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Original Paper

A Short History of the Development of Space Physics Based on Studies of Geomagnetic Storms

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Abstract

Space physics is one of the rapidly developing scientific fields, covering space from the sun to a distance of about 100 times between the sun and the earth, the region called the heliosphere. It includes parts of solar physics, geomagnetism (a study of geomagnetic storms), ionospheric physics, auroral physics, cosmic ray physics and planetary physics. The rapid progress in space physics owes a long history of debates and controversies among these sub-fields, as well as the advent of satellites and space probs, which began during the 1960s. A study of geomagnetic storms has an interesting development preceding space physics, so that it may be worthwhile to study history of space physics by following the development of the history of geomagnetic storms. The author has joined in space physics in its earliest days.

Keywords

space physics, geomagnetic storms, ionospheric physics solar physics

1. Introduction

It is generally the case that science progresses gradually. However, it is also the case that science progresses often in step-wise. Space physics is no exception. The field of space physics is rather new, compared with many other scientific fields. It was established in the early 1960s.

Before the 1960s, there were a number of fields, including parts of geomagnetism, ionospheric physics, auroral physics, solar physics and of planetary physics and cosmic ray physics. Each had its own interesting history of development. The introduction of satellites at the occasion of space age was one of the reasons to combine them together as space physics, partly because satellites carry often instruments which measure quantities relevant to many of these fields together (although each field exists as a branch of space physics). Space physics covers also now a new field called heliospheric physics, which was initiated in the 1970s, as space probs began to explore Jupiter and Saturn and eventually reached a distance of about 100 au; 1 au is the distance between the sun and the earth.

Actually, the history of studies of geomagnetic storms can cover much of pre-space physics days, because it has the longest history among them. Thus, it may be appropriate to follow history of space physics in terms of history of a study of geomagnetic storms.

References on the quoted works are omitted, although the times of the events are mentioned in order to follow the history in time.

2. Beginning

It began quite accidentally. The first discovery of solar flares, eruptions on the sun, was made by R. C. Carrington, a British solar observer. When he was making a routine sketch of sunspots, there appeared suddenly bright lights around sunspots on September 1, 1845. [In those days, automatic photography was available, but he refused to use it]. What he observed during his daily sketch of sunspots is now call a white light flare (visible), which was the most intense type of solar flares. On the next day, an intense geomagnetic storm occurred, causing troubles in electric wire communication systems in those days. The aurora was seen in many places on the same day, including in Hawaii. Carrington (1860) reported his finding and the occurrence of the geomagnetic storm by stating: “One swallow does not make a summer”.

3. Confirmation that the Sun Is Responsible

The occurrence of the solar flare and geomagnetic storm, together with Carrington’s modest statement, got an attention of Load Kelvin, the greatest physics authority in those days, who claimed that the two observed facts was “a mere coincidence” and “a fifty years’ outstanding difficulty” in his Royal Society Presidential Address (1893); he did not consider that the sun ejects a cloud of ionized gases, which is now called “coronal mass ejections, CMEs”.

It was in 1905 that E. W. Maunder at the Greenwich Observatory, mentioned that the sun is responsible for geomagnetic stoms on the basis of the recurrence tendency of geomagnetic storms (27 days) coincides with the rotation period of the sun. He stated: “First: The origin of our magnetic disturbances lies in the sun---”. This was the very *first* statement in the history of space physics that the sun is responsible for the occurrence of geomagnetic storms, which was based on the observation.

There were objections to Maunder’s statement by prominent physicists in those days, stating “the mystery is left more mysterious”.

4. Electron Theory

When electrons were discovered by J. J. Thomson in 1887, K. Birkeland and C. Stormer, Norwegian scientists, thought that the sun emitted a beam of electrons, which caused both magnetic disturbances and the aurora together; Thomson suggested later that lights from his cathode ray tube looked like auroral lights. The electron theory by Birkeland and Stormer had prevailed for about a decade or so (1920-1930). Early studies of the aurora, the beginning of auroral physics, owe their great efforts in both observation and theory.

5. Plasma Theory and the Magnetosphere Formation

S. Chapman (1931) considered that the gas emitted by the sun consists of protons and electrons (now called *plasma*), instead of an electron beam. He theorized that the plasma from the sun flows around the earth like river flow goes around a rock, forming a cavity with a long tail like a comet; the magnetic field of the earth protects the earth from the solar plasma flow.

Chapman’s theory became the foundation of space physics. This comet-shaped cavity is now called the *magnetosphere.* However, Chapman’s theory had not been firmly accepted for almost thirty years. The confirmation of his theory had to wait until a satellite detected the front boundary of the comet-shaped magnetosphere at the predicted location in 1963; it is located a distance of about ten earth radii toward the sun. Chapman defined that geomagnetic storms consist of the onset (sudden commencement, ssc), initial phase and main phase (when the earth’s magnetic field decreases and auroral activities occur).

Meanwhile, the ionosphere was discovered by E. V. Appleton in 1925, which initiated ionospheric physics. Since electric currents flow in the polar ionosphere during geomagnetic storms, ionospheric physics has become very important in a study of geomagnetic storms and radio wave communications. Since then, a large number of ionospheric sounder stations were established in the world to study the ionosphere. There were great debates on the distribution of electric currents in the ionosphere., which cause geomagnetic disturbances.

6. Comet-tails and the Solar Wind

Until about the end pf the1950s, interplanetary space was thought to be a vacuum, except occasional plasmas emitted by the sun. Based on his study of comet tails, L. Biermann (1951) suggested that the sun is blowing out its atmosphere all the time. In 1958, E. N. Parker theorized this phenomenon and coined the term *solar wind*. The solar wind was detected by Mariner-2 satellite in 1962. Thus, it has become to know that the sun blows its corona (the upper atmosphere) all the time and the comet-shaped magnetosphere is a permanent feature of the earth. It should be noted that causes of the solar wind is still a matter of great debates. It has been thought that the high temperature of the corona is responsible for the cause of the solar wind. Lee and Akasofu (2021) proposed that an electromotive force is needed to overcome the solar gravity. Actually, the cause of high temperature of the corona is not understood. The sun has still many mysteries, which have not been solved in spite of efforts during the last fifty years.

7. Discovery of the Radiation Belt

In 1957, one of the first US satellites discovered a belt of high energy particles surrounding the earth like a doughnut by J. A. Van Allen and L. Frank (1957); it is now called the Van Allen radiation belt. This discovery was the beginning of space exploration around the earth by satellites. Since then, many discoveries were made in the magnetosphere by satellites.

Subsequently, the ring current around the earth, predicted by Chapman in 1933 as the cause of the main phase of geomagnetic storms, was confirmed by satellites; a new belt of radiation belt forms during the main phase of geomagnetic storms; surprisingly oxygen ions from the ionosphere are the main particles of the ring current, rather than solar wind particles. The aurora and ionosphere have extensively been explored by satellites after the 1960s; both satellite images of the aurora (first in1972) and the detection of auroral electrons were crucial in the development of auroral physics.

8. Open Magnetosphere and Solar Wind-magnetosphere Dynamo

As mentioned earlier, Chapman theorized the comet-shaped magnetosphere. His magnetosphere is, however, isolated from its surrounding, so that it was a closed system. In studying geomagnetic storms in 1963, Akasofu and Chapman suggested that there must be an “unknown” parameter in the solar wind, other than just protons and electrons, in order to explain the development of the main phase of geomagnetic storms.

In 1964, J. W. Dungey, a British physicist, suggested that their “unknown” parameter might be the interplanetary magnetic field [the magnetic field carried by solar plasma], and further that it is directed southward]. The interplanetary magnetic field lines and magnetospheric magnetic field lines link and make the magnetosphere an *open* system with outside. Meanwhile, H. Alfven (1950, 1981) made many important theoretical suggestions in studying magnetospheric physics and space plasma physics, including his magnetohydrodynamic MHD theory.

9. Discovery of the Magnetosphere in Jupiter, Saturn and Other Planets

Planetary exploration began by space probs in the 1970s. Pioneer 10 was launched in March 1972 and arrived at Jupiter in March 1973. Voyager 2 arrived at Jupiter in 1979 and Neptune in 1989. There have been other space probs, such as Galileo, Ulysses and Parker. Many others are planned for the future. It was found that magnetized planets (Jupiter, Saturn, Uranus) have the magnetosphere and the aurora; (Mercury has also its magnetosphere, but there is no atmosphere to have the aurora). Although each planet has many new features compared with those of the earth, the basic structure of their magnetospheres is the same as the earth’s magnetosphere. Therefore, Chapman’s study of geomagnetic storms and the magnetosphere have been extended to the planets. In fact, the heliosphere is relatively moving in interstellar space, forming its own magnetosphere.

10. Conclusion

It may be said that space physics is certainly developed by the advent of satellites, but there has been the advance of the related fields which had established the foundation for its explosive development of space physics. Space physics may eventually include interstellar physics and physics of planets of stars and eventually physics of nebulas and galaxies. In fact, H. Alfven suggested those developments in his book published in 1981.

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