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PUBLICATIONS OF DEBRECEN HELIOPHYSICAL OBSERVATORY

Heliographic Series No.1

C O N T E N T S

Preface to the Series

"The daily photoheliographic programme" of the Royal Greenwich Observatory (RGO) "was terminated at the end of 1976. The programme has been taken over by the Heliophysical Observatory, Debrecen". { F.Graham Smith, *Q.Jl.R.astr.Soc.* (1978), *19*, p.462.}

Beginning from 1st January 1977 the Heliophysical Observatory of the Hungarian Academy of Sciences in Debrecen undertook the responsibility for the continuation of the Greenwich Photoheliographic Programme according to Resolution of Commission 10 (on Solar Activity) of the International Astronomical Union (IAU), approved by the IAU General Assembly in Grenoble on 2nd September 1976.

The wording of the Resolution concerned is as follows:
"Recognizing the need of ensuring the continuation of this long series of homogeneous reports performed during one century" (by RGO) "and noting the capability and interest of the Debrecen Observatory to continue such a program, Commission 10 encourages the Debrecen Observatory to undertake the following responsibilities: to carry out direct photoheliographic observations at Debrecen; to organize cooperation between other observatories willing to contribute to such a project; with the assistance of the Greenwich Observatory to ensure a homogeneous continuity of the gathering, reduction and publication of such data; to ensure the archiving of the original photographs and the access to interested scientists from around the world." { *Transactions of the IAU, Vol. XVI B*, p.107 (Proc. 16th General Assembly, ed. E.A.Müller and A.Jappel) D.Reidel, Holland, 1977; cf. also *Trans.IAU, Vol. XVII A* - Part 2, p.11 (Reports on Astronomy, ed E.A.Müller), D.Reidel, Holland, 1979.}

All of the above has also been approved by the proper authority, the Section of Mathematical and Physical Sciences of the Hungarian Academy of Sciences in its Session on 15th December 1976. { cf. *Magyar Tudomány*, (Review of the Hungarian Academy of Sciences; in Hungarian) New Ser.*Vol.XXII*, p.29, No.1, January 1977. }

Now that the present volume of "Photoheliographic Results" reached completion, the first one (No.1) of our Heliographic Series and at the same time the direct continuation of that of Greenwich's last volume (published in 1980), I wish to mention all who encouraged and helped us in order to be able to properly carry out the undertaking.

Primarily, I owe a debt of gratitude in several respects to Drs. F.Graham Smith, D.Stickland, G.H.Wilkins and B.D.Yallop of RGO, especially as they provided an opportunity for us to maintain continued homogeneity of the continuation of the records. For that purpose during 1980-1981 we were lent a few dozen original Greenwich "white-light" heliograms from RGO, obtained before 1977 on days for which we also have our own observations. Thus, we could remeasure some Greenwich plates with our methods and in this way we got a firm basis for various comparisons (see the papers of Á.Kovács and O.Gerlei on pp. 211 - 230). On the other hand, the work of RGO in question was long well-known to us as we had used Greenwich data for our statistical studies of sunspots { cf. *Publ.Debrecen Obs. Vol.1,* Nos.1-4 (1964); *Debrecen Obs. Repr.Ser.* Nos.1-3 and 5 (1965-1968), i.e. *BAC 16*, p.65, *Publ.Czech.Acad.Astr.Inst.* No. 51, p.41, p.49, and *IAU Symp. No.35*, p.70, respectively }. Moreover I sometimes visited (1966-1977) the Solar Department of RGO and also got acquainted directly with their observations and measurements.

The Debrecen Observatory has a collection from the second half of 1954 of white-light photoheliograms with an image of circ. 10 cm diameter. Before the middle of January 1958 we had taken them at the Konkoly Observatory in Budapest. In May 1972 we set up an observing station in Gyula and since then our two fairly similar heliographs are separated by about 100 km. Several full-disc photoheliograms are obtained both in Debrecen and in Gyula, whenever possible every day.

Hereby the Debrecen Observatory could often send, upon request, some copies of its heliograms to assist other observatories. Occasionally we even loaned the original negatives if this was appropriate. Some of them were used at RGO to fill in the gaps (the first one for 1966, the last two for 1976) in their combined series of heliograms.

However, the original purpose of our white-light observations has been to collect a lot of material for investigations on proper motions of sunspots associated with the developments of sunspot groups. Such studies have formed one of the main programmes of the Debrecen Observatory for many years.

Up to 1977 above all we went into the details of relative spot motions. But now, our extended programme demands even more reliable spot coordinates that should also be good enough to carry out successful solar rotation studies by the tracer method. Therefore, during the last decade we spared no effort to improve our methods of measurements and data processing. (Notwithstanding that the comparisons of random sampling, mentioned above, did not raise any plausible objection to our positions obtained through the procedure adopted and used earlier.)

Concerning the measurements of areas of sunspots we have drawn up the plan for a special television scanner. A team of specialists in electronics at the Institute of Experimental Physics of the Kossuth University of Debrecen took charge of carrying out this plan and the new area measuring instrument came into use in 1979.

When, in 1976 during the IAU General Assembly in Grenoble, after the suggestion of several foreign solar physicists, I assumed responsibility for the continuation of the Greenwich sunspot catalogue (without the photospheric faculae), I was able to do this because, among others, Dr.M.N.Gnevyshev, then Head of Kislovodsk Observatory, previously assured me of the co-operation of his institute in filling gaps in our series of observations. It was also a great satisfaction that the late M.K.Vainu Bappu, Director of Indian Institute of Astrophysics, already during the Grenoble meeting, offered his help, telling me that if necessary we also could receive heliograms from their Kodaikanal Observatory as RGO had for decades.

In order to have a firm guarantee for a long term co-operation (i.e. for lasting solar cycles), our collaborative arrangement on this point with the observatory of Kislovodsk has been incorporated within the frame of the agreements between the USSR Academy of Sciences and the Hungarian Academy of Sciences. In the vicinity of Kislovodsk, the Caucasian branch of Pulkovo Observatory of the USSR Academy of Sciences has excellent possibilities to supply us with heliograms required for measurement in Debrecen. We are very thankful to the leading scientists of Kislovodsk Drs. M.N.Gnevyshev and V.I.Makarov for their efforts in helping us to collect the wanted heliograms and even trying to make others available from various Soviet observatories.

Usually we manage to obtain white-light heliograms often on nearly 300 days per year, however our yearly requirement of original foreign heliograms still amounts to about 150, each one taken on different days. Namely, for the avoidance of systematic errors in spot positions, we need in general for each heliogram wanted a second one for checking too. Owing to this condition it was especially difficult to gather the material of observations.

Unfortunately, it was 1977 for which we encountered the most difficulties in gathering the heliograms. In the fourth quarter of 1986 we have had still insufficiently covered some days for the year 1977. Finally by courtesy of Dr.J.O.Cardús, formerly director of the Observatorio del Ebro, it was possible to overcome this obstacle.

For the time being, we rely upon the help of the Observatorio del Ebro, arranged by the favour of Dr.Cardús on other occasions too. Of course it may be that occasionally the support from other observatories could also be indispensable. However, for the future there is a hopeful possibility to have more heliograms easily available. Prof. H.Haupt, director of the Astronomical Institute of the University Graz, had long been keenly interested in the continuation of the Greenwich heliographic programme and we discussed a co-operation in this matter between the Kanzelhöhe Solar Observatory of the Graz Institute and the Debrecen Observatory several times. As a result, Dr. T.Pettauer, Head of the Solar Observatory at Kanzelhöhe, has designed the plan for building a photoheliograph analogous to the ones of Debrecen and Gyula. It is ready by now and mounted jointly with their flare-patrol equatorial telescope. Beginning with the year 1988 they intend to make regular photographic observations, taking 10 cm solar pictures on the same photo-emulsion and through the same kind of filter as we do.

In the present and forthcoming catalogues we are publishing almost all data on sunspots that RGO has also given in the fullest detail up to and including the observations of the year 1915. Later on, RGO measured the spots of a group less elaborately and generally, only in the case of larger groups have the chief components been measured individually (see particulars at the end of the volume, p.238). In addition, our catalogue gives various kinds of numerical data and indicates the magnetic spot polarities for each sunspot as well as, wherever reasonable, a special number as a mark of identification.

Concerning the magnetic polarities of sunspots, we rely first of all on the data recorded at the Mt.Wilson and Yunnan observatories. Most of these data, up to date unpublished in detail, are at our disposal by courtesy of Dr. Robert F.Howard and Prof. You-ji Ding, respectively. It is quite convenient to use both data sets since as a rule our observations are intercurrent between that of Mt.Wilson and Yunnan by less than half a day.

Of course, we also take into account the results of all other relevant magnetic observations from the literature or through personal communications if available.

It is clear that the work under discussion demanded a lot of preparations. Nevertheless the long delay of publication resulted in particular from the unexpected circumstances above-mentioned. I hope, the other backlog, i.e. the subsequent volumes, can be worked out in a rather rapid succession given convenient computer facilities for data-processing. When arrears have been overtaken the yearly observations should be measured, reduced and published within the next calendar year.

I would also like to take this opportunity to express here our sincere gratitude to all of our Hungarian colleagues and foreign scientists, especially to M.K.Vainu Bappu (†), J.O.Cardús, You-ji Ding, M.N.Gnevyshev, H.Haupt, R.F.Howard, V.I.Makarov, T.Pettauer, F.Graham Smith, D.Stickland, G.H.Wilkins and B.D.Yallop for their effort of helps. No doubt, their kind assistance has contributed significantly to the successful accomplishment of our task.

Debrecen, 21st August 1987

L. Dezső

PUBLICATIONS OF DEBRECEN HELIOPHYSICAL OBSERVATORY
Heliographic Series No.1

L.Dezső, O.Gerlei and Ágnes Kovács

PHOTOHELIOGRAPHIC RESULTS FOR THE YEAR 1977

INTRODUCTION

1. GENERAL

The present volume contains the results of measurements of positions and areas of sunspots observed during the year 1977. For long years the Royal Greenwich Observatory has published data of this kind. A detailed informative description of the *Greenwich Photoheliographic Results* for the years 1874 to 1976 inclusive is given at the end of this volume.

2. MATERIAL OF OBSERVATIONS AVAILABLE

2.1. Heliograms

All data of our own measurements here published are on the basis of 365 "white-light" photoheliograms of 1977. These heliograms have been taken as follows:

97 in Debrecen,
193 in Gyula, at our photospheric observing station,
68 at the Kislovodsk Observatory (a branch of Pulkovo) of the USSR Academy of Sciences,
5 at the Kodaikanal Observatory of the Indian Institute of Astrophysics,
2 at the Observatorio del Ebro.

In total 365 heliograms; one heliogram for each day of 1977.

To avoid incidental systematic differences in data of measurements between our heliograms and the three sets of 75 foreign heliograms, altogether 63 extra heliograms which were obtained at the three co-operating observatories were used as a control. Namely, for each heliogram missing in our series we generally need two, both taken at the same place on two consecutive days and one of these must be taken on the same day when we also have our own observation. By courtesy of the co-operating foreign observatories we were always able to use for measurements in Debrecen their original heliograms (in total 75 + 63).

The 290 Debrecen and Gyula heliograms recorded here were selected from more than 4000 heliograms, using the best one from each day. Moreover for each day (with a single exception) at least two heliograms, taken, as a rule, within less than a 10-minute period, were measured, the second one as a check-test. In 1977 our heliograph observations in Debrecen were ended in the latter part of June, while in Gyula, after some months of interruption, they were restarted at the beginning of May (cf. the end of Section 3.1). Nevertheless, we have our own daily heliograms almost over a half year in 1977 (from April 17 to October 10 inclusive except five days).

We have also had the opportunity to make an important check-test with a few copies of frames from the white-light solar patrol of the Sacramento Peak Observatory taken at the end of October 1977.

2.2. Magnetic polarities

Principally those data have been used which were determined at the Mount Wilson Observatory of the Hale Observatories (Pasadena, Ca, USA) and at the Yunnan Observatory of Academia Sinica (Kunming, China). In 1977 it was possible to determine sunspot polarities at Mt.Wilson on 273 days and at the Yunnan Observatory on 218 days. (Both of these above figures also include the incomplete daily records.) We used the copies of the original observations, i.e. the sunspot polarity drawings of Mt.Wilson and Yunnan.

In addition, we also took into consideration some published data, especially Rome observations for the second half of 1977 {V.Croce and F.Casamassima, Longitudinal magnetic fields. 1977, *Oss.Astr.Roma, Monthly Bull. Nos.233*, pp.9-13; *234*, pp.8-9; *235*, pp.5-6; *236*, pp.4-5}.

2.3. Acknowledgements are due to all observers for their participartion(listed in order of the frequency of observations).
In Debrecen: Á.Kovács, L.Gesztelyi, A.Ludmány, B.Kálmán, O.Gerlei and G.Gyertyános;
in Gyula: L.Győri, L.Márki-Zay, S.Rostás, Z.Kiss and L.Kondás;
in Kislovodsk: V.V.Makarova and V.P.Mikhailutsa;
at Ebro the observer-in-charge was José Cid;
at Mt.Wilson: T.S.Gregory, T.B.Ake and S.P.Padilla;

in Yunnan: Ding You-ji, Zhang Heng, Zhong Shu-hua, Lung Ti, Ye Hui-lian and Zhong Ling-sheng (here the names written in Chinese fashion).

We owe particular debt of gratitude to Zhong Shu-hua who kindly prepared for us duplicates of the polarity records of Yunnan.

It is clear that first and foremost we are indebted to the leading scientists M.N.Gnevyshev and V.I.Makarov, the late M.K.Vainu Bappu, J.O.Cardús, R.F.Howard and You-ji Ding, who were associated with the observatories of Kislovodsk, Kodaikanal, Ebro, Mt.Wilson and Yunnan, respectively, for arranging for us the possibility to use the material of observations required.

Last but not least we also wish to acknowledge the kind help received from the National Solar Observatory of Sacramento Peak. Namely, in August 1985, when one of us (L.D.) was lucky enough to be there, we still needed material to fill in a gap in the available series of heliograms for 1977. Therefore Deputy Director R.N.Smartt offered their assistance and Mr.L.B. Gilliam prepared and mailed us the desired copies (taken from a long roll film).

3. OBSERVATIONS

3.1. Heliographs

Two fairly similar photoheliographs are used, one of them in Debrecen, the other in Gyula. Their objectives have a diameter of about 14 cm and focal length of nearly 2 m. In both heliographs an orthoscopic-type magnifying lens system (having a focal length of about 6 cm and made by Zeiss more than a half century ago) projects the prime focus image to the secondary focal plane enlarged approximately five times. The full-disc solar photographs are taken through yellow filters on photo-emulsions of 14×14 cm size. The filters lie between the objective and the prime focus, from the latter at a distance of about 9 cm. At the focal plane of the objective a cross-hairs of two spider-wires are fixed. The wires are oriented approximately in N-S and E-W directions, i.e. they intersect perpendicularly, and the point of intersection is exactly in the optical axis of the heliograph. The exposures were carried out with shutters made in our own workshop. The shutter consisted essentially of a spring-driven metal slit of easily variable width (≥ 2 mm) which moved with a constant speed over an area of $\varnothing \approx 20$ mm parallel to the E-W spider-wire and close to it quite as much as the construction permitted.

Both heliographs are located in the open air to minimize optical degradation due to turbulence of rising hot air masses. We try to avoid turbulence inside the heliograph tube, too. Therefore, if reasonable, the daily motion of the Sun is followed with the equatorially mounted heliograph to keep its tube shaded during the whole period of observations each day. Moreover, in front of the dewcap of the objective there is a light-metal plate which is turned aside briefly (< 1 s), in a plane parallel to the objective, only during exposures. On the same equatorial mounting, parallel to the heliograph, there is a refractor with a polarization helioscope of Merz and a high-powered eyepiece. In this way, both in Debrecen and in Gyula, if feasible, before exposures the observers follow a suitable spot-configuration (those which are on the limit of visibility are the best). Thus the seeing is monitored visually and the photographs are taken at the moments of better-than-average seeing. (In order to facilitate the finding of the right exposures, at the bottom of a simple tube mounted also on the heliograph, a selenium cell under a yellow filter always points towards the Sun during observations and a microampere meter continuously shows the photocurrent.) We consider a heliogram well-exposed if sunspots are distinctly visible even when close to the solar limb and the same time the limb darkening also comes strikingly into sight at a glance.

Alternately, Kodalith pan films of estar base (of Kodak) or Gevaert Dia C diapositive glass-plates (of Agfa-Gevaert) were used together with a metal-interference-filter of about 10 nm effective half-width centered at 554 nm or with a Schott GG 11 filter, respectively. In both cases the photographs are taken practically in the same small spectral region.

During 1977: the objective aperture was nearly always stopped down to 13 cm in Debrecen, while in Gyula generally to 7-8 cm (sometimes only to 9 cm); in Debrecen the Gevaert plates, in Gyula the Kodalith films were mainly used and the diameter of solar image was about 11.0 cm and 10.4 cm, respectively.

Before beginning the observations to continue the Greenwich Photoheliographic Programme both the Debrecen and Gyula heliographs were dismounted and thoroughly re-examined, especially the steal tube gratings which assure inflexibility. At the same time in Gyula, at the top of a 40 m high water tower, the heliograph got a new equatorial mounting made by Zeiss (Jena) and a renovated massive platform with a grid floor allowing the free circulation of air. The construction of a new platform of observation for the Debrecen heliograph started only in the middle of 1977 and from this time onward no white-light heliograms had been obtained in Debrecen for more than a year. (The external appearance of the heliographs are shown in L.Dezső, Report from a Solar Observatory, *Solar Physics*, *79*, pp.195-199,1982.)

3.2. Instrumental constants

The spider-wires, when a new cross-hairs comes into use, must be checked for perpendicularity, i.e. its error in orthogonality determined, since both wires are regularly measured by us (notwithstanding the fact that for orientation a single wire would be enough). Their point of intersection, at the optical axis, is indispensable to apply the distortion corrections. When one of the wires becomes unusable (which generally one fails to notice before observation) it is still possible to measure the heliograms adequately. Namely by means of the permanent roughnesses along the spider-wire we can also find, in case of need, the position of the optical axis. This is an advantage of using the spider-wire; otherwise we give preference especially to its elastic expansion property which guarantees that it will remain taut and aligned. (The spider-wire should be boiled in water a few minutes before stretching it; then sometimes it is fit for use even for 2-3 years.)

To insure rigidity, both the objective and the photographic emulsion (hereinafter called plate), with its plate holder are at fixed places in our heliographs, and we also used the magnifying lens system in a constant position. In spite of this fact, practically no deteriorative effect to image sharpness has been observed due to slight changes of the effective focal length of the objective (in consequence of temperature variations or of the ever variable atmospheric layers acting as a supplementary lens).

On the inclination of the photographic plate: The optical axis should be perpendicular to the plane of photographic plate in the secondary focus. If in our photoheliographs this perpendicularity is in error by about 0.3° or more (< 1°), the image of the whole Sun's disc still remains, in practice, sharp enough. However, we must apply corrections to get spot positions with the required accuracy.

It is a simple and at the same time an exact method to determine the inclination of the photographic plate together with the distortion of the enlarging lens system, i.e. the main instrumental constants.

In order to determine the distortion corrections of the enlarging lens system (*E*) photographic positive glass copies of the distortion target, shown in Figure 1, were used where the diameter of the circle no.14 is diminished to 22 mm. In the heliograph, this target replaces the cross-wires and, oriented accordingly, it should be photographed with lamp-light switched on in front of the objective. In this way one can get an enlarged negative picture of the target on a glass photoplate. Here and in the (original) target let r and r_t be the corresponding distance from the optical axis (O). By means of measuring all 13 × 72 points of intersection (i.e. the crossings of circles and radii) as well as the point O in both the target and its enlargement, it is easy to find from the data set of r/r_t (viz. the scales of enlargement) the desired instrumental constants.

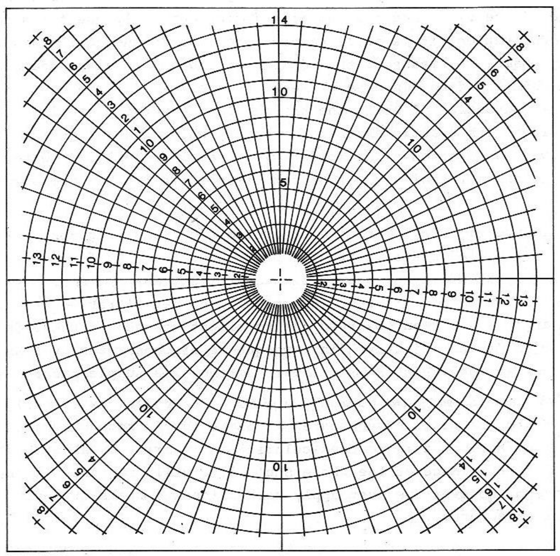

Fig.1 The distortion target

It is quite evident that if the photoplate has an undesirable inclination (ε), then along the outer circles both the r and r/r_t values should conspicuously exhibit a maximum and a minimum. In this respect the r/r_t data are rather more reliable than the r values for reasons easily accounted for (namely, nuances in r_t along each circle already spoil the smooth running of the r-curve). The position angle (P_ε) of the inclination as it points at the maximum enlargement can be found immediately and the angle of inclination (ε) may be calculated from the simple geometrical relation as follows.

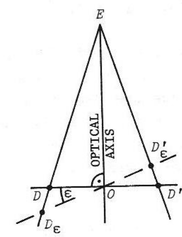

Fig.2

In Figure 2 the plane of drawing, which includes the optical axis, is perpendicular to the plane of the photographic plate. In the image of the distortion target DD' is a diameter of any circle in the untilted case while $D_\varepsilon D'_\varepsilon$ is the same if the plate is tilted by the angle ε (and the position angle of the point D_ε is P_ε).

Let OD_ε and OD'_ε the maximum and minimum values of r be r_a and r_i, respectively. Then, from the triangles ODD_ε and $OD'D'_\varepsilon$ (with $\varepsilon < 1°$) and taking also into account e.g. the triangle ODE, we have

$$\operatorname{tg} \varepsilon = \frac{q}{r} \, \frac{r_a - r_i}{r_a + r_i}$$

Here $OD = OD'$ is the actual value of r at the position angles of $P_\varepsilon \pm 90°$ and $q = OE$ is the distance between the plate (centre) and the (second principal point of the) enlarging lens system. Dividing in the second fraction both the numerator and denominator by r_t, this formula can thus be used to calculate ε (in good approximation) from the maximal and minimal enlargements (r_a/r_t and r_i/r_t respectively) given the above.

It would be a difficult task to make a fine adjustment correcting the inclination of the photographic plate to reach $\varepsilon = 0.0°$. However it is easy to compensate completely by calculation of the unwanted effect of $\varepsilon \neq 0.0°$ if the angle of inclination ($\varepsilon < 1°$) and its position angle (P_ε) are known.

In order to do so let us introduce in the plane of the photoplate a rectangular Cartesian left-handed coordinate system with its origin in the optical axis where the place of maximal enlargement (in the tilted plane) is on the positive x-axis. If the coordinates in the tilted and untilted plane are referred to as x_1, y_1 and x_2, y_2, respectively, then by means of Figure 3 the formulae of transformation of the coordinates x_1 and y_1 of any S'_ε point of the tilted plane will be as follows:

Let the orthographic projection of any point S'_ε be denoted by S_ε. If the plane of drawing of Figure 3 is

the plane I, which includes also the x-axes,

then $OS_\varepsilon = x_1$, $OS = x_2$ and the angle $SOS_\varepsilon = \varepsilon$

(The plane of the angle ε is by definition always perpendicular to the y-axis.)

Consequently

$S_0S = x_1 \cos \varepsilon$

$S_0O = x_1 \sin \varepsilon$

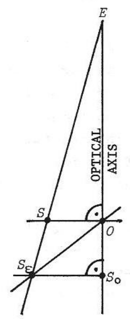

Fig.3

the plane II, which includes also the (common) y-axis,

then $S_0S_\varepsilon = y_1$ and $OS = y_2$, however the angle $SOS_\varepsilon < \varepsilon$, but since the points S_0 , O and E remained exactly the same as in the plane I therefore even now

$S_0O = x_1 \sin \varepsilon$

In both planes (I and II) from the similarly lettered triangles EOS and ES_0S_ε , with $EO = q$, we have, respectively,

$$x_2 = \frac{q\, x_1 \cos \varepsilon}{q + x_1 \sin \varepsilon} \qquad y_2 = \frac{q\, y_1}{q + x_1 \sin \varepsilon} \qquad (3.2.1)$$

———

The method outlined above is a very convenient way to determine the $(\varepsilon, P_\varepsilon)$ constants of the inclination of the photographic plate by means of the distortion target, notwithstanding the fact that there is a possibility to find these data from solar observations, too. Namely, it is easy to recognize the deviation from the wanted perpendicularity discussed above by using, as we do, heliographs of German mounting and observing regularly on both the east and west side of the pier, since systematic differences in positions, calculated from the apparent Sun's disc centre, will appear between such east and west observations.

These differences originate in the fact that the true and apparent centres of the Sun's disc do not coincide when the perpendicularity in question is not fulfilled. A clear proof may be seen at a glance from an example shown in Figure 4, where $O = C$ is the true centre of the Sun's disc and VW one diameter of the disc (i.e. $VO = OW$), perpendicular to the optical axis. The VW solar diameter turns into V_eW_e or V_wW_w if the plane of photographic plate deviates from perpendicularity by the angle ε and consequently the apparent disc centres (C_e and C_w) depart from the true centre (C). (C_e and C_w are drawn distorted in Fig.4) The e indices are used to mark such situations in which the heliograph is on the east side of its pier; the w indices show the same on the west side. Thus $P_{\varepsilon e}$ and $P_{\varepsilon w}$ are the position angles of C_e and C_w , respectively, furthermore $P_{\varepsilon w} = 180° + P_{\varepsilon e}$, as the photographic plate rotates through 180° while the heliograph is shifted from the east side to the west side of the pier.

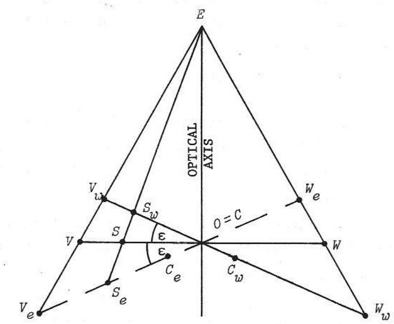

Fig.4 The enlarging lens system (E) and inclinations of the photographic plate

By using the definitions and designations introduced above and considering a spot S in Figure 4, moreover taking $|d| = C_eO = OC_w$ (> 0) and $OS = x_2$, $OS_e = x_{1e}$, $OS_w = x_{1w}$, then

$$x_{1e} = x_e + d \qquad x_{1w} = x_w - d \quad , \text{ where}$$

x_e $(= C_eS_e)$ and x_w $(= C_wS_w)$ are the actually obtained coordinates measured from the apparent centres of the Sun's disc C_e and C_w , respectively.

Applying the inclination correction to x_{1e} and x_{1w} the corrected x_{2e} and x_{2w} should agree. It is easy to see through Figures 4 and 3 that in the case of x_{2w} , the sign of the second term in the denumerator of the formula for x_2 is reversed. Accordingly

$$\frac{q\ (x_e + d)\ \cos\varepsilon}{q + (x_e + d)\ \sin\varepsilon} = \frac{q\ (x_w - d)\ \cos\varepsilon}{q - (x_w - d)\ \sin\varepsilon}$$

and from here (disregarding $2d^2 \sin\varepsilon \ll 1$) we get

$$x_w - x_e = +2d - \frac{2}{q}\ x_w x_e \sin\varepsilon$$

It should be emphasized that this relation is valid in the case of Figure 4 where the apparent centre of the Sun's disc is shifted to east when the heliograph is on the east side of the pier. Should the sense of the plate inclination be opposite and the heliograph again be on the east side of the pier, then the apparent centre of the Sun's disc will be shifted to the west. In the latter case we should interchange all e and w indices in Figure 4, and now we get

$$x_w - x_e = -2d + \frac{2}{q}\ x_w x_e \sin\varepsilon$$

In both relations of $x_w - x_e$ on the right side the first term is always larger by one order of magnitude than the second, which are negligible in the case of small x-values, especially when the spot is within 2/5 of the solar radius.

Hence it follows that the sign of the $x_w - x_e$ differences roughly also shows the direction of inclination, i.e. its position angle ($P_{\varepsilon e}$).

Accordingly, the values of ε and $P_{\varepsilon e}$ can be determined by means of a great number of differences in spot positions, which are measured on pairs of heliograms taken practically at the same time on the west and east side of the heliograph pier, and are expressed in a rectangular Cartesian left-handed coordinate system with its origin in the apparent Sun's disc centre. Considering these west-east differences as vectors, if there is sufficient data, it is possible to find a most representative "mean" vector. Its magnitude and direction can be regarded as $|2d|$ and $P_{\varepsilon e}$, respectively. Finally the value of ε can be calculated from d:

$$tg\ \varepsilon = \frac{q}{R^2}\ d$$

where R is the radius of the Sun's disc measured. This relation follows from the one used in connection with the distortion target, taking $r_a = R + d$ and $r_i = R - d$, as in Figure 4 $V_e C_e = C_e W_e = R$.

The method outlined above has the advantage that it may also be performed after the observations already done. We believe that if a sufficient number of relevant spot pairs are available, the probable errors will not be greater than in the case of the method previously outlined, at a rough guess 0.1° and 10° for ε and P_ε , respectively. In any case such differences have only inconspicuous effects on the spot positions.

For the year 1977 the observations have been reduced by using the instrumental constants as follows:

Heliograph in	ε	$P_{\varepsilon e}$	Number of the used spot pairs
Debrecen	0.76°	185°	111
Gyula	0.33°	120°	171

(The position angles are measured from astr. N toward E.)

The data given here are on the basis of results from spot positions; the distortion target method, introduced only after 1977, was used only for checking.

We wish to acknowledge the assistance of B.Kálmán in the matter of inclination.

The distortion of the magnifying lens system has been determined for both of our heliographs by means of the distortion target from the measured enlargements (r/r_t) corrected for plate inclination. Both heliographs have pincushion distortion, which is slightly larger in Debrecen than in Gyula. The results can be expressed as

$$\frac{r}{r_t} = a + br + cr^2$$

where, using the relevant q distances (cf. p.17), we have for the heliographs:

	in Debrecen	in Gyula
a =	+5.997774	+5.661418
b =	−0.000073	−0.000121
c =	+0.000015	+0.000013
(q =	38 cm	41 cm)

In consequence, the coordinates x_2 and y_2 corrected for distortion will be

$$x_3 = \frac{x_2}{D}\ ,\ y_3 = \frac{y_2}{D} \quad \text{where} \quad D = 1 + \frac{b}{a}(x_2^2 + y_2^2)^{1/2} + \frac{c}{a}(x_2^2 + y_2^2) \qquad (3.2.2)$$

3.3. Orientation of the heliograms

Since the position angle (P_0) of the northern extremity of the axis of solar rotation is measured (eastward) from the north point of the Sun's disc, our spider-wire directed roughly north-south can only serve for orientation if its exact deviation angle (ΔP_0) from the north direction is known.

The precise zero of position angles for the Debrecen and Gyula heliographs were determined by the so-called zero heliograms which were exposed twice, with an interval of about 90 seconds between the two exposures, the heliograph being firmly clamped. Two overlapping images of the Sun were thus produced and the exposures were generally so made that the line joining the points of intersections of the two solar limbs (I_n , I_s) passed approximately through the centre of the plate. The angle between this line and the north-south spider-wire ($\Delta P_0'$) is measured. For the sake of higher accuracy several points along the two solar limbs were measured instead of the immediate measurement of the points I_n and I_s and by this means the positions of intersections were calculated.

Corrections should be applied for variation in the Sun's declination (ΔP_δ) , for the slight convergence of the relevant meridians (ΔP_m) and for variation as a consequence of atmospheric refraction (ΔP_A). Accordingly, the error of the northern extremity of the spider-wire (ΔP_0) used is

$$\Delta P_0 = \Delta P_0' + \Delta P_\delta + \Delta P_m + \Delta P_A$$

(Here all position angles are measured in the same sense as P_0.)

To show these corrections explicitly, let us assume, for the sake of simplicity $\Delta P_0 = 0.0°$, i.e. the orientation of the cross-hairs is exactly in north-south and east-west directions.

(ΔP_δ) The variation in the Sun's declination reveals itself by the inclination of the Sun's path to the parallels of declination. It is easy to see that

$$\Delta P_\delta = \frac{\delta_{n+1} - \delta_n}{2\pi}$$

where $\delta_{n+1} - \delta_n$ is the relevant difference in declination from one day (n) to the next (n+1) which never exceeds 0.4°. The maximal value of $|\Delta P_\delta|$ may amount to 0.06°.

(ΔP_m)

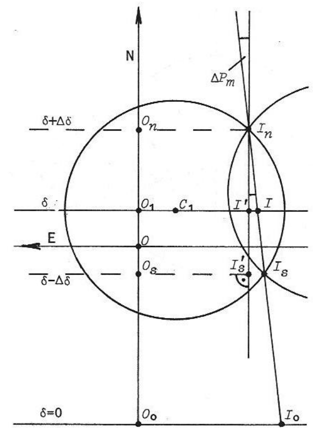

Fig.5

In (the strongly distorted) Figure 5, C_1 is the centre of the solar image at the moment of the first exposure of a zero heliogram, and O is the centre of the cross-wires of the heliograph, while the Sun's declination (δ) is constant between the two exposures. Accordingly the meaning of the other letters of the Figure are self-explanatory (I_nI' is parallel to O_nO). On the solar disc the meridian passing through the points I_n and I_s is not parallel with the meridian through the point O, as ($O_1I = O_0I_0 \cos\delta$)

$$O_nI_n = O_0I_0 \cos(\delta+\Delta\delta) \quad \text{and}$$
$$O_sI_s = O_0I_0 \cos(\delta-\Delta\delta)\ .$$

Thus from the triangle $I_sI_nI_s'$ (where the angle $I_sI_nI_s'$ is ΔP_m) we have

$$\Delta P_m = IO_1\ tg\ \delta$$

where IO_1 is an angular distance.

The maximal value of $|\Delta P_m|$ may amount to approx. 0.1°.

(As ΔP_m is in direct proportion to the distance IO_1 , measured always from the north-south wire, in 1977 at our zero heliograms ΔP_m was nearly negligible in most of the cases since this distance was then generally small.)

(ΔP_A)

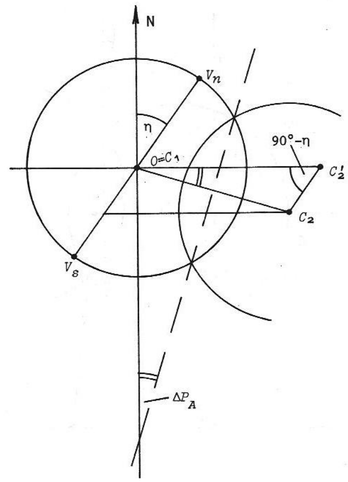

Fig.6

In Figure 6 for the sake of simplicity let the centre of the solar image (C_1) coincide with the centre of the cross-wires of the heliograph (O) in a zero heliogram at the first exposure. At the second exposure, let C_2' be the centre of the solar image if the altitude of the Sun (h) is high enough ($h > 30°$), and C_2 if the altitude is low, while during the two exposures the change in declination was assumed to be negligible. The apparent shift of the solar centre $C_2'C_2$ is a consequence of the change in atmospheric refraction (ΔA) that takes place parallel with the vertical diameter (V_nV_s) of the solar disc; η is the position angle of V_n. (Fig.6 shows the situation in the early morning.) The interval between the two exposures (Δt) expressed in angular measure is (Δt=) $C_1C_2 \approx C_1C_2'$ and the angle $C_2C_1C_2'$ is equal to the wanted ΔP_A and from the triangle $C_1C_2C_2'$ we get

$$\sin \Delta P_A = \frac{\Delta A}{\Delta t} \cos \eta$$

This correction is generally dominant below altitudes of 15°, when $\Delta P_A > 0.1°$. With respect to image quality we can fairly well use heliograms

taken even at low altitudes, sometimes as far as 6° or so. This is why the correction ΔP_A is very important.

We are grateful to I.Nagy who called our attention to the conditions that the shift of the solar disc due to change in refraction between the two exposures of a zero heliogram at low altitudes might not be negligible.

In the zero heliograms for 1977 only a part of the solar disc was visible and it was not possible to measure directly the vertical and horizontal solar diameters to determine the actual values of the differential refraction. Nevertheless all measurements of positions in the zero heliograms have been reduced by taking into account the effect of differential refraction, too. For this purpose, as well as for the correction ΔP_A Bessel's (visual) mean refraction table as republished in *Landolt-Börnstein Numerical Data etc.* {New Series, Group VI, Vol.1, p.49, 1965} was used. (Cf. also part (3a) of Section 5.)

ΔP_0 determinations: In so far as in a perfectly mounted heliograph the position of the spider-wires as well as the heliograph itself suffered no change at all, then the determined zero position angle ΔP_0 could be used once and for all. However, if the polar axis of the equatorial mounting of the heliograph does not point exactly to the celestial pole and the declination axis is not perfectly perpendicular both to the polar axis and to the optical axis, then ΔP_0 will also depend on the hour angle of the Sun (t_0) and it should be determined accordingly. Unfortunately the frame of the spider-wires has to be removed for cleaning of the magnifying lens system or for insertion of a new wire; furthermore other parts of the heliograph and its mounting also need some repairing from time to time. These circumstances may produce a change in ΔP_0 and therefore we have regularly taken zero heliograms at various hour angles on several days, as shown in the following table for the year 1977.

For each "undisturbed" period of zero observation the most probable values of ΔP_0 as a function of the hour angle (t_0) were estimated with a curve by a graphic method. If the ΔP_0-curves for two or more subsequent periods were parallel with each other in fairly good approximation, then for a longer period by superposition a joint mean ΔP_0-curve has been determined by quadratic least squares estimation. Thus, for the Debrecen observations, a single one, while for the Gyula observations three mean ΔP_0-curves could be used, as indicated in the table for the year 1977.

The periods of zero observation	Number of days with zero obs.	Max.numb. of zero obs. on a day	Total number of zero obs.	Dates of potential change in the heliograph: Wire frame removed for cleaning	Wire frame removed for insertion of a new wire	Reparation	Earthquake
in Debrecen							
Jan.1 - 18	9	7	37	Jan.19			
Jan.19 - March 4	19	8	54				March 4 (evening)
March 5 - 27	19	7	66			March 28	
Apr.1 - June 22	40	8	123				
(Jan.1 - June 22)	(87)		(280)				
in Gyula							
May 4 - 6	3	14	29	May 6			
May 7 - 20	12	19	60	May 20			
May 20 - 23	4	14	43		May 24		
May 24 - June 2	6	23	51	June 2			
June 3 - July 7	13	14	72	July 8			
July 8 - Aug.9	4	21	62	Aug.10			
Aug.10 - Sep.2	3	19	41			Sep.2	
Sep.3 - 19	1	9	9		Sep.20		
Sep.21 - Oct.10	4	20	30			Oct.10	
Oct.13 - 16	4	8	20			Oct.17	
Oct.17 - 31	3	12	14		Nov.1		
Nov.4 - Dec.31	6	26	47				
(May 4 - Dec.31)	(63)		(478)				

For the shorter periods within a longer one the expressions of

$$\Delta P_0 = a + bt_0 + ct_0^2$$

differ from each other only in the constant a. (Since in our heliographs the optical axis was not perfectly perpendicular to the declination axis, we also had a slight difference in a between observations taken on the east and west side of the pier.)

In Figure 7, as an example, for a longer period a set of ΔP_0 - observations (280) is plotted, where the solid line represents the mean curve, while the dashed lines show the standard deviation.

The asymmetry reveals an azimuthal error in the polar axis, as the heliograph in Debrecen was in place after a rush temporary installation.

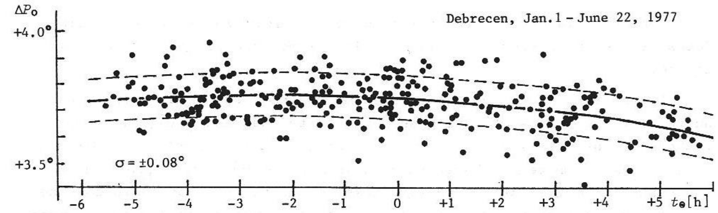

Fig.7

The three mean ΔP_0-curves of the Gyula heliograph are fairly symmetric to the zero hour angle. In the first month ΔP_0 was constant, as well, as it should be in case of a well-mounted parallactic telescope. However, the ΔP_0 - curve became slightly concave down, probably due to a change in inclination of the polar axis for the last five months of the year. (Cf. the last paragraph of Section 3.1.)

Notwithstanding that each zero heliogram was taken with great care, there is always a considerable scattering among the individual ΔP_0-data, as seen in Figure 7, too. This is due to wind, scintillation, etc. Consequently, it is indispensable to use a lot of observations for finding reliable values of ΔP_0.

The measurement and reduction of positions in the zero heliograms were carried on practically in the same way as described in Sections 4 and 5.

3.4. Co-operating observatories

At the *Kislovodsk Observatory* the heliograph has a negative lens close to the (doublet) objective. Its 13 cm aperture was used with a diaphragm of 5 cm. The effective focal length of this optical system is 8 m and has very small distortion. An image of the Sun about 8 cm in diameter was photographed without any filter on glass photoplates (ORWO FU-5) of 9×12 cm size. The effective wave-length of the solar image is 410 nm. For orientation there is an east-west directed metal wire just in front of the photoplate.

The solar photographs (on plane films of 24×24 cm size) received from the *Kodaikanal Observatory* were obtained in the same way as the ones used in RGO to fill in gaps for the Greenwich Photoheliographic Results during the former years (even for 1976). At Kodaikanal the objective aperture was

15 cm and the diameter of the solar image was about 19 cm. In the primary focus of the heliograph there is one wire fixed parallel to the celestial equator.

At the *Ebro Observatory* the solar photographs were taken as it is required for their sunspot catalogue. Up to date the last volume was published for the year 1970. {*Boletin del Observatorio del Ebro, Vol.LVIII.*, Tortosa, 1976; cf. also P.M.Balcells, L'observation solaire, *Mém.Obs.Ebro*, No.2, pp.1-34. 1909.} The Ebro heliograms used by us were taken on plane films of 13×18 cm size and had an image of the Sun of about 10 cm in diameter. The exposures were made with a slit moving in an east-west direction and its traces on the film could be used for orientation.

The position measurements on the foreign heliograms were reduced in the first approximation by using the orientation seen in the heliograms. In order to find the precise orientation of the heliograms of the foreign co-operating observatories it was necessary to measure the extra heliograms mentioned in Section 2.1. If the positions, measured on both the foreign and our heliograms taken on the same day, are in good agreement, then we can also reduce the other foreign heliogram taken at the same observatory on the preceding or following day accordingly. In so far as there are some differences in the positions between the two heliograms then from the differences the actual value of ΔP_0 can be determined.

The geographical positions of the co-operating observatories are as follows:

	LONGITUDE (East of Greenwich) λ	LATITUDE (North) φ	ALTITUDE above sea level
	h m s	° '	m
Ebro	0 01 58	40 49.2	50
Gyula	1 25 05	46 39.2	135
Debrecen	1 26 29	47 33.6	135
Kislovodsk	2 50 07	43 44.0	2130
Kodaikanal	5 09 52	10 13.8	2343

4. MEASUREMENTS

The *position* measurements were carried out by means of an ASCORECORD (3DP) coordinate measuring instrument of Zeiss (Jena). Rectangular coordinates x , y were directly recorded through an interface made at the Institute of Experimental Physics of the Kossuth University in Debrecen.

First of all, it is essential to measure some principal points in all heliograms. These are the centre of the cross-wires and at least 8 points along the limb of the Sun's disc, namely the four intersections of the cross-wires with the limb, furthermore the ends of the vertical and horizontal solar diameters. (Previously the latter four places just outside the limb had been marked with a needle.)

The position of the centre of each umbra in every sunspot was measured one by one, considering even any tiny dark core if it is quite alone in a penumbra as an umbra. In all those cases where it was not possible to see any umbra in a sunspot the position of the geometrical centre of the spot was measured for each spot, also one by one. Exceptions were taken only in cases of two or three very little close spots of about equal areas. Furthermore, not only the well separated umbrae or spots but even those which were temporarily bordered on were measured one after the other.

The sunspot *areas* were determined by means of a special area measuring instrument "DAREAL" using video facilities and also made for us at the Institute of Experimental Physics here in Debrecen.

In all cases where the positions were previously recorded, both the umbra and the whole spot (umbra + penumbra) area were measured directly in the heliograms. By using the actual predetermined radius of the solar image we get the Projected Areas $[U_p, (U+P)_p]$ expressed in millionths of the Sun's apparent disc. The Projected Areas multiplied by $\frac{1}{2} \sec\rho$, where ρ is the relevant angular distance from the centre of the apparent disc as viewed from the Sun's centre, are the Corrected Areas (U, U+P), i.e. the areas corrected for geometrical foreshortening, expressed in millionths of the Sun's visible hemisphere.

The ASCORECORD coordinate measurements of positions are recorded to two decimal places of the millimetre. Nevertheless the final results in heliographic coordinates are given only to the first decimal place of a degree.

The results of coordinate measurements over a pair of heliograms (cf. the paragraph before last in Section 2.1) agree in the overwhelming majority of cases, or have a difference of not more than 0.1°. (For more details on the errors in heliographic coordinates see on pp. 211 - 217.)

The DAREAL area measurements are recorded to the first decimal place of the area unit; however, in the final area results given in the catalogue no decimal number is used. For all that in a few special cases even an area less than the corrected area unit is given as U+P = 1 or U = 1 where it seems to be significant (cf. Section 6).

In a 10 cm image of the Sun's disc the diameter of a circular projected area unit is 0.10 mm; this distance corresponds approximately to 0.1° in heliographic coordinates around the disc centre, or to 1.7 arc sec. (The theoretical resolving power in our own heliograms is between 0.9 and 1.7 arc sec.)

The corrected area unit is $3044 \cdot 10^3$ km^2 on the Sun, considering this area as a circle its radius is 984 km, i.e. 0.08° heliocentric angle.

The accuracy of a single measurment of a sunspot area is inferior to that of the position measurement. The areas depend much more on seeing and darkening of the image than the positions. (On account of a difference in spectral regions we could find no distinction between the foreign heliograms and ours.) For some guidance: the estimated errors expressed in percentages of the here published Corrected Area data may amount to approximately

50% for $U \approx 2$, 10% for $U > 20$,
20% for $U+P \approx 2$, 5% for $U+P > 100$ (corrected) area units.

However by approaching toward the solar limb, at large ρ (> 70°), there is an additional uncertainty as the factor *sec* ρ increases rapidly. (About our area measurements see the paper on pp. 219 - 230.)

All positions and areas were measured by Á.Kovács and O.Gerlei, respectively.

5. REDUCTION OF THE COORDINATES

The heliographic coordinates are calculated from the rectangular Cartesian coordinates x_A, y_A, measured in the ASCORECORD by means of the following algorithm. (A left-handed coordinate system is always used where the positive x- and y-axes should be directed toward east and north, respectively.)

(1) All coordinates x_A, y_A are transformed into a system of coordinates x_0, y_0 through a rotation with the angle $\Delta P_0 + \alpha$ and a linear translation which takes its origin in the point of intersection of the wires (O). The angle α is the angle of intersection of the northern wire and the y_A-axis.

(2) The coordinates x_0, y_0 should be corrected for plate inclination and distortion according to Section 3.2 (see p.18 and p.22).
Rotating the coordinate system by the angle $P_{\varepsilon e}$-90° to get the coordinates x_1, y_1 and by using the formulae (3.2.1) and (3.2.2) we obtain x_2, y_2 and x_3, y_3, respectively. Then follows a rotation back to the coordinate system x_0, y_0.

Because of the corrections applied for plate inclination the coordinates of the intersection point of the northern wire with the solar limb (which was used to determine the angle α) could have a small change; therefore the angle α may also have a slight change $\Delta\alpha$. Then rotating by $\Delta\alpha$ the coordinate system, its positive y-axis will be directed exactly north.

Using the so-corrected x_0,y_0 coordinates of all points measured on the limb a least squares solution for a circle gives values for the radius and centre position of the Sun's disc (a).

(3) A linear translation of the coordinate system takes its origin from the centre of the cross-wires (O) into the centre of the Sun's disc (a) and the coordinates into x_a, y_a. Then the coordinates should be corrected for atmospheric refraction.

(3a) By means of immediate measurement of the vertical ($2R_V$) and horizontal ($2R_H$) actual diameters of the Sun's disc, the effect of the differential refraction can be eliminated, i.e. the distortion due to the difference in refraction between the centre and any other point of the disc.

The y-coordinates of all disc points in a system of coordinates which have their origin in the centre of the disc and their y-axis lies in the vertical diameter, have to be multiplied by the measure of differential refraction, i.e. R_H/R_V.

However in rare cases we had to make distinctions between the upper (R_{Vn}, i.e. the "northern") and lower (R_{Vs}, i.e. the "southern") vertical radius, since at low altitudes ($5° < h \leq 11°$) the change in atmospheric refraction (ΔA) is already significant along the vertical diameter and the true centre of the Sun's disc does not coincide with the middle point of the vertical diameter ($R_{Vn} > R_{Vs}$). Let ΔA_n and ΔA_s be the change in refraction along the radii R_{Vn} and R_{Vs} , respectively. Then from $\Delta A_n / \Delta A_s = R_{Vs}/R_{Vn}$, where $R_{Vs} + R_{Vn} = 2R_V$, the R_{Vs} and R_{Vn} are calculated by using the same mean refraction data mentioned in Section 3.3. The distance between the "apparent" and the "true" centre of the disc is $\frac{1}{2}(R_{Vn} - R_{Vs})$.

The position angle (η) of the upper half of the vertical diameter of the Sun's disc is calculated from

$$\sin \eta = \frac{\sin t_0 \cos \varphi}{\cos h}$$

$$\sin h = \sin \delta \sin \varphi + \cos \delta \cos \varphi \cos t_0$$

where h is the altitude above the horizon, t_0 the hour angle and δ the declination of the Sun, and φ is the geographical latitude of the observatory.

(3b) To make the corrections simple for differential refraction the coordinate system has temporarily to be rotated by the angle η so that the positive y-axis should coincide with the upper vertical radius of the Sun's disc.

At first only the coordinates of the limb points are corrected. (If $h \leq 11°$, $\frac{1}{2}(R_{Vs} - R_{Vn})$ should be added to the y-coordinates before correction.) Using the corrected coordinates of the limb points a repeated least squares solution for a circle give the definitive radius (R) and centre of the Sun's disc (c).

Of course one should find $R = R_H$; nevertheless insignificant differences may occur. Henceforward the values of R are used as they are based upon many more measured points than the R_H. On the other hand, the centre a coincides with centre c except when $h \leq 11°$. (For the year 1977 we had to use heliograms obtained at $h \leq 11°$ on 21 days. This is the reason why the most general procedure of reduction is treated here.)

Then all spot coordinates can be given in a coordinate system which has its origin in the centre of the Sun's disc (c). Now correcting the coordinates for differential refraction, as described above, the final coordinates x , y are obtained.

(4) The sunspot positions on the Sun's disc in polar coordinates are

$$r = (x^2 + y^2)^{\frac{1}{2}} \qquad P_r = \operatorname{arctg} \frac{x}{y}$$

The position angle P_r is measured from the north point of the disc and are reckoned eastward positive, westward negative from 0° to 180°, i.e. in the same sense as P_0 , the position angle of the north end of the Sun's axis of rotation.

The heliographic coordiantes of a point on the Sun's surface are defined with reference to the solar equator and are calculated in accordance with R.C.Carrington. {*Observations of the Spots on the Sun*, London, 1863.}

The heliographic longitudes (L) are measured from the solar prime meridian that passed through the ascending node of the solar equator on the ecliptic on 1854 January 1, Greenwich mean noon, J.D. 2398220.0; they are reckoned from 0° to 360°, in the direction of rotation, i.e. on the disc from east to west. (Carrington's zero meridian passed the ascending node 12 hours earlier.) The heliographic latitudes (B) are reckoned from the solar equator, positive towards the north.

The heliographic longitude (L_0) and latitude (B_0) of the central point of the Sun's disc, as well as the P_0 position angle are taken from *The Astronomical Ephemeris for the year 1977* {H.M.Stationary Office, London, 1975} . They are calculated with the elements determined by Carrington {1863, loc.cit. pp.221 and 244}. Thus, the following are assumed:

- sideral period of rotation: 25.38 mean solar days;
- inclination of the solar equator to the ecliptic: $I = 7°15'$;
- longitude of the ascending node to the solar equator on the ecliptic: $\Omega = 73°40' + 50.25''\,(t - 1850.0)$, where t is the time in years.

Hence $\Omega = 75°26.4'$ for 1977.0 . (In Figure 9 the angle $Q_1 N Q_2 = I$.)

The spherical coordinates of a sunspot are calculated from the polar coordinates r, P_r as follows:

In Figure 8 let ρ and ρ' be the angular distances of a spot S_s from the middle of the visible solar hemisphere C_s , as viewed from the centre of Sun and from the Earth, respectively. Furthermore let CS be the distance of the spot (r) from the centre of the Sun's apparent disc, CD the radius of the disc (R) and the angle $C\hat{O}D$ the semi-diameter of the Sun (R_0), as given in the *Ephemeris*.

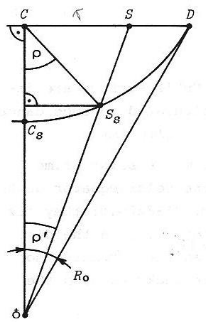

Fig.8

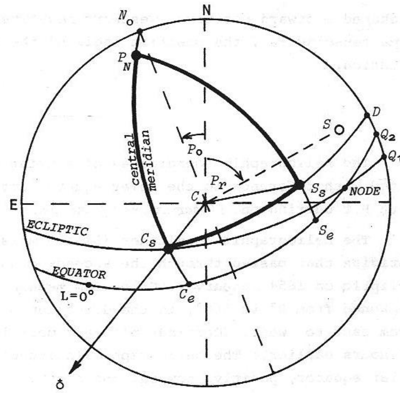

Fig.9

From the triangles $C\delta D$, $C\delta S$ and $C\delta S_s$ (as $\rho' < R_o \leq 0.272°$)

we get $\rho' = \frac{r}{R} R_o$ and $\sin(\rho + \rho') = \frac{r}{R}$,

hence

$$\rho = \arcsin\frac{r}{R} - \frac{r}{R} R_o$$

In Figure 9 let the curved lines represent great circles on the solar hemisphere and let the dashed lines be on the solar disc. (All points marked in Figure 8 can also be found in Figure 9; S_s on the surface will be seen on the disc at S.) P_N is the (north) pole of the solar equator (Q_2, S_e, C_e), and on the great circle (P_N, C_s, C_e), called the central meridian, C_s is the pole of the great circle E, N_o, N, D which defines the solar limb. ($P_N S_s S_e$ is the solar meridian through S_s.)

In the spherical triangle $S_s P_N C_s$, the three sides and two of the spherical angles are the following:

$S_s P_N = 90° - B$, as $S_s S_e = B$ according to definition of the heliographic latitude,

$P_N C_s = 90° - B_o$

$C_s S_s = \rho$

$S_s P_N C_s = (C_e S_e =) \; L - L_o = L_{CM}$ the longitude from central meridian, being reckoned westward positive (eastward negative),

$P_N C_s S_s = (D N_o =) \; P_o - P_r = \vartheta$ this position angle ϑ is measured from the north pole (N_o) of the Sun's axis in the same sense as P_o and P_r.

Then using the cosine- and sine-formulae of spherical trigonometry and considering that $sg\, L_{CM} = -\, sg\, \vartheta$, we have

$$\sin B = \sin B_o \cos \rho + \cos B_o \sin \rho \cos \vartheta$$

$$\sin (L_o - L) = \sin \rho \sin \vartheta \sec B$$

All calculations of B, L, L_{CM}, ϑ and r/R were performed by the PDP 11/40 computer of the Institute of Nuclear Research of the Hungarian Academy of Sciences, Debrecen.

6. DATA PRESENTATION

Notwithstanding that almost every detail of all sunspot groups was separately measured, the results of measurement are generally not given with full particulars.

Thus, in the Catalogue, only the groups lasting for two or more days are included. The one-day groups are omitted from this publication (nevertheless their list is available on request). However, the most important data of those 11 one-day groups which emerged not too far off from another group are given in the *"Notes on Sunspot Groups"*. On the other hand, a very little spot whose area is less than the corrected area unit is only given when it is either the first or the last day of observation of a spot lasting for two or more days; furthermore a tiny umbral area ($U < 1$) is only given if any other umbra is not at all seen in the penumbra (cf. Section 4).

The *basic data set of the Catalogue* consists of data of individual units of single spots and of two or more spots close together combined into a small cluster on the basis of direct measurements. By way of explanation Figure 10 shows characteristic examples.

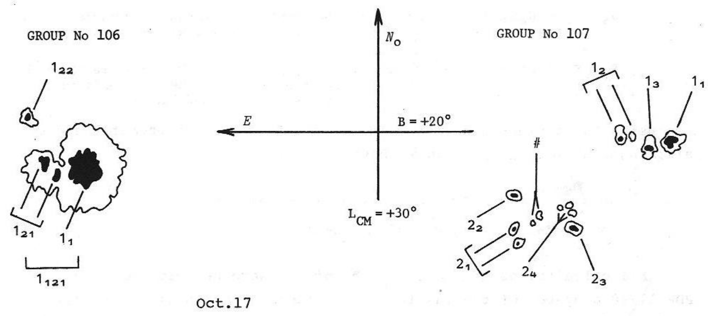

Fig.10 Sunspots in a portion of the Sun's disc drawn to scale by way of illustration. (The distance between spot 1_{22} of group 106 and spot 2_2 of group 107 is one tenth of the diameter of the Sun's disc.)

The short lines pointing to spots indicate the direct measurements. The branching lines call attention to the fact that only the position of the centre of gravity and the aggregate area were measured, although two and three little spots are recorded (# and 2_4, respectively). Linking marks (┌─┐) denote that the sum of areas and the weighted mean of the separate position measurements are to be found in the Catalogue; for whole spots (as for 1_2 and 2_1) U+P areas, for umbrae (as for 1_{21} and 1_1) U areas were used as weights. In the same way all other (combined) joint positions given in this publication are calculated as weighted arithmetic averages.

All individual units of spots which have been traceable from one day to the next got a special numbering as a mark of identification. When there is more than one umbra within a spot, the umbrae also are similarly numbered in several cases, if reasonable (e.g. in spot 1_{121}). Our numbering indicates the spot developments in a fairly good approximation, too. (Identification without any mistake is only possible if a long series of observations are available for each day.)

Distinctions were made between the spots of *p*- and *f*- polarity by designating them with odd and even numbers, respectively. Within a group a pair of consecutive large numbers (2n-1, 2n) and in general additionally small index numbers are used for all spots which may be somehow associated with one another.

Sunspots are generally arranged into groups according to old traditions and we felt obliged to follow these conventions within reasonable limits. However, taking into account the fact that the sunspot group is essentially a magnetic field system, we tried to deal with the groups in accordance with their *magnetic properties*, as far as available polarity determinations permitted.

The majority of sunspot groups clearly reveal a simple bipolar character even when one or both of its parts consist of several not too distant spots of the same magnetic polarity appearing to be connected, or the group seems to be "unipolar". (Cf. Fig.10.) Supposing that generally all extended groups can be considered as being made up of several simple bipolar groups (i.e. in reality they are "multiple" bipolar groups) we attempted to identify the individual connected pairs of spots of different magnetic polarity. A so-called "complex" group can also be divided into several simple bipolar related spot pairs, i.e. groups; and the magnetic complexity arises mainly from spot motions and new spot emergence within the group. In accordance with the above, in some cases it was possible to distinguish neighbouring groups which at first sight appeared as one.

The *Daily Results* gives, in addition to areas (U, U+P) and coordinates ($B, L, L_{CM}, \vartheta, r/R$), various other data. Mention must be made of the NUMBER OF SPOTS divided according to a new importance category and the one-letter classifications introduced for the larger umbrae and penumbrae. The number of umbrae ($U \geq 2$) in reality are the number of concentrations of considerable magnetic flux or to be more exact the number of local relative maxima of the magnetic field. Moreover, a daily pictogram shows the main character of each sunspot group using an extended version of McIntosh's classification. Furthermore, whenever there is an average position given for two or more spots then fuller particulars of the area distribution around the average position may be found in column EXTRA DATA.

A detailed description of all data presented is comprised in the *"Explanations to the Sunspot Catalogue"*.

The numeration of the synodic solar rotations is in continuation of Carrington's series (loc.cit.), No.1 being the rotation commencing on 1853 November 9. (The mean synodic rotation period is 27.2753 days.) The commencement of each rotation is defined by the coincidence of the assumed prime meridian with the central meridian.

Particulars in reference to the *Summaries of Results* are given in the headings of the tabular data and in some brief notes there. Nevertheless, it is worthwile to call attention to the reason why in Section 3.2. of the Summaries the observations relating to the limb zones were disregarded.

Unfortunately the confidence limit of the optical sunspot observations is at the farthest approximately at the 60° longitude distance from the central meridian. Nearer the limb the simple area corrections used for geometrical foreshortening are generally by no means enough and there is no way known of correcting the still inaccurate values.

It has been shown long ago that both the number and the total (corrected) areas of groups diminish from the Sun's disc center towards the limb, and this is more pronounced for smaller groups. This observational evidence has no reasonable physical explanation; especially in the cases when a small spot approaching the limb becomes invisible it is "difficult to decide whether, when nearer the limb, the spot was non-existent or had been merely overlooked through the dwarfing effect of the foreshortening or had been hidden by masses of surrounding faculae." {Annie S.D.Maunder, Catalogue of Recurrent Groups of Sun Spots for the years 1874 to 1906. *Appendix to Greenwich Observations,1907*, p.6, 1909.} The used limit of 60° (more exactly $\rho = 60°$) are supported by the data given in one of our earlier papers. {L.Dezső, (in § 8 of) Statistical Investigations of Sunspots, *Publ. Debrecen Obs. No.1*, pp.42-50, 1964.}

D A I L Y R E S U L T S

Positions, Areas and other Characteristics

of

S U N S P O T S

for each Day in the Year 1977

1. Explanations to the Sunspot Catalogue
2. Catalogue of Sunspots 1977
3. Notes on Sunspot Groups

Daily DATA of ALL SUNSPOT GROUPS LASTING for TWO or MORE DAYS are tabulated