Introduction

The solar wind is a stream of ionized solar plasma emanating from the solar atmosphere and fills the interplanetary space. It is a result of the enormous difference between the pressure in the solar corona and the interplanetary space. Embedded within the solar wind plasma is the interplanetary magnetic field (IMF). Table I shows the typical values of solar wind parameters observed[1].

Table I. Observed properties of solar wind near the Earth

Proton Density	7 cm^{-3}
Electron Density	7 cm^{-3}
Flow speed	450 km/s
Proton Temperature	1.2×10^5 K
Electron Temperature	1.4×10^5 K
Magnetic Field	7×10^{-9} T

The plasma particles in the solar wind as well as in the solar corona are highly conductive. This means that the plasma is "frozen-in" the magnetic field lines. Thus, these plasmas often referred to as magnetized plasmas and the equations of magnetohydrodynamics are used to describe their motion and the changes in the electromagnetic field in it[2].

Say, we have a piece of solar wind plasma that emanates from a source at the solar corona. As the Sun rotates, this source also rotates with it. The combination of the Sun's rotation and the solar wind's radial expansion allows the plasma to spiral "trace". Magnetic field lines frozen into the expanding plasma and their fixed source at the base of the corona must take the same shape, i.e., it will bear the same spiral form. Figure 1 shows the loci of a succession of plasma parcels (eight of them in this sketch) emitted at a constant speed from a source fixed on the rotating Sun.

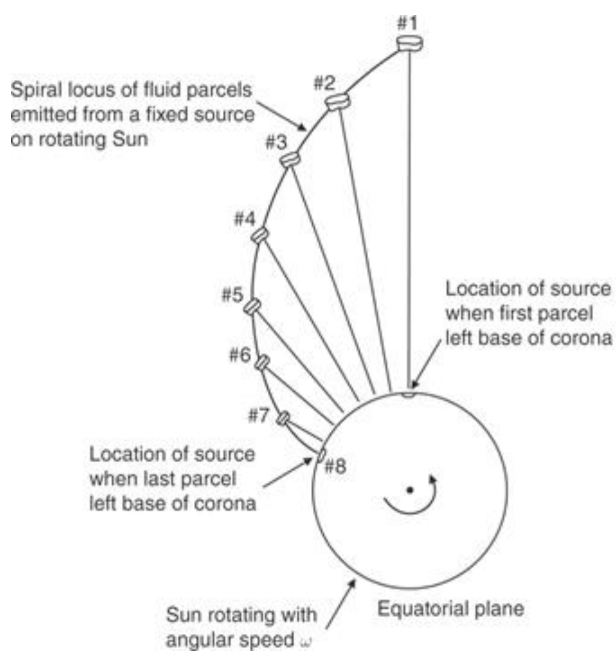

Figure 1. Spiral IMF field lines frozen into a radial solar-wind expansion[1].

The IMF has been explored by numerous spacecrafts. The two main spacecrafts that monitor the solar wind plasma properties, including the components (*Bt*, *Bx*, *By* and *Bz*) of the IMF are the Advanced Composition Explorer (ACE)[3] and Deep

[1] A.J. Hundhausen The Solar Wind (Introduction to Space Physics) Editors Margaret G. Kivelson and Christopher Russell Cambridge University Press Cambridge 1995
[2] Katsuhide Maruhabi The Sun and the Solar Wind (Science of Space Environment) editor Tadanori Ondoh and Katsuhide Maruhabi Ohmsha Ltd.Tokyo Japan 2001
[3] http://www.srl.caltech.edu/ACE/

Space Climate Observatory (DSCOVR)[4]. These spacecrafts are located at the L1 point near the Earth and monitors the solar wind magnetic field vector and plasma parameters such as proton density, speed, temperature, etc. Figure 2 shows an example of a 30-day data of the IMF components taken from December 28, 2020 to January 27, 2021 by DSCOVR. From this figure, *Bt* is the value of the magnitude of the IMF. It is the combination of the field strength in the *Bz* (north-south), *By* (east-west), and *Bx* (toward-away-from the Sun) directions. The coordinate system used is called the Geocentric Solar Magnetospheric system (GSM), which is illustrated in Figure 3.

The most important component of the IMF is Bz. Since the Earth's magnetic field is pointing toward the +z (GSM) direction (Northward), only the negatively pointing Bz (Southward) interacts with it. When this interaction happens, a geomagnetic storm will mostly happen.

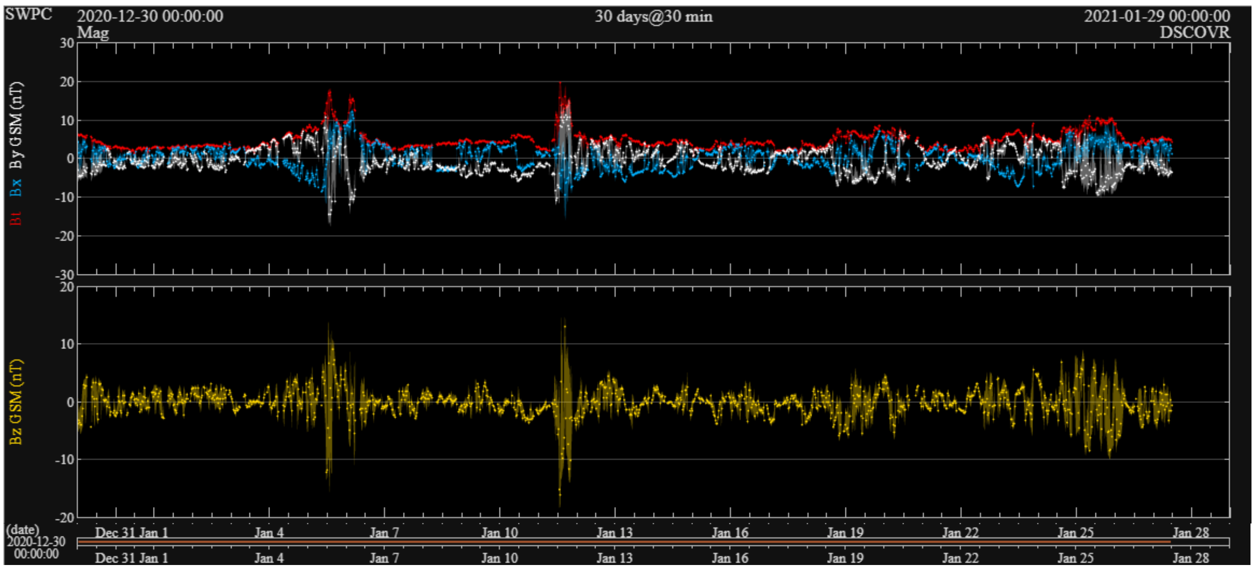

Figure 2. 30-day interplanetary magnetic field data from DSCOVR.

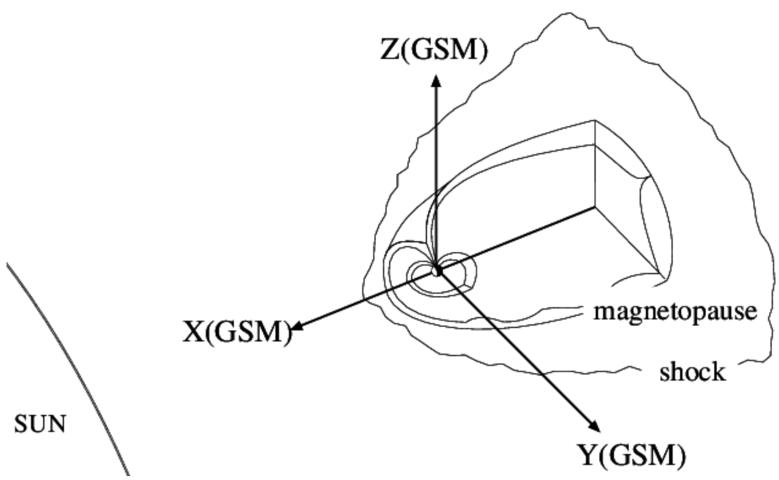

Figure 3. The GSM coordinate system.

[4] https://www.nesdis.noaa.gov/content/dscovr-deep-space-climate-observatory

In this activity, you will observe the interplanetary magnetic field parameters carried by the solar wind as enhanced by a coronal mass ejection during the September 2017 X9.3 Solar Flare event.

Materials:

- Computer
- Internet
- Photo Editing software
- Word Processor Software
- Data Graphing Software

Instructions:

1. Go to NOAA Data Browser for DSCOVR: https://www.ngdc.noaa.gov/dscovr/data/
    a. Go to the directory of the desired date.
    b. Download the **`m1m`** file for September 6-9, 2017 to your desired directory.
    c. Un-compress the files.
2. Install DSCOVR Interplanetary Magnetic Field (IMF) data reader using the installer (Read_IMF_DSCOVR.exe) provided. This is made using MATLAB so for you might need an internet to install additional files.
3. Run DSCOVR IMF data reader.
4. Load and plot the data you downloaded. The program only reads one file at a time.
5. Plot (using other tools like *Python, MATLAB, Libre Office Calc, Microsoft Excel,* or *Apple Number, etc.*) the IMF for the whole duration. That is, one continuous plot showing the 4 days of observation.
6. Document your results in a word processor software (e.g., *Microsoft Word*, *Google Doc*, *Libre Office Writer*, *Apple Pages*, etc.)
7. Observe.

*Installer can be downloaded from https://macalalade.weebly.com/research.html

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CHALLENGE 1:

1. Search the internet for the 5 strongest CME events occurred in from 2015 to 2020.
2. Download 3 days before and after the event date. Here you will get a total of 7 days.
3. Plot each event separately and compare with each other.

CHALLENGE 2:

1. Go to *SpaceWeatherLive* Twitter account (**@_SpaceWeather_**).
2. Search its timeline for 3 trans-equatorial coronal hole events.
3. Download 5 the data from the date of the tweet and 5 days after the it. Here you will get a total of 6 days.
4. Plot each event separately and check when did the IMF became southward arrived and check if a geomagnetic storm happened, i.e., Kp-index > 4.

Last Updated: June 4, 2021