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A debate on magnetic current: the troubled Einstein–Ehrenhaft correspondence

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Abstract. The unconventional correspondence between physicists Albert Einstein and Felix Ehrenhaft, especially at the height of the alleged production by the latter of magnetic monopoles, is examined in the following paper. Almost unknown by the general public, it is sometimes witty, yet it can be pathetic, and certainly bewildering. At one point the arguments they exchanged became a poetic duel between Einstein and Ehrenhaft's wife. Ignored by conventional Einstein biographies, this episode took place during the initial years of the Second World War, but was rooted in disputes dating back to the early years of the twentieth century. The interesting intersection of a series of scientific controversies also highlights some aspects of the personal dramas involved, and after so many years the whole affair in itself is still intriguing.

The issues in the Ehrenhaft–Einstein epistolary

Science has now practically forgotten the polemic figure of Felix Albert Ehrenhaft (1879–1952), an Austrian physicist who in the 1900s and 1910s assumed the existence of electric charges smaller than the electron, based on his experimental work. Three decades later, Ehrenhaft came up with what appeared to be another heresy, insisting that he had observed isolated magnetic poles. He maintained a correspondence with Albert Einstein on these subjects for about thirty years, trying to convince Einstein of the validity of his arguments, while Einstein attacked Ehrenhaft's conclusions, but followed his experimental work. The personal Ehrenhaft–Einstein correspondence examined here is remarkable and mostly unpublished.[1] Although the collection has been available for

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The author is indebted to Mrs Kirsten van der Veen, librarian at the Dibner Collection, as well as to Mag. Brigitte Kromp, Director of the Central Library for Physics, at the Vienna University, and Joe Anderson, at the Center for History of Physics, College Park, MD. He is most thankful for the careful and stimulating *BJHS* reports from anonymous peer reviewers.

1 Manuscript sources: MSS 2898: Albert Einstein and Felix Ehrenhaft, letters, notes, memoranda and queries exchanged between 1939 and 1941, with preliminary letters 1917–1932; Felix Ehrenhaft, typescript of unpublished 'Meine Erlebnisse mit Einstein 1908–1940'; *idem*, a collection of his lectures, articles and reprints; Lilly (Rona) Ehrenhaft, personal and scientific papers; Agathe Magnus, papers concerning patents by Lilly Rona. MSS122A: Albert Einstein, letter to Felix Ehrenhaft from 3 September 1939, Dibner Library of History of Science and Technology, American History Museum, Smithsonian Institution, Washington, DC, forty-seven items of correspondence (mostly in German) involving Einstein, Ehrenhaft and Lilly Rona-Ehrenhaft, besides other persons. There are also exemplars of published works of Ehrenhaft, some bearing affectionate handwritten dedications to Lilly. These items were purchased in 1960 for $2,500 by collector and historian Bern Dibner, apparently part of the personal archives of Lilly, and donated together with a substantial part of

consultation for decades now, it has seemingly not caught the attention of historians, although these letters, telegrams and handwritten notes are a valuable source, bringing out some instigating scientific, epistemological and historical questions.

The foremost scientific investigation in physics addressed by Ehrenhaft in these letters is whether Maxwell's second law holds, or if, on the contrary, there exist entirely separate magnetic north and south poles – also termed magnetic monopoles. And supposing we have an affirmative answer, in what sense can a flow of magnetic monopoles from north to south, or vice versa, be designated a 'magnetic current'? Ehrenhaft was considered by many scientists a gifted and careful experimenter, and although his results were challenged in the physics community, he remained convinced that careful repetition had yielded ground enough to support his interpretation. Instead of rejecting his data, he would rather neglect the current theoretical foundations, an epistemological path that accompanied him throughout his life. Was this a legitimate stand, or was it a cul-de-sac?

Historically examined, this episode was known to various physicists during the period of the Second World War, which entices a further question in the domain of the history of science, and one that has not been particularly well answered: how important is it in the long term to scrutinize the losing-party arguments of scientific controversies, no matter how invalid they appear to be in the short term?[2]

In biographic terms, the conflict of Ehrenhaft with Einstein is also especially interesting, as they both shared a German cultural background and a Jewish origin. Ehrenhaft remained emotionally attached to Einstein almost until the end of his life, but failed to perceive that his feelings were not reciprocated.[3]

The life and times of Felix Ehrenhaft

It is rather disappointing to look for information on the life of Felix Ehrenhaft, and until now the only extant source is a biography written by Joseph Braunbeck.[4]

Dibner's collection of rare books and manuscripts to the Smithsonian, where they have been available to scholars since 1976.

2 Of course, 'losing' (and 'winning') are themselves historical appreciations, but what is highlighted here is the context of accepted scientific belief and practice, even if this understanding is eventually altered in the course of time.

3 Ehrenhaft's dedication included contributing to the Nobel Prize attribution to Einstein. Abraham Pais, in *'Subtle Is the Lord': The Science and the Life of Albert Einstein*, Oxford: Oxford University Press, 1982, mentions Ehrenhaft's Einstein indications in 1916, 1918 and 1922. A recent book on this subject is Aant Elzinga's *Einstein's Nobel Prize: A Glimpse behind Closed Doors*, Sagamore Beach: Science History Publications, 2006, which relies on the official Nobel archives to attribute the successful nomination mainly to physicist Carl Wilhelm Oseen. Ehrenhaft, in his Einstein recollections (MSS 2898, 'Meine Erlebnisse mit Einstein'), tells a different story: the arrangements he conducted with Arrhenius behind the scene would have been responsible for the prize. It may well be that Ehrenhaft is exaggerating his importance in the affair, but the official story may not be wholly reliable either.

4 Joseph Braunbeck, *Der andere Physiker. Das Leben von Felix Ehrenhaft*, Vienna: Technisches Museum & Leykam, 2003. This biography is quite helpful, in spite of its sometimes excessively laudatory tone – a more complete biographical appreciation of Ehrenhaft emerged only with the examined letters and material at the Smithsonian, Vienna University, and Center for the History of Physics. Einstein's biographies hardly mention

Ehrenhaft was born in Vienna on 24 April 1879, the son of an affluent medical doctor. After completing the military service, and graduating as an artillery officer, he finished his studies at the University of Vienna in 1903, earning both a doctor's degree in physics and the title of mechanical engineer. Next he pursued a research programme on colloids, which enabled him to be promoted to *Privatdozent* in 1905, and afterwards engaged in other research about Brownian motion, publishing in 1907 his discovery that this erratic movement exists also in gases.[5] His finding was immediately considered another decisive step towards unveiling the inner structure of the atom.[6]

In 1908 he married his former university colleague Olga Steindler, who became the mother of their two children, and at this time he engaged in the measurement of the elementary electricity quantum, as the electron charge was then called. J.J. Thomson had argued that cathode rays were a stream of electrical particles and had proposed that what came to be called 'electrons' moved in a hypothetical positively charged fluid.[7] These ideas were further elaborated and reformulated in the following decade by Thomson himself, aided by his important research team at Cambridge, and other European scientists.[8]

The new experiments conducted by Ehrenhaft with the electron charge brought him fame, especially in Europe, but later he suffered a rapid collapse in prestige, as he repeatedly reported measured values that contradicted exactly the assumed charge quantization. As will be discussed later, this led to a controversy with Robert Millikan on the subject.

During the First World War Ehrenhaft was mobilized, and fought at the front but later served as ballistics professor in the officer artillery school. Immediately following the war's end, he devoted himself to new research, whereby he claimed in 1918 to have discovered photophoresis, a phenomenon by which light could move particles in

Ehrenhaft at all, and only the older (1947) biography by Philipp Frank, *Einstein, His Life and Times*, 2nd edn, Cambridge, MA: Da Capo (Perseus), 2002, pp. 72–73, indicates that after the First World War Einstein stayed in Vienna at Ehrenhaft's – whereas from the letters we learn that it was Ehrenhaft himself who wrote to Frank in 1940 providing information, including a series of Einstein anecdotes that are in Frank's book without disclosing the source.

5 Ehrenhaft, 'Das optische Verhalten der Metallkolloide und deren Teilchengrösse', *Annalen der Physik* (1903) **11**, p. 489; *idem*, 'Über die der Brownschen Molekularbewegung in Flüssigkeiten gleichartige Molekularbewegung in den Gasen', *Wiener Berichte* (1907) 116, p. 1175.

6 The years between 1897, when Thomson reported on the electrical particle, and 1911, when Rutherford proposed concentrating most of the atomic mass in a smaller volume of the atom (nucleus), witnessed much discussion about the atomic structure. Many uncertainties on this subject were reflected in various other areas, as in the interpretation of radioactivity, and the constitution of the periodic table – cf. Michel Serres (ed.), *Eléments pour une histoire des sciences* (1989), Portuguese translation, Lisboa: Terramar, 1996, vol. 3, pp. 77–80.

7 The assessment of Thomson's contribution, both conceptually and practically, to the history of the electron and the atomic model, is not an easy task. The reader will benefit from consulting Jed Z. Buchwald and Andrew Warwick (eds.), *Histories of the Electron*, Cambridge, MA: MIT Press, 2001. The first part is an excellent historical account of the issues related to electrons as 'corpuscles'. There were several different concepts of elementary particles of electricity, and only gradually a consensus emerged. We will not dwell upon these contrasting visions, since they are not the focus of the present work.

8 Helge Kragh, 'Particle science', in Robert Olby *et al.* (eds.), *Companion to the History of Modern Science*, London: Routledge, 1996, pp. 655–654.

suspension.[9] This was considered by many physicists just a radiometric effect – as in the well-known Crookes radiometer, a pinwheel with four blades painted alternately black and white, which when illuminated produces a thrust, due to different luminous absorption of the blades, and subsequent air heating that will make the wheel spin around its axis. Ehrenhaft dismissed the radiometric explanation after a series of new experiments, preferring to explain his observations as the direct effect of light on matter. For particles of size comparable to the wavelength of light, he maintained they might move towards the light source, an effect which he called 'negative photophoresis'. This affair increased the reproof he had been suffering from other physicists as a consequence of the previous electron charge controversy.

In 1920 Franz Exner retired as director of the physics institute at the University of Vienna. Ehrenhaft thought he was a natural candidate for the office, yet he was not elected, because the institute's senior fellows considered him a dissident with respect to mainstream physics. Besides, Exner had played a role in Vienna which went beyond physics, in the tradition of Helmholtz and Boltzmann, for he was an intellectual with broad interests, including philosophy and the evolution of culture, an advocate for the interdisciplinary benefits which the exact sciences could reap from the social sciences, while Ehrenhaft did not exhibit such a cultural profile.[10]

Einstein was consulted in this matter by the University of Vienna and his advice was against the indication of Ehrenhaft.[11] In what appears to have been a political decision, Ehrenhaft subsequently received from the university a new independent physics institute to chair, where his influence was expected to be comparatively minor.

Despite their strong scientific differences, whenever Einstein came to Vienna for conferences or congresses between the years 1921 and 1931 (Figure 1), he stayed as a guest at Ehrenhaft's house. Ehrenhaft socially entertained Einstein, took him around the city and even once arranged for Einstein to play his violin in a string quartet at a domestic reception. The personal relationship between the two was seemingly cordial at this time, and Einstein invited back the Ehrenhafts, hosting them at Caputh, near Potsdam, in the summer of 1932. Ehrenhaft's first wife died later that year, and he was married again in 1935, to Bettina Stein.

This was a period of great unrest in Vienna. Anti-Semitic newspaper articles demanded the barring of Jewish intellectuals from public activities, including the academic world. The murder of philosopher Moritz Schlick in 1936 at the University of Vienna was hailed by the Austrian fascist wing as a 'good' solution to the Jewish question – even though Schlick himself had no Jewish ancestry. In this same year the

9 Ehrenhaft, 'Die Photophorese', *Annalen der Physik* (1918) 56, p. 81.

10 Cf. Erwin Hiebert, 'Common frontiers of the exact sciences and the humanities', *Physics in Perspective* (2000) 2, pp. 6–29. In the scientific field, Exner could be associated with Mach and the tradition of Vienna indeterminism. An extensive study of Exner as a physicist, and author of the cultural evolutionist *From Chaos to the Present* can be found in Michael Stöltzner, 'Franz Serafin Exner's indeterminist theory of culture', *Physics in Perspective* (2002) 4, pp. 267–319. Ehrenhaft's agreement with Mach was probably for reasons different from Exner's; most important for Ehrenhaft was the faith that experimental facts alone formed the basis of knowledge.

11 See Einstein's letter to Vienna University of 25 June 1920, quoted in Braunbeck, op. cit. (4), pp. 36–37.

Figure 1. A lecture by Einstein in Vienna (undated) – Ehrenhaft is standing third from the right. (Courtesy of University of Vienna, Österreichische Zentralbibliothek für Physik.)

German physicist Philipp Lenard (1905 Nobel Prize), supported by Johannes Stark (1919 Nobel Prize), published the book *Deutsche Physik*, containing a manifesto against 'Jewish physics'. The book pleaded for practical physics and attacked what it called theoretical, 'modern' speculations, such as relativity and quantum theory. Nazi ideology denied the universality of science, proposing instead a 'German' science – *Deutsche Physik, Deutsche Mathematik* – a trend which was supported by only a few authoritative scientists.[12]

Ehrenhaft continued working normally after Hitler seized power in Germany in 1933, and in spite of the mounting Austrian Nazi pressure against Jews and converted Jews, he maintained positions in state commissions, such as membership in the national patent evaluation office and in the technical standards committee. However, after the 1938 *Anschluss*, he was arrested by the police and beaten up, had his money confiscated and was expelled from the University of Vienna, together with many other scientists labelled either Jewish or politically dangerous to the regime. Even so, Ehrenhaft still hoped he could be left undisturbed by the Nazi government, but then slowly changed his mind.

12 Reinhard Siegmund-Schultze, 'The problem of anti-Fascist resistance of 'apolitical' German scholars', in Monika Renneberg and Mark Walker (eds.), *Science, Technology and National Socialism*, Cambridge: Cambridge University Press, 1993, pp. 312–323.

Figure 2. Lilly Rona with 1940 bronze portrait of Ehrenhaft (*Radiocraft*, November 1944).

He finally applied for a visa, and in April 1939 left for England to further migrate to the USA in June, leaving his second wife in Vienna, where she died of a devastating cancer a few months later.

Initially Ehrenhaft lived in the USA with his first wife's brother, and later with his own son, a surgeon in the Mid-west, and it is unclear how he supported himself during this time. In Vienna he had been funded by the Rockefeller Foundation, and there was an account there in his name but he was unable to use those funds. He then made several contacts with scientists in the USA, including Einstein, trying to find an academic position, but to no avail. Eventually he managed to publish some of his recent work – especially the experiments where he claimed to have separated magnetic monopoles.[13]

He moved to New York City in 1940, where he met sculptress Lilly Rona (Figure 2), a Jewish Austrian who had emigrated earlier, and whom he would marry in March 1942.[14] Born Alice Lili Taussky in 1893 in Temesvar (now in Romania), she moved to Vienna to study physics and languages, before joining the studio of Austrian sculptor

13 Ehrenhaft, 'Diffusion, Brownian movement, Loschmidt's number and light', *Physical Review* (1940) 57, pp. 562 and 659; *idem*, 'Photophorèse, électrophorèse et magnetophotophorèse', *Annales de Physique* (1940) 13, p. 151; *idem*, 'Physical and astronomical information concerning particles of the order of magnitude of the wavelength of light', *Journal of the Franklin Institute* (1940) 230(3), pp. 381–393; *idem*, 'Photophoresis and its interpretation by electric and magnetic ions', *Journal of the Franklin Institute* (1942) 233(3), pp. 235–256; *idem*, 'Stationary electric and magnetic fields in beams of light', *Nature* (1941) 147, p. 251; *idem*, 'The magnetic current', *Science* (1941) 94, p. 232.

14 Among other US works, Lilly was commissioned to sculpt busts of Arturo Toscanini, President Eisenhower and Eleanor Roosevelt, which won her public praise.

Gustinus Ambrosius. She bought equipment for Ehrenhaft and assembled a small laboratory that allowed him to continue with his experiments on water magnetolysis (separation of the component gases through a strong homogeneous magnetic field, supposedly analogous to electrolysis) and magnetic currents. Lilly Rona also followed the scientific conversation between Ehrenhaft and Einstein, and she ended up accusing Einstein of playing a two-faced game. As a result, their relationship became ever more shattered and embittered.

The Dibner Collection correspondence between Ehrenhaft and Einstein

The earliest letter in the Dibner archives is a typed transcript by Ehrenhaft of Einstein's handwritten letter of August 1917, commenting on two of Ehrenhaft's articles, and explicitly mentioning negative photophoresis. Ehrenhaft had probably earlier used a metaphor comparing theories with the fable of the greater strength of dry twigs when bundled together, to which Einstein replied something reminiscent of what came to be known as the Duhem–Quine thesis in the philosophy of science: 'but taking one individual piece apart to show it can be broken induces error. The value of a hypothesis lies in its multiple applications. One can never demonstrate a hypothesis that belongs to a theoretical complex'.[15] The next item is a more extensive manuscript letter from Einstein, written on 23 March 1932, while returning from Pasadena to Europe on board the ship *San Francisco*, where he acknowledged and thanked Ehrenhaft for sending him an (undisclosed) amount of money. Einstein discussed some of Ehrenhaft's experimental curves, apparently linked to the subelectron question, and said he was especially interested in a 'most important question', i.e. whether uncharged particles would experience any forces in the electrical field and also whether the charge differences corresponded to the elementary electric quantum.

Most contemporary physicists regarded Ehrenhaft's results of the subelectron controversy with suspicion, and at the same time were puzzled by his experiments.[16] Could Einstein and others have been mistaken about his claims? Some of his published work on subelectrons was revisited in 1972, on occasion of a meeting about the history of twentieth-century physics at Lake Como.[17] One of the related communications there was by Gerald Holton, and another by Paul Dirac, thus giving an opportunity to know how Ehrenhaft's early work was judged in the 1970s.

15 'Abschrift eines Briefes von Prof. Einstein an Prof. Ehrenhaft, August 1917', Dibner Library of History of Science and Technology, American History Museum, Smithsonian Institution, Washington, DC, MSS 2898.

16 This is expressed in several letters kept at the Center for History of Physics (College Park, MD), as in the one written to Einstein by W.F.G. Swann from the Bertol Research Foundation on 16 November 1940: 'I suppose that most of us would agree that Ehrenhaft's interpretations of his experiments are likely to be wrong, but I personally feel that there may be something in the experiments themselves which should be further investigated'. In his reply of November 19 to Swann (op. cit.), Einstein said, 'Concerning his results about the elementary charge I do not believe in his numerical results but I believe that nobody has a clear idea about the causes producing the apparent sub-electronic charges he found in careful investigations'.

17 Paul A.M. Dirac, 'Ehrenhaft, the subelectron and the quark', in C. Weiner (ed.), *History of Twentieth Century Physics: Proceedings of the International School of Physics Enrico Fermi. Course LVII (1972)*, New York: Academic Press, 1977, p. 290. Gerald Holton's study was later included in *The Scientific Imagination: Case Studies*, London: Cambridge University Press, 1978.

Holton gives a vivid tale of the polemic Ehrenhaft got into with Robert Millikan about the value of the electric charge *e*. Ehrenhaft had been the first to publish this value in 1909, using Brownian movement in colloidal preparations, and his figure at that time was close enough to what is accepted today. Millikan used a different ('oil-drop') method and his first values were not so close, but he improved in the next years. The problem started when Ehrenhaft announced through the prestigious *Physikalische Zeitschrift* that he had also measured values smaller than *e*, which he called 'subelectrons', generally 2*e*/3, but also *e*/3 and *e*/2. Millikan said that this was a result of inadequate methods or erroneous observations, and Ehrenhaft in turn criticized Millikan's data. A new series of experiments by Millikan was viewed as a final blow to the hypothesized subelectron, the academic world at large became convinced, and Millikan received in 1923 the Nobel Prize for the charge measurement. Ehrenhaft's values and his interpretation were then generally discredited, even though he and his collaborators still carried on new experiments which kept reporting fraction charges of electricity.

Holton went back to Millikan's original notebooks to analyse his measurements, and concluded that the same values could indeed be taken as evidence for charges smaller than *e*, as pointed out by Ehrenhaft.[18] Holton also suggested that there was more at stake than rivalry between two methodologies of experimental work, pointing to Ehrenhaft's dedication to the teachings of Ernst Mach (1838–1916), usually referred to as 'positivism'. Taken as a belief that facts speak for themselves, the same things must be observed by any able experimenter – however, the positivist's faith in facts becomes an issue because data can be as much laden with ideas and subjectivities as are theories. Mach is also remembered for his stubborn denial of atoms, using the argument that an atom is not a phenomenon to be directly sensed.[19]

Ehrenhaft was imbued with the ideas that once animated that scientist–philosopher (who also greatly influenced Einstein), as seen on the occasion of the 1926 inauguration of a monument to Mach at the Vienna University. Einstein sent his salutation, which was followed by addresses of Moritz Schlick, Hans Thirring and Ehrenhaft – and with the exception of Ehrenhaft, they all distanced themselves from Mach on the subject of atomic evidence, while Ehrenhaft reaffirmed that

> Mach had the courage to fight against . . . the strong mainstream of atomistic vision . . . which in the smallest apparently has no further divisible components of matter, and recently also of electricity, believing he had the magic key, with which in the end all knowledge gates of natural science can be opened.[20]

18 Allan Franklin, in *The Neglect of Experiment*, New York: Cambridge University Press, 1986, pp. 138–164 and 215–225, challenged Holton's conclusions, stating that Millikan's data exclusion did not change the final value of *e*, yet he agreed that Millikan touched up some of his numbers, which reduced the statistical error – the larger uncertainty might have stirred up disagreement. Franklin's arguments are centred on the defence of Millikan's interpretation and selection of experimental data, and contrary to Holton, he does not contemplate Ehrenhaft's arguments.

19 See, for example, Ernan McMullin, 'The development of philosophy of science 1600–1900', in Robert C. Olby *et al.*, *Companion to the History of Modern Science*, London: Routledge, 1990, pp. 834–836.

20 Cited in Braunbeck, op. cit. (4), pp. 42–44.

The same defence of Mach by Ehrenhaft can apply in principle to Ehrenhaft and the electron, in a way other than the trivial empiricist interpretation it first seems to be. There was a deeper phenomenological question – to decide whether atoms were the smallest entity that can exist. In other words, how could one be sure atoms were indivisible? Is any so-called smallest entity truly ultimately quantized or can a further subdivision be expected beyond that stage? Ehrenhaft sided with those who thought that the ideal atom had not been found, and if, on the other hand, the electron could be broken down into further components, was there ground for believing that an ultimate electric 'unit' existed? Ehrenhaft was attacked by scientists who were pro-Millikan and consequently he was supported by anti-atomists and empiricists around Mach.

The issue opposing atomism and anti-atomism with this latter implication has reappeared, as for example in the 1960s in the context of quark theory. More recently there have been proposals even going down to subquarks, all of which could render Ehrenhaft's subelectrons more real than they had appeared at the beginning of the twentieth century.[21] Yet according to Holton it would be highly improbable that Ehrenhaft could have measured what are now hypothesized as quarks solely with the experimental arrangement he had.[22]

In the other 1972 conference, Dirac reminded his Lake Como audience that the most prominent proposed quarks were subelectrons with ⅔ of the electron charge, and he re-examined the paper published by Ehrenhaft in *Philosophy of Science* (1941) with experimental data on subelectrons. He accused Ehrenhaft of not being a good physicist because he should have identified such strange results as systematic errors, but Dirac conceded that the data showed exactly $2e/3$ charges, and wondered about the reason for that.

Returning to the Einstein–Ehrenhaft correspondence, there follows a major gap, resumed with a letter from 19 May 1939 addressed to the latter, now living in London, his first step towards American exile. Einstein started expressing his joy because Ehrenhaft had 'now escaped from that Hell. One generally says that the Austrian Nazis are even more infamous than the German ones (if that were possible . . .)'.[23] Einstein then threw cold water on Ehrenhaft's intention to publish a book in the United States, arguing that there were considerably fewer readers of scientific books there than in the German-speaking countries. The Princeton Institute, he continued, could not give Ehrenhaft a grant or be of any help to him – and ended by stating that there were no theoretical

21 Any theory conceiving of an inner structure for 'elementary particles' faces the problem of continuity versus discontinuity – an example dealing with the elementary charge is the proposed structure for the electron based on helical plasma-like filaments advanced by Winston M. Bostick in 'The morphology of the electron', *International Journal of Fusion Energy* (1985) 3, pp. 9–52.

22 Barry Barnes, David Bloor and John Henry, *Scientific Objectivity: A Sociological Analysis*, London: Athlone, 1996, pp. 18–45, have addressed the question of interpretation of experimental results, choosing as a case study exactly the historiography construed by Holton on the Millikan–Ehrenhaft subelectron debate, and the response to Holton advanced by Alan Franklin. The task of interpreting data is a complex one, often aggravated by the sociological contents of local culture, and their conclusion was that the debate is not over.

23 Dibner Library of History of Science and Technology, American History Museum, Smithsonian Institution, Washington, DC (hereafter DL), MSS 2898, letter from Einstein to Ehrenhaft, 19 May 1939.

reasons for all electric charges to be multiples of an elementary charge, though there were plenty of empirical motives that fit into that hypothesis.

On 10 July 1939, Ehrenhaft was already living in Iowa City, at his brother-in-law Steindler's, and Einstein wrote to disagree that the velocity of a minute sphere suspended in gas would be little affected by Brownian motion.[24] This subject is taken up again in a series of four letters, and in the first one (30 August 1939) Einstein wrote that, given the content of Ehrenhaft's work, he would like to prevent him from publishing, for this would 'unleash ferocious criticism, which would worsen your practical situation'.[25]

Ehrenhaft replied (September 2) that his situation was already so difficult that it could not possibly become worse, and defended his experimental work, insisting that it was necessary to work with such small particles because smaller charges would manifest themselves more easily. Einstein immediately (September 3) countered the technical objections of Ehrenhaft with some of his own epistemological conceptions: 'The experimental physicist's goal is not only to achieve reproducible results of experiments. The determining factors should also be as simple as possible, so that one can thereof deduct elementary laws that may be applicable in other situations.'[26] At the end of this letter there is a harsh comment against Ehrenhaft, with the excuse that he was being very brutish only to make himself well understood; further, 'Your opinion, that new field laws should be used to clarify the phenomena researched in your work, without indications on how to proceed, sounds simply ridiculous; compare: someone proposes to research the stock market oscillations based on Maxwell's equations.'[27] It is ironic that not Maxwell's equations, but Brownian movement itself had already been used by that time to analyse stock market oscillations.[28]

Anyway, what Ehrenhaft had in mind now was the existence of monopoles, which did demand new field laws.[29] To propose the existence of magnetic monopoles a person might have invoked an aesthetic dissatisfaction with the non-symmetry of Maxwell's equations regarding the electric and magnetic fields, but this was not the case for Ehrenhaft. He had not started from revisionist assumptions regarding the laws of physics, but worked the other way round, in the sense that his experimental results prompted him to revise the theory. In his words, 'When I came to the conclusion that there are single magnetic poles (magnetic charges), it was therefore not necessary to ask

24 Brownian motion consists of the displacement of minute particles (dust, pollen etc.) floating on liquids or suspended in gases, subject to random forces due to the thermal agitation of the fluid molecules. Einstein, in his famous 1905 article on Brownian motion, established a numerical relationship that could be experimentally tested to determine the value of Avogadro's number (the number of molecules in a mole of gas).

25 DL MSS 2898, letter from Einstein (Nassau Point) to Ehrenhaft, 30 August 1939.

26 DL MSS 122A, letter from Einstein (Nassau Point) to Ehrenhaft, 3 September 1939.

27 DL MSS 122A, letter from Einstein (Nassau Point) to Ehrenhaft, 3 September 1939.

28 Around 1900, Louis Bachelier first proposed that financial markets followed a 'random walk' which could be modelled by probability calculus and Brownian motion theory; see Sun Kelvin Hoon, 'Brownian motion and the economic world', *Surprise 95*, online journal available via www.doc.ic.ac.uk (accessed 28 June 2008).

29 Specifically, that Gauss's law for magnetism admits div $B \neq 0$, and Faraday's induction law includes a term related to the magnetic displacement current $\mathbf{j}_m$.

if they agreed with existing theories, but rather whether there are any experimental facts that contradict it.'[30]

Ehrenhaft apparently replied to all objections, as Einstein said in the next letter (6 September), that even so he could not believe at all that the charge depended on the size of the particle, and if it did so, there must exist an unknown source of errors – he concluded in a friendlier mood saying that this letter exchange brought him 'true joy, because through it I can better apprehend the problem'.

On 9 January 1940, Einstein wrote and begged Ehrenhaft (now living in New York) not to visit him with his 'artist friend' (probably Lilly Rona) for he would be too busy, and said that he had not yet talked with others about Ehrenhaft's expectations concerning work in Harvard.

The correspondence rhythm of February and March 1940 is a frenetic one. Ehrenhaft's letter from 14 February 1940 was appended with a copy of his communication on photophoresis to the forthcoming meeting of the American Physical Society (later printed in the *Journal of the Franklin Institute*). Ehrenhaft's carbon copy of this letter had a postscript: his discovery that there were charges smaller than the electron in 1910 had led him afterwards to know that light, given certain conditions, could exert upon matter not only compression forces, but also traction ones. He had discovered magnetophoresis as a symmetrical process to electrophoresis, following the footsteps of Oersted and Faraday. In his words, 'light dissociates not only electric poles, but also magnetic ones', a knowledge he had 'acquired without any resource to the atomistic hypothesis',[31] here doubtless meaning the assumption of an elementary electricity quantum.

The next day, Ehrenhaft wrote again, telling Einstein that after discovering light's action to create magnetic monopoles, he would also be able to speak of magnetic currents, and hinted that in outer space there is a flow of magnetic current from the Sun to the Earth. On 16 February Einstein replied that Ehrenhaft's opinions were probably wrong, and he also commented on Ehrenhaft's paper, soon to be presented at the American Physical Society, making some suggestions but reassuring him that its content was very good and efficient. On the following day Ehrenhaft wrote in disagreement with most of Einstein's corrections, emphasizing that in his experiment the magnetic monopoles moved along the lines of force of the homogeneous magnetic field, and not perpendicularly to them, as was also observed in the case of the Sun's corona radiation.

A short digression is worthwhile here. Dirac's 1972 paper also mentioned that in the 1930s Ehrenhaft had insisted on having discovered single magnetic poles and sought support for his discovery. Dirac refused, because Ehrenhaft's monopoles were much weaker than those predicted by his own theory.[32] According to Dirac, Ehrenhaft often approached him in the corridors to pour out his woes about the matter, since he

> was not allowed by the secretaries to speak at these [American Physical Society] meetings. His reputation had sunk so low, everybody believed him to be just a crank ... I formed the opinion

30 Ehrenhaft, 'The magnetic current', *Science* (September 1941) 94(2436), p. 232.

31 DL MSS 2898, letter from Ehrenhaft to Einstein, 14 February 1940.

32 Helge Kragh briefly mentions Dirac's refusal to discuss monopoles with Ehrenhaft in *Dirac: A Scientific Biography*, Cambridge: Cambridge University Press, 1990, pp. 216–217.

that he was in any case sincere and honest, but he must have given the wrong interpretation to his experiments.[33]

We here find a clue to the general disapproval of Ehrenhaft in mainstream physics: he was treated by many scientists as an eccentric, and, to say the least, someone to be ignored publicly to avoid embarrassment. Dirac's judgement is retrospective and his notion of Ehrenhaft's exclusion from the meetings is not exact, since Ehrenhaft did deliver his intended lecture at the American Physical Society in 1940. In Ehrenhaft's own view such presentation met with success in terms of the public interest it aroused.

Einstein (on 20 February 1940) renewed his objections, and asked Ehrenhaft why the magnetic charge should leave the particle after the radiation was interrupted, and why the magnetic monopole only appeared in small particles, which all seemed 'to be forced and anti-natural hypotheses, inasmuch as there is no broader experimental basis for them. This does not change anything, that the phenomenon itself is highly interesting'.[34]

Ehrenhaft (21 February) insisted that he was not interpreting wrongly, what he had observed was a real current, evidenced by the displacement of magnetic monopoles, and he had followed Faraday's advice: 'nothing is so good as an experiment, which removes the errors and leads to unconditional progress'.[35]

A singular personality trait of Ehrenhaft, as he would also demonstrate in his contacts with Einstein in America, was his naivety – for example, in spite of his Jewish origins he had publicly agreed in principle with right-wing radicals such as Lenard and Stark, albeit only in terms of physics. Anyhow, his endorsement of epistemological premises of 'German physics', as the above apology of practice against theory suggests, continued even after the war was over, and Ehrenhaft always chose to ignore its political content, and satisfy himself with what he thought was a vindication of his own scientific convictions.[36]

Ehrenhaft (on 27 February 1940) continued to counter the arguments of Einstein's previous letter and objected that Lorentz's force was not the explanation for the shape of the Sun's corona – Einstein had insisted on 16 February that Ehrenhaft must mention Lorentz's force, so that people would not think he was ignorant. Lorentz's force, according to Ehrenhaft, was not a sufficient explanation because with the Sun's magnetic field strength H decreasing rapidly with distance, the spiral where the particle moved should become ever smaller, whereas the solar photographs did not show that.

33 Dirac, op. cit. (17), p. 290. On a later occasion, after the alleged monopole detection in 1975 in a cosmic ray experiment, Dirac addressed the matter, and did not mention Ehrenhaft at all – see Paul Dirac, *Directions in Physics*, New York: Wiley-Interscience, 1978, pp. 39–54.

34 DL, MSS 2898, letter from Einstein to Ehrenhaft, 20 February 1940.

35 DL, MSS 2898, letter from Ehrenhaft to Einstein, 21 February 1940.

36 Paul Feyerabend, in *Killing Time* (1995), Portuguese translation, São Paulo: UNESP, 1996, p. 74, remembers when attending physics classes in 1947 that Professor Ehrenhaft still approved of the theoretical conceptions of 'German physics', and Braunbeck, op. cit. (4), p. 68, confirms that Ehrenhaft preferred to ignore the book's preface (with its anti-Semitic attacks) in favour of its physical contents. Ehrenhaft repeatedly said he followed Faraday's advice, of scepticism towards the use of theory, and precedence given to experiment (cited in Felix Ehrenhaft, 'Festrede an Michael Faraday', *Physik und Chemie* (1932) 32(5), p. 14).

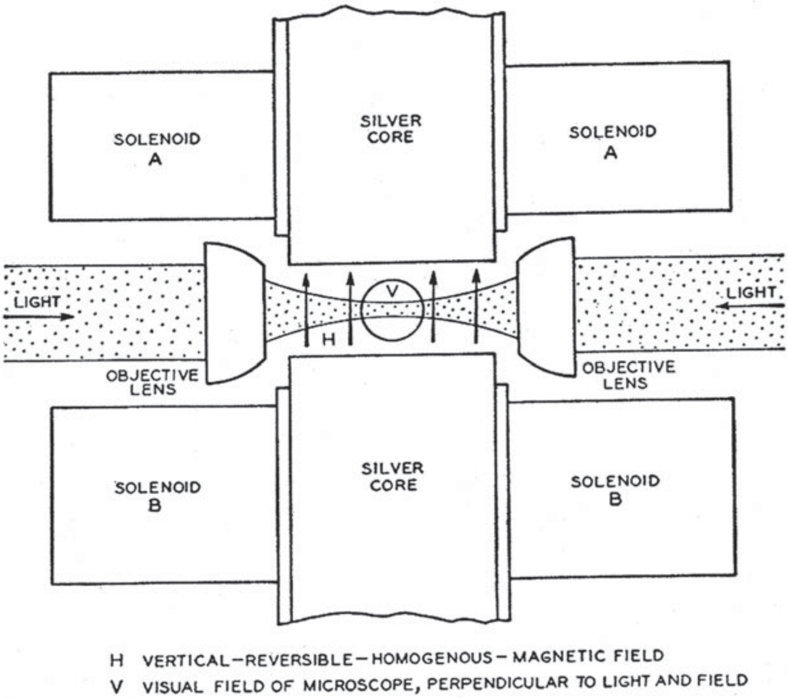

Figure 3. Condenser and coils in Ehrenhaft's apparatus (*Journal of the Franklin Institute* (September 1940) 230(3), p. 388).

As most of the letters written by Ehrenhaft to Einstein here examined are devoted to his alleged experimental production of isolated magnetic poles, this deserves a closer examination. The laboratory arrangement is described in many of his articles and also repeated in class notes taken during the year 1947 (Figure 3).[37]

He started with a glass cell of square cross section placed between the two poles of a permanent magnet (or also an electromagnet). The cell gathered probes suspended in a gas, and was provided with two thin grounded silver bands, which functioned as a Faraday cage to avoid electrostatic influence. The magnet poles had diameters varying between two and sixteen millimetres, and were conductively interconnected and grounded. To the right side of the poles was a plate condenser, to be directly viewed through a microscope.[38]

37 Ehrenhaft, 'Einzelne magnetische Nord-und-Südpole und deren Auswirkung in den Naturwissenschaften (10 Vorlesungen gehalten im Sommer-Semester 1947 v. Dr. Felix Eherenhaft – Gastprofessor an der Universität Wien' (mimeo)). See also *idem*, 'Photophoresis and its interpretation by electric and magnetic ions', *Journal of the Franklin Institute*, op. cit. (13).

38 Ehrenhaft relied very much on his condenser arrangement, first developed for the electron charge measurement. More technical details are found in Andreas Makus, 'Der Physiker Felix Ehrenhaft (1879–1952) und die Bestimmung der Elementarladung. Ein Versuchsnachbau', *Blätter für Technikgeschichte* 64 (2002), pp. 25–45.

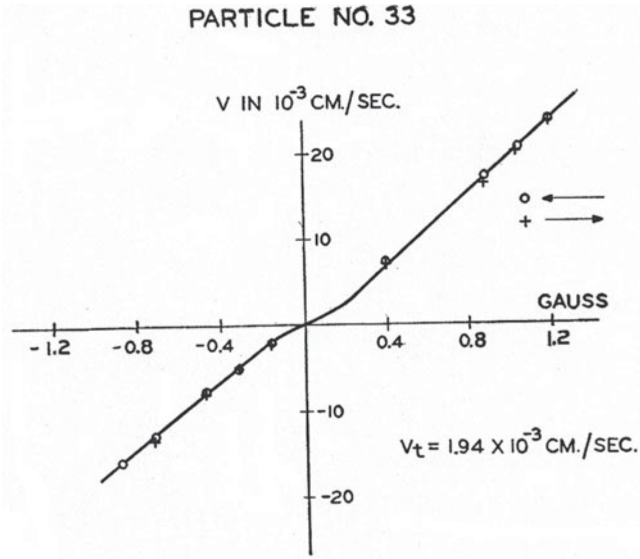

Figure 4. Magnetophoretic force – V_t velocity of fall (*Journal of the Franklin Institute* (September 1940) 230(3), p. 390).

The experiment started with a vertical, homogeneous, magnetic field, that could be switched on and off, entirely free of remanence (remaining magnetism after removal of an exciting magnetic field). Several tiny bits of matter, neither spherical nor diamagnetic, were suspended, and these particles were brought together by the action of the magnetic field in the absence of light, along the direction of the magnetic force, letting them fall under the influence of the Earth's gravity. By compensating the gravity force the particles floated. An intense light then hit them, from either side or both sides, and it was observed that the particles moved away, some towards the north end, and others towards the south side of the magnetic field, while there was light. The resulting force was proportional to the field strength (Figure 4 – Ehrenhaft stated his precision to be 3 per cent). Switching off the magnetic field, this movement was immediately interrupted, thereby causing the particles to fall.

Once again resuming the letter exchange, Ehrenhaft communicated (10 March 1940) the recent death of his second wife, and asked if he could visit Einstein in Princeton to discuss the magnetic current experiment. On 27 March 1940, Ehrenhaft thanked Einstein for sending a check for 250 dollars. The series of references concerning money (always involving that same amount) had to do with Einstein's friend Janos Plesch, whom Ehrenhaft had first met in Berlin in the early 1930s when he visited Einstein.[39] Plesch was a famous medical doctor, married to an experimental physicist, and responsible for gathering the Einstein Fund in Berlin, which was a permanently renewed

39 The acquaintance of Ehrenhaft with Einstein's medical doctor Plesch is documented in Braunbeck, op. cit. (4), p. 53. His relationship with Einstein is also in Jeremy Bernstein, *Secrets of the Old One: Einstein, 1905*, New York: Copernicus, 2005.

total of 10,000 marks, a considerable amount at the time, laid at Einstein's disposal. Plesch became a lifelong friend of Ehrenhaft's and helped him on several occasions during the exile, including lodging Ehrenhaft when he escaped to London, where Plesch was living. It is possible that money out of that fund was still available through Plesch after Einstein went to the USA, and maybe Einstein occasionally used this money to help Ehrenhaft.

In the same letter Ehrenhaft answered a question asked by Einstein's secretary (Helen Dukas) about the Rockefeller grant money: he avoided giving it right away to the Nazi authorities, but even so it had been held back in Vienna. He also mentioned that the Rockefeller Foundation was no longer supportive of research in physics, preferring biology instead. He had reviewed the literature on the Brownian movement since 1905 and found that the experiments did not confirm Einstein's theory.[40] Ehrenhaft had also talked with Bell Laboratory (apparently a suggestion given by Einstein) about conducting there his experiment on magnet discharge by light, but they gave no answer, so he added, 'it is always difficult to conduct pure scientific experiments in a technical laboratory devoted solely to profit'.[41] Ehrenhaft also questioned the numerical determination of the Loschmidt number, a German term used to designate the Avogadro constant, insisting that the correct value could only be obtained if the Brownian movement experiment proposed by Einstein were conducted in a dark room.[42]

On 28 March, Einstein reported that Ehrenhaft's manuscript (which Einstein had forwarded to Sir William Bragg over two months before) had been refused in London. Also, it would be useless for Einstein to write to the Rockefeller Foundation to intercede in favour of Ehrenhaft. In his reply (3 April 1940), Ehrenhaft said he could well understand the Royal Society's viewpoint, since it was 'the last work of a Jew in German land',[43] hastily written, incomplete and without the experimental construction instructions. He could, however, not understand James Frank's refusal in the name of *Physical Review* to publish another work of his, and gave Einstein a long list of articles whose study reinforced his conviction that photophoresis could not be a consequence of radiometric effects. To this Ehrenhaft appended a list of seven detailed technical questions concerning the measurements and experimental evidence of photophoresis. The Dibner Library keeps Einstein's refutations thereof and also Ehrenhaft's final rejoinders to the seven questions.

When he wrote to Einstein on 7 April 1940, Ehrenhaft was about to send a note to *Physical Review* (apparently not accepted) about Einstein's theory – possibly again a reference to Brownian movement. The next day Ehrenhaft told Einstein he had just come back from another talk with Marvin Kelly, head of the Research Laboratory of Bell Co. and an ex-student of Robert Millikan's. Ehrenhaft had proposed working at Bell on the

40 For that purpose he had counted on the help of a former collaborator and physics student in Vienna, Baron Robert Heine-Geldern (a descendant of the poet Heinrich Heine).

41 DL MSS 2898, letter from Ehrenhaft to Einstein, 27 March 1940.

42 This conclusion was communicated by Ehrenhaft in a published letter, 'Diffusion, Brownian movement, Loschmidt–Avogadro number and light', *Physical Review* (1940) 57(1050), pp. 562 and 659.

43 DL, MSS 2898, letter from Ehrenhaft to Einstein, 3 April 1940.

magnetophoresis experiments, but Kelly told him that meanwhile Millikan had written a letter mentioning some negative comments from Einstein to Millikan about the same subject.

On 10 April 1940, Ehrenhaft unusually wrote in English, and complained to Einstein that in a second letter to Kelly, Millikan stated that Ehrenhaft's article (the one sent to William Bragg at the Royal Society) was 'so inferior and below the average American level' that it could not be published – and how would Millikan know of that?[44] Only by being part of the editorial board, or if Einstein had written to Millikan about this subject, said Ehrenhaft. He agreed that no one was obliged to give him a job in a country where he did not seem to be welcome, but it was unacceptable to prevent him from having his article published. He felt hurt especially because of the coming international physics congress to be held in New York, following the last one in Paris before the war (1937), where Ehrenhaft had the honour of being chosen by four thousand scientists to deliver the prestigious thanking speech. Ehrenhaft was willing to go to London to defend himself against those accusations. Einstein (15 April) replied that he had asked for but not yet received Kelly's letter cited by Ehrenhaft, and thought it useless to have a conversation with Ehrenhaft, especially because he was overloaded with work and did not have time.

The intense letter exchange momentarily halted. Did Ehrenhaft suspect that the embargo in fact stemmed not only from Millikan, but also from Einstein?

The Dibner Library keeps also a letter to Einstein dated 31 May 1940, written 'under real tragical circumstances' by Richard Kobler, an Austrian engineer and ex-student of Ehrenhaft's now living in New York.[45] Kobler said that 'the "Ehrenhaft affair" threatens to take such catastrophic proportions' that he decided to address Einstein himself. Kobler and other friends had persuaded Ehrenhaft not to travel to London at all, an uncertain destination at this time, even though in England there was assurance of material support for Ehrenhaft and his experiments, exactly what was lacking in the USA. Kobler wanted to talk these matters over with Einstein in Princeton. It is not known whether Einstein answered Kobler and if such a meeting ever occurred.

Einstein wrote again to Ehrenhaft on 26 July 1940, saying he knew nothing concerning any ill feelings between them and evoked again the amount of $250 that Ehrenhaft was unable to use, and added,

> I must admit that for theoretical reasons I am firmly convinced that there cannot be any isolated magnetic pole. The reason is that the quadrupole potential appears to have an immediate physical signification, and this because Stokes' theorem excludes isolated magnetic poles. Even so you may convey your ideas to me and I will tell you what I think of them.[46]

Perhaps Einstein had in mind that the usual quadrupole derivation matched most of the experimental evidence, lending support to the assumptions behind Stokes's theorem (the surface integral of the curl of a vector function equals the line integral of that function around a closed curve bounding the surface). Ehrenhaft's position implied that

44 DL, MSS 2898, letter from Ehrenhaft to Einstein, 10 April 1940.
45 DL, MSS 2898, letter from Richard Kobler to Einstein, 31 May 1940.
46 DL, MSS 2898, letter from Einstein to Ehrenhaft, 26 July 1940.

Table 1. *Electric × magnetic current*

Electricity	Magnetism
Movement of single electrical charge. Consequence: magnetic field. *Rowland 1876*	Movement of single magnetic pole. Consequence: electrical field, induction experiment. *Faraday 1831*
Bodies move in homogeneous electrical field. Direction reversal with field reversal. Electrical ions. *Faraday 1830*	Bodies move in homogeneous magnetic field. Direction reversion with field reversal. *Ehrenhaft 1930, 1941*
Positive and negative electrical charge produced by friction	North and south magnetic poles produced by friction. *Ehrenhaft 1941*
Electrophoresis. *Reuss 1809*	Magnetophoresis. *Ehrenhaft 1941*
Particle coagulation in electrical field	Particle coagulation in magnetic field. *Ehrenhaft 1941*
Electrophotophoresis. Bodies move in homogeneous electrical field in or against field direction when strongly irradiated. They revert with the field, and speed is a function of field strength and light intensity. *Ehrenhaft 1920*	Magnetophophoresis. The same behaviour in the magnetic field as in electrical field. *Ehrenhaft 1930*
Water electrolysis. *1800*	Water magnetolysis tried (*Fresnel 1820*). Conducted by *Ehrenhaft* with electromagnets *1942*, with permanent magnets *1944*
Loss of pole strength in a Volta battery during electrolysis	Loss of pole strength of permanent magnets during magnetolysis. *Ehrenhaft*
Magnetic whirl around electric current (*Oersted*). Deviation of magnetic needle through wire connecting poles of Volta battery	Electric whirl around wire connecting both poles of permanent magnet. *Ehrenhaft 1944*
Measurement of current strength due to the work of current traversing poles	Measurement of magnetic current strength due to work of charges traversing poles. *Ehrenhaft*
None	Spiral paths of bubbles and particles in constant homogeneous magnetic field in fluids as well as gases. *Ehrenhaft*

Stokes's theorem was in this case equivalent to the denial of monopoles, and he chose not to use it.

From Ehrenhaft's letters and articles consulted, it can be said that nowhere did he clearly indicate how isolated magnetic poles or magnetic currents were to be produced from his experimental setups. He certainly thought that a causal relationship in this sense would result from further research in the foundations of physics – and he was not worried with such explanation, as for him the experimental evidence was sufficient. His research programme can be summed up in a lifetime dedication to the proof of a complete and equivalent parallel between the electric and magnetic fields. This is illustrated in Ehrenhaft's own perspective by Table 1, devised after his return to Vienna, comparing what he considered his achievements in exploring the full implications of this parallelism with other hallmarks previously established by others.[47]

47 Adapted from Ehrenhaft, 'Einzelne magnetische Nord-und-Südpole', op. cit. (37). The references to physicists and years are Ehrenhaft's.

A triangular correspondence

At this moment there appears in the correspondence the intrusive register of a third person: Lilly Rona. Her contribution is at first through poems, a form of expression she shared with Einstein – these poems are here fully presented to give the flavour of the dispute. It was Einstein who started it, writing to Ehrenhaft the following short verse on 16 August 1940:

> So it is not possible
> To force conviction
> Ultimate repetition
> Is after all no argument[48]

Ten days later Lilly Rona replied to Einstein in the same vein:[49]

> It is a beautiful speculation
> But complicates the discussion
> For in my opinion it lacks
> Total knowledge of the phenomenon

On 17 September, Lilly wrote another poem to Einstein, implying that Ehrenhaft had studied Morichini's 1812 essay about the dissociation of magnetic poles by light:[50]

> While you in the regions
> Dwell where angels live
> I found now that the magnet
> Also arises through divine light –
> Morichini, eighteen hundred,
> Admired this phenomenon.
> New physics is enforced
> Best wishes your Ehrenhaft

Ehrenhaft resumed the prose correspondence on 26 September, saying he was far from forcing conviction upon Einstein, he only wanted to keep him informed, and by the way he had another article ready, this time about Einstein's own research area, namely light. Ehrenhaft was 'convinced that our scientific opposition will in no way damage our old friendship relations'.[51] On 15 October, Einstein replied that he was sorry, for he could not invite Ehrenhaft for a conversation since he could no longer hope to achieve agreement. This very day Ehrenhaft wrote back an interesting answer, not entirely free from positivist tones:

> Scientific matters are not matters for agreement, as usually happens in politics or in men's lives, but scientific knowledge is either right or wrong. The judge of new or rediscovered knowledge

48 DL, MSS 2898, letter from Einstein to Ehrenhaft, 16 August 1940. The poem translations are my own, and I have endeavoured to keep at least some traces of the poetic flavour of the original German verses.

49 DL, MSS 2898, letter from Ehrenhaft to Einstein, 26 August 1940.

50 DL, MSS 2898, telegram from Lilly Rona to Einstein, 17 September 1940. According to Edmund Whittaker, *A History of the Theories of Aether and Electricity* (1951), College Park: American Institute of Physics, 1987, vol. 1, p. 190 n. 1, the work of Morichini in Rome was published in 1813.

51 DL, MSS 2898, letter from Ehrenhaft to Einstein, 26 September 1940.

remains solely the well-arranged experiment with the consequent conclusions and added-on knowledge.[52]

Einstein, however, remained firm in his decision, and communicated to Ehrenhaft on 17 October 1940 that 'a new discussion would be useless, because hopeless. Moreover, if the experiment alone decides or has already decided, then my participation is totally superfluous'.[53]

Ehrenhaft (24 October) answered that Einstein's behaviour was not appropriate to their almost thirty-year friendship. If Einstein could not receive him any more, Ehrenhaft for his part could not accept any longer the amount at his disposal with the warranty given by their mutual friend, Plesch, and with that letter Ehrenhaft returned Einstein a cheque (of undisclosed amount).

All of this prompted Einstein to write Ehrenhaft the following poem (26 October):[54]

You are really a genius
I was never better punished
What you so did to me
Feels masochistic indeed
It's only ill that you're hurt
Because I protected my time
Reason: I can only repeat
Your poles will give me creeps.
Poles I cannot grasp
Which in light only exist,
And which (it is not to laugh)
In darkness fade out.

Lilly did not let the chance pass by, and immediately answered this challenge (27 October):[55]

Your last poem fits well
The ostrich politics
When it, feeling the danger,
Hides its head in the desert sand
The temporary poles shine
Over your head like hot coals
Also with permanent ions
I should spare your nerves
Solitary magnets give you the creeps
As Faust gives the creeps to Gretchen
In the magic of experiment
So it is with you – I don't know how;
But it is useless to whine or play truant
Very new consequences I found

52 DL, MSS 2898, telegram from Ehrenhaft to Einstein, 15 October 1940.
53 DL, MSS 2898, telegram from Einstein to Ehrenhaft, 17 October 1940.
54 DL, MSS 2898, letter from Einstein to Ehrenhaft, 26 October 1940.
55 DL, MSS 2898, letter from Ehrenhaft to Einstein, 27 October 1940.

From light I discovered the true essence
And much about that will you read.

Afterwards (9 April 1941), Ehrenhaft explained to Einstein that according to his calculations the Earth's magnetic field ought to be nearly one million times stronger to be capable of moving monopole magnets. In his magnetic condenser, with a more sensitive arrangement and minute particles, he had nonetheless succeeded in isolating magnetic poles and proved that light magnetizes, which would explain numerous anomalies observed in Brownian movement in liquids and gases, as well as other phenomena. He repeated that Morichini had been the first to magnetize through light, besides having discovered the photoelectric effect, and said that also Humphry Davy had observed magnetization by light.

On 22 April, Lilly wrote Einstein another poem; on her carbon copy she added a note, stating that this was after she had received report from different sources that Einstein cut off Ehrenhaft's possibilities of getting a working space in the USA by defaming her husband. She appealed strongly in this poem to puns on their names, as Einstein can stand in German for 'a stone', and Ehrenhaft for 'honored one':

How relative things also in life
And changeable in theory they seem
In Einstein's fight for truth I did trust
A rock of Judah he looked to me
Insight and wisdom looked his lot to be
In clarity richer than a precious stone
With reason 'one-stone' he could call himself
He was a step towards higher knowledge.

I can't believe he would be 'a stone'
In the throat of his friend, who breaks the waves –
A stone of the wall resting on false theory
In the fight against night that light defies.
I can't believe that truth's honour
Depends on small questions –
For this what the honoured one knows and sees
The whole world shall untroubled witness.[56]

Einstein decided to write back to Lilly in a well-humoured mood on 5 May 1941:

One is no longer an evil man
Who cannot believe something.
It's not good, even though one succeeds,
When one forces another to believe.
One should not fight for truth,
This wins through its own light.
Try instead serving to find it,
Leave to others the announcement.[57]

56 DL, MSS 2898, letter from Lilly Rona to Einstein, 22 April 1941.
57 DL, MSS 2898, letter from Einstein to Lilly Rona, 10 May 1941.

The final move of this poetic quarrel was made on 12 May when Lilly wrote,

Who cannot trust something
Listens then to the other one,
Who asked for the 'high grace'
Shows to go by the fact
And bows, if acknowledged,
To argument without constraint.
When one can't trust, then
He gives his grounds
And throws fast and simply
His own opinion in the balance –

Of ethics and morality is
The second part of the poem
For seeing and not announcing truth
Is the worst of all sins.
To fight for truth's light
Is the highest duty of the noble man
Who fights for it with spirit, and strength
In righteous sense – he is honoured.[58]

On 17 May, Einstein wrote that he saw no reason for complaint, as he could not go against his own convictions. Ehrenhaft answered (29 May) that he, on the contrary, did have reasons to complain,[59] since Einstein had spoken with colleagues against Ehrenhaft's experiments, and though he had volunteered several times to demonstrate them in Princeton, Einstein had never agreed, without substantiating his refusal. Besides, he had heard that Einstein had commented to a common acquaintance (the philosopher of science Spencer Heath) that magnetism propagates at the speed of light, which was an idea similar to Ehrenhaft's. Moreover, he continued, Einstein should know that his opinions greatly influenced public opinion, and the monopole question remained a fundamental one for physics. Lilly Rona decided then to write not a poem but a direct letter to Einstein, and in English, on 2 February 1942. She said this was the day when Ehrenhaft had discovered how to measure the magnetic current, having observed it with and without light. She bluntly asked how Einstein was going to repair 'the great injustice done to Felix Ehrenhaft' through his

> attitude towards him and the unfounded and defaming reports about his discoveries [which Einstein had] spread out not only among his colleagues but also in financial circles among bankers who had wanted to help him to proceed with his research work.[60]

To one of these bankers, Lilly continued, Einstein had even said 'hands off . . . Ehrenhaft is a fantast', and she had no doubt that Einstein had been the source of all distrust and animosity against Felix Ehrenhaft, and this was unfair to someone of

58 DL, MSS 2898, letter from Lilly Rona to Einstein, 12 May 1941.

59 'Defaming' could just be the couple's impression, since it was widely held that Ehrenhaft was an iconoclast.

60 DL, MSS 2898, letter from Lilly Rona to Einstein, 2 February 1942.

whom 'Planck said to have given the finest methods of measurement to modern physics'. Lilly accused Einstein of not having kept their disagreement private, spreading rumours against her husband instead. Einstein's own ideas about the infinity of the world, Lilly went on, were followed with interest by many people, and they could as well 'be called fantastic with much more reason than the experimental work of Ehrenhaft, who was about to develop a new source of energy and give it to the world'.[61] The last phrase probably refers to magnetolysis. Lilly ended her heavy indictment by stating she was 'going to make every possible endeavor to reestablish the honor and the scientific reputation' of her very dear friend. On 18 March 1942, Lilly complained again to Einstein, attaching a copy of the previous unanswered letter, and hinting that the publication of Ehrenhaft's paper about the magnetic current, which was about to appear in the March issue of the *Franklin Journal*, might give Einstein an opportunity to correct his regrettable statement, for which it might 'be hard to bear the responsibility'.[62]

This second letter was presumably never answered either, and it can only be conjectured that, contrary to Lilly's poems which Einstein cared to answer, the letters could not be taken light-heartedly. This remains the last item in the correspondence file, even though Lilly Rona reproduced another poem written to Einstein in a manuscript of her own article kept in the Dibner Library, *Der Magnet als negativer Katalysator des Wassers*:[63]

While in the formula marshes
One gets only wet socks
In the research beds bloom
New magnet wonders.

The magnet with its poles
Unbinds and binds unconcealed,
Can – shame on the theories –
Blast gas out of water produce.

And with this gas blast
Ends the word stream
Making atomic physics pale ...
Ehrenhaft – the 'Great fantast'.[64]

An inconclusive aftermath

After the war was over, the University of Vienna asked Einstein (of all people) to give his opinion whether Ehrenhaft should be invited to come back home. Einstein's answer sounds like a final judgement: Ehrenhaft's subelectrons were a misinterpreted

61 DL, MSS 2898, letter from Lilly Rona to Einstein, 2 February 1942.

62 DL, MSS 2898, letter from Lilly Rona to Einstein, 18 March 1942. The work did appear in the *Journal of the Franklin Institute* (March 1942) 233(3).

63 DL, MSS 2898, 'Die Gravitation: ein magneto-photophoretisches Phänomen der kosmischen Strahlung', *Natur und Technik*, Heft 10–12, December 1949.

64 This poem, with slight variations, is reproduced in Braunbeck, op. cit. (4), p. 97, without acknowledging its authorship, and stating it was written during Christmas 1942.

experiment; photophoresis was an interesting result, but could be explained as a consequence of radiometric forces; and magnetic charges and currents were arbitrary interpretations. However, Einstein acknowledged, Ehrenhaft had been the first scientist to measure single elementary electric charges, and he was an able experimental physicist, in spite of drawing so many wrong conclusions, a feature which did not earn the respect of his colleagues. As Ehrenhaft was already at the age of retirement, Einstein recommended that the university award him the emeritus title and provide him with the task of lecturing on the history of physics, a subject about which he knew a lot, adding a final remark, 'This would be noble and at the same time not dangerous, and he could go to his end without bitter[ness].'[65]

The USA was at that time interested in repatriating some Austrian scientists, in order to irradiate a good image of the American way of life, and to strengthen personal ties within the academic circles of both countries. Ehrenhaft did go back, while Lilly Rona on the contrary resisted and wished to remain in the USA; in the end it was not possible to reconcile their differences and the couple decided to divorce. A note written by Lilly on 10 February 1944 already anticipated conjugal problems – she admired her husband scientifically, but sadly complained about the burden of being married to such a stubborn man, who only cared about himself, and did not give sufficient credit to his collaborators.[66] In March 1947, Ehrenhaft was again in Vienna, where he was reinstated as university professor, finally resuming his researches on magnetism and light, teaching classes and pronouncing at conferences.

One of the post-war physics students in Vienna who at first had a very sceptical attitude towards Ehrenhaft was Paul Feyerabend, as he recalled in his autobiography.[67] Accordingly, Vienna's university in 1947 had three reputed physicists: Ehrenhaft, Karl Przibram and Hans Thirring. Ehrenhaft's fame was dubious, so the students decided to unmask him; however, the professor conducted his experiments in class in such a simple and convincing manner that Feyerabend was won over and changed his opinion.

According to Feyerabend, there was 'an iron curtain' that protected established physics from Ehrenhaft, exactly like the one that had shielded Galileo's opponents.[68] This may well have been a first incentive for Feyerabend to question 'normal science', stressing that scientists did not always win just because of the merit or the 'truth' of their ideas – for him, the history of science showed that victory may lie with whoever is cleverer at producing the right propaganda. The next semester Feyerabend decided to stenograph Ehrenhaft's lectures about magnetolysis and magnetic poles, and sold copies thereof to his fellow students.[69]

In 1949 Lilly Rona went to Vienna, trying to publish scientific articles based on the work she and Ehrenhaft had conducted in New York. Ehrenhaft seemingly avoided her

65 Braunbeck, op. cit. (4), p. 105.

66 Manuscript, Center for History of Science, College Park, MD.

67 Feyerabend, op. cit. (36), pp. 73–76.

68 Feyerabend developed this argument more fully in his *Against Method*, London: NLB, 1975. The expression 'iron curtain', and the comparison between Galileo and Ehrenhaft, are Feyerabend's, op. cit. (36), Chapter 6.

69 Ehrenhaft, 'Einzelne magnetische Nord-und-Südpole', op. cit. (37).

publicly, as if embarrassed by her attempts to enter the scientific milieu, though they still exchanged letters.[70] Perhaps Ehrenhaft was too proud to now acknowledge her past participation in his work in New York.

From 1950 onwards Ehrenhaft was sick, and finally died in Vienna on 4 March 1952. Around this time Lilly Rona filed for some patents in the USA and Europe concerning magnetolysis (these are also found in the Dibner Collection). She died on 2 April 1958, in New York.

How successful a scientist was Ehrenhaft? Judging from the number of his publications, he should be relatively well known by his peers – his contributions appeared for decades in several publications in German, English and French, including some prestigious ones such as *Nature, Science, Physical Review, Comptes rendus, Annalen der Physik, Physikalische Zeitschrift* and *Zeitschrif für Physik*.[71] Sometimes a publication would include a cautionary note, as for example in the article 'Physical and astronomical information concerning particles of the order of magnitude of the wave-length of light', where the editor added the following remark, at the same time an avowal that other scientists did take notice of Ehrenhaft's work: 'While it is recognized that Professor Ehrenhaft's conclusions as to the significance of his experiments are highly controversial, the experimental results themselves are such as to have recently excited the interest of several prominent authorities.'[72] A fair reassessment of the conflict between Einstein and Ehrenhaft against the scientific tradition is very difficult. On one side is the ever more celebrated 'father of relativity', on the other a neglected physicist. There has been ongoing research on the subject of magnetic monopoles since Ehrenhaft's efforts, but it is almost entirely theoretical and the bibliography does not usually mention Ehrenhaft's publications in this field, something that could be ascribed to different concepts of what a 'magnetic monopole' is, implying different values of mass and strength. Modern experiments, some of which were initially considered as evidence of the practical existence of monopoles, were subsequently reviewed and deemed inconclusive.[73]

From the references encountered in the literature, and in various letters written by such American physicists as W.F.G. Swann, John Zeleny, G.N. Stewart, Edwin Kemble and others, it seems that Ehrenhaft, though controversial, was really

70 Their old ties appear in the letter from Ehrenhaft to Lilly, 3 May 1950 (Center for the History of Physics, College Park, MD).

71 The Central Library for Physics, Vienna University, lists about a hundred of his communications covering roughly half a century, starting in 1902. Most were published in the main physics magazines in German, though in the 1940s he also published in English (*Nature, Science, Physical Review*) and French (*Comptes rendus*). In view of that, one could hardly say that he was an unknown physicist.

72 Ehrenhaft, 'Physical and astronomical information', op. cit. (13) .

73 For downloadable articles covering this issue at arXiv.org (accessed 19 May 2007), see, for example, Kimball A. Milton, 'Theoretical and experimental status of magnetic monopoles' (22 February 2006); Helge Kragh, in 'The concept of the monopole: a historical and analytical study', *Studies in the History and Philosophy of Science* (1981) 12, pp. 159–163, recalls the false 1975 detection in Iowa; and Braunbeck, op. cit. (4), p. 136, mentions an alleged 1982 observation in Stanford. As a side note, since 1995 Joseph Newman has called attention – in quite sensationalistic tones – to a machine he invented which supposedly produces a great amount of power with a minimum of electricity. What is interesting is that Newman's Internet homepage (www.josephnewman.com – accessed 5 May 2007) reproduces Ehrenhaft's articles on the magnetic current.

considered an able experimentalist with important, albeit problematic, research.[74] To check for eventual systematic experimental errors, the best way would be to re-examine Ehrenhaft's original arrangements and methods, which have not been subject to new and more accurate investigation. Subelectrons, as well as magnetic monopoles, may indeed be hard to find in his conditions, but this possibility cannot be simply ruled out beforehand. Unfortunately, it is difficult to reconstruct his setups and interpretations based on the available documents, and after his death Ehrenhaft's experimental work has not been continued.[75]

One may feel that the opposition between Ehrenhaft and Einstein had to do with the debate of practice versus theory. Already during the Weimar period, there was a latent conflict in the German-speaking countries between theorists and experimentalists.[76] Some of the experimental physicists decried relativity and quantum theory, as the aforementioned Stark and Lenard, and when these pushed for an 'Aryan' science through the book *Deutsche Physik* the artificiality of the argument became patent, as there were 'pure' Germans like Heisenberg who sided against this movement, as well as a Jewish physicist (Ehrenhaft) who supported it.

Therefore, even though Einstein and Ehrenhaft indulged in this kind of mutual judgement of theorist and experimentalist, it has to be treated with care. Both scientists had once been practical examiners at patent offices, and notwithstanding what Einstein publicly avowed, he was well acquainted with the importance of experimental corroboration of theoretical results.

Jeroen van Dongen has written two articles which shed more light on the relationship Einstein established with the experimental field, exposing his association after 1926 with the German physicist Emil Rupp to investigate the wave–particle duality using canal radiation.[77] Einstein wanted to test whether light was instantly emitted when an atom was excited, or took a finite time span, and he rejoiced that Rupp would conduct such an experiment, even though working in Heidelberg exactly under the anti-relativist and anti-Semite Lenard. The evidence slowly built up to show that Rupp never observed what he claimed, and just reported what he believed to be Einstein's correct prediction.

There was at this time another division in the German physics community, between northern physicists who accepted the new theories, and southern conservatives who did not. Two of Rupp's supporters, Einstein and Max von Laue, were prominent theoretical

74 See, for example, the letter (Center for History of Science, College Park, MD) from Kimble (Harvard University) to Swann (Bartol Laboratory), dated 10 December 1940, commenting on electrophoresis and magnetophoresis: 'in order to stimulate a type of investigation not yet undertaken in this country it is desirable that Professor Ehrenhaft be given an opportunity to continue his work and to demonstrate the effects he has discovered. The financing of his experiments would be a service to science'.

75 One exception was Andreas Makus, op. cit. (38).

76 Klaus and Ann Hentschel refer to this as a 'protracted conflict', in *Physics and National Socialism*, Berlin: Birkhäuser, 1996. See Introduction, especially pp. lxx–lxxviii.

77 Jeroen van Dongen, 'Emil Rupp, Albert Einstein, and the canal ray experiments on wave–particle duality: scientific fraud and theoretical bias', *Historical Studies in the Physical and Biological Sciences* (2007) 37, supplement, pp. 73–120; *idem*, 'The interpretation of the Einstein–Rupp experiments and their influence on the history of quantum mechanics', *Historical Studies in the Physical and Biological Sciences* (2007) 37, supplement, pp. 121–131.

physicists in Berlin, while Lenard and Wilhelm Wien held important chairs in the south, and viewed themselves as exponents of a more experimentally oriented tradition (as did Ehrenhaft).

Van Dongen concludes that, rather than attributing Einstein's and von Laue's reactions only to sociopolitical factors, there is a much more likely cause for their continued trust in Rupp's work: the theorists' prejudices when confronted with experiment. This theoretical prejudice has a counterpoint in the experimentalist who stops searching for systematic error in his arrangement as soon as he gets the expected results. Moreover, Einstein gradually shifted the importance he attached to experience, and started believing that new insights for the creative theorist were to come just from mathematics. This might also apply to his conduct towards Ehrenhaft, even though in Rupp's case the accusations were of fraudulent works, while Ehrenhaft was until the end charged with 'systematic errors'.

On the other hand, even though Ehrenhaft strongly emphasized the intuitive approach and used in his favour the experimental examples of Franklin, Oersted and Faraday, he knew he could not simply dismiss theory.[78] It is more likely that both scientists diverged in their theoretical foundations, and as a consequence they viewed the same experimental results differently.

Ehrenhaft's personal interpretation of these differences lies in his unpublished recollections on Einstein.[79] In a section titled 'On his [Einstein's] attitude towards research', he writes,

> In my opinion there are two totally different ways of conducting research in physics. I would like to designate these two types as Faraday's method of work, and the second one as Hamilton's . . . My conversations with Einstein have convinced me that he has always preferred Hamilton's. It is known that Hamilton predicted external and internal conical refraction purely based on the differential equations for crystal optics . . . one must say, then, that Einstein predicted the gravity of light entirely in the form of Hamilton.

Ehrenhaft's attitude towards theory is the reason why, on 15 February 1940, he wrote to Einstein that his experimental findings regarding the existence of magnetic currents naturally demanded a modification of Maxwell's equations. Indirectly referring to Einstein's position, Ehrenhaft complained on 10 March 1940, 'I discovered, however, that the look of many people through the glasses of theory clouds the knowledge of experimental facts.'[80]

In his already mentioned recollections Ehrenhaft judged that although Einstein was an excellent physicist,

> he had in his chest two souls, as well as in the case of Maxwell. But one should say that, the older Maxwell grew, the more he distanced himself from atomic theory. This cannot be so clearly recognized in Einstein.[81]

78 Ehrenhaft once praised theory without experiment – in cases like special relativity. Cf. Ehrenhaft, 'Festrede in der Festsitzung der Wiener Chemisch-Physikalischen Gesellschaft anlässlich der Hundertjahrfeier der Entdeckung der elektromagnetischen Induktion durch Michael Faraday', *Physik und Chemie* (1932) 32(5), p. 12.

79 DL, MSS 2898, 'Meine Erlebnisse mit Einstein'.

80 DL, MSS 2898, letter from Ehrenhaft to Einstein, 10 March 1940.

81 DL, MSS 2898, 'Meine Erlebnisse mit Einstein'.

In the 1930s Ehrenhaft was willing to disregard Maxwell's formulation of the classical electromagnetic theory, as he found it impossible to reconcile it with his experiments. The epistemological attitude taken by scientists in face of the paradigmatic body of knowledge, when confronted with sets of conflicting experimental data, renews the question: if data do not fit the accepted theories, at what point should one distrust the results or, on the contrary, challenge the theories? The standard answer has been experimental repetition – by the same scientist or ultimately by entirely different observers.[82] However, Ehrenhaft repeated his experiments, and seemed willing to demonstrate them to others.

Helge Kragh has written an interesting essay analysing the concept of monopoles from both the historical and theoretical viewpoints, including a section devoted to Ehrenhaft's monopole.[83] He starts by supposing the existence of magnetic monopoles with the necessary consequent changes in Maxwell's equations. The quantization of the electric charge could be explained assuming the existence of monopoles – though it should be pointed out that this would not necessarily imply that the minimum charge must have the known value of *e*.

At least for part of the physics community, the existence of magnetic monopoles is nowadays considered plausible, and most 'grand unified theories' presume that, according to the 'big bang' hypothesis, in the initial stages of the universe a huge number of monopoles were produced. The so-called 'monopole problem' is exactly what happened afterwards and why monopoles seem so elusive to detect. These considerations led to the 'inflationary universe' model to explain the dilution of the monopoles.[84] Initially, such theories predicted lighter monopoles, but later the values were changed to extraordinarily heavy ones to prevent the enormous attraction they could exert, and which would crunch the universe. All taken into consideration, Ehrenhaft's claims about detection of lighter monopoles around 1940 would not seem so absurd for a theoretical physicist in the late 1970s, or even today, and of course it can always be questioned whether such monopoles would be detectable by his apparatus (as Holton argued for subelectrons).

Overall, Ehrenhaft maintained a rebel attitude towards the current theories. He appeared to be a very persistent person, perhaps sometimes in a very unpleasant manner, and his personality became abhorrent to other physicists, even to those who had themselves once dared to defy conventional explanations of physical science (as Einstein or Dirac had).

Ehrenhaft had a peculiar affection for investigating the history of physics, which he showed on many occasions, including his lengthy 1932 commemorative address on

82 See Franklin, op. cit. (18), Chapter 4.

83 Helge Kragh, op. cit. (73), pp. 141–172. His final comment is on Einstein's special relativity theory: if it is not assumed that all material velocity is subluminal, then Maxwell's equations for charges exhibiting superluminal speeds will be symmetric, and magnetic monopoles can be admitted. Should one keep this in mind to fully appreciate Einstein's reactions to Ehrenhaft's monopoles?

84 The story of this cosmological model is told by one of its authors, Alan Guth, in *The Inflationary Universe: The Quest for a New Theory of Cosmic Origins*, Reading, MA: Addison-Wesley, 1997, Chapter 9.

Faraday's discovery of induction.[85] Einstein was also considerably interested in the history of physics, but not in Ehrenhaft's opinion:

> I mention yet another observation. In a longer conversation in Caput, while we sailed I said that there existed too much writing and measuring, and stated that to be knowledgeable in physics since the year 1870 it sufficed to read no more than 25 works. Einstein thought there would be many more. We counted together and arrived at only 17 to 18, naturally excluding measurement tables among others. He agreed. In general, I observed that he is little acquainted with the history of physics, and I was amused to observe that he didn't read much either.[86]

When commenting on his own methods, Ehrenhaft repeatedly mentioned his preferred examples of Faraday and Oersted, and he often referred to himself as a continuator of their tradition, as in this letter to Einstein (14 February 1940): 'In direct continuation of Oersted's and Faradays's path I arrived at the other knowledge relative to the conflict among matter, light, electricity and magnetism.'[87]

This appeal to the epistemological procedures of Oersted and Faraday may not be casual. Perhaps Ehrenhaft viewed himself as a continuator of the German *Naturphilosophie* tradition, which certainly bore fruitful scientific results, including Oersted's discovery of the first magnetoelectric effect.[88] Even his wording is modelled after Oersted's famous communication (on the 'electric conflict') about the movement of a compass needle parallel to a current-carrying conductor. Among *Naturphilosophie*'s features there are some that reappear in Ehrenhaft's interpretation of elementary charges and magnetic monopoles, such as that matter fills space continuously by means of its primitive forces of attraction and repulsion, that matter is divisible to infinity, and that there are no discrete fluids.[89]

85 Ehrenhaft, op. cit. (78).

86 DL, MSS 2898, 'Meine Erlebnisse mit Einstein'.

87 DL, MSS 2898, letter from Ehrenhaft to Einstein, 14 February 1940.

88 Oersted's debt to *Naturphilosophie* has been minimized by H.A.M. Snelders, 'Oersted's discovery of electromagnetism', in Andrew Cunningham and Nicholas Jardine (eds.), *Romanticism and the Sciences*, Cambridge: Cambridge University Press, 1990, pp. 228–240, p. 232; as well as by Kenneth L. Caneva, 'Physics and *Naturphilosophie*: a reconnaissance', *History of Science* (1997) 35, pp. 35–106; and also by Timothy Shanahan, 'Kant, *Naturphilosophie* and Oersted's discovery of electromagnetism: a reassessment', *Studies in History and Philosophy of Science*, (1989) 20, pp. 287–305. The contrary argument, as in Robert C. Stauffer, 'Speculation and experiment in the background of Oersted's discovery of electromagnetism', *Isis* (1957) 48, pp. 33–50, is, however, still very solid and can be appreciated by reading Oersted's own works, especially his 'New investigations into the question: What is chemistry?', and 'Reflections on the history of chemistry', in Hans Christian Oersted, *Selected Scientific Works*, tr. and ed. K. Jelved, A. Jackson and O. Knudsen, Princeton: Princeton University Press, 1997. See also Robert Brain, Robert Cohen and Ole Knudsen (eds.), *Hans Christian Oersted and the Romantic Legacy in Science: Ideas, Disciplines, Practices*, Dordrecht: Springer, 2007. The influence of *Naturphilosophie* on Faraday has not been directly established, but in Joseph Agassi's *Faraday as a Natural Philosopher*, Chicago: University of Chicago Press, 1971, pp. 203–232, his ideas match well enough the presuppositions of Schelling's system, leading directly to the unity of all forces in nature.

89 Schelling's dynamical conception of matter is contrasted with the mechanical atomistic conception in Barry Gower, 'Speculation in physics: the history and practice of *Naturphilosophie*', *Studies in History and Philosophy of Science* (1973) 3, pp. 320–321. The more ancient early nineteenth-century rift between 'dynamists' and 'atomists' is described by Armin Herman, in 'Unity and metamorphosis of forces (1800–1850): Schelling, Oersted and Faraday', *Symmetries in Physics (1600–1980)*, Belaterra (Barcelona): Universitat Autònoma de Barcelona, 1983, pp. 53–63.

Ehrenhaft, obsessed with an unreturned but trusted friendship, probably posed a riddle to Einstein: should the Austrian be ignored in the field of physics? Einstein was at least relatively interested in the subelectron and later in the isolated magnetic pole experiments, but certainly not interested in the person of Ehrenhaft. On the other hand, one can say that there was a limited material support from the part of Einstein, and yet there was very little empathy. He had not endorsed Ehrenhaft's appointment to a professorship in Vienna in the 1920s, and he was not willing to help him get a position in America in the 1940s; accordingly, he did not approve of his colleague's reinstatement at the post-war Vienna Physics Institute.

Ehrenhaft, on the other hand, behaved as a very naive and politically alienated person, and tended to neglect the real outside world and to minimize the attacks he received. His work with the electron charge might have brought him resting fame, but he chose instead to emphasize small perturbations that others like Millikan neglected as non-significant errors.[90] Ehrenhaft continued believing in the results of his experiments as indicative of some hitherto hidden aspects of nature, with the result that he paid the high price of ostracism.

Judging from the examined correspondence, Ehrenhaft acted as if he expected Einstein to repay the kind treatment he had received in Vienna, while Einstein probably felt Ehrenhaft a nuisance disturbing him from his personal affairs, and his politeness started to fade out when Ehrenhaft challenged not only one but many of Einstein's major achievements: electromagnetic theory, as Ehrenhaft's attrition with Maxwell's equations might hit Einstein's special relativity grounds; the nature of light, which could impart the Nobel Prize-winning photoelectric effect explanation; and, last but not least, Einstein's theory of Brownian movement, a field where Ehrenhaft had great practical experience.

It seems worthwhile to remark that when Ehrenhaft wrote to Philipp Frank (9 February 1940) to provide some anecdotes regarding Einstein, he took the chance to urge Frank, then also in the USA, to go and see the American scientist Dayton Miller, who had been redoing Michelson-Morley's famous light-speed experiment with much more accuracy. Miller did expect to find variations in light speed according to differences in the ether velocity relative to the Earth, and one may well suspect that Ehrenhaft really had in mind challenging this basis of Einstein's relativity.[91]

Complicating an already strained relationship, Ehrenhaft indirectly brought to the arena a third person, a woman of strong personality, who had no credentials in the scientific world, but assisted him in his American experiments, to the point where she invaded the debate in a flamboyant manner. Maybe the sum of all these factors was too heavy a burden, at a moment of Einstein's life when, though a glorious political figure

90 This is a delicate point: science has witnessed historical moments when small differences became nodal points of a new theory, such as in Kepler's correction of circular to elliptic planetary paths.

91 Maurice Allais, 'The experiments of Dayton C. Miller (1925–1926) and the theory of relativity', *21st Century Science & Technology* (1998) 11(1), pp. 26–31. Allais, a Nobel Prize-winner in economics, has remained a lifelong experimental physicist; his work in Paris on this subject is described by himself in 'Should the laws of gravitation be reconsidered?', *21st Century Science &Technology* (1998) 11(3), pp. 21–33. The history of the 'ether' in physics is a question far from being settled, even though its properties did change with time – see, for instance, Joseph Lévy, *Invariance of Light Speed: Reality or Fiction?*, Paris: Encre, 1991.

and the best-known scientist in the world, he was nonetheless relegated to an academic standstill in virtue of his dissent with the dominant quantum theoretical interpretation.[92] All of that might have led to no more than silence, or maybe also to some devastating words to friends and acquaintances about Einstein's fellow physicist, as the Ehrenhaft couple believed.

It is fitting to conclude this article with an autograph note by Einstein kept at the Dibner Collection, a somewhat embittered thought of a politically disillusioned man. It sounds as a reminder that history should not be forgotten (and, may we add, neither should history of science): 'Children do not make use of their parents' life experiences, nations do not turn back to History. The bad experiences must always be renewed once more.'[93]

92 Franco Selleri, *Die Debatte um die Quantentheorie*, 2nd edn, Braunschweig: Vieweg, 1984, pp. 15–17, 57–62, 87–91 and 118–120.

93 DL, MSS 122A, loose paper, autographed and dated '12.XI.23'.