FINAL REPORT FOR NAGW-249

PHYSICS OF THE INNER HELIOSPHERE 1- 10 R_s: PLASMA DIAGNOSTICS AND MODELS

SUMMARY

While the mechanisms responsible for the solar corona and the high-speed solar wind streams are still unknown, model computations offer means of 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. A sequence of models ranging from steady one-fluid descriptions of the solar wind to multi-fluid time-dependent models were developed. Plasma diagnostics evolved from the analysis of data acquired from Skylab to SOHO, and complemented by ground-based observations.

MODEL COMPUTATIONS

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. The role of proton temperature anisotropy on the energy balance requirements for the solar wind, and the implications for coronal heating processes were also explored. The implications of current inferences of high proton and minor ion temperatures in the inner corona for the interpretation of spectral lines were also investigated.

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 (Habbal et al. 1995, Esser and Habbal 1995, Esser et al. 1997). These studies also established the necessary requirements for coronal heating mechanisms to produce such profiles;
- heavy ions play a role in the solar wind flow (Li et al. 1997);
- significant temperature anisotropies in the protons and minor ions develop in the inner corona in the presence of Alfvén waves (Allen et al. 1997, Hu et al. 1997);
- high proton temperatures in the inner corona can have a significant impact on the formation of some spectral lines there (Brickhouse and Esser 1996);

Plasma diagnostics between 1 and 10 R_s

Recently, analyses of coordinated radio occultation measurements with white light and ultraviolet observations provided the first evidence that

- the filamentary nature of structures in the solar wind are much smaller in streamer axes than in coronal holes (Woo and Habbal 1997b);
- the quiet Sun is also very likely to be a source for the fast solar wind (Woo and Habbal 1997a);
- 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).

Selected Relevant Publications from the Past 3 years

S. R. Habbal, R. Esser, M. Guhathakurta, and R. R. Fisher, Flow properties of the solar wind derived from a two-fluid model with constraints from white light and in-situ interplanetary data, *Geophys. R. Lett.*, **22**, 1465-1468, 1995.

R. Esser and S. R. Habbal, Coronal heating and plasma parameters at 1 AU, *Geophys. R. Lett.*, **22**, 2661-2664, 1995.

R. Esser, N. S. Brickhouse, S. R. Habbal, R. C. Altrock, and H. C. Hudson, Using Fe X 6374 and Fe XIV 5303 spectral line intensities to study the effect of the line of sight on coronal hole temperature inferences, *J. Geophys. Res.*, **100**, 19829 - 19838, 1995.

N. S. Brickhouse and R. Esser, Effects of high ion temperatures on spectral line diagnostics in the source region of the high speed solar wind, *Ap J*, **479**, L470, 1996.

R. Woo and S. R. Habbal, Finest filamentary structures of the inner corona in the slow and fast solar wind, *Ap. J.*, **464**, L139, 1997.

R. Esser and N. S. Brickhouse, Interdependence of solar wind models and solar wind observations, in *Robotic Exploration Close to the Sun: Scientific Basis*, S. R. Habbal, Ed., AIP Conference Proceedings **385**, 1997.

S. R. Habbal and R. Woo, Remote sensing measurements of the corona with the Solar Probe, in *Robotic Exploration Close to the Sun: Scientific Basis*, S. R. Habbal, Ed., AIP Conference Proceedings **385**, 1997.

S. R. Habbal, Imaging the source regions of the solar wind, in *Robotic Exploration Close to the Sun: Scientific Basis*, S. R. Habbal, Ed., AIP Conference Proceedings **385**, 1997.

J. V. Hollweg, and R. Esser, The solar corona and solar wind: theoretical issues, in *Robotic Exploration Close to the Sun: Scientific Basis*, S. R. Habbal, Ed., AIP Conference Proceedings **385**, 1997.

R. Esser, S. R. Habbal, Wm. Coles, and J. V. & Hollweg, Hot protons in the inner corona and their effect on the flow properties of the solar wind, *J. Geophys. Res.* **102**, 7063, 1997.

R. Woo and S. R. Habbal, Extension of coronal structure into interplanetary space, *Geophys. Res. Lett.*, **24**, 1159, 1997.

Y.-Q. Hu, R. Esser and S. R. Habbal, A fast solar wind model with anisotropic proton temperature, *J. Geophys. Res.*, **102**, 14,661, 1997.

X. Li, R. Esser, S. R. Habbal and Y.-Q. Hu, Influence of heavy ions on the high speed solar wind, *J. Geophys. Res.*, **102**, 17,419, 1997.

*S. R. Habbal, R. Woo, S. Fineschi, R. O'Neal, J. Kohl, G. Noci, and C. Korendyke, Origins of the slow and the ubiquitous fast solar wind, *Ap. J.*, **489**, L103, 1997.

*** Results featured in *Science,* 278, 387, 1997 by J. Glantz, in *Nature,* 390, 235, 1997 by K. Southwell, and *Astronomy Magazine, March 98* by R. Graham**

R. Esser and S. R. Habbal, Coronal holes and the solar wind, in *Cosmic Winds and the Heliosphere*, J. R. Jokipii, C. P. Sonett, and M. S. Giampapa (Eds.), University of Arizona Press, 1997.

Reports and Proceedings

W. I. Axford, W. Feldman, M. A. Forman, S. R. Habbal, J. C. Ling, S. Moses, A. Title, R. Woo, D. T. Young, *Close Encounter with the Sun: Report of the Minimum Solar Mission Science Definition Team, Scientific Rationale and Mission Concept*, August 1995.

D. Winterhalter, J. T. Gosling, S. R. Habbal, W. Kurth, M. Neugebauer, Eds., *Solar Wind Eight*, AIP-CP 382, American Institute of Physics, 1996.

S. R. Habbal, Ed., *Robotic Exploration Close to the Sun: Scientific Basis*, AIP-CP 385, American Institute of Physics, 1997.

Recent Invited Talks by S. R. Habbal

Inferences of Coronal Hole Plasma Parameters from Observations, IAU colloquium 154, Pune, India, January, 1995.

Probing the Acceleration Region of the Solar Wind: Observational Techniques and Models, Colloquium at the High Altitude Observatory, Boulder, March, 1995.

Impact of Ulysses observations on solar wind models, AGU Fall meeting, San Fransisco, December, 1995.

Polar Plumes, Open and Closed Fields and the Solar Wind ISSI Workshop, Bern, Switzerland, July 8-12, 1996.

Origins of the fast solar wind, 18th NSO/Sac Workshop, September, 1997.

New perspectives on the solar wind, Boston University Colloquium, October 1997.

Origins of the slow and the ubiquitous fast solar wind, MIT Space Physics colloquium, November 1997.

New Understanding of the Solar Wind: the Impact of Ulysses and SOHO Measurements, AAS, Baltimore, January 1998.