10. SOLAR ACTIVITY (ACTIVITÉ SOLAIRE)

PRESIDENT: V. Bumba SECRETARY: R. Howard
VICE PRESIDENT: E. Tandberg-Hanssen
ORGANIZING COMMITTEE: R. J. Bray, M. Dryer, O. Engvold, J. Harvey, G. Newkirk, Jr., M. Pick, D. Rust, V. E. Stepanov, H. Yoshimura, H. Zirin

This report summarizes research on solar activity over an almost three-year period from January 1, 1979, till the end of June 1981. In preparing this report we respected the advice of the I.A.U. Executive Committee to cover the highlights of work carried out in the field of solar physics relevant to our Commission, and avoiding double work. Only a limited space was made available for our Commission. Given this restraint we tried to produce a comprehensive review. With great pleasure I appreciate the excellent cooperation of the members of our Executive Committee in the preparation of this report.

During the period covered by the present report numerous solar international symposia, colloquia and workshops, as well as several world-wide solar observation campaigns demonstrated the growing importance of the solar activity phenomena for understanding of many astrophysical problems. At the XVIIth General Assembly of our I.A.U. in Montreal, the Joint Discussions have demonstrated that the majority of stars in our Galaxy have not only their chromosphere, the transient regions and coronae, but that they also lose their mass due to stellar winds. Recently, for example, during the Second University College London Astronomy Colloquium on "Solar and Stellar Magnetism and Rotation" held in the Cumberland Lodge, Windsor, it has been shown that most of these stars produce magnetic fields responsible for their stellar activities and correlated with their rotational velocities - practically of the same type like the solar one. To give an example - the results reported by R. W. Noys indicate that stellar active regions sometimes grow or decay over time-periods of weeks to months. For some stars, active longitudes tend to persist over remarkably long periods. These persistently active longitudes are sometimes accompanied by episodes of a more short-lived activity at totally different longitudes etc.

For all these reasons we believe that the reviews presented below may be of interest not only for solar physicists alone.

1. THEORY OF SOLAR CYCLE
(H. Yoshimura)

The ultimate goal for a theory of the solar cycle would be to construct a model that reproduces and predicts every detail of various characteristics of the solar cycle. The model may be in form of a set of equations and its solutions or in form of a computer code. Once such a model is constructed, it must be able to describe time-varying stellar magnetic activities similar to the solar cycle by handling a set of parameters that characterizes a particular star. Present status of our knowledge of the solar cycle is far from this goal. To near this goal, however, basic mechanisms that drive the machinery of the solar cycle are being elucidated one by one and important concepts are being built up. During the three years period reported here, active endeavors have been done along several fronts with different kinds of approximations and simplifications. The concepts developed for the solar cycle are now being applied to understanding of stellar variability (Belvedere et al,AA 88, 240; 91, 328; Stix,GAFD, in press; Durney et al, PASP, in press; Durney and Robinson, Ap J, in press; Robinson and Durney, preprint). Several good monographs related to the problem were published in the period (Krause and Rädler, Mean-Field Magnetohydrodynamics and Dynamic Theory, Pergamon Press; Moffatt, Magnetic Field Generation in Electrically Conducting Fluids. Cambridge Univ. Press; Parker, Cosmical Magnetic Fields, Clarendon Press). Various reviews related to

https://doi.org/10.1017/S0251107X00004491 Published online by Cambridge University Press

theory of solar cycle appeared in the symposia held in the period on the same and related subjects.

In order to understand the diversity of the various opinions and approaches to the problem, we must keep in mind that degree of advancement of one approach, and understanding of the phenomena of a researcher involved in the approach, can be considerably different. A theory, however, which might be regarded as too primitive at its present stage of development, might provide some important concepts to the major advancement of understanding of the solar cycle.

A model of the solar cycle must be derived from first principles of physics with given mass, chemical composition, and angular momentum distributions of the proto-Sun. This task is formidable and almost impossible at present since we must trace every detail of motions of various particles and fields. In these circumstances, we start from averaging the basic equations that describe the first principles of physics. Averaging the equations over some macro-space and time (continuum approximations), we get equations of magnetohydrodynamics (MHD) with molecular viscosity and diffusivity. Since considerably hierarchy of scales exists in structure and behaviour of flows and fields of the Sun, we need further averaging process to smooth out effects of flows and fields whose scales are smaller than those we have in mind. The concept of mean magnetohydrodynamics (MMHD) has emerged in such an averaging process. In these conceptional manipulating procedures, we like to believe that there exists another kind of basic principles that govern macro or global dynamics of the Sun and of any other physical systems. Thus we go in quest of the new kind of basic principles. This is especially important when we study *nonlinear self-organization of various kinds of physical systems. The solar cycle* with its long-term behaviour is now regarded as one of such nonlinear systems.

One front of theoretical research that demonstrates ability to reproduce and predicts various characteristics of the solar cycle to a considerable degree are the $\alpha-\omega$ dynamo theories. These theories take the standpoint that the magnetic field responsible for the solar cycle is generated by MHD dynamo driven by flows of differential rotation and helical convection. The latter is a conceptional name which represents convection that lacks symmetry with respect to the rotational axis. The theories have been treated by MMHD. The basic question we now have is what kinds of convection inside the Sun actually correspond to the helical convection. One class of theories treats it as turbulent convection assuming that granulation and/or supergranulation correspond to it. This class of turbulent dynamo theories has been criticized by Piddington (Ap J 247, 293) and Layzer et al (Ap J 229, 1126) mainly on two reasons. First, physical mechanisms of turbulent diffusion in terms of molecular diffusion are not well established. Second, the turbulence and the magnetic flux ropes observed on the Sun are roughly of equal size; MHD interactions between such fluid motions and magnetic fields are highly nonlinear and it is not straightforward to see whether or not the approximations adopted in the formulation of the theories are valid for the case of the Sun. Also, it is not clear whether the turbulence works as a dynamo or as a diffusive medium (Meneguzzi et al, preprint, submitted to PRL). Observations of dispersal of global scale magnetic features in 1960's have suggested that granulation and supergranulation work as diffusion media over a long time scale. The other class of theories regards the global convection as the helical convection responsible for the dynamo. Long-term efforts have been made to detect its velocity fields on the Sun directly by Doppler effects but nobody has succeeded yet (LaBonte and Howard, SID, 21; Howard and LaBonte, Ap J 239, 738; Gilman and Glatzmaier, Ap J 241, 793; LaBonte et al, preprint). The question we have is whether it exists only in the deep part of the convection zone; no suitable method is devised yet though it penetrates to the surface and is observable in principle (Stix, AA 93, 339). A subgroup of this class treats the problem by an MMHD procedure averaging MHD over longitude and over a time scale long enough to smooth out the effects of individual features rotating with the Sun. The dynamo equations obtained by this procedure are similar to those of the turbulent $\alpha-\omega$ dynamos or even to those of the phenomenological Babcock-Leighton model. This subgroup can bypass the criticism against the turbulent $\alpha-\omega$ dynamos to some degree. The flows of the differential rotation and the global convection are large enough to carry the individual

https://doi.org/10.1017/S0251107X00004491 Published online by Cambridge University Press

magnetic flux ropes observed on the surface as if they represent conceptional individual magnetic field lines. However, turbulent diffusion is necessary to understand the coherent hebaviour of the overall magnetic system demonstrated by the Butterfly Diagrams and Hale's polarity rules of sunspots. Surprisingly, the $\alpha - \omega$ dynamos equations either formulated by the turbulence theories or by the global convection theories can reproduce various characteristics of the observed solar cycle to an impressive degree. This suggests that the dynamo equations have captured basic processes of the solar cycle and can be a milestone to approach the goal of finding a new kind of basic principles that govern the solar cycle.

Major observational aspects of the solar cycle that were studied by the equations during the reported period are the following: (i) Long-term behaviours of the solar cycle with its hypothetical 80-year modulation and other longer time-scale modulations with prolonged eras of low state of activity like Maunder Minimum were interpreted for the first time as intrinsic properties of a nonlinear system of magnetic oscillations of the solar cycle: A new period amplitude relation of the solar cycle was predicted by the theory and verified by an analysis of the sunspot relative number curve (Yoshimura, Ap J 226, 706; 227, 1047). However, the remarkable degree of stability of the phase of solar cycle oscillations suggests that the hypothetical chronometer of Dicke (N 276, 676; 280, 34; NS 1979, July 12) could be provided by the nonlinear oscilating dynamo. The properties of the nonlinear oscillations of the solar cycle with its similarity to the geomagnetic reversals were studied using simpler systems of equations (Bräuer, AN 300, 43; 301, 203; Kleeorin and Ruzmaikin, GAFD 17, 281; Ruzmaikin, CAp 9, 85; Yoshimura, Ap J 235, 625; Krause and Roberts, ASR 1, 231). (ii) Torsional oscillations of the Sun in close association with the solar cycle (Howard and LaBonte, Ap J 239, L83) were interpreted in terms of forced oscillations driven by the solar cycle Lorentz force waves (Yoshimura, J-FS; Ap J 247, 1102; Schüssler, AA 94, L17). The 11-year period of the oscillations were regarded as an evidence to exclude the possibility that 22-year period oscillating meridional circulations might drive the solar cycle (Weiss, AS). (iii) It was pointed out that the present formalism of the $\alpha - \omega$ dynamos cannot distinguish between dipole and quadrupolar parities with opposite and same polarities in the northern and southern hemispheres (Belvedere et al, AA 86, 40). This remains a problem for further research. Theoretical efforts to further the formalism of the turbulent dynamos were deployed (Wälder et al, JFM 96, 207; Rädler, AN 301. 102).

Another subgroup of the $\alpha - \omega$ dynamos undertakes large scale projects to simultaneously solve MHD equations for the flows and magnetic fields associated with the differential rotation and the global convection without averaging over longitude (Gilman and Miller, Ap J Sup 46, 211; Gilman in WCSSSS, in press; Cuong and Busse, PEPI 24, 272). However, this subgroup has not reached the point yet to be able to simulate the solar cycle. In connection with these projects, studies to understand the dynamics of the differential rotation and the global convection advanced (Gilman and Foukal, Ap J 229, 1179; Gilman, Ap J 231, 284; Gilman and Glatzmaier, Ap J Sup 45, 335; Glatzmaier and Gilman, Ap J Sup 45, 351, 381; Geiger and Busse, GAFD, in press). Efforts to determine dynamical structure of the differential rotation in depth and in latitude with different formalisms also advanced (Durney and Spruit, Ap J 234, 1067; Belvedere et al, GAFD 14, 209; Schmidt, Thesis of Univ. of Freiburg). No definitive conclusion as to the structure of the differential rotation was reached from the studies yet. Also, an effort to solve the dynamics of the flows and the fields simultaneously within the context of a turbulent $\alpha - \omega$ dynamo was undertaken (Schüssler, AA 72, 348). These theories also adopt averaging over a certain space and time and represent the effects of unresolved flows and magnetic fields by turbulent viscosity and diffusion. Thus the theories are a part of MMHD although the equations are similar to those of MHD with molecular viscosity and diffusivity.

Among the effects of unresolved features, the dynamical role of magnetic flux tubes in the global dynamics is important. After studies of flux tubes (Schüssler, AA 71, 79; 89, 26), Schüssler (N 288, 150) proposed a simple model of the solar cycle incorporating the role of the flux tubes in the model. He interpreted two of the important observational findings in the reported period in terms of the rise time of flux tubes from a fixed layer where the toroidal field is generated and carried to the surface; the anticorrelations of appearance of X-ray bright points (Golub et al, Ap J L229, L145), and of brightness variations of sunspots (Maltby and Albregtsen, Ap J L234, L147; Albregtsen and Maltby, SP 71, 269), with the solar cycle. Contrary to the interpretation in the model, however, ephemeral magnetic regions vary with the solar cycle (Martin and Harvey, SP 64, 93). Similar conjecture but with different interpretation based on the dynamo near the bottom of the convection zone was proposed by Golub et al (Ap J 243, 309) on the implication of X-ray bright points and the role of the magnetic flux ropes. In various different models, Gokhale (KOB A 2, 217, 222, 224; Bratenahl and Baum, SID 29; Piddington, AUP 32, 671) studied the role of the magnetic flux ropes in the dynamics of the solar cycle.

An important but controversial issue for the theory of solar cycle is the luminosity and its associated radius and temperature variations. Prior to the reported period, the theory of the solar cycle was primarily concerned with the origin and evolution of magnetic and velocity fields. Since nonlinear feedback of the generated magnetic fields on the convection requires a solar cycle associated modulation of thermal structure of the convection zone, it was expected that total heat flux must vary with the 11-year solar cycle and/or its 55-year (or 80-year when only amplitude is taken into account) cycle; the latter would be more prominent if the former is smeared out by convective processes (Yoshimura, Ap J 220, 692; 226, 706). Although simple models were investigated using the mixing length theory of convection (Sofia et al, SC 204, 1306; Thomas, N 280, 662; Dearborn and Blake, Ap J 237, 616; Spiegel and Weiss, N 287, 616; Gilliland, N 286, 838), it is not clear yet theoretically how and to what a degree the total heat flux change occurs and how it manifests itself as radius, temperature, and luminosity changes. In such circumstances, we must rely on observations. Extensive observations and analyses were and are now being performed for radius (Eddy and Boornazian, BAAS 11, 437; Shapiro, SC 208, 51; Wittmann, SP 66, 223; Dunham et al, SC 210, 1243; Dunham et al, BAAS 12, 832; Parkinson et al, N 288, 548; Candell, BAAS 13, 559; Gilliland, BAAS 13, 553; Ap J 248, 1144; Howard, preprint), for temperature (Livingston, N 272, 340; White and Livingston, Ap J 226, 679; Ap J, in press; Livingston and Holweger, preprint submitted to Ap J) and for luminosity (Foukal and Vernazza, Ap J 234, 707; Willson et al, SC 207, 177; Willson et al, SC 211, 700; Willson and Hudson, Ap J 244, L185). Especially, Parkinson et al (N 288, 548) and Gilliland (Ap J 248, 1144) found evidence that the solar radius might have undergone an approximately 80-year periodic variation. Further studies are needed to establish facts and the theory of solar cycle is now entering a new era of development.

2a. EMPIRICAL ASPECTS OF THE SOLAR CYCLE
(R. Howard)

Observational studies of a long series of Doppler velocity data over the solar disk (Howard and Labonte AP J L 239, L33; SP 74, 131) have shown that the rotation rate increases and decreases in latitude zones which drift slowly equatorward. At any time there are two pairs of such zones in the northern hemisphere and two pairs in the southern hemisphere in symmetric patterns. The zones, which originate near the poles, drift to the equator in a period of about 22 years. At any one latitude, the period of this torsional oscillation is about 11 years. A fast zone originates at each pole near the minimum of the solar activity cycle, and a slow zone originates near maximum. The amplitude of this effects is about 3 m s^{-1}.

Solar activity is centered about the shear zone of this torsional pattern between a fast zone and the adjacent slow zone in the poleward direction. This leads to the conclusion that the torsional motions are in some way associated with the activity cycle.

The amplitude of the shear shows little or no variation over its 22-year lifetime. As the waves move to the equator they become thinner in latitude extent. A one-per-hemisphere torsional wave in the rotation rate has also been found. This

https://doi.org/10.1017/S0251107X00004491 Published online by Cambridge University Press

is not a travelling wave. It has a half-amplitude of about 5 m s^{-1}. The high latitudes rotate fastest at solar maximum, and the low latitudes rotate fastest near solar minimum.

A study of the large-scale distribution of magnetic fields and magnetic flux over the solar cycle has shown some fundamental properties of the cycle (Howard and Labonte SP 74, 131). During the cycle the sunspot latitudes are characterized by average magnetic fields of the preceding polarity. Following polarity fields from time to time stream poleward to form the polar fields. This poleward flow is episodic, not continuous. This streaming motion appears to result from a directed flow, not from diffusion. Results from weak fields on the solar surface show a similar result except that the predominance of preceding polarity fields at activity latitudes is not so pronounced. The polar magnetic fields of the sun have reversed polarity - the northern fields changed from positive to negative polarity in the spring of 1980, and the southern fields changed from negative to positive polarity in the autumn of 1980.

The total surface magnetic flux of the sun ($F^T = |F^+| + |F^-|$) shows remarkably little variation from activity minimum to maximum. The variations in solar cycle 20 was about a factor 2 and in cycle 21, it was a factor 3.

The flux increase per day is about a factor 10 lower than the measured flux, which means that it would require about 10 days to generate the flux we see at the surface on any one day. This ratio is relatively constant throughout the cycle. This means that magnetic flux disappears from the solar surface at a remarkably fast rate.

Practically all the magnetic flux seen on the sun is at the active region latitudes (which is where it appears and disappears). The polar fields constitute only about 1% of the total surface flux of the sun.

2b. EMPIRICAL ASPECTS OF THE SOLAR CYCLES
(M. Kopecký)

Major attention was paid to solar activity forecasting. The range of these problems was a special topic of two significant international events: "Workshop on Solar Terrestrial Predictions" in Boulder (STPP) and the "10th Consultation of Solar Physicists from Socialist Countries" in Potsdam (PSP 16 and 17). Ol and Ol (IAN 80, 12, 2569) outline a new approach to solar activity prediction, based upon the relationship between yearly mean values of geomagnetic activity in the given 11-year cycle and during the next solar cycle maximum. Moreover, these problems were dealt with by a number of authors like Simon (SP 63, 399), Vitinskij (SDB 1980, 2, 103 and 4, 104), Lomb and Andersen (MN 190, 723), Meyer (SP 70, 259) and others. A series of papers develop methods for prediction of solar activity based upon its external conditionality (Vasilyeva et al, STPP 3, A45; Romanchuk VKU 22, 34; 23 (in press)). An evaluation of the reliability of solar activity forecast was published by Vitinskij and Rubashev (IGAO 196, 3). According to Kopecký (BAC 31, 1), at the beginning of the next century a high level of solar activity may be expected, with values at 200-300 of the maximum Wolf's relative number of 11-year cycles.

The interest remains centered, however, on the problem of Maunder's minimum. The ascertainment by Eddy et al (SP 46, 3), who claimed a higher angular rotation velocity at the solar equator in the epoch of Maunder's minimum was questioned by Aberbanell and Wöhl (SP 70, 197). Different aspects of the Maunder's minimum are treated by Schove (SP 63, 423), Romanchuk (SDB 1980, 5, 103), Gleissberg and Damboldt (JBAA 89, 440), Siscoe (JGR 81, 6224). The same problems motivated also the studies of Clark and Stephenson (QJRAS 19, 387) on an interpretation of the pre-telescopic sunspot records from the Orient.

Iskhanov and Vitinskij (IAN 284, 577) investigated the long-term variations of solar rotation for the past three years on the descending branch and in the maximum activity phase. At a maximum of the cycle, differential rotation is greatest in those cycles, where the maximum is highest, while prior to a minimum, rotation is

https://doi.org/10.1017/S0251107X00004491 Published online by Cambridge University Press

smaller for those cycles, for which in a subsequent cycle the activity maximum is higher. This occurred also during the Maunder minimum period. From the distribution of 7000 flares with respect to IMF sector boundaries Levitsky (IKAO 62, 148) demonstrated that in the ascending phase and near the maximum of cycles 19 and 20 there is a stable concentration of flares at the sector boundaries (-, +).

The eighty-year period in short-lived sunspots was investigated by Ringnes (RITA 52). Kuklin confirmed (BAC 32, 224) the existence of two sunspot group populations and described their behaviour in 80-, 22- and 11-year cycles.

A number of studies dealt with various aspects of the 11-year cycle. Latitude drift (Spörer's low) of different phenomena was investigated by Chistiakova and Chistiakov (MP 1981, 41) and by Brown and Evans (SP 68, 141) who studied also the periodicity of the faculae (SP 66, 233). The 11-year cycle in the solar corona and solar wind was studied by Rušín et al (SP 61, 301), Waldmeier (SP 70, 251), Simon (SP 63, 399), Legrand and Simin (SP 70, 173), Hundhansen (RGSP 17, 2034) and Tritakis (SP 63, 207). Manifestations of the cycle were also found in the variation of the sunspot intensity in the spectral region - 0.387 - 2.35 μm - by Albregtseen and Maltby (SP 71, 209), in the far-infrared temperature minimum - Müller et al (AA 87, L3) and in the solar flux in the far ultraviolet (1175-2100Å - by Cook et al JGR 85, 2257). According to Singh and Bappu (SP 71, 101), the calcium network cellular diameters appear to be by 5% smaller at the solar maximum compared with the minimum. Godoli and Marracconi (SP 64, 247) and Balthasar and Wöhl (AA 92, 111) studied the changes of the solar differential rotation in the solar cycle in relation to the sunspots. See also Proceedings of the Symposium "Study of the solar cycle from space" (NASA).

According to Kopecký et al (BAC 31, 267), the fundamental observational series of sunspots (Greenwich, Zurich, Pulkovo) are not homogeneous if mutually compared; the authors point out some inhomogeneities within the series. The same results were obtained by Vitinskij (SDB 1979, 3, 96).

3. ACTIVE REGIONS
(H. Zirin)

In the past three years an unprecedented level of observing active regions took place in connection with the Solar Maximum Year, Flare Buildup Study and the Solar Maximum Mission. Although considerable analysis of these data has taken place, little of the material has reached the journals. We have developed, through international cooperation in the study of many of these active regions, a good picture of the buildup of stress in various regions through flux emergence and its gradual release through the flare process.

The proceedings of the Skylab Workshop on active regions, held in 1978-79 should summarize work in this field up to 1979 but unhappily are still with the printer. They will be an important milestone in this field.

A. Small Scale Fields

There has been continued interest in the structure of small scale magnetic fields but little new data. Although most workers are in agreement on the idea that fields are concentrated in knots of strong field evidenced by the filigree network, evidence of the actual field strength is still indirect. Tarbell et al (Ap J 229, 387) studied high resolution filter magnetograms and fitted their data with elements of average field strength 1200g. covering .085 of the plage area; however their data could also be fit on the assumption that their half arc second resolution resolved the field structures, which then had average field 280 gauss and covered .36 of the area.

Despite the difficulties of detecting them there has been considerable analysis of the possible properties of the tiny flux tubes. Knobloch (Ap J L247, L93) and Knobloch and Rosner (Ap J 247, 311) have discussed the way small scale magnetic features are generated by turbulent convection. Knobloch argues that for scales

https://doi.org/10.1017/S0251107X00004491 Published online by Cambridge University Press

below a cutoff, further concentration cannot take place. It is not obvious how the eddied maintain the unipolar character of the network fields. Spruit (SP 61, 363) and Spruit and Zweibel (SP 62, 15) analyzed the stability against magnetic buoyancy of flux tubes and found these to be stable for beta (ratio of gas to magnetic pressure) above 1.8, which means that photospheric tubes with fields above 1350g are stable. Stellmacher and Wiehr (AA 75, 263) analyzed the center to limb variation of filigree contrast and found it could be fitted with the Koutchmy-Stellmacher model, in which the bright walls of the flux tubes produce the desired effect. Caccin and Severino (Ap J 232, 297) arrived at similar conclusions; there are enough free parameters in these unobservable structures to make good fits possible. Chapman (Ap J 232, 923) designed a new facular model which supports the "hot wall" picture.

B. Ephemeral Active Regions

There has been continued study of the interesting ephemeral regions and their relatives, the X-ray bright points. Golub et al (Ap J L229, L145) find the number of X-ray bright points to vary inversely with the solar cycle, while Martin and Harvey (SP 64, 93) found the number of ephemeral regions on magnetograms to vary with the cycle. Martin and Harvey found the rise in ER activity to procede the rise of the cycle by at least a year; if new cycle ER were separated, their data showed the ER essentially matching the rise of the cycle. They found the ER's to generally show the correct polarity in equatorial latitudes and what may be called new cycle polarity in higher latitudes. The contradiction between the X-ray and magnetographic observations appears not to be a threshhold effect; Golub et al (SP 53, 111) found at least half the bright points to match ephemeral regions and the discrepancy is far too large to be explained by factors of 2.

These papers do agree that the fraction of flux emerging in ER's is large, far greater than that in active regions. Of course this flux is in small dipoles which disappear and hence cannot contribute much to the general solar field. Marsh (SP 59, 105) has argued that bright point flares can provide enhanced diffusion of magnetic fields by reconnection and thus play an important role in the cycle. Golub et al (Ap J 243, 312) have argued that the ER's must be generated in a subsurface region shallower than the source of active regions and be spread into the chromo spheric network by the supergranulation flows. This picture would lead, however, to a bipolar network, while the observed network is unipolar; in addition films of ER's show little if any flow influenced by the network.

C. General Active Region Studies

Despite the high level of observing in the last years (or perhaps because of it) there has been little published material on classical active regions except for analyses of UV data. Baranovsky and Severny (IKAO 60, 99) made a new model based on data in the UV lines, especially Ly alpha and beta. They found enhancements of density and temperature of about one order of magnitude relative to the quiet sun transition zone. But to explain the Ly alpha and beta intensities they required a thin ($\sim$300 meters) hot layer with densities of 10 (exp 13). Baranovsky and Stepanyan (IKAO 60, 135) analyzed line intensities in UV and visible in stable plages and found, in contrast to growing plages, that intensities at higher levels were well correlated with those in lower chromosphere lines (H alpha or Ca K). Levine and Pye (SP 66, 39) studied the temperature structure in active regions on the basis of Skylab data, deriving differential emission measures for the different regimes. They found emission measures of 3 exp 48 cm (-1) and radiative losses of 4 exp 26 ergs/sec above 100,000 deg.

Kahler (SP 62, 347) studied the preflare X-ray characteristics of active regions and found no evidence for preflare heating; in most cases flares occurred in points which were not the brightest in X-ray. Microwave observations show the same general result: the flare source is displaced from the previous source, although not very far.

D. Microwave Mapping

Microwave observations with high resolution radio arrays are beginning to reveal the magnetic and coronal structure above the active region; much of this work was summarized by Schmahl (RPS, 71). In general the results correspond to those from X-ray studies by Webb and Zirin (SP 69, 99) who found bright coronal loops ending in hot spots in the penumbra or other regions of emerging flux, and that the peak intensity was always over neutral lines. Radio results (Kundu et al AA 82, 265; Lang and Willson RPS, 109) show a single core of emission centered on a neutral line, with peaks of circular polarization. These authors derive rather strong fields (up to 900 gauss) in these such regions, much stronger than force-free calculations. Gelfreikh and Bogod (SP 67, 29) by contrast, find 40 gauss from polarization measures. Still, the observed radio require the fairly large fields, so there is a problem either way. The active regions are sufficiently complex that it is not completely sure where the radio sources fall.

The development of high resolution microwave arrays and spectrometers offers hope for the detection of current sheets and evaluation of the importance of gyroresonance absorption in the non-flaring active region (Zheleznyakov and Zlotnick RPS, 87).

E. Emergence and Decay

The process of emergence and decay of active region fields is one which deserves more attention. We know that field emerges through the emergence of flux loops marked by arch filaments. The decay process has been less closely followed. Models of the sunspot cycle have assumed they decay by outward diffusion of their fields, but optical observers have not seen any such behaviour. Howard and Wallenhorst (SP 1982) observed 25 decaying active regions at Mt. Wilson and found no increase in the surrounding field regions as they dexay; the flux simply fades away. On the other hand there is also no sign of submergence of the field, which would be marked by close approach of opposite polarity to the neutral line. If the flux were concentrated in small tubes which spread it would still be detectable by the magnetograph. The problem is intriguing.

F. The Sunspot Energy Deficit

It has long been felt that the energy which is suppressed by the sunspot phenomenon must escape the sun in the surrounding areas; in fact early models of active regions used this concept. Simultaneous data from two orbiting radiometers on the Solar Maximum Mission and on Nimbus-7 gave for the first time reliable data on these effects. The radiometers measure all energy outflowing with high accuracy. Willson et al (Sc 211, 700) and Hickey et al (EOS 61, 355) both found that small changes in the solar constant correspond to the sunspot area less the contribution from white light plages near the limb. Thus the missing flux never gets out and theorists are busy with post hoc explanations. Our picture of the convective phenomena underlying an active region will surely change.

4. SUNSPOTS
(V. Bumba)

Major progress during 1979-1981 has been made in the observations of individual sunspot fine-structure elements and their interpretation. The problem of a single large magnetic flux tube forming the sunspot umbrae has been replaced by the study of a model of a dynamical clustering of many separate flux tubes pushed together due to various, but before all convective forces. A renaissance of sunspot spectral observations seems to be seen in the growing importance of various ground-based as well as space spectrographic observations.

A. Observations of Various Fine-Structure Elements

Interesting results have been obtained in the study of the sunspot bright umbral dots. It has been demonstrated by several groups of observers that umbral dots virtually cover the umbra, including the darkest regions of large spots, where the low contrast of the dot pattern has hitherto hindered its observations (Loughhead et al, AA 79, 128). Each sunspot umbra, regardless of umbral size, magnetic field intensity, darkness, form, age and presence of a penumbra has an identical internal morphological structure and the character of this internal umbral structure does not change during the whole process of spot development and does not depend on the phase of the solar activity cycle either (Bumba and Suda, BAC 31, 101). The area covered by the bright fine umbral features takes, as a rule, about 10 $\pm$ 5% of the total area of the umbra (Abdussamatov, SDB 80, 99). Even two types of these bright features seem to exist (Sattarov, MPSA 81, 107). The life-time of the greatest part of them is longer than 30 minutes, some of them live for several hours (Sattarov, MPSA 81, 122).

An extensive discussion concerning the problem of a "morphological similarity" between the umbral fine structure and the photospheric granulation has been published by the qhoted authors, as well as by Adjabshirizadeh (CR 290, 541), Adjabshirizadeh and Koutchmy (AA 89, 88; AA 99, 111) giving ideas about the density of the umbral bright points distributions, their sizes, contrast value, brightness temperature etc.

Sattarov (AZ 57, 610) succeeded in finding some new information concerning the magnetic field action on magnetic sensitive spectral lines in the dark and bright fine structure elements in some sunspot umbrae. He found that near the center of the solar disk the lines Fe I 6303.499 Å, Ti I 6064.626 Å, Cr I 5781.759 Å show the doublet Zeeman splitting in the bright umbral dots and the triplet Zeeman splitting in the dark umbral regions. In the dark regions the intensity of the π -component of the line Fe I 6302.499 Å is greater and in the line Cr I 5781.759 Å smaller than the intensities of their σ -components. It is shown that the appearance of the strong π -component in the edge zone of the umbra may be partly due to the blurring effect.

Some theoretical interpretations have been given by Obridko (SDB 79, 101) who demonstrates that the properties of bright umbral elements are not in agreement with the characteristics of a free oscillatory convection. Instead of it a new mechanism of forced oscillatory convection is suggested. This idea seems not to be far from the Parker's conception (Ap J 234, 333), following which the subsurface magnetic field of a sunspot splits into many separate flux tubes, with field-free gass between. The field-free columns occasionally punch their way up through the overlying magnetic field to the surface, where they appear as the bright, field-free umbral dots.

The fine structure of light bridges in sunsports has been studied by Müller (SP 61, 297) on high resolution photographs, obtained at the Pic-du--Midi Observatory, and an attempt to estimate their types following their morphological details in umbra, penumbra and photosphere has been made. A very detailed description of two types of sunspot light-bridges evolution in the large August 1972 sunspot group and their dependence on the magnetic field polarity distribution is given by Bumba and Hejna (BAC 31, 257): the normal photosphere-like light bridges formed from chains of bright granules separate the umbrae or their parts of the same sign of magnetic field polarity; the light bridges formed from elongated penumbral-like fibrils are closely related to the boundary between the two opposite polarity fields.

Zirin and Moore (SP 67, 79) found a new morphological feature associated with the outer edge of the penumbra of a small spot in a large complex spot group; a small continuum bright point. They call it "penumbra-periphery bright point".

Parfinenko (SDB 80, 85) studied the structure of light rings around sunspots using high-quality stratospheric and ground based sunspot observations and a new TV method. He claims that the outer light ring is formed by a relative clustering of bright photospheric granules bordering with the sunspot penumbra and that the inner light ring is formed by the ends of light fibrils of the penumbra. In his view these light rings are observed in all developed sunspots.

Grossmann-Doerth and Schmidt (AA 95, 366) analysed a series of "white light" images of sunspots taken under very good seeing conditions at Izana (Tenerife) to derive the brightness distribution of sunspot penumbrae.

B. Spectral Observations

From observations of the French (l.P.S.P.) experiment on board OSO-8 of a sunspot and nearby plage region it was estimated (Kneer et al, SP 69, 289) that the behaviour of the emission cores of the Ca II H and K and Mg II h and k resonance lines is very similar and the correspondence in the intensity between the four lines persists in quiet Sun, umbra, penumbra and plage. The relation between the Ca and Mg emission is slightly non-linear; this must be attributed to a different response of Ca and Mg to atmospheric structure. Umbral profiles show no self-reversals but asymmetrics from which the authors infer the presence of velocities, either oscillatory or stationary, with amplitudes of about 5 km s^{-1}. The L_α emission above sunspots lacks correlation with both Ca or H_α emission. The L_α profile directly above the umbra was found narrower and of higher intensity than in the quiet chromosphere. The electron density in the L_α forming layer and temperature was estimated.

Kollatschny et al (AA 86, 245) demonstrate that the wings of the infrared Ca II lines depend in upper atmospheric layers sensitively on the temperature gradient but not essentially on the absolute value of temperature. It was observed that these lines remain almost unchanged from photosphere to umbra and are thus sensitive to parasitic light. It is shown that the conflict between the model calculations and the observed lines may be removed by adopting an opacity enhancement as introduced by Zwaan in 1974.

Firstova (AZ 57, 666) shows that the ratio of maximum intensities of the H and K Ca II lines between "quiet" portions of an umbra and umbral flashes is practically equal which may indicate a possible equality of the optical thickness in both umbral features.

Observations with an out-eclipse coronagraph and an image tube confirm the presence of the enhanced He I 10830 Å line in the sunspot umbra spectrum. A qualitative difference between the profile of this line in the umbral spectrum and a plage spectrum has been found (Borodina and Papushev, PAZ 5, 620).

The umbral brightness temperature has been determined from observations by Sitnik (SDB 80, 99) for the spectral range of 4800-21000 Å. The author estimated that in this spectral interval the continuous absorption due to the existence of H^- really dominates in the umbra, but is smaller than in the photosphere. For shorter wavelengths a new continuous absorption agent exists. It causes increase of additional opacity with decreasing temperature.

Several new identifications of molecular lines in the EUV spectrum of sunspots were reported, as for example emission lines of the CO (Jordan et al,NN 187, 473), and new molecular hydrogen lines representing fluorescence from the Werner bands, found for the first time in the solar atmosphere (Bartos et al, MN 187, 463). An analysis of 147 pure TiO lines in a high resolution sunspot umbra spectrum suggests that coherent scattering is more likely than LTE for the formation process of the studied lines (Boyer, AA Sup 40, 277). The presence of several molecular absorption band systems (mostly in UV) umbral spectra had been examined: O_2 (Joshi et al, SP 63, 79), MgO (Murty SP 63, 83), SiO (Joshi et al, SP 62, 77). It has been shown that bound-bound opacity due to electronic transitions of molecules CN, CaH, MgH

https://doi.org/10.1017/S0251107X00004491 Published online by Cambridge University Press

and TiO explains in a first approximation the line haze opacity postulated by Zwaan for the near infrared umbral spectrum (Gaur et al, SP 62, 83). In the same wave-length region the molecular opacity seems to dominate the opacity due to the negative hydrogen ion (Joshi et al, SP 64, 255) in the higher layers of the umbral atmosphere. The $^6\Sigma^+ - {}^6\Sigma^+$ IR system of the CrH molecule has been identified in the spectrum of a large sunspot (Engvold et al, AA Sup 42, 209).

The relation between the pressure and content of molecules in sunspots has been calculated using the LTE solution of the dissociative equilibrium equation for a set of sunspot models (Stefanov, VKU 22, 39).

C. Magnetic Fields

Only few new observations concerning the sunspot magnetic fields were published. Ye et al (AAS 20, 275) devoted their paper to the method of determining the gradient of magnetic field using the asymmetry of the profiles and the rotation of the wings of Zeeman components. Gurman and House (SP 71, 5) used observations of a round, unipolar sunspot in the Fe I 6302.5 line with the HAO Stokes Polarimeter to derive the vector magnetic field in the sunspot. They also demonstrated oscillations of the umbral field magnitude at a period of 180 s. Landi Degl'Innoventi (SP 63, 237) interpreted linearly polarized intensity distributions observed in sunspots with the Marshall Space Flight Center's vector magnetograph taking into account magneto-optical effects. It is shown that these effects can be responsible for the observed spiral configuration in the pattern of linear polarization, even if a purely radial, convectional sunspot model is used!

Makita (PASJ 31, 575) developed a method applying the theoretical solution of the radiative transfer problem with the magnetic field to the observed Zeeman line profile. The assumptions of a pure-absorption atmosphere and of no magneto-optical effect allow a model-free determination of the magnetic field averaged along the optical depth. The method is applied to a penumbral spectrum. Similar problems of radiation transfer through a model sunspot under a variety of conditions for a ray emerging from a typical penumbral point are solved by Landman and Finn (SP 63,221). The first phases of the sunspot magnetic fields formation were studied by Bumba (BAC 32, 129).

D. Motions

Stellmacher and Wiehr (AA 82, 157) attempted to derive a model of the velocity field of a sunspot penumbra from both spatially unresolved and resolved spectra. The profiles of lines with small Zeeman splitting were observed by them in penumbrae at various heliocentric angles θ. Spatially unresolved spectra show decreasing shifts of the line cores and increasing line asymmetries with height. It was shown that a decomposition of the asymmetric profiles into a main component and a satellite yielded contradictory results when considering the depth dependence and the center-to-limb variation of different lines. Conflicting velocity gradients were deduced from the line asymmetries and the core shifts. The lines Ti I 5222.7 and Fe II 5264.8 were observed in a sunspot penumbra et $\cos\theta = 0.7$ with a spatial resolution of about 2.5 arc s. It was found that the line widths, residual intensities and asymmetries in bright as well as in dark spectral streaks increased with increasing line shift, although in bright regions the profiles were less shifted and more asymmetric. Some model calculations were made.

Surkov and Surkova (AC 1058,3) investigated the sunspot profiles of the non-magneto-active line Fe I 5576.10 Å; they seemed to succeed in explaining some observed details of the line profile as a result of the large local motions.

Shibata (SP 66, 61) explains the repeatedly observed strong downdrafts in photospheric lines of young sunspot and pores as due to the sliding matter along the rising magnetic flux tubes. Abdussamatov (SDB 79, 93 and SP 65, 197) found that the Evershed flow observed in the lines Fe I 6302.5 Å and in the H_α was almost parallel to the solar surface. Baranov and Lazareva (SDB 79, 96) demonstrated that in the largest part of the sunspot umbrae of the group studied by them during the whole period of observations the downward motion of matter with a mean velocity of 0.2 km s^{-1} was observed.

Rassulov (SDB 78, 74) in his study of the velocity field in the H_α chromosphere above a sunspot shows that these motions are complicated and that the inflow of the material into the spot prevails and the measured velocities may be found mainly inside the plage. Obridko (SDB 79, 96) demonstrated that the existence of an insulating boundary shell around the sunspot umbra, protecting it from the overheating, required an upward flow of the matter along this shell which would be afterwards transformed into the Evershed motion.

E. Umbral Models

Baranovsky and Stepanyan (IKAO 62, 125) derived empirical models for 20 sunspot umbrae using the wings of the K Ca II and D_2 Na I lines. Five of these models represented the development of one spot during the period of 8 days. It was found in this developing spot that at first the temperature changed scarcely, but the density decreased; after that both the temperature and the density increased. The density changes reached nearly the value of one order. In general, the large dark spots revealed a tendency to a lower density.

Umbral models with enhanced continuum opacity were studied by Stellmacher and Wiehr (AA 95, 229). Clark (SP 62, 305) investigated simple thermal models of sunspots based on the concept of partial inhibition convection by strong magnetic fields. Two specific results of his study might be mentioned: deep spots should produce weak bright rings in the surrounding atmosphere, whereas shallow spots should produce intense rings which would be difficult to reconcile with observations. Only a surface layer of a spot, with thickness of the order of the temperature scale height, was cool.

Parker published an extended series of papers called Sunspots and the Physics of Magnetic Flux Tubes. In the first paper (Ap J 230, 905) he reviewed the current state of the sunspots theory and concluded that a single large magnetic flux tube could not have the properties exhibited by a sunspot. In his new model the sunspot appears as a dynamical clustering of many separate flux tubes, pressed together to form a single flux tube at the visible solar surface, but othervise distinct and separate within the interior of the Sun. In the following paper (Ap J 230, 914) he studied the aerodynamic drag on a slender flux tube stretched vertically across a convective cell, which might push the flux tube into the updrafts or into the downdrafts, depending on the density stratification and the asymmetry of the convecting fluid motions. To account for the observed strong cohesion of the cluster of flux tubes that make up a sunspot, he proposes a downdraft of the order 2 km s^{-1} through the cluster of separate tubes beneath the sunspot. He also investigated the aerodynamic lift on a rigid circular cylinder in a nonuniform free stream and applied the obtained results to the motion of flux tubes in the Sun (Ap J 231, 250). The calculations of Tsinganos (Ap J 231, 260) established that a long circular cylinder immersed in a convective flow pattern in an ideal fluid is pushed out of the upwellings and the downdrafts of the convective cell into a location midway between them. Parker also demonstrated (Ap J 231, 270) that parallel tubes in a uniform flow are attrached or repelled depending on whether they are side by side or one ahead of the other, respectively. A pulsating or undulating tube attracts all other neighbouring tubes toward itself. He also showed (Ap J 232, 282) that a cylinder moving in an ideal fluid was subject to convective instability and propelled forward in its motion by the convective forces; this convective propulsion acting on magnetic flux tubes in the solar convective zone was comparable to the forces of magnetic buoyancy, aerodynamic lift and drag exerted on the tube.

In its seventh paper of the series (Ap J 232, 291) Parker found that the downdraft postulated to operate beneath the sunspot to account for the gathering of flux tubes to form the spot, would be sufficient to reduce the heat flux to values comparable to those observed in sunspot umbrae. Moreover, the overstability in a magnetic field in a downdraft (Parker, Ap J 233, 1005) as well as the hydrodynamic instability of the buoyant fields (Tsinganos, Ap J 239, 746) were considered.

Low (SP 67, 57) described a method for generating exact solutions of magnetostatic equilibrium describing a cylindrically symmetric magnetic flux tube oriented vertically in a stratified medium.

F. Energy Transport and Oscillations

New measurements of the radiative flux deficit of two large sunspots, based on detailed isophotometric maps, were presented by Bray (SP 69, 3). The umbral and penumbral deficits were 4-5 x 10^{10} and 1-1.5 x 10^{10} erg cm^{-2} s^{-1} respectively. Over limited areas centered on the umbral cores the deficits amount to 76 and 80% of the photospheric flux. Albregtsen and Maltby (SP 71, 269) found significant intensity differences between umbrae of large sunspots, which might be explained by a systematic variation in the umbral temperature throughout the solar cycle. At the same time no center-limb variation in the umbra-photosphere intensity ratio was detected. Both authors (Ap J L234, L147) presented an evidence for a possible link between the infrared intensity of large sunspots and the occurrence of X-ray bright points. This might indicate a more general reason of the found regularities.

Margolis and Knobloch (MN 193, 345) solved the equation of heat transport for the case of a cylinder with a given thermal conductivity imbedded in an otherwise uniform medium with different conductivity. Obridko (AZ 56, 67) tried to introduce a new two-component model of the atmosphere above the sunspot to get an agreement of the optical, radio, UV and X-ray observations above the sunspots.

Nye and Hollweg (SP 68, 279) considered the propagation of Alfvén waves in a simple model of a sunspot. They find that the observations of non-thermal motions near the temperature minimum and in the corona are both consistent with an upward-propagating Alfvén energy flux density of a few times 10^7 erg cm^{-2} s^{-1}, which is too small to cool the sunspot, but is large enough to supply the energy requirements of the transition region and corona above a sunspot. Mullan (SP 70, 311) proposes that Alfvén waves may contribute significantly to prolonged energization of proton-flares in which umbral coverage occurs, due to the readier access of umbral Alfvén waves into the corona above the sunspots because of the lowering of the transition region between the chromosphere and corona in the umbral flux tubes. Zhukov (SDB 79, 83) studied the excitation of gravitational waves by Alfvén waves in which the observed rapid decrease of Alfvén waves flux with the height over the sunspot may be associated with the transformation of a part of Alfvén waves energy into the gravitational waves energy.

Schener and Thomas (SP 71, 21) identified the umbral oscillations as a resonant response of the umbral atmosphere to forcing by oscillatory convection in the photosphere. From a numerical solution of the full, linearized equations for magnetoatmospheric waves in a detailed model of the umbral atmosphere several new features of the motion follow. Antia and Chitre (SP 63, 67) examined the magnetoacoustic modes excited in a thermally conducting polytropic fluid layer in the presence of a vertical magnetic field with a view to classify them by means of phase diagrams.

Teplitskaya et al (PAZ 6, 46) discussed the spectroscopic observations of radial velocity and brightness oscillations in the sunspot chromosphere. Zhugschda and Locaus (PAZ 7, 44) considered a model of 180 s. oscillations in the chromosphere above the sunspots to determine its temperature gradient

https://doi.org/10.1017/S0251107X00004491 Published online by Cambridge University Press

as well as the temperature and effective thickness of the temperature minimum from observed periods of oscillations.

G. Radio Emission

A model for sunspot associated radio emission at 6 cm wavelength has been constructed by Alissandrakis et al (AA 82, 30). The calculations are in good agreement with the high resolution observations of the same sunspot region at 6 cm, made with the Westerbork Synthesis Radio Telescope. Comparison of the 6 cm total intensity map with D_3, H and K Ca II spectroheliograms shows that the maxima of the 6 cm emission correspond to the location of sunspots (Erskine et al, AA 83, 256).

It has been demonstrated at the Crimea Observatory (Dommin et al, IKAO 62, 176) that the degree of left- and right-handed polarization of S-component sources related to the sunspots show dependence on the strengths of the appropriate spots magnetic fields.

In papers by Akhmedova and Rybakov (SDB 80, 85), Gelfreikh and Lubyshev (AZ 56, 562) new sources models for cyclotron radiation above sunspots have been constructed.

5. PROMINENCES
(O. Engvold)

I. Introduction

The proceedings from the IAU Colloquium No 44 (PSP) contain comprehensive reviews of prominence research. Important publications on the physics of active (flare associated) prominences are included in the SF, Chapter 7, by Rust et al and in the SID.

New observational and theoretical studies have addressed the familiar questions about the magnetic field configuration which must accommodate prominence formation and the subsequent provision for support and heat shield. Classical magnetostatic models in thermal equilibrium have been elaborated. Simplified dynamical models for quiescent prominences have been advanced which present interesting perspectives. The combined use of X-ray, EUV and radio data have provided better knowledge about the P-C interface region and the associated coronal cavity, which are essential for understanding the mechanics and thermodynamics of quiescent prominences. Continued studies of the P-C transition zone and the immediate prominence environments, possibly with emphasize on good spatial resolution, should be encouraged.

II. Quiescent Prominences

a. Thermodynamics diagnostics. Kanno et al (SP 69, 313) have studied the H I LyC emission in quiescent prominences and reported slightly higher optical thickness ($\tau_{912} > 30$) than given in earlier works. The hydrogen ionization was < 50% in the central parts and appeared to increase towards the periphery of the prominences. Sitnik (SA 24, 584) derived a noticeable centre to edge decrease in the source function of subordinate Balmer lines. Lhagvazhav et al (SDB 12/74 and SDB 1/88) have investigated the radiative transfer of the resonance line λ 584Å and the continuum at λ 504Å of He I in prominences and found the source functions to depend strongly upon the H I LyC opacity. Taking prominence fine structure into account Orrall and Schmahl (ApJ 240, 908) inferred T_e=7700$\pm$800K and $N_e > 2.2\ 10^{10}$ cm^{-3} from LyC analysis of several prominences. Based on optically thin lines emission in the visible and IR Landman (ApJ 237, 988) derived T_e=7000K and $N_e \simeq 10^{11}$ cm^{-3}, and using the corresponding line widths he got T=6620$\pm$1800K and v_t=5.1$\pm$1.4 km s^{-1}. Fontenla (SP 64, 177) derived T=6400K and v_t=5.7 km s^{-1}. Measurement of

https://doi.org/10.1017/S0251107X00004491 Published online by Cambridge University Press

Stark broadning on high quantum number Balmer lines yields usually the highest values for N_e (Ruždjak, POS 1, 209). Beigman (SA L 5, 27) points out that transitions $n \rightarrow n-1$ ($n>10$) of hydrogen at sub-millimeter wavelengths may be observable in prominences and be useful for thermodynamic diagnostics.

The fact that some prominences exhibit centrally reversed lines (Ca II H, K and H_α) implies local variations of their thermodynamic conditions. Kubota (PASJ 32, 359) found that the central reversal was not correlated with line opacity as predicted by a homogeneous layer model, and concluded that the central absorption arises from 'cooler' optically thick ($\tau \approx 5$) layers near the surface of the emitting structures (cf Öhman, ApJ 128, 97). The occasionally observed branching of particular line ratios (f inst Ca II vs Balmer lines) is due to local variations in the nonthermal velocities according to Stellmacher and Wiehr (SP 71, 299). Landman and Mongillo (SP 63, 87) measured significant interprominence variations in the Balmer decrement (T_{exc}=1100--3450K). Unresolved local variations of temperature and turbulence are inferred from enhanced line wing emissions (Landman, ApJ 237, 988). The implications of spatial variations on thermodynamic modelling, particularly on a sub-arcsec scale, have been considered earlier. Equally important may possibly be temporal variations which may lead to non-stationary radiative conditions (Engvold, SP 67, 351). Sporadic observations of condensation-like processes (Mikhailutsa,SDB 12/85) and local impulsive events (Malville and Toot, BAAS 12, 504) encourages more systematic investigations of changes on short time scale.

Jensen (SP (in pr 1981)) points out that the small scale random motion of quiescent prominences has the character of MHD turbulence. He notices that supersonic velocities are reached in some cases only, which has serious implications as to local dissipation of energy via effects of compressibility.

b. Magnetic fields. The astrophysical use of the Hanle effect for magnetic field determinations have been investigated further by several groups (Bommier et al, AA 100, 231; Gopasyuk, IKAO 60, 108; Landi Degl'Innocenti, SP (In pr 1981)). The total magnetic field vector may be derived from linear polarization measurements in two lines. The easily accessible pair D_3 and H_α has limited application due to effects of H_α line opacity (Leroy, SP 71, 285). Bommier et al concluded from using D_3 and λ 10830 Å (cf Smartt and House, BAAS 11, 409; Lindsey and Mickey, BAAS 11, 409) that the angle between the magnetic field vector and the long axis of a quiescent prominence is the range 0°-20°, which is in agreement with earlier magnetographic measurements.

c. Magnetostatic models. Lerche (SP 63, 3) has shown that the thermal balance of prominence matter in magnetostatic models is susceptible to thermal pulses from the corona. The shear of the magnetic field is essential for the thermal equilibrium of prominences in regulating the thermal conduction (Milne et al, ApJ 232, 304). Low (SP (in pr 1981)) has modified the classical Kippenhahn-Schlüter solution to account for the vertically aligned fine structure of quiescent prominences.

d. Mass flow and dynamic models. The dynamic nature of quiescent prominences are demonstrated by systematic and random motions measured in disk filaments (Martres et al, SP 69, 307; Malherbe et al, AA 102, 124). These authors find upward directed slow component (≈ 3 km s^{-1}) in some filaments whereas Kubota (J-F S, 178) measures a predominantly downward flow in 2 of 3 filaments. Coronal cavities are slightly deprived of matter as compared to the 'normal' corona (Lantos and Raolt, SP 66, 375; Kundu et al, AA 94, 72), but the difference is not by far enough to form prominences. The cavities are enclosed by arcades of hot (magnetic) loops (Serio et al, SP 59, 65; Chapman, SP 71, 151), which will prevent efficient flow of mass from the corona to the filament/cavity. These reasons and the fact that the prominence sub-structures are short lived as compared to several solar rotations for the 'seat of the

https://doi.org/10.1017/S0251107X00004491 Published online by Cambridge University Press

prominence appearance', have led to investigations of dynamic models for quiescent prominences of the Pikel'ner type where matter is sucked up along the magnetic field lines from the subjacent chromosphere (cf Leroy, J-F S, 155). Uchida (J-F S, 169) assumes a quadrupole component in the photospheric magnetic field which yields a 'neutral sheat' above the central polarity reversal. He sólves the hydrodynamic equations for matter which flows from the chromosphere, through the cavity region, and condenses by radiative cooling as it approaches the neutral sheet region. Ribes and Unno (AA 91, 129) derives a hydrodynamic model of a filament using a simpler magnetic configuration. Priest and Smith (SP 64, 267) assume that the presumed downflow along the vertical structures is a cnsequence of a small scale interchange or a Rayleigh-Taylor instability inside the prominences (see also Dolginov and Ostryakov, SAL 24, 749).

e. The prominence-corona transition zone. The P-C interface region is assessed by observations of EUV emission lines and cm-wavelength radio amission. The radio disk filaments have slightly lower temperatures than the quiet Sun at corresponding frequencies (Kundu et al, AA 62, 431). The temperature determination is apparently sensitive to the spatial resolution of the observing antenna (cf Rao and Kundu, AA 86, 373). Schmahl et al (SP 71, 311) caution against the strict forward interpretation of microwave observations of disk dilaments since they exhibit substantial diversity and variability. Emission measure analysis based on absolute calibriated EUV line intensities (Schmahl and Orrall, ApJ L 231, L41) confirmes the essential of earlier works. The P-C temperature gradient is less than determined for the Ch-C zone, which implies that the thermal flux is comparatively lower (Mouradian et al, AA 79, 138). Moe et al (SP 61, 319) derived P_e=0.05-0.1 dyn cm^{-2} in the P-C interface, which is only slightly higher than the values reported by Mouradian et al. Turbulence in the P-C transition zone (Moe et al, SP 61, 319; Vial et al, SP 68, 187), which evidently originates in the prominence itself, is assumed (van Tend, SP 66, 29) to generate MHD waves which will heat coronal loops of the helmet structure (see Chapman, SP 71, 151).

III. Active Prominences

a. Loop prominences. Loop prominence system (LPS), are usually considered as a signature for energetic flares, in particular, proton events. Basically, two hypothesis are debated to account for the energy and mass of LPS. They either grow out of stationary hot coronal loops, the thermal instability is triggered somehow by a near by flare, or they are the results of reconnecting magnetic field lines which initially were torn open by an erupting filament. Observational evidences for the latter case are presented by Martin (SP 64, 165) and Schmahl (SID, 241). Malville and Schindler (SP 70, 115) proposed that the flare will lead to enhanced dissipation and heating of the foot--points of the loops, which results in evaporation of matter (cf Antiochos and Sturrock, ApJ 220, 1137) into the loops and, subsequently lead to condensation. The flare loops systems seen in Hα grow, evidently, out of hotter coronal loops (McCombi and Rust, SP 61, 143; Chapman and Neupert, ApJ 229, 799; Švestka et al, SID, 217). Hood and Priest (AA 77, 233) pointed out than an increase in the gas pressure beyond a critical value of a stable coronal loop, by f inst streching or twisting the loop, will lead to thermal instability and subsequently a cool core. Krieger (SP 56, 107) investigated coronal loops brightened by flares and concluded that the observed decay times were 10 times longer than predicted from cooling by thermal conduction. The disagreement may be caused by an anomalous conductivity, or by additional heat sources (Habbal et al, SP 64, 287; Ionson, ApJ 226, 650). Cooling of flare loops have been analysed numerically by Antiochos and Krall (ApJ 229, 788) who noted that thermal conduction dominates in the early cooling phase whereas radiative cooling is more efficient in the later phase. Antiochos

(ApJ 236, 270) assumed that the instability grew from a thermal perturbation (≯ 5%) of the loop and showed that the temperature dropped from coronal to chromospheric value in the course of 5-600 s. The entire loop gradually cooled and the matter streamed down both legs at freefall conditions. Malville and Schindler measured a pronounced enhancement in the line-of-sight velocity (rms) which evidently was associated with the destabilization of the loop system. They also found a torsional motion and oscillation of the whole loop with a period of 75 min, which presumably was sub-Alfvenic. A longer period (340 s) has been reported by Zhugzhda et al (SDB 7/98) in another event. LPS as well as hot coronal loops are well represented by the lines of force of a dipole (Wu et al, SP 70, 137; Antiochos, ApJ 236, 270; Engvold et al, SP 62, 331). The apparent twist motion of the falling matter (Tsubaki, MSUNS 29, 89) is evidence for force-free configuration of the magnetic loop which may arise by motion of their foot points (Sakurai, PASJ 31, 209).

b. Eruptive prominences. Recent studies of the kinematics and thermodynamics of eruptive prominences are based on data from X-rays, EUV and the visible. The generally accepted picture is confirmed that eruption involves real mass motions and that the force acting on the matter is directed upwards and away from the associated center of activity, the accelerations decreasing with time (Waldmeier, AMES No 371; Pittini, AMES No 373; Vršnak, HOB 4, 17; Delone et al, SDB 1/102). The trajectories of the ejected material delineates the unwinding and streching of the initially loop-like magnetic field structure (Bhatnagar, SID, 235; Kleczek, HOB 4, 35). Two peculiar cases have been noted by Bruzek (SID, 203) where ejected filament material stopped at a distant position and formed short lived filaments. Tandberg-Hanssen et al (SP 65, 357) found that the material of flare sprays originated from preexisting filaments. The majority of eruptive prominences have height-speed relation in the range between the fast sprays and the slowly ascending prominences (Engvold, SID, 173). In fact, Slonim (SA L6, 21) demonstrated that the ascending velocity varies inversely with the square of the distance between the filament and the nearest center of activity, which implies that the dynamics of eruption is a function of the magnetic field strength.

Observational evidence for rapid heating of the erupting prominence material has been presented by Webb and Jackson (SP 73, 341). Kahler et al (BAS 11, 659) concluded from studies of X-ray and Hα observations that filaments disappear in place without being ejected from the region. Also Mouradian et al (J-F S, 195) pointed out that, although material motions are observed in Hα, many cases of "disparition brusques" are likely to represent a modification in the ionization of the prominence material rather than a dramatic restructuration of the magnetic field. These authors also noted the reappearance of a filament first in high temperature lines (Mg X).

Sério et al (SP 59, 65) found out that prominences associated with young (< 4 rotations) or very old (> 8 rotations) neutral lines are significantly less stable than the average of all filaments. Unstable filaments tend to have hot coronal arcade loops spanning the filaments channel (Schmahl et al, BAAS 12, 526). Moore and LaBonte, SID, 207) proposed that the destabilization of a filament, its successive eruption and associated flare, result from reconnection of strongly sheared supporting field. Slonim (SA L6, 21) concluded that the filament eruption and its associated flares are generated by a common mechanism which involves a preliminary reorganization of the magnetic field due to emergence of new magnetic flux.

Pneuman (SP 65, 369) showed that a moderate increase in the magnetic field strength beneath the coronal helmet streamer can easily propel the prominence and the overlying arcade outwards. The mechanism which percipitates the prominence eruptions are believed also to produce coronal transients (Fisher et al, ApJ L246, L161). 70% of all coronal transients are associated with eruptive prominences (Munro et al, SP 61, 201).

c. Surges. The mechanical energy of surges dominates by order of magnitudes the radiative output from flares (Webb, SFW, 471), but they produce no detectable coronal heating or dynamic responce such as coronal transcients (Rust et al, SFW, 273). The trajectories of the ejected matter are generally found to be ballisticlike (of Schmahl, SP 69, 135), though more complex behaviour have been reported (Makhmudov, SDB 5/81) Xu et al, AAS 5, 44). Xu et al claim that the mechanical energy of surges comes from dissipation of magnetic energy of the loop structure. Their conclusion is at variance with the results of Zach and Bar (SP 73, 331) who found that an active surge producing region was stable and showed no evidence of decreasing energy. Stoyanova (SDB 3/84) noticed peculiar wave motions in surges which she proposed might give rise to condensation of matter in the magnetic structure and thus lead to the surge formation. The impulsive surge events are now also accessed in the EUV (Hence et al, BAAS 12, 532; Woodgate, BAAS 12, 535). Schmahl (SP 69, 135) analysed EUV data from Skylab and concluded that inferred pressure gradients along the surges would be able to drive material outwards at the observed speeds and distances. Noci (SID, 307) applied a steady state approximation in a siphon type model to observed O VI and Mg X emission in a surge and found evidence for transversal pressure gradients. The response of the solar atmosphere to a brief thermal pressure pulse were investigated numerically by Steinolfson et al (SP 63, 187) who solved the one-dimensional timedependent hydrodynamic equations and thus succeeded convincingly in simulating surge events. A different approach was made by Carlqvist (SP 63, 353) who proposed that surges were the consequences of local evacuation arising from current driven instabilities at the top of magnetic loops. This model seems less convincing in explaining typical behaviour of surges.

6. FLARES AND ENERGETIC PARTICLES
(D. M. Rust)

A. Activities

The Solar Maximum Mission satellite (SP 65, 5) was launched in February, 1980 and made X-ray and UV flare images for nine months. Besides the SMM, satellites launched for solar activity research included the International Sun-Earth Explorer (USA), Prognoz-8 (USSR) and Astro-A (Japan). One-arcsec observations of flares became available from the Very Large Array (USA) and Westerbork (FRG) radio telescopes. Important publications included the proceedings of the Skylab Flare Workshop (Solar Flares (SF)), and Solar System Plasma Physics (SSPP), and Solar Flare Magnetohydrodynamics (SFMHD). Major reviews of flare observations by Brown, Smith and Spicer and of flare theory by Spicer and Brown appeared in The Sun as a Star (SS). First results from the SMM experiments appeared in Ap J L244, L113.

Flare researchers lost an outstanding colleague in the death of S.I. Syrovatskii. A review, "Key problems of flare theory" (IANSSR 43, 695) was among his last works.

B. Research

I. Flare Build-up
a. Preflare magnetic fields. New observational studies of preflare fields were few, but theoretical work intensified on analytic solutions to the forcefree field equation (Low, RGSP in press). Priest and Milne (SP 65, 315) studied the evolution of arcade-like fields through a series of force-free states, finding a solution that contains a magnetic bubble. They proposed that such a bubble could undergo an eruptive instability and trigger a two--ribbon flare. Hasan (SP 67, 267) found that any force-free field with constant twist is unstable to kinking unless linked with a small, positive

https://doi.org/10.1017/S0251107X00004491 Published online by Cambridge University Press

transverse gas-pressure gradient. Hood and Priest (SP 64, 303 and SP 66, 113) suggested that an MHD kink instability can develop into a flare in magnetic loops twisted through several rotations by photospheric motions. The dominant stabilizing effect which allows the accumulation of energy in twisted fields is "line tying", i.e., the assumption that coronal field-line footpoints are fixed to specific photospheric sources. Gibons and Spicer (SP 69, 57) criticized this assumption, which is fundamental to almost all work on magnetic energy build-up.

b. Preflare emission and activation. Observations of preflare conditions in the chromosphere and corona were reviewed by Martin (SP 68, 217). She found that filament eruptions and X-ray brightenings, inter alia, were reliable flare precursors, but Mosher and Acton (SP 66, 105) and Kahler (SP 62, 347) found no peculiar soft X-ray enhancements or filament activations that would allow small flares to be anticipated. Nevertheless, large flares are almost invariably preceded by filament activation and eruption. Kuperus and Van Tend (SP 71, 125) showed that if the background field near a filament evolves from a potential to a nearly force-free state, large forces are generated along the axis of the filament, if their earlier model (SP 59, 115) is correct. They identify the filament eruption as the flare trigger. Most flare energy would be released as the magnetic fields reconnect after the eruption.

II. Flare Energy Release Processes

a. Magnetic field reconnection. Observations of H-alpha and EUV flare structures (Ap J L244, L133; Ap J L244, L179) and of the underlying magnetic fields and X-ray flare kernels (ApJ L246, L155) continue to indicate that some flares, are triggered by emerging flux. Presumably, magnetic reconnection takes place at current sheets between the emergent and ambient fields. Alternatively, reconnection may occur in small segments within a twisted loop, (Spicer, SP 70, 149). There would be no extended current sheet in this case. Mercier and Heyvaerts (SP 68, 151) reexamined the dynamics of the Petschek-type extended current sheet. They find that plasma microturbulence, which many suppose to be the primary triggering mechanism of flares, does not appear in a straightforward way. They conclude that global properties of the active region magnetic structure as well as gravity may play an important role in determining current sheet dimensions and its effectiveness as a flare trigger. Syrovatskii and Kuznetsov (RPS, 445) and Smith and Spicer (SP 62, 359) pointed out that current sheets may be detectable with high resolution microwave observations.

b. Double layers. Akasofu (SP 64, 333) revived interest in analogies between solar flares and magnetospheric substorms. The recent discovery of "double layers" above the ionosphere encourages the comparison. Double layers are narrow regions just above auroral arcs where the electric field is parallel to the magnetic field. In two-ribbon flares, Akasofu argued, the electron-accelerating layers could lie in the low corona near where the active region loop arcade intersects the chromosphere. The idea is a variation of the Alfvén and Carlqvist model(Spicer, SP 70, 149); Carlqvist (SP 63, 353).

c. Models -thermal and non-thermal. A burning issue in flare physics is the electron velocity distribution in the primary flare plasma. Current-sheet models lead to energization by joule heating (thermal model). However, accelerated electron beams (non-thermal model) are usually invoked to explain impulsive-phase X-ray bursts. In the thermal interpretation, (Smith and Lilliequist, Ap J 232, 582),hard X-rays originate in a very hot ($\sim 10^8$K) plasma, while in the non-thermal interpretation, they are the bremsstrahlung emitted by electron beams interacting with a cold, dense plasma ("thick target"). The non-thermal interpretation of hard X-ray bursts requires about twenty times the energy in impulsive phase electrons as the thermal inter-

https://doi.org/10.1017/S0251107X00004491 Published online by Cambridge University Press

pretation (Smith, SP 66, 135). Unfortunately, X-ray spectra may be interpreted with equal facility either as the superposition of several Maxwellian or power-law flux distributions. Brown et al (SP 67, 143) concluded that a single thermal source cannot describe the time development of hard X-ray spectra. They proposed that primary energy release sites consist of several small, impulsively-heated kernels, each cooled by anomalous conduction. Their model is an elaboration of de Jager's (SP 64, 135) view the impulsive-phase emission is composed of elementary flare bursts (EFBs). Evidence for EFBs is given by Karpen et al (Ap J 234, 370). Brown et al show how EFBs, which may correspond to sites of tearing-mode magnetic field dissipation (Spicer, SP 53, 305; SP 70, 149; Van Hoven, Ap J 232; 572), may be revealed in dynamic hard X-ray spectra. Emslie (Ap J 244, 653) offered an alternative interpretation in terms of a single adiabatically heated region (Wiehl and Mätzler, AA 82, 93) compressed by a time-varying, toroidal magnetic field. Kosugi (SP 71, 91) presented evidence for EFBs of ~ 3 s duration in an event with coincident bursts in hard X-ray, metric and microwave spectra. Radio interferometric observations suggested that the electron acceleration region (site of several EFBs) shifts in position after several tens of seconds.

An important advance in understanding impulsive phase energy release came with the successful operation of the HXIS (Hard X-ray Imaging Spectrometer, SP 65, 39) on the SMM satellite. Hoyng et al (Ap J L246, L155) and Duijveman et al (SP, in press) showed that 16 - 30 keV X-rays integrated over 20 - 30 s spike bursts originated at the feet of magnetic loops (one loop for each spike burst). The loop feet lay above with H-alpha flare kernels. Hoyng et al believe their data show the bremsstrahlung of electrons accelerated non-thermally within the loops. Only the first few spike bursts in each HXIS event can be described in this manner. Most of the hard X-ray emission was in a hot, diffuse source that appeared after the first minute or so and coincided with the well-known soft X-ray and H-alpha flare loops. The first X-ray imaging results, then, seem to support both thermal and non-thermal models. The extreme energy requirements of the non-thermal model are avoided because non-thermal processes dominate for only a small fraction of the total X-ray burst interval.

Marsh et al (Ap J 242, 352; Ap J L240, L111), Kundu et al (Ap J 1981 in press) and Lang et al (Ap J 247, 338) reported microwave emission from 1-2" sources between H-alpha flare kernels. In many cases, the microwave sources exhibited a double polarized structure. The circular polarization implied that the source was gyrosynchrotron emission from ~ 500 keV (non-thermal) electrons in 400 - 800 G magnetic loops.

Although observations seem to favour non-thermal models, at least at flare onset, proposed acceleration mechanisms have raised many theoretical objections (Smith, SP 66, 135). The question of whether a thermal model with a high-energy tail in the electron velocity distribution (Vlahos and Papadopoulos, Ap J 233, 717; Emslie and Vlahos, Ap J 242, 159) can describe the observations will be studied intensively as more VLA and SMM results become available.

d. Ion acceleration. Measurements of solar protons and other ions at 1 AU are only just beginning to reveal the properties of the acceleration region. Ion charge state measurements from the ISEE-3 and IMP-8 spacecraft indicate that flare particles are accelerated from plasma at 4×10^5 K to 5×10^6 K (Ma Sung et al, Ap J L245, 45; Paris Cosmic Ray Conf., 1981), not in 10^7-10^8 K kernels and not in 10^4 K ejecta. The results is exciting evidence for acceleration in ambient coronal material by shocks (Gutschenko and Zaitsev, SP 63, 337). Acceleration of electrons by shocks certainly produces type II metric bursts, but since accelerated ions emit only negligible EM radiation, their association with shocks has been much more difficult to establish. Furthermore, ion acceleration by the classical Fermi mechanism requires pre-acceleration, presumably during the impulsive phase. It appears that

https://doi.org/10.1017/S0251107X00004491 Published online by Cambridge University Press

the shock drift acceleration mechanism (Pesses et al, SSR, in press; Decker, JGR 86, 4537), in which shocks can rapidly accelerate ambient ions, may be operating in the corona as well as in interplanetary space, where it is well established.

Curious data on elemental composition in solar particle events continues to stream in. Briggs et al (Ap J L228, L83) found a strong tendency for second flares to produce H/He-enhanced energetic particle fluxes when compared with first flares from the same active region. Flares separated by > 100 h do not show the effect, which implies that flares may interrupt a gradual He enrichment process in active regions. Möbius et al (Ap J 238, 768) found that heavyion-rich events are also enriched in ^{3}He and Fe. They view this as due, not to gradual enrichment, but to preferential injection of ^{3}He and Fe by turbulent ion heating and Fermi acceleration. On the other hand, Cook et al (Ap J L238, 97) found that the average energetic particle abundances in four major flare events were similar to solar wind abundances. Small flare particle events, however, consistently show ^{3}He and heavy ion enrichments (Mason et al, Ap J 239, 1070).

Kahler (JGR, in press) showed that earlier statistical studies linking impulsive phase phenomena to proton events did not adequately account for the fact that all flare phenomena are bigger and more frequent in major flares. After this "big flare syndrome" is accounted for, no significant correlation remains between proton events and impulsive-phase phenomena except for the time-integrated microwave burst energy.

A popular two-step model, in which ion acceleration starts with injection during the impulsive phase, was challenged by first results from the SMM gamma-ray experiment (Forrest et al, SP 65,15; Chupp et al, Ap J L244, L171; Ryan et al, Eos 62, 380A). Gamma-ray emission from nuclei excited by 1 - 50 MeV ions appeared in ~ 1 s coincidence with impulsive-phase emissions from electrons and repeated quasi-periodically for ~ 40 s. The gamma-ray data clearly show that protons can be accelerated up to ~50 MeV in the impulsive phase. Few of these protons escape the Sun. Decker et al (Paris Cosmic Ray Conf., 1981) and Chambon (SP 69, 147) found that gamma-ray events produce relatively weak proton events at Earth. We may have learned how to accelerate protons in shocks (Decker, loc cit), but we must now search for a way to accelerate them quasi-periodically in the impulsive phase and on time scales that may be too short (~1 s) for shocks or wave turbulence (Barbosa, Ap J 233, 383) to operate.

III. Flare Effects in the Solar Atmosphere

a. Photosphere. The problem of whether white-light flares are the result of proton bombardment benefitted from several simultaneous gamma-ray and white-light flare observations (Dezsö et al, SP 67, 317; Hudson, Ap J L236, 91; Zirin and Neidig, Ap J L248, 45). Hudson and Dwivedi (SP, in press) analyzed the effects on the photosphere of high-energy ions capable of producing the July 11, 1978, white-light flare and found that photospheric heating by the ions would be negligible and that the emergent spectrum would be red rather than blue as observed. In the July 1, 1980, white-light flares, there was a correlation between gamma-ray and the white-light emissions only in the weakest phase of the white-light event. The brightest emission cannot be due to proton bombardment (Rust et al, SP in press).

b. Chromosphere. Models of the effects on the chromosphere of different modes of energy input have improved substantially and left us with some difficult puzzles. Machado et al (Ap J 242, 336) devised semi-empirical flare model atmospheres that approximately reproduce observations in H I, Si I C I, Ca II and Mg II. Pure particle heating models cannot produce the observed emission, and Machado et al suggest that conduction and X-ray photon heating (Henoux and Nakagawa, AA 66, 385; Henoux and Rust, AA 91, 322) make substantial contributions in the lower chromosphere. No detailed energy input

https://doi.org/10.1017/S0251107X00004491 Published online by Cambridge University Press

models have yet explained temperature minimum region heating (Emslie and Machado, SP 64, 129).

Somov et al (SP 73, 145) studied the hydrodynamic response of the chromosphere to electron beam heating. The top of the chromosphere to electron beam heating. The top of the chromosphere explodes into the corona at $<$ 1500 km/s. In denser layers, the energy can be radiated away, and a UV flash results. High-resolution simultaneous maps of hard X-ray and UV emissions showed that individual X-ray spikes can be identified with discrete UV flare kernels (Cheng et al, AP J L248, L39). Several 4" kernels brightened sequentially in one studied flare. In a limb flare studied by Poland et al (SP, in press), UV lines of O IV ($T_e \sim 2.5 \times 10^5$ K) and Fe XXI ($\sim 10^7$ K) showed that impulsive phenomena began in the chromosphere or photosphere and continued for several minutes as material was ejected into coronal loops.

Nagai (SP 68, 351) studied gas-dynamic models of flare loops heated by thermal conduction from the top or foot. Cargill and Priest (preprint) studied loops heated by slow MHD shocks initiated by magnetic reconnection, as in Pneuman's model (Solar Flare Magnetohydrodynamics, Gordon and Breach). So far, none of the models is realistic enough for detailed comparison with observations. Somov's model (SP 73, 145) predicts that the ion temperature in the impulsive phase ejects will be an order of magnitude less than the electron temperature. It willbe difficult to check this prediction since impulsive-phase turbulence broadens the lines and mimics a high ionization temperature (Culhane et al, ApJ L244, L141).

c. Corona. There is accumulating evidence for distinguishing two classes of solar flares, at least with respect to coronal manifestations. Small volume (10^{26}-10^{27} cm^3), low altitude ($< 10^4$ km) flares have short rise and decay times and a high coronal energy density (10^2-10^3 ergs cm^{-3}). A compact flare that produced an extraordinary burst of hard X-rays and gamma-rays was studied by Dennis et al (Ap J L244, L167) and Ryan et al (Ap J L244, L175).

Compact flares are not associated with coronal transcients, but long--decay ($\sim$ hours) events (LDE's), which have larger coronal loops ($\sim 5 \times 10^4$ km), larger volumes (10^{28}-10^{29} cm^3) and lower coronal energy densities (10 - 10^2 ergs cm^{-3}) are associated with prominence eruptions and with coronal transcients (Pallavicini et al, Ap J 216, 108; Pallavicini and Vaiana, SP 67, 127). Krall et al (SP 66, 371) made a one dimensional hydrodynamic model of an LDE. In agreement with other studies (Moore et al, Solar Flares, p. 341; MacCombie and Rust, SP 61, 69), they found that energy is supplied to LDE's for hours after event onset. Clearly, energy release processes both rapid (e.g. Duijveman et al, Ap J 245, 721) and slow (Pneuman, loc cit.) occur in a variety of flares and no single model or mechanism will describe them all.

7. RADIO PHYSICS
(M. Pick)

Reviews and General

A detailed review on Solar Radioastronomy has been published in book form by Krüger (ISRAR). It presents a summary of the work done during the past thirty years and covers instrumental aspects, observations and theory. In the book on the Symposium IAU No 86 (RPS), dedicated to the memory of S.F. Smerd, the present level of our understanding of Solar Radio Physics is summarized. Many books have included several aspects of the radio emission: PSP, IAU Colloquium No 44, the monographs from Skylab solar workshops, in particular: SF and CHHSWS.

In order to detect the presence of expected Langmuir waves, microwave radar observations of the Sun have been made.

The possibility of recognizing neutral current sheets in the corona by their radio emission has been discussed (Zheleznyakov and Zlotnik, SP 68, 317; Kurnetsov and Syrovatskii, SP 69, 361; Nefed´ev, PAZ 5, 96).

Quiet Sun

Fluctuations of the radiflux have been studied at 2.8 cm (Butz et al, AA 72, 211; Graf et al, ApJ 228, 312). Radio pulsations with a period of 160 min were detected at 1.9-3.5 cm (Eryushev et al, PAZ 5, 546). At decameter wavelengths, periods from 4 to 30 min were detected (Abranin et al, PAZ 4, 559). The radio granulation was observed with the RATAN-600 radiotelescope (Bagod, SSAOZ 13, 22). A map of the supergranulation network was obtained with the WSRT (Kundu et al, ApJ 234, 1122).

Brightness distribution was studied at 2.4 cm (Borovik, PAZ 6, 426). There is no change with the phase of the cycle (Borovik, AIISAOZ 11, 107). The variation of solar brightness at the extreme solar limb was observed at centimetre wavelengths (Lantos et al, SP 63, 271).

Synoptic charts of coronal holes were drawn at 9.1 cm (Wefer and Papagiannis, SP 67, 13). A model for coronal holes was derived from E UV and radio data (Chiuderi-Drago, SP 65, 237).

Slowly varying component and active regions

Various characteristics of the local radio sources have been studied: - the variation of the flux (Nakajima et al, PASJ 31, 251) and the development of fluctuations (Gel´frejkh) PAZ 5, 42) - the radio optical comparison (Akhmedov, SDB 79, 91; Gaizauskas and Tapping, SID, 33) - the polarization (Bachurin et al, IKAO 61, 37) and its variation before the occurrence of proton flares (Bachurin et al, IKAO 59, 111) - the type of spectra and the probability of flare occurrences (Steffen, SP 67, 89) - the fine structure of the spectra and its variation (Kaverin et al, SDB 78, 92, SP 63, 379, AZ 57, 778), (Zheleznyakov and Zlotnik, AZ 57, 778).

Long lived microwave pulsations were observed (Gaizauskas and Tapping, Ap J 241, 804).

High spatial resolution obsefvations of solar active regions in soft or UV rays and centimetric wavelengths were compared (Pallavicini et al, ApJ 229, 375; AA 98, 316). Maps of active regions were obtained at 6 cm with the WSRT (Erskine et al, AA 83, 256) and with the VLA (Lang and Willson, RPS; Kundu and Velusamy, ApJ L240, L63; Kundu et al, AA 94, 12). Different models for local radio sources were constructed and compared to the observations (Zhao, PBAO 2, 1; Zhao and Gian, AAS 21, 262; Alissandrakis et al, AA 82, 30; Gel´frejkh and Lubyshev, AZ 56, 562).

Filaments

Observations at 8, 15, 22 and 43 GHz have been obtained with the Haystack telescope (Schmahl et al, SP 71, 311). From a synthesis of observations, a spectrum of the brightness temperature of filaments between 3.5 mm and 6 cm has been derived (Raoult et al, SP 61, 335), and interpreted (Lantos and Raoult, SP 66, 275). An agreement between the uv and radio observations is obtained through these studies.

Microwave bursts

Kane has given a review on the impulsive phase of the flares including the radio aspects (SF, 187).

Fast time structures have been detected during the development of impulsive bursts (Kaufmann, SP 60, 367; Urpo et al, AA 93, 121). The observation of the spikes suggests the possibility that the flare energetic injections are quasiquantized in energy (Kaufmann et al, AA 87, 58). A class

https://doi.org/10.1017/S0251107X00004491 Published online by Cambridge University Press

of quasi periodic bursts is considered as an evidence for adiabatic heating (Wiehl and Mätzler, AA 82, 93). Following Wiehl et al, AA 92, 260, time delays of maximum emission at high and low microwave frequencies are considered as evidence for a collisionless conduction front.

To explain the microwave emissions, different mechanisms have been discussed: the role of thermal gyromagnetic and bremsstrahlung emission (Kovalev, PAZ 5, 133), the gyrosynchrotron emission from quasi thermal electrons (Dulk, et al, ApJ 234, 1137).

A statistical investigation of microwave burst spectra has been presented (Schoehlin and Magun, SP 64, 349). The spectral evolution of multiple impulsive solar bursts have been also analysed (Karpen et al, ApJ 234, 370). High spatial resolution observations of microwave burst have been obtained (Kundu and Vlahos, ApJ 232, 595; Kundu and Angerhofer, SP 64, 159). In particular, the VLA observations allow the determination of the burst source and from the comparison with other data, an interpretation can be obtained (Marsh et al, SP 64, 159; Marsh et al, ApJ 242, 352; Marsh and Hurford, ApJ L240, L111). Post flare loops have been observed at 20 cm with VLA (Velusamy and Kundu, ApJ L243, L103).

Type III, type U, type V bursts

Kundu et al, ApJ L236, L87, have associated type III bursts with X-ray bright flares. The sources of the type III bursts have been resolved in multiple components (Pick et al, RPS, 235) and occur in coronal regions where the magnetic field is diverging (Kane et al, ApJ L241, L113; Schmahl et al, SP 71, 311). High time resolution observations reveal that individual type III bursts coincide with corresponding elementary X-ray and microwave spike bursts (Kosugi, SP 71, 91). Some coronal structures associated with type III burst production were identified from Skylab observations (Pick et al, SP 63, 369).

A new class of type III like bursts has been identified at decimeter wavelengths (Elgaroy, AA 82, 308). The characteristics of type III bursts have been described in terms of F-H pairs and structureless bursts (Dulk and Suzuki, AA 88, 203). A strong support for the existence of F.H pairs (Poquerusse and Bougeret, AA 97, 36) have been brought by stereoscopic observations. At kilometer wavelengths, both fundamental and harmonic emissions have been detected (Hanaz et al, AA 91, 311). Propagation effects on electromagnetic waves have been discussed (Duncan, SP 63, 389; Steinberg et al, SP 64, 359).

Theoretical investigations on type III burst emission have been carried out (Takakura, SP 61, 143; SP 61, 161; SP 62, 375; SP 62, 383; Smith and Sime, ApJ 233, 998; Smith et al, ApJ 234, 348; Smith and Nicholson, EISP, 225; Goldstein et al, WISP, 245; ApJ 234, 683; Wentzel, AA 80, 268; De Genouillac and Escande, AA 94, 219). The radial variation of the plasma oscillations responsible for the type III bursts has been derived from the determination of the emissivity variation with heliocentric radial distance by Tokar and Gurnett. Observations and interpretations of type III + IIIb bursts have been discussed (Abranin and Baselyan, SP 62, 145; Kriskan et al, SP 66, 347; Subramian et al, SP 70, 375). A model explaining the transition between type I and type III bursts has been proposed (Aubier, RPS, 363).

The evolution of polarization in type U bursts was analysed and interpreted (Benz et al, AA 79, 216). Characteristics of type V bursts were analysed (Bakunin et al, AZ 56, 549; Dulk et al, AA 88, 218).

Type II - IV bursts

Type II bursts have been detected in the interplanetary medium (Boischot et al, SP 65, 397; Cane et al, BAAS 12, 546). Theories on type II bursts have been confronted with observations (Dryer and Maxwell, ApJ 231, 945; Sawant et al, SID, 257). The development of current instability in the front of magnetohydrodynamic shock which excites plasma waves, has been studied (Lebedev,

https://doi.org/10.1017/S0251107X00004491 Published online by Cambridge University Press

AZ 56, 84). The emergence of a strong magnetic field can be at the origin of the shock production (Lebedev, AZ 57, 113). From the association between coronal transients and type II-IV bursts, the coronal physical parameters can be deduced (Gergely et al, ApJ 230, 575; Dulk, RPS, 419; Stewart, SID, 333; Wagner et al, ApJ L244, L123). Estimation of the magnetic field strength has been also derived from the interpretation of type II (Karlický and Tlamicha, BAC 30, 246) or type IV bursts (Bhonsle and Degaonkar, SP 68, 339).

The spectral shape of type IV bursts has been interpreted (Li et al, AAS 20, 153). Kai, SP 61, 187, has made a statistical study of moving type IV bursts. Type IV emissions with a brightness temperature above 10^9K or 10^{13}K have been observed (Duncan et al, SID, 381). The existence of multi-stage particle acceleration can explain the type IV metric continua (Schindler, AA 73, 240). Quasi periodic modulation in type IV bursts has been analysed and has been considered as a symptom of the electron acceleration process (Pračka and Karlický, BAC 30, 257; Trottet et al, AA 79, 164).

Pulsating structure has been found to occur in the development of moving type IV bursts (Pick and Trottet, SP 60, 353; Trottet et al, AA 93, 129). A new class of drifting spikes was identified (Elgaroy and Sveen, N 278, 626). Papers have dealed with the classification (Bernold, AASup 42, 43) and theory of fine structure in solar continuum emission (Kuijpers, RPS, 341; Benz, ApJ 240, 892; Formichev and Fainshtein, SP 71, 385; Bardakov et al, PAZ 4, 272; Yao, AAS 21, 272).

Noise storms and type I bursts

Theories on type I burst emission has been developed (Yin and Ma, SS 22, 441; Benz and Wentzel, AA 94, 100; Melrose, SP 67, 357). To explain digitally recorded observations, a model for type I burst and continuum generation has been proposed (Kattenberg et al, RPS, 259). Interaction between a shock wave and a noise storm source has been found (Korolev et al, AZ 56, 387). Statistical analyses of noise storms have been presented (Šuk, BAC 30, 274; Gnezdilov, SDB 79, 82). An analysis of pulsations in a meter noise storm has been undertaken (Podstrigach et al, AZ 56, 867). Fine structure in fast drift storm bursts has been detected (McConnell and Ellis, SP 69, 161).

The scattering by coronal density fluctuations has been discussed in connection with observations of very small bursts (0.7′) (Kerdraon, AA 71, 266).

8. CORONA
(V.E. Stepanov)

The Corona of Active Regions

Schmahl (RPS, 71) generalized the data on the structure of the lower corona above AR′s, using EUV, X-ray, and centimeter observations. X-ray data are dominared by hot discrete structures with $T > 2\ 10^6$K. Arcades of loops are observed above $H_{\parallel}=0$ lines. There is no unambiguous correspondence between cool ($T < 2\ 10^6$K) and hot structure. Using 20 limb passages of AR′s, Mosher (SP 64, 109) showed that the X-ray emission in the range 1 to 4 keV is by 90% concentrated below 57000 km and by 50% below 20000 km. Using Skylab data, Cheng et al (SP 67, 259) found that in the range $5\ 10^5 < T < 3\ 10^6$K the AR loops are divided into two groups. Hot loops with $T \sim 2\text{-}3\ 10^6$K are compact and closely adjacent formations. They are most stable than relatively cool loops with $T \sim 2\text{-}3\ 10^5 - 1\ 10^6$K. Cheng (Ap J 238, 743) identifies a third group of formations observed in He_{II} - these are ribbon-like features, being the tops of loop arcades of the first group. Webb and Zirin (SP 69, 99) made a more thorough study of AR structure. They identified in AR′s five different structures of loops, including loops interconnecting AR′s, and confirmed the

https://doi.org/10.1017/S0251107X00004491 Published online by Cambridge University Press

conclusion of Moore et al (SF) that convection of matter in a loop proceeds due to variations of strong fields and chromospheric heating at loop tops. Kundu and Velusamy (Ap J 240, 63), with the aid of VLA detected a loop-like structure, connecting two large sunspots of opposite polarity. AR McMath 12690 in the range $\lambda\lambda$ 1600 - 1940 Å was studied by Mariska et al (Ap J 240,). They showed that the emission measure at T $\approx$ 7 10^5K for all parts of the AR is the same but varies over 7 $10^4 \leq T \leq 2.5$ 10^5K within two orders of magnitude.

Energy Balance and Heating Mechanisms

Using spectral lines in EUV and X-rays, Levine and Pye (SP 66, 39) determined the emission measure and radiative losses in AR's in the range $10^5 \leq Te \leq 5$ 10^6K, which turned out to be 3 10^{48} cm^{-3} and 4 10^{26} erg/sec, respectively.

Glencross (AA 83, 65) studied energy balance in arch-like structure of small size. To describe loop-like structures Vesecky et al (Ap J 233, 987) used a quasi-stationary model, based on balance of mechanical energy, due to the loss by radiation and as a consequence of heat conduction. Gravitation, variability of the loop cross-section, and other factors were taken into account. Roberts and Webb (SP 64, 77; SP 68, 87) considered the wave propagation in a magnetic field tube, surrounded by a non-isothermic atmosphere. Radiative losses cause the phase velocity to decrease and the waves, whose frequency is greater than the adiabatic one, to damp. Smith and Auer (Ap J 238, 1126) studied thermal models for the appearance of hard X-rays in an arch with an exponential density distribution, impulsive heating occurring at the top of this arch. Zweibel (SP 66, 305) and Habbal et al (SP 64, 287) studied the heating of the corona through dissipation of fast mode waves. It is shown (Zweobel, SP 66, 305) that the most probable condition for instability onset is the condensation perpendicular to field lines. The authors illustrate the possible heating of a coronal loop, if the wave flux energy density at the base of the corona is of the order 10^5 erg cm^{-2} sec^{-1}.

Hollweg (SP 70, 25) has examined the Alfvén wave propagation in closed and open magnetic tubes. He showed that "higher frequency" waves (with $P < 500$ sec) are able to transfer an energy of the order of 10^6erg cm^{-2} sec^{-1}. Levine (AZ 56, 1286) studied the heating mechanism of the corona above AR's through dissipation of the turbulence excited by fluxes of energetic electrons. Melrose (AUP 33, 121) showed that plasma emission on basic frequency results from transformation of Langmuir waves into ordinary waves. Coronal generation of waves originating from the turbulence in prominences, and the coronal heating above the transition zone were examined by van Tend (SP 66, 29), Cargill and Priest (SP 65, 251) studied isothermic and adiabatic flows in a coronal loop having a symmetric and asymmetric shape. A wide range of motions have been established: both with a subsonic velocity, and shock waves. Noci (SP 69, 63) dealt with siphon streams in arches with a subsonic and supersonic velocities and identified emission in λ 625 Å Mg_X and λ 499 Å Si_{XII}. From EUV lines Lites (SP 68, 327) found that in the transition zone above many sunspots, the gas rises with a velocity of 20 km/sec. Egan and Schneeberger (SP 64, 223) from the λ 5303 Å Fe_{XIV} line revealed both oscillations with a period of 6.1 $\pm$ 0.6 min and with an amplitude of 4.0 $\pm$ 0.35 km/sec. The amplitude enhances with altitude above the limb. Sylwester et al (SP 67, 285) proposed a new method of calculating the temperature from line intensities measured in X-rays. Zheleznyakov and Zlotnik (SP 68, 317; AZ 57, 778; AZ 57, 1038) calculated models of solar microwave radio emission (magnetic arches with hot electrons, regions of non-monotonic height variation of a magnetic field, current sheets, X-ray nuclei), the frequency spectrum of which may contain cyclotron lines.

https://doi.org/10.1017/S0251107X00004491 Published online by Cambridge University Press

Coronal Streamers

Dollfus and Mouradian (SP 70, 3) investigated, using movie pictures taken on board a balloon, the structure of coronal streamers at distances 2 - 5 $R_\odot$. Deformation of structures with rates not exceeding 10 km/sec was found. Three streamers were sloping towards corona's rotation which is evidence for the presence of zonal flows in the direction of solar rotation. Poland and McQueen (SP 71, 361) observed during five solar rotations a large coronal streamer. In contrast to previous observations, the streamer was not associated with any formation. The authors anticipate that it is associated with large-scale photospheric fields. With an increase in brightness and density of the streamer, magnetic flux is decreased. Gubchenko (FP) showed that the plasma flow in the streamer reduces the range of unstable wavenumbers, suppresses the growth rate and leads to a phase velocity in the teating mode.

Coronal Magnetic Fields

Pneuman et al (SP 59,313) calculated the global magnetic field, using the theory of potential field. A comparison is made of bright regions in the K-corona with the calculated closed magnetic fields. At 1.8 $R_\odot$ altitude, there is good agreement with the observations. However, one principal difference is revealed that coronal structures seem to be contracted towards the equator to form a narrow low-latitude band. One of the reasons for this phenomenon is the neglect of coronal currents. The same conclusion was reached by Mordvinov and Kovalenko (IGAFS 49, 41) in calculating magnetic fields near AR's. Baum et al (SP 62, 53) proposed a new approach to the analysis of magnetograms which is illustrated with a highly symmetrized example that permits integration in closed form. The proposed approach exploits the cellular structure of the flux of field lines present in a complex AR. The computer results show that the separatrix has the form of two intersecting ovoids, defining four flux cells. The two neutral points ($\bar{B} = 0$) which appear at the photospheric ends of the separator have the mixed radial-hyperbolic form, a feature requiring every field line lying on the separatrix to connext with at least one of the two neutral points Baum and Bratenahl (SP 67, 245).

Simple analytic models for the passive evaluation of arcade-line magnetic fields through a series of force-free equilibria are presented by Priest and Milna (SP 65, 315). A solution to the force-free field equations, of separable form, is discovered and it is pointed out that the existence of shear in a magnetic field does not preclude it from being potential.

Sakurai (SP 69, 343) applied a numerical method for solving the force--free magnetic field equation with a variable α . Poulain (SP 70, 229) calculated the intensity gradient in λ 5303 Å under different assumptions about the magnetic structure of the corona. It is shown that the material in the corona is enclosed basically in the lower parts of very high loops or in open structures for sub-region II and in low arches in sub-region I. Priest and Smith (SP 64, 267) discuss temperature and density structures of loop arcades with a force-free magnetic field. They examined the formation of a prominence in the corona. The material of the prominence is drawn in from the underlying layers. Hood and Priest (AA 87. 126) investigated the thermal instability of static models of coronal loops. The conditions of instability depend strongly upon the selection of boundary conditions and little upon the form of the heating function. Gelfreikh and Lubishev (AZ 56, 262), Akhmedova and Ryabov (SDB 80, 85) and Ryabov (RSRS 12, 44) investigated the structures of magnetic fields and other sources of magneto-bremsstrahlung. Bhonsle and Degaonkar (SP 68, 339) reported on one attempt based on the observation of the Razin effect in decameter continuum burst to deduce coronal magnetic field. The magnitude of field around 2 $R_\odot$ from the Sun

https://doi.org/10.1017/S0251107X00004491 Published online by Cambridge University Press

center works out to be about 6 G.

Evolution of Magnetic Structures

Dynamics and evolution of coronal structures of AR's from EUV and X-ray observations were investigated by Sheeley (SP 66, 79). At $T \sim 0.5\ 10^6$ K the emission is concentrated in separate spiky structures, whose lifetime is $\tau \sim 30$ min. At $T \sim 10^6$ K, the structures appear like loops and more diffuse spikes, with $\tau \sim 1.5$ hr while at $T \sim 2\ 10^6$ K the emission originates from loop-diffuse features, covering the entire AR. The lifetime of individual features is ~ 6 hr, and that of the whole system several days and more. The structure and evolution of a bright area in soft X-rays in a small AR was investigated by Sheeley and Golub (SP 63, 119). The area was resolved into 2-3 miniature loops, which rapidly evolved and were replaced. The lifetime of one loop was $\sim 6^m$. Howard et al (SP 63, 105) showed that bright areas in X-rays associated with evolving AR's, arise on chromospheric cell boundaries.

Somov and Syrovatskii (PAZ 6, 592) showed the possible formation in AR's of cool dense loops due to radiative losses in a current sheet and onset of a thermal instability.

Numerical calculations carried out by Krall and Antiochas (Ap J 242, 347) showed that significant variations in the heating intensity of loops arise when mass and energy interchange with underlying atmospheric levels.

Transients

a. Observations

MacQueen (PTRSL A 297, 605) gives a review of the main properties of transients observed on Skylab and with the High Altitude Observatory coronagraph. The basic types of transient are moving and expanding loops (1/3 of all cases) and clouds (1/4 of all cases). The mean velocity of transients associated with flares is 775 km/sec, while that associated with prominences 330 km/sec. These formations are in accelerated motion on the average as far as 2 $R_\odot$. The kinetic energy is 7.10^{30} erg which is comparable with the energy of a flare. However, Wagner et al (Ap J L244, L123) observed on April 7, 1980 a huge loop-shaped transient with nonradial motions. The authors found that the moving radio source of the IV type coincided with or was located very closely to the transient. Combination of the data permitted the determination of thermal, mechanical and magnetic energy. A puzzling result was obtained: the mechanical energy of the transient is more than an order of magnitude the total energy of emission in a flare while the magnetic energy of the transient is still greater. As shown by Munro et al (SP 61, 201), and McQueen (PTRSL A 297, 605) 40% of transients are associated with flares, 50% only with eruptive prominences and 70% with eruptive prominences and disappearance of filaments (with flares or without flares). Among the transients studied by Munro Trottet and McQueen (SP 68, 177) identified a group of transients which are associated with filaments, the axis of which is oriented in the N-S direction. The observations carried out by Poland et al (SP 69, 169) showed that six well-defined transients had masses ranging from 7.10^{14}g to 2.10^{16}g and velocities from 150 km/sec to 900 km/sec. It is expected that near the solar maximum they occur in a wider latitude range (from 5° to 80°). Sheeley et al (Ap J L238, L161) reported observations of a high-latitude transient on P78-I associated with the eruption of a polar prominence.

House et al (Ap J L244, L117) observed on SMM 22 transients during 52 days. For the first time they observed: emission in H-alpha in the outer corona and emission in Fe XIV at a distance of 3.2 $R_\odot$. These authors also believe that during the solar maximum transients occur more frequently than during solar activity decline. Anzer and Poland (SP 61, 95) investigated

https://doi.org/10.1017/S0251107X00004491 Published online by Cambridge University Press

temporal variations of density and mass per unit length of the transient. During $0.^d5 - 1.^d0$ the mass and density gradually increase and afterwards decrease, taking approximately the same time. Consequently, the transient lifetime seems to be $1^d - 2^d$.

A classification with respect to the character of radio emission has been proposed by Dulk (RPS). He found slow transients with $V < 400$ km/sec with no attendant radio bursts but manifest themselves in an enhancement of the level of thermal radio emission, transients with $400 < v < 1000$ km/sec with concurrent II and IV type bursts and very fast transients with $v > 1000$ km/sec associated with power flares.

b. Interpretation

Van Tend (SP 61, 89) continued developing the model of Anzer (SP 59, 111) with inclusion of the initial stage of development of the transient associated with prominence destabilization.

The interrelation between transients and eruptive prominences is used by Pneuman (SP 65, 369) to construct a model of this phenomenon. Solution of a relevant MHD equation yielded time variation, velocities, densities and magnetic fields. In the vicinity of the Sun, the velocity increases abruptly and afterwards takes on at a high rate a nearly constant value. Gas-dynamical plasma motion in a strong magnetic field with due regard for the impulsive heating by energetic electrons was treated by Somov et al (TF 110, 73; S KAPG). It was found that the evaporation of the upper part of the chromosphere upwards into the corona proceeds at a rate of about 1500 km/sec.

9. SOLAR WIND AND SOLAR-TERRESTRIAL RELATIONSHIPS
(M. Dryer)

(a) STIP Activities and Plans

Important observations of the sun, solar wind, and the latter's interaction with the terrestrial and distant planets have been obtained since the last report by Pioneers 10 and 11 (the latter also referred to as Pioneer-Saturn), Voyagers 1 and 2, Pioneer-Venus-Orbiter (often referred to as Pioneer 12), Veneras 11 and 12, Prognoz-8, ISEE-3, P78-1, Solar Maximum Mission and Helios 1 and 2. Each of these missions has contributed essential parts of the scientific puzzle posed by the interplanetary "transmission line". Much of these results continue to be published by the project teams in the literature. Also, a continuing effort to engage in open dialogue on these topics amongst a wider cross-section of the scientific community has been undertaken by the SCOSTEP project Study of Travelling Interplanetary Phenomena (STIP) in collaboration with Commission 10, COSPAR, IUPAP, and IAGA. Thus, STIP continues to operate on an informal basis with an interdisciplinary and international forum that is open to all scientists interested in this research.

The most recent account of STIP activities at this writing (October 1981) is given by Dryer and Shea (STIP NL 11). Described therein are the plans for publication of several STIP Symposia in Australia and Czechoslovakia (respectively: Symposium on Solar Radio Astronomy, Interplanetary Scintillation, and Coordination with Spacecraft, Narrabri, N.S.W., 1979 November 28-30; and Symposium on Shock Waves in the Solar Corona and Interplanetary Space, Smolenice, 1980 June 15-19). The Proceedings will be published (respectively) by Air Force Geophysics Laboratory (Bedford, Mass., USA) and by Space Science Reviews. A major activity of STIP is its intensive involvement in the Solar Maximum Year. Preliminary results are given in the Proceedings of the Crimean SMY Workshop (Obridko and Ivanov, Eds.) held in Simferopol, Crimea, USSR, in 1981 March 24-28.

STIP NL 11 provided preliminary details on solar-interplanetary events that were studied in still greater detail at the SMY Workshop in Annecy,

https://doi.org/10.1017/S0251107X00004491 Published online by Cambridge University Press

France, 1981 October 26-31, and planned for another STIP Workshop on various outstanding Intervals and Events at Maynooth, Ireland, on 4-6 August 1982. The SMY/STIP events described below were chosen on the basis of preliminary solar and interplanetary (or, more accurately, lower corona) events which indicated cause-and-effect diagnostics. In a few cases, some preliminary shock data from Helios, ISEE-3, and Pioneer-Venus were used to make preliminary assessments of the "transmission line".

The first set of SMY/STIP Events (No. 1 coordinated by S. Kane, Univ. of California, Berkeley) is an example of the rationale utilized to choose a "transmission line" candidate that will, hopefully, fill the gaps in our scientific understanding. First, it should be noted that the SMY started with STIP Interval VII (1979 August-September). On 1979 August 14, 1243 UT, a flare occurred at S22°E73°. ISEE-3 measured X-rays that were correlated with the microwave burst, P78-1 detected a white-light coronal transient. The JPL Deep Space Net's measured signals to and from Pioneer 11, Pioneer-Venus, and Voyagers 1 and 2 also indicated (Croft, AFGLR, in press) passage of a coronal transient. The Toyokawa Observatory detected high speed solar wind with the interplanetary scintillation (IPS) technique. Several days later (1979 August 18), a similar scenario, with variations, took place. At 1420 UT, another flare took place at or near the east limb (N09°E90°). Harvard's Radio Observatory detected a Type II shock wave. The Deep Space Net's signals to Voyager 1 detected a shock wave travelling at 3500 km/sec at 13 solar radio (Woo and Armstrong, N 292, 608). P78-1 again detected a white light transient. ISEE-3's radiometer detected the Type II shock from the lower corona throughout the interplanetary medium until it impacted the spacecraft where it was confirmed via the omboard magnetometer and solar wind plasma probe. The IPS observations (again) detected high speed solar wind prior to the shock's arrival at Earth where it was detected by IMP-8.

Other SMY/STIP Events that are believed to have some features in common with Event No. 1 are as follows: (a) Event No. 2, 1980 April 4 (and succeeding days), Coordinator is M. Pesses, NASA Goddard; (b) Event No. 3, 1980 April 12 (etc.), Coordinator is C. Sawyer, NCAR/HAO; (c) Event No. 4, 1980 April 27 (etc.), Coordinator is R. Stewart, CSIRO/Culgoora; (d) Event No. 5, 1980 June 27 (etc.), Coordinator is S. McKenna-Lawlor, St. Patrick's College/ Maynooth. In addition to these events, the STIP Organizing Committee has also continued its practice of declaring more extended STIP Intervals when sufficient interest is forthcoming. Thus, STIP INTERVAL VIII (1979 October 15 - December 19) was declared, with H. Sawant, INPE) São Paulo, as Coordinator. INTERVALS IX - XI, also during the SMY, are described in more detail (insofar as the spacecraft "constellations" are concerned) by Dryer and Shea, STIP NL 11. Also, an important post-SMY STIP INTERVAL XII (1981 April 10 - June 21) was declared, with three coordinators (due to the extensive solar and interplanetary activity) as follows: T. Gergely, Univ. of Maryland/College Park, O.L. Vaisberg, IKI/Moscow, and G. Zastenker, IKI/Moscow. Reports on all of these SMY/STIP Events and STIP Intervals were presented at the SMY Workshop in Annecy. Other Events were also discussed for potential addition to the above-numbered 1-5. Future STIP Intervals (including the epoch during the Comet Halley encounter in 1985-86) were also discussed for future declaration.

(b) Solar Wind and Solar-Terrestrial Relationships

Several noteworthy IAU Symposia (86 on Radio Physics of the Sun (RPS), and 91 on Solar and Interplanetary Dynamics (SID)) were held in August 1979 to address many of the scientific questions associated with this topic. The association of white light transients and radio bursts during the Skylab period were reviewed by Dulk (RPS, 419) who compared observational estimates of kinetic potential, and magnetic energies resident within a transient. Anzer (SID, 263) summarized some of the various proposed models for transients including self-prpelled loops, reconnection-driven loops, and time-

https://doi.org/10.1017/S0251107X00004491 Published online by Cambridge University Press

-dependent MHD (continuum models). The first model appears to be in error as pointed out by Yeh and Dryer (Ap J 245, 704), who note that the self-induced magnetic force on a loop will cause only contraction or expansion, not translational motion of the loop. The second model (Pneuman, SID, 317) phenomenologically treats the unbalanced magnetic gradient around a loop by hypothesizing additional flux transfer, below the loop, as a result of reconnection. The third model (Wu, SID, 448) is a two-dimensional treatment in which finite-amplitude waves (including mass motion and shock waves) are produced by thermal and/or magnetic perturbations. These perturbations (or pulses) that represent unspecified kinetic processes are input numerically in the classical initial-boundary value problem. Kuperus (SID, 547) noted that the latter calculations ought to be made in: (a) three dimensions using (b) kinetic theory in order "to give full credit to all possible wave modes and interactions." The first suggestion has since been addressed, via a non-planar approach (2D, will all three components of magnetic field and bulk motion velocity) by Nakagawa et al (Ap J 244, 331). Kuperus' second suggestion has also been considered (in part, for stellar/solar winds) by Cuperman et al (Ap J 239, 345; Ap J, in press) who derived higher moment equations for multi-component, non-equilibrium, spherically-symmetric plasma systems with nonzero relative flow velocities and skewing of velocity distribution functions in the Fokker-Planck formalism. Also, Wu (SID, 443) discussed the hierarchy of solutions ranging from continuum toward hybrid fluid-kinetic treatments that would also address Kuperus' second concern.

The "pulses" referred to above have been addressed via the fluid treatment within the chromosphere by Syrovatskii and Somov (SID, 491) and discussed in more detail by Sermulina et al (SID, 491). The latter conclude that impulsive heating (as discussed by Wu (SID, 443) for the coronal transient MHD model) can be produced by non-thermal electrons as well as by heat conductive fluxes (i.e., by the thermal model discussed elsewhere in this Report).

Meanwhile, the search for defining the solar/interplanetary "transmission line" is continuing. More radio (Stewart, SID, 333; Stone, RPS, 419), white light (McQueen, PTRSL A 297, 605; Michels et al, SID, 387 and House et al, Ap J L244, L117), and interplanetary (Intriligator, SID, 357; Burlaga et al, JGR 85, 2227; Smith et al, JGR 86, 6773; Düston et al, JGR 86, 525; Richter et al, JGR, in press) observations continue to add additional knowledge to the field of solar wind and solar-terrestrial relationships.

A recent area of interest has been the latitudinal properties of the solar wind. Complementing the remote sensing of solar wind velocity by the IPS technique (Kakinuma, STIP, 101) are more recent in situ measurements (Rhodes and Smith, JGR, in press) of the interplanetary magnetic field out-of-the ecliptic. Their results clearly show the warped current sheet that was hypothesized in earlier studies. Indeed, it has been suggested, via tilted heliospheric coordinate interactions and associations with solar surface magnetogram observations (Zhao and Hundhausen, JGR 86, 5423; and Hakamada and Akasofu, SSR, in press), that the organization of latitudinal properties may be better served by employing the heliomagnetic equator (rather than the ecliptic or solar equatorial plane) as the appropriate plane of symmetry in the heliosphere.

Finally, a word regarding the coupling between the solar wind and the magnetosphere (Earth, say) is worth mentioning not only because of its intrinsic scientific interest, but practical relevance as well. Akasofu (SSR 28, 121) has reviewed all of the proposed empirical solar wind indices that appear, from a statistical standpoint, to be relevant to auroral and geomagnetic storm activity. In a separate theoretical approach, Yeh et al (PSS 29, 425) note that the stresses between the solar wind and the magnetospheric tail are probably responsible, dynamo-like, for the coupling of solar wind energy into the Earth's magnetosphere. Akasofu (SSR 28, 121) also points out that sufficient knowledge of "input" solar boundary conditions (mathematically expressed again as an initial-boundary value problem) can, together with sufficient knowledge of the solar wind and its magnetic topology, provide "output" parameters of the solar wind (at Earth, say) that may be used empirically (and supported theoretically as noted above) to explain solar-interplanetary medium-magnetosphere relationships.

10. GROUND BASED OPTICAL SOLAR INSTRUMENTATIONS (R.J. Bray)

A. New Telescopes

Nakai (JFS, 275) has described the new domeless tower telescope (Zeiss, Oberkochen) at Hida Observatory, Japan, with particular reference to methods of eliminating telescope heating and local seeing. Test observations in 1979 showed a resolution of 0.3-0.5 arc sec.

Progress in establishing European telescopes in the Canary Islands by the Joint Organization for Solar Observations has been reported by Stenflo (OW). Germany is operating 40 cm and 45 cm vacuum test telescopes at Izana (Tenerife) and Roque de los Muchachos (La Palma) and is setting up a 60 cm vacuum tower telescope at Izana (Kiepenheuer Institute). Göttingen will be moving its Locarno facilities (Wiehr et al, SP 68, 207) to Izana, while Meudon plans a 60 cm polarization-free telescope for La Palma. The Swedish Capri Observatory has been transferred to Fuente Nueva (La Palma). Constructional details of some of these telescopes are to be found in JOSO.

Two new telescope embodying the concept of an 'open' telescope and tower pioneered by the 30 cm refractor at Culgoora are a 45 cm Cassegrain at Utrecht (Hammerschlang and Rutten, OMA 106, 115), destined for the Canaries, and a 50 cm Cassegrain in the East Pamir (Pulkovo) (Parfinenko and Mikhalev, SDB 8, 92). This concept achieves high spatial resolution at a much lower cost than the vacuum tower design.

A JOSO working group is studying the feasibility of a Large European Solar Telescope (LEST) in the 200-250 cm range; an initial report has been prepared by Engvold and Hefter (SPOW). Under consideration are vacuum and helium-filled tubes as well as an 'open' telescope based on experience to be obtained with the Dutch instrument.

At Ondřejov two 50 cm horizontal telescopes by VEB C. Zeiss Jena have been installed, with a third to follow in 1982 (Bumba, private communication). Two further such instruments, described by Gutcke (JR 24, 32) and Ambrož et al (PSP 14, 107), are under construction for other institutes in Czechoslovakia. All mirrors are made from a Soviet ceramic material called Sital. The large vacuum tower telescope ordered from VEB C. Zeiss Jena several years ago has been postponed owing to funding difficulties.

The 90 cm and 45 cm tower telescopes at the Crimea have been reconstructed and a new 50 cm coronagraph has been built (Severny, private communication).

A new double-tube chromospheric/photospheric telescope made by the Nanjing Astronomical Instrument Factory has been installed at the Shaho station of Beijing (Peking) Observatory. Under construction at the Nanjing Factory is a 35 cm refractor specifically designed for magnetic field measurements, employing a birefringent filter and either photographic or video processing. Ninety per cent of the optical path is in vacuo. The telescope will be mounted on a 20 m tower located on a peninsula in a Beijing suburban reservoir (Wang Jia-long, private communication). A 33 cm tower telescope was built for Nanjing University in 1979.

At Lake Baikal, SibIZMIR (Irkutsk) expects to start trial observations with their 76 cm vacuum telescope in the summer of 1981 (Smolkov, private communication). The same Institute has constructed a 'Solar Telescope for Operative Prediction' which incorporates a magnetograph and spectroheliograph and can also measure the apparent overall field of the Sun as a star with a sensitivity of 0.1 gauss. Further instrumental developments at SibIZMIR are

https://doi.org/10.1017/S0251107X00004491 Published online by Cambridge University Press

described in vols. 45, 47, 49 and 52 of IGAFS.

B. Stokes Polarimeters and Magnetographs

The HAO/SPO Stokes Polarimeter mounted on the 40 cm coronagraph at Sacramento Peak was extensively modified and improved, principally by replacing the photomultipliers by 128 element silicon photodiode arrays (Baur et al, SP 65, 111; 70, 395). This gave a speed increase of 50, but observations of vector fields were subsequently terminated by financial stringency. However, the detectors and associated readout electronics have now been installed in the University of Hawaii polarimeter at Haleakala (Mickey, private communication).

Two new polarimeters are in service at Kitt Peak: a full Stokes system on the McMath telescope, and an accessory to the 1 m Fourier Transform Spectrometer. The latter permits simultaneous observation of 3 Stokes parameters over broad wavelength regions in the range UV to 2.2 µm (Harvey, private communication). Baur et al (loc. cit.) have listed other photoelectric polarimeters around the world.

The new magnetograph at Meudon has been described by Rayrole (JFS, 258). A number of magnetographs have been upgraded and modernized including that of the 46 m tower at the Mt. Wilson (Howard, private communication), Ondřejov (Bumba and Klvaňa, PSP 14, 95), and the Babcock and 512 channel instruments at Kitt Peak (Harvey, private communication).

C. Miscellaneous

High resolution photography of the photosphere at the Pic-du-Midi continues to be outstandingly successful with the 50 cm objective installed in the Turret Dome. This telescope has now been equipped with a spectrograph designed at Meudon for studies of photospheric and chromospheric fine structures (Mouradian et al, JFS, 271). The status of the coronal equipment has been outlined by Rösch (ibid, 269).

At Mt. Wilson (18 m tower) a Charge Injection Device camera has been installed for observing the p-mode oscillations (Howard, private communication).

Harvey (OMA 106, 228) has outlined long-range plans for the improvement of the major facilities at Kitt Peak. Despite budget cutbacks, KPNO plans to continue to provide state-of-the-art auxiliary equipment for observing and data handling. The Fourier Transform Spectrometer, now in use, has been described by Brault (OMA 106, 33). This instrument has a maximum path length of 1 m and a spectral resolution comparable with or exceeding that of a large conventional grating spectrograph.

Title and Ramsey (AO 19, 2046) have described an improved birefringent element incorporating a wide field solid Michelson interferometer. A filter made of such elements offers greatly reduced sensitivity of wavelength to temperature. Other improvements to filters are discussed by Leroy (JFS, 288). The Universal Birefringent Filter at Sacramento Peak has been extensively upgraded by replacing the original electronic, mechanical and thermal subsystems.

Another development at SPO is a new type of velocity meter, called a 'Fourier Tachometer' (Beckers and Brown, OMA 106, 189), designed to measure velocities with an accuracy of a few meters per second. A specialized instrument has been constructed to observe from the South Pole long-period oscillations in the solar limb darkening (SPOW, 390). SPO continues development of two-dimensional CCD arrays for a variety of solar applications, together with associated computer systems; other instrumental advances have been described by Cram (SP 69, 411).

https://doi.org/10.1017/S0251107X00004491 Published online by Cambridge University Press

11. THE SOLAR MAXIMUM YEAR

The Solar Maximum Year (SMY), which took place from August 1, 1979 to February 28, 1981, was designed as a period around solar maximum for a world-wide effort to obtain coordinated observations of solar activity. The SMY was organized by the Scientific Committee for Solar-Terrestrial Physics (SCOSTEP) around three existing studies, viz. the Flare Build-up Study under Dr. Z. Švestka, the Study of Energy Release in Flares under Dr. D. Rust and the Study of Travelling Interplanetary Phenomena under Dr. M. Dryer. Dr. C. de Jager was the SMY chairman and Dr. P. Simon the secretary. All major, and many smaller, observatories around the world, as well as two satellite missions (Solar Maximum Mission (SMM) and Hinotori) participated in the SMY effort. The following report on the SMY was prepared jointly by Drs. M. Dryer, W. Henze, D. Rust, Z. Švestka, K. Tanaka, and E. Tandberg-Hanssen.

The Flare Build-Up Study (FBS)

In 1980, 67 institutes of 27 countries and 6 experiments on the SMM took part in the main FBS program of intense solar observations during six weeks in May and June and four weeks in September and October. During selected short periods also the 'giant' radiotelescopes (VLA, Westerbork, Bonn, Owens Valley) participated in the FBS ACTIONS (see the FBS/SERF Manual edited by P. Simon, Meudon, France).

Solar activity was at high level during the May/June 1980 period and 7 FBS ACTIONS were declared. The relatively quiet September period offered the opportunity for coordinated 'bright-point' observations. Three additional ACTIONS were accomplished in October. Six active periods (May 20-22, May 23-27, June 12-13, June 20-24, June 24-30 and October 20-25), the bright-point data, and two general topics ('Homologous Flares' and 'Simple Flares') were selected for further study, and nine working groups were established to study these selected situations and topics. Seven of the WG's met at Greenbelt, MD USA, in February 1981 and several WG's met in Crimea, USSR, in March 1981. Preliminary results were presented and discussed at the SMY Workshop at Annecy, France, in October 1981.

The Study of Energy Release in Flares (SERF)

Research objectives for SERF were developed at the Cambridge Workshop (Rust and Emslie, UAG 72, WDCA). Work focussed on whether the primary energy release process is thermal or nonthermal, whether either process leads to an acceptable description of the flare atmosphere, whether flare-associated mass motions spring from thermodynamic or magnetic forces, and how atomic particles, especially ions, are accelerated.

Collaborative observations during fifteen SERF "actions" yielded data on several hundred flares. Four teams studying SERF problems met at the SMY Workshop in Annecy, France, October 1981 and presented preliminary results. The post-workshop efforts will be described at the SMY Symposium in Ottawa.

The Study of Travelling Interplanetary Phenomena (STIP)

See: 9. Solar Wind and Solar-Terrestrial Relationships by M. Dryer.

Observations by Hinotori

Hinotori (ASTRO-A), the Japanese second astronomy satellite launched by the Institute of Space and Aeronautical Science of the University of Tokyo, has been operating continuously since February 26, 1981, obtaining extensive observations of solar flares in X-rays and γ-rays. Hinotori carries five instruments; viz. (1) hard X-ray imaging telescope in the energy range of

10-60 keV (SXT). (2) Bragg spectrometers for 1.7-2.0 Å (SOX), (3) soft X-ray spectrometer for 2-20 keV (FLM), (4) hard X-ray spectrometer for 17-340 keV (HXM), and (5) γ-ray spectrometer for 240-700 keV (SGR). All the instruments monitor the full sun.

During early operations through July 31, 1981, Hinotori observed 261 flares including 13 X-class events. Several large events have been analyzed to reveal very compact sources for hard (12-30 keV) X-ray bursts, indicating high density and suggesting the thick target origin of the hard X-ray emission. On the other hand, a duble-source structure with unbalanced intensities was found in a large X5.5 limb event (April 27), where the separation between the two sources was 1.2' and the sources had dimensions less than 30". After July 1981 observations with the higher energy ranges (20-40 keV) have been obtained.

The SOX has obtained many high resolution spectra which include emission lines from Fe XIX to Fe XXVI, K_α and K_β (1.75 Å). The L_α and satellites of Fe XXVI have been well resolved; their ratios give electron temperatures considerably higher (3-10 million degrees) than the temperatures derived from the Fe XXV pair. In some impulsive events one sees intensity fluctuations of 10-20% and temperature fluctuations of up to five million degrees in correspondence with hard X-ray spikes. Linear polarization of about 10% seems associated with some of these rapid variations. In other impulsive flares the mean temperature increases steadily from about 15×10^6 K to 30×10^6 K in the rising phase. The differential emission measure exhibits a pronounced peak about 20×10^6 K which shifts to higher temperatures and then returns to lower temperatures. Line broadening of about 250 km s^{-1} has been seen before the increase of the temperature.

The soft X-ray spectra in the range of 2-10keV obtained by the FLM have given evidence for gradual heating of the flare plasma in the rising phase of small flares; in these spectra the emission lines from the He-like and H-like ions of Ar, Ca, Ti, Fe and Ni appear and become enhanced successively in this order. The γ-ray spectrometer (SGR) has detected significant emissions of the following lines (shown in MeV) at least in two events: 0.51 ($e^+ + e^-$), 0.84 (^{54}Fe), 1.37 (^{24}Mg), 1.64 (^{14}N or ^{20}Ne), 2.22 (D), 4.44 (^{12}C), 6.14 (^{16}O). Unidentified emission has been seen at 1.0 MeV. In the limb event (April 27) the 2.2 MeV line was less intense by an order of magnitude than the 4.4 MeV line. This supports the photospheric origin of the 2.2 MeV line. Continuum spectra extending to 7 MeV have been observed; they tend to show a break near 1 MeV.

Solar Maximum Mission (SMM)

Coronagraph/Polarimeter (L.L. House, PI): The use of an H alpha filter permitted the first direct observation of H_α-emitting material out to 3.7 $R_\odot$. The material was in the form of an eruptive prominence centered within a coronal transcient. No H_α emission has been observed in the outer loops of coronal transients, thus confirming previous suggestions that the source of material in loop transients is not the cool prominence. Simultaneous observations of flare-related coronal transients and Type IV radio sources yield the result that the magnetic energy density is much greater than the thermal and kinetic energy densities, except possibly in the fastest leading edge where the kinetic and magnetic energy densities may have been comparable.

Ultraviolet Spectrometer and Polarimeter (E. Tandberg-Hanssen, PI): Use of the polarimeter which can measure the four Stokes parameters has allowed the first observations of the Zeeman effect and its associated circular polarization in the solar ultraviolet spectrum below 2000 Å. Observations in the C IV 1548 Å line, formed in the transition region at $\sim 10^5$K, show line-of-sight magnetic field strengths of more than 1000 gauss above the umbra of large sunspots. Oscillations in the transition region above sunspots have also been observed. The amplitude is a few kilometers per second and the periods range from 130 to 190 seconds. Density determinations have been obtained from observations of the Si IV 1403 Å and O IV 1401 Å lines. The ratio of the two lines is sensitive of electron density above $\sim 5 \times 10^{10}\ cm^{-3}$ and is useful for active region and flare studies. During flares, the UV brightening at individual locations in the flaring region correlates well with individual spikes in the hard X-ray light curve.

X-Ray Polychromator (Flat Crystal Spectrometer and Bent Crystal Spectrometer) (L. Acton, L. Culhane and A. Gabriel, PI's): Observations of line ratios and line widths in the soft X-ray spectral region have been obtained for active regions and flares. In active regions, the ratio of Ne IX to Mg XI lines yields a temperature of 4×10^6K while the line widths show excess broadening corresponding to small scale velocities of 100 km s^{-1}. In flares, the ratios of satellite to resonance lines in Ca XIX and Fe XXV yield temperatures of 12 to 22 x 10^6K; the line widths again show excess broadening due to turbulent motions of up to 100 km s^{-1}. The observed Fe K_α flux can be produced by fluorescence rather than by ionization.

Hard X-Ray Imaging Spectrometer (C. de Jager, PI): Images of flares in hard X-ray spectral bands indicate that the emission originates in arcades of loops with differing spectral hardness. In one flare the spectrum was harder in the legs or foot points and softer at the top of the loop. Temperatures in excess of 8×10^7K have been found in the impulsive phase although a powerlaw spectrum may fit the observations better.

Hard X-Ray Burst Spectrometer (K. Frost, PI): High time resolution observations of flares have shown complex intensity variations on time scales of 100 ms and spectral variations on time scales of seconds. One flare showed quasi-periodic intensity spikes with the time intervals between spikes varying from 7 to 11 s.

Gamma Ray Spectrometer (E. Chupp. PI): Both line and continuum emission from flares have been observed. The continuum emission, excited by high energy electrons is impulsive while the line emission at 2.223 MeV decays more slowly. The line results from neutrom capture by hydrogen with the neutrons being produced by reactions involving energetic ions.

Active Cavity Radiometer Irradiance Monitor (R. Willson, PI): Decreases in the solar irradiance are observed that correlate well with the passage of sunspots across the solar disk. A future goal will be to identify the source of the increases above the average to answer the question of what happens to the missing radiative energy from sunspots.

ABBREVIATIONS

AA	Astronomy and Astrophysics
AAS	Acta Astronomica Sinica
AASup	Astronomy and Astrophysics Supplement
AC	Astronomicheskij Tsirkular
AFGLR	AFGL Report, Bedford, Mass., USA
AIISAOZ	Astrofiz. Issled. Izv. Spets., Astrofiz. Obs., Zelenchukskaya
AIP	La Jolla Institute Workshop on Gamma Ray Transients and Related Astrophysical Phenomena; to be publ. American Inst. of Physics
AMES	Astronomische Mitteilungen Eidg. Sternw. Zürich
AN	Astronomische Nachrichten
AO	Applied Optics
Ap J	Astrophysical Journal
Ap J L	Astrophysical Journal Letters
Ap J Sup	Astrophysical Journal Supplement
AS	The Ancient Sun (Pepin et al, Eds.), Pergamon Press
ASR	Adv. Space Research
ASS	Astrophysics and Space Science
AUP	Australian Journal of Physics
AZ	Astronomicheskij Zhurnal Akad. Nauk SSSR

BAAS	Bulletin of the American Astronomical Society
BAC	Bulletin of the Astronomical Institutes of Czechoslovakia
CAp	Comments on Astrophysics
CHHSWS	Coronal Holes and High Speed Wind Streams Skylab Solar Workshop, Colorado Assoc. Univ. Press
CNRS	Centre National de la Recherche Scientifique
CR	Comptes Rendus de l'Academie des Sciences, Paris
DAN	Doklady Akademii Nauk SSSR
EOS	EOS American Geophysical Union
GAFD	Geophysical and Astrophysical Fluid Dynamics
HOB	Hvar Observatory Bulletin
IAN	Izvestiya Akademii Nauk SSSR
IGAFS	Issl. po Geomagn. Aeronom. i Fiz. Solntsa
IGAO	Izvestiya Glavnoi Astronomicheskoi Observatorii, Pulkovo
IKAO	Izvestiya Krymskoj Astrofizicheskoj Observatorii
ISRAR	Krüger, Introduction to Solar Radio Astronomy and Radiophysics, Reidel P. C. 1979
JBAA	Journal of the British Astron. Association
JFM	Journal of Fluid Mechanics
JFs	Proceedings of the Japan-France Seminar on Solar Physics (Moriyama and Henoux, Eds.), JSPS-CNRS 1980
JG	Journal of Geophysics
JGR	Journal of Geophysical Research
JOSO	JOSO Annual Report
JR	Jena Reviews
KOB	Kodaikanal Observatory Bulletin
MP	Magnitnye Polya i Dvizhenie Aktivnykh Obrazovanij na Solnce, Vladivostok 1981
MPSA	Morphology and Periodicity of Solar Activity, Tashkent 1981
MN	Monthly Notices of the Royal Astronomical Society
MSUNS	Mem. Shiga Univ. Nat. Sci.
N	Nature
NASA	National Aeronautics and Space Administration
NS	New Scientist
OMA	Oss. Mem. Oss. Astrofis. Arcetri
OW	Oxford Workshop
PASJ	Publications of the Astronomical Society of Japan
PAZ	Pisma v Astronomicheskij Zhurnal Akad. Nauk SSSR
PBAO	Publ. Beijing Astron. Obs.
PEPI	Physics of the Earth and Planetary Interiors
POS	Publ. Obs. Sarajevo
PRL	Physical Review Letters
PS	Physica Solariterrestris, Potsdam
PSP	The Physics of Solar Prominences IAU Colloquium No. 44
PSS	Planetary and Space Science
PTRSL	Philosophical Transactions of the Royal Society, London
QJRAS	Quarterly Journal of Royal Astronomical Society
RGSP	Reviews of Geophysics and Space Physics
RITA	Report of the Institute of Theoretical Astrophysics, Blindern-Oslo
RPS	Radio Physics of the Sun (Kundu and Gergely, Eds.), IAU Symp. No 86, Reidel P. C.
RSRS	Research of the Sun and Red Stars, Riga
SA	Soviet Astronomy
SAL	Soviet Astronomy Letters
SaS	The Sun as a Star, NASA and CNRS
Sc	Science
SDB	Solnechnye Dannye Byulleten

SF	Solar Flares (Sturrock, Ed.), Skylab Solar Workshop II, Colorado Assoc. Univ. Press 1980
SFMHD	Solar Flare Magnetohydrodynamics, Gordon and Breach
SID	Solar and Interplanetary Dynamics (Dryer and Tandberg-Hanssen, Eds.) IAU Symp. No 91, Reidel P. C.
SKAPG	Symp. KAPG Askhabad 1979
SMM	Solar Maximum Mission Satellite
SMY	Solar Maximum Year
SP	Solar Physics
SPOW	Sacramento Peak Observatory Workshop
SS	Scientia Sinica
SSAOZ	Soobshch. Spets. Astrofiz. Obs. Zelenchukskaya
SSPP	Solar System Plasma Physics (Parker et al, Eds.), North-Holland P. C. 1980
SSR	Space Science Reviews
STIP	Study of Travelling Interplanetary Phenomena (Shea et al, Eds.), Reidel P. C. 1977
STIP NL	STIP Newsletter
STPP	Solar Terrestrial Predictions Proceedings (Donnelly, Ed.), US Dep. of Commerce 1979
TF	Trudy Fizicheskogo Instituta Akademii Nauk
VKU	Vestnik Kievskogo Universiteta
WCSSSS	Proceedings of the Second Workshop on Cool Stars, Stellar Systems and the Sun
WDC-A	World Data Center A
WISP	Wave Instabilities in Space Plasma (Palmadesso and Papadopoulos, Eds.), Reidel P. C.

V. Bumba
President of the Commission

https://doi.org/10.1017/S0251107X00004491 Published online by Cambridge University Press