Auroral research in 18th and 19th century

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Northern lights in the 18th and 19th century

From nowadays point of view the research of the northern lights in early life was more or less equivalent to studies on geomagnetism – even though nobody suspected the aurora to have something in common with magnetism, and by no means with the Sun. In fact the awareness that there is a link among them came up not earlier than in the 1890's, as RICHARD CARRINGTON observed a sudden disturbance of a pair of sunspots and a magnetic storm was detected only a few hours later. The farest cry between auroral research today and in former days is actually that all observations were ground-based, since there were no spaceships available. The most important instrument for observers of the geomagnetic field was the compass or – in a more conveniant arrangement – the magnetic needle, hence we should take a closer look hereon.

The ordinary compass was already invented in China around the year 1000 and it found a fast way to all over the world. By 1600 people already knew quite much about the magnetic field of the earth, e.g. that it has more or less the shape of a magnetic dipole (Even if the concept of a magnetic dipole was introduced only at the beginning of the 18th century by Poisson.) and that the magnetic north pole is not located in the true North Pole. In 1839 CARL FRIEDRICH GAUSS and his associates calculated that only 99% of the Earth's magnetic field has its origin inside the Earth; the rest must have origins in external sources in space. In order to refine these results, the measurement systems had also to be improved. In 1777 CHARLES COULOMB built an instrument for the measurement of the magnetic declination by clinging a *magnetic needle* on a string which was fixed on a stable device. In this alignment friction is minimised and the needle responds to even less changing fields. There were related devices even earlier, but with less accuracy, since in those setups the needle was not suspended by a string, but laid out on a polished crystall as a point of rotation. The typical dimension of such needles were about 300 mm and their ends were very sharp. The scales, vested with magnifying glasses, allowed to read angles down to the order of angle-minutes. To increase the fidelity of measurements even more, a little mirror was attached to the string in Coulomb's setup, reflecting a sharp light beam: the variation of the reflected beam corresponded to the alteration of the needle's angle and therefore with the declination of the magnetic field. Setups like this coped with geomagnetism for close to 200 years.

By observations of the magntic needle it was known that the Earth's magnetic field is betimes disturbed for about a day. This was the time when the term "magnetic storms" first appeared in history; but nobody knew about their origin by then, nor wether they are a local phenomenon or not. In 1741 detected the Swedish astronomer CELSIUS a large magnetic storm contemporaneously with GRAHAM in London. By further observations it was soon clear, that magnetic storms are a nonlocal event. In the end of the 18th century Gauß and his associate Weber started to build up a large network of magnetic observatories and by increasing the number of series of the magnetic weather it was soon clear, that – unlike the real weather – the magnetic storms are not only nonlocal, but even a worldwide phenomenon! This was the state of science by the beginning 19th century. And thitherto there was no perceived idea, that there is a connection between the Sun and the aurora.

New ideas are sometimes hard to implement in everydays thoughts of scientists. So it was not always easy for people in those days – unfortunately even not nowadays! – to get their ideas accepted. So there were new concepts in science for sure, but often topics remained static because of exactly this reason, that new brainchilds were unheard. So it happened in 1826 when the German hobby astronomer SAMUEL HEINRICH SCHWABE began to observe spots on the surface of the Sun. He published his results after ten years of every-day-observations, as far as weather conditions allowed to watch the sun, and proposed a ten-year-cycle of the sun-spots. Since there was no obvious link to current science, he got no response. He tried again several years later with a more detailed analysis, but again there was no reaction from the scientists, until ALEXANDER VON HUMBOLDT paid attention to Schwabe's work and included it in his famous cyclopaedia "Kosmos". With one shot nearly the hole astronomic world watched out for sunspots and they were counted with high accuracy and great interest. Figure 1 shows a table of a sunspot series published by Schwabe in 1850 in the German journal *Astronomische Nachrichten.*

It did not take not too much time until an interrelation between the sunspots and the geomagnetic storms was found aground on archived and recent data and it was in 1852 when the British scientist EDWARD SABINE claimed that the occurrence of magnetic storms was correlated and at the same frequency as the sunspot cycle. At this point people remembered that is was already over 100 years ago, when Celsius observed in 1741 a deflection of the magnetic needle while the aurora was visible on the sky.

This was the point, as the first time a direct connection between the Sun and the aurora ever

Sonnen-Beobachtungen im Jahre 1850, von Herrn Hofrath *Schwabe*.

Dessau 1850. December 31.

Monate.	Anzahl der Gruppen.	No. der Gruppen.	Flecken-freie Tage.	Beob.-Tage.
Januar	15	von No. 1 bis 15	0	16
Februar	16	„ „ 16 „ 31	0	21
März	12	„ „ 32 „ 43	0	28
April	20	„ „ 44 „ 63	0	25
Mai	19	„ „ 64 „ 82	0	30
Juni	23	„ „ 83 „ 105	0	30
Juli	18	„ „ 106 „ 123	2	31
August	19	„ „ 124 „ 142	0	31
September	14	„ „ 143 „ 156	0	30
October	12	„ „ 157 „ 168	0	22
November	12	„ „ 169 „ 180	0	27
December	6	„ „ 181 „ 186	0	17

aus, so dass die Sonne schon von diesem Nachmittag an vollkommen fleckenlos erschien. Am 26sten Juli waren aber wieder zwei neue Gruppen unter 118 und 119, nur aus Punkten bestehend, sichtbar geworden, und erst am 29sten trat ein mittler behofter Kernflecken ein. Die Gruppen vermehrten sich nach und nach auf die vorhin angegebene tägliche Anzahl; jedoch zeigten sich die Gruppen an Flecken reicher als früher, und schon am 7ten August waren sogar 7 Gruppen zugleich vorhanden. Hierbei wurde es deutlich klar, dass die eine Halbkugel der Sonne an Fleckenbildung thätiger war als die andere.

Die grössten Gruppen zeigten sich: 1) am 5ten Septbr. Nr. 142, welche eine Ausdehnung von Ost nach West (die Länge) von 5′ 2″0 hatte. 2) am 23sten September Nr. 149, von 10′ 5″0 Länge. 3) am 13ten December von 7′ 48″0 Länge.

Die grössten Flecken mit unbewaffnetem Auge sichtbar

Figure 1. Abridgement of Schwabe's work published in the *Astronomische Nachrichten* in 1850. The left side shows a table with sunspot-observations. The second column entries are the number of sunspots counted in the corresponding month. Counting sunspots was very popular in those days.

was predicated. Finally, the following happening gave reason to believe in this connection. On September 1, 1859, the British astronomer RICHARD CARRINGTON was occupied with watching out for sunspots in line with a eight-year study as he suddenly saw a thitherto unknown phenoma:

> *Two patches of intensely bright und white light broke out (...), the brilliancy was fully equal to that of direct sun-light. (...) Seeing the outburst very rapidly on the increase, and being somewhat flurried by the surprise, I hastlily ran to call someone to witness the exhibition with me, and returning within 60 seconds, was mortified to find that it was already much changed and enfeebled. Very shortly afterwards the last trace was gone, and although I maintained a strict watch for nearly an hour, no reoccurence took place.*

But Carrington was not unlucky at all, as fortunately the British astronomer HODGSON took notice of the same phenomenon in his house in Highgate, England. It is very worthy to point out the carefulness of communication in that time, as it advances in the end of Carrington's publication:

> *It has been gratifying to me to learn that our friend Mr. Hodgson (...) was a witness of what he also considered a very remarkable phenomenon. I have carefully avoided exchanging any information with that gentleman, that any value which the accounts may possess may be increased by their entire independence.*

Only 17 hours after that observation commenced a unusually intense magnetic storm. Even if Carrington and Hodgson refused to conclude an overhasty connection between these two events (*"One swallow does not make a summer."*), there was an inner hope for sure to have revealed something very fundamental. It took only a few years until other instances have observed similar happenings and soon it was trusted that there was a connection between the Sun and the geomagnetic field and finally the aurora displays. Any further observations that followed from then on are based on this fundament – that there is a link between Earth and Sun, however it looks like.

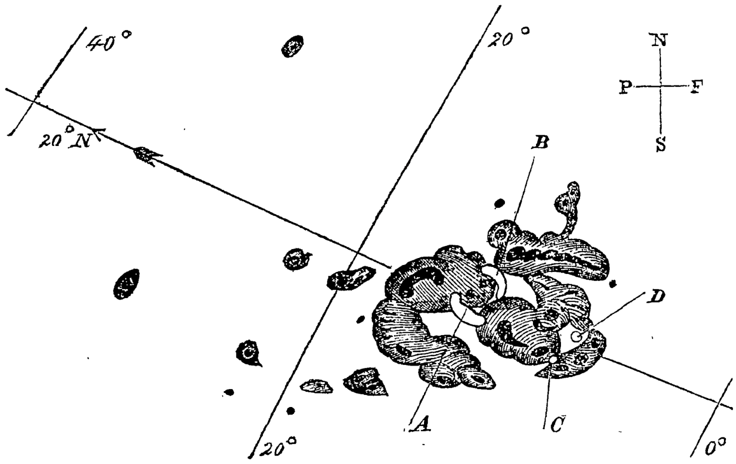

Figure 2. Draft of sunspots made by Hodgson. The extremely bright emerges were situated in A and B. The elaborateness of work in those days is still remarkable, considering the equipment. This picture was published in the *Monthly Notices of the Royal Astronomical Society* in 1859.

A hapless approach

It may seem, that the way, which led to the knowledge about the connection between the auroral phenomenon and the Sun was straight forward. In fact this was not the case, as we can see very well by reckoning Maximilian Hell, a Viennese astronomer and Jesuit Father of the 18th century. The king of Denmark-Norway sent Father Hell on a mission to Vardø (Norway) in order to observe the venus transit on 3 June 1769. Beyond this main task, Hell planned a couple of lower priority tasks to do during his journey, inter alia to observe the variations of the geomagnetic field. In Hell's notebooks this was called the "observations of the magnetic needle". There was hardly enough time for these additional observations since his journey took more than two years.

The departure from Vienna was on 28 April 1768 and after a turbulent journey of nearly half a year, both overland to Trondheim and oversea up to Vardø, Hell reached his destination on 11 October in the same year. He spent the followong six months to build a small observatory in Vardø. Most of the scientific records were made in the first half of 1769 and during the homeward journey.

In those days it was already known and confirmed by many scientists – among them Celsius and Graham – that the northern lights and magnetic perturbations tend to occur at the same time. It is quite sure, that Hell knew about these results. Nevertheless he tried to establish and confirm his own theories of the aurora, first as an electric event, being inspired by discharges and glows of electrifying machines of the 18th century. On his northbound journey he observed that Northern lights had no effect on his electric equipment and he abolished this "electric" theory. Instead he claimed the aurora to be an optical or meteorological emergence, caused by tiny particles in the upper atmosphere being gleamed by the moon or sun. This theory flung him back into the early mainstream science of the 18th century — and there was no place for a connection between the northern lights and magnetism. In fact this thoughts affected his mind in a very strong way and he rejected to believe in other ideas:

> *The observers of the magnetic needle at times with aurora borealis still surprise me. I would wish — as I wrote recently — that these observers had done more observations of the needle at times without aurora. I shall now only maintain that the magnetic needle has as little reaction to the aurora borealis as it has to the rainbow of the sun or moon (...) How embarrassing it will be to those meticulous observers (...) when they understand that my theory of the aurora borealis is unquestionable, and read my extremely accurate observations (...) recorded almost every hour of the day.*

Figure 3. Maximilian Hell in his observatory in Vardø. Etching or drawing from 1771. (http://www.math.uni-hamburg.de/spag)

However Hell's utterances have to be consumed with precaution, even if he made very careful and frequent observations. The main part of his magnetic observations of the magnetic needle took place in April and May. So a statement as "there were no northern lights" has to be taken into consideration, as at the latitude of Vardø observations of northern lights during this time of year are nearly totally excluded because of the bright sky.

But what made Hell so sure about his theory? Having a look at his notebooks from Vardø there is an enunciative entry of 27 May 1769:

> *In the afternoon (...) we saw a magnificent aurora borealis created by the sun. The sun was in northwest covered by a dense cloud (...). Another dense cloud was 30 degrees further northeast, also high in the sky. The rest of the sky was clear. From the first cloud to the other splendid rays were stretching themselves out, long and numerous.*

Today we know this phenomenon to be crepuscular rays, rays of light that can be seen when a low Sun is gleaming particles in the atmosphere from behind a cloud. Happenings like that surely caused a false sureness and made Hell really believing in the absence of a link from the aurora to magnetism.

Nevertheless Hell's observations were of high accuracy. He tried to avoid any external influences which could affect the declination of the magnetic needle, as we can conclude from this cite:

> *All possible precautions were taken to secure good observations. In order to exclude draught all observations were carried out with doors and windows shut. At night candles without candlesticks or oil chambers were used, with keys, knives etc. having been removed from the pockets.*

After a few days he even built up a new observatory in the caretakers storage in order to reduce further disturbances:

> *The reason of this new observatory was an iron oven in the labatory of the astronomical observatory situated 10 feet from the pillar with the magnetic needle. I gradually became suspicious that the iron effected the magnetic observations, and got this confirmed when I started observing in the new observatory: the oven had caused an error of 20 minutes.*

Believing in the high correctness of his records, he postulated a 30-day-cycle of the magnetic disturbances, which is very adventurous, as his series covers a period of only three months, and that assumption brought his thoughts even further away from a Sun-involvement.

In fact the cause of the variation [of the magnetic needle (the author)] *is quite another, and I suspect I have found the relation between my Vardø observations which I carried out over a three months' period at almost all hours, day and night. These observations all seem to point in one direction: that the variations of the magnetic needle are connected to the monthly motion of the Moon (...) just like the regular variations of the barometer and the tides of the sea.*

If he had looked more closely to his records and maybe extended them for another few months, it would have been obvious, that the cycle was in fact the Sun-cycle due to rotation, which is about 27 days. In fact, the data existing today covers even a shorter time of nearly two months. So this conclusion drawn by Hell ist very daring. But evaluating these facts we must not forget that Hell's main mission was to study the Venus transit before the sun, as this was his order. Taking this into account and the fact, that Hell was a really 18th century scientist with a broad spread of interests also researched in Vardø, it is an admirable act that he built up on of the first known laboratories for geomagnetic observations during this time. The time series of the magnetic declinations could also have yielded to an earlier knowledge of the diurnal variation of the magnetic field, if it would have been published. A longer observation of higher priority would have led Hell to a connection between the Sun and geomagnetic disturbances, and eventually to the northern lights.

Closing words

Now you may have seen that history was – and still is! – not straight forward at all. It took many false starts in science until the important knowledge of an existing connenction between the Sun and the Earth finally was established in peoples minds, like it was in later days in the context of quantum mechanics or the relativistic theory. But nevertheless this important connection was the fruit which was gathered from the long and thornful way which then-scientists went with their work. When students nowadays find their way into lecture about the Northern lights, the relation to the Sun might be clear for them from the very beginning, if not in detail, so at least they roughly heard of it. We should keep in mind, that there were times, when this was not the case, times, when people were forced to stretch their heads to achieve this knowledge. And maybe that's the right time to appreciate the ideas of Celsius, Coulomb, Carrington, Hodgson and many others.

References

Aspaas, P. P., Hansen, T. L. (2007). Geomagnetism by the North Pole, anno 1769: The Magnetic Observations of Maximilian Hell during his Venus Transit Expedition. *Centaurus, 49*(2), 138–164.

Carrington. (1859). Description of a Singular Appearance seen in the Sun on September 1, 1859. *Monthly Notices of the Royal Astronomical Society, 20*, 13–15.

Chapman, S. (1964). *Solar Plasma, Geomagnetism and Aurora.* New York, London: Gordon and Breach.

Schwabe. (1850). Sonnen-Beobachtungen im Jahre 1850, von Herrn Hofrath Schwabe. *Astronomische Nachrichten, 32*, 109.

Stern, D. P. (1989). A Brief History of Magnetospheric Physics Before the Spaceflight Area. *Reviews of Geophysics, 27*, 103–114.