THE SENSORIUM OF GOD: NEWTON AND ABSOLUTE SPACE

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Abstract

The physics of the *Principia* is based on the notion of absolute space, and Newton regarded absolute space as the sensorim of God, hence as existing in its own right independent of matter. Leibniz took Newton to task for this conception of space, and it has often been held that Einstein's general relativity theory showed Leibniz was correct in some of his criticisms. However, in the past ten years the ideas of absolute space and time have reappeared in cosmological physics, these notions being defined by either the constant mean curvature foliation of hypersurfaces, or in terms of the rest frame of the Cosmic Background Radiation (CBR). I shall compare and contrast Newton's concept of absolute space with the new meaning of absolute space in general relativity, and also analyze his notion of sensorium with the modern idea of the mind as a computer program. Newton regarded his *Principia* in part as a work of natural theology: a treatise on physics which provided evidence for the existence of God. Does modern science also suggest that "... there is a Being incorporeal, living, intelligent, omnipresent, who in infinite space, as it were in his sensory, sees the things themselves intimately..."? Perhaps, if the above attributes of this "Being" are defined appropriately.

Newtonian absolute space and God's sensorium

No part of the *Principia* was, or is, as controversial as the Scholium to Definition 8:

> I. Absolute, true, and mathematical time, of itself, and from its own nature, flows equably without relation to anything external, and by another name is called duration...
>
> II. Absolute space, in its own naturen without relation to anything external, remains always similar and immovable. Relative space is some movable dimension or measure of the absolute spaces; which our senses determine by its position to bodies; and which is vulgarly taken for immovable space;...
>
> III. Place is a part of space which a body takes up, and is according to the space, either absolute or relative....
>
> IV. Absolute motion is the translation of a body from one absolute place into another; and relative motion, the translation from one relative place into another....

Newton admitted that no local experiment could tell us if particles in rectilinear motion were moving with respect to absolute space, that is, he was aware that his equations of motion were invariant under Galilean transformations; but he argued that *acceleration* with respect to absolute space was detectable, and that in particular such absolute acceleration could be measured in his famous rotating bucket experiment:

> If a vessel hung by a long cord, is so often turned about that the cord is strongly twisted, then filled with water, and held at rest together with the water; thereupon, by the sudden action of another force, it is whirled about the contrary way, and while the cord is untwisting itself, the vessel continues for some time in this motion; the surface of the water will at first be plain, as before the vessel began to move; but after that, the vessel, by gradually communicating its motion to the water, will make it begin sensibly to revolve, and recede by little and little from the middle, and ascend to the sides of the vessel, forming itself into a concave figure (as I have experienced), and the swifter the motion becomes, the higher will the water rise, till at last, performing its revolutions in the same times with the vessel, it becomes relatively at rest in it. This ascent of the water shows its endeavour to recede from the axis of its motion; and the true and absolute circular motion of the water, which is here directly contrary to the relative, becomes known, and may be measured by this endeavour. At first, when the relative motion of the water in the vessel was greatest, it produced no endeavour to recede from the axis; the water showed no tendency to the circumference, nor any ascent towards the sides of the vessel, but remained of a plain surface, and therefore its true circular motion had not yet begun. But afterwards, when the relative motion of the water had decreased, the ascent thereof towards the sides of the vessel proved its endeavour to recede from the axis; and this endeavour showed the real circular motion of the water continually increasing, till it had acquired its greatest quantity, when the water rested relatively in the vessel [*Principia,* Scholium to Definition 8; translation in ref.].[1]

As is well-known, this experiment was criticized by Mach at the end of the 19th century, on the grounds that it did not rule out the possibility that the bucket was not rotating absolutely, but rather rotating relative to the fixed stars. Mach argued that the compass of inertia was fixed by the collectivity of all matter in the Universe.

Much earlier than Mach, in February of 1716, Leibniz had also attacked Newton's concept of absolute space. Leibniz's critique appeared in a series of letters between himself and Newton's supporter Samuel Clarke, the collection of letters being published in 1717. Leibniz based his criticism on two philosophical principles, namely the Principle of Sufficient Reason, and the Principle of the Identity of Indiscernibles:

> I say then, that if space was an absolute being, there would something happen for which it would be impossible there should be a sufficient reason. Which is against my axiom. And I prove it thus. Space is something absolutely uniform; and without the things placed in it, one point of space does not absolutely differ in any respect whatsoever from another point of space. Now from hence it follows (supposing space to be something in itself,

> besides the order of bodies among themselves,) that 'tis impossible there should be a reason, why God, preserving the same situations of bodies among themselves, should have placed them in space after one certain manner, and not otherwise; why every thing was not placed the quite contrary way, for instance, by changing East into West. But if space is nothing else, but that order or relation; and is nothing at all without bodies, but the possibility of placing them; then those two states, the one such as it now is, the other supposed to be the quite contrary way, would not at all differ from one another. Their difference therefore is only to be found in our chimerical supposition of the reality of space in itself. But in truth the one would exactly be the same thing as the other, they being absolutely indiscernible. [paragraph 5 of Liebniz's Third Letter to Clarke].[1]

In his replies to this (see in particular Clarke's Third and Fourth Repky),[1] Clarke tries to argue that space is not a substance but rather a property. In taking this approach, Clarke was alone amongst the Newtonians; the Newtonian absolute space *is* a substance; though of a different nature from material bodies.

To understand this, it is helpful to express Newtonian gravitational theory in geometrical language. This was originally done by Cartan in 1923, generalized by Trautman[2,3] in 1965, and further by Misner[4] in 1969. I shall use the notation of Misner, Thorne, and Wheeler.[4] (Space indices labeled by Latin letters: i = 1,23; and spacetime indices labeled by Greek letters: m = 0,1,2,3. Repeated indices are summed over).

As pointed out by Penrose,[5] Newtonian spacetime has the structure of a fiber bundle over R^1 with fiber M, where M is a three dimensional manifold (generally $M = R^3$). This implies that there is a scalar field t, called universal time, which labels each fiber. The base space is absolute time, and each fiber is absolute space. Newtonian gravity arises by assuming that there exists in Newtonian spacetime a covariant derivative ∇, such that the 1-form **dt** is covariantly constant; i.e., $\nabla_{\mathbf{u}}\mathbf{dt} = 0$ for all vectors **u**. This covariant derivative defines geodesics via the usual geodesic equation $\nabla_{\mathbf{u}}\mathbf{u} = 0$, and a curvature tensor. If we require that freely falling particles describe geodesics, which read universal time (or some multiple $\lambda = at + b$), then the equations for the freely falling particles $d^2x^i/dt^2 + \partial\Phi/\partial x^i = 0$ can be rewritten $d^2t/d\lambda^2 = 0$, and $d^2x^i/d\lambda^2 + \partial/\partial x^i(dt/d\lambda)^2 = 0$. Comparing these with the geodesic equation in component form tells us that $\Gamma^i 00 = \partial\Phi/\partial x^i$, with all other $\Gamma^\alpha \beta\gamma$ being zero. Putting these into the standard equation for the Riemann tensor, we find that $R^i{}_{0k0} = - R^i{}_{00k} = \partial^2\Phi/\partial x^i\partial x^k$, all other components of the Riemann tensor vanish. Poisson's equation $\nabla^2\Phi = 4\pi\rho$ is seen to be equivalent to

$$\mathbf{Ricci} = 4\pi\rho\mathbf{dt} \quad \mathbf{dt} \tag{1}$$

where **Ricci** is the usual Ricci tensor, or in component form, $R_{00} = 4\pi\rho$, with all other $R_{\alpha\beta} = 0$. If **n** is the separation vector between two geodesics with tangent vector **u**, the equation of geodesic deviation is

$$\nabla_{\mathbf{u}}\nabla_{\mathbf{u}}\mathbf{n} + \boldsymbol{R}(\mathbf{n},\mathbf{u})\mathbf{u} = 0 \tag{2}$$

which in component form can be written

$$\mathbf{d^2n^0/dt^2} = \mathbf{0} \tag{3a}$$

$$\mathbf{d^2n^i}/dt^2 + (\partial^2\Phi/\partial x^i \partial x^k)n^k = 0 \tag{3b}$$

if we assume the particle's clocks measure universal time t.

In terms of this geometrical language, the statement that the water particles in Newton's rotating bucket are in absolute motion means that they do not follow geodesics; i.e., $\nabla_{\mathbf{u}}\mathbf{u} \neq 0$, which is an invariant independent of the coordinate system. If a tensor like $\nabla_{\mathbf{u}}\mathbf{u}$ vanished in *any* coordinate system, it would vanish in all systems. This does not address Mach's objection, since the fixed stars and all other matter collectively define the inertial frames via the field equations. But nevertheless we do not have the material bodies only as Leibniz and Mach would have it: the manifolds R^1 and M, together with the material bodies embedded in M, are all regarded as real, as different types of substances.

Hitherto I have used a Galilean coordinate system in which $x^0 = t$, $(\partial/\partial x^i)_i(\partial/\partial x^j) = \delta_{ij}$, and $\Gamma^i_{00} = \partial\Phi/\partial x^i$, for some scalar field $\mathbf{\Phi}$. As pointed out for example by Misner, Thorne, and Wheeler[4], there is actually a large class of Galilean coordinate systems, those which leave the geodesic equations and the field equations invariant (in general the potential $\mathbf{\Phi}$ has to be transformed along with the coordinates). In Newtonian theory as I have developed it so far, there is no way to select one of these systems above another; we need additional structure if we want to define absolute space.

The additional structure comes from a consideration of Newtonian cosmology[6,7], first developed by McCrea and Milne over 50 years ago[6]. In Newtonian cosmology it is assumed that the Universe is filled with pressureless dust particles, such that at any universal time t, there is a Galilean frame in which the matter is homogeneous and isotropic. It can be shown[7] that this implies

$$\mathbf{n} = a(t)\mathbf{n}_0 \tag{4a}$$

$$\rho = \rho(t) \tag{4b}$$

where $\mathbf{n}$ is the separation vector (only space components) between the particles, $\mathbf{n}_0$ is the separation at the arbitrarily chosen initial instant $t = 0$ (hence $a(t_0) = 1$), and ρ is the mass density of the particles. If we adopt coordinates comoving with these particles, then conservation of particles is expressed by

$$\nabla_{\mathbf{u}}(\rho V) = 0 = d/dt(\rho a^3) \tag{5}$$

which implies

$$\rho(t) = \rho(t_0)a^{-3}(t) \tag{6}$$

If we put (6) and the field equations $R_{00} = 4\pi\rho$ into the equation of geodesic deviation (3b), we obtain an equation for a(t):

$$a^2 d^2a/dt^2 + 4\pi\rho(t_0)/3 = 0 \qquad (7)$$

which is identical to the Einstein dynamical equation for the scale factor a(t) of the Friedmann universe.

The important thing to notice is that the frame in which the cosmic fluid of dust particles appears homogeneous and isotropic is unique. Further, it defines what we mean by absolute space: a body is in absolute motion if it has a velocity relative to this unique cosmological frame, or more precisely, it has a velocity relative to the "fundamental" dust particle at its location. It is thus possible for a particle to be freely falling (its trajectory is a geodesic, and hence its locally measured acceleration is zero), and yet be in absolute motion.

The problem is, how does one identify this absolute rest frame? If one can find the fundamental particles, say they are galaxies or clusters of galaxies, then since the redshift can be shown to work as in relativistic cosmology[7,8], the universal rest frame is defined to be the one in which the redshift from all fundamental particles at a given distance **r** is the same in all directions. In principle, then, an absolute frame of rest, absolute space, exists in a realistic Newtonian universe, and can be identified experimentally.

In two passages of the *Opticks,* Newton identified his absolute space with the Sensorium of God. The first is in Query 28:

> ... does it not appear from phenomena that there is a Being incorporeal, living, intelligent, omnipresent, who in infinite space, as it were in His sensory, sees the things themselves intimately, and thoroughly perceives them, and comprehends them wholly by their immediate presence to Himself: of which things the images only carried through the organs of sense into our little sensoriums, are there seen and beheld by that which in us perceives and thinks.

The second is in Query 31, where Newton claims that God is He who being in all places, is able by His will to move the bodies within his boundless uniform sensorium."

In his first Letter of the Leibniz-Clarke Correspondence, Leibniz takes Newton to task for these statements, saying that Newton believes space to be "... an organ, which God makes use of to perceive things by." In his reply, Clarke denies this: space is not an organ which conveys to the Mind of God an image of the bodies in the world. Rather, the Mind of God is immediately present at each point in the universe; the things in the Universe are already in God's Mind, and so their images do not have to be conveyed to Him. In contrast, human eyes and optic nerves must carry information about physical entities to our sensoria, which in our case may be regarded as the visual field, the images of reality, generated by our minds. The philosopher Burtt further claims that "... it is safe to say that at Newton's time for practically all educated people, especially those to whom ideas meant images, the soul was conceived as occupying a seat, or a small portion of extension, within the brain, which place had come to be known as the sensorium."[9] As Newton himself says at the end of Query 28 in his *Opticks*:

> Is not the sensory of animals that place to which the sensitive substance is present, and into which the sensible species of things are carried through the nerves and brain, that there they may be perceived by their immediate presence to that substance?

Probably in response to Leibniz's criticism, Newton added in 1717 the following clarification at the end of Query 31 in the *Opticks*:

> And yet we are not to consider the world as the body of God, or the several parts thereof, as the parts of God. He is a uniform Being, void of organs, members or parts, and they are his creatures subordinate to him, and subservient to his will; and he is no more the soul of them, than the soul of man is the soul of the species of things carried through the organs of sense into the place of its sensation, where it perceives them by means of its immediate presence, without the intervention of any third thing. The organs of sense are not for enabling the soul to perceive the species of things in its sensorium, but only for conveying them thither; and God has no need of such organs, he being every where present to the things themselves.

In the third and last section I shall address the question of whether absolute space in general relativity can in any meaningful sense be regarded as a sensoria of some omnipresent being, but first let me establish that absolute space has a meaning in general realtivity, in fact, a meaning quite close to its meaning in Newtonian cosmology.

Absolute space in general relativity

In general relativity the geometric object is not a fiber bundle which has a universal time defined in its most basic topological structure, but rather it is a 4-dimensional manifold M upon which there is a globally defined spacetime metric g of Lorentzian signature. The existence of the Lorentz metric is equivalent to the existence of an everywhere non-vanishing vector field, and the existence of such a field places some contraints on M; for example, if M is closed (compact without boundary), then its Euler characteristic must be zero. The flow lines of this vector field define a local time direction, but there will be many such time-defining vector fields, and worse, the level surfaces of the flow lines might not be hypersurface forming for any of these vector field. If the flow lines are not hypersurface forming, then there is no global time definition at all. In other words, the situation could be much worse than in special relativity, where the only problem is the lack of uniqueness; the Poincaré Group defines not one, but rather a 10-parameter group of natural global space and time frames. So how can we hope to define absolute space and time?

We shall define them as we previously did in the Newtonian case, by restricting attention to a realistic cosmological model, rather than trying to define these concepts in a general spacetime. First of all, it seems reasonable to restrict attention to spacetimes which are *stably causal*, those spacetimes which have no closed timelike curves; and further, if you perturb them slightly, they are still free of closed timelike curves. If closed timelike curves are present, then time travel is possible; such travel does not seem to be a property of the universe we live in. Hawking and Ellis have shown[10] that stably causal spacetimes admit at least one global foliation by everywhere spacelike C^2 hypersurfaces; this foliation (a foliation is a complete slicing of spacetime by 3-dimensional hypersurfaces) defines a global time. In general, of course, this global time will be far from unique. Minkowski space, for instance, is stably causal, and the boosts of the Lorentz Group define a 3-parameter set of foliations of this spacetime.

Newton's evolution equations ar deterministic in the sense of Laplace; given initial data at one instant of time, the equations determine the entire future and past uniquely. Einstein's equations will be similarly deterministic only if the initial data are given on a *Cauchy hypersurface*, that is, a spacelike hypersurface which every timelike curve in spacetime intersects exactly once. If a spacetime contains a Cauchy hypersurface, then the spacetime can be shown to be *globally hyperbolic*; that is, sets of the form $J^+(p) \cap J^-(q)$, where p and q are spacetime events and $J^+(p)$ and $J^-(p)$ are the causal future and past of p respectively,[10] are compact sets. Thus global hyperbolicity and the existence of a Cauchy hypersurface are equivamlent conditions.

Geroch has shown[10] that a globally hyperbolic spacetime can actually be foliated by Cauchy hypersurfaces, and further, all of these Cauchy hypersurfaces have the same topology, so that the spacetime manifold M is topologically $R^1 \times S$, where S is the topology of a Cauchy hypersurface. (all Cauchy hypersurfaces in a given spacetime must have the same topology). As in the Newtonian spacetime, the R^1 factor defines the time direction, a direction normal to the Cauchy hypersurfaces. Compact Cauchy hypersurfaces have particularly nice properties: if a spacetime has a compact Cauchy hypersurface, then *any* spacelike C^2 compact hypersurface in the spacetime will in fact be a Cauchy hypersurface (see ref.[11], section 10.3 for discussion).

Spacetimes with compact Cauchy hypersurfaces are often termed *closed universes*. Such universes have aesthetic advantages over *open universes*, those universes with non-compact Cauchy hypersurfaces. For example, since closed universes have no boundary or regions at spatial infinity, it is not necessary to impose spatial boundary conditions. As Hawking expressed it in a different context, the only boundary condition is that there is no boundary condition. Einstein, in fact, assumed his first cosmological model to have topology S^3 for just the reason of elegance: no boundary conditions at infinity. Misner, Thorne, and Wheeler have expressed the opinion (ref.[4], p. 704) that the Einstein theory of gravity is the Einstein field equations combined with the requirement that there exist a compact Cauchy hypersurface; they call this compactness requirement the *Einstein Boundary Condition*. I shall assume this Einstein boundary condition in what follows.

The archetypical closed universe is the dust-filled Friedmann universe with S^3 spatial topology. This model starts at an initial all-encompassing singularity (Big-Bang singularity), expands to a maximal hypersurface, and recollapses to a final singularity (Big-Crunch singularity). The final and initial singularities are very strong, crushing everything, space and time and matter, out of existence. Technically speaking, this annihilation property is expressed by saying the Friedmann singularity is a *crushing singularity*, and also a *strong curvature singularity* (Presice definitions in ref.[11], section 10.3).

If this singularity behaviour is typical of physically realistic closed universes, and it is generaly believed that it is, then it can be shown (technical details in ref.[11], section 10.3) that there exists a *unique* foliation of a closed universe by compact Cauchy hypersurfaces: the constant mean extinsic curvature hypersurfaces. The extrinsic curvature of a spacelike hypersurfaces is, roughly speaking, its relative rate of expansion with time. In the Friedmann universe, this relative rate of expansion is measured by the Hubble parameter, defined by $H = (1/a)da/dt$, where $a(t)$ is the Friedmann scale factor (essentially the same $a(t)$ that we encountered in our discussion of Newtonian cosmology). However, in a general cosmology, it is possible for the universe to expand faster in some directions than others, so the Hubble parameter must the generalized to a second rank tensor in order to express properly this directional dependence. This tensor is the extrinsic curvature. The mean extrinsic curvature is the contraction of the extrinsic curvature tensor; roughly speaking, the mean extrinsic curvature is the sum of the Hubble expansion in the three spatial directions. A constant mean extrinsic curvature hypersurface is a spacelike hypersurface on which the mean extrinsic curvature is the same at all points. The hypersurfaces of isotropy and homogeneity in the Friedmann universe are constant mean extrinsic curvature hypersurfaces in which the mean extrinsic curvature is 3H.

I claim this unique foliation of spacetime by constant mean extrinsic curvature hypersurfaces defines absolute space and time in general relativity: the hypersurfaces are absolute space, and the timelike trajectories which are everwhere normal to the hypersurfaces are absolute time. If a particle is following a timelike curve which does not coincide with one of these trajectories, it is in absolute motion.

Why should we exalt this Cauchy hypersurface foliation of spacetime above all other foliations of spacetime? First, it is a natural foliation, in the sense that it is defined by the global distribution of matter and gravitational waves, in much the same way as the freely falling trajectories were generated in Newtonian cosmology by the matter distribution (In general relativity, analogous freely-falling trajectories will not generate spacelike hypersurface foliations in generic closed universes. In the closed Friedmann universe, however, the trajectories normal to the hypersurfaces of homogeneity and isotropy *do* generate a spacelike hypersurface foliation, and this foliation is exactly the same as the constant mean extrinsic curvature foliation). Second, we adopt the constant mean extrinsic curvature foliation as the standard of space and time for the same reason we require clocks to measure universal time in Newtonian spacetime; we adopt the time and space standard so that motion looks simple.

Misner, Thorne, and Wheeler present a detailed analysis (ref.[4], pp. 23-29) showing that in principle any other time and space standard can be used in Newtonian mechanics, but these other standards would require the introduction of forces one knows to be fictitious; a free particle, for example, would follow a curved path rather than a straight line if any other time standard than Newtonian universal time were used. The simplicity of motion in Newtonian universal time is a manifestation of the underlying geometrical structure of Newtonian spacetime, for this structure is, in fact, being used to construct the global coordinate system.

The constant mean extrinsic curvature foliation plays an analogous role in general relativity. York has shown (details in ref.[4], chapter 21) that the initial value and evolution Einstein equations are enormously simplified if one used this foliation. Terms in the Einstein equations analogous to the fictitious forces in Newtonian mechanics disappear if one adopts this standard of absolute space and time. As in Newtonian spacetime this simplification is a manifestation of the underlying geometrical structure of a generic closed universe.

A third reason for adopting the constant mean extrinsic curvature foliation as the standard is that in a universe which is very close to the Friedmann case of homogeneity and isotropy (as our universe is) the rest frames of the foliation will coincide with the rest frames of the Cosmic Background Radiation (CBR). We can thus measure our motion with respect to the CBR by looking for a dipole temperature anisotropy in the CBR, for the radiation will be blue-shifted in the direction of motio (made hotter in this direction) and red-shifted in the opposite direction (made colder in the opposite direction). These measurements have been done; the Sun is currently moving with respect to this globally defined rest frame of the Universe in the direction of the constellation Leo, more precisely, in the direction[12] of Right Ascension 11.2 ($\pm$ 0.1) hours, Declination —7 ($\pm$ 2) degrees at a speed of 360 km/sec. The reader can feel free to correct for the motion of the Earth in its orbit around the Sun, and for the rotation of the Earth on its axis, using the velocities appropriate for the instant the reader is reading these words, thereby calculating the reader's absolute motion at that instant. Not only is it possible in principle to measure our absolute motion; we actually *have* measured it, and to fairly high accuracy.

H. G. Alexander, who edited the Leibniz-Clarke Correspondence in 1956, concluded his Introduction with the words, "To some writers it has seemed that when in the Correspondence Leibniz criticizes the concepts of absolute space and time, he is anticipating Einstein. On the other hand, Leibniz's fundamental postulate is that space and time are unreal. If therefore one insists on awarding points to Leibniz and Clarke, in the light of modern physics, it is perhaps best to call it a drawn contest".

I disagree. The development of physics during the 1980's has proven that absolute space and time do in fact exist, and we have succeeded in measuring our absolute motion. Newton's magnificent intuition, as shown in the *Principia,* has been fully vindicated.

The Ω point theory: God's sensorium in the cosmology of the 1980's

Something very close to Newton's absolute space exists, but is it also true that it is in a sense the "sensorium of God"? Perhaps, if the words "sensorium" and "God" are given modern physical interpretations, but interpretations which are similar to the traditional ones. I shall just outline the ideas here, having developed them in detail in references 11 and 13. I should warn the reader that the following ideas are *extremely* speculative. In stark constrast, the concepts put forward in the previous sections are solid physics.

Absolute space can be a sensorium only if it is the seat of some form of life in some general sense. Now the essence of life is the processing, communication, and storage of information; in particular the human mind, or soul, is a form of computer program.

It is astonishing how similar the mind-as-program idea is to the traditional concept of the "soul." Both are fundamentally "immaterial:" a program is a sequence of integers, and an integer exists "abstractly" as the class of all couples. The symbol "2" is a *representation* of the number 2, and not the number itself. In fact, Aquinas and Artistotle defined the *soul* to be "the form of activity of the body." In Aristotelian language, the *formal* cause of an action is the abstract cause, as opposed to the material and efficient causes. For a computer, the program is the formal cause, while the material cause is the properties of the matter of which the computer is made, and the efficient cause is the opening and closing of electric circuits. For Aquinas, a human soul needed a body to think and feel, just as a computer program needs a physical computer to run.

Aquinas thought the soul had two faculties: the agent intellect (*intellectus agens*) and the receptive intellect (*intellectus possibilis*), the former being the ability to acquire concepts, the latter being the ability to retain and use the acquired concepts. Similar distinctions are made in computer theory: general rules concerning the processing of information coded in the central processor are analogous to agent intellect; the programs coded in RAM or on tape are the analogues of the receptive intellect. (In a Turing machine, the analogues are the general rules of symbol manipulation vs. the tape instructions, respectively.) Furthermore, the word "information" comes from the Aristotle-Aquinas' notion of "form;" we are "informed" if new forms are added to the receptive intellect. Even semantically, the information theory of the soul is the same as Aquinas' theory.

Since absolute time is real, the universe is in a state of evolution; in particular life (or information processors) evolves. There was a time in the past when there was no life at all, and currently life is restricted to a very limited region of the cosmos. But this need not be the case forever. We are actually looking at the universe at a very early time in its history. We would, therefore, expect that in the future life would spread out from its current locations, and possibily engulf the cosmos, provided it has sufficient time to do so. Let us now consider what the universe must be like in order for life to continue without limit.

I will, by definition, say that "life" can continue forever if: (1) information processing can continue indefinitely along at least one future-endless timelike curve γ all the way into the future c-boundary of the universe; (2) the amount of information processed in the past light cone of γ ($I^-(\gamma)$) between now and the c-boundary can be infinite; (3) the amount of information stored in $I^-(\gamma) \cap S(t)$, where S(t) is the constant mean extrinsic curvature foliation of the spacetime, can diverge as the leaves of the foliation approach the future c-boundary.

Recall that Penrose introduced the concept of *c-boundary* to precisely define the topology of the singularities and the regions at temporal infinity. Roughly speaking, points differ on the future c-boundary only if different future-endless timelike curves which hit them have different past light cones. Von Neumann and others have shown that information processing (more precisely, irreversible permanent storage) is constrained by Second Law of Thermodynamics. Thus the information processed between now and c-boundary is

$$I = \int(dI/dt)dt \leq (k\ln 2)^{-1}\int T^{-1}(dE/dt)dt \qquad (8)$$

where T is the temperature, t is the time with the upper limit of integration being the value of t at the c-boundary, and E is the energy dissipated by the computer. We need an energy source sufficient for the right-most integral to diverge.

In the far future, the dominant energy density will be shear energy (energy in universe-size gravitational waves). In closed universes, shear energy density diverges as $1/a^6$, where a(t) is the scale factor as before. Thus available energy goes as $(1/a^6)a^3 \propto t^{-1}$, where t is the proper time to the final singularity at $t = 0$; so $dE/dt \propto t^{-2}$, $T^{-1} \propto a \propto t^{1/3}$, and hence

$$I \leq C\int(t^{-2})t^{1/3}dt \propto t^{-2/3} \qquad (9)$$

which *diverges* as the final singularity is approached. Thus even though there is only a *finite* amount of proper time, there is sufficient energy in shear to allow infinite information processing. Even though the future is finite in proper time, it is *infinite* in subjective time, so it is reasonable to say life exists "forever."

A similar calculation in open and flat universes shows that there is sufficient shear energy for the right-most integral of (8) to diverge also. But this also means that information processing must occur over arbitrarily increasing proper volumes. This makes impossible any communication between opposite sides of the "living" region, because the redshift means that arbitrarily large amounts of energy must be used to signal (This result is due to Freeman Dyson). This gives the first testable prediction of *omega point theory*: the Universe must be closed.

However, there is a communication problem in typical closed universes; event horizons are present in general, due to the rapid approach to singularity. But there are no event horizons if all future-endless timelike curves eventually enter same light cone; i.e., if the future c-boundary consists of a single point. (For purposes of comparison, the c-boundary is a 3-sphere for the closed Friedmann universe.) Thus we have the second (testable?) prediction of the *omega point theory*: the future c-boundary is a single point; call it the *omega point*. (Hence the name of the theory here developed).

There is a further problem with information storage in a closed universe: information is stored by letting different energy levels have different occupation numbers, so the energy level difference must exceed the thermal fluctuation energy (of order kT), which diverges near the final singularity. But the energy level difference cannot diverge too fast, otherwise the shear energy would be insufficient to populate higher levels. Since the information stored at any given time must diverge, the density of particle states must diverge with energy, but this density cannot diverge too fast or the available shear energy would be exhausted by the filling of energy levels. The result of the detailed calculation is the third (obviously testable) prediction of the *omega point theory*: there is always a resonance of energy M in the energy range $E < M < E^3$, where $E >$ room temperature $=$ 300 degrees K (energy is measured in degrees Kelvin). Furthermore, dn/dE must diverge as $E \to \infty$, but dn/dE is bounded above by the asymptote E^2, where dn/dE is the density of particle states (resonances).

What does all this have to do with the Sensorium of God? Just this: a closer analysis shows that in order for the information processing operations outlined above to be carried out arbitrarily near the *omega point*, life must have extended its operations so as to engulf the entire Cosmos. We can say that life near the *omega point* is omnipresent. As the *omega point* is approached survival dictates that life collectively gains control of all matter and energy sources available near the final state, with this control becoming total at the *omega point*. We can say that life at the *omega point* is omnipotent. Since the information stored diverges at the *omega point*, it is reasonable to say that the *omega point* is omniscient; it knows whatever can be known.

The *omega point* has a fourth property. Mathematically, the c-boundary is a completion of spacetime; it is not actually in spacetime, but rather just "outside" it, forming its "boundary." From the c-boundary definition, a single c-boundary point would be formally equivalent to the entire collection of spacetime points, and yet from another point of view, it is outside space and time altogether. We thus can naturally say that the *omega point* is "both transcendent to and immanent in" all of spacetime.

When life has completely engulfed the entire universe, it will incorporate more and more material into itself, and thus the distinction between living and non-living matter will lose its meaning. In effect, the entire universe will have become the sensorium of life, in Newton's sense of "sensorium." At this stage, absolute space will indeed have become the Sensorium of God.

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