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The 1924-1944 Discussion Regarding the Velocity of Light

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In 1924 the British physicist, Maurice Edmond J. Gheury de Bray, who worked in London, was studying the values of the velocity of light determined by A.A. Michelson. During this study Gheury de Bray wanted to have a list of the determinations of the velocity of light. He naturally consulted a number of standard works, but he realized that many of these works quoted the measurements incorrectly. For this reason Gheury de Bray decided to consult the original references himself in order to make a satisfactory list.[1] Carrying out this historical work, Gheury de Bray discovered that there appeared to be a secular variation of the values of the velocity of light. This discovery was the beginning of an interesting scientific debate. During the 1930s, a large number of articles dealt with the problem. Most of them were published in **Nature.** In the 1940s two articles, one by Raymond T. Birge[2] in 1941 and the other by N. Ernest Dorsey[3] in 1944, seemed to have brought the debate to a conclusion that was generally accepted by the scientific community. Recently Barry Setterfield[4] has reconsidered the question, and has arrived at the contrary conclusion claiming that there is, in fact, some evidence pointing to a decreasing value for the velocity of light in a vacuum.

In this paper I am going to consider the debate in the 1930s and the 1940s from a historical point of view in order to find some of the crucial reasons for the rejection of Gheury de Bray's hypothesis. In section 1 Gheury de Bray's hypothesis will be discussed in some detail. Roy J. Kennedy claimed that the hypothesis is in conflict with experimental and astronomical data. These claims will be considered in section 2. In section 3 the consequences of the theories of relativity, with which some authors during the 1930s confronted the hypothesis, will be discussed. Some scientists in the period in question felt that the hypothesis had to be related to problems in the defining of physical units. I am going to deal with these views in section 4. During the 1930s very few attempts were made to criticize the empirical basis of Gheury de Bray's hypothesis. However, in their papers during the 1940s Birge and Dorsey published important experimental criticisms of the empirical basis, so I will briefly consider their contributions in section 5. In the conclusion some fundamental reasons for the rejection of the hypothesis will be presented.

1. GHEURY DE BRAY'S HYPOTHESIS

In Gheury de Bray's opinion the evidence with respect to the velocity of light which was available in 1927 was clearly in favour of a systematic decrease in that quantity. In 1931 he claimed that the new determination of the velocity made by Karolus and Mittelstaedt, which was lower than the last one obtained, made this evidence even stronger.[5] Later the same year he even claimed that 'if some misguided physicist attempted to demonstrate that it (the velocity of light) is constant, the present observations would be called to witness to silence him conclusively!'[6]

As regards the concrete mathematical form of the decrease, Gheury de Bray maintained in 1931 that the observations could fit the 'linear law of variation' in an excellent way.[7] In 1934 however, Edmundson[8] pointed out that the observations are better represented by the formula

$$c = (299{,}885 + 115 \sin(2\pi/40\,(t - 1901)))\,\text{km/sec}$$

where c is the velocity of light in km/sec and t the time in years. Later the same year Gheury de Bray admitted that there is a 'remarkably close agreement of Edmondson's sine law with the observations'.[9] In 1936 he published some calculations of the yearly change in the velocity of light.[10] In the period from 1875 to 1883 he found that the change was 16.6964 km/sec/year, whereas he calculated that the change for the period 1875 to 1926 was 3.99 km/sec/year. For this reason he stated that a formula like the one suggested by Edmundson might represent the data

better than the linear law. Gheury de Bray pointed out that, if Edmundson was right, it would turn out after a few years, since the velocity of light would be increasing during the period 1936-1941 according to the formula. In 1941 Birge[11] mentioned that Edmundson's equation was 'already completely disproved' by Anderson measuring the velocity of light in 1940. But this is not to say that Gheury de Bray's hypothesis (about a secular variation of the value of the velocity of light) was disproved in 1940. Gheury de Bray never did insist on any particular formula for the variation.

Gheury de Bray presented his hypothesis on a purely empirical basis. But although he was never able to deduce a formula for the variation from a general theory, he did make some theoretical suggestions. In 1931 he stated that 'the velocity of light is affected by magnetism'.[12] He did not intend to suggest that a decrease in the velocity of light could be caused by a variation of the earth's magnetic field,[13] although V.S. Vrkljan obviously understood his idea in this way.[14] In Gheury de Bray's opinion a possible variation of the earth's magnetic field was only one of the factors which might affect the velocity of light.[15] Gheury de Bray admitted that he was unable to formulate a theory which could explain the decrease in the velocity of light. He based his hypothesis on empirical reasons alone. His only attempt to link his hypothesis to a general theory concerned cosmology. Gheury de Bray's idea was that the expansion of the universe was the main reason for the decrease in the velocity of light. He pointed out that the expansion of the universe 'causes the light to take longer, as time goes on, to travel between two points of space defined by their position with respect to the whole'.[16] In a paper in August 1931, V.S. Vrkljan[17] criticized Gheury de Bray's theoretical suggestions. In his comments on Gheury de Bray's cosmological explanation, Vrkljan pointed out that 'without a mathematical deduction one cannot clearly gather what he really means'. Vrkljan demonstrated that if all distances increase at the same rate as the velocity of light decreases, then Gheury de Bray's hypothesis would according to the third law of Kepler imply that, for example, "the time which the earth takes to revolve around the sun, would have been increased in the last fifty years by one third of a day!"[18] It should be pointed out that according to Vrkljan this result can only be derived on the assumption that the masses of the celestial bodies, as well as the constant of gravity, are unchanged.

In conclusion it can be said that Gheury de Bray's hypothesis was purely presented in an empirical way. He did not relate it to any new theory. According to his hypothesis there is a secular variation in the velocity of light. This variation could be a continuous decrease in the velocity of light, or it could be some velocity fluctuation.[19] The concrete mathematical form of it had to be explored by experiments and observations. According to him, the question regarding the constancy of the velocity of light had been settled, in the international society of physicists, owing to considerations of a theoretical order only. He suggested that the question should be reconsidered from an empirical point of view. In 1931 he wrote: "Certainly it is time that the constancy of this velocity should be established beyond doubt on experimental evidence, instead of merely postulated theoretically."[20]

2. KENNEDY'S ARGUMENTS

In August 1932 Roy J. Kennedy[21] published a paper in which he outlined the results of his experimental work. He claimed that these results established experimental proof that no variability in the velocity of light exists. According to Kennedy the number of waves retarding in any interference arrangement is

$$n = \frac{\nu \Delta s}{c}$$

where ν is the frequency and As is the path-difference. On the assumption that the frequency is constant in time, it follows that

$$\frac{dn}{dt} = -\frac{\nu \Delta s}{c^2}\frac{dc}{dt}$$

In Kennedy's experiment $\frac{dc}{dt} = -4$ km/sec/year (corresponding to Gheury de Bray's hypothesis) would imply that one should find a change in n of 0.023 fringe per day. According to Kennedy's measurements the real change stands in the ratio 6×10^{-4} to this amount.

In April 1935 Kennedy published another paper[22] in which he argued that Gheury de Bray's hypothesis was in conflict with some astronomical data. He demonstrated that if the velocity of light is variable, then there will be a shift in the frequency of the light emitted from a star. He showed that this shift, $\Delta\nu$, must be related to the velocities of light at the time of emission, $c(t_1)$, and at the time of observation, $c(t_2)$:

$$\frac{\Delta\nu}{\nu} = \frac{c(t_2)}{c(t_1)} - 1$$

Kennedy argued that if Gheury de Bray's idea of a linear decrease is used, then there would be a fractional frequency shift of more than one part in a thousand for a star only 100 light-years distant, and for stars outside the galactic system the shift would be enormous. For this reason Kennedy concluded

that Gheury de Bray's idea is "definitely ruled out by observation". Regarding Edmondson's function, Kennedy showed that it would imply a systematic effect which "could scarcely have escaped observation".

It should be noticed that Kennedy's arguments lose their power if all atomic frequencies are supposed to vary in direct proportion to the variation in the velocity of light. Kennedy was obviously aware of this fact, for he admitted that it is "not altogether absurd to suppose that . . . the variation in velocity might leave the length of day unaffected, while modifying the frequency of a spectral line just enough to offset the effect of the variation in velocity on the positions of the interference bands." In his opinion, however, this assumption would seem "far-fetched and without sufficient warrant at present". It turns out that Kennedy's conclusion agrees with what H.J. Gramatzki[23] pointed out in 1933: *"1st de Bray's Schlussfolgerung richtig,* dass die *Lichtgeschwindigkeit abgenommen habe, so muesste sich also die Frequenz geaendert* haben." English translation — If de Bray's conclusion, that the velocity of light has declined, is correct, then the frequency must accordingly have changed.)

Kennedy's arguments did not result in any effective rejection of Gheury de Bray's hypothesis, since they did not deal directly with Gheury de Bray's empirical basis. Kennedy introduced some new empirical data, but obviously one set of measurements cannot be effectively rejected by means of another set of empirical data. If someone would demonstrate that the secular variationists were wrong, he would have to argue that the measurements of the velocity of light carried out from 1850 to 1930 did not indicate any secular variation. The fact that very few attempted to do so during the 1930s might have been due to Gheury de Bray's very careful discussion of the experimental data.[24,25] However, there can be no doubt that Kennedy regarded Gheury de Bray's empirical basis for the hypothesis of secular variation as almost useless. He stated that small variations should not be sought "by taking differences between measurements of the whole, but rather by some . . . experimental method. . .".[26]

3. RELATIVITY AND THE POSSIBLE VARIATION IN THE VELOCITY OF LIGHT

The first physicist to discuss the relationship between the theories of relativity and the ideas of a secular variation in the velocity of light was V.S. Vrkljan. In a paper published in 1930, he claimed that a decrease in the velocity of light does not contradict the general theory of relativity.[27] Vrkljan repeated his view in a paper the following year,[28] stating that "one could interpret this eventual decrease in accordance with this theory (the general theory of relativity), that is, with the changes in time of g_{hk}".

In 1933 W.R. Mason[29] confronted the eventual secular variation in the velocity of light with the general theory of relativity. He claimed that since according to the general theory of relativity time and space coordinates are members of the same coordinate system, the general theory implies that an observer at one time should find the same value for the velocity of light as another observer at another time. He concluded that if a fundamental quantity such as the velocity of light or the frequency of an emitting atom is found to vary with time, then the partnership of space and time cannot be upheld in the general theory of relativity and thus the general theory of relativity must be revised.

Mason's view seems to contradict the conclusions which Vrkljan formulated in his 1930 and 1931 papers. This apparent disagreement disappears if Vrkljan's view is understood as the claim that the general theory of relativity might be revised in order to admit a secular variation in the velocity of light. This interpretation of Vrkljan's paper seems to be natural. He would probably agree that the revision of the general theory of relativity, which is necessary in order to incorporate a secular variation in the velocity of light, would imply that the velocity of light in a certain sense is a measure of time itself (although the relation is rather complex, since any determination of the velocity of light must involve a determination of a duration). It appears that the acceptance of a secular variation in the velocity of light leads to some notion of an absolute and cosmic time. Hence, this acceptance seems to be in conflict with at least the usual version of the special theory of relativity. For this reason it may be doubted that Henri Arzelies is right in claiming that 'however real this variation (of the velocity of light) may be, it can have no effect upon the foundations of special relativity; we should simply have to use the value of c which was appropriate at any given time.'[30]

4. THE CONSTANCY OF THE VELOCITY OF LIGHT AND DEFINITIONS OF PHYSICAL UNITS

Several authors realized that problems with the possible variation in the velocity of light are closely related to questions of defining physical units of space and time. The first writer to offer a detailed analysis of this relationship was Olin G. Wilson,[31]

who concentrated on the definition of the metre. He explained that the standard metre can be measured in terms of the wavelength of the red cadmium line, and he quoted observations on the metre in 1892 and 1902. During these fourteen years it turned out that the change in the number of wavelengths in the standard metre was less than 1/1,000,000. In fact, the difference between the two observations was negligible. For this reason Wilson concluded that if the length of the standard metre is defined as constant in time, then the wavelength of the red cadmium line must also be constant in time. In consequence, Wilson argued, if the velocity of light depends on time, then the frequency corresponding to the red cadmium line will depend on time in the same way. But this variation of the frequency cannot be detected directly since we have no direct intuition of the equality of two intervals of time.[32] Wilson concluded that "if c depends on time, we may not unreasonably expect such a variation to appear in experiments other than those which give direct measurements of the velocity." This means that an eventual variation of the velocity of light would be rather difficult to detect. It can only be settled by convention what it means that the length of the standard metre is constant in time and what it means that two durations are equal.

In 1935 Herbert Jehle[33] pointed out that if the metre is defined in terms of the wavelength of the red cadmium line, and if the second is defined in terms of the corresponding frequency, then the constancy of the velocity of light is also a matter of definition. If the question regarding the constancy of the velocity of light is to be seriously discussed, the independent definitions of time units and length units must be utilized.

5. THE EXPERIMENTAL CRITICISMS

During the 1930s very few writers discussed the experimental basis of Gheury de Bray's hypothesis. In 1941 R.T. Birge[34] published an interesting paper in which he showed that Edmondson's suggested harmonic variation was completely disproved, because of the measurements in 1940, and in which he argued that the assumption of a constant value of c was consistent with all experimental evidence. Birge claimed that if the probable error of each result is taken into consideration, all evidence would fit into the assumption that the velocity of light in a vacuum is 299,777.8 ± 2.5 km/sec. Birge did not claim to have demonstrated that Gheury de Bray was wrong. In fact, his final argument is philosophical:

> *'Now my own philosophy of science — a philosophy that* has been stated *most eloquently by H. Poincare (1913) — is that the simplest satisfactory explanation of a given set of phenomena should always be chosen. If the assumption of a constant value of c satisfies the data, it is gratuitous to postulate a systematically changing value.'*[35]

In another study published two years later, N. Ernest Dorsey[36] from the National Bureau of Standards offered a detailed investigation of the empirical basis. Dorsey's criticism of the works of Michelson, who measured the velocity of light in 1879, 1924 and 1926 and found decreasing values, should be mentioned:

> *'Not one of his reports contains sufficient detailed information to enable a reader to form* an independent and *objective evaluation of the result. Whatever value he may attach to it, is purely subjective, resting solely on his confidence in Michelson.'*[37]

For this reason Dorsey concluded that Michelson's reports were deficient in essential details, and in consequence they should not be trusted too much. Dorsey concluded that there is no secular variation in the velocity of light, since according to him all apparent ranges include the value 299,773 km/sec. Hence Dorsey suggested the value 299,773 ± 1 km/sec.

CONCLUSION

After the publication of the studies of Birge and Dorsey, the question of the constancy of the velocity of light seems to have been almost settled. These two authors studied the same material, but they found different values for the velocity of light. Dorsey's value is very close to the modern value. They did, however, agree that Gheury de Bray's hypothesis does not necessarily follow from the empirical basis. Their works are important because they carried out the only kind of study which could give rise to an effective attack on the hypothesis. One might wonder why this kind of work was not carried out during the 1930s.

A part of Birge's conclusion was based on philosophical considerations. According to him all the measurements are consistent with the assumption that the velocity of light is constant in a vacuum. They were, however, also consistent with a decreasing velocity of light. Birge's reason for assuming the constancy of the velocity had to do with simplicity, but simplicity is not something objective. It appears that Birge felt the assumption of constancy was more natural than to assume

decrease, since he could not imagine any explanation for a change in the velocity of light. And since he did not need any specific explanation for the constancy, he felt that this assumption was the more natural of the two.

It appears that the weakness of Gheury de Bray's assumption was the lack of explanation. Most scientists considered the suggestion to be unsatisfactory since no explanation was offered.

It should be admitted, however, that the formulation of a theory which includes Gheury de Bray's hypothesis, is a difficult task, since it has to be cosmological, it has to pay due regard to the general theory of relativity, and it has to establish independent definitions of the units of space and time.

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