Die Physik des Nichts – Ein ontologischer Ansatz zur kritischen Analyse von Urknall, Relativitätstheorien und Quantenmechanik

Addendum englischer Originalzitate:

Vorwort:

001:
»In entering upon any scientific pursuit, one of the student's first endeavours ought to be, to prepare his mind for the reception of truth, by dismissing, or at least loosening his hold on, all such crude and hastily adopted notions respecting the objects and relations he is about to examine as may tend to embarrass or mislead him; and to strengthen himself, by something of an effort and a resolve, for the unprejudiced admission of any conclusion which shall appear to be supported by careful observation and logical argument, even should it prove of a nature adverse to notions he may have previously formed for himself, or taken up, without examination, on the credit of others.«

002:
»A mystery is a phenomenon that people don't know how to think about – yet.«

003:
»We do not yet have the final answers to any of the questions of cosmology and particle physics [...], but we do know how to think about them. The mysteries haven't vanished, but they have been tamed. They no longer overwhelm our efforts to think about the phenomena, because now we know how to tell the misbegotten questions from the right questions […].«

Teil I

007:
»As ideas are preserved and communicated by means of words, it necessarily follows that we cannot improve the language of any science, without at the same time improving the science itself; neither can we, on the other hand, improve a science without improving the language or nomenclature which belongs to it.«

I.1

010:
»Language is the principal tool with which we communicate; but when words are used carelessly or mistakenly, what was intended to advance mutual understanding may in fact hinder it; our instrument becomes our burden.«

014:
»O, what a world of unseen visions and heard silences, this insubstantial country of the mind! What ineffable essences, these touchless rememberings and unshowable reveries!«

I.2

016:
»Statements, or systems of statements, convey information about the empirical world only if they are capable of clashing with experience; or more precisely, only if they can be subjected [...] to tests which *might* result in their refutation.«

017:
»In so far as a scientific statement speaks about reality, it must be falsifiable; and in so far as it is not falsifiable, it does not speak about reality.« Einstein meinte: »Insofern sich die Sätze der Mathematik auf die Wirklichkeit beziehen, sind sie nicht sicher, und insofern sie sicher sind, beziehen sie sich nicht auf die Wirklichkeit.«

018:
»In point of fact, no conclusive disproof of a theory can ever be produced; for it is always possible to say that the experimental results are not reliable, or that the discrepancies which are asserted to exist between the experimental results and the theory are only apparent and that they will disappear with the advance of our understanding. … If you insist on strict proof (or strict disproof) in the empirical sciences, you will never benefit from experience, and never learn from it how wrong you are.«

020:
»And my present view is that the number of auxiliary hypotheses is simply intolerable: according to my theory of science, *this is not science*. It is (1) introducing a new auxiliary hypothesis every time the theory is refuted; and (2), it is *mutual support* of cosmological *theory* and particle *theory* – but criticism, and critical experiments (= attempted refutations) are ignored out of hand. And not only is it *not* stressed by the upholders of the theory that it is all speculation without tests, but it is presented as if the theory were a proven *fact*. This is horrid; impermissible; against scientific ethics. [...] I once *was* an enthusiastic admirer of (Friedmann's) Big Bang. I am *now* a disgusted opponent.«

Teil II

II.1

031:
»The universe,so called,is not a distinct body,and there are no bodies without it with which it could interact. Operations with the term Infinite in analogy to operations with finite terms are as illegitimate in physics as they are in mathematics. [...] It follows that all cosmogonies which purport to be theories of the origin of the universe as an absolute whole, in the light of physical or dynamical laws, are fundamentally absurd.«

032:
»The cosmos is all that is or ever was or ever will be. Our feeble contemplations of the cosmos stir us – there is a tingling in the spine, a catch in the voice, a faint sensation of a distant memory, as if we were falling from a great height. We know we are approaching the greatest of mysteries. The size and the age of the cosmos are beyond ordinary human understanding. Lost somewhere between immensity and eternity is our tiny planetary home.«

037:
»There must have been a time between ten and twenty billion years ago when the density of the universe was infinite. This is called the big bang. It would have been the beginning of the universe.«

038:
»There was a time when ›universe‹ meant ›all there is‹. [...] The word's meaning now depends on context. Sometimes ›universe‹ still connotes absolutely everything. Sometimes it refers only to those parts of everything that someone such as you or I could, in principle, have access to. Sometimes it's applied to separate realms, ones that are partly or fully, temporarily or permanently, inaccessible to us.«

039:
»For now, we'll avoid wrestling with abstract definitions by adopting the approach famously applied by Justice Potter Stewart to define pornography. While the U. S. Supreme Court struggled to delineate a standard, Stewart declared, ›I know it when I see it‹.«

II.2

041:
»The universe may be a 4-dimensional soap bubble in an 11-dimensional space as some supersymmetry theorists argued in May of 1983. Who knows?«

042:
»The idea sounds impossible, preposterous. I mean, think about it: Everything from nothing – the galaxies, the stars in the heavens coming from a pinpoint. How can it be that everything comes from nothing? But if you think about it for a while you begin to realize that it all depends on how you define *nothing*.«

043:
»I think there are two kinds of nothing. First, there is something I call *absolute nothing* – no equations, no space, no time, absence of anything the human mind can conceive of, just *nothing*. But then I think, there's the vacuum, which is nothing but the absence of matter.«

047:
»From the outside, from the bird's eye view of these multiple big bang universes, indeed each looks like a bubble that's expanding. But if you are inside one of those bubbles, it turns out that your understanding of space and time differs from the outside perspective and inside it looks like space goes on infinitely far. There is no edge to the bubble that you could ever encounter. The edge, it turns out, is a *moment in time*, not a place in space. The only way you could encounter the edge would be to go back in time. And that's something we don't think we can do.«

III.3

052:
»Theoretical evidence is mounting to support the existence of the multiverse, in which entire universes continually sprout or ›bud‹ off other universes. If true, it would unify two of the great religious mythologies, Genesis and Nirvana. Genesis would take place continually within the fabric of timeless Nirvana.«

054:
»I don’t really know what to say in terms of what is between the universes. It is almost not a fully well defined question in that case. There are these two universes, they both exist, but they don’t exist in a common space in any real sense, in any sense that is akin to the space you see in the room where you are now sitting. So, mathematically I know where they sit, [...] they sit inside of Hilbert Space. But if you don’t speak that language there are really just these two universes that sit in an abstract environment with no real sense of being able to traverse the separation between them. That’s an idea that doesn’t even apply to these universes.«

055:
»The standard, ›global‹ picture is that of an eternally inflating ›multiverse‹, containing an infinite number of bubbles, or pocket universes, corresponding to each vacuum in the landscape. Each bubble is an infinite open universe, and if it has positive cosmological constant, it will itself harbor an infinite number of daughter universes.«

058:
»A page from a journal of modern experimental physics will be as mysterious to the uninitiated as a Tibetan mandala. Both are records of enquiries into the nature of the universe.«

059:
»The phenomenon may be described in broad terms as an idolatry of which ›The Universe‹ is the god. Precisely what ›The Universe‹ means is not always easy to discover; its worship is sometimes mono- and sometimes poly-theistic, and no two votaries appear to bow before the same altar. But its various forms have this in common, that they transcend observation and cannot be derived by induction from observation alone. [...] This cosmolatry, as might be expected, came by metaphysics out of mathematics. What is more surprising is that the world of science generally is accepting it with at best a silent protest, kept inarticulate by a lurking fear that what cannot be understood might haply be true. Thus we find among the general public a vague belief that physics is simply the study of the universe, and in the scientific world itself the wholesale publication of spineless rhetoric the irrationality of which is obscured by a smokescreen of mathematical symbols.«

Teil III

III.1

061:
»Ever since humans began to think, we have worshipped that which we cannot understand. As millennia have passed, we have understood an ever-increasing amount about the world around us. [...] Yet we are now in a position of facing the ultimate unknowable, which can never be penetrated as long as we remain in our present physical form. The ultimate unknowable is the black hole.«

062:
»People regard black holes as troubling, because they are the enemy you cannot defeat. They always win in the end. [...] We now believe that in the long run most of the mass of the universe is going to end up being eaten by a black hole. Thee and me and all that we know will probably be swallowed by one of these dragons in the long run.«

067:
»A luminous star of the same density as the earth, and whose diameter was two hundred and fifty times greater than that of the sun, would not, because of its attraction, allow any of its rays to arrive at us; it is therefore possible that the largest luminous bodies of the universe may, through this cause, be invisible.«

068:
»He pointed out that a star that was sufficiently massive and compact would have such a strong gravitational field that light could not escape. [...] Such objects are what we now call black holes.«

071:
»[...] a hole in space into which anything can fall and be lost forever: a black hole. You will discover that such fantastic *objects* are science fact not fiction because astronomers are now almost certain that black holes *really exist* out in space.« (Hervorh. d. Verf.)

075:
»A star that collapses under its own gravity is trapped in a region whose boundary eventually shrinks to zero size. This means that all the matter in the star will be compressed into a region of zero volume, so the density of matter and the curvature of space-time become infinite.«

076:
»You give me any object and if I squeeze it sufficiently small, then according to the classical laws of General Relativity, if you make it small enough, it will be a tiny black hole. There is nothing that you can give me that I couldn't turn into a black hole by squeezing it sufficiently small.«

077:
»When a black hole forms by the implosion of a star – which is how most black holes probably form – the matter implodes. And as it get's more and more compact, its mass generates the warping of space and time around it. Its spin generates the whirling motion of space around it. But the matter continues to shrink smaller and smaller and smaller. Shrinks down to the very center where it gets destroyed in a singularity – a region of infinite warped space and time. And it's gone. When it's gone there's nothing left except the warped space and the warped time. So the common idea that a black hole is just made of very compacted matter, it's wrong. It's just simply wrong. It may have been created from very compacted matter, but the matter is gone. It's been completely destroyed. It no longer exists. And all that's left behind is the warped space and the warped time and this little nugget of a singularity at the center of the black hole that we don't understand.«

III.2

087:
»Hidden from view inside their ›horizons‹, they [black holes] hold secrets that transcend the physics we understand. The central ›singularity‹ involves the same physics that occurred at the initial instants of the Big Bang and will recur again if the universe recollapses. When we really understand black holes, we will understand the origin of the universe itself.«

088:
»The big bang was the abrupt creation of the Universe from literally nothing: no space, no time, no matter. This is a quite extraordinary conclusion to arrive at – a picture of the entire physical Universe simply popping into existence from nothing.«

089:
»Is the universe itself a black hole? To investigate this question, the customary view of the universe, which is necessarily internal, is not sufficient; it has to be supplemented with an external view – I assume that there exists, outside our universe, an external world from which one may take a ›detached‹ look at our universe.«

091:
»We are now faced with several questions: How did the universe come to be a black hole – through a gravitational collapse, followed by a phase of expansion? In the cosmos, which includes the exterior as well as the interior of the universe, can our universe be unique? If not, what would its status be *vis-a-vis* other such structures in the cosmos? Investigation of these and other related questions, including the possible existence of an hierarchy of black holes, is clearly a matter of some importance.«

093:
»These results suggest that observed astrophysical black holes may be Einstein-Rosen bridges, each with a new universe inside that formed simultaneously with the black hole. Accordingly, our own Universe may be the interior of a black hole existing inside another universe.«

III.3

098:
»An important characteristic of gravity within the framework of general relativity is that the theory is nonlinear. Mathematically, this means that if g_{ab} and y_{ab} are two solutions of the field equations, then $ag_{ab} + by_{ab}$ may not be a solution. This fact manifests itself physically in two ways. First, since a linear combination may not be a solution, we cannot take the overall gravitational field of the two bodies to be the summation of the individual gravitational fields of each body.«

105:
»$R_{\mu\nu} = 0$ seems to imply that there is no matter at all, and yet the thing has mass! Here, both L and C suffer from the misconception that a gravitational field cannot have a mass of its own. But Einstein's equations are non-linear, and this is why gravitational fields *can* be the source of additional amount of gravity, so that a gravitational field can support itself.«

107:
»The main discussion is based on Schwarzschild's solution of the Einstein vacuum equations. This solution represents the gravitational field exterior to a spherically symmetrical body.« (Hervorh. d. Verf.)

109:
»It is known as the Schwarzschild solution. It holds outside the surface of the body producing the field, where there is no matter. Thus it holds fairly accurately outside the surface of a star.« (Hervorh. d. Verf.)

113:
»Thus, according to the cosmologists, matter is both present and absent by the very same mathematical constraint: $T_{\mu\nu} = 0$. This is impossible. Consequently, $R_{\mu\nu} = 0$ contains no matter for the very same reason de Sitter's universe contains no matter, and so $R_{\mu\nu} = 0$ cannot produce a black hole. Being a space that excludes matter $R_{\mu\nu} = 0$ has no physical meaning.«

114:
»Black holes were first discovered as purely mathematical solutions of Einstein's field equations. This solution, the Schwarzschild black hole, is a nonlinear solution of the Einstein equations of General Relativity. *It contains no matter*, and exists forever in an asymptotically flat space-time.« (Hervorh. d. Verf.)

107:
»A big misconception is that a black hole is made of matter that has just been compacted to a very small size. That's not true. A black hole is made from warped space and time. It may have been created by an imploding star. But the star's matter is destroyed at the hole's center, where space-time is infinitely warped. There's nothing left anywhere but warped space-time.«

118:
»Also, suppose two black holes collided and merged together to form a single black hole. Then the area of the event horizon of the final black hole would be greater than the sum of the areas of the event horizons of the original black holes.«

123:
»In an idealized but illustrative calculation, Oppenheimer and Snyder [...] showed in 1939 that a black hole in fact does form in the collapse of ordinary matter. They considered a 'star' constructed out of a pressureless 'dustball'. [...] ... . Due to the selfgravity of this 'star', it immediately begins to collapse. Each mass element of the pressureless star follows a geodesic trajectory toward the star's center; as the collapse proceeds, the star's density increases and more of the spacetime is described by the Schwarzschild metric. Eventually, the surface passes through r=2M. At this point, the Schwarzschild exterior includes an event horizon: A black hole has formed.«

124:
»GR black holes occur in certain highly-specialized exact solutions of Einstein's field equations and so far only solutions containing a single centrally-placed black hole are known. There is, therefore, no way of asserting through some analogy with Newtonian gravitational theory that a black hole could be a component of a close binary system or that two black holes could collide. An existence theorem would first be needed to show Einstein's field equations contained solutions which described such configurations.«

127:
»In a mathematical calculation of a physics problem, each step need not be checked for a corresponding, physically possible situation. Such a requirement obviously corresponds to an experimental approach, whereas the mathematical validity of an argument cannot depend on an intermediate ontology.«

III.4

130:
»The advent of the term *black hole* in 1967 was terminologically trivial but *psychologically powerful*. After the name was introduced, more and more astronomers and astrophysicists came to appreciate that black holes might not be a figment of the imagination but astronomical objects worth spending time and money to seek.« (Hervorh. d. Verf.)

131:
»Keep in mind that the horizon is a global concept. The existence, location, size, and shape of a horizon depend not only on past occurrences, but also on future events. We ourselves could right now be at the horizon of a gigantic black hole caused by matter yet to collapse in the future. The horizon in classical relativity is simply the mathematical surface which separates those points from which any light ray must hit a singularity from those where light may escape to infinity. A mathematical surface of this sort should have no local effect on matter in its vicinity.«

Teil IV

IV.1

137:
»Until further evidence is available, both the present writers wish to express an open mind with respect to the ultimately most satisfactory explanation of the nebular redshift and, in the presentation of purely observational findings, to continue to use the phrase ›apparent‹ velocity of recession. They both incline to the opinion, however, that if the redshift is not due to recessional motion, its explanation will probably involve some quite new physical principles.«

138:
»Well, perhaps the nebulae are all receding in this peculiar manner. But the notion is rather startling. The cautious observer naturally examines other possibilities before accepting the proposition even as a working hypothesis. [...] Light may lose energy during its journey through space, but if so, we do not yet know how the loss can be explained.«

142:
»While optical coherence is taught to all physicists, while we see laser beams almost every day, while ISRS is studied for more than thirty years, it is incomprehensible that Raman coherent effects are ignored in astrophysics. [...] With an exception to the origin of radio and microwave frequencies, all properties, [...] of the quasars are explained by the hypothesis of a magnetic field in a plasma next to the quasar [...]. The theory is much simpler than the conventional theory, it needs only usual matter and regular spectroscopy.«

143:
»The shifts of the spectra produced either by a Doppler effect, or by ILCRS are very similar. However ILCRS is subject to a dispersion which perturbs slightly the spectra. ILCRS is the key of a model of quasars which explains all observations, without any new matter or physical theory: no fast moving cloud, no dark matter, no variation of the fine structure constant, no invisible object. [...] A few molecules per cubic metre would produce the whole cosmological redshift [...]. ILCRS gives an elementary explanation of probably all observations about the quasars with the simple hypothesis of a magnetic field in their halos. It seems to explain easily lots of other observations, for instance the thermal spectrum of bright objects without dust; it weakens the two main proofs of the big bang.«

149:
»What he found was that [...] all the galaxies he observed were moving away from the Earth with speeds that were proportional to their distance. [...] The *observation* that speed of recession is proportional to distance is known as Hubble's law.« (Hervorh. d. Verf.)

150:
»The crucial *observational fact* of modern cosmology is that the Universe is expanding. This revolutionary idea was first proposed by Alexander Alexandrovich Friedmann, a young Russian mathematician and meteorologist. [...] This prediction was *confirmed* when the Universe was *in fact observed* to be expanding – distant galaxies *were found* to be moving away from us (and from each other) with velocities proportional to their relative distances.« (Hervorh. d. Verf.)

151:
»The simplest interpretation of the observed accelerating expansion of the universe is that it is driven by a constant vacuum energy density, which is about three times greater than the present density of nonrelativistic matter.«

152:
»But if the cause of these redshifts is misunderstood, then distances can be wrong by factors of 10 to 100, and luminosities and masses will be wrong by factors up to 10,000. We would have a totally erroneous picture of extragalactic space, and be faced with one of the most embarrassing boondoggles in our intellectual history.«

154:
»Thus the explorations of space end on a note of uncertainty. [...] We know our immediate neighbourhood rather intimately. With increasing distance our knowledge fades, and fades rapidly. Eventually, we reach the dim boundary – the utmost limits of our telescopes. There, we measure shadows, and we search among ghostly errors of measurement for landmarks that are scarcely more substantial.«

IV.2

166:
»Before the WMAP results, astronomers and physicists had put together a very implausible picture of our universe. It had a tiny amount of ordinary matter. It had a modest amount of dark matter, whatever that is. It had an overwhelming amount of dark energy, which is a strange beast. I have to confess I was very sceptical of this picture. But the WMAP results have convinced me.«

171:
»Over the course of the last 50 years, it has been amply demonstrated that it is simply not possible to acquire any information of interest, near the water resonance in biological NMR, by data processing a spectrum obtained from an aqueous sample without a priori water suppression.«

173:
»Removal of a contaminating signal, which exceeds the signal of interest by up to a factor of 1,000, requires ability to control the sample at the source. This requirement can never be met by the WMAP team. It is impossible to remove this contamination and thereby ›see beyond the galaxy‹. [...] The galactic problem alone is sufficient to bring into question any conclusion relative to anisotropy from both WMAP and COBE.«

174:
»Because any real signal will be weak, and the contaminating signal is so strong, the WMAP team is unable to distinguish spurious ghosts related to either processing or acquisition from the actual signal of interest. This is true at every image location. [...] It is clear that the WMAP signal to noise is below 2:1 and probably below 1.5. [...] The WMAP team is unable to confirm that the anisotropic ›signal‹ observed at any given point is not noise. The act of attributing signal characteristics to noise does not in itself create signal.«

IV.3

182:
»Black holes were once considered to be science fiction. Einstein himself wrote a paper in 1939 that ›proved‹ that black holes could never form. Yet today the Hubble Space Telescope and the Chandra X-ray telescope have revealed thousands of black holes in space.«

183:
»Because it was clear to us that these stars were moving so fast that the supermassive black hole hypothesis had to be right. It is the gravity of the supermassive black hole that makes these stars orbit. So the curvature [of the orbits] was the *definitive proof* of a supermassive black hole at the center of our galaxy.« (Hervorh. d. Verf.)

184:
»There are black holes in the centers of galaxies. We *know* this because we have looked at galaxies. We are talking about systems that have a hundred billion stars. In their center is a supermassive black hole, in some cases of billion times the mass of the sun.« (Hervorh. d. Verf.)

IV.4

190:
»The visible matter in the Universe is insufficient to explain the motion under gravity of the stars in galaxies and the galaxies in rich clusters. Either gravity theory is wrong or there exists matter that is not visible, dark matter. Most cosmologists prefer the latter.«

192:
»Our findings suggest that unseen dark matter – which emits no light but has mass – has had a major effect on the formation and evolution of galaxies, and that bright active galaxies are only born within dark matter clumps of a certain size in the young universe.«

198:
»There is speculation that dark matter might be an ordinary galaxy hovering above us in another membrane universe. We could feel the gravity of this galaxy, since gravity can ooze its way between universes, but the other galaxy would be invisible to us because light moves underneath the galaxy. In this way, the galaxy would have gravity but would be invisible, which fits the description of dark matter.«

199:
»If galaxies were gravitationally bound systems, their outer mass should follow Kepler's laws of motion and be slower than the inner mass. The flat rotation curves of galaxies has been cited as the strongest physical evidence for the existence of dark matter. […] When an electric field is present in a plasma and has a component perpendicular to a magnetic field, inward convection of the charged particles occurs. Both electrons and ions drift [...] so that the plasma as a whole moves radially inwards. The material thus forms as magnetic ropes around magnetic flux tubes. Magnetic ropes thus contain material filaments that have a higher density than the surrounding plasma.«

200:
»The arm is susceptible to the diocotron instability [...]. This instability appears as a wave motion in each arm. The rotation curves are not really flat; they show appreciable structure representative of an instability mechanism within the arms.«

IV.6

208:
»It's amazing to realise that we turned on our detectors on the centenary of the year Einstein's general theory of relativity was published and at exactly the right time to receive this signal coming to us from 1.5 billion years ago – when far out in the Universe two black holes spiralled in to collide.«

209:
»This fantastic discovery is a reminder of the virtues of exploring the unknown. We can now listen to the symphony of the cosmic orchestra played to us from the darkest, densest regions of the universe and eagerly anticipate the new science that the gravitational wave universe will reveal to us.«

214:
»To make this possible took a global collaboration of scientists – in Glasgow we are proud to have led a UK team that created and delivered the heart of the advanced LIGO gravitational wave detectors - the ultra-low noise suspended mirrors that a passing gravitational wave moves. These were critical to making the detection - technology is the key to enabling progress in science.«

216:
»We've spent the last ten years performing large computer simulations of black holes colliding, so we will know what their gravitational wave signals will look like. This helps us to find them and to measure the properties of the black holes. We now know exactly what those signals should look like.«

218:
»In 1916, the year after the final formulation of the field equations of general relativity, Albert Einstein predicted the existence of gravitational waves. He found that the linearized weak-field equations had wave solutions: transverse waves of spatial strain that travel at the speed of light, generated by time variations of the mass quadrupole moment of the source.«

219:
»The statement that in the relativity theory gravitational waves are propagated with the speed of light [...] is only true in a very conventional sense. If coordinates are chosen so as to satisfy a certain condition which has no very clear geometrical importance, the speed is that of light; if the coordinates are slightly different the speed is altogether different from that of light. The result stands or falls by the choice of coordinates and, so far as can be judged, the coordinates here used were purposely introduced in order to obtain the simplification which results from representing the propagation as occurring with the speed of light. The argument thus follows a vicious circle.«

220:
»It is not possible to obtain an expression for the energy of the gravitational field satisfying both the conditions: (i) when added to other forms of energy the total energy is conserved, and (ii) the energy within a definite (three dimensional) region at a certain time is independent of the coordinate system. Thus, in general, gravitational energy cannot be localized. The best we can do is to use the pseudotensor, which satisfies condition (i) but not condition (ii). It gives us approximate information about gravitational energy, which in some special cases can be accurate.«

223:
»Now it is well known that differential invariants of the 1^0 order which are intrinsic i.e., like G*, exclusively formed with the coefficients of ds^2 and with their first derivatives, do not exist. This is enough to render, at least in general, not admissible the form of the gravitational tensor taken by Einstein.«

225:
»This is the first direct observation of the final (and until now, the most elusive) prediction from Einstein's theory of General Relativity. In addition, we have the first ever direct observation of black holes, and of two black holes colliding.«

226:
»The observation of GW150914 is the proof that binary black holes exist: they form, evolve and die. It is also the most convincing evidence to date that the strange mathematical objects predicted by Einstein's theory correspond to those produced by Nature. This completes our quest for the last elusive experimental validation of Einstein's theory. More significantly, it is the dawn of a new era for astronomy and astrophysics.«

227:
»The most stupid procedures and the most laughable result in their domain are surrounded with an aura of excellence. It is time to cut them down to size and to give them a lower position in society.«

IV.6

229:
»The difference between myth and science is the difference between divine inspiration of ›unaided reason‹ on the one hand and theories developed in observational contact with the real world on the other. [It is] the difference between the belief in prophets and critical thinking, between *Credo quia absurdum* (I believe because it is absurd -Tertullian) and *De omnibus est dubitandum* (Everything should be questioned - Descartes). To try to write a grand cosmical drama leads necessarily to myth.«

230:
»The Hartle-Hawking derivation of the unconditional probability of the existence of a universe of our sort is inconsistent with classical theism. The unconditional probability is very high, near to 1. For purposes of simplification, we are saying the probability is 99 percent; there is a 99 percent probability that a universe of our sort—I will call it a Hartle-Hawking universe – exists uncaused. […] The universe exists uncaused since the probability amplitude is determined by a summation or path integral over all possible histories of a finite universe. That is, the probability that a Hartle-Hawking universe exists follows directly from the natural-mathematical properties of possible finite universes; there is no need for a cause, probabilistic or otherwise, for there to be a 99 percent probability that a Hartle-Hawking universe will exist.«

Teil V

V.1

238:
»Through his theories of relativity, Einstein jolted our thinking about space and time and revealed the principal part they play in the evolution of the universe. Ever since, space and time have been the *sparkling jewels of physics*. They are at once familiar and mystifying; fully understanding space and time has become physics' most daunting challenge and sought-after prize.« (Hervorh. d. Verf.)

243:
»This universe that you create would in essence create its own space. It wouldn't encroach on your space by expanding into your domain, into your house, into your region. Instead, it would expand like your universe does, but expand by creating new space, space that hadn't existed before. So it would be off on its own, if you will, creating a new bubble, a new bubble universe that would be a universe in its own right.«

245:
»There is nothing in the world except empty curved space. Matter, charge, electromagnetism, and other fields are only manifestations of the curvature of space.«

246:
»If you take empty space and that means get rid of all the particles, all the radiation, absolutely everything, so there is nothing there, if that nothing weighs something, then it contributes a term like this. Now, that sounds ridiculous. Why should nothing weigh something? Nothing is nothing. The answer is nothing isn't nothing any more in physics. Because of the laws of quantum mechanics and special relativity, on extremely small scales nothing is really a boiling bubbling brew of virtual particles that are popping in and out of existence in a time scale so short you can't see them.«

252:
»[...] at contra nulli de nulla parte neque ullo tempore inane potest vacuum subsistere rei, quin, sua quod natura petit, concedere pergat [...].«

253:
»It might be inferred that I am alluding to the curvature of space supposed to exist according to the teachings of relativity, but nothing could be further from my mind. I hold that space cannot be curved, for the simple reason that it can have no properties. [...] Of properties we can only speak when dealing with matter filling the space. To say that in the presence of large bodies space becomes curved, is equivalent to stating that something can act upon nothing. I, for one, refuse to subscribe to such a view.«

V.2

265:
»...Webster defines ›a time‹ as ›a period‹, and the latter as ›a time‹, which doesn't seem to be very useful. Perhaps we should say: ›Time is what happens when nothing else happens.‹ Which also doesn't get us very far. Maybe it is just as well if we face the fact that time is one of the things we probably cannot define (in the dictionary sense), and just say that it is what we already know it to be: it is how long we wait! What really matters anyway is not how we define time, but how we measure it.«

271:
»We never really see time. We see only clocks. [...] We say we measure time with clocks, but we see only the hands of the clocks, not time itself. And the hands of a clock are a physical variable like any other. So in a sense we cheat because what we really observe are physical variables as a function of other physical variables, but we represent that as if everything is evolving in time.«

277:
»Absolute, true, and mathematical time, in and of itself and of its own nature, without reference to anything external, flows uniformly and by another name is called duration. Relative, apparent, and common time is any sensible and external measure (precise or imprecise) of duration by means of motion; such as a measure – for example, an hour, a day, a month, a year – is commonly used instead of true time.«

278:
»On the other hand, we know that time has these very bizarre properties, that it apparently can be created in the Big Bang, and if you think about black holes, time actually stops. So our concept of time might be too naïve and I'm personally very interested in whether or not we can use some of our ideas that we have seen in other areas. For instance, we have been able to make sense of space in a more significant way. Perhaps the greatest breakthrough during the last 20 years was actually by Juan Maldacena- he's here at the Institute too- who showed that in certain physical systems, space can emerge out of it naturally. The physical system doesn't have space but in certain limits, certain space comes out and relativity comes out. So there's something more fundamental than space, something more fundamental than Einstein's equations. Now you might think that this also works for time but time is always different. It has a completely different role than space. Now I can move up and down in space. I can't move up and down in time. I'm actually frozen now in a certain moment in time. I have to go through each time; I can't see my whole history at once. I can see my whole body at once, so it's a very asymmetric experience. You can try to use string theory and other theoretical ideas; you can play any of these games with time that we have been playing with space. [...] So if you think about time as a river, you can say well, how do I think if I have a river and I go upstream, upstream, upstream; it becomes less volume and at some point you know. I get a little brook and perhaps you get a few little streams, and then what do you get? A few raindrops. So at some point the whole idea of the river disappears and there's something else. Well here we know it's H2O molecules or something. So I think all these efforts are finding something--what are the molecules of time? What are the bits of time?«

V.3

281:
»Since there exists in this four dimensional structure [space-time] no longer any sections which represent ›now‹ objectively, the concepts of happening and becoming are indeed not completely suspended, but yet complicated. It appears therefore more natural to think of physical reality as a four dimensional existence, instead of, as hitherto, the evolution of a three dimensional existence.«

285:
»In 1988, physicist Kip Thorne of the California Institute of Technology and his collaborators made the astonishing (and risky) claim that time travel is indeed not only possible, but probable under certain conditions. They published

their claim not in an obscure ›fringe‹ journal, but in the prestigious Physical Review Letters. This marked the first time that reputable physicists, and not crackpots, were scientifically advancing a claim about changing the course of time itself.«

293:
»If one made a research grant application to work on time travel, it would be dismissed immediately. No government agency could afford to be seen to be spending public money, on anything as way out as time travel. Instead, one has to use technical terms, like *closed time like curves*, which are code for time travel.«

294:
»The paradigm of the special relativistic upheaval of the usual concept of time is the twin paradox. Let us emphasize that this striking example of time dilation proves that time travel (towards the future) is possible. As a gedanken experiment (if we neglect practicalities such as the technology needed for reaching velocities comparable to the velocity of light, the cost of the fuel and the capacity of the traveller to sustain high accelerations), it shows that a sentient being can jump, ›within a minute‹ (of his experienced time) arbitrarily far in the future, say sixty million years ahead, and see, and be part of, what (will) happen then on Earth. This is a clear way of realizing that the future ›already exists‹ (as we can experience it ›in a minute‹).«

299;
»According to the theory, if you have two exactly similar clocks, A and B, and one is moving with respect to the other, they must work at different rates, i.e. one works more slowly than the other. But the theory also requires that you cannot distinguish which clock is the ›moving‹ one; it is equally true to say that A rests while B moves and that B rests while A moves.«

300:
»The question therefore arises: how does one determine, consistently with the theory, which clock works the more slowly? Unless this question is answerable, the theory unavoidably requires that A works more slowly than B and B more slowly than A – which it requires no super-intelligence to see is impossible.«

<u>V.4</u>

303:
»There is no dynamics within space-time itself: nothing ever moves therein; nothing happens; nothing changes. [...] In particular, one does not think of particles as ›moving through‹ space-time, or as ›following along‹ their world-lines. Rather, particles are just ›in‹ space-time, once and for all, and the world-line represents, all at once the complete life history of the particle.«

304:
»At the same time I realized that such myths may be developed, and become testable; that historically speaking all--or very nearly all--scientific theories originate from myths, and that a myth may contain important anticipations of scientific theories. Examples are Empedocles' theory of evolution by trial and error, or Parmenides' myth of the unchanging block universe in which nothing ever happens and which, if we add another dimension, becomes Einstein's block universe (in which, too, nothing ever happens, since everything is, four-dimensionally speaking, determined and laid down from the beginning). I thus felt that if a theory is found to be non-scientific, or ›metaphysical‹ (as we might say), it is not thereby found to be unimportant, or insignificant, or ›meaningless‹, or ›nonsensical‹. But it cannot claim to be backed by empirical evidence in the scientific sense – although it may easily be, in some genetic sense, the ›result of observation‹.«

312:
»These arguments have not stopped many physicists, mathematicians and philosophers from embracing the block universe idea, with its static time, wholeheartedly. The mathematician Hermann Weyl describes the block universe thus: ›The objective world simply *is*, it does not *happen.*‹«

Teil VI

322:
»The principle of relativity is that the laws of physics are the same in every reference frame. That principle existed before Einstein. Einstein added one law of physics - the law of physics is that the speed of light is the speed of light, c. If you combine the two things together - that the laws of physics are the same in every reference frame, and that it's a law of physics that light moves with certain velocity, you come to the conclusion that light must move with the same velocity in every reference frame. Why? Because the principle of relativity says that the laws of physics are the same in every reference frame, and Einstein announced that it is a law of physics that light moves with a certain velocity.«

323:
»Therefore, demanding that the laws of physics are the same in all inertial frames implies that the speed of any light wave, measured in any inertial frame, must be 186,300 miles per second. This then is the entire content of the Theory of Special Relativity: the Laws of Physics are the same in any inertial frame, and, in particular, any measurement of the speed of light in any inertial frame will always give 186,300 miles per second.«

VI.1

»It is probably safe to say that all the changes of factual knowledge which have led to the relativity theory, resulting in a very great theoretical development, are completely trivial from any point of view except their relevance to the structure of a theoretical system.«

326:
»The principle of relativity according to which the laws of physical phenomena should be the same, whether for an observer fixed, or carried along in a uniform motion of translation, so that we have not and could not have any means of discerning whether or not we are carried along in such a motion.«

330:
»The symbol v, representing a presumed *nonzero* speed of relative translatory motion, in the Lorentz transformation is paradoxically deduced to be zero....A simple resolution, unwelcome to most physicists, presents itself:The Lorentz transformations are untenable.«

VI.2

333:
»Light is propagated in vacuo, relatively to any inertial reference system, with a velocity c, constant and equal for all directions, no matter whether the source emitting it is fixed or moving with respect to that system. This is shortly referred to as uniform and isotropic light propagation in any inertial system.«

334:
»The Maxwell-Lorentz equations imply that there exists (at least) one inertial frame in which the speed of light is a constant regardless of the motion of the light source. Einstein's version of the relativity principle (minus the ether) requires that, if this is true for one inertial frame, it must be true for all inertial frames. But this seems to be nonsense. How can it happen that the speed of light relative to an observer cannot be increased or decreased if that observer moves towards or away from a light beam? Einstein states that he wrestled with this problem over a lengthy period of time, to the point of despair.«

337:
»To state that the speed of light is independent of the velocity of the observer is very counterintuitive. Some people even refuse to accept this as a logically consistent possibility, but in 1905 Einstein was able to show that it is perfectly consistent if you are prepared to give up assumptions about the absolute nature of space and time.«

338:
»In the earlier but long since discarded theory of the universal ether, the independence of the light wave from the state of motion of the emitting body was readily understood… The constancy of velocity of light is today the only valid remnant of the ether concept. If at present we should speak of an ether, we would have to assign a separate ether to every frame of reference, i.e. speak e.g. of a primed and an umprimed ether. We now regard Lenard's ›Absolute ether‹ merely as a freak.«

340:
»A velocity is a ratio quantity defined as the ratio of a space interval measure as distance to a time interval measure as duration. A ratio can not be an absolute quantity because as a ratio it defines an equivalence relation. For every unique choice of a distance unit of measure, there exists a corresponding time unit, and for every unique choice of time unit there corresponds a distance unit. To say that the velocity of light is a constant is absurd because this depends upon the choice of measure units used in the definition. In physics, a ratio can never be defined as the basis for units of measurement, because it can only define an equivalence relation which has infinity of solutions. Hence, Einstein's theory of relativity is founded upon a serious blunder which contradicts the sound principles of physical measurement.«

341:
»Einstein actually, despite the word relativity, adhered to a very strict absolute. And that absolute was the speed of light. He took that to be his guiding constraint. And by sticking to it rigidly he said, ›I'll give up anything else but the

constancy of the speed of light‹. And by doing so he gave up on the absolute nature of space and time. I mean that's just much harder to let go of intuitively and a much greater violation of our common sense, but it was right. […] From this one constraint you could trace the line, not only to the relativity of space and time but the expansion of the universe; the existence of black holes; the ideal that the entire space has a shape, all of these things burgeoned from this really tight constraint.«

VI.3

362:
»Gravity makes the medium optically more dense in the vicinity of the sun than far away from it. As a result, light waves will be bent around the sun.«

363:
»Refraction of light rays is a well known optics-phenomenon. This provides an alternative explanation of bending of light near a star. When light ray, from space (near vacuum), enters the star's atmosphere (medium); the light ray bends near the star due to refraction.«

364:
»The total deviation (bending of light) is same as that predicted by the celebrated general-relativity and found experimentally correct. The approach (physics) of the present explanation, however, is altogether different and is much simpler. The new approach is based on the commonly well-known phenomenon of refraction of light [...]. The authors aim to emphasize that though refraction-phenomenon approach and general-relativity approach are in agreement as far as result is concerned but the physics of both the approaches are quite different.«

365:
»In perspective of refraction phenomenon discussed for bending of light, the so called gravitational-lensing is in fact 'real' refraction-lensing of light due to refraction through atmospheric-layer of star or galaxy (note-both star & galaxy are surrounded with cloud of gases/materials, both can cause refraction-bending of light and thus lensing).«

367:
»After investigating the proposal that the 'Tests of General Relativity' may be explained and predicted without any recourse to Einstein's theory, it has been found that this is very much the case. Many in the public domain are led to believe that Einstein and his theories of relativity are the final word on gravitational theory but, in reality, this is not the case. Einstein and his work have reached levels of reverence so much that they are held up to be automatically true, with anybody brave enough to question them being branded a scientific heretic. In fact even the words and opinions of the man who gave birth to general relativity are ignored in order to maintain the status quo of 'conventional wisdom'. It is now for others to reflect on this position and do so dispassionately with minds cleared of any previously held views which might prejudice a true examination of the position. If nothing else, science must be open minded when searching for answers to questions; if not, then truth will escape discovery!«

VI.4

371:
»My concept of dogs is inextricably linked to every dog I've ever known. It's as if I have a card catalogue of dogs I have seen, complete with pictures [...]. If I think about Great Danes, the first memory that pops into my head is Dansk, the Great Dane owned by the headmaster at my high school. The next Great Dane I visualize is Helga, who was Dansk's replacement. The next is my aunt's dog in Arizona, and my final image comes from an advertisement for Fitwell seat covers that featured that kind of dog. My memories usually appear in my imagination in strict chronological order, and the images I visualize are always specific. there is no generic, generalized Great Dane.«

372:
»The Lord's Prayer was incomprehensible until I broke it down into specific visual images. The power and the glory were represented by a semicircular rainbow and an electric tower. These childhood visual images are still triggered every time I hear the Lord's Prayer. The word ›thy will be done‹ had no meaning when I was a child, and today the meaning is still vague. Will is a hard concept to visualize. When I think about it, I imagine God throwing a lightning bolt. [...] The word ›Amen‹ at the end of the prayer was a mystery: a man at the end made no sense.«

374:
»I think in pictures. Words are like a second language to me. I translate both spoken and written words into full-color movies, complete with sound, which run like a VCR tape in my head. When somebody speaks to me, his words are instantly translated into pictures.«

379:
»[...] Scientists (including mathematicians) scored significantly higher than both humanities and social sciences students, confirming an earlier study that autistic conditions are associated with scientific skills. Within the sciences, mathematicians scored highest.«

380:
»Our recent single case studies of very high achieving mathematicians, physicists, and computer scientists with AS show that this condition need not be any obstacle to achieving the highest levels in these fields.«

386:
»I can remember the frustration of not being able to talk at age three. This caused me to throw many a tantrum. I could understand what people said to me, but I could not get my words out. [...] I can remember logically thinking to myself that I would have to scream because I had no other way to communicate. [...] One minute I was fine, and the next minute I was on the floor kicking and screaming like a crazed wildcat. I can remember the day I bit my teacher's leg. It was late in the afternoon and I was getting tired. I just lost it. But it was only after I came out of it, when I saw her bleeding leg, that I realized I had bitten her.«

423:
»Einstein, therefore, is great in the public eye partly because he has made revolutionary discoveries which cannot be translated into the common tongue. We stand in proper awe of a man whose thoughts move on heights far beyond our range, whose achievements can be measured only by the few who are able to follow his reasoning and challenge his conclusions.«

VI.5

435:
»The results of the test were claimed as a triumph for Einstein, and his worldwide fame dates from this event. Ironically enough, attempts made at later eclipses suggest that Eddington underestimated the uncertainties inherent in such a difficult observation, and even today Einstein's prediction has not been tested with the precision one would wish.«

436:
»In the South American eclipse of 1919, less than 15% of the actual measured data was used in obtaining the announced result. [...] All non-radial components of the actual measures were discarded as ›accidental errors‹. [...] The actual stellar displacements, when freed from all assumptions, do not show the slightest resemblance to the predicted Einstein deflections: they do not agree in direction, in size, or in the rate of decrease with distance from the sun. [...] The actual measured displacements, if real, can best be explained by some refractive effect of the earth's atmosphere.«

438:
»As the world knows, the prediction was confirmed within the limits of the accuracy of the observations, to general applause. Einstein became a celebrity overnight. What is not so well remembered is that the measurements in 1919 were not particularly accurate. The standard error of the measurements was roughly 30 percent, while the displacement of the images of different stars in the field near the eclipsed Sun ranged from half to twice the deflection Einstein had predicted. And later eclipse measurements have not been much better, largely because of the difficulties of making accurate measurements from the ad hoc observatories that have to be established.«

439:
»Now after laborious measurements and tedious calculations the conclusion was arrived at that Einstein was right, and this was published under sensational headlines in all newspapers. It caused a tremendous stir in the civilized world, as I have already described in another chapter. There was an Einstein craze, everybody wanted to learn what it was all about, and he became the victim of a publicity racket. I used this for my own purposes. I announced a series of three lectures in the biggest lecture-hall of the University of Einstein's theory of relativity and charged an entrance fee for my Department. It was a colossal success, the hall was crowded and a considerable sum collected. [...] The money thus earned helped us for some months, but as inflation got worse, it evaporated quickly and new means had to be found.«

450:
»There are many who would have us throw aside the well-tested theories upon which have been built the entire structure of modern scientific and mechanical development in favor of psychological speculations and fantastic dreams about the universe. [...] Whenever a new observation is made which apparently does not directly fit into the old-time theories these modern disciples of scientific unrest rush into some weird explanation involving psychological speculations as to the constitution of matter or our fundamental concepts of mathematics. [...] The fact that such a bending effect has now been measured is of great scientific importance, and the results may change some of the hitherto accepted ideas as to the density and distribution of matter near the sun, but I fail to see how such an observation can prove the existence of a fourth dimension, or can overthrow the fundamental concepts of geometry.«

451:
»Not a single one of the fundamental concepts of varying time, of warped or twisted space, of simultaneity, or of the relativity of motion is any way involved in Einstein's prediction of, or formulas for the deflection of light. The many and elaborate eclipse expeditions have, therefore, been given a fictitious importance. Their results can neither prove, nor disprove the relativity theory.«

459:
»The great majority of physical scientists, including practically all those who conduct experiments in physics and are best known to the world as leaders in science, when pressed to answer allegedly fatal criticism of the theory, confess either that they regard the theory as nonsensical but accept it because the few mathematical specialists in the subject say they should do so, or that they do not pretend to understand the subject at all, but, again, accept the theory as fully established by others and therefore a safe basis for their experiments.«

461:
»But in order for them to come back together and make the comparison, Paul must either stop at the end of the trip and make a comparison of clocks or, more simply, he has to come back, and the one who comes back must be the man who was moving, and he knowns this, because he had to turn around. When he turned around, all kinds of unusual things happened in his space ship – the rockets went off, things jammed up against one wall, and so on – while Peter felt nothing. So the way to state the rule is to say that the man who felt the accelerations, who has seen things fall against the walls, and so on, is the one who would be the younger; that is the difference between them in an ›absolute‹ sense, and it is certainly correct.«

463:
»›How could the same thing happen at different rates?‹ I asked myself. I formed the impression that speed somehow distorts clock rates, so that the time dilation was some sort of illusion – an *apparent* rather than a *real* effect. I kept wanting to ask which twin experienced real time and which was deluded. [...] I had to admit I could not visualize time running at two different rates and I took this to mean that I did not understand the theory. [...] It was then that I realized why I had been confused. So long as I could imagine the time dilation and other effects actually happening *and could work out the quantities involved*, that was all that was needed.« (Hervorh. d. Verf.)

464:
»I have no doubt that there will arise a new generation who will look with a wonder and amazement [...] at our galaxy of thinkers, men of science, popular critics, authoritative professors, and witty dramatists, who have been satisfied to waive their common sense in view of Einstein's absurdities. Then to these will succeed another generation, whose interest will be that of a detached and half-amused contemplation; and in the limbo of forgotten philosophies they may search for the cenotaph of Relativity.«

VI.6

468:
»Walking the streets of Tokyo with Hawking in his wheelchair [...] I felt as if I were taking a walk through Galilee with Jesus Christ [as] crowds of Japanese silently streamed after us, stretching out their hands to touch Hawking's wheelchair. [...] The crowds had streamed after Einstein as they streamed after Hawking seventy years later. [...] They showed exquisite choice in their heroes. [...] Somehow they understood that Einstein and Hawking were not just great scientists, but great human beings.«

470:
»[The Theory of Relativity] is a mass of errors and deceptive ideas violently opposed to the teachings of great men of science of the past and even to common sense. […] The theory wraps all these errors and fallacies and clothes them in magnificent mathematical garb which fascinates, dazzles and makes people blind to the underlying errors. The theory is like a beggar clothed in purple whom ignorant people take for a king. Its exponents are very brilliant men, but they are metaphysicists rather than scientists. Not a single one of the relativity propositions has been proved.«

Teil VII

VII.1

473:
»Newton really had *explained* the fall of an apple and the motion of the Moon with one set of laws. In doing so, he removed the mystery from the behavior of heavenly bodies, and opened the eyes of scientists to the fact that the behavior of the stars and planets – the behavior of the whole universe – might be *explained* using the same laws of physics that are derived from studies carried out in laboratories on Earth.« (Hervorh. d. Verf.)

477:
»Any sound scientific theory [...] should in my opinion be based on the most workable philosophy of science: the positivist approach put forward by Karl Popper and others. According to this way of thinking, a scientific theory is a mathematical model that *describes* and codifies the observations we make. A good theory will *describe* a large range of phenomena on the basis of a few simple postulates and will make definite predictions that can be tested.« (Hervorh. d. Verf.)

481:
»What's the best part of being a mathematician? I'm not a religious man, but it's almost like being in touch with God when you're thinking about mathematics. God is keeping secrets from us, and it's fun to try to learn some of the secrets.«

484:
»It is entirely possible, though not at all firmly established, that God used a big bang as His method of creation. You cannot affirm it as a certainty, but neither can you deny it apodictically. Because the Bible does not specify how God did it, we are left to choose the hypothesis that seems to have the best supporting material. [...] nothing in the biblical doctrine excludes the big bang.«

493:
»However, could it ever be possible to give a description of the external reality involving no baggage? If so, our description of entities in the external reality and relations between them would have to be completely abstract, forcing any words or other symbols used to denote them to be mere labels with no preconceived meanings whatsoever.«

497:
»The essential fact is that all the pictures which science now draws of nature, and which alone seem capable of according with observational facts, are mathematical pictures

498:
»The most powerful method of advance that can be suggested at present is to employ all the resources of pure mathematics in attempts to perfect and generalize the mathematical formalism that forms the existing basis of theoretical physics, and after each success in this direction, to try to interpret the new mathematical features in terms of physical entities.«

502:
»I believe that mathematical reality lies outside of us, that our function is to discover or *observe* it, and that the theorems which we prove, and which we describe grandiloquently as our ›creations‹, are simply our notes of our observations. This view has been held, in one form or another, by many philosophers of high reputation from Plato onwards, and I shall use the language which is natural to a man who holds it [...].«

VII.2

511:
»The duodecimal tables are easy to master, easier than the decimal ones; and in elementary teaching they would be so much more interesting, since young children would find more fascinating things to do with twelve rods or blocks than with ten. Anyone having these tables at command will do these calculations more than one-and-a-half times as fast in the duodecimal scale as in the decimal. This is my experience; I am certain that even more so it would be the experience of others.«

514:
»The rule-of-signs (-1) (-1) = (+1) which we set up to govern the multiplication of negative integers, is a consequence of our desire to preserve the distribution law a(b+c) = ab + ac. [...] It took a long time for mathematicians to realize that the ›Rule-of-Signs‹ together with all the other definitions governing negative integers and fractions cannot be ›proved‹. They were created by us in order to attain the freedom of operation while preserving the fundamental laws of arithmetic. [...] Even the great Euler resorted to a thoroughly unconvincing argument to show that (-1)(-1) ›must‹ be equal to +1. For, as he reasoned, it must either be +1 or –1, and cannot be –1, since –1 = (+1)(-1).«

520:
»One hundred thirty-seven is the inverse of something called the fine-structure constant. ...The most remarkable thing about this remarkable number is that it is dimension-free. ...Werner Heisenberg once proclaimed that all the quandaries of quantum mechanics would shrivel up when 137 was finally explained.«

521:
»Alpha sets the scale of nature --the size of atoms and all things made of them, the intensity and colors of light, the strength of magnetism, and the metabolic rate of life itself. It controls everything that we see. [...] In 137, apparently, science had found Nature's PIN Code.«

525:
»The discovery of Minkowski... is to be found... in the fact of his recognition that the four-dimensional space-time continuum of the theory of relativity, in its most essential formal properties, shows a pronounced relationship to the three-dimensional continuum of Euclidean geometrical space. In order to give due prominence to this relationship, however, we must replace the usual time co-ordinate t by an imaginary magnitude $\sqrt[2]{-1}\cdot ct$, proportional to it. Under these conditions, the natural laws satisfying the demands of the (special) theory of relativity assume mathematical forms, in which the time co-ordinate plays exactly the same role as the three space-coordinates.«

VII.3

529:
»This book is meant for all those people – which is pretty much everyone I know – who are curious about such exotic sounding concepts as black holes, space warps, the Big Bang, time travel and parallel universes. In writing the book I have asked myself whether complete non-experts can learn a little about some of the ideas of modern physics without feeling the urge to check that their IQ is up to the task before embarking.«

531:
»To those who do not know mathematics it is difficult to get across a real feeling as to the beauty, the deepest beauty, of nature. … If you want to learn about nature, to appreciate nature, it is necessary to understand the language that she speaks in.«

534:
»The scientist has to take 95 per cent of his subject on trust. He has to because he can't possibly do all the experiments, therefore he has to take on trust the experiments all his colleagues and predecessors have done. Whereas a mathematician doesn't have to take anything on trust. Any theorem that's proved, he doesn't believe it, really, until he goes through the proof himself, and therefore he knows his whole subject from scratch. He's absolutely 100 per cent certain of it. And that gives him an extraordinary conviction of certainty, and an arrogance that scientists don't have.«

536:
»All mathematicians live in two different worlds. They live in a crystalline world of perfect platonic forms. An ice palace. But they also live in the common world where things are transient, ambiguous, subject to vicissitudes. Mathematicians go backward and forward from one world to another. They're adults in the crystalline world, infants in the real one.«

537:
»The thing I want you especially to understand is this feeling of divine revelation. I feel that this structure was ›out there‹ all along I just couldn't see it. And now I can! This is really what keeps me in the math game-- the chance that I might glimpse some kind of secret underlying truth, some sort of message from the gods.«

549:
»At first, I believed that disorder would decrease when the universe recollapsed. This was because I thought that the universe had to return to a smooth and ordered state when it became small again. This would mean that the contracting phase would be like the time reverse of the expanding phase. People in the contracting phase would live their lives backward: they would die before they were born and get younger as the universe contracted. This idea is attractive because it would mean a nice symmetry between the expanding and contracting phases.«

554:
»Groups and individuals within the mathematics community have from time to time tried being less compulsive about details of arguments. The results have been mixed, and they have occasionally been disastrous. Yet today in certain areas there is again a trend toward basing mathematics on intuitive reasoning without proof. To some extent this is the old pattern of history being repeated by those unfamiliar with it.«

555:
»Certainly in Europe it had become clear by 1900 that a bifurcation had occurred: there were sufficiently many physicists who concentrated solely on the theoretical side of their work that one could identify two distinct communities.«

556:
»The result of the lack of predictions is that these physicists are cut off from their presumptive experimental community; they have no source of relevant physical facts to constrain and inspire their theorizing. Since progress comes from the interaction between theory and experiment, a theoretical group cannot exist long in isolation.
Indeed much of the mainstream physics community regards these developments with suspicion, because of their isolation from the so-called ›real world‹. But these physicists are not in fact isolated. They have found a new ›experimental community‹: mathematicians. It is now mathematicians who provide them with reliable new information about the structures they study. Often it is to mathematicians that they address their speculations to stimulate new ›experimental‹ work. And the great successes are new insights into mathematics, not into physics. What emerges is not a new particle but a description of representations of the ›monster‹ sporadic group using vertex operators in Kac-Moody algebras. What is produced is not a new physical field theory but a new view of polynomial invariants of knots and links in 3-manifolds using Feynman path integrals or representations of quantum groups.
These physicists are still working in the speculative and intuitive mode of theoretical physics. Many have neither training for nor interest in rigor. They are doing theoretical mathematics.
[...] the new relationship between mathematics and physics may well collapse. Physicists will go back to their traditional partners; rigorous mathematicians will be left with a mess to clean up; and mathematicians lured into a more theoretical mode by the physicists' example will be ignored as a result of the backlash.«

VII.4

562:
»The very name energy, though first used in its present sense by Dr. Thomas Young about the beginning of this century, has only come into use practically after the doctrine which defines it had [...] been raised from mere formula of mathematical dynamics to the position it now holds of a principle pervading all nature and guiding the investigator in the field of science.«

563:
»The energy has a large number of different forms, and there is a formula for each one. These are: gravitational energy, kinetic energy, heat energy, elastic energy, electrical energy, chemical energy, radiant energy, nuclear energy, mass energy.«

564:
»It is important to realize that in physics today, we have no knowledge of what energy *is.* We do not have a picture that energy comes in little blobs of a definite amount. It is not that way. However, there are formulas for calculating some numerical quantity [...]. It is an abstract thing in that it does not tell us the mechanism or the *reasons* for the various formulas.«

565:
»The law is called the *conservation of energy.* It states that there is a certain quantity, which we call energy, that does not change in the manifold changes which nature undergoes. That is a most abstract idea, because it is a mathematical principle; it says that there is a numerical quantity which does not change when something happens. It is not a description of a mechanism, or anything concrete; it is just a strange fact that we can calculate some number and when we finish watching nature go through her tricks and calculate the number again, it is the same.«

572:
»Dark energy, or the energy of nothing or empty space, is now re-emerging as the driving force in the entire universe. No one at the present time has any understanding of where this ›energy of nothing‹ comes from.«

576:
»When matter meets antimatter, both vanish, into *pure energy*. But both existed; I mean, there was a condition we'll call ›existence‹. Think of one and minus one. Together they add up to zero, nothing, nada, niente, right? Picture them together, then picture them separating – peeling apart. [...] Now you have something, you have two somethings, where once you had nothing.« (Hervorh. d. Verf.)

577:
»By matter I do not just mean all the stars, planets and other solid objects, but *everything* of substance in the Universe. This may be in the form of dust, gas, subatomic particles, even *pure energy.*« (Hervorh. d. Verf.)

578:
»It would take a civilization far more advanced than ours, unbelievably advanced, to begin to manipulate negative energy to create gateways to the past. But if you could obtain large quantities of negative energy – and that's a big ›if‹ – then you could create a time machine that apparently obeys Einstein's equation and perhaps the laws of quantum theory.

582:
»Somehow the popular notion took hold long ago that Einstein's theory of relativity, in particular his famous equation $E=mc^2$, plays some essential role in the theory of fission. Albert Einstein had a part in alerting the United States government to the possibility of building an atomic bomb, but his theory of relativity is *not required* in discussing fission. The theory of fission is what physicists call a nonrelativistic theory, meaning that relativistic effects are too small to affect the dynamics of the fission process significantly.« (Hervorh. d. Verf.)

587:
»The more important fundamental laws and facts of physical science have all been discovered, and these are now so firmly established that the possibility of their ever being supplanted in consequence of new discoveries is exceedingly remote. [...] An eminent physicist remarked that the future truths of physical science are to be looked for in the sixth place of decimals.«

VII.5

589:
»I have learnt that all our theories are not Truth itself, but resting places or stages on the way to the conquest of Truth, and that we must be contented to have obtained for the strivers after Truth such a resting place which, if it is on a mountain, permits us to view the provinces already won and those still to be conquered.«

591:
»A hypothesis is a *proposed explanation* for an observable phenomenon. [...] For a hypothesis to be put forward as a scientific hypothesis, the scientific method requires that one can test it. [...] Even though the words ›hypothesis‹ and ›theory‹ are often used synonymously in common and informal usage, a scientific hypothesis is not the same as a scientific theory.« (Hervorh. d. Verf.)

592:
»A scientific theory comprises a collection of concepts, including abstractions of observable phenomena expressed as quantifiable properties, together with rules that express relationships between observations of such concepts.«

Teil VIII

VIII.1

595:
»The object I chiefly proposed, was to discover the nature, and ascertain the properties of what is termed Radiant Heat. No part of physical science appeared so dark, so dubious and neglected.«

600:
»Lampblack, although it does not absorb quite the whole of the incident radiation, yet possesses the property of absorbing very nearly, if not quite, the same proportion of the incident radiation whatever the wave-length, and so this substance is taken as a standard.«

603:
»The simple derivation of the radiation law [...] depends on the use of assumed special materials which emit and absorb radiation only at a unique wavelength. [...] The assumption of the existence of such a material is perhaps the most questionable assumption in the proof.«

604:
»The most radically defective point, in my opinion, is the assumption on *a priori* grounds of an imaginary body which would emit but one radiation, and would absorb this radiation and no other.«

605:
»The assumption, that such a plate is possible, is, however, justified by nothing.«

607:
»These demonstrations in which imaginary bodies are employed (bodies perfectly absorptive for negligible thickness, perfectly transparent or totally reflecting bodies which neither emit nor absorb at any temperature) may be considered as far removed from ordinary experience.«

609:
»[My] remarks will show...that previous efforts at theoretical proof have not been on the right track at all, and also how little even in the simplest special cases they have been capable of making Kirchhoff's first law plausible.«

610:
»Hilbert's approach was completely free from experimental thinking. In contrast to the experimentally influenced ways of reasoning of earlier theorists, he set up a general manifold of possible situations and solutions and then imposed conditions (here of light propagation and equilibrium) that provided the solution. Mathematical necessity played the central role, not a mechanism, nor a conceived sequence of experimental actions.«

611:
»Kirchhoff's law of thermal emission, through its claims of the universal nature of radiation within enclosures, represents one of the most profound dismissals of experimental science in the history of physics.«

613:
»Kirchhoff's orientation was, to a great extent, that of a theoretical physicist, and for him theory had a life and an integrity of its own.«

614:
»His teaching had a considerable influence on the development in Germany of a flourishing school of theoretical physics during the first three decades of the twentieth century.«

626:
»Browsing through the literature, one may find an occasional use of Kirchhoff's law in some experimental physics, but the only place where it is treated at all seriously today is in the astrophysical literature.«

VIII.2

630:
»›Let us worry about beauty first and truth will take care of itself!‹ Such is the rallying cry of fundamental physicists. Some physics equations are so ugly we cannot bear to look at them, let alone write them down. Certainly, the Ultimate Designer would use only beautiful equations in designing the universe, we proclaim.«

631:
»What I remember most clearly was that when I put down a suggestion that seemed to me cogent and reasonable, Einstein did not in the least contest this, but he only said, ›Oh, how ugly.‹ As soon as an equation seemed to him to be ugly, he really rather lost interest in it and could not understand why somebody else was willing to spend much time on it. He was quite convinced that beauty was a guiding principle in the search for important results in theoretical physics.«

VIII.3

648:
»Einstein's photoelectric equation played an enormous part in the development of the modern quantum theory. But in spite of its generality and of the many successful applications that have been made of it in physical theories, [it] is [...] based on a concept of radiation - the concept of ›light quanta‹ - completely at variance with the most fundamental concepts of the classical electromagnetic theory of radiation.«

652:
»I fear that your hatred of the zero-point energy extends to the electrodynamic emission hypothesis that I introduced and that leads to it. But what's to be done? For my part, I hate discontinuity of energy even more than discontinuity of emission.«

657:
»I have almost completed an improved formulation of the quantum hypothesis applied to thermal radiation. I am more convinced than ever that zero-point energy is an indispensable element. Indeed, I believe I have the strongest evidence for it.«

658:
»I have also found that the velocity is independent of the ultraviolet light intensity, and thus concluded that the energy at escape does not come from the light at all, but from the interior of the particular atom. The light only has an initiating action, rather like that of the fuse in firing a loaded gun. I find this conclusion important since from it we learn that not only the atoms of radium [...] contain reserves of energy, but also the atoms of the other elements; these too are capable of emitting radiation.«

659:
»A misconception which most physicists acquire in their formative years is that the photoelectric effect requires the quantization of the electromagnetic field for its explanation. [...] It is an historical accident that the photon concept should have acquired its strongest early support from Einstein's considerations on the photoelectric effect.[...]
once granted the existence of atoms, we shall see that all of the experimental photoelectric phenomena are described by a theory in which the electromagnetic field is treated classically while only the matter is treated quantum mechanically.«

660:
»We understand the photoeffect as being the result of a classical field falling on a quantized atomic electron. The introduction of the photon concept is neither logically implied by nor necessary for the explanation of the photoelectric effect.«

661:
»It should be apparent from the title of this article that the author does not like the use of the word ›photon‹. In his view, there is no such thing as a photon. Only a comedy of errors and historical accidents led to its popularity among physicists and optical scientists. I admit that the word is short and convenient. Its use is also habit forming. [...] It is high time to give up the use of the word ›photon‹, and of a bad concept which will shortly be a century old. Radiation does not consist of particles.«

XIII.4

667:
»In the treatment of atomic problems, actual calculations are most conveniently carried out with the help of a Schroedinger state function, from which the statistical laws governing observations obtainable under specified conditions can be deduced by definite mathematical operations. It must be recognized, however, that we are dealing here with a purely symbolic procedure, the unambiguous physical interpretation of which in the last resort requires reference to the complete experimental arrangement.«

669:
»There was a time when we wanted to be told what an electron is. The question was never answered. No familiar conceptions can be woven around the electron; it belongs to the waiting list.«

672:
»But it is necessary to insist more strongly than usual that what I am putting before you is a model—the Bohr model atom—because later I shall take you to a profounder level of representation in which the electron instead of being confined to a particular locality is distributed in a sort of probability haze all over the atom.«

674:
»The wave quality of light is the same as that of the electron. The wave determines the probable location of the photon of light when it is detected. The wave character of light is not vibrating stuff like a wave of water but rather a wavelike function encoding information about where you'll find the photon of light once it is detected. Until it reaches the detector plate, like the electron, it is seemingly passing through both slits simultaneously, making its mind up about its location only once it is observed [...].
It's this act of observation that is such a strange feature of quantum physics. Until I ask the detector to pick up where the electron is, the particle should be thought of as probabilistically distributed over space, with a probability described by a mathematical function that has wavelike characteristics. The effect of the two slits on this mathematical wave function alters it in such a way that the electron is forbidden from being located at some points on the detector plate. But when the particle is observed, the die is cast, probabilities disappear, and the particle must decide on a location.«

677:
»The concept of a particle, e.g. a grain of sand, implicitly contains the idea that it is in a definite position and has definite motion. But according to quantum mechanics it is impossible to determine simultaneously with any desired accuracy both position and velocity.«

680:
»The very small quantum world, it seems, is a mixture of possibilities. The quantum fields to which all particles belong are the sum of these possibilities and, somehow, one possibility is chosen out of all the existing ones just by seeing it, just by the very act of detecting it, whenever one tries to probe a particle's nature. Nobody knows why or how this happens.«

681:
»One of the most curious consequences of quantum physics is that a particle like an electron can seemingly be in more than one place at the same time until it is observed, at which point there seems to be a random choice made about where the particle is really located. Scientists currently believe that this randomness is genuine, not just caused by a lack of information. Repeat the experiment under the same conditions and you may get a different answer each time.«

686:
»Physicists speak of the particle representation or the wave representation. Bohr's principle of complementarity asserts that there exist complementary properties of the same object of knowledge, one of which if known will exclude knowledge of the other. We may therefore describe an object like an electron in ways which are mutually exclusive—

e.g., as wave or particle—without logical contradiction provided we also realize that the experimental arrangements that determine these descriptions are similarly mutually exclusive. Which experiment—and hence which description one chooses—is purely a matter of human choice.«

687:
»Heisenberg's uncertainty relation measures the amount by which the complementary descriptions of the electron, or other fundamental entities, overlap. Position is very much a particle property - particles can be located precisely. Waves, on the other hand, have no precise location, but they do have momentum. The more you know about the wave aspect of reality, the less you know about the particle, and vice versa. Experiments designed to detect particles always detect particles; experiments designed to detect waves always detect waves. No experiment shows the electron behaving like a wave and a particle at the same time.«

688:
»Bohr's principle of complementarity is the most revolutionary scientific concept of this century and the heart of his fifty-year search for the full significance of the quantum idea.«

690:
»No mathematician should ever allow him to forget that mathematics, more than any other art or science, is a young man's game. [...] Galois died at twenty one, Abel at twenty-seven, Ramanujan at thirty-three, Riemann at forty. There have been men who have done great work later; [...] [but] I do not know of a single instance of a major mathematical advance initiated by a man past fifty. [...] A mathematician may still be competent enough at sixty, but it is useless to expect him to have original ideas.«

692:
»I wish to have a quite definite picture of any phenomenon. An electron, for me, is a particle which is at a given point in space at a given time. If the electron collides with an atom, penetrates it and after numerous adventures leaves it, then I visualize a certain line along which the electron travelled in the atom.«

693:
»I have lost the conviction that my research was leading to the objective truth and I do not know what I have lived for. My only regret is that I did not die five years back when everything still seemed clear to me.«

694:
»How wonderful that we have met with a paradox. Now we have some hope of making progress.«

695:
»One cannot, damn it, reduce the whole of philosophy to a screen with two holes.«

696:
»Heisenberg: If the inner structure of the atom is as closed to descriptive accounts as you say, if we really lack a language for dealing with it, how can we ever hope to understand atoms? Bohr: We may have to learn what the word ›understanding‹ really means.«

701:
»[T]he atoms or elementary particles themselves are not real; they form a world of potentialities or possibilities rather than one of things or facts.«

702:
»The atom of modern physics can only be symbolized by a partial differential equation in an abstract multidimensional space.«

703:
»But it is necessary to insist more strongly than usual that what I am putting before you is a model—the Bohr model atom—because later I shall take you to a profounder level of representation in which the electron instead of being confined to a particular locality is distributed in a sort of probability haze all over the atom.«

705:
»In the world of the very small, where particle and wave aspects of reality are equally significant, things do not behave in any way that we can understand from our experience of the everyday world...all pictures are false, and there is no physical analogy we can make to understand what goes on inside atoms. Atoms behave like atoms, nothing else.«

714:
»The difficulty really is psychological and exists in the perpetual torment that results from your saying to yourself, ›But how can it be like that?‹ which is a reflection of uncontrolled but utterly vain desire to see it in terms of something familiar. [...] If you will simply admit that maybe [Nature] does behave like this, you will find her a delightful, entrancing thing. Do not keep saying to yourself, if you can possible avoid it, ›But how can it be like that?‹ because you will get ›down the drain‹, into a blind alley from which nobody has escaped. Nobody knows how it can be like that.«

715:
»After making his groundbreaking discoveries in quantum physics, Werner Heisenberg recalled, ›I repeated to myself again and again the question: Can nature possibly be so absurd as it seemed to us in these atomic experiments?‹ Einstein declared after one discovery, ›If it is correct it signifies the end of science.‹ Schrödinger was so shocked by the implications of what he’d cooked up that he admitted, ›I do not like it and I am sorry I had anything to do with it.‹ Nevertheless, quantum physics is now one of the most powerful and well-tested pieces of science on the books. Nothing has come close to pushing it off its pedestal as one of the great scientific achievements of the last century. So there is nothing to do but to dive headfirst into this uncertain world.«

716:
»There is no quantum world. There is only an abstract physical description. It is wrong to think that the task of physics is to find out how nature is. Physics concerns what we can say about nature.«

VIII.5

717:
»The trajectory of a simple molecule of air or vapour is regulated in a manner as certain as that of the planetary orbits; the only difference between them is that which is contributed by our ignorance. Probability is relative in part to this ignorance and in part to our knowledge.«

719:
»The ideas of probability are certainly useful in describing the behavior of the 1022 or so molecules in a sample of a gas, for it is clearly impractical even to attempt to write down the position or velocity of each molecule. When probability was first applied to such problems, it was considered to be a convenience – a way of dealing with very complex situations.«

721:
»We now believe that the ideas of probability are *essential* to a description of atomic happenings. According to quantum mechanics, the mathematical theory of particles, there is always some uncertainty in the specification of positions and velocities.«

722:
»The universe, according to quantum mechanics, participates in a game of chance. Although there is still controversy over precisely how these developments should be interpreted, most physicists agree that probability is deeply woven into the fabric of quantum reality. Whereas human intuition, and its embodiment in classical physics, envision a reality in which things are always definitely one way *or* another, quantum mechanics describes a reality in which things sometimes hover in a haze of being partly one way *and* partly another.«

733:
»All the choir of heavens and furniture of earth, in a word all those bodies which compose the mighty frame of the world, have not any substance without the mind. [...] So long as they are not actually perceived by me, or do not exist in my mind, or that of any other created spirit, they must either have no existence at all, or else subsist in the mind of some Eternal Spirit.«

743:
»The idea that the thermodynamic arrow of time arose from a gigantic fluctuation leads to an amusing form of solipsism. From the standpoint of entropy, I, sitting at my keyboard typing these lines, am a pretty big fluctuation. A tree that I remember seeing is also a big fluctuation. It would be a smaller fluctuation, entropy-wise, not to have the tree, but to change my brain slightly and create the memory of that tree. Therefore, in terms of likely or unlikely fluctuations it would be far more likely that the tree doesn’t exist. You, reading this, should similarly doubt the existence of the writer.«

744:
»The logical conclusion of this line of reasoning is utterly solipsistic. The most likely fluctuation consistent with everything you know is simply your brain (complete with ›memories‹ of the Hubble Deep fields, WMAP data, etc.) fluctuating briefly out of chaos and then immediately equilibrating back into chaos again.«

745:
»dS space is a thermal system. In such a system people, planets, and galaxies can appear from dS space due to thermal fluctuations, without passing through the usual stage of the big bang evolution.«

747:
»In a long-lived vacuum with positive cosmological constant, structure can form in two ways. Structure can form in the conventional way (through a period of inflation followed by reheating), or it can form spontaneously as a rare thermal fluctuation. Because de Sitter space is thermal, if the vacuum is sufficiently long-lived spontaneous structure formation will occur. […] The overwhelming majority of observers arise from quantum fluctuations and not by conventional evolution. […] Most observers are isolated brains which fluctuate from the vacuum in the absence of any other structure.«

748:
»Such an examination seems especially timely because of recent discussions drawing conclusions from the possible existence (in a very large universe) of vacuum fluctuated brains (also known as ›Boltzmann brains‹ or ›freak observers‹). Astounding conclusions have been drawn using arguments that involve these possibilities, that the universe must be limited in time and space in order to avoid having too many fluctuated brains that would make human observers untypical.«

749:
»Even if the probability of spontaneous creation of an observer in the future is incredibly small, an infinite fraction of observers will live in the future because the total volume where they can materialize is infinite. Why then did we appear after inflation instead of being created later? Why are we so *atypical*? […] One way to avoid this paradox is to assume that the universe in the future is not expanding exponentially because its decay rate is faster than the rate of the doubling of its volume. This suggests that our universe is going to die in about 10^{10} years.«

750:
»Observations that we are highly unlikely to be vacuum fluctuations suggest that our universe is decaying at a rate faster than the asymptotic volume growth rate, in order that there not be too many observers produced by vacuum fluctuations to make our observations highly atypical.«

751:
»To make predictions for an eternally inflating ›multiverse‹, one must adopt a procedure for regulating its divergent spacetime volume. Recently, a new test of such spacetime measures has emerged: normal observers — who evolve in pocket universes cooling from hot big bang conditions — must not be vastly outnumbered by ›Boltzmann brains‹ — freak observers that pop in and out of existence as a result of rare quantum fluctuations. If the Boltzmann brains prevail, then a randomly chosen observer would be overwhelmingly likely to be surrounded by an empty world, where all but vacuum energy has redshifted away, rather than the rich structure that we observe. Using the scale-factor cutoff measure, we calculate the ratio of Boltzmann brains to normal observers. We find the ratio to be finite, and give an expression for it in terms of Boltzmann brain nucleation rates and vacuum decay rates. We discuss the conditions that these rates must obey for the ratio to be acceptable, and we discuss estimates of the rates under a variety of assumptions.«

Teil IX

IX.1

760:
»Down-conversion is a process in which one ultraviolet photon converts into two photons inside a nonlinear crystal. This process allows one to construct ›two-particle interferometers‹ that entangle the two photons in a way that needn't involve polarization at all. Many experimental groups independently came up with this idea, but the first explicit proposal was made by two of us.«

762:
»And although Bohr was normally most considerate and friendly in his dealings with people, he now struck me as an almost remorseless fanatic, one who was not prepared to make the least concession or grant that he could ever be mistaken.«

763:
»PDC occurs when a beam of coherent light from a laser, often referred to as the pump, is incident on a nonlinear optical crystal. A rainbow emerges from the crystal, each frequency, or colour, being emitted in a certain direction.

More specifically, if the pump frequency is ω_0, then the PDC rainbow contains all frequencies less than ω_0, and the angle at which a given frequency ω emerges depends on ω and ω_0. For example, if the pump's wavelength is 300nm, which is in the near ultraviolet, and the crystal is potassium dihydrogen phosphate (KDP), then the down converted light at 450nm, which is blue, will be at an angle of 8.2 degrees to the pump, while that at 600nm (yellow) will be at 10.5 degrees, and that at 900nm (near infrared) at 16.6 degrees.«

765:
»A 4 mm thick -BBO crystal is pumped by 50 fs laser pulses and rotated around the optical *Z* axis, and the SPUC from 480 to 520 nm and the SPDC from 530 to 600 nm have been alternately observed. The experimental and theoretical results indicate that SPUC is directly generated by the sum frequency of the quantum noise and the fundamental laser pulses.«

770:
»The weakness of the quantum theory case is known to those in the field – one sees occasional references in the literature to ›loopholes‹. These, as it turns out, are the key to the realist solutions. Faith in the universal success of quantum theory leads editors, referees and the experimenters to believe that they will eventually be closed, and that meantime science is best served by choosing the quantum theory interpretation of the results. But in my view they are perpetuating a myth, one that is undermining science by the introduction of magic.«

771:
»If light is a purely wave phenomenon, it is possible for photodetectors to respond nonlinearly to intensity. This, as is clear from the structure of the basic realist prediction, can cause high coincidence curve visibilities and associated infringements of Bell tests.«

773:
»Some of the assumptions allow them to use tests that are, in my view, completely invalid. The best known is concerned with the so-called ›detection loophole‹, and this is generally mentioned, though in rather a casual manner. But there is another, often of great numerical importance, that is made regularly and yet never mentioned at all. It is that of the independence of the emission events, and it is used to justify a data adjustment—the ›subtraction of accidentals‹ – that, in almost all cases, forces their test statistic up and over its limit. The subtraction changes results that can be explained realistically into ones that require quantum magic. There is no mention in published papers of the assumptions behind the adjustment, and insufficient information given for the reader to work out what the unadjusted data was.«

775:
»Of course, minute as its impact may be in our physical universe, the fact of quantum entanglement is this: If one logically inexplicable thing is known to exist, then this permits the existence of all logically inexplicable things.«

IX.2

784:
»This is to find the heating effect of the *ß*-rays from radium E. If the energy of every disintegration is the same then the heating effect should be between 0.8 and $1{,}0 \cdot 10^6$ volts per atom. [...] It is at least equally likely that the heating effect will be nearer $0.3 \cdot 10^6$ volts per atom, that is, will be just the mean kinetic energy of the disintegration electrons.«

785:
»[...] by taking special precautions it has been possible to show that the average energy emitted at each disintegration of radium E is 340,000 ± 30,000 volts. This result is a striking confirmation of the hypothesis that the continuous spectrum is emitted as such from the nucleus, since the average energy of the particles [...] gives a value about 390,000 volts, whereas if the energy emitted per disintegration were equal to that of the fastest b-rays, the corresponding value of the heating would be three times as large, in fact, 1,050,000 volts.«

793:
»Just now nuclear physicists are writing a great deal about hypothetical particles called neutrinos supposed to account for certain peculiar facts observed in ß-ray disintegration. We can perhaps best describe the neutrinos as little bits of spin-energy that have got detached. I am not much impressed by the neutrino theory. In an ordinary way I might say that I do not believe in neutrinos.«

794:
»To account for the extra energy loss, Klarmann and Bothe and Champion have suggested the emission of neutrinos as well as x-rays. To test this hypothesis, a 2-Mev beam of electrons was directed on a target immersed in

mercury, the assembly acting as a calorimeter. Experiments using beryllium, gold, and mercury targets show that within the experimental error, which is somewhat less than one percent, *no energy is carried out of the calorimeter by neutrinos or other penetrating radiation*.« (Hervorh. d. Verf.)

IX.3

804:
»Forces don't happen because of any sort of action at a distance, they happen because of virtual particles that spew out of things and hit other things, knocking them around. However, this is misleading. Virtual particles are really not just like classical bullets.«

805:
»Suppose that we are trying to calculate the probability that some amount of momentum, p, gets transferred between a couple of particles that are fairly well- localized. The uncertainty principle says that definite momentum is associated with a huge uncertainty in position. A virtual particle with momentum p corresponds to a plane wave filling all of space, with no definite position at all. It doesn't matter which way the momentum points; that just determines how the wavefronts are oriented. Since the wave is everywhere, the photon can be created by one particle and absorbed by the other, no matter where they are. If the momentum transferred by the wave points in the direction from the receiving particle to the emitting one, the effect is that of an attractive force.«

806:
»The virtual photon's plane wave is seemingly created everywhere in space at once, and destroyed all at once. Therefore, the interaction can happen no matter how far the interacting particles are from each other.[...] the virtual photon can go from one interacting particle to the other faster than light! [...] This ›superluminal‹ propagation had better not transmit any information if we are to retain the principle of causality.«

807:
»In quantum mechanics, the future quantum state of a system can be derived by applying the rules for time evolution to its present quantum state. No measurement I make when I ›receive‹ the particle can tell me whether you've ›sent‹ it or not, because in one frame that hasn't happened yet! Since my present state must be derivable from past events, if I have your message, I must have gotten it by other means. The virtual particle didn't ›transmit‹ any information that I didn't have already; it is useless as a means of faster-than-light communication. The order of events does not vary in different frames if the transmission is at the speed of light or slower. Then, the use of virtual particles as a communication channel is completely consistent with quantum mechanics and relativity. That's fortunate: since all particle interactions occur over a finite time interval, in a sense all particles are virtual to some extent.«

808:
»It isn't classically possible for a charged particle to just emit a photon and remain unchanged itself. The state with the photon in it has too much energy, assuming conservation of momentum. However, since the intermediate state lasts only a short time, the state's energy becomes uncertain, and it can actually have the same energy as the initial and final states. This allows the system to pass through this state with some probability without violating energy conservation.
Some descriptions of this phenomenon instead say that the energy of the system becomes uncertain for a short period of time, that energy is somehow ›borrowed‹ for a brief interval. This is just another way of talking about the same mathematics.«

810:
»Some kind of information mediator between two particles is needed. [...] We call them force carriers or ›exchange particles‹. The (hypothetical) force carrier of gravity is called ›graviton‹. It has not yet been observed.«

811:
»We do not know, but physicists believe that because gravity is a force that shares many technical similarities to the other three natural forces, it must also have a quantum particle that mediates it, and this is called the graviton. It is very unlikely we will ever detect individual gravitons because they interact about 1040 times weaker than the electromagnetic force produced by photons.«

812:
»The gravitational force between the sun and the earth is ascribed to the exchange of gravitons between the particles that make up these two bodies. Although the exchanged particles are virtual, they certainly do produce a measurable effect – they make the earth orbit the sun!«

813:
»You don't have to accept that gravity is a ›force‹ in order to believe that gravitons might exist. According to QM, anything that behaves like a harmonic oscillator has discrete energy levels. General relativity allows gravitational waves, ripples in the geometry of spacetime which travel at the speed of light. Under a certain definition of gravitational energy (a tricky subject), the wave can be said to carry energy. If QM is ever successfully applied to GR, it seems sensible to expect that these oscillations will also possess discrete ›gravitational energies‹, corresponding to different numbers of gravitons.«

815:
»The best description of what happens in quantum field theory is that the exchanged particle carries negative momentum - not an easy thing to visualize. The exchanged gauge bosons are in fact all virtual particles, can never be directly observed, and ›borrow‹ momentum from the quantum field, subject only to the limitations of the Heisenberg Uncertainty relation.«

817:
»All I have to do is include situations in which the photon is emitted in the future and goes ›backward in time‹, and take its momentum to be minus what it really is! As long as I remember what's really going on, this trick is formally OK and saves a lot of trouble; it was introduced by Richard Feynman.«

818:
»Since the forward-going transfer represents a repulsive force, and it is cancelled out by the backward-going transfer, it must be the case that the latter represents an attractive force. This is the same as saying that the momentum of a photon propagating in the negative t direction is negative, which is consistent with what we would calculate for the momentum of a massive particle going backward in time.«

819:
»Quantum particles do not behave like tennis balls, but like the quantum particles they are. To get from one place to another, they take *all* the possible paths in space and time as long as these paths link their starting point to their end point. The particle [...] literally went everywhere. Simultaneously. To the left and to the right of the post. And through it. And outside the room. And into the future and back - until the moment when it hit a detector on the wall.«

820:
»The vacuum is capable of producing interactions between particles at effectively space like separations. This occurs when quantum fluctuations in the vacuum cause a particle to zigzag backward and forward through space-time. Let me explain. No doubt the idea of motion backward in time makes a grievous assault on common sense. The world just does not seem to operate that way, as our ever-aging bodies testify. However, to a particle physicist [...], motion backward in time is not all that disturbing. All fundamental particle interactions work backward as well as forward and, with rare exceptions, do not distinguish between directions of time.«

821:
»Physicists often say, and laypersons' books repeat, that the two electrons *exchange virtual photons*. But those are just words, and they lead to many confusions if you start imagining this word ›exchange‹ as meaning that the electrons are tossing photons back and forth as two children might toss a ball. It's not hard to imagine that throwing balls back and forth might generate a repulsion, but how could it generate an attractive force? The problem here is that the intuition that arises from the word ›exchange‹ simply has too many flaws. To really understand this you need a small amount of math, but zero math is unfortunately not enough. It is better, I think, for the layperson to understand that the electromagnetic field is disturbed in some way, ignore the term ›virtual photons‹ which actually is more confusing than enlightening, and trust that *a calculation has to be done* to figure out how the disturbance produced by the two electrons leads to their being repelled from one another, while the disturbance between an electron and a positron is different enough to cause attraction.«

IX.4

829:
»In 1954, shortly after [James] Gordon and I built a second maser and showed that the frequency of its microwave radiation was indeed remarkably pure, I visited Denmark and saw Niels Bohr, the great physicist and pioneer in the development of quantum dynamics. As we were walking along the street together, he quite naturally asked what I was doing. I described the maser and its performance. ›But that is not possible!‹ he exclaimed. I assured him it was. Similarly, at a cocktail party in Princeton, New Jersey, the Hungarian mathematician John von Neumann asked what I was working on. After I told him about the maser and the purity of its frequency, he declared, ›That can't be right!‹ But it was, I replied, telling him it had already been demonstrated. Such protests were not offhand

opinions about obscure aspects of physics; they came from the marrow of these men's bones. These were objections founded on principle – the uncertainty principle.«

IX.5

838:
»Then, in the closing months of the century, Professor Max Planck of Berlin brought forward a tentative explanation of certain phenomena of radiation which had so far completely defied interpretation. Not only was his explanation non-mechanical in its nature; it seemed impossible to connect it up with any mechanical line of thought. Largely for this reason, it was criticised, attacked and even ridiculed. But it proved brilliantly successful, and ultimately developed into the modern ›quantum theory‹, which forms one of the great dominating principles of modern physics. Also, although this was not apparent at the time, it marked the end of the mechanical age in science, and the opening of a new era.«

839:
»The lesson to be learned from what I have told of the origin of quantum mechanics is that probable refinements of mathematical methods will not suffice to produce a satisfactory theory, but that somewhere in our doctrine is hidden a concept, unjustified by experience, which we must eliminate to open up the road.«

840:
»Physics stands at a grave crisis of ideas. In the face of this crisis, many maintain that no objective picture of reality is possible. However, the optimists among us (of whom I consider myself one) look upon this view as a philosophical extravagance born of despair. We hope that the present fluctuations of thinking are only indications of an upheaval of old beliefs which in the end will lead to something better than the mess of formulas that today surrounds our subject.«

Am Ende

841:
»The history of science shows that the progress of science has constantly been hampered by the tyrannical influence of certain conceptions that finally come to be considered as dogma. For this reason, it is proper to submit periodically to a very searching examination of principles that we have come to assume without discussion.«

846:
»It is impossible that the Big Bang is wrong. We may have to make it more complicated to cover the observations, but it is hard to think of anything that could refute the theory itself.«

854:
»From our home on the Earth, we look out into the distances and strive to imagine the sort of world into which we are born. [...] The search will continue. The urge is older than history. It is not satisfied and it will not be suppressed.«