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TURBULENCE AND WAVE PARTICLE INTERACTIONS IN SOLAR-TERRESTRIAL PLASMAS

ANNUAL STATUS REPORT

(1 July 1983 - 30 June 1984)

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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

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ANNUAL STATUS REPORT
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Turbulence and Wave Particle Interactions in Solar-Terrestrial Plasmas

CONTENTS

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.

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Muschietti, L., Goldman, M. V., and Newman, D. 1984, "Quenching of the Beam-Plasma Instability by 3-D Spectra of Large Scale Density Fluctuations," submitted to Sol. Phys.

Moon, H. T., and Goldman, M. V. 1984, "Intermittency and Solitons in the Driven Dissipative Nonlinear Schroedinger Equation," submitted to Phys. Rev. Lett.

Morrow, C. A., and Zweibel, E. G. 1984, "Effect of Magnetic Fields on Neutron Star Oscillations," AAS Bull. 16, No. 2, 47.12.

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Zweibel, E. G. 1984, "Application of the MHD Energy Principle to Magnetostatic Atmospheres," submitted to Geophys. Astrophys. Fluid Dynamics.

Appendix A

Publications Related To This Grant

"Turbulence and Wave Particle Interactions
in Solar Terrestrial Plasmas

1 July 1983 - 30 June 1984[1]

[1] List compiled October 1984.

PUBLICATIONS RELATED TO THIS GRANT
(inclusive; status as of October 1984)

"Stellar Convection Theory. III. Dynamical Coupling of the Two Convection Zones in A-Type Stars by Penetrative Motions," J. Latour, J. Toomre, and J.-P. Zahn, Astrophys. J. 248, 1081 (1981).

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"Compton Conversion of Langmuir Waves into High Frequency Electromagnetic Waves in the Presence of an Ultra Relativistic Electron Beam," D. Newman, submitted to Phys. Fluids (1984).

"Quenching of the Beam-Plasma Instability by 3-D Spectra of Large Scale Density Fluctuations," L. Muschietti, M. V. Goldman, and D. Newman, submitted to Sol. Phys. (1984).

"Multiple Raman Up-conversion of Radiation from Pre-existing Langmuir Turbulence," D. Russell, M. Goldman, and D. Newman, submitted to Phys. Fluids (1984).

Appendix B

Invited Papers

"Turbulence and Wave Particle Interactions
in Solar Terrestrial Plasmas"

1 July 1983 - 30 June 1984[1]

[1]List compiled October 1984.

INVITED PAPERS
(inclusive; status as of June 1984)

1. "Soliton Collapse and Electromagnetic Emission," Martin V. Goldman (at the invitation of the Soviet Academy of Sciences), Tbilisi School-Workshop on Plasma Physics and Controlled Thermonuclear Fusion, Telavi, USSR; October 8, 1980.

2. "A Review of Solar Radio Wave Emission," Martin V. Goldman, 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.

6. "Coherence and Chaos in Nonlinear Systems," David A. Russell, 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, Problems of Solar and Stellar Pulsations, Crimea, USSR, Sept. 1981 (Sol. Phys. 82, 401 [1983]).

9. "Anelastic Modal Convection," J. Toomre (with J. Latour and J.-P. Zahn), IAU Colloquium No. 66, Problems of Solar and Stellar Pulsations, Crimea, USSR, Sept. 1981 (Sol. Phys. 82, 387 [1983]).

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.

12. "Precipitation of Solar Flare Electrons by Maser Radiation," G. A. Dulk, NASA/Goddard Space Flight Center; May 1982.

13. "Theory of Type III Solar Radio Wave Emission," Martin V. Goldman, Institute for Theoretical Physics, University of California at Santa Barbara, Goleta, California; March 1982.

14. "Status of Observations of Type III Solar Radio Wave Emission," Martin V. Goldman, Institute for Theoretical Physics, University of California at Santa Barbara, Goleta, California; March 1982.

15. "Emission of Electromagnetic Waves from Beam-Plasma Systems," Martin V. Goldman, University of California at Berkeley; April 1982.

16. "Solar Convection and Probing it with Five-Minute Oscillations," J. Toomre, University of Barcelona, Spain; May 1982.

17. "Compressible Convection in the Solar Convection Zone," Juri Toomre, Observatory of Pic du Midi, Toulouse, France; June 1982.

18. "Five-Minute Oscillations of the Sun and their Coupling to Convection," Juri Toomre, University of Barcelona, Spain; May 1982.

19. "Compressible Convection in the Solar Convection Zone," Juri Toomre, Observatory of Pic du Midi, Toulouse, France; June 1982.

20. "The Propagation of Energetic Ions in Magnetic Loops and γ-ray Emission from Solar Flares," Ellen G. Zweibel, Space Sciences Seminar, University of California, Berkeley, October 7, 1982.

21. "The Propagation of Energetic Ions in Magnetic Loops and γ-ray Emission from Solar Flares," Ellen G. Zweibel, Physics Colloquium, San Francisco State University, November 15, 1982.

22. "Type II bursts, shock waves, and coronal transients," D. E. Gary, American Geophysical Union, San Francisco, December 1982 (EOS Transactions 63 [45], 1086 [1982]).

23. "Strange Attractors in Double-Diffusive Convection," Juri Toomre, invited seminar, M.I.T. Mathematics Department; February 1983.

24. "Double-Diffusive Convection and Strange Attractors," Juri Toomre, Mathematics Seminar, University of Colorado; March 1983.

25. "Time-dependent Thermocl[illegible]al Convection," Juri Toomre, invited talk, Engineering Societies Meeting on Double-Diffusive Convection, Santa Barbara; March 1983.

26. "Planetary Radio Emissions," Robert G. Hewitt, Astro-Geophysics Departmental Seminar, University of Colorado, Boulder, CO, March 7, 1983.

27. "Electron Cyclotron Masers," George A. Dulk, CSIRO Colloquium, Sydney, Australia; March 1983.

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

29. "Solar Flares Observed with the VLA," George A. Dulk, CSIRO Colloquium, Sydney, Australia; 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.

32. "Planetary Radio Emissions," R. G. Hewitt, NASA Goddard Space Flight 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.

35. "Solar Seismology," Juri Toomre, invited seminar, Polytechnical 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.

38. "Modelling of Nonlinear Compressible Convection in Stars," Juri Toomre, invited seminar, Observatory of Arcetri, University of Florence, Italy; June 1983.

39. "Nonlinear Compressible Convection in Stars," Juri Toomre, invited seminar, Max Planck Institute for Physics and Astroiphysics, 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, Converence 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.

43. "MHD Stability in the Solar Atmosphere," E. G. Zweibel, National Center for Atmospheric Research, High Altitude Observatory, Boulder, Colorado; October 1983.

44. "The Radio Frequency (Maser) Heating Model of Flares," G. A. Dulk, Space Research Institute (Utrecht); October 1983.

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

46. "Stellar Radio Astronomy," G. A. Dulk, ETH seminar, Zurich, Switzerland; November 1983.

47. "Maser Operation in the Planets, Sun and Stars," G. A. Dulk, University of Bern colloquium, Bern, Switzerland; November 1983.

48. "Strong Langmuir Turbulence: Theory and Application to Space and Laboratory Experiments," Martin V. Goldman, invited review talk at the Annual Plasma Physics Division Meeting of the American Physical Society, Los Angeles, California; November 1983 (Bull. Am. Phys. Soc. 28, 1980 [1983]).

49. "Nonlinear Numerical Simulations of Compressible Convection in Stars," J. Toomre, invited paper presented at All-Union Session of the American Geophysical Union, San Francisco, December 1983 (EOS 64, 657 [1983]).

50. "RF Heating as a Means of Energy Transport During Flares," G. A. Dulk, SMM Workshop, Goddard; February 1984.

51. "Structure and Dynamics of the Convection Zone," J. Toomre, invited presentation at Workshop on Solar Physics sponsored by Solar Groups in the STTP, Stanford University, March 19-21, 1984.

52. "Strong Langmuir Turbulence--with Application to Space Plasma," M. V. Goldman, invited lecture at Statistical Physics of Fusion Plasmas Conference, Nagoya, Japan, February 17-26, 1984.

53. "Penetrative Convection Overshoot," Juri Toomre, invited talk, Instabilities and Material Mixing in Astrophysical Fluid Dynamics, Center for Nonlinear Studies, Los Alamos, New Mexico; April 1984.

54. "Electron-Cyclotron Maser Emission in a Hot Plasma," R. M. Winglee, Department of Physics, University of Iowa; May 1984.

55. "Nonlinear Compressible Convection," N. E. Hurlburt, Department of Applied Mathematics and Theoretical Physics, University of Cambridge, Cambridge, England; May 1984.

56. "Nonlinear Compressible Convection," N. E. Hurlburt, NORDITA, University of Copenhagen Observatory; May 1984.

57. "Compressible Magnetoconvection," N. E. Hurlburt, Nice Observatory, Nice, France; May 1984.

58. "Effect of Boundary Conditions on MHD Stability of the Solar Atmosphere," E. G. Zweibel, National Center for Atmospheric Research, High Altitude Observatory, Boulder, Colorado; May 1984.

59. "Cyclotron Masers in Astronomy and in RF Heating in Flares," G. A. Dulk, Astrophysical, Planetary and Atmospheric Sciences Colloquium, University of Colorado; May 1984.

60. "Compressible Penetrative Convection," N. E. Hurlburt, Observatory of Pic du Midi, Toulouse, France; June 1984.

61. "Nonlinear Compressible Convection," N. E. Hurlburt, Max Planck Institute for Astrophysik, Munich, W.Germany; June 1984.

62. "Compressible Magnetoconvection," N. E. Hurlburt, Polytechnical University of Barcelona; June 1984.

Appendix C

Contributed Papers Related To This Grant

"Turbulence and Wave Particle Interactions
in Solar Terrestrial Plasmas"

1 July 1983 - 30 June 1984[1]

[1]List compiled October 1984.

CONTRIBUTED PAPERS RELATED TO THIS GRANT
(Published Abstracts Listed when applicable, status as of June 1984)

1. "Harmonic Emission by Adiabatically Collapsing Langmuir Solitons," B. Hafizi and M. V. Goldman, Plasma Physics Divisional Meeting of the American Physical Society, San Diego, November 1980 (Bull. Am. Phys. Soc. 25, 914 [1980]).

2. "Langmuir Collapse in a Weak Magnetic Field," J. C. Weatherall, M. V. Goldman, and D. Nicholson, Plasma Physics Divisional Meeting of the American Physical Society, San Diego, November 1980 (Bull. Am. Phys. Soc. 25, 984 [1980]).

3. "Dimension of Strange Attractors," D. A. Russell, J. D. Hanson, and E. Ott, Plasma Physics Divisional Meeting of the American Physical Society, San Diego, November 1980 (Bull. Am. Phys. Soc. 25, 989 [1980]).

4. "Microwave and Hard X-ray Observations of the Flare on 1980 June 29, 0230 UT," G. A. Dulk, B. Dennis, and K. Kai, Solar Physics Division of the American Astronomical Society, Taos, New Mexico, January 1981 (Bull. Amer. Astron. Soc. 12, 902 [1980]).

5. "Convective Overshooting in Highly Stratified Media," J. Latour, J.-P. Zahn, J. Massaguer and J. Toomre, European Mechanic Colloquium No. 138, Karlsruhe, West Germany, March 1981 (Proc. Euromech. 138, [1980]).

6. "Two-Dimensional Compressible Convection Extending Over Many Scale Heights," J. Massaguer, N. Hurlburt, J. Toomre and E. Graham, European Mechanics Colloquium No. 138, Karlsruhe, West Germany, March 1981 (Proc. Euromech. 138, [1980]).

7. "Nonlinear Simulations of Rotation Effects in Supergranules," D. H. Hathaway and J. Toomre, Solar Physics Division of the American Astronomical Society, Taos, New Mexico, January 1981 (Bull. Am. Astron. Soc. 12, 894 [1980]).

8. "Two-Dimensional Compressible Convection Extending Over Multiple Scale Heights," N. Hurlburt, J. Toomre, J. M. Massaguer, and E. Graham, Solar Physics Division of the American Astronomical Society, Taos, New Mexico, January 1981 (Bull. Am. Astron. Soc. 12, 894 [1980]).

9. "Steady Flows in the Solar Transition Region Observed with the UVSP Experiment on SMM," K. B. Gebbie, F. Hill, J. Toomre, L. R. November, G. W. Simon, and 7 co-authors, Solar Physics Division of the American Astronomical Society, Taos, New Mexico, January 1981 (Bull. Am. Astron. Soc. 12, 907 [1980]).

10. "The Lifetime of Solar Mesogranulation," L. J. November, J. Toomre, K. B. Gebbie, F. Hill, and G. W. Simon, Solar Physics Division of the American Astronomical Society, Taos, New Mexico, January 1981 (Bull. Am. Astron. Soc. 12, 895 [1980]).

11. "Anelastic Modal Theory Applied to the Solar Convection Zone," J. Toomre, J. Latour, and J.-P. Zahn, Solar Physics Division of the American Astronomical Society, Taos, New Mexico, January 1981 (Bull. Am. Astron. Soc. 12, 895 [1980]).

12. "OSO-8 Observations of Coherent Chromospheric Oscillations," F. Hill, J. Toomre, and L. J. November, Solar Physics Division of the American Astronomical Society, Taos, New Mexico, January 1981 (Bull. Am. Astron. Soc. 12, 894 [1980]).

13. "Cosmic Ray Confinement in Molecular Clouds," E. G. Zweibel and J. M. Shull, International School of Plasma Physics, Varenna, Italy, August 1981.

14. "Solitons and Ionospheric Modification," D. R. Nicholson, P. J. Hansen, G. L. Payne, J. C. Weatherall, M. V. Goldman and J. P. Sheerin, Symposium on Active Experiments, Ionospheric Modification Session, URSI XXth General Assembly, Washington, D.C., August 10-19, 1981.

15. "Evolution of Bump-on-tail Instability During Type III Solar Radio Bursts," D. Smith, B. Hafizi, J. Weatherall, M. V. Goldman, and D. Nicholson, Plasma Physics Division of the American Physical Society, New York, October 1981 (Bull. Am. Phys. Soc. 26, 940 [1981]),

16. "Steady State Langmuir Turbulence," J. C. Weatherall, M. V. Goldman, and D. R. Nicholson, Plasma Physics Division of the American Physical Society, New York, October 1981 (Bull. Am. Phys. Soc. 26, 1026 [1981]).

17. "Beam Instability in a Plasma with Low Frequency Turbulence," M. V. Goldman and D. F. Dubois, Plasma Physics Division of the American Physical Society, New York, October 1981 (Bull. Am. Phys. Soc. 26, 1062 [1981]).

18. "Modulational Interaction of Nonlinear Waves and Recurrence," C. F. Meyers and B. Hafizi, Plasma Physics Division of the American Physical Society, New York, October 1981 (Bull. Am. Phys. Soc. 26, 1010 [1981]).

19. "Strong Langmuir Turbulence: Zakharov Theory," A. O. Barut and B. Hafizi, Plasma Physics Division of the American Physical Society, New York, October 1981 (Bull. Am. Phys. Soc. 26, 1039 [1981]).

20. "Solitons and Ionospheric Modification," J. P. Sheerin, P. J. Hansen, D. R. Nicholson, G. L. Payne, M. V. Goldman, and J. C. Weatherall, Plasma Physics Division of the American Physical Society, New York, October 1981 (Bull. Am. Phys. Soc. 26, 938 [1981]).

21. "Electron Cyclotron Masers as the Source of Certain Radio Bursts from the Sun, Stars, Jupiter and the Earth, D. B. Melrose and G. A. Dulk, American Geophysical Union, San Francisco, California, December 1981 (EOS Transactions 62 (45), 1011 [1981]).

22. "Two-Dimensional Nonlinear Penetrative Convection in a Compressible Medium, N. Hurlburt, J. Toomre, J. M. Massaguer, American Geophysical Union, San Francisco, California, December 1981 (EOS Transactions 62 (45), 1008 [1981]).

23. "Intrinsic Stochasticity of Beam-Driven Langmuir Waves, D. A. Russell and M. V. Goldman, American Geophysical Union, San Francisco, California, December 1981 (EOS Transactions 62 (45), 1011 [1981]).

24. "Scattering and Collapse of Langmuir Waves During Type III Solar Radio Bursts," B. Hafizi, J. C. Weatherall, and D. H. Nicholson, American Geophysical Union, San Francisco, California, December 1981 (EOS Transactions 62 (45), 1008 [1981]).

25. "Effect of Density Fluctuations on Beam-Unstable Langmuir Waves," J. C. Weatherall, M. V. Goldman, D. F. Smith, American Geophysical Union, San Francisco, California, December 1981 (EOS Transactions 62 (45), 1019 [1981]).

26. "A Kinetic Theory Formulation of the Anomolous Heat Conduction Problem for Solar Coronal Loops," D. F. Smith and L. M. Muth, American Geophysical Union, San Francisco, California, December 1981 (EOS Transactions 62 (45), 1008 [1981]).

27. "Solar Five-Minute Oscillations as Probes of Velocity and Temperature Fields," F. Hill, J. Toomre, and L. J. November, Amer. Astron. Soc., Boulder, Colorado, January 1982 (Bull. Am. Astron. Soc. 13, 860 [1981]).

28. Nonlinear Anelastic Models of Solar Convection," J. Toomre, J. Latour, and J.-P. Zahn, Amer. Aston. Soc., Boulder, Colorado, January 1982 (Bull. Am. Astron. Soc. 13, 907 [1981]).

29. "Nonlinear Penetrative Convection in a Compressible Medium," N. Hurlburt, J. Toomre, and J. M. Massaguer, Amer. Astron. Soc., Boulder, Colorado, January 1982 (Bull. Am. Astron. Soc. 13, 912 [1981]).

30. "Evidence for a Shock Wave in Visible Light and Radio Observations of the 1980 June 29 Event," D. E. Gary, G. A. Dulk, L. L. House, W. J. Wagner, R. I. Illing, C. Sawyer, and D. J. McLean, Fifth International Symposium on Solar-Terrestrial Physics, XXIV COSPAR, Ottawa, Canada, May 1982 (Adv. Space Res. 2 [11], eds. Z. Svestka, D. M. Rust, and M. Dryer, Pergamon Press, Oxford, p. 253 [1983]).

31. "On the Effects of Electron-Cyclotron Masers During Flares," G. A. Dulk and D. B. Melrose, Fifth International Symposium on Solar-Terrestrial Physics, XXIV COSPAR, Ottawa, Canada, May 1982 (Adv. Space Res. 2 [11], eds. Z. Svestka, D. M. Rust, and M. Dryer, Pergamon Press, Oxford, p. 185 [1983]).

32. "Comparison of Theoretically Predicted and Observed Solar Maximum Mission X-ray Spectra for the April 13 and May 9, 1980, Flares," D. F. Smith andL. E. Orwig, Fifth International Symposium on Solar-Terrestrial Physics, XXIV COSPAR, Ottawa, Canada, May 1982.

33. "Microwave Signature of Thick Target Electron Beams in Solar Flares," A. G. Emslie and D. F. Smith, IAU General Assembly, Patras, Greece, August 1982.

34. "Radiation from Beam-Plasma Systems," M. V. Goldman, J. C. Weatherall, D. Newman, and D. DuBois, Plasma Physics Division of the American Physical Society, New Orleans, November 1982 (Bull. Am. Phys. Soc. 27, 1022 [1982]).

35. "Fully Developed Turbulence in Beam-Plasma Systems," J. C. Weatherall, M. V. Goldman, and F. D. Tappert, Plasma Physics Division of the American Physical Society, New Orleans, November 1982 (Bull. Am. Phys. Soc. 27, 946 [1982]).

36. "Wave Cascade to High-k Via Density Fluctuations," D. A. Russell and M. V. Goldman, Plasma Physics Division of the American Physical Society, New Orleans, November 1982 (Bull. Am. Phys. Soc. 27, 1025 [1982]).

37. "Theory of Beam-Driven Langmuir Waves near a Planetary Bow Shock," D. A. Russell and M. V. Goldman, American Geophysical Union, San Francisco, December 1982 (EOS Transactions 63 (45), 19085 [1982]).

38. "Theory of Type III Solar Radio Waves," M. V. Goldman, J. C. Weatherall, and D. Russell, American Geophysical Union, San Francisco, December 1983, (EOS Transactions 63 (45), 1088 [1982]).

39. "AM Herculis: An Outburst at 4.9 GHz," T. S. Bastian, G. A. Dulk, and G. Chanmugam, Workshop on Cataclysmic Variables, Boston, MA, January 1983, (Cataclysmic Variables and Low-mass X-ray Binaries, eds. D. Q. Lamb and J. Patterson [Dordrecht: Reidel]).

40. "Heating of the Corona by Masers in Solar Flares," George A. Dulk, Solar Maximum Mission (SMM) Satellite Data Analysis Workshop at Goddard Space Flight Center, January 1983.

41. "The Lateral Deflection of Large-Scale Convective Flow by Scale Height Effects Below the Solar Surface," N. E. Hurlburt and J. Toomre, Amer. Astron. Soc., Boston, January 1983 (Bull. Am. Astron. Soc. 14, 938 [1982]).

42. "Solar Five-Minute Oscillations, Subsurface Velocities and Inverse Theory," D. O. Gough, F. Hill and J. Toomre, Amer. Astron. Soc., Boston, January 1983 (Bull. Am. Astron. Soc. 14, 938 [1982]).

43. "Z-Mode Radiation Generated by a Loss-cone Driven Electron Maser," R. G. Hewitt and D. B. Melrose, American Geophysical Union, Baltimore, May 1983 (EOS Transactions 64 (18), 288 [1983]).

44. "Electron Distribution Functions in Solar Flares," S. M. White, D. B. Melrose, and G. A. Dulk, Astron. Soc. Australia, Sydney, May 1983.

45. "Low Frequency Observations of Centaurus A," O. B. Slee, A. G. Little, K. V. Sheridan, and G. A. Dulk, Astron. Soc. Australia, Sydney, May 1983.

46. "Radio Frequency Heating of the Soft X-Ray Plasma," G. A. Dulk, UK/SMM Workshop, Oxford, England, September 1983.

47. "Recent Radio Observations of Activity and Magnetic Fields in Stars," G. A. Dulk, Japan-France Seminar, Paris, October 1983.

48. "Multiple Raman Up-Scatter of Radiation in Turbulent Plasma," D. Russell, D. Newman, and M. V. Goldman, Plasma Physics Division of the American Physical Society, Los Angeles, California, November 1983 (Bull. Am. Phys. Soc. 28, 1968 [1983]).

49. "The Concentration of Magnetic Fields by Compressible Convection and its Effects on Penetration and Mixing," N. E. Hurlburt, Instabilities and Material Mixing in Astrophysical Fluid Dynamics, Center for Nonlinear Studies, Los Alamos, New Mexico; April 1984.

50. "Enhanced Growth of Whistlers Due to Bunching of Untrapped Electrons," R. M. Winglee, American Geophysical Union, Cincinnati, Ohio, May 1984 (EOS Transactions 65, 267 [1984]).

51. "Radio Emission from AM Herculis: Spectrum and Temporal Variations," T. S. Bastian, G. A. Dulk and G. Chanmugam, Workshop on Cataclysmic Variable Stars, Baton Rouge, Louisiana; February 1984.

52. "Quenching of the Beam-Plasma Instability by Large Scale Density Fluctuations," L. Muschietti, M. Goldman, and D. Newman, International Conference on Plasma Physics, Lausanne, Switzerland; June 1984 (Proceedings of Contributed Papers, Vol. 1, pg. 84 (ed. M. Q. Tran and M. L. Sauly).

53. "Effect of Magnetic Fields on Neutron Star Oscillations," C. A. Morrow and E. G. Zweibel, Amer. Astron. Soc., Baltimore, June 1984 (Bull. Am. Astron. Soc. 16, 542 [1984]).

54. "Horizontal Velocities in the Solar Convection Zone Inferred from High Degree 5-Minute Oscillations," F. Hill, J. Toomre and D. O. Gough, Amer. Astron. Soc., Baltimore, June 1984 (Bull. Am. Astron. Soc. 16, 451 [1984]).

55. "Simulations of Effects of Atmospheric Seeing on Observations of Solar Five-Minute Oscillations," W. G. Merryfield, J. Toomre, F. Hill, and D. O. Gough, Amer. Astron. Soc., Baltimore, June 1984 (Bull. Am. Astron. Soc. 16, 532 [1984]).

56. "Effects of Spherical Harmonic Filtering on Analysis of Five-Minute Solar Oscillations of High Degree," D. Haber, J. Toomre and F. Hill, Amer. Astron. Soc., Baltimore, June 1984 (Bull. Am. Astron. Soc. 16, 533 [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 Dept. of Applied Mathematics and Mullard Radio Astronomy Observatory, U. of Cambridge, England, September 1983.

George Dulk visited Rutherford-Appleton Laboratories, Didcot, 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 participated in the third SMM Satellite Data Analysis Workshop at Goddard Space Flight Center, January 1984.

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, member of Scientific Organizing Committee for Stellar Continuum Radio Workshop, January-August 1984.

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

George Dulk attended meeting of NASA Solar Physics Advisory Group, Lanham, Maryland, 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 Obervatoire de Paris, Meudon, June-July 1984.