7. STAR CLUSTERS IN THE MAGELLANIC CLOUDS

Chairman: P. Demarque

Supporting Commissions:

28, 35, 37

A report of this Meeting will appear in Transactions of the International Union, Volume XXB, as part of the report of Commission 37, Star Clusters and Associations.

https://doi.org/10.1017/S1539299600008649 Published online by Cambridge University Press

ADDITIONAL JOINT COMMISSION MEETING

https://doi.org/10.1017/S1539299600008649 Published online by Cambridge University Press

SYSTEMATIC OBSERVATIONS OF THE SUN

A Joint Commission Meeting in honour of

HELEN DODSON PRINCE

Chairmen and Editors: J.C. Pecker and P. Wilson

Supporting Commissions:

10, 12

COMMISSIONS 10 and 12
SYSTEMATIC OBSERVATIONS OF THE SUN

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This meeting was dedicated to Helen DODSON-PRINCE who has contributed so much to the field. Unfortunately, she was unable to attend the General Assembly, but a telegram has been approved by acclamations and sent to her, expressing to our colleague and friend the deep admiration and the friendly feelings of the solar community, as gathered in Baltimore.

SUMMARY

One can say that, from the one-day discussion, there emerged two challenges, one scientific and the other one science-political.

The scientific challenge has several aspects. Firstly, the purely MHD treatment of solar magnetic fields cannot yet provide a satisfactory diagnosis of solar synoptic magnetic observations. Secondly, the convective structure of the Sun and its relation to magnetic phenomena is still uncertain. Models of both doughnut-shaped toroidal cells and banana cells have been proposed but it is far from clear whether one or other should be preferred at all times and latitudes or whether transitions may occur from high to low latitudes and at different phases of the solar cycle. Finally, the equatorward migration of solar phenomena oven an 18-22 year period, which has been referred to as the "extended cycle", has been contrasted with suggestions that the cyclic phenomena may operate, to some extent, independently at low and high latitudes.

The science-political challenge is to organize and coordinate a Solar Synoptic Network (SSN) of observatories located at appropriate longitudes and dedicated to the daily pursuit of synoptic studies of active phenomena, both to follow the physics of individual centers and to record consistently the long-term variations of the observable

D. McNally (ed.), Highlights of Astronomy, Vol. 8, 671–678.

parameters of the cycle.

1. OBSERVATIONS (morning session)

The observational papers covered a wide range of phenomena.

1.1. P. McINTOSH compared the properties of Hα synoptic charts and synoptic magnetic maps generated by solar magnetographs. Data from 23 years were used to argue that the large-scale magnetic fields originate from giant-cell, convectively-driven sources of magnetic flux, and that they are continually renewed by weak flux eruption rather than by diffusion from sunspots. He found that long-lived patterns of polarity create boundaries which are preferred locations of the stronger active regions, and the centers of certain of these patterns are preferred locations for coronal holes which play an important role in the cycle. He suggested that the cycle can now be defined independently of sunspots by observing the changes in rotation rate, wavenumber, and pattern scale of large-scale magnetic fields, and that poleward-moving and equatorward-moving patterns co-exist among the patterns obtained from Hα synoptic charts.

1.2 H. SNODGRASS then discussed the large-scale velocity fields. He outlined the problem of differentiating between the several components of the large-scale velocity fields (i.e. rotational, longitude-dependent azimuthal, meridional, and radial flows). He noted the problem of the limb-effect, whereby the nett blue-shift of lines observed near disk center results in an apparent red-shift of lines near the limb. He then discussed the different indicators of rotation and differential rotation, noting that the supergranule rate is significantly greater than that obtained from other tracers and from spectroscopic data. Finally, he showed that contour plots of the greater-than-average shear zones correspond closely to the butterfly diagram in sunspot latitudes, but extend backwards in time to higher latitudes, so that the preceding component of the butterfly diagram is overlapped, forming a "herringbone diagram".

1.3. Z. MOURADIAN discussed systematic local deviations from the mean differential rotation. Using filaments as tracers, he showed that in many cases they are not drawn out by the differential rotation but mark limited regions of rigid rotation which rotate about a central or "pivot point" during several solar rotation. He pointed out that activity centers frequently appear close to pivot points, whereas filaments exhibiting the normal differential rotation show no similar correlation. He argued that the activity centers may emerge as a consequence of local dynamos and that the pivot point may be the surface signature of the associated velocity fields.

https://doi.org/10.1017/S1539299600008649 Published online by Cambridge University Press

1.4. Z. MOURADIAN then presented a contribution on magnetic tracers of convective patterns, on behalf of E. Ribes. Using observations of the meridional motions of young sunspots and of predominantly east-west oriented filaments, she has the suggested existence of azimuthal convective rolls, having mean plasma velocities 15-20 m s^{-1}, lifetimes 2-3 years, typical sizes 200,000 km and exhibiting alternate magnetic polarities. The rolls first appear some two years after sunspot minimum at mid-latitudes, following the appearance of major activity phenomena, and subsequently appear at lower latitudes as the emerging active regions trace out the butterfly diagram. She suggested that the rolls reach the polar regions shortly after sunspot maximum and contribute to the polarity reversals.

1.5. K. HARVEY compared the statistical properties of ephemeral active regions (ERs) (areas in the range of 0.3-5.0 sq.deg.) and small active regions (ARs) (areas $\geq$ 2.5 sq.deg.). Although the number distributions of the two populations are different, they vary with the cycle in a similar manner, so that the differences are maintained. She found that, while ERs occur at all latitudes throughout the cycle, there is statistical evidence for a distinct high-latitude population in which the emerging ERs tend to adopt orientations consistent with the Hale-Nicholson law for the following cycle. Further, she found that small ARs, exhibiting a clear tendency to a similar orientation, appeared at mid-latitudes as early as 1982, suggesting that the new cycle 22 was in operation at that time.

1.6. This suggestion was supported by R. ALTROCK, who reviewed the coronal green line emission data of Trellis and others during cycle 19 and more recent results from cycle 20 and 21 obtained at the N.S.O. When plotted on synoptic charts, these data show a close correspondence with the butterfly diagram at low latitudes and a high-latitude component which, from the maximum to sunspot latitudes and appears to connect smoothly with the low-latitude component. However, in the N.S.O. data, Altrock found that, at the minimum between cycles 20 and 21, a bifurcation occurred and a high-latitude branch proceeded from mid-latitudes towards the poles, closely parallelling the "rush to the poles" of the polar crown filaments. He has also discussed the apparent occurrence of a double maximum in the total emission when averaged over several cycles, but concluded that this was not a real property of individual cycles.

1.7. P. SIMON presented a review by himself and J.-P. LEGRAND describing the behaviour across the cycle of coronal holes, solar wind streams and geomagnetic disturbances. These long series of solar and solar-related data can be used to study the cyclic behaviour of the toroidal and poloidal components of the solar magnetic field. Estimating the strength of the toroidal field from the sunspot number at maximum and the poloidal component from the maximum intensity of the solar dipole and the thickness of the helioneutral sheet, he defined an integrated magnetic field cycle. The poloidal component begins at mid-latitudes after sunspot maximum and builds towards the maximum of the solar dipole which occurs at the commencement of the following sunspot cycle and is followed by the development of the associated toroidal field. Thus the duration of the magnetic cycle is 17-19 years but its periodicity is ~ 11 years.

1.8. G. ALISSANDRAKIS then reviewed the radio-data, coming from interferometric E-W Nançay data, and from 2-dimensional images (Culgoora, Nançay, Clark Lake), as a source of information from a large range of altitudes. These data show well the coronal holes and emission regions. In particular, Earth's rotation aperture synthesis maps (Nançay, 169 MHz) show that solar emission comes from coronal holes, arch regions associated with the neutral magnetic line, and weak type I continuum, and the correlation with K-coronameter synoptic charts is good. The maps at metric and decametric wavelengths are the *only means* of studying the physical conditions of coronal features and their long-term variability from disk observations. They permit studies of the correlations between coronal structures and their chromospheric and photospheric counterparts and can be used to determine the position of the base of the heliosheet and the physical conditions therein.

1.9. Finally, H. NECKEL reported on variations of photospheric features, describing a long-term program, started in 1986 by himself and D. Labs at Kitt Peak, to record regularly during cycle 22, the solar limb-darkening at selected continuum wavelengths and high-resolution spectra (FTS) in the 330-400 nm band. The 1986-7 results and earlier observations (1981, CLV of 2 nm-wide spectral bands) revealed unexpected short-term variations of the intensities along the observed diameter, with amplitudes up to 1 % in the continuum, and up to 2 % in the 2 nm spectral bands. Time scales range from minutes to days. The spectra show related changes in line profiles and in line wavelengths.

1.10. The observational session concluded with the announcement of the following poster presentations by their authors: P. PETROPOULOS, in a poster with X. POULAKIS, described the distribution of solar flares for the period 1986-7. M.H. GOKHALE commented about sunspot activity as originated from interference of solar global magnetic oscillations. SIVARAMAN presented a review and a discussion of the long series of synoptic observations of the Sun at Kodaikanal. Finally, J. PAP has shown how the solar irradiance variations (as measured by SMM/ACRIM) are related to different active events, notably to emerging new activity.

https://doi.org/10.1017/S1539299600008649 Published online by Cambridge University Press

2. MODELLING IMPLICATIONS (afternoon session)

2.1. P. WILSON discussed the implications of high-latitude data. He described two fundamentally different approaches to an understanding of cyclic phenomena; in one, a magnetic wave is generated by an unknown mechanism below the convection zone and, in the other, a dynamo operates within or at the base of the convection zone. He pointed out that, in the first approach, the surface phenomena are the incidental by-products of the mechanism, which remains "obscured" by the convection zone. However, in the second, the surface fields and their subsurface connections are, through their interaction with the convective and rotational motions, an essential part of the mechanism. Clearly, observations assume a greater significance in the latter approach.

Wilson then surveyed the high-latitude data which, on synoptic charts, exhibit negative latitude gradients and appear to run smoothly into the corresponding low-latitude patterns. Since the latter coincide with the butterfly diagram for the next cycle and the high-latitude ERs and small ARs tend to exhibit orientations appropriate to that cycle, these data suggest that the high-latitude components are part of an extended overlapping cycle, in which case relaxation models such as that of Babcock are excluded.

However, Wilson noted an alternative view in which the low-and high-latitude components operate independently of each other, having opposite magnetic signatures and this view was later argued by P. Gilman. Wilson stressed that the resolution of this question is of considerable importance, pointing out that the first view supports the concept of a propagating dynamo wave in the form of magnetic toroids (two per hemisphere), as first proposed by Parker. He also showed that a doughnut roll model of the fundamental mode of convection yields the appropriate direction of propagation (towards the equator). Nevertheless, it is well known that some phenomena (e.g., the polar crown) propagate polewards, which suggests that a more complex system of dynamo waves is operating. Wilson argued that the polar field reversals may provide a crucial test for the various models and that careful observations of the details of the reversals should have a high priority.

2.2. P. GILMAN then presented a review on "theory and observations of the solar cycle, and global circulation". He pointed out that global convection models for the solar convection zone do produce about the right differential rotation. The driving convection takes the form of rolls with north-south axes near the equator, which transport angular momentum towards the equator from high latitudes, and he showed that

https://doi.org/10.1017/S1539299600008649 Published online by Cambridge University Press

axisymmetric meridional circulations are very weak in such models.

However, these models also predict angular velocity decreasing with depth, and nearly constant on cylinders concentric with the rotation axis, and Gilman pointed out that recent estimates of interior rotation of the Sun, derived from oscillation measurements, indicate there may be very little radial gradient of angular velocity in the convection zone. This raises problems for the global convection models and suggests an interior rotation rate intermediate between the maximum and minimum surface rates. He referred to recent work by Cherilynn Ann Morrow which suggests a near balance of torques between the convection zone and interior, with low latitudes of the convection zone attempting to pull the interior ahead, while high latitudes are pulling it back. There is therefore a cycling of angular momentum between the convection zone and the interior, with a necessary flow of angular momentum from low latitudes to high within a transition zone just below the convection zone.

Gilman noted that the so-called α-ω dynamos, applied to the solar convection zone, can produce the correct solar butterfly diagram only if the angular velocity increases with depth within the convection zone, whereas global convection models predict instead a decrease with depth. Thus the oscillation measurements which indicate zero gradient, along with other considerations, led him to suggest that the seat of the solar dynamo is at the interface between the convection zone and the interior. He described how strong radial gradients of rotation in the interface region, of opposite sign in low and high latitudes, as inferred from the oscillation measurements, coupled with helicity pumped into this region from the convection zone above, could drive a solar dynamo with the appropriate butterfly diagram.

Gilman raised questions about the evidence for an extended solar cycle. In particular, he argued that the torsional oscillation measurements in low and high latitudes may not indicate a true migration from high latitudes to low. He also displayed recent data from Mt. Wilson (provided by Ulrich) suggesting the possibility of a longitude dependence of the torsional signal, and thus raising doubts about its axisymmetric nature. He introduced the question of magnetic contamination of the torsional oscillation signal and emphasized how small the torsional oscillation signal is as a Doppler shift -about 0.1 mÅ. Gilman also argued that evidence for an extended cycle in coronal data took insufficient account of poleward migration of coronal features, and put forward an alternative explanation of the equatorward migration in terms of changes in time of the "tilted dipole" in the large-scale solar magnetic fields. He also gave his opinion that the evidence for an extended cycle in the ephemeral regions data was a very minor and uncertain effect, suggesting instead that the occurrence of ephemeral regions seems to be nearly uniform with latitude and varies over all latitudes by a factor of 2 or 3 during the solar cycle. He suggested that dynamo theories should concentrate on explaining these large amplitude effects, rather than the much less certain signals suggesting an extended cycle.

2.3. There followed a vigorous discussion in which several speakers took issue with some of Gilman's arguments. Snodgrass asserted that the problem of the magnetic contamination of the Doppler signal had been resolved. Altrock rejected the criticism of the coronal data and pointed out that no mechanism had been put forward to support the tilted dipole model and that it was not supported by the data. Clearly the question is still to be conclusively resolved.

3. FUTURE WORK (afternoon session, second part)

W. LIVINGSTON first presented the case for the establishment of a Solar Synoptic Network of observatories (or a SSN) situated at appropriate longitudes, which would work towards the continuous study of the evolution of solar activity phenomena and large-scale features over periods which are not limited by the observing day at a single observatory.

An open discussion followed during which all participants agreed on such a need in particular Gurtovenko, Ai, Hiei and Sivaraman; and most of them openly regretted the closure of the operations of several solar observatories, including the radio interferometers in Culgoora and Clark Lake, at sensible longitudes. In particular, K. ZWAAN noted that, in order to get a SSN started, it is essential to restrict combined observing programs to the data that are really needed to follow the variable Sun and to back-up other programs. He emphasized that truly synoptic programs should be distinguished from campaign-type programs that also require a network of facilities, but that explore either transient phenomena or phenomena with time constant less than one year and that do not need full-disk data. As to the synoptic program, the features to be observed should be rated according to priorities and the required time resolution established in a modest fashion. Campaing-type programs may use some or all of the SSN instruments and may involve many of the scientists taking part in the synoptic program. In this way, SSN may be, according to Zwaan, a stimulus for a very broad sector of solar physics. But a first priority in setting up a SSN is a draft for a contained and truly synoptic program. It was agreed, in the discussion, that all astronomers interested in the SSN should contact Livingston. The participants of the meeting stressed the importance of the resolution voted by Commissions 10 and 12 concerning the pursuit and development of solar observations. The need to continue to observe solar eclipses has also been expressed, notably by E. HIEI.

In conclusion, and coming back to the confrontation between theory and observations of the solar cycle, L. PATERNO (who had chaired section 2) noted that the knowledge of the structure and evolution of the Sun is of overwhelming importance for understanding stellar phenomena: at the present, we have to fit more than two observational constraints of luminosity and radius, which are easily fitted, by varying two free parameters (as the helium abundance and mixing-length ratio) of the theory of convection, in the classic evolutionary models of the Sun. Paterno then noted that the recent large flows of good quality helioseismological data and the consequent very accurate determination of the p-mode spectrum, together with the features of the internal dynamics, impose new constaints to be satisfied. The comparison of the calculated eigenfrequencies with the observed ones indicates, indeed, that the present models of the Sun are basically wrong in the very inner and outer layers. The inversion of the helioseismological data has shown that the interior of the Sun rotates essentially as a rigid body, except perhaps in the very inner core, where the p-mode probing fails. The consequences of this discovery raise very important questions concerning the possible existence of a magnetic field in the Sun's core, the history of the solar angular momentum and the location of the source of the solar activity. Paterno therefore emphasized the need to turn towards three-dimensional models of the solar structure and, by consequence, of the stellar structure, in cases where stars exhibit magnetic activity and star spots. In order to achieve this goal, Paterno noted that highly accurate g-mode observations from space are needed. They would represent the key for penetrating the details of the structure and dynamics of the inner core, essential for understanding the physical mechanisms operating in the stars.

The meeting was then adjourned.