1. Purpose of LabWork-1 This Lab Work aims to introduce you the interplanetary environment (solar wind) near the Earth. You are expected to analyze spacecraft data located at L1 position using simple statistical methods. For this purpose event date and hours are chosen as 2000/19/11 00.00 to 2000/19/11 06.00.

2. Time Series Plots

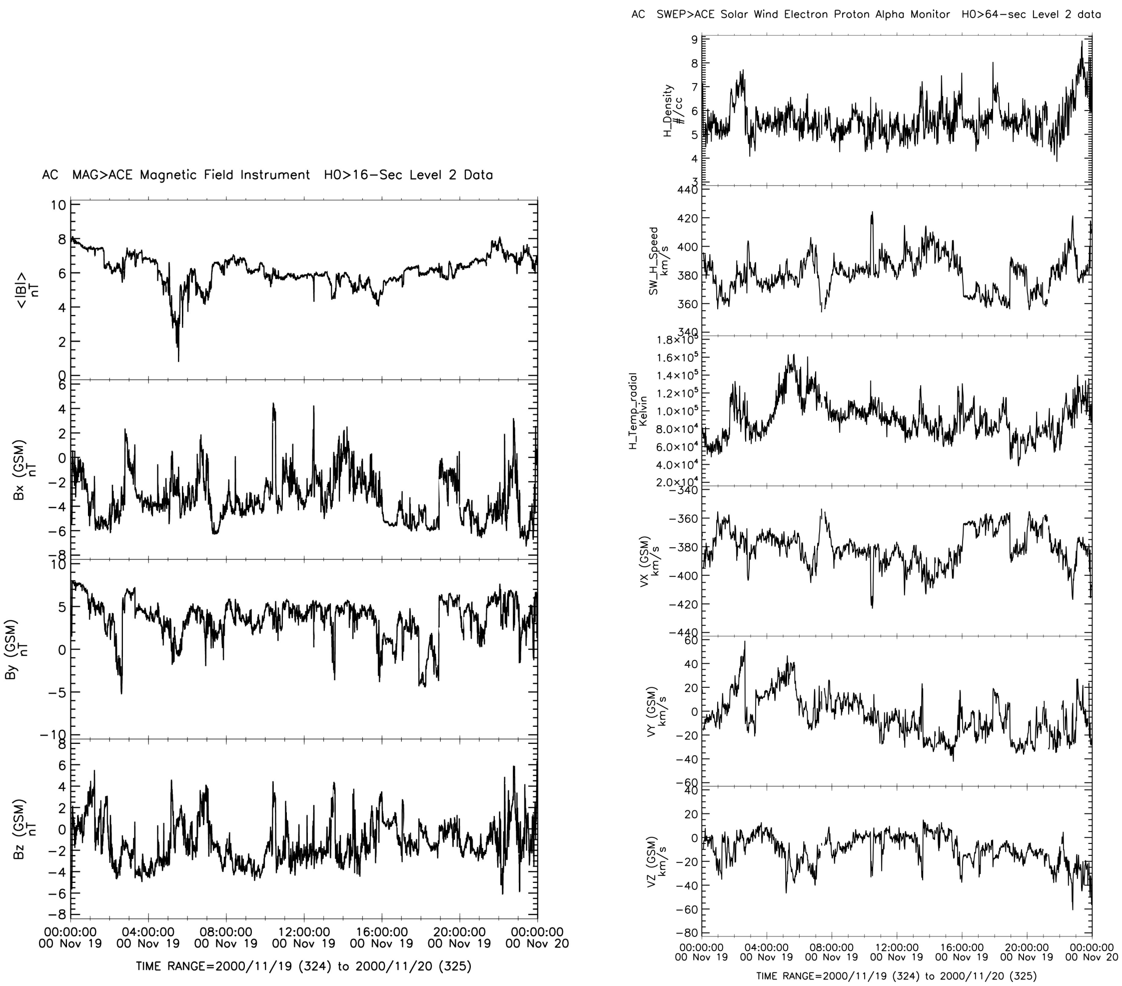


Figure 1: Time Series Plots of Solar Wind Quantities using Cdaweb

3. Name of the Instruments

MAG - ACE Magnetic Field Instrument : To measure local interplanetary magnetic field (IMF) direction and magnitude.

SWEPAM - Solar Wind Electron Proton Alpha Monitor : To measure solar wind plasma electron and ion fluxes direction and energy.

4. Orbit Plot for ONE full ORBIT

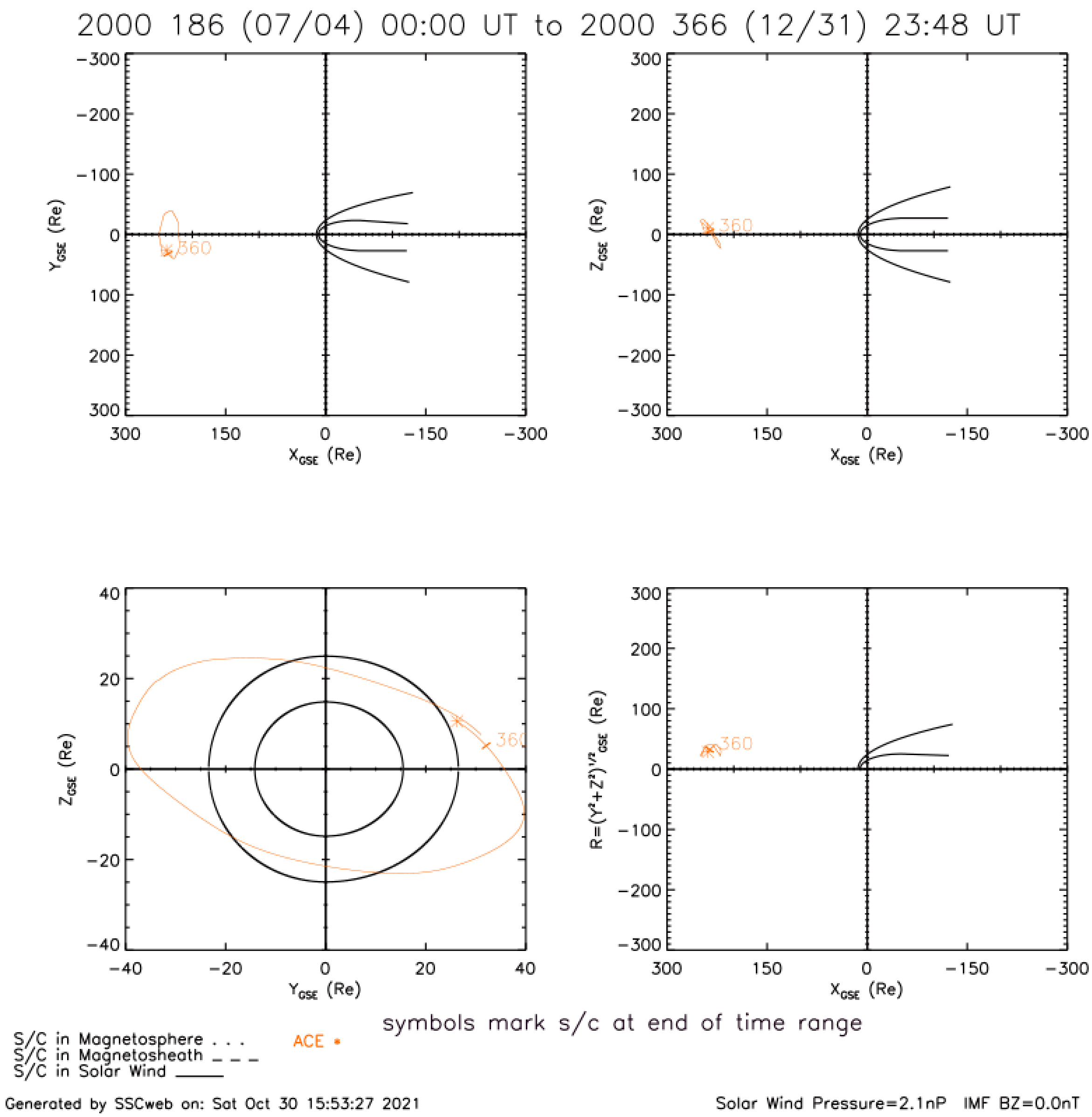


Figure 2: Orbit Plot for ONE Full ORBIT Obtained From sscweb - 4 July to 31 Dec 2000 -

5. Table-1 : Statistical properties of Solar wind at 1 AU

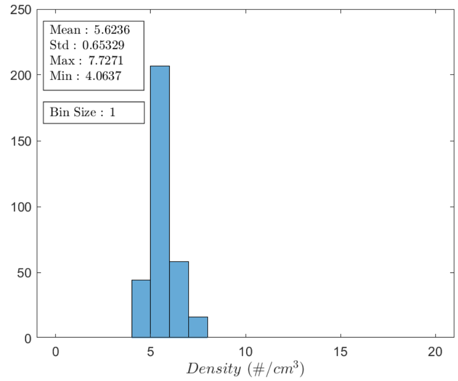
SPACECRAFT NAME : ACE					
PERIOD FROM : 2000/11/19 00:00:00 to 2000/11/19 06:00:00					
	Mean	**Median**	**Max**	**Min**	**Standart Deviation**
Density($\#/cm^3$)	5.62	5.48	7.73	4.06	0.65
$V_{tot}(km/sec)$	376.81	376.29	403.76	356.02	8.12
$V_x \geq 0(km/sec)$					
$V_x < 0(km/sec)$	-375.91	-375.24	-355.35	-403.60	8.09
$V_y \geq 0(km/sec)$	20.86	18.87	59.10	0.256	11.97
$V_y < 0(km/sec)$	-7.84	-7.58	-0.358	-21.20	4.50
$V_z \geq 0(km/sec)$	4.61	3.93	21.45	0.005	3.89
$V_z < 0(km/sec)$	-13.11	-11.02	-0.048	-46.84	10.83
Temp(eV)	8.06	7.43	14.06	4.14	2.49
IMF $B_{tot}(nT)$	6.39	6.73	8.14	0.79	1.27
IMF $Bx \geq 0(nT)$	0.974	1.10	2.36	0.000	0.69
IMF $Bx < 0(nT)$	-3.43	-3.63	-0.043	-6.19	1.46
IMF $By \geq 0(nT)$	4.49	4.46	7.98	0.012	1.93
IMF $B_y < 0(nT)$	-1.43	-1.07	-0.001	-5.19	1.31
IMF $Bz \geq 0(nT)$	1.60	1.36	5.51	0.016	1.16
IMF $Bz < 0(nT)$	-2.57	-2.79	-0.013	-5.66	1.34
$P_{dyn}(nPa)$	1.33	1.30	1.85	1.01	0.16
$P_{gas}(nPa)$	0.015	0.013	0.029	0.006	0.005
$P_{mag}(nPa)$	0.017	0.018	0.026	0.00025	0.006
$C_s(km/sec)$	50.17	48.75	67.03	36.38	7.66
Mach Number	7.68	7.74	10.51	5.61	1.14

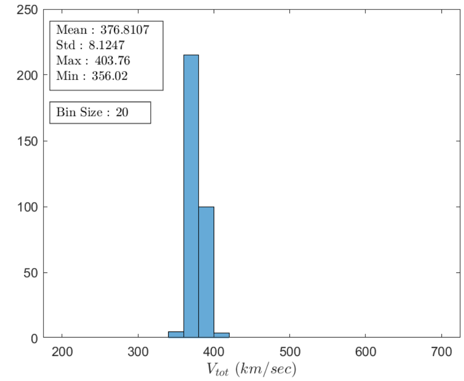
6. Calculation and Comparison of Pressures

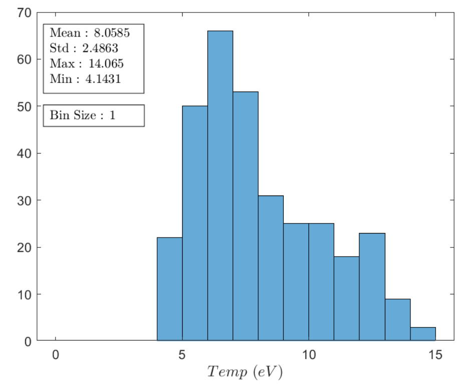
$\boxed{P_{dyn} = \rho \times V_{bulk}^2}$; where $n_e = n_p = n$ and also $m_p >>> m_e$ so $\rho = nm_p$, $m_p = 1.67 \times 10^{-27}\ kg$ and n is proton density with unit of $\#/cc$. $\boxed{P_{gas} = nk(T_p + T_e)}$; where k is Boltzmann's constant ($k = 1.38 \times 10^{-23}$ $joule/^\circ K$); With assuming $T_p = T_m = T$; $P_{gas} = 2nkT$. $\boxed{P_{mag} = B^2/(2\mu_0)}$; where $\mu_0 = 4\pi \times 10^{-7}\ Henry/m$ or $kgm/coul^2$ also noting that $1\ Tesla = 1\ kg/coul.sec$

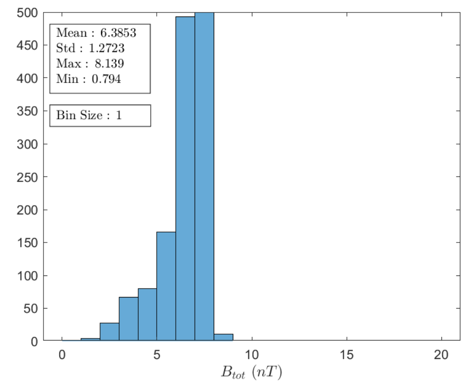
After the units were converted to MKS system, the calculations were made with obtained n, V_{bulk} and B_{tot} data from ACE satellite. Results are given in the CGS system. According to Table-1 all pressure values of solar wind relatively small with order of $10^{-9}\ Pascal$. Also even P_{gas} and P_{mag} are close to each other, they are much more smaller than P_{dyn} -max value of P_{gas} is smaller than 1/3 times of min value of P_{dyn} - so they can be ignored. Total pressure can be assumed as equal to P_{dyn}.

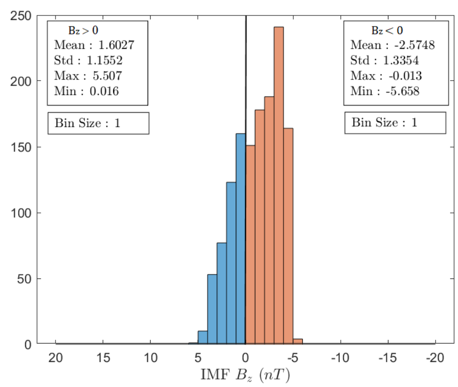
7. Bar Plots

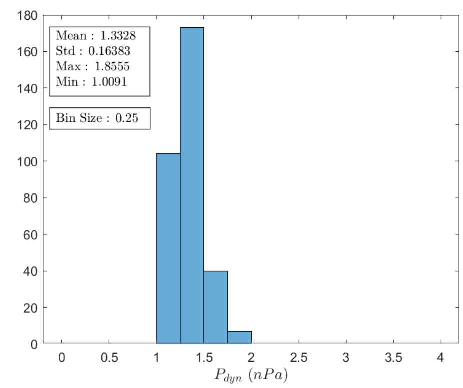

Mean : 5.6236
Std : 0.65329
Max : 7.7271
Min : 4.0637
Bin Size : 1
$Density\ (\#/cm^3)$

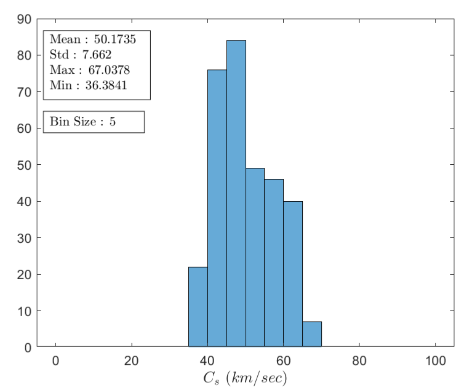

Mean : 376.8107
Std : 8.1247
Max : 403.76
Min : 356.02
Bin Size : 20
$V_{tot}\ (km/sec)$

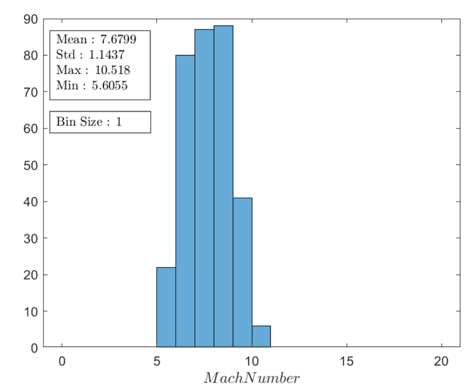

Mean : 8.0585
Std : 2.4863
Max : 14.065
Min : 4.1431
Bin Size : 1
$Temp\ (eV)$


Mean : 6.3853
Std : 1.2723
Max : 8.139
Min : 0.794
Bin Size : 1
$B_{tot}\ (nT)$


Bz > 0
Mean : 1.6027
Std : 1.1552
Max : 5.507
Min : 0.016
Bin Size : 1
Bz < 0
Mean : -2.5748
Std : 1.3354
Max : -0.013
Min : -5.658
Bin Size : 1
IMF $B_z\ (nT)$


Mean : 1.3328
Std : 0.16383
Max : 1.8555
Min : 1.0091
Bin Size : 0.25
$P_{dyn}\ (nPa)$


Mean : 50.1735
Std : 7.662
Max : 67.0378
Min : 36.3841
Bin Size : 5
$C_s\ (km/sec)$


Mean : 7.6799
Std : 1.1437
Max : 10.518
Min : 5.6055
Bin Size : 1
$MachNumber$

8. Interpretations

When above table and bar plots are examined, comments listed below were made.

- Proton number density ranges from 4 to $8/cm^3$. But average density ($5.6/cm^3$) is slightly lower than expected when evaluated together with the bulk velocity values.

- Bulk velocity changes from 380 to 400 km/sec with relatively low deviation, 8.12, for velocity property. values can be categorized as low speeds. Because of low velocity with relatively low density value, as expected, calculated dynamic pressure P_{dyn} values are lightly smaller than expected value at 1 AU. Additionally, X component of bulk speed, V_x, has no positive part and also it affects the overall speed the most.

- IMF B_{tot} ranges between 0.79 and 8.14 nT with deviations of 1.27. Mean value, 6.39 nT, is as expected 7 nT.

- Normally, IMF B_z values are expected to be much smaller or not at all than IMF B_x and B_y values, but in the chosen event IMF B_z values increased enough to dominate the total IMF magnetic field at some intervals. In total negative z component of IMF B_z data are observed more than positive component. It may be said that solar activity strength is low or moderate.

- Sound of speed, C_s, is dependent on P_{gas} and reciprocal of density, ρ. High deviation of C_s values, 7.66, can be explained with deviations of these properties.

- Mach number is related with reciprocal of C_s and V_{tot}. Mean is 8.

- In general there are no relatively sharp changes in observed properties.

9. Learning Outcomes

What are done?

- Continuous data of interplanetary magnetic field and solar wind plasma properties (proton number density, temperature, velocity) are obtained from ACE (Advanced Composition Explorer), robotic spacecraft which is located at Sun-Earth $L1$ Lagrange point, for chosen 6 hours. One full orbit of ACE are drawn. Pressures ($P_{dyn}, P_{gas}, P_{mag}$), sound of speed ($C_s$) and Mach number values are calculated with proper equations and obtained data. Using pressure formulas is given and comparison is made. Statistic of quantities belong to chosen event are made then Table-1 and bar plots are prepared and interpreted. Report is written with LaTeXaccording to guidance.

What are learned?

- In order to understand and predict the Sun-Earth interaction, it is important to examine the solar winds that spread from the corona holes of Sun to the interplanetary space and carry magnetic energy with them. Therefore, simultaneous information is received from the spacecrafts specially at $L1$ Lagrange point.

- Solar wind has low density, relatively high temperature, high velocity and low pressure effects. They are supersonic.