VI. SUMMARY AND FUTURE DIRECTIONS

OBSERVATIONAL NEEDS FOR PROGRESS IN SOLAR/STELLAR MAGNETIC ACTIVITY: OVERVIEW

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Recent observational and theoretical findings have clarified the physical mechanisms which underlie magnetic activity production in stars, and point the way naturally to a number of new or more crisply defined questions, whose answers can lead to major progress in the near future. Concerning observational programs, a guiding principle has been evident throughout this symposium: We should rely heavily on the Sun for understanding the detailed physics of magnetic activity and its generation, while at the same time we study analogous stellar phenomena for comparison with the Sun, and for new insights and extension to different regions. I list below some broad observational areas in which conditions seem ripe for important progress in understanding solar and stellar magnetic activity, leaving to other summarizers the discussion of particular observational programs.

1. SOLAR AND STELLAR INTERIORS

Solar "seismology" has given tantalizing hints of surprises in store, such as the possible existence of a rapidly rotating interior. This type of investigation holds great promise both for pinning down fundamental properties like the depth d_c of the convection zone and of the depth dependence of angular velocity $\Omega(r)$. Both are basic to understanding magnetic field generation.

Although the analogous stellar problem is vastly more difficult than that of solar seismology, the detection of stellar oscillations in the near future seems likely. Empirical determination of d_c or $\Omega(r)$ for another star may lie well in the future, but initial detection of the analogue of the spectrally unresolved "5-minute" solar oscillation will start us on the way.

On the Sun, the search for "giant cells", i.e. a large-scale circulation pattern, is continuing at improved levels of velocity sensitivity and precision, and one may hope for a definitive resolution of this important problem in the near future. It is imortant to continue efforts to determine convection-related properties at the surfaces of late-type stars, by analysis of line profile broadening and asymmetries. In addition, such studies can yield information on the surface differential rotation of relatively rapidly rotating stars (see below).

The above observations should not be confined solely to main sequence stars. Effects may be larger and more observable in giants, and the insights gained from the different gravity and internal structure of giants should provide further clues to the overall physical mechanisms involved.

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2. STELLAR ROTATION, DIFFERENTIAL ROTATION, AND ACTIVITY

The relation between rotation rate and activity needs to be extended to a large number of lower main sequence stars of varying degrees of chromospheric and coronal activity and age. This is required to build a convincing statistical picture of the relation between activity level, (i.e. chromospheric emission, coronal emission, surface magnetic fields, or other indicators) and rotation rate, spectral type, and age. Of particular interest is extending the data base to both earlier and later spectral types, as well as to very old and very young stars. In the latter connection, independent determination of stellar age is very important.

In the light of recent results on the rotation and differential rotation of the solar surface layers, and their variation with time, it is clear that further studies along this line stand to give us critically important information about the solar dynamo. In a complementary fashion, the vastly cruder information on differential rotation seen on some stars (both from line profile measurements as mentioned above and from rotationally-modulated light curves) represents potential key extensions of the data to different physical regimes. Observations spanning a stellar activity cycle could reveal cycle-dependent changes of mean rotation rate or differential rotation, if these are significantly larger than the Sun's.

3. ACTIVITY CYCLES

Needless to say, programs to study activity cycles, similar to the seminal long-term series of observations begun by Olin Wilson, should continue and be extended. Important questions which can be addressed include: where in the H-R diagram do cycles occur? How do their amplitude, period, cycle shape, or other attributes vary with rotation, age, and basic stellar properties? Are stellar analogues of the Maunder Minimum revealed by the statistics for cycles of other stars? It would be useful to study how other properties vary over stellar cycles, in addition to the Ca II emission by which they were originally discovered. Examples include: coronal emission levels, surface manetic fields, and spot areas, as well as the rotation and differential rotation parameters mentioned above.

4. SURFACE STRUCTURE OF MAGNETIC ACTIVITY

The realization that magnetic flux on the Sun is concentrated in flux bundles with field strengths of a kilogauss or more has significantly changed our understanding of surface activity, and of the underlying field generation mechanisms. Several times during the Symposium the need has been emphasized to resolve these flux knots completely, in order to delineate better their interaction with the convective motions below, and with heating of the structured atmosphere above. This objective is a key application of new high resolution techniques under development for both space- and ground-based observations.

On main sequence stars, significant spatial resolution does not seem directly attainable in the near future. Nevertheless, much information is potentially available in rotationally-modulated light curves, concerning: longitude and latitude distribution of activity, size and brightness (or darkness) of chromospheric plages (or spots), strengths and area coverage of photospheric magnetic fields, lifetime of active regions or spots, and growth and decay properties of surface magnetic activity. The rich store of information available for such data is just beginning to be tapped.

All in all, it appears that research into solar and stellar magnetic activity continues to be an area driven heavily by observations. It is abundantly clear from present observational opportunities that this situation will continue for some time to come. It is creative observers, always with due regard to the theoretical implications of their work, who will lead and in some cases define the new attacks on one of astronomy's most fascinating research areas.

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