

Original Paper

Magnetic Reconnection: Phantom Theory

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Abstract

In any scientific field, there is always a possibility, in which a particular theory dominates for many years. In this paper, the theory of magnetic reconnection in solar physics and auroral physics is reviewed as an example. It has prevailed for more than a half century in both fields as the “only one” without a concrete progress in understanding the source of energy for solar flares and auroral activities. This unusual situation is analyzed why and how it occurred. Since such a situation could occur in any scientific field, it may be useful to analyze how this situation happened. Actually, it is pointed out that a study of global warming may also be in a similar situation.

Keywords

Paradigm, magnetic reconnection, solar flares, aurora

1. Introduction

It is perhaps somewhat unusual that a particular theory has overwhelmingly prevailed for more than a half century without a concrete understanding its purpose, namely understanding the source of energy for solar flares and auroral substorms. In this particular case, the situation is something like an event, in which theorists have tried to build a sandcastle in a sand box and then are leaving the box.

Initially, the theory of magnetic reconnection was conceived as the source process of energy for solar flares. The requirement was an explosive release of a large amount of energy. For this reason, solar physicists came up an idea that an anti-parallel magnetic configuration in the solar atmosphere might annihilate itself explosively (forming an X-line) and releasing a large amount of energy, regardless if such a process could really occur in nature; Figure 1.

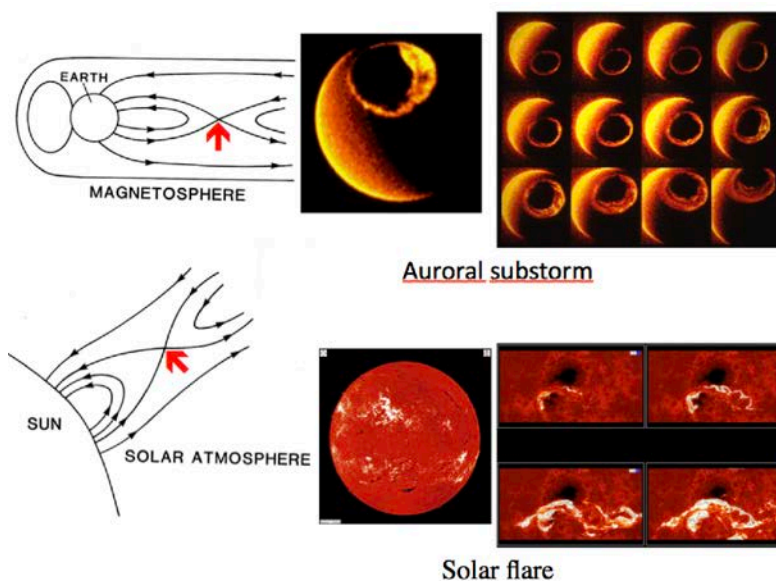


Figure 1. The Auroral Activity Called Auroral Substorms in the Polar Region of the Earth and Solar Flares on the Sun. The Theory of Magnetic Reconnection Assumes That an Anti-Parallel Magnetic Configuration (Forming an X-line) in the Tail Region of the Magnetosphere and Solar Atmosphere, Respectively, Annihilates Itself, Producing Explosively a Large amount of Energy

This theory has overwhelmingly prevailed in a study of solar flares in solar physics and auroral activities in auroral physics, respectively during more than a half century. The theorists have published countless papers over the years (modifications after modifications) without confirming their theory by themselves or by observations, and further leaving the field without pursuing how the released energy could explain the observed phenomena (the output from magnetic reconnection is claimed to be a fast plasma flow. However, they have not elaborated enough how such a flow can explain specifically various observed features of both phenomena).

After all, magnetic reconnection is an idea (or may be more appropriate to express it as an imagination), hoping that it could produce the required (amount, explosive) energy for solar flares and auroral activity called auroral substorms.

The first problem is that it really did not matter if such a process could realistically occur in nature. Secondly, the theorists firmly believed that such a process must occur and that there is no other process in understanding both phenomena.

Since such a situation could occur in any scientific field (although the period of a half century is unusual), it is worthwhile to analyze why and how such a situation has happened, because many factors for its cause are present in any field of science. In fact, global warming by carbon dioxide may be another example, as explained in Section 4.

2. History

Solar physicists had been looking for energy supply processes for solar flares in the 1950s. They considered that the flare process must be explosive, capable of releasing a large amount of energy (10^{25} J) during a relatively short period (say, less than one hour). They considered that the source of energy must be magnetic energy in a sunspot area, where the intensity of the magnetic field is large. They considered that in considering the required magnetic field configuration for this process, magnetic field lines must have an anti-parallel configuration to be “annihilated”. This idea should have been a gedankenexperiment, but they considered that magnetic reconnection must realistically occur.

Thus, the theorists have believed that such an anti-parallel configuration must annihilate itself by magnetic reconnection, producing rapidly the desired energy. Further, it was thought that magnetic reconnection was the only process, by which magnetic energy can be converted into flare energy. By using the term “annihilate”, they must have considered anti-parallel magnetic field lines are like matter and anti-matter; magnetic field lines are imaginary lines in physics.

In 1964, a near anti-parallel magnetic configuration was discovered by Ness et al. (1964) in a comet-shaped structure around the earth (the magnetotail). Since the concept of auroral substorms [the explosive auroral activity] by Akasofu (1964) was also published in the same year, it was perhaps natural for many auroral physicists to consider that the explosive auroral activity [like solar flares] was caused by magnetic reconnection. Thus, it has become overwhelmingly popular to study the explosive auroral activity *only* in terms of magnetic reconnection in the magnetotail; since the magnetotail is accessible by satellites, it was claimed that the magnetotail is a test ground for the theory by satellites.

Actually, there have been some serious criticisms on the concept of magnetic reconnection in the past. For example, Alfven (1986, p. 786) stated that magnetic reconnection is “pseudoscience” and mentioned further: “There is no [magnetic] field line reconnection that can transfer energy to the particles nor release energy in any way”. This is found to be actually the case as explained later; see also Alfven (1977, p. 273). However, his warning has been ignored. All ideas different from magnetic reconnection have been said to be “at odds”.

3. Analysis

3.1 The “Only One” Mentality

A good example of the “only one” mentality is expressed by Vasylunas, who stated: “The process variously known as magnetic merging, magnetic field annihilation or magnetic reconnection (or re-connection) plays a crucial role in determining the most plausible, if not only, way of tapping the energy stored in the magnetic field in order to produce large dissipative events, such as solar flares and auroral substorms”.

Such a situation of “only one” can occur in any scientific field, but it generally lasts for a decade or so, because a new “only one” will appear sooner or later. However, in solar physics and auroral physics

(also in space physics), this paradigm has been abnormally long lasting, a half century, namely by at least a few generations of researchers.

Another problem of the overwhelmingly “only one” mentality has been that following theorists, observers have the tendency of following theorists, trying to understand their observational phenomenon *only* in terms of a prevailing theory. Any observations contradictory to the theory is thus often left behind or dismissed. This circumstance has encouraged theorists to pursue further their efforts of “improving” the theory and so on.

3.2 Theorist's Attitude

This situation in solar physics and auroral physics may partly be related to the following particular circumstance. It so happened in the 1960s, and 1970s, both the field of magnetohydrodynamics (MHD) and plasma physics became explosively popular subjects in the field of physics. Many young physicists who were trained in these subjects, tried to apply their skill on the theory of magnetic reconnection, because it was a very attractive and challenging theoretical problem. Such a participation of younger generations is actually a welcome trend in both fields, because new generations of researchers are always needed.

However, the problem was that they were not particularly interested in learning much about solar flare and auroral phenomena. They treated both phenomena as a given pure mathematical physics problem. They consider that the mathematical formulation is their own task.

Further, those theorists have begun to believe that they are the only ones who hold the secrets of both phenomena, because the problem was a theoretical problem. Since they are interested only in the mathematical formulation, they are hardly interested in estimating the total amount of energy released and the release rate for the actual conditions, actually avoiding the estimation of the energy and its release rate, leaving them for others.

Actually, it is not difficult to show how untenable the theory is by demonstrating that the magnetotail does not have enough magnetic energy for an auroral substorm to begin with (Akasofu, 2017), although there have been enough data (the intensity of magnetic field in the magnetotail even in as early as 1964, but the theorists did not try to make such a simple (5 min.) estimate.

One of the reasons they hesitate to estimate the released energy by magnetic reconnection is that in estimating the output, the theorists have no choice but to introduce one critical factor, something like “equivalent resistivity”, which might not really cannot clearly be defined in a collisionless (an extremely rarified) condition. However, this quantity is supposed to determine both how rapidly magnetic reconnection would occur (how rapidly solar flares or auroras occur) and how much energy would be released. Thus, this is the very key quantity for both phenomena in terms of magnetic reconnection. This is one of the reasons for them to remain only in the formulation of the theory and to avoid in considering the realistic situations.

In their simulation studies of the observe features of both phenomena, however, they have no choice but to choose arbitrarily some value for “equivalent resistivity” in order to reproduce their phenomena, so that their simulation results do not provide any proof of the theory.

3.3 Lack of Efforts to Prove the Theory

Since the most important role of magnetic reconnection is supposed to generate explosively a large amount energy in a short time for auroras and solar flares, respectively, the most crucial confirmation of the theory of magnetic reconnection must specifically demonstrate observationally that the energy for auroras and solar flares, respectively, can be rapidly released from an anti-parallel magnetic configuration by magnetic reconnection.

Although there have been a number of satellite observations which claim to confirm magnetic reconnection by direct observations around the X-line by satellites in the magnetotail (Angelopoulos et al., 2008; Burch et al., 2016), none of them estimated observationally the total energy produced in the reconnection region and the reconnection rate, as well as “equivalent resistivity”, in spite of their claim that the magnetotail is their test ground for the theory of magnetic reconnection.

3.4 Simultaneous Occurrence

As far as the total energy is concerned, they rely on the simultaneous occurrence of auroral substorms and solar flares, assuming that magnetic reconnection is the “only one” process to cause both phenomena. This cannot be justified, because there may be other processes which can supply the energy. This is explained in the following.

3.5 Lack of the Basic Approach

Solar flares and auroral activities are manifestations of electromagnetic energy dissipation processes. Thus, the basic way to study them must consider a chain of processes, consisting of power supply (dynamo), transmission (electric currents/circuits) and dissipation (solar flares, auroral substorms). Both solar physicists and auroral physicists had forgotten to take this basic approach in dealing with electromagnetic phenomena.

In fact, in as early as 1967, Alfven (1967) in his paper entitled “The second approach to cosmical electrodynamics” emphasized the above approach, the “electric current approach”, instead of his MHD theory, the magnetic field line approach (including magnetic reconnection). In his paper, he mentioned that we have to advance beyond magnetohydrodynamics by considering electric currents, instead of magnetic field lines, particularly in rarified plasma in nature. If the theorists would have taken this approach, it is quite likely that they would have considered processes different from magnetic reconnection, a dynamo process on the photosphere and a loop current as the source configuration, rather than an anti-parallel configuration, simpler and more realistic problem (Akasofu & Lee, 2019). Thus, *the cause-effect relationship could be reversed*, namely that the source process may be in the photosphere and whatever happening in the anti-parallel configuration is an after effect. Here again, the “only one” idea prevented other possibilities.

4. On Global Warming

Although the situation may be somewhat different, many atmospheric scientists, particularly young ones—like young solar and auroral physicists, have attempted to predict the temperature in 2100 on the basis of what they have learned in atmospheric science, believing that man-made cause (carbon dioxide) is the “only one” cause—like magnetic reconnection. Further, they claim that they are climatologists and understand best climate change without much knowledge of climate change. They are not aware the most basic fact that climate change consists of natural change and man-made change, considering that all changes are caused by carbon dioxide (man-made), forgetting that their study of day-to-day weather change and past. Climate changes are basically all natural changes.

It is the fact that the recent temperature rising rate has become much smaller ($0.1\text{--}0.2^\circ\text{C}$) during the last two decades than their prediction $0.5^\circ\text{--}1.0^\circ\text{C}$, in spite of the fact that the amount of carbon dioxide is still rapidly increasing (cf., Kerr, 2009). They dismiss also the observed fact that the temperature decreased by 0.1°C from 1945 to 1975 in spite of the fact that the amount of carbon dioxide in the atmosphere was rapidly increasing at that time. One obvious possibility is that there is at least another process which controls climate change. It is also obvious that some *known* natural components are working in addition to carbon dioxide (for example, the “recovery” from the Little Ice Age (1850-2000--), the Pacific Decadal Oscillation, PDO).

The problem is that even if they could learn about the existence of natural changes in climate, such as the Little Ice Age, a higher temperature at the end of the Glacier Age than the present one, the “recovery” from the Little Ice Age [rising temperature from 1850, PDO, etc. (cf. Akasofu, 2010)], their causes are unknown. Thus, they have no choice but to ignore them, because they cannot program in their simulation studies.

Thus, they take an uncertain temperature rising rates which contain both natural and man-made components—like “equivalent resistivity”; this is the reason why the predicted temperatures are so widely different among them. On the other hand, following the theorists, observers interpret many observed changes in terms of man-made changes; they use often the word “unprecedented” in describing their observations (for example, receding glaciers), although similar events happened many times hundreds of years ago (as many old records show).

In any climate study, the first task is to try to find causes of natural changes to begin with and subtract them from the observed temperature; without this study, it is not possible to estimate how much carbon dioxide is contributing to the temperature rise. However, the problem here is that they believe that they understand climate change best, and almost demand that everyone has to believe their computer results by saying that those who disagree with their study are “deniers” like the case of “at odd” in magnetic reconnection.

5. Concluding Remarks

It is important to avoid the situation of the “only one” in any scientific field in progress. Unfortunately, such a situation could delay the progress in the field.

In order to avoid such long-lasting situations, theorists (particularly computer-based researchers) should learn as much as possible the phenomenon they want to study. Observers should be independent of any theory.

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