General Disclaimer

One or more of the Following Statements may affect this Document

- This document has been reproduced from the best copy furnished by the organizational source. It is being released in the interest of making available as much information as possible.

- This document may contain data, which exceeds the sheet parameters. It was furnished in this condition by the organizational source and is the best copy available.

- This document may contain tone-on-tone or color graphs, charts and/or pictures, which have been reproduced in black and white.

- This document is paginated as submitted by the original source.

- Portions of this document are not fully legible due to the historical nature of some of the material. However, it is the best reproduction available from the original submission.

Produced by the NASA Center for Aerospace Information (CASI)
TURBULENCE AND WAVE PARTICLE INTERACTIONS IN SOLAR-TERRESTRIAL PLASMAS

ANNUAL STATUS REPORT

(1 July 1983 - 30 June 1984)

Grantee: The Regents of the University of Colorado
Boulder, Colorado 80309

Co-Principal Investigators:
George A. Dulk, Professor
Martin V. Goldman, Professor
Juri Toomre, Professor
Department of Astrophysical, Planetary and Atmospheric Sciences
University of Colorado
Boulder, Colorado 80309
Telephone: (303) 492-8913

Grant Title: Turbulence and Wave Particle Interactions in Solar-Terrestrial Plasmas

Grant Number: NASA Grant NAGW-91
University of Colorado Account 1-5331-48
ANNUAL STATUS REPORT  
(1 July 1983 – 30 June 1984)

Turbulence and Wave Particle Interactions  
in Solar-Terrestrial Plasmas

CONTENTS

Status Reports:
A. Particle and Wave Processes in Solar Flares ................. 1
B. Solar Convection Zone Turbulence .......................... 2
C. Solar Radio Emission ........................................ 2
D. Solar Magnetic Fields and Hydromagnetic Waves in Inhomogeneous Media .... 4
References .......................................................... 5

Appendices:
A. Publications Related to This Grant .......................... 6
B. Invited Papers ................................................ 13
C. Contributed Papers Related to This Grant .................... 18
D. Conferences, Seminars, and Other Grant-Related Activities ......... 24
A. Particle and Wave Processes in Solar Flares - led by G. Dulk

We have continued to investigate the amplification of cyclotron maser radiation in solar flares. An RF heating model for the corona surrounding the energy release site was developed (Melrose and Dulk 1984; Dulk and Melrose in SMM Workshop). This model permits a considerably simplified interpretation of several facets of flares: rapid precipitation of fast electrons from magnetic traps, cross-field transport of significant energy at the speed of light, development of macroscopic turbulence which can broaden lines of heavy ions.

Several important aspects of maser emission were investigated: (1) The relative growth and damping rates of various modes and harmonics were determined and it was concluded that the z mode probably grows fastest under many circumstances and coupling between two z mode waves may produce harmonic radiation of the kind observed (Melrose, Hewitt and Dulk 1984). (2) The presence of a background plasma of moderate to high temperature was found to have a significant effect on the growth rate, allowing growth of fundamental, x-mode radiation at densities some four times higher than previously thought possible (Winglee 1984a). (3) The importance of bunching of electrons in particular phases of waves was investigated and found to have probable consequences in triggered VLF emissions in the Earth's magnetosphere (Winglee 1984b).

Other studies included several review papers on radio emission processes by Dulk and collaborators, an investigation of the circumstances when radio emission accompanies shock waves by Gary et al. (1984) and an investigation of the circumstances when plasma emission occurs in the solar wind at the fundamental vs. the harmonic (Dulk, Steinberg and Hoang 1984).
B. Solar Convection Zone Turbulence - led by J. Toomre

Our nonlinear simulations of compressible convection display prominent penetration by plumes into regions of stable stratification at the base of the solar convection zone, leading to the excitation of internal gravity waves there. The inclusion of magnetic fields into these calculations yields regions of very concentrated fields, with such flux sheets or tubes becoming substantially evacuated of plasma.

C. Solar Radio Emission - led by M. Goldman

During this period our work on Langmuir turbulence and radiation associated with Type III solar radio emission and planetary bow-shock emission divides into three main categories: linear saturation of electron beam-driven Langmuir waves by ambient density fluctuations; nonlinear saturation by "strong turbulence" processes; and radiation emission mechanisms. There have been major recognized achievements in all three areas. These are described in 5 published articles, 3 additional submitted articles, and 2 principal invited papers at international conferences.

In the area of linear saturation, our earlier research on the saturation of beam-excited Langmuir waves in the foreshock of the Jovian bow-shock by multiple scatter off (measured) short-scale ion-acoustic turbulence has been published (Russell and Goldman 1983). We have now developed a variation of this idea, and applied it to Type III burst associated Langmuir waves. In a paper submitted to Solar Physics (Muschietti, Goldman and Newman 1984), we have explored the quenching of the beam-plasma instability by diffusion from a 3-D spectrum of large-scale ambient density fluctuations, and come to the
significant conclusion that this effect is so powerful that unless such density fluctuations are highly anisotropic in space, the Langmuir waves are often completely suppressed. This indirect evidence for "duct-shaped" ambient density fluctuations fits nicely with recent theories (Dulk, Steinberg and Hoang 1984) of ducted radio-wave emission from remote sources.

Our past work on nonlinear saturation by strong turbulence effects has been summarized in two review articles (Goldman 1983, 1984), the latter solicited from the editors of Review of Modern Physics after an invited review talk before the Plasma Physics Division of the American Physical Society in November, 1983. In recent research still underway, we have studied the evolution of strong Langmuir turbulence in the vicinity of planetary bowshocks, where backscatter off thermal ion-acoustic waves may occur, and calculated the level and angular distribution of 2nd harmonic emission from the resulting turbulent spectrum (Newman, Muschietti, Moon, and Goldman 1984). In two other recent developments, we have observed driven self-focusing of Langmuir waves for the first time in a 2-d particle in cell simulation (Russell, Goldman, and Dubois 1984), and explored the intermittency of Langmuir solitons in a beam-driven plasma (Moon and Goldman 1984).

Finally, we have completed, and submitted for publication, detailed calculations on two new mechanisms by which Langmuir turbulence may produce electromagnetic emission well above the electron plasma frequency. The first mechanism is Compton conversion of Langmuir waves in the presence of a relativistic electron beam (Newman 1984), and the second is multiple Raman scatter of radiation from pre-existing Langmuir waves.
D. **Solar Magnetic Fields and Hydromagnetic Waves in Inhomogeneous Media**

- **led by E. Zweibel**

Influence of Lower Boundary Condition on MHD Stability on the Solar Corona: There has been some controversy in the literature concerning the correct boundary conditions to use in studies of coronal MHD stability. It is generally agreed that the inertia of the photospheric gas should provide some stabilization by line tying, but the effect of vertical displacements of the corona-photosphere boundary has not been analyzed. I showed (Zweibel 1984) that vertical motions of the boundary are strongly stabilized by the density stratification of the solar atmosphere. This calculation provides a context for choosing boundary conditions and ties together some apparently discrepant results in the literature.

Effect of Magnetic Fields on Stellar Oscillations: Although the field of solar and stellar oscillations is quite active, very few calculations have been done which incorporate the effect of a magnetic field. Calculations presently underway (in collaboration with H. van Horn's group at the University of Rochester) show that the magnetic field can have a strong effect on oscillations which are localized (or trapped) within the surface layers of a neutron star. This is true even though the field may be unimportant over most of the interior of the star (Morrow and Zweibel 1984). We expect a similar effect in magnetic white dwarfs and in solar active regions.

A program focused on magnetic effects of solar oscillations is underway in collaboration with T. Brown (HAO) and C. Morrow (graduate student, CU). This program involves observations of solar oscillations with the Fourier tachometer at Sac Peak, a new instrument developed by Brown, as well as theoretical analysis. We are studying the modification of the oscillation spectrum by magnetic fields which are concentrated into intense flux tubes, as the solar field is observed to be.
REFERENCES


Appendix A

Publications Related To This Grant

"Turbulence and Wave Particle Interactions in Solar Terrestrial Plasmas

1 July 1983 — 30 June 1984

[List compiled October 1984.]
PUBLICATIONS RELATED TO THIS GRANT
(Inclusive; status as of October 1984)


Appendix B

Invited Papers

"Turbulence and Wave Particle Interactions in Solar Terrestrial Plasmas"

1 July 1983 — 30 June 1984

1 List compiled October 1984.
INVITED PAPERS
(inclusive; status as of June 1984)

   (at the invitation of the Soviet Academy of Sciences), Tbilisi School-Workshop
   on Plasma Physics and Controlled Thermonuclear Fusion, Telavi, USSR; October
   8, 1980.

   Radiophysics Laboratory, Commonwealth Scientific and Industrial Research
   Organization, Epping, Australia; March 1981.

3. "Strange Attractors," Martin V. Goldman, University of Sydney,
   Australia; March 1981.

4. "Solitary Waves and Solar Radio Wave Emission," M. V. Goldman,
   invited colloquium, University of New South Wales, Sydney, Australia, March,
   1981.

5. "Langmuir Turbulence," Martin V. Goldman, invited paper at Workshop
   on Stochasticity and Turbulence, Los Alamos Center for Nonlinear Studies; June
   1981.

   Workshop on Stochasticity and Turbulence, Los Alamos Center for Nonlinear
   Studies; June 1981.

7. "Variability in the Power Spectrum of Five-Minute Oscillations,"
   J. Toomre (with F. Hill and L. November), IAU Colloquium No. 66, Problems of
   Solar and Stellar Pulsations, Crimea, USSR, Sept. 1981 (Sol. Phys. 82, 411
   [1983]).

8. "On the Detection of Subphotospheric Convective Velocities and
   Temperature Fluctuations," D. O. Gough and J. Toomre, IAU Colloquium No. 66,
   Phys. 82, 401 [1983]).

   Zahn), IAU Colloquium No. 66, Problems of Solar and Stellar Pulsations,

10. "Turbulence and Wave Particle Interactions in Solar Terrestrial
    Plasmas, G. A. Dulk, M. V. Goldman, D. F. Smith, and J. Toomre, American
    Geophysical Union, San Francisco, California, December 1981 (EOS
    Transactions 62 (45), 1015 [1981]).

11. "Heating of the Corona by Radio Waves During Flares," G. A. Dulk,
    High Altitude Observatory, National Center for Atmospheric Research, Boulder,
    Colorado; April 1982.

    Dulk, NASA/Goddard Space Flight Center; May 1982.

    Institute for Theoretical Physics, University of California at Santa Barbara,
    Goleta, California; March 1982.


28. "Plasma Phenomena in Close Binary Stars," George A. Dulk, Department of Theoretical Physics, University of Sydney Colloquium; March 1983.


30. "AM Herculis-Type Binaries," George A. Dulk, CSIRO Colloquium, Sydney, Australia; April 1983.
31. "Overview of Solar Seismology: Oscillation Modes of the Sun used as
Probes of its Internal Dynamics and Structure," Juri Toomre, Invited Overview
Presentations at NASA Headquarters, organized by F. McDonald, to Associate and
Assistant Administrators, April 15, 1983.

Center, May 1983.

33. "Search for Solar Giant Cells Using Five-Minute Oscillations as
Probes of Velocity Structures," J. Toomre, invited paper presented at American
Geophysical Union, Baltimore, May 1983 (EOS 64, 303 [1983]).

34. "Masers Operating in Solar and Stellar Flares," George A. Dulk, CSIRO
Colloquium, Sydney, Australia; June 1983.

University of Barcelona, Spain; June 1983.

36. "Chaos and Strange Attractors in Thermosolutal Convection: Period
Doubling for Partial Differential Equations," Juri Toomre, invited seminar,
Observatory of Pic du Midi, Toulouse, France; June 1983.

37. "Solar Seismology: Search for Solar Giant Cells Using the
Five-Minute Oscillations as Probes of Internal Dynamics and Structure," Juri
Toomre, invited seminar, Observatory of Arcetri, University of Florence,
Italy; June 1983.

Toomre, invited seminar, Observatory of Arcetri, University of Florence,
Italy; June 1983.

seminar, Max Planck Institute for Physics and Astrophysics, Munich, W.
Germany; July 1983.

40. "Internal Velocity Fields Inferred from Inversion of Solar
Oscillation Data," invited seminar, Kiepenheuer Institute for Solar Physics,
Freiburg, W. Germany; July 1983.

41. "Nonlinear Compressible Convection," Juri Toomre, invited major
paper, Conference on Small-Scale Dynamical Processes in Quiet Stellar
Atmospheres, National Solar Observatory; August 1983.

42. "Nonlinear Double-Diffusive Convection and Strange Attractors," Juri
Toomre, invited seminar, Harvard Center for Astrophysics, Nonlinear Dynamics
Group, Boston; October 1983.

Center for Atmospheric Research, High Altitude Observatory, Boulder, Colorado;
October 1983.

Space Research Institute (Utrecht); October 1983.

45. "Electron Cyclotron Masers in the Sun and Stars," G. A. Dulk,
Observatoire de Paris seminar; October 1983.


Appendix C

Contributed Papers Related To This Grant

"Turbulence and Wave Particle Interactions in Solar Terrestrial Plasmas"

1 July 1983 - 30 June 1984

[List compiled October 1984.]
CONTRIBUTED PAPERS RELATED TO THIS GRANT
(Published Abstracts Listed when applicable, status as of June 1984)


Appendix D

Conferences, Seminars, and Other Grant-Related Activities

"Turbulence and Wave Particle Interactions in Solar Terrestrial Plasmas"

1 July 1983 – 30 June 1984
CONFERENCES, SEMINARS AND OTHER GRANT-RELATED ACTIVITIES
(1 July 1983 - 31 June 1984)

George Dulk, Senior Visiting Scientist, at Observatoire de Paris, France, July-December 1983.

George Dulk attended the UK/SMM Workshop, Oxford University, England, September 1983.


George Dulk visited Space Research Laboratory, Utrecht, Netherlands, October 1983.

George Dulk attended meeting of Japan-France Seminar, Paris, October 1983.

George Dulk visited Dept. of Applied Physics, University of Bern, Switzerland, November 1983.


Juri Toomre and Ellen Zweibel attended the Workshop on Solar Physics sponsored by the solar groups in the STTP, Stanford University, March 16-21, 1984.

George Dulk conducted site visit to NRAO Tucson, Az., January 1984.

George Dulk attended SMM Workshop, Goddard SFC, February 1984.

George Dulk attended workshop on cataclysmic variable stars, LSU, Baton Rouge, La., February 1984.

George Dulk conducted observing program on cataclysmic variable stars, VLA, March 1984; on flare stars in Orion and the Pleiades, VLA, March 1984.


George Dulk attended meeting of NRAO Visitors Committee, Charlottesville, VA, April 1984.


George Dulk, attended meeting of NRAO Users Committee, Socorro, NM, May 1984.
George Dulk attended General Assembly of COSPAR, Graz, Austria, June 1984.

George Dulk conducted joint EUV rocket and VLA radio experiment, June 1984.

George Dulk conducted invited working visit to Observatoire de Paris, Meudon, June-July 1984.