A DUTCH UNCLE TIRADE ABOUT RELATIVITY MATTERS

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Abstract: This tirade is directed at the establishment for having silently accepted a situation that in effect has emasculated the principle of general covariance and at the Galileans for having taken negative establishment attitudes too seriously. A refinement and further development of the principle of general covariance resolve many problems of the Galileans as well as the establishment predicament of failing to reconcile quantum theory and relativity. Seeds for these developments were sown long ago in the Twenties and in the Thirties. They are here presented to be preserved for posterity. Yet, they come with a Dutch Uncle warning: There is no gain without the strain of exploring the interaction of new mathematical and physical concepts. Earlier this century mathematics made a transition from local to global points of views. This transition culminated in the work of de Rham, for whom electromagnetism has been a source of inspiration. Physics can now take advantage of these developments and find itself rewarded with new insight.

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1. Introductory Remarks

Over the years contributors to Galilean Electrodynamics have been focusing on contradictory aspects of what is normally referred to as the special theory of relativity (STR). Since we live in a less than perfect world, no theory, no matter how well established, can be expected to be free of blemishes. The "raison d'être" for any new theory should be that it resolves more contradictions than it creates. Its figure of merit might be taken to be the ratio of contradictions of the new theory over the contradictions of the old theory. The closer this ratio gets to zero the better the theory. Does STR meet that condition? Many contributors of Galilean Electrodynamics hold opinions that STR has a Figure of Merit considerably greater than one. These opinions may be expected to have a measure of subjectiveness that changes with the eye of the beholder.

Since past efforts at resolving these conceptual difficulties on a one by one basis have not led to all-round satisfaction, it was believed that the present effort should instead be looking at a possibly common origin of some of those remaining stumbling blocks.

Major causes of conflict occur when people single out isolated philosophical principles and use them at the exclusion of others. There is a famous example, the after effects of which are still present today. It took place in the olden days, when the Greek rationalists ridiculed work of the empiricists. In doing so they may have held back experimental research until the Galilean breakthrough. Kant was one of the first philosophers to point out limitations of an exclusive use of methods of pure reason.

One would have thought that man might have learned from these earlier experiences. The truth is, these conflicts reoccur on all sorts of different levels. Almost throughout the nineteenth century a conflict lingered on between those who believed that atoms and molecules, such as used in chemistry, were realistic physical entities, opposed by those who felt that atoms and molecules could at best claim the status of very successful work hypotheses. Even Mach, credited by Einstein for much relativity inspiration, was known to belong to the latter category. Ironically later, Einstein's work on Brownian motion would swing the balance in favor of real atoms and molecules.

In mathematics a formalist-intuitionist conflict developed into a crisis during the Twenties of this century. The truth may well be found somewhere in the middle by making the observation that formalists have been known using intuitive arguments and intuitionists have been known using formal arguments. However, this rather emotional episode in the history of mathematics helped create greater awareness needed for probing the limits of new principles. Problems arise mostly when people become monomaniacal about one and the same method.

Nineteenth century physics witnessed an emerging Maxwell theory as a manifestation of a rationalism using new mathemafics. It was seeking to exhaust the consequences of new empirical findings in the realm of electromagnetism. It became a triumph of a new joint rational empirical effort, commonly referred to as phenomenology. Note how the old conflict between rationalists and empiricists had grown into a happy union of joint endeavor such as now manifest in the methods of phenomenology.

Twentieth century physics has placed for its conceptualization an emphasis on Heisenberg's idea of physical observables. Bridgman's operationalism can be regarded as pursuing a similar course of action. Einstein did not like that approach, he feared too many disconnects with classical physics. Supposedly he referred to Copenhagen's abundance of conceptually new nonclassical injections as an epistemic orgy. Today we would call it an ontic orgy, because ontics represents short range ad hoc solutions. Only a logical interrelation revealing the origin of ontic solutions approaches the goal of a true epistemology.

Before we pass judgment on Einstein's creation of STR it is important to take cognizance of his varied activities in other areas, because they testify to his conscientious efforts in maintaining a strong logical relation with classical physics.

2. Early Symptoms of Spacetine Description

In fairness to the prime instigators of all these relativity ventures, let it be known that Einstein himself was dissatisfied with the state of STR. That is exactly why he kept looking for a sequel, which in time became known as the **general** theory of relativity (GTR). It took a decade to bring this endeavor to fruition. A final coherent presentation of these matters turned out to be contingent on a very incisive change in fundamental assumptions. The Galilei, Newton and Minkowski image of a uniformly (infinitely) extended Euclidian-type spacetime now needed to be abandoned to be replaced by a nonuniform Riemannian spacetime. The latter permitted more realistic thoughts about global structure. Hubble's discovery of receding galaxies soon invited cosmologists to make assertions about that global spacetime structure.

A major reason for this one decade time interval was the new realm of mathematics Einstein had to explore. This new realm enabled him to step out of the confines of the Lorentz- and Galilei frames of reference. In the pursuit of this goal he consulted with a number of mathematical colleagues to inform himself about the general features of transformation theory. The study of the ensuing differential invariants and their implications for the concepts of Riemannian geometry had to be mastered prior to any new physics adventures. Later Einstein would refer to these mathematical requirements and their conceptual bearing on physics as the principle of general covariance (PGC).

The colleagues, who helped him along in the convoluted realm of differential invariants, comitants and concomitants must have been rather amazed by the sudden ambitions of this kind and friendly physicist, who was already pushing middle-age. In fact, some of them had critical remarks about limitations of his mathematical ability and knowledge. It shows how even at the frontiers of science, people have trouble escaping that wretched teacher's syndrome of prematurely grading capabilities of pupils. In defense of those teachers, let it also be said that some later frankly admitted that he surprised them. They never expected him to do those rather unusual things with their teachings. In fact Minkowski[1] took up Einstein's cause with a vengeance and contributed very essential spacetime perspectives. He was the one who first explicitly defined the concept of a spacetime metric, which later became a key element of the GTR.

Whittaker[2] mentions how Hargreaves earlier noted features of physical description that were inviting spacetime description as a propre companion of space description with an unchanging time. One could argue that the implicit signs of spacetime description go back to Legendre and Hamilton. The

Hamilton equations of motion are the integrability conditions of the spacetime differential form of action $Hdt-p_\lambda dq^\lambda$.

Lagrange should be credited for having identified geodetic line features of the equations of motion. The extended invariance properties of the Lagrangean and Hamiltonian methods have in many ways paved the road for a natural transition to relativity.

3. Early Reactions to the General Theory

What were the first reactions just after the first publications of the general theory of relativity (GTR) and the prediction of its three crucial effects? Even before Eddington's expedition had confirmed the predicted bending of light rays in strong gravitational fields, criticism of the principle of general covariance (PGC) by Kretschmann[3] led to a deemphasis of the physical implications of PGC.

Einstein[4] acknowledged Kretschmann's observations as relevant. Unlike Lorentz' transformation, the realm of general transformations (Diffeo-4)* did not have immediate physical implications. Yet, he maintained that, by contrast, the indirect implications were plenty and overwhelming. In fact, as far as Einstein was concerned, he would have never been able to formulate GTR if it had not been for the PGC. Bridgman,[5] a pioneer of the operationalist point of view later capitalized on the concession part of Einstein's response. A structurally creative role of the PGC in bringing about the GTR apparently did not fit an operationalism, as it was seen by Bridgman.

The laboratory observed gravity and acceleration red shifts, as measured with the help of the Mössbauer effect,[6] may serve, among many others, as evidence that GTR and its seminal PGR principle have led to consequences of operational significance. Bridgman did not have to conceive GTR, he could afford to play down its mathematical entourage. It is now not hard to anticipate the upshot of this Kretschmann-Bridgman episode for the future setting of teaching GTR.

Just open up any book on GTR and one finds in reference to Kretschmann and Bridgman an apologetic discussion of the PGC principle. The practical impact of the Kretschmann-Bridgman episode now became predictable. It brought about a relaxing of the mathematical apparatus needed for entering the realm of GTR. Tell any student crowd they can skip some requirements and a majority happily embraces that new situation. In following this course of action, a major part of Einstein's motivations that had led him to GTR now fell between ship and shore. It is exactly the part for which Einstein endured condescending remarks from some of his teacher colleagues. Even the experimental confirmation of the three crucial effects could not earn him recognition for how he had done what he had done. He received more recognition for the myth surrounding his persona than for the physical reality of his actual contributions.

4. Contemporary Teaching of STR and GTR

The atmosphere surrounding the emergence of STR and GTR had a crippling effect on the teaching of the subject matter. While STR is standard in many physics curricula, most institutions of higher learning don't have standard courses in GTR. As a result the student body misses out on how STR fits into a wider picture. Contemporary students of physics thus stop short at the point where the young Einstein was beginning to realize a measure of incompleteness in his earlier STR creation. Therefore, it seemed unavoidable that many students experienced a similar dissatisfaction as Einstein had felt himself about his STR creation. The chances of a new generation to come up with an equivalent of a GTR development were naturally slim. Many contributions to Galilean Electrodynamics testify to the reality of this situation. They generate suspicion that many STR instructors of the past have been unable to communicate that wider picture, because that wider picture was never passed on to them.

The contemporary student of relativity is in a much less favorable position than Einstein, who at the time of his GTR work was a full professor. He could prevail on mathematical colleagues, even if, at times, a requested cooperation was rendered in a disgruntled

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[*] In the modern mathematical literature the collective of general, invertible and differentiable transformations in n dimensions are referred to as Diffeo-n; *i.e.*, Diffeo-4 for n=4.

manner. Einstein's era had another advantage, the mathematicians of his days could be expected to have a fair background knowledge in physics.

By contrast, the contemporary physics student will have a hard time finding mathematical specialists willing to teach the theory of differential invariants. That topic used to be a specialty at the end of the nineteenth century. Even if a course in differential forms ought to cover at least part of this subject matter, chances are that it would not be presented in a manner palatable to physics or physicists. Specialization is a symbol of the times, and contemporary mathematicians don't have to take cognizance of physics.

These are reasons why explicit courses in the GTR are rare. In the light of fashionable confessions to the physically superfluous nature of PGC, it is less than inspiring to carry around its mathematical ballast. If GTR courses do exist at all, the chances are that mathematical prerequisites are given by uninspired physicists. They present the subject with the typical apologetic PGC bias. Nobody less than Bridgman can be called upon to support that negativism

Teachers of STR ordinarily make references to a GTR follow-up. Perhaps enough to peak the curiosity but not enough to personally relive the Einstein battle from 1905 to 1915.

5. Emancipating the PGC

A positive alternative to the negative Kretschmann-Bridgman emasculation of the PGC is to seek a refinement that can give it a more constructive role in physics. Programs of this kind were independently initiated by Kottler,[7] Cartan[8] and van Dantzig[9] during the Twenties and the Thirties. Since these studies remained inconsequential in terms of producing striking new effects that might have earned the discoverers contracts, grants or other rewards, the interest in these developments soon waned.

Without entering into the technical details of these developments, let us lift out the high points and their conceptual implications for physics. References 7,8,9 came to the joint conclusion that the basic field laws of electromagnetism are Diffeo-4 invariant statements, independent of the spacetime metric structure. These findings have not had any impact on a subsequent textbook literature on E&M. A German monograph by Küssner[10] is an exception and so are a Handbuch der Physik article by Truesdell and Toupin[11] and a monograph by Post.[12]

It is amazing how establishment physics missed out on the potential simplifications of these metric-free techniques. They showed how many of the covariant derivatives with their unwieldy three index Christoffel terms were in fact utterly meaningless!! Christoffel terms became the despair of many students.

Let us recall Minkowski introduced the spacetime metric structure and it was the latter that assumed a major role in GTR. From these facts it follows that **metric-independent law statements are independent of gravity.** Furthermore, since metric structure is our one and only gauge for small and large, the **metric-independent law statements can be expected to retain validity in the micro-domain, even if originally established in the macro-domain.**

At this point I hear readers object and ask: how can fundamental E&M laws be metric independent, if light rays are bent in gravitational fields? The answer is: the metric, and the metric only, provides constitutive information of spacetime E&M behavior. One finds that a metric-free formulation of the basic laws invokes four field quantities **E,B** and **D,H;** as already anticipated by Giorgi's MKS units. Hence, old habits have thwarted recognition of the spacetime constitutive structure, even the earlier cgs units are culpable .

Now the question arises whether these new perspectives in organizational structure translate in a more hands-on interpretation of the EM laws. Here we find again that partial answers have been around right from the beginning. We just need a little perception. Consider the conservation of electric charge and combine this statement with present knowledge about the existence of elementary quanta of electric charge ±e. It then follows that charge conservation becomes a matter of counting identical charges leaving or entering an enclosure. Since counting requires identification of presence and no metric-type measurements, it stands to reason why charge conservation permits a metric-free mathematical rendition.

Since the early Sixties physics has witnessed the existence of flux quanta h/2e. It means now Faraday's induction law emerges as another statement endowed with an optional counting aspect, which, in turn, may be considered as accounting for its metric-independent Diffeo-4 invariance.

Since Faraday's induction law is experimentally revealed to us as a global statement of physical law, de Rham[13] theory of period integrals now presents itself as an important tool for application. Gauss' law of electrostatics may be considered as a forerunner of this integration technique. In mathematics Cauchy used the method in his famous residue theorem of complex integration. De Rham followed up by extending these methods and making them into a general tool for exploring manifold topology.

In the spirit of the de Rham theory, which in many ways seems inspired by E&M, it is now possible to come up with a complete system of period integrals that give a fundamental delineation of electromagnetic field configurations. They are:

I. A 1-dimensional period integral of Aharonov-Bohm counts flux quanta in units h/2e.

II. A 2-dimensional Ampère-Gauss law counts net charge in units of ±e.

III.A 3-dimensional "product" integral of integrals I and II, proposed by Kiehn,[14] counts action or integrated spin-angular momenta in units ±h.

These period integrals cover a gamut of quantum situations.**Their metric-independence covers macro- micro applicability and assures independence of gravity. The Diffeo-4 invariance of I, II and III defy statements about a fundamental incompat-ibilities of quantum theory and GTR.** Applications of these integrals to quantum Hall effect and the electron's moment anomaly are given by Post.[15]

What do these reasonably well established facts mean for the physics establishment and its dissidents?

6. To the Politically Correct Establishment

Since the contemporary representatives of the establishment have been mostly educated in a Bridgman tradition of operationalism, STR makes the grade and GTR makes a partial grade without PGC. Anything based on an extended version of PGC, as here considered is, therefore, bound to remain outside the main stream of ideas the establishment will consider as acceptable for their media. A survey of the published literature easily confirms that conclusion.

From the start GTR has invoked distinctions between contravariant and covariant transformation behavior. Einstein was well aware that some physical quantities also need to be assigned density properties, but for his purpose he explicitly mentions how to get around that detail by specifying that the determinant of the metric tensor be taken equal to one. The upshot of that situation is a series of undecided situations. For instance, speaking of what is known as the energy-momentum tensor, what do we mean? Has it two covariant labels (indices)? Or should it be assigned two contravariant labels? Or perhaps should it be assigned one covariant - and one contravariant label?

Here are immediately three unresolved questions, still compounded by a fourth issue concerning the density properties of the tensor. By making the metric determinant equal to one, Einstein had given us at least a temporary recipe for getting around that problem.

The early versions of GTR give a recipe of pulling indices up and down with the help of the metric, sort of suggesting that all these co-contravariant distinctions don't matter. However, how could that possibly be, if the metric is a carrier of gravitational information? These are merely questions generated by one important tensor, how about the electromagnetic field tensor(s)?

Clearly, only the initiated can find a way through this labyrinth of options. Einstein had that instinct. Checking the many texts on GTR, they almost all follow that same instinctive path initiated by Einstein; after all he knew what he was heading for. It seems strange that notwithstanding the mathematical critiques Einstein had to endure that none of those criticists came up with an attempt at resolving these open questions. A perhaps lonely exception in this respect is a paper by Dorgelo and Schouten,[16] which has been given a spacetime follow-up in reference 12.

The modern establishment has turned away from tensors and now prefers differential forms. Yet forms can't do anything unless the path between forms and tensors is mathematically and physically transparent: *i.e.*, without the usual salesman gimmicks about coordinate-free virtues. An extended PGC is bound to have a role in resolving open questions in this realm.

7. To the Galilean Electrodynamicists

Those. who have been unable to swallow these establishment decision reached by default, have found themselves penalized for their honesty. The politically correct crowd undeservingly riding high on the coattails of Einstein's instinct, ruled with iron fist. Those exiled had no privileges of being heard in establishment media, they have sought refuge in dissident journals. Galilean electrodynamics has been serving a category that feels that Galilean transformations remain closer to their sense of reality than Lorentz transformations. While this group does not deny the stark reality of relativity related discoveries, they do hold out for a view that many of these things can still be resolved in a Galilean context. In fact, Einstein himself was pretty good in that sort of considerations. His ideas on red shift and gravity-induced light bending originated from a Galilean beginning, presumably the perihelium shift of Mercury had to call on a fuller GTR machinery and so does Shapiro's added time delay in the bounce of radar signals from the Venus surface.

The question here confronted is whether an extended PGC can cast a better light on the asymptotic legitimacy of those very valuable classic procedures. Here are some thoughts on this subject matter.

The fact is that the Galilei group of translations is not a subgroup of the Lorentz group, yet it remains a subgroup of Diffeo-4. Unlike the Lorentz group, the Galilei group of translations naturally relates to transformations describing accelerated motion. Both categories though are contained in Diffeo-4! **All of this places the Lorentz group in the unique position of an exclusive *interrelator* of inertial frames.**

Galileans have explored paradoxes of relativity, they know well how arguments invariably arise when thought experiments are considered requiring a return path that cannot be achieved without calling on an accelerated motion. Acceleration is not covered by the Lorentz group. **The earlier identified isolated position of the Lorentz group as an *inertial frame interrelator* makes it bad epistemolgy to get out of the confines of that group.** The Thomas precession is so far an isolated example of an infinitesimal step outside the Lorentz realm. Stepping out of the inertial frame condition is no problem for the Galilean group, for the Lorentz group it is. The key is: Galilean translations permit continuous transitions to accelerations, the Lorentz group does not. These are indicators that the Lorentz group should be treated as a much more abstract entity then presently customary.*

Yet, the Lorentz group is a powerful tool in anticipating properly constructed Lagrangeans. These are situations where the Galilei group cannot give answers. Examples discussed in ch.X of ref.14 show how a STR correction omitted in the Dirac-Sommerfeld Lagrangean automatically leads to terms that until now were considered as belonging in a separate realm known as Weber electrodynamics.[17] These Weber corrections have a higher order effect on the fine structure of hydrogen-like atoms It thus seems that Weber electrodynamics can be legally integrated into a Diffeo-4 invariant Maxwell theory, simply by correcting a Sommerfeld omission. Dirac in his quantum theory of the electron adopts the Sommerfeld Lagrangean and ends up with the same fines tructure formula

A similar shing can be said about the so-called Hertzian electrodynamics. The critical point here is one of correctly performing a time differentian on an integral with time changing boundary. Unfortunately many text books specify that **a total time derivative operating on an integral becomes a hydrodynamic-type derivative under the integral. The latter mathematical translation of the Faraday induction experiment is wrong.** In ref. 12 it is shown how extra terms due to boundary motion give in addition to the source-free Maxwell equations a familiar expression E'=E+v^B, in which E' is measured on the boundary

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[*] An seminal experiment by Champeny and Moon (see ref.6) demonstrates the absence of a rotary Doppler shift, thus illustrating basic STR-GTR distinctions.

moving with velocity v, whereas E is measured in the stationary reference. Multiplication with particle charge q converts this expression into the Lorentz force.

Finally an argument that helps dispel remaining doubts about the indispensable role of Diffeo-4. Almost all fundamental laws of physics can be cast in a form in which integrability criteria assume a prominent role. Hamiltonian mechanics and electrodynamics provide striking evidence for these integrability features, either in the context of Diffeo-3 or Diffeo-4. A mathematical expression that is not Diffeo invariant cannot unambiguously convey an integrability property of the system under consideration. The requirement of Diffeo invariance is the one and only criterion for ascertaining that one deals with intrinsic system properties that cannot be perturbed by an inadvertent choice of reference frame. Standard methods of mathematical communication in contemporary physics are quite inadequate for conveying such information.

The Kretschmann-Bridgman initiative of playing down the physical role of the PGC, and a textbook literature paying lip service to this idea, have for all practical purposes closed the door on improvements of mathematical communication in contemporary physics.

Consistent with the original intention not to get into specifics of a diversity of applications, permit me to leave my Galilean Electrodynamicists with this attempt at reinstating Galilean relevance. I hear them saying: "nothing new, we knew that all along." Right you are! Your point is well taken. However, whatever you are going to do. Try to understand and respect why Albert Einstein took out ten years of his life to understand the theory of differential invariants under Diffeo-4 and try to respect what he did with it. From Kretschmann and Bridgman we can learn not to prematurely discard things that might become valuable and needed later.

8. Conclusion

The here depicted odyssey of methodology in physics and its associated mathematics reflects a familiar pattern of vacillation between ontic and epistemic values. According to Zerin[18] ontology pursues truth with less of a concern where the truth comes from, by contrast, epistemology also wants to know where truth comes from to find out how it relates to other truth.

Every exploration starts out in an ontic vein. Only after several vaguely related ontic realms have been verified as relevant truth, does it become possible to establish a more solid epistemic connection. For example, electricity and magnetism started out as disconnected ontic realms, later to be connected by the epistemic insights of electromagnetism.

Based on the principle that elementary matters should not be cluttered with complexity to be called on only at later stages, the choices of mathematical methodology in physics have tended to be ontological in nature. The use of diverse systems such as vector analysis, several levels of tensor analysis, and differential forms testify to what might be considered as an ontic disconnecting of an epistemics that was mathematicaaly already there.

The system of vector anlysis is restricted to SR(3) invariance. It subsumes unproven spacetime uniformity and excludes consideration of mirror operations. Between Cartesian tensors and GTR tensors there is an utterly confusing gamut of options. As presented in modern mathematical text books, differential forms and de Rham theory are presented without the original distinctions between pair and impair forms. Even if de Rham did not do much with it, he had introduced this distinction in the process of drawing on E&M sources. Only a tensor text by Schouten[16] covers territory that permits a one to one relation with the pair-impair de Rham distinction. The ontic disruption ensuing from leaving out these mirror distinctions has now culminated in a state of chaos. Enantiomorphism, parity, helicity, chirality and **even spin** are all concepts that exist by virtue of the pair-impair distinctions. Perhaps a class action by students is needed to create order.

The just cited facts mostly cover the mathematical support system. They illustrate how an isolated operationalism on the grounds of a misguided pragmatism creates serious problems. In the light of orientability neglect leaving tensor transformation undetermined, it is not surprising that the GTR courses that are being taught are hardly popular.

Let us face it, Einstein got something out of it, because he knew where he was going. He had the solutions, before he had succeeded in deriving his field equations. Hilbert had the field equations before Einstein, but he did not know what to do with them. In fact, Felix Klein took him to task about a mistaken conclusion concerning energy conservationm. Hilbert conceded, the error was then rectified by Emmy Noether. The Hilbert, Klein, Noether exchange *openly* appeared in the 1916-1918 Göttinger Nachrichten. Today, QED people take pride in slightly misquoting Noether's Theorem as a *universal* proof of energy-momentum conservation. Not true!

Noether's conclusion restricted e&m conservation to the general linear group, which covers STR and that was just fine with what QED wants. Hilbert deserves a credit here; he not only publicly admitted his mistake, in doing so he for the first time claimed that there might be **no universal energy-momentum conservation under Diffeo-4.** (*Die Hilbertsche Behauptung*) Emmy Noether proved that statement to be correct.

Apart from this as yet uncontested conclusion, the Hilbert-Klein-Noether exchange in the Göttinger Nach-richten brings out an entirely different, yet equally essential precondition for constructive scientific work. **The openness of discussion in the Göttinger Nach-richten strikes us as being in sharp contrast with what transpires from contemporary publications.**

The question is how Imperial Germany at the end of World-War I and the contemporary US physics community compare in terms of a primary need for freedom of expression. An attempt at answering that question should give some reason for thought.

Science needs openness and diversity, but stopping short of foolishness. To stop excess foolishness, another breed of operationalists have dictated anonymity of peer review to simplify matters in a litigious society. This measure can and does risk a funding related overextension of loyalties to undeserving causes. So, could it be true: was German science in 1918 more open than US science in the Nineties? Then look, it happened again just prior to World-War II; Otto Hahn's seminal paper appeared in the open literature!

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