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ESSAY

Corona Discharges on von Reichenbach's Terrellae?

Marinus Anthony van der Sluijs

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HIGHLIGHTS

Light formations unlike known polar aurora phenomena were reported during classic experiments with a miniature model that simulated the earth's magnetic and electric properties. The nature of these observed anomalies remains intriguing and elusive.

ABSTRACT

In the 1840s, extensive experimentation led von Reichenbach to postulate an "Odic force" associated with "Odic light" or "magnet light," of which the polar aurora would be an example in space. The physical nature of the visible phenomena reported by his assistants during the experiments has never been satisfactorily identified. It is argued that "Od" compares to plasma or ionised gas, while at least a subset of the investigations, conducted on terrellae, represented the first experimental work on corona discharges. Accordingly, the glows on the terrellae cannot be directly compared to the aurora.

OD

The German baron Carl Ludwig von Reichenbach (1788–1869) was an eccentric naturalist, geologist, chemist, metallurgist, philosopher, and industrialist who embarked on an extensive study of disorders of the human nervous system upon his retirement from industry. Taking certain people diagnosed as "sensitives" into a completely dark room with magnets, magnetic devices, or crystals and allowing them ample time to adjust to the lack of light, he relied on their testimony in his theory of "a peculiar force in nature, which spans the whole universe . . . different from all hitherto known forces, here designated by the word 'Od'" (von Reichenbach, 1849a, p. 210; 1851, p. 221).[1] Fancifully named after the native Scandinavian god Odin (von Reichenbach, 1852, p. 198; 1860, p. 84), this "Odic force" was supposed to be tied to but nevertheless distinct from magnetism and electricity. It would manifest in "Od light," in five formal categories: glow-like, flame-like, thread-, fibre-, and fluff-like, smoke-like, and spark-like (von Reichenbach, 1849b, p. 53, cf. 435–436; 1851, p. 270, cf. 223).[2]

Von Reichenbach earned his reputation as an oddball even in his own lifetime primarily by his understanding

Carl Ludwig von Reichenbach

of Od as a form of "life energy" that produced the radiant wraiths of the newly dead and what some would now call "auras." The concept was similar to the *prāṇa* of Indian and the *qì* of Chinese metaphysics—though with an emphasis on electric and magnetic aspects, not on air and breath. In this respect, it resembled Franz Anton Mesmer's theory of "animal magnetism," which was beginning to fall out of fashion at the time (Alvarado, 2009, pp. 366–368, 375). Od can also be compared to younger vitalistic hypotheses such as Henri Bergson's *élan vital* and Wilhelm Reich's orgone. Quite different from the orthodox repertoire of intellectually acceptable notions at the time, such esoteric connotations, together with the claim that only "sensitives" were capable of perceiving Od, explain why the subject has always remained so odious to scientists.

OD AS PLASMA

The "sorcerer of Cobenzl"—as von Reichenbach was nicknamed, after his castle on the outskirts of Vienna—was far from incompetent or scientifically illiterate, however; he composed unsensational reports more sedulous than credulous. In hindsight, some of his observations on the Odic influence on living organisms prefigure the findings of Robert Otto Becker (1923–2008) and other bioelectromagnetists by more than a century; though many of these were dubious, they were not unscientific in essence. What von Reichenbach called "magnet light" (*Magnetlicht*) was in effect a successor to Edmond Halley's notion of "magnetic effluvia" rendered visible in the polar aurora (Halley, 1716, pp. 421–423; cf. Briggs, 1967, pp. 492–493; Hansteen, 1827, p. 340). Yet whereas Halley had only theorised its existence in analogy to electric glows seen in laboratories, von Reichenbach claimed to have observational evidence for it. Leaving the broader mystery of its physical nature for others to solve, a subset of von Reichenbach's experimentation undertaken in the years 1844–1847 appears to simply represent early unwitting work on self-sustaining gaseous discharges not powered by electrostatic friction. This can be gathered from the inclusion in many of the experiments of an armature or electromagnet and rarefaction by means of an air-pump:

> *The Odic light appearances of the magnet change under varied air pressure. They gain in strength considerably upon rarefaction of the air* (von Reichenbach, 1849b, p. 162 [cf. 159–161, 168, 172, 231–235]; 1851, p. 381 [cf. 378–380, 382, 386, 390, 442–444]).

> More beautiful, though, and more distinctly marked was the appearance on *electromagnets*. Here I was able to . . . heighten the appearances more and make them more clearly perceptible . . . (von Reichenbach, 1849b, p. 175 [cf. 176–178, 212–214, 222–223]; 1851, p. 394 [cf. 395–396, 426–428, 435]).[3]

Because the "magnet light" intensified with vacuum, it was arguably—at least in such cases—a glow or corona discharge produced before scientists comprehended that electric discharges can be sustained by direct current (DC). In the 1830s, the English scientist Michael Faraday (1791–1867) had revived the study of glow discharges and, inspired by Ørsted and Ampère, laid much of the groundwork for that of electromagnetism, proving the fundamental identity of static electricity, Voltaic electricity or electric current, electricity induced by a magnet, and animal electricity (Faraday, 1833; 1839, pp. 76–109). However, for years this work had failed to ignite interest (Hiebert, 1995, pp. 95–97). The faintness of the glows reported by von Reichenbach's volunteers must variously have been due to weakness of the electric component, wavelengths at the boundary of the visible spectrum, or a low degree of vacuum—close to normal air.[4]

O'Byrne (1926, pp. 110–117), a translator of von Reichenbach's work, cited visible discharges between a cathode and an anode in a vacuum tube as a method that might bring the effects of Odic force within the ken of "non-sensitives," but he insisted that Od, the electrified matter, had to be something different from electricity alone. The electron, electrical conductivity by ions, and ionisation of matter remained unknown during von Reichenbach's lifetime. Glow and corona discharges are electrical discharges that feature a visible plasma, that is, a visible partly ionised gas. "Od" though it may sound, von Reichenbach's imponderable force may actually be a state of matter that equates to plasma—equally unknown at the time, with the single exception of the "radiant matter" hypothesised by Faraday in 1816 (Jones, 1870, pp. 195–196, 268–270; cf. van der Sluijs, 2019, pp. 87–88; 2011, p. 663). Despite his Mesmerist proclivities and mystifying vocabulary, von Reichenbach would, accordingly, qualify as a respectable pioneer of plasma physics—and of plasma cosmology.

VON REICHENBACH'S WORK ON TERRELLAE

Von Reichenbach (1849b, pp. 234–239; 1851, pp. 445–448) postulated that the earth's magnetic field is generated by iron diffused through the earth's interior but is continually modified by "accessions" from the sun and moon. Specifically, he believed the iron to subsist in a cool, crystallised state, emitting Odic light that caused

the magnetisation. Like Halley before him, he regarded the northern and southern lights, or aurorae, as visible outflow of the earth's magnetic field.

One series of experiments aimed at deciphering the riddle of the aurorae involved terrellae "after the manner of Barlow" (von Reichenbach, 1852, p. 172; 1860, p. 76; cf. 1849b, p. 217; 1851, p. 431), which the Maverick referred to by the French "terrelles" (von Reichenbach, 1849b, pp. 210–224, 234–240; 1851, pp. 425–437, 444–449).[5] A terrella ("little earth" or "earthlet") is a miniature model of the earth, mostly used to simulate the earth's magnetic and electric properties. Von Reichenbach worked in succession with two smooth hollow globes of sheet iron, each composed of two hemispheres tightly fitted together, which he suspended by a silken cord passing through a hole in the joint between the halves. Inside each sphere he placed an electromagnet in the form of an iron bar wound with silk-covered copper wire. This was positioned upright inside the terrella, its ends being in immediate contact with the sphere. The two extremities of the wire were connected to an external Voltaic zinc-and-silver battery through two little holes in the sphere (von Reichenbach, 1849b, pp. 211, 218; 1851, pp. 425, 431).

Several light formations purportedly seen on these terrellae, in all categories of "Odic light," are worth singling out. An all-encompassing shell of light around the first terrella constituted one type of formation. One attendant, Sophie Pauer *née* Streicher (1791–1861), beheld "a delicate grey misty gauze spread all over the ball's surface, which she discerned most distinctly in profile and which rose above the ball's surface to a height of a centimetre" (von Reichenbach, 1849b, p. 213; 1851, p. 427). Von Reichenbach (1849b, p. 217; 1851, p. 431; cf. 1852, p. 172; 1860, p. 75) called this "*a luminous vapour shell*, a kind of delicate *photosphere*, which surrounds it," consisting of "an opaque veil of light, which does not rest on the globe's surface, but is located at a little distance from it, and floats freely in the air above its surface, like a spherical shell." A second distinct structure, showing again on the first terrella, was a radiant girdle around the equator. Sophie Pauer described this as "a more luminous, narrow and whitish-yellow ring laid all around the equator" (1849b, p. 213; 1851, p. 427). Another viewer, Cæcilie Bauer (born circa 1819), reported that "the equator itself formed a narrow, somewhat lightened band all round the globe" (1849b, p. 213; 1851, p. 428). Josephine Zinkel (born circa 1822), too, "perceived the belt that followed the equator around the globe," "a luminous streak, which follows the greatest circumference horizontally around and thus divides the globe into two halves, in an upper and a lower one," which is to be "understood like a fine comb with countless very short teeth, which sit up at right angles and point to the poles" (1849b, p. 214; 1851, p. 428).

Finally, perhaps the most significant morphology is that of vertical filamented beams above the poles. "Above the globe, as well as below it," witness Josephine Fenzl saw "lights as thick as an arm streaming out of the polar points, which then, according to her own expression, spread like open parasols over the globe, concentric with it, both above and below, but at a little distance from it" (1849b, p. 212; 1851, p. 426). Josephine Zinkel had it that the light emerging from the poles "formed towards the equator a great star, with apparently innumerable points, or rather thread-like radiant prolongations, which ran down the globe in colours . . ." (1849b, p. 214; 1851, p. 428). She "likened the whole Od-flame to a loosely-bound sheaf of grain, which, standing upright on the ground, bent over its ears and stalks in curves on all sides, so that they lay apart horizontally upon one another over the bundle" (1849b, p. 217; 1851, p. 430). Other descriptions she used were "an overhanging wheat-sheaf" and "a tassel turned the wrong way upwards" (1849b, p. 219; 1851, p. 432). According to Cæcilie Bauer, the continuous "luminosity of the globe over its surface" resolved itself into

> innumerable clearly distinguishable filaments, which to her seemed . . . about one millimetre thick (knitting needle, she said), and ran from the blue patch of the upper pole and the red one of the lower perpendicularly towards the girdle . . . She described these filaments as not so much independent isolated streaks, as rather merely lines of greater intensity of light, alternating with lines of lower intensity of light, so as to give a streaked appearance to the whole as if nothing but threads ran down from the poles. They were all of the colour corresponding to the point of the compass toward which they were directed . . . (1849b, p. 214; 1851, p. 428)

This woman, too, used the simile of a star, noticing how the coloured patches at the poles "became subdivided, and graded into the filaments which ran downwards over the succeeding zones; this gave the polar patches a star-like appearance;" "apparent projections and hollows developed and so formed a kind of star shape to the eye" (1849b, p. 215; 1851, p. 429).

At a later time, when the second, much larger terrella was taken into use, observer Marie von Augustin *née* Regelsberg von Thurnberg (1807–1886) noticed

> at both poles short luminous columns flowing out as a kind of vapour, reddish at the positive pole and blue at the negative one . . . These columns or stalks of light, as she called them, spread out

> at the top and turned over. She compared them with the image afforded by a palm-tree, where the leaves, directed at right angles to the stem, stretch out and diverge on all sides. (1849b, p. 218; 1851, p. 432)

Wilhelmine Glaser (born circa 1821), a different witness on the same occasion, resorted to the metaphor of a tree as well, as she "perceived the entire globe to be streaked in colours, from top to bottom":

> The coloured streaks were about of a hand's breadth where they passed over the equator, and were separated from each other by an opaque, indistinct, transitional streak of the same breadth, in which the colours were blended together. She saw a mass of blue light above, which she also described as resembling a tree of which the stem ascended from the pole and which lowered its branches away from each other, overhanging on all sides. (1849b, pp. 218–219; 1851, p. 432)

Another visitor, Anka Hetmanek (born circa 1824), again "saw streams of light issuing above and below from the globe; that is, from both poles, which spread out on all sides in the manner of a tree" (1849b, p. 219; 1851, p. 432). The baron concluded with respect to these "coloured meridians" running "from pole to pole":

> . . . now for the Od-flame. One such flowed out from each pole, perpendicularly to the surface of the globe, 5 to 6 centimetres in height and 3 to 4 centimetres thick, but then *it expanded on top and on all sides bent down parallel to the globe's surface*, broke up and frayed, and at once flowed out parallel into the air in filaments of Od-flame . . . The streaks of this Od-flame did not remain at rest, but flickered and scintillated constantly backwards and forwards, shortened and lengthened, shot out radiantly . . . *flaming lights exist over the poles of the magnet* . . . this *flaming appearance appears mobile, undulating, frequently serpentine, like rolls of riband blown about by the wind*; often enlarging and shrinking itself, then shooting out rays, scintillating, variegated, also *vaporous* . . . (von Reichenbach, 1849b, pp. 218, 217, 232; 1851, pp. 432, 430, 443)

> On top at the place where the north-pointing pole of the electromagnet was located, a column of light tending towards the blue rose hand-high over the ball, then bent over in all directions, like an opened umbrella, and streamed down all around over the ball, at a distance of two to three inches from it. From the other pole, the south-pointing one below, a similar tuft of fire ascended all around over the ball in reddish light. Both frayed and faded out before they reached the ball's equator. (von Reichenbach, 1852, p. 172; 1860, pp. 75–76)

Thus, each of the two iron globes appeared to provide support for the conclusion that "the 'Northern-Lights' are positive od-lights" (1852, p. 173; 1860, p. 76; cf. 1849b, p. 240; 1851, p. 449):

> . . . so we recognise in it a kind of *terrelle, which exhibits artificial northern and southern lights in miniature . . . Their poles emit . . . delicate light visible only in the darkness of night. High above both poles it turns over and flows on all sides towards the tropical zones*, broken up in the way of filaments and rays on the great terrestrial globe just as on the little *terrelle* . . . (1849b, p. 234; 1851, p. 444; cf. 1845, pp. 5, 23–26; 1849a, pp. 5, 19–22; 1849b, pp. 210–211, 217, 231–233, 239–240; 1851, pp. 22–23, 39–41, 425, 431, 442–443, 449; 1852, pp. 171–173; 1860, pp. 75–76)

AURORAE OR CORONA DISCHARGES?

The various luminous emanations from von Reichenbach's terrellae were reported with remarkable consistency. From a modern perspective, possible correlates in the geomagnetic dipole field are readily imagined: a fully ionised sphere—or "ionosphere"—around the globe, a ring current around the magnetic equator, and the field lines above the auroral ovals that outline the hollow centre of the toroidal plasmasphere. The fine filamentary structure that the savant's companions observed in the funnels and even the equatorial belt is characteristic of plasma, as is well known from the field-aligned rays in the aurora (e.g., Peratt, 2015, pp. 2, 22, 26, 41, 46). Of the three basic types identified above, von Reichenbach himself associated only the polar funnels with the earth's aurora. In the mid-19th century, the existence of the ionosphere and the equatorial ring current was not yet suspected. Neither these two structures nor the greater parts of the polar funnels—everything above the familiar auroral ovals—are normally seen to glow visibly.

The similarities between von Reichenbach's results and the auroral reality in space are in fact deceptive. For one thing, the actual earth's auroral rings comprise a dayside and a nightside sector formed by different mechanisms. On

the dayside, charged particles from the solar wind flow in directly and without much acceleration through the polar cusps, producing the near-continuous but usually feeble or subvisual daytime aurora as they collide with nitrogen and oxygen atoms residing in the polar upper atmosphere on that side. By contrast, particles diverted along the magnetopause create the more characteristic intermittent aurorae associated with geomagnetic substorms and storms by being accelerated from the central plasma sheet in the magnetotail or the radiation belts towards the nightside of the polar upper atmosphere and colliding with the same types of atoms there, with much more vigour than on the dayside (Simmons, 1998, pp. 247–251, 255–256; Eather, 1980, pp. 218–230; Iijima & Potemra, 1976). Evocative though the structural analogy may be between the polar funnels on von Reichenbach's terrellae and those in real space, it should, therefore, not be pushed too far.

That aside, the glows on these globes were probably of a wholly different character than the true aurorae. The visible aurorae are discharges in glow and arc mode occurring in the highly rarefied air of the upper atmosphere. Von Reichenbach did not use the air-pump in combination with the terrellae, so that the light effects seen over them all must have taken place at atmospheric pressure. Unfortunately, he did not provide a circuit diagram or illustration of the setup in his book, complicating efforts to picture the experiments accurately or replicate them. They do not appear to have involved a pair of electrodes. Taking into account that the Volt unit was only introduced in 1861, it is also unclear what voltage von Reichenbach applied to the apparatus. All these uncertainties notwithstanding, a barely visible direct-current corona discharge ionising the air around a spherical conductive surface might be the correct interpretation of the "Od light" on the terrellae. Corona discharges, also called incomplete discharges, tend to occur at air pressure and focus on sharp points, as in the classic St. Elmo's fire, but can also spread out over a single hemispherical or spherical electrode (Riba et al., 2018; Giao & Jordan, 1968). Due to the weakness of the radiation, they can be descried only in darkness. Moreover, most of the radiation falls within the ultraviolet spectrum (Riba et al., 2018, p. 3). While St. Elmo's fire is easily seen by anyone, the air being ionised enough, corona discharges can usually be detected only by the comparatively few humans who are capable of seeing ultraviolet or near-ultraviolet light or are otherwise equipped with acute vision:

> The corona discharge emits radiation in the 280–405 nanometer (nm) spectral range, mostly in the ultraviolet (UV) range, and therefore is invisible to the human eye. However, relatively weak emission at about 400 nm might be observed at night under conditions of absolute darkness. (Chan et al., 2008, p. 7-5)

Typically reporting a whitish-violet light, people who can make out this feeble light will have been the type considered "sensitive" by von Reichenbach. Aphakia, which is the condition of lacking a lens, was probably not the cause of their ability to see ultraviolet light, as it is usually associated with impaired vision and old age.

The particular manifestations beheld by the "sensitives" as polar rays read most like the streamer mode and the pulseless glow mode, fixed at one point, of a negative corona discharge; these two stages convert into one another with a change in voltage (Giao & Jordan, 1968, pp. 1208–1209, 1213, 1215; cf. Riba et al., 2018, pp. 4–5) (Figure 1 and Figure 2). The pattern that von Reichenbach called a "photosphere" must be a type of positive corona discharge on a spherical electrode known as Hermstein's glow, "an ionized layer adhering to the electrode surface," which forms "when the density of the negative space charge becomes high enough to completely suppress the onset streamers." (Giao & Jordan, 1968, p. 1209, cf. 1210, Fig. 4, 1210–1212, 1214). The filamentary structures on von Reichenbach's terrellae would have traced the electric field lines followed by ions created in the discharge. This does not preclude the involvement of the magnetic dipole field produced by the electromagnet, by which von Reichenbach meant to simulate the geomagnetic dipole field. According to a recent study, "the effect of the magnetic field" supplied by a permanent magnet on a direct-current corona discharge "increases as the degree of vacuum increases" and "is the most significant with the negative corona discharges rather than with positive corona discharge" (Elabbas, 2014, p. 189, cf. 191–194). This might mean that the magnetic dipole field around von Reichenbach's terrellae was modestly influential on the discharge. The equatorial ring was apparently perpendicular to the junction of the two hemispheres from which each terrella was forged. Hence it could not have been an artefact of the material imperfection along this circumference and was probably the faint spontaneous product of the dipole field.

An electric field of the order of 100 kV/m is typically required to create discharges in air. Corona discharges occur around power lines and in the laboratory when electric potentials of the order of 100 kV are reached. It remains a *desideratum* to know whether or not von Reichenbach possessed equipment capable of generating such voltages or whether any of the experiments perchance took place during conditions conducive to thunderstorms.

Figure 1. Direct-current corona discharge of negative polarity on a spherical surface, showing a stage with few moving streamers in blue to purple colours (from Riba et al., 2018, p. 10, fig. 4a left).

Figure 2. Direct-current corona discharge of negative polarity on a spherical surface, showing a stage with an amalgam of moving streamers blurring into a broad glow in blue to purple colours (from Riba et al., 2018, p. 10, fig. 4b).

CONCLUSION

In sum, von Reichenbach's *magnum opus* on terrellae could prove to be the earliest known experimental work on corona discharges. It is difficult to be certain on this count, however, as long as some of the specifics of his setup remain unknown, notably the achieved voltages. And did his work foreshadow elements of modern geophysical theory? Absent the aid of a crystal ball to gaze directly into the past, the only way to find out may be to keep the ball rolling on a veritable Od-yssey of unprejudiced research in real and space laboratories alike.

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NOTES

[1] In citations from von Reichenbach's texts, page numbers in the original German edition are given before the numbers in the contemporary English translation. All translations quoted in the text of this article are mine.

[2] The English edition from 1851 translated "Incandescence," "Flame," "Threads, streaks, and nebulæ," "Smoke," and "Sparks."

[3] The armature is mentioned passim.

[4] For recent progress in the production of atmospheric-pressure glow discharges (APGDs), see Wang et al., 2018.

[5] Nahm (2012), in his informative overview of von Reichenbach's dramatic life and work, made no mention of the terrella work or electric discharges.

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