ON THE DETERMINATION OF HELIOGRAPHIC POSITIONS
AND ROTATION VELOCITIES OF SUNSPOTS

I. Comparison of Results from Different Observatories
and Different Observing Procedures*

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Abstract. Heliographic coordinates of several small but stable sunspots, which were determined at five
different observatories in 1979, are compared. Some systematic differences within these results are found,
which suggest a more detailed analysis of the data accumulation procedures and the physical interpretation.
The same holds for the rotation velocities derived from the position data.

1. Introduction

The interest in precise heliographic positions of sunspots was revived again by several
new results found from a modern analysis of the Greenwich Photoheliographic Results
(1874–1976). Among these results are the dependence of the differential rotation of
sunspots on the phase of the cycle (Balthasar and Wöhl, 1980), new rotation elements
of the Sun (Stark and Wöhl, 1981), and the detection of a systematic decrease of the
rotation velocity of individual recurrent sunspots (Balthasar et al., 1982; Arévalo et al.,
1982).

Although a complete analysis of the Greenwich Photoheliographic Results by means of
modern computing techniques and due to modern scientific demands is not yet per-
formed, there exist some indications that the analysis of high-precision positions of
sunspots may yield several interesting details of the actions of magnetic flux tubes on
the solar plasma and vice versa.

Among these indications are the constancy of the rotation velocity down to less than
\( \pm 5 \, \text{m s}^{-1} \) for many sunspots (Koch et al., 1981), the approximation of the rotation
velocity of very old recurrent sunspots to the rotation velocity of the photospheric
plasma (Balthasar et al., 1982) and the dependence of the mean rotation velocity of
sunspots of a cut-off value for the longitudes of the spots determined near to the limb
(Arévalo et al., 1982).

Within the last decade a new computer controlled method to determine positions on
the Sun was developed by the author at the Locarno observatory of the Göttingen
University (Schröter and Wöhl, 1975). Occasionally some comparisons of heliographic
positions of sunspots were performed using data obtained by this technique and from
observations at the German solar observatory at Anacapri and the Austrian solar
observatory at the Kanzelhöhe. The results seemed to be satisfying.

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Mainly to obtain information about *Debrecen Heliographic Results* as compared to other available data a more complete comparison of sunspot positions from four sunspots observed at five observatories was collected.

## 2. Data Collected

Since the new technique to determine heliographic positions at the Locarno observatory mentioned is rather time consuming and only about a dozen spots per year were observed within the last 8 years material from this observatory served as a reference to select spots.

The spots Mt. Wilson No. 20646, 20658, 20883, and 20882 from June and September 1979 were chosen, but the last one had to be omitted because it was a complex group and it was not known which parts of the group were selected. According to the *Solar Geophysical Data* (SGD) the spots were of types C to H, H, H to C and D, respectively.

(a) *Data from the Locarno observatory.* The observations at the Locarno observatory were performed by A. Koch using the equipment described by Schröter and Wöhl (1975) and Wiehr *et al.* (1980). The spots were observed on a TV-screen (about 1″ mm⁻¹). The positions were measured between one and four times per day. Each position given is already an average from several positions of pronounced features within the border of the penumbra to the umbra of the spot.

The conversions from observed $X$–$Y$-coordinates to heliographic coordinates was also performed by A. Koch.

(b) *Data from the Kanzelhöhe observatory.* The observations at the Sonnenobservatorium Kanzelhöhe were performed by E. Ludescher, G. Lustig, T. Pettauer, and A. Schroll using the solar telescope with an aperture of 110 mm. The projected image of the Sun of 250 mm in diameter was drawn on a sheet of paper. Details of the observing and reducing procedures are given by Lustig (1982).

(c) *Data from the Debrecen observatory.* The observations at the Gyula station of the Debrecen Heliophysical Observatory were performed by S. Rostas, L. Győri, and Zsuzsa Kiss using the refractor stopped down to a diameter of 9 cm and a secondary image of 10.4 cm in diameter, which was photographed behind an interference filter at 554 nm (7 nm passband) on Kodalith film. The determinations of coordinates of spots and calculations of their positions were performed by Agnes Kovács.

The equipment used is the same, which is used to obtain the *Debrecen Photoheliographic Results*. In the case of the three sunspots the number of observations per day was between two and twelve.

(d) *Data from observations at Dietzenbach.* These observations were performed by a group of amateurs from Dietzenbach in West Germany. They used a 150 × 2300 mm coudé refractor, a yellow filter and AGFA Ortho film. The east–west direction of their photographic images of the Sun (38 mm $\varnothing$) was determined from a second photograph taken on the same film (drift method).
The measurements of the spot positions were performed by H. Lenhardt using a LEITZ measuring microscope with a precision of $\pm 5 \mu m$.

The transformation of measured $X$-$Y$-coordinates to heliographic positions was performed by the author using his HPL program on a HEWLETT-PACKARD 9825 desktop computer.

The observations were performed only once a day. The data exist in comparable form only for the groups Mt. Wilson No. 20646 and 20658.

(e) Solar Geophysical Data. Although the sunspot coordinates given in the Solar Geophysical Data (SGD) serve mainly to identify spots, they are often the only existing source for positions available. Therefore it may be of interest to compare the data given in the SGD with the others.

3. Data Representation

Since some hundred positions of sunspots were collected it is not possible to give these original digital data here – it is also not useful, because the observing times differ too much to allow a direct comparison.

It is also not useful to give graphs, because the positions depending on time are placed on a straight line with a correlation coefficient being very close to one in the case of the longitudes. Therefore linear regression curves through the longitudes and latitudes depending on the time were performed and typical positions calculated for the east, the center and the west on the solar disk. In addition the central meridian passages, the rotation velocities (= the gradient of the regression) and their errors were determined.

In Table I these data are given together with the total numbers of observations per spot at the different observatories.

The time for the calculated positions is 0 UT on the given days.

4. Results and Discussion

Already a brief inspection of Table I shows that there are some systematic differences in the data obtained; we exclude the SGD first and discuss them later.

(a) The longitudes determined differ to a maximum of nearly 2 deg at the limb and 0.5 deg in the disk centre.

(b) The latitudes determined differ to a maximum of about 0.8 deg at the limb and 0.5 deg in the disk centre.

(c) In the cases of large differences in longitudes these also occur for the latitudes. The differences in both coordinates increase from spot Mt. Wilson No. 20646 over 20658 to 20883.

(d) The amounts of the determined rotation velocities have a fixed order: The Locarno results are the slowest, while the Kanzelhöhe results are the fastest.

The differences as compared to Locarno are:

Kanzelhöhe $(0.258 \pm 0.019) \text{ deg day}^{-1}$,

Dietzenbach $(0.118 \pm 0.008) \text{ deg day}^{-1}$,

Debrecen $(0.095 \pm 0.020) \text{ deg day}^{-1}$.
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**TABLE I**

Positions, central meridian passages and rotation velocities of the spots investigated

(*L* = longitude, *B* = latitude, CMP = central meridian passage)
Except for the Kanzelhöhe results the differences are not significant, when taking the individual errors of the rotation velocities into account.

(e) The errors of the fits for the rotation velocities show that a stability of \( \pm 0.007 \text{ deg day}^{-1} \), which equals to \( \pm 1 \text{ m s}^{-1} \), is obtained twice for the Debrecen data with more than 100 observations per passage.

Taking the number of observations into account, the Debrecen, Dietzenbach, and Locarno results for the rotation velocities show the same precision, while those from the Kanzelhöhe are a little worse.

(f) When dividing the data of the passages into three parts for the limb, the centre and the limb, higher rotation velocities are found for the central parts as compared to the limb parts. The differences are between 0.13 deg day\(^{-1}\) and 0.26 deg day\(^{-1}\) for Debrecen and Locarno, respectively. (In the other cases the amount of data is too small.)

When using cut-off longitudes in general the rotation velocities determined are increased with decreasing cut-off longitudes, except in the case of the data from the Kanzelhöhe.

An example is given in Figure 1 for the spot Mt. Wilson No. 20646. For the other spots the general behaviour is the same.

The interpretation of these results, which can be made by wrong solar image radii, image distortion and the Wilson-effect, will be given in another paper.
(g) When comparing the rotation velocities determined in the eastern and western hemispheres no significant differences could be found.

(h) Taking the SGD into account it is obvious, that the position differences are bigger than given in (a) and (b). The rotation velocities determined are between those from the Kanzelhöhe and Debrecen, except for the third spot, where the value determined from the SGD is much bigger and the error extremely high.

Taking the number of observations into account, the errors for the rotation velocities determined from SGD are about twice as big as those determined from the other observations.

As already known, the SGD can only be used for spot identifications and cannot serve for precise positions and rotation velocities.

5. Conclusions

When comparing sunspot positions and rotation velocities obtained at different observatories and obtained with different methods rather big differences must be expected. These are at least some tenths of a degree for the heliographic coordinates and about 0.1 deg day$^{-1}$ to 0.3 deg day$^{-1}$ for the rotation velocities. As shown e.g. by the papers of Arévalo et al. (1982) and Balthasar and Wöhl (1980) the Greenwich Photoheliographic Results are rather homogeneous for the period 1874 until 1976. When comparing results reduced from this material with those from other observations and reductions a careful inspection of possible systematic differences is needed.

Acknowledgements

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