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13. ABSTRACT *(Maximum 200 words)*

This grant has supported a number of different activities related to the primary Air Force grant F49620-95-1-0008, "Environmental Conditions Responsible for Solar Activity." Under this AASERT grant, students Frankie Liu and Aaron Birch approached several problems relevant to solar activity. Liu calculated the coronal magnetic field from vector magnetograph data when the field is assumed to be force-free but not current-free. Liu solved the problem by the method of "simulated annealing." This approach led to the development of a program that quickly converged to a stable configuration, leading to a resolution the 180-degree ambiguity in the transverse component of the magnetic field. Liu also worked on the general problem of coronal heating by analyzing images from the Yohkoh SXT X-ray telescope. Liu's analysis confirmed the conclusion drawn from earlier studies that the heating occurs at a considerable height above the solar surface, certainly above 0.5 solar radius for the region investigated. Liu concluded that, in open field regions, the mechanism of coronal heating is closely related to the mechanism that drives the solar wind. Finally, Liu investigated whether fast magnetoacoustic waves, generated from the chromosphere or below, can couple into slow magnetoacoustic modes which can dissipate their energy in the corona. Liu found that the coupling is small, so that this process is not promising as an explanation of coronal heating.

14. SUBJECT TERMS
"Helioseismology"; "vector magnetograph"; "yohkoh", "soho", "coronal heating," "magnetoacoustin waves', "solar activity"

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Augmentation Awards for Science & Engineering Research Training (AASERT)

Determining the Magnetic Environment in which Solar Activity Occurs

Final Technical Report

For the Period July 1, 1994 through June 30, 1998

Principal Investigator: Professor Peter A. Sturrock

Grant No.: F49620-94-1-0288

Program Manager: Dr. Henry R. Radoski

This grant has supported a number of different activities related to the primary Air Force grant F49620-95-1-0008. Student Frankie Liu took up a problem relevant to flare prediction, that of calculating the coronal magnetic field from vector magnetograph data, when the field is assumed to be force-free but not current-free. This is the problem of resolving the 180-degree ambiguity in the transverse component of the magnetic field. Liu approached this problem by the method of simulated annealing. A smoothness function was adopted in the role of the "energy" of the system. For this procedure, it was necessary to determine the tranverse field at a few locations. We chose locations at which the line-of-sight component was close to zero, and determined the sense of the transverse field from inspection of the gradient of the line-of-sight component. This approach led to the development of a program that quickly converged to a stable configuration, leading to a resolution the 180-degree ambiguity in the transverse component of the magnetic field.

Frankie Liu also worked for some time on the general problem of coronal heating. By analyzing images from the Yohkoh SXT X-ray telescope, we were able to obtain additional insight into the location of coronal heating in diffuse regions. This analysis confirmed the conclusion drawn from our earlier studies that the heating occurs at a considerable height above the solar surface, certainly above 0.5 solar radius for the region investigated. This leads to the conclusion that, in open field regions, the mechanism of coronal heating is closely related to the mechanism that drives the solar wind.

Liu also investigated a topic related to the problem of coronal heating. The question addressed was whether fast magnetoacoustic waves, generated from the chromosphere or below, can couple into slow magnetoacoustic modes which, as is well known, can dissipate their energy in the corona. It was hypothesized that this coupling might occur in the transition region, that separates the chromosphere from the corona, if the magnetic field has an oblique direction. A Lagrangian variational method was used to derive the equations of motion, from which a general dispersion relation was obtained. Also the relevant boundary conditions were established. In this way, we were able to calculate the coefficients of power reflection and transmission for the various modes. A number of cases were investigated by means of a computer program. It was found that the coupling is small, so that this process is not promising as an explanation of coronal heating.

As another project, Physics Research Student Aaron Birch studied helioseismology data obtained by the MDI experiment on the SOHO spacecraft to obtain further information about possible variations in the internal solar rotation rate, and the possible mechanism of long-lived active regions. In his analysis of the internal rotation rate, Birch used data from the MDI-SOI (Michelson-Doppler imager-solar oscillation investigation), GONG (Global Oscillations Network Group) and BBSO (Big Bear Solar Observatory) helioseismology data. Birch found that there is considerably more variability in the rotation rate in the polar regions than has been realized in the past. The rotation rate appears to be slowest during solar minimum and substantially higher during solar maximum. If this change in the surface rotation rate reflects changes deeper in the solar interior, over a wider range of latitude, it could help explain the changes that show up in time-series analysis of the solar activity parameters. These changes in rotation rate may also be related to the excitation of r-mode oscillations that we believe play an important role in modulating solar activity.

We have considered the possibility that long-lived active regions may be due to long-lived vortex tubes. It has not been possible to find evidence for or against this hypothesis in helioseismology data. However, we find that computer simulations of convection in the solar convection zone shows that the zone may contain vortex tubes of many scales, including large-scale coherent structures spanning the full vertical extent of the domain involving multiple density scale heights (Brummell et al. 1996). It appears that further study of helioseismology data and of simulations of the hydrodynamics of the convection zone could yield further information that would help understand some of the patterns in solar activity that show up in time-series analysis. This could give further insight into the mechanisms responsible for solar activity.