A STUDY OF THE STRUCTURE OF THE SOURCE REGION OF THE SOLAR WIND IN SUPPORT OF A SOLAR PROBE MISSION

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INTRODUCTION

Despite the richness of the information about the physical properties and the structure of the solar wind provided by the Ulysses and SOHO observations, fundamental questions regarding the nature of the coronal heating mechanisms, their source, and the manifestations of the fast and slow solar wind, still remain unanswered. The last unexplored frontier to establish the connection between the structure and dynamics of the solar atmosphere, its extension into interplanetary space, and the mechanisms responsible for the evolution of the solar wind, is the corona between 1 and 30 R_s.

A Solar Probe mission offers an unprecedented opportunity to explore this frontier. Its uniqueness stems from its trajectory in a plane perpendicular to the ecliptic which reaches within 9 R_s of the solar surface over the poles and 3 - 9 R_s at the equator. With a complement of simultaneous in situ and remote sensing observations, this mission is destined to detect remnants and signatures of the processes which heat the corona and accelerate the solar wind.

In support of this mission, we fulfilled the following two long-term projects:

- Study of the evolution of waves and turbulence in the solar wind
- Exploration of signatures of physical processes and structures in the corona

A summary of the tasks achieved in support of these projects are given below. In addition, funds were provided to support the Solar Wind 9 International Conference which was held in October 1998. A brief report on the conference is also described in what follows.

MODELING THE ACCELERATION REGION OF THE SOLAR WIND

While the mechanisms responsible for the solar corona and the high-speed solar wind streams are still unknown, model computations offer means for predicting the properties of such mechanisms in light of the empirical constraints currently available. Modeling and data analysis efforts were aimed at understanding the plasma properties of the acceleration of the solar wind, its filamentary nature, and the conditions needed to account for a rapidly accelerating solar wind, reaching its terminal speed within 10 R_s. Studies of two and three fluid solar wind models concentrated on the effects of heating, momentum addition and Alfvén waves, on the flow of electrons, protons, minor ions and neutral hydrogen. In addition, a study was focused on the role of proton temperature anisotropy on the energy balance requirements for the solar wind, and the implications for coronal heating processes. Also the

implications of current inferences of high proton and minor ion temperatures in the inner corona for the interpretation of spectral lines were explored.

Model computations complemented by data analysis played a key role in the realization that

- the fast solar wind undergoes very rapid acceleration in the inner corona and reaches its asymptotic speed by 10 R_s (*Esser et al.* 1997). These studies established the necessary requirements for coronal heating mechanisms to produce such profiles;
- significant temperature anisotropies in the protons and minor ions develop in the inner corona in the presence of Alfvén waves (*Hu et al.* 1997, *Allen et al.* 1998, *Li et al.* 1998);
- the heating and cooling of protons by turbulence-driven ion cyclotron waves can be achieved in the fast and slow solar wind (*Li et al.*, 1999);
- how the expansion of polar plumes occurs in the fast solar wind (*Casalbuoni et al.*, 1999).
- The cascade effect of Alfvén waves below 10 R_s, neglected in earlier studies of the solar wind, was found to play an important role in the coronal heating, solar wind acceleration, and the radial evolution of the Alfvén wave spectrum (*Hu and Habbal*, 1999, *Hu, Habbal and Li*, 1999).
- Investigations of the warm plasma dispersion relation showed that the heating rate due to the dissipation of waves is enhanced in the warm plasma approximation compared to the cold plasma approximation (*Li and Habbal*, 1999).

Characteristics of the inner heliosphere between 1 and 10 R_s

A number of Coordinated SOHO: UVCS,CDS, LASCO, TRACE observations with MGS, Galileo and Cassini radio occultation measurements were obtained to explore the characteristics of the inner heliosphere and the source regions of the fast and slow solar wind.

Analyses of coordinated white light x-ray observations provided further evidence that:

- the imprint of the coronal density extends radially outwards from the solar surface into the corona, except for streamers which undergo significant evolution in the corona before tapering into stalks (*Woo and Habbal*, 1999; *Woo et al.*, 1999);
- the quiet Sun is also very likely to be a source for the fast solar wind (*Woo and Habbal*, 1997);
- the fast wind is ubiquitous in the inner corona, the streamer axes are the locus of the slowest solar wind, and a velocity shear exists between the fast and slow solar wind at the boundaries of streamers and along their axes (*Habbal et al.*, 1997);
- the radial evolution of density structure is preserved in the solar corona, with the exception of coronal streamers (*Woo and Habbal*, 1999);

- the connection between the Sun and the solar wind makes the connection with interplanetary space measurements rather straightforward as the imprint of the fast solar wind is evident in the Ulysses measurements (*Woo and Habbal*, 2000; *Habbal and Woo*, 2001).

Solar Wind 9 International Conference

The Solar Wind 9 International Conference held in Nantucket, Massachusetts, 5-9 October 1998, hit a record for the largest such conference with 248 registered scientists. The conference was opened with two historical perspectives by Eugene Parker and Marcia Neugebauer. In appreciation for their pioneering work in Solar Wind Physics, the organizers, with support from this grant, bestowed medals upon both Eugene Parker and Marcia Neugebauer. The Proceedings, published by the American Institute of Physics, set a new record with the number of papers and the speed of publication of 6 months after the conference. The proceedings also included a CD-Rom of color figures and movies not included in the text.

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The Solar Probe Mission Spring AGU, Boston, May 1998.

Origin and Evolution of the Solar Wind, Cambridge Workshop on Space Plasmas, Lisbon, June 1998

Public Lectures by S. Rifai Habbal

Solving Some Solar Enigmas, **Boston Museum of Science**, April 15, 1998.

The Solar Wind Sherpas, **Center for Astrophysics Women's Program Committee**, Cambridge, MA, June 8, 1998.

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