Space Physics
Practical 2B
Data Analysis

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2 Time Series Data

2.1 Question 1

Where in the magnetosphere are the observations made? Motivate you answer!
The measurment taken on 2002-03-02 at 03:29-03:30 is taken at the time when the satellite was crossing the border of magnetopause.
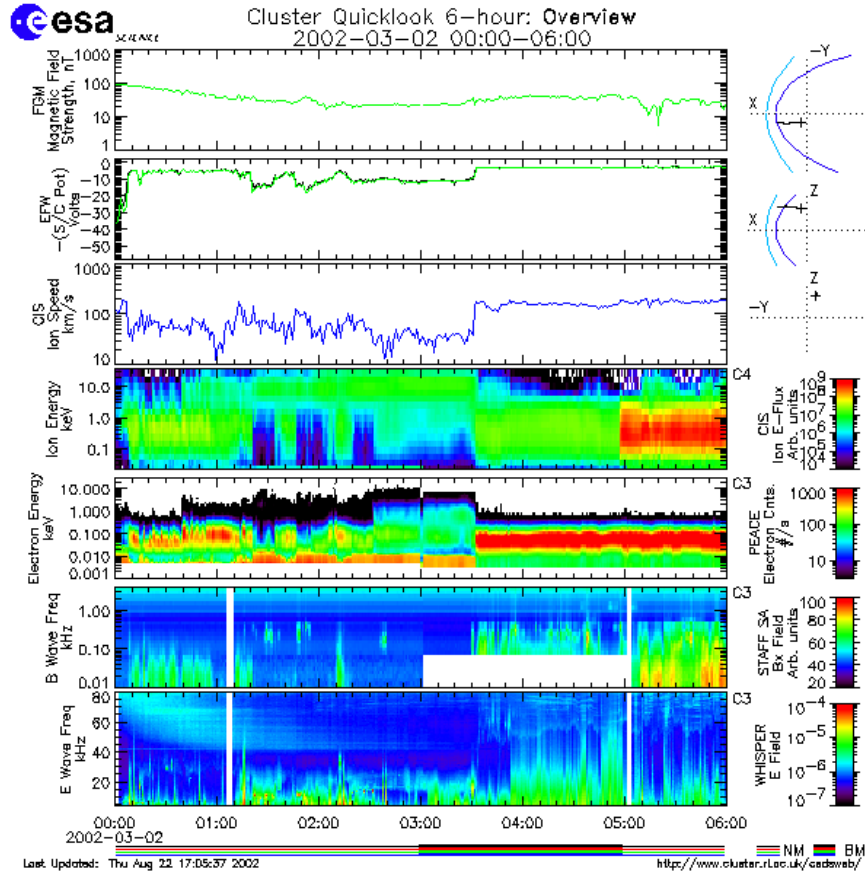
Figure 1: Cluster Quicklook 6-hours overview.

2.2 Question 2

Plot the time series (all components) from the three instruments. Can you identify any waves? What type of waves are we looking at: Electrostatic or electromagnetic? Is there a need to correct the data somehow? If so, why and how do you do that?
Electromagnetic between 20 and 30 s. Electrostatic between 55 and 60 s. x component is facing towards the sun. It should fluctuate around zero, like the y-component does it. It happens because of the photon emission, which is captured by the probes. Thus, data correction is needed.

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Figure 2: EFW Measurement Data

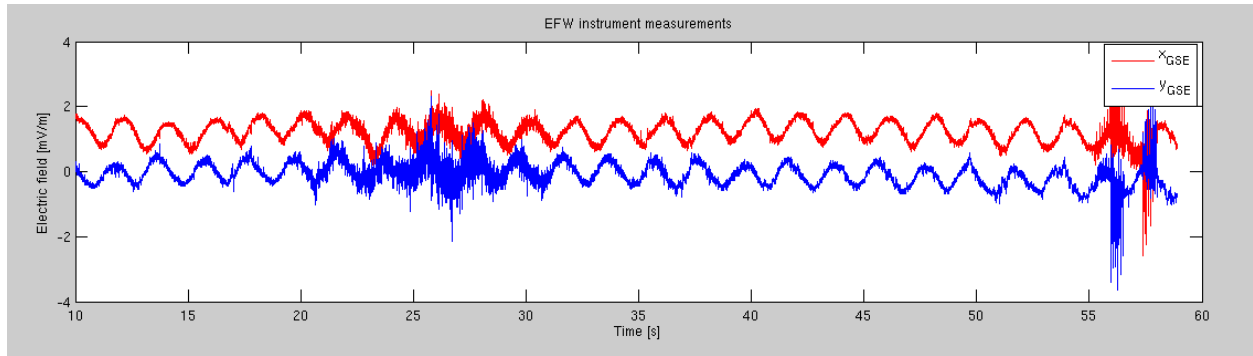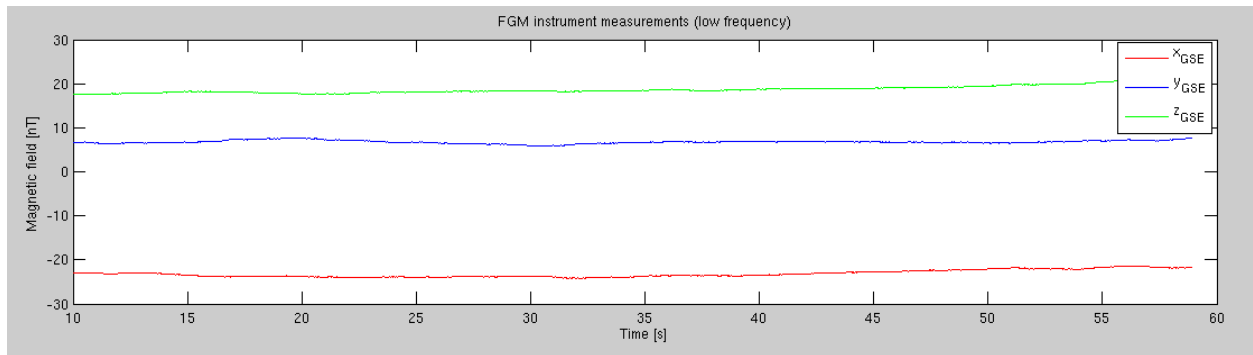Figure 3: FGM Measurement Data

2.3 Question 3

Estimate the frequency of the waves by looking at the times series only. Describe how you do. What is you result?

Roughly estimated wave period is about 0.01 s (zoomed in and estimated between 2 peaks). Frequency = $1/0.01 = 100$ Hz.

2.4 Question 4

Compute the fundamental frequencies (electron and proton gyrofrequencies and the electron plasma frequency) in the plasma. The background magnetic field you have in the data. The density can be found from the overview data. However, the ion density is usually underestimated. Therefore, it is a good idea to compare with the high frequency emissions obtained by the WHISPER instrument. In the WHISPER data you can identify the electron plasma frequency directly, as a thin horizontal line visible most of the time. What density does the WHISPER signal correspond to? Compare the wave frequency with the fundamental frequencies. What are you conclusions?

From overview data, ion density is $1.5cm^3$.

The estimated plasma frequency from WHISPER is 16 kHz.

2.5 Question 5

Compute the PSD of the electric and magnetic wave fields for the entire time period. If you want you can use the Matlab-function PSDvsFREQ(). Compare with your results obtained in 2 and 3. Change the resolution
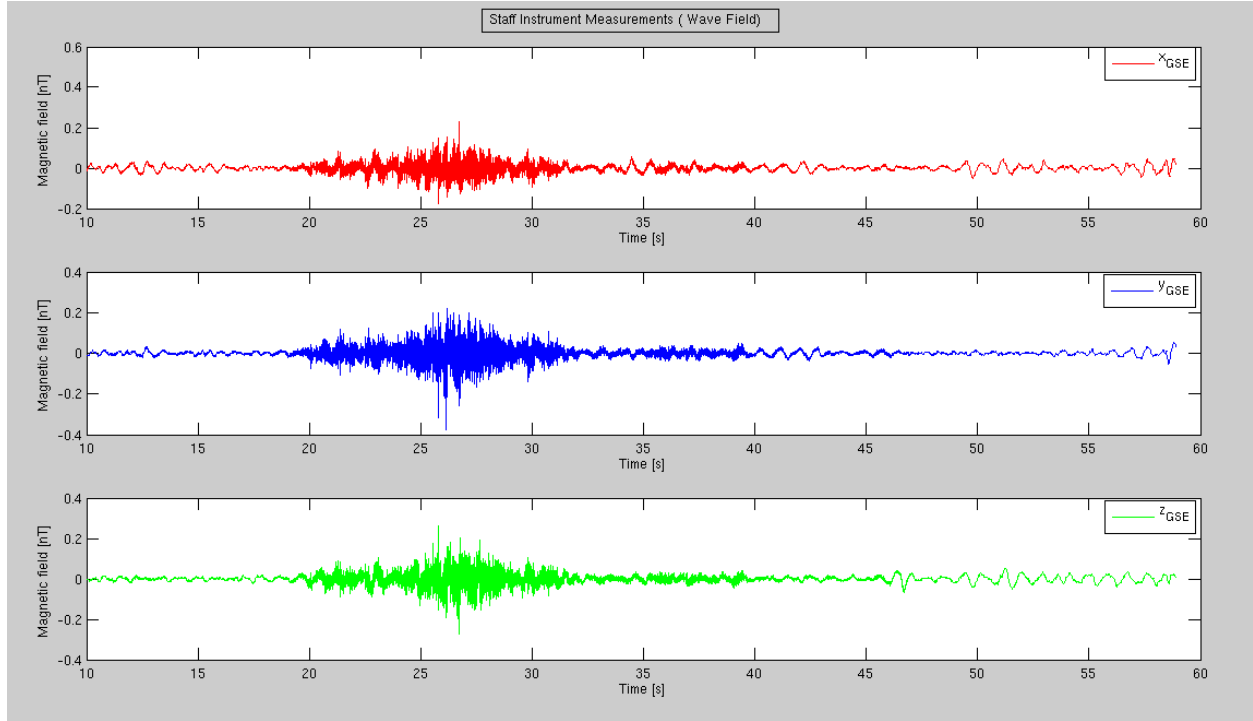
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Figure 4: Staff Instrument Measurement Data

of the PSD to clearly resolve the frequencies you found in 2. The frequency resolution is given by $f = 1/Nt$, where t is the time between two samples and N is the record length used in the Fourier transform.
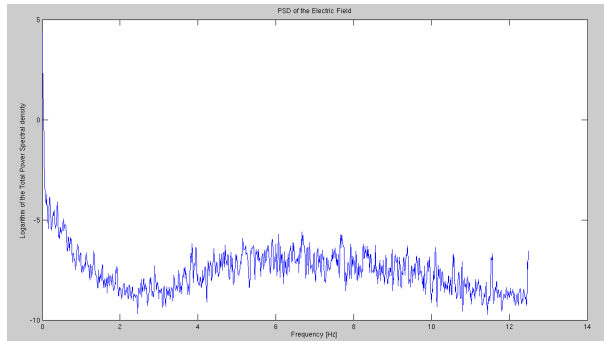The peaks are around 90-100 Hz. Which corresponds to our rough estimation in question 3.
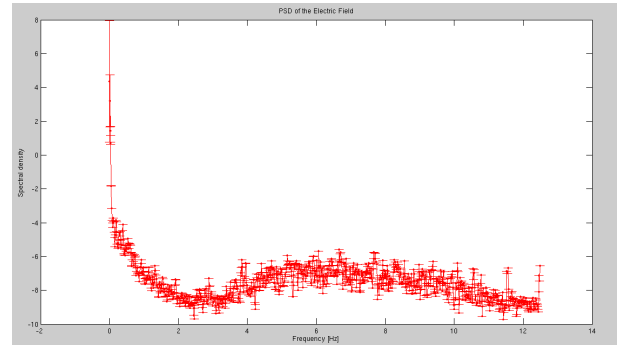

Figure 5: PSD of Electric Field.

Figure 6: PSD of Electric Field with Error Bar

2.6 Question 6

Look at (=make PSDs for) two different frequency ranges: 0-225 Hz and 0-2 Hz. You should aim at good statistics so the frequency resolution should be different in the two plots. The frequency resolution is given by $f = 1/Nt$, where t is the time between two samples and N is the record length used in the Fourier transform. For each of the plots: provide all the information about the PSD you present: The length of the record, the shift between records and the total number of records used.
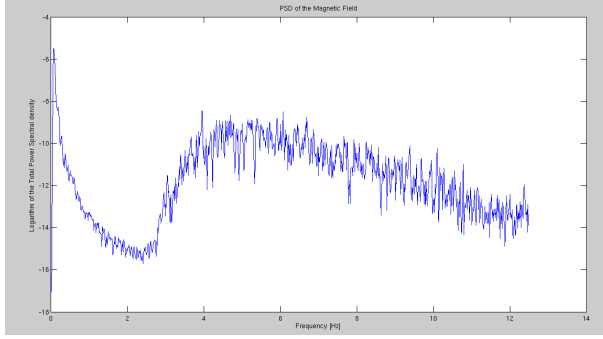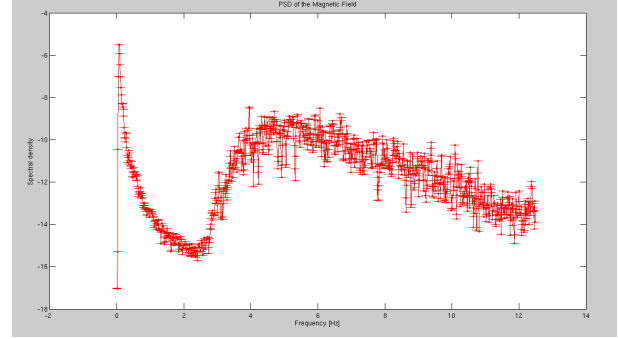
5

Figure 7: PSD of Magnetic Field.
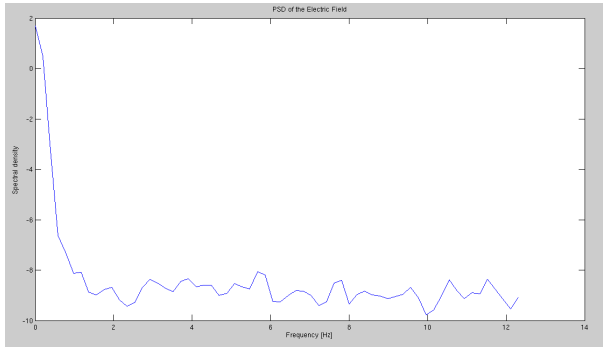

Figure 8: PSD with Error Bar

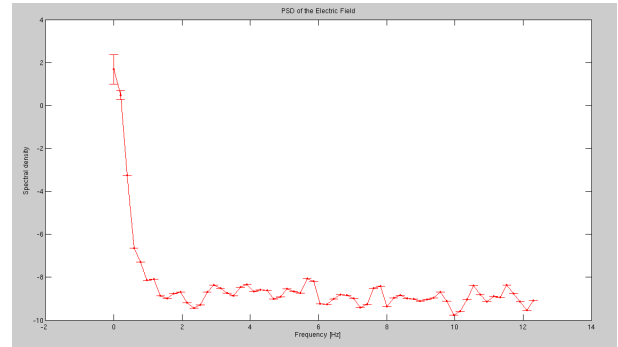Figure 9: PSD of Electric Field with less records

Figure 10: PSD with Error Bar and less records

2.7 Question 7

Plot spectrograms (=PSD versus time and frequency) of both the electric and magnetic fields. You can do this by using the Matlab function means() and ignoring the wave vector output. Try different resolutions in time and frequency.What are you conclusions?

2.8 Question 7

Now we can produce a so-called hodogram , which shows how the wave field vector moves in the plane perpendicular to B0. If the field vector moves in the same direction as a positive ion would gyrate then the wave is left-hand polarized. If the vector rotates in the opposite direction the wave is righthand polarized. Plot the magnetic field vector in this plane and determine the polarization of the waves. Sometimes it is easier to see the rotation if you normalize the length of the vectors to 1. Do the same with the electric field wave vector.
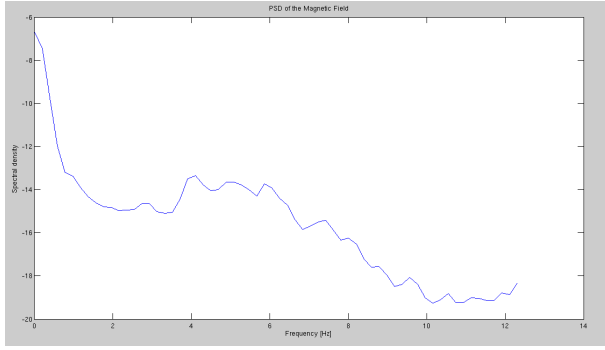
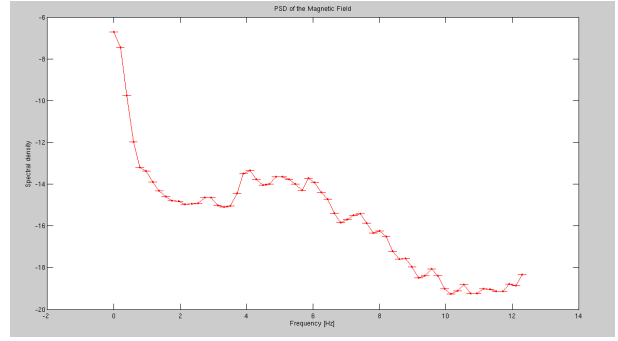Figure 11: PSD of Magnetic Field with less records.
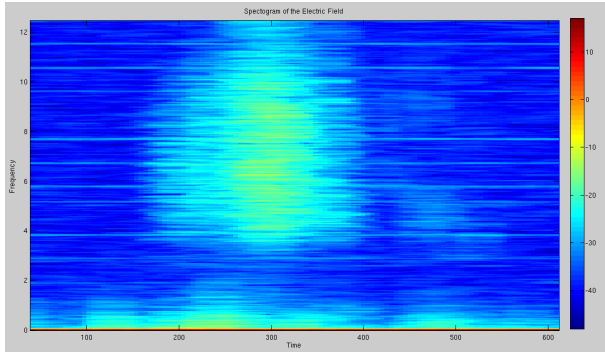

Figure 12: PSD with Error Bar with less records

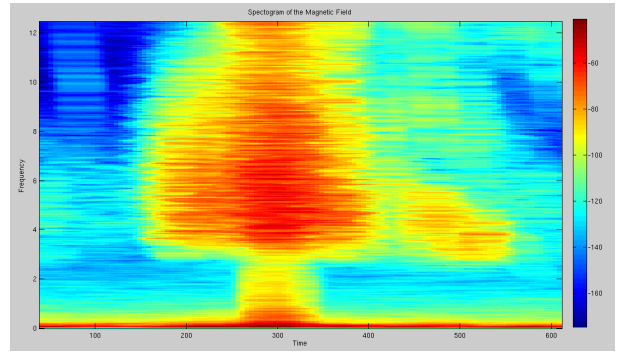Figure 13: Spectrogram of Electric Field with high time and frequency resolution

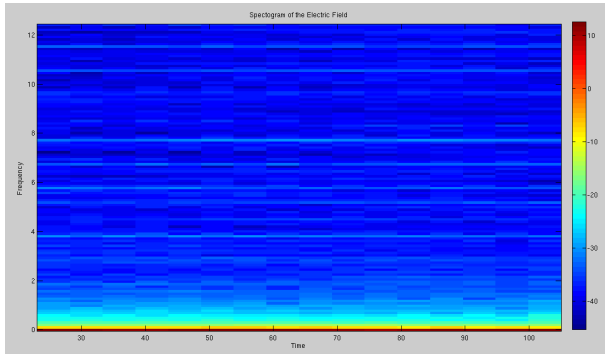Figure 14: Spectrogram of Magnetic Field with high time and frequency resolution

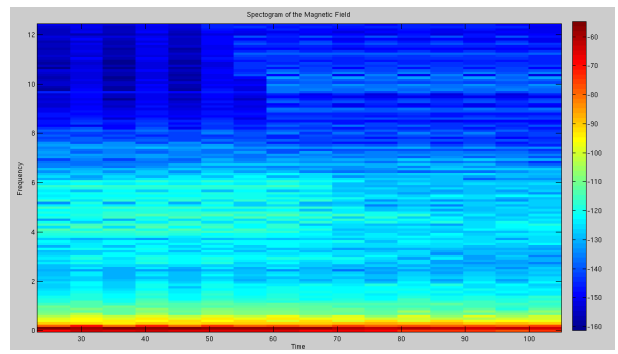Figure 15: Spectrogram of Electric Field with low time and frequency resolution

Figure 16: Spectrogram of Magnetic Field with low time and frequency resolution

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3 Particle Measurements

For this part of the practical we have been provided the particle data from the SWIM instrument onboard the Chandrayaan-1 spacecraft. Chandrayaan-1 orbits the moon at an altitude of 100 km. The position of the spacecraft at different times is shown in the Figures 17 and 18, which also show the position of the moon with respect to Earth.
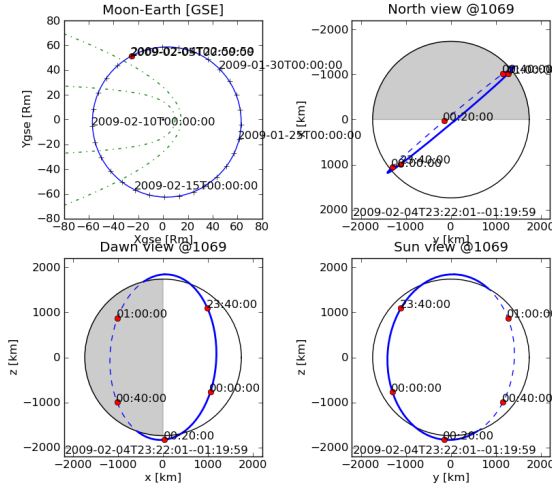

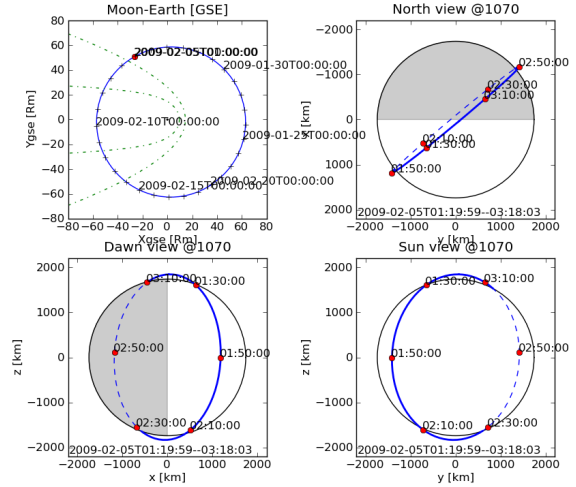Figure 17: Position of the instrument in Orbit 1069

Figure 18: Position of the instrument in Orbit 1070

3.1 Question 1

Plot spectrograms, that is, the number of counts versus time and energy, for the two orbits. The different energy levels you find in a comment line in the data files. Once every orbit SWIM looks at the solar wind. Identify when this happens in the two orbits.

The spectrograms for the orbits 1069 and 1070 is shown in Figure 19 and 20 respectively. When SWIM looks at the solar wind the number of solar wind particles that hit the instrument increases significantly which is observable as the red portion in Figures 19 and 20. For orbit 1069, it occurs approximately between $100th$ and $350th$ observation time bin which corresponds to UTC 05:29 to UTC 06:02 hours. For orbit 1070, it occurs approximately between $25th$ and $250th$ observation time bin which corresponds to UTC 07:22 to UTC 08:12 hours.

3.2 Question 2

Protons are the main ions in the solar wind, but can you identify any other components? Motivate you answer!

Helium double plus. I am not sure.

3.3 Question 3

Make energy spectra, this is, plot observed counts versus energy for a selected time interval around the solar wind observation.

The energy spectra for the time when the SWIM instrument looks at the solar wind for the orbit 1069 and orbit 1070 is shown in Figure 21 and 22 respectively
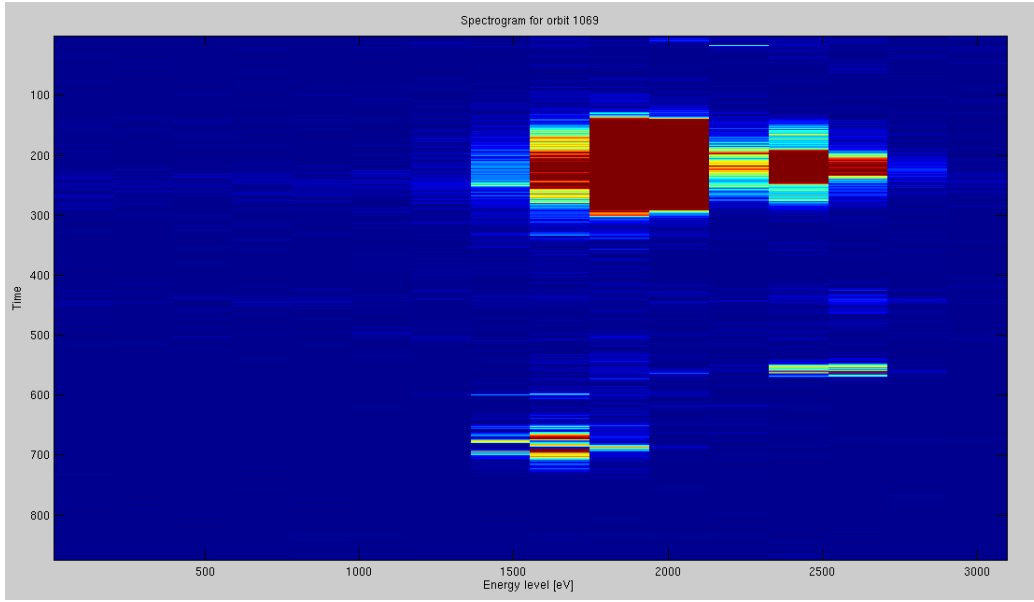
8

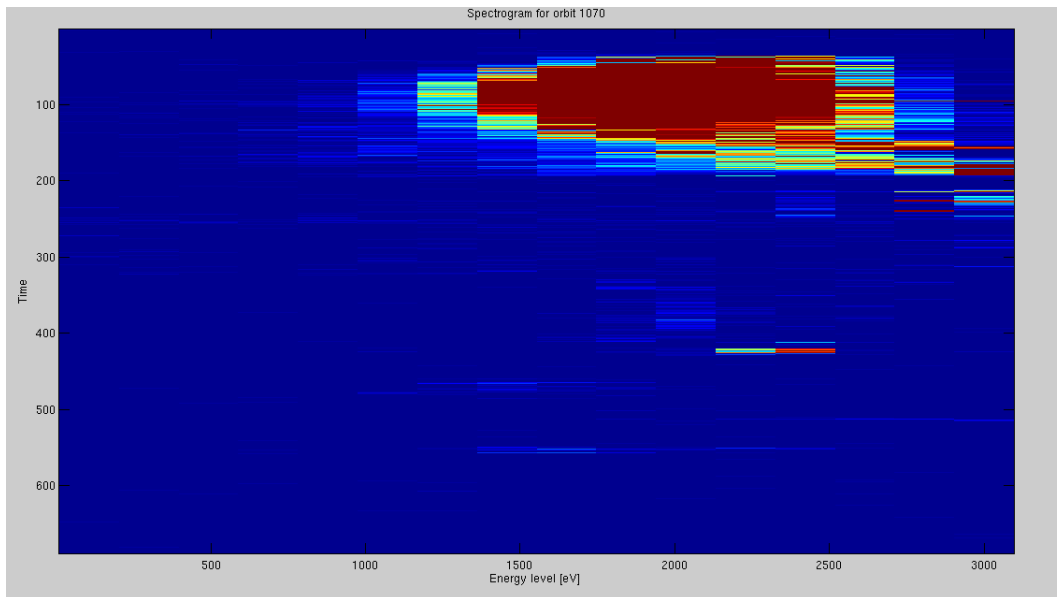Figure 19: Spectrogram of the 1069 Orbit

Figure 20: Spectrogram of the 1070 Orbit

3.4 Question 4

Determine the solar wind proton velocity and temperature by first transforming the data from energy to velocity space and then fitting a Maxwellian distribution. What temperatures and velocities do you get? Are there differences between the orbits? If so, why?
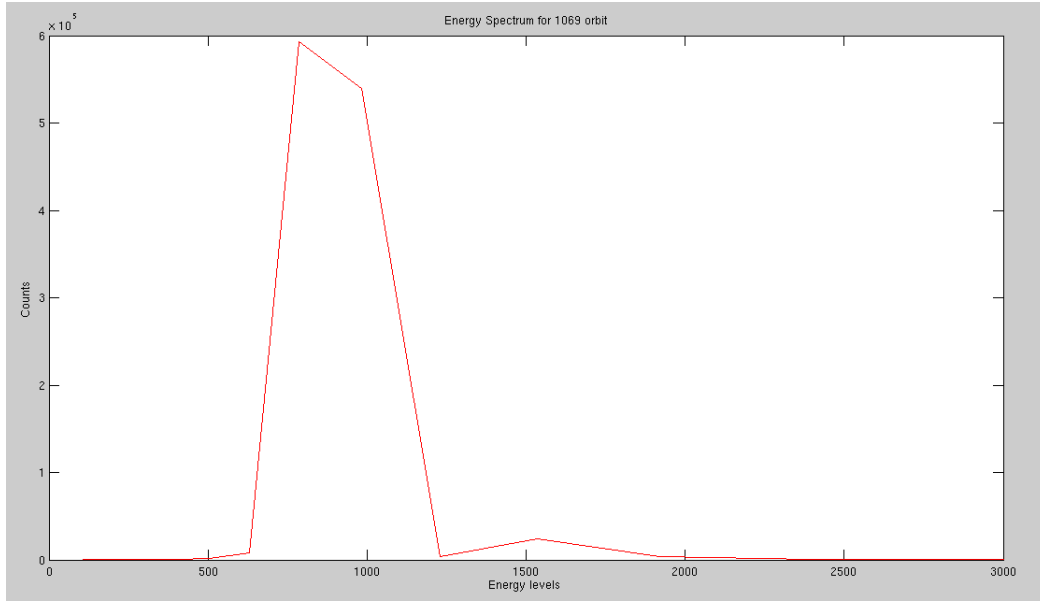
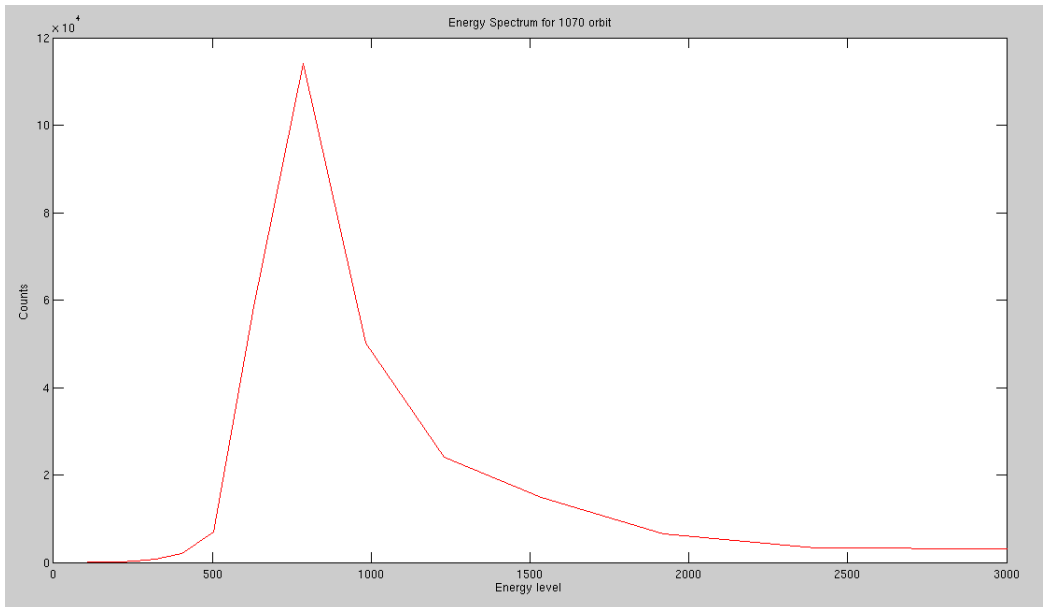Figure 21: Energy Spectra of the 1069 Orbit

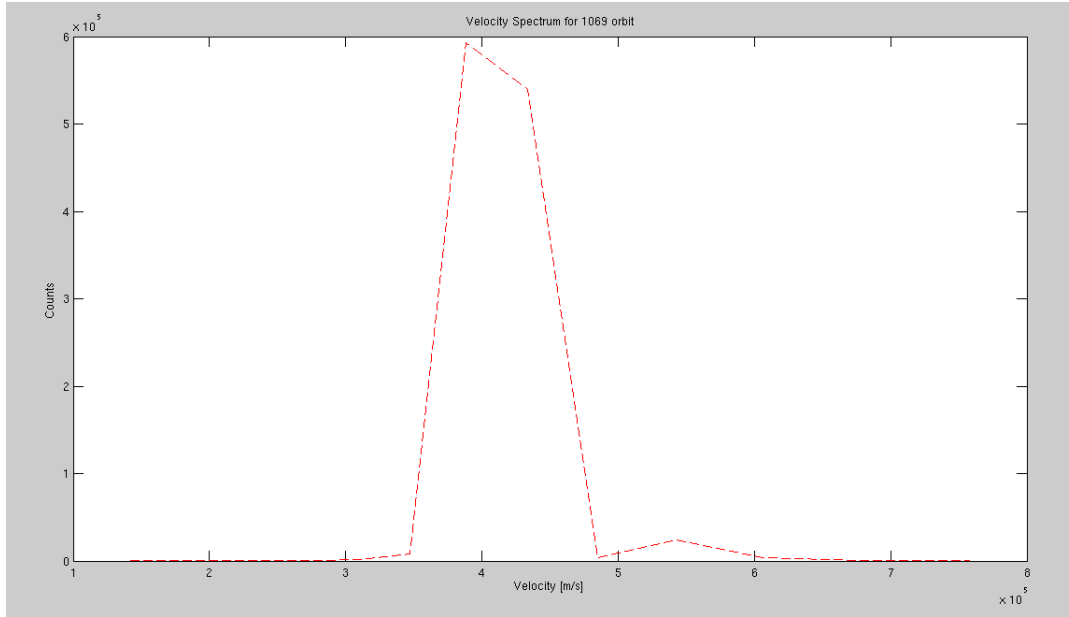Figure 22: Energy Spectra of the 1070 Orbit

4 Conclusion

Figure 23: Velocity Spectra of the 1069 Orbit

References

[1] Enmark A. (2012). *Assignment 3. Optimization of phased array antenna radiation pattern and array configuration.* Luleå University of Technology, Kiruna, Sweden.

[2] Skolnik M. I. (2001). *Introduction to Radar Systems.* The McGraw-Hill Companies, Inc., New York, United States.

[3] Röttger J. (2000). *The Instrumental Principles of MST Radars and Incoherent Scatter Radars and The Configuration of Radar System Hardware.* Max Planck Institut Für Aeronomie, Katlenburg-Lindau, Germany.

[4] Wikipedia.org. (2012). *Phased array.* `http://en.wikipedia.org/wiki/Phased_array`.
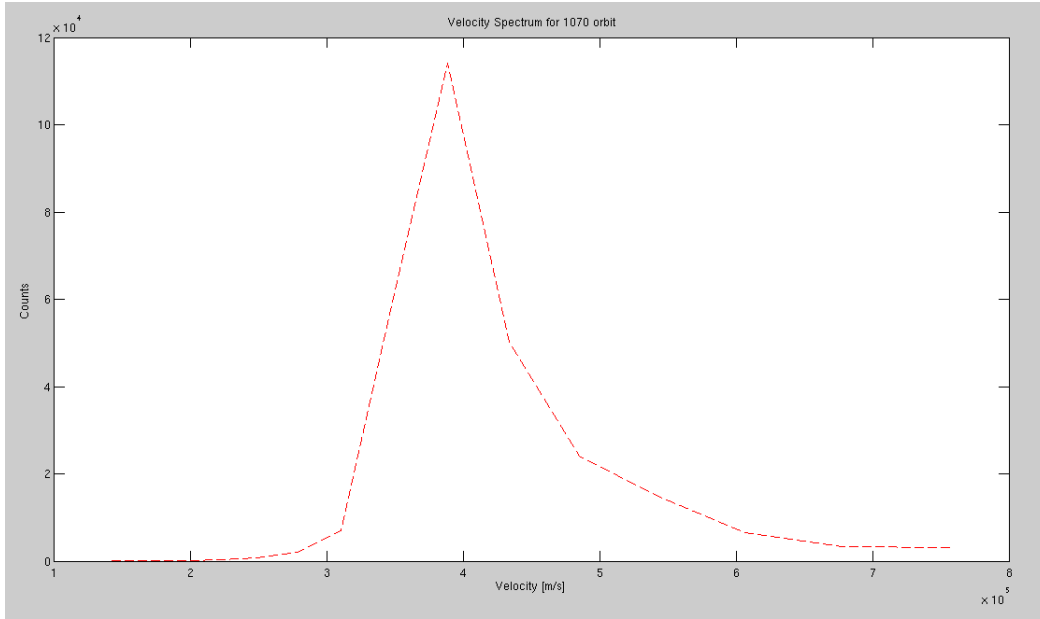
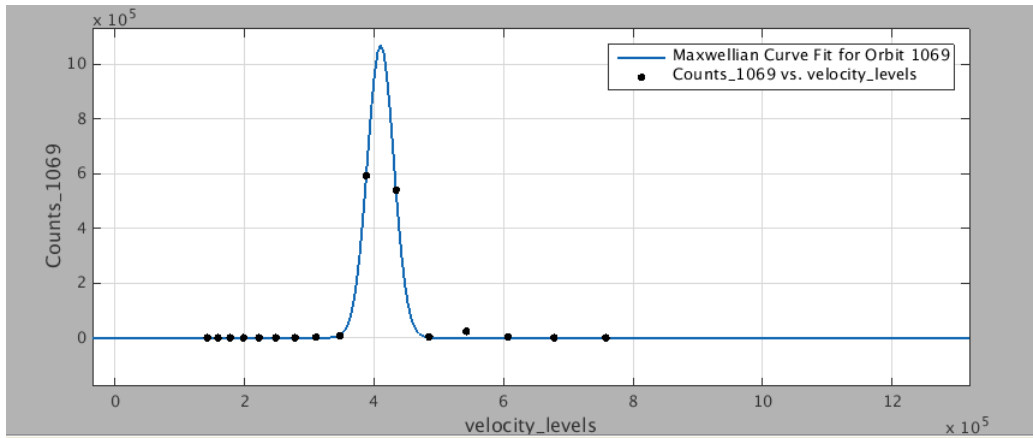Figure 24: Velocity Spectra of the 1070 Orbit

Figure 25: Maxwellian Curve fit for data from Orbit 1069
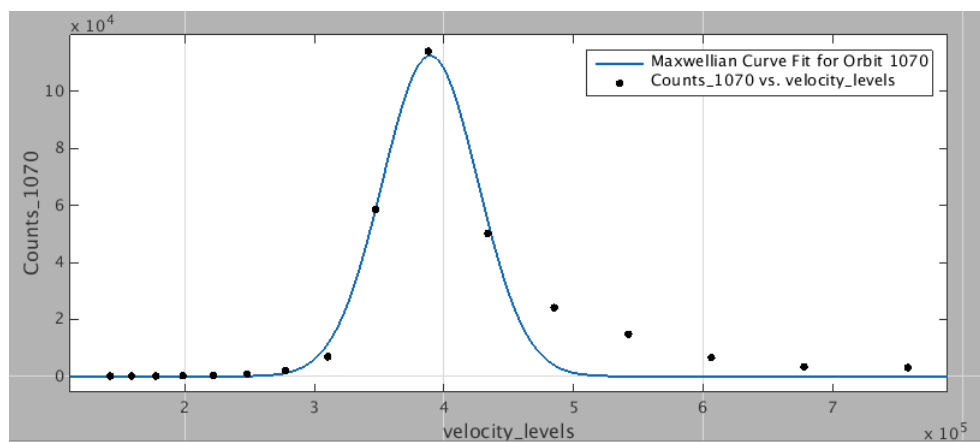
5   Appendix 1. Matlab code

Figure 26: Maxwellian Curve fit for data from Orbit 1070