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PHYS 370

Formal Lab Report Draft

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Magnetopause Simulation Diagnosis

ABSTRACT

Magnetopause is the region where solar wind interacts with the Earth's magnetic field. This region marks the location where solar wind from the sun is paused. An evaluation of this region has yielded models that can predict this location based on certain parameters. Through a simulated solar event, we analyzed this predicted location in units of RE (Earth radius units). Through this investigation, we evaluated multiple time slots where the input parameters changed. These times gave us the necessary graphs to understand the location of the magnetopause under the specific conditions. Through this analysis, we found that the magnetopause fit with the number density and velocity squared yielded a power function with an exponential factor of -0.164 +- 0.006 for the simulation approximation and -0.175 +- 0.003 from the plot estimations. The functions produced coefficients of 100 +- 9 for the simulation and 113 +- 6 for the plot considerations. These values support the general theoretical assertions of the magnetopause location under specific number density and velocity conditions where the accepted coefficient value is 107 and exponential factor of -1/6.

INTRODUCTION

Outer space has many particles that float around. Space physics attempts to unravel the mysteries of activities in regions of space that lie between celestial bodies. The sun emits solar winds at a constant rate but vary in intensity. Flares from the sun reach the earth all year long. Winds interact with the Earth's magnetic field and are deflected around the earth. This protects much of the Earth from large solar winds called coronal mass ejections. Because of the magnetic field, the winds are directed around the Earth making lights on the poles in the sky commonly known as the aurora borealis. The region in which these flares are stopped due to the magnetic field is known as the magnetopause. This region can be understood through a simple relation that predicts the location of the magnetopause that depends on the number density and the velocity of the incident wind.

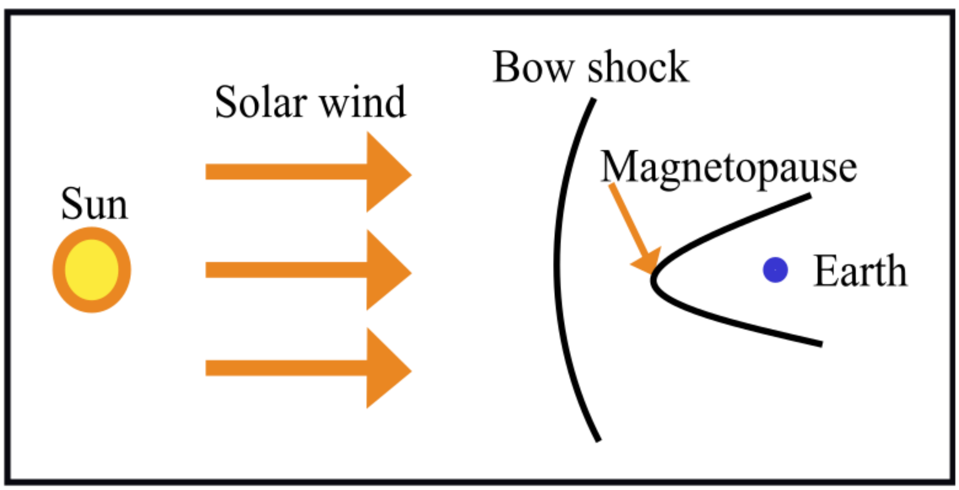

Figure 1

A representation of the physical situation. The sun has coronal mass ejections that go towards earth. The magnetosphere protects the earth from these solar winds.

Using simulation and empirical data to represent the location, one can analyze the implications of different conditions.

THE EXPERIEMENT AND RELEVENT EQUATIONS

$$r_o(R_E) = 107.4(n_{sw}v_{sw}^2)^{-\frac{1}{6}}\ (1)$$

Ro = magnetosphere standoff location

R_E = unit representing earth radii.

N_sw = number density of solar winds

V_sw = velocity of solar winds

PROCEDURE

To understand this system represented in fig. 1, start by creating a data set that varies two variables, Vx and n, in different time periods. The data set is structured to have a step function resemblance, meaning it changes abruptly at certain intervals. After creating the data set, submit it to the NASA simulation supercomputer and wait for a response with their digested data. Then view the results of the magnetosphere through a GIF and analyze the standoff data and its graphs. Using the simulation, estimate the location of the magnetopause during the input time period and print off the graphs where new data was created. From there, make estimates as to where the magnetopause location was on each graph. Next, we take the simulation estimates and the estimates from the graphs and put them to a power fit. There should be four fits, and each should resemble the inverse function of (1). Finally, analyze the data and resulting fits to establish an understanding of where the magnetopause location is.

DATA INTERPRETATION

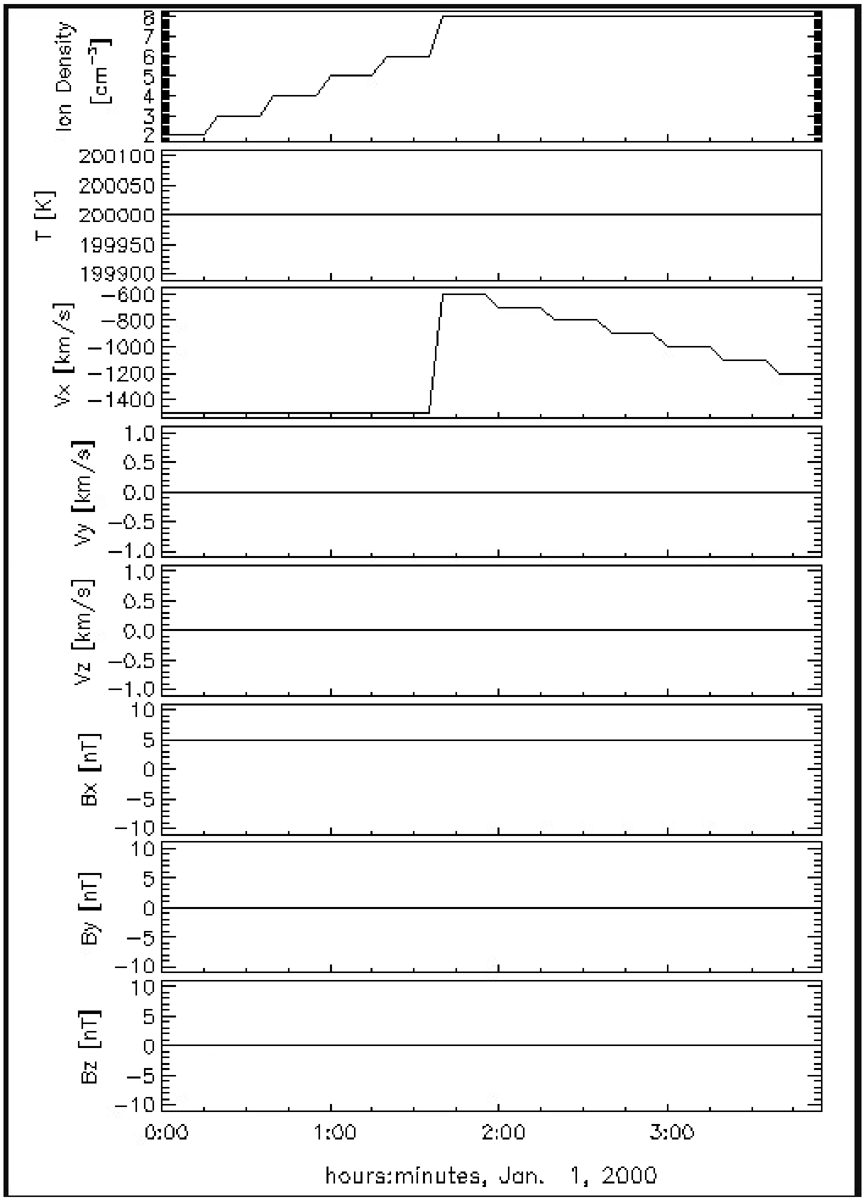

Figure 2

Input data with step values. We varied number density (n) and solar wind speed (Vx). Number density was varied in the first half of the simulation and wind speed was varied in the second half. These variations are what creates the step functions.

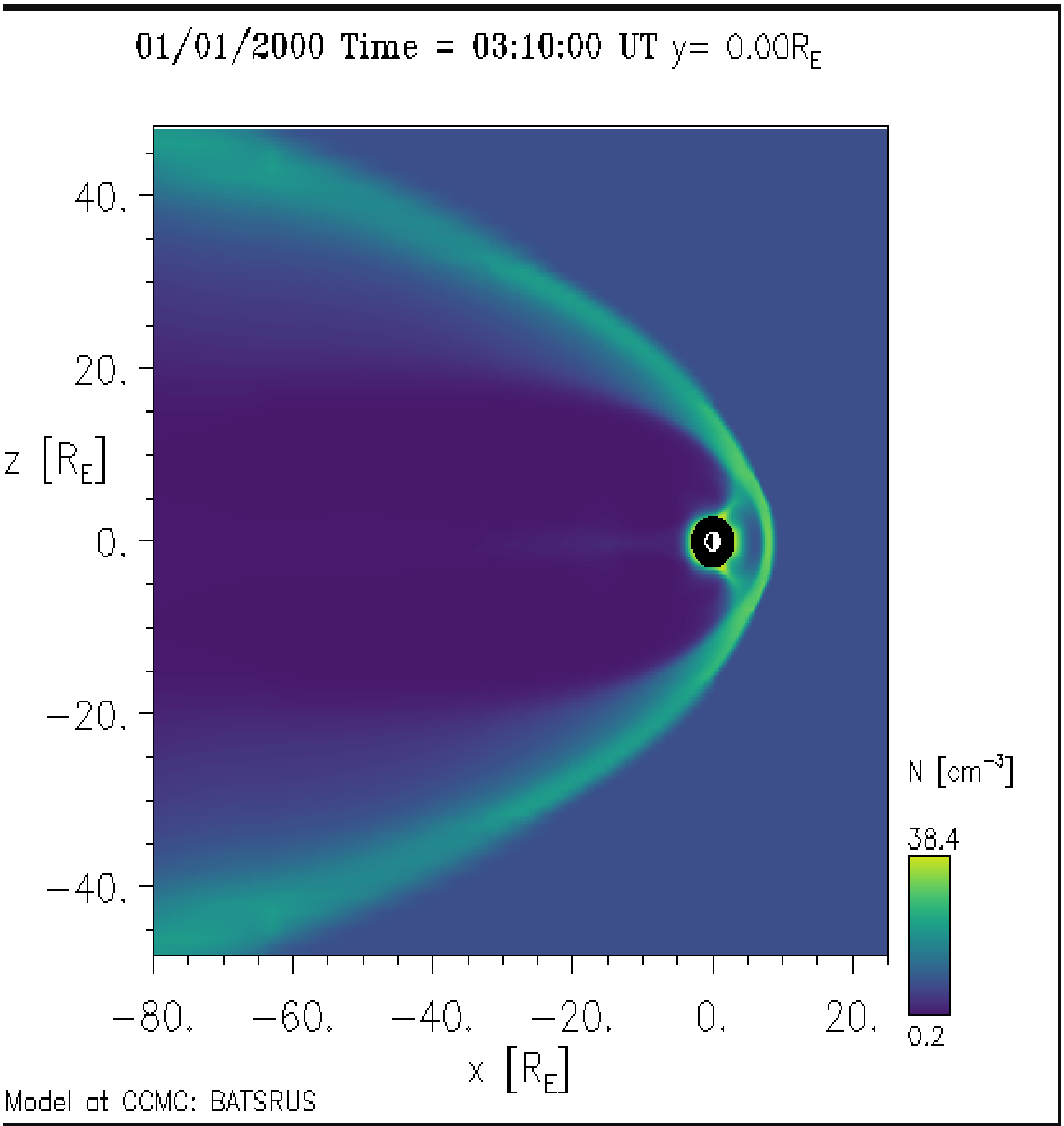

Figure 3

A frame of the input data gif without magnetic topology. This represents the magnetopause region as time goes forward.

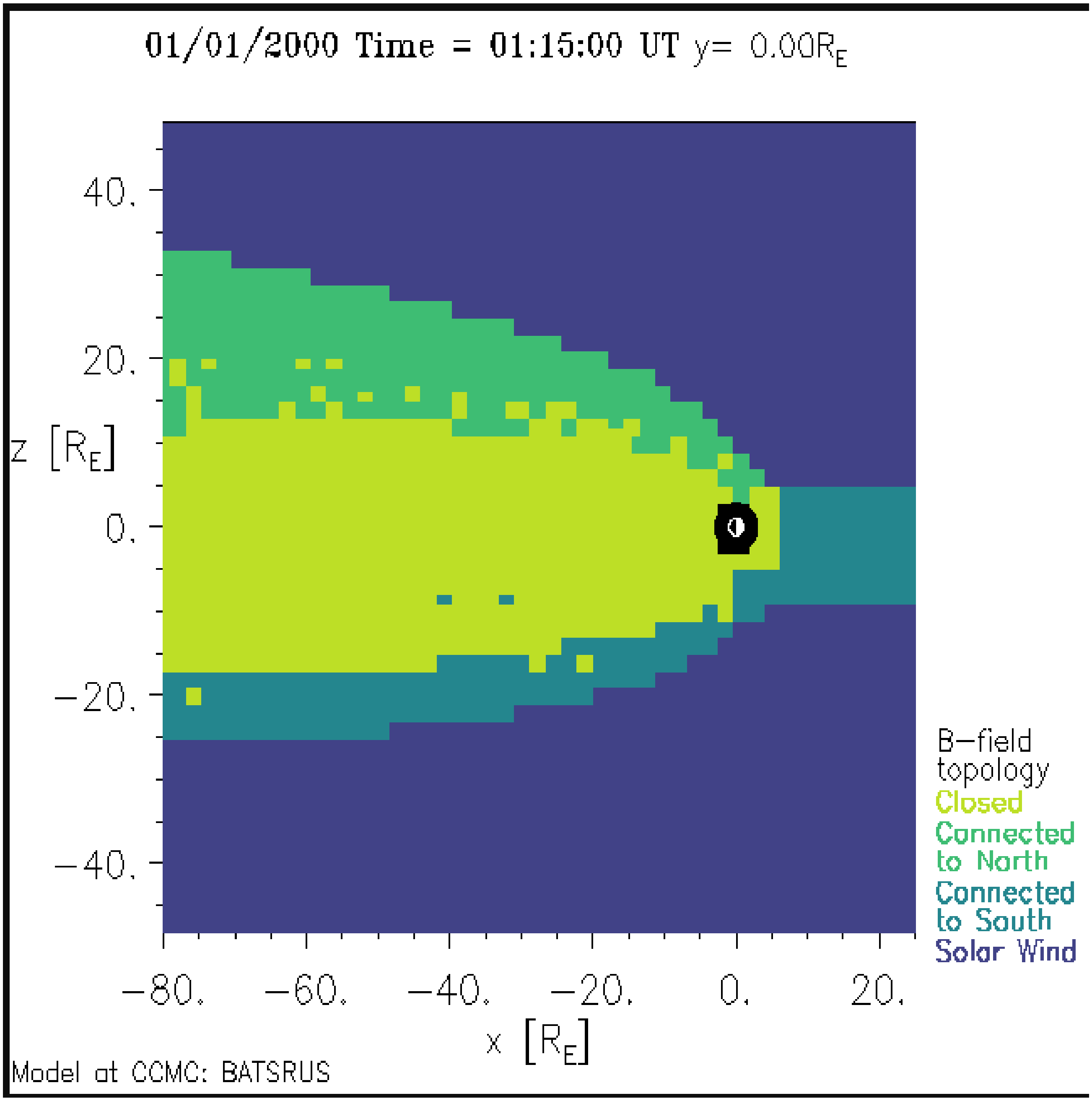

Figure 4

A gif representation of the input data with magnetic topology. Showcasing the magnetopause location as a function of time.

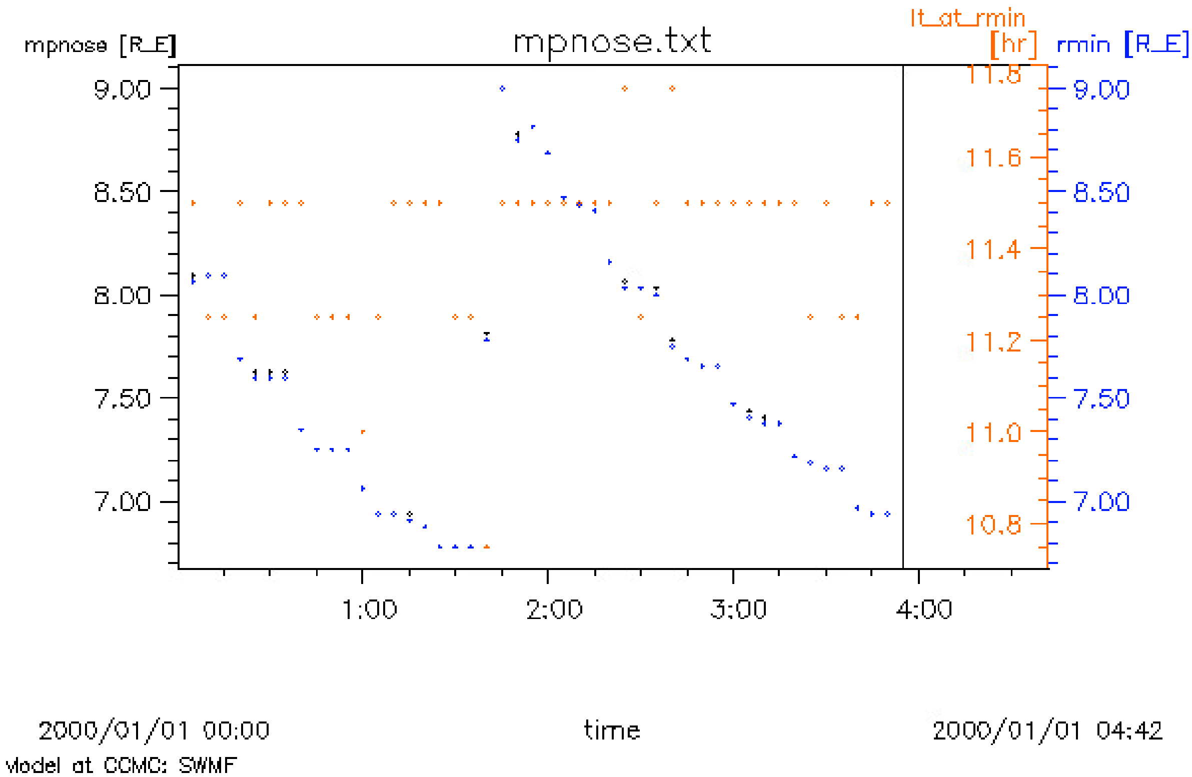

Figure 5

A plot for simulation estimates. The left axis is the mpnose values which are the distances to the center of the Earth to the subsolar point of the magnetopause.

The following graph in fig 6. was used to determine magnetopause locations. To interpret this graph, one must locate the estimate for each graph and then find the average of the three marking the estimated magnetopause length. One graph is included below. Nine more were taken during the simulation estimations in regions where input data was varied. These estimations were then plotted in fig. 9 and fig. 10. Fig. 9 shows the function of the magnetopause location when Vx was fixed. Fig. 10 showcases the location as n was fixed.

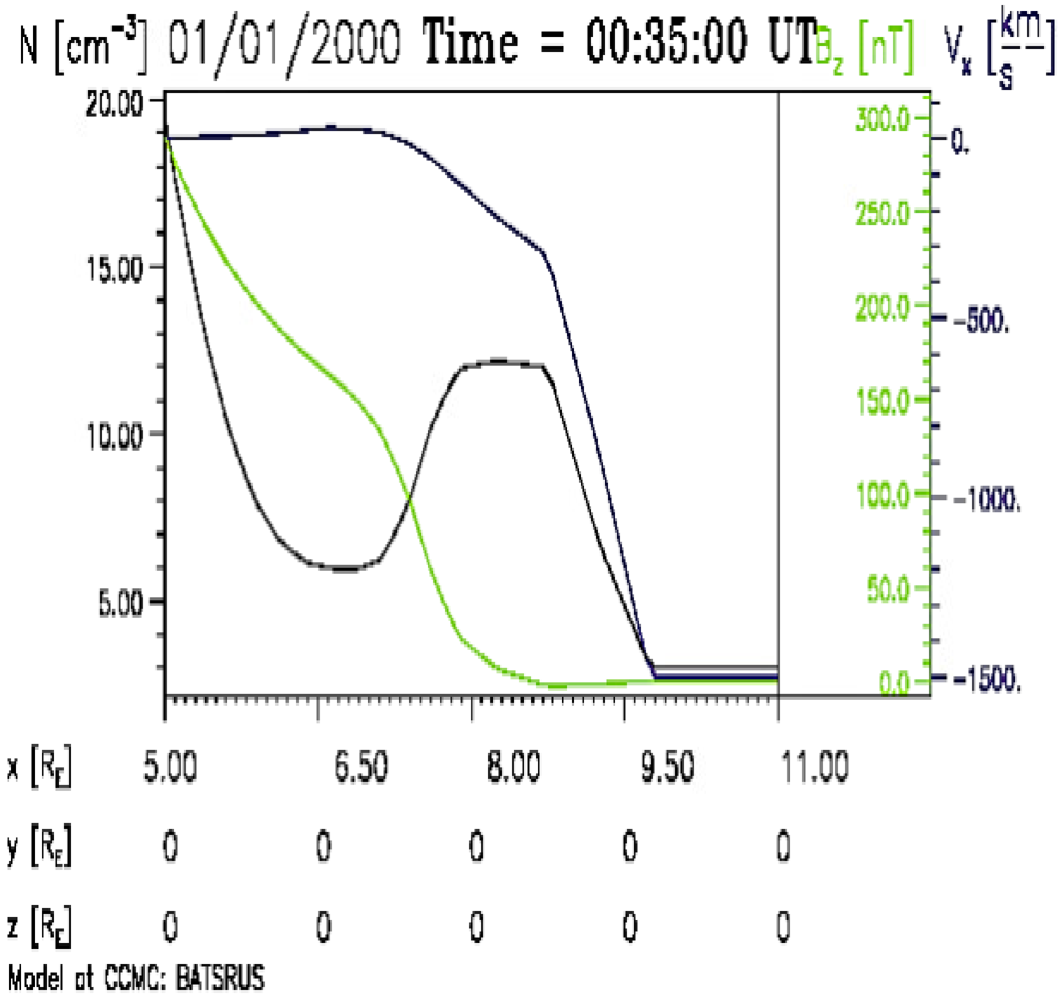

Figure 6

Graph with an approximate location of 7.25 Re. The graph above indicates regions that can represent magnetopause. In the number density graph, the magnetopause is located on the inner boundary of the bump in number density. This is because the bump in N indicates a region where plasma flow is stopped right before the magnetopause. In the Vx graph or the plasma velocity in the x component, the magnetopause is located in the region where it goes from 0 to a different slope. In the Bz graph or magnetic field in the z direction, the magnetopause is in the region where the graph transitions from a 1/r^3 function to a linear decline.

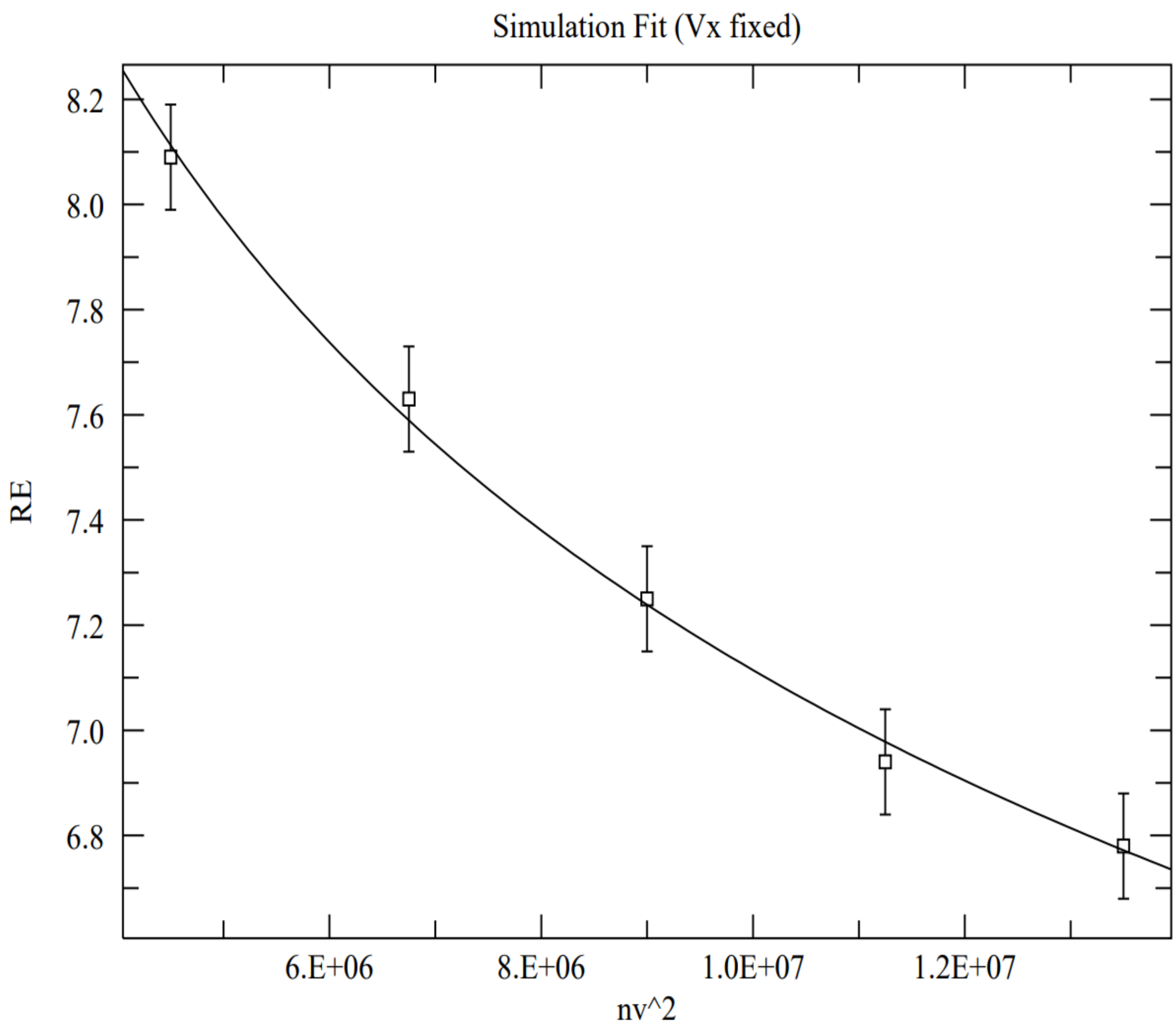

Figure 7

Data representation of simulation estimates related to equation (1). Where the B value represents the power and A is the coefficient alpha.

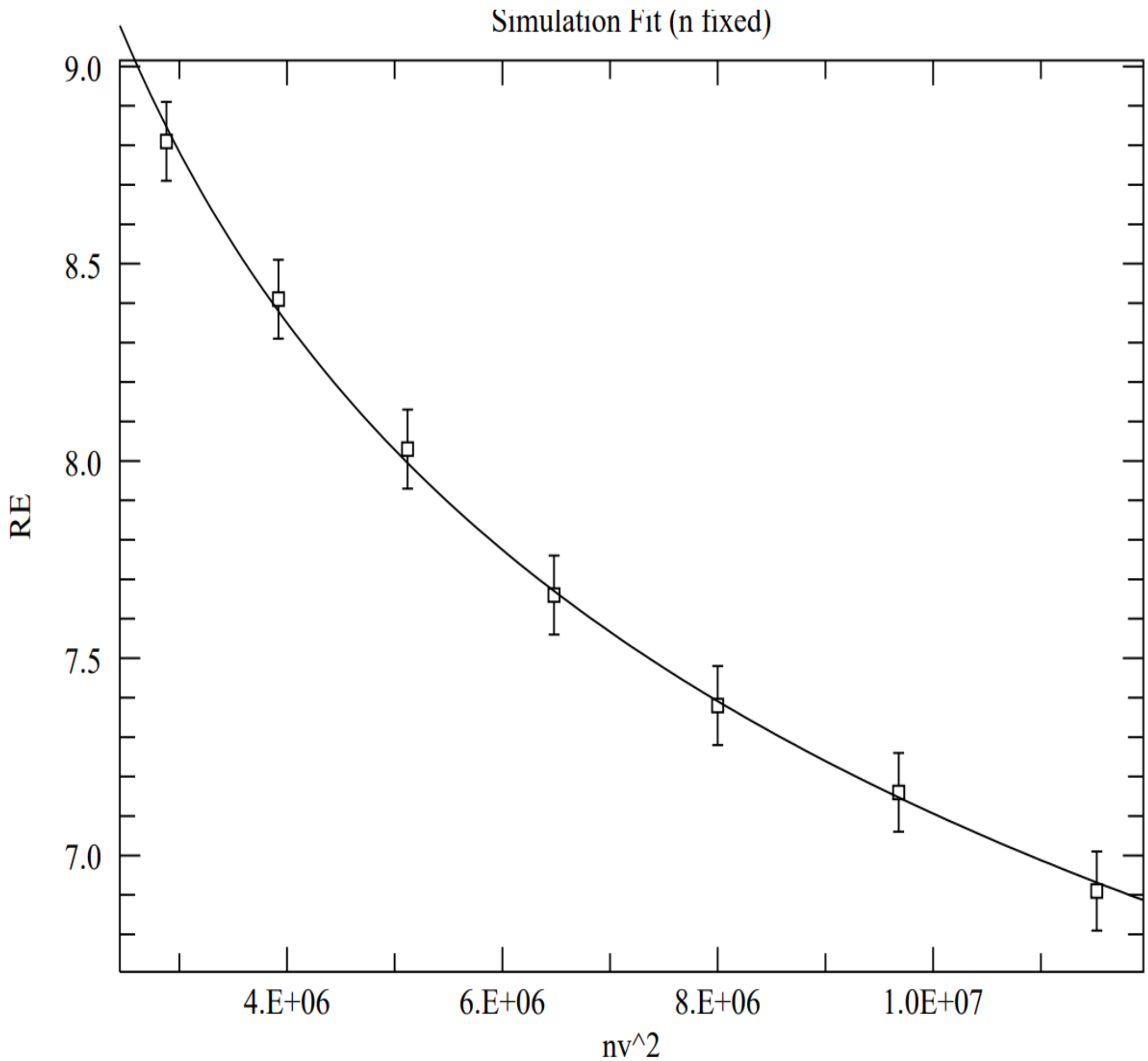

Figure 8

Data representation of simulation estimates related to equation (1). Where the B value represents the power and A is the coefficient alpha.

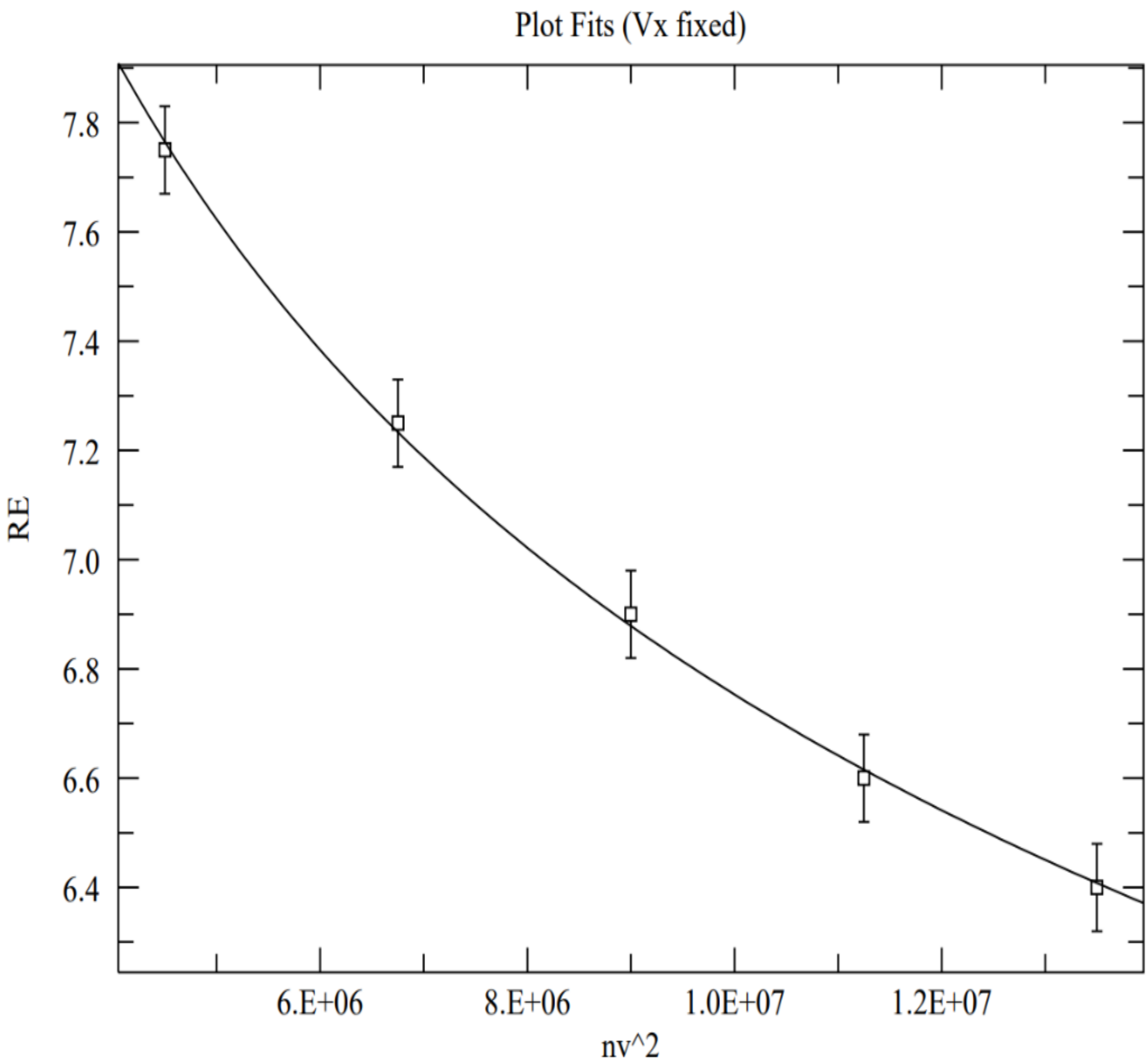

Figure 9

Data representation of graph estimates related to equation (1). Where the B value represents the power and A is the coefficient alpha.

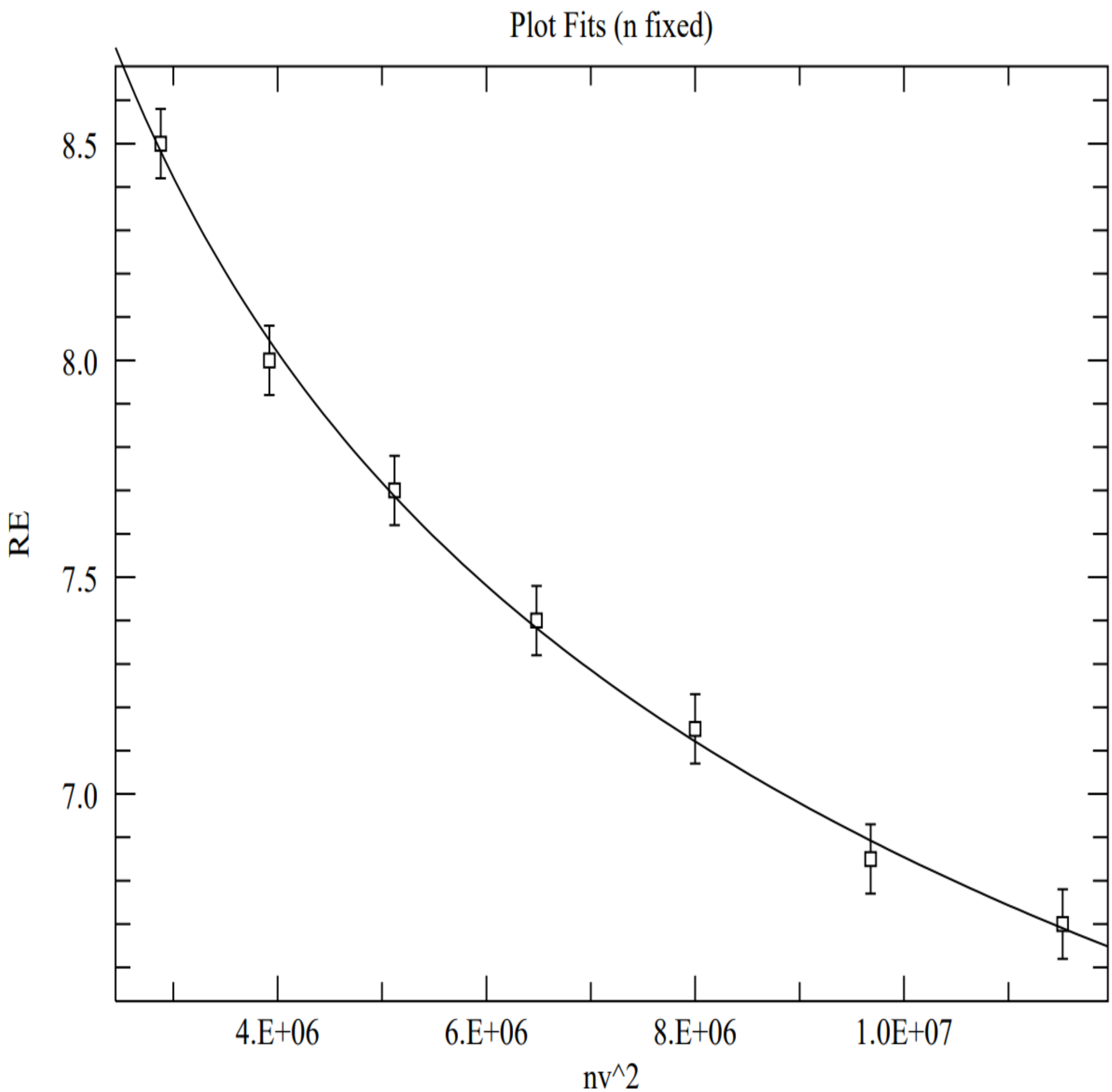

Figure 10

Data representation of graph estimates related to equation (1). Where the B value represents the power and A is the coefficient alpha.

	Coefficient Value (A parameter)	**Exponential Factor (B parameter)**	**Chi – Squared (Fitness test)**
Simulation fit – Vx fixed (fig. 7)	**100.7 +- 9**	**-0.164 +- 0.006**	**0.13**
Simulation fit – n fixed (fig. 8)	**121 +- 6**	**-0.176 +- 0.003**	**0.09**
Plots fit – Vx fixed (fig. 9)	**113 +- 6**	**-0.175 +- 0.003**	**0.065**
Plots fit – n fixed (fig. 10)	**108 +- 6**	**-0.171 +- 0.036**	**0.18**

Figure 10

Fit results from simulation and plot estimates. Each chi – squared value is very low meaning the fits were consistent with an exponential function. It also means our uncertainties were relatively high and encompassed the fit function. All but fig. 8 were within the expected coefficient value. The exponential factor in fig. 7 worked with (1). The others were slightly outside of the range.

CONCLUSIONS

Through this aspect of the lab, we found the location of the magnetopause. Through a NASA simulation, we confirmed the original formula for calculating the location. Our data fit nicely with the inverse function stated in the theory. Our B values resemble the power that the nv^2 was raised to. From this, we found very close powers to –1/6. For our A values, we found that our coefficients matched this value closely. This was interesting to understand the process that solar wind takes in getting to Earth. It was fascinating to see how much the magnetopause location fluctuates with solar wind events.

CONSIDERATIONS

Watch the movie that you made of your simulation results again and compare the behavior of the magnetopause to your input solar wind conditions. Describe what happens to the magnetosphere as the solar wind conditions vary. Pay particular attention to what happens when there are large changes in the solar wind conditions. How quickly do changes in the magnetosphere propagate from one end of the magnetosphere to the other?

> When significant changes are made to the solar wind, the magnetopause propagates proportionately. The propagation is quick in the GIFs. The full propagation takes 15 minutes roughly.

Compare your two sets of estimates of the magnetopause location. Do they agree within uncertainties? Are there systematic differences between the two? If so, attempt to explain why.

> Our estimates are very close to equation (1). Fit values in fig. 10 reflect the outcomes of the fits. Our first fit had a coefficient of 113 +- 8 and an exponent value of -.17 +- 0.003. Our second fit had a coefficient value of 108 +- 6 and exponent value of –0.170 +- 0.003. These are consistent with 107 and –1/6. The simulation estimates had close results as well. The first coefficient being 100 +- 8 and exponent value of –0.164 +- 0.006, the second coefficient was 121 +- 6 and –0.176 +- 0.008.

How do those values compare to each other and to 107.4?

My values were close to the predicted estimation of 107.4. This means that our variation in parameters behaved in a predictable manner.

What are some possible reasons why in the BATSRUS model the value for the magnetopause constant (107.4) changes? What approximations are being made when dealing with MHD in space?

I think the value of 107.4 changes because the space solar winds change based on different coronal mass discharges and variations in space conditions. These need to be approximated because it is always changing

ACKNOWLEDGEMENTS

I would like to thank my partner Brody Beskar and my instructor Jim Crumley for their substantial help with this project.

REFERENCES

1. CSBSJU Advanced Lab PHYS 370 Manual, Jim Crumley
2. “Home.” *NASA*, NASA, https://ccmc.gsfc.nasa.gov/.