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Final Technical Report for Award N00014-86-K-0056
OFFICE OF NAVAL RESEARCH
for Research on
Synoptic Solar Magnetic and Velocity Field Observations
Using the 150-foot Solar Tower on Mt. Wilson

Period of performance: 12/16/85 to 3/31/91
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University of California at Los Angeles



Summary of Scientific Results from Research.

This report describes results from work supported by the Office of Naval Research under award N00014-86-K-0056. A major emphasis in the 150-foot Solar Tower project has been to understand the 11-year solar cycle and the project is best understood as part of a continuing effort. The major advances in our analysis of the dynamics of the solar surface during the performance period were:

1. We instituted a program of multiple magnetogram observation per day in order to reduce the solar noise introduced due to oscillations and supergranulation. The analysis of the velocity from this program shows systematic and reproducible structure in the previously poorly defined torsional oscillations. We believe these velocity structures play a critical role in the solar cycle of activity although this role is not yet understood.
2. We have developed several new polar oriented displays of the solar motion and magnetic fields. The magnetogram and dopplergram data can now be placed in a FITS format for analysis with standard software packages.
3. We resolved the high latitude velocity structure which was present for 18 months from the beginning of 1986 to the middle of 1987 into velocity components parallel and perpendicular to the solar equator. This structure is well described as a sheet flow over the north solar pole and rotated with a rate consistent with the polar rotation period.

Summary of Observational Programs

The major programs of observation which are continuing at the 150-foot tower include:

1. The synoptic observation of the solar magnetic field and velocity field using $\lambda 5250$ and $\lambda 5237$ is made daily in the format begun by Howard.
2. Drawings are made each morning of all sunspots on the solar image. Peak magnetic fields for each spot group are measured and included in a sunspot report that is updated monthly.
3. Scans of the solar velocity and magnetic fields are made throughout the day at roughly 30 minute intervals using both $\lambda 5250$ and $\lambda 5237$. These scans have coarser spatial resolution than the scans in 1.

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4. On most days the magnetogram/dopplergram program is interrupted for 1 to 2.5 hours to make spectral line profile scans of selected lines. The major emphasis in this program has been to measure the profile of the Na D₁ line in integrated sunlight in order to determine if the profile changes as a result of the presence of active regions. Resolved sunlight observations are made as part of this program to study the energy propagation properties of the oscillations at different altitudes in the solar atmosphere.

Programs 1 and 2 are continuations of the original programs that were in place during Howard's stewardship. Programs 3 and 4 are new initiatives begun by Ulrich.

Summary of Instrument Upgrades

The telescope and spectrograph are being developed and improved steadily as the program continues. As a result, the capability of the instrument and the quality of the data grows with each year of operation. Care is taken to maintain the continuity of the data stream during any instrument changes. Redundant backup units are normally purchased where feasible to avoid introducing any new single point failure modes.

Instrumental changes and improvements presently in progress include:

1. The grating assembly was unsatisfactory has been replaced. Installation of the new assembly occurred at the beginning of September 1990. The old assembly caused vignetting for grating tilts other than those close to the 58° required for λ5250 in 5th order. The trunion axis was inadequate to prevent the grating from creeping after it has been moved from one wavelength to another. The acquisition of different spectral lines was difficult because of the imprecision of the grating tilt. These problems were solved in the new design. A complete report describing this new system has been published in Solar Physics.
2. A new KDP polarizer assembly has been completed and is being installed. The old KDP which is still in use requires a voltage at the limit of the high voltage power supply. Under these conditions the power supply is not adequately controllable and we are unable to adjust the voltage swings to provide a precise ±λ/4 change in the retardance. The errors in the control of the KDP produce a sensitivity to linear polarization which causes a diurnally variable global magnetic field. The new KDP has a higher sensitivity to electric field so that the operating voltage is within the capacity of the power supply and the system can be properly adjusted. Although the polarizer assembly is complete, it is being modified to allow a precise control of the orientation of the critical components during its alignment.

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Publications from Project Studies

- Bahcall, J.N. and Ulrich, R.K. 1988, *Rev. Mod. Phys.* **60**, 297
- Damé, L., Ulrich, R.K., Martic, M. and Boumier, P. 1990, in: *OJI Seminar on Progress of Seismology of the Sun and Stars - Hakone, Japan, December 11-14, 1989, Lecture Notes in Physics*, ed: H. Shibahashi, (Springer-Verlag, New York), p. 265.
- Korzennik, S.G., Cacciani, A., Rhodes, E.J., Jr. and Ulrich, R.K. 1990, in: *OJI Seminar on Progress of Seismology of the Sun and Stars - Hakone, Japan, December 11-14, 1989, Lecture Notes in Physics*, ed: H. Shibahashi, (Springer-Verlag, New York), p. 341.
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- Ulrich, R.K., Boyden, J.E., Webster, L. and Shieber, T. 1988, in: *Seismology of the Sun & Sunlike Stars*, ed: V. Domingo and E.J. Rolfe, (European Space Agency SP-286, Noordwijk, The Netherlands), p. 325.
- Ulrich, R.K., Boyden, J.E., Webster, L., Snodgrass, H.B., Gilman, P.I., Padilla, S.P., and Shieber, T.L. 1988, *Solar Phys.* **117**, 291
- Ulrich, R.K., Webster, L., Boyden, J.E., Magnone, N. and Bogart, R.S. 1991, *Solar Phys.* **135**, 211

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Contract/Grant Title: Solar Magnetic and Velocity Field Measurements Using the 150-foot Solar Tower on Mt. Wilson
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- a. Number of Papers Submitted to Referred Journal but not yet published: 0
b. Number of Papers Published in Referred Journals: 8
(list attached)
c. Number of Books or Chapters Submitted but not yet Published: 0
d. Number of Books or Chapters Published: 1
(list attached)
e. Number of Printed Technical Reports and Non-Refereed Papers: 4
(list attached)
f. Number of Patents Filed: 0
g. Number of Patents Granted: 0
(list attached)
h. Number of Invited Presentations at Workshops or Prof. Society Meetings: 0
i. Number of Presentations at Workshops or Prof. Society Meetings: 0
j. Honors/Awards/Prizes for Contract/Grant Employees: 0
(list attached)
k. Total number of Graduate Students and Post-Docs Supported at least %25
this year on this contract grant: Grad Students: 0 Post Docs: 0

Grad Student Female: 0
Grad Student Minority: 0
Grad Student Asian e/n: 0
Post-Doc Female: 0
Post-Doc Minority: 0
Post-Doc Asian e/n: 0

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Papers Published in Refereed Journals

- J.N. Bahcall, R.K. Ulrich 1988, "Solar models, neutrino experiments, and helioseismology", *Rev. Mod. Phys.* **60**, 297
- Korzennik, S.G. and Ulrich, R.K. 1989, "Seismic Analyses of the Solar Interior I. Can Opacity Changes Improve the Theoretical Frequencies?", *Astrophys. J.* **339**, 1144
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- Ulrich, R.K., Damé, L. and Martić, M. 1991, "Possibilities for Quantification and Reduction of Solar Velocity Noise Induced by Active Regions", in *COSPAR Proceedings, Helioseismology from Space, Advances in Space Research, Vol. 11, No. 4*, ed. B. Foing, (Pergamon Press, New York), p. (4)203

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- Rhodes, Jr., E.J., Brown, T.M., Cacciani, A., Korzennik, S.G. and Ulrich, R.K. 1991, "Measurements of Intermediate- and High-Degree ($20 < \ell < 60$) p-Mode Solar Oscillation Power and Energy", in *Challenges to Theories of the Structure of Moderate-Mass Stars*, ed. D. Gough and J. Toomre, (Springer-Verlag, Berlin), p. 277
- Rhodes, Jr., E.J., Cacciani, A., Korzennik, S.G. and Ulrich, R.K. 1991, "Further Evidence for Radial Variations in the Solar Equatorial Angular Velocity Profile", in *Challenges to Theories of the Structure of Moderate-Mass Stars*, ed. D. Gough and J. Toomre, (Springer-Verlag, Berlin), p. 285
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