COMMISSION 12: RADIATION AND STRUCTURE OF THE SOLAR ATMOSPHERE (RADIATION ET STRUCTURE DE L'ATMOSPHERE SOLAIRE)

Report of Meetings Held in Conjunction with the 19th General Assembly

PRESIDENT: Robert W. Noyes

I. BUSINESS MEETING OF COMMISSION 12

A business session was held on November 20, chaired by R. Noyes. A second brief meeting was held on November 26. Items addressed were:

1. Election of Organizing Committee.

The Commission elected the following slate of officers and members of the Organizing Committee for the term 1985 to 1988:

President	Max Kuperus
Vice President	John W. Harvey
Organizing Committee:	G.E. Brueckner
	J. Christensen-Dalsgaard
	L.E. Cram
	E.A. Gurtovenko
	E. Hiei
	V.A. Kotov
	K.R. Sivaraman
	J.O. Stenflo
	R.W. Noyes (Past President)

2. Election of New Members of the Commission.

Applications for membership were made by 72 individuals, of whom some were new members of the IAU, others old IAU members who had indicated their interest in joining the Commission, and still others whose membership had not formally been entered in the IAU records. All were welcomed by acclamation.

3. Commission Resolutions.

After discussion of the threatened closure of a number of optical and radio astronomy observatories around the world, the Commission co-sponsored the following Commission Resolution:

Commission 10 and 12,

considering the importance of ground-based optical and radio solar observatories for obtaining data which are critical to our understanding of the Sun, which are complementary to solar space projects, and which have scientific importance beyond solar physics, and

that many ground-based solar observatories aorund the world are threatened by closure,

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recommends that the appropriate organizations within the countries involved cooperate to ensure that an adequate network of observatories be maintained to study the Sun, taking account of the need for proper longitude coverage as well as the special contributions of some unique instruments.

Also, because the progress of both solar and solar-related stellar research at Mt. Wilson Observatory (which is also threatened with closure) are central to the activities of Commission 12, the following joint Commission Resolution was passed:

Commission 29, 36, and 12,

recognizing the continuing excellence of the facilities of the Mount Wilson Observatory for solar, stellar and interstellar research,

encourage efforts to ensure continuity of research at this observatory.

Both of these resolutions were subsequently endorsed by the General Assembly.

4. Working Group on Eclipses.

Dr. Fiala reported that the Working Group on Eclipses had not been asked to submit a report, but that it was still active. The Commission reconfirmed the importance of this Working Group and voted that a report of its activities should be presented at the next General Assembly.

5. Discussion of Scientific Scope of Commission 12.

Dr. Noyes reviewed the discussions of the relation of commissions 12 and 10, and the question whether they should be combined. It was pointed out that their activities are complementary but not redundant. Whereas Commission 10 emphasizes solar activity both as a physical phenomenon and with reference to its effect on the heliosphere and geophysics, Commission 12 emphasizes the Sun as a star, with particular reference to astrophysics. The purview of Commission 12 has broadened in recent years beyond the study of the solar atmosphere by itself, due to the development of observational and theoretical studies of the solar interior. There was discussion of changing the name of the Commission to reflect this broadened purview; a name such as "Solar Structure" was generally felt to be more appropriate to the present situation. However, it was decided to postpone decision on such an important matter, pending widespread discussion within the Commission and a possible formal vote in connection with the next General Assembly.

II. SCIENTIFIC MEETINGS SPONSORED BY COMMISSION 12

1. Small-scale Structure and Dynamics of the Solar Atmosphere

This meeting, co-organized by R. W. Noyes and Y. Uchida (Chairman), was held on November 20. The purpose was to discuss observations and theories of small-scale motions and magnetic fields in the photosphere and chromosphere, and their effects on coronal structure and energetics.

R. Muller discussed "Spatial Properties of the Solar Granulation", reviewing the morphological, evolution,and brightness properties of the granulation, as well as its vertical temperature and velocity structure. Of particular interest was the question of the penetration of granules, according to their size, into the stable photospheric layers. The origin and properties of the smallest granules (smaller than one arcsec) were discussed.

J. Leibacher, on behalf of the Solar Optical Universal Polarimeter (SOUP) team of investigators, discussed "Solar Granulation Time Series Obtained from the Space Shuttle". White light distortion-free images of the photospheric granulation were obtained by the SOUP instrument on Spacelab in August 1985. The data were obtained during approximately 12 hours of observing time, with a spatial resolution of about 0.4 arcsec; image stabilization in the seeing-free space environment permitted obtaining excellent data strings of a sunspot, an active region, and the quiet photosphere.

A. Dollfus described the use of the FPSS (Filtre Polarisant Solaire Selectif) instrument for high angular resolution two-dimensional imagery of solar line profile parameters. These include doppler shift (longitudinal velocity), circular polarization (longitudinal magnetic field), depth, strength, and halfwidths of spectral lines. Vector polarization maps may be obtained, and transverse magnetic field measurements are possible. A detailed description is given in *Astron. Astrophys.*, **151**, 253 (1985).

N. Weiss discussed "Theory of Interaction of Magnetic Fields and convection," stressing that the structure of photospheric magnetic fields is determined by the interaction of granular convection and isolated flux tubes. He summarized current understanding of compressible convection and magnetoconvection, and related this to the formation and location of the photospheric network of strong magnetic fields.

P. Venkatakrishnan discussed "Inhibition of Convective Collapse of Magnetic Flux Tubes by Radiative Diffusion." Using simplified models, he discussed the role played by convection in the formation of thin magnetic flux tubes. The inclusion of heat transport by radiative diffusion reduces the efficiency of collapse for the formation of strong fields. The twin effects of radiative diffusion and external convection on magnetic flux concentration leads to the prediction of three classes of flux tubes: (1) thick ($>$ 300 km) and strong (1400 G); thin ($<$ 100 Km) and weak (700 G); and intermediate size, oscillating between strong and weak phases. This result has interesting testable observational consequences, given sufficient angular resolution.

G. E. Brueckner presented "New Results of the High Resolution Telescope and Spectrograph (HRTS) Instrument on Spacelab". This instrument consists of a 30 cm Gregorian telescope with a stigmatic Tandem Wadsworth Spectrograph for the uv wavelength region 1200 to 1700 A, plus a 50A bandwith heliograph centered at 1550A and a 0.8A bandwidth mica interference filter centered on Hα. Spectra can be obtained either in a single position on the solar disk or as a raster. Time resolution can be as short as 0.9 seconds. The rasters allow construction of images of intensity, doppler shift, and linewidth. Data were presented showing observations of impulsive energy release, apparently with enough energy dissipation to heat the corona.

John Cook, with co-authors J.-D. F. Bartoe, G. Brueckner, K. P. Dere, and D. G. Socker, described "HRTS Spacelab 2 Observations of Spicular Emission at the Solar Limb". These observations were taken in all three of the wavelength bands mentioned above. The data show evolution of EUV spicules and transient bursts in chromospheric and transition region line emission above the limb over approximately 15 minutes of observations with relatively stable pointing.

Jagdev Singh, S. K. Jain, P. Venkatakrishnan, F. Recely, and W. C. Livingston discussed "Temporal Variations of HeI 10830A in the Solar Chromosphere". Very preliminary measurements of the line depth at one location on the Sun indicate periodicities near 2 min, 5 min, and 10 min. These periodicities could have their origin in either coronal dynamics, or chromospheric dynamics, or both. However, a clearer picture will emerge only after complete analysis of the data at all the 512 spatial locations that were observed.

Y. Uchida discussed "Formation of Fine Structures in the Solar Chromosphere and Corona". The origin of fibrils and spicules in the chromosphere, and fine loops in the corona above active regions, were considered in terms of a magnetodynamic picture. The mere presence of a potential magnetic field does not by itself produce activity, or even any inhomogeneity as long as the field lines have their footpoints in an iso-enthalpy potential level in a static photosphere, although it defines the shape of the structure to be produced. The coupling of the magnetic field with the motion in the high-β ($=p_g/p_m$) sub-photospheric layers, however, can introduce conspicuous inhomogeneity or activity in the low-β overlying layers. Emphasis was given to a mode of energization of the mean magnetic field by magnetic twists coming out from subphotospheric layers. This process can solve the problem of the mass supply as well as the energization of these structures. It was suggested that the vorticity in the large scale convection can be the source of the helicity to produce mass-filled hot structures in active regions, while that in the granular motion may give rise to the mass-filled structures in the quieter regions.

V. Krishan discussed "Collisions and Coalescence of Solar Coronal Loops". The corona is observed to be threaded by loop-like structures, which have their footpoints in the convection zone. The footpoints are continuously jostled by the eddies in the convection zone, as a result of which the coronal loops move in a random manner in the atmosphere in a plane perpendicular to the direction of gravity. The author studied the binary collisions between these loops and what happens at the contact surface when the loops collide. Depending upon the collision velocity, the coronal loops may coalesce and stay that way or may separate after colliding. Coronal loops with the same sense of twist have oppositely directed azimuthal components of the magnetic field, which undergoes reconnection during the collision. If the kinetic energy associated with the relative motion of the loops is more than the energy associated with the diffused or reconnnected magentic field, the loops separate after the collision; otherwise they stay bound together. An estimate of the critical collision velocity was made.

P. Sturrock discussed "Small-scale Energetic Phenomena in the Solar Atmosphere". He investigated the possibility that solar activity, known to occur on a wide range of scales of length, time, and energy, extends down to the scale characteristic of solar granulation, and what the possible observational consequences might be. He suggested that spicules are the small-scale analogues of surges, and proposed an MHD process that is responsible for both spicules and surges. He proposed that coronal heating may be attributed to the small-scale analogue of the same mechanism that produces hot plasma in solar flares.

S. Jordan described "The Solar Optical Telescope". This is the premier NASA facility for solar studies; its purpose is to obtain high-resolution data for studying the dynamics of magnetic fields at the scales where the basic physical processes occur. The SOT telescope and focal plane payload were described, as well as the major scientific objectives of the SOT mission.

Finally, two papers were read by title only, and the text made available to the attendees at the meeting. The first, by V. N. Karpinsky, discussed "Some Results of Photospheric Fine Structure Investigations at Pulkovo Observatory". Observations with the Soviet Stratospheric Observatory and Pamirs telescope lead to the conclusions that (a) the photosphere is strongly inhomogenous, with excitation temperature differences as large as 1000 K over small distances; (b) the spatial power spectrum of granulation may be represented by two power functions K^n with n=1.2 and n=-5 for the ascending and descending branches respectively; (c) the photospheric velocity field may be represented by homogenous vertical columns, abruptly terminating in a very thin (20-50 km) transition layer about 300 km above $\tau_5=1$; (d) the idea of convective overshoot is not a constructive explanation for the major observed facts concerning the granulation. The second paper, by A. B. Delone, E. Makarova, and G. V. Yakunina, dealt with "The Interpretation of Profiles of the Coronal Red and Green Emission lines for the Eclipses of 1965, '68, '70, '72, and '81: Interferometric Observations". Many of the observed profiles of both emission lines have a complicated shape. This is interpreted as a result of small moving structures in the corona, even though they were undetected by previous authors. It is suggested that earlier authors failed to detect such moving structures because of insufficient spatial resolution.

2. Convection and the Solar Radiative Output

This meeting, co-organized by W. C. Livingston and K. R. Sivaraman (chair), was held on November 26. The purpose was to discuss how convection influences the global radiation from the Sun, and by extension similar stars, as well as other aspects of the global solar radiation.

D. Dravins delivered a paper "Solar and Stellar Granulation". He noted that the study of granulation now has impact on several fields of astrophysics, for example: (a) the physics of stellar convection (possible replacement of "mixing length" concepts), (b) mechanisms of spectral line broadening (possible replacement of "turbulence" concepts), (c) interpretation of stellar radial velocity variations, such as required in the search for extra-solar system planets, (d) constraints on magnetic flux concentrations in stellar photospheres. Promising areas for study include: (a) differences between active and quiet region granulation, and between different epochs in the solar cycle, (b) differences between line profiles for lines with different conditions of formation, such as Fe I and Fe II, (c) stellar granulation, inferred through the photospheric line asymmetry signature, (d) numerical simulations of the hydrodynamics of stellar granular convection.

R. Muller discussed "Variation of the Solar Granulation". He noted that the mean intergranular distance decreases with increasing activity, while the number of granules per unit area increases; this was derived from measurements directly from photographs. Muller and Roudier have numerically processed Pic du Midi Observatory granulation photographs, obtained between 1977 and 1984. This work confirms that the number of granules per surface area decreases with decreasing activity, from 47 per 10" x 10" area in 1979 to 38 in 1984. The image processing shows that the granulation has a critical size at which changes of granule properties occur, both in the power spectrum of the area distribution, and in the fractal dimension. In addition granules of a *critical* size are the main contributors to the granule area and radiation. This critical size varies over the solar cycle from 1.15" in 1979 (solar maximum) to 1.30" in 1984. The fact that the number of granules increases with increasing global magnetic flux (active plus quiet) might indicate that the variation of granulation scale is due to the interaction between convection and global magnetic flux. On the other hand the number of granules is a decreasing function of the number of network bright points in the quiet Sun; this might indicate that the interaction occurs locally. Additional observations are needed to determine at which scale the interaction occurs.

D. Gray discussed "Stellar Granulation as Seen in Spectral Line Bisectors". Asymmetries in stellar spectral lines have been known for some time (Gray, *Ap.J.*, **235**, 508; **251**, 583). Line bisectors have been used in interpretation of these asymmetries in terms of stellar granulation (Dravins *et al.*, *Astr. Ap.*, **96**, 345; Gray, *Ap. J.*, **255**, 200; Gray and Toner, *Publ.Astr.Soc.Pac.*, **97**, 543). Granulation is observed to be more vigorous in stars of higher luminosity and higher effective temperature. Two separate effects in line bisectors lead to these conclusions. First, the velocity span of the bisectors is greater for hotter and for more luminous stars. Second, the blueward displacements of the bisectors continues right into the cores of the lines for these stars, indicating substantially greater height penetration than seen with the solar granulation. Numerical simulations involving disk integrations of two-stream models can reproduce the observed stellar line asymmetries. Disk-integration effects are very important and so introduce complications not experienced by solar observers. One prediction of the numerical simulations is a rotation effect, which was subsequently looked for and found (Gray, *Publ.Astr.Soc.Pac.*, 1986) and which allows a measure of the mean velocity of rise of the granules that is nearly independent of the other parameters of the simulation. Values of 1.5 to 2.0 km/s are deduced.

K. R. Sivaraman, R. Kariyappa, and W. C. Livingston presented a review paper "Solar Line Bisectors as a Function of Disk Position". Wavelength shifts and line asymmetries are an important diagnostic tool to infer atmospheric inhomogeneities and convective motions in solar and stellar atmospheres. After correction for sun-earth motion and gravitational redshift, typical photospheric lines show a blueshift of 300-400 m/sec, decreasing toward the limb. In addition, they show asymmetry, which also varies toward the limb. The asymmetries and their center-to-limb variation are different for different lines, depending most strongly on the height of formation. Observations made by the authors of 17 Fe I lines were analyzed, and suggest the existence of a poleward meridional motion; this result is in qualitative agreement with earlier conclusions from the migration of Hα filaments, and also Mt. Wilson and Stanford velocity data.

W. Livingston discussed "Activity Cycle Dependence of Line Bisectors in the Solar Irradiance Spectrum". Two pieces of evidence were presented that suggest a granulation component to irradiance variability. With the advent of minimum activity a slight increase of bisector amplitude is noted, which is the converse of the weakening noted at solar maximum. Secondly, his line strength archives indicate that Mn 5394 is more variable than Fe 5250, in agreement with high resolution granulation samples. In plage the opposite is true, so it is inferred that there is a significant granulation signature in the variability of the Sun observed as a star.

Jagdev Singh and T. P. Prabhu discussed "Variations in the Solar Rotation Rate Derived from Ca II Plage Areas". Daily calcium plage areas for 1951-1981 were used to derive the solar rotation period in four latitude belts. The rotation period was found to change with time quasi-periodically, with time scales ranging from the solar activity cycle period down to about 2 years. Variations in adjacent latitude belts are in phase, whereas those in different hemispheres are uncorrelated. Rotation rates from sunspot numbers have a similar behavior, although a variation on the timescale of the solar cycle is not very apparent. The total plage area, integrated over the disk, shows a dominant periodicity of 7 years in rotation rate.

H. Neckel discussed "Radiative Output of the Sun from 330 to 1250 nm". A detailed analysis of the absolute energy distributions of the Sun, of Vega, and of three "solar analog" stars yielded the results: (a) The magnitude differences between "solar analog" and the Sun can be described by a gradient proportional to $1/\lambda$, on which is superimposed a wavy pattern with amplitude of about 0.02 mag. (b)This wavy pattern is not real but is caused by systematic errors of order 0.01 mag, which affect the energy distributions of both Sun and Vega. (c) The relative gradients, spectral types, and nearly all results of detailed spectrocopic studies yield about the same position of the Sun among the stars: somewhere between 16 Cyg A and 16 Cyg B. (d)The UBV- data for the Sun are: $B\text{-}V = 0.650 \pm 0.005$, $U\text{-}B = 0.195 \pm 0.005$, $V = -26.75 \pm 0.025$.

J.P.Goutail, D. Labs, H. Neckel, P.C.Simon, and G. Thuillier presented a paper "Solar Spectral Irradiance Measured from Spacelab 1". The presentation gave a short description of the experiment conception, the calibration procedure, the problems experienced in orbit and on the ground, and some results. A full length paper will be published in *Solar Physics.*

G. Brueckner described "Solar Irradiance Measurements in the Ultraviolet". A series of Solar Ultraviolet Spectral Irradiance Monitors (SUSIM) has been developed at the Naval Research Laboratory. Their purpose is to improve solar UV output data in order to define the magnitude of UV variability over a solar activity cycle. The instruments carry several spectrometers and in-flight calibration sources to distinguish between solar UV output changes and variation of instrument sensitivity. The first SUSIM was flown on Spacelab-2 . From the calibration data obtained before, during, and after this flight it should be possible to derive absolute solar UV intensities which have error not greater than a few percent. Parallel to the instrument development an extensive calibration program has been carried out, using the Synchrotron Storage Ring at the National Bureau of Standards, which will be used to track the instrument sensitivity over the next 11 years.

III. OTHER SCIENTIFIC MEETINGS CO-SPONSORED BY COMMISSION 12

Two scientific meetings were sponsored by Commission 10 and co- sponsored by Commission 12. The first, on November 21, was *Reconnection in Astrophysical Plasmas* . The second, on November 26, was *Coronal Activity and Interplanetary Disturbances.* These are described in the Report of Commission 10.

In addition, Commission 12 was a co-sponsor of two Joint Discussions. The first was *Solar and Stellar Non-Radial Oscillations* (November 22). The second was *Stellar Activity: Rotation and Magnetic Fields* (November 25). The texts of these two Joint Discussions will appear in **Highlights of Astronomy**.

IV. REPORTS OF OBSERVATORIES

Two observatories submitted brief reports to Commission 12:

a) Uttar Pradesh State Observatory, Naini Tal, India (M.C. Pande)

Equivalent widths of molecular absorption lines of C O, C_2, C H, Mg H, N H, O H, and Si II have been calculated for different photospheric and facular models. The calculations indicate that observations of these lines can be useful to test homogeneous and inhomogeneous models of these regions (Tripathi *et al., Bull.Astron.Soc.India*, **10**, 150, 334). The observed center-to-limb behavior of rotational temperatures of the 0-0 band of the C_2 Swan system has been compared with model calculations, accounting for saturation effects. The modeled excitation temperatures near the limb are slightly lower than observations (Sinha, *Bull.Astron.Soc.India*, **12**, 172). Line profiles of CH at disk center and near the limb yield a photospheric turbulent velocity of 4.0 km/sec with a very slight increase toward the limb (Punetha and Joshi, *Bull.Astron.Soc.India*, **12**, 249). The oscillator strength of C_2 Phillips systems was determined from observations (Sinha, *Bull.Astr.Soc.India*, **12**, 45) and found to be in good agreement with other results. Several unidentified lines in the photospheric spectrum (4800 to 5200A) were identified as lines of the C_2 Swan system (Sinha, *Bull.Astr.Soc.India*, in press).

b) Purple Mountain Observatory, Nanjing, People's Republic of China (Chen Biao).

This report stressed mainly work in China on the area of solar activity. A memorable event was the international workshop on solar physics and interplanetary travelling phenomena held at Yunnan Observatory in the fall of 1983. This was the first international meeting on such subjects ever held in China. There were comprehensive reviews of observational data from the previous solar maximum, and its interpretation. Following this meeting, a project was undertaken to organize scientific studies of the coming solar maximum. Through a series of workshops it was decided to emphasize:

1. Observations and studies on solar magnetic fields and velocity fields.

2. Observations and studies on pre- and post-flare phenomena, concentrating upon the real-time sequence high-time resolution radio and optical (10830A included) observations. Special attention should be paid to the impulsive phase of solar flares.

3. Solar activity prediction. Since Chinese astronomers are not prepared to start systematic research on fine structures on the Sun within the Chinese boundary, they have decided to join efforts with their European colleagues in the LEST Project. The Yunnan Observatory has applied for a membership in LEST Foundation and the Nanjing Astronomical Instrument Factory has also committed itself to some research efforts for this project. In a joint effort with HAO, the possibility will be explored of the installation of a K-coronagraph in the western parts of China. It is hoped that there will be increased activity on the theoretical study of solar seismology and internal motion in the solar interior.