different equilibrium states, a distance, a jump whereby their distance and the wavelength they exchange energy in changes with a discrete amount.

If particle properties are cause and effect of their interactions, then a particle cannot, as in CM, have an infinitely sharp, fundamental boundary where it, its properties end and spacetime begins,[1] implying the existence of fields:

> Particles are epiphenomena arising from fields. Thus the Schrödinger field is a space-filling physical field whose value at any spatial point is the probability amplitude for an interaction to occur at that point. The field for an electron *is* the electron; each electron extends over both slits in the 2-slit experiment and spreads over the entire pattern … Quantum fields have one particle-like property that classical fields don't have: They are made of countable quanta. Thus quanta cannot partly vanish but must (like particles) be entirely and instantly created or destroyed. Quanta carry energy and momenta and can thus "hit" like a particle. … When a field changes its energy by a single quantum, it must do so instantaneously, because a non-instantaneous change would imply that, partway through the change, the field had gained or lost only a fraction of a quantum. Such fractions are not allowed because energy is quantized. Field quanta have an all-or-nothing quality. The QFT [quantum field theory] language of creation and annihilation of quanta expresses this nicely. A quantum is a unified entity even though its energy might be spread out over light

[1] So de Broglie's pilot theory is out. If there would be such boundary, then space would exist, be defined even when devoid of energy.

years--a feature that raises issues of nonlocality intrinsic to the quantum puzzle. "Fields are all there is" should be understood literally. For example, it's a common misconception to imagine a tiny particle imbedded somewhere in the Schrödinger field. There is no particle. An electron *is* its field. … any free … relativistic quantum "particle" must, if it's localized to a finite region to begin with, *instantly* have a positive probability of being found an arbitrarily large distance away. But this turns out to violate Einstein causality (no superluminal signaling). The conclusion is then that an individual free quantum can never--not even for a single instant--be localized to any finite region. … Field-particle duality exists only in the sense that quantized fields have certain particle-like appearances: quanta are unified bundles of field that carry energy and momentum and thus 'hit like particles;' quanta are discrete and thus countable. But quanta are not particles; they are excitations of spatially unbounded fields. Photons and electrons, along with atoms, molecules, and apples, are ultimately disturbances in a few universal fields.[1]

If the energy, the properties of a particle then cannot reside within a finite volume, then it looks more like a (point-) particle at the times in its cycle when its energy, its rate of change in space and time is higher, as the indefiniteness in its position is smaller, whereas in the phase its energy, its rate of change in space and time is lower, as its position is less definite, it, its energy acts more equally and more simultaneously from all points –and hence weaker– within a larger region –more like a wave phenomenon– so spacetime has properties related to the properties of particles and vice versa.

Since according to the UP the strength, the energy of a field cannot be *and* remain zero, what looks like empty space contains energy in the form of virtual particle-antiparticle pairs which continually pop up out of the vacuum to vanish after a time which is shorter as their energy is higher. Though there exist no particles; if energy only exists, can act if it has a location to act from, then we can call what is present at the position it acts from 'particle.' If the frequency 'particles' exchange energy at depends on their rest energy, their distance and relative motion so it takes energy to change their relative state of motion, then this manifests itself as inertia, as opposition to such change, so the energy exchange by means of which they express and preserve their properties entangles them to each other.

If according to relativity theory a measuring rod is observed to look shorter, a clock to run at a slower pace as the gravitational field at the rod and clock is stronger than it is at the observer and it is localized energy which makes positions at different distances physically different, distinguishable –i.e., the observed pace of clocks and length of rods– and the energy of a particle, its rate of change in space and time varies within every cycle of its oscillation and with it its gravitational field, then a massive particle is a modulation of (and in) spacetime in the sense that the observed pace of clocks and length of rods in the region where it can be localized varies within every cycle of its oscillation. It is because particles express and at the same time preserve their properties by exchanging energy why their energy is a dynamic, wavelike quantity, in one phase is as positive as it is negative in the next.

[1] *There are no particles, there are only fields*. (2012) Art Hobson: https://arxiv.org/ftp/arxiv/papers/1204/1204.4616.pdf

Overthrowing the concept of a universal "now" was, according to Einstein himself, by far the most difficult step in arriving at special relativity. –Frank Wilczek. [1]

The past is never dead. It's not even past. W Faulkner[2]

2
The relativity of time

Though BBC aims to describe the universe from within; if it has certain properties and at any (moment in cosmic) time is in some particular state as a whole as seen from within, then it has the same properties and is in the same state as 'seen' from the outside so it has an external reality no matter that there is nothing outside of it by definition. In saying that the universe has a beginning, a definite age, that it is the same time, that time passes at the same pace everywhere (in empty space, far from masses[3]) BBC in fact states that the universe lives in a time continuum not of its own making: that time passes, is defined even outside of it so here past, present and future are absolute, *global* notions –as opposed to a SCU where, as it only exists as seen from within so contains, creates all time inside of it, time cannot be observed to pass at the same pace at all distances, past, present and future are relative, *local* –observer dependent– notions.

If energy only can be a source of gravity if it has a position to act from –and according to the UP, the energy of a particle or an object is higher as its position or the position of the mass center of the object is less indefinite– and it is localized energy which makes positions at different distances physically different –the observed pace of clocks and length of rods– which turns an abstract space where, if it would make sense to speak about time, it would pass at the same pace everywhere, into a real, physical spacetime –here *defined* as a space where two points only can be observed to be spatially separated if time is observed to pass at a slightly slower pace and a rod to look shorter at the more remote point– then the creation of energy *is* the creation, not of space in time but of spacetime.

By contrast, as the concept 'energy density of the universe' central to BBC defines energy and space as independent quantities, here space exists, is defined even when devoid of energy –which if true would mean that energy cannot cause space to curve nor expand as energy only can act upon energy.
If when the universe cannot have some particular property –a definite energy density, for example– nor be in any particular state *as a whole*, if it only exists as seen from within so there is no universal now, no cosmic time then the Friedmann equations obviously don't apply to a SCU.

Though a prominent physicist like Carlo Rovelli seems to agree

[1] *The lightness of being* (2008) Frank Wilczek Ch. 8.
[2] In *Requiem for a Nun* (1951)
[3] In an expanding big bang universe, only clocks which always are at rest relative to the Hubble flow since the big bang show the same time.

> … the idea that there exists a ''now'' all over the universe does not square with what we know about the universe. … The picture of a Universe changing from one global instant to the next is incompatible with what we know about the world.[1]
> … 'past' and 'future' do not have a universal meaning. Instead, they have a meaning which changes between here and there. [2]

and is aware that it makes no sense to speak about the properties and state of a system which doesn't interact (for lack for something to interact with)

> If there was an object that had no interactions, no effect upon anything, emitted no light, attracted nothing and repelled nothing, was not touched and had no smell, … it would be as good as nonexistent. To speak about of objects that never interact is to speak of something -even if it existed- that could not concern us. It is not even clear what it would mean to say that such object 'exists'.[3]

and that

> The physical world can be described as a net of interacting components, when there is no meaning to "the state of an isolated system." The state of a physical system is the net of the relations it entertains with the surrounding systems. The physical structure of the world is identified with this net of relationships.[4]

so it makes no sense to speak about the properties and state of the universe nor about the time it has those properties and is in that state; he hasn't yet concluded that BBC then cannot be a valid description of the universe.
If when particles, particle properties are cause and effect of their interactions their communication –and the transmission of light– then must be instantaneous[5] –not over any space distance as the speed of light then would have to be infinite (action at a distance)– but over any spacetime distance, then we don't, as in a BBU, see a distant galaxy as it *was*, of itself, in a distant past, in *the* past, at some particular moment in cosmic time but as it *is*, to *us*, when we look at it, in what only to *us* is the present, and, if time in a SCU is observed to pass at a slower pace at larger distances, in an earlier phase of its evolution as it is more distant.
We shouldn't then think of the constant of nature *c* called "the speed of light" as a velocity but as a property of spacetime: only in a universe which lives in a time continuum not of its own making, where there is a universal 'now,' where we can determine what in an absolute sense precedes what,[6] what is cause of what, would we see the galaxy as it was, of itself, in a distant past, in *the* past and would *c* refer to a velocity.

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[1] *The Disappearance of Space and Time* by Carlo Rovelli in *The Ontology of Spacetime* (2006) p. 34 Edited by Dennis Dieks
[2] *The order of time* (2017) Carlo Rovelli p. 100
[3] *Helgoland* (2020) Carlo Rovelli p 68, ISBN 978 0 241 45469 5
Similarly, Lee Smolin: "… there is no wave function of the universe, because there is no observer outside the universe who could measure it." in *Einstein's Unfinished Revolution* (2019) P. 231
[4] *Quantum Gravity* (Dec. 30, 2003) Carlo Rovelli p. 154 http://www.cpt.univ–mrs.fr/~rovelli/book.pdf
[5] Although concepts like simultaneity and instantaneity are relative; if, as will be discussed, we can *define* a photon transmission as proceeding instantaneously (over any spacetime distance) if we cannot, even in principle, determine what precedes what in an absolute sense.
[6] That is, in the global view, by an observer who could see the entire universe as it is, of itself, at some particular moment in cosmic time, without the time delay due to the speed of light.

If clocks in a SCU are observed to run at a slower pace as they are more distant so the energy of a particle, the frequency it oscillates at is lower as observed from a larger distance and a lower energy can be associated with an earlier evolutionary phase (not with an earlier moment in cosmic time as there is no such thing in a SCU) so particles at the rim of each other's interaction horizon (IH) observe each other to have an infinitesimal energy, to be in the earliest phase of their evolution, then a particle can have a beginning without this meaning that the universe has a beginning as a whole. As it only exists as seen from within, as there is no universal 'now,' it doesn't even make sense to ask which of all particles was the very first to start to exist –in which case the universe would have a beginning, the point being that in a SCU we aren't allowed to imagine looking from outside the universe in. Not just because a single particle in an otherwise empty universe cannot exist itself; in a SCU every particle can consider itself to be the beginning of its universe, to be (at) its center, its alpha and omega.

If a particle owes its energy to all particles within its IH, and the contribution to its energy of another particle is smaller as its energy is lower and it is more distant, then we can think of its (rest) energy, of the wavelength λ associated with it as the sum, the superposition of all wavelengths it simultaneously exchanges energy in with particles at all distances. As its observed energy –defined as proportional to the frequency it is observed to oscillate at or inversely proportional to the wavelength λ associated with it– also depends on the energy of the observing particle, its distance and motion relative to it, it has a different energy, a different birth date, so to say, is in a different phase of its evolution to elementary particle to different observing particles or identical observing particles at different distances.

As according to the UP the energy of a particle is higher as its position is less indefinite, in this text the distance between particles is *defined* to be less definite as there is less energy involved in a change of their distance per unit distance, as they are farther apart, as it matters less, energetically to the particles and their environment how large their distance exactly is, just like a wavelength is less definite as it is longer, as the exact position and hence the distance between the tops of successive wave crests is less definite as the wavelength is longer –and with it the distance between two particles exchanging energy in that wavelength. The farther apart two particles are, the longer, the less definite their distance is, the lower the energy they observe each other to have, the longer the wavelength they exchange energy in, the earlier the evolutionary phase the observe each other to be in (if, as will be discussed, particles tend to evolve to higher energies); the shorter their distance, the less indefinite it is, the shorter, the less indefinite the wavelength they exchange energy in, the higher the energy they observe each other to have, so in this text a higher rest energy of a particle is defined as a less indefinite energy (which is contrary to custom). Though a higher (rest) energy of a particle means that its rate of change in space and time is greater; that doesn't mean that its exact value at any time then is more uncertain, less definite even though it may be more difficult to measure exactly.

If the UP implies that the wavelength particles exchange energy in is longer, less definite as their distance is greater –if particles cannot exchange energy in a wavelength which is smaller than the indefiniteness in their distance, then this results in a (spacetime-) distance redshift or time dilation, in which case they observe each other to have a lower energy or time to pass at a slower pace at the other particle as they are farther apart even when they are at rest relative to each other. The farther apart they are, the less definite their distance is and/or the lower their rest energy is, the lower the energy they observe each other to have, the less they contribute to each other's energy; the shorter, the less indefinite their distance is, and/or the higher their rest energy is, the shorter the wavelength they exchange energy in, the higher the energy they observe each other to have, the more they contribute to each other's energy.
The lower they observe each other's energy to be, the weaker they interact, the less definite they observe each other's position and motion to be, the less defined, evolved they observe each other's properties to be. The father apart they are, the less their interaction horizons, their universes coincide, overlap, the lower the frequency they exchange energy at or, equivalently, the slower they observe time to pass at the other particle, the 'earlier' the evolutionary phase they observe each other to be in, the less defined they observe each other's properties to be, the less their behavior is related, the weaker they interact, the less they have in common, the less it makes sense to say that it is the same time, that time passes at the same pace at both particles.

If the evolution of particles in *statu nascendi* to the real elementary particles we know would proceed continuously, without fits and starts then the relatively high energy a particle has, the relatively late evolutionary phase it is observed to be in by a nearby observer could be thought of as the superposition, the sum of all wavelengths it exchanges energy in with particles at all distances, the superposition of all 'earlier,' lower-energy phases of its evolution, all of which remain active, keep contributing to the relatively high energy it has according to the nearby observer, to be in what to her is a relatively late phase of its evolution – though we can as well say that it is the relatively high energy it has as seen from nearby why it is observable by, can interact with particles at large distances, to which it owes part of its energy and to the energy of which it contributes, so the past indeed is never dead, it isn't even past –even though the mechanics of their evolution is unclear.
As the energy of particles varies within every cycle of their oscillation, they repeat, in some sense, the 'earlier', lower-energy phases of their evolution in every cycle, as if they create and uncreate each other in every cycle of their energy exchange.[1]
If the energy of a galaxy to some extent similarly can be thought of as the sum of all wavelengths it (its particles) exchange(s) energy at with all objects within its IH, in a longer wavelength as they are more distant so they observe the galaxy to have a lower energy, to be in an earlier evolutionary phase, time to pass at a slower

[1] As the energy of a particle, its rate of change in space and time for a short time is zero twice in every cycle, it would seem that it then doesn't exist for that time. However, as the phase it is observed to be in also depends on the distance it is observed from, we cannot say that it ceases to exist for that time if the point of view of all observing particles is equally right.

pace as it is more distant, then all earlier evolutionary phases of the galaxy keep existing, contributing to the high energy it has, the late phase it is in according to a nearby observer, just as it its relatively high energy as seen from nearby which makes it observable by, enables it to interact with objects at large distances.

If for reasons to be discussed, we can associate a lower energy of a particle or galaxy with an earlier evolutionary phase (and not with an earlier moment of cosmic time as there is no such thing in a SCU), and the universe only exists as seen from within so contains, produces all time inside of it, if there is no universal now, nothing relative to which we can determine what in an absolute sense precedes what, what is cause of what –like we can, in the global view in a BBU– then we can no longer think of distant events as having happened, been completed in *the* past, that we observe a distant galaxy as it was, of itself, in *the* past. If the rim of the interaction horizon of a particle can be defined as lying at that distance at which it observes time to pass at an infinitesimal pace, where it observes particles to have an infinitesimal, nonzero energy, their creation to proceed at an infinitely slow pace, then we can say that the observed particles always have existed and, as there always will be low-energy particles at the rim of its IH, always will exist.
As there is a gradual transition between a zero and an infinitesimal, nonzero energy of a particle and this corresponds to an infinite indefiniteness in its position then we might say that it always has existed everywhere, be it that the effects of its existence then also are infinitesimal, almost indistinguishable from its non-existence. As it cannot witness its own nonexistence, from its own point of view there is no time in which it –and the universe it observes– didn't yet exist.

As he rejected the idea of a universal 'now,' it is curious that Einstein nevertheless accepted big bang cosmology as it hinges on precisely that assumption: that the universe at any (moment in cosmic) time is in some particular state as a whole, that it has a definite age, that the concept of 'cosmic time' means that there is a universal 'now.' It is the interpretation of *c* as a velocity –the idea that the universe grows older as light travels, through space, in time, that there is a universal 'now'– why we assume that we see a distant galaxy as it was, in a distant past, in *the* past. If all objects and observers everywhere only would be real, live within a thin time slice 'now,' then we shouldn't even speak about spacetime but of space and time as the universe as it was a second ago then doesn't, *shouldn't* exist anymore.

If when a star in a distant galaxy in a SCU explodes in a supernova, then we don't see it as it happened in a distant past, at some particular moment in cosmic time, in *the* past, as we would in a BBU, but, for what we see of it, when we observe it to happen, in what only to us is the present.
As the star owes its energy to all objects within its IH, the supernova is an event which happens over all of spacetime, everywhere and when it is observed to happen, where and when it affects the state of affairs: in a SCU all particles affected by it or affecting it participate in it, are part of its 'cause' and 'effect.'

The fact that there is nothing relative to which the pace of (cosmic) time can be quantified, whether it passes fast or slow should have alerted us to the possibility that there is something fundamentally wrong with the concept of cosmic time,

with the idea that time always passes at the same particular, unperturbable pace everywhere in empty space, far from masses, that it only is the gravitational and velocity time dilation which affects its *observed* pace, not the pace at which it passes, of itself: i.e., that its pace is unrelated to anything.
As a selfcreating, self-contained universe creates all time inside of it, time cannot be observed to pass at the same pace at all distances but, for reasons to be discussed shortly, must be observed to pass at a slower pace at larger distances, to be infinitesimal at the rim of the interaction horizon of any observer, anywhere. As its observed pace somewhere is relative, as past, present and future in a SCU are relative, local notions, it makes no sense to speak about the pace at which time passes of itself –discussion to be continued.

3
The speed of light

The fact that light always and everywhere travels at 299,792,458 meter per second is quite remarkable for how can it know at what speed it must move and maintain that exact velocity? Does it have some kind of GPS and cruise control on board?
According to relativity theory, the observed pace of a clock is slower as it moves faster relative to the observer, to stop, to freeze at the speed of light. As a particle moving at the speed of light is completely frozen in time, according to its own clock its voyage takes no time at all: it arrives at one place at the time it departs at the other so from its own point of view there is no distance in space nor time between the points it is transmitted. If a particle at the speed of light is completely frozen in time so its state, its energy cannot change as it travels, then it cannot express its properties, its energy in interactions with the objects in the environment it is supposed to travel through. If at the speed of light it cannot interact so doesn't exist, has no physical reality to the objects in its environment nor these objects to the particle, then its position is completely indefinite: as it doesn't then make any sense to specify relative to what it moves, we shouldn't think of the constant of nature *c* as a velocity but as a property of spacetime.
Only in mathematics can we speak about the relative velocity of objects without requiring that they have a physical reality to each other, that they interact.
In physics we only can speak about the motion of a particle if it matters, energetically, to the particle and to the objects relative to which it moves how fast it moves in what direction as its motion affects its observed energy, the frequencies it exchanges energy at in different directions with the objects in its environment, to which it owes its energy and to the energy of which it contributes.
Only if its properties would only be the cause and not also, the effect of its interactions –if it would have an autonomous existence so wouldn't have to interact to keep existing– and only then would *c* be a velocity and would it at any time have a definite position even at the speed of light. It is because the position of a particle at the speed of light in a SCU is completely indefinite or, equivalently, because it is completely frozen in time why it cannot express its properties in interactions why a particle moving at the speed of light is massless, why a massless particle 'moves' at the 'speed' of light.

Though we can predict where we can intercept, detect a photon when if we know where and when it was emitted in what direction; that doesn't mean that we may think of it as some kind of bullet which moves through space, in time if it only makes sense to speak about its location and velocity if it keeps existing to, interacting with the objects relative to which it moves –which it doesn't at the 'speed' of light. It is the belief that the universe has been created by some outside intervention, that it has an external reality, a beginning, a definite age, that there is a universal 'now' and particles have an autonomous existence, that their properties only are the cause of forces– why *c* came to be thought of as a velocity. If when particle properties in a SCU are source and product of their interactions, their communication –and hence the transmission of light– then must be instant, it is obvious why nothing goes faster than light, so at 299,792,458 m/s it ceases to be a velocity.

If in a misty field at night a laser is switched on, its beam perpendicular to our line of sight and some distance above the horizon, and we watch from afar the motion of the front of the light beam as it is reflected by the mist droplets in our direction, then we see the beam front move at a constant velocity away from the laser.
While this observation is explained by assuming that time passes at the same pace every-where and that light for some unknown reason moves at a finite velocity of through space, in time, the universe growing older as it travels; we see the same if the light is instantly everywhere on its path and, via the mist droplets, in our eyes as soon as the laser is switched on in a universe where time is observed to pass at a slower pace at larger distances so a clock at the laser is observed to run at a slower pace as it is more distant as measured from the laser via the path of its light to us.

If in a space where time passes at the same pace everywhere there is a light source *S* and two observers *A* and *B* moving at a different velocity relative to *S* in the same plane –in the same time slice 'now'– and light, a photon at any time would have a definite location and move at a finite, constant velocity, then you'd expect *A* and *B* to measure the photon to have a different velocity. If they nevertheless measure the same light speed then that is because the observer observes her path to shrink and clocks along her path to run at a slower pace as she moves faster. However, the observer only finds the speed of light to be independent from her own motion if the ratio between the length she observes her path to have when moving and when at rest varies in the same manner with her velocity as the ratio between the pace she observes clocks along her path to run when she is moving and when at rest: if space and time are intrinsically related. This they only are in a universe where two points only can be observed to be at different distances if time is observed to pass at a (slightly) slower pace at the more remote point, not in a universe which lives in a time continuum not of its own making, where, as its pace isn't related to anything, it is a mystery why there is time at all.

As the emission of a photon by an excited hydrogen atom *A* and its absorption by another hydrogen atom *B* in its ground state changes the energy of both atoms, *A* observes *B*'s state to change at the time it emits the photon since as soon as *A*'s energy changes, the world it observes, including *B*, changes, looks different to *A* after the emission of the photon, while *B* observes *A*'s state change at the time it absorbs the photon, as its own state changes due to the absorption of the photon and hence its observation of, its interactions with the objects in its environment, including *A*. That is, unless we assume that atom *B*, after absorbing *A*'s photon sends back a message to *A* to confirm the receipt of the photon, a thank-you note informing *A* that it can, as of this moment, the receipt of the note, start to see *B* in its new state, with an increased energy, start to interact differently with *B* –as would be the case if *c* would be a velocity instead of a property of spacetime.

Only an imaginary observer outside a universe where light moves at a constant velocity who could observe it as it is, of itself, at any moment in cosmic time, would be able to determine what in an absolute sense precedes what, what is cause of what –the emission of the photon by *A* or its absorption by *B*– if, as in a BBU, there is a universal 'now.' In a universe where time is observed to pass at a slower pace at larger distances so past, present and future are relative, local notions, we cannot ask what precedes what in an absolute sense –its emission or absorption– which of the atoms caused the photon transmission, so if from the point of view of the photon its transmission is instantaneous, then observers near *A* and *B* are equally right about the time of the transmission –when they observe it to happen. As a global view isn't legitimate in a universe which, as it only exists as seen from within, doesn't live in a time continuum of its own making so we cannot determine even in principle what precedes what, then we cannot think of *c* as a velocity as a definite direction of motion requires that we can determine what precedes what.

If according to the photon its transmission is instant, if its departure by *A* doesn't precede its arrival at *B*, then *A* cannot emit a photon without the cooperation of *B*, by any atom or particle which is to absorb it. Moreover, as the photon carries momentum and energy, the momentum and energy of *A* and *B* change due to its transmission: as this affects all particles within the IH's of *A* and *B*, they all take part in the transmission, are part of its cause-and-effect, so to say, so if they contribute to or absorb some of the momentum and energy of the photon, then the transmission is an event which simultaneously happens everywhere within the IH's of *A* and *B*. It is because time in a SCU is observed to pass at a slower pace at larger distances which creates the illusion that such change propagates through space, in time, why we came to think of the transmission of light in terms of cause and effect, of light as something which moves through space, in time, the universe growing older as it travels:

> In QED the photon is introduced as the unit of excitation associated with a quantized mode of the radiation field. As such it is associated with a plane wave of precise momentum, energy and polarization. Because of Bohr's principle of complementarity we know that a state of definite momentum and energy must be completely indefinite in space and time. This points to the first difficulty in conceiving of the photon. If it is a particle, then in what sense does it have a location? This problem is only deepened by the puzzling fact that, unlike other observables in quantum theory, there is no Hermetian operator that straightforwardly corresponds to position for photons. Thus while we can formulate a well-defined quantum-mechanical concept

> of position for electrons, protons and the like, we lack a parallel concept for the photon … The simple concept of spatiotemporal location must therefore be treated quite carefully for photons. We are also accustomed to identifying an object by a unique set of attributes. My height, weight, shoe size, etc. uniquely identify me. Each of these has a well-defined value. Their aggregate is a full description of me. By contrast the single photon can, in some sense, take on multiple directions, energies and polarizations. … Thus the single photon should not be thought of as like a simple plane wave having a unique direction, frequency or polarization. Such states are rare special cases. Rather the superposition state for single photons is the common situation. Upon detection, of course, light appears as if discrete and indivisible possessing well-defined attributes. In transit things are quite otherwise.[1]

What in the classical view are three separate, unrelated events which happen one after the other, the supposedly autonomous, spontaneous, random emission of a photon by *A*, its voyage in some random direction and its accidental absorption by *B* –unrelated in the sense that once emitted, there is no communication between the traveling photon and *A* nor with any object it eventually is to be deflected or absorbed by;[2] in a SCU it is a single event which happens simultaneously everywhere within the entire interaction horizons of *A* and *B*: not over all of space at some particular moment in cosmic time but over all of spacetime. It is because time is observed to pass at a slower pace at larger distances why the emission of the photon by *A* seems to precede its absorption by *B*.

Whereas the fact that we can switch on a lamp seems to prove that light emerges from the lamp, that its emission causally precedes its arrival elsewhere at a later time; the lamp is a device designed so that once supplied with energy, the probability of a photon emission becomes extremely close to 1. We cannot cause a particle to 'move' at the 'speed' of light; we only can improve the probability for a photon transmission to occur –which is a subtle but important difference. In a SCU the lamp cannot emit a single photon without the cooperation of the environment which is to absorb it. It is because there usually are plenty other objects prepared to absorb the photon why its emission doesn't seem to depend on anything, as if the light source is the autonomous cause of the emission, as if light is something which moves through space, in time. In a SCU we see a distant galaxy not as it was, of itself, in a distant past, in *the* past, but as it is as we look at it: because a photon transmission requires the cooperation of the object which is to absorb it, a supernova in a galaxy happens when we observe it to happen, at what only to us is the present, for the part we observe of it, for the radiation we receive, so we –any object within the IH of the star, which contributes to and owes part of its energy to the star– participate in the supernova, is part of its cause-and-effect, so to say.

4
Richard Feynman's path integral

[1] Arthur Zajonc, in *Light reconsidered* (2003) https://www.arthurzajonc.org/wp-content/uploads/2016/06/LIght-Reconsidered.pdf

[2] Though light is said to be deflected as it skims a heavy object; from the point of view of the photon its path is straight in the sense that it is the shortest path.

John Wheeler about Feynman's path integral –or 'sum-over-histories'– method:

> Back in 1940 or 1941, Feynman had come up with a new way to look at quantum phenomena that I called 'sum-over-histories.' The idea, in brief, is this: In quantum mechanics, if you to want to find out how something at point *A* influences something at point *B*, you can get the answer by pretending that all of the ways that *A might* send a signal to *B* happen *at once*; the actual effect is then a sum of all the 'virtual' effects from all of the different paths. It is as if a baseball pitcher, instead of throwing a single ball toward the batter, could launch simultaneously a thousand balls that travel a thousand different paths through space and time on their way to the batter. Each of these thousand balls has a 'history' as it flies from pitcher's mound plate. What the batter sees and swings at is the result of all these histories combined. A mind-bending idea, to be sure, but it's just what happens in the quantum world. [1]

If the pitcher and batter represent atoms *A* and *B* between which a photon (baseball) is transmitted and *A* would autonomously emit the photon, independent from what is and happens elsewhere, then the photon should follow a single path, not split into thousand virtual photons which follow simultaneously thousand different paths of the same length. If all these paths contribute to the end result, then that agrees with the proposition that all particles within the IH's of *A* and *B* participate in the transmission, that they are part of its cause and effect.
Only if their communication with *A* and *B* is instant can the effects from all paths be summed, superposed, processed simultaneously into the actual photon transmission, the effects associated with the properties, motion and location of all particles within the IH's of *A* and *B*, particles which, as the transmission affects their own energy and momentum, participate in it, effects which then have to be weighed and processed in the end result –which only is possible if there is a continuous, instant exchange of energy, of information between all involved particles. As they are part of its cause-and-effect, the transmission is an event which simultaneously happens everywhere within the IH's of *A* and *B*: it's because time is observed to pass at a slower pace at larger distances which creates the illusion that such change propagates at a finite velocity through space, in time.
What Wheeler's thousand balls do is collect and distribute some of the energy and momentum involved in the transmission between all particles participating in it: to communicate and weigh all physically relevant information associated with the photon transmission, to process what classically would be cause into effect.

As every particle can consider itself to be the center of its own IH, its own universe, it contains, in its own properties, location and motion relative to all objects within its IH all relevant information about its environment, not of *the* universe as there is no such thing, but of the universe it observes. Like a hologram fragment contains information of the entire hologram; if its properties are cause and effect of its interactions then a particle contains, in its own properties, location and motion relative to all other particles within its IH all physically relevant information about them, about its universe, information which is refreshed in every cycle of its energy exchange with all particles within its interaction horizon.

[1] *Geons, Black Holes, and Quantum Foam* (1998) J.A. Wheeler p 167–168

Like the fragment gives a vaguer, fuzzier picture of the entire hologram as it is smaller; the information a particle represents, contains in its properties, location and motion about its universe is vaguer, less defined, detailed as its rest energy is lower, as its position is less definite and hence the world it observes from that, fuzzier location. The lower its rest energy, the less definite its position and motion are, the less defined, evolved its properties are, the less defined it observes their position and motion to be, the lower it observes the energy to be of the objects in its environment, the earlier the evolutionary phase it observes them, its universe to be in, the earlier the phase it is in itself. If a particle, like a hologram fragment, contains all information about its universe, including the presence of the observer so she and her measuring device are depicted in the fragment she examines, then she cannot but affect what she observes.

The theory of general relativity teaches that the inertia of a given body is greater as there are more ponderable masses in proximity to it; thus it seems very natural to reduce the total inertia of a body to interaction between it and the other bodies in the universe …
Albert Einstein [1]

5
Gravity and time

If according to general relativity (GR) the inertia, the mass of an object is cause and effect of its interactions with all other bodies in the universe so its mass is greater as there are more ponderable masses in proximity to it or, equivalently, if according to UP the energy, the mass of particles increases as the uncertainty in their position decreases –as they contract to clusters– and in a universe where particle properties are cause and effect of their interactions, mass cannot causally precede gravity, then instead of saying that particles contract to clusters because they have been endowed with mass at their creation and masses for some reason attract –that their mass is the cause of their gravitational attraction; in a SCU their energy, their mass only increases *if and when* they contract to clusters, to what eventually will evolve to stars and galaxies.
This they are bound to do as the gravitational field of their neighbors they sit in increases as they contract and with it the gravitational time dilation which tends to freeze in time a state in which they are nearer together above a state in which they are farther apart, i.e., a state of higher above a state of lower energy, a higher energy which, as it is a source of gravity, increases the mass they observe each other to have, the gravitational time dilation which tends to keep them at that, shorter distance.

The misleading thing about gravity, then, is that in driving the changes we experience as the passing of time –the contraction of particles to stars and galaxies– we have a sequence between events we misinterpret as proof that their mass is the cause of their contraction, as if mass can causally precede gravity and time always passes at the same particular, unperturbable pace, whether or not some-

[1] A. Einstein, *Geometry and Experience*. Lecture before the Prussian Academy of Sciences, Jan. 27, 1921

thing happens. In a SCU it is gravity, the tendency of energy to increase, to keep creating itself which drives (the changes we experience as the passing of) time.
This, however, seems to contradict the observation that a contracting particle cluster emits radiation, energy: as pulling masses apart takes energy, the mass of the cluster they contract to must be smaller than the sum of the masses of its particles when far apart. One consideration is that the contraction of particles isn't just the motion of particles toward each other through space, as if space already exist even when devoid of energy and is unaffected by whatever it contains.

As the speed of light is the same everywhere as measured locally, the gravitational time dilation doesn't only mean that a clock is observed to run at a slower pace, but also that a measuring rod near the clock looks shorter as the gravitational field at the clock and rod is stronger than it is at the observer.[1]
The gravitational field of a massive object, of a black hole, say, then is a region of 'condensed' spacetime as seen from outside the field, from a vantage point where its field is weak, a region which contains more spacetime as seen from within than as seen from outside the field –quote marks on condensed as it wrongly suggests that the mass of the hole causes an already existing volume of space to contract about the hole. Though the black hole does curve spacetime in its environment, a spacetime as it would exist even in the absence of the hole; as it is its own energy which makes positions at different distances physically different, as seen from outside the field, where it is weak, the field nearer to the hole is a more local, more private extension of spacetime, so to say, a spacetime which unfolds to a photon penetrating it and which, if *c* would be a velocity and we could observe the photon as it travels, would move increasingly slower as it nears the event horizon of the hole –though it remains to be seen whether a black hole in a SCU can have an event horizon and a gravitational singularity at its center.
If a gravitational field is a region of condensed spacetime as seen from outside of it and it is localized energy which makes positions at different distances physically different –the pace of clocks and length of rods– which turns an abstract space into a real, physical spacetime –where two points only can be observed to be at different distances if time is observed to pass at a slower pace at the more remote point– then the creation of energy *is* the creation, not of space in time but of spacetime. Energy, then, is stored in the extent to which the pace of clocks and length of rods is observed to differ at different distances from its mass center as seen from outside the gravitational field it is the source of.

If particles observe each other to have a higher energy, if they exchange energy at a higher frequency as their distance is smaller, less indefinite, and a higher energy corresponds to a stronger gravitational field they feel and produce, to a greater time dilation, then they'll tend to contract to clusters at places rather than move apart, a process whereby the indefiniteness in their position decreases and that in their momentum increases, meaning that the variation in its magnitude and direc-

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[1] If we define the meter as the distance light covers during 1/ 299,792,458 second and the second as the time it takes light to cover a distance of 299,792,458 meter, then the speed of light obviously is the same everywhere as measured locally.

tion increases as the particles confine each other to a smaller space and with it their kinetic energy and, as it is a source of gravity, their mass.
However, if according to the UP their energy increases as their position becomes less indefinite, as they contract to clusters and the creation of energy *is* the creation of spacetime, of distance between the contracting clusters, then the mass of the clusters may seem to decrease as they contract if we don't account for this spacetime creation.

Though as measured from inside of it, the gravitational field of a body increases the spacetime distance between its mass center, the point its energy can be thought to act from and the objects in its environment so its field decreases the expression of its own mass, the gravitational force it exerts on these objects; as seen from the opposite direction, from inside the field out, from its mass center, the same field, the same gravitational time dilation accelerates the pace at which clocks outside the field are observed to run, the frequency particles oscillate at, at which they exchange energy with the body, thereby enhancing their energy as seen from the mass center of the body, the mass of objects in its environment, as if to make up for the distance increasing, force-diluting effect the field has as seen from the other direction. As a result, objects can interact gravitationally, exchange energy over large distances even if they seem too far apart to be able to noticeably affect each other –so it's somewhat misleading to say that gravity is a very weak force.

Only if the rest energy of particles would be a privately owned quantity, only the cause of forces would mass causally precede gravity, the universe have an external reality, live in a time realm not of its own making and the constant of nature *c* be a velocity, though its creation then cannot be understood even in principle for if their properties then would be fixed, static quantities so they cannot gain anything by behaving in some particular manner, by moving apart or toward each other, say, then they wouldn't be able to interact, to exert and feel any force at all so it wouldn't even be properties and there would be no particles, no universe. Only if their properties are as much the cause as the effect of their interactions so their communication is instantaneous over any spacetime distance *and* energy tends to increase, to keep creating itself can particles interact, contract to stars, galaxies, evolve to elementary particles, to ever-higher energies. Clearly, if it is localized energy which makes positions at different distances physically different, which turns an abstract space into a real, physical space where the observed pace of time and length of rods is different at different distances –so the creation of energy *is* the creation of spacetime– then we can as well say that it is spacetime which tends to keep creating itself.

The trick for the universe, for energy to create itself, to keep existing, then, is to invent time, to stretch its existence over time so it simultaneously exists, manifests itself at different times and places, if it creates the environment to exist in and keeps creating itself –'simultaneously' meaning that the low energy a particle at one time, in an early phase of its evolution acquires remains part of the higher energy it may evolve to so remains active at later times.

If localized energy is the source of a gravitational field and the field is a region of 'condensed' spacetime, then what looks like empty spacetime must be more or less 'uncondensed,' so the creation of energy doesn't only involve the creation of a condensed spacetime in the form of gravitational fields, but also of a spacetime which is emptier, flatter farther from masses, so we cannot have a 'contraction' without an associated 'expansion' –not of space in time but of spacetime.

To summarize: if particles, particle properties in a SCU are as much the cause as the effect of their interactions, then this has some interesting consequences:

- the communication between particles and transmission of light then must be instant over any spacetime distance.
- as the universe only exists as seen from within so creates all time inside of it, time cannot be observed to pass at the same pace at all distances so past, present and future are relative notions, meaning that there is no universal 'now,' no cosmic time, no such thing as *the* past and *the* present.
- a particle then doesn't have an infinitely sharp, fundamental boundary separating it, its properties from its environment, cause from effect.
- if the energy of a particle, its rate of change in space and time varies within every cycle of its oscillation, then so does the indefiniteness in the position its energy curves spacetime, so a massive particle is a modulation *of* and *in* spacetime itself, a tiny region of spacetime which alternately curves and uncurves, becomes flat for a short time twice in every cycle, at a frequency proportional to its energy.
- if the energy of a particle is a dynamic, wavelike quantity, if its magnitude and sign varies in a wavelike manner within every cycle of its oscillation, then so should be the magnitude and sign of any kind of charge which contributes to and is an expression of its energy.[1]
- if the energy involved in one interaction, due to one kind of charge, one force, powers and is powered by all other interactions a particle at the same time is involved in due other kinds of charge, then what seem to be unrelated, qualitatively different kinds of charge are different expressions of a single quantity, of their energy: it only would be unrelated, static, qualitatively different, ununifiable quantities if their properties would only be the source and not, also the product of their interactions.
- if their properties are cause and effect of forces between them, then a force cannot be either attractive or repulsive, of itself. As a force between particles only can be as strong as the counter force it meets or can evoke, they only can achieve a stable equilibrium, evolve to elementary particles if they can adjust the effective magnitude of the different kinds of charge by adjusting their distance and motion.

If a force cannot be either attractive or repulsive, but particles nevertheless contract due to gravity, if gravity seems to be an exclusively attractive force, then that is because it is the expression of the tendency of energy to increase, to keep

[1] While this holds for the color charge in quantum chromodynamics; it is unclear why the electric charge of particles seems to be a static quantity, either positive or negative, always.

creating itself, a tendency which results from the gravitational time dilation of general relativity –according to which gravity shouldn't be thought of as a force.
However this may be, if the distance between two particles at equilibrium changes to a new equilibrium distance, then that is because the distance at which their attraction and repulsion due to different kinds of charge are equal changes when the system absorbs or emits energy and these opposite forces have a different distance dependence. If, as in classical mechanics, their properties would be privately owned and hence static, fixed quantities, only the cause of forces and any force would be either attractive or repulsive, of itself, so it only is the expression of their properties which varies with their distance and motion, then they would go sit and stay on top of each other once their attraction due to one kind of charge at some distance overcomes their repulsion due to another kind of charge.
By contrast, in quantum mechanics it is the uncertainty principle which forbids this as a zero indefiniteness in their position corresponds to an infinite energy: as it is the environment which has to supply that energy, here it is the environment which determines the distance at which they can be at equilibrium, the actual magnitude of the charges powering both their attraction and repulsion. If particles wouldn't be able to adjust the strength of the different forces between them, the effective magnitude of any kind of charge to circumstances *and* their communication would not be instantaneous, then they wouldn't be able to achieve a stable equilibrium, form stable matter so there would be no particles, no universe.

If the energy of a particle, its rate of change in space and time varies in a wavelike manner within every cycle of its oscillation and it is its energy which makes points at different distances from its mass center physically different, distinguishable –pace of clocks and length of rods– then the particle is itself a modulation of and in spacetime, its energy 'stored' in the extent to which spacetime is curved in the region where it can be localized, its curvature varying in tandem with its energy, greater in the phase in which its energy, its rate of change in space and time is higher, as its position is less indefinite so it acts more like a (point-) particle, to act more wavelike in the phase in which the curvature of spacetime is smaller, as its energy, its rate of change in space and time is lower, as the position its energy acts from is less definite, as it acts more simultaneously and more equally –and hence weaker– from all points within a larger region.

If in a SCU a particle has no infinitely sharp, fundamental boundary where it, its properties end and its environment begins, if it is its energy which makes positions at different distances physically different, distinguishable, then what looks like empty space cannot be devoid of energy. If its energy, its rate of change in space and time varies within every cycle of its energy exchange and with it the observed pace of time and length of rods in the region where the probability to find it is high, then it is as if the particle alternately moves in forward and backward time direction about some zero-time point –as indeed, particles keep creating and uncreating each other time and time again in every cycle of their energy exchange.
As its energy in one phase is as positive as it is negative in the next, it is as if the particle in one phase tries to undo the effects of its existence in the previous phase

6
Time dilation

It takes much more energy to increase the distance between a nail and a magnet from 1 to 2 millimeter than to increase it from 1 to 2 meter, so if we were to define their distance in terms of the energy involved in a change of their distance –if we were to define the unit length as the displacement which takes 1 joule of energy, say– then we'd conclude that there is increasingly more space 'condensed' within what to us looks like a small distance, in a smaller volume nearer to the magnet – smaller according to a ruler the length of which isn't affected by the magnet.

Likewise, if according to the inverse-square law it takes more energy to increase the distance between two masses when they are nearer to each other than the same displacement when farther apart, then a gravitational field is a region of 'condensed' spacetime. Now if we could see, from outside the gravitational field of a black hole, from a vantage post at rest relative to the hole, where its field is weak, a flashing light moving toward the hole, then the nearer to its event horizon it is, the stronger the field is at the flashlight than it is at us, the slower we see the light move and flash and the more redshifted its light looks, then the gravitational time dilation can be thought of as a spacetime-distance redshift.

If so, then a clock should be observed to run at a slower pace as it is more distant even when at rest relative to the observer and even in the absence of gravitational fields: that two points only can be observed to be at different distances if time is observed to run at a (slightly) slower pace at the more remote point.

If so, if the gravitational time dilation can be thought of as a distance redshift, then galaxies look shifted farther to red as they are more distant even if at rest relative to the observer though if energy keeps creating itself and with it spacetime, then there may be an additional velocity redshift[1] associated –not with the expansion of space in time– but with the creation of spacetime.

It was formerly believed that if all material things disappeared out of the universe, time and space would be left. According to relativity theory, however, time and space disappear together with the things. Albert Einstein [2]

7
Mach's principle

As going back in time in a big bang universe space contracts but its energy content remains the same, all energy must have been concentrated within an infinitesimal volume at the big bang so energy and space in BBC are thought of as unrelated quantities, meaning that energy exists, is defined even in the absence of space so space exists, is defined even when devoid of energy.[3] As this contradicts Einstein's own statement that space and time would disappear along with matter, with

[1] A Hubble constant of 70 km/s/Mpc corresponds to an expansion of about 2 millimeter per 1,000 kilometer per million years.

[2] https://en.wikipedia.org/w/index.php?title=Hole_argument&oldid=520160850 (1921)

[3] If its energy content is finite, then who or what determined the amount to be created (and relative to what it is measured ?), whereas if it is infinite, it cannot have been created within a finite time.

energy, it is curious that he didn't reject the big bang hypothesis, for if energy and space indeed would be independent quantities, then energy wouldn't be able to curve nor expand space as energy only can act upon energy.
By contrast, going back in time in a SCU an observer would see the energy of stars and galaxies and hence of particles decrease as the stars and galaxies de-contract, the position of their mass centers become less and less definite so all positions in space would become more identical to the particles as their energy decreases, the observed pace of time to become more equal everywhere until all energy vanishes and with it space and time.

Though Einstein was inspired to his theory of general relativity by what he came to call Mach's principle –the proposition that the inertia of a body is something it has relative to all other masses in the universe,

> The theory of general relativity teaches that the inertia of a given body is greater as there are more ponderable masses in proximity to it; thus it seems very natural to reduce the total inertia of a body to interaction between it and the other bodies in the universe, as indeed, ever since Newton's time, gravity has been completely reduced to interaction between bodies. From the equations of the general theory of relativity it can be deduced that this total reduction of inertia to interaction between masses -as demanded by E. Mach, for example- is possible only if the universe is spatially finite.[1]

on closer examination

> …the general theory of relativity does not fully entail Mach's principle as conceived by Einstein in the sense that the energy tensor unequivocally and completely determines the metric of spacetime. It could be shown that a particle in an otherwise empty universe can possess inertia… Einstein's confidence in the principle gradually waned, so much so that eventually, a year before his death, he declared that "one should no longer speak at all of Mach's principle." [2]
> The observed fact that a gravitational force is *locally* indistinguishable from an inertial force, in that each induces the same acceleration in all bodies, suggested to Einstein that it is the gravitational influence of the whole universe which gives rise to inertia. General relativity was devised to incorporate this idea, but, as emphasized by Einstein, it failed to do so. Einstein showed that his field equations implied that a test-particle in an otherwise empty universe has inertial properties.[3]

Clearly, if the universe would contain only a single particle, then all points in space would be physically identical, indistinguishable to the particle –which is the same as there being no space at all and, as nothing then can change, there also would exist no time. The idea of an otherwise empty universe presupposes that space exists, is defined even when devoid of energy –if we may ignore the energy of the particle itself, which we can, for if there is nothing relative to which it can be said to exist, nothing it can interact with to express its properties, its existence, then it obviously cannot have energy, exist itself. That we even consider the existence of a single particle in an otherwise empty universe shows how deeply ingrained the classical assumption is that particles have an autonomous existence, that their

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[1] A. Einstein, *Geometry and Experience*. Lecture before the Prussian Academy of Sciences, Jan. 27, 1921
[2] *Concepts of Mass in Contemporary Physics and Philosophy* (2002) Max Jammer p. 150.
[3] *On the origin of inertia* (1953) D.W. Sciama 1953MNRAS. 113…34S

properties only are the cause and not, also, the effect of forces, implying that the universe has been caused into existence by some outside intervention. This begs the question whether, despite the many tests of general relativity, there is something wrong with his field equations, or with his own causal interpretation thereof as we only accuse energy of causing space to curve or expand if (Minkowski) space already exists even when devoid of energy, which it doesn't as energy only can act upon energy –and if it nevertheless would exist, would constitute the background he wanted to get rid of.

The Stanford Encyclopedia of Philosophy: [1]

> Imagine we are far out in space, in a rocket ship accelerating at a constant rate *g* = 9.98 m/s². Things will feel just like they do on the surface of the Earth; we will feel a clear up–down direction, bodies will fall to the floor when released, etc. … There is one key element left out of this success story, however, and it is crucial to understanding why most physicists reject Einstein's claim to have eliminated absolute states of motion in GRT. Going back to our accelerating rocket, we accepted Einstein's claim that we could regard the ship as hovering at rest in a universe-filling gravitational field. But one can see why the Machian interpretation Einstein hoped he could give to the curved spacetimes of his theory fails to be plausible, by considering a few simple 'worlds' permitted by GRT. In the first place, for our hovering rocket ship, if we are to attribute the gravity field it feels to matter, there has got to be all this other matter in the universe. But if we regard the rocket as a mere 'test body' (not itself substantially affecting the gravity present or absent in the universe), then we can note that according to GRT, if we remove all the stars, galaxies, planets etc. from the world, the gravitational field does not disappear. On the contrary, it stays basically the same locally, and globally it takes the form of empty Minkowski spacetime, precisely the quasi-absolute structure Einstein was hoping to eliminate. … physicists do not doubt that something like our accelerating rocket –in otherwise empty space– is possible according to the theory. We see clearly, then, that GRT fails to satisfy Einstein's own understanding of Mach's Principle, according to which, in the absence of matter, space itself should not be able to exist. A second example: GRT allows us to model a single rotating object in an otherwise empty universe (e.g., a neutron star). Relationalism of the Machian variety says that such rotation is impossible, since it can only be understood as rotation relative to some sort of absolute space. In the case of GRT, this is basically right: the rotation is best understood as rotation relative to a 'background' space-time that is identical to the Minkowski spacetime of SRT, only 'curved' by the presence of matter in the region of the star.

If the inertia of a given body is greater as there are more ponderable masses in proximity to it and its inertia equals its mass, then there should be mass created as particles contract to stars and galaxies, agreeing with the UP according to which the energy (and, as it is a source of gravity), the mass of particles is greater as their position (relative to each other) is less uncertain, as they contract to clusters.
Though the sum of the masses of the particles of a cluster when far apart is greater than the mass of the cluster they contract to; this energy creation may be masked by the fact that, as discussed in § 5, the creation of energy is the creation of space-

[1] Absolute and Relational Theories of Space and Motion (2018) Nick Huggett, Carl Hoefer § 9.3 – 9.4

time, of distance between the mass centers of neighboring particle clusters as measured inside their gravitational fields.

As the mass of particles in CM, in BBC only is the cause of interactions, it is unclear why the gravitational mass of a body equals is inertial mass. Wolfgang Rindler:

> Albert Einstein developed his general theory of relativity starting from the assumption that this correspondence between inertial and (passive) gravitational mass is not accidental: that no experiment will ever detect a difference between them. However, in the resulting theory, gravitation is not a force and thus not subject to Newton's third law, so the equality of inertial and active gravitational mass ... remains as puzzling as ever. In general relativity two of Einstein's concerns merged: gravity as an aspect of inertia, and the elimination of the absolute (that is, uninfluenceable) set of extended inertial frames. The new inertial standard is spacetime, and this is directly influenced by active gravitational mass via the field equations. Yet in the total absence of mass and other disturbances like gravitational waves, spacetime would straighten itself out into the old family of extended inertial frames. This would seem to contradict Mach's idea that *all* inertia is caused by cosmic masses. Einstein was eventually equally quite willing to drop that idea, and so shall we. The equality of inertial and *active* gravitational mass then remains as puzzling as ever. It would be nice if the inertial mass of an accelerating particle were simply a back-reaction to its own gravitational field, but that is not the case.[1]

In the total absence of energy, there would be no space nor time, no Minkowski space, no uninfluenceable inertial frames. If particles have to keep exchanging energy to express and preserve their, each other's properties, then their inertia, their opposition to a change of their state of motion originates in the fact that it takes energy to change their velocity and direction of motion, the frequency they exchange energy at, the energy they exhibit in different directions. If the inertia, like the mass of a particle originates in all interactions it simultaneously is involved in, to which it owes its energy, then its inertia obviously equals its mass. Only if their energy would only be the cause and not also the effect of their interactions would the equality of mass and inertia be a mystery.

Though the proposition that the inertia of a body is something it has relative to all other masses in the universe was the first inkling of the insight that particles, particle properties must be cause and effect of their interactions; if Mach didn't express this explicitly, then that may have been because it seems to imply, to require their communication to be instantaneous (action at a distance) –which is impossible in a universe where time passes at the same pace everywhere. This is different in a universe where, as it contains, creates all time inside of it, time cannot be observed to pass at the same pace at all distances, where we don't see a distant galaxy as it was, of itself, in a distant past, in *the* past, but as it is, to us, when we look at it, in what only to us is the present.

[1] *Relativity: Special, General and Cosmological* (2001),Wolfgang Rindler 2nd edition p 22

A physical entity does not do what it does because it is what it is, but is what it is because it does what it does. –Max Jammer[1]

8
The origin of particle species

In a universe which contains only two particles *A* and *B*, the wavelength they exchange energy in might vary continuously with their distance if not for the fact that to be able to exert force upon each other, to express their energy, to *have* energy, requires, according to Newton's 3rd law, the existence of particles in opposite directions to oppose any force between *A* and *B*, particles which to exist, to have energy themselves, to be able to provide this service, in turn require the existence of other particles at larger distances *and* their communication to be instant. As they only can exchange energy at equilibrium when in counterphase – which they are at distances equal to 1/2, 3/2, 5/2 … times the wavelength they exchange energy in– their distance is quantified and with it the energy they emit or absorb as they jump between different equilibrium states, a jump whereby their distance and the wavelength they exchange energy in changes with a discrete amount.

The problem of particle properties as privately owned and hence fixed quantities, as being only the cause of forces, is that they cannot then gain anything by behaving in some particular manner, by moving apart or toward each other, say, so they wouldn't be able to interact and it wouldn't even be properties, whereas if when their properties would be cause and effect of their interactions and vary continuously with their distance, with the conditions they find themselves in then it also wouldn't be properties and there also would exist no particles, no universe.

It is gravity, the tendency of energy to increase, to keep creating itself which determines the direction of processes, of events,[2] which drives the contraction of particles: because (UP) their energy increases as the uncertainty in their relative position decreases as they contract to clusters or, equivalently, because (GR) the inertia of a body is greater as there are more ponderable masses in proximity to it or because the gravitational time dilation favors processes whereby their energy increases above opposite processes– combined with the fact that their distance and energy is quantized and their communication is instant over any spacetime distance which enables them to interact yet preserve their properties as they can adjust their distance and relative motion to adjust the effective magnitude of the different kinds of charge so the strength of the opposite forces they power can vary with their energy, with their distance and motion yet remain equally strong, be at equilibrium at different –quantized– energies and form stable matter.

As particles in a BBU popped up readymade, all properties measured off to the last decimal at the big bang, their properties causally precede, predetermine the properties of and processes in the stars and galaxies they eventually contract to – which then don't evolve but develop following a strictly prescribed plan, implying

[1] *The Philosophy of Quantum Mechanics* (1974) Max Jammer p. 54
[2] In general, not necessarily of every individual event.

that all events ever to happen have been predetermined to happen to the last detail and decimal at the big bang, implying an improbable fine-tuning of particle properties and physical constants to create a viable universe, as if it has been caused into existence by some outside intervention –unless we assume that there are many different universes and ours accidentally has those properties which enable the evolution of observers able to wonder about its existence. The problem is that the slightest inaccuracy in the magnitude of some charge or constant of nature eventually would let processes get out of hand and put an end to the universe, that it is hard to see how coupling constants and constants of nature could adopt the right values even before these processes started, as if there has been a calculation preceding the big bang.

The advantage of an evolution whereby elementary particles, the building bricks of the universe acquire properties, are shaped and baked in the building process, as they contract to stars and galaxies, as the edifices take form (including space-time, the building plot), is that it enables a feedback whereby particles as they contract to what eventually will evolve to stars and galaxies, by adjusting their distance and motion relative to each other can adjust their properties, evolve to elementary particles and with it adjust the processes in stars and galaxies to the circumstances they find themselves in (and create) in a trial and error process –what survives … survives– so can form stable galaxies, a feedback which requires the communication between objects in all phases of their evolution to be instant over any spacetime distance –and the universe fine-tunes itself in a natural way.

If the different particle species are the result of an evolution which starts as soon they cross the threshold between a zero and an infinitesimal, nonzero energy, as soon they start to interact, to contract to clusters, to what eventually will become stars and galaxies and the energy they observe each other to have, the frequency they exchange energy at depends on their distance and relative motion and any degree of freedom, any independent way they can move relative to each other in some more or less stable configuration of evolving particles affects the energy of the configuration in some specific manner, then every degree of freedom, any independent motion can be associated with some conserved quantity, with a different property or kind of charge, a configuration of particles which, as their evolution proceeds, as the conditions (temperature, pressure) they find themselves in (and create) become favorable to the formation of configurations which increasingly resemble (what turns out to be) the behavior of subatomic particles in protons and neutrons, in atomic nuclei, in star plasma –the number of degrees of freedom also depending on the number of particles of the configuration and, in atomic nuclei in stars, of adjacent configurations.

If a massive particle is a modulation of and in spacetime, if its energy, its rate of change in space and time varies within every cycle of its oscillation and with it the indefiniteness in its position, then its properties are less definite, less defined, less evolved in the phase its energy is lower, as its position and motion is less definite. The farther apart two particles are or the lower their energy is in some configuration, the less definite they observe each other's position and motion to be, the less definite, the less evolved they observe each other's properties to be, the less definite or the fuzzier the configuration is they are part of, the less definite or fuzzier their positions and trajectories[1] are, the more they can be thought of as being part of different configurations simultaneously or the more the different configurations coincide, overlap, the less they differ energetically, the less defined their properties are in such configurations, the weaker they interact, the less forcefully they limit each other's freedom of behavior, the less they impose each other some specific behavior, the less related their behavior is, the properties they observe each other to have. The shorter, the less indefinite their distance is, the shorter, the less indefinite the wavelength they exchange energy in, the less indefinite their relative position and motion is, the higher the energy they observe each other to have, the less indefinite they observe each other's properties to be, the greater the force associated with some kind of charge is, the magnitude of any kind of charge they observe each other to have. The more particles contract within a smaller space, the more they have to coordinate their behavior to fit within that smaller volume, the more they limit each other's freedom of motion, the more forcefully they confine each other to less indefinite distances and trajectories it takes more energy to deviate from, the greater their opposition is to a change of their behavior, of the associated properties, the less indefinite, the more evolved the properties they observe, cause each other to have.

The lower the rest energy of a particle is, the less definite its position is, the weaker it interacts, the less definite it observes the position to be of the mass center of other particles, of stars and galaxies, the longer, the less definite the wavelength it exchanges energy with them, the lower the energy it observes them to have, the less defined, evolved it observes their properties to be, the earlier the evolutionary phase it observes them –its universe– to be in, the earlier the phase it is in itself. If it matters energetically to a particle, if it can distinguish whether another particle nears or recedes from it, moves up or down or from the left to the right or the other way around through its 'sky' –the background of all objects within its IH– moving or spinning in this or that direction and each of the different, independent ways they can move relative to each other affects the frequency they in some configuration exchange energy at in some specific manner can be associated with some particular property or kind of charge, then the different forces of nature will have a different distance and motion dependence, as if powered by qualitatively different, unrelated kinds of charge.
However, if when particle properties are cause and effect of their interactions, the energy involved in one interaction, associated with one kind of charge powers and is powered by all other interactions a particle is simultaneously involved in, then the different kinds of charge are related. If the different forces, charges arise from the different, independent ways particles can move relative to each other within some configuration, each of which affects their exchange frequency in a specific

[1] Though in quantum mechanics one only can speak about the probability to find a particle somewhere, not of its trajectory; if the evolution of its wave function determines how the probability to find it at some particular place and time changes in time, then we can call the collection of its most probable successive position its trajectory even if it doesn't actually visits those positions.

manner and all interactions each of the particles participates in contributes to their energy within that configuration, to the energy of the configuration, of an atomic nucleus in a star, say, then the different forces, powered by what seem to be qualitatively different, unrelated kinds of charge are balanced, 'unified,' in the behavior of the subatomic particles within that configuration, in the star.

Though an equilibrium between particles in some configuration is a balance between opposite forces powered by different kinds of charge; if their charge would be fixed quantities, only the cause of forces, then any equilibrium would be unstable since as soon as their attraction due to one charge at some distance overcomes their repulsion due to another charge, they would go sit and stay on top of each other –in which case the uncertainty in their position would become zero, their energy infinite. However, as this energy has to be supplied by all particles within their IH, we can as well say that it is the environment which prevents them to stay on top of each other, which determines the distance and motion they can be at equilibrium, their energy, the effective magnitude of any charge in that configuration, of forces between them.

The advantage of a trial and error evolution is that no calculation is needed as to what particle species and properties, what laws and constants of nature might result in a viable universe: it is gravity, the tendency of energy to increase, to keep creating itself which, by prolonging in time the appearance of more compact, higher energy above less compact, lower-energy configurations determines which from all possible, temporary random particle configurations survives, which selects the properties of the different particles within these configuration, what particle species, properties and associated constants of nature will survive, which creates the conditions, the temperature and pressure they can evolve in.
A SCU is itself a kind of calculator the components of which take form, which materializes as the trial and error calculation/evolution proceeds, a calculation where particles at all distances, which observe each other to be in all possible phases of their evolution, as part of stars and galaxies participate in, an evolution which cannot but obey the Nix law which defines the universe as a perpetuum mobile, yielding as much as its costs: nothing –which is to say, a universe which has no external reality but only exists as seen from within.

If particles keep creating and uncreating each other, repeating in some sense their evolution to elementary particles in every cycle of their energy exchange with particles at all distances, particles they observe to be in an earlier phase of their evolution, to have less defined properties as they are more distant, then an instant exchange of energy, of information may constitute a feedback from stars and galaxies to instruct particles what behavior, what properties to adopt to eventually evolve to elementary particles and become part of stars and galaxies themselves, then stars, galaxies create themselves the particles, the building blocks they are going to consist of. As the evolution of particles to elementary particles, atoms and molecules, to life, to humans takes a long time, we cannot observe nearby galaxies in an early phase of their evolution.

It is gravity which, in imposing a direction on events, acts like the ratchet which in a clock prevents its hands to turn counterclockwise, which prevents processes to reverse, which enables particles to acquire properties, to evolve, gradually and sometimes in fits and starts to ever-higher energies, to eventually end up in black holes at the center of galaxies, a change we experience as the passing of time.

9

The energy of space

As according to the uncertainty principle a field cannot be *and* remain zero, space is supposed to contain energy in the form of matter and force fields the quanta (virtual particle-antiparticle pairs) of which continually pop up out of the vacuum to annihilate after a time which is shorter as their energy is higher, meaning that 'over sufficiently small distances and sufficiently brief intervals of time, the very geometry of spacetime fluctuates.[1] The problem, now, is that space is calculated to have a vacuum energy density which is some 120 orders of magnitude greater than would agree with observations.

As the gravitational effects this energy should have aren't observed, some physicists have started to doubt quantum mechanics itself.[2] Gerard 't Hooft, about his fellow Nobelist, Martinus Veltman:

> Veltman was not to be convinced that what we call empty space perhaps is filled to the brim with invisible particles. He would persist for a long time that he thought this incredible. … For shouldn't all these particles in empty space betray their presence by their gravitational field? You can establish a theory in such a manner that this gravitational field exactly is compensated by other invisible particles or by a mysterious contribution of empty space itself. How nature manages to mask the gravitational effects of invisible vacuum particles so completely that we don't notice any effect, is a mystery.[3] The most radical view ... is that space and time only exist as a separate set of points; [that] particles can only be at those points but not in between. … this would be the most logical interpretation, for 'quantum fluctuations' would ensure that all points where particles can be automatically stay at least one Planck length apart. But it isn't that easy, for how do we then explain how these points are related to form the known space and time? [4]

If the universe cannot have particular properties nor be in any particular state as a whole, then we cannot think of space as if it comes with a regular 3-dimensional grid with Planck-length sized meshes (the vertices of which can be occupied by particles) as space then would exist even when devoid of energy, the length of the meter be defined even outside the universe. Clearly, if when the energy of particles varies in a wavelike manner in every cycle of their oscillation and with it the indefiniteness in their position, their distance, if a particle is a modulation in

[1] https://en.wikipedia.org/wiki/Quantum_foam (18-8-22)

[2] Lee Smolin in *The Trouble with Physics* (2006) p. 319: "Like 't Hooft, much of his [Roger Penrose] work in the last two decades is motivated by his conviction that quantum mechanics is wrong." Also see: https://spookyactionbook.com/2013/10/07/does-some-deeper-level-of-physics-underlie-quantum-mechanics-an-interview-with-nobelist-gerard-t-hooft/

[3] *De bouwstenen van de schepping* (1st ed. 1992) Gerard 't Hooft, p 197. This quote does *not* appear in the 6th ed. 2002) (*In search of the ultimate building blocks*)

[4] *De bouwstenen van de schepping* (6th ed. 2002) Gerard 't Hooft, p. 106

and of spacetime itself, then we cannot, as in the above quote –or, as in quantum loop gravity where space and time are granular, discrete– think of space as if it comes in minimum building blocks, of time as passing in discrete, minimum amounts. The problem with the idea that time passes in discrete amounts, in jumps, is that it presupposes the existence of a clock relative to which can be quantified how much time passes per jump and the duration of the pauses between successive jumps during which time is supposed to stand still, a clock the dial marks of which are separated by even shorter time intervals. Likewise, to measure the size of a minimum block of space requires the existence of a ruler the marks of which are separated by even shorter distances, not to mention that space, the length of the meter then would be defined even outside the universe.

If particles in a SCU only can be at equilibrium at distances equal to 1/2, 3/2 … times the wavelength they exchange energy in, then it isn't so much space which is discrete, but the distance between particles which is quantified. Moreover, if the energy of particles varies within every cycle and with it the indefiniteness in their position, then so does the discreteness in their distance. The farther apart they are or the longer the wavelength they exchange energy in, the less energy is involved in a jump between successive equilibrium distances, the less it matters energetically how large their distance exactly is, the less definite, the less discrete their distance is; the shorter their distance is or the shorter the wavelength they exchange energy in, the more energy is involved in the jump, the smaller, the less indefinite, the more discrete –and the shorter– the length of a jump to the next equilibrium distance is.

Though

> … the whole of spacetime is occupied by the fields of the elementary particles. Even in the absence of matter, the fields of the *virtual* particles constitutes an all-pervasive background which can in no way be eliminated. In fact, matter is only a small perturbation of it. This background … can be looked upon as a modern ether. Since it possesses no net energy it makes no contribution to curvature ... but it does suggest the *a priori* existence of spacetime, which matter merely modifies and does not create.[1]

if the universe cannot have any particular property, be in any particular state as a whole, then we cannot think of space as uniformly filled with virtual particles, with a vacuum energy density (and Higgs field) which is the same everywhere, always.

> The density of this energy depends critically on where the frequency of the zero-point fluctuations cease. Since space itself is thought to break up into a kind of quantum foam at a tiny distance scale called the Planck length (10^{-35} *m*), it is argued that the zero-point fluctuations must cease at the corresponding Planck frequency. If that is the case, then the zero-point energy density would be 108 orders of magnitude greater than the radiant energy at the center of the Sun. … This energy is so enormous that most physicists believe that even though zero-point energy seems to be an inescapable consequence of quantum field theory, it cannot be physically real, and so is subtracted away in calculations by ad hoc means.[2]

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[1] *Relativity: Special, General and Cosmological* (2001),Wolfgang Rindler 2nd edition p 244.

[2] E. W. Davis c. s., http://www.calphysics.org/articles/Davis_STAIF06.pdf P 1, 2, 5

However, if the energy of particles is higher as their position is less indefinite –and we must specify relative to what we measure it– then the vacuum energy density somewhere should, like the price of real estate, depend on where they pop up, be lower where their position is less definite –which it is in empty space, far from masses and be higher near masses– in which case the vacuum energy density is much lower than calculations suggests.

If real particles can be thought of as virtual particles which managed to set up a continuous energy exchange by means of which they force each other to reappear again and again after every disappearance and their energy, its rate of change in space and time varies within every cycle and with it the indefiniteness in their position, then the virtual particles of empty space can be thought of as the volatile interference products of the real particles of stars and galaxies, constituting their gravitational field. If so, then the effects of the presence of the virtual particles of the vacuum already is accounted for in the existence of all particles to the energy of which they contribute and to which they owe their energy, including the real particles of stars and galaxies. Instead of, once ordered to keep popping up by the UP, assume that their energy only is the cause of the events we want them to explain and think of the vacuum energy density as an intrinsic property of space, the same everywhere, always, we ought to ask to what they owe their energy and to the energy of what they contribute, relative to what they exist, have, express their energy. It is our addiction to causality why we invented a concept like the 'energy density of the universe' –which defines energy and space as unrelated quantities, meaning that space exists even when devoid of energy so we can accuse energy of causing space to curve and expand –which it cannot if space is devoid of energy and energy only can act upon energy.

Julian Barbour [1]

> Density is defined as an amount of mass divided by the volume it occupies. That's unproblematic in a laboratory with scales to weigh the mass and rulers to measure the volume. But in extrapolation to the universe, where are the scales and rod?
> In his *Autobiographical Notes* … Einstein acknowledged that the conceptual structure of general relativity contained a flaw. Besides the notion of four-dimensional space-time, it introduced measurement rods and clocks as independent elements. Einstein commented: "This, in a certain sense, is inconsistent; strictly speaking measuring rods and clocks should be represented as solutions of the basic equations (objects consisting of moving atomic configurations), not, as it were, as theoretically self-sufficient entities." He argued that, in the absence of a theory of measuring rods and clocks, his procedure was a justifiable stopgap that allowed physical interpretation of the theory, but the defect, which he called a sin, should be eliminated "at a later stage of the theory." …
> His dream, from the early 1920s to his death in 1955, was a theory in which there is no matter at all, just curved geometry that evolves in a way which gives it the appearance of the matter we find around us. He never found that theory.

It seems that in introducing clocks and measuring rods –the use of the constant *c* in the equations of GR connects the duration of the second to the length of the

[1] *The Janus point* (2020) Julian Barbour p. 247 and 249

meter– he introduced Minkowski space –which then is subsequently warped by localized by energy, as if space exists even in the absence of energy.
As in a SCU there is no fundamental boundary between a particle, its properties and its environment, it is itself a modulation of spacetime, 'just curved spacetime.'

If when the energy of particles, real and virtual, is proportional to its rate of change in space and time so varies, then so does the (in)definiteness in their position: the lower their energy is, its rate of change in space and time in one phase, the less definite the position and hence their motion is, the behavior from which their properties can be inferred, the less defined, evolved their properties are in that phase, then particles in some sense repeat their evolution to elementary particles in every cycle of their oscillation. The virtual particles of empty space then can be thought of as the offspring *and* predecessors of the real particles of stars and galaxies, particles which in appropriate circumstances may evolve to elementary particles, to the particles of stars and galaxies –in which case galaxies create themselves the particles, the building blocks they are going to consist of.

If particles are modulations in and of spacetime, regions where the curvature of spacetime –the observed pace of time and length of rods– varies within every cycle of their oscillation, then it is their continuous creation and 'uncreation' which produces, maintains what we observe as spacetime.

Carlo Rovelli:

> In Newtonian physics, if we take away the dynamical entities [particles, fields] what remains is space and time. In relativistic physics, if we take away the dynamical entities, nothing remains. The space and time of Newton and Minkowski are reinterpreted as a configuration of one of the fields, the gravitational field. … The world is made by fields. Physically, these do not live on spacetime. They live, so to say, on one another. Not anymore fields on spacetime, just fields on fields. … In prerelativistic physics, spacetime is a fixed nondynamical entity over which physics happens. It is a sort of structured container which is the home of the world. In relativistic physics, there is nothing of the sort. There are only interacting fields and particles: the only notion of localization which is present in the theory is relative: dynamical objects can be localized only with respect to one another. …
> Einstein's discovery is that Newtonian spacetime and the gravitational field, are the same entity. This can be expressed in two equivalent manners. One is that there is no space-time: there only is the gravitational field. The second is that there is no gravitational field: it is spacetime that has dynamical properties. [1] …
> One consequence is that the quanta of the field cannot live in spacetime: they must build "spacetime" themselves.[2]

To arrive at a theory of quantum gravity we have to stop confusing causality with reason in quantum mechanics and general relativity and acknowledge that gravity is the expression of the tendency of energy to increase, to keep creating itself and with it spacetime, driving the changes we experience as the passing of time. While the law which says that energy cannot be created nor destroyed applies to the definition of kinetic energy as positive and the potential gravitational energy as

[1] *Quantum Gravity* (Dec. 30, 2003) Carlo Rovelli p. 53 – 55 http://www.cpt.univ–mrs.fr/~rovelli/book.pdf
[2] Ibid, p. 7

negative; to avoid violating any conservation law, the energy of particles in a SCU must be a wavelike quantity, as positive in one phase as it is negative in the next.

It was Werner Heisenberg who first realized the need to free ourselves from the belief that, say, an electron has a well determined position at every time. When it is not interacting with an external system that can detect its position, the electron can be "spread out" over different positions. … [he] first recognized that the electron does not have a well-defined position when it is not interacting.[1]

10
Why quantum mechanics works

In the basic version of the **double-slit experiment** [2]

> … a coherent light source, such as a laser beam, illuminates a plate pierced by two parallel slits, and the light passing through the slits is observed on a screen behind the plate. The wave nature of light causes the light waves passing through the two slits to interfere, producing bright and dark bands on the screen –a result that would not be expected if light consisted of classical particles. However, the light is always found to be absorbed at the screen at discrete points, as individual particles (not waves), the interference pattern appearing via the varying density of these particle hits on the screen. … The particles do not arrive at the screen in a predictable order, so knowing where all the previous particles appeared on the screen and in what order tells nothing about where a future particle will be detected. If there is a cancellation of waves at some point, that does not mean that a particle disappears; it will appear somewhere else. Ever since the origination of quantum mechanics, some theorists have searched for ways to incorporate additional determinants or "hidden variables" that, were they … known, would account for the location of each individual impact with the target.
> … electrons are found to exhibit the same behavior when fired towards a double slit.

If we find a similar interference pattern if we shoot electrons one at a time, then that must mean that each electron goes through both slits, so the experiment shows that an electron has no infinitely sharp, fundamental boundary where it, its properties end and spacetime begins –as would be the case in classic mechanics, in a universe where it has an autonomous existence, where its properties only are the cause of interactions (so space would exist, be defined even when devoid of energy) –and the observed interference pattern would be impossible.
As its energy, its rate of change in space and time varies within every cycle of its oscillation, so does the indefiniteness in its position, so if this indefiniteness twice in every cycle exceeds the distance between the slits, then it goes through both slits and interferes with itself from both splits. As it has to keep interacting with all particles within its IH to keep existing, from the point of view of the electron its environment splits into two slightly different worlds as it nears the slits, worlds which from both splits and both sides of the plate interact with the electron.

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[1] https://plato.stanford.edu/entries/qm–relational/ (7–10–2019)
[2] https://en.wikipedia.org/wiki/Double–slit_experiment (2–10–2019)

It acts more like a wave phenomenon at the times in its cycle when its energy, its rate of change in space and time is lower, as its position less definite so acts weaker, more simultaneously and more equally from all points within a larger region, which twice in every cycle comprises both slits and both sides of the plate.

Schrödinger's cat is a thought experiment which asks when a quantum system stops existing as a superposition of states and become one or the other.

> The principle of quantum superposition states that if a physical system may be in one of many configurations—arrangements of particles or fields—then the most general state is a combination of all of these possibilities, where the amount in each configuration is specified by a complex number. … Paul Dirac:
> The general principle of superposition of quantum mechanics applies to the states ... of any one dynamical system. It requires us to assume that between these states there exist peculiar relationships such that whenever the system is definitely in one state we can consider it as being partly in each of two or more other states. The original state must be regarded as the result of a kind of superposition of the two or more new states … Any state may be considered as the result of a superposition of two or more other states, and indeed in an infinite number of ways. Conversely, any two or more states may be superposed to give a new state... The … Copenhagen interpretation, says that a quantum system remains in superposition until it interacts with, or is observed by the external world. When this happens, the superposition collapses into one or another of the possible definite states. [1]

Though an electron has no well-defined position relative to the observer until she interacts with it by measuring its position; if it has to keep interacting with the particles within its IH to keep existing, then we cannot say that it doesn't interact, that it has no well-defined position relative to these particles. It is because it acts more simultaneously from all positions in a larger region in the phase in which the rate of change of its energy in space and time is lower why we can say that it is at different places at the same time. As it preserves its existence by exchanging energy with all particles within its IH so participates in all interactions they are involved in, it is in some sense present everywhere it affects things.

Its wave function describes the extent to which it is at different places, an extent which is different at different places and times, which varies in space and time in every cycle because its properties are cause and effect of its interactions with all particles within its IH –which then affect the probability to find it in different places at different times, so it isn't so that it has no well-defined position until we measure it. It only assumes a well-defined position relative to our measurement device -the external system- when subjected to a measurement interaction.
If it actually could be at two places at once, then so would its mass:

> According to the standard model, the electron … can be in two places at once because it is described by a wave function. And according to general relativity, the mass of the electron curves space-time around it. But around which location?
> General relativity cannot answer this question, since a curvature doesn't have quantum properties and can't be in two places at once. … after a measurement of

[1] https://en.wikipedia.org/wiki/Quantum_superposition (23-8-2022)

> its position, the wave function must be updated so that the measured state now has a probability of 1. This update -sometimes referred to as “collapse” or “reduction”- is instantaneous; it happens at the same moment for the entire wave function, regardless of how far the wave function was spread out. [1]

If it could be at two places at once with all of its energy and electric charge, say, then this would violate conservation laws so if this is impossible, then it cannot actually be at, act from two places at once with all of its energy and charge.
If its energy, its rate of change in space and time varies within every cycle and its wave function gives the extent to which it is present at different places at different times, then it also gives the extent to which its mass is present at those places and times, a mass which is smaller at the times in its cycle when its position is less definite and greater in the phase in which the its position is less indefinite. If its energy, its rate of change in space and time varies in every cycle, then so does the curvature in the region where it can be localized, where the probability to find it as a (point-) particle is large: as it is a modulation of and in spacetime itself, the curvature of spacetime where it can be localized as given by the wave function should follow the rate of change of its energy in space and time.
However, if its properties are cause and effect of its interactions, then we can as well say that a particle is present everywhere it affects, participates in events.

The idea that an atom can be in different states or at different places at the same time, that its particles can be part of slightly different configurations at the same time or that its state or position is indeterminate until it by some measurement interaction is forced to choose between either one of its possible states or locations inspired Erwin Schrödinger to his famous thought experiment.
A cat sits in a closed box with a radioactive atom and a device which releases poison gas when it detects the radiation the atom emits when it decays –and the cat is poisoned and dies, a decay the time of which cannot be predicted.
The supposition is that as long as we don’t look in the box, as long as its contents it isn’t acted upon from the world outside the box, the atom and cat are in a mixed state: that the atom is neither decayed nor undecayed, the cat dead *and* alive, and that it is the act of looking into the box –of interacting with its contents– which nudges the atom into a single state, decayed *or* undecayed and causes the cat to die *or* leave it be alive.
The flaw of this thought experiment, however, is that if the box actually would isolate its content completely from interactions with the world outside of it, including gravity, then the atom, device, poison and cat would cease to exist, be no longer be part of the universe outside the box, of the world of the observer so it wouldn’t even make sense to ask after the health of the cat or even say that time passes inside the box. The thought experiment only would make sense if particle properties would only be the cause and not also the effect of their inter-actions so they would keep existing even when isolated from interactions.

If the energy of particles varies within every cycle of their oscillation and with it the indefiniteness in their position, then the particles of the atom can temporarily

[1] *Lost in math* (2018) Sabine Hossenfelder, p 179 and p 120

be part of different configurations, including configuration corresponding to one of its decayed state. Though its decay seems to be random; if particle properties are cause and effect of their interactions, then the atom cannot autonomously decay, without the cooperation of the environment.

Quantum entanglement: the EPR paradox

As Einstein believed that there is an objective reality at the origin of our observations, he couldn't accept the indeterminacy implied in the UP according to which a particle cannot have both an exact position and momentum at the same time, so to show the absurdity of this, he proposed, together with Boris Podolsky and Nathan Rosen a thought experiment showing that such indeterminacy would imply action at a distance –which special relativity forbids.
In the EPR paper Einstein, Podolski and Rosen suppose that [1]

> we have two systems, I and II, which we permit to interact from the time $t = 0$ to $t = T$, after which time we suppose that there is no longer interaction between the two parts.

Systems I and II can be a pair of two spin ½ particles into which a spin-zero particle can decay, particles which become entangled at their creation.

> Since the total spin before and after this decay must be zero (conservation of angular momentum), whenever the first particle is measured to be spin up on some axis, the other, when measured on the same axis, is always found to be spin down. (This is called the spin anti-correlated case; and if the prior probabilities for measuring each spin are equal, the pair is said to be in the singlet state.) …. The paradox is that a measurement made on either of the particles apparently collapses the state of the entire entangled system—and does so instantaneously, before any information about the measurement result could have been communicated to the other particle (assuming that information cannot travel faster than light) and hence assured the "proper" outcome of the measurement of the other part of the entangled pair. In the Copenhagen interpretation, the result of a spin measurement on one of the particles is a collapse into a state in which each particle has a definite spin (either up or down) along the axis of measurement. The outcome is taken to be random, with each possibility having a probability of 50%. However, if both spins are measured along the same axis, they are found to be anti-correlated. This means that the random outcome of the measurement made on one particle seems to have been transmitted to the other, so that it can make the "right choice" when it too is measured. The distance and timing of the measurements can be chosen so as to make the interval between the two measurements spacelike, hence, any causal effect connecting the events would have to travel faster than light. [2]

Clearly, to say that after the creation of the particles "there is no longer interaction between the two parts" is to deny that they are entangled. The assumption that there is no communication between them presumes that particle properties only are the cause and not also, simultaneously, the effect of their interactions.
If particles in a SCU have to keep interacting to keep existing to each other, to express and preserve their, each other's properties, if their properties are source

[1] http://www.drchinese.com/David/EPR.pdf p 779
[2] https://en.wikipedia.org/wiki/Quantum_entanglement (22-5-2021)

and product of their interactions, then all particles within each other's interaction horizon are to some extent entangled. This only implies an instant communication in a universe where it is the same time, where time passes at the same pace everywhere in empty space, far from masses, not in a universe where time is observed to pass at a slower pace at larger distances.
Though to explain away what is supposed to be 'spooky action at a distance,' to be able to hold on to causality, to determinism, to the assumption that we live in a universe where it is the same time everywhere, the existence of hidden variables was proposed so the spin direction of the particles isn't indeterminate:

> A possible resolution to the paradox is to assume that quantum theory is incomplete, and the result of measurements depends on predetermined "hidden variables." The state of the particles being measured contains some hidden variables, whose values effectively determine, right from the moment of separation, what the outcomes of the spin measurements are going to be. This would mean that each particle carries all the required information with it, and nothing needs to be transmitted from one particle to the other at the time of measurement. [1]

experiments[2] show that it *is* indeterminate –neither up nor down along some axis– before the measurement, that we don't measure the state they already are in, but that it is the measurement which forces them to adopt either one of the possible spin directions, information which then needs to be communicated instantly.[3]

The answer to the question the EPR paper asks –whether the quantum mechanical description of physical reality is complete– of course depends on whether or not there *is* a completely knowable, *objective* reality. As the universe cannot have any particular property nor be in any particular state a whole as 'seen' from without as well as seen from within, there is no single, objective, universal completely knowable reality at the origin of our observations as this requires that we can, in principle though not in actual practice, look from outside the universe in (without the time delay due to the speed of light so we can 'see' the entire universe as it is, of itself, at some particular moment in cosmic time) –as opposed to a self-creating universe where we must specify the observer or observing particle when describing –not *the* universe as there is no such thing– but the universe they observe, a reality which is different to different observers / observing particles.

It is because particle properties are cause and effect of their interactions why their behavior isn't deterministic, why their communication is instantaneous, why a measurement cannot but affect what is measured –instantaneous as there is nothing in nor outside the universe relative to which can be determined what in an absolute sense precedes what, what is cause of what: because the universe only exists as seen from within.
Werner Heisenberg, in 1927:[4]

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[1] https://en.wikipedia.org/wiki/Quantum_entanglement (1–4–2021)
[2] https://en.wikipedia.org/wiki/Bell%27s_theorem#Testing_by_practical_experiments (26-3-2021)
https://arxiv.org/ftp/arxiv/papers/0811/0811.3129.pdf
[3] *Relational EPR* (2007) Matteo Smerlak, Carlo Rovelli, https://arxiv.org/pdf/quant-ph/0604064v3.pdf
[4] The actual content of quantum theoretical kinematics and mechanics. P. 32
https://ntrs.nasa.gov/api/citations/19840008978/downloads/19840008978.pdf

> … in the rigorous formulation of the law of causality –"If we know the present precisely, we can calculate the future" – it is not the conclusion which is faulty, but the premise. We simply can not know the present in principle in all its parameters. Therefore all perception is a selection from a total of possibilities and a limitation of what is possible in the future. Since the statistical nature of quantum theory is so closely to the uncertainty in all observations or perceptions, one could be tempted to conclude that behind the observed, statistical world a "real" word is hidden, in which the law of causality is applicable. We want to state explicitly that we believe such speculation to be both fruitless and pointless. The only task of physics is to describe the relation between observations. The true situation could rather be described better by the following: Because all experiments are subject to the laws of quantum mechanics and hence to equation $p_1q_1 \sim h$, it follows that quantum mechanics once and for all establishes the invalidity of the law of causality.

If causality at the most fundamental -quantum- level goes out the window, then so should our notion of time, the illusion that it is the same time, that time passes at the same pace anywhere, i.e., the assumption that the universe has a beginning, that it makes sense to speak about its properties and state.
While it is gravity, the tendency of energy to increase, to keep creating itself which drives the changes we experience as the passing of time, which in imposing a direction on events seems to enable us to distinguish cause from effect, what precedes what in an absolute sense; as the energy involved in the (de)composition of a macroscopic object out of (into) atoms is less than a billionth of the energy as contained in its mass ($E = mc^2$), its particles don't really notice what macroscopic object they are part of, a rock, an apple or a cat, of events they are involved in, of the macroscopic world they are the building blocks of, of a reality which is objective and obeys causality only at this, macroscopic, secondary level.

The problem with (super) determinism –if the universe at quantum level would be causal so every event ever to happen would be determined to the last detail at the big bang, is that it is hard to see how all this information can be encoded in the properties of particles (as all particles of a species are identical), in the laws and constants of nature or its initial conditions at the big bang –besides that it would be pointless to actually start the universe if everything ever to happen would be determined at its beginning.

At this time, the Big Bang, all the matter in the universe, would have been on top of itself. The density would have been infinite. It would have been what is called, a singularity. At a singularity, all the laws of physics would have broken down. Stephen Hawking.[1]

11

The second law of thermodynamics

The observation that the pigment particles in a drop of ink disperse in water or that temperature or density differences in a gas in a closed, isolated container decrease in the course of time –that an inequilibrium in a closed system tends to turn into an equilibrium state– led to the formulation of the 2nd law of thermodynamics according to which the entropy of a perfectly isolated system only can

[1] https://www.hawking.org.uk/the-beginning-of-time.html (16-7-2018) This link doesn't exist anymore.

increase in time. Entropy is a measure of the information needed to specify the state of a system, of the disorder, indefiniteness or randomness of the system, its lack of information: the more homogeneous the distribution of the ink particles in a glass of water, of gas molecules in a container is or the smaller differences in temperature or pressure are, the higher the entropy of the system is:

> … entropy is a measure of the number of microscopic configurations corresponding to a macroscopic state. Because thermodynamic equilibrium corresponds to a vastly greater number of microscopic configurations than any non-equilibrium state, it has the maximum entropy, and the second law follows because random chance alone practically guarantees that the system will evolve towards such thermodynamic equilibrium.[1] … Entropy can be thought of as a measure of microscopic disorder; thus the Second Law implies that time is asymmetrical with respect to the amount of order in an isolated system: as a system advances through time, it becomes more statistically disordered. This … can be used empirically to distinguish between future and past.

As a SCU is self-contained, as there is nothing outside of it so nothing can leave or enter it –as its particles only exist to each other if, to the extent and for as long as they interact– it is a perfectly closed, isolated system. The problem is that if the universe cannot have any particular property, be in any particular state as a whole, then it makes no sense to speak about the entropy of the universe and say that there is an arrow of time according to which time passes in the direction whereby the entropy of the universe increases. As there is no cosmic time, no universal now in a SCU so it's impossible to specify at what time its entropy is to be measured, the 2nd law doesn't apply to a SCU.

Only if particles would have an autonomous existence so would keep existing even when isolated from interactions can we put a drop of ink in a glass water and isolate it completely from the world outside of it by putting it in the same box Schrödinger proposed to put his cat in and can we ask what the entropy inside the box is and how it changes in time –if not for the problem that if its content indeed would be completely isolated from the world outside of it so no interaction, no communication would be possible between the content of the box and the world outside of it, the ink, water and glass wouldn't exist, have no physical reality to the observer outside the box. As they wouldn't then be part of the universe of the observer, it makes no sense to ask from outside a perfectly isolated system what the entropy inside of it is and how it changes in time or even say that time passes inside of it. If we only can ask what the entropy inside the box is if its contents keeps interacting with, existing to the world outside of it so a different entropy inside of it would make the world outside of it slightly different and vice versa, then the entropy of a system only can change if it is *not* perfectly isolated.

If we were to assume that a big bang universe is a perfectly closed, isolated system which can have a definite entropy, an entropy which only can increase in time, then its entropy must have been minimal at the big bang, its initial state be a state of maximal inequilibrium. Now if we *define* the entropy of a system to be lower as

[1] https://en.wikipedia.org/wiki/Entropy (22–3–2019)

it is farther out of equilibrium but a state only can be unstable, out of equilibrium, be a state of low entropy if there are laws operational by means of which the initial state can, *must* convert into a state which is less far out of equilibrium, then this begs the question where the information as contained in these laws and initial conditions comes from, who or what determined its initial conditions and installed the laws prescribing how one state is to transform into the next. If the initial state is specified by the physical laws which prescribe how it is to change, to transform into another state which is less far out of equilibrium, with a higher entropy, if the initial state only becomes defined, unstable as soon as the laws become operational which force it to transform into a state which is less far out of equilibrium – if these laws determine the nature of all consecutive states, each next state closer to the final equilibrium state of maximum entropy– but a state only can convert into the next if the information as contained in the later state already is present in the previous state (like the chicken in some sense is present, preordained in the egg) so all later consecutive states already are present, predetermined in its initial state –which then contains, *in potentia*, all information universe ever will contain– then how can the transition from one state to the next increase the entropy, the information content of the universe? Moreover, if a state only can be out of equilibrium when such laws are operational, then shouldn't they prevent the creation of any initial inequilibrium state –of a big bang– in the first place? Though this doesn't mean that ink particles in water collect just as easily to a drop of ink as they disperse or an egg becomes as easily unbroken as it breaks; the evolution of the chicken does constitute an entropy decrease as it unbroke the egg.

While going back in time the entropy of a BBU decreases to a minimum at the big bang, to a very orderly, unlikely state the origin of which many physicists worry about because they suspect it to invalidate big bang cosmology; if going back in time in a SCU an inside observer observes stars and galaxies expand, disintegrate into their composite particles the position of which becomes less definite as they move apart as their energy decreases so all points in space become more identical, less distinguishable so spacetime vanishes and with it the universe as their energy goes to zero, there is no initial information, no initial entropy.