**FINAL REPORT**

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GRANT TITLE:

# SOLAR WIND ACCELERATION, HEATING, AND EVOLUTION WITH WAVE-PARTICLE INTERACTIONS

Submitted to

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## SOLAR WIND ACCELERATION, HEATING, AND EVOLUTION WITH WAVE-PARTICLE INTERACTIONS

### I. SYNOPSIS.

We have achieved all the goals stated in our grant proposal. Specifically, we have extended the utilities of our global hybrid model for the solar wind. The model follows the kinetic evolution of the particle distributions along an inhomogeneous field line under various physical effects. The physical effects that were considered included wave-particle interactions, ambipolar electric field which was consistent with the particle distributions themselves, and Coulomb collisions. The hybrid characteristic of the model, which consists of a fluid and a kinetic part, allows us to utilize the model as an ideal tool for comparing the effects of wave-particle interactions and the suprathermal electrons in term of driving and accelerating the solar wind.

We have generated results in the case where the tail of the electron distributions were described by a global kinetic collisional approach. Such an approach enabled us to incorporate the complete effects due to the suprathermal electrons on the solar wind flow. We have also considered another case in which the entire electron population was taken to be a Maxwellian distribution. Thus, by comparing the two cases, we were able to determine the significance of the impact due to the suprathermal electron population.

Our calculations have indicated that the contribution to the driving and acceleration of the fast solar wind due to the suprathermal electron effect is rather insignificant in comparison with that due to wave-particle interactions. We have also extended our calculations to examine the situation of an outflow with a lower wind speed. A similar conclusion was reached.

## II. PUBLICATIONS.


S. W. Y. Tam and T, Chang, "Effect of electron resonant heating on the kinetic evolution and acceleration of the solar wind", *Geophys. Res. Lett.,* vol. 28, (2001), p. 1351.

S. W, Y. Tam and T. Chang, "Kinetic evolution and acceleration of the solar wind", *Geophys. Res. Lett.,* vol. 26, (1999), p. 3189.

S. W. Y. Tam and T. Chang, "Solar wind acceleration, heating, and evolution with wave-particle interactions", *Comments on Modern Phys.,* vol. 1C, (1999), p. 141.

S. W. Y. Tam and T. Chang, "Comparison of the effects of wave-particle interactions and the kinetic suprathermal electron population on the acceleration of the solar wind", *Astronomy* dc *Astrophysics,* vol. 395, (2002), p. 1001.

S. W. Y. Tam and T. Chang, "Comparison of solar wind driving mechanisms: ion cyclotron resonance versus kinetic suprathermal electron effects", *Solar Wind Ten, AIP Conference Proceedings,* vol. 679, (2003), p. 259.

T. Chang, ""Complexity" induced plasma turbulence in coronal holes and the solar wind", *Solar Wind Ten, AIP Conference Proceedings,* vol. 679, (2003), p. 481.

T. Chang, S.W.Y. Tam, and C.C. Wu, "Complexity Induced Anisotropic Bimodal Intermittent Turbulence in Space Plasmas", *Physics of Plasmas,* vol. 11, (2004), p. 1287.

T. Chang, S.W.Y. Tam, C.C. Wu, and G. Consolini, "Complexity, Forced and/or Self-Organized Criticality, and Topological Phase Transitions in Space Plasmas", *Space Science Reviews,* vol. 107, (2003), p. 425.

T. Chang, S. Chapman, and A. Klimas, "Forced and/or Self-Organized Criticality (FSOC) in Space Plasmas", *"Special issue of Journal of Atmospheric and Solar-Terrestrial Physics"* Volume 63, Number 13, ISSN 1364-6826, September, (2001).

T. Chang, "Complexity in Space Plasmas", University of Cambridge Press, (2005).

## III. ACTIVITIES.

- **Guest Co-Editor:** Special Topics Section of Physics of Plasmas on "Modes of Transport", 2002.
- **Co-Convener:** Special sessions on "Transport Phenomena in Space Plasmas", AGU Fall Meeting in San Francisco, December 2001.
- **Co-Convener,** Symposium on Solar System Physics, Joint EGS-AGU-EUG Assembly, Nice, France, 2003.
- **Scientific Advisor:** Goddard Space Flight Center
- **Member:** Program Committee, International Workshop on Nonlinear Waves and Chaos in Space Plasmas, India, 2002.
- Co-convener: Conference on Sun Earth Connection – Multiscale Coupling of Sun Earth Processes, Big Island, Hawaii, 2004.
- Visiting Professor, University of Louvain-La-Neuve, Belgium, 2004.

**Invited Lectures:**

- Conference on Sun Earth Connection - Multiscale Coupling of Sun Earth System, Big Island, Hawaii, 2004.
- Triennial Tutorial Lecturer for the 2002 General Assembly of the International Union of Radio Science, Maastricht, Netherlands.
- Symposium on Complexity in Space Plasma Processes, IUGG Assembly, Sapporo, Japan, 2003.
- Per Bak Memorial Session on Nonlinear Processes in Space Plasmas, Joint EGS-AGU-EUG Assembly, Nice, France, 2003.

- Session on Solar System Physics, Joint EGS-AGU-EUG Assembly, Nice, France, 2003.
- Huntsville Workshop on Particle Acceleration in Space and Astrophysical Plasmas, Huntsville, TN, 2002.
- Eringen Symposium, Society of Engineering Science, State College, PA, 2002.
- Second International Astrophysical Conference on Waves and Turbulence in Interplanetary and Astrophysical Media, Palm Springs, CA, 2003.
- PARS (Polar Aeronomy and Radio Science) Workshop, Lake Arrowhead, CA, 2002.

**Visiting Scientists and Students:**

Sandra Chapman [University of Warwick].

Nick Watkins [British Antarctic Survey].

George Rowlands [University of Warwick]

Jay Johnson [Princeton Plasma Physics Laboratory].

Vincenzo Vitelli [Imperial College].

Andrew Yau [University of Calgary].

Tom March [University of Warwick].

James Merrifield [University of Warwick].

**Listing**, 2000 Outstanding Scientists of the 20th Century.