Proposal

Vorticity in the Saturnian System

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PDS
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During the course of 2006, a NASA sponsored program was created to help educate college undergraduates in research, by placing them in such an environment. By utilizing the PDS (Planetary Data System) nodes, the program allows students to work with faculty professors, using the most up to date archive available. The purpose of the program is to grant experience and knowledge to possible future PDS scientists.

The choice of the individual problem fell on the shoulders of each student. Being part of this project, I was given the opportunity to choose the problem I wished to pursue. My decision led me to analyzing the Saturnian system, and more precisely the dynamics of the system seen through its fluctuating magnetism. Being helped by Dr. Raymond Walker, I decided to analyze the vortexes occurring in the plasma behind the planet Saturn. First seen by Pioneer 11 in 1979 and later confirmed by the Cassini space probe, these magnetic vortexes have hindered the proper conceptualization of Saturn's magnetic field for years.

The interest lies in drawing a connection between mass, energy and momentum in the system. The interactions that shape these different aspects will serve us in visualizing what is actually occurring. The idea is to analyze these connections in three steps, or on three levels per say. The first being the solar wind, the plasma emitted by the Sun which hits the planet and creates a bow wave not unlike our Earth's. The second tier to examine becomes the magnetic field of the planet, or in other words the magnetosphere, which is affected by the solar wind. And finally the last aspect to look at is the planet itself, and more precisely the upper reaches of its atmosphere, to see what role it plays in the plasma distortions that occur behind the planet. These points of interest will allow us to narrow down the exact causes for the apparition of these vortexes, and give us a better understanding of the underlying reasons for the occurrences that are observed.

This further leads to the examination of the Saturnian system being a rotating one. The fact that Saturn rotates makes it of much more importance. In the study of Saturn, we can come to some conclusion on the behavior of plasmas in other rotating systems such as the Earth. In other words a better understanding of the processes that have been witnessed occurring behind this gas-giant would help us understand those seen behind our planet.

The first question which has to be asked is. What in fact is going to be studied? Our job is first to define the theoretical aspects of the project, the foundations on which the research shall be based on. Field aligned currents, first theorized by a plasma physicist named Kristian Birkeland, and then restated by Hannes Alfven in 1939, are the tools we shall use in order to study all the processes within the Saturnian system. The only source of information being the magnetic field data provided by the satellites is directly linked to the behavior of the Birkeland/Alfven waves. The most needed theories are the Maxwell equations of the 19^{th} century. The four laws that make up the collection are essential in deriving the critical law theory having to do with plasmas known as "Frozen in Flux." From the mixing of these equations and then inserting them into Ohm's Law, the derivation of the Frozen in Flux law is achieved.

It is a simple idea which entails that under certain conditions magnetic field lines are bounded to the plasma in which they reside. In other words plasmas are influenced by magnetic fields and vice versa, meaning plasmas are constituted of moving charges. The general equation reaches a simplified form of:

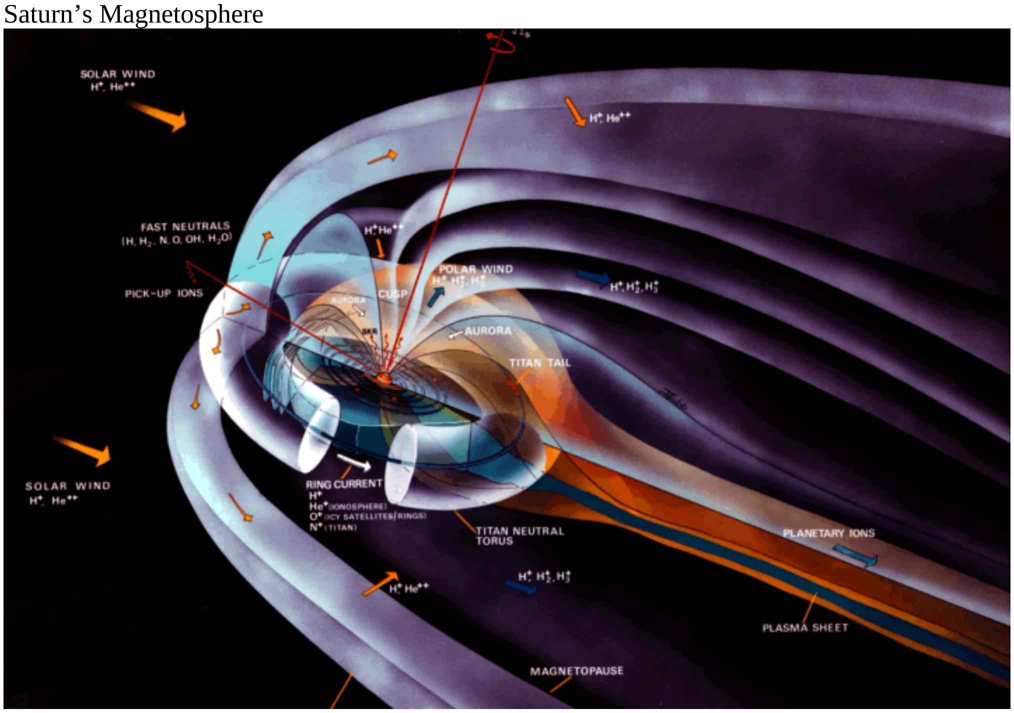
$$\mathbf{V} = \frac{(\mathbf{E} \times \mathbf{B})}{\mathbf{B}^2}$$

This in turn also provides a context for the analysis of plasma behavior. The notion of plasma needs to also be defined. Discovered in 1879, plasmas are now considered a totally independent state of matter. It is usually defined by the ionized form of the substance. Plasmas are a melting pot of electrons and nuclei. Because of the presence of free electrons, we see that the theory of Frozen in Flux is valid in reference to plasmas, because in fact they do carry electric charges. Due to Faraday's Law of Induction, one of Maxwell's equations, these moving charges produce a magnetic field, which in turn affects the overall magnetic behavior of the Saturn's magnetosphere.

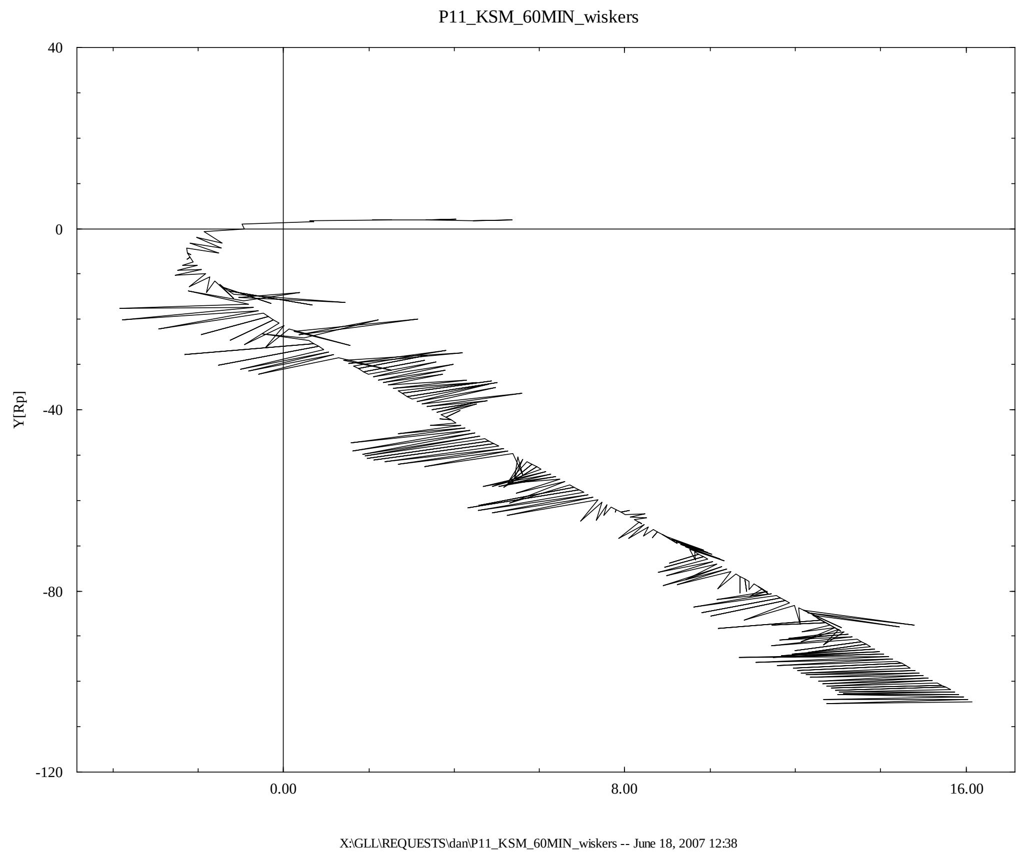
$$\oint_C \mathbf{E} \cdot d\mathbf{l} = -\int_S \frac{\partial \mathbf{B}}{\partial t} \cdot d\mathbf{A}$$

Faraday's Law of Induction

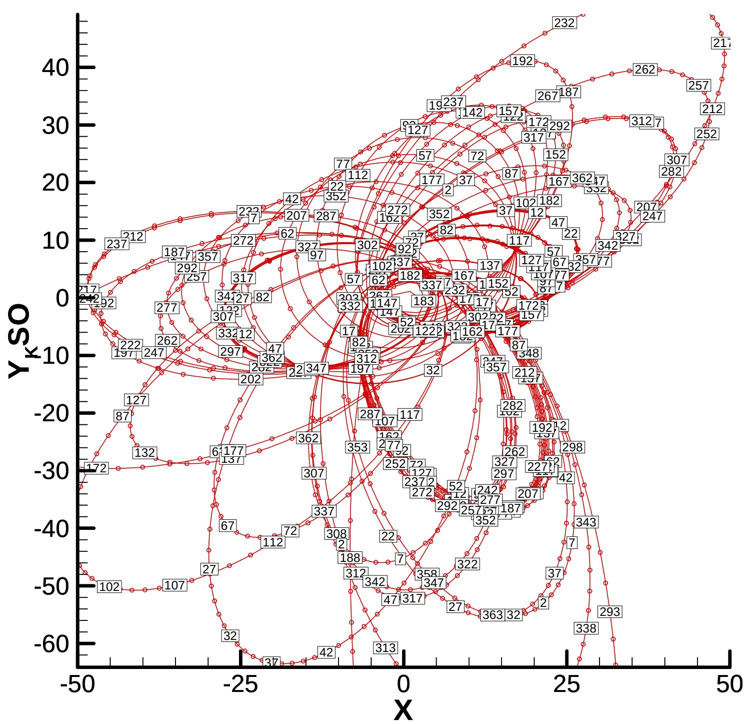
Saturn's Magnetosphere



After understanding the concepts of these theories we move onto the actual work that will be done by my mentor and me. It breaks down into two parts; the first involves taking a look at the previous research done in the 1980's with the Pioneer 11 magnetometer data. Before going further a brief description of the Pioneer mission is required. Launched in 1973, Pioneer 11 was the first space probe to ever be sent to Saturn. It was a flyby mission, meaning it did not go into orbit around Saturn. But during the flyby its main objective was to study magnetic fields and solar wind properties around the planet using its Helium Vector Magnetometer. What it recorded were these magnetic disturbances occurring on the dawn side of the planet. This unexpected magnetometer data was what first turned physicists on the idea of these magnetic vortexes. Once we take a look at the old data we will need to spend time converting it into a useable form. Because it was collected in PE coordinated, in the spacecraft's reference frame, we will need to create a new field defined coordinate frame, perhaps looking at the planet being the origin or maybe the Sun. We will also have to process the data into an average time frame, looking at greater chunks of time. This will probably be achieved by some data processing in the form of simple averaging or Taylor series approximations. With the approximation we will try to model an accurate representation of the magnetic environment for the entire flyby mission. This model will most likely be in the form of a vector plot, more commonly known as a whisker plot. The plot will be aligned along the spacecraft's trajectory and will show us the flipping, or rotating, magnetic field.



The second step of the research actually incorporates the new data given to us by Cassini. Launched in 1995, Cassini was destined to be an orbiter of Saturn. Unlike, Pioneer 11, Cassini provides actual data streams from the Saturnian system. Because it is an orbiter, the amount of data being received is much more than before. The first task will then be to narrow down the data to specific location where we believe these vortexes to exist. This in turn will probably be achieved with the help of a visual representation of Cassini's orbit trajectory versus data collection times. Once the selection of certain orbits has been made, the next stage will be to try and recreate the Pioneer 11 data results only now with Cassini. This will require a long data processing period, where unlike the Pioneer set where we only had about a day's worth of data here we have over a year. If the results are favorable we shall move onto applying some sort of model to the new data as well. These new models will in turn be more detailed and will encompass the entire Saturnian system. Hopefully after the work is complete we would have reached a better understanding of the dynamics that are active within the system, and how they relate to the general rotating planet behavior.



Cassini Trajectory Data

The outlined plan for work distribution is 40 hours per week during the summer of 2007 and continuing on to 10 hours during the school year. The entire program will continue until June 2008 when it shall be completed. During the course of the program we shall give a presentation to the PDS Management Council which will take place at UCLA in August 2007. Also the program includes travel to Maryland and Florida following the summer of 2007 in order for the entire group to meet. Hopefully that provides some sort of glimpse into the work that is ahead. Please note some of the dates are liable to change.