Space Physics in the Earliest Days, as I Experienced

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1. Introduction

It was my undergraduate and graduate student days at the Tohoku University, Sendai, Japan (1949–1958), when I decided to study geomagnetic storms and the aurora.

Born in Japan (1930), I had no knowledge about geomagnetic storms and the aurora. As an undergraduate student, I got a job at the magnetic observatory at the university. One of my jobs was to work on magnetometers, which monitor daily changes of the magnetic field of the Earth. Magnetic changes were displayed in a dark room (actually a cave) as movement of a spot of light on a photographic paper wrapped around a cylinder, which rotated once a day. My task was to change the paper and develop it. After developing the photo paper, one could see magnetic changes, which followed the trace of the spot in a day.

The only thing visible in the dark room in the observatory was a light plot, which showed mysterious movements. I was fascinated by the delicate movements of the spot and watched its movements for hours. When I asked what caused the movements of the spot, the observatory manager told me that the aurora in Siberia or Alaska may be responsible, but that very little was known about the cause.

I wondered how the aurora at such a great distance in Alaska could move the spot like a magic hand. At the same time, I recalled suddenly a favorite song (lullaby) my mother would often sing. The beginning of the lines was “I wonder if I should go ahead or return back under the aurora.” Thinking of the significance, I decided to study the aurora and the movements of the spot, which turned out to display geomagnetic storms. This subject has become my life-long study.

During my graduate student days (1955–1958) in Sendai, I learned that the magic hand was varying magnetic fields produced by the aurora. I was then inspired to learn geomagnetism. It so happened that in a meeting, T. Nagata, Tokyo University, told me that I was not qualified to study geomagnetic storms, unless I understood a paper by Chapman and Ferraro (1931). As I began to read their paper, it was so difficult; I decided to write to Sydney Chapman, selecting about 10 questions among many. However, I learned he was at the Oxford University and was the highest authority in geomagnetism. I, a fresh graduate student, felt a bit intimidated and hesitated to send my letter.

A little later, I learned that he spent a few months of each year at the Geophysical Institute of the University of Alaska in Fairbanks. I got my courage up (together with my interest in mountaineering in Alaska) and sent the letter to Alaska. I got an unexpected response. Chapman wrote that if I wanted to better understand, I could study under him in Alaska. I accepted and arrived in Fairbanks in December 1958, soon after a solar eclipse observation at an inhabited coral reef in the South Pacific Ocean, without knowing the corona is the source of flow of solar gas, the solar wind (Parker, 1958); my task was to operate the first Japanese electronic magnetometer to observe changes of the equatorial electrojet during the eclipse.

2. Discovery of the Magnetosphere

The solar wind blows around the Earth and its magnetic field, confining them within a comet-shaped cavity in the solar wind, which is called the magnetosphere. The theory of the formation of the magnetosphere by Chapman and Ferraro (1931) has become the foundation of magnetospheric physics today. As mentioned in the above, this is the very paper that had led me to Chapman and the Geophysical Institute.

Chapman and Ferraro were the first to consider the streaming solar gas consisting of protons and electrons, which we now call plasma; Irving Longmuir introduced the term earlier when he was experimenting on an
electrical discharge process (Rosenfeld, 1996). I asked Chapman why he considered plasma. Chapman published a paper on geomagnetic storms in 1918 (what he called later a “phony” theory), in which he considered a beam of electrons from the Sun (Chapman, 1918). He told me that F. A. Lindemann, British physicist, criticized his paper, stating that a beam of electrons would disperse itself by electrostatic force and would not reach the Earth. He suggested considering a gas consisting of an equal number of protons and electrons in order to avoid the dispersion, after estimating himself that plasma must be fully ionized. The Mariner 2 observed the solar wind plasma in 1962 (Neugebauer & Snyder, 1966).

Chapman told me that people did not accept their paper for a long time. Carl Stormer, Norwegian auroral physicist, had his own electron beam theory and stated in 1952 that Chapman-Ferraro’s theory could not explain anything on the aurora, while his own theory could explain the detail of the aurora. Others stated also that it was only of historical interest.

Thus, Chapman was very happy in 1963 when I showed him the paper by Larry Cahill, the University of New Hampshire, in Journal of Geophysical Research (Cahill & Amazeen, 1963). They reported the passage of the Explorer 12 satellite across the dayside magnetopause at about 10 Re (Re = the Earth’s radius). They showed that the magnetic field intensity just inside the magnetopause was twice of that of the Earth’s dipole field (because the solar wind compresses it), the most crucial test of their theory.

I recall vividly Chapman’s joy. “It is very rare that a theory can be confirmed 30 years after it was proposed,” he said.

Before the Explorer 12 event, the Explorer 10 satellite crossed the flank of the magnetopause on 26 March 1961. I worked at the Goddard Space Flight Center (GSFC) at that time and listened a discussion on the puzzling event by Jim Heppner, Norman Ness, and Joe Cain, all at GSFC, since it was uncertain what really happened; it was the first crossing of the magnetopause by a satellite and thus the first time when a satellite went outside of the magnetosphere (Heppner et al., 1963). It may be noted that Tom Gold, Cornell University, coined the term “magnetosphere” (Gold, 1959).

One of the memorable events for many of us at that time was a long-time debate between Chapman and Hannes Alfven on the formation of the magnetosphere (see Akasofu, 2003). Their debate was initiated by Alfven (1951), which criticized the Chapman-Ferraro paper on the ground that the solar wind plasma is not diamagnetic. I met Alfven for the first time during the Birkeland Symposium on Aurora and Magnetic Storm in Sandefjord, Norway, in 1967. I was a little afraid of him and the potential that he would continue his argument with me. However, he did not mention it at all. Instead, he emphasized that I should study the aurora in terms of electric currents, not on the basis of his own magnetohydrodynamic (MHD) theory with the concept of “frozen-in” field. His reason was that MHD theory might not applicable for a very rarified (collisionless) plasma in the magnetosphere. I have taken his advice ever since, although most magnetospheric researchers have adopted the MHD theory.

### 3. “Unknown” Quantity (Parameter) in the Solar Wind and the Interplanetary Magnetic Field

Chapman’s, 1918 paper had a good statistical study of geomagnetic storms, establishing the present standard concept of geomagnetic storms, which consists of the storm sudden commencement (ssc), the initial phase, the main phase, and the recovery phase. The ssc is a step-function-like increase of the magnetic field, which signifies of the arrival of solar plasma flow (now interpreted as the arrival of the shock wave advancing at the front of the coronal mass ejection, CME).

After I joined Chapman at the Geophysical Institute, he asked me to work on the main phase of geomagnetic storms. I told him that I did not know much about geomagnetic storms and wanted to examine a large number of geomagnetic storm records (magnetograms) from observatories from all over the world.

It was my great surprise that a large number of geomagnetic storms were not the standard type. Some of them had a large ssc (indicating a strong solar wind) and long initial phase, but not the main phase. In some others, the main phase began before ssc, and further, some others had a large main phase without ssc.

After much thought, I wondered if there might be an element in the solar wind that controls the development of the main phase. Chapman agreed with my conclusion by examining magnetograms together. We
published a joint paper (Akasofu & Chapman, 1963, p.129), stating that there must be some “intrinsic differences” in the solar wind in causing a variety of development, but the nature of their differences was “unknown.” I recall that many colleagues could not accept such a conclusion, because it was firmly believed that an intense solar wind was the sole cause of geomagnetic storms. Some of my colleagues told me that such an idea was unacceptable, because I denied the Chapman-Ferraro’s theory. Chapman was unmoved and kept me under his wing (Figure 1).

Chapman presented our “unknown” results in the First Solar Wind Conference held at the Jet Propulsion Laboratory on 1–4 April 1964. According to the transcript (and what Chapman told me later), there were some lively discussions on our results; Jim Dungey, the Imperial College, London commented: “I think the main phase of the storm is caused by something in the high-pressure gas, and the best guess is a strong southward interplanetary field. However, this is a question still to be answered.”

Fortunately, in 1966, Don Fairfield of the Pennsylvania University published a paper with Cahill, in which they found that the southward component of the interplanetary magnetic field (IMF) plays a crucial role in the development of geomagnetic storms.

They concluded: “It is suggested here that this [unknown] parameter is a southward component [of the interplanetary magnetic (IMF)] field.” by referring to our paper (Fairfield & Cahill, 1966, p. 167). Later, it was found that the controlling factor of geomagnetic storms is more complicated, which is a function of the solar wind speed, the intensity of the IMF, and the polar angle of the IMF (or the IMF $B_z$ component), which is now understood to be the power produced by the interaction between the solar wind and the magnetosphere, the solar wind-magnetosphere dynamo, which provides the power for auroras and geomagnetic storms (Perrault & Akasofu, 1978).

4. Discovery of the Van Allen Radiation Belts and the Ring Current

After successfully theorizing the formation of the magnetosphere and ssc in 1931, Chapman and Ferraro (1933) tried very hard to explain the main phase, during which the Earth’s magnetic field decreases. They thought that there must be a westward electric current around the Earth (the ring current), but they, as well as many theorists, could not find the way by which the solar wind plasma could get inside the magnetosphere to form the ring current.

Chapman was delighted by the news of the discovery of the Van Allen radiation belts (Van Allen & Frank, 1959). He thought that the radiation belts must be the ring current and took me to the University of Iowa to discuss this possibility with James Van Allen. Both asked me to compute the current intensity of the belt at the GSFC, where there was an IBM 7090, a supercomputer at that time.

I found that the current in the belts consists of an eastward current in the inner part of belt and a stronger westward current in the outer part but is too weak to produce the main phase, suggesting that an intense new belt is formed during geomagnetic storms (Akasofu et al., 1961). A few years later, Cahill showed me the magnetic records from a magnetometer carried by the Explorer 26 satellite that crossed the storm-time ring current belt for the first time on 19 April 1965. I was very happy to confirm that his data are close to what my calculation (the magnetic field of the ring current as a function of the radial distance from the Earth) predicted (Chahill, 1966, Figure 14).

As the index of the intensity of geomagnetic storms, we use the Dst index as a measure of the intensity of the ring current. On the basis of magnetic records from a very few observatories, Chapman (1918, 1935) analyzed statistically the storm field into two components on the basis of a number of storms; one did not depend on local time (Dst; storm time) and the other depended on local time (SD, solar daily magnetic disturbance). I told Chapman that there were several number of International Geophysical Year (IGY) magnetic observatories along the magnetic equator to estimate the Dst index for individual storms; the present Dst index uses this practice (Akasofu & Chapman, 1961). The SD component is now understood to be partially due to the asymmetric development of the ring current during an early epoch of geomagnetic storms as protons in the ring current belt drift westward from the midnight sector (Akasofu & Chapman, 1964; Fok, 2003).
5. Discovery of the Auroral Oval

Elias Loomis determined the auroral zone in 1860 (Loomis, 1860); it is the circular (annular) belt centered around the geomagnetic pole in the geomagnetic coordinate system; its width is 5° (between 65 and 70° in geomagnetic latitude). Thus, if the auroras were to appear along the auroral zone, they should appear overhead in Fairbanks (geomagnetic latitude 65°), Alaska, as soon as darkness sets in midwinter nights. However, I found that auroral arcs almost always appear first in the northern sky in the evening.

When I asked Chris Elvey, the University of Alaska Geophysical Institute director, about my observation, he told me that auroral arcs formed perhaps along the center line (67°) of the auroral zone and then shifted equatorward (toward Fairbanks) in the evening. Thus, I examined all-sky films from Fort Yukon (which is located at the center line, 67°), but the arcs appeared also from the northern horizon. The same was even true in Barrow, Alaska, at 70° (the northern boundary of the auroral zone). Thus, I thought that something was not quite right regarding the auroral zone.

I forgot about that puzzle (because I was preparing my PhD thesis) until I found a 1963 paper by Yasha Feldstein (Figure 2), Institute of Terrestrial Magnetism, Ionosphere and Radio Wave Propagation in Moscow, in which the actual belt of the aurora is significantly different from the auroral zone. He called the new belt the auroral oval (Feldstein, 1963). The auroral oval solved my early puzzle. I wrote to Feldstein that my observation agreed with his oval.

On the other hand, many auroral researchers disagreed with Feldstein, because the auroral zone was the paradigm for about 100 years. I visited him in Moscow and discussed how to prove the validity of the auroral oval. As one of the methods, I set up a chain of all-sky cameras between Fairbanks and Thule, Greenland, hoping that the chain could scan the polar cap sky like an azimuth-scan radar at airports. This large scanning device using the Earth’s rotation revealed clearly the shape of the auroral oval (Snyder & Aklasofu, 1972); this project was supported by my first National Science Foundation grant.

However, it was difficult to convince many of our colleagues with our observation alone. In the end, we had to wait 9 years for a satellite to image the oval from above. This was accomplished by Cliff Anger of the University of Calgary in 1972, who installed an imager on the ISIS-2 Canadian satellites (Anger et al., 1973). After this event, the arguments on the auroral oval faded without any further debate; Tony Lui, who worked with me on this study, became my first postdoc from the University of Calgary and has been working closely with me since then.
Then, our colleagues said that they would accept the auroral oval, if I could find and prove why the auroral oval has such an odd shape (different from the annular ring shape, the auroral zone). It so happened that I was spending a year at the University of Iowa, when Van Allen was working on the location where the outer surface of the outer radiation belt reaches the ionosphere, namely, the intersection line between them (Figure 3). I found that his intersection line agreed with the auroral oval and thus rushed into his office, showing the result. Van Allen’s initial response was: “You should know that particles in the radiation belts cannot produce the aurora,” but he soon understood the significance of the agreement (electrons stream into the ionosphere along the outer surface of the outer radiation belt to produce the aurora), and asked me to report the result in the University of Iowa Department of Physics publication series; the result is reproduced in Akasofu (2007, Figure 2.9c).

It so happened also that Al Zumuda, the Johns Hopkins University, found my University of Iowa report and was pleased that his plot of the location of field-aligned currents agreed with the location of the auroral oval. His study was the first satellite observation of the field-aligned currents and thus confirmed validity of the auroral oval and the significance of his observation, because this was the first direct observation between the aurora/auroral oval and field-aligned currents on a global scale (Zmuda & Armstrong, 1974).

6. Auroral Substorms

I read a number of articles and books by early polar explorers at the Institute library, who described auroral beauty, streaming, and whirling green, pink, and red lights, exclaiming that there was no words to convey the splendor of scene, and I myself witnessed such magnificent and overwhelming displays by myself on the hill, where the present Geophysical Institute building stands.

In those days, it was firmly believed after a pioneering study of the aurora by Veryl Fuller of the University of Alaska in the 1930s that statistically the aurora was quiet in the evening, active around midnight, became patchy in morning hours, and that the Earth and auroral observers went around under such a pattern once a night (Fuller & Bramhall, 1937). However, when I scanned films from Fairbanks and other locations, I found such a pattern often repeated twice or three times in one night. For a moment, I thought, believing in the pioneer’s work, that the Earth rotated a few times a night. Since this could not happen, I thought that something was not quite right regarding Fuller’s study.

During the IGY, Chapman (the president of the IGY) and Elvey took the leadership in installing a large number of all-sky cameras in the polar region; photographs were taken once a minute in dark hours. I had a very fortunate opportunity to scan a great number of all-sky camera films; the Geophysical Institute was the World Data Center for all-sky films.

Thus, I could study simultaneous auroral activities all over the polar region, so that I could examine what happened in Siberia (located in the evening sector) and Canada (located in the morning sector), when the aurora in Fairbanks (in the midnight sector) showed great displays.

However, it was a very confusing and frustrating experience to examine simultaneous films from many locations, because all-sky images are very distorted (like an image of fish-lens camera) and auroras change greatly even in just one minute; I had to use the Polestar to determine the northern direction, because a camera installed on a drifting ice in the Arctic Ocean rotated from time to time; some crucial films were missing because the camera operator could not change the films because polar bears were nearby, etc.

It took about 2 years until finally I found some common, distinct features in the displays; I found that if I could choose the moment of a sudden brightening of the aurora in Fairbanks (the southern edge of the AURORAL OVAL);
auroral oval), it could represent the beginning of polar-wide activities in an orderly way as a function of time for about 3 hr (the lifetime of auroral activities), including a spectacular poleward advance of auroral arcs in the midnight sector, a westward traveling surge (a wavy disturbance propagating toward the evening sky along the auroral oval), and eastward drifting patches in the morning sky. This was true even if I chose other locations (Norway, Siberia, and Canada) in the midnight sector.

I recall that Chapman was very happy with my work and suggested the term “auroral substorms”; several auroral substorms occur during one geomagnetic and auroral storm, so that they are the elements of auroral storms (Akasofu & Chapman, 1963). The paper was submitted to Journal of Geophysical Research but was rejected (perhaps with no substance) and thus resubmitted to Planetary Space Science (Akasofu, 1964); in those days, a study of the aurora was mostly confined in spectroscopy and excitation process of auroral emission lines and bands, and thus global auroral activities were a side issue. In fact, I recall that a friend of mine was puzzled by my all-sky camera work by saying, “The aurora over Alaska and Norway is the same. Why do you have to study auroras in both locations?” However, this paper became one of the most-referenced space physics papers for years. Ching Meng joined me to study all-sky films as my first graduate student at that time (Figure 4).

At that time, few researchers had a chance to study all-sky camera films, so that many colleagues had difficulties to accept the concept of auroral substorms, because no one can remain at the midnight hour for 6 hours in order to witness the development of auroral substorms twice. Thus, I asked National Aeronautics and Space Administration (NASA) officials if I could observe auroral substorms in the NASA Galileo plane from the East Coast to Alaska against the Earth’s rotation, remaining in the midnight sector for 6 hours (the constant local-time flight; Figure 5). I recall that Elvey was very pleased by scanning the all-sky films together, saying “Syun, you did a great job.” Actually, we flew all over the polar region; I recall that Bob Eather excitingly shouted through the intercom: “The aurora is red!”, when we observed the midday aurora (the midday part of the oval) over the Norwegian Sea (the darkest region the Northern Hemisphere around the winter solstice). It was just before the Space Shuttle days, so that a NASA psychologist was on board, observing our behavior (confined in a small space in extreme conditions).

An U.S. Air Force plane (the Flying Ionospheric Sounder) also joined in confirming the shape of the oval and also in the constant-local time flight during those days. At that time, the Defense Meteorological Satellite Program (DMSP) began to operate and provided us with high-resolution images of the aurora over almost the whole polar region once in about 100 min (a sort of snap shots of auroral substorms). At its very
beginning, it had been speculated that the auroral lights in Siberia were mysterious secret experiments (?). Thus, I was asked to examine the images at the Air Force Geophysical Laboratory in Boston to confirm that the lights were the aurora.

Sometime later, on my way back from Boston after receiving newly released DMSP images, I visited the University of Iowa and met Don Gurnett; he was wondering if the low-frequency radio waves, which he received from a satellite, were related to the aurora. It so happed that the period of the DMSP data I had in my hands coincided with the period when he received the radio waves; it was very clear that the radio emissions occurred during periods when the aurora was active; he called it the auroral kilometric radiation (Voots et al., 1977).

However, after all that work, we had to wait for the imager on the Explorer satellite (a highly eccentric orbit allowed auroral observations for several hours from well above the polar region) designed by Lou Frank, University of Iowa (Frank et al., 1982). I was waiting for the first images at the University of Iowa and congratulated Frank’s success, and he congratulated me for the confirmation of my concept of auroral substorms; it was 18 years after the publication of my auroral substorm paper in 1964.

Dungey was among the firsts to be interested in my substorm paper (Dungey, 1966). Dungey told me later that he could explain substorms by considering that piles of magnetic field lines (caused by the solar wind) on the backside of Earth go suddenly back toward Earth. However, I told him that before a sudden brightening of an arc near the southern boundary of the oval (the onset of the expansion phase of auroral substorms), there is no auroral activities (expected as effects from the magnetotail) in the northern part of the oval. Further, I had difficulties in considering of moving magnetic field lines. In a later date, he and I sat on a bench at the Hyde Park, London, having a long conversation. He concluded with, “We have a friendly disagreement.”

![Figure 4. Ching Meng and Syun Akasofu, working on all-sky films. (Courtesy of the IBM.)](image1)

![Figure 5. The National Aeronautics and Space Administration (NASA) airborne auroral expedition. The NASA Galileo plane, a westward traveling surge observed during the expedition, and Syun Akasofu working on the plane. (Courtesy of NASA.)](image2)
In the year 1964 (the year of publication for my auroral substorm), Petschek (1964) proposed a theory of magnetic reconnection based on an antiparallel magnetic configuration for solar flares. Ness et al. (1964) discovered the magnetotail, where the magnetic field lines are nearly antiparallel. Perhaps, because of these three simultaneous events, the magnetotail was thought to be the source of the energy of auroral substorms.

Alfvén was also interested auroral substorms from the point of view of electric currents. He asked me to work on the electric current system for auroral substorms; Rolf Bostrom (1964), one of his students at that time, was already working on the current at that time. The reason for his interest in the substorm current system was that there appeared two influential papers in 1961, one by Axford and Hines (1961) and Dungey (1961) on auroral activities and polar magnetic disturbances. Both are explicitly based on Chapman’s SD current in the ionosphere (or a spherical shell; Chapman, 1935). Alfvén thought that the substorm current system is intrinsically a 3-D system (unlike the 2-D SD current). Actually, Akasofu et al. (1965) showed also that the impulsive current system during the expansion phase of auroral substorms is fundamentally different from the daily averaged SD current system. Meanwhile, DeForest and McIlwain (1971) and Akasofu et al. (1974) found that energetic protons produced during auroral substorms form the ring current belt, so that the main phase of geomagnetic storms is caused by a frequent occurrence of intense auroral substorms.

Alfvén used to tell me “too slow, too slow” whenever we met. I thought at that time that the distribution of magnetic observatories in the polar region was not systematically distributed to make a satisfactory study. Thus, I proposed to establish a set of meridian chains of magnetic observatories to the International Magnetosphere Study project. I was very happy that six meridian chains (with about 50 stations) were completed in the late 1970s (Kamide et al., 1982; see the participants in References); the data analysis has been continued with my colleagues until the present.

In the fall of 1974, Alfvén with his wife visited the Geophysical Institute of the University of Alaska. I told him that there is Chapman’s bust on campus. Although I was not sure how he would respond (because of their old debate), he immediately said that he wanted to see it and proposed to take a photograph with me at its front (Figure 6).

The analysis of the network observatory data work has been tedious. However, by combining our ground-based data and satellite data, we finally confirmed Bostrom’s 3-D current system, which is, in my view, responsible for the expansion phase of auroral substorms (the most active epoch of auroral substorms, lasting for 30 min). Since his current system can be driven by an earthward directed electric field of 50 mV/m, the direct cause of auroral substorms may be narrowed down to find the generation of this earthward electric field at about 6 Re for a medium intensity substorm (Akasofu, 2017).

7. Concluding Remarks

Chapman’s desire was to understand what caused of the main phase of geomagnetic storms. Looking back the earliest days of research and later development of the field by a large number of space physicists, the trigger for the main phase may be key to understanding the cause of auroral substorms. A great challenge is ahead of us.

One lesson I learned during my research career is that a simple statement in a monograph or paper, for example “auroral arcs are distributed along the auroral oval,” takes a long time to become the present knowledge (in fact, at least 9 years in this case); the term auroral zone had been common for a century. Present prominent theories will be eventually replaced. Otherwise, there would not be any progress.
Changing of paradigms is inevitable (as the readers must have recognized in a few small examples in this article). It is important to challenge on a paradigm, if one find something not quite right about it, although it is rarely quick, requiring the responsibility to prove as the proposer, his/her patience, hard work, and even courage.

Space physics in the very earliest days was described in “James Van Allen” by A. Foerstner, (2007). The AGU published “Discovery of the Magnetosphere” in 1997 (Gillmore & Spriter, 1997); I had an opportunity to discuss with all the authors in it. The AGU published also Pioneer of Space Physics 1 and 2 at the occasion of the 75th Anniversary of AGU (1996); there were also many other authors contributed to space physics in the earliest days. “The Solar Wind” edited by Neugebauer and Snyder (1966) has a number of papers at the time of the first observation of the solar wind.

In this short article, however, I limited to describe only the above subjects based directly on my own experience.

One of the major subjects to advance in the future is space weather. It is not possible to make an accurate prediction of the intensity of geomagnetic and auroral storms without being able to predict the intensity of the IMF $B_z$ component of CMEs. Unfortunately, there has not been much progress, in my opinion, in this respect for the last few decades; during every sunspot cycle, there had been erroneous warnings of a great geomagnetic storms and auroral displays after major solar flares; first of all, there is no quantitative way to predict the intensity of solar flares (Akasofu, 2018a). This is the subject, in which solar physicists, the solar wind physicists, and magnetospheric physicists must work together to advance our knowledge of the magnetic field configuration of CMEs. My suggestion is to attempt first to reconstruct observed magnetic field configuration of CMEs and to get some idea on it (Akasofu, 2018b; Figure 13) before numerically simulating CMEs, so that we may know better what to simulate.

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I would like to thank all my colleagues in the earliest days, as well as many later colleagues, who guided and discussed with me on various subjects in space physics for the last 60 years.

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